SERVICE MANUAL

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MITSUBISHI
MILLER CYCLE GAS ENGINE
GS16R-PTK

MITSUBISHI HEAVY INDUSTRIES
ENGINE & TURBOCHARGER, LTD.

Foreword

This service manual describes the maintenance and adjustment procedures, and specifications for the Mitsubishi miller cycle gas engine.

To maintain the performance of the engine for many years and to ensure safe operation, it is important to use the engine correctly and conduct scheduled inspection and maintenance, and it may also be necessary to take appropriate measures which involve disassembly, inspection, repair and assembly works of the engine and engine parts.

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

The contents of this manual are based on the engine model produced at the time of publication. Please note that the contents of this manual may change due to improvements made thereafter.

HOW TO USE THIS MANUAL

This service manual consists of several chapters, which will give you quick references to specifications, maintenance standards, adjustment and service procedures including practices to disassemble, inspect, repair and assemble the Mitsubishi miller cycle gas engine.

A short summary describing the contents of each chapter is given in the CHAPTER INDEX page, and there is also a detailed table of contents at the beginning of each chapter.

Regarding the procedures for operation and scheduled maintenance of the engine, refer to the Operation and Maintenance Manual. For information on the engine components and ordering of service parts, refer to the Parts Catalogue. Structure and function of the engine are described in the relevant training manuals.

If you have an inquiry, please check the engine model and serial number, and contact our service department.

Brief summary of the system used in compiling this service manual:

(1) Index numbers allotted to parts in exploded views are not only a call-out of part names listed in the text but also an indication of the sequence of disassembly.

(2) Inspections to be conducted during disassembly process are indicated in boxes in the relevant exploded views.

(3) Maintenance standards required for inspection and repair works are indicated in the appropriate positions in the text. They are also collectively indicated in the Chapter 2.

(4) The tightening torque with engine oil applied on the thread, is specified [Wet]. Unless otherwise specified, the tightening torque is of dry condition.

(5) In this manual, important safety or other cautionary instructions are emphasized with the following head marks.

DANGER	Indicates an immediately hazardous situation which, if not avoided, will result in death or serious injury.
WARNING	Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
CAUTION	Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.
CAUTION	Indicates a potentially hazardous situation which, if not avoided, may result in property damage.
NOTICE	Emphasizes important matter, or indicates information useful for operation or maintenance of the engine.

Terms used in this manual

Nominal value

means the basic nominal size of a part to be measured.

Standard value

means the quantitative requirement for dimension of a part, clearance between parts or performance. The values are rounded off for the inspection job, and do not necessarily conform to the design values.

Limit value

means the value, which the measured value reaches, the part needs repair or replacement with a new one.

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 : Japanese Industrial Standards
- LLC : Long Life Coolant
- MIL : Military Specifications and Standards (U.S.A.)
- MSDS : Material Safety Data Sheet
- SAE : Society of Automotive Engineers (U.S.A.)
- P/N : Part Number

Unit of Measurement

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

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

Safety Cautions

Fire and Explosion Protection

⚠ WARNING

Keep Flames Away

Do not use flames near the engine (in the engine room). The flame is dangerous to ignite combustibles and cause a fire. Wipe off spilled engine oil and LLC immediately and thoroughly. Spilled engine oil and LLC may ignite and cause a fire. Store the engine oil in a well ventilated area. Make sure that the fuel and engine oil container caps are tightly fastened.

Do Not Operate the Engine If Gas Leak Is Noticed

If you notice a gas leak, do not operate the engine. Or stop the engine immediately when the engine is running. Close the main gas valve, call out "FIRE BAN", and ventilate the area quickly. Failure to do so can result in serious accidents such as an explosion and fire, or gas poisoning.

Pay Attention to Gas Pipes

Close the gas main valve and discharge gas completely from the pipes before disassembling the gas pipe system. Serious accidents such as explosion and fire may result, if significant amount of gas remains in the pipe.

Tidy Up Around the Engine

Do not place combustible or explosive material, such as engine oil and LLC or explosive powder near the engine. Such substances can cause a fire or explosion. Thoroughly remove dust, dirt and other foreign material collected on the engine and the area around the engine. Such material can cause a fire or the engine to overheat. In particular, clean the top surface of the battery thoroughly. Dust can cause a short circuit. Always place the engine at a position at least 1 m [3.28 ft.] apart from buildings and other facilities to prevent a possible fire caused by engine heat.

Do Not Open Side Covers Until Engine Cools

Do not try to open the side cover of crank case before the engine cools down. Wait at least 10 minutes after stopping the engine. Opening the cover when the engine is hot allows fresh air to flow into the crank case, which can cause oil mist to ignite and explode.

Pay Attention to Gas, Oil and Exhaust Gas Leak

If any gas, oil or exhaust gas leakage is found, immediately take corrective measures to stop it. Such leakages, if left uncorrected, can cause engine oil to reach hot engine surfaces or hot exhaust gas to contact flammable material, may results in a fire, personal injury and damage to the equipment.

Use Explosion-Proof Light

When inspecting gas, engine oil, coolant, battery electrolyte, and others, use an explosion-proof light. If the lighting is not an explosion-proof type, it may ignite and cause an explosion.

Prevention of Electric Short Circuit

Avoid inspecting or servicing the electrical system with the battery cable connected to the battery. Otherwise, a fire could result from a short circuit. Be sure to disconnect the battery cable from the negative (-) terminal before starting work. A loose terminal and a damaged cable or wire may result in a short circuit and a fire. Inspect, and if any defect is found, repair or replace it before starting work.

Keep Fire Extinguishers and First-Aid Kit Handy

Keep fire extinguishers handy, and become familiar with their usage. Keep a first-aid kit at the designated place to be ready for use in an emergency. Make counteract procedures against a fire or an accident. Provide the contact person and means of communication in case of emergency.

Pay Attention to Gas Leak

Be sure to conduct the maintenance and check of the operation of gas detector and cut-off device based on the facility control standard to prevent gas from leaking. If gas leak is occurred during engine operation, stop the engine immediately, keep flames away and ventilate the room without delay. Be sure to close the fuel gas main valve before a prolonged resting period. Gas leak may results in a serious accident such as explosion and fire. Also it may cause a serious health hazard such as poisoning and suffocation.

Pay Attention to Overhaul

Be sure to replace the gaskets and packings with new ones on the periodical overhauls. Operation without the gasket or packing replacement will results in serious accident by the explosion of explosive gas in crank case.

Pay Attention to Unburned Gas

Close the fuel gas main valve, crank the engine with starter and discharge fuel gas completely from inlet/exhaust pipes and cylinder before re-starting or re-starting after a start stall.

If unburned gas remains in the inlet/exhaust pipes and cylinder on re-starting, it will be ignited and cause explosion, and may lead to personnel injury.

Pay Attention to Smoke Duct Explosion

The flow resistance of smoke duct and exhaust pipe from the gas engine must be the specified value or lower. Do not share the smoke duct and exhaust pipe with high temperature exhaust gas from boiler and others. The exhaust pipe and smoke duct of gas engine may explode and cause a serious accident.

Stay Away From Rotating and Moving Parts

WARNING

Install Protective Covers Over Rotating Parts After Inspection and Maintenance Work

Check the covers over engine rotating parts for correct installation. Repair any damaged or loosed covers. Never remove the protective covers over rotating parts during operation. When the engine is coupled to a radiator or other equipment, install protective covers over the exposed connecting belt and coupling.

Check Work Area for Safety Before Starting

Before starting the engine, make sure that no one is near the engine and that tools are not left on or near the engine. Verbally notify persons within the immediate area when starting the engine. When the starter device is tagged with the warning sign saying DO NOT RUN, never start the engine.

Stay Away From Moving Parts During Operation

Keep away from the rotating parts during operation. Do not leave any objects that may get caught in rotating parts. If clothes or a tool gets caught in rotating parts, serious injury will result.

Lockout and Tagout

Be sure to lockout and tagout before starting inspection and maintenance. Lockout and tagout are effective methods of cutting off machines and equipment from energy sources. To accomplish the lockout/tagout, remove the starter switch key, set the battery switch to the OFF position and attach a DO NOT RUN or equivalent caution tag to the starter switch. The starter switch key must be kept by the person who performs inspection and maintenance work.

Be Sure to Stop Engine Before Inspection/Maintenance

Be sure to stop the engine before proceeding to inspection and maintenance work. Never try to make adjustments on the engine parts while the engine is running. Rotating parts such as belt can reel in your body and cause serious injuries.

Always Put Turning Tool Back in Place After Use

Be sure to remove the turning tool used for inspection and maintenance work. Make sure to pull back the turning gear to the engine running position before starting the engine. If the engine is started with the turning tool inserted or left in the turning condition, it can not only cause a damage to the engine, but also lead to a personal injury.

Prevention of Exhaust Gas Poisoning

⚠ WARNING

Pay Attention to Ventilation When Operating Engine

If the engine is installed in an enclosed area, and the exhaust gas is ducted outside, make sure that duct joints are free from gas leak. Exhaust gas from the engine sometimes contains harmful components. Operating the engine in an ill-ventilated area can cause gas poisoning.

Prevention of Hearing Loss

⚠ WARNING

Wear Ear Plugs

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

Fall Prevention

⚠ WARNING

Lift Engine Carefully

Use slings or wire ropes strong enough to lift the load considering the engine weight. To lift the engine, attach the proper slings to the lifting hangers prepared on the engine. To lift the engine, keep the engine in a well-balanced position, thinking carefully of the engine center of gravity.

The hangers prepared on the engine are designed for lifting the weight of engine only. In the case where the generator, marine gear, and others are installed to the engine, consider that the additional weight will not affect the hangers of the engine.

Keep the angle formed by slings attached to hangers within 60°. If the angle exceeds this limit, excessive load may be applied to the hangers and damage the hangers. If the wire rope contacts the engine part directly, place a cloth or other soft pad to avoid damage to the part and wire rope. Remove the engine part if necessary.

Do Not Climb Onto the Engine

Do not climb onto the engine, nor step on any engine parts on the engine sides. To work on parts located high on the engine, use a ladder, footing, and others to prevent from slipping and falling. Climbing onto the engine may result in engine part damage and your injury by falling down.

Always Prepare a Stable Footing

When working on the upper part of the engine and other hard-to-reach places, use a stable footing. Standing on an old footstool or parts box may result in personal injury. Do not put any unnecessary objects on the footing.

Be Careful When Handling Fuel Gas, Engine Oil or LLC

⚠ WARNING

Use Specified Fuel Gas, Engine Oil and Long-Life Coolant (LLC) Only

Use the fuel gas, oil and LLC specified in this manual only, and handle them carefully. Use of material other than the specified one, or improper handling may cause various engine defects and malfunctions. Get the MSDS issued by the fuel, oil and LLC suppliers, and follow the directions in the MSDS for proper handling.

Be Careful with Coolant

When handling coolant, wear rubber gloves and a protective face mask. If the coolant contacts your skin, or get into your eyes or mouth, it may cause injury of skin or eyes, or poisoning. If coolant is accidentally swallowed, induce vomiting immediately and seek medical attention. If coolant enters your eyes, flush them immediately with plenty of water and seek medical attention. If coolant contacts your skin or clothing, wash it away immediately with plenty of water. Keep flames away from coolant. Coolant can catch flames and cause a fire. Drained coolant is a hazardous material. Do not discard it in an unauthorized procedure. Practice the applicable laws and regulations when discard drained coolant.

Proper Procedure to Discard Waste Oil and Coolant

Do not discard waste engine oil or coolant in an unauthorized procedure. Such a way of disposal is strictly prohibited by laws and regulations. Discard waste oil, coolant and other environmentally hazardous waste in accordance with the applicable laws and regulations.

Burn Protection

⚠ WARNING

Do Not Touch the Engine During or Immediately After Operation

Do not touch any parts of the engine during or immediately after operation. You can get burned. Before starting the maintenance and inspection work, check the water temperature meter to make sure that the engine is cooled down.

Do Not Open Pressure Cap When Engine is Hot

Never open the pressure cap while the engine is running or immediately after the engine stop. Stop the engine and give a sufficient time to allow the coolant to cool down before opening the cap. When opening the pressure cap, slowly open the cap so as to release the internal pressure. To prevent hot steam scald, wear thick rubber gloves, or cover the cap with a cloth. When closing the pressure cap, tightly close the cap. Do not open the pressure cap during engine running or immediately after the engine stop. Otherwise hot steam and coolant gush out and can cause burns.

Refill Coolant Only After the Coolant Temperature Dropped

Refill the coolant after the coolant temperature drops to a room temperature. Replacement job immediately after the engine stop may cause burns.

Do Not Remove Heat Shields

The exhaust system, which becomes extremely hot while the engine is running, is provided with various heat shields. Never remove the heat shields. If any of these heat shields were inevitably removed for the inspection and maintenance, be sure to install them after the work.

Burn Prevention When Changing Oil

Wear gloves when draining oil or changing oil filters. If your skin contacts hot oil or hot parts, you get burn injury.

Battery Safety Precautions

⚠ CAUTION

Be Careful When Handling Battery

- Never use flames or generate sparks near the battery. The battery gives off highly flammable hydrogen gas and oxygen gas. Any flame or spark near a battery may cause an explosion.
- Do not use the battery if its fluid level is below the lower limit line. Wrong use of the battery may result in an explosion.
- Do not short the battery terminals with a tool or other metal object.
- When disconnecting battery cables, always remove from negative (-) terminal first. When reconnecting the cables, always connect the positive (+) terminal first.
- Charge the battery in a well-ventilated area, with all battery cables removed.
- Make sure the cable clamps are securely fastened to the battery terminals. A loose terminal can cause sparks that may result in an explosion.
- Before servicing electrical components or conducting electric welding, set the battery switch to the [Open/OFF] position or disconnect the cable from the negative (-) battery terminal to cut off the electrical current.
- Electrolyte (battery fluid) contains dilute sulfuric acid. Careless handling of the battery may lead to the loss of sight and/or skin burns. Also, do not swallow battery fluid.
- Wear protective goggles and rubber gloves when working with the battery (such as adding water or charging).
- If battery electrolyte is spilled onto the skin or clothing, immediately wash it away with lots of water. Use soap to clean thoroughly.
- Battery fluid can make you blind if splash into your eyes. Immediately flush it away with plenty of clean water, and seek immediate medical attention.
- If battery fluid is accidentally swallowed, gargle with plenty of water, then drink lots of water, and seek immediate medical attention.

When Abnormality Occurs

⚠ CAUTION

Do Not Add Coolant Immediately After a Sudden Stop Due to Overheating

If the engine stops suddenly due to overheating, or you suddenly stop the engine by any reason, do not add coolant immediately. If coolant is added immediately, parts such as cylinder heads can be damaged due to the sudden drop of temperature. Add coolant slowly after the engine becomes cool.

Be Careful When Starting After an Abnormal Stop

If the engine stops abnormally, do not restart the engine immediately after the stopping. If the engine stops or is stopped, inspect the engine to clarify the cause of the defect and correct the cause before restarting. If the engine is kept operating in such a condition, it can result in serious engine failure.

When the Engine Oil Pressure Decreases, Stop the Engine Immediately

If the engine oil pressure drops significantly, stop the engine immediately, and inspect the lubrication system to find the cause. Continuous engine operation with low oil pressure may cause bearings and other parts to seize.

Other Precautions

⚠ CAUTION

Do Not Tamper

If tampered, the warranty is totally void even in the warranty period. Tampering with the engine can not only damage the engine but also may lead to personal injury.

Perform Pre-Operation Inspection and Periodic Inspections

Conduct the daily inspection and periodic inspection/ maintenance as described in this manual.

Failure to conduct the specified inspections may cause various engine problems, damage to parts, and a serious accident.

Wear Proper Work Clothing and Protective Gears

Wear a hard hat, a face shield, safety shoes, a dust mask, gloves, ear plugs and other protective gears as needed. When using compressed air, wear ear plugs, safety goggles, a hard hat, gloves and other necessary protective gears. Works without wearing proper protective gears may result in serious injury.

Check the Engine After Operation

After the engine operation, check each part of engine once again. If any defect is found, correct immediately.

Break-in the Engine

To break-in a new engine or an overhauled engine, operate the engine at a speed lower than the rated speed in a light load condition during the first 50 hours of operation. Operating a new engine or an overhauled engine in a severe condition during the break-in period shortens the service life of the engine.

Warm-Up the Engine Before Use

After starting the engine, run the engine at a low idling speed for warming-up, Start the work after the coolant temperature is raised. Warm-up operation circulates lubricant in the engine, and works for the longer service life and economical operation. Do not continue the warm-up operation for a longer time than necessary. Long warm-up operation causes carbon deposits in the cylinders, and may lead to incomplete combustion.

Cool Down the Engine Before Stopping

Cool down the engine at a low idling for five to six minutes before stopping it. Stopping the engine immediately after a high-load operation will cause local heat up of engine parts and shorten the service life of the engine. During the cooling operation, check the engine for abnormalities.

Do Not Splash Water on Engine

Use care to protect engine from water such as rain entering through the air inlet or exhaust openings. Do not wash the engine while it is running. Cleaning fluid or water can be sucked into the engine. Starting the engine with water inside the combustion chamber can cause the water hammering, and may result in engine inner parts damage and serious accident.

Air Cleaner Maintenance Precautions

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

- Do not service the air cleaner during operation. Foreign material enters the turbocharger and may result in a serious failure.
- Remove the air cleaner slowly to prevent foreign substances on the element from falling off. After removing the air cleaner, cover the opening (inlet port of air cleaner) with plastic sheet or similar means to prevent dust from entering the engine.
- An air cleaner with a dust indicator gives an alarm when it is clogged. Conduct the maintenance when the alarm is given.

Obey Safety Rules at Work Site

Obey the safety rules established at the workplace when operating and maintaining the engine. Do not operate the engine if you are in bad health. Consult your supervisor about your condition. Operation of the engine with decreased attention may cause improper operation and results in an accident. When working in a team of two or more people, use specified hand signals to communicate among workers.

Use Proper Tools for Maintenance Work

Always keep in mind to select most appropriate tools for the work, and use them correctly. If a tool is damaged, replace it with a new tool. Do Not Operate Starter Continuously

Do not use the starter for more than 10 seconds at a time. If the engine does not start, wait for at least 1 minute before starting again. Continuous operation of the starter to start a stubborn engine may lead to a flat battery or starter burning out.

Do Not Turn Off the Battery Switch During Operation

Do not turn off the battery switch during operation. The indicators will not operate when battery switch is turned off during operation.

Engine Transportation Precautions

To road-transport the engine, consider the engine weight, width and height, and obey applicable laws and regulations such as road traffic laws, vehicle road acts and vehicle restriction ordinances.

Cautions for Continuous Low-Load Operation

Prolonged low-load operation, at 50% or below, will allow lubrication oil to enter the cylinder. This will cause contamination of the combustion chamber, which affects adversely the engine life. And unburnt gas discharge may result with the worsened combustion condition. So, the low-load operation is not recommended except the occasions of emergency such as a blackout. Clean the combustion chamber by operating the engine at a load of 70% or higher for two hours after the low-load operation.

Pay Attention to Engine Room Ventilation

Always keep the engine room well-ventilated. Insufficient intake air amount of the engine can cause an increase in the engine temperature, and could result in a decrease in the output power and poor performance. It is highly recommended to calculate the required amount of air supply to the engine and install an adequate ventilation system before installing the engine.

Warning Labels

CAUTION

Maintenance of Warning Labels

Make sure all warning/caution labels are legible.

Clean or replace the warning or caution label when the description or illustration is not clear to read.

For cleaning the warning/caution labels, use a cloth, water and soap. Do not use cleaning solvent, gasoline or other chemicals to prevent the label from fading and peering.

Replace a damaged or missing label with a new one.

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

To get new warning labels, contact your MHI dealer.

Common Warning Labels

Points on Disassembling and Assembling

This service manual contains the recommended practices to service the engine. The manual also contains dedicated special tools made for the work, and the basic safety cautions to obey when working. Note that this manual does not cover all potential hazards that could occur during maintenance, inspection and service works of the engine.

When working on the engine, follow the related instructions in this manual and also be careful about following points:

Points on Disassembling

- Use correct tools and instruments. Or serious damage or accident may result.
- Do not use jack bolts having sharp edge, as they may cause damage to the surface.
- Use a footing and workbench to place disassembled parts if necessary, and obey the disassembling procedures described in this manual. Do not place the parts on the floor directly. Place them on a workbench or the like.
- Place the engine parts in the order of removal to prevent from missing. Place the parts in the serial order for reassembling.
- When reusing the engine parts, unless there are special reasons, install them to their original positions.
- Pay attention to assembling marks. Put your marks on the parts, if necessary, to ensure correct assembling.
- Carefully check each part for defects during disassembling or cleaning. Do not miss the chance to find symptoms which can not be found after disassembling or cleaning.
- Pay attention to the safety, especially for the balancing of disassembled parts and carrying of heavy parts. (Get the help, and use jacks, chain blocks and guide bolts as necessary.)
- Use protective gloves when you touch overheated or frozen parts. Touching such a part with a bear hand can cause burns.

Points on Assembling

- Wash all engine parts, except such parts as oil seals, O-rings and rubber seats, in cleaning oil, and dry them with compressed air.
- Use correct tools and instruments.
- Use only high-quality lubricating oil and grease of the appropriate type. Be sure to apply oil, grease or adhesive to specified surfaces.
- Use a torque wrench to tighten parts correctly when their tightening torques are specified. Refer to "Tightening torque table."
- Replace gaskets, packings and O-rings with new ones. Apply adhesive as required. Do not apply adhesive too much.
- Use protective gloves when you touch overheated or frozen parts. Touching such a part with a bear hand can cause burns.

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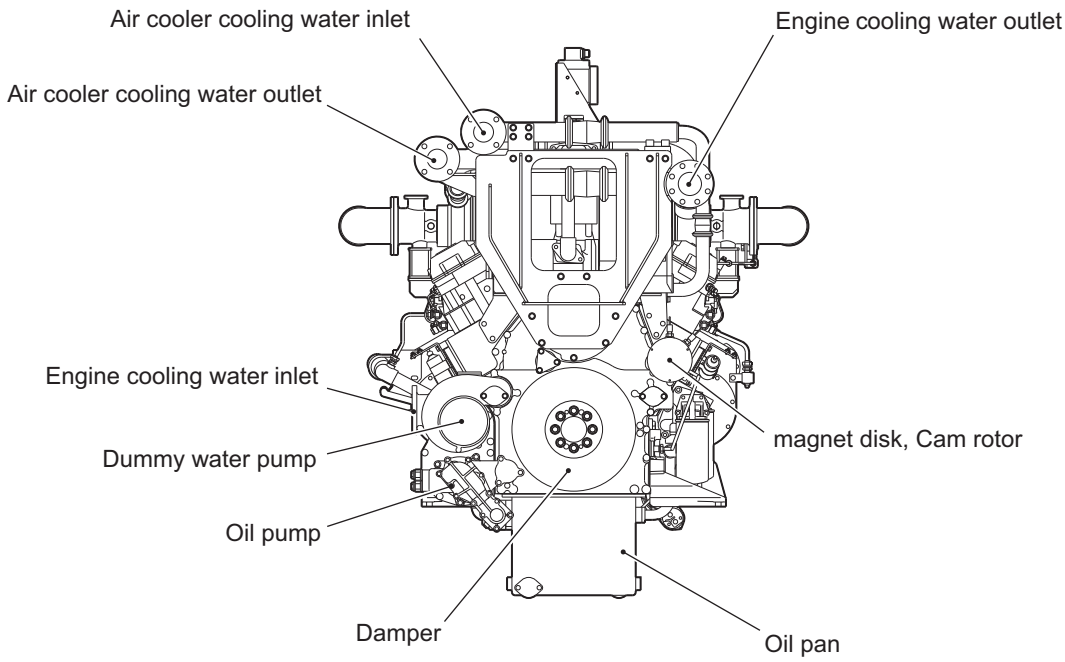
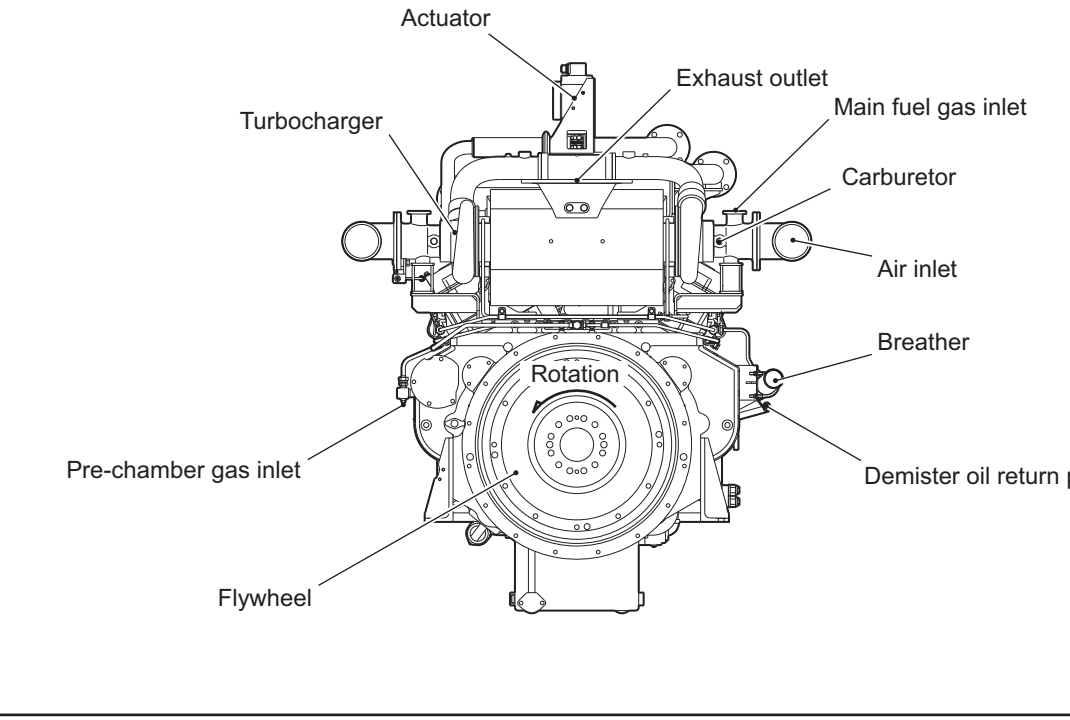
Chapter 1 GENERAL

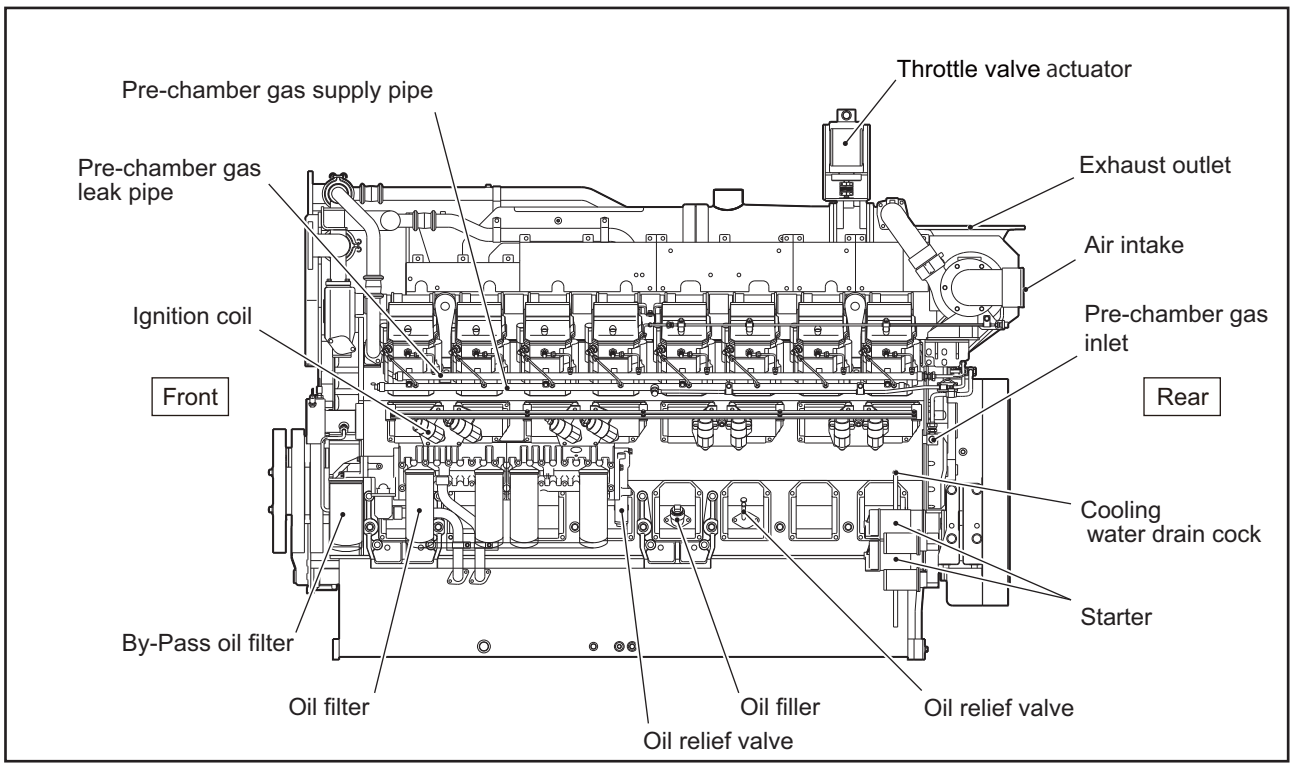
1. External View



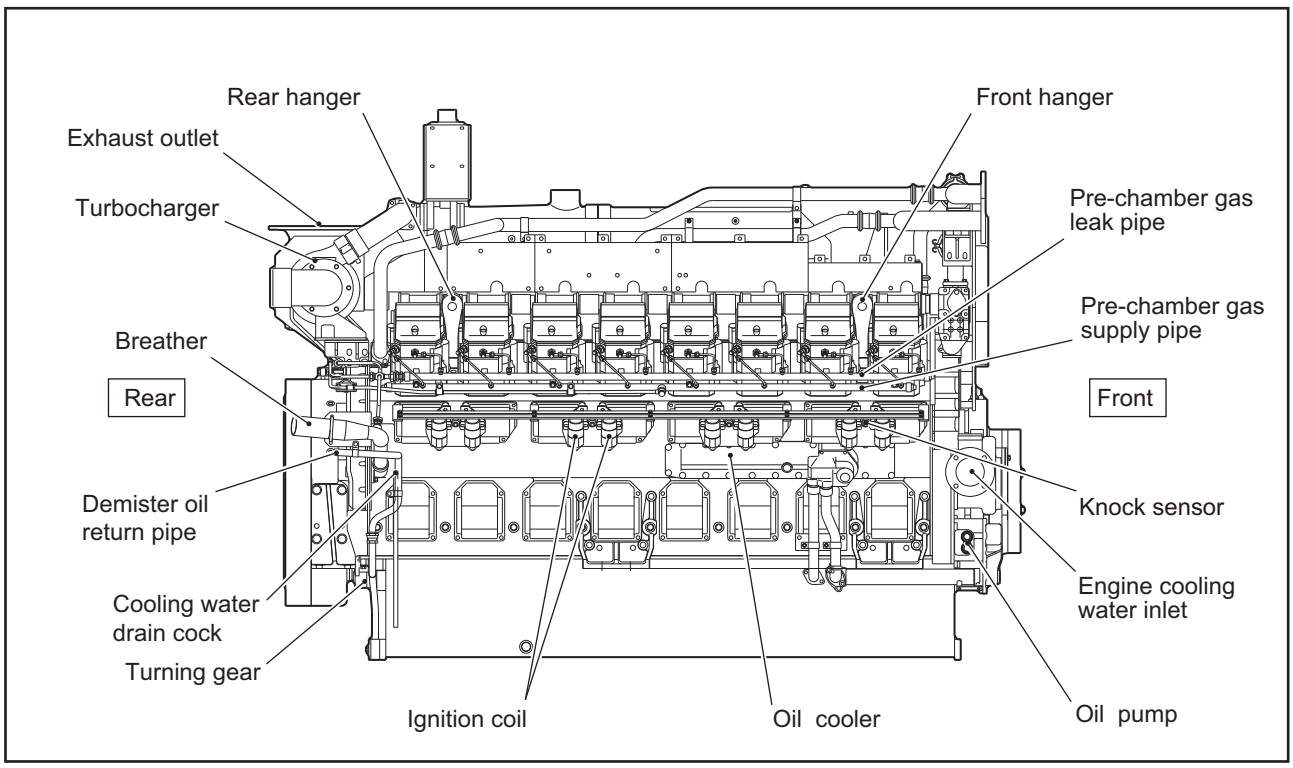
Engine Front View



Engine Rear View



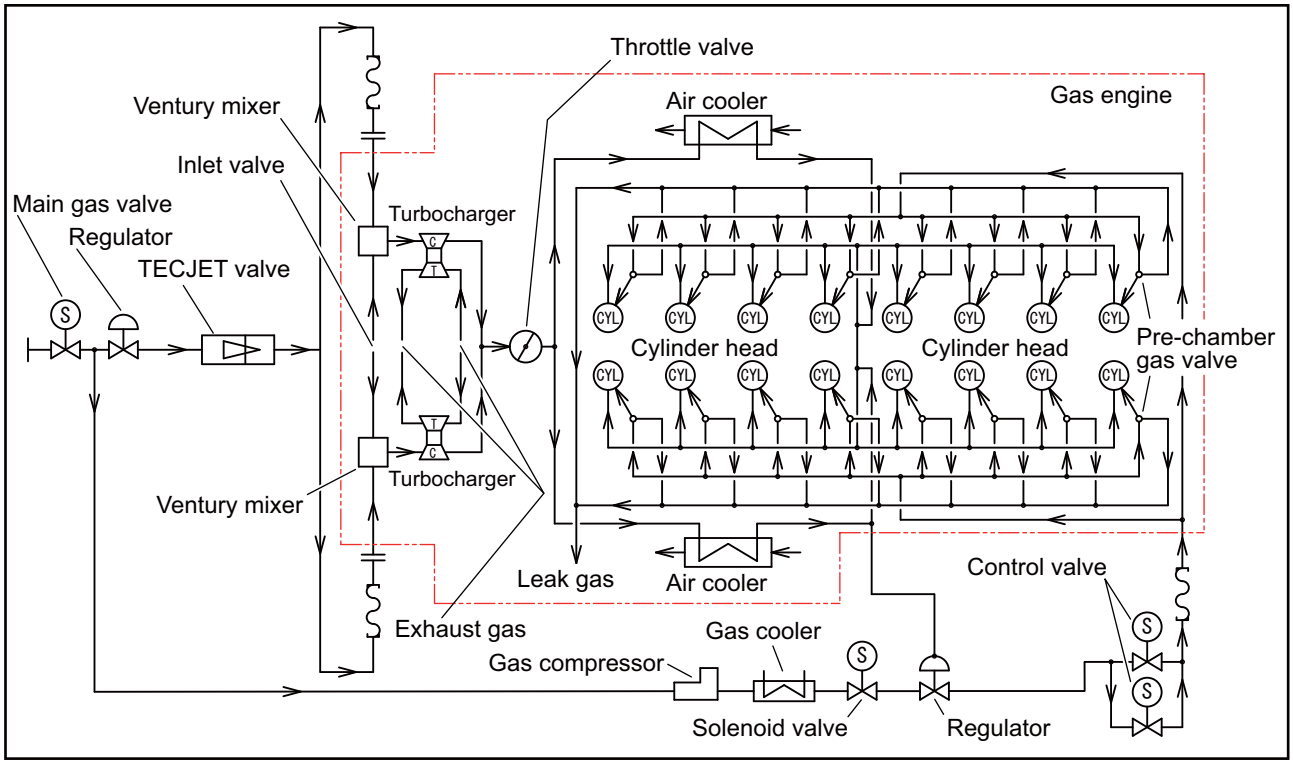
Left Side View



Right Side View

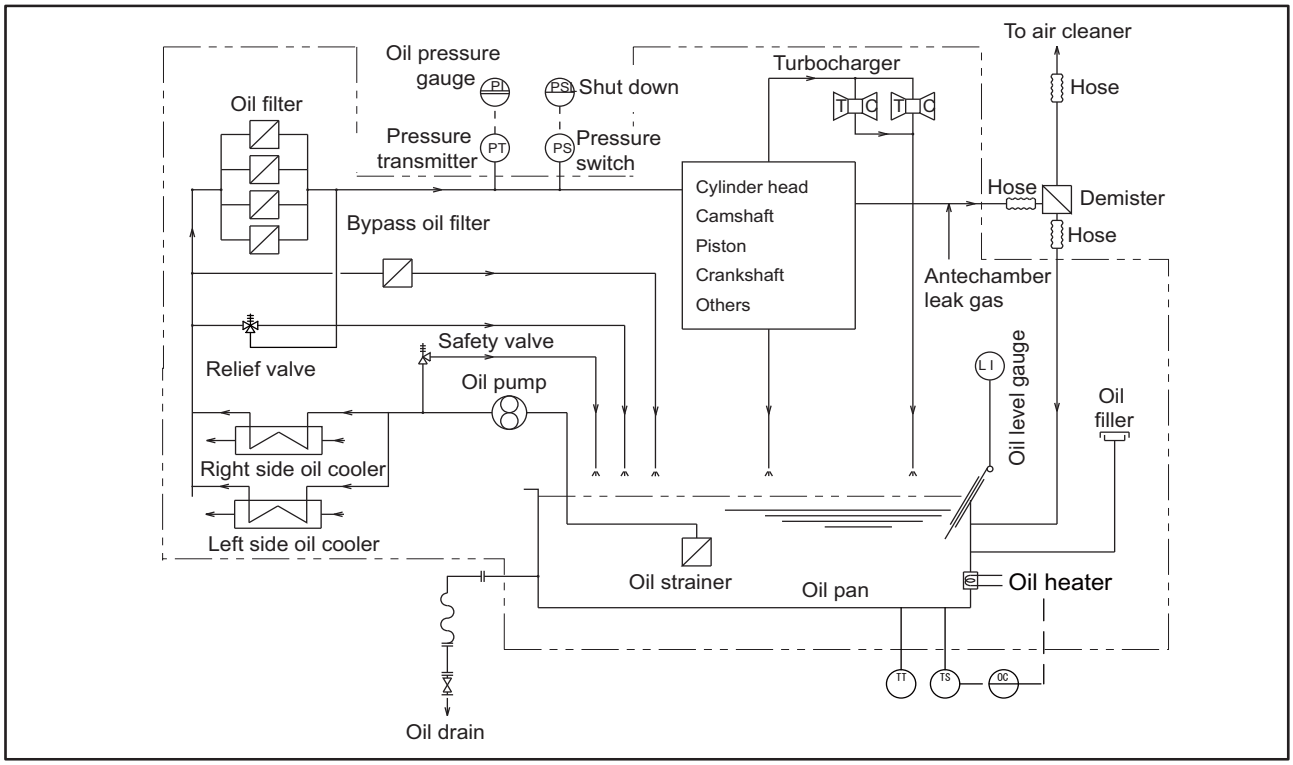
2. Outline of Systems

2.1 Outline of Fuel System



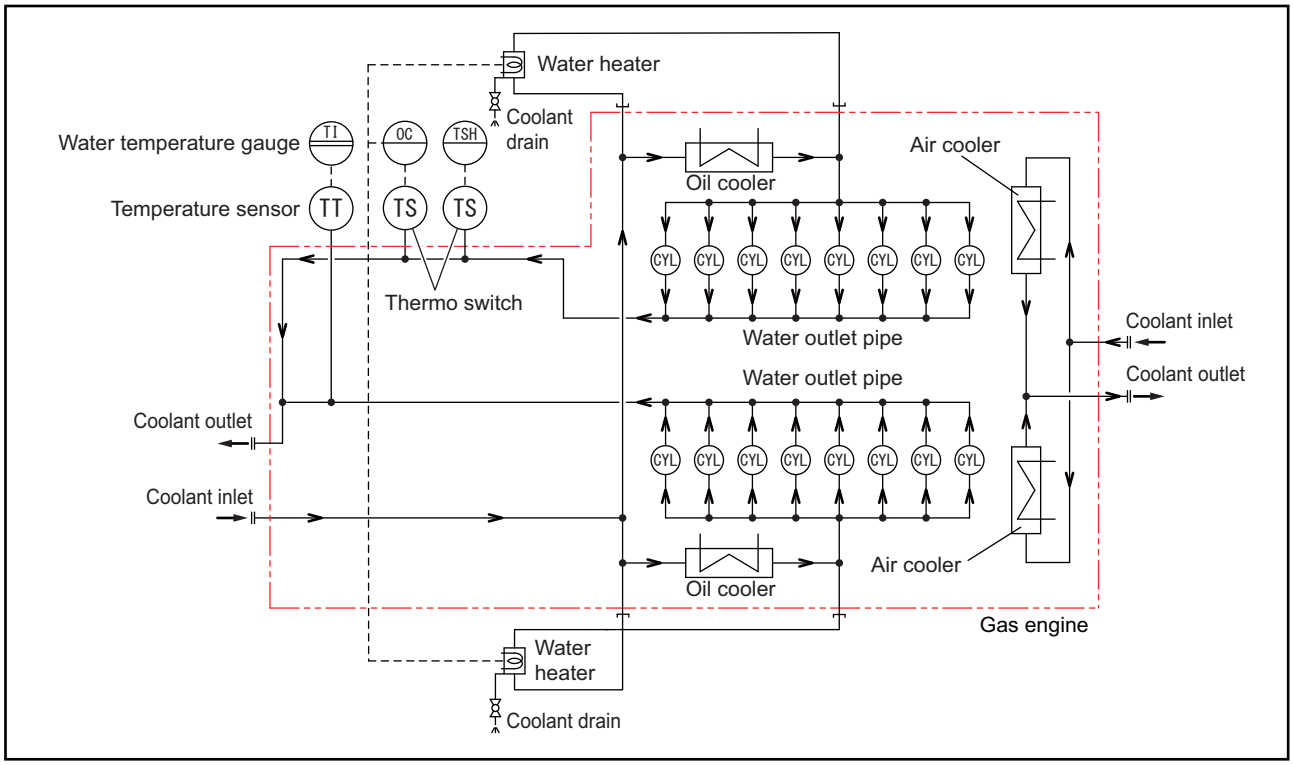
Outline of Fuel System

2.2 Outline of Lubrication System



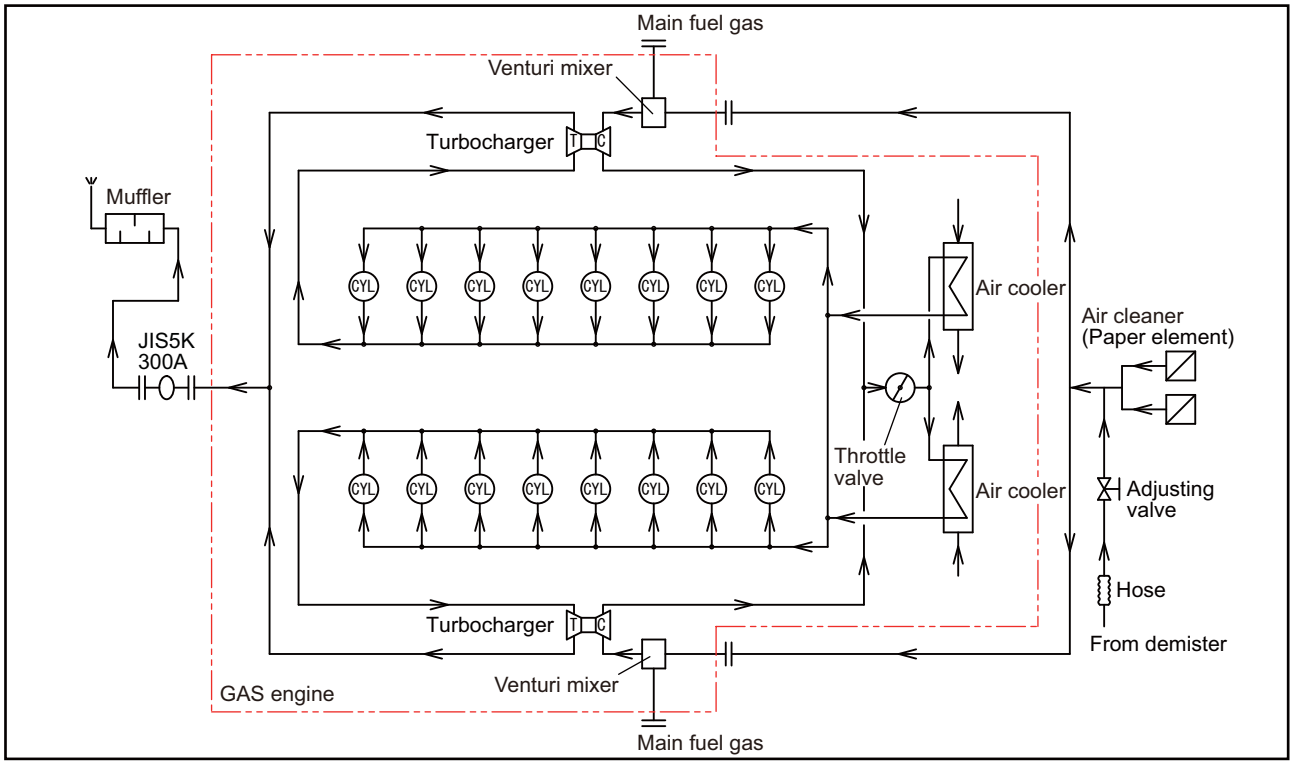
Outline of Lubrication System

2.3 Outline of Cooling System



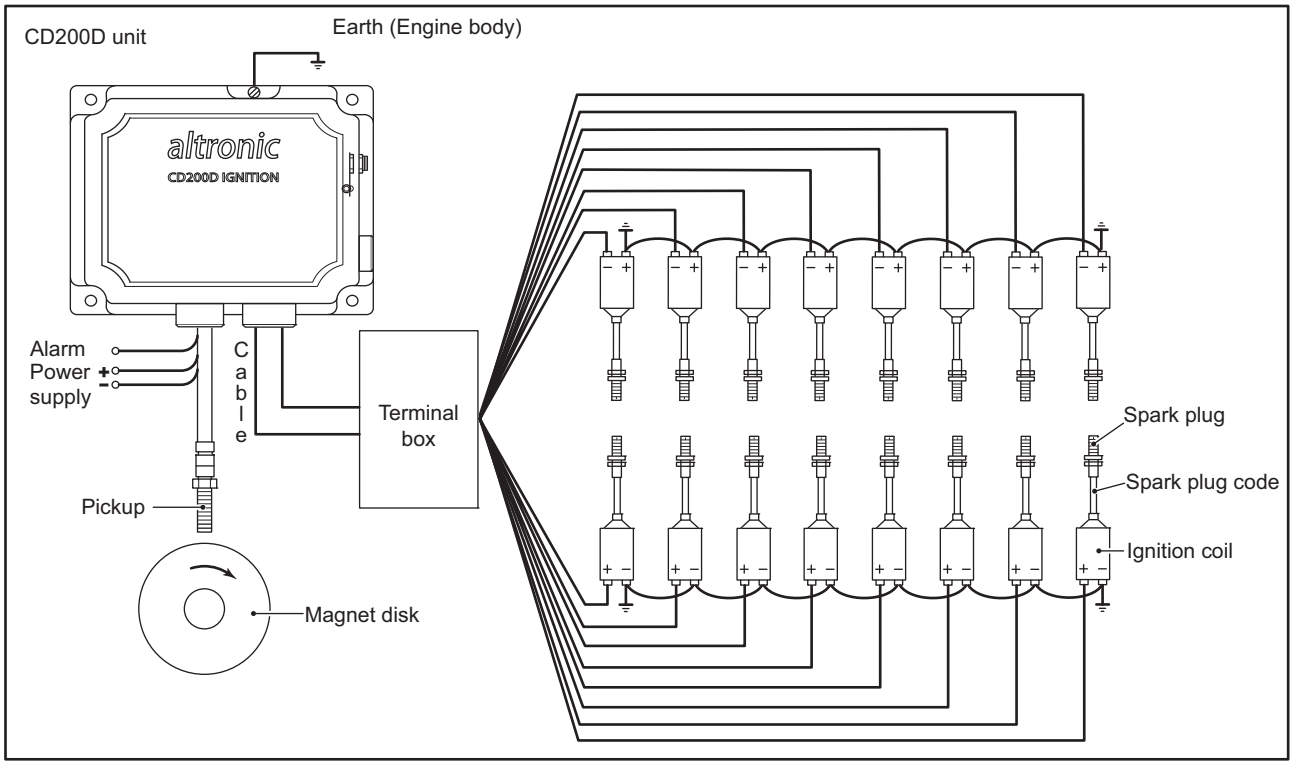
Outline of Cooling System

2.4 Outline of Inlet and Exhaust System

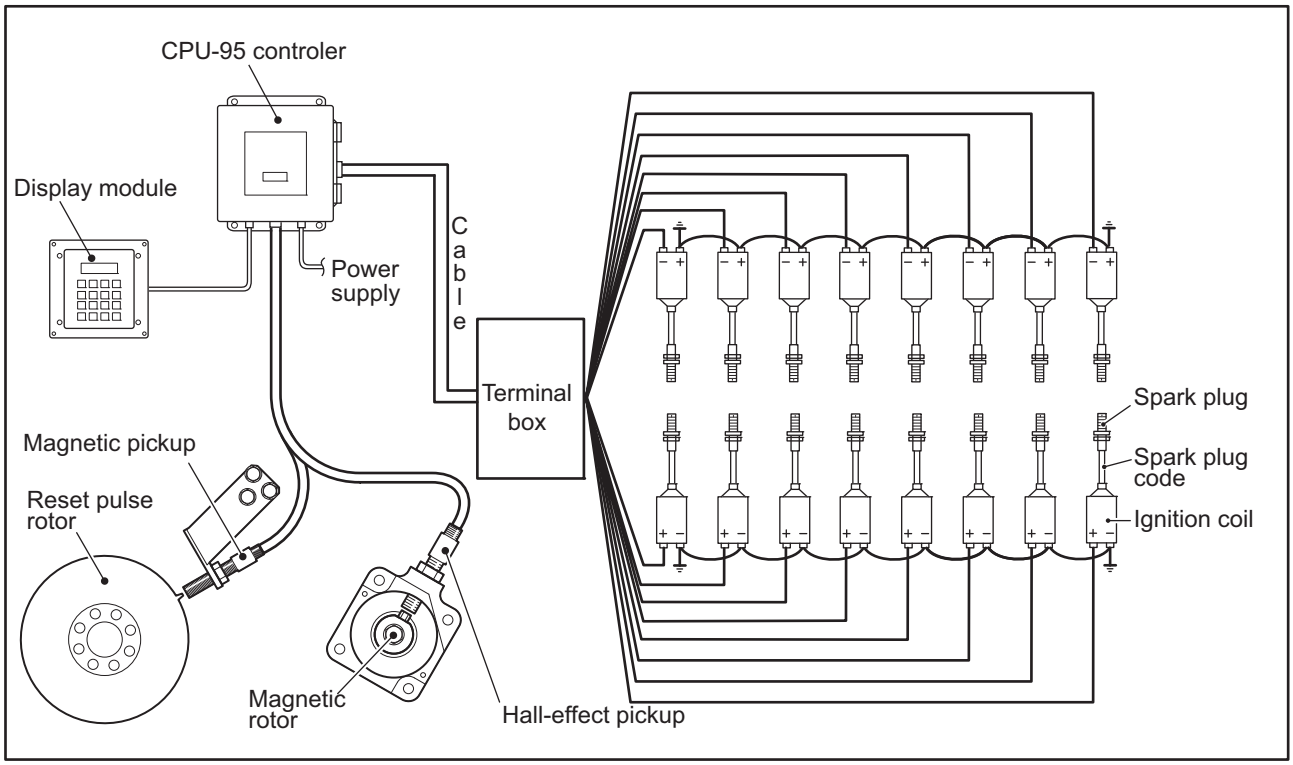


Outline of Inlet and Exhaust System

2.5 Outline of Ignition System



Outline of Ignition System (CD200D)



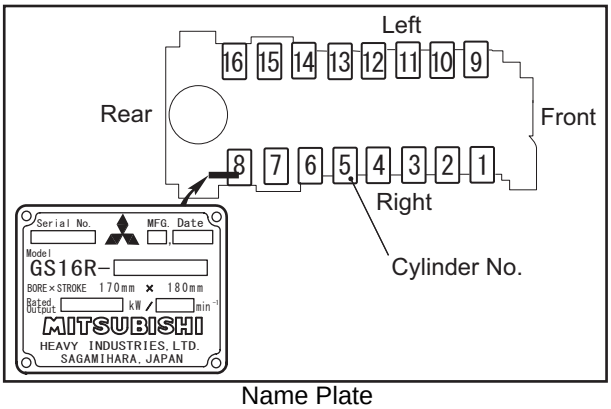
Outline of Ignition System (CPU-95)

3. Indications of Plate and Label

3.1 Name Plate

The name plate is located on the lateral side of the engine, and indicates the following information:

- Engine serial number
- Manufactured date
- Engine model name
- Bore x stroke
- Engine rated output and speed



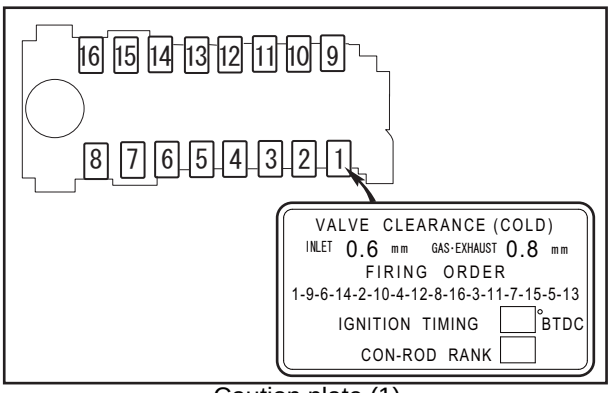
Name Plate

3.2 Caution Plate

The caution plate is located on the top face of the rocker cover of No. 1 cylinder and indicates the following information:

3.2.1 Caution plate (1)

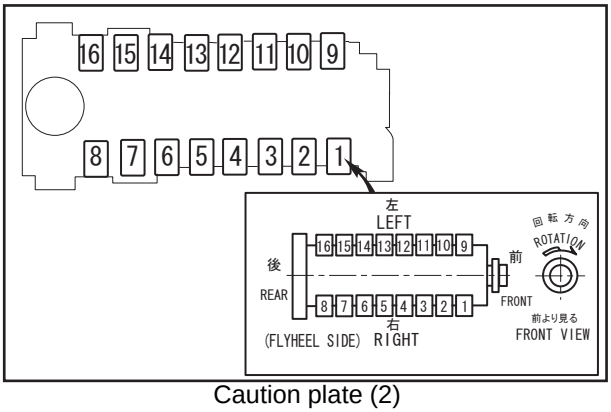
- Valve clearance
- Firing order
- Ignition timing
- Connecting rod weight rank



Caution plate (1)

3.2.2 Caution plate (2)

- Front/rear and right/left positions
- Cylinder Number
- Direction of rotation



Caution plate (2)

4. Specifications

Engine model		GS16R-PTK	
		1200 min^{-1}	1500 min^{-1}
Type		Water cooled, 4 stroke cycle, Miller cycle engine turbocharged with air cooler	
No. of cylinders - arrangement		16-V	
Combustion system		Spark-ignition lean-burn engine with pre-chamber	
Valve mechanism		AD Miller cycle	
Cylinder bore x stroke		170 × 180 mm [6.69 × 7.09 in.]	
Total displacement		65.37 L [3989 cu.in.]	
Compression ratio (from bottom dead center)		15.0 : 1	
Fuel		City gas 13A	
Firing order		1-9-6-14-2-10-4-12-8-16-3-11-7-15-5-13	
Direction of rotation		Counterclockwise as viewed from flywheel side	
Dimensions	Length	2933 mm [115.47 in.]	2876 mm [113.23 in.]
	Width	1820 mm [71.65 in.]	1820 mm [71.65 in.]
	Height	2137 mm [84.13 in.]	2137 mm [84.13 in.]
Dry weight		6830 kg [15057.6 lb.]	6770 kg [14925.3 lb.]
Ignition system	Output unit	ALTRONIC CD200D or CPU-95	
	Ignition coil	ALTRONIC 501 061	
	Spark plug	DENSO GK2-2 gap 0.22 mm [0.0087 in.], NGK T7415X gap 0.3 mm [0.0118 in.]	
Knock detection system		ALTRONIC DET-1600	
Integrated control system	Controller	W/W ECM3	
	Fuel gas control	W/W TECJET 52	
	Air-fuel mixture control	W/W PROACT4 ISC	
	Pre-chamber gas control	Flow control valve	
Lubrication method		Forced circulation (oil pump pressure feed system)	
Engine oil	Standard	JX Nippon Oil & Energy TES GXL-193B(SAE#40), KH40 (M) (SAE#40) IDEMITSU Apolloil Co-gene Alpha CG40M (SAE#40)	
	Volume	Engine total: approx. 385 liters [101.7 US gal.] (Oil pan: approx. 355 L [93.79 US gal.], Level gauge between H-L 60 L [15.85 US gal.])	
Oil pump	Type	Gear pump type	
Relief valve	Type	Piston valve type	
Oil cooler	Type	Water cooled multi-plate type (integrated in the crankcase)	
Full-flow oil filter	Type	Cartridge type paper element	
Bypass oil filter	Type	Cartridge type paper element	
Cooling method		Forced-circulation water cooling with external pump	
Coolant volume (engine body)		Approx. 170 liters [44.9 US gal.]	
Turbocharger	Model	TD13	
	Quantity	2 units	
Voltage, grounding method		24V, earth type (single wire type)	
Starter	Model number	Nikko Electric Industry 0-23000-8440	
	Type	Pinion shift type (reduction type) 7.5 kw × 2 pcs	

Chapter 2 SERVICE DATA

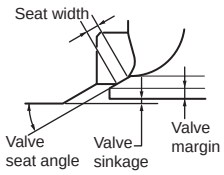
1. Maintenance Service Data

1.1 General Maintenance Service Data of Engine

Item		Nominal value	Standard value	Limit value	Remark
Maximum speed		5 to 10 % higher than rated speed		Faulty if lower or 15 % higher than rated speed	The rated speed is stamped on the name-plate.
Minimum speed		600 to 650 min^{-1}			
Compression pressure		2.6 MPa {26.5 kgf/cm²} [377.1 psi]		1.95 MPa {19.9 kgf/cm²} [282.82 psi]	Approx. at 120 min^{-1}
Engine oil pressure	Rated speed	0.49 to 0.64 MPa {5.00 to 6.53 kgf/cm²} [71.07 to 92.82 psi]		0.39 MPa {3.98 kgf/cm²} [56.56 psi]	When oil temperature is 60 to 70 ºC [140 to 158 ºF]
	Idling	0.20 to 0.29 MPa {2.04 to 2.96 kgf/cm²} [29.01 to 42.06 psi]		0.10 MPa {1.02 kgf/cm²} [14.50 psi]	
Valve timing	Inlet opening	BTDC 5.5°	±2° (crank angle)		When valve clearance is 2 mm [0.08 in.] (the value to check valve timing)
	Inlet closing	BBDC 44°			
	Exhaust open	BBDC 28.5°			
	Exhaust close	BTDC 8°			
Valve clearance (when cold)	Inlet		0.6 mm [0.024 in.]		
	Exhaust		0.8 mm [0.032 in.]		
	Pre-chamber		0.8 mm [0.032 in.]		
Ignition timing		BTDC	±1° (crank angle)		Varies according to specifications. Refer to the caution plate on No. 1 rocker cover.

1.2 Maintenance Service Data of Engine Body

Unit: mm [in.]

Item			Nominal value	Standard value	Limit value	Remark
Rocker	Rocker bushing inside diameter		ø36 [1.42]	36.000 to 36.040 [1.4173 to 1.4189]	36.090 [1.4209]	
	Rocker shaft outside diameter		ø36 [1.42]	35.966 to 35.991 [1.4160 to 1.4170]	35.940 [1.4150]	
Valve	Valve stem outside diameter		ø10 [0.39]	9.940 to 9.960 [0.3913 to 0.3921]	9.910 [0.3902]	
	Valve guide inside diameter		ø10 [0.39]	10.000 to 10.015 [0.3937 to 0.3943]	10.140 [0.3992]	Same for both inlet and exhaust valves
	Valve bridge lower face to valve rotator top face clearance			1.5 [0.059] or more		
Valve seat ring and valve	Valve seat angle		30°	29°45' to 30°15'		
	Valve sinkage		0 [0.00]	-0.2 to 0.2 [-0.008 to 0.008]	1.0 [0.039]	
	Seat width	IN	2.3 [0.091]	2.15 to 2.45 [0.0846 to 0.0965]	2.8 [0.110]	
		EX	4.6 [0.181]	4.45 to 4.75 [0.1752 to 0.1870]	5.1 [0.201]	
	Valve margin		3.0 [0.118]	2.8 to 3.2 [0.110 to 0.126]	2.5 [0.098]	
	Inside diameter of valve seat ring housing		ø60 [2.36]	60.000 to 60.030 [2.3622 to 2.3634]	60.06 [2.3646]	
	Valve seat ring outside diameter		ø60 [2.36]	60.100 to 60.130 [2.3661 to 2.3673]		IN: Black two lines (ID ø49 [1.93])
						EX: Pink two lines (ID ø47 [1.85])
	Valve seat interference			0.070 to 0.130 [0.0028 to 0.0051]		
Valve spring	Free length			73 [2.87]	71 [2.80]	
	Squareness			A=1.5°or less B=1.9 [0.075] or less Lf=73 [2.87]	B=2.2 [0.087]	
	Set length / load (mm [in.]/N {kgf} [lbf])			66.0 [2.598]/289 to 319 {29.47 to 32.53} [64.97 to 71.71]		
Pre-chamber gas valve	Gas valve outside diameter		ø8 [0.32]	7.960 to 7.980 [0.3134 to 0.3142]	7.930 [0.3122]	
	Valve holder inside diameter		ø8 [0.32]	8.000 to 8.015 [0.3150 to 0.3156]	8.060 [0.3173]	
	Valve protrusion		3 [0.12]	2.85 to 3.15 [0.1122 to 0.1240]	2.0 [0.079]	
	Valve margin		3 [0.12]	2.85 to 3.15 [0.1122 to 0.1240]	2.5 [0.098]	
	Valve seat angle		30°	29°45' to 30°15'		
	Seat width		2 [0.08]	1.9 to 2.1 [0.075 to 0.083]	2.0 [0.079]	
	Valve holder height		126 [4.96]	125.8 to 126.2 [4.953 to 4.968]	125 [4.92]	
	Valve holder leak rate			13 L [3.43 US gal.]/ min or less		Air press. 0.2 MPa {2.04 kgf/cm^2} [29.01 psi]
Pre-chamber gas valve spring	Free length			55 [2.17]	54 [2.13]	
	Squareness			A=1.5°or less B=1.44 [0.0567] or less Lf=55 [2.17]	B=1.5 [0.059]	
	Set length / load (mm [in.]/N {kgf} [lbf])			46 [1.81]/137.3 to 166.7 {14.0 to 17.0} [30.87 to 37.48]		

Unit: mm [in.]

Item			Nominal value	Standard value	Limit value	Remark
Push rod	Runout			0.50 [0.0197] or less		TIR
Cylinder head	Distortion of bottom surface			0.03 [0.0012] or less	0.07 [0.0028]	
Cylinder head gasket	Thickness		1.8 [0.071]	1.77 to 1.83 [0.0697 to 0.0720]		
Cylinder liner	Inside diameter		ø170 [6.69]	170.020 to 170.040 [6.6937 to 6.6945]	170.100 [6.6968]	
	Roundness			0.02 [0.0008] or less		
	Cylindricity			0.02 [0.0008] or less		
	Flange protrusion			0.11 to 0.20 [0.0043 to 0.0079]		
	Flange thickness			14.16 to 14.20 [0.5575 to 0.5591]		
	Top ridge height			0.16 to 0.24 [0.0063 to 0.0094]		
Piston	Outside diameter		ø170 [6.69]	169.759 to 169.799 [6.6834 to 6.6850]	169.66 [6.6795]	At a height of 40 mm [1.575 in.] from the piston lower end in the right angle to piston pin
	Weight difference			Within ±10 g [0.35 oz.]		
	Piston pin hole inside diameter		ø70 [2.76]	70.002 to 70.015 [2.7560 to 2.7565]	70.040 [2.7575]	
Piston cooling nozzle	Valve opening pressure			0.10 to 0.15 MPa {1.02 to 1.53 kgf/cm^2} [14.50 to 21.76 psi]		
Piston ring	End gap	No.1 compression		0.6 to 0.8 [0.024 to 0.032]	2.0 [0.079]	
		No.2 compression		0.6 to 0.8 [0.024 to 0.032]	2.0 [0.079]	
		Oil		0.3 to 0.5 [0.012 to 0.020]	2.0 [0.079]	
Piston pin	Outside diameter		ø70 [2.76]	69.987 to 70.000 [2.7554 to 2.7559]	69.970 [2.7547]	
Connecting rod	Inside diameter of connecting rod bushing		ø70 [2.76]	70.020 to 70.040 [2.7567 to 2.7575]	70.070 [2.7587]	
	Bend and twist			0.05/100 [0.0020/3.94] or less		
	End play			0.6 to 0.9 [0.024 to 0.035]	1.4 [0.055]	
	Inside diameter of big end bore		ø131 [5.16]	131.000 to 131.025 [5.1575 to 5.1585]	Minimum: 130.950 [5.1555] Maximum: 131.050 [5.1594]	
	Circularity of inside diameter of big end bore				0.100 [0.0039]	
	Big end side face width			59.7 to 59.8 [2.350 to 2.354]		

Unit: mm [in.]

Item				Nominal value	Standard value	Limit value	Remark
Connecting rod bearing	Standard			3.000 [0.1181]	2.957 to 2.970 [0.1164 to 0.1169]	2.930 [0.1154]	
	Thickness at center	Under-size	0.25 [0.0098]	3.125 [0.1230]	3.082 to 3.095 [0.1213 to 0.1219]	3.055 [0.1203]	
			0.50 [0.0197]	3.250 [0.1280]	3.207 to 3.220 [0.1263 to 0.1268]	3.180 [0.1252]	
			0.75 [0.0295]	3.375 [0.1329]	3.332 to 3.345 [0.1312 to 0.1317]	3.305 [0.1301]	
			1.00 [0.0394]	3.500 [0.1378]	3.457 to 3.470 [0.1361 to 0.1366]	3.430 [0.1350]	
Flywheel	Face runout (reference)				0.336 [0.0132] or less		
	Radial runout (reference)				0.130 [0.0051] or less		
Spacer	Face runout (reference)				0.3 [0.012] or less		
	Radial runout (reference)				0.3 [0.012] or less		
Oil pump drive	Inside diameter of oil pump bearing cover to fit bearing			ø110 [4.33]	110.000 to 110.035 [4.3307 to 4.3321]		
	Pump plate inside diameter to fit bearing			ø110 [4.33]	109.987 to 110.022 [4.3302 to 4.3316]		
	Bearing		Outside diameter	ø110 [4.33]	109.985 to 110.000 [4.3301 to 4.3307]		
			Inside diameter	ø50 [1.97]	49.988 to 50.000 [1.9680 to 1.9685]		
	Outside diameter of oil pump gear to fit bearing			ø50 [1.97]	49.993 to 50.013 [1.9682 to 1.9690]		
Front mechanism	Backlash				0.12 to 0.28 [0.0047 to 0.0110]	0.50 [0.0197]	
	Front idler bushing inside diameter			ø50 [1.97]	50.000 to 50.025 [1.9685 to 1.9695]	50.060 [1.9709]	
	Front idler shaft outside diameter			ø50 [1.97]	49.950 to 49.975 [1.9665 to 1.9675]	49.900 [1.9646]	
	Front idler gear end play				0.20 to 0.40 [0.0079 to 0.0157]	0.60 [0.0236]	
Rear mecha-nism	Backlash				0.12 to 0.18 [0.0047 to 0.0071]	0.50 [0.0197]	
	Rear idler bushing inside diameter			ø65 [2.56]	65.000 to 65.030 [2.5591 to 2.5602]	65.060 [2.5614]	
	Rear idler shaft outside diameter			ø65 [2.56]	64.951 to 64.970 [2.5571 to 2.5579]	64.900 [2.5551]	
	Rear idler gear end play				0.30 to 0.60 [0.0118 to 0.0236]	1.0 [0.039]	
Camshaft	Cam lift (major dia.- minor dia.)		IN		5.3 [0.209]	4.45 [0.1752]	
			EX		9.3 [0.366]	8.45 [0.3327]	
	Runout				0.05 [0.0020] or less	0.08 [0.0032]	TIR
	Journal diameter			ø84 [3.31]	83.92 to 83.94 [3.3039 to 3.3047]	83.87 [3.3020]	
	Camshaft bushing inside diameter			ø84 [3.31]	84.02 to 84.095 [3.3079 to 3.3108]	84.100 [3.3110]	
	End play				0.10 to 0.25 [0.0039 to 0.0098]	0.40 [0.0157]	

Unit: mm [in.]

Item					Nominal value	Standard value	Limit value	Remark
Crankshaft	Crankpin outside diameter	Standard			ø125 [4.92]	124.930 to 124.950 [4.9185 to 4.9193]	124.890 [4.9169]	
		Under-size	0.25 [0.0098]			124.680 to 124.700 [4.9087 to 4.9094]	124.640 [4.9071]	
			0.50 [0.0197]			124.430 to 124.450 [4.8988 to 4.8996]	124.390 [4.8972]	
			0.75 [0.0295]			124.180 to 124.200 [4.8890 to 4.8898]	124.140 [4.8874]	
			1.00 [0.0394]			123.930 to 123.950 [4.8791 to 4.8799]	123.890 [4.8775]	
	Crankshaft journal outside diameter	Standard			ø170 [6.69]	169.920 to 169.940 [6.6898 to 6.6905]	169.880 [6.6882]	
		Under-size	0.25 [0.0098]			169.670 to 169.690 [6.6799 to 6.6807]	169.630 [6.6783]	
			0.50 [0.0197]			169.420 to 169.440 [6.6701 to 6.6709]	169.380 [6.6685]	
			0.75 [0.0295]			169.170 to 169.190 [6.6602 to 6.6610]	169.130 [6.6586]	
			1.00 [0.0394]			168.920 to 168.940 [6.6504 to 6.6512]	168.880 [6.6488]	
	Parallelism of journal and crankpin					0.01 [0.0004] or less	0.03 [0.0012]	
	Circularity of journal and crankpin					0.01 [0.0004] or less	0.03 [0.0012]	
	Cylindricity of journal and crankpin					0.01 [0.0004] or less	0.03 [0.0012]	
	Fillet radius of pin				R7 [0.276]	6.8 to 7.0 [0.268 to 0.276]		
	Fillet radius of journal				R8.5 [0.335]	8.3 to 8.5 [0.327 to 0.335]		
	Hardness of journal and crankpin					Hv > 590		
	Finishing surface roughness					Ra 0.2 µm [7.87 µin.]		
	Angular deviation between pins					±20'		
	Crankpin width				120 [4.72]	120.20 to 120.30 [4.7323 to 4.7362]		
	Rearmost crank journal width	Standard			67 [2.64]	67.00 to 67.05 [2.6378 to 2.6398]		
		Over-size	0.25 [0.0098]	One side		67.25 to 67.30 [2.6476 to 2.6496]		
				Both sides		67.50 to 67.55 [2.6575 to 2.6594]		
			0.50 [0.0197]	One side		67.50 to 67.55 [2.6575 to 2.6594]		
				Both sides		68.00 to 68.05 [2.6772 to 2.6791]		
			0.75 [0.0295]	One side		67.75 to 67.80 [2.6673 to 2.6693]		
				Both sides		68.50 to 68.55 [2.6968 to 2.6988]		
	Runout					0.04 [0.0016] or less	0.10 [0.0039]	TIR
	End play					0.200 to 0.500 [0.0079 to 0.0197]	0.600 [0.0236]	

Unit: mm [in.]

Item				Nominal value	Standard value	Limit value	Remark
Main bearing	Thickness at center	Standard		4.500 [0.1772]	4.467 to 4.480 [0.1759 to 0.1764]	4.425 [0.1742]	
		Undersize	0.25 [0.0098]	4.625 [0.1821]	4.592 to 4.605 [0.1808 to 0.1813]	4.550 [0.1791]	
			0.50 [0.0197]	4.750 [0.1870]	4.717 to 4.730 [0.1857 to 0.1862]	4.675 [0.1841]	
			0.75 [0.0295]	4.875 [0.1919]	4.842 to 4.855 [0.1906 to 0.1911]	4.800 [0.1890]	
			1.00 [0.0394]	5.000 [0.1969]	4.967 to 4.980 [0.1956 to 0.1961]	4.925 [0.1939]	
Thrust plate	Thickness	Standard		5.00 [0.1969]	4.78 to 4.85 [0.1882 to 0.1909]	4.71 [0.1854]	
		Oversize	0.25 [0.0098]	5.25 [0.2067]	5.03 to 5.10 [0.1980 to 0.2008]	4.96 [0.1953]	
			0.50 [0.0197]	5.50 [0.2165]	5.28 to 5.35 [0.2079 to 0.2106]	5.21 [0.2051]	
			0.75 [0.0295]	5.75 [0.2264]	5.53 to 5.60 [0.2177 to 0.2205]	5.46 [0.2150]	
Crankcase	Distortion of top surface				0.1 [0.004] or less	0.2 [0.008]	
	Inside diameter of main bearing housing			ø179 [7.05]	179.000 to 179.025 [7.0472 to 7.0482]	179.045 [7.0490]	
	Depth of counterbore in crankcase			14 [0.55]	14.00 to 14.05 [0.5512 to 0.5531]		
	Height from journal center to top face (reference)				549.45 to 549.55 [21.6318 to 21.6358]		

1.3 Maintenance Service Data of Lubrication System

Unit: mm [in.]

Item		Nominal value	Standard value	Limit value	Remark
Oil pump	Backlash between drive gear and driven gear		0.100 to 0.200 [0.0039 to 0.0079]	0.400 [0.0157]	
	Top clearance between gear teeth and case		0.100 to 0.148 [0.0039 to 0.0058]	0.350 [0.0138]	
	Side clearance between gear width and case depth		0.040 to 0.116 [0.0016 to 0.0046]	0.210 [0.0083]	
	Drive gear shaft outside diameter	ø30 [1.18]	29.887 to 29.900 [1.1767 to 1.1772]	29.840 [1.1748]	
	Driven gear shaft outside diameter		29.947 to 29.960 [1.1790 to 1.1795]	29.920 [1.1780]	
	Bushing inside diameter	ø30 [1.18]	30.000 to 30.021 [1.1811 to 1.1819]	30.055 [1.1833]	
	Safety valve opening pressure		1.3 ± 0.13 MPa {13.3 ± 1.32 kgf/cm²} [188.5 ± 18.85 psi]		
	Safety valve spring installed length/load		65.8 [2.591]/359 N {36.61 kgf} [80.71 lbf]	65.8 [2,591]/ 314 N {32.02 kgf} [70.59 lbf]	
	Free length of safety valve spring		78 [3.07]		
Relief valve	Valve opening pressure		0.59 ± 0.02 MPa {6.02 ± 0.20 kgf/cm²} [85.57 ± 2.90 psi]		
	Spring free length		188 [7.40]		

1.4 Maintenance Service Data of Cooling System

Unit: mm [in.]

Item				Nominal value	Standard value	Limit value	Remark
Dummy water pump	inside diameter of bearing to fit	Pump case		ø120 [4.72]	119.987 to 120.022 [4.7239 to 4.7253]		
		Bearing cover		ø110 [4.33]	110.005 to 110.040 [4.3309 to 4.3323]		
	Bearing	Large	Outside diameter	ø120 [4.72]	119.985 to 120.000 [4.7238 to 4.7244]		
			Inside diameter	ø55 [2.17]	54.985 to 55.000 [2.1648 to 2.1654]		
		Small	Outside diameter	ø110 [4.33]	109.985 to 110.000 [4.3301 to 4.3307]		
			Inside diameter	ø50 [1.97]	49.988 to 50.000 [1.9680 to 1.9685]		
	Outside diameter of shaft to fit bearing			ø55 [2.17]	55.011 to 55.024 [2.1658 to 2.1663]		
				ø50 [1.97]	50.011 to 50.024 [1.9689 to 1.9694]		

Note: The water pump is separately installed. Use the dummy pump as the idler gear and water passage.

1.5 Maintenance Service Data of Inlet and Exhaust System

Unit: mm [in.]

Item		Nominal value	Standard value	Limit value	Remark
Throttle valve	Shaft diameter	ø20 [0.79]	19.991 to 20.000 [0.7870 to 0.7874]	19.96 [0.7858]	
	Bushing-A inside diameter	ø20 [0.79]	20.038 to 20.096 [0.7889 to 0.7912]	20.25 [0.7972]	
	Bushing-B inside diameter	ø20 [0.79]	20.040 to 20.107 [0.7890 to 0.7916]	20.50 [0.8071]	

1.6 Maintenance Service Data of Electrical System

Unit: mm [in.]

Item			Nominal value	Standard value	Limit value	Remark
Starter	Pinion shaft	Rear shaft outside diameter	ø30 [1.18]	30.002 to 30.011 [1.1812 to 1.1815]		
		Front shaft outside diameter	ø18 [0.71]	17.997 to 18.005 [0.7085 to 0.7089]		
		End play	0.5 [0.020]			
	Brush length		23 [0.91]		13 [0.51]	
	Pressure of brush spring		44.13 N {4.500 kgf} [9.9209 lbf]	39.23 to 49.03 N {4.000 to 5.000 kgf} [8.8193 to 11.0224 lbf]	39.23 N {4.000 kgf} [8.8193 lbf]	
	Armature	Shaft runout		0.05 [0.0020] or less		TIR
		Front shaft outside diameter	ø20 [0.79]	20.002 to 20.011 [0.7875 to 0.7878]		
		Rear shaft outside diameter	ø10 [0.39]	10.001 to 10.007 [0.3937 to 0.3940]		
		End play	0.5 [0.020]			
	Commutator	Outside diameter	ø43 [1.69]		42 [1.65]	
		Runout		0.06 [0.0024] or less	0.10 [0.0039]	TIR
		Undercut depth		0.7 to 0.9 [0.028 to 0.035]	0.2 [0.008]	

1.7 Maintenance service data for ignition system

Unit: mm [in.]

Item			Nominal value	Standard value	Limit value	Remark
Spark plug	Denso (GK2-2 ·)	Gap (initial)	0.22 [0.0087]	0.22 ± 0.03 [0.0087 ± 0.0011]		
		When gap is adjusted		0.17 [0.0067]		
		Internal resistance value		2 to 10 kΩ		
		Insulation resistance value		50 MΩ or higher		
	NGK (T7415X)	Gap (initial)	0.3 [0.012]	0.3 ± 0.05 [0.012 ± 0.0019]		
		When gap is adjusted		0.3 [0.012]		
		Internal resistance value		3 to 7.5 kΩ		
		Insulation resistance value		100 MΩ or higher		
Ignition coil		Resistance of primary coil		0.1 to 0.2 Ω		
		Resistance of secondary coil		4.4 to 6.9 kΩ		
Resistance of spark plug cord			11.7 kΩ	9.9 to 17.0 kΩ		within +45-15 %
Clearance between pickup and magnet disk or cam rotor				1.0 [0.039] or less		
Clearance between pickup and flywheel ring gear				1.4 [0.055]		

2. Tightening Torque Table

2.1 Tightening Torque Specs for Engine Body

Description	Thread size Dia. × Pitch	Tightening torque			Remark
		N·m	kgf·m	lbf·ft	
Cylinder head bolt	M 22 × 2.5	(539 ± 27)	(54.96 ± 2.75)	(397.55 ± 19.91)	Use the controlled angle tightening as a general rule. [Wet] 2-time tightening method, see Note (a) and (e). Figure in parentheses is for the torque method.
Rocker case	M 12 × 1.25	108 ± 5.4	11.01 ± 0.55	79.66 ± 3.98	
Rocker shaft	M 14 × 2.0	147 ± 7.4	14.99 ± 0.75	79.66 ± 3.98	
Rocker-arm lock nut	M 12 × 1.25	64 ± 3.2	6.53 ± 0.32	47.20 ± 2.36	Adjusting screw
Bridge lock nut	M 10 × 1.25	55 ± 2.8	5.61 ± 0.28	40.57 ± 2.06	Adjusting screw
Rocker cover	M 10 × 1.25	33	3.37	24.34	
Camshaft gear (rear)	M 12 × 1.25	127 ± 6.4	12.95 ± 0.65	93.67 ± 4.72	
Camshaft thrust plate	M 12 × 1.25	59 ± 5.9	6.02 ± 0.60	43.52 ± 4.35	
Main bearing cap	M 24 × 3.0	588 ± 29.4	59.96 ± 2.99	433.69 ± 21.68	[Wet], Note (b), (e)
Main bearing cap side bolt	M 20 × 2.5	392 ± 19.6	39.97 ± 1.99	289.12 ± 14.45	[Wet], Note (b), (e)
Hanger	M 20 × 1.5	392 ± 19.6	39.97 ± 1.99	289.12 ± 14.45	
	M 16 × 1.5	216 ± 10.8	22.03 ± 1.10	159.31 ± 7.96	
Piston cooling nozzle	M 12 × 1.75	34 ± 1.7	3.47 ± 0.17	25.08 ± 1.25	See Note (c).
Timing gear case	M 16 × 1.5	255 ± 12.8	26.0 ± 1.30	188.08 ± 9.44	With a hard washer
Rear plate	M 12 × 1.25	108 ± 5.4	11.01 ± 0.55	79.66 ± 3.98	
	M 16 × 1.5	255 ± 12.8	26.0 ± 1.30	188.08 ± 9.44	With a hard washer
Front mounting bracket	M 20 × 1.5	392 ± 19.6	39.97 ± 1.99	289.12 ± 14.45	
		245 ± 12.3	24.98 ± 1.25	180.70 ± 9.07	Right front lower bolt only
Center mounting bracket	M 20 × 1.5	392 ± 19.6	39.97 ± 1.99	289.12 ± 14.45	
Rear mounting bracket	M 20 × 1.5	392 ± 19.6	39.97 ± 1.99	289.12 ± 14.45	
Connecting rod cap	M 22 × 1.5	637 ± 31.9	64.96 ± 3.25	469.83 ± 23.52	[Wet] 2-time tightening method, Note (d), (e) Bolt identification mark "CS, CL"
Balance weight	M 22 × 1.5	490 ± 24.5	49.97 ± 2.49	361.41 ± 18.07	[Wet], Note (e)
Flywheel	M 22 × 1.5	588 ± 29.4	59.96 ± 2.99	433.69 ± 21.68	[Wet], Note (e)
Ring gear	M 10 × 1.25	33 ± 1.7	3.37 ± 0.17	24.34 ± 1.25	
Double damper (bolt)	M 22 × 1.5	490 ± 24.5	49.97 ± 2.49	361.41 ± 18.07	
Triple damper (nut)	M 22 × 1.5	294 ± 14.7	29.98 ± 1.49	216.84 ± 10.84	
Rear idler shaft	M 20 × 1.5	392 ± 19.6	39.97 ± 1.99	289.12 ± 14.45	Apply MOLYKOTE
Rear idler shaft thrust collar (nut)	M 18 × 1.5	196 ± 9.8	19.99 ± 0.99	144.56 ± 7.22	
Front gear case	M 12 × 1.25	59 ± 3.0	6.02 ± 0.30	43.52 ± 2.21	
	M 16 × 1.5	216 ± 10.8	22.03 ± 1.10	159.31 ± 7.96	
Front plate	M 12 × 1.25	59 ± 5.9	6.02 ± 0.60	43.52 ± 4.35	
Front idler shaft	M 12 × 1.25	108 ± 10.8	11.01 ± 1.10	79.66 ± 7,96	
Front idler shaft thrust plate	M 10 × 1.25	60 ± 6.0	6.12 ± 0.61	44.25 ± 4.42	
Oil pump and water pump mounting plate	M 12 × 1.25	59 ± 5.9	6.02 ± 0.60	43.52 ± 4.35	
Bearing cover for oil pump and dummy water pump drive	M 12 × 1.25	108 ± 10.8	11.01 ± 1.10	79.66 ± 7,96	
Throttle valve coupling	M 6 × 1.0	11.7 ± 1.0	1.19 ± 0.10	8.63 ± 0.73	Hexagon socket bolt

Note:(a) Use the controlled-angle method to tighten the cylinder head bolt as a general rule.

