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

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

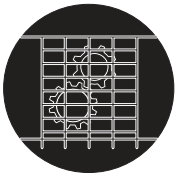
Before inspecting or servicing the electrical/electronic system, disconnect the negative (-) cable from the battery terminal. Failure to observe this can cause the circuit to short, possibly starting a fire.
Loose terminals and damaged cables/wires can cause short circuit or even fire. Before carrying 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

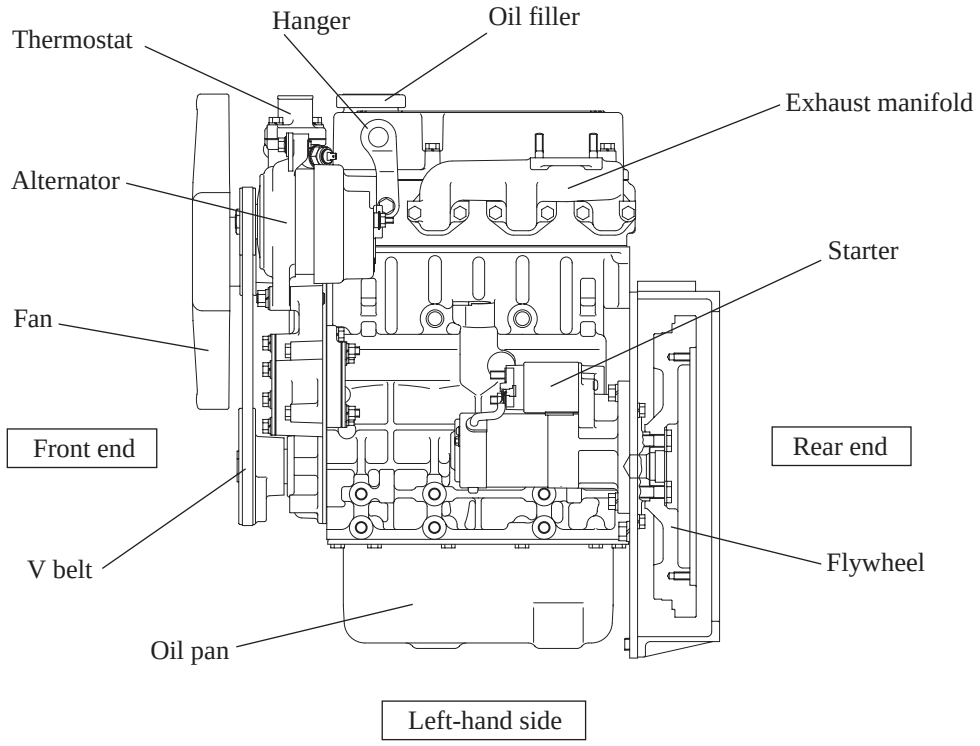
When transporting the engine on public roads, the weight, width and height of the electric power generator should be taken into account while observing the relevant laws regarding road traffic and haulage, and vehicle restrictions and requirements.

