Open front screen

INDUSTRIAL
DIESEL ENGINE

AA-6SD1T
MODEL

WORKSHOP MANUAL

ISUZU MOTORS LIMITED

Foreword

This Workshop Manual has been prepared as a guide for the service and repair of the Model AA-6SD1T diesel engine.

A general table of contents is shown on the following page, and more detailed subsections are listed at the beginning of each respective chapter.

This manual was first prepared in April, 2001, but subsequent changes in design may result in modifications to certain values and other information in this Manual.

TABLE OF CONTENTS

Note:
Before using this manual to perform maintenance and repairs, be sure to read the section "General Servicing Precautions" included in Chapter 1 (General Information).

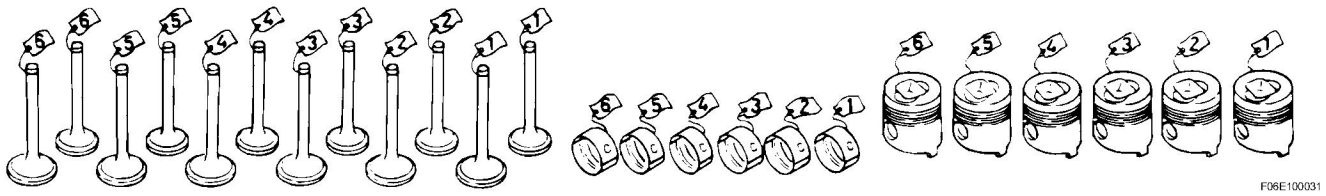
CHAPTER 1

GENERAL INFORMATION

CONTENTS

GENERAL SERVICING PRECAUTIONS

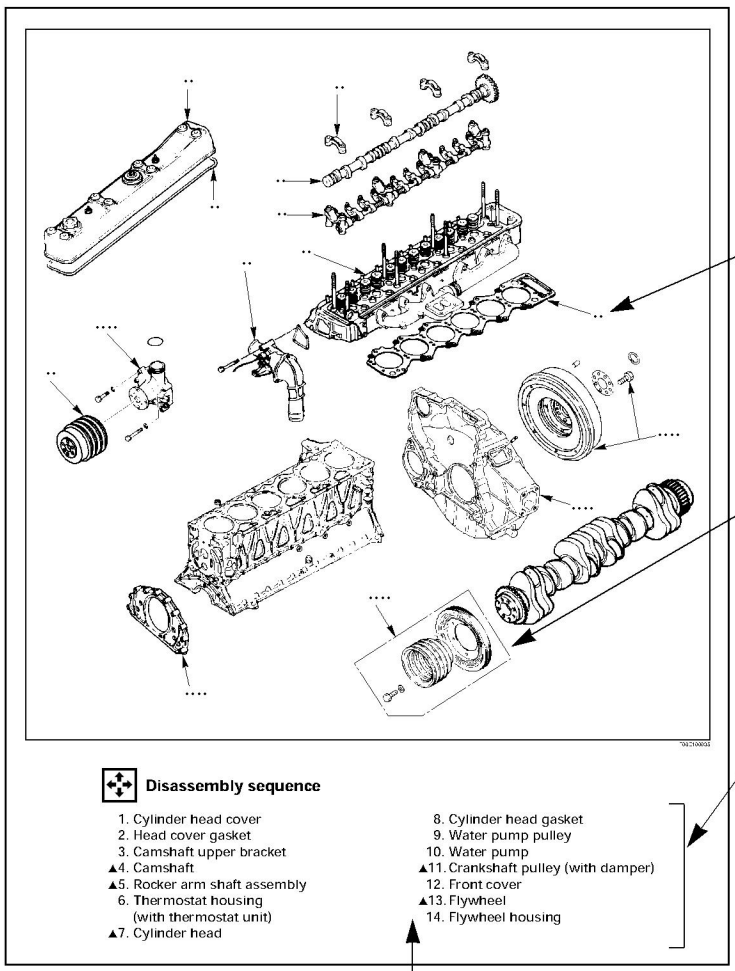
1. Before performing any inspections or maintenance work, disconnect the battery's ground cable to prevent any damage from shorted wires.
2. Always use the proper tool for the job.
   When a special tool is designated for a job, be sure to use only that special tool.
3. When replacement parts are required, consult the appropriate Isuzu parts catalog and use only "Genuine Isuzu Parts."
4. Never reuse any cotter pins, gaskets, seals, o-ring, lock washers, or self-locking nuts removed in the course of disassembly.
5. To facilitate reassembly, lay out engine parts in logical groups in the order in which they are removed. Be especially careful to replace nuts and bolts in their proper locations, since characteristics such as length and hardness may differ depending on the installation position.
6. Use identification labels or tags to mark valves, bearings, and pistons, to prevent confusing their proper order and sequence.



7. Clean all parts before inspection and reassembly.
   Be particularly sure to use compressed air to blow out oil ports and openings, to assure that they are free of obstructions.
8. Be sure to apply oil or grease as appropriate to all rotating and sliding surfaces before reassembly.
9. Use sealants to prevent leaks where necessary.
10. Tighten all nuts and bolts to specified tightening torques.
11. After completing inspections and repairs, double check your work to confirm that the job has been done properly.

NOTES ON THE FORMAT OF THIS MANUAL

1. Use the Table of Contents at the beginning of the Manual to find the general areas required.
2. Common technical data such as general maintenance, repair specifications, and tightening torques are listed in the General Information chapter.
3. Each chapter is composed of "disassembly, inspection" and "repair, assembly" sections. the only exception is the treatment of the engine body itself, which is divided into three independent chapters for ease of explanation.
4. When similar maintenance procedures are applicable to multiple operations or parts, the manual will cross-reference the page where the appropriate information can be found.
5. To provide brevity and conciseness, simple disassembly and repair operations are omitted, while more space is devoted to explaining complex procedures such as adjustments and tightening torques.
6. The descriptions given in each chapter begin with an exploded diagram of the applicable parts, with numbers indicated as shown below.

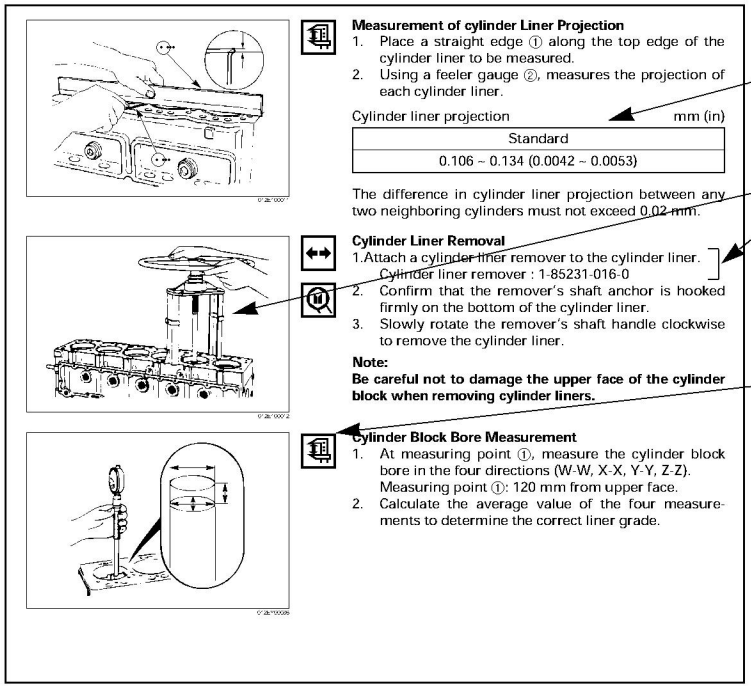


Disassembly sequence

1. Cylinder head cover
2. Head cover gasket
3. Camshaft upper bracket
▲4. Camshaft
▲5. Rocker arm shaft assembly
6. Thermostat housing (with thermostat unit)
▲7. Cylinder head
8. Cylinder head gasket
9. Water pump pulley
10. Water pump
▲11. Crankshaft pulley (with damper)
12. Front cover
▲13. Flywheel
14. Flywheel housing

- This number indicates the sequence of the procedure.
- Items enclosed in a frame are removed and installed as a single unit, and the order of disassembly and reassembly is indicated in the illustration.
- Parts listed beneath "Disassembly Steps" or "Assembly Steps" are listed in the sequence in which they are removed or assembled.
- The triangle mark ▲ indicates a particularly important part or operation, and is accompanied by detailed instructions in the text.

7. The following is a sample of the text in the Workshop Manual.



Measurement of cylinder Liner Projection

1. Place a straight edge ① along the top edge of the cylinder liner to be measured.
2. Using a feeler gauge ②, measures the projection of each cylinder liner.

Cylinder liner projection mm (in)

Standard
0.106 ~ 0.134 (0.0042 ~ 0.0053)

The difference in cylinder liner projection between any two neighboring cylinders must not exceed 0.02 mm.

Cylinder Liner Removal

1. Attach a cylinder liner remover to the cylinder liner.
   Cylinder liner remover : 1-85231-016-0
2. Confirm that the remover's shaft anchor is hooked firmly on the bottom of the cylinder liner.
3. Slowly rotate the remover's shaft handle clockwise to remove the cylinder liner.

Note:
Be careful not to damage the upper face of the cylinder block when removing cylinder liners.

Cylinder Block Bore Measurement

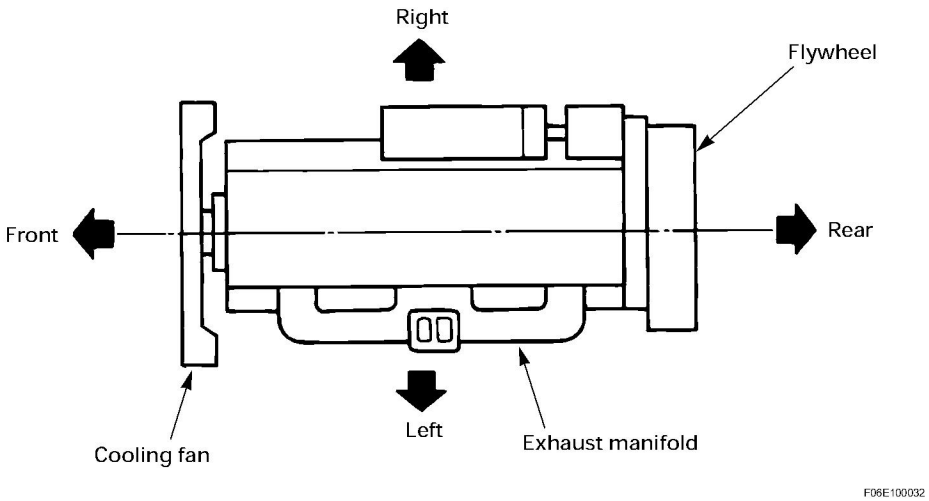
1. At measuring point ①, measure the cylinder block bore in the four directions (W-W, X-X, Y-Y, Z-Z).
   Measuring point ①: 120 mm from upper face.
2. Calculate the average value of the four measurements to determine the correct liner grade.

- These tables indicate repair standards.
- Special tools are identified by name and/or number. The illustration also indicates the proper procedure for using the special tool.
- Symbols indicate the type of operation or sequence to be performed. A detailed explanation of these symbols is given below.

8. The following symbols appear throughout this Manual, indicating the type of service operation or procedure to be performed.

....	Removal	....	Adjustment
....	Installation	....	Cleaning
....	Disassembly	...	Important operation; special care required
....	Assembly	....	Tighten to specified torque
....	Alignment (marks)	....	Special tool use required (Isuzu Tools)
....	Directional indication	....	Use commercially available special tool
....	Inspection	....	Lubrication with engine oil
....	Measurement	....	Apply grease
....	Apply sealant		

9. Measurements are indicated by "standard" or "limit";
   a "standard" value refers to the standard values at time of assembly.
   A "limit" value is a maximum or minimum; measurements up to that value are usable.
   Measurements falling beyond that value mean the part must be serviced, adjusted, or replaced.
10. Directional indications adopted within this manual are as follows;
    Front: Toward the cooling fan when viewed from the flywheel side.
    Right: Toward the fuel injection pump when viewed from the flywheel side.
    Left: Toward the exhaust manifold when viewed from the flywheel side.
    Rear: Toward the engine's flywheel side.
11. "Cylinder numbers" and "Engine rotation direction": Cylinder numbers are counted in sequence beginning form the front side of the engine.
    As a result, the first cylinder at the very front of the engine is cylinder No. 1, while the last cylinder toward the rear is cylinder No. 6. The direction of engine rotation is clockwise when viewed from the cooling fan side.



12. "ASM" is an abbreviation for "assembly."

ABOUT ANGULAR TIGHTENING

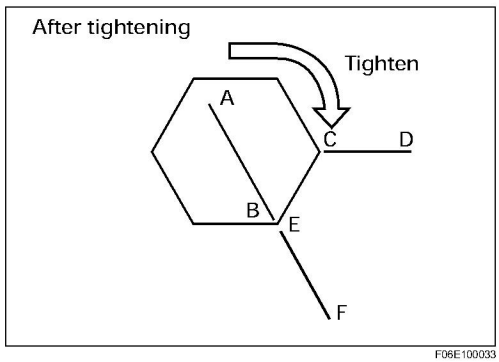
At present, the method most commonly used to tighten bolts is to specify a torque value to which the bolts should be tightened. This method, however, has the disadvantage of being characterized by considerable fluctuation in axial force for a given torque, with the result that when attempting to maintain the minimum necessary axial force, the bolt may be sheared at its upper limit value.
In order to produce less fluctuation in axial force, the ideal method would be to tighten the bolt while measuring the amount of its stretch, but since this is impossible in practice, a substitute method was conceived, namely considering the relationship of thread pitch to bolt stretch. The angular tightening method thus focuses on the amount the bolt is turned — directly related to thread pitch — in order to allow tightening of the bolt up unto the region of plasticity, thus reducing the variation in axial force.

TIGHTENING METHOD

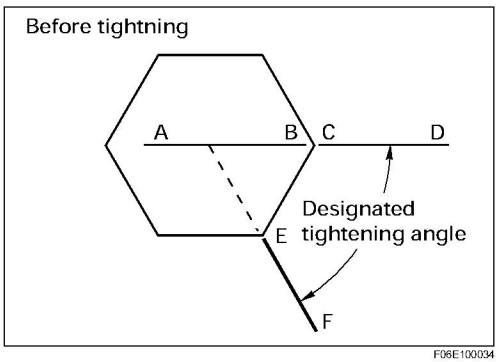
1. Apply molybdenum disulfide grease to the threads and setting faces of the nuts and bolts.
2. Tighten all bolts to the designated tightening torque values.
3. Next, make a mark at a point corresponding to one edge of the bolt as shown in the accompanying illustration, then tighten the bolt by turning it by the designated angle.
   Afterwards, be sure to check the mark to confirm whether the bolt has been tightened to the specified angle.
   If this confirmation is not performed, and if the bolt is subsequently retightened using the angular tightening method, it may break.

Note:

1. **Tighten bolts in their designated sequence.**
2. **When using the angular tightening method, do not retighten.**



Use a wrench to rotate the bolt until the line (A — B) on the bolt is aligned with the designated angle line on the material (line E — F).



On the surface of the bolt and material to be tightened, draw a line extending through the center of the bolt (A — B on the bolt, C — D on the material), and a line on the material surface which is aligned with the center of the bolt at the designated tightening angle (line E — F).

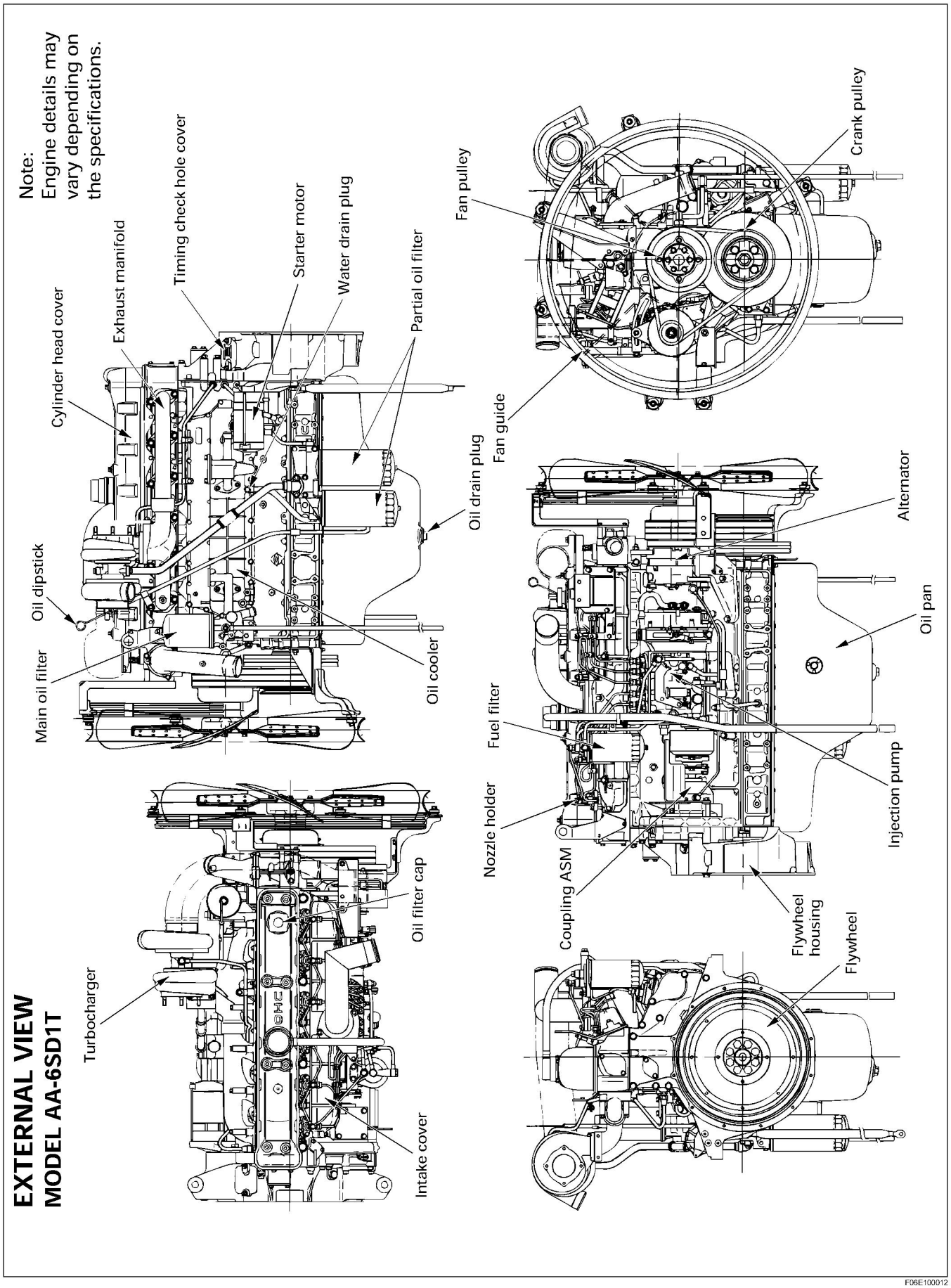
LOCATIONS OF USE OF ANGULAR TIGHTENING METHOD

1. Cylinder head bolts (M14 bolts only)
2. Lower crankcase bolts (M14 bolts only)
3. Connecting rods, bearing cap nuts
4. Flywheel bolts
5. Idle gear shaft bolt (A)

MAIN DATA AND SPECIFICATIONS

Item \ Engine Model				AA-6SD1T
Engine type				4-cycle, water-cooled vertical in-line overhead camshaft
Combustion chamber type				Direct injection
Cylinder liner type				Dry type
Number of cylinders; bore x stroke		mm		6 – 120 x 145
Total exhaust displacement		L (cid)		9.839 (601)
Compression ratio				16.8 : 1
Dimensions (L x W x H)		mm	*	1379 x 859 x 1158
Weight		kg	*	693
Ignition sequence				1-5-3-6-2-4
Fuel used				Diesel (2-D)
Fuel-injection pump type				In-line Bosch
Governor				Variable speed, mechanical, RSV type or electrically controlled type (Red IV)
Injection nozzle type				Multi-hole type
Injection starting pressure		MPa (kg/cm^2/psi)	*	17.7 – 22.1 (180 – 225/2570 – 3200)
Fuel injection timing (BTDC)			*	7°
Compression pressure (warm engine, 200 rpm)		MPa (kg/cm^2/psi)		2.84 (29/412)
Inlet valve	Open (BTDC)			15°
	Close (ATDC)			39°
Exhaust valve	Open (BTDC)			40°
	Close (ATDC)			14°
Valve clearance (cold engine)	Inlet valve	mm		0.4
	Exhaust valve			0.4
Lubricating system				Forced circulation type
Engine oil capacity; Oil pan		L (qts)	*	Max 30 (31.7), Min 25 (26.4)
Total system capacity		L (qts)	*	Max 35 (37), Min 30 (31.7)
Lubricating engine oil				API service type CD, or Isuzu Besco S-3
Oil cooler				Water-cooled, internally mounted
Cooling method				Forced circulation, pressurized water-cooled type
Cooling system volume		L (qts)		About 19 (20) (engine only)
Cooling fan			*	Dia. 850 mm, 6-blade, sucker type
Alternator		V–A	*	24 – 50
Starter		V–kW	*	24 – 5.5

Specifications marked with an asterisk (*) will vary according to engine application.


EXTERNAL VIEW
MODEL AA-6SD1T
Note:
Engine details may vary depending on the specifications.
Turbocharger
Oil filter cap
Intake cover
Oil dipstick
Main oil filter
Cylinder head cover
Exhaust manifold
Timing check hole cover
Starter motor
Water drain plug
Partial oil filter
Oil cooler
Oil drain plug
Fan pulley
Fan guide
Crank pulley
Alternator
Oil pan
Fuel filter
Nozzle holder
Coupling ASM
Flywheel housing
Flywheel
Injection pump

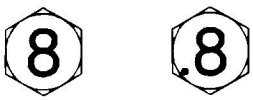
F06E100012

TIGHTENING TORQUE SPECIFICATIONS

The tightening torque values given in the table below are applicable to the bolts unless otherwise specified.

STANDARD BOLT

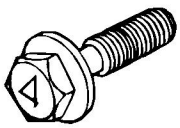
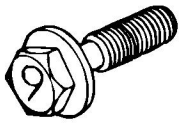
kgf·m (lb.ft/N·m)

Bolt Identification / Bolt Diameter × pitch (mm)			
M6 × 1.0	4 – 8 (0.4 – 0.8/3 – 6)	5 – 10 (0.5 – 1.0/4 – 7)	———
M8 × 1.25	8 – 18 (0.8 – 1.8/6– 13)	12 – 23 (1.2 – 2.3/9 – 17)	17 – 30 (1.7 – 3.1/12 – 22)
M10 × 1.25	21 – 34 (2.1 – 3.5/5 – 25)	28 – 46 (2.8 – 4.7/20 – 33)	37 – 62 (3.8 – 6.4/28 – 46)
* M10 × 1.5	20 – 33 (2.0 – 3.4/15 – 25)	28 – 45 (2.8 – 4.6/20 – 33)	36 – 60 (3.7 – 6.1/27– 44)
M12 × 1.25	49 – 74 (5.0 – 7.5/36 – 54)	61 – 91 (6.2 – 9.3/45 – 67)	76 – 114 (7.7 – 11.6/56 – 84)
* M12 × 1.75	45 – 69 (4.6 – 7.0/33 – 51)	57 – 84 (5.8 – 8.6/42 – 62)	72 – 107 (7.3 – 10.9/53 – 79)
M14 × 1.5	77 – 115 (7.8 – 11.7/56 – 85)	93 – 139 (9.5 – 14.2/69 – 103)	114 – 171 (11.6 – 17.4/84 – 126)
* M14 × 2.0	72 – 107 (7.3 – 10.9/53 – 79)	88 – 131 (9.0 – 13.4/65 – 97)	107 – 160 (10.9 – 16.3/79 – 118)
M16 × 1.5	104 – 157 (10.6 – 16.0/77 – 116)	135 – 204 (13.8 – 20.8/100 – 150)	160 – 240 (16.3 – 24.5/118 – 177)
* M16 × 2.0	100 – 149 (10.2 – 15.2/74 – 110)	129 – 194 (13.2 – 19.8/96 – 143)	153 – 230 (15.6 – 23.4/113 – 169)
M18 × 1.5	151 – 226 (15.4 – 23.0/110 – 166)	195 – 293 (19.9 – 29.9/144 – 216)	230 – 345 (23.4 – 35.2/169 – 255)
* M18 × 2.5	151 – 226 (15.4 – 23.0/110 – 166)	196 – 294 (20.0 – 30.0/145 – 217)	231 – 346 (23.6 – 35.5/171 – 255)
M20 × 1.5	206 – 310 (21.0 – 31.6/152 – 229)	270 – 405 (27.5 – 41.3/199 – 299)	317 – 476 (32.3 – 48.5/234 – 351)
* M20 × 2.5	190 – 286 (19.4 – 29.2/140 – 211)	249 – 375 (25.4 – 38.2/184 – 276)	293 – 440 (29.9 – 44.9/216 – 325)
M22 × 1.5	251 – 414 (25.6 – 42.2/185 – 305)	363 – 544 (37.0 – 55.5/268 – 401)	425 – 637 (43.3 – 64.9/313 – 469)
* M22 × 2.5	218 – 328 (22.2 – 23.4/161 – 242)	338 – 507 (34.5 – 51.7/250 – 374)	394 – 592 (40.2 – 60.4/291 – 437)
M24 × 2.0	359 – 540 (36.6 – 55.0/265 – 398)	431 – 711 (43.9 – 72.5/318 – 524)	554 – 831 (56.5 – 84.7/409 – 613)
* M24 × 3.0	338 – 507 (34.5 – 51.7/250 – 374)	406 – 608 (41.4 – 62.0/299 – 448)	521 – 782 (53.1 – 79.7/384 – 576)

An asterisk (*) indicates that the bolts are used for female threaded parts that are made of soft materials such as casting. Those shown in parentheses in the strength class indicate the classification by the old standard.

FLANGED HEAD BOLT

kgf·m (lb.ft/N·m)

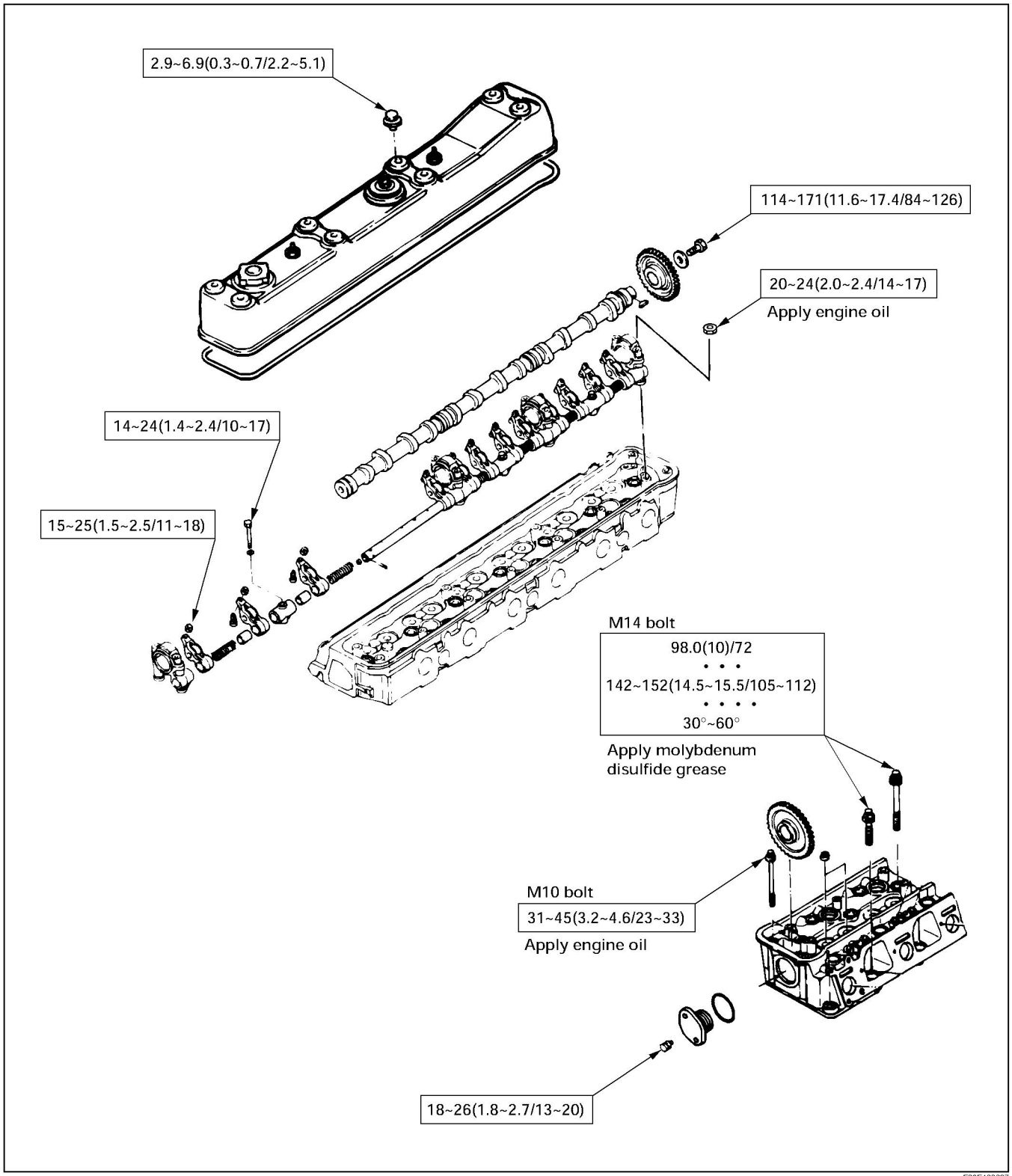
Bolt Identification / Bolt Diameter × pitch (mm)			
M6 × 1.0	5 – 9 (0.5 – 0.9/4 – 7)	6 – 12 (0.6 – 1.2/4 – 9)	———
M8 × 1.25	11 – 20 (1.1 – 2.0/8 – 15)	15 – 28 (1.6 – 2.9/12 – 21)	18 – 34 (2.1 – 3.4/15 – 25)
M10 × 1.25	23 – 39 (2.4 – 3.9/17 – 28)	35 – 59 (3.6 – 6.1/26 – 44)	42 – 71 (4.3 – 7.2/31 – 52)
* **M10 × 1.5**	22 – 37 (2.3 – 3.8/17 – 28)	35 – 58 (3.5 – 5.8/25 – 42)	40 – 67 (4.1 – 6.8/30 – 49)
M12 × 1.25	55 – 82 (5.6 – 8.4/40 – 61)	77 – 117 (7.9 – 11.9/57 – 86)	85 – 128 (8.7 – 13.0/63 – 94)
* **M12 × 1.75**	51 – 77 (5.2 – 7.8/38 – 56)	71 – 107 (7.3 – 10.9/53 – 79)	80 – 119 (8.1 – 12.2/59 – 88)
M14 × 1.5	83 – 125 (8.5 – 12.7/62 – 92)	115 – 172 (11.7 –17.6/85 – 127)	123 – 185 (12.6 – 18.9/91 – 137)
* **M14 × 2.0**	77 – 116 (7.9 – 11.8/57 – 85)	108 – 162 (11.1 – 16.6/80 – 120)	116 – 173 (11.8 – 17.7/85 – 128)
M16 × 1.5	116 – 173 (11.8 – 17.7/85 – 128)	171 – 257 (17.4 – 26.2/126 – 190)	177 – 265 (18.0 – 17.1/130 – 196)
* **M16 × 2.0**	109 – 164 (11.2 – 16.7/81 – 121)	163 – 244 (16.6 – 24.9/120 – 180)	169 – 253 (17.2 – 25.8/124 – 187)

A bolt with an asterisk (*) is used for female screws of soft material such as cast iron.

TIGHTENING TORQUES FOR MAIN PARTS

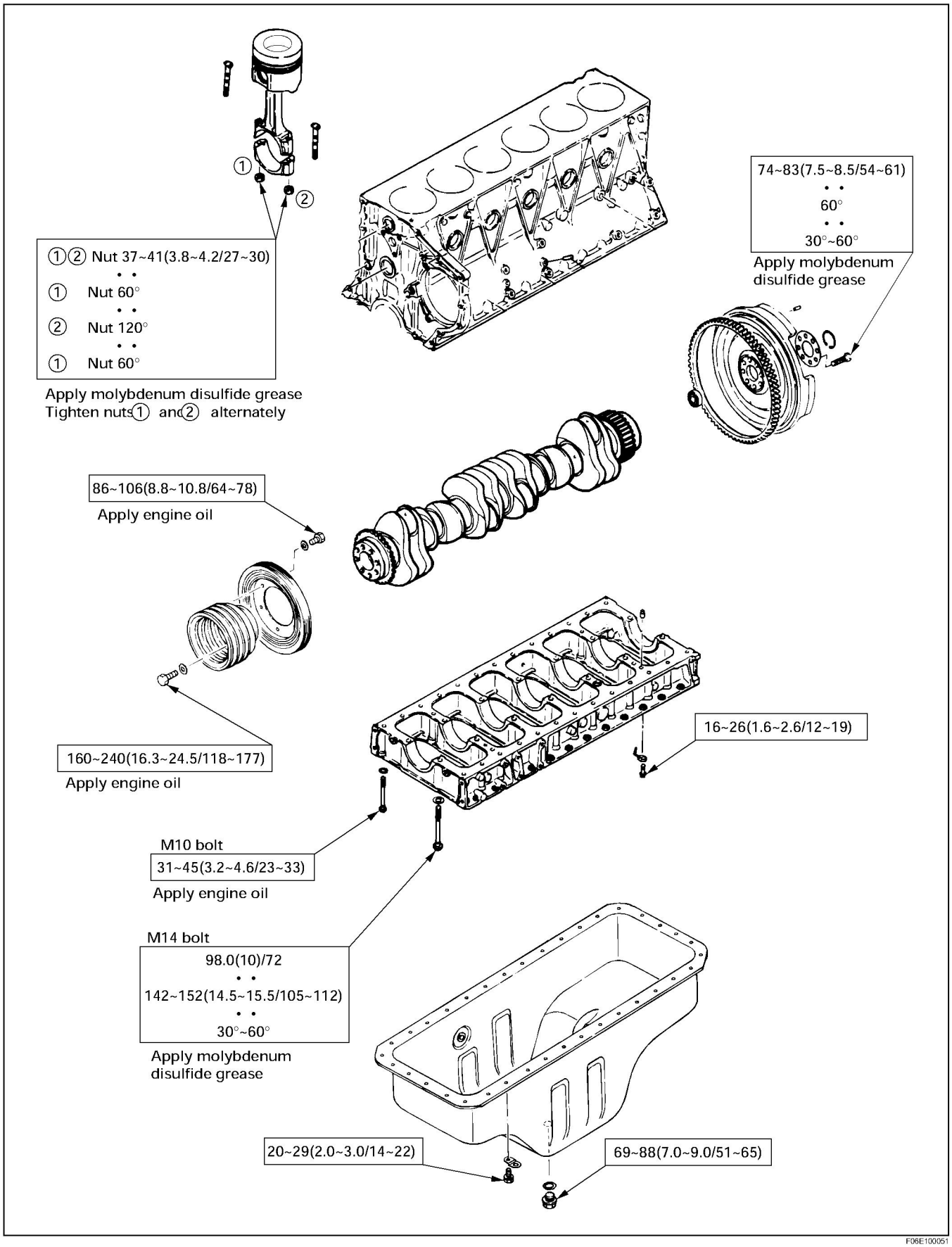
Cylinder head cover, cylinder head, camshaft bracket, rocker arm shaft bracket

N·m (kgf·m/lb·ft)



Lower crankcase, connecting rod bearing caps, crank damper pulley, flywheel, oil pan

N·m (kgf·m/lb·ft)



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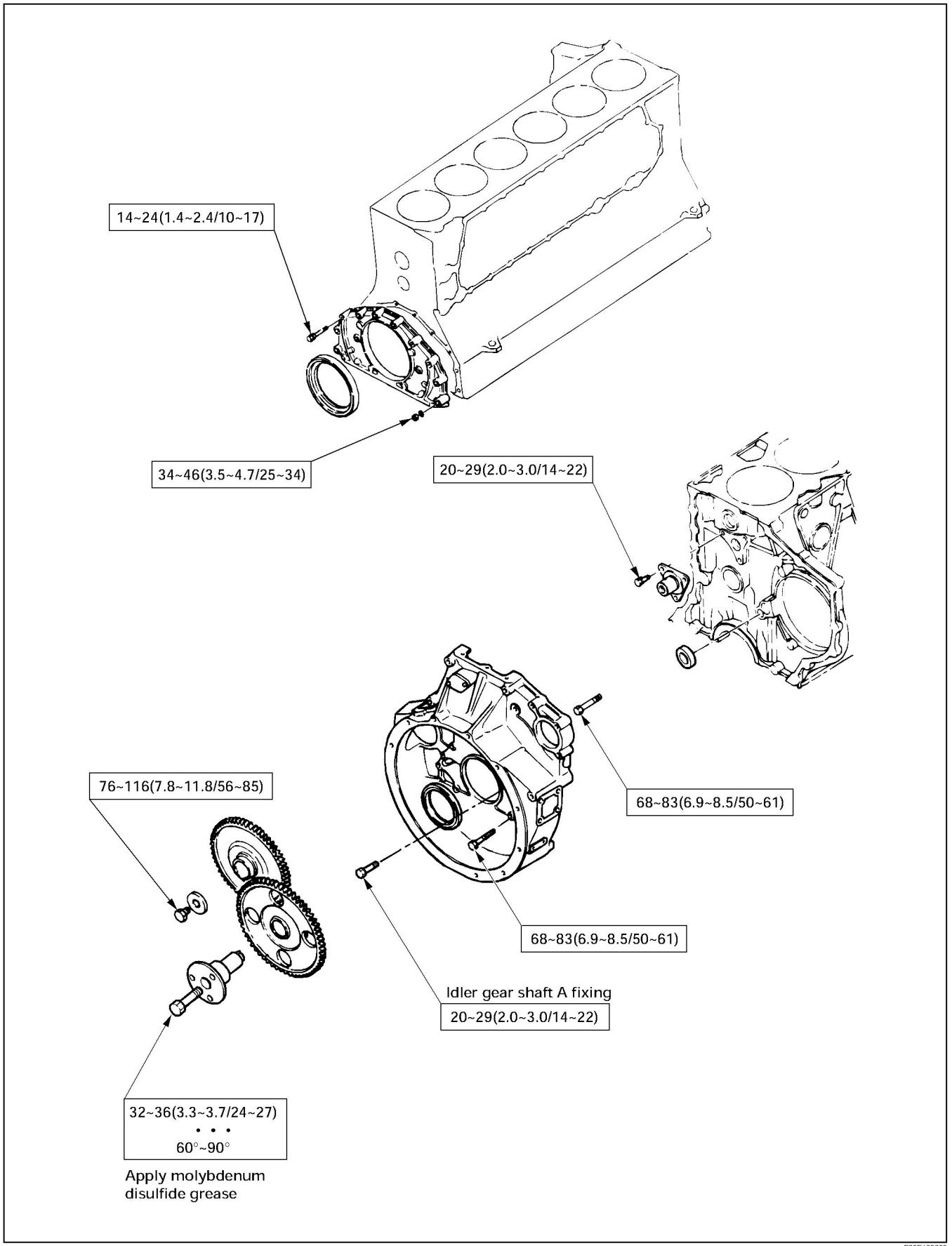
Front cover, flywheel housing, idler gear

N·m (kgf·m/lb·ft)



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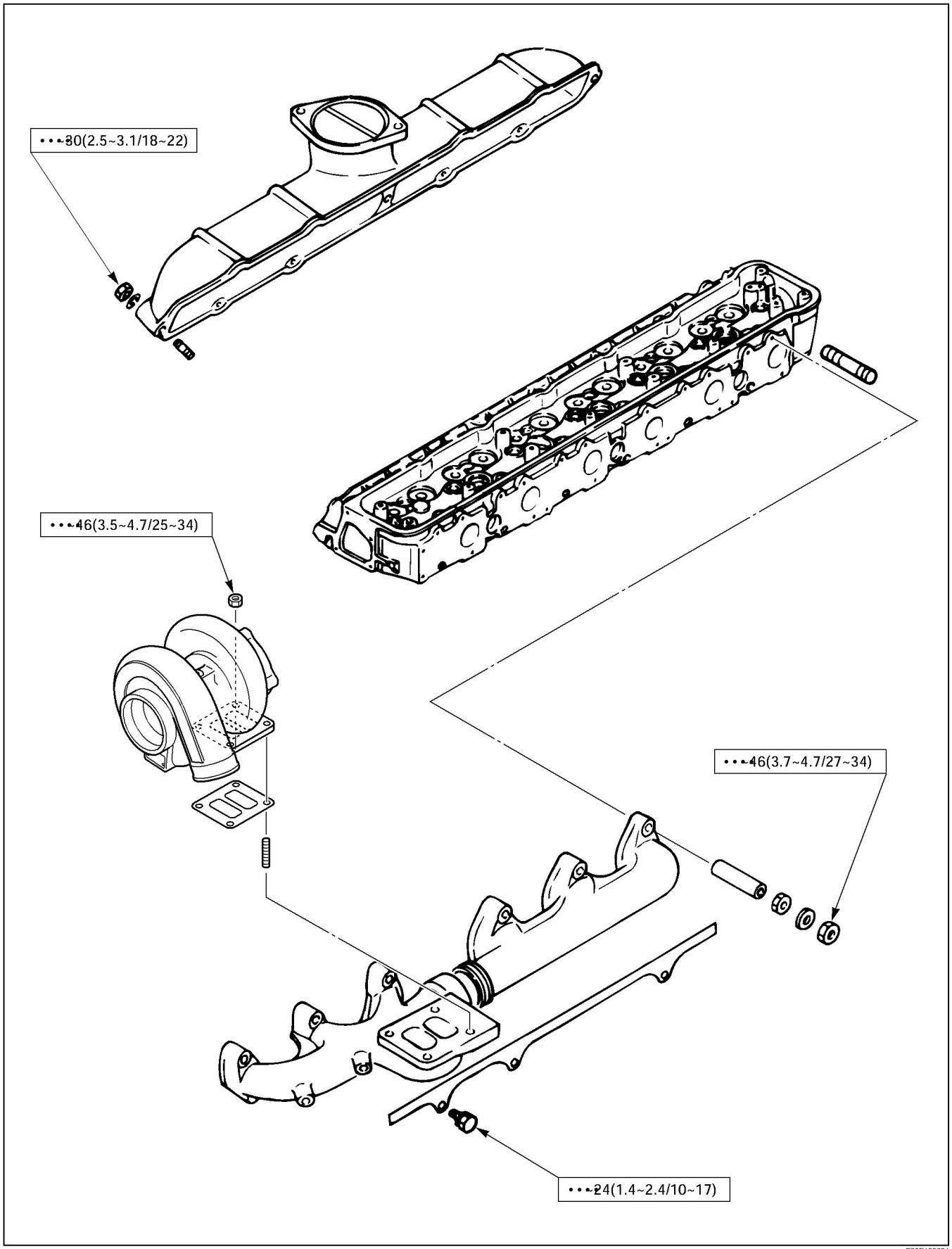
Intake manifold, exhaust manifold, turbocharger

N·m (kgf·m/lb·ft)



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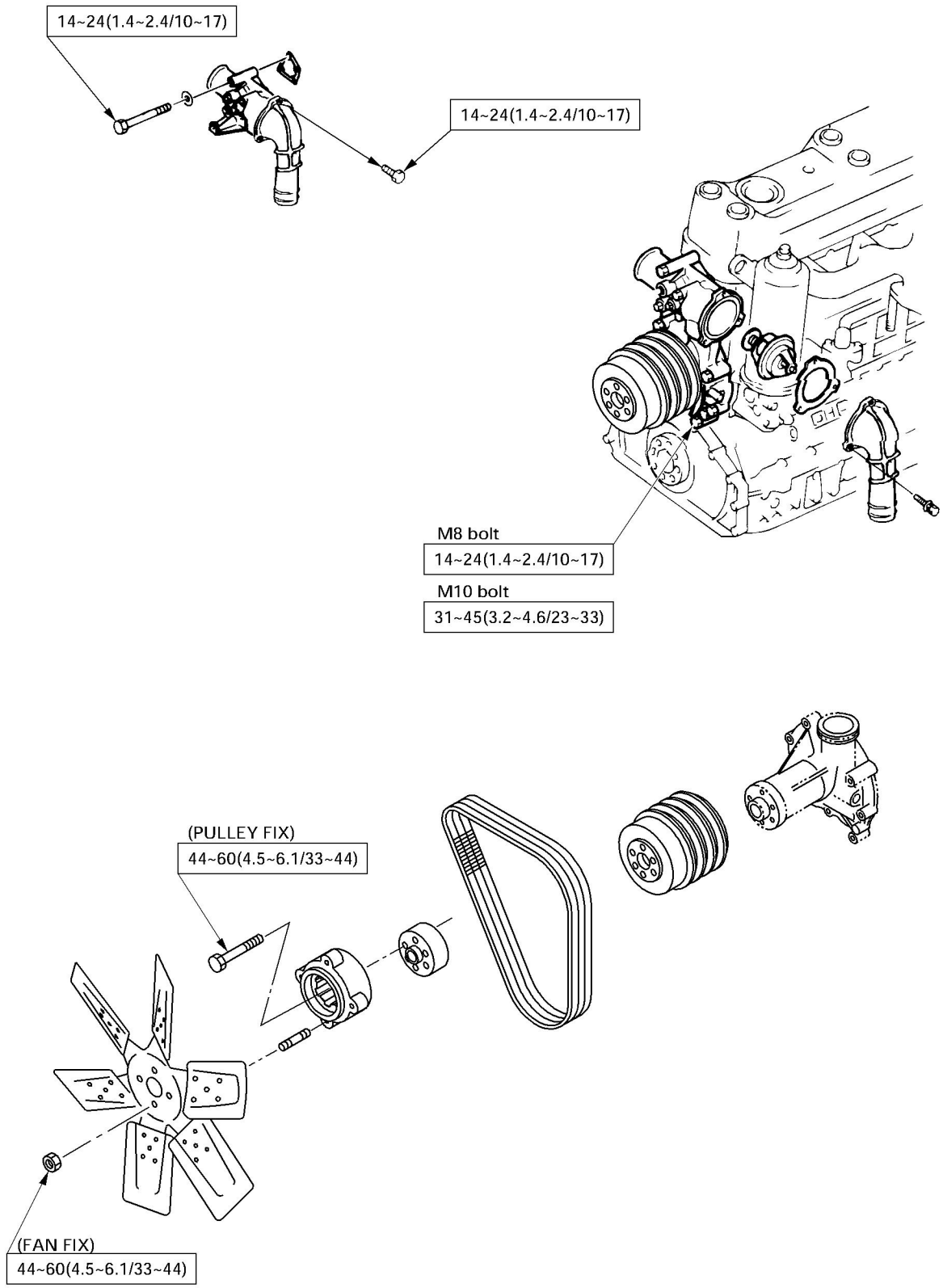
Cooling system

N·m (kgf·m/lb·ft)



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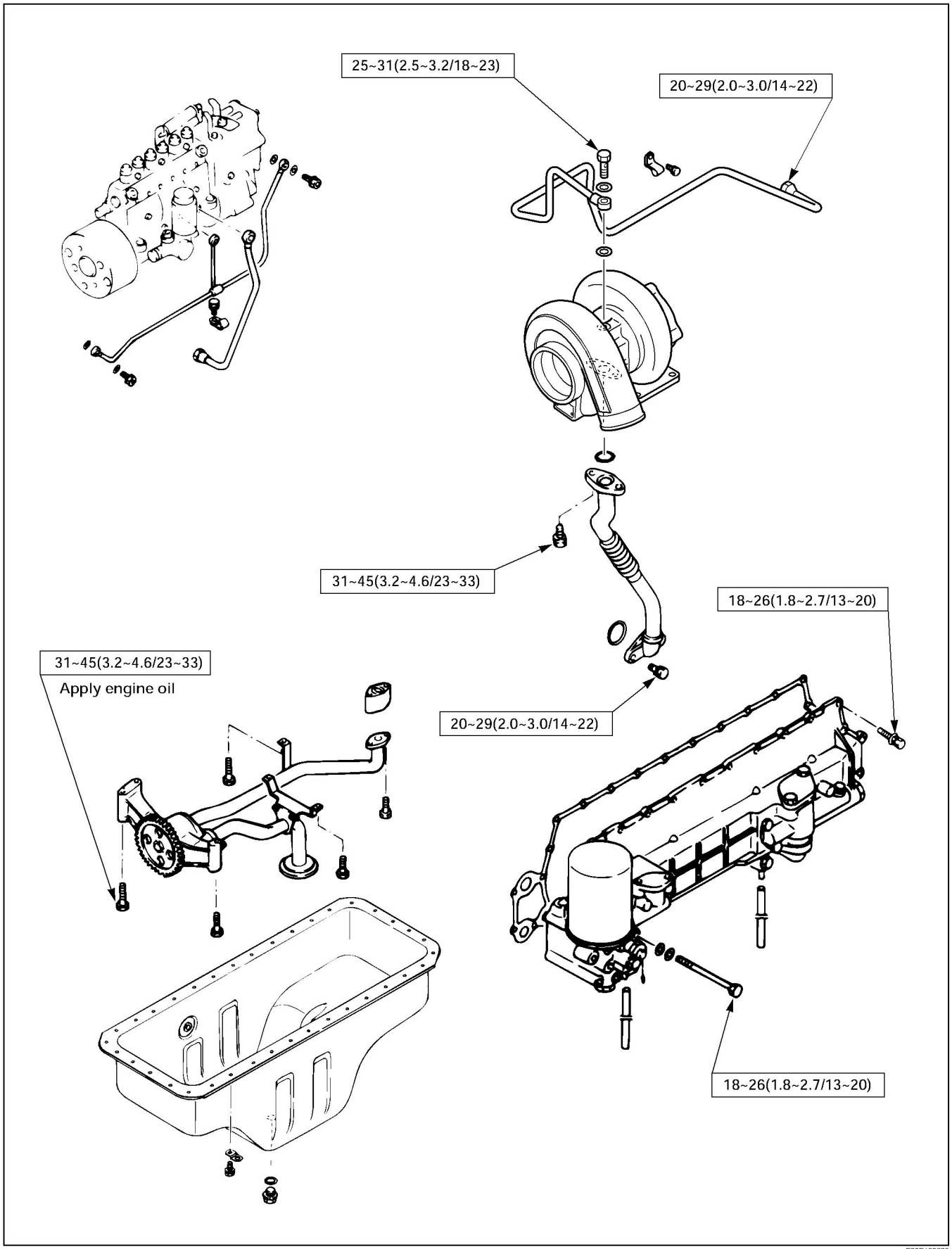
Lubricating system