1) Tighten the bolts with a snug torque of 294 ± 14.7 N·m {30 ± 1.5 kgf·m} [217 ± 11 lbf·ft].
2) Angle tighten further 65 ± 3 degrees.
3) Loosen all bolts, and then retighten them in the sequence shown in the above 1) and 2). (2-time tightening)
For tightening procedure, see "Cylinder Head Bolt - Tighten" of "ENGINE BODY - ASSEMBLE".

(b) Tighten main bearing cap bolts and main bearing cap side bolts, following the specified sequence. Snug tighten all the bolts to the half of the specified torque, and after the snug tightening of all the bolts, tighten them to the specified torque. For the tightening procedure, see "Main Bearing Cap - Install" of "ASSEMBLY OF BASIC ENGINE."

(c) Be sure to tighten the piston cooling nozzle to the specified torque. Do not overtighten exceeding the specified torque. Excessive tightening may cause check valve failure and result in piston seizure.

(d) Follow the procedure below to tighten the cylinder head bolts using controlled-angle tightening method.

Bolt mark	Part number	Torque method (2-time tightening)	Angle method (2-time tightening)
CS	37519-21301	637 ± 31.9 N·m {65 ± 3.25 kgf·m} [470 ± 24 lbf·ft]	Snug torque 245 ± 12.3 N·m {25 ± 1.25 kgf·m} [180 ± 9 lbf·ft] → 60 ± 3°
CL	37519-11401		Snug torque 294 ± 14.7 N·m {30 ± 1.5 kgf·m} → 60 ± 3°

(e) When [Wet] is indicated, apply engine oil to the thread and bolt bearing face.

(f) Parts (bolts/nuts) indicated by 2-time tightening are to be tightened to the specified torque, and loosen, then retighten to the specified torque.

2.2 Tightening Torque Specifications for Fuel Gas System

Description	Thread size Dia × Pitch	Tightening torque			Remark
		N·m	kgf·m	lbf·ft	
Pre-chamber	M 18 × 1.5	49 ± 2.5	5.0 ± 0.25	36.14 ± 1.84	Apply anti-seize compound (37594-01700).
Gas valve holder	M 27 × 1.5	177 ± 8.9	18.05 ± 0.90	130.55 ± 6.56	Apply anti-seize compound (37594-01700).
Gas-valve rocker arm	M 8 × 1.25	30 ± 1.5	3.06 ± 0.15	22.13 ± 1.10	
Gas-valve lock nut	M 10 × 1.25	55 ± 2.8	5.61 ± 0.28	40.57 ± 2.06	Adjusting screw
Antler pipe union nut	M 14 × 1.5	39	3.98	28.77	

2.3 Tightening Torque Specifications for Lubrication System

Description	Thread size Dia.× Pitch	Tightening torque			Remark
		N·m	kgf·m	lbf·ft	
Oil pump	M 12 × 1.25	108 ± 10.8	11.01 ± 1.10	79.66 ± 7.96	
Oil pump cover	M 10 × 1.25	33.4 ± 6.67	3.41 ± 0.68	24.64 ± 4.91	
Oil pump safety valve plug	M 24 × 1.5	88 ± 10	8.97 ± 1.02	64.91 ± 7.37	
Oil pump safety valve assembly	M 32 × 2.0	74 ± 10	7.55 ± 1.02	54.58 ± 7.37	
Oil pan	M 12 × 1.25	59 ± 5.9	6.02 ± 0.60	43.52 ± 4.35	

2.4 Tightening Torque Specifications for Cooling System

Description	Thread size Dia. × Pitch	Tightening torque			Remark
		N·m	kgf·m	lbf·ft	
Dummy water pump	M 12 × 1.25	108 ± 10.8	11.01 ± 1.10	79.66 ± 7.96	
Dummy water pump gear (nut)	M 30 × 1.5	390 ± 78.4	39.77 ± 7.99	287.65 ± 57.82	For oil pump drive

2.5 Tightening Torque Specifications for Inlet and Exhaust System

Description		Thread size Dia. × Pitch	Tightening torque			Remark
			N·m	kgf·m	lbf·ft	
Exhaust manifold V-clamp	(Static pressure)	M 8 × 1.25	20 ± 1.0	2.04 ± 0.10	14.75 ± 0.73	D120
	(Dynamic pressure)	M 6 × 1.0	8.35 ± 0.45	0.85 ± 0.04	6.16 ± 0.33	
Exhaust manifold mounting bolt		M 10 × 1.5	98 ± 4.9	9.99 ± 0.50	72.28 ± 3.61	
Exhaust pipe coupling		1/4-28 UNF	8.8 ± 1.0	0.90 ± 0.10	6.49 ± 0.73	
Turbocharger mounting bolt		M 12 × 1.25	108 ± 10.8	11.01 ± 1.10	79.66 ± 7.96	
Air cooler		M 10 × 1.25	60 ± 5.4	6.12 ± 0.55	44.52 ± 3.98	

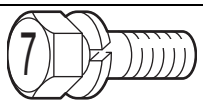
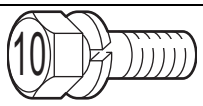
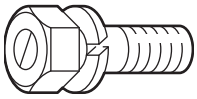
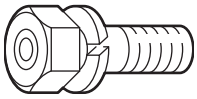
2.6 Tightening Torque Specifications for Electrical System

Description	Thread size Dia. × Pitch	Tightening torque			Remark
		N·m	kgf·m	lbf·ft	
Starter	M 12 × 1.25	59 ± 5.9	6.02 ± 0.60	43.52 ± 4.35	

2.7 Tightening Torque Specifications for Ignition System

Description	Thread size Dia. × Pitch	Tightening torque			Remark
		N·m	kgf·m	lbf·ft	
Spark plug	M 14 × 1.25	20 ± 1.0	2.04 ± 0.10	14.75 ± 0.73	Apply anti-seize compound (37594-01700).
Knocking sensor	M 8 × 1.25	20 ± 1.0	2.04 ± 0.10	14.75 ± 0.73	Do not use a washer or the like.

2.8 Tightening Torque for Standard Bolts

Threads	Thread size Dia. × Pitch (M-thread)	Width across flats (mm) [in.]	Strength classification					
			7T			10.9		
								
			N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
Metric automobile screw thread	8 × 1.25	12 [0.47]	17	1.7	12.3	30	3.1	22.4
	10 × 1.25	14 [0.55]	33	3.4	24.6	60	6.1	44.1
	12 × 1.25	17 [0.67]	60	6.1	44.1	108	11.0	79.6
	14 × 1.5	22 [0.87]	97	9.9	71.6	176	17.9	129.5
	16 × 1.5	24 [0.94]	145	14.8	107.1	262	26.7	193.1
	18 × 1.5	27 [1.06]	210	21.4	154.8	378	38.5	278.5
	20 × 1.5	30 [1.18]	291	29.7	214.8	524	53.4	386.2
	22 × 1.5	32 [1.26]	385	39.3	284.3	694	70.8	512.1
	24 × 1.5	36 [1.42]	487	49.7	359.5	878	89.5	647.4
	27 × 1.5	41 [1.61]	738	75.3	544.7	1328	135.5	980.1
Metric course screw thread								
			N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
	10 × 1.5	14 [0.55]	32	3.3	23.9	58	5.9	42.67
	12 × 1.75	17 [0.67]	57	5.8	42.0	102	10.4	75.2
	14 × 2	22 [0.87]	93	9.5	68.7	167	17.0	123.0
	16 × 2	24 [0.94]	139	14.2	102.7	251	25.6	185.2
	18 × 2.5	27 [1.06]	194	19.8	143.2	350	35.7	258.2
	20 × 2.5	30 [1.18]	272	27.7	200.4	489	49.9	361.0
	22 × 2.5	32 [1.26]	363	37.0	267.6	653	66.6	482.0
	24 × 3	36 [1.42]	468	47.7	345.0	843	86.0	622.0
	27 × 3	41 [1.61]	686	70.0	506.3	1236	126.0	911.4

Note:(a) The tightening torque listed in this table is for standard bolts and nuts.

(b) The numerical values in the table are the values when spring washers are used.

(c) The table shows the standard values with a maximum tolerance value of ±10%.

(d) Use the tightening torque in this table unless otherwise specified.

(e) Do not apply oil to threaded portions. (Dry)

2.9 Tightening Torque for Standard Union Bolts

Thread size Dia. × Pitch (M-thread)	Width across flats (mm) [in.]	Strength classification		
		4T		
		N·m	kgf·m	lbf·ft
8 × 1.25	12 [0.47]	8 ± 1	0.8 ± 0.1	5.90 ± 0.73
10 × 1.25	14 [0.55]	15 ± 2	1.5 ± 0.2	11.06 ± 1.47
12 × 1.25	17 [0.67]	25 ± 3	2.5 ± 0.3	18.44 ± 2.21
14 × 1.5	19 [0.75]	34 ± 4	3.5 ± 0.4	25.08 ± 2.95
16 × 1.5	22 [0.87]	44 ± 5	4.5 ± 0.5	32.45 ± 3.68
18 × 1.5	24 [0.94]	74 ± 5	7.5 ± 0.5	54.58 ± 3.68
20 × 1.5	27 [1.06]	98 ± 10	10.0 ± 1.0	72.28 ± 7.37
24 × 1.5	32 [1.26]	147 ± 15	15.0 ± 1.5	108.42 ± 11.06
27 × 1.5	41 [1.61]	226 ± 20	23.0 ± 2.0	166.69 ± 14.75

(Dry)

2.10 Tightening Torque for Standard Union Nuts

Nominal	Cap nut thread size Dia. × Pitch (M-thread)	Width across flats (mm) [in.]	N·m	kgf·m	lbf·ft
63	14 × 1.5	19 [0.75]	39	4	28.76
80	16 × 1.5	22 [0.87]	49	5	36.14
100	20 × 1.5	27 [1.06]	78	8	57.53
120	22 × 1.5	30 [1.18]	98	10	72.28
150	27 × 1.5	32 [1.26]	157	16	115.80
180	30 × 1.5	36 [1.42]	196	20	144.56
200	30 × 1.5	36 [1.42]	196	20	144.56
220	33 × 1.5	41 [1.61]	245	25	180.70
254	36 × 1.5	41 [1.61]	294	30	216.84

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

2.11 Flex Coupling - Install

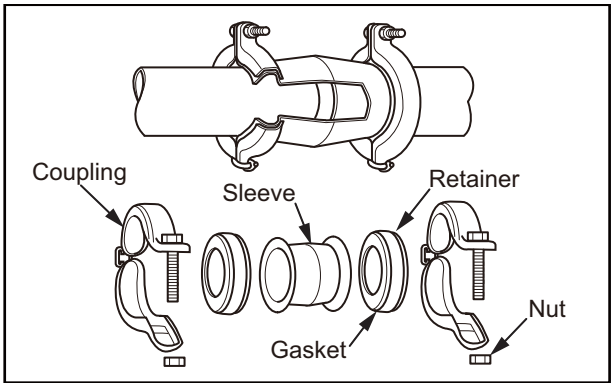
(1) Remove rust from the pipe surface with sandpaper, etc. If there are burrs on the pipe end, remove.

(2) Insert gasket on retainer, and fit the retainer with the gasket side facing toward the sleeve. When it is difficult to insert the gasket because the pipe surface is dry, use water or soap solution. Do not use grease or oil.

(3) Press the sleeve against the surface of rubber gasket so as to wrap with the coupling. The rubber gasket should be evenly inserted around the pipe.

(4) Tighten the coupling nut to the specified torque in the table.

(5) Secure the pipe so as not to move in the axial direction.

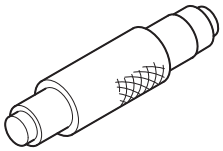
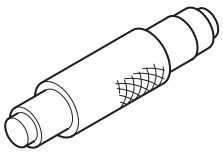
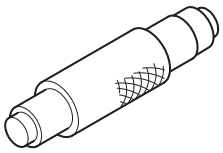
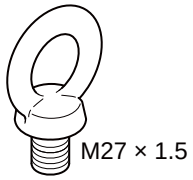
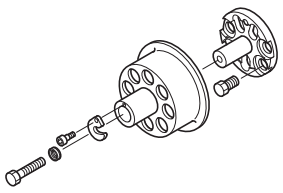


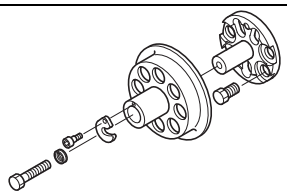
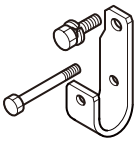
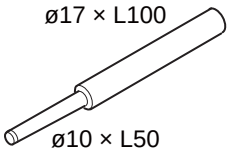
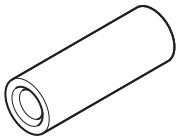
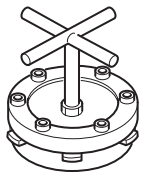
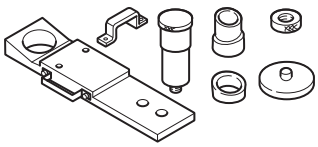
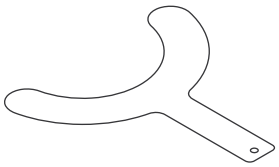
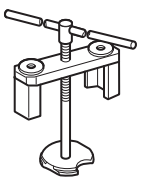
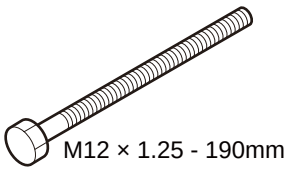
Coupling used in each model and tightening torque when it is new

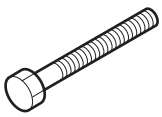
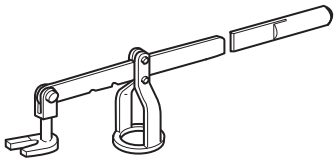
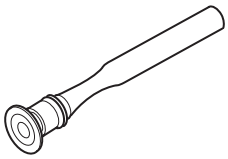
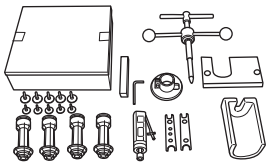
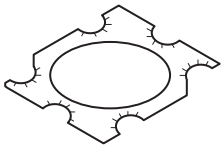
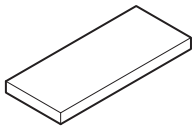
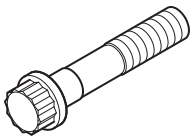
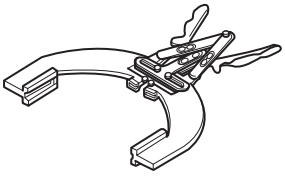
Model	Part number	Nominal diameter	Manufacturer part number	Tightening torque		
				N·m	kgf·m	lbf·ft
GA6A3	35A47-08200	32	M1600-125-0325	11.5	1.17	8.5
GS12A2	32636-09800	25	NH1625-100B0250	5.5	0.6	4.1
	04826-40025	25	M1600-100-0288	11.5	1.17	8.5
GS6R2	04826-42050	50	NH1625-200B00350	11.5	1.17	8.5
GS12R	35A47-08200	32	M1600-125-0325	11.5	1.17	8.5
	04826-40040	40	M1600-150-0350	11.5	1.17	8.5
	35A47-08600	80	M1600-300-0650	21.5	2.19	15.9
GS16R	35A47-08200	32	M1600-125-0325	11.5	1.17	8.5
	04826-42050	50	NH1625-200B0350	11.5	1.17	8.5
	04826-40065	65	M1600-250-650	21.5	2.19	15.9
	35A47-08600	80	M1600-300-0650	21.5	2.19	15.9
GS16R2	04826-40050	50	M1600-200-0400	11.5	1.17	8.5
	04826-42050	50	NH1625-200B0350	11.5	1.17	8.5
	35A47-08600	80	M1600-300-0650	21.5	2.19	15.9

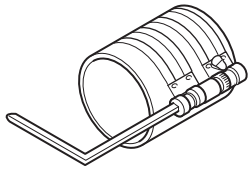
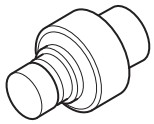
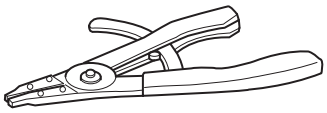
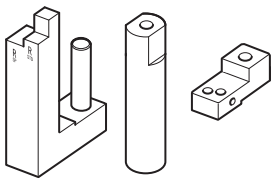
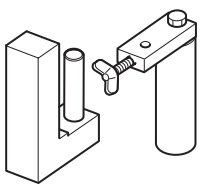
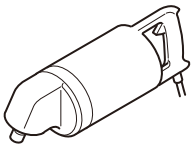
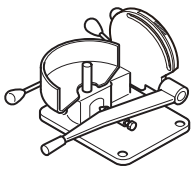
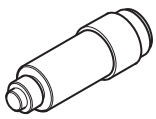
Chapter 3 SERVICE TOOLS

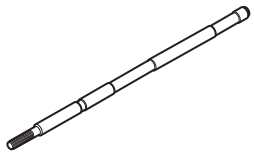
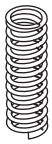
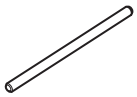
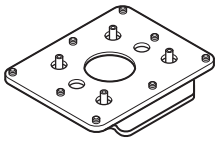
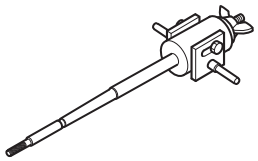
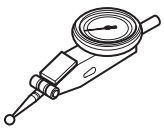
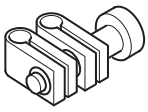
1. SPECIAL TOOL

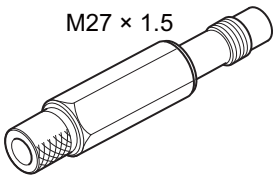
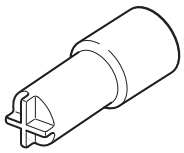
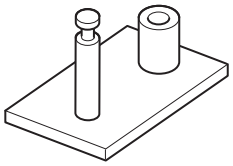
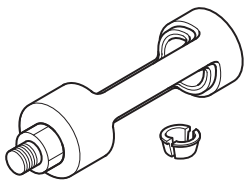
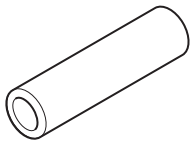
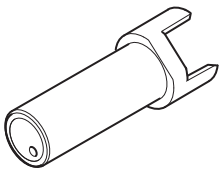
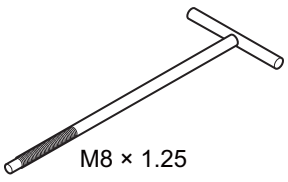
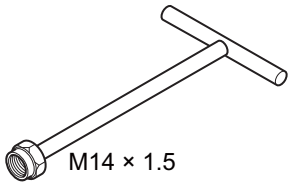
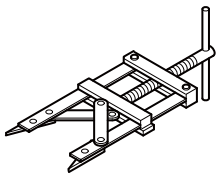
Maintenance item	Tool name	Part number	Configuration	Intended use
Engine	Rocker bushing tool	37591-02600		Rocker Bushing - Replace Bushing inside and outside diameter ø36 × ø40 [1.42 × 1.57 in.]
	Front idler bushing puller	32591-02500		Front Idler Bushing - Replace Bushing inside and outside diameters ø50 × ø55 [1.97 × 2.17 in.]
	Rear idler bushing installer	37791-02500		Rear Idler Bushing - Replace Bushing inside diameter ø65 × ø70 [2.56 × 2.76 in.]
	Eye bolt	37591-02500		Lifting of piston and others
	Eye bolt	05930-00200 (2 pcs)		Lifting of cylinder head, gear case and others
	Eye bolt	45815-32401 (2 pcs)		Lifting of timing-gear-case spacer
	Eye bolt	37791-02100 (2 pcs)		Main Bearing Cap - Remove
	Front seal installer assembly	37891-07000		Installation of front oil seal for triple damper spec. (Usable for double damper spec)

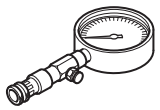
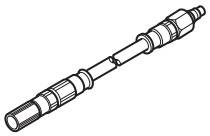
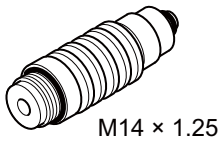
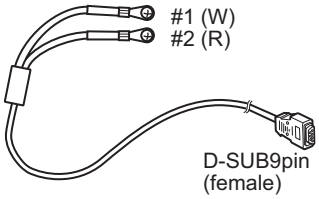
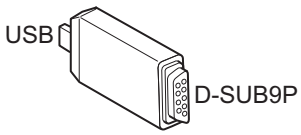
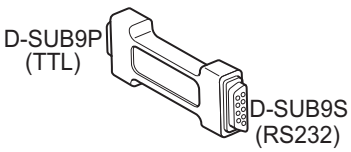
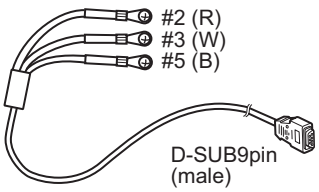
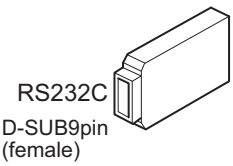
Maintenance item	Tool name	Part number	Configuration	Intended use
Engine	Rear seal installer assembly	37791-06010		Rear Oil Seal - Install
	Support	37791-04100		To hold the extension bar of socket wrench when using turning gear
	Valve guide remover	33591-04300		Valve Guide - Remove Applicable valve guide inside/outside dia.: ø10 × ø17 [0.39 × 0.67 in.]
	Guide and seal installer	37191-11500		Valve guide and stem seal - Install Guide height : 31.5 mm [1.240 in.] Stem seal height : 34.3 mm [1.350 in.]
	Crankcase grinder	37591-07010		Crankcase liner counterbore refacing
	Connecting rod bushing installer	37591-01010		Connecting Rod Bushing -Install and Remove
	Connecting rod gauge	Sheet thickness : 0.5 mm [0.020 in.] 37791-01500 Sheet thickness : 0.6 mm [0.024 in.] 37791-01600		Connecting rod end play - Setting
	Cylinder liner remover	37591-04100		Cylinder Liner - Remove Applicable cylinder liner inner dia: ø170 mm [6.69 in.]
	Jack bolt	37791-02200 (2 pcs)		Extra Flywheel and Damper - Remove

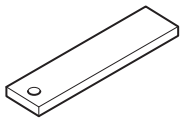
Maintenance item	Tool name	Part number	Configuration	Intended use
Engine	Jack bolt	64362-68500 (2 pcs)	 M12 × 1.25 - 95mm	Flywheel and spacer - removal
	Valve spring pusher	33591-04500		Valve Spring - Installation and Removal
	Valve lapper	Sucking disk ø40 [1.57 in.] 30091-08800		Valve lapping
	Valve seat puller	32591-04200		Valve Seat - Remove
	Head bolt plate	37598-08900		Controlled angle tightening of head bolt
	Projection plate	37598-09201		Crankcase counter bore depth measurement L230 × W50 × T15 mm [L9.06 × W1.97 × T0.59 in.]
	Bolt	37591-06300 (4 pcs)	 M22 × 2.5 - 115mm	Cylinder liner flange protrusion measurement (Liner presser jig)
	Liner pusher	37591-06200 (4 pcs)		Cylinder liner flange protrusion - measure (Liner presser jig)
	Ring expander	37191-03200		Piston Ring - Install and Remove Applicable to ø101.6 to ø177.8 mm [4.000 to 7.000 in.]

Maintenance item	Tool name	Part number	Configuration	Intended use
Engine	Piston installer	37191-07100		Piston - Install Applicable piston diameter: ø89 to ø178 [3.50 to 7.01 in.]
	Bearing installer	37791-03700		Press fitting of throttle valve bearing (bushing) Bushing inside and outside dia ø20 × ø26 [0.79 × 1.02 in.]
	Ring pliers	45191-08400		Snap ring - installation/removal
	Pre-chamber gauge tool	35A91-07100		Pre-chamber Valve Sinkage - Measure
	Valve gauge tool	37591-07400		Valve Sinkage - Measure
	Seat grinder motor	37891-09100		Valve Seat Ring - Grind Seat grinder tool set: 37891-09010
	Stone dresser	37891-08100		
	Stone holder	37891-08200 (2 pcs)		
	Wheel stone	37891-08300 (2 pcs)		

Maintenance item	Tool name	Part number	Configuration	Intended use
Engine	Pilot shaft	37891-08400		Valve Seat Ring - Grind Seat grinder tool set: 37891-09010
	Spring	37891-09200		
	Shaft	37891-08900		
	Bracket assembly	37891-08800		Common fixing bracket of pilot shaft for grinding and measuring tool set for measuring
	Bolt, washer assembly	F1805-12020 (2 pcs)		
	Measuring tool set	37891-08500		Valve seat face and radial runouts - Measure
	Measuring gauge	37891-08600		
	Cage clamp	37891-08700		

Maintenance item	Tool name	Part number	Configuration	Intended use
Pre-chamber and gas valve	Extension bar guide	35A91-29900		Pre-chamber - installation and removal Combined use of pre-chamber cross socket and extension bar
	Pre-chamber cross socket	37591-09200		Small volume pre-chamber - installation and removal Socket □12.7 mm [0.500 in.]
	Gas valve stand	35A91-08800		Pre-chamber gas-valve spring - installation and removal Combined use with valve spring pusher
	Stem seal remover	35A91-06810		Stem Seal of Pre-chamber Gas Valve - Remove
	Stem seal installer	35A91-08601		Pre-chamber Gas Valve Stem Seal - Install Stem seal height: 12.8 mm [0.504 in.]
	Pipe installer	35A91-06400		Antler Pipe- Install
	Pipe remover	35A91-06500		Antler Pipe - Remove Jack bolt
	L joint tool	35A91-06100		L joint (for antler pipe) - Installation and positioning
Dummy water pump	Snap ring pliers	37591-03100		Dummy water-pump cover hole snap ring - Installation and removal Applicable size: ø180 to ø300 [7.09 to 11.81]

Maintenance item	Tool name	Part number	Configuration	Intended use
Test and adjustment	Compression gauge	35A91-03300		Compression Pressure - Measure 0 to 4 MPa {0 to 41 kgf/cm^2} [0 to 580 psi]
	Gauge hose	35A91-03400		Compression Pressure - Measure 0 to 4 MPa {0 to 41 kgf/cm^2} [0 to 580 psi]
	Gauge adapter	35A91-03500		
	RS485 cable	37791-06400		ICS, EGS02 setting cable Wire dia. 0.75 mm^2 [0.0295 in^2.]
	RS485-USB converter	37791-06500		ALTORO/EGS02 setting Adaptor for USB conversion cable and dedicated cable
	RS232-TTL converter	37791-06600		ICS,TECJET52 setting Adopter for USB conversion cable and dedicated cable
	RS232C cable	37791-06700		ICS, PROACT/TECJET setting cable Wire dia. 1.25 mm^2 [0.0492 in^2.]
	RS232C-RS485 Converter	37791-06300		Knock detection system Adaptor between DET-1600/CD200D and PC

Maintenance item	Tool name	Part number	Configuration	Intended use
Actuator coupling	Gauge	37791-14200		Clearance adjustment for Pro Act Actuator coupling during installation

Chapter 4 OVERHAUL INSTRUCTIONS

1. Determining Overhaul Timing

1.1 Definition of Overhaul

Overhaul is to disassemble the engine and replace parts within a specified period to keep the engine in good conditions until the next overhaul.

When the soundness of a part may not be maintained until next overhaul even if the part is in the standard condition at the moment, the part must be replaced.

1.2 Determining Overhaul Timing

In most cases, the engine should be overhauled when the compression pressure of the engine decreases. An increase in engine oil consumption and blow-by gas should be considered when evaluating the engine condition.

Such symptoms as the output decrease, fuel gas consumption increase, oil pressure decrease, engine starting difficulty and noise increase should be considered to evaluate overhaul timing, although these symptoms are often affected by various causes, and are not always effective to consider overhaul timing.

Decreased compression pressure shows a variety of symptoms and engine conditions, thus making it difficult to accurately determine when the engine needs an overhaul.

Typical symptoms are:

(1) Decrease in output power
(2) Increase in fuel gas consumption
(3) Increase in engine oil consumption
(4) Increase in combustion gas leaks due to wear of cylinder liner, piston ring, etc., and as a result, increase in blow-by gas through the breather (Visually check the blow-by amount.)
(5) Increase in gas leaks due to poor seating of inlet and exhaust valves
(6) Worsened Startability
(7) Increase in noise of engine parts
(8) Abnormal exhaust color after engine warm-up

The engine shows above symptoms in various combinations.

Some of those symptoms are directly caused by worn engine parts, while others are not.

Phenomena described in items (2) and (6) can result from improper ignition timing, pre-chamber gas valve wear, faulty conditions of spark plug and electrical devices such as battery and starter.

The most valid reason to overhaul the engine is the compression pressure decrease due to worn cylinder liner and piston ring, as described in item (4). And once this symptom appears, it is reasonable to take other symptoms into consideration for making the final decision.

2. Compression Pressure - Measure

CAUTION

(a) Be sure to measure the compression pressure for all the cylinders. It is not a good practice to measure the compression pressure for two or three cylinders and assume the compression pressure is the same for all cylinders.

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

(c) It is important to measure the compression pressure at regular intervals, and know the change of the pressure.

(1) Remove the spark plug from the cylinder head where the compression pressure is to be measured.

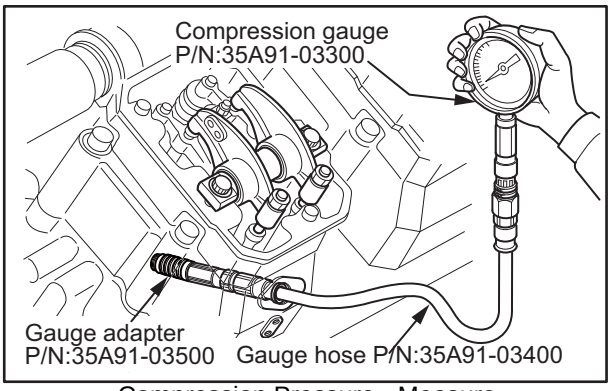
(2) Install the gauge adapter into the spark plug hole with the gauge hose inserted condition.
Hand tighten the cage adapter to be held in the thread hole by rotating the hose, then connect the compression gauge to the hose.

(3) Shut off the fuel gas supply, and crank the engine with the starter.
Read the engine speed and compression pressure while the engine is running at a stable speed.

Note: Ensure the battery being fully charged to crank the engine with the starter.
If the battery voltage is low, the compression pressure cannot be measured properly because of a low cranking speed.

(4) If the measured value exceeds the limit, overhaul should be done to perform inspection.

Item	Standard value	Limit value	Rotational speed at the standard pressure
Compression pressure	2.6 MPa {26.5 kgf/cm^2} [377.1 psi]	1.95 MPa {19.9 kgf/cm^2} [282.82 psi]	Approx. at 120 min^{-1}



Compression Pressure - Measure

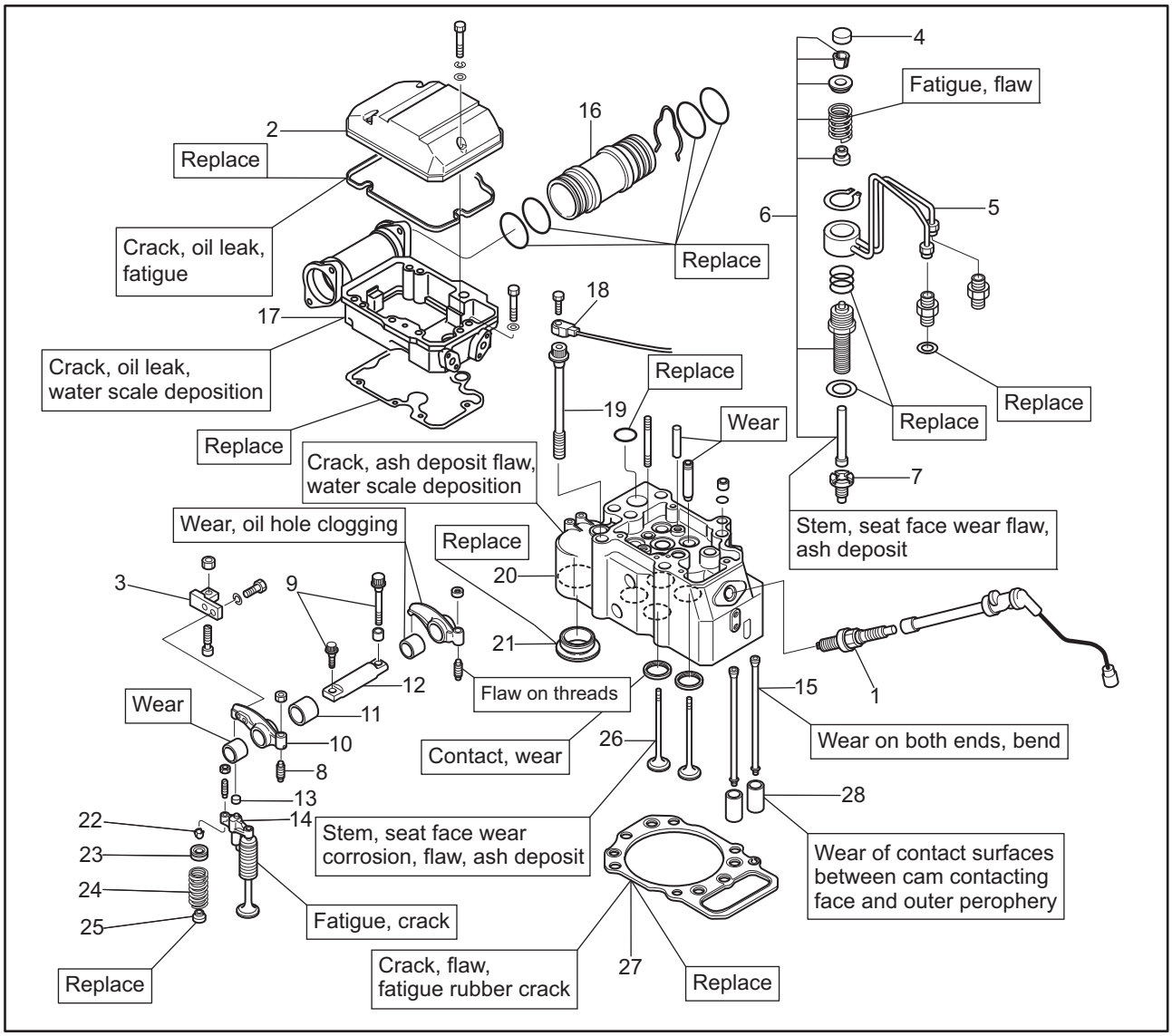
Chapter 5 DISASSEMBLY OF BASIC ENGINE

1. Cylinder Head and Valve Mechanism - Disassemble and Inspect

Understanding of the current engine condition before disassembling is very important to find the cause of trouble and to perform efficient maintenance work.

Depending on the maintenance work or purpose, it is desirable to inspect some of the following items before proceeding with any job.

- Valve Clearance and Pre-chamber Valve Clearance- Inspect
- Clearance Between Bottom Face of Valve Bridge and Top Face of Valve Rotator - Inspect
- Valve Sinkage and Pre-chamber Valve Protrusion - Measure



Cylinder Head and Valve Mechanism - Disassemble and Inspect

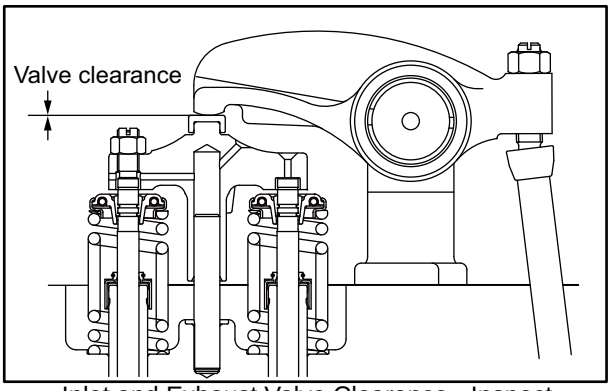
Disassembly sequence

1 Spark plug
2 Rocker cover
3 Pre-chamber gas valve rocker arm
4 Gas valve cap
5 Antler pipe
6 Pre-chamber gas valve assembly
7 Pre-chamber
8 Adjusting screw
9 Bolt
10 Rocker arm
11 Spacer
12 Rocker shaft
13 Bridge cap
14 Valve bridge
15 Push rod
16 Water outlet connector
17 Rocker case
18 Knock sensor
19 Cylinder head bolt
20 Cylinderhead(Approx.35kg[77lb.])
21 Inlet port packing
22 Valve cotter
23 Valve rotator
24 Valve spring
25 Stem seal
26 Valve
27 Cylinder head gasket
28 Tappet

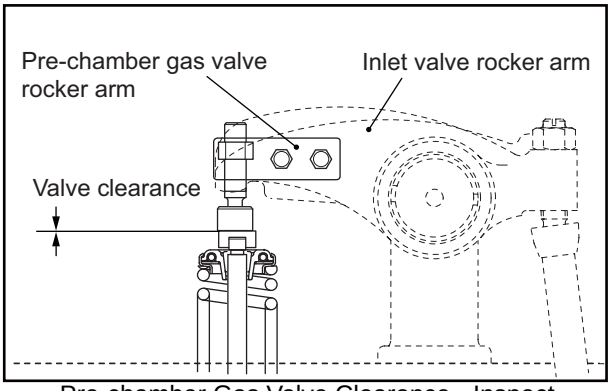
1.1 Valve Clearance - Inspect

Check the clearance of inlet, exhaust, and pre-chamber gas valves to understand the current state.

For the inspection procedure, see "Valve Clearance - Inspect and Adjust" of "ENGINE BODY - ASSEMBLE."



Inlet and Exhaust Valve Clearance - Inspect



Pre-chamber Gas Valve Clearance - Inspect

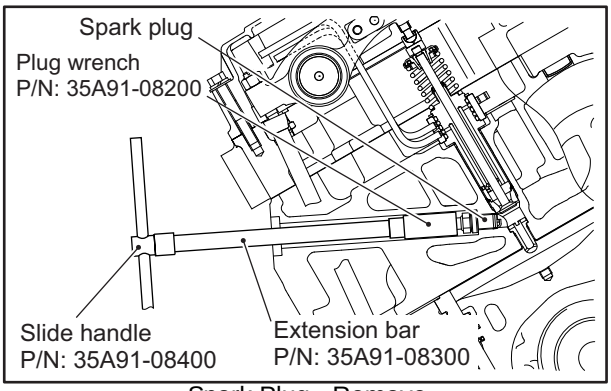
1.2 Spark Plug - Remove

CAUTION

(a) Before removing the spark plug, wipe dust off around the hole where the spark plug is inserted.

(b) Use care not to allow dust to enter the cylinder head when the spark plug is removed.

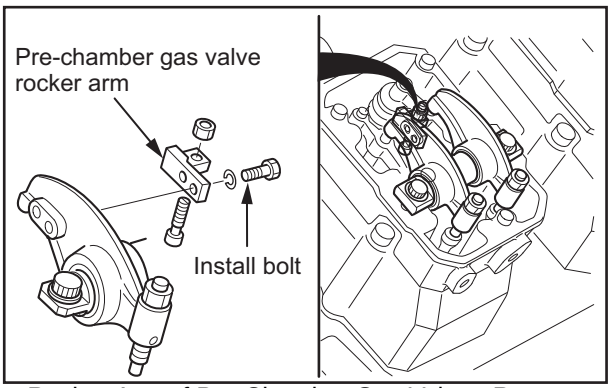
Remove the spark plug code, and remove the spark plug from cylinder head with the plug wrench, extension bar, and slide handle.



Spark Plug - Remove

1.3 Rocker Arm of Pre-Chamber Gas Valve - Remove

Remove the pre-chamber gas-valve rocker arm installed on the inlet-valve rocker arm.



Rocker Arm of Pre-Chamber Gas Valve - Remove

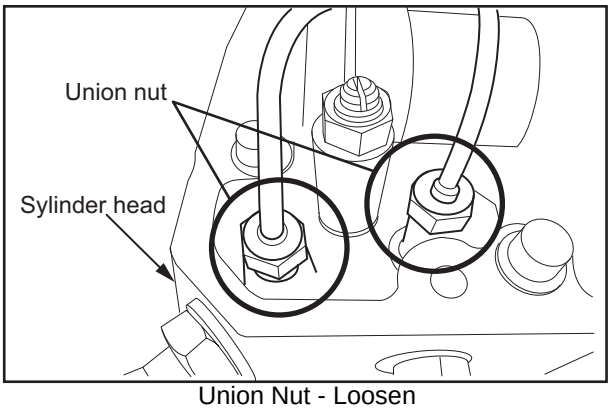
1.4 Antler Pipe - Remove

(1) Loosen the union nuts at the ends of antler pipe.

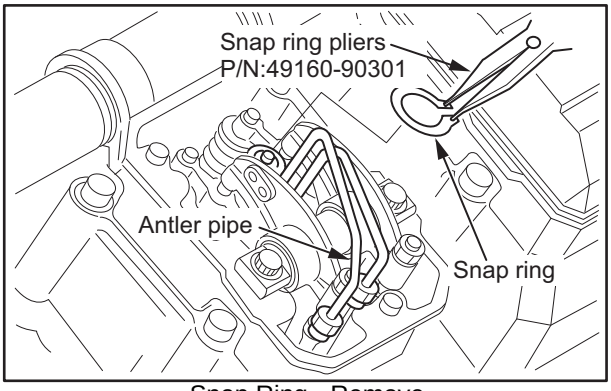
(2) Remove the snap ring with snap ring pliers. At this moment, hold the snap ring firmly with the snap ring priers.

(3) Screw the pipe remover (jack bolt) into the welded nut on the antler pipe, and remove the antler pipe.

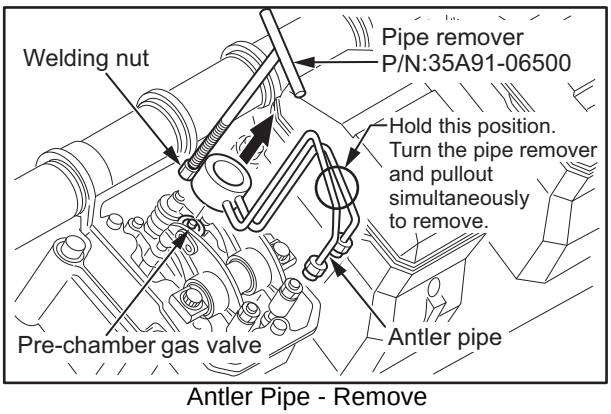
Note: Do not forcibly pull the pipe by holding it.



Union Nut - Loosen



Snap Ring - Remove



Antler Pipe - Remove

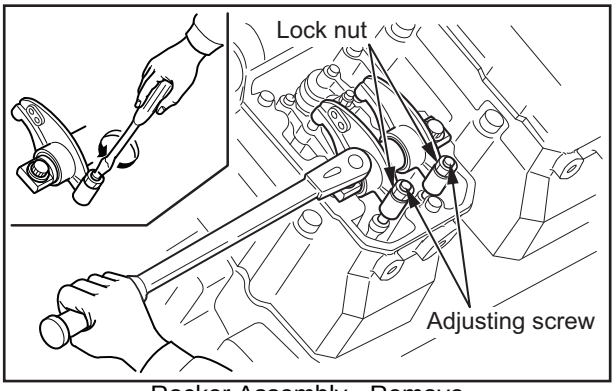
1.5 Rocker Assembly - Remove

(1) Loosen the adjusting screw of rocker arm.

(2) Remove the rocker assembly from rocker case.

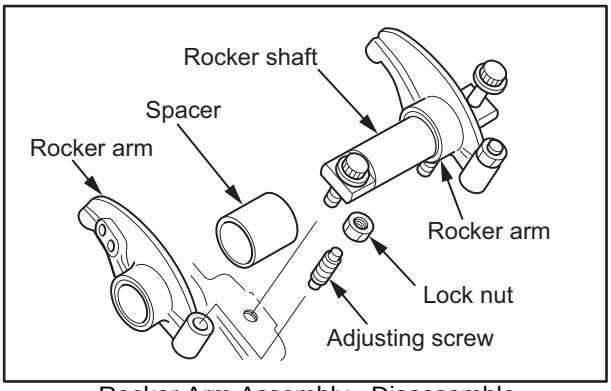
Note: Keep the removed rocker assembly and bolts together.

(3) Remove the push rod.



Rocker Assembly - Remove

(4) Disassemble the rocker assembly.

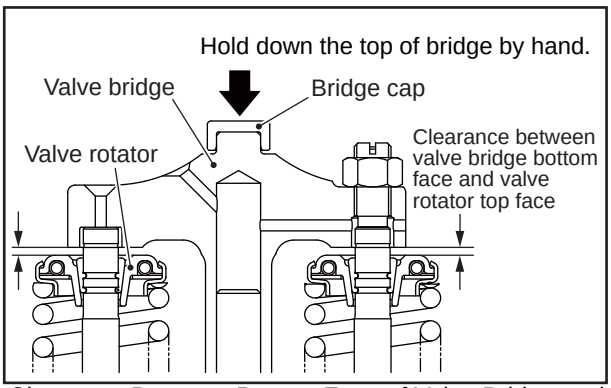


Rocker Arm Assembly - Disassemble

1.6 Clearance Between Bottom Face of Valve Bridge and Top Face of Valve Rotator - Inspect

Inspect the clearance between the bottom face of valve bridge and the top face of valve rotator to check the current condition.

For the inspection procedure, see "Clearance Between Bottom Face of Valve Bridge and Top Face of Valve Rotator - Inspect" of "ENGINE BODY - ASSEMBLE."

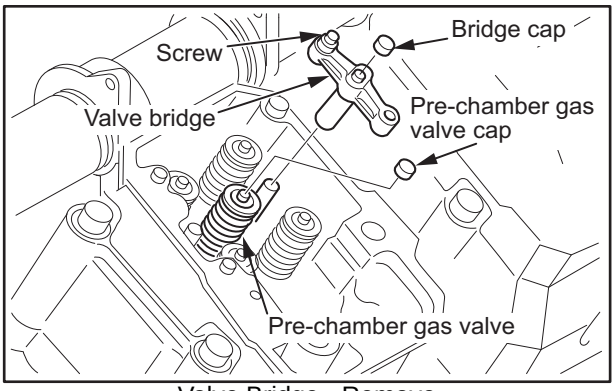


Clearance Between Bottom Face of Valve Bridge and Top Face of Valve Rotator - Inspect

1.7 Valve Bridge - Remove

Remove the valve bridge, bridge cap, and pre-chamber gas valve cap.

Note: Be careful not to drop the bridge cap into the push rod hole.

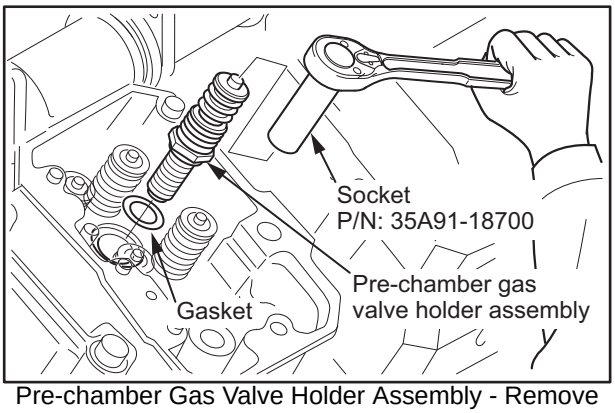


Valve Bridge - Remove

1.8 Pre-chamber Gas Valve Holder Assembly - Remove

(1) Remove the pre-chamber gas valve holder assembly using the socket.

(2) Remove the gasket.



Pre-chamber Gas Valve Holder Assembly - Remove

1.9 Pre-chamber Gas Valve Protrusion - Measure

Measure the pre-chamber gas valve protrusion, and understand the current condition.

For the measurement procedure, refer to "Pre-chamber Gas-Valve Holder - Correct" of "ENGINE BODY- INSPECT AND REPAIR."

1.10 Pre-chamber - Remove

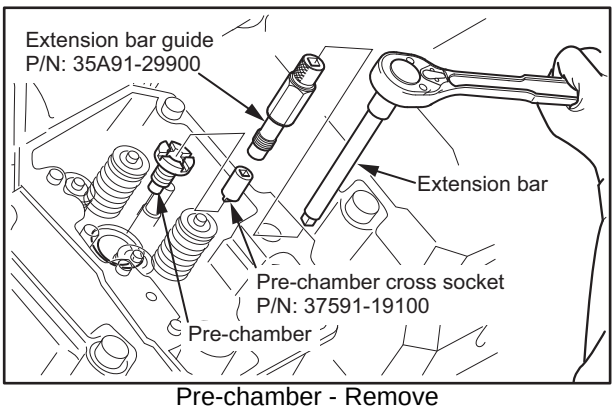
CAUTION

Before removing, spray a thread-loosening agent to the pre-chamber.

(1) Insert the extension bar into the extension bar guide, and put the pre-chamber cross socket in the tip of the extension bar.

(2) Insert the tool assembled with the three parts into the pre-chamber groove in pre-chamber gas valve hole.

(3) Loosen the pre-chamber, and remove the pre-chamber from the cylinder head.

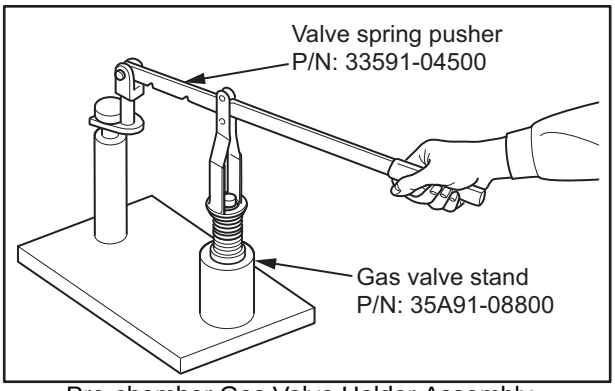


Pre-chamber - Remove

1.11 Pre-chamber Gas Valve Holder Assembly - Disassemble

Using the gas valve stand and valve spring pusher, compress the gas valve spring evenly, and remove the cotter, and then remove the rotator, gas valve spring, and gas valve.

Note: If gas valves are to be reused, mark each gas valve and the mating gas valve holder for identification. Do not change the gas valve and gas valve holder combination.

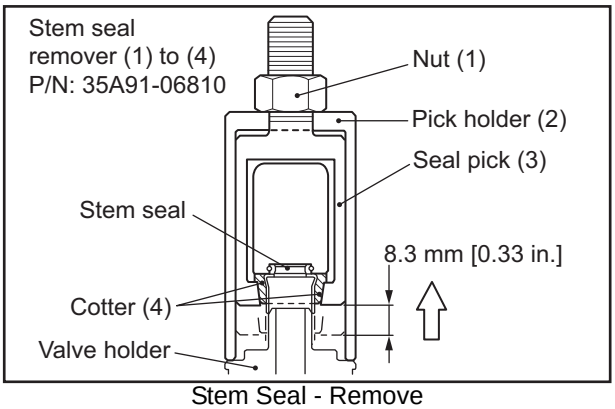


Pre-chamber Gas Valve Holder Assembly - Disassemble

1.12 Stem Seal of Pre-chamber Gas Valve - Remove

Remove the stem seal with the pre-chamber gas-valve stem-seal remover.

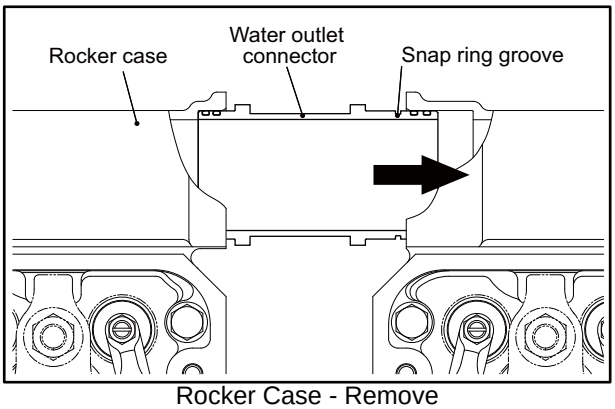
(1) Fully loosen the nut, and install the pick holder and seal pick over the valve holder.
(2) Install cotters between seal pick and stem seal.
(3) Tighten the nut.
The stem seal will come off as the seal pick moves upward.



Stem Seal - Remove

1.13 Rocker Case - Remove

(1) Remove the snap ring from the water outlet connector.
(2) Slide the water outlet connector to the snap ring groove side, and separate it from the adjacent rocker case.
(3) Remove the rocker case from the cylinder head.



Rocker Case - Remove

1.14 Cylinder Head Assembly - Remove

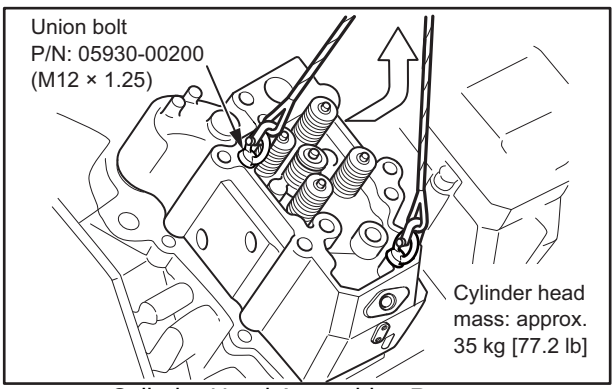
CAUTION

When removing the cylinder head gasket, be careful not to damage the cylinder head and crankcase surface with a screwdriver or the like.

(1) Remove the cylinder head bolt.
(2) Remove the cylinder head by lifting with a hoist.

Note: Dowel pins are used to retain the cylinder head in a position. Therefore, pull the cylinder head vertical to the mounting surface when lifting.

(3) Remove the cylinder head gasket.



Cylinder Head Assembly - Remove

1.15 Valve Sinkage - Measure

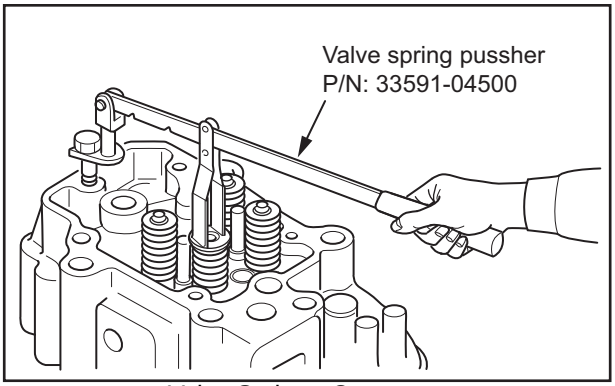
Measure the valve sinkage to check the current condition.

For the measurement procedure, refer to "Valve Sinkage - Measure" of "ENGINE BODY - ASSEMBLE."

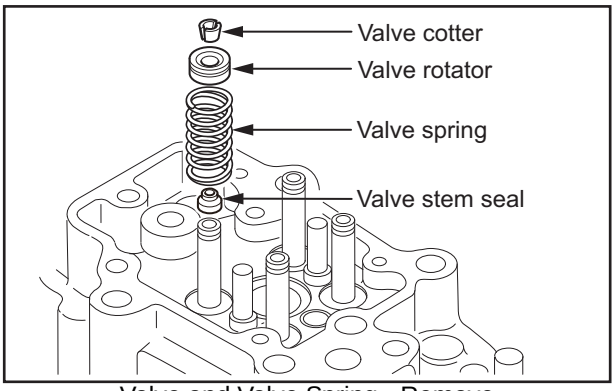
1.16 Valve and Valve Spring - Remove

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

Note: If valves are reusable, mark the each valve seat and the mating valve to identify their original positions. Do not change the combination of the valve seat and the valve when reassembling.



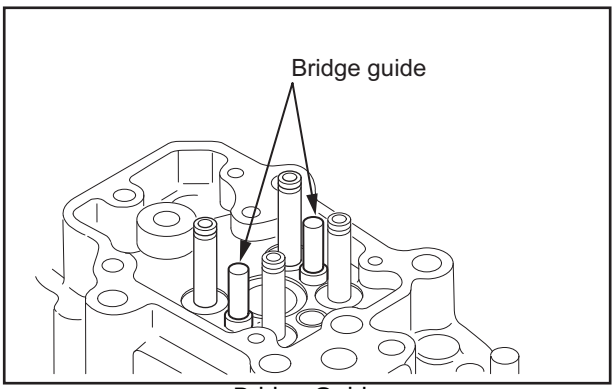
Valve Spring - Compress



Valve and Valve Spring - Remove

1.17 Bridge Guide

Do not remove the bridge guide from the cylinder head unless it is necessary. When removed, replace with new bridge guide by press-fit.



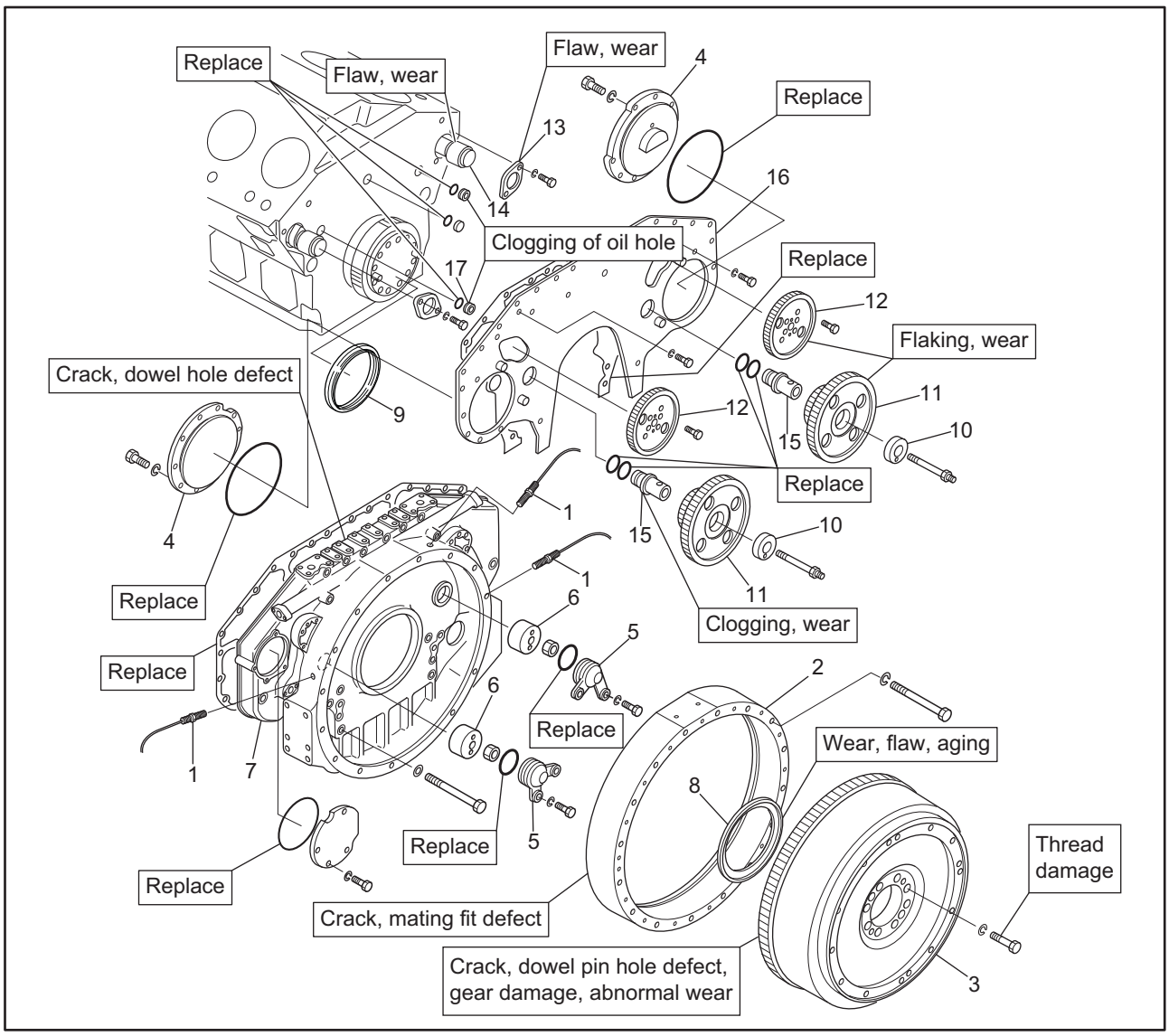
Bridge Guide

2. Rear Mechanism - Disassemble and Inspect

Understanding of the current engine condition before disassembling is very important to find the cause of trouble and to perform efficient maintenance work.

Depending on the maintenance work or purpose, it is desirable to inspect some of the following items before proceeding with any job.

- Face and Radial Runouts of Flywheel and Spacer - Measure
- Timing Gear Backlash - Measure
- End Play of Rear Idler Gear and Camshaft - Measure



Rear Mechanism - Disassemble and Inspect

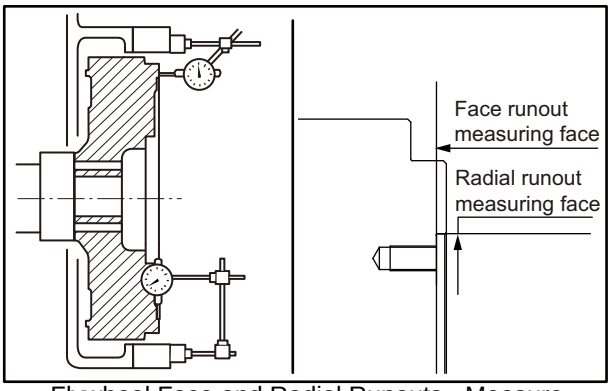
Disassembly sequence

1 Pickup
2 Spacer (approx. 105 kg [231.5 lb.])
3 Flywheel (approx. 565 kg [1245.6 lb.])
4 Rear plate cover
5 Cover
6 Thrust collar
7 Timing gear case (approx. 185 kg [407.9 lb.])
8 Oil seal
9 Oil seal slinger
10 Thrust plate
11 Idler gear
12 Camshaft gear
13 Thrust plate
14 Camshaft (approx. 50 kg [110.2 lb.])
15 Idler shaft
16 Rear plate (approx. 30 kg [66.1 lb.])
17 Nozzle plate

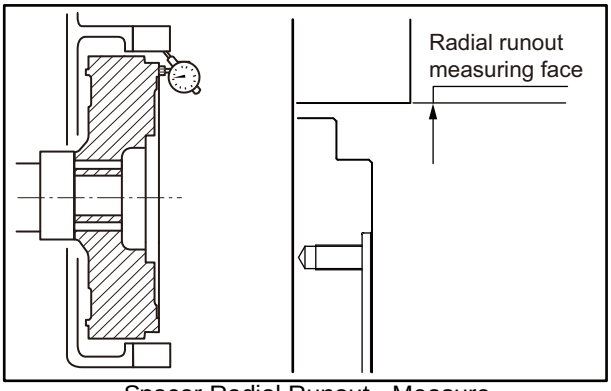
2.1 Face and Radial Runouts of Flywheel and Spacer - Measure

Measure the face and radial runouts of the flywheel and spacer, and understand the current condition.

For the measurement procedure, refer to "Flywheel Face and Radial Runouts - Measure" and "Spacer Radial Runout - Measure" of "ENGINE BODY - ASSEMBLE".



Flywheel Face and Radial Runouts - Measure



Spacer Radial Runout - Measure

2.2 Spacer - Remove

⚠ CAUTION

Be careful not to drop or hit the spacer. It can, not only cause damage, but also may cause personnel injury.

The spacer is mounted on the timing gear case with bolts which head painted red after alignment. Do not remove the spacer from the timing gear case unless it is necessary.

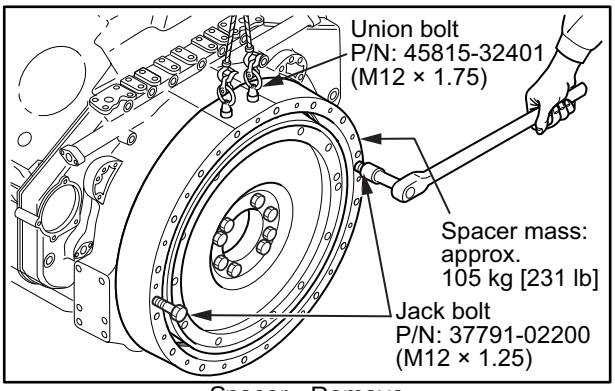
If removed, centering adjustment is necessary when assembling.

(1) Attach a hoisting tool to the spacer to prevent it from falling off.

(2) Screw two jack bolts evenly into the jack bolt holes, and remove the spacer.

Note:(a) Do not remove the spacer from the timing gear case unless it is necessary.

(b) When removed, adjust the centering before assembling.



Spacer - Remove

2.3 Flywheel - Remove

⚠ CAUTION

(a) Be careful not to drop or hit the flywheel. It can, not only cause damage, but also may cause personnel injury.

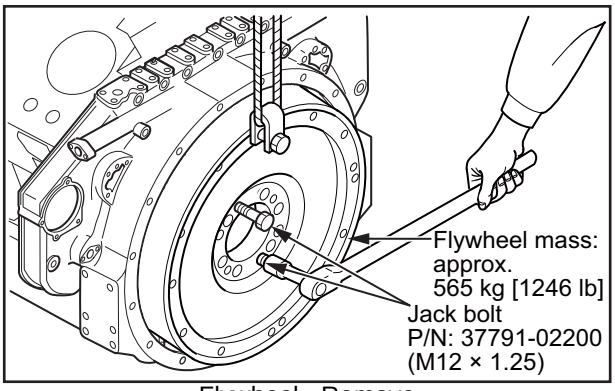
(b) Be careful not to cut your hands with the ring gear when pulling-out the flywheel.

CAUTION

Be sure to remove the pickups before removing the flywheel.

(1) Attach a sling to the flywheel to prevent it from falling off.

(2) Screw two jack bolts evenly into the bolt holes, and remove the flywheel.



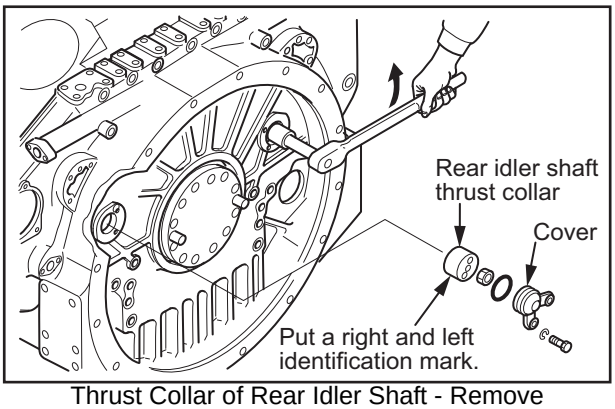
Flywheel - Remove

2.4 Thrust Collar of Rear Idler Shaft - Remove

(1) Remove the cover from the timing gear case.

(2) Install the bolts (M6 × 1.0 mm) into the dedicated bolt holes for removal of rear idler shaft thrust collar, and remove the rear idler shaft thrust collar.

Note: Mark the collar installing position of right or left to ensure the correct backlash and end play on assembling.



Thrust Collar of Rear Idler Shaft - Remove

2.5 Timing Gear Case - Remove

⚠ CAUTION

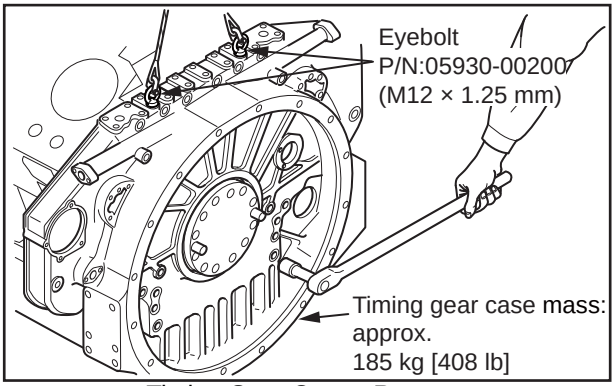
Be careful not to drop or hit the timing gear case. It can, not only cause damage, but also may cause personnel injury.

(1) Attach a sling to the timing gear case to prevent it from falling off.

(2) Lift the timing gear case to disengage the dowel pins, and remove the timing gear case.

(3) Remove the oil seal from the timing gear case.

Note: Replace the removed oil seal with a new one. Oil seal cannot be re-used.

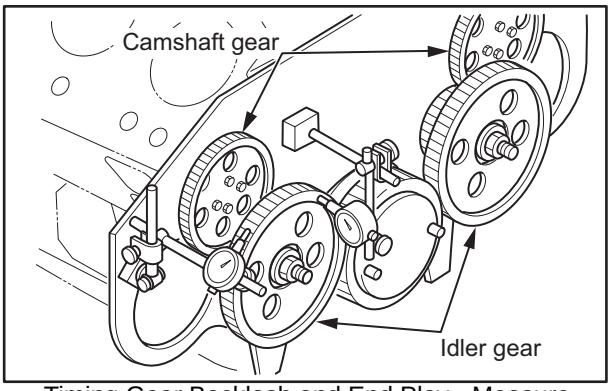


Timing Gear Case - Remove

2.6 Timing Gear Backlash - Measure

Measure the timing gear backlash to check the current condition.

For measurement procedure, see "Timing Gear Backlash - Measure" of "ENGINE BODY - ASSEMBLE".



Timing Gear Backlash and End Play - Measure

2.7 Rear Idler Gear End Play - Measure

Measure the rear idler gear end play, and understand the current condition.

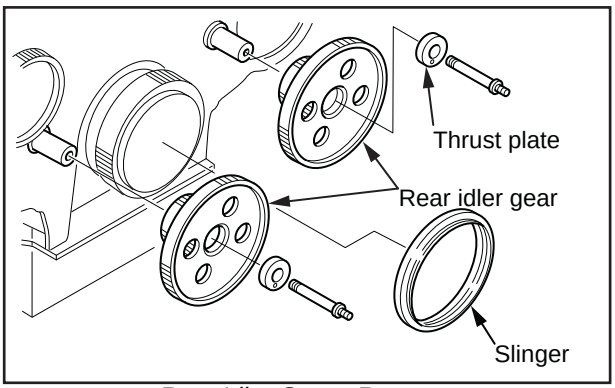
For the measurement procedure, refer to "Rear Idler Gear End Play - Measure" of "ENGINE BODY - ASSEMBLE."

2.8 Rear Idler Gear - Remove

(1) Remove the oil seal slinger from the crankshaft.

(2) Remove thrust plate.

(3) Remove the rear idler gears (right and left.)

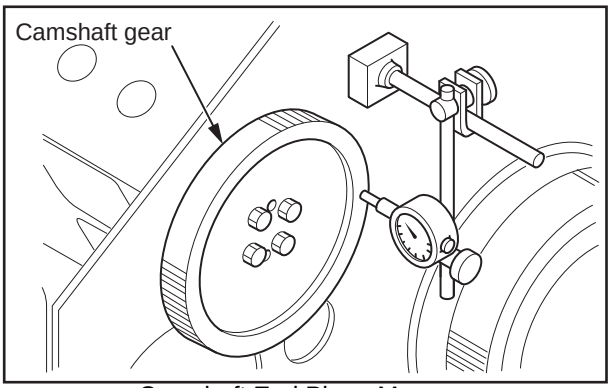


Rear Idler Gear - Remove

2.9 Camshaft End Play - Measure

Measure the camshaft end play to check the current condition.

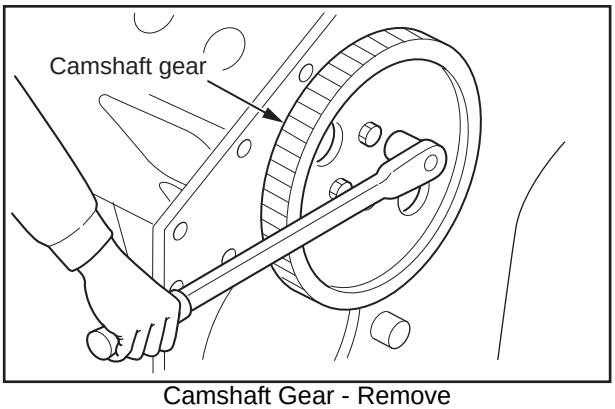
For measurement procedure, see "Camshaft End Play - Measure" of "ENGINE BODY - ASSEMBLE".



Camshaft End Play - Measure

2.10 Camshaft Gear - Remove

Remove the camshaft gear from the camshaft.



Camshaft Gear - Remove

2.11 Camshaft - Remove

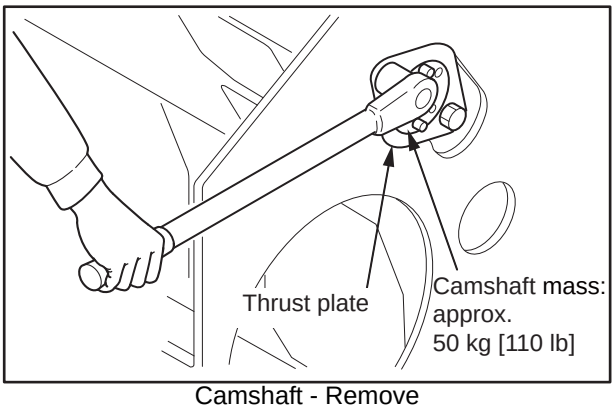
CAUTION

Support the camshaft with a wood stick or the like through the side cover opening. Carefully remove the camshaft so as not to cause damage to the crankcase and camshaft bushing.

(1) Remove thrust plate.

(2) Support the camshaft through the side cover opening, and remove the camshaft from the crankcase.

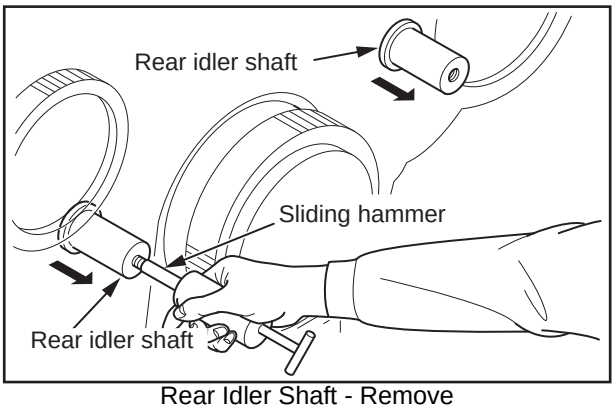
Note: Before removing camshaft, remove the oil seal case, oil seal, and coupling from the cam shaft front end.



Camshaft - Remove

2.12 Rear Idler Shaft - Remove

Install the sliding hammer to the top face thread (M22 × 1.5 mm [0.059 in]) for removal, and remove the rear idler shaft.

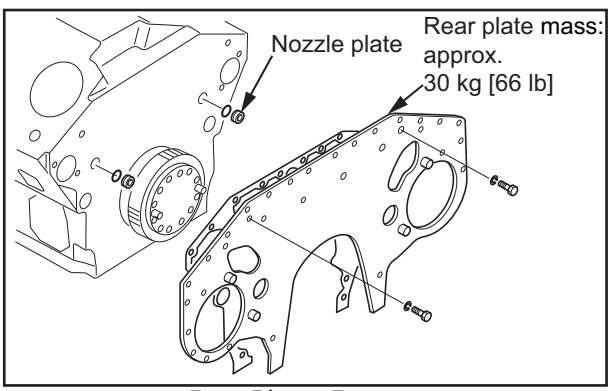


Rear Idler Shaft - Remove

2.13 Rear Plate - Remove

(1) Remove the rear plate from the crankcase.

(2) Remove the nozzle plate from the crankcase.



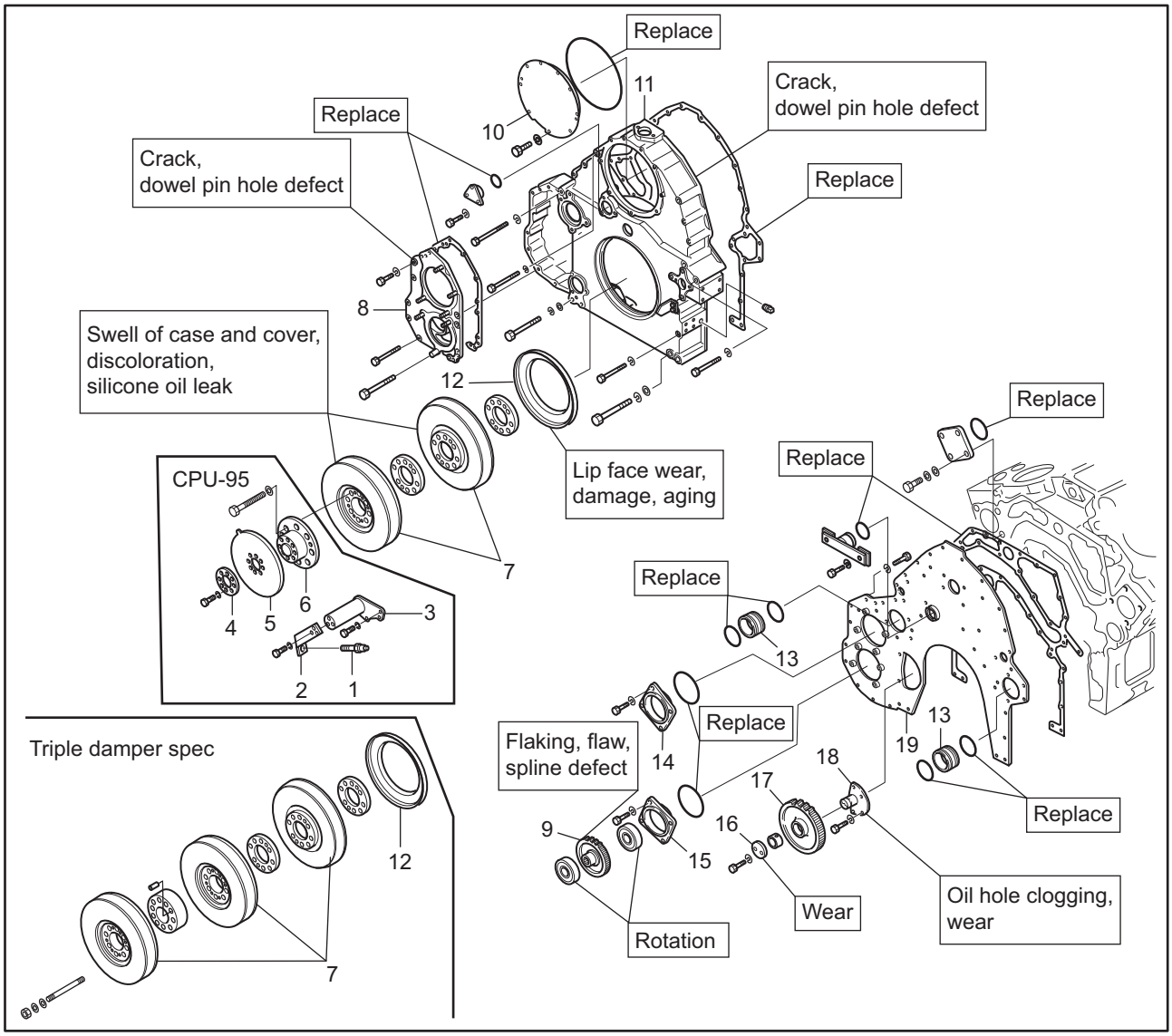
Rear Plate - Remove

3. Front Mechanism - Disassemble and Inspect

Understanding of the current engine condition before disassembling is very important to find the cause of trouble and to perform efficient maintenance work.

Depending on the maintenance work or purpose, it is desirable to inspect some of the following items before proceeding with any job.

- ♦Front Idler Gear Backlash - Measure
- ♦Front Idler Gear End Play - Measure



Front Mechanism - Disassemble and Inspect

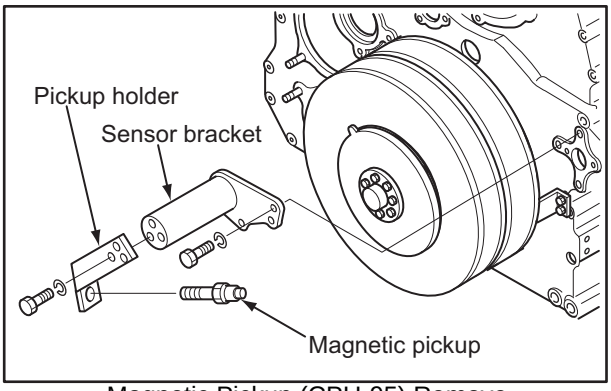
Disassembly sequence

1 Magnetic pickup
2 Pickup holder
3 Sensor bracket
4 Rotor plate
5 Reset pulse rotor
6 Rotor space
7 Damper (approx. 50 kg [110.2 lb.])
8 Pump plate
9 Oil pump gear
10 Gear case cover
11 Front gear case (approx. 75 kg [165.3 lb.])
12 Oil seal
13 Water coupling
14 Water pump bearing cover
15 Oil pump bearing cover
16 Thrust plate
17 Idler gear
18 Idler shaft
19 Front plate (approx. 25 kg [55.1 lb.])

3.1 Magnetic Pickup (CPU-95) - Remove

(1) Remove the pickup holder and magnetic pickup as a set from the sensor bracket.

(2) Remove the sensor bracket from the mounting bracket.

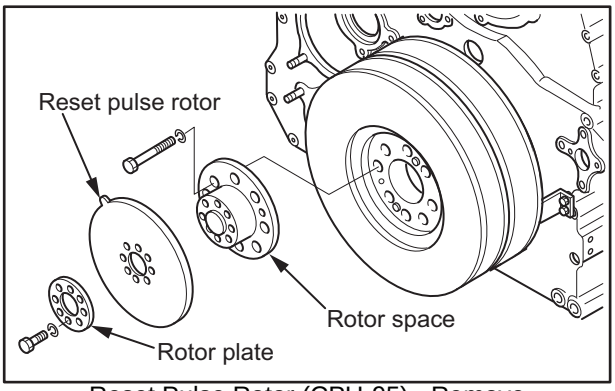


Magnetic Pickup (CPU-95) Remove

3.2 Reset Pulse Rotor (CPU-95) - Remove

(1) Remove the rotor plate and reset pulse rotor.

(2) Screw in two jack bolts evenly, and remove the rotor space.



Reset Pulse Rotor (CPU-95) - Remove

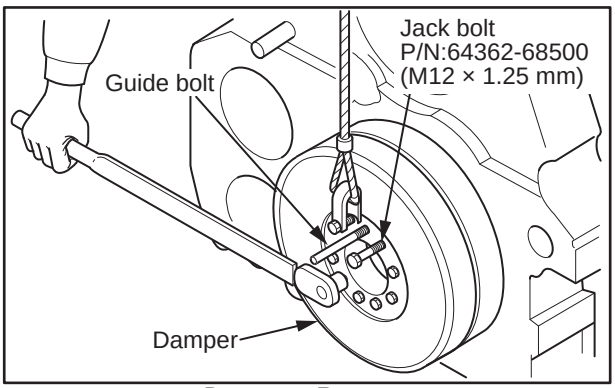
3.3 Damper (Double) -Remove

⚠ CAUTION

Be careful not to drop or hit the damper. It can, not only cause damage, but also may cause personnel injury.

(1) Install guide bolt in damper mounting bolt hole on crankshaft.

(2) While supporting the damper with a sling, screw two jack bolts evenly into bolt holes, and remove the damper.



Damper - Remove

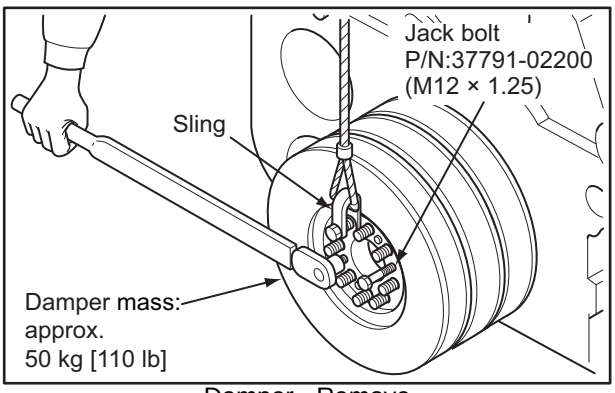
3.4 Damper (Triple) - Remove

⚠ CAUTION

Be careful not to drop or hit the damper. It can, not only cause damage, but also may cause personnel injury.

(1) Remove the damper setting nut and use the stud bolt as a guide.

(2) While supporting the damper with a sling, screw two jack bolts evenly into bolt holes, and remove the damper.

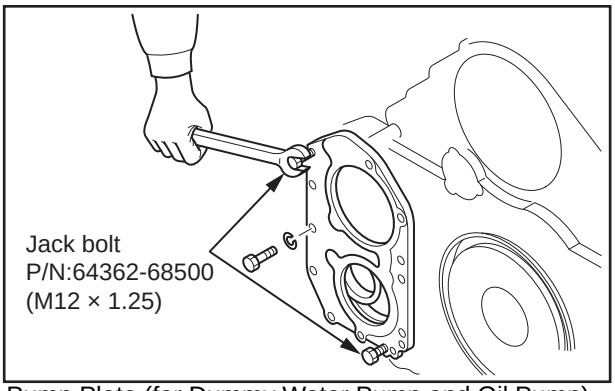


Damper - Remove

3.5 Pump Plate (for Dummy Water Pump and Oil Pump) - Remove

Install two jack bolts evenly into the jack bolt holes, and remove the pump plate.

