Workshop Manual

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D25A MS, D25A MT
D30A MS, D30A MT

Marine Engines

D25A & D30A MS/MT

Content

Safety Information

Introduction

The Manual contains technical data, descriptions, and repair instructions for the designated Volvo Penta engines or engine versions. Make sure that the correct workshop literature is used.

Read the following safety information and the General Information and Repair Instructions in the Workshop Manual carefully before starting service work.

Important

The following special warning symbols are used in the Workshop Manual and on the engine.

WARNING! Warns of risk of bodily injury, serious damage to product or property, or that a serious malfunction can occur if the instructions are not followed.

IMPORTANT! Used to attract attention to things that can cause damage or malfunction to product or property.

NOTE! Used to attract attention to important information, to simplify work procedures or handling.

The following list provides an overview of the risks and cautionary procedures that should always be observed.

Prevent the engine from being started by disconnecting the power with the main switch (switches) and locking it (them) in the disconnected position. Post warning signs stating “Work in progress!” in every position from wich the engine can be started.

Maintenance and service should be performed on a stationary engine. However, some procedures, e.g. certain adjustments, require the engine to be running. Approaching an engine that is running is a safety risk. Remember that loose clothes or long hair can fasten in rotating parts and cause severe injury.
A careless movement or dropped tool while working in the vicinity of an engine that is running, can in the worst case lead to injury. Observe caution with hot surfaces (exhaust pipe, turbo, charge air pipe, starter element etc.) and hot fluids in the lines and hoses of an engine that is running, or has just been stopped. Refit all guards dismantled during service work before starting the engine.

Make sure that the warning or information decals on the product are always clearly visible. Replace labels that have been damaged or painted over.

Never start the engine unless the air filter is fitted. The rotating compressor wheel in the turbo can cause severe injury. Foreign objects in the inlet pipe can also damage the machine.

Never use starter spray or the like. Risk of in the inlet pipe. Risk of personal injury.

Avoid opening the coolant filler cap when the engine is hot. Steam or hot coolant can spray out, and built up pressure will be lost. Open the filler cap slowly and release the overpressure in the cooling system if the filler cap or cock must be opened, or if a plug or coolant pipe must be removed when the engine is hot. Steam or hot coolant can flow out in an unpredicted direction.

⚠ Hot oil can cause burn injuries. Avoid skin contact with hot oil. Make sure that the oil system is not pressurised before working on it. Never start, or run the engine with the oil filler cap removed due to the risk of ejecting oil.

⚠ Stop the engine and close the bottom valve before working on the cooling system.

⚠ Only start the engine in a well-ventilated area. Exhaust fumes and crankcase gases should be bled out of the engine compartment or workshop when working in closed environments.

⚠ Always use protective glasses for work where there is a risk of splintering, sparks, or splashing of acid or other chemicals. The eyes are extremely sensitive, and an injury could cause blindness!

⚠ Avoid skin contact with oil! Prolonged or frequent skin contact with oil can degrease the skin, resulting in irritation, drying out, eczema, and other skin complaints. Used oil is more dangerous than new oil from a health care point of view. Use protective gloves and avoid oil-drenched clothes and rags. Wash your hands regularly, especially before meals. Use special hand cream to counteract drying out, and to simplify cleaning the skin.

⚠ The majority of chemicals intended for the product (e.g. engine and timing gear oils, glycol, petrol and diesel oil) or chemicals for workshop use (e.g. degreasing agent, enamels and solvents) are hazardous to health. Read the instructions on the pack carefully. Always follow the given safety instructions (e.g. the use of breathing protection, protective glasses, or gloves, etc.) Make sure that other personnel are not exposed to hazardous substances, e.g. by inhaling the air. Make sure there is adequate ventilation. Handle consumed and surplus chemicals in the prescribed manner.

⚠ Observe extreme caution when tracing fuel leaks in fuel systems and when testing fuel nozzles. Wear protective glasses. The jet from a fuel nozzle has a very high pressure and penetrating force. The fuel can penetrate deeply into bodily tissue and cause serious injury. Risk of blood poisoning.

⚠ All fuels, as well as many chemicals, are inflammable. Make sure no naked flames or sparks can cause ignition. Petrol, certain thinners, and hydrogen from batteries are extremely inflammable and explosive when mixed with air. Smoking is prohibited! Ventilate well and take the necessary precautions before welding or grinding in the immediate vicinity. Always have a fire extinguisher handy in the workshop.

⚠ Make sure that rags drenched in oil and petrol, including old fuel and lubricant filters, are stored safety. Oil drenched rags can in certain conditions self-ignite. Old fuel and oil filters are environmentally hazardous waste, and together with spent lubricant, contaminated fuel, paint residue, solvent, degreasing agent and suds, should be handed in to a waste-handling unit for destruction.

⚠ Batteries must never be exposed to naked flames or electrical sparks. Never smoke in the vicinity of batteries. Hydrogen develops when batteries are charged, which in combination with air forms an explosive gas. This gas is highly inflammable and very explosive. One spark from connecting the batteries incorrectly is sufficient to cause the battery to explode and cause injury. Do not touch the connection when starting (risk of spark) and do not lean over the batteries.

⚠ Never confuse the plus and minus terminals when fitting the batteries. This can cause serious damage to the electrical equipment. Check the wiring diagram.

⚠ Always use protective glasses when charging and handling batteries. The battery electrolyte contains strongly corrosive sulphuric acid. Upon contact with the skin, wash with soap and plenty of water. If battery acid gets into the eyes, rinse immediately with water, and contact a doctor without delay.

⚠ Stop the engine and turn off the power with the main switch (switches) before working on the electrical system.

⚠ The clutch should be adjusted when the engine is idle.

⚠ Use the lifting hooks mounted on the engine/reversing gear when lifting the drive unit. Always check that the lifting equipment is in good condition and has the correct capacity for the lift (weight of engine plus reversing gear and extra equipment where appropriate).

For safe handling, and to avoid damaging the components mounted on top of the engine, the engine should always be lifted with a lifting bar adjusted to the engine. All chains or wires should run in parallel with each other and as perpendicular to the top of the engine as possible. Special lifting equipment may be required to ensure the right balance and safe handling if other equipment connected to the engine alters its centre of gravity.

Never work on an engine supported only by lifting equipment.

⚠ Never work alone when heavy components are to be dismantled, even when safe lifting (e.g. lockable block and tackle) equipment is used. In most cases, two persons are required even when lifting equipment is used: one to handle the equipment and one to make sure that components are not damaged. When working onboard a boat always make sure in advance that there is sufficient space to allow dismantling in situ, without the risk of personal injury or material damage.

⚠ **WARNING!** The components in the electrical system and fuel system on Volvo Penta products are designed and manufactured to minimise the risks of explosion and fire. The engine must not be run in environments surrounded by explosive media.

⚠ Pressure pipes must not bent, turned, or exposed to other strain. Replace damaged pressure pipes.

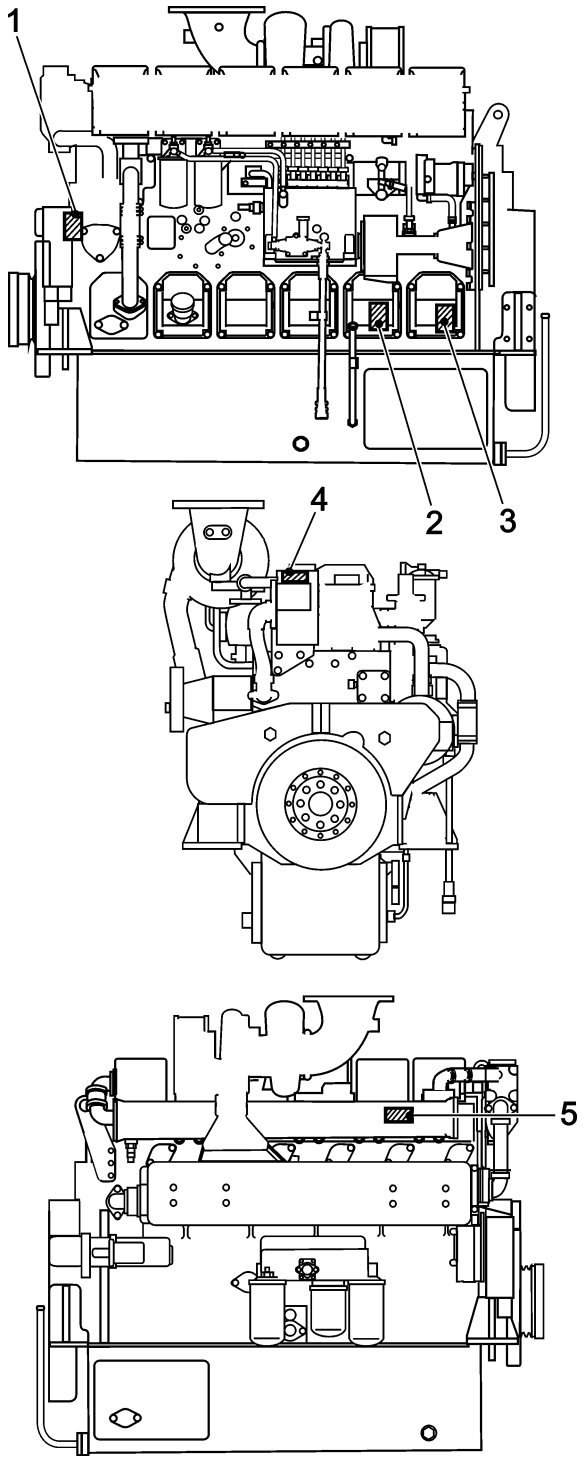
⚠ Observe the following when cleaning with high-pressure wash: Never point the jet of water at seals, rubber hoses, or electrical components. Never use the high-pressure function when washing the engine.

⚠ Always use Volvo Penta recommended fuel. See the instruction manual. The use of inferior quality fuel could damage the engine. The use of inferior fuel in a diesel engine could cause the control rod to jam and the engine to overspeed, with the risk of personal injury or damage to the machine. Inferior fuel can also lead to higher maintenance costs.

Warning labels D25A / D30A MS

The engine carries ‘Warning Labels’ at places where you are required to pay special attention. Please read them carefully and make sure you understand the content of each label and the meaning of their position.

1. Make sure the labels are legible. If you find any letter or picture illegible in a label, remove soil from the label, or replace it.
2. Clean the label with cloth and water or cleanser. Do not use organic solvent or gasoline, this would dissolve the label’s adhesive and cause the label to fall off.
3. If any label is damaged, lost or illegible, replace it. When replacing a label, make sure the new label is identical to the old one. For new labels, please contact your dealer.



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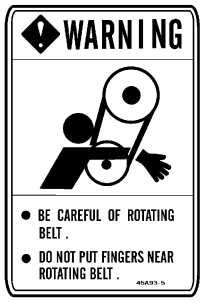

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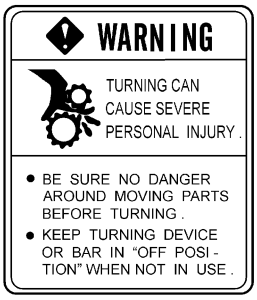

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Warning labels D25A / D30A MT

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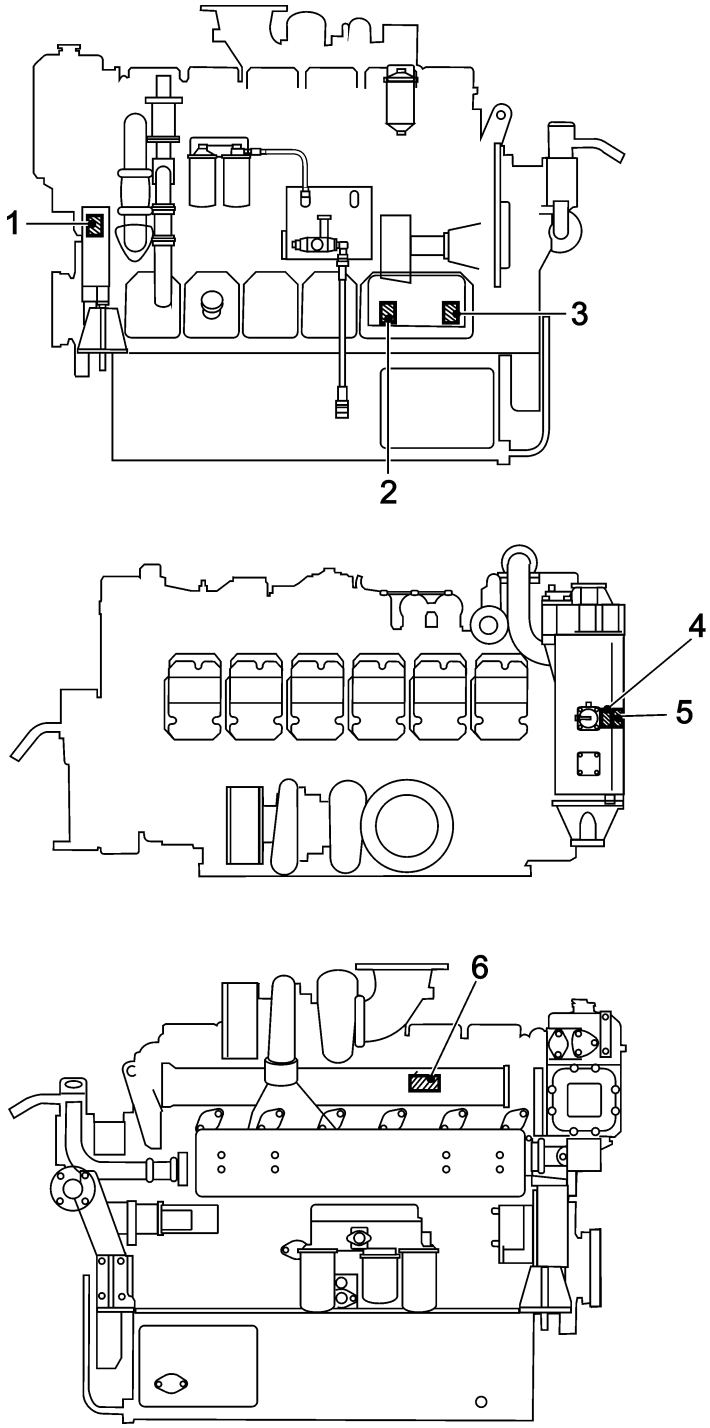

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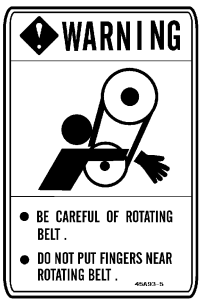

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General Information

About the Workshop Manual

This Workshop Manual contains technical information, descriptions, and instructions for the standard versions of the D25A and D30A engines. The engine designation and numbers are to be found on the engine identification plate, refer to section “Identification numbers”. The motor designation and number should always be given during all correspondence with Volvo Penta.

The Workshop Manual is primarily produced for Volvo Penta service workshops and their qualified personnel. It is therefore assumed that persons using this manual have a basic knowledge of marine drive systems, and are able to carry out the related mechanical and electrical nature. Volvo Penta is continuously developing their products. We therefore reserve the right to make changes. All the information contained in this book is based on product data available prior to publication. Any essential changes or modifications in production or updated or revised service methods introduced after publication will be communicated by means of Service Bulletins.

Spare parts

Spare parts for the electrical and fuel systems are subject to different national safety requirements, e.g. U.S. Coast Guard Safety Regulations. Volvo Penta Genuine Spare Parts comply with these requirements. All types of damage resulting from the use of non genuine Volvo Penta spare parts for the product in question will not be regulated by the warranty undertakings of Volvo Penta.

Certified engines

For service and repair on an engine certificated for any area where exhaust emissions are regulated by law, the following is important:

Certification means that an engine type is inspected and approved by the authorities. The engine manufacturer guarantees that all engines manufactured of that type correspond to the certified engine.

This places special requirements on maintenance and service as follows:

- The maintenance and service intervals recommended by Volvo Penta must be observed.
- Only genuine Volvo Penta replacement parts may be used.
- The service of injection pumps and injectors or pump settings must always be carried out by an authorized Volvo Penta workshop.
- The engine must not be modified in any way except with accessories and service kits approved by Volvo Penta.
- No modifications to the exhaust pipes and air supply ducts for the engine may be undertaken.
- Seals may only be broken by authorized personnel.

Otherwise the general instructions contained in the Operator’s manual concerning operation, service and maintenance must be followed.

⚠ **IMPORTANT!** Neglected or deficient maintenance/service and the use of non-original spare parts will entail Volvo Penta renouncing any responsibility for the engine corresponding to the certified version. Volvo Penta will not compensate for damage and/or costs arising from the above.

Repair instructions

The working methods described in the Service Manual apply to work carried out in a workshop. The engine has been removed from the boat and is installed in an engine fixture. Unless otherwise stated reconditioning work which can be carried out with the engine in place follows the same working method.

Warning symbols occurring in the Workshop Manual (refer to section “Safety information”) are not in any way comprehensive since it is impossible to predict every circumstance under which service work or repairs may be carried out. For this reason we can only highlight the risks that can arise when work is carried out incorrectly in a well-equipped workshop using working methods and tools developed by us.

All procedures for which there are Volvo Penta special tools in this Workshop Manual are carried out using these. Special tools are developed to rationalize working methods and make procedures as safe as possible. It is therefore the responsibility of any person using tools or working methods other than the ones recommended by us to ensure that there is no danger of injury, damage or malfunction resulting from these.

In some cases there may be special safety precautions and instructions for the use of tools and chemicals contained in this Workshop Manual. These special instructions should always be followed if there are no separate instructions in the Workshop Manual.

Certain elementary precautions and common sense can prevent most risks arising. A clean workplace and engine eliminates much of the danger of injury and malfunction.

It is of the greatest importance that no dirt or foreign particles get into the fuel system, cooling system, lubrication system, intake system, turbocharger, bearings and seals when they are being worked on. The result can be malfunction or a shorter operational life.

Our joint responsibility

Each engine consists of many connected systems and components. If a component deviates from its technical specification the environmental impact of an otherwise good engine may be increased significantly. It is therefore vital that wear tolerances are maintained, that systems that can be adjusted are adjusted properly and that Volvo Penta Genuine Parts as used. The engine Maintenance Schedule must be followed.

Some systems, such as the components in the fuel system, require special expertise and special testing equipment for service and maintenance. Some components are sealed at the factory for environmental reasons. No work should be carried out on sealed components except by authorized personnel.

Bear in mind that most chemicals used on boats are harmful to the environment if used incorrectly. Volvo Penta recommends the use of biodegradable degreasing agents for cleaning engine components, unless otherwise stated in a workshop manual. Take special care when working on-board, that oil and waste is taken for destruction and is not accidentally pumped into the environment with bilge water.

How to Use This Manual

1. Parts in illustrations are numbered to correspond with references to these numbers in text.
2. Items or conditions to be inspected during disassembly are listed in the disassembled views.
3. Maintenance standards for inspection and repair are described in text where relevant. For a quick summary of maintenance standards refer to section “Maintenance Standards” of this manual.
4. The sequence in which parts are to be reassembled is summarized below each assembled view. Such as:

5. Tightening torque under wet conditions is indicated as “(wet)” in text, drawings, and tables. When so indicated, apply engine oil to the threaded portion of the fastener. Unless indicated as (wet), the tightening torque should be dry.

Terms used in this manual

Before you read this manual, note that the following special terms are used in dimensional and other specifications.

Assembly standard

Indicates the dimension of a part, the dimension to be attained at the time of reassembly or the standard performance.

Norminal value

Indicates the standard dimension of a part.

Repair limit

A part which has reached this limit must be repaired.

Service limit

A part which has reached this limit must be replaced.

Standard clearance

Indicates the clearance to be obtained between mating parts at reassembly.

Disassembly and Reassembly

This service manual covers recommended procedures to be followed when servicing diesel engines. It also contains information on special tools required and basic safety precautions.

It is the responsibility of service personnel to be familiar with these requirements, precautions, and potential hazards and to discuss these points with their foreman or supervisor.

Study this manual carefully and observe the following general precautions to prevent serious personal injury and to avoid damage to the engine, equipment, and parts.

⚠ **WARNING!** Use the correct tools and instruments. Serious injury or damage to the engine can result from using the wrong tools and instruments

⚠ **WARNING!** When lifting or carrying heavy parts, get someone to help you if the part is too awkward for one person to handle. Use jacks and chain blocks when necessary.

⚠ **IMPORTANT!** Use an overhaul stand or work bench if necessary.

⚠ **IMPORTANT!** Always read the Service Bulletins to learn about changes in procedures and/or technical data.

NOTE! Pay attention to the marks on assemblies, components, and parts for positions or directions. Put on your own marks, if necessary, to aid reassembly.

NOTE! Carefully check each part for faults during removal or cleaning. Signs of abnormal wear will tell if parts or assemblies are functioning improperly.

NOTE! Use assembly bins to keep the parts in order of removal and lay down disassembled or cleaned parts in the order in which they were removed. This will save you time at reassembly

NOTE! Wash all engine parts, except oil seals, O-rings, rubber seals, etc. in cleaning solvent and dry them with compressed air

NOTE! Use a torque wrench to tighten parts when specified tightening torques are required.

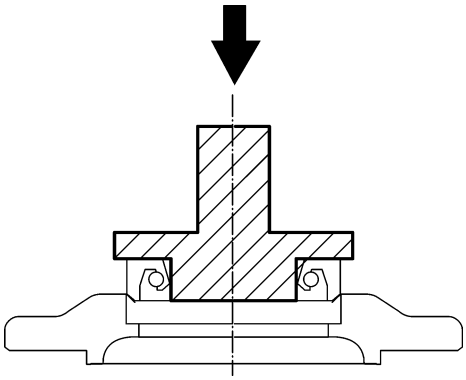
NOTE! Use only good quality lubricating oils and greases. Be sure to apply a coat of oil, grease, or sealant before reassembly, to parts as specified.

NOTE! Replace all gaskets and packing. Apply appropriate amount of adhesive or liquid gasket when required.

NOTE! Always apply “high temperature anti-seizing compound” to bolts and nuts that are exposed to high temperatures, e.g. exhaust manifold, turbo charger, exhaust flanges, etc.

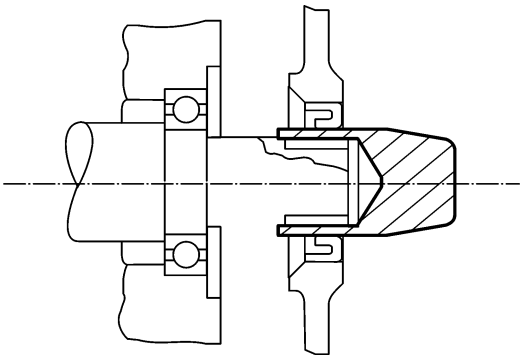
Oil Seals

When installing oil seals, carefully observe the following points.



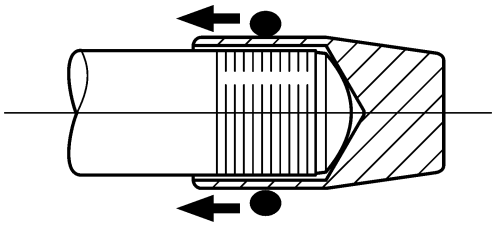
Driving oil seals into housings

1. Check the seal lip for damage, and be sure to position correctly in the housing.
2. Apply a smear of grease to the surface of the oil seal (to be fitted into the housing bore).
3. Use an oil seal driver shown to guide the seal lip and drive the outer diameter squarely. To avoid damage to the oil seal and leaking, never hammer on it directly.



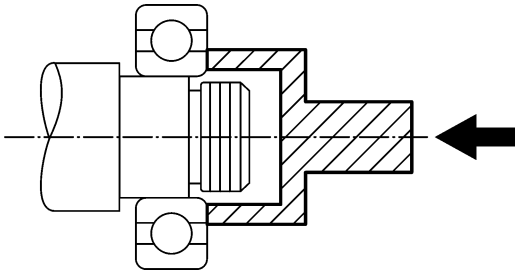
Driving oil seals onto shafts

1. Apply a smear of grease to the oil seal lip.
2. Use an oil seal guide of the type shown when driving the oil seal over the stepped portion, splines, threads, or key way to prevent damage to the oil seal lip.



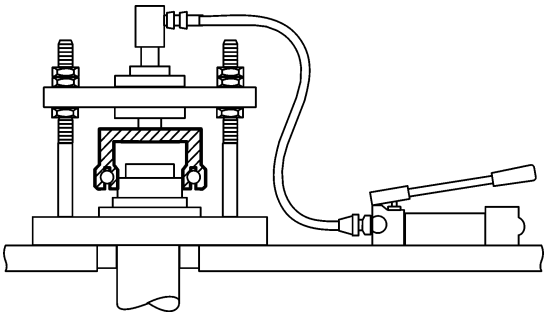
O-rings

Use an O-ring guide to install an O-ring over stepped parts, splines, threads, or key way to prevent damage to the ring. Apply a smear of grease to the O-ring before installation.

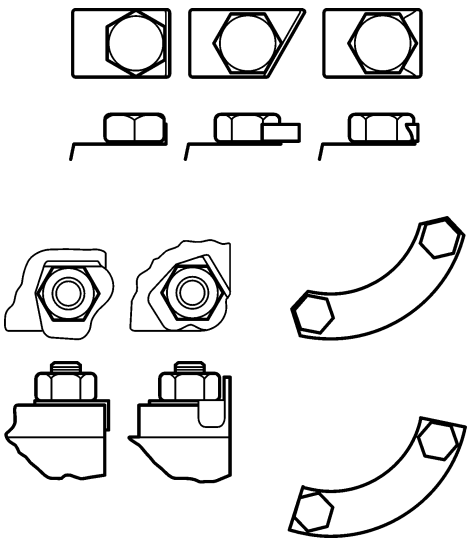


Bearings

1. When installing a rolling bearing, be sure to push the inner or outer race by which the bearing is fitted. Be sure to use a bearing driver like the one shown.



2. Whenever possible, use a press to minimize shock to the bearing and to assure proper installation.



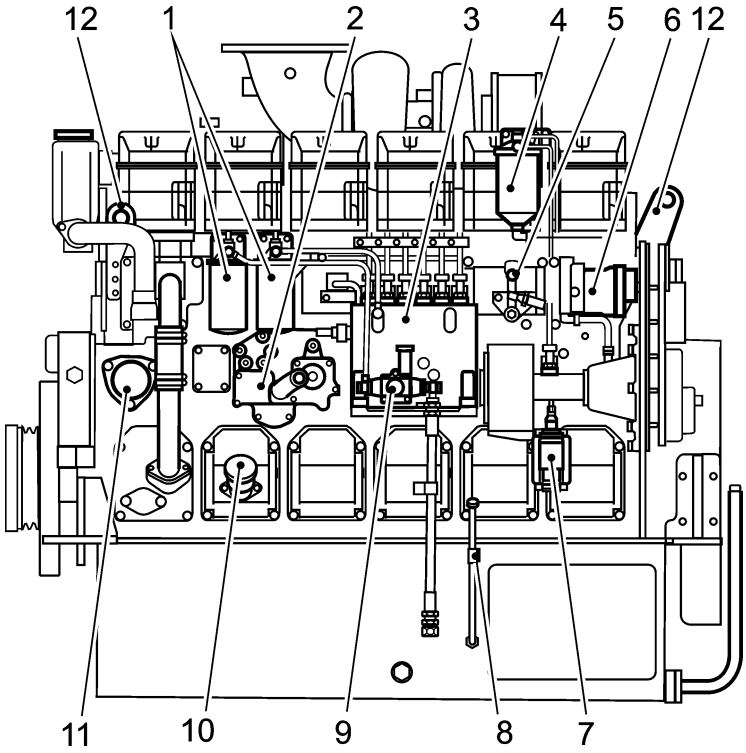
Lock Plates

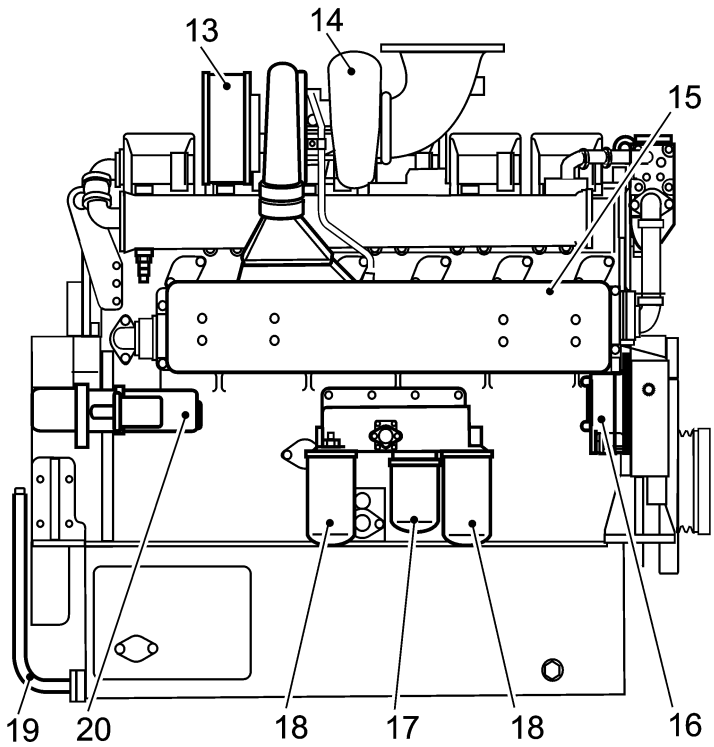
Bend lock plates against the flats of the nuts or bolt heads as shown.

Split Pins and Spring Pins

Generally, split pins are to be replaced once disturbed. Insert the pin fully and spread it properly. Drive each spring pin into position to hold it in place after later installation of parts has been completed.

Presentation D25A/D30A MS

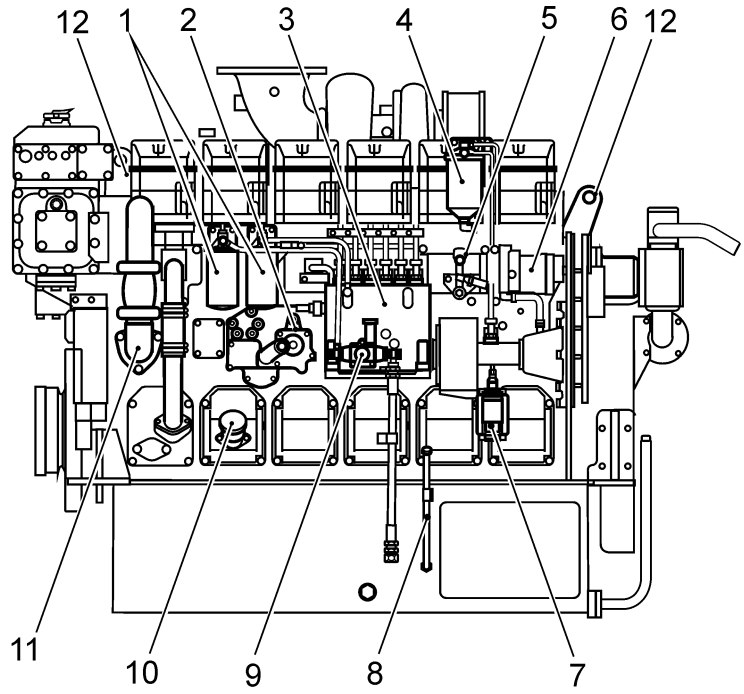


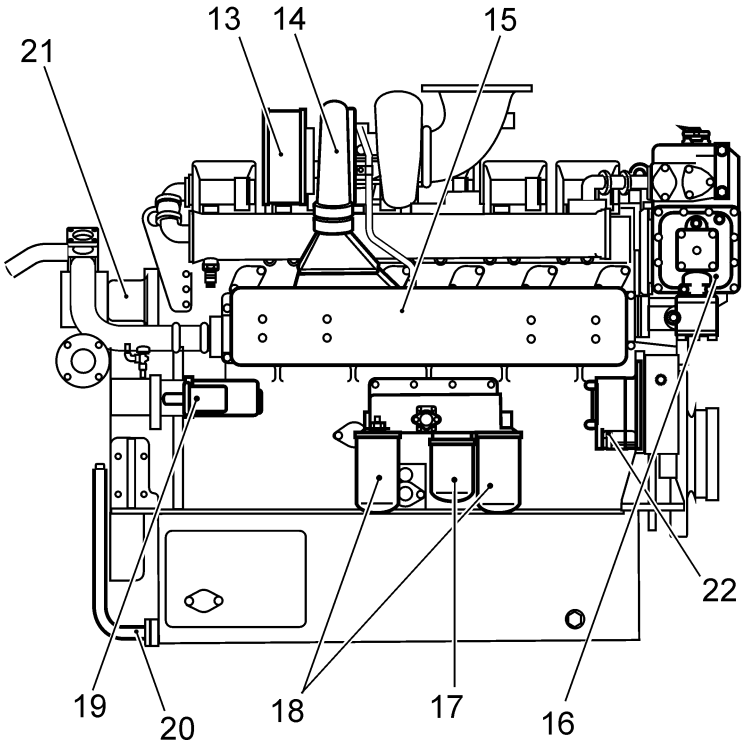


D25A/D30A MS

1. Fuel filters
2. Oil cooler
3. Fuel injection pump
4. Governor oil filter
5. Manual stop lever
6. Governor
7. Stop solenoid
8. Oil dipstick
9. Fuel feed pump
10. Oil filler cap
11. Fresh water pump
12. Lifting eye
13. Intake air silencer
14. Turbocharger
15. Charge air cooler
16. Alternator
17. By-pass filter for engine oil
18. Oil filters
19. Engine oil drain pipe
20. Starter motor

Presentation D25A/D30A MT





D25A/D30A MT

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12. Lifting eye
13. Intake air silencer
14. Turbocharger
15. Charge air cooler
16. Heat exchanger
17. By-pass filter for engine oil
18. Oil filters
19. Starter motor
20. Engine oil drain pipe
21. Sea water pump
22. Alternator

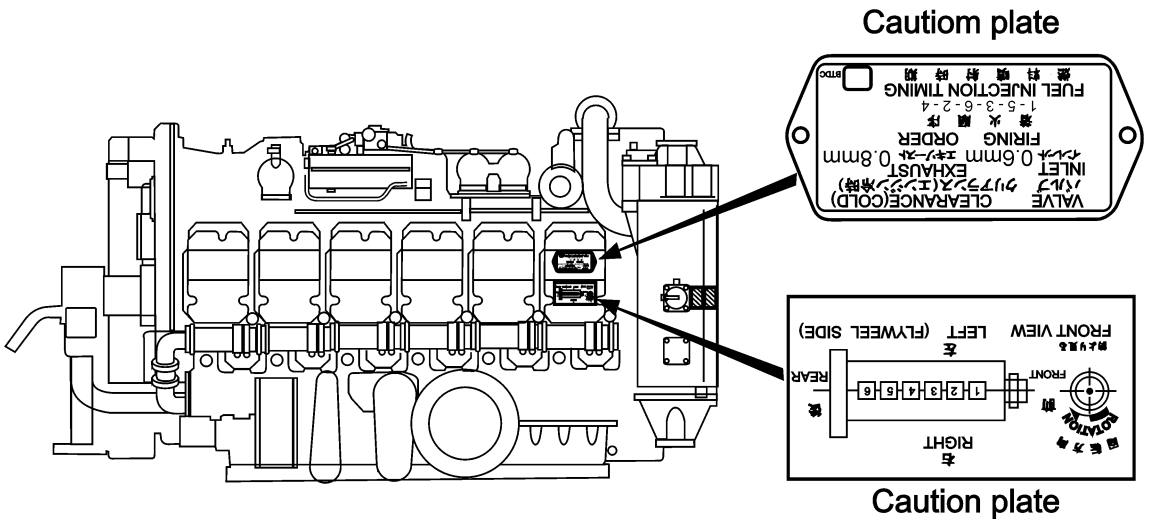
Identification numbers D25A/D30A

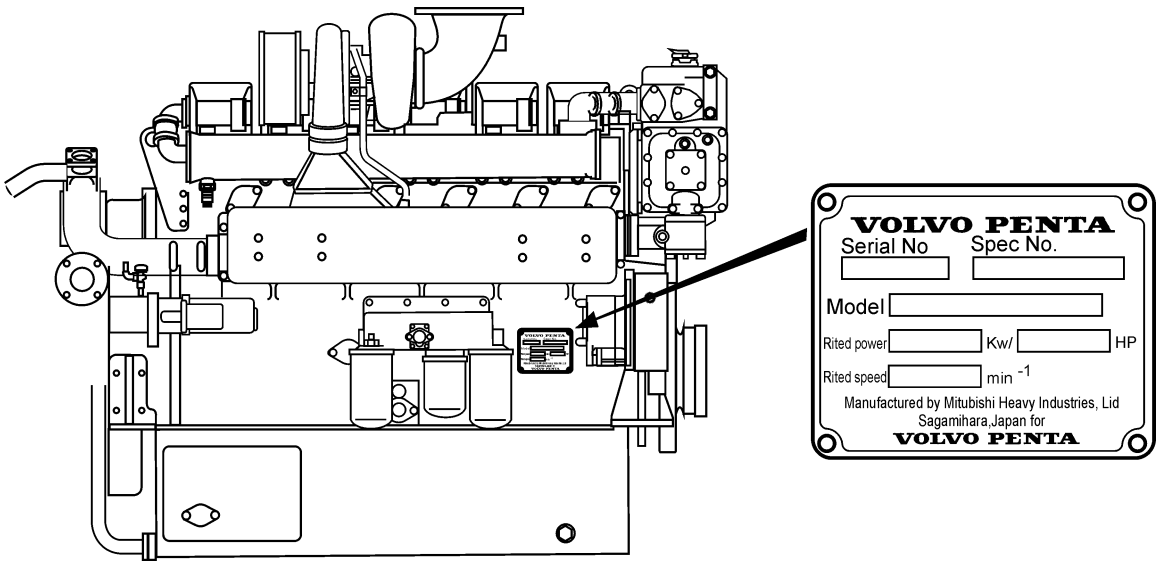
Type plates with identification numbers can be found on the engine and the transmission or generator. This information must always be used as a reference when ordering service and spare parts.

Engine .....
Product designation .....
Serial and basic engine number .....
Product number .....

Certification, IMO .....
Decal, part No. .....
Approval No. .....

Transmission / Generator .....
Product designation .....
Serial number .....
Product number .....





Specification D25A/D30A

General specification

Model	Water-cooled,4-stroke, turbocharged diesel with intercooler
No. of cylinders	6
Arrangement	in-line
Combustion type	Direct injection
Valve mechanism	Overhead
Cylinder bore,mm [in.]	170[6.70]
Cylinder stroke,mm [in.]	180 [7.10]
Displacement, litres [U.S. gal]	24.51 [6.47]
Compression ratio	14.0:1
Firing order	1-5-3-6-2-4
Rotational direction	Counterclockwise as viewed from flywheel
Engine support method	4 point support

Weight (Dry)(without marine gear), kg [lb]	D25A MS	D25A MT	D30A MS	D30A MT
	2320[5115]	2900 [6395]	2420 [5335]	3000 [6615]

Engine main parts

Cylinder liner type	Wet type
Piston rings:	
Compression rings, pcs	2
Oil ring(w/expander), pcs	1
Valve timing (when warm):	
Inlet valve	open BTDC 37°
Inlet valve	close ABDC 44°
Exhaust valve	open BBDC 57°
Exhaust valve	close ATDC 24°

Fuel system

Fuel

JIS K2204	TYPE 1, TYPE 2, TYPE 3
ASTM. D975	No.1-D, No.2-D
BS2869	CLASS-A1, CLASS-A2,
DIN51601	DIESEL-FUEL
ISO8217	DMX-CLASS

Injection pump

Model	PS6 type
Manufacturer	Mitsubishi Heavy Industries, Ltd.
Plunger outside diam., mm [in.]	17 [0.67]
Plunger lead, mm [in.]	Counterclockwise, left-hand 35 [1.38] lead
Cam lift, mm [in.]	15 [0.59]

Fuel feed pump

Model	Zexel
Manufacturer	Zexel
Cam lift, mm [in.]	12 [0.47]

Governor

Control system	Woodward Hydraulic PSG

Fuel system cont.

Fuel injector

Type	Hole type
Manufacturer	Zexel
No. of spray holes	10
Spray hole diameter, mm [in.]	0.325 [0.013]
Spray angle, deg.	160°
Injection press., Mpa(kgf/cm²)[psi]	34.32 to 34.81 (350 to 355) [4979 to 5050]

Fuel filter

Type	Paper element cartridge changeover, spin-on type

Oil system

Lubricating type	Forced circulation type (pressure feed by oil pump)
Engine oil Standard	CF oil (API service classification) or better
Engine oil volume:	
Oil sump,liter [U.S. gal]	140 [37.0] approx
Complete engine, liter [U.S. gal]	160 [42.3] approx

Oil pump

Type	Gear pump
Delivery capacity, liter [U.S. gal]	325 [85.9] (at engine speed 1650 rpm)

Relief valve

Type	Piston valve type
Opening press., MPa(kgf/cm³)[psi]	0.46 (4.7) [67]

Oil cooler

Type	Water-cooled, multi-plate type (housed in the engine block)

Full-flow oil filter

Type	Paper element changeover type (spin on)

By-pass oil filter

Type	Paper element type (spin on)

Oil thermostat

Type	Wax type
Valve opening temp., °C [°F]	80 to 84 [176 to 183.2]

Cooling system

Cooling type	Water-cooled, forced circulation

Coolant capacity (engine only), liter [U.S. gal]	D25A MS	D25A MT	D30A MS	D30A MT
	50 [13.2]	115 [30.4]	55 [14.5]	120 [31.7]

Fresh water pump

Type	Centrifugal
Pump capacity, liter [U.S. gal]/min.	800 [211], Total head 0.20 MPa (20 mAq) (at 2925 rpm pump speed)
Pump drive belt type	V-belt
Outside circumference, mm [in]	1535 [60]

Thermostat

Type	Wax
Valve opening temp.,°C [°F]	71+/-2 [160+/- 35.6]
Valve fully opened, °C [°F]	85+/-2 [185+/- 35.6]

Raw water pump (only on MT)

Type	Rubber rotor
Pump capacity, liter [U.S. gal]/min.	450 [119], Total head 0.10 MPa (10 mAq)(at 1800 rpm pump speed)

Inlet and exhaust system

Turbocharger

Type	TD13 or TD15
No. of units	1

Electrical system

Voltage-polarity	24V earth float

Starter

Manufacturer	Nikko Electric Industry
Pinion mesh type	Pinion shift (Reduction type)
Output	V (kW) 24 (7.5)
No. of starters	2
No. of pinion tooth/ring gear tooth	11 / 182

Alternator

Type	3-Phase alternating generator, Internal IC regulator
Manufacturer	Mitsubishi Electric
Output	V-A 24-35
Rated generated	27V, 35A at 5000 rpm
Regulated voltrage	V 28.5 +/- 0.5
Drive belt:	
type	V-belt
outside circumference, mm [in.]	1250 [49]

Maintenance Standards Table

General

Maximum rpm

Nominal Value ..... 5 – 10 % higher than rated rpm
Repair limit ..... Lower or 20 % higher than rated rpm
NOTE! Rated rpm stamped on the nameplate. Check governor setting.

Minimum rpm

Nominal value ..... 600 to 650 rpm

Compression pressure MPa (Bar) [psi]

Nominal Value ..... 2.85 (28.5) [263] minimum (at 120 rpm)
Repair limit ..... 2.30 (23.0) [185] or lower
NOTE! Oil and water temp. 20 to 30°C [68 to 86°F]

Lube oil pressure MPa (Bar) [psi]

Nominal Value ..... 0.5 (5.0) [72]
At idling speed ..... 0.20 – 0.29 (2.0 – 2.9) [28 to 43]
Repair limit ..... 0.10 (1.0) [14] or lower at idling speed
NOTE! Oil temp. 60 to 70°C [140 to 158°F]

Valve timing **(2 mm[0.8 in.] clearance valve side, cold)**

Nominal Value:
Inlet valve opens ..... 2.5° BTDC ±2° (crank angle)
Inlet valve closes ..... 13° ABDC ±2° (crank angle)
Exh. valve opens ..... 26° BBDC ±2° (crank angle)
Exh. valve closes ..... 10.5° BTDC ±2° (crank angle)
NOTE! Values are only for checking valve timing and are different from the actual ones.

Valve clearance (cold), mm [in.]

Inlet valves:
Standard Clearance .. 0.6 [0.024]
Exhaust valves:
Standard Clearance .. 0.8 [0.031]

Injection timing

Nominal Value ..... XX° BTDC ±1° (crank angle)
NOTE! XX varies according to specifications. Refer to caution plate on No. 1 rocker cover.

Engine main parts

Valves

Valve stem diameter, mm [in.]

Nominal Value ..... Ø10 [0.39]
Assembly Standard ... 9.940 to 9.960 [0.39134 to 0.39213]
Service Limit ..... 9.910 [0.39016]
NOTE! The same for both inlet and exhaust valves.

Valve guide inside diameter, mm [in.]

Nominal Value ..... Ø10 [0.39]
Assembly Standard ... 10.000 to 10.015 [0.39370 to 0.39429]
Service Limit ..... 10.060 [0.39606]
NOTE! The same for both inlet and exhaust valves.

Valve seat angle(A)

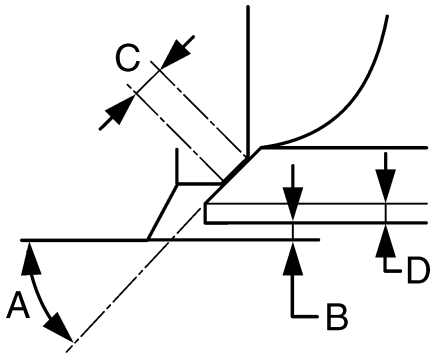
Nominal Value ..... 30°

Valve depth(B), mm [in.]

Nominal value 0
Assembly Standard ... -2.0 – 0.2 [-0.008 – 0.008]
Repair Limit ..... 1.0 [0.039]

Seat width(C), mm [in.]

Nominal value ..... 2.3 [0.091]
Assembly Standard ... 2.15 to 2.45 [0.0846 to 0.0965]
Repair Limit ..... 2.8 [0.110]



Valve margin(D), mm [in.]

Nominal Value ..... 3.0 [0.12]
Assembly Standard ... 2.8 – 3.2 [0.110 to 0.126]
NOTE! Refacing permissible up to 2.5 [0.098]

Cylinder head bore and valve seat diameter, mm [in.]

Nominal Value ..... Ø60 [2.36]
Assembly Standard ... -0.070 – -0.130 [-0.00276 – -0.00512]
NOTE! - (minus) indicates interference

Valve springs

Free length (A), mm [in.]

Assembly standard ... 73 [2.87]
Service limit ..... 71 [2.80]

Perpendicularity (B), mm [in.]

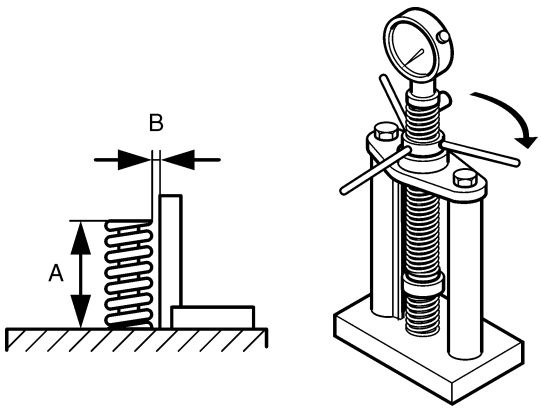
Service limit ..... 2.2 [0.087] (at end)

Length under test force, mm [in.]

Assembly standard ... 66.0 [2.6]

Test force, N (kgf) [lbf]

Assembly standard ... 289–319 (29.45 to 32.55) [65 to 72]



Valve push rods

Deflection, mm [in.]

Assembly Standard ... 0.5 [0.020] maximum
Service Limit ..... 0.5 [0.020]

Rockers

Rocker bushing inside diameter, mm [in.]

Nominal Value ..... Ø36 [1.42]
Assembly Standard ... 36.000 to 36.040 [1.41732 to 1.41889]
Service Limit ..... 36.090 [1.42086]

Rocker shaft diameter, mm [in.]

Nominal Value ..... Ø36 [1.42]
Assembly Standard ... 35.966 to 35.991 [1.41598 to 1.41697
Service Limit ..... 35.940 [1.41496]Cylinder heads

Cylinder head

Flatness of gasket surface, mm [in.]

Assembly Standard ... 0.03 [0.0012] or less
Repair Limit ..... 0.07 [0.0028]
Service Limit ..... 0.50 [0.0197]
NOTE! Reface if necessary

Thickness of gasket when tightened, mm [in.]

Nominal Value ..... 1.8 [0.07]
Assembly Standard ... 1.77 to 1.83 [0.0697 to 0.0720]

Cylinder liners

Inside diameter, mm [in.]

Nominal Value ..... Ø170 [6.69]
Assembly Standard ... 170.000 to 170.040 [6.69290 to 6.69447]
Repair Limit ..... 170.200 [6.70078]
Service Limit ..... 170.500 [6.71259]

Roundness, mm [in.]

Assembly Standard ... 0.02 [0.0008] or less

Cylindricity, mm [in.]

Assembly Standard ... 0.02 [0.0008] or less

Squareness of flange lower face to liner center line, mm [in.]

Assembly Standard ... 0.03 [0.0012] or less

Protrusion of cylinder liner at flange, mm [in.]

Assembly Standard ... 0.11 to 0.20 [0.0043 to 0.0089]

Pistons and cylinderheads

Clearance between piston top and cylinder head, mm [in.]

Standard Clearance .. [1.22 to 1.95) ([0.0480 to 0.0768])

Pistons

Outside diameter, mm [in.]

Nominal Value ..... Ø170 [6.69]
Assembly Standard ... 169.76 to 169.80 [6.6835 to 6.6850]
Service Limit ..... 169.66 [6.6795]
NOTE! Meaure diameter perpendicular to pin at piston skirt.

Weight difference between pistons in one engine

Assembly Standard ... ±10 g [±0.35 oz]
NOTE! Only one type of piston available for service replacement.

Pin bore diameter, mm [in.]

Nominal Value ..... Ø70 [2.76]
Assembly Standard ... 70.002 to 70.015 [2.75598 to 2.75649]
Service Limit ..... 70.040 [2.75747]

Protrusion, mm [in.]

Assembly Standard ... 0.06 to 0.65 [0.0024 to 0.0256]
NOTE! From the cylinder block

Piston rings

Gaps Top ring, mm [in.]

Assembly Standard ... (0.6 to 0.8) ([0.024 to 0.031])
Service Limit ..... (2.0) ([0.079])
NOTE! If gauge is not available, the general value can be obtained at the cylinder bore.

Gaps Second ring, mm [in.]

Assembly Standard ... (0.6 to 0.8) ([0.024 to 0.031])
Service Limit ..... (2.0) ([0.079])
NOTE! If gauge is not available, the general value can be obtained at the cylinder bore.

Gaps Oil ring, mm [in.]

Assembly Standard ... (0.3 to 0.45) ([0.012 to 0.018])
Service Limit ..... (2.0) ([0.079])
NOTE! If gauge is not available, the general value can be obtained at the cylinder bore.

Piston pins

Diameter, mm [in.]

Nominal Value ..... Ø70 [2.76]
Assembly Standard ... 69.987–70.000 [2.75539 to 2.75590]
Service Limit ..... 69.970 [2.75472]

Connecting rods

Bushing inside diameter, mm [in.]

Nominal Value ..... Ø70 [2.76]
Assembly Standard ... 70.020–70.040 [2.75669 to 2.75747]
Service Limit ..... 70.070 [2.75866]

Bend and twist, mm [in.]

Assembly Standard ... 0.05/100 [0.0020/3.9] or less

End play (rod and crankpin widths), mm [in.]

Nominal Value ..... 67 [2.64]
Assembly Standard ... (0.2–0.6) ([0.008 to 0.016])
Service Limit ..... (1.0) ([0.039])

Weight difference between connecting rods in one engine

Assembly Standard ... ±30 g [±1.06 oz]
NOTE! All connecting rods in one engine must be with the same classification letter.

Big end bore diameter, mm [in.]

Nominal Value ..... Ø131 [5.16]
Assembly Standard ... 131.000 to 131.025 [5.15747 to 5.15845]
Service Limit ..... 131.050 [5.15944]
NOTE! To be measured in combination with caps. Roundness less than (0.1 mm [0.004 in.] - service limit)

Connecting rod bearings

Thickness of center, STD, mm [in.]

Nominal Value ..... 3.000 [0.11811]
Assembly Standard ... 2.972 to 2.985 [0.11701 to 0.11752]
Service Limit* ..... 2.930 [0.11535]

Thickness of center, –0.25 [–0.0098], mm [in.]

Nominal Value ..... 3.125 [0.12303]
Assembly Standard ... 3.097 to 3.110 [0.12193 to 0.12244]
Service Limit* ..... 3.055 [0.12028]

Thickness of center, –0.50 [–0.0197], mm [in.]

Nominal Value ..... 3.250 [0.12795]
Assembly Standard ... 3.222 to 3.235 [0.12685 to 0.12736]
Service Limit* ..... 3.180 [0.12520]

Thickness of center, –0.75 [–0.0295], mm [in.]

Nominal Value ..... 3.375 [0.12287]
Assembly Standard ... 3.347 to 3.360 [0.13177 to 0.13228]
Service Limit* ..... 3.305 [0.13012]

Thickness of center, –1.00 [–0.0394], mm [in.]

Nominal Value ..... 3.500 [0.13780]
Assembly Standard ... 3.472 to 3.485 [0.13669 to 0.13720]
Service Limit ..... 3.430 [0.13504]
***NOTE!** Replace bearings if worn down to service limit. Regrind crankpins and use undersize bearings if necessary.

Flywheel

Face runout, mm [in.]

Assembly Standard ... 0.285 [0.0112] to less

Radial runout, mm [in.]

Assembly Standard ... 0.127 [0.0050] or less

Injection pump accessory drive

Bearing bore inside diameter, mm [in.]

Nominal Value ..... Ø90 [3.54]
Assembly Standard ... 89.987 – 90.022 [3.54279 – 3.54417]

Bearing bore inside diameter, mm [in.]

Nominal Value ..... Ø100 [3.94]
Assembly Standard ... 99.987– 100.022 [3.93649 – 3.93787]

Bearing, Outside diameter, mm [in.]

Nominal Value ..... Ø90 [3.54]
Assembly Standard ... 89.985 – 90.000 [3.54272 – 3.54331]

Bearing, Outside diameter, mm [in.]

Nominal Value ..... Ø100 [3.94]
Assembly Standard ... 99.985 – 100.000 [3.93642 – 3.93701]

Bearing, Inside diameter, mm [in.]

Nominal Value ..... Ø45 [1.77]
Assembly Standard ... 44.988 to 45.000 [1.77118 to 1.77165]

Bearing, Inside diameter , mm [in.]

Nominal Value ..... Ø50 [1.97]
Assembly Standard ... 49.988 to 50.000 [1.96803 to 1.96850]

Drive shaft bearing journal diameter, mm [in.]

Nominal Value ..... Ø45 [1.77]
Assembly Standard ... 45.002 to 45.013 [1.77173 to 1.77216]

Drive shaft bearing journal diameter, mm [in.]

Nominal Value ..... Ø50 [1.97]
Assembly Standard ... 50.002 to 50.013 [1.96858 to 1.96901]

Damper

Radial runout (at periphery), mm [in.]

Assembly Standard ... 0.5 [0.020] or less
Service Limit ..... 1.5 [0.059]

Radial runout (at periphery), mm [in.]

Assembly Standard ... 0.5 [0.020] or less
Service Limit ..... 1.5 [0.059]

Timing gears

Backlash, mm [in.]

Assembly Standard ... (0.12 to 0.18) ([0.0047 to 0.0071])
Repair Limit ..... (0.30) ([0.0118])
Service Limit ..... (0.50) ([0.0197])

Idle gear shaft bushing inside diameter, mm [in.]

Nominal value ..... Ø50 [1.97]
Assembly standard ... 50.000–50.025 [1.96850–1.96848]
Service limit ..... 50.060 [1.97086]

Idle gear shaft diameter, mm [in.]

Nominal value ..... Ø50 [1.97]
Assembly standard ... 49.950–49.975 [1.96653–1.96752]
Service limit ..... 49.900 [1.96456]

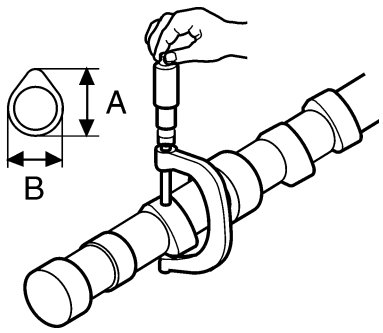
Idle gear end play, mm [in.]

Standard clearance ... 0.2–0.4 [0.008–0.016]
Service limit ..... 0.6 [0.024]

Camshaft

Cam lift (A-B), mm [in.]

Nominal Value ..... 9.247 [0.36405]
Assembly Standard ... 9.197 to 9.297 [0.36209 to 0.36602]
Service Limit ..... 8.45 [0.3327]



Deflection, mm [in.]

Assembly Standard ... 0.05 [0.0020] or less
Repair Limit ..... 0.08 [0.0031]

NOTE! Deflection at center bushing measured with both ends supported. Repair or replace, if necessary.

Journal diameter, mm [in.]

Nominal Value ..... Ø84 [3.31]
Assembly Standard ... 83.92 to 83.94 [3.3039 to 3.3047]
Service Limit ..... 83.87 [3.3020]

Camshaft bushing inside diameter (as installed in crank case), mm [in.]

Nominal Value ..... Ø84 [3.31]
Assembly Standard ... 84.00 to 84.035 [3.30708 to 3.30846]
Service Limit ..... 84.10 [3.3110]

NOTE! Replace bushings and ream them, if necessary

End play, mm [in.]

Nominal Value ..... 8 [0.3]
Assembly Standard ... 0.10 to 0.25 [0.0039 to 0.0098]
Service Limit ..... 0.40 [0.0157])

NOTE! Replace thrust bearing, if necessary.

Crankshaft

Crankshaft pin diameter, mm [in.]

Nominal Value ..... Ø125 [4.92]
Assembly Standard ... -0.050 – -0.070 [0.00197 – -0.00276]
Repair Limit ..... -0.110 [-0.00433]

Crankshaft journal diameter, mm [in.]

Nominal Value ..... Ø140 [5.51]
Assembly Standard ... -0.050 – -0.070 [0.00197 – -0.00276]
Repair Limit ..... -0.110 [-0.00433]

Journal and crankpin center to center distance, mm [in.]

Nominal Value ..... 90 [3.54]
Assembly Standard ... ±0.1 [±0.004]

Parallelism between journals and crankpins, mm [in.]

Assembly Standard ... 0.01 [0.0004] or less at pin length
Repair Limit ..... 0.03 [0.0012]

Roundness of journals and crankpins, mm [in.]

Assembly Standard ... 0.01 [0.0004] or less in diameters
Repair Limit ..... 0.03 [0.0012]

Cylindricity of journals and crankpins, mm [in.]

Assembly Standard ... 0.02 [0.0008] or less in diameters
Repair Limit ..... 0.03 [0.0012]

Fillet radius of crankpins, mm [in.]

Nominal Value ..... 7 [0.28]
Assembly Standard ... 7.0 – 7.2 [0.268 – 0.276]

Fillet radius of journals, mm [in.]

Nominal Value ..... 7 [0.28]
Assembly Standard ... 7.0 – 7.2 [0.268 – 0.276]

Hardness of journals and crankpins

Assembly Standard ... Hv>620

Angularity

Assembly Standard ... ±0°20’

Deflection, mm [in.]

Assembly Standard ... 0.04 [0.0016] or less
Repair Limit ..... 0.10 [0.0039]
NOTE! Repair or replace if necessary

Thrustbearing journal length, mm [in.]

Nominal Value ..... 66 [2.60]

Crankshaft end play, mm [in.]

Nominal Value ..... 66 [2.60]
Assembly Standard ... 0.20 to 0.40 [0.0079 to 0.0157]
Service Limit ..... 0.50 [0.0197] (+ 1.18[0.0465] crank shaft width)
NOTE! Replace thrust bearings if worn down to service limit. Use oversize thrust bearings if worn beyond repair limit.

Main bearing

Thickness of center, STD, mm [in.]

Nominal Value ..... 3.500 [0.138]
Assembly Standard ... 3.467 to 3.480 [0.13650 to 0.13701]
Service Limit ..... 3.425 [0.13484]
NOTE! Replace bearings if worn down to service limit. Regrind crankpins and use undersize bearings if worn beyond service limit.

Thickness of center, –0.25 [–0.0098], mm [in.]

Nominal Value ..... 3.625 [0.14272]
Assembly Standard ... 3.592 to 3.605 [0.14142 to 0.14193]
Service Limit ..... 3.550 [0.13976]
NOTE! Replace bearings if worn down to service limit. Regrind crankpins and use undersize bearings if worn beyond service limit.

Thickness of center, –0.50 [–0.0197], mm [in.]

Nominal Value ..... 3.750 [0.14764]
Assembly Standard ... 3.717 to 3.730 [0.14634 to 0.14685]
Service Limit ..... 3.675 [0.14468]
NOTE! Replace bearings if worn down to service limit. Regrind crankpins and use undersize bearings if worn beyond service limit.

Thickness of center, –0.75 [–0.0295], mm [in.]

Nominal Value ..... 3.875 [0.15256]
Assembly Standard ... 3.842 to 3.855 [0.15126 to 0.15177]
Service Limit ..... 3.800 [0.14961]
NOTE! Replace bearings if worn down to service limit. Regrind crankpins and use undersize bearings if worn beyond service limit.

Thickness of center, –1.00 [–0.0394], mm [in.]

Nominal Value ..... 4.000 [0.15748]
Assembly Standard ... 3.967 to 3.980 [0.15618 to 0.15669]
Service Limit ..... 3.925 [0.15453]
NOTE! Replace bearings if worn down to service limit. Regrind crankpins and use undersize bearings if worn beyond service limit.

Crankcase

Flatness of gasket surface, mm [in.]

Assembly Standard ... 0.1 [0.004] or less
Repair Limit ..... 0.2 [0.008]
NOTE! Reface if necessary

Main bearing bore diameter, mm [in.]

Nominal Value ..... Ø147 [5.79]
Assembly Standard ... 147.000 to 147.025 [5.78739 to 5.78837]
Service Limit ..... 147.035 [5.78877]

Inlet and exhaust system

Turbocharger TD13

Inside diameter of bearing-fitted housing section, mm [in.]

Nominal Value ..... 30 [1.18]
Service Limit ..... 30.006 [1.18134]

Bearing outside diameter, mm [in.]

Service Limit ..... 29.876 [1.17622]

Bearing inside diameter, mm [in.]

Service Limit ..... 18.050 [0.71063]

Bearing length, mm [in.]

Service Limit ..... 17.440 [0.68661]

Shaft journal diameter, mm [in.]

Nominal Value ..... 18 [0.709]
Service Limit ..... 17.996 [0.70850]

Shaft deflection, mm [in.]

Service Limit ..... 0.015 [0.00059]

Ring gap clearance, mm [in.]

Standard Clearance .. 0.05 to 0.25 [0.00197 to 0.00984]

Shaft & turbine wheel and turbine housing clearance, mm [in.]

Standard Clearance .. 0.29 to 0.91 [0.01142 to 0.03583]

Shaft end play, mm [in.]

Assembly Standard ... 0.075 to 0.135 [0.00295 to 0.00531]

Turbine backplate and turbine wheel clearance, mm [in.]

Standard Clearance .. 0.55 to 1.15 [0.02165 to 0.05315]

Turbocharger TD15

Inside diameter of bearing-fitted housing section, mm [in.]

Nominal Value ..... Ø34 [1.34]
Service Limit ..... 34.016 [1.33921]

Bearing outside diameter, mm [in.]

Service Limit ..... 33.882 [1.33393]

Bearing inside diameter, mm [in.]

Service Limit ..... 19.929 [0.78460]

Bearing length, mm [in.]

Service Limit ..... 19.440 [0.76535]

Shaft journal, mm [in.]

Nominal Value ..... Ø20 [0.79]
Service Limit ..... 19.863 [0.78201]

Shaft deflection, mm [in.]

Service Limit ..... 0.015 [0.00059]

Ring gap clearance, mm [in.]

Standard Clearance .. 0.05 to 0.20 [0.00197 to 0.00787]

Shaft & turbine wheel and turbine housing clearance, mm [in.]

Standard Clearance .. 0.63 to 1.18 [0.02480 to 0.04646]

Shaft end play, mm [in.]

Assembly Standard ... 0.075 to 0.135 [0.00295 to 0.00531]

Turbine backplate and turbine wheel clearance, mm [in.]

Standard Clearance .. 0.85 to 1.35 [0.03346 to 0.04528]

Lubrication system

Oil Pump

Backlash between drive gear and driven gear, mm [in.]

Assembly Standard ... (0.10 to 0.20) [0.0039 to 0.0079]
Service Limit ..... (0.4) [0.0157]

Drive gear and driven gear clearance, mm [in.]

Nominal Value ..... Ø60 [2.36]
Standard Clearance .. (0.100 to 0.148) [0.00394 to 0.00583]
Clearance ..... Tip clearance (0.35) [0.0138]

Gear end clearance in case, mm [in.]

Nominal Value ..... 72.5 [2.854]
Standard Clearance .. (0.040 to 0.116) [0.00157 to 0.00457]
Clearance ..... [0.21] [0.0083]
NOTE! Remove the cover packing (width of 0.04 [0.0016]) for mesurement.

Shaft diameter, mm [in.]

Nominal Value ..... Ø25 [0.98]
Assembly Standard ... 24.947 to 24.960 [0.98216 to 0.98268]
Service Limit ..... 24.900 [0.98031]

Bushing inside diameter, mm [in.]

Nominal Value ..... Ø25 [0.98]
Assembly Standard ... 25.000 to 25.021 [0.98425 to 0.98508]
Service Limit ..... 25.100 [0.98819]

Safety valve

Valve opening pressure MPa (Bar) [psi]

Assembly Standard ... 1.37±0.10 (13.7±1.0) [199±14]

Spring set length/load mm [in.]/N (kgf) [lbf]

Assembly Standard ... 67.2 [2.64]/384 (38.2) [86.4]

Relief valve

Valve opening pressure, MPa (Bar) [psi]

Assembly Standard ... 0.46 (4.6) [66.8]

Oil thermostat

Temperature at which valve starts opening

Assembly Standard ... 80 to 84°C [176 to 183°F]

Temperature at which valve lift more than 11 mm [0.43 in.]

Assembly Standard ... 95°C [203°F]

Piston cooling nozzle

Valve opening pressure, MPa (Bar) [psi]

Assembly Standard ... 0.26 to 0.32 2.6 to 3.2 [38 to 47]

Cooling system

Fresh water pump

Bearing bore inside diameter, mm [in.]

Nominal value ..... Ø80 [3.15]
Assembly Standard ... 79.998–80.018 [3.14913–3.15031]
Service limit ..... 80.025 [3.15058]

Bearing bore inside diameter, mm [in.]

Nominal value ..... Ø90 [3.54]
Assembly Standard ... 89.987–90.022 [3.54279–3.54416]
Service limit ..... 90.025 [3.54428]
NOTE! Same as the bearing cover.

Bearing, Outside diameter, mm [in.]

Nominal value ..... Ø80 [3.15]
Assembly Standard ... 79.985–80.000 [3.14902–3.14961]

Bearing, Outside diameter, mm [in.]

Nominal value ..... Ø90 [3.54]
Assembly Standard ... 89.985–90.000 [3.54272–3.54331]

Bearing, Inside diameter, mm [in.]

Nominal value ..... Ø40 [1.57]
Assembly Standard ... 39.988–40.000 [1.57433–1.57480]

Shaft bearing journal diameter, mm [in.]

Nominal value ..... Ø40 [1.57]
Assembly Standard ... 40.002–40.013 [1.57488–1.57531]
Service limit ..... 39.995 [1.57492]

Vane front face clearance, mm [in.]

Nominal value ..... 0.72 [0.028]
Standard Clearance .. 0.14 to 1.3 [0.006 to 0.051]

Thermostat

Temperature at which valve starts opening

Assembly Standard ... 71±2°C [159.8±3.6°F]
NOTE! Check in atmospheric pressure

Temperature at which valve lift is more than 11 mm [0.43 in.]

Assembly Standard ... 85°C [185°F]
NOTE! Check in atmospheric pressure

Sea water pump

Impeller

Repair Limit ..... Replace if cracked.

Pump seals

Repair Limit ..... Replace if water leaks.

Bearing

Repair Limit ..... Replace if worn excessively.

Holder bearing bore inside diameter, mm [in.]

Nominal value ..... Ø90 [3.54]
Assembly Standard ... 89.975–90.010 [3.54232–3.54362]
Service Limit ..... 90.013 [3.54381]

Bearing, Outside diameter, mm [in.]

Nominal value ..... Ø90 [3.54]
Assembly Standard ... 90.000–90.015 [3.54330–3.54389]

Bearing, Inside diameter, mm [in.]

Nominal value ..... Ø30 [1.18]
Assembly Standard ... 29.990–30.000 [1.18071–1.18110]

Bearing, Inside diameter, mm [in.]

Nominal value ..... Ø40 [1.57]
Assembly Standard ... 39.988–40.000 [1.57433–1.57480]

Shaft bearing journal, mm [in.]

Nominal value ..... Ø30 [1.18]
Assembly Standard ... 30.002–30.012 [1.18118–1.18157]
Service Limit ..... 29.995 [1.18090]

Shaft bearing journal, mm [in.]

Nominal value ..... Ø40 [1.57]
Assembly Standard ... 40.002–40.013 [1.57488–1.57531]
Service Limit ..... 39.995 [1.57460]

Fuel system

Fuel injector

Valve opening pressure, MPa (kgf/cm^2) [psi]

Nominal value ..... 34.32 (350) [4977]

Assembly Standard ... 34.32 to 34.81 350 to 355 [4977 to 5048]

Spray cone angle

Nominal value ..... 160°

NOTE! Check nozzle with a hand tester (at fuel oil temperature 20°C [68°F]. Replace the nozzle if the spray pattern is still bad after washing in clean fuel oil.

Feed pump

Feed pump discharge start time

Assembly Standard ... 20 sec or less

Priming pump discharge start

Assembly Standard ... No. of pumping operations: 30 strokes or less

Feed pump feed rate (pump at 600 rpm)

Assembly Standard ... 900 cm^3 [54.9 cu.in.]/15 sec

Injection pump

Overall clearance at tappet roller, mm [in.]

Service Limit ..... 0.2 [0.00787]

Wear of contact surface between tappet and plunger, mm [in.]

Service Limit ..... 0.2 [0.00787]

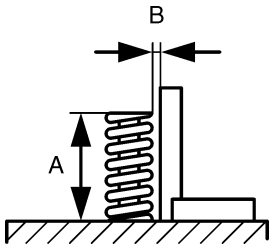
Outside diameter at contact surface of camshaft oil seal, mm [in.]

Nominal value ..... Ø35 [1.378]
Assembly Standard ... 34.963 to 34.938 [1.37649 to 1.37551]
Service Limit ..... 34.800 [1.37001]

Camshaft deflection, mm [in.]

Assembly Standard ... 0.05 [0.00197]
Repair Limit ..... 0.15 [0.00591]

Plunger Spring, mm [in.]



Free length (A), mm[in.]
Assembly Standard ... 70.8 [2.787]
Perpendicularity (B), mm[in.]
Service Limit ..... 1.8 [0.071]

Length under test force, mm [in.]

Assembly standard ... 60.0 [2.36]

Test force, N (kgf) [lbf]

Assembly standard ... 299–366 (30.5–37.3) [67.2–82.2]

Delivery valve spring, mm [in.]

Free length (A)
Assembly Standard ... 18 [0.71]
Perpendicularity (B)
Service Limit ..... 0.6 [0.024]

Length under test force, mm [in.]