N·m (kgf·m/lb·ft)



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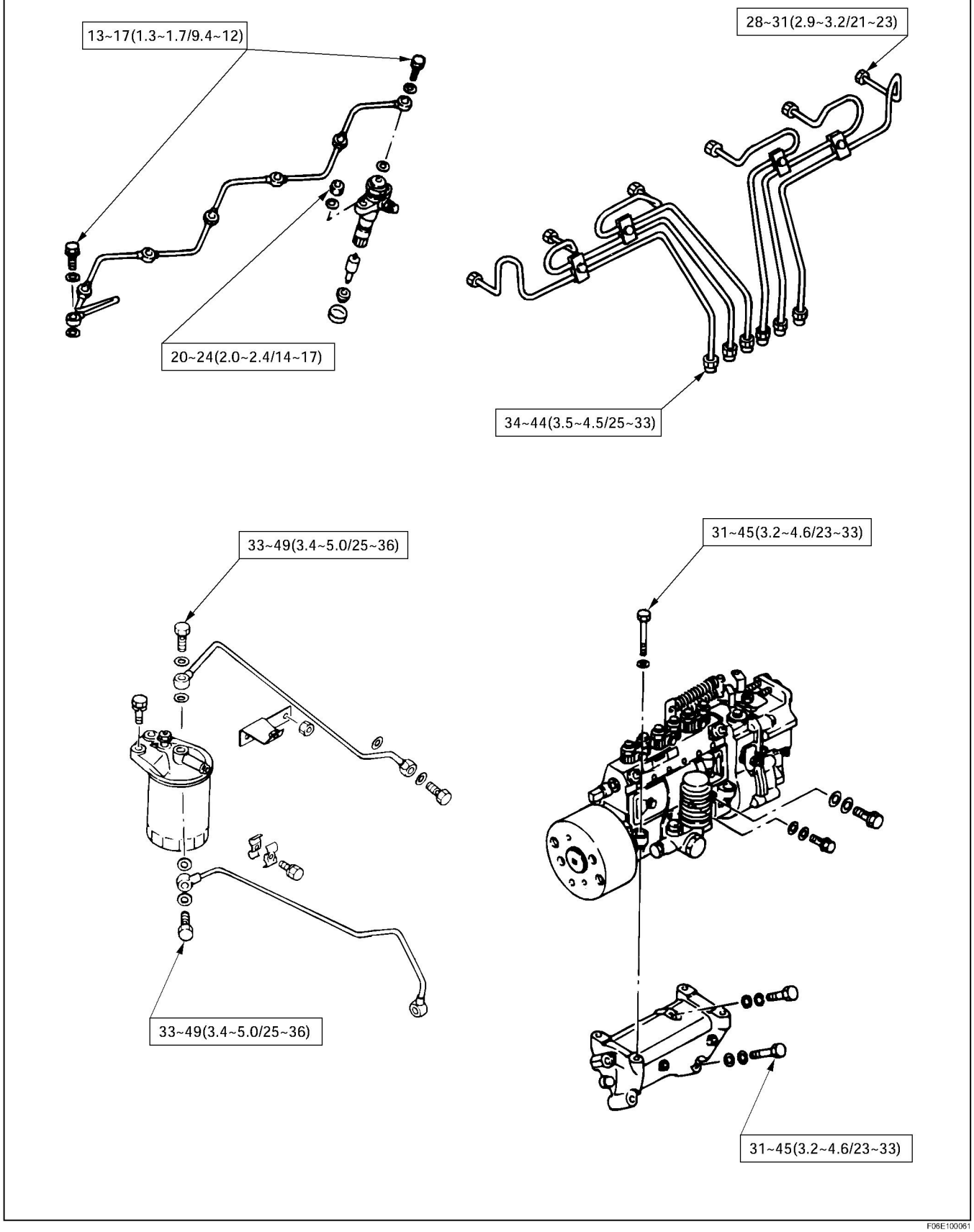
Fuel system

N·m (kgf·m/lb·ft)



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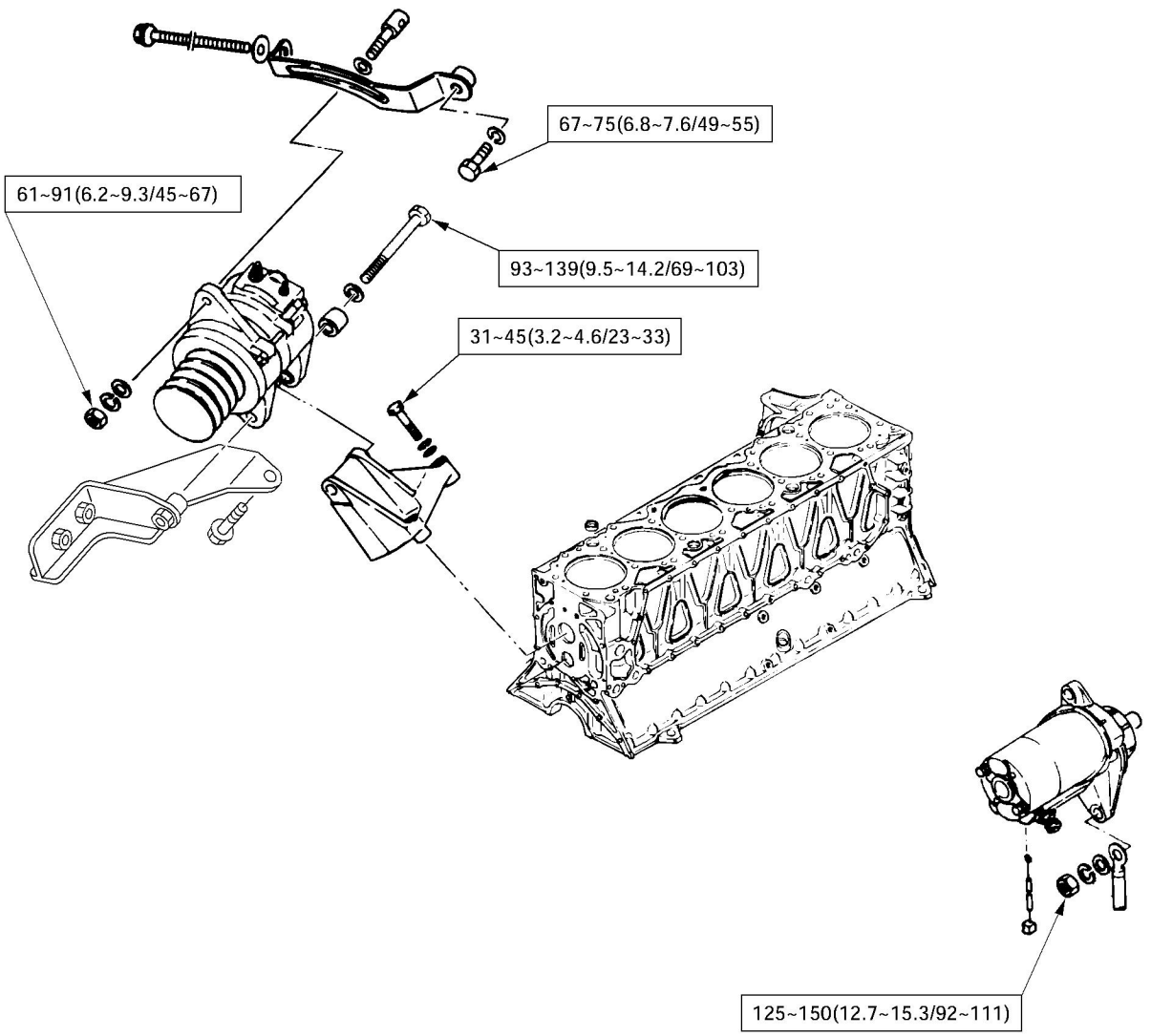
Engine electrical, mounting bracket

N·m (kgf·m/lb·ft)



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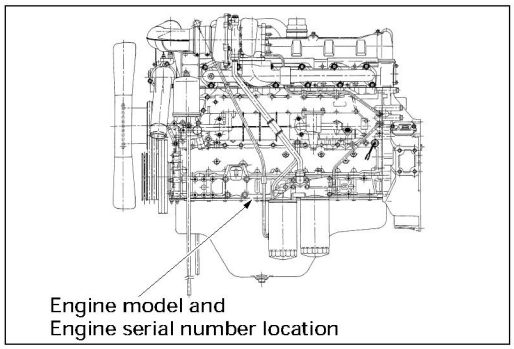
MODEL AND IDENTIFICATION SERIAL NUMBERS

ENGINE MODEL AND SERIAL NUMBER



The engine model and serial number are stamped in the middle of the lower left side of the cylinder block (crankcase).

MEMO

CHAPTER 2

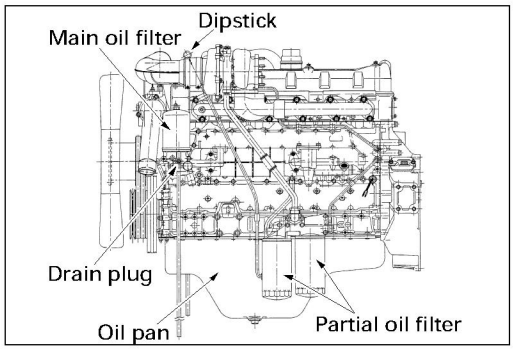
MAINTENANCE

CONTENTS

Note:
See the "Operating Manual" for specifications regarding fuel filter and oil filter replacement periods.

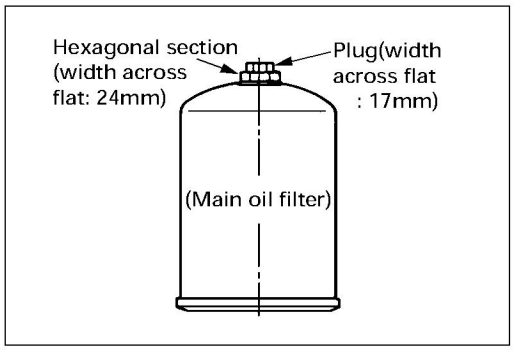
LUBRICATING SYSTEM

REPLACEMENT OF MAIN OIL FILTER ELEMENT (CARTRIDGE TYPE)



Removal

1. Remove the drain plug and drain the oil from the filter. Place a receptacle beneath the drain port to contain the drained oil. Removing the plug at the top of the main filter will facilitate draining the oil.

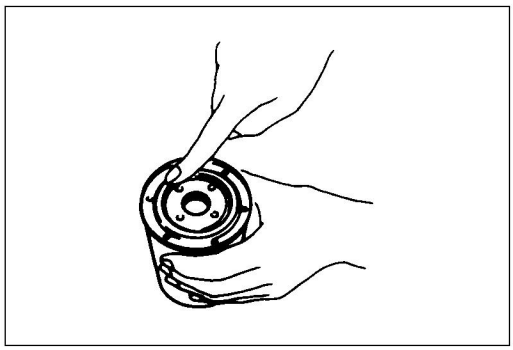


2. After draining the oil, replace the filter's drain plug.

Drain plug tightening torque N·m (kgf·m/lb·ft)

First	Second	Third
22 ~ 31 (2.2 ~ 3.2/16 ~ 23)	Loosen	13 ~ 23 (1.3 ~ 2.3/9 ~ 17)

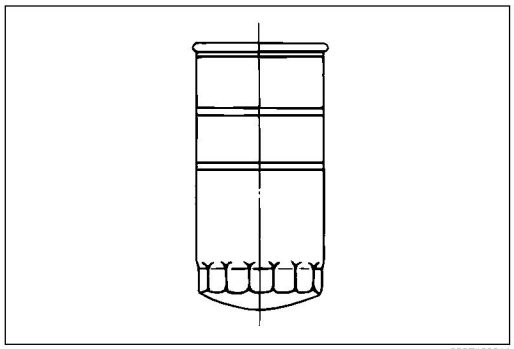
3. Place a wrench on the cartridge's second hex lug and rotate counter-clockwise to remove the cartridge. Discard the removed cartridge.



Installation

1. Clean the cartridge mounting surface on the engine.
2. Lightly apply a film of clean engine oil to the gasket on the new cartridge.
3. Screw the cartridge in lightly until the gasket surface contacts the mounting surface on the engine.
4. Using a filter wrench, tighten the filter by turning one revolution more.
5. After replenishing engine oil to the designated capacity, start the engine and check for leaks around the filter.
6. Stop the engine, wait for 10 — 20 minutes, then recheck the engine oil level and replenish if necessary.

REPLACEING THE PARTIAL FLOW OIL FILTER ELEMENT (CARTRIDGE TYPE)


050E100014

Removal

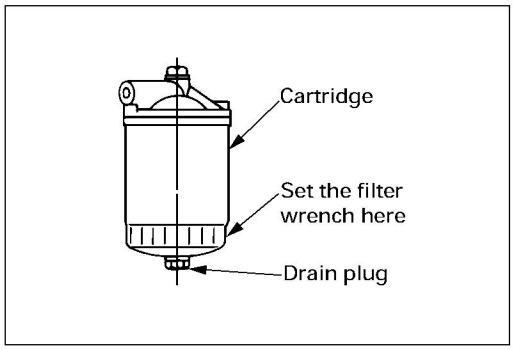
Use an oil filter wrench to rotate the filter cartridge counter-clockwise and remove. Be careful not to spill the oil contained in the filter.

Installation

1. Apply a thin film of clean engine oil to the new cartridge gasket.
2. Screw in the new filter element until its gasket contacts the mounting surface, then use the filter wrench to tighten the element by turning between 1 and 1 and 1/8 turns more.

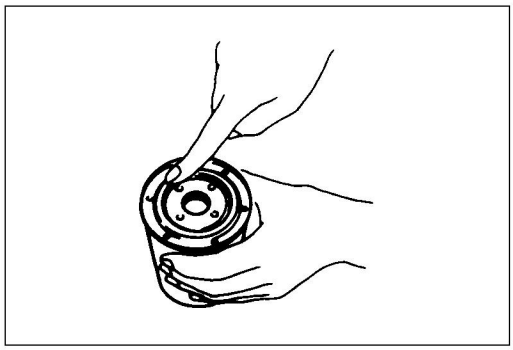
FUEL SYSTEM

REPLACING THE FUEL FILTER ELEMENT (CARTRIDGE TYPE)



Removal

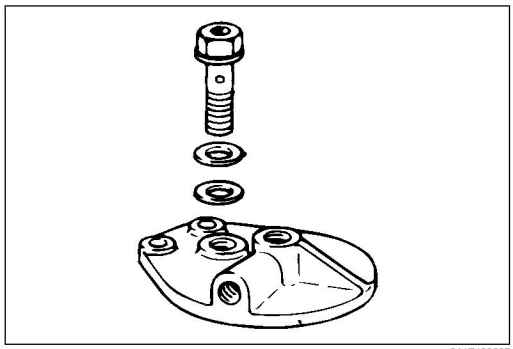
1. Remove the drain plug at the bottom of the filter, and drain out any fuel inside the cartridge.
   Place a receptacle beneath the cartridge to prevent soiling surrounding engine parts.
2. Using a filter wrench, rotate the cartridge counter-clockwise to loosen.
   Discard the removed filter cartridge.
   Filter wrench: commercially available



Installation

1. Clean the cartridge installation surface on the engine.
2. Apply a thin film of clean engine oil to gasket surface of the new filter cartridge.
3. To facilitate air bleeding, fill the filter with fuel.
4. Lightly screw in the filter cartridge until its gasket contacts the installation surface on the engine.
5. Using a filter wrench, tighten the cartridge by an additional 1/2 to 3/4 turn.

Note:
Be careful not to overtighten the cartridge, since it could twist and cause a fuel leak.

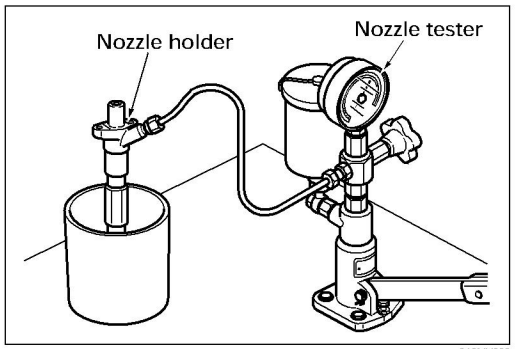

041E100007

Inspection of overflow valve

Inspect the overflow valve for clogging. Check for suction leakage on the ball side.

Overflow valve opening pressure	kPa (kgf/cm^2/psi)
245 (2.5 / 36)	

INJECTION NOZZLE



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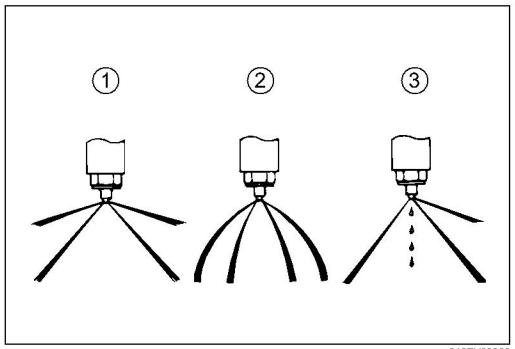
Opening Pressure and Spray Condition Check

1. Use an injection nozzle tester to check the nozzle opening pressure.
   If the opening pressure is above or below the specified value, the injection nozzle must be replaced or adjusted.
   Refer to "Adjustment of Injection Nozzle Opening Pressure."

injection nozzle opening pressure MPa (kg/cm^2/psi)

1st stage	17.7 (180/2570)
2nd stage	22.1 (225/3200)



040EY00030

WARNING:
Test fluid from the injection nozzle tester will spray out of the injection nozzle under great pressure. It can easliy puncture a person's skin.
Keep your hands away from the injection nozzle at all times.

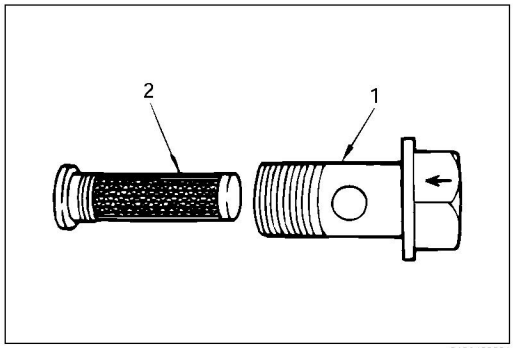
2. Check the spray condition.
   If the spray condition is bad, the injection nozzle must be replaced or reconditioned.

   (1) Correct
   (2) Incorrect (Restrictions in orifice)
   (3) Incorrect (Dripping)

Injection Nozzle Adjustment

Refer to "injection Nozzle" in this manual.

FEED PUMP STRAINER

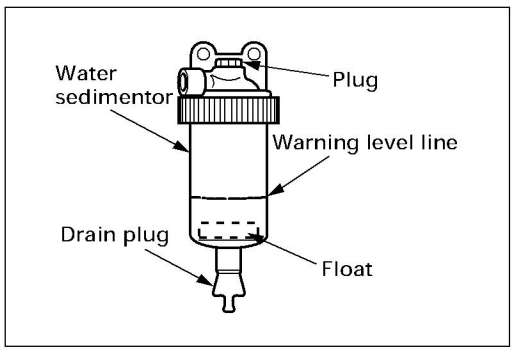


040A100001

Cleaning the strainer

1. Remove the feed pump joint bolt (1).
2. Use a screwdriver to remove the strainer (2) from inside the joint bolt.
3. Wash the strainer in clean diesel fuel.

WATER SEPARATOR (WATER SEDIMENTER)
(If so equipped)



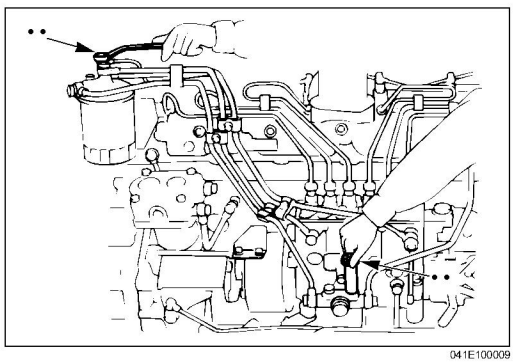
Inspect Float Level

Inspect the water sedimenter's float level.
If the float is above the "water bleed level," loosen the drain plug and allow the water to drain, then retighten the drain plug securely.

Drain plug tightening torque N·m (kgf·m/lb·ft)

2.9 ~ 3.9 (0.3 ~ 0.4 / 2.2 ~ 2.9)

AIR BLEEDING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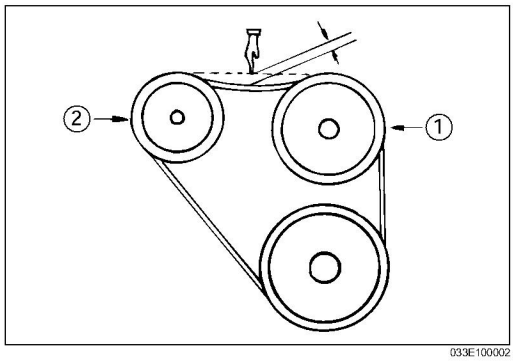
Air bleeding

1. Loosen the fuel injection pump's feed pump cap (1).
2. Loosen the fuel filter's overflow valve (2).
3. Operate the feed pump's handle up and down, and fill the filter with fuel, then retighten the level loosened in step 2.
4. Continue to operate the feed pump; the air bleeding is completed when the handle becomes difficult to move and the sound of air passing through the orifice can be heard.
5. Operate the feed pump several times, and check to confirm that no fuel leaks from the feed pump or fuel filter.
6. Tighten the feed pump cap securely.

COOLING SYSTEM

COOLING FAN DRIVE BELT



033E100002

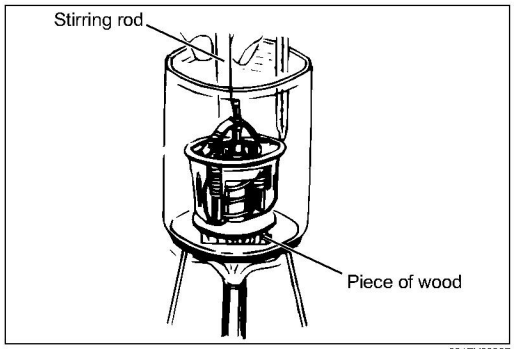
Inspection and Adjustment of Belt Tension

1. Check the cooling fan drive belt for cracking and other damage.
2. Exert a force of 100 N (10kg/22lb) at a point midway between the fan pulley ① and alternator pulley ②, and measure the belt deflection.
3. Loosen the alternator mounting bolt and adjust plate bolt, and adjust the tension by moving the alternator. Following adjustment, be sure to retighten the loosened bolts.

Fan belt deflection mm (in)

8.5 – 10.5 (0.30 – 0.41)

THERMOSTAT



031EY00027

Inspection

Visually inspect the thermostat; if excessive wear or damage is detected, replace the thermostat. Measure the amount of valve lift.

Valve lift at 90 °C (194 °F) mm (in)

10 (39) or more

Valve opening temperature °C (°F)

76.5 (170)

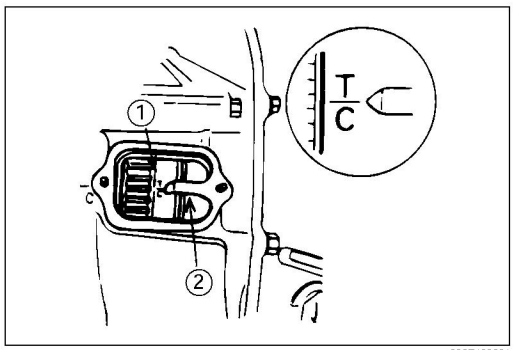
VALVE CLEARANCE ADJUSTMENT

Note:
Tightening of cylinder head bolts is performed by the "angular tightening method"; as a result, no re-tightening is necessary prior to valve clearance adjustment. Adjust the valve clearance when the engine is cold.

Checking for mounting bolt looseness
Before adjusting the valve clearance, check the rocker arm bracket mounting bolts for looseness, and retighten if necessary.

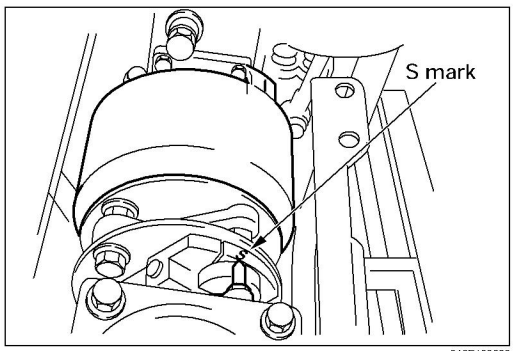
Rocker arm bracket mounting bolt tightening torque
N·m (kgf·m/lb·ft)

14 – 24 (1.4 – 2.4 / 10 – 17)



020E100001

Adjustment
1. Rotate the crankshaft clockwise to bring the TDC mark ① on the flywheel in alignment with the timing pointer ② on the flywheel housing.
   At this time, if the S-mark on the drive-side flange of the injection pump coupling is in alignment with the pointer, the No. 1 cylinder's piston is in the TDC position of the compression stroke.

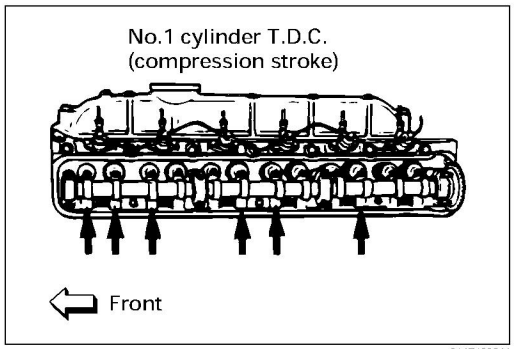


040E100030

2. Adjust the valve clearance when either the No. 1 cylinder or No. 6 cylinder is in the TDC position as noted below.

Valve clearance (intake and exhaust) mm (in)

0.4 (0.016) (cold engine)



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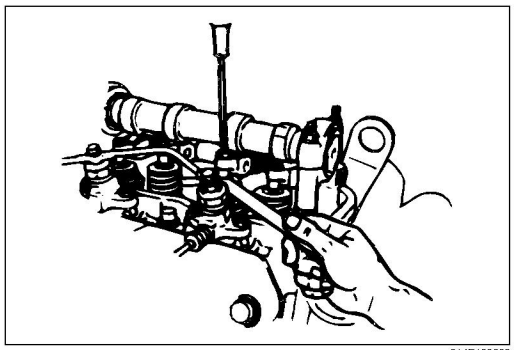
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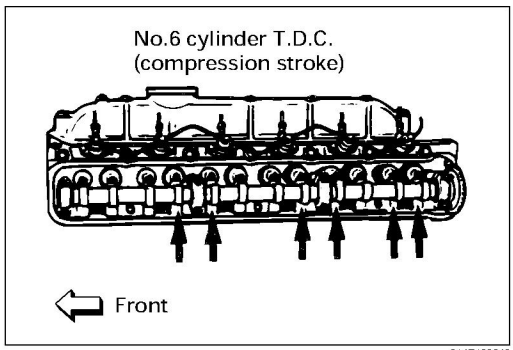


014E100048

3. When the No. 1 cylinder is at the TDC position on the compression stroke, adjust the valves indicated by arrows in the illustration (valve indicated by a circle in the table).
4. Loosen the locknut on the adjust screw affixed to the rocker arm, and place a feeler gauge of the proper thickness between the rocker arm and valve stem end.
5. Tighten the adjust screw until a slight amount of resistance is felt in the movement of the feeler gauge.
6. Taking care not to allow the adjust screw to turn, tighten the locknut.

Locknut tightening torque N·m (kgf·m/lb·ft)

15 – 25 (1.5 – 2.5 / 11 – 18)

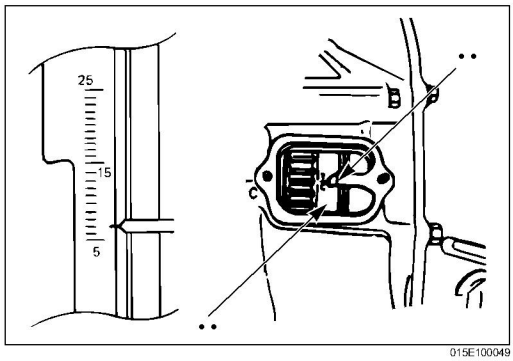
7. Following adjustment with the No. 1 cylinder at the TDC position, rotate the crankshaft one full turn.
8. Once again, align the flywheel's TDC mark with the pointer on the flywheel housing (the No. 6 cylinder will be at compression TDC).

9. Adjust the clearance of the remaining valves noted by the arrows in the illustration (indicated by • •in the table).

Cylinder No.	1		2		3		4		5		6	
Valve sequence	In-take	Ex-haust	In-take	Ex-haust	In-take	Ex-haust	In-take	Ex-haust	In-take	Ex-haust	In-take	Ex-haust
No.1 cylinder (compression TDC)	•	•	•			•	•			•		
No. 6 cylinder (compression TDC)				•	•			•	•		•	•

FUEL INJECTING TIMING

INJECTION TIMING INSPECTION

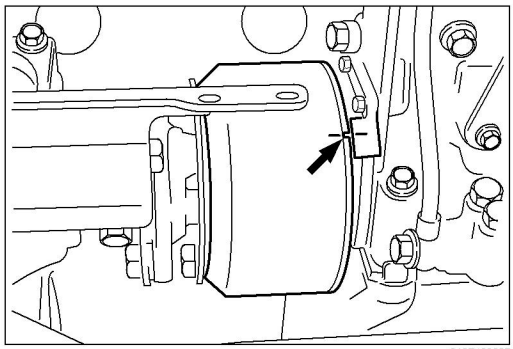


015E100049

Inspection

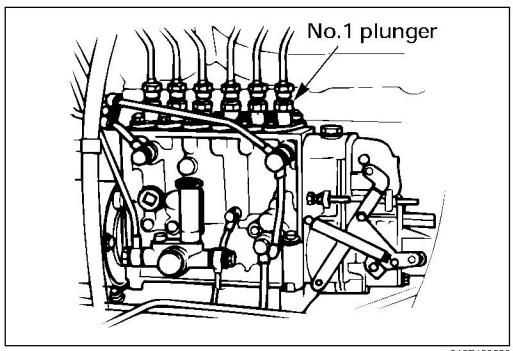
1. To set the injection for the proper timing, rotate the crankshaft clockwise, aligning the engraved line (compression BTDC) on the flywheel (1) with the flywheel housing pointer (2).

Injection timing (B.T.D.C)	deg
7°	


040E100037

2. Confirm that the line engraved on the pump body is aligned with the line engraved on the timer side.
3. If the line engraved on the pump body is not aligned with the line engraved on the timer side, align the timer mark with the pump body mark, adjusting the coupling bolts.
   After adjusting, tighten the coupling bolts to the specified torque.

ADJUSTING THE INJECTION TIMING



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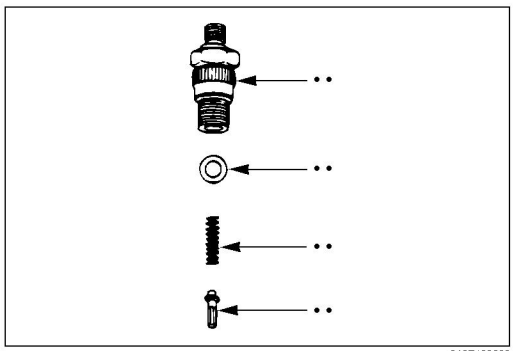
Adjustment

1. Remove the No. 1 injection pipe.
   This is done to allow visual confirmation of the beginning of the fuel injection at the No. 1 plunger.


040E100023

2. Remove the No. 1 delivery valve holder (1), washer (2), valve spring (3), and delivery valve (4).

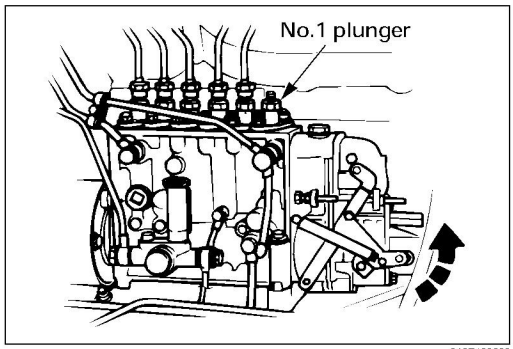
Note:
When removing the delivery valve, be careful not to allow dirt to enter the injection pipe.

3. Install the delivery valve holder, and tighten to the designated torque.
   Do not install the delivery valve spring or delivery valve at this time, since they are installed only after completing this procedure.

Delivery valve holder tightening torque N·m (kgf·m/lb·ft)

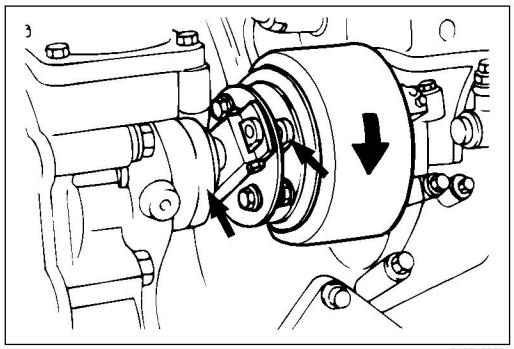
108 – 118 (11.0 – 12.0 / 80 – 87)

Note:
Over-tightening or under-tightening the delivery valve holder may cause engine hunting or fuel leakage.

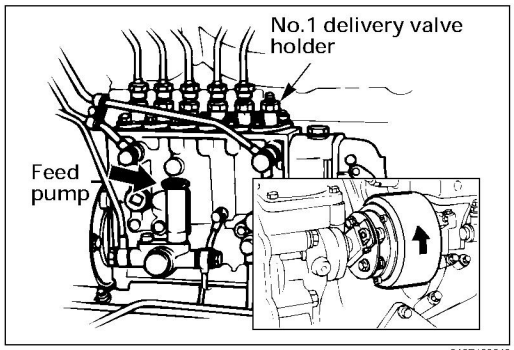


040E100028

4. Keep the fuel control lever at the full open position.

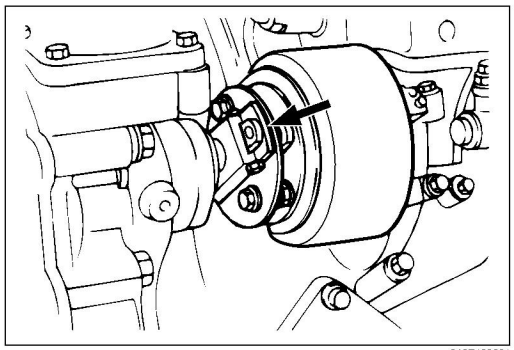

040E100038

5. Loosen the coupling plate's two joint bolts.
6. Rotate the automatic timer clockwise.



040E100040

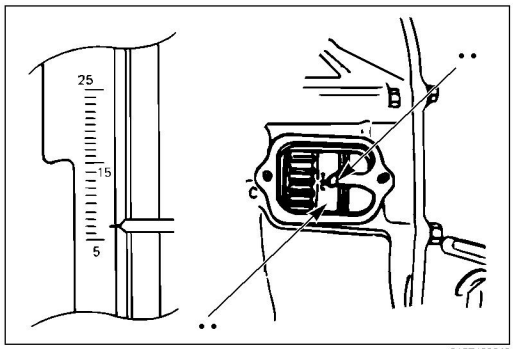
7. While operating the feed pump, confirm that fuel flows out from the No. 1 delivery valve holder.
8. While confirming the outflow of fuel, slowly rotate the automatic timer counterclockwise, and the fuel flow will gradually decrease, and finally stop.
   This position is the fuel injection beginning point.


040E100021

9. Tighten the two coupling plate joint bolts to the designated torque.

Joint bolt tightening torque N·m (kgf·m/lb·ft)

103 – 113 (10.5 – 11.5 / 76 – 83)



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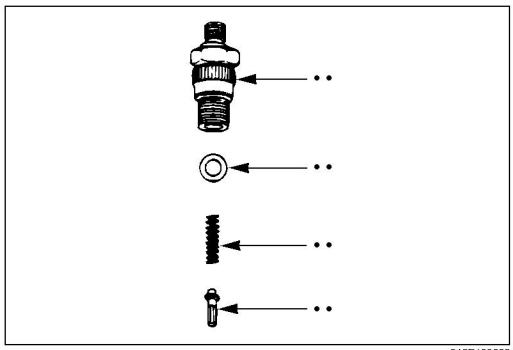
10. While operating the feed pump, slowly rotate the crankshaft clockwise, and at the point the fuel flow stops from the No. 1 delivery valve holder, confirm that the pointer (2) on the flywheel housing is aligned with the 7° mark engraved on the flywheel (1).



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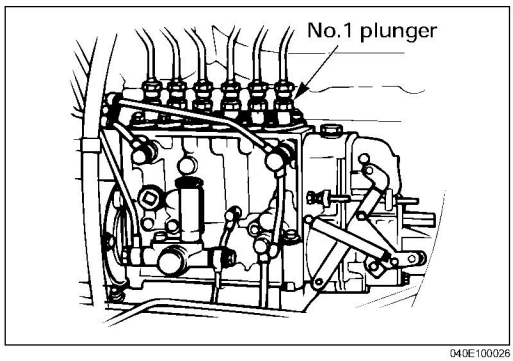
11. Remove the No. 1 plunger delivery valve holder (1), and insert the valve spring (3) and delivery valve (4). Install the washer (2) and delivery valve holder, and tighten to the designated torque.

Delivery valve holder tightening torque N·m (kgf·m/lb·ft)

108 – 118 (11.0 – 12.0 / 80 – 87)



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12. Install the No. 1 plunger delivery valve, and screw on the feed pump cap.

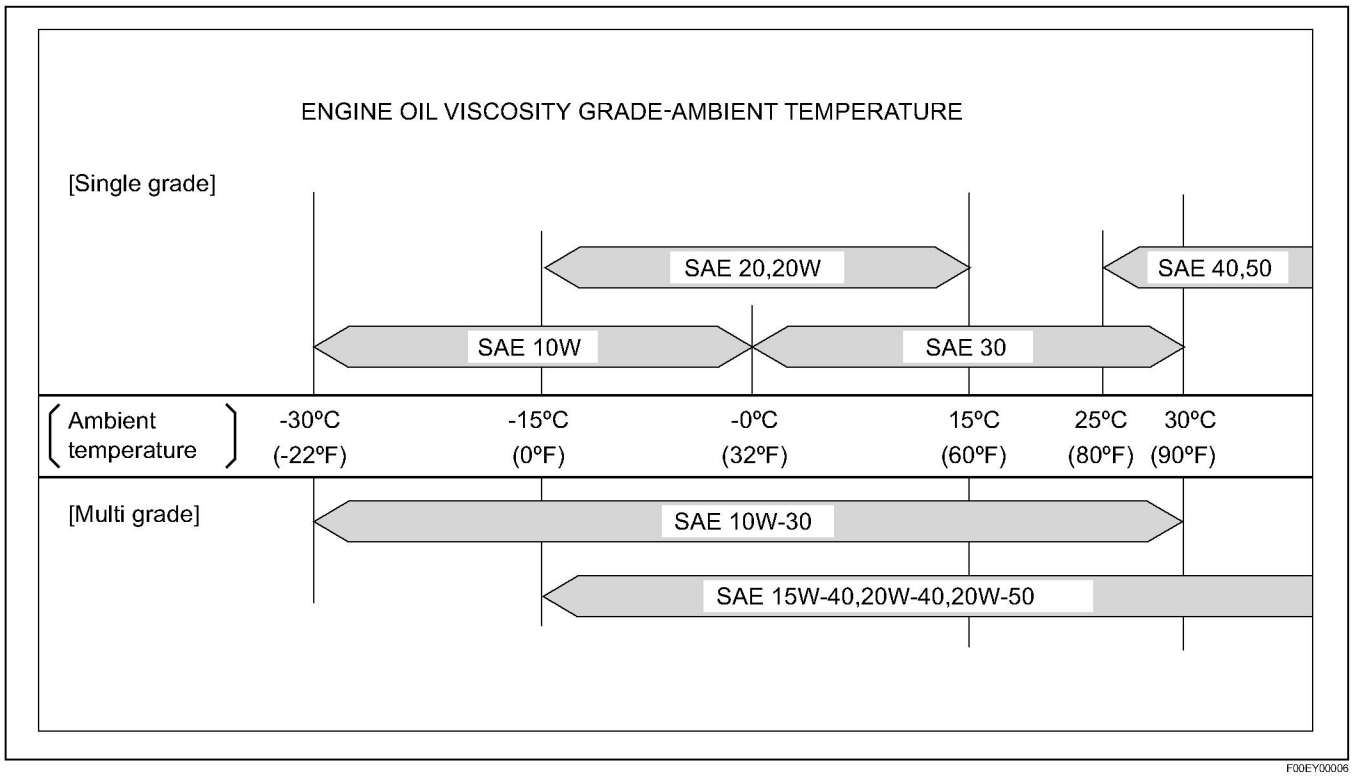
Note:
The feed pump may be damaged if the engine is started when the feed pump cap is not screwed on.

RECOMMENDED LUBRICATING OIL

ENGINE CLASS AND ENGINE OIL GRADE

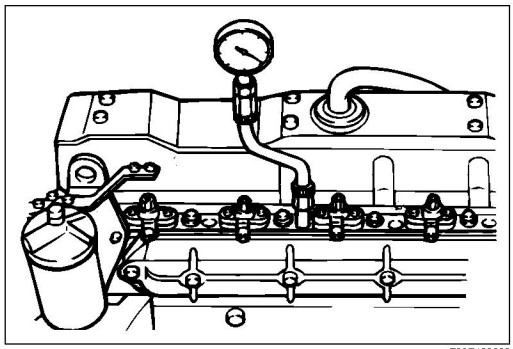
Engine class	Turbocharged diesel engine
Engine oil grade (API service class)	CD grade

ENGINE OIL VISCOSITY CHART



Since the choice of engine oil viscosity influences the engine's starting characteristics, driving characteristics, oil consumption, friction wear, piston scorching, and other aspects of engine performance, be sure to choose the oil used in accordance with the ambient temperature, as indicated in the chart.

CYLINDER COMPRESSION PRESSURE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MEASURING THE COMPRESSION PRESSURE

Measurement

1. Start the engine and operate until warm.
   (The radiator coolant must be about 80°C at the time of this measurement)
2. Remove all glow plugs.
3. Install the adapter and compression gauge in the No. 1 cylinder's glow-plug hole.
   Compression gauge: (commercially available)
   Gauge adapter: 5-85317-001-0
4. Make sure that the fuel delivery lever is close (no fuel being sent to the engine).
5. Use the starter to crank the engine, and read the value from the compression gauge's indicator needle.
   Perform each measurement at least twice.

Cylinder compression pressure (Sea level, 200 rpm)

MPa (kgf/cm^2/psi)

Standard	Limit
2.84 (29/410)	2.06 (21/300)

The measured compression pressure at each cylinder indicates the approximate value. The variation in pressure between cylinders must not exceed the limit value noted below.

kPa (kgf/cm^2/psi)

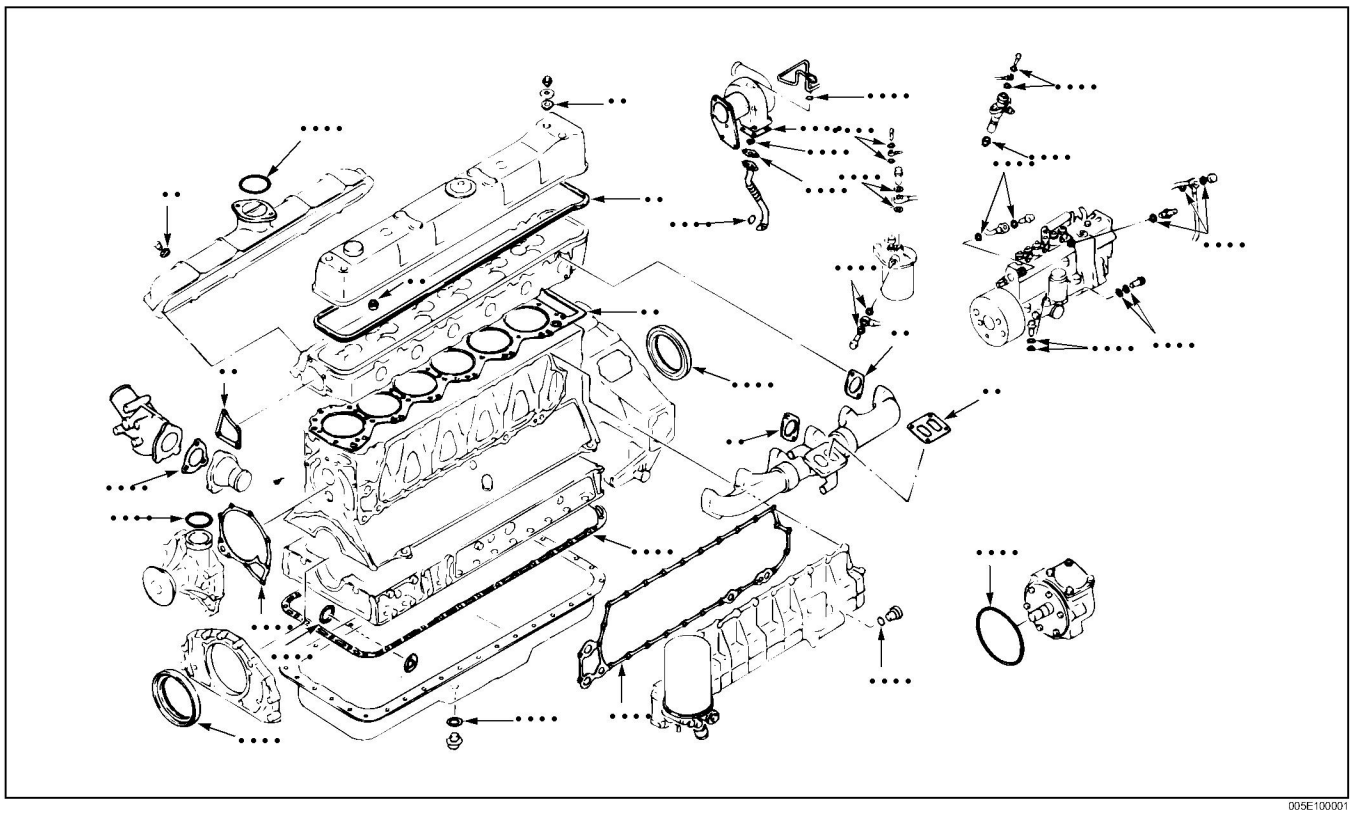
Limit variation of pressure between cylinders	196 (2/28)

If the measured pressure exceeds the absolute limit value or the limit for variation between cylinders, inspect all items related to compression pressure.

6. Repeat steps 3 and 5 for the remaining cylinders. If the measured value is less than the designated value, consult the troubleshooting section of this manual, and repair as required.

ENGINE REPAIR KIT

THE PARTS SHOWN BELOW ARE INCLUDED IN THE ENGINE REPAIR KIT.



