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GENERAC® POWER SYSTEMS, INC.

# 37.0 LITER

## DIESEL

**Mitsubishi**

S12H

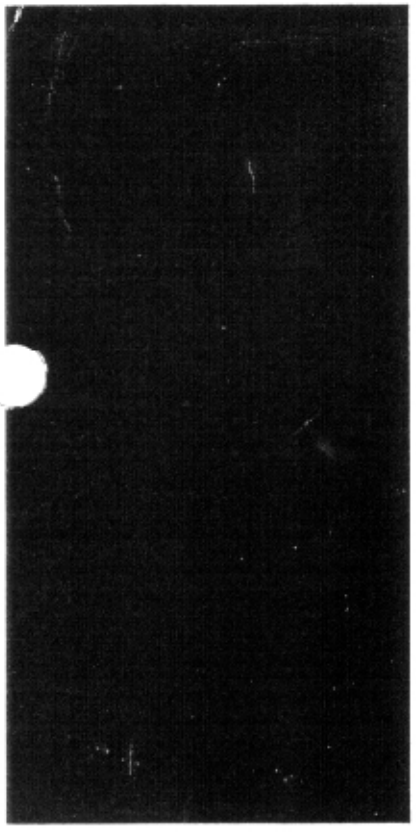
# *ENGINE SERVICE MANUAL*

*P.O. BOX 8 WAUKESHA WI 53187*

*PRINTED IN U.S.A.*

*ISSUED: 2001*

# SERVICE MANUAL



# MITSUBISHI DIESEL ENGINE

# S12H

# 1020kW

MITSUBISHI
HEAVY INDUSTRIES, LTD.

# INTRODUCTION

This Service Manual is written to familiarize you with the specification, maintenance and service procedures of your Mitsubishi Diesel Engine.

For long productive life and efficient performance, it is essential to perform proper operation and regular maintenance together with appropriate disassembly, inspection, modification and assembly.

We hope you read this manual carefully to get to know your new engine and learn how to service it before starting disassembly, inspection and repair, and reassembly.

The description contained in this manual is of the serial number of the engine manufactured at the time this manual was approved for printing.

Mitsubishi reserves the right to change specifications or design without notice.

Pub. No. 99269-03100

# SCOPE AND HOW TO USE THIS MANUAL

This Service Manual covers the standard specification model of Mitsubishi Diesel Engine and describes, group by group, the specifications, maintenance standards, adjustments, disassembly, inspection and repair, and reassembly of the engine.

The groups and their contents will be found in "Table of contents" and the contents of each group in the first page of the group.

The operation and periodical maintenance are described in OPERATION & MAINTENANCE MANUAL, the component parts and ordering of service parts in PARTS CATALOGUE and the construction and function in the various training manuals.

## 1. HOW TO USE THIS MANUAL

(1) The parts in the texts or shown in the illustrations are numbered in the disassembling sequence prescribed for each system or assembly.

(2) The item to be inspected during disassembly are indicated in [ ] in the disassembled view.

(3) The maintenance standards to be referred to for inspection and repairs are indicated in easy-to-refer passages of the texts and also in GROUP No. 2 in a tabulated form.

(4) The sequence in which the parts are to be reassembled are shown in the form of, for example, ⑤→②→④→③→① below the assembled view.

(5) The following marks are used in this manual to emphasize important and critical instructions:

⚠**DANGER** — Operating procedures, practices, etc., which if not correctly followed, will result in personal injury or loss of life.

⚠**WARNING** — Operating procedures, practices, etc., which if not strictly followed, may result in personal injury or loss of life.

⚠**CAUTION** — Operating procedures, practices, etc., which if not strictly followed, will result in minor/medium injury or destruction of engine.

**NOTE**———— Additional explanations

(6) Tightening torque in "wet" conditions is indicated as [wet]. Unless indicated as such, the torque is to be considered in "dry" condition.

## 2. DEFINITION OF TERMS

Nominal value ———— Indicates the standard dimension of a part.

Assembly standard —— Indicates the dimension of a part, the dimension to be attained at the time of reassembly or the standard performance. Its value is rounded to the nearest whole number needed for inspection and is different from the design value.

Standard clearance —— Indicates the clearance to be obtained between mating parts at the time of reassembly.

Repair limit ———— A part which has reached this limit must be repaired.

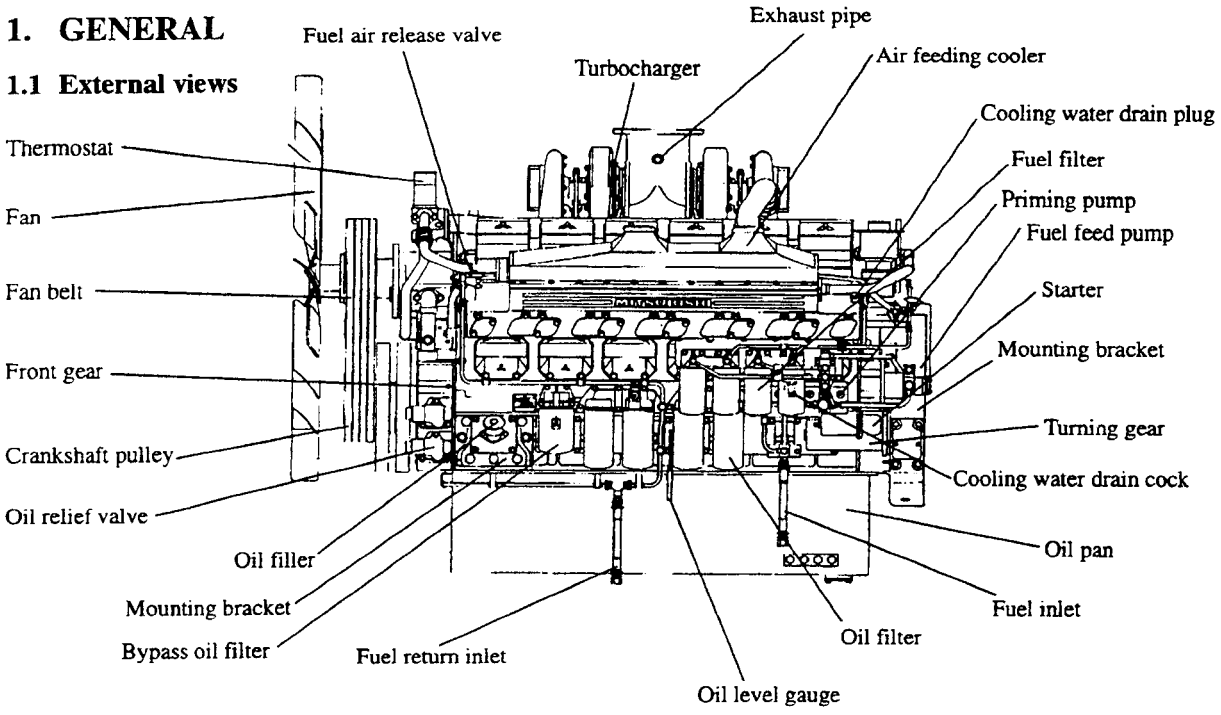
Service limit ———— A part which has reached this limit must be replaced.

# TABLE OF CONTENTS

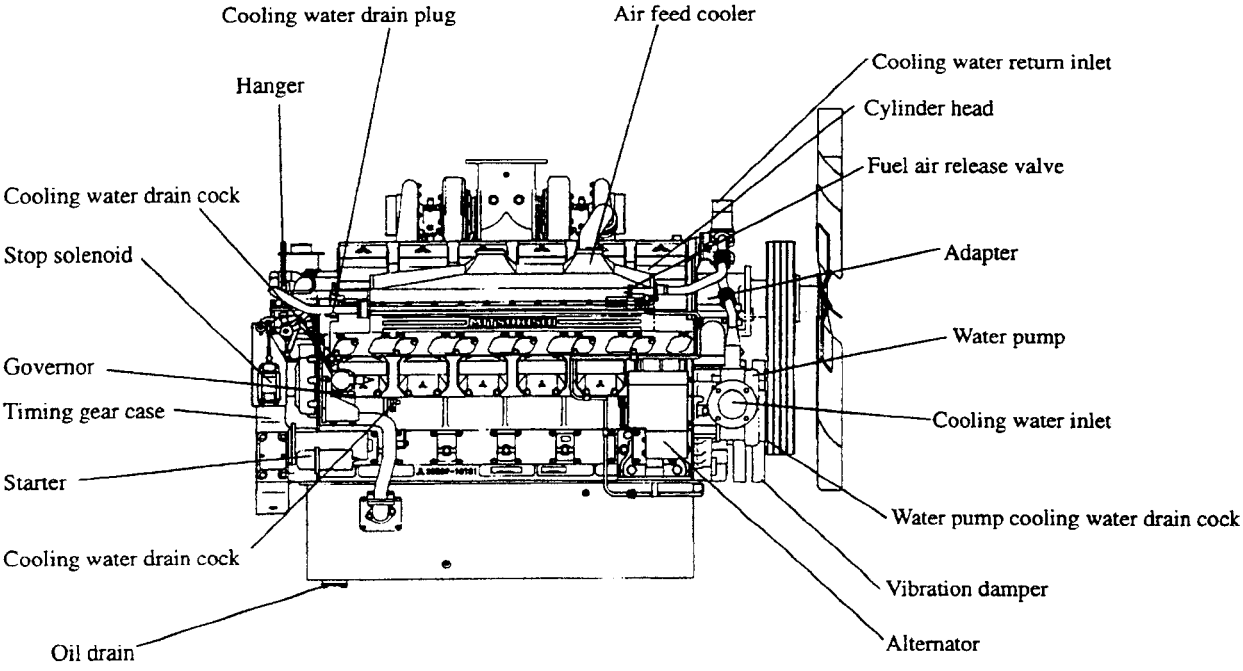
# GENERAL

# 1. GENERAL

## 1.1 External views




Left side




Right side

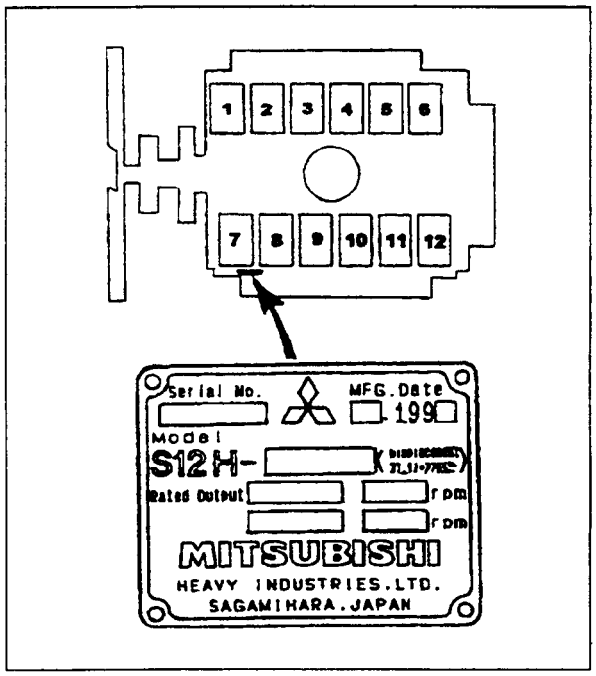
## 1.2 Engine serial number location

The engine serial number is stamped on the nameplate attached to the right front side of the engine.

<Example>

| Model | Serial number |
|---|---|
| S12H | 30012 |

On the nameplate are also stamped the engine serial number, output and rated speed. The numbers in the illustrations show cylinder numbers.




## 1.3 Engine model and application codes

S □□-□□

- Sagamihara Machinery Works
- No. -of-cylinders code
- Series code
- Application code { P ..... Generator drive and prime power; L ..... Locomotive drive; MP .... Marine generator drive and marine general mechanical drive
- { "TA" ..... stands for turbocharged, aftercooled unit.; "TK" ..... stands for turbocharged, aftercooled unit.

## 2. SPECIFICATIONS

| Model designation | | | | S12H | |
|---|---|---|---|---|---|
| | | | | TA | TK |
| General | Type | | | Water-cooled, 4-stroke cycle diesel, turbocharged | |
| | | | | After-cooled | Inter-cooled |
| | No. of cylinders - arrangement | | | 12V | |
| | Combustion chamber type | | | Direct injection | |
| | Valve mechanism | | | Overhead | |
| | Cylinder bore × Stroke | | mm [in.] | 150×175 [5.91×6.9] | |
| | Piston displacement | | ℓ [U.S.gal.] | 37.11 [9.80] | |
| | Compression ratio | | | 14.0:1 | |
| | Fuel | | | Light oil (JIS K 2204 Special Grade 1 to Special Grade 3) or A heavy oil (Use reputable domestic brand fuel only) | |
| | Firing order | | | 1-12-5-8-3-10-6-7-2-11-4-9 | |
| | Direction of rotation | | | Counterclockwise as viewed from flywheel side | |
| | Dimensions (no fan) | Overall length | mm [in.] | 1954 [76.99] | |
| | | Overall width | mm [in.] | 1472 [58] | |
| | | Overall height | mm [in.] | 1694 [66.74] | |
| Engine proper | Weight (dry) | | N (kg) [lbf] | 38245.94 (3900) [8597.9] | |
| | Cylinder liner | Type | | Wet | |
| | Piston ring | Number | | Compression ring: 2<br>Oil ring (with expander): 1 | |
| | Valve timing | Inlet valve | Open | 55°BTDC | |
| | | | Close | 65°ABDC | |
| | | Exhaust valve | Open | 65°BBDC | |
| | | | Close | 55°ATDC | |
| | Valve clearance (cold) mm [in.] | Inlet | | 0.6 [0.024] | |
| | | Exhaust | | 0.8 [0.031] | |
| | Engine support | | | 4-point support | |
| | Starting system | | | Starter or air-motor | |
| IN and EX systems | Air cleaner | Type | | Paper element type or turbine silencer type | |
| | Turbocharger | Type | | TD 13 | |
| | | No. of units | | 2 | |
| | Air cooler | Type | | Laminated-fin plate type | |
| | | Water flow | Vℓ[U.S.gal]/min | 300 [79.26] (for both bank) | |
| Oil system | Lubrication system | | | Forced circulation (pressure feed by oil pump) | |
| | Engine oil | Specification | | Class CD oil (API Service Classification) | |
| | | Capacity (oil filter including | ℓ[U.S.gal] overall engine) | 200 (180 for oil pan only), approx.<br>[about 54.82 (47.56 for oil pan only)] | |
| | Oil pump | Type | | Gear pump | |
| | | Reduction ratio | | 1.125 (Z=64) | |
| | | Delivery capacity | ℓ[U.S.gal]/min | 370 [97.75] (at 1500 engine rpm)<br>450 [118.89] (at 1800 engine rpm) | |
| | | Safety valve | Type | Piston valve | |
| | | | Valve opening pressure MPa (kgf/cm²) [psi] | 1.4±0.1 (14±1)<br>[199±14] | |

| Model designation | | | S12H | |
|---|---|---|---|---|
| | | | TA | TK |
| Oil system | Relief valve | Type | Main gallery pressure detection type | |
| | | Valve opening pressure MPa{kgf/cm²}[psi] | 0.58±0.05 {5.9±0.5}[84±7] | |
| | Oil cooler | Type | Water-cooled multi-plate type | |
| | | Element | 15 layers (100 x 558mm [3.94 x 21.97 in.]) | |
| | Oil filter | Type Paper element (spin-on type) | | |
| | Bypass oil filter | Type Paper element (spin-on type) | | |
| | Oil filter alarm | Type | Piston valve with built-in electric contact point | |
| | | Valve opening pressure (differential pressure) MPa{kgf/cm²}[psi] | 0.23 - 0.26 {2.3 - 2.7}[33-38] (Contact points close at 0.15 - 0.18 MPa {1.5 - 1.8}[21-26]) | |
| | Oil cooler bypass valve | Valve opening pressure (differential pressure) MPa{kgf/cm²}[psi] | 0.44 {4.5}[64] | |
| | Piston cooling oil jet | Type | Check valve | |
| | | Valve opening pressure (differential pressure) MPa{kgf/cm²}[psi] | 0.29±0.03 {3±0.3}[43±4.3] | |
| Cooling system | Cooling type | | Water-cooled, forced circulation | |
| | Capacity (engine) | ℓ[U.S.gal] | 100 [26.42], approx. | |
| | Water pump | Type | Centrifugal | |
| | | Reduction ratio | 1,829 (75/41) | |
| | | Delivery capacity ℓ[U.S.gal]/min | 1450 [383] (at 1800 engine rpm) 1200 [317] (at 1500 engine rpm) | |
| | Thermostat | Type | Wax (2 stage opening/closing) | |
| | | Valve opening temperature °C[°F] | Primary valve: 71±2 [160±36], secondary valve: 74±2 [165±36], full opening: 85 [185] | |
| | Radiator | Type | Plate fin or corrugated fin | |
| | Cooling fan | Type | Starter or air motor | |
| | Fan belt | Type | Low-edge cog "C" (4 belts) | |
| | | Pulley ratio | 0.55 ···1800 rpm (248/448) 0.66 ···1500 rpm (248/373) | |
| | | Outer circumference mm[in.] | 2085[82.09] | 1955[76.97] |
| Fuel system | Injector | Type | Mitsubishi unit injector | |
| | | Manufacturer | Mitsubishi Heavy Industries, Ltd. | |
| | | Plunger diameter mm[in.] | 14[0.55] | |
| | Feed pump | Type | Trochoid type pump TOP-2HAMTVB | |
| | | Manufacturer | Japan Oil Pump | |
| | | Theoretical delivery capacity | 12.0 cc/rev. | |
| | Governor | Control system | <Hydraulic> • Woodward PSG | <Electrical> • Toho SG4030 • Barber Colman DANA8200 |
| | Injection nozzle | Type | Hole type | |
| | | Manufacturer | ZEXEL | |
| | | No. of spray orifice | 10 | |
| | | Spray orifice inside diameter - Spray anglemm[in.] | ø0.29[0.011]/0.31[0.012]-160° | |
| | | Valve opening pressureMPa{kgf/cm²}[psi] | 29.4 {300}[4267.5] | |
| | Injection timing | | 10° before upper dead point | |
| | Fuel filter | Type | Paper element (spin-on type) | |

| Model designation | | | S12H | |
|---|---|---|---|---|
| | | | TA | TK |
| Electrical system | Voltage - polarity | | 24V - Negative (-) ground | |
| | Starter | Type | 8-23000-7271, 7511 | |
| | | Manufacturer | Nikko Electric | |
| | | Pinion type | Pinion shift | |
| | | Output V-kW | 24-7.5×2 | |
| | | Ring gear/pinion ratio | 16.545 (182/11) | |
| | Alternator | Type | 3-phase AC with silicon rectifier (add-on type) | |
| | | Manufacturer | Mitsubishi Electric | |
| | | Output V-A | 24-30 | |
| | | Rated output generating speed rpm | 5000 or less (at 27V, 30A) | |
| | | Regulator adjusting voltage V | 28.0 - 29.0 | |
| | | Reduction ratio | $2.25\ (1.829 \times \frac{123}{100})$ | |
| | Safety relay (for starter chattering prevention) | Manufacturer | Nominal voltage | |
| | | Nominal voltage V | 24 | |
| | | Rated voltage sec | 30 | |
| | | Operating voltage V | 8 to 24 | |
| | | Operating interval (with 24 V) | SS-SW ON-OFF 1 cycle 2.5 to 3.0 | |
| | | Allowed temperature °C [°F] | –20 to +50 [24.8 to 122] | |
| | | Grounding system | Double-wire system | |
| Air start system | Air motor | Type | Turbine | |
| | | Manufacturer | T.D.I. (U.S.) | |
| | | Pinion type | Pinion shift | |
| | | Nominal output PS | 20 (0.93MPa {9.5 kgf/cm²}[135.14psi] | |
| | | Ring gear/pinion ratio | 13 (182/14) | |

# 3. TIPS ON DISASSEMBLY AND REASSEMBLY

This Service manual deals with Mitsubishi's recommended procedures to be followed in servicing the Mitsubishi diesel engine and contains information on the special tools and basic safety precautions.

The safety precautions contained herein, however, are not the whole of work. It is the responsibility of the service personnel to know that specific requirement, precautions and work hazards exist and to discuss these with his foreman or supervisor.

Study this manual carefully and observe the following general precautions to help prevent serious injury to the personnel and damage to the engine.

## 3.1 Disassembly

(1) Use only right tools and instruments.

(2) Prepare a work table or a shelf for disassembled parts as required. Disassemble the engine according to the specified order.

(3) Place disassembled parts in an orderly manner so that they may not be lost.

(4) Pay attention to the assembly match mark during disassembly. Put match marks on parts that have no marks for assembly as required.

(5) Check for abnormality during disassembly and washing. Try to find all potent failures that cannot be detected after washing.

(6) Pay attention to safety during the work. In particular, be careful for balance of disassembled parts and movement of heavy parts. (Use a jack or chain block as required.)

### 3.2 Assembly

(1) Wash parts except for oil seal, O-ring or rubber sheet with washing oil. Dry them completely with compressed air.

(2) Use appropriate parts and equipment.

(3) Use appropriate oil or grease in good quality.

Be sure to apply oil, grease or adhesive where specified. (Refer to page 2-10)

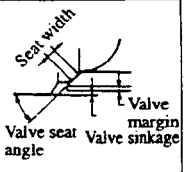
(4) Be sure to use the torque wrench where specified. Tighten bolts to the specified torque. (Refer to page 2-7)

(5) Replace gaskets and packings with new ones. Apply adhesive to them as required. Do not apply it excessively.

# MAINTENANCE STANDARDS

# 1. MAINTENANCE STANDARDS

Unit: mm [in.]

| Group | Inspection point | | Nominal value (standard clearance) | Assembly standard (clearance) | Repair limi (clearance) | Service limit | Remark |
|---|---|---|---|---|---|---|---|
| Engine (General) | Maximum rpm | | 5 ~ 10% higher than rated rpm | | Lower or 15% higher than rated rpm | | The rated rpm is stamped on the nameplate. Check governor setting. |
| | Minimum rpm | | 600 ~ 650 rpm | | | | |
| | Compression pressure MPa(kgf/cm²)[psi] | | 24 (24.4) [347.1] at 120 rpm, minimum | | More than 1.9 (19.3) [274.5] | | Oil and water temp. 20 - 30°C [68~86°F] |
| | Lube oil pressure MPa (kgf/cm²)[psi] | | 0.49~0.59 (5~6) (at rated rpm), minimum [71.13~85.35]<br>0.20~0.29 (2~3) (at idling rpm), minimum [28.45~42.68] | | More than 0.49 (5) [71.13]<br>More than 0.10 (1) [14.23] | | Oil temperature 60 - 70°C[140~158°F] |
| | Valve timing [2-mm clearance on valve side, when cold] | | Inlet valve opens<br>Inlet valve closes<br>Exhaust valve opens<br>Exhaust valve closes | 14°B.T.D.C.<br>23°A.B.D.C.<br>25°B.B.D.C.<br>15°A.T.D.C.<br>±2°(crank angle) | | | Figures are for valve timing measurement, and they differ from actual valve opening and closing timing. |
| | Valve clearance (cold) | Inlet valve | | 0.6[0.024] | | | |
| | | Exhaust valve | | 0.8[0.031] | | | |
| | Injection timing | | B.T.D.C. | ±10° (crank angle) | | | Varies according to specifications. Refer to caution plate on No.1 rocker cover. |
| Engine proper | Rocker | Rocker bushing inside diameter | ø44 [1.734] | 44.011 ~ 44.045 [1.734~1.735] | | 44.095 [1.736] | |
| | | Rocker shaft diameter | ø44 [1.734] | 43.957 ~ 43.991 [1.732~1.733] | | 43.030 [1.694] | |
| | Valve | Valve stem diameter | ø10 [0.394] | 9.940 ~ 9.960 [0.3916~0.3924] | | 9.910 [0.390] | |
| | | Valve guide inside diameter | ø10 [0.394] | 10.000 ~ 10.015 [0.394~0.3945] | | 10.060 [0.3961] | |
| | Valve seat and Valve | Seat angle | 30° | | | |  |
| | | Valve sinkage | 0 | -0.1 ~ 0.2[-0.004~0.008] | 1.0 [0.039] | | |
| | | Seat width | 2.3[0.09] | 2.15 ~ 2.45[0.08~0.1] | 2.8 [0.110] | | |
| | | Valve margin | 3.0[0.12] | 2.8 ~ 3.2[0.11~0.13] | Refacing is permissible up to 2.5[0.1] | | |
| | | Cylinder head bore inside diameter and valve seat outside diameter | ø55 [2.165] | -0.070 ~ -0.130 [-0.003~-0.005] | | | Minus (-) indicates interference. |
| | Valve spring | Free length | | 70.5[2.78] | | 69 [2.72] | |
| | | Squareness |  | q= 1.5°, maximum | | D=2.2[0.09] over the length | |
| | | Length under test force/ test force mm/N (mm/kgf) [in./lbf] | | 61.8/254.4~281.2 (61.8/25.94~28.67) [2.60/57.2~63.21] | | | |
| | Valve push-rod | Runout | | Less than 0.5 [0.02] | | 0.5 [0.02] | |
| | Cylinder head | Warpage of gasketed surface | | 0.03, maximum [0.001] | 0.07 [0.003] | 0.50 [0.02] | Regrind slightly. |
| | Cylinder liner | Inside diameter | ø150 [5.906] | 150.000 ~ 150.040 [5.906~5.907] | | 150.140 [5.911] | |
| | | Out-of-roundness | | 0.02, maximum[0.0008] | | | |
| | | Taper | | 0.02, maximum[0.0008] | | | |
| | | Squareness with respect to lower face of flange | | 0.03, maximum [0.001] | | | |
| | | Protrusion of cylinder liner flange above gasketed surface | | 0.10 - 0.19 [0.004 ~ 0.007] | | | |

Unit: mm[in.]

| Group | Inspection point | | | Nominal value (standard clearance) | Assembly standard (clearance) | Repair limi (clearance) | Service limit | Remark |
|---|---|---|---|---|---|---|---|---|
| Engine proper | Piston | Diameter | | ø150 [5.906] | 149.78 ~ 149.82 [0.58~5.90] | | 149.68 [5.893] | Measure diameter in direction transverse to piston pin and at skirt. |
| | | Variance in weight among pistons per engine | | | 30 g, maximum [1.18] | | | |
| | | Piston pin bore diameter | | ø58 [2.283] | 58.002 ~ 58.012 [2.2852~2.2856] | | 58.020 [2.29] | |
| | | Protrusion | | | 0.38 ~ 0.89[0.01~0.04] | | | |
| | | Clearance between ring groove and ring width | Top | 3.00 [0.12] | (0.08 ~ 0.11)[0.003~ ~0.004] | | (2.0) [0.079] | Insert a new ring for measurement. |
| | | | Second | 2.55 [0.10] | (0.07 ~ 0.10)[0.003~ 0.004] | | (2.0) [0.079] | |
| | | | Oil | 5.00 [0.197] | (0.05 ~ 0.09)[0.002~ 0.004] | | (2.0) [0.079] | |
| | Cylinder head gasket | As-installed thickness | | 18 [0.07] | 1.77~1.83[0.07~ 0.072] | | | |
| | Pistons and cylinder heads | Clearance between piston top and cylinder head | | | (0.88 - 1.45) [0.035~0.057 | | | |
| | Piston ring | Gap | Top | | (0.6 ~ 0.8) [0.02~0.03] | | (0.20) [0.08] | If gauge is not available,check approximate gaps at the cylinder bore. |
| | | | Second | | (0.5 ~ 0.7) [0.0197~0.0275] | | (0.15) [0.08] | |
| | | | Oil | | (0.5 ~ 0.7) [0.0197~0.0275] | | (0.15) [0.08] | |
| | Piston pin | Outside diameter | | ø58 [2.283] | 57.987 ~ 58.000 [2.2847~2.2852] | | 57.970 [2.28] | |
| | Connecting rod | Bushing inside diameter | | ø58 [2.283] | 58.020 ~ 58.040 [2.286~2.2868] | | 58.070 [2.29] | |
| | | Bend and twist | | | 0.05/100, maximum [0.002/3.94] | | | |
| | | End play (crankpin and big end widths) | | 54 x 2 [2.13x0.08] | (0.4 ~ 0.6) [0.016~0.024] | | (0.8) [0.03] | |
| | | Variance in weight among connecting rods per engine | | | 40 g, maximum [0.09 ~ 1b] | | | |
| | | Big-end bore diameter | | ø110 [4.334] | 110.000 ~ 110.022 [4.334~4.3348] | | 110.047 [4.34] | To be used in combination with metal caps. |
| | Connecting rod metal | Thickness of central part | STD | 3.000 [0.12] | 3.000 ~ 2.982 [0.118~0.117] | | 2.950 [0.116] | Replace metals if worn down to service limit. Regrind journals and use undersize metals if metals are worn beyond service limit. |
| | | | - 0.25[-0.01] | 3.125 [0.123] | 3.125 ~ 3.107 [0.123~0.122] | | 3.075 [0.121] | |
| | | | - 0.50[-0.02] | 3.250 [0.128] | 3.250 ~ 3.232 [0.128~0.127] | | 3.200 [0.126] | |
| | | | - 0.75[-0.03] | 3.375 [0.1329] | 3.375 ~ 3.357 [0.1329~0.1322] | | 3.325 [0.131] | |
| | | | - 1.00[-0.04] | 3.500 [0.1379] | 3.500 ~ 3.482 [0.1379~0.1371] | | 3.450 [0.1359] | |
| | Flywheel | Face runout | | | 0.28, maximum[0.11] | | | |
| | | Radial runout | | | 0.13, maximum[0.005] | | | |
| | Fuel feed accessory drive | Fit of bearing outer race in drive case | | ø68 [2.679] | 67.988 ~ 68.018 [2.6787~2.6799] | | | |
| | | Bearing | Outside diameter | ø68 [2.679] | 67.987 ~ 68.000 [2.6787~2.6792] | | | |
| | | | Inside diameter | ø40 [1.576] | 39.988 ~ 40.000 [1.573~1.576] | | | |
| | | Diameter of drive shaft bearing journals | | ø40 [1.576] | 39.995 ~ 40.011 [1.5758~1.5764] | | | |

Unit: mm

| Group | Inspection point | | | Nominal value (standard clearance) | Assembly standard (clearance) | Repair limi (clearance) | Service limit | Remark |
|---|---|---|---|---|---|---|---|---|
| Engine proper | Crankshaft | Hardness of journal and crankpin | | | Hv>620 | | | |
| | | Angular error of crankpin | | | ±0.3° | | | |
| | | Runout | | | 0.04[0.002], maximum | 0.10 [0.004] | | Repair or replace. |
| | | End play (thrust journal length) | | 58 [2.29] | (0.20 - 0.40) [0.01~0.016] | | (0.50)[0.02] +1.18[+0.05] for crankshaft width | Replace thrust plate if worn down to repair limit. Use oversize thrust plate if worn beyond repair limit. Oversize thrust plates: +0.25, +0.50, +0.75 [+0.0099, +0.0197,+0.0296] |
| | Main metal | Thickness of center part | STD | 3.500 [0.138] | 3.467 ~ 3.480 [0.1366~0.1371] | | 3.425 [0.135] | Replace metals if worn down to service limit. Regrind crankpins and use undersize metals if worn beyond service limit. |
| | | | -0.25 [-0.01] | 3. 625 [0.143] | 3.592 ~ 3.605 [0.1415~0.1420] | | 3.550 [0.140] | |
| | | | -0.50 [-0.02] | 3.750 [0.148] | 3.717 ~ 3.730 [0.146~0.147] | | 3.675 [0.145] | |
| | | | -0.75 [-0.03] | 3. 875 0.153] | 3.842 ~ 3.855 [0.151~0.152] | | 3. 800 [0.150] | |
| | | | -1.00 [-0.04] | 4.000 [0.158] | 3.967 ~ 3.980 [0.156~0.157] | | 3.925 [0.155] | |
| | Crankcase | Main metal bore diameter | | ø147 [5.792] | 147.000 ~ 147.025 [5.792~5.793] | | 147.045 [5.79] | |
| | | Warpage of gasketed surface | | | 0.05, maximum [0.002] | 0.20 [0.008] | | |
| Lubrication system | Oil pump | Base tangent length of drive gear and driven gear | | | (27.983 ~ 28.055) [1.1025~1.1054] | | (27.93) [1.1004] | |
| | | Clearance between drive gear and driven gear | | | (0.095 ~ 0.140) [0.004~0.006] | | Tip clearance (0.190) [0.007] | |
| | | Clearance between gear width and case | | 97 [3.82] | (0.095 ~ 0.140) [0.004~0.006] | | (0.29) [0.0114] | |
| | | Outside diameter of drive shaft and driven shaft | | ø40 [1.576] | 39.984 ~ 40.000 [1.575~1.576] | | 39.930 [1.573] | |
| | | Bushing inside diameter | | | 40.040 ~ 40.059 [1.577~1.578] | | 40.140 [1.582] | |
| | Safety valve | Opening pressure | | | 1.4±0.1 MPa (14±1 kgf/cm²) [199.15±14.23 psi] | | | |
| | | Spring | Installation length mm | | 73.4 [1.710] | | 73.4 [1.710] | |
| | | | LoadN {kgf}[lbf] | | 970{99.0} [218] | | 833{85.0}[187] | |
| | Relief valve | Opening pressure | | | 0.58±0.05 MPa (5.9±0.5 kgf/cm²) [83.93±7.12 psi] | | | |
| | Oil filter alarm | Opening pressure (differential pressure) | | | 0.25±0.02 MPa (2.5±0.2 kgf/cm²) [35.56±2.85 psi] | | | Contact points should close at 0.15 MPa (1.5 kgf/cm²) [21.34 psi]. 1 mm shim changes 0.007 MPa (0.07 kgf/cm²) [1.00 psi]. |
| Cooling system | Water pump | Inside diameter of pump | | ø120 [4.728] | 119.987 ~ 120.022 [4.7274~4.7289] | | | |
| | | | | ø110 [4.334] | 110.005 ~ 110.040 [4.3342~4.3356] | | | The same applies to the bearing cover. |
| | | Bearing | Outside diameter | ø120 [4.728] | 119.982 ~ 120.000 [4.7273~4.7280] | | | |
| | | | | ø110 [4.334] | 109.982 ~ 110.000 [4.3333~4.3340] | | | |
| | | | Inside diameter | ø55 [2.167] | 54.985 ~ 55.000 [2.1664~2.1670] | | | |

Unit: mm[in.]

| Group | | Inspection point | | Nominal value (standard clearance) | Assembly standard (clearance) | Repair limi (clearance) | Service limit | Remark |
|---|---|---|---|---|---|---|---|---|
| | | Diameter of shaft on which bearing inner race is fitted | | ø55 [2.167] | 55.002 ~ 55.015 [2.1670~2.1676] | | | |
| | | Vane front face clearance in pump case | | 1.04 [0.04] | (0.58 ~ 1.50) [0.02~0.06] | | | |
| | Thermostat | Temperature at which valve starts opening | | | 71±2°C [159.8±35.6°F] | | | Check at atmospheric pressure. |
| | | Temperature at which valve lift is more than 10 mm, minimum | | | 85°C [185°F] | | | |
| | Fan drive | Inside diameter of pump case in which bearing outer races are fitted | | ø110 [4.334] | 109.987 - 110.022 [4.3335~4.3349] | | | |
| | | | | ø120 [4.728] | 119.987 - 120.022 [4.7275~4.7289] | | | |
| | | Bearing | Outside diameter | ø110 [4.334] | 109.985 - 110.000 [4.3334~4.334] | | | |
| | | | | ø120 [4.728] | 119.982 - 120.000 [4.7273~4.728] | | | |
| | | | Inside diameter | ø45 [1.773] | 44.988 - 45.000 [1.7725~1.773] | | | |
| | | | | ø50 [1.970] | 49.985 - 50.000 [1.9694~1.970] | | | |
| | | Diameter of shaft on which bearing inner races are fitted | | ø45 [1.773] | 45.002 - 45.013 [1.7731~1.7735] | | | |
| | | | | ø50 [1.970] | 50.002 - 50.013 [1.9701~1.9705] | | | |
| Fuel system | Fuel injection nozzle | Valve opening pressure | | 29.42 MP [300 kgf/cm$^2$] [4268 psi] | 28.93 - 30.89 MPa (295~315 kgf/cm$^2$) [4196~4481 psi] | | | |
| Electrical system | Starter | Pinion shaft diameter and bushing inside diameter on front side | | ø19 [0.749] | (0.045 - 0.138) [0.002~0.005] | | (0.25) [0.01] | |
| | | Pinion shaft diameter on rear side | | ø30 [1.182] | 30.002 - 30.011 [1.1820~1.1824] | | | |
| | | Armature shaft diameter on front side | | ø25 [0.985] | 25.002 - 25.011 [0.9850~0.9854] | | | |
| | | Armature shaft diameter on rear side | | ø10 [0.394] | 10.001 - 10.007 [0.3940~0.3942] | | | |
| | | Commutator diameter | | ø39 [1.537] | | | ø38 [1.479] | |
| | | Runout of armature shaft | | | 0.05 [0.002] | | | |
| | | Runout of commutator | | | 0.015, maximum [0.0006] | | 0.100 [0.004] | |
| | | Mica depth in commutator | | | 0.5 - 0.8 [0.02~0.03] | 0.2 [0.008] | | |
| | | Height of brush | | | 20 [0.79] | | 12 [0.47] | |
| | | Tension of brush spring (installed) | | | 39.2 - 49.0N (4.0 - 5.0 kgf) [8.82~11.02 lbf] | | Less than 39.2N (4.0 kgf) [8.82 lbf] | |
| | | End play of armature | | | 0.2 - 0.6 [0.008~0.02] | | | |
| | | End play of pinion shaft | | | 0.2 - 0.6 [0.008~0.02] | | | |
| | Alternator | Diameter of spring | | 41 [1.62 | 40.8 - 41.2 [1.61~1.62] | | 40.6 [1.60] | Wear limit line indicated on brush. |
| | | Height of brush | | 18.5 [0.73] | | | 11.5 [0.45] | |
| | | Tension of brush spring | | 3.7N (380 gf)[0.83 lbf] | 3.1 - 4.3N (320 - 440 gf)[0.7~1.0 lbf] | | 2.0N (200 gf) [0.45 lbf] | |

# 2. TIGHTENING TORQUE

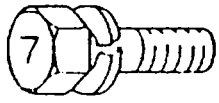
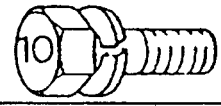
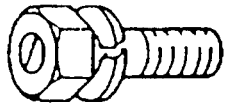
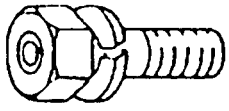
## 2.1 Important bolts and nuts

| Secured part or component | Thread dia. - pitch (metric) | Width across flats mm [in.] | Width across flats | | | Tightening torque Remark |
|---|---|---|---|---|---|---|
| | | | kgf-m | lbf-ft | N.m | |
| Cylinder head | 22 × 2.5 | 27[1.06] | 55 | 398 | 539 | Wet |
| Rocker case | 10 × 1.25 | 14[0.55] | 6 | 43 | 59 | |
| | 12 × 1.25 | 17[0.67] | 11 | 80 | 108 | |
| Rocker shaft | 16 ×2 | 22[0.87] | 17 | 123 | 167 | |
| Rocker arm rocknut | 12 ×1.25 | 17[0.67] | 6.5 | 47 | 64 | |
| Camshaft gear | 14 ×1.5 | 22[0.87] | 18 | 130 | 177 | |
| Camshaft thrust plate | 12 × 1.25 | 17[0.67] | 11 | 80 | 108 | |
| Cam follower shaft | 12 × 1.25 | 17[0.67] | 9 | 65 | 88 | |
| Adapter | 12 × 1.25 | 17[0.67] | 8 | 58 | 78 | |
| Main metal cap | 22 × 2.5 | 27[1.06] | 50 | 362 | 490 | Wet |
| Main metal cap side bolt | 16 × 1.5 | 22[0.87] | 15 | 108 | 147 | Wet |
| Front hanger | 12 × 1.25 | 17[0.67] | 11 | 79 | 108 | |
| Rear hanger | 16 × 1.5 | 24 [0.95] | 26 | 188 | 255 | |
| Oil jet nozzle | 12 × 1.75 | 17[0.67] | 3.5 | 25 | 34 | |
| Timing gear case | 12×1.25 | 17[0.67] | 10 | 72 | 98 | Tighten the crankcase. |
| | 12×1.25 | 17[0.67] | 7 | 51 | 68 | Tighten plates and nuts. |
| | 16×1.5 | 24[0.95] | 26 | 188 | 255 | |
| Rear plate | 12×1.25 | 17[0.67] | 11 | 80 | 108 | |
| Oil pan | 10×1.25 | 14[0.55] | 4 | 29 | 39 | |
| Mounting bracket (front) | 20×1.5 | 30[1.18] | 40 | 289 | 392 | |
| Mounting bracket (rear) | 18×2.5 | 27[1.06] | 30 | 217 | 294 | |
| Connecting rod metal cap | 18×1.5 | 27[1.06] | 35 | 253 | 343 | |
| Balance weight | 16×1.5 | 24[0.95] | 20 | 145 | 196 | |
| Fly wheel | 22×1.5 | 32[1.26] | 60 | 434 | 588 | |
| Viscous damper | 22×1.5 | 32[1.26] | 50 | 362 | 490 | |
| Timing idler gear shaft | 12×1.25 | 17[0.67] | 11 | 80 | 108 | |
| Timing idler shaft thrust plate | 10×1.25 | 14[0.55] | 3 | 22 | 29 | |
| Front gear case | 12×1.25 | 17[0.67] | 10 | 72 | 98 | Tighten the crankcase. |
| | 12×1.25 | 17[0.67] | 7 | 51 | 68 | Tighten plates and uts. |
| | 16×1.25 | 24[0.95] | 26 | 188 | 255 | |
| Front plate | 12×1.25 | 17[0.67] | 11 | 80 | 108 | |
| Idler gear shaft | 12×1.25 | 17[0.67] | 11 | 80 | 108 | |
| Idler gear thrust plate | 16×1.5 | 24[0.95] | 22 | 159 | 216 | |
| Exhaust manifold | 10×1.5 | 14[0.55] | 5~6 | 36~43 | 49~59 | |
| Oil pump | 10×1.25 | 14[0.55] | 6 | 43 | 59 | |
| Oil pump cover | 10×1.25 | 14[0.55] | 3.5~7.5 | 25.3~54.2 | 34.3~73.5 | |
| Oil pump safety valve plug | | | 18~22 | 130~159 | 177~216 | |

Note: Apply oil to screw threads of parts specified to be [wet].

| Secured part or component | Thread dia. - pitch (metric) | Width across flats mm [in.] | Tightening torque | | | Remark |
|---|---|---|---|---|---|---|
| | | | kgf-m | lbf-ft | N.m | |
| Water pump | 12 x 1.25 | 17 [0.67] | 11 | 80 | 108 | |
| Water pump shaft pulley (nut) | 30 x 1.5 | 46[1.81] | 40 | 289 | 392 | For starting alternater |
| Turbocharger lubrication (eyebolt type) | 10 x 1.5 | 14[0.55] | 3 | 22 | 29 | |
| Turbocharger lubrication (flange type) | 10 x 1.5 | 14[0.55] | 5.9 | 42.7 | 58 | |
| Unit injector gland stud (screw-in side) | 16 x 2 | — | 9.6 | 69 | 94 | Apply thread locking compound |
| Unit injector gland (nut) | 16 x 1.5 | 24[0.95] | 13 | 94 | 127 | |
| Governor lever | 8 x 1.25 | 12[0.47] | 2.5 | 18.1 | 24 | Tighten twice |
| Unit injector retaining (nut) | 45 x 1.5 | 41[1.62] | 31~33 | 224~239 | 304~324 | |
| Unit injector nozzle retaining (nut) | 30 x 1.5 | 32[1.26] | 21.5~22.5 | 156~163 | 211~221 | |
| Fuel pipe (nut) | 10 x 1.25 | 17[0.67] | 1.5 | 11 | 15 | |
| Fuel filter inlet/outlet (eyebolt) | 14 x 1.5 | 19[0.75] | 2.0~2.5 | 14.5~18.1 | 19.6~24.5 | |
| Fuel filter air plug | 6 x 1.25 | 14[0.55] | 0.8~1.0 | 5.8~7.2 | 7.8~9.8 | |
| Priming pump inlet/outlet plug | 14 x 1.5 | 19[0.75] | 2.0~2.5 | 14.5~18.1 | 19.6~24.5 | |
| Priming pump (eyebolt) | 16. x 1.5 | 22[0.87] | 3.5 | 25 | 34 | |
| Feed pump inlet/outlet | 20 x 1.5 | 27[1.06] | 6 | 43 | 59 | |
| Governor drive case | 12 x 1.25 | 17[0.67] | 11 | 80 | 108 | |
| Starter | 12 x 1.25 | 17[0.67] | 6 | 43 | 59 | |

## 2.2 General bolts and nuts

| | Screw thread diameter x pitch mm [in.] | Width across flats mm [in.] | Strength | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 7T | | | 10.9 | | |
| | | |  | | |  | | |
| | | | kgf·m | lbf·ft | N·m | kgf·m | lbf·ft | N·m |
| Metric thread for automobiles | 8 x 1.25 [0.32x0.05] | 12 [0.47] | 1.7 | 12 | 17 | 3.1 | 22 | 30 |
| | 10 x 1.25 [0.39x0.05] | 14 [0.55] | 3.4 | 25 | 33 | 6.1 | 44 | 60 |
| | 12 x 1.25 [0.47x0.05] | 17 [0.67] | 6.1 | 44 | 60 | 11.0 | 80 | 108 |
| | 14 x 1.5 [0.55x0.06] | 22 [0.87] | 9.9 | 72 | 97 | 17.9 | 129 | 176 |
| | 16 x 1.5 [0.63x0.06] | 24 [0.95] | 14.8 | 107 | 145 | 26.7 | 193 | 262 |
| | 18 x 1.5 [0.71x0.06] | 27 [1.06] | 21.4 | 155 | 210 | 38.5 | 278 | 378 |
| | 20 x 1.5 [0.79x0.06] | 30 [1.18] | 29.7 | 215 | 291 | 53.4 | 386 | 524 |
| | 22 x 1.5 [0.87x0.06] | 32 [1.26] | 39.3 | 284 | 385 | 70.8 | 512 | 694 |
| | 24 x 1.5 [0.95x0.06] | 36 [1.42] | 49.7 | 359 | 487 | 89.5 | 647 | 878 |
| | | |  | | |  | | |
| | | | kgf·m | lbf·ft | N·m | kgf·m | lbf·ft | N·m |
| Metric coarse thread | 10 x 1.5 [0.39x0.06] | 14 [0.55] | 3.3 | 24 | 32 | 5.9 | 43 | 58 |
| | 12 x 1.75 [0.47x0.07] | 17 [0.67] | 5.8 | 42 | 57 | 10.4 | 75 | 102 |
| | 14 x 2 [0.55x0.08] | 22 [0.87] | 9.5 | 69 | 93 | 17.0 | 123 | 167 |
| | 16 x 2 [0.63x0.08] | 24 [0.95] | 14.2 | 103 | 139 | 25.6 | 185 | 251 |
| | 18 x 2.5 [0.71x0.1] | 27 [1.06] | 19.8 | 143 | 194 | 35.7 | 258 | 350 |
| | 20 x 2.5 [0.79x0.1] | 30 [1.18] | 27.7 | 200 | 272 | 49.9 | 361 | 498 |
| | 22 x 2.5 [0.87x0.1] | 32 [1.26] | 37.0 | 268 | 363 | 66.6 | 482 | 653 |
| | 24 x 3 [0.95x0.12] | 36 [1.42] | 47.7 | 345 | 468 | 86.0 | 622 | 843 |

Notes:

(a) This table shows tightening torque of general bolts and nuts.

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

(c) The values in the table are to be used as standard with tolerance of +10%.

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

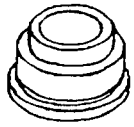
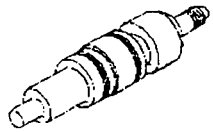
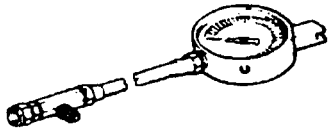
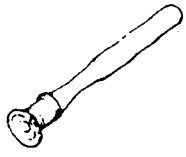
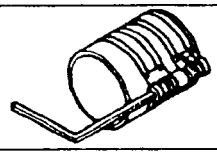
(e) Do not apply oil to threads. (dry)

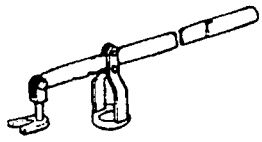
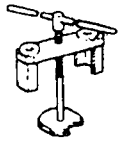
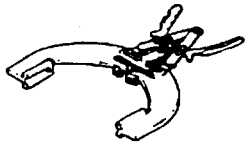
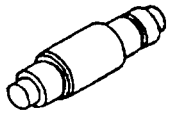
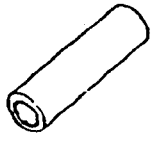
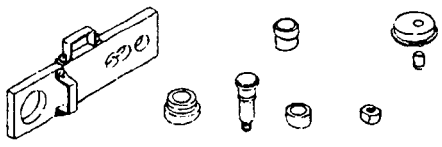
# 3. SEALANT AND LUBRICANT

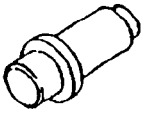
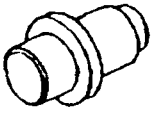
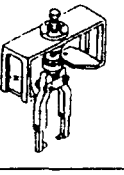
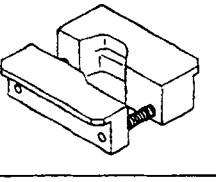
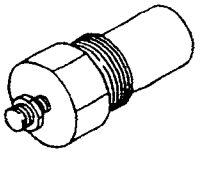
| Group | Application point | | Sealant or lubricant | How to use |
|---|---|---|---|---|
| Engine proper | Cylinder head sealing cap | | ThreeBond 1215 | Apply to holes in crankcase. |
| | Cylinder head copper tube | | ThreeBond 1211 or 1215 | Apply to the end joint. |
| | Water outlet connector (rocker case) | | Grease | Apply to O-ring grooves. |
| | Cylinder liner | | Engine oil | Apply to O-ring grooves. |
| | Front plate, gear case, oil pan and crankcase | | HERDITE | Apply to joint surfaces. |
| | Rear plate, gear case, oil pan and crankcase | | HERDITE | Apply to joint surfaces. |
| | Crankcase taper plug | | SEALOC, LOCTITE (ThreeBond-make) | Apply to taper threads by coating. |
| | Oil pan and crankcase | | HERDITE | Apply to packing joint surfaces. |
| | Oil seal | | Engine oil | Apply to lip. |
| Fuel system | Unit injector | | Grease | Nozzle gasket |
| | | | Engine oil | O-ring installation location |
| Lubrication system | Oil pump | Cover and case | ThreeBond 1215 | Apply to both sides of packing. |
| Cooling system | Water pump | Oil seal | Engine oil | Apply to lip of inner seal and floating ring seat. |
| | | Unit seal | LLC solution (anti-freeze) | |
| | Fan drive | Oil seal | Engine oil | Apply to lip. |
| Air inlet system | Air cooler | Space between element and plates | SHINETSU-KAGAKU KE45-W or equivalent silicone sealant | Apply to gap. |
| Others | Taper plugs and cocks not precoated with ThreeBond thread sealant | | Vulcanized sealing tape | Wrap threads with 2 turns of tape. |

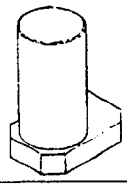
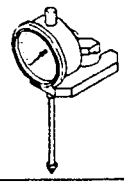
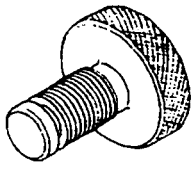
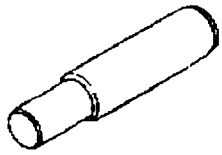
# SPECIAL TOOLS

# SPECIAL TOOL LIST

| Tool name | Part No. | Shape | Use |
|---|---|---|---|
| Tube tool | 35C91-21010 |  | Press-fit of injection nozzle copper tube |
| Cam bushing installer | 35C91-11600 |  | Press-fit of camshaft bushing |
| Front installer | 37591-05010 |  | |
| Rear seal installer | 35B91-06010 |  | Press-fit of rear oil seal |
| Gauge adapter | 35C91-12200 |  | Compression pressure measurement |
| Compression gauge | 33391-02100 |  | Compression pressure measurement |
| Adjustable wrench | F9611-15000 |  | |
| Valve lapper | 30091-08800 |  | Valve lapping |
| Torque wrench | 32191-03100 |  | |
| Piston installer | 37191-07100 |  | Piston installation |

| Tool name | Part No. | Shape | Use |
|---|---|---|---|
| Valve spring pusher | 33591-04500 |  | Valve spring removal/installation |
| Ring pliers | 45191-08400 |  | Snap ring removal/installation |
| Cylinder liner remover | 32591-04100 |  | Cylinder liner removal |
| Piston ring tool | 37191-03200 |  | Piston ring removal/installation |
| Idler bushing puller | 32591-02500 |  | Idler bushing removal |
| Eye nut | 37591-02400 |  | Cylinder head lifting |
| Piston remover | MM321420 |  | Piston removal |
| Valve guide and seal installer | 32591-10300 |  | Valve guide and valve stem seal installation |
| Connecting rod bushing installer | 32591-18010 |  | Connecting rod bushing removal/ installation |

| Tool name | Part No. | Shape | Use |
|---|---|---|---|
| Follower bushing installer | 35C91-01700 |  | Cam follower shaft bushing removal/installation |
| Rocker bushing installer | 35C91-01800 |  | Rocker bushing removal/ installation |
| Offset wrench | 35C91-00500 |  | |
| Copper tube hand installer | 35C91-01500 |  | Injection nozzle copper tube installation |
| Camgear stop bolt | 35B91-06500 |  | |
| Height gauge | 35C91-01100 |  | Injection nozzle installation measurement |
| Injection nozzle puller | 35C91-11400 |  | Injection nozzle removal |
| Clamp | 48749-01000 |  | Injection nozzle disassembly/ reassembly |
| Connector | 48749-00100 |  | Injection nozzle valve opening pressure adjustment |

| Tool name | Part No. | Shape | Use |
|---|---|---|---|
| Gauge | 48749-03080 |  | Unit injector prestroke adjustment |
| Gauge stand | 48749-02010 |  | Rocker bushing removal/ installation |
| Plug | 48749-00200 |  | |
| Copper tube pusher | 35B91-06600 |  | Copper tube removal |

# OVERHAUL INSTRUCTIONS

# 1. DETERMINING WHEN TO OVERHAUL THE ENGINE

Generally, when to overhaul the engine is to be determined by taking into consideration a drop in compression pressure as well as an increase in lubricating oil consumption and excessive blowby gas.

Low power or loss of power, increase in fuel consumption, drop in lubricating oil pressure, hard starting and excessive abnormal noise are also engine failures. These failures, however, are not always the result of low compression pressure and give no valid reason for overhauling the engine.

The engine develops failures of widely different varieties when the compression pressure drops. The following are the typical failures caused by low compression pressure:

(a) Lower power or loss of power

(b) Increase in fuel consumption

(c) Increase in lubricating oil consumption

(d) Excessive blowby through breather due to worn cylinder liners, pistons, etc.

(e) Excessive blowby due to poor seating of worn inlet and exhaust valves

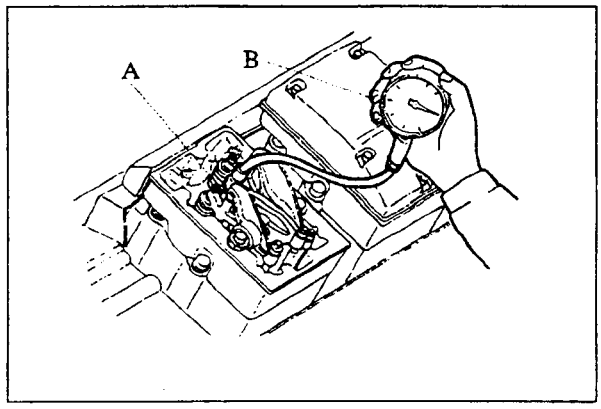
(f) Hard starting

(g) Excessive abnormal noise

In most cases, these failures occur concurrently. Some of them are directly caused by low compression pressure, but others are not. Among the failures listed above, (b) and (f) are caused by a fuel injection pump improperly adjusted with respect to injection quantity or injection timing, worn injection pump plungers, faulty injection nozzles, or poor care of the battery, starter and alternator.

The failure to be considered as the most valid reason for overhauling the engine is (d) Excessive blowby through breather due to worn cylinder liners, pistons, etc.; in actually determining when to overhaul the engine, it is reasonable to take this failure into consideration in conjunction with the other failures.

## 2. TESTING THE COMPRESSION PRESSURE




(1) **Remove the injection nozzle from a cylinder on which the compression pressure is to be measured.**

(2) **Attach the adapter (A) (35C91-02200) to the cylinder, and connect a compression gauge (B) (33391-02100) to the adapter.**

(3) **Crank the engine by means of the starter, and read the compression gauge indication when the engine begins to run at the specified speed.**

(4) **If the compression pressure is lower than the repair limit, overhaul the engine.**

**⚠CAUTION**

(a) **Be sure to measure the compression pressure on all cylinders. It is not a good practice to measure the compression pressure on two or three cylinders and judge the compression pressure of the remaining cylinders therefrom.**

(b) **The compression pressure varies with change of engine rpm. This makes it necessary to check engine rpm at the time of measuring the compression pressure.**

Unit: MPa (kgf/cm²)[psi]

| | Assembly standard | Repair limit |
|---|---|---|
| Compression pressure | 2.4 {24.4} [347.1] | maximum 1.9 {19.3}[274.5] |

NOTE: Measure the compression pressure with the engine running at 120 rpm.

**⚠CAUTION**

(a) **It is important to measure the compression pressure at periodical intervals to obtain the data on the gradual change of the pressure.**

(b) **The compression pressure would be slightly higher than the assembly standard in a new or overhauled engine owing to breakingin of the piston rings, valve seats, etc. It drops as the engine parts wear down.**

# ADJUSTMENTS, BENCH TEST, PERFORMANCE TESTS

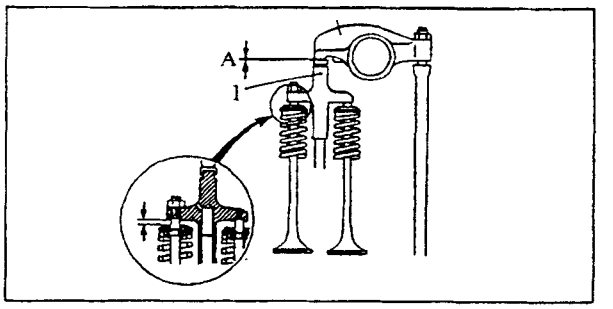
# 1. ADJUSTMENTS

## 1.1 Valve clearance

Inspect and adjust the valve clearance when the engine is cold.

Unit: mm [in.]

| | | Assembly standard |
|---|---|---|
| Valve clearance (A) | Inlet valve | 0.6 [0.024] |
| | Exhaust valve | 0.8 [0.031] |

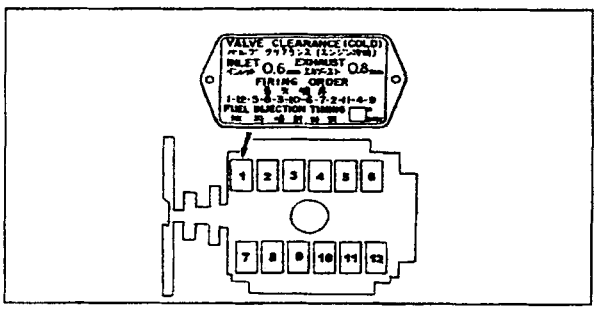



NOTE: (a) The bridge ① -to-valve rotator clearance (B) should be 1.5 mm [0.06 in.] or more after the front and rear valve heights have been adjusted.

If the clearance is too small, grind the bridge to obtain the specified clearance.

(b) The left is the inlet valve and the right is the exhaust valve as viewed from the front side of the cylinder head.

(c) The valve clearance standard is also indicated on the caution plate on the rocker cover of the No. 1 cylinder.

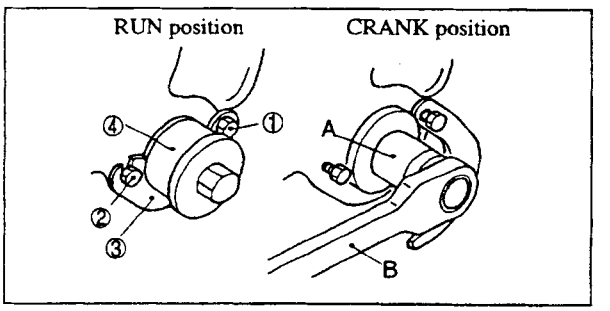


### (1) Inspecting valve clearance

(a) Inspect the valve clearance by the firing order, by turning the crankshaft 60° in normal direction at a time to bring the piston to its top dead center on compression stroke.

**FIRING ORDER**

| Cylinder No. | 1-12-5-8-3-10-6-7-2-11-4-9 |
|---|---|




**NOTE**: How to use the turning gear

a) Loosen bolts ① and ②, and take plate ③ off the groove of shaft ④, then push shaft ④ in all the way.

b) Put socket (A) and ratchet handle (B) to turn shaft ④. Press down the ratchet handle to crank the engine.

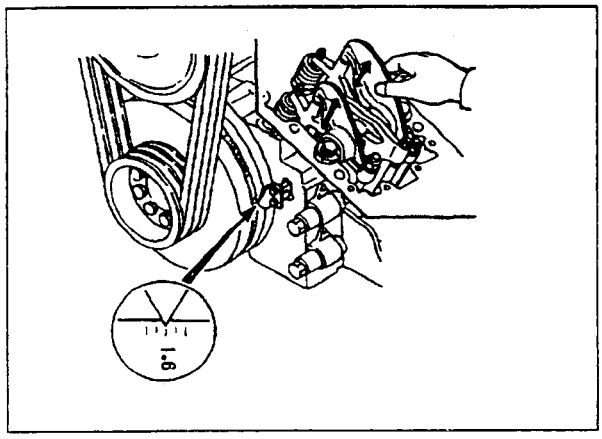
c) After cranking the engine, pull out shaft ④, make sure that plate ③ is properly inserted into the groove of shaft ④.

**⚠CAUTION**

**When starting the engine, make sure that the turning gear is in RUN position.**

(d) The top dead center on compression stroke of the piston is identified by the timing mark (provided on the torsional vibration damper) being aligned with the pointer. With the piston so located, the inlet and exhaust valve rocker arms are not being pushed up by their pushrods.

(e) Insert a feeler gauge between the rocker arm and the bridge cap, and inspect the valve clearance.

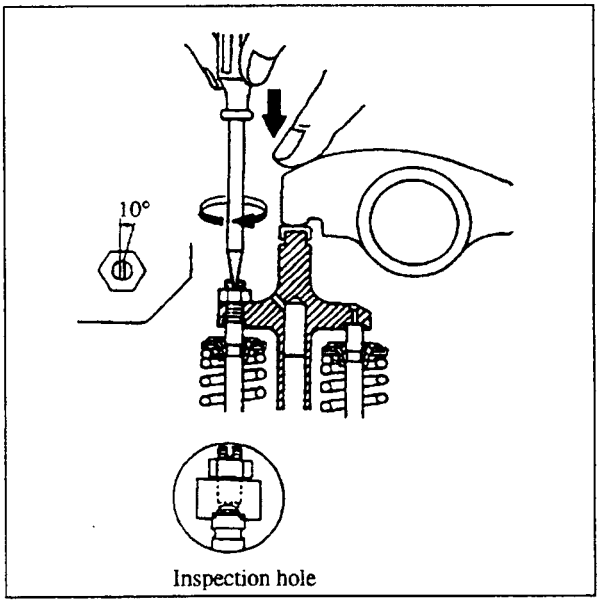


**(2) Adjusting the valve bridge (valve height)**

(a) Before adjusting the valve clearance, check to see if two valves are set to a proper height, equally. Normally there should be no need of adjusting the valve height but, as the valve seats wear progressively in a long course of time, the two valves might become unequal in height to affect the valve clearance.

(b) Loosen lock nut for adjusting screw, and back off the screw.

(c) Push down the rocker arm, and slowly run in the screw until it touches the top end of the valve stem. From that position of the screw, tighten it by turning about 10°, and set it there by tightening the lock nut.



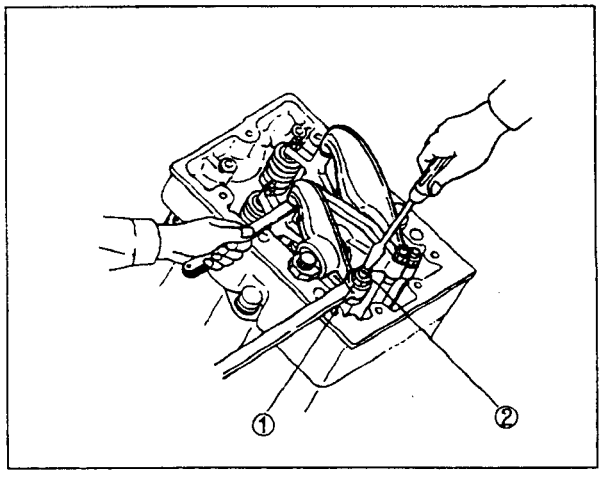

**⚠CAUTION**

**If the valve bridge-to-rotator clearance is too small, the valve cotters are apt to come off. Be sure to maintain specified clearance (1.5 mm [0.06 in.] ) between the bridge and the rotator.**

**(3) Adjusting valve clearance**

(a) Insert a feeler gauge between the rocker arm and the bridge cap, and adjust the clearance by turning the screw in either direction to the extent that the gauge is slightly gripped between the rocker arm and the bridge cap.

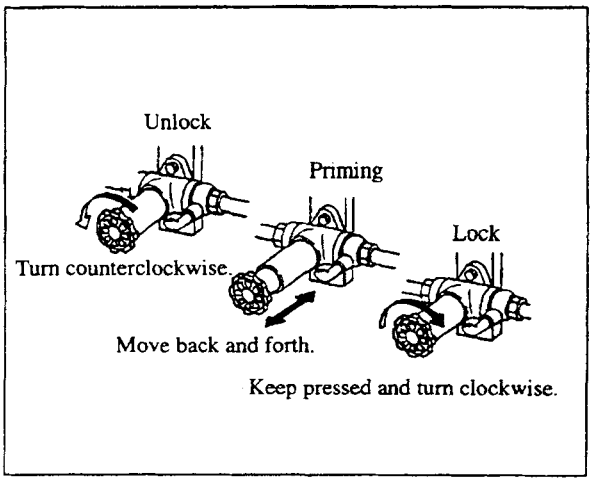
(b) After adjusting the clearance, tighten the lock nut, and again inspect the clearance, making sure that it is correct.



### 1.2 Fuel system priming

**⚠WARNING**

- **Wipe off fuel spilt from the vent holes completely with a cloth. Otherwise, a fire may occur.**
- **After priming, lock the priming pump cap securely. If the lock is loose, the pump may be damaged, resulting in fuel leakage. Then a fire may occur. Lock the priming pump cap with a hand. Use of a tool gives excessive torque and the pump may be damaged.**




PRIMING PUMP

Prime the fuel filters and the fuel return pipe in this order, from the closer position to the fuel tank.

**(1) Fuel filter**

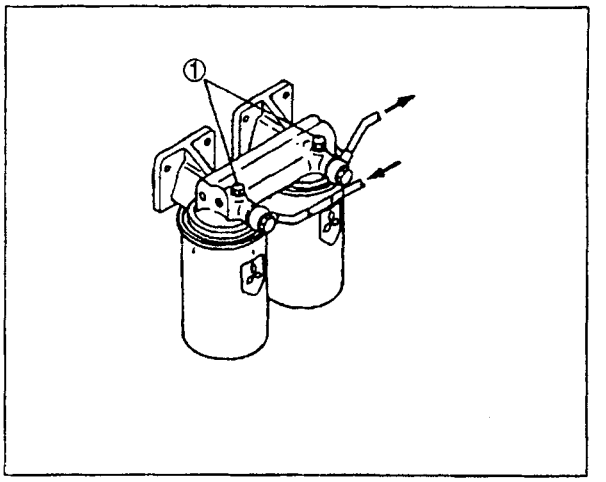
(a) Loosen air vent plugs (1) at the top of fuel filters (by about 1.5 turns).

(b) Unlock the priming pump by twisting the cap counterclockwise, and move it back and forth.

(c) Tighten the air vent plugs when fuel flows from the vent hole without bubbles.

(d) Do the same on the left fuel filter as the right.

**NOTE**: Priming of switch type fuel filter should be performed according to the caution plate.




FUEL FILTER

**(2) Fuel return pipe**

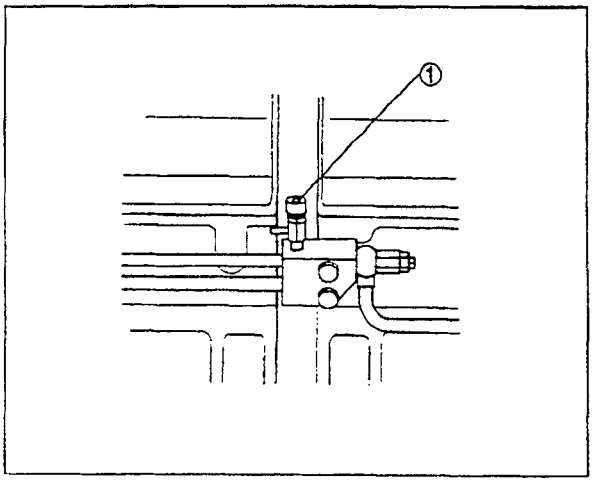
(a) Loosen air vent plug (1) of the fuel return pipe (by about 1.5 turns).

(b) Move the priming pump cap back and forth.

(c) When fuel flows from the vent hole without bubbles, lock the priming pump by turning its cap clockwise while pushing it down.

(d) Tighten the air vent plug.

**NOTE**: If all vent plugs are tightened before the priming pump handle is locked, fuel pressure acts on the feed pump, making it impossible to restore the handle.




FUEL RETURN PIPE

### 1.3 Fuel injection timing inspection and adjustment

#### (1) Fuel injection timing and indication

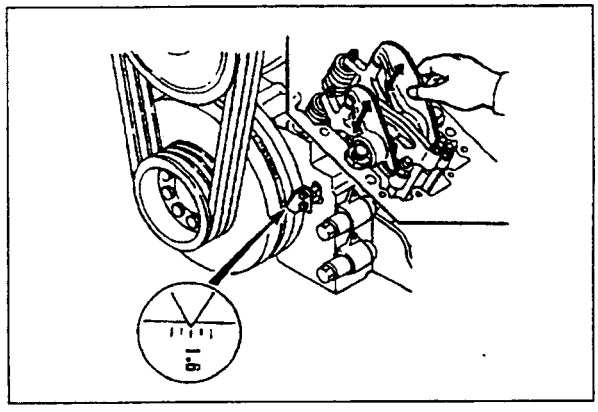
The injection timing is stamped on the caution plate attached to the No. 1 rocker cover. Be sure to verify the timing by referring to this caution plate. The injection timing for each model of the engine varies according to its output, speed and specification.

#### (2) Bringing No. 1 piston to top dead center on compression stroke

(a) Put the socket and the ratchet handle to the turning gear, and turn the crankshaft in normal direction (clockwise as viewed from the front side of engine).
Press down the ratchet handle to start cranking.

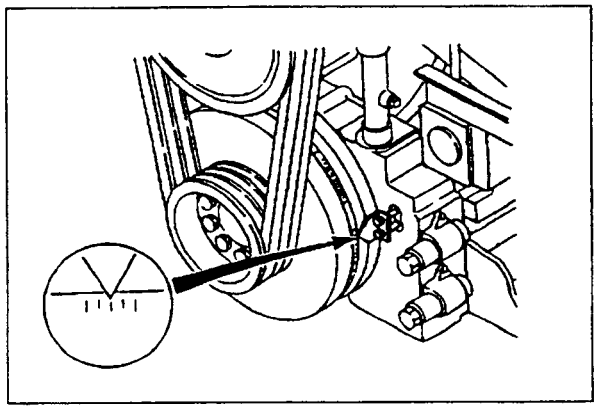
(b) Stop cranking the engine when the timing mark (1.6) on the vibration damper is aligned with the pointer.

(c) Move the inlet and exhaust valve rocker arms for the No. 1 cylinder up and down to make sure that they are not being pushed up by their pushrods.



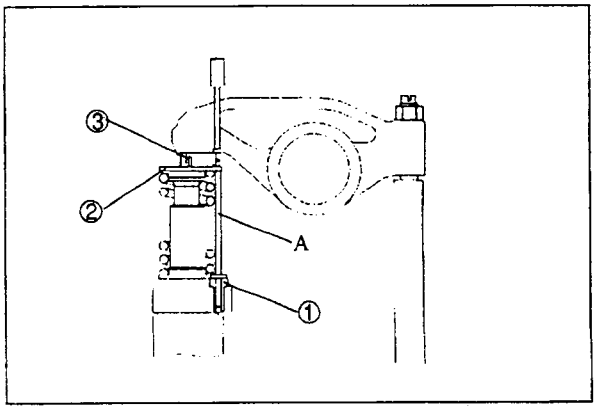
**⚠CAUTION**

**Do not confuse the top dead center on compression stroke for No. 1 cylinder with that for No. 6 cylinder.**



#### (3) Inspecting fuel injection timing

(a) Once turn the crankshaft about 60° to the reverse direction, then, turn it a little at time in normal direction to align timing mark (number stamped on the caution plate) on the damper with the pointer.
Insert height gauge A (35C91-01100) into the injector gauge stand ① and make sure that the top surface of injector tappet ② is aligned with gauge protrusion ③. Perform this inspection for all cylinders.
If the top surface of the tappet is not alighted with the height gauge protrusion, adjust it as follows.