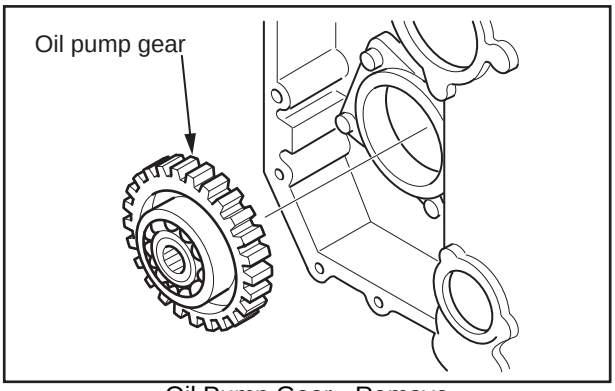
Note: Remove the oil pump and dummy water pump, then remove the pump plate.
Refer to the chapter "OIL SYSTEM" for the removal of oil pump.
Refer to the chapter "COOLING SYSTEM" for the removal of dummy water pump.



Pump Plate (for Dummy Water Pump and Oil Pump) - Remove

3.6 Oil Pump Gear - Remove

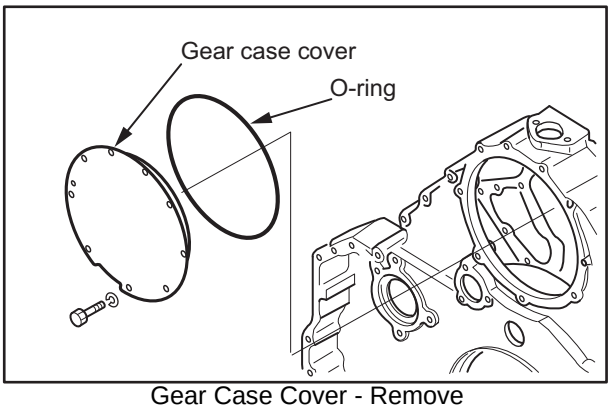
Remove the oil pump gear together with the bearing.



Oil Pump Gear - Remove

3.7 Gear Case Cover - Remove

Remove the gear case cover and O-ring.



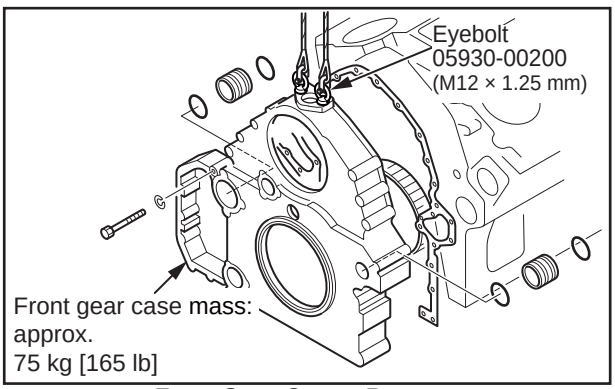
Gear Case Cover - Remove

3.8 Front Gear Case - Remove

CAUTION

When removing the front gear case, be careful not to damage the oil seal or not to distort the pointer by hitting.

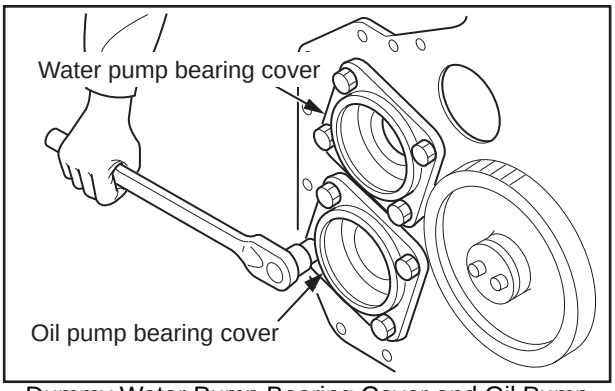
(1) Attach slings to the front gear case.
(2) Lift the front gear case to disengage the dowel pins, and remove the front gear case.
(3) Remove the oil seal from the front gear case.



Front Gear Case - Remove

3.9 Dummy Water Pump Bearing Cover and Oil Pump Bearing Cover - Remove

Remove the dummy water pump bearing cover and oil pump bearing cover from the front plate.

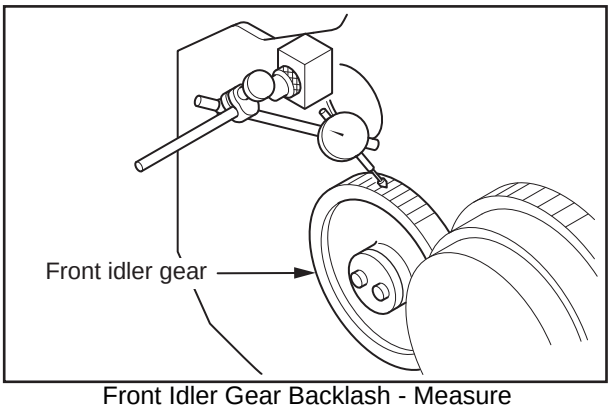


Dummy Water Pump Bearing Cover and Oil Pump Bearing Cover - Remove

3.10 Front Idler Gear Backlash - Measure

Measure the front idler gear backlash to understand the current condition.

For the measurement procedure, refer to "Front Idler Gear Backlash - Measure" of "ENGINE BODY - ASSEMBLE."

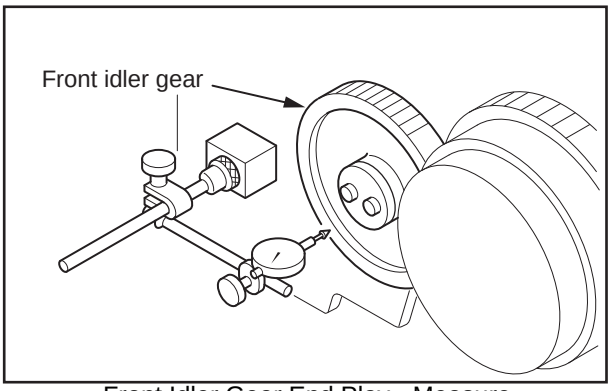


Front Idler Gear Backlash - Measure

3.11 Front Idler Gear End Play - Measure

Measure the end play of front idler gear to understand the current condition.

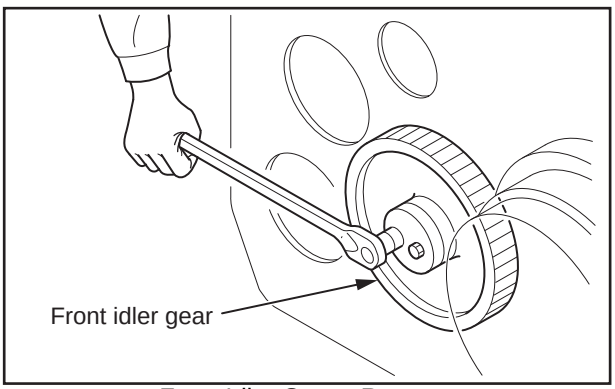
For the measurement procedure, refer to "End Play of Front Idler Gear - Measure" of "ENGINE BODY - ASSEMBLE"



Front Idler Gear End Play - Measure

3.12 Front Idler Gear - Remove

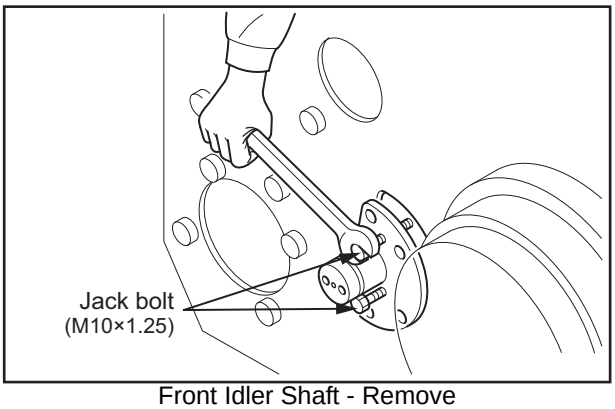
Remove the thrust plate and front idler gear from the front idler shaft.



Front Idler Gear - Remove

3.13 Front Idler Shaft - Remove

Do not remove the front idler shaft unless it is necessary. To remove, screw two jack bolts evenly into the front idler shaft.

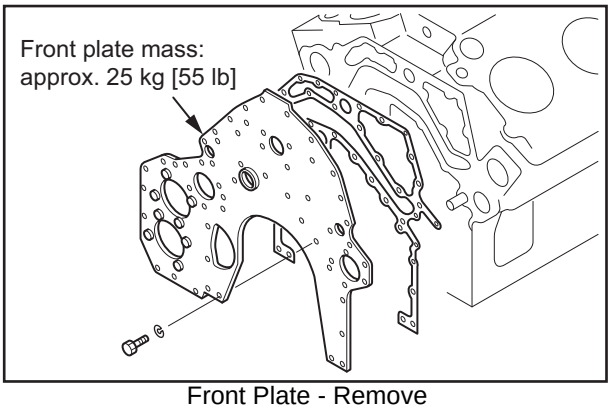


Front Idler Shaft - Remove

3.14 Front Plate - Remove

Remove the bolts, and remove the front plate from crankcase.

Note: If it is difficult to remove the front plate, lightly tap it with a plastic hammer paying attention not to bend.



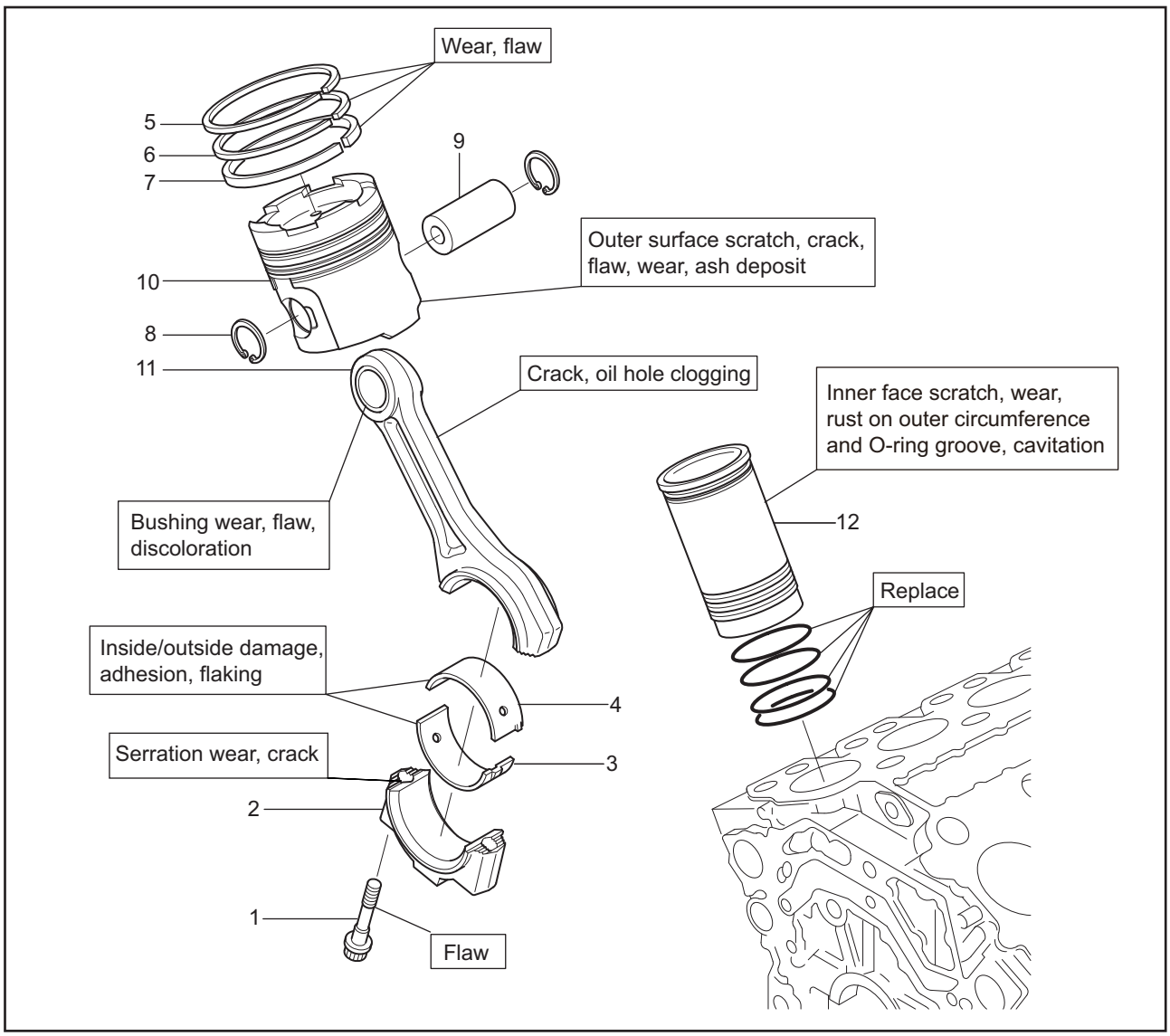
Front Plate - Remove

4. Cylinder Liner, Piston, and Connecting Rod - Disassemble and Inspect

Understanding of the current engine condition before disassembling is very important to find the cause of trouble and to perform efficient maintenance work.

Depending on the maintenance work or purpose, it is desirable to inspect some of the following items before proceeding with any job.

- Connecting Rod End Play - Measure
- Cylinder Liner Inside Diameter - Measure
- Cylinder Liner Flange Protrusion - Measure



Cylinder Liner, Piston, and Connecting Rod - Disassemble and Inspect

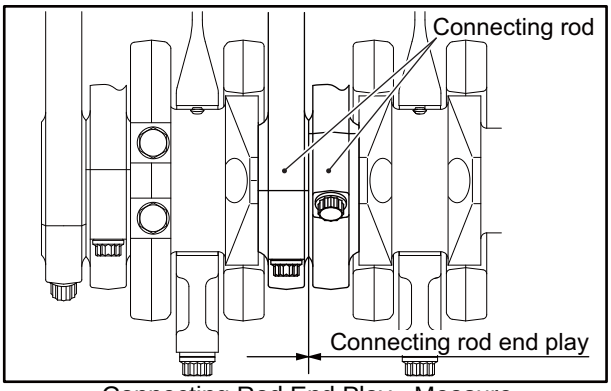
Disassembly sequence

1 Connecting rod cap bolt
2 Connecting rod cap
3 Lower connecting rod bearing
4 Upper connecting rod bearing
5 No. 1 compression ring
6 No. 2 compression ring
7 Oil ring
8 Snap ring
9 Piston pin
10 Piston
11 Connecting rod (approx. 11 kg [24.3 lb.])
12 Cylinder liner (approx. 16 kg [35.3 lb.])

4.1 Connecting Rod End Play - Measure

Measure the connecting rod end play to check the current condition.

For measurement procedure, see "Connecting Rod End Play - Measure" of "ENGINE BODY - ASSEMBLE".



Connecting Rod End Play - Measure

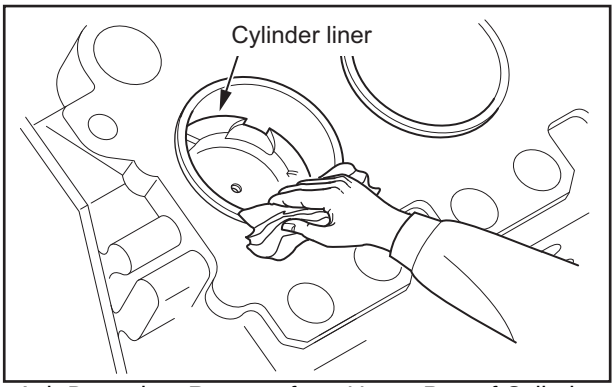
4.2 Ash Deposits - Remove from Upper Part of Cylinder Liner

CAUTION

Be sure to remove ash deposits from the upper part of the cylinder liner before removing the piston. Ash deposits, if not removed, cause damage to the piston and piston rings.

Using a proper remover, remove ash deposits from the upper part of the cylinder liner.

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

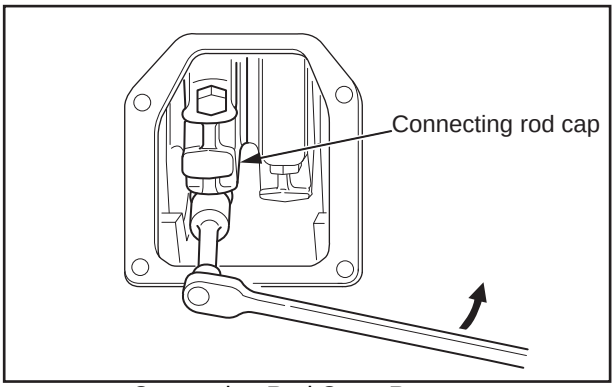


Ash Deposits - Remove from Upper Part of Cylinder Liner

4.3 Connecting Rod Cap - Remove

Using a socket wrench, remove the connecting rod bolts through the inspection window on the side of the crankcase, and remove the connecting rod cap and connecting rod bearings.

Note: Make marks, such as cylinder number and distinction between upper and lower, on the removed connecting rod bearings to ensure the correct reassembly.



Connecting Rod Cap - Remove

4.4 Piston - Remove

⚠ CAUTION

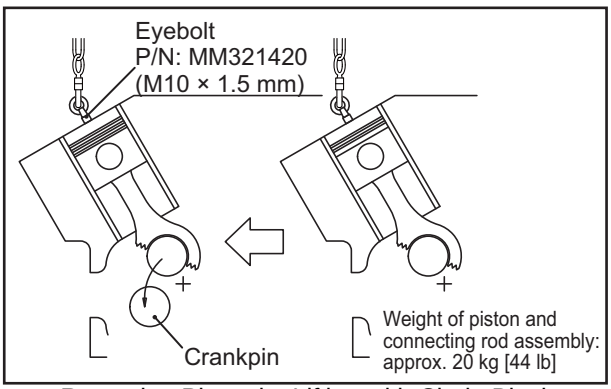
When holding the connecting rod with your hand to prevent it from swinging, be very careful. You may suffer hand injuries from accidental movement of the connecting rod.

CAUTION

(a) When pulling out the piston, be careful not to drop the upper connecting rod bearing.
(b) When removing the piston, be careful not to damage the cylinder liner with connecting rod movement.
(c) When only a few pistons remain in the cylinders, the crankshaft tends to turn due to weight imbalance. Be sure to hold the crankshaft to prevent it from rotating while removing pistons.
(d) Make sure that the connecting rod does not damage the piston cooling nozzle when removing the piston.
(e) When pulling the piston out of the cylinder liner, hold the piston by hand so that the piston does not tilt. If the piston tilts, the piston inner surface collides against the connecting rod, and results in the damage of piston.

4.4.1 Removing Piston by Lifting with Chain Block

(1) Remove the connecting rod cap, and turn the crankshaft to bring the piston to the top dead center position.
(2) Install the eye bolt to the bolt hole on the piston top, and support the piston to prevent it from falling down.
(3) Rotate the crankshaft to place the crank pin slightly near to the inspection window so that the connecting rod big end will not contact the cylinder liner.
(4) Carefully pull out the piston by making sure that the connecting rod big end moves into the cylinder liner.



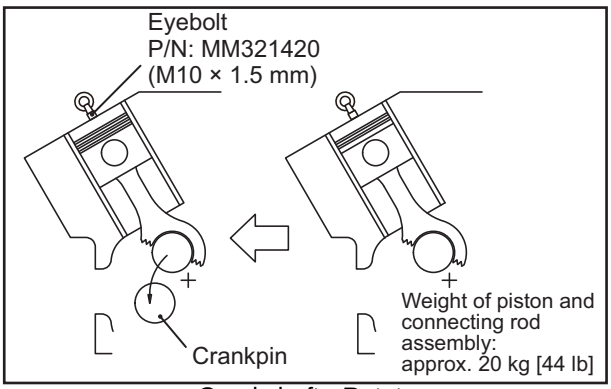
Removing Piston by Lifting with Chain Block

4.4.2 Removing Piston by Pushing-up Connecting Rod Big End

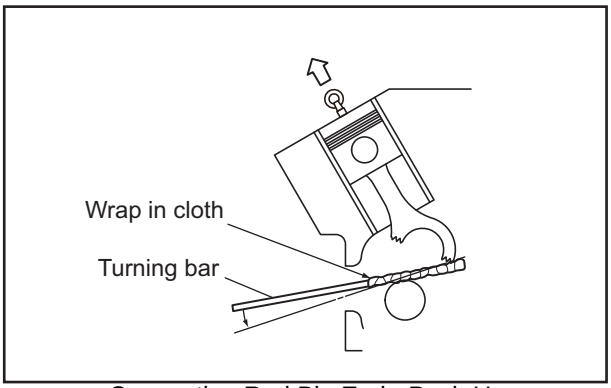
(1) Turn the crankshaft to bring the piston, which connecting rod cap being removed, to the top dead center position.
(2) Install the eye bolt to the bolt hole on the piston top, and support the piston to prevent it from falling down.
(3) Rotate the crankshaft carefully until the crankpin is displaced from the connecting rod, and the lower bolt hole can be seen through the inspection window.
(4) Insert a bar wrapped with cloth, and push up the bottom of connecting rod carefully using the crankpin as a fulcrum.

Note: Wrap the bar with cloth or rubber to protect the crankpin and connecting rod big end from damage.

(5) Push up the connecting rod and piston while adjusting the fulcrum position.
When the oil ring is slid out of the cylinder liner, place the ring carefully on the top face of cylinder liner.
(6) Lift the piston using eye bolt on the piston top, and pull-out the piston from cylinder liner.



Crankshaft - Rotate



Connecting Rod Big End - Push Up

4.5 Piston Ring - Remove

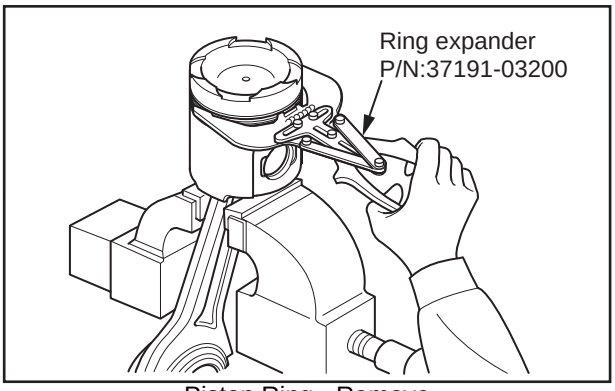
⚠ CAUTION

When removing the piston ring, be careful not to be pinched your hand between the piston and connecting rod by the piston tilt movement.

CAUTION

A free swing of piston and its bump to connecting rod may result in piston damage.

Hold the piston and connecting rod in a vise, and remove the piston rings with ring expander.



Piston Ring - Remove

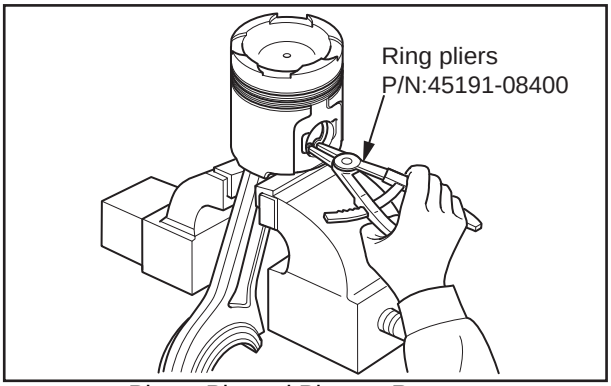
4.6 Piston Pin and Piston - Remove

(1) Remove the snap ring with ring pliers.

(2) Place a piece of wood to piston pin end and lightly tap with hammer to remove the piston pin, and separate the piston from connecting rod.

Note:(a) Do not tap the piston pin directly with hammer.

(b) If the piston is stubborn, heat the piston with heater or in hot water.

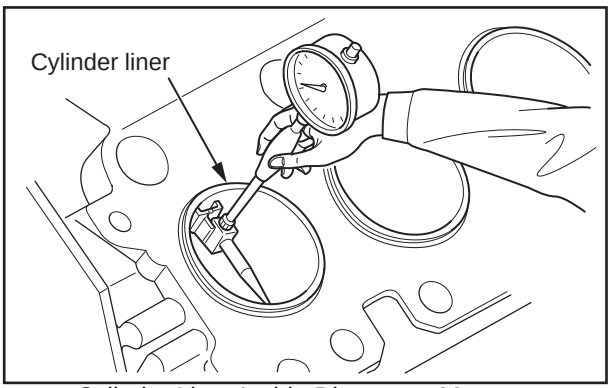


Piston Pin and Piston - Remove

4.7 Cylinder Liner Inside Diameter - Measure

Measure the cylinder liner inside diameter to check the current condition.

For measurement procedure, see "Cylinder Liner Inside Diameter - Measure" of "ENGINE BODY - ASSEMBLE".

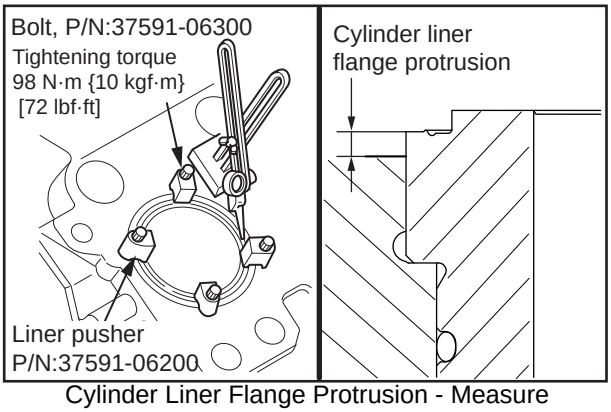


Cylinder Liner Inside Diameter - Measure

4.8 Cylinder Liner Flange Protrusion - Measure

Measure the cylinder liner flange protrusion to check the current condition.

For measurement procedure, see "Cylinder Liner Flange Protrusion - Measure" of "ENGINE BODY - ASSEMBLE".



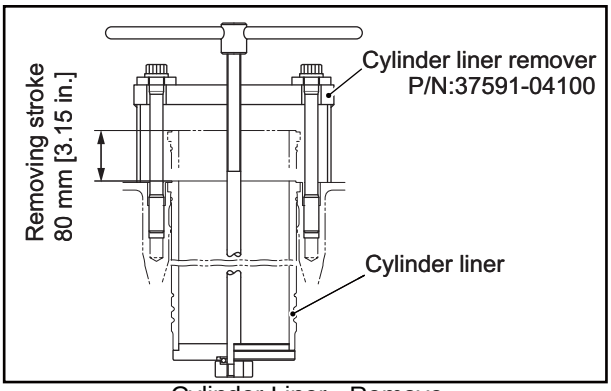
Cylinder Liner Flange Protrusion - Measure

4.9 Cylinder Liner - Remove

(1) Install the cylinder liner remover to the cylinder liner.

Note: Use care not to hit the piston cooling nozzle when installing the remover plate to the bottom of cylinder liner.

(2) Rotate the handle, and remove the cylinder liner.



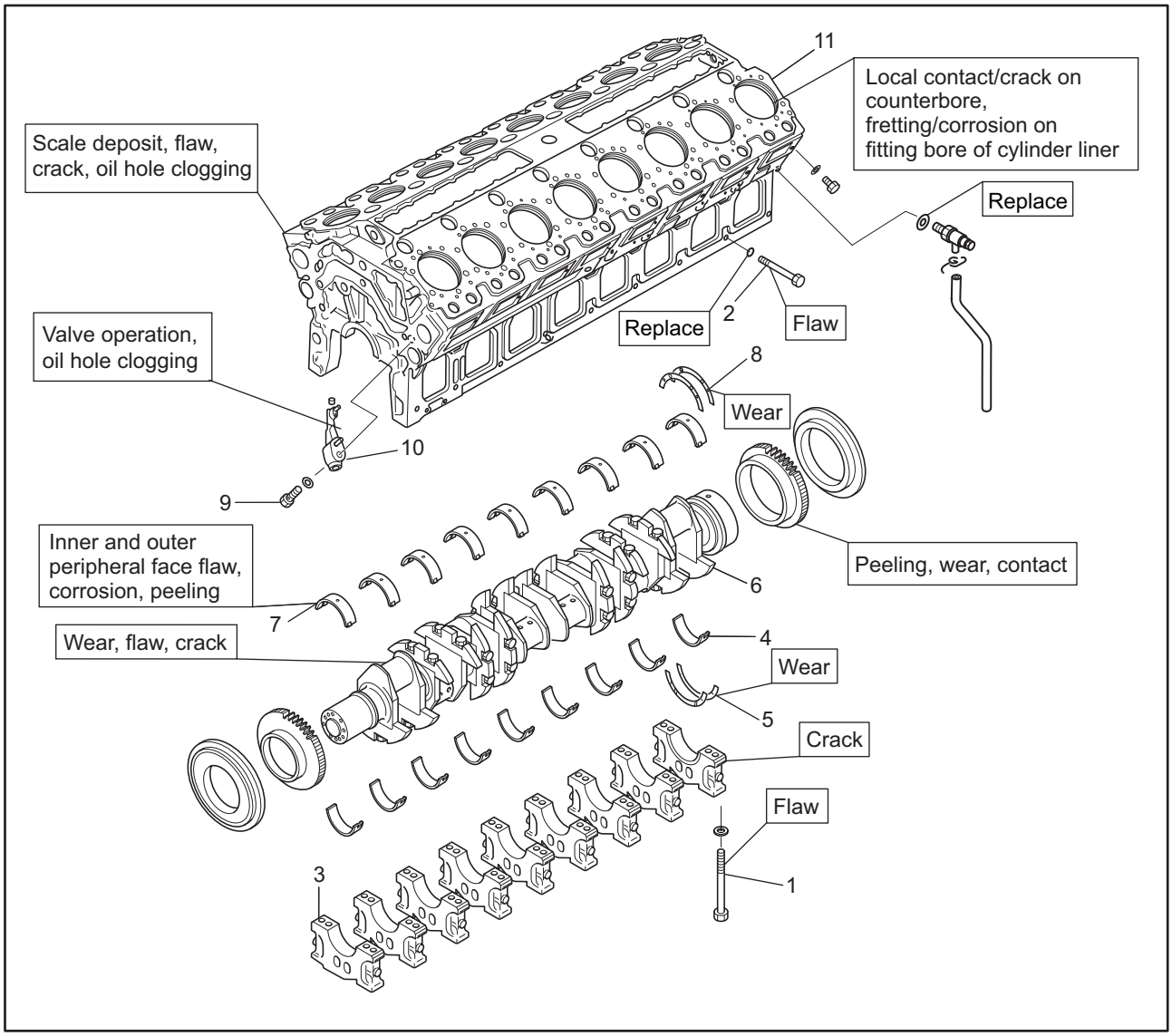
Cylinder Liner - Remove

5. Crankcase, Crankshaft, and Main Bearing - Disassemble and Inspect

Understanding of the current engine condition before disassembling is very important to find the cause of trouble and to perform efficient maintenance work.

Depending on the maintenance work or purpose, it is desirable to inspect some of the following items before proceeding with any job.

♦Crankshaft End Play - Measure



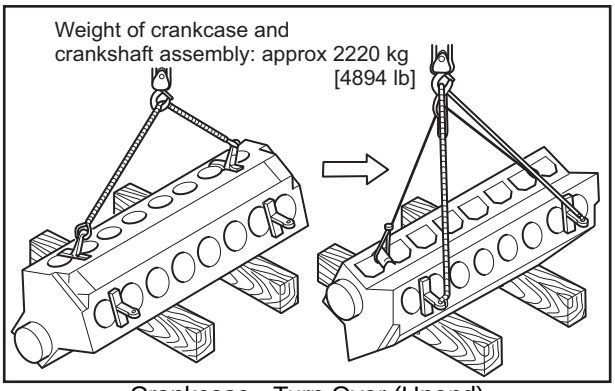
Crankcase, Crankshaft, and Main Bearing - Disassemble and Inspect

Disassembly sequence

1 Main bearing cap bolt
2 Side bolt
3 Main bearing cap (approx 17 kg [37.5 lb.])
4 Lower main bearing
5 Lower thrust plate
6 Crankshaft (approx. 620 kg [1366.9 lb.])
7 Upper main bearing
8 Upper thrust plate
9 Union bolt
10 Piston cooling nozzle
11 Water drain cock
12 Crankcase (approx. 1400 kg [3086.5 lb.])

5.1 Crankcase - Turn Over (Upend)

Using a turnover machine, turn over the crankcase. When the turnover machine is not available, attach slings to the crankcase using wood pieces and cloth pads, and raise the crankcase with a hoist or crane. Then lay it on the wooden block with its side face downward. Then, change the positions of the slings, and turn over to upend the crankcase.

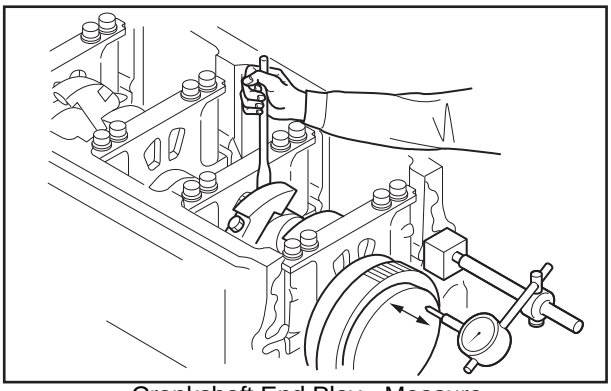


Crankcase - Turn Over (Upend)

5.2 Crankshaft End Play - Measure

Measure the crankshaft end play to check the current condition.

For measurement procedure, see "Crankshaft End Play - Measure" of "ENGINE BODY - ASSEMBLE".



Crankshaft End Play - Measure

5.3 Piston Cooling Nozzle - Remove

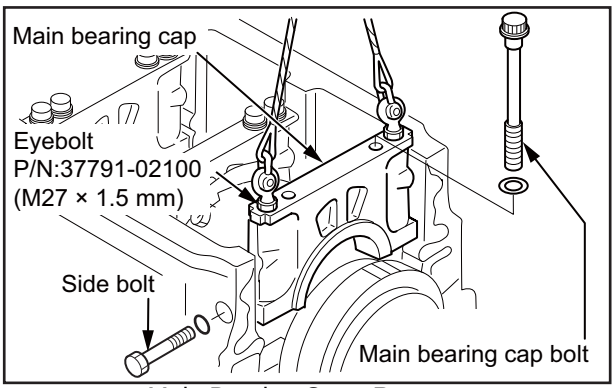
Remove the piston cooling nozzle from the crankcase.

5.4 Main Bearing Cap - Remove

CAUTION

When removing the main bearing cap, be careful not to damage the main bearing or the thrust plate attached to the cap. Also be careful not to drop these parts from the cap, which may result in crankshaft damage.

(1) Remove the main bearing cap bolts and side bolts.
(2) Install the eye bolts to the outer bolt holes on the main bearing cap.
(3) Give a light shake, and remove the main bearing cap by raising gradually.
(4) Remove the lower thrust plate from the rearmost main bearing cap.



Main Bearing Cap - Remove

5.5 Crankshaft - Remove

CAUTION

(a) When removing the crankshaft, remove the front upper thrust plates first, and be careful not to drop into the crankcase.

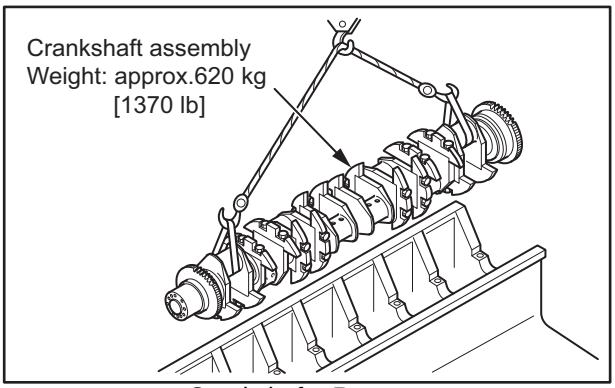
(b) When placing the crankshaft onto a pallet or other stands, be careful not to damage the crankshaft. Once placed on a pallet, place some support to prevent the crankshaft from rolling.

(1) Push a mating face of upper and lower of the front upper thrust plate, and remove while rotating.

(2) Lift the crankshaft in a horizontal position, and slowly remove the crankshaft upward.

Note: Do not attach a chain directly onto crankshaft, as it will damage the crankshaft. Place cloth belts or pads in the positions before lifting the crankshaft.

(3) Remove the upper main bearing from crankcase, paying attention to the lug position, and remove the upper thrust plate on the rear side.



Crankshaft - Remove

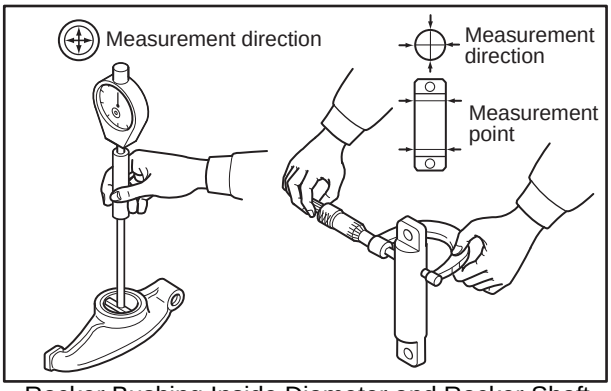
Chapter 6 INSPECTION AND REPAIR OF BASIC ENGINE

1. Cylinder Head and Valve Mechanism - Inspect and Repair

1.1 Rocker Bushing Inside Diameter and Rocker Shaft Outside Diameter - Measure

Measure the inside diameter of the rocker bushing and the outside diameter of the rocker shaft. If the measurement exceeds the limit, replace the rocker bushing or rocker shaft with a new one.

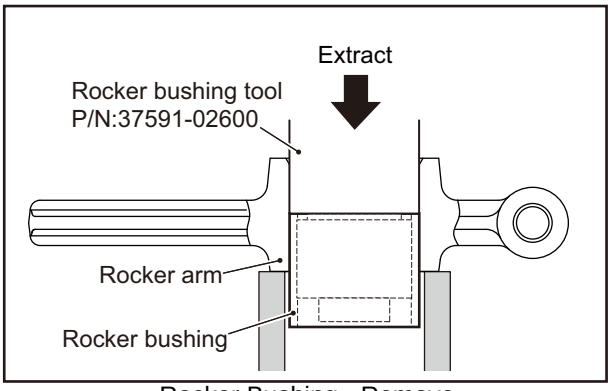
Item	Nominal value	Standard value	Limit value
Rocker bushing inside diameter	ø36 mm [1.42 in.]	36.000 to 36.040 mm [1.4173 to 1.4189 in.]	36.090 mm [1.4209 in.]
Rocker shaft outside diameter	ø36 mm [1.42 in.]	35.966 to 35.991 mm [1.4160 to 1.4170 in.]	35.940 mm [1.4150 in.]



Rocker Bushing Inside Diameter and Rocker Shaft Outside Diameter - Measure

1.2 Rocker Bushing - Replace

(1) Pull-out the rocker bushing with rocker bushing tool.



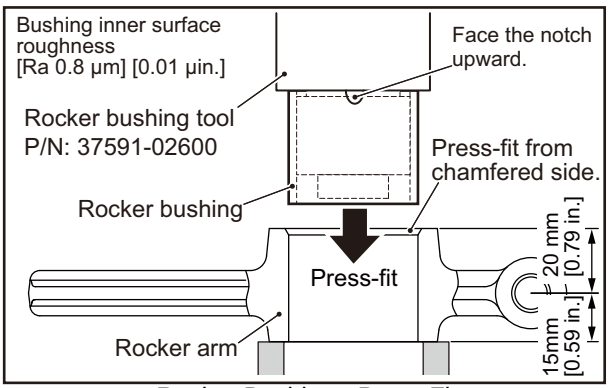
Rocker Bushing - Remove

(2) Install new rocker bushing with rocker bushing tool.
Place the positioning notch (4 mm [0.16 in.] width) of the rocker bushing upside, align the notch in a vertical position to the rocker arm. Press fit the rocker bushing from the chamfered side of the rocker arm hole.

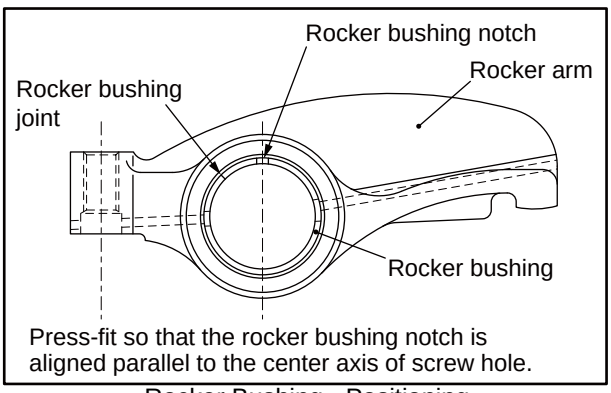
Note:(a) Make sure the position of the notch is at the upper and vertical position of the rocker arm.
(b) The shapes of intake and exhaust rocker arms are different, however, positions of the positioning notches are the same.

(3) Make sure that the oil hole of rocker arm, rocker bushing, and joint are positioned as shown in the illustration. The out of alignment between the rocker arm and bushing is allowed unless the oil passage diameter becomes ø3 mm [0.12 in.] or less.

(4) Measure the inside diameter of installed rocker bushing. If the value is not within the standard value, ream the inside diameter to the standard.



Rocker Bushing - Press Fit



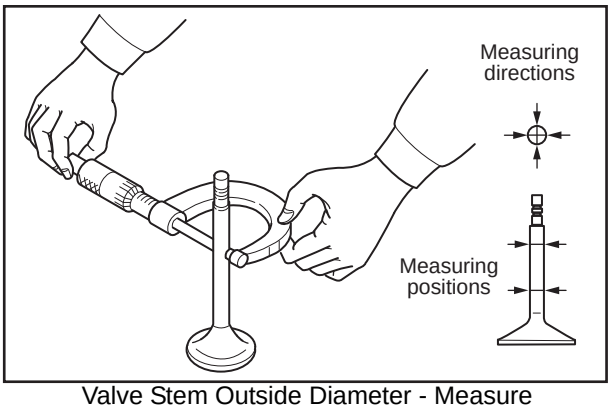
Rocker Bushing - Positioning

1.3 Valve Stem Outside Diameter and Valve Guide Inside Diameter - Measure

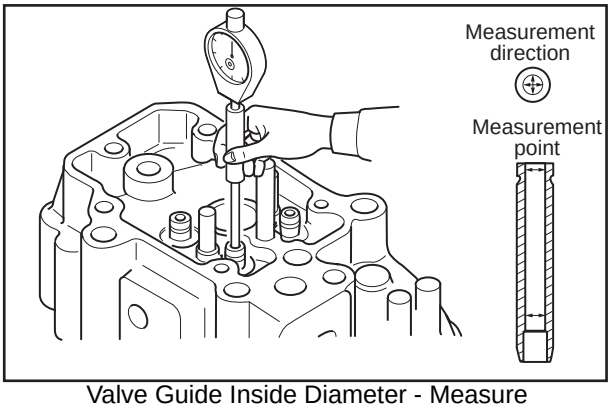
Measure the outside diameter of valve stem and the inside diameter of valve guide at the top and bottom sliding ends in mutually right-angle directions, as the sliding surfaces tend to wear at the top and bottom ends. If the measurement exceeds the limit, replace the valve guide or the valve with a new one.

Note: Lap the valve and valve seat ring whenever a new valve is installed.

Item	Nominal value	Standard value	Limit value
Valve stem outside diameter	ø10 mm [0.39 in.]	9.940 to 9.960 mm [0.3913 to 0.3921 in.]	9.910 mm [0.3902 in.]
Valve guide inside diameter	ø10 mm [0.39 in.]	10.000 to 10.015 mm [0.3937 to 0.3943 in.]	10.140 mm [0.3992 in.]



Valve Stem Outside Diameter - Measure



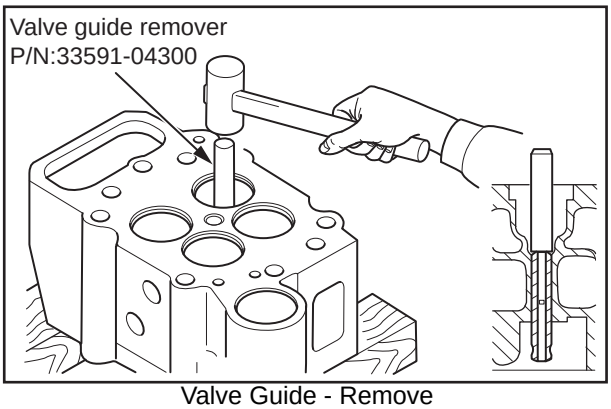
Valve Guide Inside Diameter - Measure

1.4 Valve Guide - Replace

CAUTION

The valve guide must be inserted to the specified depth. Be sure to use the guide and seal installer when press fitting the valve guide.

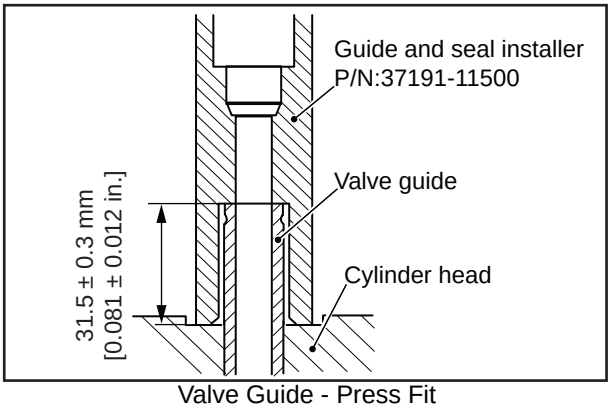
(1) Remove the valve guide with the valve guide remover.



Valve Guide - Remove

(2) Install a new valve guide slowly with the guide and seal installer.

Note: The inside diameters of inlet and exhaust valve guides are different. Be careful not to make a mistake.

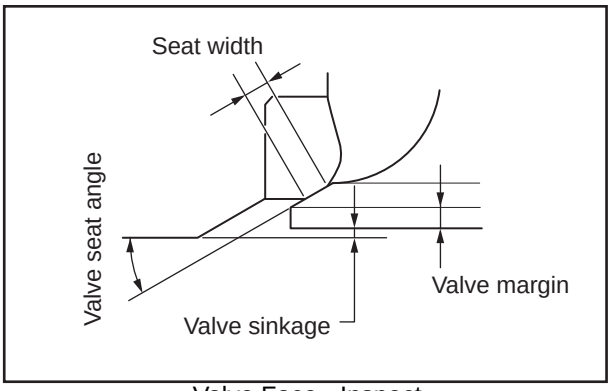


Valve Guide - Press Fit

1.5 Valve Face - Inspect

Inspect the valve face after the valve guide is inspected or replaced. Lap the valve and valve seat whenever the valve is refaced.

Also, refer to "Valve Seat Grinding" in "ENGINE BODY - INSPECT AND REPAIR" to replace the valve or seat.



Valve Face - Inspect

1.5.1 Valve Margin - Inspect

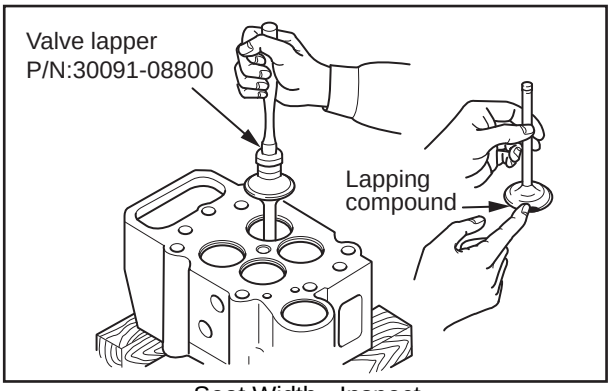
Measure the valve margin. Replace the valve with a new one if the limit is exceeded.

1.5.2 Seat Width - Inspect

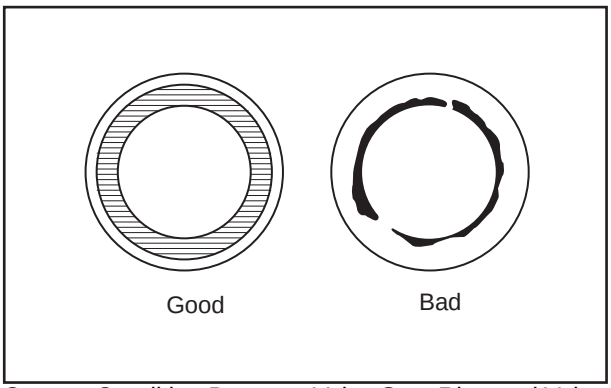
Apply a thin coat of lead-free coloring paste on the valve seat face, and tap the valve against valve seat ring with the valve lapper to check the contact condition. If the contact is not even, or any defects are found, or if the measurement exceeds the limit, reface or replace the valve.

Note: Do not rotate the valve when pressing valve face coated with lead-free coloring paste against valve seat ring.

Item			Standard value	Limit value
Valve seat	Valve seat angle		30° (nominal)	-
	Seat width	IN	2.15 to 2.45 mm [0.0846 to 0.0965 in.]	2.8 mm [0.110 in.]
		EX	4.45 to 4.75 mm [0.1752 to 0.1870 in.]	5.1 mm [0.201 in.]
Valve margin			2.8 to 3.2 mm [0.110 to 0.126 in.]	2.5 mm [0.098 in.]



Seat Width - Inspect



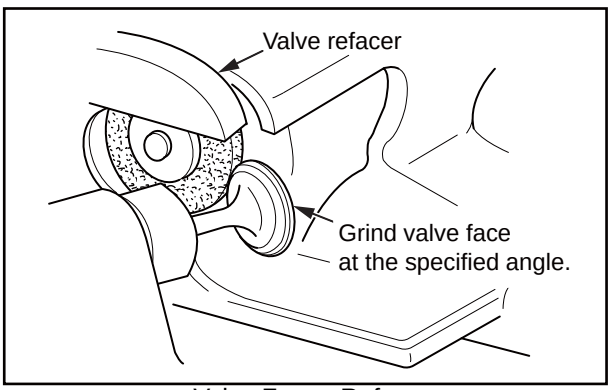
Contact Condition Between Valve Seat Ring and Valve

1.6 Valve Face - Reface

When refacing valve face to reuse, use the valve refacer.

Note:(a) Grind the valve face with valve refacer adjusted to the specified angle.

(b) Check the valve margin after refacing.



Valve Face - Reface

1.7 Valve Seat Ring - Reface

If any damage or inclusions are found, grind the seat face.

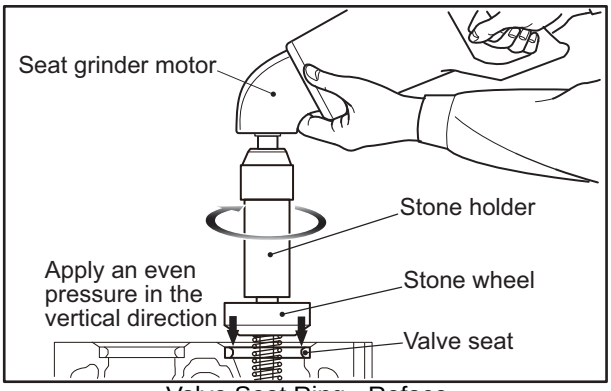
(1) When refacing valve seat to reuse, use a seat grinder motor.

(2) Lap the valve and valve seat ring.

Note:(a) Keep the valve seat refacing depth to the minimum.

(b) If the seat width cannot be corrected to the standard value, or a line contact on valve seat outer periphery is presented, replace the valve seat ring with a new one.

(c) If the valve sinkage exceeds the specified limit after refacing, replace the valve seat ring with a new one.



Valve Seat Ring - Reface

1.8 Valve Seat Ring - Replace

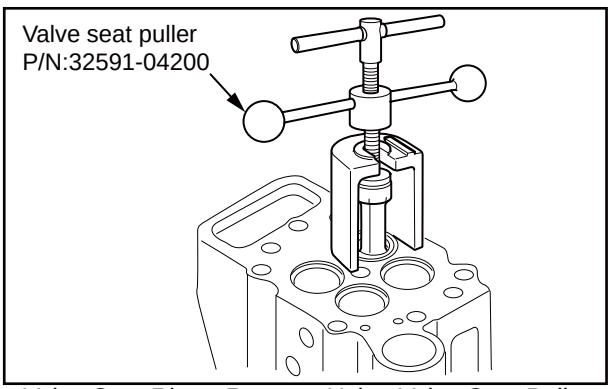
CAUTION

Ensure the proper interference. Improper interference will cause the valve seat ring to fall off or the cylinder head to crack.

Be careful not to damage the machined surface of cylinder head when removing the valve seat ring.

1.8.1 Valve Seat Ring - Remove Using Valve Seat Puller

Remove valve seat ring with the valve seat puller.



Valve Seat Ring - Remove Using Valve Seat Puller

1.8.2 Valve Seat Ring - Install

(1) Before installing the valve seat ring, measure the inside diameter of valve seat counterbore in cylinder head and the outside diameter of valve seat ring to make sure that the interference is within the range of standard value.

Item	Standard value	Limit value	Remark
Inside diameter of valve seat counterbore	60.000 to 60.030 mm [2.3622 to 2.3634 in.]	60.06 mm [2.3646 in.]	-
Valve seat ring outside diameter	60.100 to 60.130 mm [2.3661 to 2.3673 in.]	-	IN Two black lines (inside diam. ø49 mm [1.93 in.])
			EX Two pink lines (inside diam. ø47 mm [1.85 in.])
Valve seat interference	0.070 to 0.130 mm [0.0028 to 0.0051 in.]	-	-

(2) Cool the valve seat ring at least for 4 minutes in liquid nitrogen, and keep the cylinder head in a room temperature.

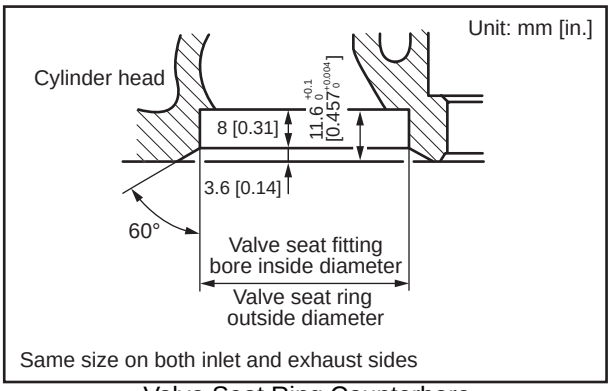
(3) Clean the counterbore on cylinder head by blowing air or others. Verify the cleanliness of valve seat ring contact faces.

(4) Install the valve seat into the cylinder head using the insert caulking tool until the bottoming sound can be heard.

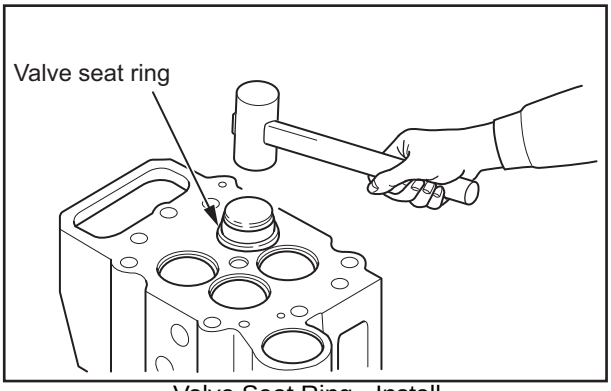
Note: The inside diameter and sectional shape are different between the inlet and exhaust valve seat rings. Be careful not to make a mistake when assembling.

(5) Use an oversized valve seat ring if the valve seat counterboring diameter is expanded and exceeds the standard value.

Oversize		Part name	Part number
For intake (ID mark: Three black lines)	0.03 mm [0.0012 in.]	SEAT,FIN. +3/100,W26R	37501-17932
For intake (ID mark: Four black lines)	0.06 mm [0.0024 in.]	SEAT,FIN. +6/100,W26R	37501-17962
For exhaust (ID mark: Three pink lines)	0.03 mm [0.0012 in.]	SEAT,FIN. +3/100,PB74	37501-04530
For exhaust (ID mark: Four pink lines)	0.06 mm [0.0024 in.]	SEAT,FIN. +6/100,PB74	37501-04560



Valve Seat Ring Counterbore



Valve Seat Ring - Install

1.9 Valve Seat Ring - Grind

Grind the seat ring face after replacing the valve seat ring with a new one, or before lapping with a valve.

(1) Install the bracket on the cylinder head with bolts.

(2) Reverse the cylinder head to place the bracket at the bottom. Use block woods or others to support the cylinder head.

(3) Install the pilot shaft into the valve guide where the seat ring is to be ground.

(4) Insert the manual turning shaft to the side hole of pilot shaft. Then secure the shaft into the pin on bracket. Do not screw in the pilot shaft more than necessary.

(5) Remove the manual turning shaft from the pilot shaft. Then install the spring.

(6) Set the stone wheel to the stone holder, and install it to the pilot shaft.

Note:(a) Make sure that there is a clearance between the stone wheel and valve seat ring.

(b) The two stone holders with grinding stones are for inlet and exhaust. Use them separately.

(7) Install the seat grinder motor on the top of holder.

(8) Rotate the seat grinder motor keeping a floating condition of the stone wheel. Then press the stone to grind the ring seat face.

Note:(a) When grinding valve seat face, apply an even pressure in the vertical direction to avoid an eccentricity.

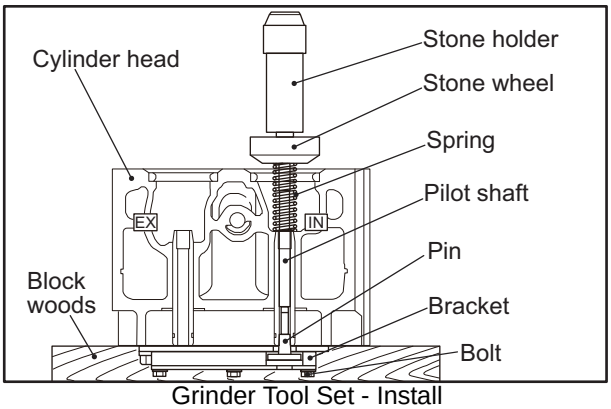
(b) Pay attention not to seize the seat face.

(c) Check the even grinding by grinding sparks.

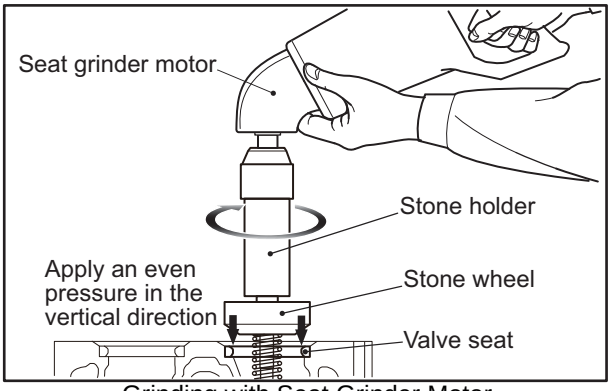
(d) When the grinding stone clogging is significant, restore the grinding face of stone with a stone dresser. (Standard value of seat face angle: 30°)

(e) Remove the grinding shaft after grinding. Check for defects on each area. Then proceed with the grinding of another seat.

Item	Nominal value	Limit value
Valve seat width (IN)	2.3 mm [0.091 in.]	2.8 mm [0.110 in.]
Valve seat width (EX)	4.6 mm [0.181 in.]	5.1 mm [0.201 in.]



Grinder Tool Set - Install



Grinding with Seat Grinder Motor

1.10 How to Use Stone Dresser

(1) Install the stone holder with stone wheel on the stone dresser shaft.

(2) Loosen lever 2 and adjust the notch of angle adjuster to 30 °of the scale, then tighten lever 2.

(3) Loosen lever 1, and adjust the shaft position so that the stone wheel grinding face comes into contact with the tip end when operating lever 3.

(4) After adjusting the position, firmly tighten lever 1, and make sure that the shaft location and tip angle are fixed.

(5) Install the seat grinder motor on top of the stone holder, and rotate the stone wheel.

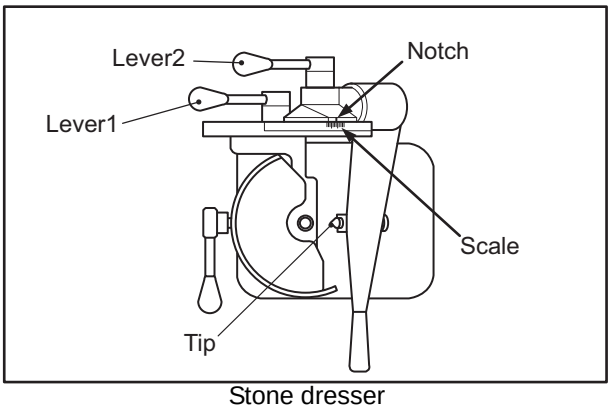
Note: Avoid the wobbling of seat grinder motor during the job.

(6) Operate lever 3 to grind the stone-wheel grinding face with the tip end to restore.

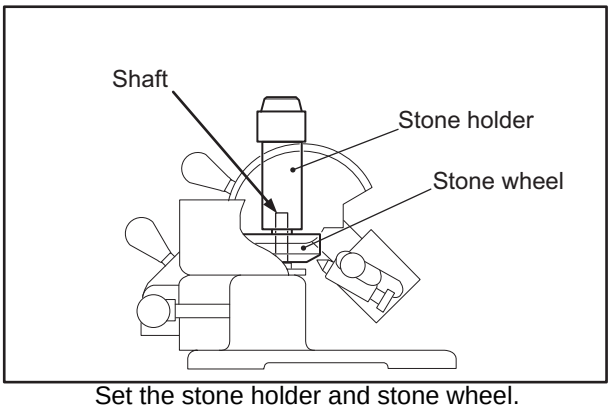
Note:(a) Make sure that the grinding face is being uniformly refaced while polishing.

(b) Turn the tip screw to adjust the stone-wheel grinding depth.

(c) The restoration of stone wheel is needed once in three or four valve seat grinding jobs.



Stone dresser



Set the stone holder and stone wheel.

1.11 Valve Seat Face Runout and Radial Runout - Measure with Special Tool

Measure the runout after grinding the valve seat face with the electric special tool or after other occasions.

(1) Install the bracket on the cylinder head upper face with bolts.

(2) Reverse the cylinder head to place the bracket at the bottom. Use block woods, etc. to support the cylinder head so that load will not be applied to the bracket.

(3) Install the measuring tool set in the valve guide where the seat ring is to be measured.

(4) Insert the shaft in the measuring tool set. Then secure the shaft into the pin on bracket. Do not screw in the measuring tool set more than necessary.

(5) Temporary install the measuring gauge in the measuring-tool-set stay with a clamp.

Note: Be careful not to hit the tip of measuring gauge.

(6) Place the measuring gauge tip so that it lightly touches the center of valve seat face, then tighten the clamp to hold.

Note: The positions of measuring gauge are different between in the inlet and exhaust sides. Adjust respectively.

(7) Adjust the gauge reading to 0 at the initial position. Then measure at 90°intervals. Record the deviations of the measuring gauge reading.

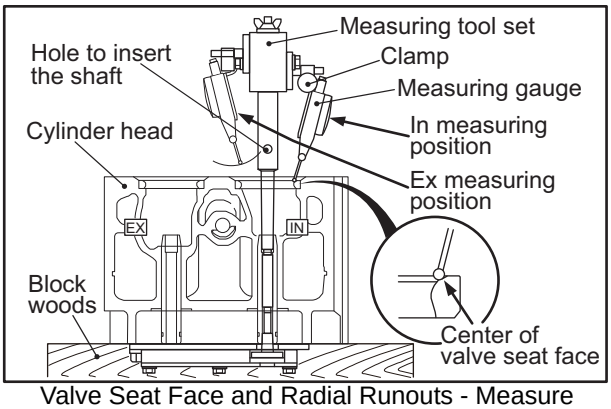
Note:(a) Verify the 0 position before and after the measurement.

(b) To measure, fix the measuring tool set, and rotate the upper section.

(c) Adjust the wing nut for the proper rotation.

(8) Loosen and remove the measuring tool set after the measurement. Check the measured value for defects and then measure another valve seat.

Note: Loosen the clamp and place the measuring gauge probe tip far from the valve seat face. Then remove the measuring tool set.



Valve Seat Face and Radial Runouts - Measure

1.12 Valve Pressure After Assembling Cylinder Head - Measure

(1) Apply pressure of 650 mmHg to each cylinder head valve, and hold the vacuum for 15 seconds. Check the pressure to be held for the period.

(2) If the valve can not retain the pressure, lap the valve and valve seat ring.

1.13 Valve and Valve Seat Ring - Lap

Lap the valve and valve seat ring whenever the valve seat ring is refaced or the valve is replaced, or the contact surfaces fail to keep a pressure in the pressure test after assembling.

(1) Apply a thin coat of lapping compound evenly on valve seat face.

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

(b) The compound spreads more evenly when it is mixed with a small amount of engine oil.

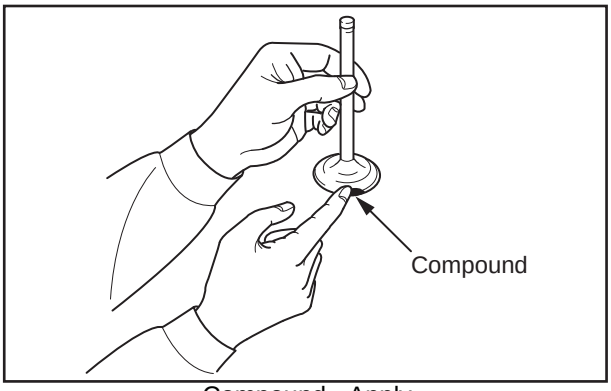
(c) Use a medium-grain compound (120 to 150 mesh) for initial lapping, then use the fine-grain compound (200 mesh) for finishing.

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

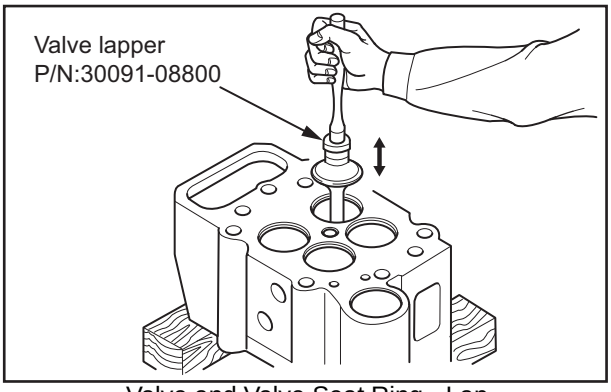
(3) Wash off the compound using diesel fuel.

(4) Apply engine oil on mating surfaces, and lap for finishing.

(5) Apply a thin coat of lead-free coloring paste on the valve face, and tap the valve face against the valve seat using a valve lapper to check the contact condition.



Compound - Apply



Valve and Valve Seat Ring - Lap

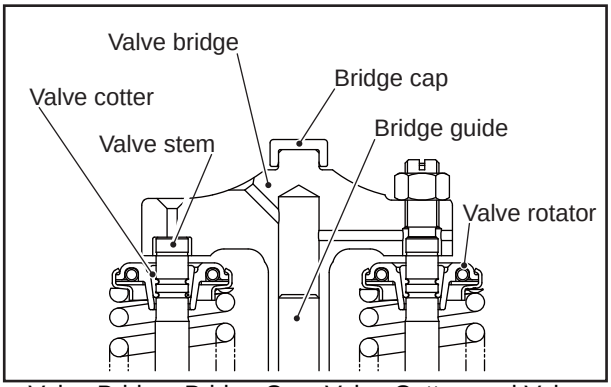
1.14 Valve Sinkage - Record

Measure the valve sinkage after assembling the cylinder head. And record the result corresponding to the cylinder head maintenance ID marks.

For the detail, refer to "Valve Sinkage - Measure" of "ENGINE BODY - ASSEMBLE".

1.15 Valve Bridge, Bridge Cap, Valve Cotter, and Valve Rotator - Inspect

(1) Inspect the contact surfaces between the valve bridge and the valve stem, and the sliding surfaces between the valve bridge and the bridge guide. If significant wear or uneven contact is found, replace them with new ones.
(2) Check the bridge cap for wear. If significant wear is found, replace the bridge cap with a new one.
(3) Check the valve rotator for rotation. If any defect is found, replace the valve rotator with a new one.
(4) Inspect the contact surfaces between valve cotter and valve stem, and valve cotter and valve rotator. If uneven wear or significant dent is found, replace with new ones.

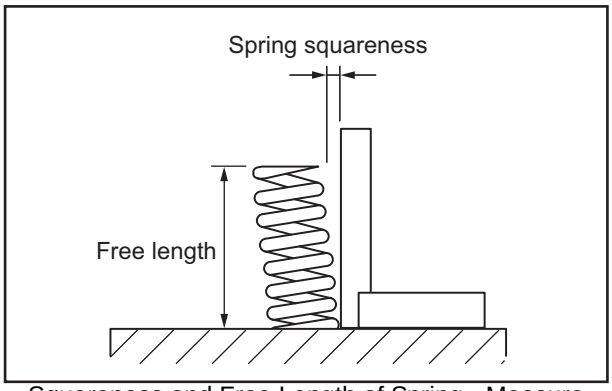


Valve Bridge, Bridge Cap, Valve Cotter, and Valve Rotator - Inspect

1.16 Squareness and Free Length of Valve Spring - Measure

Measure the squareness and the free length of valve spring. If the free length or squareness exceeds the limit, replace the valve spring with a new one.

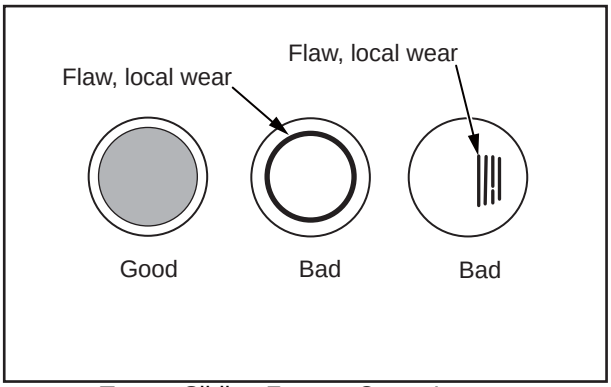
Nominal value	Standard value	Limit value
Free length	73 mm [2.87 in.]	71 mm [2.80 in.]
Squareness	 A=1.5°or less B=1.9 mm [0.075 in.] or less Lf=73 mm [2.87 in.]	B=2.2 mm [0.087 in.]
Set length / load	66.0 mm [2.598 in.] / 289 to 319 N {29.45 to 32.55 kgf} [64.97 to 71.71 lbf]	-



Squareness and Free Length of Spring - Measure

1.17 Tappet - Inspect

Inspect the tappet sliding face to cam for local wear. If defective, replace the tappet with a new one.

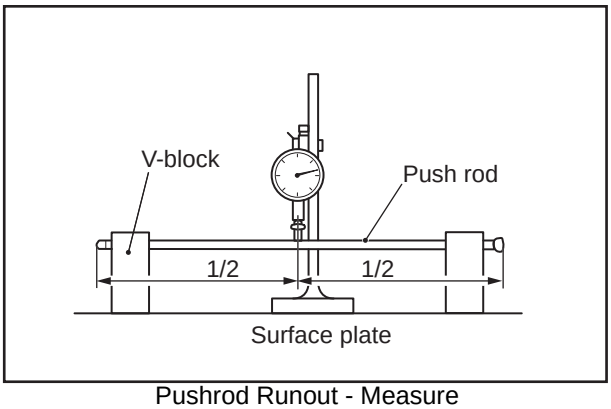


Tappet Sliding Face to Cam - Inspect

1.18 Pushrod Runout - Measure

Measure the runout of pushrod in the total indicator reading (TIR). If the runout exceeds the standard, replace the push-rod with a new one.

Item	Standard value	Remark
Pushrod runout	0.50 mm [0.0197 in.] or less	TIR



Pushrod Runout - Measure

1.19 Distortion of Cylinder Head Bottom Surface - Measure

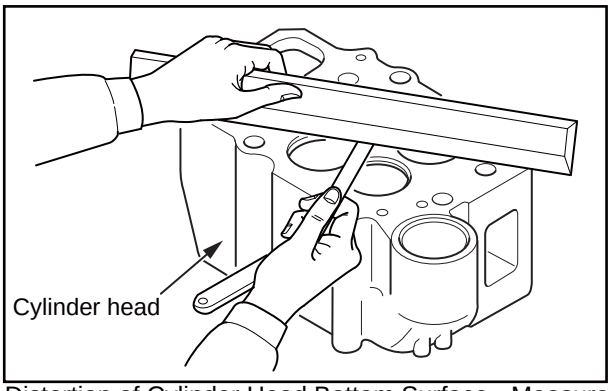
CAUTION

Keep the grinding amount of cylinder head to the minimum. Excessive grinding of the cylinder head may result in defects such as contact between piston and valve.

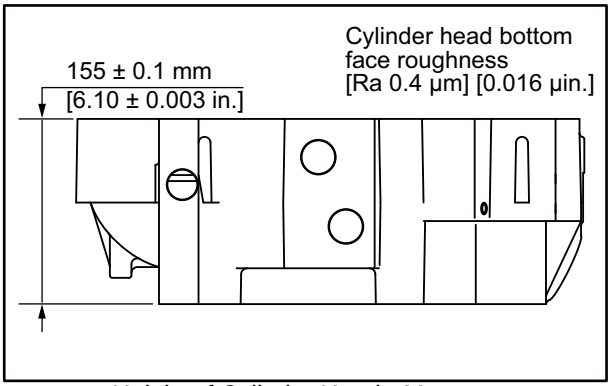
With a straight edge placed on the bottom face of cylinder head, measure the bottom face distortion with feeler gauges. If the value exceeds the limit, replace with a new one, or grind to correct.

When ground, record the maximum depth of grinding. Note that total grinding amount, which includes grinding depth of top face of crankcase, must be 0.50 mm [0.020 in.] or less.

Item	Standard value	Limit value
Distortion of cylinder head bottom surface	0.03 mm [0.0012 in.] or less	0.07 mm [0.0028 in.]
Height of cylinder head (reference)	154.9 to 155.1 mm [6.098 to 6.106 in.]	-



Distortion of Cylinder Head Bottom Surface - Measure



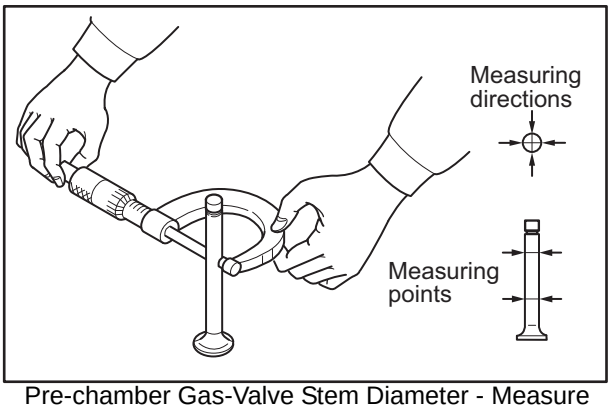
Height of Cylinder Head - Measure

1.20 Stem Diameter of Pre-chamber Gas Valve and Valve Holder Inside Diameter - Measure

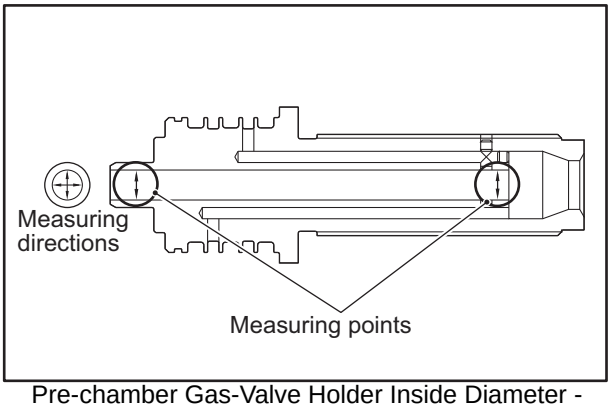
Measure the outside diameter of pre-chamber gas valve stem and the inside diameter of valve holder at the top and bottom sliding ends in mutually right-angle directions, as the sliding surfaces tend to wear at the top and bottom ends. If the measurement exceeds the limit, replace the pre-chamber gas valve or the pre-chamber gas-valve holder with a new one.

Note: Lap the valve and valve seat ring whenever a new valve is installed.

Item	Nominal value	Standard value	Limit value
Pre-chamber gas valve outside diameter	ø8 mm [0.32 in.]	7.960 to 7.980 mm [0.3134 to 0.3142 in.]	7.930 mm [0.3122 in.]
Pre-chamber gas-valve holder inside diameter	ø8 mm [0.32 in.]	8.000 to 8.015 mm [0.3150 to 0.3156 in.]	8.060 mm [0.3173 in.]



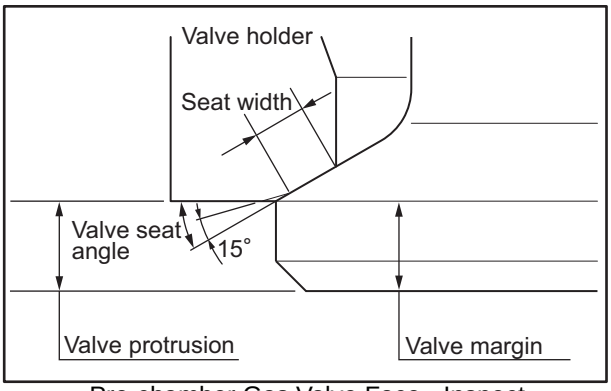
Pre-chamber Gas-Valve Stem Diameter - Measure



Pre-chamber Gas-Valve Holder Inside Diameter - Measure

1.21 Pre-chamber Gas Valve Face - Inspect

Inspect the valve face after the valve holder is inspected or replaced. Lap the valve and valve seat ring whenever the valve is refaced or replaced.



Pre-chamber Gas Valve Face - Inspect

1.21.1 Pre-chamber Gas Valve Margin - Inspect

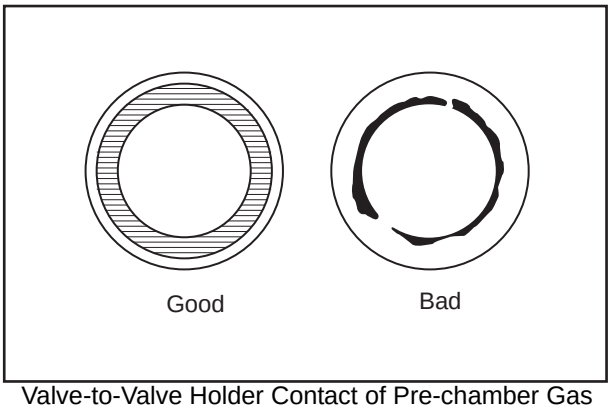
Measure the valve margin. If the value exceeds the limit, reface or replace the valve with a new one.

1.21.2 Seat Width - Inspect

Apply a thin lead-free coloring paste on the gas valve seat face, and check its contact with the valve seat. If the contact is not even, or any defects are found, or if the measurement exceeds the limit, reface or replace the gas valve.

Note: Do not rotate the valve when pressing valve face coated with lead-free coloring paste against valve seat ring.

Item		Nominal value	Standard value	Limit value
Valve seat	Valve seat angle	30°	29°45' to 30°15'	-
	Seat width	2 mm [0.08 in.]	1.9 to 2.1 mm [0.075 to 0.083 in.]	-



Valve-to-Valve Holder Contact of Pre-chamber Gas Valve

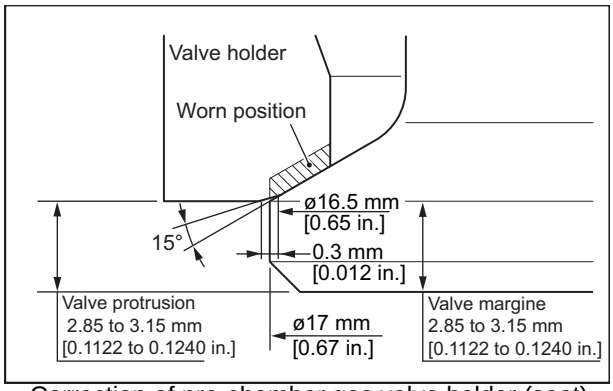
1.22 Pre-chamber Gas Valve Dimensions - Measure

The pre-chamber volume varies depending on the wear amount of the valve face and seat of the prechamber gas valve. The wear rate of these parts is usually not uniform among the cylinders. Therefore, the difference in the pre-chamber volume among the cylinders becomes larger as time goes by. This adversely affects the startability of the engine and the emission control of nitrogen oxides (NOx) and makes the combustion unstable, possibly resulting in frequent misfires.

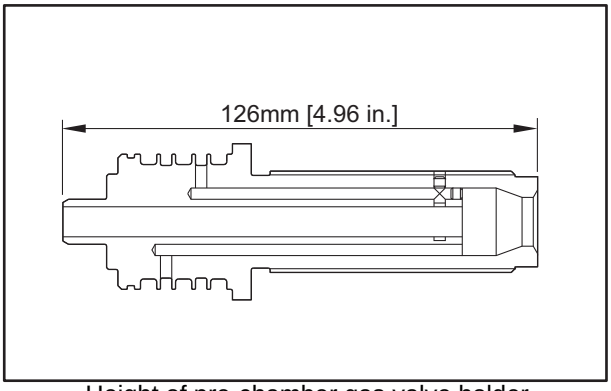
(1) Measure the valve protrusion and valve margin. Replace the valve with a new one if the limit is exceeded.

(2) When machining the valve holder to achieve the proper valve protrusion, take care not to exceed the reworking limit.

Item	Nominal value	Standard value	Limit value
Valve protrusion	3 mm [0.12 in.]	2.85 to 3.15 mm [0.1122 to 0.1240 in.]	2.0 mm [0.079 in.]
Valve margin	3 mm [0.12 in.]	2.85 to 3.15 mm [0.1122 to 0.1240 in.]	2.5 mm [0.098 in.]
Valve holder height	126 mm [4.96 in.]	125.8 to 126.2 mm [4.953 to 4.969 in.]	125 mm [4.92 in.] (Reworking dimension)



Correction of pre-chamber gas valve holder (seat)



Height of pre-chamber gas valve holder

1.23 Cautions for Reworking Pre-chamber Gas Valve

If reworking on the pre-chamber gas valve is inevitable, be sure to observe the instructions below. Also adjusting work such as pre-chamber gas valve pressure re-adjustment may require depending on conditions.

(1) When refacing valve, estimate the amount of wear occurs in the period between overhauls so that the valve margin will not reach 2 mm [0.08 in.] or less before the next overhaul.

(2) Dimension of valve holder after reworking should be the same among all cylinders. Also when replacing some of cylinders with new ones, make sure to add machining so that the dimension of valve holder among all cylinder becomes the same.

1.24 Pre-chamber Gas Valve and Valve Holder - Lap

Be sure to lap the gas valve and valve holder whenever the valve and/or valve holder are repaired or replaced.

(1) Apply a thin coat of lapping compound evenly on valve seat face.

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

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

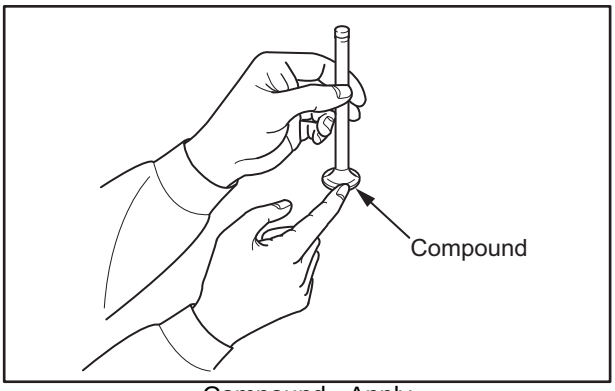
(c) Use a medium-grain compound (120 to 150 mesh) for the initial lapping, then use a fine-grain compound (200 mesh or higher) for the finish.

(2) Strike the valve against the valve holder while rotating the valve little by little.

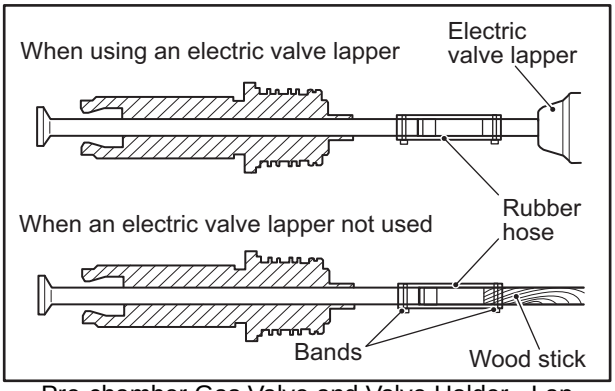
(3) Wash off the compound using diesel fuel.