GENERAL

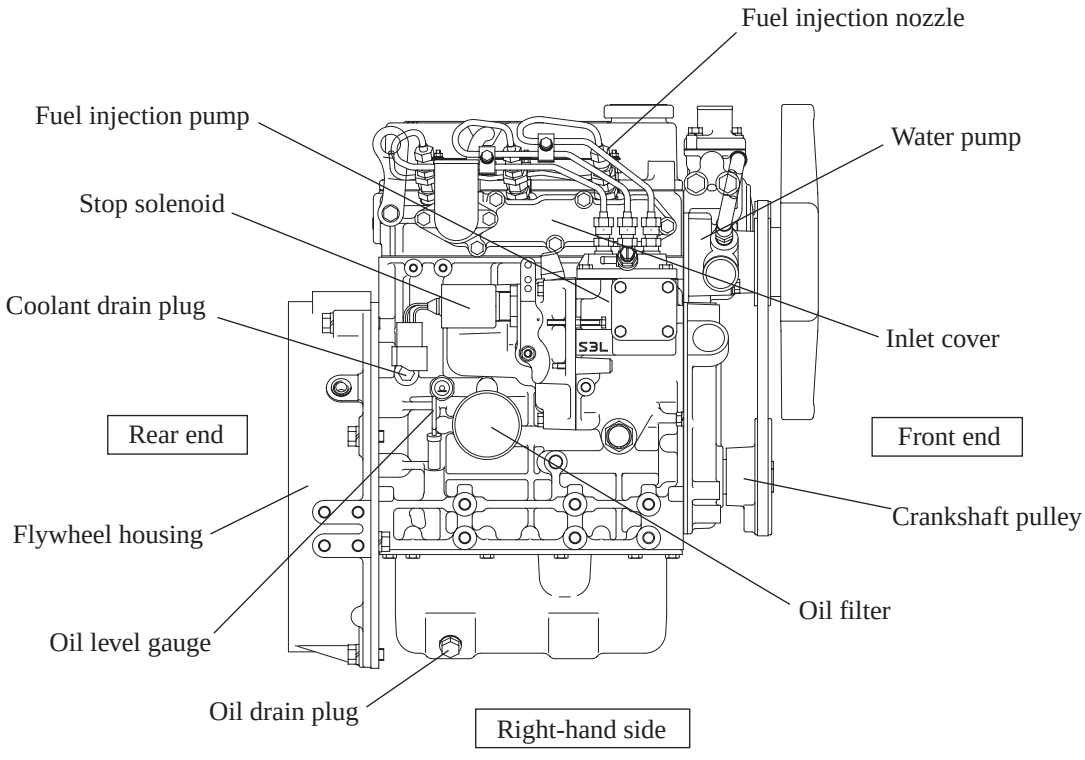
1. Overview

1.1 Outline Drawing

S3L, S3L2

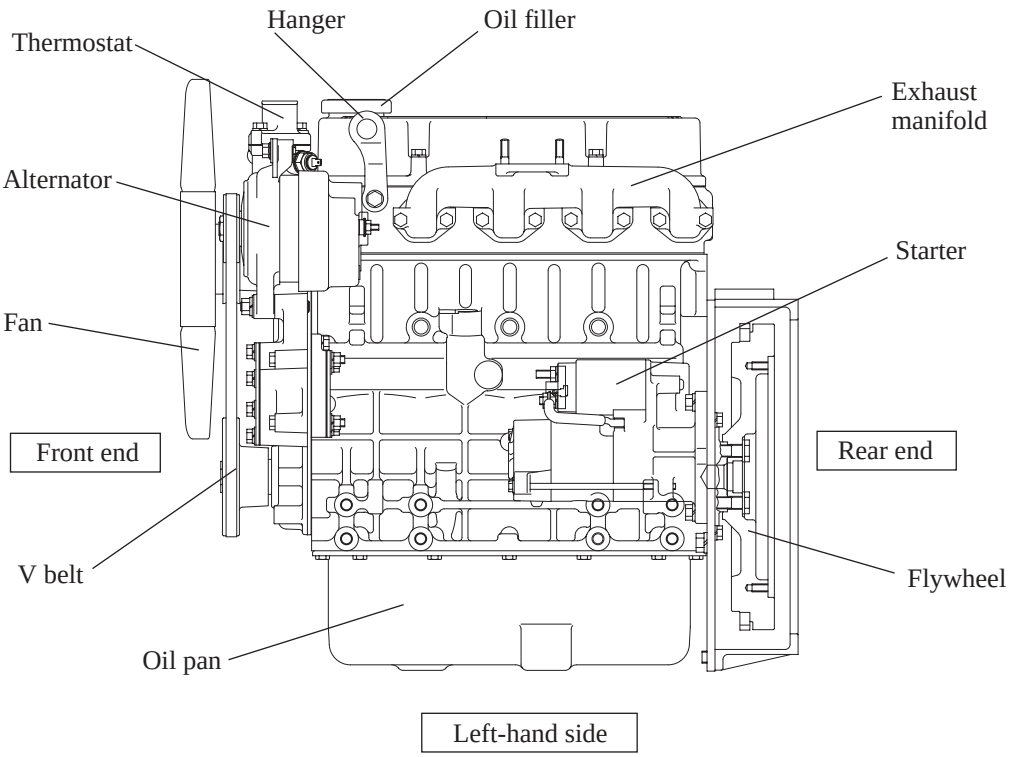


Engine LH side view

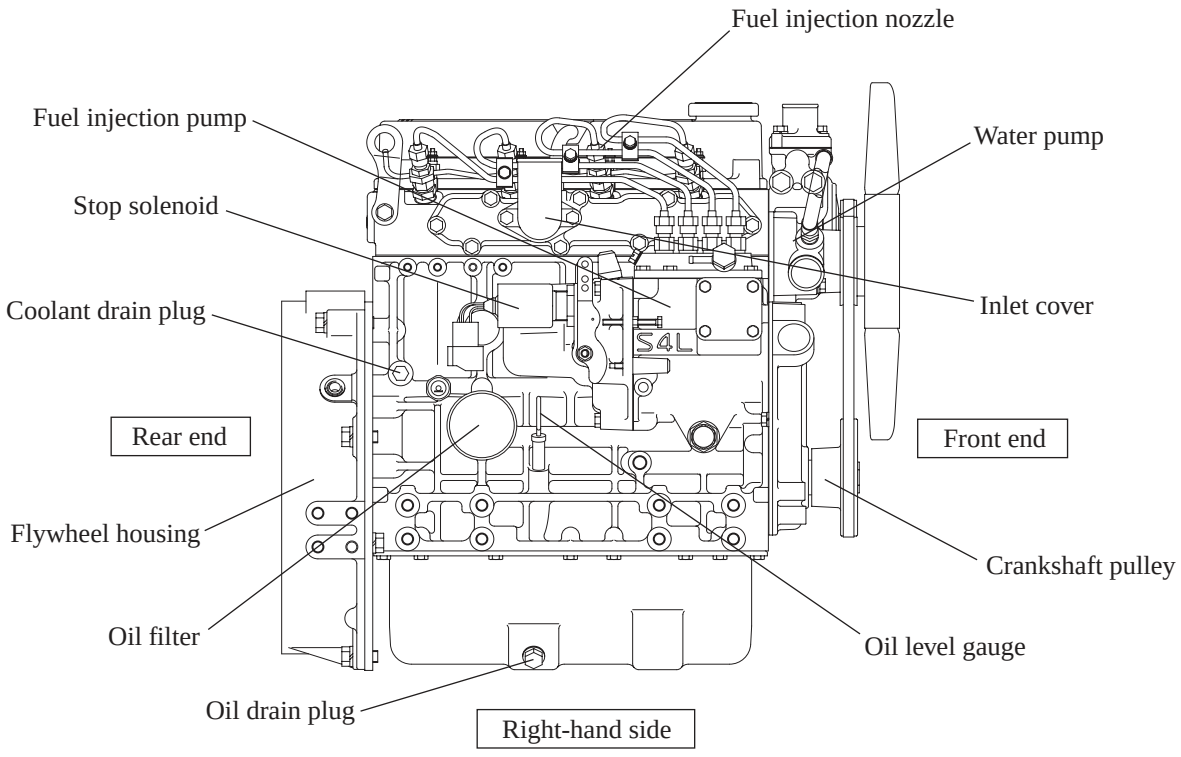


Engine RH side view

S4L, S4L2

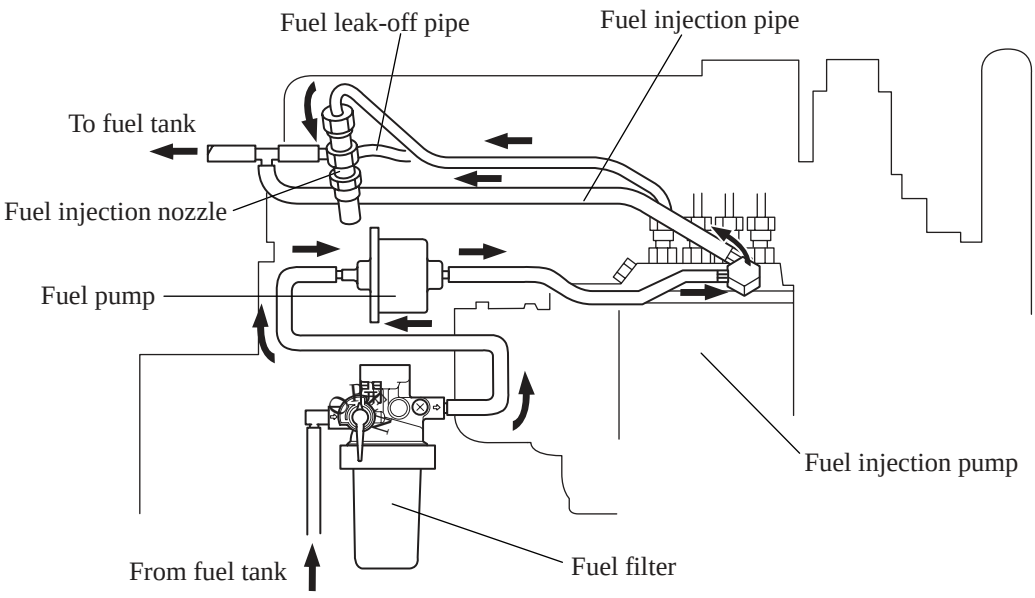


Engine LH side view



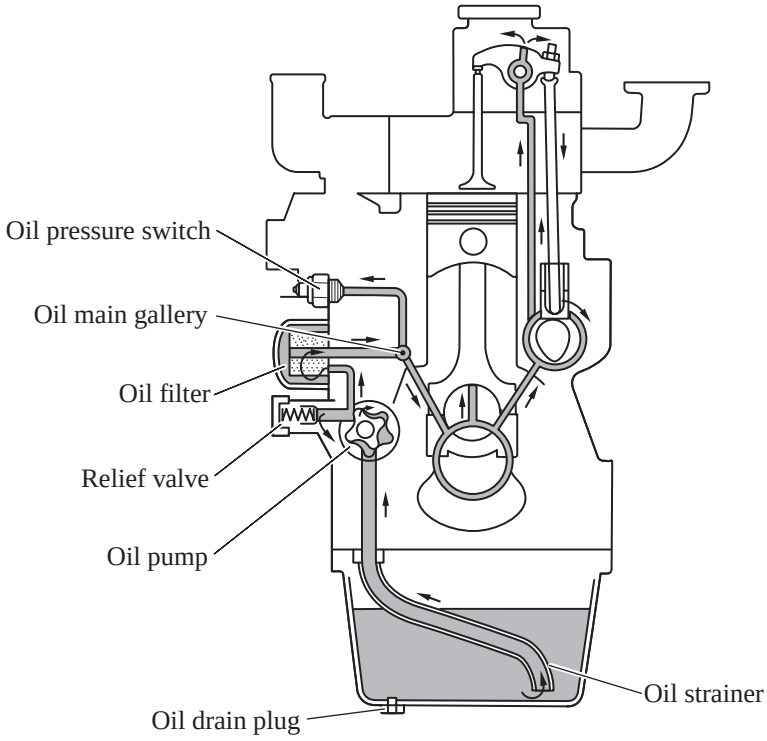
Engine RH side view

1.2 Fuel System Schematic



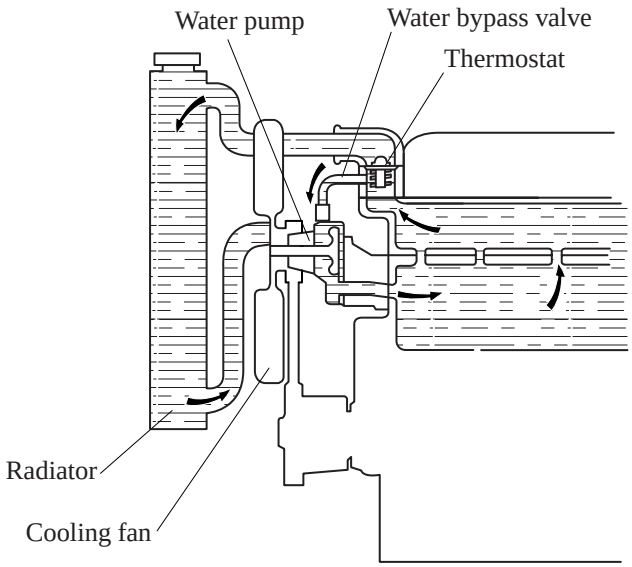
Fuel system schematic

1.3 Oil System Schematic



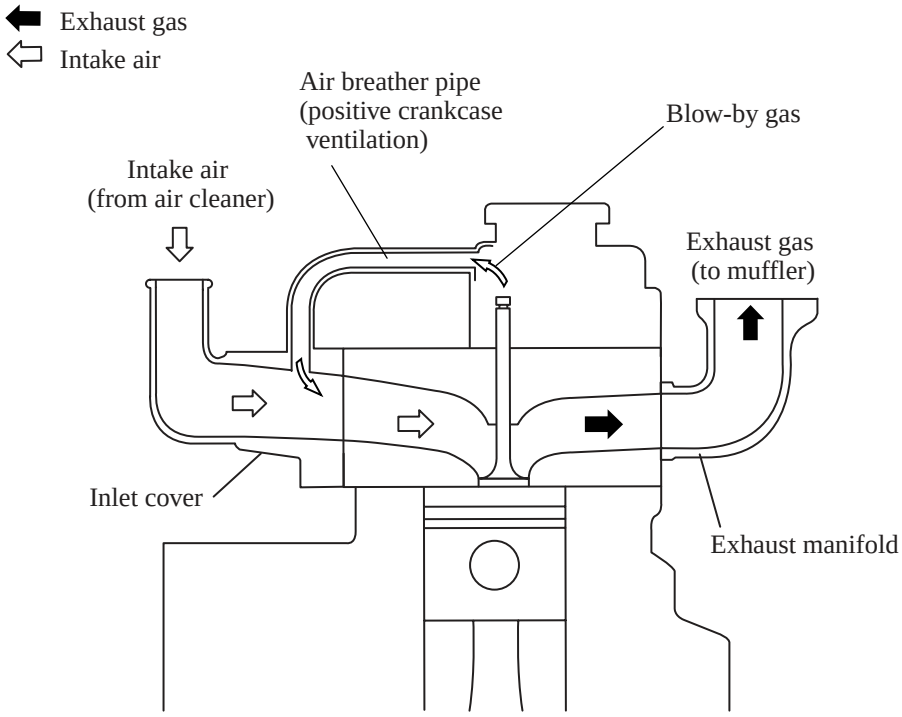
Oil system schematic

1.4 Cooling System Schematic



Cooling system schematic

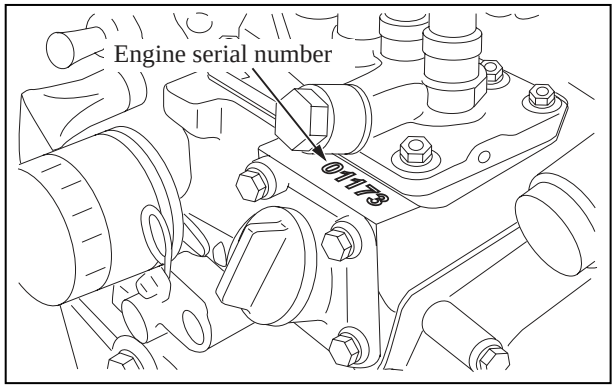
1.5 Inlet / Exhaust System Schematic



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.

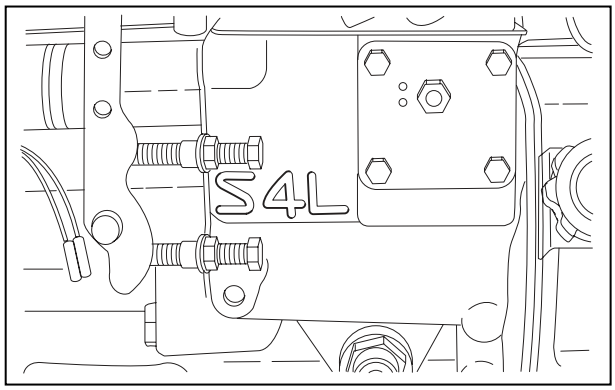


Engine serial number location

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 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.

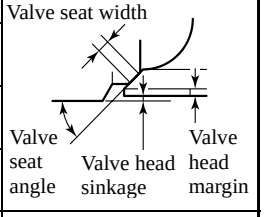
(3) Use good-quality oil and grease. Never fail to apply oil, grease, sealant and adhesive to the relevant locations if so instructed in the manual.

(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.

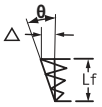
SERVICE STANDARDS

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

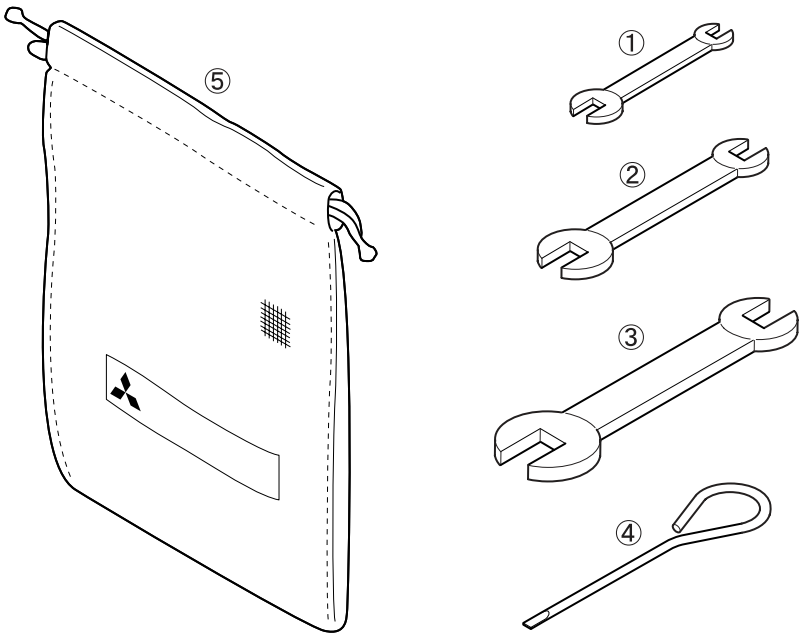
Size	Tightening into aluminum			Tightening into iron		
	N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
NPTF1/16	4.90 to 7.85	0.5 to 0.8	3.6 to 5.8	7.85 to 11.8	0.8 to 1.2	5.8 to 8.7
PT1/8	7.85 to 11.8	0.8 to 1.2	5.8 to 8.7	14.7 to 21.6	1.5 to 2.2	10.8 to 15.9
PT1/4, NPTF1/4	19.6 to 29.4	2.0 to 3.0	14.5 to 21.7	34.3 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

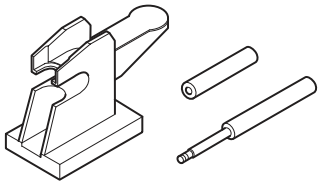
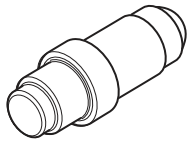
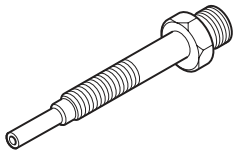
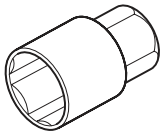
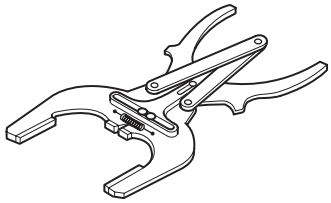
TOOLS LIST

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

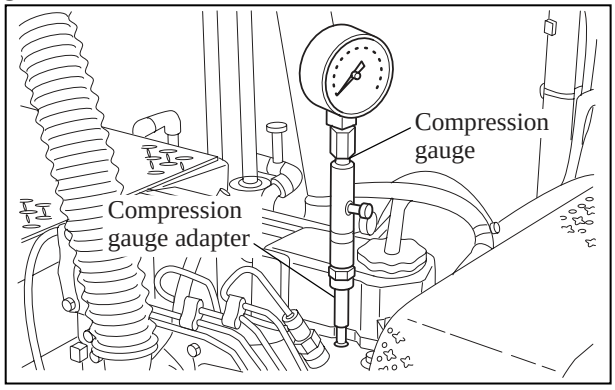
(1) Move the control lever to STOP position.

(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

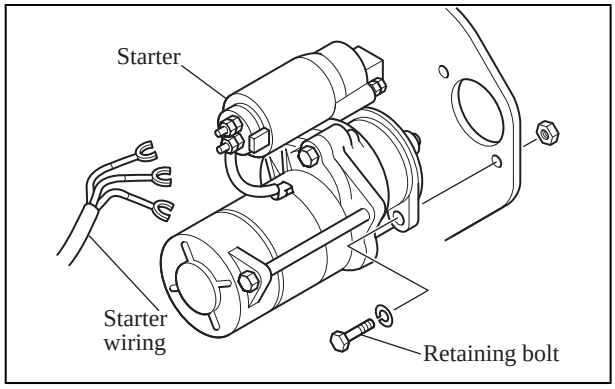
1. Preparations

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.

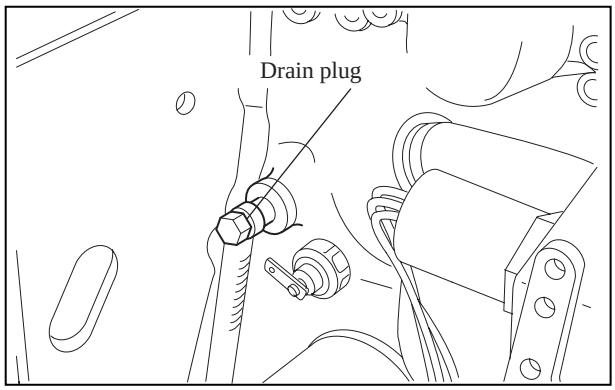
- Starter
- Switches



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

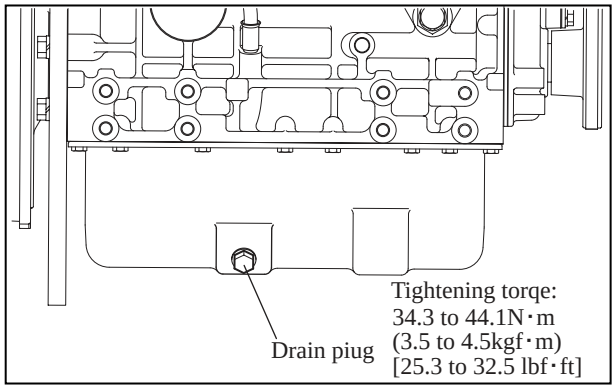
Remove the engine oil drain plug from the oil pan to drain the engine oil.

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

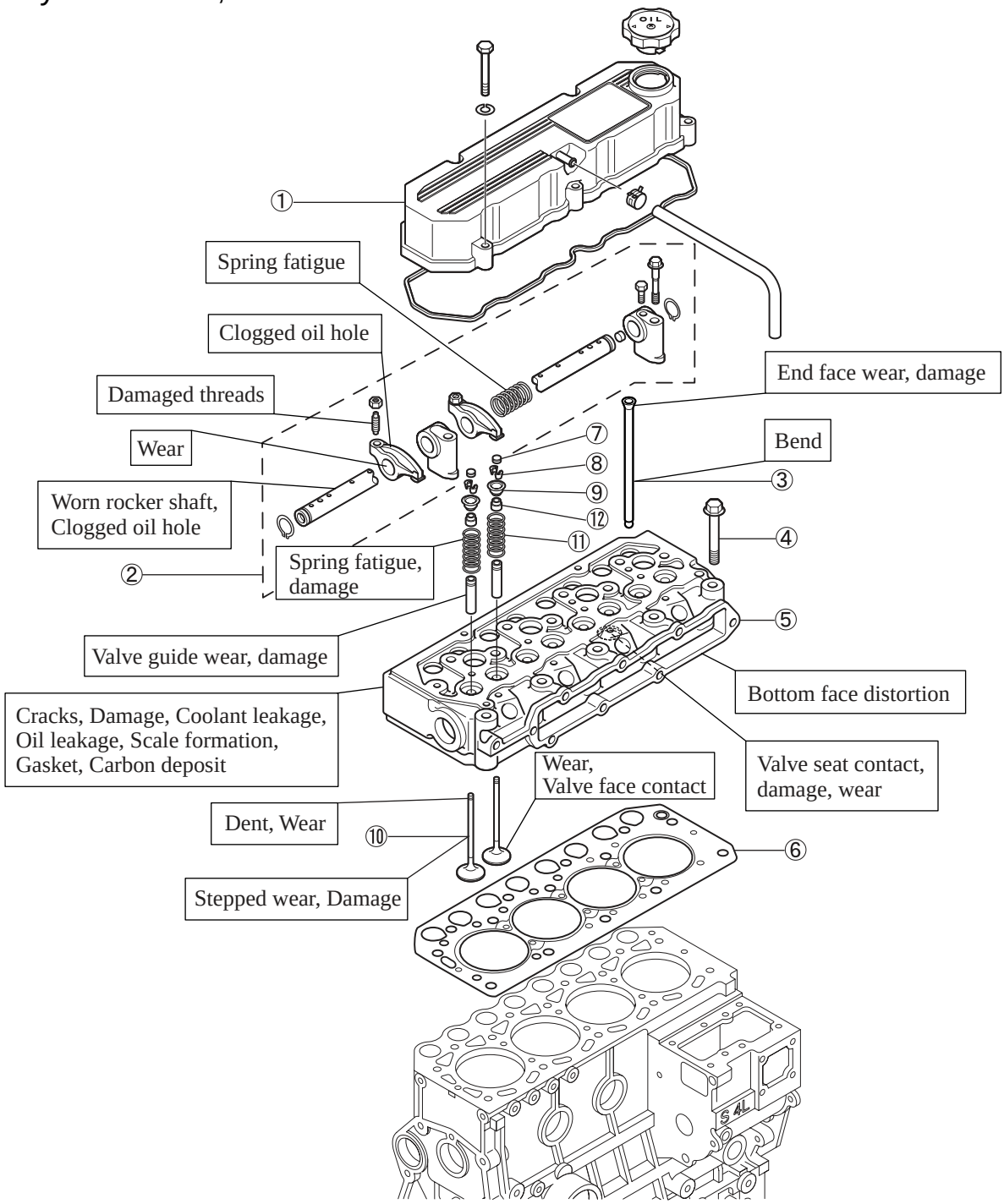
Do not touch the engine oil which may be extremely hot as it can cause burns.