**(4) Adjusting fuel injection timing**

**⚠CAUTION**

**Adjust the fuel injection timing on all cylinders starting from the No. 1 cylinder.**

(a) Make sure that the timing mark (the number on the caution plate) for No. 1 cylinder on the damper is aligned with the pointer ①.

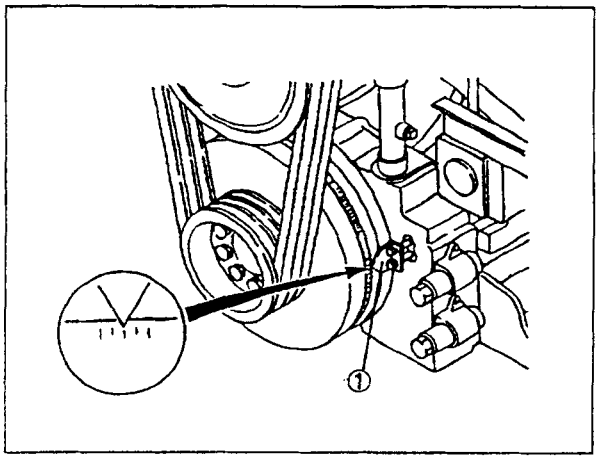
(b) Loosen lock nut ③ of adjusting screw ②.

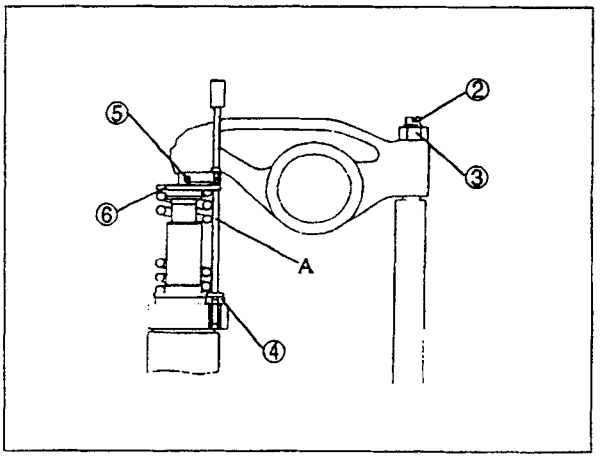
(c) Insert height gauge (A) (35C91-01100) into gauge stand ④ of the injection nozzle body. Tighten the adjusting screw so that protrusion ⑤ of the height gauge is aligned with the top surface of tappet ⑥.

(d) When the height gauge is aligned, fix the adjusting screw with the lock nut.

(e) Adjust on all cylinders after the No. 2 cylinder in the same way.

(f) Crank the engine again (2 turns) to check the fuel injection timing.



### 1.4 No-load minimum speed (idling) speed and maximum speed setting inspection and adjustment

**⚠CAUTION**

**(a) No-load minimum (idling) speed and maximum speed are set for each engine on the test bench at the factory and the set bolts are sealed. These settings are to be inspected and adjusted at Mitsubishiauthorized service shop only.**

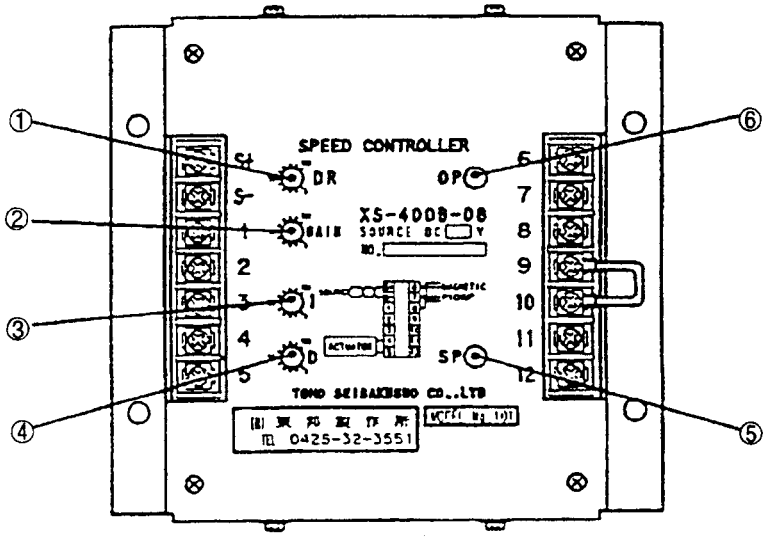
**(b) After authorized adjustment of the governor, which has to be effected by breaking the seals, be sure to re-seal all visible stoppers, making them appear as if they were sealed at the factory.**

**(c) The stoppers to be sealed are specified. Whether the seals are intact or not has important bearing on the validity of claims, if any, under warranty.**

**(d) When inspecting and adjusting these settings, be on standby to operate the engine stop lever manually in the event of engine overrun.**

NOTE: For inspection and adjustment, warm up the engine thoroughly until the coolant and oil temperature rises to 70°C [158°F].

**Speed control device for SG4030BR governor**



**(1) Adjusting trimmer**

① DR trimmer (droop adjusting trimmer)
Adjust this when droop operation is required. Apply the load in the order of 0%, 100%, 0% and 100%. Adjust the droop rate from the difference in engine revolution at 0% and 100%. Turn the trimmer clockwise to increase the droop rate. If terminals 2-3 are shortcircuited, the droop rate is forcibly set for high speed revolution.

② Gain trimmer (deviation amplified output (gain) adjusting trimmer)
It amplifies the engine revolution and the setting. Turn it clockwise to increase the amplification.

**⚠CAUTION**

**In parallel operation, do not adjust the gain trimmer. Otherwise, the droop changes and the load balance may become uneven.**

③ Trimmer (integral trimmer)
Adjust the controller response speed for difference between the set revolution and the actual revolution. Turn the trimmer clockwise to increase the response speed.

④ D trimmer (differential adjusting trimmer)
Difference between the set revolution and the actual revolution is predictably judged. Turn the trimmer clockwise to increase the prediction time.

⑤ SP trimmer (revolution setting trimmer)
Unlike other trimmers, multi-rotating trimmer (18 rotations) is used. Turn the trimmer clockwise to increase the setting revolution. Do not change the settings if the automatic parallel operation device is installed. (Change of setting does not allow automatic parallel operation.)

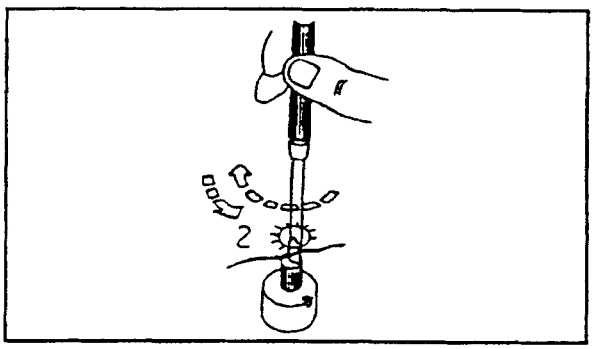
Indicator

⑥ OP (operation red LED)
When the power is supplied to the controller and the input signal from the magnetic pickup is 10 Hz or more, the LED lights. If this indicator does not light, the controller does not function. This function prevents over-revolution of the engine if the pickup signal is not available (disconnection, etc.).

**(2) Controller limit adjustment (rough adjustment)**

Procedures of limit adjustment (rough adjustment)

① Gain trimmer

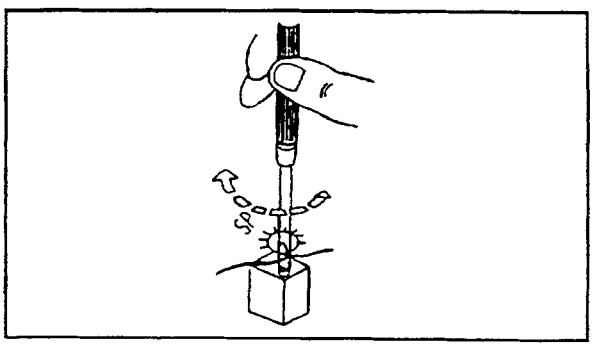


**⚠CAUTION**

**Carefully move the actuator lever not to be caught.**

Turn the trimmer clockwise slowly. When the engine start hunting, turn it counterclockwise. Set the trimmer at the position where hunting stops. Then turn it half the graduation. If the engine does not start hunting when the trimmer is turned all the way clockwise, move the actuator lever with a hand to start hunting.

② D trimmer
Adjust the D trimmer same as the gain trimmer.



③ SP trimmer
When the gain trimmer and the D trimmer are adjusted, the revolution changes. Use the SP trimmer to adjust the revolution to the setting value.

**(3) Checking load operation**

Raise load of the engine up to the rating (110% rating if required) and make sure that there is no hunting.

**(4) Adjustment of overshoot prevention trimmer**

Operate the engine until it reaches normal operating temperature. Increase the load gradually. If the engine speed drops before the seal-point load is applied and if the engine speed increases when the actuator lever is pushed by hand toward the INCREASE side, adjust the overshoot trimmer.

To adjust the trimmer, remove the nameplate on the controller and locate two trimmers. Adjust the trimmer on the right. This trimmer is set between 50 and 60% (12:00 and 13:00 positions) at the factory.

## ADJUSTMENT PROCEDURES

1. Adjust all linkages and controller (Gain, I, D, etc.).

2. Operate the engine until it reaches normal operating temperature. Increase the load gradually. Observe that the engine speed drops before the seal-point load is applied.

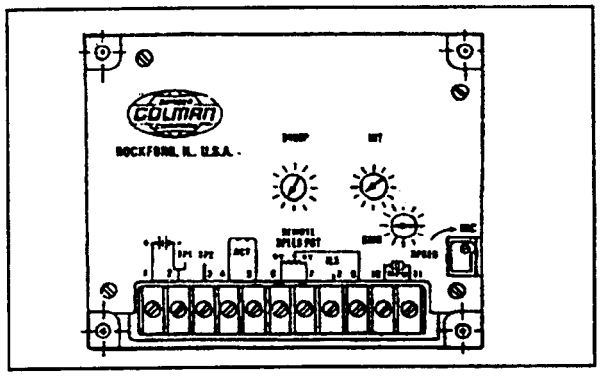
3. Push the actuator lever by hand toward the INCREASE side, and check to make sure the engine speed increases.

4. Remove the nameplate on the controller. Slowly turn the right trimmer counterclockwise while reading the engine speed. When the engine speed reaches the rated speed, turn the trimmer 10 degrees more in the counterclockwise direction.

**⚠WARNING**

**(a) Adjust the trimmer when the engine and actuator are sufficiently warm.**

**(b) This trimmer prevents overshooting of the engine at startup. When the trimmer is turned clockwise, the effect of overshoot prevention control reduces.**
**Turning the trimmer fully in the counterclockwise direction can result in an engine overshoot (excessive speed).**




**Barber-Colman Dyna 8000 type governor**

**(1) Adjusting speed setting**

(a) Turn the power source switch OFF, and stop the engine.

(b) Make sure that the potentiometers are set as follows:

"I" potentiometer ..... "1" position

"GAIN" potentiometer ..... "3" position

"DROOP" potentiometer..... Turn all the way counterclockwise for isochronous operation. Set in the desired position for droop operation (12% of 35° operation).

(c) Turn the power source and starter switches ON, and start the engine.

(d) Turn "SPEED" potentiometer within 20 rotations until the specified engine speed is obtained. This potentiometer can be turned clockwise to increase the speed or counterclockwise to decrease it, but it has no stopper for limiting the rotation in either direction.

(e) Set "SPEED" potentiometer for idling speed or so. (temporary setting)

(f) Turn the power source switch OFF, making sure that the engine stops.

**(2) Correcting hunting**

(a) If the actuator lever fails to gain stability (hunting does not stop), slowly turn "GAIN" potentiometer counterclockwise. After the lever has gained stability, tap on the lever, making sure that the engine restores to the set speed without hunting.

(b) If the actuator lever is in stable conditions, slowly turn "GAIN" potentiometer clockwise until hunting occurs, then slowly turn it counterclockwise until hunting stops. After the lever has gained stability, tap on the lever, making sure that the engine quickly restores to the set speed without hunting.

**(3) Correcting overshooting**

(a) After setting the speed, turn the power source switch OFF, and stop the engine.

(b) Restart the engine to see if the engine speed overshoots the setting; if so, turn "I" potentiometer counterclockwise.

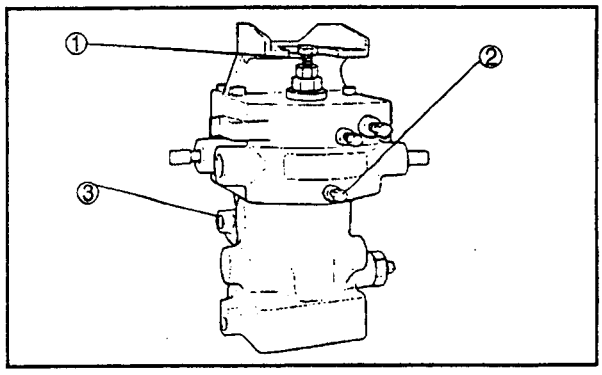
(c) If the time required to restore to the set speed is too long, turn "I" potentiometer clockwise.

(d) When "GAIN" and "I" potentiometers are adjusted, the set speed will slightly vary. Set the speed correctly by means of "SPEED" potentiometer.

**(4) Changing droop setting**

The governor would become unstable if "DROOP" potentiometer is turned clockwise from the set position after "GAIN" potentiometer of the controller has been adjusted. This can be corrected by turning "GAIN" potentiometer clockwise just a little.

**PSG-type governor**




**(1) Inspecting and adjusting no-load minimum (idling) speed setting**

(a) Make sure that the speed control lever is in the idling position, and measure the engine speed (rpm).

(b) If the idling speed is out of the specified range, reset it by means of adjusting screw ①.

**(2) Inspecting and adjusting no-load maximum speed setting**

(a) Move the speed control lever to the maximum speed position, and measure the engine speed (rpm).

(b) If the maximum speed is out of the specified range, reset it by means of governor set bolt ②.

(c) Manually change the engine speed to test the governor for response, verifying the ability of the governor to sense changes in speed and regulate it to the steady-state speed promptly.

**(3) Correcting hunting**

(a) If the engine hunts, reset needle valve ③. Open the needle valve by turning it counterclockwise (2 to 3 rotations) until the engine hunts. Keep the engine hunting for about 30 seconds until air is vented from the governor.

(b) Slowly close the needle valve by turning it clockwise until the engine stops hunting.

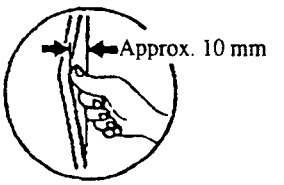
(c) Over-closing of the needle valve will delay speed regulation with respect to changes in load. Be sure to keep the valve backed off at least 1/4 rotation from the fully closed position.

(d) Seal each set bolt.

### 1.5 Fan and alternator drive belt inspection and adjustment

**⚠CAUTION**

- **If any peeling or damage is found on the belt, replace the belt with a new one.**
- **Do not apply lubricant to the belt. Otherwise, slippage may shorten the life.**




Apply thumb pressure (approx. 98N (10 kgf) [22.05 lbf] ) to the belt midway to inspect the belt tension. Approx. 10 mm [0.394 in.] tension is considered acceptable.

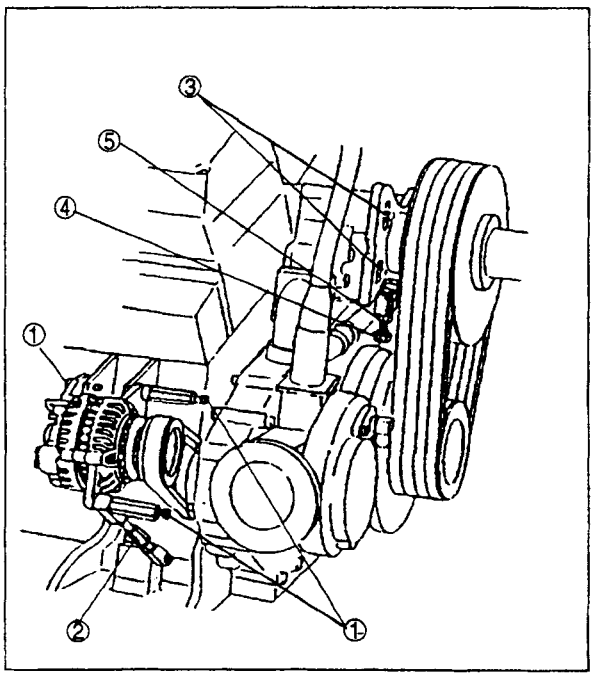
If the tension is incorrect, make an adjustment according to the following procedures:

**Alternator side**

1. Remove the cover of the alternator.
2. Loosen the alternator and their fixing bolts ①.
3. Turn adjusting rod ② to adjust the belt tension.
4. Then, tighten all bolts fixing the alternator.

**Fan side**

1. Loose bracket mounting bolt ③ of the fan pulley.
2. Loosen lock nut ⑤ of adjusting bolt ④ and tighten the bolt for appropriate tension.
3. Then, fix the belt with the lock nut and tighten the bracket mounting bolt.



## 2. BENCH TEST

An overhauled engine should be tested for performance on a dynamometer. This test is also for "breaking-in" of the major parts of the engine. To test the engine, proceed as follows:

### 2.1 Starting up

(1) Inspect the levels in the radiator, oil pan and fuel tank. Prime the fuel and cooling systems to bleed air out.

(2) Crank the engine with the starter for about 10 seconds to permit lubricating oil to circulate through the engine.

(3) Slightly move the control lever in the direction of increasing fuel injection, and turn the starter switch to START for starting the engine. (Do not move the control lever to "full injection" position.)

(4) After the engine starts, let it idle under the no-load condition by operating the control lever.

### 2.2 Inspection after starting up

After starting up the engine, check the following points. Upon discovery of any faulty condition, immediately stop the engine, and investigate the cause to take necessary actions.

(1) Lubricating oil pressure: It should 0.39 ~ 0.67 MPa (4 ~ 7 kgf/cm$^2$ )[56.90 ~ 99.58 psi] at rated speed or 0.20 ~ 0.29 MPa (2 ~ 3 kgf/cm$^2$) [28.45 ~ 42.68 psi] at idling speed.

(2) Coolant temperature: It should be 65° to 85° [149.0 ~ 185.0 °F].

(3) No leakage of oil, coolant and fuel. Especially oil leakage from turbocharger lubricating oil pipe connections.

(4) Knocking: It should die away as the coolant temperature rises. No other defects should be noted.

(5) Exhaust color and abnormal smell.

### 2.3 Bench test time

The relationship between the bench test and the operation time is as shown in the right.

| | Speed (rpm) | Load (PS) | Time (min) |
|---|---|---|---|
| 1 | Idling | No load | 5 |
| 2 | 1000 | No load | 5 |
| 3 | 1200 | No load | 10 |
| 4 | Rated speed | 25% | 10 |
| 5 | Varies according to specifications. | 50% | 10 |
| 6 | | 75% | 30 |
| 7 | | 100% | 20 |

### 2.4 Inspection and adjustment after bench test

(a) Adjustment of valve clearance

(b) Adjustment of injection timing

(c) Retightening of exhaust manifold mounting bolts

# 3. PERFORMANCE TESTS

Various ways of performance tests are available. This section explains the performance test method for construction diesel engine (in accordance with JIS D 1005, 1986). It is necessary to add other test methods according to the usage. The engine performance is judged from the overall test results.

## 3.1 Standard equipment

The cooling fan, air cleaner and alternator are the standard equipment of an engine to be tested.

## 3.2 Test items

(1) Fuel consumption test

(2) No-load maximum speed test

(3) No-load minimum speed test

## 3.3 Test methods

### (1) Fuel consumption test

(a) Engine speed

(b) Fuel injection quantity

(c) Engine output

### (2) No-load maximum speed test

For this test, the governor should be set for no-load maximum speed.

### (3) No-load minimum speed test

(a) The control lever should be set to the stable minimum speed position. By "stable minimum speed" is meant a minimum speed to which the engine rpm can be quickly dropped from the maximum rpm without stalling.

(b) The no-load minimum speed should be as specified.

### (4) Others

During the performance test, inspect for leakage of gas, coolant, lubricating oil and fuel, noise or hunting.

### (5) Correcting the engine output

The diesel engine output depends on the atmospheric pressure and temperature. Therefore, it is necessary to set the condition at the standard atmosphere (atmospheric pressure 750 mmHg, temperature 25°C [77°F], atmospheric vapor pressure 11.4 mmHg).

The measured shaft output and shaft torque are corrected by multiplying the factor calculated from the following equation:

$$k=\left\{\left[\frac{P_0}{P}\right]\cdot\left[\frac{\theta}{\theta_0}\right]^{0.7}\right\}^{fm}$$ (Not turbocharged)

$$k=\left\{\left[\frac{P_0}{P}\right]^{0.7}\cdot\left[\frac{\theta}{\theta_0}\right]^{1.5}\right\}^{fm}$$ (Turbocharged)

$P_0$: Measured value of atmospheric pressure (mmHg)

P: Standard dry atmospheric pressure (743 mmHg, 99 kPa(1.01kgf/cm²) [14.36 psi])

θ: Measure value of temperature (°C +273)

θ: Standard atmospheric temperature (298K, 25°C [77.0°F])

**fm, fm′ : Air-fuel ratio**

$$fm=0.036\frac{q}{r}-1.14\ \left(40\leqq\frac{q}{r}\leqq 65\right)$$

$$=0.3\ \left(\frac{q}{r}\leqq 40\right)$$

$$=1.2\ \left(65\leqq\frac{q}{r}\right)$$

q: Quantity of fuel supply per 1 ℓ piston displacement and 1 cycle (mg/ℓ, cycle)

r: Compression ration of turbocharger compressor (r=1 for nonturbocharged engine)

The range of k should be:

$600\leqq P\leqq 825$ mmHg {$80\leqq P\leqq 110$ kPa (1.122 kgf/cm₂) [15.95 psi]}

$10\leqq\theta-273\leqq 40$°C [104.0°F] {$283\leqq\theta\leqq 313$ K}

and $0.9\leqq k\leqq 1.1$.

If k is out of the range and P and θ are within the range, indicate the corrected output using the correction factor. Record the test conditions on the test report.

# ENGINE ACCESSORY 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.

## 1. PREPARATORY STEPS

(a) Shut off the fuel supply, and disconnect the starting system from the engine.

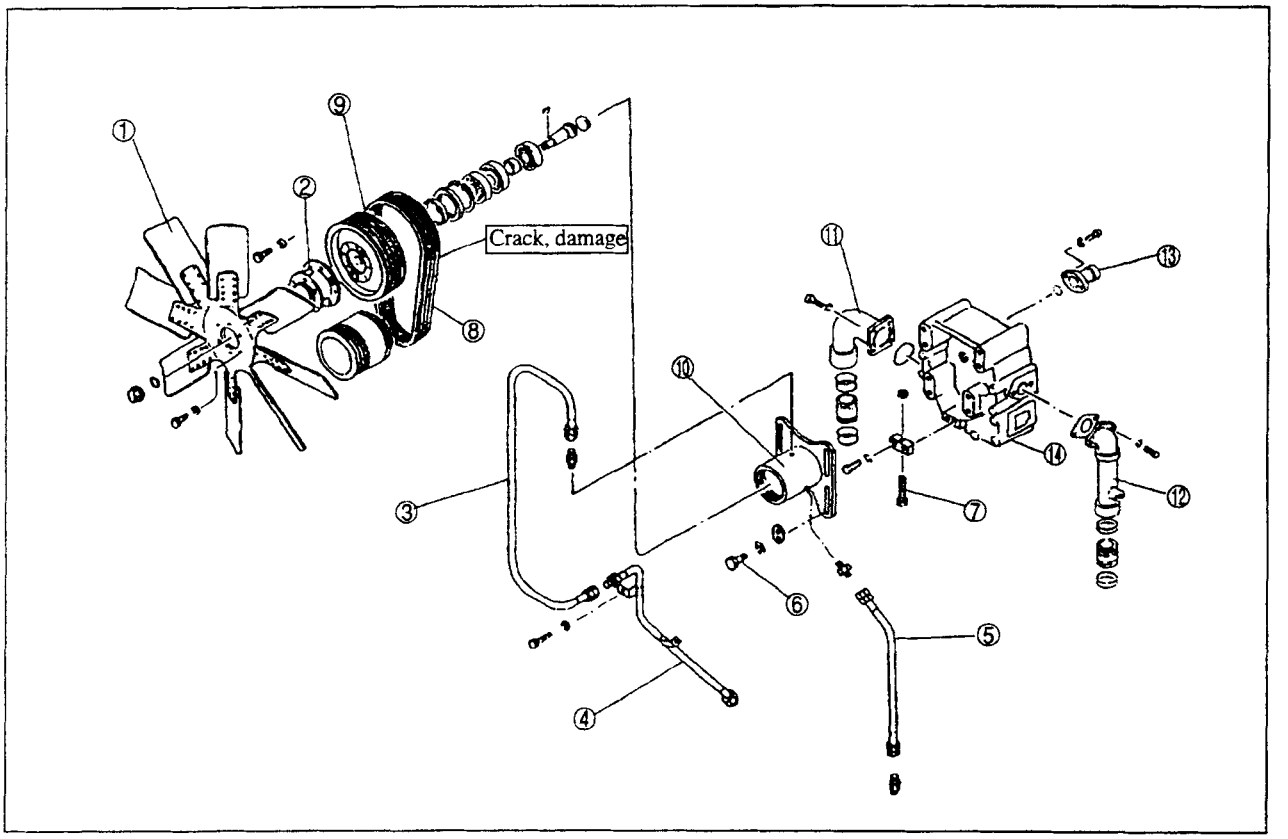
(b) Loosen the drain cock, on the right/left rear sides of the crankcase, and drain coolant.

(c) Loosen the oil pan drain plug, and drain engine oil. (Oil pan capacity: 180ℓ [47.56 [u.s.gal.])

**⚠CAUTION**

**Hot engine oil can cause personal injury if it come in contact with the skin. Be careful when draining the oil.**

## 2. REMOVING FAN AND FAN DRIVE




**(1) Removing fan and spacer**

(a) Unscrew fan mounting bolts and remove fan ①.

(b) Unscrew spacer ② mounting bolts and remove the spacer.

**(2) Removing fan drive oil pipe**

Remove fan drive oil pipes ③, ④ and ⑤.

**(3) Removing fan belt and fan pulley**

(a) Loosen fan drive mounting bolts ⑥ and adjusting bolts ⑦ and remove fan belt ⑧ and fan pulley ⑨.

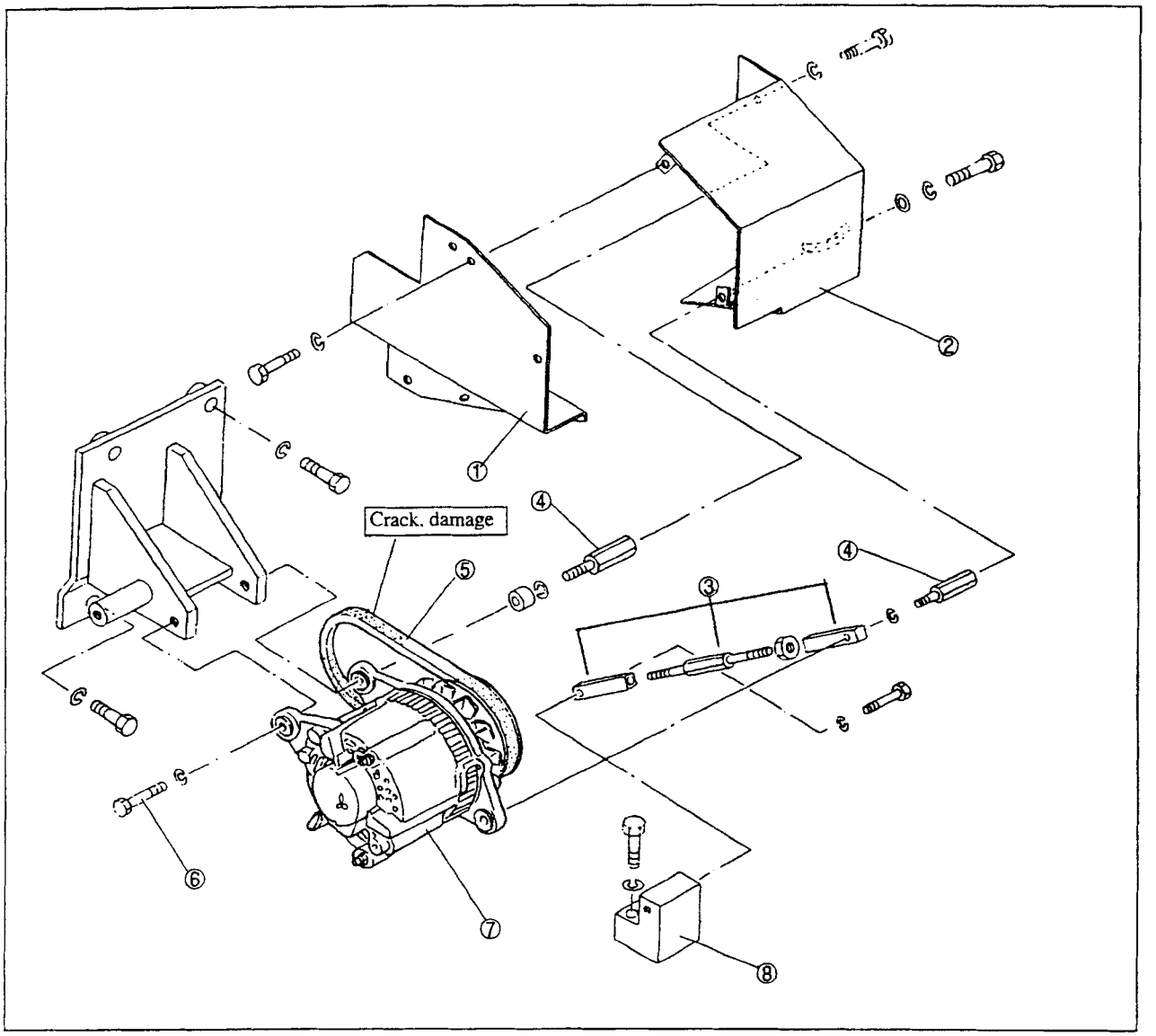
**(4) Removing fan drive and adapter**

(a) Loosen fan drive mounting bolts ⑥ and remove fan drive ⑩.

(b) Remove water pipe ⑪ and oil pipe ⑫ from adapter ⑭.

(c) Loosen the adapter mounting bolts and remove the adapter and connector ⑬.

## 3. REMOVING ALTERNATOR




**(1) Removing belt cover**

Loosen belt cover mounting bolts and remove belt covers ① and ②.

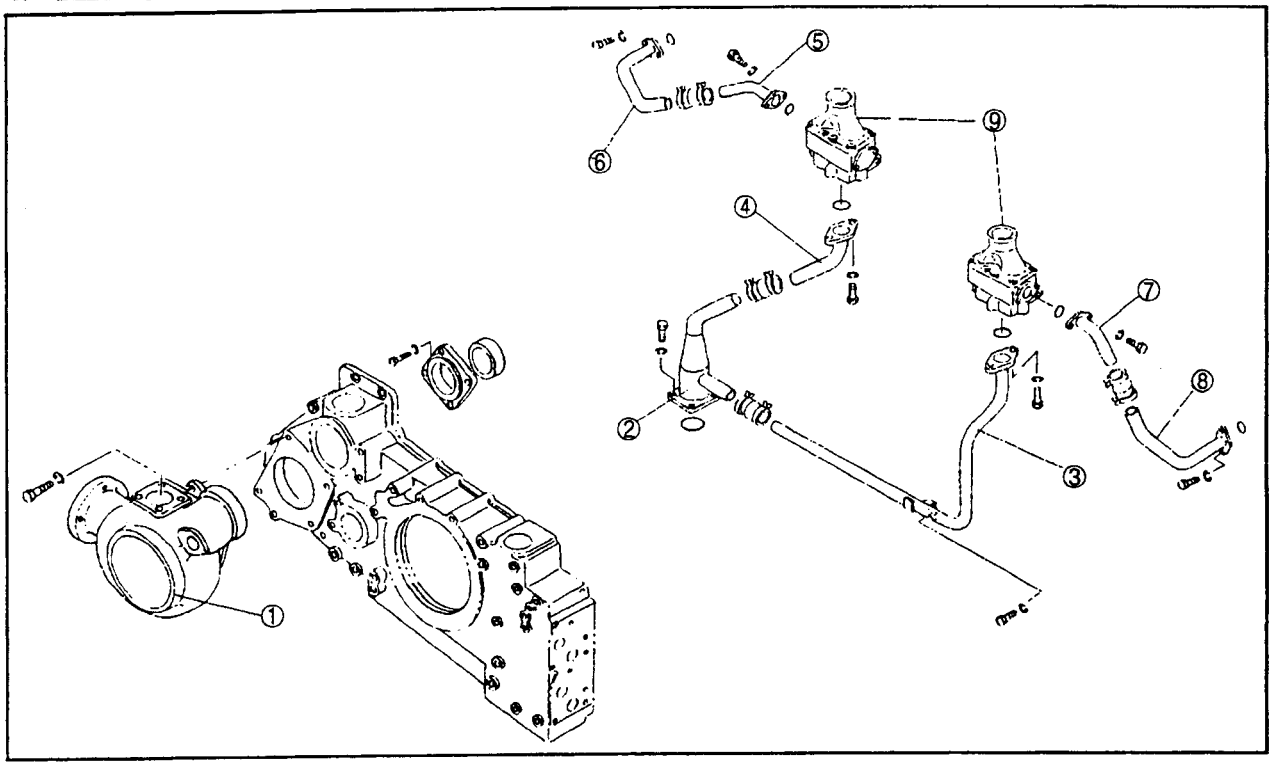
**(2) Removing V belt and alternator**

(a) Disconnect the harness and loosen alternator mounting bolts ④ and ⑥ and adjusting rod ③. Remove V belt ⑤.

(b) Loosen alternator mounting bolts ④ and ⑥and remove adjusting rod ③. Remove alternator ⑦.

(c) Loosen bracket mounting bolts and remove bracket ⑧.

## 4. REMOVING WATER PUMP AND THERMOSTAT




**(1) Removing water pump**

(a) Disconnect bypass pipe ② from water pump ①.

(b) Loosen the water pump pulley mounting nut and remove the water pump pulley.

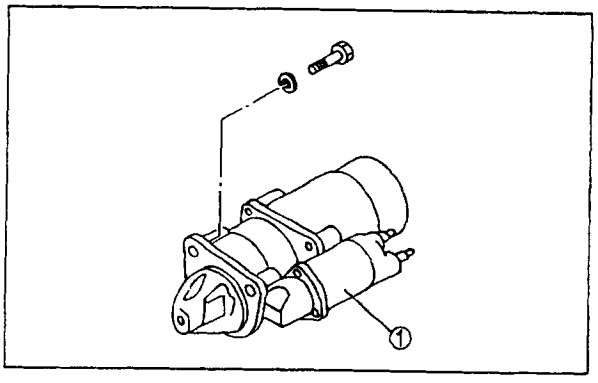
(c) Loosen the water pump mounting bolts and remove water pump ①.

**(2) Removing thermostat**

(a) Disconnect bypass pipes ②, ③ and ④, and air cooler pipes ⑥, ⑦ and ⑧. Remove thermostat ⑨.

## 5. REMOVING STARTER

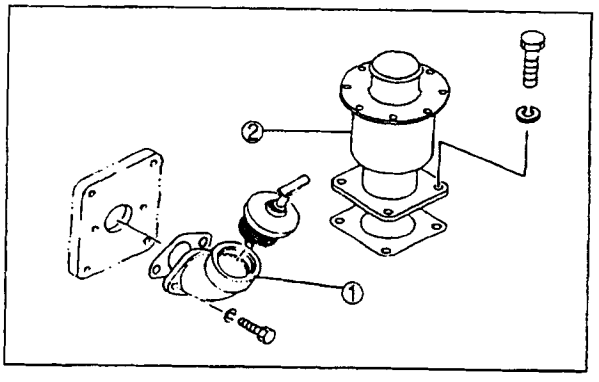
Disconnect the harness and loosen the starter mounting bolts. Remove starter ①.




## 6. REMOVING OIL FILLER AND BREATHER

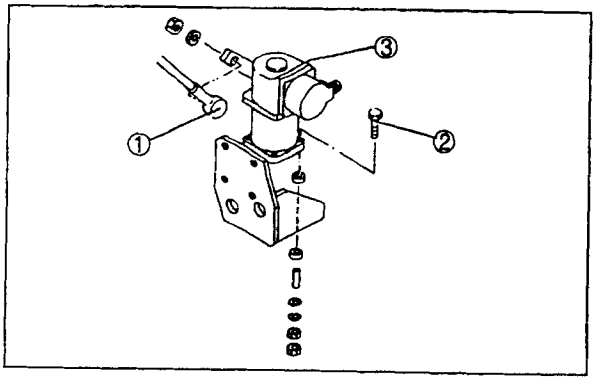
(a) Loosen the oil filler mounting bolt at the left side of the engine and remove oil filler ①.

(b) Loosen the breather mounting bolts on the timing gear case and remove breather ②.




## 7. REMOVING GOVERNOR (ELECTRONIC GOVERNOR)

Disconnect the harness and loosen governor mounting bolt ②. Remove governor ③.



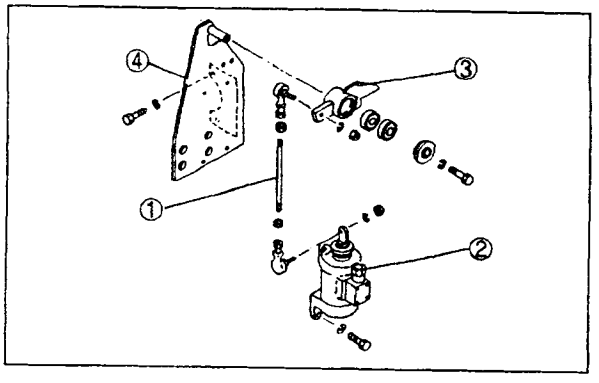

## 8. REMOVING STOP SYSTEM

(a) Remove linkage ①.

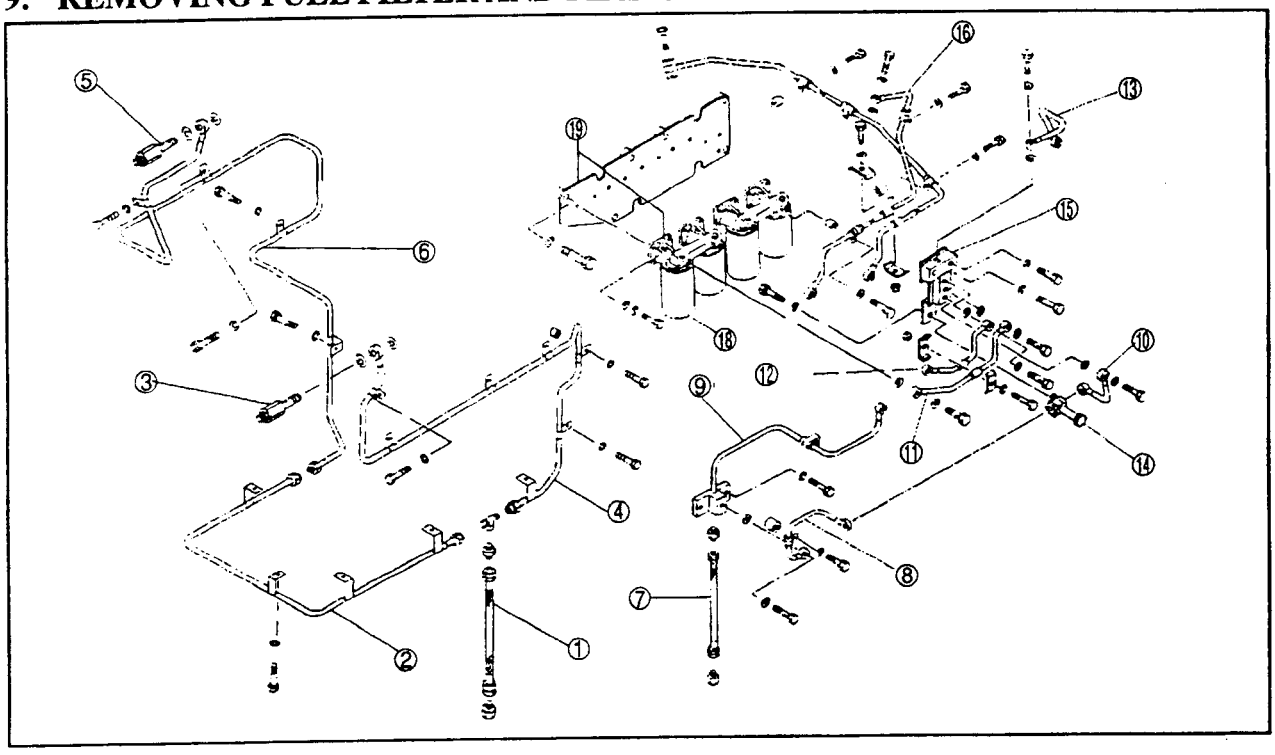
(b) Disconnect the harness and loosen the stop solenoid mounting bolt. Remove stop solenoid ②.

(c) Loosen the stop lever mounting bolt and remove stop lever ③.

(d) Loosen the bracket mounting bolts and remove bracket ④.



## 9. REMOVING FUEL FILTER AND PIPING




**(1) Removing return pipe**

Remove drain pipe ①, fuel leak pipe ②, left check valve ③, LH fuel pipe ④, right check valve ⑤ and RH fuel pipe ⑥.

**(2) Removing fuel pipe**

Disconnect inlet pipe ⑦ and fuel pipes ⑧, ⑨, ⑩, ⑪, ⑫ and ⑬, and remove priming pump ⑭ and bracket ⑮.

**(3) Removing fuel filter**

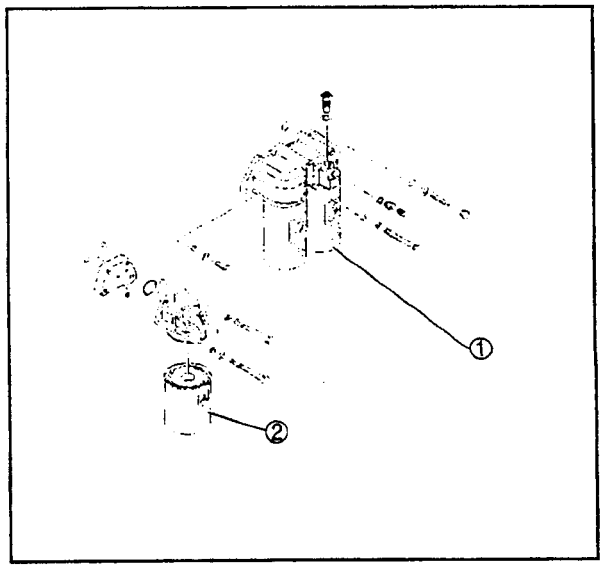
(a) Disconnect fuel pipes ⑯ and ⑰ and remove fuel filter ⑱.

(b) Remove the bracket mounting bolts and remove bracket ⑲.

## 10. REMOVING OIL FILTER

(a) Loosen the oil filter mounting bolts and remove oil filter ①.

(b) Loosen bypass filter mounting bolts and remove bypass filter ②.

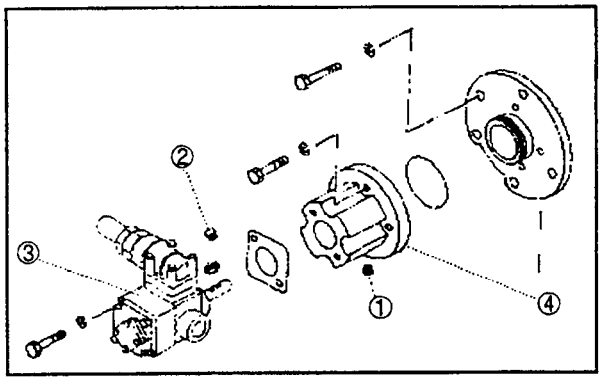


## 11. REMOVING FEED PUMP AND ACCESSORY DRIVE

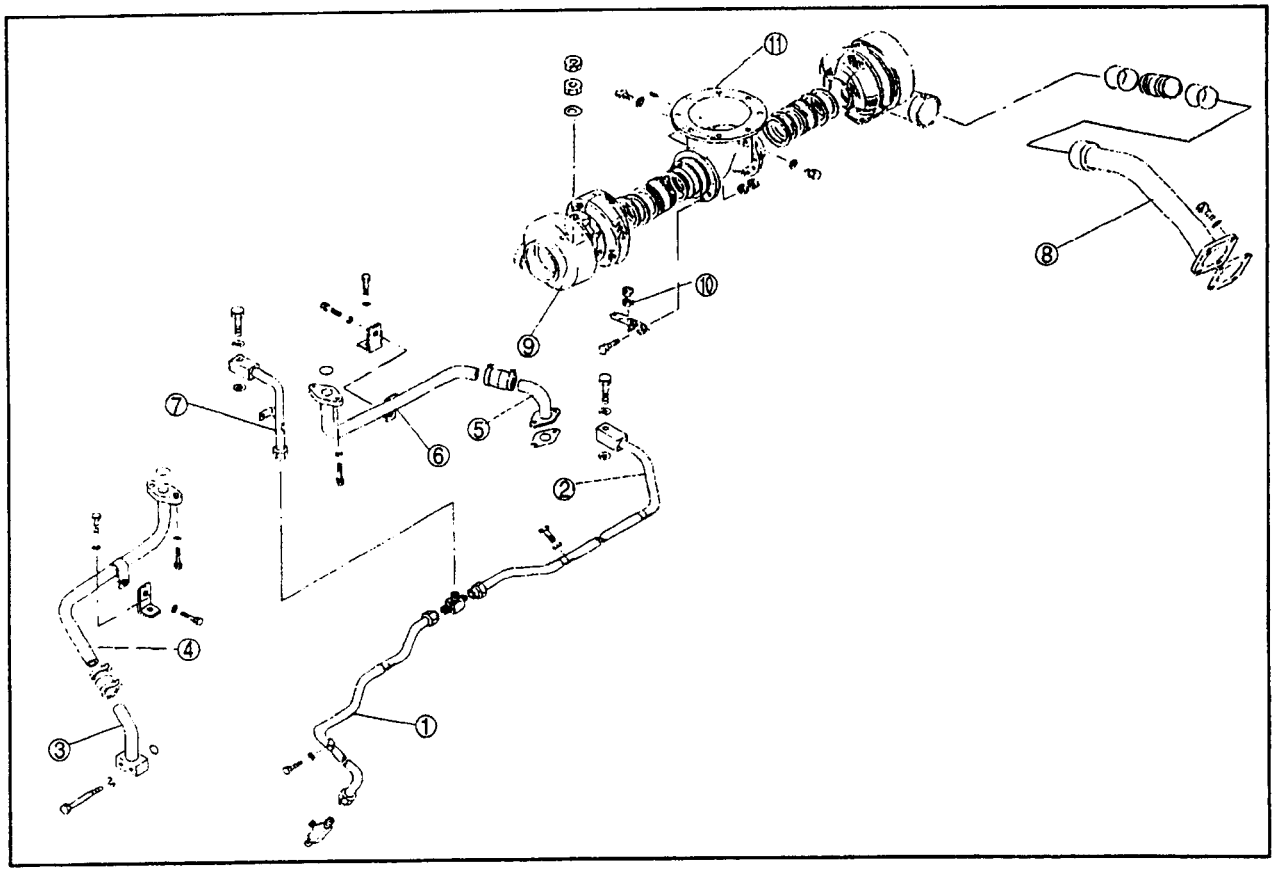
(a) Remove plug ①, and loosen screw ② that is securing the key in place.

(b) Loosen the feed pump mounting bolts and remove feed pump ③.

(c) Loosen the accessory drive mounting bolts and remove accessory drive ④.




## 12. REMOVING TURBOCHARGER AND EXHAUST PIPE




**(1) Removing oil pipe**

(a) Disconnect oil pipes ① and ②.

(b) Disconnect drain pipes ③, ④, ⑤ and ⑥.

(c) Remove oil pipe ⑦.

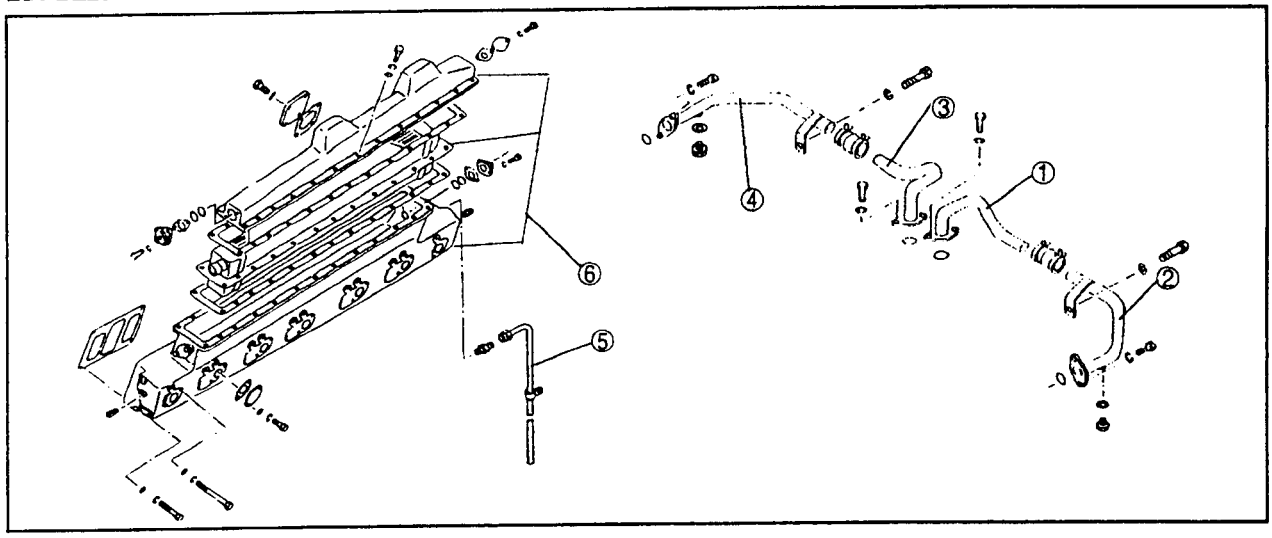
**(2) Removing turbocharger**

Disconnect inlet duct ⑧ from the air cooler and remove turbocharger ⑨.

**(3) Removing exhaust pipe**

Remove bracket ⑩ from the exhaust manifold and remove exhaust pipe ⑪.

## 13. REMOVING AIR COOLER




**(1) Removing air cooler pipe**

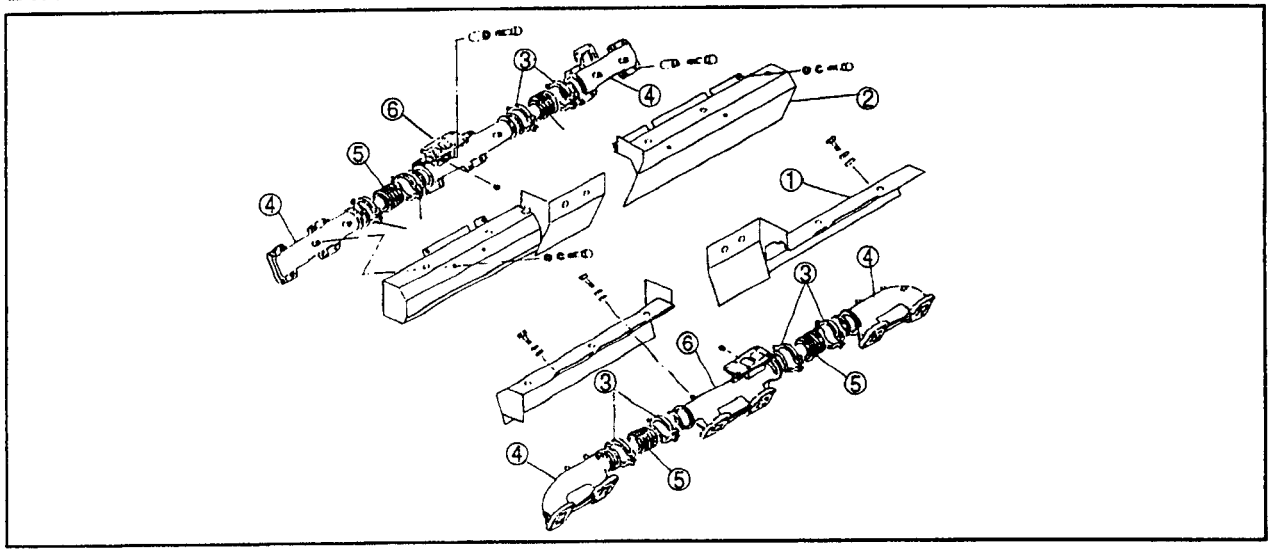
(a) Remove air cooler pipe ① and ② from the left air cooler.

(b) Remove air cooler pipe ③ and ④ from the right air cooler.

**(2) Removing air cooler**

Remove left/right oil pipes ⑤ and remove left/right air coolers ⑥.

## 14. REMOVING EXHAUST MANIFOLD



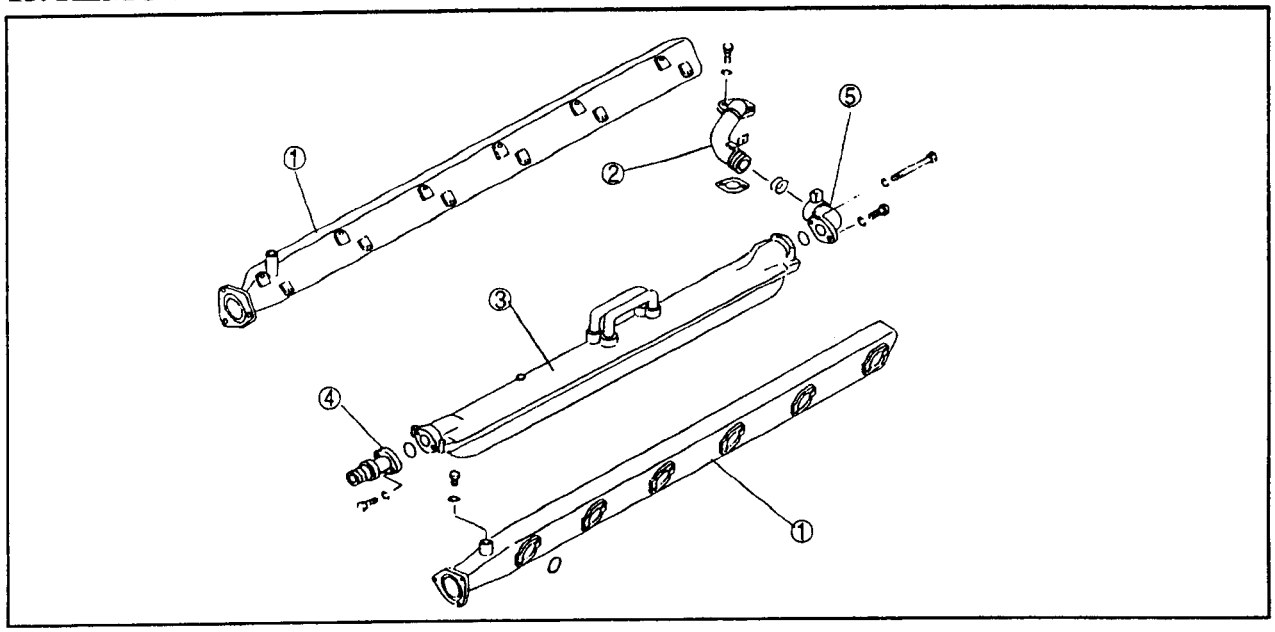

**(1) Removing insulator**

Remove left/right insulators ① and ②.

**(2) Removing exhaust manifold**

Remove left/right couplings ③ and remove exhaust manifold ④, joint ⑤ and exhaust manifold ⑥.

## 15. REMOVING WATER OUTLET PIPE AND OIL COOLER




**(1) Removing water outlet pipe**

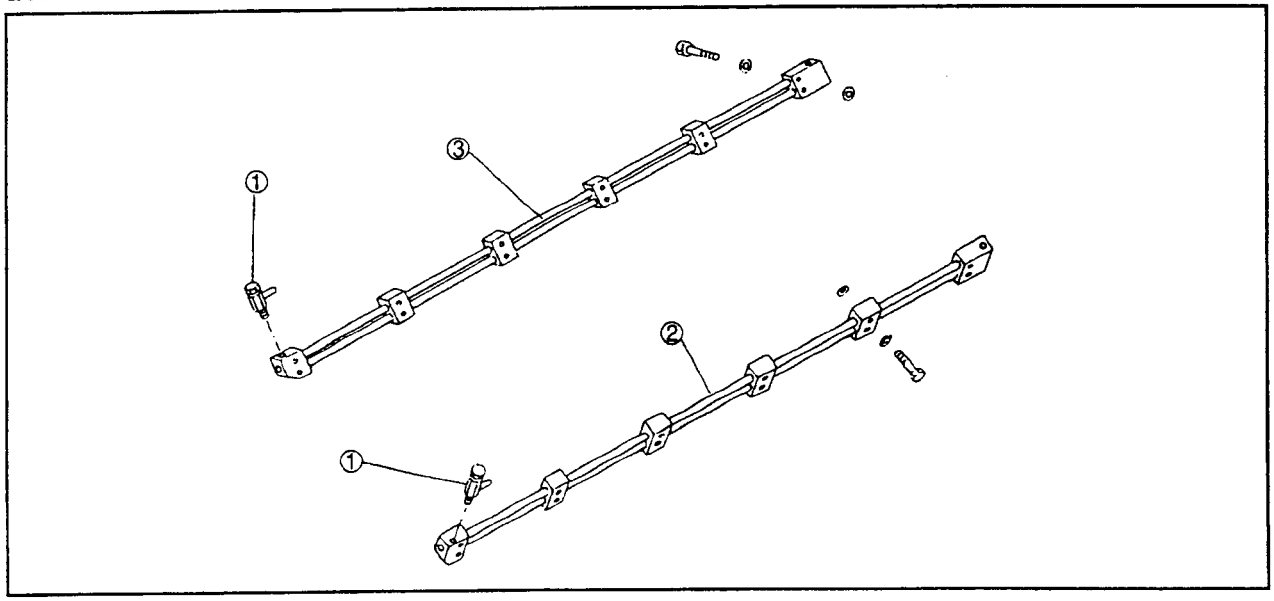
Loosen the left/right water outlet pipe mounting bolts and remove left/right water outlet pipe ①.

**(2) Removing oil cooler**

(a) Remove oil pipe ②.

(b) Loosen the oil cooler mounting bolts together and remove oil cooler ③ together with connectors ④ and ⑤.

## 16. REMOVING FUEL PIPE

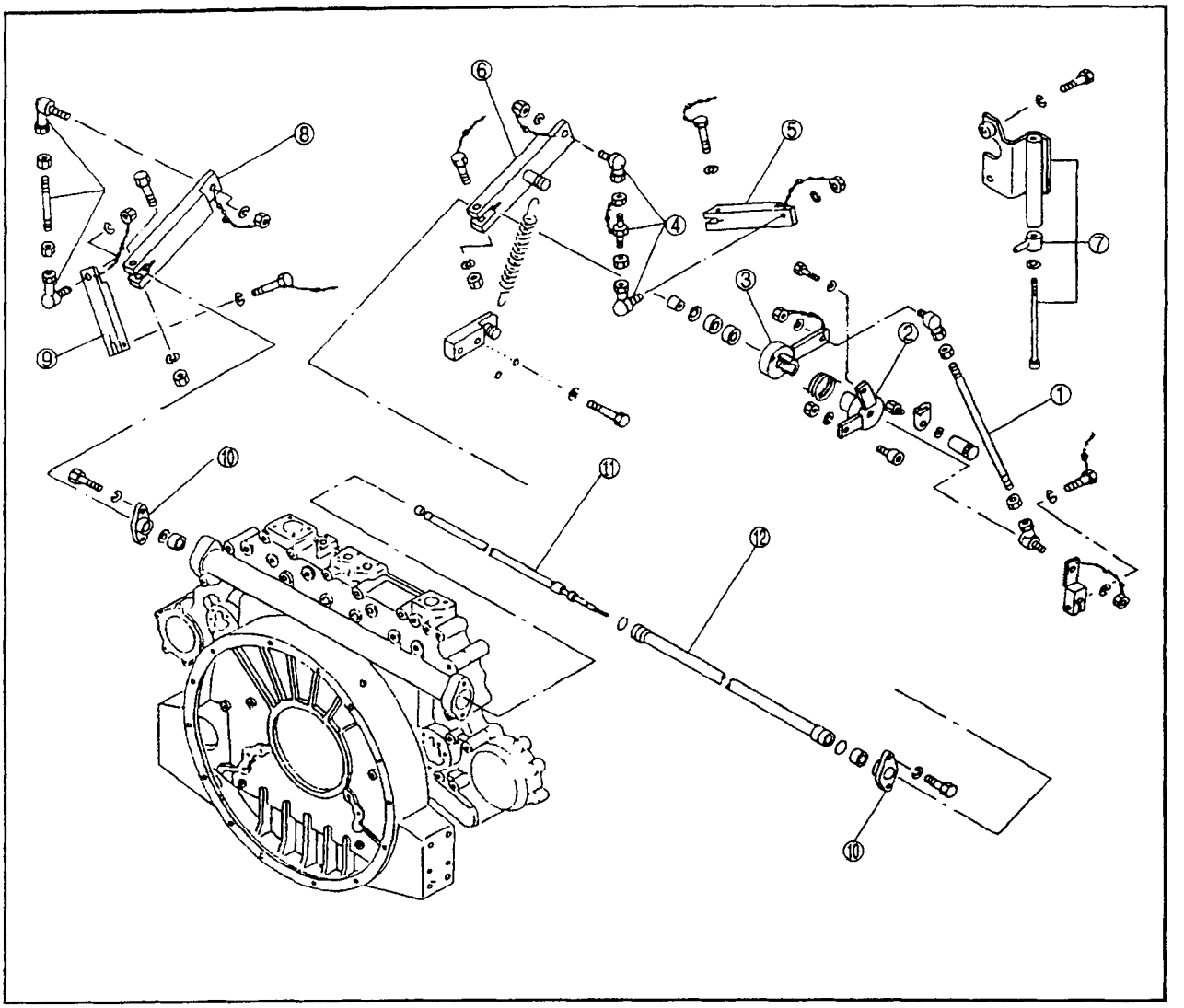



**(1) Removing fuel pipe**

(a) Remove left/right air valves ①.

(b) Loosen the fuel pipe mounting eyebolts and remove fuel pipes ② and ③.

## 17. REMOVING FUEL LINKAGE




**(1) Removing control ring**

(a) Remove control link ① and remove stop lever ② and control lever ③.

(b) Remove control link ④ and remove control levers ⑤ and ⑥.

(c) Remove control link ⑦ and remove control lever ⑧ and ⑨.

**(2) Removing control shaft**

Remove left/right bearing covers ⑩ on the timing gear case and remove control shaft ⑪ and timing case pipe ⑫.

## 18.ENGINE ACCESSORY INSTALLATION

(1) **To install the engine accessories, use reverse of the removal procedures. After installing them, service as follows:**

(a) Tighten bolts according to the **"Table of tightening torque for major bolts"**. (Refer to the Service Standard.)

(b) Adjust the fuel linkage.

(c) Refill the engine with recommended oil up to the specified level.

(d) Refill the cooling system with coolant.

(e) Check each pipe connection for oil or coolant leaks.

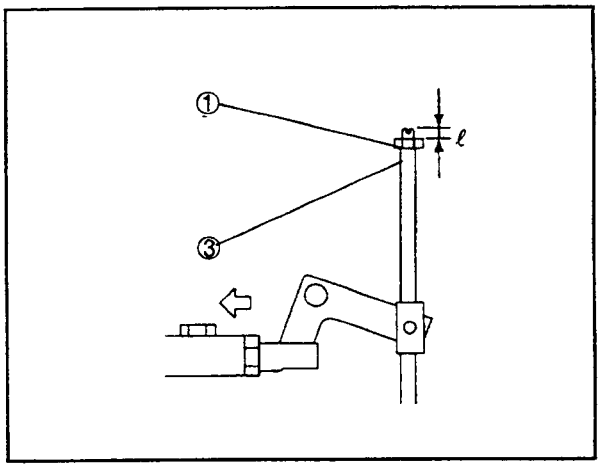
(f) Prime the fuel system. (Refer to Engine Adjustment.)

(g) Adjust the V belt tension. (Refer to Engine Adjustment.)

## 19. ADJUSTING FUEL LINKAGE

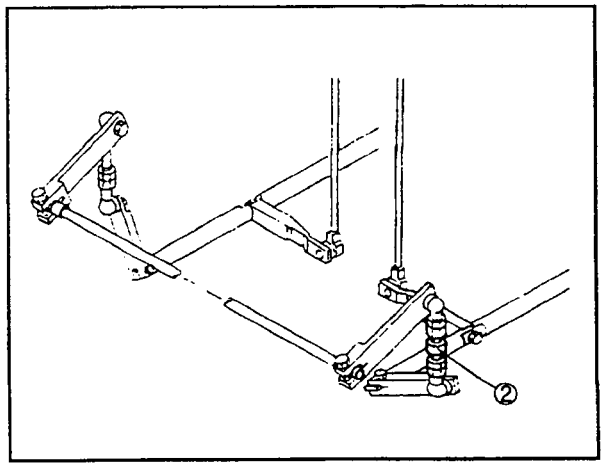
(1) **Press the injection nozzle rack all the way to the rack stopper (full to the non-injection side) and adjust cancel rod ① of the link so that there may be no play on each linkage.**

Note: In this case, adjust the screw protrusion ($\ell$) in the range of 7±1.5 mm [0.28 ± 0.06 in.]. (The engine is usually adjusted to this range for shipment.) If dimension $\ell$ is greatly out of the range, remove turnbuckle ② (right side only) for left/right linkage adjustment. Follow the steps (2) to (4) after (1) above.



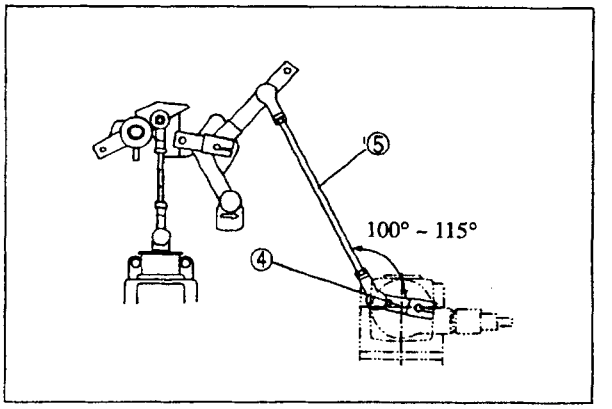

(2) **Steps (3) to (5) shown below are required when nuts other than lock nut ③ of the cancel rod is removed. These steps are not normally required. Make adjustment and lock the link to prevent looseness at each side.**

Note: Carry out the steps (2) and (3) above, while the rack is in contact with the injection nozzle rack stopper. (The link moves to the non-injection side by its weight.)



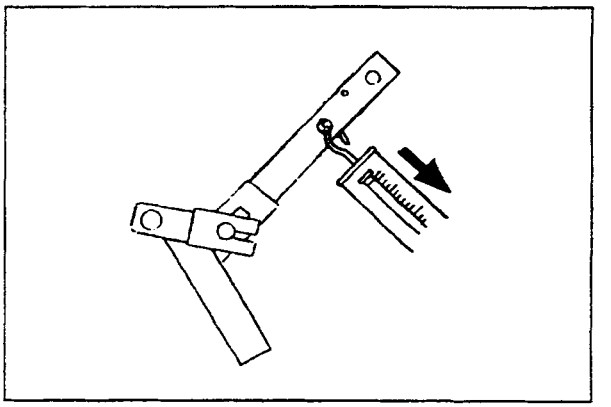

(3) **Make sure that the injection nozzle rack for all cylinders is in contact with the rack stopper (non-injection). If any rack of the cylinder is not in contact with the stopper, repeat step (2) above.**

(4) **When steps (1) to (3) are completed, make sure that the angle between actuator lever ④ of the electronic governor and link ⑤ is 100°-115° while the rack is in contact with the stopper.**




(5) **Move the linkage and make sure that the movement is smooth.**

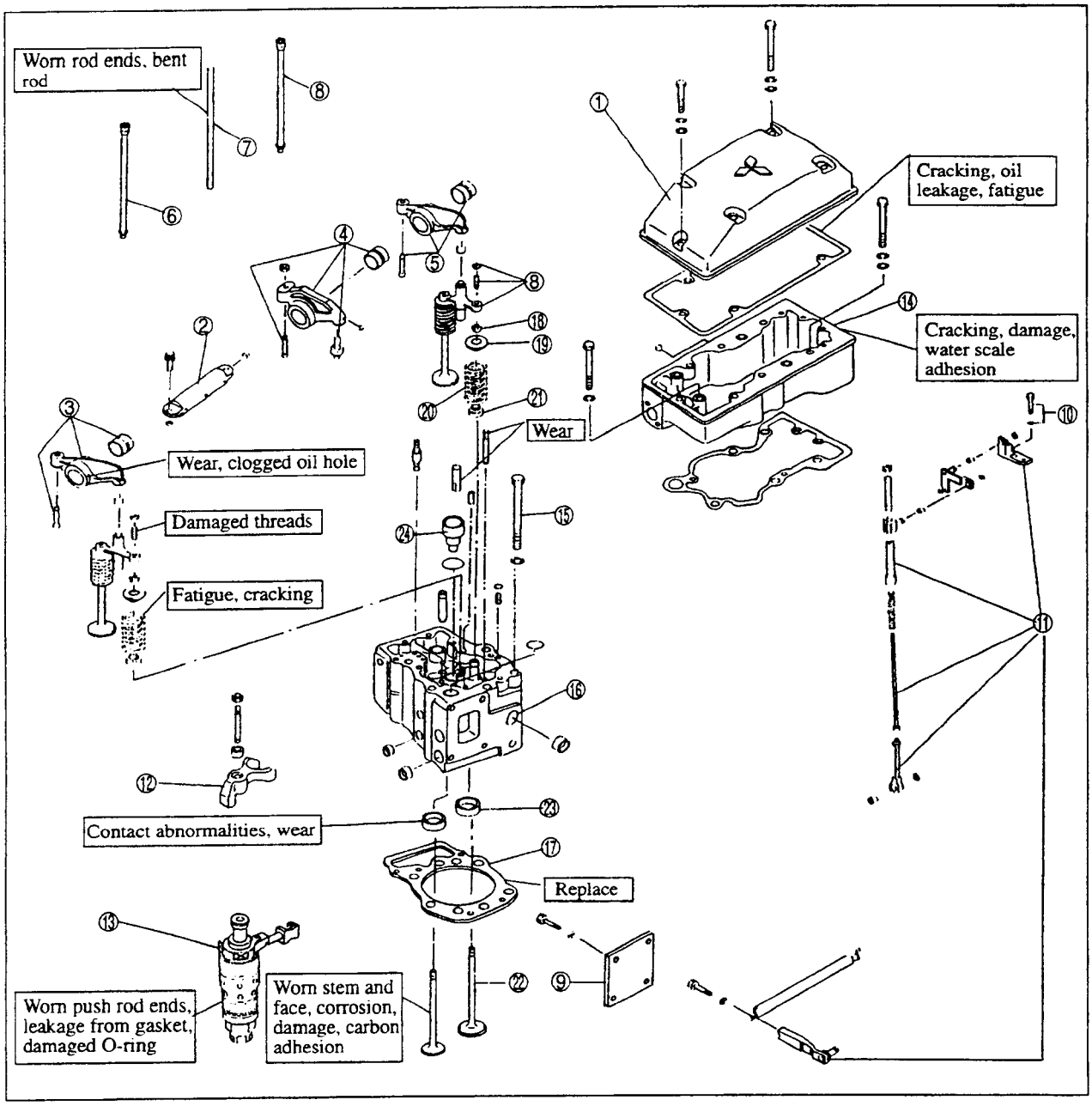
**(The linkage should move with the force of 19.6 N (2.0 kgf) [4.41 lbf] or less at the link hole to the governor.)**



# ENGINE PROPER

# 1. CYLINDER HEAD AND VAVLE MECHANISM

## 1.1 Disassembly



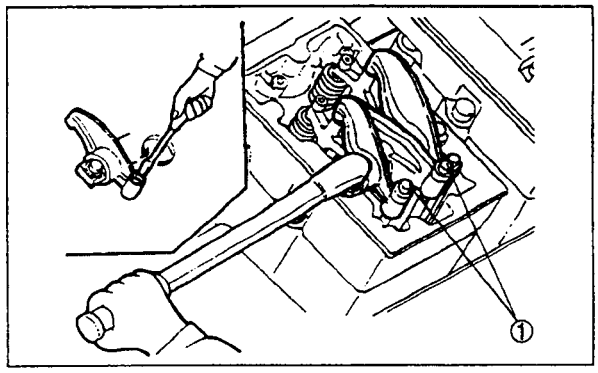

① Rocker cover
② Rocker shaft
③ EXH rocker
④ UI rocker
⑤ IN rocker
⑥ IN & EXH push rod
⑦ UI push rod
⑧ Bridge
⑨ Cover
⑩ Bolt
⑪ Cancel rod
⑫ Gland
⑬ Injection nozzle
⑭ Rocker case
⑮ Cylinder head bolt
⑯ Cylinder head
⑰ Gasket
⑱ Cotter
⑲ Rotor
⑳ Spring
㉑ Valve stem seal
㉒ Valve
㉓ Valve seat
㉔ Copper tube

**(1) Disassembling rocker shaft assembly**

(a) Loosen adjusting screw ① of each rocker in advance.