Assembly standard ... 14.15 [0.56]

Test force, N (kgf) [lbf]

Assembly standard ... 51.6-61.4 (5.26–6.26) [11.60–13.80]

Camshaft thrust clearance, mm [in.]

Standard Clearance .. 0.02 to 0.06 [0.00079 to 0.00236]

Resistance in rack movement

Assembly Standard ... 500 g [1.102 lb]
NOTE! Make sure rack moves smoothly. Total rack stroke should be 36 mm [1.42 in.].

Injection start interval

Assembly Standard ... 60°±0.5°
NOTE! Camshaft angle

Nozzle valve opening pressure MPa (Bar) [psi]

Assembly Standard ... 34.3 (343) [4978.75]

Feed pressure MPa (Bar) [psi]

Assembly Standard ... 0.16 (1.6) [22.76]

PSG governor drive

Diameter of case bore, drive shaft-side bearing section, mm [in.]

Nominal Value ..... 52 [2.05]
Assembly Standard ... 51.988–52.018 [2.04677–2.04795]

Drive shaft side bearing

Outside diameter, mm [in.]
Nominal Value ..... 52 [2.05]
Assembly Standard ... $51.987^{+0.15}$–$52.000^{+0.0059}$ [2.04673–2.04742]
Inside diameter, mm [in.]
Nominal Value ..... 25 [0.98]
Assembly Standard ... 24.990–25.000 [0.98386–0.98425]

Drive shaft diam., bearing section, mm [in.]

Nominal Value ..... 25 [0.98]
Assembly Standard ... 25.002–25.011 [0.98433–0.98468]

Case bore diam., idler shaft-side bearing section, mm [in.]

Nominal Value ..... 47 [1.85]
Assembly Standard ... 46.989–47.014 [1.84996 –1.85094]

Idler shaft side bearing diameter

Outside diameter, mm [in.]
Nominal Value ..... 47 [1.85]
Assembly Standard ... 46.988–47.000 [1.84992–1.85039]
Inside diameter, mm [in.] $^{+0.10}$ $^{+0.00394}$
Nominal Value ..... 20 [0.79]
Assembly Standard ... 19.990–20.000 [0.78701–0.78740]

Idler shaft diam., bearing section, mm [in.]

Nominal Value ..... 20 [0^{0}79]
Assembly Standard ... 20.002–20.011 [0.78749–0.78783]

Electric system

Starter

Diameter of commutator, mm [in.]

Nominal Value ..... Ø43 [1.69]
Service Limit ..... Ø42 [1.65]

Runout of commutator, mm [in.]

Assembly Standard ... 0.06 [0.0024], or less
Service Limit ..... 0.10 [0.0039]

Mica depth in commutator, mm [in.]

Assembly Standard ... 0.7–0.9 [0.028–0.035]
Service Limit ..... 0.2 [0.0079]

Height of brushes, mm [in.]

Assembly Standard ... 21–22 [0.83–0.87]
Service Limit ..... 13 [0.51]

Tension of brush springs, N (kgf) [lbf]

Nominal Value ..... 44.13 [4.5] [10]
Assembly Standard ... 39.23–49.03 (4.0–5.0) [9–11]
Service Limit ..... 39.23 (4.0) [9], maximum

Armature shaft diameter (rear), mm [in.]

Nominal Value ..... Ø14 [0.55]
Assembly Standard ... 13.941–13.968 [0.54886–0.54992]
Repair Limit ..... $Ø10^{+0.25}$ [$0.39^{+0.0098}$]

Armature shaft diameter (front), mm [in.]

Nominal Value ..... Ø25 [0.98]
Assembly Standard ... 25.002–25.011 [0.98433–0.98468]
Reapir Limit ..... $Ø25^{+0.25}$ [$0.98^{+0.0098}$]

Armature shaft deflection, mm [in.]

Assembly Standard ... 0.06 [0.00236]

Pinion shaft diameter (rear), mm [in.]

Nominal Value ..... Ø30 [1.8]
Assembly Standard ... 30.002 to 30.011 [1.18118 to 1.1853]
Reapir Limit ..... Ø30 $^{+0.011}$ [1.18 $^{+0.0043}$]

Pinion shaft diameter (front), mm [in.]

Nominal Value ..... Ø19 [0.75]
Assembly Standard ... (18.90 to 18.94) ([0.7441 to 0.7457])
Reapir Limit ..... Ø19 $^{+0.06}$ [0.75 $^{+0.00236}$]

Metal, Pinion

Nominal Value ..... Ø19 [0.75]
Assembly Standard ... 19.000 to 19.033 [0.7480 to 0.7493]
Reapir Limit ..... Ø19 $^{+0.033}$ [0.75 $^{+0.00130}$]
Service Limit ..... 0.25 [0.0098]
NOTE! Clearance between shaft and metal.

End play of armature, mm [in.]

Assembly Standard ... 0.3 to 0.7 [0.012 to 0.028]

End play of pinion shaft, mm [in.]

Assembly Standard ... 0.2 to 0.8 [0.008 to 0.031]

Alternator

Output current (27 V), 2500 rpm

At 2500 rpm:
Assembly Standard ... 30 A or higher when cold
At 5000 rpm:
Assembly Standard ... 35 A or higher, when hot

Regulator adjusting voltage (alternator at 5000 rpm, load at 5 A or lower)

Assembly Standard ... 28.5±0.5 V

Field coil resistance (at 20°C [68°F])

Assembly Standard ... 7.3 to 8.6 W

Tightening torques D25A

Description	Thread Diam.xPitch (M-Thread)	Torque Nm	kpm	lbf.ft	Notes
Cylinder Head	22 x 2,5	539	55	398	(a) (b) (c)
Cylinder head nozzle gland (studs)	14 x 2,0	69-78	7-8	51-58	
Rocker case	12 x 1,25	108	11	80	
Rocker shaft	14 x 2,0	147	15	108	
Rocker arm lock nuts	12 x 1,25	64	6,5	47	
Bridge lock nuts	10 x 1,25	55	5,6	40	
Camshaft gear	12 x 1,25	127	13	94	
Camshaft thrust plate	12 x 1,25	59	6	43	
Main bearing caps	22 x 2,5	490	50	362	(a)
Hanger	12 x 1,25	108	11	80	
Piston cooling nozzle	12 x 1,75	34	3,5	25	(d)
Timing gear case	16 x 1,5	216	22	159	
Rear plate	12 x 1,25	108	11	80	
Oil pan	12 x 1,25	59	6	43	
Front mounting bracket	12 x 1,25	108	11	80	
Rear mounting bracket	16 x 1,5	216	22	159	
Connecting rod bearing caps	22 x 1,5	539	55	398	(a) (e)
Flywheel	22 x 1,5	539	55	398	(a)
Viscous damper	22 x 1,5	490	50	362	
Rear idler shaft	12 x 1,25	108	11	80	
Rear idler shaft thrust plate	10 x 1,25	29	3	22	
Exhaust manifold V-clamp nuts	8 x 1,25	19,6	2	14,5	
Exhaust manifold mounting bolts	1/4 x 28	9	0,9	6,5	UNF
Exhaust pipe V-clamps	10 x 1,5	98	10	72	
Oil pump	12 x 1,25	108	11	80	
Oil pump cover	10 x 1,25	26,3-39,7	2,7-4,1	18-32	
Fresh water pump	12 x 1,25	59	6	43	
Fresh water pump shaft pulley (nuts)	24 x 1,5	245	25	181	For alternator drive.

(a) Wet , apply lubrication oil to the threads of the nut and bolt.

(b) 2-step tightening method,

(c) Tighten cylinder head bolts according to the angle method, tighten to 294 Nm [30 kpm; 217 lbf.ft], then tighten 60° more.

(d) Extremely important to use torque wrench in tightening the piston cooling nozzles. Failure to do so may result in excessive tightening torque, which may cause valve malfunctions that could lead to seizing of pistons due to insufficient lubrication.

(e) Tighten connecting rod caps according to the angle method, tighten to 245 Nm [25 kpm; 181 lbf.ft], then tighten 60° more.

Description	Thread Diam.xPitch (M-Thread)	Torque Nm	kpm	lbf.ft	Notes
Sea water pump cam (screw)	10 x 1,25	15,7-21,6	1,6-2,2	11,6-15,9	
Sea water pump casing	8 x 1,25	7,4-9,8	0,75-1,0	5,42-7,23	
Sea water pump cover	8 x 1,25	7,4-9,8	0,75-1,0	5,42-7,23	
Sea water pump drive gear (nut)	24 x 2,0	191-201	19,5-20,5	141-148	
Injection pump	12 x 1,25	108	11	80	
Injection pump bracket	12 x 1,25	108	11	80	
Injection pump drive case	12 x 1,25	108	11	80	
Injection pump gear (nuts)	30 x 1,5	392	40	289	
Injection pump laminate plate	12 x 1,25	103-113	10,5-11,5	76-83	
Injection pump flywheel (nuts)	24 x 1,5	392	40	289	
Injection pump coupling shaft	14 x 1,5	167-177	17-18	123-130	Tighten the slit part.
Injection pump plunger assembly	12 x 1,25	78-83	8-8,5	58-61	
Injection pump delivery valve holder	30 x 1,5	235-255	24-26	174-188	
Injection nozzle gland (nut)	14 x 1,5	98	10	72	
Injection nozzle chip (nut)	28 x 1,5	177-196	18-20	130-145	
Nozzle holder cap nuts	14 x 1,5	69-78	7-8	51-58	
Injection nozzle set screw	10 x 1,5	34-44	3,5-4,5	25-33	
Injection nozzle inlet connector	16 x 1,5	64-74	6,5-7,5	47-54	
Injection pipes	18 x 1,5	49-69	5-7	36-51	
Fuel filter air vent plug	–	7,8-9,8	0,8-1,0	5,8-7,2	
Fuel rack control lever	8 x 1,25	25	2,5	18	(b)
Governor drivecase	12 x 1,25	108	11	80	
Starter	12 x 1,25	59	6	43	
Turbocharger compressor wheel (nut)	11 x 1,0	–	–	–	FD13(f)(g)(h)
Turbocharger V-clamp	–	7,8-9,8	0,8-1,0	5,8-7,2	FD13 (g)
Turbocharger compressor wheel (nut)	1/2 x 20	–	–	–	FD15UNF(f)(i)
Turbocharger turbine housing	10 x 1,5	25-28	2,6-2,9	19-21	FD15 (g)
Turbocharger V-clamp	–	9,8-10,8	1,0-1,1	7,2-8,0	FD15 (g)

(a) Wet , apply lubrication oil to the threads of the nut and bolt.

(b) 2-step tightening method,

(c) Tighten cylinder head bolts according to the angle method, tighten to 294 Nm [30 kpm; 217 lbf.ft], then tighten 60° more.

(d) Extremely important to use torque wrench in tightening the piston cooling nozzles. Failure to do so may result in excessive tightening torque, which may cause valve malfunctions that could lead to seizing of pistons due to insufficient lubrication.

(e) Tighten connecting rod caps according to the angle method, tighten to 245 Nm [25 kpm; 181 lbf.ft], then tighten 60° more.

(f) Left-handed thread.

(g) Apply Moly Disulfide to thread.

(h) Tighten the lock nut to 49 Nm [5 kpm; 36 lbf.ft] firs, then loosen it completely. Retighten to 14,7 Nm [1,5 kpm; 0,8 lbf.ft], then tighten 80±3° more.

(i) Tighten the lock nut to 69 Nm [7 kpm; 51 lbf.ft] then loosen it completely. Apply Loctite No. 962T to the threads. Retighten to 9,8 Nm [1 kpm; 7,2 lbf.ft], then tighten 90±3° more.

Tightening torques D30A

Description	Thread Diam.xPitch (M-Thread)	Torque Nm	kpm	lbf.ft	Notes
Cylinder Head	22 x 2,5	539	55	398	(a)(b)(c)
Cylinder head nozzle gland (studs)	14 x 2,0	69-78	7-8	51-58	
Rocker case	12 x 1,25	108	11	80	
Rocker shaft	14 x 2,0	147	15	108	
Rocker arm lock nuts	12 x 1,25	64	6,5	47	
Bridge lock nuts	10 x 1,25	55	5,6	40	
Camshaft gear	12 x 1,25	127	13	94	
Camshaft thrust plate	12 x 1,25	59	6	43	
Main bearing caps	22 x 2,5	490	50	362	(a)
Hanger	12 x 1,25	108	11	80	
Piston cooling nozzle	12 x 1,75	34	3,5	25	(d)
Timing gear case	16 x 1,5	216	22	159	
Rear plate	12 x 1,25	108	11	80	
Oil pan	12 x 1,25	59	6	43	
Front mounting bracket	12 x 1,25	108	11	80	
Rear mounting bracket	16 x 1,5	216	22	159	
Connecting rod bearing caps	22 x 1,5	539	55	398	(a) (e)
Flywheel	22 x 1,5	539	55	398	(a)
Viscous damper	22 x 1,5	490	50	362	
Rear idler shaft	12 x 1,25	108	11	80	
Rear idler shaft thrust plate	10 x 1,25	29	3	22	
Exhaust manifold V-clamp nuts	8 x 1,25	19,6	2	14,5	
Exhaust manifold mounting bolts	1/4 x 28	9	0,9	6,5	UNF
Exhaust pipe V-clamps	10 x 1,5	98	10	72	
Oil pump	12 x 1,25	108	11	80	
Oil pump cover	10 x 1,25	26,3-39,7	2,7-4,1	18-32	
Fresh water pump	12 x 1,25	59	6	43	
Fresh water pump shaft pulley (nuts)	24 x 1,5	245	25	181	For alternator drive.

(a) Wet , apply lubrication oil to the threads of the nut and bolt.

(b) 2-step tightening method,

(c) Tighten cylinder head bolts according to the angle method, tighten to 294 Nm [30 kpm; 217 lbf.ft], then tighten 60° more.

(d) Extremely important to use torque wrench in tightening the piston cooling nozzles. Failure to do so may result in excessive tightening torque, which may cause valve malfunctions that could lead to seizing of pistons due to insufficient lubrication.

(e) Tighten connecting rod caps according to the angle method, tighten to 245 Nm [25 kpm; 181 lbf.ft], then tighten 60° more.

Description	Thread Diam.xPitch (M-Thread)	Torque Nm	kpm	lbf.ft	Notes
Sea water pump cam (screw)	10 x 1,25	15,7-21,6	1,6-2,2	11,6-15,9	
Sea water pump casing	8 x 1,25	7,4-9,8	0,75-1,0	5,42-7,23	
Sea water pump cover	8 x 1,25	7,4-9,8	0,75-1,0	5,42-7,23	
Sea water pump drive gear (nut)	24 x 2,0	191-201	19,5-20,5	141-148	
Injection pump	12 x 1,25	108	11	80	
Injection pump bracket	12 x 1,25	108	11	80	
Injection pump drive case	12 x 1,25	108	11	80	
Injection pump gear (nuts)	30 x 1,5	392	40	289	
Injection pump laminate plate	12 x 1,25	103-113	10,5-11,5	76-83	
Injection pump flywheel (nuts)	24 x 1,5	392	40	289	
Injection pump coupling shaft	14 x 1,5	167-177	17-18	123-130	Tighten the slit part.
Injection pump plunger assembly	12 x 1,25	78-83	8-8,5	58-61	
Injection pump delivery valve holder	30 x 1,5	235-255	24-26	174-188	
Injection nozzle gland (nut)	14 x 1,5	98	10	72	
Injection nozzle chip (nut)	28 x 1,5	177-196	18-20	130-145	
Nozzle holder cap nuts	14 x 1,5	69-78	7-8	51-58	
Injection nozzle set screw	10 x 1,5	34-44	3,5-4,5	25-33	
Injection nozzle inlet connector	16 x 1,5	64-74	6,5-7,5	47-54	
Injection pipes	18 x 1,5	49-69	5-7	36-51	
Fuel filter air vent plug	–	7,8-9,8	0,8-1,0	5,8-7,2	
Fuel rack control lever	8 x 1,25	25	2,5	18	(b)
Governor drivecase	12 x 1,25	108	11	80	
Starter	12 x 1,25	59	6	43	
Turbocharger compressor wheel (nut)	11 x 1,0	–	–	–	FD13 (f) (g) (h)
Turbocharger V-clamp	–	7,8-9,8	0,8-1,0	5,8-7,2	FD13 (g)
Turbocharger compressor wheel (nut)	1/2 x 20	–	–	–	FD15 UNF (f) (i)
Turbocharger turbine housing	10 x 1,5	25-28	2,6-2,9	19-21	FD15 (g)
Turbocharger V-clamp	–	9,8-10,8	1,0-1,1	7,2-8,0	FD15 (g)

(a) Wet , apply lubrication oil to the threads of the nut and bolt.

(b) 2-step tightening method,

(c) Tighten cylinder head bolts according to the angle method, tighten to 294 Nm [30 kpm; 217 lbf.ft], then tighten 60° more.

(d) Extremely important to use torque wrench in tightening the piston cooling nozzles. Failure to do so may result in excessive tightening torque, which may cause valve malfunctions that could lead to seizing of pistons due to insufficient lubrication.

(e) Tighten connecting rod caps according to the angle method, tighten to 245 Nm [25 kpm; 181 lbf.ft], then tighten 60° more.

(f) Left-handed thread.

(g) Apply Moly Disulfide to thread.

(h) Tighten the lock nut to 49 Nm [5 kpm; 36 lbf.ft] firs, then loosen it completely.
Retighten to 14,7 Nm [1,5 kpm; 0,8 lbf.ft], then tighten 80±3° more.

(i) Tighten the lock nut to 69 Nm [7 kpm; 51 lbf.ft] then loosen it completely. Apply Loctite No. 962T to the threads.
Retighten to 9,8 Nm [1 kpm; 7,2 lbf.ft], then tighten 90±3° more.

Standard Bolts and Nuts

Fine threads

Thread	Strength classification					
diameter x pitch	7T			10.9		
mm [in.]	Nm	kpm	lbf.ft	Nm	kpm	lbf.ft
M10 x 1,25 [0.39 x 0.049]	33	3,4	25	60	6,1	44
M12 x 1,25 [0.47 x 0.049]	60	6,1	44	108	11,0	80
M14 x 1,5 [0.55 x 0.059]	97	9,9	72	176	17,9	129
M16 x 1,5 [0.63 x 0.059]	145	14,8	107	262	26,7	193
M18 x 1,5 [0.71 x 0.059]	210	21,4	155	378	38,5	278
M20 x 1,5 [0.79 x 0.059]	291	29,7	215	524	53,4	386
M22 x 1,5 [0.87 x 0.059]	385	39,3	284	694	70,8	512
M24 x 1,5 [0.94 x 0.059]	487	49,7	359	878	89,5	647
M27 x 3 [1.06 x 0.12]	738	75,3	544	1328	135,5	980
Coarse threads						
M8 x 1,25 [0.31 x 0.049]	17	1,7	12	30	3,1	22
M10 x 1,5 [0.39 x 0.059]	32	3,3	24	58	5,9	43
M12 x 1,75 [0.47 x 0.069]	57	5,8	42	102	10,4	75
M14 x 2 [0.55 x 0.079]	93	9,5	69	167	17,0	123
M16 x 2 [0.63 x 0.079]	139	14,2	103	251	25,6	185
M18 x 2,5 [0.71 x 0.098]	194	19,8	143	350	35,7	258
M20 x 2,5 [0.79 x 0.098]	272	27,7	200	489	49,9	361
M22 x 2,5 [0.87 x 0.098]	363	37,0	268	653	66,6	482
M24 x 3 [0.94 x 0.12]	468	47,7	345	843	86,0	622
M27 x 3 [1.06 x 0.12]	686	70,0	506	1236	126,0	911

Standard eyebolts

Thread	Strength classification		
diameter x pitch	4T		
mm [in.]	Nm	kpm	lbf.ft
M8 x 1,25 [0.31 x 0.049]	8±1	0,8±0,1	5,8±0,72
M10 x 1,25 [0.39 x 0.049]	15±2	1,5±0,2	10,8±1,45
M12 x 1,25 [0.47 x 0.049]	25±3	2,5±0,3	18,1±2,17
M14 x 1,5 [0,55 x 0.059]	34±4	3,5±0,4	25,3±2,89
M16 x 1,5 [0.63 x 0.059]	44±5	4,5±0,5	32,5±3,62
M18 x 1,5 [0.71 x 0.059]	74±5	7,5±0,5	54,2±3,62
M20 x 1,5 [0.79 x 0.059]	98±10	10,0±1,0	72,3±7,23
M24 x 1,5 [0.94 x 0.059]	147±15	15,0±1,5	108,5±10,8
M27 x 3 [1.06 x 0.12]	226±20	23,0±2,0	166,3±14,5

(Dry)

Standard union nuts

Cap nut size diameter x pitch mm [in.]	Strength classification Nm	kpm	lbf.ft	Nominal diameter
M14 x 1,5 [0.55 x 0.059]	39	4	29	63
M16 x 1,5 [0.63 x 0.059]	49	5	36	80
M20 x 1,5 [0.79 x 0.059]	78	8	58	100
M22 x 1,5 [0.87 x 0.059]	98	10	72	120
M27 x 1,5 [1.06 x 0.059]	157	16	116	150
M30 x 1,5 [1.18 x 0.059]	196	20	145	180
M30 x 1,5 [1.18 x 0.059]	196	20	145	200
M33 x 1,5 [1.30 x 0.059]	245	25	181	220
M36 x 1,5 [1.42 x 0.059]	294	30	217	254

(Dry)

High pressure fuel injection pipes

Cap nut size diameter x pitch mm [in.]	Strength classification Nm	kpm	lbf.ft
M12 x 1,5 [0.49 x 0.059]	39±5	4±0,5	29±3,6
M14 x 1,5 [0.55 x 0.059]	49±5	5±0,5	36±3,6
M18 x 1,5 [0.71 x 0.059]	59±1	6±1,0	43±7,2

(Dry)

Sealants and Lubricants Table

Engine main parts

Cylinder head sealing caps

Sealant ..... refer to parts catalogue
How to use ..... Coat holes in crankcase

Water outlet connectors (Rocker case)

Lubricant ..... Grease
How to use ..... Grease O-ring joint

Cylinder liners

Sealant or lubricant ... Engine Oil
How to use ..... Grease O-ring joint

Front plate, gear case, oil pan, and crankcase

Sealant ..... refer to parts catalogue
How to use ..... Coat three face-mating portions only

Rear plate, gear case, oil pan, and crankcase

Sealant ..... refer to parts catalogue
How to use ..... Coat three face-mating portions only

Crankcase plugs

Sealant ..... Loctite
How to use ..... Apply to threads

Oil pan and crankcase

Sealant ..... refer to parts catalogue
How to use ..... Coat three face-mating portions only

Front plate, front gear case and timing gear case

Sealant ..... refer to parts catalogue

Oil Seals

Lubricant ..... Engine oil
How to use ..... Coat lip of each oil seal

Drive case

Sealant ..... refer to parts catalogue
How to use ..... Apply to flange surface

Cylinder head gasket

Sealant ..... refer to parts catalogue
How to use ..... Apply around tappet chambers

Lubrication system

Oil pump, Cover and case

Sealant ..... refer to parts catalogue
How to use ..... Coat both sides of packing

Cooling system

Fresh water pump, Oil seal

Lubricant ..... Engine oil
How to use ..... Coat lip of inner seal

Fresh water pump, Unit seal

Lubricant ..... Coolant
How to use ..... Coat floating seat

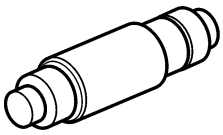
Sea water pump, Unit seal

Lubricant ..... Grease
How to use ..... Apply to surface that contacts bushing

Sea water pump, Oil seal

Lubricant ..... Grease
How to use ..... Apply to hollow part and lip of oil seal

Special Tools



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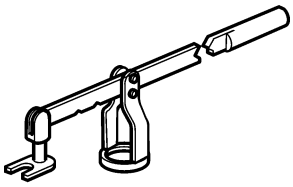

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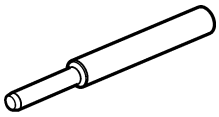

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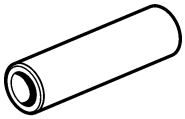

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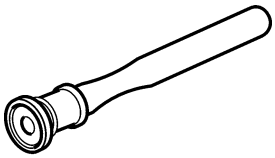

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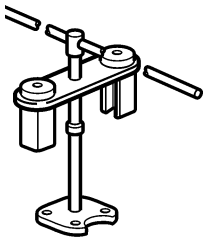

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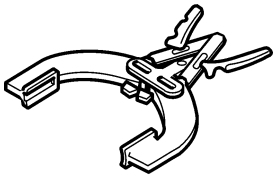

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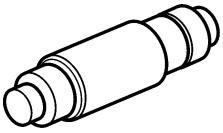

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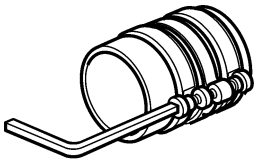

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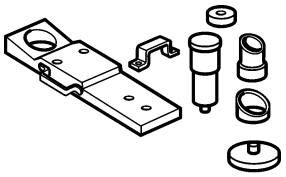
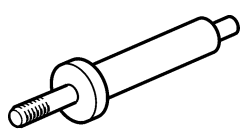


885420

885423	Rocker bushing tool	885452	Ring pliers
885422	Cylinder head lifting	885425	Cylinder liner remover
885391	Valve spring pusher	885414	Piston ring tool
885410	Valve guide remover	885396	Idler bushing puller
885413	Valve guide and seal installer	885443	Piston installer
885386	Valve lapper	885420	Connection rod bushing installer



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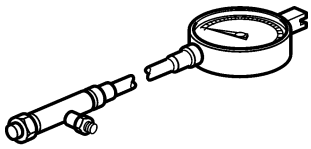

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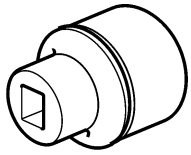

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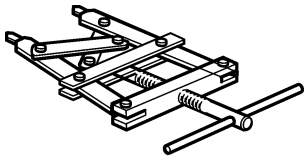

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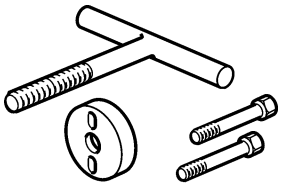

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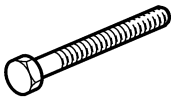

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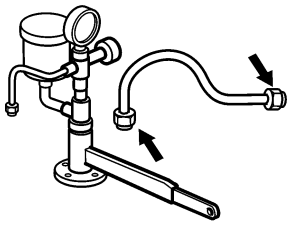

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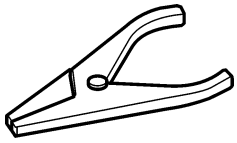

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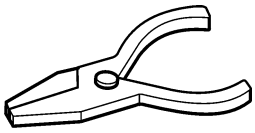

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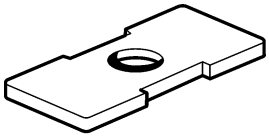
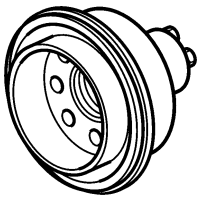


885428

885421	Compression gauge adaptor
885409	Compression gauge
885445	To remove/install injection pump gear and waterpump shaft pulley nut.
885447	Tool for lifting piston
885446	Waterpump pliers
885424	Impeller remover
885455	To remove oil and water pump plate and flywheel
885451	Nozzle tester
885439	To remove and install snap ring
885441	To remove and install snap ring
885440	To remove and install snap ring
885428	Injection coupling gauge



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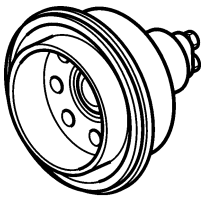

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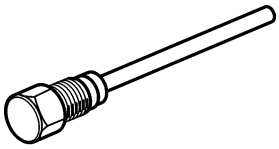

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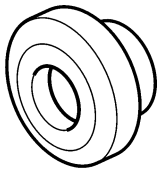

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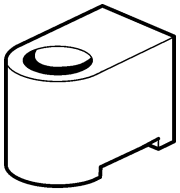

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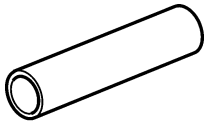

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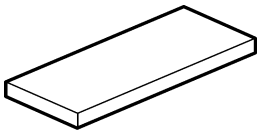

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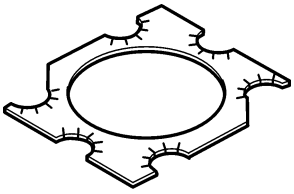

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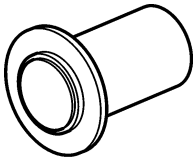

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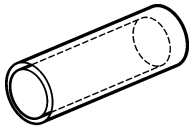

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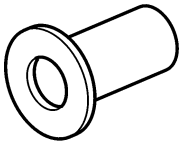


885408

885426	To install front oil seal
885435	To installa rear oil seal
885430	Valve seat cutter shaft
885431	Valve seat cutter
885448	Liner pusher
885429	Bolt for liner pusher
885432	Spacer for liner pusher head bolt
885450	Measure crankcase counter bore depth
885449	To tighten cylinder head bolts
885399	Installation of fan drive oil seal
885407	Installation of fan drive bearing
885408	Installation of fan drive beaing

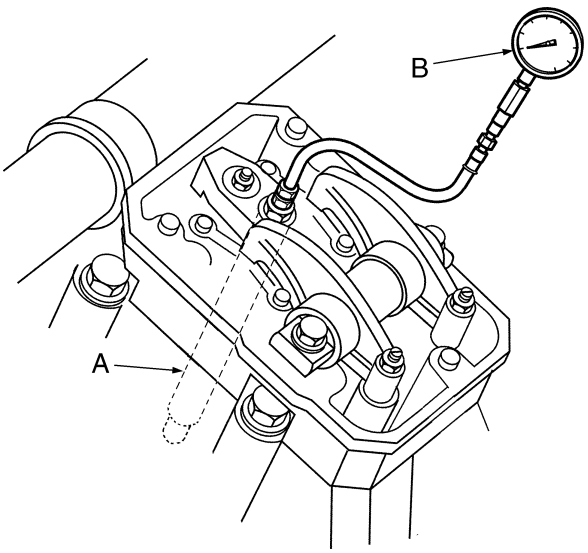
Determination of overhaul timing

In most cases the engine should be overhauled when the engine's compression pressure is low. Other factors that indicate the necessity of engine overhaul are:

A. Decreased power
B. Increased fuel consumption
C. Increased engine oil consumption
D. Increased blow-by gas volume through the breather due to abrasion of liner and piston rings
E. Decreased engine oil pressure
F. Gas leakage due to poor seating of inlet and exhaust valves
G. Starting problems
H. Increased noise from engine parts
I. Abnormal color of exhaust gas after warm-up

Anyone or a combination of these symptoms may indicate that engine overhaul is required. Item D requires special consideration because decreased pressure, due to wear of the cylinder liner and the piston rings, is one of the most obvious signs that the engine requires overhauling. Test the compression pressure. Some items listed above are not directly related to the need of an engine overhaul. B and G are more likely to be affected substantially by

- Injection volume of the fuel injection pump
- Fuel injection timing
- Wear of injection-pump plunger
- Fitting of the injection nozzle
- Condition of equipment: battery, starter, or alternator



Testing the compression pressure

Measure the compression pressure at regular intervals to obtain correct data. If the compression pressure is lower than the repair limit, overhaul the engine.

1. Remove the injector from the cylinder to be measured. Attach the compression gauge adapter (A) to the adapter and connect compression gauge (B).
2. Crank the engine. Read the compression pressure with the engine running at specified speed.

Compression pressure, Mpa (Bar) [psi]

Assembly Standard ... 2.85 (28.5) [263] min.
Repair Limit ..... 2.30 (23.0) [185] max.

⚠ **IMPORTANT!** Measure the compression pressure on all cylinders.

NOTE ! Compression pressure varies with engine speed. Measure the compression pressure at 120 rpm

NOTE ! The compression pressure will be slightly higher on new or overhauled engines. Pressure will drop gradually by wear of parts.

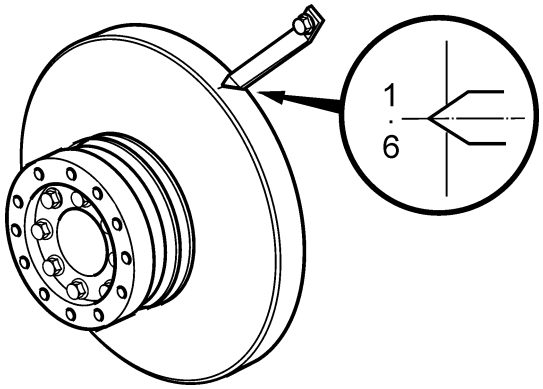
Adjustment and Benchtesting

Valve Clearance

Check and adjust the valve clearance on a cold engine. The valve height is adjusted first, and then the clearance of the rocker arm.

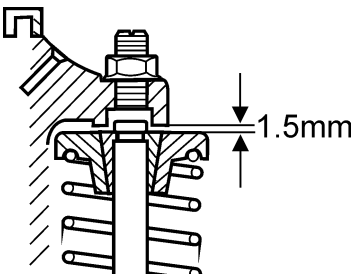
⚠ **IMPORTANT!** The engine must under no circumstances be running when checking and adjusting the valve clearance since the valves can knock against the pistons and cause serious damage.

⚠ **IMPORTANT!** Make sure that the stop lever is pulled out and the starter key switched off.



Top dead center on compression stroke

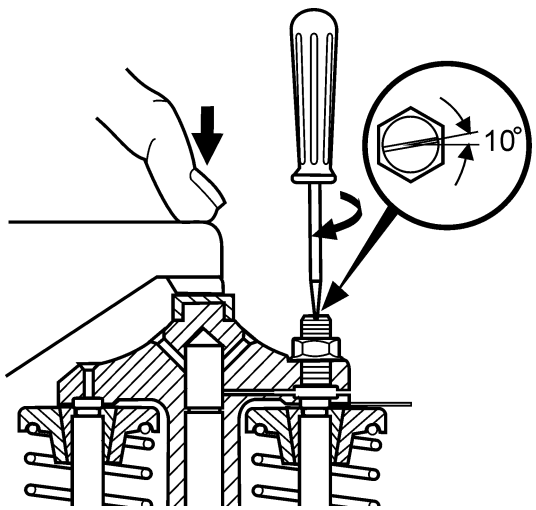
1. Turn the engine in the normal direction to align the timing mark [1 .6] on the damper with the pointer as shown.
2. Remove the cylinder cover and make sure the inlet and exhaust valves have some clearance. If the timing mark [1 .6] is aligned with the pointer, either the No. 1 or No. 6 piston is at top dead center on the compression stroke.



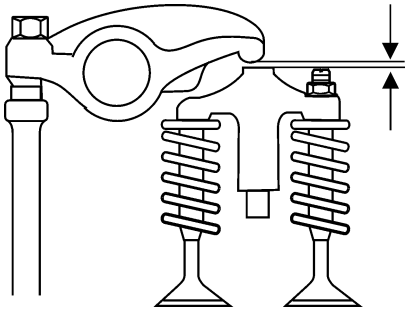
Adjust valve height

⚠ **IMPORTANT!** Clearance between valve yoke and rotator should be min. 1.5 mm [0.059 in.]. If not, interference will occur and cause the valve cones to get out of place. If clearance is less than 1.5 mm [0.059 in.] after valve adjustment, consult your dealer.

NOTE! If the valve seats are worn, one valve will differ from another in height, increasing the clearance between the valve stem and yoke, leading to an increased valve clearance.



1. Unscrew lock nut and adjusting screw on the valves so that there is clearance between the yoke and the valve stem.
2. Press the valve yoke down.Turn the adjusting screw until it touches the valve stem. Turn an additional 10 degrees. Lock the adjusting screw with the lock nut.



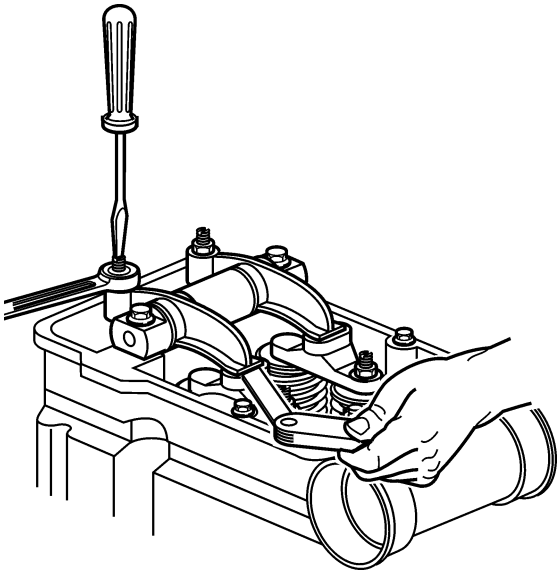
Valve clearance inspection

1. Check the valve clearance with feeler gauges inserted between the rocker arm and yoke cap.

Valve Clearance:

Inlet valve ..... 0.6 mm [0.024 in.]
Exhaust valve ..... 0.8 mm [0.031 in.]

2. The clearance is correct if feeler gauge is slightly gripped between the rocker arm and the yoke cap. If the feeler does not fit into the clearance exactly, perform adjustments as described below.



Adjust valve clearance

1. Loosen the lock nut of the adjusting screw.
2. Turn the adjusting screw in either direction until the feeler gauge is slightly gripped between the rocker arm and yoke cap.
3. After adjusting the clearance, tighten the lock nut of the adjusting screw while holding the adjusting screw in position.

Firing order

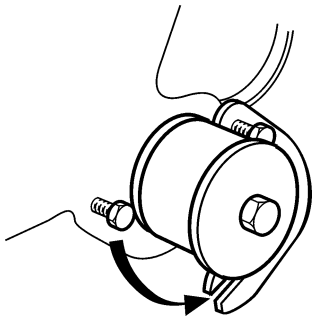
Check and adjust the valve clearance in the firing order (injection sequence), turning the engine with each cylinder piston at top dead center on compression stroke.

Firing order	1	5	3	6	2	4

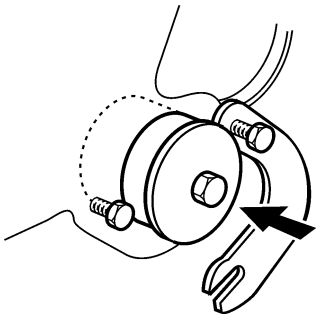
(Example): After checking and adjusting the cylinder No.1, turn the engine 120° and check and adjust the cylinder No. 5.

Cylinder No.	1	5	3	6	2	4
Timing (°)	0	120	240	360	480	600

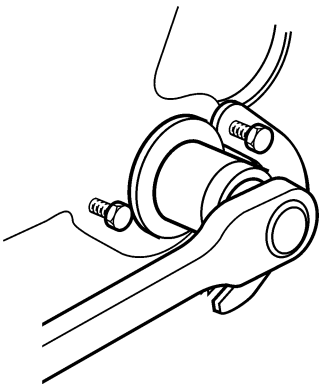
How to use the Turning Gear



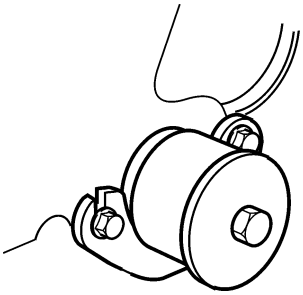
1. Loosen the two bolts securing the shaft lock plate and remove the plate from the shaft (groove).



2. Push in the shaft all the way to the TURN position.



3. Put a socket to the hexagonal end of the shaft and turn the shaft with a ratchet handle for turning.

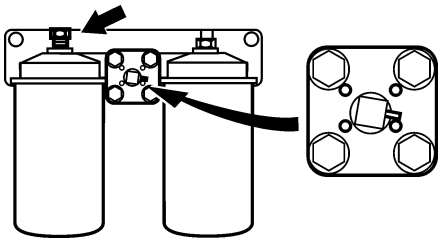


4. After turning the engine, pull the shaft back to the RUN position, secure the shaft with the locking device and tighten the plate bolts. Make sure the plate is secured properly.

⚠ **WARNING!** Before starting the engine, make sure the turning gear is in the RUN position and is locked.

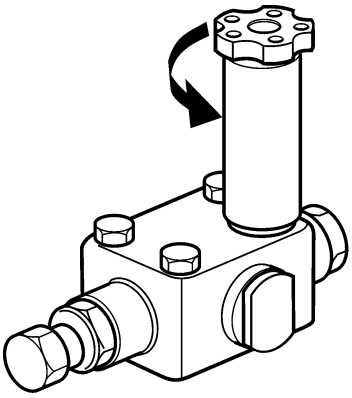
Fuel system bleeding

Prime the fuel filters and fuel injection pump in the following sequence:

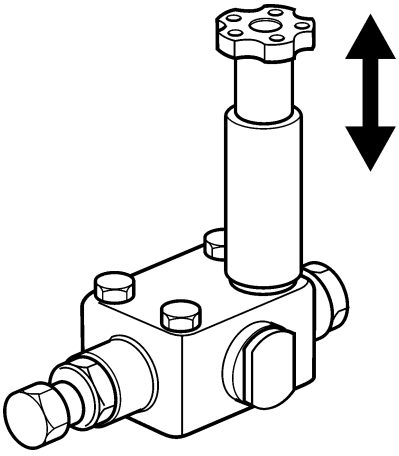


Bleeding the Fuel filter

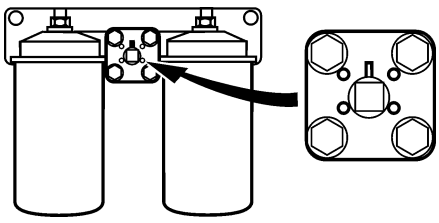
1. Put the fuel filter switching cock in the left filter bleed position and loosen the left air vent plug.



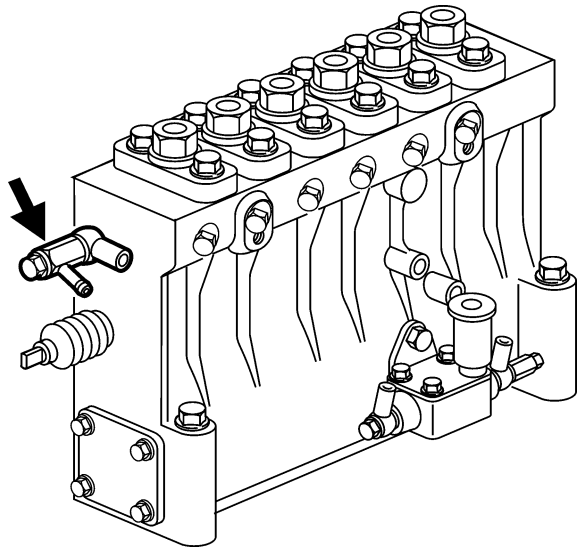
2. Turn the priming pump plunger counterclockwise to unlock the mechanism.



3. Move the plunger up and down until fuel free of air flows out, then tighten the air vent plug.

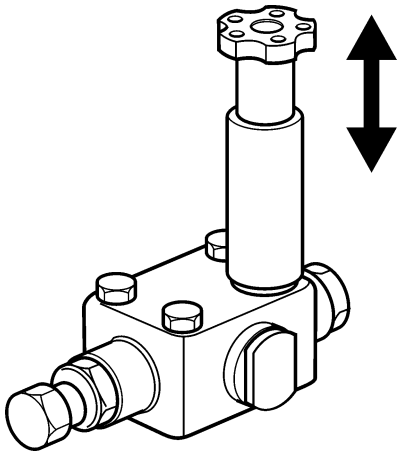


4. Put the fuel filter switching cock in the neutral position and repeat the procedure with the other fuel filter.



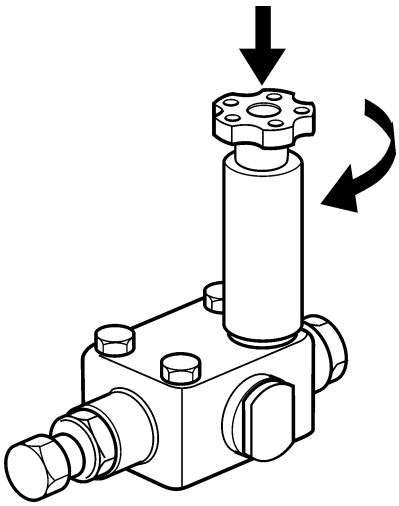
Bleeding the fuel injection pump

1. Loosen the air vent cock on the fuel injection pump about 1.5 turns.



2. Pump the priming pump to start the flow of fuel through the system.
3. When fuel without visible bubbles comes out of the air vent cock, lock the priming pump cap while holding it down. Tighten the air vent cock.

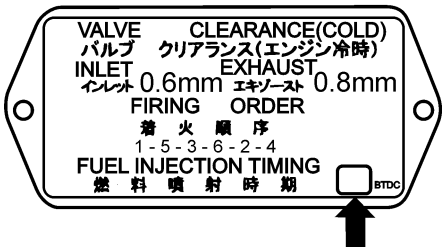
NOTE! Be sure to lock the priming pump cap before tightening the air vent plugs and cock. If not, the cap will not return to the original position due to pressure in the priming pump.



4. Tighten the priming pump cap by hand until the tightening force increases, normally this occurs after approximately 70 to 90 degrees. Mark this position on the priming pum.
5. Tighten the priming pump cap an additional 120 to150 degrees using a wrench.

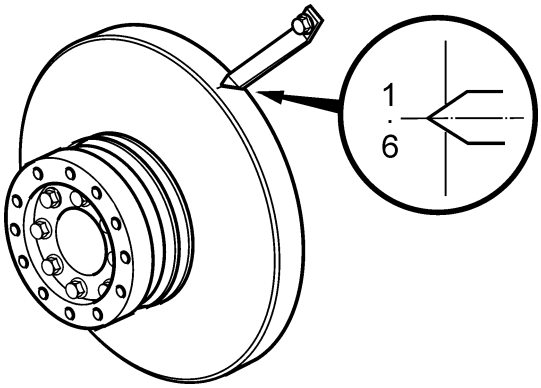
⚠ IMPORTANT! If the priming pump cap is tightened too much (more than 240 degrees in total), the top of the pump might be damaged.

⚠ IMPORTANT! If the pump cap is not tightened properly, engine vibration may cause excessive wear to the internal threads of the pump. This may cause the priming pump cap to eject and oil to flow out leading to engine failure and damage to the installation.



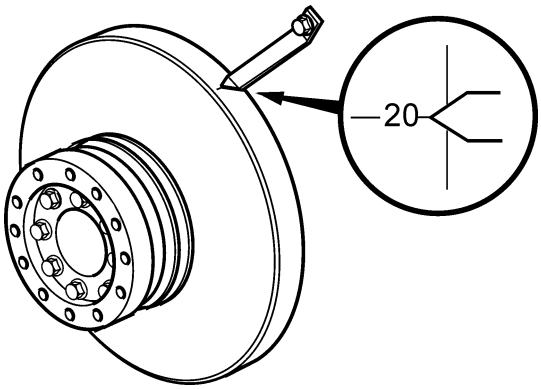
Fuel injection timing

The injection timing is indicated on the caution plate attached to the No. 1 rocker cover. Check it before inspection. Bring the piston for No. 1 cylinder to top dead center on compression stroke as follows:

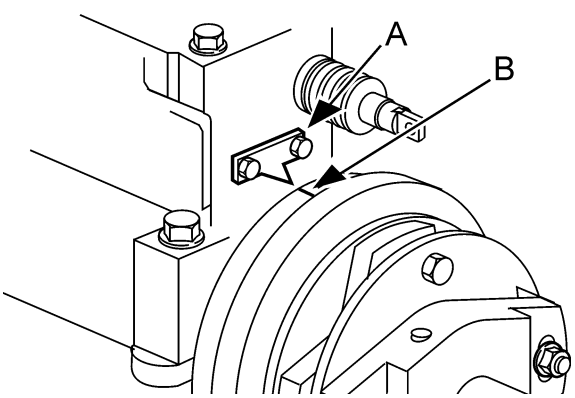


1. Turn the engine in the normal direction to align the timing mark [1 .6] on the damper with the pointer as shown.
2. Remove the No. 1 rocker cover and make sure the inlet and exhaust valves for No. 1 cylinder have some clearance. If these valves have no clearance, turn the engine once again to align the timing mark [1 .6].

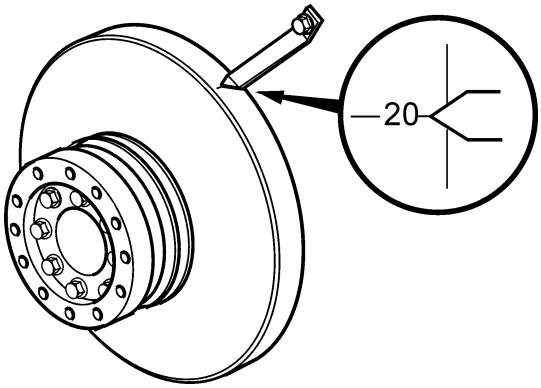
NOTE! Do not confuse the No. 1 cylinder with No. 6. When the piston for the No. 1 cylinder is in the above-mentioned position, its inlet and exhaust valve are seated, presenting some clearance.



3. Turn back the engine approximately 60 degrees, and turn it in the normal direction slowly until the specified timing (indicated on the caution plate) aligns with the pointer.

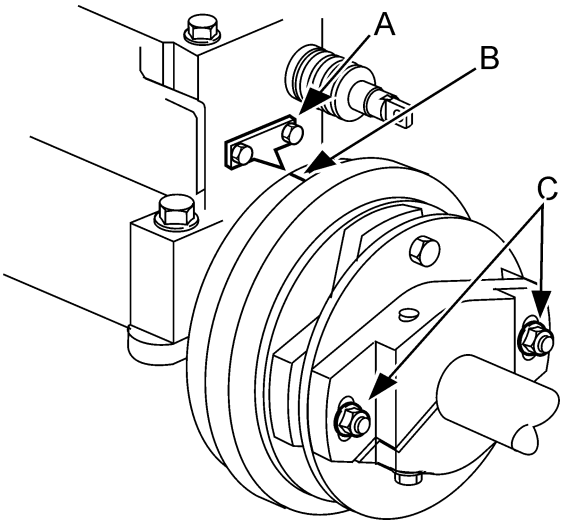


4. To ensure proper injection timing, make sure that the timing mark (B) on the coupling flywheel aligns with the pointer (A) on the fuel injection pump.



Adjust fuel injection timing

1. Make sure the timing mark (indicated on the caution plate) is aligned with the pointer, with the piston for the cylinder at top dead center on compression stroke.



2. Loosen the bolts(C) for the fuel injection pump coupling.
3. Turn the coupling flywheel until the timing mark(B on the coupling flywheel aligns with the pointer(A) on the fuel injection pump.
4. Tighten the one nut for fuel injection pump coupling. Turn the engine to tighten the other side nut.
5. Turn the engine (two turns) to recheck the injection timing for verification.

Speed setting

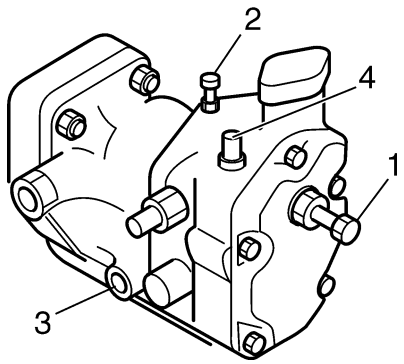
⚠ **IMPORTANT!** When working with speed settings, stand by to stop the engine manually to avoid engine overspeed.

⚠ **IMPORTANT!** Set screw no. 4 adjusts maximum fuel to engine and is factory set and should not be touched.

NOTE! The idling speed and maximum speed are set at factory bench testing, and the set bolts are sealed. These settings are to be inspected and adjusted at Volvo Penta Workshops only.

NOTE! After adjusting the governor be sure to seal the stopper. Whether the seals are intact or not has bearing on the validity of claims under the warranty.

NOTE! Prior to inspection and adjustment, run the engine until coolant and oil temperature is 70°C [158°F] or higher.



PSG Governor

Check and adjust idling speed setting

1. Make sure the speed control lever is in idling position, measure engine rpm.
2. If idling speed is out of the specified range, reset with the adjust screw (1).

Check and adjust no-load max. speed setting

1. Move speed control lever to max. speed, measure engine rpm.
2. If max. speed is out of the specified range, reset with the governor set bolt (2).
3. Manually change the engine speed to test the governor response, its ability to sense changes in speed and adjust it promptly to nominal speed.

Correcting hunting

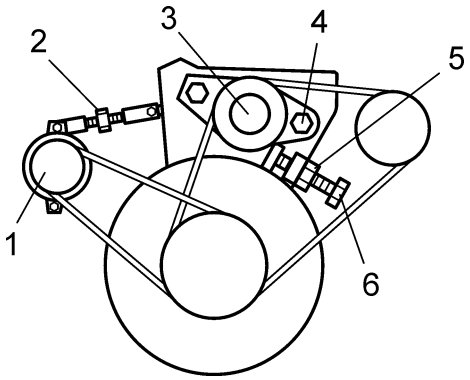
1. If the engine hunts, adjust with the needle valve (3). Open the needle valve (counterclockwise, 2 to 3 rotations) until the engine hunts. Keep it hunting for 30 seconds, until air is vented from the governor.
2. Slowly close the valve until the hunting stops.

NOTE! If the needle is closed too far, speed regulation with respect to changes in load will be delayed. Keep the valve backed off at least 1/4 rotation from the fully closed position.

3. Seal all set bolts.

Measure V-belt deflection

Measure the deflection of the belt. Apply approximately 98 to 147 N (10 to 15 kgf) [22 to 33 lbf] force midway between the pulleys. The deflection should be approximately 10 to 15 mm [0.4 to 0.6 in.]. Adjust the belt if the deflection is not correct.



Alternator

1. Loosen all the bolts securing the alternator.
2. Turn the turn buckle (2) to adjust the belt tension.
4. While maintaining this condition, tighten all the mounting bolts (4) to secure the alternator.

Raw water pump

1. Loosen all the bolts securing the tension pulley (3).
2. Loosen the lock nut(5) on the adjusting bolt(6) and fasten the bolt to tighten the belt.
3. While maintaining this condition, tighten all the mounting bolts (4) to secure the alternator.

Bench testing

An overhauled engine should be performance tested on a dynamometer. This test is also for breaking in the major running parts of the engine. To test the engine, follow these procedures:

Start Up

1. Check levels in radiator, oil pan, and fuel tank. Prime the fuel and cooling systems.
2. Crank the engine for about 10 seconds to permit lubricating oil to circulate through the engine.

NOTE! Do not supply fuel to the engine, place the stop lever in stop position.

3. Move the speed control lever slightly in the direction of increasing fuel injection, turn the starter switch to START to start the engine. Do not move the control lever to “full fuel injection” position.
4. After the engine starts, let it idle under no load by operating the speed control lover.

Inspection after Start Up

After starting up the engine, check the following points. If you find anything wrong, immediately stop the engine and investigate the cause.

1. Lubricating oil pressure should be 0.49 to 0.64 Mpa (5 to 6.5 kgf/cm2) [71 to 92 psi] at rated speed or over 0.20 to 0.29 Mpa (2 to 3 kgf/cm2) [28 to 43 psi] at idling speed.
2. Coolant temperature should be 71 to 85°C [165 top 185°F].
3. Check for leakage of oil, coolant, fuel, especially oil pipe connections for turbocharger lubrication.
4. Knocking should die away as coolant temperature rises. No other defective noise should be heard.
5. Check exhaust color and for abnormal odors.

Bench test (dynamometer) conditions

Summary table of bench testing conditions.

Step 1

Speed (rpm) ..... Idling
Load ..... No load
Time (min.) 5

Step 2

Speed (rpm) 1000
Load ..... No load
Time (min.) 5

Step 3

Speed (rpm) 1200
Load ..... No load
Time (min.) 10

Step 4

Speed (rpm) ..... Rated*
Load 25%
Time (min.) 10

Step 5

Speed (rpm) ..... Rated*
Load 50%
Time (min.) 10

Step 6

Speed (rpm) ..... Rated*
Load 75%
Time (min.) 30

Step 7

Speed (rpm) ..... Rated*
Load 100%
Time (min.) 20

*Rated speed: Varies according to specifications.

After Bench Testing

1. Adjust valve clearance
2. Adjust injection timing
3. Re-tighten external bolts and nuts

Engine auxiliaries removal and installation

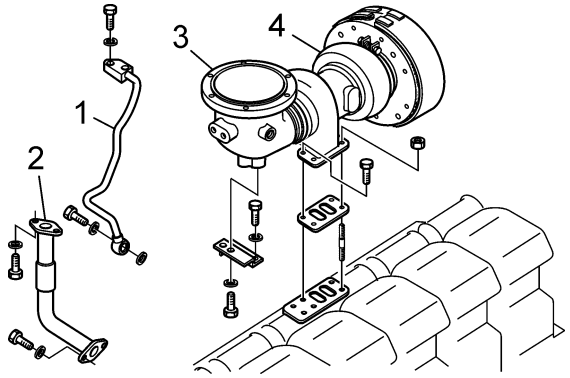
This section explains the procedures and tips for removal and installation of the accessories – the preliminary process to go through for overhauling the engine.

Preparation

1. Shut off the fuel supply, and disconnect the starting system from the engine.
2. Loosen the drain cocks, on the left rear side of crankcase, and drain coolant.
3. Loosen the oil pan drain plug, and drain engine oil.

Oil capacity: 160 l [42.3 U.S. gals] (Whole engine)

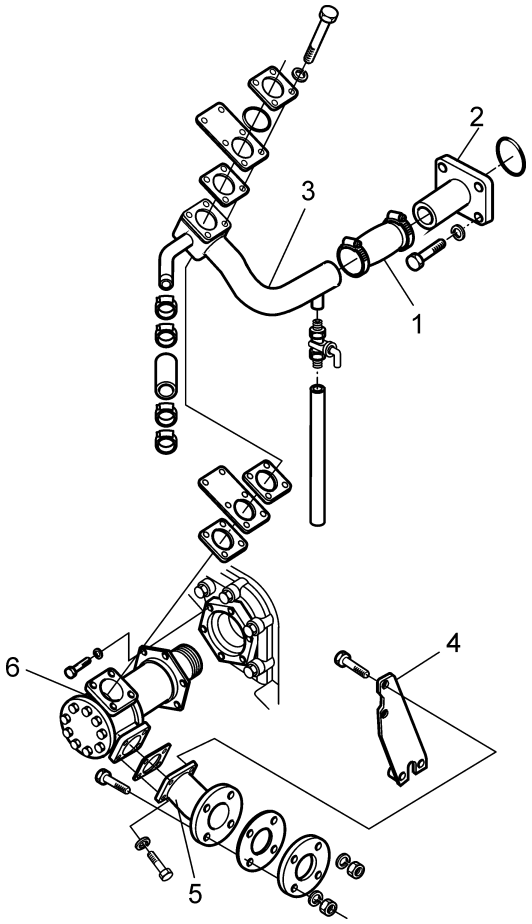
⚠ **WARNING!** Hot engine oil can cause personal injury if it contacts the skin. Be careful when draining the oil.



Engine Auxiliaries Removal

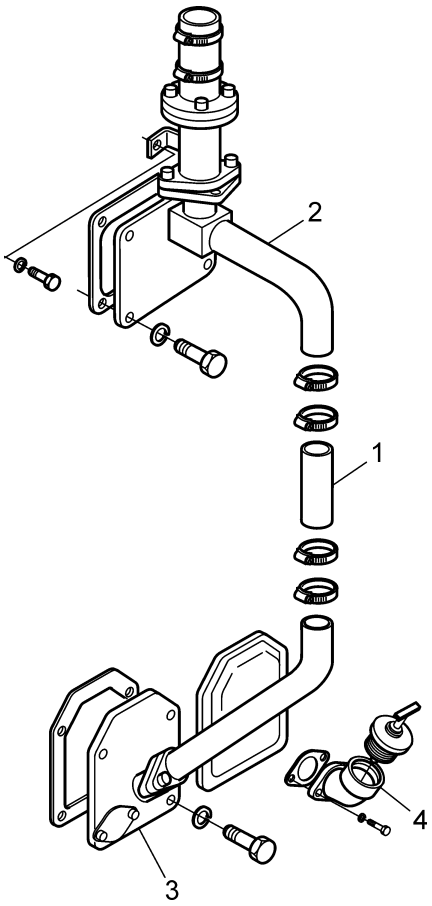
Remove turbocharger

1. Remove turbocharger oil supply pipe (1) and drain pipe (2).
2. Remove exhaust duct (3) and turbocharger (4).



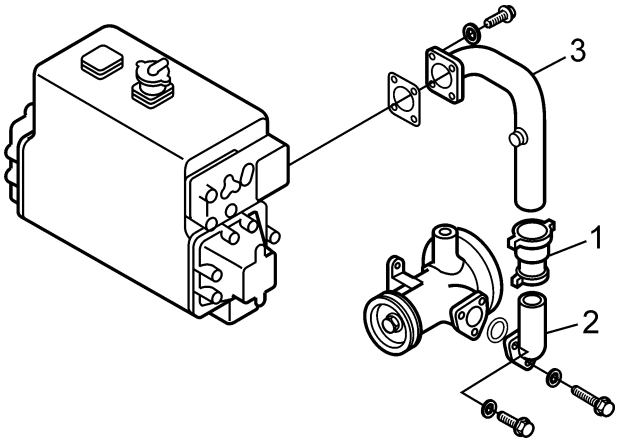
Remove raw water pump

1. Remove turbocharger oil supply pipe (1) and drain pipe (2).
2. Remove raw water pipe (3) from raw water pump.
3. Remove pipe bracket (4) and remove raw water pipe (5).
4. Unscrew raw water pump mounting bolts and dismount the pump (6).



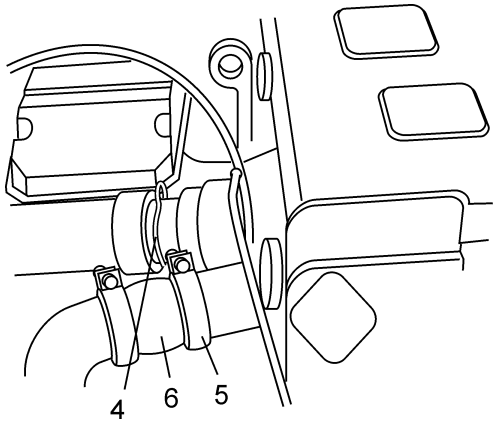
Remove breather and oil filler

1. Remove hose clamps and rubber hose (1).
2. Remove cam cover (2) with breather pipe attached.
3. Remove side cover (3) with breather pipe attached.
4. Remove oil filler (4).

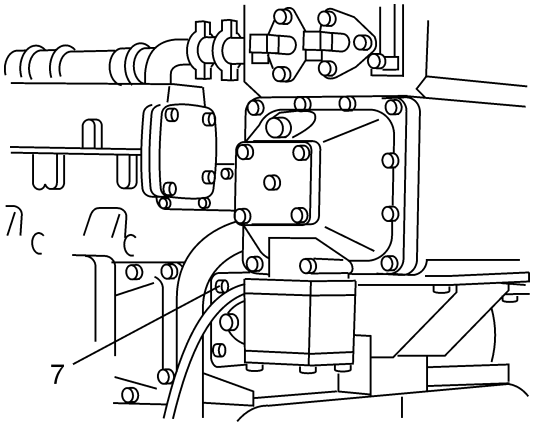


Remove heat exchanger

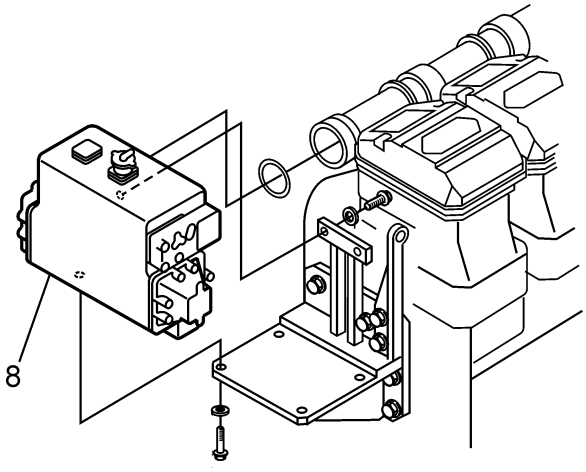
1. Remove coupling (1) and dismount water pipe (2) from the fresh water pump.
2. Remove water pipe (3) from the heat exchanger.



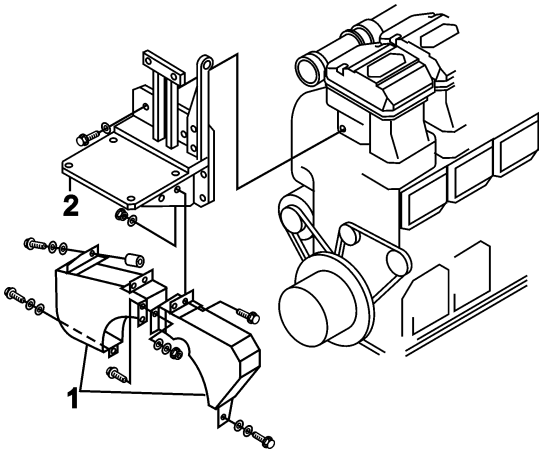
3. Remove snap ring (4) and move connector (5) towards the cylinder head to disconnect it from the heat exchanger.
4. Remove coupling (6) to disconnect from the exhaust manifold.



5. Remove four bolts to disconnect from the air cooler (7).

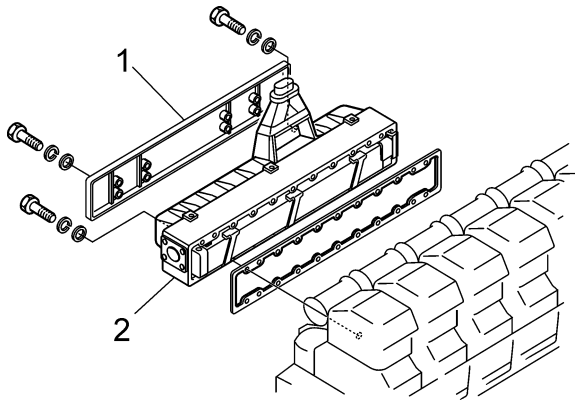


6. Unscrew heat exchanger mounting bolts and remove the heat exchanger (8).



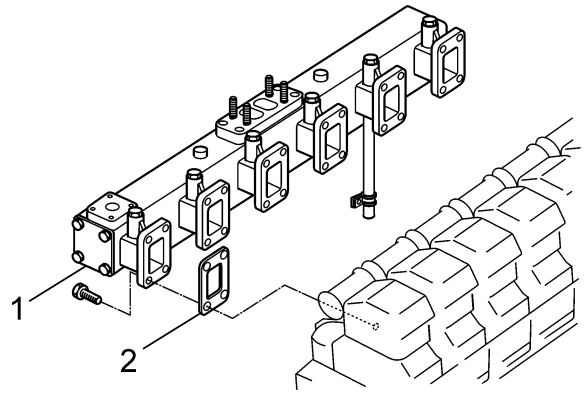
Remove belt covers and heat exchanger bracket

1. Remove left and right belt covers (1).
2. Remove heat exchanger bracket (2).



Remove air cooler

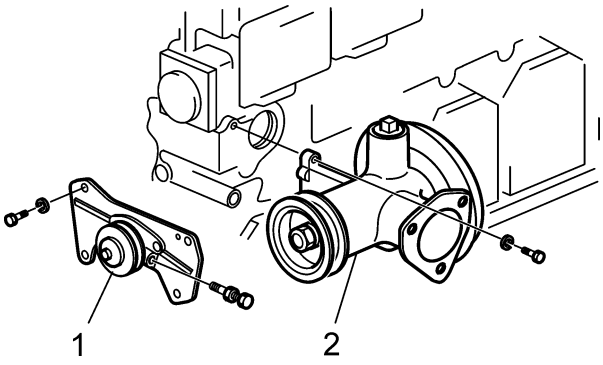
Remove the manifold cover (1) remove also the air cooler (2) and air cooler cover (as a set).



Remove exhaust manifold

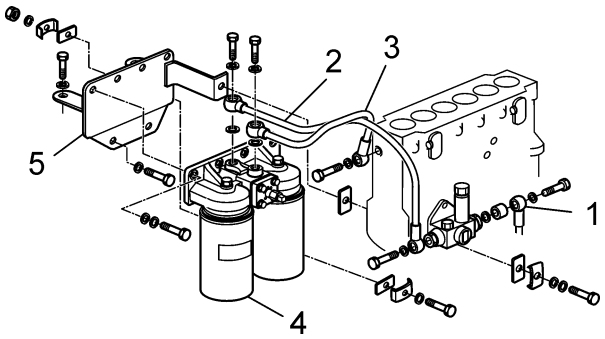
Unscrew manifold mounting bolts and remove manifold (1) and gasket (2).

NOTE! When installing the manifold, place each gasket with its side marked as “MANIFOLD” facing the manifold.



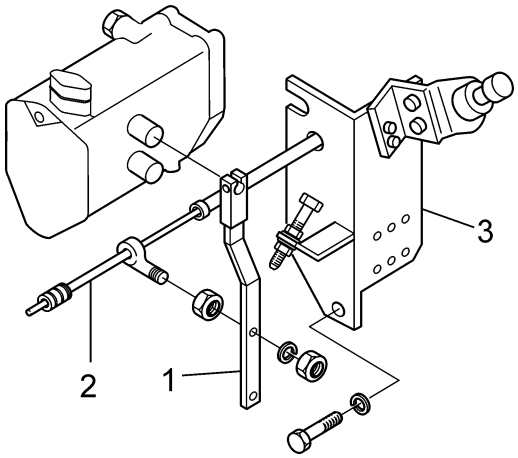
Remove fresh water pump and tension pulley

1. Loosen tension pulley and remove the v-belt (1).
2. Unscrew tension pulley mounting bolts and remove the pulley (3).
3. Unscrew fresh water pump mounting bolts and remove the pump (2).



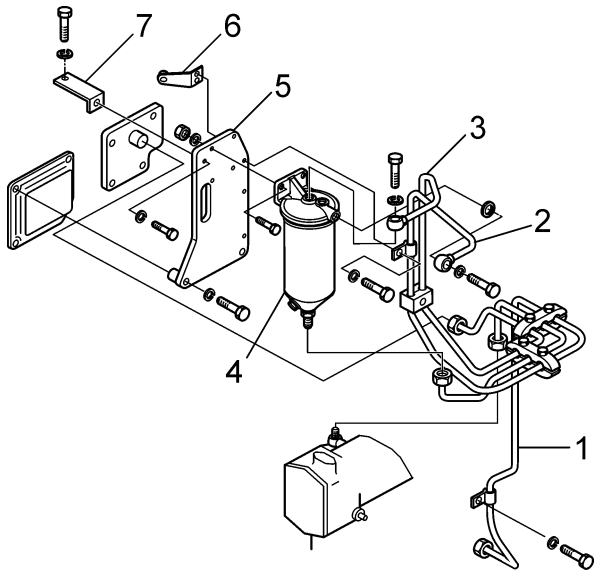
Remove fuel filter

1. Remove joint (1)..
2. Remove fuel pipes (2) and (3).
2. Remove fuel filter (4) and bracket (5).



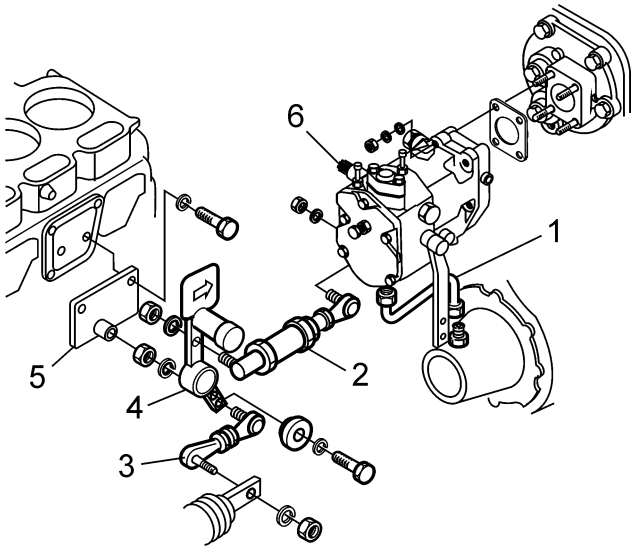
Remove the speed control knob

1. Remove the lock nut from the governor lever (1) to disconnect control cable (2) from the lever.
2. Remove control bracket (3) and speed control knob as a set.