Drain plug on the oil pan

ENGINE MAIN PARTS - DISASSEMBLY

1. Cylinder Head, Valve Mechanism



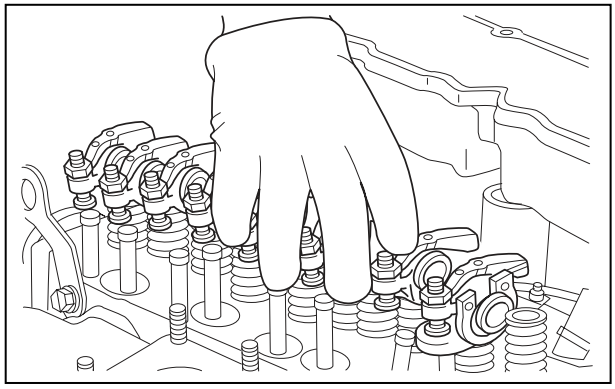
Disassembly of cylinder head and valve mechanism

<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

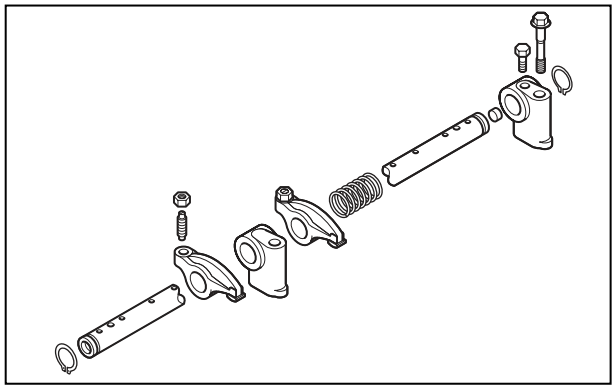
(1) Loosen the rocker stay bolts. Remove the rocker shaft assembly together with the rocker stay bolts.
(2) Remove the valve caps.
(3) Keep the rocker shaft assembly with the rocker stay bolts.



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.

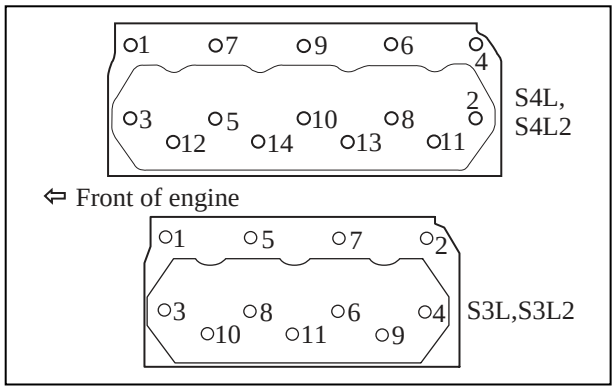


Disassembling the rocker shaft assembly

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.

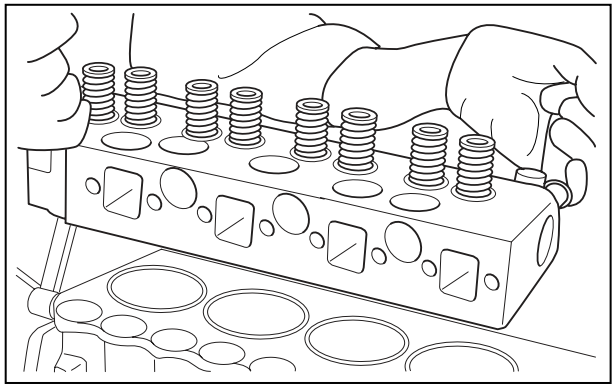


Tightening order for cylinder head bolts

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.



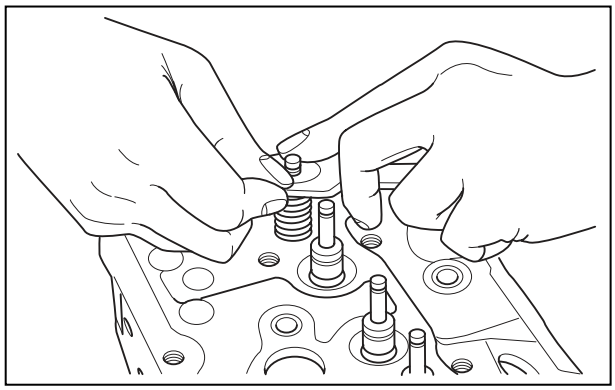
Removing the cylinder head assembly

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.

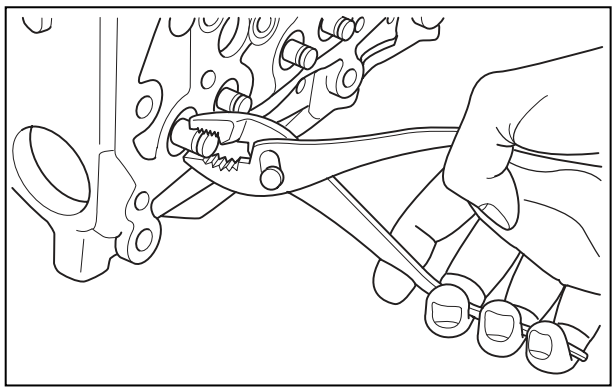


Removing the valve spring

1.6 Removing the valve stem seals

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

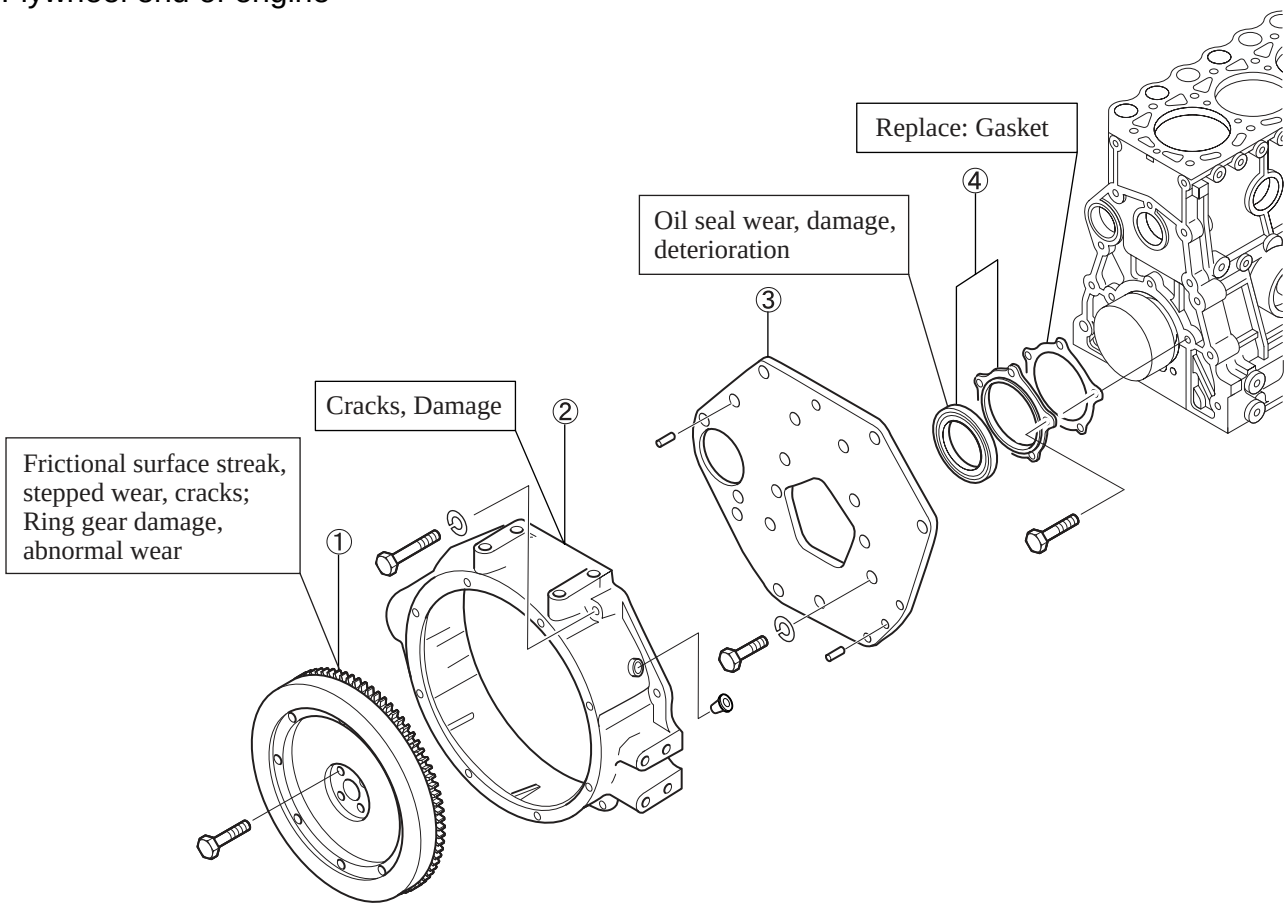
Note: Replace the old valve stem seals with new parts upon reassembly.



Removing the valve stem seal

2. Flywheel, Timing Gear, Camshaft

Flywheel end of engine

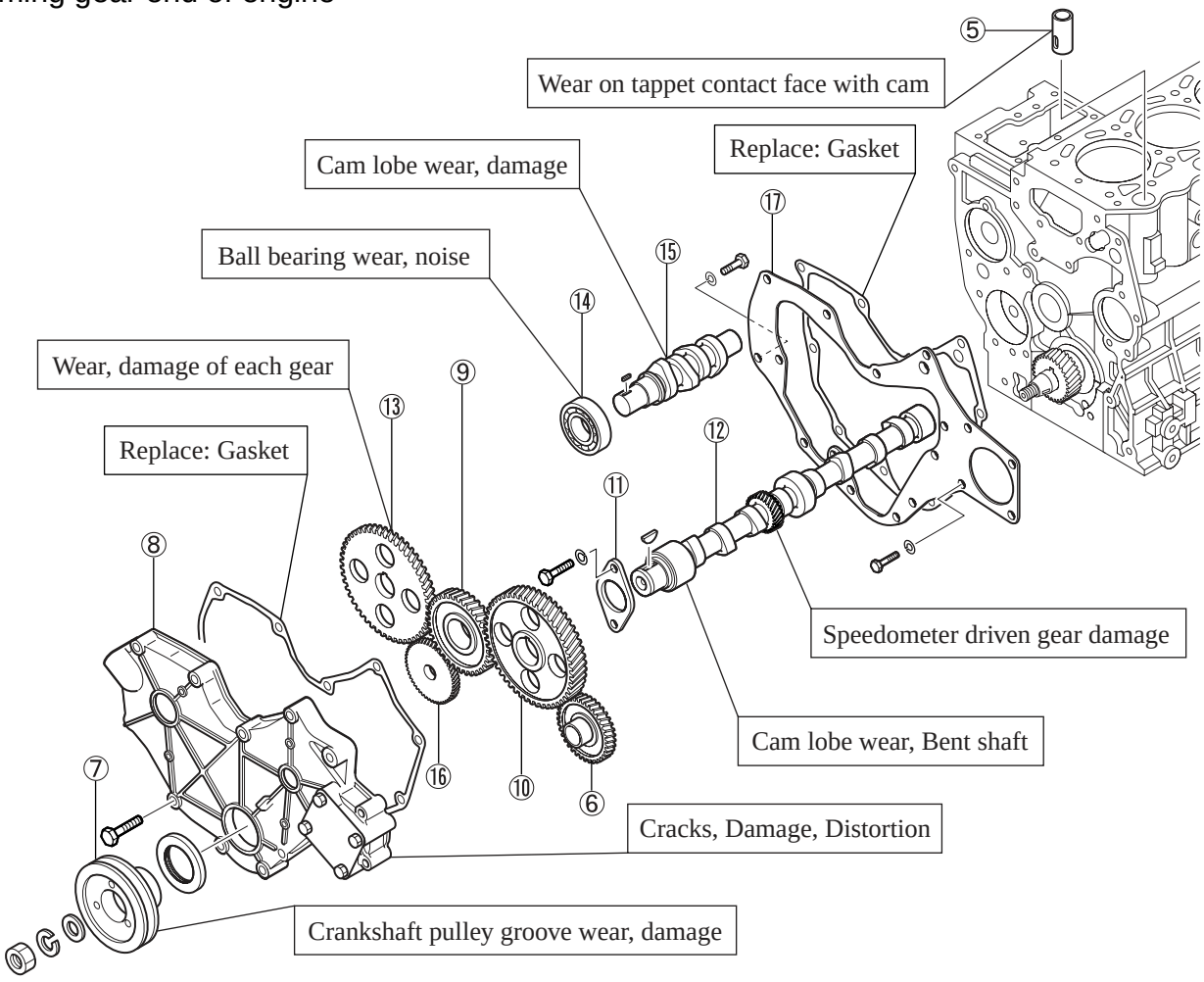


Disassembly of flywheel

<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

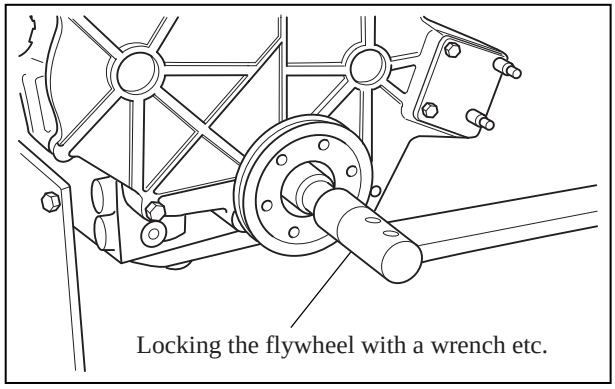
2.1 Removing the flywheel

(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.