(4) Apply engine oil on mating surfaces, and lap for finishing.

(5) Check valve mating face contact.



Compound - Apply

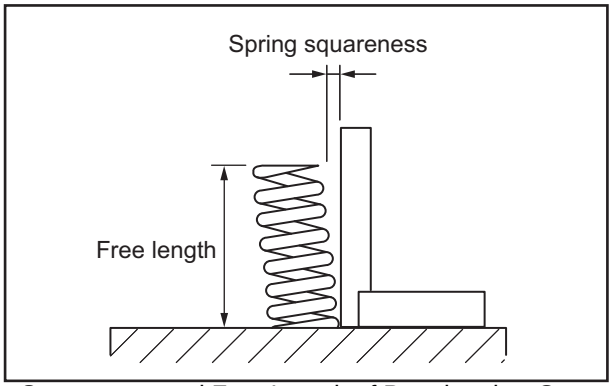


Pre-chamber Gas Valve and Valve Holder - Lap

1.25 Squareness and Free Length of Pre-chamber Gas-Valve Spring - Measure

Measure the squareness and the free length of valve spring. If the free length or squareness exceeds the limit, replace the valve spring with a new one.

Nominal value	Standard value	Limit value
Free length	55 mm [2.17 in.]	54 mm [2.13 in.]
Squareness	 A=1.5°or less B=1.44 mm [0.0567 in.] or less Lf = 55 mm [2.17 in.]	B = 1.5 mm [0.059 in.]
Set length / load	46.0 mm [1.811 in.] / 137.3 to 166.7 N {14.00 to 17.00 kgf} [30.866 to 37.476 lbf]	-



Squareness and Free Length of Pre-chamber Gas-Valve Spring - Measure

1.26 Pre-chamber Gas Valve Assembly - Inspect After Assembling

Conduct the pre-chamber gas-valve holder pressure test, and leak amount check after completing the assembling.

1.26.1 Pre-chamber Gas Valve Holder Pressure Test

(1) Prepare devices below for the inspection:
- ○ Pressure test pipe
  Make the pipe as shown in the drawing, or use the antler pipe as a substitute.
- ○ Commercial agent recommended for leak test:
  Leak catch (for gas leak detection)
  Distribution source: Koike Sanso Kogyo Co., Ltd.
- ○ Pressure gauge
- ○ Manual open/close valve
- ○ Air compressor
- ○ Others such as hoses for pressurized air connection

(2) Connect the pressure check pipe in the order from compressor, manual open/close valve, pressure gauge, and pressure test pipe.

(3) Pay attention to the mounting direction of the pressure test pipe.

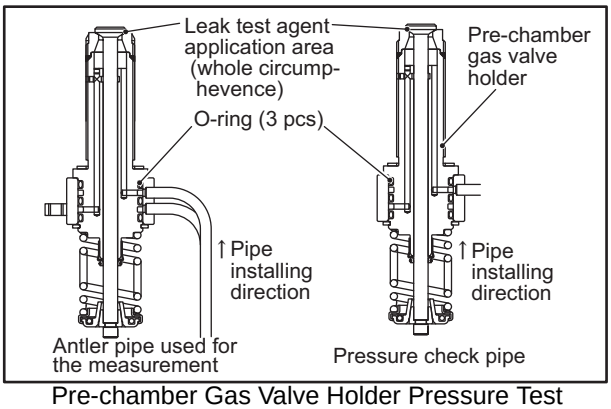
(4) Apply the leak test agent to the whole circumference of valve seat on pre-chamber gas valve holder.

(5) Hold the pressure test pipe by hand, and slowly open the manual open/close valve to apply pressure of 0.2 MPa {2.04 kgf/cm^2} [29.01psi].
Keep the pressure for 10 seconds or longer, and check the leak at positions where the leak test agent was applied.

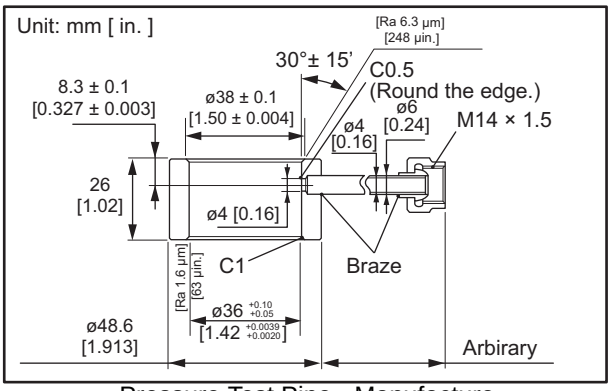
Note: If a leak is found, lap the valve and check again.

(6) Remove the leak test agent by blowing with compressed air or wiping with a waste cloth after the pressure test.

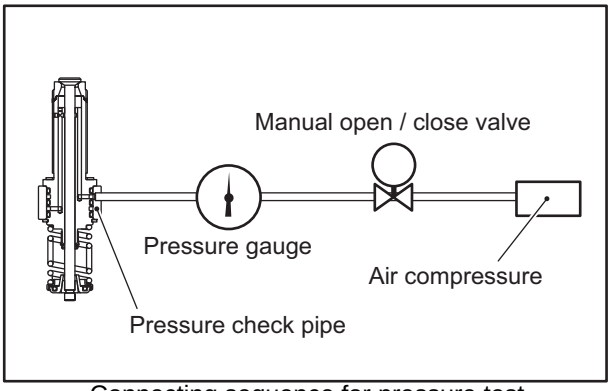
(7) Check the valve holder O-ring for damage after removing the pressure test pipe.
If any defect is found, replace the O-ring with a new one.



Pre-chamber Gas Valve Holder Pressure Test



Pressure Test Pipe - Manufacture



Connecting sequence for pressure test

1.26.2 Pre-chamber Gas-Valve Holder Leak Amount - Test

(1) Prepare devices below for the inspection:
- ○ Flow meter
  Name: CMS0050 Distribution source: Meiji Electric Industries Co., Ltd.
- ○ AC-DC converter (power source of flow meter)
  Name: SVA24SA Distribution source: Meiji Electric Corporation Co., Ltd.
- ○ Pressure gauge (for the adjustment of supply air pressure)
  Name: S10-350KP-DG
  Distribution source: Sayama Corporation
- ○ Closing valve
- ○ Regulator valve
- ○ Dedicated connector
  Inlet side (37503-18400),
  Discharge side (37503-28500)
- ○ Thin flexible tube (6 mm [0.24 in.])
- ○ Others such as Antler pipe(37503-98101),
  Hoses for the connection of compressed air

(2) The supply side connection to the antler pipe is in the order from the regulator valve, pressure gauge and connector as shown in the illustration.
The discharge side is from the discharge connector, flow meter, and closing valve.

(3) Pay attention to the mounting direction of the pressure test pipe.

(4) Apply the leak test agent to the whole circumference of valve seat on pre-chamber gas valve holder.

(5) Hold the pressure test pipe by hand, and slowly open the manual open/close valve and apply pressure of 0.2 Mpa {2.04 kgf/cm^2} [29.01psi].
Keep the pressure for 10 seconds or longer, and check the leak at positions where the leak test agent was applied.

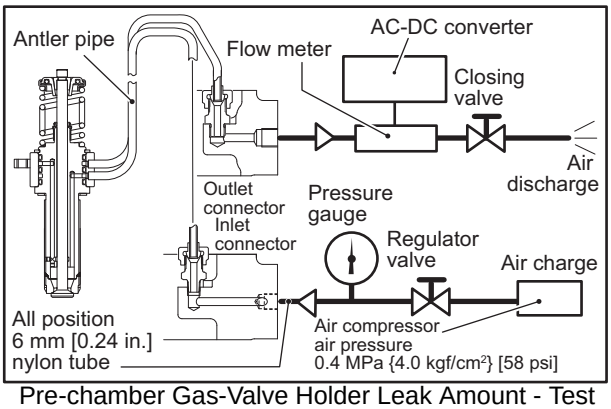
Note: If a leak is found, lap the valve and check again.

(6) Measure the flow rate and confirm the rate is below the standard.

Item	Standard value
Leak rate	13 L [3.43 US gal.]/min or less (Air press. 0.2 MPa {2.04 kgf/cm^2} [29.01psi])

(7) Remove the leak test agent by blowing with compressed air or wiping with a waste cloth after the pressure test.

(8) Check the valve holder O-ring for damage after removing the pressure test pipe.
If any defect is found, replace the O-ring with a new one.



Pre-chamber Gas-Valve Holder Leak Amount - Test

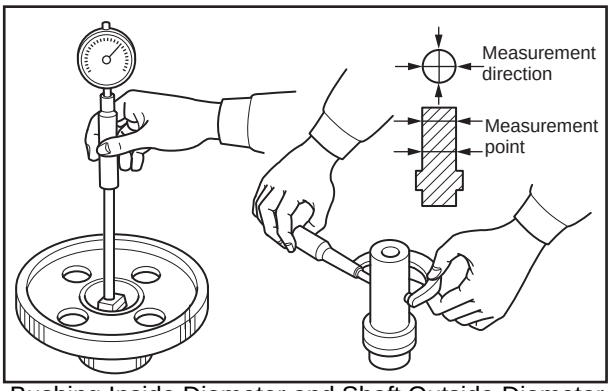
2. Rear Mechanism - Inspect and Repair

2.1 Rear-Idler-Bushing Inside Diameter and Rear-Idler-Shaft Outside Diameter - Measure

Measure the rear-idler-bushing inside diameter and the rear-idler-shaft outside diameter. If the value exceeded the limit, replace the rear idler gear assembly or rear idler shaft with a new one.

Note: When replacing the idler bushing only, finish the bushing inside diameter by reaming.

Item	Nominal value	Standard value	Limit value
Rear idler bushing inside diameter	ø65 mm [2.56 in.]	65.000 to 65.030 mm [2.5591 to 2.5602 in.]	65.060 mm [2.5614 in.]
Rear idler shaft outside diameter	ø65 mm [2.56 in.]	64.951 to 64.970 mm [2.5571 to 2.5579 in.]	64.900 mm [2.5551 in.]



Bushing Inside Diameter and Shaft Outside Diameter of Rear Idler - Measure

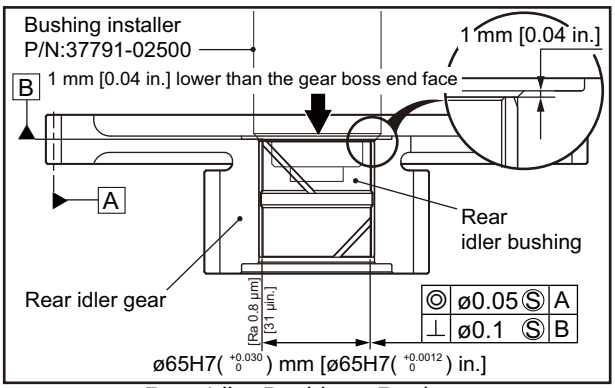
2.2 Rear Idler Bushing - Replace

(1) Using the removal side of the idler bushing installer, remove the rear idler bushing.

(2) Set the oil grooves of rear idler bushing as shown in the illustration, and using the bushing installer installing side, press-in the rear idler bushing from the large gear side.

(3) Ream the bore of installed rear idler bushing and finish the bore to the dimension as shown.

Note: Reaming after press-fit is necessary, as the rear idler bushings are supplied in a semi-finished condition.

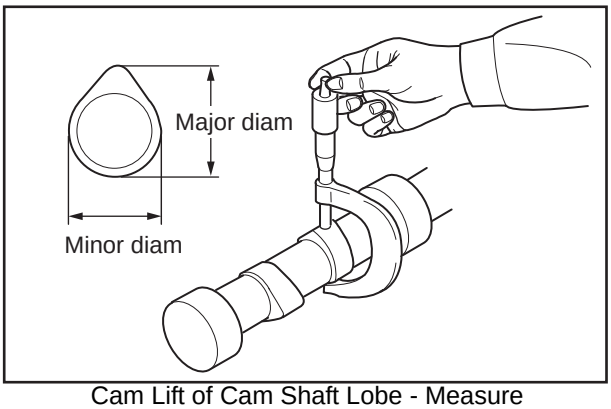


Rear Idler Bushing - Replace

2.3 Cam Lift of Cam Shaft Lobe - Measure

Measure the major diameter and the minor diameter of cam lobe to calculate the cam lift. If the value exceeds the limit, replace the camshaft with a new one.

Item		Standard value	Limit value
Cam lift of camshaft (major diameter - minor diameter)	IN	5.3 mm [0.209 in.]	4.45 mm [0.1752 in.]
	EX	9.3 mm [0.366 in.]	8.45 mm [0.3327 in.]



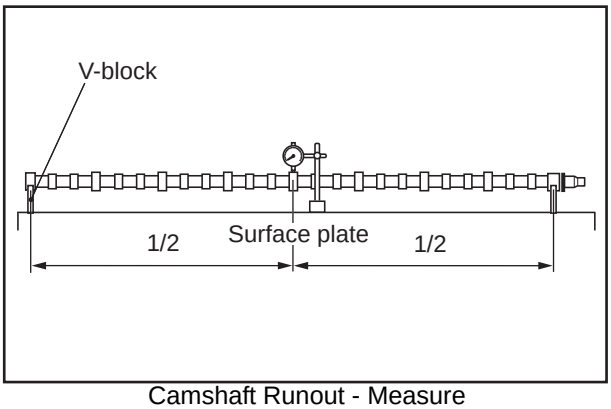
Cam Lift of Cam Shaft Lobe - Measure

2.4 Camshaft Runout - Measure

Measure the runout of camshaft in TIR. If the value exceeds the limit, correct the camshaft using a press, or replace the camshaft with a new one.

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

Item	Standard value	Limit value	Remark
Camshaft runout	0.05 mm [0.0020 in.] or less	0.08 mm [0.0031 in.]	TIR

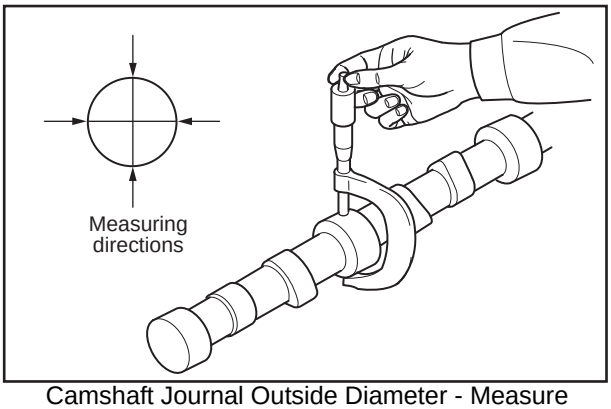


Camshaft Runout - Measure

2.5 Camshaft Journal Outside Diameter - Measure

Measure the diameter of each camshaft journal in two directions at right angles to each other. If the value exceeds the limit, replace the camshaft with a new one.

Item	Nominal value	Standard value	Limit value
Camshaft journal outside diameter	ø84 mm [3.31 in.]	83.92 to 83.94 mm [3.3039 to 3.3047 in.]	83.87 mm [3.3020 in.]



Camshaft Journal Outside Diameter - Measure

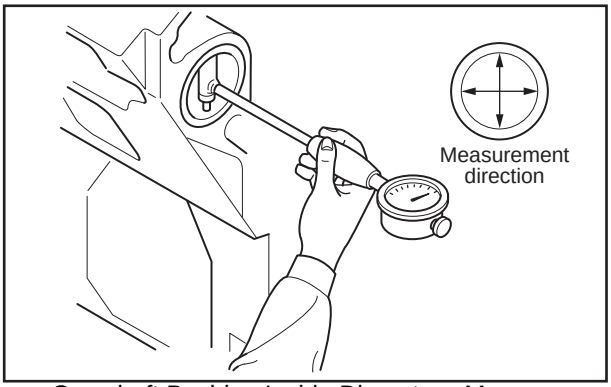
2.6 Camshaft Bushing - Inspect

(1) Check inside surface of each bushing for damage, corrosion, flaking and other abnormalities. If any defect is found, replace the camshaft bushing with a new one.

(2) Measure the camshaft bushing inside diameter with bushing installed in the crank case. If the measurement exceeds the limit, replace the bushing with a new one.

Note: Be careful not to damage the inner surface of camshaft bushing when measuring the inside diameter.

Item	Nominal value	Standard value	Limit value
Camshaft bushing inside diameter	ø84 mm [3.31 in.]	84.020 to 84.095 mm [3.3079 to 3.3108 in.]	84.100 mm [3.3110 in.]



Camshaft Bushing Inside Diameter - Measure

2.7 Camshaft Bushing - Replace

CAUTION

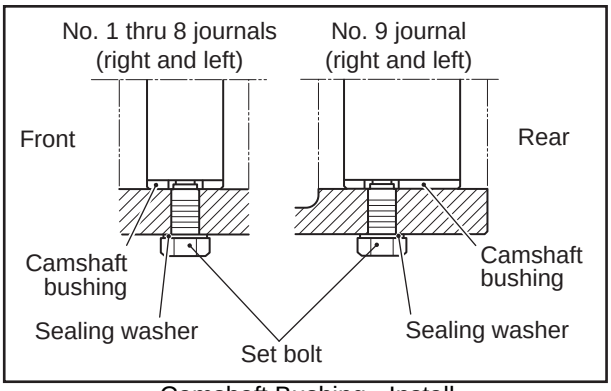
Before tightening the set bolt, be sure to check that the set bolt is in alignment with the set bolt hole in the camshaft bushing.

Make sure that the oil hole in the camshaft bushing is in alignment with the crankcase.

(1) Remove the camshaft bushing set bolt and remove the camshaft bushing.

(2) Before inserting the camshaft bushing in the bushing hole on the crank case, be sure to check the position of oil hole and set bolt hole.

(3) Before securing the set bolt, be sure to check that the set bolt is in alignment with the oil hole.

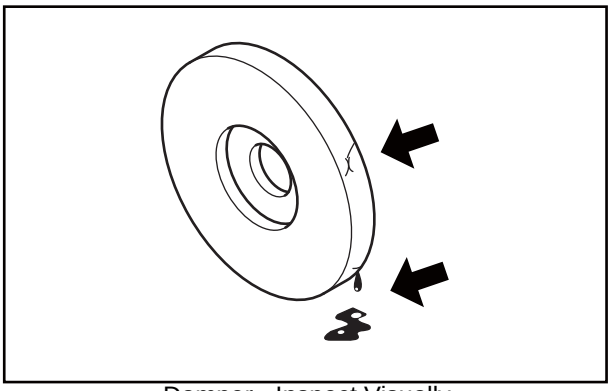


Camshaft Bushing - Install

3. Front Mechanism - Inspect and Repair

3.1 Damper - Inspect Visually

Check the damper for cracks around the outer periphery, swelling in the end plate, silicone oil leakage, and discoloration and peeling of the coating due to overheating. If any defect is found, replace the damper with a new one.



Damper - Inspect Visually

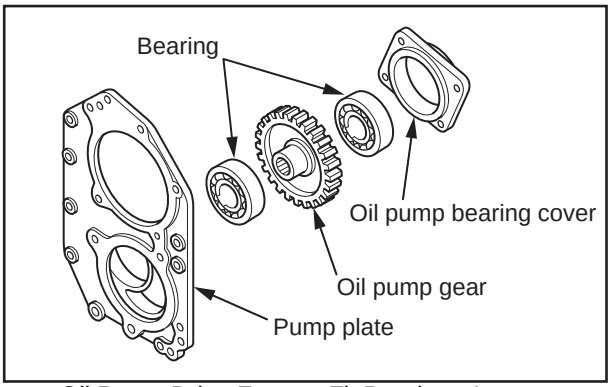
3.2 Outside Diameter and Inside Diameter of Oil Pump Drive Bearing Fit - Inspect

Rotate the bearing and if the rotation is not smooth, replace the bearing with a new one.

Inspect the fit between the oil pump bearing cover and the bearing. If significant wear is found, replace them with new ones.

Inspect the fit between the pump plate and the bearing. If significant wear is found, replace them with new ones.

Inspect the fit between oil pump gear and bearing. If significant wear is found, replace them with new ones.



Oil Pump Drive Face to Fit Bearing - Inspect

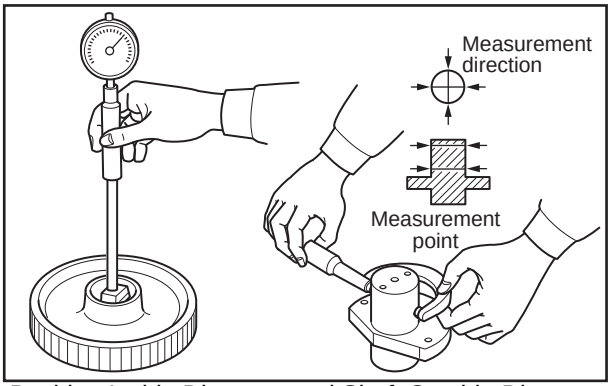
Item		Nominal value	Standard value
Inside diameter of oil pump bearing cover to fit bearing		ø110 mm [4.33 in.]	110.000 to 110.035 mm [4.3307 to 4.3321 in.]
Pump plate inside diameter to fit bearing		ø110 mm [4.33 in.]	109.987 to 110.022 mm [4.3302 to 4.3316 in.]
Bearing	Outside diameter	ø110 mm [4.33 in.]	109.985 to 110.000 mm [4.3301 to 4.3307 in.]
	Inside diameter	ø50 mm [1.97 in.]	49.988 to 50.000 mm [1.9680 to 1.9685 in.]
Outside diameter of oil pump gear to fit bearing		ø50 mm [1.97 in.]	49.993 to 50.013 mm [1.9682 to 1.9690 in.]

3.3 Bushing Inside Diameter and Shaft Outside Diameter of Front Idler - Measure

Measure the front idler bushing inside diameter and the front idler shaft outside diameter. If the value exceeds the limit, replace the front idler gear assembly or front idler shaft with a new one.

Item	Nominal value	Standard value	Limit value
Front idler bushing inside diameter	ø50 mm [1.97 in.]	50.000 to 50.025 mm [1.9685 to 1.9695 in.]	50.060 mm [1.9709 in.]
Front idler shaft outside diameter	ø50 mm [1.97 in.]	49.950 to 49.975 mm [1.9665 to 1.9675 in.]	49.900 mm [1.9646 in.]

Note: When replacing the idler bushing only, finish the bushing inside diameter by reaming.



Bushing Inside Diameter and Shaft Outside Diameter of Front Idler - Measure

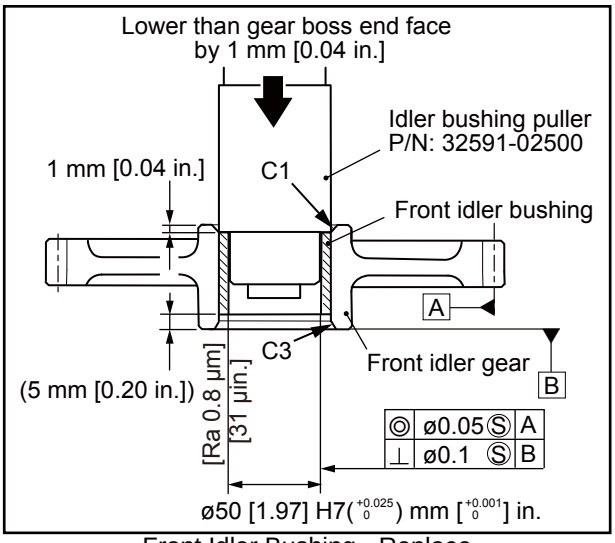
3.4 Front Idler Bushing - Replace

(1) Using the removal side of the idler bushing puller, remove the front idler bushing.

(2) Using the installation side of the idler bushing puller, push-in the front idler bushing to the 1 mm [0.04 in.] chamfered side until the bushing end face becomes flush with the gear boss end face. Furthermore, using the removal side of the idler bushing puller, lower the idler bushing end face from end face of gear boss by 1 mm [0.04 in.]

(3) Ream the installed front idler bushing inside diameter to finish it to the dimension shown.

Note: Reaming after press-fit is necessary, as the front idler bushing is supplied in a semi-finished condition.

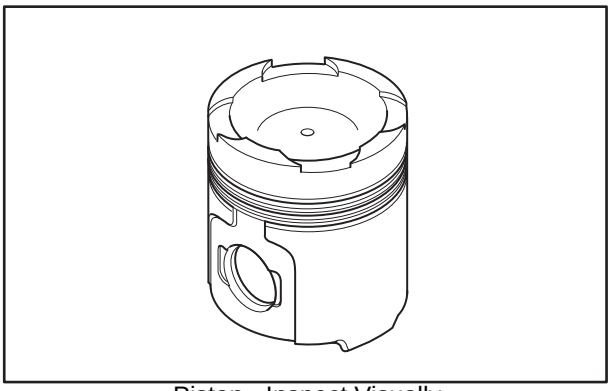


Front Idler Bushing - Replace

4. Piston and Connecting Rod - Inspect and Repair

4.1 Piston - Inspect Visually

Check the combustion surface, piston pin bore, ring groove, sliding surface, and bottom surface of the piston. If any defect is found, replace the piston with a new one.



Piston - Inspect Visually

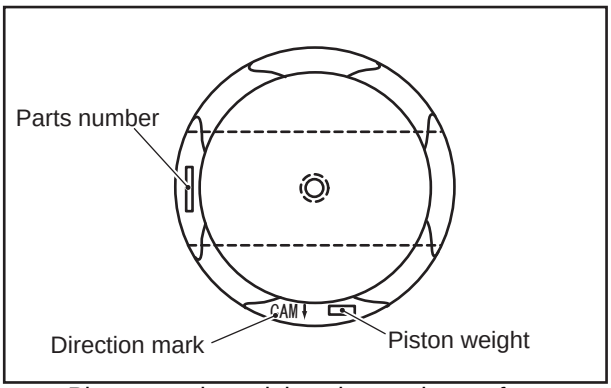
4.2 Piston Weight

Check the weight marking stamped on the piston top face. When replacing pistons, be sure to keep the weight difference in one engine within the standard range.

Item	Standard value
Weight difference in one engine	±10 g [0.353 oz.]

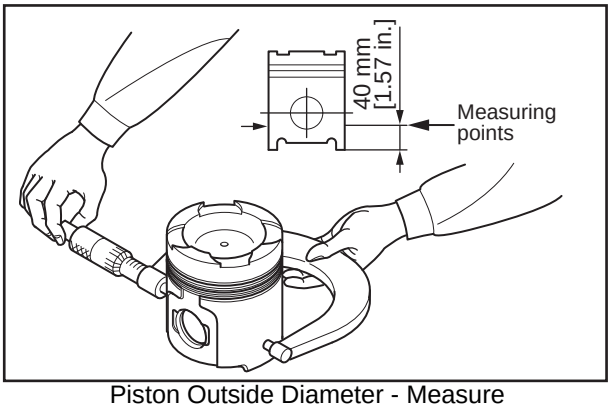
4.3 Piston Outside Diameter - Measure

Measure the piston outside diameter of piston skirt in the right angle to the piston pin. If the value exceeds the limit, replace the piston with a new one.



Piston punch mark location on the top face

Item	Nominal value	Standard value	Limit value
Piston outside diameter	ø170 mm [6.69 in.]	169.759 to 169.799 mm [6.6834 to 6.6850 in.]	169.660 mm [6.6795 in.]



Piston Outside Diameter - Measure

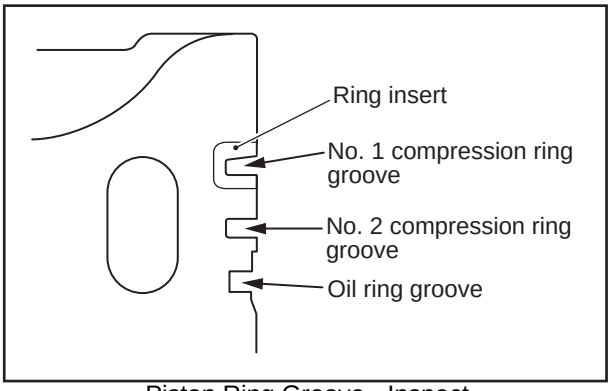
4.4 Piston Ring Groove - Inspect

CAUTION

Remove carbon deposits from the piston and inspect the whole circumference of piston.

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

(2) Visually check each ring groove for wear or damage. If defective, replace the piston with a new one. Inspect the ring trager of No. 1 compression ring groove by dye penetration test for cracks and separation.

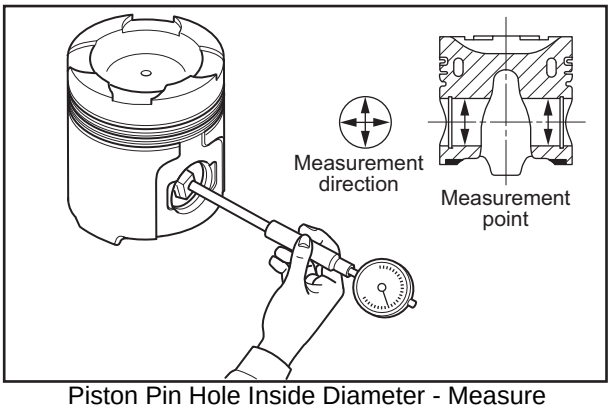


Piston Ring Groove - Inspect

4.5 Piston Pin Hole Inside Diameter - Measure

Measure the piston pin bore diameter. If the value exceeds the limit, replace the piston with a new one.

Item	Nominal value	Standard value	Limit value
Piston pin hole inside diameter	ø70 mm [2.76 in.]	70.002 to 70.015 mm [2.7560 to 2.7565 in.]	70.040 mm [2.7575 in.]



Piston Pin Hole Inside Diameter - Measure

4.6 Piston Ring - Inspect Visually

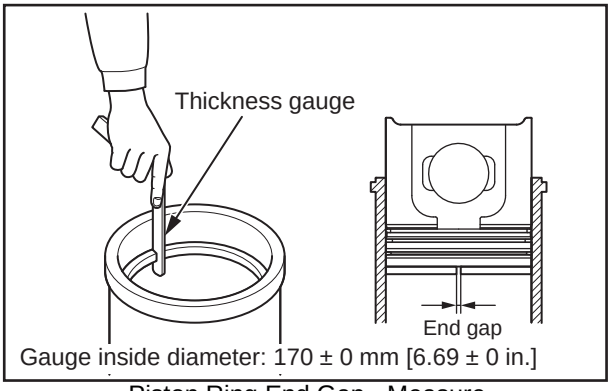
Check the sliding surface, the top and bottom surfaces for seizing, wear, foreign material inclusion, and plating flaking. If any defect is found, replace the piston ring with a new one.

4.7 Piston Ring End Gap - Measure

Place the piston ring in the gauge or a new cylinder liner, and measure the end gap. If the value exceeds the limit, replace the piston rings with a new set of rings.

Note: Using the piston, push the piston ring squarely into the gauge or cylinder liner.

Item		Standard value	Limit value
Piston ring end gap	No.1 Compression	0.6 to 0.8 mm [0.024 to 0.032 in.]	2.0 mm [0.079 in.]
	No.2 Compression	0.6 to 0.8 mm [0.024 to 0.032 in.]	
	Oil	0.3 to 0.5 mm [0.012 to 0.020 in.]	



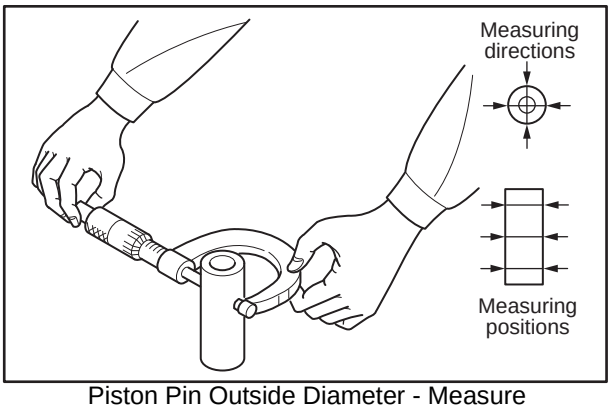
Piston Ring End Gap - Measure

4.8 Piston Pin Outside Diameter - Measure

Measure the piston pin outside diameter.

If the value exceeds the limit, replace the piston pin with a new one.

Item	Nominal value	Standard value	Limit value
Piston pin outside diameter	ø70 mm [2.76 in.]	69.987 to 70.000 mm [2.7554 to 2.7559 in.]	69.970 mm [2.7547 in.]



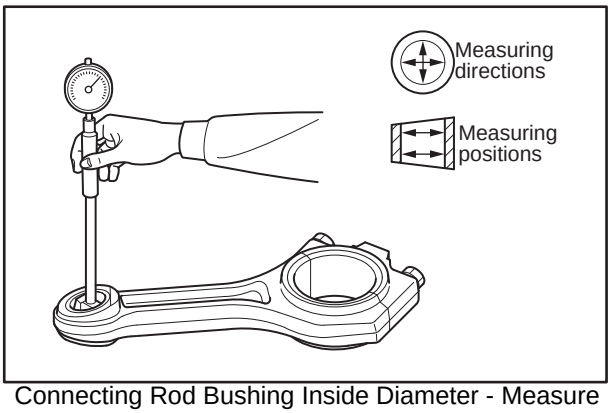
Piston Pin Outside Diameter - Measure

4.9 Connecting Rod Bushing Inside Diameter - Measure

Measure the inside diameter of the connecting rod bushing.

If the value exceeds the limit, replace the connecting rod bushing with a new one.

Item	Nominal value	Standard value	Limit value
Inside diameter of connecting rod bushing	ø70 mm [2.76 in.]	70.020 to 70.040 mm [2.7567 to 2.7575 in.]	70.070 mm [2.7587 in.]



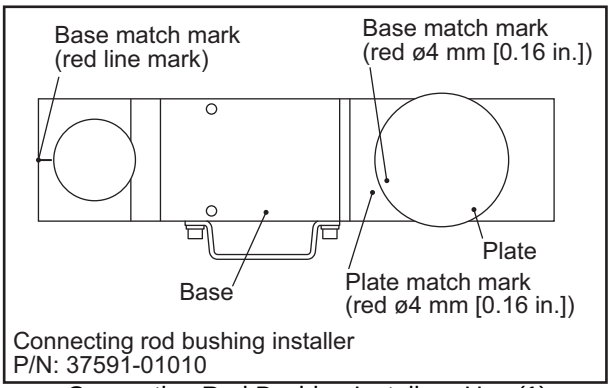
Connecting Rod Bushing Inside Diameter - Measure

4.10 Connecting Rod Bushing - Replace

Replace the connecting rod bushing using the connecting rod bushing installer.

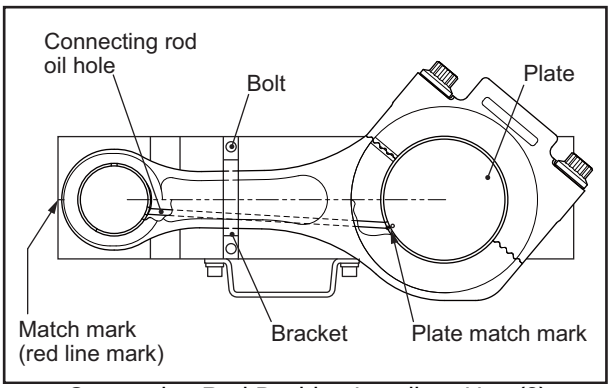
4.10.1 Installer Base and Connecting Rod - Fix

(1) Align the match mark on the base with the match mark on the plate, and install the plate.



Connecting Rod Bushing Installer - Use (1)

(2) With the connecting rod bearing removed from the connecting rod, install the connecting rod cap to the plate.
(3) Align the match mark, and install the connecting rod on the plate.
(4) Tighten the connecting rod bolts to the specified torque.
(5) Secure the connecting rod with the bracket.



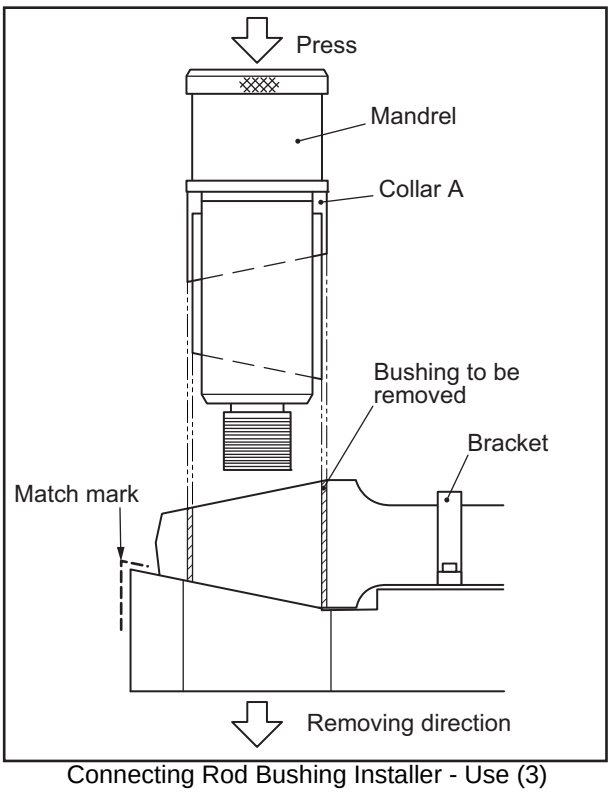
Connecting Rod Bushing Installer - Use (2)

4.10.2 Connecting Rod Bushing - Remove

(1) Apply engine oil on inner surface of connecting rod bushing.

(2) Attach the collar A to mandrel, and insert the mandrel into connecting rod bushing while aligning the match mark (red line) on collar A with mark on the base.

(3) Using a pressing machine, apply pressure slowly on the mandrel head to push-out the connecting rod bushing.



Connecting Rod Bushing Installer - Use (3)

4.10.3 Connecting Rod Bushing - Press Fit

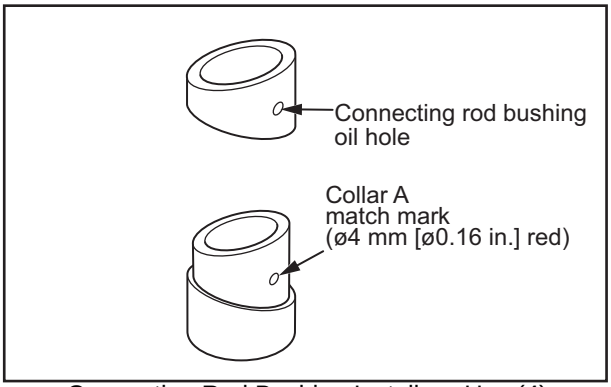
CAUTION

(a) Make sure that the match marks (red lines) on collars A and B are aligned.

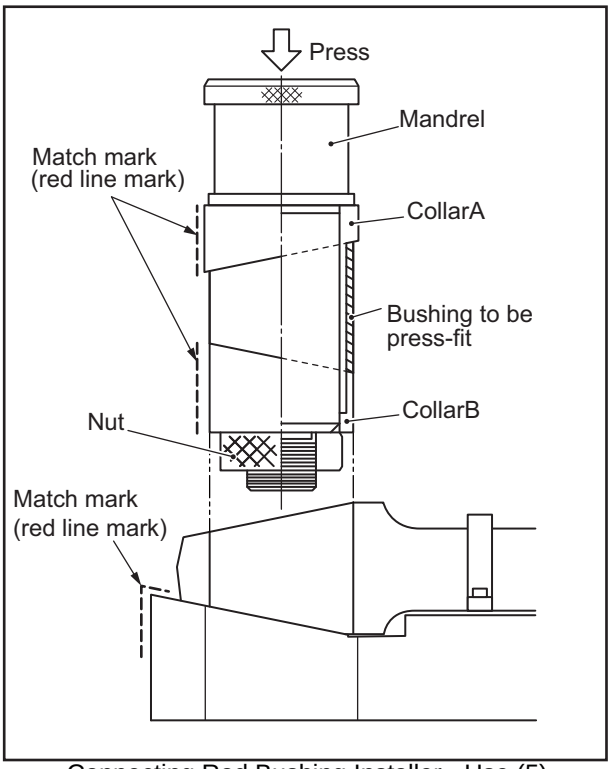
(b) Make sure that the oil hole of connecting rod bushing is in alignment with match mark (red ø4 mm [ø0.16 in.]) on collar A.

(1) Align the oil hole with the match mark on collar A (ø4 mm [0.16 in.] red), and install the new connecting rod bushing on the collar A.

(2) Install the collar A and collar B to the mandrel, and secure them with the nut.

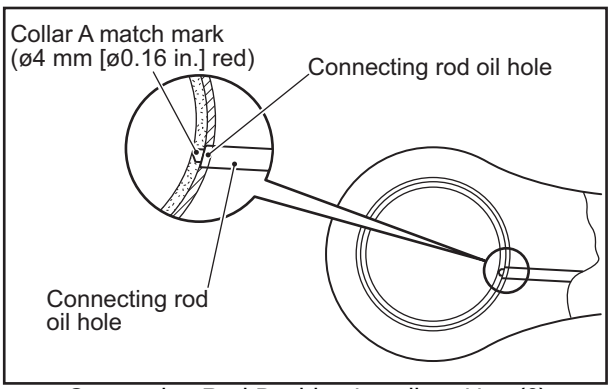


Connecting Rod Bushing Installer - Use (4)



Connecting Rod Bushing Installer - Use (5)

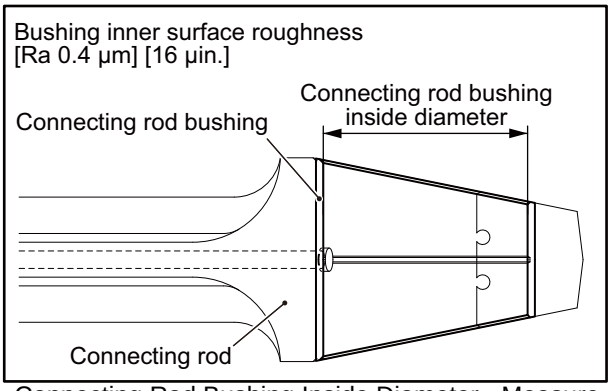
(3) Apply engine oil on the outer surface of connecting rod bushing. Align the match mark (red line) on collar A with the mark of collar B to align the oil hole of connecting rod bushing and the oil hole of connecting rod. Press fit the bushing into the connecting rod with a pressing machine.



Connecting Rod Bushing Installer - Use (6)

(4) Measure the inside diameter of the connecting rod bushing.
If the value is not within the standard value, ream the inside diameter to the standard.

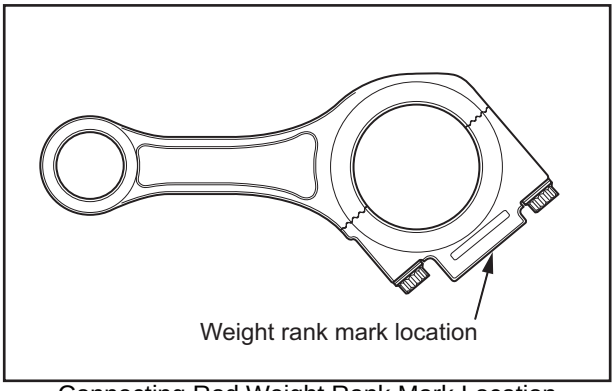
Item	Standard value
Inside diameter of connecting rod bushing	70.020 to 70.040 mm [2.7567 to 2.7575 in.]



Connecting Rod Bushing Inside Diameter - Measure

4.11 Weight of Connecting Rod Assembly

The weight of connecting rod assembly is stamped on the cap.
The weight allowance in the engine is 60 g [2.12 oz] or less.

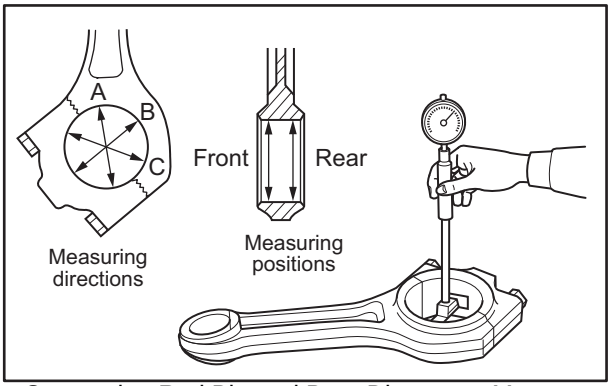


Connecting Rod Weight Rank Mark Location

4.12 Inside Diameter and Roundness of Connecting Rod Big-End Bore - Measure

Measure the connecting rod bore diameter at the front and rear ends respectively in the directions A, B, and C as shown in the illustration. The roundness is determined by subtracting the minimum value from the maximum value among measurements of A, B, and C.
If the value exceeds the limit, replace the connecting rod with a new one.

Item	Nominal value	Standard value	Limit value	Limit value of roundness
Connecting rod big-end bore diameter	ø131 mm [5.16 in.]	131.000 to 131.025 mm [5.1575 to 5.1585 in.]	Minimum: 130.950 mm [5.1555 in.] Maximum: 131.050 mm [5.1594 in.]	0.100 mm [0.0039 in.]



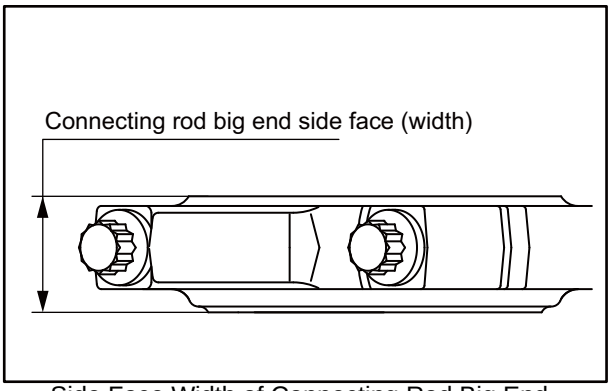
Connecting Rod Big-end Bore Diameter - Measure

4.13 Side Face Width of Connecting Rod Big End - Measure

(1) Visually inspect the side face of connecting rod big end. If any defect such as wear or flaw is observed, replace the connecting rod with a new one.

(2) Measure the side face width of connecting rod big end. If the value exceeds the limit, replace with a new one.

Item	Standard value
Side face width of connecting rod big end	59.7 to 59.8 mm [2.350 to 2.354 in.]



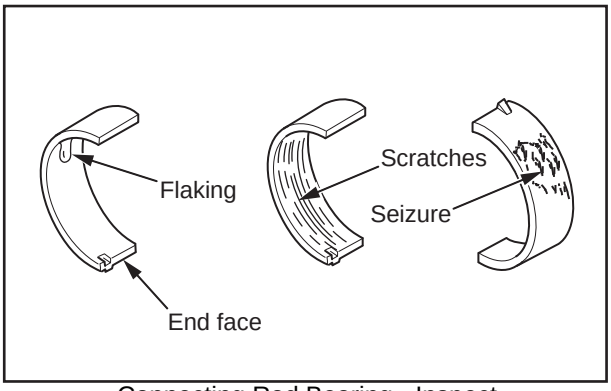
Side Face Width of Connecting Rod Big End - Measure

4.14 Connecting Rod Big End Serration and Bolt Holes - Inspect

Inspect the connecting rod big-end serration and the bolt holes with the magnetic particle inspection. If there is any defect such as cracks, fretting, and foreign material inclusion, replace the connecting rod with a new one.

4.15 Connecting Rod Bearing - Inspect

Inspect the sliding surface, back surface, and end surfaces of the connecting rod bearing. If there is any defect such as local contact, sliding scratches, corrosion, and foreign material inclusion, replace the bearing with a new one.



Connecting Rod Bearing - Inspect

4.16 Connecting Rod Bearing Thickness - Measure

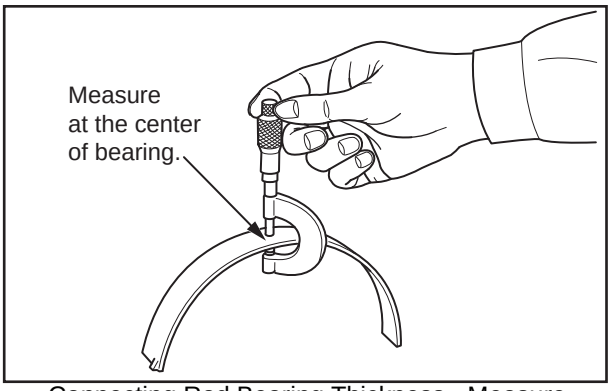
Measure the thickness of the connecting rod at its center position.

If the value exceeds the limit, replace both upper and lower connecting rod bearing shells with new ones as a set.

When the crankshaft is re-ground due to wear of the crank pin, use the undersize bearing.

For crankshaft grinding procedure, see "Crankpin and Crank Journal - Grind" of "ENGINE BODY - INSPECT AND REPAIR".

Note: Replacement shells for undersized connecting rod bearing are available in sizes of 0.25, 0.50, 0.75 and 1.00 mm [0.0098, 0.0197, 0.0295 and 0.0394 in.].



Connecting Rod Bearing Thickness - Measure

Item	Size		Nominal value	Standard value	Limit value
Connecting rod bearing thickness at center	Standard		3.000 mm [0.1181 in.]	2.957 to 2.970 mm [0.1164 to 0.1169 in.]	2.930 mm [0.1154 in.]
	Undersize	0.25 mm [0.0098 in.]	3.125 mm [0.1230 in.]	3.082 to 3.095 mm [0.1213 to 0.1219 in.]	3.055 mm [0.1203 in.]
		0.50 mm [0.0197 in.]	3.250 mm [0.1280 in.]	3.207 to 3.220 mm [0.1263 to 0.1268 in.]	3.180 mm [0.1252 in.]
		0.75 mm [0.0295 in.]	3.375 mm [0.1329 in.]	3.332 to 3.345 mm [0.1312 to 0.1317 in.]	3.305 mm [0.1301 in.]
		1.00 mm [0.0394 in.]	3.500 mm [0.1378 in.]	3.457 to 3.470 mm [0.1361 to 0.1366 in.]	3.430 mm [0.1350 in.]

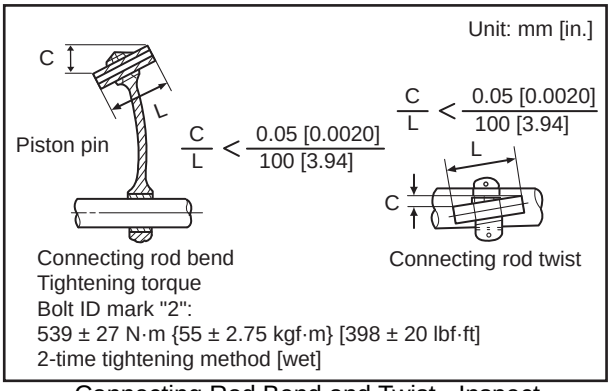
4.17 Connecting Rod Bend and Twist - Inspect

(1) Measure the dimensions of C and L as shown in the illustration to check bend and twist of the connecting rod. Correct the connecting rod with a press machine so that the measured value meets the standard.
If the value exceeds the limit, replace with a new one.

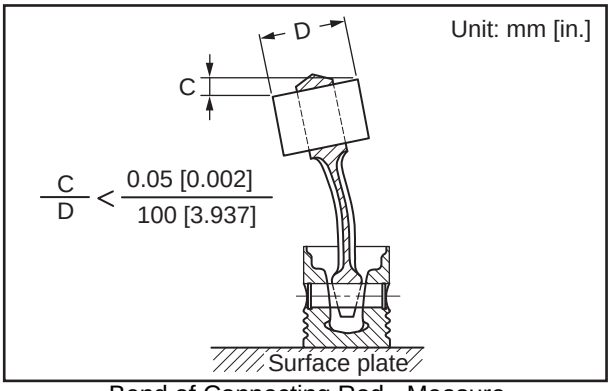
Note: Tighten the connecting rod cap to the specified torque and check bend and twist.

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

Item	Standard value
Connecting rod bend and twist (C/L and C/D)	0.05/100 mm [3.94/3.94 in.] or less



Connecting Rod Bend and Twist - Inspect



Bend of Connecting Rod - Measure

5. Crankcase and Crankshaft - Inspect and Repair

5.1 Crankcase Top Surface Distortion - Measure

CAUTION

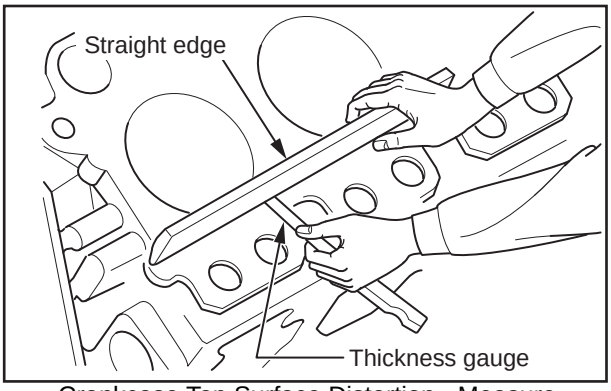
Keep the grinding depth of the crankcase to the minimum.

Excessive grinding of the crankcase may result in defects such as defective combustion and stamping between piston and valve.

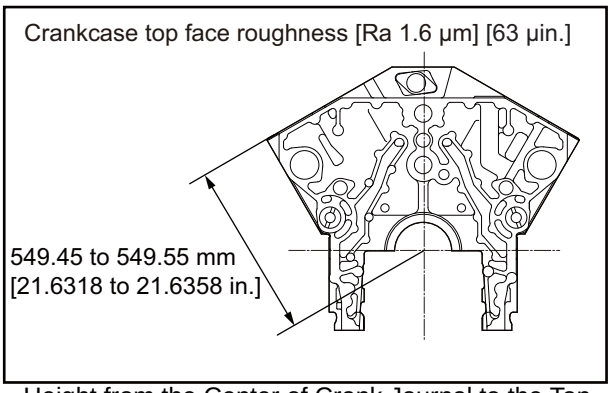
Apply a straight edge to the top surface of the crankcase and measure its distortion with feeler gauges. If the value exceeds the limit, replace with a new one, or grind to correct.

When ground, record the maximum depth of grinding. Note that the total grinding amount, which includes the grinding depth of the bottom surface of the cylinder head, must be 0.50 mm [0.0197 in.] or less.

Item	Standard value	Limit value
Crankcase top surface distortion	0.1 mm [0.004 in.] or less	0.2 mm [0.008 in.]
Height from the center of crank journal to the top face of crankcase (Reference value)	549.45 to 549.55 mm [21.6318 to 21.6358 in.]	-



Crankcase Top Surface Distortion - Measure



Height from the Center of Crank Journal to the Top Face of Crankcase

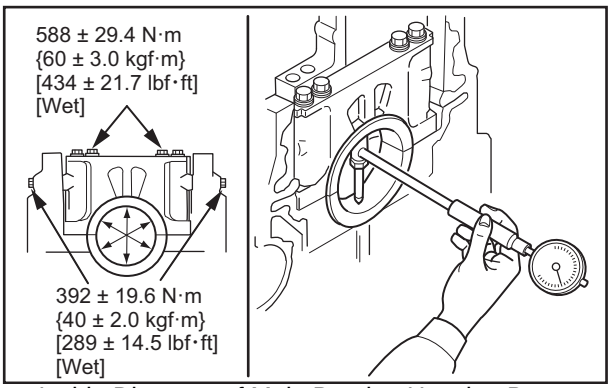
5.2 Inside Diameter of Main Bearing Housing Bore - Measure

(1) Assemble the main bearing cap in crankcase in accordance with the specified method.

Note: For tightening procedure for main bearing cap, refer to "Main Bearing Cap - Install" of "ENGINE BODY - ASSEMBLE".

(2) Measure the main bearing housing diameter in vertical and the two diagonal directions.

Item	Nominal value	Standard value	Limit value
Inside diameter of main bearing housing bore	ø179 mm [7.05 in.]	179.000 to 179.025 mm [7.0472 to 7.0482 in.]	179.045 mm [7.0490 in.]

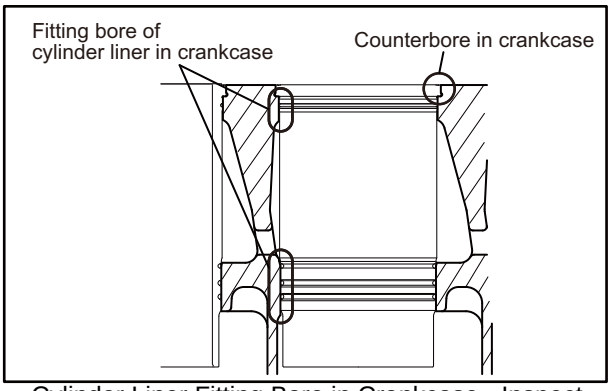


Inside Diameter of Main Bearing Housing Bore - Measure

5.3 Cylinder Liner Fitting Bore in Crankcase - Inspect

(1) Inspect the counterbore in the crankcase. Check for cracks on edges, uneven contact between the counterbore and the bottom face of the cylinder liner flange. If any defect is found, reface the counterbore in the crankcase.

(2) Inspect the cylinder liner fitting section in the crankcase. Check for the defects such as fretting and corrosion.

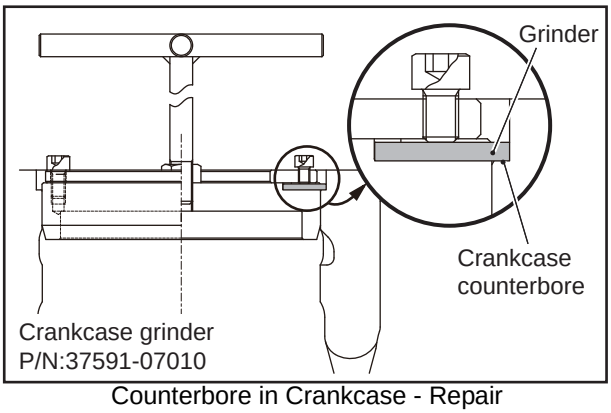


Cylinder Liner Fitting Bore in Crankcase - Inspect

5.4 Counterbore in Crankcase - Repair

If a local contact is found on the counterbore in the crankcase, grind and repair. Grind the counterbore with the crankcase grinder to correct the depth differences at four directions in circumference to be less than 0.05 mm [0.0020 in.].

After the grinding of counterbore in the crankcase is completed, measure the cylinder liner flange protrusion.



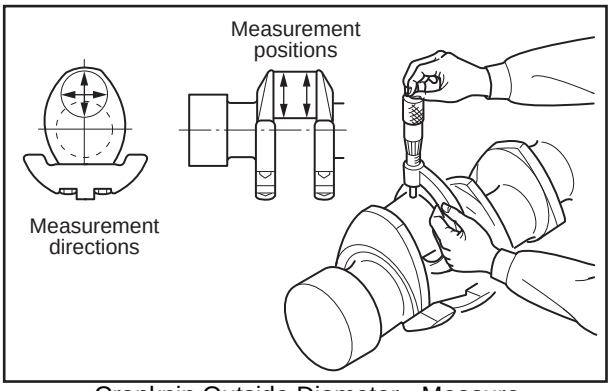
Counterbore in Crankcase - Repair

5.5 Crank Pin and Journal Outside Diameters - Measure

(1) Measure the outside diameter of the crankshaft pin and journal.

If the value exceeds the limit, use the undersize bearing, and grind the crankshaft to fit the undersize bearing.

If the value exceeds the limit even when 1.00 mm [0.0394 in.] undersized bearing is used, replace the crankshaft with a new one.



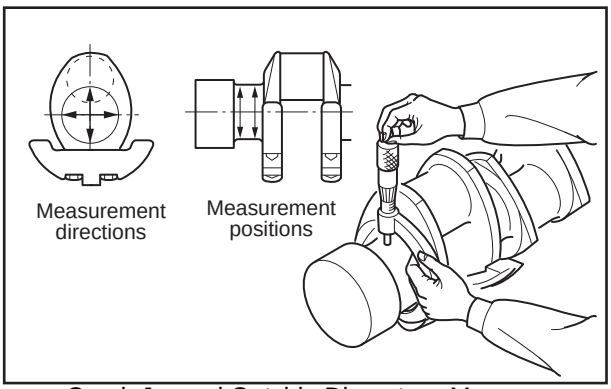
Crankpin Outside Diameter - Measure

5.5.1 Crankshaft Pin and Journal - Grind

When using the undersize bearing, grind to the specified value that meets the undersize bearing.

Do not change the fillet radius and the bearing journal width when grinding. If a remarkable decrease in hardness is found, quench the crankshaft again and inspect it with the magnetic particle inspection.

After the grinding, measure the width of crankpins and rear-most crank main journal.



Crank Journal Outside Diameter - Measure

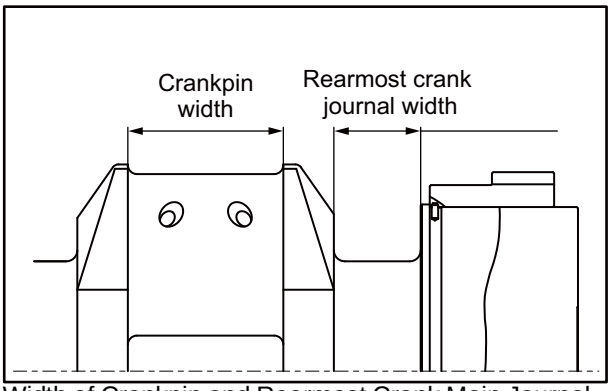
Item			Nominal value	Size		Standard value	Limit value
Crankpin outside diameter			ø125 mm [4.92 in.]	Standard		124.930 to 124.950 mm [4.9185 to 4.9193 in.]	124.890 mm [4.9169 in.]
				Undersize	0.25 mm [0.0098 in.]	124.680 to 124.700 mm [4.9087 to 4.9094 in.]	124.640 mm [4.9071 in.]
					0.50 mm [0.0197 in.]	124.430 to 124.450 mm [4.8988 to 4.8996 in.]	124.390 mm [4.8972 in.]
					0.75 mm [0.0295 in.]	124.180 to 124.200 mm [4.8890 to 4.8898 in.]	124.140 mm [4.8874 in.]
					1.00 mm [0.0394 in.]	123.930 to 123.950 mm [4.8791 to 4.8799 in.]	123.890 mm [4.8775 in.]
Crankshaft journal outside diameter			ø170 mm [6.69 in.]	Standard		169.920 to 169.940 mm [6.6898 to 6.6905 in.]	169.880 mm [6.6882 in.]
				Undersize	0.25 mm [0.0098 in.]	169.670 to 169.690 mm [6.6799 to 6.6807 in.]	169.630 mm [6.6783 in.]
					0.50 mm [0.0197 in.]	169.420 to 169.440 mm [6.6701 to 6.6709 in.]	169.380 mm [6.6685 in.]
					0.75 mm [0.0295 in.]	169.170 to 169.190 mm [6.6602 to 6.6610 in.]	169.130 mm [6.6586 in.]
					1.00 mm [0.0394 in.]	168.920 to 168.940 mm [6.6504 to 6.6512 in.]	168.880 mm [6.6488 in.]
Pin and journal	Parallelism		-	-		Runout through the pin whole length: 0.01 mm [0.0004 in.] or less in TIR	0.03 mm [0.0012 in.]
	Roundness		-	-		Diameter difference, 0.01 mm [0.0004 in.] or less	0.03 mm [0.0012 in.]
	Cylindricity		-	-		Diameter difference, 0.01 mm [0.0004 in.] or less	0.03 mm [0.0012 in.]
	Fillet radius	Pin	R7 [0.276 in.]	-		6.8 to 7.0 mm [0.268 to 0.276 in.]	-
		Journal	R8.5 [0.335 in.]	-		8.3 to 8.5 mm [0.327 to 0.335 in.]	-
	Hardness		-	-		Hv > 590	-
	Finishing surface roughness		-	-		Ra 0.2 µm [7.87 µin.]	-
Angular deviation between pins			-	-		±20'	-

5.6 Width of Crankpin and Rearmost Crank Main Journal - Measure

(1) Inspect the ends of crankshaft for harmful flaw and wear.

(2) Measure the width of crankpins and rearmost crank journal.

When using undersize thrust plates due to wear of rearmost crank main journal width, grind the crankshaft for the use with the undersize thrust plates.



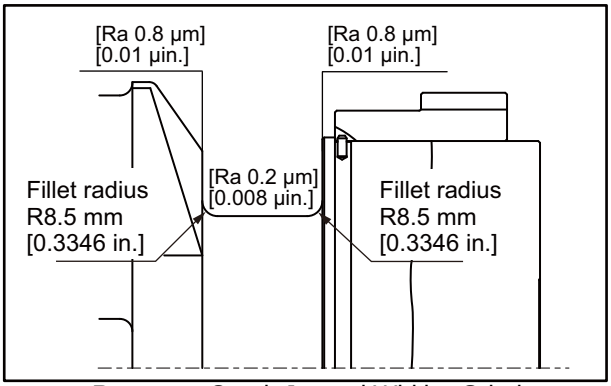
Width of Crankpin and Rearmost Crank Main Journal - Measure

5.6.1 Rearmost Crank Journal Width - Grind

When using the undersize thrust plates, grind the rearmost crank main journal width for the use with the undersize thrust plates.

Do not change the fillet radius when grinding. Quench the crankshaft if its surface hardness is significantly decreased, and perform the magnetic particle testing after quenching. Ensure that the finishing surface roughness after grinding is within the standard value.

Note: The difference between the front and rear thrust plate in thickness must be 0.25 mm [0.0098 in.] or less.



Rearmost Crank Journal Width - Grind

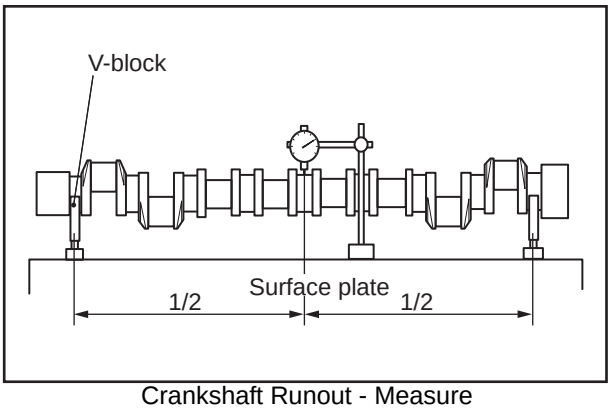
Item	Nominal value	Size			Standard value
Crankpin width	120 mm [4.72 in.]	-			120.20 to 120.30 mm [4.7323 to 4.7362 in.]
Rearmost crank journal width	67 mm [2.64 in.]	Standard			67.00 to 67.05 mm [2.6378 to 2.6398 in.]
		Undersize	0.25 mm [0.0098 in.]	One side	67.25 to 67.30 mm [2.6476 to 2.6496 in.]
				Both sides	67.50 to 67.55 mm [2.6575 to 2.6594 in.]
			0.50 mm [0.0197 in.]	One side	67.50 to 67.55 mm [2.6575 to 2.6594 in.]
				Both sides	68.00 to 68.05 mm [2.6772 to 2.6791 in.]
			0.75 mm [0.0295 in.]	One side	67.75 to 67.80 mm [2.6673 to 2.6693 in.]
				Both sides	68.50 to 68.55 mm [2.6968 to 2.6988 in.]

5.7 Crankshaft Runout - Measure

Support the crankshaft at the front and rear main journals with V-blocks, and measure the crankshaft runout at the center journal with a dial gauge. If the runout deviates slightly from the standard values, correct the crankshaft by grinding. If the value exceeds the standard value considerably, straighten the crankshaft with a press machine.

If the value exceeds the limit, replace the crankshaft with a new one.

If the crankshaft is corrected by grinding or pressing, inspect the crankshaft for cracks and other harmful damages with the magnetic particle inspection.



Crankshaft Runout - Measure

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

5.8 Crankshaft Gear - Inspect

If there is any defect on the crankshaft gear tooth, such as flaking, wear, or local contact, replace the crankshaft gear with a new one.

5.9 Crankshaft Gear - Replace

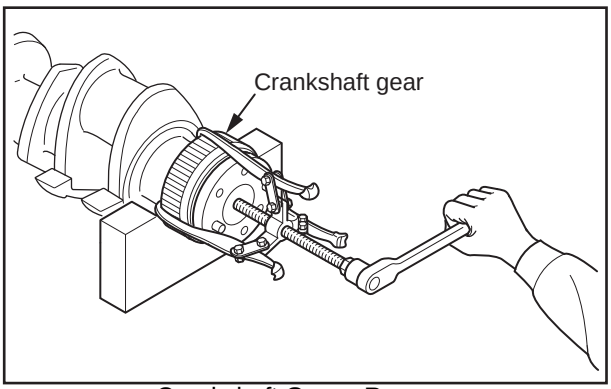
⚠ CAUTION

Use protective gloves when you touch hot parts.
Handling with bear hands could result in burns.

5.9.1 Crankshaft Gear - Remove

Remove the gear from the crankshaft with a gear puller.

Note: When removing the crankshaft gear by heating, the heating temperature shall be 180°C [356 °F] or less.



Crankshaft Gear - Remove

5.9.2 Crankshaft Gear - Install

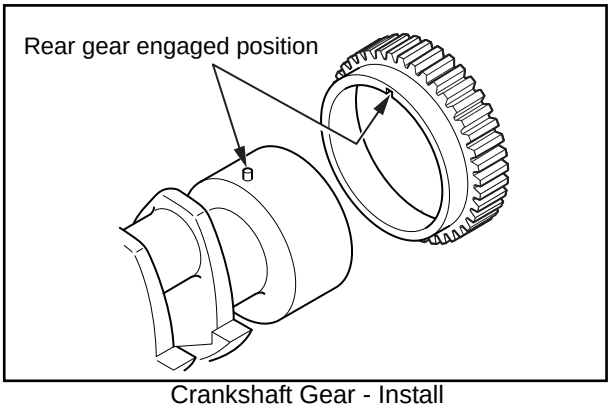
CAUTION

(a) Make sure the correct orientation and position of crankshaft gear when installing.

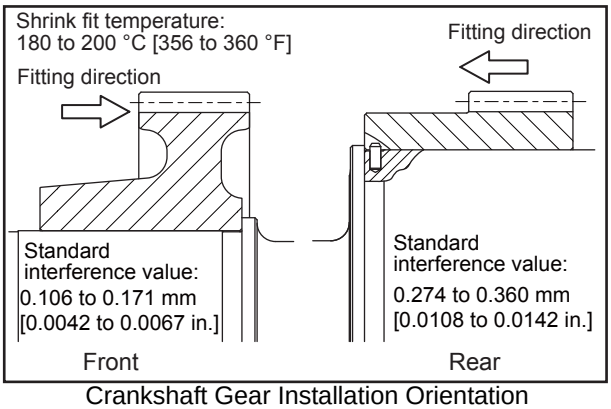
(b) To shrinkage-fit the crankshaft gear to the crankshaft, heat the crankshaft gear evenly at the specified temperature or below.

(1) Measure the outside diameter of crankshaft and the inside diameter of crankshaft gear, and check the interference.

(2) Heat the crankshaft gear evenly at the specified temperature or below. After checking gear orientation and position, install the crankshaft gear.



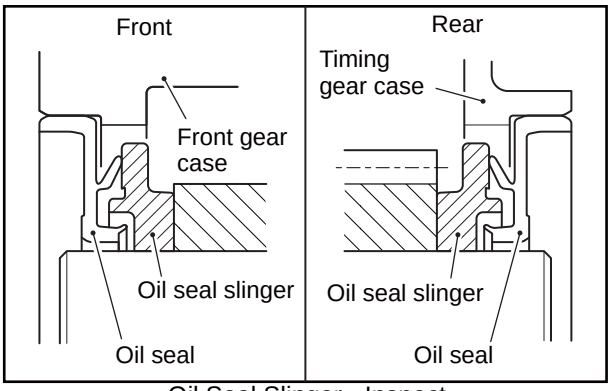
Crankshaft Gear - Install



Crankshaft Gear Installation Orientation

5.10 Oil Seal Slinger - Inspect

If any defect such as dent, damage, wear, or looseness that can lead to oil leakage is found, replace the oil seal slinger with a new one.



Oil Seal Slinger - Inspect

5.11 Oil Seal Slinger - Replace

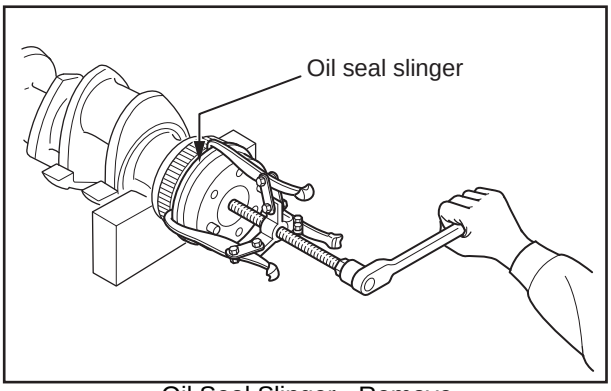
⚠ CAUTION

Use protective gloves when you touch hot parts.
Handling with bear hands could result in burns.

5.11.1 Oil Seal Slinger - Remove

Using a gear puller, pull out the oil seal slinger from crankshaft.

Note: When removing the oil seal slinger by heating, the heating temperature should be 100°C [212°F] or less.

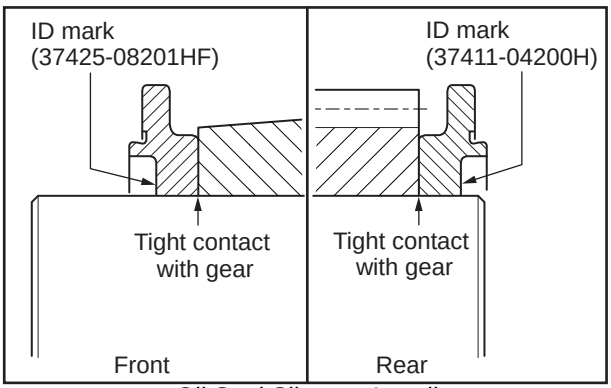


Oil Seal Slinger - Remove

5.11.2 Oil Seal Slinger - Install

(1) Measure the outside diameter of crankshaft and inside diameter of oil seal slinger, and check the interference.

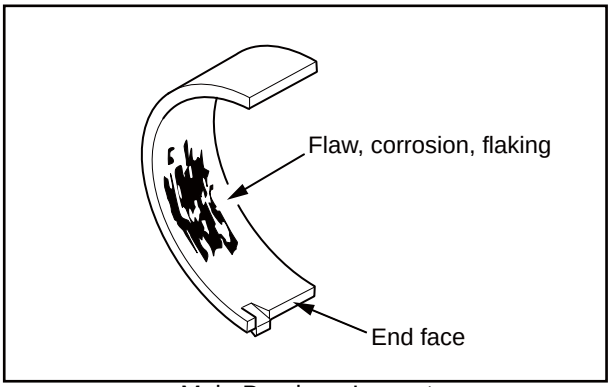
(2) Heat the oil seal slinger evenly at temperature of 110ºC [230°F] or below. After checking the correct direction and position of slinger, install the slinger.



Oil Seal Slinger - Install

5.12 Main Bearing - Inspect

Inspect the sliding surface, back surface and end surfaces of the main bearing. If any defect such as local contact, sliding scratches, corrosion and foreign material inclusion is found, replace the main bearing with a new one.



Main Bearing - Inspect

5.13 Thickness of Main Bearing - Measure

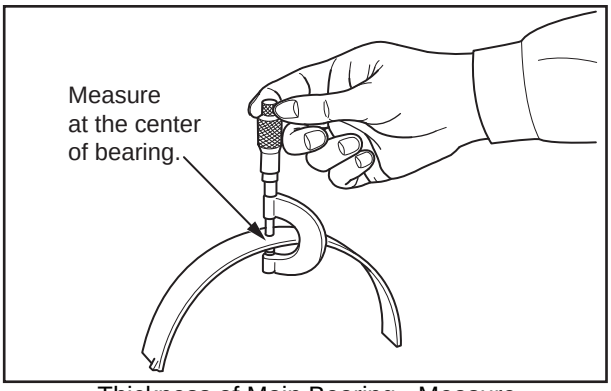
Measure the thickness of main bearing shell at the center position.

If the value exceeds the limit, replace both upper and lower main bearing shells with new ones as a set.

When the crankshaft is re-ground due to wear of crank journal, use the undersize bearings.

For crankshaft grinding procedure, see "Crankpin and Crank Journal - Grind" of "ENGINE BODY - INSPECT AND REPAIR."

Note: Replacement shells for undersized connecting rod bearing are available in sizes of 0.25, 0.50, 0.75 and 1.00 mm [0.0098, 0.0197, 0.0295 and 0.0394 in.].

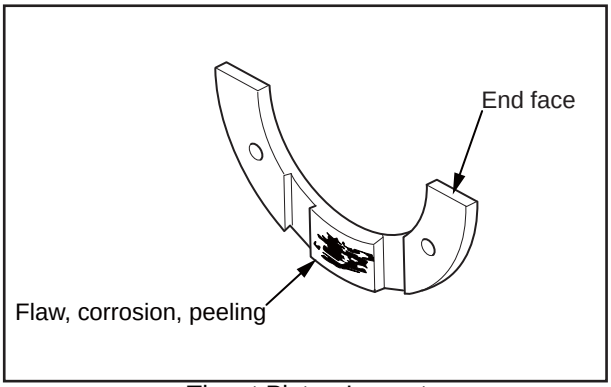


Thickness of Main Bearing - Measure

Item	Size		Nominal value	Standard value	Limit value
Main bearing thickness at the center position	Standard		4.500 mm [0.1772 in.]	4.467 to 4.480 mm [0.1759 to 0.1764 in.]	4.425 mm [0.1742 in.]
	Undersize	0.25 mm [0.0098 in.]	4.625 mm [0.1821 in.]	4.592 to 4.605 mm [0.1808 to 0.1813 in.]	4.550 mm [0.1791 in.]
		0.50 mm [0.0197 in.]	4.750 mm [0.1870 in.]	4.717 to 4.730 mm [0.1857 to 0.1862 in.]	4.675 mm [0.1841 in.]
		0.75 mm [0.0295 in.]	4.875 mm [0.1919 in.]	4.842 to 4.855 mm [0.1906 to 0.1911 in.]	4.800 mm [0.1890 in.]
		1.00 mm [0.0394 in.]	5.000 mm [0.1969 in.]	4.967 to 4.980 mm [0.1956 to 0.1961 in.]	4.925 mm [0.1939 in.]

5.14 Thrust Plate - Inspect

Inspect the sliding surface, back surface, and end surfaces of the thrust plate. If any defect such as local contact, sliding scratches, corrosion, and foreign material inclusion is found, replace the thrust plate with a new one.



Thrust Plate - Inspect

5.15 Thickness of Thrust Plate - Measure

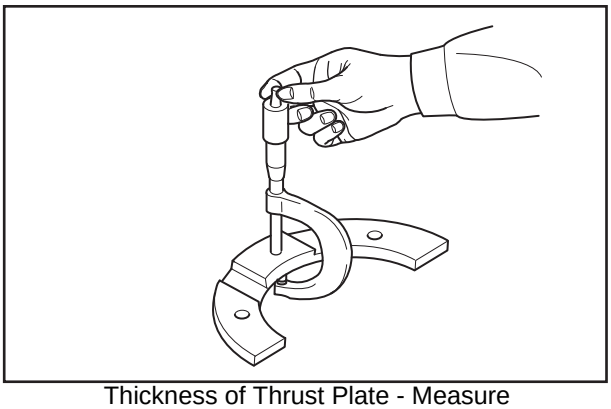
Measure the thickness of thrust plate.

If the value exceeds the limit, replace the thrust plate with a new one. When the crankshaft is re-ground due to wear, use the oversize thrust plates.

For crankshaft grinding procedure, see "Rearmost Crank Journal Width - Grind" of "ENGINE BODY - INSPECT AND REPAIR".

Note:(a) Replacement thrust plates are available in three oversizes of 0.25, 0.50, and 0.75 mm [0.0098, 0.0197, and 0.0295 in.].

(b) Because the oversize thrust plate can be used in only one side (a set of upper and lower plates), the end play can be adjusted with a minimum depth of the crankshaft grinding.



Thickness of Thrust Plate - Measure

Item	Size		Nominal value	Standard value	Limit value
Thickness of thrust plate	Standard		5.00 mm [0.1969 in.]	4.78 to 4.85 mm [0.1882 to 0.1909 in.]	4.71 mm [0.1854 in.]
	Oversize	0.25 mm [0.0098 in.]	5.25 mm [0.2067 in.]	5.03 to 5.10 mm [0.1980 to 0.2008 in.]	4.96 mm [0.1953 in.]
		0.50 mm [0.0197 in.]	5.50 mm [0.2165 in.]	5.28 to 5.35 mm [0.2079 to 0.2106 in.]	5.21 mm [0.2051 in.]
		0.75 mm [0.0295 in.]	5.75 mm [0.2264 in.]	5.53 to 5.60 mm [0.2177 to 0.2205 in.]	5.46 mm [0.2150 in.]

5.16 Piston Cooling Nozzle - Inspect

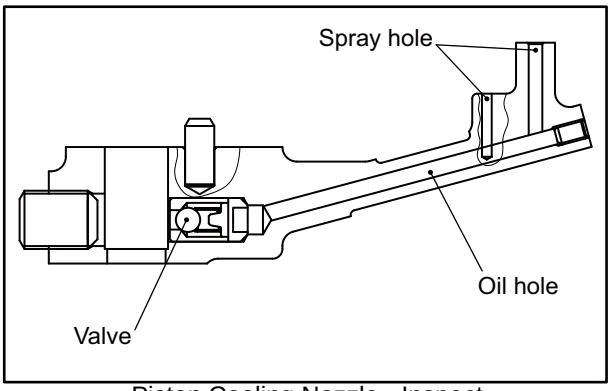
CAUTION

If the oil jet pipe of piston cooling nozzle is bent or deformed, a piston seizure may occur due to insufficient cooling performance.

Inspect the piston cooling nozzle.

If there is any defect such as valve malfunction and oil hole clogging, replace the piston cooling nozzle with a new one.

Item	Standard value
Valve opening pressure of piston cooling nozzle	0.10 to 0.15 MPa {1.02 to 1.53 kgf/cm^2} [14.50 to 21.76 psi]



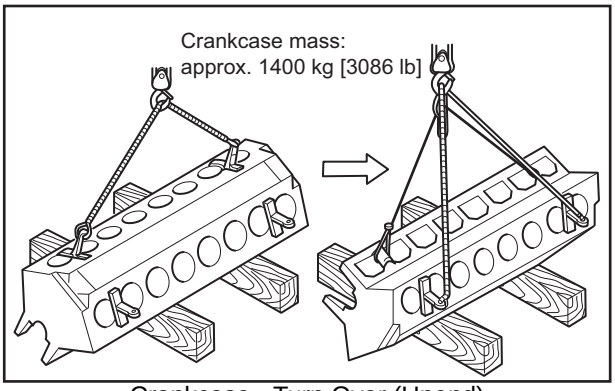
Piston Cooling Nozzle - Inspect

Chapter 7 ASSEMBLY OF BASIC ENGINE

1. Crankshaft and Main Bearing - Install

1.1 Crankcase - Turn Over (Upend)

Using a turnover machine, turn over the crankcase. When the turnover machine is not available, attach slings to the crankcase using wood pieces and cloth pads, and raise the crankcase with a hoist or crane. Then lay it on the wooden block with its side face downward. Then, change the positions of the slings, and turn over to upend the crankcase.



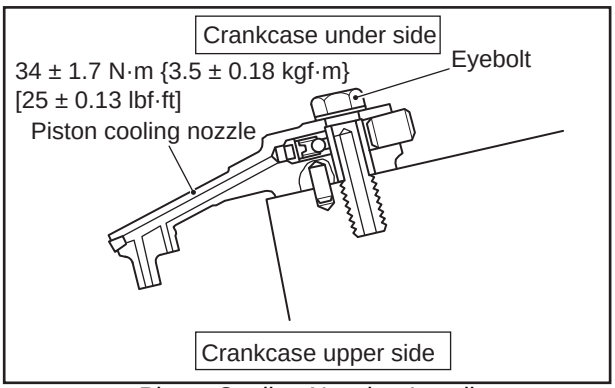
Crankcase - Turn Over (Upend)

1.2 Piston Cooling Nozzle - Install

CAUTION

Be sure to tighten the piston cooling nozzle to the specified torque using a torque wrench. If excessively tightened, piston seizure may occur due to check valve malfunction.

Install the piston cooling nozzle into the crankcase, and tighten the eye bolts to the specified torque.



Piston Cooling Nozzle - Install

1.3 Upper Main Bearing - Install

CAUTION

(a) Do not apply engine oil on the back face of the main bearing shell and the main bearing housing in the crankcase when installing the main bearing. Wash those surfaces to remove foreign material, oil, and grease using a washing solvent before installing the main bearing.