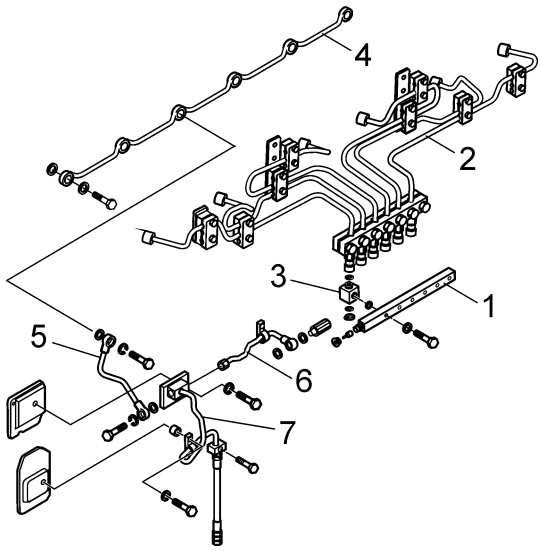
Remove governor oil filter

1. Remove oil pipes (1), (2) and (3).
2. Remove oil filter (4).
3. Remove oil tank bracket (5), oil tank stay (6) and stay (7).



Remove the governor

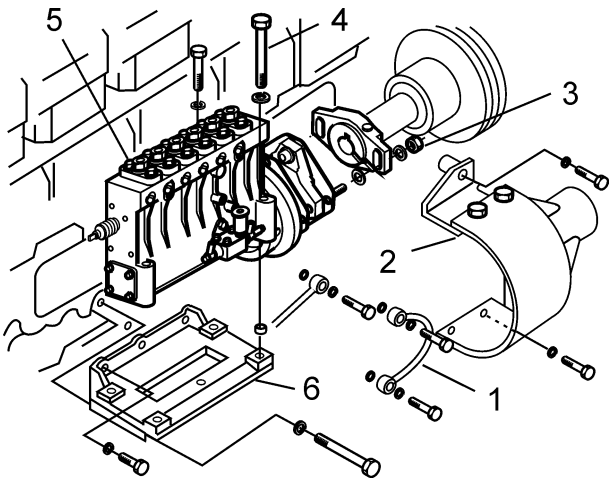
1. Remove governor drain pipe (1).
2. Remove control links (2) and (3) as a set.
3. Remove control lever (4) and lever bracket (5).
4. Remove governor mounting bolts and governor (6)



Remove fuel pipes

1. Remove fuel leak-off pipes (1).
2. Disconnect six fuel pipes (2) and six leak connectors (3).
3. Disconnect and remove leak-off pipes (4), (5), (6), and (7).

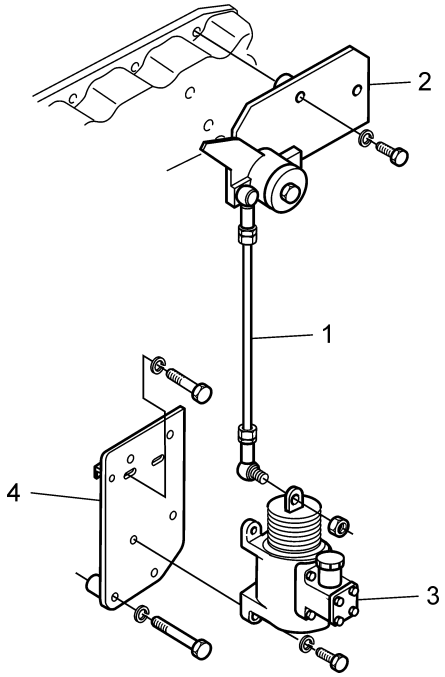
NOTE! Cover the openings of the injection pump and nozzle inlet connectors with rubber caps to prevent dust from entering the system.



Remove fuel injection pump

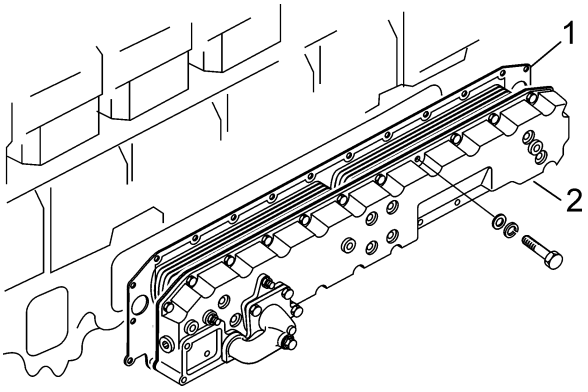
1. Remove the two lubrication oil pipes (1).
2. Remove the coupling cover (2).
3. Remove tcoupling joint nut (3).
4. Unscrew pump mounting screw (4). With the coupling attached to the injection pump side, remove the injection pump (5) by pulling it towards the front using a stick to give leverage.

   Weight: approx 60 kg [132 lb]
5. Unscrew bracket mounting bolts and remove the bracket (6).



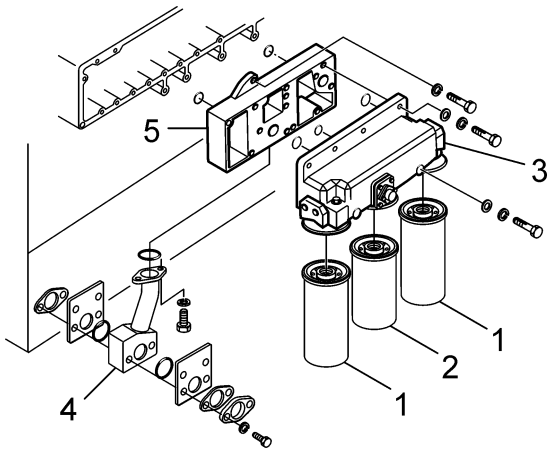
Remove stop solenoid

1. Disconnect linkage (1).
2. Remove lever bracket (2) together with the stopper lever.
3. Unscrew stop solenoid mounting bolts, and remove stop solenoid (3).
4. Remove the solenoid bracket (4) .



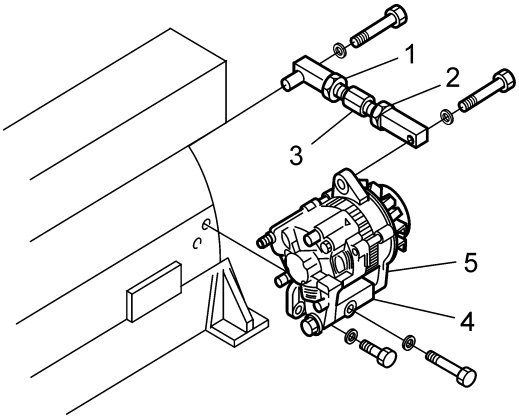
Remove oil cooler

Remove oil cooler (1) and cover (2) as a set.



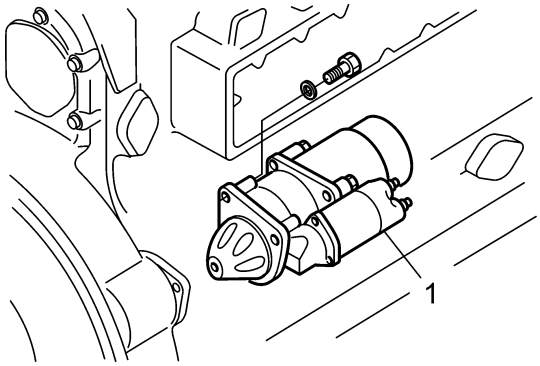
Remove oil filters

1. Remove two oil filters (1) and oil by-pass filter (2).
2. Unscrew filter bracket mounting bolts and remove bracket (3).
3. Remove oil emergency pipe (4).
4. Remove oil filter adaptor (5).



Remove the alternator

1. Loosen lock nuts (1) (left-handed thread) and lock nut (2). Turn adjusting rod and remove the V-belt.
2. Remove the adjusting rod and attached parts as a set.
3. Unscrew alternator bracket mounting bolts and remove bracket (4) and alternator (5) as a set.



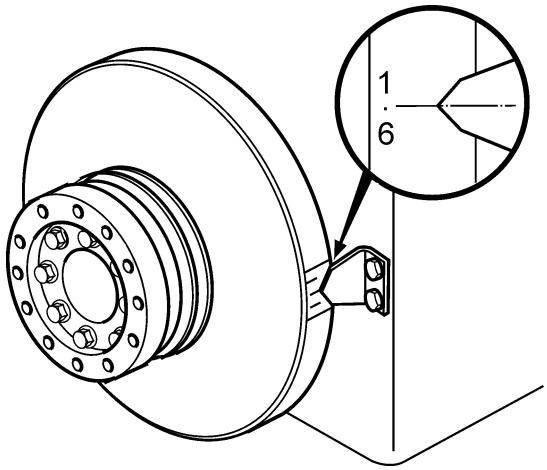
Remove the starter

Remove starters (1) by unscrewing the starter mounting bolts.

Engine Auxiliaries Installation

To install the engine auxiliaries, follow the removal procedures in reverse. After installation, service them as follows:

1. Refill the engine with the recommended oil up to the specified level.
2. Refill the cooling system with coolant.
3. For easy engine starting, pour engine oil for the governor into the oil filter from its vent plug.
4. Check each pipe connection for oil or coolant leaks.
5. Prime the fuel system.
6. Installation of the fuel injection pump is described below. After installing the fuel injection pump, be sure to inspect and adjust the injection timing. (Refer to Section 1.3 of Chapter 5, “Adjustments and Bench Testing.”

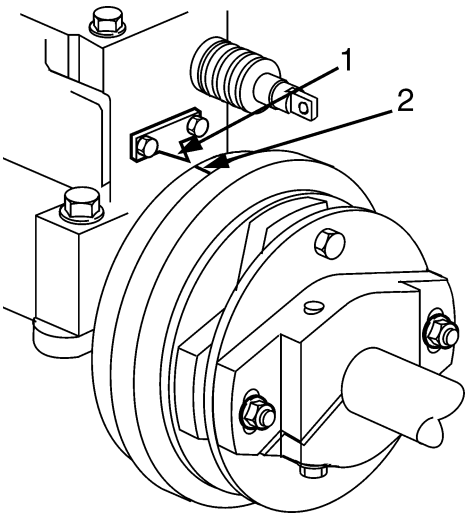


Fuel Injection Pump Installations:

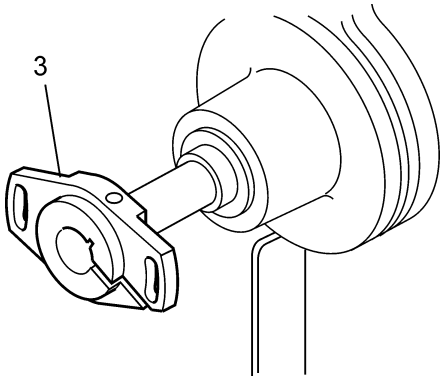
1. Turn the crankshaft in normal direction to align the timing mark “1 • 6” on the viscous damper with the pointer.

NOTE! Verify the injection timing by referring to the caution plate attached to the No. 1 rocker cover.

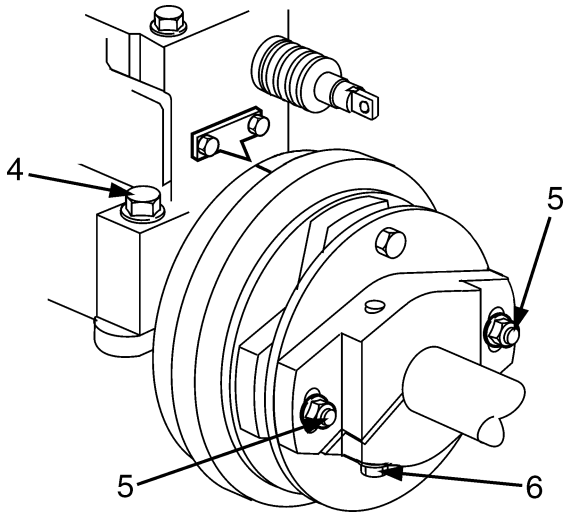
2. Move the No. 1 cylinder inlet and exhaust valve rocker arms to make sure that they are not being pushed up by the push rods.
3. Turn the crankshaft about 60° in reverse. Turn it a little at a time in the normal direction to align the timing mark on the damper with the pointer.



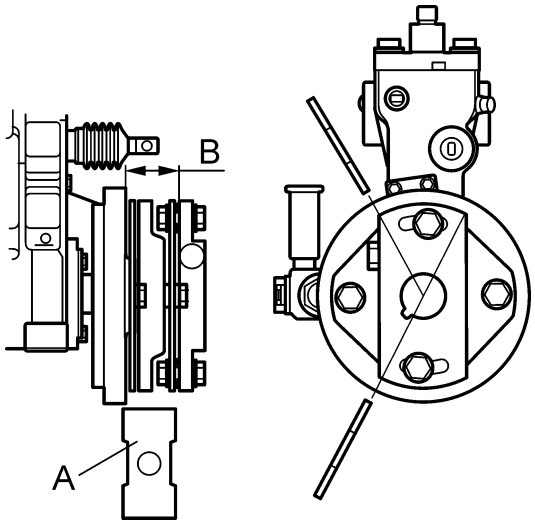
4. Install the coupling to the injection pump, then align the pointer (1) on the pump case with mark (2) on the coupling.



5. Connect the pump drive coupling (3) to the drive shaft. Loosen the coupling mounting bolts.



6. Put the pump case on the pump bracket, then tighten the mounting bolts (4) temporarily.
7. Connect the fuel pipe and the oil pipe to the injection pump.
8. Tighten the two coupling bolts (5) temporarily.



9. Insert the side of the Injection coupling gauge (A) marked with “GO” to determine clearance (B) between the flywheel and coupling, then tighten the bolts to specified torque.

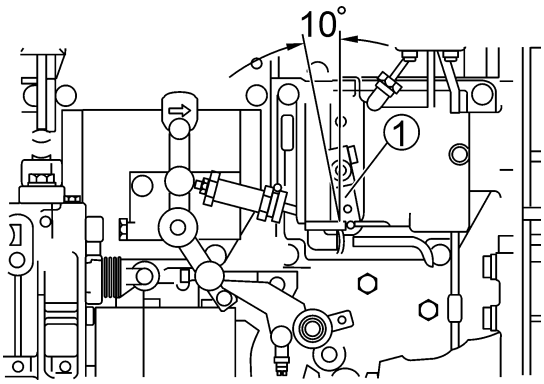
NOTE! Only the side marked with “GO” should fit into the gap. If not, loosen the bolt and readjust the clearance.

Flywheel and coupling clearance, mm[in.]

Standard clearance ... 49±0.25 [1.93±0.010

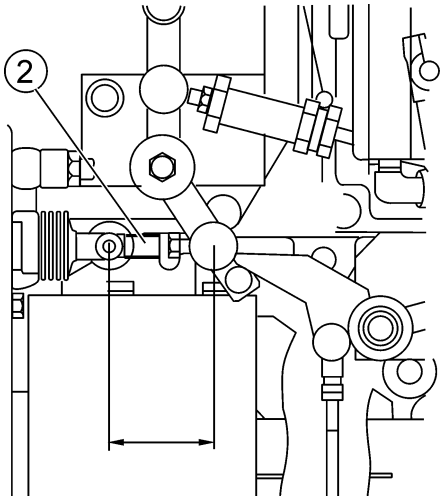
10. Tighten the pump mounting bolt (4) firmly. Be sure that the coupling mark (B) aligns with the pump case pointer (A). Tighten the two connecting nuts (5) to specified torque.
11. Tighten the shaft tightening bolt (6) of the coupling to specified torque.

NOTE! Coupling damage or wrong injection timing can be caused by improper tightening of bolts.

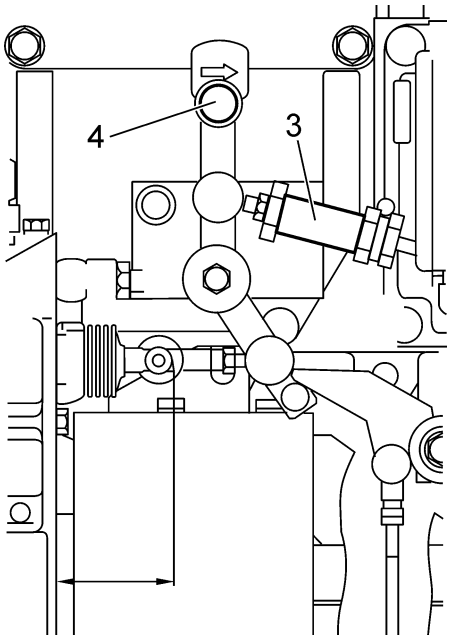


Adjust injection quantities of pumps

1. Check to make sure the output shaft of the governor is positioned on the side marked with “0” (no-injection side).
2. Install governor lever (1) at an angle of 10°.



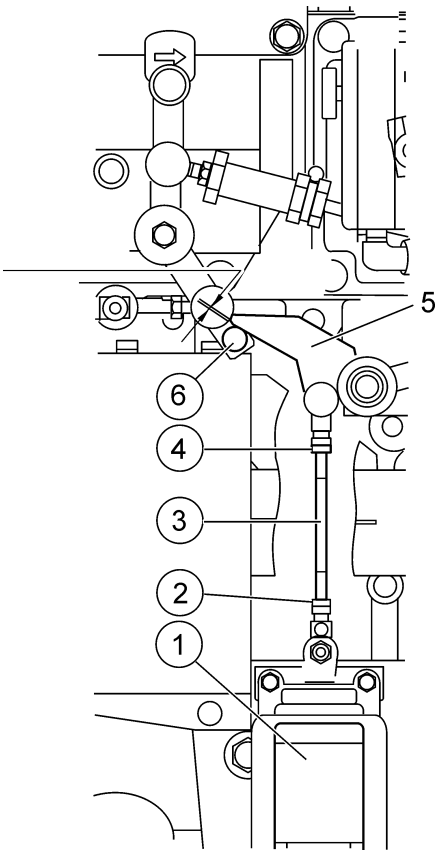
3. Install link (2) , make sure that the installation length is 62±0.7 mm [2.4±0.028 in.].



4. Install the rod (3) while adjusting the length of it to achieve a distance of 67.5–68.5 mm [2.66–2.70 in.] between the rack end surface and pump case end surface.

NOTE! Make sure that at least 8 mm [0.35 in.] of the thread of the rod and the ball joint are engaged at both ends.

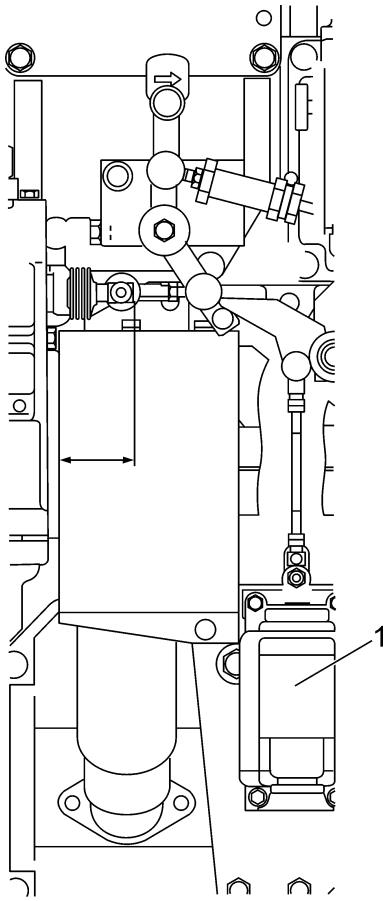
5. Make sure the rack stroke is approx. 2mm [0.08 in.] when stop lever (4) is pulled fully towards STOP.



Stop-solenoid

Adjustment

1. Supply power to solenoid (1) (contracted).
2. Loosen nuts (2) and (3).
3. Rotate rod (4) to adjust the clearance between lever (5) and follower (6) to be from 0.5 to 1.0 mm [0.020 to 0.039 in.].
4. Tighten nuts (2) and (3).



Inspection

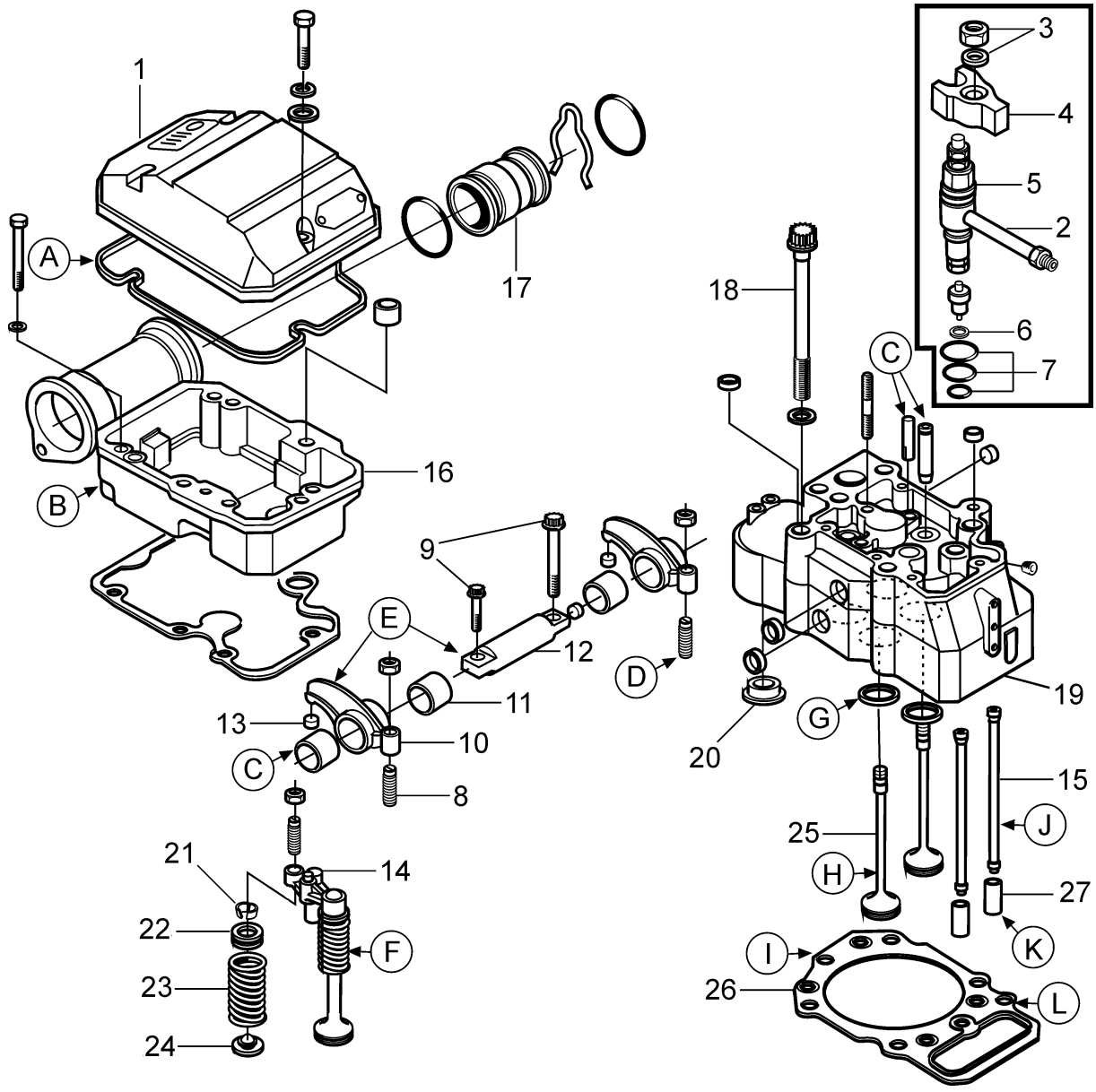
1. Cut off power to solenoid (1) (extended).
2. After adjusting the exhaust temperature, run the engine at high idling speed.
3. Supply electric current to solenoid (1) (contracted condition).
4. After the engine stops completely, check to make sure the distance between the rack end surface and pump case end surface is 68 to 69 mm [2.68 to 2.72 in.] on both banks.

NOTE! It should be noted that the engine may not stop if the distance between the rack end surface and pump case is 70 mm [2.76 in.] or more.

NOTE! When adjusting the adjusting rod, make sure the rack moves without interference. If the rack does not move smoothly, the governor cannot operate properly.

Group 21 Engine Body

Cylinder heads and valve mechanism

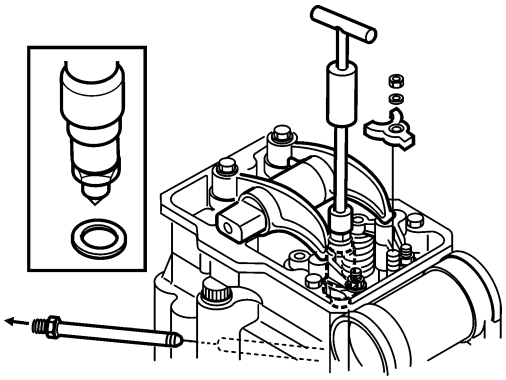


Disassembly:

1. Rocker cover
2. Fuel inlet connector
3. Nut, washer
4. Injection nozzle gland
5. Injection nozzle
6. Gasket
7. O-ring
8. Adjusting screw
9. Bolt
10. Rocker
11. Spacer
12. Rockershaft
13. Bridge cap
14. Valve bridge
15. Push rod
16. Rocker case
17. Water outlet connector
18. Cylinder head bolt
19. Cylinder head
20. Inlet port packing
21. Valve cotter
22. Valve rotator
23. Valve spring
24. Stem seal
25. Valve
26. Cylinder head gasket
27. Tappet

Look for:

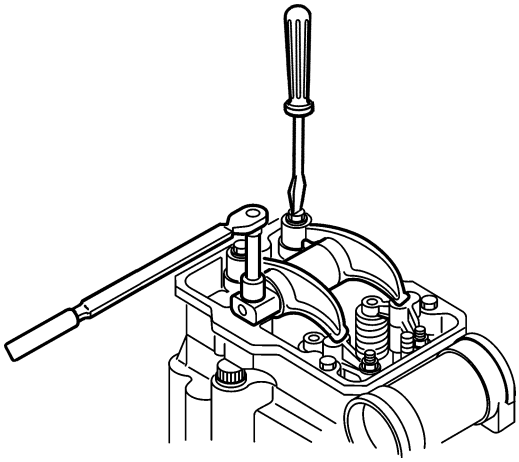
A. Cracks, oil leaks, deterioration
B. Cracks, damage, carbon and scale deposits
C. Wear
D. Damaged threads
E. Wear, clogged oil hole
F. Distortion, cracks
G. Matching, wear
H. Worn stem or face, corrosion, damage, or carbon deposits
I. Cracks, damage, deterioration, rubber parts cracked
J. Worn ends, distortion
K. Worn cam contact face or sliding surface
L. Replace gasket



Removing fuel injector assemblies

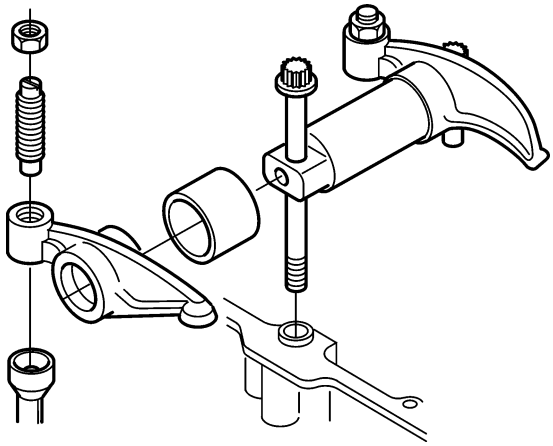
1. Remove the fuel inlet connector and the nozzle gland
2. Use the Nozzle remover to remove the injector assembly. Take out the gasket if it is left behind in the cylinder head.
3. Store the injector and the inlet connector as a set to avoid swapping.

⚠ **IMPORTANT!** Do not damage the nozzle.



Removing the rockershaft assemblies

1. Loosen the adjusting screw of each rocker.
2. Store the shaft assembly and mounting bolts together as a set.



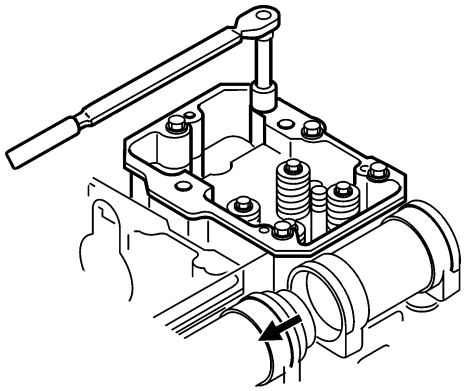
Disassembling rockershaft assemblies

Arrange the disassembled rockers in the order removed, so you can install them in that order at reassembly. This will ensure the same rockershaft clearance as before.

Remove the valve bridge

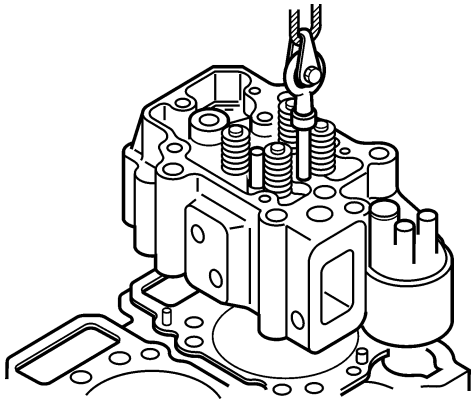
Remove the valve bridge and bridge cap.

NOTE! Do not drop the bridge cap or other parts into the crankcase through the push rod hole.



Removing the rocker cases

1. Remove the snap ring of the water outlet connector. Slide the connector towards the snap ring.
2. Unscrew the rocker case mounting bolts, then remove the rocker case from the cylinder head.



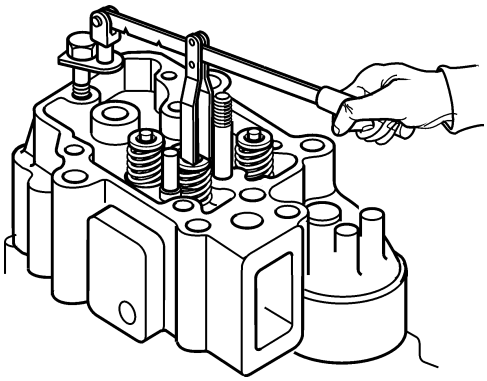
Removing cylinder head assemblies

1. Each cylinder head is located relative to the crankcase with dowel pins. Use the Eye nut to lift the head off the crankcase at a slant.

Cylinder head weight: approx. 35 kg (77 lb)

2. Remove the cylinder head gasket

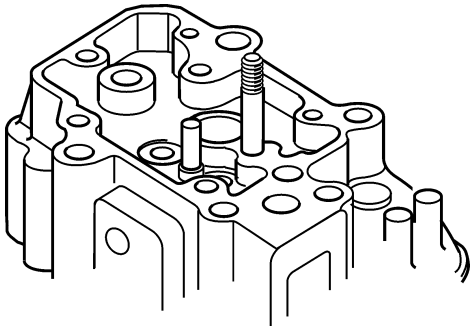
⚠ **IMPORTANT!** Do not damage the cylinder head or crankcase surfaces when you remove the gasket with a screwdriver or other tool.



Removing valves and valve springs

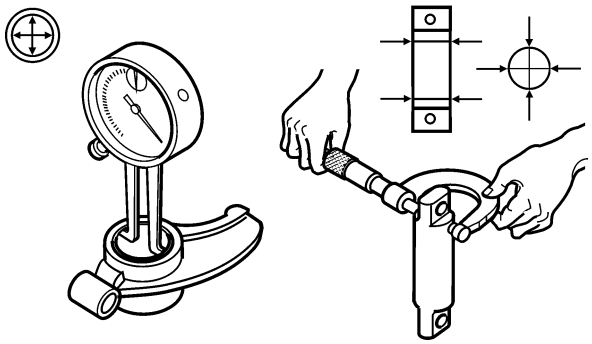
Use the valve spring pusher to compress the valve spring squarely, then remove the valve cotters.

NOTE! If the valves are to be reused, do not change the combination of the valve seat and valve guide.



Removing studs, guides, etc.

Do not remove the nozzle gland mounting studs or the bridge guide from the cylinder head unless absolutely necessary. If any of these parts have been removed, apply thread adhesive to the threads when installing it or a new part to the cylinder head.



Inspection and Repair

Rocker Bushings and Rockershaft

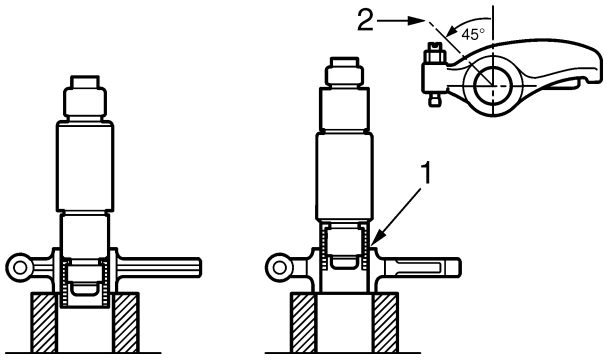
1. Measuring rocker bushing inside diameter and rockershaft diameter. If the measurement exceeds the service limit, replace the bushing or shaft.

Rocker bushing inside diameter, mm [in]

Normal Value	Ø36 [1.42]
Assembly Standard ...	36.000–36.040 [1.41732–1.41889]
Service limit	36.090 [1.42086]

Rockershaft diameter, mm [in]

Normal Value	Ø36 [1.42]
Assembly Standard ...	35.966–35.991 [1.41598–1.41697]
Service limit	35.940 [1.41496]



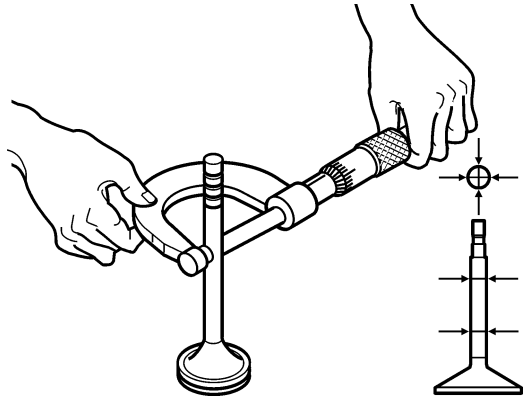
Replacing rocker bushings

Use the Rocker bushing tool to remove the rocker bushings for replacement.

NOTE! Press a new bushing into the rocker from the chamfered side(1) of the bore.

NOTE! Align the oil holes in the bushing and rocker.

NOTE! Check bushing joint mark(2)



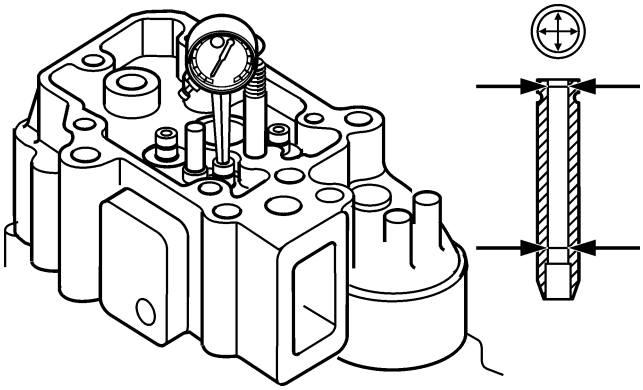
Valve Guide and Valve Stems

Measure valve stem and valve guide.

The valve guide wears more rapidly at its ends than at any other location. Measure the inside diameter of the guide at its ends in two directions. If the service limit is exceeded, replace the guide.

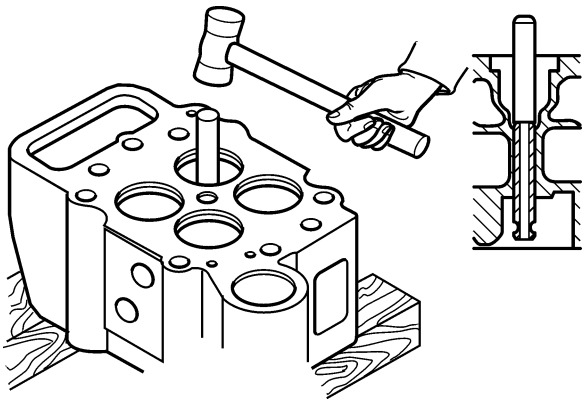
Valve stem diameter, mm [in]

Normal Value	Ø10 [0.39]
Assembly Standard ...	9.940–9.960 [0.39134–0.39213]
Service limit	9.910 [0.39016]



Valve guide inside diameter, mm [in]

Normal Value	Ø10 [0.39]
Assembly Standard ...	10.000–10.015 [0.39370–0.39429]
Service limit	10.060 [0.39606]

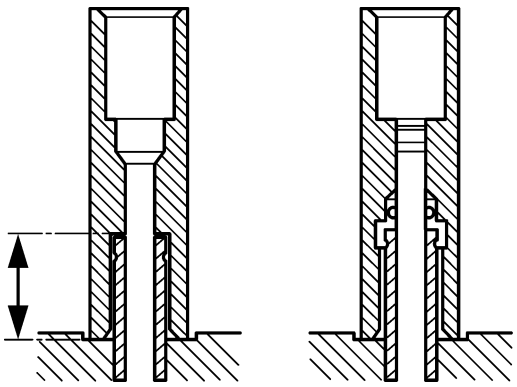


Replacing valve guides and stem seals

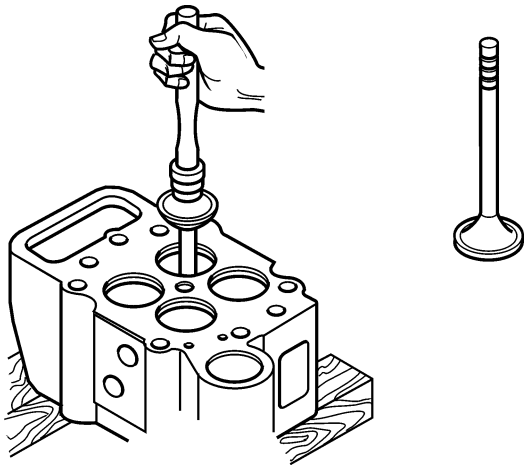
1. Use the Valve guide remover to remove the valve guide for replacement.
2. Use the Valve guide seal installer to install slowly a new guide with a press.

⚠ **IMPORTANT!** The installation depth for the valve guide is specified, so use the Valve guide seal installer to secure the correct depth.

⚠ **IMPORTANT!** Do not apply any oil or sealant to the surface of the stem seal that comes in contact with the valve guide. When installing the stem seal, apply lub oil to valve stem to ensure initial lubrication of the stem seal lip.



⚠ **IMPORTANT!** Use a new stem seal whenever removed.



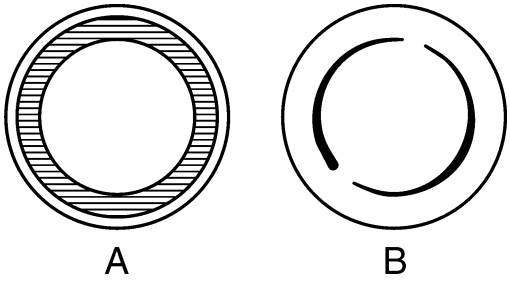
Valves and Valve Seats

Inspecting the valve

Coat the valve face lightly with red lead. Use the Valve lapper to inspect the valve contact with its seat. If the contact is not uniform, or if the valve is defective, or if the repair limit is exceeded, repair or replace the valve and valve seat.

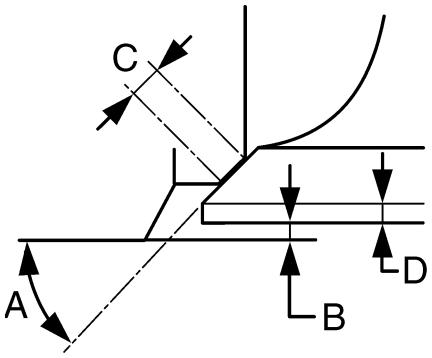
NOTE! Inspect the valve face after the inspection or replacement of the valve guide.

NOTE! When you press the valve coated with red lead into the valve seat, do not rotate the valve.



A. Good contact

B. Bad contact



Valve seat, mm [in]

Angle (A)

Assembly Standard ... 30°

Valve sinkage (depth)(B)

Assembly Standard ... -0.2–0.2 [-0.008–0.008]

Repair limit ..... 1.0 [0.039]

Width (C)

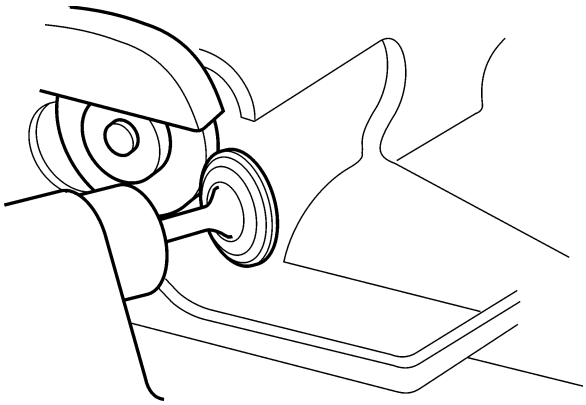
Assembly Standard ... 2.15–2.45 [0.0846–0.0965]

Repair limit ..... 2.8 [0.110]

Valve margin (thickness)(D), mm [in]

Assembly Standard ... 2.8–3.2 [0.110–0.126]

Repair limit(refacing) . 2.5 [0.098]

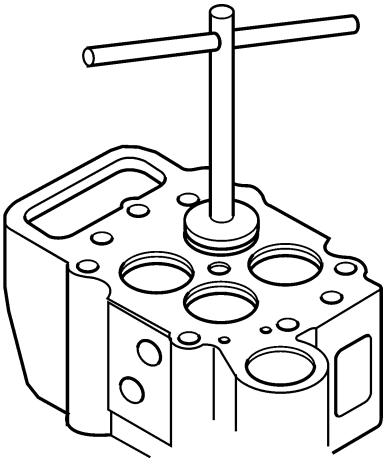


Refacing the valve face

If the valve face is badly worn, reface it with a valve refacer

NOTE! Set a valve refacer at an angle of 30°.

NOTE! Grind the valve as little as possible. If the margin seems to exceed the repair limit as a result of grinding, replace the valve.



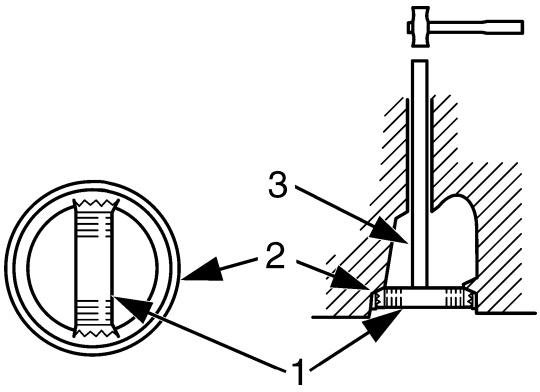
Refacing valve seats

1. Use the Valve seat cutter or a valve seat grinder to reface the valve seat. After refacing, grind the seat lightly using #400 grade sandpaper inserted between the cutter and valve seat.
2. Lap the valve in the valve seat.

NOTE! Cut or grind the valve seat only as needed for refacing.

NOTE! Replace the valve seat if the seat width is more than the repair limit as a result of wear or cutting.

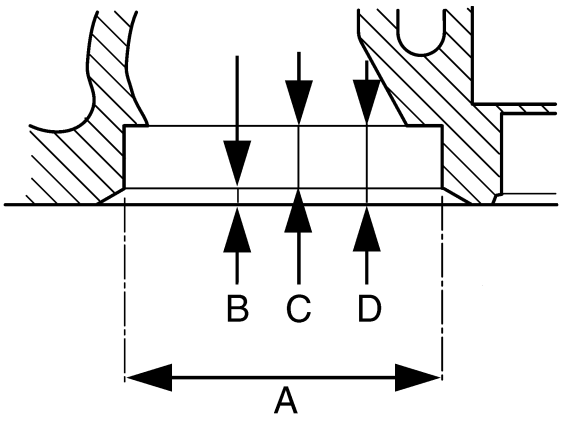
NOTE! Replace the valve seat if the valve sinkage exceeds the repair limit after refacing.



Replacing valve seats

1. Weld a stud(1) to the valve seat(2). Insert a shaft(3) into the valve guide holder from the upper side of the cylinder head. Drive the seat off the head as shown.

NOTE! When you weld the stud, do not permit splatter to come in contact with the machined surfaces of the cylinder head.



2. Before inserting a new valve seat, measure the inside diameter of the cylinder head bore and the outside diameter of the valve seat to make sure that clearance (fit) is within clearance standards.

Valve seat dimensions, mm [in.]

Cylinder head bore diameter (A)

Nominal value ..... 60.000-60.030 [2.36220-2.36338]

Valve seat diameter (A)

Nominal value ..... 60.100-60.130 [2.36614-2.36732]

Cylinder head bore / Valve seat clearance

standard clearance* .. -0.070 – -0.130 [-0.00276 – -0.00512]

B

Nominal value ..... 3.6 [0.142]

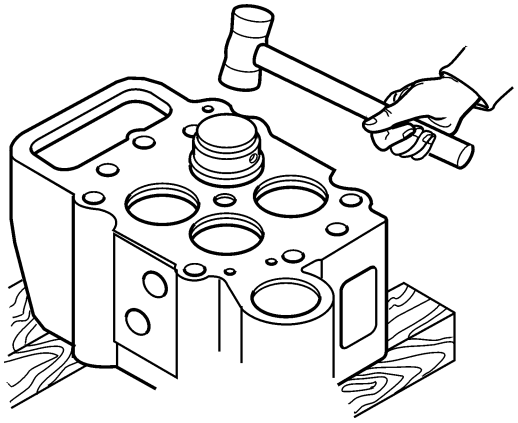
C

Nominal value ..... 8.0 [0.315]

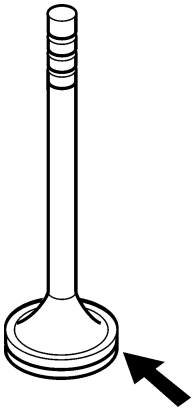
D

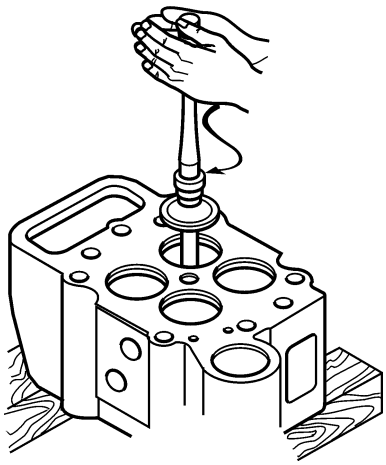
Nominal value ..... 11.6–11.7 [0.4567–0.4606]

*A minus (–) indicates interference.



3. Chill the valve seat in liquid nitrogen -70°C [-274°F] for more than 4 minutes with the cylinder head kept at normal temperature, or heat the cylinder head to 80 to 100 °C [176 to 212 °F] with the valve seat chilled in ether or alcohol containing dry ice.
4. Use the Installer to install the valve seat.





Lapping valves in valve seats

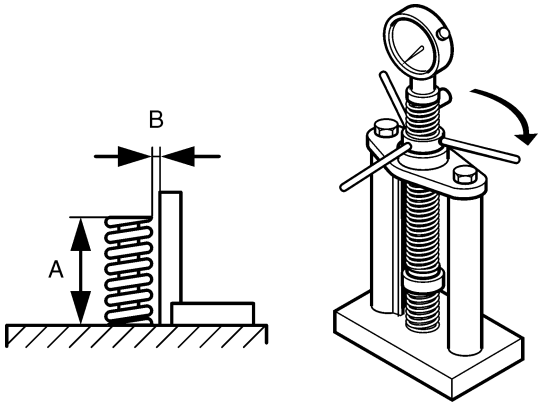
Be sure to lap the valves in the valve seats after the seats has been replaced.

1. Coat the valve face lightly with a lapping compound.
2. Lap the valve in the seat using the valve lapper. Raise the valve off the seat, then rotate the valve only a partial turn and strike it against the seat.
3. Wash off the compound with diesel fuel.
4. Coat the valve face with engine oil, then lap the valve again.
5. Check the valve face for contact.

NOTE! Do not permit the compound to come in contact with the valve Stern.

NOTE! Use a compound of 120 to 150 mesh for initial lapping and a compound finer than 200 mesh for finish lapping.

NOTE! Mixing the compound with a small amount of engine oil will facilitate coating.



Valve spring clearance and free length

Measure the free length and clearance of each valve spring. If the free length or clearance (perpendicularity) exceeds the service limit, replace the spring.

Free length (A), mm [in.]

Assembly standard ... 73 [2.87]
Service limit ..... 71 [2.80]

Perpendicularity (B), mm [in.]

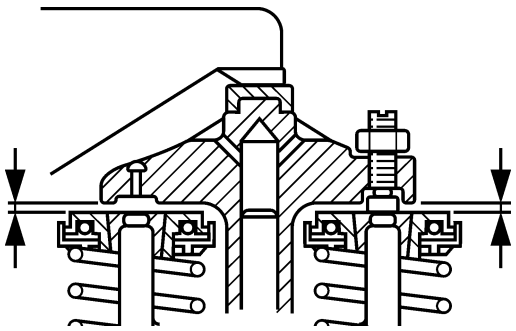
Service limit ..... 2.2 [0.087] (at end)

Length under test force, mm [in.]

Assembly standard ... 66.0 [2.6]

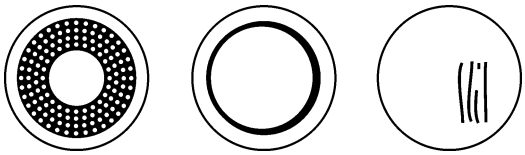
Test force, N (kgf) [lbf]

Assembly standard ... 289–319 (29.45 to 32.55) [65 to 72]



Bridge-to-rotator clearance

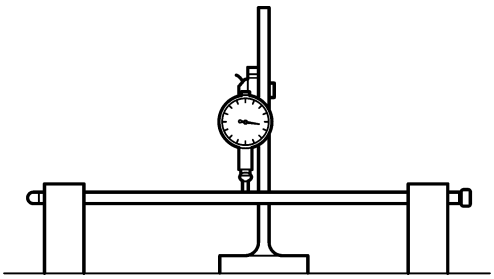
1. When clearance is less than 1.5 mm [0.059 in.], check the valve stem top for cupping. If the stem top is badly cupped, replace the valve to obtain more than 1.5 mm [0.059 in.] clearance.
2. Check the condition of the bridge cap. Replace it if it is badly worn.



Tappets and Push Rods

Inspecting cam contact faces of tappets

Replace the tappets if their cam contact faces are abnormally worn.

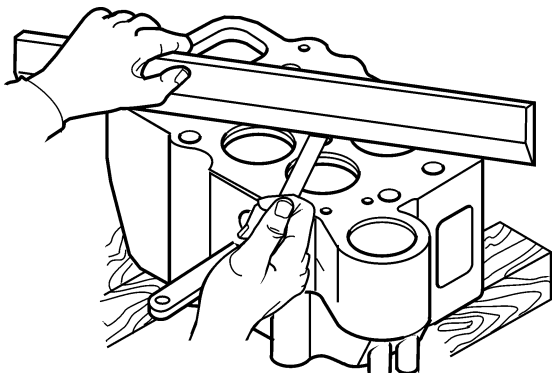


Measuring valve pushrod deflection

If the deflection exceeds the assembly standard, replace the push rods.

Push rod deflection, mm [in.]

Assembly standard ...	Less than 0.5 [0.020] max.



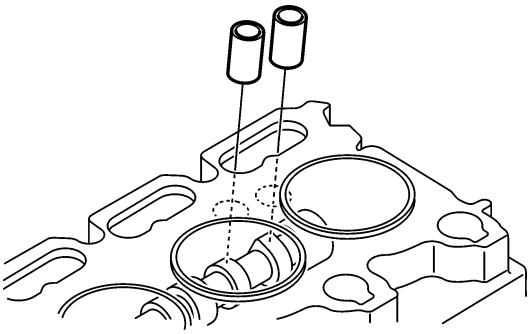
Cylinder Head

Measuring head gasket flatness of surface

Use a straight edge and feeler gauges to measure warping on each cylinder head. If warping exceeds the repair limit, reface the gasket surface with a surface grinder.

Flatness, mm [in.]

Assembly standard ...	<0.03 [0.0012]
Repair limit	0.07 [0.0028]
Service limit	0.50 [0.0197]



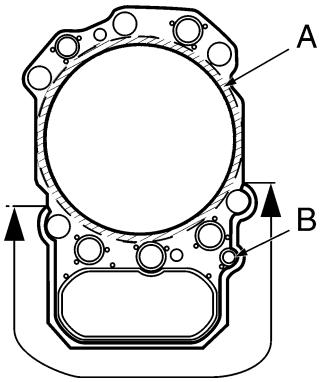
Reassembly

Reassembly sequence:

Reverse the order of disassembly.

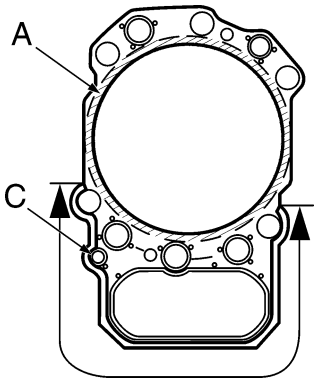
Installing tappets

Insert tappets coated with engine oil into the tappet holes and make them seat softly on the camshaft.



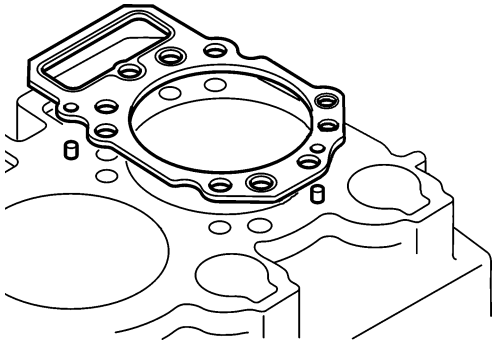
Installing cylinder head gaskets

1. Clean the gasketed surfaces of the cylinder head and crankcase thoroughly with a solvent or degreasing solution.
2. Apply a thin coat of Three Bond 1211 to areas 5 to 8 mm [0.197 to 0.315 in.] from the periphery of the head gasket, around tappet holes and oil passage holes, on both sides of the head gasket (to areas indicated in the diagram on the right). Spread the liquid gasket with a finger to a thickness of 0.2 to 0.5 mm [0.008 to 0.020 in.].

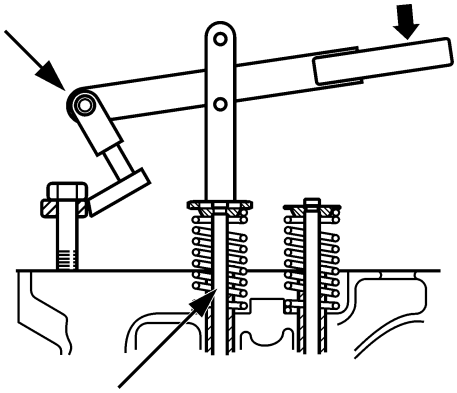


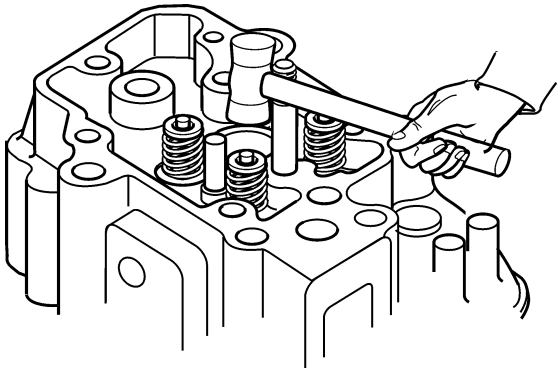
NOTE! Liquid gasket should be applied to areas indicated in the diagram on the right. Do not apply an excessive amount of liquid gasket, since it can press the head gasket O-rings and cause deformation.

NOTE! Do not allow liquid gasket to adhere within an area of 10 mm [0.394 in] around the cylinder bore **(A)**, this may cause gas leakage. Sections **B** and **C** are very close to O-rings. Make sure that there is no large amount of liquid gasket on the edge at these sections.



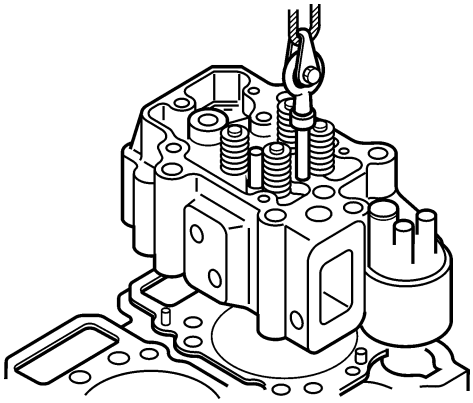
2. Install the gasket before the liquid gasket dries. Place the gaskets on the crankcase, making sure that the dowel pins enter their holes in the gaskets.





Reassembly of the cylinder heads

1. Coat the valve Stems with engine oil, then insert them into the valve guides.
2. Install the valve springs and rotators to the valve guides. Compress each valve spring with the Valve spring pusher, then install the valve cotters on the valve Stem.
3. Lightly tap on the top of each valve stem with a soft-faced mallet to make sure that the valve spring and cotters are properly installed.

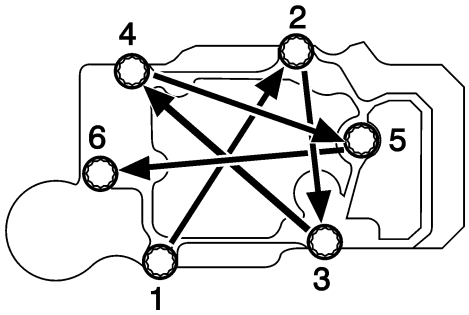


Install cylinder head assemblies

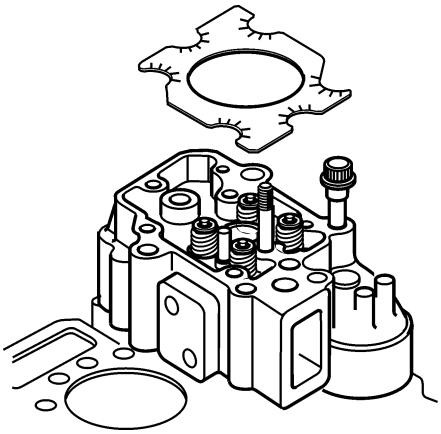
⚠ **IMPORTANT!** Before you install the cylinder head assembly, measure the protrusion of each piston. Make sure that the protrusion is correct.

1. Install the exhaust connector to the cylinder head, while pushing down the exhaust connector so it touches the edge of the bolt hole.

NOTE! Place the gasket so its ”MANIFOLD” printed side aligns with the connector side.

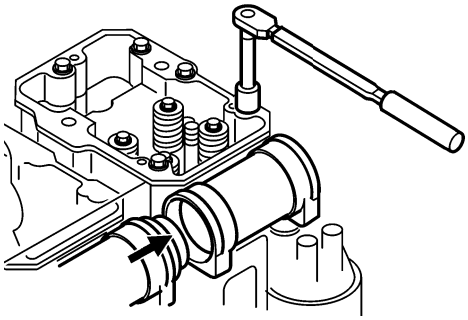


2. Install the Eye nut to the stud bolt, and lift up the cylinder head assembly. Locate the head aligning its holes with the dowel pins, and keep the head being slightly separated from the cylinder. Apply engine oil to the threads and bearing surfaces of head bolts, then wipe off the excessive oil before tightening.
3. Tighten the cylinder head bolts with the specified torque in the order shown in the drawing.



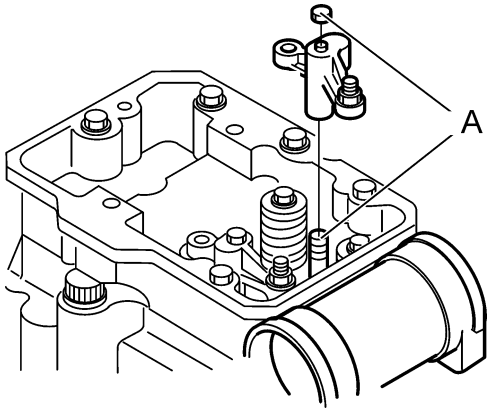
Tightening cylinder head bolts

1. Place the Head bolt plate on the cylinder head.
2. Tighten each head bolt to 294 N·m (30 kgf·m) [217 lbf·ft] torque (initial torque).
3. The head bolt plate has graduations at 30° intervals. Place a reference point mark on each head bolt.
4. Tighten each bolt 30°. After tightening all bolts, turn each bolt another 30° (totally 60°).
5. After tightening all cylinder heads, loosen all bolts and retighten again according to 1 – 4.



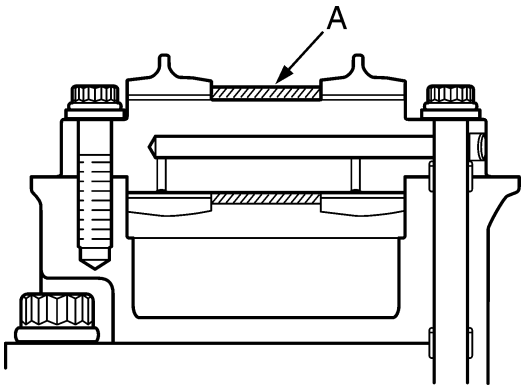
Installing the rocker case

1. Insert the water outlet connector fully into the rocker case.
2. Install the rocker case so it meets the dowel pins
3. Tighten the rocker case mounting bolts to the specified torque.
4. Insert the water outlet connector by sliding it from the next rocker case after coating the O-ring with grease. Install the snap ring.



Installing valve bridges and caps

1. Coat the bridge guides with engine oil (A), then install the bridges to the guides with the adjusting screws positioned on the exhaust manifold side.
2. Coat the bridge contact face of the bridge caps (A) with engine oil. Install the caps in position, being careful not to let them fall into the crankcase through the push rod holes.

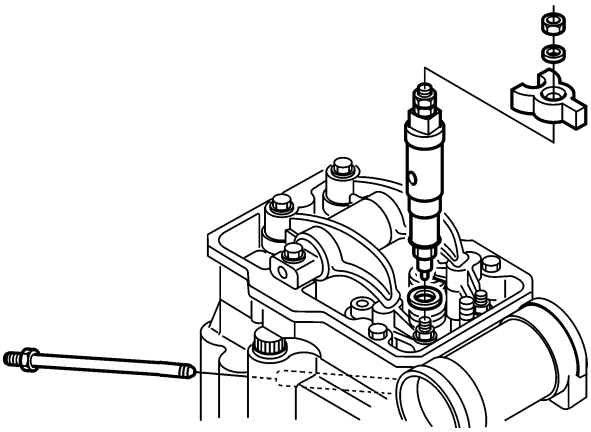


Installing rocker shaft assemblies

1. Install the spacer (A) on the rocker shaft and mount the rockers on both sides.
2. Align the pin hole of the rocker shaft with the positioning pin, and install the rocker shaft assembly to the rocker case. Move the rocker arm up and down to make sure that the arm is free.

NOTE! While tightening the bracket mounting bolts temporarily, install the bracket in place so the rocker tip comes in contact with the bridge caps evenly.

NOTE! Tighten the long bolt securing the head and rocker bracket first, then tighten the short bolt to the specified torque.



Install fuel injector

1. Disconnect the fuel inlet connector from the injector assembly.

NOTE! Always keep track of the inlet connector and injector assembly pairs so that inlet connectors are reassemblied to the same injector as before.

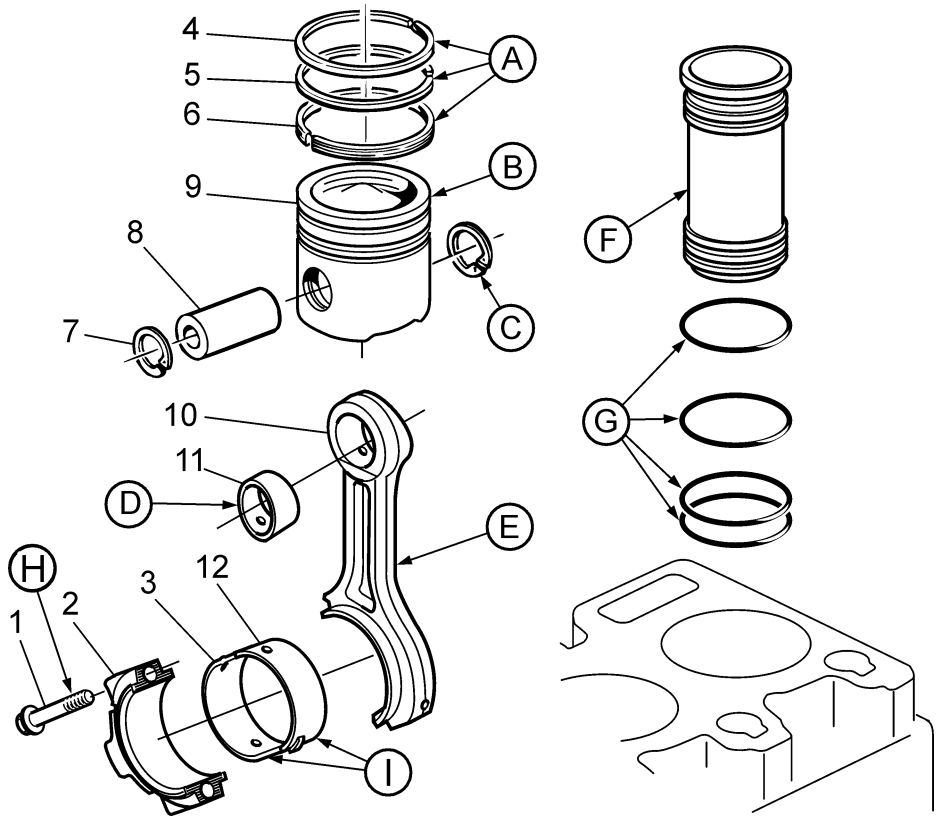
2. Put three O-rings on the injector and coat them with normal grease.
3. Coat the copper gasket with anti-seizing compound and attach it to the injector. Insert the injector assembly into the cylinder head aligning its connector hole with the rocker case hole.

NOTE! Always align the inlet connector with the center of the hole, i.e. the connector should never touch the walls of the hole in the cylinder head.

⚠ **IMPORTANT!** The anti-seizing compound must be high temp. resistant and must not cover the nozzle holes.

4. Install all fuel lines to the inlet connectors with a loose fit. When all inlet connectors are installed and aligned, tighten nozzle gland mounting nut to the specified torque.
5. Tighten the fuel inlet connector to the specified torque.
6. Align all high pressure fuel lines in such a way that they fit in their clamps with the least possible strain.
7. Tighten high pressure fuel pipes to fuel inlet connectors to the specified torque.

Cylinder liners, Pistons and Connecting rods

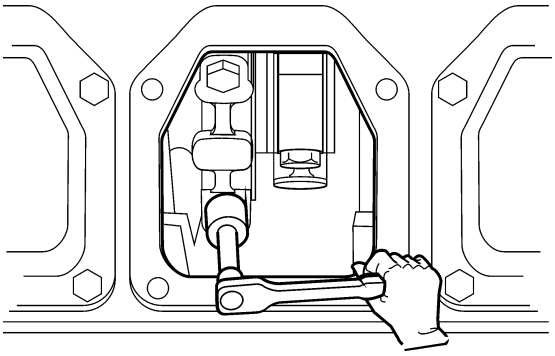


Disassembly:

1. Bolt
2. Connecting rod cap
3. Connecting rod bearing (lower shell)
4. Top compression ring
5. Second compression ring
6. Oil ring
7. Snap ring
8. Piston pin
9. Piston
10. Connecting rod
11. Connecting rod bushing
12. Connecting rod bearing

Look for:

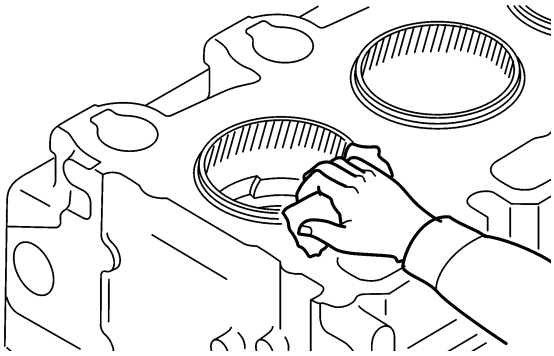
A. Wear, scratches, damage
B. Fatigue
C. Scratches, cracks, damage, wear, carbon deposits on outside surface
D. Cracks, clogged oil hole
E. Scratches, wear on inside surface, rust on outside surface
F. Damage
G. Wear, scratches, discolored inside surface
H. Scratches, seizure, wiping out of overlay on both sides
I. Damaged threads



Removing connecting rod caps

Open the inspection hatches, remove the connecting rod caps. For identification, mark the removed connecting rod bearing with cylinder number and upper or lower shell.

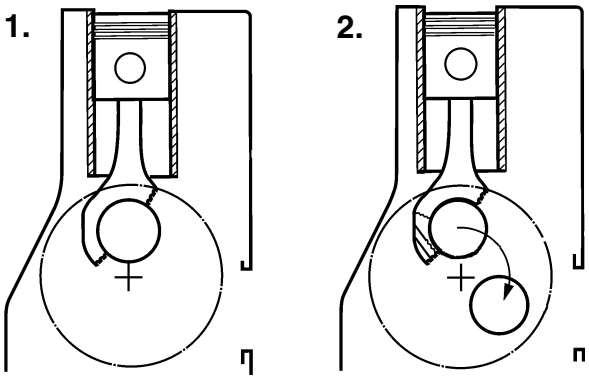
⚠ **IMPORTANT!** Handle bearings with care.



Removing pistons

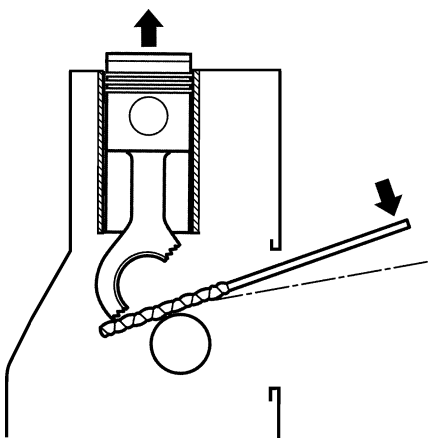
Preparations

Use a cloth or oil paper to remove all carbon deposits from the upper areas of the cylinder liner.Carbon deposits make it difficult to pull the piston out.



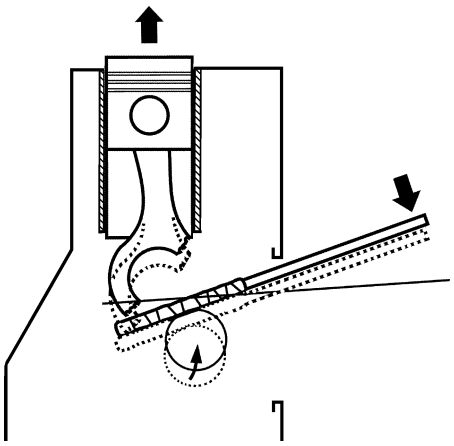
Removing pistons

1. Turn the crankshaft to bring the piston assembly (from which the connecting rod cap has been removed) to top dead center.
2. Turn the crankshaft in reverse until the crank pin comes off the connecting rod and the bolt hole of the rod is visible through the inspection hatch on the side of the crankcase.