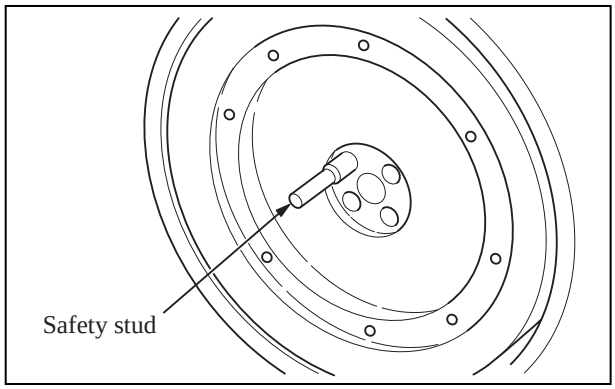
(4) While holding the flywheel with both hands, rock the flywheel towards you and away to pull it out straight towards you.

⚠ 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.

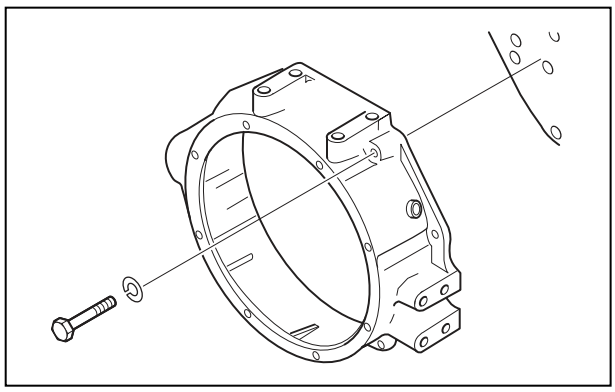
(c) The ring gear has been shrink-fit onto the flywheel. Do not attempt to remove the ring gear unless it is faulty.



Removing the flywheel

2.2 Removing the flywheel housing

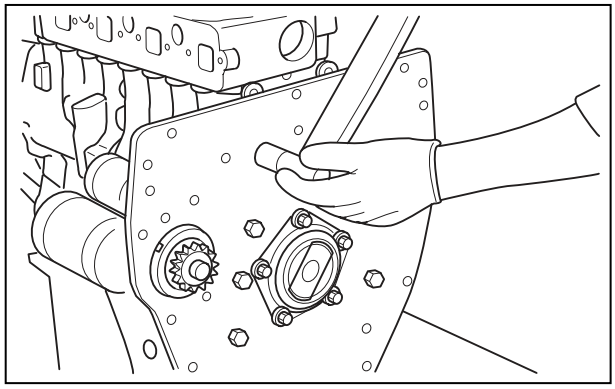
Remove the flywheel housing retaining bolts. Remove the flywheel housing.



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.



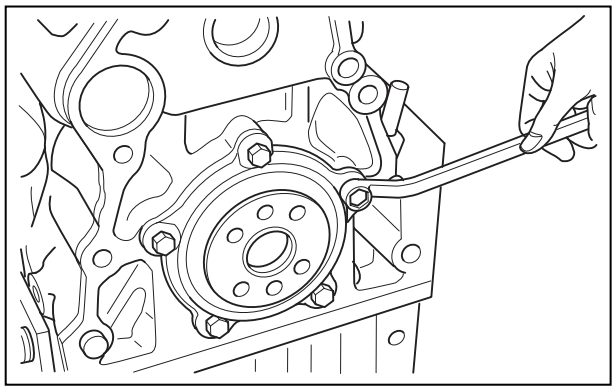
Removing the rear plate

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.

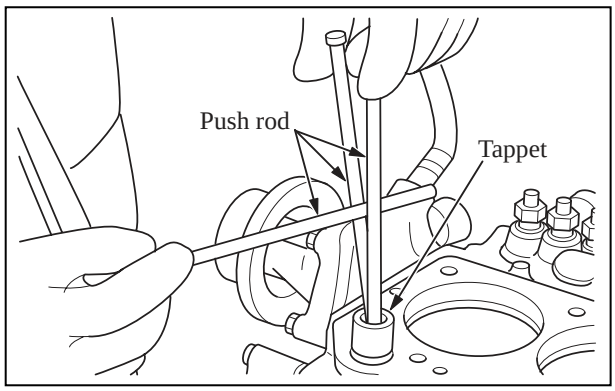


Removing the oil seal case

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

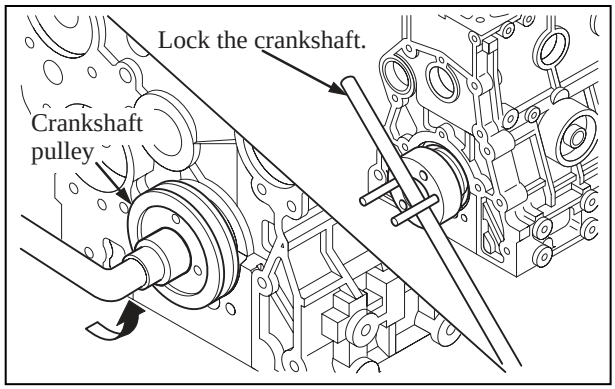
2.6 Removing the crankshaft pulley

(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.



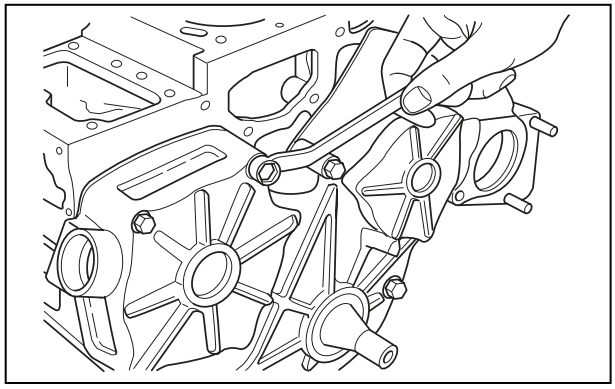
Removing the crankshaft pulley

2.7 Removing the timing gear case

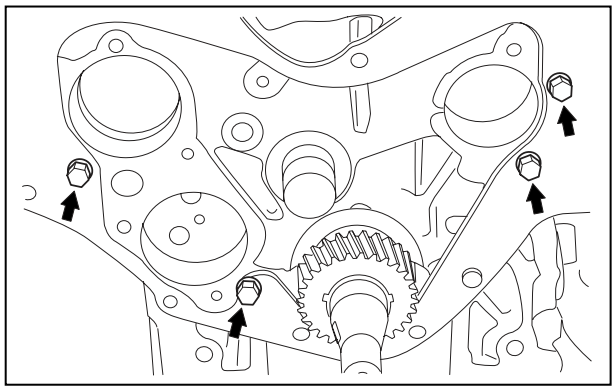
Remove the timing gear case retaining bolts. Then, remove the timing gear case.

⚠ 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

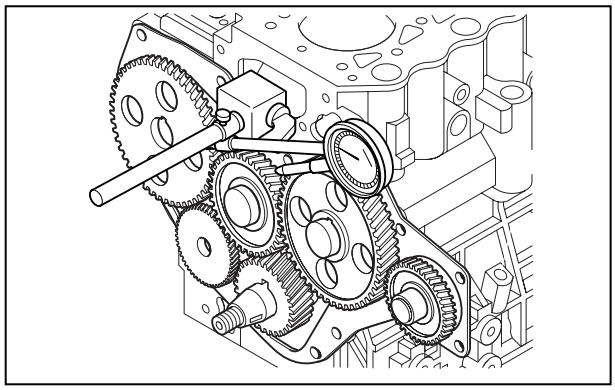
2.8 Measuring the timing gear backlash

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.)

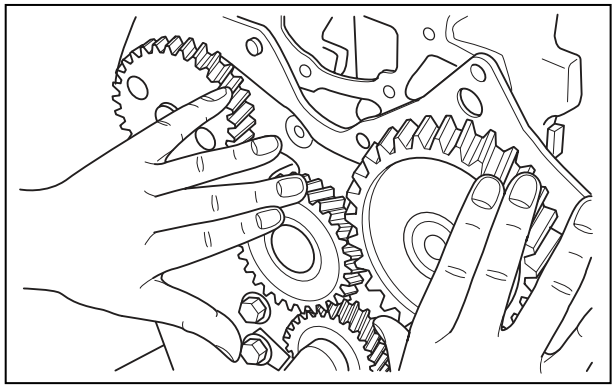
		Standard value	Limit
Timing gear backlash	Crank gear - idler gear	0.04 to 0.12 (0.0016 to 0.0047)	0.30 (0.0118)
	Idler gear - valve camshaft gear		
	Idler gear - pump camshaft gear		
	Valve camshaft gear - PTO gear	0.08 to 0.19 (0.0031 to 0.0075)	
	Pump camshaft gear - oil pump gear	0.07 to 0.20 (0.0028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



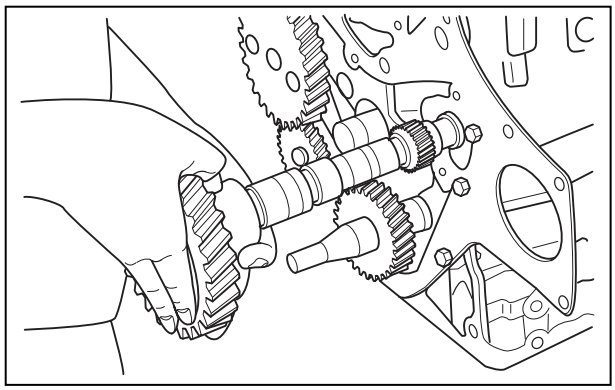
Removing the idler gear

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

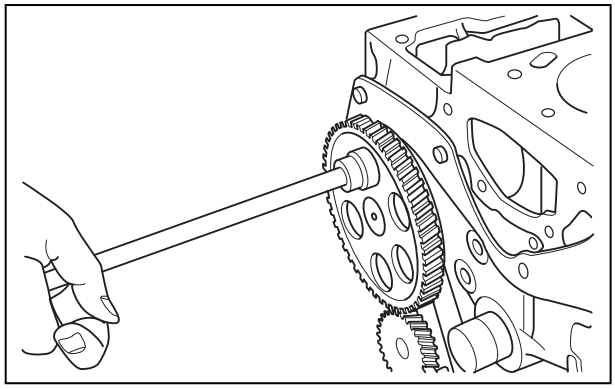
When pulling out the camshaft, pay attention to the cams as they tend to be caught by the surrounding parts.



Pulling out the camshaft

2.11 Removing the fuel injection pump camshaft

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

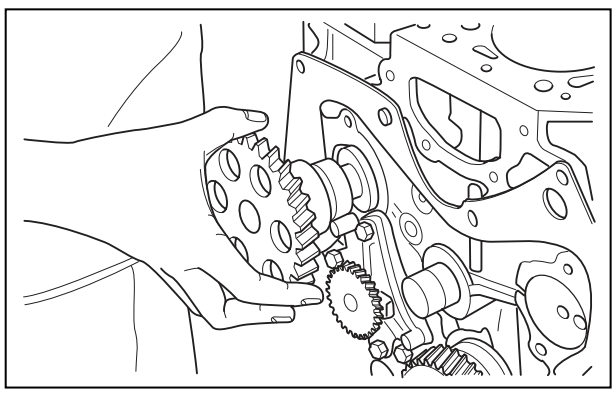


Removing the pump camshaft stopper bolt

(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)

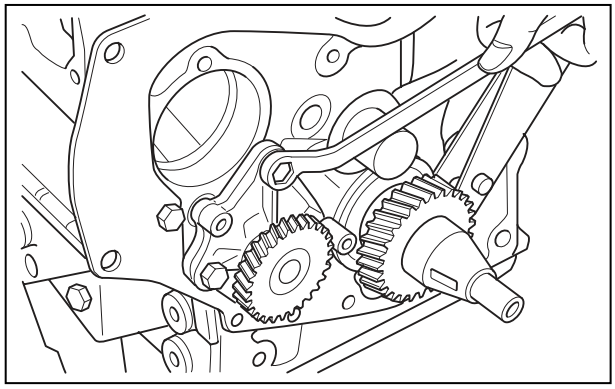
Using a hydraulic jack, remove the camshaft gear and the fuel injection pump camshaft gear from the respective shafts.



Removing the pump camshaft

2.13 Removing the oil pump

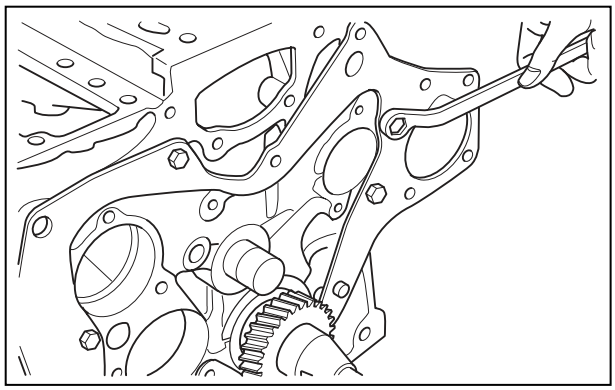
Remove the oil pump retaining bolts. Then, remove the oil pump from the cylinder block.