(b) When installing main bearings, be careful not to confuse the upper shell with the lower shell.
The upper main bearing shell can be identified by a machined oil hole, and the lower main bearing shell has no oil hole nor groove. Be careful not to install the main bearings upside down.

(c) Be careful not to damage the bearing when installing.

(1) Clean the main bearing housing and the main bearing cap mating surfaces using cleaning solvent, and make sure that these surfaces are free from any foreign material.

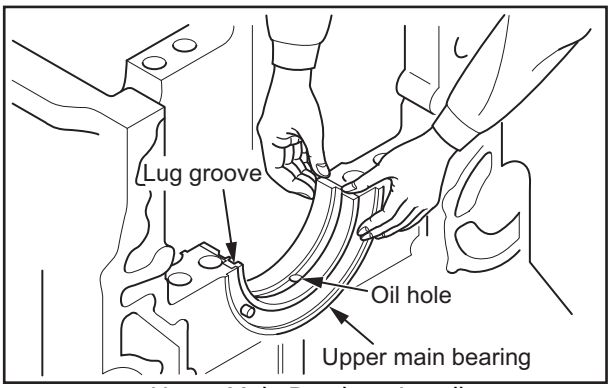
(2) Make sure that the main bearing is free from damage or contamination.

(3) Fit the upper main bearing shell in the crankcase bore by aligning the lug on the shell with the lug slot in the crankcase.

Note:(a) Make the main bearing crush heights even at both ends.

(b) The oil hole in the upper main bearing shell is aligned with the oil hole in the crankcase by aligning the lug on the upper shell with the lug slot in the crankcase.

(4) Apply an even coat of clean engine oil on the sliding surface of upper main bearing shell.



Upper Main Bearing - Install

1.4 Rear Upper Thrust Plate - Install

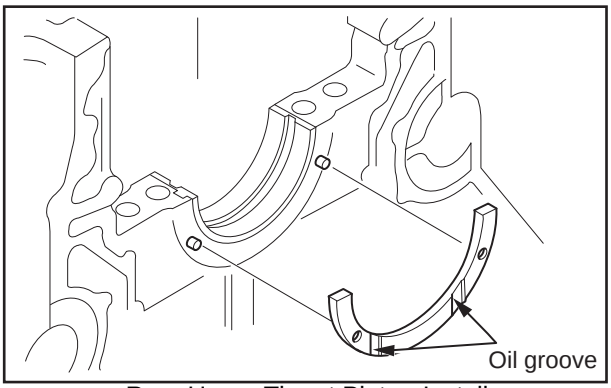
CAUTION

Be careful not to damage the rear thrust plate when installing.

(1) With the oil grooves of the thrust plate facing outside, install the rear upper thrust plate to the dowel pins on the crankcase rearmost main journal.

(2) Apply engine oil evenly to the sliding surface.

Note: Front upper thrust plate shall be installed after crankshaft is installed.



Rear Upper Thrust Plate - Install

1.5 Crankshaft - Install

(1) After installation, make sure that the sliding surfaces of the upper main bearing shells in the crankcase are evenly coated with clean engine oil.

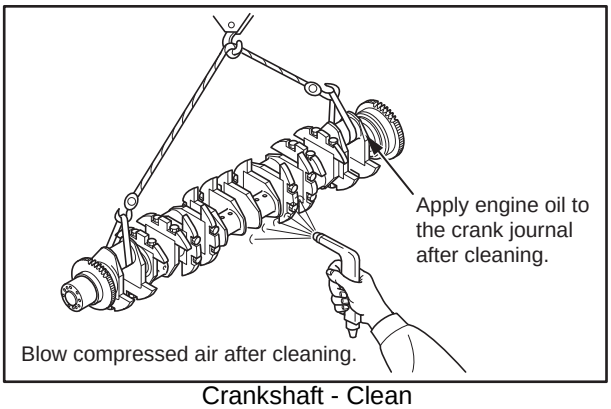
(2) Thoroughly clean the crankshaft with cleaning oil, and blow off the oil with compressed air. Then, apply an even coat of clean engine oil on the crankshaft journals.

Note: When cleaning the crankshaft, be sure to thoroughly clean the crank journals, crankpins, and oil holes, and make sure that the crankshaft is free from foreign material such as machining chips and dirt. Make sure that oil holes are free from burrs.

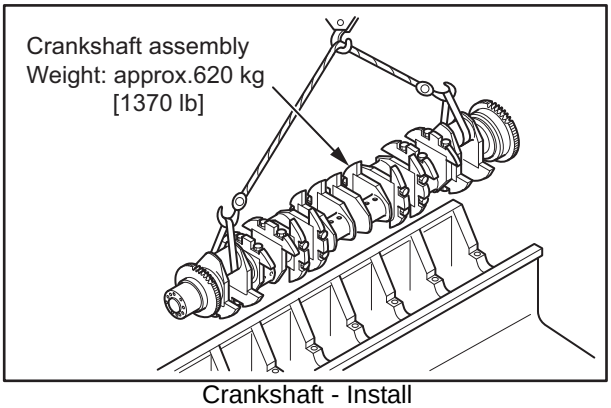
(3) Lift the crankshaft by keeping it in a horizontal attitude, and slowly install into the crankcase.

Note: When lifting the crankshaft, use fiber slings or pads to avoid any damages to the crankshaft.

(4) Slowly rotate the crankshaft to verify a smooth rotation of the crankshaft.



Crankshaft - Clean



Crankshaft - Install

1.6 Front Upper Thrust Plate - Install

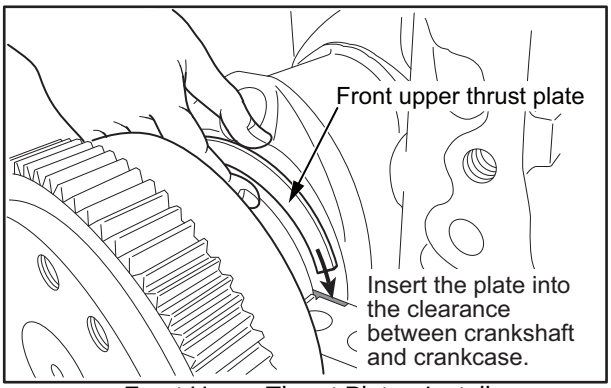
CAUTION

Install the front-upper thrust plate paying attention not to damage the plate.

(1) Push the installed crankshaft softly toward the engine front direction to contact the installed rear upper thrust plate with the crank journal web face.

(2) With the oil grooves on the front upper thrust plate facing outside, insert the front upper thrust plate into the clearance between the crankshaft and crankcase.

(3) Move the crankshaft back and forth to verify the proper end play.



Front Upper Thrust Plate - Install

1.7 Lower Main Bearing Shell and Lower Thrust Plate - Install

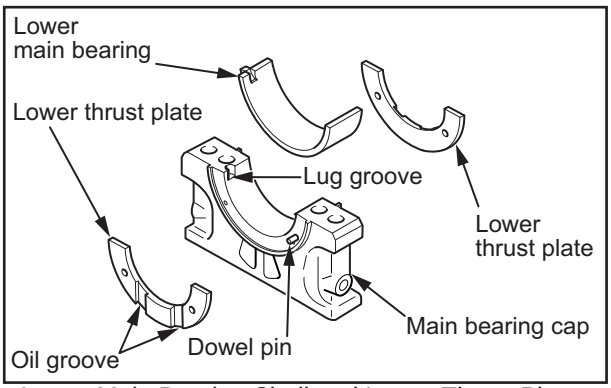
(1) Install the lower main bearing shell by aligning the lug with the lug slot in the main bearing cap.

Note: Make the crush heights even.

(2) Apply an even coat of clean engine oil on sliding surface of lower main bearing shell.

(3) Install the lower thrust plates by aligning with the dowel pins on the rearmost main bearing cap.

Note: Install the lower thrust plates so that the oil grooves faces outward.



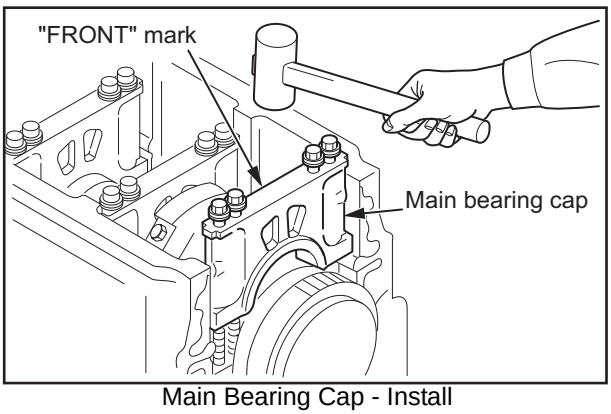
Lower Main Bearing Shell and Lower Thrust Plate - Install

1.8 Main Bearing Cap - Install

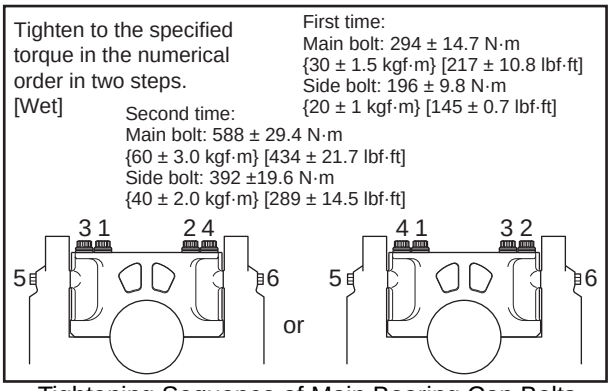
CAUTION

Be sure to tighten the main bearing cap bolts and side bolts in the specified tightening sequence.

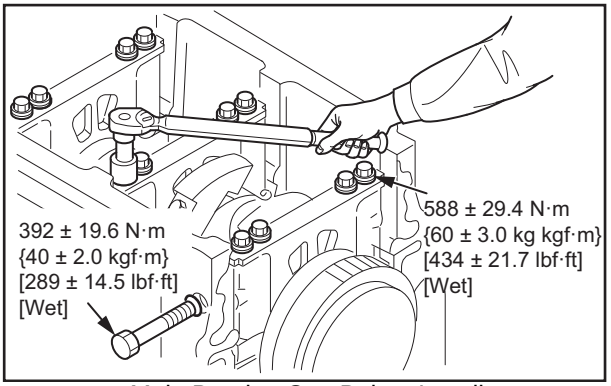
(1) Make sure that the main bearings and the thrust plates installed on the main bearing caps are evenly coated with clean engine oil.
(2) Install the main bearing caps so that their stamp numbers are arranged in numerical order from engine front to rear, and all lug slots are aligned on the same side, which shows the embossed mark of "FRONT" faces toward the engine front.
(3) Apply engine oil on the main bearing cap bolts and washers, and hand tighten them.
(4) Install the main bearing cap evenly with a soft-head hammer.
(5) Apply oil on the side bolts and O-rings, and hand tighten them.
(6) Temporarily tighten the main bearing cap bolts and side bolts except the rearmost ones, to the half of specified torque in the specified tightening sequence as shown in the illustration.
(7) Then tighten the main bearing cap bolts and side bolts except the rearmost ones to the specified torque in the specified sequence shown in the illustration.
(8) Hand tighten the rearmost cap bolts and side bolts to make the rearmost main bearing seated lightly.
Measure the crankshaft end play in this condition.



Main Bearing Cap - Install



Tightening Sequence of Main Bearing Cap Bolts



Main Bearing Cap Bolts - Install

1.9 Crankshaft End Play - Measure

(1) Verify smooth rotation of the crankshaft.

(2) Apply the dial gauge plunger to the rear end face of crankshaft.

(3) With a bar, move the crankshaft fully to front and rear, and read each measurement. The end play is difference between the front and rear measurements.

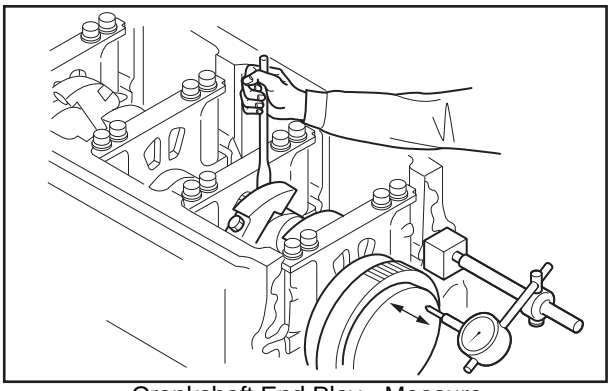
If the value exceeds the standard, inspect the thrust plates and crankshaft.

If the end play is less than the standard value, loosen rear most bearing cap bolts and move the crankshaft back and forth, and measure the end play again.

(4) After tightening rearmost main bearing cap to the specified torque, measure the end play again to verify.

(5) Again, verify the crankshaft smooth rotation.

(6) Verify again all the main bearing cap bolts and side bolts to make sure that they are tightened properly.

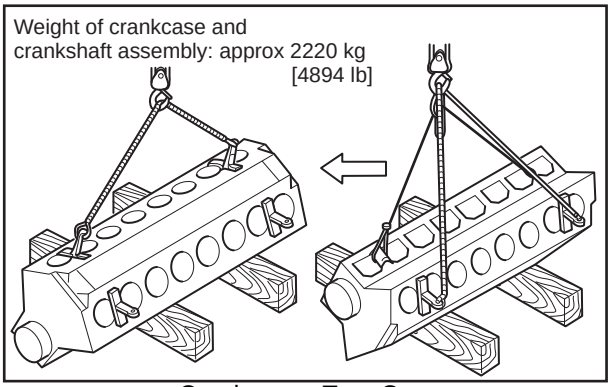


Crankshaft End Play - Measure

Item	Standard value	Limit value
Crankshaft end play	0.200 to 0.500 mm [0.0079 to 0.0197 in.]	0.600 mm [0.0236 in.]

1.10 Crankcase - Turn Over

Using a turnover machine, turn over the crankcase. When the turnover machine is not available, attach slings to the crankcase using wood pieces and cloth pads, and raise the crankcase with a hoist or crane. Then lay it on the wooden block with its side face downward. Then, change the sling positions. Turn over the crankcase on the wooden blocks to turn it to the normal position.



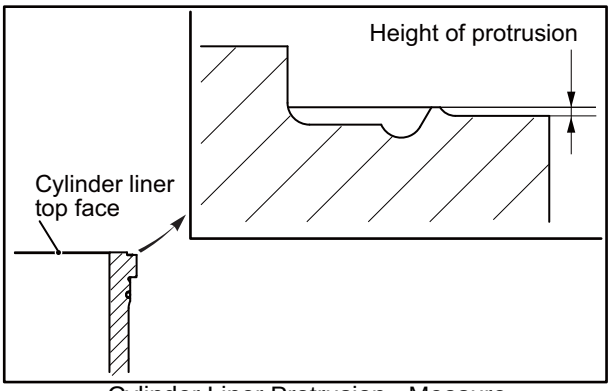
Crankcase - Turn Over

2. Cylinder Liner, Piston, and Connecting Rod - Assemble

2.1 Cylinder Liner Protrusion - Measure

(1) Place a dial gauge probe on the top surface of cylinder liner flange, and adjust the dial to zero.
(2) Place the probe to measure the protrusion of the cylinder liner at four places.
(3) If the value exceeds the limit, or if the ridge is cracked, replace the cylinder liner with a new one.

Item	Standard value
Cylinder liner protrusion	0.16 to 0.24 mm [0.0063 to 0.0094 in.]



Cylinder Liner Protrusion - Measure

2.2 Cylinder Liner Flange Protrusion - Calculate (When Cylinder Liner Not Installed)

CAUTION

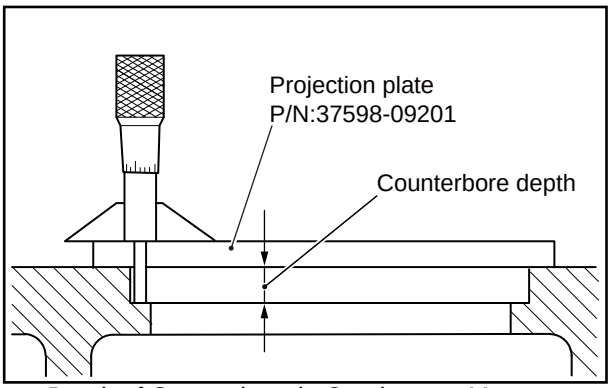
If the amount of protrusion is not enough, the contact pressure of cylinder head gasket becomes low, and it can cause gas and water leaks.

(1) Inspect cylinder liner contact surface of the crankcase. If uneven contact is presented, reface counterbore with the crankcase grinder to correct the difference of depth at four places in circumference to be less than 0.05 mm [0.0020 in.].
For repair procedure, see "Counterbore in Crankcase - Repair" of "ENGINE BODY - INSPECT AND REPAIR".
(2) Make sure that the top and bottom faces of cylinder liner flange, top surface of crankcase, and fitting surfaces of cylinder liner are clean before measurement.
(3) Measure the depth of counterbore in crankcase.

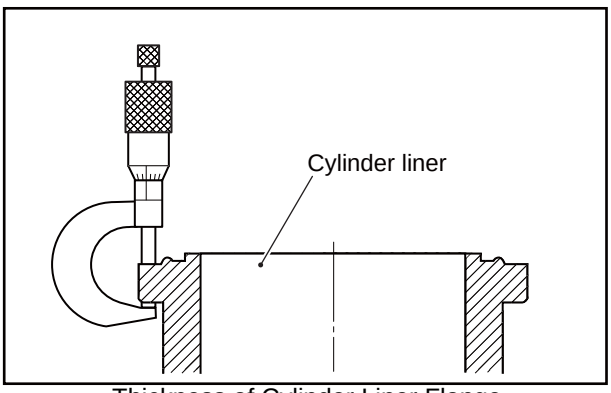
Item	Standard value
Depth of counterbore in crankcase	14.00 to 14.05 mm [0.5512 to 0.5531 in.]

(4) Measure the thickness of cylinder liner flange.

Item	Standard value
Thickness of Cylinder Liner Flange	14.16 to 14.20 mm [0.5575 to 0.5591 in.]



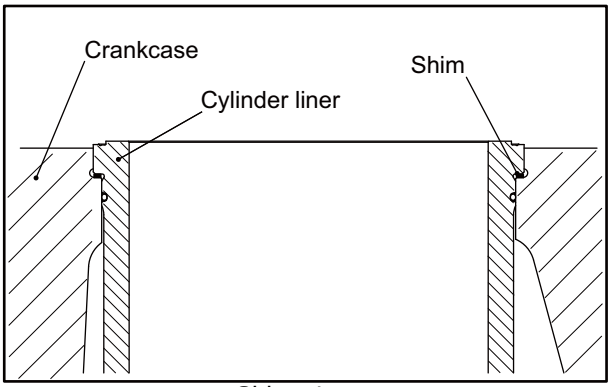
Depth of Counterbore in Crankcase - Measure



Thickness of Cylinder Liner Flange

(5) Determine the cylinder liner flange protrusion by subtracting the depth of counterbore in crankcase from the thickness of cylinder liner flange.
If the value exceeds the limit, insert a shim under the cylinder liner flange. Select the shim which makes the cylinder liner flange protrusion largest within the tolerance.

Note:(a) Shims are available in thickness: 0.05, 0.10 and 0.15 mm [0.0020, 0.0039 and 0.0059 in.].
(b) Do not use two or more shims.



Shim - Insert

Item	Standard value
Cylinder liner flange protrusion	0.11 to 0.20 mm [0.0043 to 0.0079 in.]

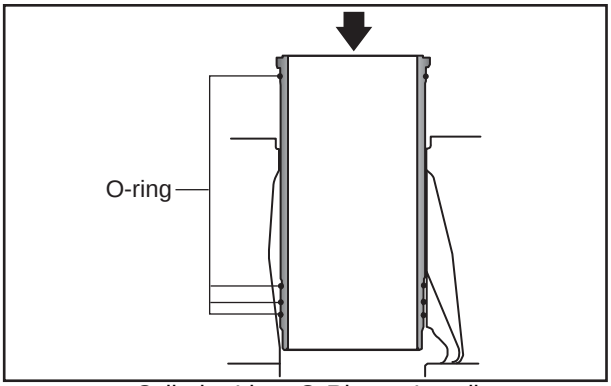
Shim thickness	Part number
0.05 ± 0.02 mm [0.0020 ± 0.0007 in.]	37507-12510
0.10 ± 0.02 mm [0.0039 ± 0.0007 in.]	37507-12500
0.15 ± 0.02 mm [0.0059 ± 0.0007 in.]	37507-12520

2.3 Cylinder Liner - Install

CAUTION

Apply engine oil on O-ring sliding surface in the crankcase to prevent O-rings from twisting.
DO NOT apply engine oil on O-ring grooves on cylinder liner.

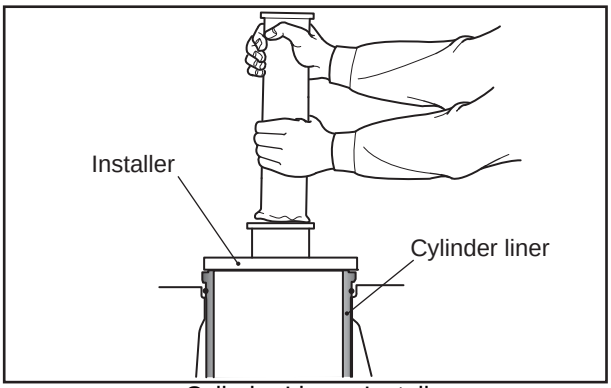
(1) Install the O-rings on the cylinder liner.
(2) Insert the shim into the cylinder which needs the adjustment of the cylinder liner flange protrusion.
(3) Apply engine oil on O-ring sliding surface in the Crankcase and on the cylinder liner O-rings.



Cylinder Liner O-Rings - Install

(4) Slowly insert the cylinder liner into the bore in the crankcase. With a proper cylinder liner installer, lightly tap the cylinder liner until its flange contacts snugly on the seating surface of the crankcase. And then, lightly tap the liner several times to verify the stable seating.

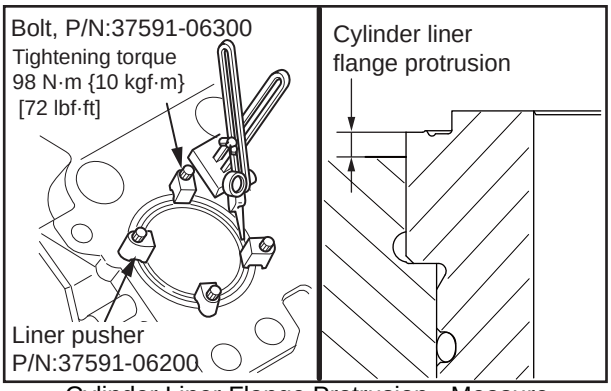
Note: To verify the correct O-rings installation, measure the roundness of inside diameter of the cylinder liner (especially at installed position of O-ring).



Cylinder Liner - Install

2.4 Cylinder Liner Flange Protrusion - Measure (in Cylinder Liner Installed Condition)

(1) Remove dust and dirt from the crankcase top face and the cylinder liner top face.
(2) Place the liner pushers on 4 equally-spaced locations of the cylinder liner upper rim, and tighten the pusher bolts evenly to make a close contact of the cylinder liner and the crankcase.
(3) Apply a dial gauge probe to the top face of the crankcase, and adjust the gauge to zero.
(4) Slide the probe to measure the flange protrusion at four places on the top of the cylinder liner, and obtain the mean value.
(5) If the mean value of the protrusion is smaller than the standard, insert a shim under the cylinder liner flange.
For the shim and the standard value, see "Cylinder Liner Flange Protrusion - Calculate (When Cylinder Liner Not Installed)" of "ENGINE BODY - ASSEMBLE."

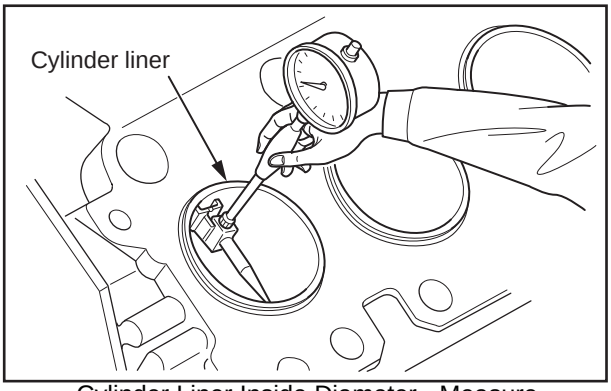


Cylinder Liner Flange Protrusion - Measure

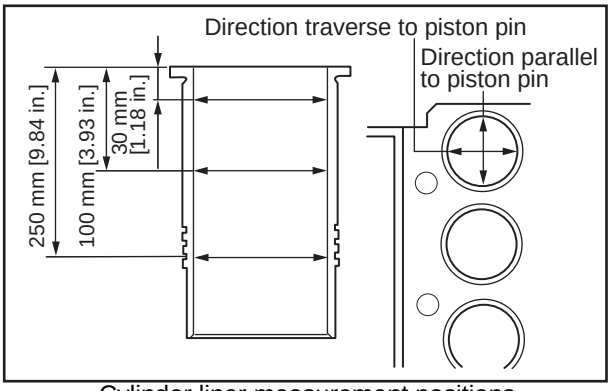
2.5 Cylinder Liner Inside Diameter - Measure

Measure the inside diameter of the cylinder liner at three locations, i.e., the upper position (the position of No.1 compression ring when the piston is at the top dead center), the liner middle position, and the O-ring installed position, in both parallel and perpendicular directions to the piston pin direction.
Replace the cylinder liner if the value exceeds the limit. If the liner is distorted, re-install the liner.

Item	Nominal value	Standard value	Limit value
Inside diameter	ø170 mm [6.69 in.]	170.020 to 170.040 mm [6.6937 to 6.6945 in.]	170.100 mm [6.6968 in.]
Roundness	-	0.02 mm [0.0008 in.] or less	-
Cylindricity	-	0.02 mm [0.0008 in.] or less	-



Cylinder Liner Inside Diameter - Measure



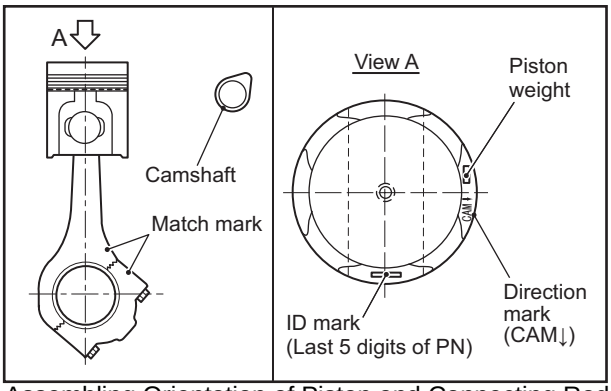
Cylinder liner measurement positions

2.6 Piston and Connecting Rod - Assemble

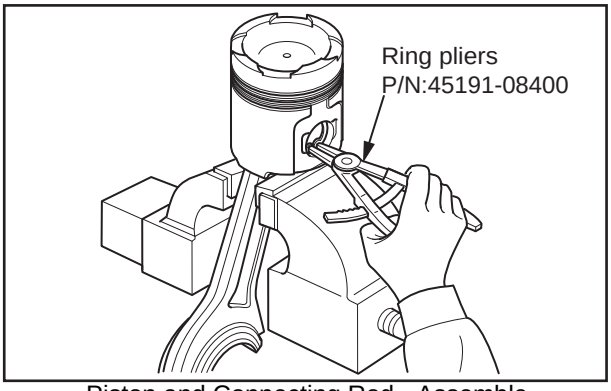
(1) Apply engine oil on the piston pin, and assemble the piston and the connecting rod. The orientation of the piston and the connecting rod is as shown in the illustration.

Note: The piston and the piston pin are made for a clearance fit. However, the piston pin is more easily inserted into the piston if the piston is warmed up with a heater or with hot water.

(2) Install the snap ring with ring pliers. Make sure that the snap ring is fully engaged in the ring groove.



Assembling Orientation of Piston and Connecting Rod



Piston and Connecting Rod - Assemble

2.7 Piston Ring - Install

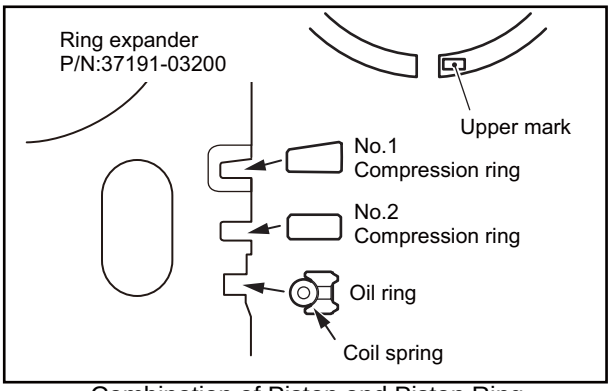
CAUTION

Every piston ring has an upper face mark near the end gap. Install the piston ring with the mark facing upward.

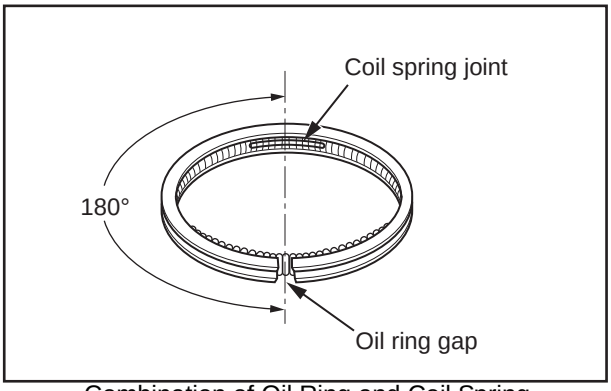
Be careful not to install the piston rings upside down. If the piston rings are assembled incorrectly, it results in defects such as engine seizure.

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

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



Combination of Piston and Piston Ring

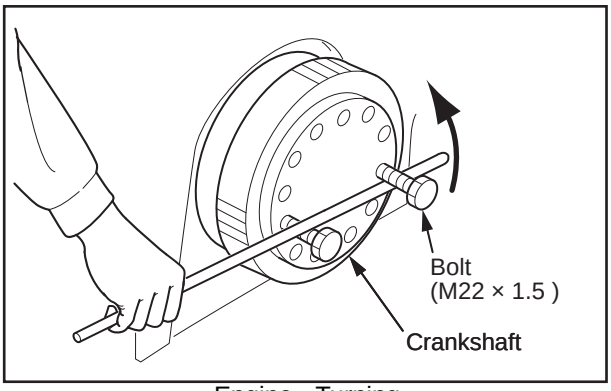


Combination of Oil Ring and Coil Spring

2.8 Engine - Turning

(1) Install two bolts in flywheel mounting holes of crankshaft.

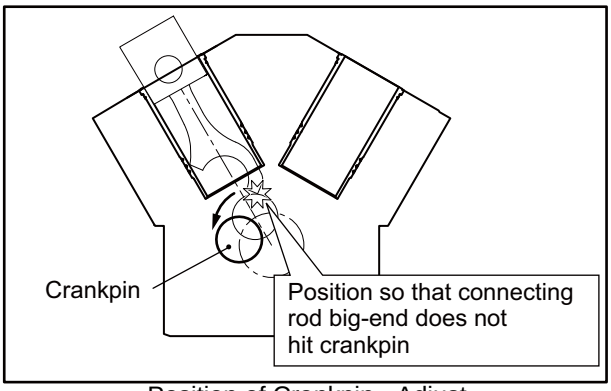
(2) Using the bolts, turn crankshaft with a bar.



Engine - Turning

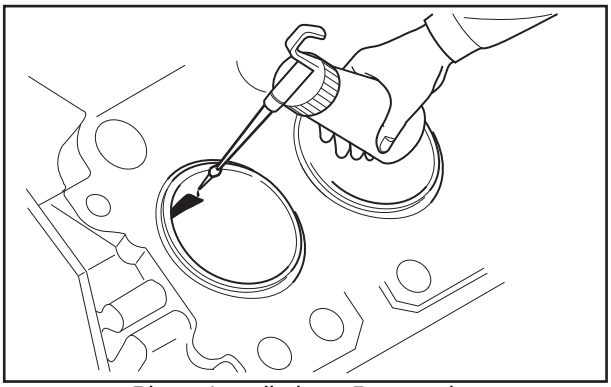
2.9 Piston Installation - Preparation

(1) When installing the piston, turn the crankshaft to a position where the connecting rod big end does not hit the crankpin.



Position of Crankpin - Adjust

(2) Clean the cylinder liner inner surface and the crankpin, and apply engine oil to the cylinder liner.



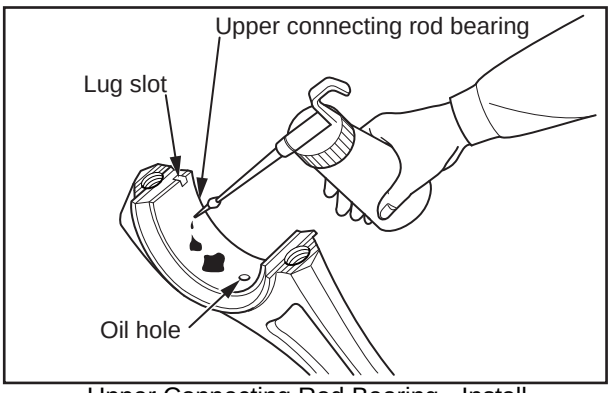
Piston Installation - Preparation

2.10 Upper Connecting Rod Bearing - Install

CAUTION

Be careful not to get engine oil on the back face of upper connecting rod bearing.

Install the upper connecting rod bearing on the connecting rod big end by aligning the lug and the lug slot. Apply engine oil on sliding surface. Make sure the oil hole of connecting rod is aligned with the oil hole of bearing.



Upper Connecting Rod Bearing - Install

2.11 Piston - Install

⚠ CAUTION

When installing the piston, install the eye bolt in the bolt hole on the piston top, and lift the piston with chain block. When the installation work is inevitably done by hand, be sure to take preventive measures so that the piston does not fall down, and be very careful not to hurt your hands and fingers or not to damage the parts.

CAUTION

(a) Make sure that the punch mark on the piston top faces the camshaft side.

(b) Checking through the inspection window on the side of crankcase, make sure that the connecting rod does not bump the piston cooling nozzle when installing the piston.

(c) To prevent the oil ring from damaging by impact shock, slowly insert the piston.

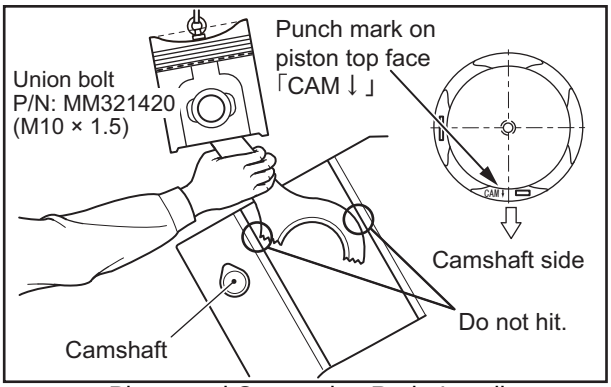
(1) Insert the connecting rod into the cylinder liner carefully so as not to hit the liner, and slowly lower the piston onto the upper surface of crankcase.

(2) Apply engine oil on the piston rings.
Arrange the piston ring end gaps at equally spaced positions, avoiding piston pin and thrust/anti-thrust directions.

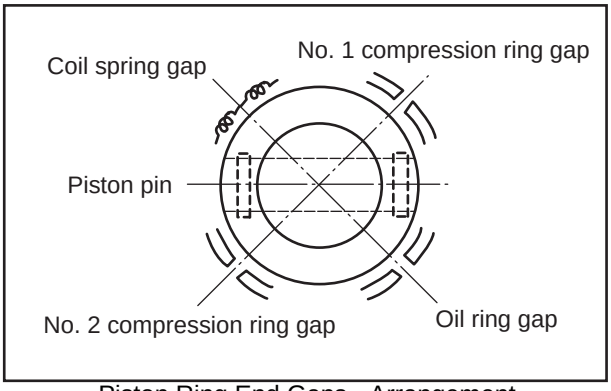
(3) Hold the compression ring positions of piston with hands, and slowly insert the piston skirt into the cylinder liner.

(4) Verify again the piston ring arrangement.
Apply engine oil on the piston rings.
Apply engine oil on the inner surface of the piston installer.
Make sure that the oil ring is properly placed in the groove. And then, compress the piston rings with the piston installer.

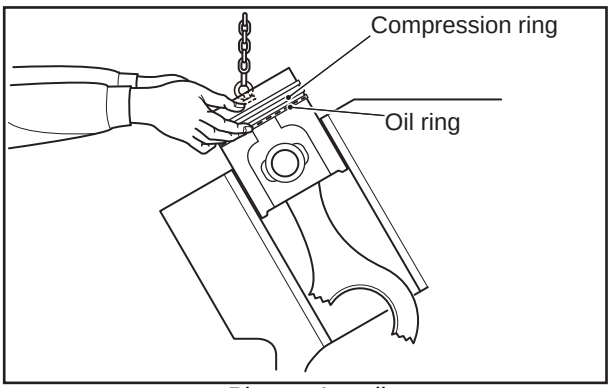
Note: For the piston ring arrangement, see above (2).



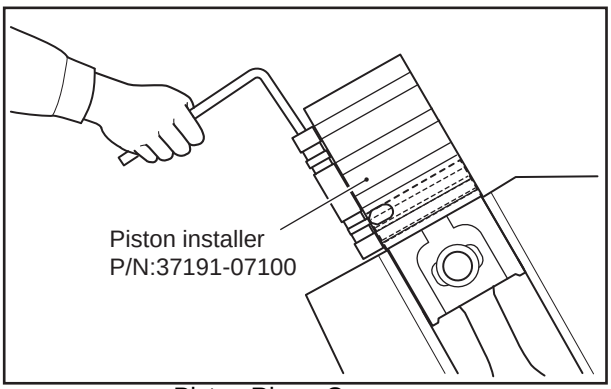
Piston and Connecting Rod - Install



Piston Ring End Gaps - Arrangement



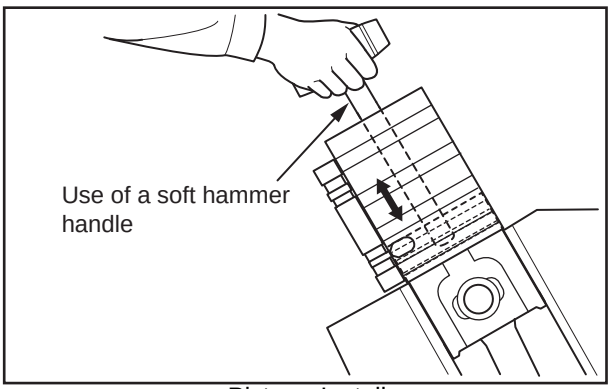
Piston - Install



Piston Ring - Compress

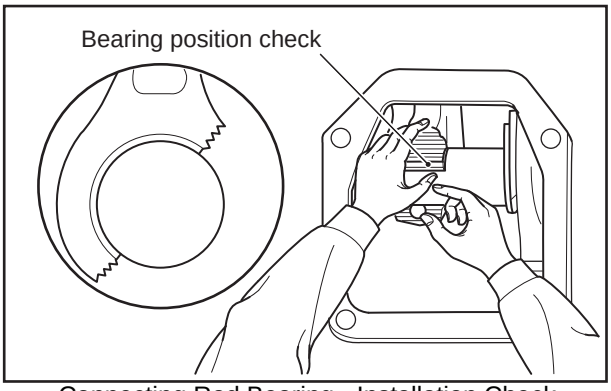
(5) Install the piston into the cylinder liner by tapping the piston top with a soft-head hammer.

Note: Make sure that the piston does not get stuck in the cylinder liner and the connecting rod big end does not bump the crank pin.



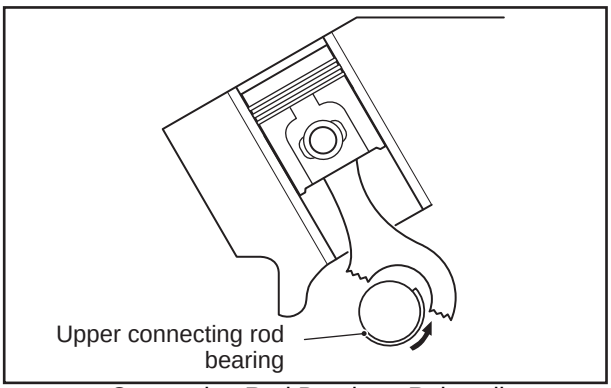
Piston - Install

(6) Check the proper installation of the upper connecting rod bearing shell through the inspection window on the crankcase side face. If the bearing shell is not positioned properly, push the bearing upward by hand to correct the position.



Connecting Rod Bearing - Installation Check

(7) If the upper connecting rod bearing is disengaged from the connecting rod big end, rotate the crankshaft to make a space between the connecting rod big end and the crank pin. Then, insert the connecting rod bearing, sliding on the crankpin, and make sure that the lug on the bearing shell is correctly positioned in the lug slot of the connecting rod.



Connecting Rod Bearing - Reinstall

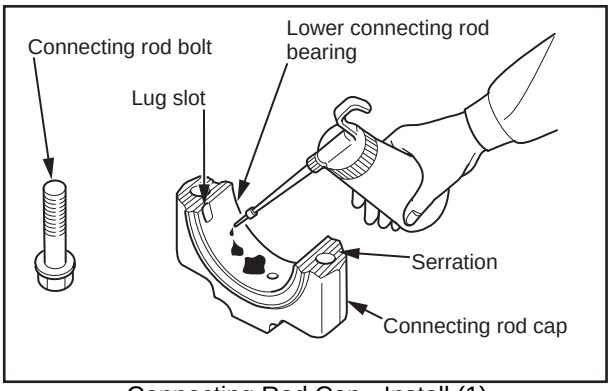
2.12 Connecting Rod Cap - Install

CAUTION

(a) Make sure that the matching numbers on the connecting rod and the connecting rod cap are on the same side and in alignment.

(b) Make sure that the installing position of connecting rod bolt with the identification mark.

(c) When installing the connecting rod cap, make sure that dust or metal particles are not caught in the serrations, bolt seating surfaces, and the bolt threads.



Connecting Rod Cap - Install (1)

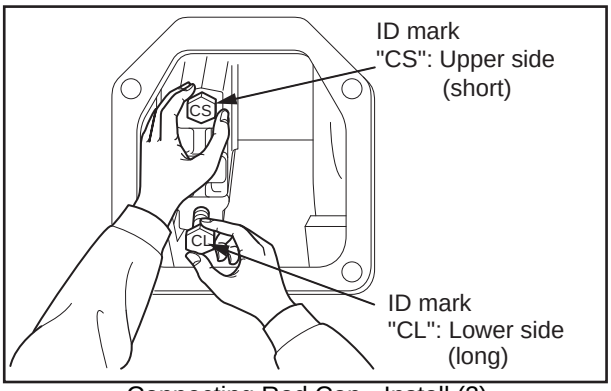
(1) Install the lower connecting rod bearing, aligning its lug with the lug slot of the connecting rod bearing cap.

(2) Apply engine oil on the connecting rod bolt threads and seating surfaces, and the sliding surface of the lower connecting rod bearing shell.

(3) Make sure the matching numbers on the connecting rod cap and the connecting rod are on the same side and in alignment, and then install the connecting rod cap to the connecting rod.

(4) Hand tighten the connecting rod bolts.

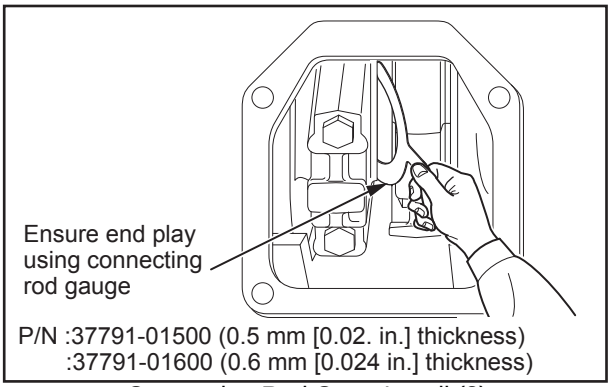
Note: Bolt identification mark
"CS": upper (short) (part No.: 37519-21301)
"CL": lower (long) (part No.: 37519-11401)



Connecting Rod Cap - Install (2)

(5) Secure the rod end play by flushing the connecting rod with rod cap side face.

Note: To ensure the minimum end play, the connecting rod gauge may be inserted between the two connecting rods for adjustment.



Connecting Rod Cap - Install (3)

(6) Measure the connecting rod end play, and adjust the end play within the standard value.

(7) Tighten the connecting rod bolts to the specified torque. After tightening to the specified torque, loosen the bolts completely and tighten again to the specified torque. Measure the end play again.

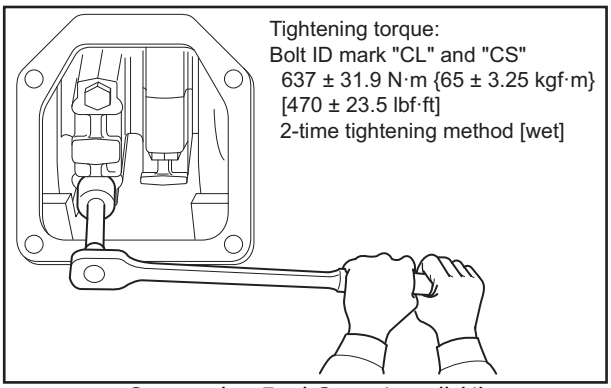
Note: To tighten the connecting rod bolts with the angle control tightening method, follow the steps below.

Bolt location	Bolt identification mark	Snug torque	Part number
Upper	CS	245 ± 12.3 N·m {25.0 ± 1.25 kgf·m} [180.70 ± 9.07 lbf·ft]	37519-21301
Lower	CL	294 ± 14.7 N·m {30.0 ± 1.49 kgf·m} [216.84 ± 10.84 lbf·ft]	37519-11401

(a) Tighten the bolts to the snug torque.

(b) Tighten the bolt further by 60 °± 3°.

(c) Loosen all bolts, and then tighten them again with the angle method. (2-time tightening)



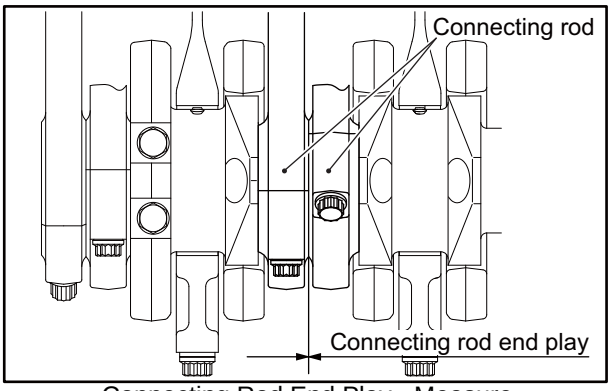
Connecting Rod Cap - Install (4)

2.13 Connecting Rod End Play - Measure

Measure the end play of the connecting rod.

If the value exceeds the limit, find the causal parts, and replace them with new ones.

Item	Standard value	Limit value
Connecting rod end play	0.6 to 0.9 mm [0.024 to 0.035 in.]	1.4 mm [0.055 in.]

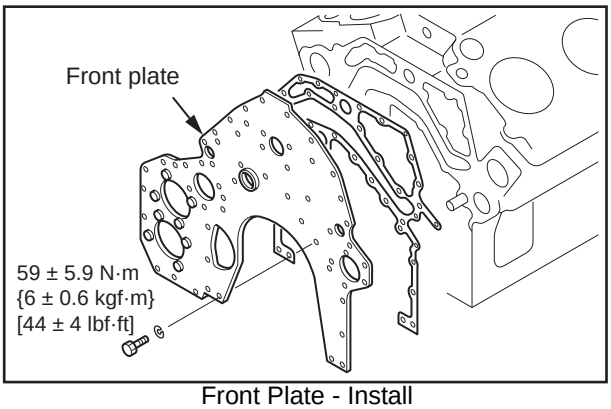


Connecting Rod End Play - Measure

3. Front Mechanism - Assemble

3.1 Front Plate - Install

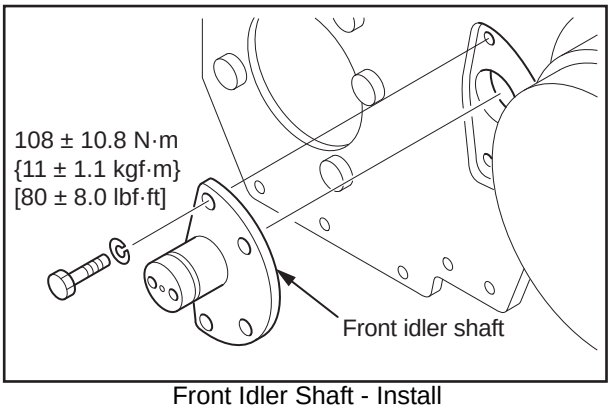
(1) Apply sealant (ThreeBond 1211) on the front plate packing mounting surface of the crankcase, and install the packing aligning with the dowel pin.
(2) Install the front plate over the packing aligning with dowel pin.
(3) Tighten the bolts to the specified torque.
(4) Make sure that the bottom face of the front plate is flush with the bottom face of the crankcase. Trim excess packing.



Front Plate - Install

3.2 Front Idler Shaft - Install

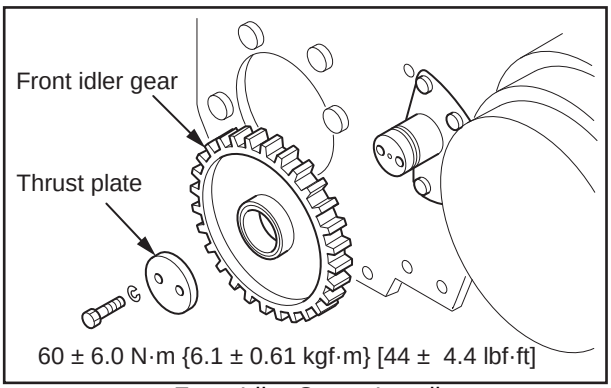
(1) Install the front idler shaft in the crankcase.
(2) Tighten the bolts to the specified torque.



Front Idler Shaft - Install

3.3 Front Idler Gear - Install

(1) Apply engine oil on the front idler gear shaft.
(2) Install the front idler gear.
(3) Install the thrust plate, and tighten the bolt to the specified torque.

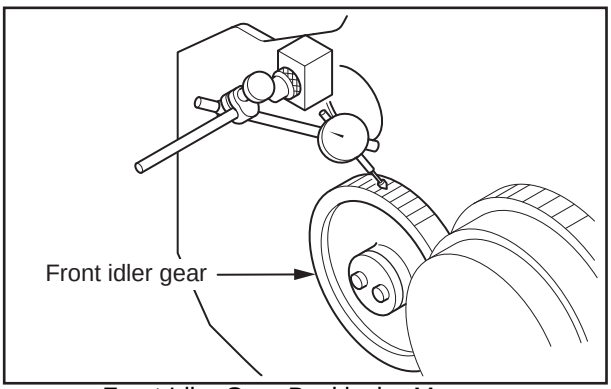


Front Idler Gear - Install

3.4 Front Idler Gear Backlash - Measure

Measure the backlash of the front idler gears by either of the following methods: measure the gear backlash with a dial gauge applied to a tooth flank on the pitch circle at a right angle to the tooth axis, or measure the clearance between gears by inserting a feeler gauge between the engaging gear teeth. If the value exceeds the limit, replace the gears with new ones.

Item	Standard value	Limit value
Front idler gear backlash	0.11 to 0.28 mm [0.0043 to 0.0110 in.]	0.50 mm [0.0197 in.]

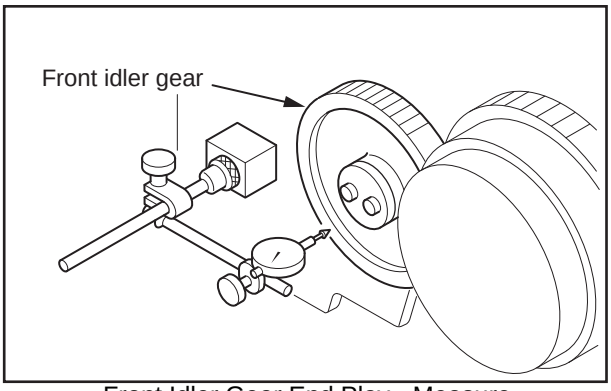


Front Idler Gear Backlash - Measure

3.5 Front Idler Gear End Play - Measure

Measure the end play of the front idler gear. If the value exceeds the limit, replace the thrust plate or idler gear with a new one.

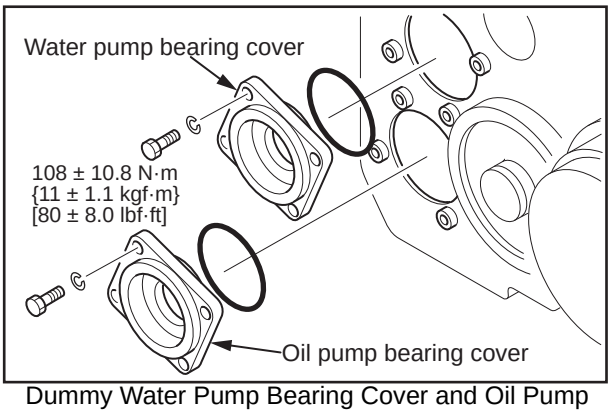
Item	Standard value	Limit value
Front idler gear end play	0.20 to 0.40 mm [0.0079 to 0.0157 in.]	0.60 mm [0.0236 in.]



Front Idler Gear End Play - Measure

3.6 Dummy Water Pump Bearing Cover and Oil Pump Bearing Cover - Install

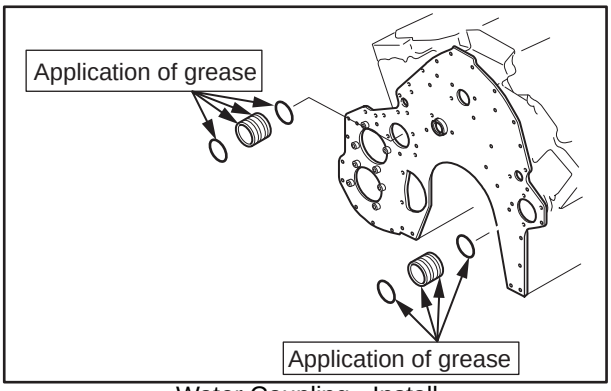
(1) Install the dummy water pump bearing cover and oil pump bearing cover on the front plate.
(2) Tighten the bolts to the specified torque.



Dummy Water Pump Bearing Cover and Oil Pump Bearing Cover - Install

3.7 Water Coupling - Install

(1) Apply silicone grease G-30M (P/N:37594-05400) to the whole face of the O-ring.
(2) Install the water couplings of crankcase and gear case to the crankcase, taking care not to damage the O-ring.



Water Coupling - Install

3.8 Front Oil Seal Slinger - Install

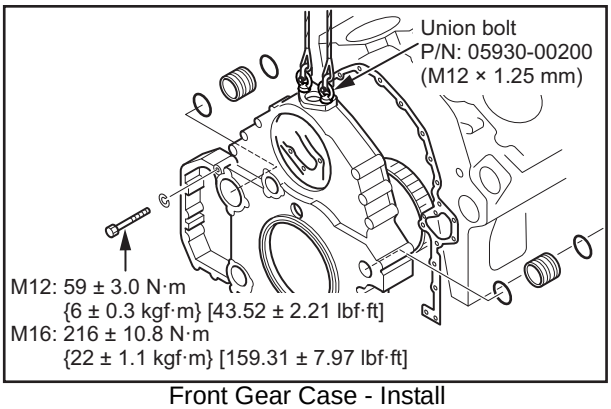
Refer to "Oil Seal Slinger - Replace" of "ENGINE BODY - INSPECT AND REPAIR. "

3.9 Front Gear Case - Install

(1) Apply sealant (ThreeBond 1211) on the front gear case packing mounting surface of the crankcase, and install the packing. Apply the same sealant (ThreeBond 1211) on the packing, and then install the front gear case.

(2) Tighten the bolts evenly to the specified torque.

(3) Make sure that the bottom face of the front gear case is flush with the bottom face of the crankcase. Cut off excessive packing carefully.



Front Gear Case - Install

3.10 Front Oil Seal - Install

Double damper spec.

Using the front seal installer assembly, install the front oil seal.

(1) Apply clean engine oil evenly on the oil seal lip.

Note: Pay attention to the mounting orientation of the oil seal, and be careful not to damage the oil seal.

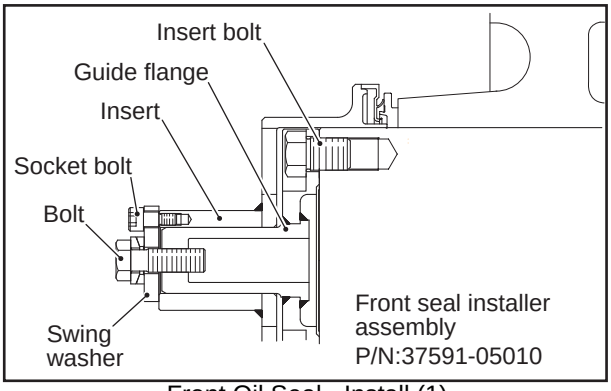
(2) Install the front guide flange onto the crankshaft, and fix it with insert bolt.

(3) Set the oil seal to the insert, and install to the guide flange.

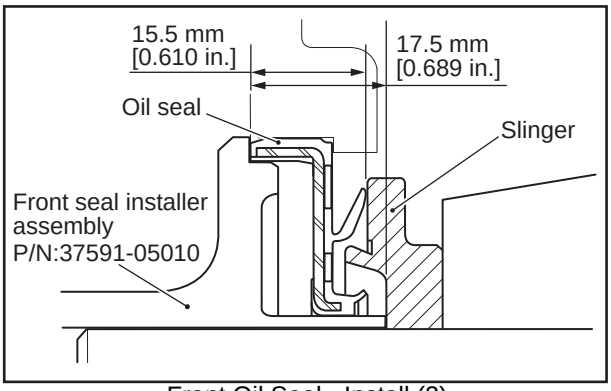
(4) Tighten the bolt attached to the insert to install the oil seal into the front cover.

(5) Loosen the socket bolt, remove the swing washer from the bolt and pull out the insert.

(6) Remove the insert bolt, and then remove the guide flange from the crankshaft.



Front Oil Seal - Install (1)



Front Oil Seal - Install (2)

Triple damper spec.

Using the front seal installer assembly, install the front oil seal.

(1) Apply clean engine oil evenly on the oil seal lip.

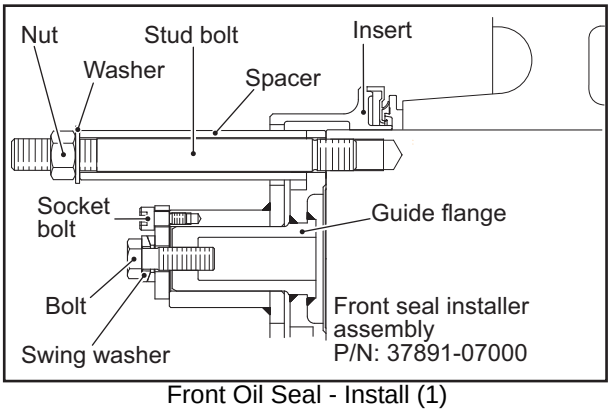
Note: Pay attention to the mounting orientation of the oil seal, and be careful not to damage the oil seal.

(2) Install the guide flange to the stud on the front end of the crankshaft, insert the spacer, and secure them with the nut.

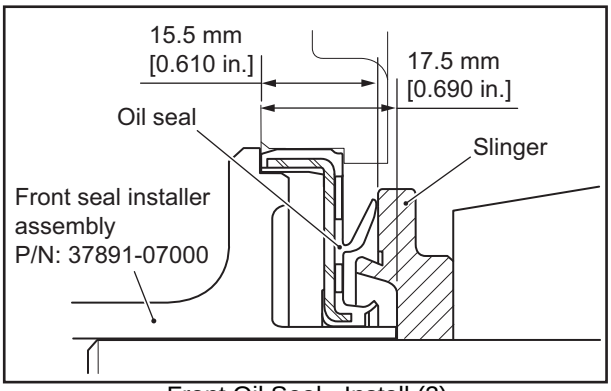
(3) Set the oil seal to the insert, and install to the guide flange.

(4) Tighten the bolt on the guide flange to insert the oil seal into the front cover.

(5) Remove the installer assembly.



Front Oil Seal - Install (1)



Front Oil Seal - Install (2)

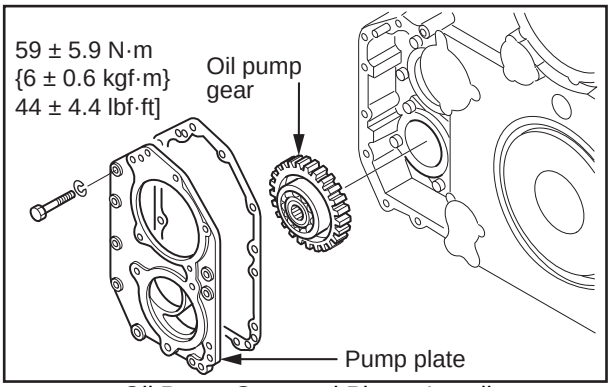
3.11 Oil Pump Gear and Plate - Install

(1) Install the bearing to the oil pump gear.

(2) Insert the oil pump gear.

(3) Install the pump plate in the front case.

(4) Tighten the bolts to the specified torque.

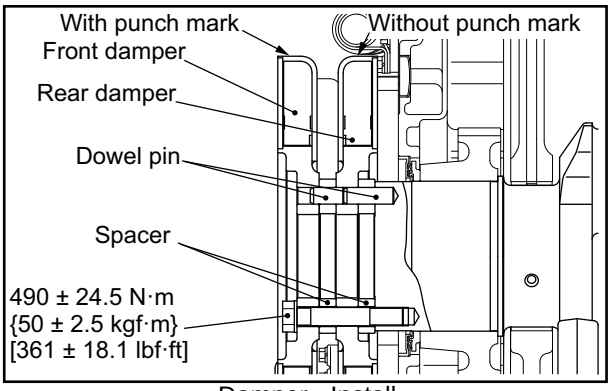


Oil Pump Gear and Plate - Install

3.12 Damper (Double) - Install

(1) Install guide bolt in damper mounting bolt hole on crankshaft.
(2) Placing spacer and damper alternately, install them aligning with dowel pin.
(3) Tighten the bolts to the specified torque.

Note: Make sure the correct positions and orientations of dampers.

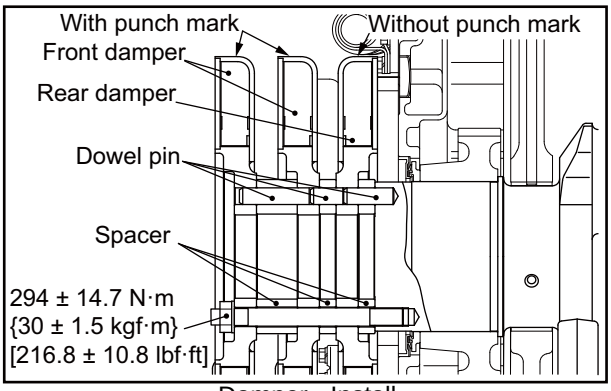


Damper - Install

3.13 Damper (Triple) - Install

(1) Place the spacer and damper alternately to the stud bolts on crank shaft front end, and install them aligning with the dowel pin.
(2) Tighten the nuts to the specified torque.

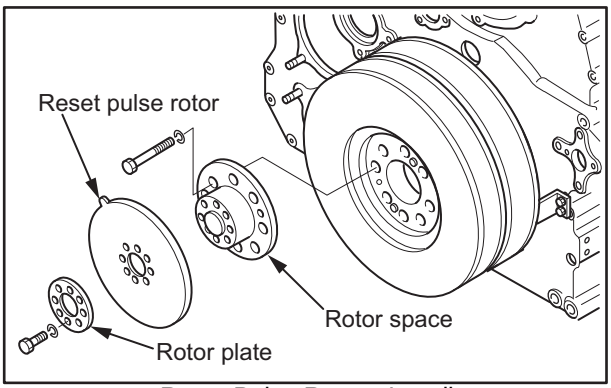
Note: Make sure the correct positions and orientations of dampers.



Damper - Install

3.14 Reset Pulse Rotor (CPU-95) - Install

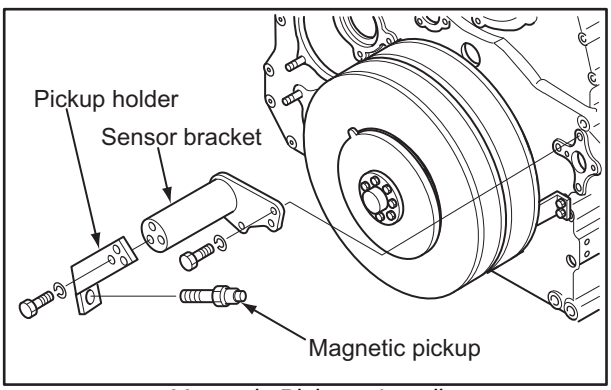
(1) Install the rotor space.
(2) Install the reset pulse rotor and rotor plate.



Reset Pulse Rotor - Install

3.15 Magnetic Pickup (CPU-95) Install

(1) Install the sensor bracket on the mounting bracket.
(2) Install the pickup holder on the sensor bracket.
(3) Install the magnetic pickup on the mounting position of pickup holder.
(4) Adjust the clearance between the reset rotor protrusion and magnetic pickup to the specified value. Refer to "Magnetic Pickup - Install" of "IGNITION SYSTEM" for the installation and adjustment.



Magnetic Pickup - Install

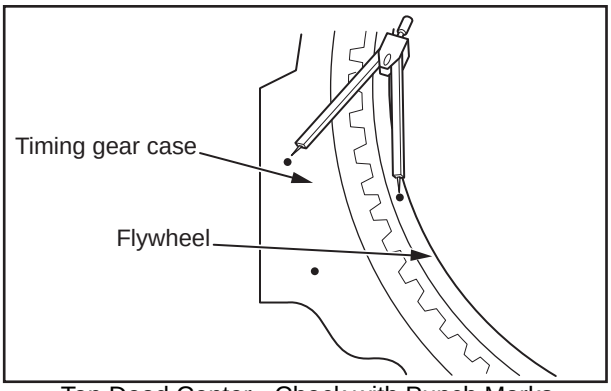
3.16 Pointer - Install and Adjust

(1) Install the pointer on the front gear case.

(2) Turn the crankshaft to the top dead center of No. 1 cylinder. Align the top dead center line of No. 1 cylinder on the circumference of damper with the pointer.

(3) At the No.1 cylinder top dead center, the flywheel punch mark is positioned at the same distance from the two punch marks stamped on the timing gear case.

Note: To check the top dead center by the piston movement, see "Piston Protrusion - Measure" of "ENGINE BODY - ASSEMBLE."

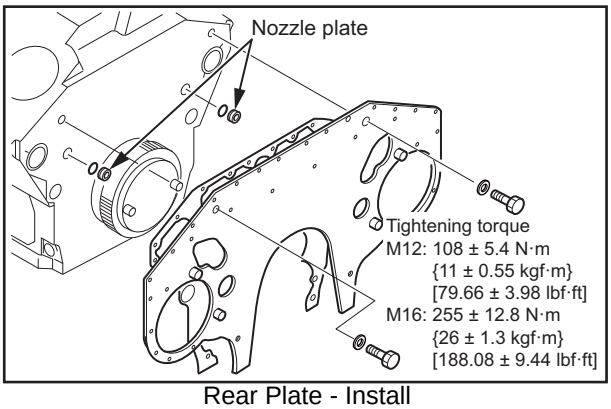


Top Dead Center - Check with Punch Marks

4. Rear Mechanism - Assemble

4.1 Flywheel Face and Radial Runouts - Measure

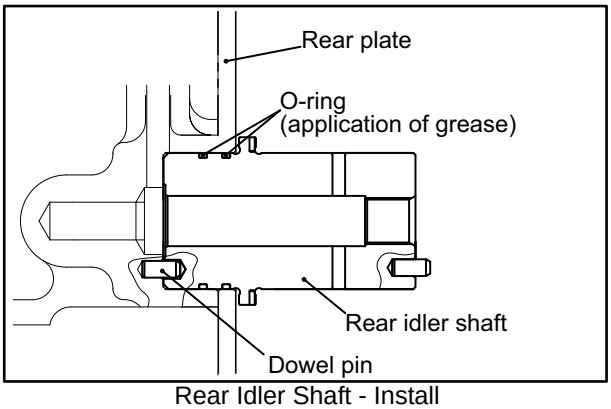
(1) Install the nozzle plates.
(2) Apply sealant (ThreeBond 1211) on the rear plate packing mounting surface of the crankcase, and install the packing.
(3) Apply the same sealant (ThreeBond 1211) on the packing, and then install the rear plate.
(4) Tighten the bolts to the specified torque.
(5) Make sure that the bottom face of the rear plate is flush with the bottom face of the crankcase. Cut off excessive packing carefully.



Rear Plate - Install

4.2 Rear Idler Shaft - Install

Install the O-rings on the rear idler shaft and apply grease on the O-rings.
Align the rear idler shaft with the dowel pin, and install the rear idler shaft on the crankcase.



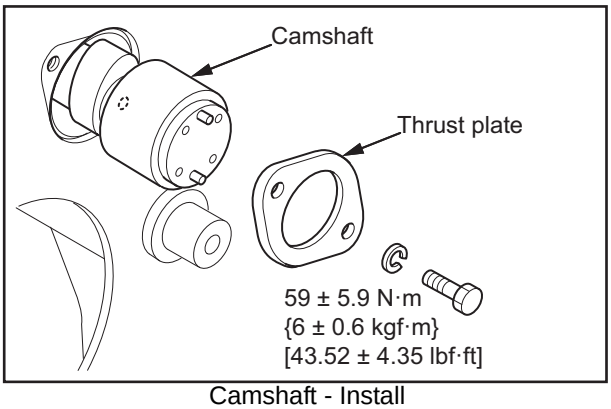
Rear Idler Shaft - Install

4.3 Camshaft - Install

CAUTION

Install the camshaft by supporting it with a bar through the crankcase window. Be careful not to bump the camshaft to avoid the damage to cam lobe and bushing.

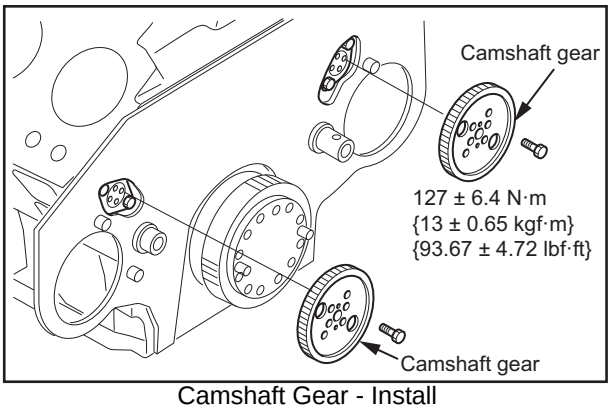
(1) Apply engine oil on inner surface of camshaft bushing.
(2) Apply engine oil on camshaft oil galleries, journals, and lobes.
(3) Support camshaft with a bar, and slowly insert camshaft into crankcase.
(4) Install thrust plate, and tighten bolts to the specified torque.
(5) Make sure that the camshaft rotates.



Camshaft - Install

4.4 Camshaft Gear - Install

(1) Install the camshaft gear by aligning its hole with the dowel pins on camshaft.
(2) Tighten the bolts to the specified torque.
(3) Verify the camshaft smooth rotation.

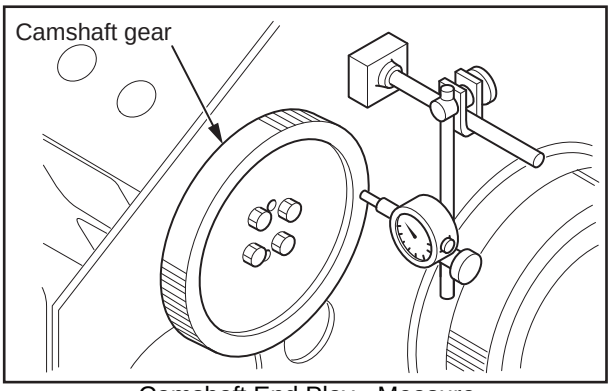


Camshaft Gear - Install

4.5 Camshaft End Play - Measure

Measure the camshaft end play. If the value exceeds the limit, find the causal parts, and replace them with new ones.

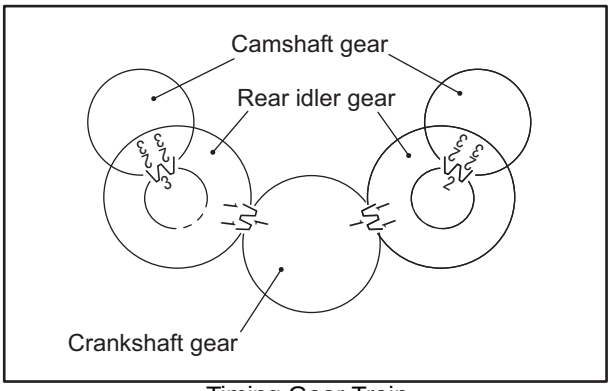
Item	Standard value	Limit value
Camshaft end play	0.10 to 0.25 mm [0.0039 to 0.0098 in.]	0.40 mm [0.0157 in.]



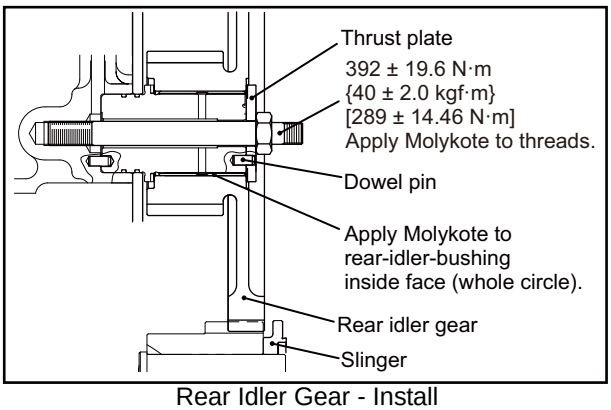
Camshaft End Play - Measure

4.6 Rear Idler Gear - Install

(1) Turn crankshaft to bring No. 1 cylinder to the top dead center.
(2) Apply Molykote on the idler shaft.
(3) Install the idler gear by aligning with match marks.
(4) Install the thrust plate on the idler shaft.
(5) Tighten the bolts to the specified torque.
(6) Make sure match marks on timing gears are properly aligned as shown in the illustration.



Timing Gear Train



Rear Idler Gear - Install

4.7 Rear Idler Gear End Play - Measure

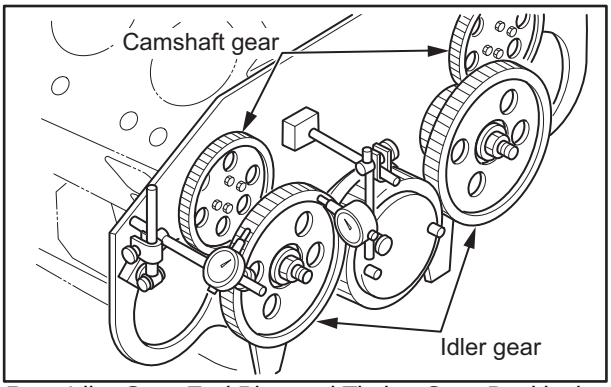
Measure the end play of the rear idler gear. If the value exceeds the limit, replace the thrust plate or idler gear with a new one.

Item	Standard value	Limit value
Rear idler gear end play	0.30 to 0.60 mm [0.0118 to 0.0236 in.]	1.0 mm [0.039 in.]

4.8 Timing Gear Backlash - Measure

Measure the backlash of timing gears using either method: measure the gear backlash with a dial gauge applying its probe to a tooth flank on the pitch circle at a right angle to the tooth axis, or measure the clearance between gears by inserting feeler gauges between the engaging gear teeth. If the value exceeds the limit, replace the gears with new ones.

Item	Standard value	Limit value
Backlash between crank gear and rear idler gear	0.11 to 0.28 mm [0.0043 to 0.0110 in.]	0.50 mm [0.0197 in.]
Backlash between idler gear and camshaft gear	0.12 to 0.18 mm [0.0047 to 0.0071 in.]	0.50 mm [0.0197 in.]



Rear Idler Gear End Play and Timing Gear Backlash - Measure

4.9 Rear Oil Seal Slinger - Install

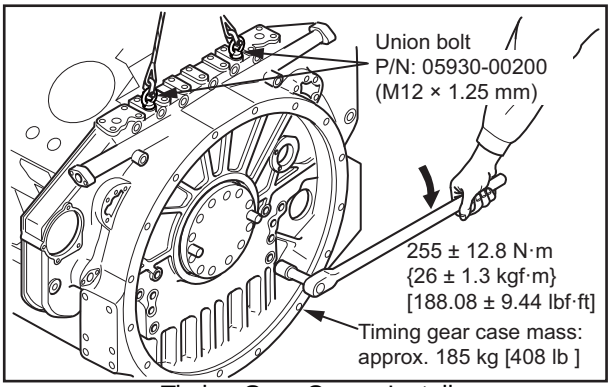
Refer to "Oil Seal Slinger - Replace" of "ENGINE BODY - INSPECT AND REPAIR. "

4.10 Timing Gear Case - Install

⚠ CAUTION

Be careful not to drop or hit the timing gear case. It may result in personnel injury as well as damage to the timing gear case.

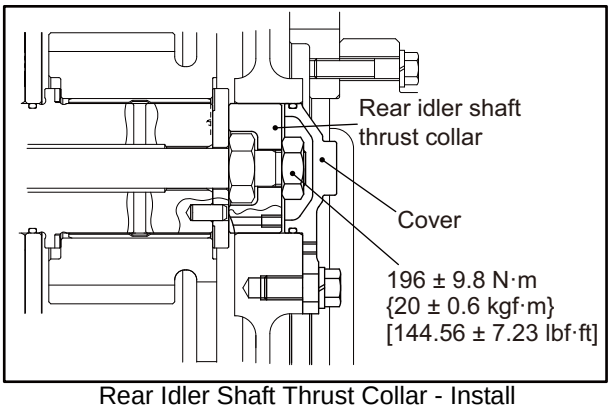
(1) Apply sealant (ThreeBond 1211) on the rear plate packing mating surface, and install the packing.
(2) Apply sealant (ThreeBond 1211) on the packing mating surface to timing gear case.
(3) Attach the lifting equipment to the timing gear case, align the case with the dowel pins, and install the case.
(4) Tighten the bolts to the specified torque.
(5) Carefully cut off excessive packing protruding from the bottom of crankcase.



Timing Gear Case - Install

4.11 Rear Idler Shaft Thrust Collar - Install

(1) Apply grease on the rear idler shaft thrust collars, and insert the collars in the timing gear case.
Be sure that the alignment mark "TOP" is positioned at the top. Also install the parts in accordance with the identification marks made during removal.
(2) Tighten the nuts to the specified torque.
(3) Install the cover on the timing gear case.



Rear Idler Shaft Thrust Collar - Install

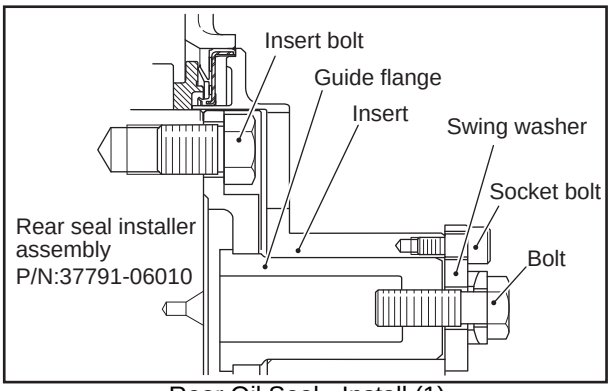
4.12 Rear Oil Seal - Install

Using the rear seal installer assembly, install the rear oil seal.

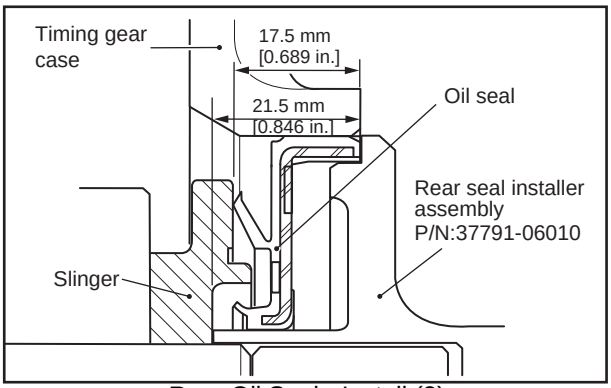
(1) Apply clean engine oil evenly on the oil seal lip.

Note: Pay attention to the mounting orientation of the oil seal, and be careful not to damage the oil seal.

(2) Install the guide flange on the crankshaft rear end face, and fix it with insert bolts.
(3) Set the oil seal to the insert, and install to the guide flange.
(4) Tighten the bolt on the guide flange to insert the oil seal into the timing gear case.
(5) Remove the installer assembly.



Rear Oil Seal - Install (1)



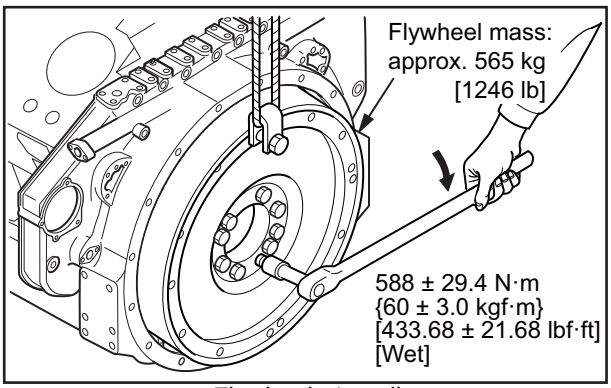
Rear Oil Seal - Install (2)

4.13 Flywheel - Install

⚠ CAUTION

Be careful not to drop or bump the flywheel. It may cause damage to the flywheel or may result in personnel injury.

(1) Check the mounting surfaces of flywheel and crankshaft to make sure that they are free from any foreign material or damage.
(2) Attach sling to the flywheel.
(3) Install the flywheel by aligning its hole with the dowel pin on the crankshaft.
(4) Apply engine oil on the bolt threads and bolt seat surfaces, then tighten the bolts to the specified torque.



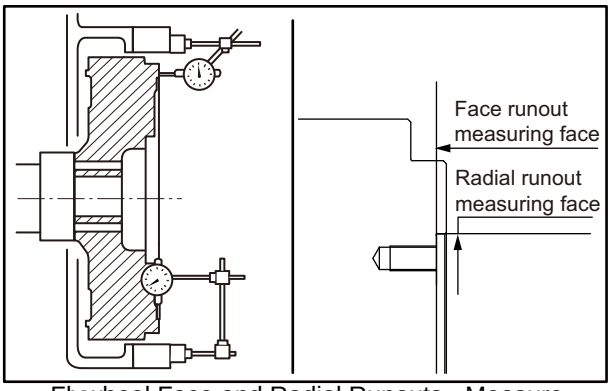
Flywheel - Install

4.14 Flywheel Face and Radial Runouts - Measure

Measure the face and radial runouts of the flywheel.

If the value exceeds the limit significantly, check the assembled condition such as a loose bolt or foreign material adhesion on the mounting faces.

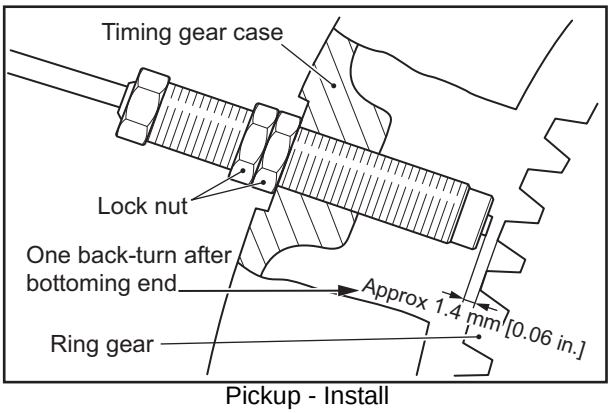
Item	Standard value
Face runout (reference)	0.336 mm [0.0132 in.] or less
Radial runout (reference)	0.130 mm [0.0051 in.] or less



Flywheel Face and Radial Runouts - Measure

4.15 Pickup - Install

(1) Turn the crankshaft to align a top face of ring gear tooth with the center line of pickup mounting hole.
(2) Insert the pickup into the hole slowly and carefully by hand.
(3) When the tip of pickup contacts with the ring gear tooth top, loosen the pickup to adjust the clearance to standard value.
(4) Secure the pickup with the lock nut.