3. Cover a bar with a cloth for protection. Put the tip of the bar under the bottom of the big end of the connecting rod and pry the bar slightly downwards using the crank pin as a fulcrum. This will push the piston assembly upwards.

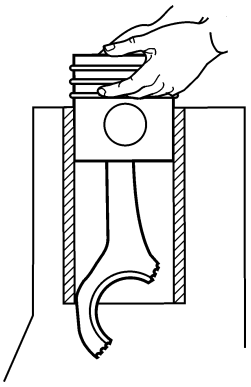
NOTE! If you insert the turning bar too far, you may not be able to pry the piston assembly upwards. Insert the bar 10 to 20 mm [0.39 to 0.79 in.] beyond the big end.



4. Turn the crankshaft a little at a time to raise the crank pin (fulcrum), while pushing the outer end of the bar, to further raise the piston assembly.

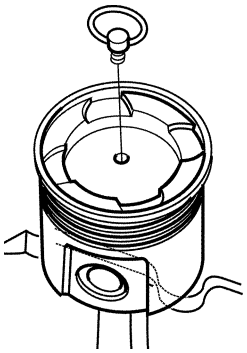
⚠ **IMPORTANT!** Raise the piston assembly carefully so that the connecting rod don't interfere with the oil jet nozzle for piston cooling.

5. When the oil ring of the piston comes out of the cylinder liner, lower the piston a little and carefully rest the oil ring on the edge of the liner.



NOTE! To avoid damage to the oil ring, lower the piston slowly and carefully. Do not rotate the piston.

6. Holding the compression ring portion of the piston and carefully pull the piston from the cylinder liner. Rest its skirt on the top of the crankcase.
7. Hold the piston pin portion of the piston, and lift the piston assembly off the liner.



Using the Piston remover

1. Turn the crankshaft to bring the piston assembly to 50° after top dead center.
2. Attach the Piston remover to the top of the piston. Grip the handle of the remover, then lift the piston and the connecting rod off the liner.

⚠ **IMPORTANT!** Do not damage the piston when you pull it out from the cylinder liner. Do not let it hit the connecting rod with its skirt. Support the connecting rod to avoid the cylinder liner bore from scratching.

⚠ **IMPORTANT!** Do not use a crane to remove pistons and connecting rods. Forces applied by cranes are far to uncontrollable.

Removing the piston ring

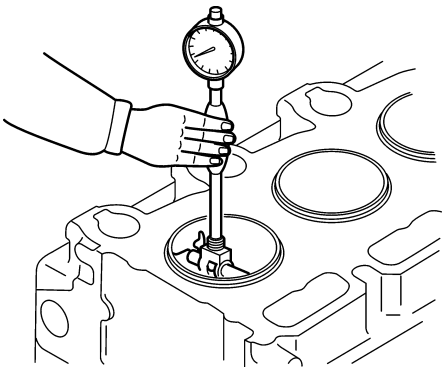
Use the Piston ring tool to remove the piston rings.

Removing piston pins

1. Use the Ring pliers to remove the snap rings.
2. Remove the piston pin to separate the piston from the connecting rod.
3. If it is difficult to pull out the pin, heat the piston with a piston heater or in hot water to expand the pin bore.

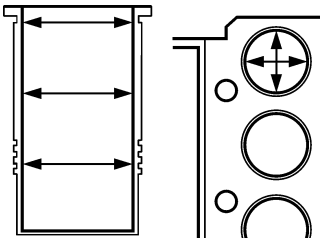
Inspection and Repair

Cylinder Liners



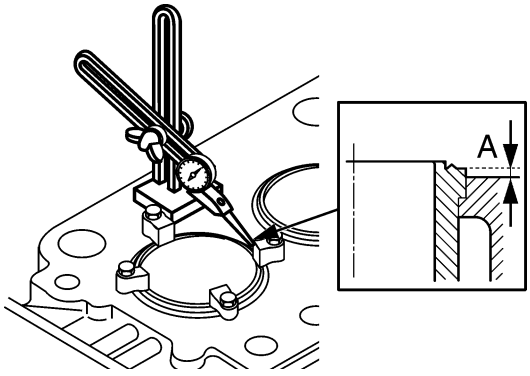
Inside diameter

Measure the inside diameter of each liner in two directions, parallel and transverse to the piston pin, at three positions, top (worn position), middle and low. If measurements exceed the service limit, replace the liner.



Cylinder liner side diameter, mm [in.]

Normal value	Ø170 [Ø6.69]
Assembly standard ...	170.000–170.040 [6.69290–6.69447]
Service limit	170.500 [6.71259]



Measuring cylinder liner protrusion

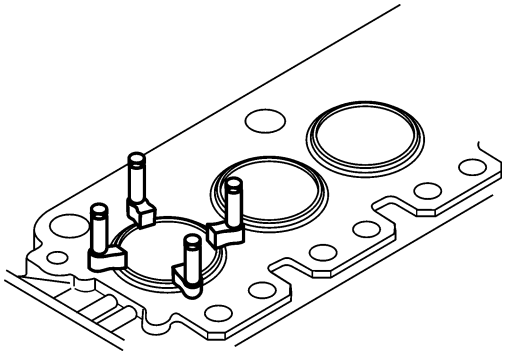
Measure the protrusion of each liner at its flange with a dial gauge.

NOTE! The method of measuring the protrusion of an used liner differs from that of newly installed one.

Cylinder liner protrusion at flange (A), mm [in]

Assembly standard ...	0.11–0.20 [0.0043–0.0079]

⚠ **IMPORTANT!** If the protrusion is less than the assembly standard, the gasket will fail to seal the bore resulting in gas leakage.

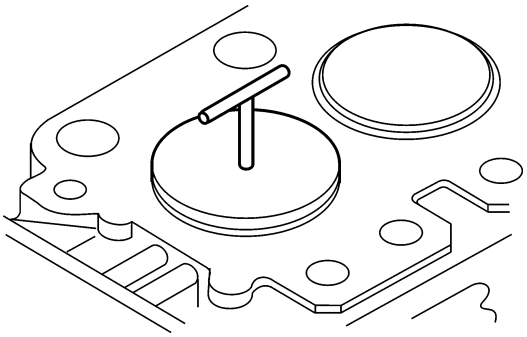


When cylinder head has just been removed

1. Clean the gasketed surface of the crankcase and the top of the liners.
2. Secure the top of the liner uniformly at four places with the Liner pusher and the Bolts.

NOTE! Use the Head bolt spacers when tightening the Line pushers using head bolts.

3. Set up the dial gauge at the top face of the crankcase, then set the gauge pointer to zero (0).
4. Measure the protrusion at four places at the flange of the liner. Take the average of the four measurements.
5. If the average is less than the assembly standard, insert a shim under the collar of the cylinder liner.

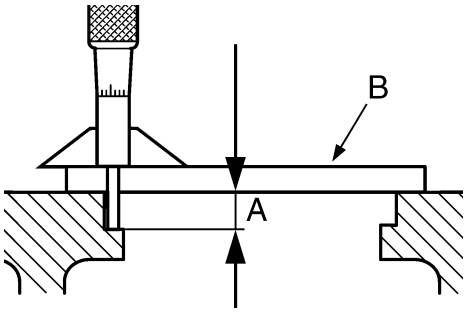


When replacing cylinder liner

1. Remove the cylinder liner (Refer to section Replace cylinder liners) and observe the cylinder liner contacting surface to the crankcase.

2. If the cylinder liner contacts the crankcase only on one side, use a rotary grinder to grind the surface to keep the differences of depth in four positions within 0.05 mm [0.0020 in.].

3. Use the Projection plate (B) and measure the counter bore depth of the crankcase in four positions and obtain the average.

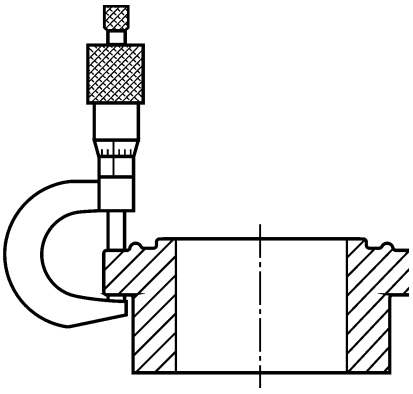


4. Subtract the Projection plate thickness from the measured counter bore depth to obtain the actual counter bore depth from the top surface of the crankcase.

Crankcase counter bore depth (A), mm [in]

Assembly standard ... 14.00–14.05 [0.5500–0.5520]

5. Measure the thickness of the cylinder liner collar.

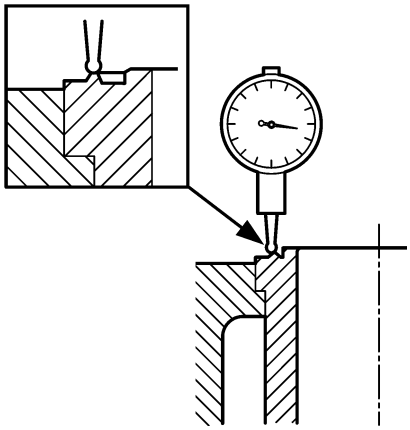


Thickness of cylinder liner collar, mm [in]

Assembly standard ... 14.16–14.20 [0.5563–0.5579]

7. Subtract the crankcase ridge depth from the cylinder liner collar thickness. This value is the cylinder liner protrusion.

8. If the value is less than the assembly standard, insert a shim under the collar of the cylinder liner.



Measuring step height of cylinder liner collar

1. Place a dial gauge on the rim of the liner collar, and set the indicator to 0 (zero).

2. Measure the cylinder liner step at four locations, and obtain the average.

Cylinder liner step height, mm [in]

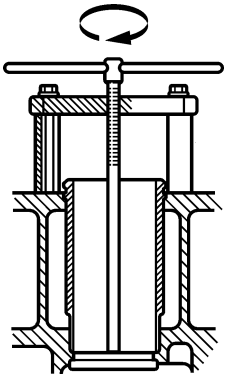
Assembly standard ... 0.16–0.24 [0.006–0.010]

3. If the average is less than the assembly standard or if the step has sectional chipping, replace the cylinder liner.

Cylinder liner shim

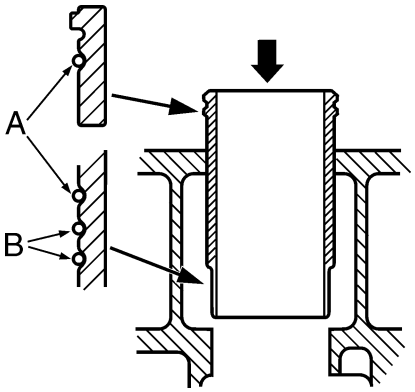
Insert a shim between the cylinder liner and the crankcase.

NOTE! Select the shim that achieves the largest protrusion within the assembly standard range.



Replace cylinder liners

1. Use the Cylinder liner remover to remove the cylinder liner from the crankcase.

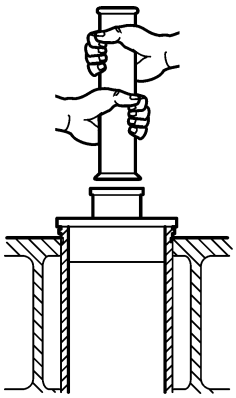


2. Coat the O-rings with engine oil to prevent twisting and attach them to the new cylinder liner.

   A – black o-ring

   B – red o-ring

   Carefully insert the liner into the bore of the crankcase.



3. Lightly tap liner on the top with the installer so it rests on its flange on the counterbore in the crankcase. After seating the liner, tap on it several times more to secure the proper seating.

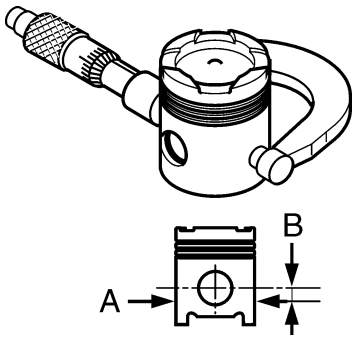
⚠ **IMPORTANT!** After installing the liners on all bores, test the liner fitting for water tightness by applying water under pressure.

NOTE! Check all liners to be sure its protrusion is within assembly standards.

Pistons

Inspecting the piston outside surfaces

Check the combustion surfaces and inside surfaces of the pin bosses. Replace the piston if any defects are found.



Measuring piston diameter

Measure the diameter of each piston perpendicular (A) to the piston pin and 30 mm [1.18 in.] below the center of the piston pin (B). If the service limit is exceeded, replace the piston. If any pistons have to be replaced, select new pistons so that weight difference in an engine is within assembly standards.

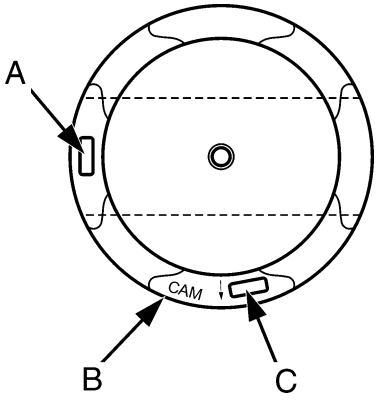
Piston diameter, mm [in.]

Normal value	Ø170 [Ø6.69]
Assembly standard ...	169.76–169.80 [6.6835–6.6850]
Service limit	169.66 [6.6795]

Weight difference in an engine, g [oz]

Assembly standard ...	+/- 10g [+/- 0.35] max.

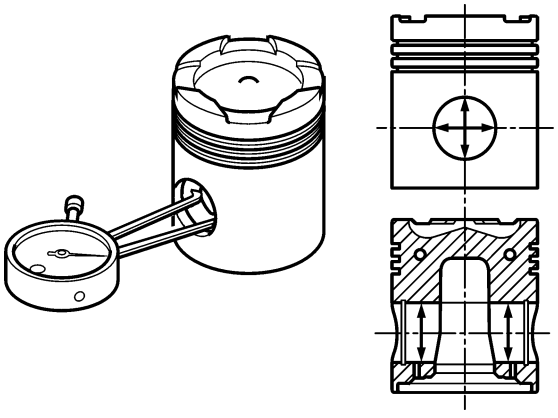
Information stamped on top of each piston:



A – Part no.

B – Engine front side mark

C – Piston weight

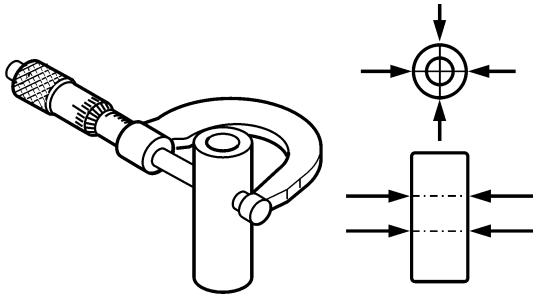


Measuring piston pin diameter

Using a micrometer, measure the outside diameter of each piston pin. If the measurement exceeds the service limit, replace the pin.

Piston pin outside diameter, mm [in]

Nominal value	Ø70 [2.76]
Assembly standard ...	69.987–70.000 [2.75539–2.75590]
Service limit	69.970 [2.75472]

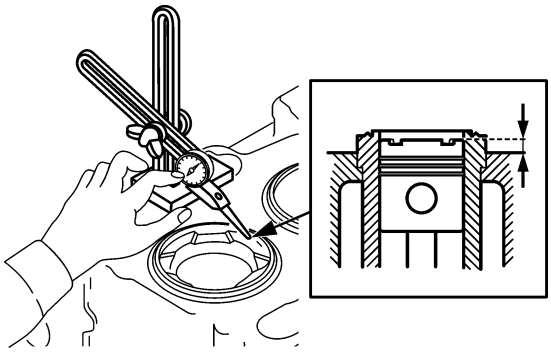


Measuring piston pin bore diameter

Using calipers or a cylinder gauge, measure the piston pin bore diameter. If the service limit is exceeded replace the piston.

Piston pin bore diameter, mm [in.]

Normal value	Ø70 [Ø2.76]
Assembly standard ...	70.002–70.015 [2.75598–2.75649]
Service limit	70.040 [2.75747]



Measuring piston protrusion

Measure the protrusion (height from cylinder head to piston head) of each piston at top dead center. If it is not within standards for piston protrusion measurement, inspect the clearance of the parts.

1. Set the dial gauge to zero (0) on top of the crankcase and measure the protrusion at four places on top of the piston head. Average the four measurements to determine the protrusion.
2. Subtract the piston protrusion from the thickness of the cylinder head gasket (as installed) to determine the clearance between the piston top and cylinder head.

Piston protrusion, mm [in]

Assembly standard ...	0.06 60 0.065 [0.0024 to 0.0256]

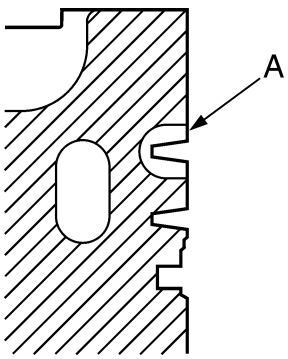
Cylinder head gasket thickness, mm [in]

Assembly standard ...	1.77 to 1.83 [0.0697 to 0.0720]

Piston top and cylinder head clearance, mm [in]

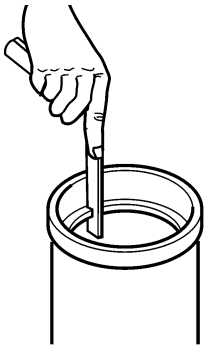
Assembly standard ...	1.22 to 1.95 [0.0480 to 0.0768]

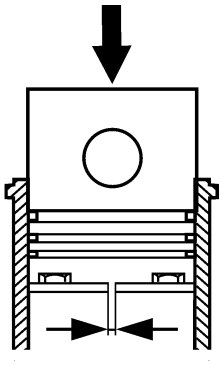
⚠ **IMPORTANT!** Keep the piston protrusion within assembly standard range to prevent the valves from stamping on the piston and to maintain high engine performance.



Inspecting piston ring grooves

Check the piston ring grooves for wear and damage, replace the piston if necessary. Pay special attention to the Ni-resist insert in the top groove (A) for cracks.





Piston Rings

Measuring piston ring gaps

Place the rings in the new or master cylinder liner. Measure the gap of each ring. If the service limit is exceeded, replace all the rings on that piston.

NOTE! Use a piston to place the piston ring in the liner by pushing it squarely.

Piston ring gap, Top ring, mm [in]

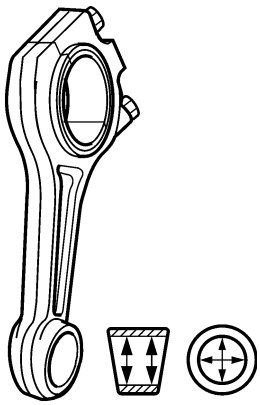
Standard clearance ... 0.6–0.8 [0.024–0.031]
Service limit ..... 2.0 [0.079]

Piston ring gap, Second ring, mm [in]

Standard clearance ... 0.6–0.8 [0.024–0.031]
Service limit ..... 2.0 [0.079]

Piston ring gap, Oil ring, mm [in]

Standard clearance ... 0.3–0.45 [0.012 –0.018]
Service limit ..... 2.0 [0.079]



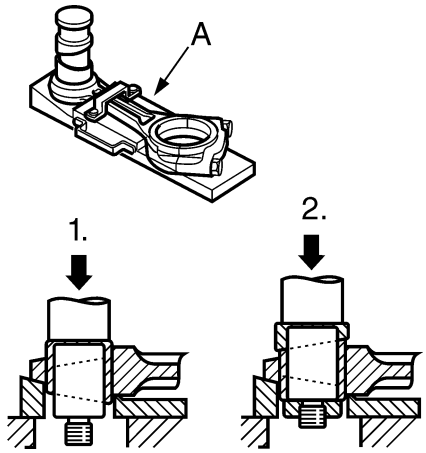
Connecting Rods, Bearings, and Bushings

Measuring connecting rod bushing inside diameter

Measure the inside diameter of each bushing in two directions and on two locations(see picture). If the service limit is exceeded, replace the bushing.

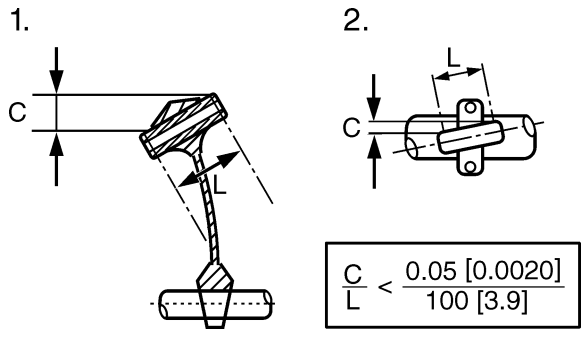
Connection rod bushing inside diameter, mm [in.]

Normal value	Ø70 [2.76]
Assembly standard ...	70.020–70.040 [2.75669–2.75747]
Service limit	70.070 [2.75866]



Replacing connecting rod bushings

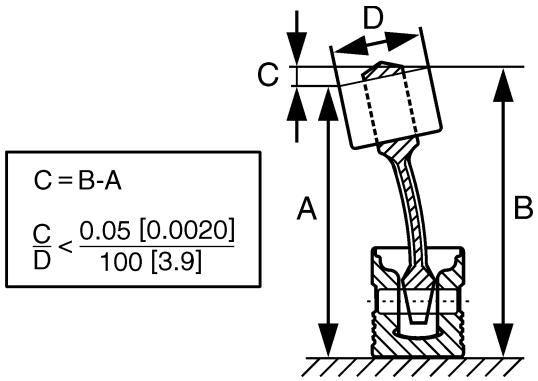
1. Use the Connecting rod bushing installer(A) to remove(1) the bushing for replacement as shown.
2. When installing a new bushing(2), align the oil holes in the bushing and connecting rod.
3. After installing the bushing, measure it and ream to correct size if necessary. Insert the piston pin, and make sure that the pin rotates freely without rattling.



Connecting rods bend(1) and twist(2)

Measure C and L. If the measurement at C is larger than 0.05 mm [0.0020 in.] per 100 mm [3.9 in.] of L, straighten the rod with a press

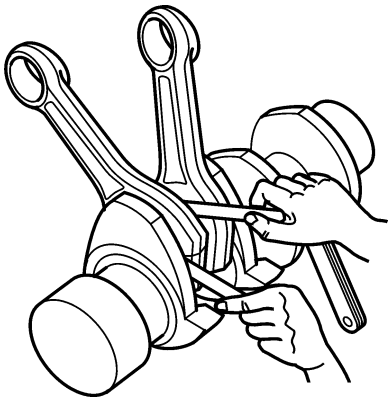
NOTE! To inspect for bend and twist, install the cap to the connecting rod, then tighten the cap bolts to the specified torque.



To inspect the rod bend when assembled with the piston, place the piston on a surface plate. Insert a round bar of the same diameter as the crank pin into the big end bore, then measure heights A and B of the bar.

Connecting rod bend C/D, mm [in]

Assembly standard ...	0.05/100 max. [0.0020/3.9]



Inspecting connecting rod large-end bearings

Inspect each bearing shell for flaking, scratching, seizure, pitting, and other defects. If any defects are found, replace the shell.

Measuring connecting rod end play

Install the connecting rod to its crank pin, then tighten its cap bolts to the specified torque. Use feeler gauges to measure the end play. If the end play exceeds the service limit, replace the connecting rod.

Connecting rod end play*, mm [in]

Nominal value	67 [2.34]
Standard clearance ...	0.2 to 0.6 [0.008 to 0.024]
Service limit	1.0 [0.039]

* Axial play over crankpin

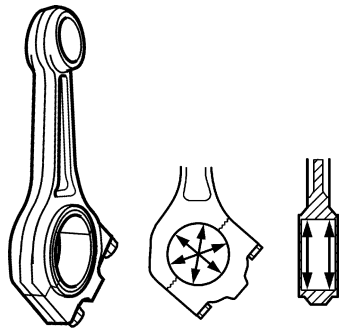
Weight difference of connecting rods in an engine

When replacing connecting rods, make sure that the weight difference of connecting rods in an engine is within the assembly standards below.

Weight difference of connecting rods, g [oz]

Assembly standard ...	+/- 30 [+/-1.06]

NOTE! Connecting rods are classified with capital letters. In one engine all connecting rods have to be of the same letter classification. The classification of the connecting rods can be found on the engine plate (latest models) or on the connecting rods (older models).



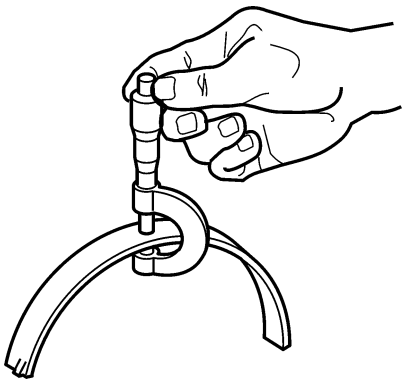
Big end bore diameter

Measure the connecting rod big-end bore diameter in directions 3, 4 and 5 and at front and rear positions 1 and 2, as shown in the drawing. To obtain the roundness value, subtract the smallest measured value from the largest measured value. If the diameter exceeds the servi

Big end bore diameter, mm [in]

Nominal value	Ø131 [5.16]
Assembly standard ...	131.000–131.025 [5.15747–5.15845]
Service limit	131.050 [5.15944]
Service limit*	0.100 [0.0039]

*Roundness



Serration on connecting rod big-end.

Inspect the serration on connecting rod. big-end by conducting a Magnaflux (magnetic particle) test. If cracking or damage is found, replace the connecting rod.

Connecting rod bearing thickness

Use a ball-point micrometer to measure the center of each bearing shell. If the thickness exceeds the service limit on the upper or lower shell, replace both shells as a set.

Connecting rod bearing thickness STD, mm [in]

Nominal value ..... 3.000 [0.11811]
Assembly standard ... 2.9 72–2.985 [0.11701–0.11752]
Service limit ..... 2.930 [0.11535]

Bearing thickness –0.25 [-0.0098], mm [in]

Nominal value ..... 3.125 [0.12303]
Assembly standard ... 3.097–3.110 [0.12193–0.12244]
Service limit ..... 3.055 [0.12028]

Bearing thickness –0.50 [-0.0197], mm [in]

Nominal value ..... 3.250 [0.12795]
Assembly standard ... 3.222–3.235 [0.12685–0.12736]
Service limit ..... 3.180 [0.12520]

Bearing thickness –0.75 [-0.0295], mm [in]

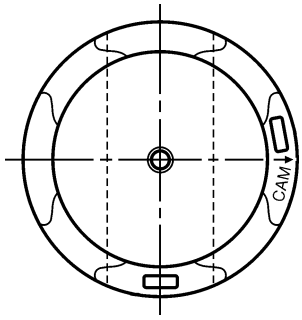
Nominal value ..... 3.375 [0.13287]
Assembly standard ... 3.347–3.360 [0.13177–0.13228]
Service limit ..... 3.305 [0.13012]

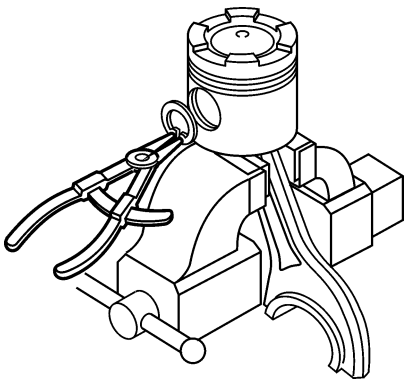
Bearing thickness –1.00 [-0.0394], mm [in]

Nominal value ..... 3.500 [0.13780]
Assembly standard ... 3.472–3.485 [0.13669–0.13720]
Service limit ..... 3.430 [0.13504]

Reassembly

Reassembly is done in the reverse order of disassembly.

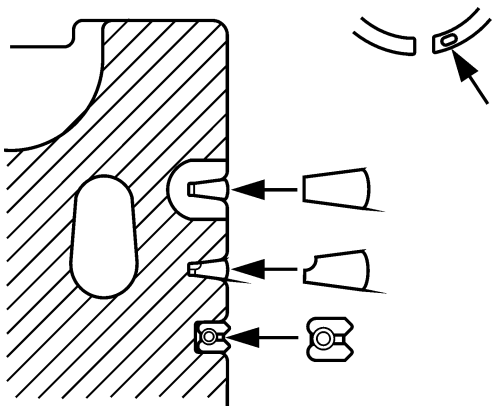




Pistons and connecting rods

1. The piston pin is clearance-fitted to the piston. To facilitate pin insertion, heat the piston with a piston heater or in hot water.
2. Coat the piston pin with engine oil, then insert it in position through the connecting rod.
3. Install the connecting rod to the piston with the matching marks on the large end on the camshaft side.
4. Use the Ring pliers to install the snap rings in the grooves of the piston. Make sure that the rings are not fatigued and that they fit in the grooves properly.

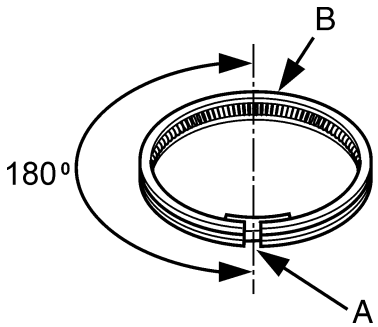
NOTE! Position the ends of both snap rings at the bottom of the pin bore.



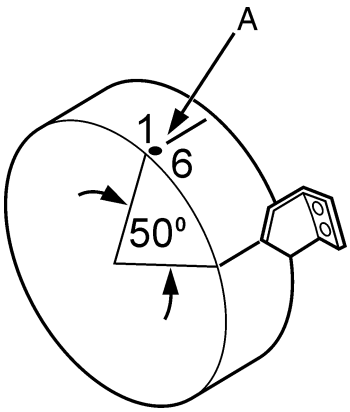
Piston rings

1. Use the Piston ring tool to install the piston rings on the piston

⚠ **IMPORTANT!** The top piston ring and second piston ring are marked “RH”, and the oil ring is marked “R” near the gap. Install the rings with these marks upwards. Faulty mounting will cause excessive oil consumption and overheating.



2. Install the oil ring with its gap positioned at 180° from the coil spring joint.

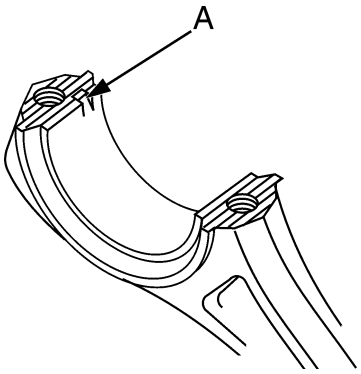


Preparation before installing pistons

Clean the cylinder liner bore surface and crank pin by wiping with a cloth, then coat it with engine oil.

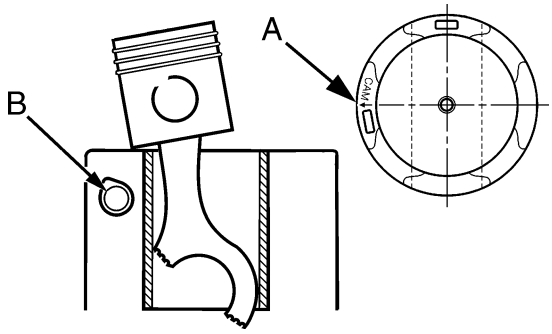
Pistons for right bank cylinders

Turn the crankshaft in the normal direction until the number (stamped on the damper)(A) of the cylinder to which the piston is to be installed is at the position of approximately 50° before top dead center.



Connecting rod bearing upper shells

Install the upper shell of the bearing in the rod by fitting its locating lug in the lug groove of the rod(A). Coat the inside surface of the shell with engine oil. Make sure the oil holes in the rod and bearing are aligned.

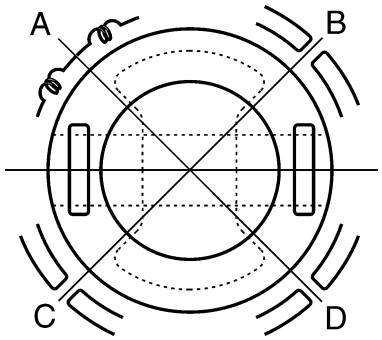


Inserting pistons

1. Put the connecting rod in the cylinder liner, and carefully rest the piston on top of the crankcase.

⚠ **IMPORTANT!** Make sure the arrow mark above the “CAM-arrow”(A) on top of the piston points towards the camshaft(B).

⚠ **IMPORTANT!** When placing the connecting rod in the liner, have another service man to observe the rod through the inspection hole to keep it away from the oil cooling nozzle. Do not rotate the piston.

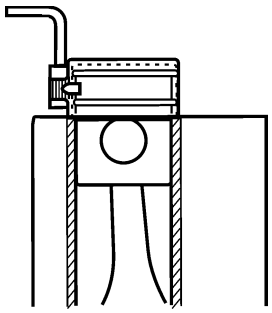


2. Coat the piston rings with engine oil, then position the ring gaps as shown:
   A – Joint of coil spring
   B – Gap of top compression ring
   C – Gap of second compression ring
   D – Gap of oil ring

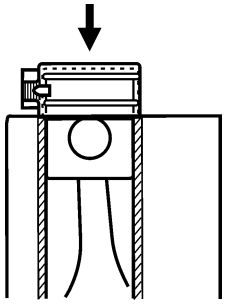
3. Hold the compression ring portion of the piston, and carefully insert the piston into the cylinder liner.

NOTE! Do not pinch your fingers between the oil ring and cylinder liner.

Insert the piston slowly not to damage the oil ring.



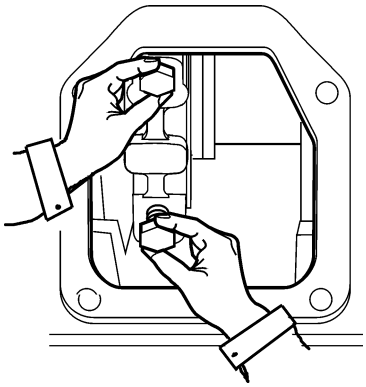
4. Coat the rings with engine oil and clamp them, using the Piston installer. Coat the inside surface of the installer with engine oil.



5. Lightly tap on the piston head with a soft-head mallet to insert the piston into the cylinder liner. If the piston will not go into the liner, move the large end of the connecting rod back and forth through the crankcase inspection hole.

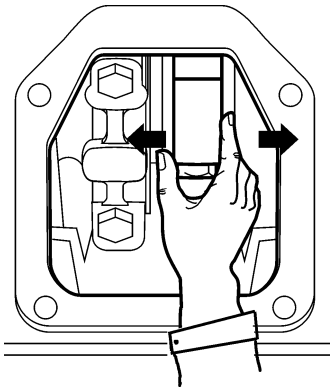
6. Make sure that the upper shell of the bearing is properly positioned in the big end of the connecting rod.

Installing connecting rod cap bolts



1. Place the connecting rod bearing on the connecting rod, fitting its lug in the lug groove. Coat the threads of the cap bolts and the inside surface of the lower shells of the connecting rod bearing with engine oil.

2. Install each cap in position. Hold the upper end of the cap, then tighten the bolt at the lower end first. This will help prevent the cap from dropping into the oil pan. Coat the threads and bearing surfaces of the bolts with engine oil, then tighten the bolts temporarily.



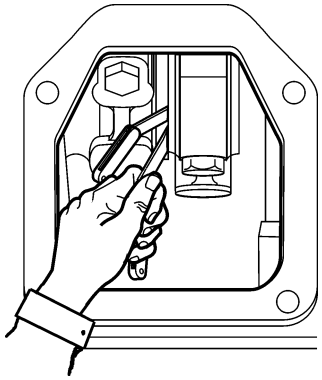
3. Touch the joint between the cap and rod. Make sure that the cap is fit in place, and tighten the bolts to the specified torque.

⚠ **IMPORTANT!** Make sure that the matching marks on the cap and rod are on the same side and show the same number.

4. Install the other connecting rod to the crank pin. Temporarily tighten the cap bolts of the rod installed later, then press it squarely toward the rod already installed by tapping. Move the large end of this rod in the thrust direction. Make sure that the rod has correct end play (insert feeler gauges while tightening).

5. Tighten the cap bolts to the specified torque.

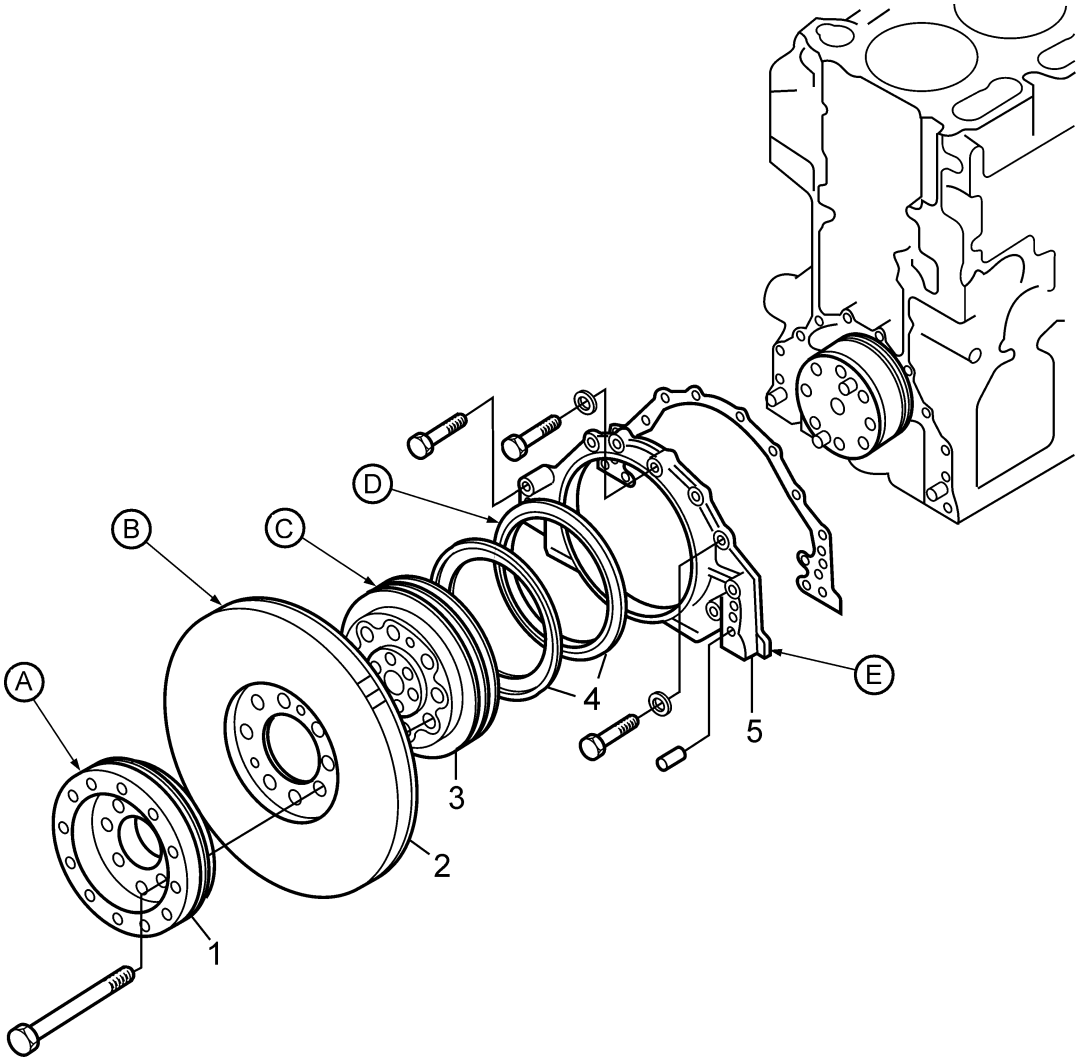
NOTE! Tighten connecting rod cap bolts according to the angle method. Tighten to 245 N.m (25 kgf.m) [181 lbf.ft], then 60° more.



6. Use feeler gauges to measure the end play of the connecting rod. Make sure that the end play is equal on both top and bottom sides of the crank pin.

⚠ **IMPORTANT!** Before installing the cylinder head, measure the protrusion of the piston. Make sure that the measurement is correct.

Viscous damper and front gears

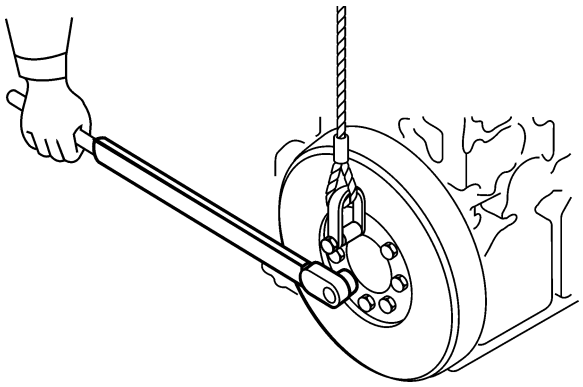


Disassembly:

1. Crankshaft pulley
2. Viscous damper
3. Pulley (water pump & alternator drive)
4. Front oil seal
5. Front cover

Look for:

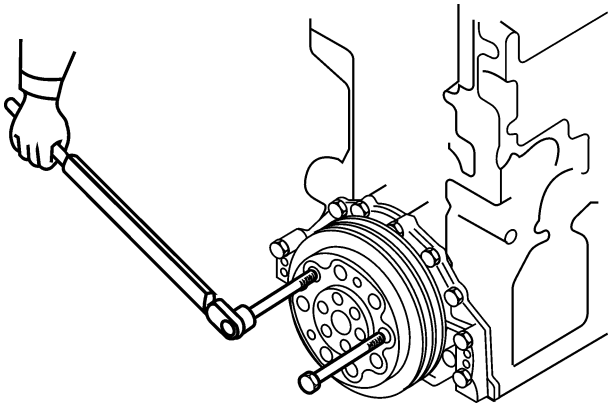
A. Worn belt groove
B. Cracks, oil leakage
C. Worn belt groove
D. Worn lip, wear, deterioration
E. Cracks, defective dowel pin hole



Viscous damper

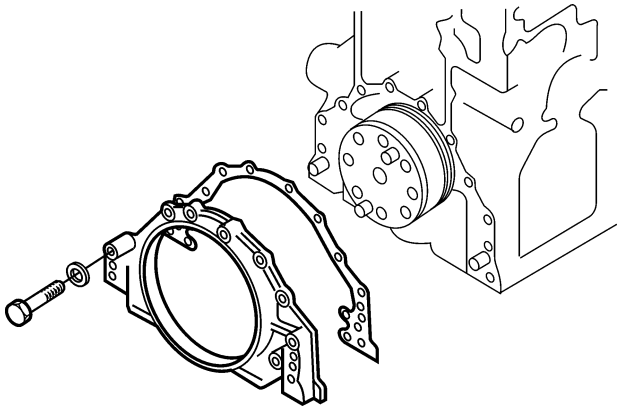
1. Attach a sling to the viscous damper. Unscrew the mounting bolts.
2. Screw the jack-bolts (M14x1.5-40 mm [0.55 x 0.059 - 1.57 in.]) into the threads evenly, then remove the viscous damper.

Weight: Approx. 50 kg [110 lb]



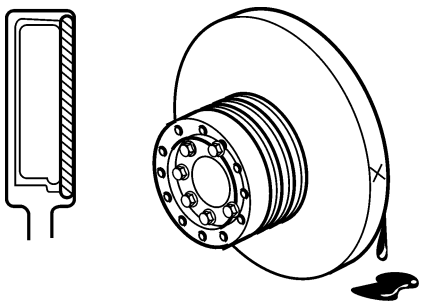
Water pump and alternator drive pulley

Remove the crankshaft pulley by screwing the two jack-bolts M12 x 1.25 mm [0.47 x 0.049 in.]) evenly into the pulley.



Front cover

Unscrew the front cover mounting bolts and remove the lcover. Be careful not to damage the oil seal.

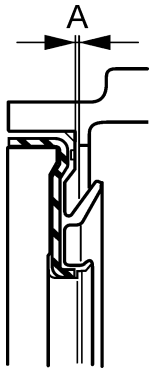


Viscous damper inspection and repair

Check the viscous damper for cracks, deformations or cracks, leakage of silicone oil, discolored or peeling paint due to excessive heat. Replace it with a new one after 8000 to 12000 hours of service, even when no defect is observed.

NOTE! Damper may also be sent to authorized Volvo Penta workshop for inspection.

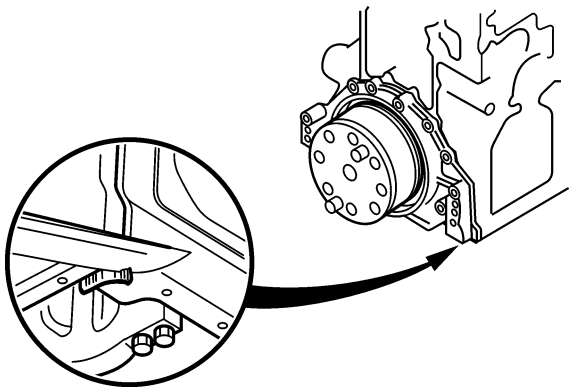
Reassembly



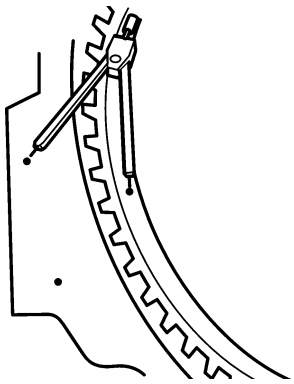
Installing the front cover

1. Apply engine oil to the lip section of the oil seal. Install the oil seal in the front cover. Clearance A should be 1 mm [0.04 in.].

NOTE! Make sure the oil seal is flush with the end face of the oil seal installation hole of the front cover



2. Apply sealant to the front cover mounting surface of the crankcase, then place the packing in position. Apply the same sealant to the packing, then install the front cover.
3. Replace the dowel pins if worn, or if the front plate has been replaced.
4. Make sure that the lower end of the front plate is flush with the bottom of the crankcase. Cut off the excess of the packing neatly along the edge of the plate.



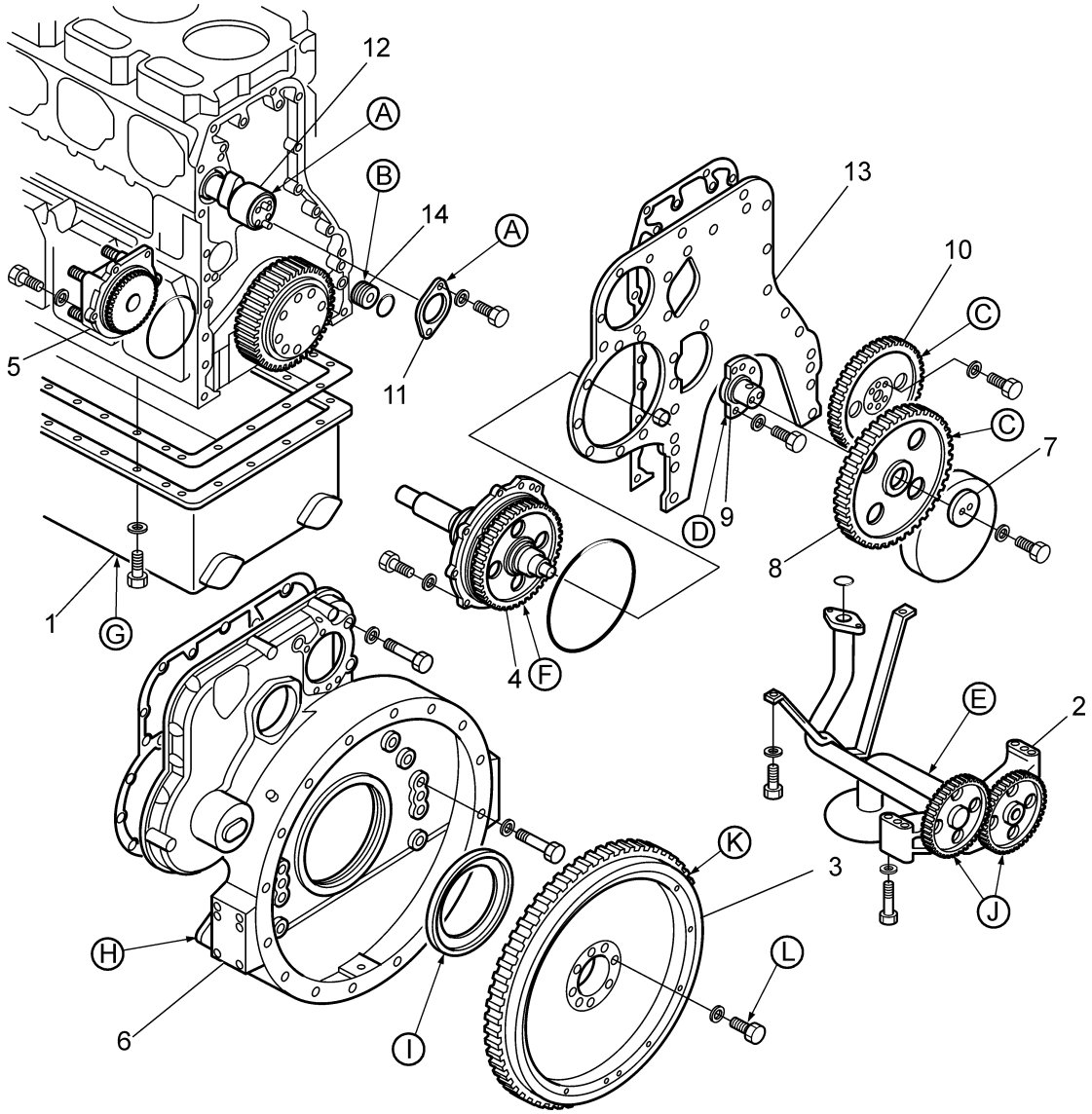
When the Pointer is out of place

To determine the top dead center on the compression stroke of No. 1.6 cylinder, for example, bring the mark on the flywheel to where it is at an equal distance from the marks stamped on the timing gear case.

Installing Pulleys and damper

Tighten the pulley and damper mounting bolts to the specified torque.

Flywheel, Timing gears, Camshaft and Oilpan

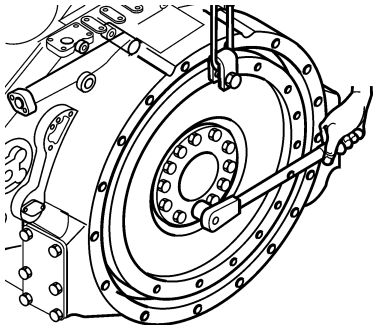


Disassembly:

1. Oil pan
2. Oil strainer, oil pipe, oil pump
3. Flywheel
4. Injection pump drive
5. Governor drive
6. Timing gear case, oil seal
7. Thrust plate
8. Idler gear
9. Idler shaft
10. Camshaft gear
11. Thrust plate
12. Camshaft
13. Rear plate
14. Nozzle plate

Look for:

A. Damage, wear
B. Clogged oil hole
C. Loss of overlay, wear
D. Clogged oil hole
E. Cracks
F. Faulty bearing operation, damaged seal
G. Cracks
H. Cracks, damaged dowel pin hole
I. Worn lip, damage, deterioration
J. Loss of overlay, wear
K. Damaged gear, wear
L. Stripped threads



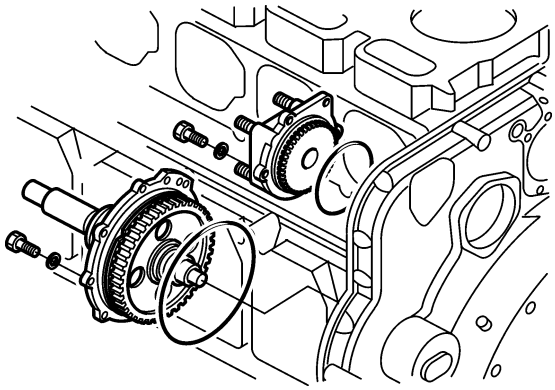
Remove the flywheel

1. Attach a sling to the flywheel.
2. Unscrew the mounting bolts.
3. Screw the two jack-bolts into the holes in the flywheel evenly, then remove the flywheel.

Weight: Approx. 140 kg [309 lb]

⚠ **IMPORTANT!** When you remove the flywheel, do not drop it or bump it against a hard object.

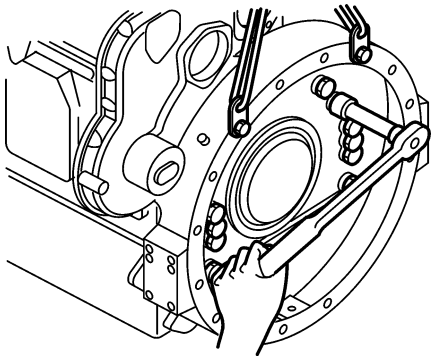
⚠ **IMPORTANT!** The ring gear is bolt mounted to the flywheel. Do not remove the gear except when it has to be replaced.



Governor and injection pump drives

Unscrew the mounting bolts and remove the governor drive and injection pump drive case.

NOTE! Be careful not to damage the gear teeth

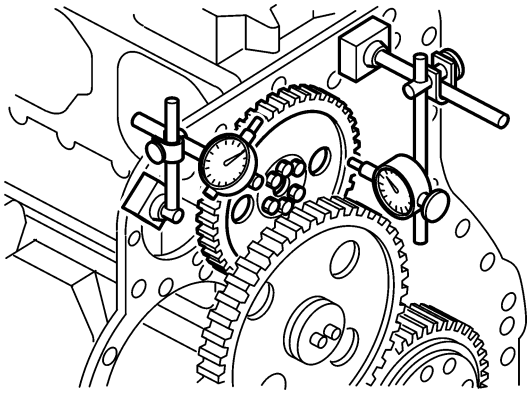


Remove the timing gear case

1. Attach slings to the timing gear case.
2. Unscrew the timing gear case mounting bolts.
3. Remove the timing gear case by lifting it up and pulling it away from the engine until it separates from the dowel pins.

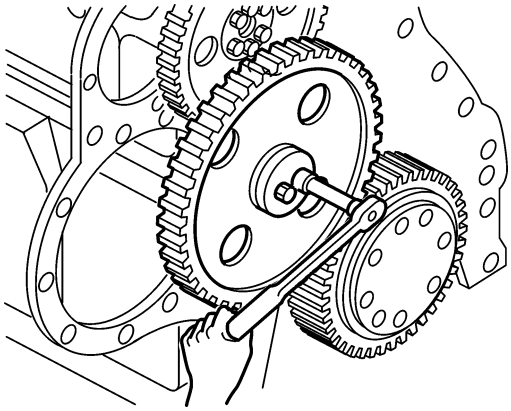
NOTE! Keep the timing gear case suspended and do not damage the oil seal.

Weight: Approx. 85 kg [187 lb]



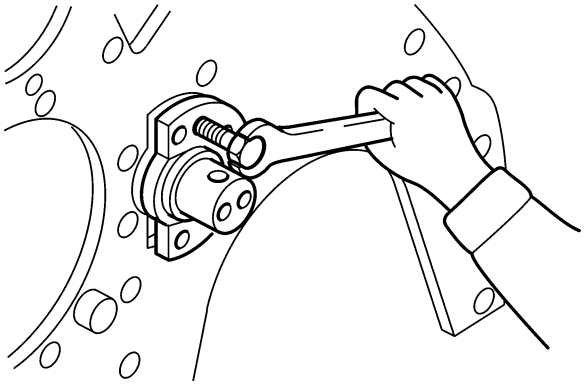
Measure backlash and end play

Measure the backlash and end play of each gear to obtain data to evaluate need of parts replacement.



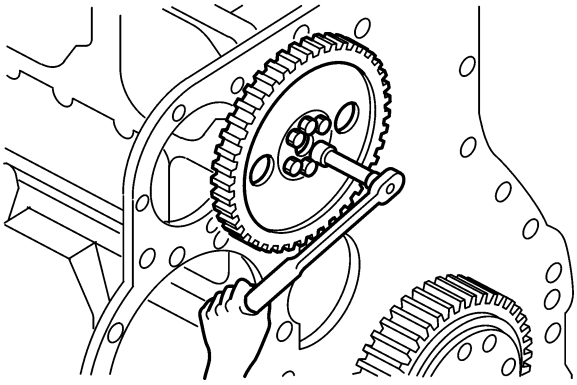
Remove idler gears

Align the pointer with the mark for top dead center of piston no. 1 in compression stroke. Remove the thrust plate mounting bolts and the idler gear.



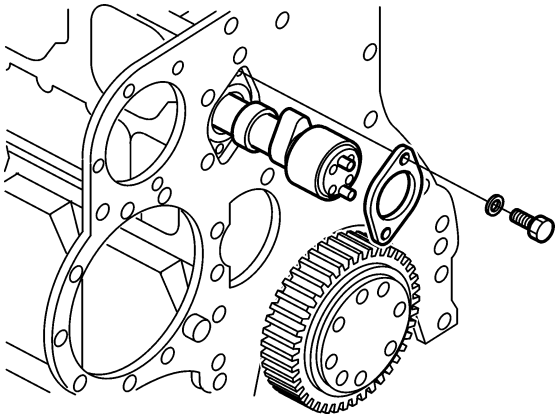
Remove the idler shaft

Remove the idler shaft mounting bolts. Install two jack bolts (M10 x 1.25 mm [0.39 x 0.049 in.] in the holes for shaft removal. Screw the bolts evenly to remove the idler shaft.



Remove camshaft gears

Unscrew the camshaft gear mounting bolts, then remove the camshaft gear.



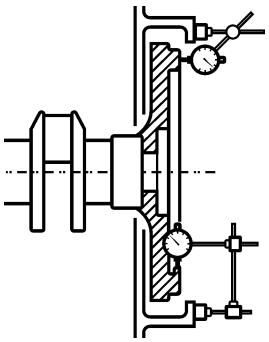
Remove camshafts

Unscrew the thrust plate mounting bolts, then pull out the camshaft from the crankcase.

Weight: Approx. 32 kg [71 lb]

⚠ **IMPORTANT!** When pulling out the camshaft, support it with a bar inserted through the camshaft inspection hole of the crankcase to prevent damage to the cam surfaces and bushings.

Inspection and Repair



Flywheel face and radial runouts

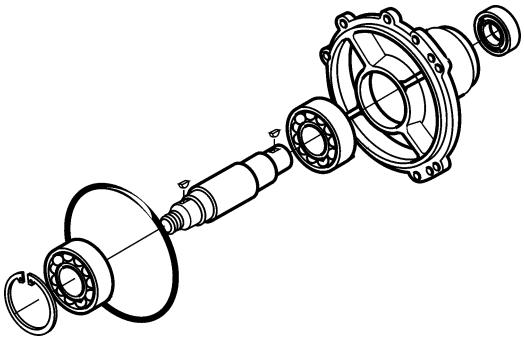
Measure the runouts of the flywheel installed on the crankshaft. If the runouts exceed the assembly standard, check for loose bolts or obstacles lodged between the mounting faces of the flywheel and crankshaft.

Flywheel face runout, mm [in]

Assembly standard ... 0.285 [0.0112] max.

Flywheel radial runout, mm [in]

Assembly standard ... 0.127 [0.0050] max.



Injection pump drive and bearing

1. Measure inside and outside diameters of bearing-fitted sections of injection pump drive.
2. Check bearings, drive shaft, and oil seal. Replace if not running smoothly or if otherwise defective.
3. Check the fit of the drive shaft in the bearing and the fit of the bearing in the drive case. Replace excessively worn parts.

Bearing outside diameter, mm [in]

Nominal value ..... Ø90 [3.54]
Assembly standard ... 89.985–90.000 [3.54272]

Bearing outside diameter, mm [in]

Nominal value ..... Ø100 [3.94]
Assembly standard ... 99.985–100.000 [3.93642–3.93701]

Bearing inside diameter, mm [in]

Nominal value ..... Ø45 [1.77]
Assembly standard ... 44.988–45.000 [1.77118–1.77165]

Bearing inside diameter, mm [in]

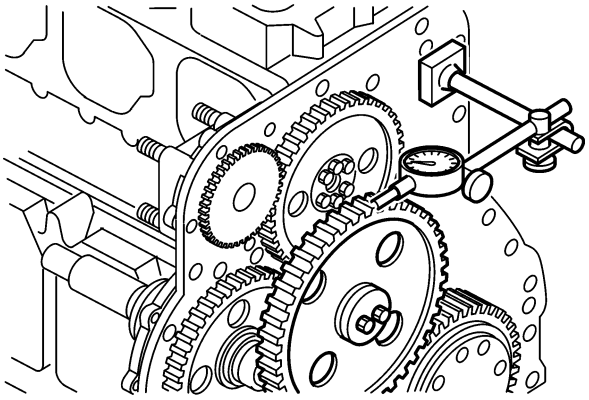
Nominal value ..... Ø50 [1.97]
Assembly standard ... 9.988–50.000 [1.96803–1.96850]

Drive shaft bearing diameter, mm [in]

Nominal value ..... Ø45 [1.77]
Assembly standard ... 45.002–45.013 [1.77173–1.77216]

Drive shaft bearing diameter, mm [in]

Nominal value ..... Ø50 [1.97]
Assembly standard ... 50.002–50.013 [1.96858–1.96901]

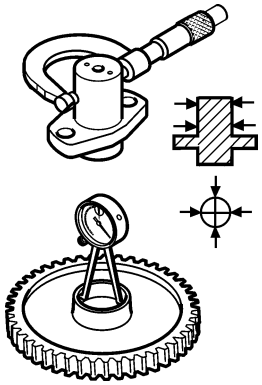


Timing gear backlash

To measure the backlash between the gears, set up a dial gauge so that it contacts the pitch circle of the gear to measure. If a dial gauge is not available, measure the backlash by inserting feeler gauges between the gear teeth. If the backlash exceeds the service limit, replace the worn gears.

Timing gear backlash, mm [in]

Standard clearance ...	0.12–0.18 [0.0047–0.0071]
Repair limit	0.30 [0.0118]
Service limit	0.50 [0.0197]



Idler gears, bushings, and shafts

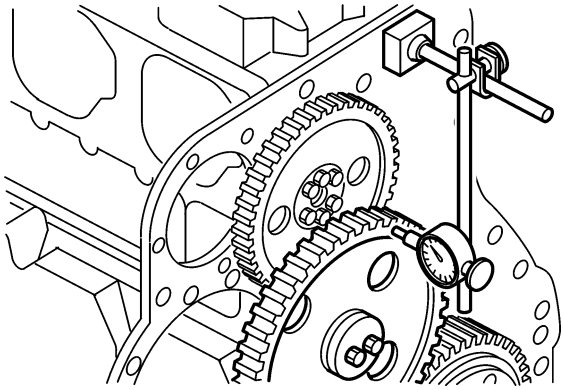
Measure idler gear bushing inside diameter and idler gear shaft diameter. If the service limit is exceeded, replace the bushing or shaft (whichever is worn).

Idler gear bushing inside diameter, mm [in]

Nominal value	Ø50 [1.97]
Assembly standard ...	50.000–50.025 [1.96850–1.96848]
Service limit	50.060 [1.97086]

Idler gear shaft diameter, mm [in]

Nominal value	Ø50 [1.97]
Assembly standard ...	49.950–49.975 [1.96653–1.96752]
Service limit	49.900 [1.96456]

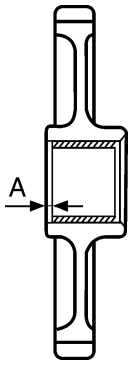


Idler gear end play

Measure the end play with feeler gauges or dial gauge. If the idler gear end play exceeds the service limit, replace the thrust plate.

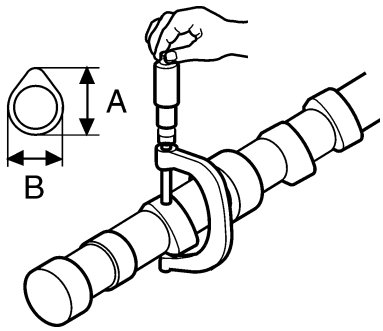
Idler gear end play, mm [in]

Standard clearance ...	0.2–0.4 [0.008–0.016]
Service limit	0.6 [0.024]



Replace idler bushing

1. Use the Idler bushing puller to remove the bushing.
2. Install a new bushing to the gear by pressing it until the end face of the bushing is 1 mm [0.04 in.] (A) recessed from that of the gear boss.
3. After installing the bushing, make sure that its inside diameter is within the assembly standard. If not, ream the bushing to the correct diameter (0.4 Ra).



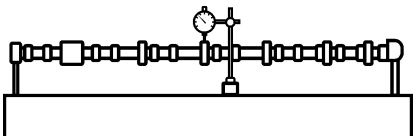
Camshafts and Camshaft Bushings

Measure cam lift

Use a micrometer to measure the diameters of “A” and “B” on each cam to determine the reduction in cam lift. If the cam lift is less than the service limit, replace the camshaft.

Cam lift (A-B), mm [in]

Assembly standard ...	9.197–9.297 [0.36209–0.36602]
Service limit	8.45 [0.3327]



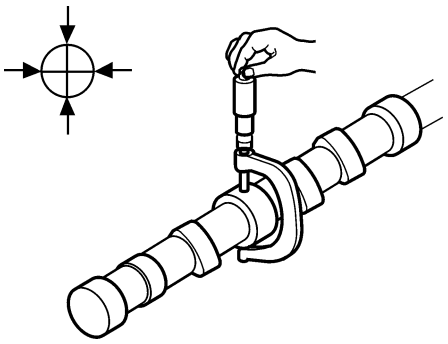
Measuring camshaft deflection

If the deflection exceeds the repair limit, straighten the camshaft with a press, or replace it with a new one.

⚠ **IMPORTANT!** Set up a dial gauge on the camshaft, then turn the camshaft. Take one-half of the gauge indication as the deflection.

Camshaft deflection, mm [in]

Assembly standard ...	0.05 [0.0020] max
Repair limit	0.08 [0.0031]

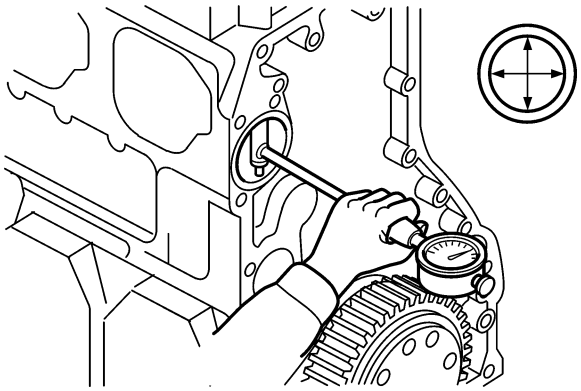


Measuring camshaft journal diameters

Use a micrometer to measure each camshaft journal in two directions at right angles to each other. If the diameter exceeds the service limit, replace the camshaft.

Camshaft journal diameter, mm [in]

Nominal value	Ø84 [3.31]
Assembly standard ...	83.92–83.94 [3.3039–3.3047]
Service standard	83.87 [3.3020]

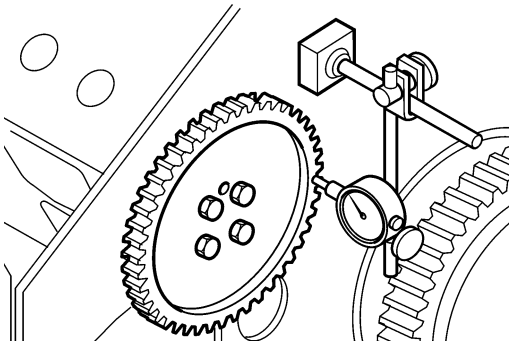


Measuring camshaft bushing inside diameter

Use a cylinder gauge to measure the inside diameter of the camshaft bushings fitted to the crankcase. If the inside diameter exceeds the service limit, replace the bushings.

Camshaft bushing inside diameter, mm [in]

Nominal value	Ø84 [3.31]
Assembly standard ...	84.000–84.035 [3.30708 –3.30846]
Service limit	84.10 [3.3110]

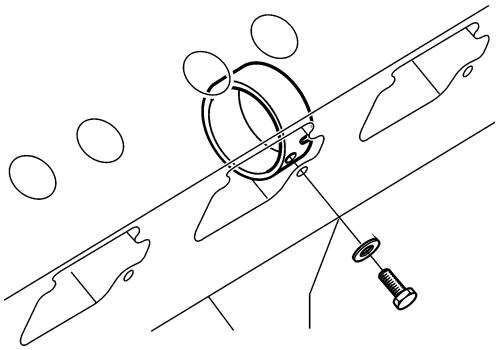


Measuring camshaft end play

Use a dial gauge to measure the end play of the camshaft to which the camshaft gear is installed. If the end play exceeds the service limit, replace the thrust plate.

Camshaft end play, mm [in]

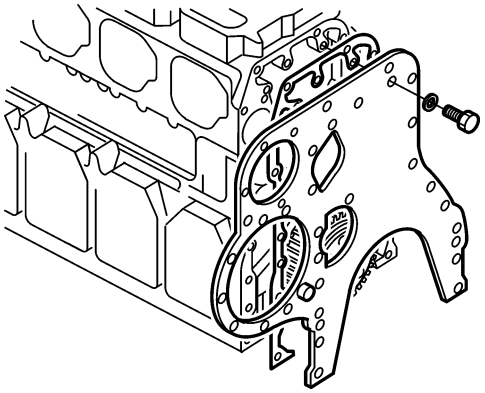
Standard clearance ...	0.10–0.25 [0.0039–0.0098]
Service limit	0.40 [0.0157]



Replacing camshaft bushings

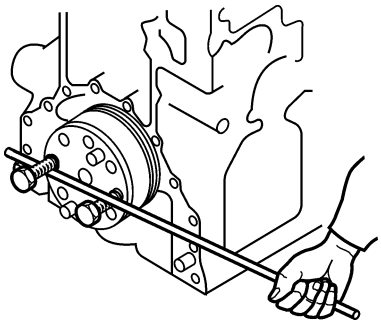
Install the bushings in the crankcase, then secure them in place with the set screws. Before tightening the screws, be sure that the screw holes in the bushings and crankcase are aligned and that the oil holes in the bushings are aligned with those leading to the oil gallery in the crankcase. Use a wide bushing as the bearing for the rear section, and insert it in the correct attitude.

Reassembly



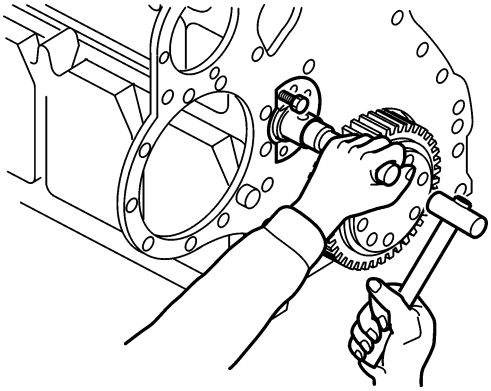
Install the rear plate

1. Apply sealant to the rear plate mounting surface of the crankcase, then place the packing in position. Apply the same sealant to the packing, then install the rear plate.
2. Replace the dowel pins if worn, or if the rear plate has been replaced.
3. Make sure that the lower end of the rear plate is flush with the bottom of the crankcase. Cut off the excess of the packing neatly along the edge of the plate.



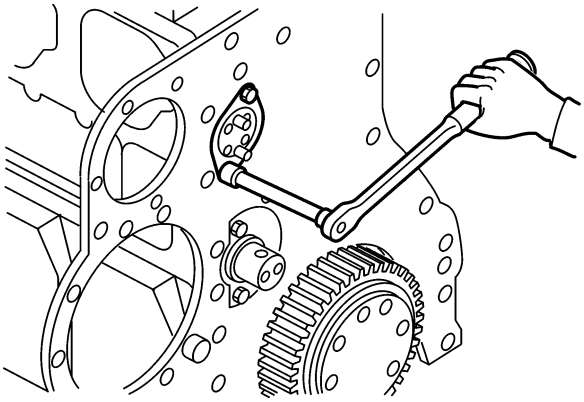
Crank the engine

1. Install the bolts (M22 x 1.5 mm [0.87 x 0.059 in.]) to the viscous damper mounting holes.
2. Using these bolts, turn the crankshaft with a bar to bring the No. 1 cylinder piston to the top dead center.