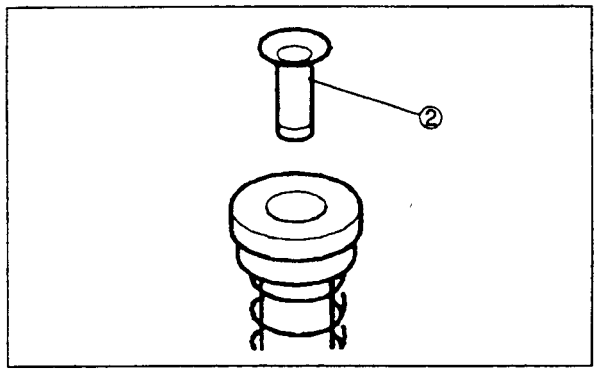
(b) Remove each rocker shaft assembly. Keep the shaft assembly and mounting bolts in a set.

(c) The rocker shaft assembly may have plunger push rod ②. In this case, carefully remove the plunger pushrod.




**(2) Disassembling rocker shaft assemblies**

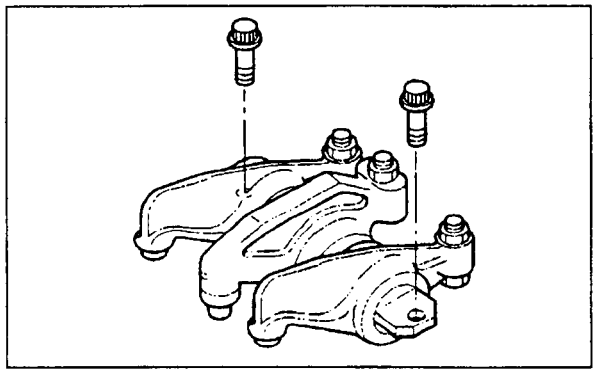
Lay the disassembled rockers in the order removed, and install them in that order at the time of reassembly. This is for ensuring the same rocker shaft-to-rocker clearance as before.




**(3) Removing valve bridge**

Remove the valve bridge and the bridge cap.

NOTE: Be careful not to let the bridge caps fall into the crankcase through the pushrod holes.



**(4) Removing injection nozzle**

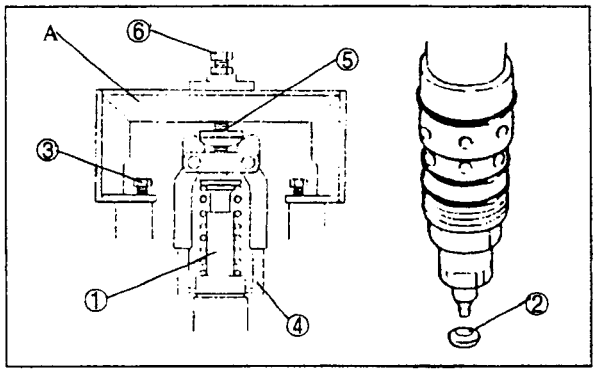
(a) Remove the cancel rod and the gland.

(b) Install unit injector puller (A) (35C91-11400) on the cylinder head using bolts ③. (Use rocker cover bolts or similar bolts). Position claws ④ of the unit injector puller into holes on the unit injector. Turn nut ⑤ by hand until the claws are securely inserted in the holes. Turn bolt ⑥ to remove the injector.

(c) Remove gasket ② from the inside of the cylinder head using a wire or other tool.

**⚠CAUTION**

**Install the unit injector puller on the cylinder head before removing the gland nut. Removing the gland nut without the puller in place can cause the injector to eject abruptly.**



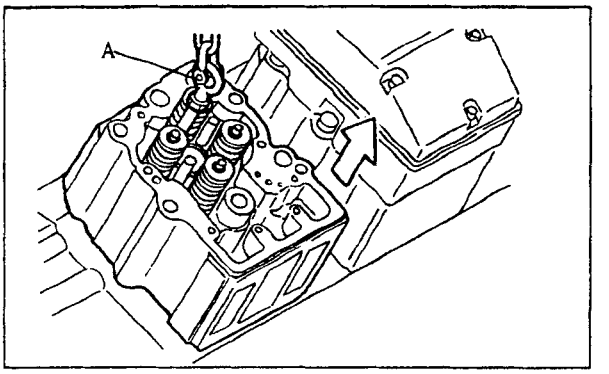
**(5) Removing cylinder head assemblies**

(a) Each cylinder head is located on the crankcase with dowel pins. Using eye nut (A) (37591-02400), lift the head diagonally.

(b) Remove the cylinder head gasket.

**⚠CAUTION**

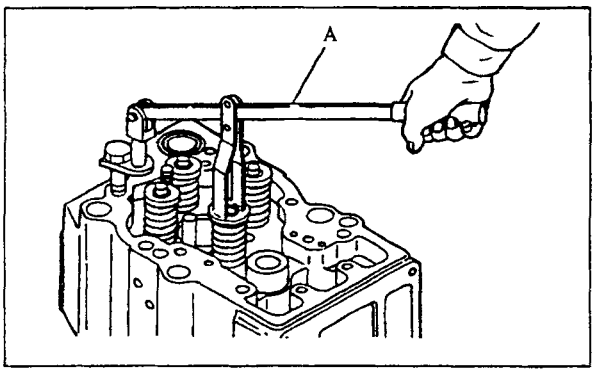
**Be careful not to damage the cylinder head and the crankcase surfaces with a screwdriver when removing the gasket.**




**(6) Removing valve and valve spring**

Using valve spring pusher (A) (33591-04500), compress the valve spring squarely, and remove the valve cotters.

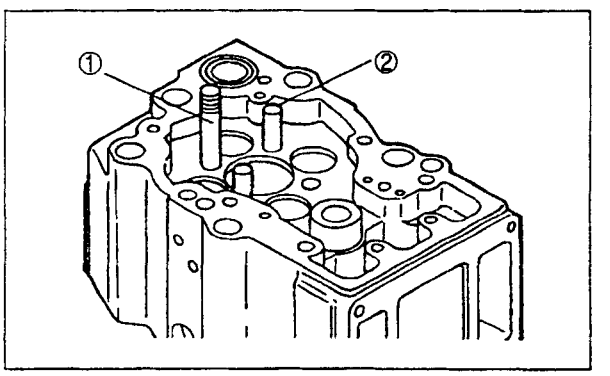
**NOTE**: If the valves are to be reused, mark them for their seats to produce the same combination of the valve and the seat as before at the time of reassembly.




**(7) Removing stud and bridge guide**

Do not remove gland mounting stud ① and bridge guide ② off the cylinder head if not required. If the studs and guides are removed, use new studs and guides at the time of reassembly. Apply thread sealant to their cylinder head-side before installing them.

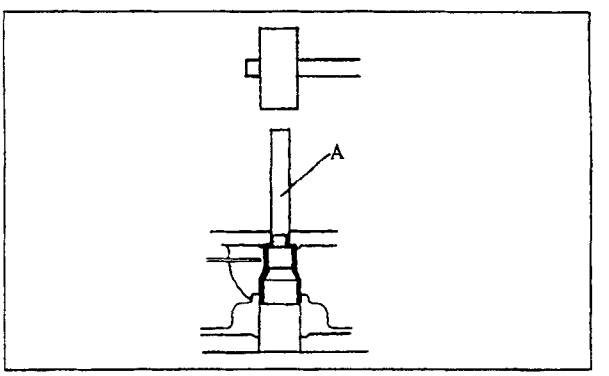
Embedding torque: M16 × 2 94 N·m {9.6 kgf·m} [69 lbf·ft]




**(8) Removing copper tube**

Place copper tube pusher (A) (35B91-0600) on the lower end surface of the copper tube from underneath the cylinder head, and use a hammer to remove the copper tube.

**NOTE**: Remove the copper tube gradually. Do not attempt to remove it by a single strike of a hammer.



### 1.2 Inspection and repair

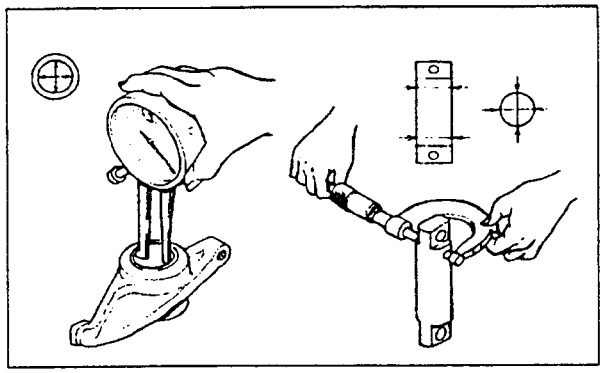
**Rocker, rocker bushing and rocker shaft**

**(1) Measuring rocker bushing inside diameter and rocker shaft diameter**

If the diameter exceeds the service limit, replace the bushing.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Rocker bushing inside diameter | ø44 [1.734] | 44.011 ~ 44.045 [1.734 ~ 1.735] | 44.095 [1.736] |
| Rocker shaft diameter | ø44 [1.734] | 43.957 ~ 43.991 [1.732 ~ 1.733] | 43.030 [1.694] |



Measuring rocker bushing inside diameter and rocker shaft diameter

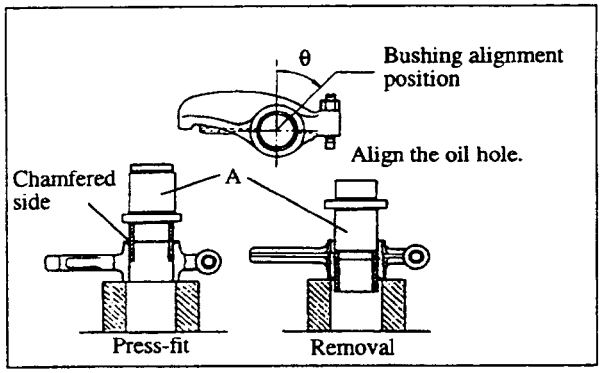
**(2) Replacing rocker bushing**

Using rocker bushing puller (A) (35C91-01800), remove the rocker bushing (worn) for replacement.

**NOTE**: (a) Press a new bushing into the rocker from the internally chamfered side of the bore.

(b) Align the oil holes in the bushing and the rocker.

| Rocker | Θ(° ) |
|---|---|
| IN, EXH | 55° |
| UI | 45° |




Replacing rocker bushing

(c) After installing the bushing, measure its inside diameter to make sure that it is ø44 $^{+0.045}_{+0.011}$ mm [1.734 $^{+0.0018}_{+0.0004}$ in.].
If the diameter is out of this tolerance, refinish it to ø44 $^{+0.045}_{+0.011}$ [1.734 $^{+0.0018}_{+0.0004}$ in.] $\frac{3.2S}{\nabla\nabla\nabla}$ by reaming.

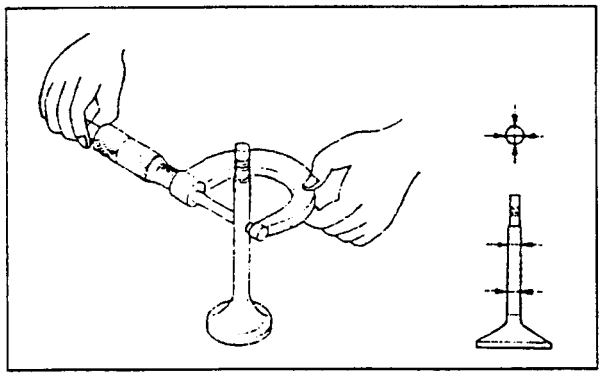
**Valve guide and valve stem**

**(1) Measuring valve stem diameter and valve guide inside diameter**

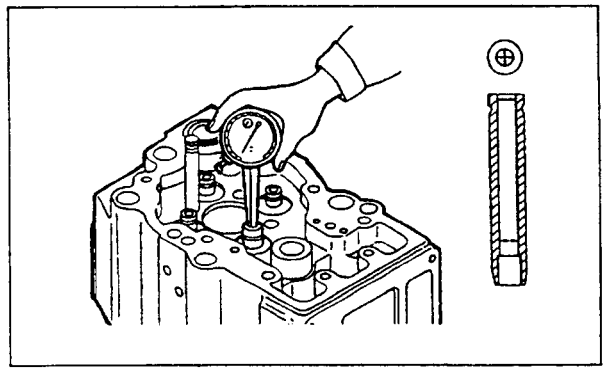
The valve guide wears more rapidly at its both ends than at any other parts. Measure the inside diameter of the guide at its ends and at middle part in two directions. If the service limit is exceeded, replace the guide.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Valve stem diameter | ø10 [0.394] | 9.940 ~ 9.960 [0.3916~ 0.3924] | 9.910 [0.390] |
| Valve guide inside diameter | ø10 [0.394] | 10.000 ~ 10.015 [0.394 ~ 0.3945] | 10.060 [0.3961] |



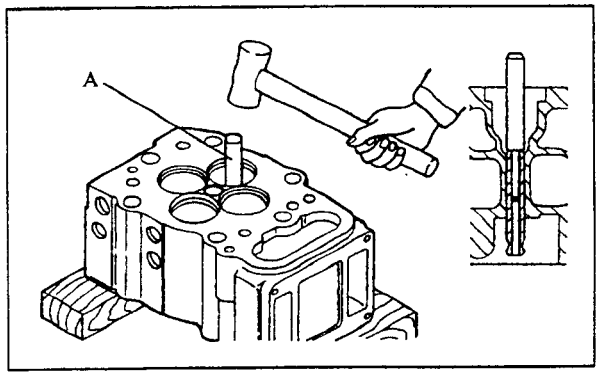
Measuring valve stem outside diameter



Measuring valve guide inside diameter

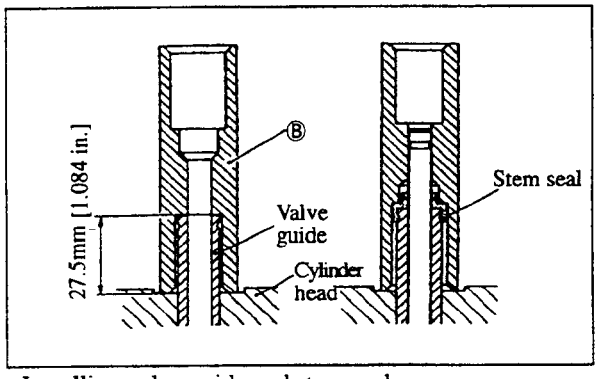
**(2) Replacing valve guide and stem seal**

(a) Using valve guide remover (A) (33591-04300), remove the valve guide for replacement.




Removing valve guide

(b) To install a new valve guide, use valve guide and seal installer (B) (32591-10300) and a press.




Installing valve guide and stem seal

**⚠CAUTION**

**(a) As installed depth is specified for the valve guide, be sure to use the valve guide and seal installer to secure this depth.**

**(b) 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, coat the valve stem to ensure initial lubrication of the stem seal lip.**

**(c) Be sure to use new stem seals for reassembly.**

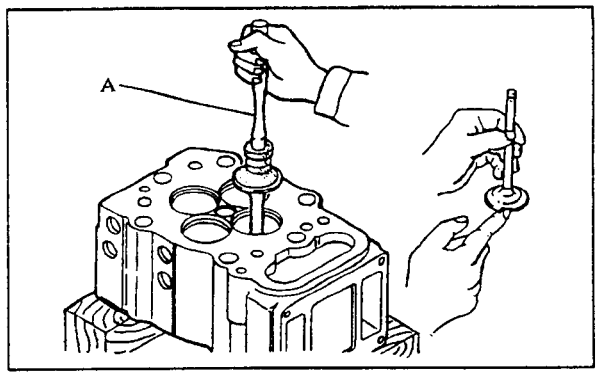
**Valve and valve seat**

**(1) Inspecting valve face**

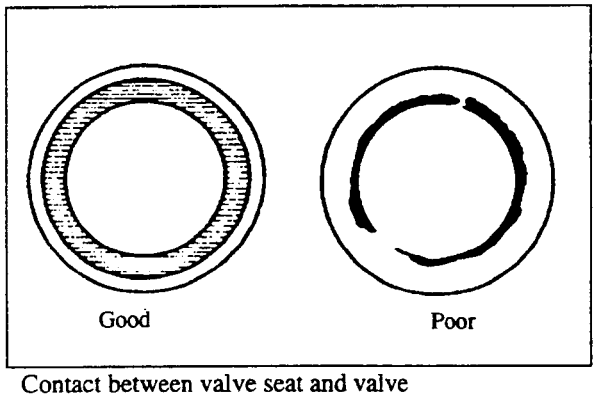
Coat the valve face lightly with red lead. Using valve lapper (A) (30091-08800), inspect the valve contact with its seat. If the contact is not uniform, or if the valve is defective or the repair limit is exceeded, repair or replace the valve and the valve seat.

**NOTE**: (a) Inspect the valve face after inspecting or replacing the valve guide.

(b) When pressing the valve coated with red led into the valve seat, do not rotate the valve.



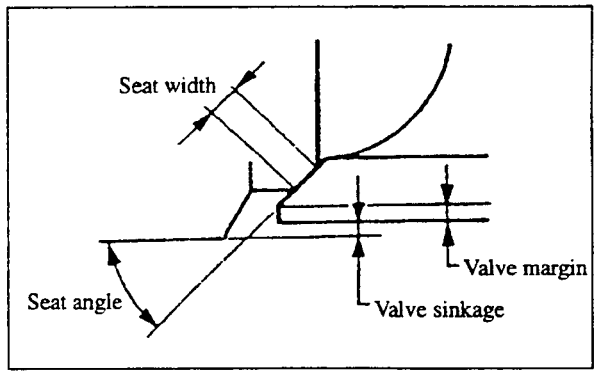

Refacing valve




Contact between valve seat and valve

Unit: mm [in.]

| | | Assembly standard | Repair limit |
|---|---|---|---|
| Valve seat | Angle | 30° | |
| | Valve sinkage | - 0.1 ~ 0.2 [-0.004 ~ 0.008] | 1.0 [0.039] |
| | Width | 2.15 ~ 2.45 [0.08 ~ 0.1] | 2.8 [0.110] |
| Valve margin | | 2.8 ~ 3.2 [0.11 ~ 0.13] | 2.5 [0.1] by refacing |

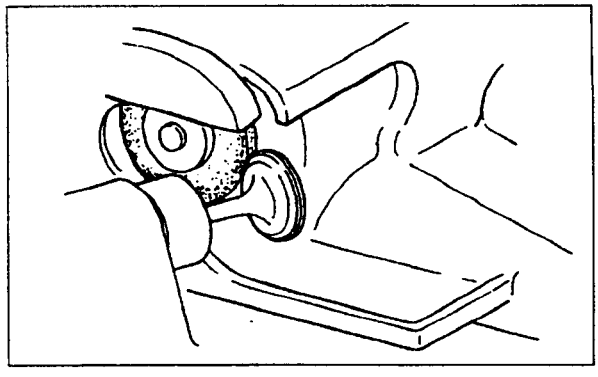



**(2) Refacing valve**

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

**NOTE**: (a) Set a valve refacer at an angle of 30°.

(b) Grind the valve stock to a minimum. If the margin seems to become less than the repair limit by grinding, replace the valve.



Refacing valve

### (3) Refacing valve seat

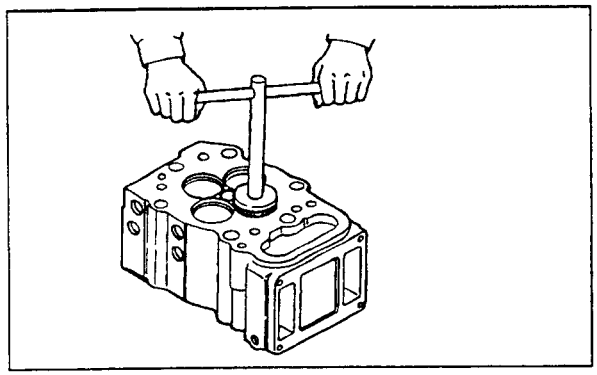
(a) Using a valve seat cutter or a valve seat grinder, cut the valve seat. After cutting, grind the seat lightly by using sand paper of #400 grade or so, inserted between the cutter and the valve seat.

(b) Lap the valve in the valve seat.

**NOTE**: (a) Cut or grind the valve seat only as necessary for refacing.

(b) Replace the valve seat if the seat width is more than the repair limit as a result of wear or cutting.

(c) Replace the valve seat if the valve sinkage is more than the repair limit after refacing.

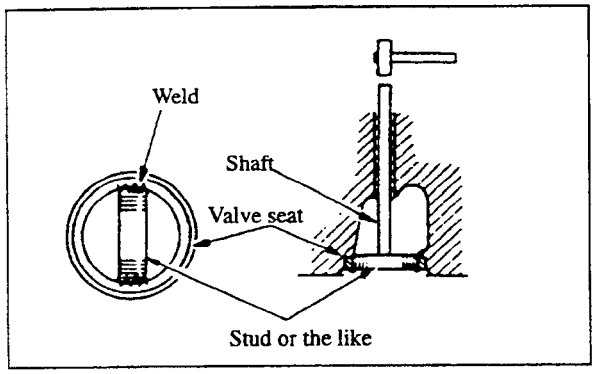


Refacing valve seat

### (4) Replacing valve seat

(a) Weld a stud to the valve seat, insert a shaft into the valve guide hole from the upper side of the cylinder head, and drive the seat off the head as shown.

**NOTE**: When welding the stud, be careful not permit spatters to come in contact with the machined surfaces of the cylinder head.



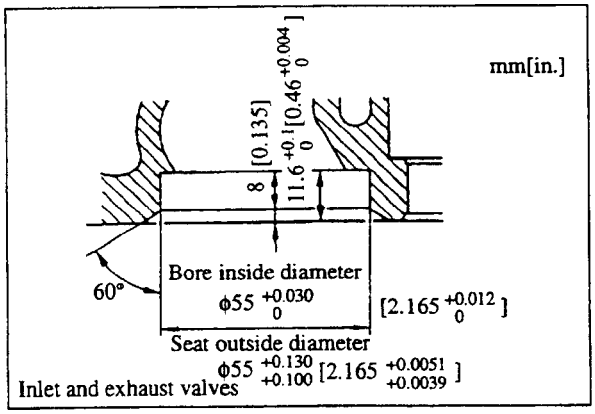

Removing valve seat

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

Unit: mm [in.]

| | Nominal value | Assembly standard |
|---|---|---|
| Cylinder head bore inside diameter and valve seat outside diameter | ø55 [2.165] | - 0.070 ~ - 0.130 [-0.003 ~ -0.005] |

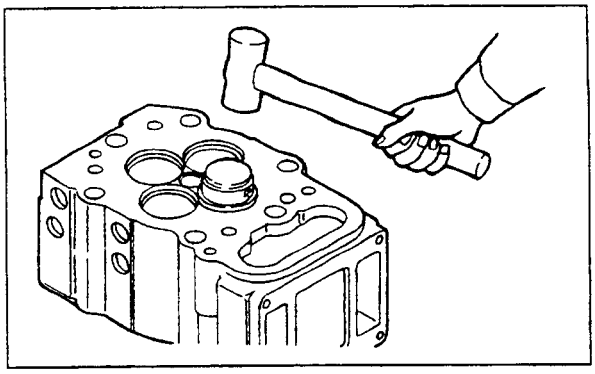
**NOTE**: - (minus) of the standard clearance represents tightening.




Valve seat dimensions

(c) Chill the valve seat in liquid nitrogen (about -170°C [-274°F]) for more than 4 minutes with the cylinder head kept at normal temperature, or heat the cylinder head to 80°C ~ 100°C [176.0°F ~ 212.0°F] with the valve seat chilled in ether or alcohol containing dry ice.

(d) Using the installer, install the valve seat.



Installing valve seat

### (5) Lapping valves in valve seats

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

(a) Coat the valve face lightly with a lapping compound.

NOTE: (a) Do not permit the compound to come in contact with the valve stem.

(b) Use the compound of 120 to 150 mesh for initial lapping and the compound of finer than 200 mesh for finish lapping.

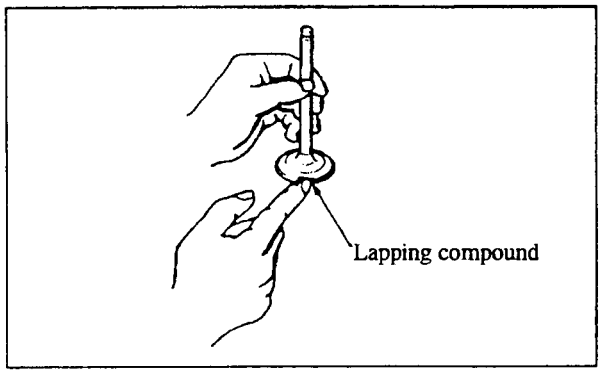
(c) Mixing the compound with a small amount of engine oil will facilitate coating.

(b) Using valve lapper (A) (30091-08800), lap the valve in the seat. To lap, rotate the valve only a part of turn, then raise the valve off the seat, rotating to a new position.

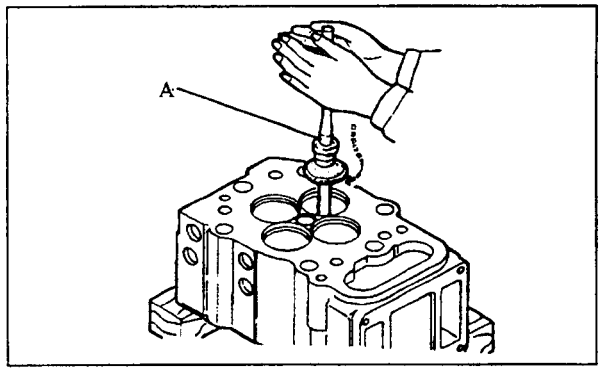
(c) Wash off the compound with diesel fuel.

(d) Coat the valve face with engine oil, and again lap the valve.

(e) Check the valve face for contact.




Coating valve with lapping compound



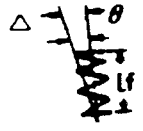

Lapping valve in valve seat

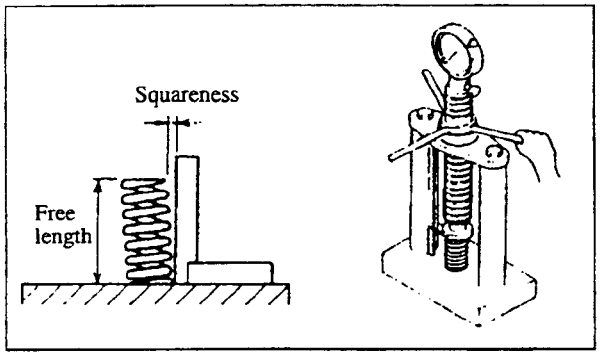
### Valve spring

### Measuring squareness and free length

Measure the free length and the squareness of each valve spring. If the free length and the squareness exceeds the service limit, replace the spring.

Unit: mm [in.]

| | Assembly standard | Service limit |
|---|---|---|
| Free length | 70.5 [2.78] | 69 [2.72] |
| Squareness | θ = 1.5°, maximum  | = 2.2 [0.09] over the length |
| Length under test force/test force mm/N (mm/kgf) [in./lbf] | 61.8/254.4~281.2 (61.8/25.94~28.67) [2.60/57.2~63.21] | |



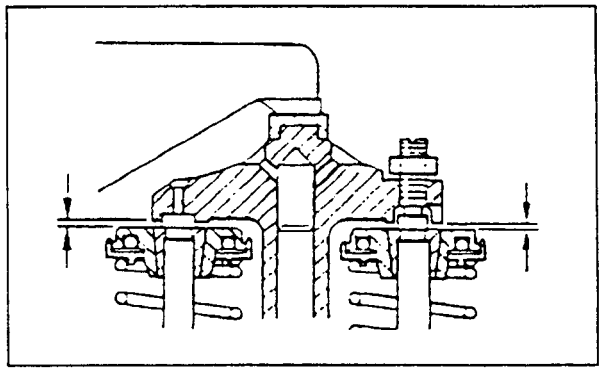

Measuring squareness and free length of spring

### Valve bridge and bridge cap

### Inspecting clearance between bridge and rotators (cotters)

(a) If the clearance is 1.5 mm [0.06 in.] or less, check the valve stem top for cupping. When the valve stem top is badly cupped, replace the valve to obtain more than 1.5 mm [0.06 in.] clearance.

(b) Check the bridge cap for condition, and replace a badly worn cap.



Inspecting bridge-to-rotator (cotter) clearance

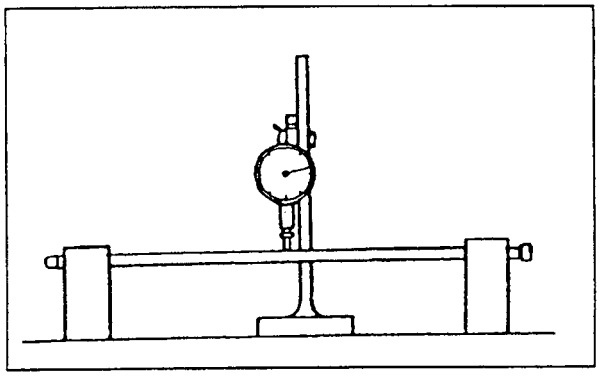
### Pushhrod

#### (1) Inspecting valve pushrods for runout

If the runout exceeds the assembly standard, replace the pushrod.

Unit: mm [in.]

| | Assembly standard |
|---|---|
| Pushrod runout | 0.5 [0.02] maximum |



Measuring valve pushrod runout

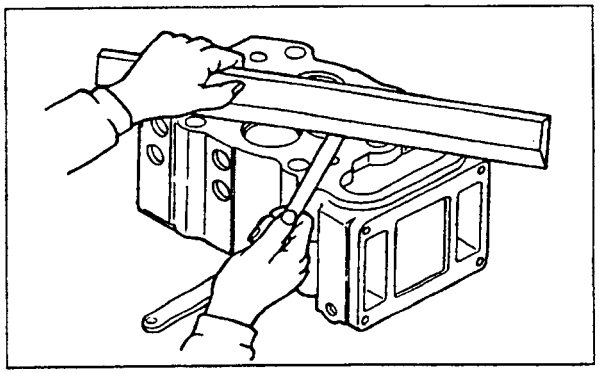
### Cylinder head

#### Measuring gasketed surface warpage

Measure warpage on each head with a straight edge and a feeler gauge. If the warpage exceeds the repair limit, reface the gasketed surface with a surface grinder.

Unit: mm [in.]

| | Assembly standard | Repair limit | Service limit |
|---|---|---|---|
| Cylinder head gasketed surface warpage | 0.03 [0.001] maximum | 0.07 [0.003] | 0.50 [0.02] |



Measuring cylinder head gasketed surface warpage

### 1.3 Assembly

To assemble, follow the disassembly sequence in reverse.

#### (1) Installing copper tube

(a) Install O-ring ① inside the cylinder. Apply liquid gasket (ThreeBond No. 1211 or No. 1215) to the inside wall (22.6 mm in diameter) of the cylinder head. Make sure that liquid gasket does not extend to the side indicated by ·※· in the diagram.

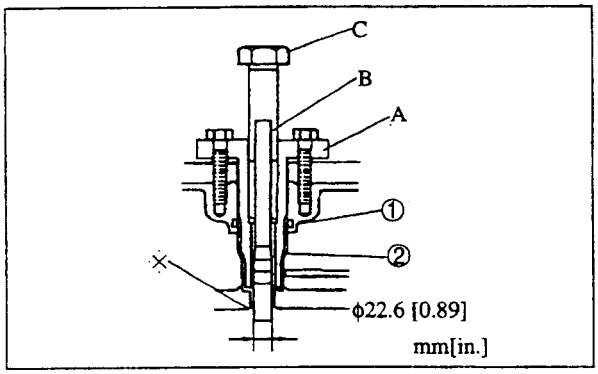
(b) Insert copper tube ② into the cylinder head. Wipe off any excess liquid gasket on the bottom surface of the cylinder head.

(c) Install tube tool (A) (35C91-21010) on the top surface of the cylinder head (tightening torque: 14.7 to 19.6 N·m {1.5 to 2.0 kgf·m}).

(d) Apply engine oil to nozzle tube stamp (B) of the tube tool. Insert the copper tube. During this step, make sure that the stamp tip protrudes from the bottom side of the cylinder head.

(e) Press nozzle tube bolt (C) of the tube tool until the stamp can be pulled out from the bottom side of the cylinder head.

(f) Remove the tube tool, and inspect the copper tube for abnormalities.



**(2) Installing cylinder head gasket**

(a) Remove oil and grease from the bottom face of the cylinder head and the top face of the crankcase by wiping with a clean cloth.

(b) Apply liquid gasket around tappet holes and oil passage holes on the head gasket to prevent oozing (oil bubbles) of oil through the gasket.

**• Application of liquid gasket**

Apply a thin coat of ThreeBond 1211 (37594-01300) around tappet holes and oil passage holes on both sides of the head gasket. Install the gasket before the liquid gasket dries.

Do not apply an excessive amount of liquid gasket, since it can press the head gasket O-ring and cause deformation. Do not allow liquid gasket to adhere around the bore; otherwise, gas leakage can occur.

Before installation, be sure to wipe off oil and grease from the bottom face of the cylinder head, the top face of the crankcase and the head gasket, and make sure they are clean.

The diagram on the right shows the areas and amounts of liquid gasket application.

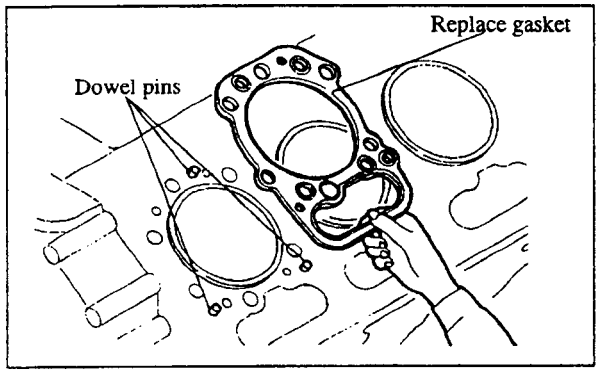
**NOTE**: (a) Apply liquid gasket (37594-01300) to areas 5 to 8 mm [0.197~0.315 in.] from the periphery of the head gasket.

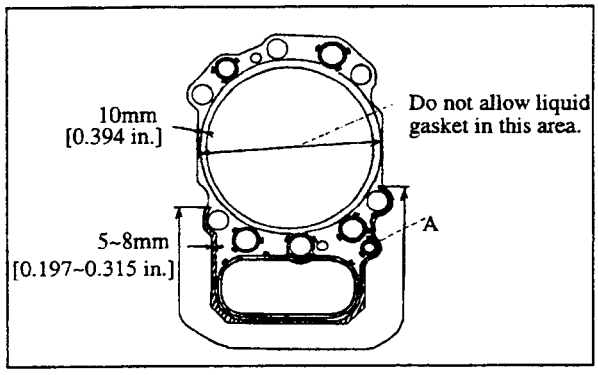
(b) Liquid gasket should be applied to areas indicated in the diagram on the right.

(c) Apply liquid gasket to both sides of the head gasket. Spread the liquid gasket with a finger to a thickness of 0.2 to 0.5 mm [0.008~0.020 in.].

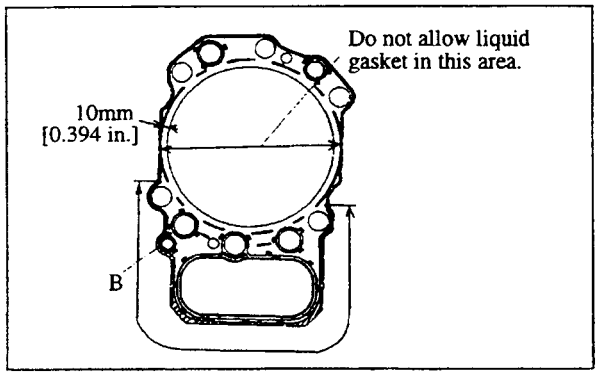
(d) Sections (A) and (B) are very close to O-rings. Make sure that there is no large amount of liquid gasket on the edge at these sections.

(c) Install the cylinder head gasket by aligning holes with the dowel pins.




Application of liquid gasket on head-facing side

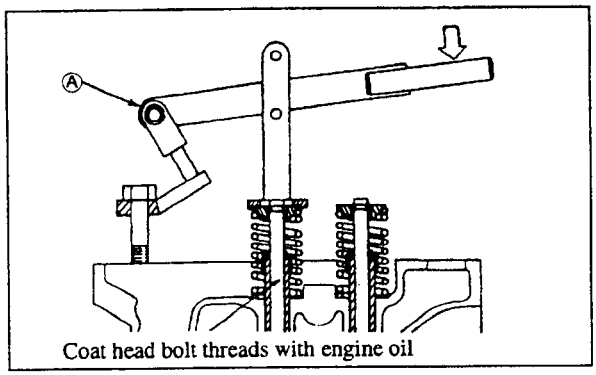



Application of liquid gasket on crankcase-facing side

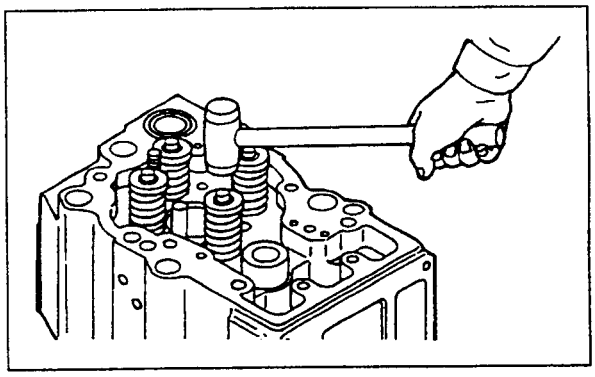
**(3) Reassembling cylinder gasket**

(a) Coat the valve stems with engine oil, and insert them into the valve guides.

(b) Install the valve springs and rotators to the valve guides. Compress each valve spring with valve spring pusher (A) (33591-04500), and install the valve cotters to the valve stem.



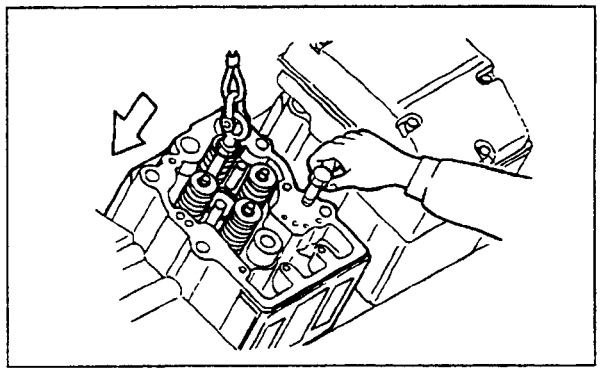

(c) Lightly tap on the top of each valve stem with a soft hammer to make sure that the valve spring and cotters are properly installed.



**(4) Installing cylinder head assembly**

(a) Screw eye nut (A) (37591-02400) onto the stud bolt. Attach a shackle and wire rope to the eye nut, and sling the cylinder head assembly. Keep the head assembly slightly lifted off the crankcase with the dowel pins entering their holes. Coat the threads of cylinder head bolts and bolt seats with engine oil, and insert the bolts into the head assembly.

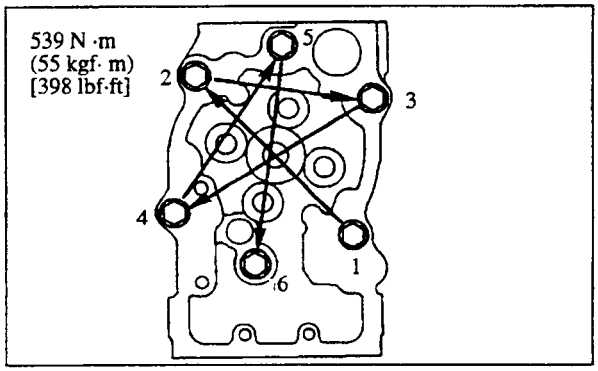
(b) Tighten the cylinder head bolts to the specified torque in the sequence shown.



**⚠CAUTION**

**(a) Make sure excessive engine oil is not on the cylinder head bolt before installation.**

**(b) Before installing the cylinder head assembly, measure the protrusion of each piston, making sure that the protrusion is correct.**

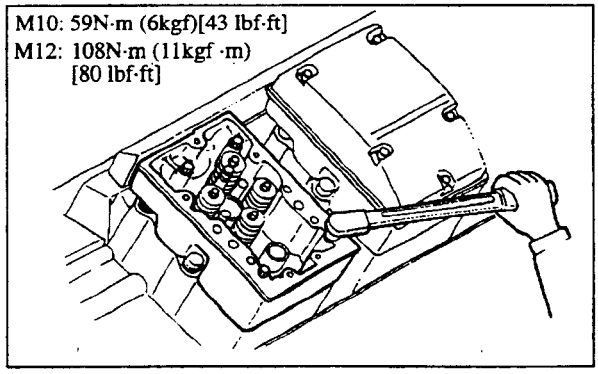



Cylinder head bolt tightening sequence

**(5) Installing rocker case**

(a) Install the rocker case with the dowel pins entering their holes.

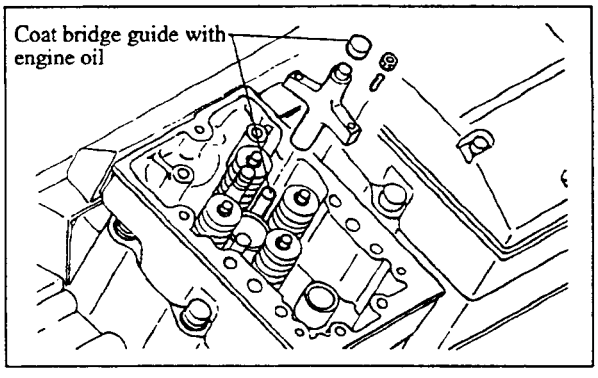
(b) Tighten the rocker case mounting bolts to the specified torque.




**(6) Installing valve bridge and cap**

(a) Coat the bridge guides with engine oil, and install the bridges to the guides with the adjusting screw positioned on the exhaust manifold side.

(b) Coat the bridge contact face of bridge caps with engine oil, and install the caps in position, being careful not to drop them into the crankcase through pushrod holes.



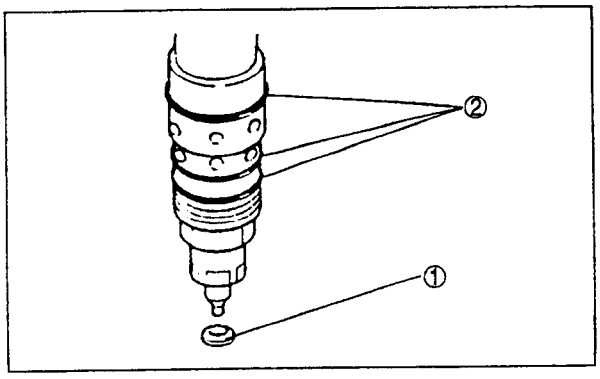
(7) **Installing injection nozzle assembly**

(a) Apply grease to gasket ① and attach the gasket to the nozzle.

(b) Clean the injection nozzle mounting hole of the cylinder head so that no foreign matter such as dust may not remain. Dust in the hole may result in gas leakage or fuel leakage.

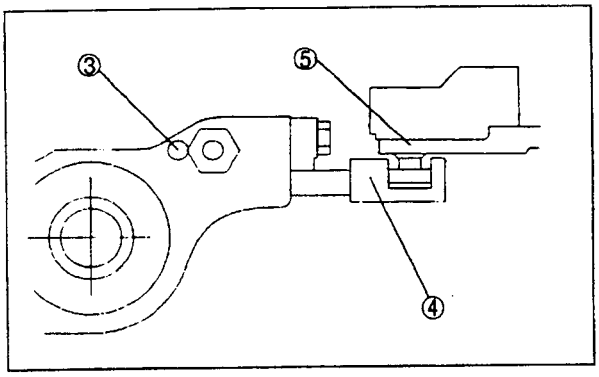
(c) Make sure to check that the old gasket is completely removed from the bottom inner surface of the copper tube by using a wire or other tool.

(d) Apply grease, silicon oil or lubricant to O-ring ② outside the injection nozzle.



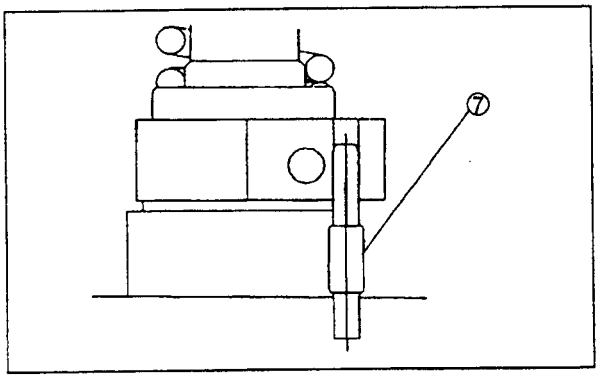

**⚠CAUTION**

**Handle the injection nozzle carefully to prevent dust, or do not damage the O-ring.**
**Make sure that the old gasket is completely removed from the bottom section of the copper tube. If a new gasket is installed on top of the previous gasket, damage can occur in the injector.**



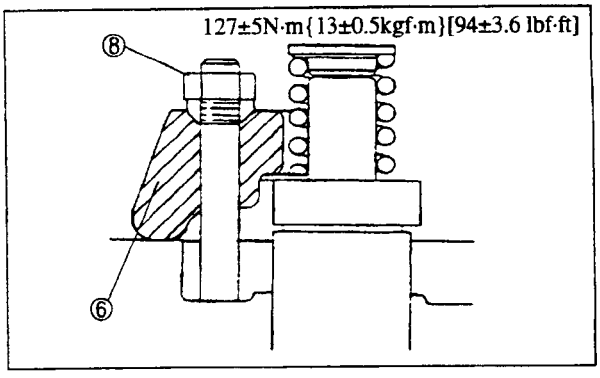

(e) Insert the injection nozzle into the cylinder head. Insert it completely so that dowel pin hole ③, rack ④ and linkage ⑤ are aligned.

(f) Install gland ⑥ and tighten the fixing nut manually. Make sure that the injection nozzle is fully inserted, that dowel pin ⑦ is inserted, that the gland is not on the injection nozzle, and that the control rack is engaged with link bearing.



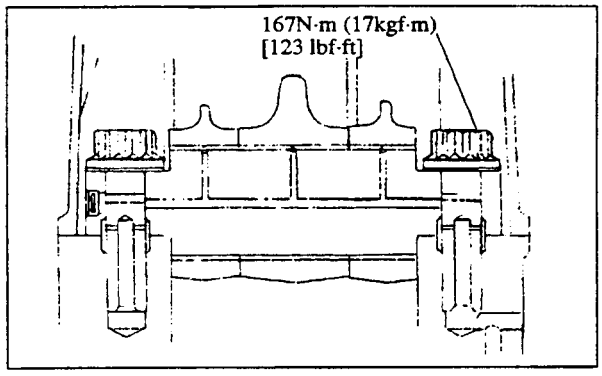

(g) Tighten fixing nut ⑧ to the specified torque.

(h) Adjust the linkage of the unit injection nozzle. (Refer to Removing accessory.)



**(8) Installing rocker shaft assembly**

(a) Install the rocker shaft assembly to the rocker case with the locating pin entering its hole.




**⚠CAUTION**

**(a) Move the rocker arm up and down to make sure that the arm is free.**

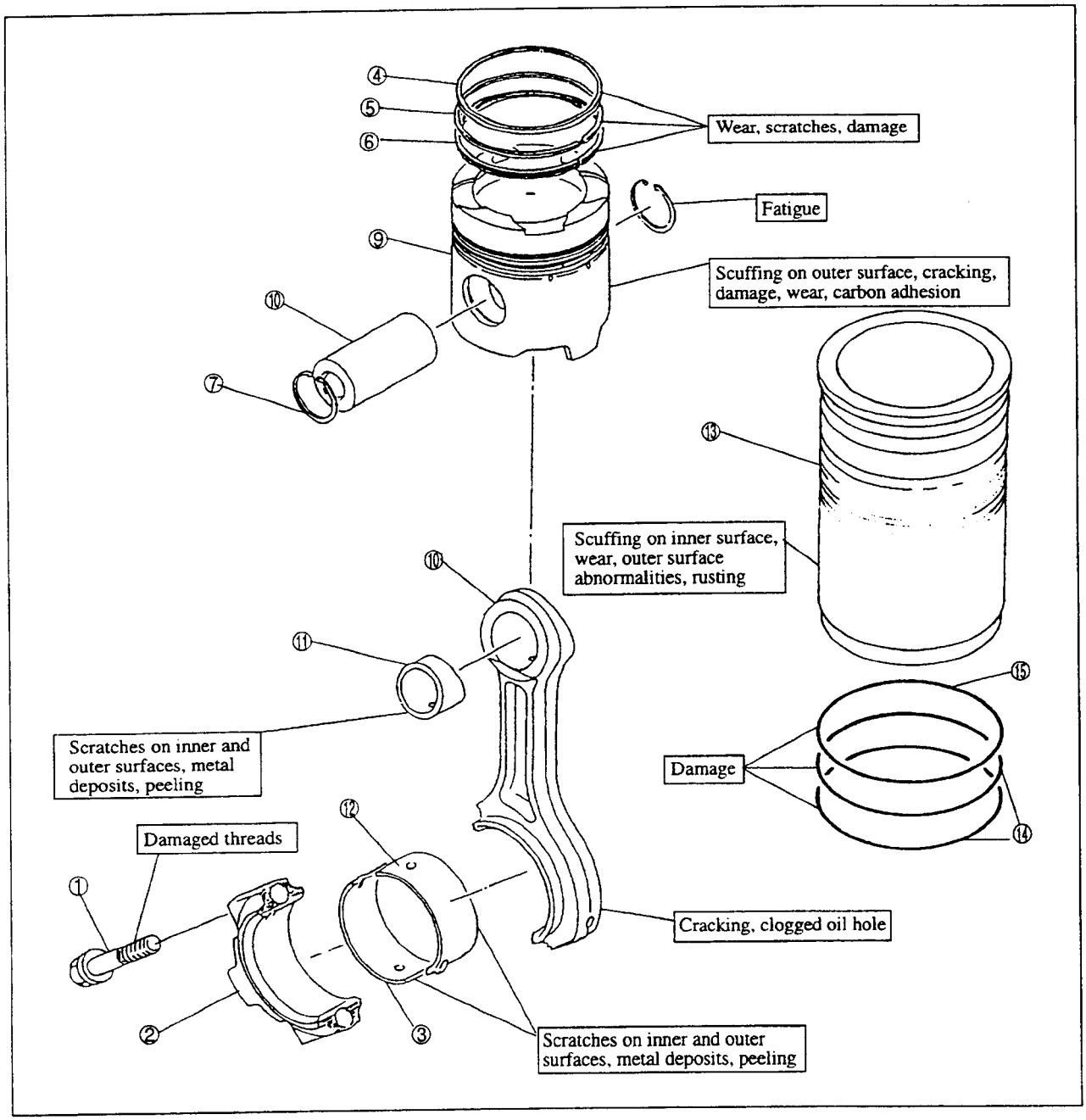
**(b) While tightening the bracket mounting bolts temporarily, install the bracket in place so that the rocker tip comes in contact with bridge cap evenly.**

**(9) Adjusting valve clearance**

(Refer to Adjusting engine.)

# 2. CYLINDER LINER, PISTON AND CONNECTING ROD

## 2.1 Disassembly



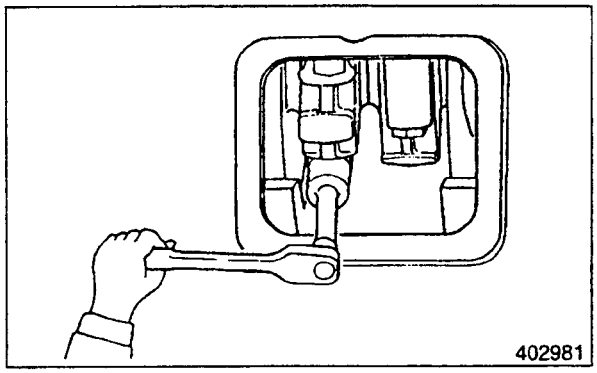

① Bolt
② Connecting rod cap
③ Metal lower
④ Top compression ring
⑤ Second compression ring
⑥ Oil ring
⑦ Snap ring
⑧ Piston pin
⑨ Piston
⑩ Connecting rod
⑪ Connecting rod bushing
⑫ Bearing upper
⑬ Cylinder liner
⑭ O-ring
⑮ O-ring

**(1) Removing connecting rod cap**

Unscrew the cap bolts and remove the caps through the inspection hole on the side of the crankcase.

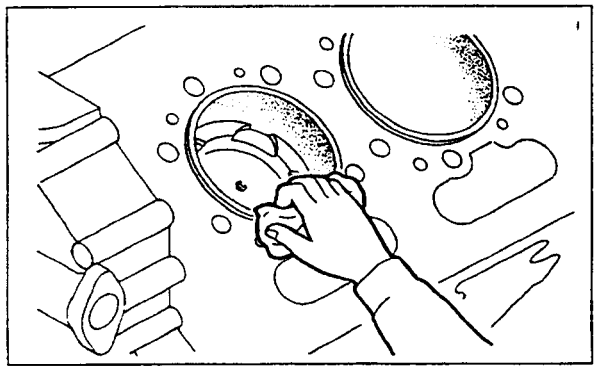
**NOTE:** (a) Be careful neither to drop metals into the oil pan not to damage them.

(b) Mark the removed connecting rod metals for identification of cylinder numbers and for upper and lower shells.




**(2) Preparatory step for removing pistons**

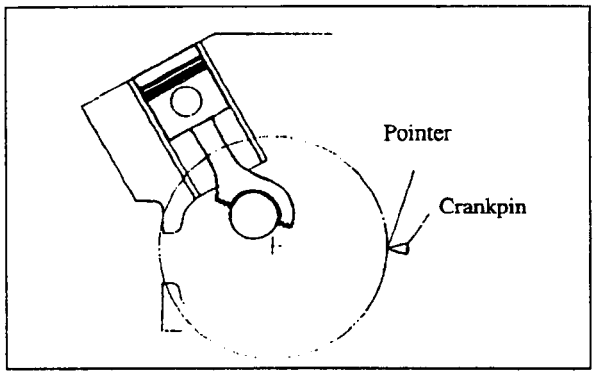
Remove all carbon deposits from the upper areas of cylinder liners with cloth or oil paper. Carbon deposits, if any, will make it difficult to pull the pistons upward.



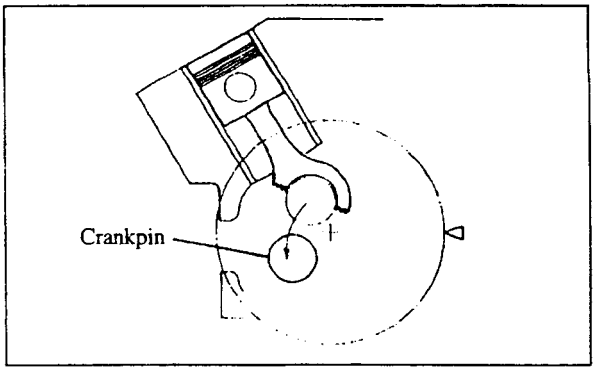
**(3) Removing pistons**

**(For the right side cylinder)**

(a) Bring the piston assembly, from which the connecting rod bearing cap has been removed, to top dead center by turning the crankshaft.

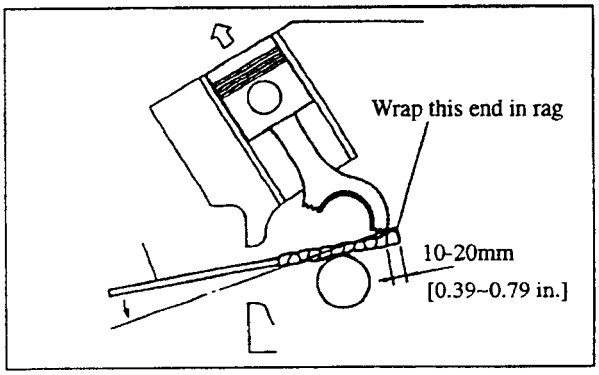



(b) Turn the crankshaft in normal direction until the crankpin comes off the connecting rod and the bolt hole is visible in the inspection hole on the side of the crankcase.



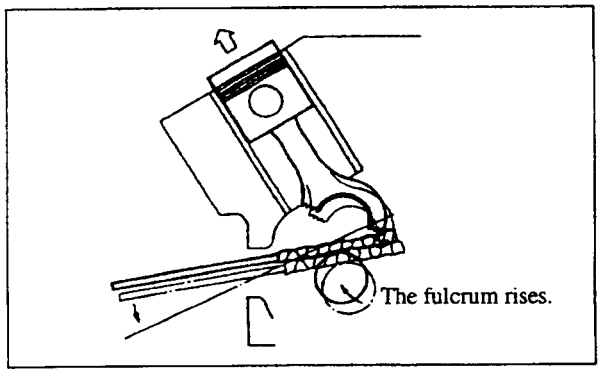
(c) Wrap bar (A) in rag. Insert one end of the bar into the bolt hole in the connecting rod end, and raise the piston assembly just a little by making use of the crankpin as a fulcrum.

**NOTE**: Do not insert the bar too deep, or it will hit the liner, making it difficult to remove the piston assembly. Insert the bar so that it protrudes 10 ~ 20 mm [0.39 ~ 0.79 in.] from the connecting rod end.




(d) Turn the crankshaft in normal direction just a little at a time to raise the crankpin (fulcrum) while pushing down on the other end of the bar to raise the piston assembly.

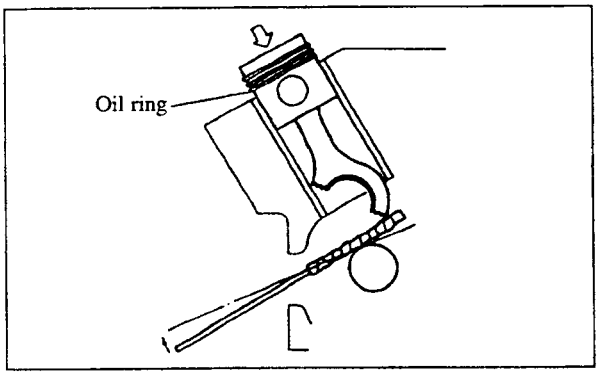
**NOTE**: During the piston assembly removal, the connecting rod will come near the piston cooling nozzle. Be careful not to hit the rod against the jet.




(e) When the oil ring of the piston comes out of the cylinder liner, raise the bar just a little, and carefully rest the oil ring on the edge of the liner.

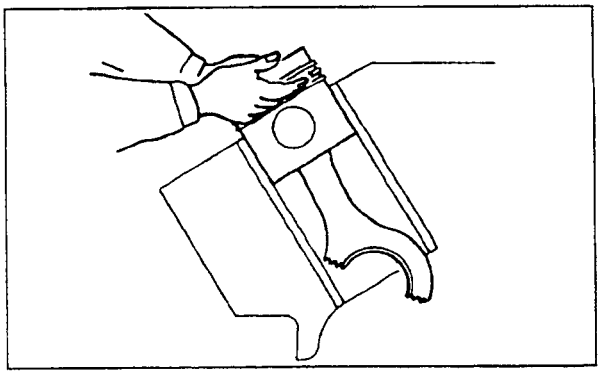
**⚠CAUTION**

**Raise the bar slowly and carefully, or the oil ring will suffer damage. Do not rotate the piston either.**
**Do not allow the connecting rod to contact oil jets when removing the piston. If the connecting rod contacts oil jets and causes damage, piston seizing can result.**



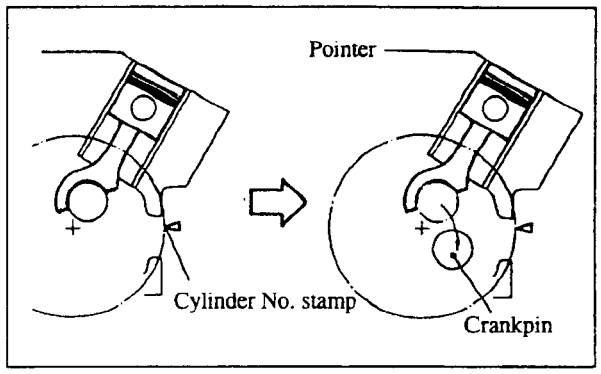

(f) Hold the compression ring portion of the piston by hands, carefully pull the piston from the cylinder liner, and rest its skirt on the top of crankcase.

(g) Hold the piston pin portion of the piston by hands, and lift the piston off the liner.



**(4) Removing piston (For the left side cylinder)**

The procedures are the same as the piston removal for the right side cylinder. The crankpin position and the crankshaft rotating direction are opposite.




**(5) Removing piston (By the use of piston remover)**

(a) Position the crank of a piston to be removed at about 50° after top dead center.

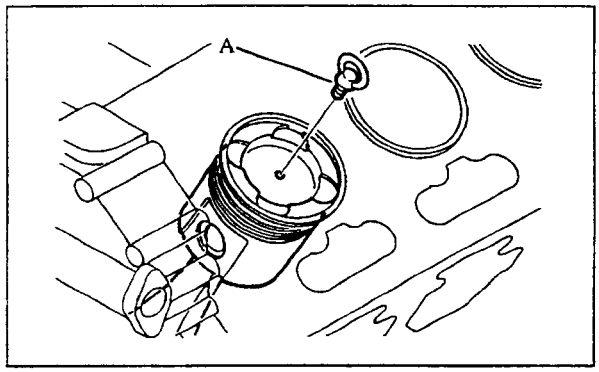
(b) Attach eye bolt (A) (MM321420) to the top of the piston, and lift the piston off the cylinder liner slowly.

**⚠CAUTION**

**(a) When the piston is removed from the cylinder liner, it moves. Do not damage the connecting rod by the contact of the piston skirt. Hold it securely before removal.**

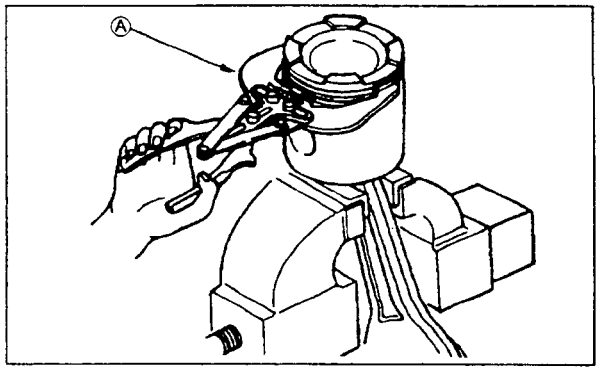
**(b) Hold the connecting rod securely not to damage the cylinder liner surface.**

**(c) Do not allow the connecting rod to contact oil jets when removing the piston. If the connecting rod contacts oil jets and causes damage, piston seizing can result.**




**(6) Removing piton ring**

Use piston ring pliers (A) (37191-03200) to remove the piston rings.

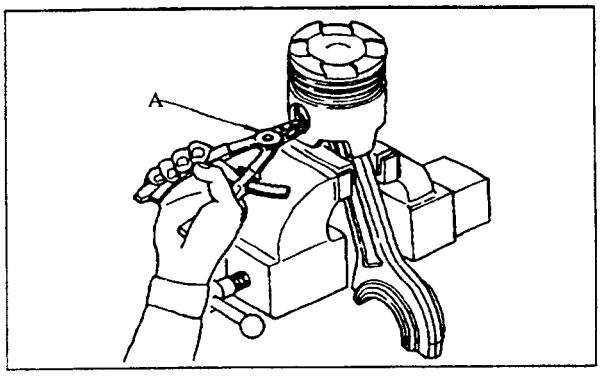


### (7) Removing piston pin

(a) Using ring pliers (A) (45191-08400), remove the snap ring.

(b) Remove the piston pin to separate the piston form the connecting rod.

(c) 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.




## 2.2 Inspection and repair

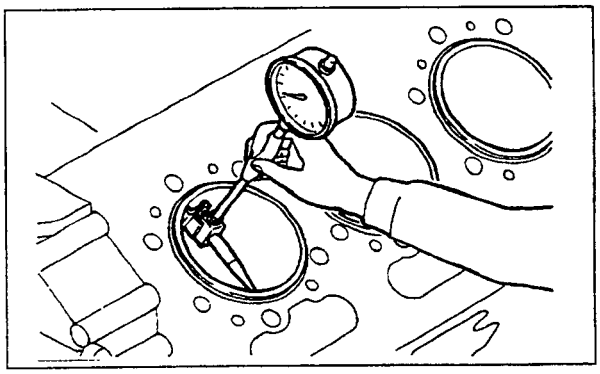
### Cylinder liner

### (1) Measuring cylinder liner inside diameter

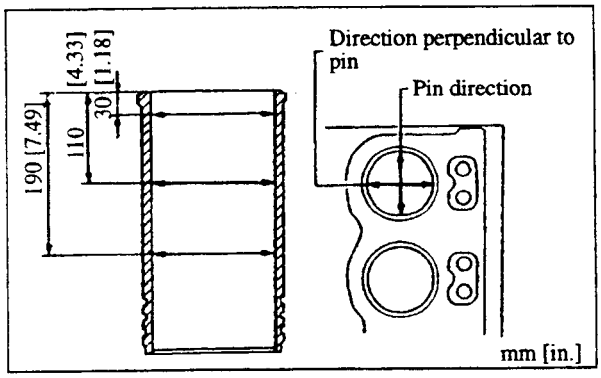
Measure the inside diameter of each liner in two directions, parallel and transverse to the position pin, at three positions, top (ridged area), middle and bottom as shown. If the inside diameter exceeds the service limit, replace the liner.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Cylinder liner inside diameter | ø150 [5.906] | 150.000 ~ 150.040 [5.906 ~ 5.907] | 150.140 [5.911] |



Measuring cylinder liner



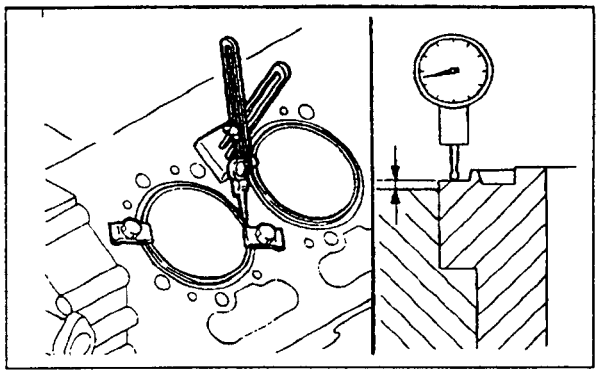

Cylinder liner measuring diagram

### (2) Measuring cylinder liner protrusion

Measure protrusion of each liner at its flange with a dial gauge as shown. If the protrusion is not within the assembly standard range, change the position of the liner relative to its bore, or use the liner in any other bore.

Unit: mm [in.]

| | Assembly standard |
|---|---|
| Cylinder liner protrusion at flange | 0.10 ~ 0.19 [0.004 ~ 0.007] |



Measuring cylinder liner protrusion

**⚠CAUTION**

**If the protrusion is less than the assembly standard, the gasket fails to exert sufficient sealing force around the bore, causing exhaust gas leakage.**

(a) Clean the gasketed surfaces of the crankcase and the top of the liners.

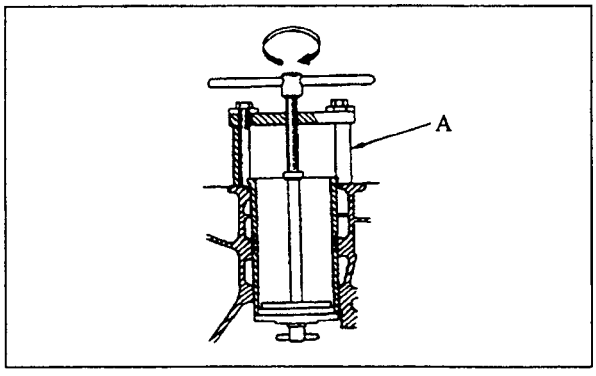
(b) Secure the top of the liner uniformly at two places with clamps and bolts (M22 × 2.5).

(c) Set up the dial gauge at the top of the liner, and set the gauge pointer to zero (0).

(d) Measure protrusion at four places on the top of the liner. Take the average from the four measurements.

### (3) Replacing cylinder liners

(a) Using cylinder liner remover (A) (37591-04100), remove the cylinder liner from the crankcase for replacement.




(b) Attach O-rings to each new cylinder liner, and carefully insert the liner into the bore of the crankcase.

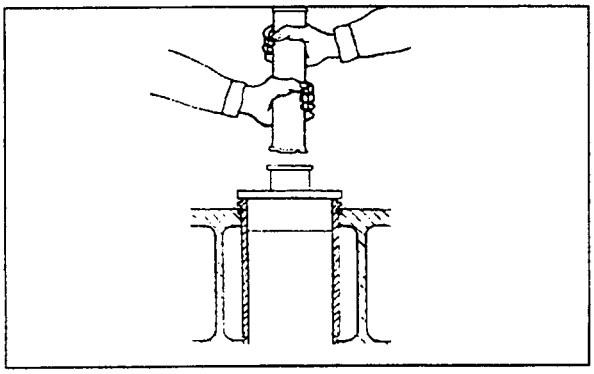
**⚠CAUTION**

**When inserting the liner, coat the O-rings with engine oil to prevent them from twisting.**

(c) After inserting the liner into the bore, lightly tap on its top, using installer, to rest its flange in the crankcase. Then, make sure that the liner is securely seated by tapping several times.

NOTE: (a) After installing the liners, test the joints for water-tightness by applying pressure water.

(b) Check to make sure that the protrusion of each liner is within the assembly standard range.



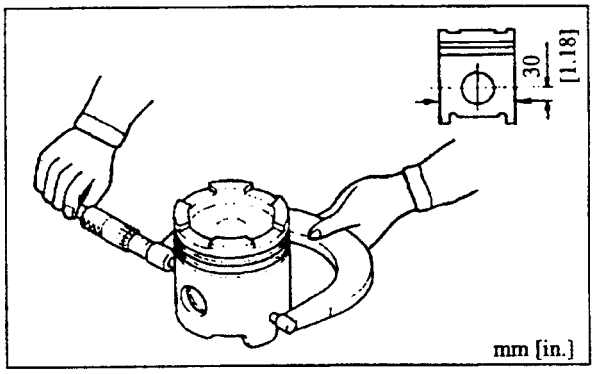
**Pistons**

Inspect the combustion chamber and the inside surfaces of piston bosses. Replace the piston if any defect is found there.

**(1) Measuring piston diameter**

(a) Using a micrometer, measure the diameter of each piston in the direction transverse to the piston pin, at the position shown.

If the diameter exceeds the service limit, replace the piston. If any piston has to be replaced, select new pistons so that the variance in weight among pistons per engine is within the assembly standard.

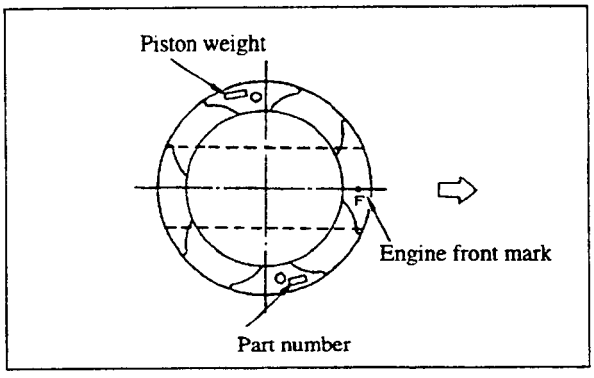



Measuring piston diameter

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Piston diameter | ø150 [5.906] | 149.78 ~ 149.82 [5.897 ~ 5.898] | 149.68 [5.893] |
| Variance in weight among pistons per engine | — | 30g [0.07 lb], maximum per engine | |

(b) The piston weight is stamped on the top of each piston.

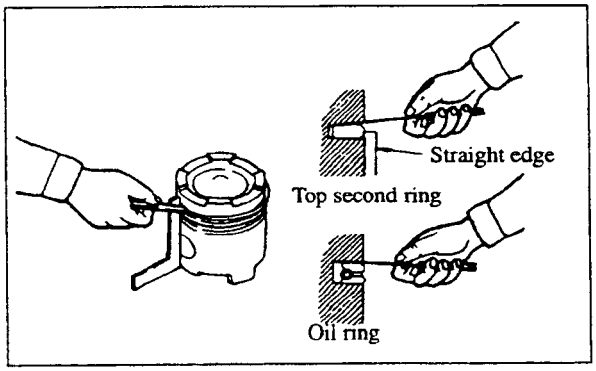



Piston weight stamp location

**(2) Inspecting piston ring grooves**

Inspect the piston ring grooves for wear and damage, and replace the piston if necessary.

Inspect the Ni-resist insert for crack, and replace the piston if the insert shows crack.



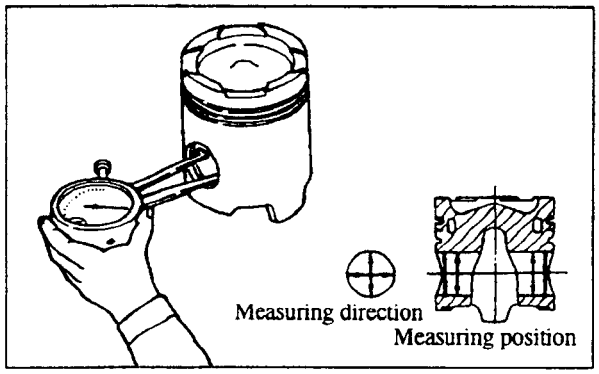

Measuring piston ring side clearance

### (3) Measuring piston pin bore diameter

Using a caliper gauge or a cylinder gauge, measure the piston pin bore diameter.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Piston pin bore diameter | ø58 [2.283] | 58.002 ~ 58.012 [2.2852 ~ 2.2856] | 58.020 [2.29] |




Measuring piston pin bore diameter

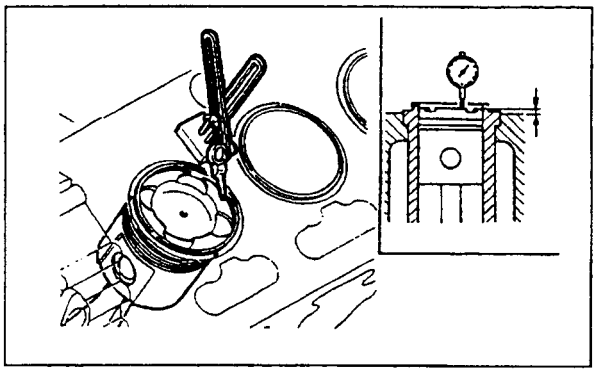
### (4) Measuring piston protrusion

Measure protrusion of each piston, and if it is not within the assembly standard range, inspect the various parts for clearance.