005E100001

1. Head cover nut seal
2. Head cover gasket
3. Cylinder head gasket
4. Valve guide seal
5. thermostat housing gasket
7. Intake cover gasket
9. Exhaust manifold gasket
10. Drain plug gasket
11. Fuel pipe gasket
12. Oil pan gasket
13. Front oil seal
14. Rear oil seal
15. Oil relief valve gasket
16. Oil cooler gasket
17. Leakoff pipe gasket
18. Injection nozzle gasket
19. Bearing case gasket
20. Water pump gasket
21. Water pump gasket
22. Oil level switch gasket
23. Thermostat housing gasket
24. Intake pipe gasket
26. Turbocharger gasket
27. Turbocharger feed pipe gasket
28. Turbocharger return pipe gasket
29. Turbocharger return pipe gasket
30. Turbocharger return pipe gasket

MEMO

CHAPTER 3

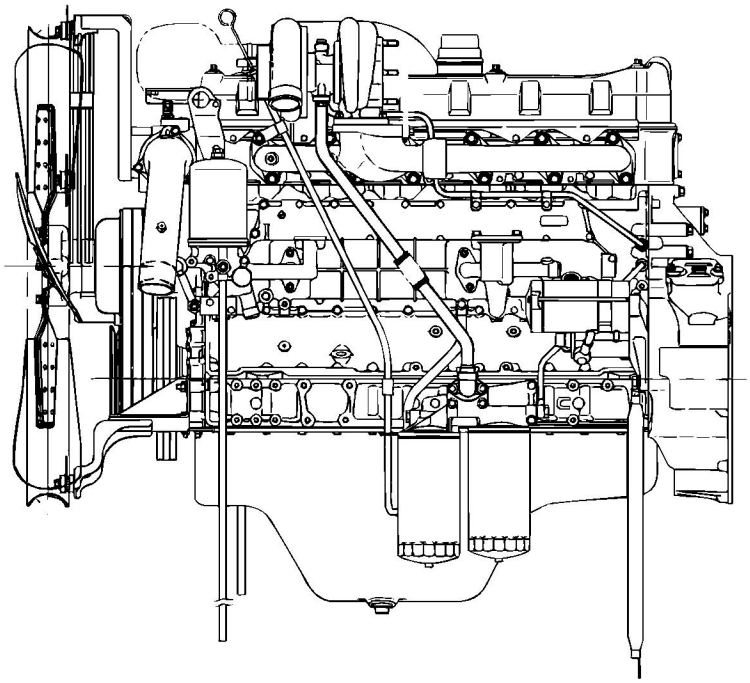
ENGINE I

(DISASSEMBLY)

CONTENTS

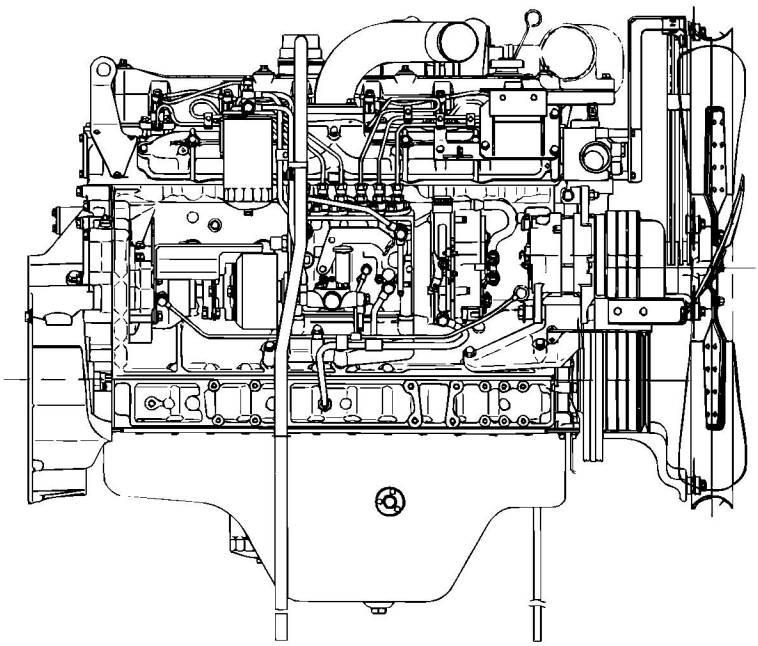
EXTERNAL VIEW

(Left side view)



F06E100010

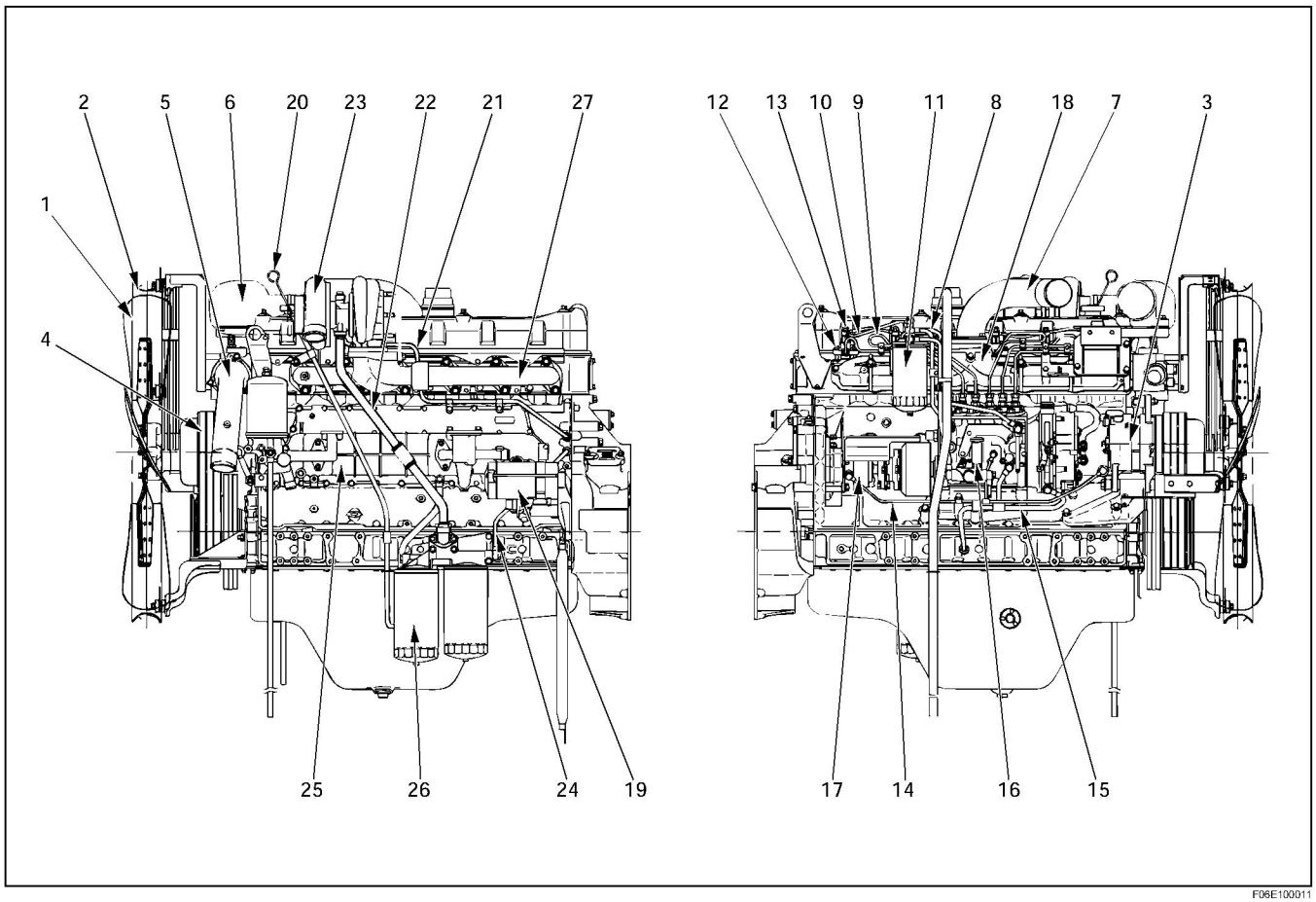
(Right side view)



Note:
Specification may vary according to the type of equipment on which the engine is installed.

F06EY00171

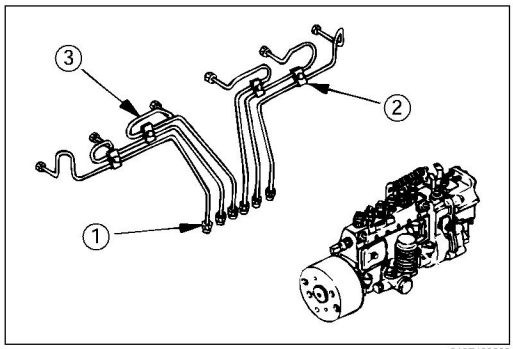
DISASSEMBLY 1



F06E100011

Disassembly sequence

1. Cooling fan
2. Fan guide
3. Alternator
4. Fan belt
5. Water pipe
6. Air duct
7. Intake pipe
8. Fuel pipes
▲9. Injection pipe
10. Fuel leakoff pipe
11. Fuel filter
▲12. Glow plug and connectors
▲13. Nozzle holder
14. Oil pipe
15. Oil pipe
▲16. Injection pump
17. Coupling ASM
▲18. Intake cover
19. Starter motor
20. Oil dipstick
21. Oil feed pipe
22. Oil return pipe
▲23. Turbocharger
24. Oil pipe
▲25. Oil cooler with oil filter
26. Partial oil filter
27. Exhaust manifold



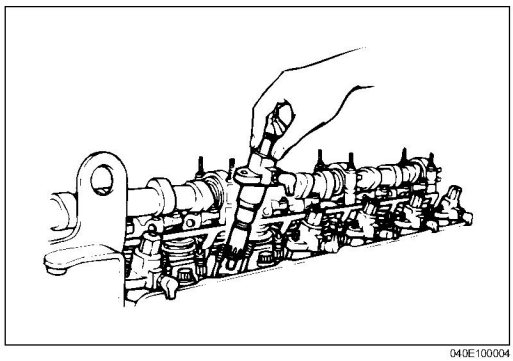
040E100003

IMPORTANT OPERATIONS

9. Fuel injection pipe

(1) Loosen the sleeve nut ① on the delivery valve side of the fuel injection pipe.
Take care not to exert excessive force on the injection pipe when doing this.
(2) Loosen the clip ②.
(3) Remove the fuel injection pipe ③.

Note:
In order to prevent dirt and other foreign materials from entering the delivery valve, place a plastic cap over the hole in the delivery valve holder.

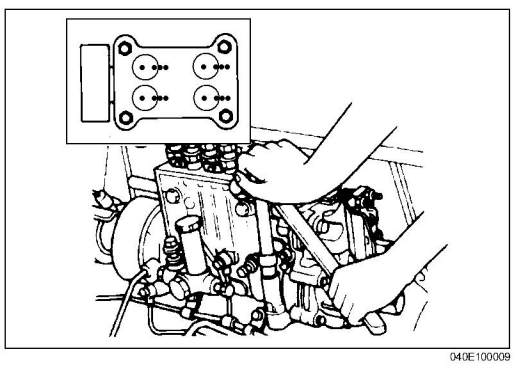

040E100004

12. Glow plugs and connectors

13. Nozzle holders

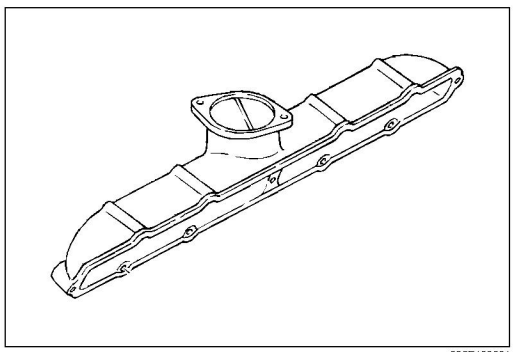
If the nozzle is to be reused, it must be installed in its original position.

Note:
Use paper labels or tags to mark the cylinder numbers of the nozzles.
Take care not to damage the nozzle tips.


040E100009

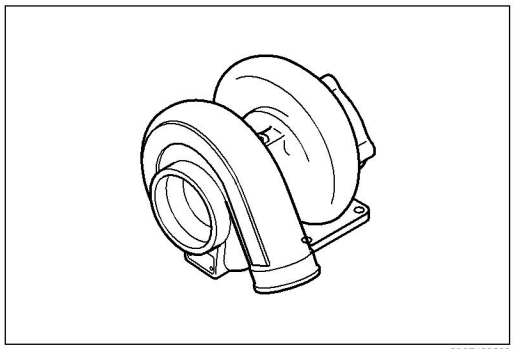
16. Injection pump

(1) Remove the two coupling bolts and separate the injection pump from the coupling.
(2) Remove the injection pump's four mounting bolts.
(3) Remove the injection pump.


025E100001

18. Intake cover

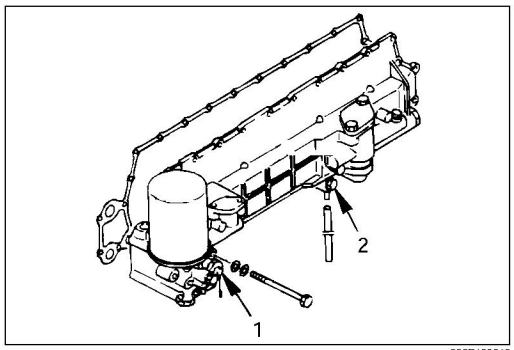
A sealant has been applied to the intake cover at time of assembly.
Screw holes (M8 x 1.25) are provided at both ends of the intake cover; using bolts of the appropriate size (M8 x 1.25, shaft length 30 mm or more), screw in the bolts evenly on both sides to press away the cover, and remove.



036E100002

23. Turbocharger

To prevent entry of foreign material, attach a cap to the turbocharger's oil port after removal of the oil pipe.

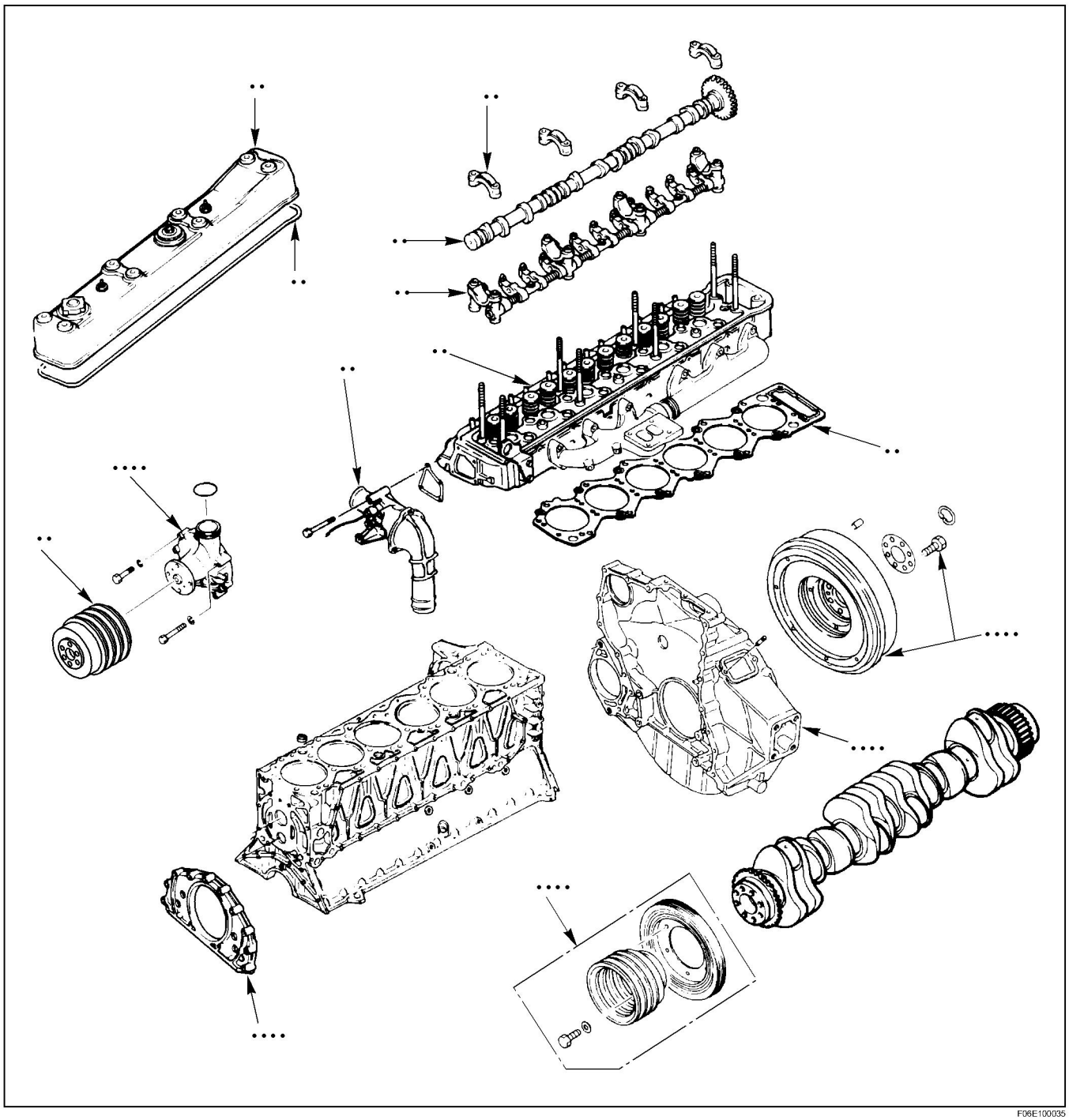


050E100015

25. Oil cooler (with oil filter)

(1) Remove the oil drain plug (1) and allow the oil to drain from inside the filter.
(2) Loosen the water drain plug (2) and drain the coolant.
(3) Remove the oil cooler mounting bolt.
(4) Use a plastic hammer to lightly strike the periphery of the oil cooler case, and remove the oil cooler.

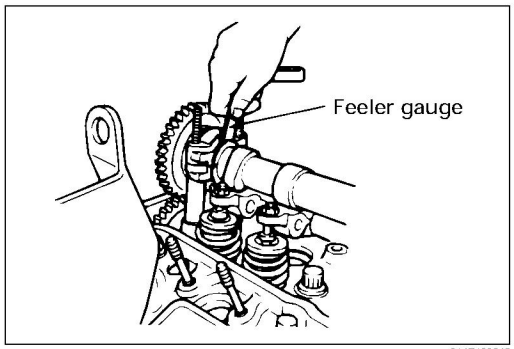
DISASSEMBLY 2



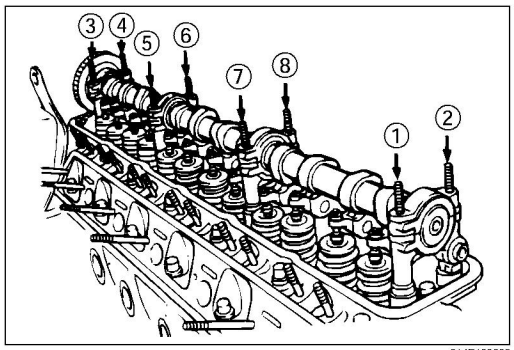
F06E100035

Disassembly sequence

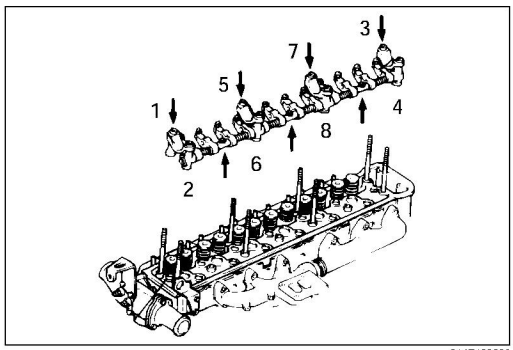
1. Cylinder head cover
2. Head cover gasket
3. Camshaft upper bracket
▲4. Camshaft
▲5. Rocker arm shaft assembly
6. Thermostat housing (with thermostat unit)
▲7. Cylinder head
8. Cylinder head gasket
9. Water pump pulley
10. Water pump
▲11. Crankshaft pulley (with damper)
12. Front cover
▲13. Flywheel
14. Flywheel housing



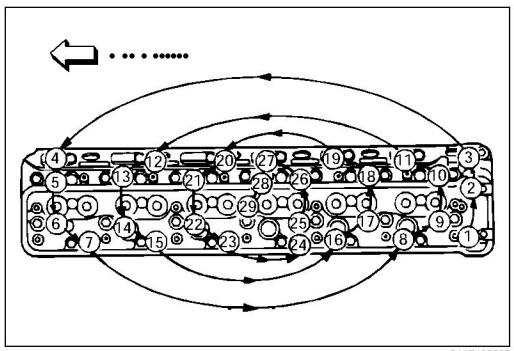
014E100045

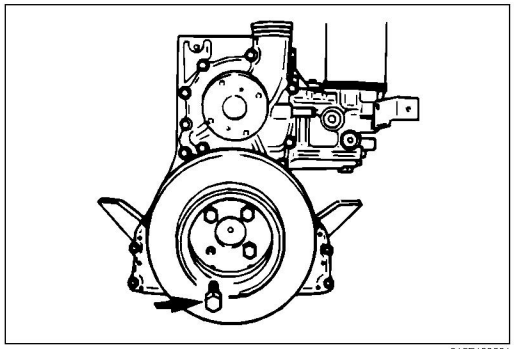


014E100005



014E100006


011E100025


015E100001

IMPORTANT OPERATIONS

4. Camshaft

(1) Fully loosen the rocker arm's adjust screw, and measure the gap at the end of the camshaft.

Camshaft axis gap mm (in)

Standard	Limit
0.055 ~ 0.205 (0.0022 ~ 0.0081)	0.40 (0.016)

(2) Gradually loosen the camshaft bracket bolts in the order shown.

Note:
The camshaft may be adversely affected if one bracket bolt is fully loosened all at once. As a result, be sure to loosen the bolts gradually in the numbered sequence.
Protect the bearing surface of the camshaft upper bracket to prevent damage.

5. Rocker arm shaft assembly

Gradually loosen the rocker arm lower bracket bolts in the sequence shown.

Note:
The rocker arm shaft may be adversely affected if one bolt is fully loosened all at once. As a result, be sure to loosen the bolts gradually in the numbered sequence.

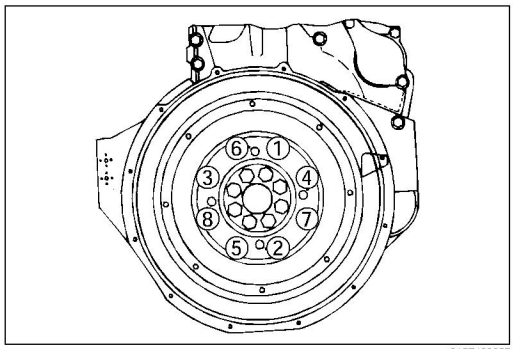
7. Cylinder head

Loosen the cylinder head bolts evenly in the sequence shown.

Note:
The lower surface of the head may be damaged if one bolt is fully loosened at once. As a result, be sure to loosen the bolts gradually in the numbered sequence.

11. Crankshaft pulley (with damper)

(1) Insert a steel bar or wedge into the flywheel ring gear to prevent the crankshaft from turning.
(2) Loosen the crankshaft pulley's mounting bolts, and remove the pulley.

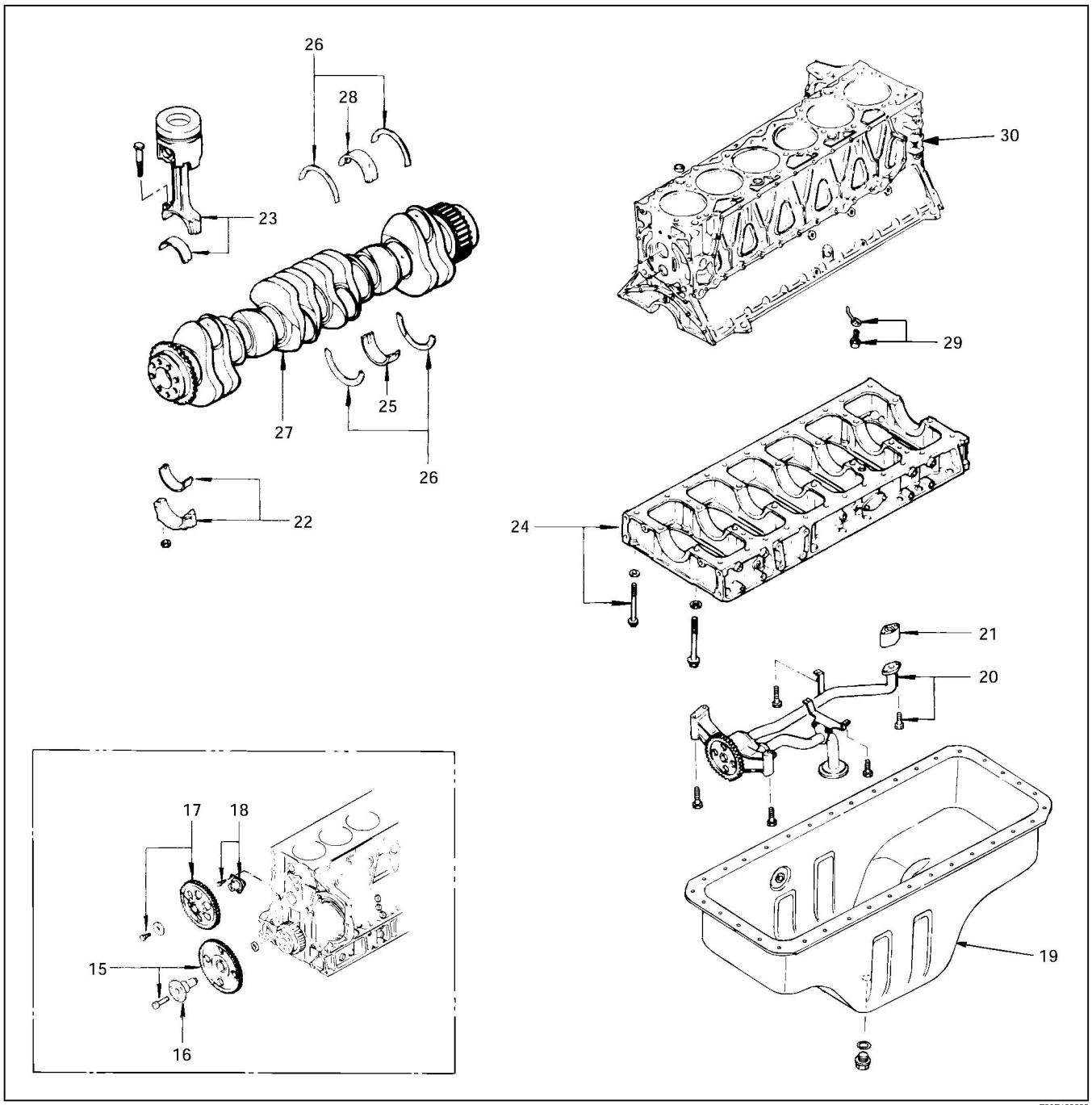


015E100057

13. Flywheel

Stop the crankshaft from turning, and loosen the bolts gradually in the sequence shown.

DISASSEMBLY 3



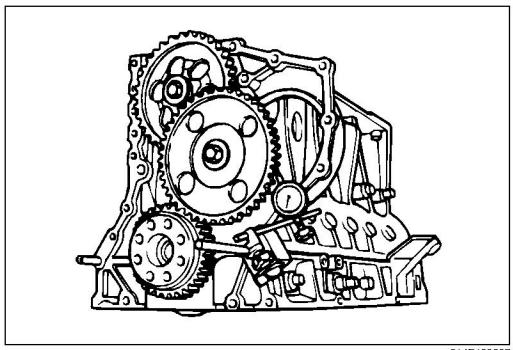
F06E100005

Disassembly sequence

▲15. Idler gear "A"
16. Idler gear shaft "A"
▲17. Idler gear "B"
18. Idler gear shaft "B"
19. Oil pan
20. Oil pump
21. Anti-drain valve
▲22. Connecting rod bearing cap (with lower bearing)
▲23. Piston and connecting rod (with upper bearing)
▲24. Cylinder block lower crankcase
▲25. Crankshaft lower bearing
▲26. Thrust bearing
27. Crankshaft
▲28. Crankshaft upper bearing
29. Oil jet
30. Cylinder block

IMPORTANT OPERATIONS

15. Idler gear "A"
17. Idler gear "B"
Before removing the idle gear, measure each gear's backlash and end play.


014E100007

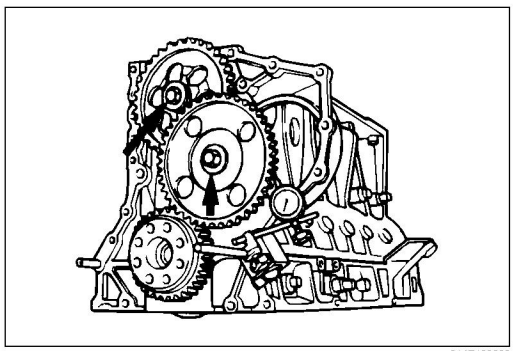
Backlash measurement
(1) Attach a dial gauge to the idle gear to be measured.

Note:
When the gear to be measured is meshed with another gear, fix that gear in position and prevent it from moving.

(2) Move the gear to be measured to left and right, and read the fluctuation of the needle on the dial gauge. If the measured value exceeds the limit value, replace the timing gear.

Backlash mm (in)

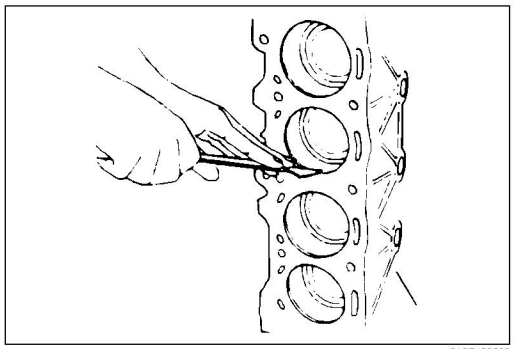
Standard	Limit
0.1 (0.0039) or less	0.3 (0.012)


014E100008

Measuring idler gear end play
(1) Insert a feeler gauge between the idle gear and the thrust washer, and measure the gap.
(2) If the measured value exceeds the limit value, replace the thrust washer or the gear.

Idle gear end play mm (in)

Standard	Limit
0.04 ~ 0.19 (0.0016 ~ 0.0075)	0.30 (0.012)

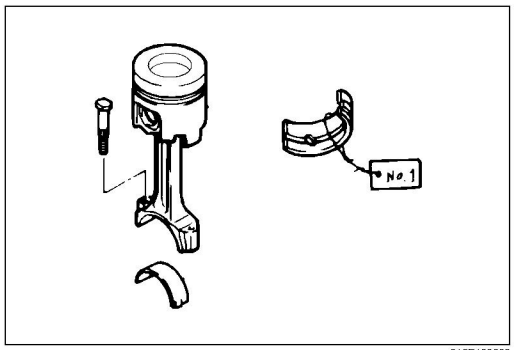

012E100003

22. Connecting rod bearing cap (with lower bearing)

23. Piston and connecting rod (with upper bearing)

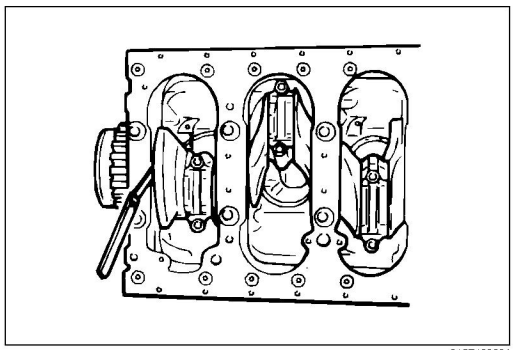
(1) Before removing the piston and connecting rod, remove any carbon deposits on the upper portion of the cylinder liner.

(2) Set the piston at the BDC position, remove the connecting rod cap, then rotate the crankshaft and bring the piston to the TDC position.
Lightly tap the connecting rod's large end with the handle of a hammer to drive the piston out with the connecting rod attached.



015E100003

Note:
When removing the piston, take care not to damage the cylinder liner and oiling jet.
If the connecting rod bearings are to be reused, attach a tag clearly indicating the position from which each is removed.

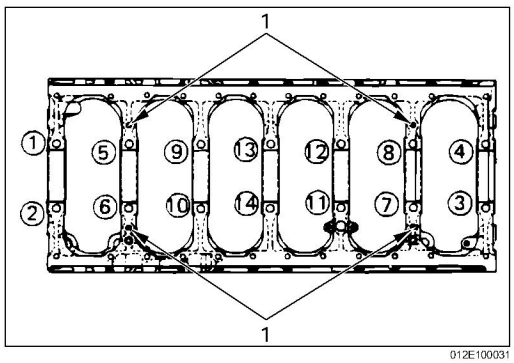

015E100004

24. Cylinder block lower crankcase

(1) As shown in the illustration, measure the end play at the rear end of the crankshaft.
Perform this measurement before removing the lower crankcase. If the measurement exceeds the limit value, replace the thrust bearing.

Crankshaft end play mm (in)

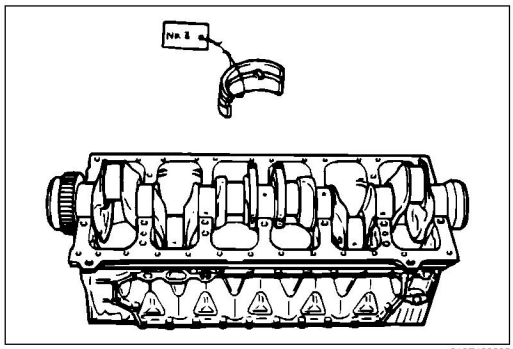
Standard	Limit
0.10 ~ 0.285 (0.0039 ~ 0.0112)	0.40 (0.016)



012E100031

(2) Loosen the lower crankcase bolts in the following sequence:
First stage: Loosen the M10 bolts on the outer edge of the crankcase
Second stage: Gradually loosen the M14 bolts ① — ⑭ on the inside edge of the crankcase in the numerical order shown.
Third stage: Screw the removed M10 bolts in the replacer holes (1) and tighten evenly, pressing the lower crankcase out and away to remove.

Note:
The cylinder block and lower crankcase are manufactured as a single unit; as a result, if it is necessary to replace either one, both must be replaced together.

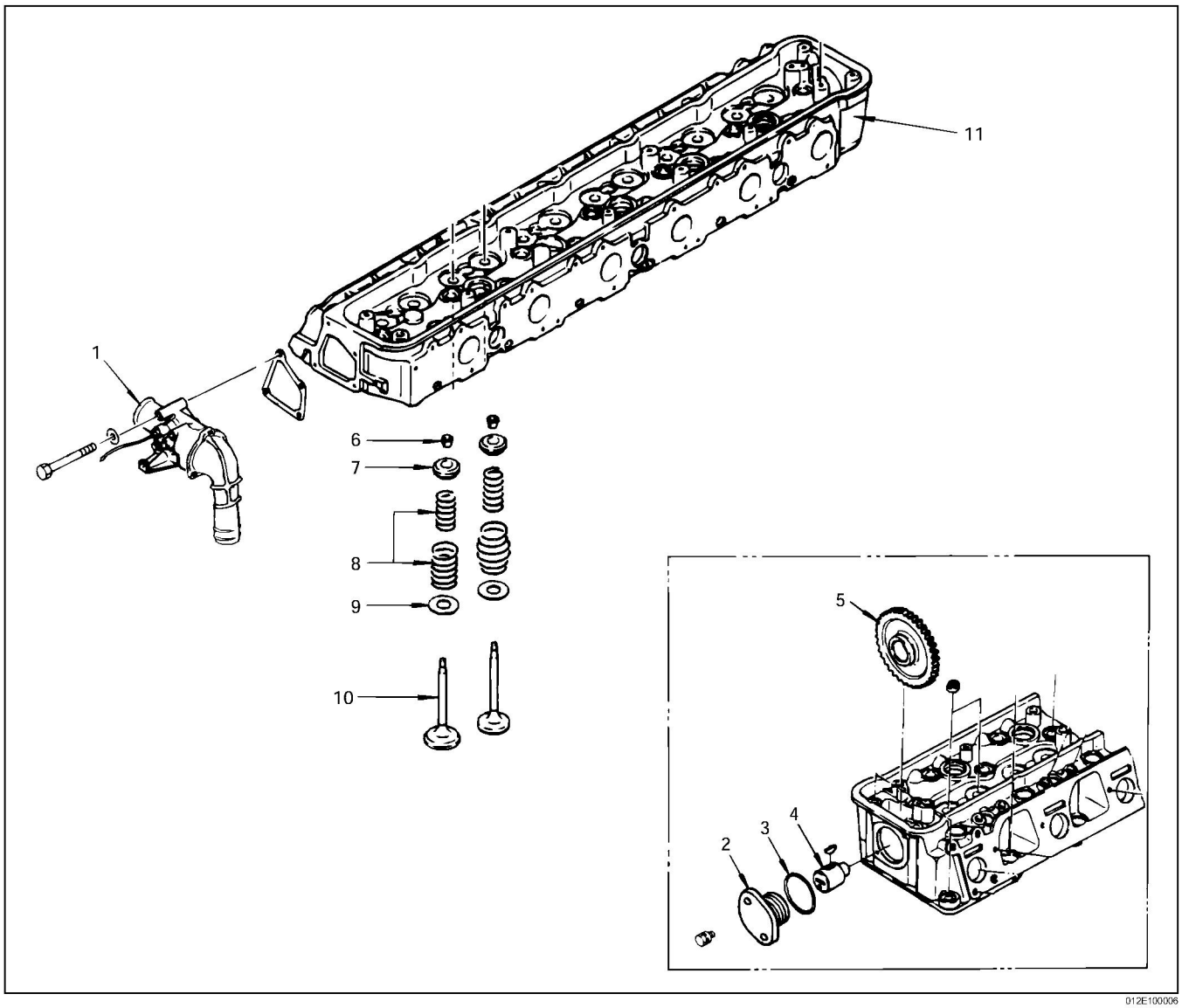


012E100005

25. **Crankshaft lower bearing**
26. **Thrust bearing**
28. **Crankshaft upper bearing**

If the bearings are to be reused, be sure to attach a tag clearly indicating the position from which each one is removed.

CYLINDER HEAD DISASSEMBLY

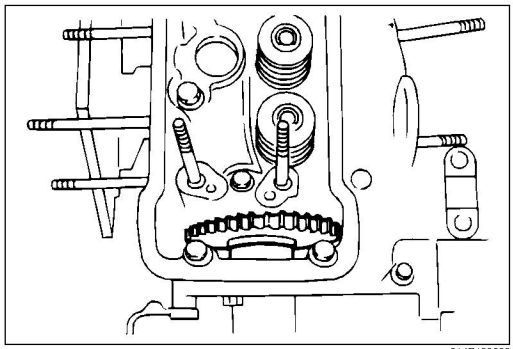


012E100006

Disassembly sequence

1. Thermostat housing
2. Idler gear cover
3. Idler gear gasket
4. Idler gear shaft "C"
▲5. Idler gear "C"
▲6. Split collar
7. Valve spring upper seat
8. Valve spring
9. Valve spring lower seat
▲10. Intake and exhaust valves
11. Cylinder head

IMPORTANT OPERATIONS


014E100009

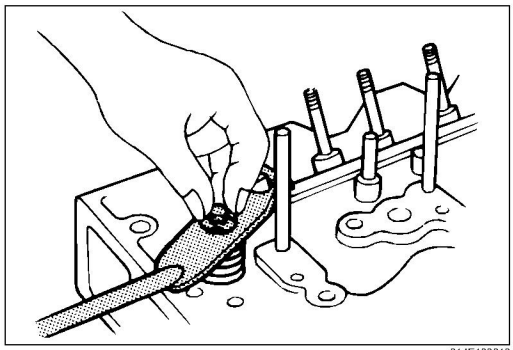
5. Idler gear "C"

(1) Using a feeler gauge, measure the idler gear "C" end play.

Idler gear "C" end play mm (in)

Standard	Limit
0.047 ~ 0.218 (0.0019 ~ 0.0086)	0.40 (0.016)

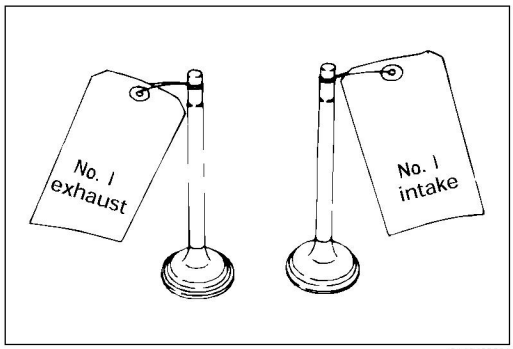
(2) Remove the idler gear.


014E100010

6. Split collar

(1) Lay the cylinder head on a flat surface.

(2) Use a spring compressor to remove the split collar.
Take care not to allow the valve to fall from the head.
Spring compressor: 1-85235-007-0

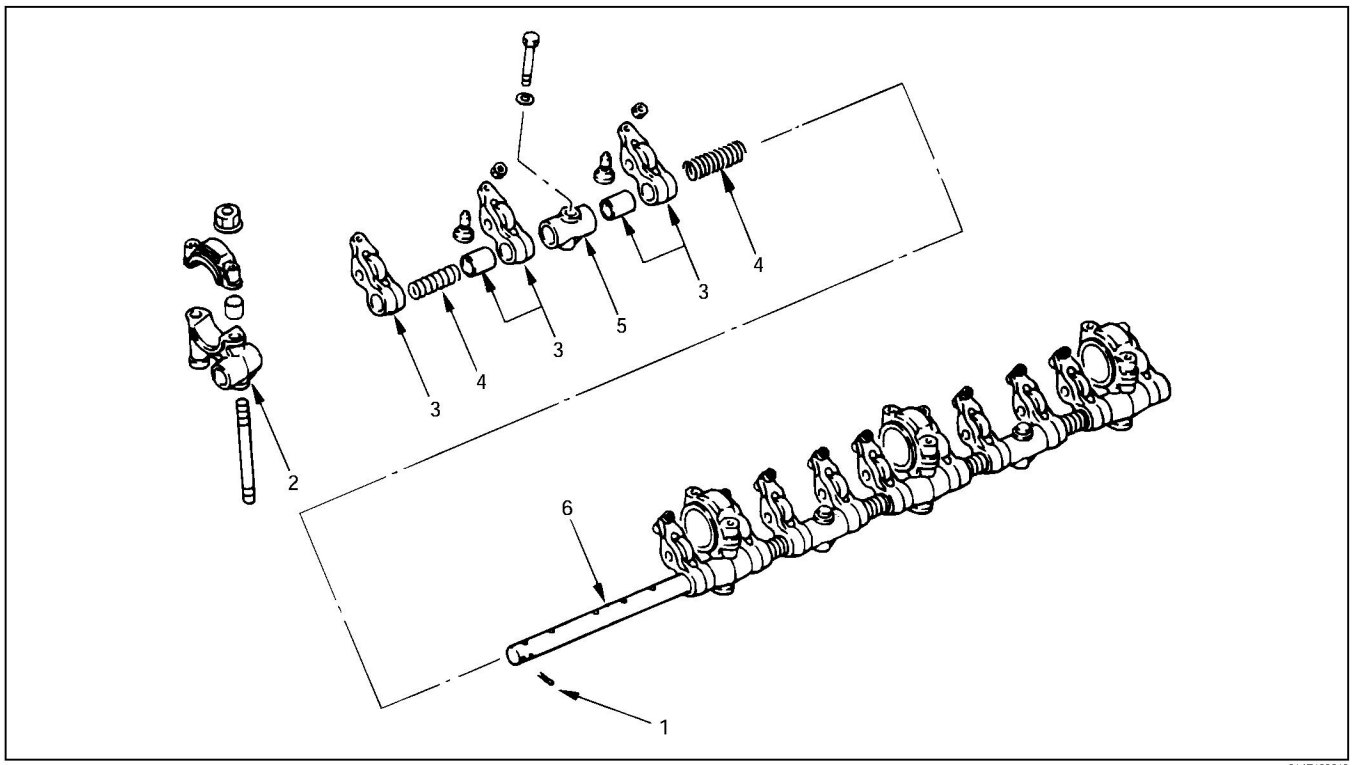


014A100001

10. Intake and exhaust valves

Attach a tag to each valve noting the position from which it was removed.
When installing new valves, be sure to install new valve guides at the same time.

ROCKER ARM SHAFT ASM DISASSEMBLY

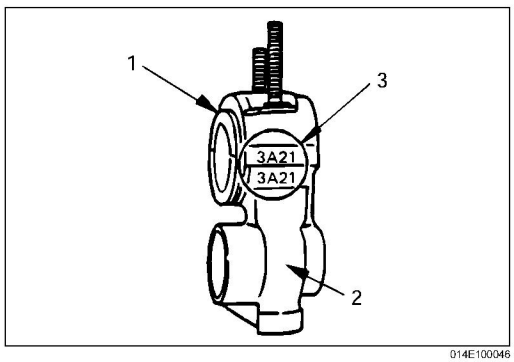


014E100012

Disassembly sequence

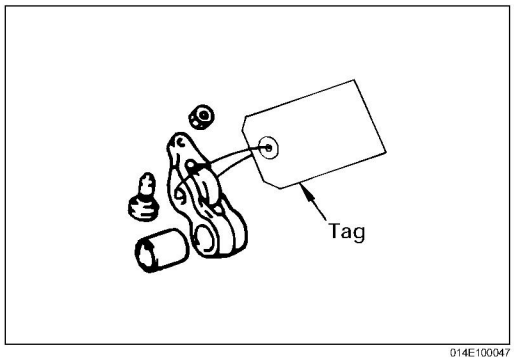
1. Split pin
▲2. Camshaft lower bracket
▲3. Rocker arm
4. Rocker arm spring
5. Rocker arm bracket
6. Rocker arm shaft

IMPORTANT OPERATIONS



014E100046

2. Camshaft lower bracket
Be sure to store the removed upper (1) and lower (2) brackets together (note alignment mark (3)).

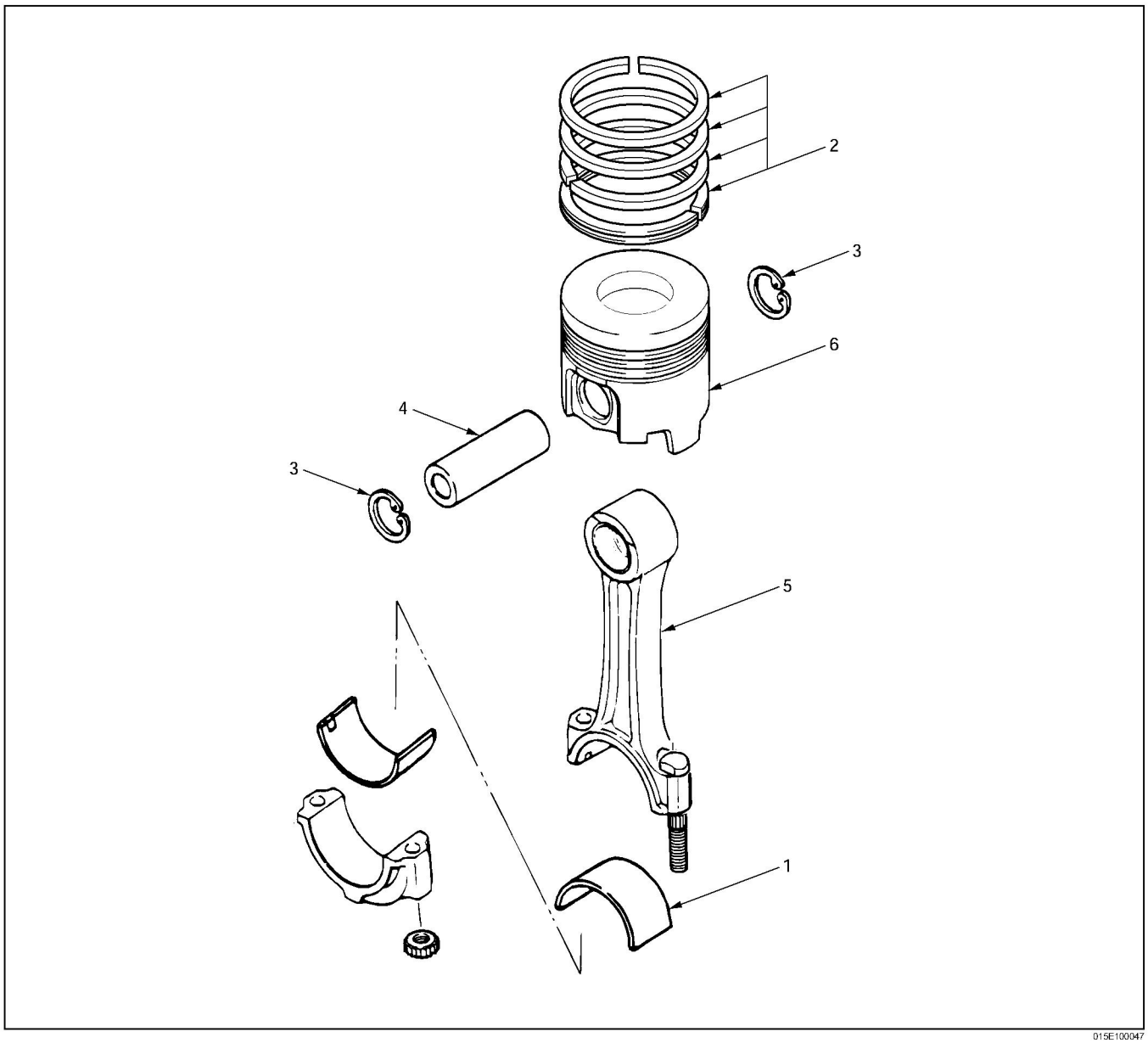


014E100047

3. Rocker arm
If the removed rocker arms are to be reused, be sure to label with tags noting the cylinder number and whether for intake or exhaust.

Note:
In the movable portion of the adjust screw, the "ball" is peened to match the "pan", so do not subject it to excessive shock.