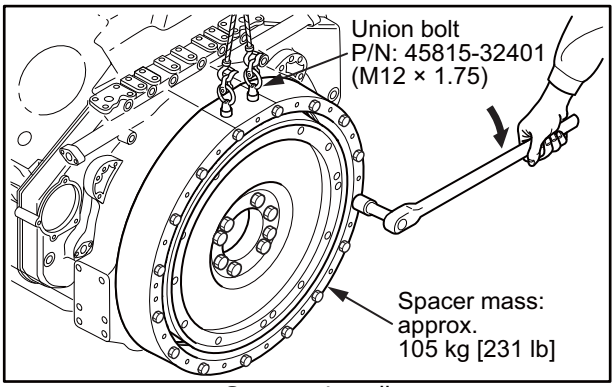
Pickup - Install

4.16 Spacer - Install, and Face and Radial Runouts - Measure

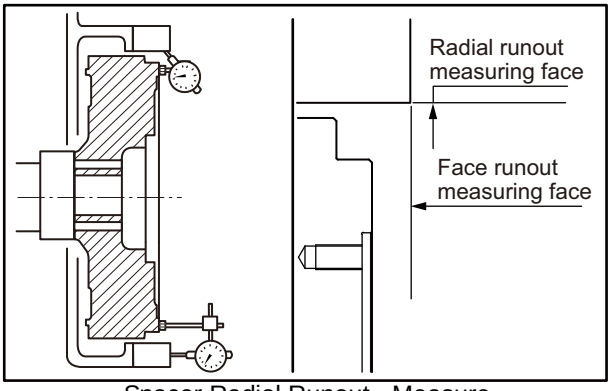
(1) Attach a sling to the spacer and lift it. Align the spacer with timing gear case mounting surface.
(2) Hand tighten the spacer mounting bolt, and measure the face and radial runouts.
(3) After verifying the face and radial runouts are within the specification, tighten the bolt.

Item	Standard value
Face runout (reference)	0.3 mm [0.012 in.] or less
Radial runout (reference)	0.3 mm [0.012 in.] or less

Note: Correct the spacer radial runout value after measuring the oil clearance of main bearing.
When the oil clearance is not measured, correction values of 0.2 mm [0.008 in.] for vertical clearance and 0.1 mm [0.004 in.] for horizontal clearance may be used.



Spacer - Install



Spacer Radial Runout - Measure

5. Cylinder Head and Valve Mechanism - Assemble

5.1 Cylinder Head - Assemble

CAUTION

(a) Be careful when inserting the stem seal through the valve, as the edge of valve can cause damage to the stem seal lip.

(b) Do not apply oil or liquid sealant on the fitting faces between the stem seal and the valve guide.

(c) Always replace the stem seal with a new one.

(1) Apply engine oil on the valve stem, and insert the valve into the valve guide.

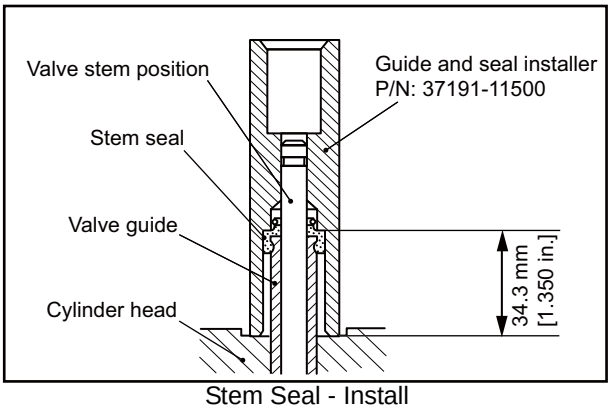
(2) Install stem seal to valve guide with the guide and seal installer.

Note: Place the valve in the valve guide before installing the stem seal. The valve stem seal is centered with the valve stem.

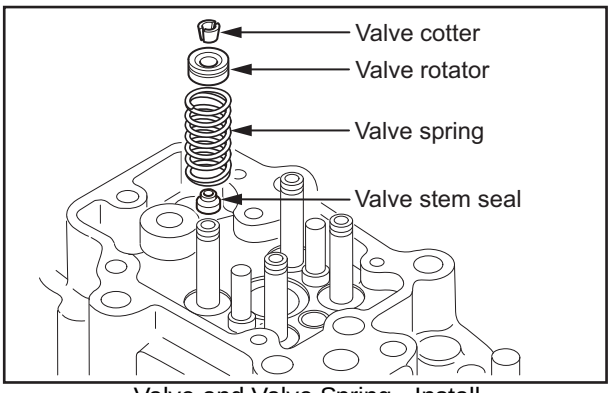
(3) Apply engine oil on the lip of stem seal.

(4) Install the retainer, valve spring, and rotator on valve guide, and install the valve cotters with valve spring pusher.

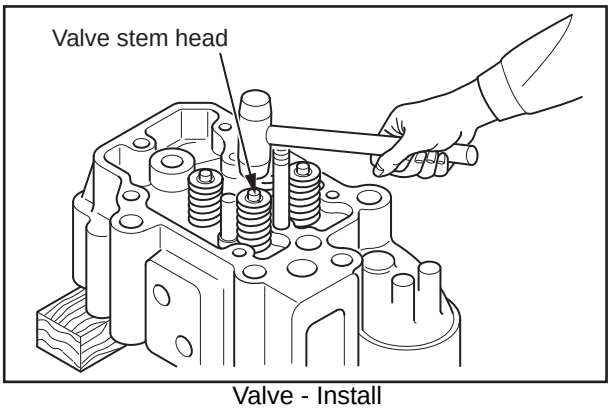
(5) Tap the top of valve stem lightly several times with a soft-head hammer to ensure the valve spring and valve cotters are properly installed and seated firmly.



Stem Seal - Install



Valve and Valve Spring - Install



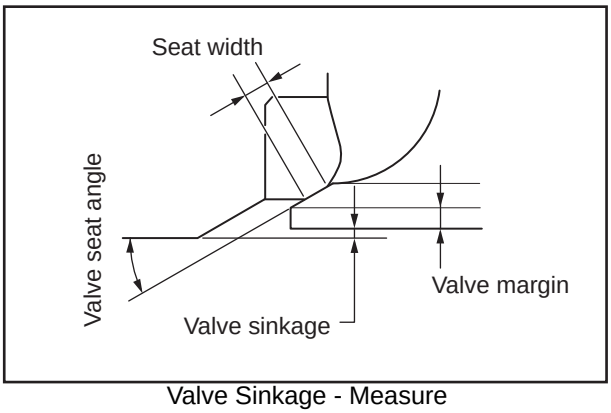
Valve - Install

5.2 Valve Sinkage - Measure

Measure the valve sinkage.

If the value exceeds the limit, replace the valve or valve seat ring with a new one. Lap the valve and valve seat ring whenever the valve or the valve seat ring is refaced or replaced.

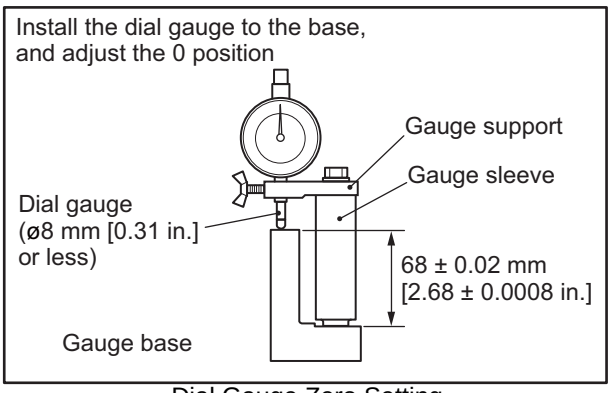
Item	Standard value	Limit value
Valve sinkage	-0.2 to 0.2 mm [-0.008 to 0.008 in.]	1.0 mm [0.039 in.]



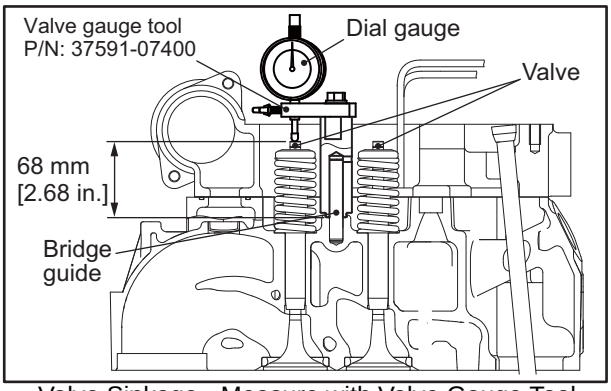
Valve Sinkage - Measure

5.2.1 Valve Sinkage - Measure with Valve Gauge Tool

(1) Install the dial gauge on the gauge support.
(2) Then, install the dial gauge on the gauge base.
(3) The height of gauge base, to which the dial gauge is installed, is the reference plane. Adjust the reading of dial gauge to 0.
(4) Remove dial gauge from the gauge base.
(5) Remove the rocker and bridge from the cylinder head.
(6) Install the gauge sleeve with dial gauge on the bridge guide of cylinder head.
(7) Place the dial gauge probe on the valve top face, and measure the height (dial gauge reading).
This dial gauge reading is the valve sinkage.



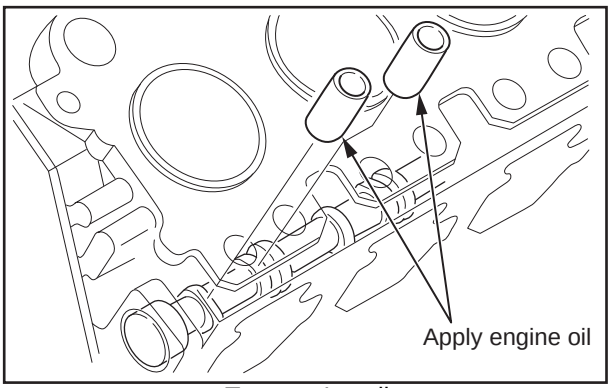
Dial Gauge Zero Setting



Valve Sinkage - Measure with Valve Gauge Tool

5.3 Tappet - Install

Apply engine oil on the tappet outside face, insert the tappet into the tappet hole, and place the tappet softly on the cam-shaft.



Tappet - Install

5.4 Cylinder Head Gasket - Install

5.4.1 Liquid Gasket - Apply

CAUTION

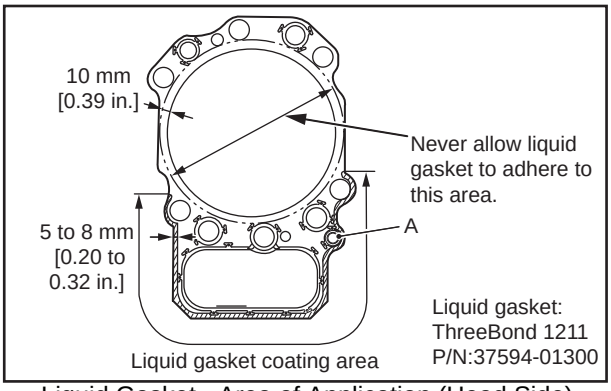
(a) Do not apply the liquid gasket excessively. It results in O-ring deformation. Be careful to apply gasket on the portions A and B. The space to the O-ring is very narrow.

(b) Do not apply liquid gasket around the periphery of cylinder bore. It results in gas leaks.

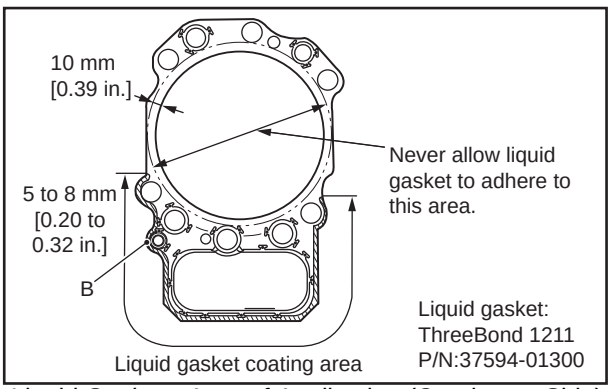
(1) Wipe off oil, grease, and other contaminants from the cylinder head gasket, cylinder head bottom surface, and crankcase top surface.

(2) Apply a thin coat of liquid gasket on both sides of the cylinder head gasket around tappet holes and oil passages. Beads of liquid gasket shall be 5 to 8 mm [0.20 to 0.31 in.] wide from the cylinder head gasket outer edge and 0.2 to 0.5 mm [0.008 to 0.020 in.] thick. The area of application is as shown in the illustration.

Note: After the application of the liquid gasket on the cylinder head gasket, install the cylinder head before the liquid gasket dries.



Liquid Gasket - Area of Application (Head Side)

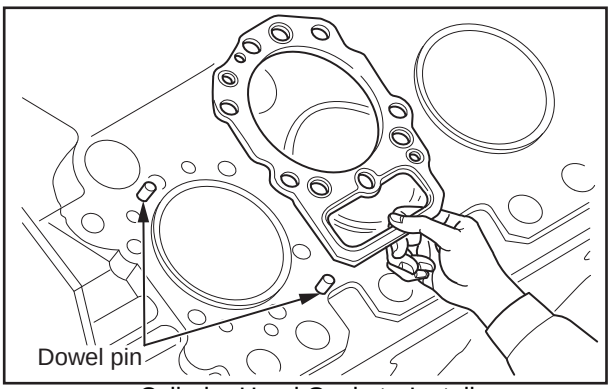


Liquid Gasket - Area of Application (Crankcase Side)

5.4.2 Cylinder Head Gasket - Install

(1) Wipe off oil, grease, and other contaminants from the cylinder head bottom surface and the crankcase top surface.

(2) Install the cylinder head gasket coated with liquid gasket onto the crankcase with the dowel pins and holes in alignment.



Cylinder Head Gasket - Install

5.5 Cylinder Head Assembly - Install

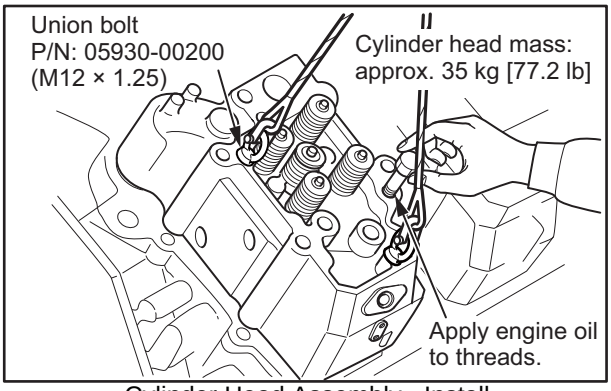
5.5.1 Installing on Crankcase

(1) Apply engine oil on cylinder head bolt threads, bolt seats, and washer surfaces.

Note: Do not apply excessive amount of engine oil. Remove excess oil before assembling.

(2) Install the eye bolt, and lift the cylinder head assembly.

(3) Slowly lower the cylinder head, and install the cylinder head aligning dowel pins with holes. Make sure that the dowel pins are inserted in the holes. Then hand tighten the cylinder head bolts.



Cylinder Head Assembly - Install

5.5.2 Head Bolts - Tightening

In general, tighten head bolts by the following controlled tightening method:

(1) Tighten cylinder head bolts to the specified snug torque in the sequence shown in the illustration.

(2) Place the head bolt plate on the top of cylinder head.

(3) Put a mark on the cylinder head bolt.

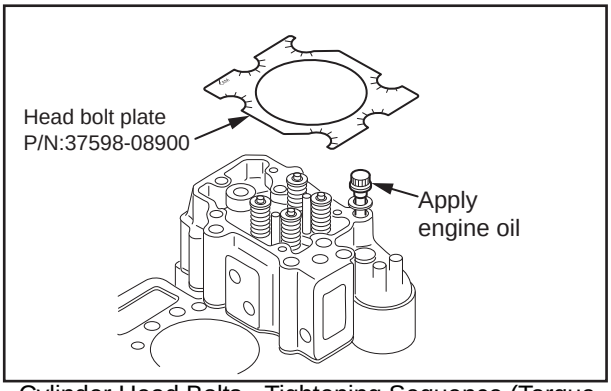
(4) Tighten bolts by turning 60 ± 3° in the specified sequence.

(5) Loosen all bolts, and then tighten them again with the angle method. (2-time tightening)

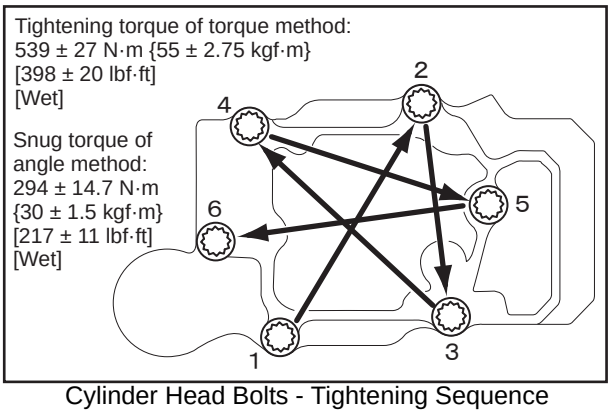
Note: When the torque method is used to tighten the head bolt by necessity, follow the procedure below:

(1) Tighten cylinder head bolts progressively to the specified torque in the sequence shown in illustration.

(2) Loosen all bolts, and then, tighten them again according to the torque method. (2-time tightening)



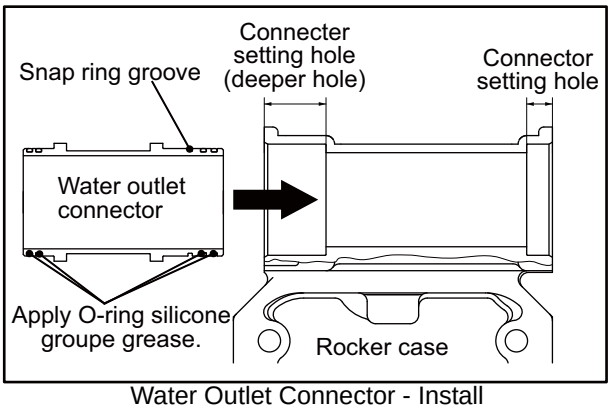
Cylinder Head Bolts - Tightening Sequence (Torque Method)



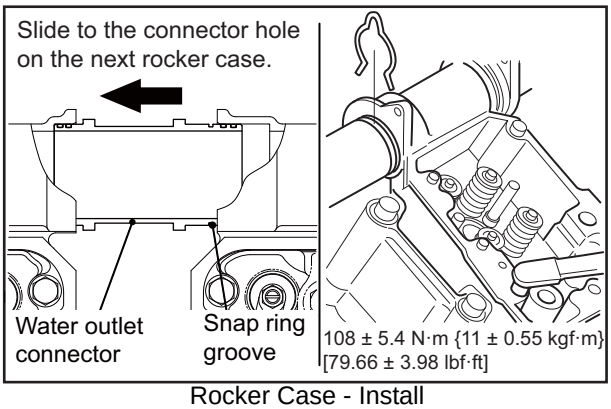
Cylinder Head Bolts - Tightening Sequence (Torque Method)

5.6 Rocker Case - Install

(1) Install the O-ring to the water outlet connector, and apply silicone grease G-30M (P/N:37594-05400) on the whole circle of the O-ring.
(2) Apply grease on connector mounting hole of rocker case.
(3) Install the snap ring groove end of water outlet connector to the deeper connector mounting hole of rocker case, and fully insert the water outlet connector.
(4) Install the rocker case by aligning its holes with the dowel pins.
(5) Tighten the bolts to the specified torque.
(6) Slide the water outlet connector into the adjacent connector mounting hole of rocker case to install.
(7) Install the snap ring in snap ring groove of water outlet connector.



Water Outlet Connector - Install

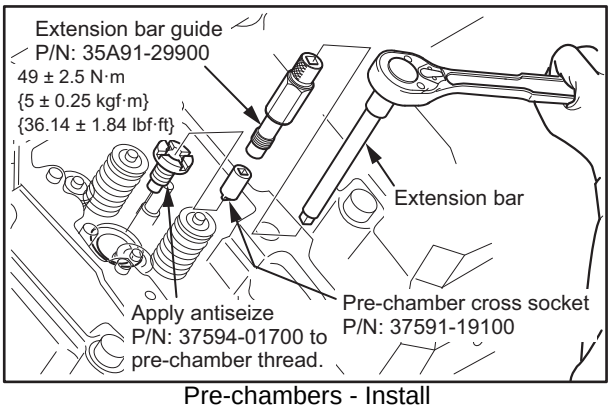


Rocker Case - Install

5.7 Pre-chambers - Install

(1) Assemble the pre-chamber cross socket, extension bar guide, and extension bar.
(2) Using the tool just have assembled above, install the pre-chamber in the cylinder head, and tighten it to the specified torque.

Note: Before installing the pre-chamber, lubricate its threads with high temperature stainless steel grade anti-seize compound "NEVER-SEEZ".



Pre-chambers - Install

5.8 Pre-chamber Gas Valve Assembly - Assemble

(1) Apply engine oil on the gas valve stem, and insert the gas valve on the gas valve holder.

(2) Set the pre-chamber gas-valve holder with gas valve in the gas valve stand.

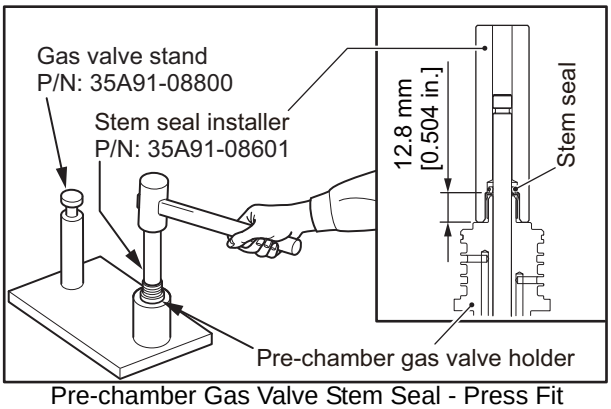
(3) Insert the stem seal on the pre-chamber gas-valve holder using a stem seal installer.

Note: To install the stem seal, install the gas valve first, then press fit the stem seal while centering with the valve stem.

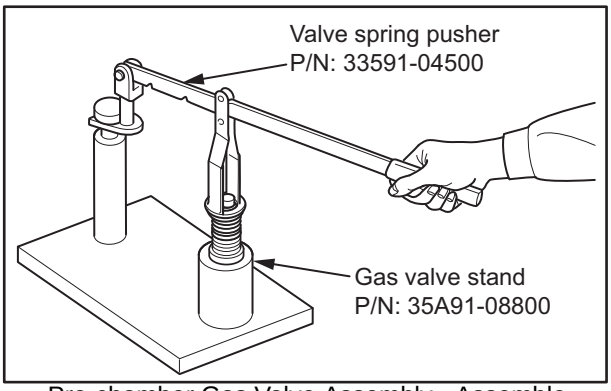
(4) Apply engine oil on the lip of stem seal.

(5) Install the valve spring and rotator on pre-chamber gas valve holder, and install the valve cotters with valve spring pusher.

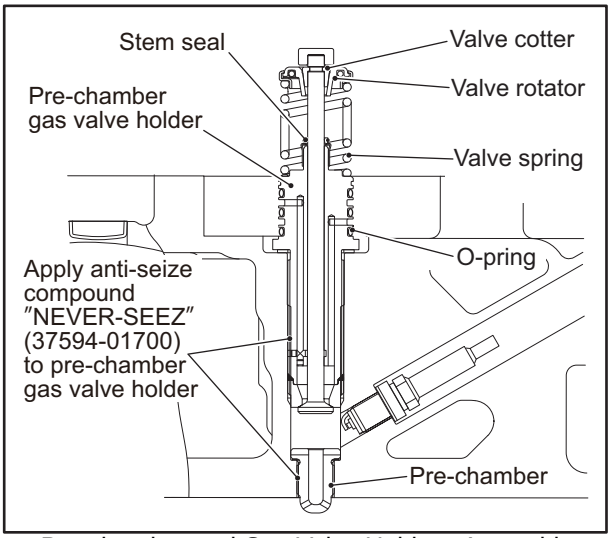
(6) Install the O-ring on the periphery of pre-chamber gas valve holder.



Pre-chamber Gas Valve Stem Seal - Press Fit



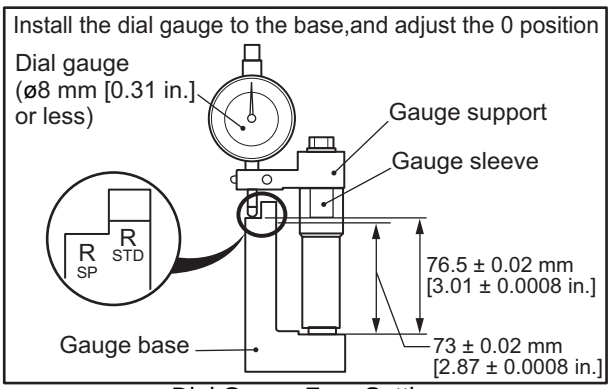
Pre-chamber Gas Valve Assembly - Assemble



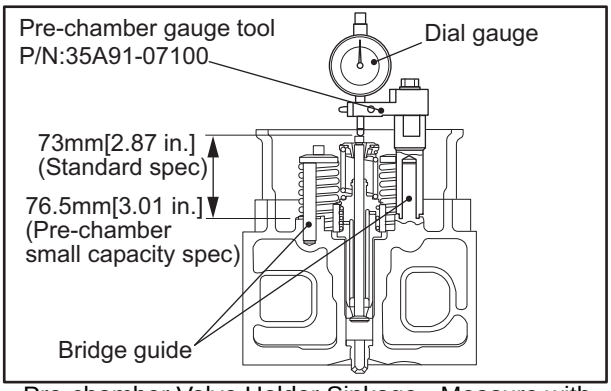
Pre-chamber and Gas Valve Holder - Assemble

5.8.1 Pre-chamber Valve Holder Sinkage - Measure with Valve Gauge Tool

(1) Install the dial gauge on the gauge support.
(2) Then, install the dial gauge on the gauge base.
(3) Adjust the dial gauge scale to 0 as the gauge base top face is the reference height of the pre-chamber height.
(4) place the gauge on the [R STD] marking position for the STD cylinder head, and on the [R SP] marking position for the small volume pre-chamber cylinder head.
(5) Remove the gauge sleeve (dial gauge) from the gauge base.
(6) Remove the rocker and bridge from the cylinder head.
(7) Install the gauge sleeve with dial gauge on the bridge guide of cylinder head.
(8) Place the dial gauge probe on the pre-camber valve top face, and measure the height (dial gauge reading).
This dial gauge reading is the valve sinkage.



Dial Gauge Zero Setting



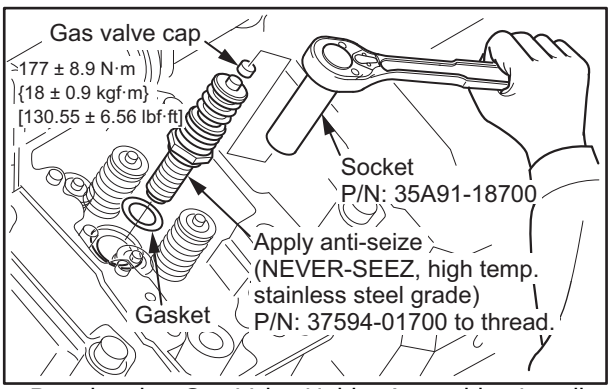
Pre-chamber Valve Holder Sinkage - Measure with Valve Gauge Tool

5.9 Pre-chamber Gas Valve Holder Assembly - Install

(1) Insert the gasket rings in the cylinder head.
(2) Using a gas valve installation/removal socket, install the pre-chamber gas valve holder assembly on the cylinder head, and tighten it to the specified torque.

Note: Before installing the gas valve, lubricate its threads with high temperature stainless steel grade anti-seize compound "NEVER-SEEZ".

(3) Apply engine oil on the valve contact surface of the gas valve cap, then install the cap on the valve.

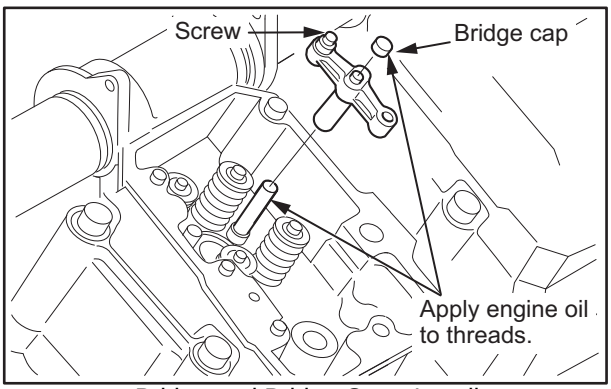


Pre-chamber Gas Valve Holder Assembly - Install

5.10 Bridge and Bridge Cap - Install

Note: Cover the pushrod hole to prevent the bridge cap from falling into the crankcase through the push rod hole.

(1) Apply engine oil on the bridge guide.
(2) Orient the screw-fitted end of the bridge on the exhaust manifold side, and install the bridge on the bridge guide.
(3) Apply engine oil on the contact face of bridge cap , and install the cap on the bridge.



Bridge and Bridge Cap - Install

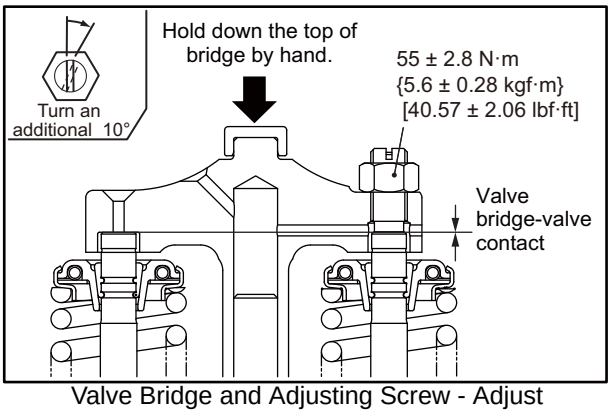
5.11 Valve Bridge and Adjusting Screw - Adjust

Adjust the contact of valve stem top faces to ensure the smooth sliding of bridge on the guide and the balanced pushing to valves.

(1) Loosen the adjusting screw so that the screw top face protrudes from the top face of nut by 6 to 7 mm [0.23 to 0.27 in.].

(2) Press the top of bridge by hand so that the bridge solid side (without the screw) contacts firmly to the valve stem top face.

(3) Turn the adjusting screw slowly until the screw comes into contact with the top face of valve stem. Then, turn the screw further by 10 degrees, and tighten the lock nut to the specified torque.



Valve Bridge and Adjusting Screw - Adjust

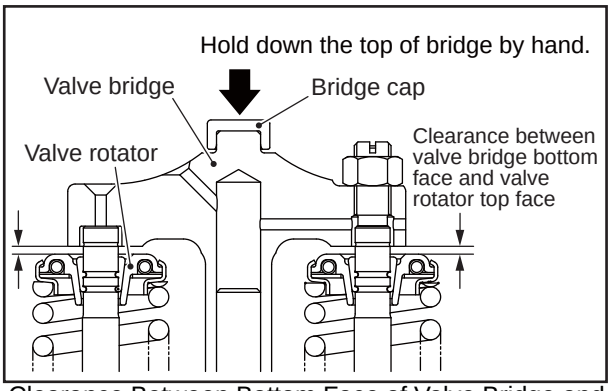
5.12 Clearance Between Bottom Face of Valve Bridge and Top Face of Valve Rotator - Inspect

CAUTION

Be sure to secure the standard clearance between the valve bridge and the valve rotator. If the clearance is smaller than the standard, the valve cotter may come off or get damage.

Push the valve bridge by hand to make the close contact of top end face of valve stems. Then, check the clearance between the bottom face of valve bridge and the top face of valve rotator. If the clearance deviates from the limit value, find the causal parts, and replace them with new ones.

Item	Limit value
Clearance between bottom face of valve bridge and top face of valve rotator	1.5 mm [0.059 in.] or more



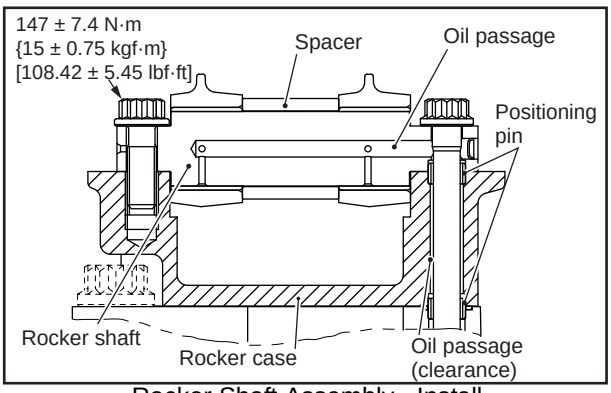
Clearance Between Bottom Face of Valve Bridge and Top Face of Valve Rotator - Inspect

5.13 Rocker Shaft Assembly - Install

(1) Install the spacer on the rocker shaft, and install the rocker arms on both sides.

(2) Align the dowel pin hole of rocker shaft with dowel pin, and install the rocker shaft assembly in rocker case.

(3) Tighten the bolts to the specified torque.



Rocker Shaft Assembly - Install

5.14 Antler Pipe- Install

(1) Install the seal washer on L-joint, install it on the rocker case, and tighten with the nut. Using the L-joint tool, adjust the position so that the L-joint connection to antler pipe faces straight up.

(2) Check the antler pipe for flaw and dent on the inside face of fitting sleeve and the pipe end.

(3) Apply engine oil to O-rings (3 pcs) in the pre-chamber gas valve holder assembly.

(4) Apply engine oil on inner surface of antler pipe fitting sleeve.

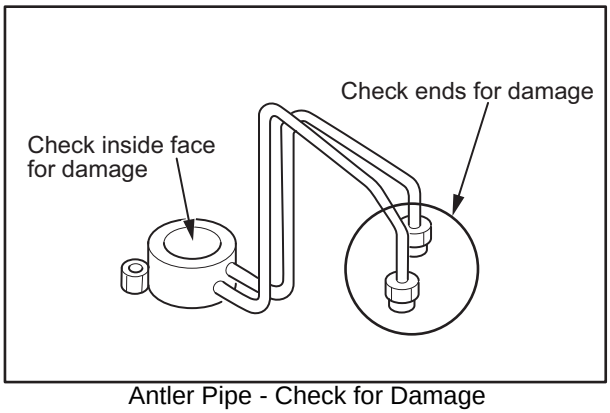
(5) Place the union nuts of antler pipe on the connectors, and install the antler pipe temporary with the pre-chamber gas valve holder assembly.

(6) Face the pipe installer positioning hole toward the pipe side, install the installer over the antler pipe, and press the top of the installer squarely by hand to seat the antler pipe firmly in position.

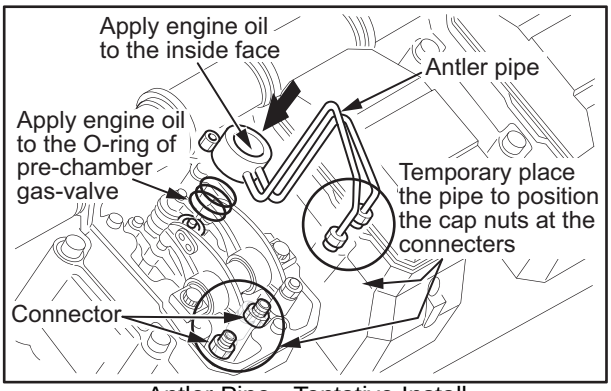
(7) Tap the top of pipe installer with a plastic hammer to ensure firm seating.

(8) Install the snap ring with snap ring pliers to secure the antler pipe.

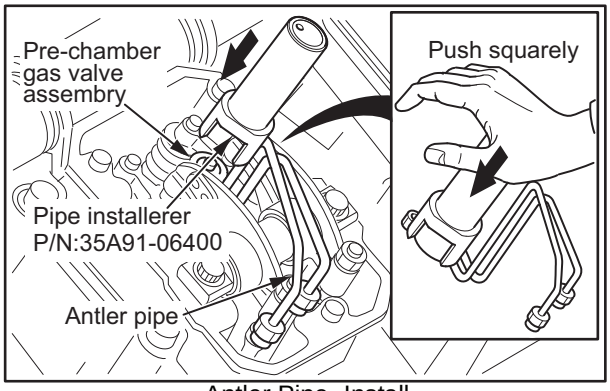
(9) Connect the union nuts of antler pipe and tighten them to the specified torque.



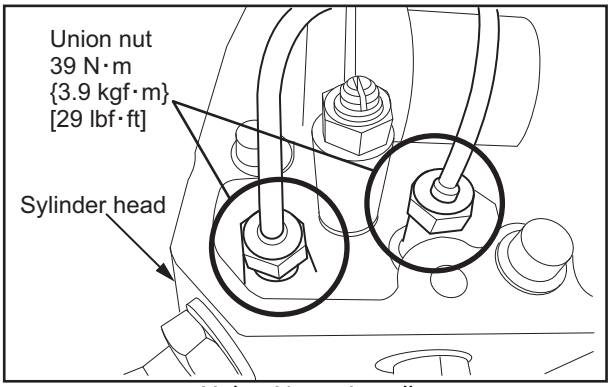
Antler Pipe - Check for Damage



Antler Pipe - Tentative Install



Antler Pipe- Install

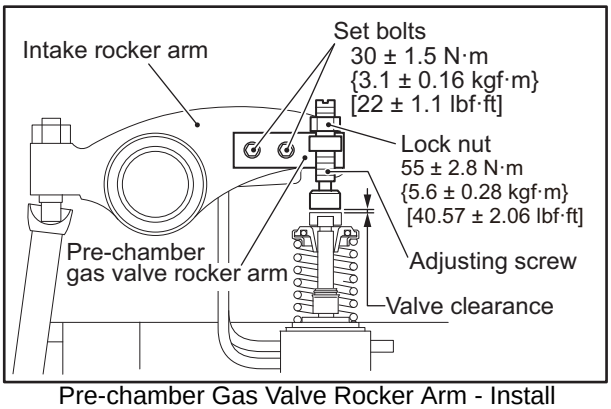


Union Nuts - Install

5.15 Pre-chamber Gas Valve Rocker Arm - Install

(1) Install the pre-chamber gas valve rocker arm on the intake rocker arm, and tighten to the specified torque.

(2) Install the adjusting screw and lock nut on the pre-chamber gas-valve rocker arm.



Pre-chamber Gas Valve Rocker Arm - Install

5.16 Valve Clearance - Check and Adjust

Adjust the valve clearance when the engine is cold.

Note:(a) The inlet valves are located on the left side and the exhaust valves are located on the right when the cylinder head is viewed from the camshaft side.

(b) The valve clearance standard values are indicated on the caution plate on the No. 1 cylinder rocker cover.

(c) Adjust the gas valve clearance after adjusting the inlet valve clearance.

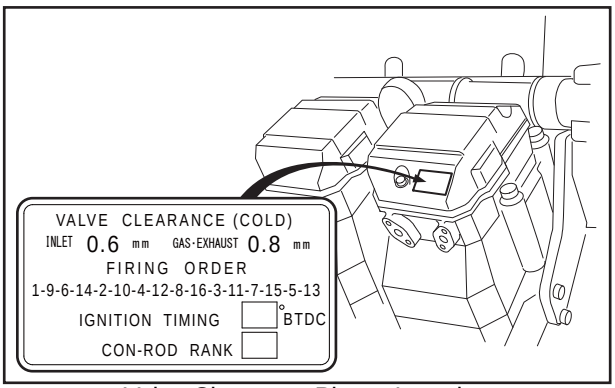
Item		Standard value
Valve clearance	Inlet	0.6 mm [0.024 in.]
	Exhaust	0.8 mm [0.032 in.]
	Gas valve	0.8 mm [0.032 in.]

(1) According to the firing order, adjust the valve clearance at the top dead center (TDC) of compression stroke by turning the crankshaft in the normal direction.

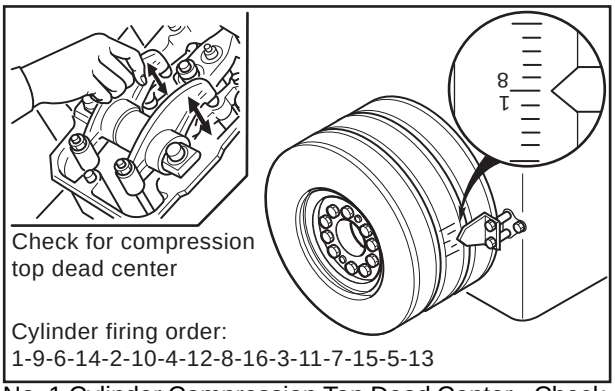
(2) On each cylinder, the piston is at the top dead center on compression stroke, when the corresponding cylinder number stamped on the damper is aligned with the pointer, and the inlet valve and the exhaust valve are not pushed with the push rods.

(3) Insert a feeler gauge between the rocker arm and the bridge cap to measure the clearance. Tighten or loosen the screw to adjust the clearance where the movement of feeler gauge is slightly restricted.

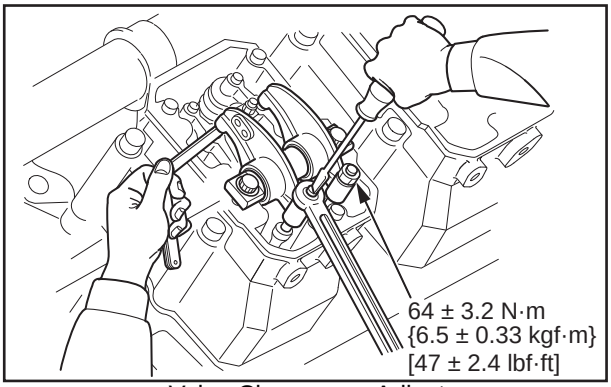
(4) After adjustment, tighten the lock nut firmly to the specified torque. Then, check the clearance again.



Valve Clearance Plate - Location



No. 1 Cylinder Compression Top Dead Center - Check



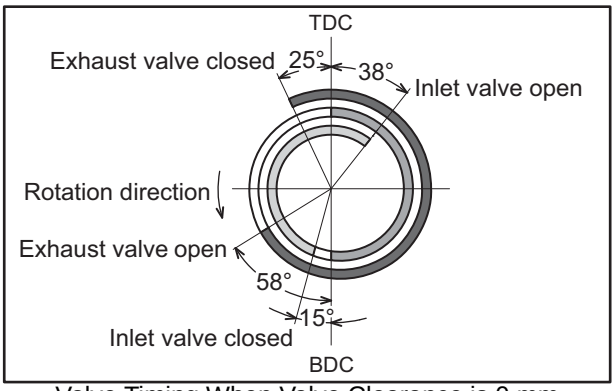
Valve Clearance - Adjust

5.17 Valve Timing - Inspect

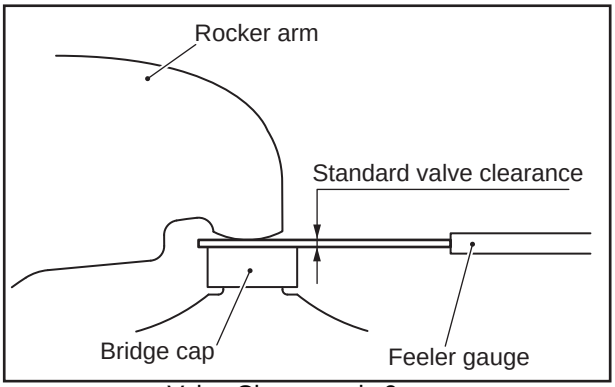
The specified valve timing will be obtained by assembling the gears according to the matching marks, and adjusting the valve clearances to the specified value. To make sure, check the valve timing as follows:

5.17.1 Valve Timing at Normal Valve Clearance (Clearance is 0 mm with Feeler Gauge Inserted)

(1) Make sure that the valve clearance has been adjusted to the standard.
(2) Insert a feeler gauge, which has the same thickness as the specified valve clearance, between bridge cap and rocker arm. (Valve clearance 0 mm)
(3) Turn the crankshaft in normal direction little by little, and find a position where the feeler gauge is tightly gripped (valve open position) and a position where the feeler gauge is released (valve closed position).
(4) Make sure that the values match the standard.



Valve Timing When Valve Clearance is 0 mm

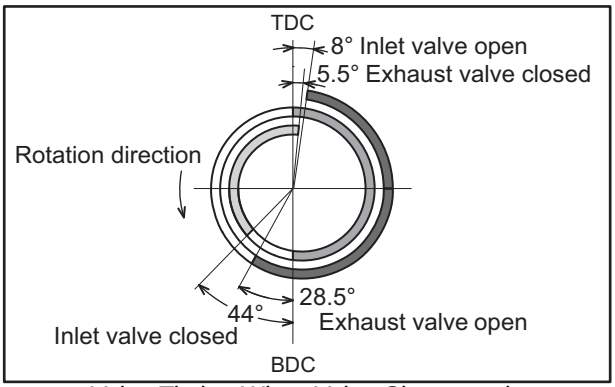


Valve Clearance is 0 mm

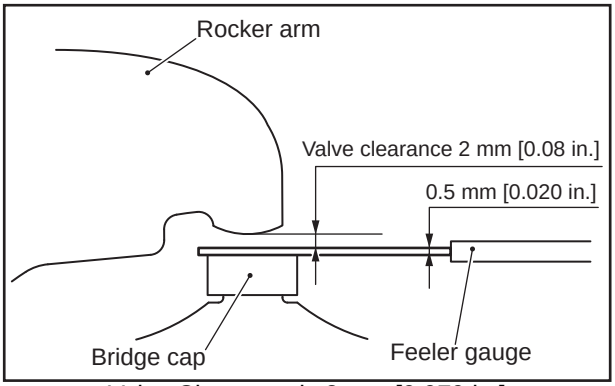
5.17.2 Valve Timing When Valve Clearance is 2 mm [0.079 in.]

To check the timing more accurately, adjust the clearance to 2.5 mm [0.098 in.] position where the valve movement changes rapidly.

(1) Insert a feeler gauge of 0.5 mm [0.020 in.] between bridge cap and rocker arm. (Valve clearance is 2 mm [0.079 in.])
(2) Turn the crankshaft in normal direction little by little, and find a position where the feeler gauge is tightly gripped (valve open position) and a position where the feeler gauge is released (valve closed position).
(3) Check that the obtained angle meets the angle shown in the illustration.
(4) Adjust the valve clearance to the standard value.



Valve Timing When Valve Clearance is 2 mm [0.079 in.]



Valve Clearance is 2 mm [0.079 in.]

5.18 Spark Plug - Install

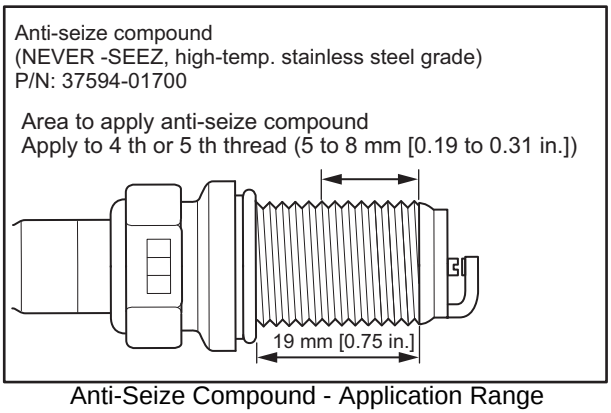
CAUTION

(a)If tightened with an excessively high torque, the thread may be damaged.

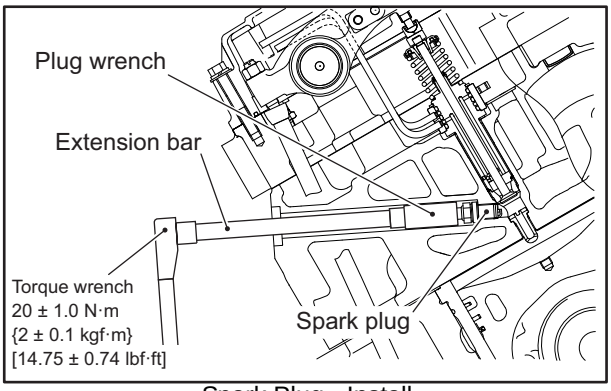
(b)Apply a thin coat of anti-seize compound on the specified area only.

(1) Before installing the spark plug, lubricate its threads with high temperature stainless steel grade anti-seize compound "NEVER-SEEZ".

(2) Using a plug wrench and extension bar, install a spark plug into the cylinder head, and tighten it to the specified torque.



Anti-Seize Compound - Application Range

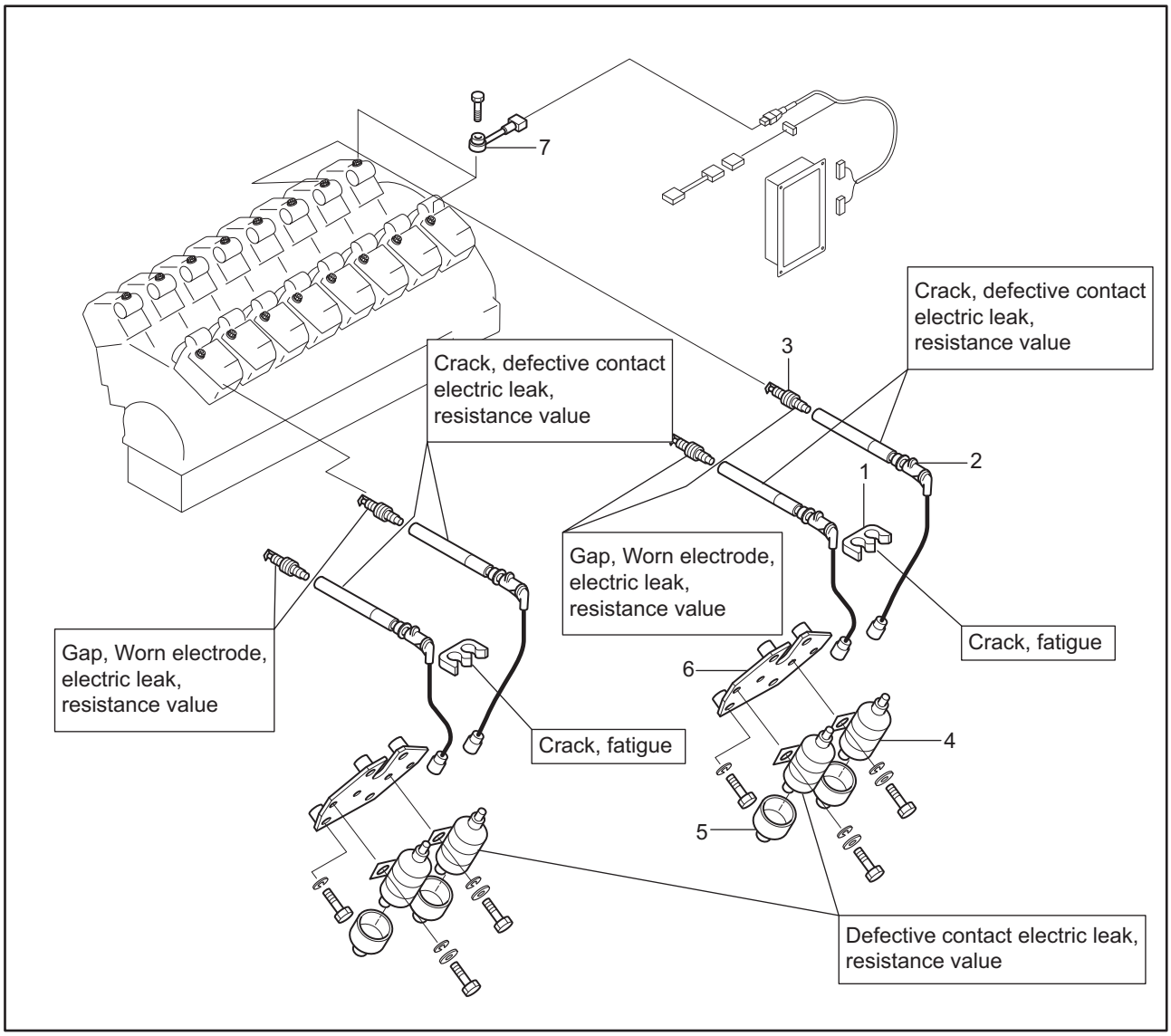


Spark Plug - Install

Chapter 8 IGNITION SYSTEM

1. Ignition System - Remove

1.1 Ignition Coil and Spark Plug - Remove



Ignition Coil and Spark Plug - Remove

Removal sequence

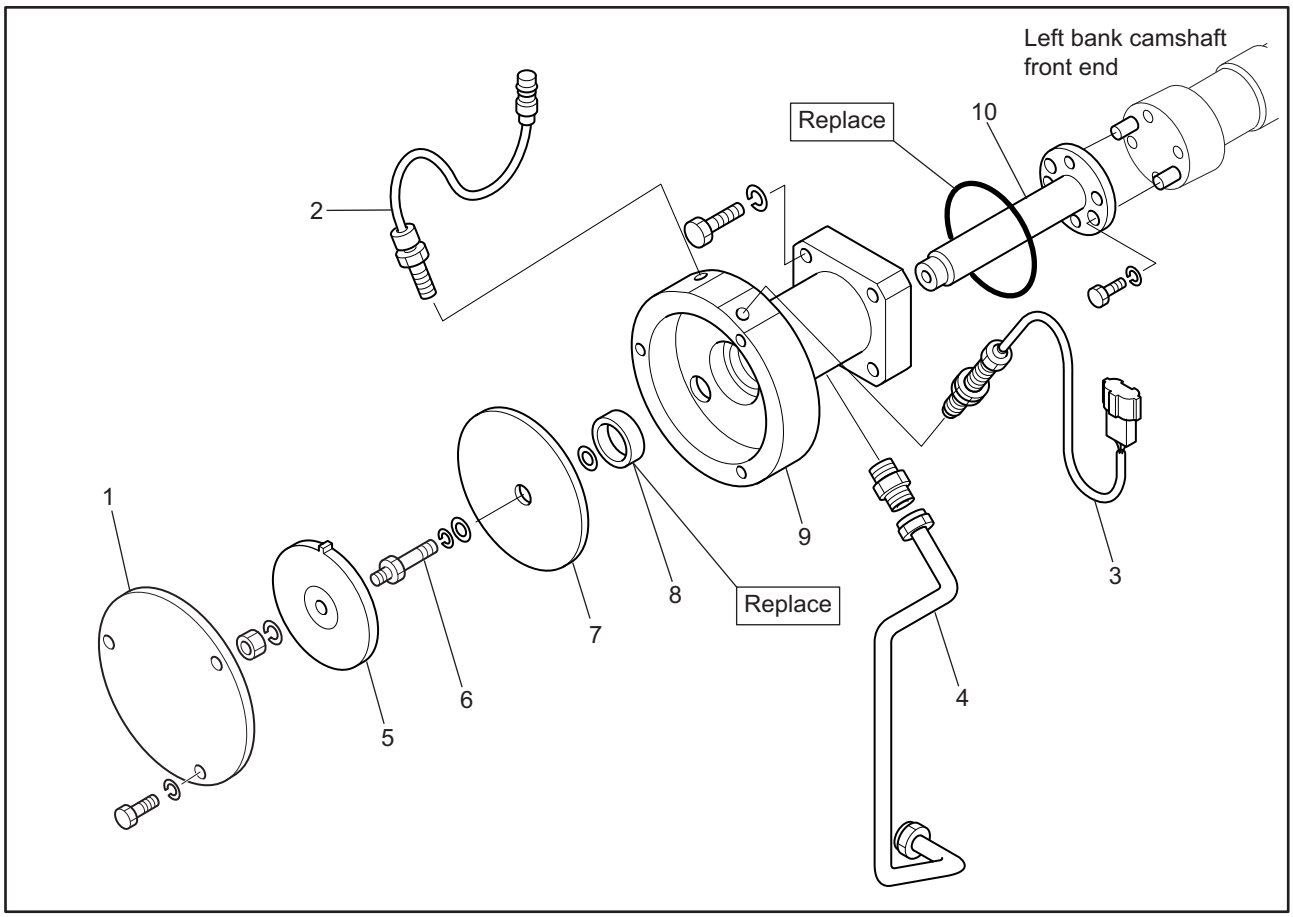
1 Cord clamp
2 Spark plug code
3 Spark plug
4 Ignition coil
5 Ignition coil boot
6 Bracket
7 Knock sensor

CAUTION

When pulling out the cables, always hold them by the cap, not by the cord.

2. Ignition System - Disassemble, Inspect, and Assemble

2.1 Cam Rotor, Magnet Disk, and Pickup (CD200D) - Disassemble

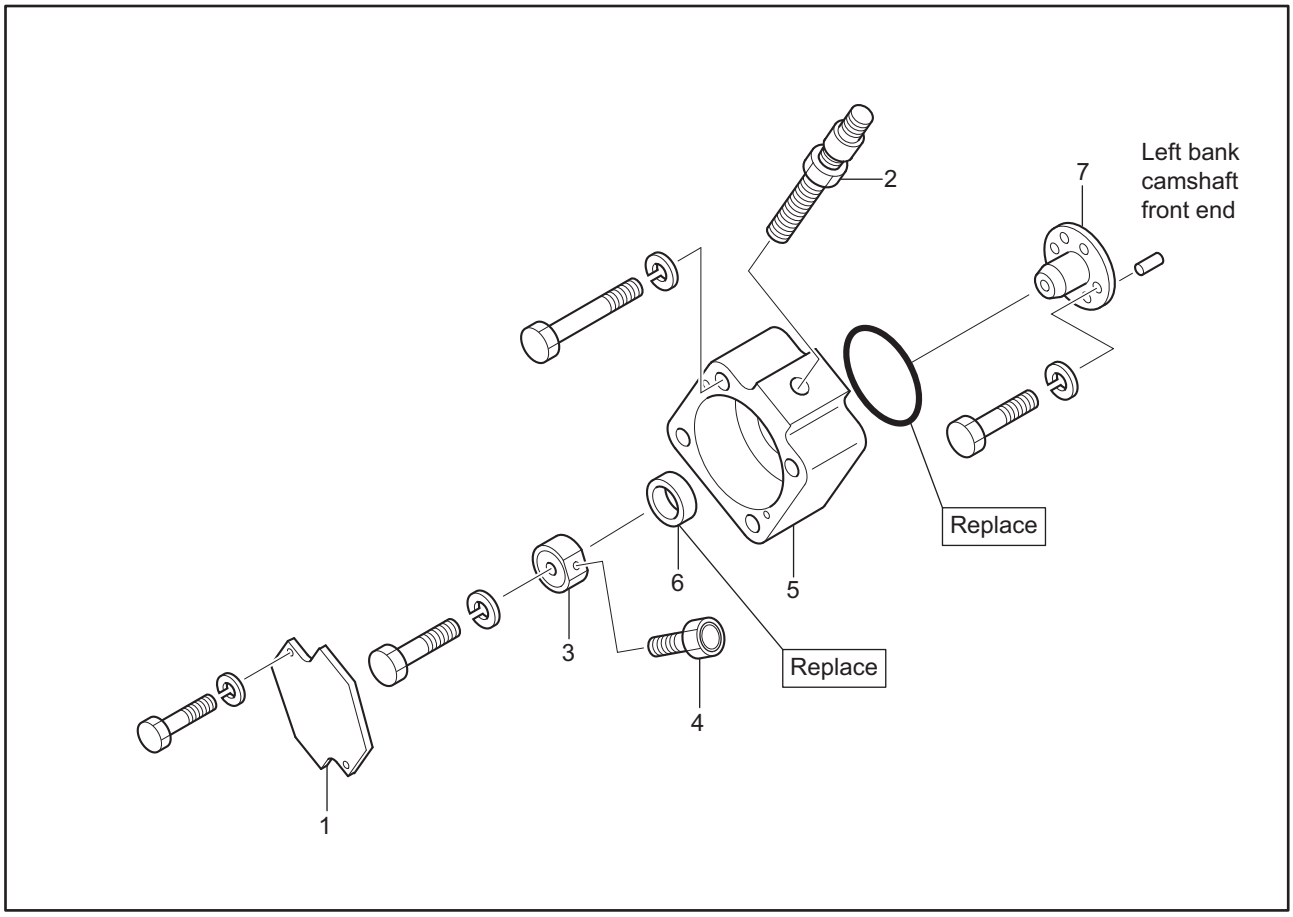


Cam Rotor, Magnet Disk, and Pickup (CD200D) - Disassemble

Disassembly sequence

1 Disc cover
2 Hall effect pickup
3 Plug
4 Drain pipe
5 Magnet disc
6 Oil seal
7 Pickup holder
8 Disc coupling

2.2 Cam Rotor, Magnet Disk, and Pickup (CPU-95) - Disassemble

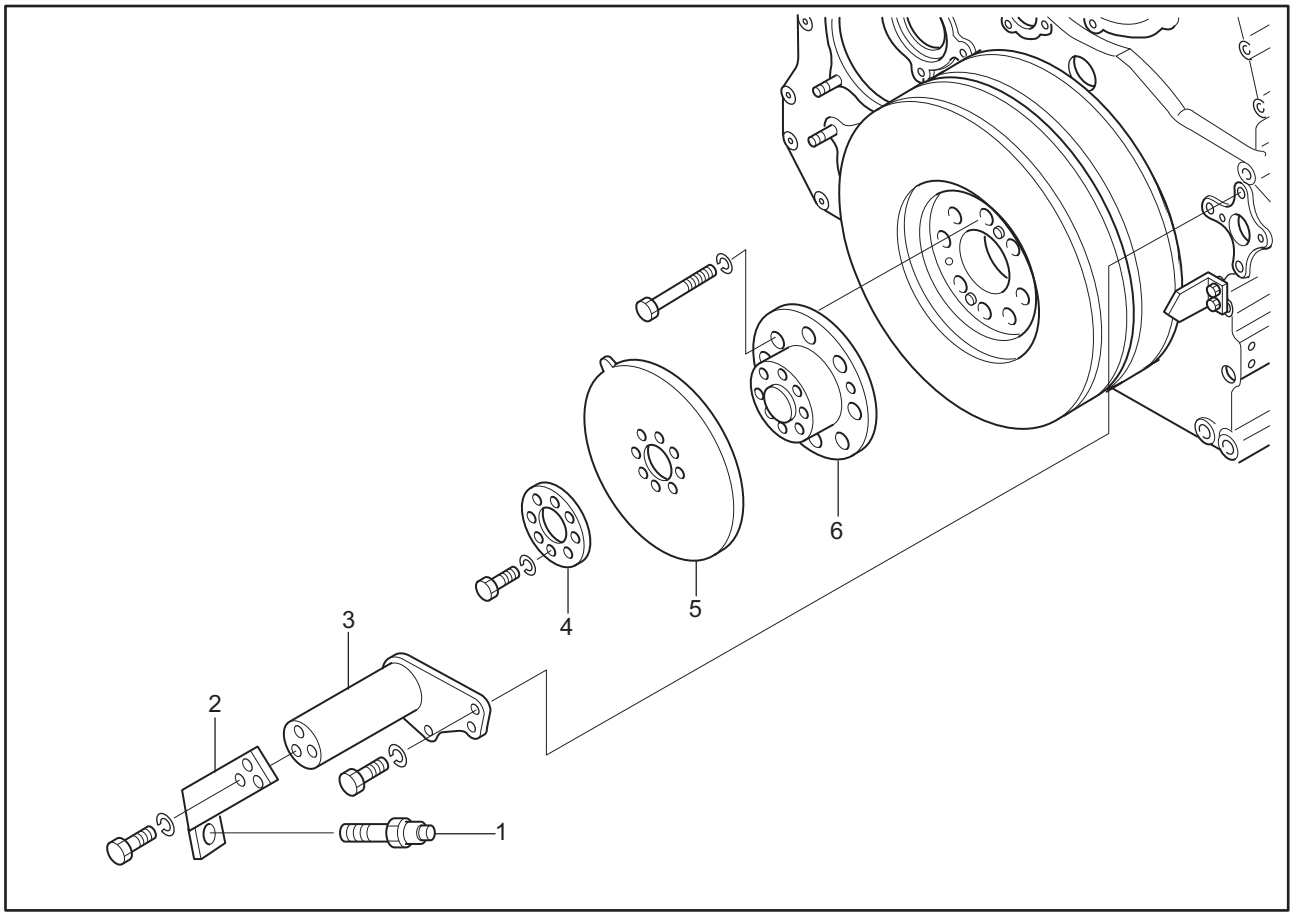


Cam Rotor, Magnet Disk, and Pickup (CPU-95) - Disassemble

Disassembly sequence

1 Cam rotor cover
2 Hall effect pickup
3 Magnet rotor
4 Magnetic assembly
5 Hall effect pickup holder
6 Oil seal
7 Cam rotor coupling

2.3 Reset Pulse Rotor and Pickup (CPU-95) - Disassemble



Reset Pulse Rotor and Pickup (CPU-95) - Disassemble

Disassembly sequence

1 Magnetic pickup
2 Pickup holder
3 Sensor bracket
4 Rotor plate
5 Reset pulse rotor
6 Rotor spacer

2.4 Ignition Timing System - Install

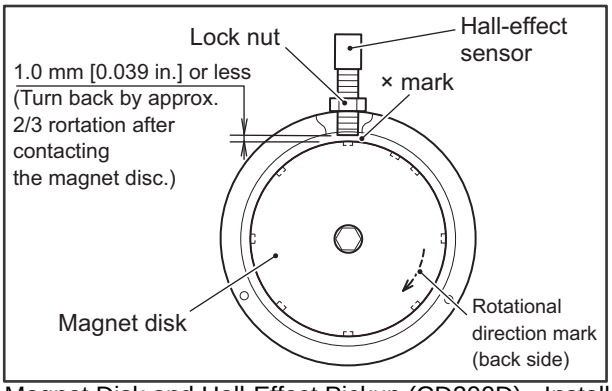
2.4.1 Magnet Disk and Hall-Effect Pickup (CD200D) - Install

(1) Bring the crank angle of cylinder No. 9 to 6° before compression top dead center.

(2) Align the "×" mark on the magnet disc with the Hall-effect pickup, and secure the magnetic disc in that position.

Note that the rotation direction mark is located on the back side in this condition.

(3) Adjust the clearance between the Hall-effect pickup and magnetic disc to the specified value and then secure the sensor with the lock nut.



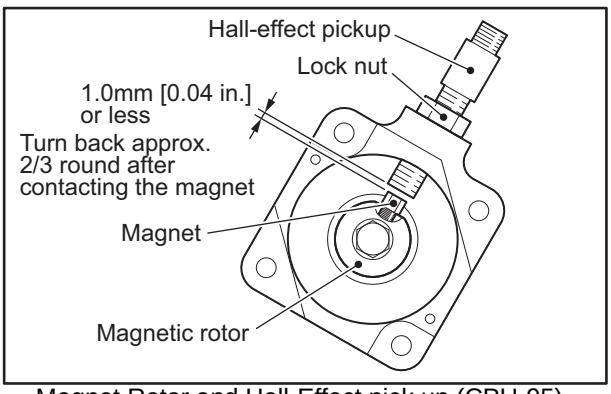
Magnet Disk and Hall-Effect Pickup (CD200D) - Install

2.4.2 Magnet Rotor and Hall-Effect pick up (CPU-95) - Install

(1) Bring the crank angle of cylinder No. 1 to 30° before compression top dead center.

(2) Align the pickup with the magnet of magnet rotor, and secure the magnet rotor in that position.

(3) Adjust the clearance between the pickup and magnet to the specified value and then secure the pickup with the lock nut.



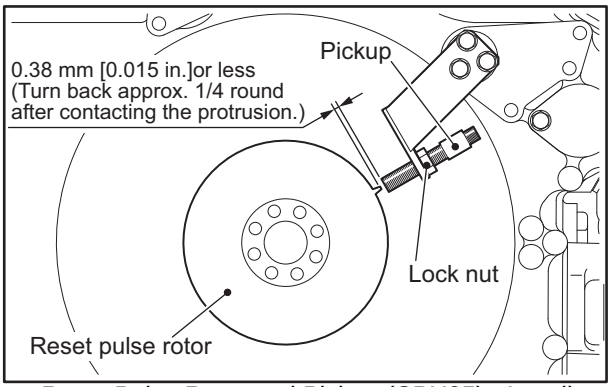
Magnet Rotor and Hall-Effect pick up (CPU-95) - Install

2.4.3 Reset Pulse Rotor and Pickup (CPU-95) - Install

(1) Bring the crank angle of cylinder No. 1 to 30° before compression top dead center.

(2) Aligned the pickup with the reset pulse rotor tooth, and secure the reset pulse rotor in that position.

(3) Adjust the clearance between the pickup and the reset pulse rotor tooth the specified value or less, and then secure the pickup with the lock nut.

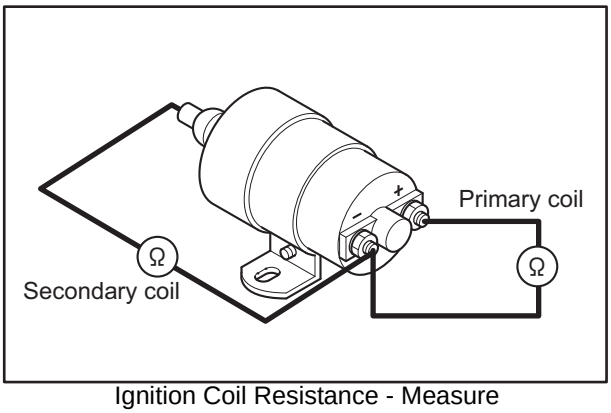


Reset Pulse Rotor and Pickup (CPU95) - Install

2.5 Ignition Coil Resistance - Measure

(1) Measure the resistances of primary coil and secondary coil.

Item	Standard value
Resistance of primary coil	0.1 to 0.2 Ω
Resistance of secondary coil	4.4 to 6.9 kΩ



Ignition Coil Resistance - Measure

2.6 Spark Plug Code - Check

Perform the following inspections: If any faulty part is found, replace the spark plug code with the new one.

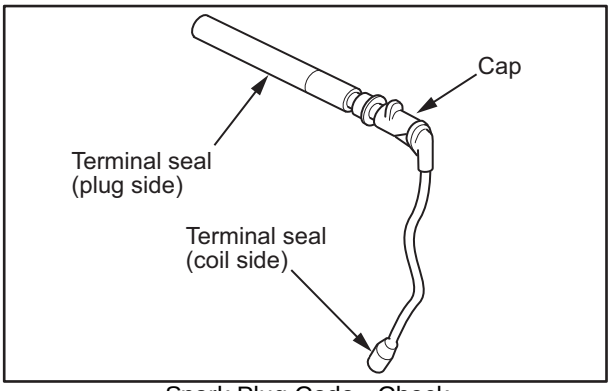
(1) Check the caps and the sheath for cracks.

(2) Check the metal parts inside the terminal seal for rust and dirt.

(3) Measure resistance between the end caps of each spark plug cord.

Item	Standard value
Resistance of spark plug cord	8.5 to 14.5 kΩ

(4) Check the terminal seal on the plug side for deterioration and cracks.



Spark Plug Code - Check

2.7 Spark Plug - Check

(1) Visual inspection

- ♦Burn of insulator, damage, and flashover (electrical leak by improper insulation)
  If a trace of flashover is shown, also check the plug code.
- ♦Carbon accumulation
- ♦Gasket surface flaws
- ♦Wear, short, or sputtering of electrode

(2) Resistance measurement

Item		Standard value
Internal resistance value	Denso (GK2-2)	2 to 10 kΩ at room temp.
Insulation resistance value		50 MΩ or more at room temp.
Internal resistance value	NGK (T7415X)	3 to 7.5 kΩ at room temp.
Insulation resistance value		100 MΩ or more at room temp.

(3) Clean

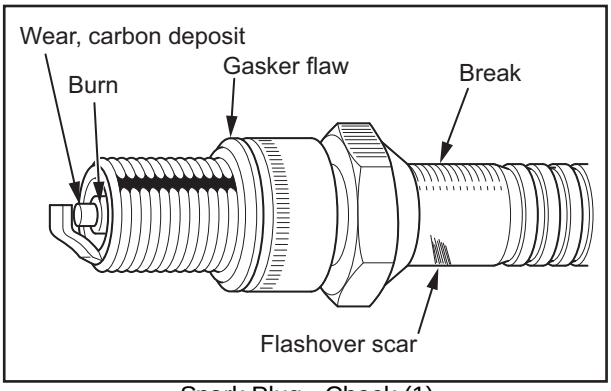
Remove contaminants such as carbon and rust with a plug cleaner or a wire brush.

(4) Measurement and adjustment of plug gap

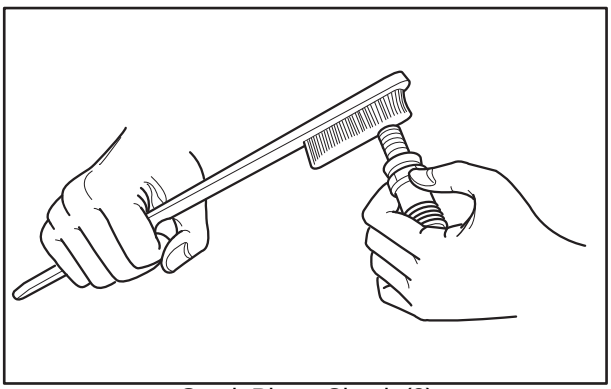
Measure the gap with feeler gauges.

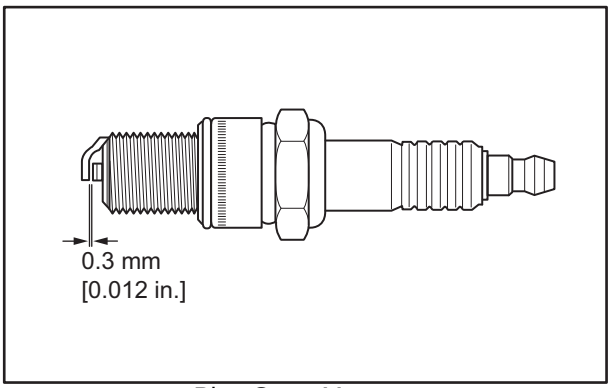
Item			Standard value
Plug gap	Denso (GK2-2)	Initial	0.22 ± 0.03 mm [0.0087 ± 0.0011 in.]
		When gap is adjusted	0.17 mm [0.0067 in.]
	NGK (T7415X)	Initial	0.3 ± 0.05 mm [0.012 ± 0.0019 in.]
		When gap is adjusted	0.3 mm [0.012 in.]

Note: (a) Verify the gap even when a new plug is used.
(b) Tap with a copper hammer to narrow the gap.
(c) Use a proper tool to widen the gap without touching the iridium tip.



Spark Plug - Check (1)


Spark Plug - Check (2)



Plug Gap - Measure

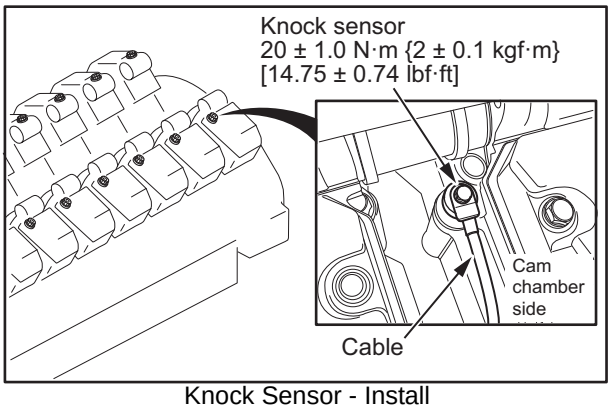
3. Ignition System - Install

♦To install, follow the removal sequence in reverse. (See the illustration for disassemby.)

3.1 Knock Sensor - Install

(1) Install the knock sensor on the cylinder head bolt. Tighten the bolt without using a washer.

Note: To install the knock sensor, place the cable to the cam chamber side as shown in the illustration.

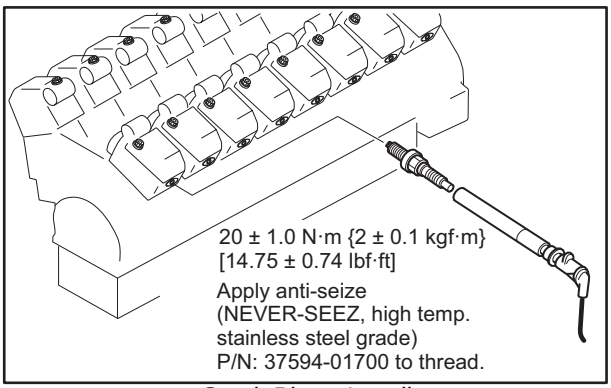


Knock Sensor - Install

3.2 Spark Plug - Install

(1) Apply anti-seize compound on the spark plug threads.

(2) Install the spark plug on the cylinder head, and tighten to the specified torque.