(a) Determine the top dead center of piston with a dial gauge.

(b) Set up the dial gauge at the top of crankcase, and set the gauge pointer to zero (0).

(c) Measure the protrusion at four places on the piston head, and average the four measurements to determine the protrusion. Subtract the piston protrusion from the as-installed thickness of the cylinder head gasket to determine the clearance between the piston top and the cylinder head.



Measuring piston protrusion

Unit: mm [in.]

| | Assembly standard |
|---|---|
| Piston protrusion | 0.38 ~ 0.89 [0.01 ~ 0.04] |
| As-installed thickness (cylinder head gasket) | 1.77 ~ 1.83 [0.07 ~0.072] |
| Clearance between piston top and cylinder head | 0.88 ~ 1.45 [0.035 ~ 0.057] |

**⚠CAUTION**

**Keeping the piston protrusion within the assembly standard range is important not only for engine performance but also for prevention of interference of the valves with the pistons.**

## Piston ring

### (1) Measuring piston ring gap

Place the rings in a new or a master cylinder, and measure the gap of each ring.

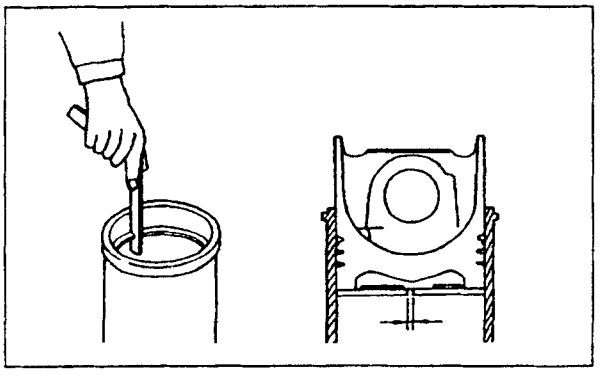
If the gap of any ring exceeds the service limit, replace all rings as a set.

Inside diameter of master cylinder liner: 150 ± 0 mm [5.91 ± 0 in.]

**NOTE**: Place the piston rings in the master cylinder liner by pushing them squarely with the piston.

Unit: mm [in.]

| | | Assembly standard | Service limit |
|---|---|---|---|
| Piston ring gap | Top | 0.6 ~ 0.8 [0.02 ~ 0.03] | 0.2 [0.08] |
| | Second | 0.5 ~ 0.7 [0.0197 ~ 0.0275] | 0.15 [0.08] |
| | Oil | 0.5 ~ 0.7 [0.0197 ~ 0.0275] | 0.15 [0.08] |



Measuring piston ring gap

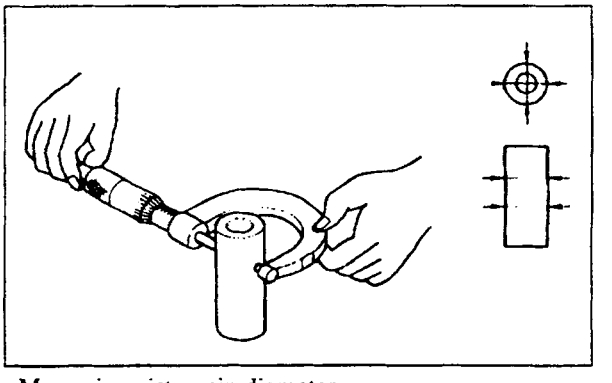
## Piston pin

### (1) Measuring piston pin diameter

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

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Piston pin outside diameter | ø58 [2.283] | 57.987 ~ 58.000 [2.2847 ~ 2.2852] | 57.970 [2.28] |



Measuring piston pin diameter

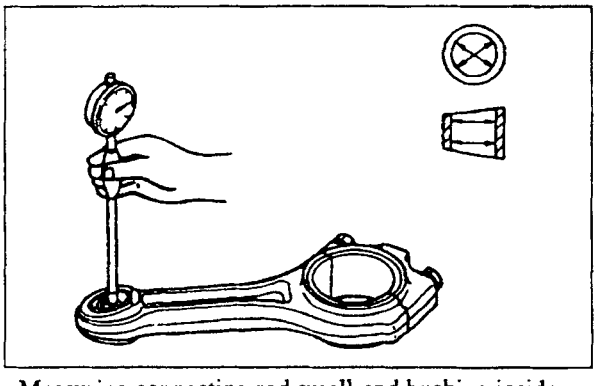
## Connecting rod, connecting rod metal and small-end bushing

### (1) Measuring small-end bushing inside diameter

Using a cylinder gauge, measure the inside diameter of each cylinder. If the inside diameter exceeds the service limit, replace the bushing.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Connecting rod small-end bushing inside diameter | ø58 [2.283] | 58.020 ~ 58.040 [2.286 ~ 2.2868] | 58.070 [2.29] |



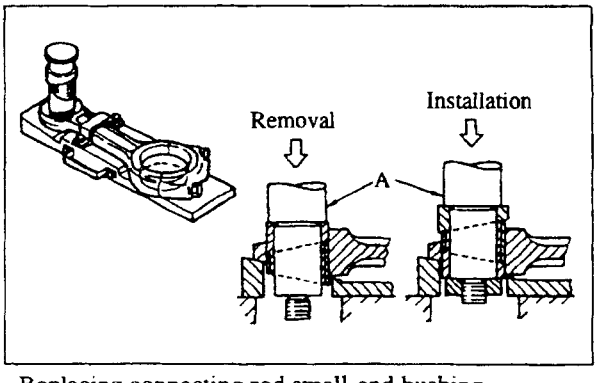
Measuring connecting rod small-end bushing inside diameter

### (2) Replacing connecting rod small-end bushing

(a) Using connecting rod bushing installer (A) (32591-18010), as shown, for replacement.

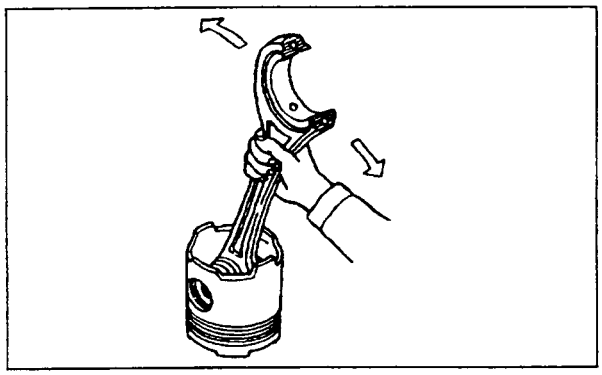
(b) When installing a replacement bushing, align oil holes in the bushing and connecting rod.

(c) After installing the bushing, ream its inside diameter to ø58 $^{+0.040}_{+0.020}$ [2.283 $^{+0.0016}_{+0.0008}$] $\frac{1.6S}{\nabla\nabla\nabla}$ mm and its paralle-lism to the big end bearing to 0.05 mm [0.002 in.].




Replacing connecting rod small-end bushing

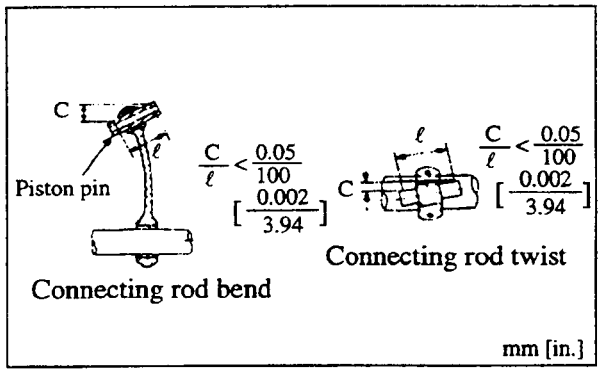
(d) After installing the bushing, insert the piston pin, and make sure that the pin rotates freely without rattling.



### (3) Inspecting connecting rod for bend and twist

(a) Measure "C" and "$\ell$". If the measurement at "C" is larger than 0.05 mm [0.002 in.] per 100 mm [3.94 in] of "$\ell$", straighten the rod with a press.

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

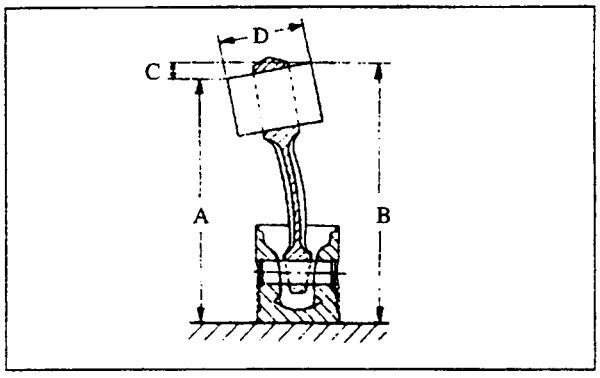



Inspecting connecting rod

(b) To inspect the rod installed to the piston, place the piston on a surface plate, insert a round bar corresponding to the crankpin in diameter into the big end bore, and measure the heights "A" and "B" of the bar.

Unit: mm [in.]

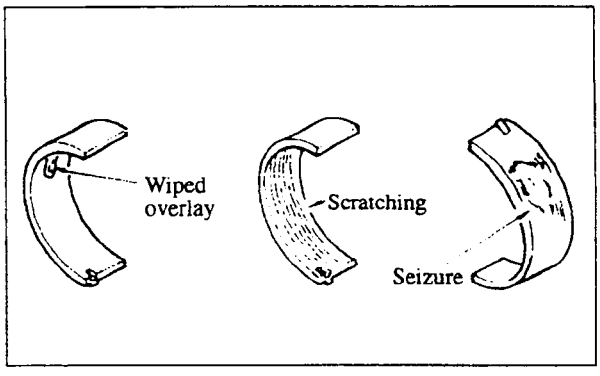
| | Assembly standard |
|---|---|
| Connecting rod bend and twist (C/D) | 0.05/100 [0.002/3.94], maximum |




Inspecting connecting rod installed to piston

### (4) Inspecting connecting rod big-end bearing

Inspect each bearing shell for wiped overlay, scratching and other defects. If any of these defects is present, replace the shell.

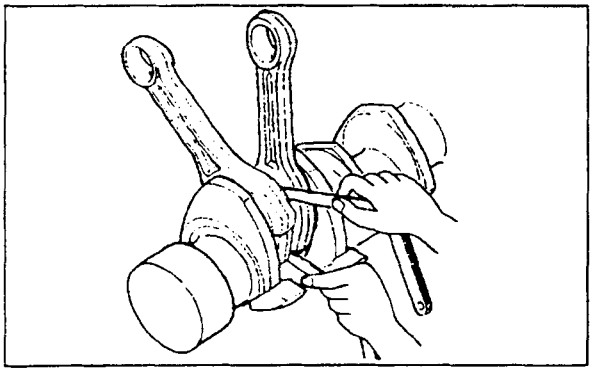


### (5) Measuring connecting rod end play

Install the connecting rod to the mating crankpin, and tighten its cap bolts to the specified torque. Then, using a feeler gauge, measure the end play. If the end play exceeds the repair limit, replace the connecting rod.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Connecting rod end play (widths of connecting rod and crankpin) | 54×2 [2.13×0.08] | 0.4 ~ 0.6 [0.016 ~0.024] | 0.8 [0.03] |



Measuring connecting rod end play

### (6) Variance in weight among connecting rods per engine

When replacing connecting rods, make sure that the variance in weight among connecting rods per engine is within the assembly standard shown below.

| | Assembly standard |
|---|---|
| Variance in weight among connecting rods per engine | 40g [0.09 lb], maximum |

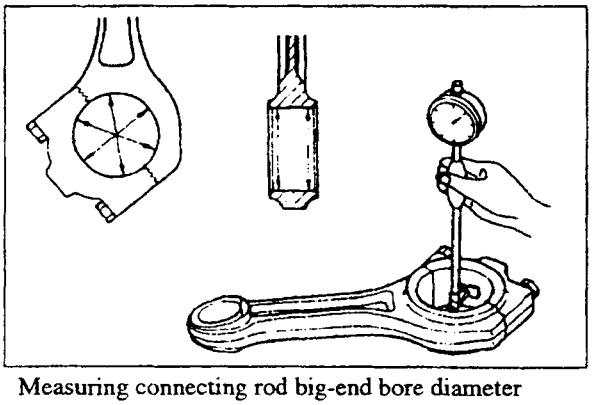
### (7) Measuring connecting rod big-end bore diameter

Measure the bore in two positions, front and rear, and in two directions.

If the diameter exceeds the service limit, replace the connecting rod.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Connecting rod big-end bore diameter | ø110 [4.334] | 110.000 ~ 110.022 [4.334 ~ 4.3348] | 110.047 [4.34] |



Measuring connecting rod big-end bore diameter

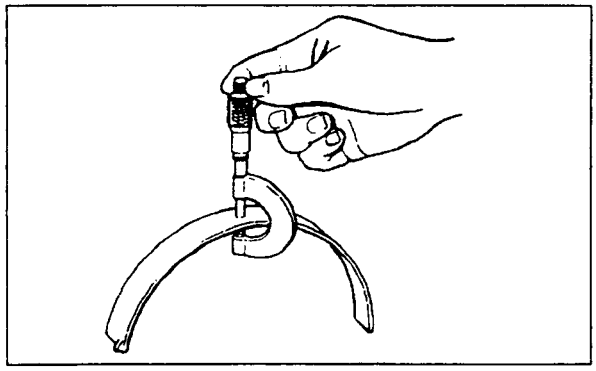
### (8) Measuring connecting rod metal thickness

Using a ball-point type micrometer, measure the center of each metal shell. If the thickness exceeds the service limit, on either upper or lower shell, replace both shells as a set.

Unit: mm [in.]

| | | Nominal value | Assembly standard | Service limit |
|---|---|---|---|---|
| Connecting rod metal thickness | STD | 3.000 [0.12] | 3.000 ~ 2.982 [0.118 ~ 0.117] | 2.950 [0.116] |
| | -0.25 [-0.01] | 3.125 [0.123] | 3.125 ~ 3.107 [0.123 ~ 0.122] | 3.075 [0.121] |
| | -0.50 [-0.02] | 3.250 [0.128] | 3.250 ~ 3.232 [0.128 ~ 0.127] | 3.200 [0.126] |
| | -0.75 [-0.03] | 3.375 [0.13329] | 3.375 ~ 3.357 [0.1329 ~ 0.1322] | 3.325 [0.131] |
| | -1.00 [-0.04] | 3.500 [0.1379] | 3.500 ~ 3.482 [0.1379 ~ 0.1371] | 3.450 [0.1359] |

**NOTE**: Four undersizes are available for the connecting rod bearings; namely, -0.25, -0.50, -0.75 and -1.00 mm [-0.01, -0.02, -0.03 and -0.04 in.].



Measuring connecting rod metal thickness

## 2.2 Reassembly

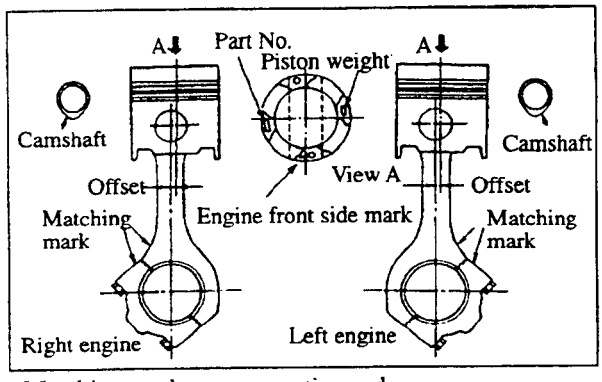
**Reassemble parts in the reverse order of disassembly.**

**(1) Reassembling pistons on connecting rods**

(a) Though the piston pin is to be clearance-fitted in the piston, heat the piston with a piston heater or in hot water to facilitate pin insertion.

(b) Coat the piston pin with engine oil, and insert it into position through the connecting rod.

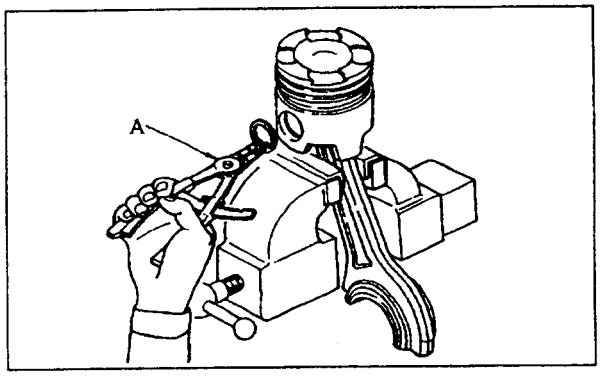
(c) Install the connecting rod to the piston with the matching marks (cylinder No.) on its big end on the side opposite to the camshaft.




Matching marks on connecting rod

(d) Using ring pliers (A) (45191-08400), install the snap rings to the grooves in the pistons. Make sure that the rings are not fatigued and that they are fitted in their grooves properly.

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



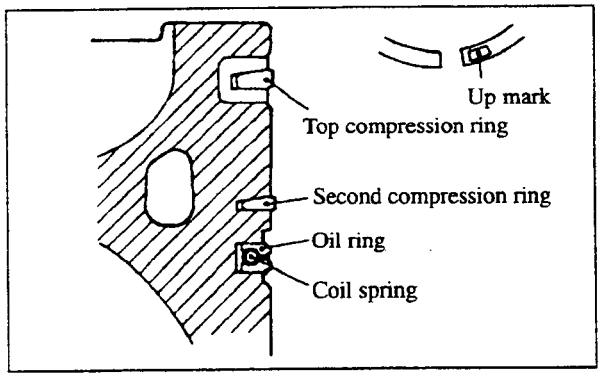

**(1) Installing piston rings**

(a) Using piston ring tool (37191-03200), install the piston rings, to the piston.

**⚠ CAUTION**

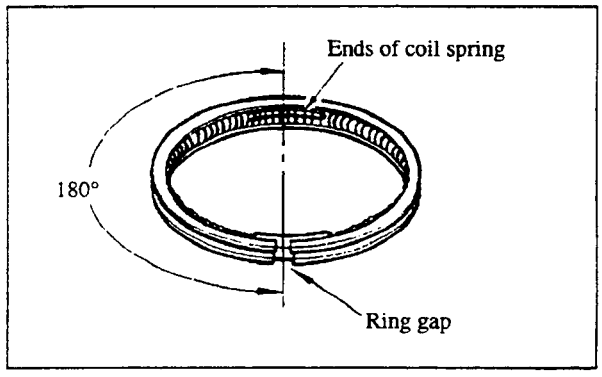
**The top ring is marked "R", the second ring is "R2" and the oil ring is R on the side to be up when installed on the piston, at one end.**

**If the ring is installed with the mark down, excessive oil consumption or piston seizure will result.**




Piston and piston rings

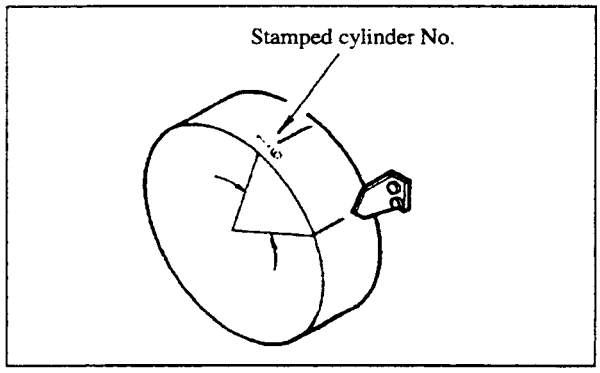
(b) Install the oil ring with its gap positioned at 180° to that of coil spring.




**(3) Preparatory steps for installing pistons**

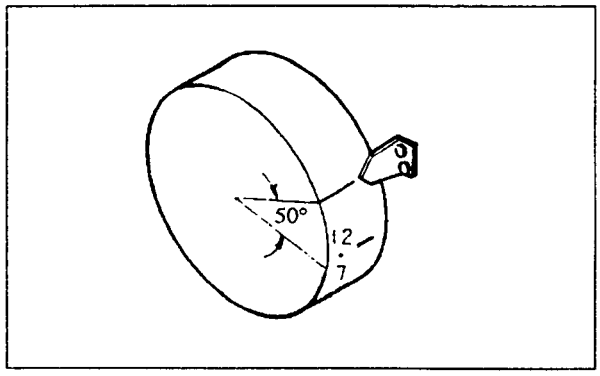
(a) **Right cylinder**

Turn the crankshaft in normal direction until the number of a cylinder to which the piston is to be installed is at the position of approx. 50° after the top dead center.

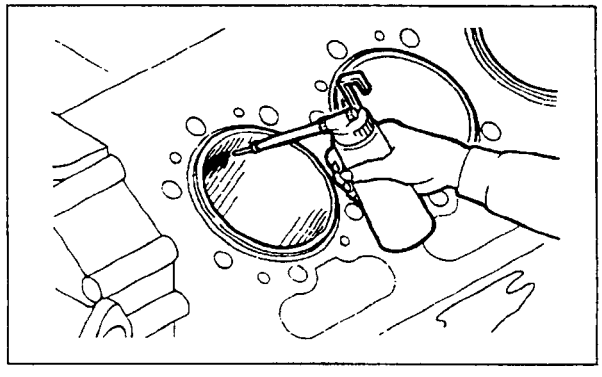



(b) **Left cylinder**

Turn the crankshaft in normal direction until the number of a cylinder to which the piston is to be installed is at the position of approx. 50° after the top dead center.

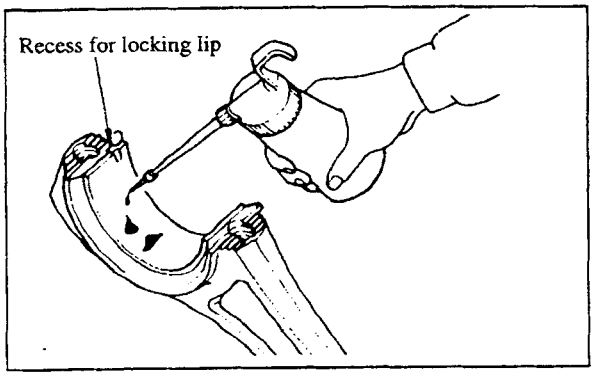



(c) Clean the cylinder liner bore surface and crankpin by wiping with cloth, and coat it with engine oil.



**(4) Installing connecting rod bearing upper**

Install the upper shell of the bearing in the rod by fitting its locking lip in the recess provided in the rod. Coat the inside surface of the shell with engine oil. Make sure that the oil holes in the rod and bearing are aligned.




**(5) Inserting pistons**

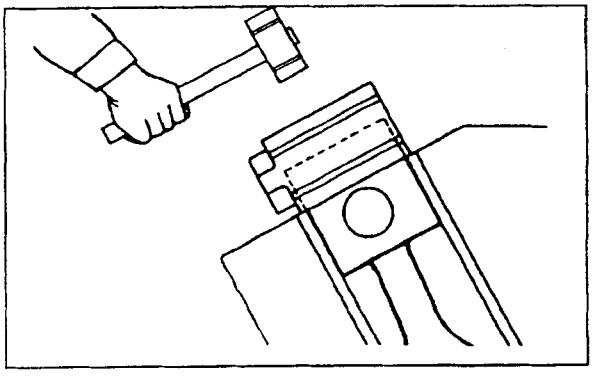
(a) Put the connecting rod in the cylinder liner, and carefully rest the piston on top of the crankcase.

**⚠CAUTION**

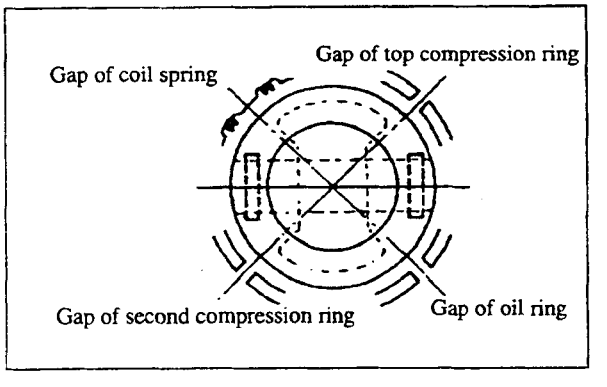
**Make sure that the "F" mark on the piston upper surface is facing front side of the engine.**

**When inserting the piston assembly into the cylinder liner, keep the connecting rod away from the oil jet by looking into the inspection hole of the crankcase.**

**Do not rotate the piston.**



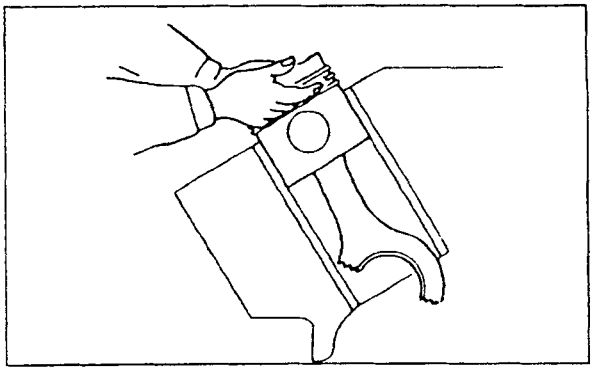
(b) Coat the piston rings with engine oil, and position the ring gaps away from the axis of the piston pin and the anti-thrust direction.




(c) Hold the compression ring portion of the piston by hands, and carefully insert the piston skirt into the cylinder liner.

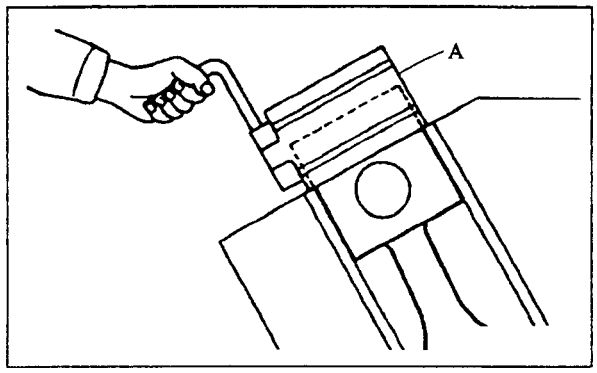
NOTE: (a) Be careful not get your little finger pinched between the oil ring and the cylinder liner.

(b) Slowly insert the piston, being careful not to damage the oil ring.

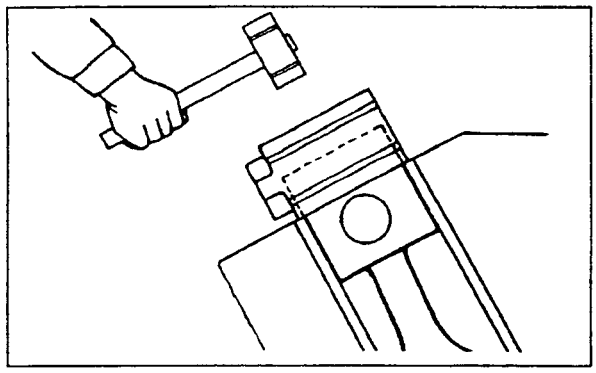


(d) After making sure that the piston ring gaps are positioned properly, coat the rings with engine oil, and clamp them, using piston installer (A) (37191-07100).

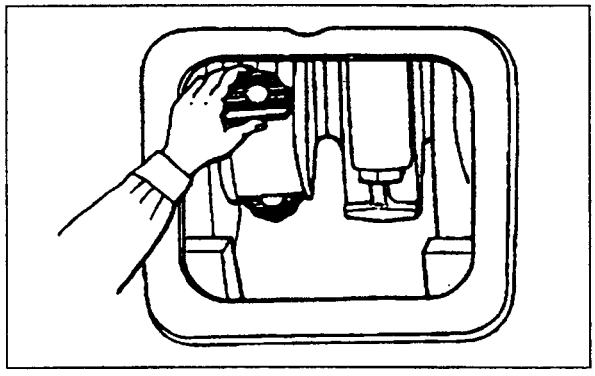
At this time, coat the inside surface of the installer with engine oil.




(e) Lightly tap on the piston with a soft hammer to insert the piston into the cylinder liner. If the piston will not go into the liner, move the big end of the connecting rod back and forth through the inspection hole of the crankcase.

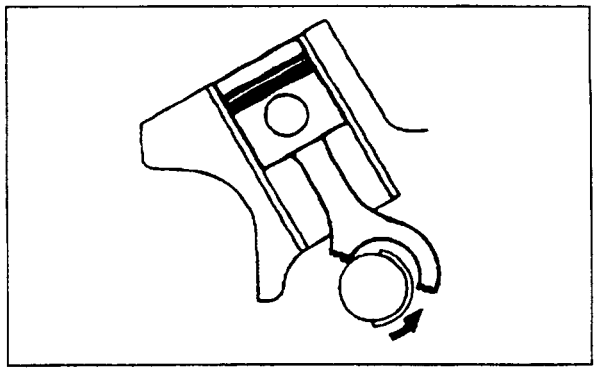


(f) Make sure the upper shell of the metal is properly positioned in place in the connecting rod big end, by inserting the hand through the inspection hole of the crankcase. If the metal shell is slightly out of place, reposition it by lightly tapping on it by the palm of a hand.



**(When the rod metal upper shell is misaligned)**

Turn the crankshaft, and allow clearance between the connecting rod big-end and the crankshaft pin. Contact the rod metal closely with the crankpin and insert it by sliding.

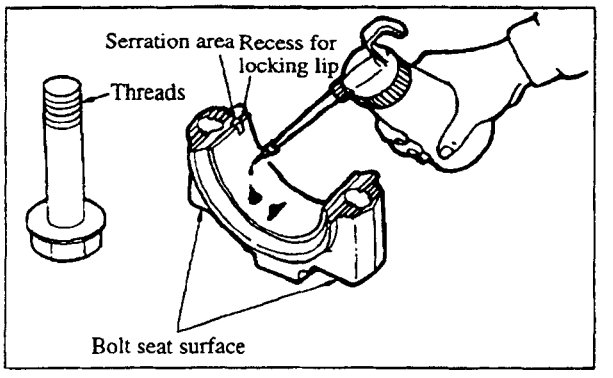


**(6) Installing connecting rod caps**

**⚠CAUTION**

**When installing the connecting rod caps, make sure that dust or metal chip does not enter the cap serration, the seat surface and the bolt threads.**

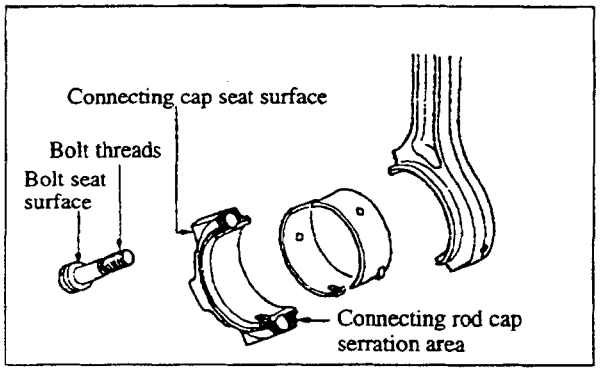
(a) Insert the lower shell of the connection rod metal along with the recess for locking lip.




(b) Apply engine oil to the following positions.

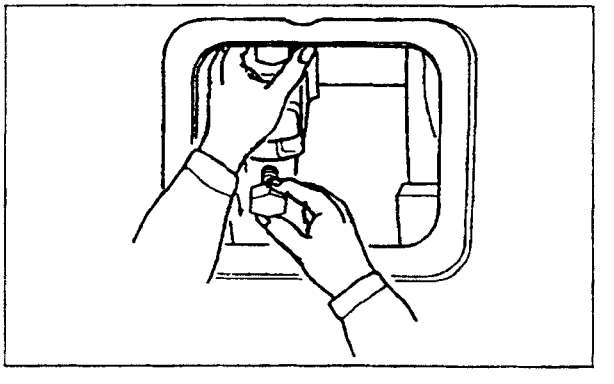
| Parts | Position |
|---|---|
| Connecting rod metal lower | Inside surface |
| Connecting rod cap | Bolt seat surface on the serration area |
| Connecting rod bolt | Threads |

**NOTE**: Apply engine oil with a clean cloth or a clean finger.




(c) Install each connecting rod cap. Hold the upper end of the cap by hand, and tighten the bolt at the lower end first. This will help prevent dropping the cap into the oil pan. Coat the threads and seats of bolts with engine oil, and tighten the bolts temporarily.

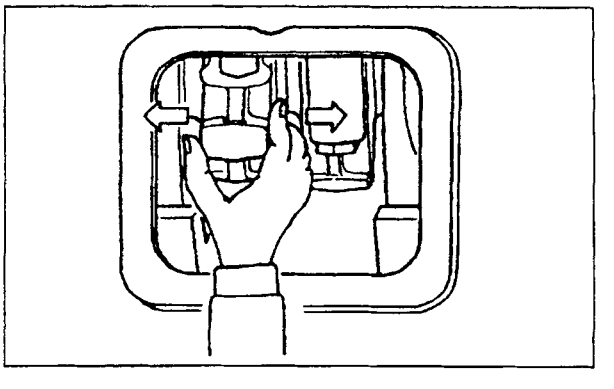
(d) Touch the joint between the cap and the rod, making sure that the cap and rod surfaces are flush with each other, and tighten the bolts to the specified torque.



**⚠CAUTION**

**Make sure that the matching marks on the cap and the connecting rod are on the same side.**

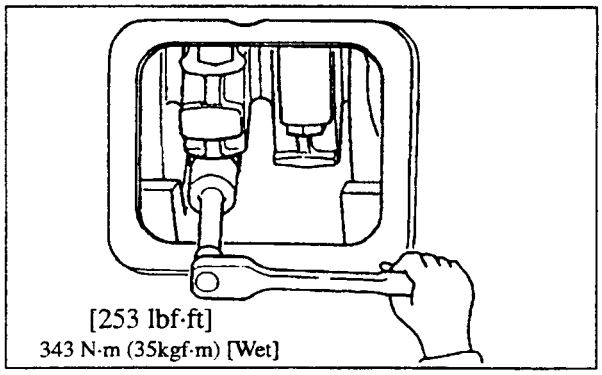
(e) After temporarily tightening the connecting rod installed later, tap the connecting rod tightened first evenly. Move each rod in the thrust direction, making sure that the rod has correct end play (specified rattling).



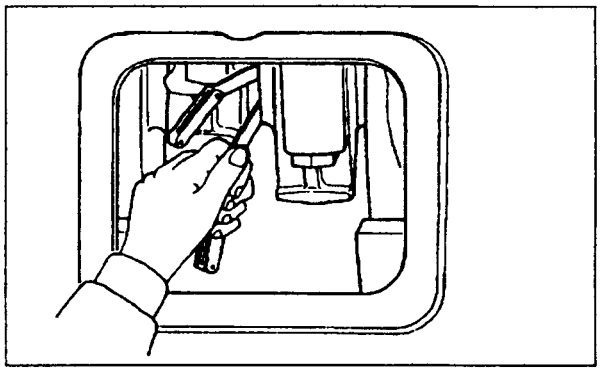
(f) After tightening the mounting bolts of the connecting rod cap to the specified torque, loosen them completely and tighten again to the specified torque.

**NOTE**: (a) Tighten 2 connecting rod bolts evenly.

(b) Tighten in two or three steps before finally tightening to the specified torque (example: to achieve tightening torque of 343 N·m {35 kgf·m}[253 lbf·ft], tighten the bolt in three separate steps to 98, 196 and 343 N·m {10, 20 and 35 kgf·m}[72, 144 and 253 lbf·ft]. Then loosen the bolt, and re-tighten to 343 N·m {35 kgf·m}[253 lbf·ft] in the same three-step method. (two-time tightening method))




(g) Using a feeler gauge, measure the end play of the connecting rod, making sure that the end play is equal on both top and bottom sides of the crankpin. If the clearance exceeds the service limit, replace the connecting rod with a new one.



Unit: mm [in.]

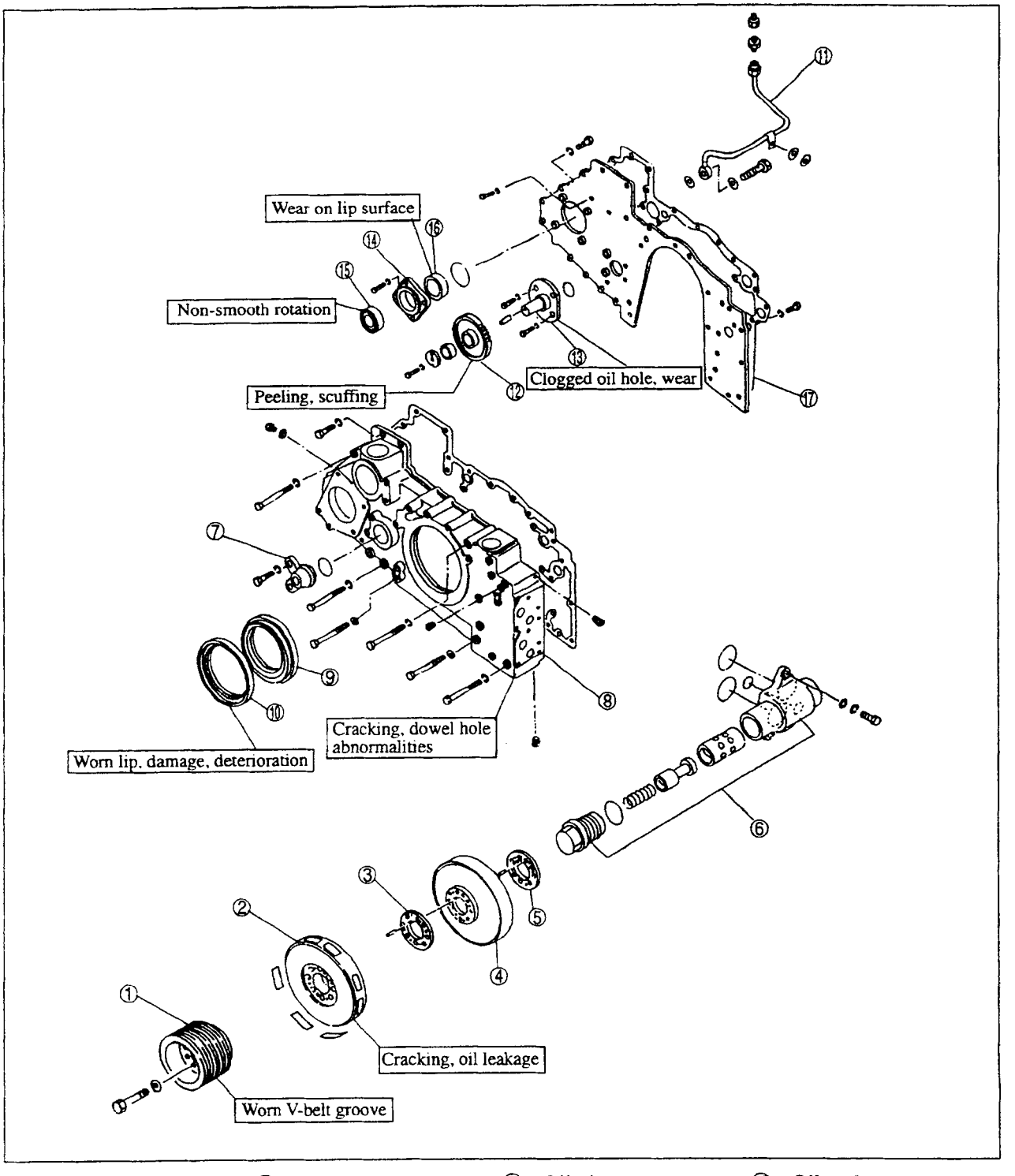
| | Standard clearance | Service limit |
|---|---|---|
| End play (widths of connecting rod and crankpin) | 0.4 ~ 0.6 [0.016 ~ 0.024] | 0.8 [0.03] |

**⚠CAUTION**

**Before installing the cylinder head, measure the protrusion of the piston, making sure that it is correct.**

# 3. VISCOUS DAMPER AND FRONT GEAR

## 3.1 Disassembly

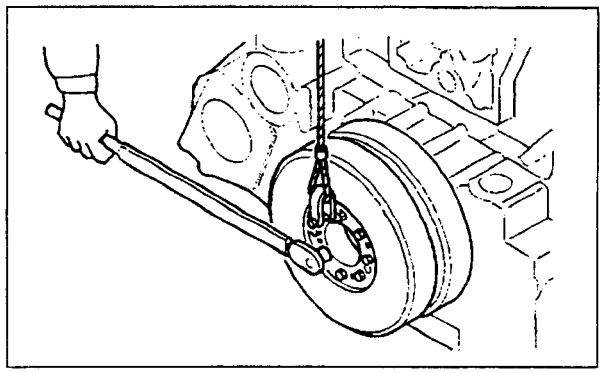



① Crank pulley
② Viscous damper
③ Viscous spacer
④ Damper
⑤ Spacer
⑥ Relief valve
⑦ Cover
⑧ Front gear case
⑨ Slinger
⑩ Oil seal
⑪ Oil pipe
⑫ Idler gear
⑬ Idler shaft
⑭ Bearing cover
⑮ Ball bearing
⑯ Oil seal
⑰ Front plate

**(1) Removing viscous damper**

(a) Attach a sling and fittings on the viscous damper and loosen the damper mounting bolts.

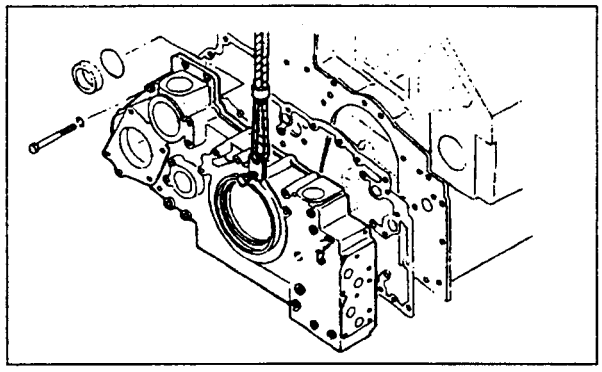
(b) Screw 2 jack bolts (M12 × 1.25 - 50 mm [197 in.]) evenly into the damper, and remove the viscous damper by lifting.



**(2) Removing front gear case**

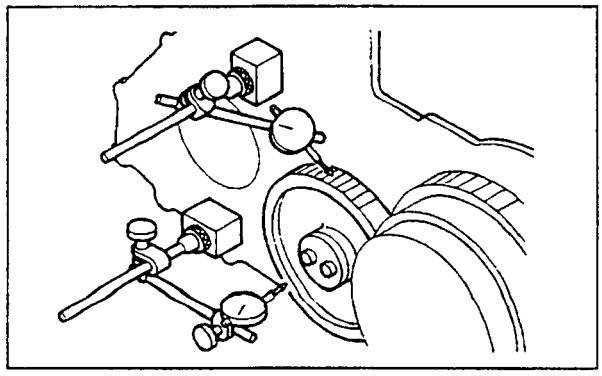
(a) Attach a sling and fittings on the front gear case.

(b) Loosen the front gear case mounting bolts and pull out the gear case until interference with the positioning dowel pin does not occur. When removing the gear case, be careful not to damage the oil seal and the pointer by hitting.



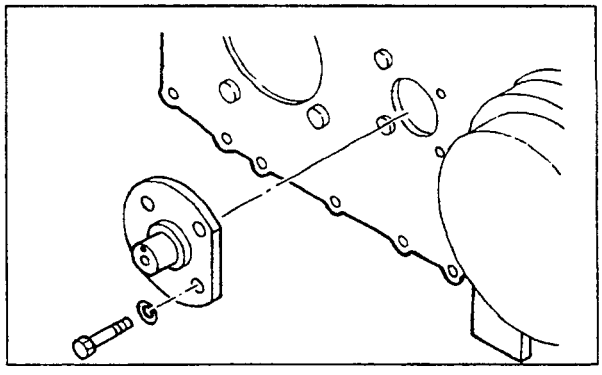
**(3) Measuring backlash and end play of idler gear**

Measure the backlash and the end play of the idler gear for reference of replacement.



**(4) Removing idler shaft**

Do not remove the idler shaft if not required. When removing the idler shaft, loosen mounting bolts and screw 2 jack bolts (M10 × 1.25) evenly into the idler shaft, and pull out the idler shaft.

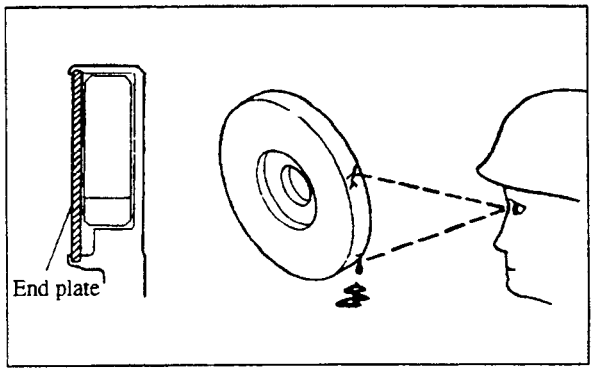


## 3.2 Inspection and repair

### Inspecting the viscous damper

(a) Check for crack, bulge and crack on the end plate, leakage of silicon oil, discoloration of paint due to overheating, or peeling visually.

If there is no abnormality and operation hours exceed 8,000 hours, replace the damper with a new one.



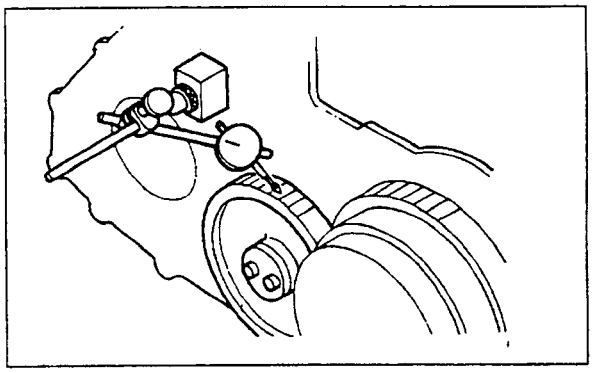

Inspecting viscous damper

### Measuring gear backlash

Put the dial gauge square to the gear pitch circumference to measure rattling. Or measure the backlash by inserting a feeler gauge between the teeth of the gears. If the backlash exceeds the service limit, replace a worn gear.

Unit: mm [in.]

| | Standard clearance | Service limit |
|---|---|---|
| Backlash | 0.12 ~ 0.18 [0.005 ~ 0.007] | 0.50 [0.02] |



Measuring timing gear backlash

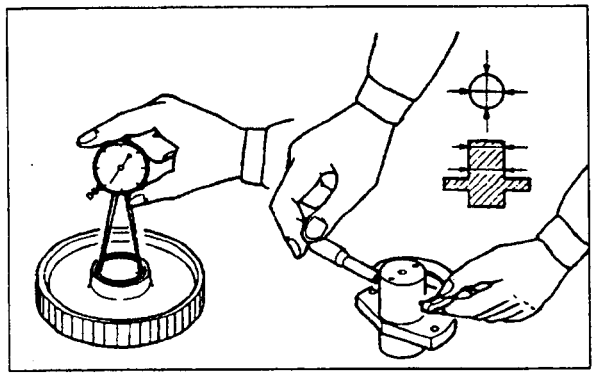
### Idler gear, idler bushing and idler shaft

#### (1) Measuring inside diameter of idler bushing and outside diameter of idler shaft

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

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Idler bushing inside diameter | ø50 [1.967] | 50.000 ~ 50.025 [1.970 ~ 1.971] | 50.060 [1.972] |
| Idler shaft outside diameter | ø50 [1.967] | 49.950 ~ 49.975 [1.968 ~ 1.969] | 49.900 [1.966] |



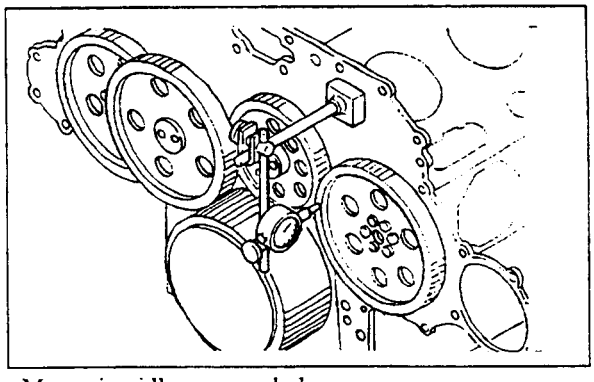
Measuring idler bushing and shaft

#### (2) Measuring end play of idler gear

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

Unit: mm [in.]

| | Standard clearance | Service limit |
|---|---|---|
| Idler gear end play | 0.3 ~ 0.5 [0.0121 ~ 0.02] | 0.7 [0.03] |



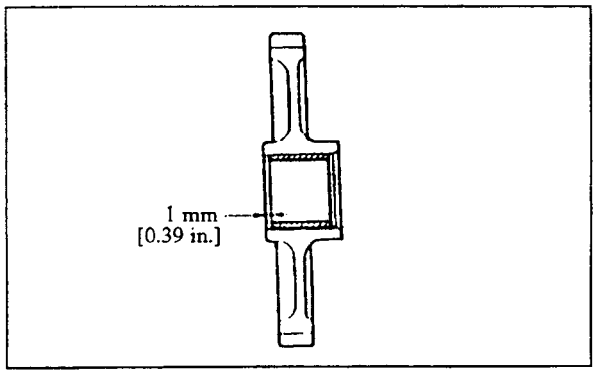
Measuring idler gear end play

**(3) Replacing idler gear bushing**

(a) Using idler bushing puller (32591-02500), remove the bushing.

(b) Install a new bushing to the gear by pressing it from the boss side of the gear by 1 mm lower.

(c) After installing the bushing, make sure that its inside diameter is within the assembly standard. If it is less than the assembly standard, ream the bushing to finish its inside diameter to $\phi 50^{+0.025}_{0}$ mm [1.967 $^{+0.001}_{0}$ in.] $\frac{3.2S}{\nabla\nabla}$.



Replacing idler bushing

### 3.3 Reassembly

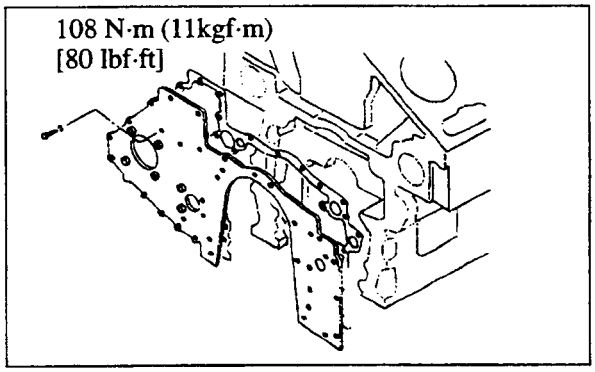
**Install the parts in the reverse order of disassembly.**

**(1) Installing front plate**

(a) Apply sealant (HERDITE) to the front plate mounting surface of the crankcase, and place the packing in position. Apply the same sealant to the packing and install the front plate.

(b) Replace the dowel pins if worn, or if the front plate has been replaced.

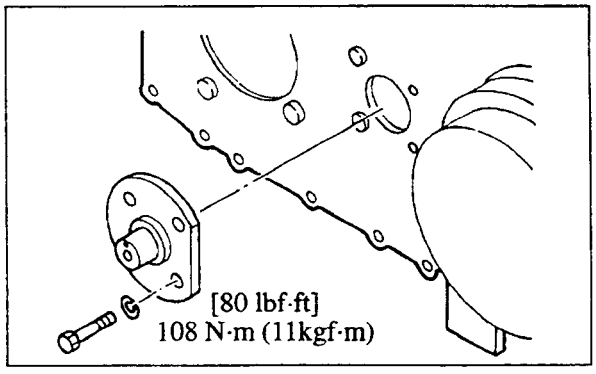
(c) Make sure that the lower end of the front plate is flush with the bottom of the crankcase. Cut off the excess of the packing neatly along the edge of the plate.




**(2) Installing idler shaft**

(a) Insert the idler shaft with the guide bolt.

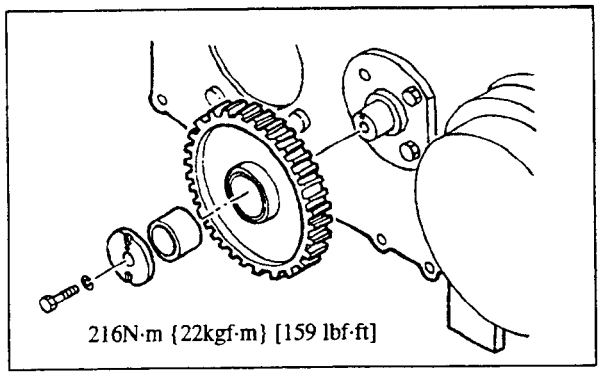
(b) Tighten the shaft mounting bolts to the specified torque.



**(3) Installing idler gear**

(a) Insert the idler gear into the shaft and install the thrust plate.

(b) Tighten the thrust plate mounting bolts to the specified torque.




**(4) Installing front gear case and pointer**

(a) Apply sealant (HERDITE) to the front gear case packing mounting surface of the crankcase, and place the packing in position. Apply the same sealant to the packing, and install the front gear case.

(b) Replace the dowel pins if worn, or if the front cover has been replaced.

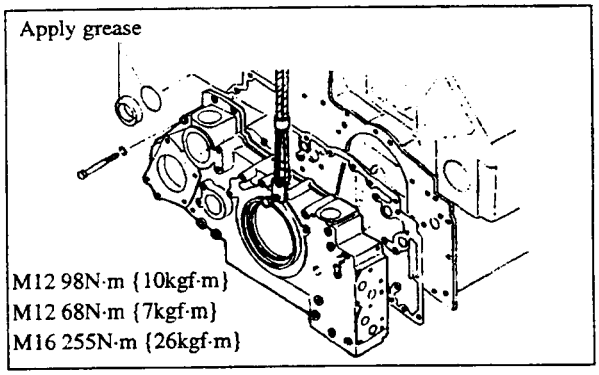
(c) Tighten the case mounting bolts evenly to the specified torque.

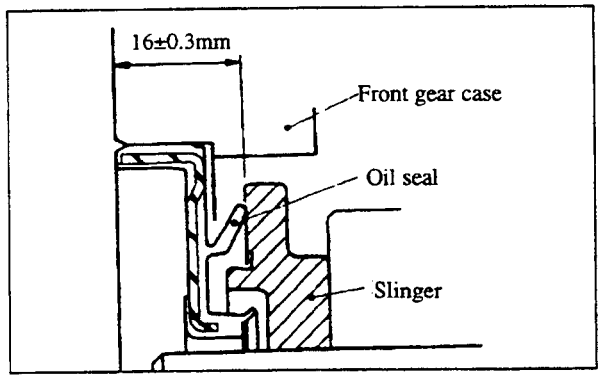
(d) Make sure that the lower end of the front gear case is flush with the bottom of the crankcase. Cut off the excess of the packing neatly along the edge of the cover.

(e) Install the oil seal on the front gear case.

(f) Coat the lip of the oil seal with engine oil.

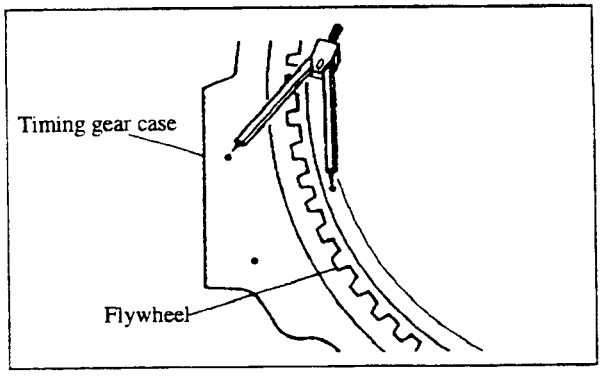
(g) Insert the oil seal so that the clearance to the slinger is as shown in the figure.



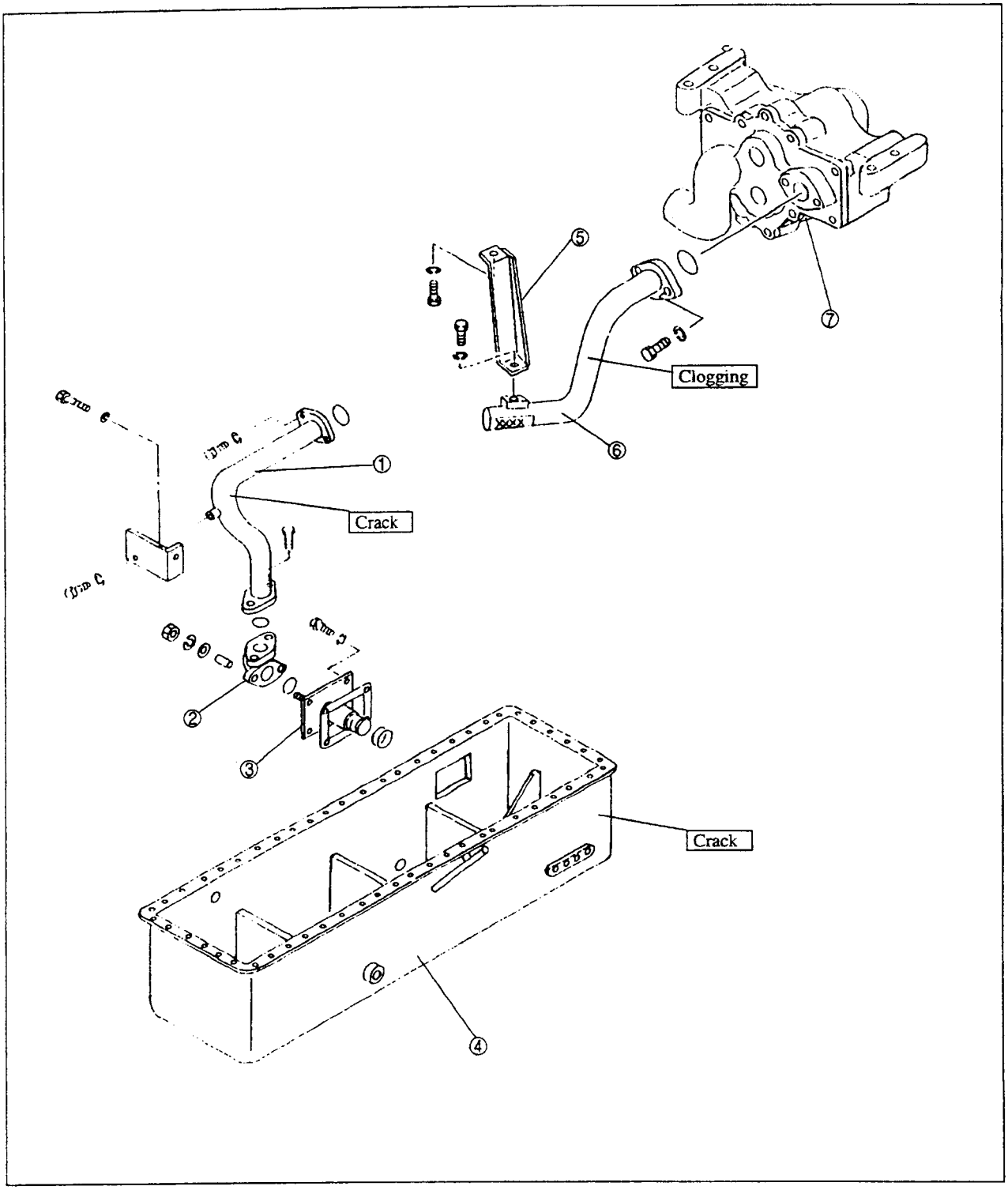

**(When the pointer has been out of place or when the pointer has been offset by hitting)**

To determine the top dead center on compression stroke of No. 1 or No. 6 cylinder, bring the mark on the flywheel to the position where it is at equal distances from two marks stamped on the timing gear case.



# 4. FLYWHEEL, TIMING GEAR, CAMSHAFT

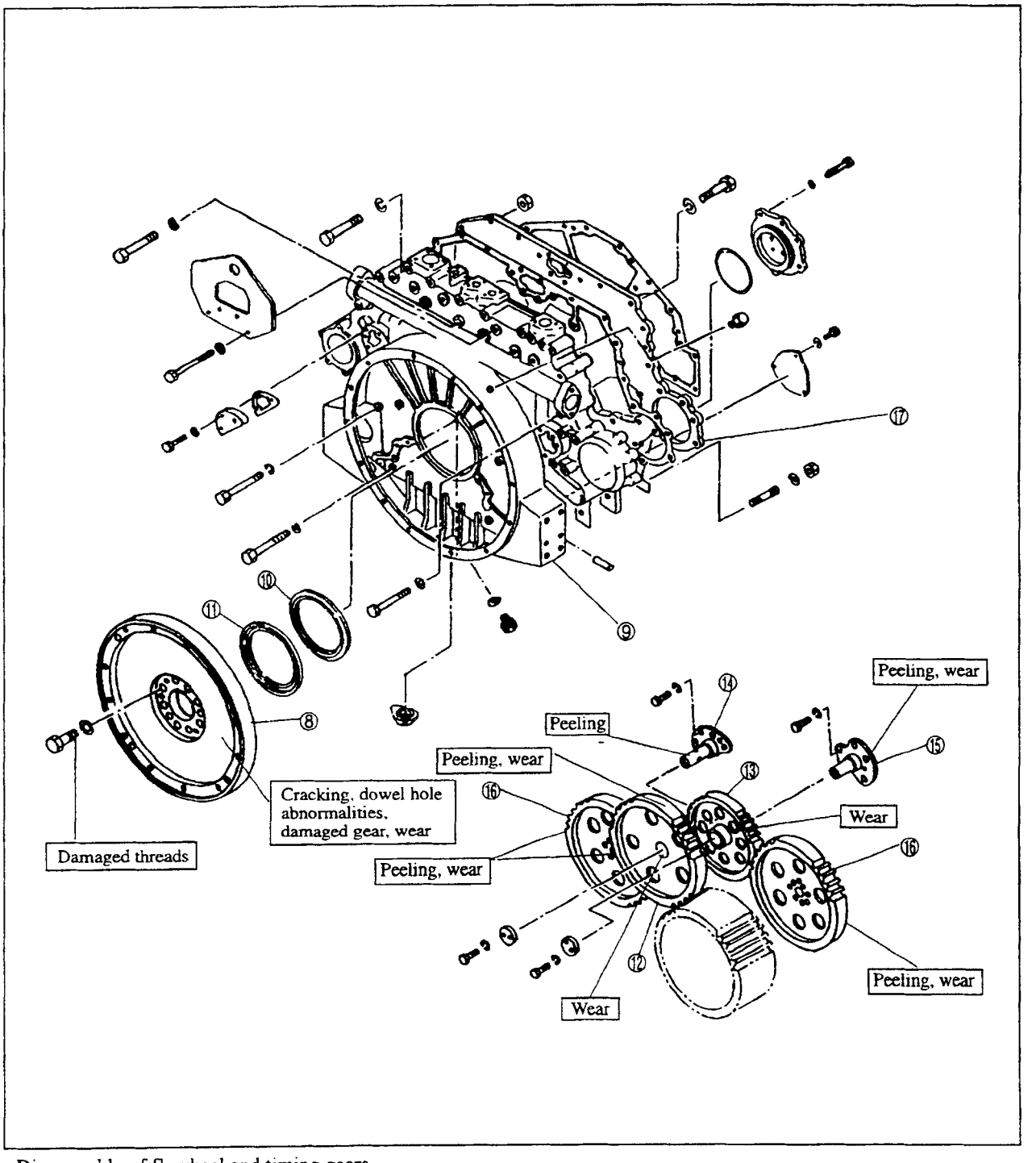
## 4.1 Disassembly




Removal of oil pump

① Oil pipe
② Connector
③ Connector
④ Oil pan
⑤ Strainer stay
⑥ Oil strainer
⑦ Oil pump

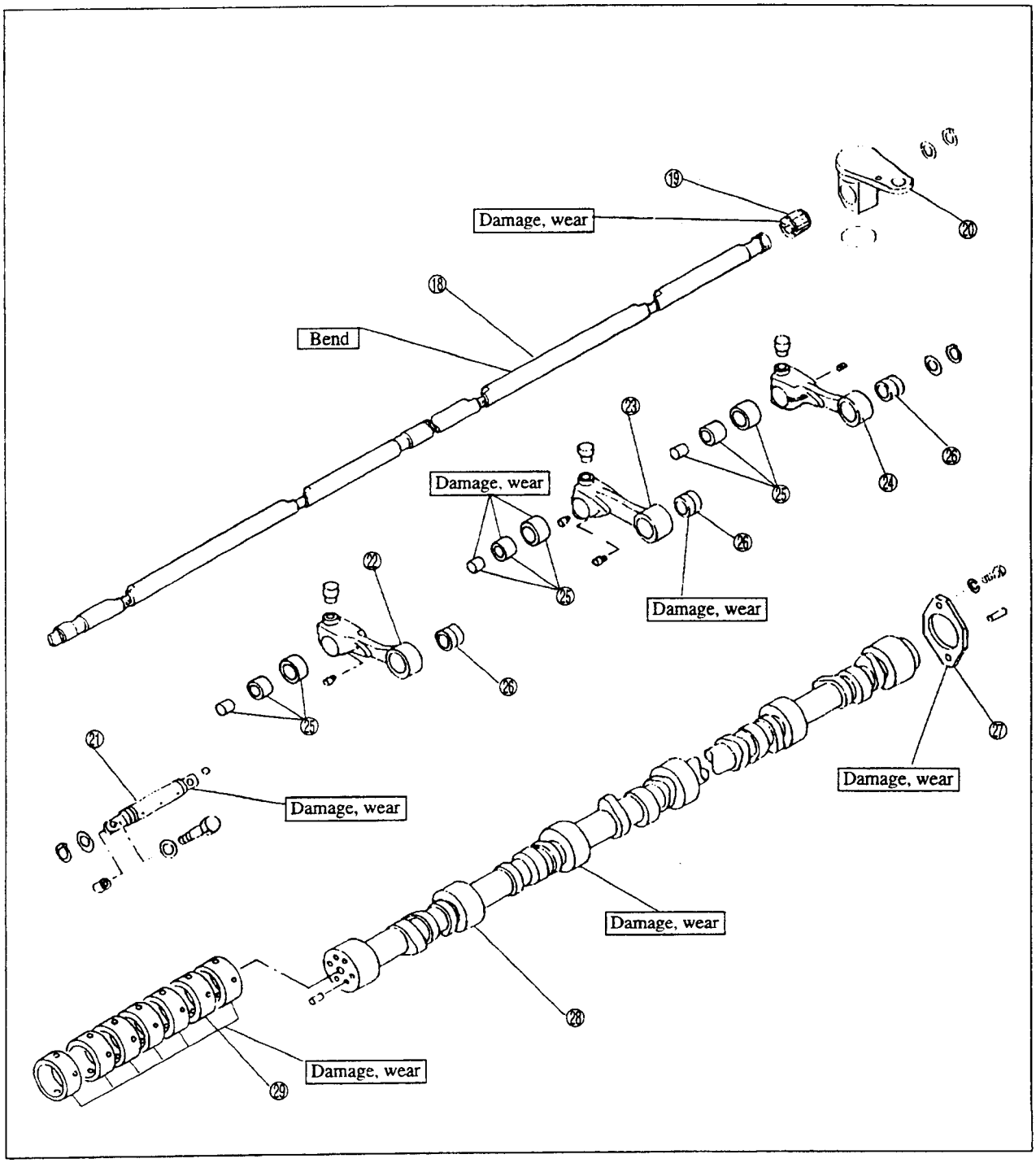
**Disassembling flywheel and timing gear**




Disassembly of flywheel and timing gears

⑧ Flywheel
⑨ Timing gear case
⑩ Slinger
⑪ Oil seal
⑫ Idler gear
⑬ Idler gear
⑭ Idler shaft
⑮ Idler shaft
⑯ Camshaft gear
⑰ Rear plate

**Disassembling camshaft and fuel link**




Disassembly of camshaft and fuel link

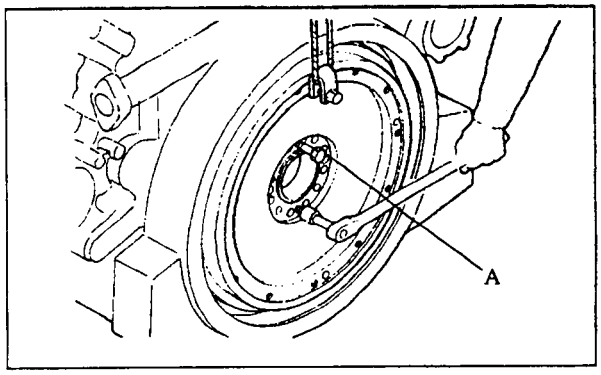
⑱ Control shaft
⑲ Needle cage
⑳ Control bracket
㉑ Cam follower shaft
㉒ IN follower
㉓ UI follower
㉔ EXH follower
㉕ Tappet roller
㉖ Follower bushing
㉗ Thrust plate
㉘ Camshaft
㉙ Cam bushing

**(1) Removing flywheel**

(a) Attach a sling and fittings to the flywheel.

(b) Unscrew the flywheel mounting bolt.

(c) Screw two jacking bolts (A) (M12 × 1.25 ) into the holes in the flywheel uniformly, and remove the flywheel. (weight: 100 kg [220.5 lb], approx.)




**⚠CAUTION**

**(a) When removing the flywheel, be careful not to drop or bump it against a hard object.**

**(b) The ring gear is shrinkage-fitted to the flywheel. Do not remove the gear except when it has to be replaced.**

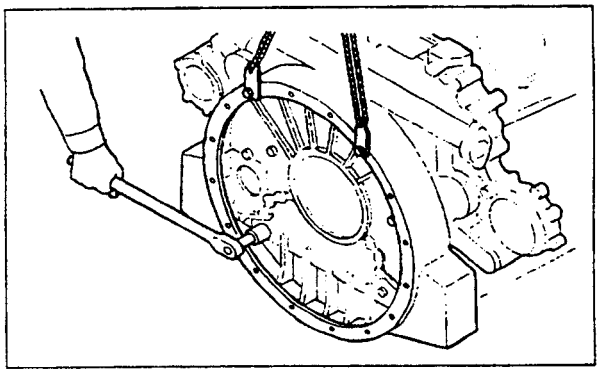
**(2) Removing timing gear case**

(a) Attach a sling and fittings to the timing gear case.

(b) Unscrew the case mounting bolt.

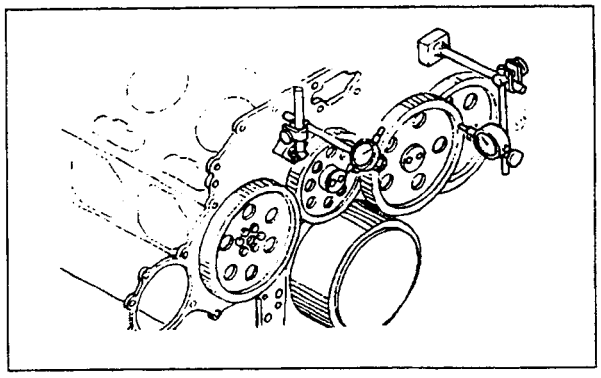
(c) Pull out the case in suspended state until the dowel pins come out of the holes. Be careful not to damage the oil seal.

(Timing gear case weight: 170 kg [374 lb], approx.)



**(3) Measuring backlash and end play**

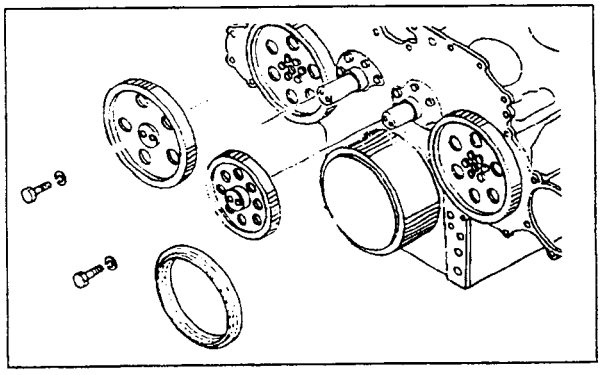
Measure the backlash and end play of each gear to obtain the data for parts replacement.



**(4) Removing idler gear**

(a) Remove the slinger of the crankshaft.

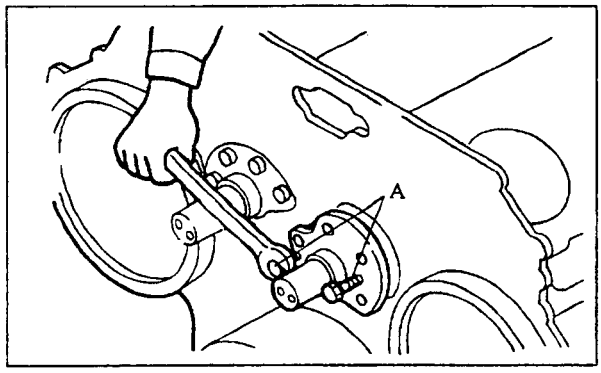
(b) Remove the left/right idler gears.



**(5) Removing idler shaft**

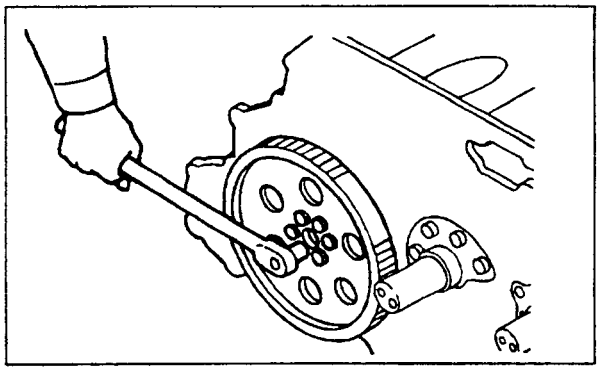
Do not remove the gear except when it has to be replaced.