PISTON AND CONNECTING ROD DISASSEMBLY

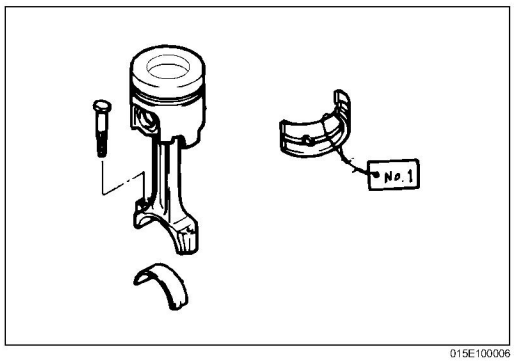


015E100047

Disassembly sequence

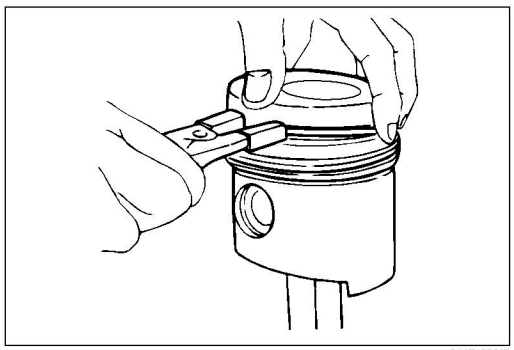
▲1. Connecting rod bearing
▲2. Piston ring
▲3. Snap ring
▲4. Piston pin
5. Connecting rod
6. Piston

IMPORTANT OPERATIONS

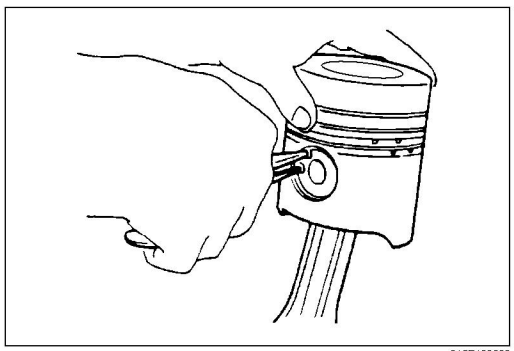


015E100006

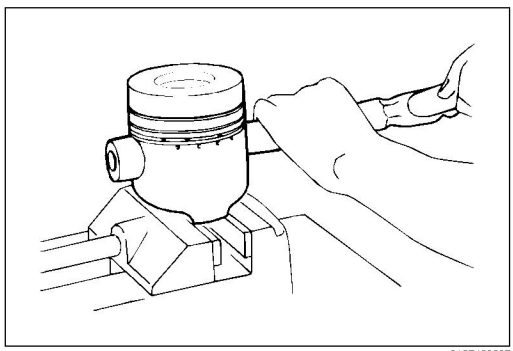
1. Connecting rod bearing
If the connecting rod bearings are to be reused, mark each one with the cylinder number so that they are reinstalled in the same position.


014E100060

2. Piston ring
(1) Fix the connecting rod in a vice.
Take care not to damage the connecting rod.
(2) Use a piston pin replacer to remove the piston rings.
Piston ring replacer: 1-85221-029-0
Do not use other tools to remove the rings, since they may stretch the rings, resulting in reduced ring tension.


015E100023

3. Snap ring
Use a pair of snap ring pliers to remove the piston pin snap ring.


015E100007

4. Piston pin
Remove the piston pin by lightly tapping with a hammer and a brass bar.
If the piston pins are to be reused, label each one with the cylinder number, and be sure to replace in the same location.

MEMO

CHAPTER 4

ENGINE II

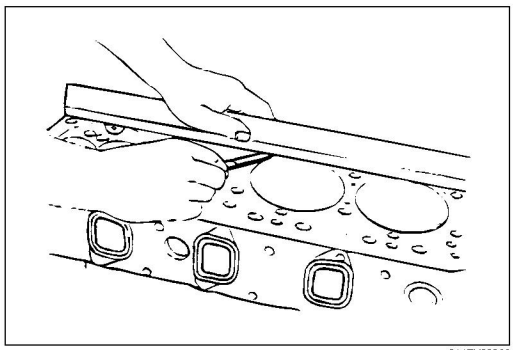
(INSPECTION AND REPAIR)

CONTENTS

INSPECTION AND REPAIR (1)
(Cylinder Head)

If excessive wear or damage is discovered during inspection, the appropriate parts must be adjusted, repaired, or replaced.

CYLINDER HEAD

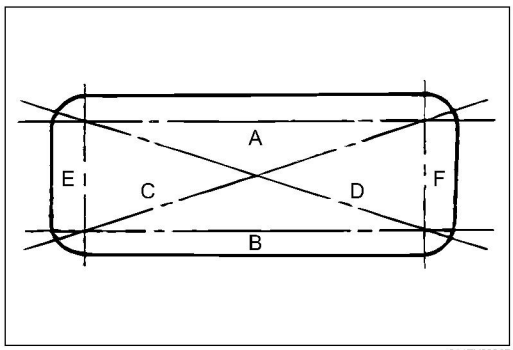

011EY00066

Warpage of lower face of cylinder head

1. Use a straight edge (ruler) and a feeler gauge to measure the warpage of the four sides and the two diagonals of the lower face of the cylinder head as shown.
2. If the measured values are greater than the specified limit, the cylinder head must be replaced.

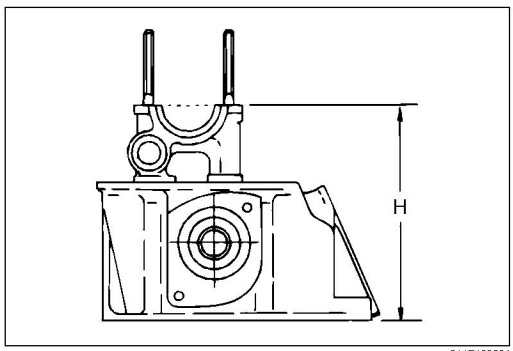
Warpage of lower face of cylinder head mm (in)

Standard	Limit
0.05 (0.002) or less	0.2 (0.0079)



011EY00067

Note:
Lower face of cylinder head can not be reground because 6SD1 model has overhead camshaft construction with the valve gear train.



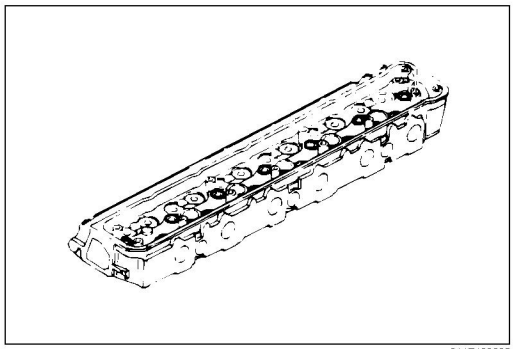
011E100004

Cylinder head height

Cylinder head height (reference); H mm (in)

Standard	Limit
173.0 ~ 173.025 (6.811 ~ 6.812)	172.775 (6.8022)

Note:
Do not regrind the lower face of the cylinder head.


011E100005

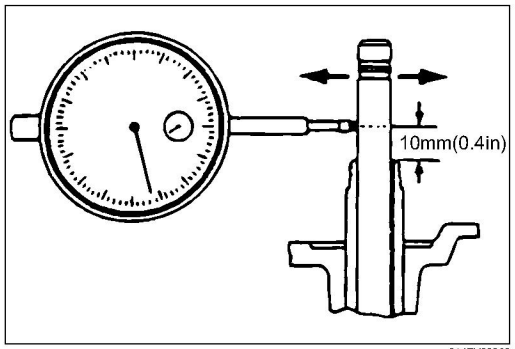
Water jacket pressure test

1. Blow air in the water jacket to check for blockages.
2. In the hydraulic pressure test, apply the designated pressure for 3 minutes and check all parts for water leaks.

kPa(kgf/cm^2/psi)

Test Pressure	490 (5/71)

VALVE GUIDES



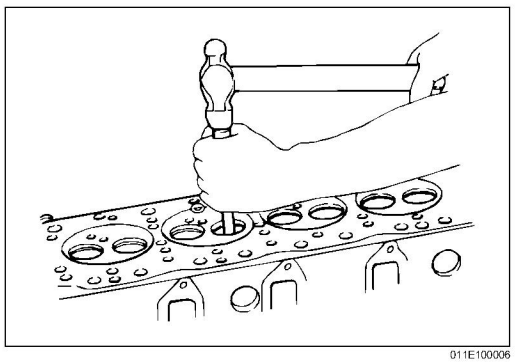
014EY00062

Clearance between valve stem and valve guide
Measurement

1. With the valve stem inserted in the valve guide as shown, set a dial gauge with its needle to "0" at a point about 10 mm from the upper end of the guide.
2. Move the valve head forward and back and read the dial indicator, recording the maximum measurement. If the measured value is less than the limit value, the valve and valve guide must be replaced as a set.

Valve stem and valve guide clearance mm (in)

	Standard	Limit
Intake valve	0.040 ~ 0.077 (0.0016 ~ 0.0030)	0.15 (0.006)
Exhaust valve	0.065 ~ 0.102 (0.0026 ~ 0.0040)	0.20 (0.008)

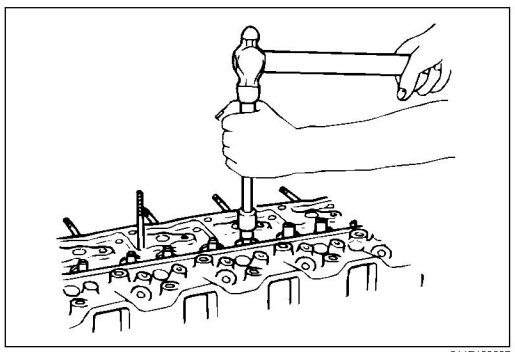

011E100006

Valve guide replacement

Removal

Use a hammer and valve remover to tap out the valve guide from the head's lower side toward the upper side.

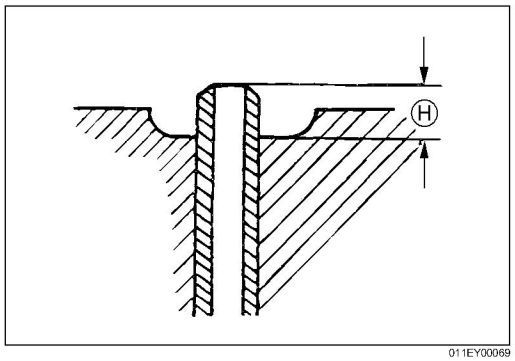
Valve guide remover: 9-8523-1202-2


011E100007

Installation

1. Apply clean engine oil the outer periphery of the valve guide.
2. Attach the installer to the valve guide.
3. Use a hammer to drive in the valve guide from the upper face of the head until the installer's lower edge meets the head surface.

Valve guide installer: 9-8523-1202-0



011EY00069

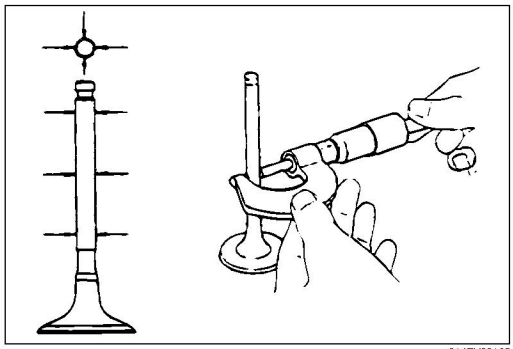
4. After installation, measure the distance (height) from the cylinder head's upper surface to the upper edge of the valve guide.

Height to valve guide upper edge; H mm (in)

22.0 (0.87)

Note:
Whenever the valve guide is removed, always replace both valve and valve guide together with a new set.

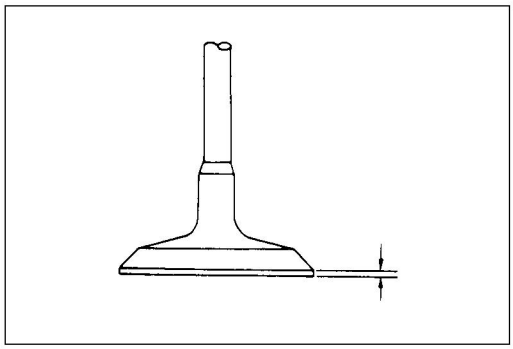
VALVE AND VALVE SEAT INSERT


014EY00165

Valve stem diameter
Use a micrometer to measure the valve stem diameter in three locations as shown.
If the measured value is less than the limit value, replace the valve and valve guide as a single set.

mm (in)

	Standard	Limit
Intake valve	10 (0.39)	9.92 (0.391)
Exhaust valve	10 (0.39)	9.90 (0.390)

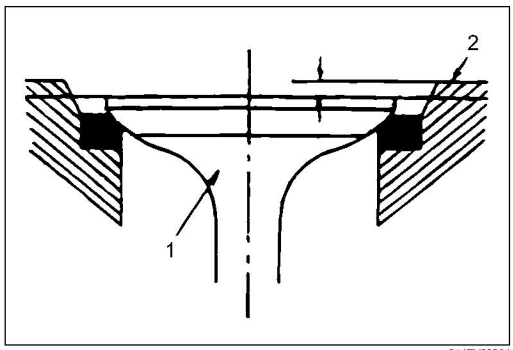


Valve thickness
Inspect the valve seat for damage or step wear, then measure the thickness.
If the measured value is less than the limit value, both the valve and valve guide must be replaced with a new set.

Valve thickness mm (in)

	Standard	Limit
Intake valve	2.50 (0.098)	2.00 (0.079)
Exhaust valve	2.35 (0.092)	1.85 (0.073)

The same values apply to valves which have been reground

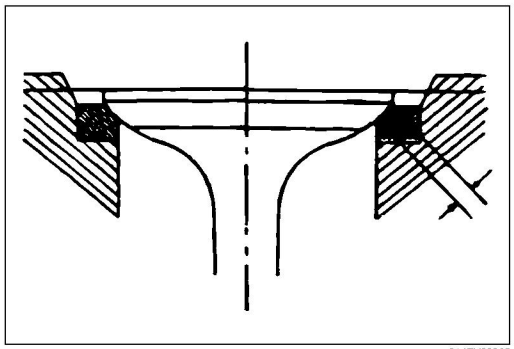


014EY00064

Valve depression
1. Install the valve (1) in the cylinder head (2).
2. Using a depth gauge or two rulers, measure the amount of depression from the lower face of the cylinder head to the surface of the valve head. If the measured value exceeds the limit, the valve seat insert must be replaced.

Valve depression mm (in)

	Standard	Limit
Intake valve	0.48 (0.019)	1.48 (0.058)
Exhaust valve	1.60 (0.063)	2.60 (0.10)

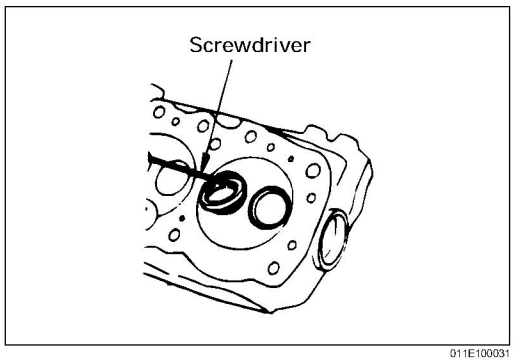

014EY00065

Valve contact width

1. Inspect the valve contact for roughness and unevenness.
   If necessary, smooth the surface of the valve contact.
2. Measure the contact surface width.
   If the measured value exceeds the limit, the valve seat insert must be replaced.

Valve contact width mm (in)

	Standard	Limit
Intake valve	2.7 (0.106)	3.5 (0.138)
Exhaust valve	2.4 (0.094)	3.2 (0.126)

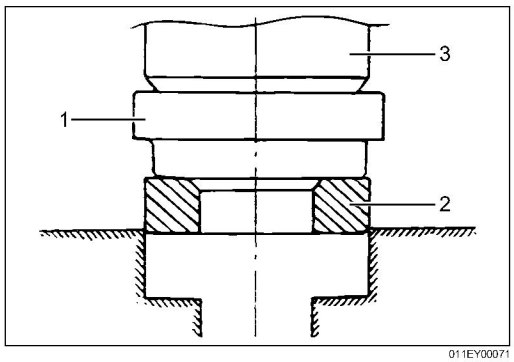


011E100031

Valve insert replacement

Removal

1. Use an acetylene torch to heat the inner surface of the valve seat insert on two opposing sides (700 ~ 800°C).
2. Allow the insert to cool for 3 ~ 5 minutes (do not cool too suddenly).
3. Use a screwdriver as shown to pry out the insert.
   Take care not to scar the cylinder liner.
4. Carefully remove any carbon deposits or other debris from the insert installation holes.



011EY00071

Installation

1. Place the attachment (1) (with smaller outside diameter than the valve seat insert) on top of the valve seat insert (2) as shown.

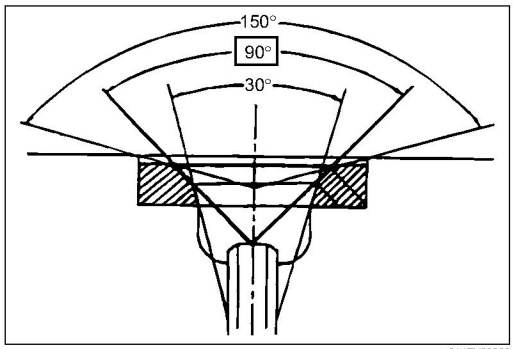
Note:
Be sure the smooth surface of the attachment contacts the valve seat insert.

2. Using a bench press (3), gradually apply pressure on the attachment so as to drive the valve seat insert into the head.

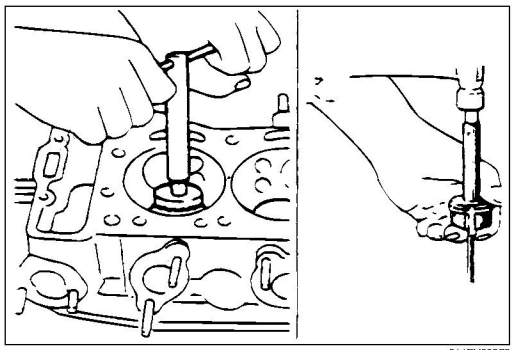
kN (kg)

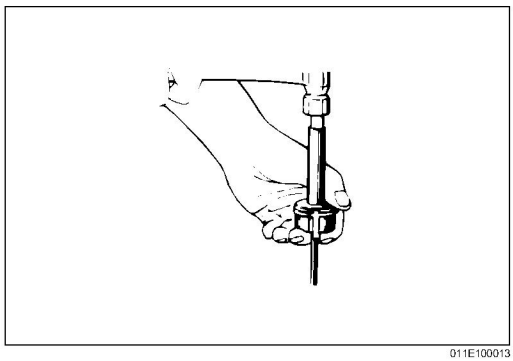
Insertion pressure	9.81 ~ 14.7 (1000 ~ 1500)

Note:
When pressing the valve seat insert, to not apply excessive pressure since damage to the valve seat will result.



011EY00032


011EY00072


011E100013

Correction of the valve seat insert

1. Remove carbon deposits from the surface of the valve seat insert.
2. Using valve cutters (blade angles 15°, 45°, 60°, 75°), or a valve seat grinder, trim the contact edge of the valve seat to remove scratches and roughness.
   This procedure can be used to return the contact surface width to standard values. When performing this repair, take care to remove only scratches and roughness, and do not cut away sound parts of the valve seat.

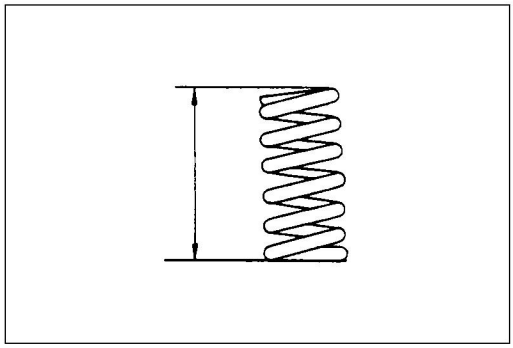
Valve seat angle

Intake side	30°
Exhaust side	45°

Note:
Use an adjustable valve cutter.
Take care not to allow the valve cutter or seat grinder to wobble inside the valve guide.

3. Apply cutting compound to the surface of the valve seat insert.
4. Use a valve grinder to lap the valve.
5. Following lapping, inspect for proper valve contact.

VALVE SPRINGS

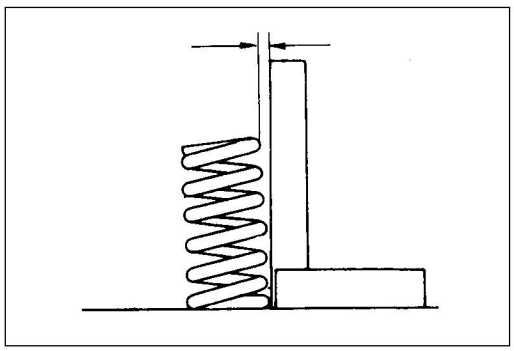


Valve spring free height

Use calipers to measure the valve spring free height. If the measured value is less than the limit value, replace the spring.

Inner and outer spring free length mm (in)

	Intake side		Exhaust side	
	Standard	Limit	Standard	Limit
Inner	62.5 (2.46)	60.5 (2.38)	69.2 (2.72)	67.2 (2.65)
Outer	59.3 (2.33)	57.3 (2.26)	80.7 (3.18)	78.7 (3.10)

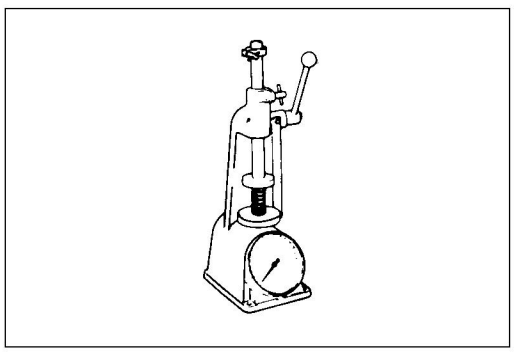


Valve spring inclination

Using a surface plate and square, measure the valve spring inclination.

Inner and outer spring inclination mm (in)

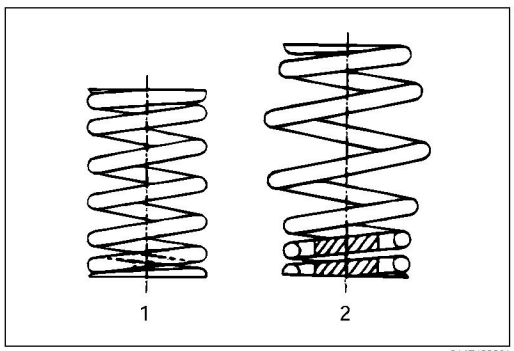
	Limit
Inner	3.0 (0.12)
Outer	3.5 (0.14)



Valve spring tension

Using a spring tester, measure the valve spring tension. If the measured value is more than 10% under the standard value, replace the spring.

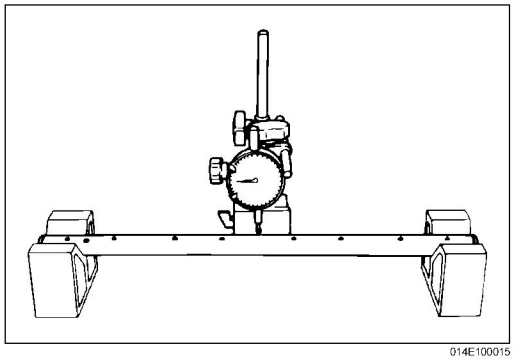
	Intake side		Exhaust side	
	Compressed length (mm)	Standard N (kg)	Compressed length (mm)	Standard N (kg)
Inner	46.2	111.8 (11.4)	46.2	284.4 (29.0)
Outer	48.7	292.2 (29.8)	48.7	500.1 (51.0)



Color Coding

Intake side spring (1)	Inner	Green
	Outer	Green
Exhaust side spring (2)	Inner	Yellow
	Outer	Yellow

ROCKER ARM SHAFT AND ROCKER ARM

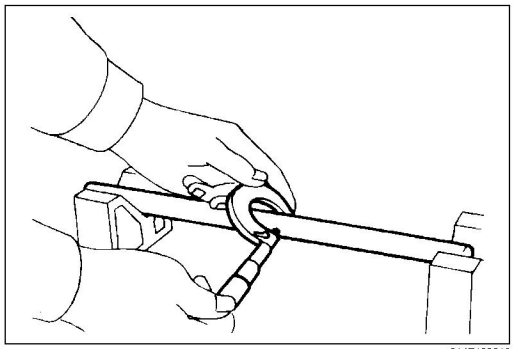

014E100015

Rocker arm shaft runout

1. Place the rocker arm shaft on a V-block.
2. Using a dial gauge, measure the rocker arm shaft runout in the center of the shaft. If the runout is very slight, it may be corrected with a bench press while cold.
   If the measured value exceeds the limit value, the rocker arm shaft must be replaced.

Rocker arm shaft deflection (1/2 of runout) mm (in)

Limit
0.3 (0.012)

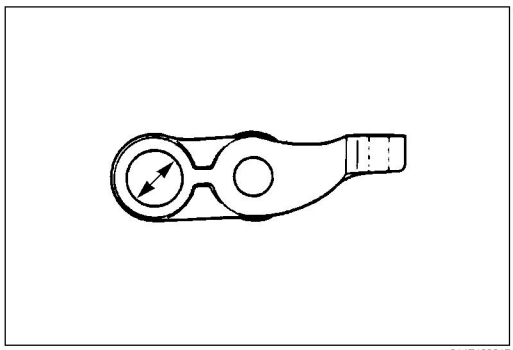

014E100016

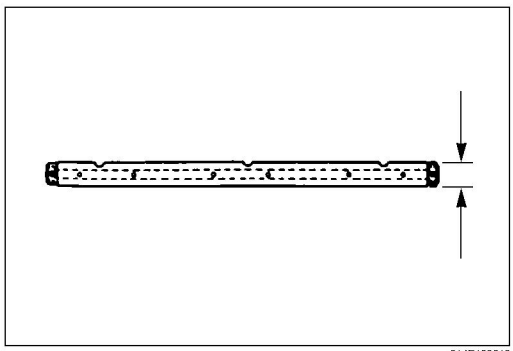
Rocker arm shaft diameter

Use a micrometer to measure the shaft diameter at the points where the rocker arms are attached.
If the measured value is less than the limit value, the rocker arm shaft must be replaced.

Rocker arm shaft diameter mm (in)

Standard	Limit
19.00 (0.748)	18.85 (0.742)


014E100017

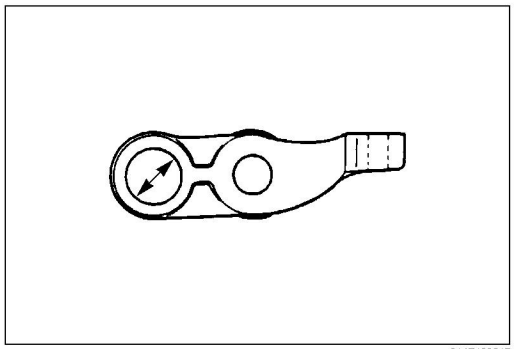

014E100018

Rocker arm shaft and rocker arm clearance

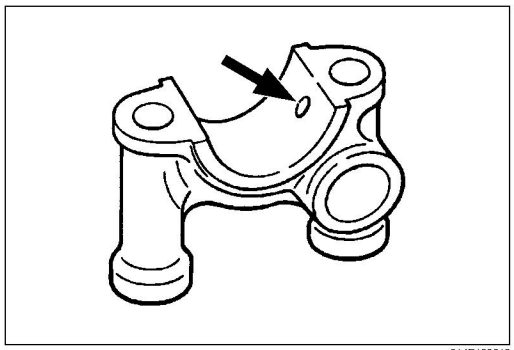
1. Use inside calipers or an inside dial gauge to measure the inside diameter of the rocker arm bushing.
2. Measure the outside diameter of the rocker arm shaft.
3. Use the two measurements to calculate the clearance.
   If the measured value exceeds the limit, replace either the rocker arm shaft or the rocker arm.

Rocker arm and rocker arm shaft clearance mm (in)

Standard	Limit
0.01 ~ 0.05 (0.0004 ~ 0.0020)	0.2 (0.0079)


014E100017

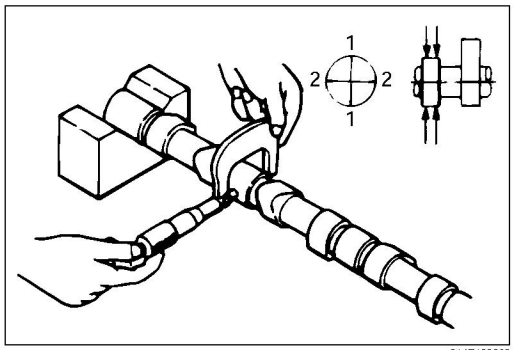
4. Inspect the rocker arm oil ports to confirm that no clogging is present.
   If clogged, clean out debris by blowing with compressed air.
   Also check for any friction or unevenness on the roller surface.


014E100019

Lower camshaft bracket
Inspect the oil ports on the bracket (rear side) for any clogging, and clean if necessary.

CAMSHAFT

Inspection
Visually check journals, cams, and camshaft brackets for excessive wear and other damage.
If any damage is evident, replace with a new part.

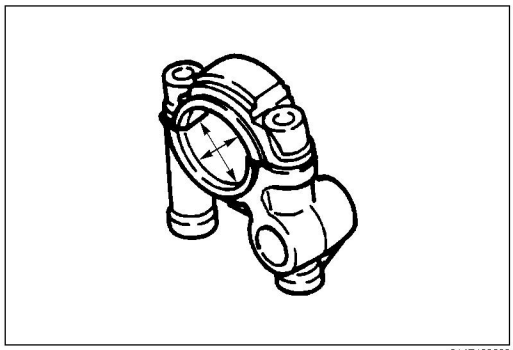


014E100062

Journal diameter
Use a micrometer to measure the diameter of each journal in both directions (1) and (2) as shown in the illustration.
If the measured value is less than the limit value, replace the camshaft.

Journal diameter mm (in)

Standard	Limit
39.915 ~ 39.940 (1.5726 ~ 1.5724)	39.89 (1.5704)

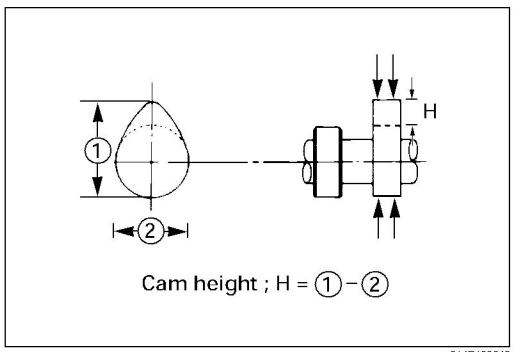

014E100020

Camshaft and camshaft bracket clearance
Use a dial gauge to measure the inner diameter of the bracket.
If the clearance between the camshaft bracket (inner diameter) and the camshaft journal (outer diameter) exceeds the limit value, replace either the camshaft bracket, or the camshaft, or both.

Camshaft bracket clearance mm (in)

Standard	Limit
0.06 ~ 0.11 (0.0024 ~ 0.0043)	0.16 (0.0062)

Note:
when replacing one camshaft bracket, replace the entire parts set.

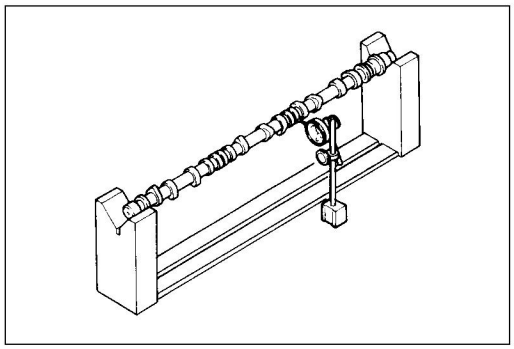


014E100049

Cam lobe height
Use a micrometer to measure the cam lobe height.
If the measured value is less than the limit, the camshaft must be replaced.

Cam height; H mm (in)

Standard	Limit
5.92 (0.233)	5.56 (0.219)

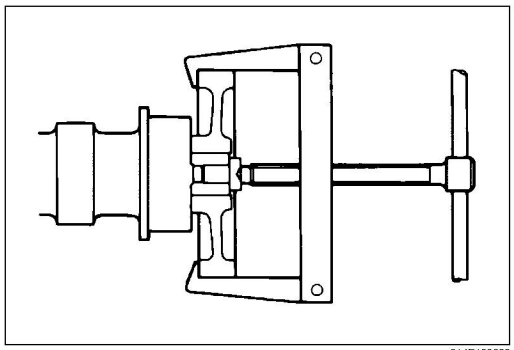


Camshaft runout

Set a dial gauge on the No. 3 or No. 4 journal; rotate the shaft gently on full turn, and read the gauge.
If the measured value exceeds the limit, the camshaft must be replaced.

Camshaft Runout mm (in)

Standard	Limit
0.05 (0.002)	0.10 (0.004)



Camshaft gear removal

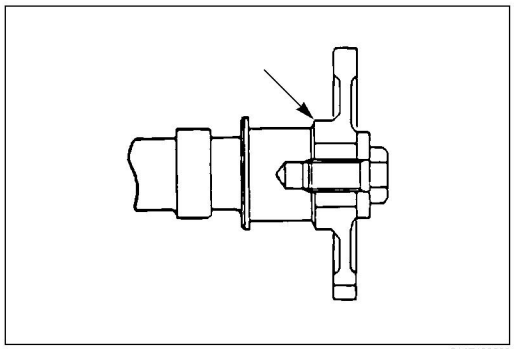
1. Remove the camshaft gear bolt.
2. Using a gear puller, remove the camshaft gear.

Note:
When removing the gear, be careful not to damage the gear teeth.

If the gear puller pressed directly against the teeth, the teeth may be deformed; as a result, a brass plate should be placed between the puller tip and the gear.

Inspection

Visually inspect the teeth of the camshaft gear; if any wear or damage is found, replace the gear.



Camshaft gear installation

1. Insert the key in the camshaft key slot.
2. Apply clean engine oil to the threads of the gear bolt and the gear setting surface.
3. Install the gear with the large bossing (arrow) mounted toward the camshaft.

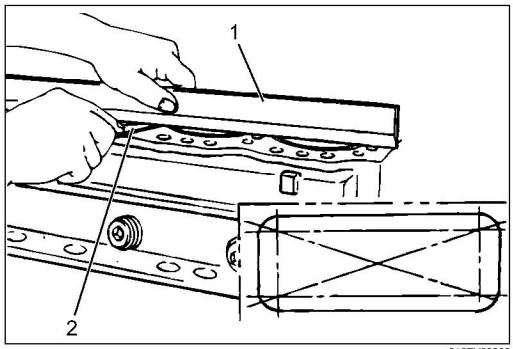
Camshaft gear tightening torque N·m (kgf·m/lb·ft)

114 ~ 171 (11.6 ~ 17.4 / 84 ~ 126)

INSPECTION AND REPAIR (2)
(Cylinder block)

Visually inspect the cylinder block for wear, cracks, water leaks, and other abnormalities.

CYLINDER BLOCK, CYLINDER LINER



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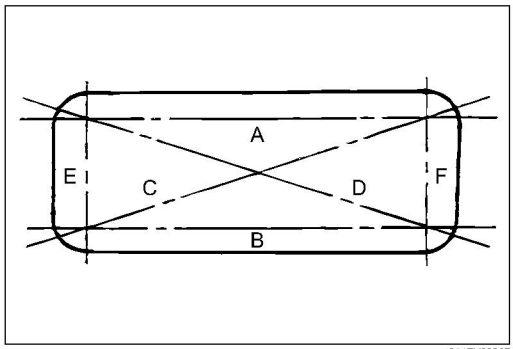

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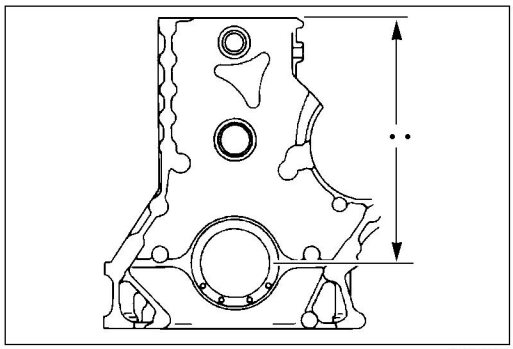
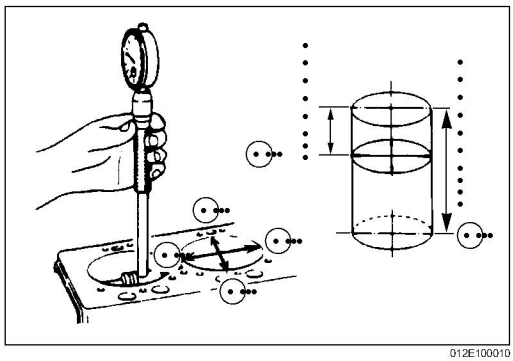

012E100009


012E100010

Warpage of upper face of cylinder block

1. Remove the block's dowel pins.
2. Remove the cylinder liner.
   The procedure for removal is listed in the section "cylinder liner replacement."
3. Use a ruler (1) and feeler gauge (2) as shown to measure the four sides and diagnosis of the cylinder block's upper face for warpage.
   If the measured value exceeds the limit, replace the cylinder block.

Cylinder block upper face warpage mm (in)

Standard	Limit
0.05 (0.0020) or less	0.2 (0.0079)

Note:
Do not attempt to use a surface grinder to regrind the upper face of the cylinder block.

4. If the height of the cylinder block is less than the standard value, replace the cylinder block.

Cylinder block height (reference); H mm (in)

Standard
369.47 ~ 370.54 (14.546 ~ 14.588)

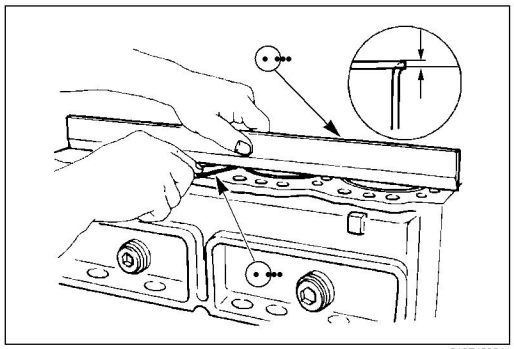
5. Refer to the section "Cylinder Block Bore Measurement" for instructions on installation of the cylinder liner.
6. Install the dowel pins.

Cylinder liner bore measurement

Use a cylinder gauge to measure the bore of the cylinder liner at points ① and ④ in order to measure the thrust direction (② — ②) and axial (③ — ③) directions.
Measuring point ① is 24 mm from the top face, while measuring point ④ is 120 mm from the top face.
If the maximum measured values exceed the limit, replace the cylinder liner.

Cylinder liner bore mm (in)

Standard	Limit
120 (4.724)	120.3 (4.736)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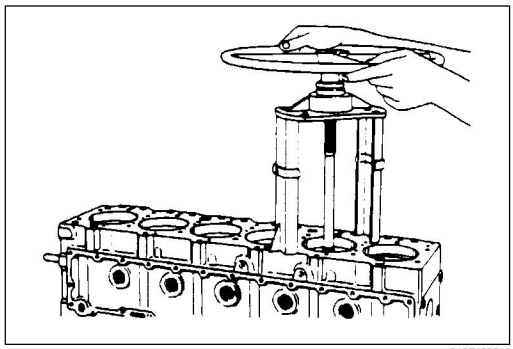
Measurement of cylinder liner projection

1. Place a straight edge ① along the top edge of the cylinder liner to be measured.
2. Using a feeler gauge ②, measures the projection of each cylinder liner.

Cylinder liner projection mm (in)

Standard
0.106 ~ 0.134 (0.0042 ~ 0.0053)

The difference in cylinder liner projection between any two neighboring cylinders must not exceed 0.02 mm.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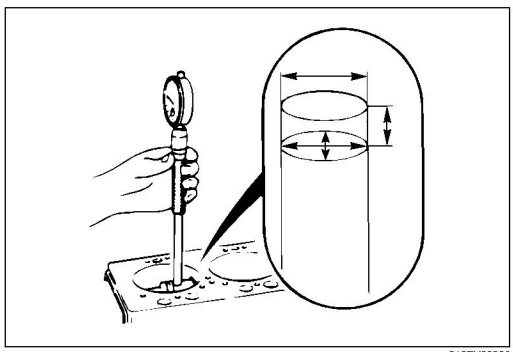
Cylinder liner removal

1.Attach a cylinder liner remover to the cylinder liner.
Cylinder liner remover : 1-85231-016-0

2. Confirm that the remover's shaft anchor is hooked firmly on the bottom of the cylinder liner.
3. Slowly rotate the remover's shaft handle clockwise to remove the cylinder liner.

Note:
Be careful not to damage the upper face of the cylinder block when removing cylinder liners.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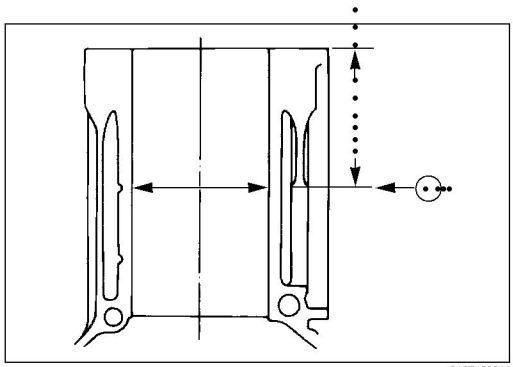
Cylinder block bore measurement

1. At measuring point ①, measure the cylinder block bore in the four directions (W-W, X-X, Y-Y, Z-Z).
Measuring point ①: 120 mm from upper face.
2. Calculate the average value of the four measurements to determine the correct liner grade.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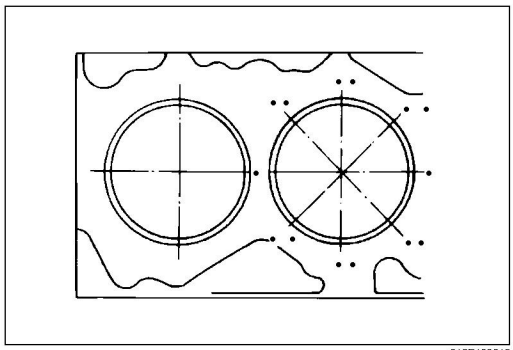
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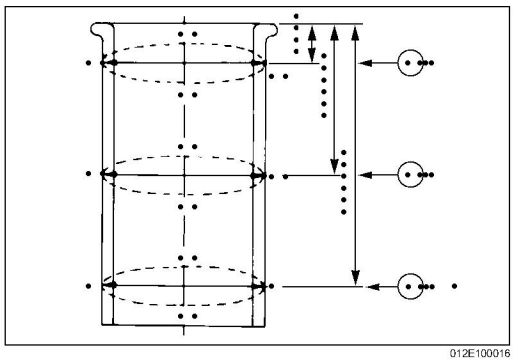

012E100016

Selection of liner grade

The "liner grade" mentioned here refers to the combination of the cylinder block bore (before insertion of the liner), and the outer diameter of the liner.

A liner which has an outside diameter that is too small (loose) for the cylinder block will result in poor cooling efficiency, leading to engine damage. Conversely, a liner that is too big for the block will be impossible to install properly.

In order to avoid such problems, it is important to measure the cylinder block bore to allow selection of the proper liner grade.

Cylinder liner O.D. measurement

1. Measure the outside diameter of the cylinder liner for both directions (X-X and Y-Y) at each of the three measuring points ①, ②, and ③.

Measuring points (distance from top face) mm (in)

①	18 (0.71)
②	114 (4.49)
③	210 (8.27)

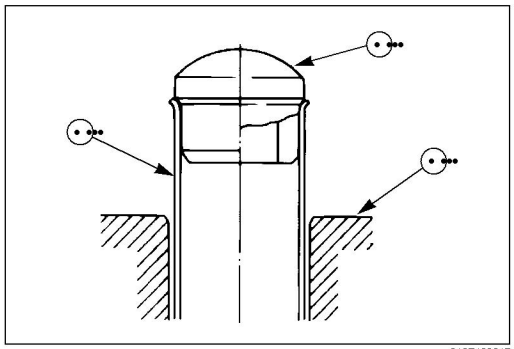
2. Calculate the average of the six measurements and use that figure when selecting the liner grade.

Standard Liner Interference mm (in)

0.011 ~ 0.029 (0.00043 ~ 0.00114)

Combination of cylinder block bore diameter and liner O.D. mm (in)

Grade	Cylinder block bore	Liner O.D.
1	123.001 ~ 123.010 (4.8426 ~ 4.8429)	123.021 ~ 123.030 (4.8433 ~ 4.8437)
2	123.011 ~ 123.020 (4.8429 ~ 4.8433)	123.031 ~ 123.040 (4.8437 ~ 4.8441)
3	1230.21 ~ 123.030 (4.8433 ~ 4.8437)	123.041 ~ 123.050 (4.8441 ~ 4.8445)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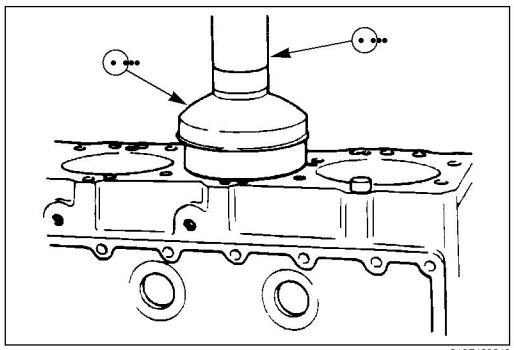

012E100018

Cylinder liner installation

1. When using special tools
   (1) Clean the outside of the liner and the inside walls of the cylinder block with clean kerosene or diesel fuel.
   (2) Used compressed air to dry off all cleaned surfaces.

Note:
All engine oil and other foreign matter must be removed from the liner and cylinder block bore before installation.

   (3) Press in the liner ① from the top of the cylinder block ②.
   (4) Set the liner installer ③ on top of the liner as shown.
   Cylinder liner installer: 1-85221-073-0
   (5) Position the body so that the centerline of the installer ③ is aligned with the centerline of the bench press shaft ④.

Note:
Set the body so that the liner is perpendicular to the bench press, taking care that no unevenness occurs between the liner and bench press.

   (6) Use the bench press to apply an initial force of 5 kN (500 kg) on the liner, to press it into the cylinder block.
   (7) Next, apply 25 kN (2500 kg) of force to seat the liner fully.
   (8) After installation of the liner, measure the cylinder liner projection.

Note:
The projection cannot be a negative value.
Refer to the section "Measurement of Cylinder Liner Projection" (P.67).

2. Installation Using Dry Ice
   Cooling the liner with dry ice will cause it to contact, facilitating installation.

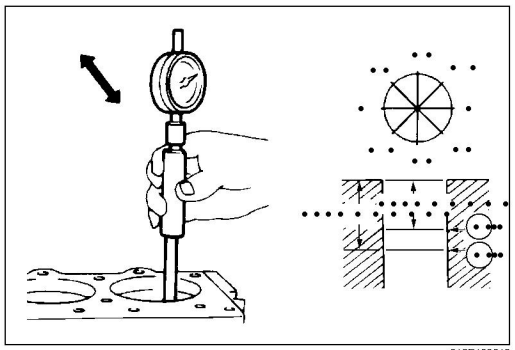
Note:
This method must be performed immediately after cooling the liner.

WARNING:
Dry ice must be handled with great care, since careless handling can result in severe frostbite.

Piston grade selection

"Piston grade" means that the proper piston for the combination of piston O.D. and cylinder liner bore measurements.

Selection of the proper piston grade is important to allow optimum engine operation without damage to liner and pistons.



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Cylinder liner bore measurement

After installation of the cylinder liner, measure the liner bore to allow selection of the proper piston grade.

1. Follow the instructions in the previous section on Cylinder Liner Bore Measurement, and measure the liner bore.
   Measuring point ① .....120 mm from upper face
   Measuring point ② .....216 mm from upper face
2. Take measurements in the four radial directions (W-W, X-X, Y-Y, X-X) at each of the measuring points ① and ②.
3. Calculate the average value from the eight measurements taken, and use that figure as the cylinder liner bore.

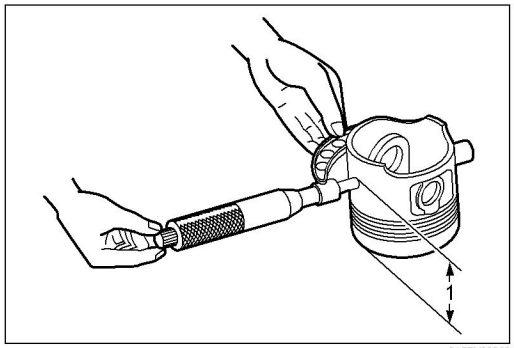
Cylinder liner bore mm (in)

Standard	Limit
120 (4.724)	120.3 (4.7362)

Note:

Selection of the proper piston grade is very important, since using an improper piston size will result in engine failure.

PISTON



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Piston outside diameter measurement
Measure the piston O.D., and select from either grade AX or CX so that the standard clearance is obtained between liner and piston.
Measurement point ① .....98 mm (3.86 in.) from piston face

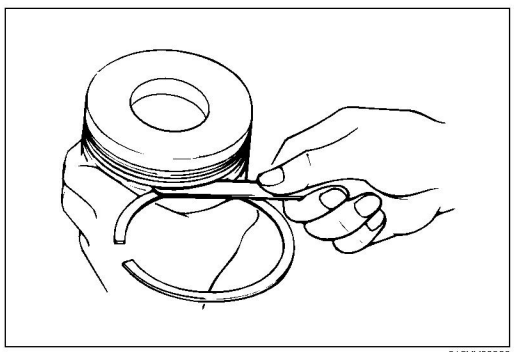
Clearance between cylinder liner and piston mm (in)

0.131 ~ 0.175 (0.0052 ~ 0.0069)

Cylinder liner bore and piston O.D. for service parts
mm (in)

Grade	Cylinder liner bore	Piston O.D.
AX	120.000 ~ 120.020 (4.7244 ~ 4.7252)	119.849 ~ 119.864 (4.7185 ~ 4.7191)
CX	120.021 ~ 120.040 (4.7252 ~ 4.7260)	119.865 ~ 119.890 (4.7191 ~ 4.17201)

Note:
The clearance between liner and piston is correct at time of manufacture, but when a liner is removed from the cylinder block and later reinstalled, the amount of clearance may be reduced.
As a result, it is always necessary to measure the clearance again after any reinstallation of a removed liner.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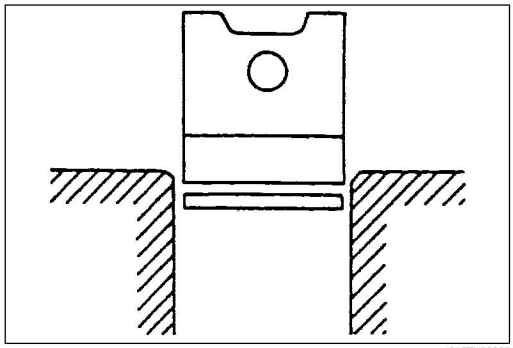
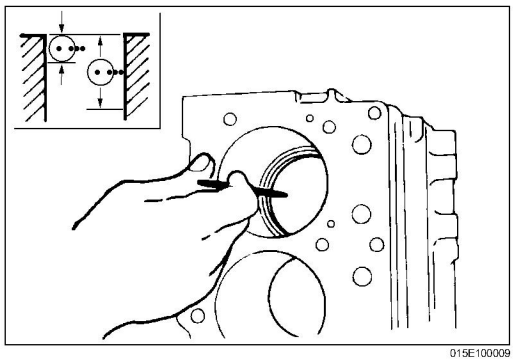
Clearance between piston rings and piston ring grooves
Use a feeler gauge to measure the clearance between the piston ring and the piston ring groove at several points around the piston.
If the clearance between the piston ring and the ring groove exceeds the limit, the piston ring must be replaced.