Removing the oil pump

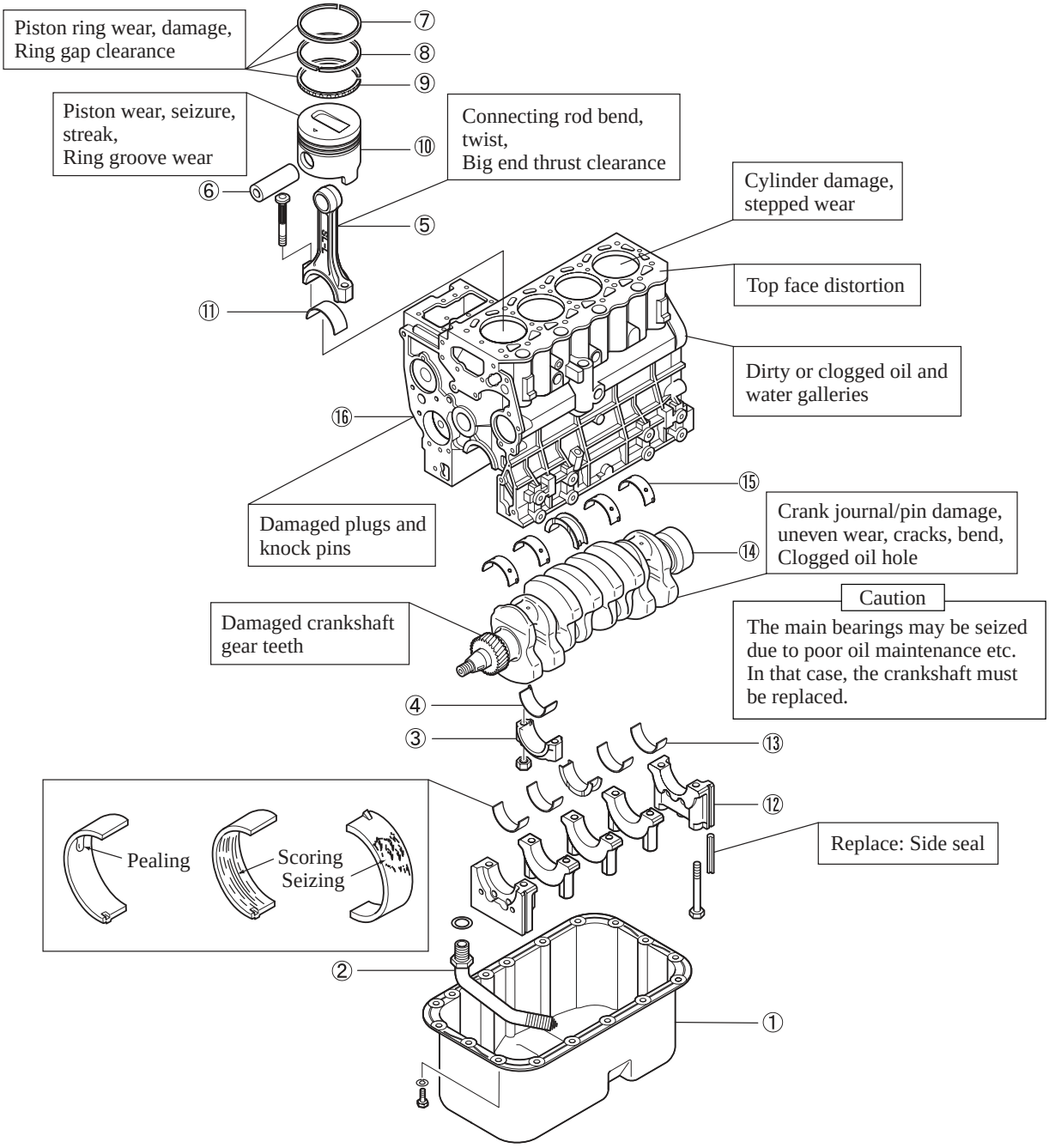
2.14 Removing the front plate

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.

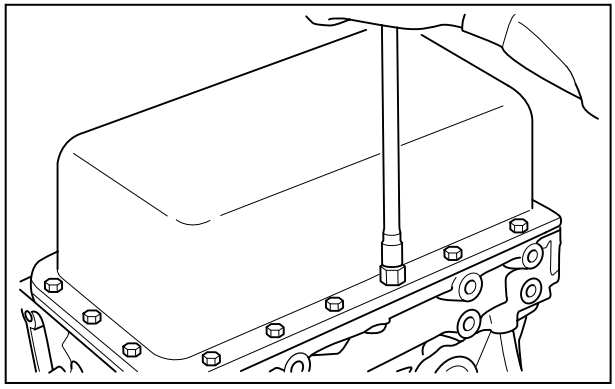
3.1 Removing the oil pan

(1) Turn the engine upside down.

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

⚠ CAUTION

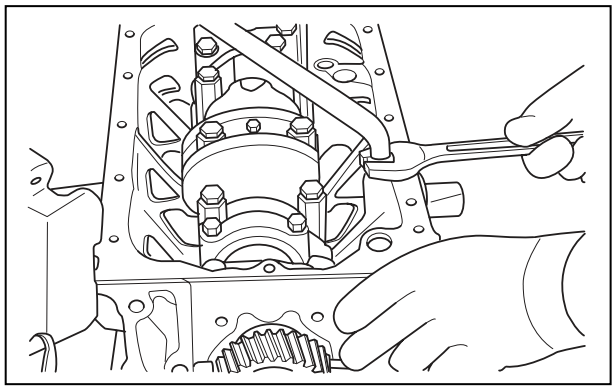
Do not insert a chisel or a screwdriver between the oil pan and the cylinder block to remove the oil pan. Otherwise, the oil pan flange face will be deformed.



Removing the oil pan

3.2 Removing the oil strainer

Loosen the nut to remove the oil strainer.



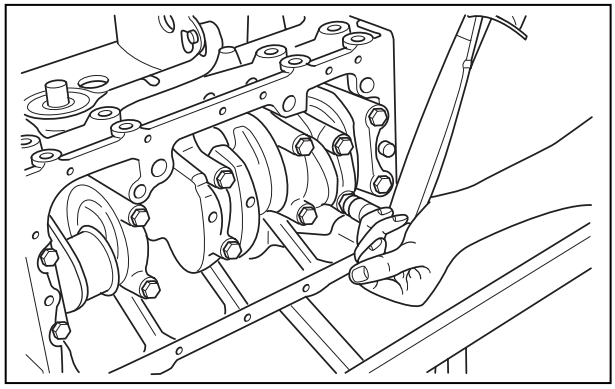
Removing the oil strainer

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.

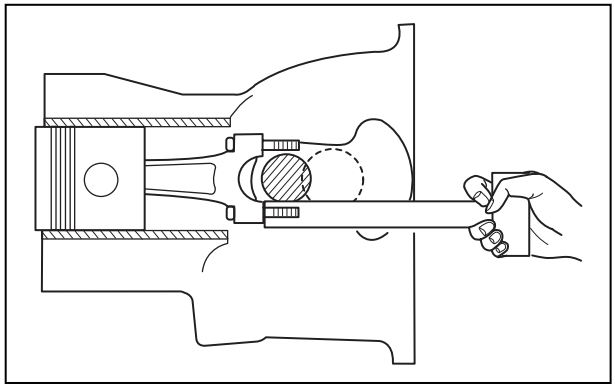


Removing the connecting rod caps

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

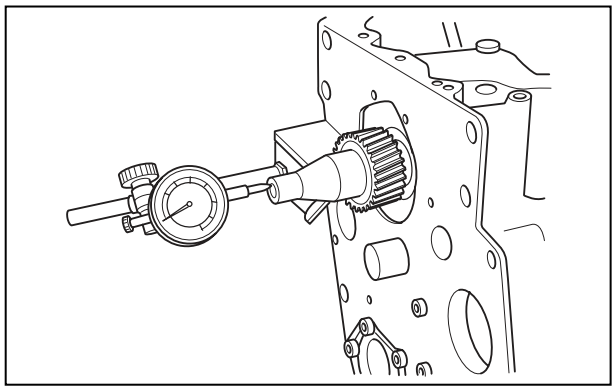
3.5 Measuring the crankshaft end play

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)



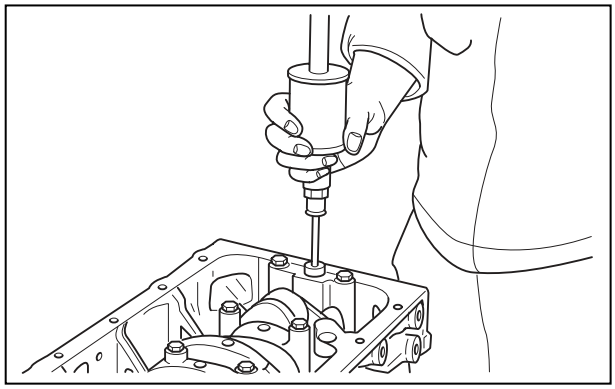
Measuring the crankshaft end play

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

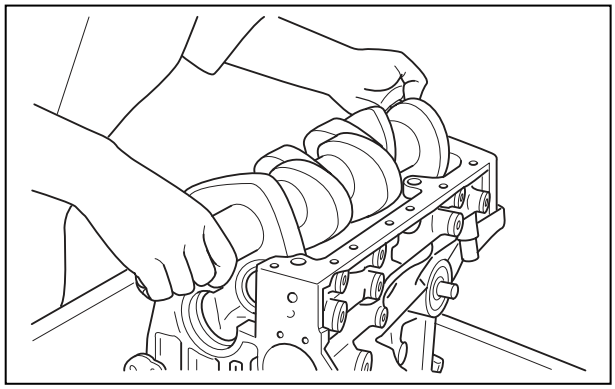
3.7 Removing the crankshaft

(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.

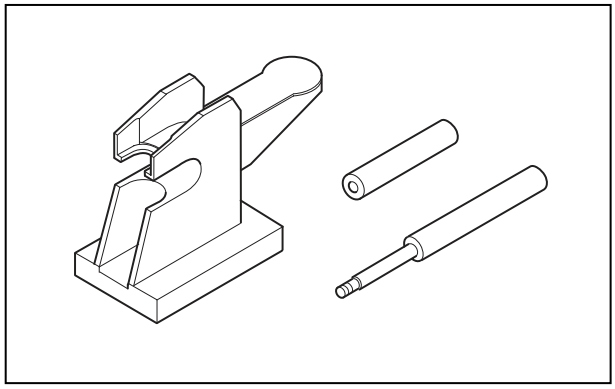


Removing the crankshaft

3.8 Separating the piston from the connecting rod

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

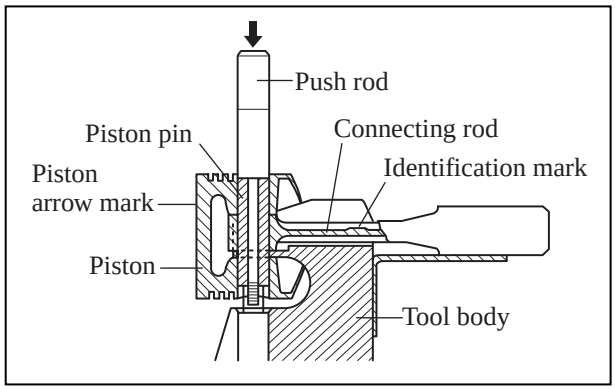
Special tool	Part number
Piston Pin Setting Tool	31A91-00100



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.

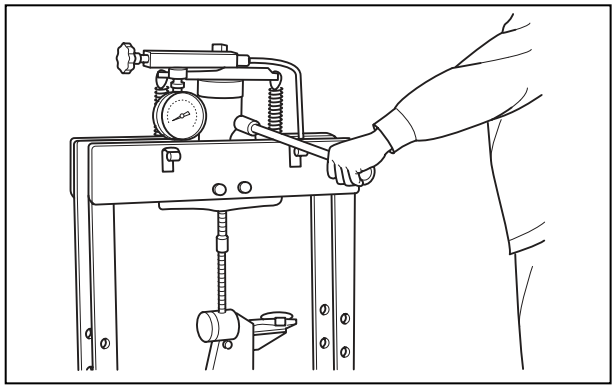


Removing the piston pin (1)

⚠ 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

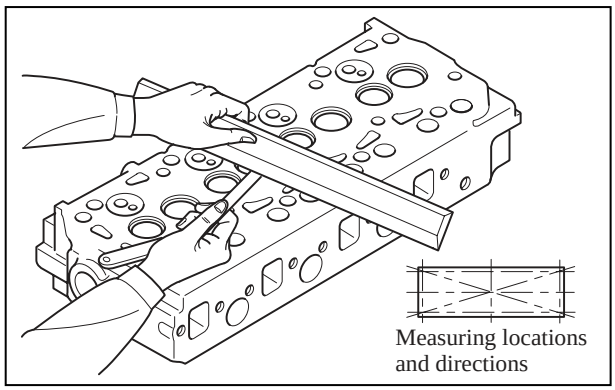
1. Cylinder Head, Valve Mechanism

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)



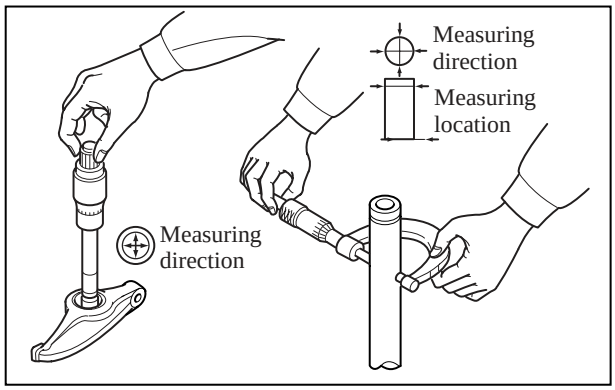
Measuring the cylinder head bottom face for distortion

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)



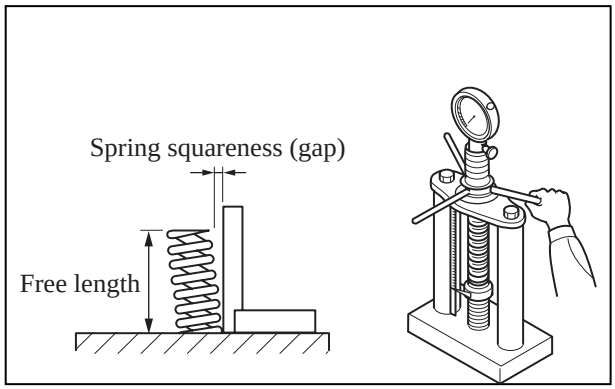
Measuring the rocker arm inner diameter and the rocker shaft diameter

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 △ Lf	θ =2.0° or less △(gap)=0.2 (0.0079) or less 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

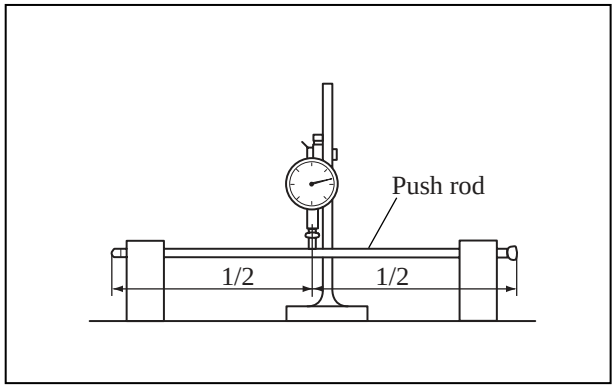
1.4 Measuring the push rod for bend

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.