Screw two jacking bolts (A) (M10 × 1.25 ) into the holes in the shaft uniformly, and remove the shaft.




**(6) Removing camshaft gear**

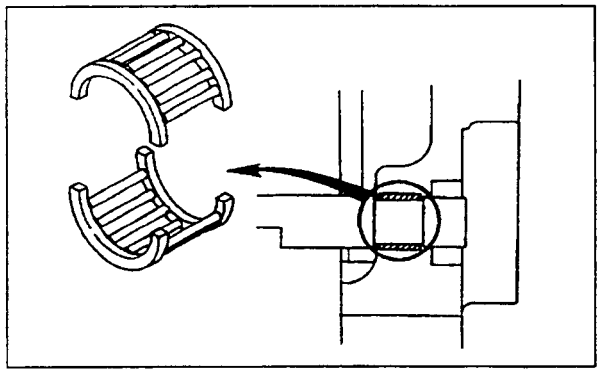
Unscrew the camshaft gear mounting bolts, and remove the gear.



**(7) Removing control shaft**

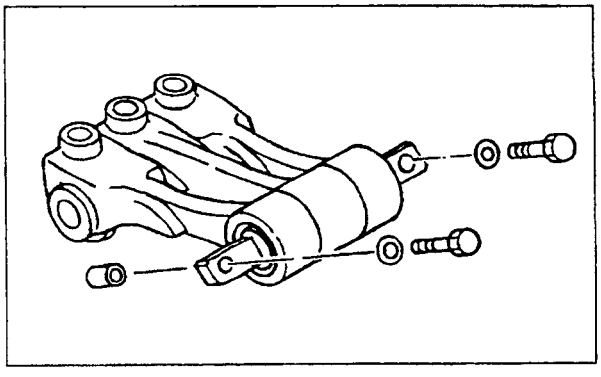
Remove the control shaft out of the crankcase.

**NOTE:** When removing the control shaft, do not drop the needle cage in the crankcase. The needle cage is shaped like a compound of two half-round objects.



**(8) Removing follower**

Loosen the cam follower shaft mounting bolts and remove the follower.

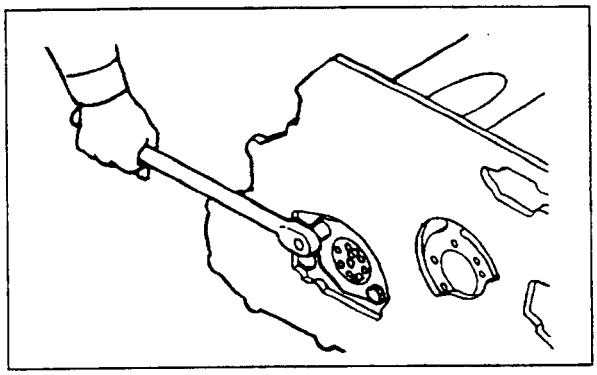


**(9) Removing camshaft**

Unscrew the thrust plate mounting bolt, and pull the camshaft from the crankcase.

**⚠CAUTION**

**When pulling the camshaft, support it with a bar-like tool inserted through the side cover hole to prevent damage to the cam surfaces and bushings.**



## 4.2 Inspection and repair

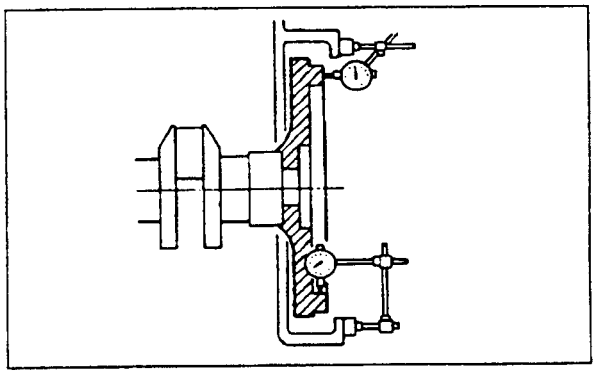
### Flywheel and ring gear

**(1) Measuring flywheel face and radial runout**

Measure the runouts with the flywheel installed to 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.

Unit: mm [in.]

| | Assembly standard |
|---|---|
| Face runout | 0.28 [0.011], maximum |
| Radial runout | 0.13 [0.005], maximum |



Measuring flywheel runouts

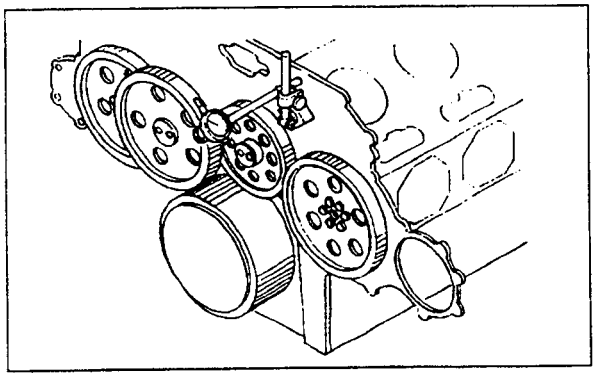
### Timing gear

**(2) Measuring backlash**

Set up a dial gauge so that it contacts with the pitch circle of the gear and move one gear back and forth to measure the backlash between the gears. If the dial gauge is not available, measure the backlash by inserting a feeler gauge between the teeth of the gears. If the backlash exceeds the service limit, replace a worn gear.

Unit: mm [in.]

| Item | Standard clearance | Service limit |
|---|---|---|
| Right camshaft gear to idler gear | 0.11 ~ 0.25 [0.0043 ~ 0.0099] | 0.50 [0.0197] |
| Idler gear to idler gear | 0.12 ~ 0.22 [0.0047 ~ 0.0086] | 0.50 [0.0197] |
| Crankshaft gear to idler gear | 0.11 ~ 0.26 [0.0043 ~ 0.0102] | 0.50 [0.0197] |
| Left camshaft gear to idler gear | 0.10 ~ 0.24 [0.0039 ~ 0.0095] | 0.50 [0.0197] |



Measuring timing gear backlash

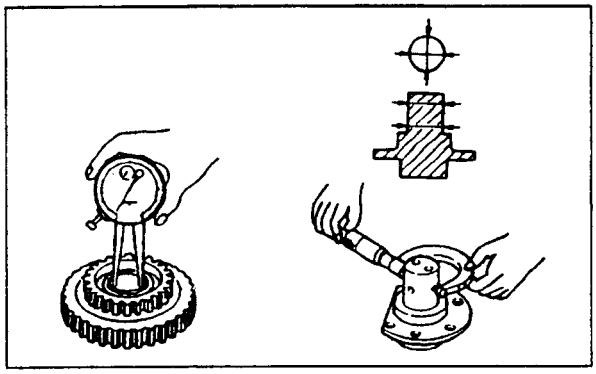
### Idler gear, idler gear bushing and idler gear shaft

#### (3) Measuring idler gear bushing inside diameter and idler gear shaft diameter

If the diameter exceeds the service limit, replace the bushing or shaft whichever is worn.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Idler gear bushing inside diameter | ø50 | 50.000 ~ 50.025 [1.97 ~ 1.9709] | 50.060 [1.97] |
| Idler gear shaft diameter | ø50 | 49.950 ~ 49.975 [1.968 ~ 1.969] | 49.900 [1.966] |



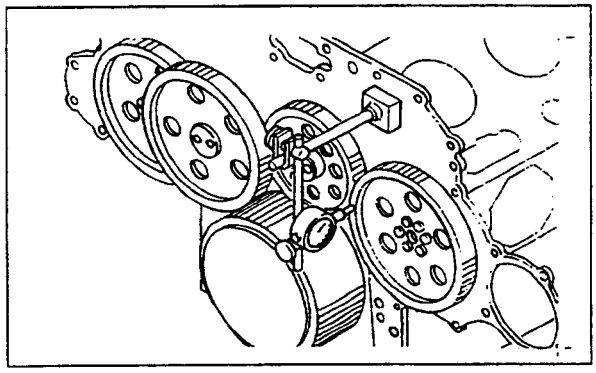
Measuring idler gear bushing and shaft

#### (4) Measuring idler gear end play

Measure the end play with a feeler gauge or a dial gauge. If the end play exceeds the service limit, replace the thrust collar.

Unit: mm [in.]

| | Standard clearance | Service limit |
|---|---|---|
| Idler gear end play | 0.3 ~ 0.5 [0.01 ~ 0.02] | 0.7 [0.027] |



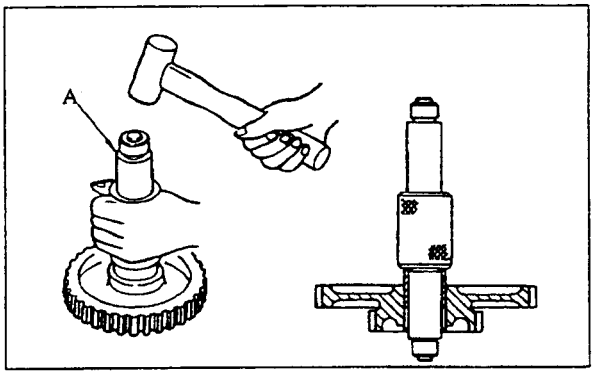
Measuring idler gear end play

#### (5) Replacing idler gear bushing

(a) Using idler bushing puller (A) (32591-02500), remove the existing bushing.

(b) Install a new bushing to the gear by pressing it from the boss side of the gear by 1 mm [0.04 in.] lower.

(c) After installing the bushing, make sure that its inside diameter is within the assembly standard. If it is less than the assembly standard, ream the bushing to finish its inside diameter to ø50 $^{+0.025}_{0}$ mm [1.97 $^{+0.0010}_{0}$ in.] $\frac{1.6S}{\nabla\nabla\nabla}$.




Replacing idler gear bushing

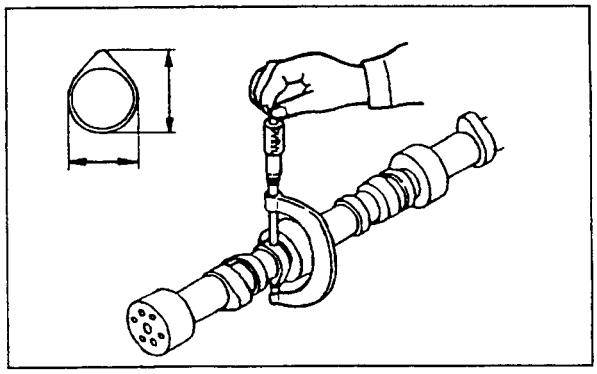
### Camshaft and camshaft bushing

#### (6) Measuring cam lift

Using a micrometer, measure the diameters "A" and "B" on each cam to determine the loss in the cam lift. If the cam lift exceeds the service limit, replace the camshaft.

Unit: mm [in.]

| | | Standard clearance | Service limit |
|---|---|---|---|
| Cam lift (A-B) | Intake | 14.525 ~ 14.625 [0.572 ~ 0.576] | 13.78 [0.543] |
| | Exhaust | 9.425 ~ 9.525 [0.371 ~ 0.375] | 8.68 [0.342] |



Measuring cam lift

### (7) Measuring camshaft runout

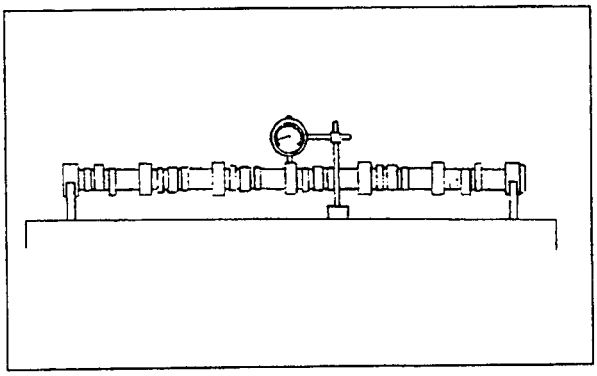
If the runout exceeds the repair limit, straighten the camshaft by means of a press, or replace it with a new one.

**⚠CAUTION**

**Set up a dial gauge on the camshaft, and turn the camshaft. Take on half (1/2) of the gauge indication as the runout.**

Unit: mm [in.]

| | Assembly standard | Repair limit |
|---|---|---|
| Camshaft runout | 0.05 [0.002], maximum | 0.08 [0.003] |



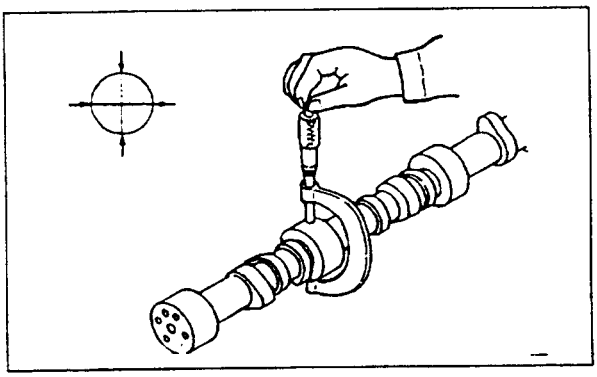
Measuring camshaft runout

### (8) Measuring camshaft journal diameter

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

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Camshaft journal diameter | ø100 [3.94] | 99.92 ~ 99.94 [3.937 ~ 3.938] | 99.86 [3.934] |



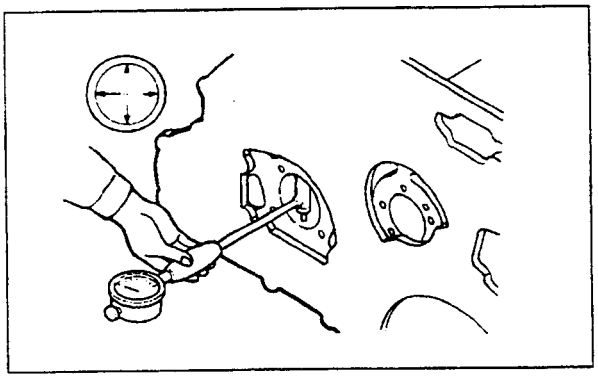
Measuring camshaft journal diameter

### (9) Measuring camshaft bushing inside diameter

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

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Camshaft bushing inside diameter | ø100 [3.94] | 100.000 ~ 100.115 [3.94 ~ 3.945] | 100.160 [3.946] |



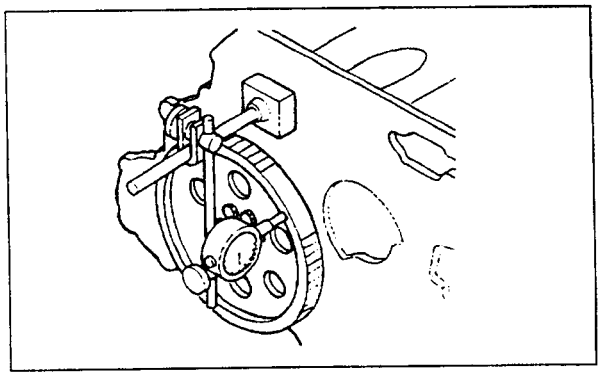
Measuring camshaft bushing inside diameter

### (10) Measuring camshaft end play

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

Unit: mm [in.]

| | Standard clearance | Service limit |
|---|---|---|
| Camshaft end play | 0.2 ~ 0.4 [0.008 ~ 0.016] | 0.55 [0.022] |



Measuring camshaft end play

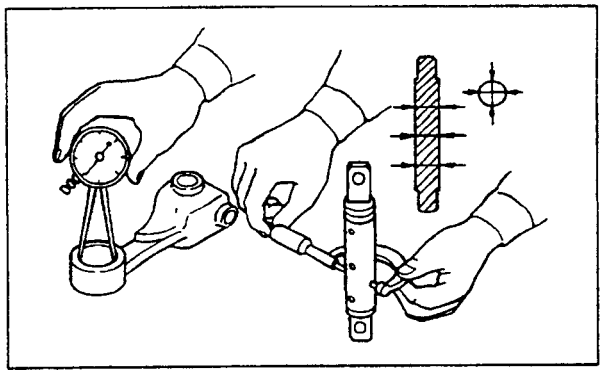
**Cam follower shaft, follower bushing and tappet roller**

**(11) Measuring follower bushing inside diameter and follower shaft diameter**

Measure the follower bushing inside diameter and the follower shaft diameter. If the diameter exceeds the service limit, replace it with a new one.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Follower bushing inside diameter | ø30 [1.182] | 30.000 ~ 30.075 [1.182 ~ 1.184] | 30.125 [1.187] |
| Cam follower shaft diameter | ø30 [1.182] | 29.959 ~ 29.980 [1.180 ~ 1.181] | 29.930 [1.179] |



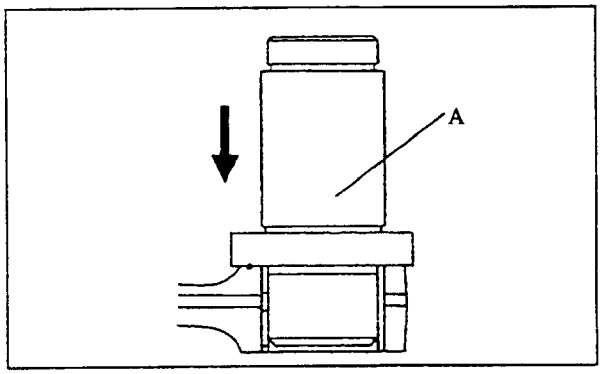
Measuring follower bushing inside diameter and follower shaft diameter

**(12) Replacing follower bushing**

(a) Using follower bushing installer (A) (35C91-01700), replace the bushing.

(b) Install the bushing so that the punch mark (oil hole match mark for bushing) on the follower may match with the bushing notch at the opposite side.

(c) After installing the bushing, make sure that its inside diameter is within the assembly standard. If it is less than the assembly standard, ream the bushing to finish its inside diameter to ø30 $^{+0.075}_{0}$ [1.182 $^{+0.003}_{0}$ in.] ▽▽▽ .



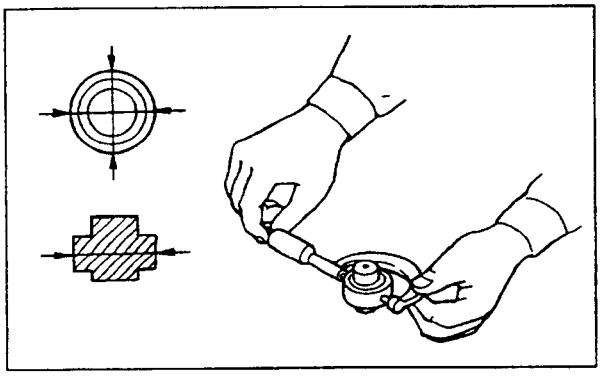

Replacing follower bushing

**(13) Replacing tappet roller**

Measure the outside diameter of the tappet roller and if the diameter exceeds the service limit, replace it with a new one.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Tappet roller outside diameter | ø41 [1.615] | 40.995 ~ 41.050 [1.615 ~ 1.617] | 40.985 [1.6148] |

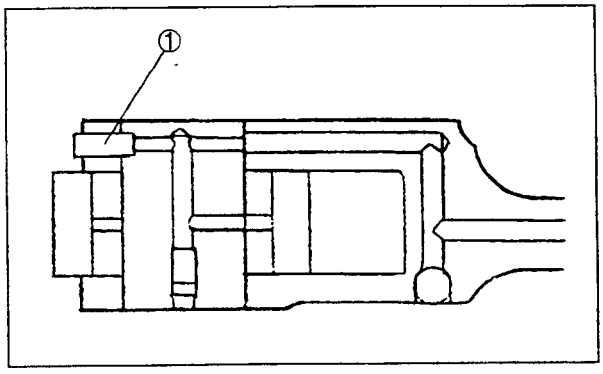


Measuring tappet roller outside diameter

**(14) Replacing tappet roller**

(a) When installing the tappet roller on the follower, match the pin oil hole with the follower. For this purpose, drive in the pin set screw to match with the follower set screw.

(b) Apply Loctite to the set screw and tighten the screw, and retighten it.




Replacing tappet roller

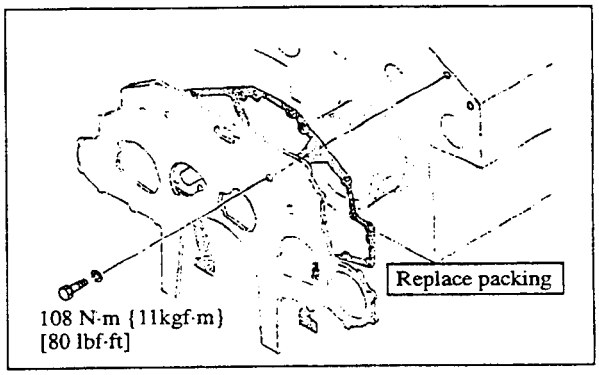
## 4.3 Reassembly

### (1) Installing rear plate

(a) Apply sealant (HERDITE) to the rear plate mounting surface of crankcase, and place the packing in position. Apply the same sealant to the packing, and install the rear plate to the crankcase.

(b) Replace the dowel pins if worn, or if the rear plate has been replaced.

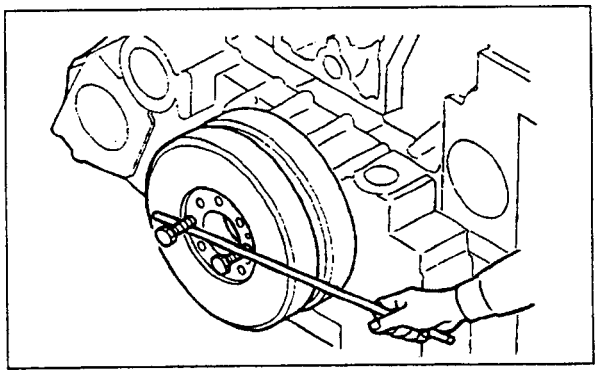
(c) Make sure that lower end of rear plate is flush with the bottom of crankcase. Cut off the excess of the packing neatly along the edge of the plate.




### (2) Cranking engine

(a) Put the bolts (M22 × 1.5) into the viscous damper mounting holes.

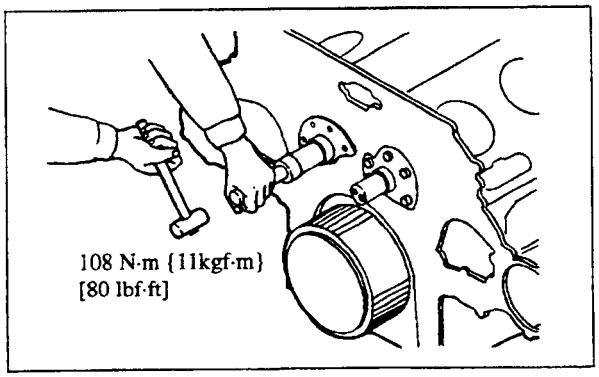
(b) Using bolts, turn the crankshaft to bring the No. 1 cylinder to the top dead center with a bar.



### (3) Installing idler gear shaft

(a) Drive in the idler gear shaft, using a guide bolt.

(b) Tighten the idler gear shaft mounting bolts to the specified torque.



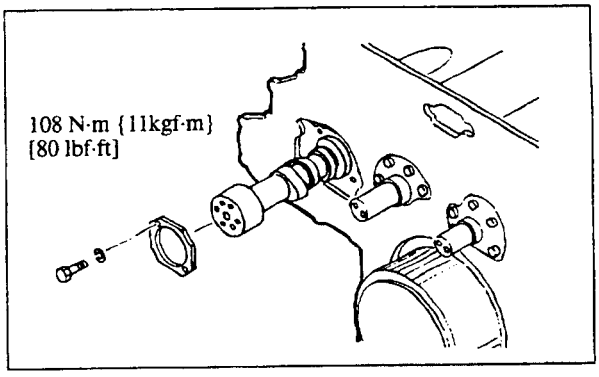

### (4) Installing camshaft (L/R)

(a) Insert the camshaft into the crankcase, and install the thrust plate.

(b) Tighten the thrust plate mounting bolts to the specified torque.

(c) Make sure that the camshaft rotates lightly.

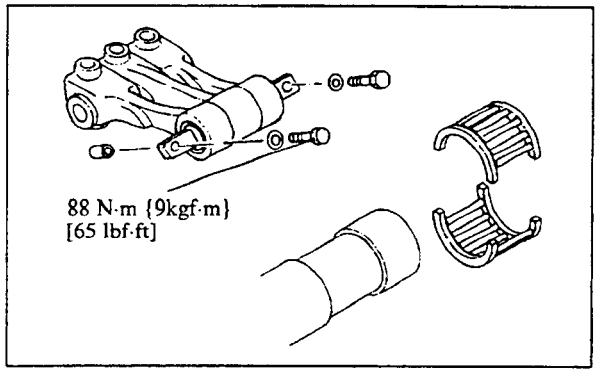
**NOTE**: Install the camshaft to the correct side.



**(5) Installing cam follower and control shaft**

(a) Tighten the cam follower shaft mounting bolts to the specified torque.

(b) Insert the control shaft into the crankcase so that the needle cage may not fall off.

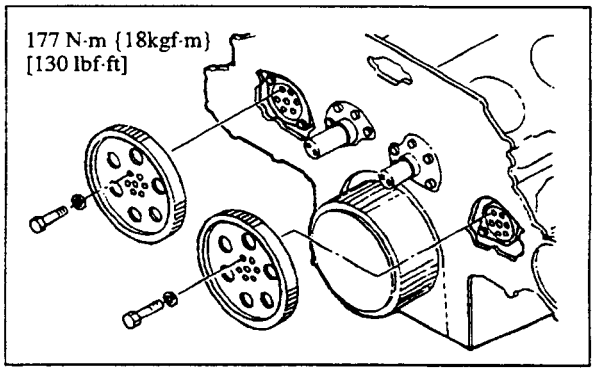



**(6) Installing camshaft gear**

(a) Install the camshaft gear to the camshaft with the dowel pin entering its hole.

(b) Tighten the gear mounting bolt to the specified torque.

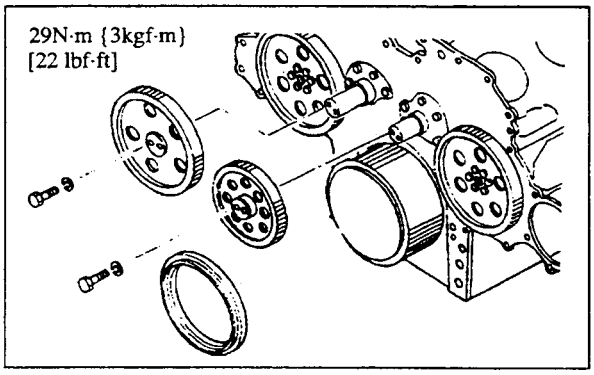
(c) Make sure that the camshaft rotates lightly.



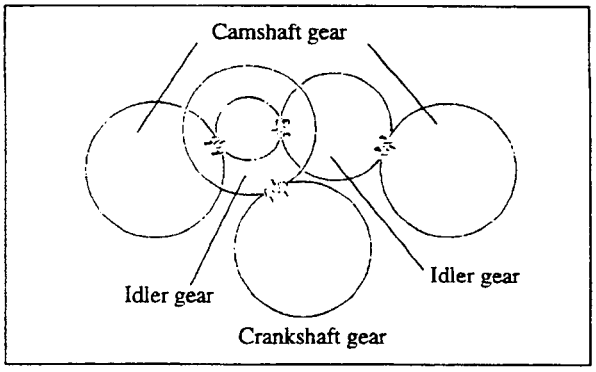

**(7) Installing idler gear**

(a) Install the idler gear by aligning its matching mark with those on the crankshaft gear and camshaft gear, and tighten the idler gear mounting bolts to the specified torque.

(b) Insert the slinger into the crankshaft.




(c) Bring the match marks for the timing gear as shown in the right.



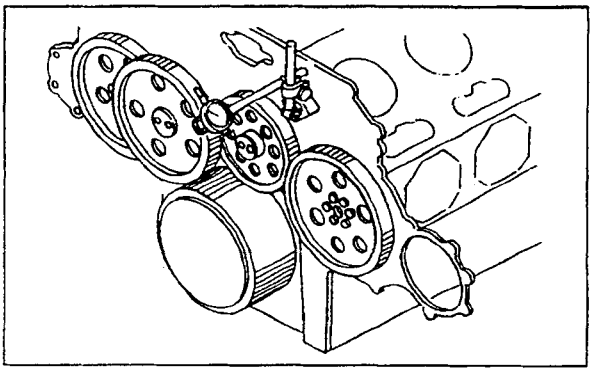

Timing gear train

### (8) Inspecting and adjusting timing gear after installation

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

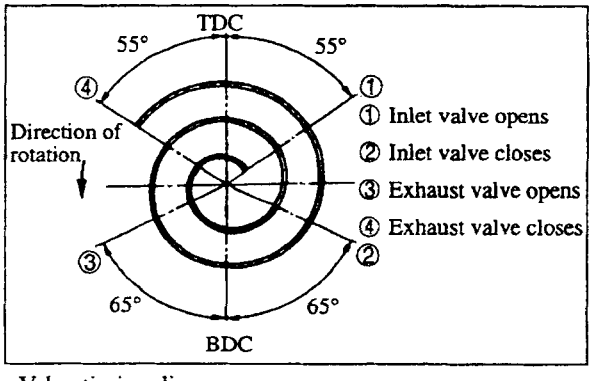
(a) Inspecting timing gear backlash and end play

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

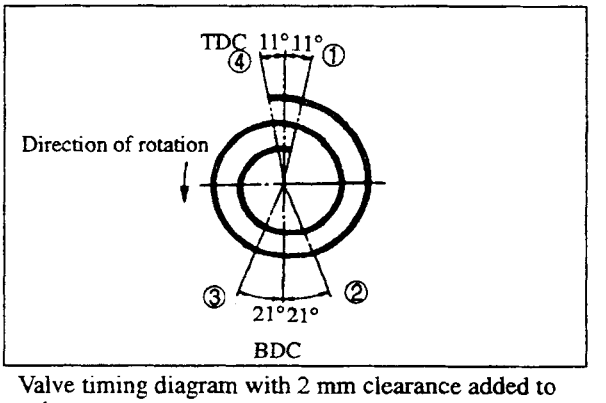


(b) (Inspecting valve timing)

It is not necessary to inspect the valve timing, provided that all matching marks on the timing gears are aligned.
Inspect the timing for verification as follows: Using a 2 mm [0.08 in.] feeler gauge, set the clearance of the inlet and exhaust valves of No.1 cylinder to 2mm [0.08 in.]. Then, insert a 0.05 mm [0.002 in.] feeler gauge into between the bridge cap and rocker, slowly turn the crankshaft, trying to find a position where the feeler gauge is firmly gripped (the valve starts opening) and that where the gauge just becomes free (the valve starts closing).
Check to make sure that these positions coincide with the angular positions shown in the valve timing diagram with 2 mm [0.08 in.] clearance added to the valves.




Valve timing diagram



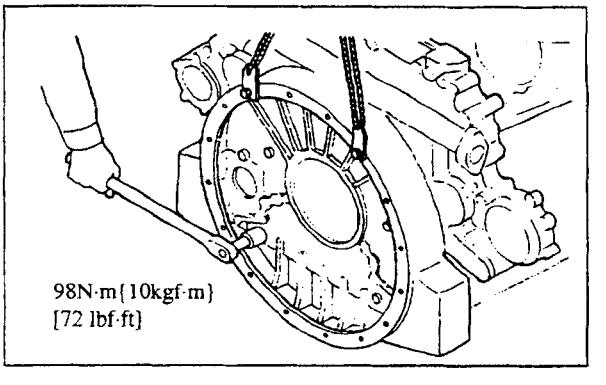

Valve timing diagram with 2 mm clearance added to valves

### (9) Installing timing gear case

(a) Apply sealant (HERDITE) to the timing gear case mounting surface or rear plate, and place the packing in position. Apply the same sealant to the packing, and install the gear case to the rear plate. Cut off the excess of packing neatly along the bottom edge of crankcase.

(b) Replace the dowel pins if worn, or if the gear case has been replaced.

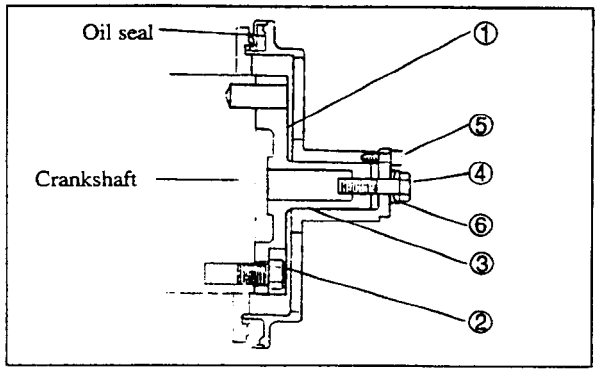
(c) Tighten the gear case mounting bolts uniformly to the specified torque.

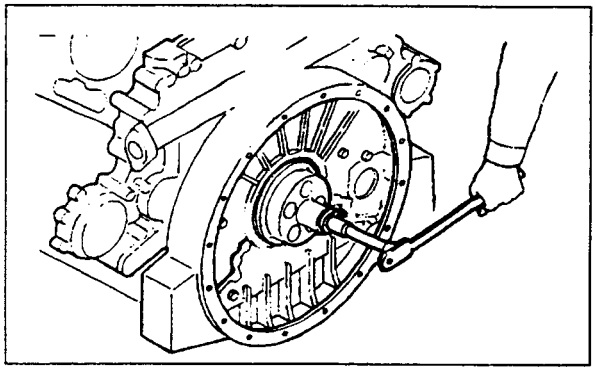


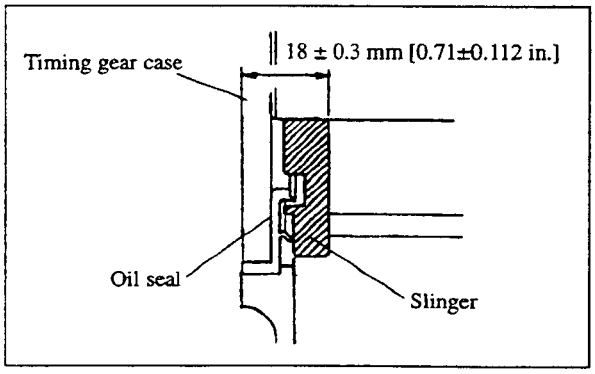
(d) Coat the oil seal lip with engine oil, and insert the seal into the bore of the timing gear case.

(e) Using rear seal installer (35B91-06010), insert the oil seal so that the dimensions with the slinger may be as shown in the figure.

- Install guide ① at the rear end of the crankshaft with insert bolt ②.
- Set the oil seal on installer ③ and insert it into the shaft of guide ①.
- After insertion, tighten bolt ④ on installer ③. Install the oil seal on the gear case.
- Loosen socket bolt ⑤ and remove swing washer ⑥ from bolt ④. Pull out installer ③.
- Loosen insert bolt ② and remove guide ① from the crankshaft.



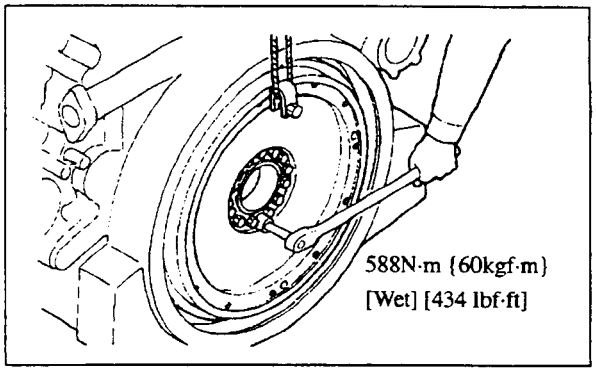



**(10) Installing flywheel**

(a) Install the flywheel, making sure that the dowel pins enter their holes.

(b) Coat the threads and the seats of the flywheel mounting bolts with engine oil, and tighten the bolts to the specified torque.

Inspect the face and radial runouts of the flywheel.

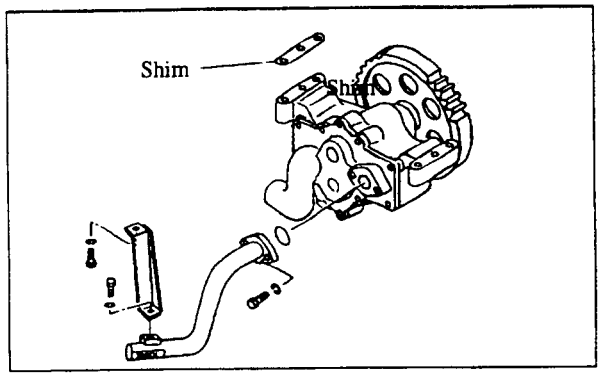


### (11) Installing oil pump and oil strainer

Measure the backlash between crankshaft gear and oil pump drive gear, and, if it is not enough, make a shim adjustment.

Unit: mm [in.]

| | Assembly standard |
|---|---|
| Backlash of crankshaft and oil pump gear | 0.11 ~ 0.26 [0.004 ~ 0.010] |

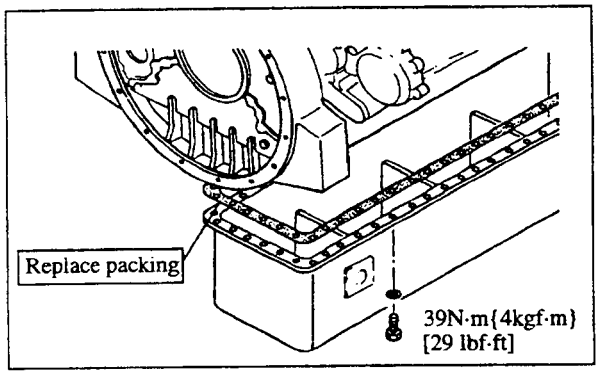



### (12) Installing oil pan

(a) Apply sealant (Hermeseal S-2) to separated areas (4 places) of oil pan packing and place the packing in position.

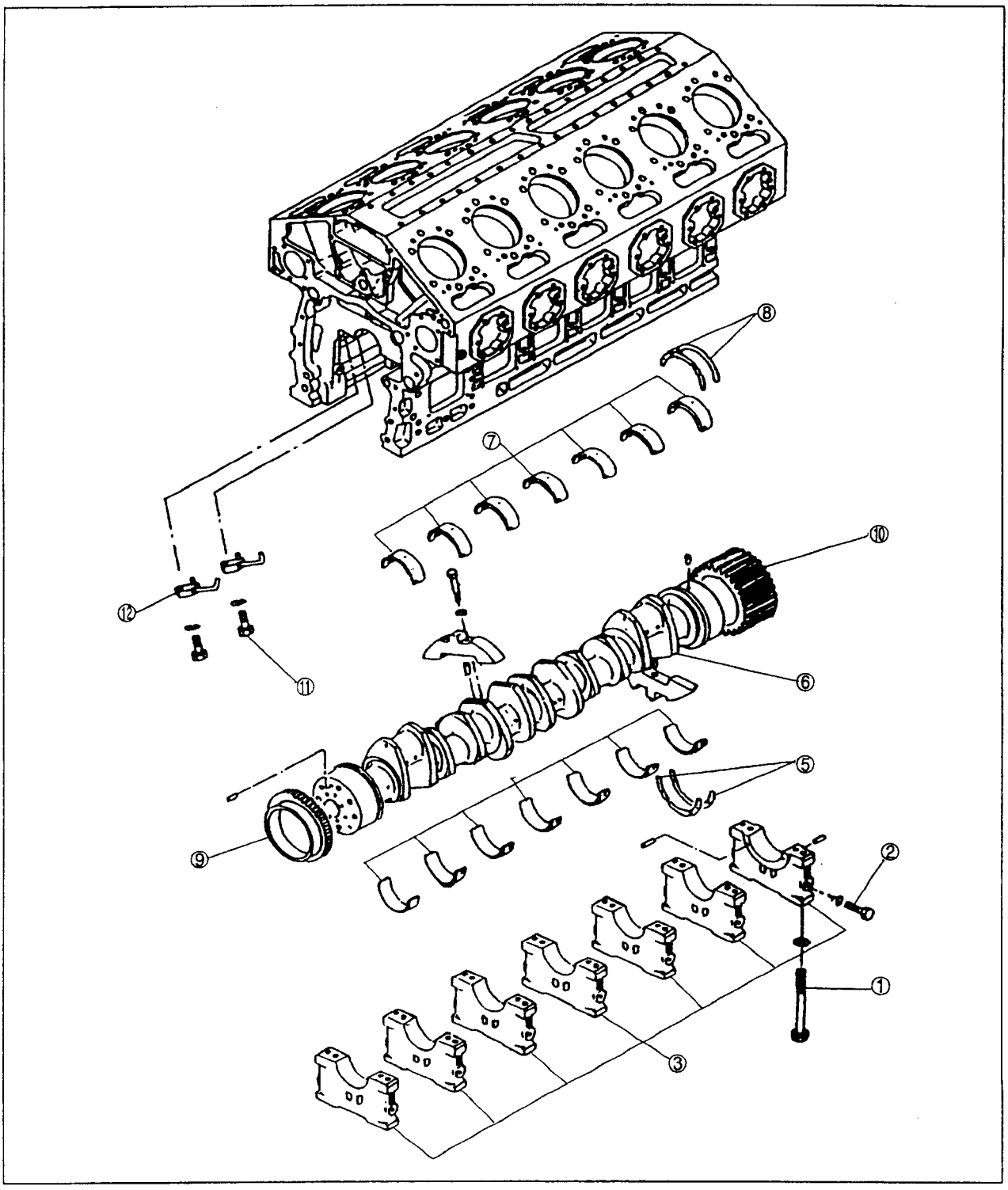
(b) Screw in two guide bolts into the crankcase and install the oil pan.

(c) Tighten the oil pan mounting bolts to the specified torque.



# 5. CRANKCASE, CRANKSHAFT AND MAIN METAL

## 5.1 Disassembly

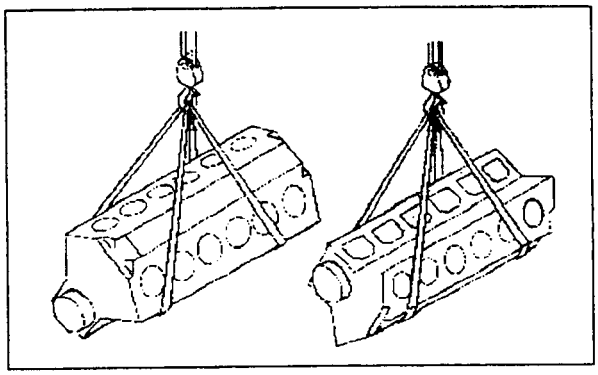



① Main metal cap bolt
② Side bolt
③ Main metal cap
④ Main metal (lower shell)
⑤ Thrust plate
⑥ Crankshaft
⑦ Main metal (upper)
⑧ Thrust plate
⑨ Crankshaft gear (front)
⑩ Crankshaft gear (rear)
⑪ Check valve
⑫ Oil jet nozzle

**(1) Turning crankcase upside down**

Using a chain block and shackles, lay the crankcase by its side. Then, attach wire ropes to the crankcase, and turn it upside down.

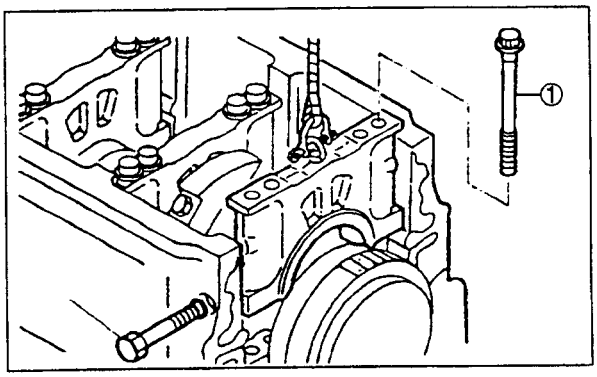
(Crankcase and crankshaft weight: 1300kg, approx.)



**(2) Removing main bearing cap**

(a) Loosen main bearing cap bolt ① and side bolt ②. Remove the main bearing cap with a cap remover or a crane (eyebolt M12 × 1.25).

(b) Remove the thrust plates carefully not to damage them from the No.7 bearing cap.

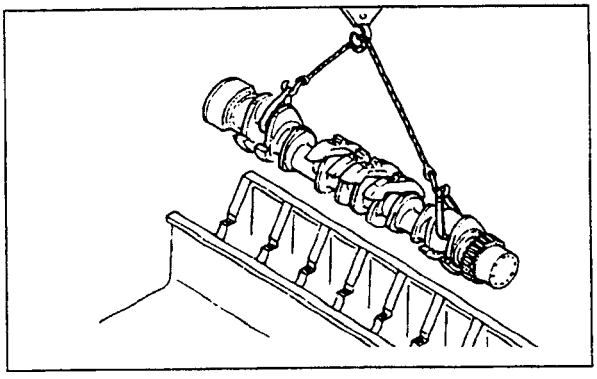



**(3) Removing crankshaft**

(a) Remove the upper halves of thrust plates while turning the crankshaft slowly.

(b) Hold the crankshaft in a horizontal position and carefully lift it off the crankcase.

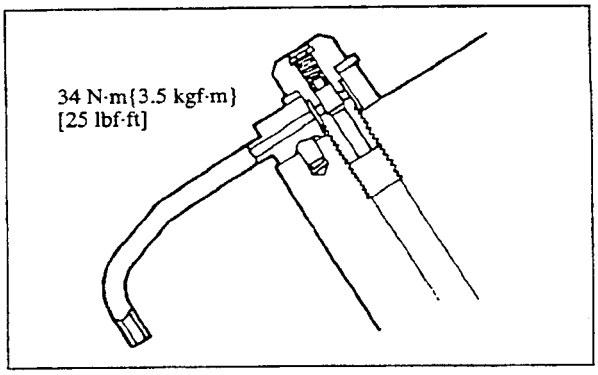
(c) Remove the rear upper halves of thrust plates from the crankcase.



**(4) Removing oil jet nozzle**

Do not remove the nozzles unless their oil holes are clogged or they are defective in spray angle.

**NOTE**: When reinstalling the nozzles which have been removed for servicing, tighten the check valve to the specified torque.



## 5.2 Inspection and repair

### Crankshaft

**(1) Measuring crankpin and journal diameter**

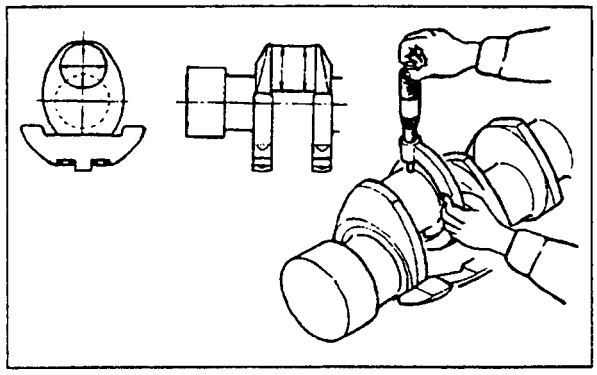
(a) Using a micrometer, measure the crankpin and journal diameters. If the diameter exceeds the repair limit, grind them to the next undersize (-0.25, -0.50, -0.75 or -1.00 [-0.010, -0.020, -0.030, -0.040 in.]).

(b) Measure the crankpins and journals to determine the amount of out-of-roundness and taper.

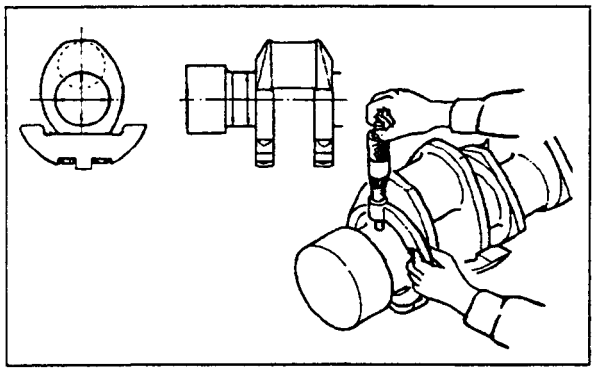
(c) If the -1.00 mm [-0.040 in.] undersize journals and crankpins exceed the repair limit, replace the crankcase.

Unit: mm [in]

| | | | Nominal value | Assembly standard | Repair limit |
|---|---|---|---|---|---|
| Crankpin diameter | | | ø104 [4.098] | -0.080 ~ -0.100 [-0.003 ~ -0.004] | -0.140 [-0.006] |
| Journal diameter | | | ø140 [5.516] | -0.050 ~ -0.070 [-0.002 ~ -0.003] | -0.130 [-0.005] |
| Crank-pin and journal | Out of roundness | | | 0.01 [0.0004] in diameter difference, max | 0.03 [0.001] |
| | Taper | | | 0.02 [0.0008] in diameter difference, max | 0.03 [0.001] |
| | Fillet radius | Crank-pin | 7 [0.28] | 7.0 [0.28] | |
| | | Journal | 7 [0.28] | 7.0 [0.28] | |
| | Hardness | | | Hv>620 | |



Measuring crankpin diameter



Measuring journal diameter

**(2) Grinding crankshaft**

If the crankshaft is refinished in compliance with any grinding dimension of the undersizes and the bearings are replaced by the undersize ones, further job of checking the bearing contact pattern may be eliminated.

When grinding the crankpins and journals, be sure to produce the same fillet radius as the original one. They should have a hardness of 620 or more in terms of Vickers Hardness Number. If necessary, reharden the crankpins and journals, and inspect them for cracks by conducting a magnalux (magnetic particle) test.

After grinding the crankpins and journals, finish them to $\overset{0.8S}{\nabla\nabla\nabla}$.

Crankshaft refinishing dimension

Unit:mm[in.]

| | Under-size | Finishing dimension | Out-of-roundness | Taper |
|---|---|---|---|---|
| Crankpin diameter | 0.25 [0.01] | 103.65 ~ 103.67 [4.083 ~ 4.084] | 0.01 [0.0004], maximum | 0.02 [0.0008], maximum |
| | 0.50 [0.02] | 103.40 ~ 103.42 [4.073 ~ 4.074] | | |
| | 0.75 [0.03] | 103.15 ~ 103.17 [4.0641 ~ 4.0648] | | |
| | 1.00 [0.04] | 102.90 ~ 102.92 [4.054 ~ 4.055] | | |
| Journal diameter | 0.25 [0.01] | 139.68 ~ 139.70 [5.503 ~ 5.504] | | |
| | 0.50 [0.02] | 139.43 ~ 139.45 [5.493 ~ 5.494] | | |
| | 0.75 [0.03] | 139.18 ~ 139.20 [5.483 ~ 5.484] | | |
| | 1.00 [0.04] | 138.93 ~ 138.95 [5.473 ~ 5.450] | | |

### (3) Measuring crankshaft end play

(a) Install the thrust plates in position, and secure the bearing cap. Under this condition, measure the end play. If the end play exceeds the Standard clearance, replace the thrust plates.

(b) If the end play still exceeds the repair limit even after new thrust plates have been installed, replace the plates with the next oversize ones. There are three oversizes for the thrust plates; namely, +0.25 mm [0.01 in.], +0.50 mm [0.02 in.] and +0.75 mm [0.03 in.]. Generally, the rear journal is likely to be worn more rapidly than the front journal. This means that replacement of the rear thrust plates will, in most cases, gains the purpose.

Unit: mm[in.]

| | Standard clearance | Service limit |
|---|---|---|
| Camshaft end play | 0.20 ~ 0.40 [0.01 ~ 0.016] | 0.50 [0.02] |

Crankshaft journal grinding dimension for oversize thrust plate

Unit: mm[in.]

| | Oversize for journal or thrust plate | Oversize for journal and thrust plate | Tolerance |
|---|---|---|---|
| +0.25 [0.01] O.S. | 58.25 [2.295] | 58.50 [2.305] | $^{+0.03}_{0}$ [0.001] |
| +0.50 [0.02] O.S. | 58.50 [2.305] | 59.00 [2.325] | |
| +0.75 [0.03] O.S. | 58.75 [2.315] | 59.50 [2.344] | |

### (4) Measuring crankshaft runout

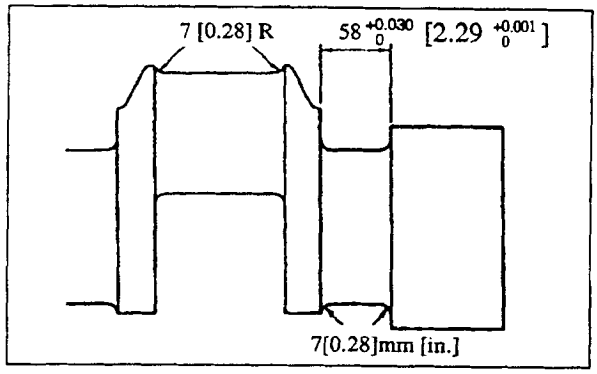
Support the crankshaft on its journals in V-blocks, and measure the runout at the center journal, using a dial gauge. Depending on the amount of runout, repair the crankshaft by grinding or straightening with a press. If the runout exceeds the repair limit, replace the crankshaft.

Unit: mm[in.]

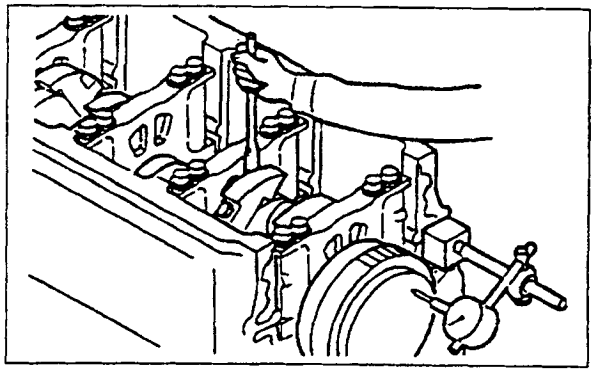
| | Standard clearance | Service limit |
|---|---|---|
| Crankshaft runout | 0.04 [0.002], maximum | 0.1 [0.004] |

### (5) Replacing oil seal slinger

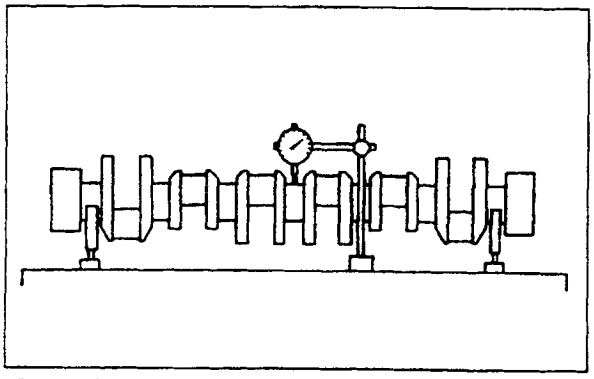
If the slingers are pitted, scratched or distorted to such an extent as to cause oil leakage, replace them with new ones as follows:



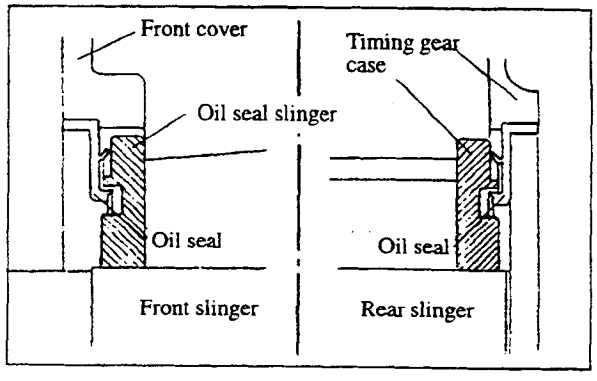

Measuring thrust bearing journal length



Measuring crankshaft end play

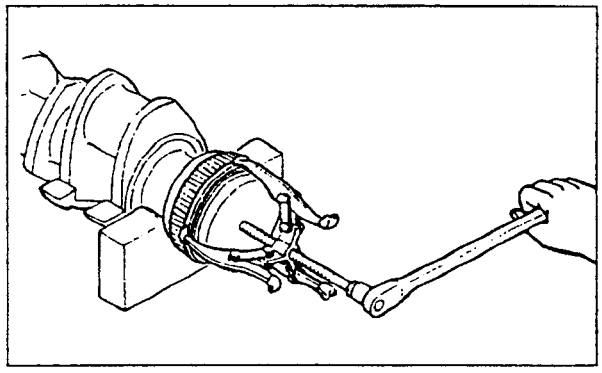


Measuring crankshaft runout



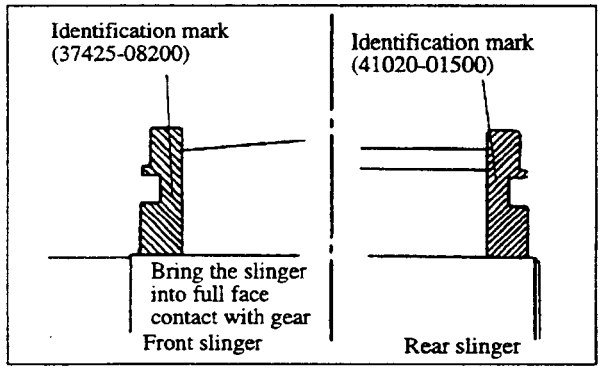
**(Removing slinger)**

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



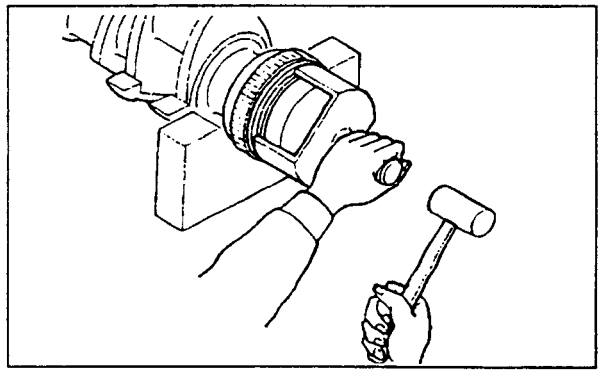
**(Installing slinger)**

(a) Discriminate the front slinger from the rear one.




(b) Using an installer, drive the slinger heated above 110°C [230°F] onto the crankshaft.

If the installer gets fast halfway, give blows of a copper hammer to the center or shoulder of the installer.

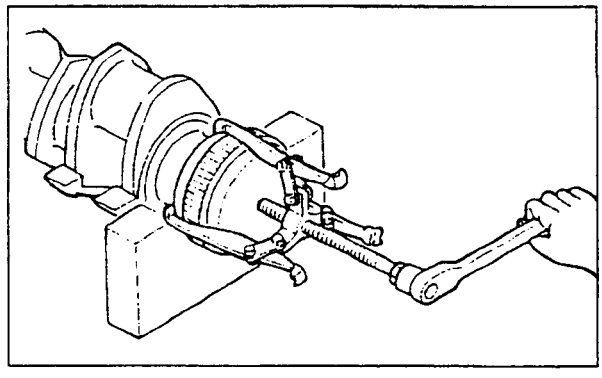


**(6) Replacing crankshaft gear**

**(Removing the gear)**

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

**NOTE**: Do not remove the gear by driving with a hammer.



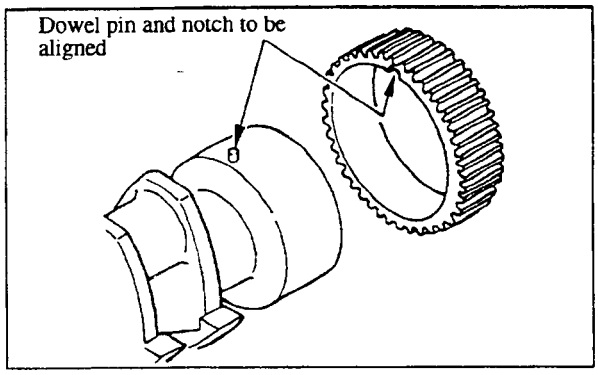
**(Installing gear)**

(a) Measure the diameter of crankshaft and the inside diameter of crankshaft gear to make sure that the fit is within the standard (front: 0.106 to 0.171 mm [0.004 to 0.007 in.], rear: 0.115 to 0.180 mm [0.005 to 0.0.007 in.]) .

(b) Heat the gear up to 180 to 200°C [356 to 392°F].

(c) Drive the gear onto the crankshaft by giving light blows of a copper hammer to the end face of the gear, making sure that the crankshaft dowel pin enters the notch in the gear.

Insert the front crankshaft gear at any position because it has no specified position for matching.

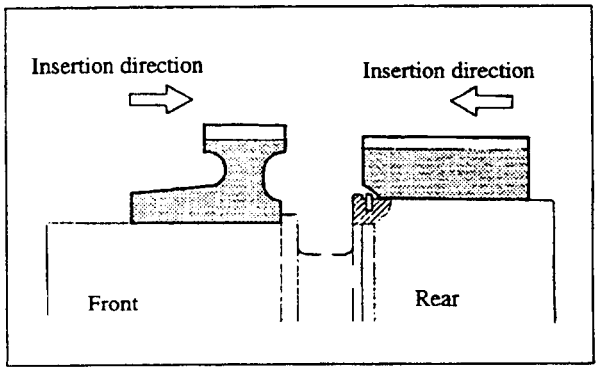



**⚠CAUTION**

**(a) Do not heat the gear above 200°C [392°F].**

**(b) Drive the gear until it touches the flange of the crankshaft.**

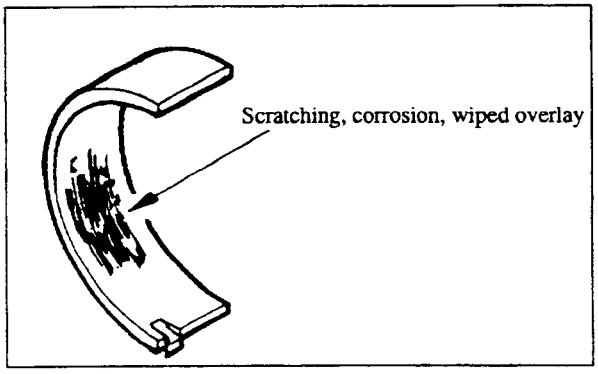
**(c) Be sure to install the gear correctly in direction.**




**Main metal**

**(1) Inspection**

Inspect each metal shell for abnormal contact, scratching, corrosion, wiped overlay and other defects. Also check for a sign of poor seating in the bore of the crankcase or the metal cap.



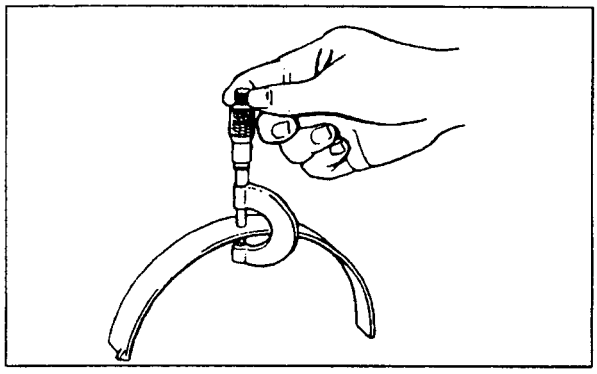
### (2) Measuring metal thickness

Using a ball-point type micrometer, measure the center of each metal shell. If the thickness exceeds the service limit on any of the upper and lower shells, replace the upper and lower shells as a set.

Unit: mm

| | | Nominal value | Assembly standard | Service limit |
|---|---|---|---|---|
| Main metal thickness (standard size) | STD | 3.500 [0.138] | 3.467 ~ 3.480 [0.1366 ~ 0.1371] | 3.425 [0.135] |
| | -0.25 [-0.01] | 3.625 [0.143] | 3.592 ~ 3.605 [0.1415 ~ 0.1420] | 3.550 [0.140] |
| | -0.50 [-0.02] | 3.750 [0.148] | 3.717 ~ 3.730 [0.146 ~ 0.147] | 3.675 [0.145] |
| | -0.75 [-0.03] | 3.875 [0.153] | 3.842 ~ 3.855 [0.151 ~ 0.152] | 3.800 [0.150] |
| | -1.00 [-0.04] | 4.000 [0.158] | 3.967 ~ 3.980 [0.156 ~ 0.157] | 3.925 [0.155] |

**NOTE**: Four undersizes are available for the main metals; namely, -0.25, -0.50, -0.75 and -1.00 [-0.01, -0.02, -0.03 and -0.04 in.].



Measuring main metal thickness

### (3) Replacing main metal

If the thickness exceeds the service limit, either replace the main metals as above, or refinish the crankshaft and use undersize metals. If the crankshaft is refinished in compliance with any of the undersizes, any further job of checking the metal contact pattern may be eliminated.

## Crankcase

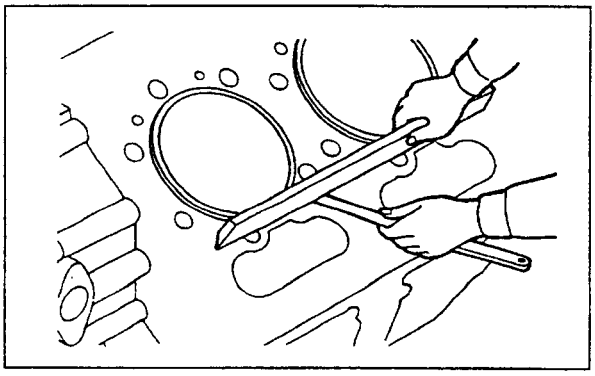
### (1) Measuring gasketed surface warpage

Measure warpage with a straightedge and a feeler gauge. If the warpage exceeds the assembly standard, reface the gasketed surfaces with a surface grinder.

Unit: mm[in.]

| | Assembly standard | Repair limit |
|---|---|---|
| Crankcase gasketed surface warpage | 0.05 [0.002], maximum | 0.20 [0.008] |

**NOTE**: Do not grind the surfaces more than are necessary for removing warpage to prevent the piston protrusion from exceeding the assembly standard.



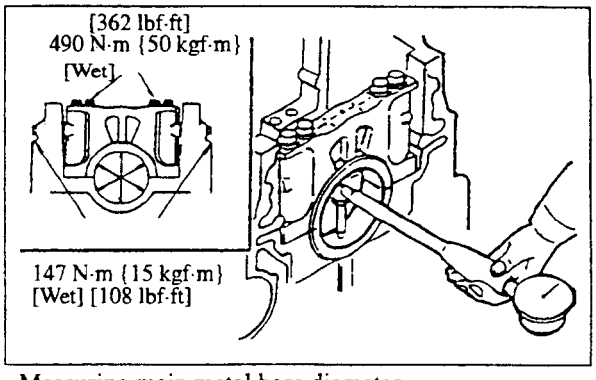
Measuring crankcase gasketed surface

### (2) Measuring main metal bore diameter

Secure each metal cap to the specified torque, and measure the bore diameter in the criss-cross directions.

Unit: mm[in.]

| | Nominal value | Assembly standard |
|---|---|---|
| Main metal bore diameter | ø147 [5.792] | 147.000 ~ 147.025 [5.792 ~ 5.793] |




Measuring main metal bore diameter

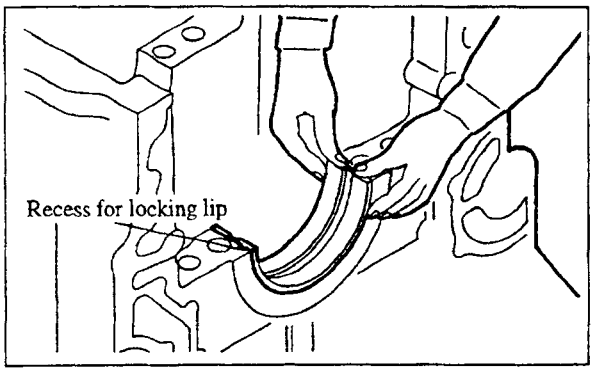
### 5.3 Reassembly

**Reassemble the parts in the reverse order of disassembly.**

**(1) Installing main metal**

(a) Install each upper shell of main metal in the crankcase by fitting its locking lip in the recess. The oil holes in the metals and crankcase will be aligned when the metals are so installed.

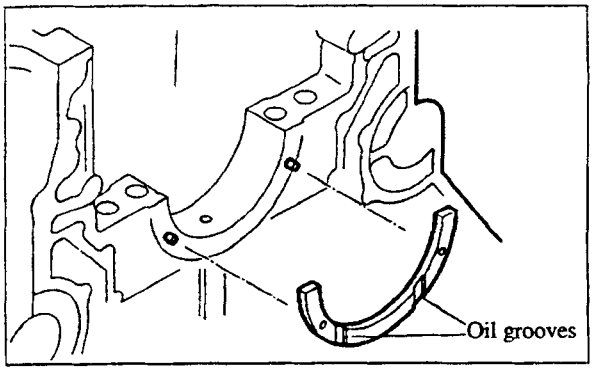
(b) Lightly coat the inside surface of the shells with engine oil.




**(2) Installing thrust plate**

(a) Install the thrust plate to No.7 metal seat outside the crankcase, with the oil groove side of the plate facing outside.

(b) Install the thrust plate to the same bearing seat inside the crankcase, with the oil groove side of the plate facing inside.



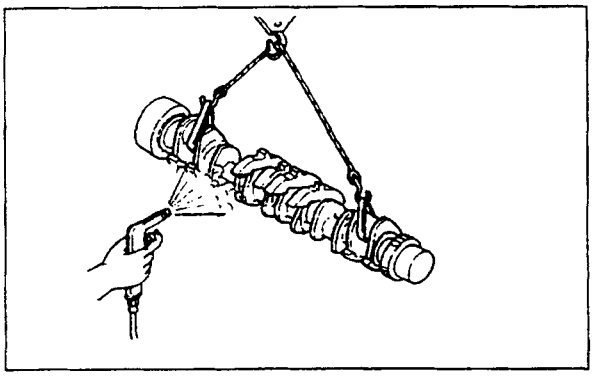

**(3) Installing crankshaft**

(a) Wash the crankshaft with cleaning solvent, and dry it by applying a blast of pressure air.

NOTE: After washing the crankshaft, make sure that the oil holes are clean and free from dirt or foreign matter.

(b) Hold the crankshaft in a horizontal position by using a hoist, and carefully put it on the crankcase.

(c) Lightly coat the journals with engine oil.



**(4) Installing main metal cap**

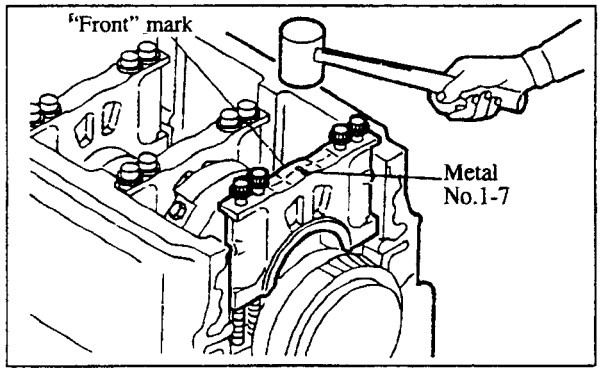
(a) Fit the lower shell of the metal to each metal cap.

(b) Install the thrust plates to No.7 metal cap with the oil groove side of the plates facing outside.

(c) Metal numbers "1" thru "7" (from the front side of crankcase) are stamped on the caps. Install the caps with these numbers and "FRONT" mark on the front side of the crankcase.

(d) Coat the threads of metal cap bolts with engine oil, and temporarily install the bolts.

(e) Using a soft hammer, drive in the metal cap evenly.



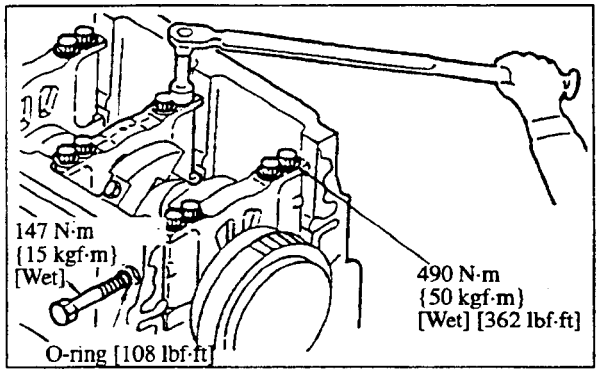

**(5) Installing metal cap bolt**

(a) Temporarily tighten metal cap coated with engine oil. Tighten four bolts alternately to the specified torque.

(b) Tighten the side bolts on the right side of engine.

(c) Tighten the side bolts on the left side of engine.

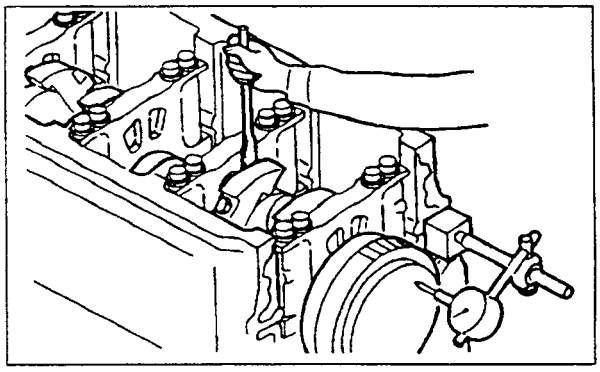
(d) Make sure that the crankshaft rotates smoothly.