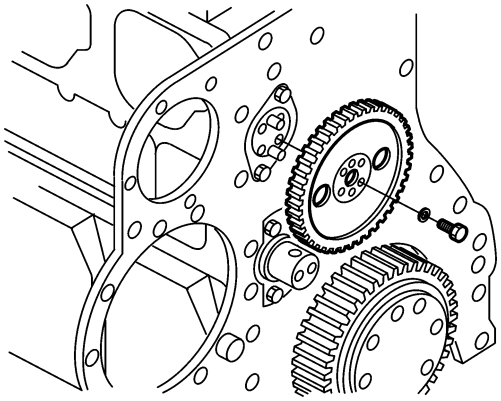
Install idler gear shafts

Drive the idler gear shaft in using a guide bolt. Tighten idler gear shaft mounting bolts to specified torque.



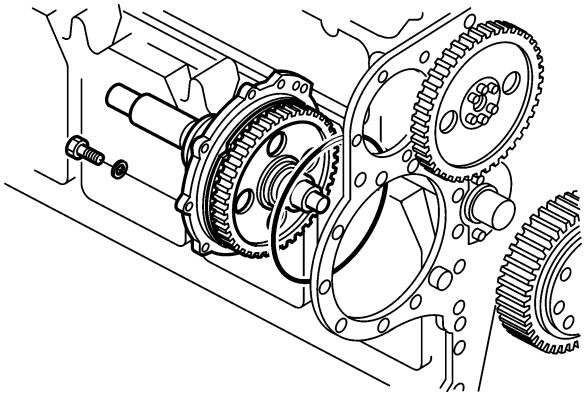
Install camshaft

1. Insert the camshaft into the cylinder block, then install the thrust plate.
2. Tighten the thrust plate mounting bolts to the specified torque.
3. Check and make sure that the camshaft turns smoothly.



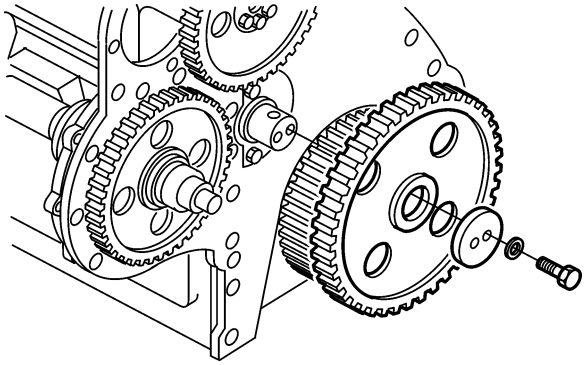
Installing camshaft gears

1. Install the camshaft gears to meet the dowel pin.
2. Tighten the camshaft gear mounting bolts to the specified torque.
3. After installing the camshaft gear, make sure the gear rotates smoothly.



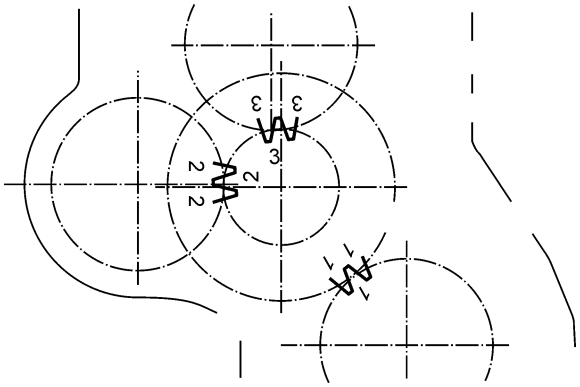
Installing the injection pump drive

1. Install the injection pump gear to the drive shaft, then tighten it to the specified torque.
2. Fit the O-ring to the installation surface of the drive case, and install the case to the rear plate.
3. Tighten the drive case mounting bolts to the specified torque.



Installing idler gears

1. Install the idler gear by aligning its matching mark with that on the crankshaft gear and camshaft gear, and install the thrust plate.
2. Tighten the ithrust plate mounting bolts to the specified torque.



3. Align the matching marks of the timing gears as the drawing show on the right.

Inspect and adjust timing gears

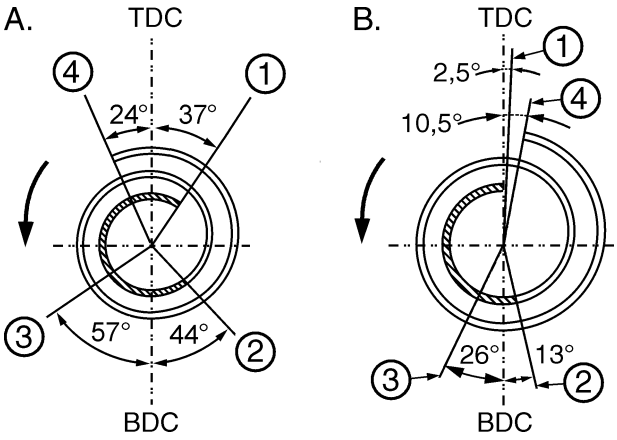
After installing the timing gears, be sure to inspect and adjust them as follows.

Inspect timing gear backlash and end play

After installing the timing gears, inspect the backlash between the gears in mesh, and the end play of each gear.

Inspect Valve Timing

It is not necessary to inspect the valve timing, provided that all match marks on the timing gears are aligned. Inspect the timing for verification as explained below.



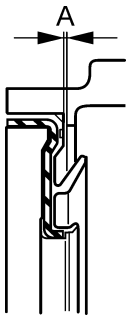
Valve timing diagrams

A. Standard

B. with 2 mm [0.08 in.] valve clearance added

1. Inlet valve opens
2. Inlet valve closes
3. Exhaust valve opens
4. Exhaust valve closes

Use a 2 mm [0.08 in.] feeler gauge, add 2 mm [0.08 in.] clearance to the inlet and exhaust valves of the No. 1 cylinder. Then insert a 0.05 mm [0.020 in.] feeler gauge between the bridge cap and rocker. Slowly turn the crankshaft to find the position where the feeler gauge is firmly gripped (the valve starts opening) and the position where the gauge is released (the valve starts closing). Check that these positions coincide with the angular positions shown in the valve timing diagram B.

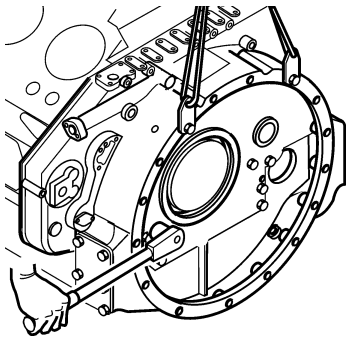


Install the timing gear case

1. Apply engine oil to the lip section of the oil seal. Install the oil seal in the case. Clearance A should be 1 mm [0.04 in.].

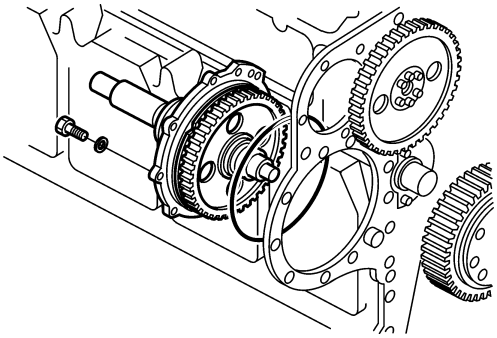
NOTE! Make sure the oil seal is flush with the end face of the case.

2. Apply sealant to gear case surface. Mount the packing. Apply sealant to packing.



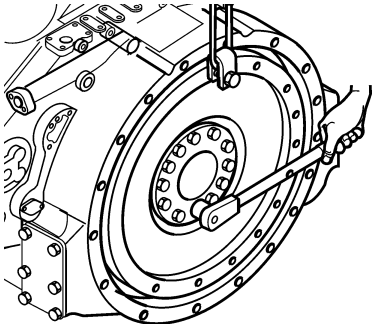
3. Replace dowel pins if worn, or if gear case has been replaced.

4. Tighten gear case mounting bolts evenly to the specified torque. Cut off excess packing along the edge of the crankcase.



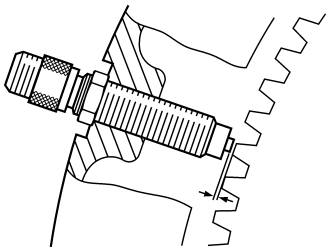
Install governor drive

Fit the o-ring to the mounting flange of the drive case (to wich the drive shaft and gear have been installed), and install the case to the rear plate. Tighten the case mounting bolts to the specified torque.



Install the flywheel

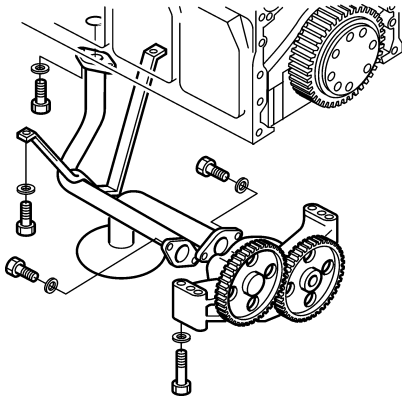
1. Install the flywheel. Check that all dowel pins enter their holes.
2. Coat the threads and the bolt bearing surface of the flywheel mounting bolts with engine oil. Tighten the bolts to the specified torque. Inspect the face and radial runouts of the flywheel.



Install the pickup

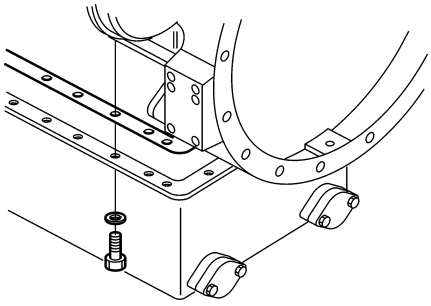
1. Turn the engine to position a tooth of the ring gear at the center of the pickup mounting hole.
2. Screw the pickup gently into the hole by hand. When the pickup touch the gear tooth, loosen it 1½ turn, then tighten the lock nut to secure the pickup in place.

NOTE! Installing the pickup too close to the teeth may result in too strong a signal.



Install oil pump and oil strainer

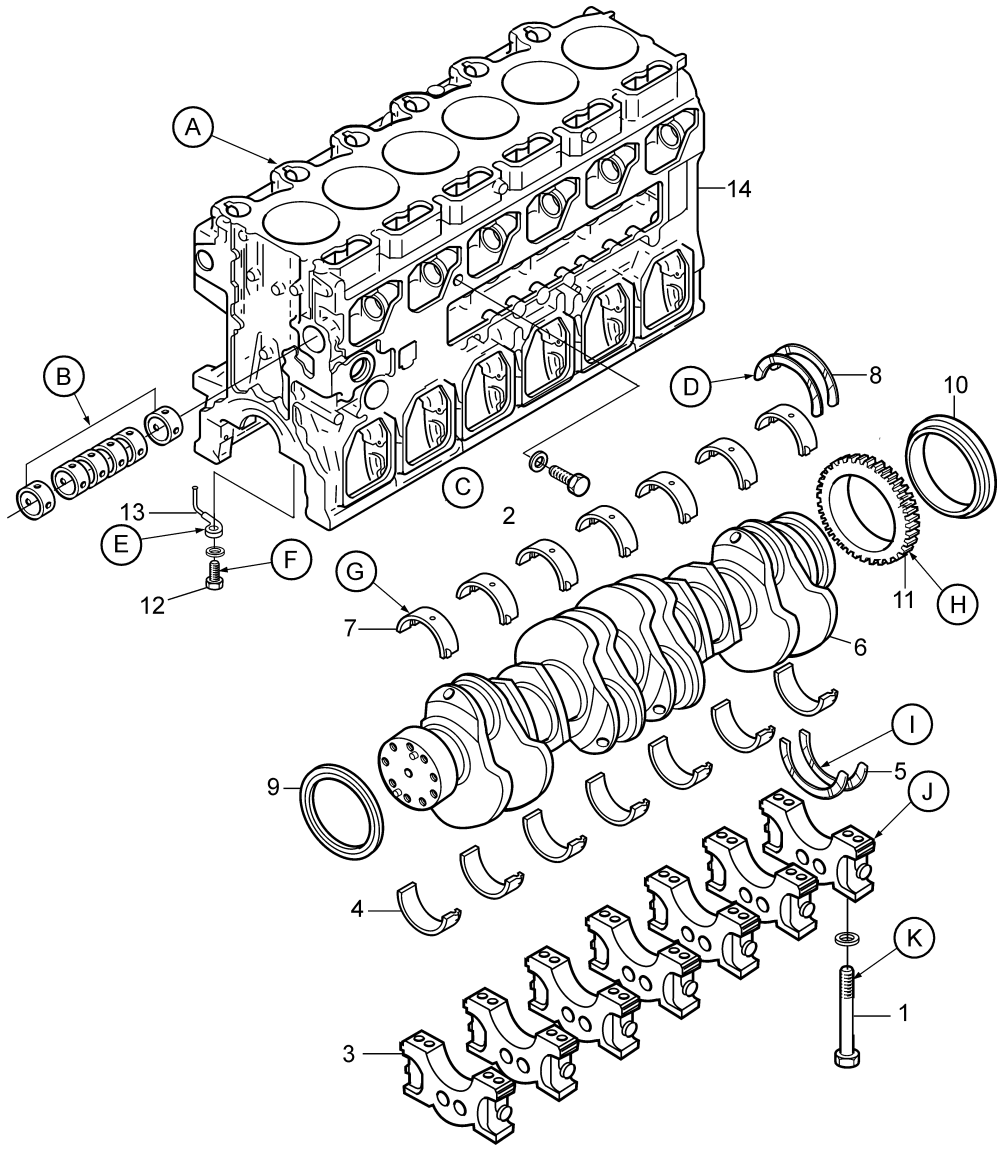
Measure the backlash between crankshaft gear and oil pump drive gear, adjust with shims if necessary.



Install the oil sump

Apply sealant to the joint surface of the oil sump and place the packing on the sump. Apply the same sealant to the packing and mount the sump on the crankcase. Tighten the bolt uniformly to specified torque.

Crankcase, Crankshaft and Main bearings

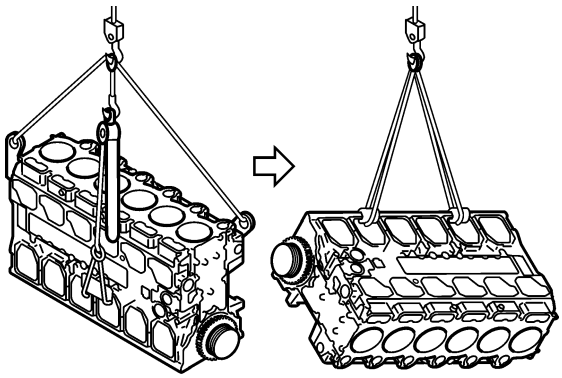


Disassembly:

1. Main bearing cap bolt
2. Side bolt
3. Main bearing cap
4. Main bearing (lower)
5. Thrust bearing
6. Crankshaft
7. Main bearing (upper)
8. Thrust bearing
9. Slinger (front)
10. Slinger (rear)
11. Crankshaft gear
12. Check valve
13. Piston cooling nozzle
14. Crankcase

Look for:

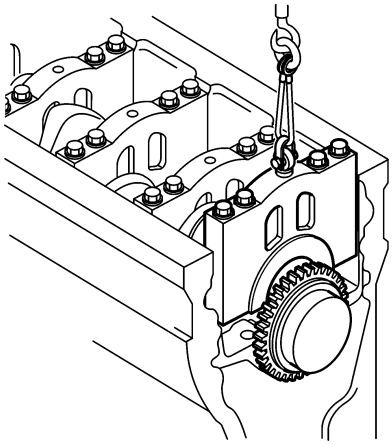
A. Scale damage, cracks, clogged oil holes
B. Wear scratching pitting, scoring
C. Stripped threads
D. Wear
E. Clogged oil hole
F. Check valve movement
G. Scoring, pitting, flaking, chipping, cracks, corrosion
H. Wear, chipping, abnormal tooth contact
I. Wear
J. Cracking
K. Stripped threads



Turning the crankcase upside down

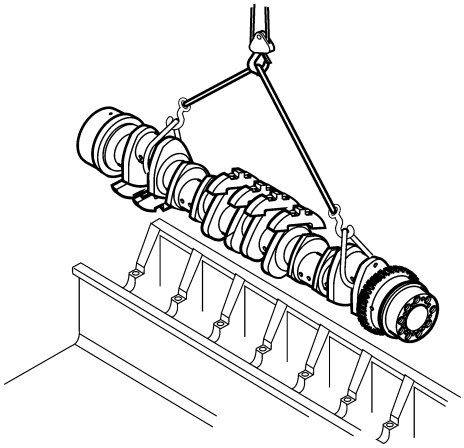
Use such lifting tool as a chain block and shackles to play the crankcase on its side. Then add slings to the crankcase, and turn it upside down.

Weight: Approx. 1000 kg [2205 lb]



Removing the main bearing caps

1. Unscrew the cap bolts and side bolts. Remove the main bearing cap using cap removers (injector remover) or a chain block (use 2 eye bolts, M27 x 1.5 mm [1.06 x 0.059 in.]).
2. Remove the thrust bearings from the No. 7 bearing cap. Do not damage the thrust bearings.



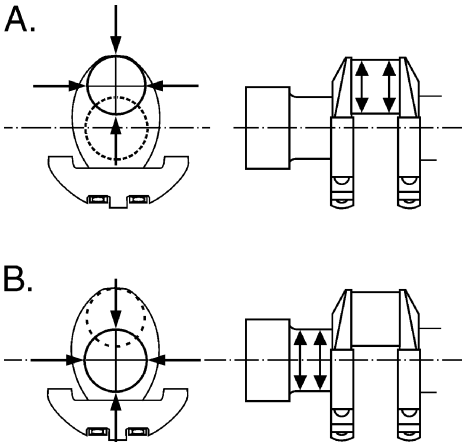
Removing the crankshaft

1. Remove the front upper halves of the thrust bearings by rotating them slowly.
2. Carefully lift the crankshaft off the crankcase, keeping it horizontal.
3. Remove the rear upper halves of the thrust bearings on the crankcase

Removing the piston cooling nozzles

Do not remove the nozzles unless such defects as clogging are observed.

NOTE! Tighten the piston cooling nozzle to the specified torque when reassembling.



Inspection and Repair

Crankshaft

Crank pin and crank journal diameters

1. Using a micrometer, measure the crank pin(A.) and crank journal (B.) diameters. If the repair limit is exceeded, grind them to the next lower size:

   -0.25 mm [-0.0098 in.],-0.50 mm [-0.0197 in.], -0.75 mm [-0.0295 in.], or -1.00 mm [-0.0394 in.].

NOTE! If the –1.00 mm [0.0394 in.] undersize journals and crank pins exceed the repair limit, replace the crankshaft.

2. Measure the crank pins and journals to determine the roundness and cylindricity

Crank pin diameter (A), mm [in]

Nominal value ..... Ø125 [4.92]
Assembly standard ... -0.050– -0.070 [-0.00197– -0.00276]
Repair limit ..... -0.110 [-0.00433]

Crank journal diameter (A), mm [in]

Nominal value ..... Ø140 [5.51]
Assembly standard ... -0.050– -0.070 [-0.00197– -0.00276]
Repair limit ..... -0.110 [-0.00433]

Pin & Journal roundness, mm [in]

Assembly standard ... Dia. diff. 0.01 [0.0004] max.
Repair limit ..... 0.03 [0.0012]

Pin & Journal cylindricity, mm [in]

Assembly standard ... Dia. Diff. 0.02 [0.0008] max.
Repair limit ..... 0.03 [0.0012]

Pin & Journal fillet radius mm [in]

Nominal value ..... 7 [0.28]
Assembly standard ... $7.0\ ^{0\ /\ -0.2}$ [$0.276\ ^{0\ /\ -0.008}$]

Pin & Journal hardness

Assembly standard ... Hv>620

Grinding dim. for undersize crankshaft

Crankpin diam. undersize 0.25 [0.0098], mm [in]

Finishing dimension .. 124.68–124.70 [4.9087–4.9094]
Roundness ..... Dia. Diff. 0.01 [0.0004] max
Cylindricity ..... Dia. Diff.e 0.02 [0.0008] max

Crankpin diam. undersize 0.50 [0.0197], mm [in]

Finishing dimension .. 124.43–124.45 [4.8988–4.8996]
Roundness ..... Dia. Diff. 0.01 [0.0004] max
Cylindricity ..... Dia. Diff. 0.02 [0.0008] max

Crankpin diam. undersize 0.75 [0.0295], mm [in]

Finishing dimension .. 124.18–124.20 [4.8890–4.8898]
Roundness ..... Dia. Diff. 0.01 [0.0004] max
Cylindricity ..... Dia. Diff. 0.02 [0.0008] max

Crankpin diam. undersize 1.00 [0.0394], mm [in]

Finishing dimension .. 123.93–123.95 [4.8791–4.8799]
Roundness ..... Dia. Diff. 0.01 [0.0004] max
Cylindricity ..... Dia. Diff. 0.02 [0.0008] max

Journal diam. undersize 0.25 [0.0098], mm [in]

Finishing dimension .. 139.68–139.70 [5.4992–5.5000]
Roundness ..... Dia. Diff. 0.01 [0.0004] max
Cylindricity ..... Dia. Diff. 0.02 [0.0008] max

Journal diam. undersize 0.50 [0.0197], mm [in]

Finishing dimension .. 139.43–139.45 [5.4894–5.4901]
Roundness ..... Dia. Diff. 0.01 [0.0004] max
Cylindricity ..... Dia. Diff. 0.02 [0.0008] max

Journal diam. undersize 0.75 [0.0295], mm [in]

Finishing dimension .. 139.18–139.20 [5.4795–5.4803]
Roundness ..... Dia. Diff. 0.01 [0.0004] max
Cylindricity ..... Dia. Diff. 0.02 [0.0008] max

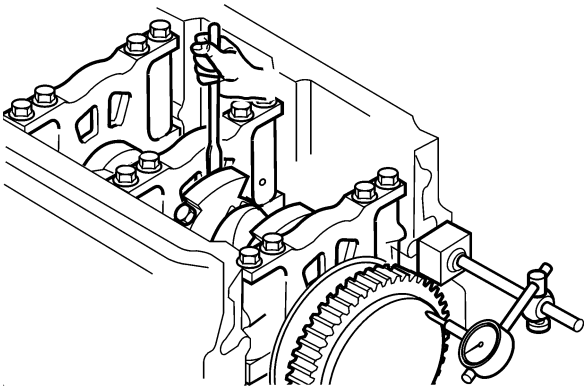
Journal diam. undersize 1.00 [0.0394], mm [in]

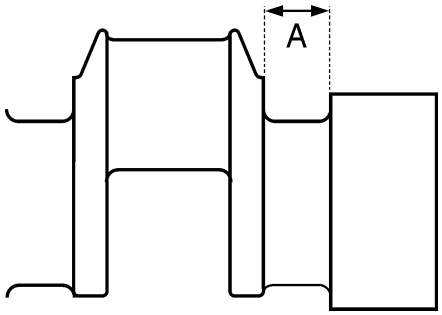
Finishing dimension .. 138.93–138.95 [5.4697–5.4705]
Roundness ..... Dia. Diff. 0.01 [0.0004] max
Cylindricity ..... Dia. Diff. 0.02 [0.0008] max

Grinding the crankshaft

Refinish the crankshaft according to the dimensions of the undersize main bearing and connecting rod bearing.

When grinding the crank pins and journals, be sure to produce the same fillet radius as the original. They should have a hardness of 590 (Vickers Hardness Number). If necessary, re-harden the crank pins and journals, and inspect them for cracks by conducting a Magnaflux (magnetic particle) test. After grinding, finish the journals and crank pins to 0.2 Ra.





Measuring crankshaft end play

1. Install the thrust bearings in position, then secure the bearing cap. Under this condition, measure the end play. If the end play exceeds the standard clearance, replace the thrust bearings.
2. If the end play still exceeds the repair limit even after the new thrust bearings have been installed, replace the bearings with the next oversize bearings. There are three sizes for the thrust bearings:

   + 0.25 mm [+0.0098 in]

   + 0.50 mm [+0.0197 in]

   + 0.75 mm [+0.0295 in]

NOTE! Generally the rear journal is likely to wear more rapidly than the front journal. This means that replacement of the rear thrust bearings will generally be sufficient.

Thrust bearing journal length (A), mm [in]

Nominal value ..... 66.000–66.030 [2.6000–2.6012]

Crankshaft end play, mm [in]

Standard Clearance .. 0.20–-0.40 [0.0079–0.0157]
Service limit ..... 0.50 [0.0197]

Crankshaft Journal grinding dimensions
(oversize thrust bearings)

+0.25 [0.0098] , mm [in]

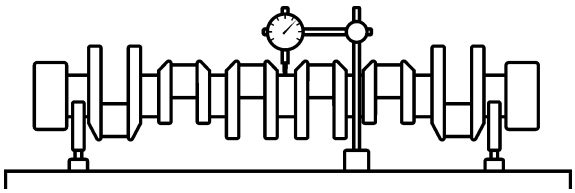
Oversizes for Journal or Thrust bearings 66.25 [2.6083]
Oversizes for Journal and Thrust bearings 66.50 [2.6181]
Tolerance ..... +0.03 / 0 [+0.0012 / 0]

+0.50 [0.0197] , mm [in]

Oversizes for Journal or Thrust bearings 66.50 [2.6181]
Oversizes for Journal and Thrust bearings 67.00 [2.6378]
Tolerance ..... +0.03 / 0 [+0.0012 / 0]

+0.75 [0.0295] , mm [in]

Oversizes for Journal or Thrust bearings 66.75 [2.6280]
Oversizes for Journal and Thrust bearings 67.50 [2.6575]
Tolerance ..... +0.03 / 0 [+0.0012 / 0]



Measuring crankshaft deflection

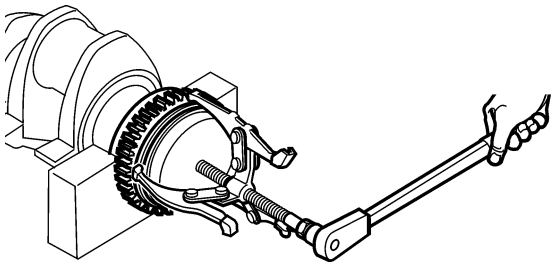
Support the crankshaft on its journals in V-blocks, then measure the deflection at the center journal with a dial gauge. Depending on the amount of deflection, repair the crankshaft by grinding or straightening with a press. If the deflection exceeds the repair limit, replace the crankshaft.

Crankshaft deflection, mm [in]

Assembly standard ... 0.04 [0.0016] max.
Repair limit ..... 0.10 [0.0039]

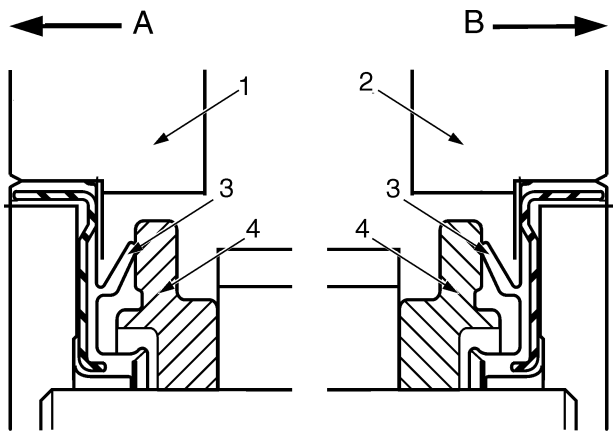
Replace the oil seal slinger

Replace the slinger if it is pitted, scratched, or distorted enough to cause oil leaks.



Remove the Slinger

Use a gear puller to remove the slinger from the crankshaft.



Install the Slinger

1. Identify the front slinger and the rear slinger, and pay attention to their attitudes

   A. Front

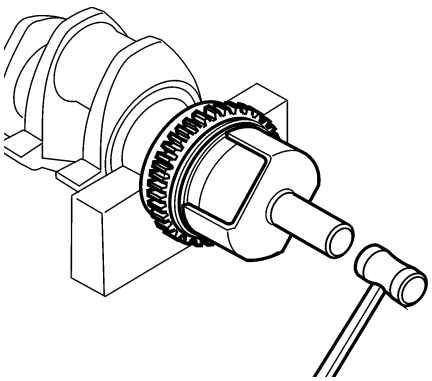
   B. Rear

   1. Front cover

   2. Timing gear case

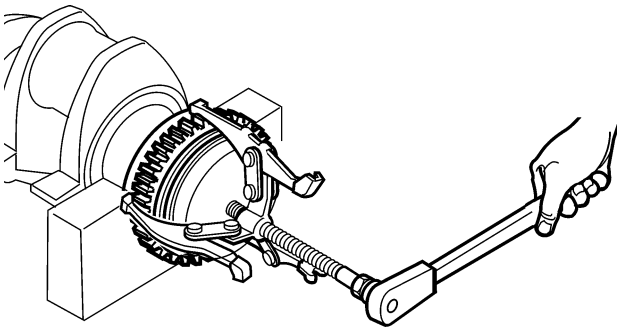
   3. Oil seal

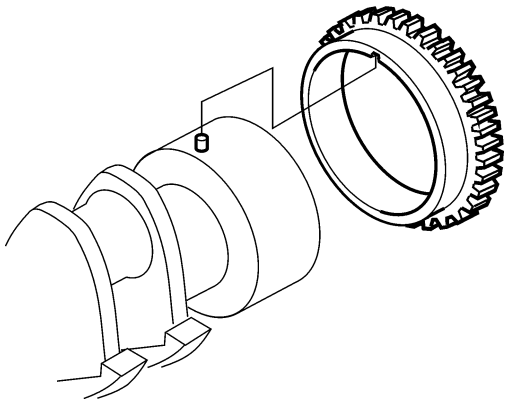
   4. Slinger

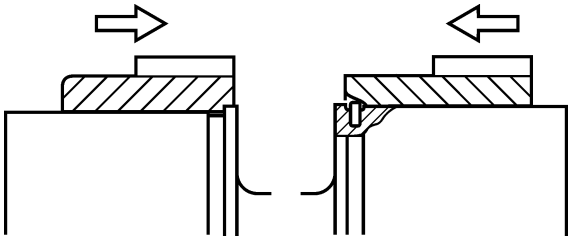


2. Use a slinger installer to install the heated (above 110 °C [230 °F]) slinger to the crankshaft until it contacts the gear.

⚠ **IMPORTANT!** If the slinger has stopped before it touches the gear, tap the center or shoulder of the installer with a copper hammer.







Replace the crankshaft gear

Remove the Gear

Use a gear puller to remove the gear from the crankshaft.

NOTE! Do not remove the gear by hitting it with a hammer.

Install the Gear

1. Before installing the crankshaft gear, measure the inside diameter of the crankshaft gear. to be sure that the fit is within the specified value.

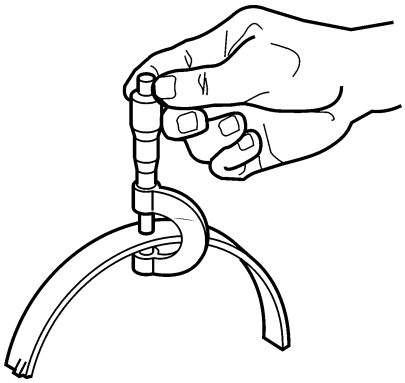
Front side	0.106–0.171 mm [0.00417–0.00673 in]
Rear side	0.274–0.358 mm [0.01079–0.01409 in]

2. Heat the gear to the range 180 to 200 °C [356 to 392 °F. (Do not heat the gear above 200 °C [392 °F].)

3. Drive the rear crankshaft gear onto the crankshaft by tapping the end face of the gear lightly with a copper hammer. Be sure the crankshaft dowel pin enters the notch in the gear.

⚠ **IMPORTANT!** Install the gear to the crankshaft until it contacts the collar.

⚠ **IMPORTANT!** Do not mistake the direction of gear installation



Main Bearing

Bearing surfaces

Inspect each bearing shell for abnormal contact such as scratching, corrosion, flaking, etc. Also check for signs of poor seating in the bore of the crankcase or bearing cap.

Bearing thickness

Use a ball point micrometer to measure the center of each hearing shell. If the service limit is exceeded on any of the shells, replace the upper and lower shells as a set.

Main bearing thickness (center) STD, mm [in]

Nominal value	3.500	[0.138]
Assembly standard ...	3.467–3.480	[0.13650–0.13701]
Service limit	3.425	[0.13484]

Main bearing thickness (center) –0.25 [0.0098], mm [in]

Nominal value	3.625	[0.14272]
Assembly standard ...	3.592–3.605	[0.14142–0.14193]
Service limit	3.550	[0.13976]

Main bearing thickness (center) –0.50 [0.0197], mm [in]

Nominal value	3.750	[0.14764]
Assembly standard ...	3.717–3.730	[0.14634–0.14685]
Service limit	3.675	[0.14468]

Main bearing thickness (center) –0.75 [0.0295], mm [in]

Nominal value	3.875	[0.15256]
Assembly standard ...	3.842–3.855	[0.15126–0.15177]
Service limit	3.800	[0.14961]

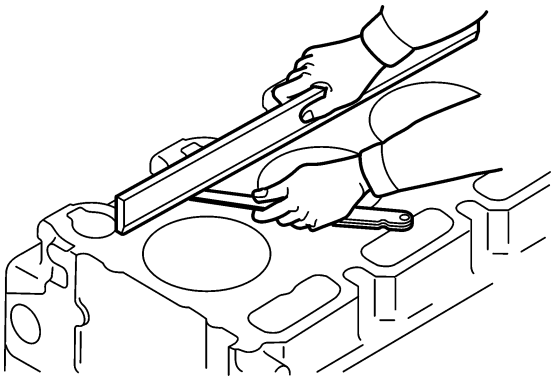
Main bearing thickness (center) –1.00 [0.0394], mm [in]

Nominal value	4.000	[0.15748]
Assembly standard ...	3.967–3.980	[0.15618–0.15669]
Service limit	3.925	[0.15453]

NOTE! Four undersizes are available for the main bearings; -0.25 mm [-0.0098 in], -0.50 mm [-0.0197 in], -0.75 mm [-0.0295 in] and –1.00 mm [-0.0394].

Replace main bearings.

If the thickness exceeds the service limit, either replace the main bearings as above, or refinish the crankshaft and use undersize bearings.



Crankcase

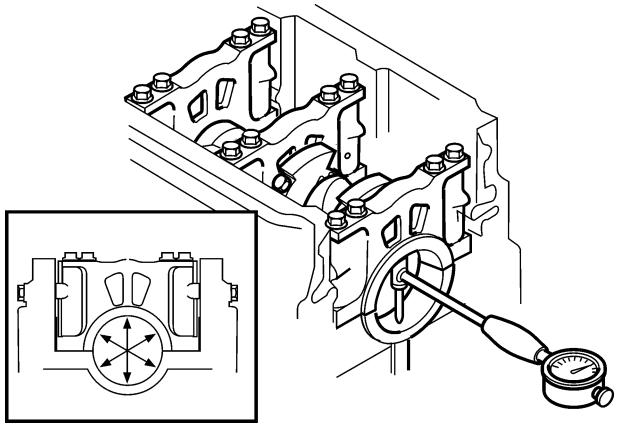
Flatness of gasket surface

Measure flatness with a straight edge and feeler gauges. If the warpage exceeds the assembly standard, reface the gasketed surfaces with a surface grinder.

Crankcase gasket surface flatness, mm [in]

Assembly standard ...	0.1 [0.004] max
Repair limit	0.2 [0.008]

NOTE! Do not grind the crankcase more than necessary to remove warpage. Excessive grinding can cause the piston protrusion to exceed assembly standard.



Main bearing bore diameter

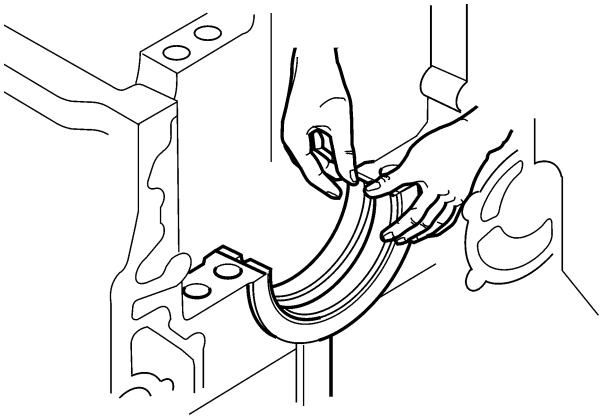
Secure the end bearing cap to the specified torque, and measure the bore diameter in the three directions.

Main bearing bore diameter, mm [in]

Nominal value	Ø147 [5.79]
Assembly standard ...	147.000–147.025 [5.78739–5.78837]
Service Limit	147.035 [5.78877]

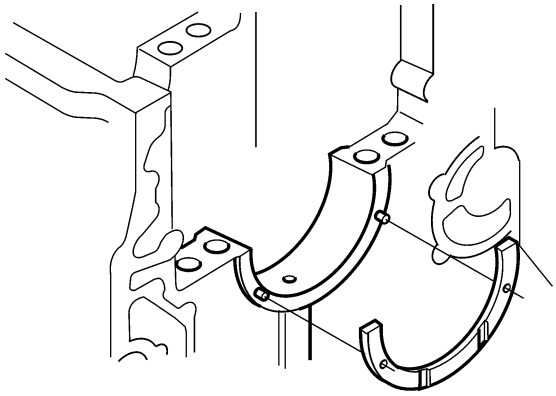
Reassembly

Reassembly is done in the reverse order of disassembly.



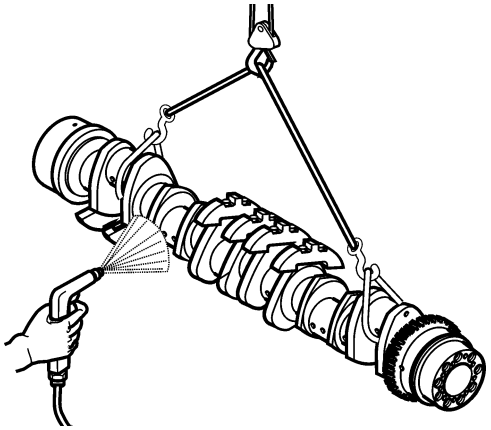
Main bearing

1. Install each upper shell of the main bearing in the crankcase by fitting its locating lug in the lug groove. The oil holes in the bearings and crankcase Will be aligned when the bearings are installed in this way.
2. Lightly coat the inside surface of the shells with engine oil.



Installing thrust bearings

1. Install the thrust bearings to the No. 9 bearing seat of the crankcase, with the oil groove side of the bearings facing out.
2. After installing the crankshaft, install the inner thrust hearing with the oil groove facing inside the crankcase.



Crankshaft

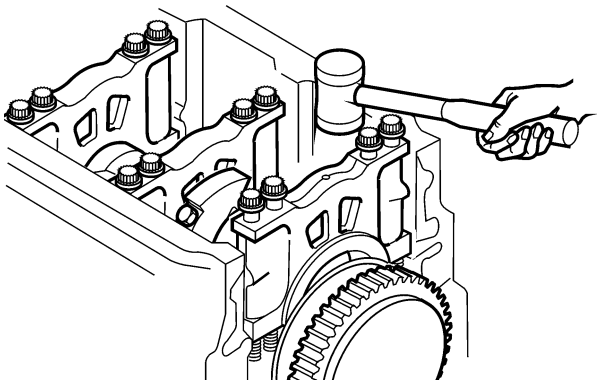
1. Wash the crankshaft with cleaning solvent, and dry it with compressed air.

NOTE! After washing the crankshaft, make sure that the oil holes are clean and not clogged.

2. Hold the crankshaft horizontally with a hoist, then carefully put it on the crankcase.
3. Lightly coat the journals with engine oil.

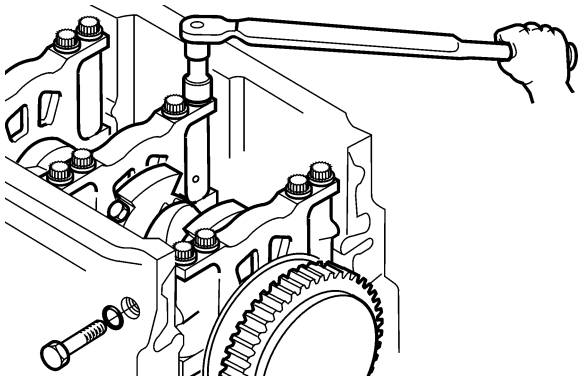
Main bearings

Main bearing caps



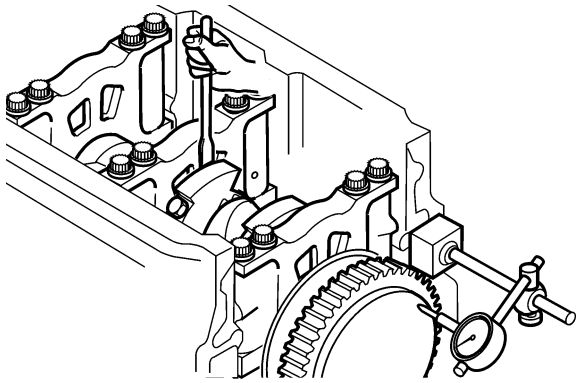
1. Fit the lower shell of the bearing to each bearing cap.
2. Install the thrust bearings to the No. 7 bearing cap, with the oil groove side of the bearing facing out.
3. From the front side of the crankcase, hearings No. 1 to No. 7 are stamped on the caps. Install the caps with these numbers and “FRONT” mark on the front of the crankcase.
4. Coat the threads of the metal cap bolts with engine oil, then temporarily tighten the bolts.
5. Use a softhead mallet to drive in the metal caps evenly.

Bearing cap bolts



1. Temporarily tighten the bearing cap coated with engine oil. Tighten the four bolts progressively and evenly to the specified torque.
2. Tighten the left and right side bolts progressively and evenly to the specified torque.
3. Make sure that the crankshaft rotates smoothly.

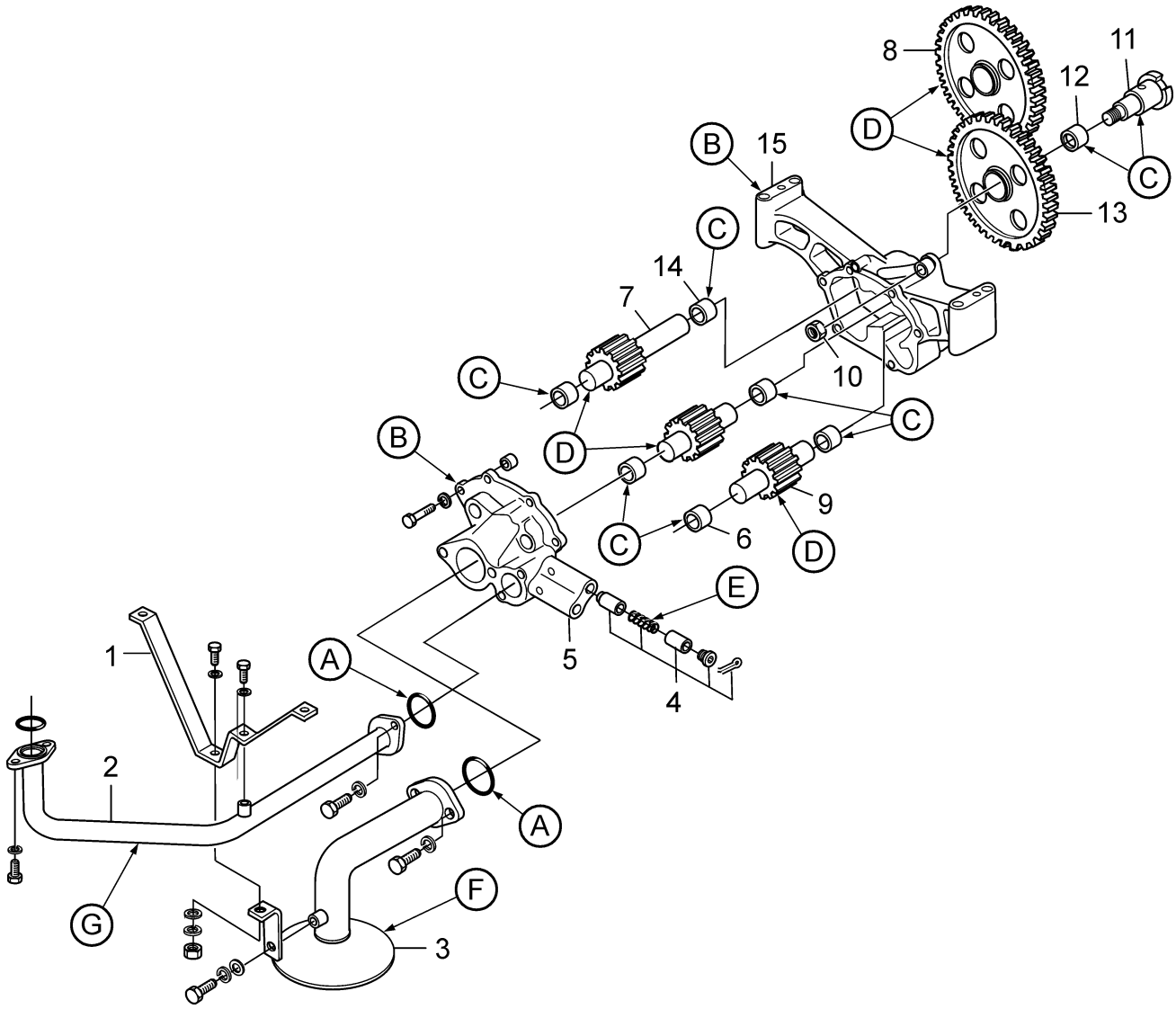
Crankshaft end play



1. Tighten No. 1 through No. 6 bearing cap bolts and side bolts to the specified torque, with the No. 7 cap bolt temporarily tightened, then measure the end play.
2. After tightening the No. 7 cap bolts, make sure that the end play is correct.
3. Confirm that all cap bolts and side bolts are tightened to the specified torque.

Group 22 Lubrication system

Oil Pump and Safety Valve

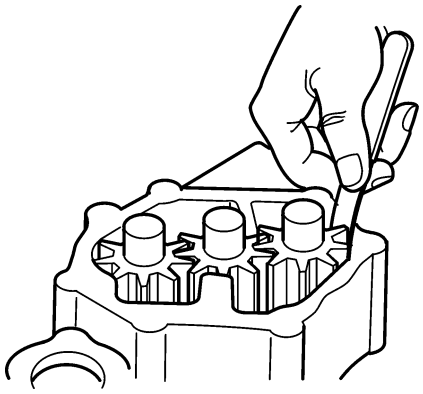


Disassembly

1. Support
2. Oil pipe
3. Oil strainer
4. Safety valve
5. Pump cover
6. Bushing
7. Drive gear
8. Oil pump gear
9. Driven gear
10. Nut
11. Spindle
12. Bushing
13. Idler gear
14. Bushing
15. Pump case

Look for:

A. Replace o-ring
B. Cracks, damage
C. Wear
D. Wear, chipped gear teeth
E. Weak, worn or broken spring
F. Cracks, clogged strainer
G. Cracks



Inspection

Measure gear backlash

If the backlash exceeds the service limit, replace the gears.

Drive gear and driven gear backlash, mm [in.]

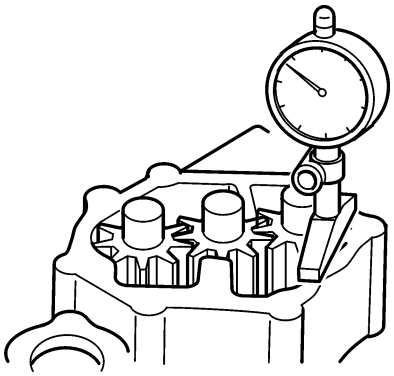
Standard Clearance ..	0.087–0.316 [0.034–0.0124]
Service Limit	0.3 [0.012]

Measure gear radial clearance

Use feeler gauges to measure the clearance. If the clearance exceeds the service limit, replace the gears or case, whichever is badly worn.

Drive gear and driven gear clearance, mm [in.]

Nominal Value	Ø60 [2.36]
Standard Clearance ..	0.100–0.196 [0.00394–0.00772]
Service Limit	
Tip clearance:	0.35 [0.0138]



Measure pump gear end clearance

Use a dial gauge to measure the clearance. If the clearance exceeds the service limit, replace the gears or case, whichever is badly worn.

Pump gear end clearance, mm [in.]

Nominal Value	34.0 [1.34]
Standard Clearance ..	0.050–0.114 [0.00197–0.00449]
Service Limit	0.25 [0.0098]

Measure shaft and bushing diameters

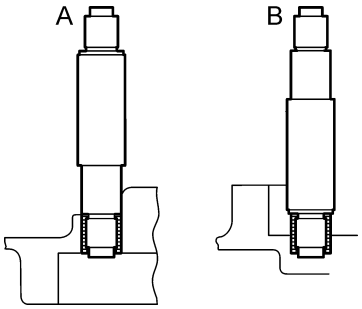
1. Check the gear teeth. Replace gears if they are defective.
2. Measure the gear shafts and bushings using a dial gauge. If the diameter exceeds the service limit, replace the parts.

Gear shaft diameter, mm [in.]

Nominal Value	Ø25 [0.98]
Assembly Standard ...	24.947–24.960 [0.98216–0.98268]
Service Limit	24.900 [0.98031]

Bushing inside diameter, mm [in.]

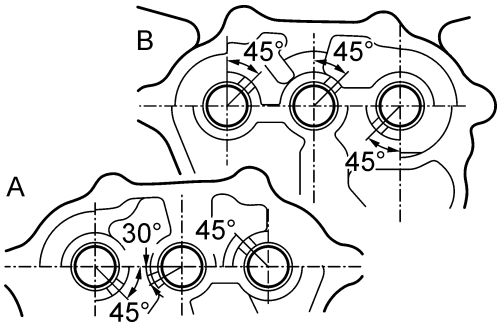
Nominal Value	Ø25.0 [0.98]
Assembly Standard ...	25.000–25.021 [0.98425–0.98508]
Service Limit	25.100 [0.98819]



Replace oil pump bushings

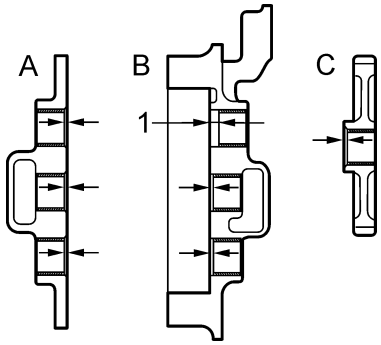
Remove (A) and install (B) oil pump bushings using the oil pump bushing tool

1. Remove the oil pump bushing as needed. If it is tooo difficult to remove the bushings replace the bushings and related parts as an assembly.



2. When you install the pump cover bushing, place the bushing joint positions as shown in the right drawing.
   A. Pump cover
   B. Pump case

NOTE! Do not align with the lubrication oil groove.



3. Insert the bushing to the position shown in the drawing on the right:
   A. Pump cover, depth 1.0 mm [0.04 in.]
   B. Pump case, depth 1.0 mm [0.04 in.] except at pos. 1 (5 mm [0.20 in.])
   C. Idler gear, depth 1.0 mm [0.04 in.]
4. After you press a new bushing into position, finish its inside diameter to $25H7^{+0.021/0}$ mm [$0.98H7^{+0.00083/0}$ in.] 0.8 R_a.

Inspect the safety valve

Check the valve spring of the oil pump safety valve for fatigue. If excessive fatigue, wear or break is found, replace the valve spring.

Safety valve opening press., MPa (kgf/cm²) [psi]

Assembly Standard ... 1.37±0.10 (14±1.0) [199±14.0]

Safety valve spring set length/set force, mm/N (in/kgf) [lbf]

Assembly Standard ... 67.2/384 (2.64/39.2) [86.4]

Measure crankshaft gear and oil pump driven gear backlash

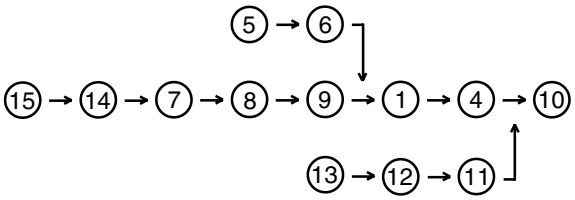
If backlash exceeds assembly standard, adjust it with shims.

Crankshaft gear – idler gear backlash, mm[in.]

Assembly Standard ... 0.11 – 0.38 [0.0043 – 0.0150]

Reassembly

Reassembly sequence:

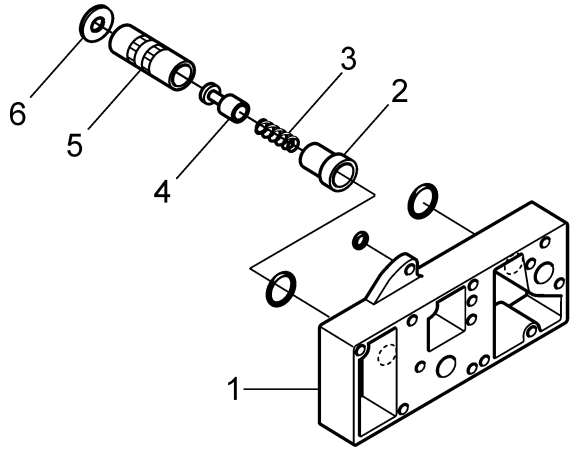


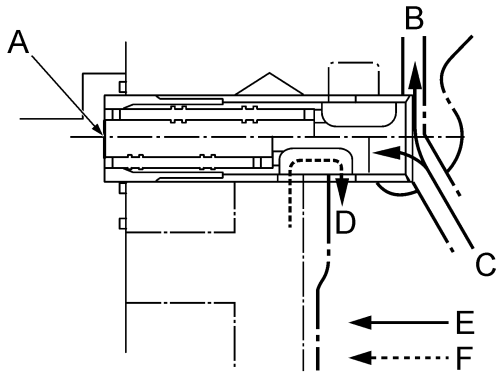
NOTE! Coat the pump parts with engine oil before installing them. Apply a thick coat of engine oil to the threads and seating faces of nuts and bolts (except flange nuts) before tightening tightening.

NOTE! Degrease idler gear nut and spindle and apply Loctite 262 to their threads before tightening them to the specified torque.

NOTE! Replace o-rings when refitting oil pipe and strainer.

Relief valve



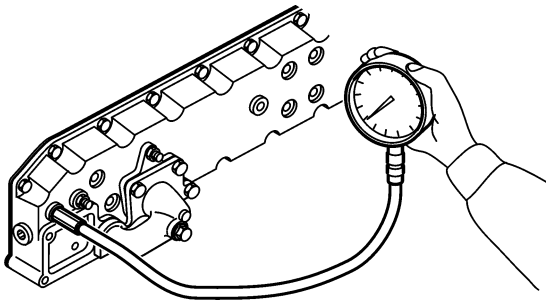


Disassembly

1. Adapter, o-ring
2. Stopper
3. Spring
4. Relief valve
5. Sleeve
6. Plate

Schematic:

A. Pressure adjusting shim
B. To turbocharger
C. From main bearing
D. Drain
E. Normal pressure
F. High pressure



Inspection

Test relief valve setting

1. Connect a pressure gauge to the oil pressure sensor send-out port (PT 1/8) on the oil cooler cover.
2. Run the engine until oil temperature rises to 70–90°C [158–194°F].
3. Measure oil pressure at idling speed and at maximum speed.
4. If the relief valve setting differs from the assembly standard, remove the oil pipe and adjust the setting by inserting shims between the adapter and the spring.

Relief valve setting (at max. rpm), MPa (Bar) [psi]

Assembly Standard ... 0.49-0.64 (4.9–6.4) [71.1–92.4]

Relief valve opening pressure, MPa (Bar) [psi]

Assembly Standard ... 0.46 (4.6) [66.86]

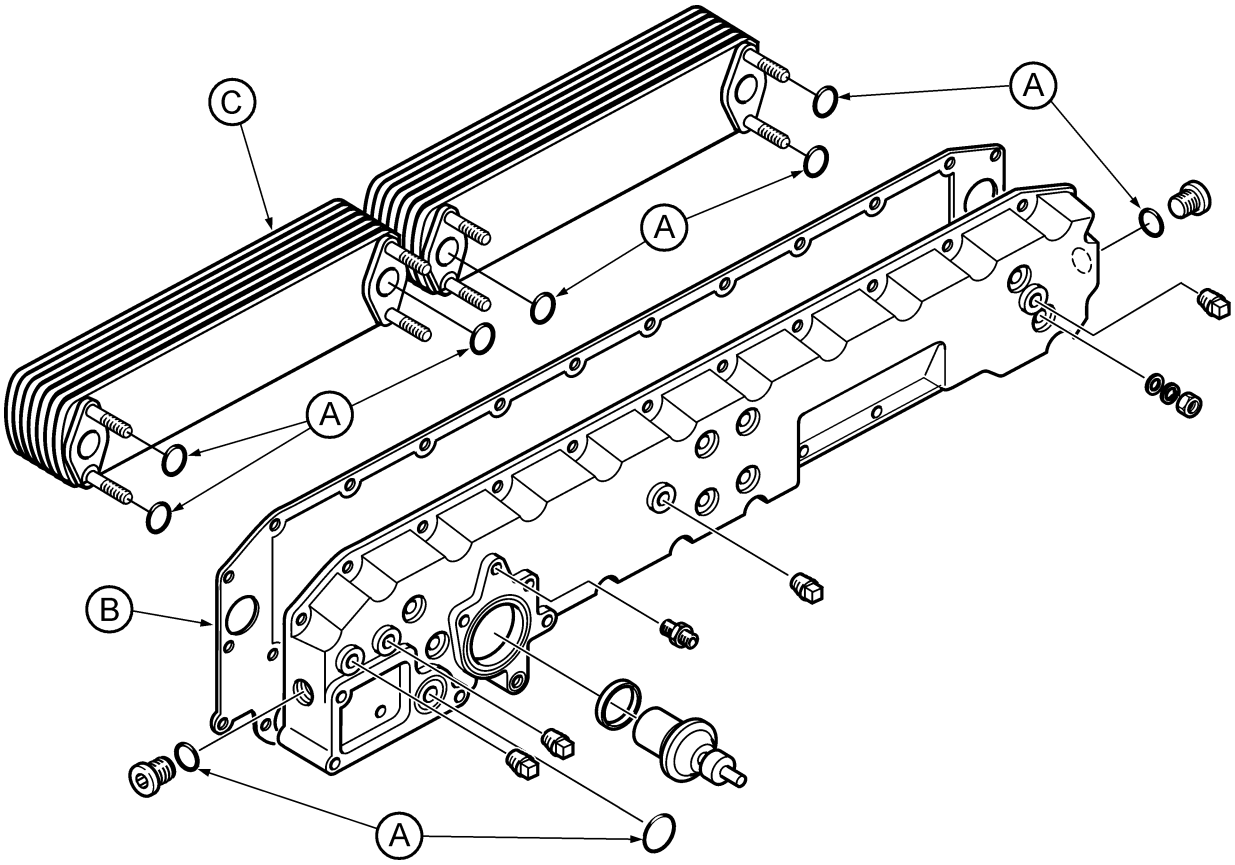
NOTE! If the setting can not be adjusted with shims, replace the relief valve and spring.

Reassembly

Reassembly is done in the reverse order of disassembly.

NOTE! Replace O-rings at reassembly.

Oil Cooler and Thermostat

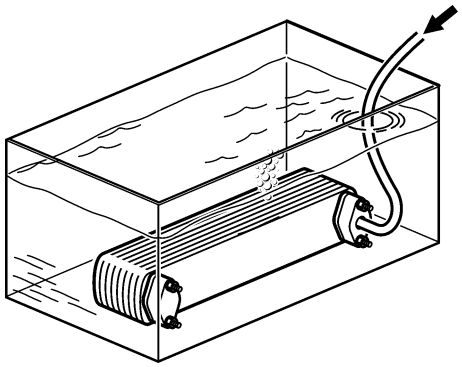


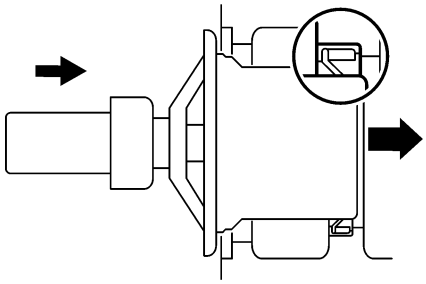
Look for:

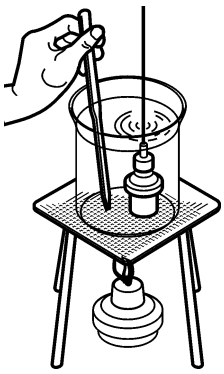
A. Clogging, rupture, cracks

B. Replace O-ring

C. Replace packing







Inspection

Inspect oil cooler

Test the oil path with compressed air of 1.47 MPa (1.47 Bar) [213 psi] for damage or cracks in the element. If there is any leakage, replace the element.

Inspect oil thermostat

1. Inspect the oil thermostat seal for deterioration and cracks. If any are found, replace the seal.
2. Refer to the drawing on the right that shows the correct direction for seal installation.
3. Operation testing

Immerse the thermostat in engine oil, then measure the temperature where the valve opens, then measure it again when the valve lift is 11 mm [0.43 in.]. Replace the thermostat if temperatures are not within standard.

Temperature for valve opening, °C [°F]

Assembly Standard ... 80–84 [176–183.2]

Temp. for 11 mm [0.43 in.] valve lift, °C [°F]

Assembly Standard ... 95 [203]

⚠ **IMPORTANT!** Stir the oil to maintain even temperatures during the test.

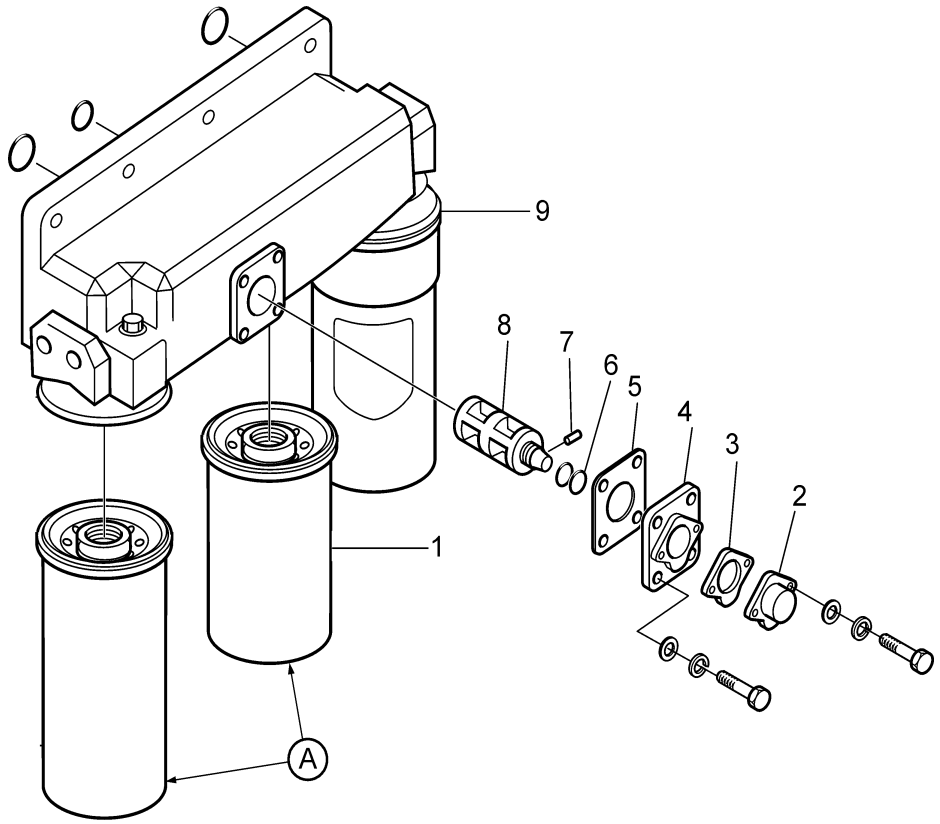
⚠ **IMPORTANT!** At reassembly, confirm the valve opening temperature stamped on its mounting flange.

Reassembly

Reassembly is the reverse procedure of disassembly.

1. Replace packing and O-rings for reassembly.
2. Before reassembly, clean the oil paths of the oil cooler cover and other parts with cleaning solvent. Use compressed air to remove dust and cleaning solvent before reassembly.

Oil Filter



Disassembly

1. Oil filter (cartridge type)
2. Cover
3. Packing
4. Cover
5. Packing
6. O-ring
7. Pin
8. Cock
9. Filter bracket

Look for:

A. Clogging, cracks

Inspection

Inspect the oil filter

When replacing filter element, sample about 500 cm^3 [30.5 in^3.] of oil and look for metal particles. If particles are found, unfold the pleats of the element and check the color and shape of the particles to identify the cause.

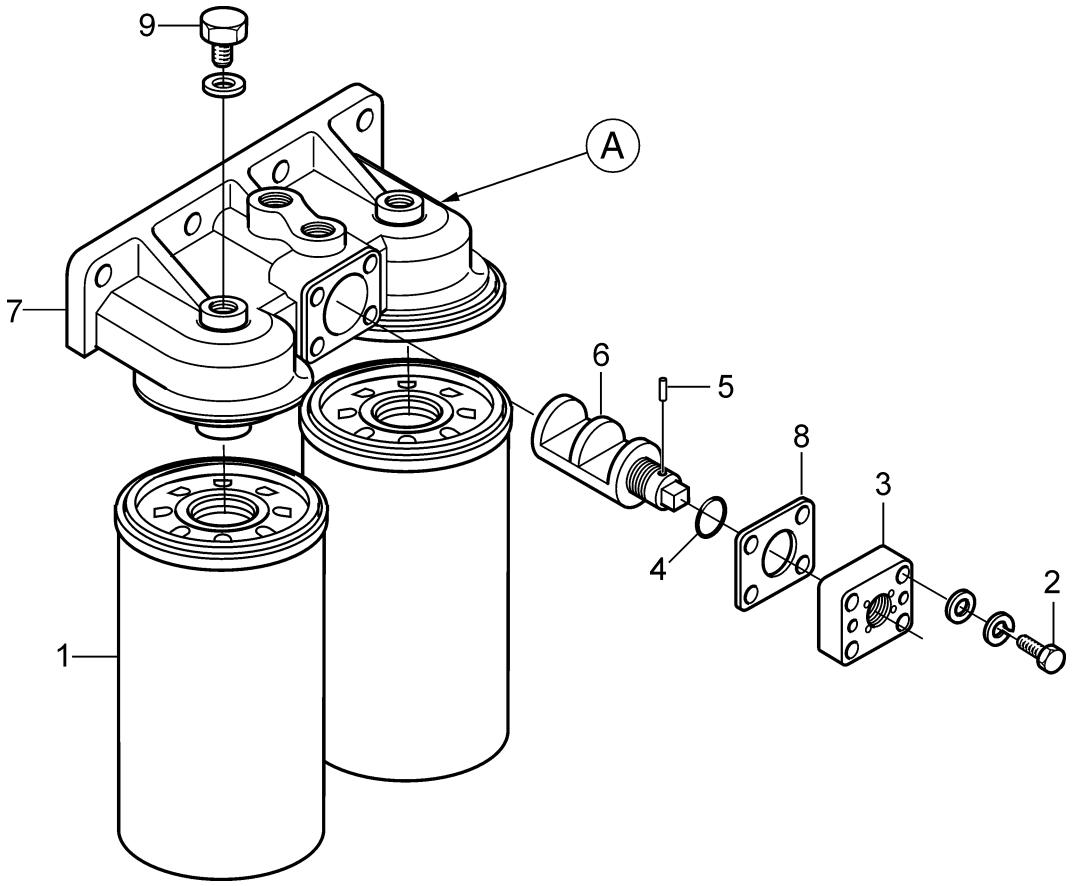
Reassembly

Reassembly is the reverse procedure of disassembly.

1. Clean oil paths of the filter bracket, etc. with cleaning solvent. Use compressed air to dry and remove dust.
2. Replace packings and O-rings.
3. Mount the oil filter element on the bracket before installation.

Group 23 Fuel System

Fuel Filters



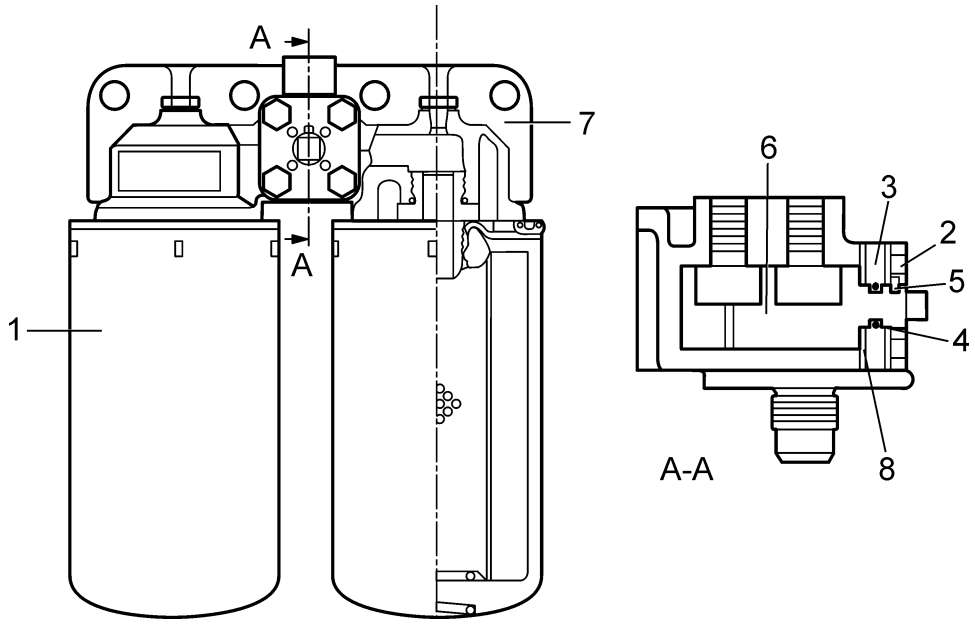
Disassembly

1. Filter element
2. Bolt
3. Cover
4. O-ring
5. Pin
6. Cock
7. Fuel filter bracket
8. Packing
9. Air vent plug

Look for

A. Cracks, damaged threads

Reassembly



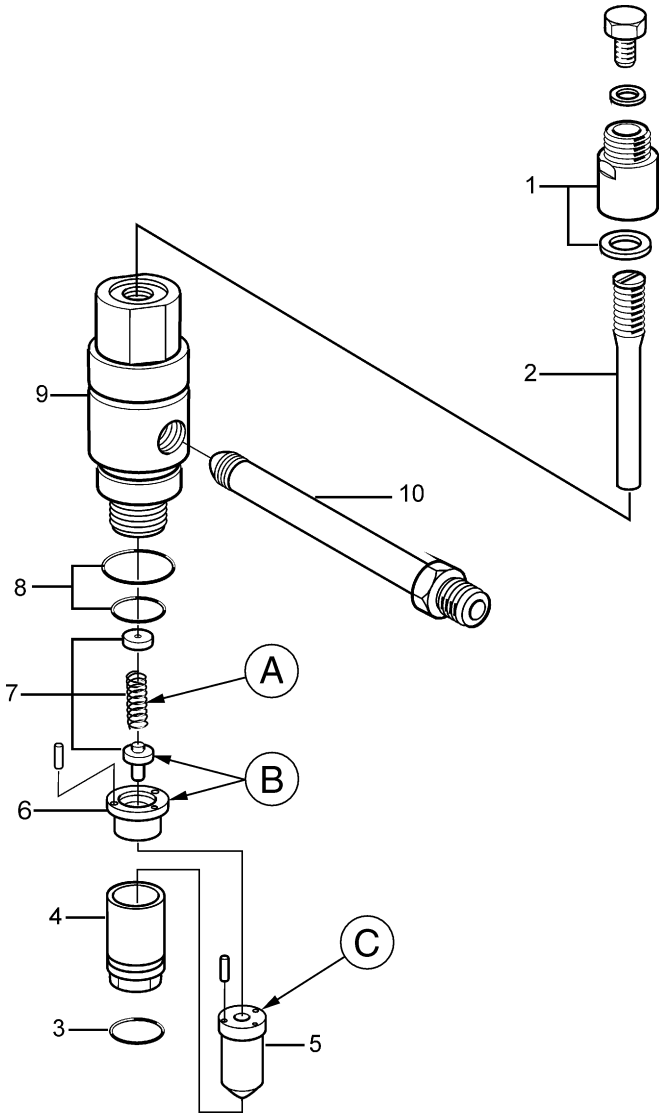
Reassembly sequence:

⑦ → ⑤ → ④ → ⑥ → ⑧ → ③ → ② → ①

To install the filter, clean the mounting surface and apply fuel oil to the gasket. After bringing the gasket into contact with the sealing surface of the bracket, tighten the filter with your hand about one-half to three quarters of a full tum. Bleed the filter.