Clearance between piston ring and piston ring groove
mm (in)

	Standard	Limit
No. 1 compression ring	0.105 ~ 0.140 (0.0041 ~ 0.0055)	0.20 (0.0079)
No. 2 compression ring	0.105 ~ 0.140 (0.0041 ~ 0.0055)	0.20 (0.0079)
No. 3 compression ring	0.085 ~ 0.120 (0.0033 ~ 0.0047)	0.20 (0.0079)
Oil ring	0.020 ~ 0.060 (0.0008 ~ 0.0024)	0.15 (0.0059)

PISTON RING





Piston ring gap measurement

1. Holding the piston ring horizontally, insert it into the cylinder liner to the liner's bore measuring point.
2. As shown in the illustration, use an inverted piston to press the ring inside the liner until it reaches either measuring point ① or measuring point ②.
   The liner diameter is narrowed at these two points. Be sure that the inserted ring is kept perfectly horizontal while being inserted.
   Measuring point ①: 10 mm
   Measuring point ②: 160 mm
3. Using a feeler gauge, measure the gap where the ends of the ring come together.
   If the measured value exceeds the limit, replace the ring for that piston.

Piston ring openng gap mm (in)

	Standard	Limit
No. 1 compression ring	0.35 ~ 0.50 (0.0138 ~ 0.0197)	1.0 (0.039)
No. 2, 3 compression ring		
Oil ring	0.25 ~ 0.45 (0.0098 ~ 0.018)	0.8 (0.031)

4. Visually inspect the piston ring grooves.
   If any of the grooves are damaged or deformed, replace the piston.

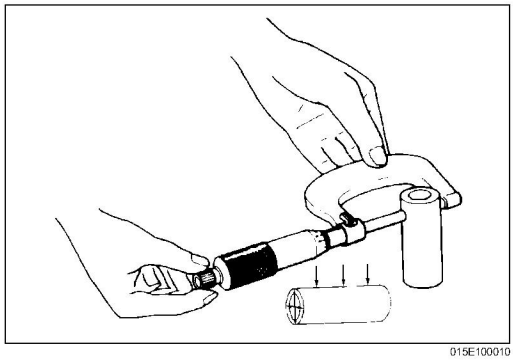
Ring tension

Measure piston ring tension with a piston ring tension gauge.

Ring tension N (kgf)

	Standard	Limit
No. 1 compression	24.1 ~ 31.8 (2.46 ~ 3.24)	14.7 (1.5)
No. 2 compression	15.4 ~ 21.3 (1.57 ~ 2.17)	9.8 (1.0)
No. 3 compression	17.7 ~ 24.5 (1.80 ~ 2.58)	11.8 (1.2)
Oil	53.9 ~ 73.5 (5.5 ~ 7.5)	37.3 (3.8)

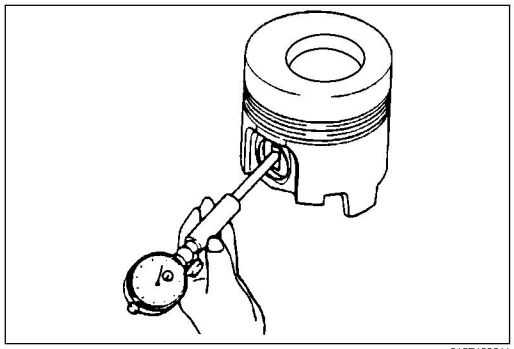
PISTON PIN



Piston pin diameter
Use a micrometer to measure the diameter of the piston pin at each of the six locations shown in the illustration. If the measured value is less than the limit, replace the pin.

Piston pin diameter mm (in)

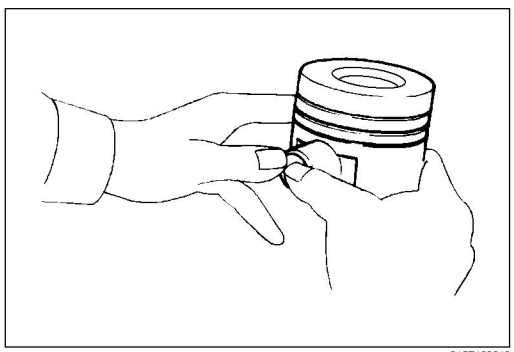
Standard	Limit
43.0 (1.693)	42.98 (1.692)



Clearance between piston pin and piston pin hole
Use an internal dial gauge to measure the diameter of the piston pin hole, and use that figure to calculate the clearance with the piston pin.

Clearance of piston pin and piston pin hole mm (in)

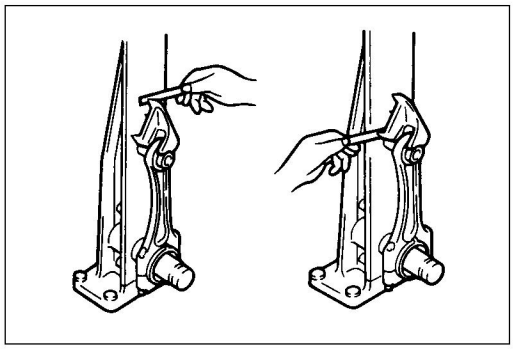
Standard	Limit
0.004 ~ 0.017 (0.00016 ~ 0.00067)	0.05 (0.00197)



If an internal dial gauge is not available, use the following procedure to check the piston pin clearance.

1. Use a piston heater to heat the piston to about 100°C.
2. Strongly push the piston pin into the piston pin hole with your thumbs. With proper pin clearance, the piston pin should go into the hole without any, or with very little, resistance.

CONNECTING RODS

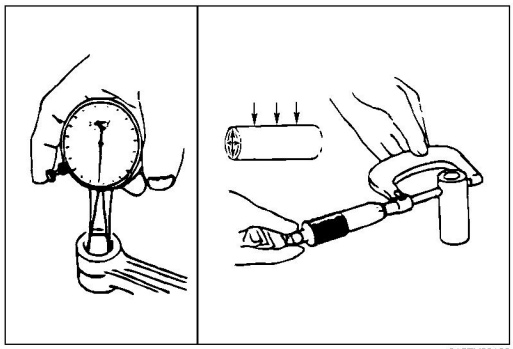


Connecting rod twist and parallelism

Use a connecting rod aligner to measure the connecting rod's twist distortion and parralelism between the rod's large and small ends.
If the measured value exceeds the limit, replace the connecting rod.

Connecting rod parallelism (per 100 mm length) mm (in)

	Standard	Limit
Twist, parallelism	0.03 (0.0012) or less	0.10 (0.0039)

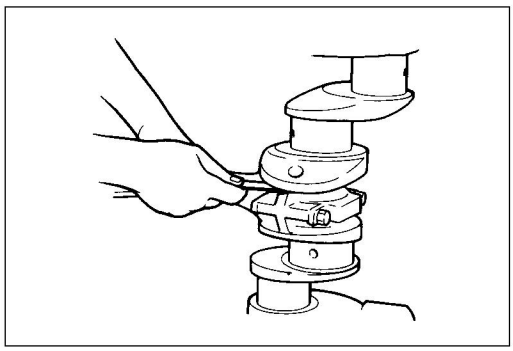


Connecting rod small end bushing clearance

Use an inside dial gauge and micrometer to measure the inside diameter of the connecting rod's small hole bushing and the outside diameter of the piston pin.
If the measured clearance exceeds the limit value, the piston pin, or the connecting rod's small hole bushing must be replaced.

Connecting rod small end bushing clearance mm (in)

Standard	Limit
0.012 ~ 0.027 (0.00047 ~ 0.0011)	0.10 (0.0039)



Connecting rod side face clearance

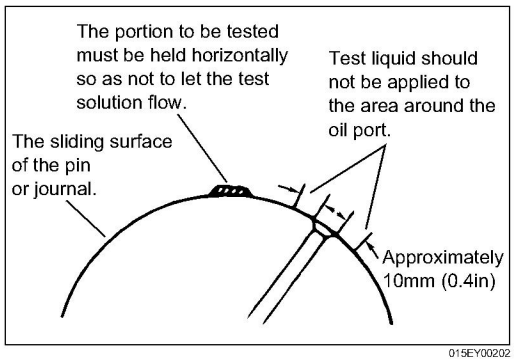
1. Install the connecting rod to the crankpin.
2. Use a feeler gauge to measure the clearance between the side face of the connecting rod's big end and the side face of the crankpin's arm.
   If the measured value exceeds the limit, the connecting rod must be replaced.

Connecting rod large end side face clearance mm (in)

Standard	Limit
0.17 ~ 0.28 (0.0067 ~ 0.0110)	0.35 (0.014)

CRANKSHAFT

- The crankshaft of the model 6SD1T engine has been treated by soft nitriding (tufftriding) in order to enhance the crankshaft's strength.
  As a result, crankshaft wear cannot be rectified by shaft grinding and use of undersize bearings.
  Further, no undersize bearings are made available for the crankshaft.
- If surface scorching or other damage to the crankshaft exceeds the limit values, the crankshaft assembly must be replaced.



Inspection of the crankshaft's tufftriding layer

1. Thoroughly clean the crankshaft.
   Be particularly careful to clean the inspection area by using an organic solvent to clean away all oil.
2. Prepare a solution of 5 ~ 10 % ammonium cuprous chloride (dissolved in distilled water).
3. Using a dropper, place a drop of the solution on the test area of the crankshaft.
   Be sure to stabilize the test area and hold flat so the solution does not run.

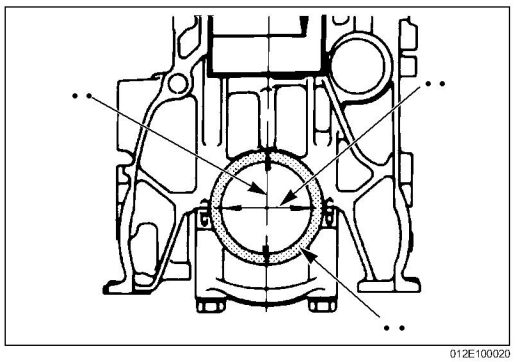
Note:
Do not allow the test solution to drip in or around the oil ports.

Results

1. Wait 30 ~ 40 seconds after dripping the solution.
   If no color change occurs after 30 ~ 40 seconds, the crankshaft is usable.
   If a color change occurs (test surface turns copper color), the crankshaft must be replaced. (The test solution is originally thin blue in color).
2. Following completion of the test, quickly wipe the test solution from the surface of the crankshaft and clean well with steam.

Note:
Since ammonium cuprous chloride is highly corrosive, it must be cleaned from the test surface immediately following completion of the test.

CRANKSHAFT AND BEARINGS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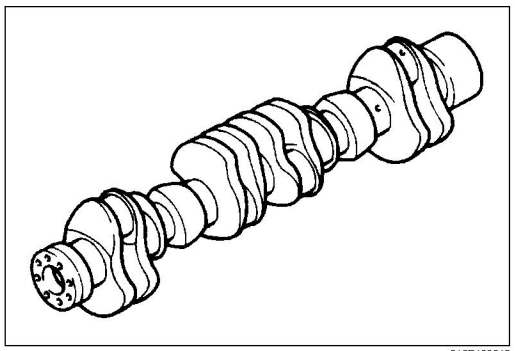
Basic measurement procedures:

When the

1. Main bearing inside diameter = A,
2. Crankshaft journal diameter = B, and
3. Clearance between crankshaft journal and main bearing = C,
   the relationship between the three is
   A – B = C
   This section discusses the method used to measure the "C" dimension.
   The same description is also applicable to measuring the clearance C' between the crankpin and the control rod bearing.
   These C and C' dimensions are decisive for determining whether the crankshaft of the crank bearing must be replaced.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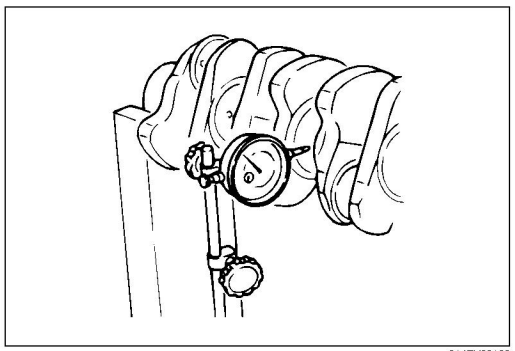
Inspection of crankshaft and bearing

1. Visually inspect the crankshaft journal and pin for excessive friction and damage.
2. Inspect the oil seal contact surfaces at the front and back of the crankshaft for excessive wear and damage.
3. If any excessive wear or damage is discovered, the crankshaft must be replaced or repaired.
4. Inspect the oil ports for clogging, and if necessary blow out with compressed air.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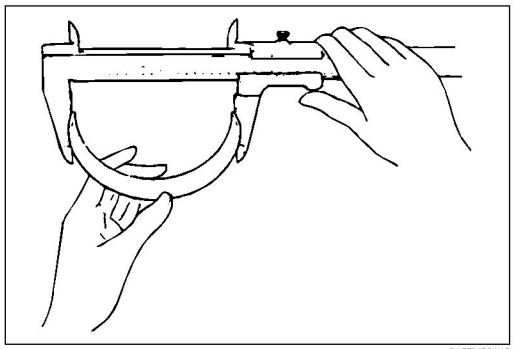
Crankshaft runout

1. Set up a dial gauge on the No. 4 journal of the crankshaft.
2. Slowly rotate the crankshaft one full turn clockwise, and read the dial gauge.
   If the measured value exceeds the limit, the crankshaft must be replaced with a new one.

Crankshaft runout mm (in)

Standard	Limit
0.08 (0.003) or less	0.15 (0.0059)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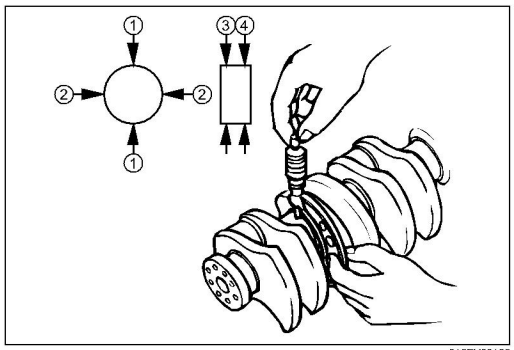

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Bearing spread

Use calipers to measure the spread of the bearing arc.
If the measured value is less than the limit, the bearing must be replaced.

Bearing arc spread mm (in)

	Limit
Crank bearing	96 (3.779)
Control rod bearing	85 (3.346)

Outside diameter of crank journal and crank pin

1. Use a micrometer to measure the diameter of each crank journal at each of the measuring points ③ and ④ shown in the illustration.
2. At each measuring point, measure in both directions ①-① and ②-②.
3. Use the same method to measure the diameter of the crank pin. If the measured value is less than the limit, the crankshaft must be replaced.

Crank journal outside diameter mm (in)

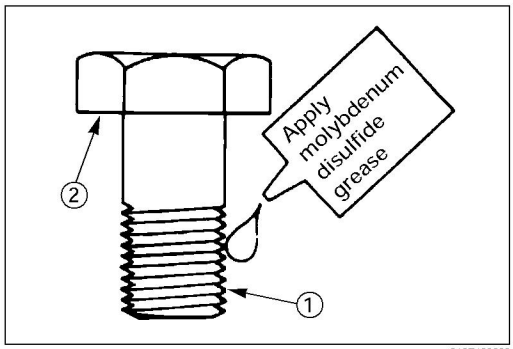
Standard
89.909 ~ 89.929 (3.5397 ~ 3.5405)

Crankpin outside diameter mm (in)

Standard
79.894 ~ 79.914 (3.1454 ~ 3.1462)

Crank journal and crankpin uneven wear mm (in)

Standard	Limit
0.001 (0.00004)	0.05 (0.002)



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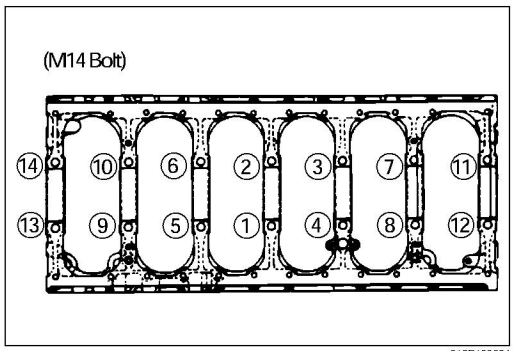
Measuring the crank journal and bearing inside diameter and clearance

Measure the crank bearing's inside diameter and its clearance with the crank journal.

1. Clean the mounting surfaces of the cylinder block and lower crankcase, and the bearing installation surfaces.
2. Apply a thin coat of molybdenum disulfide grease to the threads ① and the seating area ② of the mounting bolts, and to the surfaces of the washers.
3. Install the lower crankcase (with bearings) to the cylinder block, and tighten the bolts as noted in the following:



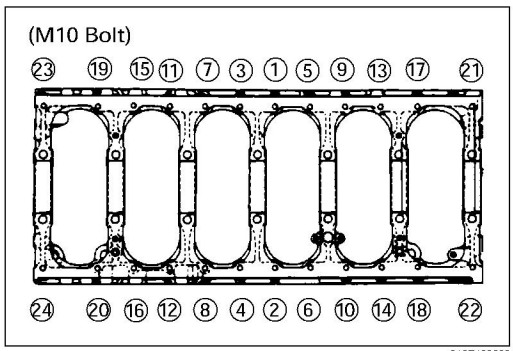
012E100034

Sequence 1 (M14 bolts)

Using the angular tightening method, evenly tighten the inner layer of crankcase bolts in the order shown (① to ⑭).

Crankcase M14 bolts tightening torque N·m (kgf·m/lb·ft)

98 (10/72) → 142 ~152 (14.5 ~ 15.5 / 105 ~ 112) → 30° ~60°



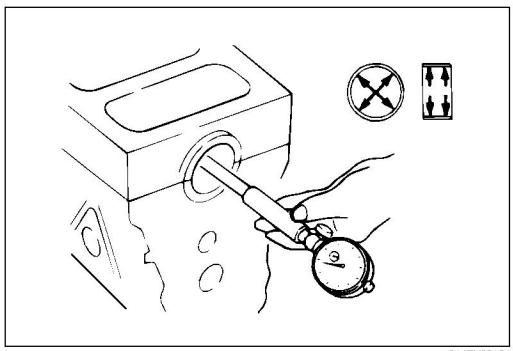
012E100033

Sequence 2 (M10 bolts)

Next, evenly tighten the outer layer of crankcase bolts in the order shown ① to ㉔.

Crankcase M10 bolts tightening torque N·m (kgf·m/lb·ft)

31 ~ 45 (3.2 ~ 4.6 / 23 ~ 33)


014EY00121

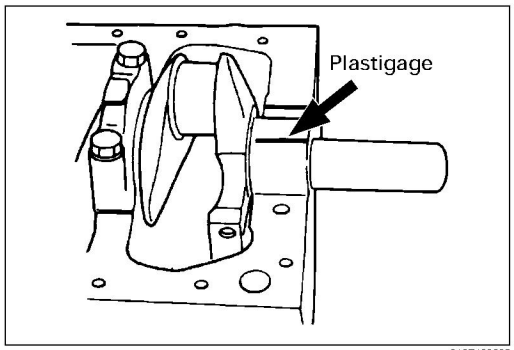
4. Using a dial gauge, measure the inside diameter of the crank journal bearing, and calculate its clearance with the outer diameter of the crank journal.
   If the clearance with the crank journal exceeds the limit value, the bearing or the crankshaft must be replaced.

Crank journal and bearing clearance mm (in)

Standard	Limit
0.045 ~ 0.110 (0.0018 ~ 0.0043)	0.16 (0.0063)

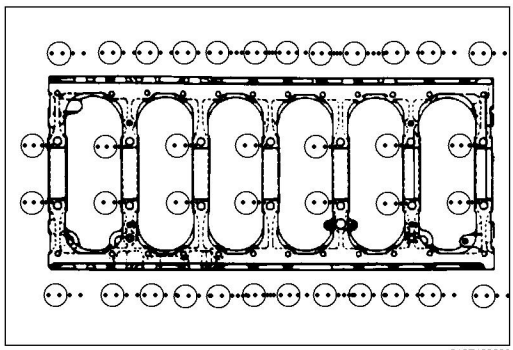
Note:
The cylinder block and the lower crankcase are manufactured as a single unit. As a result, if either part requires replacement, both parts must be replaced as a single set.

Using Plastigage to measure clearance between the crank journal and bearing

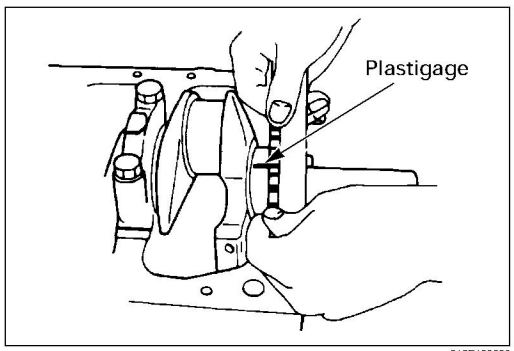


012E100035

1. Thoroughly clean the cylinder block, particularly the bearing installation parts, lower crankcase and bearings.
2. Install the bearings in their mounts.
3. Carefully set the crankshaft on the bearings.
4. Next, rotate the crankshaft about 30 times to stabilize the bearings.
5. As shown in the illustration, set the plastigage across the entire width of the bearing.
6. Install the crankcase with bearings.


012E100026

7. Tighten the crankcase bolts using the designated order and method. Refer to the section Engine, "Crank Journal and Bearing Clearance."
   When installing the crankcase, take care to prevent the Plastigage from slipping.
8. Remove the crankcase.

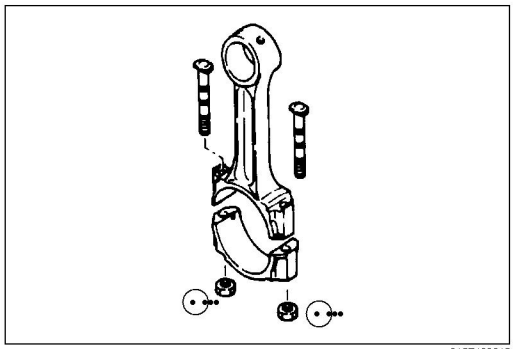


012E100036

9. Measure the width of Plastigage affixed to the crankshaft or bearing, using the gauge printed on the plastigage box.
   If the measured value exceeds the limit, take the following additional steps:
   (1) Use a micrometer to measure the diameter of the crank journal.
   (2) Using an inside dial gauge, measure the bearing's inner diameter. If the clearance calculated between the journal and bearing exceeds the limit value, the crankshaft or the bearing must be replaced.

Crankshaft and bearing clearance mm (in)

Standard	Limit
0.045 ~ 0.110 (0.0018 ~ 0.0043)	0.16 (0.0063)

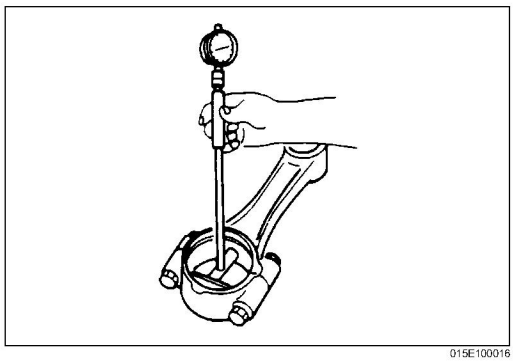

015E100015

Connecting rod bearing clearance

1. Install the bearing on the large end of the connecting rod.
2. Apply molybdenum disulfide grease to the bolt threads and nut setting faces.
3. Use the following angular tightening method to tighten the bearing cap nuts.

Bearing cap nut torque — N·m (kgf·m/lb·ft)

Order	Tightening nut	Tightening torque and angle
1	Tighten nuts ① and ② alternately	37 ~ 41 (3.8 ~ 4.2 / 27 ~ 30)
2	Right side nut ①	60°
3	Left side nut ②	120°
4	Right side nut ①	60°


015E100016

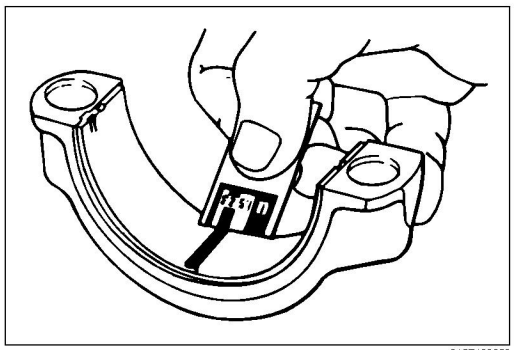
4. Using a dial gauge, measure the bearing's inside diameter and calculate the clearance between the bearing and crankpin.
   If the clearance between the bearing and crankpin exceeds the limit, replace the bearing or the crankshaft.

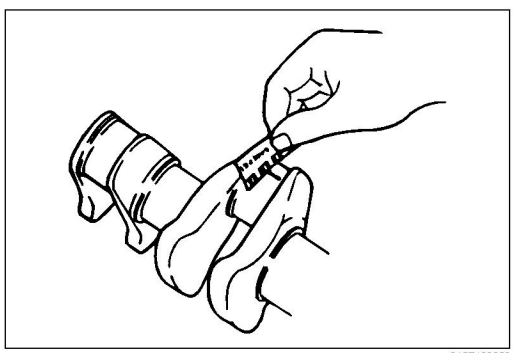
Crankpin and bearing clearance — mm (in)

Standard	Limit
0.04 ~ 0.106 (0.0016 ~ 0.0042)	0.16 (0.0063)

Using plastigage to measure the connecting rod bearing clearance

1. Thoroughly clean the crankshaft, connecting rod, bearing cap and bearing.
2. Assemble the bearing in the large end of the connecting rod and the bearing cap.
   Keep the crankshaft immobile so that is does not move while assembling the bearing cap.
3. Stabilize the connecting rod so that is does not move.
4. Apply Plastigage to the crankpin. If the Plastigage is stuck on with some engine oil, it will stick better and make the job easier.
5. Install the bearing cap, and tighten the bolts in the designated order, using the designated tightening method and torque. (Apply the Plastigage flat, and avoid the area of the crankpin"s oil port.)
   Consult the section "Engine II: Connecting Rod Bearing Clearance."
   Keep the connecting rod steady so that is does not move during assembly and tightening of the bearing cap.
6. Remove the bearing cap.
7. Measure the width of Plastigage affixed to the crankpin or bearing, using the gauge printed on the Plastigage box.
   If the measured value exceeds the limit, perform the following procedure:
   (1) Use a micrometer to measure the diameter of the crankpin.
   (2) Using an inside dial gauge, measure the inside diameter of the bearing. From these two figures calculate the crankpin and bearing clearance, and if it exceeds the limit, replace the crankshaft or bearing.

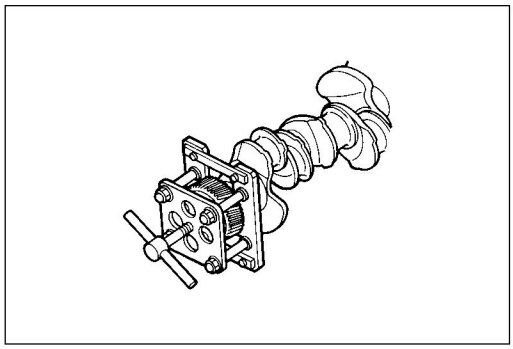

015E100052


015E100053

Crankpin and bearing clearance mm (in)

Standard	Limit
0.04 ~ 0.106 (0.0016 ~ 0.0042)	0.16 (0.0063)

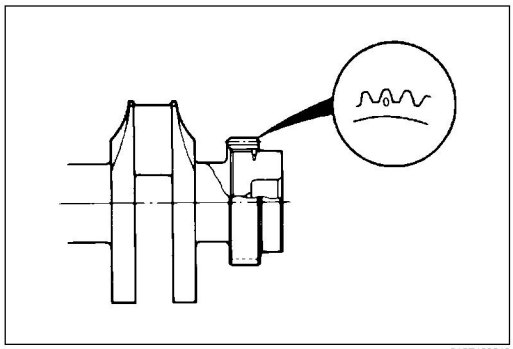
Crank gear replacement



Removal

1. Using the crank gear puller, pull off the crank gear.
   Crank gear remover: 1-85210-051-0
2. Remove the key from the crankshaft.

Note:
When removing the crank gear, take care not to damage the gear teeth with the gear puller.



015E100018

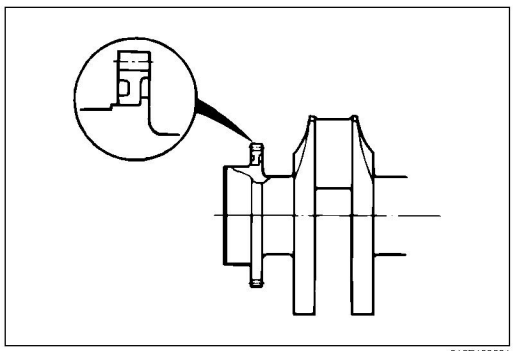
Installation

1. Warm the crank gear with an oil heater (oil temperature 170 ~ 180°C).
2. With the timing mark "0" facing the flywheel side (front), align the gear's key groove with the crankshaft's knock pin, and install so that there is no gap with the crankshaft's end.
   Crank gear installer: 1-85221-072-0

Oil pump drive gear replacement

Removal

See the section "Crank Gear Replacement."



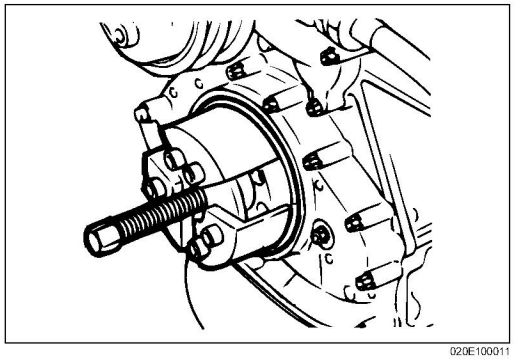
015E100021

Installation

1. Warm the drive gear with an oil heater (oil temperature 170 ~ 180°C).
2. Install the gear facing the direction shown in the illustration, and allow no gap with the crankshaft's end.
   Drive gear installer: 1-85221-075-0

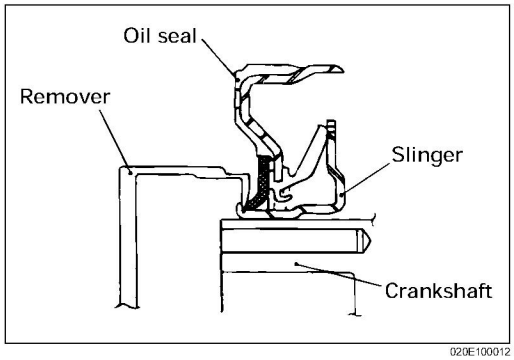
FRONT COVER OIL SEAL

Front cover oil seal replacement

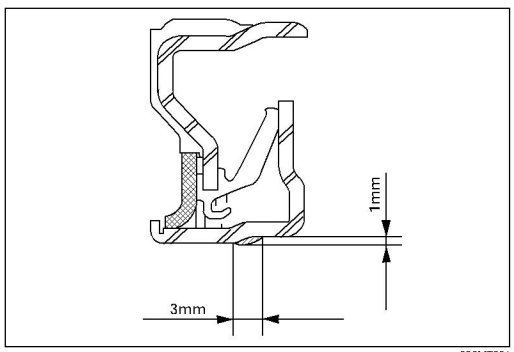

020E100011

Removal

Use the oil seal remover to remove the oil seal slinger.
Oil seal remover: 1-85220-052-0



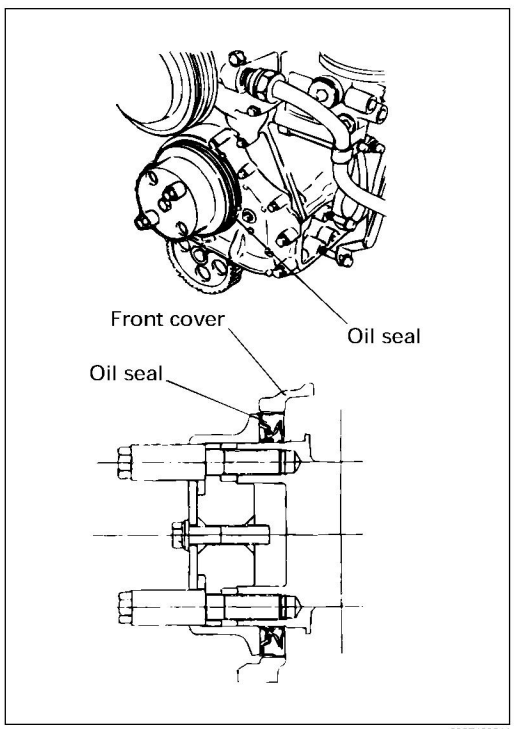
020E100012



020MT001

Installation

1. If there is some small scratch on the crankshaft after removing the oil seal, apply threebond 1207C or equivalent on the slinger as shown in the illustration.

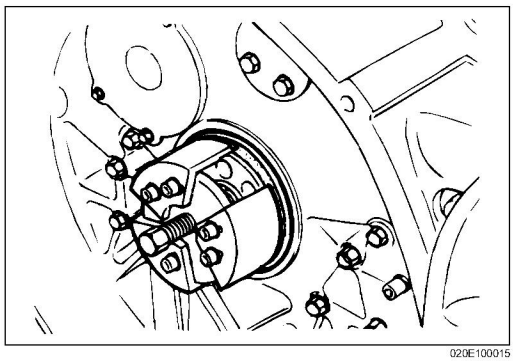


020E100014

2. Use the oil seal installer to install the oil seal with slinger.
   - Tighten the center bolt until the installer comes into contact with the guide.
   - Check that the oil seal is flush with front cover.
     Oil seal installer: 1-85220-057-0

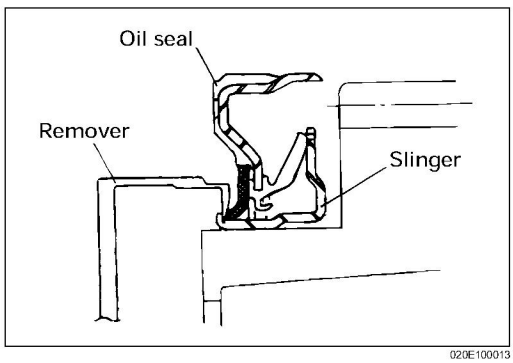
CRANKSHAFT REAR OIL SEAL

Crankshaft rear oil seal replacement

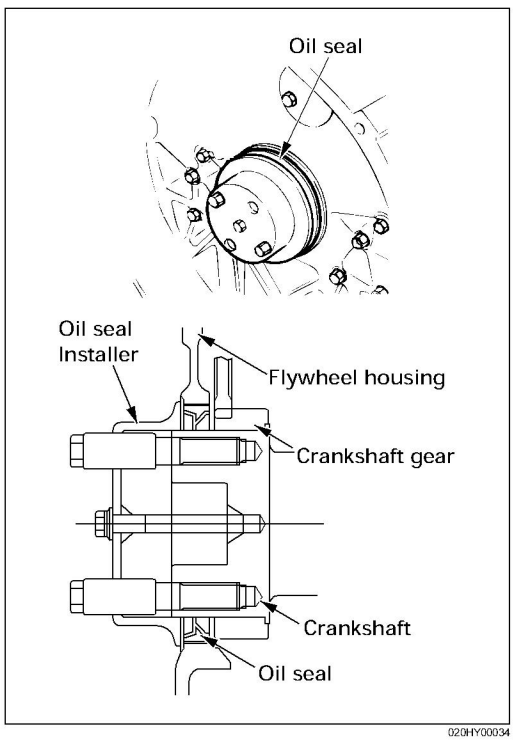

020E100015

Removal

Use the oil seal remover to remove the oil seal slinger.
Oil seal remover: 1-85220-052-0



020E100013

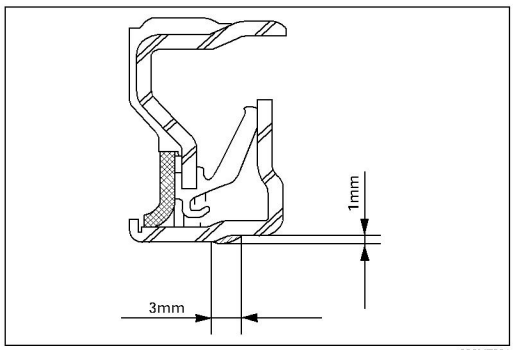


020HY00034

Installation

Use the oil seal installer to install the oil seal with slinger.

- Tighten the center bolt until the installer comes into contact with the guide.
- Check that oil seal is flush with flywheel housing.
  Oil seal installer: 1-85220-057-0



020MT001

If there is some scratch on the crankshaft after removing the oil seal, apply threebond 1207C or equivalent on the slinger as shown in the illustration.

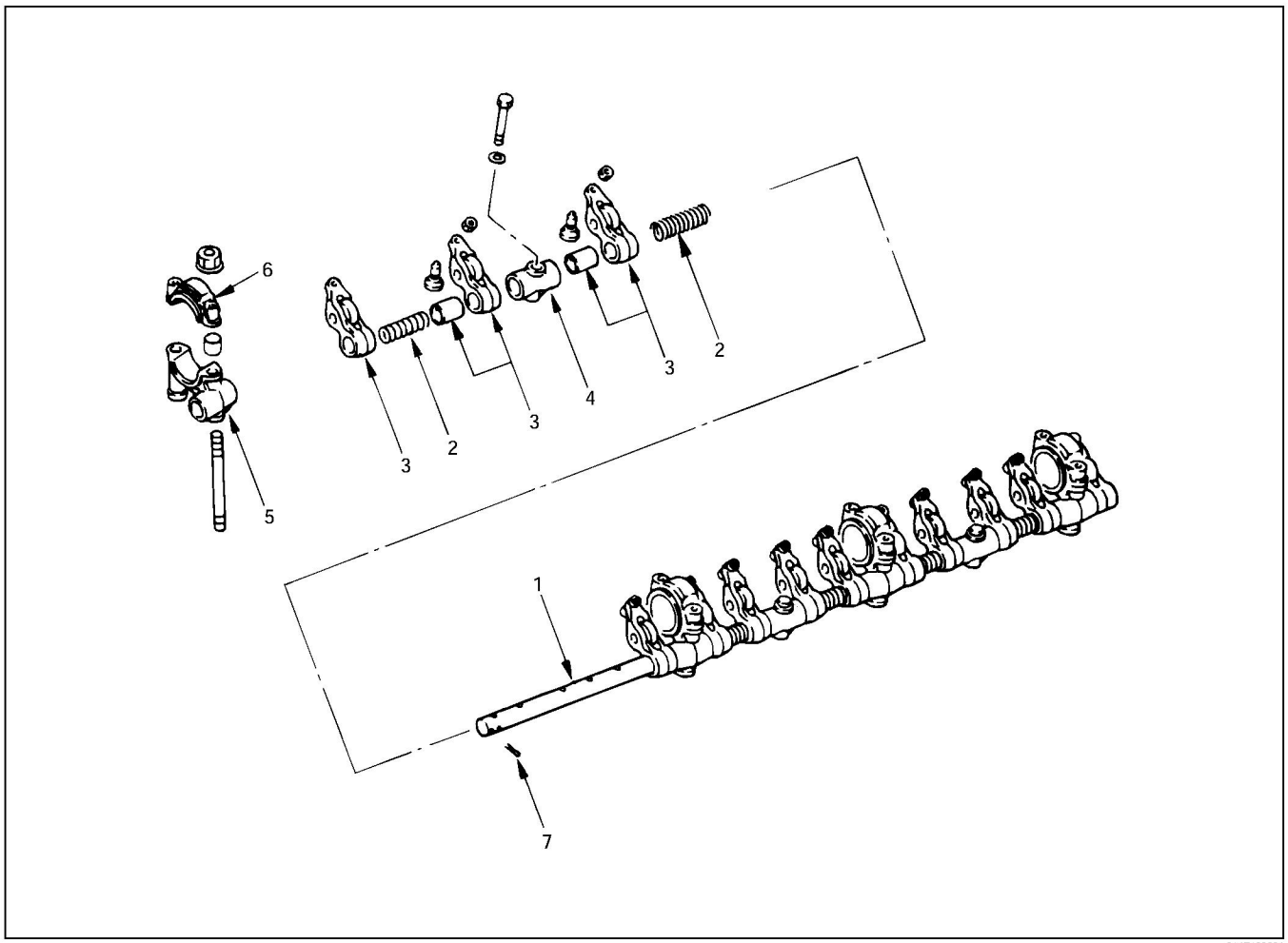
CHAPTER 5

ENGINE III

(ASSEMBLY)

CONTENTS

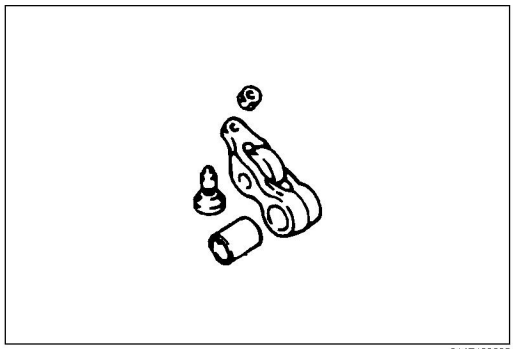
ROCKER ARM SHAFT ASSEMBLY



014E100024

Assembly sequence

1. Rocker arm shaft
2. Rocker arm spring
▲3. Rocker arm
4. Rocker arm bracket
▲5. Camshaft lower bracket
6. Camshaft upper bracket
7. Cotter pin

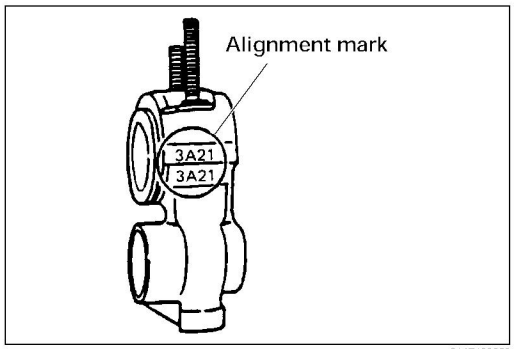

014E100025

IMPORTANT OPERATIONS

3. Rocker arm

5. Camshaft lower bracket

(1) Apply engine oil to the rocker arm shaft, each rocker arm, rocker arm bushing, and the lower bracket's shaft holes.



014E100050

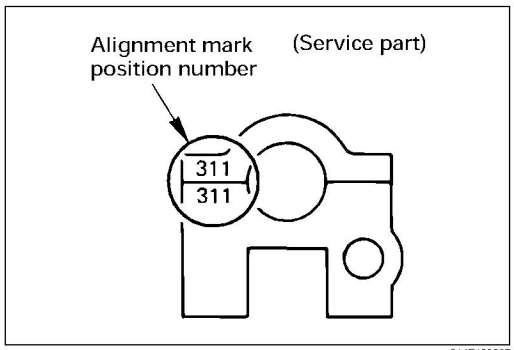
(2) Install all parts in accordance with the assembly sequence.

1) When reusing parts

① When reusing the rocker arms, replace them in the original positions as noted on tags attached during removal.

② When reusing the camshaft bracket, confirm the alignment mark positioning number, and return it to its original position.

3 A21
- A21: Set number: terminating numbers 00 ~ 99
- 3: Installation position number (from front: 1, 2, 3, 4)



014E100067

2) When using new parts

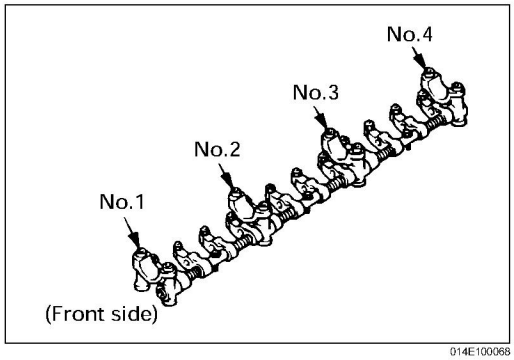
When installing new parts as the result of "Inspection and Repair" performed under chapter 4 ("Engine II"):

① Replace all four upper and lower brackets together as a single set.
Never replace only one bracket.

② Confirm position numbers when installing

New parts (service parts) position numbers

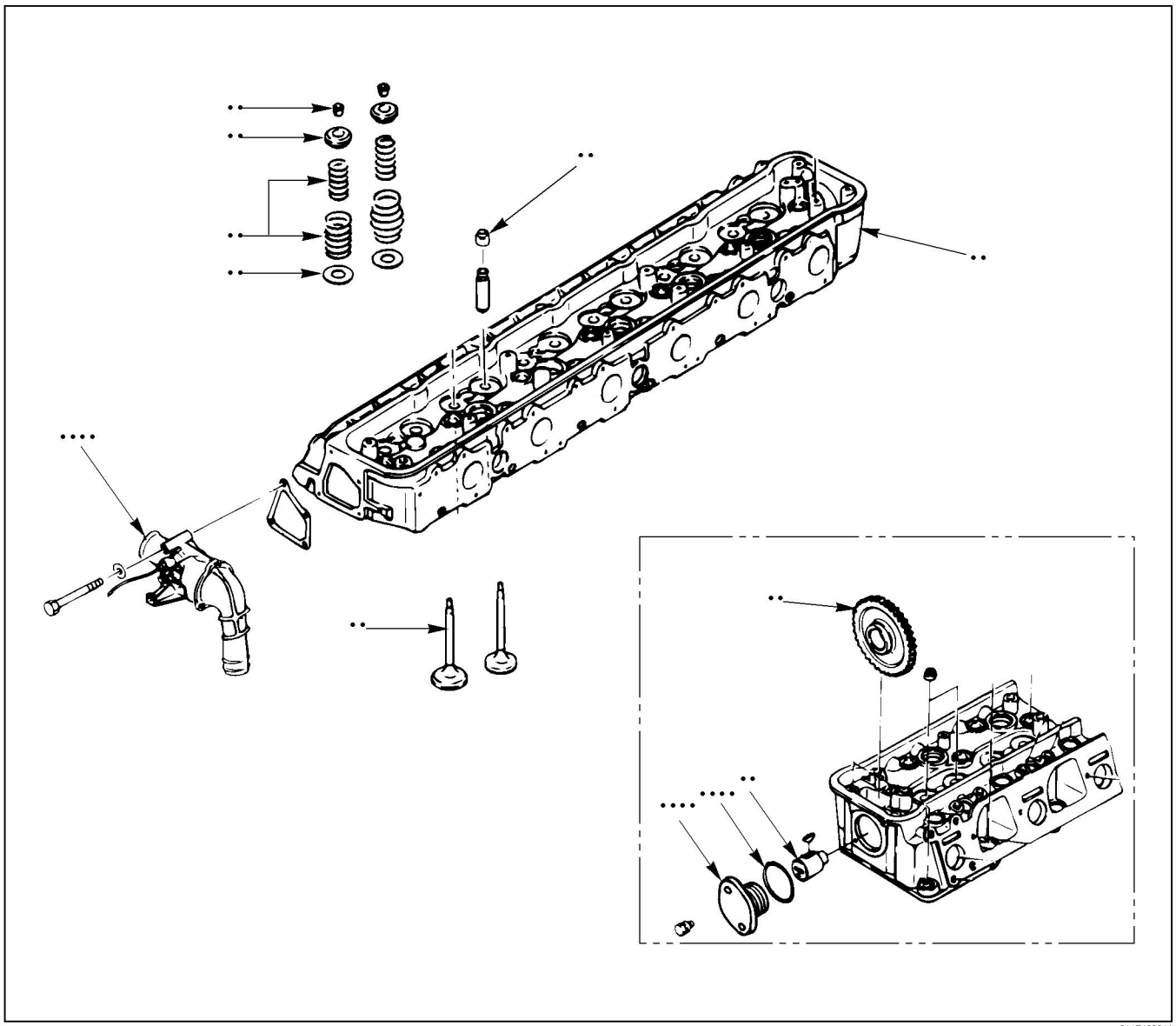
3 11
- 11: Set number: terminating numbers 00 ~ 99
- 3: Installation position number (from front: 1, 2, 3, 4)



014E100068

3) Install the camshaft upper bracket and hand tighten.