**(6) Measuring crankshaft end play**

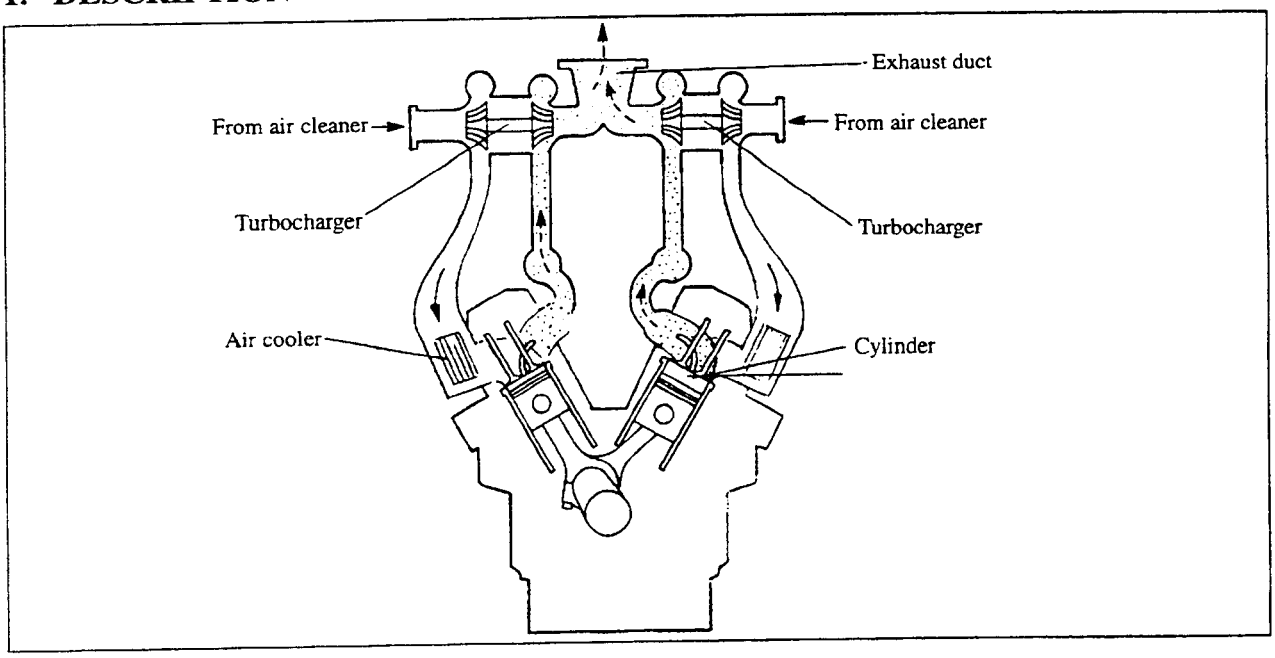
(a) Tighten No.1 thru No.6 metal cap bolts to the specified torque, with No.7 cap bolts being temporarily tightened, and measure the end play.

(b) After tightening the No.7 cap bolts, make sure that the end play is correct. Again make sure that all cap bolts are tightened to the specified torque.



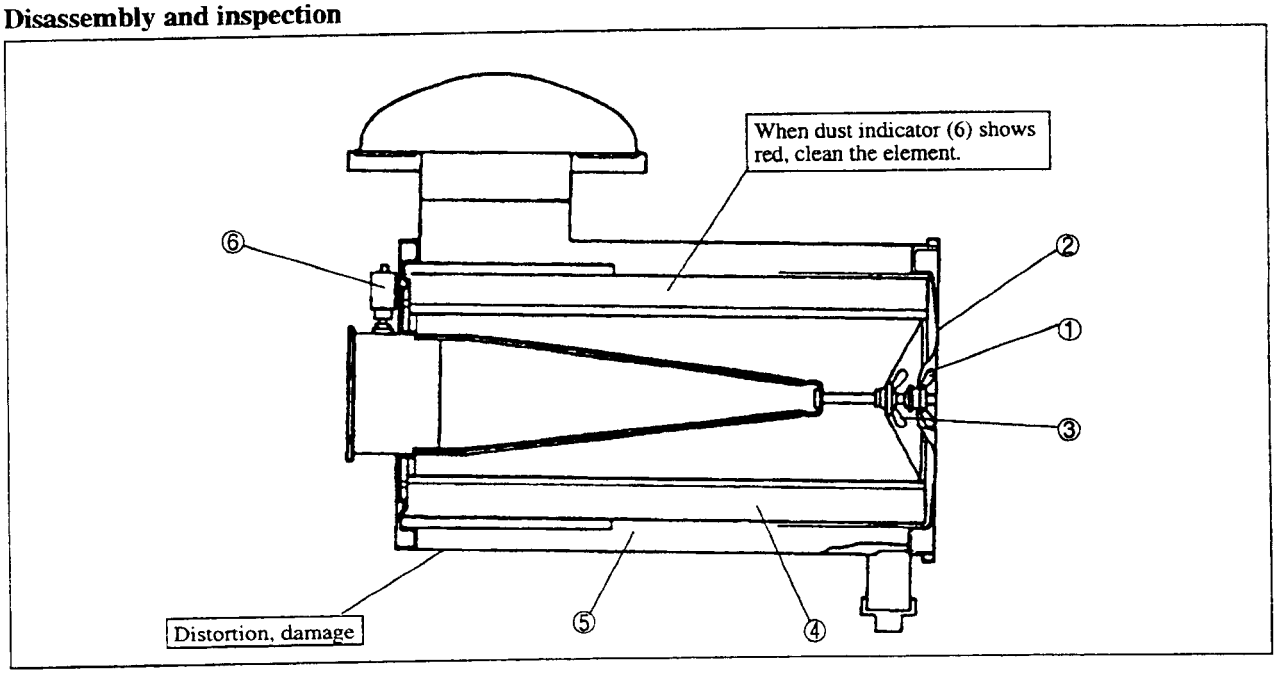
# INLET AND EXHAUST SYSTEM

# 1. DESCRIPTION




# 2. PAPER-ELEMENT TYPE AIR CLEANER

**Disassembly and inspection**



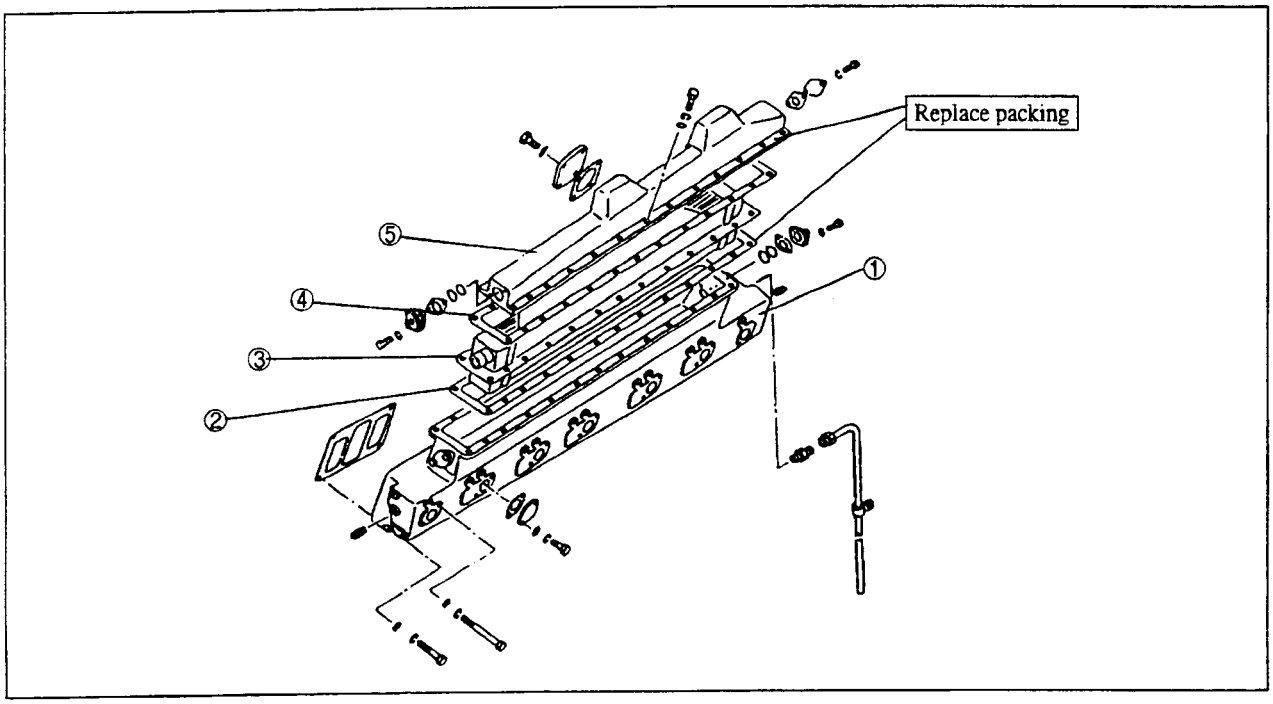

① Wing nut
② Cover
③ Wing nut
④ Element
⑤ Air cleaner body
⑥ Dust indicator

**⚠CAUTION**

**When removing the air cleaner for servicing, be sure to stop the engine and cover the air inlet port to prevent dirt from entering the engine.**

# 3. AIR COOLER

## 3.1 Disassembly



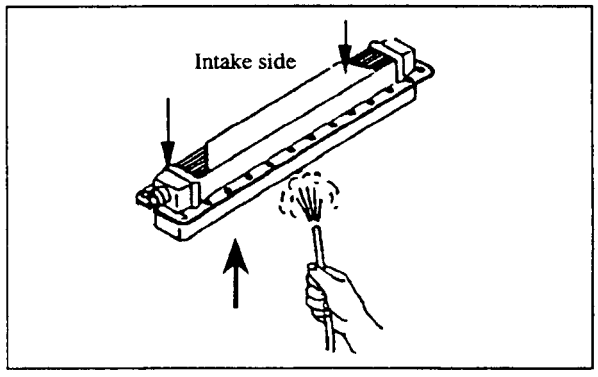

① Inlet manifold
② Packing
③ Element
④ Packing
⑤ Air cooler cover

## 3.2 Inspection

### (1) Cleaning air cooler

(a) Remove dirt buildup from the air cooler by directing pressure air of (0.29 ~ 0.49 MPa (3 - 5 kgf/cm²) [42.68 ~ 71.13 psi]) maximum in the direction opposite to the air flow. Then, inspect the cooler for corrosion and crack.

(b) Wash the fresh-water or the sea-water passages in water and caustic soda or soda lime, and remove scale deposits.

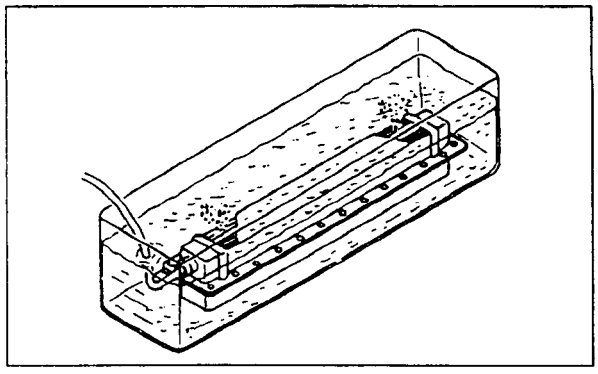



### (2) Inspecting air cooler for air tightness

Immerse the air cooler in water, and apply pressure air of (0.39 MPa (4 kgf/cm²) [ 56.9 psi]) to the coolant side to inspect for air leakage.

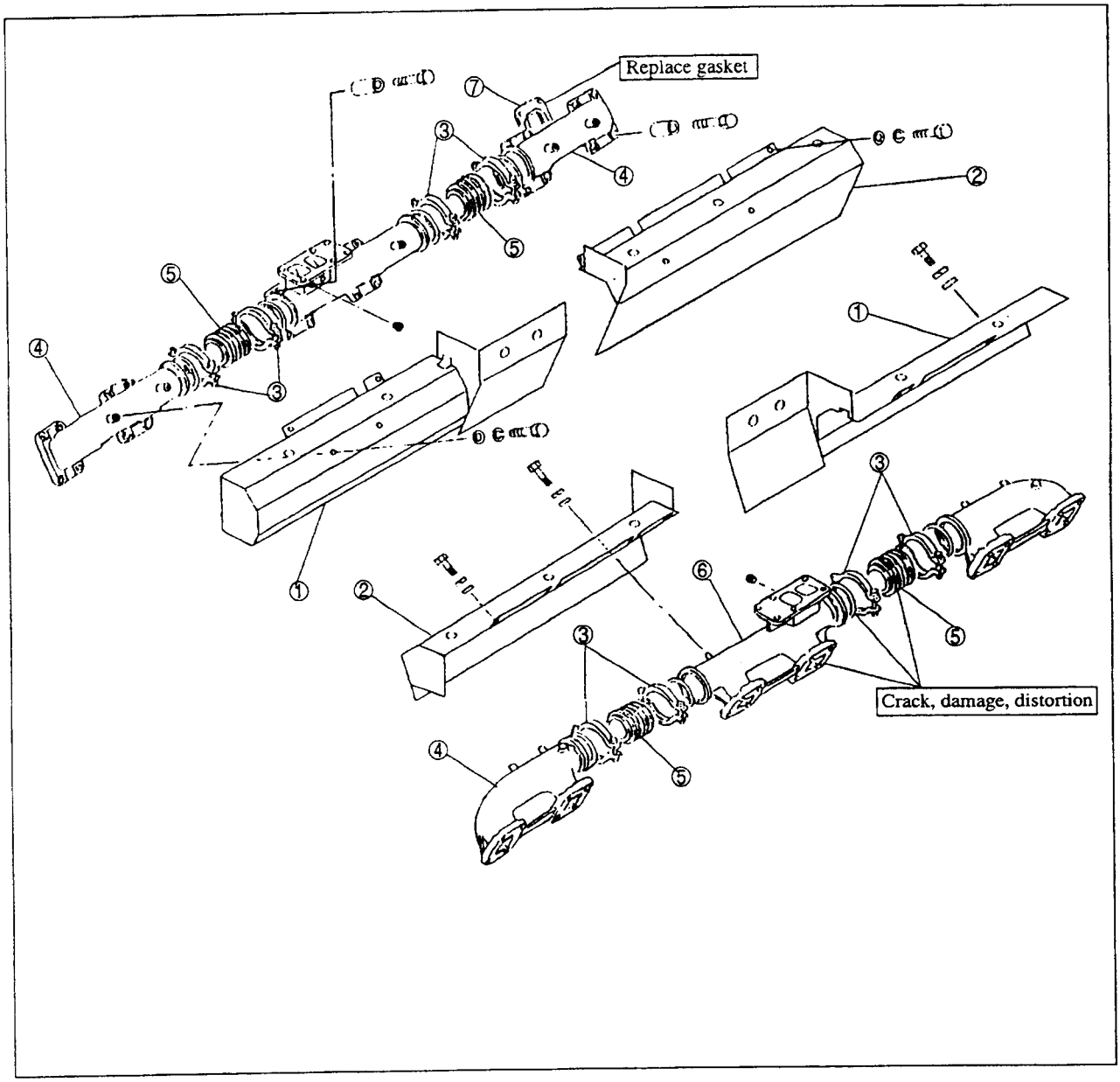
**⚠ CAUTION**

**Fresh-water type air cooler differs from sea-water type air cooler in construction and material. With this kept in mind, carefully handle the air cooler.**



## 4. EXHAUST MANIFOLD

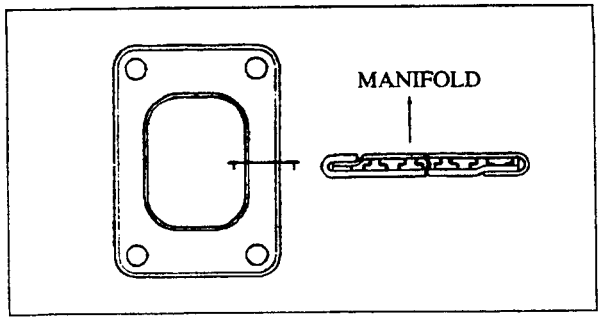
**Disassembly and inspection**




① Insulator
② Insulator
③ Coupling
④ Exhaust manifold
⑤ Joint
⑥ Exhaust manifold
⑦ Gasket

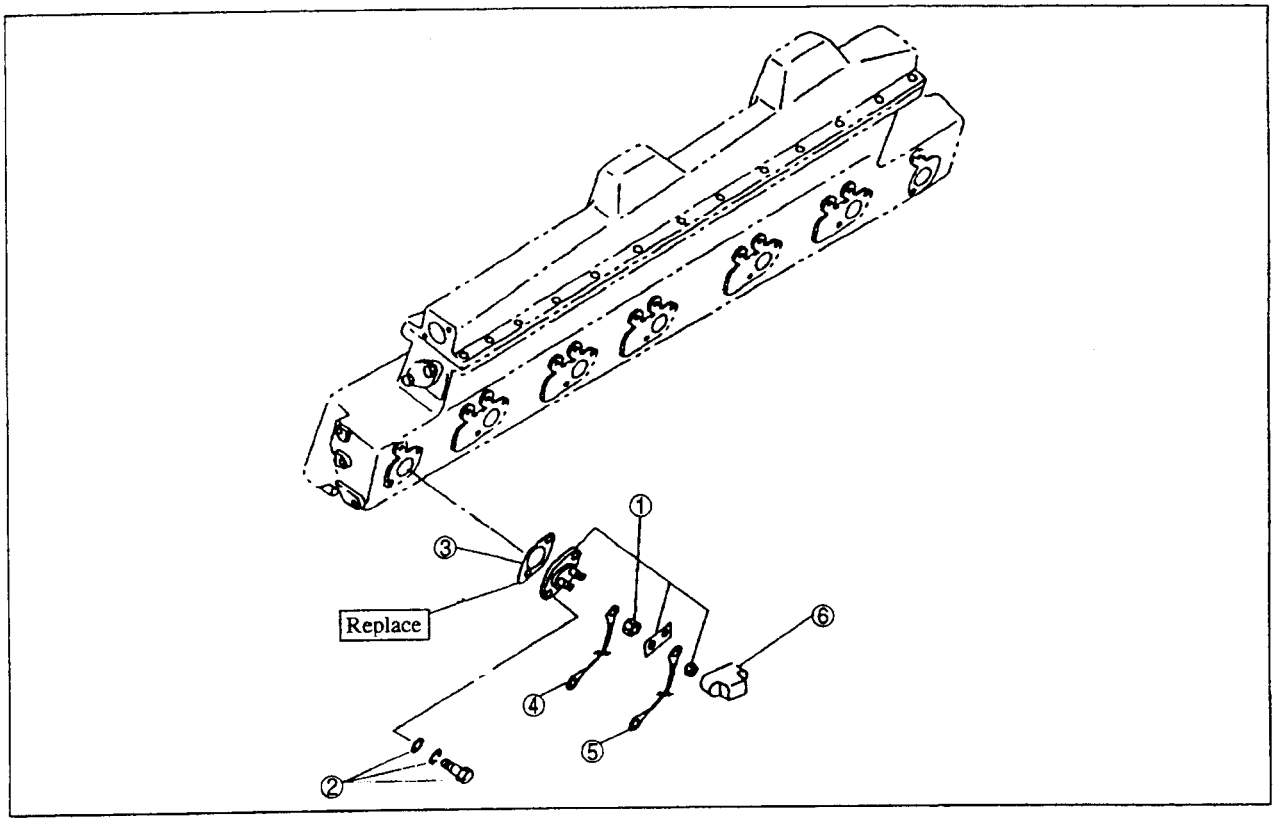
NOTE: (a) Place each gasket with "MANIFOLD" mark on the exhaust manifold side.

(b) If any of the gaskets has to be replaced, replace all gaskets.



# 5. AIR HEATER

## 5.1 Disassembly




① Air heater assembly
② Bolt and washers
③ Gasket
④ Short wire
⑤ Short wire
⑥ Terminal cap

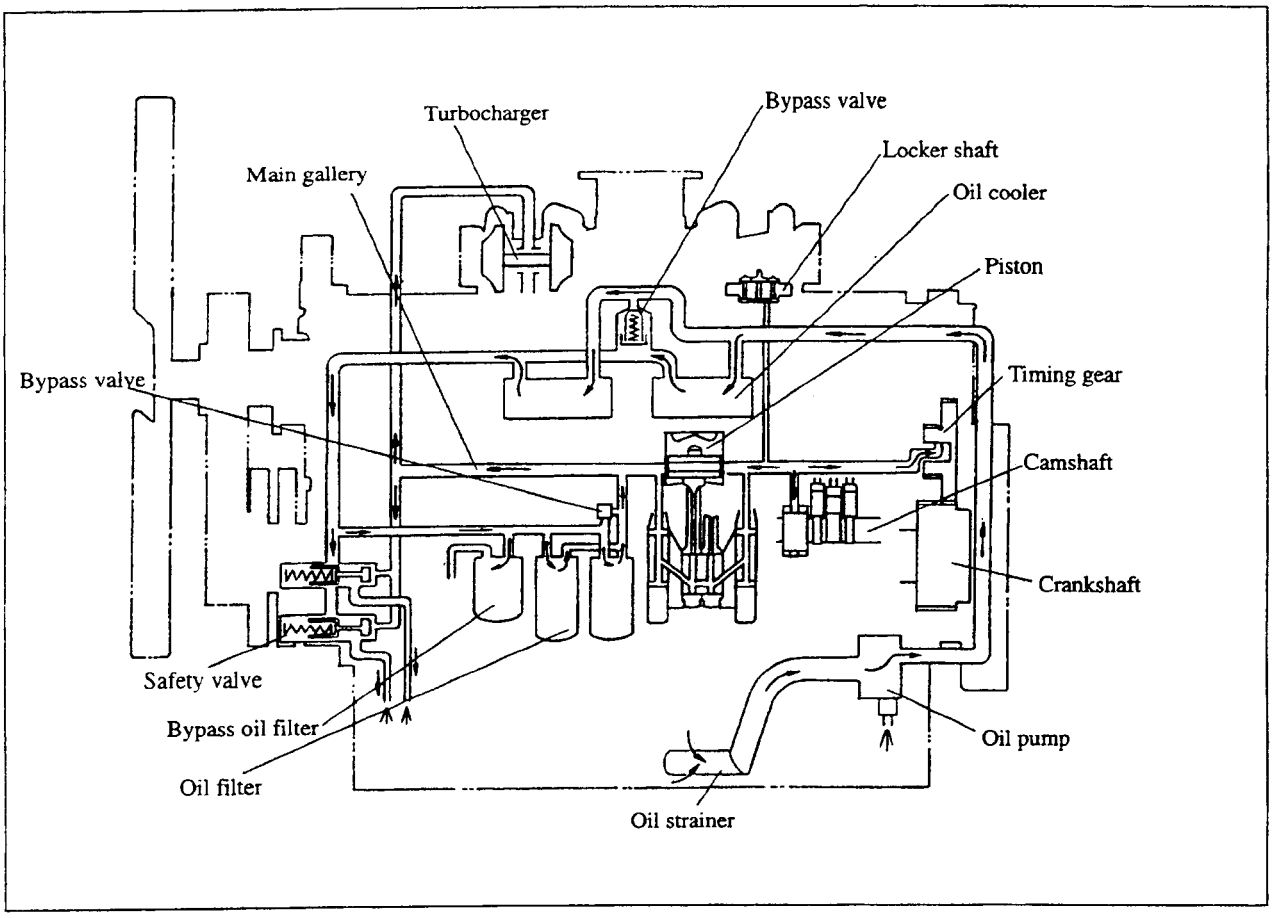
## 5.2 Inspection

(a) Using an ammeter or a test lamp, check to make sure that the current flows to the indicator, the heater relay and the air heater when the starter switch is turned to HEAT position, and that the current is cut off when the switch is turned to ON or OFF position.

(b) Check to make sure that the indicator takes 50 to 60 seconds to glow red after the starter switch is turned to HEAT position. If the indicator glows red too early or it fails to glow red, check the indicator and the air heater for short or open circuit with a tester.

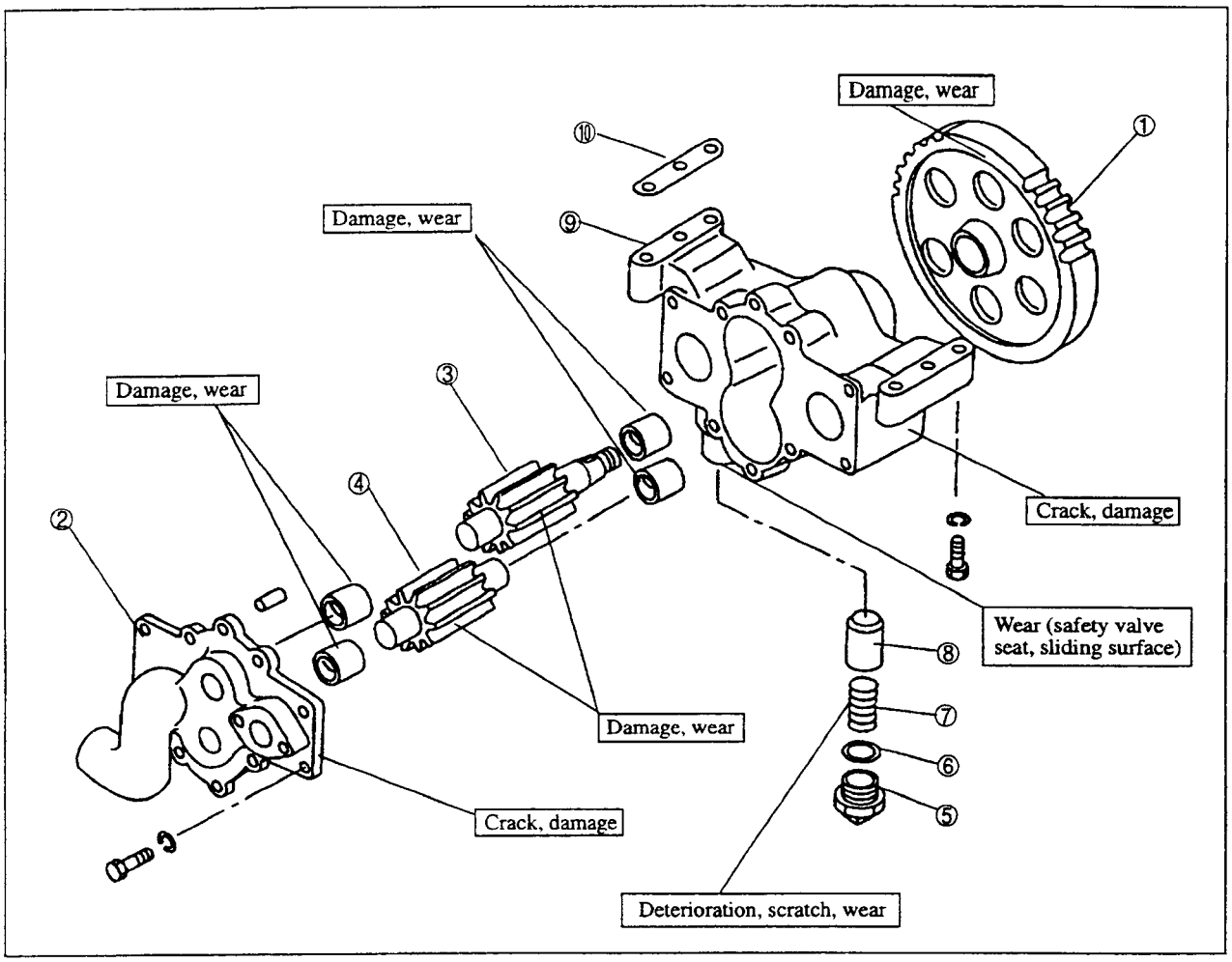
# LUBRICATION SYSTEM

# 1. OUTLINE OF LUBRICATING SYSTEM



## 2. OIL PUMP AND SAFETY VALVE

### 2.1 Disassembly




① Driving gear
② Pump cover
③ Drive gear
④ Driven gear
⑤ Plug
⑥ Shim
⑦ Spring
⑧ Safety valve
⑨ Oil pump case
⑩ Shim

## 2.2 Inspection

### (1) Measuring backlash between drive gear and driven gear

Check the base tangent length of drive gear and driven gear. If the measured value exceeds the service limit, replace the gears.

Unit: mm[in.]

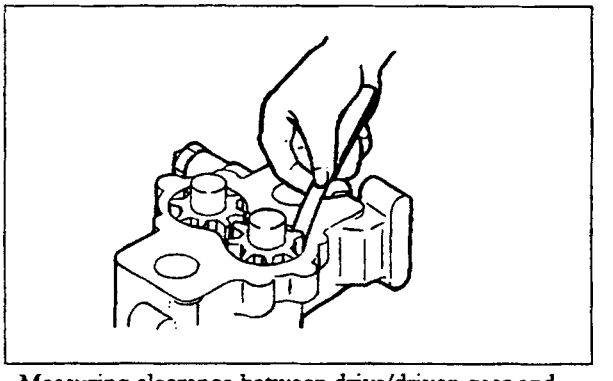
| | Standard clearance | Service limit |
|---|---|---|
| Base tangent length of drive gear and driven gear | 27.983 ~ 28.055 [1.1025 ~ 1.1054] | 27.93 [1.1004] |

### (2) Measuring clearance between drive gear/ driven gear and case

Using a feeler gauge, measure the clearance. If the clearance exceeds the service limit, replace the gears or bodies whichever is badly worn.

Unit: mm [in.]

| | Standard clearance | Service limit |
|---|---|---|
| Clearance between drive gear/driven gear and case | 0.095 ~ 0.140 [0.004~0.006] | 0.190 [0.007] |



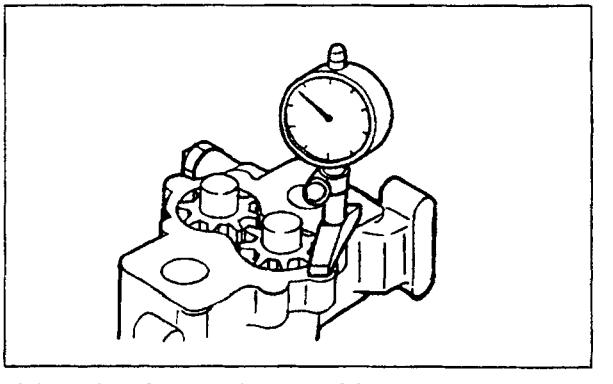
Measuring clearance between drive/driven gear and case

### (3) Measuring clearance between drive/driven gear widths and case

Using a dial gauge, measure the end clearance. If the clearance exceeds the service limit, replace the gears or case whichever is badly worn.

Unit: mm [in.]

| | Nominal value | Standard clearance | Service limit |
|---|---|---|---|
| Clearance between gear width and case | 97 [3.82] | 0.095 ~ 0.140 [0.005~0.006] | 0.29 [0.0114] |



Measuring clearance between drive/driven gear width and case

### (4) Measuring drive and driven gear shaft diameters and bushing inside diameter

(a) Check gear teeth, and replace gears if defective.

(b) If the diameter exceeds the service limit, replace the gears.

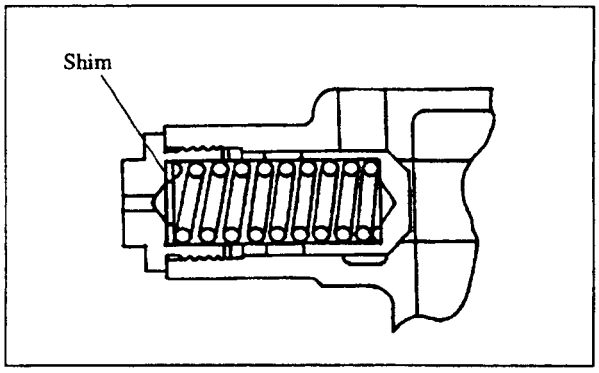
Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Shaft diameter | ø40 [1.576] | 39.984 ~ 40.000 [1.575~1.576] | 39.930 [1.573] |
| Bushing inside diameter | | 40.040 ~ 40.059 [1.577~1.578] | 40.140 [1.582] |

**(5) Inspecting safety valve**

(a) Check for deterioration of the valve spring on the oil pump safety valve. If it is excessively deteriorated, worn or scratched, replace it.

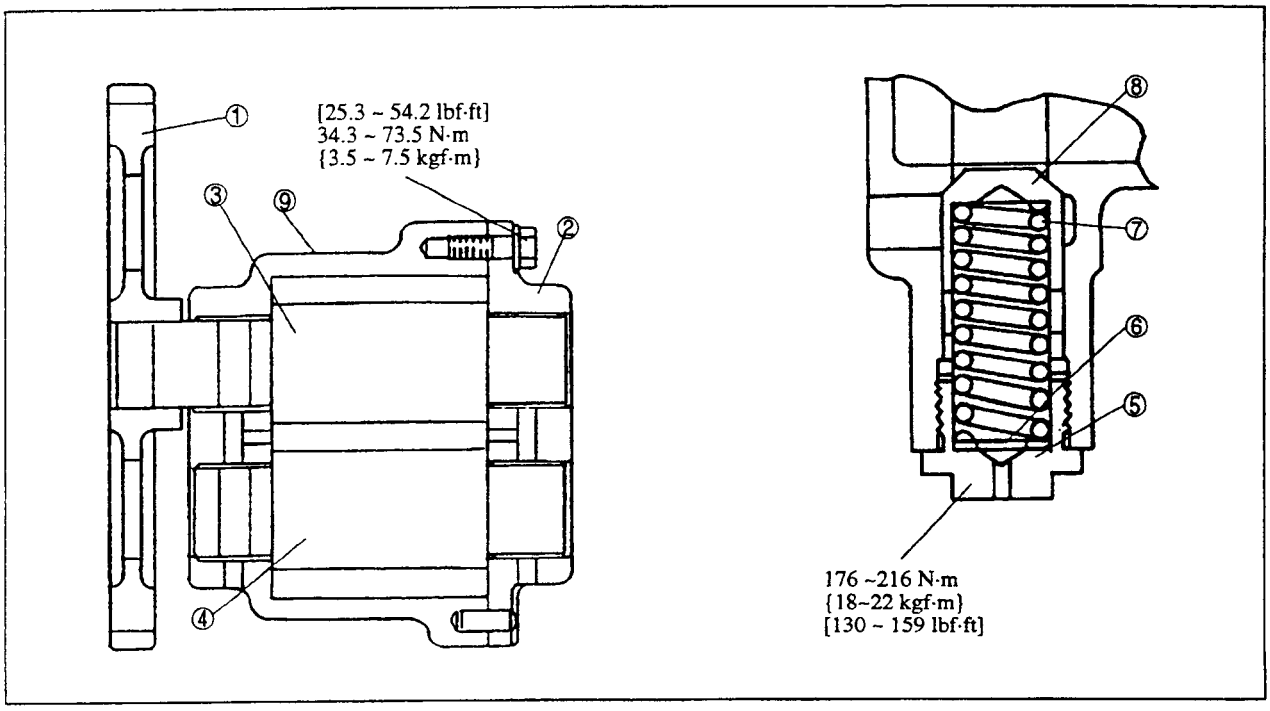
(b) Measure the valve opening pressure of the safety valve. If the pressure is not within the assembly standard, insert shim between the spring and the plug for adjustment.




Unit: mm²

| | | Assembly standard | Service limit |
|---|---|---|---|
| Safety valve opening pressure | | 1.4 ± 0.1 MPa {14±1kgf/cm²} [199.15±14.23 psi] | |
| Safety valve spring | Installation length | 73.4 [1.710] | 73.4 [1.710] |
| | Load | 970N {99.0kgf} [218 lbf] | 833N {85.0kgf} [187 lbf] |

## 2.3 Reassembly



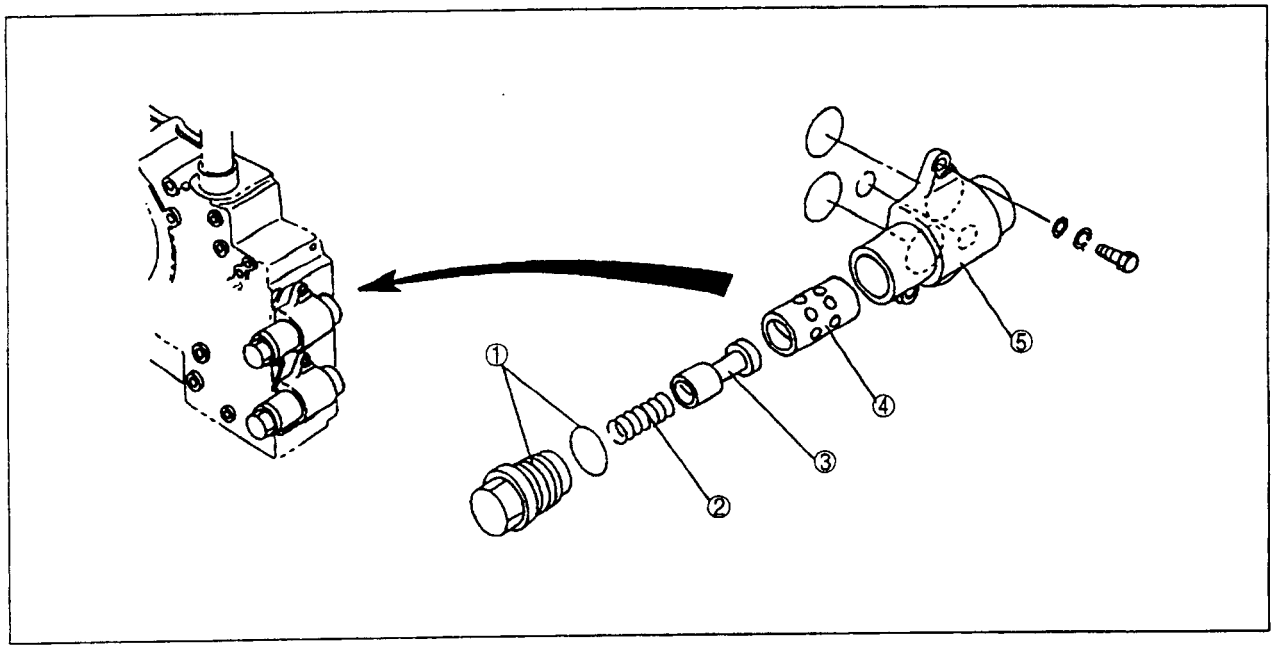

**NOTE:** Coat each part of components with engine oil in reassembly.

Reassembling sequence

⑨→③→④→②→⑧→⑦→⑥→⑤→①

# 3. RELIEF VALVE

## 3.1 Disassembly




① Plug, O-ring
② Spring
③ Relief valve
④ Sleeve
⑤ Case

## 3.2 Inspection

**Testing relief valve setting**

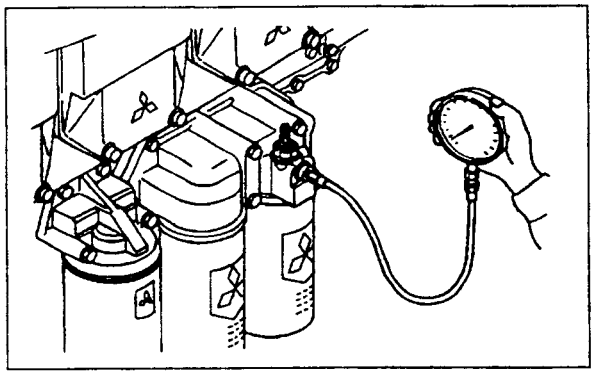
(a) Remove the taper plug at the top of oil filter bracket, and attach a pressure gauge.

(b) Warm up the engine until the oil temperature rises to 70 to 90°C [158~194F°].

(c) Measure the oil pressure at idling speed and at maximum speed.

(d) If the relief valve setting is not within the assembly standard, remove the oil pipe, and adjust the setting by inserting shims into between the oil pipe and spring.

One piece of 2 mm[0.08 in.] shim provides pressure difference of approx. 0.04 MPa {0.4 kgf/cm²} [5.69 psi].



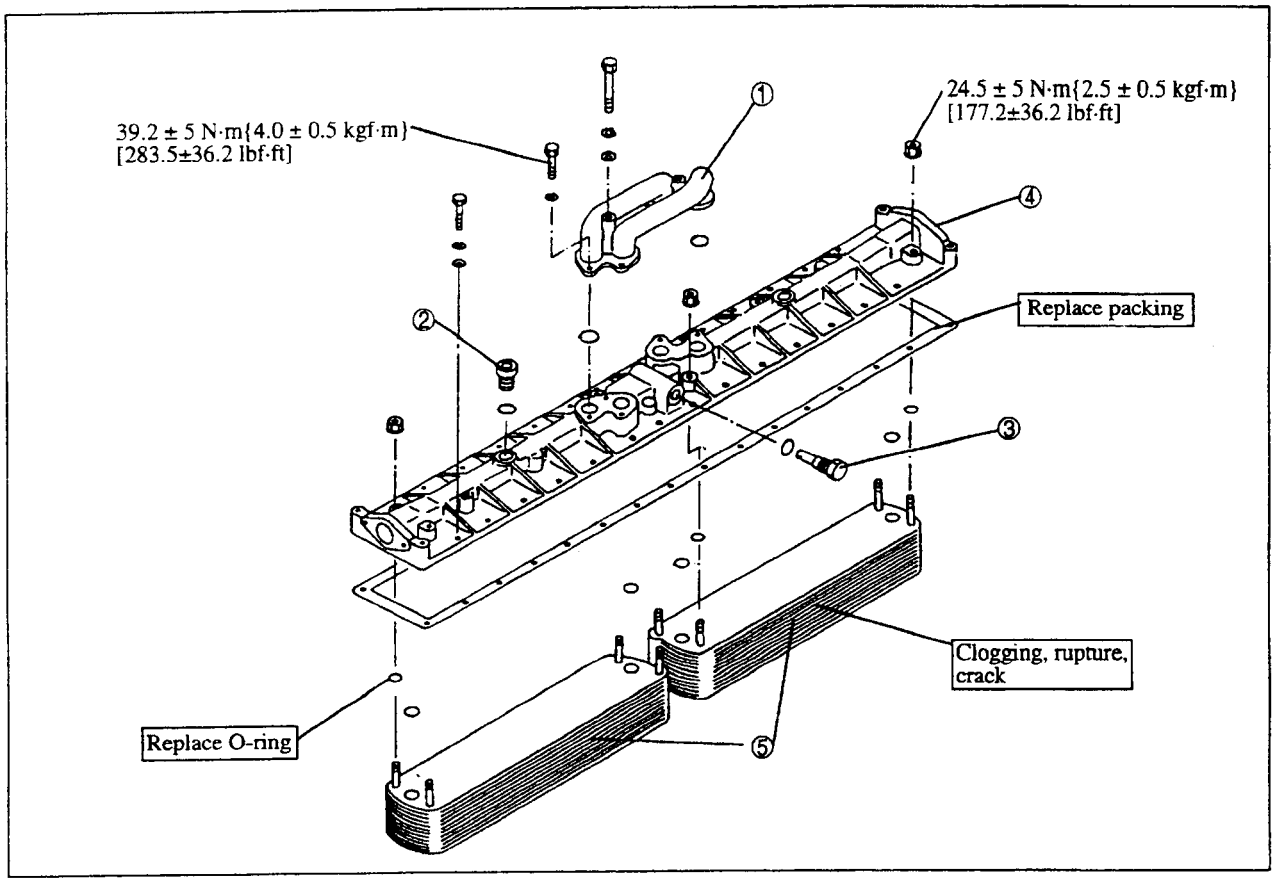
Testing relief valve setting

Unit: MPa {kg/cm²} [psi]

| | Assembly standard |
|---|---|
| Relief valve opening pressure | 0.58 ± 0.05 MPa {5.9±0.5kg/cm²} [83.93±7.12 psi] |

# 4. OIL COOLER

## 4.1 Disassembly




① Pipe
② Plug
③ Bypass valve
④ Cover
⑤ Element

## 4.2 Inspection

(1) Test the element for tears or other defects by applying air pressure of 1.47 MPa {15kgf/cm²} [213.38 psi] and replace it if leakage occurs.

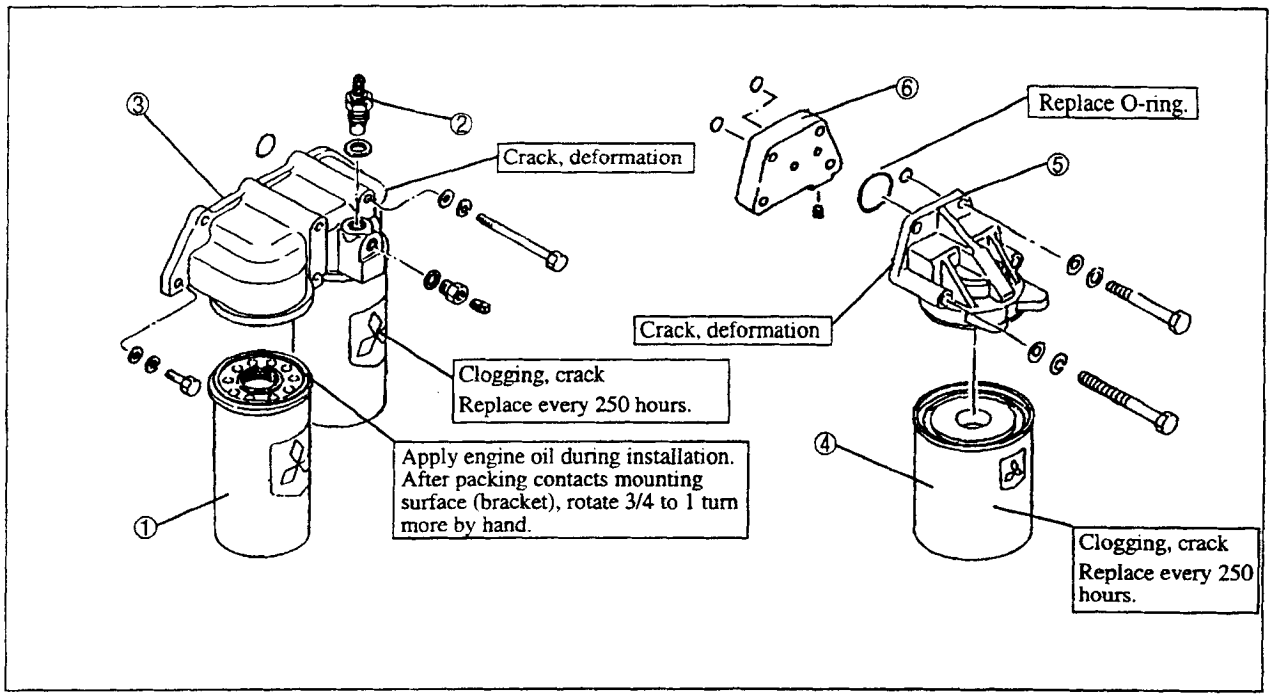
(2) Check the bypass valve opening pressure. If it exceeds the assembly standard, replace it.

Unit: MPa {kgf/cm²} [psi]

| | Assembly standard |
|---|---|
| Bypass valve opening pressure | 0.44 MPa {4.5kgf/cm²} [64.01] |

# 5. OIL FILTER, BYPASS FILTER AND OIL FILTER ALRAM

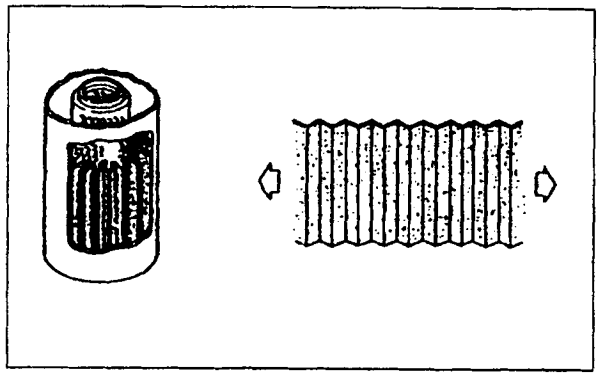
## 5.1 Disassembly




① Oil filter element
② Oil filter alarm
③ Oil filter bracket
④ Bypass filter element
⑤ Bypass filter bracket
⑥ Spacer

## 5.2 Inspection

(1) When replacing the paper element, investigate by sampling about 500 cc [0.13 U.S. gal] of the oil. If any metallic particles or other foreign matter is found, unfold the pleats of the removed element and inspect the element for quantity and material of metallic particles trapped in the pleats to locate the cause.



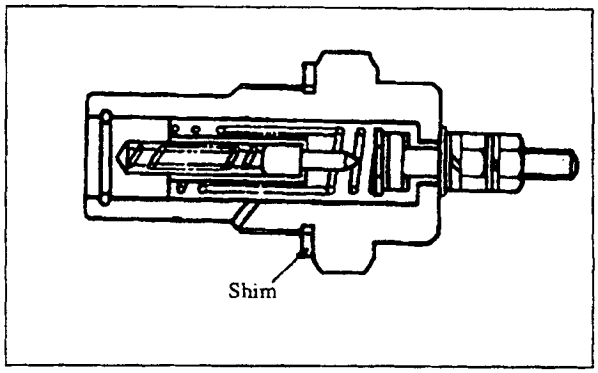
**(2) Inspecting oil filter alarm**

(a) Using a tester, test the alarm for insulation and continuity. Disassemble and repair the alarm if defective with respect to insulation or continuity. Replace the alarm if the bakelite and the rubber insulators are deteriorated or damaged.

(b) If the valve opening pressure is out of the assembly standard, adjust it by inserting shims. 1 mm thickness of shim corresponds to a change in pressure of 0.007 MPa (0.07 kgf/cm²) [1.00 psi].

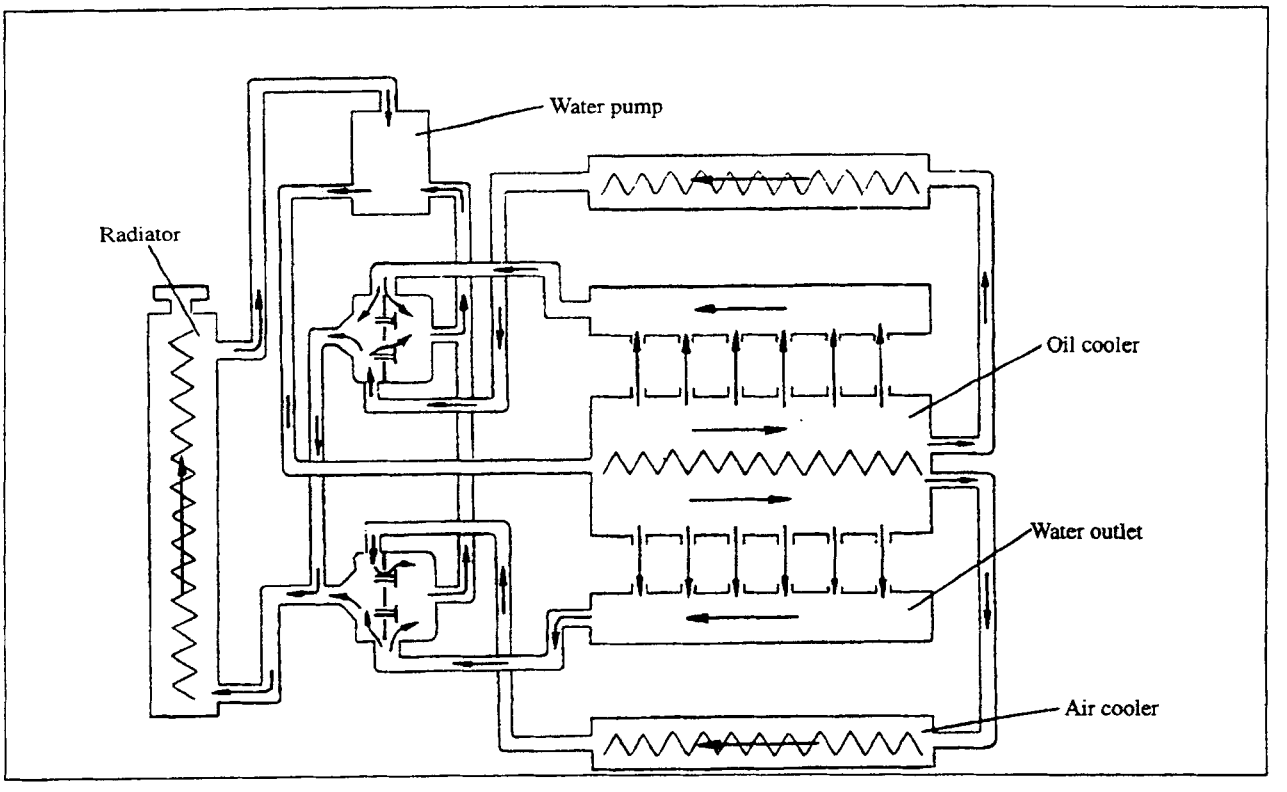
Unit: MPa {kgf/cm²}[psi]

| | Assembly standard |
|---|---|
| Pressure difference across oil filter alarm that makes its valve open | 0.25 ± 0.02<br>{2.5±0.2}<br>[35.56±2.85] |
| Pressure difference across oil filter alarm when its contact is closed | 0.15<br>{15}<br>[21.34] |



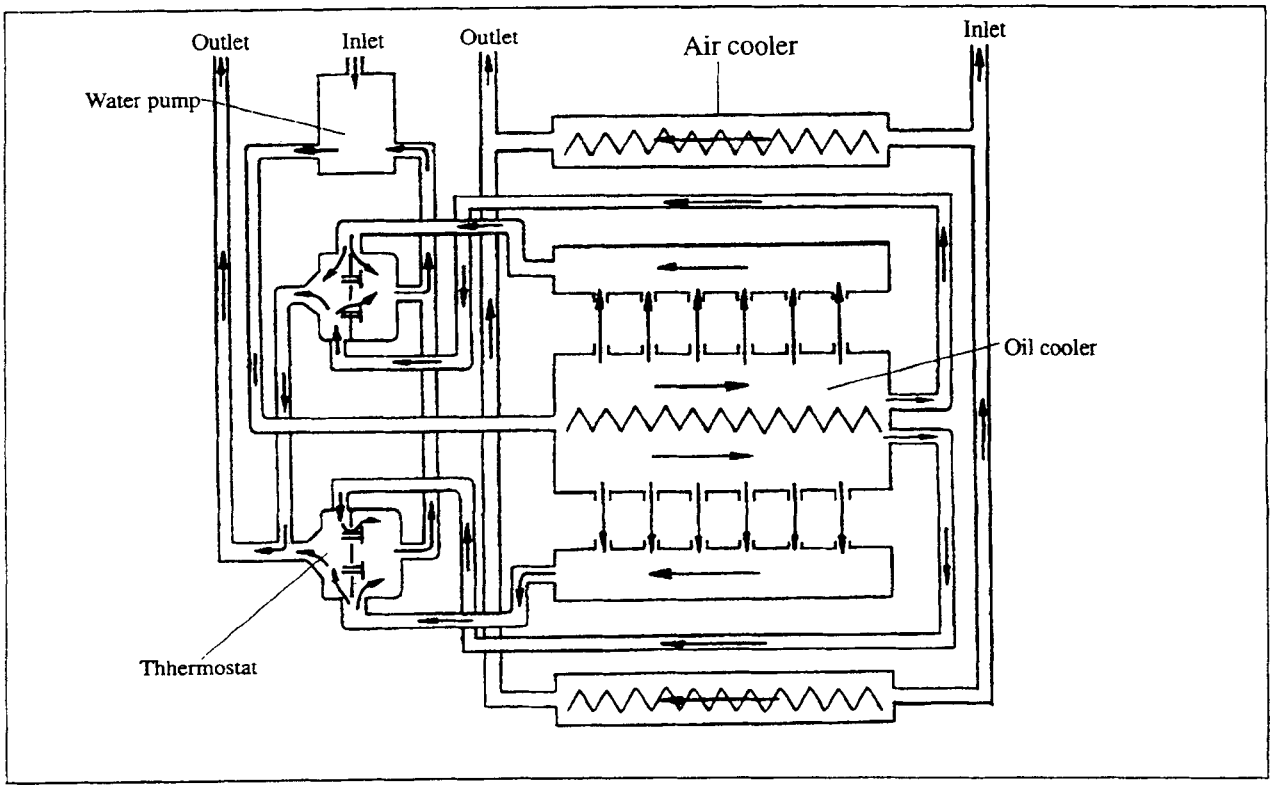
# COOLING SYSTEM

## 1. COOLING SYSTEM WITH RADIATOR



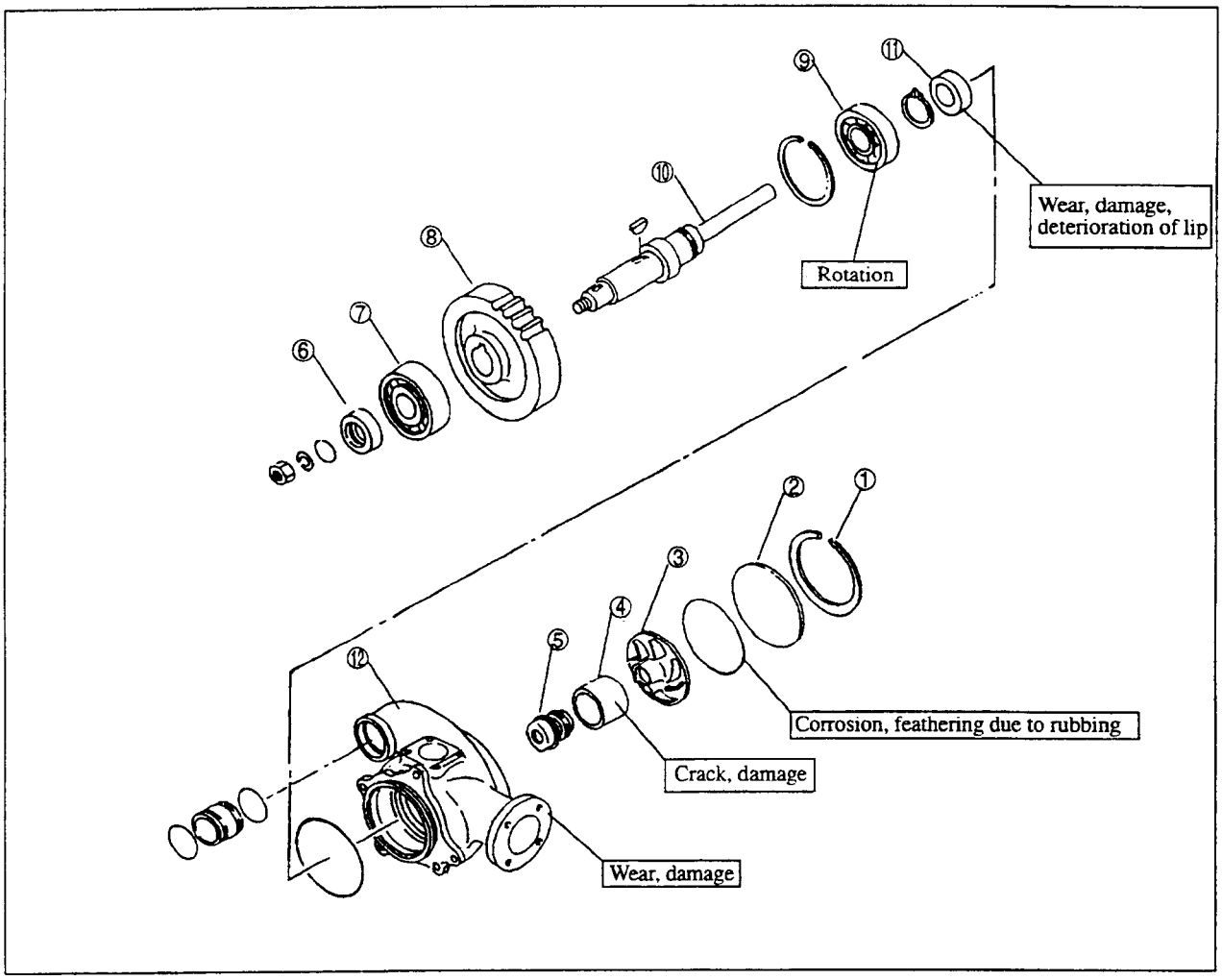

## 2. COOLING SYSTEM WITH A REMOTE WATER SUPPLY

2. Parallel type using raw water and fresh water (PTK)



# 3. WATER PUMP

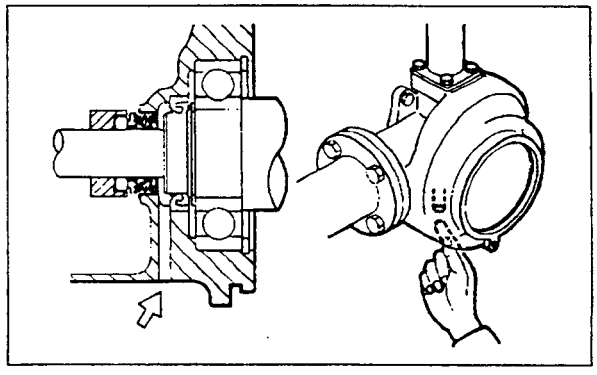
## 3.1 Disassembly




① Snap ring
② Cover
③ Water pump impeller
④ Ring
⑤ Unit seal
⑥ Oil seal sleeve
⑦ Bearing
⑧ Water pump gear
⑨ Bearing
⑩ Water pump shaft
⑪ Oil seal
⑫ Pump case

### (1) Inspecting water pump on engine

Touch the drain port located at the bottom of the center of pump case with a finger. If the port is oozing water, inspect the unit seal for condition. If it is oozing oil, the oil seal would be defective.



### (2) Removing water pump shaft

**⚠CAUTION**

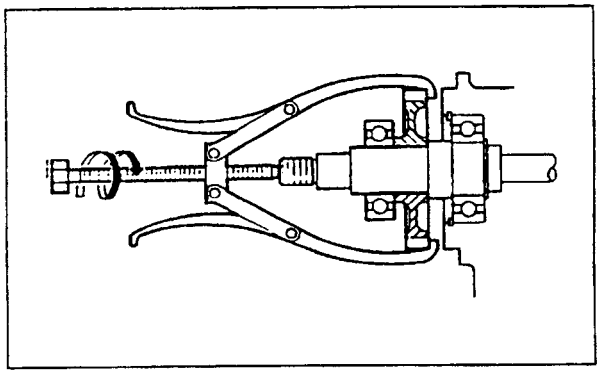
**Be careful not to damage the water pump shaft and impeller during removal of the impeller from the shaft.**

### (3) Removing water pump gear

(a) Remove the oil seal sleeve.

(b) Using a gear puller, pull out the gear and the ball bearing at the same time.

(c) Remove the snap ring from the ball bearing at the impeller side.



Removing water pump gear

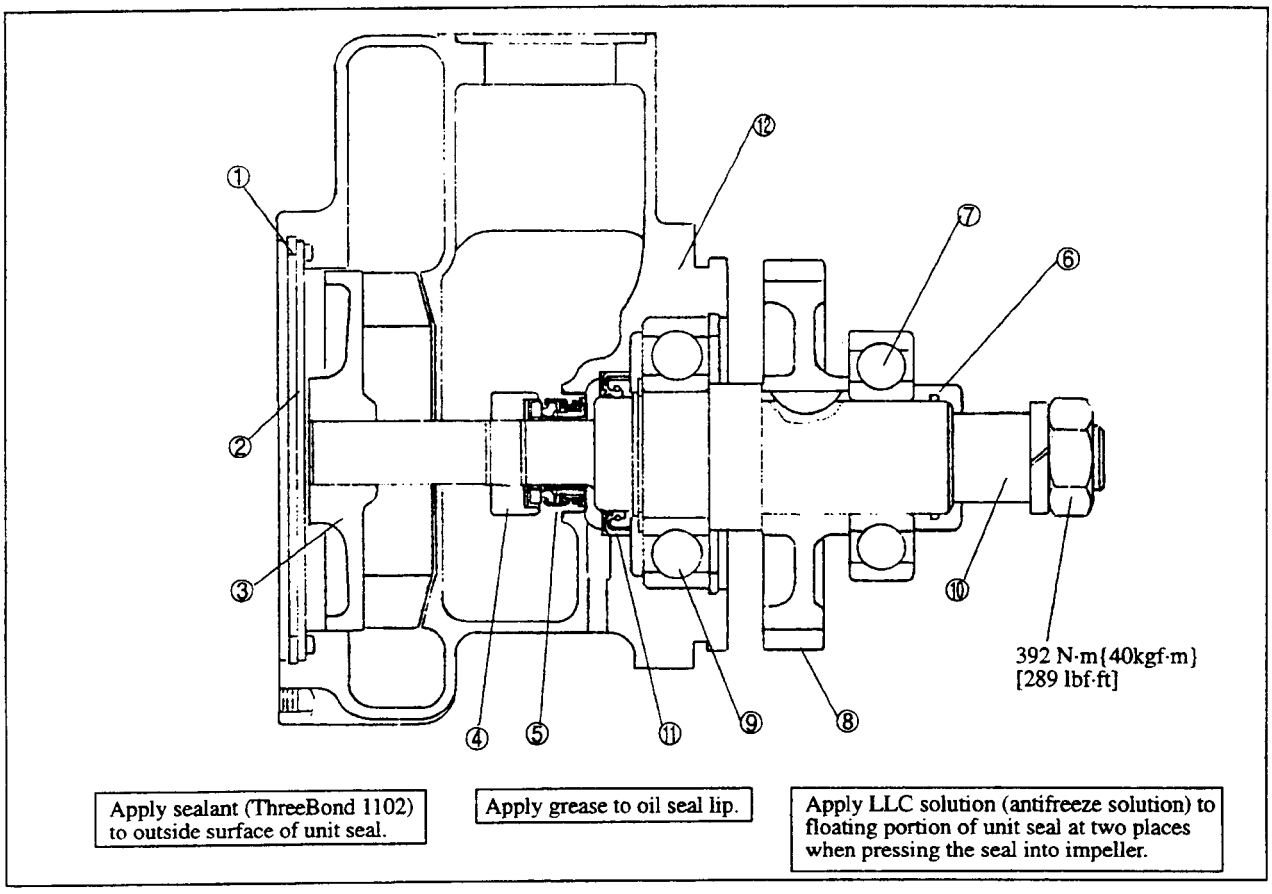
## 3.2 Inspection

Measure the inside diameter of the water pump case, the bearing cover and the shaft to which the bearing is fitted. If the case is excessively worn or damaged, replace the bearing, the case or the shaft.

Unit: mm[in.]

| | | Nominal value | Assembly standard |
|---|---|---|---|
| Inside diameter of pump case bore to which bearing outer race is fitted | | ø120 [4.728] | 119.987 ~ 120.022 [4.7274 ~4.7289] |
| Inside diameter of cover to which bearing is fitted | | ø110 [4.334] | 110.005 ~ 110.040 [4.3342~4.3356] |
| Bearing | Diameter | ø120 [4.728] | 119.982 ~ 120.000 [4.7273~4.7280] |
| | | ø110 [4.334] | 109.982 ~ 110.000 [4.3333~4.3340] |
| | Inside diameter | ø55 [2.167] | 54.985 ~ 55.000 [2.1664~2.1670] |
| Diameter of pump shaft on which bearing inner race is fitted | | ø55 [2.167] | 55.002 ~ 55.015 [2.1670~2.1676] |

### 3.3 Reassembly




Reassembling sequence

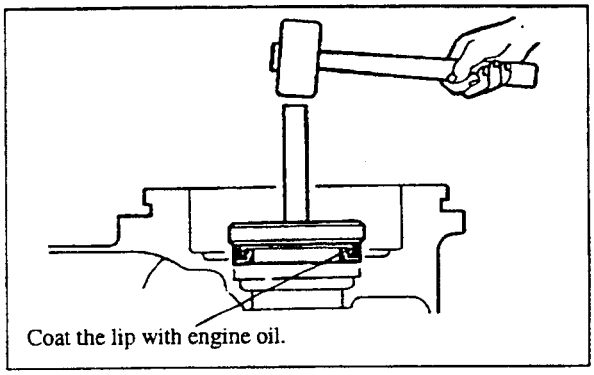
⑫→⑪→⑤→⑧→⑦→⑥→④→③→②→①
⑩→⑨

**⚠CAUTION**

**Replace O-rings, oil seals and unit seal during reassembly.**

(1) Install the oil seal with the installer.

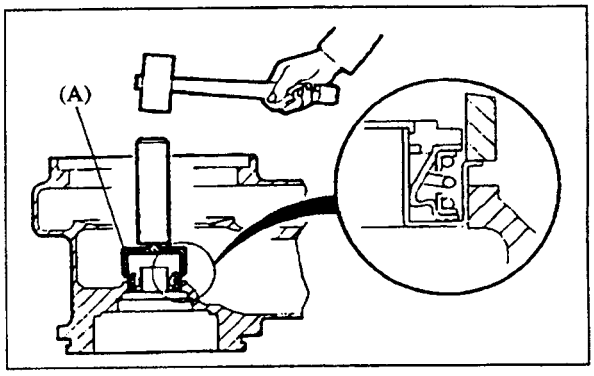
**NOTE**: Coat the oil seal lip with engine oil.




(2) Insert the unit seal into the pump case using fixture (A).

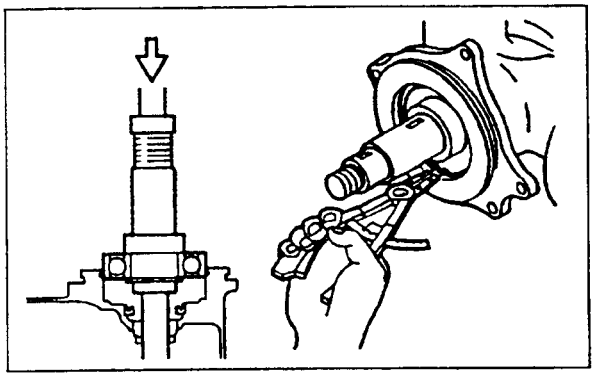
When the unit seal is removed out of the pump case, be sure to replace it with a new one.

**NOTE**: Apply sealant (ThreeBond 1102) to the outside surface of the unit seal before assembly.



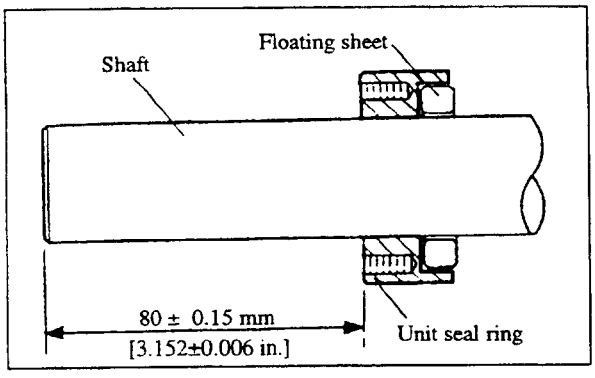

(3) Insert the pump shaft with the ball bearing at the impeller side into the pump case using a press.

Assemble the snap ring with its opening downward into the pump case.

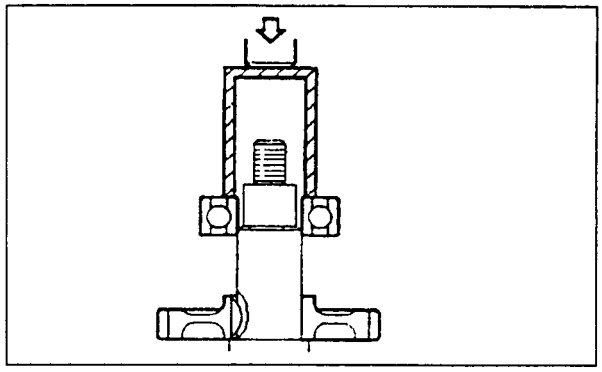


(4) Insert the unit seal ring, which is fitted with the floating sheet, to the specified dimensions carefully using a press.

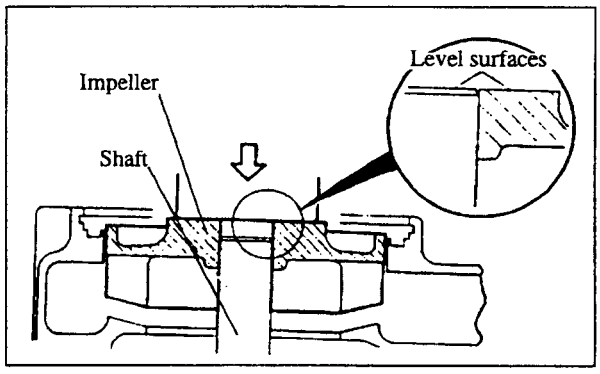
**NOTE**: Apply LLC solution (antifreeze solution) to two places on the floating sheet before assembly.



(5) Engage the gear with the shaft by aligning the key. Install the ball bearing at the nut side using a press.

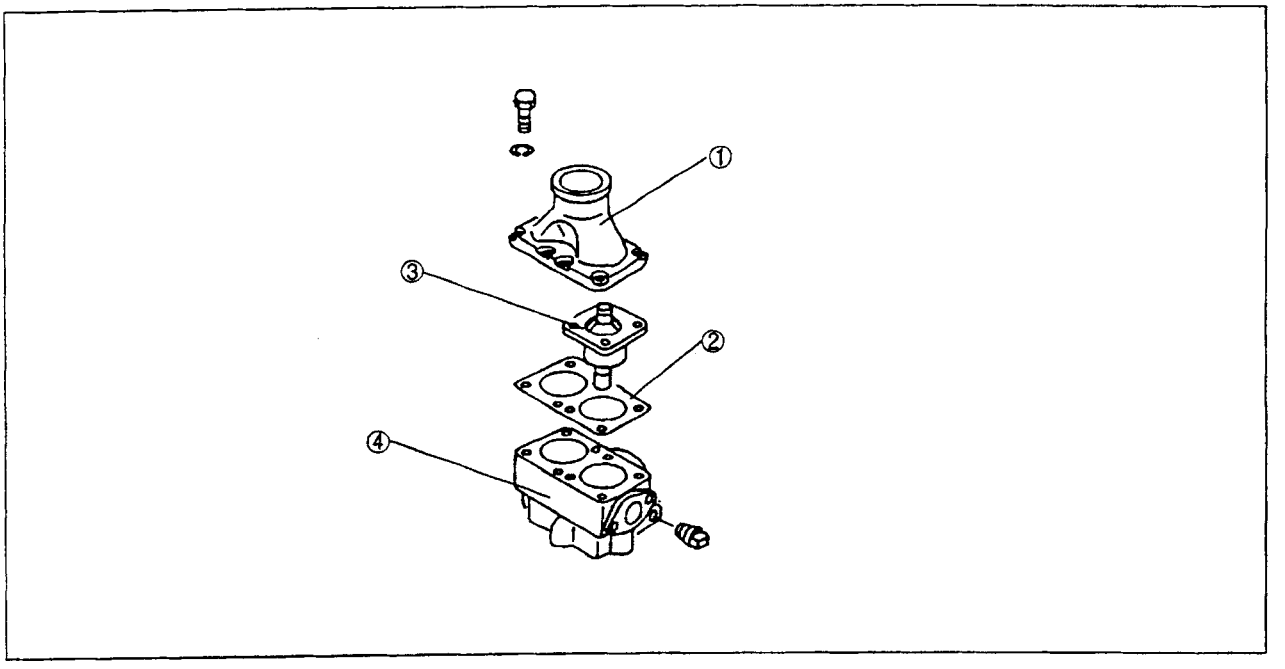


(6) Install the impeller using a press so that the boss end surface of the impeller may be flush with the pump shaft end surface.