NOTE! After installing the fuel filter on the engine start the engine and look for leaks.

Fuel Injectors



Disassembly

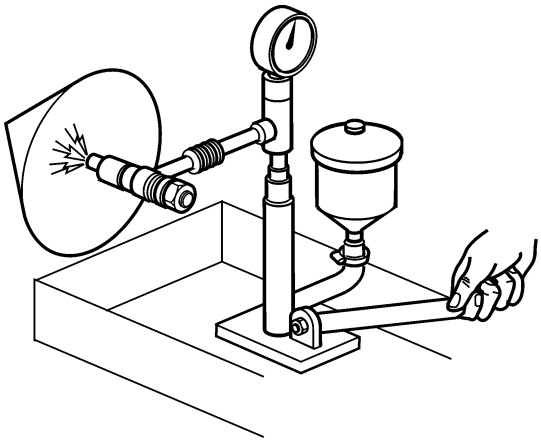
1. Cap nut, gasket
2. Adjusting screw
3. O-ring
4. Retaining nut
5. Nozzle
6. Spacer
7. Pushrod, nozzle spring, spring seat
8. O-ring
9. Nozzle holder
10. Fuel inlet connector

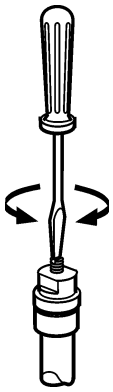
Look for

A. Fatigue, damage, length

B. Wear, damage

C. Carbon deposits, clogged spray hole, sticking needle valve





Inspection and Adjustment

Injection pressure

1. Install the nozzle on the nozzle tester. Operate the handle of the tester at a rate of about 1 stroke per setond to observe the pressure at which fuel is being injected. If the pressure is out of standard, adjust it.

Injection pressure, MPa (kgf/cm2) [psi]

Assembly Standard ... 34.32–34.81(350–355)[4979–5050]

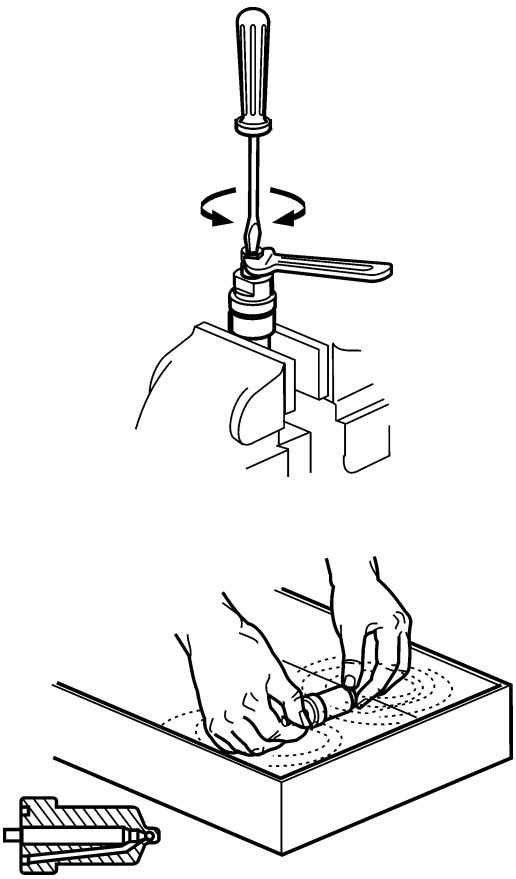
⚠ **WARNING!** Never touch the spray hole of the injection nozzle during injection testing.

2. To adjust injection pressure, remove the set screw from the nozzle holder, loosen the cap nut, and then turn the adjusting screw. To increase the injection pressure, tighten the screw. To decrease the injection pressure, loosen the screw.
3. After completing the adjustment, tighten the set screw and the cap nut to the specified torque.
4. Re-check the injection pressure to be sure that it is correct.

Spray pattem

1. When you are testing the injection pressure, inspect each nozzle for clogged or leaking holes.

   Also examine the spray pattem. If the nozzle is faulty, wash or replace it.
2. When tested on the nozzle tester, the nozzle should spray fuel from all ten holes at the same time in a straight cone of 160 degrees. The spray should tonsist of finely atomized fuel particles without large droplets. The spray should terminate without dripping at the top.



Washing or replacing the nozzle

1. The nozzle is spring loaded. Remove the set screw and loosen the adjusting screw until it can be loosened by hand.
2. Loosen the retaining nut, remove the nozzle and wash the needle valve and body.

⚠ **IMPORTANT!** When pulling out the nozzle, do not damage the tip.

3. Wash the nozzle in clean diesel fuel oil. After washing, assemble the needle valve and body in clean diesel fuel.

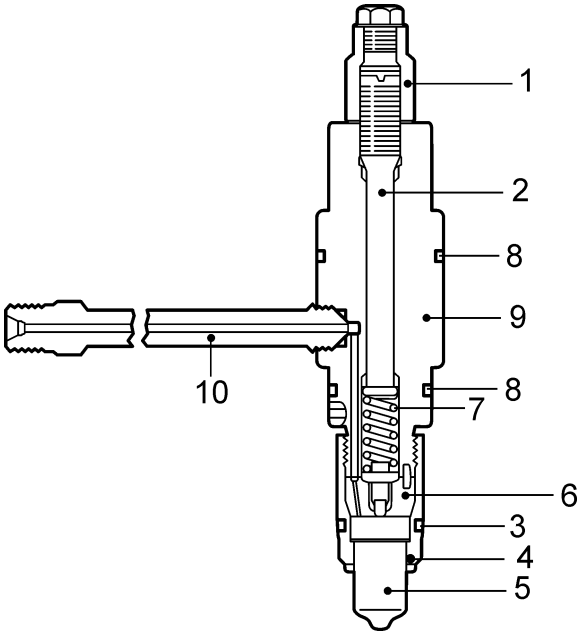
NOTE! The needle valve and body are finely finished. Do not change the pairing of needle valve and body when cleaning more than one nozzle at the time

4. Tighten the retaining nut to the specified torque.
5. If the spray pattem is still bad after the nozzle has been adjusted and cleaned, replace the nozzle.

NOTE! New nozzle tips are coated with vaseline to preserve them. Wash them in diesel fuel before you install them.

NOTE! Avoid getting “Copa slip” or “Molycote” on the needle.

Reassembly



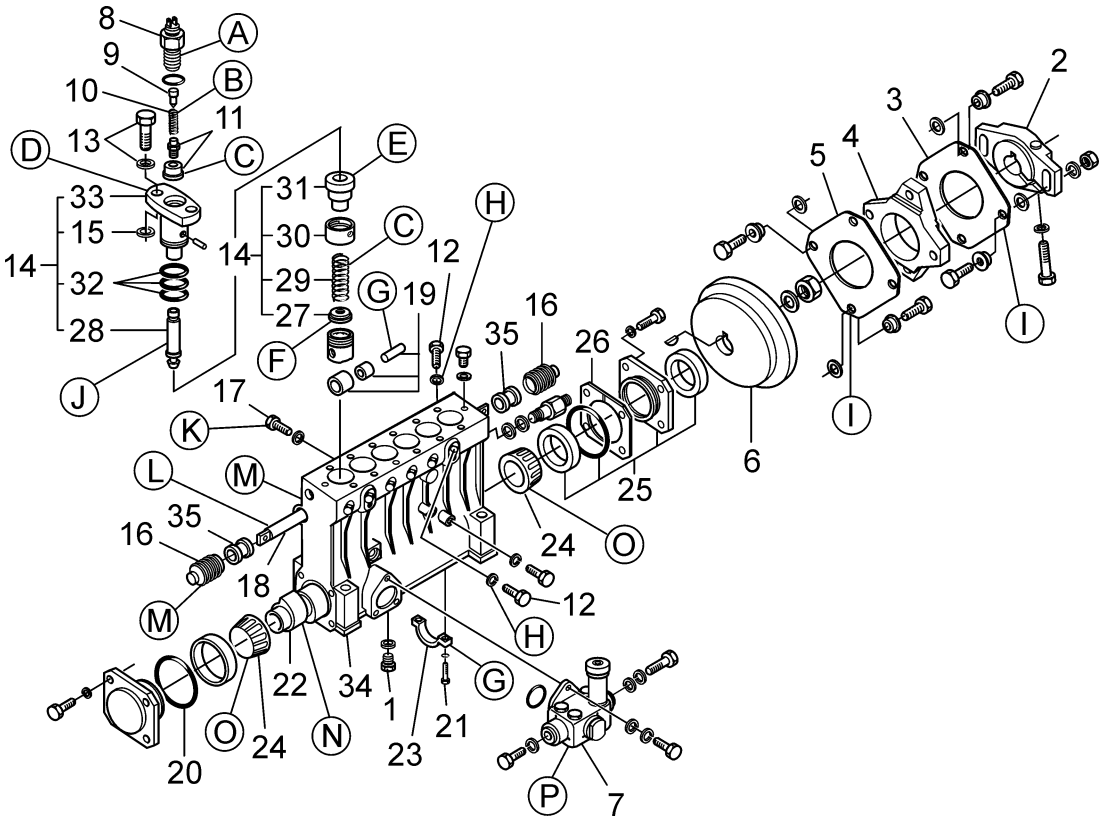
Reassembly Sequence:

⑨ → ③ → ⑧ → ⑦ → ⑥ → ⑤ → ④ → ⑩ → ② → ①

⚠ **IMPORTANT!** Tighten the retaining nut to the specified torque. Excessive torque on the retaining nut will cause sticky movement of the needle and will result in exhaust smoke or the needle stick.

NOTE! Always replace all o-rings at reassembly.

Fuel Injection Pump

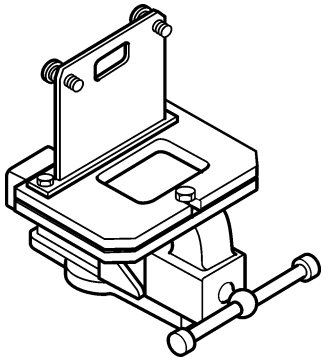


Disassembly

1. Drain plug
2. Coupling
3. Laminated plate
4. Cross coupling
5. Laminated plate
6. Flywheel
7. Feed pump
8. Valve holder
9. Spring seat
10. Delivery valve spring
11. Delivery valve assembly
12. Deflector bolt
13. Barrel bolt, washer
14. Plunger assembly
15. Barrel shim
16. Bellows
17. Set screw
18. Control rack
19. Tappet
20. Front cover, O-ring, bearing outer race
21. Bolt
22. Camshaft
23. Center bearing
24. Bearing inner race
25. Rear cover, oil seal, bearing outer race
26. Shim
27. Lower spring seat
28. Plunger
29. Plunger spring
30. Upper spring seat
31. Pinion
32. O-ring
33. Barrel
34. Pump case
35. Rack bushing

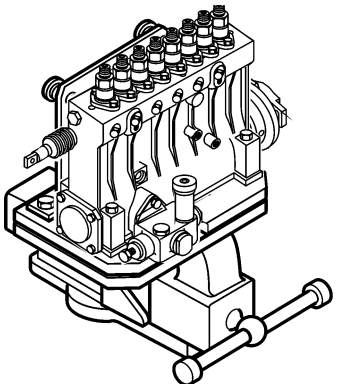
Look for:

A. Damage of threads
B. Fatigue
C. Seat contacting surface
D. Contact surface
E. Wear and cracks on teeth, worn sliding surfaces
F. Ridges caused by abrasion, cracks
G. Wear, scratches
H. Erosion
I. Damage and scratches on bushing contact surfaces, cracks
J. Wear, scratches, discoloration, corrosion, erosion
K. Wear
L. Rack sliding resistance, wear of teeth
M. Cracking
N. Damage and scratches on key grooves and seal contact surfaces, wear of cam surface
O. Rotation condition
P. Pitching, roller surface roughness

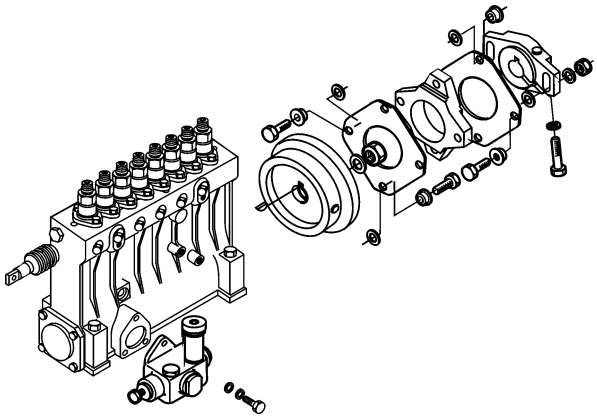


Preparing for disassembly

1. Hold the pump assembly stand with a vice.
2. Remove the drain plug from the bottom of the pump and drain oil from the case.

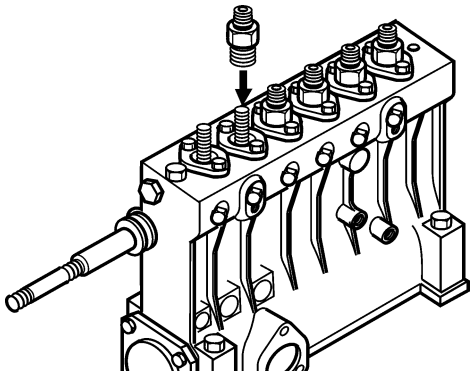


3. Clean the outer surface of the injection pump, and mount the pump on the pump assembly stand.



4. Remove the couplings, laminated plates, cross coupling, flywheel and feed pump.

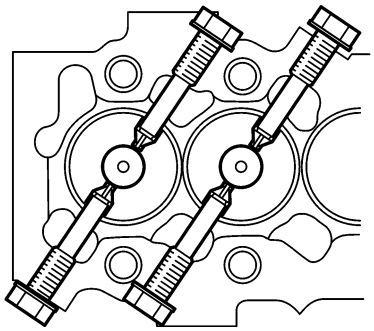
NOTE! When removing the flywheel mounting nut, insert turning bar into the turning bar hole located at the flywheel periphery, in order for the flywheel to avoid slipping.

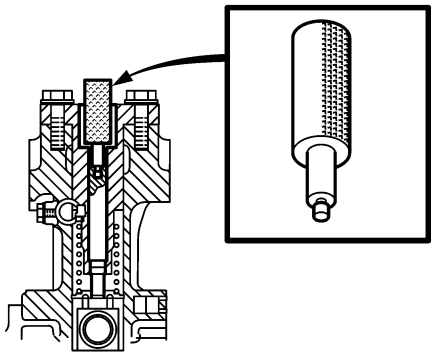


Removing delivery valves

Remove delivery valve holders. Remove the spring seat, delivery valve spring, delivery valve and valve seat from each valve holder.

NOTE! Place each pair of delivery valve and valve seat in clean diesel fuel. Do not swap the original combinations of delivery valves and valve seats.



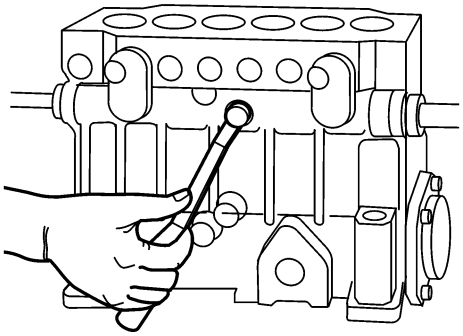


Removing plunger assemblies

1. Position the tam at the bottom dead center in the cylinder from which the plunger assembly is removed.
2. Remove the deflector bolt located on the back side of the pump case.

⚠ **IMPORTANT!** Be sure to remove the deflector before removing the plunger assembly. If the plunger assembly is removed without removing the deflector bolt first, damage results in the deflector bolt and plunger assembly.

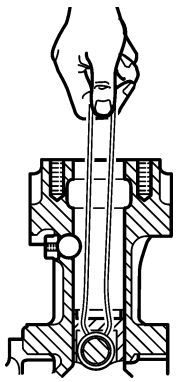
3. Screw the Plunger holder (48291-00301) in the threaded hole on the upper end of the plunger.
4. Loosen two barrel bolts altemately, and lift the plunger assembly and remove.



Removing the control rack

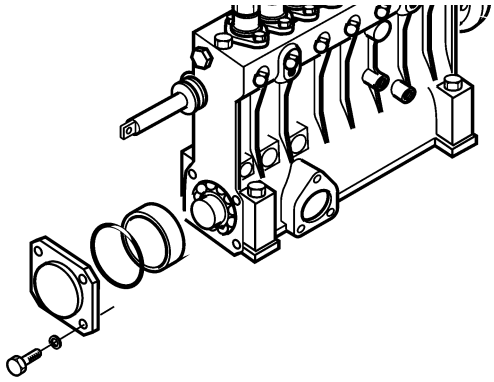
1. Dislodge the bellows from the grooves of the control rack and rack bushing installed in the pump case, and remove the bellows.
2. Remove the set screw from the back side of the pump case, and pull out the control rack.

NOTE! After removing the set screw, conduct a color check or magnaflux inspection to make sure there are no cracks.
NOTE! Do not remove the rack bushing unless necessary.



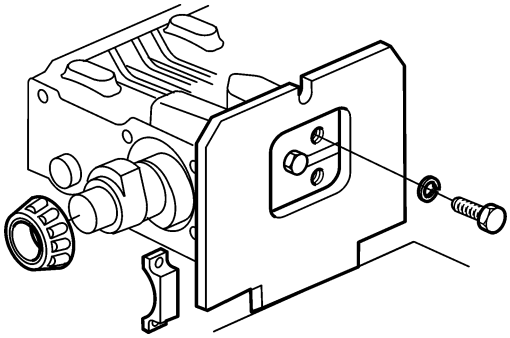
Removing tappets

Hook a wire to two small holes (4-mm (0.16 in.) dia.) on the upper side of the tappet, and pull out the tappet.

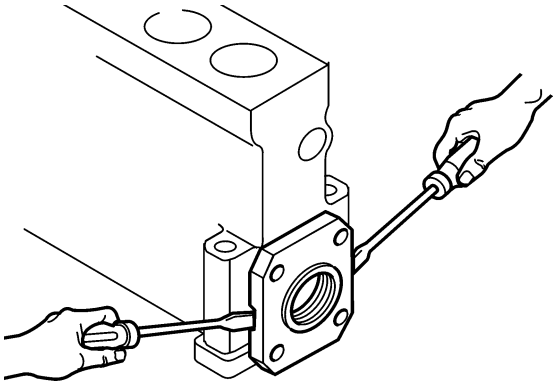


Removing the camshaft

1. Unscrew four front cover mounting bolts, and remove the front cover and bearing outer race.

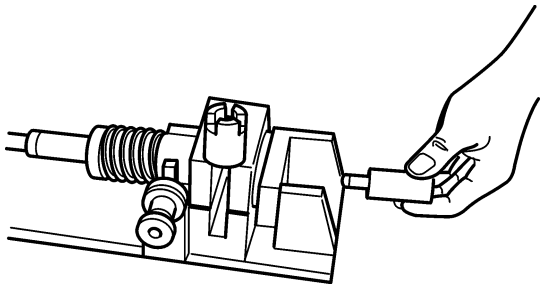


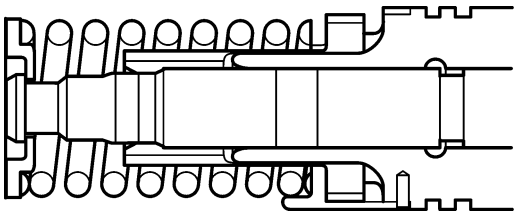
2. Tilt the pump case sideways, and remove two center bearing mounting bolts.
3. Strike the camshaft on the drive-side end with a soft hammer to remove the camshaft and center bearing.
4. Remove the bearing inner races from both ends of the camshaft.

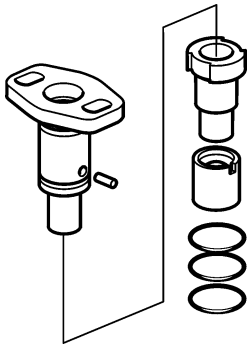


Removing the rear cover

Remove the rear cover mounting bolts. Insert the tips of screwdrivers into the notch located on the side of the rear cover, and pry out. Remove the shim.







Disassembling plunger

1. Mount the plunger assembly on the plunger spring compression jig (4829 1-00200).
2. Press the knob on the jig to tompress the plunger spring, then remove the plunger holder jig.
3. Loosen the compression of the plunger spring gradually, and remove the lower spring seat, plunger and plunger spring from the barrel.

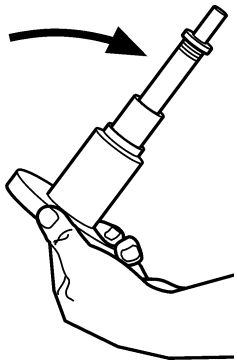
⚠ **IMPORTANT!** Handle plungers carefully to prevent damage and scratches.

⚠ **IMPORTANT!** Place the removed plungers in a tray with clean diesel fuel, do not change the original combinations of plungers and barrels.

4. Remove the barrel from the plunger spring compression jig, then remove the upper spring seat, pinion and O-ring.

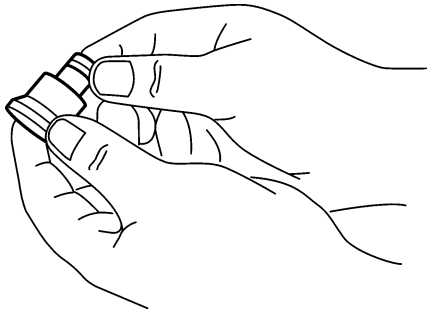
Inspection

NOTE! After disassembly, wash parts in clean diesel oil. Replace defective or damaged parts.



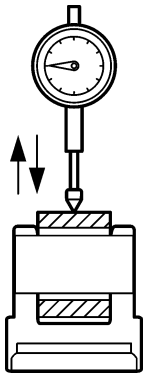
Plungers and barrels

1. Inspect the lead section and tip of each plunger for wear, scratches, discoloration, and erosion.
2. After washing with clean diesel fuel, check each plunger by tilting approximately 15’ and lifting it approximately 30 to 35 mm [1.18 to 1.38 in.], as shown in the diagram. The plunger must fall smoothly on its own weight. Change the plunger position by turning it slightly and check again. Repeat this test two or three times for each plunger.
3. If the plunger falls too quickly or sticks before it reaches the bottom, replace the plunger and barrel as a set.



Delivery valves

1. In each delivery valve, inspect the valve seat and sliding surfaces for scratches and check contacting surface to the barrel.
2. Wash parts with clean diesel oil. Lift the valve and let it fall, making sure that it slides down smoothly to the valve seat.
3. If the valve sticks, replace the delivery valve and valve seat as a set.

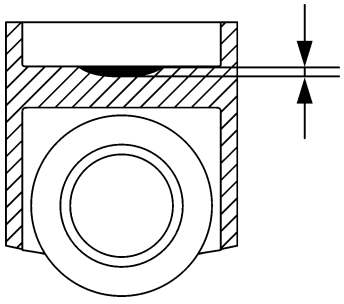


Tappets

1. Check each tappet roller, roller bearing and tappet pin for flaking, lotal wear and scratches.
2. Check overall clearance of tappet, taper roller, roller bearing and tappet pin. If the measurement exceeds the service limit, replace with a new assembly.

Overall clearance of tappet roller, mm [in.]

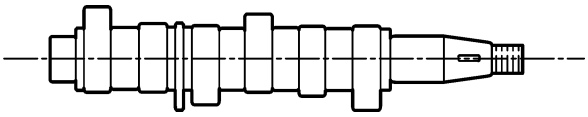
Service Limit ..... 0.2 [0.00787]

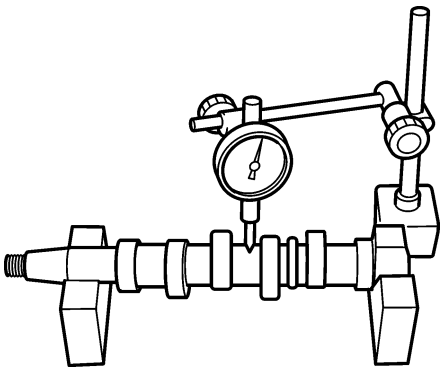


3. Inspect the plunger contact surface of each tappet. If the amount of wear exceeds the service limit, replace with a new assembly.

Tappet wear of plunger contact area, mm [in.]

Service Limit ..... 0.2 [0.00787]





Camshaft

1. Check the key and key groove for excessive play. Also check the tapered section for scratches, and the tam surfaces for flaking, local wear and scratches. If damage is found, replace the camshaft.
2. Check the oil seal contacting surface for wear. If the amount of wear exceeds the service limit, replace with a new part.

Camshaft diam. at oil seal contact area, mm [in.]

Assembly Standard ...	34.938–34.963 [1.37551–1.37649]
Service Limit	34.800 [1.37001]

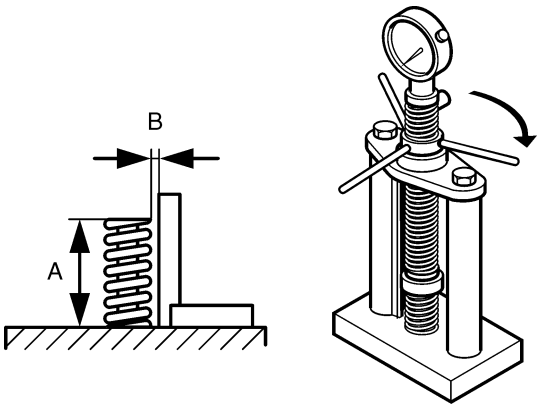
3. Support the camshaft with V blocks, and measure runout at the center bearing section using a dial gauge. If the amount of runout exceeds the repair limit, correct with a press or replace with a new part.

Camshaft deflection, mm [in.]

Assembly Standard ...	0.05 [0.00197]
Repair Limit	0.15 [0.00591]

Bearing

Check the bearing for flaking, abnormal abrasion and noise. If damage is found, replace with a new part.



Plunger and delivery valve springs

1. Check the surface of each spring for scratches and rust.
2. Using a square, measure the perpendicularity (gap, B) at the upper end of the spring.
   If the measurement exceeds the service limit, replace the spring.

Plunger Spring, mm [in.]

Free length (A)

Assembly Standard ... 70.8 [2.787]

Perpendicularity (B)

Service Limit ..... 1.8 [0.071]

Length under test force, mm [in.]

Assembly standard ... 60.0 [2.36]

Test force, N (kgf) [lbf]

Assembly standard ... 299–366 (30.5–37.3) [67.2–82.2]

Delivery valve spring, mm [in.]

Free length (A)

Assembly Standard ... 18 [0.71]

Perpendicularity (B)

Service Limit ..... 0.6 [0.024]

Length under test force, mm [in.]

Assembly standard ... 14.15 [0.56]

Test force, N (kgf) [lbf]

Assembly standard ... 51.6-61.4 (5.26–6.26) [11.60–13.80]

Valve holders

1. Check the contacting surfaces of injection pipe and delivery valve on each valve holder for scratches.
2. If the contact surfaces are scratched, replace the valve holder since surface scratches can cause fuel leakage.

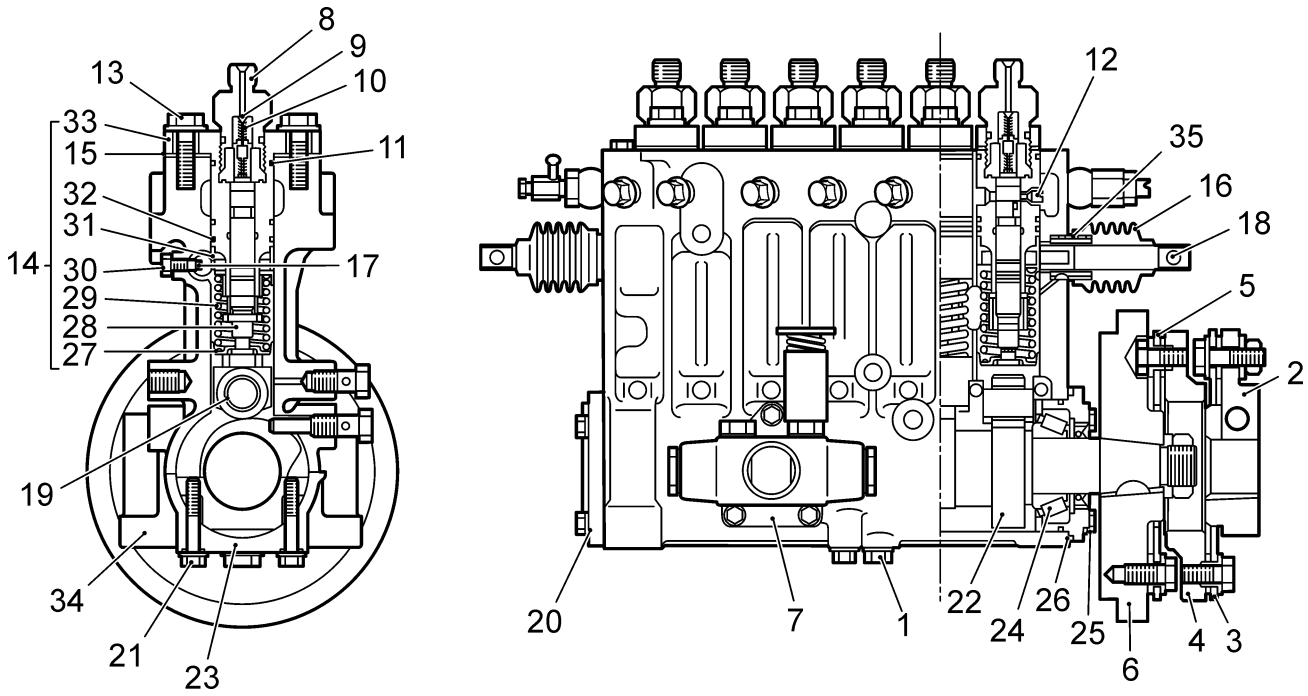
Pump case

Check the pump case for surface scratches, dents, cracks and damage. If critical flaws are found, replace with a new part.

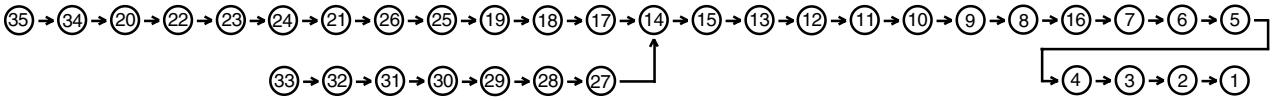
O-rings and bellow

Replace O-rings, gaskets and below with new ones once disturbed.

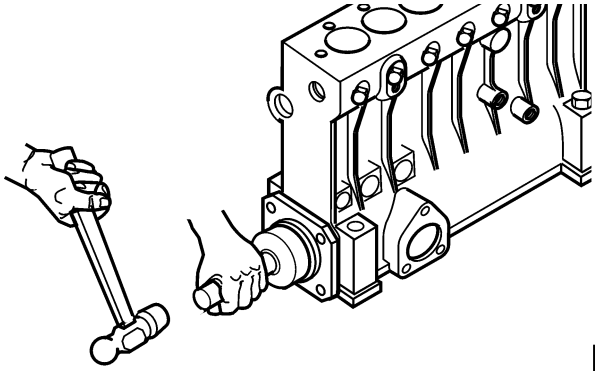
Reassembly



Reassembly sequence:

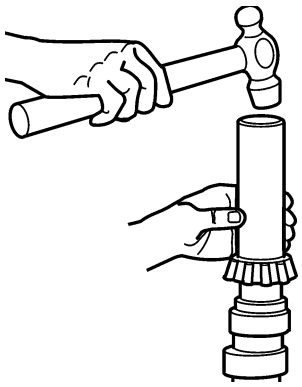


NOTE! The reassembly of the jam nut (4) and subsequent steps should be performed after the parts are mounted on the engine and adjusted properly.



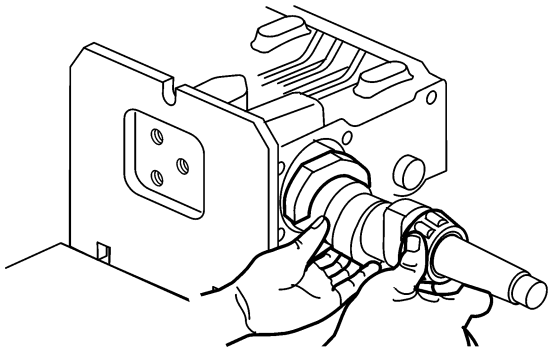
Assembling the bearing and front cover

1. Install the O-ring and bearing outer race on the front cover.
2. Install the front cover on the pump case by striking with a hammer.
3. Tighten the front cover mounting bolts.

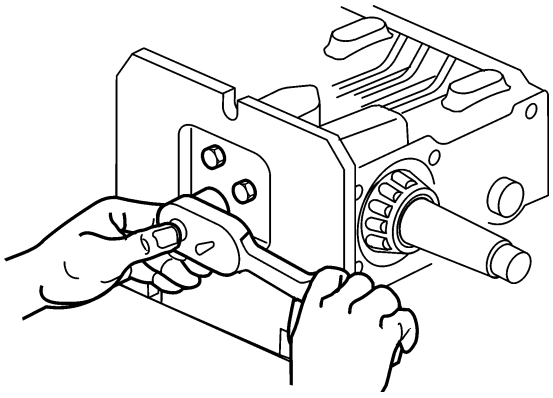


Assembling the camshaft center bearing

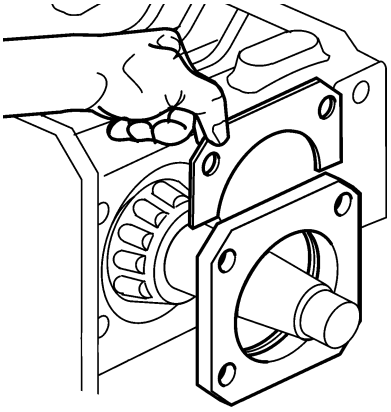
1. Install the bearing inner race on the camshaft by striking with a hammer.



2. Lay the pump case on its side.
3. Place the center bearing on the camshaft, and insert the shaft into the pump case.

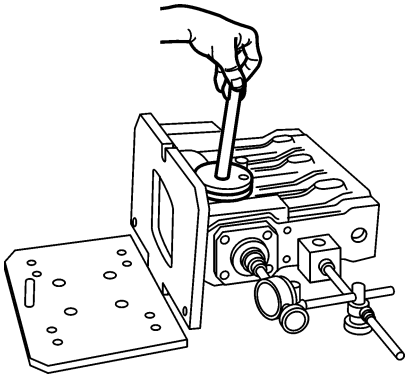


4. Slowly rotate the camshaft and align the bolt hole in the center bearing with the bolt hole in the pump case, then tighten the mounting bolt.



Assembling the rear cover

1. Install the bearing outer race on the rear cover.
2. Install the O-ring and shim on the rear cover, and install the rear cover on the pump case.



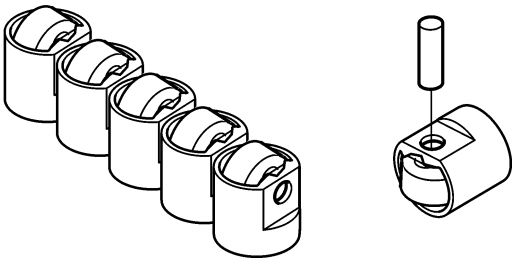
Camshaft thrust clearance

1. Set a dial gauge on the end surface of the camshaft, and measure end play using the Cam thrust ejector.

Camshaft thrust end play, mm [in.]

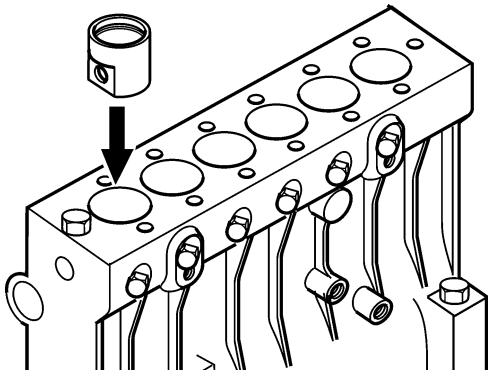
Assembly Standard ... 0.02–0.06 [0.00079–0.00236]

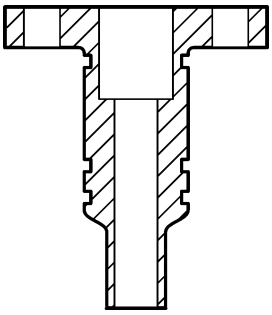
2. If the measured clearance deviates from the assembly standard, increase or decrease the shim thickness to make adjustment.
3. Tum the camshaft to make sure if it rotates smoothly.



Installing tappets

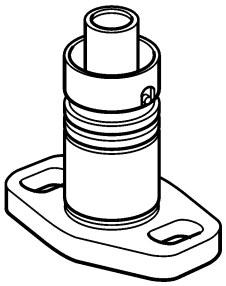
1. Install the tappet roller and roller bearing in each tappet, and insert the tappet pin in each assembly.
2. Apply lubricating oil to each part.
3. After the assembly, make sure the roller rotates smoothly without sticking.
4. Install tappets in the pump case by positioning each tappet so the falt faces of the tappet engages securely with the stopper pin.



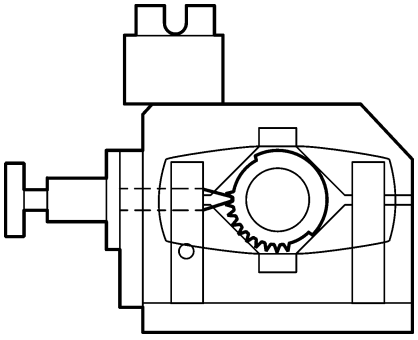


Assembling plunger assemblies

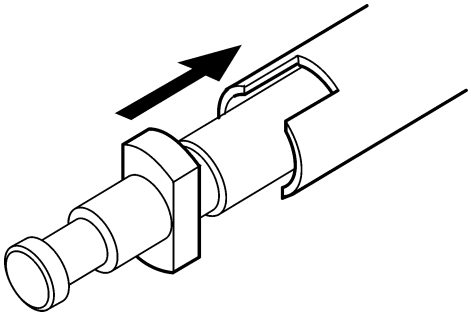
NOTE! Wash each part with clean diesel fuel before assembly. Use new O-rings and apply grease to the O-rings to prevent damage during assembly. Install the O-rings in the sequence of **A**, **B** and **C**.



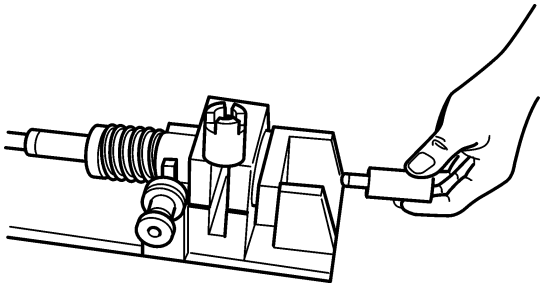
1. Install three O-rings on each barrel.
2. Install the pinion and upper spring seat on each barrel by tapping with a hammer. Make sure the pin inserted in the barrel is positioned at the notch of the upper spring seat.



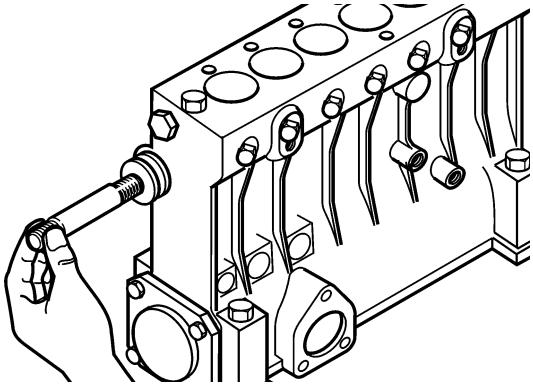
3. Set the assembly of the barrel, pinion, upper spring seat on the plunger spring compression jig. Insert the jig stopper in the pinion tooth section (missing tooth section). This stopper positions the missing tooth section (for prevention of incorrect engagement with rack) of the pinion to the center of the inspection hole in the upper spring seat.



4. Align the flange section of the plunger properly with the plunger seating section of the pinion using a screwdriver.

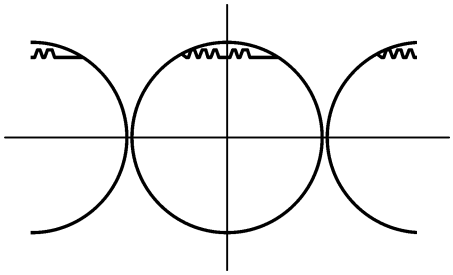


5. Press down the knob of the jig to insert the plunger into the plunger seating section of the pinion, then screw the plunger holder to the threaded section of the plunger head.

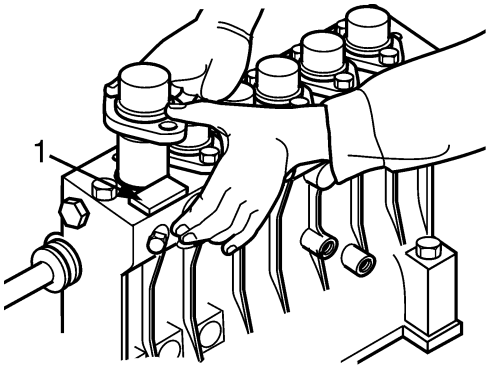


Installing the control rack

1. Insert the control rack in the pump case, making sure the “F” mark on the end surface or the threaded section is positioned on the driven side, then tighten the set screw to 21 Nom (2.1 kgf-m) [15 lbf-ft].



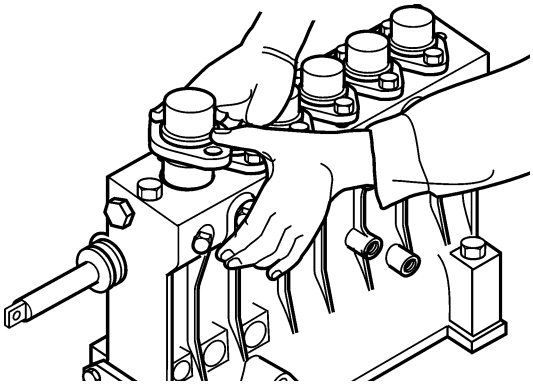
2. Look through the cylinder from the upper side of the pump case, and move the control rack so the thick tooth (three times thicker than other teeth for prevention of incorrect engagement with pinion) is positioned at the center of the cylinder in the pump case.



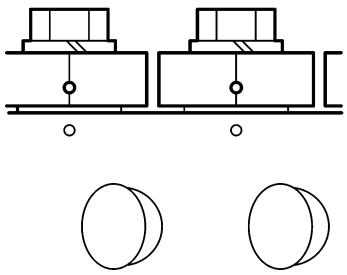
Installing plunger assemblies

1. Position the cam at the bottom dead center in the cylinder to which the plunger assembly is installed.
2. Place the Stopper plate (1) on top of the pump case to prevent damage to the pinion and control rack during the installation of the plunger assembly.

NOTE! If the stopper plate is not used during plunger assembly installation, the teeth on the pinion hit the teeth on the rack, causing rough edges that hinder smooth rack movement.



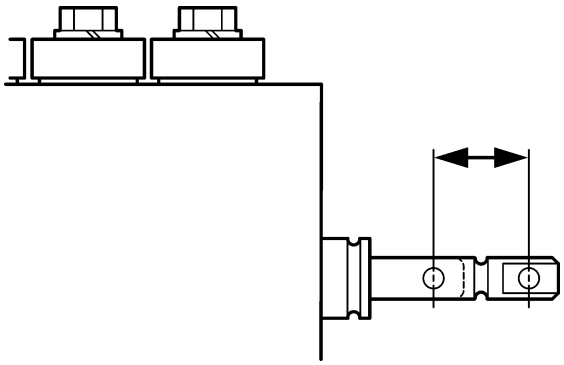
3. Hold the flange of the barrel with both hands and press down the plunger assembly until the bottom side of the flange contacts the stopper plate.
4. Remove the stopper plate, and lower the plunger assembly by serching the correct meshing slowly. Do not apply excessive forte to press down the plunger assembly. If the plunger assembly is jammed, turn the flange by jiggling back and forth, then press down.



5. Insert standard barrel shims (thickness: 1.0 mm [0.04 in.]) under each barrel flange, and align the reference mark on the barrel flange with the alignment mark (1.5-mm [0.06 in.]diameter hole) on the pump case.

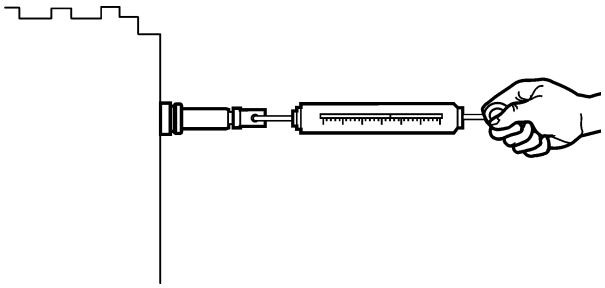
⚠ **IMPORTANT!** In each cylinder, insert barrel shims of the same thickness, one in front and one in back. (Do not use two or more shims at one location.) If the shim thickness varies in the front and back of a cylinder, the rack may not move smoothly, causing hunting or other problems.

6. Install washers on the barrel bolts, and screw the bolts snug. Then, using a torque wrench, tighten the bolts progressively and evenly to 78 to 83 N*m (8.0 to 8.5 kgf m) [58 to 61 lbf ft].



7. Remove the Plunger holder. Make sure the control rack slides and strokes smoothly.

⚠ **IMPORTANT!** Move the rack after installing each plunger assembly to make sure it moves smoothly (sliding resistance: 4.9 N (0.5 kgf) [1.10 lbfJ or less). At the same time, check to make sure the total rack stroke is 36 mm [1.42 in.].



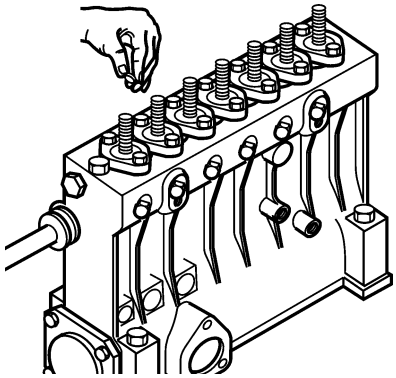
Control rack sliding resistance

1. After the pump assembly is completed, attach a spring balancer to the control rack and make sure the control rack moves smoothly over the entire stroke.

Control rack sliding resistance, N (kgf) [lbf]

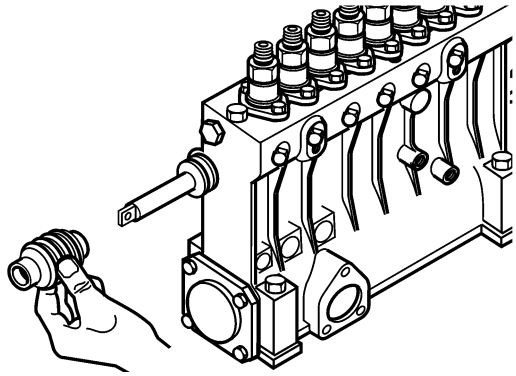
Assembly Standard ... 4.9 (0.5) [1.10] or less

2. After making sure the rack sliding resistance is lower than the standard value, install the deflector bolts on the pump case to 41 N*m (4.2 kgfem) [30 lbf.ft].



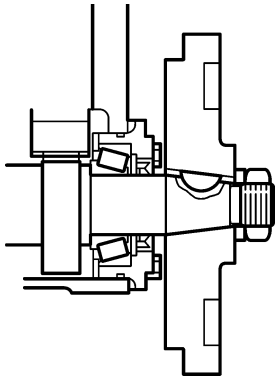
Assembling delivery valves

1. In each barrel, install delivery valve, valve spring, spring seat and valve holder in that order.
2. Apply grease to a new O-ring to prevent 0; ring from damage, then install the O-ring on each valve holder.
3. Using a torque wrench, tighten the valve holders to 235 to 255 N*m (24 to 26 kgfam) [174 to 188 lbfaft].



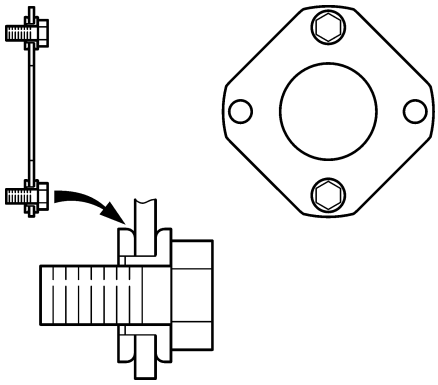
Installing the bellows

Insert the protrusions on the bellows into the grooves on the control rack and rack bushing and install the bellows.



Installing the flywheel

Install the flywheel, making sure it aligns with the woodruff key of the camshaft, then tighten the jam nut to 329 N*m (40 kgf-m) [289 lbf&].

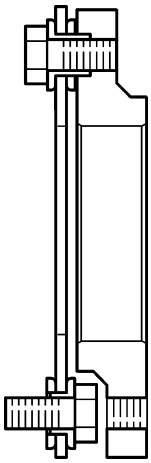


Installing the coupling assembly

1. Install sets of short bushings, short bolts and coupling washers in two diagonally located holes in the laminated plate.

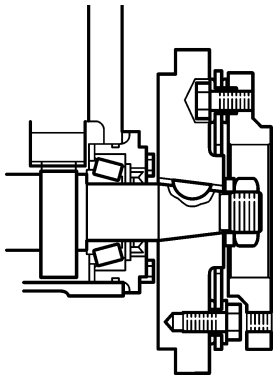
⚠ **WARNING!** If the coupling washer is installed in the wrong direction, the laminated plate can break. When the laminated plate breaks, bolt damage occurs and can result in a serious accident.

NOTE! Set the side of the coupling washer with a radiused outer edge on the laminated plate.



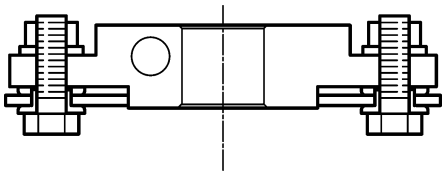
2. While making sure that the short bolts and coupling washers installed on the laminated plate remain in place, install the laminated plate to the cross coupling by screwing short bolts with long bushings and coupling washers in the remaining two holes in the laminated plate from the opposite side. Tighten the short bolts to 103 to 113 N-m (10.5 to 11.7 kgf-m) [76 to 83 lbf-ft].

NOTE! Use a spanner-type torque wrench to tighten the short bolts.

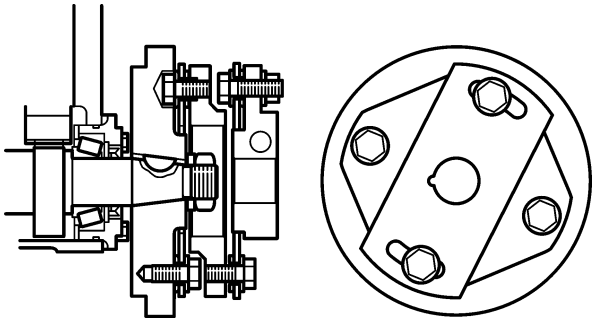


3. Tighten the two remaining short bolts on the laminated plate mounted with the cross coupling to install the laminated plate securely to the flywheel. Tighten the bolts to 103 to 113 N-m (10.5 to 11.5 kgf-m) [76 to 83 lbf-ft].

NOTE! When tightening the short bolts be sure not to drop the coupling washers.

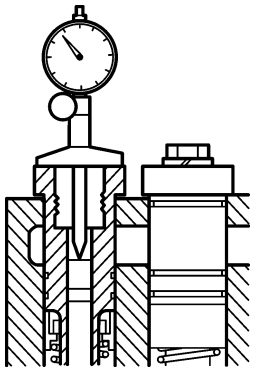


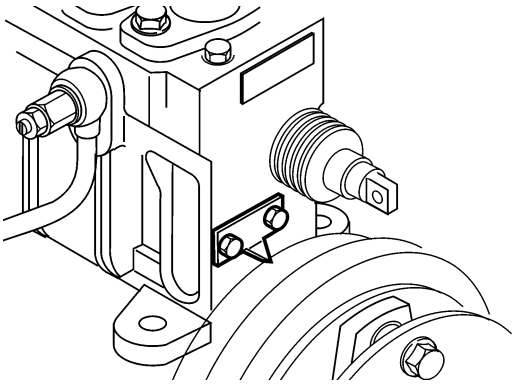
4. Install short bushings, long bolts and coupling washers to two diagonally located holes in the other laminated plate.
5. Install the laminated plate to the coupling on the drive side using the wide coupling washers. Tighten the flange nuts to 103 to 113 Nrn (10.5 to 11.5 kgf-m) [76 to 83 lbf ft].

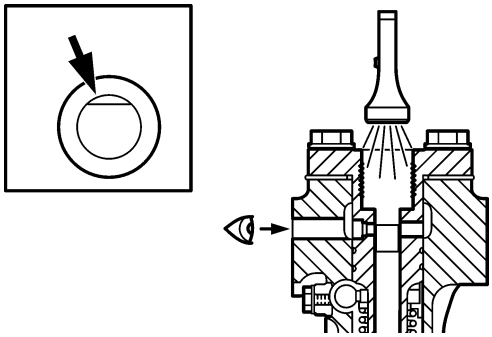


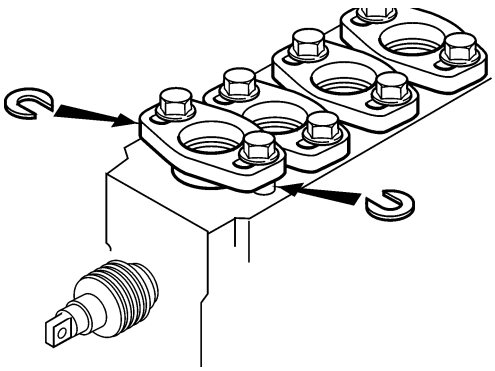
6. Install sets of long bushings and coupling washers to the laminated plate, and install the laminated plate to the cross coupling with short bolts. Tighten the short bolts to 103 to 113 N-m (10.5 to 11.5 kgf-m) [76 to 83 lbf ft].

NOTE! Make sure the coupling on the drive side is positioned so that the key groove of the drive coupling faces the black line on the flywheel, as shown in the diagram.









Adjustment of Injection Timing

Adjustment of the prestroke

After the pump assembly is completed, place it on an injection pump tester, and make the following adjustments.

1. Remove the deflector bolt from the back side of the pump case.
2. Remove the valve holder from cylinder No. 1 (counter-drive side), then remove the spring seat, valve spring and delivery valve.
3. Set the measuring tip of a dial depth gaugeon the head of the plunger. Rotate the camshaft by hand to bring the plunger to the bottom dead center by reading the indication on the depth gauge. Set the depth gauge indicator to “0”.
4. Tum the camshaft in the normal operating direction until the dial depth gauge indicates 5 mm [0.2 in.].
5. With the camshaft in this position, check to make sure the pointer located on the pump case end surface aligns with the stamped line on the flywheel. If they are not aligned, stamp a new line on the flywheel at the pointer position.
6. Point a flashlight from the top of the pump case, and look through the deflector bolt hole and check the position of the upper end of the plunger.
7. Rotate the camshaft until the upper end of the plunger closes the barrel suction hole. With the camshaft in this position, the pointer should align with the stamped line on the flywheel. If not, change the shims so the pointer aligns with the line.

NOTE! Increase of shim thickness retards injection timing and decrease of shim thickness advances injection timing.

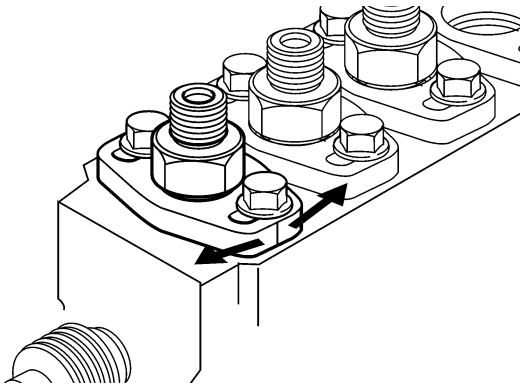
⚠ **IMPORTANT!** Never use more than one shim on each side. Use shims of the same thickness on both sides of the cylinder.

Adjustment of injection intervals

1. For cylinder No. 2 and subsequent cylinders, use the injection start timing of cylinder No. 1 as the reference point and check the injection start intervals on the angle scale on the pump tester according to the injection sequence.
2. If the injection intervals deviate from the specification, make adjustment by adjusting the thickness of the barrel shims in the same way for prestroke adjustment.

NOTE! Injection start intervals 45°±0.5°

Adjustment of Injection Volume



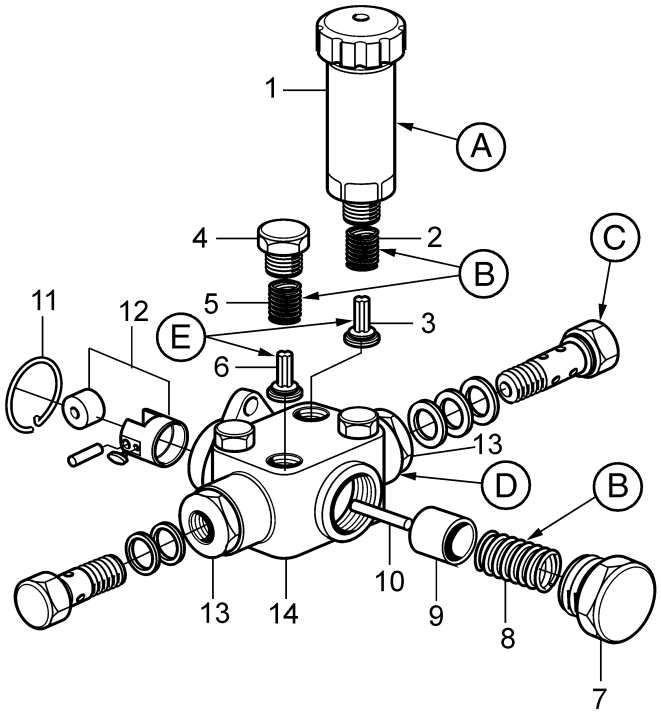
1. Install a fuel hose and the specified fuel pipe to the fuel injection pipe.

Adjustment conditions.

Nozzle holes Ø(10)	0.31 mm [0.012 in.]
Nozz. opening press. .	34.32 MPa (350 kgf/cm^2) [4979 psi]
Feed pressure	
MPa(kgf/cm^2)[psi]	0.3±0.05 (3±0.5) [42.7±7.1]
Fuel pipe dimensions	
out Ø x in Ø x L	(7x2.8x817 mm) [0.28x0.11x32.2 in.]
Test fuel	JIS Class 2 diesel fuel
Test fuel temp.	40±10°C [104±18°F]

3. To adjust the injection volume, loosen barrel bolts and slowly turn the barrel.
4. After adjustment, tighten the barrel bolts alternately to 78 to 83 N•m (8 to 8.5 kgf•m) [58 to 61 lbf•ft] torque.

Feed Pump



Disassembly

1. Priming pump
2. Spring
3. Valve
4. Plug
5. Spring
6. Valve
7. Plug
8. Spring
9. Piston
10. Puch rod
11. Snap ring
12. Tappet
13. Adapter
14. Pump housing

Look for

A. Scuffing, rust on piston and cylinder

B. Fatigue

C. Dust particles Gauze filter: Wash with diesel fuel

D. Cracks, damage of threads

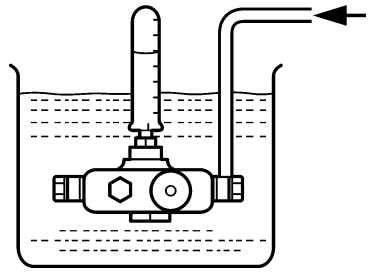
E. Wear of seat

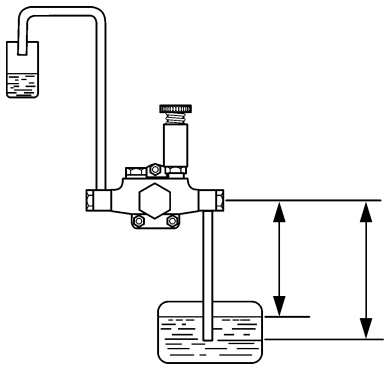
⚠ **IMPORTANT!** Do not disassemble the gauge filter if it is clogged, the filter may become twisted and damaged. Remove as much dust as possible through the small holes, then disassemble the gauge filter with a screwfriver.

Reassembly

Reassembly Sequence:

⑭ → ⑬ → ⑫ → ⑪ → ⑩ → ⑨ → ⑧ → ⑦ → ⑥ → ⑤ → ④ → ③ → ② → ①





Testing

Airtightness test

Plug the discharge port. Apply air pressure of 0.2 MPa (2 kgf/cm^2) [28.4 psi] to the suction port, immerse the pump in diesel fuel, and check for air leakage (bubbles).

Feed pump test

Testing conditions

Fuel pipe, mm [in.]

Outside diameter ..... 15 mm [0.59 in.]
Inside diameter ..... 13 mm [0.51 in.]
Length ..... 2000 mm [78.7 in.]

Cam, mm [in.]

Lift per revolution ..... 12 mm [0.47 in]

Run the pump under the above conditions, and measure the discharge start time.

Feed pump discharge start at 100 rpm, sec

Assembly Standard ... 20 sec or less

Priming pump suction capacity

Discharge fuel completely from the feed pump in the testing conditions described in the feed pump test. Then, operate the priming pump at a rate of 60 to 100 strokes per minute, and count the number of pumping operations required for fuel to reach the pump.

Priming pump discharge start, strokes

Assembly Standard ... 30 or less

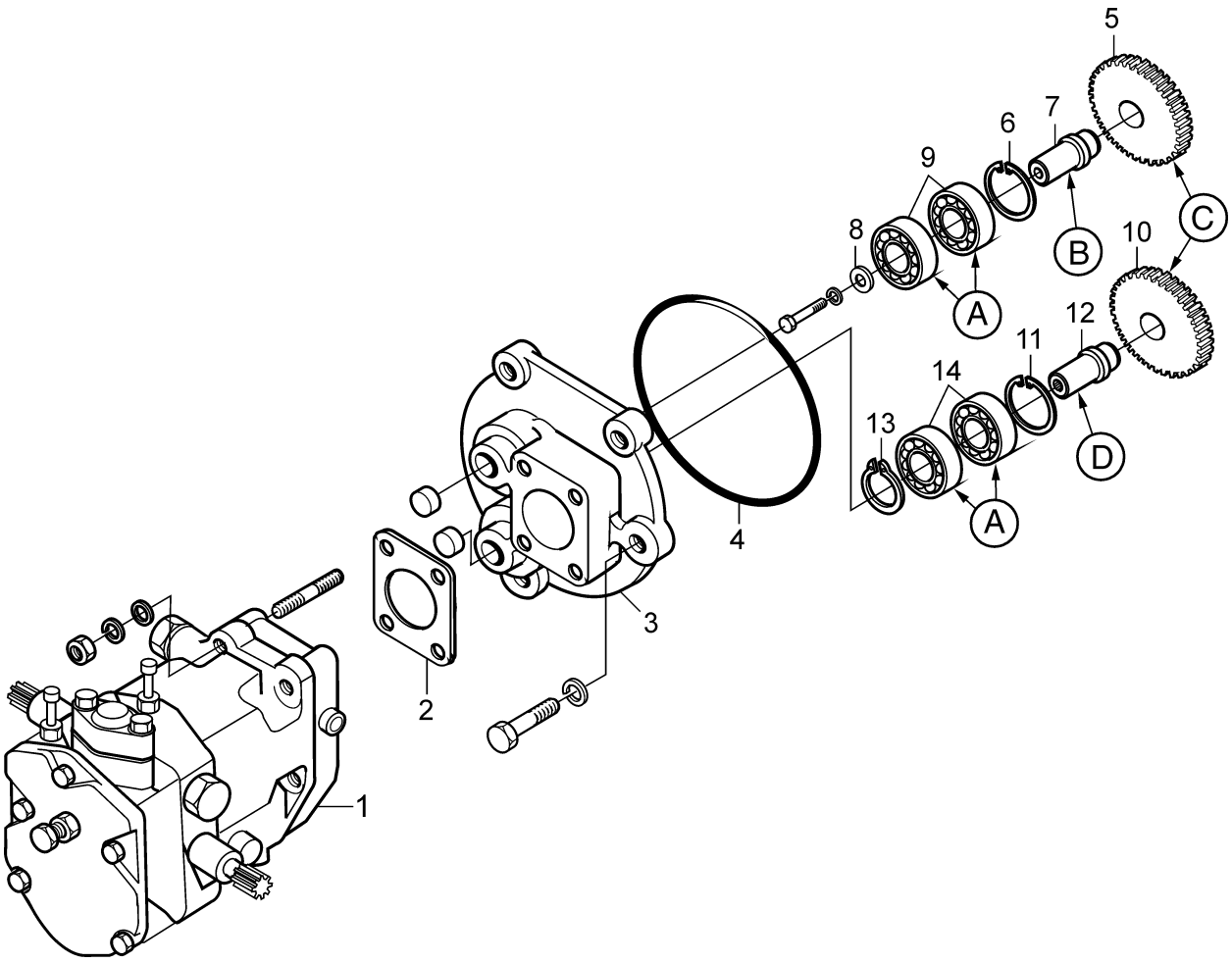
Feed rate test

Open the valve on the discharge side in the testing conditions described in the feed pump test. Operate the pump and measure the amount of oil fed during the first 15 seconds.

Feed rate at 500 rpm, cm^3 [cu.in.]/15 sec.

Assembly Standard ... 1100 [67.1] or more

PSG Woodward Governor and Drive



Disassembly

1. PSG governor
2. Packing
3. Drive case
4. O-ring
5. Idler gear
6. Snap ring
7. Idler shaft
8. Washer, bolt
9. Bearings
10. Drive gear
11. Snap ring
12. Drive shaft
13. Snap ring
14. Bearings

Look for

A. Rotation
B. Wear
C. Wear of teeth
D. Wear of spline

Inspection

Inspection of bearings

Rotate each bearing to check for rotation. Replace a bearing which fails to rotate smoothly. Check the fit of the bearings on the drive shaft and idler shaft. Replace the shaft or bearings whichever are badly worn. Check the fit of bearings in the drive case and replace a worn part.

Case bore diam., drive shaft-side, mm [in.]

Nominal Value ..... 52 [2.05]
Assembly Standard ... 51.988–52.018 [2.04677–2.04795]

Drive shaft side bearing, mm [in.]

Outside diameter
Nominal Value ..... 52 [2.05]
Assembly Standard ... 51.987–52.000 [2.04673–2.04742]
Inside diameter
Nominal Value ..... 25 [0.98]
Assembly Standard ... 24.990–25.000 [0.98386–0.98425]

Drive shaft diam., mm [in.]

Nominal Value ..... 25 [0.98]
Assembly Standard ... 25.002–25.011 [0.98433–0.98468]

Case bore diam., idler shaft side, mm [in.]

Nominal Value ..... 47 [1.85]
Assembly Standard ... 46.989 to 47.014 [1.84996 to 1.85094]

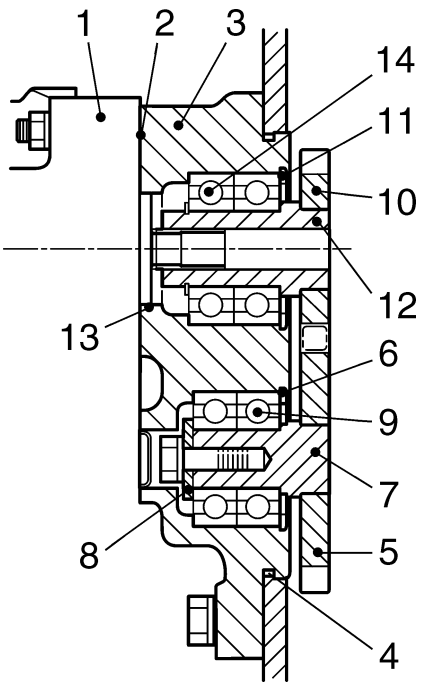
Idler shaft side bearing diameter, mm [in.]

Outside diameter
Nominal Value ..... 47 [1.85]
Assembly Standard ... 46.988–47.000 [1.84992–1.85039]
Inside diameter
Nominal Value ..... 20 [0.79]
Assembly Standard ... 19.990–20.000 [0.78701–0.78740]

Idler shaft diam., mm [in.]