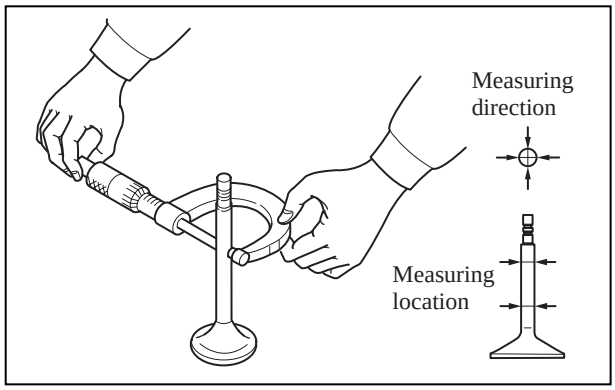
Measuring the push rod bend

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

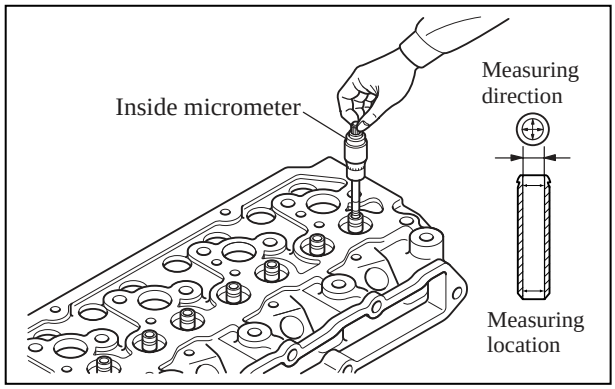
Measure the valve guide inner diameter using an inside micrometer.

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

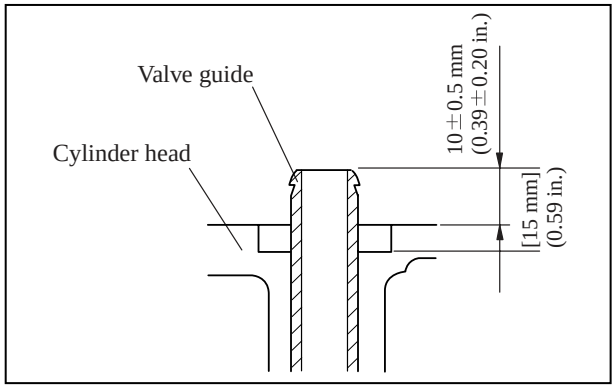
1.7 Replacing the valve guide

(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.

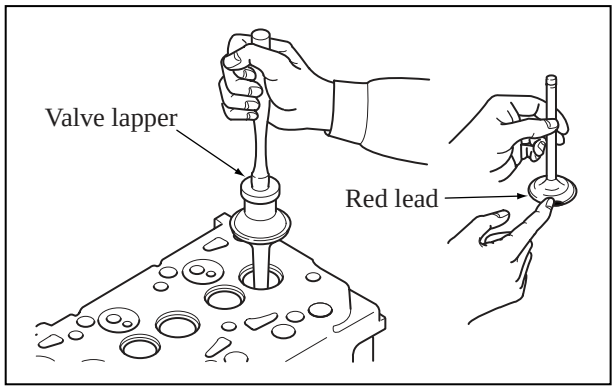
(4) Check the valve face-to-seat contact.



Valve guide protrusion
above the cylinder head face

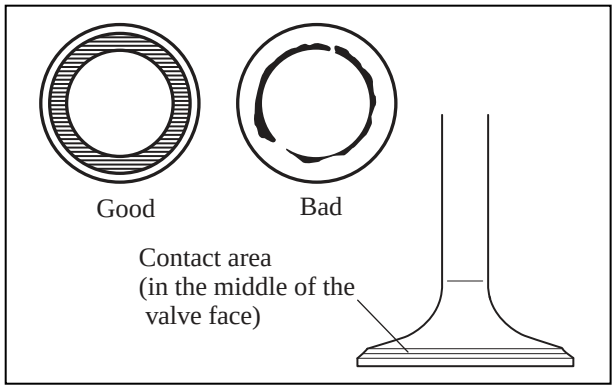
1.8 Inspecting the valve face

(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.

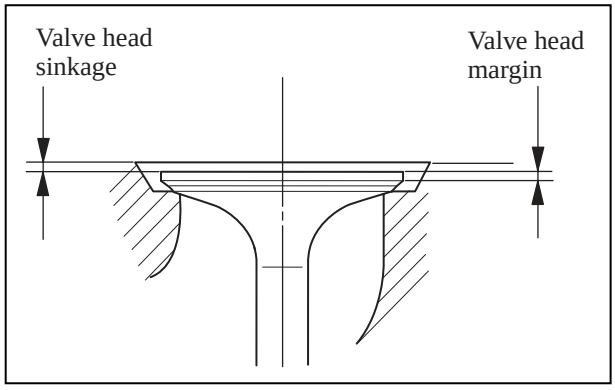


Valve seat-to-face contact

(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 (0.0531 to 0.0650)	0.5 (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.)

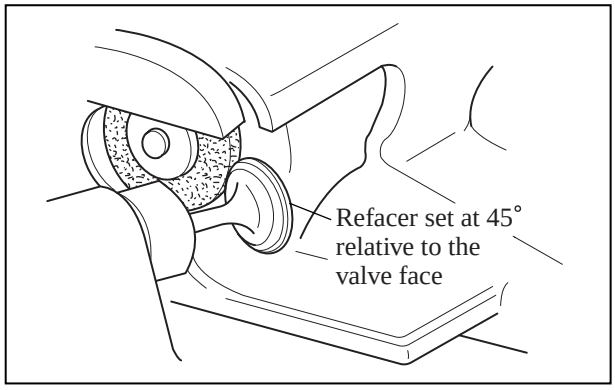
	Standard value	Limit
Valve head sinkage	0.25 to 0.75 (0.0098±0.0295)	1.5 (0.0600)

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.



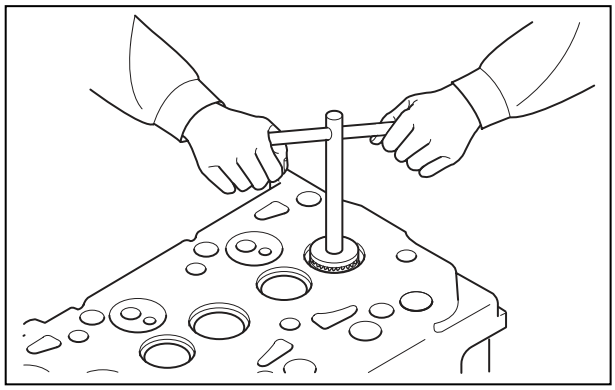
Correcting the valve face

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.

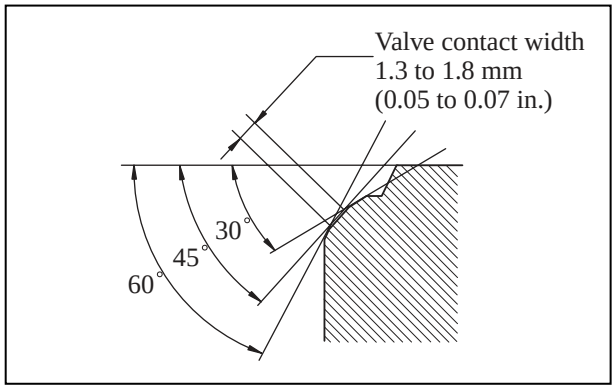


Correcting the valve seat

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).

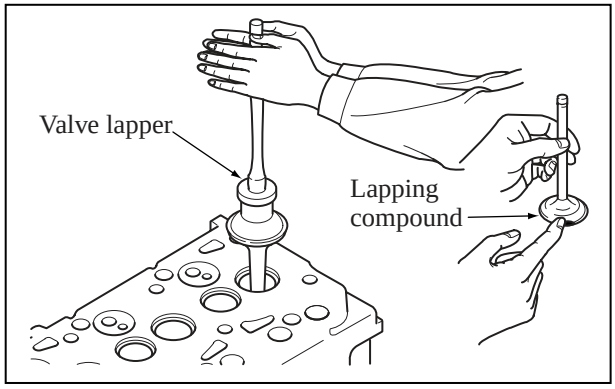
(c) Lapping compound spreads more evenly if it is mixed with a small amount of engine oil.

(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.

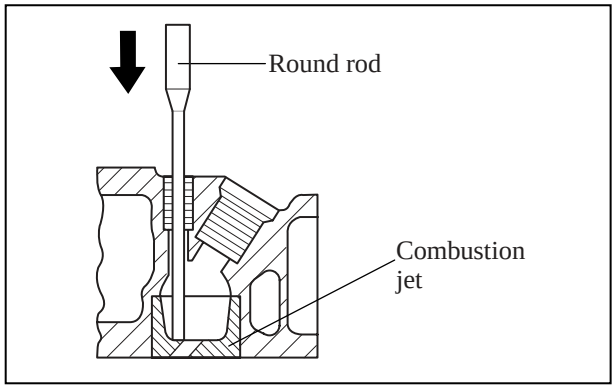


Lapping the valve face against the valve seat

1.12 Replacing the combustion jets

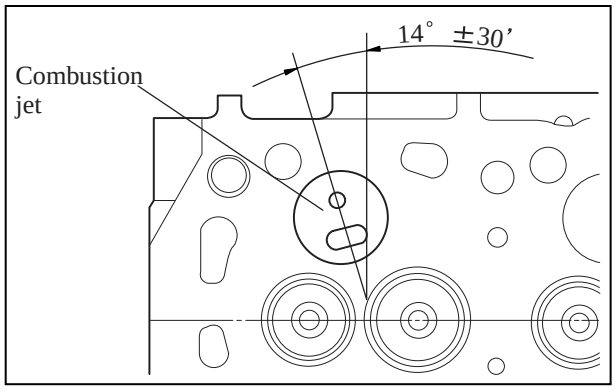
Replace the combustion jets only when they are cracked or faulty.

(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

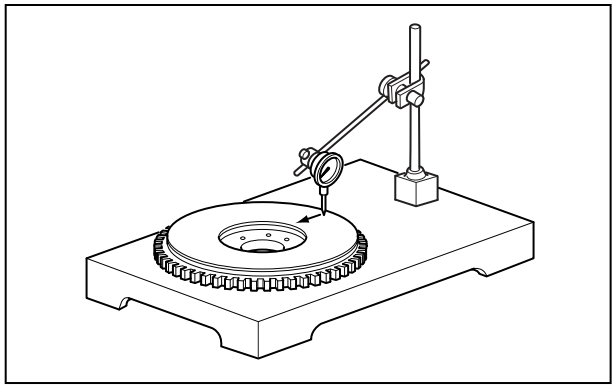
2.1 Measuring the flywheel flatness

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.

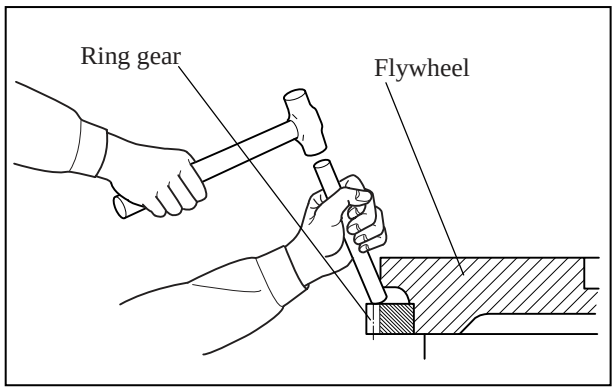
(1) Removing the ring gear

(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.



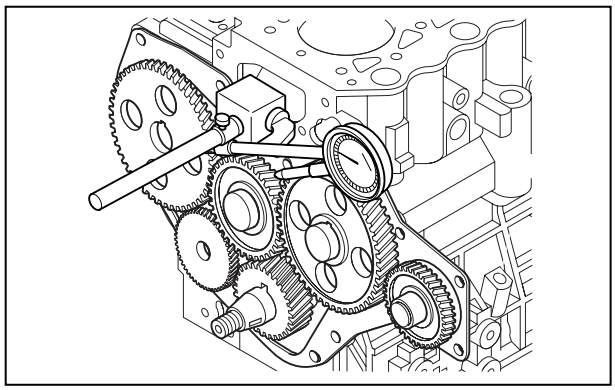
Removing the ring gear

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)	



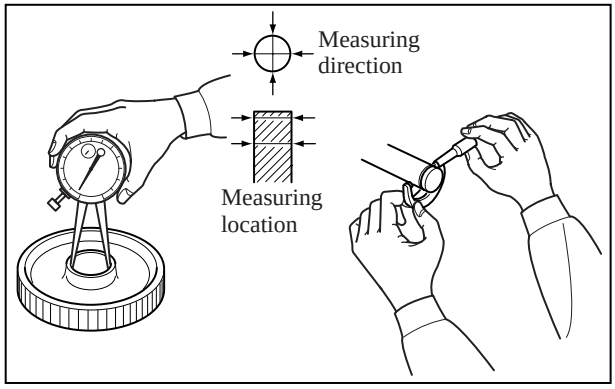
Measuring the timing gear backlash

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.)

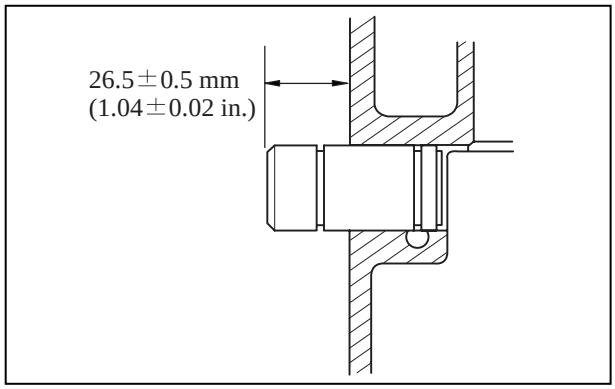
	Standard value	Limit
Idler gear-to-shaft clearance	0.020 to 0.070 (0.0008 to 0.0028)	0.200 (0.0079)



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.