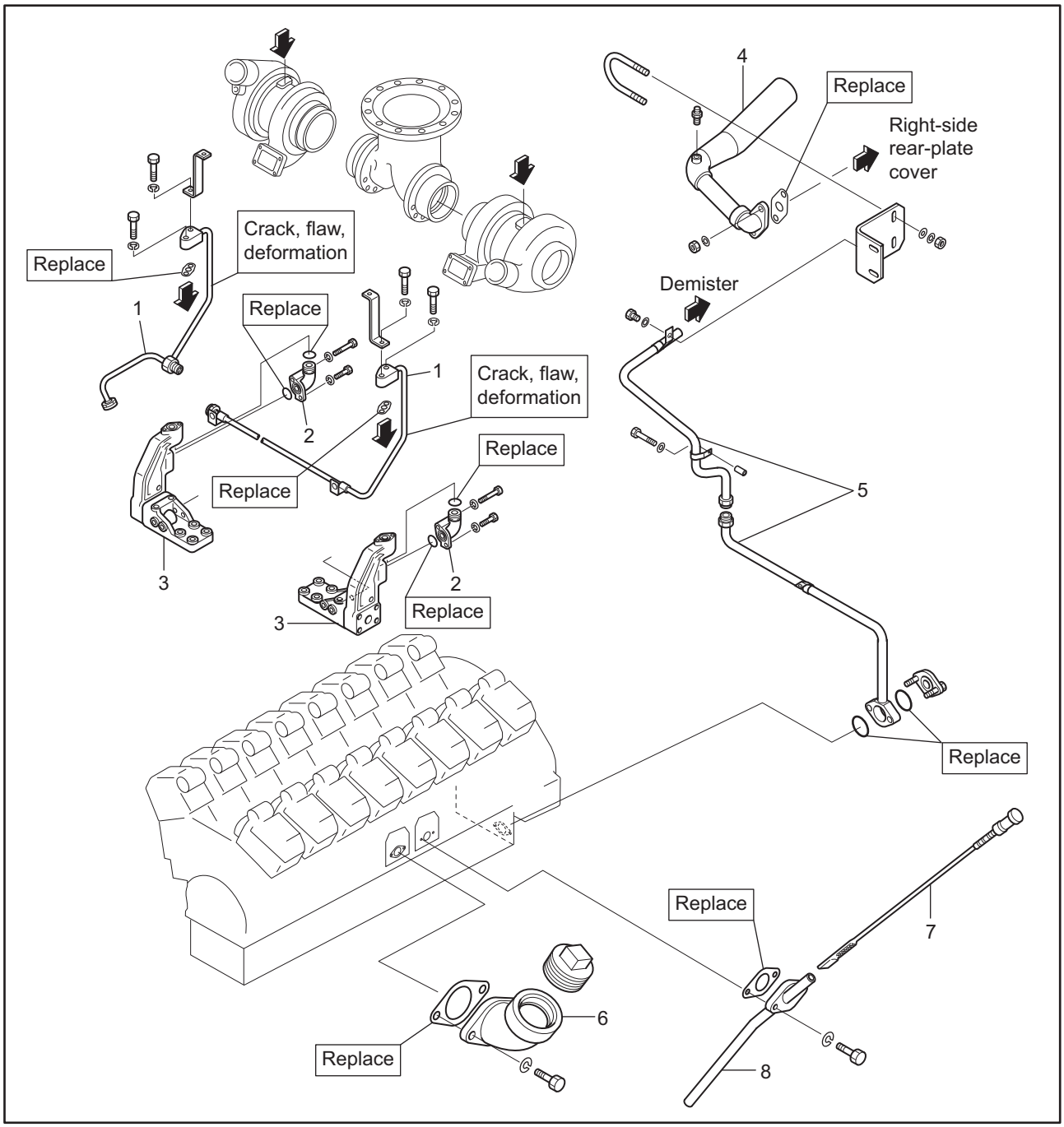


Spark Plug - Install

Chapter 9 LUBRICATION SYSTEM

1. Lubrication System - Remove and Inspect

1.1 Oil Filler, Oil Level Gauge, Breather, and Turbocharger Oil Pipe - Remove and Inspect

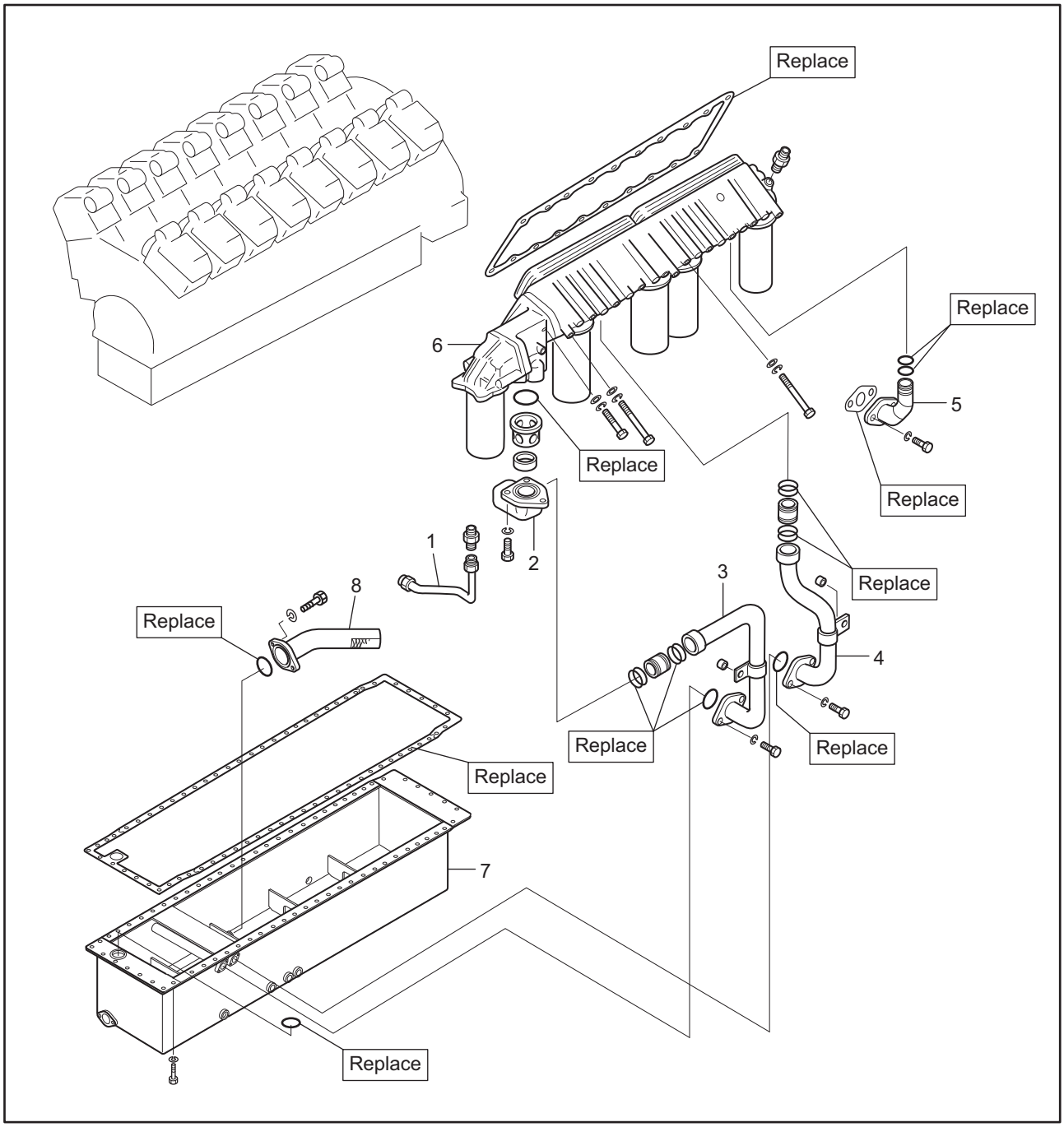


Oil Filler, Oil Level Gauge, Breather, and Turbocharger Oil Pipe - Remove and Inspect

Removal sequence

1 Oil pipe
2 Drain connector
3 Bracket
4 Breather pipe
5 Drain pipe
6 Oil filler
7 Oil level gauge
8 Guide

1.2 Oil Filter, Oil Pan, and Oil Pipe - Remove and Inspect

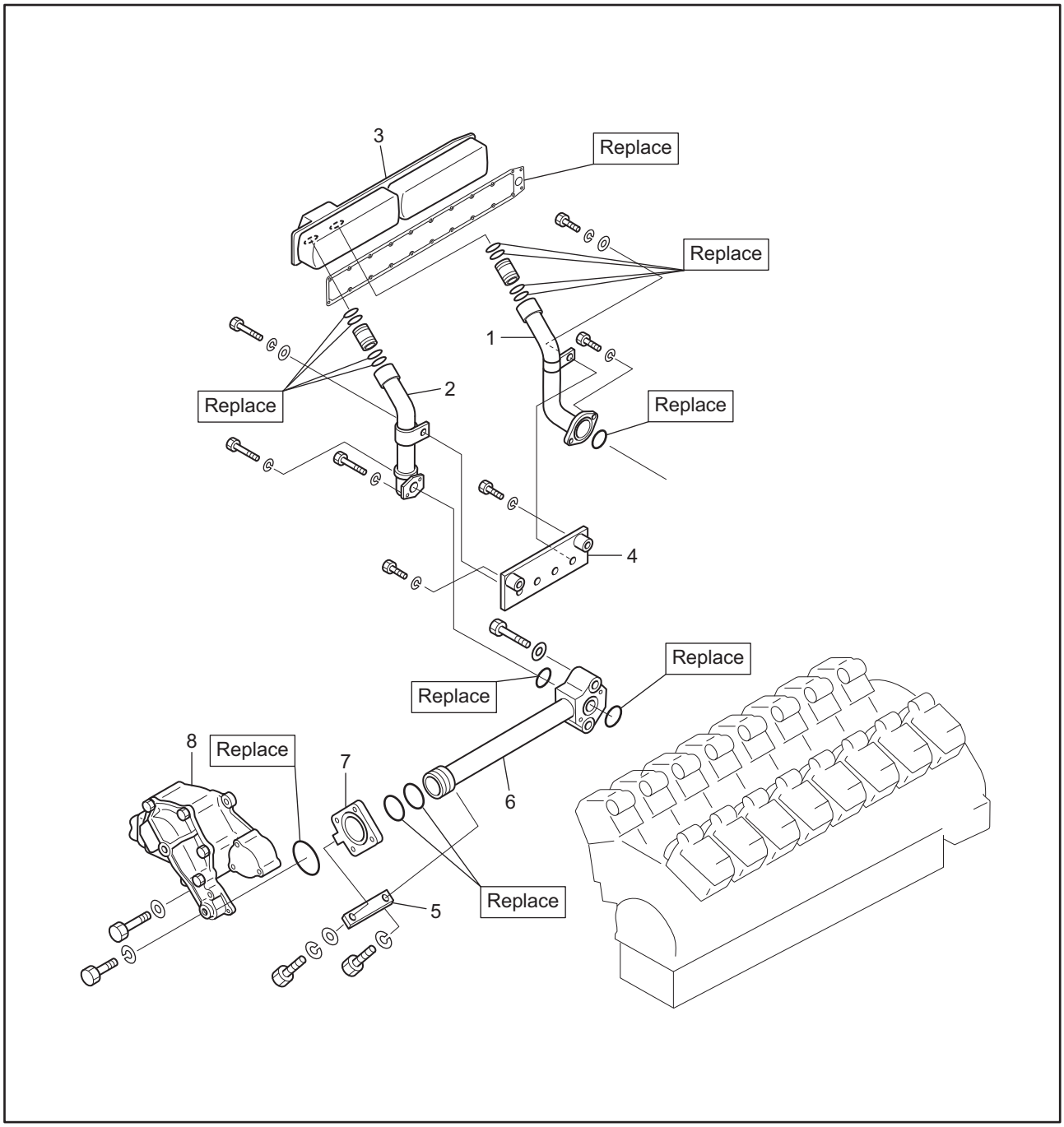


Oil Filter, Oil Pan, and Oil Pipe - Remove and Inspect

Removal sequence

1 Bypass drain pipe
2 Connector
3 Oil pipe
4 Oil pipe
5 Oil pipe
6 Oil filter assembly (approx. 40 kg [88 lb])
7 Oilpan(approx.190kg[419lb])
8 Oil strainer

1.3 Oil Cooler, Oil Pipe, and Oil Pump - Remove and Inspect



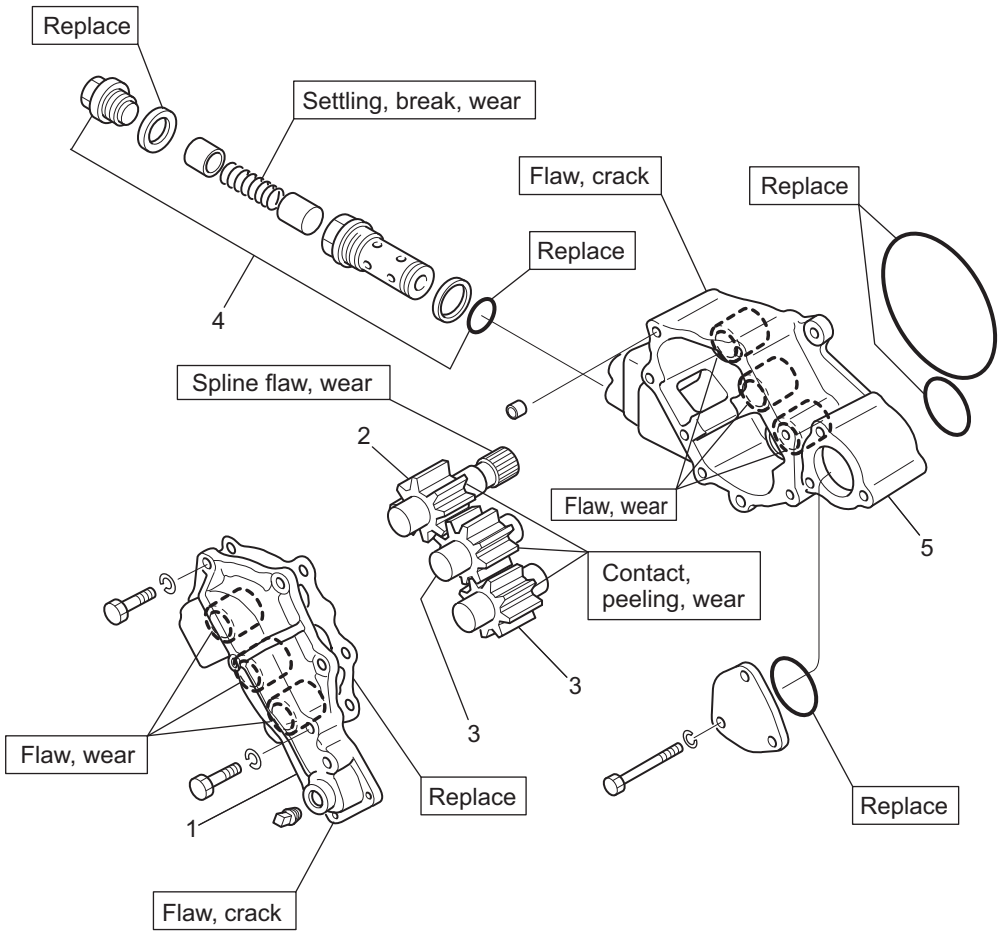
Oil Cooler, Oil Pipe, and Oil Pump - Remove and Inspect

Removal sequence

1 Oil pipe
2 Oil pipe
3 Oil cooler assembly (approx. 25 kg [55 lb])
4 Clamp bracket
5 Stay
6 Oil pipe
7 Connector
8 Oil pump (approx. 26 kg [57 lb])

2. Lubrication System - Disassemble, Inspect, and Assemble

2.1 Oil Pump and Safety Valve - Disassemble and Inspect



Oil Pump and Safety Valve - Disassemble and Inspect

Disassembly sequence

1 Oil pump cover
2 Drive gear
3 Driven gear
4 Safety valve assembly
5 Oil pump case

2.2 Oil Pump and Safety Valve - Inspect

2.2.1 Backlash Between Drive Gear and Driven Gear - Measure

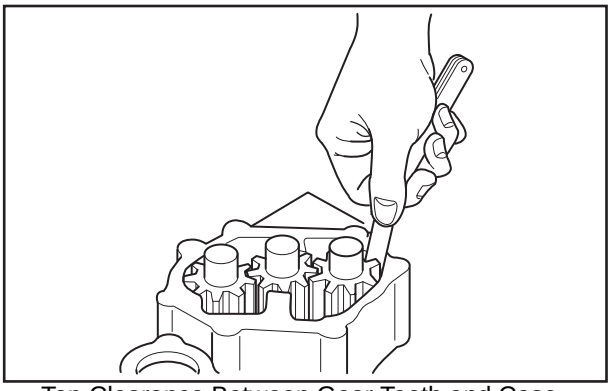
Measure the backlash between drive gear and driven gear. If the value exceeds the limit, replace the gears with new ones.

Item	Standard value	Limit value
Backlash between drive gear and driven gear	0.100 to 0.200 mm [0.0039 to 0.0079 in.]	0.400 mm [0.0157 in.]

2.2.2 Top Clearance Between Gear Teeth and Case - Measure

Measure the top clearance between the drive and driven gear teeth and case housing. If the value exceeds the limit, replace the gear or the case with a new one.

Item	Standard value	Limit value
Top clearance between gear teeth and case	0.100 to 0.148 mm [0.0039 to 0.0058 in.]	0.350 mm [0.0138 in.]

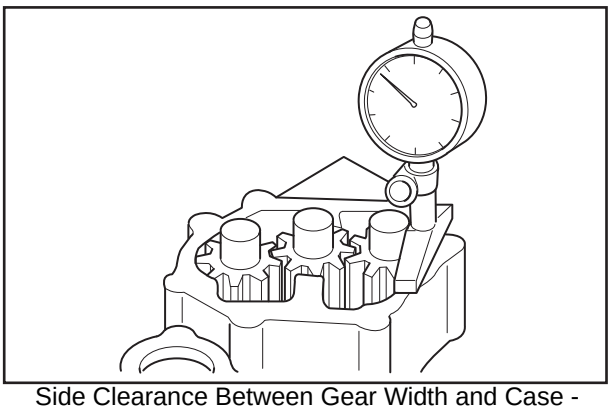


Top Clearance Between Gear Teeth and Case - Measure

2.2.3 Side Clearance Between Gear Width and Case - Measure

Measure the side clearance between the gear width and case depth. Remove the cover mounting packing (0.04 mm [0.0016 in.] thick) to measure the clearance. If the value exceeds the limit, replace the gear or the case with a new one.

Item	Standard value	Limit value
Side clearance between gear width and case depth	0.040 to 0.116 mm [0.0016 to 0.0046 in.]	0.210 mm [0.0083 in.]



Side Clearance Between Gear Width and Case - Measure

2.2.4 Drive and Driven Gear Shaft Outside Diameters and Bushing Inside Diameters - Measure

(1) Check the gear teeth. If any defect is found, replace the gear with a new one.

(2) Measure the drive and driven gear shaft outside diameters and bushing inside diameters. If any of the gear or bushing exceeds the limit, replace them as a set with new ones.

Item	Nominal value	Standard value	Limit value
Drive shaft outside diameter	ø30 [1.18]	29.887 to 29.900 mm [1.1767 to 1.1772 in.]	29.840 mm [1.1748 in.]
Driven shaft outside diameter		29.947 to 29.960 mm [1.1790 to 1.1795 in.]	29.920 mm [1.1780 in.]
Bushing inside diameter		30.000 to 30.021 mm [1.1811 to 1.1819 in.]	30.055 mm [1.1833 in.]

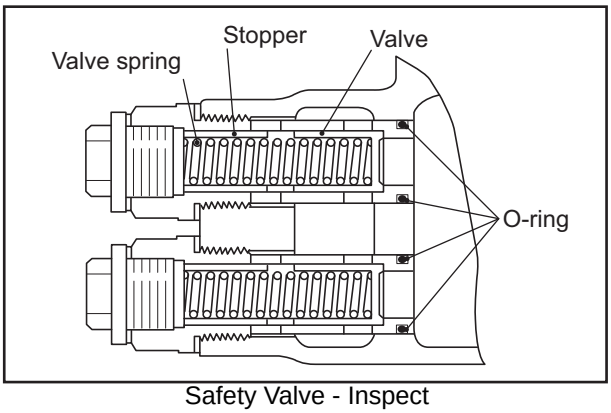
2.2.5 Oil Pump Safety Valve - Inspect

Item	Standard value
Safety valve opening pressure	1.3 ± 0.13 MPa {13.3 ± 1.32 kgf/cm^2} [188.5 ± 18.85 psi]

(1) Inspect the oil pump safety valve spring, and if any deformation, wear, or damage is found, or if the measured value exceeds the limit, replace it with a new one.

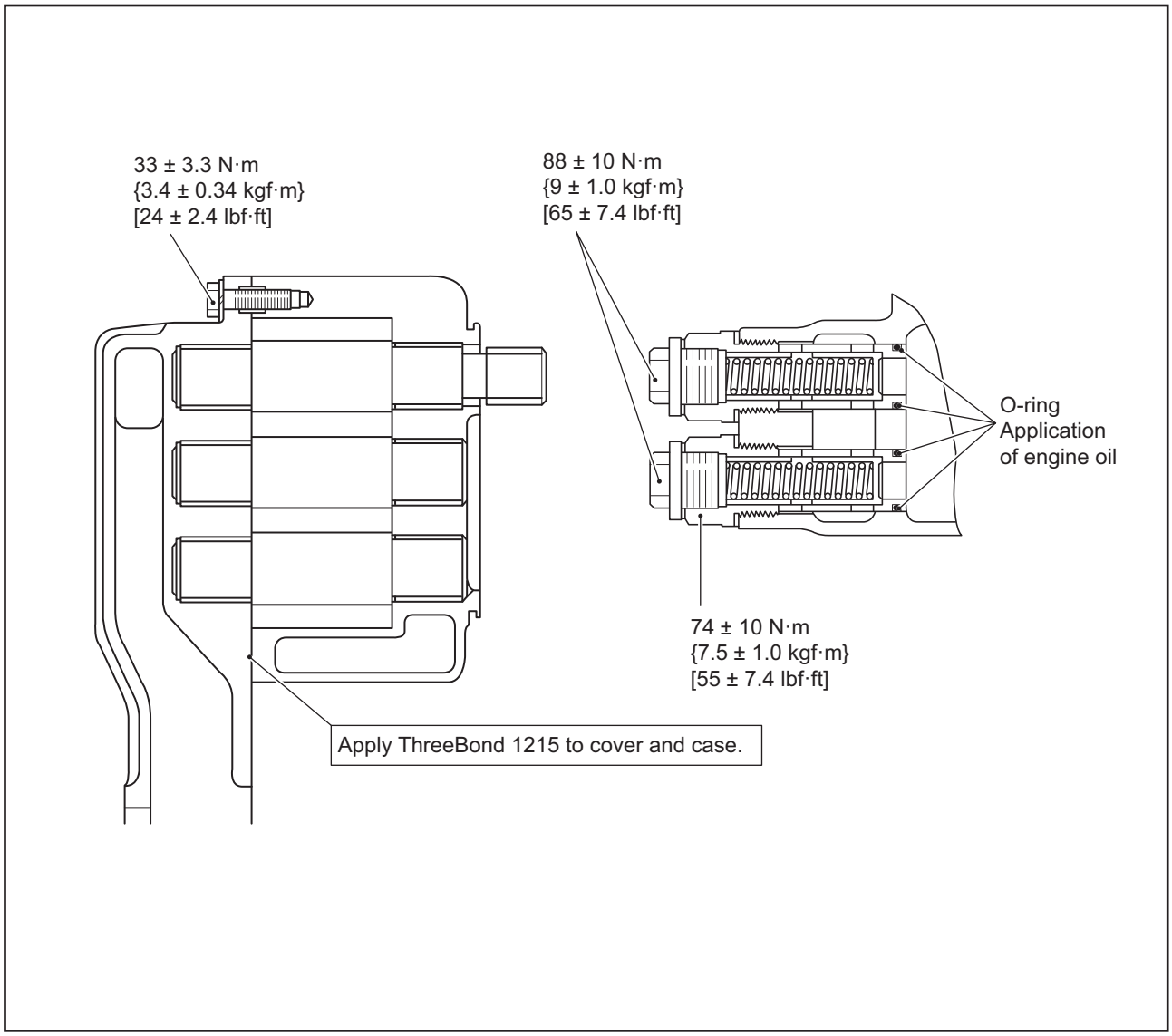
Item	Standard value	Limit value
Safety valve spring installed length/load	65.8 mm [2.591 in.] / 359 N{36.6 kgf} [80.71 lbf]	65.8 mm [2.591 in.] / 314 N{32.0 kgf} [70.59 lbf]
Free length of safety valve spring	78 mm [3.07 in.]	-

(2) Inspect the valve and stopper. If significant wear or malfunction of sliding parts is found, replace them with new ones.



Safety Valve - Inspect

2.3 Oil Pump and Safety Valve - Assemble

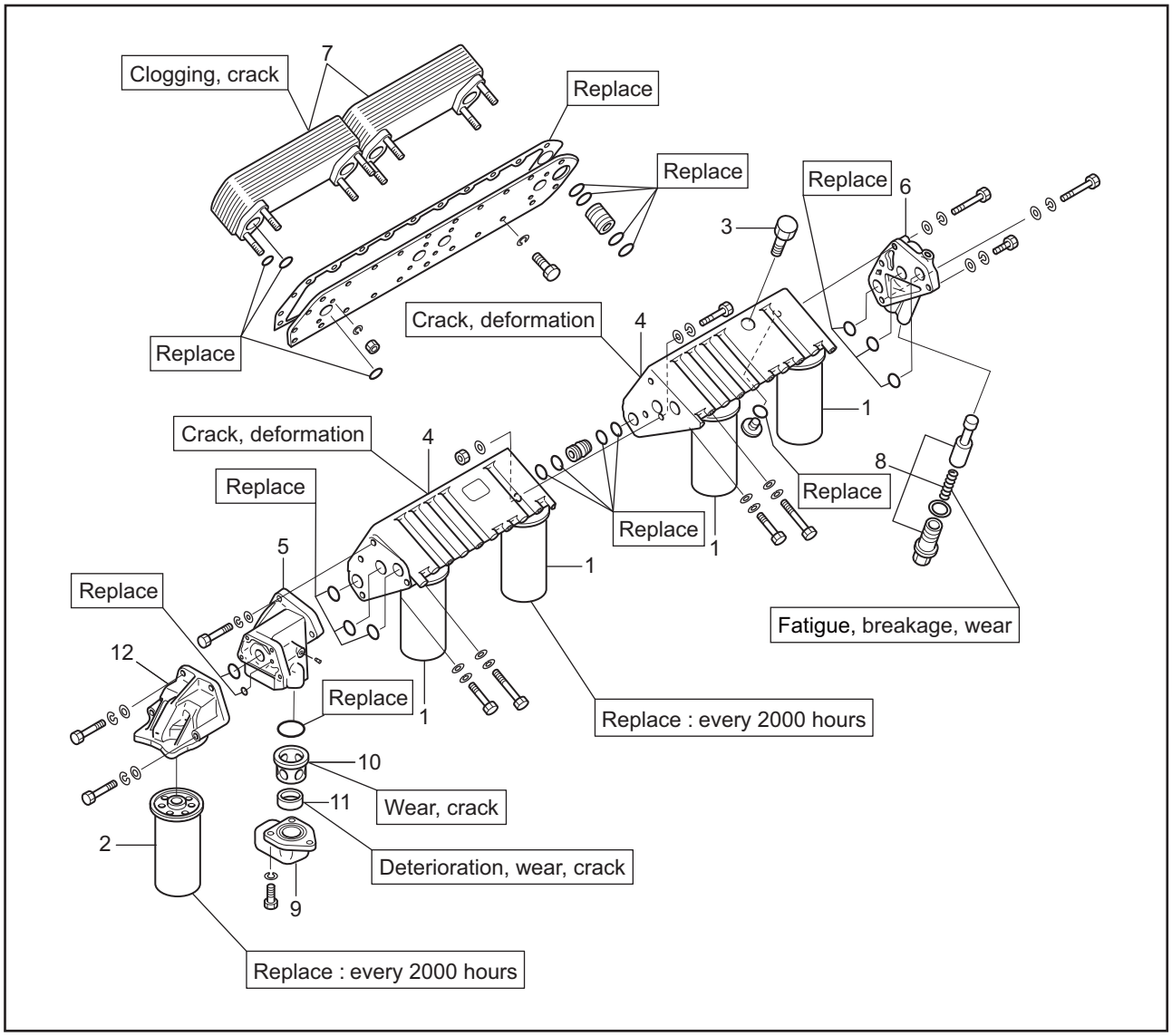


Oil Pump and Safety Valve - Assemble

CAUTION

Apply engine oil on each part when assembling. Apply a thick coat of engine oil on threads and seating surfaces of the nuts and bolts before tightening them.

2.4 Oil Filter, Oil Filter Alarm, Relief Valve and Left Side Oil Cooler - Disassemble and Inspect



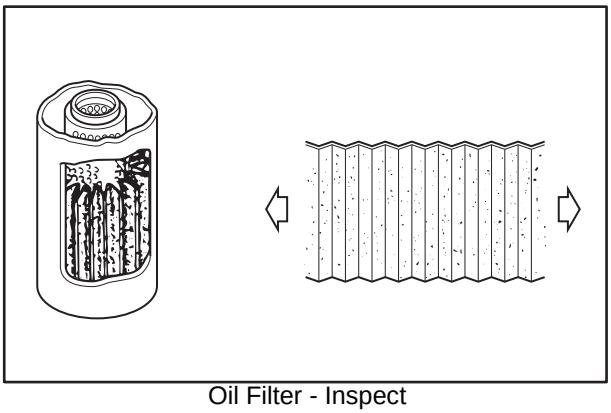
Oil Filter, Oil Filter Alarm, Relief Valve and Left Side Oil Cooler - Disassemble and Inspect

Disassembly sequence

1 Full-flow oil filter
2 Bypass oil filter
3 Plug
4 Bracket
5 Thermostat adapter
6 Body assembly
7 Oil cooler element
8 Relief valve assembly
9 Connector
10 Thermo dummy
11 Thermostat seal
12 Bracket

2.5 Oil Filter - Inspect

When replacing the oil filter, sample the oil (500 ml [0.13 US gal]) and check for metal and other particles. If metal or other particles are found, cut and unfold the element, and inspect the color and shape of metal particles trapped in element to identify the cause.



Oil Filter - Inspect

2.6 Relief Valve Opening Pressure - Measure

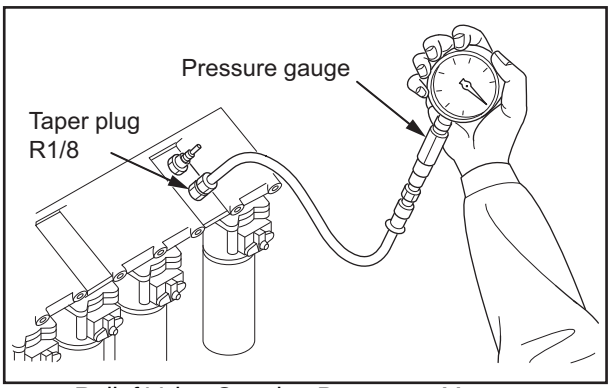
(1) Remove the taper plug (R1/8) from the top of the oil filter bracket, and set a pressure gauge.

(2) Warm-up the engine until the oil temperature reaches 70 to 90 °C [158 to 194 °F].

(3) Measure the oil pressure at idling and maximum speed respectively.

Note: When the oil temperature is low, the oil pressure may rise above the set pressure, but it returns to the set pressure as the oil temperature rises.

Item	Standard value
Relief valve opening pressure	0.59 ± 0.02 MPa {6.02 ± 0.20 kgf/cm^2} [85.57 ± 2.90 psi]



Relief Valve Opening Pressure - Measure

2.7 Relief Valve - Inspect

(1) Inspect the relief valve spring, and if any deformation, wear or damage is found, replace the spring with a new one.

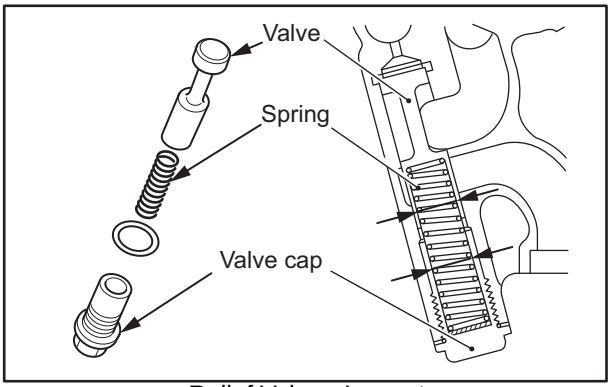
Item	Standard value
Free length of relief valve spring	188 mm [7.40 in.]

(2) Measure the inside diameter of relief valve and relief valve cap, and if wear is found, replace with new one.

Item	Standard value
Inside diameter of relief valve and cap	28.8 to 29.2 mm [1.134 to 1.150 in.]

(3) Inspect the valve, and if any wear, flaw, or sliding malfunction is found, replace the valve with a new one.

Note: Replace the adapter assembly when the oil pressure is low even after replacing the spring or valve.



Relief Valve - Inspect

2.8 Oil Filter and Relief Valve - Assemble

2.8.1 Oil Filter Bracket - Assemble

To assemble, follow the disassembly sequence in reverse. Thoroughly clean oil passages with wash oil, and dry the cleaned parts with compressed air.

2.8.2 Oil Filter Cartridge - Install

CAUTION

(a) To install the oil filter cartridge, tighten the oil filter cartridge by hand. Do not use filter wrenches.

(b) Be careful not to dent or scratch the surface of oil filter cartridge.

(1) Clean the mounting surface of the oil filter cartridge.

(2) Apply clean engine oil on oil filter gasket.

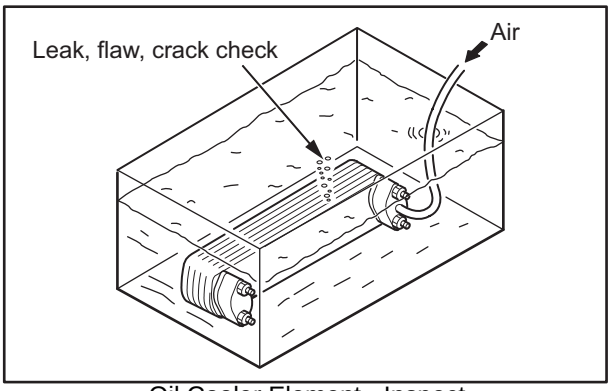
(3) After the oil filter gasket contacts with the base surface, tighten the cartridge by 3/4 to 1 turn by hand.

(4) Start the engine, and make sure there is no leaks.

Note: The oil filter cartridge should be installed just before starting the engine.

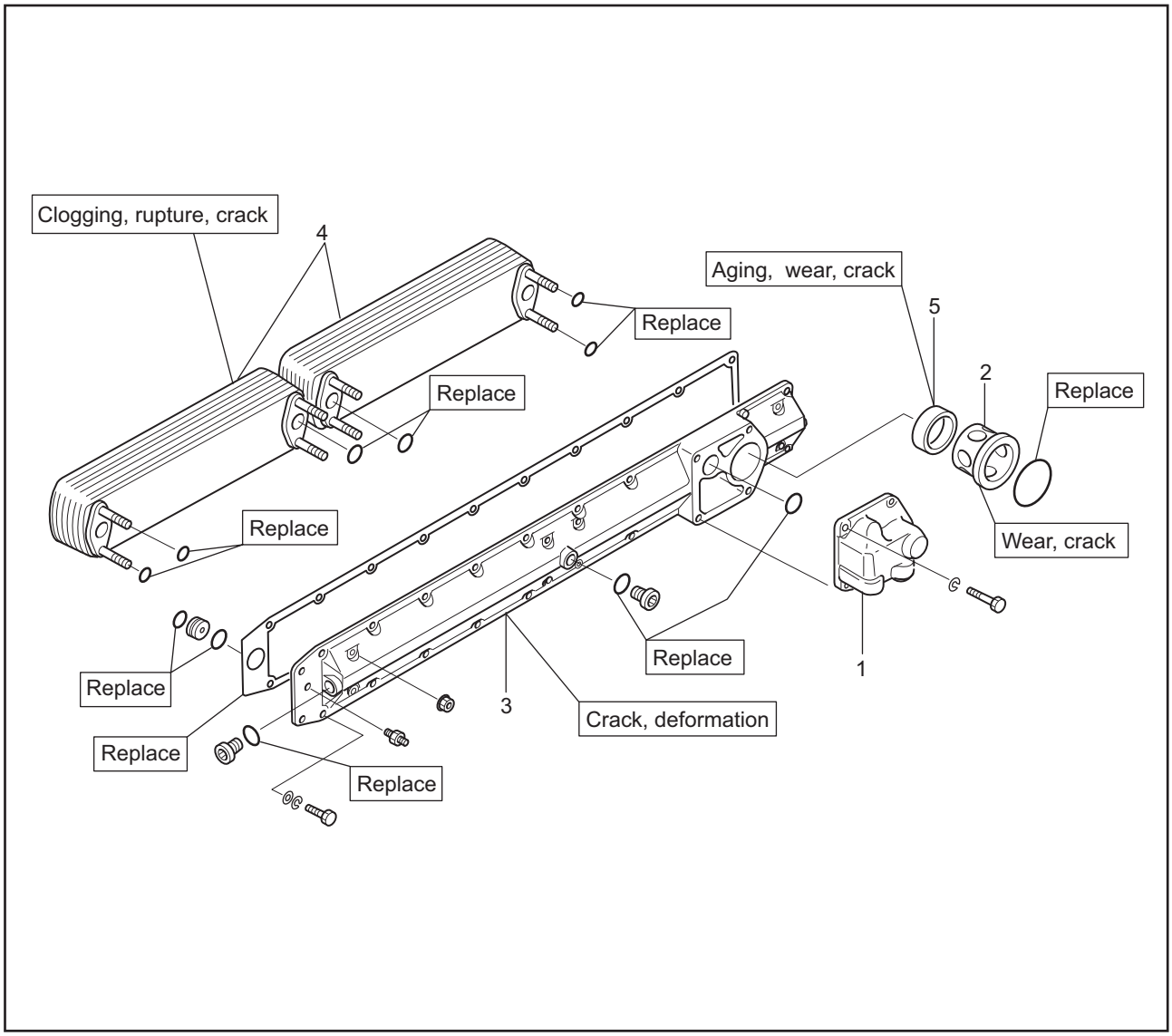
2.9 Oil Cooler Element - Inspect

Apply a pneumatic test pressure of 1.5 MPa {15.3 kgf/cm^2} [217.56 psi] to the engine oil passage in element to check flaw and crack. If any leak is found, replace the element with a new one.



Oil Cooler Element - Inspect

2.10 Right Side Oil Cooler - Disassemble and Inspect



Right Side Oil Cooler - Disassemble and Inspect

Disassembly sequence

1 Connector
2 Thermo dummy
3 Oil cooler cover
4 Oil cooler element
5 Thermostat seal

2.11 Right Side Oil Cooler - Inspect

Inspect in the same manner as described for left side.

Replace the part if any defect is found.

2.12 Oil Cooler - Assemble

To assemble, follow the disassembly sequence in reverse.

(1) When assembling, use new gaskets and O-rings.

(2) Thoroughly clean oil passages with wash oil, and dry the cleaned parts with compressed air.

3. Lubrication System - Install

♦To install, follow the removal sequence in reverse. (See the illustration for disassembly.)

♦Thoroughly clean oil passages and dry them well.

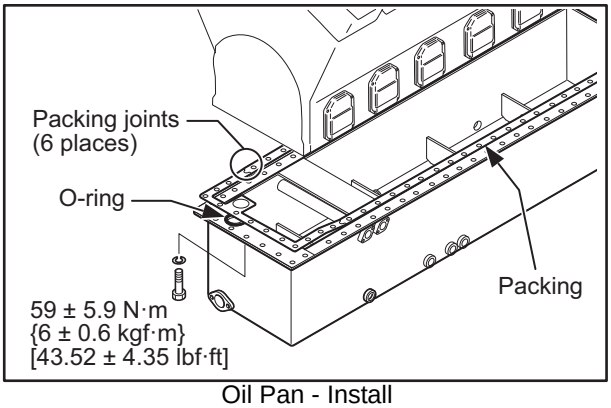
3.1 Oil Pan - Install

(1) Install the O-ring in the oil passage of the oil pan mounting surface.

(2) Install the packing to the oil pan mating face, aligning with the oil passage bolt holes and placing joints (6places) in position. Apply ThreeBond 1211 to the joints.

(3) Install the guide bolt in crankcase, and install the oil pan.

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

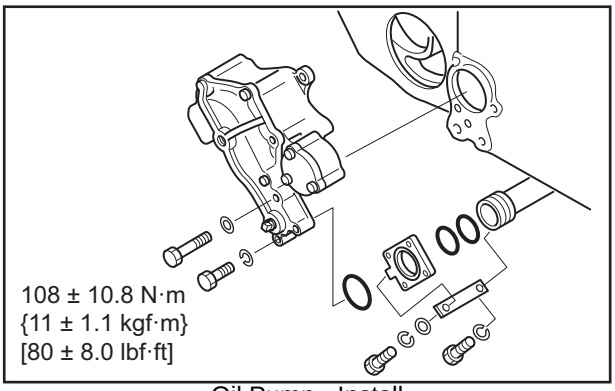


Oil Pan - Install

3.2 Oil Pump - Install

(1) Install the oil pan aligning the drive gear shaft on oil inlet side with each spline of oil pump gear on engine body and also aligning the outlet side with oil pan flange.

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

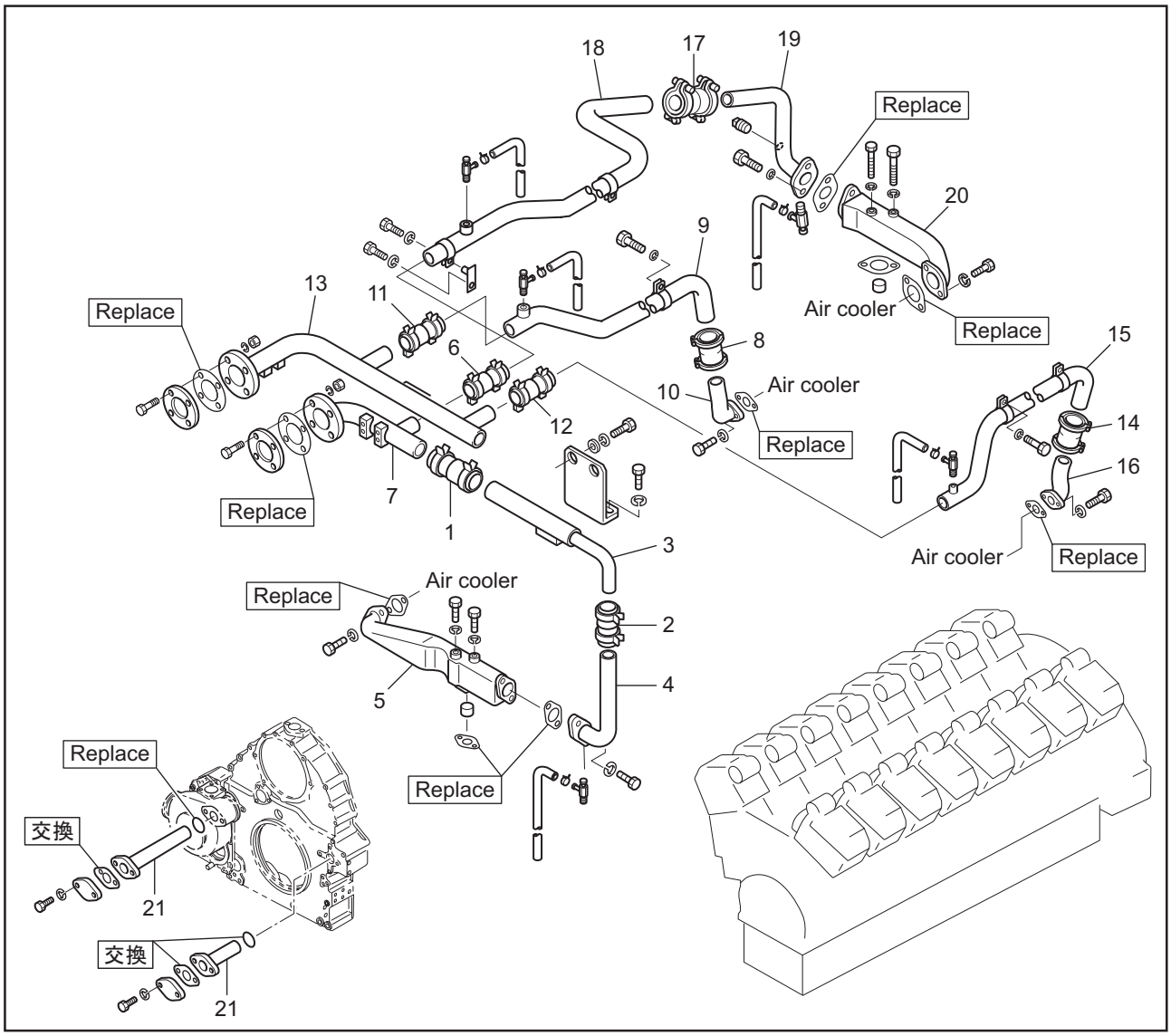


Oil Pump - Install

Chapter 10 COOLING SYSTEM

1. Cooling System - Remove and Inspect

1.1 Water Pipe - Remove and Inspect

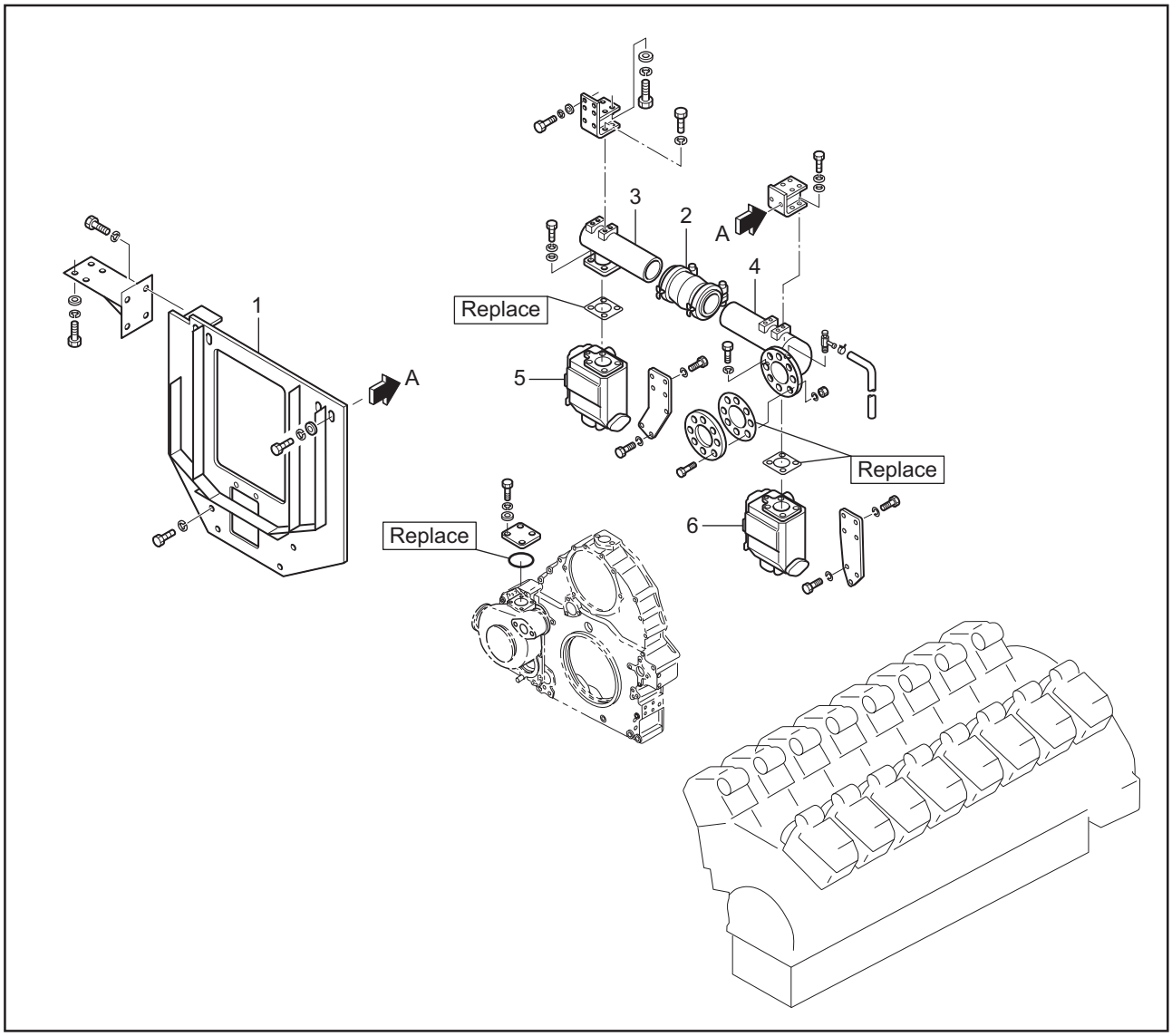


Water Pipe - Remove and Inspect

Removal sequence

1 Coupling
2 Coupling
3 Water pipe
4 Water pipe
5 Water pipe
6 Coupling
7 Water pipe
8 Coupling
9 Water pipe
10 Water pipe
11 Coupling
12 Coupling
13 Water pipe
14 Coupling
15 Water pipe
16 Water pipe
17 Coupling
18 Water pipe
19 Water pipe
20 Water pipe
21 Water heater connecting pipe

1.2 Thermostat Case - Remove and Inspect

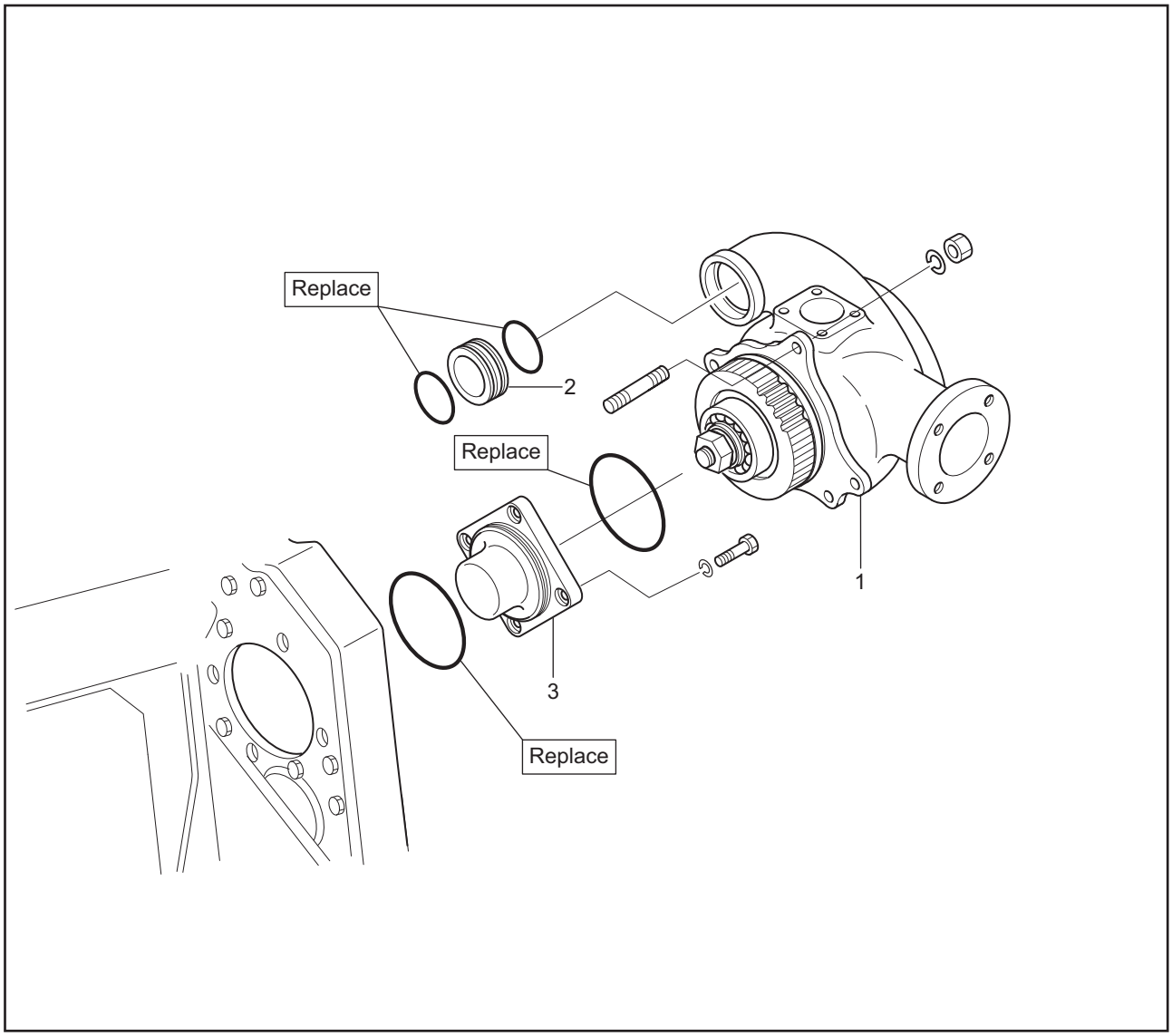


Thermostat Case - Remove and Inspect

Removal sequence

1 Pipe stay
2 Coupling
3 Water pipe
4 Water pipe
5 Thermostat case (case only)
6 Thermostat case (case only)

1.3 Dummy Water Pump - Remove



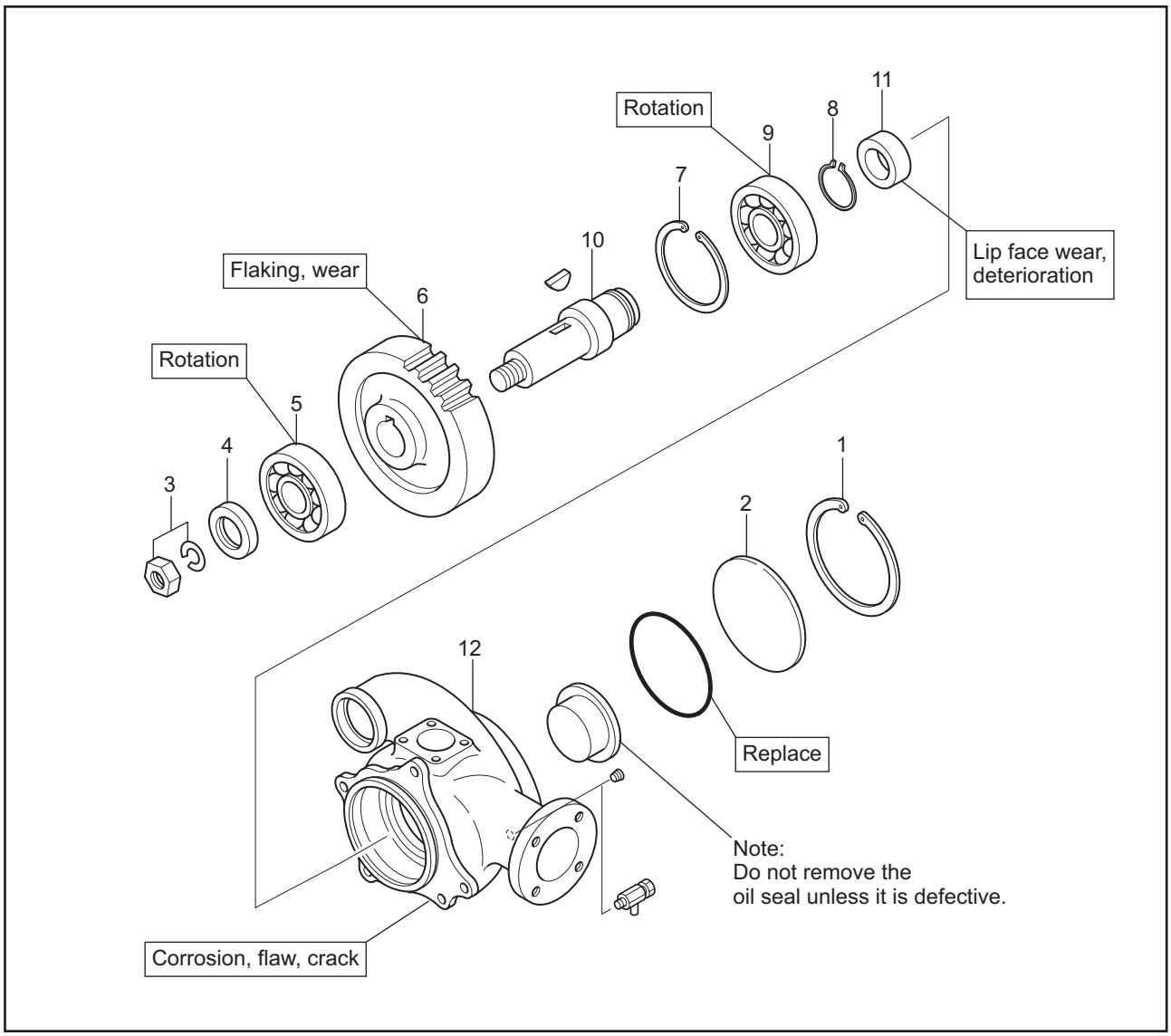
Dummy water pump - Remove

Removal sequence

1 Dummy water pump (weight: approx. 35 kg [77 lb])
2 Joint
3 Bearing cover

2. Cooling System - Disassemble, Inspect, and Assemble

2.1 Dummy Water Pump - Disassemble and Inspect



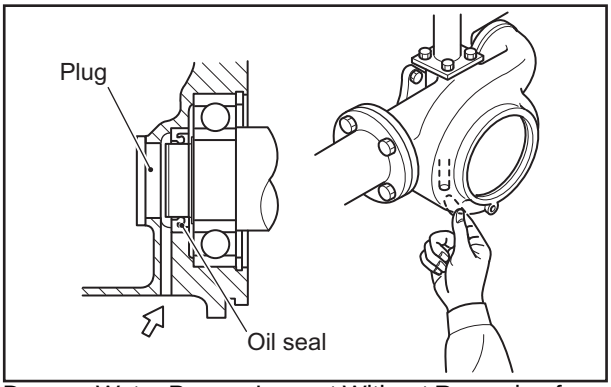
Dummy Water Pump - Disassemble and Inspect

Removal sequence

1 Snap ring
2 Cover
3 Nut (M30 × 1.5)
4 Spacer
5 Ball bearing
6 Head gear
7 Snap ring
8 Snap ring
9 Ball bearing
10 Water pump shaft
11 Oil seal
12 Pump case (approx. 28 kg [62 lb])

2.1.1 Dummy Water Pump - Inspect Without Removing from Engine

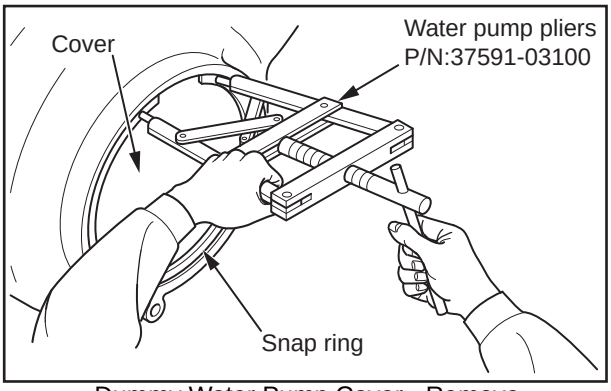
Touch the drain port at the center of the pump case bottom with fingers. If it is wet with water, the plug is defective.



Dummy Water Pump - Inspect Without Removing from Engine

2.1.2 Dummy Water Pump Cover - Remove

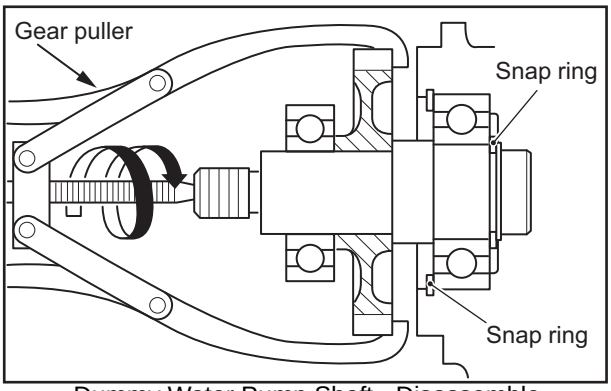
Remove the snap ring that holds the cover using the snap ring pliers, and remove the cover.



Dummy Water Pump Cover - Remove

2.1.3 Dummy Water Pump Shaft - Remove

(1) Remove the nut, spring washer, and spacer.
(2) Remove the gear and ball bearing together using the gear puller.
(3) Remove the snap ring located inside the pump case, and remove the pump shaft together with bearing from the pump case.
(4) Remove the snap ring from the pump shaft, then pull out the bearing.



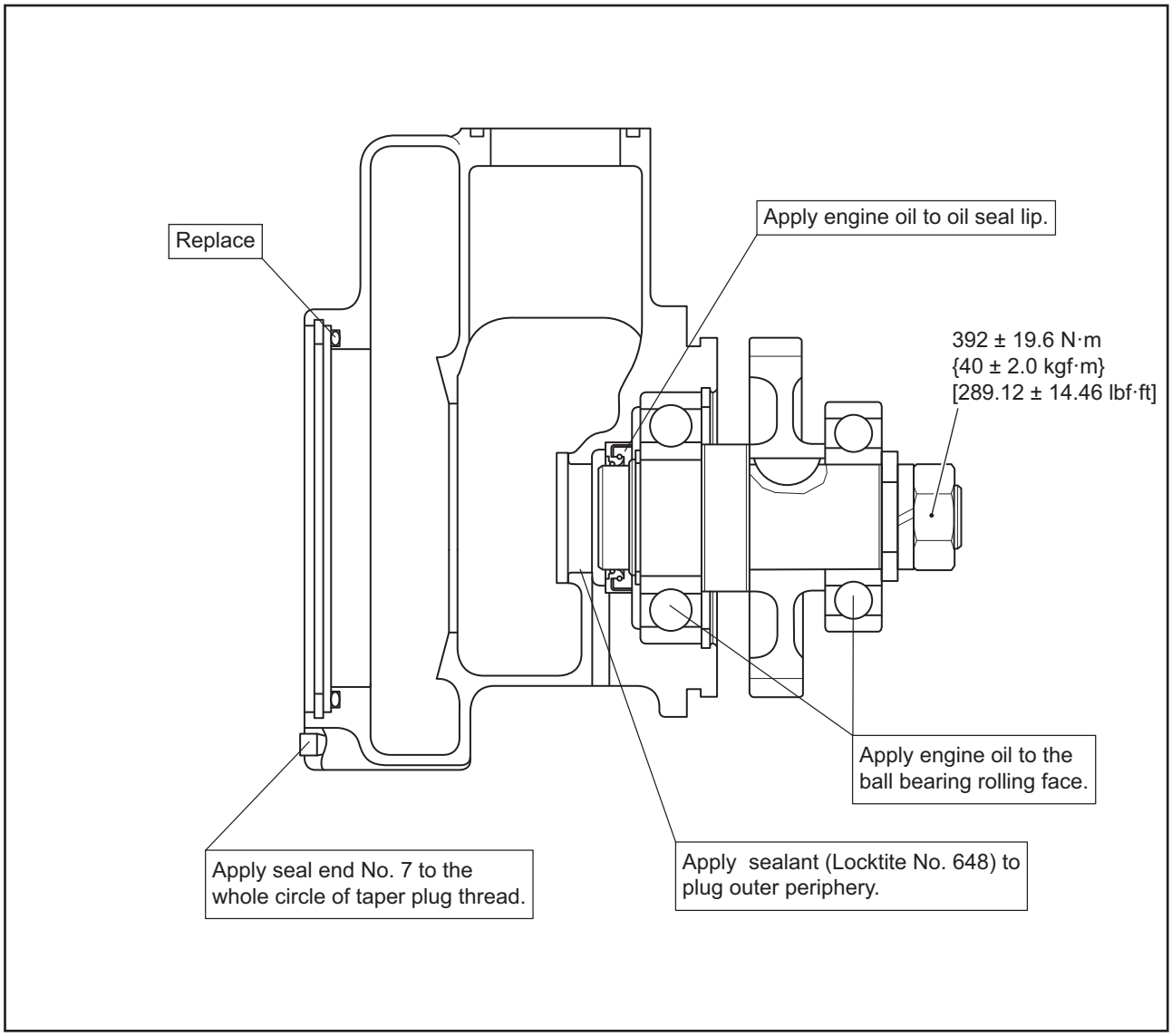
Dummy Water Pump Shaft - Disassemble

2.1.4 Dummy Water Pump - Inspect

Measure the inside diameter of water pump case fit to bearing, and the outside diameter of shaft fit to bearing, and the inside and outside diameters of bearing. If the measurement is out of the standard, replace the part with a new one.

Item			Nominal value	Standard value
Inside diameter of bearing to fit	Pump case		ø120 mm [4.72 in.]	119.987 to 120.022 mm [4.7239 to 4.7253 in.]
	Bearing cover		ø110 mm [4.33 in.]	110.005 to 110.040 mm [4.3309 to 4.3323 in.]
Bearing	Large	Outside diameter	ø120 mm [4.72 in.]	119.985 to 120.000 mm [4.7238 to 4.7244 in.]
		Inside diameter	ø55 mm [ø2.17 in.]	54.985 to 55.000 mm [2.1648 to 2.1654 in.]
	Small	Outside diameter	ø110 mm [4.33 in.]	109.985 to 110.000 mm [4.3301 to 4.3307 in.]
		Inside diameter	ø50 mm [1.97 in.]	49.988 to 50.000 mm [1.9680 to 1.9685 in.]
Outside diameter of shaft to fit bearing			ø55 mm [ø2.17 in.]	55.011 to 55.024 mm [2.1658 to 2.1663 in.]
			ø50 mm [1.97 in.]	50.011 to 50.024 mm [1.9689 to 1.9694 in.]

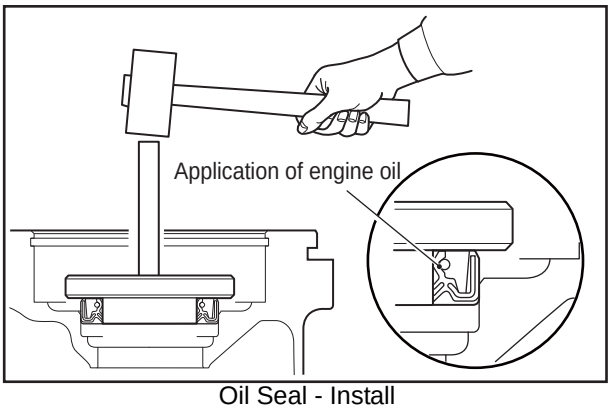
2.2 Dummy Water Pump - Assemble



Dummy Water Pump - Assemble

2.2.1 Oil Seal - Install

(1) Install the oil seal with installer, making sure that oil seal surface is flush with water pump housing face.
(2) Apply engine oil on the oil seal lip.



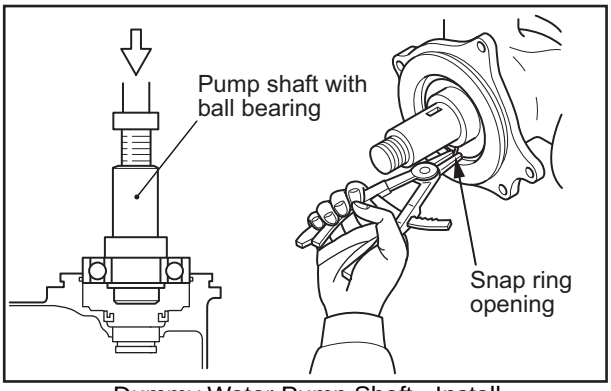
Oil Seal - Install

2.2.2 Dummy Water Pump Shaft - Install

CAUTION

Be careful not to damage the oil seal inside the pump case when press fit the dummy water pump shaft.

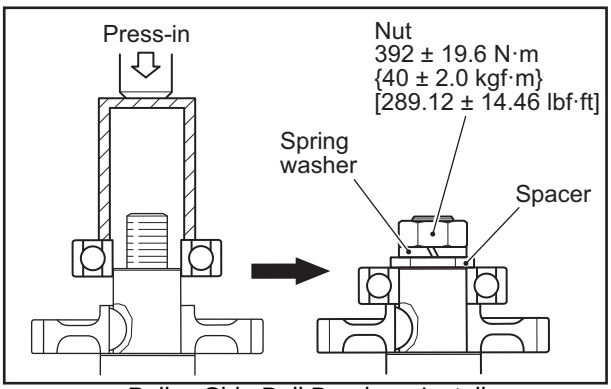
(1) Press the pump case side ball bearing into the dummy water pump shaft, and install the snap ring.
(2) Push the dummy water pump shaft slowly until the end of ball bearing comes into contact with the pump case.
(3) Securely install the snap ring in the groove.



Dummy Water Pump Shaft - Install

2.2.3 Gear and Ball Bearing - Install

(1) Install the gear on the shaft through the key.
(2) Using a press, press-fit the ball bearing on the nut side.
(3) Install the spacer and spring washer.
(4) Take a measure to prevent rotation so as not to damage the gear, and tighten the nut to the specified torque.



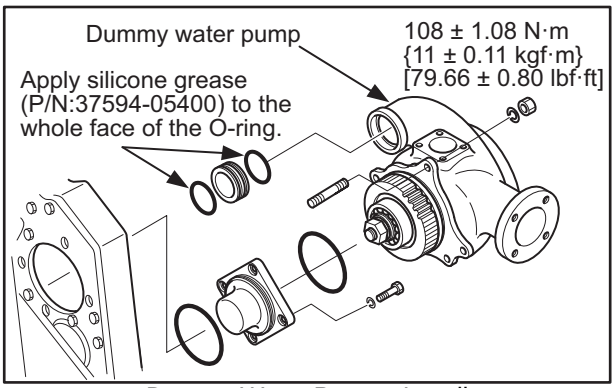
Pulley Side Ball Bearing - Install

3. Cooling System - Install

- To install, follow the removal sequence in reverse. (See the illustration for disassembly.)
- Thoroughly clean and dry the cooling water passage.

3.1 Dummy Water Pump - Install

Tighten the mounting nuts to the specified torque.

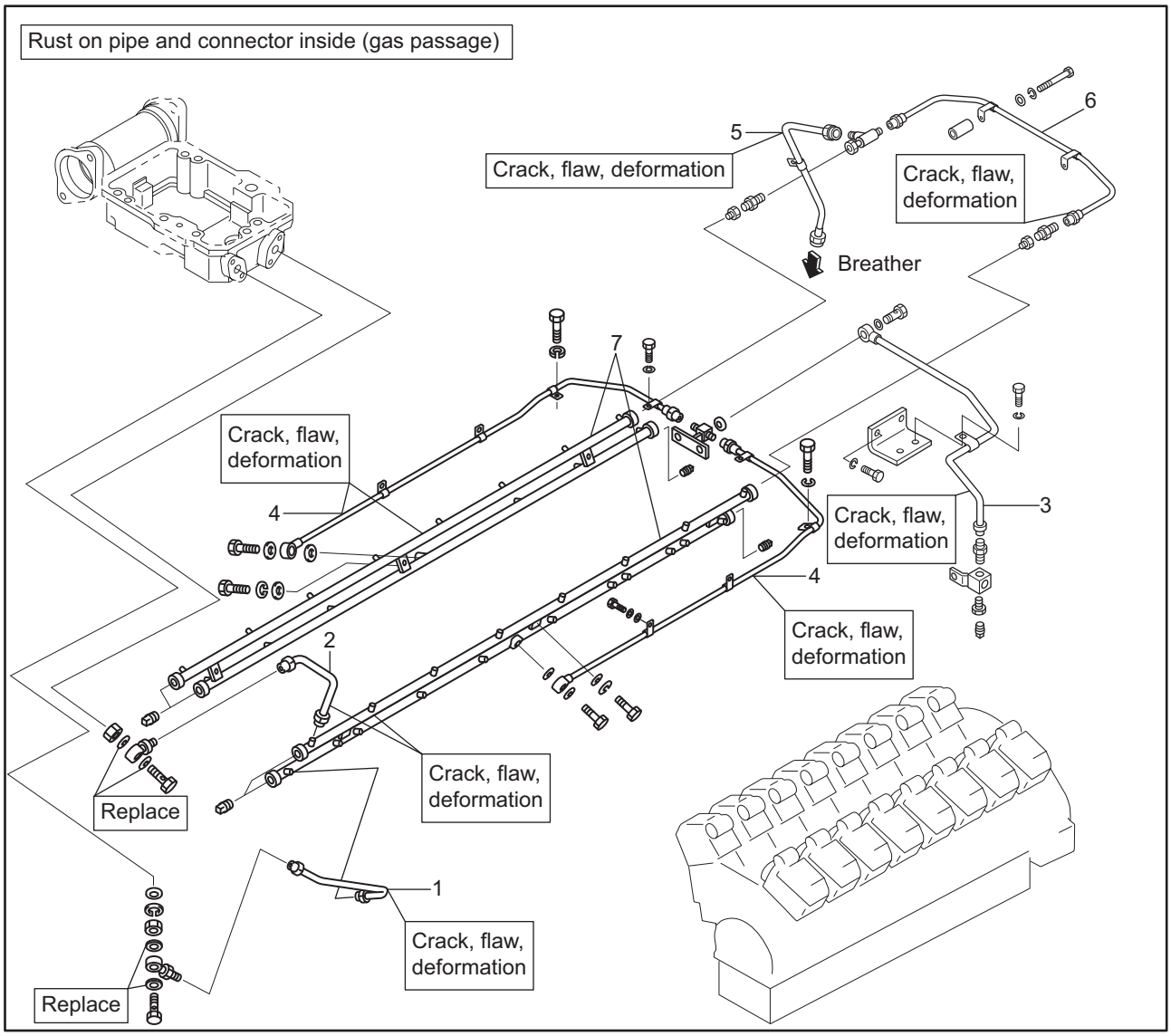


Dummy Water Pump - Install

Chapter 11 INLET AND EXHAUST SYSTEMS

1. Inlet and Exhaust Systems - Remove and Inspect

1.1 Pre-chamber Gas Pipe - Remove

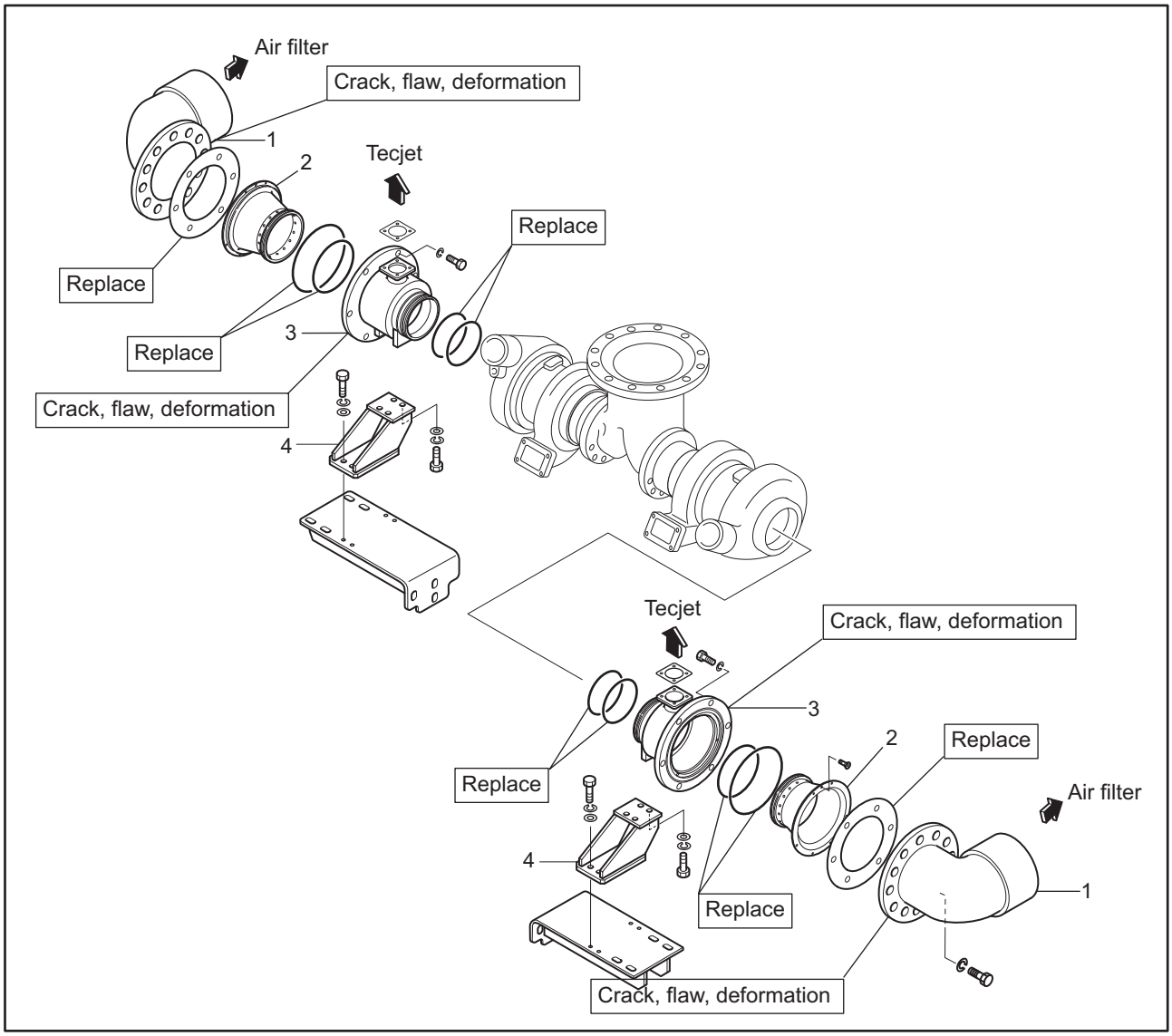


Pre-chamber Gas Pipe - Remove

Removal sequence

1 Gas inlet pipe
2 Gas leak pipe
3 Gas supply pipe
4 Gas pipes (right and left)
5 Gas leak pipe
6 Gas leak pipe (connecting right and left banks)
7 Gas pipe (inlet and leak)

1.2 Carburetor and Air Duct - Remove and Inspect

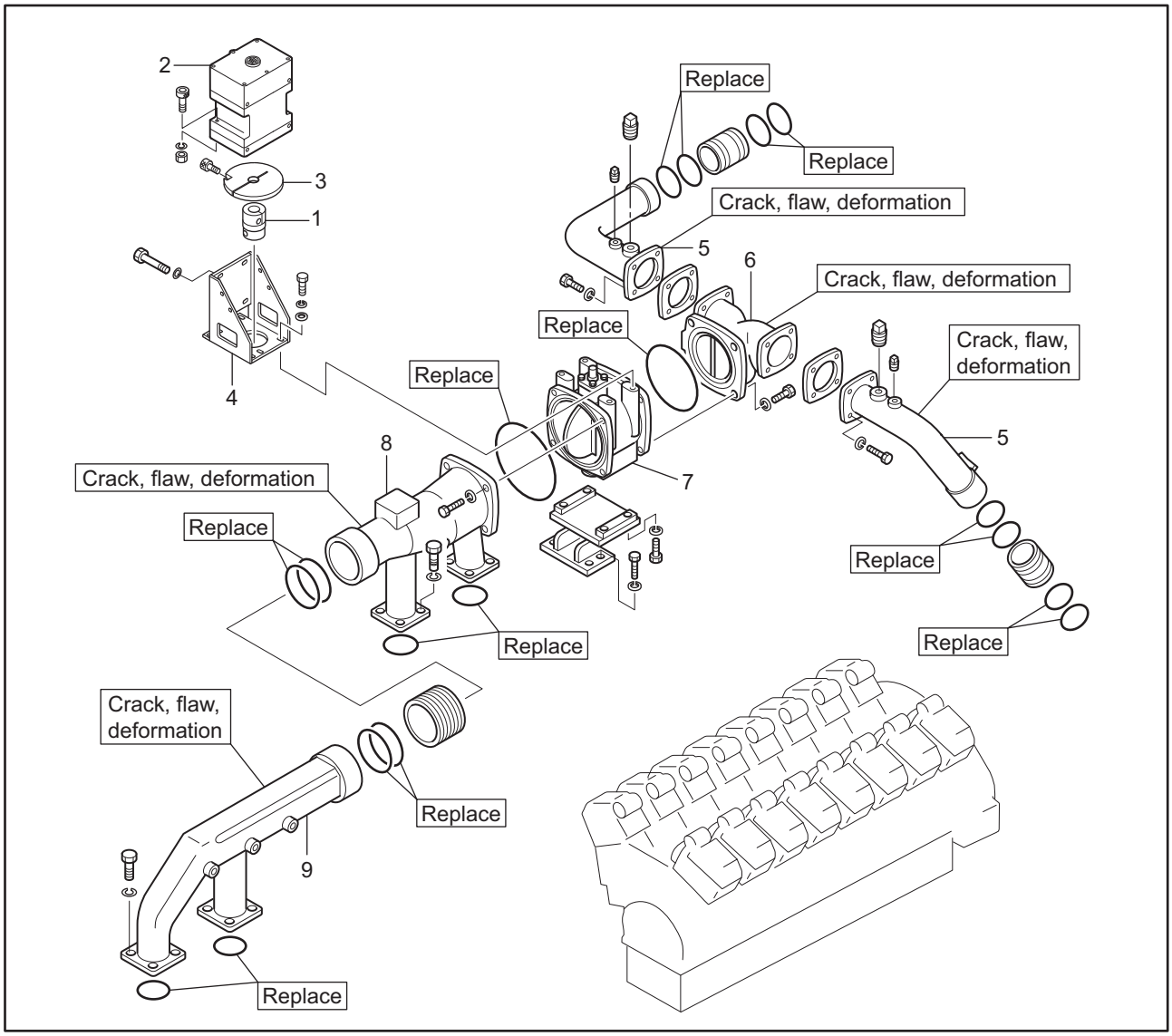


Carburetor and Air Duct - Remove and Inspect

Removal sequence

1 Air duct
2 Carburetor nozzle
3 Carburetor case
4 Bracket

1.3 Governor, Throttle Valve, and Air Duct - Remove and Inspect

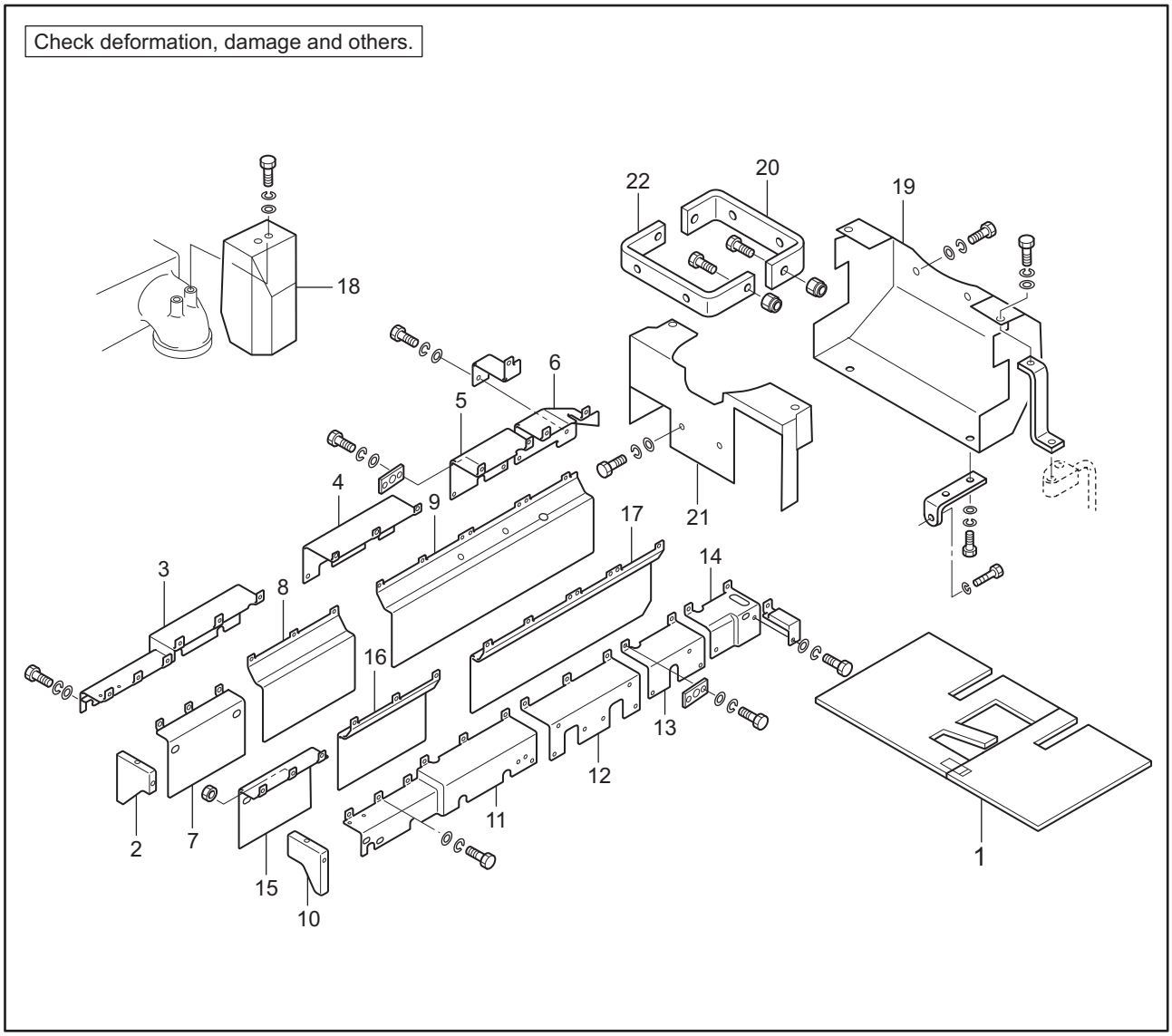


Governor, Throttle Valve, and Air Duct - Remove and Inspect

Removal sequence

1 Coupling
2 Governor actuator
3 Scale plate
4 Bracket
5 Air duct (turbocharger)
6 Air duct (manifold)
7 Throttle valve
8 Air duct (air cooler)

1.4 Insulator - Remove

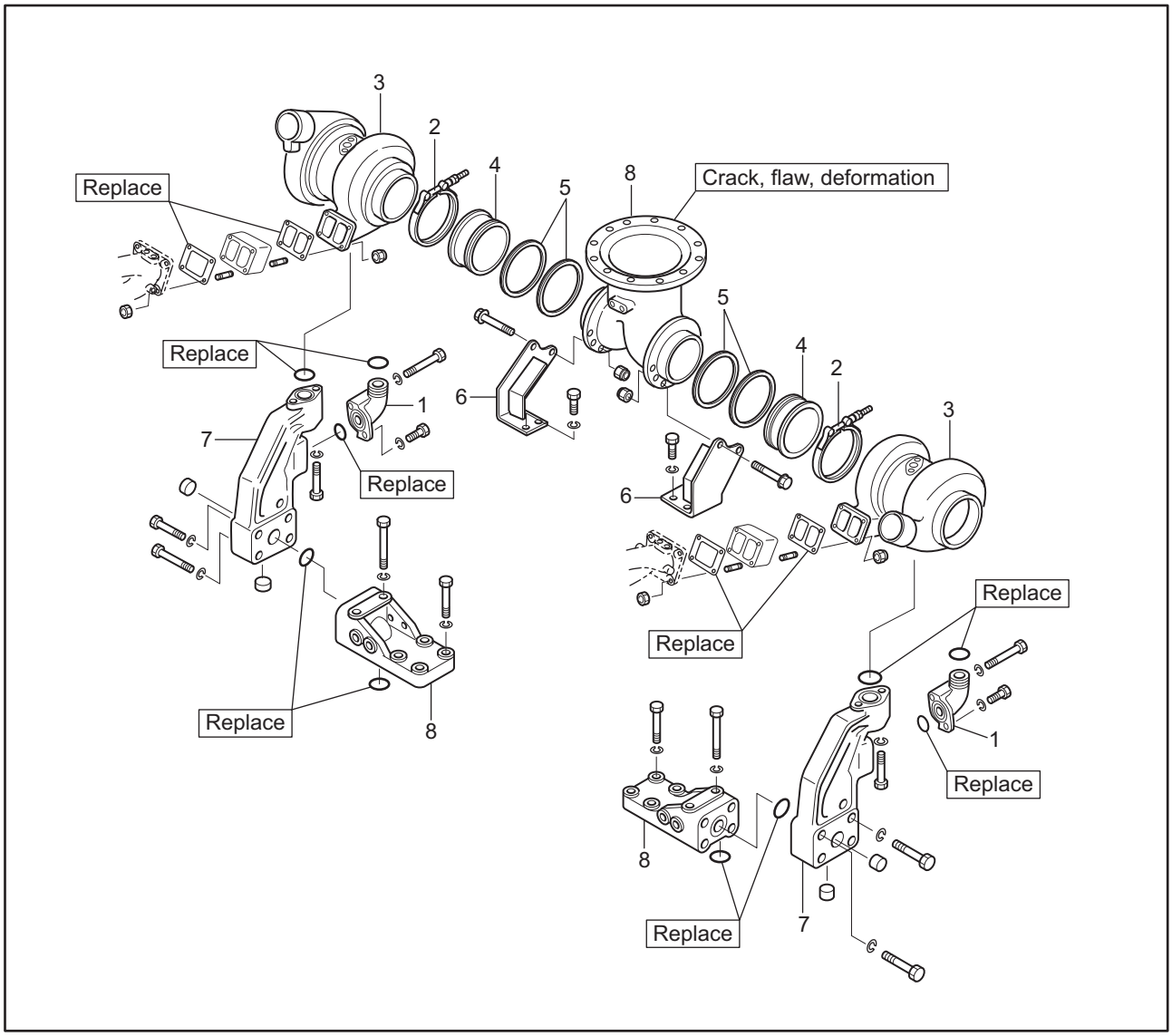


Insulator - Remove

Removal sequence

1 Heat shielding sheet (right and left)
2 Front insulator (#1 and #9)
3 Upper insulator
(Exhaust manifold × Cylinder head)
4 Medium insulator
(Exhaust manifold × Air duct)
5 Lower insulator
(Exhaust connector x air cooler)
6 Turbocharger insulator (front and rear)
7 Stay
8 Inlet port insulator