Nominal Value ..... 20 [0.79]
Assembly Standard ... 20.002–20.011 [0.78748–0.78783]

Reassembly

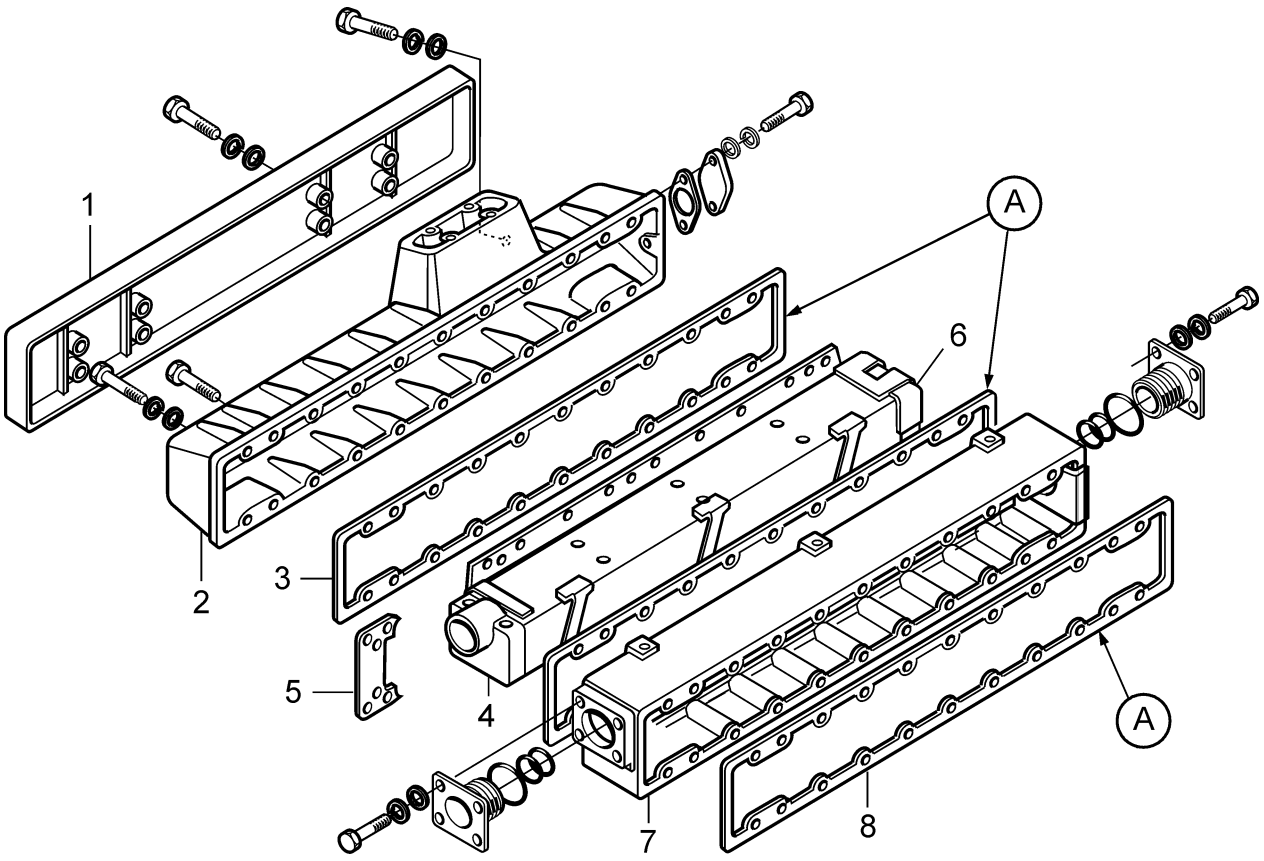


Reassembly Sequence:

③ → ⑨ → ⑦ → ⑧ → ⑥ → ⑤ → ⑭ → ⑫ → ⑬ → ⑪ → ⑩ → ② → ① → ④

Group 25 Inlet and Exhaust System

Air Cooler

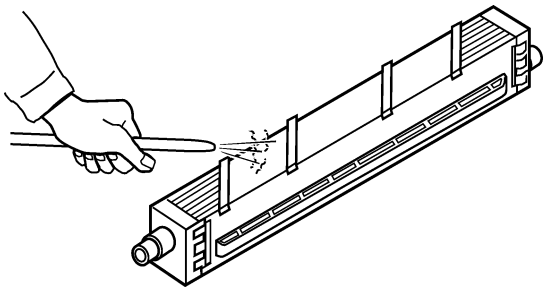


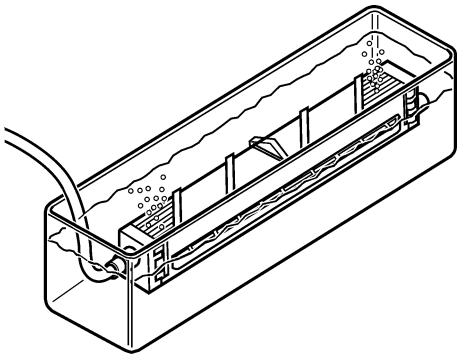
Disassembly

1. Manifold cover
2. Air cooler cover
3. Packing
4. Air cooler element
5. Plate
6. Packing
7. Air cooler case
8. Packing

Look for:

A. Replace packing





Inspection

Cleaning air cooler

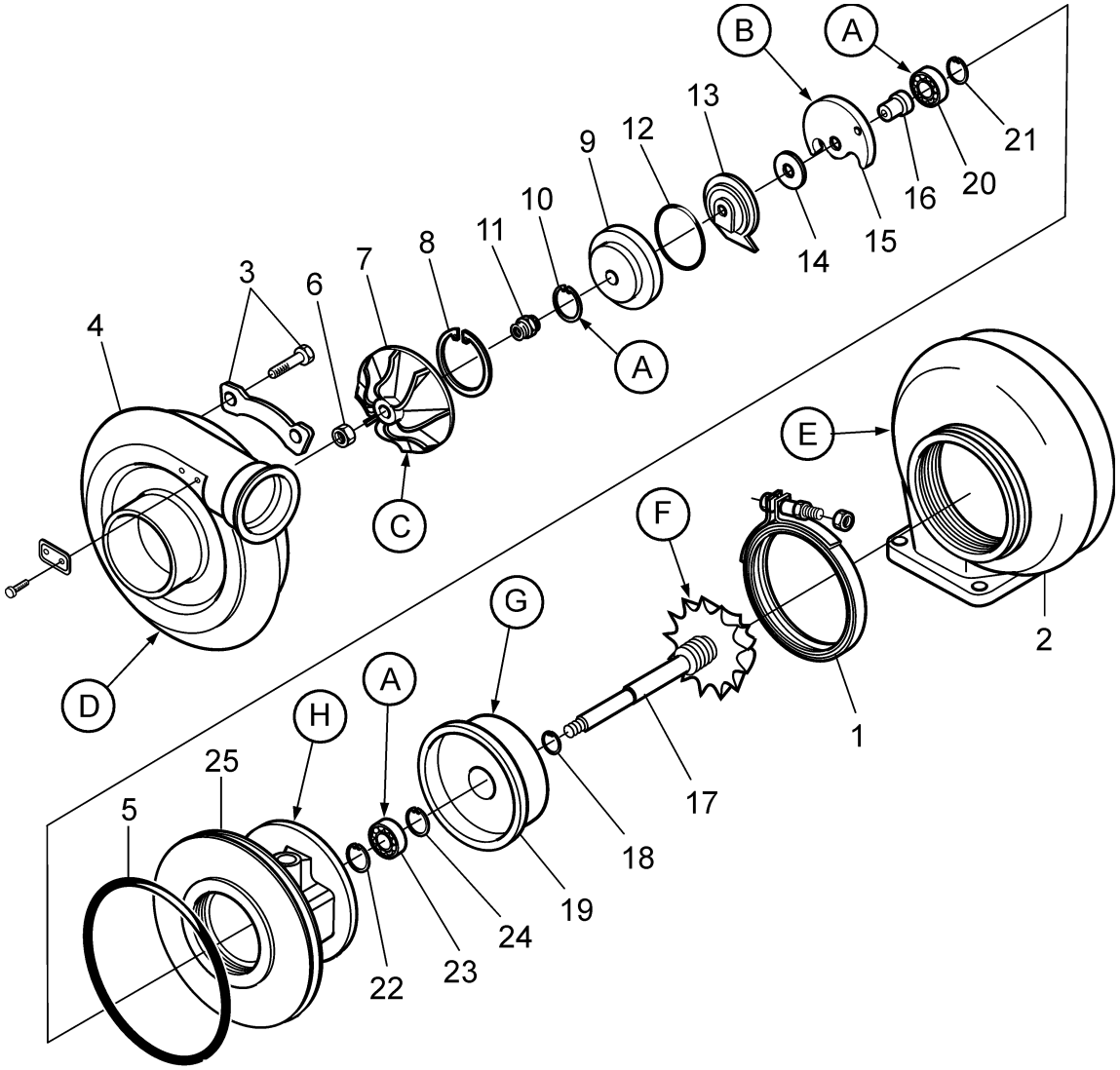
1. Remove dirt built up from the air cooler by directing high pressure air of {max press. 0.29 to 0.49 MPa (3 to 5kgf/cm^2) [43 to 71 psi]} in the opposite direction of the air flow. Inspect the cooler for corrosion and cracks.
2. Wash the fresh water or salt water pipes in water and caustic soda lime, then remove scale deposits by inserting a 3 mm [1/8 in.] bar into each pipe.

Inspecting air cooler for air tightness

Immerse the air cooler in water, then apply high pressure air {max press. 0.39 MPa (4 kgf/cm^2) [57 psi]} to the coolant side to inspect for air leaks.

NOTE! Keep record of the water/air temperatures(using infrared temp. gun) to determine when the cooler needs cleaning.

Turbocharger [TD13]



Disassembly

1. V-clamp
2. Turbine housing
3. Lock plate
4. Compressor cover
5. O-ring
6. Lock nut
7. Compressor wheel
8. Snap ring
9. Insert
10. Piston ring
11. Finger sleeve
12. O-ring
13. Oil deflector
14. Thrust ring (compressor)
15. Thrust bearing
16. Thrust ring (turbo)
17. Shaft and turbine wheel
18. Piston ring
19. Turbine backplate
20. Bearing
21. Snap ring
22. Snap ring
23. Bearing
24. Snap ring
25. Bearing housing

Look for:

A. Wear

B. Thrust face wear

C. Vane distortion, damage, rubbing contact on back face and gas erosion

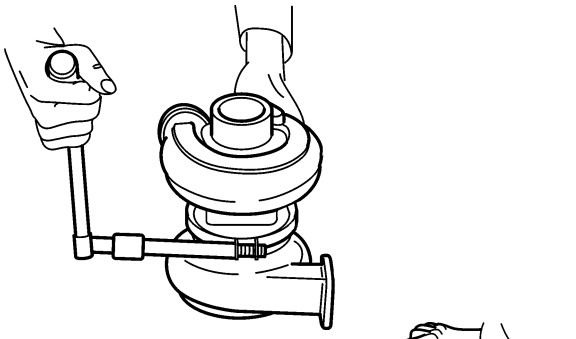
D. Rubbing contact with compressor wheel

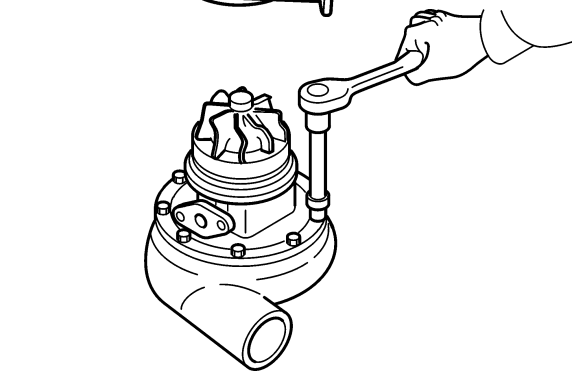
E. Rubbing contact with turbine wheel, cracks and distortion

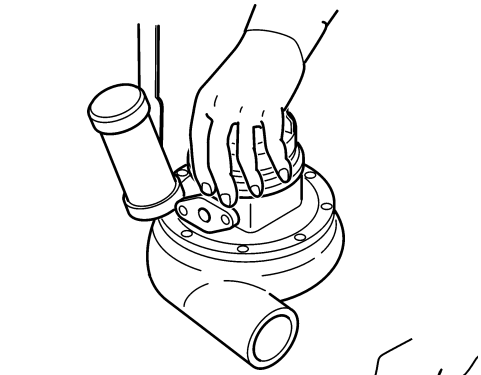
F. Vane distortion, damage, rubbing contact on back face and gas erosion and damage to ring grooves

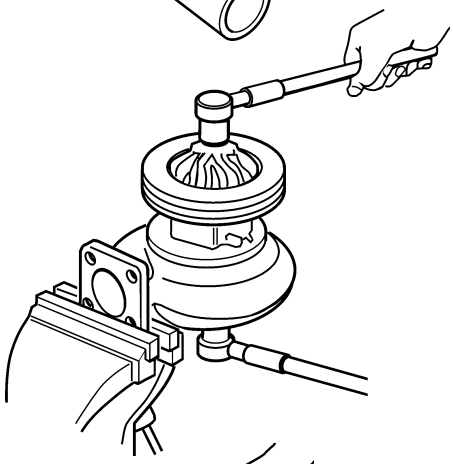
G. Rubbing contact with turbine wheel and damage

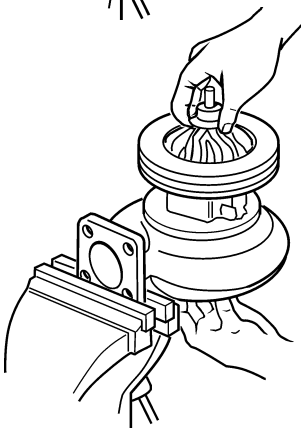
H. Damage to bearing bore, gas erosion and distortion of turbine side flange











Disassembly

Remove the turbine housing

Remove the V-clamp and the turbine housing (in that order) from the turbocharger.

⚠ **IMPORTANT!** The compressor cover, bearing housing and turbine housing must be reassembled in correct orientation. Therefore, put alignment marks with a punch or marker.

Remove the compressor cover

1. Put the turbocharger on a workbench with the compressor cover down. Unscrew the bolts and remove the lockplates.

2. Lightly tap around the compressor cover with a soft-faced hammer to remove the cover. Also remove the o-ring from the bearing housing.

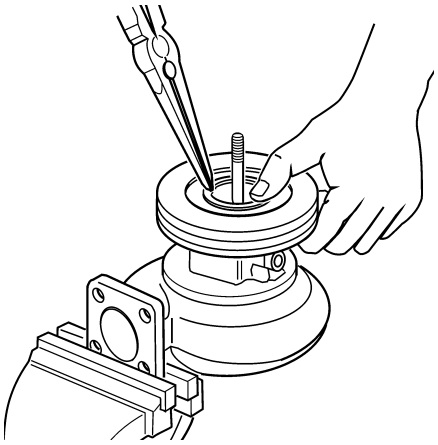
Remove the compressor wheel

⚠ **IMPORTANT!** Handle the compressor wheel and turbine wheel with care during disassembly and assembly. Vanes can easily bend when dropped or hit.

1. Fasten the flange of the turbine housing in a vise and install the bearing housing to the turbine housing with the v-clamp..
2. Hold the boss of the shaft & turbine wheel and remove the lock nut holding the compressor wheel.

NOTE! The lock nut has left-handed threads.

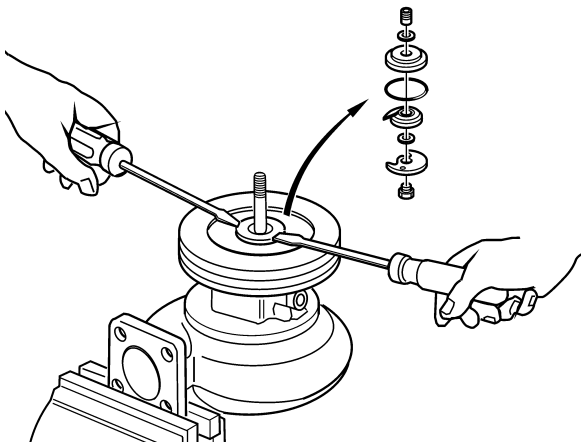
3. While holding the turbine wheel with one hand, turn the compressor wheel lightly with the other hand and remove.



Removing the snap ring

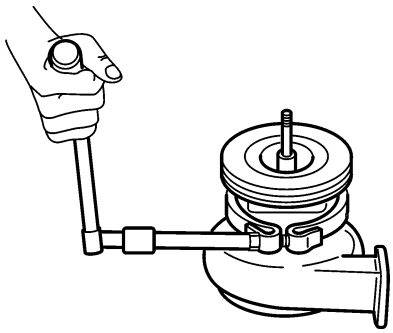
NOTE! Use only snap ring pliers to remove snap rings.

NOTE! Put your thumb on the snap ring to prevent it from flying out in case the pliers lose grip.



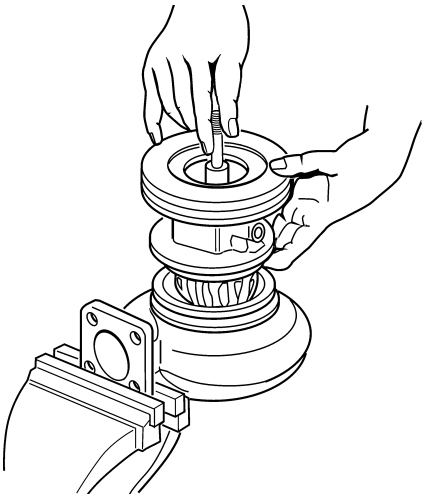
Removing the insert and oil deflector

1. Using two screwdrivers, gently pry out the insert from the bearing housing.
2. Separate the finger sleeve together with the piston ring from the insert.
3. Remove the o-ring, the oil deflector, the compressor thrust ring, the thrust bearing, and the turbo thrust ring from the bearing housing.



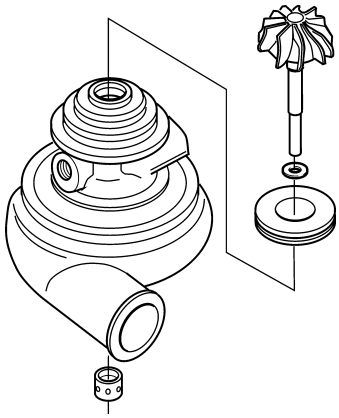
Remove the v-clamp

Loosen the v-clamp with a socket wrench and dislodge the clamp from its position

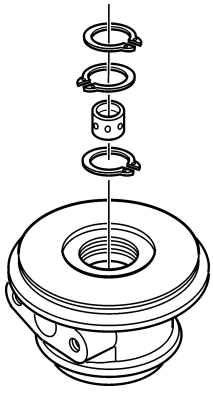


Removing the shaft & turbine wheel

1. Remove the bolts and lock plates.
2. While gripping the shaft of the shaft & turbine wheel with one hand, hold the bearing housing with the other hand and slowly remove the shaft & turbine wheel from the turbine housing.



3. Turn the bearing housing (turbine wheel face up) and place it on the compressor cover. Remove the shaft and turbine wheel, the piston ring, the turbine backplate and the bearing(compressor side).

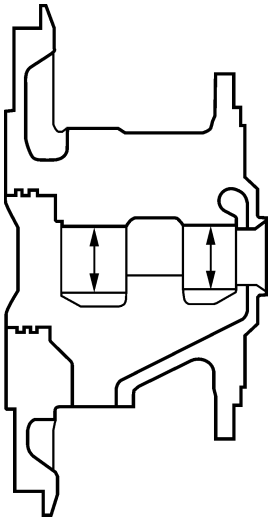


Removing the snap ring and bearing

⚠ **IMPORTANT!** Remove the snap ring with care and make sure not to damage the inside surface of the bearing house or the seal (turbine side) of the piston ring.

Place the bearing housing on a workbench with the compressor side face up. Then remove the 3 snap rings and the bearing.

Inspection



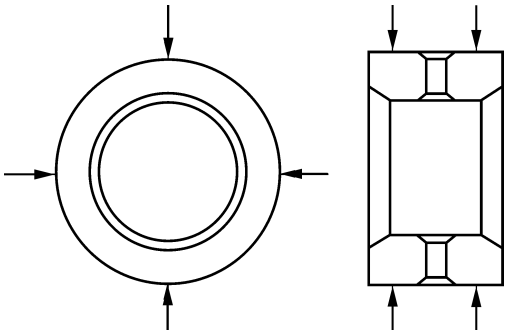
Bearing housing

Measure inside diameter of bearing-fitted section

If the measured diameter exceeds the service limit, replace the bearing housing.

Inside diam. bearing-fitted section, mm [in.]

Service Limit ..... 30.006 [1.18134]



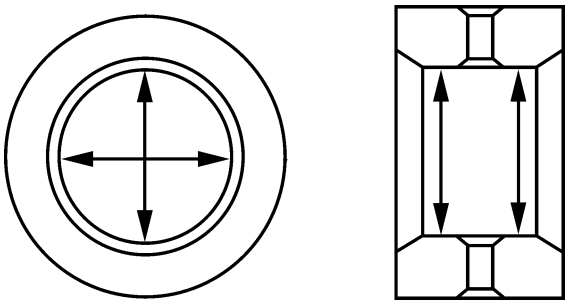
Bearing

Measure bearing outside diameter

If the measured diameter is less than the service limit, replace the bearing.

Bearing inside diameter, mm [in.]

Service Limit ..... 29.876 [1.17622]

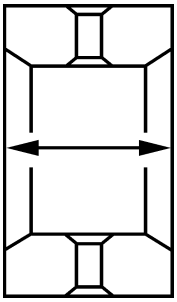


Measure bearing inside diameter

If the measured diameter exceeds the service limit, replace the bearing.

Bearing inside diameter, mm [in.]

Service Limit ..... 18.050 [0.71063]

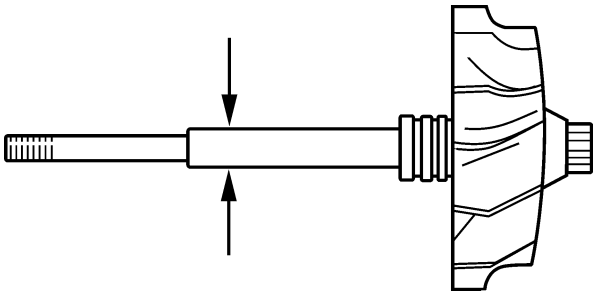


Measuring bearing length

If the measured length is less than the service limit, replace the bearing.

Bearing length, mm [in.]

Service Limit ..... 17.440 [0.68661]



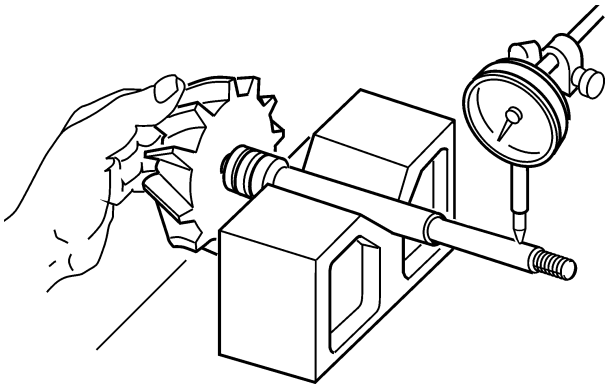
Shaft & turbine wheel

Measure journal diam. of shaft & turbine wheel

If the measured diameter is less than the service limit, replace the shaft & turbine wheel.

Shaft journal diameter, mm [in.]

Service Limit ..... 17.996 [0.70850]



Measure shaft deflection

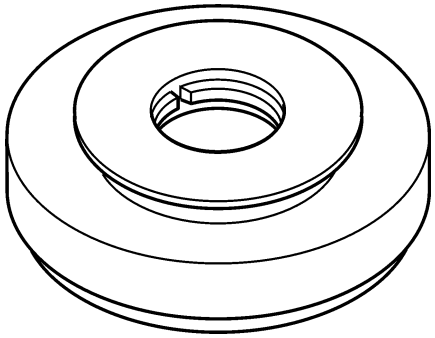
1. Set a dial gauge at a location next to the threaded section of the shaft, and measure shaft deflection. If the deviation indicated by the dial gauge exceeds the service limit, replace the shaft & turbine w heel.

   ⚠ **IMPORTANT!** If the shaft is bent, replace. Do not attempt to correct the bend.

2. If the surface of the shaft journal is rough, mount the shaft on a lathe, and gently polish the surface using #400 sandpaper and engine oil while rotating at 300-600 min^{-1}.

Shaft deflection, mm [in.]

Service Limit ..... 0.015 [0.00059]



Insert

Measure piston ring end gap

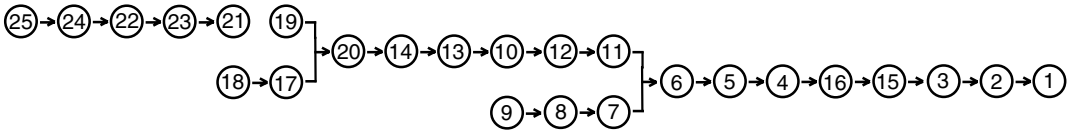
Install a new piston ring squarely in the insert then measure the piston ring end gap. If the end gap deviates from the assembly standard, replace the insert.

Ring end gap, mm [in.]

Assembly Standard ... 0.05–0.25 [0.00197–0.00984]

Reassembly

Reassembly sequence:

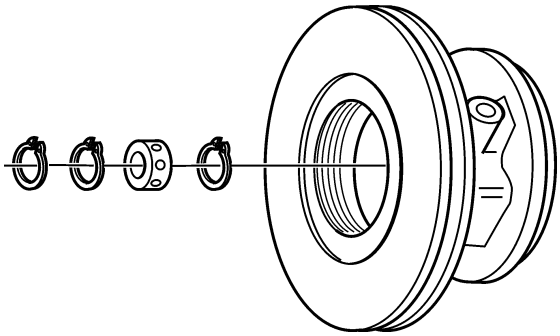


NOTE! Always replace the following parts at disassembly:

4. O-ring
9. Piston ring
11. O-ring
19. Piston ring

⚠ **IMPORTANT!** If vanes are damaged or cracked, do not reuse the part.

⚠ **IMPORTANT!** After reinstalling the overhauled turbocharger, crank the engine to lubricate moving parts of the turbo.

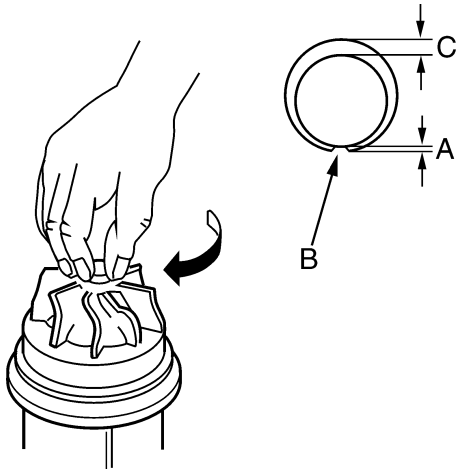


Install shaft & turbine wheel and bearing

1. Install the bearing housing, the snap rings and the bearing on the turbine side, and the snap ring on the compressor side.

NOTE! Use only snap ring pliers to install snap rings. After installing the snap ring, rotate it with a finger to make sure it rotates smoothly.

NOTE! Apply engine oil to the outside and inside surfaces of the bearing before installation.



2. Place the bearing housing on the compressor cover, and install the turbine backplate.

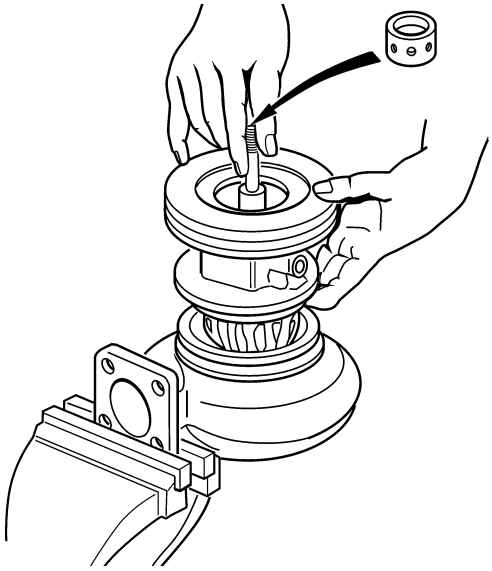
3. Insert the piston ring into the groove on the shaft & turbine wheel

4. When installing the shaft & turbine wheel mounted with the piston ring in the bearing housing, position the ring on the shaft so that there is a small space (A) at the ring end gap side (B) and a large space (C) on the other side. Then insert the shaft & turbine wheel while rotating.

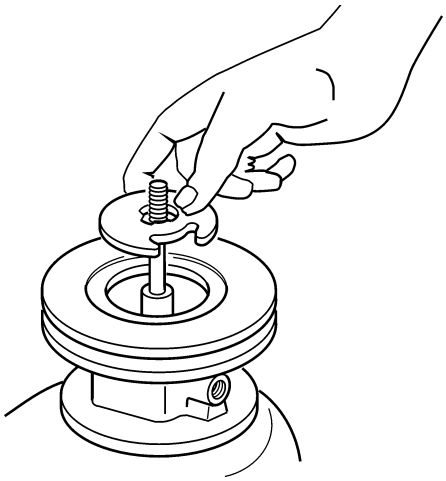
⚠ **IMPORTANT!** Do not expand the piston ring excessively or twist the ends when installing on the shaft & turbine wheel.

⚠ **IMPORTANT!** Do not apply excessive forte without tentering the shaft properly during the installation of the shaft & turbine wheel.

NOTE! After installing the piston ring in the ring groove, apply Moly Disulfide to the ring before assembly.

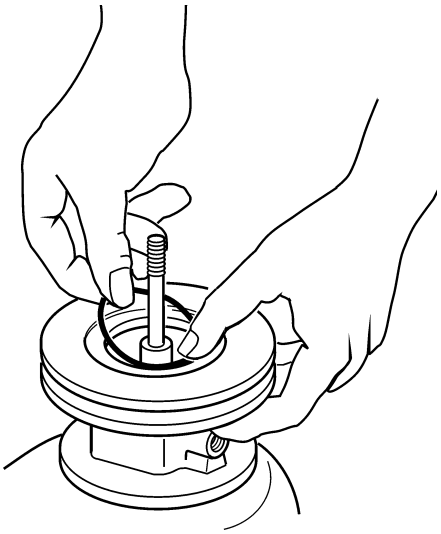


5. Hold the shaft end and tum the assembly over so the compressor side faces up. Install the bearing on the compressor side and then mount the bearing housing in the turbine housing and fasten the v-clamp temporarily.



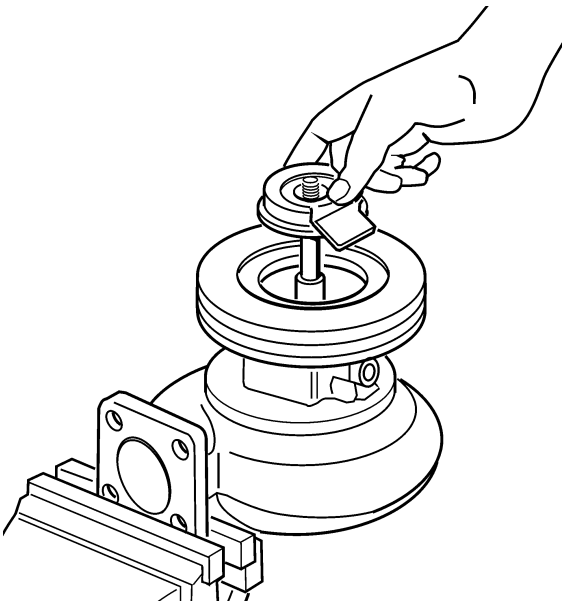
Install the thrust bearing

Apply engine oil to both sides of the thrust ring and thrust bearing. To install the thrust bearing, align the notch with the groove pin.



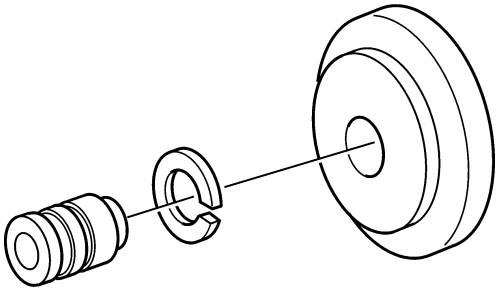
Install the O-ring

Apply grease to the O-ring and install.



Install the oil deflector

Apply engine oil to both sides of the thrust ring and install. Then install the oil deflector with the baffle facing down.



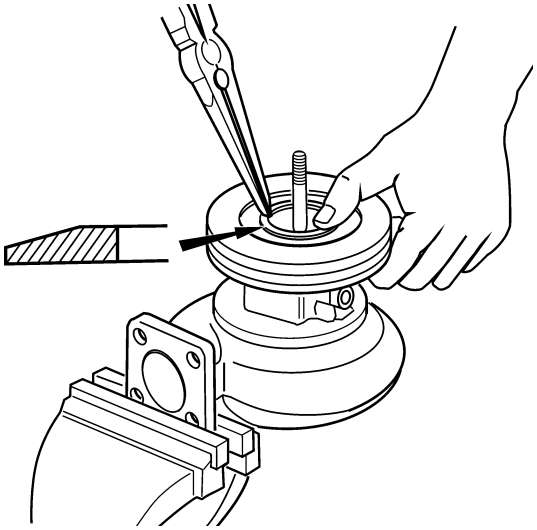
Assembly of the insert sub-assembly

1. Install the finger sleeve and the piston ring in the insert.

⚠ **IMPORTANT!** Do not expand the piston ring excessively or twist the ends when installing on the finger sleeve.

⚠ **IMPORTANT!** Apply Moly Disulfide to the piston ring installed on the finger sleeve, then install on the insert carefully so as to avoid piston ring damage.

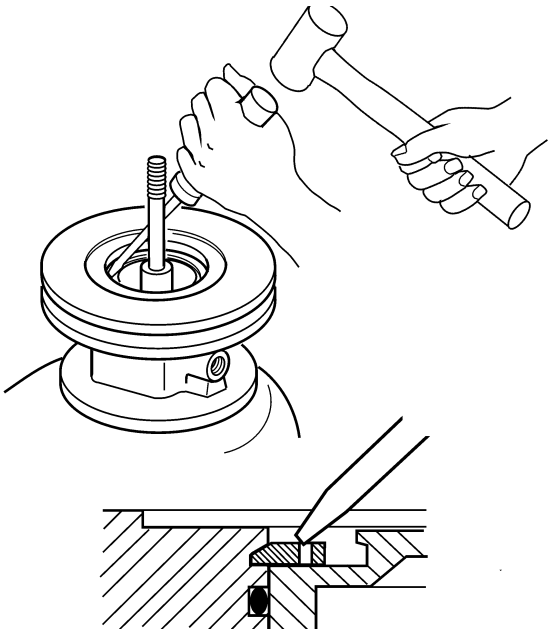
2. After installing the above parts, irrstall the sub assembly in the bearing housing.



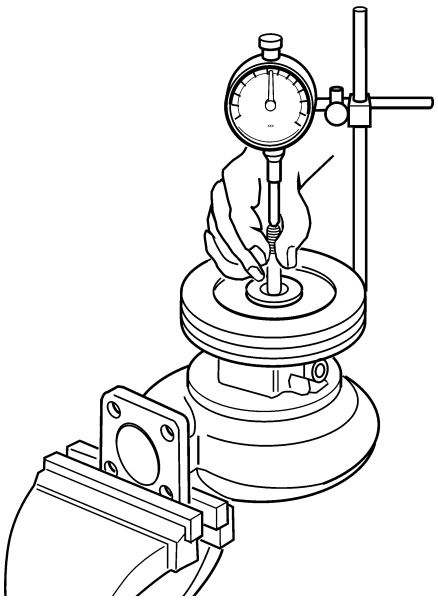
Install the snap ring

Install the snap ring with the tapered side face up in the bearing housing.

NOTE! Make sure you install the snap ring correctly!



NOTE! Lightly drive both ends of the snap ring using a screwdriver and hammer to securely insert the ring into the groove on the bearing housing. Make sure the screwdriver does not hit the bearing housing.



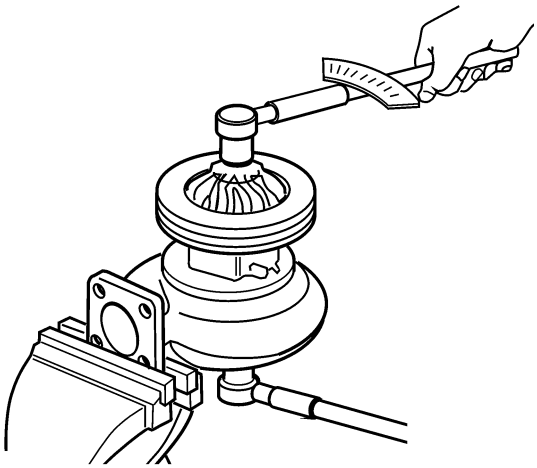
Turbine wheel and housing clearance

Set a dial gauge on the end face of the shaft & turbine wheel. Read the dial gauge indication while moving the shaft & turbine wheel in the axial direction.

If the dial gauge indication deviates from the assembly standard, disassemble and locate the cause of the problem.

Clearance turbine wheel and housing, mm [in.]

Standard Clearance .. 0.29–0.91 [0.01142–0.03583]

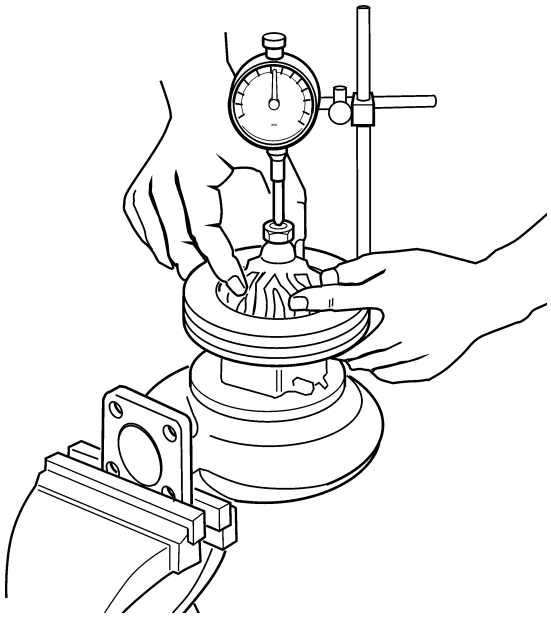


Install the compressor wheel

Install the compressor wheel. Apply Moly Disulfide to the threads of the lock nut, then tighten to the specified torque.

Lock nut tightening method

1. Tighten the lock nut to torque of 49 N•m (5 kgf•m) [36 lbf•ft], then loosen it completely.
2. Retighten to a snug torque of 14.7 N•m (1.5 kgf•m) [10.8 lbf•ft], then turn another 80±3°.



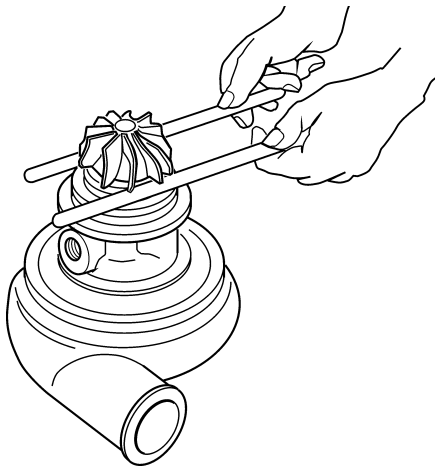
Shaft & turbine wheel axial play

Set a dial gauge on the end face of the shaft & turbine wheel. Measure the amount of play while moving the compressor wheel in the axial direction.

If the measured play deviates from the standard value, disassemble and locate the cause of the problem.

Shaft & turbine wheel axial play, mm [in.]

Assembly Standard ... 0.075–0.135 [0.00295–0.00531]



Turbine wheel and backplate clearance

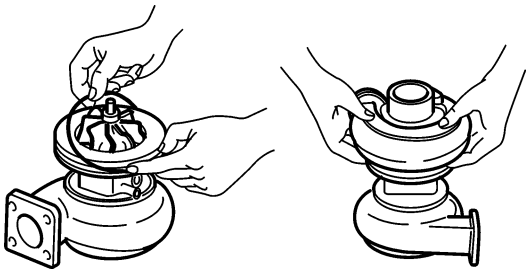
Remove the bearing housing from the turbine housing and install it in the compressor cover. Measure the clearance between the turbine backplate and the back side of the turbine wheel using feeler gauges.

NOTE! Use two feeler gauges, and measure at vane tips.

If the clearance deviates from the assembly standard, disassemble and locate the cause of the problem.

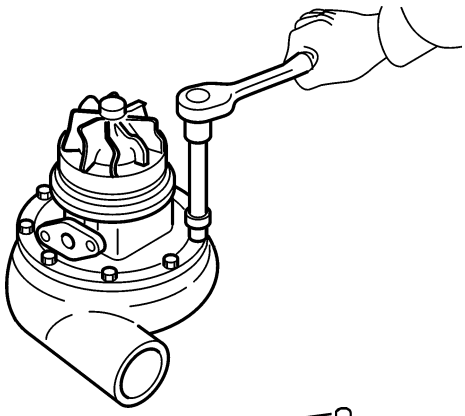
Turbine wheel and backplate clearance, mm [in.]

Standard Clearance .. 0.55–1.15 [0.02165–0.04528]



Install the compressor cover

1. Apply grease to the o-ring and install it.
2. Mount the compressor cover on the bearing housing and be sure to follow the alignment marks made during disassembly.

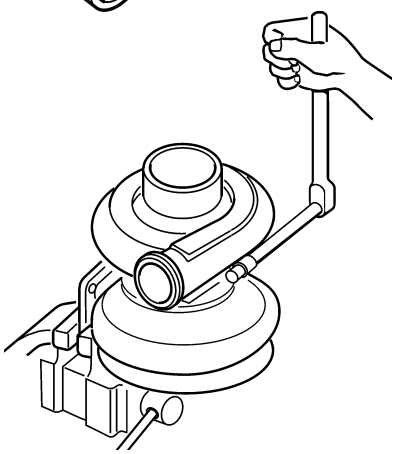


Install the lock plates

Install the lock plates to the compressor cover

Install the turbine housing

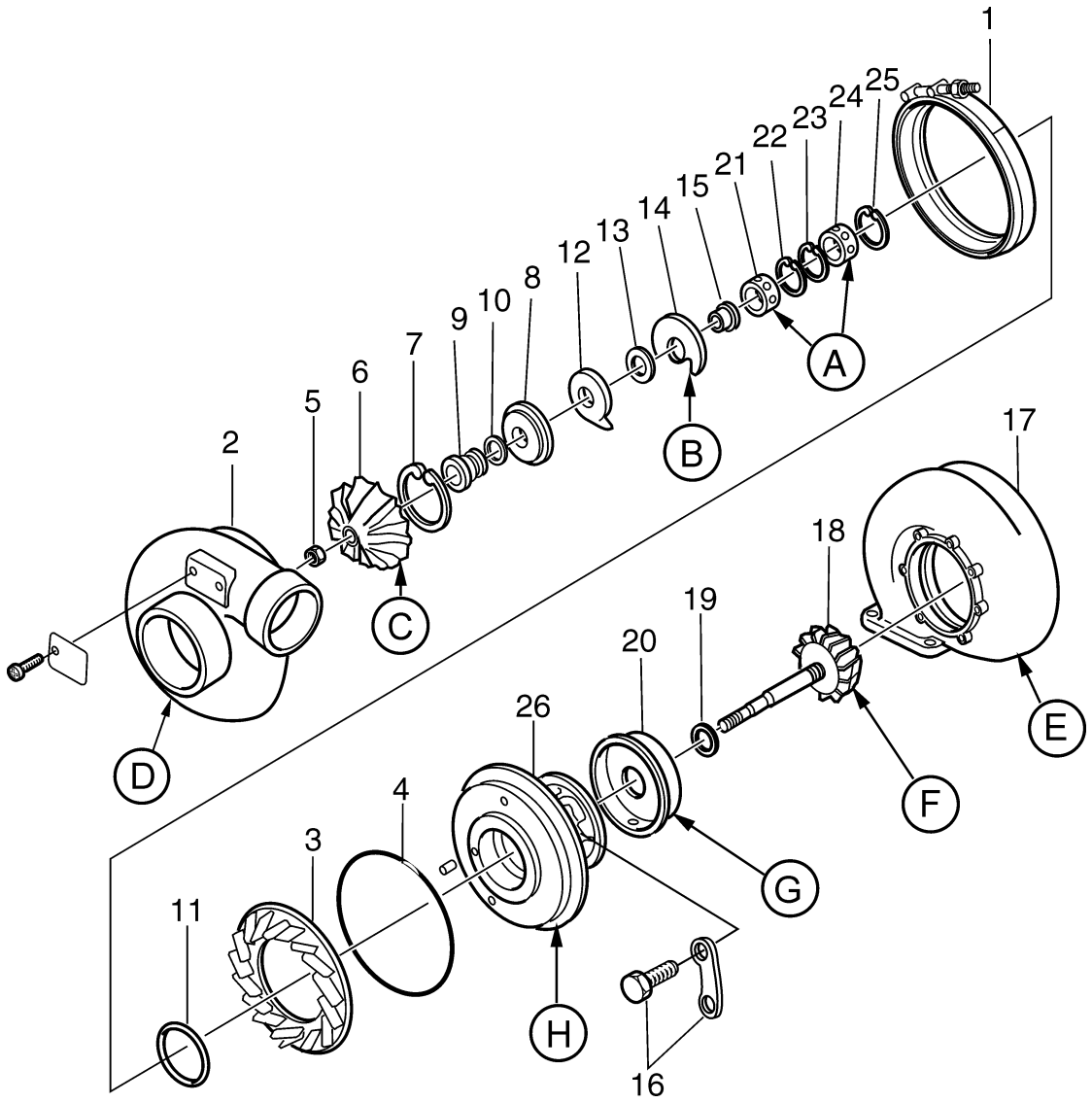
Mount the turbine housing on the bearing housing and be sure to follow the alignment marks made during disassembly.



Installing the V-clamp

Install the V-clamp to the compressor cover and tap around it with a soft-faced hammer for more than 3 times and tighten to the specified torque.

Turbocharger [TD15]



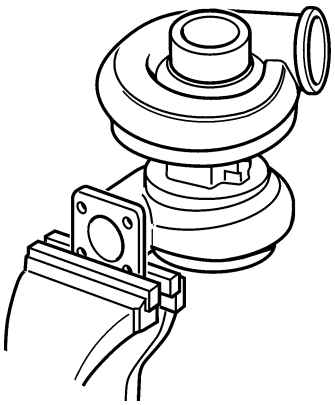
Disassembly

1. V-clamp
2. Compressor cover
3. Diffuser
4. O-ring
5. Lock nut
6. Compressor wheel
7. Snap ring
8. Insert
9. Finger sleeve
10. Piston ring
11. O-ring
12. Oil deflector
13. Thrust ring (compressor)
14. Thrust bearing
15. Thrust ring (turbo)
16. Bolt
17. Turbine housing
18. Shaft and turbine wheel
19. Piston ring
20. Turbine backplate
21. Bearing
22. Snap ring
23. Snap ring
24. Bearing
25. Snap ring
26. Bearing housing

Look for:

A. Wear
B. Thrust face wear
C. Vane distortion, damage, rubbing contact on back face and gas erosion
D. Rubbing contact with compressor wheel
E. Rubbing contact with turbine wheel, cracks and distortion
F. Vane distortion, damage, rubbing contact on back face and gas erosion and damage to ring grooves
G. Rubbing contact with turbine wheel and damage
H. Damage to bearing bore, gas erosion and distortion of turbine side flange

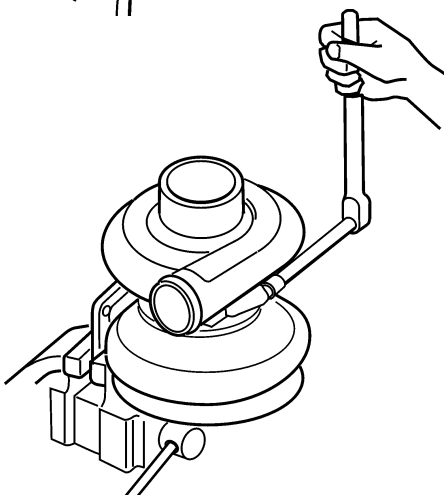
Disassembly



Preparing for disassembly

Mount the turbine housing In a vice by clamping at the flange.

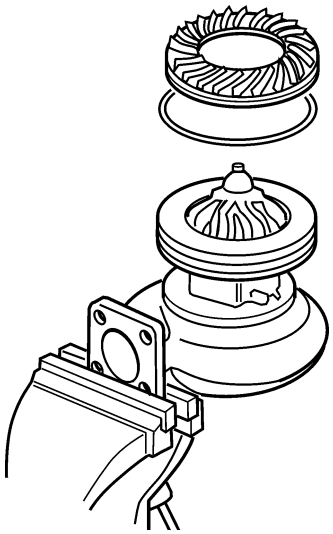
⚠ **IMPORTANT!** Clamp the flange securely to prevent the turbine housing from loosening or moving during work.



Removing the compressor cover

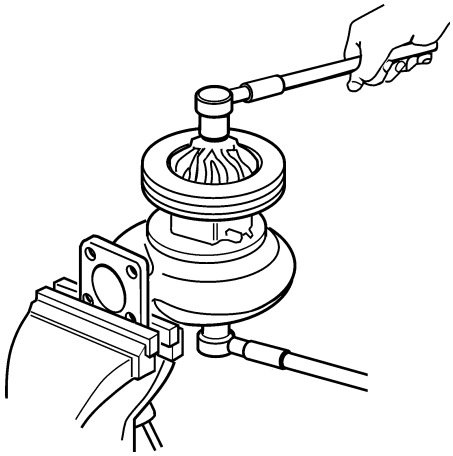
⚠ **IMPORTANT!** The compressor cover, bearing housing and turbine housing must be reassembled in correct orientation. Therefore, put alignment marks with a punch or marker.

1. Loosen the V-clamp using a socket wrench.
2. Lightly tap around the compressor cover with a soft-faced hammer to remove the cover.



Removing the diffuser

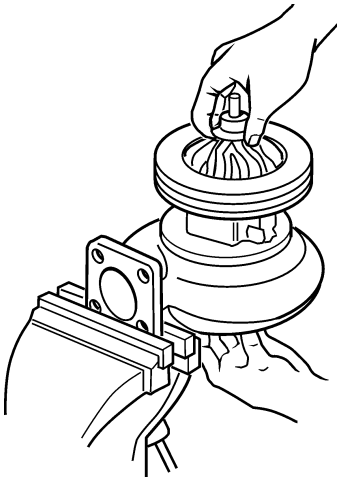
1. Lightly tap around the diffuser with a soft faced hammer to remove the diffuser.
2. Remove O-ring from the bearing housing.

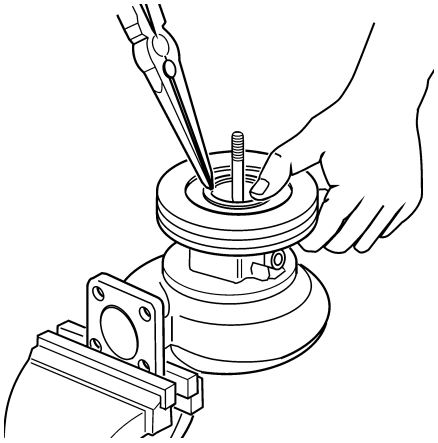


Removing the compressor wheel

⚠ **IMPORTANT!** Handle the compressor wheel and turbine wheel with care during disassembly and assembly. Vanes can easily bend when dropped or hit.

1. While holding the boss of the shaft & turbine wheel remove the lock nut fastening the compressor wheel.
2. While holding the turbine wheel with one hand, turn the compressor wheel lightly with the other hand and remove.

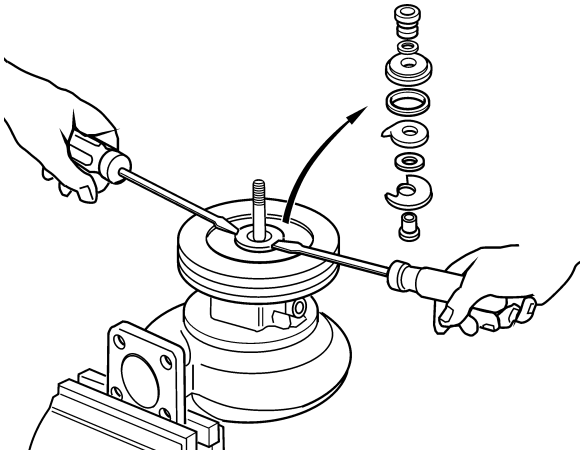




Removing the snap ring

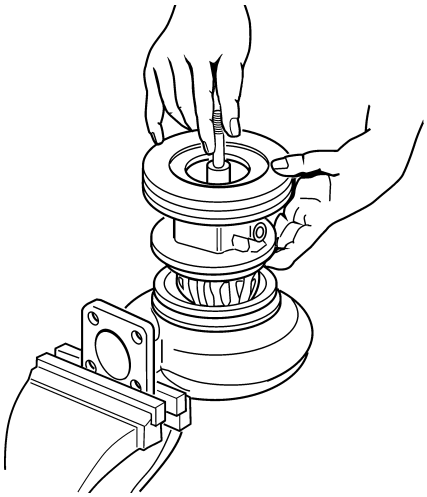
NOTE! Use only snap ring pliers to remove snap rings.

NOTE! Put your thumb on the snap ring to prevent it from flying out in case the pliers lose grip.



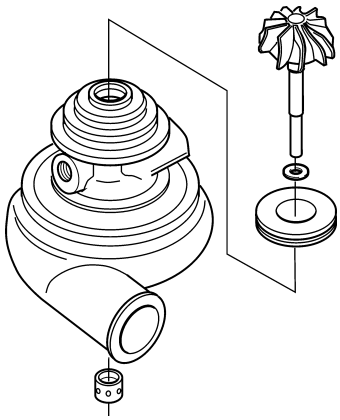
Removing the insert and oil deflector

1. Using two screwdrivers, gently pry out the insert from the bearing housing.
2. Separate the finger sleeve together with the piston ring from the insert.
3. Remove the o-ring, the oil deflector, the compressor thrust ring, the thrust bearing, and the turbo thrust ring from the bearing housing.

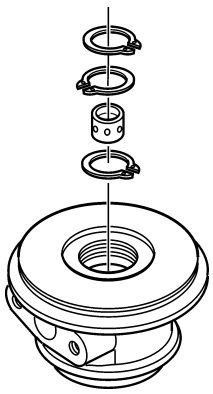


Removing the shaft & turbine wheel

1. Remove the bolts and lock plates.
2. While gripping the shaft of the shaft & turbine wheel with one hand, hold the bearing housing with the other hand and slowly remove the shaft & turbine wheel from the turbine housing.



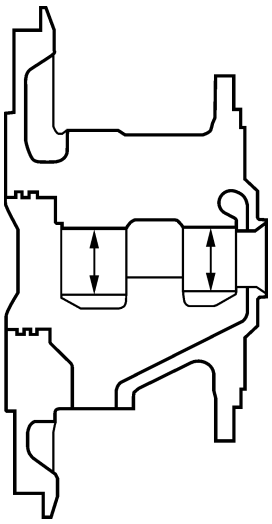
3. Turn the bearing housing (turbine wheel face up) and place it on the compressor cover. Remove the shaft and turbine wheel, the piston ring, the turbine backplate and the bearing(compressor side).



Removing the snap ring and bearing

⚠ **IMPORTANT!** Remove the snap ring with care and make sure not to damage the inside surface of the bearing house or the seal (turbine side) of the piston ring.

Place the bearing housing on a workbench with the compressor side face up. Then remove the 3 snap rings and the bearing.



Inspection

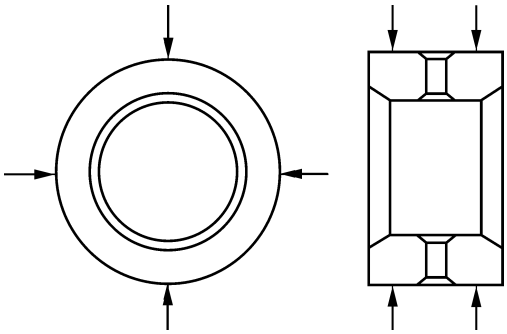
Bearing housing

Measure inside diameter of bearing-fitted section

If the measured diameter exceeds the service limit, replace the bearing housing.

Inside diam. bearing-fitted section, mm [in.]

Service Limit ..... 34.016 [1.33921]



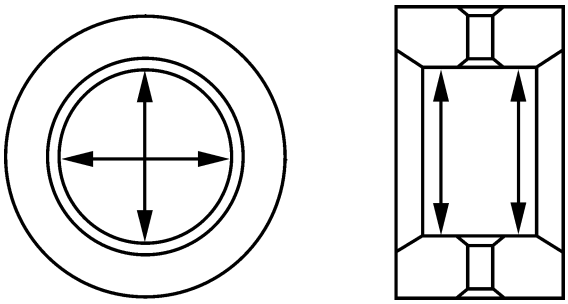
Bearing

Measure bearing outside diameter

If the measured diameter is less than the service limit, replace the bearing.

Bearing inside diameter, mm [in.]

Service Limit ..... 33.882 [1.33393]

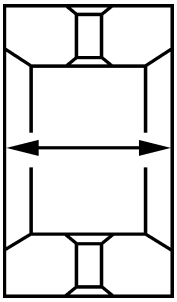


Measure bearing inside diameter

If the measured diameter exceeds the service limit, replace the bearing.

Bearing inside diameter, mm [in.]

Service Limit ..... 19.929 [0.78460]

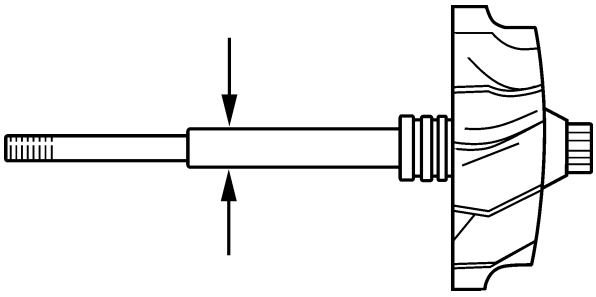


Measuring bearing length

If the measured length is less than the service limit, replace the bearing.

Bearing length, mm [in.]

Service Limit ..... 19.44 [0.76535]



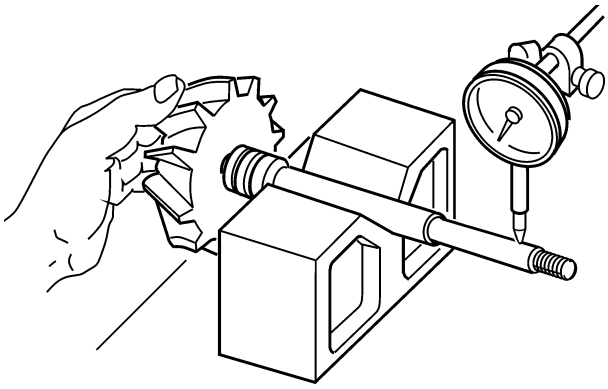
Shaft & turbine wheel

Measure journal diam. of shaft & turbine wheel

If the measured diameter is less than the service limit, replace the shaft & turbine wheel.

Shaft journal diameter, mm [in.]

Service Limit ..... 19.863 [0.78201]



Measure shaft deflection

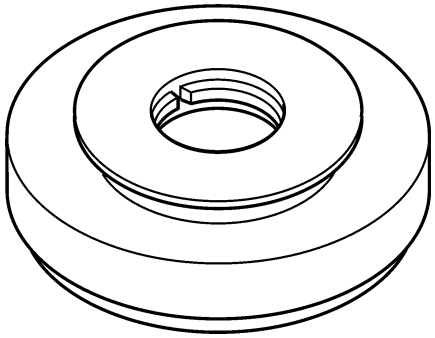
1. Set a dial gauge at a location next to the threaded section of the shaft, and measure shaft deflection. If the deviation indicated by the dial gauge exceeds the service limit, replace the shaft & turbine w heel.

   ⚠ **IMPORTANT!** If the shaft is bent, replace. Do not attempt to correct the bend.

2. If the surface of the shaft journal is rough, mount the shaft on a lathe, and gently polish the surface using #400 sandpaper and engine oil while rotating at 300-600 min^{-1}.

Shaft deflection, mm [in.]

Service Limit ..... 0.015 [0.00059]



Insert

Measure piston ring end gap

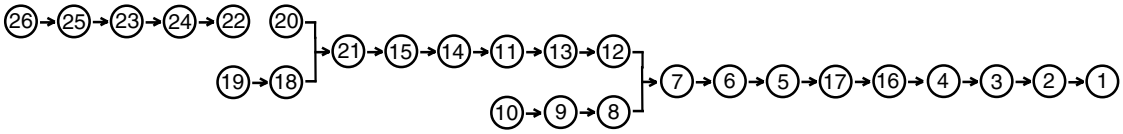
Install a new piston ring squarely in the insert then measure the piston ring end gap. If the end gap deviates from the assembly standard, replace the insert.

Ring end gap, mm [in.]

Assembly Standard ... 0.05–0.20 [0.00197–0.00787]

Reassembly

Reassembly sequence:

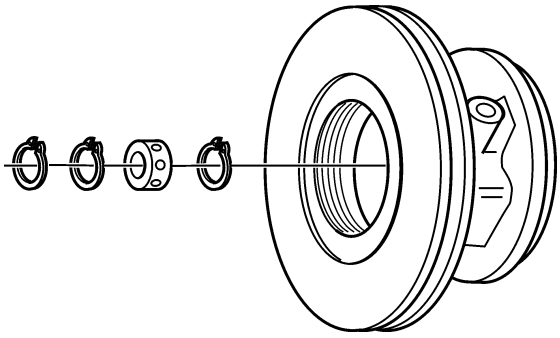


NOTE! Always replace the following parts at disassembly:

4. O-ring
9. Piston ring
11. O-ring
19. Piston ring

⚠ **IMPORTANT!** If vanes are damaged or cracked, do not reuse the part.

⚠ **IMPORTANT!** After reinstalling the overhauled turbocharger, crank the engine to lubricate moving parts of the turbo.

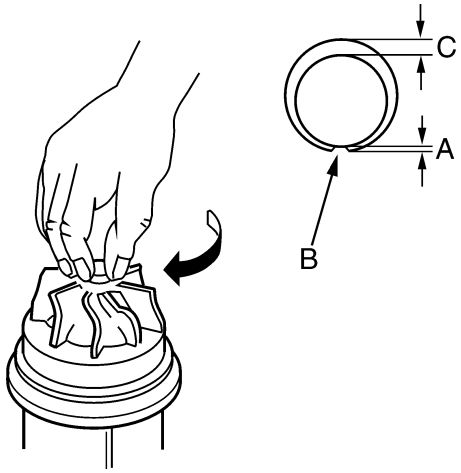


Install shaft & turbine wheel and bearing

1. Install the bearing housing, the snap rings and the bearing on the turbine side, and the snap ring on the compressor side.

NOTE! Use only snap ring pliers to install snap rings. After installing the snap ring, rotate it with a finger to make sure it rotates smoothly.

NOTE! Apply engine oil to the outside and inside surfaces of the bearing before installation.



2. Place the bearing housing on the compressor cover, and install the turbine backplate.

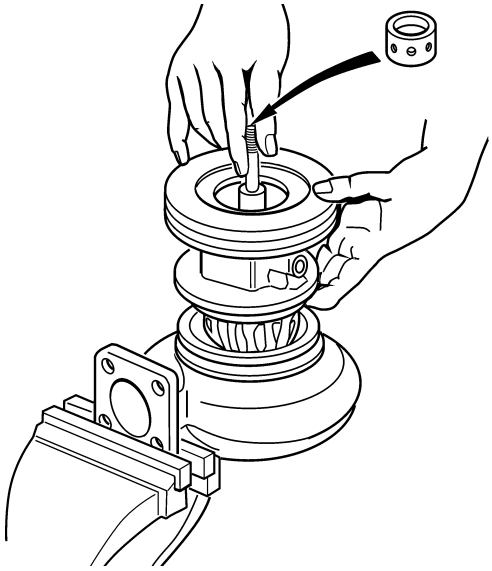
3. Insert the piston ring into the groove on the shaft & turbine wheel

4. When installing the shaft & turbine wheel mounted with the piston ring in the bearing housing, position the ring on the shaft so that there is a small space (A) at the ring end gap side (B) and a large space (C) on the other side. Then insert the shaft & turbine wheel while rotating.

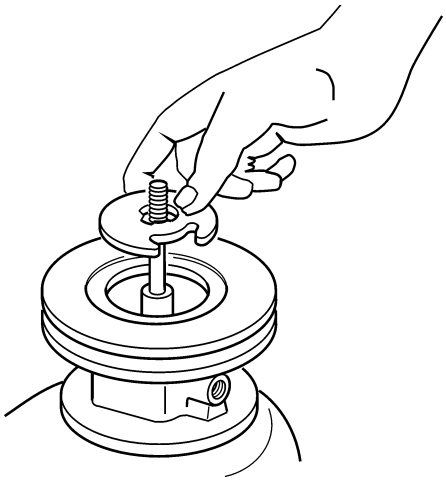
⚠ **IMPORTANT!** Do not expand the piston ring excessively or twist the ends when installing on the shaft & turbine wheel.

⚠ **IMPORTANT!** Do not apply excessive forte without tentering the shaft properly during the installation of the shaft & turbine wheel.

NOTE! After installing the piston ring in the ring groove, apply Moly Disulfide to the ring before assembly.

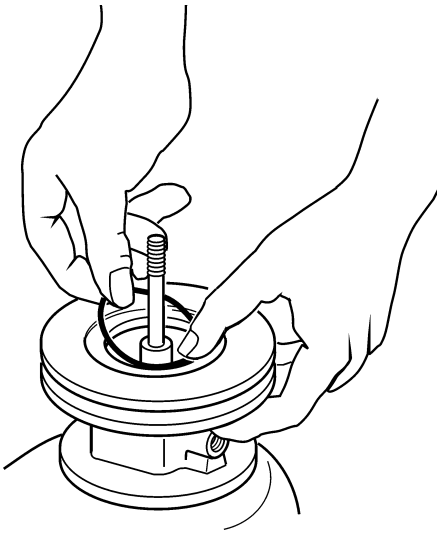


5. Hold the shaft end and tum the assembly over so the compressor side faces up. Install the bearing on the compressor side and then mount the bearing housing on the turbine housing and fasten the bolt temporarily.



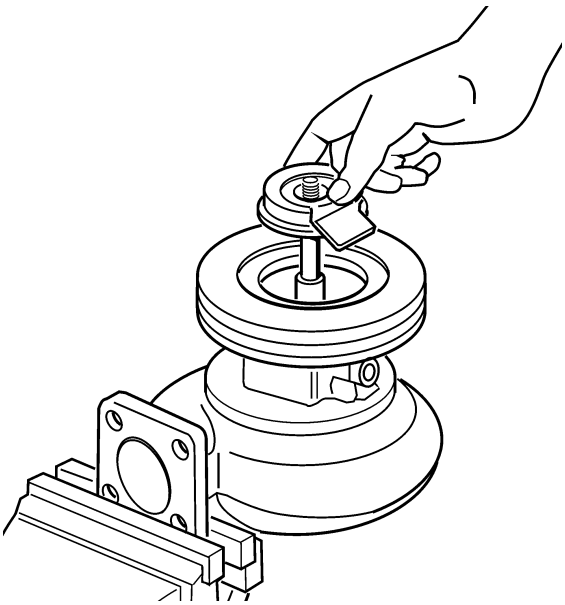
Installing the thrust bearing

Apply engine oil to both sides of the thrust ring and thrust bearing. To install the thrust bearing, align the notch with the groove pin.



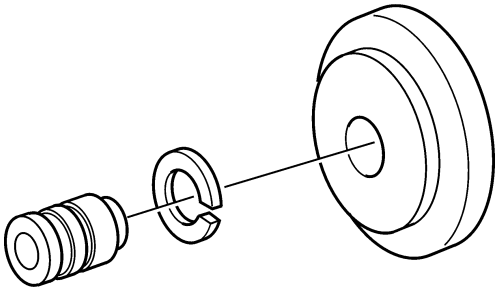
Installing the O-ring

Apply grease to the O-ring and install.



Installing the oil deflector

Apply engine oil to both sides of the thrust ring and install. Then install the oil deflector with the baffle facing down.



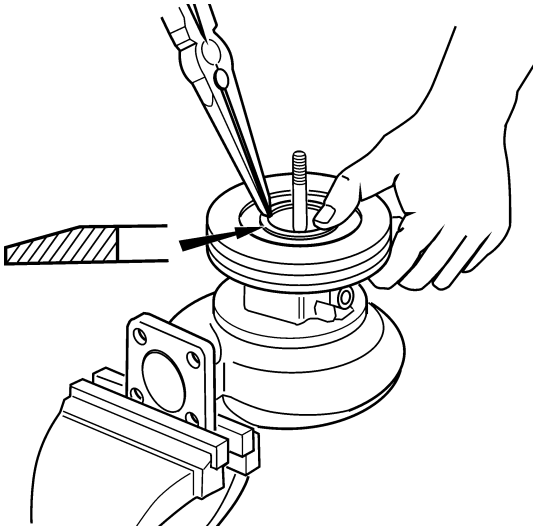
Assembling the insert sub-assembly

1. Install the finger sleeve and the piston ring in the insert.

⚠ **IMPORTANT!** Do not expand the piston ring excessively or twist the ends when installing on the finger sleeve.

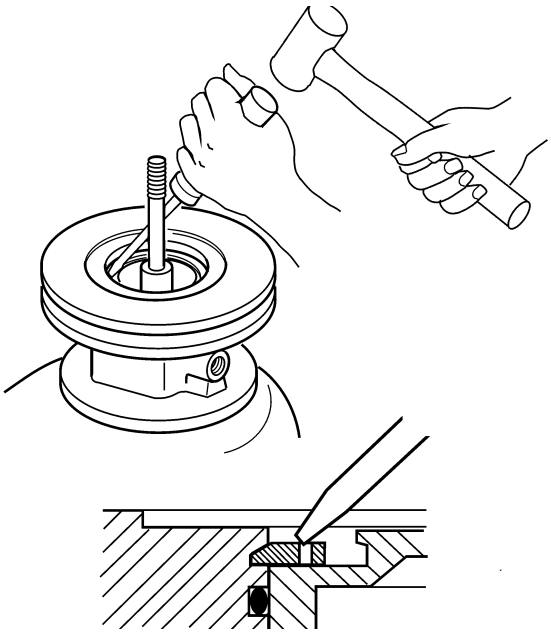
⚠ **IMPORTANT!** Apply Moly Disulfide to the piston ring installed on the finger sleeve, then install on the insert carefully so as to avoid piston ring damage.

2. After installing the above parts, irrstall the sub assembly in the bearing housing 26.

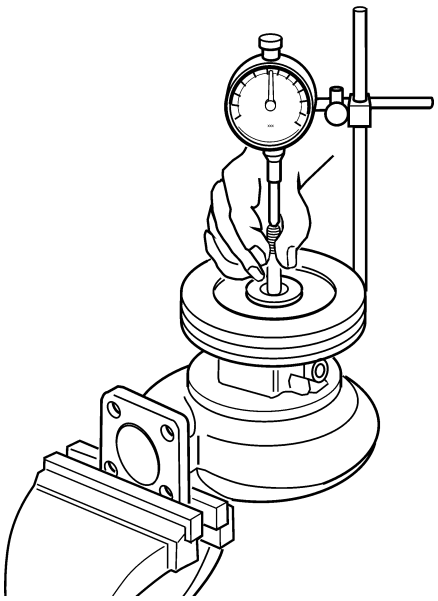


Installing the snap ring

Install the snap ring with the tapered side face up in the bearing housing. **Make sure you install the snap ring correctly!**



NOTE! Lightly drive both ends of the snap ring using a screwdriver and hammer to securely insert the ring into the groove on the bearing housing. Make sure the screwdriver does not hit the bearing housing.



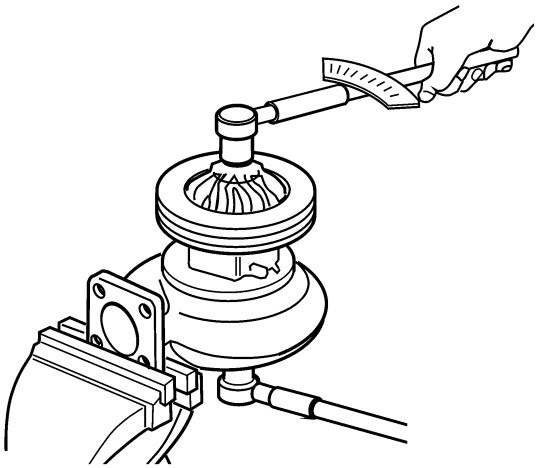
Turbine wheel and housing clearance

Set a dial gauge on the end face of the shaft & turbine wheel. Read the dial gauge indication while moving the shaft & turbine wheel in the axial direction.

If the dial gauge indication deviates from the assembly standard, disassemble and locate the cause of the problem.

Clearance turbine wheel and housing, mm [in.]

Standard Clearance .. 0.63–1.18 [0.02480–0.04646]

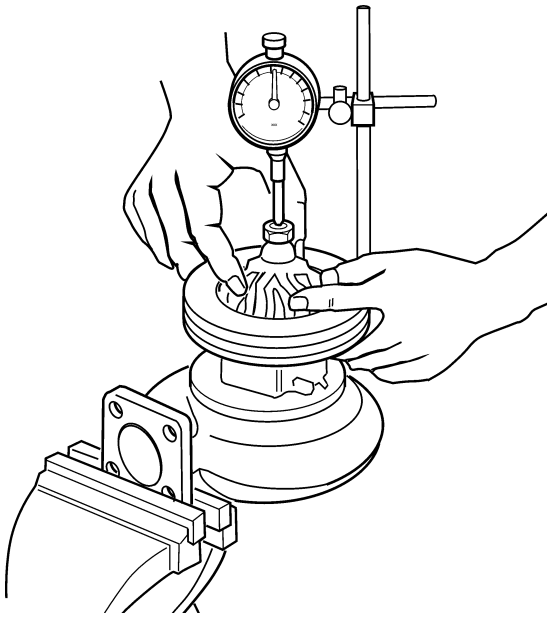


Installing the compressor wheel

Install the compressor wheel. Tighten the lock nut to the specified torque.