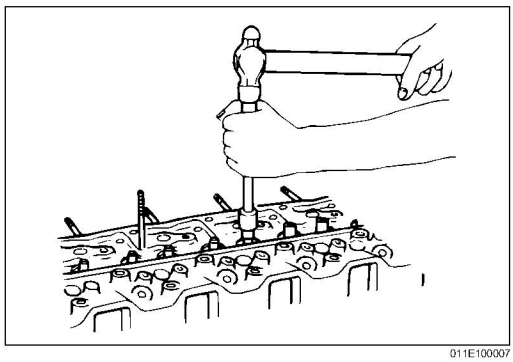
CYLINDER HEAD ASSEMBLY



011E100014

Assembly sequence

1. Cylinder head
2. Valve spring lower seat
▲3. Valve stem seal
▲4. Intake and exhaust valves
5. Intake and exhaust valve springs
6. Valve spring upper seat
▲7. Split collar
8. Idle gear shaft "C"
9. Idle gear "C"
10. Idle gear gasket
11. Idle gear cover
12. Thermostat housing


011E100007

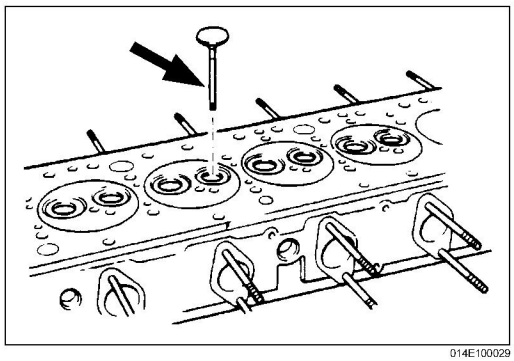
IMPORTANT OPERATIONS

3. Valve stem seal
When inserting valve stem seals, apply oil to the periphery of the valve guide and press in securely until it strikes the upper surface of the seal guard.

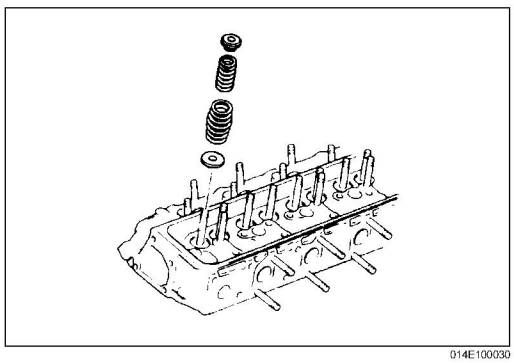
Note 1:
Take care not to scar the seal lip.

Note 2:
After inserting the seal, confirm that the spring does not fall out.

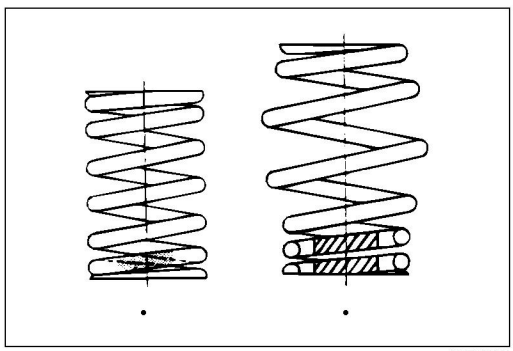
Special tool: 1-85232-001-0


014E100029

4. Intake and exhaust valves
(1) Before installing, apply clean engine oil to each valve stem.
(2) Install the intake and exhaust valves.
(3) Turn over the cylinder head to install the valve springs.
Take care when doing this so that the valves do not fall out.

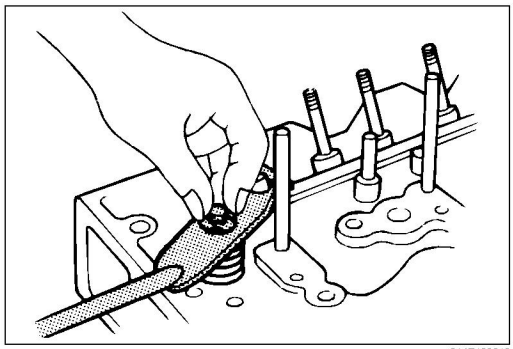

014E100030

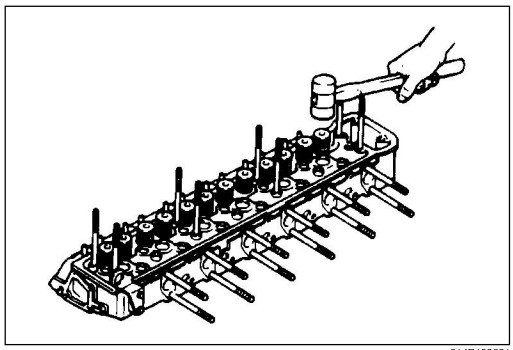
5. Intake and exhaust valve springs
The valve springs are installed so that the end with narrow pitched coils (the side with color) are installed pointing down.


014E100064

Spring color coding

Intake side (1)	Inner	Green
	Outer	
Exhaust side (2)	Inner	Yellow
	Outer	


014E100010


014E100031

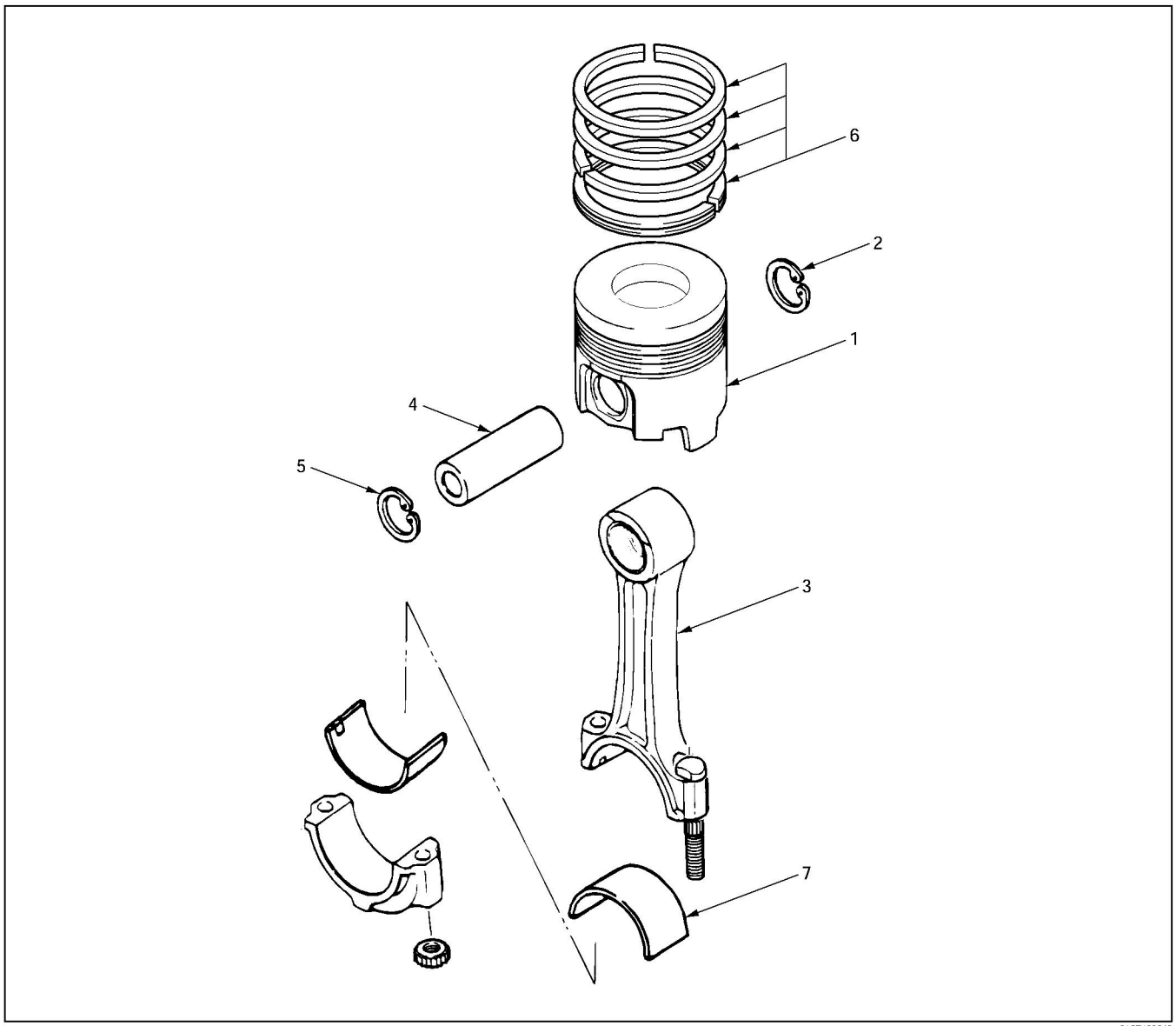
7. Split collar

(1) Use the spring compressor to compress the valve springs in their mounted position.
Spring compressor: 1-58235-007-0

(2) Install the split collar onto the valve stem.

(3) Use a rubber hammer to tap the edge of the split collar to seat it properly.

PISTON AND CONNECTING ROD ASSEMBLY

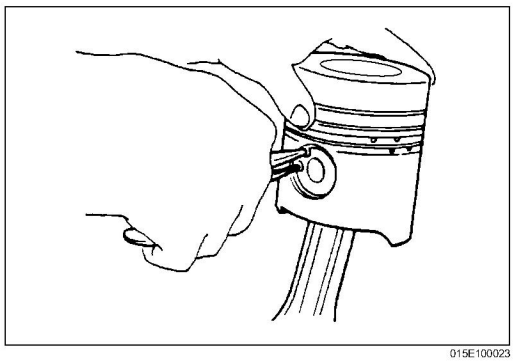


015E100048

Assembly sequence

▲1. Piston
▲2. Snap ring
▲3. Connecting rod
▲4. Piston pin
▲5. Snap ring
▲6. Piston ring
▲7. Connecting rod bearing

IMPORTANT OPERATIONS


015E100023

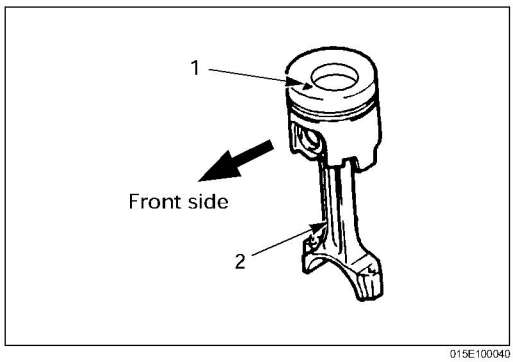
1. **Piston**
2. **Snap ring**
3. **Connecting rod**

   Use a piston heater to heat the piston to about 100°C.

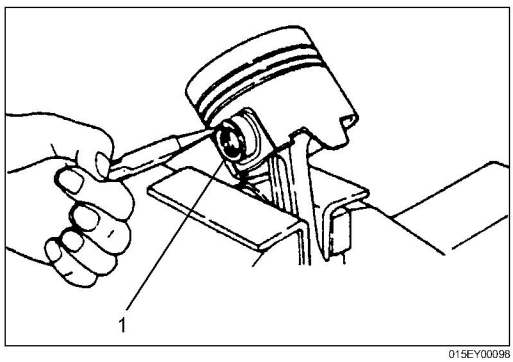
   (1) Using snap-ring pliers, install one snap ring in the piston.

   (2) Fix the connecting rod in a vice.
   Hold the connecting rod in copper plates to prevent damage to the connecting rod.

   (3) Assemble the piston to the connecting rod. Install the piston so that the front mark (1) on the piston's head and the forged "ISUZU" mark on the connecting rod (2) are pointing toward the engine's front.



015E100040



015EY00098

4. **Piston pin**
5. **Snap ring**

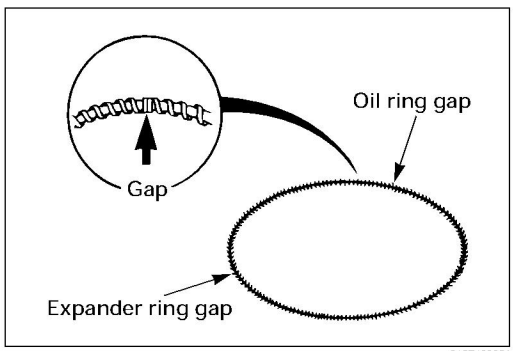
   (1) Apply a liberal coat of clean engine oil to the piston pin, connecting rod, and the piston's hole.

   (2) Align the piston and the connecting rod's piston hole, and press in the piston pin strongly.

   (3) Use snap ring pliers to install the other snap ring in the position.

Note:
Confirm that the snap ring is securely installed in the ring groove.

   (4) Remove the piston and connecting rod assembly from the vise and check that the connecting rod moves smoothly.



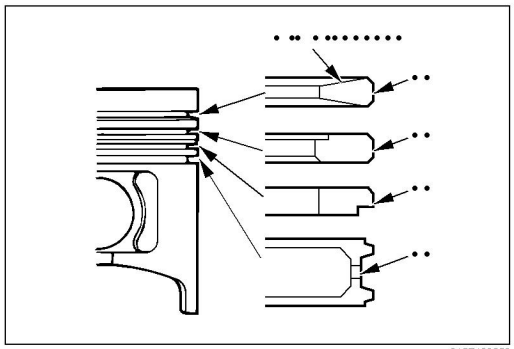
015E100054

6. **Piston rings**

   (1) Assemble the oil ring and expander ring.

Note:
Assemble the two rings so that their gaps are located on opposite sides (180° apart) from each other.

   (2) Apply clean engine to the piston rings and piston ring grooves.

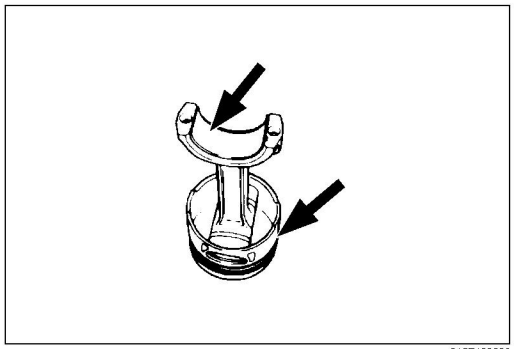

015E100050

(3) Use a piston ring replacer to install the piston rings in the sequence shown.
(1) Oil ring
(2) 3rd compression ring
(3) 2nd compression ring
(4) 1st compression ring

Note:
Install the 1st, 2nd and 3rd compression rings so that the "1R", "2R" and "3R" marks are oriented toward the top of the piston respectively.

Piston ring replacer: 1-85221-029-0

(4) Confirm that each piston ring moves smoothly in its groove.

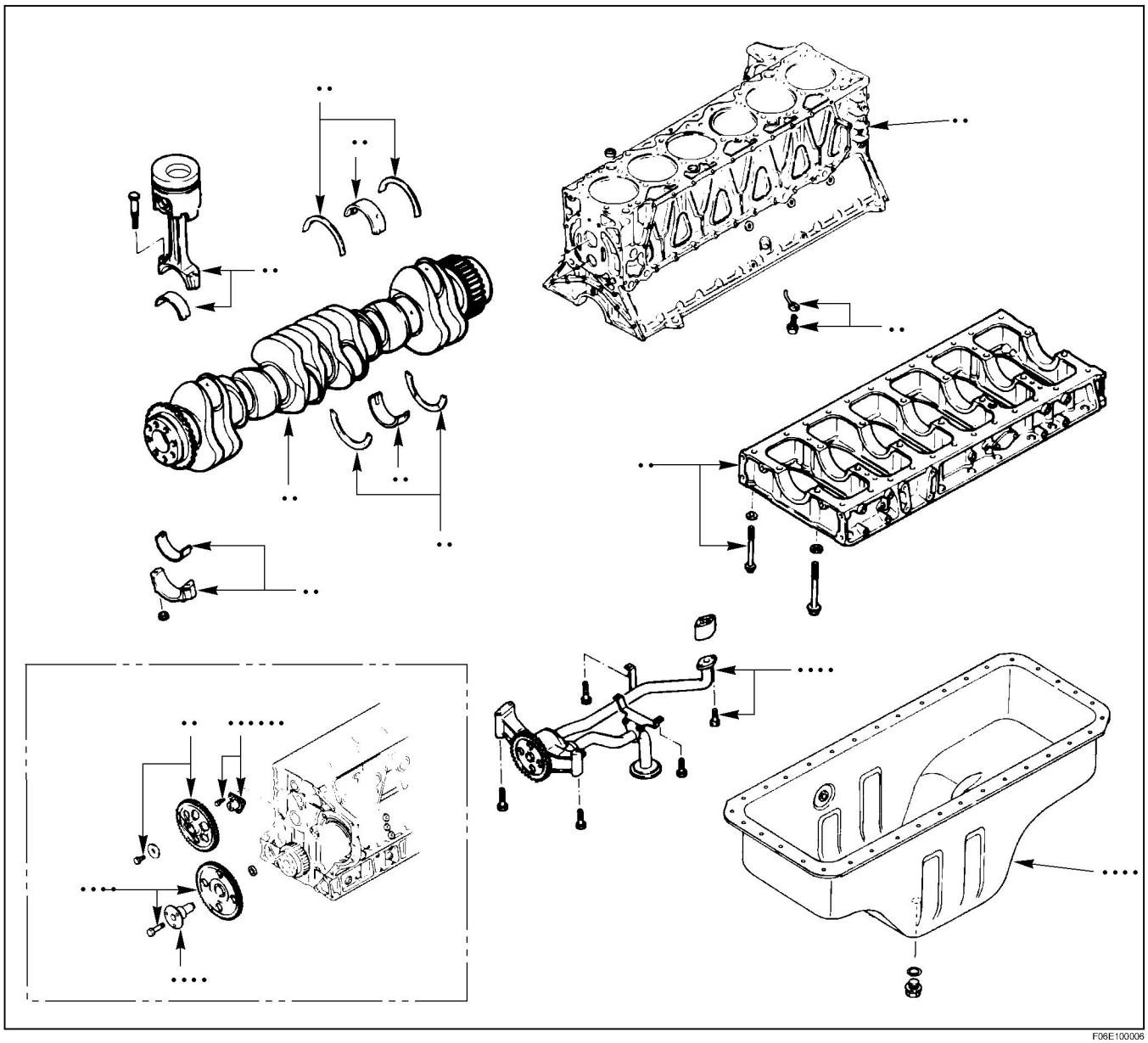

015E100026

7. Connecting rod bearing

While clean the rear surface of the connecting rod bearing and the inner surface of the large end of the connecting rod, and confirm that no foreign material is on either surface.

Note:
Do not apply engine oil to the rear surface of the connecting rod bearing and the inner surface of the large end of the connecting rod.

ASSEMBLY 1

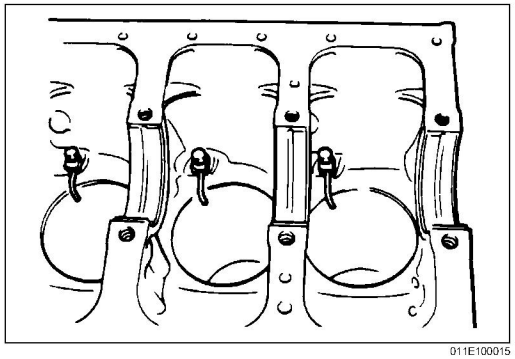


Assembly sequence

1. Cylinder block
▲2. Oil jet
▲3. Crankshaft upper bearing
▲4. Crankshaft
▲5. Thrust bearings
▲6. Crankshaft lower bearing
▲7. Cylinder block lower crankcase
▲8. Piston and connecting rod (with upper bearing)
▲9. Connecting rod bearing cap (with lower bearing)
▲10. Front cover
▲11. Oil pump
▲12. Oil pan
▲13. Idler gear shaft "B"
▲14. Idler gear "B"
▲15. Idler gear shaft "A"
▲16. Idler gear "A"

IMPORTANT OPERATIONS

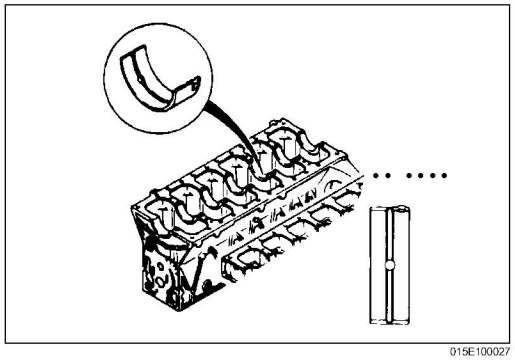
Note:
Before assembling, use compressed air to thoroughly blow out the inside of the cylinder block, particular the oil ports and water jacket.


011E100015

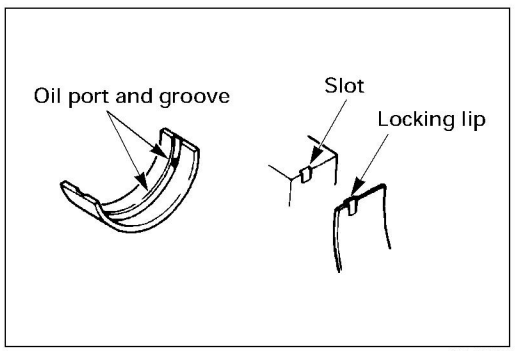
2. Oil jet
Tighten the oil jets with the designated torque.

Note:
When installing the jets, take care not to damage the nozzles, or to deform the nozzle angle by impact.

Oil jet tightening torque	N·m (kgf·m/lb·ft)
16 ~ 25 (1.6 ~ 2.6 / 12 ~ 19)	


015E100027

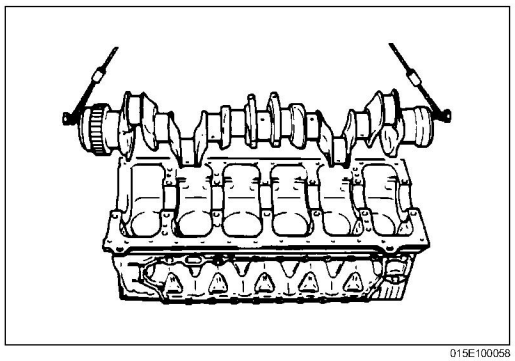
3. Crankshaft upper bearing
Thoroughly clean the upper bearing.
When reusing bearings which were previously removed, be sure to reinstall them in the same positions from which they were removed, in accordance with the tags affixed at the time of removal.



015E100041

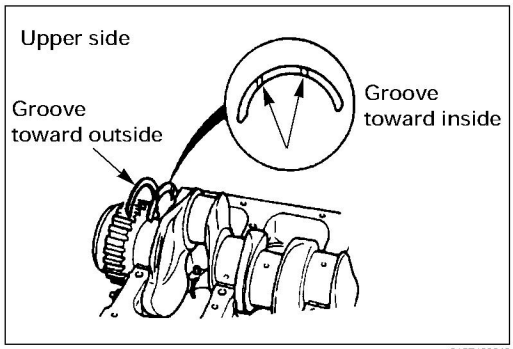
Be sure the bearing's locking lip fits securely in the slot machined in the bearing mount.

Note:
The upper bearings can be discriminated from lower bearings since the upper bearings have oil ports and a groove along their entire surface. In contrast, the lower bearings have no oil port and only a partial groove. Be sure to install the bearings in their correct locations.


015E100058

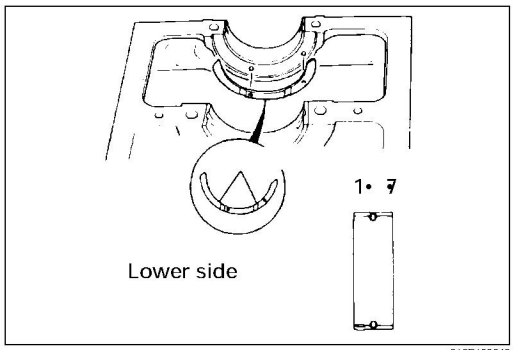
4. Crankshaft
Before installing the crankshaft, apply a liberal coat of clean engine oil to the journals and the inner surface of the bearings.

Note:
Do not apply engine oil to the rear surface of the bearings, or to the bearing mounts in the cylinder block.



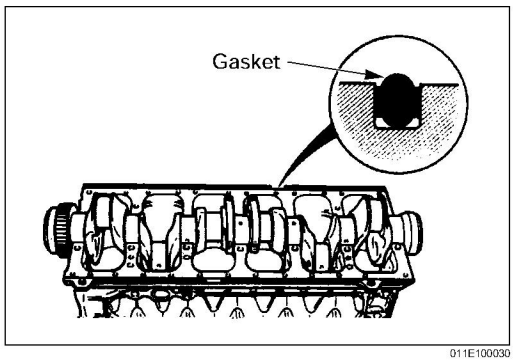
015E100042

5. Thrust bearings (upper)
Before installing, apply a liberal coat of clean engine oil to the thrust bearings.
The oil groove of the thrust bearings must be facing the crankshaft's No. 7 contact surface.

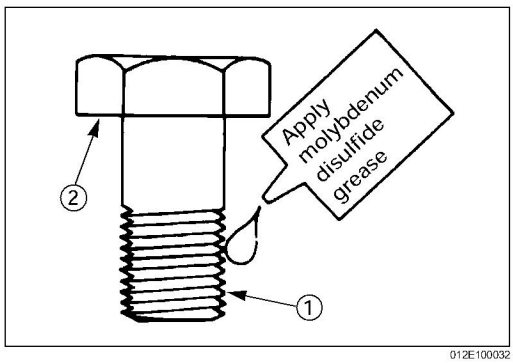


015E100043

5. Thrust bearings (lower)
6. Crankshaft lower bearing
7. Cylinder block lower crankcase
(1) Thoroughly clean the lower bearings, thrust bearings, and lower crankcase.
(2) Apply clean engine oil to the lower bearings and the contact surface of the thrust bearings.
Do not apply engine oil to the rear surface of the lower bearings, or to the bearing mounts in the lower crankcase.
(3) Install the bearings in the lower crankcase.
Be sure the bearing's alignment notch fits securely in the slot machined in the bearing mount.
(4) Pack sealant into the crankcase groove as shown.



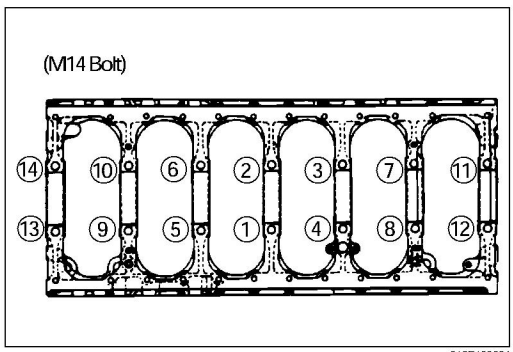
011E100030



012E100032

(5) Apply a light coat of molybdenum disulfide grease to the threads ① and seating faces ② of the lower crankcase's M14 bolts.
(6) Install the crankcase (with bearings) to the cylinder block, and tighten the bolts in the following sequence.

Note:
Take care not to drop the lower bearings and thrust bearings.

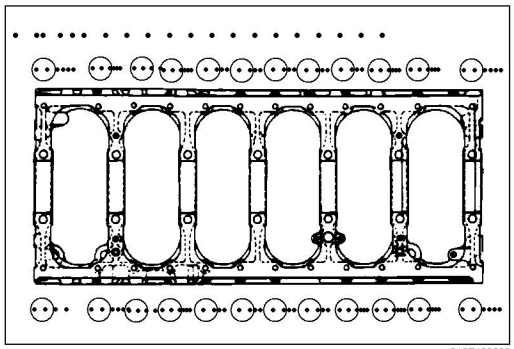


012E100034

Sequence 1 (M14 bolts)
Using the angular tightening method, evenly tighten the inner row of crankcase bolts in the sequence shown in the illustration (① to ⑭).

Crankcase M14 bolts tightening torque N·m (kgf·m/lb·ft)

98 (10/72) → 142~152 (14.5~15.5/105~112) → 30° ~ 60°


012E100023

Sequence 2 (M10 bolts)
Evenly tighten the outer row of crankcase bolts in the sequence shown in the illustration (① to ㉔).

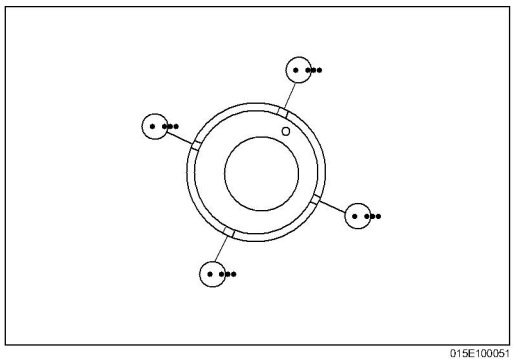
Crankcase M10 bolt tightening torque N·m (kgf·m/lb·ft)

31 ~ 45 (3.2 ~ 4.6 / 23 ~ 33)

Note:
The cylinder block and lower crankcase are manufactured as a single unit. As a result, if either part requires replacement, both parts must be replaced as a single set.
See Engine II "Inspection and Repair" (2).

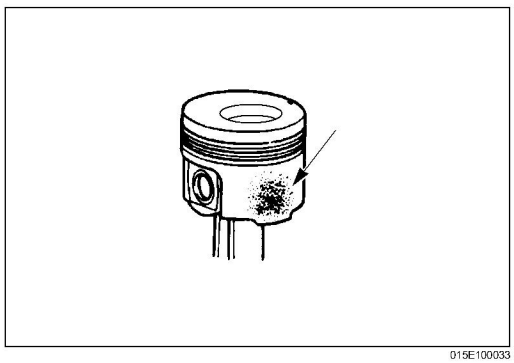
Note:
Crankcase bolts may be reused only two times.

8. Piston and connecting rod (with upper bearing)
9. Connecting rod cap (with lower bearing)
(1) Apply clean engine oil to the piston and piston rings.

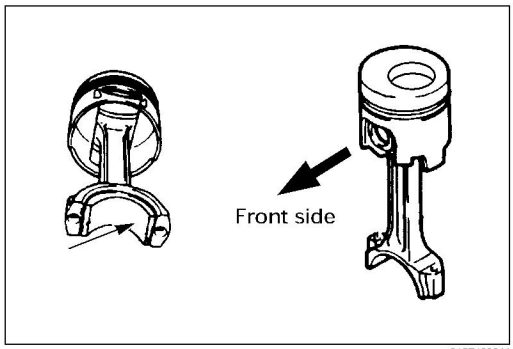

015E100051

(2) Turn the piston rings so that their gaps are positioned in the positions shown in the illustration.
① No. 1 compression ring
② No. 2 compression ring
③ No. 3 compression ring
④ Oil ring

Note:
The piston ring gaps must not be positioned in the direction of horizontal thrust, but in the direction of the piston end, namely, in the position where they will not be exposed to side pressure.
Also, the oil ring and expander ring gaps should be positioned on opposite sides (180°) from each other.

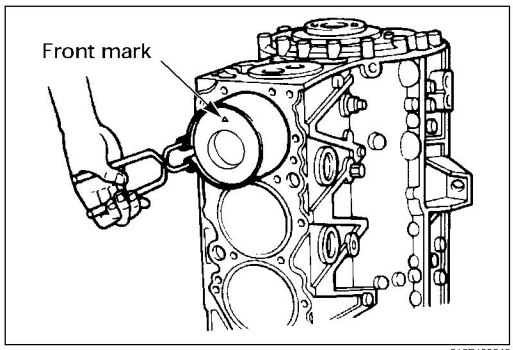

015E100033

(3) Apply molybdenum disulfide grease to the piston's skirts as shown; this will facilitate smooth break-in when the engine is first started after reassembly.



015E100044

(4) Apply a coat of clean engine oil to the upper bearing's contact surface and to the bore of the cylinder liner.
(5) Install the piston so that the "front mark" (△) on the head is oriented toward the front end of the engine.

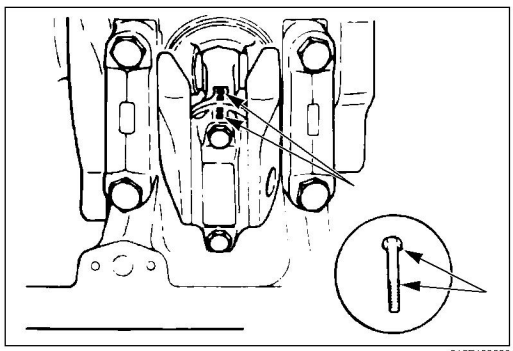


015E100045

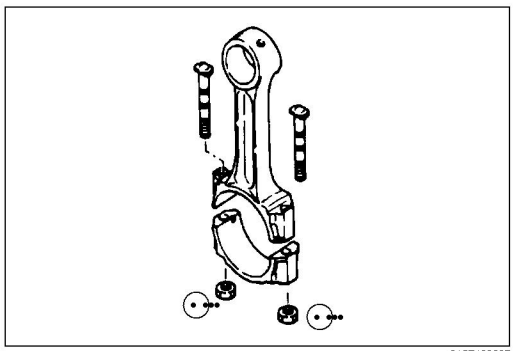
(6) Using a ring compressor, compress the piston rings.
Piston ring compressor: 1-85221-082-0
(7) Use the handle of a hammer to push in the piston until the connecting rod's large end makes contact with the crankpin.
While pushing in the piston, turn the crankshaft as necessary to bring the crankpin to the BDC position.

Note:
Take special care to prevent the large end of the connecting rod from contacting the oil jets.

Note:
The ring compressor must be set flush with the cylinder block or the piston rings will be damaged.


015E100036

(8) Orient the bearing cap's cylinder number and the connecting rod's cylinder number marks as shown in the illustration.
The engraved cylinder number marks must be facing toward the injection pump side.
(9) Apply a coat of molybdenum disulfide grease to the threads and seating area of the connecting rod bearing cap bolts.

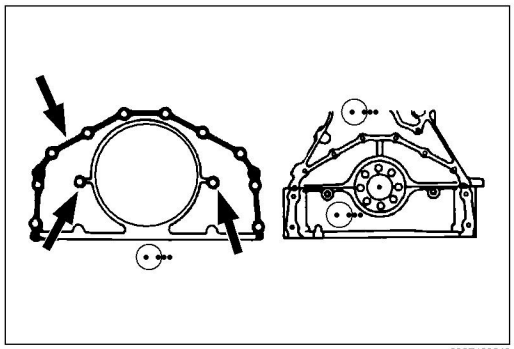

015E100037

(10) Using the angular tightening method, tighten the bearing cap nuts.
Bearing cap nut tightening data

N·m (kgf·m/lb·ft)

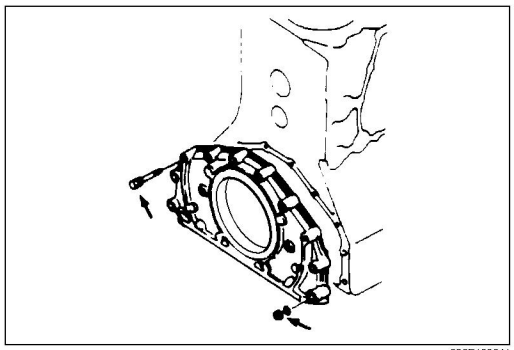
	Sequence	Tightening torque and angle
1	Tighten ① and ② alternately.	37 ~ 41 (3.8 ~ 4.2/27 ~ 30)
2	Nut ①	60°
3	Nut ②	120°
4	Nut ①	60°

Note:
After tightening the bearing cap nuts, confirm that the oil jet is facing toward the oil channel hole for piston cooling.


020E100040

10. Front cover

(1) As shown in the illustration, apply sealant "Belco Bond No. 4" to the front cover ①, and "Three Bond No. 1207C" to the cylinder block ② and the ladder frame ③.


020E100041

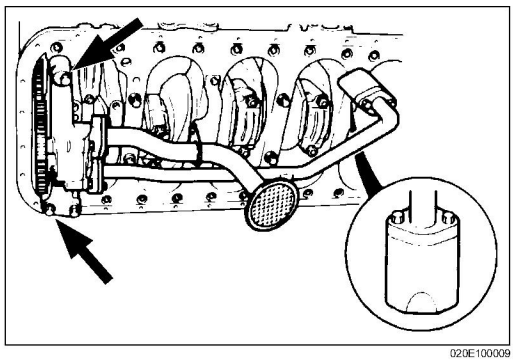
(2) Install the front cover to the cylinder block and ladder frame, then tighten the bolts and nuts alternately to the proper torque.

Front cover bolts and nuts tightening torque

N·m (kgf·m/lb·ft)

Bolts	Nuts
14 ~ 24 (1.4 ~ 2.4/10 ~ 17)	34 ~ 46 (3.5 ~ 4.7/25 ~ 34)

Note:
Take care not to damage the oil seal.

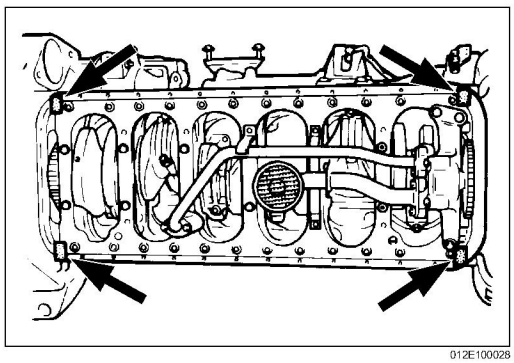

020E100009

11. Oil pump

Install the oil pump together with the anti-drain valve and tighten the bolts to the designated torque.

Oil pump bolts tightening torque N·m (kgf·m/lb·ft)

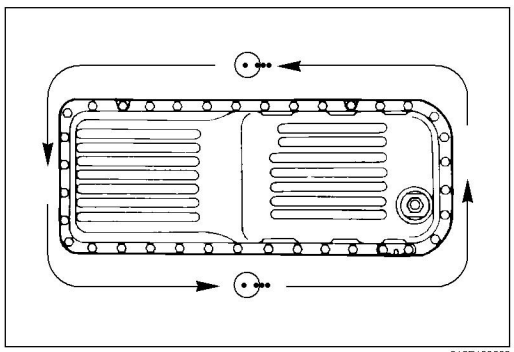
31 ~45 (3.2 ~ 4.6 / 23 ~33)


012E100028

12. Oil pan

(1) Apply a coat of sealant "Seal End No. 242" about 2 mm thick and 3 mm wide to the joining surfaces of the cylinder block, flywheel housing, and front cover.

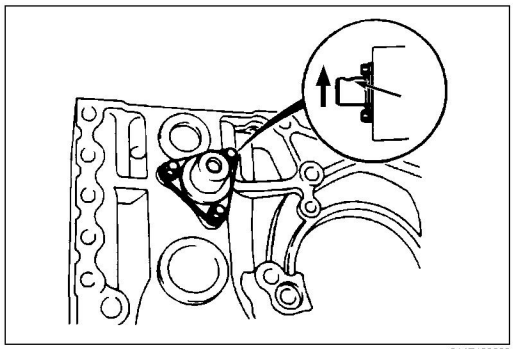
Note:
Take care not to apply so much sealant that it drips inside the engine.


013E100003

(2) Install the oil pan with the sealant's silicon coating facing the oil pan side, then tighten the bolts evenly in the designated order.

Oil pan bolts tightening torque N·m (kgf·m/lb·ft)

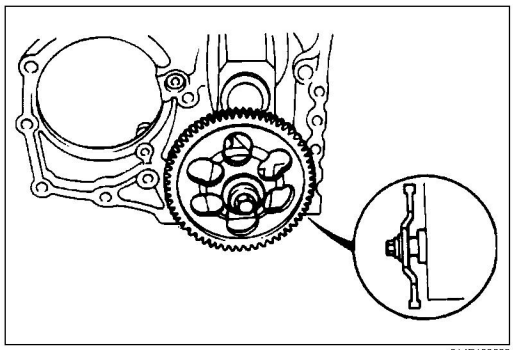
14 ~ 24 (1.4 ~ 2.4/10 ~ 17)


014E100032

13. Idler gear shaft "B"
Install the shaft so that its oil port is facing up.

Idler gear shaft "B" tightening torque N·m (kgf·m/lb·ft)

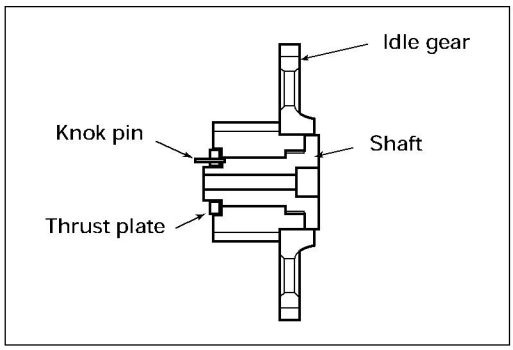
20 ~ 29 (2.0 ~ 3.0/14 ~ 22)


014E100033

14. Idler gear "B"
(1) Apply clean engine oil to the inside surface and thrust section of the idler gear "B."
(2) Install and tighten the idler gear as shown in the illustration.

Idler gear "B" bolt tightening torque N·m (kgf·m/lb·ft)

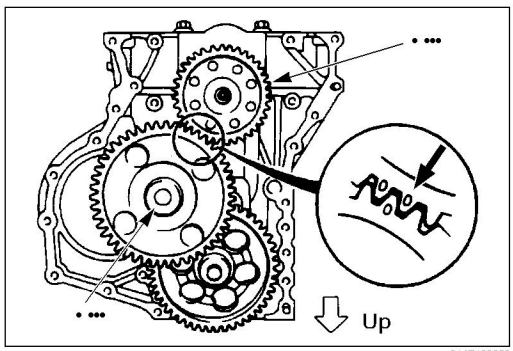
76 ~ 116 (7.8 ~ 11.8/56 ~ 85)



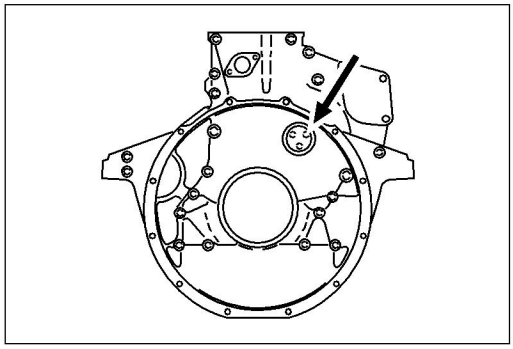
15. Idler gear shaft "A"
16. Idler gear "A"
(1) Install the thrust plate and the shaft to the idler gear "A."
(2) Apply clean engine oil to the inside and thrust areas of the idle gear.
(3) Align the timing mark "O" on the crankshaft gear ② with the timing mark "O" on the idle gear.
(4) Tighten the idler gear "A" to the specified torque.

Idler gear "A" tightening torque N·m (kgf·m/lb·ft)

32 ~ 36 (3.3 ~ 3.7 / 24 ~ 27) → 60° ~ 90°



014E100053

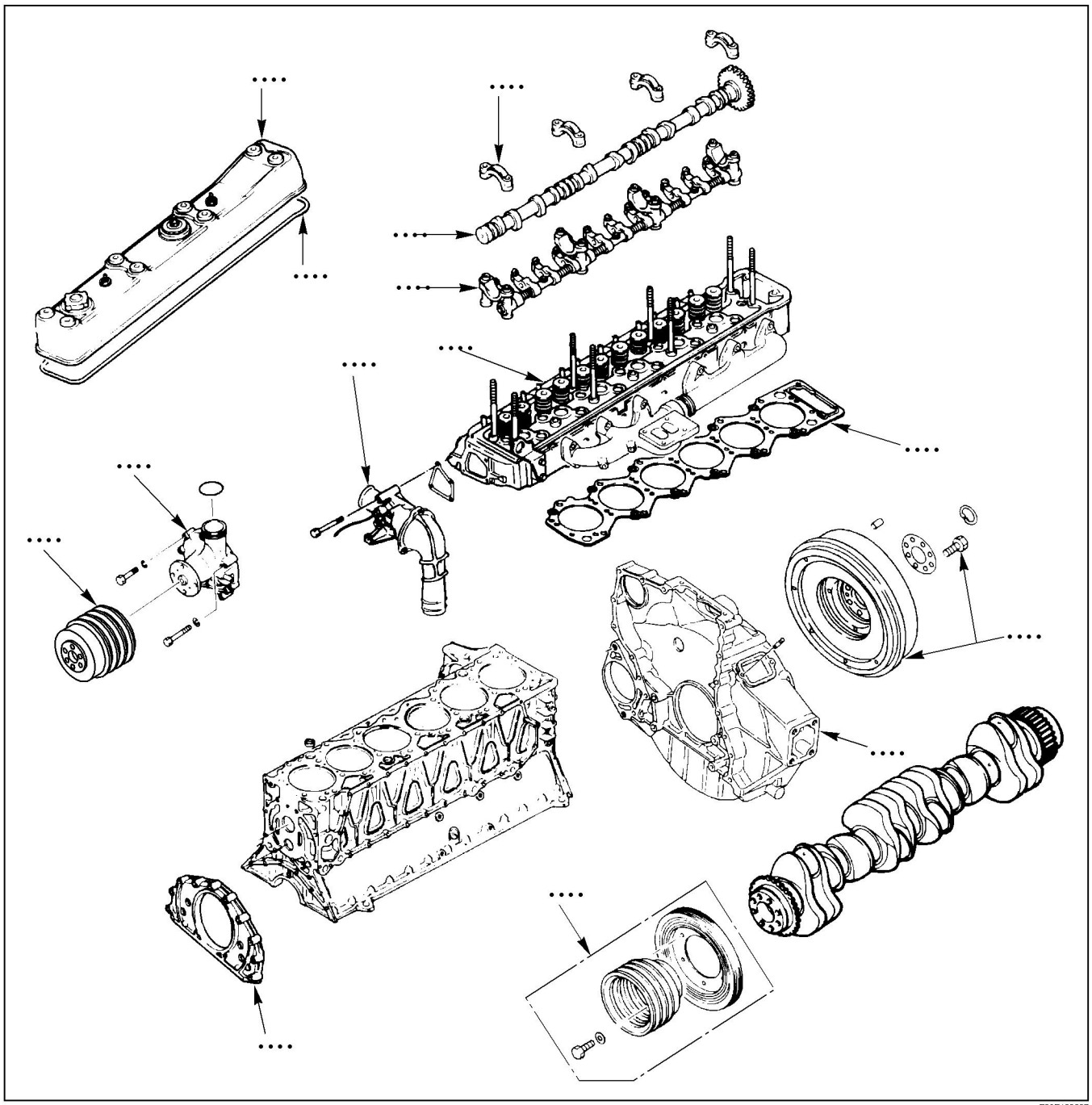


(5) Tighten the idle gear shaft to the specified torque from the flywheel side after installing the flywheel housing.

Idler gear shaft "A" tightening torque N·m (kgf·m/lb·ft)

20 ~ 29 (2.0 ~ 3.0 / 14 ~ 22)

ASSEMBLY 2

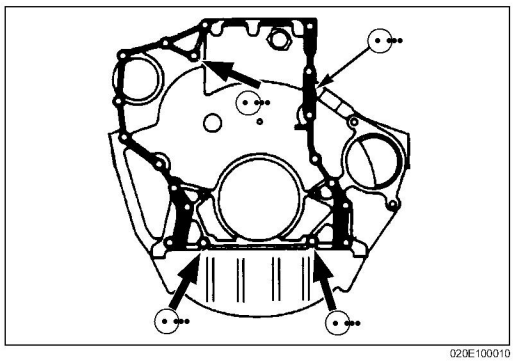


F06E100007

Assembly sequence

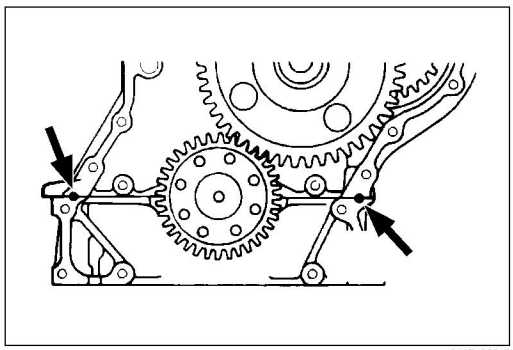
▲18. Flywheel housing
▲19. Flywheel
▲20. Crankshaft pulley (with damper)
▲21. Water pump
22. Water pump pulley
▲23. Cylinder head gasket
▲24. Cylinder head
▲25. Thermostat housing (with thermostat)
▲26. Rocker arm shaft assembly
▲27. Camshaft
▲28. Camshaft upper bracket
▲29. Cylinder head cover gasket
▲30. Cylinder head cover

IMPORTANT OPERATIONS


020E100010

18. Flywheel housing

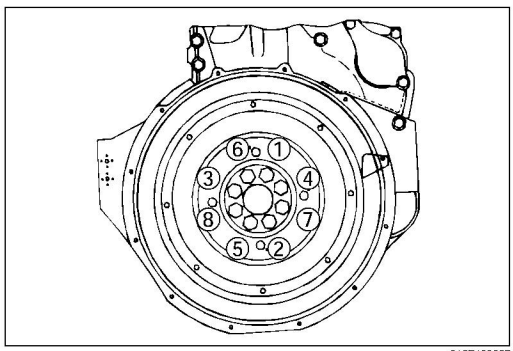
(1) Apply sealant "Belco Bond No. 4" to the flywheel housing mounting surface ①, and to the areas indicated by arrows in the illustration.


011E100019

(2) Apply sealant "Three Bond No. 1207C" to the joining surfaces of the cylinder block and ladder frame.

(3) Install the flywheel housing to the cylinder block and tighten the bolts evenly to the specified torque.