1.5 Turbocharger and Exhaust Pipe - Remove

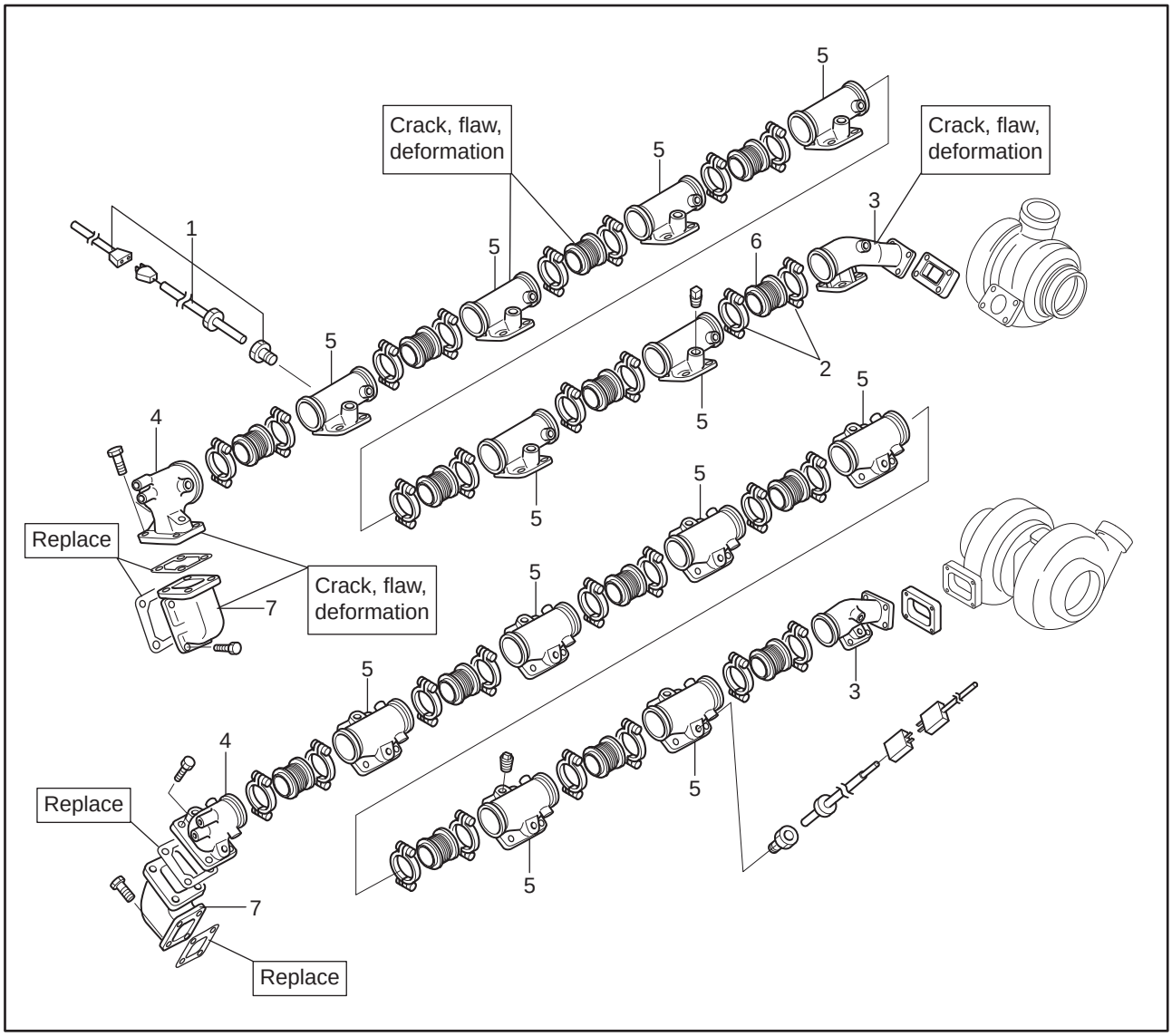


Turbocharger and Exhaust Pipe - Remove

Removal sequence

1 Drain connector
2 V-clamp
3 Turbocharger
4 Coupling
5 Seal ring
6 Stay
7 Bracket
8 Bracket

1.6 Exhaust Manifold (Static Pressure Supercharge Spec) - Remove and Inspect

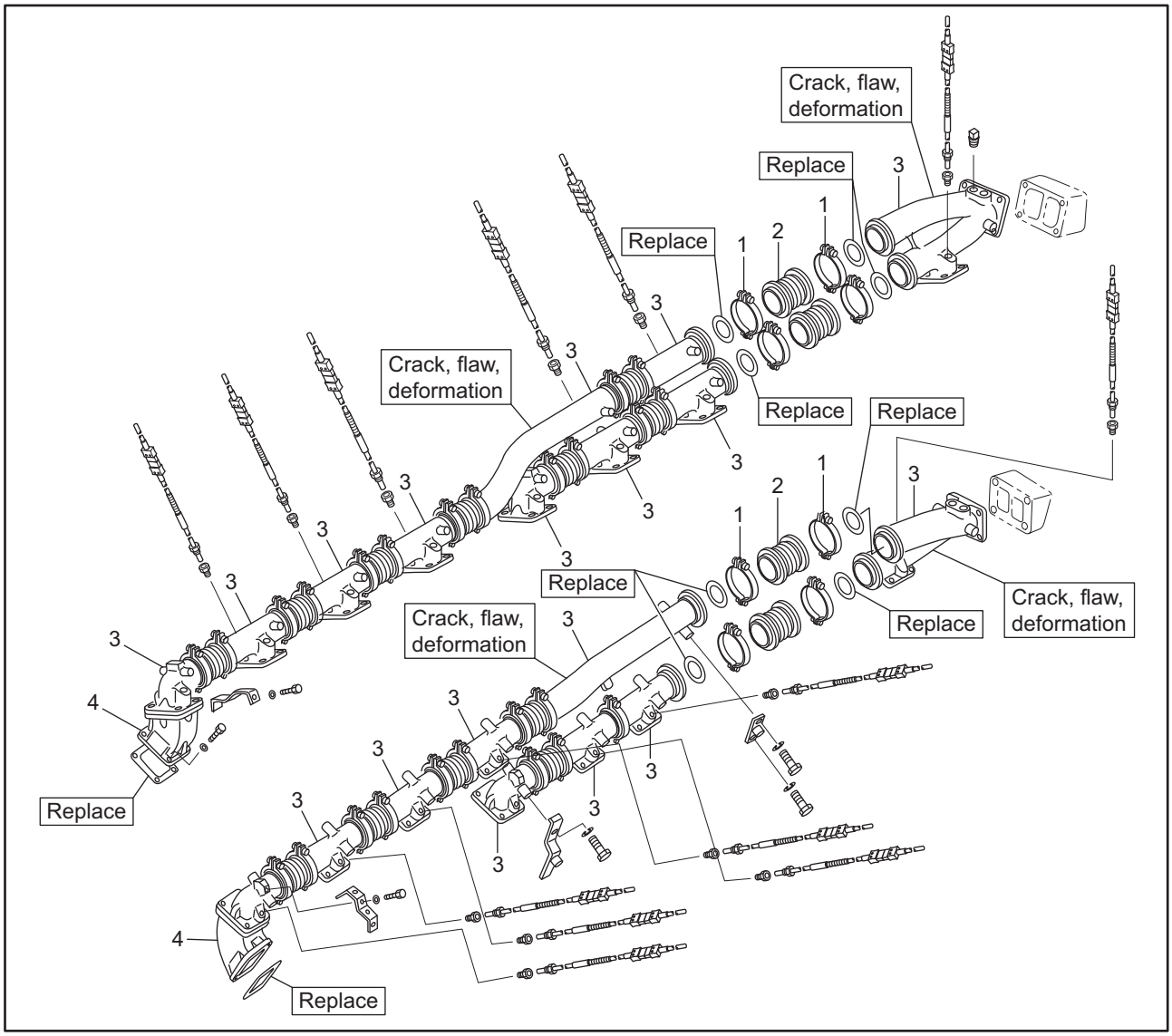


Exhaust Manifold - Remove and Inspect

Removal sequence

1 Thermocouple
2 V-clamp
3 Exhaust manifold (#8 and #16)
4 Exhaust manifold (#1 and #9)
5 Exhaust manifold
6 Flexible joint
7 Connector

1.7 Exhaust Manifold (Dynamic Pressure Supercharge Spec) - Remove and Inspect

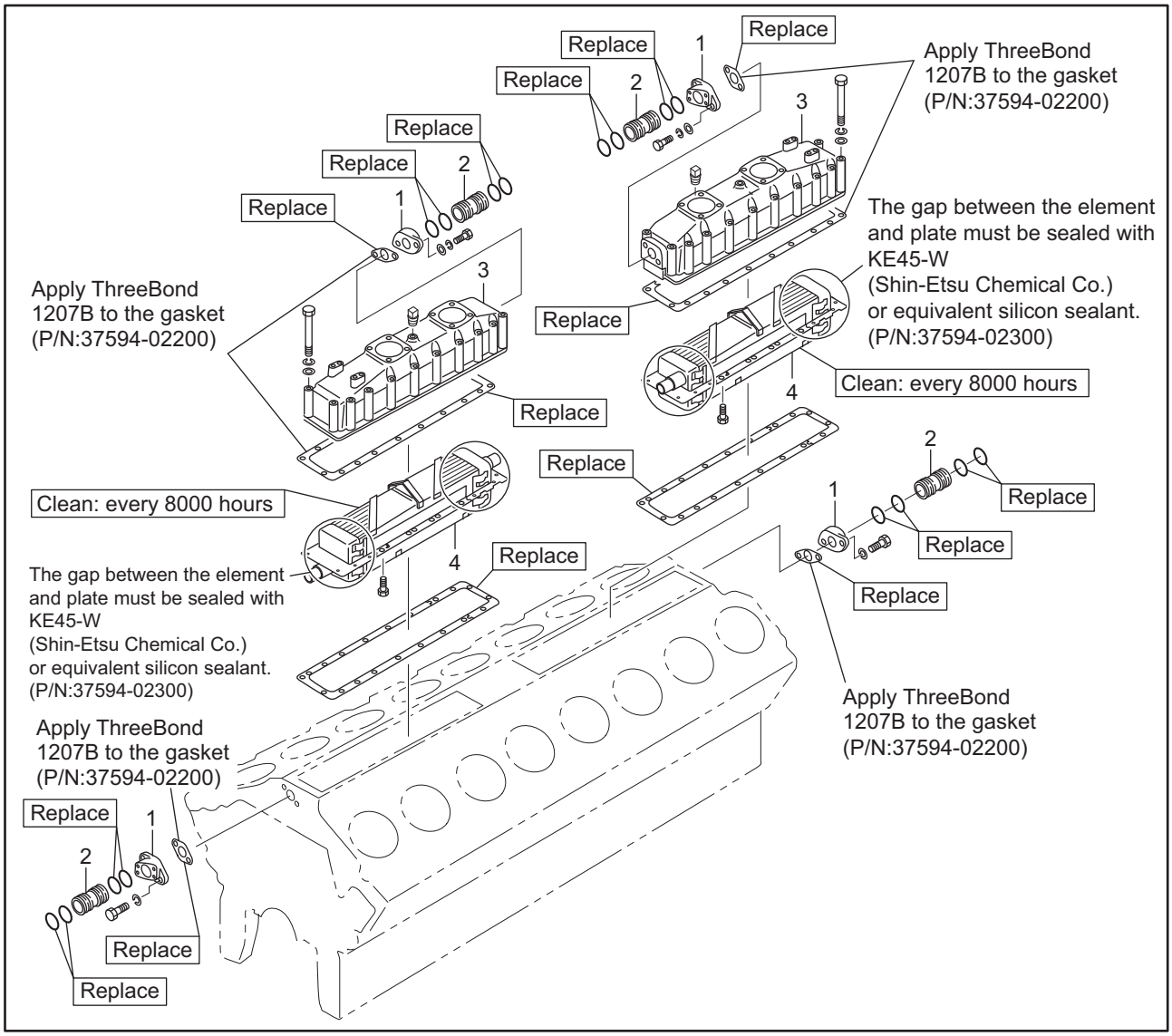


Exhaust Manifold - Remove and Inspect

Removal sequence

1 Coupling
2 Flexible joint
3 Exhaust manifold
4 Exhaust connector

1.8 Air Cooler - Remove and Inspect



Air Cooler - Remove and Inspect

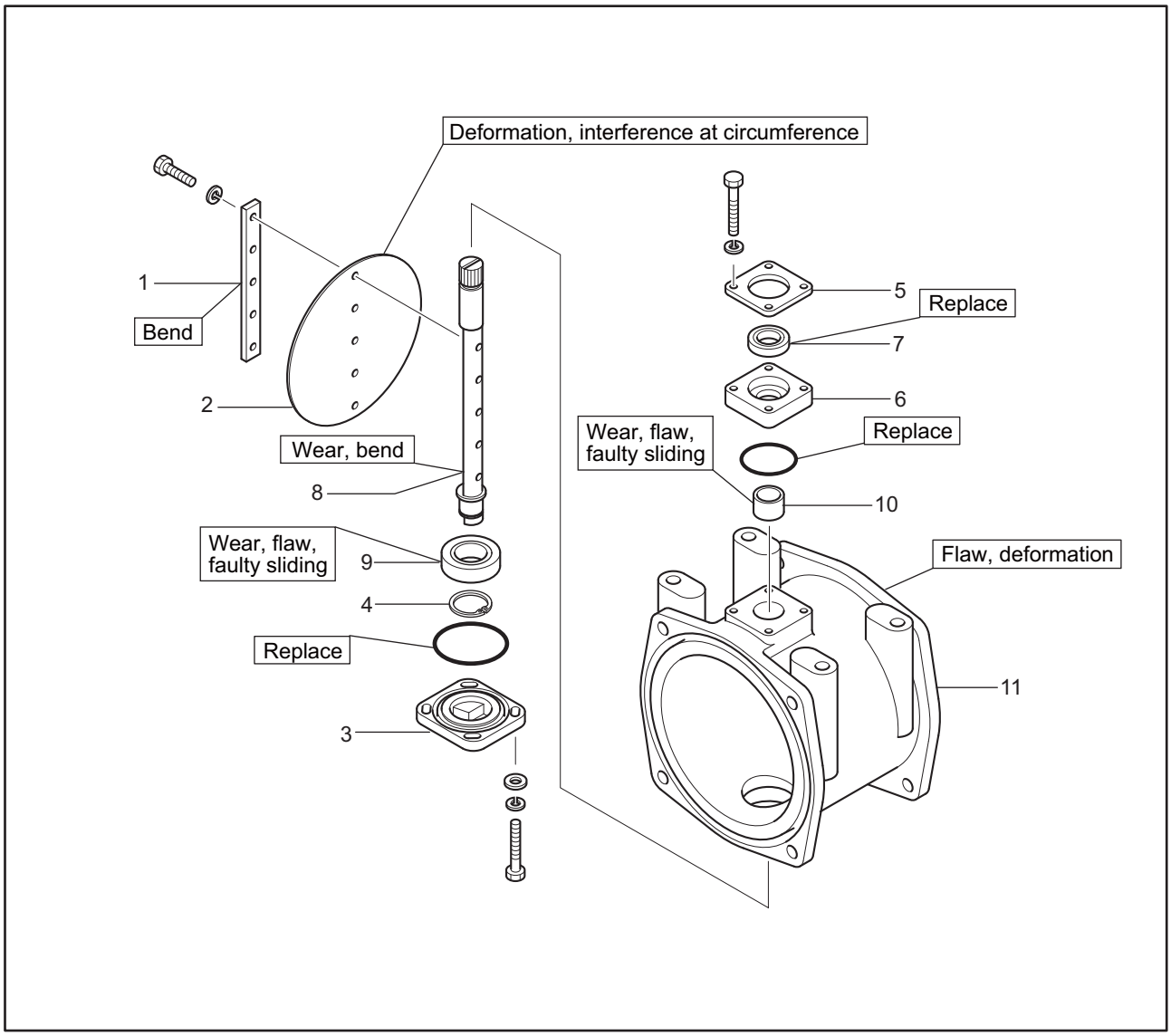
Removal sequence

1 Connector
2 Pipe
3 Air cooler cover
4 Air cooler element

2. Inlet and Exhaust Systems - Disassemble, Inspect, and Assemble

2.1 Throttle Valve - Disassemble, Inspect, and Assemble

2.1.1 Throttle Valve - Disassemble and Inspect



Throttle Valve - Disassemble and Inspect

Disassembly sequence

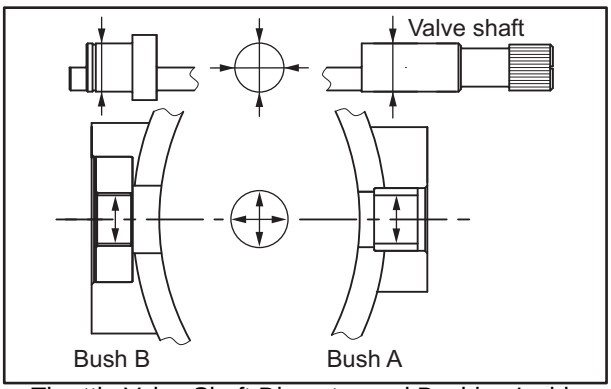
1 Plate
2 Valve
3 Cover
4 Snap ring
5 Back plate
6 Seal case
7 Oil seal
8 Valve shaft
9 Bushing B
10 Bushing A
11 Valve case

Note: Do not disassemble the bushings A and B unless necessary.

2.1.2 Throttle Valve Shaft Diameter and Bushing Inside Diameter - Measure

The throttle valve and bushing tend to be worn in a specific direction by the effect of pressure distribution of fuel air mixture. Measure at the maximum worn position and its perpendicular direction.

Item	Nominal value	Standard value	Limit value
Shaft diameter	ø20 mm [0.79 in.]	19.991 to 20.000 mm [0.7870 to 0.7874 in.]	19.96 mm [0.7858 in.]
Bushing-A inside diameter	ø20 mm [0.79 in.]	20.038 to 20.096 mm [0.7889 to 0.7912 in.]	20.25 mm [0.7972 in.]
Bushing-B inside diameter	ø20 mm [0.79 in.]	20.040 to 20.107 mm [0.7890 to 0.7916 in.]	20.50 mm [0.8071 in.]

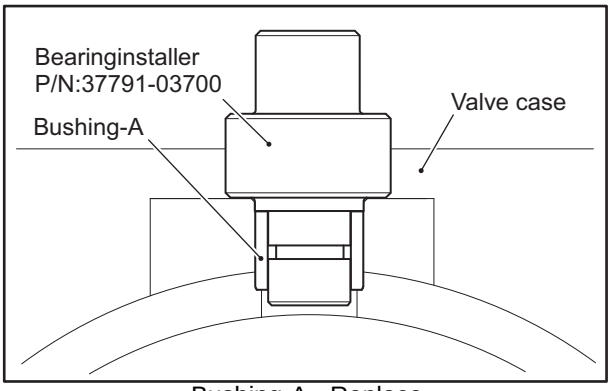


Throttle Valve Shaft Diameter and Bushing Inside Diameter - Measure

2.2 Throttle Valve - Assemble

2.2.1 Bushing-A - Replace

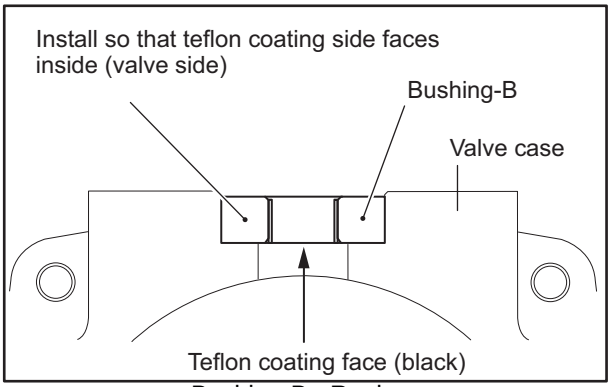
(1) Push the end of the bushing-A from inside to remove.
(2) Install the bushing-A using a bearing installer.



Bushing-A - Replace

2.2.2 Bushing-B - Replace

(1) Push the end of the bushing-B from inside to remove.
(2) Face the teflon coated face of bushing-B toward the inside (valve side) and push the bushing until it contacts the valve case.



Bushing-B - Replace

2.2.3 Throttle Valve - Install

CAUTION

Adjust the throttle valve to allow its smooth movement through the moving range without interfering with the case.

(1) Install the shaft cover on the case.
Position the stopper plate inside the cover as shown in the illustration, and tentatively tighten the plate.

(2) Install the shaft in bushing-A and bushing-B.

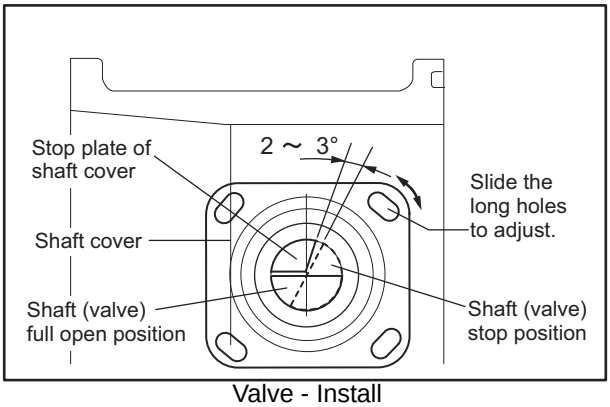
(3) Install the throttle valve on the shaft, and tentatively tighten.

(4) Adjust the clearance between the valve outer periphery and case so that the clearance is equal in vertically and horizontally when the shaft is in the closed stop position. (Upper and lower clearance: 0.6 to 0.9 mm [0.024 to 0.035 in.], right and left equally adjusted)

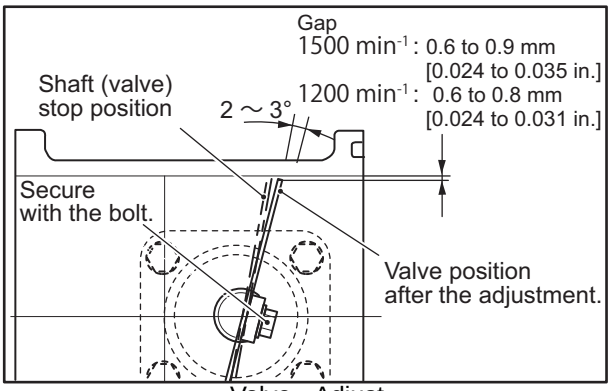
Note:(a) Adjust the stopping position of shaft within the oval hole area on shaft cover.

(b) Correct uneven clearance of the valve outer periphery by loosing the valve set bolt.

(5) Make sure the valve moves smoothly without interference with case, then tighten the bolts of cover and valve.



Valve - Install



Valve - Adjust

2.3 Air Cooler - Inspect

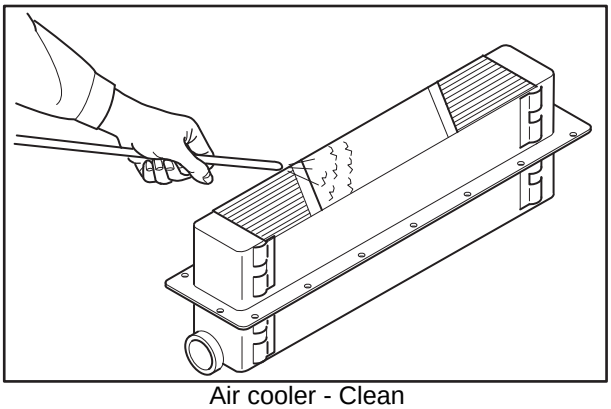
2.3.1 Air Cooler - Clean

⚠ CAUTION

When handling sodium hydroxide (caustic soda) or soda lime, always use a hand protection such as rubber gloves.

(1) Blow compressed air (at a pressure of 0.29 to 0.49 MPa {3 to 5 kgf/cm^2} [42 to 71 psi] or less) through the air cooler in the opposite direction to the normal air flow (from below in the assemble condition) to remove the accumulation of dust and dirt. Then, inspect for corrosion and cracks.

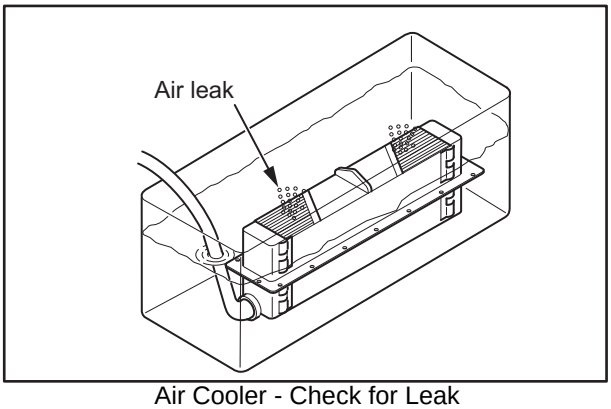
(2) Flush the fresh water pipes thoroughly with water holding sodium hydroxide (caustic soda) or soda lime in solution to remove scales.



Air cooler - Clean

2.3.2 Air Cooler - Check for Leak

Immerse the air cooler in a water tank, and apply compressed air pressure (0.39 MPa {4 kgf/cm^2} [57 psi]) to the coolant side to check the leak.



Air Cooler - Check for Leak

3. Inlet and Exhaust Systems - Install

♦To install, follow the removal sequence in reverse. (See the illustration for disassembly.)

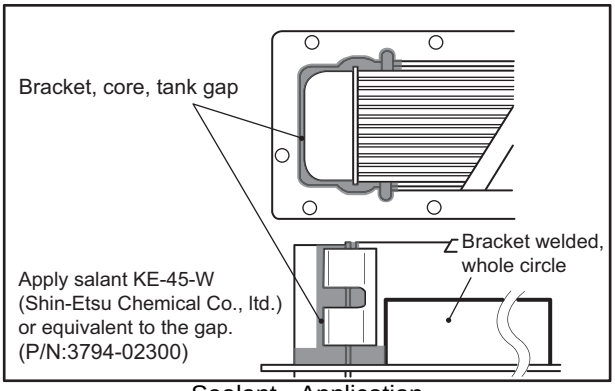
♦Be careful not to deform the V-clamp.

3.1 Air cooler - Install (When Sealant Is Applied)

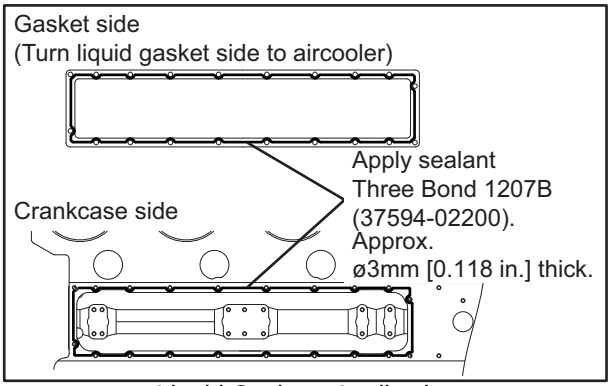
(1) When the reuse is not available even after retouching, remove the sealant, and apply silicone sealant on the positions on air inlet side of element for sealing up as shown in the illustration.
○ Clearance between bracket, core, and tank (shown in grey color)
○ Whole periphery of bracket welding (thick line)

(2) Apply liquid gasket on the mounting faces of element, crank case and others as shown, and install.

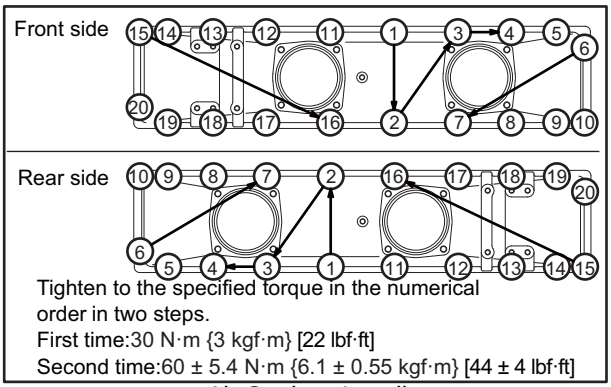
(3) Tighten the mounting bolts to the specified torque.



Sealant - Application



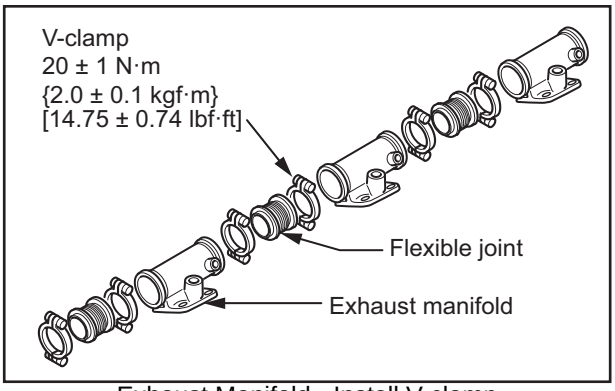
Liquid Gasket - Application



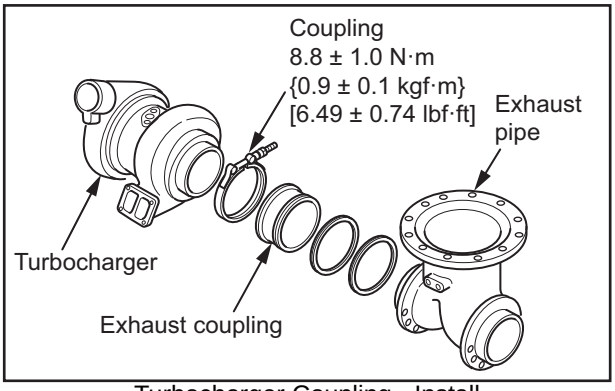
Air Cooler - Install

3.2 Exhaust Manifold V-clamp and Turbocharge Coupling - Install

(1) Apply MOLYKOTE (molybdenum disulfide anti-seize) or equivalent on the bolt.
(2) Tighten the nuts to the specified torque.
(3) Lightly shake the outer circumference of V-clamp and coupling to make a snug contact between the each mating face and the V-clamp/coupling tapered face.
(4) Re-tighten the nut to the specified torque.
(5) Lightly shake again to check the loose bolt.



Exhaust Manifold - Install V-clamp



Turbocharger Coupling - Install

3.3 Actuator and Throttle Valve Coupling - Install

(1) Install the pointer on the bottom of actuator.

(2) Install the scale plate on the actuator shaft. Turn the actuator shaft fully anti-clockwise, place the 0 position of scale plate to the pointer 0, and tighten the hexagon socket bolt of the plate to the specified torque. Then, make sure the clearance between the scale plate and the actuator is 4 mm.

(3) Install the actuator on the bracket, and tighten the bolts to the specified torque.

(4) Tentatively assemble by connecting the coupling to the actuator shaft.

(5) Install the actuator shaft with the bracket aligning with the coupling hole of throttle valve.

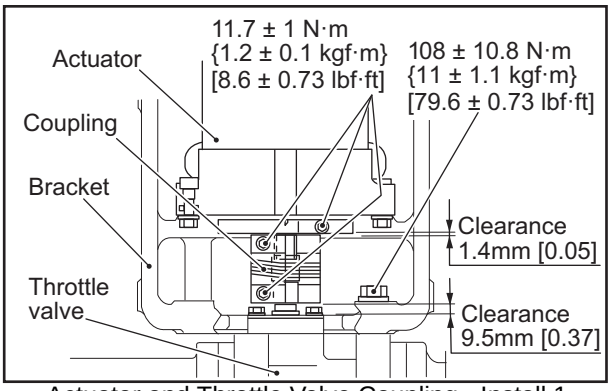
(6) Temporarily tighten the bolts on coupling the throttle valve side only.

(7) Align the throttle valve shaft and actuator shaft, and tighten the bracket fixing bolts of actuator bracket to the specified torque. Rotate the throttle valve assembly and actuator shaft by hand, and verify that the actuator shaft and coupling shaft hole do not interfere with each other. (Smooth rotation is attained if the alignment is correct.)

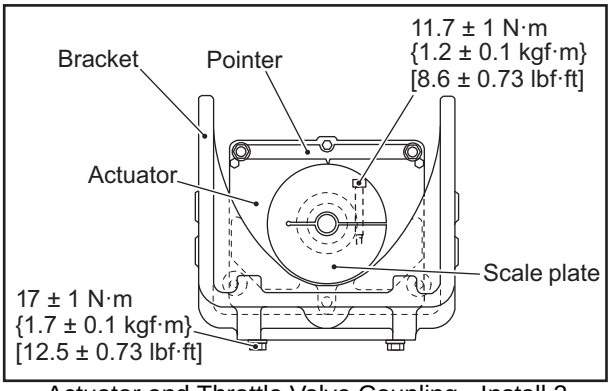
(8) Tighten the remaining hexagon socket bolts on the actuator side temporarily aligning the actuator 0 (position) and throttle valve fully closed 0 (position). In this job, adjust the actuator stopper to be stopped before the throttle stopper, and the valve remains to be opened by 1 to 2 degrees. (If the throttle stopper is stopped before the actuator stopper, excessive stress is applied to the coupling.)

(9) Make sure the coupling is free from detrimental deflection, and the clearances on both sides are within the specifications. And then, tighten the bolts to the specified torque.

(10) Rotate the coupling by hand after the assembling, and verify the smooth movement of the valve.



Actuator and Throttle Valve Coupling - Install 1



Actuator and Throttle Valve Coupling - Install 2

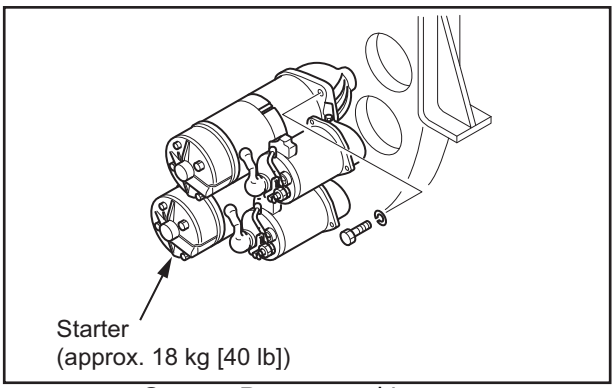
Chapter 12 ELECTRICAL SYSTEM

1. Electrical System - Remove and Inspect

1.1 Starter - Remove and Inspect

(1) Disconnect the harness.

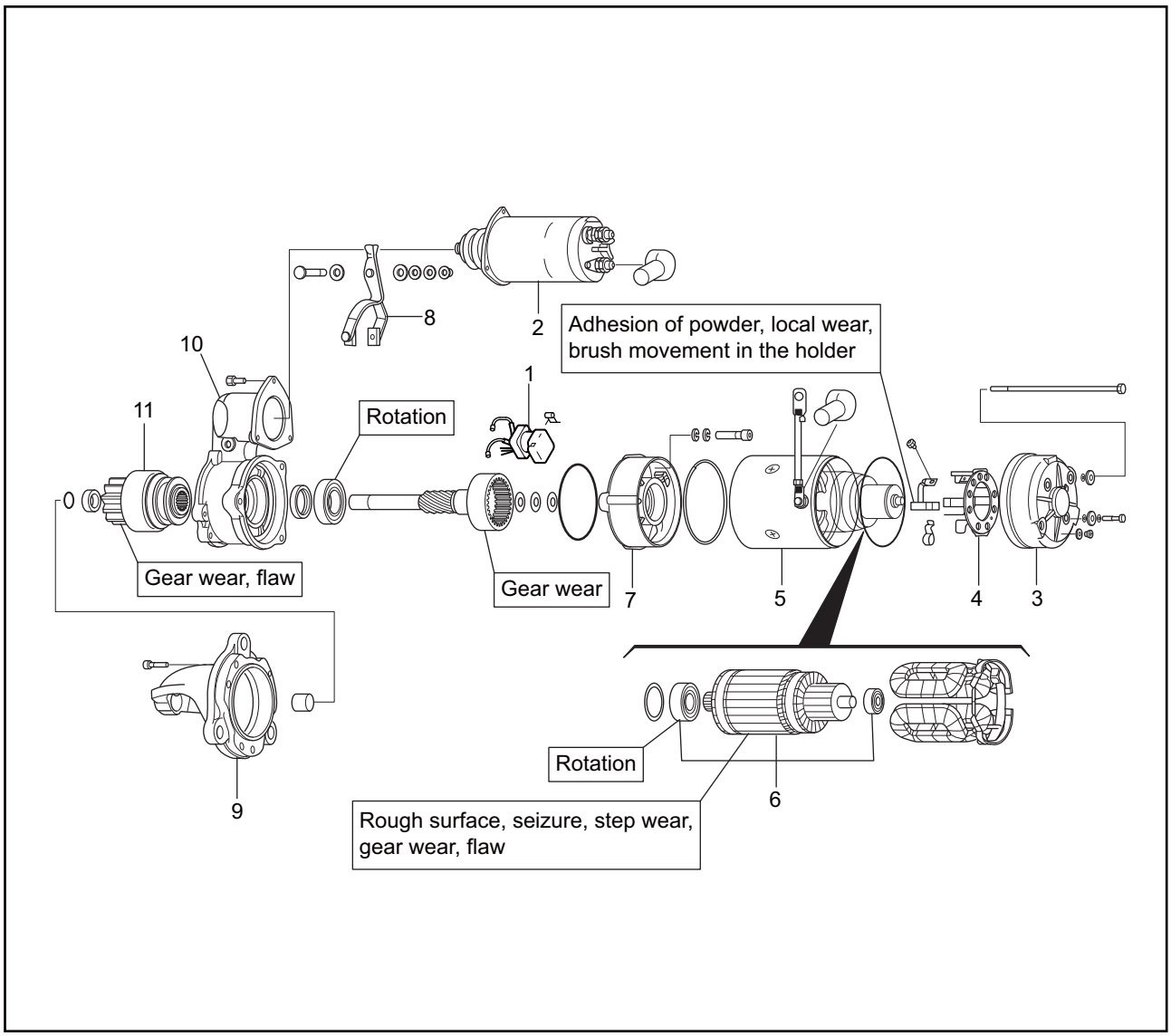
(2) Remove the starter.



Starter - Remove and Inspect

2. Electrical System - Disassemble, Inspect and Assemble

2.1 Starter - Disassemble and Inspect



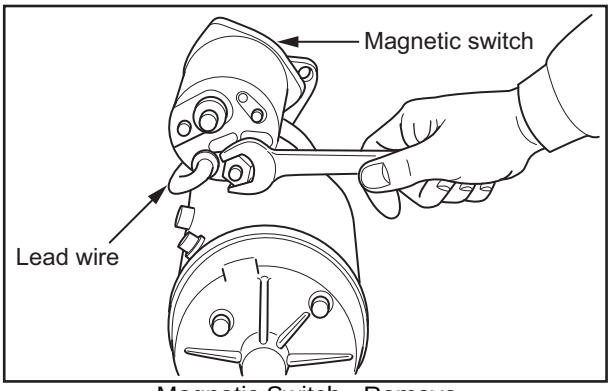
Starter - Disassemble and Inspect

Disassembly sequence

1 Safety switch
2 Magnetic switch assembly
3 Rear bracket
4 Brush holder assembly
5 Yoke assembly
6 Armature assembly
7 Center bracket
8 Lever assembly
9 Front bracket
10 Pinion case
11 Pinion clutch assembly

2.1.1 Magnetic Switch - Remove

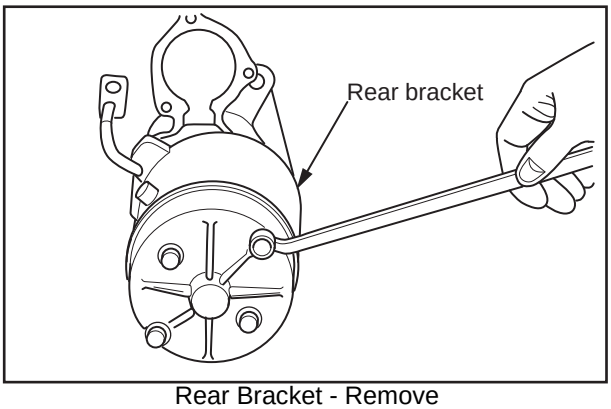
Disconnect the safety switch and leads, and remove the magnetic switch.



Magnetic Switch - Remove

2.1.2 Rear Bracket - Remove

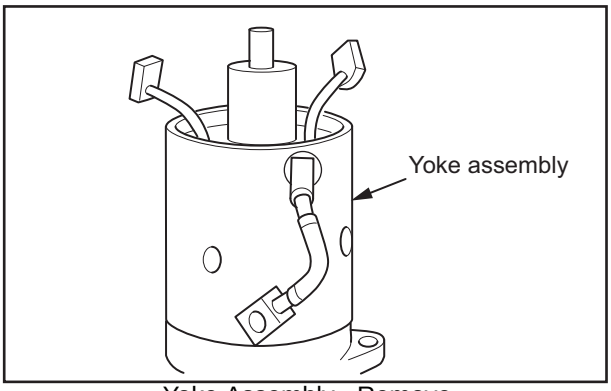
Remove the through bolts and screws of the brush holder, and then remove the rear bracket.



Rear Bracket - Remove

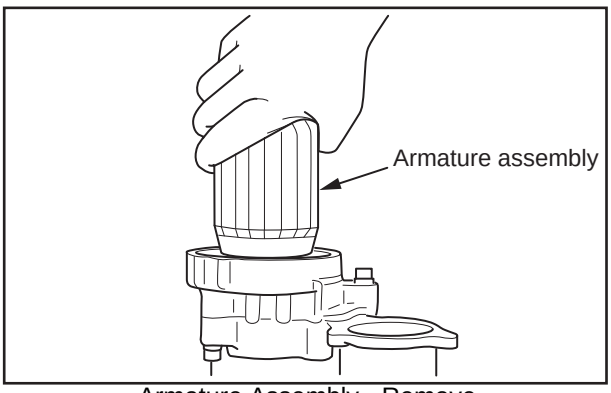
2.1.3 Armature and Yoke Assembly - Remove

(1) Remove the brushes from the brush holder assembly, then remove the yoke.



Yoke Assembly - Remove

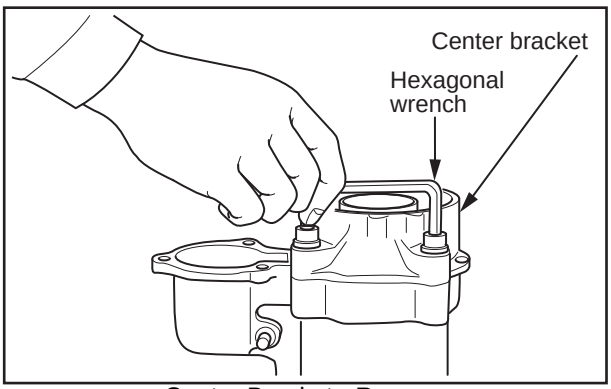
(2) Pull out the armature assembly.



Armature Assembly - Remove

2.1.4 Center Bracket - Remove

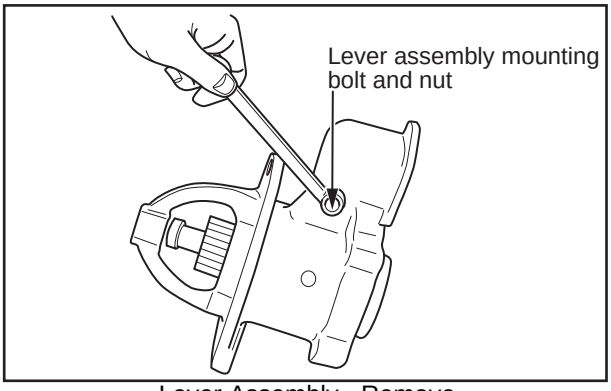
Remove the center bracket.



Center Bracket - Remove

2.1.5 Pinion Set - Remove

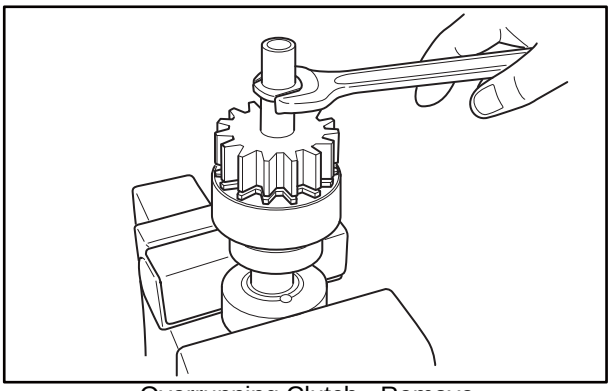
(1) Remove the lever pin, the inner housing, and the shift lever from the pinion case.



Lever Assembly - Remove

(2) Detach the pinion stopper, and then remove the overrunning clutch.

Measure the diameter of pinion shaft at bearing fitting face. If the measured value does not meet the standard, replace the pinion shaft with a new one.

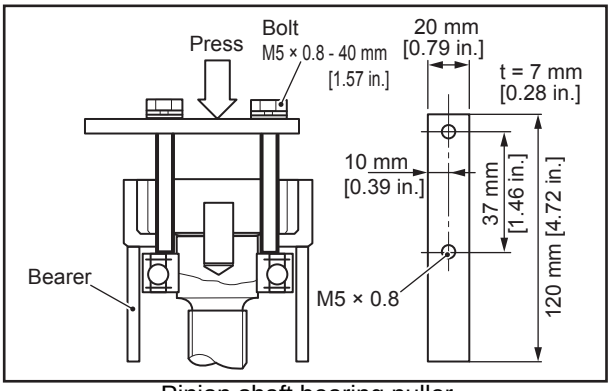


Overrunning Clutch - Remove

Item		Nominal value	Standard value
Pinion shaft	Rear shaft outside diameter	ø30 mm [1.18 in.]	30.002 to 30.011 mm [1.1812 to 1.1815 in.]
	Pinion stopper diameter on front end	ø18 mm [0.71 in.]	17.997 to 18.005 mm [0.7085 to 0.7089 in.]

Note: The pinion stopper can be removed by turning clockwise (in the reverse direction to normal).

To replace the pinion shaft bearing, the use of a bearing puller tool shown in the illustration is recommended.

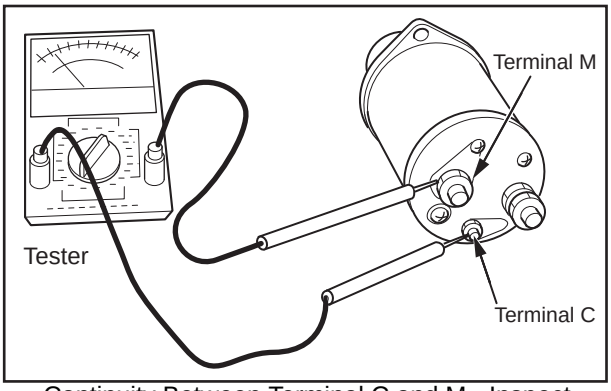


Pinion shaft bearing puller

2.2 Starter - Inspect and Repair

2.2.1 Magnetic Switch Coil Continuity - Inspect (Between M terminal and C terminal)

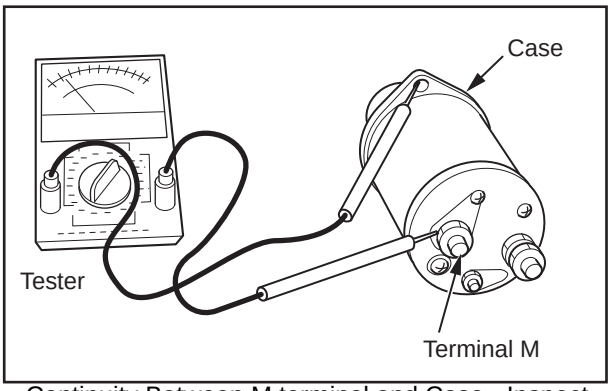
Check the continuity between M terminal and C terminal. If defective, replace the magnetic switch with a new one.



Continuity Between Terminal C and M - Inspect

2.2.2 Magnetic Switch Continuity - Inspect (Between M terminal and Case)

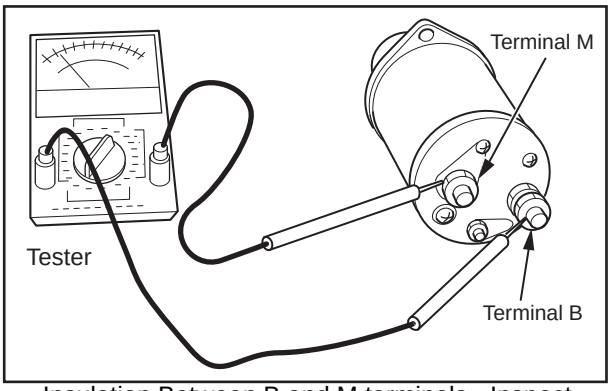
Check the continuity between M terminal and the case. If defective, replace the magnetic switch with a new one.



Continuity Between M terminal and Case - Inspect

2.2.3 Insulation of Magnetic Switch - Inspect (Between M and B Terminals)

Make sure there is no continuity between the M terminal and the B terminal. If defective, replace the magnetic switch with a new one.

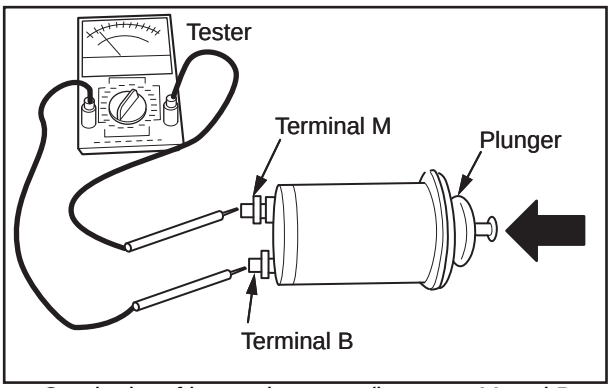


Insulation Between B and M terminals - Inspect

2.2.4 Magnetic Switch Continuity - Inspect (Between M and B Terminals)

(1) Push the plunger so as to bring the contact point inside to the closed position.

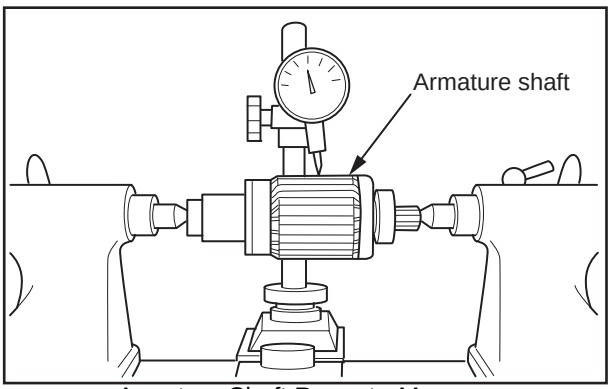
(2) Check that there is continuity between the M terminal and the B terminal. If defective, replace the magnetic switch with a new one.



Continuity of internal contact (between M and B terminals) - Inspect

2.2.5 Armature Shaft Runout - Measure

Using a dial gauge, measure the shaft runout. If the runout exceeds the standard, repair or replace the armature.



Armature Shaft Runout - Measure

2.2.6 Armature Shaft Bearing Fitting Face - Measure

Measure the diameter of armature shaft at the bearing fitting face. If the measured value exceeds the limit, replace the armature with a new one.

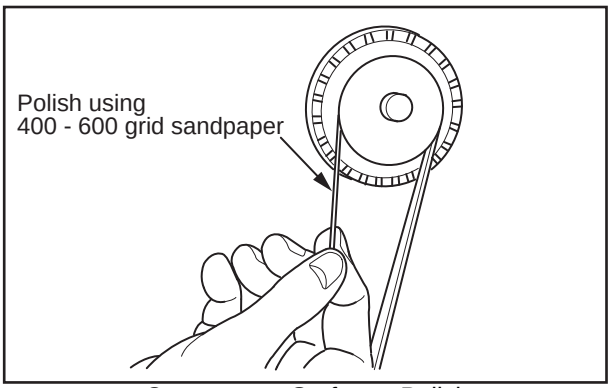
Item	Standard value
Armature shaft runout	0.05 mm [0.0020 in.] or less

Item		Nominal value	Standard value
Armature	Front shaft outside diameter	ø20 mm [0.79 in.]	20.002 to 20.011 mm [0.7875 to 0.7878 in.]
	Rear shaft outside diameter	ø10 mm [0.39 in.]	10.001 to 10.007 mm [0.3937 to 0.3940 in.]

2.2.7 Commutator Runout - Measure

(1) Inspect the commutator surface. If the surface is rough, polish it using a 400 to 600 grit sandpaper.

(2) Measure the commutator runout with a dial gauge. If the measured value exceeds the limit, replace the armature with a new one.

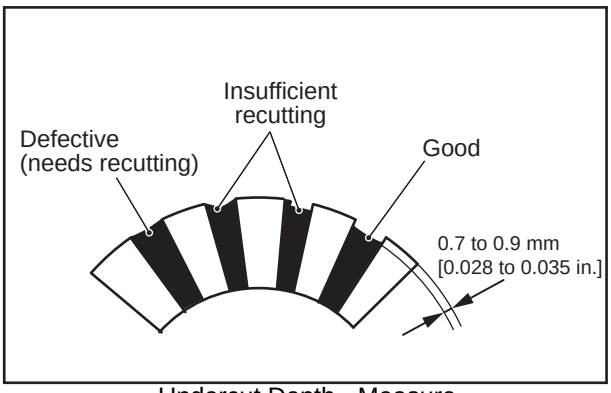


Commutator Surface - Polish

Item	Standard value	Limit value
Commutator runout	0.06 mm [0.0024 in.] or less	0.10 mm [0.0039 in.]

2.2.8 Undercut Depth - Measure

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



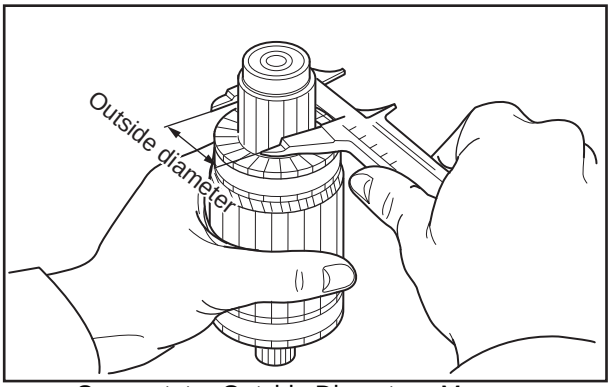
Undercut Depth - Measure

Item	Standard value	Limit value
Undercut depth	0.7 to 0.9 mm [0.028 to 0.035 in.]	0.2 mm [0.008 in.]

2.2.9 Commutator Outside Diameter - Measure

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

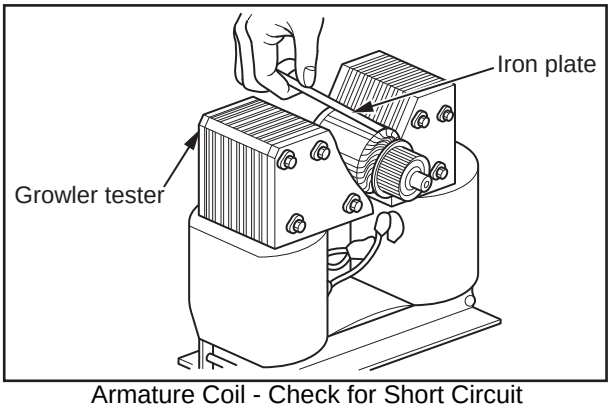
Item	Nominal value	Limit value
Commutator outside diameter	ø 43 mm [1.69 in.]	42 mm [1.65 in.]



Commutator Outside Diameter - Measure

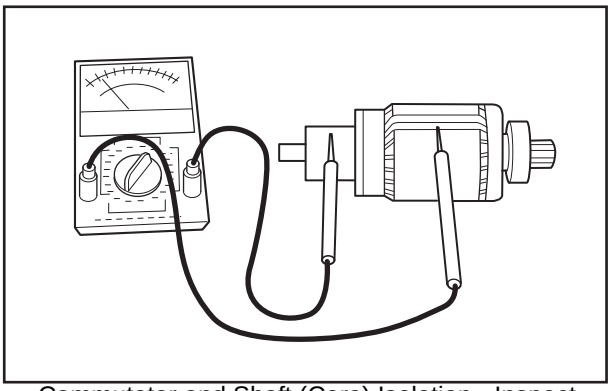
2.2.10 Armature Coil - Inspect

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



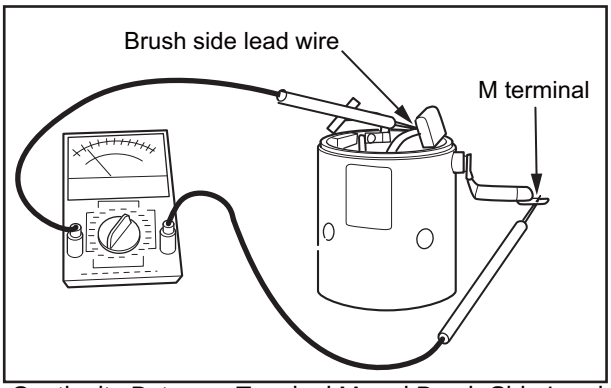
Armature Coil - Check for Short Circuit

(2) Check that the commutator and the shaft (core) are isolated. If any continuity is observed, replace the armature with a new one.
(3) Check that there is continuity between each segment. If defective, replace the armature with a new one.


Commutator and Shaft (Core) Isolation - Inspect

2.2.11 Continuity of Yoke Assembly - Inspect

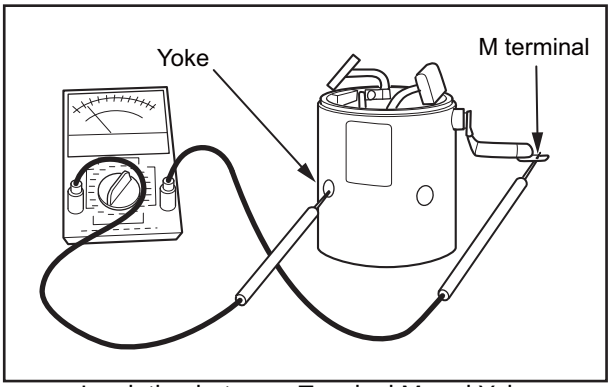
Check that there is continuity between the M terminal of the field coil and the lead wire for the brush. If defective, replace the yoke assembly with a new one.



Continuity Between Terminal M and Brush Side Lead Wire - Inspect

2.2.12 Insulation Between Field Coil and Yoke - Inspect

Check that there is no continuity between field coil and yoke. If defective, replace the yoke assembly coil with a new one.



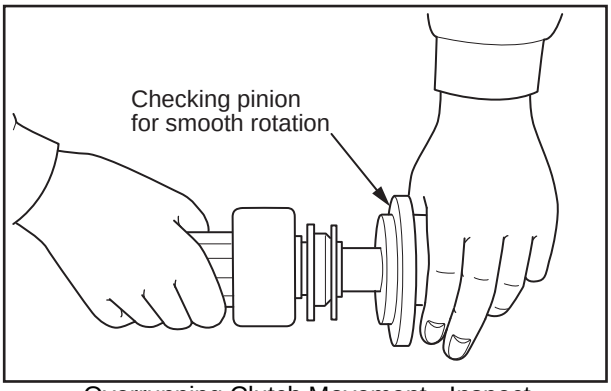
Insulation between Terminal M and Yoke

2.2.13 Overrunning Cluch - Inspect

CAUTION

Do not clean the overrunning clutch with cleaning oil.

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

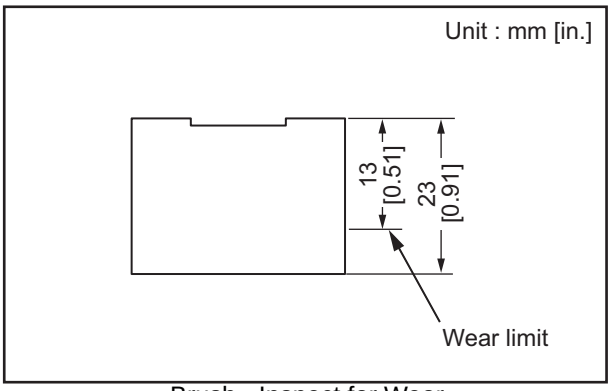


Overrunning Clutch Movement - Inspect

2.2.14 Brush - Inspect for Wear

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

Item	Nominal value	Limit value
Brush length	23 mm [0.91 in.]	13 mm [0.51 in.]



Brush - Inspect for Wear

2.2.15 Brush Spring Load - Measure

Using a new brush, measure the spring load at which the spring lifts from the brush. If the spring pressure is less than the limit, replace the spring with a new one.

Item	Standard value	Limit value
Spring pressure (With brush installed)	39.23 to 49.03 N {4.000 to 5.000 kgf} [8.8193 to 11.0224 lbf]	39.23 N {4.000 kgf} [8.8193 lbf]

2.2.16 Safety Switch Operation - Inspect

CAUTION

Pay special attention to ensure the battery's polarities for the connection.

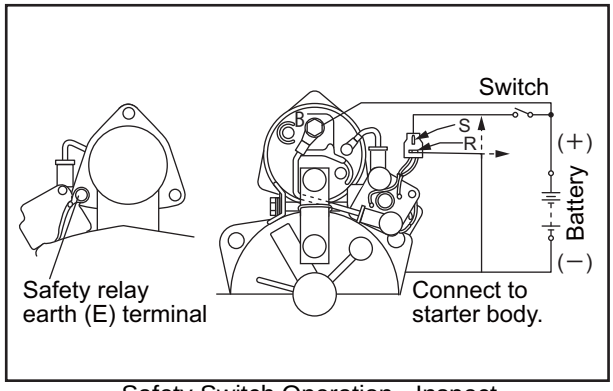
Connect the components as shown. Check the operation of starter and safety switch.

(1) Connect terminal R to the battery negative terminal.

(2) Turn on the switch and check if the starter operates (rotates).

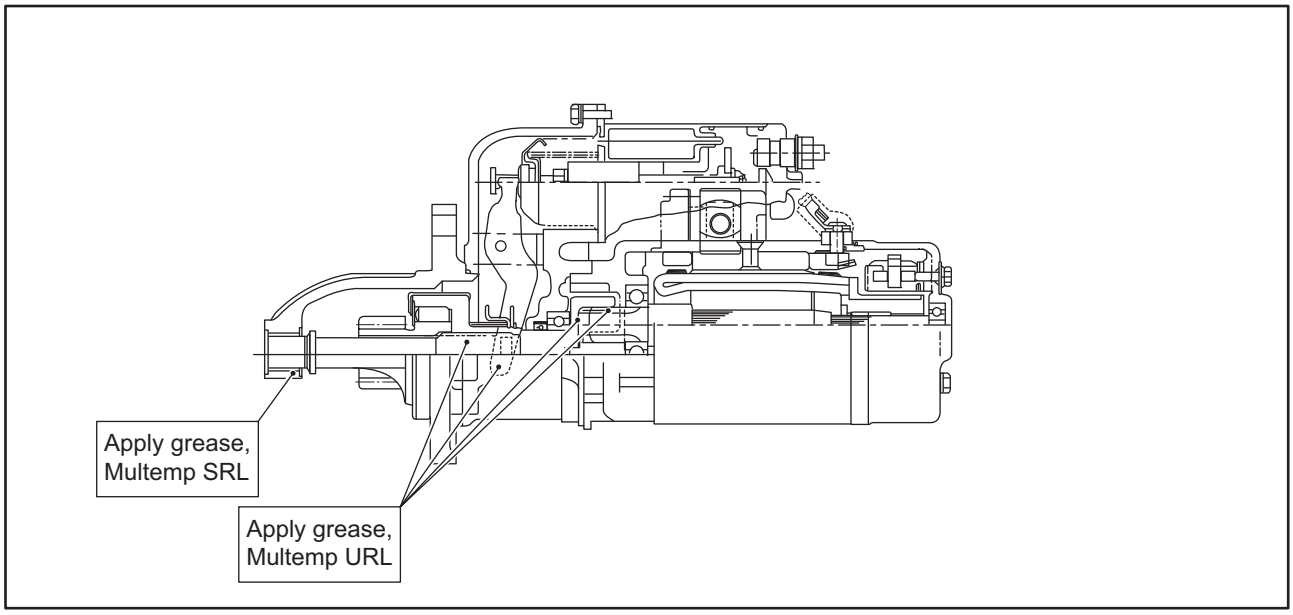
(3) While operating the starter, disconnect terminal R from the battery negative terminal and connect terminal R to the battery positive terminal. Check if the starter stops.

Note: On some specifications, starter stops operation when the connection to the battery negative terminal is disconnected.



Safety Switch Operation - Inspect

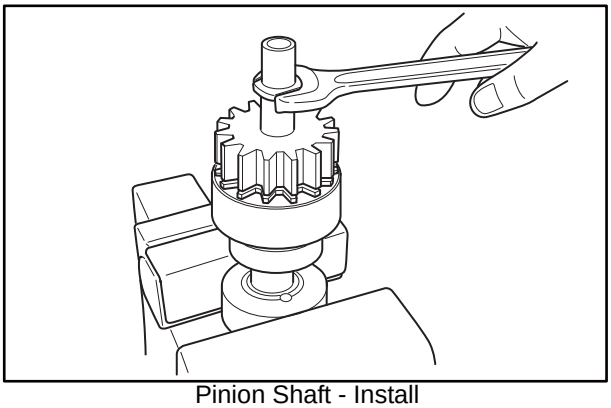
2.3 Starter - Assemble



Starter - Assemble

2.3.1 Pinion Shaft - Install

Secure the shaft, and install the pinion stopper. Use an assisting tool such as a piece of pipe if necessary.

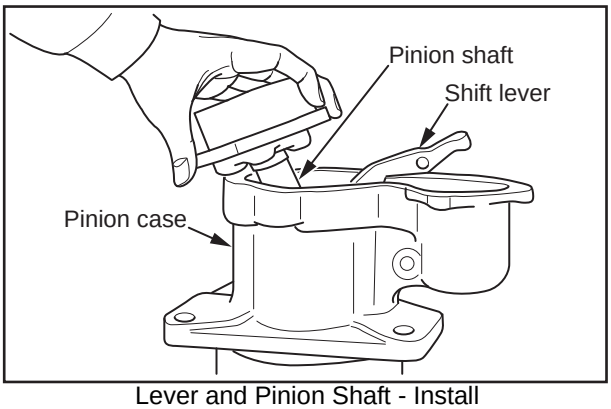


Pinion Shaft - Install

2.3.2 Lever and Pinion Shaft - Install

(1) Install the shift lever and pinion shaft on the front bracket while aligning the mark on the shift lever with the mark on the bracket.

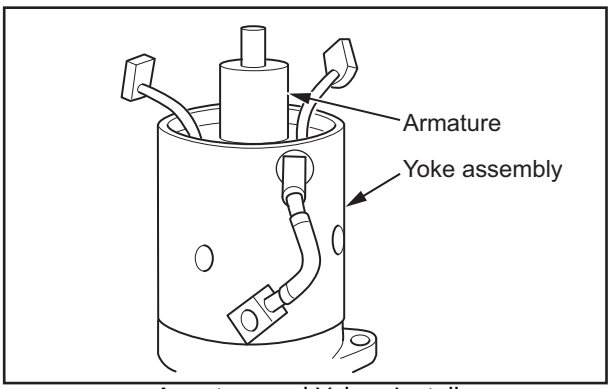
(2) Thoroughly coat the internal gear of the pinion shaft with Nikko Grease R.



Lever and Pinion Shaft - Install

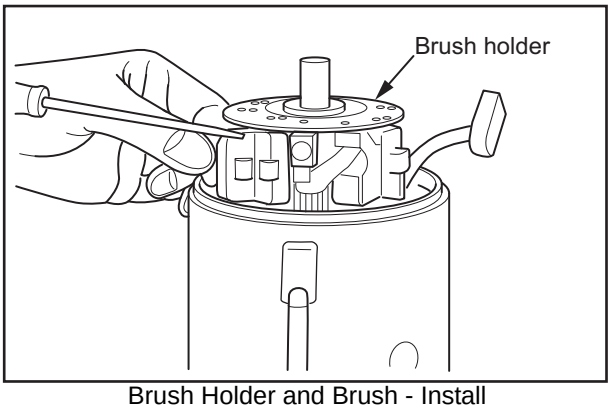
2.3.3 Armature, Yoke, Brush, and Brush holder - Install

(1) Align the knock pin with the center bracket, and assemble the armature to the yoke.



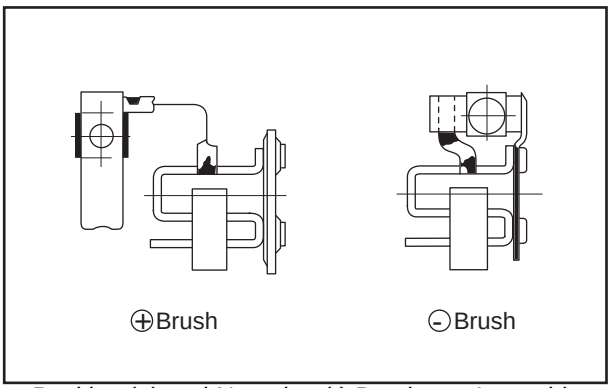
Armature and Yoke - Install

(2) Install the brush holder and brushes.



Brush Holder and Brush - Install

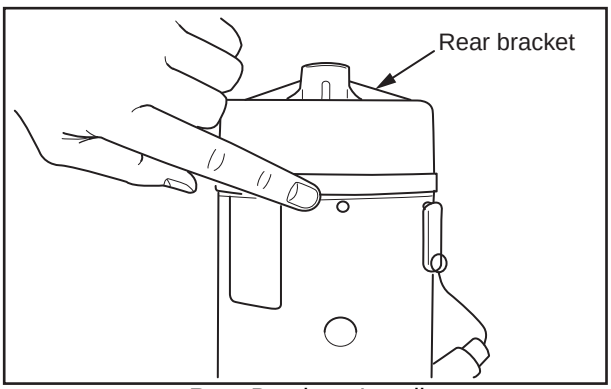
Note: Install the positive (+) and negative (-) brushes as shown in the illustration on the right.



Positive (+) and Negative (-) Brushes - Assemble

2.3.4 Rear Bracket - Inspect

Install the rear bracket on the yoke assembly by aligning match marks, tighten the brush holder with bolts, and secure the rear bracket with the through bolts.

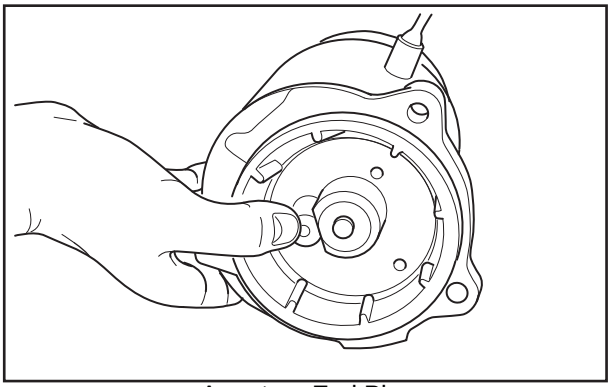


Rear Bracket - Install

2.3.5 Armature End Play - Measure

Measure the armature end play. If the measured value does not meet the nominal value, adjust the end play at the rear end.

Item	Nominal value
Armature end play	0.5 mm [0.020 in.]

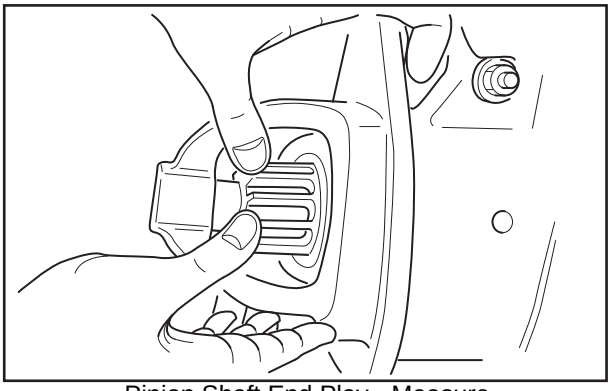


Armature End Play

2.3.6 Pinion Shaft End Play - Measure

Measure the pinion shaft end play. If the measurement does not meet the nominal value, adjust the end play on the internal gear side.

Item	Nominal value
Pinion shaft end play	0.5 mm [0.020 in.]



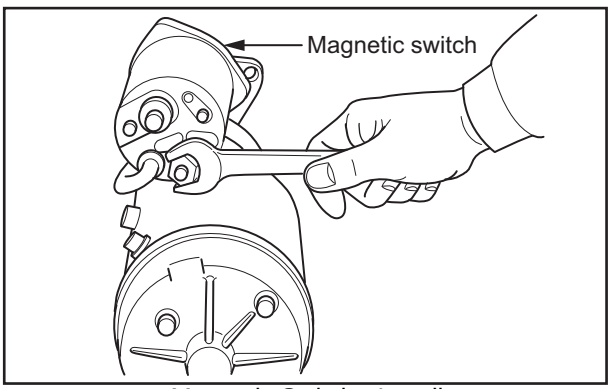
Pinion Shaft End Play - Measure

2.3.7 Magnetic Switch - Install

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

2.3.8 Safety Switch - Install

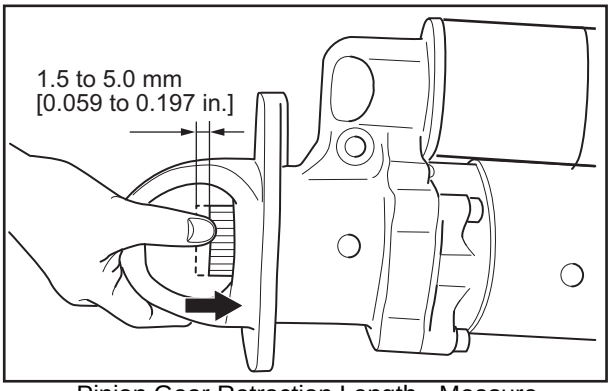
(1) Tighten the lead wire.
(2) Install the safety switch.



Magnetic Switch - Install

2.3.9 Pinion Gear Retraction Length - Measure

Apply a voltage of 24 V between terminals B and C. Connect the lead wire and apply a current between terminals B and M (for 1 second or less). After the pinion is moved, push the pinion gear and measure the pinion gear retraction length. If the measured value is not within the standard range, adjust the length using the adjust screw of the magnetic switch.



Pinion Gear Retraction Length - Measure

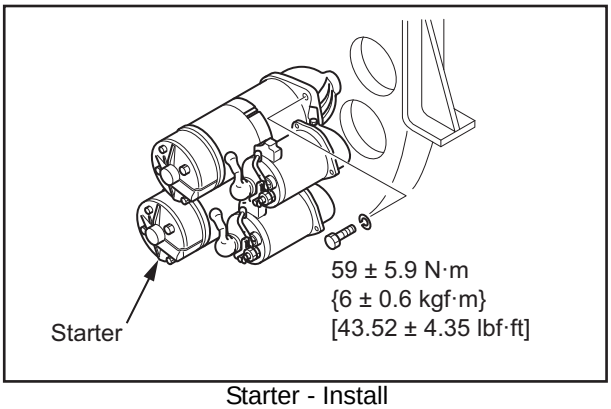
3. Electrical System - Install

3.1 Starter - Install

(1) While engaging the flywheel ring gear with the pinion gear, install the starter on the timing gear case.

(2) Tighten the starter mounting bolts to the specified torque.

(3) Install the harness.



Starter - Install

Chapter 13 ADJUSTMENT AND OPERATION

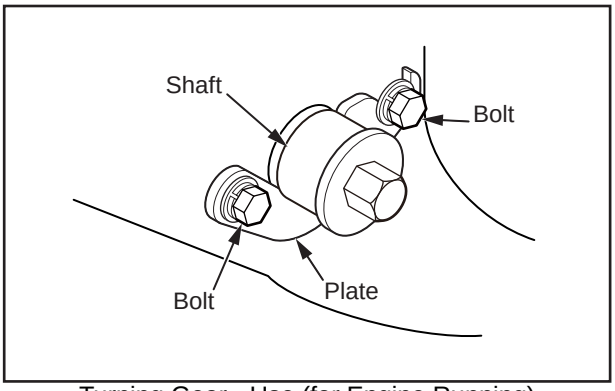
1. Engine - Adjust

1.1 Turning Gear - Use

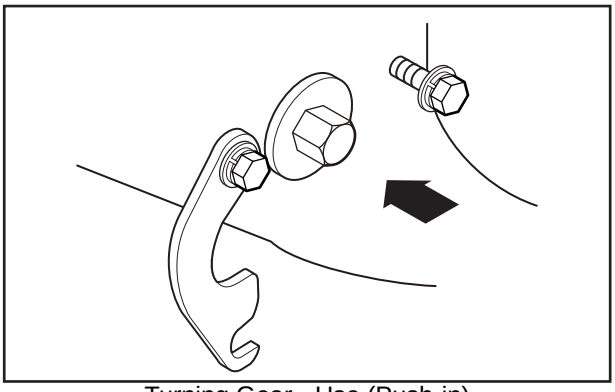
⚠ WARNING

Before starting the engine, make sure that the turning gear is in the engine running position. If the engine is started with the turning gear engaged (pushed-in position), it will result in personal injury as well as damage to ring gear.

(1) Loosen the two bolts, and remove the plate from the slot.
(2) Push-in the shaft all the way so that it engages with ring gear.



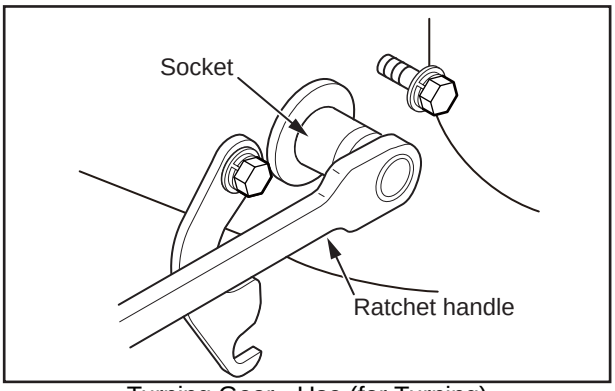
Turning Gear - Use (for Engine Running)


Turning Gear - Use (Push-in)

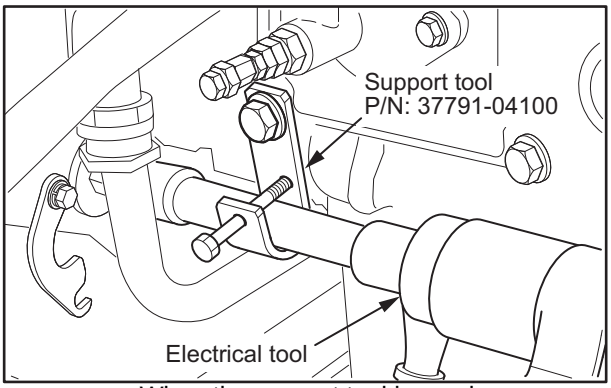
(3) Using a socket and ratchet handle, rotate the shaft for turning crankshaft.
(4) When an extension bar is added to the socket, use the support tool on the side cover.
(5) After the turning, pull-out the shaft, insert the plate into slot of shaft, and tighten the bolts.

CAUTION

Make sure that the plate is firmly engaged in the slot of shaft.



Turning Gear - Use (for Turning)



When the support tool is used

1.2 Valve Bridge and Adjusting Screw - Check

Check the adjustment of valve bridge and adjusting screw. If it is not adjusted, adjust it to the standard value.

For adjustment, see "Valve Bridge and Adjusting Screw - Adjust" of "ENGINE BODY - ASSEMBLE".

1.3 Valve Clearance - Check

Check the valve clearance.

If it is not adjusted, adjust it to the standard value.

For adjustment, see "Valve Clearance - Inspect and Adjust" of "ENGINE BODY - ASSEMBLE".

1.4 Clearance Between Bridge and Valve Rotator - Check

If it is not adjusted, adjust it to the standard value.

For the adjustment procedure, refer to "Clearance Between Bottom Face of Valve Bridge and Top Face of Valve Rotator - Inspect" of "ENGINE BODY - ASSEMBLE".

1.5 Pre-chamber Gas Valve Clearance - Check

Check the pre-chamber gas valve clearance.

If it is not adjusted, adjust it to the standard value.

For adjustment, see "Valve Clearance - Inspect and Adjust" of "ENGINE BODY - ASSEMBLE".

1.6 Ignition Timing - Inspect and Adjust

1.6.1 Check with Engine Stopped

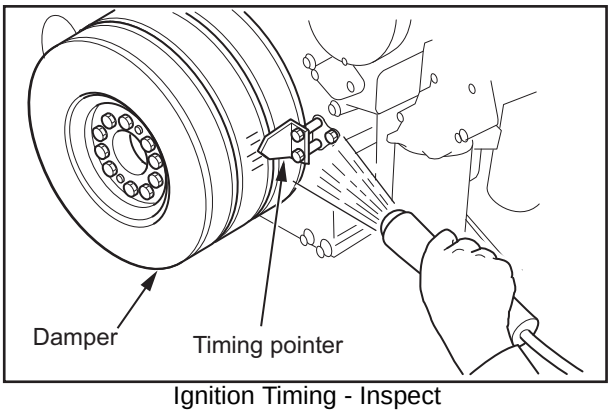
Check the adjustment of the magnet disk installed on the front end of left camshaft.

If it is not adjusted, adjust it to the standard value.

For adjustment, see “Magnetic Disk and Hall-Effect Pickup (CD200D) - Install" of "IGNITION SYSTEM”.

1.6.2 Check During Engine Running

(1) Connect CD200D output unit.
(2) Fasten the input side clip of the timing light to the spark plug cord of the No. 1 cylinder.
(3) Start the engine, and operate at the rated speed.
(4) Illuminate the pointer and damper using the timing light. The angle which is aligned with the pointer is the ignition timing.
(5) When the ignition timing does not meet the standard value, adjust the timing as follows:



Ignition Timing - Inspect

1.6.3 Ignition Timing - Adjust

CAUTION

Do not make any sudden large adjustments, such as change from 0 to 7 or from 7 to 0 while the engine is running. Such sudden large timing adjustments can result in an engine shut down or damage to the engine.

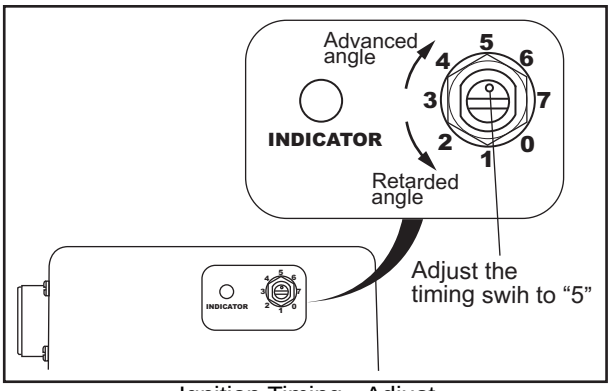
For the adjustment during disassembly and assembly, use PC monitoring tool.

In the event of emergency, adjust with guide switch as follows:

(1) Adjust the ignition timing by turning the timing switch on the CD200D unit.

(2) After completing the adjustment at the No. 1 cylinder, check again at the No. 9 cylinder and at the rated speed.

(3) Check the scale position of the timing switch after the adjustment.



Ignition Timing - Adjust

2. Break-In Operation

2.1 Preparation Before Engine Starting

♦Check the levels of engine oil and coolant, and also bleed air from the cooling system.

♦Check the smooth rotation of actuator output shaft, coupling and throttle valve. Check the actuator scale of throttle valve is placed at the "0" position when the engine is stopped.

♦Check the wiring of electrical system (sensor, meter alarm panel, starter, emergency stopping device, ECM3 controller, and battery). Turn ON the controller main switch to check for abnormality.
Set ECM3 controller so that the engine runs at a low idle speed after the start-up.

♦Activate the emergency stopping device, and verify the specified operation of fuel gas supply device and governor.

♦Install the pressure gauge, thermometer, and flow meter as required.

2.2 Engine Start-up

(1) Stop the gas supply, and crank the engine for approx. 10 seconds with starter to circulate engine oil in the engine. Repeat the cranking 2 or 3 times with one minute interval between them.
Check that there is no abnormality such as abnormal noise or rotation speed fluctuation.

(2) Start the engine in the normal procedure.
Make sure that the engine can run at a low idle speed after start-up.

(3) Make sure that the oil pressure increases immediately, and the coolant circulates.

(4) Make sure there are no engine oil, coolant or fuel gas leak as well as abnormal noise and vibration.

(5) After making sure that the engine is running at low idling speed without any problem, turn the key switch to OFF position, and make sure that the engine stops.

2.3 Break-In Operation

CAUTION

Be prepared to activate the emergency stop for an unforeseeable trouble of engine operation.

2.3.1 Break-in Operation Load and Time

The load during break-in operation shall be increased progressively as shown in the table below.
Note that the time shown in the table is the minimum time required to check the engine in a stable condition.

Break-in operation time			
	Rotating speed (min^{-1})	Load factor (kW)	Duration (min)
1	Idling	No-load	5
2	1000	No-load	5
3	1200	No-load	10
4	1500	No-load	10
5	Rated speed	25 %	10
6		50 %	10
7		75 %	30
8		100 %	20

2.3.2 Engine - Inspect during Operation

During the break-in operation, pay attention to the followings and make sure that there is no abnormality.

- Oil pressure and oil temperature
- Coolant temperature and level
- Leak of oil, water and fuel gas; especially oil leak from the turbocharger pipe connection of lubricating oil
- Noise and vibration
- Intake air pressure and intake air temperature
- Exhaust color and odor
- Exhaust temperature
- Fluctuation in exhaust temperature between right and left banks
- Blow-by gas (amount and color)
- Rotational fluctuation
- Face and radial runouts of rotating parts
- Indication and operation of meters and warnings

2.3.3 After Break-in Operation - Inspect and Adjust

- Valve clearance
- Pre-chamber gas valve clearance
- Ignition timing
- Re-tightening of external bolts and nuts
- Inspection and repair of defects such as oil leak

3. Engine - Test and Adjustment

CAUTION

(a) Engine test and adjustment shall be performed at the certified maintenance shop only.

(b) Performance check and adjustment of the engine shall be conducted when the water and oil temperatures become stable after sufficient warm-up operation.

When the engine runs normally after the break-in operation, check and adjust the performance and functions of the engine. Record the test results by referring to the engine data at factory.

3.1 Engine - General Performance Test

Fuel consumption rate, various temperatures, and pressures

3.2 Exhaust Gas - Test

Exhaust gas analyses

3.3 Governor - Performance Test

- Load sudden application and rejection tests
- Governor droop, hunting, and rotational fluctuation - check
- Setting conditions of governor controller and others - check

3.4 Warning Activation and Emergency Stop - Test

Oil pressure decrease, water temperature increase, and over-speed

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