Lock nut tightening method

1. Tighten the lock nut to torque of 69 N•m (7 kgf•m) [51 lbf•ft], then loosen it completely.
2. Apply Loctite No. 962T to the threads.
3. Retighten to a snug torque of 9.8 N•m (1 kgf•m) [7.2 lbf•ft], then turn another 90±3°.



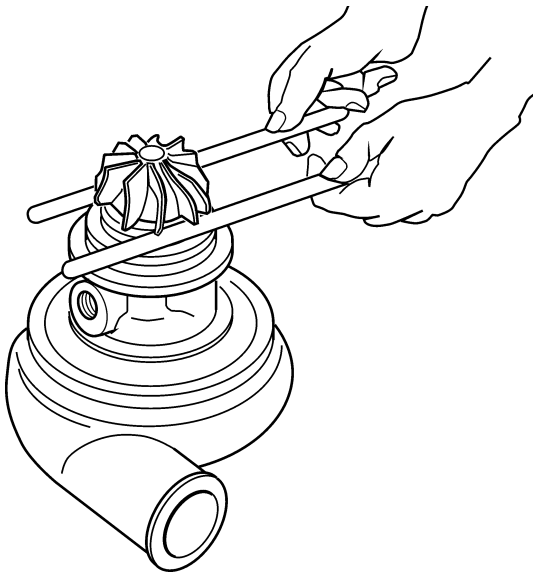
Shaft & turbine wheel axial play

Set a dial gauge on the end face of the shaft & turbine wheel. Measure the amount of play while moving the compressor wheel in the axial direction.

If the measured play deviates from the standard value, disassemble and locate the cause of the problem.

Shaft & turbine wheel axial play, mm [in.]

Assembly Standard ... 0.075–0.135 [0.00295–0.00531]



Turbine wheel and backplate clearance

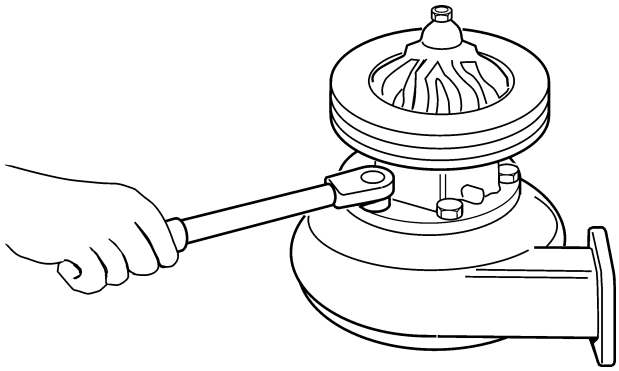
Remove the turbine housing from the bearing housing and install the compressor cover. Measure the clearance between the turbine backplate and the back side of the turbine wheel using feeler gauges.

NOTE! Use two feeler gauges, and measure at vane tips.

If the clearance deviates from the assembly standard, disassemble and locate the cause of the problem.

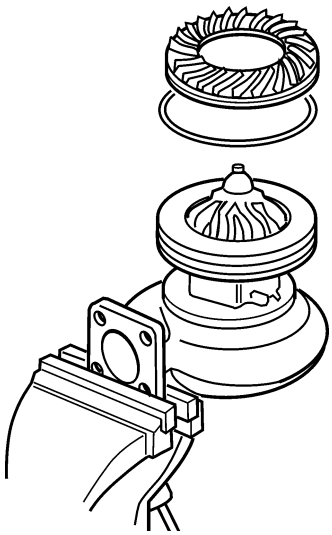
Turbine wheel and turbine backplate clearance, mm [in.]

Standard Clearance .. 0.85–1.35 [0.03346–0.04528]



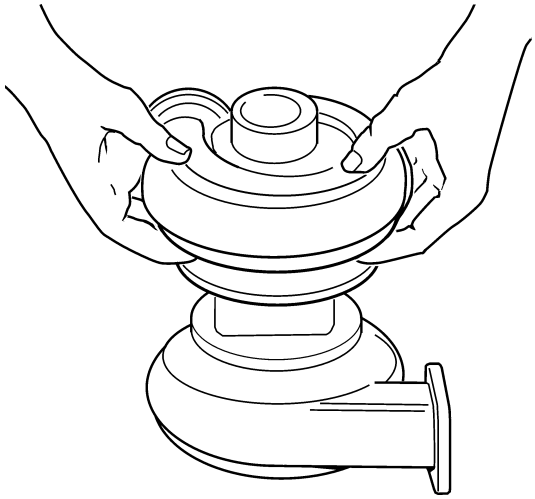
Installing the turbine housing

1. Check the mounting direction of the turbine housing, then install on the bearing housing.
2. Apply Moly Disulfide to the threads of the bolt, and tighten to the specified torque.



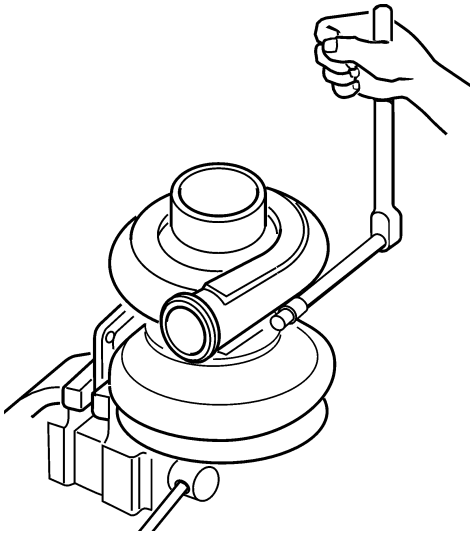
Installing the diffuser

1. Apply grease to the diffuser and install the bearing housing.
2. Install the diffuser.



Installing the compressor cover

Check the mounting direction of the compressor cover, then install.

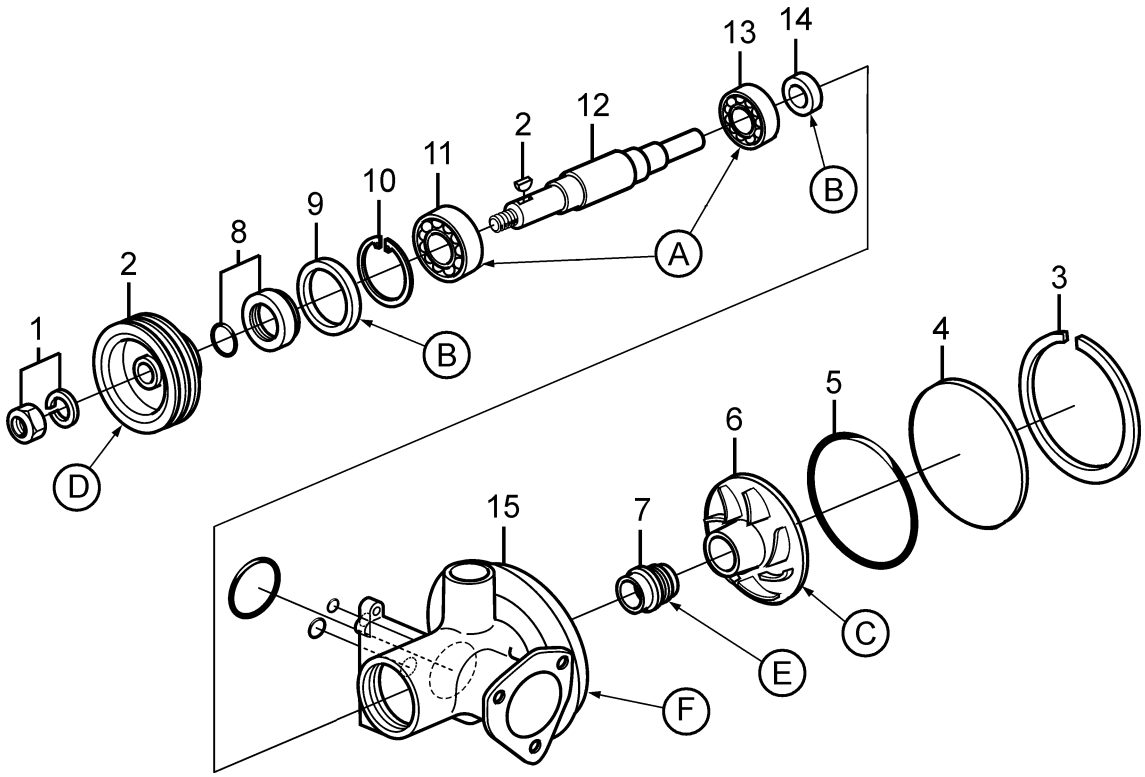


Installing the V-clamp

Install the V-clamp to the compressor cover and tap around it with a soft-faced hammer for more than times and tighten to the specified torque.

Group 26 Cooling System

Fresh Water Pump

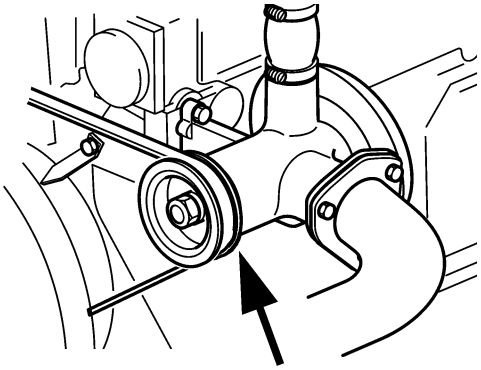


Disassembly

1. Nut, washer
2. Water pump pulley, key
3. Snap ring
4. CoverRing
5. O-ring
6. Impeller
7. Unit seal
8. Spacer, o-ring
9. Oil seal
10. Snap ring
11. Bearing
12. Water pump shaft
13. Bearing
14. Oil seal
15. Case

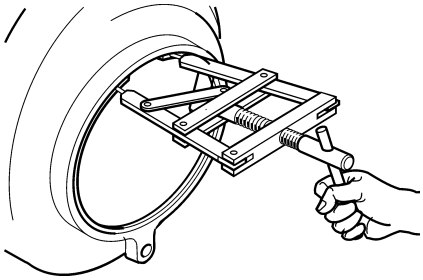
Look for:

A. Rotation
B. Wear, deterioration of lip
C. Corrosion, feathering
D. Wear, damage of belt groove
E. Wear, damage
F. Corrosion, cracks, damage



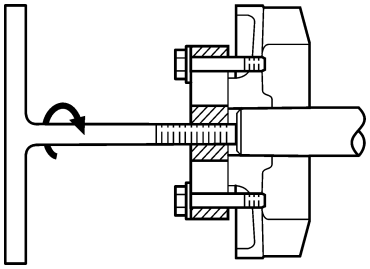
Fresh water pump

Touch the drain port located at the bottom of the pump with your finger. If the port is leaking water, check the condition of the unit seal. If it is leaking oil, the oil seal is defective.



Remove the impeller

1. Remove the snap ring the water pump pliers then remove the cover.



2. Remove the impeller with the impeller remover.

Remove the water pump shaft

1. Remove the snap ring from the front bearing.
2. Drive the pump shaft out towards the gear side, complete with bearing, using a press or a soft hammer.

NOTE! Be careful not to damage the pump shaft or the impeller when removing the impeller fron the shaft.

Inspection

Water pump

Measure the inside diameter of the pump case bore to which the bearing outer race is fitted. Measure the diameter of the pump shaft on which the bearing inner race is fitted. If the bearing, case, or shaft is worn, replace it

Inside diameter of pump case bearing, mm [in.]

Nominal value ..... Ø80 [3.15]
Assembly standard ... 79.988–80.018 [3.14913–3.15031]
Service limit ..... 80.025 [3.15058]

Pump case bore diameter, mm [in.]

Nominal value ..... Ø90 [3.54]
Assembly standard ... 89.987–90.022 [3.54279–3.54417]
Service limit ..... 90.025 [3.54428]

Bearing Diameter, mm [in.]

Nominal value ..... Ø80 [3.15]
Assembly standard ... 79.985–80.000 [3.14902–3.14961]

Bearing Diameter, mm [in.]

Nominal value ..... Ø90 [3.54]
Assembly standard ... 89.985–90.000 [3.54272–3.54331]

Bearing Inside diameter, mm [in.]

Nominal value ..... Ø40 [1.57]
Assembly standard ... 39.988–40.000 [1.57433–1.57480]

Bearing Inside diameter, mm [in.]

Nominal value ..... Ø40 [1.57]
Assembly standard ... 40.002–40.013 [1.57488–1.57531]

Diameter of pump shaft, mm [in.]

Nominal value ..... Ø55 [2.17]
Assembly standard ... 55.011–55.024 [2.16578–2.16629]
Service limit ..... 39.995 [1.57460]

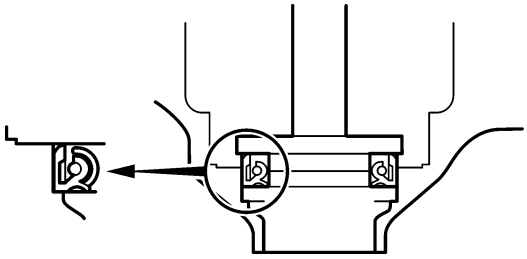
Reassembly

Reassembly sequence:

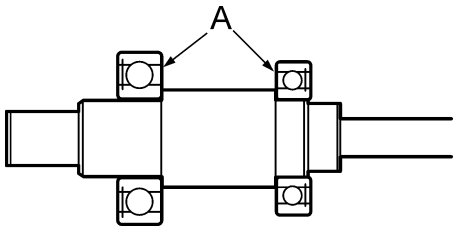
⑮ → ⑭ → ⑬ → ⑫ → ⑪ → ⑦ → ⑩ → ⑨ → ⑧ → ⑥ → ⑤ → ④ → ③ → ② → ①

NOTE! Replace O-rings, unit seal and oil seal at reassembly.

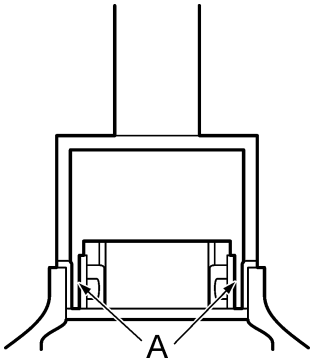
NOTE! Install the bearings to the shaft with sideplates on the oil side.



1. Use the oil seal installer to press-fit oil seal into case. Apply grease to the lip surface of the oil seal.



2. Install bearing s to the water pump shaft by striking with a hammer. Make sure the shield plate (A) of each bearing faces the oil seal side.

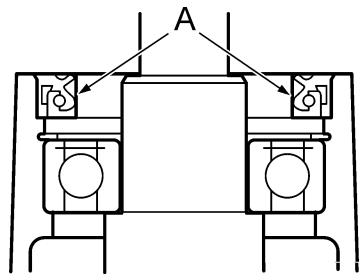


3. Use the unit seal installer to press-fit unit seal into case.

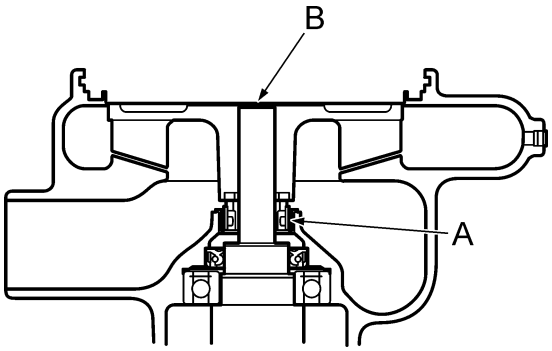
NOTE! If the unit seal is removed at disassembly, replace it at reassembly.

NOTE! Apply sealant to the periphery (A) of the unit seal.

4. Install the shaft to the case by striking with a hammer. Install the snap ring to secure it in place.

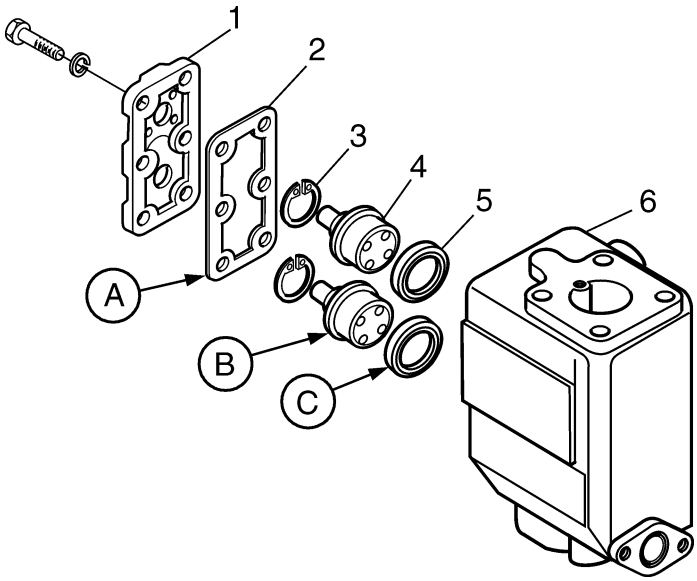


5. Use the oil seal installer to press-fit oil seal into case. Make sure the oils seal surface is flush with the case face. Apply grease to the lip surface (A) of the oil seal.



6. Install the floating seat (A) of the unit seal to the impeller and install the impeller to the pump shaft by striking with a hammer. Make sure end faces are flush (B).

Thermostats

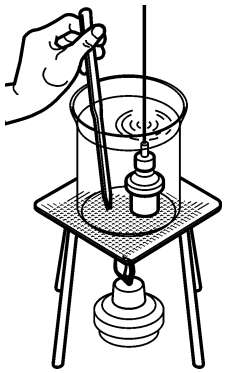


Disassembly

1. Thermostat cover
2. Packing
3. Snap ring
4. Thermostat
5. Thermostat seal
6. Thermostat case

Look for:

A. Deteriorated, worn, cracked
B. Replace packing
C. Worn, cracked



Inspection

Heat the thermostat in the water. Measure the temperature when the valve opens. Measure it again when the valve lift is 11 mm [0.43 in.]. Replace if not within standard.

Opening temp., °C [°F]

Assembly standard ... 71±2 [159.8±3.6]

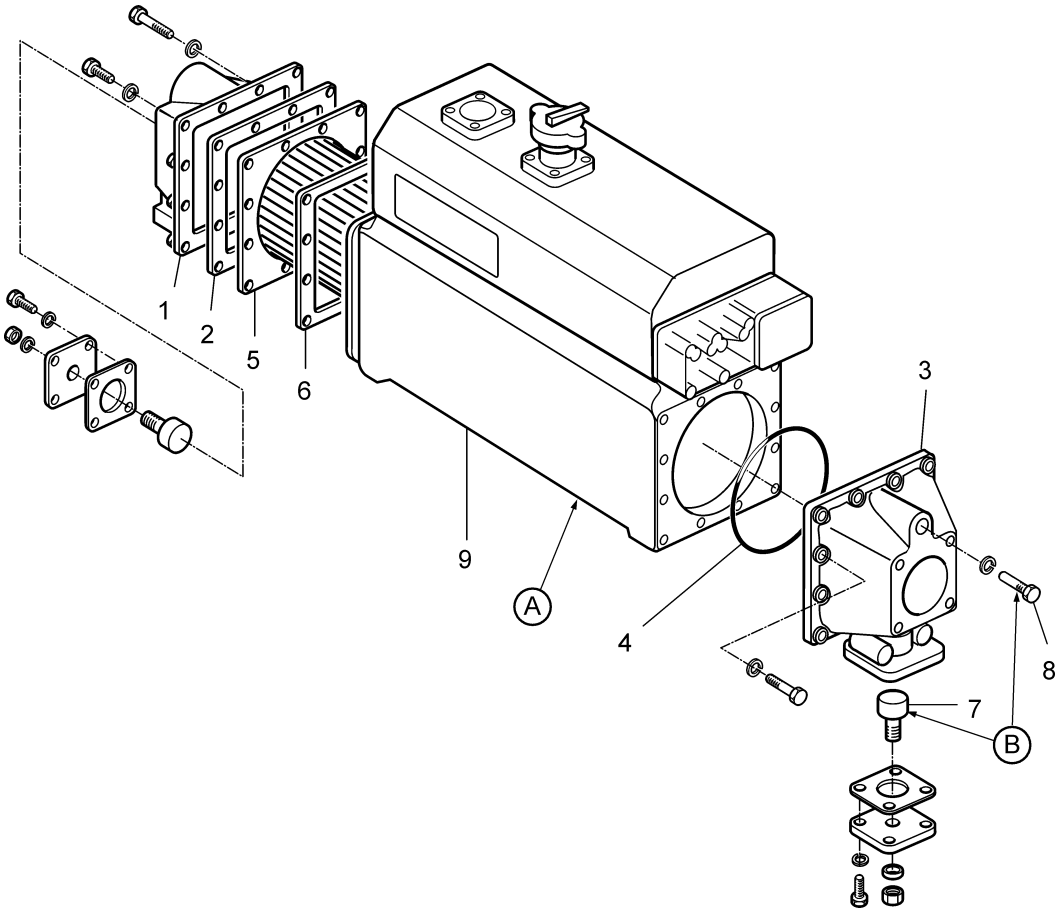
Valve lift 11 mm [0.43 in.] temp., °C [°F]

Assembly standard ... 85 [185]

NOTE! Stir the water to maintain even temperatures during the test.

NOTE! Confirm the valve opening temperature (stamped on its mounting flange).

Heat Exchanger



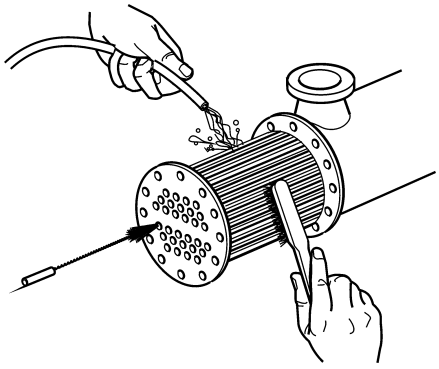
Disassembly

1. Cover
2. Packing
3. Cover
4. O-ring
5. Zinc rod
6. Element
7. Body

Look for:

A. Pipes clogged, leaks

B. Change if less than 50% remains

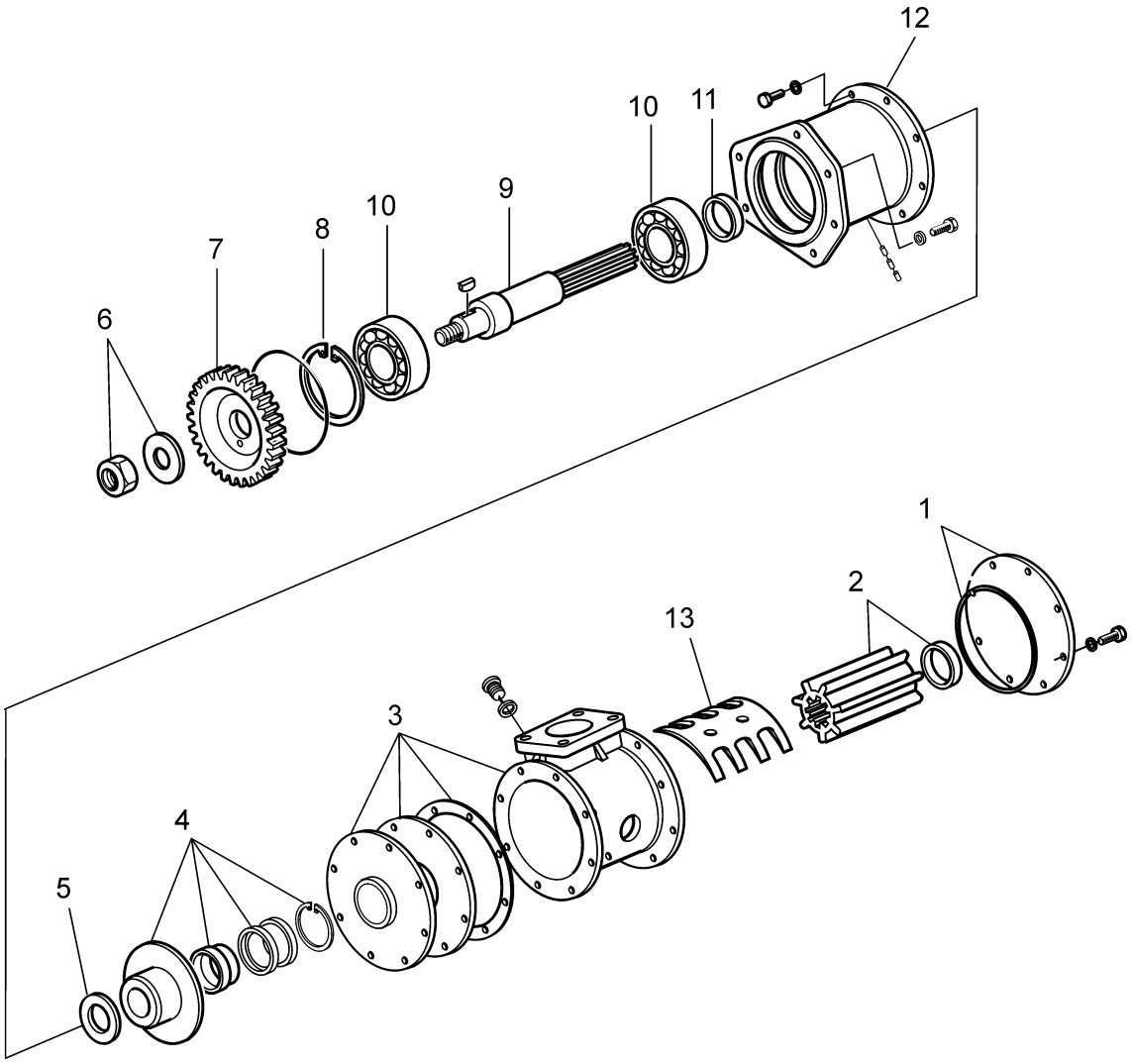


Inspection

Cleaning of element

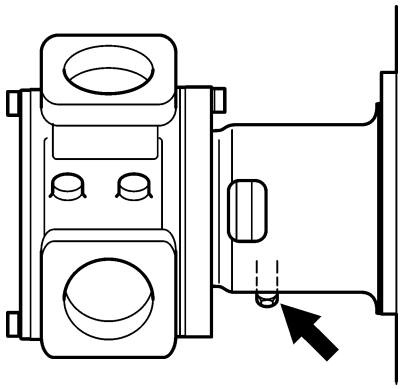
1. While pouring running water onto the outer surface of the element, clean with a wire brush. Check the element for corrosion and tears.
2. Insert a stick into the pipe and remove deposits.

Raw Water Pump(standard rubber impeller)



Disassembly

1. Cover, O-ring
2. Impeller
3. Casing, gasket, plate, gasket
4. Bushing, unit seal
5. Slinger
6. Nut, spring washer
7. Gear
8. Snap ring
9. Shaft, key
10. Bearing
11. Oil seal
12. Holder
13. Cam



Inspection

Inspect mounted pump

Touch the drain port located at the bottom of the pump with your finger. If the port is leaking water, check the condition of the unit seal. If it is leaking oil, the oil seal is defective.

Bearing dimensions

Measure the dimensions of the bearing installation sections of the sea water pump holder and shaft. If excessive wear or damage is observed, replace the bearing, holder and shaft.

Inside diameter at bearing position, mm [in.]

Nominal value ..... Ø90 [3.54]
Assembly standard ... 89.975–90.011 [3.54232–3.54369]
Service limit ..... 90.013 [3.54381]

Bearing outside diameter, mm [in.]

Nominal value ..... Ø90 [3.54]
Assembly standard ... 90.000–90.015 [3.54330–3.54389]

Bearing inside diameter, mm [in.]

Nominal value ..... Ø30 [1.57]
Assembly standard ... 29.990–30.000 [1.18071–1.18110]

Bearing inside diameter, mm [in.]

Nominal value ..... Ø40 [1.57]
Assembly standard ... 39.988–40.000 [1.57433–1.57480]

Shaft diam. at bearing position, mm [in.]

Nominal value ..... Ø30 [1.18]
Assembly standard ... 30.002–30.012 [1.18118–1.18157]
Service limit ..... 29.995 [1.18090]

Shaft diam. at bearing position, mm [in.]

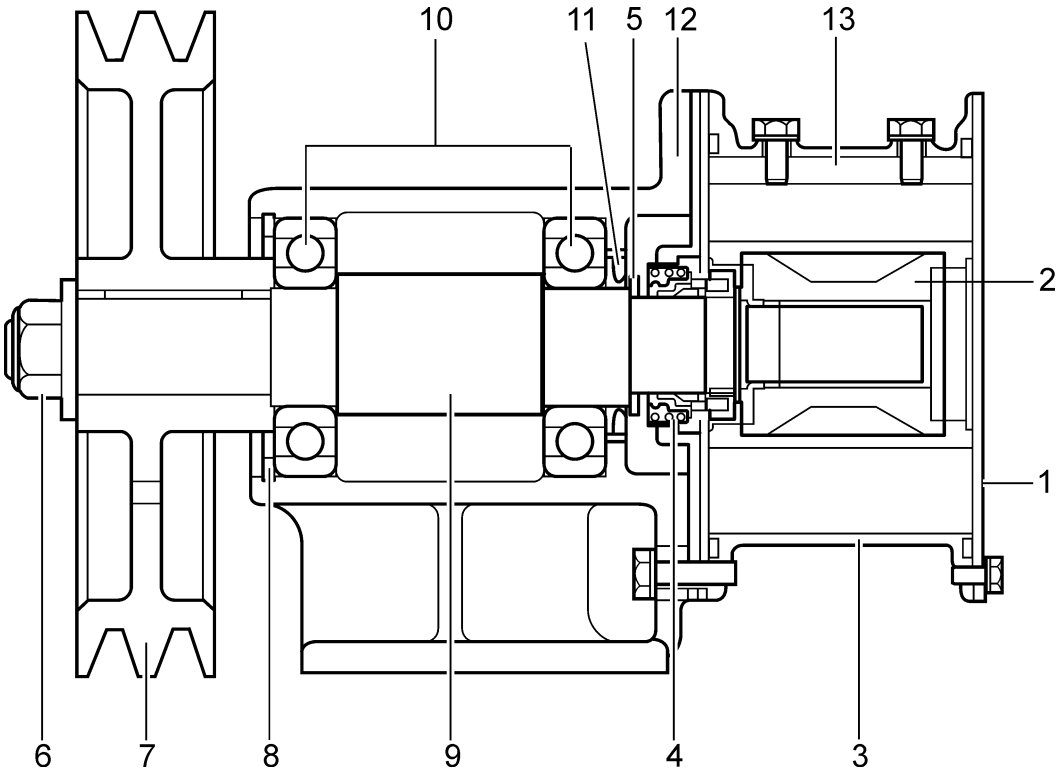
Nominal value ..... Ø40 [1.57]
Assembly standard ... 40.002–40.013 [1.157488–1.57531]
Service limit ..... 39.995 [1.57460]

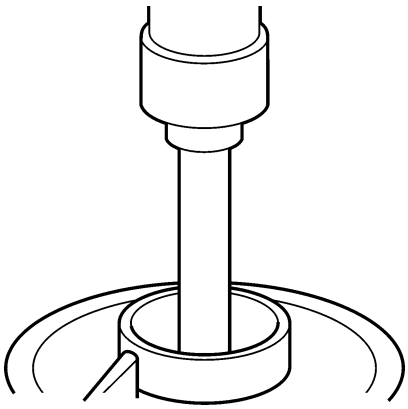
Reassembly

Reassembly sequence:

⑫ → ⑪ → ⑨ → ⑧ → ⑤ → ④ → ③ → ② → ① → ⑦ → ⑥

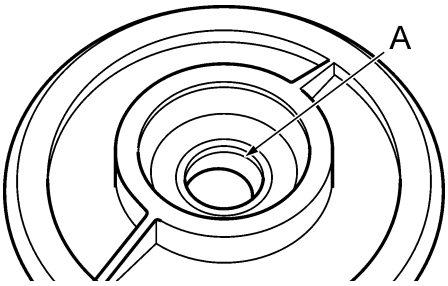
⑩ ↑ ⑬ ↑



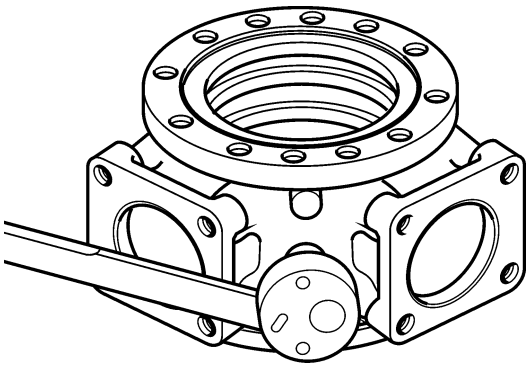


1. Install the oil seal squarely to the holder using a jig and a hammer.

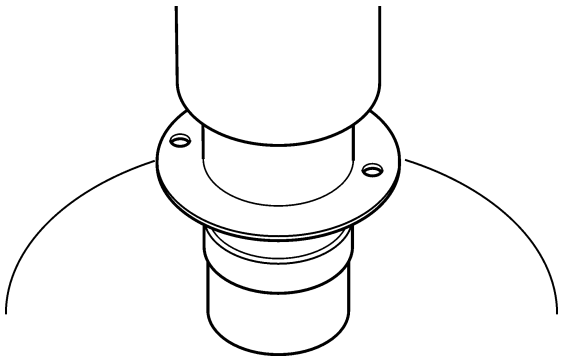
NOTE! Always replace the oil seal at reassembly.



2. Apply grease to the hollow section and the lip of the oil seal (A).

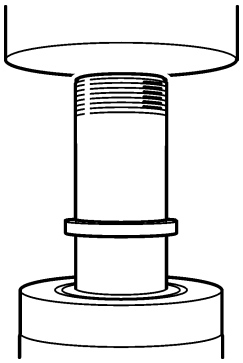


3. Install the cam to the casing, and tighten the screw to the specified torque. The contact surfaces must be coated with ThreeBond 1102.

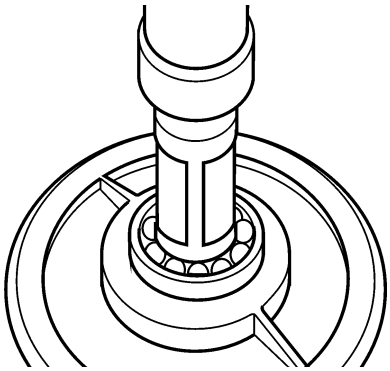


4. Install the unit seal to the bushing by striking with a hammer, making sure the unit seal remains square to the bushing during installation. The contact surface must be coated with ThreeBond 1102

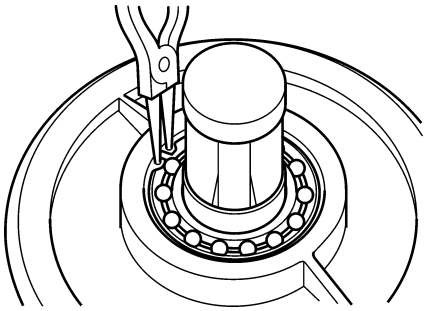
NOTE! Be sure to replace the unit seal with a new part



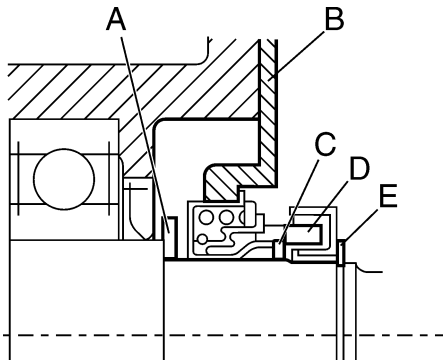
5. Using a jig and a hammer, install the bearing to the shaft, making sure the bearing remains square to the center line of the shaft.



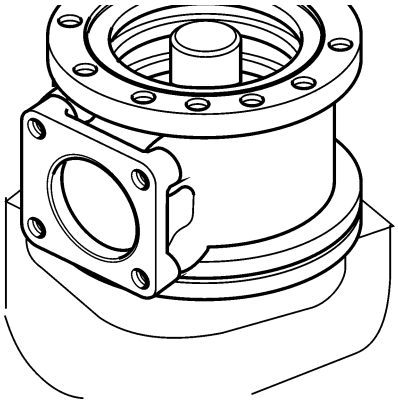
6. Install the shaft and the bearing assembly to the holder with a hammer.



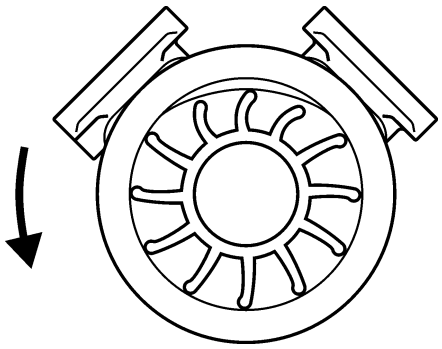
7. Install the snap ring to the holder.



8. Install the slinger (A) to the holder. Install the bushing (B) with unit seal to the holder. Clean the sliding surface (C) on the seat side of the unit seal with ethyl alcohol, then coat with turbine oil. Install the seat side (D) onto the shaft, and fasten with the snap ring (E).

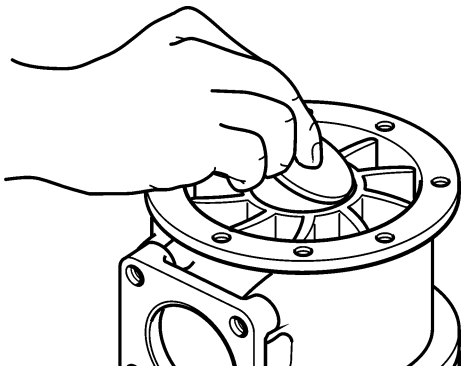


9. Install the casing to the holder via the plate. The contact surface must be coated with ThreeBond 1102. Tighten the bolts to 7.4 to 9.8 N*m (0.75 to 1.0 kgf*m) [5.42 to 7.23 lbf*ft].

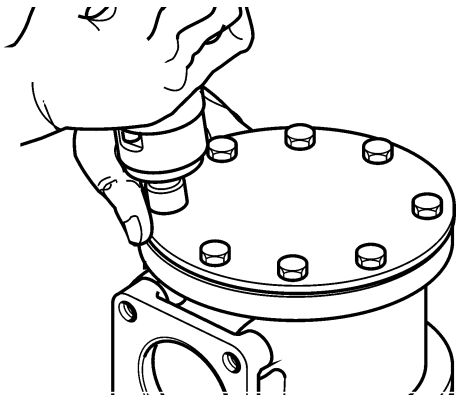


10. Install the impeller to the shaft by striking with a hammer.

NOTE! Make sure the impeller vane tips are pointed in the direction opposite to the rotational direction.

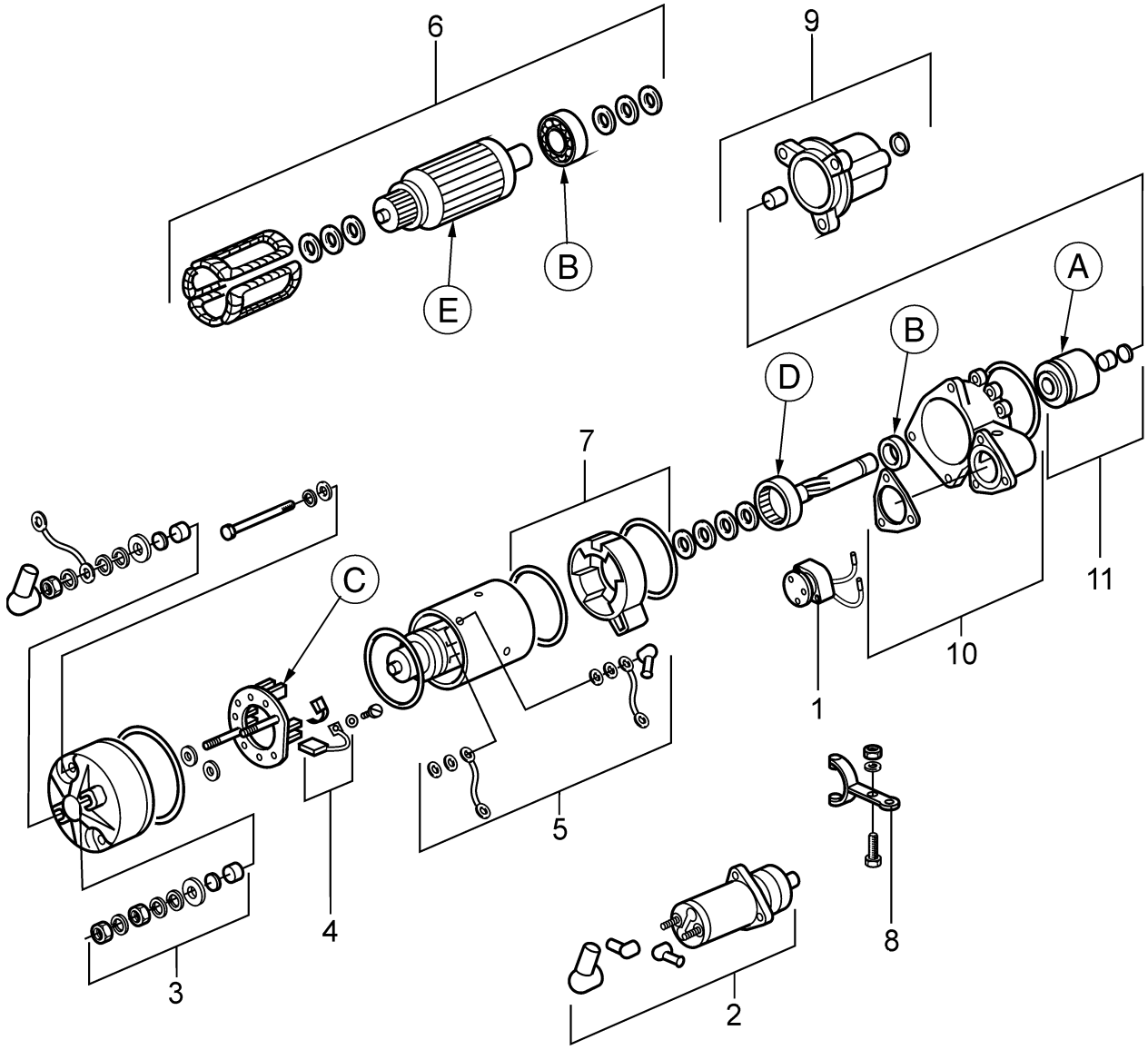


11. Install the impeller cover.



12. Install the O-ring to the casing, and mount the cover. Tighten the bolts to the specified torque.
13. Tighten the nut to secure the drive gear in place (tightening torque: 191.2–201.0 N•m (19.5–20.5 kgf•m) [141.0–148.3 lbf•ft]).

Group 30 Electrical System
Starter

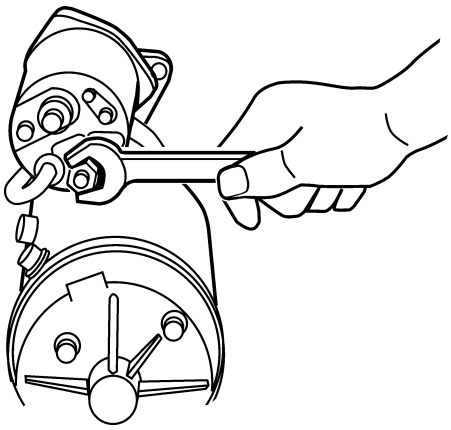


Disassembly

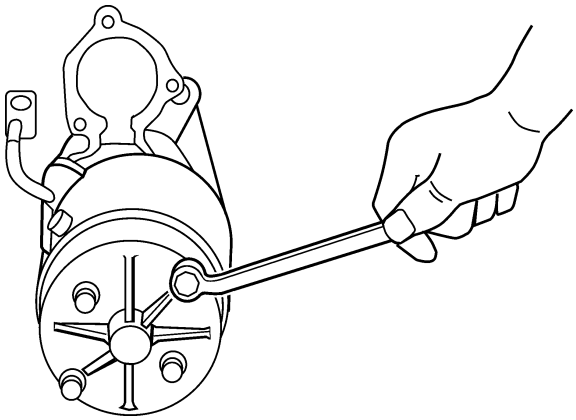
1. Safety switch
2. Magnetic switch assembly
3. Rear bracket
4. Brush holder assembly
5. Yoke assembly
6. Armature assembly
7. Center bracket
8. Shift lever assembly
9. Front bracket
10. Pinion case
11. Pinion clutch assembly

Look for

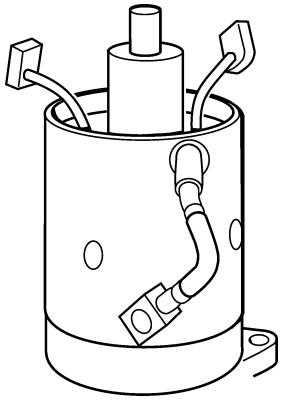
A. Wear of gear, damage
B. Play and unsmooth rotation
C. Adhesion of brush particles, irregular wear, brush movement in holder
D. Wear of gear
E. Surface roughness, seizure, wear and damage



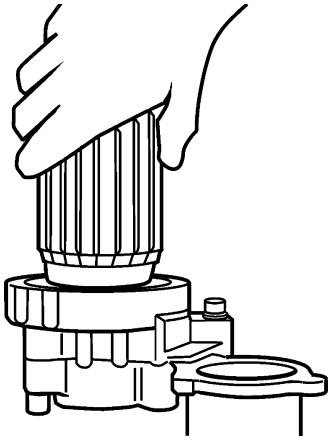
1. Remove the safety switch, wires and cables and the magnetic switch assembly.



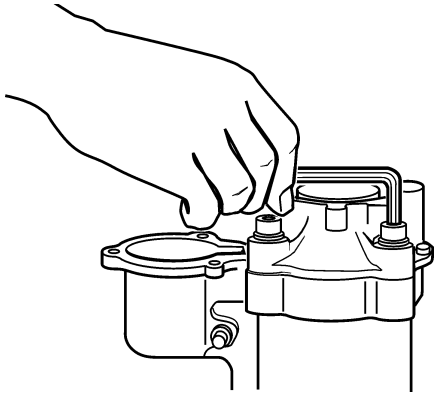
2. Unscrew the through bolts and the brush holder mounting screws. Remove the rear bracket.



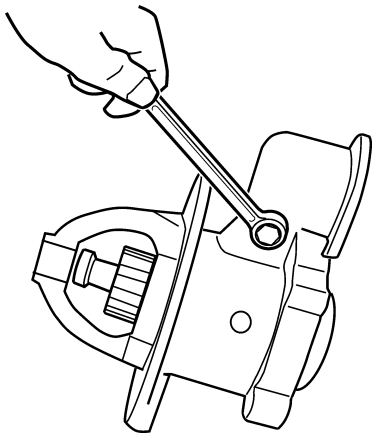
3. Remove the brushes from the brush holder assembly and then remove the yoke.



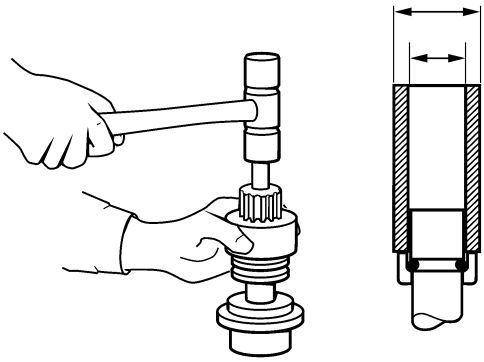
4. Pull out the armature assembly



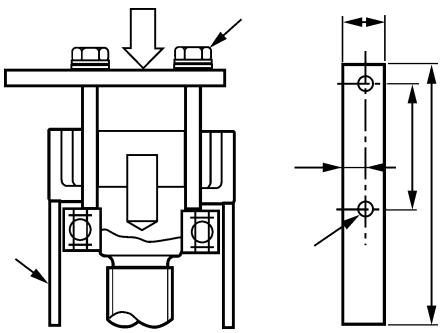
5. Remove the center bracket.



6. Remove the lever pin, inner housing, and shift lever from the pinion case.



7. Using a jig, remove the pinion stopper, then remove the overrunning clutch from the pinion shaft.

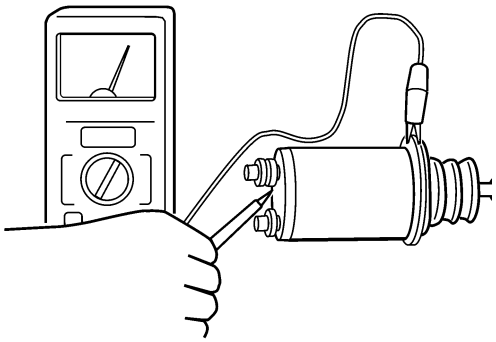


NOTE! To remove the shaft bearing for replacement, use a bearing puller as shown in the drawing.

Inspection and Repair

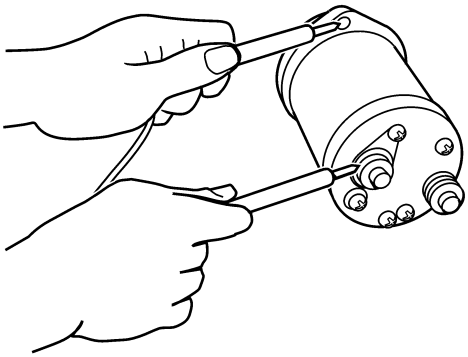
Magnetic Switch

Testing the magnetic switch coil

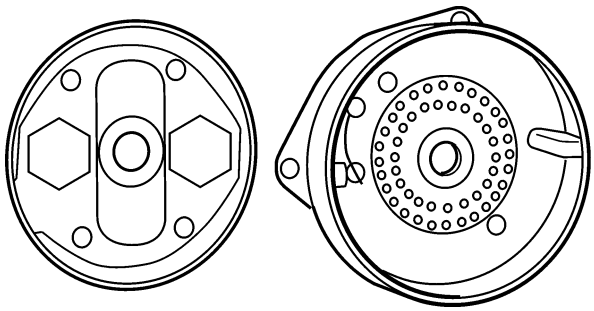


1. Test the pressure coil and holding coil for an open ciruit. The coils are open-circuited if there is no continuity between the M terminal of the magnetic switch and the case.

Resistance: 1.4 ohms (approx.)



2. Apply voltage of 24 volts between the M terminal of the magnetic switch and the case. Now push in the plunger by hand. When you release your hand, the plunger should not be attracted.



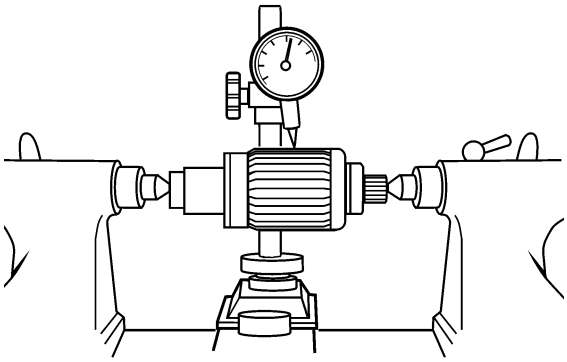
Testing magnetic switch contact points

Measure the load current flowing through the starter.

If the voltage drop between terminals B and M exceeds 0.3 volts per 100 amperes, clean or replace the contact points.

If the starter switch is tumed to OFF during voltage measurement, the battery voltage is directly applied to the voltmeter. This can damage the voltmeter. Always turn the starter switch to ON before measuring the voltage, then turn it OFF after measuring the voltage.

⚠ **IMPORTANT!** Do not apply 24 V on terminals to test the magnetic switch movement.



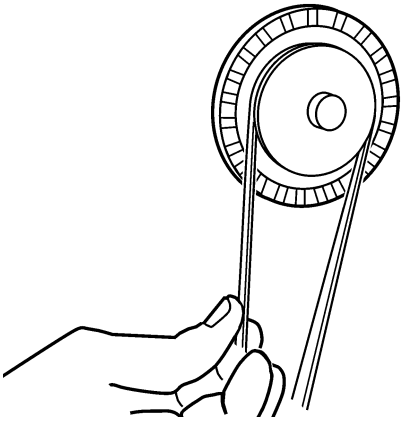
Armature

Measuring the armature runout

Measure the runout with a dial gauge. If the deflection exceeds the assembly standard, repair or replace the armature.

Armature deflection, mm [in.]

Assembly Standard ... 0.05 [0.00197]

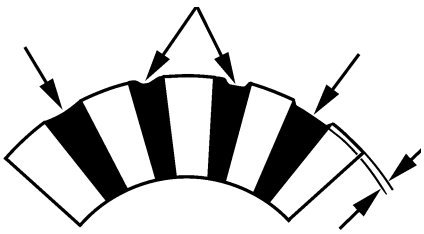


Inspecting the commutator

1. Check the condition of the commutator surface. If it is rough, polish it with #400 to #600 sandpaper. Check the commutator for runout with a dial gauge. Replace the commutator if the deflection exceeds the service limit.

Commutator deflection, mm [in.]

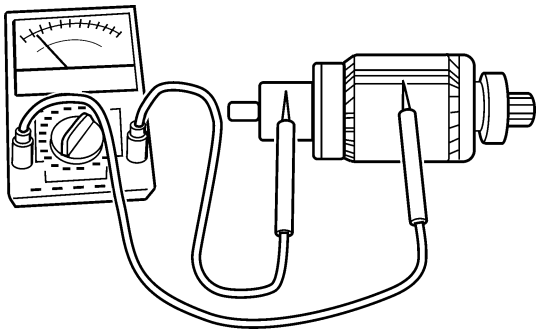
Assembly Standard ... 0.06 [0.0024] maximum
Service Limit ..... 0.10 [0.0039]



2. Measure the mica depth. Use a depth gauge to measure the depth of each mica undercut. If the depth exceeds the repair limit, re-condition the mica.

Commutator mica depth, mm [in.]

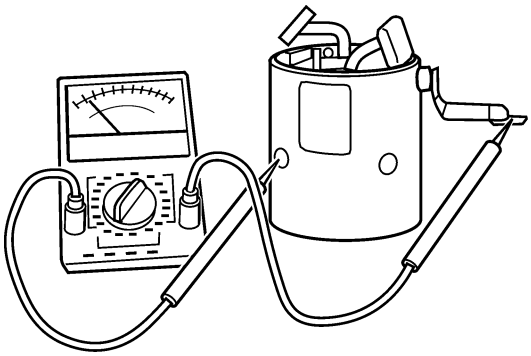
Assembly Standard ... 0.7 to 0.9 [0.028–0.035]
Repair Limit ..... 0.2 [0.0079]



Testing the armature

1. Use a growler to test the armature for short circuits. If the hacksaw blade vibrates against the core, replace the armature.

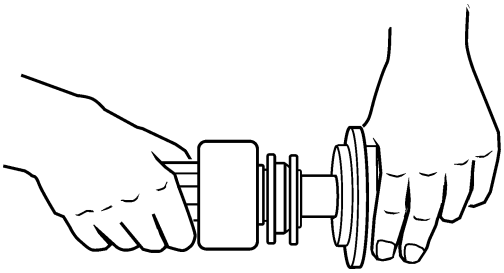
2. If there is continuity between the commutator and shaft, replace the armature.



Field coil

Testing for open circuits

1. If there is no continuity between the M terminal of the field coil and the lead wire on the brush side, replace the field coil.

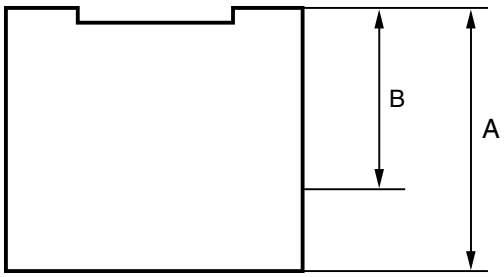


Overrunning Clutch

The clutch is in good condition if it rotates freely in one direction when tumed by hand.

Check the pinion teeth for wear or damage. If they are damaged, replace the pinion.

⚠ **IMPORTANT!** Do not immerse the overrunning clutch in cleaning solvent to clean it. Immersion in cleaning solvent Will cause grease inside the clutch to run out, causing clutch parts to seize when operating.



Brushes

Inspecting for wear

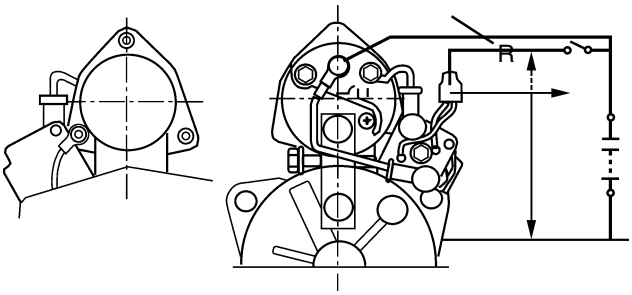
Brush height, mm [in.]

Assembly Standard ... 21–22 [0.83–0.87](A)
Service Limit ..... 13 [0.51](B)

Testing brush spring tension

Brush spring tension, N (kgf) [lbf]

Assembly Standard ... 39.23–49.03 (4.0–5.0 [9–11]
Service Limit ..... 39.23 (4.0 [9] maximum



Safety Switch

Connect the safety switch as shown, and check the starter and safety switch operations.

1. Connect the R terminal to the battery minus (-) side.

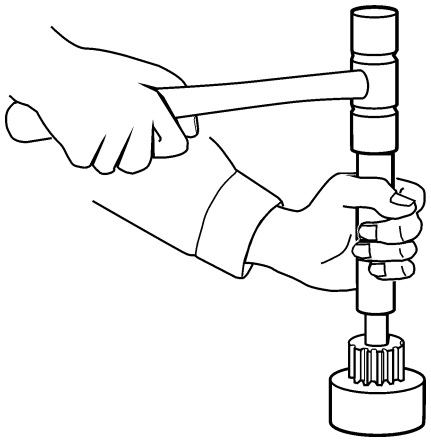
2. Turn the switch on, and check that the starter tums.

3. After step (2) above is completed, if you remove the R terminal from the battery minus (-) side, or if you connect the terminal to the battery plus (+) side after removal, make sure you stop the starter operation.

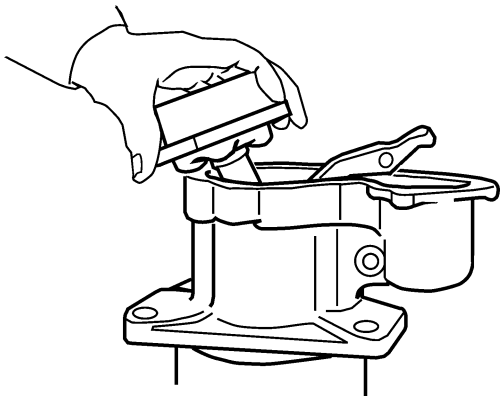
   ⚠ **IMPORTANT!** When you are making connections, pay special attention to the battery's polarity.

Reassembly

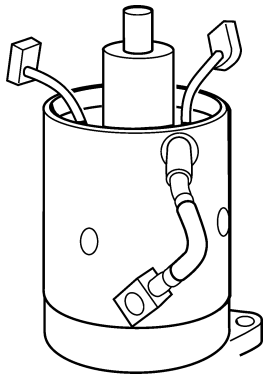
Reassembly sequence: ⑨→⑧→⑩→⑦→⑥→⑤→④→③→②→①



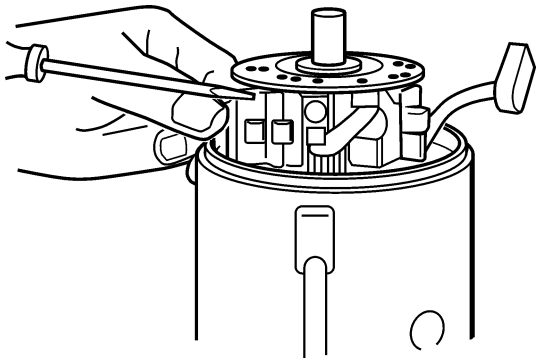
1. Install the center bracket, overrunning clutch, and pinion stopper to the pinion shaft. Insert the shaft in position by tapping it with a soft-head mallet.



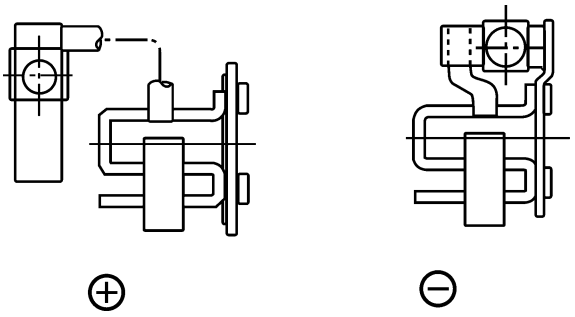
2. Install the shift lever and pinion shaft to the front bracket by aligning the matching mark on the shifi lever.



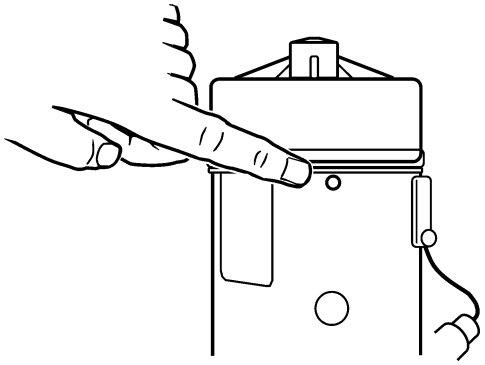
3. Install the armature and yoke to the center bracket, making sure that the dowel pin enters its hole.



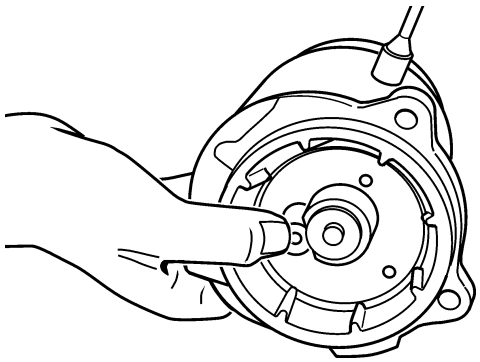
4. Install the brushes and brush holders.



NOTE! Install the positive (+) side brush and negative (-) side brush as shown.



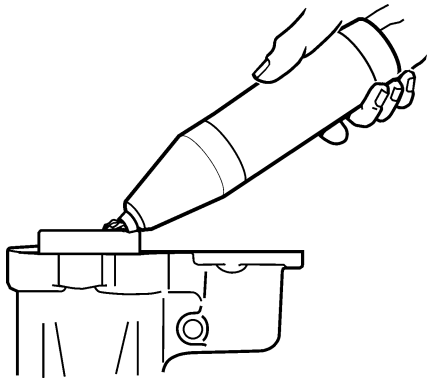
5. Install the rear bracket to the yoke by aligning the matching marks. Secure the brush holders with bolts, then tighten the through bolts.



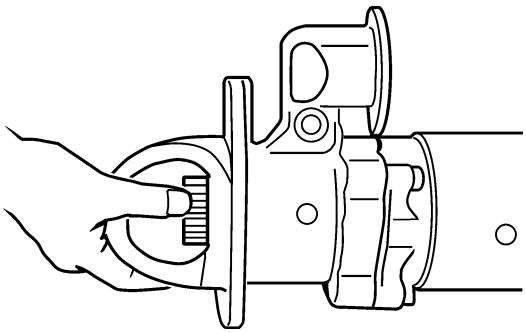
6. Measure the end play of the armature. If the end play exceeds the assembly standard, adjust it on the rear side.

Armature end play, mm [in.]

Assembly Standard ... 0.3–0.7 [0.012–0.028]



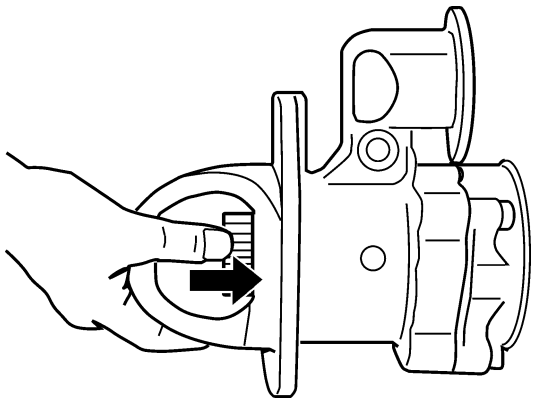
7. Liberally coat the internal gear with grease, then install the pinion shaft to the gear.



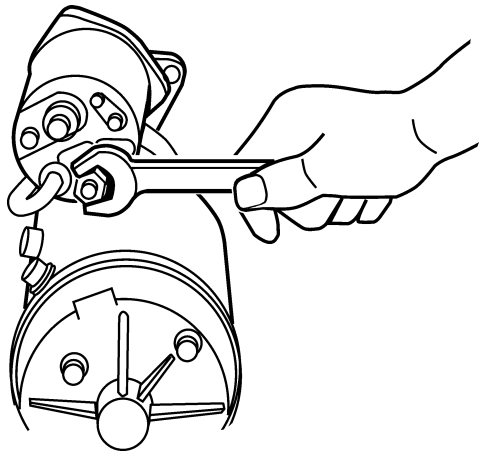
8. Measure the end play of the pinion shaft. If the end play exceeds the assembly standard, adjust it on the internal gear side.

Pinion shaft end play, mm [in.]

Assembly Standard ... 0.2–0.8 [0.008–0.031]

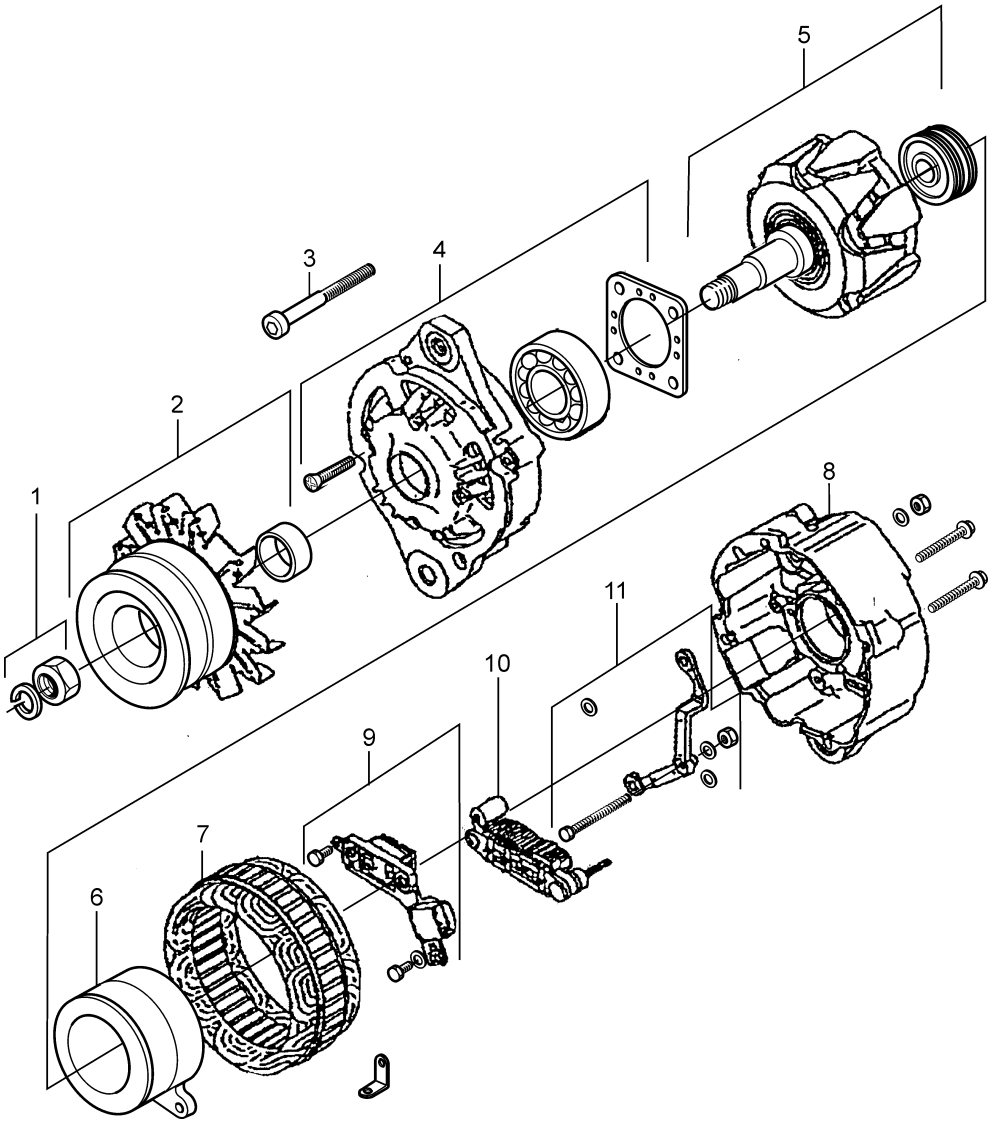


9. Install the magnetic switch. Apply a voltage of 24 volts between the C and E terminals. Connect the lead wire and energize the circuit between the M and E terminals (within 1 setond). After the pinion has shifted, measure retraction length of the pinion. If the measurement is not within 2.5 to 5.5 mm CO.098 to 0.22 in.], use the magnetic switch adjusting screw to make adjustments.



10. Secure the lead wire.
11. Install the safety switch.

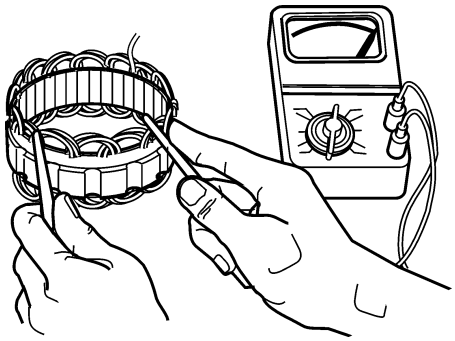
Alternator



Disassembly

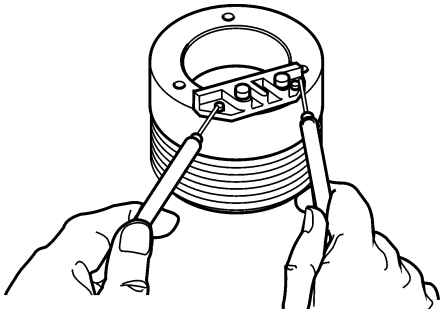
1. Nut, washer
2. Pulley assembly
3. Set screw
4. Front bracket assembly
5. Rotor assembly
6. Field coil
7. Stator
8. Rear bracket
9. Regulator assembly
10. Rectifier assembly
11. Terminal assembly

Inspection and repair



Stator

1. Testing the stator coil for open circuits
   If there is no continuity among the three lead wires, replace the stator.
2. Testing the stator coil for grounding
   If there is continuity between the coil and core, replace the stator.

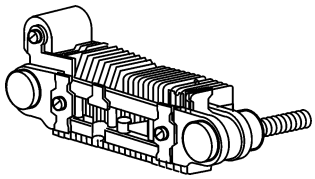


Field coil

Measure resistance between the terminals of the field coil. If the measured resistance deviates from the standard value, replace the coil.

Field coil resistance, Ω

Assembly Standard ... 7.3–8.6



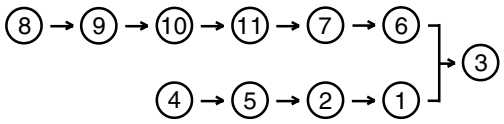
Inspecting rectifier

To check individual diodes, measure resistance between the diode lead wire and heat sink. Connect the positive (+) test lead wire to the diode and measure resistance. Then, connect the negative (-) test lead wire to the diode and measure resistance again. If both measured values are close to 0 (zero), the circuit is shorted.

NOTE! If the diode has an open circuit or is shorted, it is defective, and the rectifier must be replaced.

Reassembly

Reassembly sequence



⚠ **WARNING!** The alternator requires no grease. Keep the bearing box free of oil and grease since oil and grease can cause creeping of the bearing on the rear side.

⚠ **WARNING!** Heat the bearing box of the rear bracket for assembly.

Notes

Notes

Notes

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