Flywheel housing tightening torque	N·m (kgf·m/lb·ft)
68 ~ 83 (6.9 ~ 8.5 / 50 ~ 61)	



015E100057

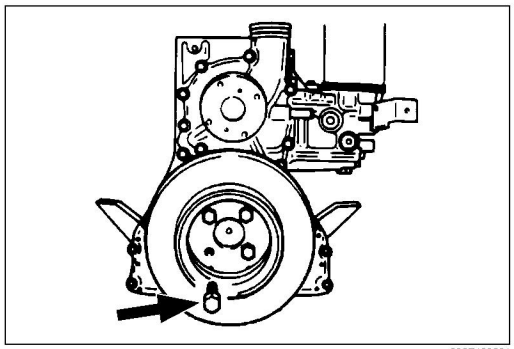
19. Flywheel

(1) Apply molybdenum disulfide grease to the threads and seating surfaces of the flywheel's installation bolts and washers.

(2) Use the angular tightening method to tighten the flywheel bolts in the sequence shown.

Flywheel tightening torque	N·m (kgf·m/lb·ft)
74 ~ 83 (7.5 ~ 8.5 / 54 ~ 61) → 60° → 30° ~ 60°	

Note:
The flywheel installation bolts may be reused only tow times.


030E100001

20. Crankshaft pulley (with damper)

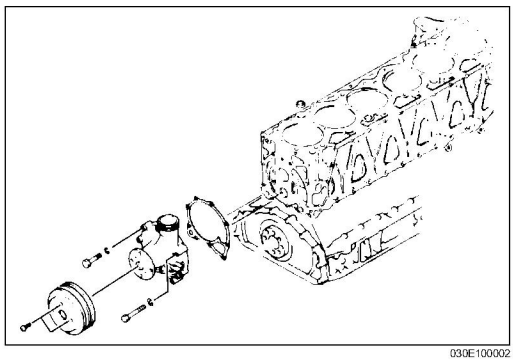
(1) Apply clean engine oil to the threads and seating surfaces of the four pulley bolts, and to the washers.

(2) Install the pulley (with damper) to the crankshaft and tighten.
The front end of the crankshaft has eight bolt holes; installation can be performed in any desired position.

Crankshaft pulley tightening torque	N·m (kgf·m/lb·ft)
160 ~ 240 (16.3 ~ 24.5 / 118 ~ 177)	

There is normally no need to remove the damper from the pulley.
If the damper is removed, reused, or replaced, be sure to tighten to specified torque.

Damper tightening torque	N·m (kgf·m/lb·ft)
86 ~ 106 (8.8 ~ 10.8 / 64 ~ 78)	

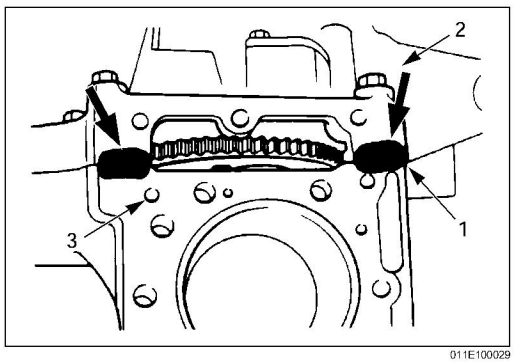

030E100002

21. Water pump

(1) Install the water pump together with its gasket, and tighten in place.

Water pump tightening torque		N·m (kgf·m/lb·ft)
M8 bolts	M10 bolts	
14 ~ 24 (1.4 ~ 2.4/10 ~ 17)	31 ~ 45 (3.2 ~ 4.6/23 ~ 33)	

(2) Apply molybdenum disulfide grease to the o-ring and install on the water pump.

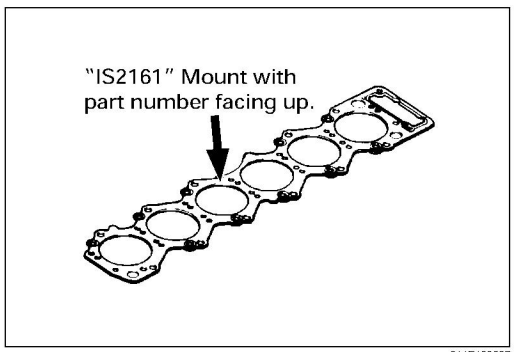


011E100029

23. Cylinder head gasket

(1) Apply a coating of sealant "Parmatex No. 6" about 2 mm thick and 3 mm wide to the joint between the cylinder block (1) and flywheel housing (2).

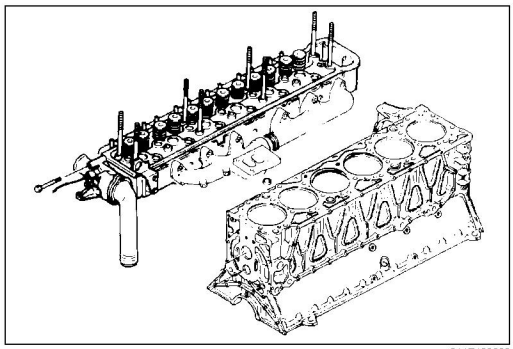
Note:
Do not block the cylinder's oil ports (3) with the sealant.



011E100027

(2) Install the head gasket, aligning it with the cylinder block's dowel pins.

Note:
Install the gasket with the part number (at the No. 3 cylinder position) facing up.

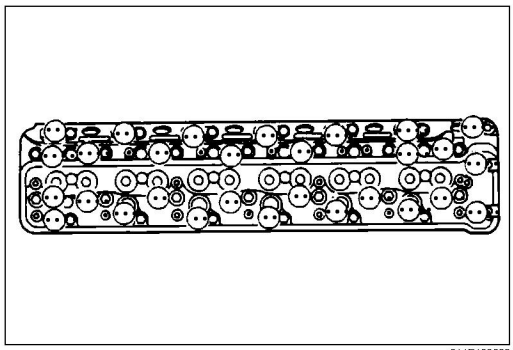


011E100022

24. Cylinder head

(1) Align the teeth of the idler gear "C" and idler gear "B", and carefully install the cylinder head.

Note:
Be sure to securely align the three dowel holes in the cylinder head with the dowel pins in the cylinder block. Take care not to damage the gasket when setting the cylinder head on top of the gasket.



011E100023

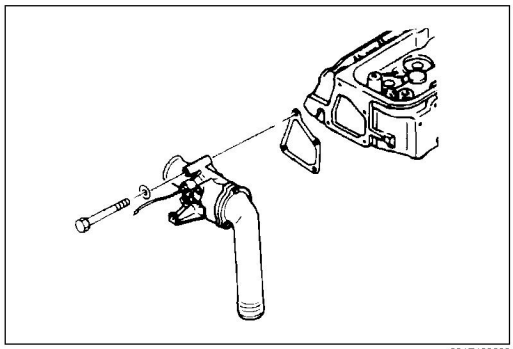
(2) Apply molybdenum disulfide grease to the threads and seating surfaces of the cylinder head bolts.

(3) Use the angular tightening method to tighten the cylinder head bolts to in the sequence shown.

Cylinder head bolt tightening torque N·m (kgf·m/lb·ft)

M14 bolts ① ~ ㉖	98 (10/72) → 142 ~ 152 (14.5 ~ 15.5 / 105 ~ 112) → 30° ~ 60°
M10 bolts ㉗ ~ ㉙	31 ~ 45 (3.2 ~ 4.6 / 23 ~ 33)

Note:
The cylinder head bolts may be reused only two times. After tightening the cylinder head bolts, plug the timing gear hole with a rag, etc., in order to prevent entry of any foreign matter.



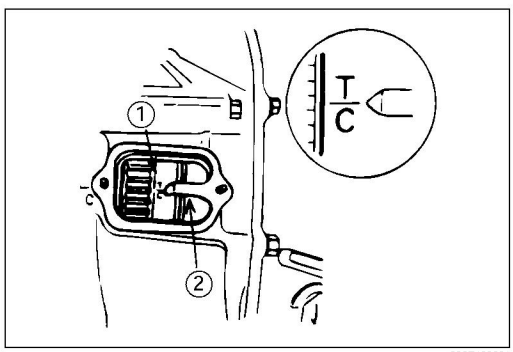
031E100002

25. Thermostat housing (with thermostat unit)

Install the thermostat housing, thermostat and water outlet pipe assembly to the cylinder head.

Thermostat housing bolt tightening torque
N·m (kgf·m/lb·ft)

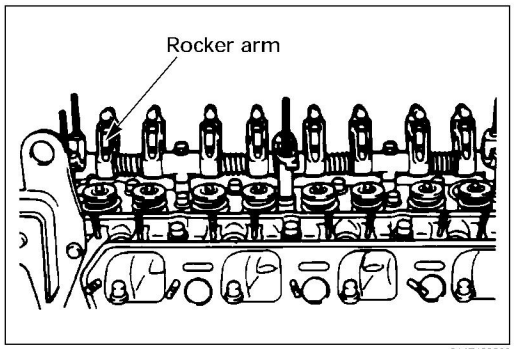
14 ~ 24 (1.4 ~ 2.4 / 10 ~ 17)



020E100001

26. Rocker arm shaft assembly

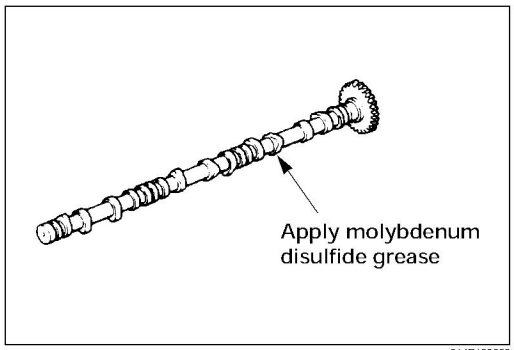
(1) Rotate the crankshaft clockwise, and align the flywheel's TDC mark with the flywheel housing's pointer.



014E100066

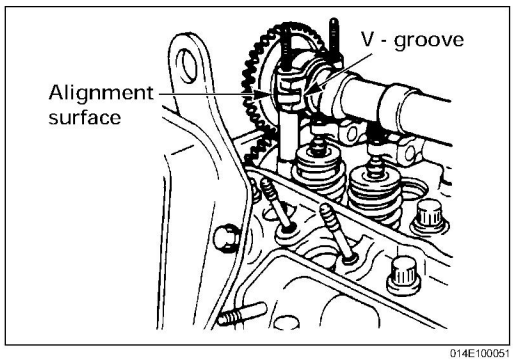
(2) Apply clean engine oil to the roller section of the rocker arm.
(3) Install the rocker arm shaft assembly to the cylinder head.

Note:
Be careful during installation, since the rocker arm must be stood on end and lowered to be installed.



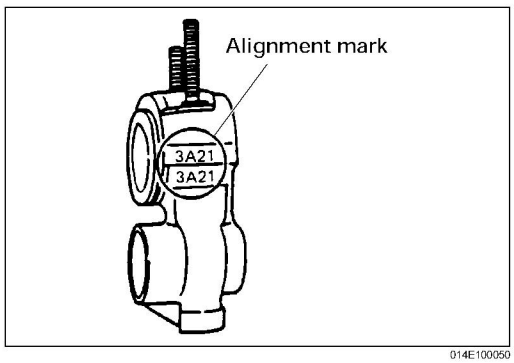
014E100052

27. Camshaft
(1) Apply clean engine oil liberally to the bearing surfaces of the camshaft lower brackets.
(2) Apply molybdenum disulfide grease to the cam profiles of the camshaft.



014E100051

(3) Install the camshaft to the lower bracket, aligning the V-groove on the camshaft with the alignment surface of the bracket (intake manifold side).



014E100050

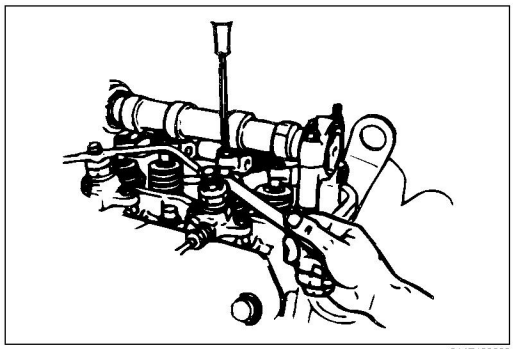
28. Camshaft upper bracket
Install the brackets, align the stamped numbers, and first tighten by hand from the camshaft gear side, finally tightening to the designated torque.

Note:
Confirm that the V-groove and bracket alignment surface are securely joined.
See the "Important Operations" entry in the section Engine III, "Rocker Arm Shaft Assembly."

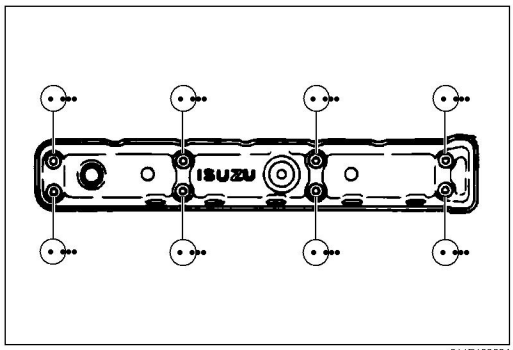
Camshaft upper bracket nut tightening torque
N·m (kgf·m/lb·ft)

20 ~ 24 (2.0 ~ 2.4 / 14 ~ 17)

Note:
The rocker arm's adjust screw must be fully loosened (increase valve clearance) before installing the camshaft.


014E100002

Valve clearance adjustment
See the section "Valve Clearance Adjustment" in chapter 2 (Maintenance) (P. 28).



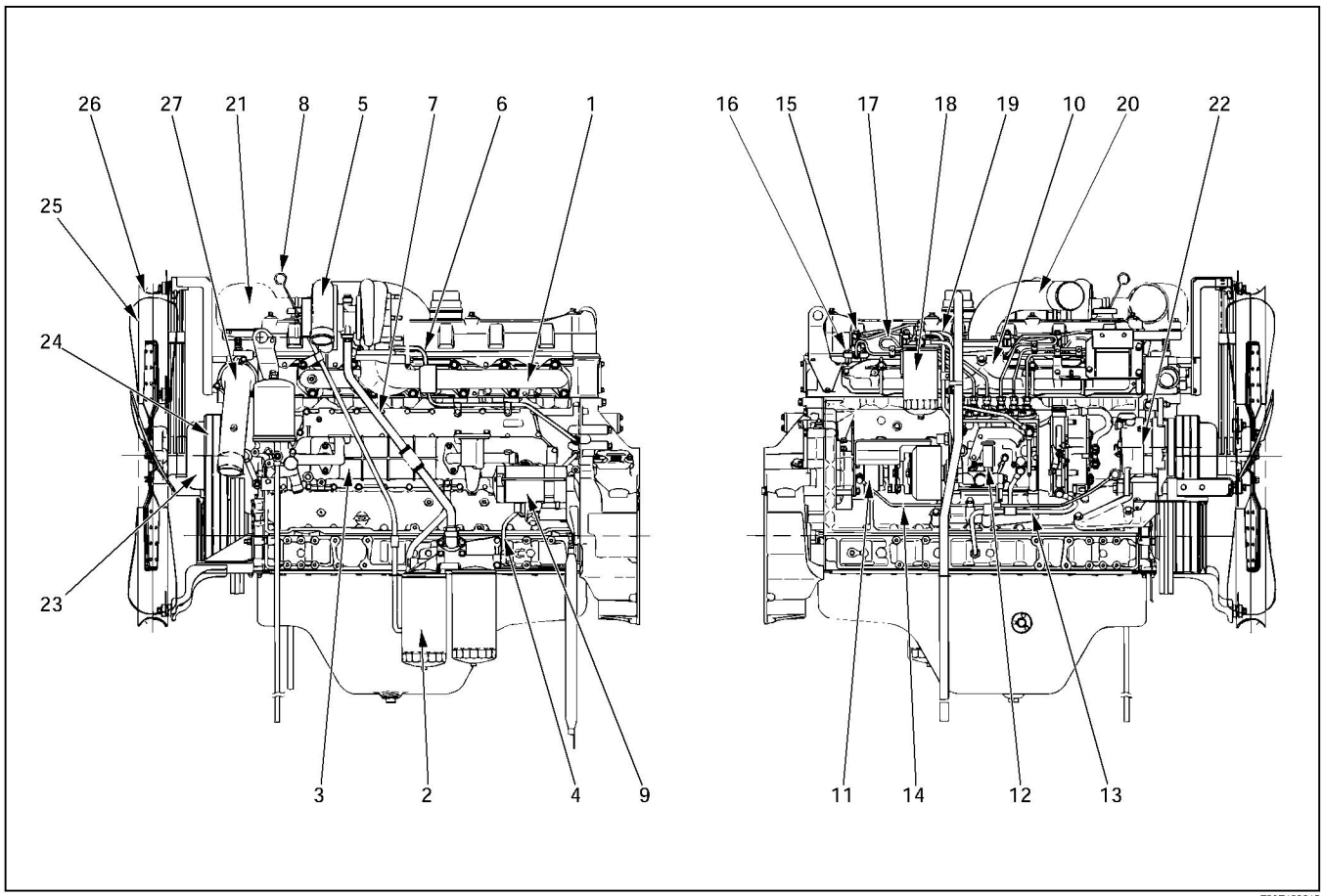
011E100024

29. Cylinder head cover gasket
30. Cylinder head
(1) Apply sealant " Three Bond No. 1208" to the head cover gasket.
(2) Install the head cover, tightening the bolts in the sequence shown.

Head cover bolt tightening torque N·m (kgf·m/lb·ft)

2.9 ~ 6.9 (0.3 ~ 0.7 / 2.2 ~ 5.1)

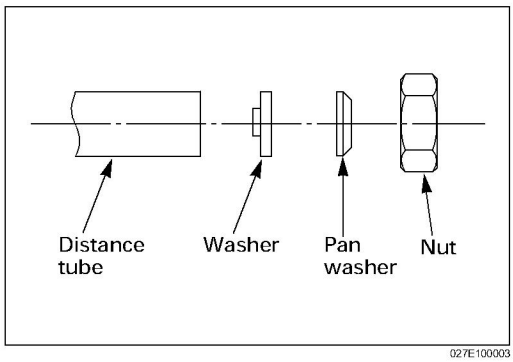
ASSEMBLY 3



F06E100015

Disassembly sequence

▲ 1. Exhaust manifold
2. Partial oil filter
▲ 3. Oil cooler
4. Oil pipe (partial oil filter)
▲ 5. Turbocharger
▲ 6. Oil feed pipe
▲ 7. Oil return pipe
8. Oil dipstick
▲ 9. Starter motor
▲10. Intake cover
▲11. Coupling ASM
▲12. Injection pump
▲13. Oil return pipe
▲14. Oil feed pipe
▲15. Nozzle holder
▲16. Glow plug
▲17. Injection pipe
18. Fuel filter
▲19. Fuel pipes
20. Intake pipe
21. Intake duct
▲22. Alternator
▲23. Water pump pulley and adapter
▲24. Fan belt
25. Cooling fan
26. Fan guide
27. Water pipe



027E100003

IMPORTANT OPERATIONS

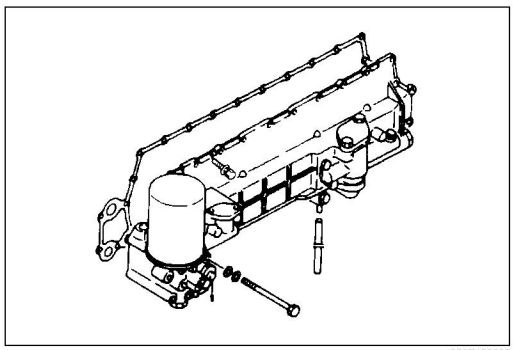
1. Exhaust manifold

(1) Install the exhaust manifold gasket on the stud bolts.

(2) Install the exhaust manifold and tighten to the designated torque.

Exhaust manifold bolt tightening torque N·m (kgf·m/lb·ft)

36 ~ 46 (3.7 ~ 4.7 / 27 ~ 34)


050E100007

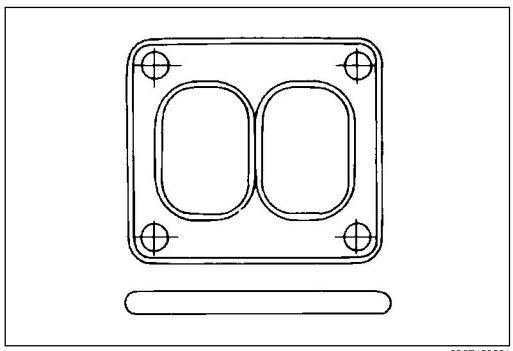
3. Oil cooler (with oil filter)

(1) Apply sealant "Helmes Seal No. 123T" to the oil cooler gasket, and stick the gasket to the cylinder block.

(2) Install the oil cooler and tighten the bolts alternately from inside to outside.

Oil cooler bolt tightening torque N·m (kgf·m/lb·ft)

18 ~ 26 (1.8 ~ 2.7 / 13 ~ 20)

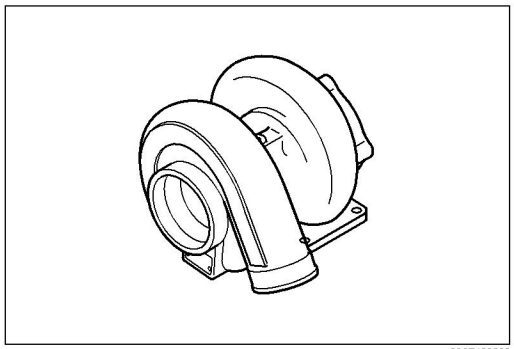

036E100001

5. Turbocharger

(1) Install the turbocharger gasket, with the upper surface of the gasket facing up.
The illustration shows the upper surface of the gasket.

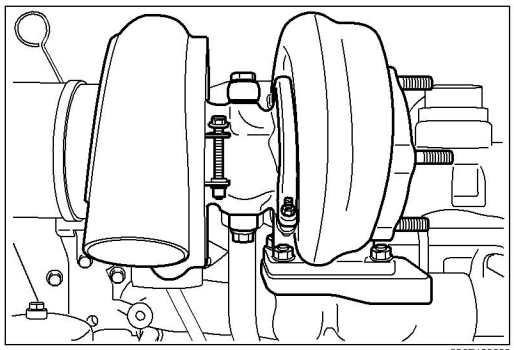
(2) Install the turbocharger, taking care not to damage the gasket.

Note:
Always use new nuts and washers when installing.


036E100002

6. Oil pipe (turbo feed)
7. Oil pipe (turbo return)
(1) Before installing the oil pipe, fill the pipe through the pipe mounting hole with about 100 ~ 130 cc of CD grade engine oil.
(2) Turn the rotor shaft by hand to lubricate the bearing.

Note:
If steps (1) and (2) are not performed, the turbocharger may seize upon engine startup.


036E100003

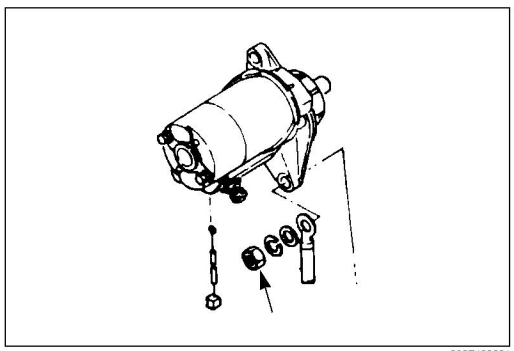
(3) Install the oil feed pipe and oil return pipe and tighten the turbocharger's mounting nut.
(4) Tighten the oil pipe.

Turbocharger nut tightening torque N·m (kgf·m/lb·ft)

34 ~ 46 (3.5 ~ 4.7 / 25 ~ 34)

Oil pipe bolt tightening torque N·m (kgf·m/lb·ft)

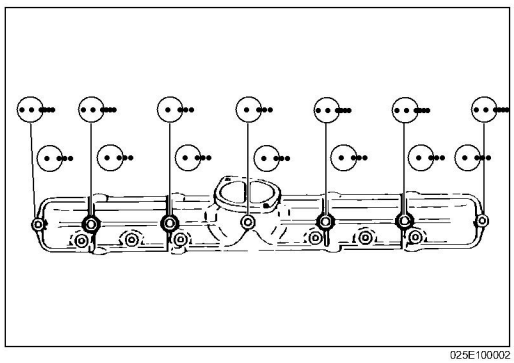
	Turbocharger side	Cylinder block side
Feed pipe	25 ~ 31 (2.5 ~ 3.2 / 18 ~ 23)	20 ~ 29 (2.0 ~ 3.0 / 14 ~ 22)
Return pipe	31 ~ 45 (3.2 ~ 4.6 / 23 ~ 33)	20 ~ 29 (2.0 ~ 3.0 / 14 ~ 22)


060E100001

9. Starter
Install the starter and tighten to the designated torque.

Starter tightening torque N·m (kgf·m/lb·ft)

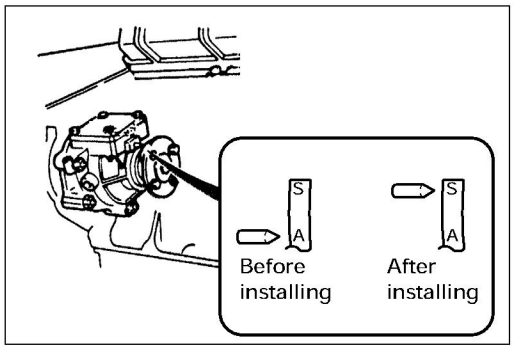
125 ~ 150 (12.7 ~ 15.3 / 92 ~ 111)


025E100002

10. Intake cover
(1) Apply sealant "Three Bond No. 1207C" to the intake cover.
(2) Install the intake cover and tighten the bolts gradually in two passes, using the tightening sequence shown.

Intake cover bolt tightening torque N·m (kgf·m/lb·ft)

25 ~ 30 (2.5 ~ 3.1 / 18 ~ 22)



11. Coupling ASM

(1) Align the V-groove on the camshaft with the alignment surface of the cam bracket on the intake manifold side (at compression TDC on the No. 1 cylinder). Confirm that the pointer on the flywheel housing points to the TDC mark on the flywheel.

(2) If the injection pump drive gear has been removed from the coupling, reinstall it to the gear, being sure to align the key correctly.

Injection drive gear tightening torque N·m (kgf·m/lb·ft)

206 ~ 304 (21.0 ~ 31.0 / 152 ~ 224)

(3) As shown in the illustration, align the **A mark** with the coupling pointer.

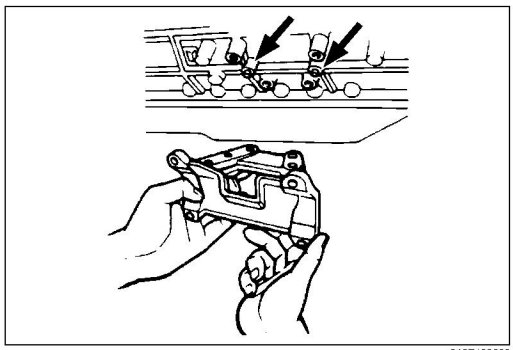
(4) Apply sealant "Three Bond No. 1208" to three points around the o-ring, and insert the o-ring into the coupling's groove.

(5) Install the coupling to the timing gear case and tighten to the designated torque.

(6) After installing the coupling, confirm that the coupling's pointer is in alignment with the **S mark**.

Coupling bolt tightening torque N·m (kgf·m/lb·ft)

83 ~ 102 (8.5 ~ 10.4 / 61 ~ 75)



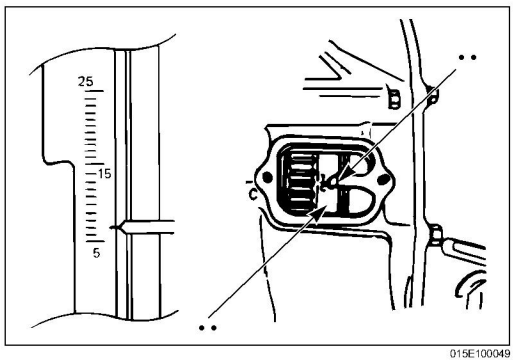
040E100008

12. Injection pump

(1) Install the injection pump bracket, aligning it with the positioning pins on the cylinder block.

Pump bracket bolt tightening torque N·m (kgf·m/lb·ft)

31 ~ 45 (3.2 ~ 4.6 / 23 ~ 33)

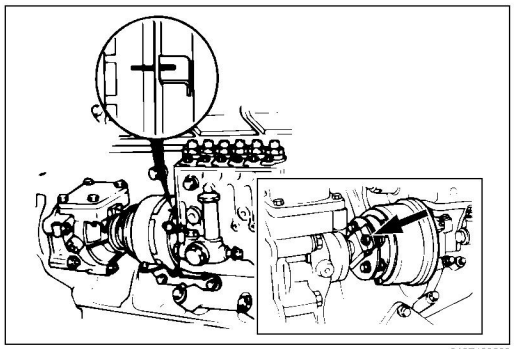


015E100049

(2) Rotate the crankshaft clockwise and align the timing pointer (2) with the engraved lines on the flywheel (1), so that the No. 1 cylinder is set to injecting timing.

Injection timing (BTDC)

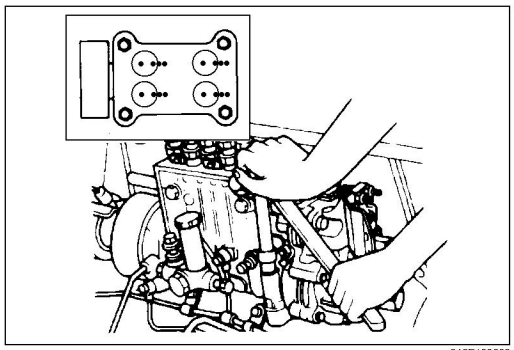
7°


040E100029

(3) Hand-tighten the injection pump on the bracket, aligning the line engraved on the pump body with the line on the timer, and tighten the coupling.

Coupling tightening torque N·m (kgf·m/lb·ft)

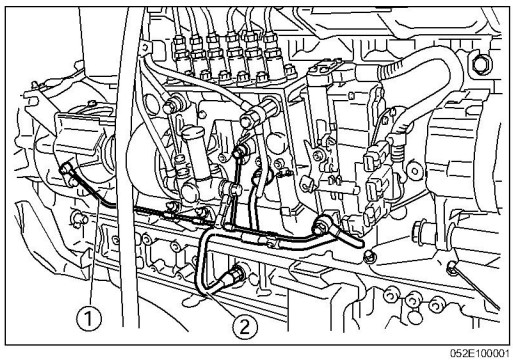
103 ~ 113 (10.5 ~ 11.5 / 76 ~ 83)


040E100009

(4) Tighten the injection pump bolts in the sequence shown.

Injection pump bolts tightening torque N·m (kgf·m/lb·ft)

31 ~ 45 (3.2 ~ 4.6 / 23 ~ 33)



052E100001

13. Oil return pipe

Install the oil return pipe (2) and tighten to the designated torque.

Tightening torque N·m (kgf·m/lb·ft)

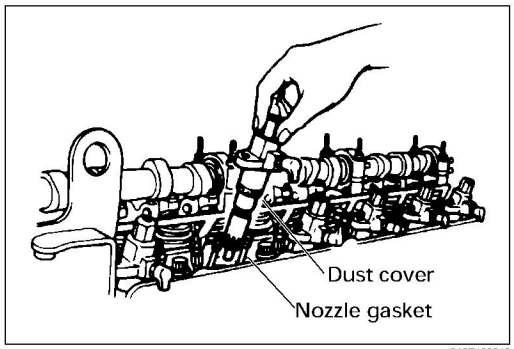
33 ~ 49 (3.4 ~ 5.0 / 25 ~ 36)

14. Oil feed pipe

Install the oil feed pipe (1) and tighten to the designated torque.

Tightening torque N·m (kgf·m/lb·ft)

24 ~ 31 (2.4 ~ 3.2 / 17 ~ 23)



040E100013

15. Nozzle holder

(1) Install the dust cover and nozzle gasket to the nozzle holder.

Note:
Take care not to damage the nozzle tip.

(2) Install the nozzle holder flange and nuts, and hand tighten.

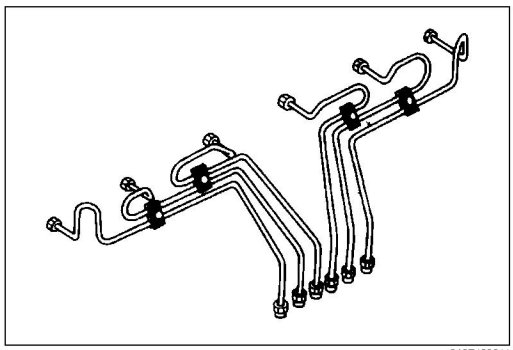
Note:
Do not fully tighten until after installing the injection pipe.

16. Glow plug

Install the glow plugs, and tighten to the designated torque, then fasten the connectors.

Glow plug tightening torque N·m (kgf·m/lb·ft)

22 ~ 27 (2.25 ~ 2.75 / 16.3 ~ 19.9)


040E100011

17. Injection pipe

(1) Install the injection pipe and hand tighten

(2) Tighten the nozzle holder flange nuts in alternate order, finally tightening evenly to the designated torque.

Flange nut tightening torque N·m (kgf·m/lb·ft)

20 ~ 24 (2.0 ~ 2.4 / 14 ~ 17)

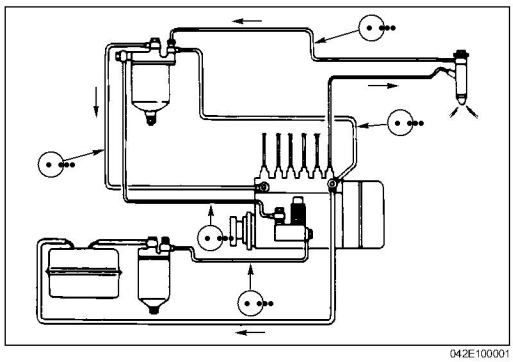
(3) Tighten the injection pipe to designated torque.

Injection pipe tightening torque N·m (kgf·m/lb·ft)

Nozzle holder side	28 ~ 31 (2.9 ~ 3.2 / 21 ~ 23)
Injection pump side	34 ~ 44 (3.5 ~ 4.5 / 25 ~ 32)

(4) Install the injection pipe clip in the designated position, and tighten.

Note:
If the pipe clip is installed in the incorrect position, the pipe may be damaged and fuel pulsing sound may be heard.

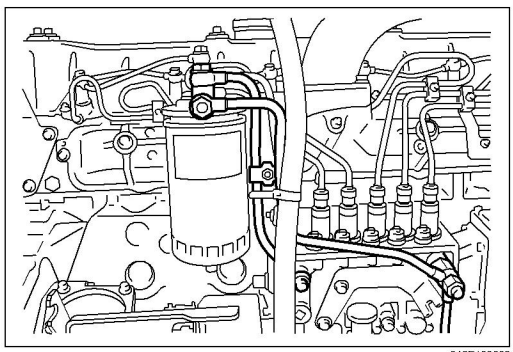

042E100001

19. Fuel pipes

(1) Install fuel pipes ①, ②, ③ and ④, together with the return pipe ⑤.

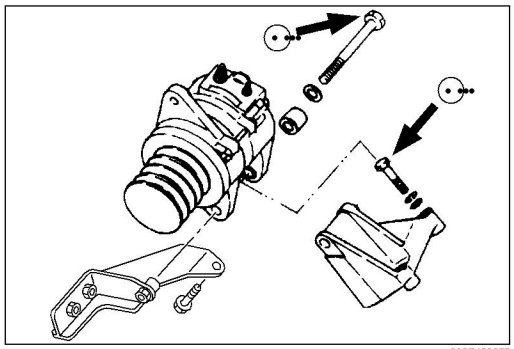
Fuel pipe tightening torque N·m (kgf·m/lb·ft)

33 ~ 49 (3.4 ~ 5.0 / 25 ~ 36)


042E100003

(2) Install the clips in their designated positions.

Note:
When tightening the fuel pipes, take care not to allow the pipes to turn together with the nuts, since the pipes may be deformed.


060E100075

22. Alternator
Install the alternator bracket and alternator, and tighten to the designated torque.

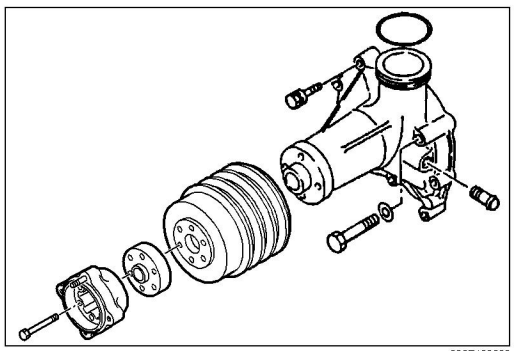
Alternator bracket tightening torque ① N·m (kgf·m/lb·ft)

31 ~ 45 (3.2 ~ 4.6 / 23 ~ 33)

Alternator bolt tightening torque ② N·m (kgf·m/lb·ft)

93 ~ 139 (9.5 ~ 14.2 / 69 ~ 103)

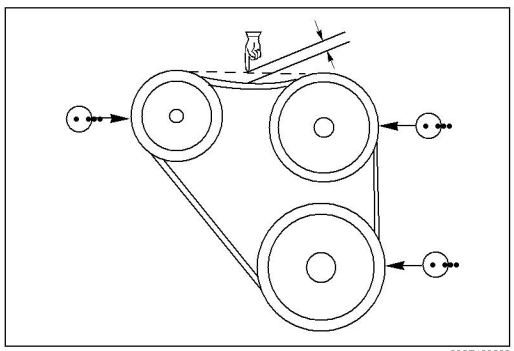
Tighten the alternator bolts first by hand; then adjust the fan belt tension and finally tighten the bolts to the designated torque.


030E100023

23. Water pump pulley and adapter
Attach the pulley and adapter to the water pump and tighten to the designated torque.

Tightening torque N·m (kgf·m/lb·ft)

44 ~ 60 (4.5 ~ 6.1 / 33 ~ 44)


033E100003

24. Fan belt
Adjust the belt tension by moving the generator and adjusting plate.
(1) Crank pulley
(2) Water pump pulley
(3) Alternator pulley

See chapter 2, Maintenance, "Cooling system." (P. 27)

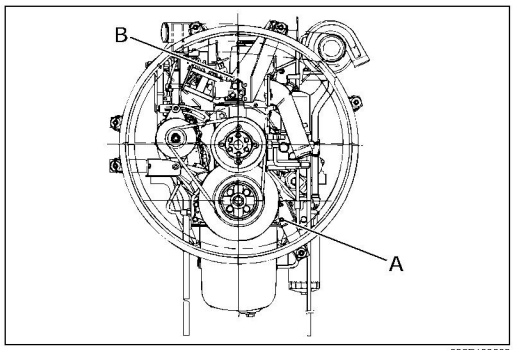
Note:
When replacing a belt, replace both belts as a single set.

25. Cooling fan

Install the cooling fan to the water pump pulley adapter.

Tighten the bolt to the designed torque.

Tightening torque	N·m (kg/cm^2/lb·ft)
44 ~ 60 (4.5 ~ 6.1 / 33 ~ 44)	



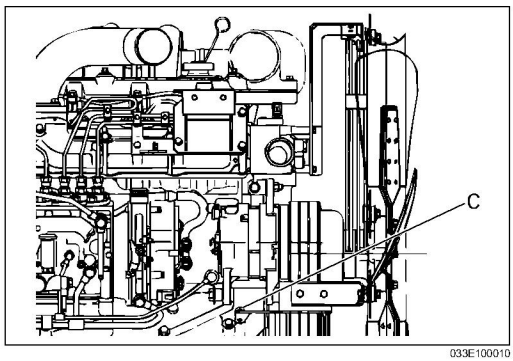
033E100009

26. Fan guide

(1) Install the fan guide brackets.

Tighten the nuts and bolt to the designed torque.

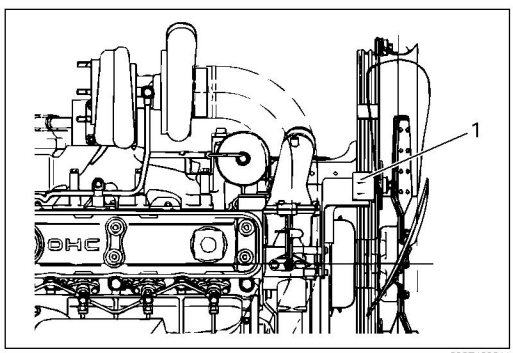
Tightening torque	N·m (kg/cm^2/lb·ft)
Nut A	43 ~ 57 (4.4 ~ 5.8 / 32 ~ 42)
Bolt B	20 ~ 29 (2.0 ~ 3.0 / 14 ~ 22)



033E100010

Tighten the bracket bolt to the designed torque.

Tightening torque	N·m (kg/cm^2/lb·ft)
Bolt C	20 ~ 29 (2.0 ~ 3.0 / 14 ~ 22)

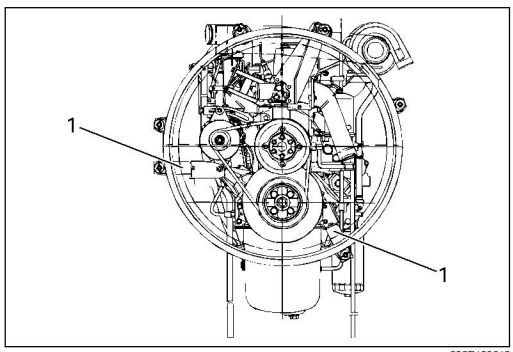


033E100011

(2) Install the stay (1) to the fan guide bracket.

Tighten the bolts to the designed torque.

Tightening torque	N·m (kg/cm^2/lb·ft)
44 ~ 60 (4.5 ~ 6.1 / 33 ~ 44)	



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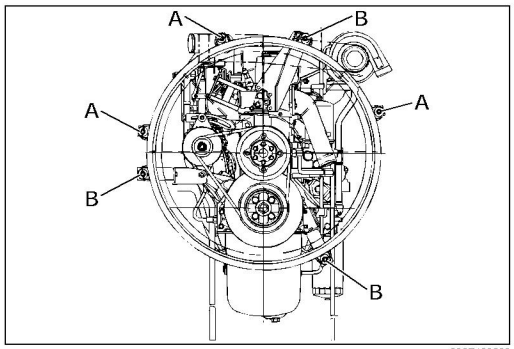
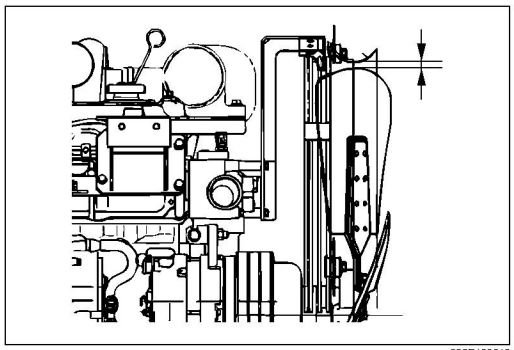


033E100008

(3) Install the fan guide and fan guard.
Tighten the bolts to the designed torque.

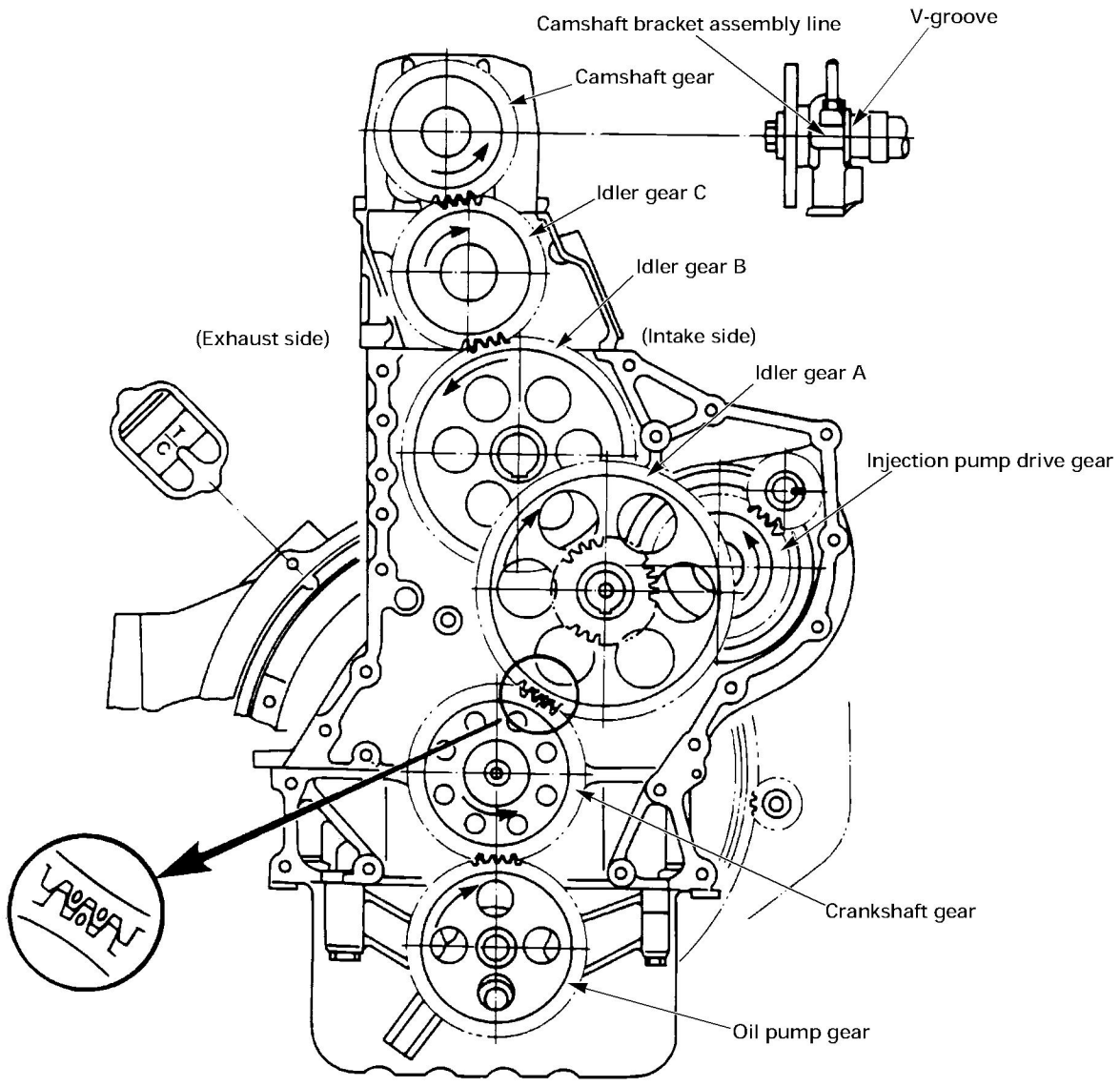
Tightening torque	N·m (kg/cm^2/lb·ft)
Bolt A and B	44 ~ 60 (4.5 ~ 6.1 / 33 ~ 44)


033E100012

(4) Adjust the fan tip clearance.