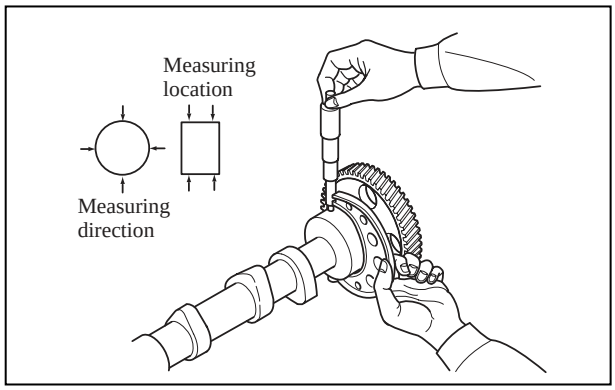
Replacing the idler shaft

2.6 Measuring the clearance between the camshaft journal and the bushing

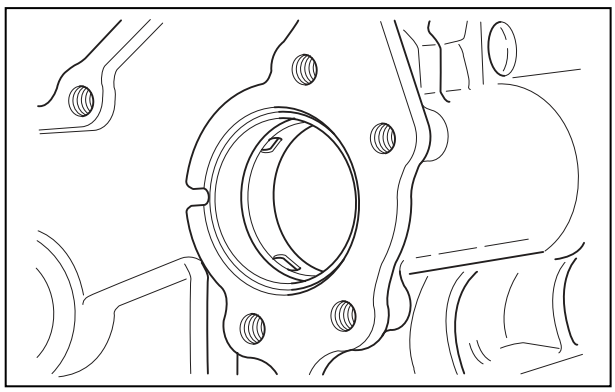
Measure the camshaft journal diameter. Measure the inner diameter of the bushing on the cylinder block. If the difference between them exceeds the limit, replace the bushing.

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

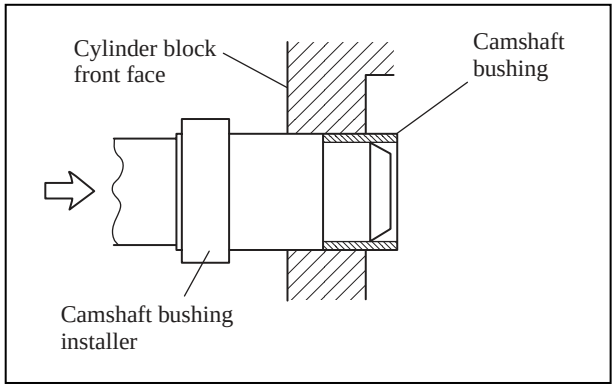
2.7 Extracting the camshaft bushing

(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.

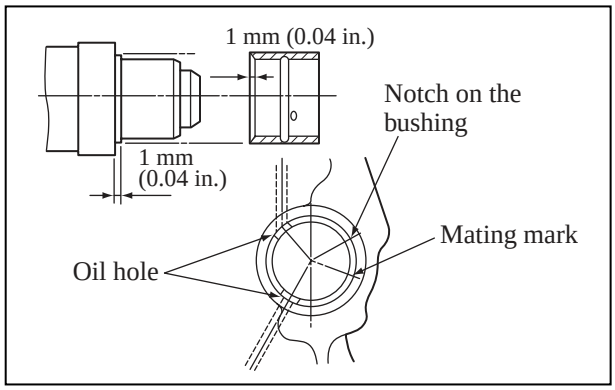
(3) Using the punching side of the installer, punch the bushing off and into the cylinder block. Take it out of the block by slightly deforming it.



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.



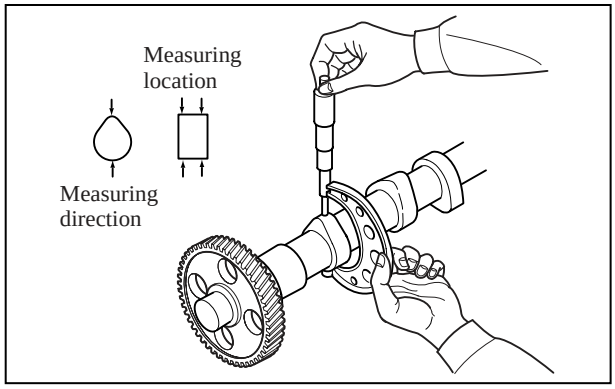
Press-fitting the camshaft bushing

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)



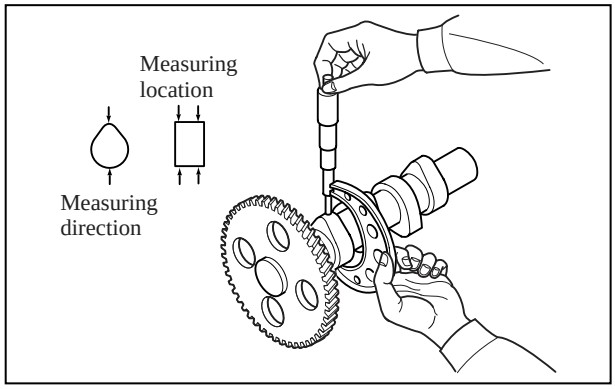
Measuring the camshaft cam height

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.)

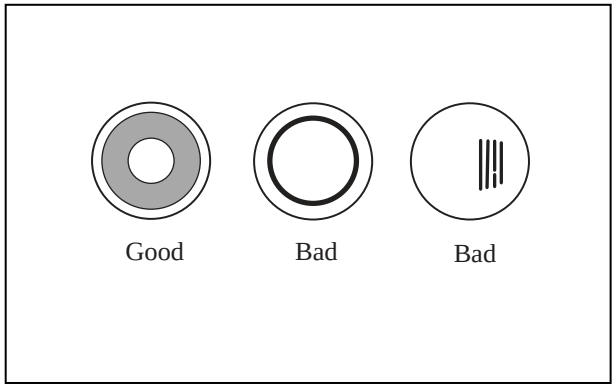
	Standard value	Limit
Fuel injection pump shaft cam height (including lobe)	44±0.1 (1.736±0.0039)	43 (1.6942)



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.



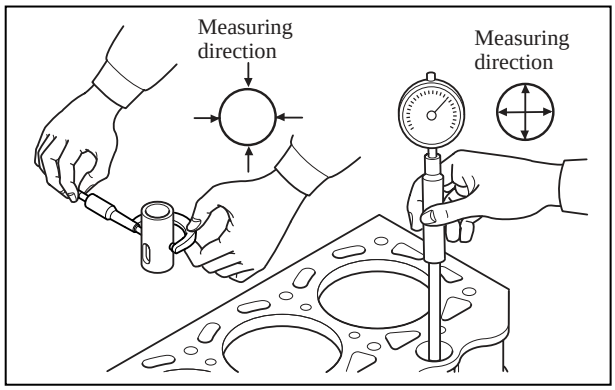
Cam-to-tappet contact

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)



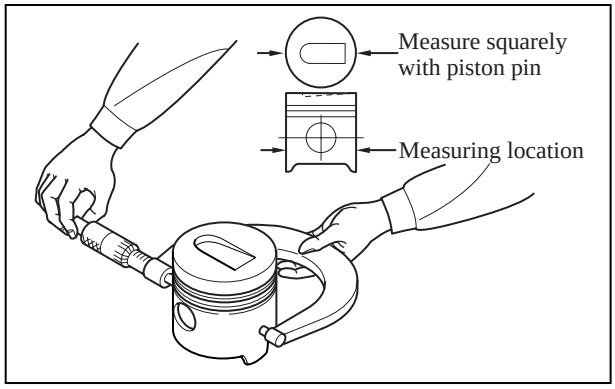
Measuring the clearance between the tappet and the tappet guide

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).



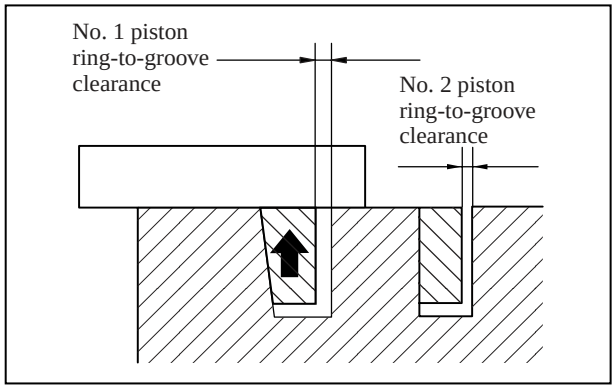
Measuring the piston diameter

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.)

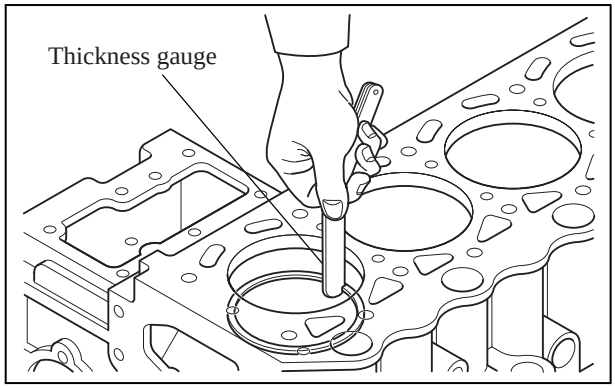
	Standard value	Limit
No. 1 ring	0.09 to 0.11 (0.0035 to 0.0043)	0.300 (0.012)
No. 2 ring	0.07 to 0.11 (0.0028 to 0.0043)	0.200 (0.008)
Oil ring	0.03 to 0.07 (0.0012 to 0.0028)	0.200 (0.008)

(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.)

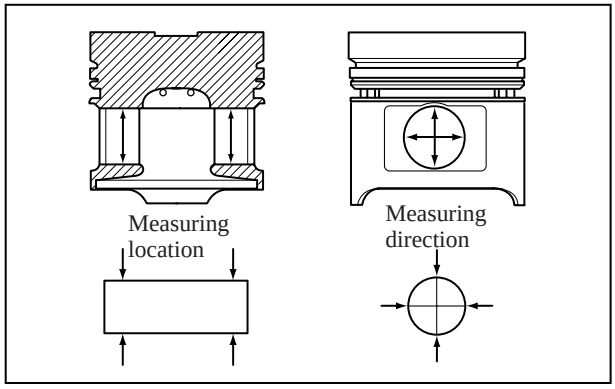
		Standard value	Limit
Piston ring gap	No. 1 ring	0.15 to 0.30 (0.006 to 0.012)	1.50 (0.06)
	No. 2 ring	0.15 to 0.35 (0.006 to 0.014)	
	Oil ring	0.20 to 0.40 (0.008 to 0.016)	

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)



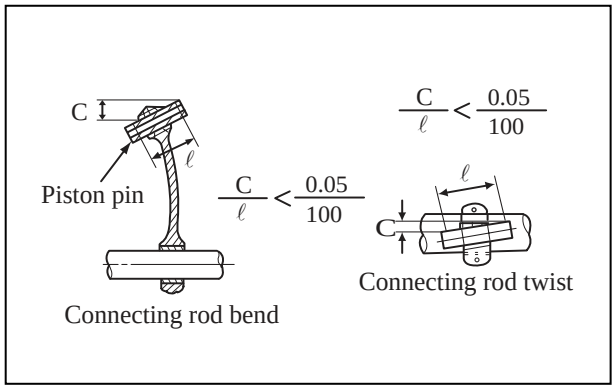
Measuring the piston pin-to-boss clearance

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.)

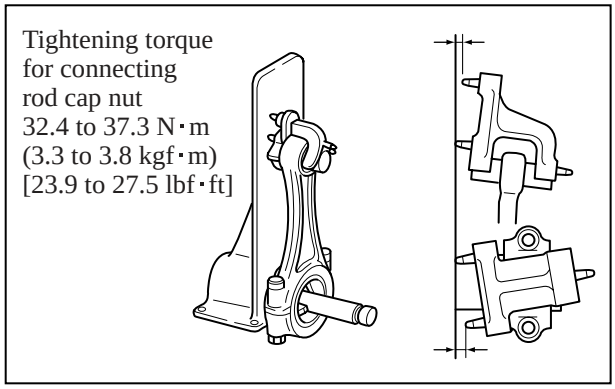
	Standard value	Limit
Connecting rod bend and twist	0.05/100 (0.002/3.940) or less	0.15/100 (0.006/3.940)



Measuring the connecting rod bend and twist

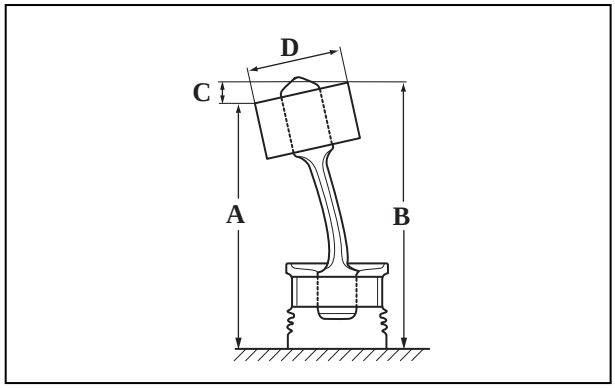
(2) Normally, a connecting rod aligner is used to measure the connecting rod for bend and twist.

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

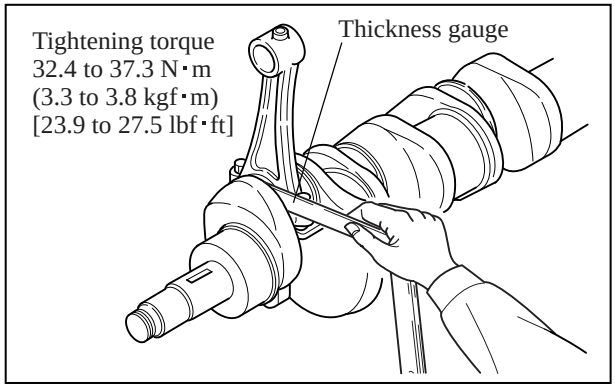
3.6 Measuring the connecting rod end play

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.

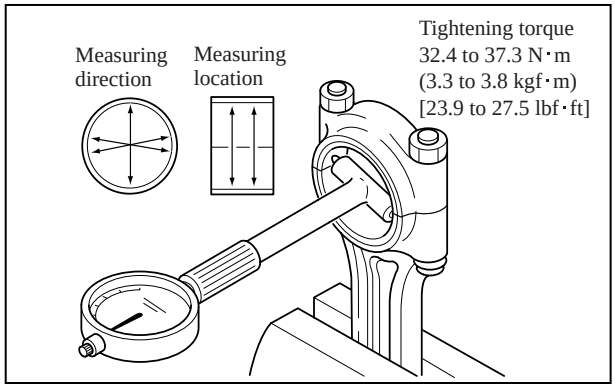
(4) If the measured oil clearance still exceeds the limit, use the undersize bearings [0.25 mm (0.0098 in.), 0.50 mm (0.0197 in.), 0.75 mm (0.0295 in.) U.S.]