# 4. THERMOSTAT

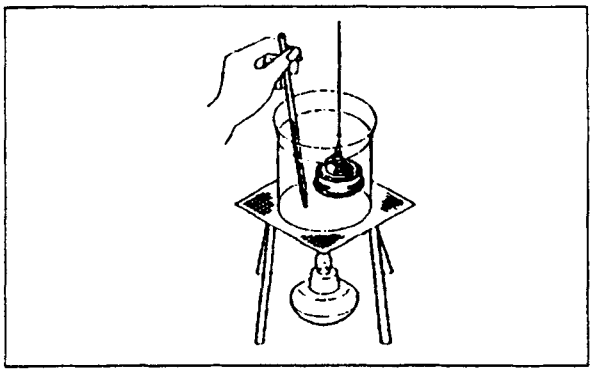
## 4.1 Disassembly




① Case cover
② Packing
③ Thermostat
④ Thermostat case

## 4.2 Inspection

Place each thermostat in a water tub, and test it for thermostatic action by heating the tub to raise the water temperature. In the test, measure the temperature at which the valve starts opening and that at which the valve lift is 10 mm[0.4 in.] or more. If these measurements are out of the assembly standard, replace the thermostat.

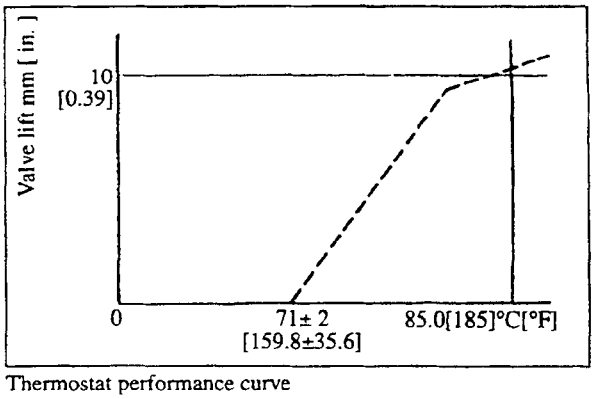


**⚠CAUTION**

**(a) Stir the water in the tub with a stick to maintain its temperature uniform during the test.**

**(b) Be sure to place each thermostat in correct position by ascertaining the valve opening temperature stamped on the side face of the thermostat valve during reassembly.**

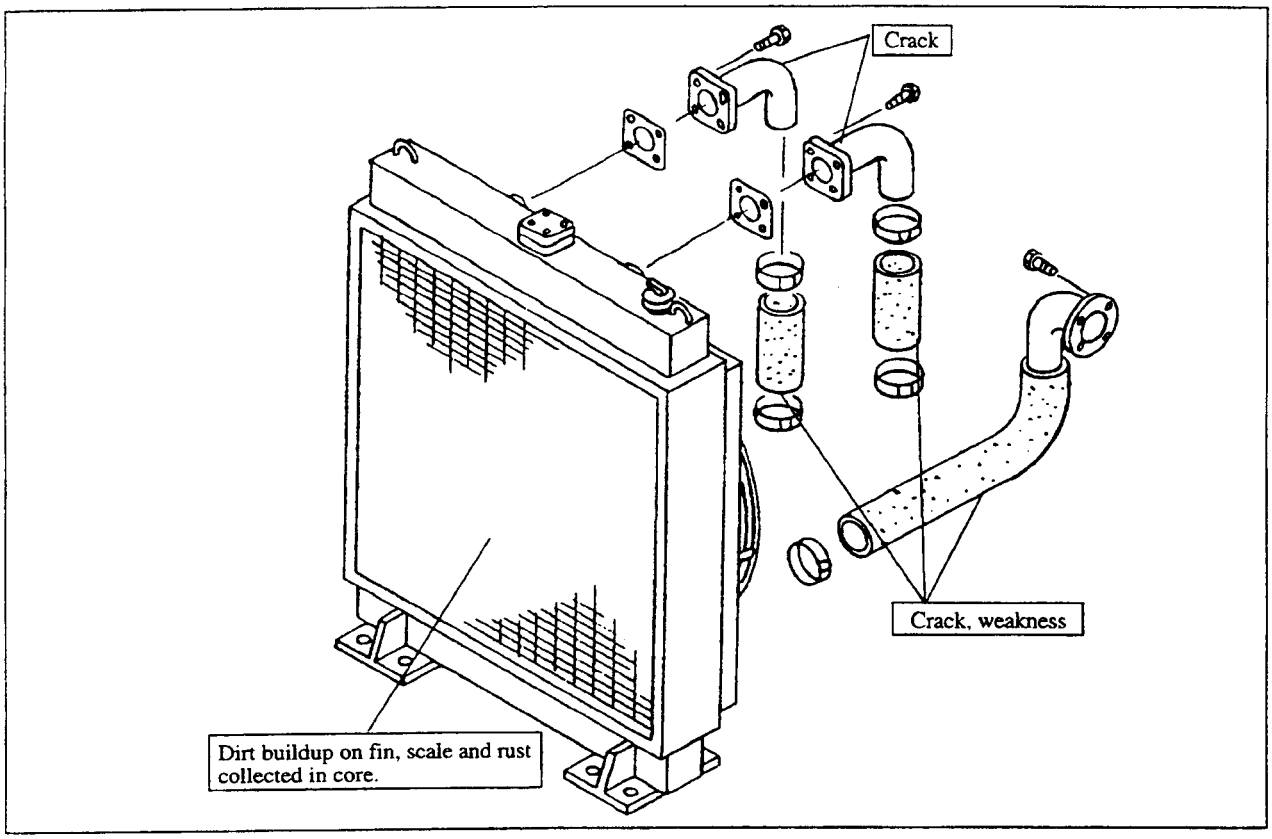
| | Assembly standard |
|---|---|
| Temperature at which valve starts opening | 71 ± 2°C [159.8 ± 35.6°F] |
| Temperature at which valve lift is 10 mm[0.4 in.], minimum | 85 ± 2°C [185.0 ± 35.6°F] |




Thermostat performance curve

## 5. RADIATOR

**Inspection**

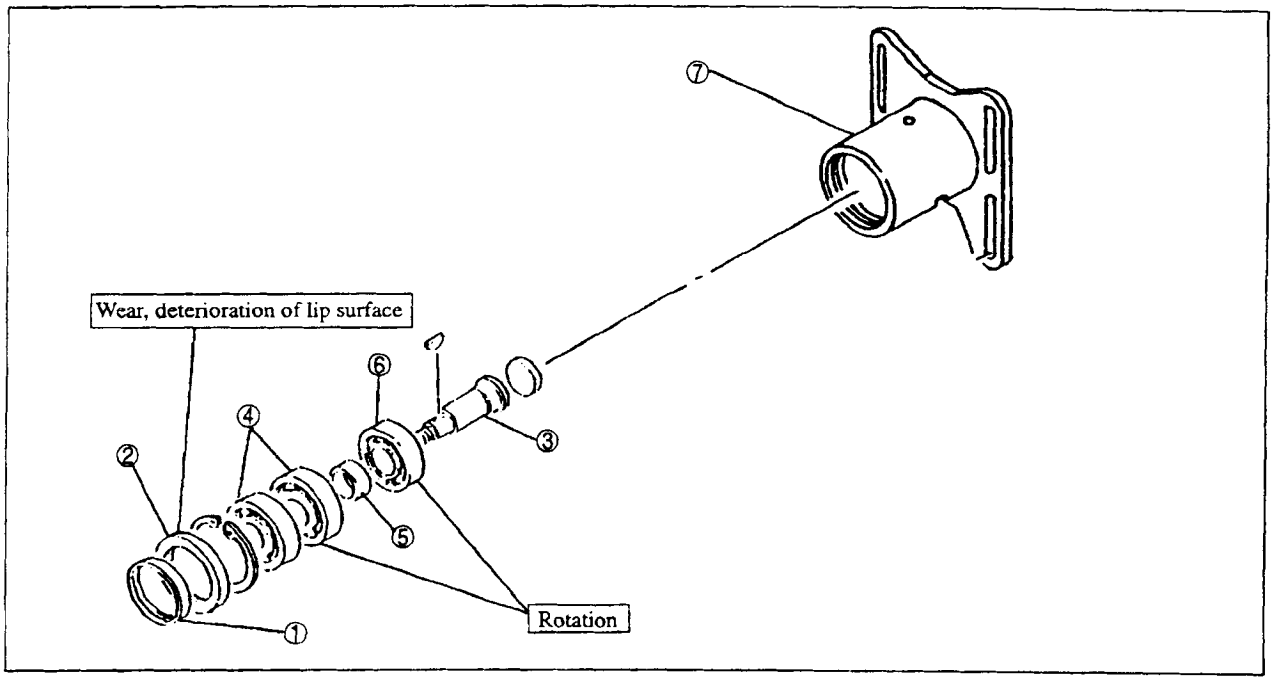



(1) Inspect the radiator fins for trash buildup. Also check the core interior for scale deposit and rusting. Clean the radiator as recommended.

(2) Inspect the rubber hoses and clamps, and replace defective parts if any.

# 6. FAN DRIVE

## 6.1 Disassembly




① Oil seal
② Snap ring
③ Shaft
④ Bearing
⑤ Spacer
⑥ Bearing
⑦ Case

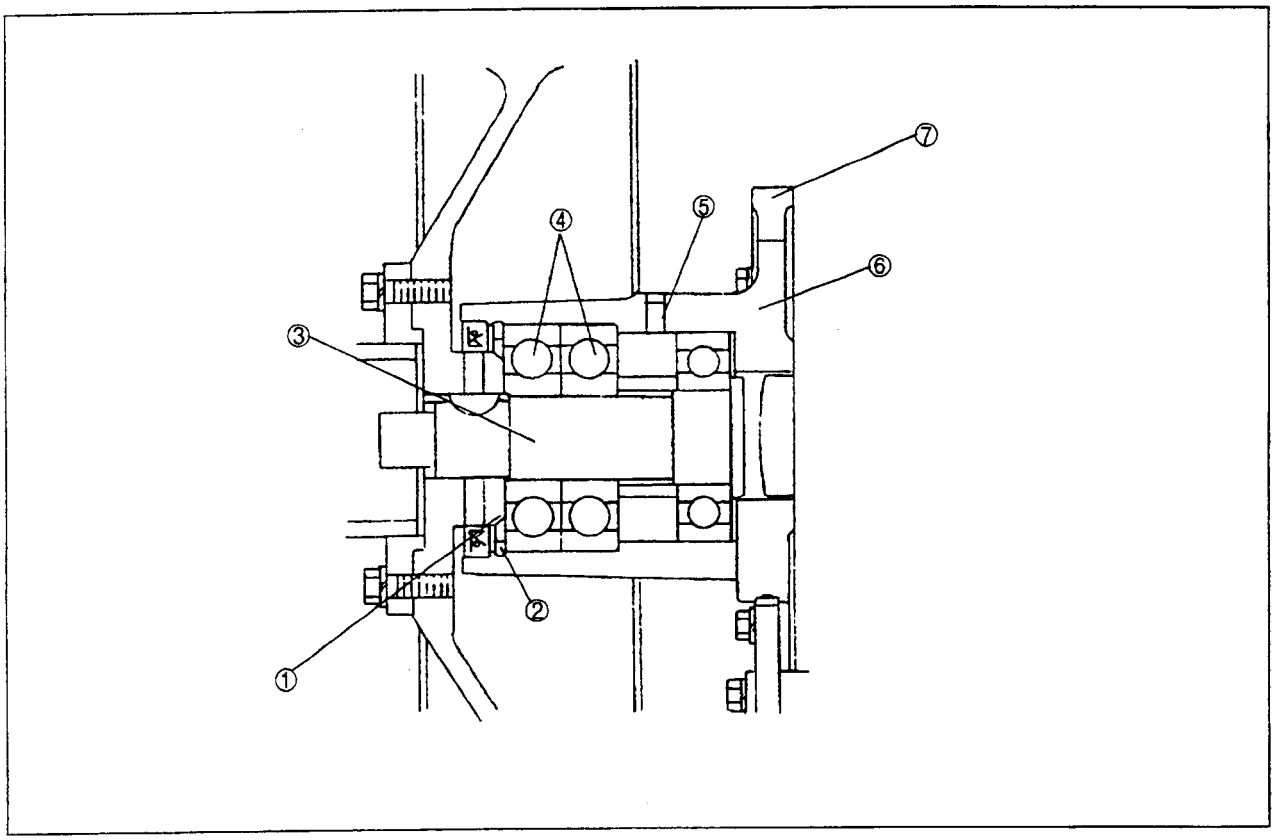
## 6.2 Inspection

(1) Measure the diameter of shaft and the inside diameter of the fan drive case bore to which the bearing races are fitted. If the case or the shaft is excessively worn or damaged, replace the bearing, the shaft or the case.

Unit: mm[in.]

| | | Nominal value | Assembly standard |
|---|---|---|---|
| Inside diameter of fan case bore to which bearing outer race is fitted | | ø110 [4.334] | 109.987 ~ 110.022 [4.3335~4.3349] |
| | | ø120 [4.728] | 119.987 ~ 120.022 [4.7275~4.7289] |
| Bearing | Diameter | ø110 [4.334] | 109.985 ~ 110.000 [4.3334~4.3340] |
| | | ø120 [4.728] | 119.982 ~ 120.000 [4.7273~4.7280] |
| | Inside diameter | ø45 [1.773] | 45.988 ~ 45.000 [1.7725~1.7730] |
| | | ø50 [1.970] | 49.985 ~ 50.000 [1.9694~1.9700] |
| Diameter of pump shaft on which bearing inner race is fitted | | ø45 [1.773] | 45.002 ~ 45.013 [1.7731~1.7735] |
| | | ø50 | 50.002 ~ 50.013 [1.9701~1.9705] |

### 6.3 Reassembly

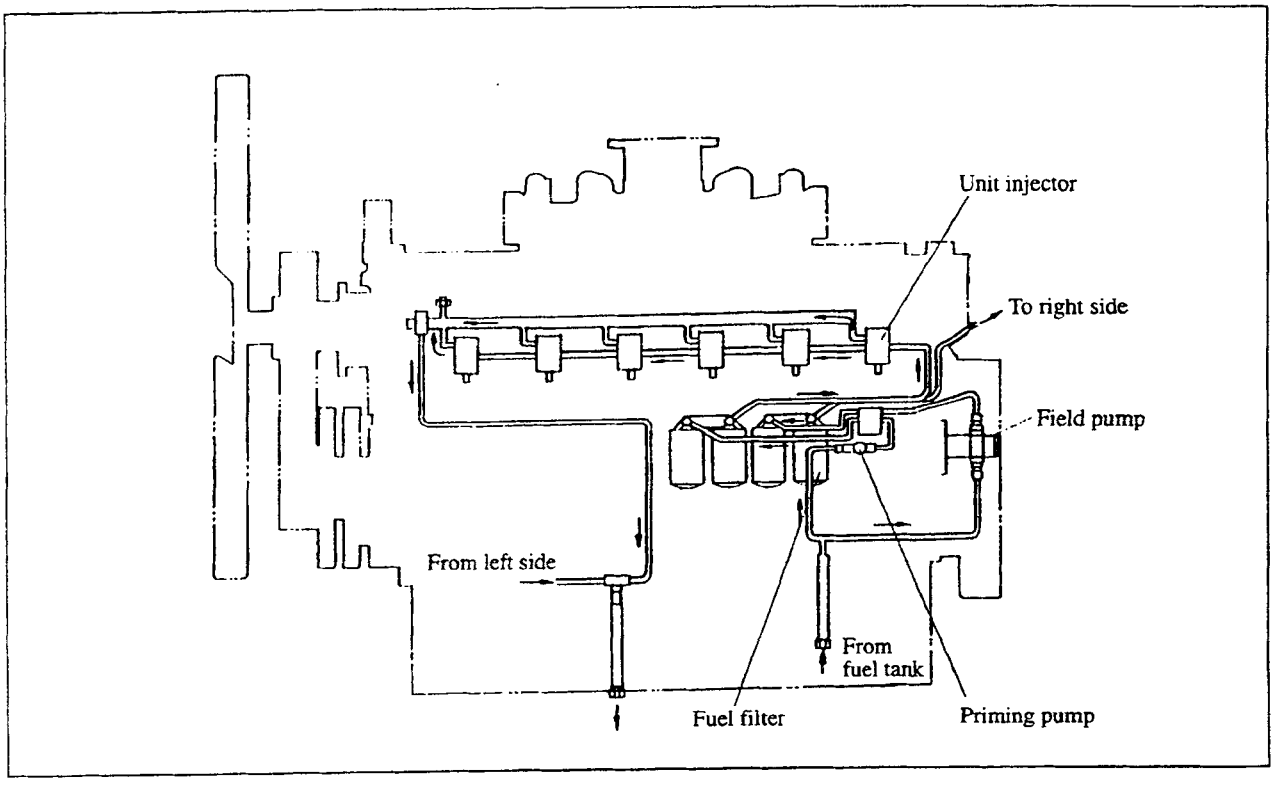



Reassembling sequence

③→⑥→⑤→④→⑦→②→①

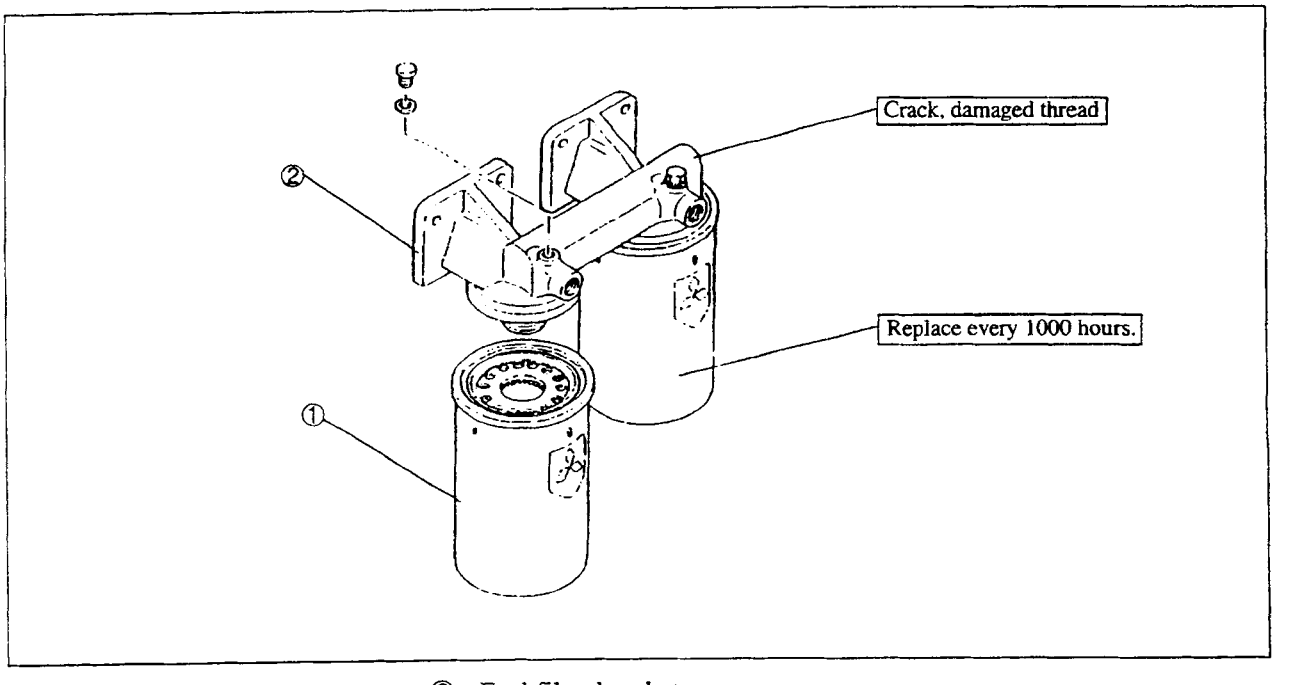
# FUEL SYSTEM

# 1. DESCRIPTION



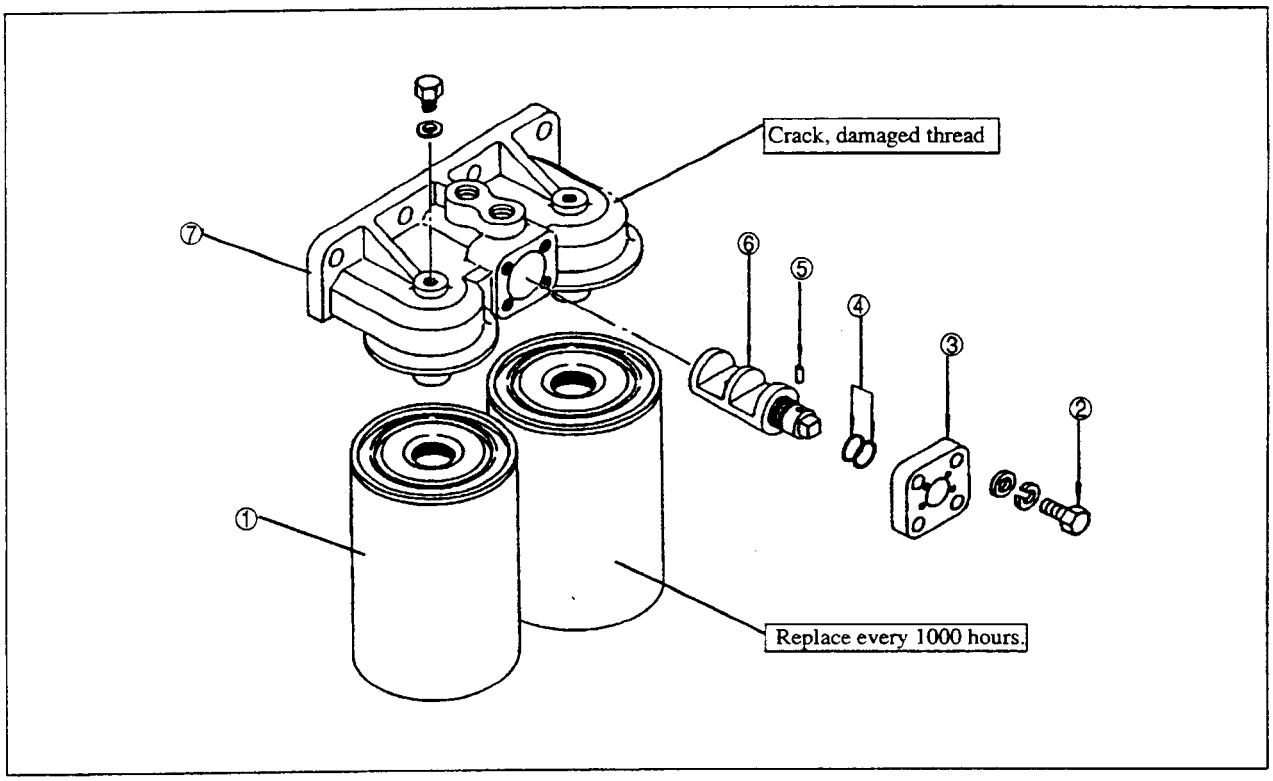

# 2. FUEL FILTER

## 2.1 Disassembly and inspection



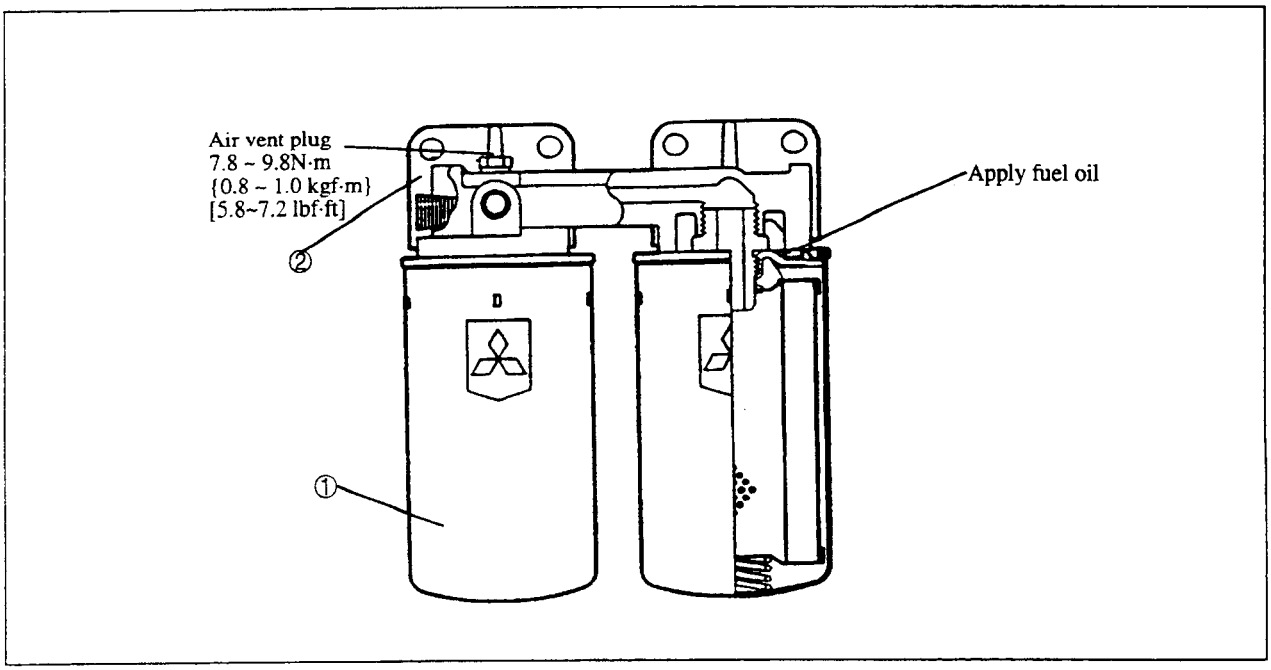

① Element ② Fuel filter bracket

**(Selector type)**




① Element
② Bolt
③ Cover
④ O-ring
⑤ Pin
⑥ Handle
⑦ Fuel filter bracket

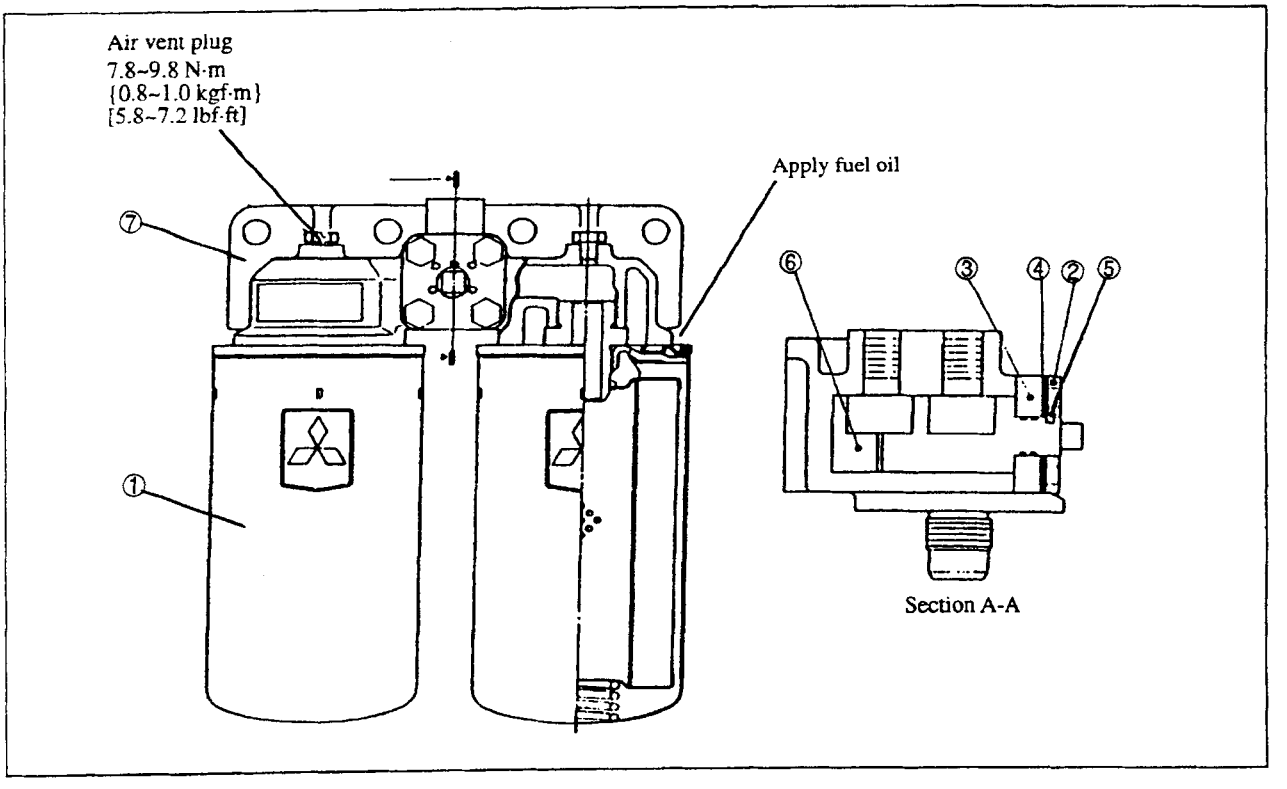
## 2.2 Reassembly




Reassembling sequence

②→①

**(Selector type)**




Reassembling sequence

⑦→⑤→④→⑥→③→②→①

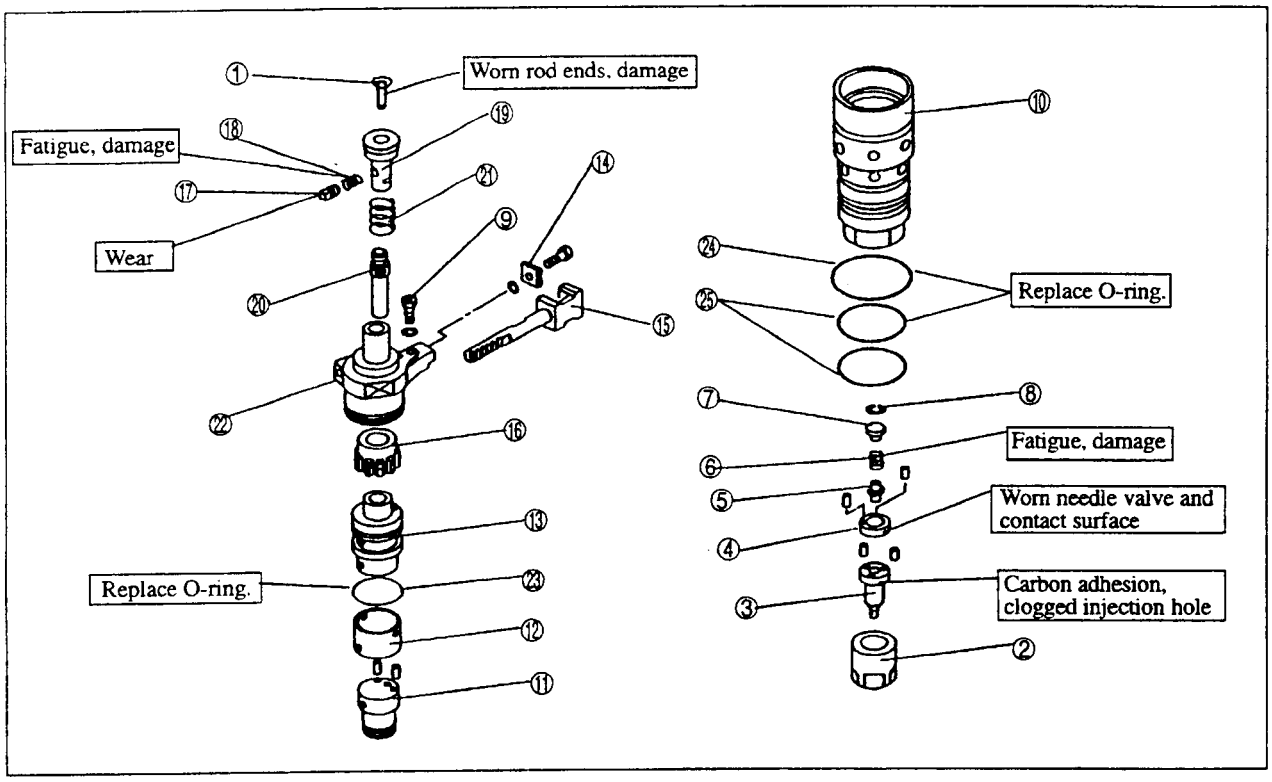
When installing cartridge, clean its mounting seat, and coat its gasket with clean fuel oil. After bringing the gasket into contact with the sealing surface of the bracket, hand-tighten cartridge 3/4 to 1 turn.

**⚠CAUTION**

**After installing the fuel filter on the engine, start the engine, and make sure that the filter is free from fuel leakage.**

# 3. UNIT INJECTOR

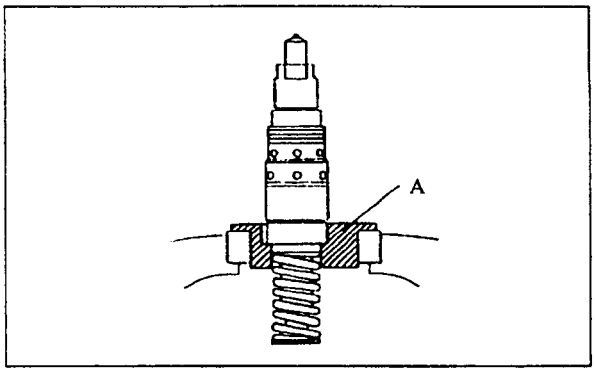
## 3.1 Disassembly




① Plunger push rod
② Nozzle retaining nut
③ Nozzle tip
④ Distance piece
⑤ Lower retainer
⑥ Needle valve spring
⑦ Spring seat
⑧ Needle valve shim
⑨ Stand
⑩ Body retaining nut
⑪ Spring cage
⑫ Spill deflector
⑬ Plunger barrel
⑭ Adjusting plate
⑮ Control rack
⑯ Pinion
⑰ Stopper
⑱ Stopper spring
⑲ Plunger tappet
⑳ Plunger
㉑ Plunger spring
㉒ Body
㉓ O-ring
㉔ O-ring
㉕ O-ring

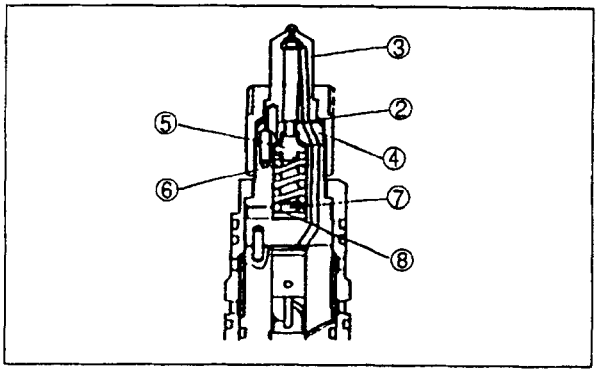
**⚠CAUTION**

- **Use clamp A (48749) to fix the unit injector on the vice for disassembly.**
- **Arrange the disassembled unit injector for each cylinder. Make sure that the parts are not mixed with other cylinder parts.**



**(1) Removing plunger push rod**

Remove plunger push rod ① from plunger tappet ⑲.




**(2) Removing nozzle tip**

Remove carbon deposits thoroughly from the nozzle using a wire brush. Remove the copper gasket.

If the copper gasket is not on the unit injector, it is still attached to the engine cylinder head. In that case, be sure to remove it from the cylinder head. Loosen nozzle retaining nut ②, and remove nozzle tip ③, distance piece ④, lower retainer ⑤, needle valve spring ⑥, spring seat ⑦ and needle valve shim ⑧.

**⚠CAUTION**

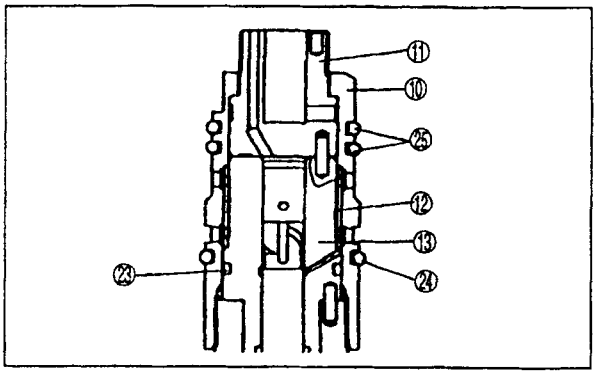
**Remove carbon and dust from the nozzle tip contact area of the nozzle retaining nut.**

**If dust and carbon remains between the nozzle tip and nozzle retaining nut, combustion gas can enter the unit injector insertion section. This can cause the injector to eject due to a pressure buildup of gas that entered during disassembly, thus leading to injuries and accident.**

NOTE: Make sure that needle valve shim ⑧ is not left inside spring cage ⑪.

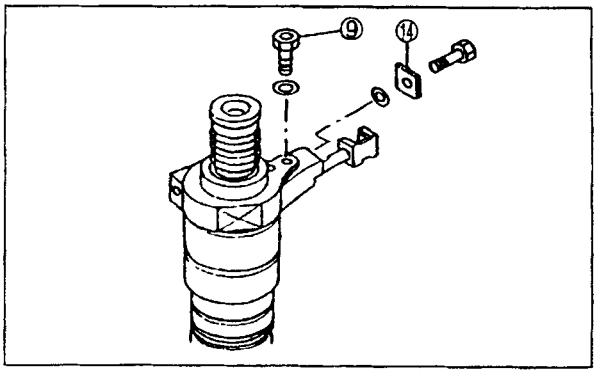
**(3) Removing plunger barrel**

Loosen body retaining nut ⑩, and remove spring cage ⑪, spill deflector ⑫ and plunger barrel ⑬. Remove O-rings ㉓ through ㉕, and install new O-rings.



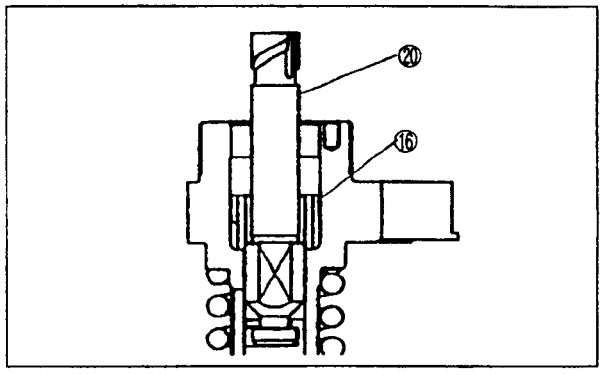

**(4) Removing control rack**

Remove stand gauge ⑨ and shim. Remove the screw, and remove adjusting plate ⑭ and shim.



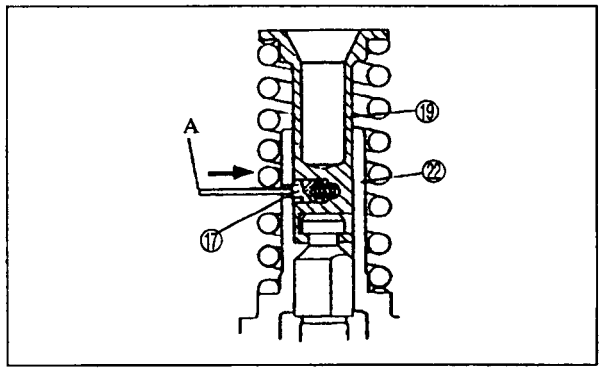
**(5) Removing pinion**

Remove pinion ⑯ from plunger ⑳.



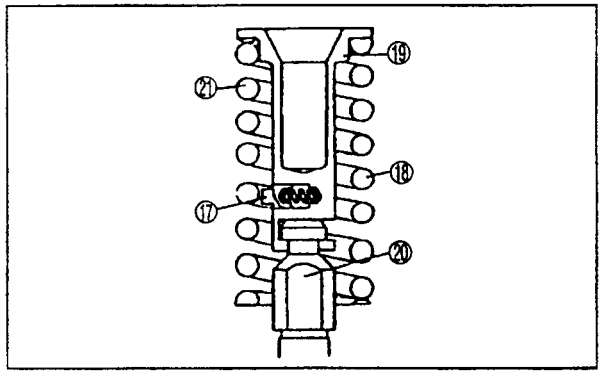

**(6) Removing stopper**

Push stopper ⑰ with pin (A), guide it into the vertical groove on body ㉒, then slowly pull out plunger tappet ⑲.




**(7) Disassembling tappet sub-assembly**

Remove plunger spring ㉑, then take out stopper ⑰ and stopper spring ⑱. Separate plunger tappet ⑲ from plunger ⑳.



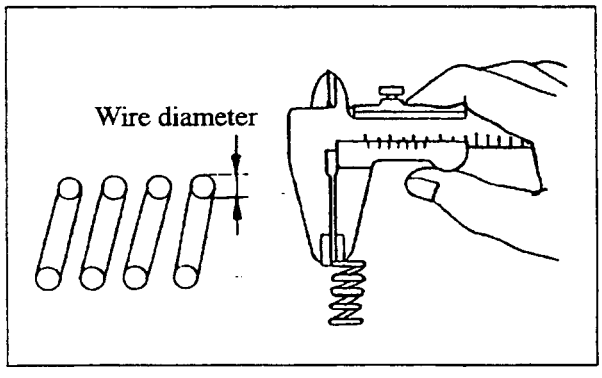

## 3.2 Inspection

**(1) Measuring wire diameter of stopper spring**

Measure the wire diameter of the stopper spring. If the measured diameter is smaller than the service limit, replace with a new part.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Stopper spring wire diameter | φ0.4 [0.016] | 0.3992 ~ 0.4008 [0.0157 ~ 0.0158] | 0.25 [0.0099] |

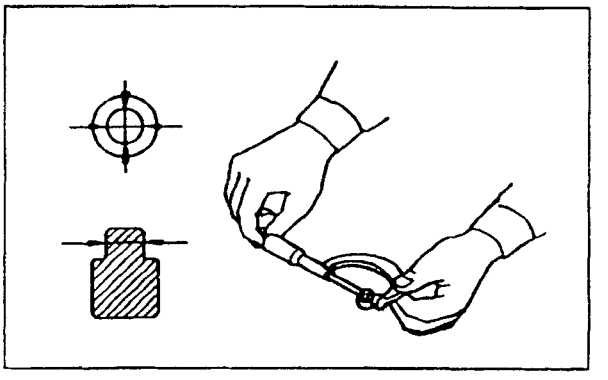


### (2) Measuring outside diameter of protruded section of stopper

Measure the outside diameter of the protruded section of the stopper. If the measured diameter is smaller than the service limit, replace with a new part.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Stopper protrusion outside diameter | ϕ4 [0.1576] | 3.85~3.95 [0.1517~0.1556] | 3.7 [0.1458] |

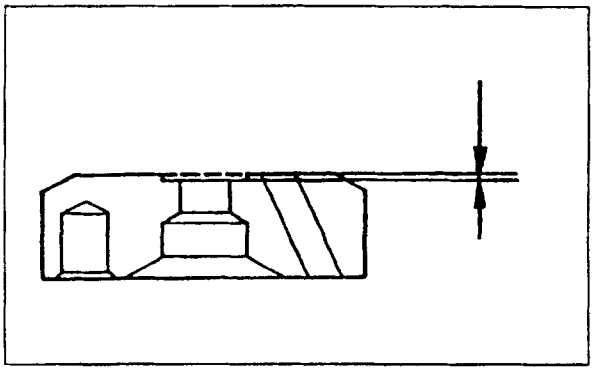


### (3) Measuring wear on needle valve contact area of distance piece

Measure the amount of wear on the needle valve contact area of the distance piece. If the measured value exceeds the service limit, replace with a new part.

Unit: mm [in.]

| | Assembly standard | Service limit |
|---|---|---|
| Wear on needle valve contact area of distance piece | 0 [0] | -0.2 [-0.0079] |

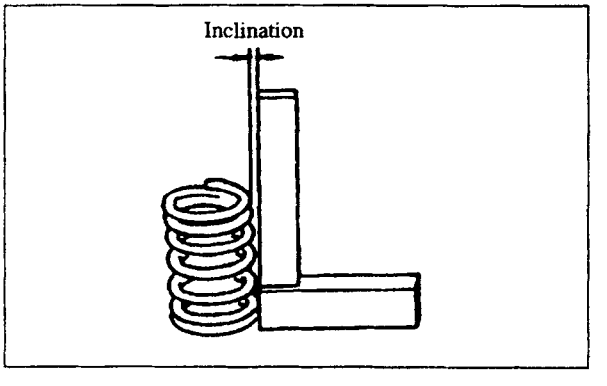


### (4) Measuring needle valve spring inclination and free length

Inspect the amount of needle valve spring inclination and the decrease of free length. If the measured value exceeds the service limit, replace with a new part.

Unit: mm [in.]

| | Assembly standard | Service limit |
|---|---|---|
| Free length | 27.6 [1.0874] | -1 [-0.0394] |
| Inclination | 0.5 [0.0197] max. | |



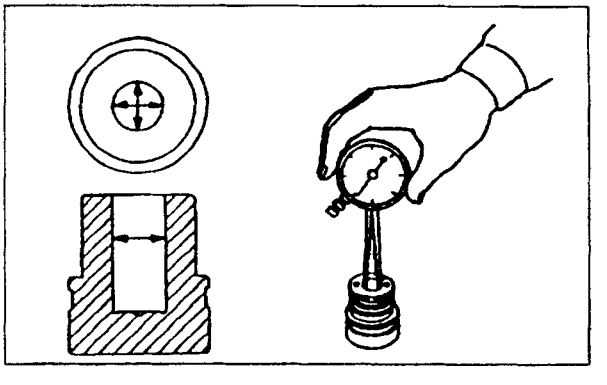

### (5) Measuring inside diameter of spring cage

Measure the inside diameter of the spring cage. If the measured diameter exceeds the service limit, replace with a new part.

Diameter measured at groove caused by wear must not exceed the service limit.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Spring cage inside diameter | ϕ14 [0.552] | 14.01~14.02 [0.5520~0.5524] | 14.6 [0.5752] |

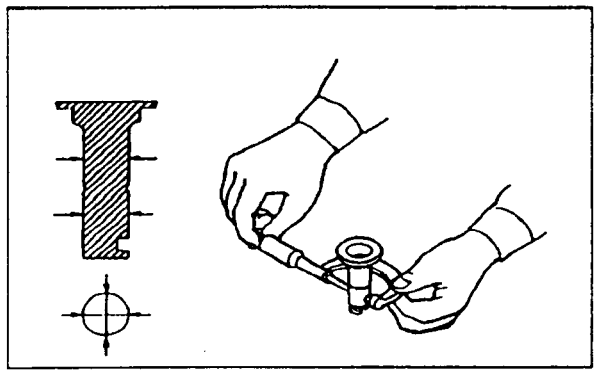


### (6) Measuring outside diameter of plunger tappet

Measure the outside diameter of the plunger tappet. If the measured diameter is smaller than the service limit, replace with a new part.

Unit: mm [in.]

| | Nominal value | Assembly standard | Service limit |
|---|---|---|---|
| Plunger tappet outside diameter | ϕ18 [0.710] | 17.966~17.984 [0.7079~0.7086] | 17.959 [0.7076] |

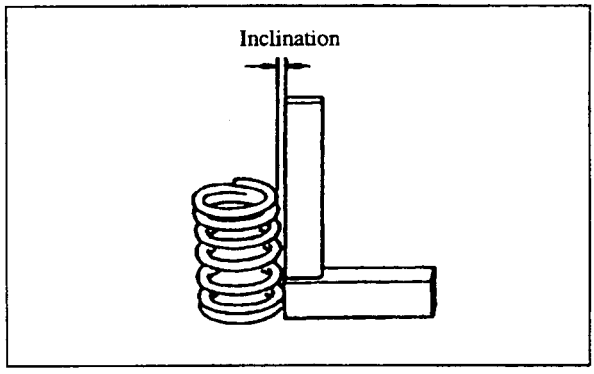


### (7) Measuring plunger spring inclination and free length

Inspect the amount of needle valve spring inclination and the decrease of free length. If the measured value exceeds the service limit, replace with a new part.

Unit: mm [in.]

| | Assembly standard | Service limit |
|---|---|---|
| Free length | 84 [3.310] | –2.0 [–0.079] |
| Inclination | 0 [0] | 1.5 [0.060] |



**(8) Inspecting nozzle tip**

(a) Inspect the nozzle tip spray condition.

Refer to the "3.3 Adjustment" section.

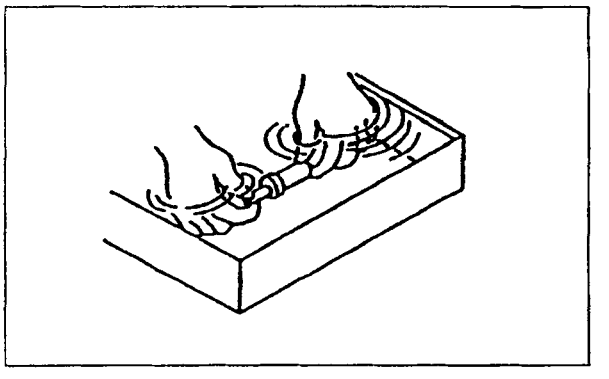
(b) Check the needle valve movement, injection hole clogging and carbon adhesion. If any abnormality is found, clean or replace the nozzle tip.

**(9) Cleaning nozzle tip**

(a) Clean the needle valve and body in cleaning solution.

**⚠CAUTION**

**Be use to use clean solution.**

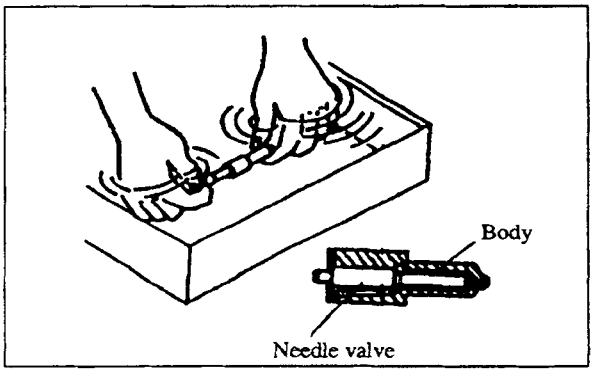


(b) After cleaning, immerse the needle valve and body in clean diesel fuel, and assemble in diesel fuel.

NOTE: The needle valve and body are precision parts. Therefore, handle them with care, and never change the combination of the original needle valve and body set.

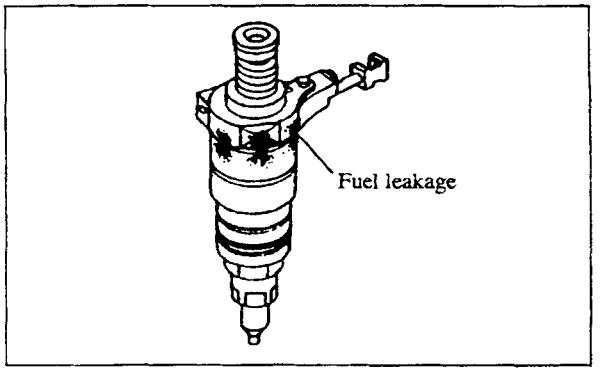
(c) If the spray condition does not improve after adjustment and cleaning, replace the nozzle tip with a new assembly.

NOTE: New nozzle tips are pre-coated with Vaseline and a rust-preventive agent. Be sure to wash off these coatings with cleaning solution, then clean again with diesel fuel (engine fuel) before assembling.




**(10) Inspecting for fuel leakage**

Inspect the entire surface of the body for marks left by leaked fuel. If fuel leakage is suspected, inspect O-ring ⑳ on the plunger barrel, and tighten the nozzle retaining nut or body retaining nut to the specified torque.



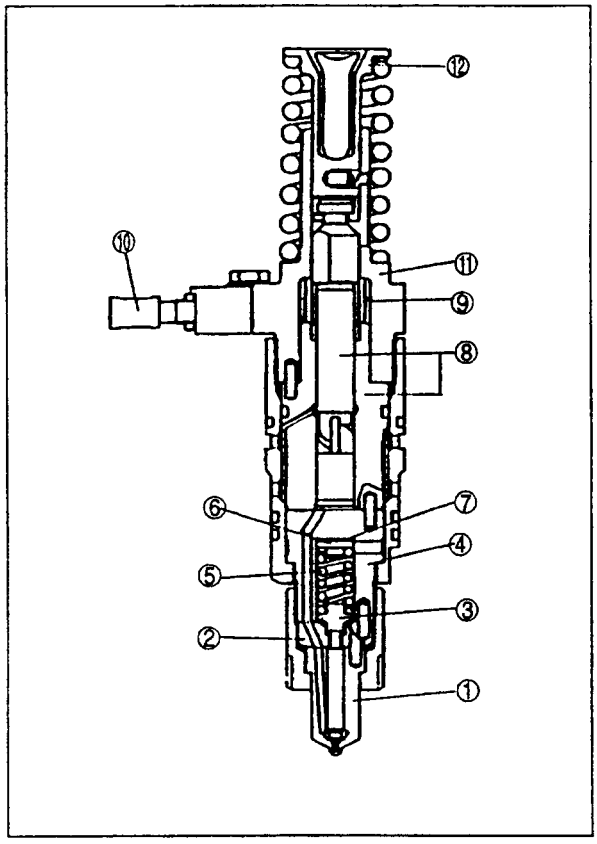
### 3.3 Adjustment

**⚠CAUTION**

- **Special equipment is required for the adjustment of unit injectors. Therefore, unit injectors must be adjusted by a service shop equipped with proper tools.**
- **Adjustment items vary depending on parts to be replaced. Make necessary adjustments according to the following table. If unit injectors are overhauled as specified, it is necessary to perform all designated adjustments.**

Items to be adjusted when parts are replaced

| Replaced part | | Valve opening pressure adjustment | Injection volume adjustment | Prestroke adjustment |
|---|---|---|---|---|
| 1 | Nozzle tip | ○ | | |
| 2 | Distance piece | ·×· | | |
| 3 | Lower retainer | ·×· | | |
| 4 | Spring cage | ·×· | | |
| 5 | Needle valve spring | ○ | | |
| 6 | Spring seat | ·×· | | |
| 7 | Shim | ·×· | | |
| 8 | Plunger assembly | | ○ | ○ |
| 9 | Pinion | | ○ | |
| 10 | Control rack | | ○ | |
| 11 | Body | | ○ | ○ |
| 12 | Plunger tappet | | | ○ |




○ : Adjustment is necessary even when no other part is replaced.

·×· : Adjustment is necessary only when another part is also replaced. Adjustment is not necessary when no other part is replaced.

**(1) Valve opening pressure**

(a) Insert dowel pin ② into spring cage ①, then install connector (A) (48749-00100).

(b) Tighten body retaining nut ③ to the specified torque using the two-time tightening method.

**NOTE**: Before tightening the body retaining nut, apply engine oil to the threads and the shoulder section of the spring cage.

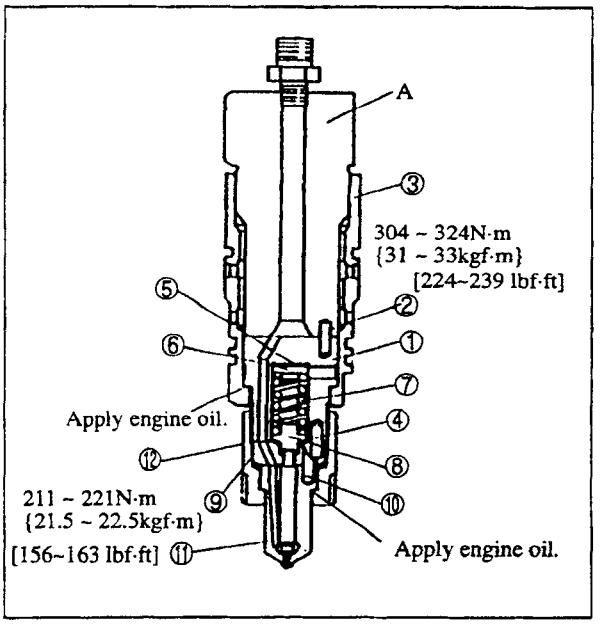
(c) Insert dowel pin ④ into the spring cage. Install needle valve shim ⑤, spring seat ⑥, needle valve spring ⑦ and lower retainer ⑧, then place distance piece ⑨ in position.

**NOTE**: Be sure to install needle valve shim ⑤ and spring seat ⑥ in proper order.

(d) Insert dowel pin ⑩ into the distance piece. Install nozzle tip ⑪, then tighten nozzle retaining nut ⑫ to the specified torque using the two-time tightening method.

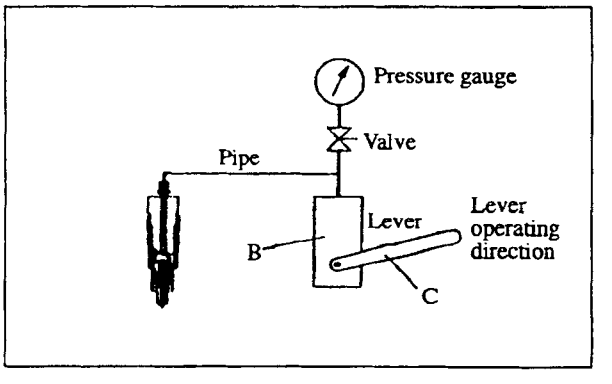
**NOTE**: Before tightening the nozzle retaining nut, apply engine oil to the threads and the shoulder section of the nozzle tip.

(e) Connect nozzle tester (B). Press handle (c) at a rate of once every 1 second and read the pressure level at which fuel injection begins. Also, visually check the spray pattern for abnormalities. If the measured value deviates from the assembly standard, replace the shim.




Unit: MPa {kgf/cm²} [psi]

| | Assembly standard |
|---|---|
| Valve opening pressure | 28.93 ~ 30.89<br>{295 ~ 315}<br>[4196 ~ 4481] |




**⚠CAUTION**

**Do not touch fuel spray. Fuel is sprayed from the nozzle under high pressure, and it can penetrate the skin, thus causing serious health problems.**

**Shim types**

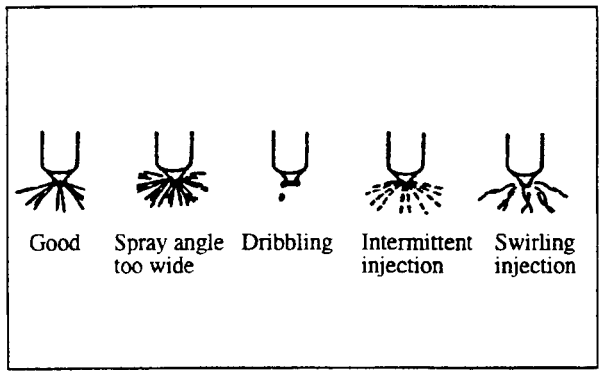
| Part No. | Shim thickness mm [in.] | Valve opening pressure (MPa {N·m}[psi]) |
|---|---|---|
| 48742-00311 | 0.40 [0.016] | -3.20 {-32.6}[-463.7] |
| 48742-00321 | 0.50 [0.020] | -1.60 {-16.3}[-231.9] |
| 48742-00331 | 0.60 [0.024] | 0.0 {0.0}[0.0] Standard |
| 48742-00341 | 0.70 [0.028] | 1.60 {-16.3}[231.9] |
| 48742-00351 | 0.80 [0.032] | 3.20 {-32.6}[463.7] |

**NOTE**: If the specified valve opening pressure cannot be achieved with a 0.80mm[0.032 in.] shim, replace needle valve spring ⑦.

(f) Spraying condition

When a nozzle tester is used for pressure adjustment, be sure to check injection hole clogging, spray condition and fuel leakage at the same time. If fuel is not sprayed properly, clean or replace the nozzle tip.

When the handle of the nozzle tester is pressed down with force, fuel should spray through all ten injection holes and fine a fuel mist should spread into a uniform cone shape having an angle of 160 degrees. Sprayed fuel should not have large fuel particles, and no fuel should remain on the injection holes after injection.




Nozzle spray conditions

(g) After adjusting the valve opening pressure, disassemble to prepare for final reassembly.

### (2) Injection volume adjustment

**⚠CAUTION**

**Subsequent adjustments require special equipment. Do not attempt to make adjustments at a maintenance or repair site. To make a fuel injection adjustment, it is necessary to measure the injection volume at the operation adjustment point.**

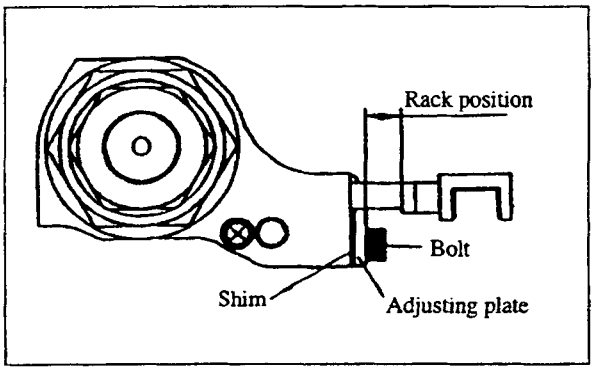
Injection volume adjustment and check points

| Part No. Identification code | Unit injector part No. | Nozzle type mm[in.] | Cam rotating speed rpm | Rack position mm [in.] | Injection volume g/400 strokes | Remarks |
|---|---|---|---|---|---|---|
| AA | 48740-03010 | ϕ0.29[0.011] −160° 10 holes | 750 | 8.5 [0.33] | 18 ~ 22 | Operation adjustment point |
| | | | | 19 [0.74] | 147 ~ 163 | Injection volume check |
| | | | 300 | 11 [0.43] | 18 ~ 32 | Injection volume check |
| AB | 48740-03020 | ϕ0.31[0.012] −160° 10 hholes | 900 | 8 [0.31] | 15 ~ 19 | Operation adjustment point |
| | | | | 19 [0.75] | 147 ~ 163 | Injection volume check |
| | | | 300 | 11 [0.43] | 11 ~ 26 | Injection volume check |

**[Assembly and operating conditions]**

| | |
|---|---|
| • Nozzle gland tightening torque | 98.1±4.9N·m{10±0.5kf·m} [72.33±3.62 lbf·ft] |
| • Rocker shaft tightening torque | 98.1±4.9N·m{10±0.5kgf·m} [72.33±3.62 lbf·ft] |
| • Height gauge length | 83±0.05mm [3.270±0.002 in.] |
| • Height gauge length adjustment timing | 30° B.T.D.C. (to be set during cam base circle) |
| | **NOTE**: The height gauge used for this adjustment is different from the height gauge used for engine assembly. |
| • Fuel supply pressure | 0.39±0.05MPa{4±0.5kgf/cm²}[56.9±7.11 psi] |
| • Lubricating oil supply pressure | 0.59±0.05MPa{6±0.5kgf/cm²}[85.6±7.11 psi] |
| • Fuel temperature | 35±5°C [95±41°F] |

(a) Using a shim, adjust the rack installation position at the operation adjustment point to the specified value, then mount on a test stand.




(b) Measure the volume of fuel injected at the operation adjustment point by 400 strokes. Check to see if the fuel volume is within the specified range. If the measured value deviates from the specified range, adjust by varying the shim thickness.

mm [in.]

| Part No. | Shim thickness | Part No. | Shim thickness |
|---|---|---|---|
| 48722-00310 | 0.40 [0.016] | 48722-00360 | 0.90 [0.035] |
| 48722-00320 | 0.50 [0.020] | 48722-00370 | 1.00 [0.039] |
| 48722-00330 | 0.60 [0.024] | 48722-00380 | 1.10 [0.043] |
| 48722-00340 | 0.70 [0.028] | 48722-00390 | 1.20 [0.047] |
| 48722-00350 | 0.80 [0.032] | — | — |

**NOTE**: In the SH series, when a thicker shim is installed, the injection volume increases.

(c) When the injection volume is within the specified range at the operation adjustment point, check to see if the injection volume is within the specified range at the injection volume check point.

(d) After adjusting the injection volume, secure the adjusting plate in place using the bolt, and mark the bolt, plate and body with paint to indicate the completion of adjustment.

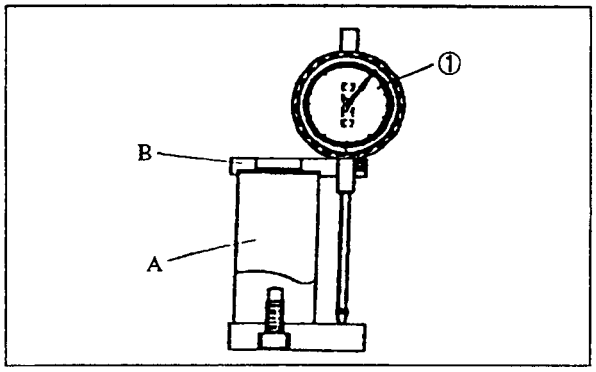
(3) **Adjusting prestroke**

(a) Set special tool gauge (A) (48749-03080) and gauge stand (B) (48749-02010) as shown in the diagram. Set the indicator of dial gauge (1) to "0."

(b) Remove the gauge stand.

(c) Install a unit injector on test stand (C), and connect the pipe as shown in the diagram on the right.

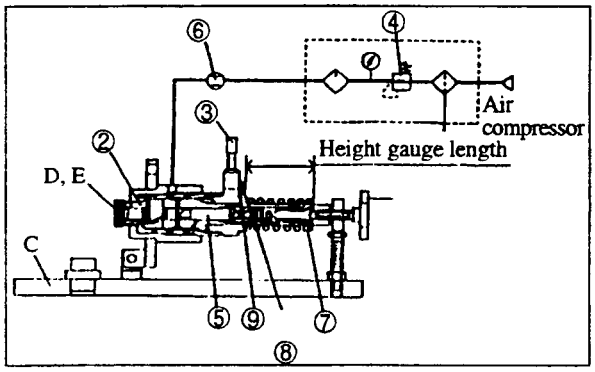
(d) Install plug (E) (48749-00200) attached with O-ring (D) (F3150-01010) on spring case ② to cover the leak-off hole.




**[Test conditions]**

- Air temperature — Ordinary temperature
- Air supply pressure — 0.10 MPa {1 kgf/cm²} [14.23 psi]min.
- Adjust regulator valve ④ so that air flows at a rate of approximately 850 cc[0.22 U.S.gal]/min when control rack ③ is pressed in (rack 0).

  (Gauge pressure: approx. 0.01 MPa {0.1 kf/cm²}[1.42 psi])




(e) Pull the control rack fully (maximum injection volume).

(f) Rotate handle (F) of the test stand while ensuring that plunger ⑤ is pressed at all times to prevent a backlash. Stop turning the handle when air flow meter ⑥ indicates 200±10 cc[0.05±0.003 U.S.gal]/min.

(g) Measure the distance between plunger tappet ⑦ and stand gauge ⑧. Using a shim, adjust the height gauge to a length of 80±0.05 mm[3.15±0.0002 in.], then tighten to the specified torque.

Tightening torque: 7.8 to 9.8 N·m {0.8 to 1.0 kgf·m[5.79 to 7.23 psi]}

(h) After adjusting the height gauge length, mark the body with paint from the side of the stand gauge. This paint mark also serves as an indication of adjustment completion.

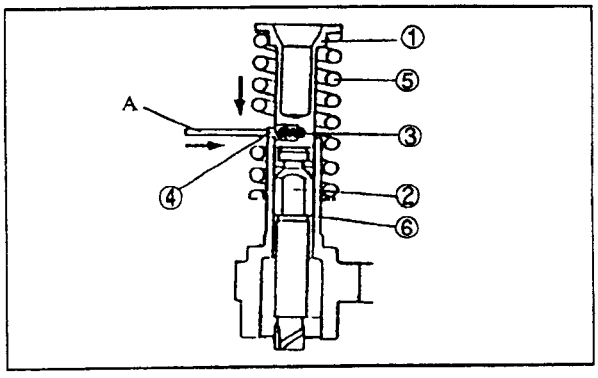
### 3.4 Reassembly

#### (1) Installing tappet

(a) Install plunger ②, stopper spring ③ and stopper ④ in plunger tappet ①, and place plunger spring ⑤ in position.

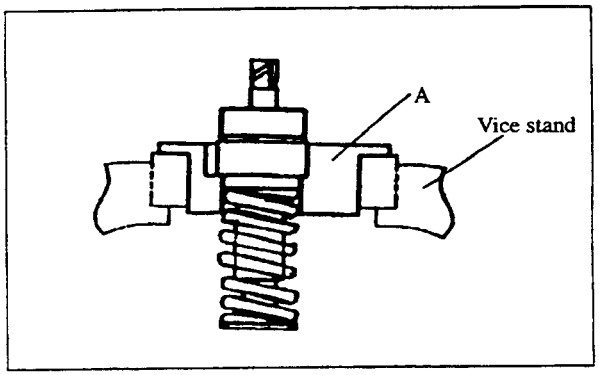
(b) Push in stopper ④ using pin (A), and insert the plunger and plunger tappet into body ⑥. Position the stopper into the vertical groove on the body.

(c) Check to make sure stopper ④ is firmly positioned in the vertical groove on body ⑥.




#### (2) Mounting on vice stand

Using clamp (A) (48749-01000), secure the unit injector in a vice stand.

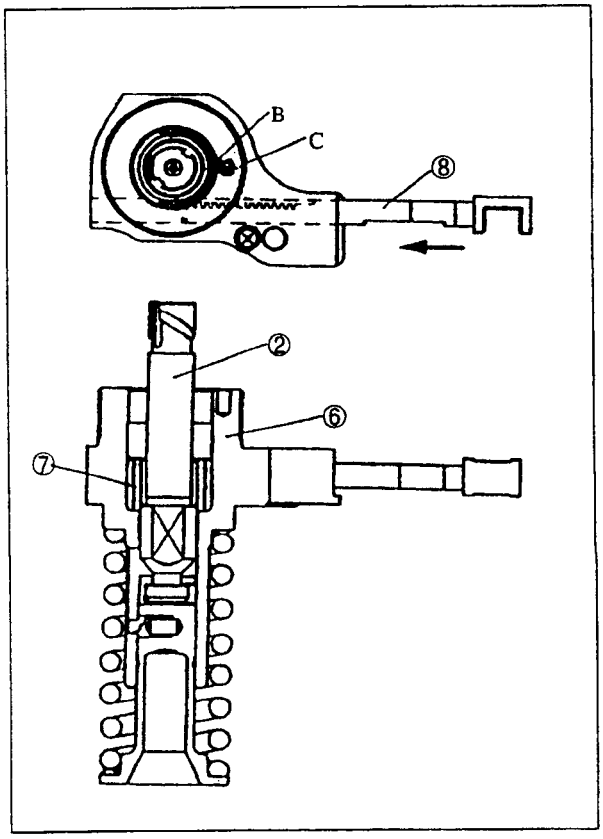



#### (3) Installing control rack

(a) Install pinion ⑦ in plunger ②, making sure that the teeth of the pinion faces up (fuel injection side).

(b) Align mark (B) on pinion ⑦ with dowel pin hole (c).

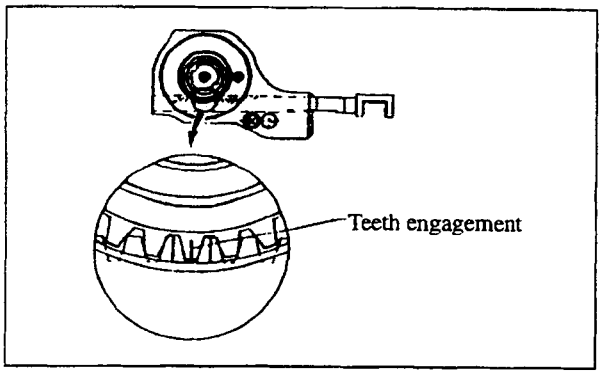
(c) With parts in the above condition, insert control rack ⑧ in body ⑥, making sure that the teeth of the control rack faces pinion ⑦.



**(4) Checking pinion and control rack teeth engagement**

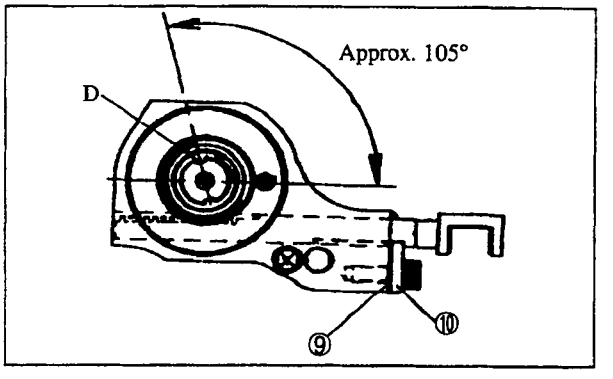
(a) Press control rack ⑧ down to check that the alignment mark on the control rack aligns with the mark on pinion ⑦.

NOTE: engagement is achieved.




(b) Install shim ⑨, and temporarily install adjusting plate ⑩.

(c) Press control rack ⑧ down to check that the angle formed by vertical groove (D) on plunger ② and dowel pin hole (c) is approximately 105 degrees. If the groove position deviates significantly, repeat from above step (a).




**(5) Installing plunger barrel**

(a) Insert dowel pin ⑪ into body ⑥. Insert plunger barrel ⑫ into plunger ②, making sure that there is no interference between the plunger barrel and plunger.

NOTE: If the plunger is not properly engaged to pinion ⑦, a gap (approx. 2 mm) is produced at section (E). To prevent this gap, check to make sure the end faces contact each other. If a gap is observed, repeat the procedures starting from section (3).

(b) Install new O-ring ⑬ on the plunger barrel, and apply engine oil.