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

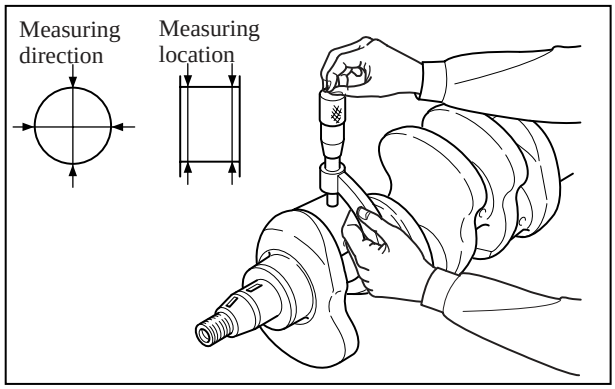
Crank pin ground dimensions

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

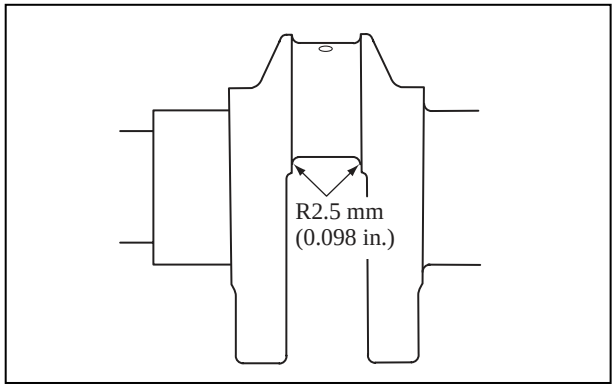


Measuring the crank pin diameter

⚠ 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.).

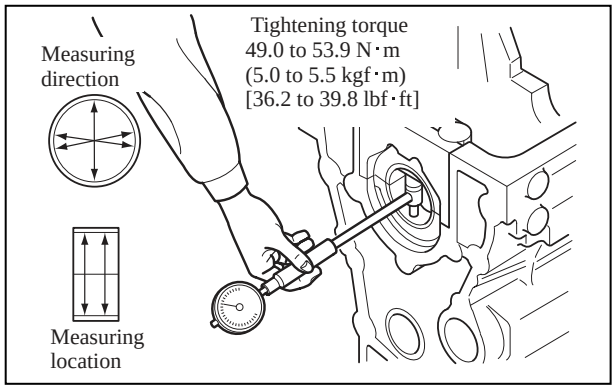


Finished radius dimension of fillet

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

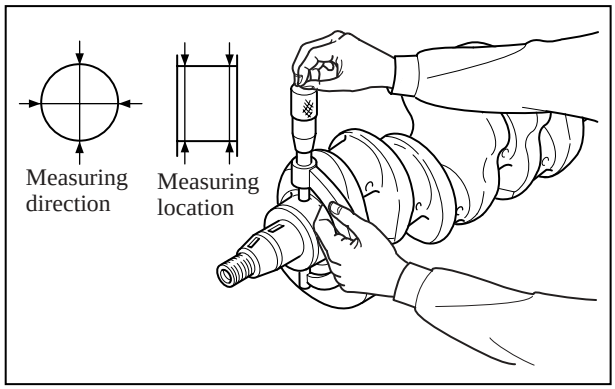
Unit: mm (in.)

	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

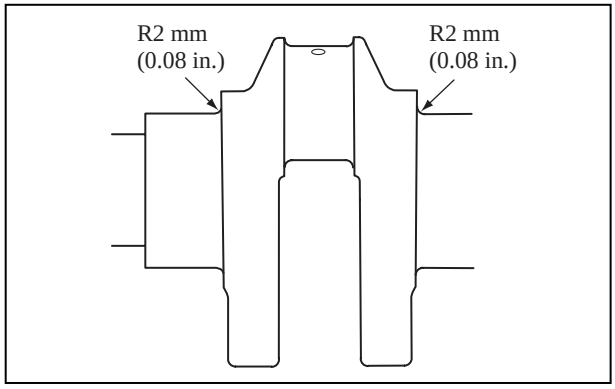
Crank journal ground dimensions

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.).

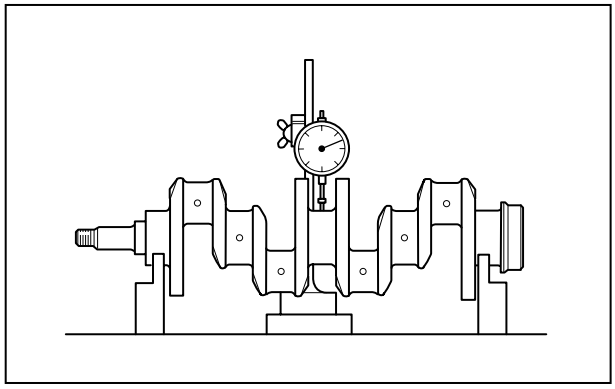


Finished radius dimension of fillet

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

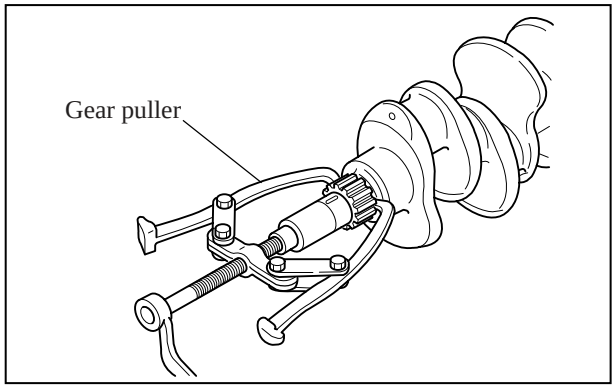
Unit: mm (in.)

	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.

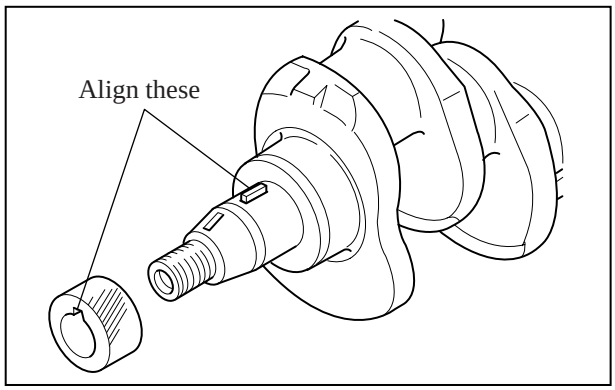
Note: Do not remove the crankshaft gear unless the crankshaft or the gear is faulty.



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.

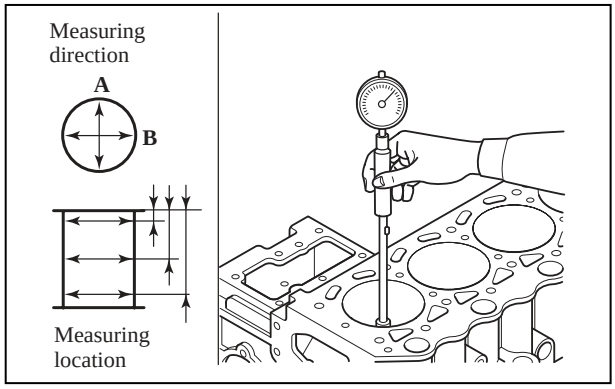


Installing the crankshaft gear

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

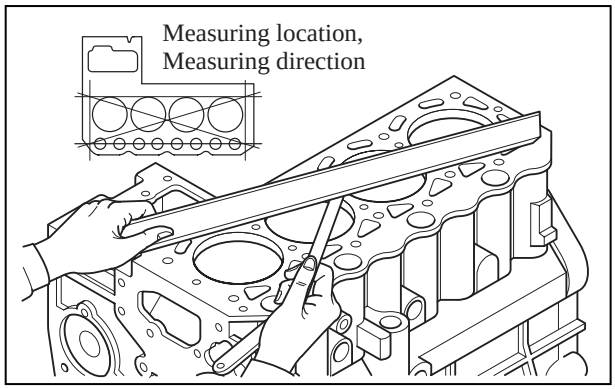
Unit: mm (in.)

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		± 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.).

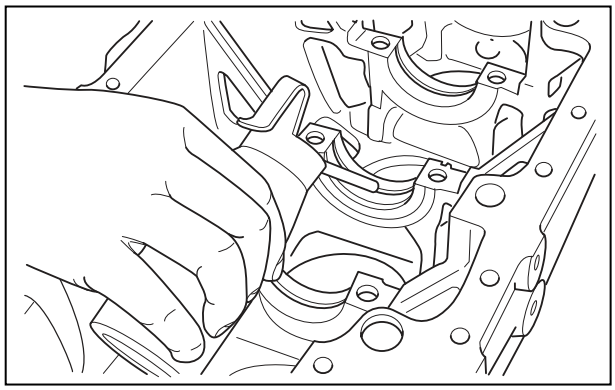
ENGINE MAIN PARTS - REASSEMBLY

1. Cylinder Block, Crankshaft, Pistons, Oil Pan

To reassembly, follow the disassembly sequence in reverse.

1.1 Installing the main bearings

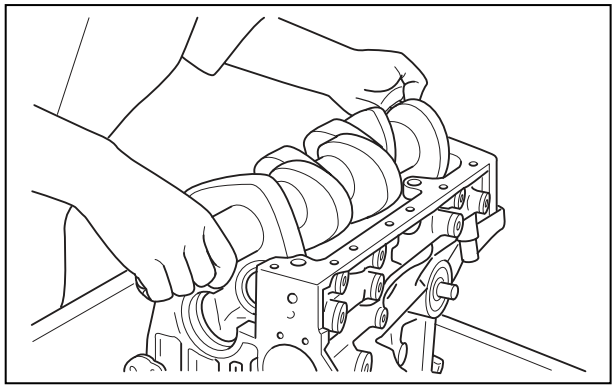
(1) Install the main bearings (upper and lower) onto the cylinder block and the main bearing cap, ensuring that the lugs engage with the lug grooves.
(2) The flanged main bearings should be installed onto the No. 3 crank journal.
(3) Lightly coat the inner surface of each bearing with engine oil.



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.



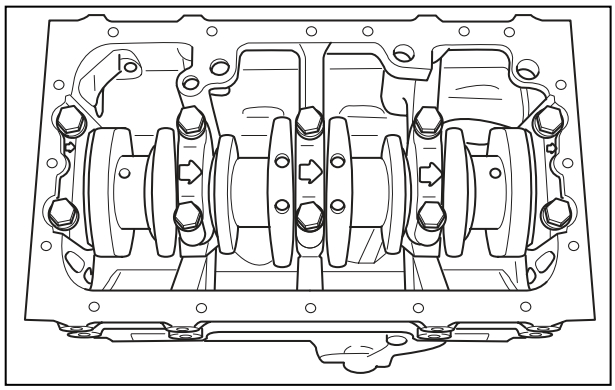
Installing the crankshaft

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

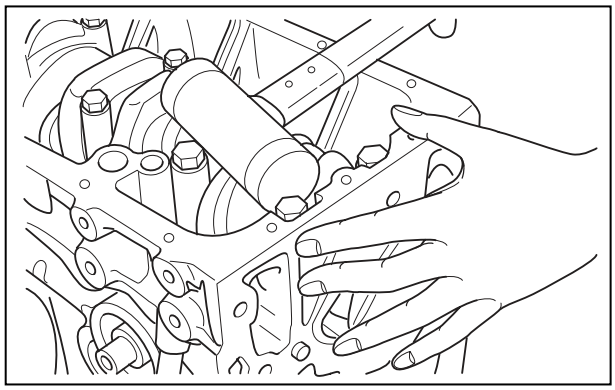
(2) Install the main bearing caps so that their arrow marks point the front of the engine and that the cap numbers are in the order from the front to the rear of the engine.
(3) Loosely tighten the cap retaining bolts.



Correct installation of main bearing caps

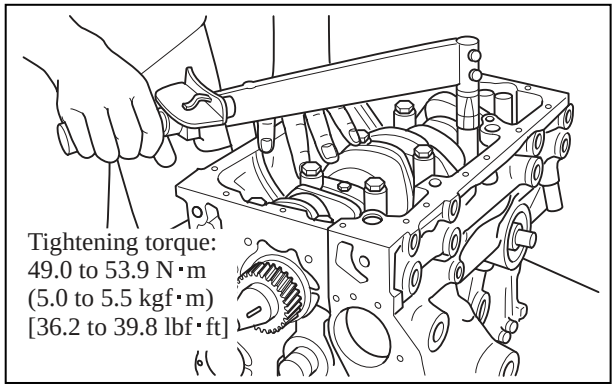
⚠ CAUTION

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



Installing the main bearing cap

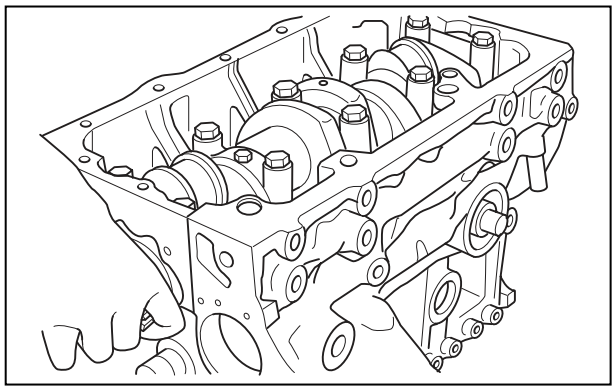
(4) Tighten the main bearing cap bolts progressively in diagonal sequence and tighten to the specified torque at the final step.



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.



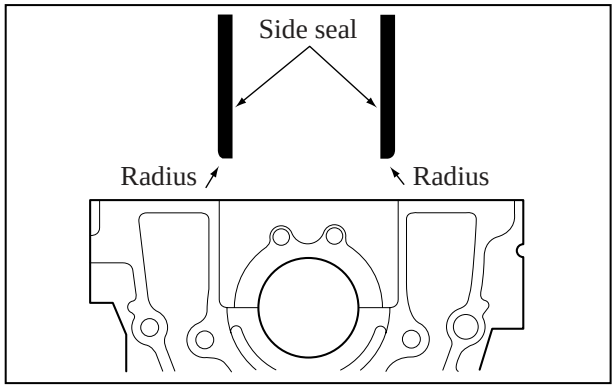
Ensure that the crankshaft rotates smoothly

1.4 Inserting the side seals

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

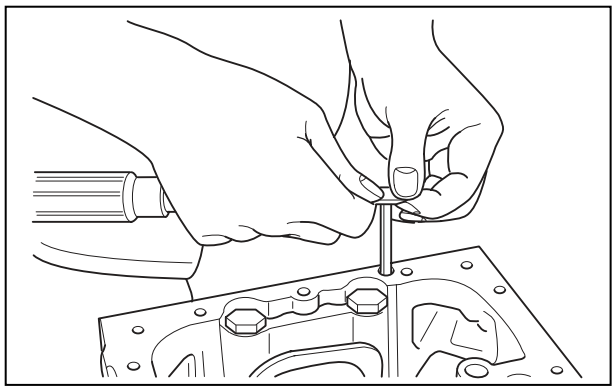
Sealant	ThreeBond 1212

(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