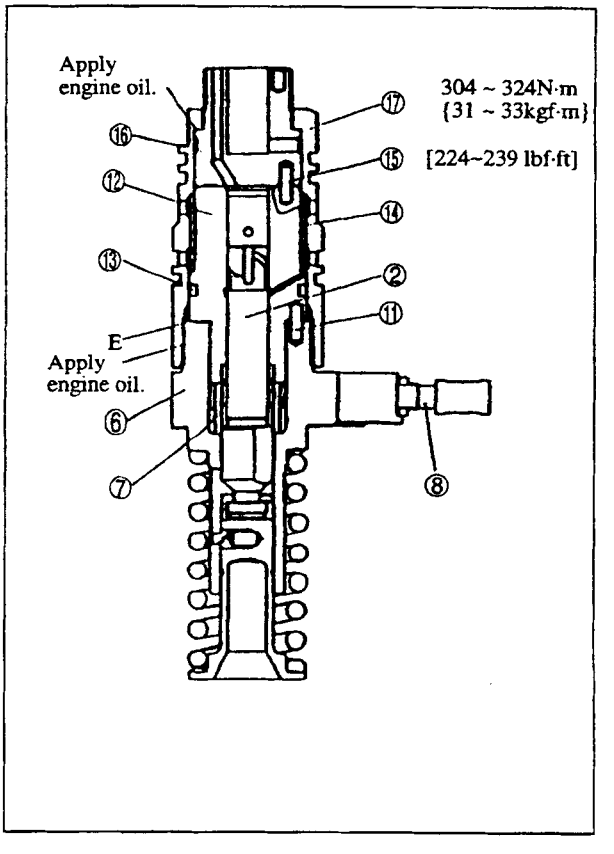
(c) Install spill deflector ⑭, then check to make sure it rotates smoothly.

(d) Insert dowel pin ⑮ into the plunger barrel, then install spring cage ⑯.

(e) Tighten body retaining nut ⑰ to the specified torque using the two-time tightening method. (Loosen the nut until it can be turned by hand before tightening second time to the specified torque.)

NOTE: Before tightening the body retaining nut, apply engine oil to the threads, the shoulder section of the spring cage, and O-ring. Be sure to tighten to the specified torque. Excessive tightening force can result in plunger sticking, while insufficient tightening force can cause fuel leaks.

(f) Check control rack ⑧ for smooth movement. (Slide resistance: 50 g max.)



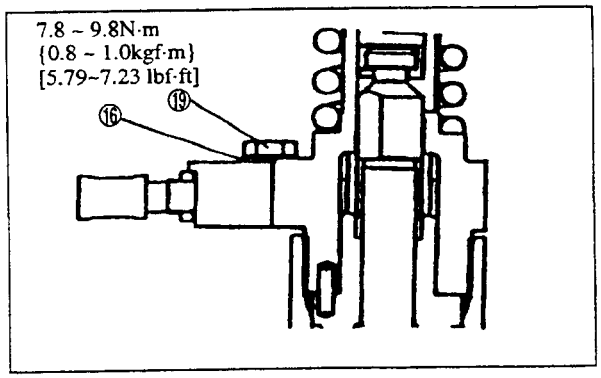
**(6) Adjusting prestroke**

(a) Install shim ⑱, and temporally tighten gauge stand ⑲.

(b) Adjust the prestroke.

(c) After adjustment, tighten the gauge stand to the specified torque.

(d) After tightening, mark the side of the bolt with paint to indicate the completion of adjustment.




**(7) Installing nozzle tip**

(a) Insert pre-adjusted needle valve shim ⑳ in spring cage ⑯. Install spring seat ㉑, needle valve spring ㉒ and lower retainer ㉓.

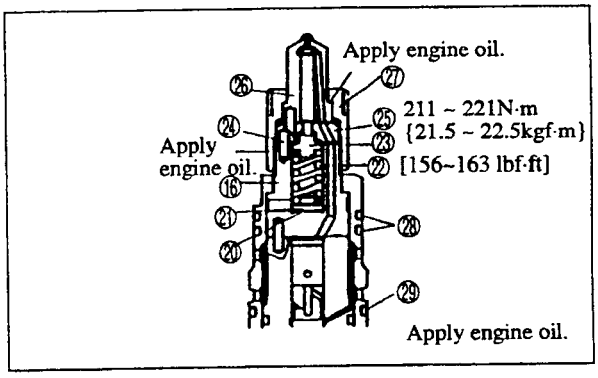
(b) Install dowel pin ㉔ into the spring cage. Install distance piece ㉕.

(c) Insert the dowel pin into the distance piece. Install nozzle tip ㉖.

(d) Tighten nozzle retaining nut ㉗ to the specified torque using the two-time tightening method. (Loosen the nut until it can be turned by hand before tightening second time to the specified torque.)

**NOTE:** Before tightening the nozzle retaining nut, apply engine oil to the threads and the shoulder section of the nozzle tip. Be sure to tighten to the specified torque. Excessive tightening force can result in nozzle needle valve sticking, while insufficient tightening force can cause fuel leaks.

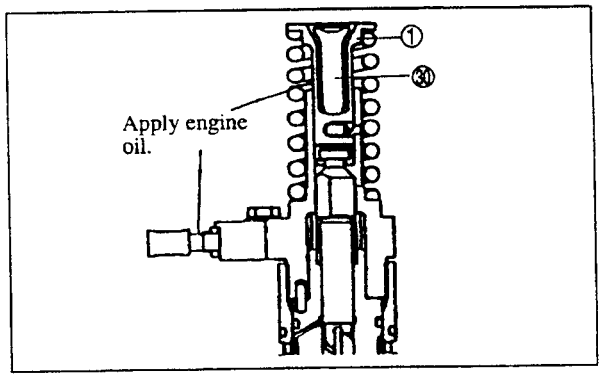
(e) Install new O-rings ㉘, ㉙, and apply engine oil.




**(8) Installing plunger push rod**

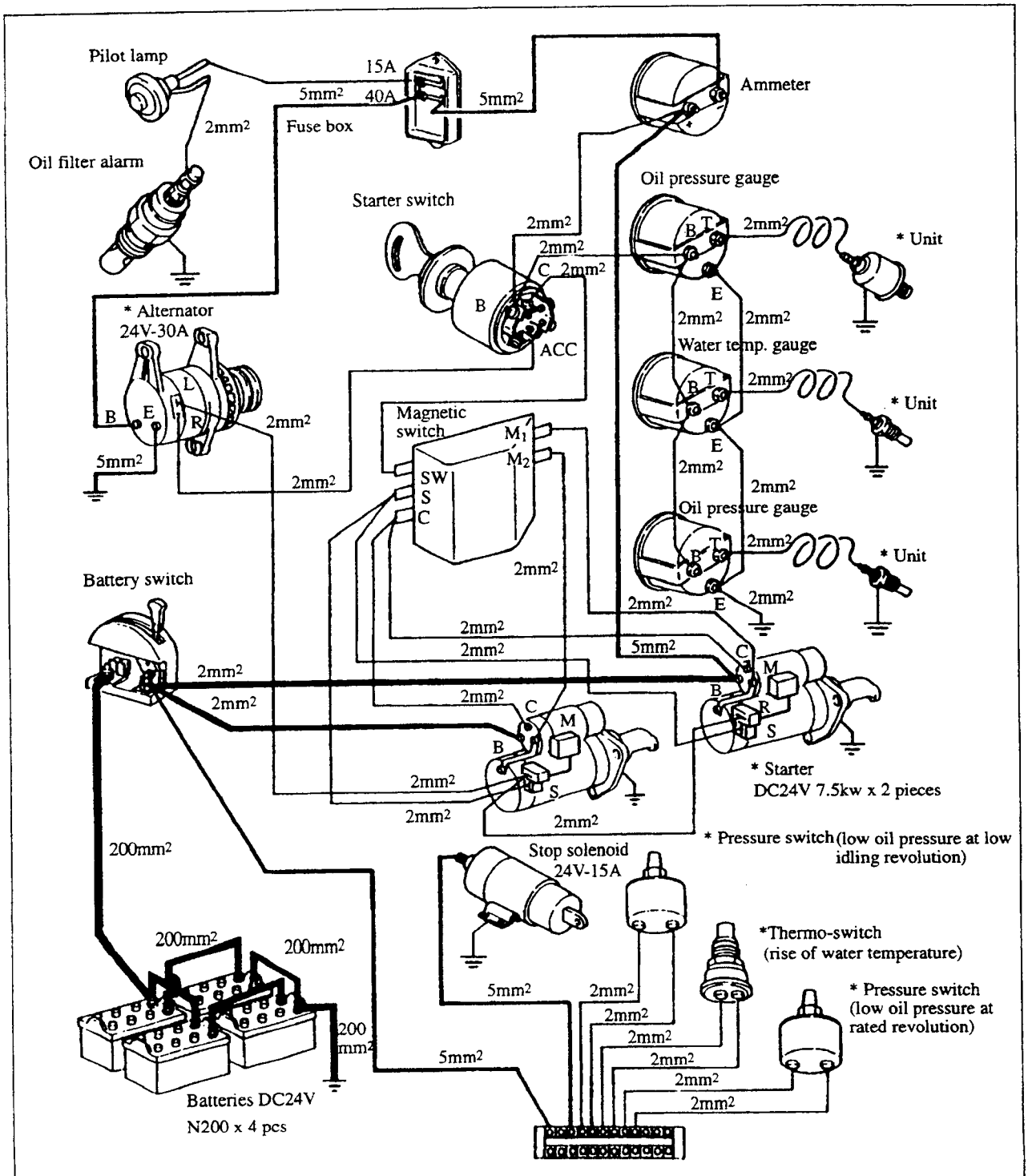
Install plunger push rod ㉚ to plunger tappet ①.

**NOTE:** Apply engine oil to sliding surfaces of the plunger tappet and control rack ⑧.



# ELECTRICAL SYSTEM

# 1. DESCRIPTION




**Remark**: (a) The circuit shown above is for standard model. The circuit varies from one specification and application of the engine to another.

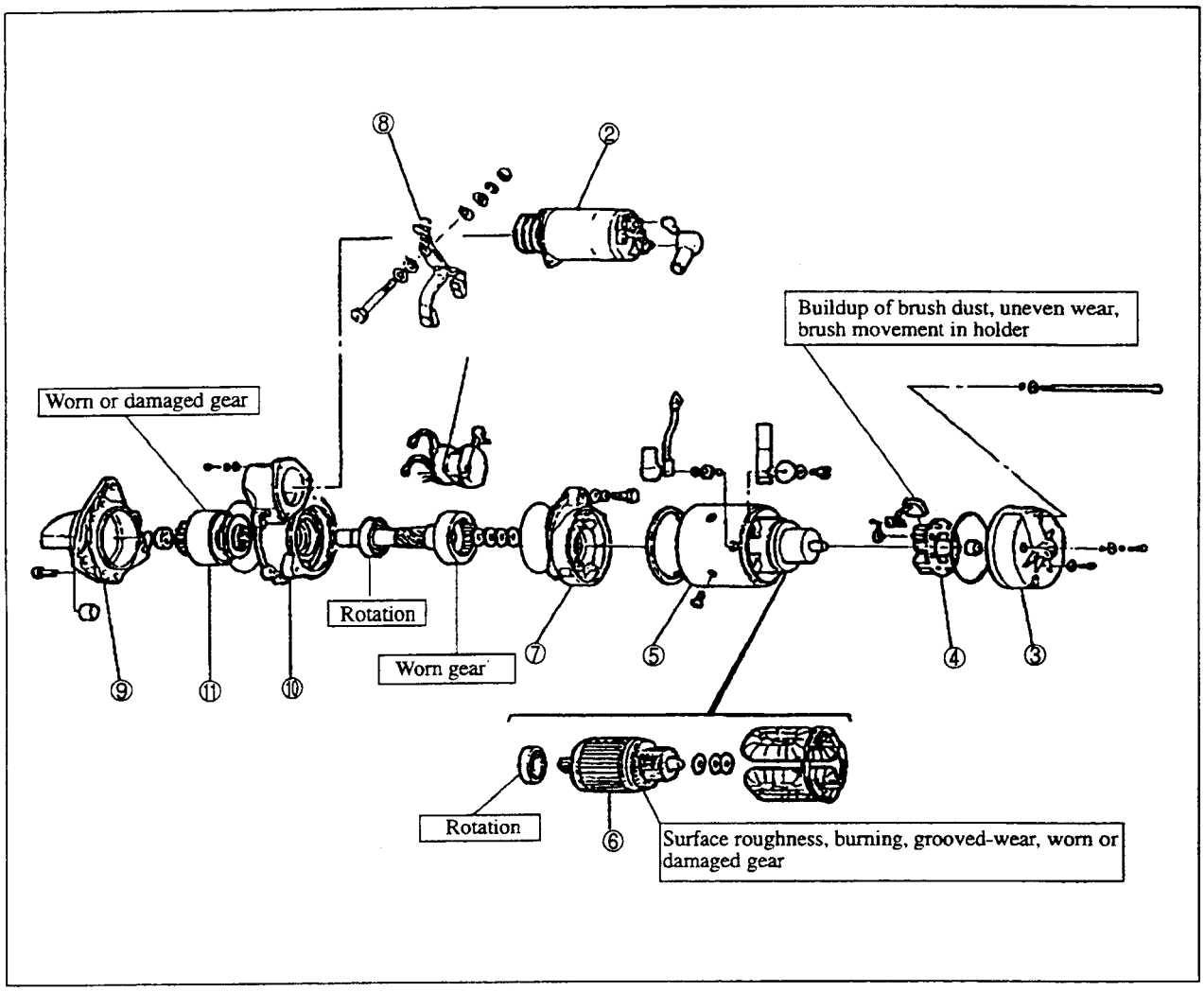
(b) Wiring involved in the circuit is to be prepared in field.

(c) Items bearing asterisk (*) furnished with the engine. Items bearing no mark are to be supplied individually.

Wiring diagram

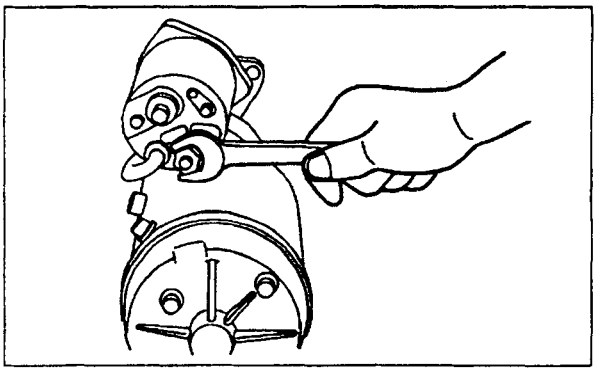
## 2. STARTER

### 2.1 Disassembly

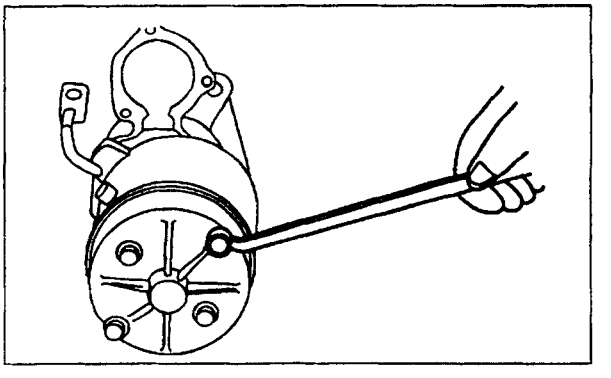



① Safety switch
② Magnetic switch assembly
③ Rear bracket
④ Brush holder assembly
⑤ Yoke assembly
⑥ Armature assembly
⑦ Center bracket
⑧ Lever assembly
⑨ Front bracket
⑩ Pinion case
⑪ Pinion clutch assembly

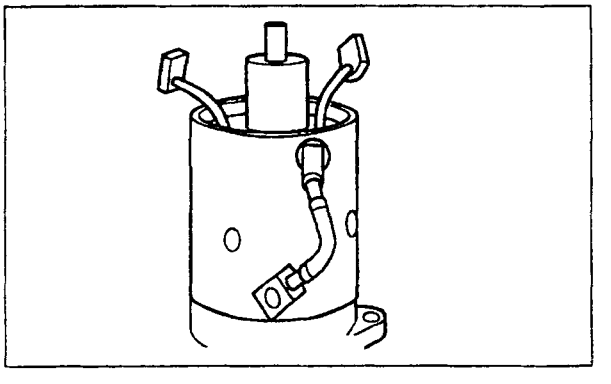
(1) After removing the safety switch, disconnect the lead wire, and remove the magnetic switch.



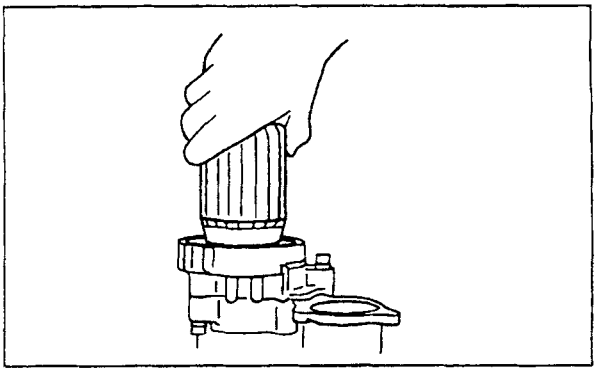
(2) Unscrew the through bolts and the brush holder mounting screws, and remove the rear bracket.



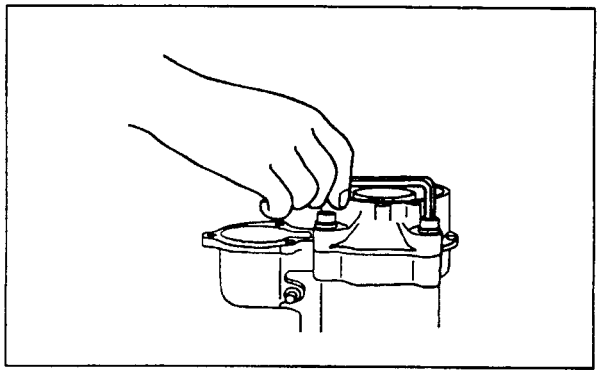
(3) Remove the brushes from the brush holder assembly, and take off the yoke.



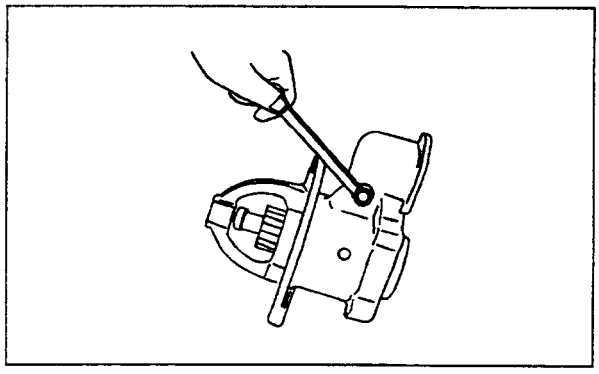
(4) Withdraw the armature assembly.



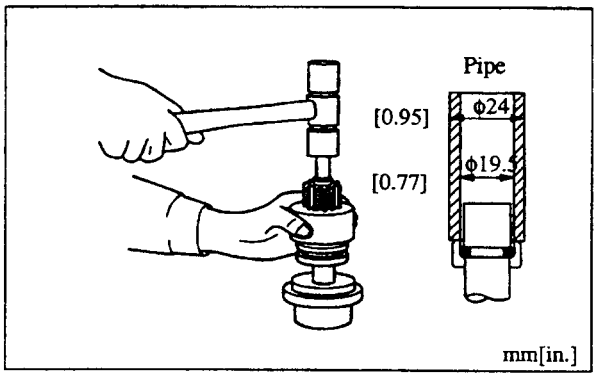
(5) Remove the center bracket.



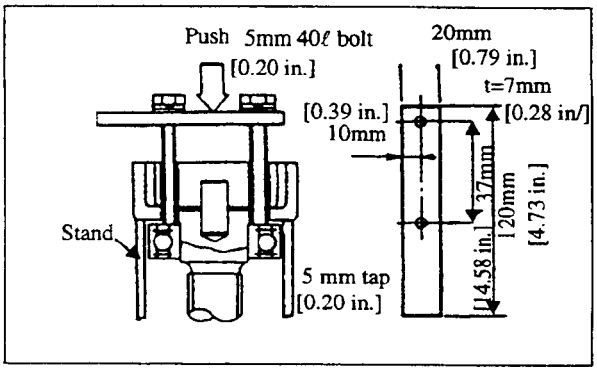
(6) Remove the lever pin, the inner housing and the shift lever from the pinion case.



(7) Using a jig, remove the pinion stopper, then, remove the overrunning clutch from the pinion shaft.




**NOTE**: Use a bearing puller of the type shown to remove the pinion shaft bearing for replacement.

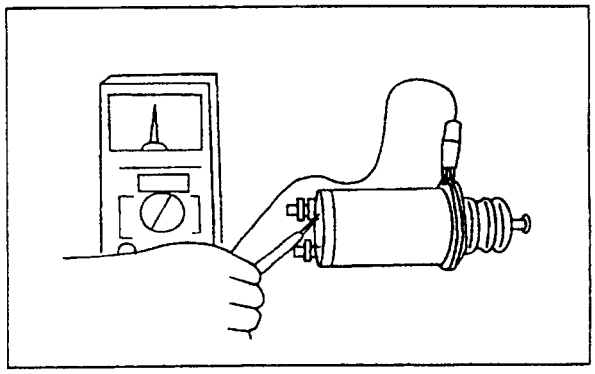


## 2.2 Inspection and repair

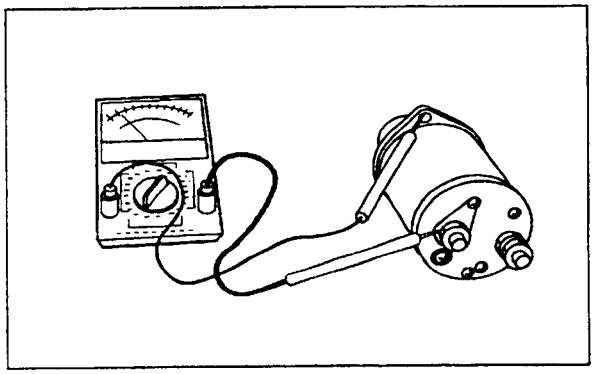
### Magnetic switch

**(1) Testing magnetic switch coil**

(a) Test the pressure coil and the holding coil for open circuit. The coils are open-circuited if there is no continuity between the terminal "M" of magnetic switch and the case.

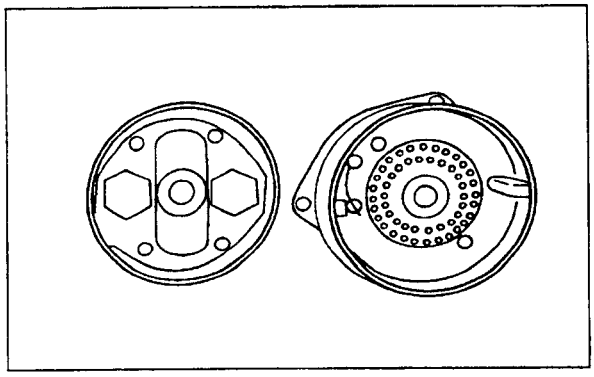


(b) Apply 24 volts between the terminal "M" of magnetic switch and the case. Under this condition, push in the plunger by hand. The plunger should not be attracted when the hand is released.



(2) Mμeasure the load current flowing through the starter. If the voltage drop between the terminals "B" and "M" exceeds 0.3 volt per 100 amperes of current, polish or replace the contact points.

**NOTE**: If the starter switch is turned to OFF during voltage measurement, the battery voltage is directly applied to the voltmeter and damage it. With this kept in mind, be sure to turn the starter switch to ON before measuring the voltage and turn it to OFF after measuring the voltage.



**⚠CAUTION**

**Under no circumstances should only the magnetic switch be tested.**

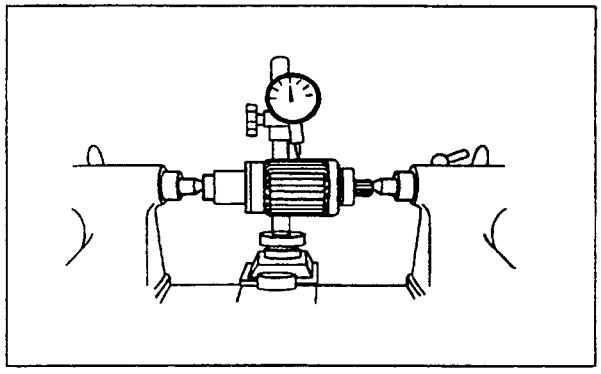
## Armature

### (1) Inspecting armature shaft for runout

Measure the runout with a dial gauge. If the runout exceeds the assembly standard, repair or replace the armature.

Unit: mm [in.]

| | Assembly standard |
|---|---|
| Armature shaft runout | 0.05 [0.002] |



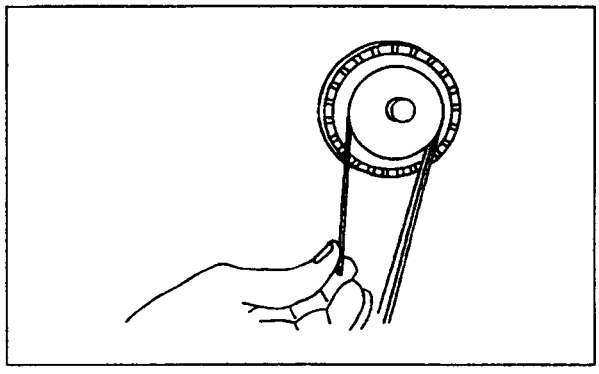
### (2) Inspecting commutator

(a) Check the commutator surface for condition. If the surface is rough, polish it with #400 to # 600 sandpaper.

Also check the commutator for runout with a dial gauge. Replace the commutator if the runout exceeds the service limit.

Unit: mm [in.]

| | Assembly standard | Service limit |
|---|---|---|
| Commutator runout | 0.015 [0.0006], maximum | 0.100 [0.004] |



(b) Using a depth gauge, measure the depth of each mica undercut. If the depth exceeds the repair limit, recondition the mica.

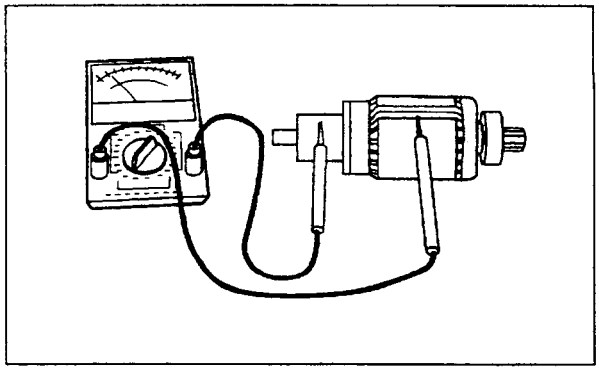
Unit: mm [in.]

| | Assembly standard | Repair limit |
|---|---|---|
| Commutator mica depth | 0.5 ~ 0.8 [0.02~0.03] | 0.2 [0.008] |

### (3) Testing armature

(a) Test the armature for short circuits on a growler. If the hacksaw blade vibrates against the core, replace the armature.

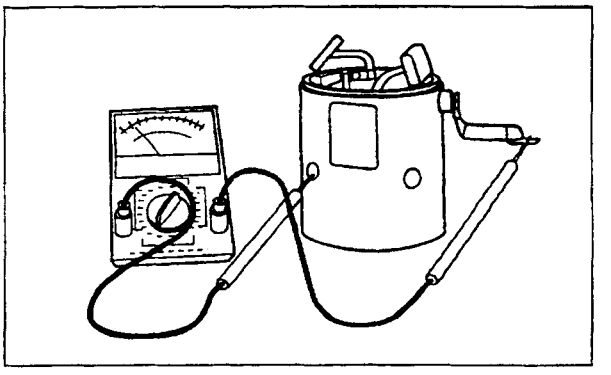
(b) If there is continuity between the commutator and the shaft, replace the armature.



### Field coil

**(1) Testing for open circuit**

If there is no continuity between the terminal "M" of field coil and the brush-side lead wire, replace the field coil. If there is continuity between the field coil and the yoke, replace the field coil.



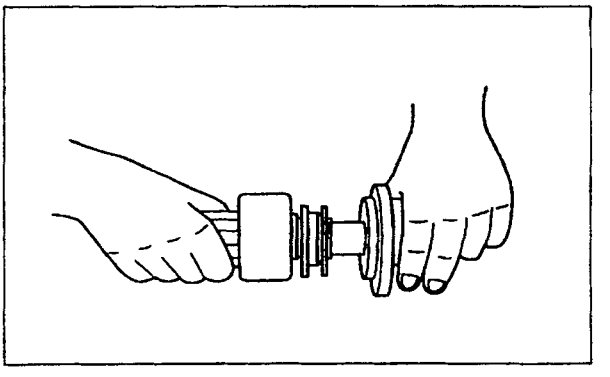
### Overrunning clutch

The clutch is in good condition if it rotates freely in one direction when turned by hand.

Check the pinion teeth for wear or damage, and replace the pinion if they are damaged.

**⚠CAUTION**

**Do not immerse the overrunning clutch in cleaning solvent when cleaning the clutch. This will cause grease to flow out from inside the clutch, resulting in seizure of clutch parts.**



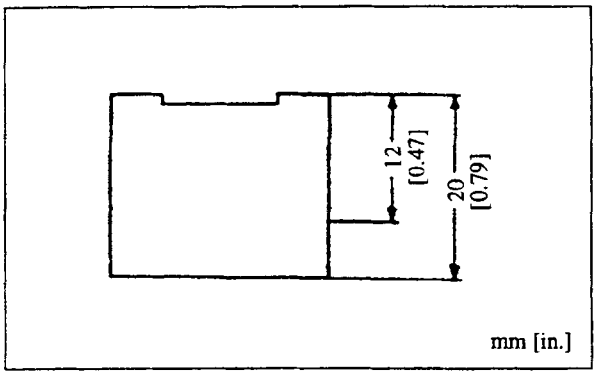
### Brush

**(1) Inspecting for wear**

Unit: mm [in.]

| | Assembly standard | Service limit |
|---|---|---|
| Brush height | 20 [0.79] | 12 [0.47] |

If the brushes are unevenly worn or roughened, recondition them.




mm [in.]

**(2) Testing brush spring tension**

Unit: N (kg·f) [lbf]

| | Assembly standard | Service limit |
|---|---|---|
| Brush spring tension (when installed) | 39.2 ~ 49.0 (4.0 ~ 5.0) [8.82~11.02] | Less than 39.2 (4.0) [8.82] |

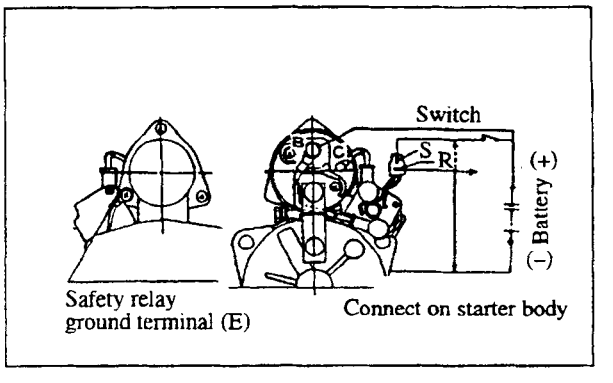
### Safety switch

Connect the wires as shown, and test the starter and safety switch.

(1) Connect the terminal "R" to the negative (-) terminal of the battery.

(2) Close the switch to make sure that the starter runs.

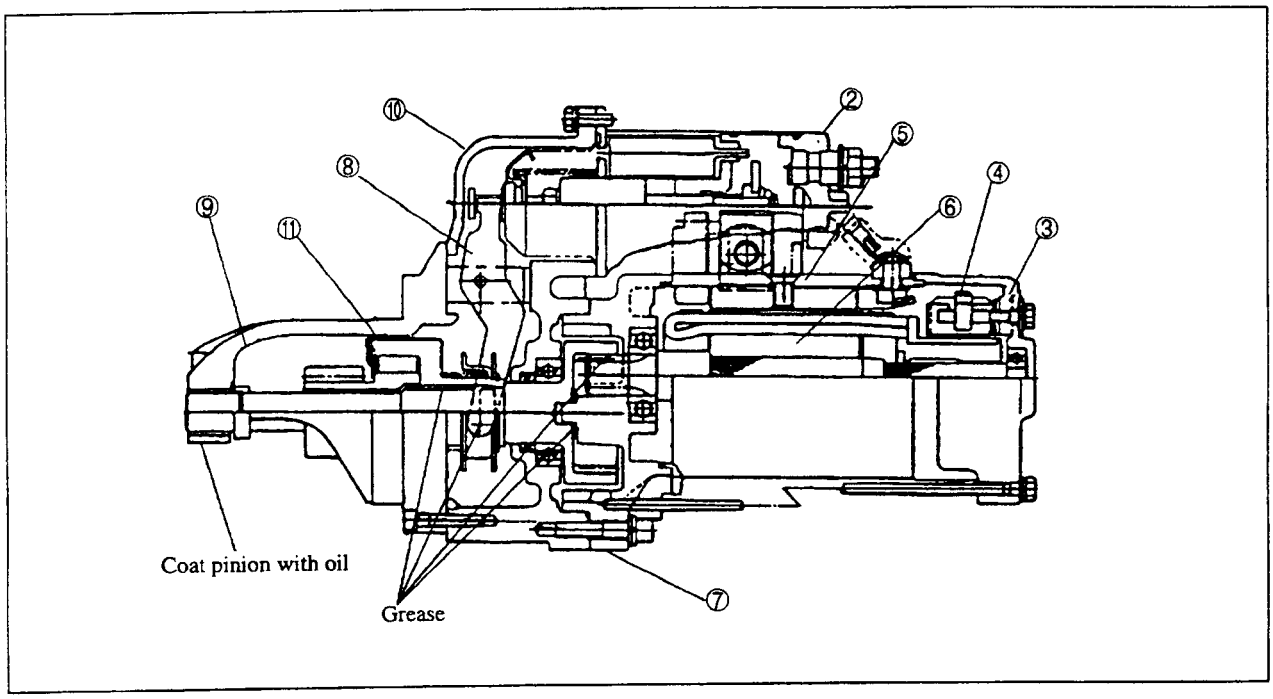
(3) Make sure that the starter stops running when the terminal "R" is disconnected from the negative (−) terminal of the battery, or when it is reconnected to the positive (+) terminal of the battery after disconnecting it.




**⚠CAUTION**

**Make sure that the polarity of each battery cable is correct when connecting the wires.**

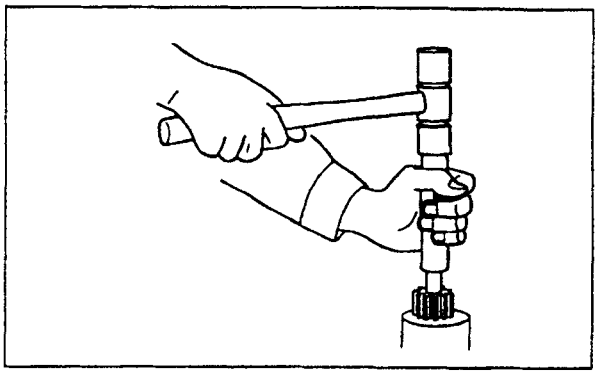
## 2.3 Reassembly



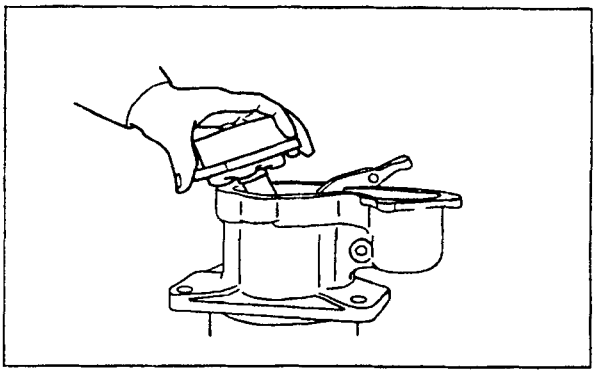

Reassembling sequence

⑩→⑨→⑪→⑧→⑦→⑥→⑤→④→③→②→①

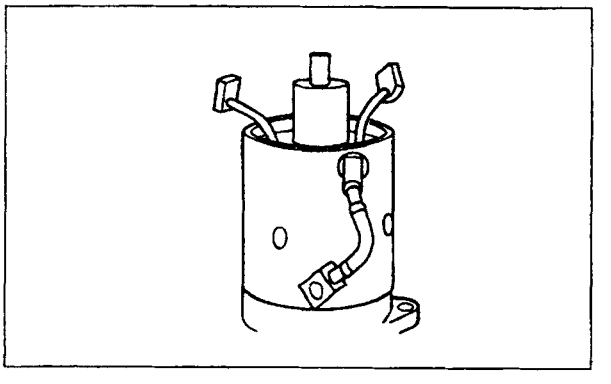
(1) Install the center bracket, the overrunning clutch and the pinion stopper to the pinion shaft, and insert the shaft into position by tapping with a plastic hammer.



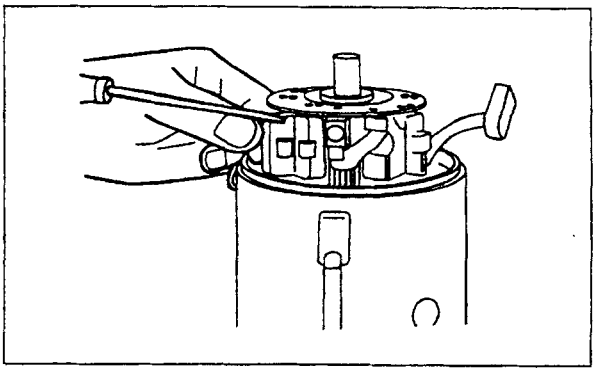
(2) Install the shift lever and the pinion shaft to the front bracket by aligning matching mark on the shift lever.



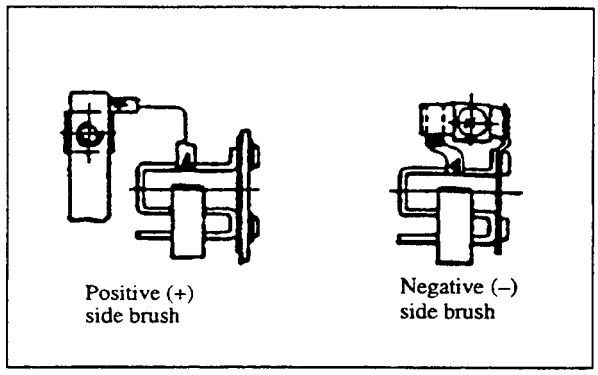
(3) Install the armature and the yoke to the center bracket, making sure that the dowel pin enters its hole.



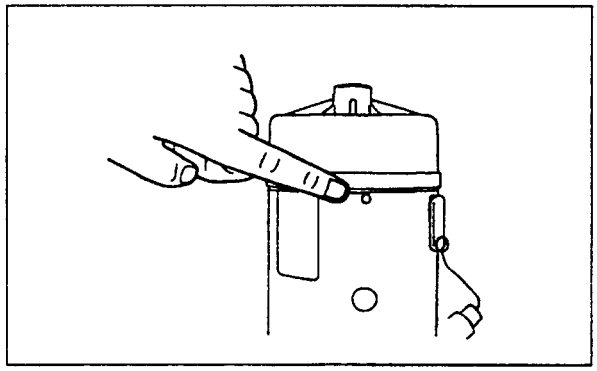
(4) Install the brushes and the brush holders.



**NOTE**: Install the positive (+) side brush and the negative (–) side brush as shown.




(5) Install the rear bracket to the yoke by aligning matching marks, secure the brush holders with bolts, and tighten the through bolts.

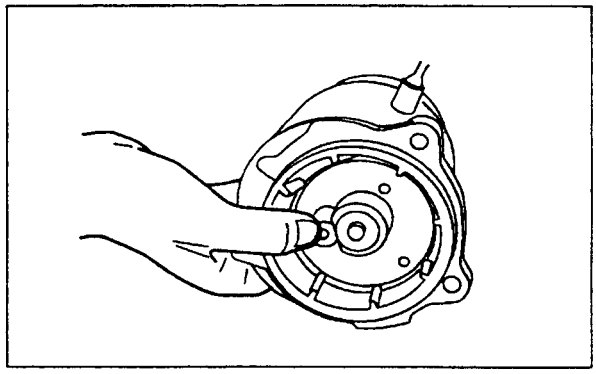


(6) Measure the end play of the armature. If the end play exceeds the assembly standard, adjust it on the rear side.

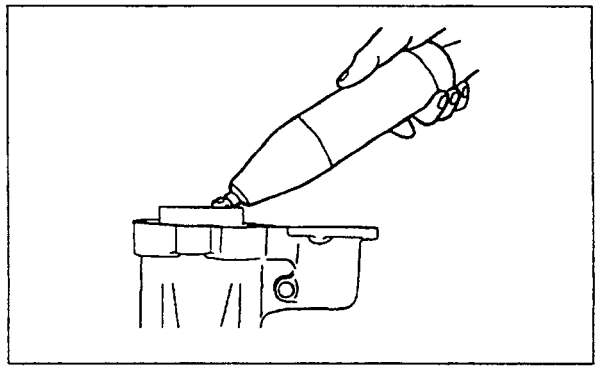
Test the motor to make sure that the voltage and the current are below 24 volts and 90 amperes respectively.

Unit: mm [in.]

| | Assembly standard |
|---|---|
| Armature end play | 0.2 ~ 0.6<br>[0.008~0.024] |



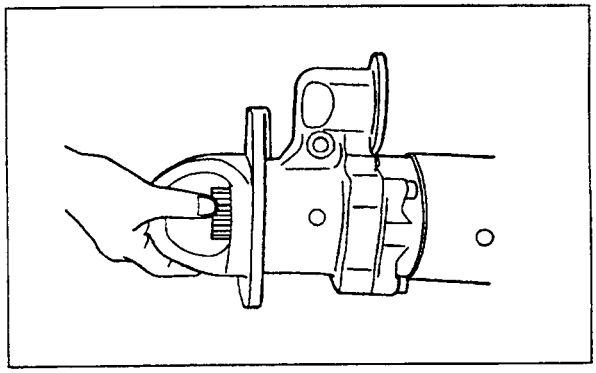
(7) Liberally coat the internal gear with grease, and install the pinion shaft to the gear.



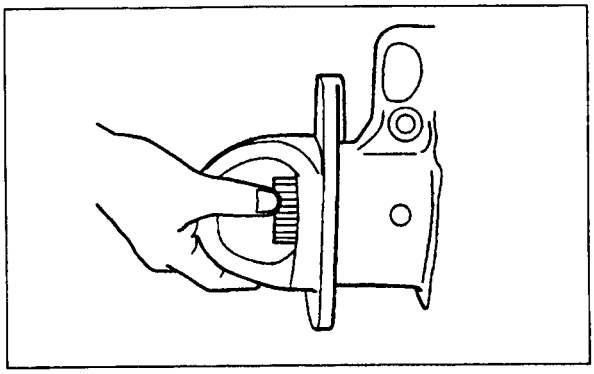
(8) Measure the end play of pinion shaft. If the end play exceeds the assembly standard, adjust it on the terminal gear side.

Unit: mm [in.]

| | Assembly standard |
|---|---|
| Pinion shaft end play | 0.2 ~ 0.6<br>[0.008~0.024] |

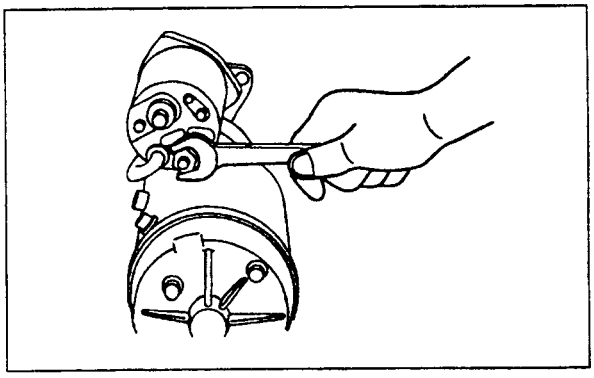


(9) Install the magnetic switch. Apply 24 volts between the terminals "C" and "E", connect the lead wire and energize the circuit between the terminals "M" and "E" (within 1 second). After the pinion has shifted, measure how much the pinion returns. If the measurement is not 1.5 to 5 mm [0.06~0.20 in.], make an adjustment by means of the magnetic switch adjusting screw.



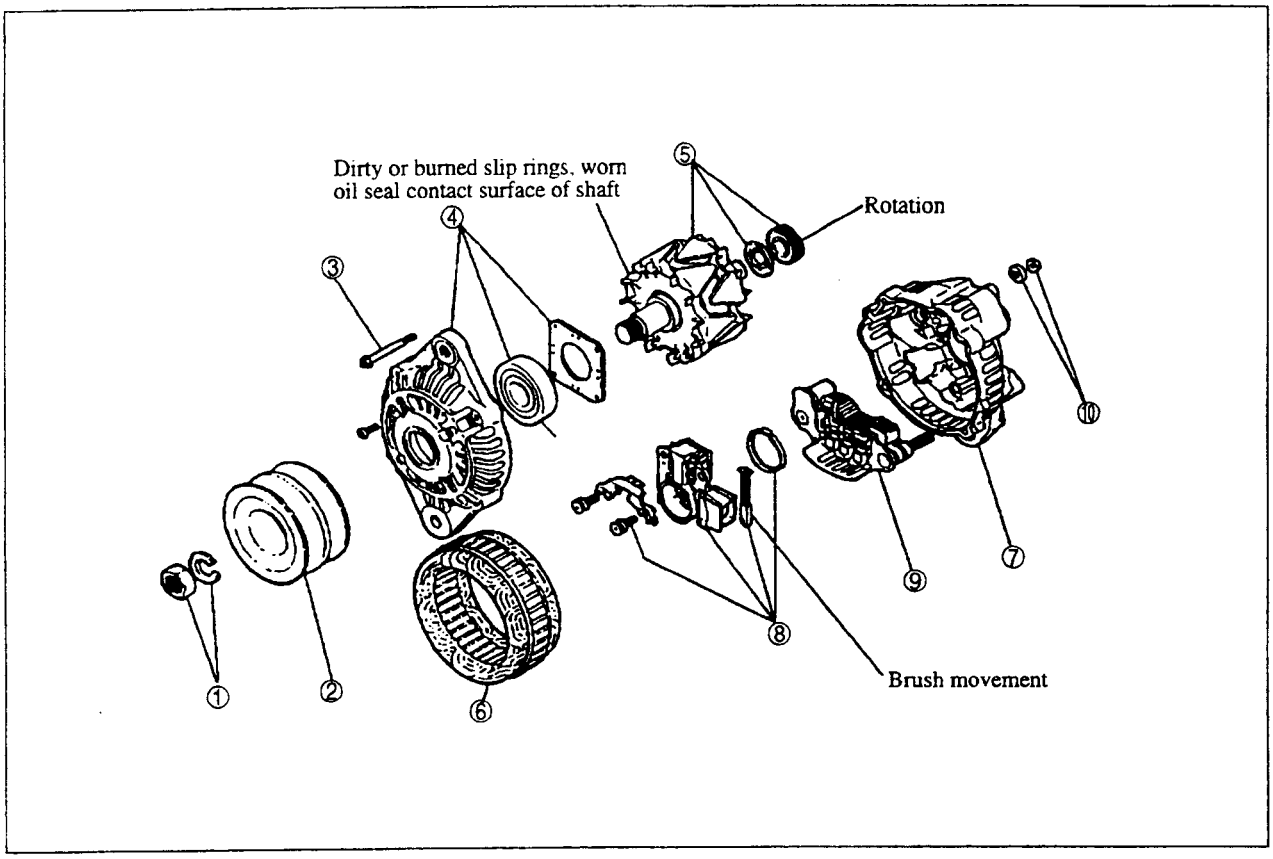
(10) Secure the lead wire.

(11) Install the safety switch.



# ALTERNATOR

## 3.1 Disassembly




① Nut, washer
② Pulley
③ Screw
④ Front bracket assembly
⑤ Rotor assembly
⑥ Stator
⑦ Rear bracket
⑧ Regulator assembly
⑨ Rectifier assembly
⑩ Nut set

## 3.2 Inspection and repair

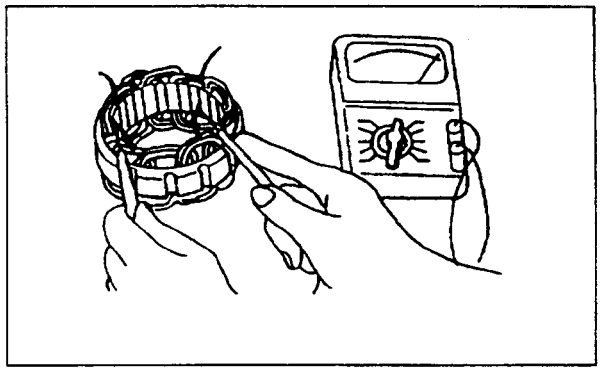
### (1) Stator

**(a) Testing stator coil for open circuit**

If there is no continuity among four lead wires, replace the stator.

**(b) Testing stator coil for grounding**

If there is continuity between the coil and the core, replace the stator.



Inspecting stator coil

### (2) Rotor

#### (a) Testing rotor coil for open circuit

If there is no continuity between the slip rings, replace the rotor.

#### (b) Testing rotor coil for grounding

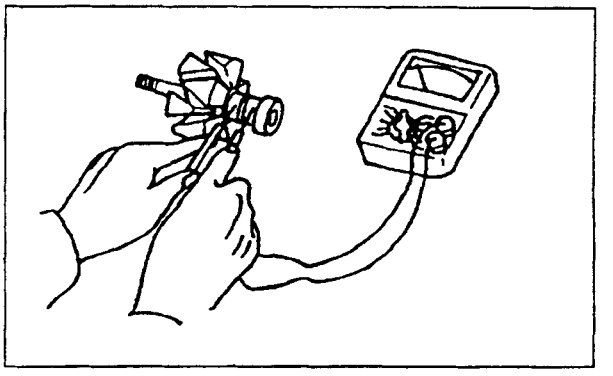
If there is continuity between the slip rings and the shaft (or core), replace the rotor.

#### (c) Measure slip ring outside diameter

Using calipers, measure the outside diameter of each slip ring. If the diameter exceeds the service limit, replace the slip ring.

Unit: mm [in.]

| | Assembly standard | Service limit |
|---|---|---|
| Slip ring outside diameter | 40.8 ~ 41.2 [1.61~1.62] | 40.6 [1.60] |



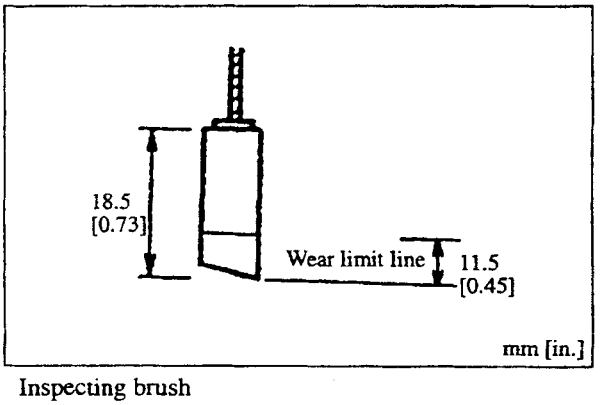
Inspecting field coil

### (3) Brush and brush spring

#### (a) Wear of brush

Unit: mm [in.]

| | Nominal value | Service limit |
|---|---|---|
| Brush height | 18.5 [0.73] | 11.5 [0.45] |




Inspecting brush

#### (b) Brush spring tension

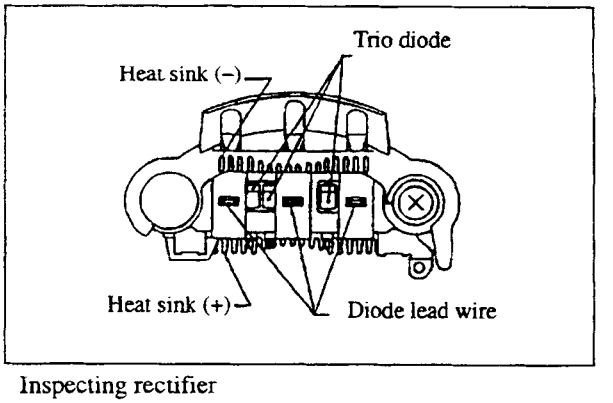
Unit: N (gf) [lbf]

| | Assembly standard | Service limit |
|---|---|---|
| Brush spring tension | 3.1 ~ 4.3 (320 ~ 440) [0.7~1.0] | 2.0 (200) [0.45] |

### (4) Inspecting rectifier

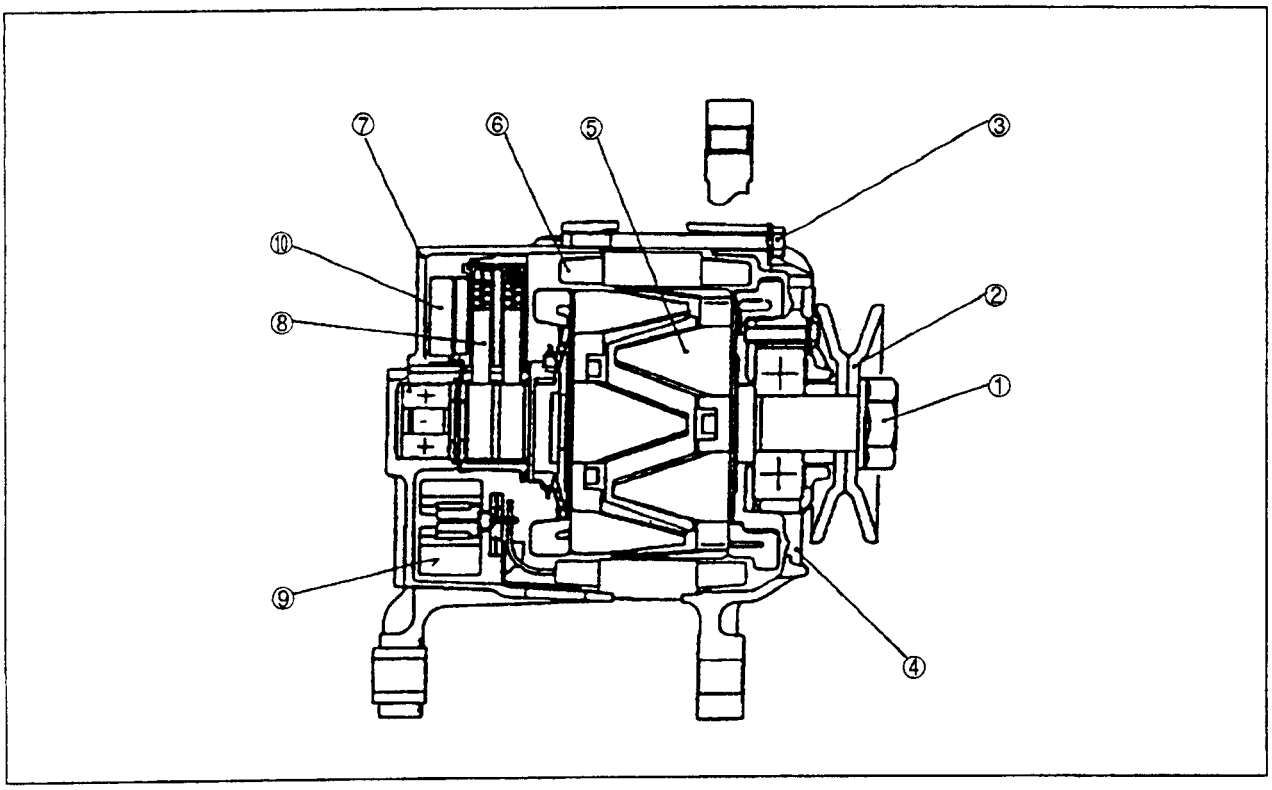
Check the resistance between the diode lead wire and the heat sink for each diode. Take measurements when the positive (+) side of the test lead wire is connected to the diode and when the negative (–) side is connected to the diode. If the resistance is infinite, the circuit is open. If the resistance is close to 0, the circuit is shorted.

If the circuit is open or shorted, replace the rectifier because the diode is defective.




Inspecting rectifier

### 3.3 Reassembling

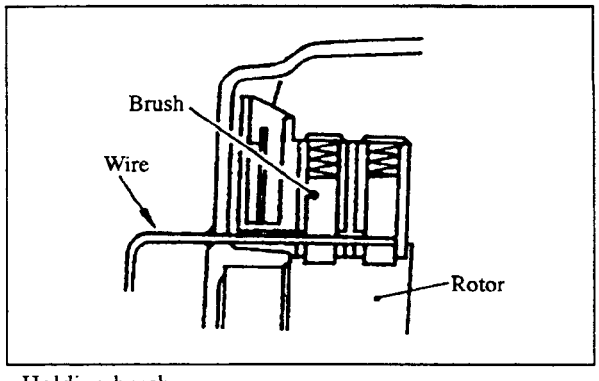



Reassembling sequence

⑦→⑩→⑨→⑧→⑥→⑤→④→③→②→①

**(1) Holding brush for installing rotor**

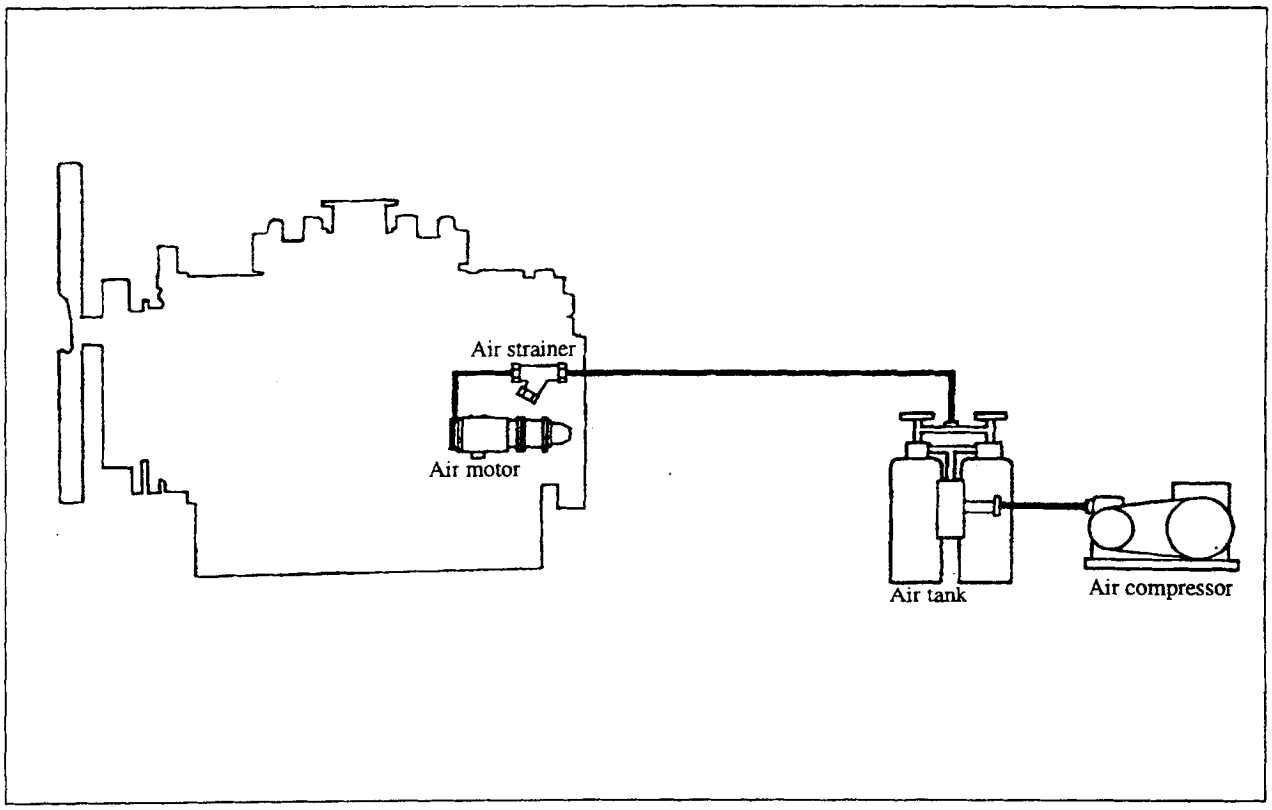
Push the brush into the holder, and hold it there, using a piece of wire as shown in the right. Then, install the rotor. Be sure to remove the wire after installing the rotor.




Holding brush

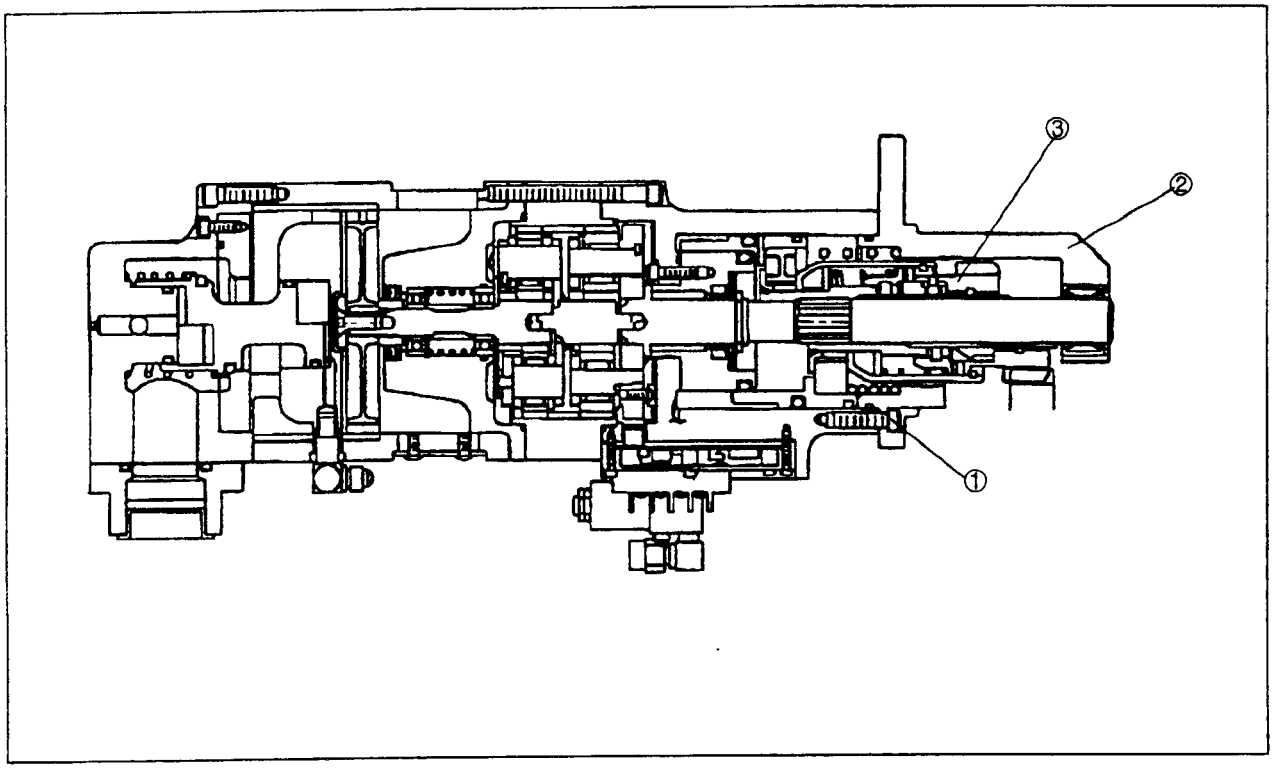
# AIR START SYSTEM

# 1. DESCRIPTION OF AIR MOTOR SYSTEM



## 2. AIR MOTOR

### 2.1 Disassembly and reassembly



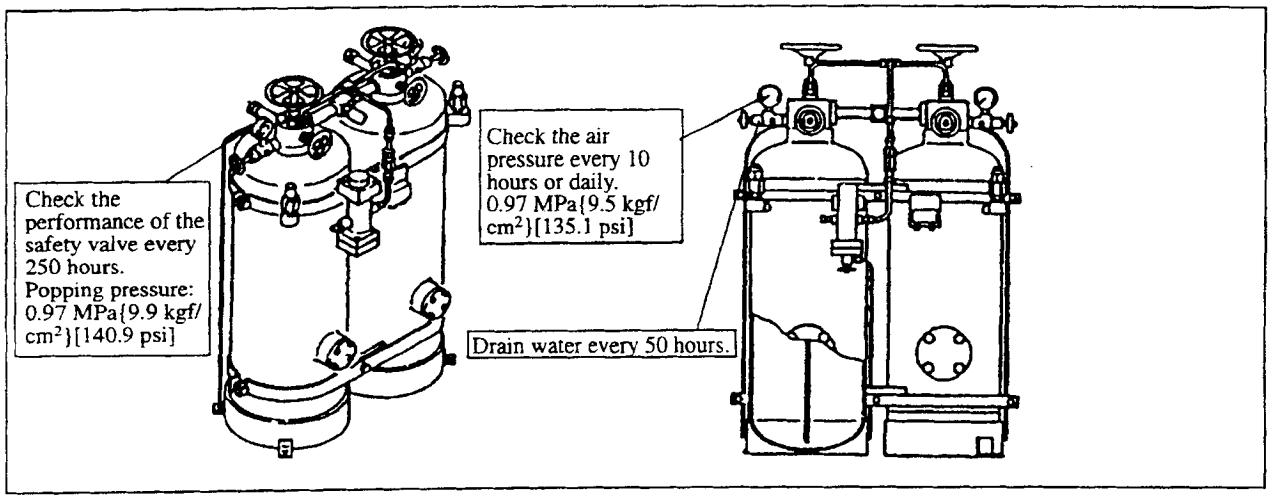

① Bolt
② Pinion case
③ Clutch assembly

### 2.2 Inspection

Clean each part of the air motor and check for wear and damage. If the part is worn, replace it.

Replace the clutch assembly together with the pinion assembly.

## 3. AIR TANK
### Inspection



# Others

# 1. DISASSEMBLY AND REASSEMBLY OF GENERAL PARTS

## 1.1 Oil seals

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

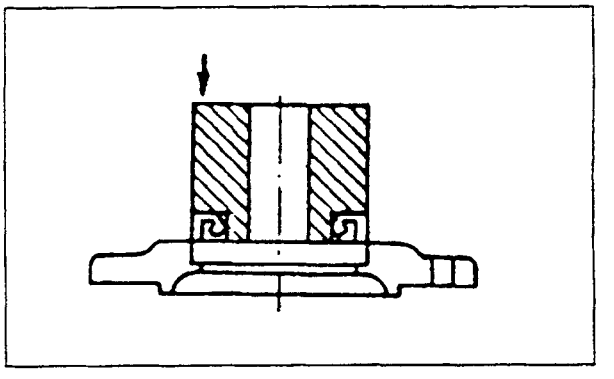
**When installing oil seals into housings**

(a) Check the lip surface for scratches and damage, and position the lip in the correct direction.

(b) Apply a small amount of grease to the periphery (housing contact area) of the seal before installation.

(c) To install a seal, use a special tool (similar to the one shown in the diagram on the right) that guides the seal lip and presses the seal uniformly, and tap the tool straight down on the seal.

Do not hit a seal directly with a hammer, since it can damage the seal and lead to oil leakage.

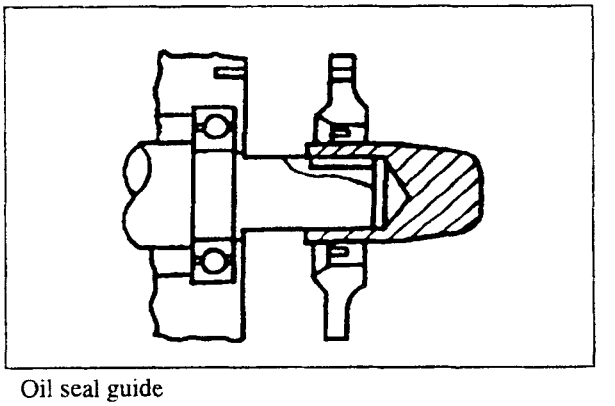


Oil seal driver

**When installing seals on shafts**

(a) Apply grease to the seal lip surface.

(b) When installing a seal on a ridge, spline, threaded section or key groove, use a guide (similar to the one shown in the diagram on the right).

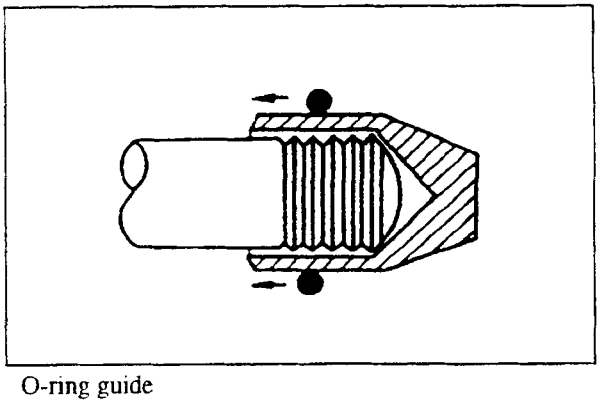


Oil seal guide

## 1.2 O-rings

When installing an O-ring on a ridge, spline, threaded section or key groove, use a guide.

Also, apply a small amount of grease to the O-ring.



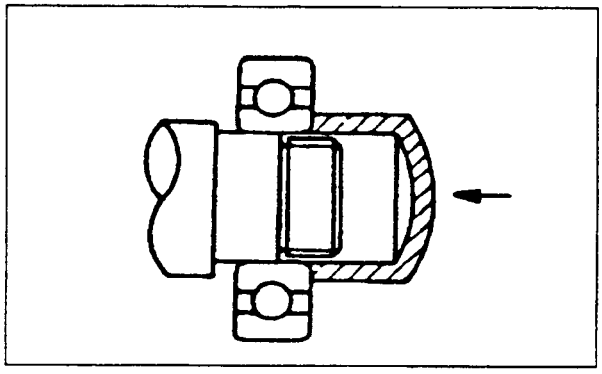
O-ring guide

### 1.3 Bearings

(a) When installing a bearing, be sure to press the race that is fitted to the part.

(When an inner race is fitted to the part, press the inner race. When an outer race is fitted to the part, press the outer race.)

Be sure to use a bearing driver that contacts the race to be fitted.

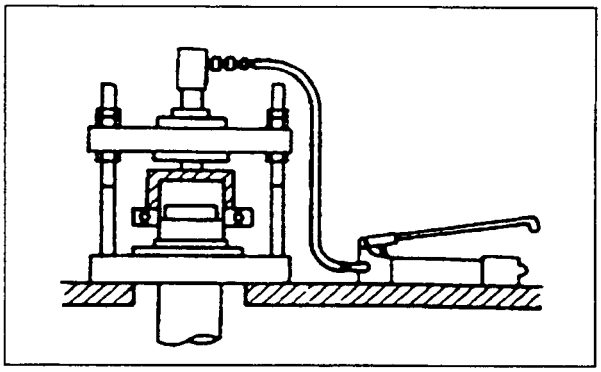


(b) Use of a press minimizes impact to the bearing and assures proper installation.

### 1.4 Lock plates

Be sure to bend lock plates firmly against flats of nuts or bolt heads.

Good and bad examples of lock plate bending are shown in the diagram on the right.

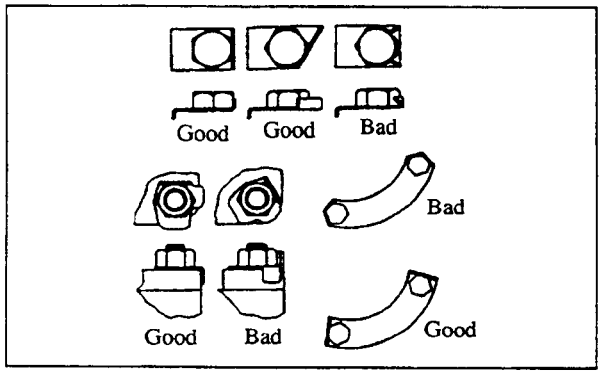


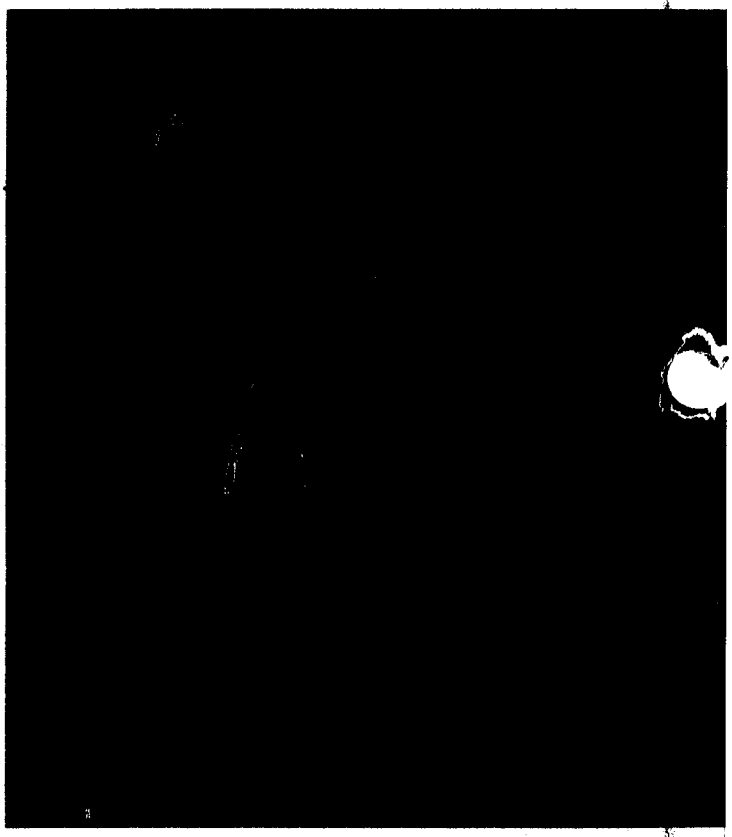
### 1.5 Split pins and spring pins

As a general rule, removed split pins should not be reused.

When installing a split pin, be sure to separate and bend the two pieces of the pin sufficiently.

When installing a spring pin, be sure to drive it firmly in place.





March 1999
Printed in Japan

Pub. No. 99269-03100

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POWER SYSTEMS, INC.