Tip clearance	mm(in)
10 (0.39)	

TIMING GEAR TRAIN DIAGRAM



With No. 1 cylinder at compression TDC

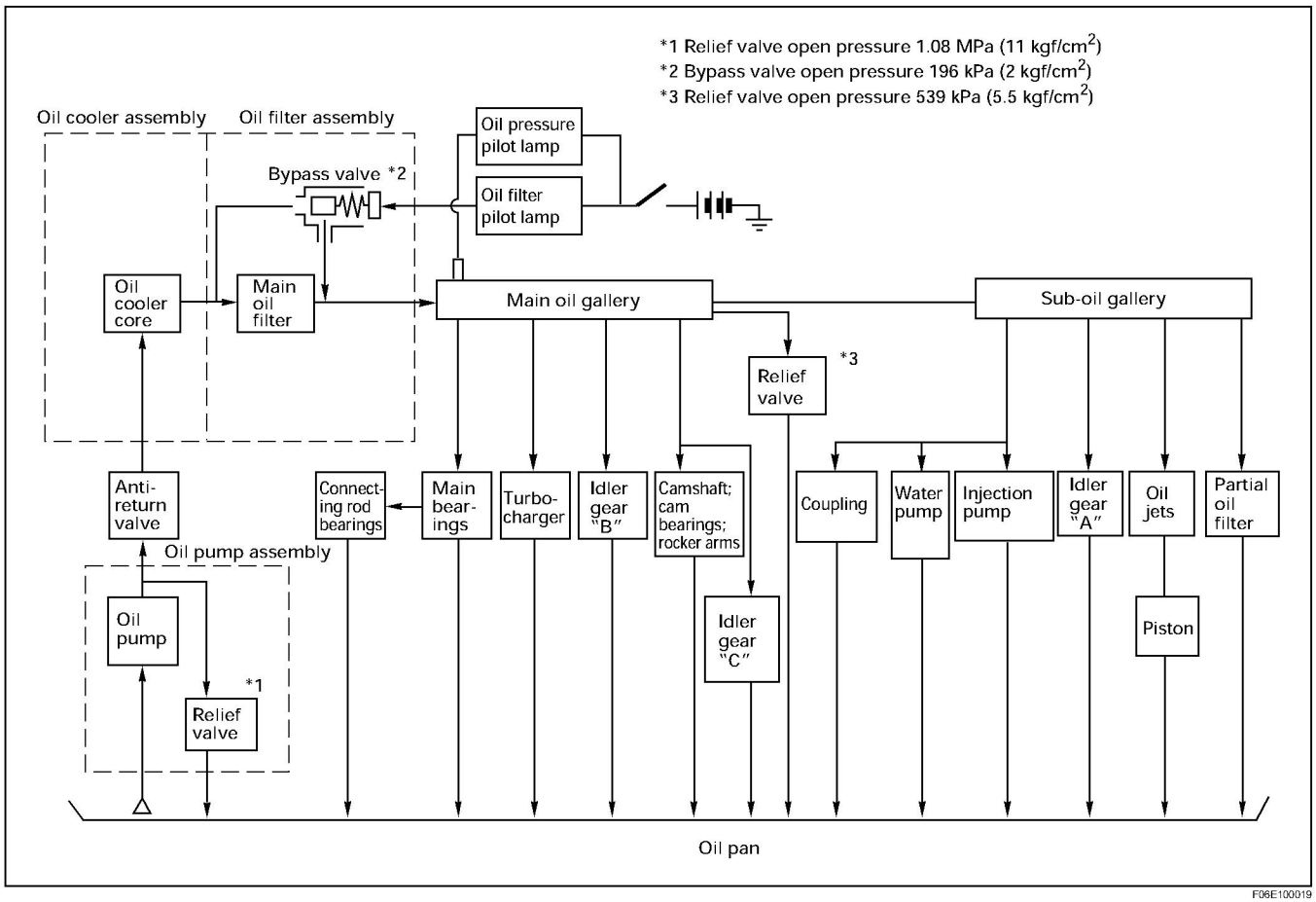
014E100054

CHAPTER 6

LUBLICATION SYSTEM

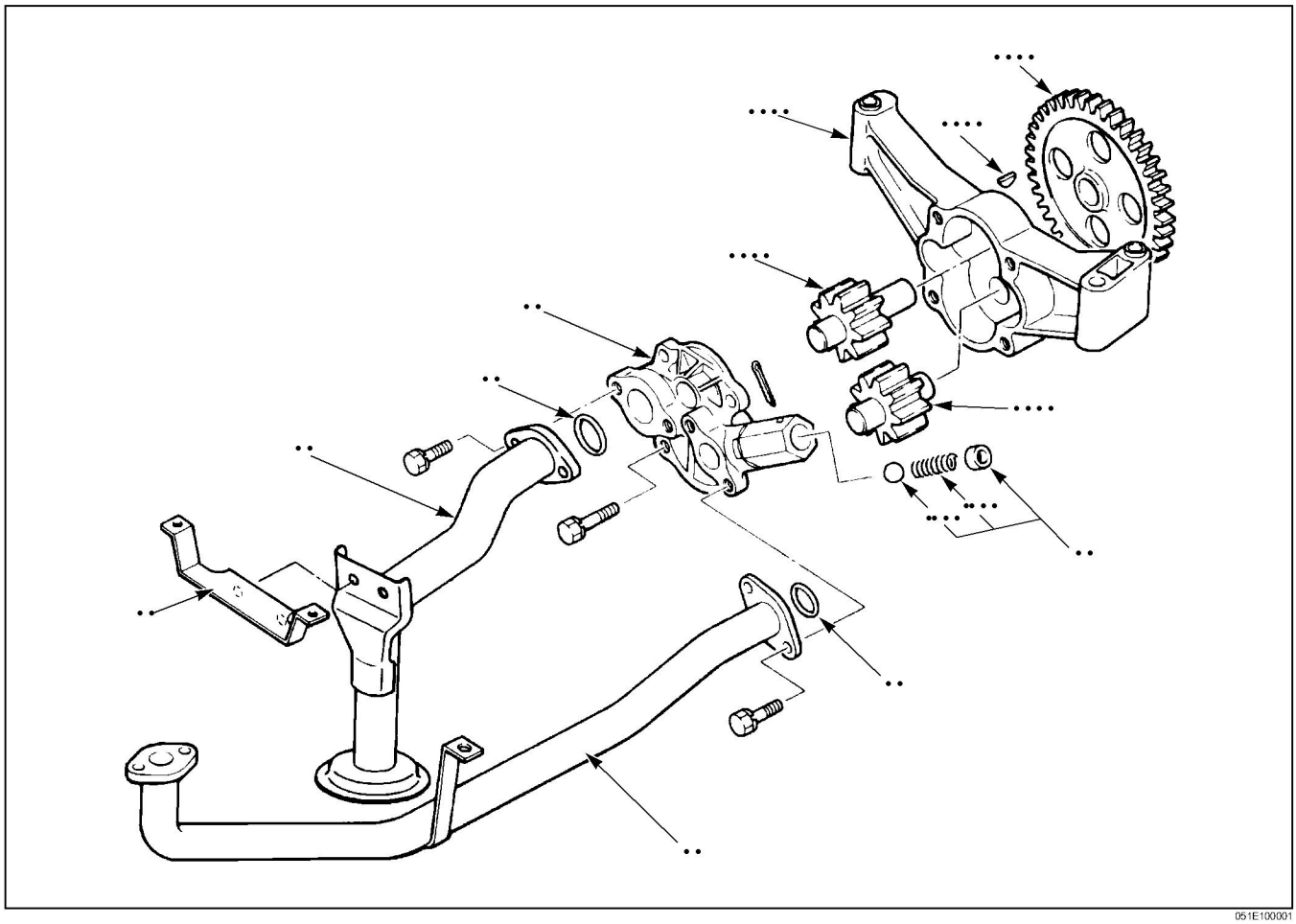
CONTENTS

INTRODUCTION



OIL PUMP

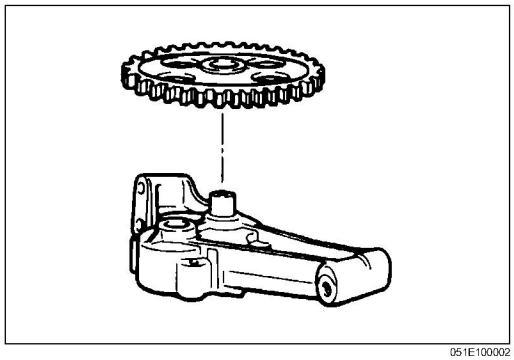
DISASSEMBLY



051E100001

Disassembly sequence

1. Oil strainer stay
2. Oil strainer
3. Gasket
4. Oil pump
5. Gasket
6. Spring seat
7. Spring
8. Oil relief valve
9. Oil pump body cover
10. Driven gear
▲11. Drive gear
12. Key
13. Drive gear shaft
14. Oil pump body



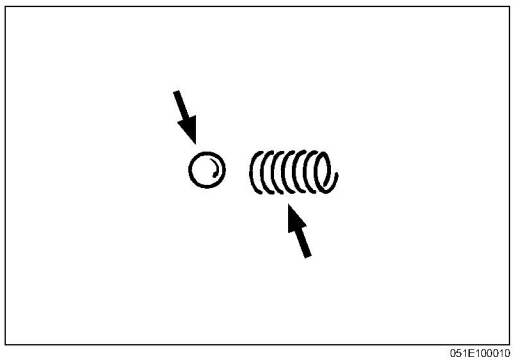
051E100002

IMPORTANT OPERATIONS

11. Drive gear
Use a gear puller to remove the drive gear.

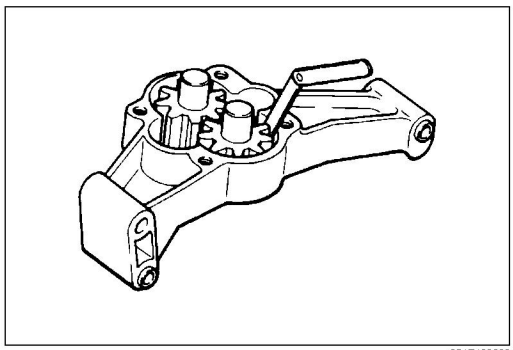
INSPECTION AND REPAIR

If excessive wear or damage is discovered during inspection, the appropriate parts must be adjusted, repaired, or replaced.



051E100010

Oil relief valve and spring
Visually inspect the relief valve and spring, and replace if any damage is discovered.

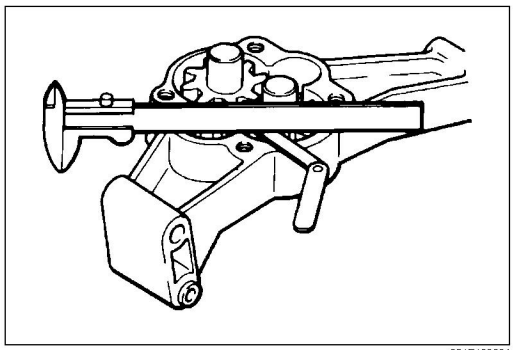


051E100003

Clearance between gear and pump cover inner wall
Use a feeler gauge to measure the clearance between the gear and the cover's inner wall.
If the measured clearance exceeds the limit, replace either the gear or the cover assembly.

Gear and cover inner-wall clearance mm (in)

Standard	Limit
0.100 ~ 0.196 (0.0039 ~ 0.0077)	0.15 (0.0059)



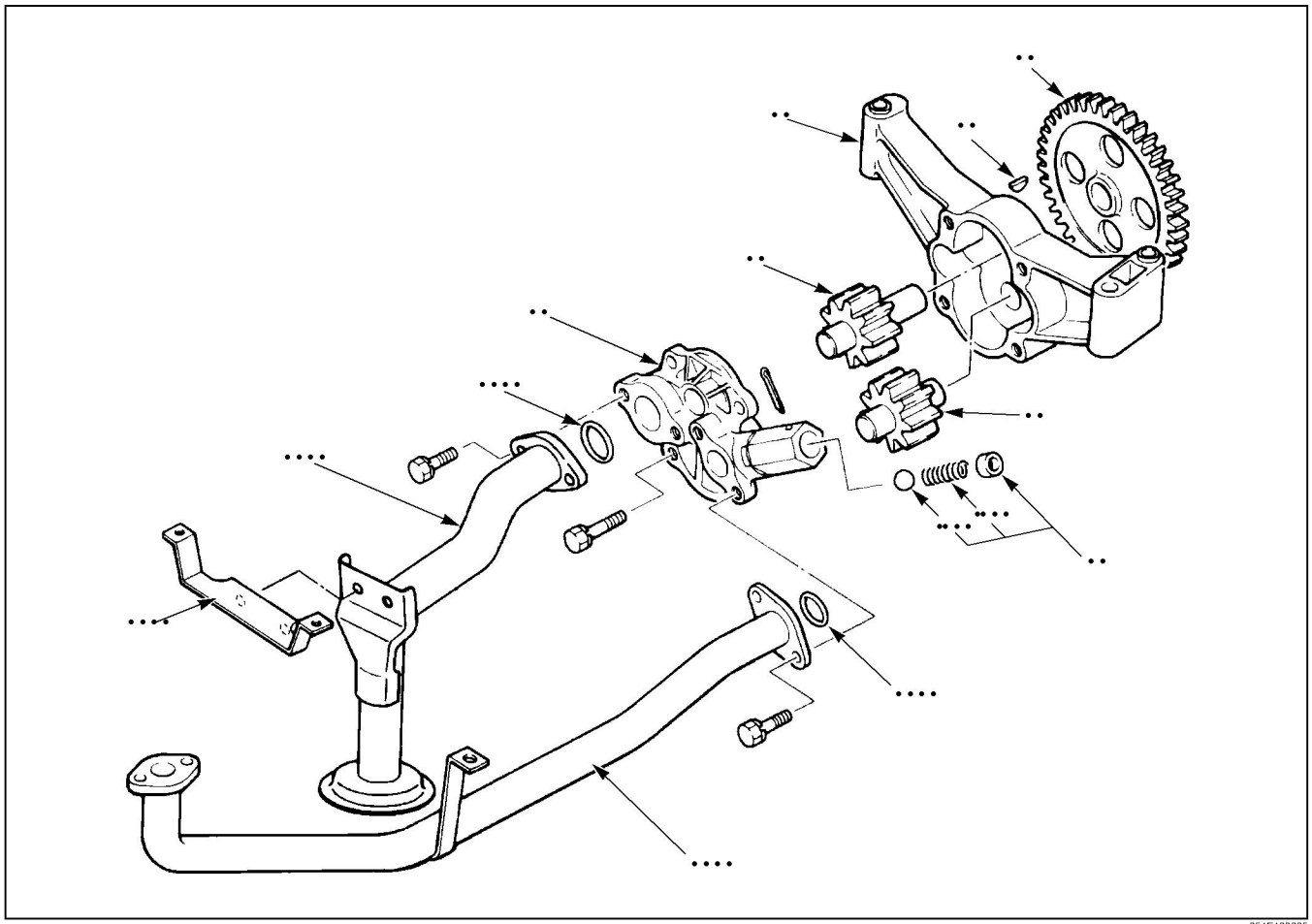
051E100004

Clearance between gear face and upper surface of cover
Use a feeler gauge and square to measure the clearance between the gear face and the upper surface of the cover.
If the measured clearance exceeds the limit, the gear or the gear assembly must be replaced.

Gear face and cover clearance mm (in)

Standard	Limit
0.040 ~ 0.093 (0.0016 ~ 0.0037)	0.15 (0.0059)

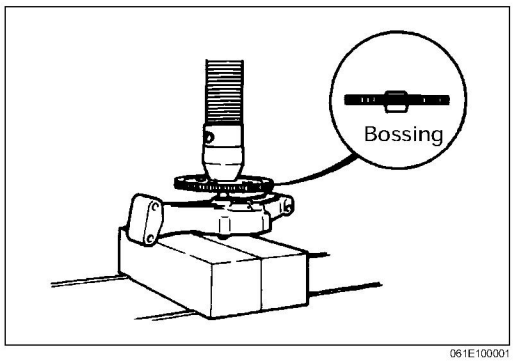
ASSEMBLY



Assembly sequence

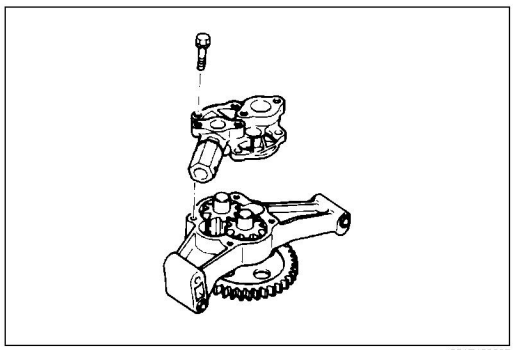
1. Oil pump body
2. Drive gear shaft
3. Key
▲ 4. Drive gear
5. Driven gear
▲ 6. Oil pump body cover
7. Oil relief valve
8. Spring
9. Spring seat
10. Gasket
▲11. Oil pipe
12. Gasket
▲13. Oil strainer
14. Oil pump strainer stay

IMPORTANT OPERATIONS



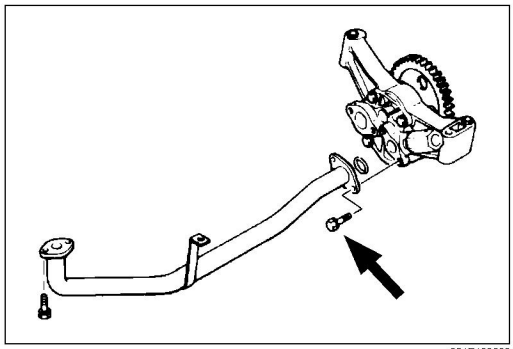
061E100001

4. Drive gear
(1) Apply clean engine oil to the drive gear and the drive gear shaft.
(2) Use a bench press to press the drive gear onto the shaft.
Install the gear with its large bossing toward the shaft.
Hold the shaft perpendicular and never apply pressure at an angle.


051E100007

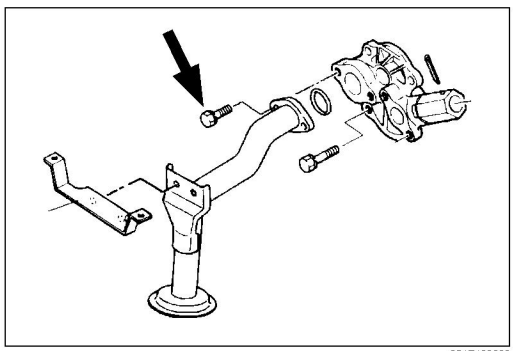
6. Oil pump body cover
After installing the driven gear, tighten the oil pump body cover at the designated torque.

Body cover bolt tightening torque	N·m (kgf·m/lb·ft)
13 ~ 23 (1.3 ~ 2.3 / 9.4 ~ 16.6)	


051E100008

11. Oil pipe
Install the oil pipe on the pump body cover, and tighten to the designated torque.

Oil pipe bolt tightening torque	N·m (kgf·m/lb·ft)
14 ~ 24 (1.4 ~ 2.4 / 10 ~17)	


051E100009

13. Oil strainer
Install the oil strainer to the pump body cover and tighten to the designated torque.

Oil strainer bolt tightening torque	N·m (kgf·m/lb·ft)
14 ~ 24 (1.4 ~ 2.4 / 10 ~ 17)	

OIL FILTER

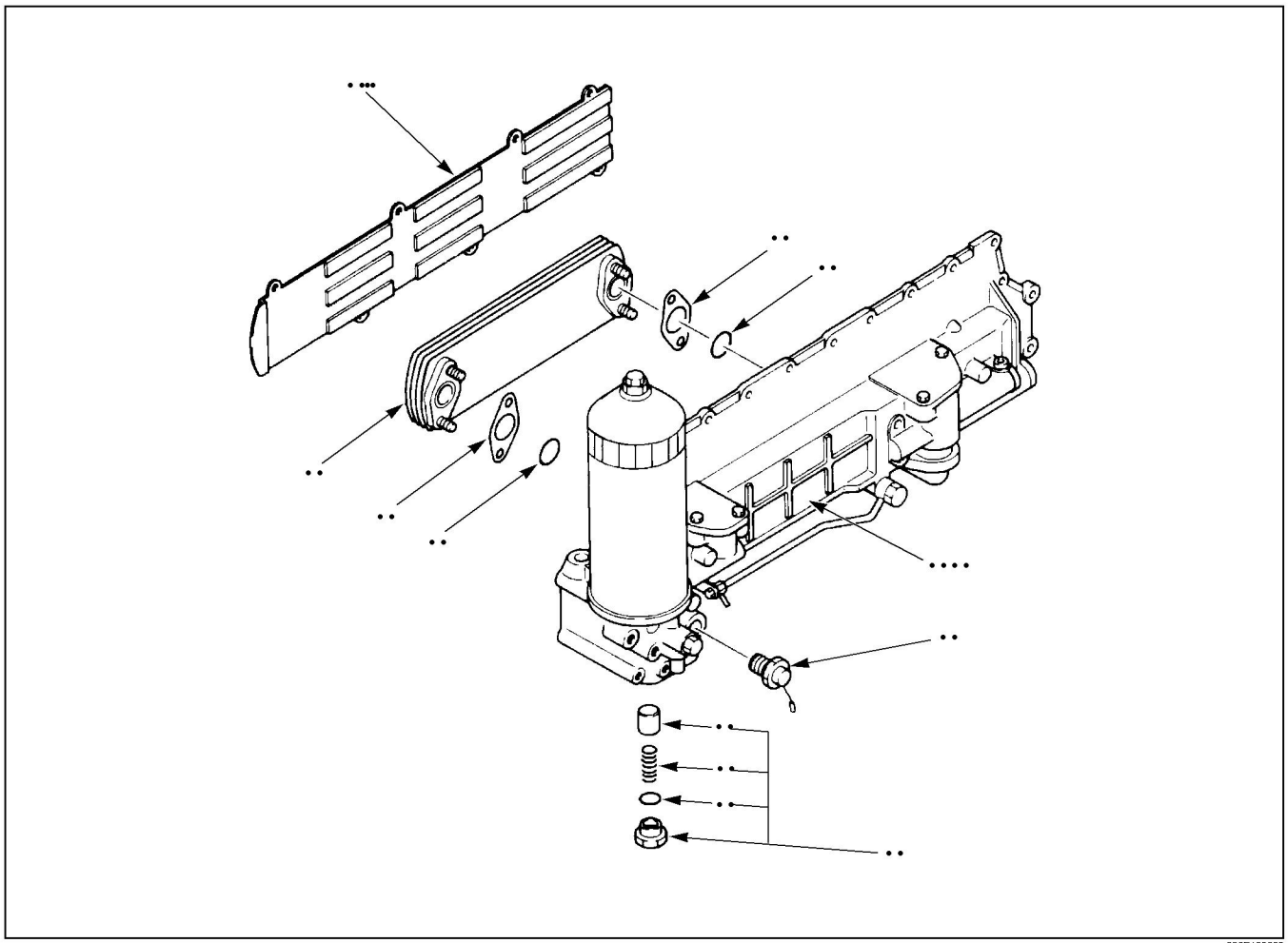
MAIN OIL FILTER

PARTIAL OIL FILTER

See Chapter 2 Maintenance, "Lubrication System" (p. 22, 23)

OIL COOLER

DISASSEMBLY



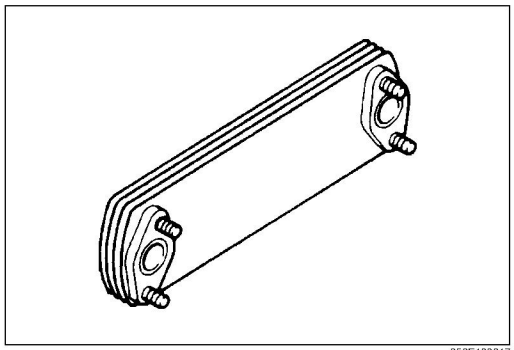
050E100009

Disassembly sequence

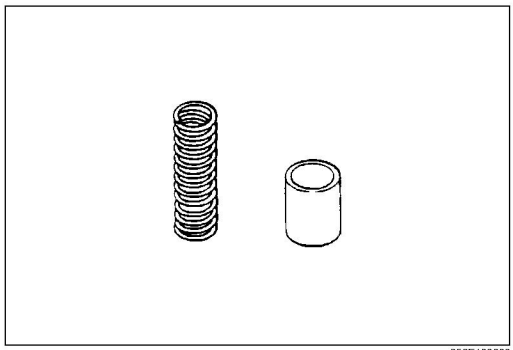
1. Water guide
2. Oil cooler
3. Gasket
4. Gasket
5. Oil filter warning switch
6. Plug
7. Gasket
8. Spring
9. Bypass valve
10. Body case

INSPECTION AND REPAIR

If excessive wear or damage is discovered during inspection, the appropriate parts must be adjusted, repaired, or replaced.


050E100017

Oil cooler core
If necessary, use red dye to check for cracks in the core.

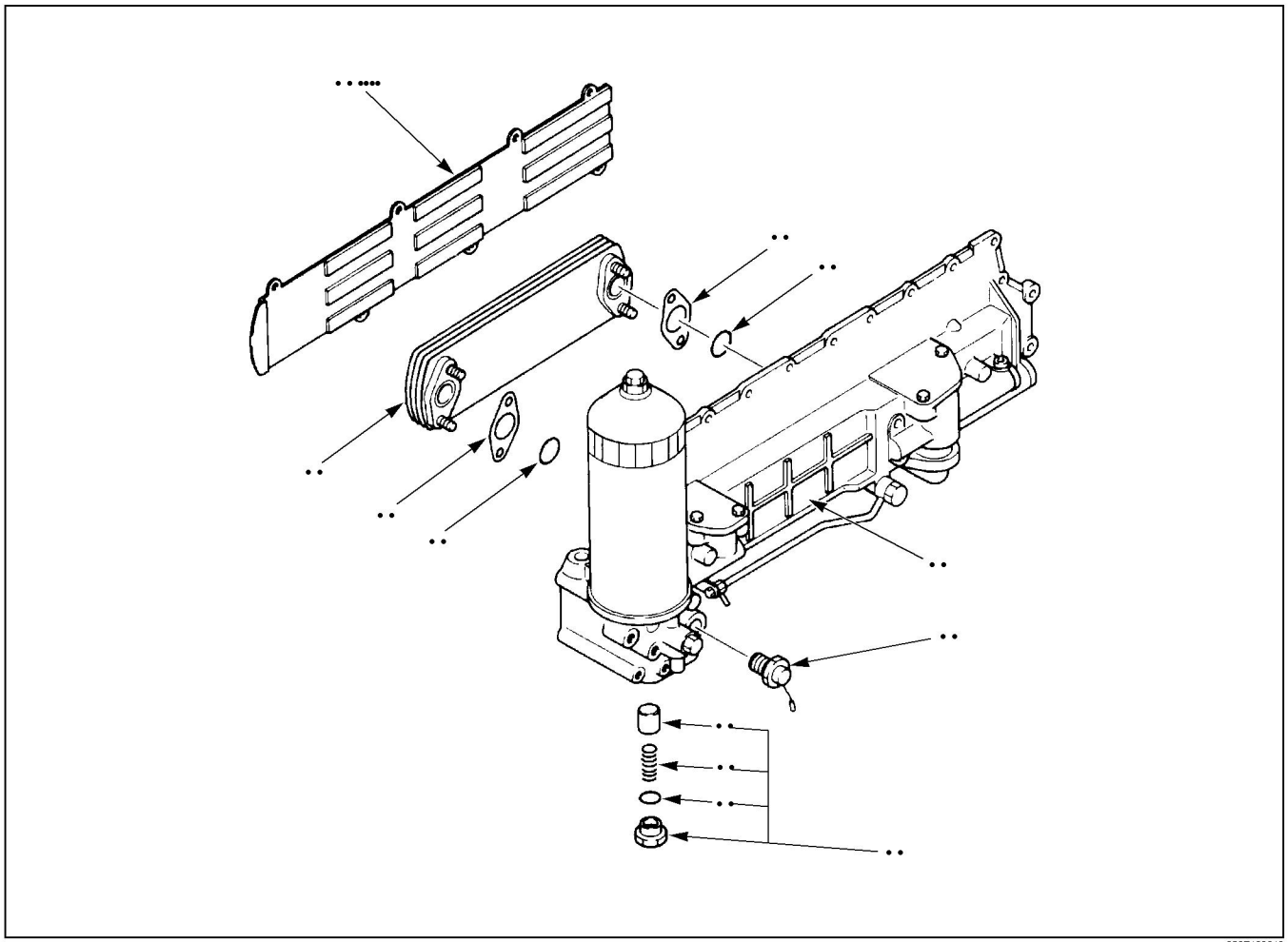

050E100008

Bypass valve
1. Check for wear or damage to the bypass valve seat.
2. Inspect the valve spring for weakening.

Oil cooler element inspection
- Fill the element with cleaning fluid and allow to stand for about 10 hours.
  Then drain about 1/3 of the cleaning fluid and apply about 200 (2) kPa (kgf/cm^2) of pressurized air to the oil port, to force out the cleaning solution through the element.
  Repeat this procedure to clean out the element as required.
  Never use cleaning fluid in the vicinity of fire or flame; when handling cleaning fluid, always wear goggles and gas mask, and use only in a well-ventilated room.

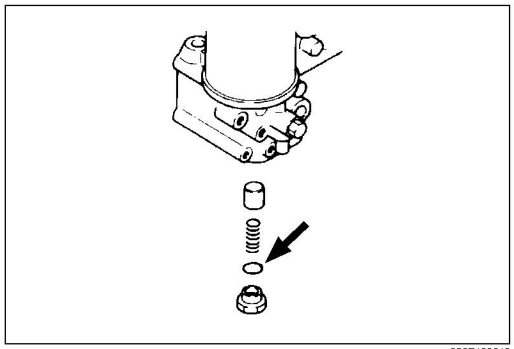
	Straight solution	Diluted with diesel fuel
Haiarom 25 (Nisseki)	○	—
Suwazol 310 (Maruzen)	○	—
Haizol (Showa shell)	○	—
Mobizol A (Mobil Oil)	—	○

ASSEMBLY



Assembly sequence

1. Body case
▲2. Bypass valve
3. Spring
4. Gasket
5. Plug
▲6. Oil filter warning switch
7. Gasket
8. Gasket
▲9. Oil cooler element
10. Water guide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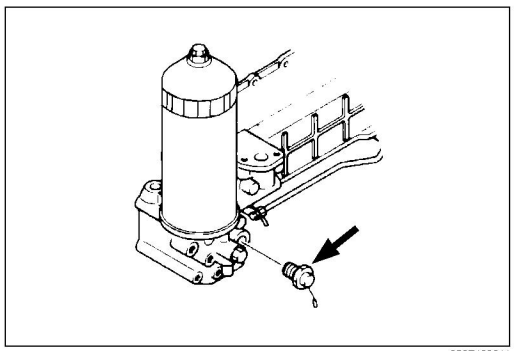
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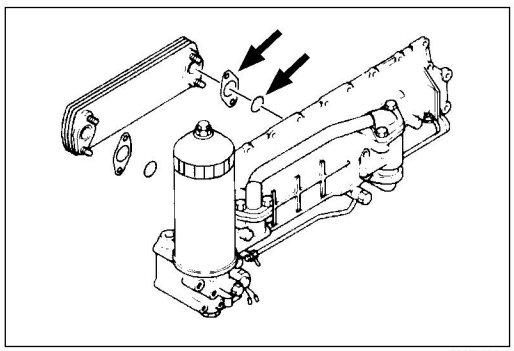

050E100012

IMPORTANT OPERATIONS

2. Bypass valve

(1) Install the bypass valve and spring in the body case.
(2) Apply clean engine to the gasket and install together with the plug, then tighten to the designated torque.

Bypass valve plug tightening torque	N·m (kgf·m/lb·ft)
29 ~ 39. (3.0 ~ 4.0 / 22 ~ 29)	

6. Oil filter warning switch

(1) Install the valve and spring in the body case.
(2) Install the warning switch and tighten to the designated torque.

Warning switch tightening torque	N·m (kgf·m/lb·ft)
39 (4/29)	

9. Oil cooler element

(1) Apply sealant to the body case's o-ring groove.
(2) Install the o-ring and gasket to the element.
(3) Install the oil cooler element to the body case and tighten to the designated torque.

Oil cooler element tightening torque	N·m (kgf·m/lb·ft)
15 ~ 25 (1.5 ~ 2.5 / 11 ~ 18)	

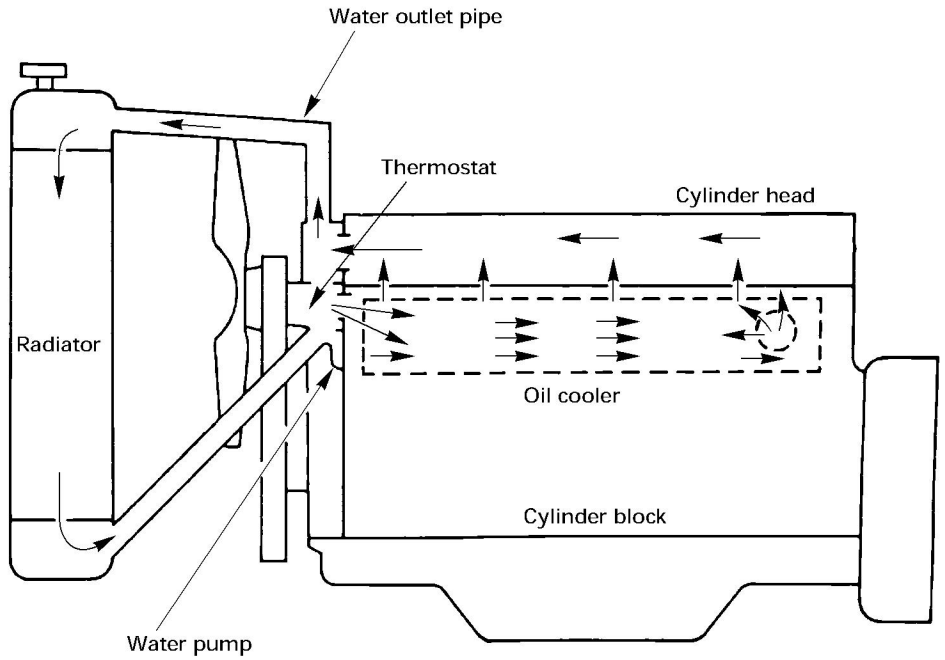
MEMO

CHAPTER 7

COOLING SYSTEM

CONTENTS

INTRODUCTION



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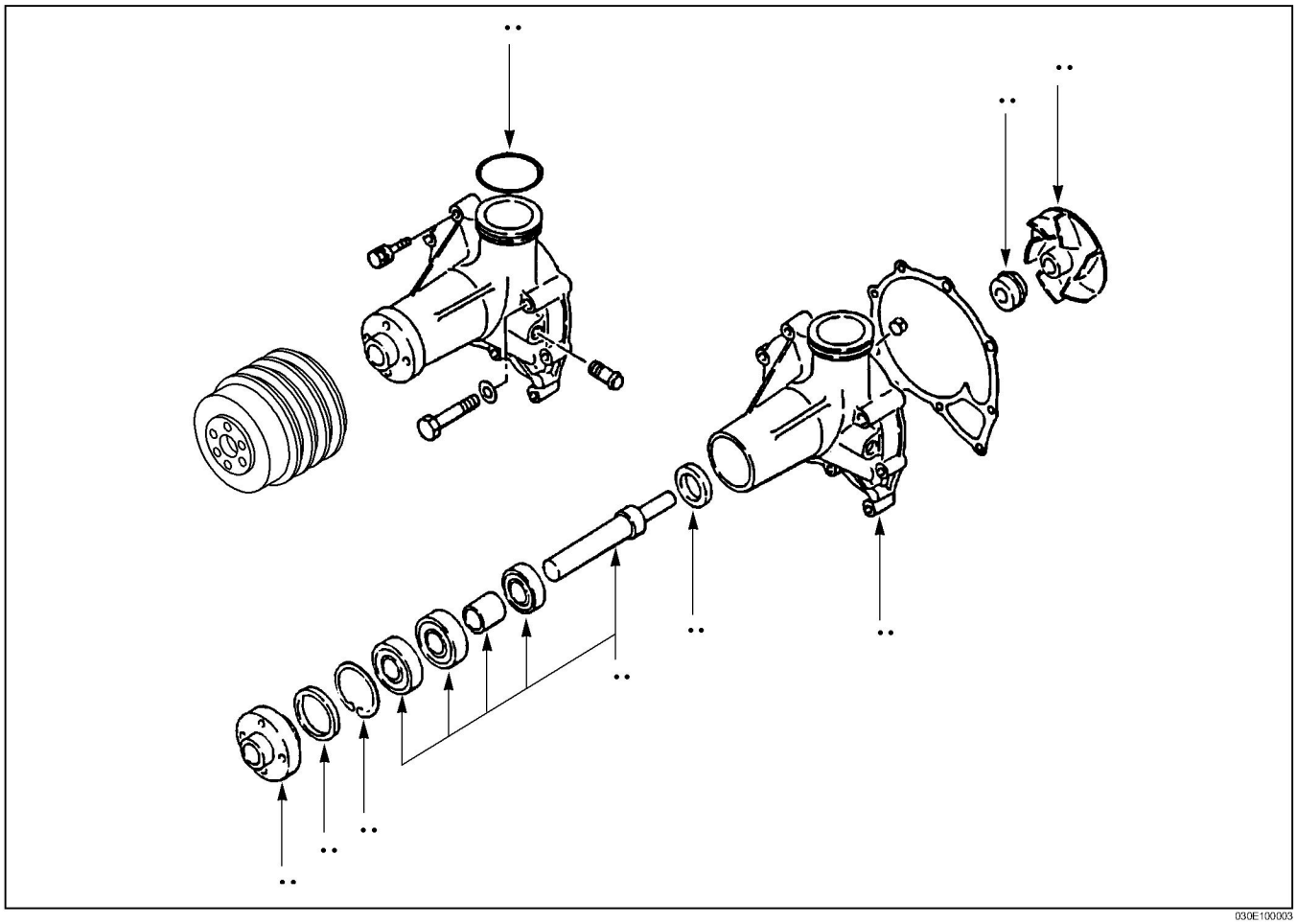
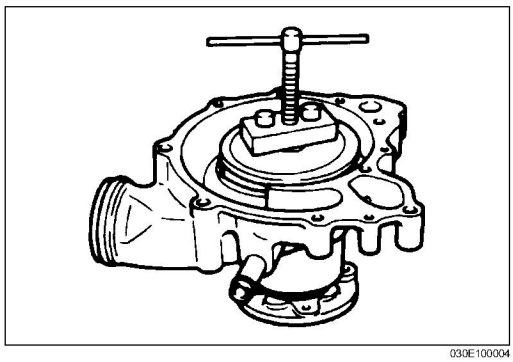
WATER PUMP

DISASSEMBLY



Disassembly sequence

1. Gasket
▲2. Impeller
3. Impeller seal unit
▲4. Pulley center
5. Oil seal (pulley center side)
6. Snap ring
▲7. Water pump shaft (with ball bearing)
8. Oil seal (impeller side)
9. Water pump body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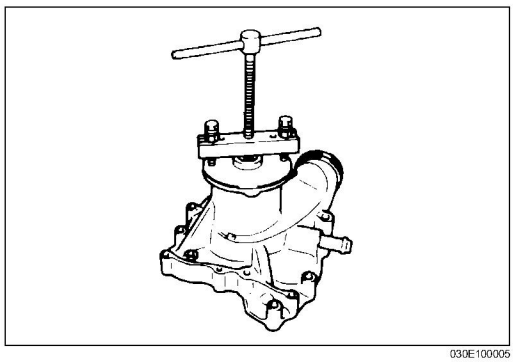
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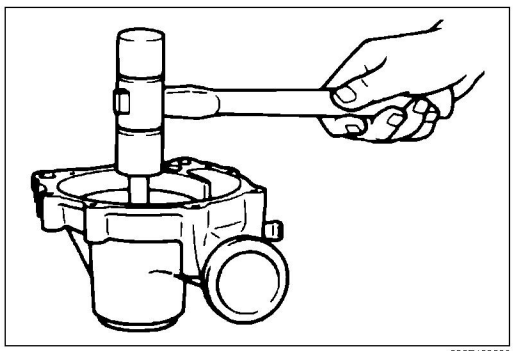

030E100006

IMPORTANT OPERATIONS

2. Impeller

(1) Support the pulley center with a vice.

(2) Use an impeller remover to remove the impeller.
Impeller remover: 1-85210-047-0

Note:
Do not remove the impeller by striking it, since it may be damaged.

4. Pulley center

Use a pulley remover to remove the pulley center.

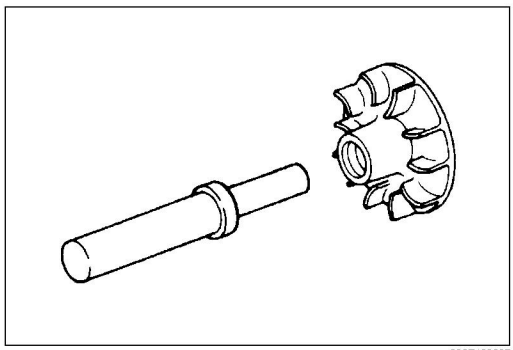
7. Water pump shaft (with ball bearing)

(1) Remove the snap ring on the pulley center side.

(2) Remove the water pump shaft by using a plastic hammer to tap the shaft free from the water pump body.

INSPECTION AND REPAIR

If excessive wear or damage is discovered during inspection, the appropriate parts must be adjusted, repaired, or replaced.



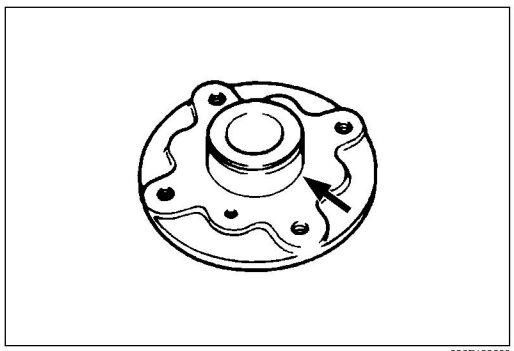
030E100007

Impeller

1. Inspect the impeller for corrosion, excessive wear on the seal unit fitting face, and other damage.
2. Measure the interference between the pump shaft and impeller.

Interference mm (in)

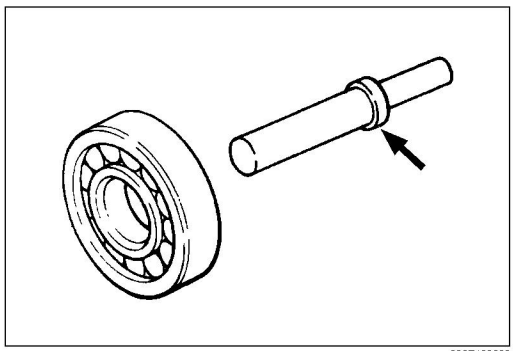
0.025 ~ 0.060 (0.0010 ~ 0.0024)



030E100008

Pulley center

Inspect the pulley center's oil seal fitting face for excessive wear or damage.

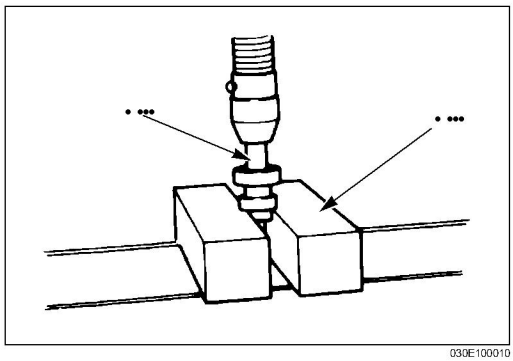


030E100009

Pump shaft (with ball bearing)

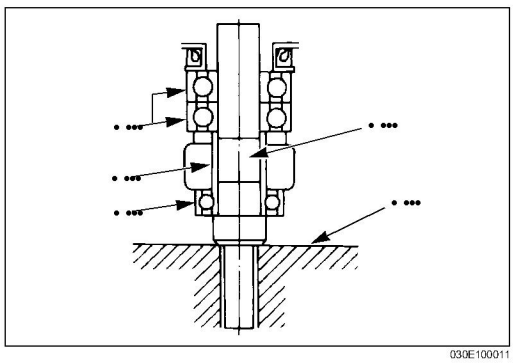
1. Inspect the pump shaft's oil seat fitting face for excessive wear or damage.
2. Inspect the bearing for separation, wear and abnormal noise.
   (1) Check between the balls for scratches and separation in the race.
   (2) Check for rattling between the balls and race.
   (3) Rotate the bearings by hand and check for any abnormal resistance. If any abnormalities are discovered, replace the ball bearings.

Ball bearing replacement


030E100010

Removal

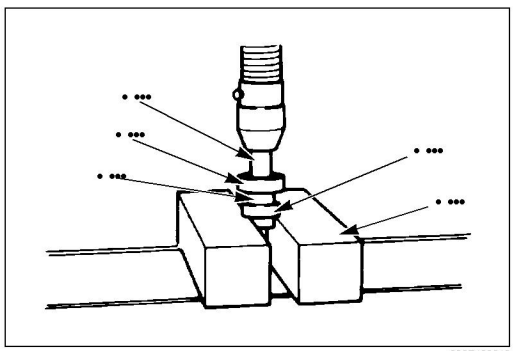
Place the water pump shaft (1) with the bearing attached, between the base plates (2) of a bench press, and slowly apply pressure to force the shaft from the bearing.


030E100011

Installation

1. Apply clean engine oil to the inside surface (shaft side) of the bearing's inner race.
2. Place the water pump shaft (1) between the base plates (2) of a bench press.

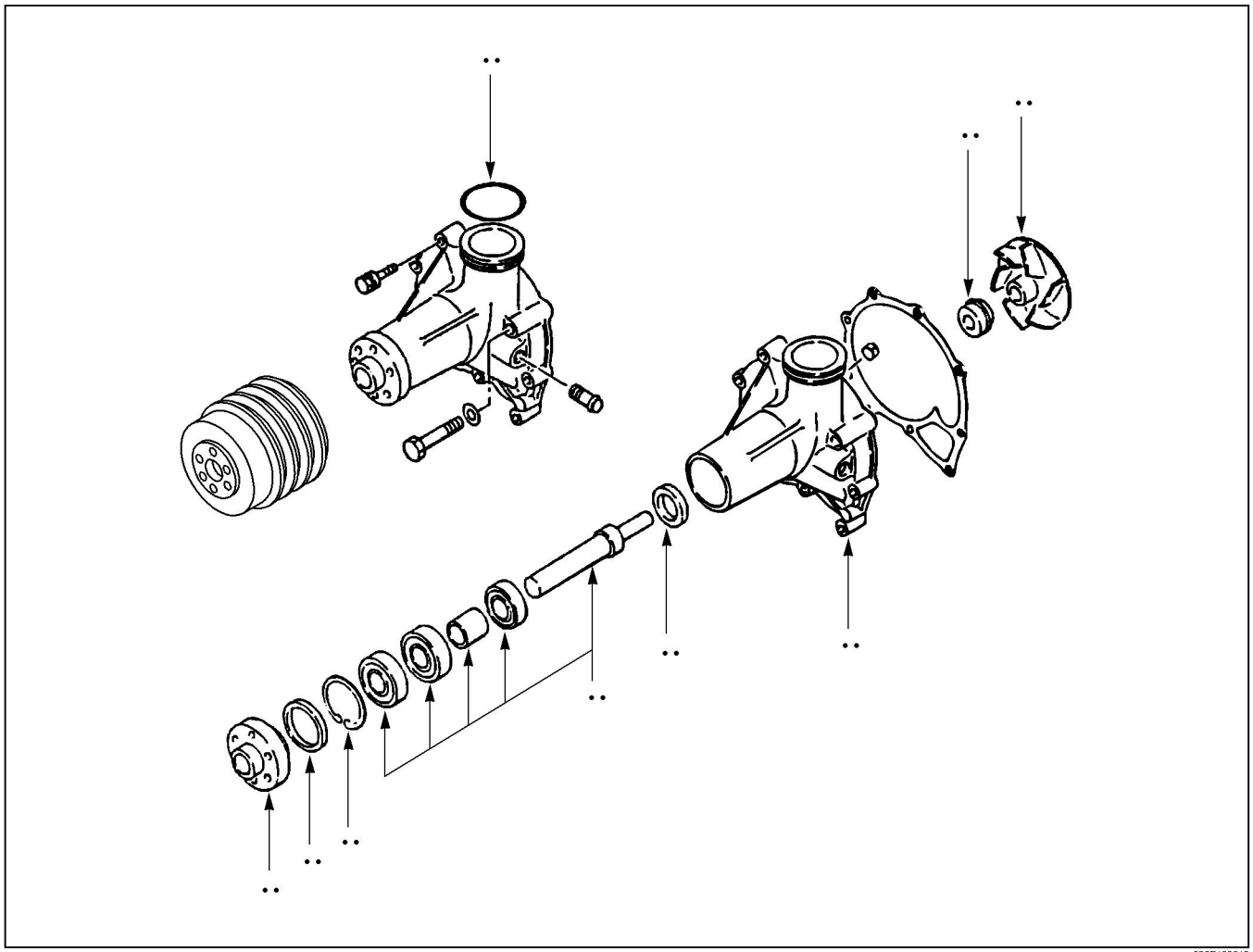
Note:
To prevent damage to the water pump shaft, place soft brass or copper sheets between the base plates and the water pump shaft.


030E100012

3. Place the small-diameter bearings (3) on the shaft, and using a pipe with the same diameter as the shaft, slowly press the bearing onto the shaft.
4. Install the spacer (4).
5. Insert the large-diameter bearing (5) and slowly press onto the shaft.
   Press on the final large-diameter bearing in the same way.

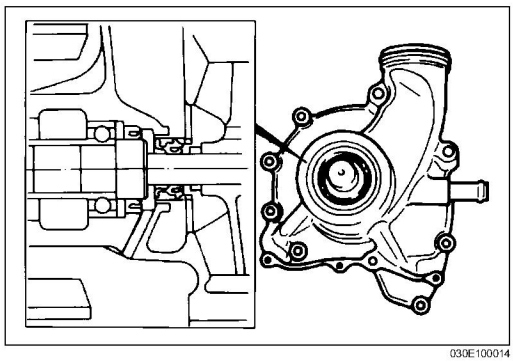
Note:
1. **When pressing the bearings, be sure to maintain the pump shaft in a perpendicular position.**
2. **When pressing, do not hit the outer race with the pressing pipe.**

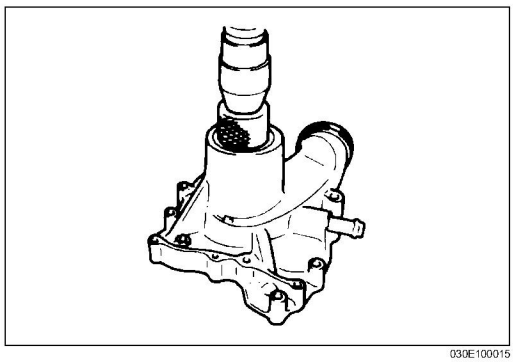
ASSEMBLY



Assembly sequence

1. Water pump body
▲2. Oil seal (impeller side)
▲3. Water pump shaft (with ball bearings)
4. Snap ring
▲5. Oil seal (pulley center side)
▲6. Pulley center
▲7. Seal unit
▲8. Water pump impeller
9. Gasket


030E100014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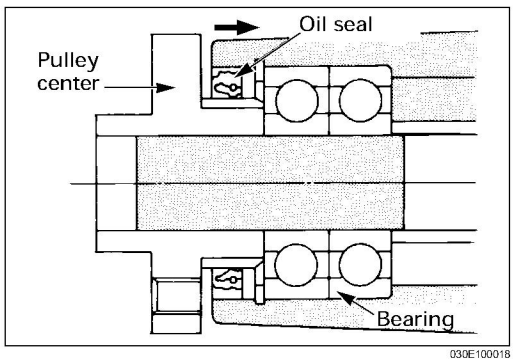

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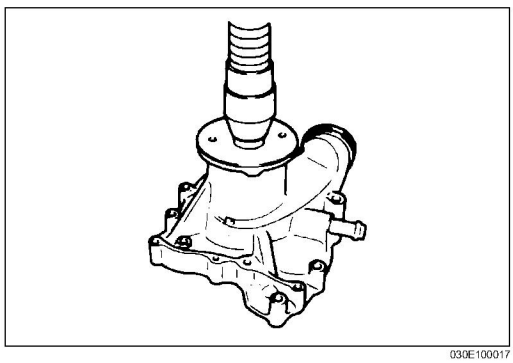

030E100017

IMPORTANT OPERATIONS

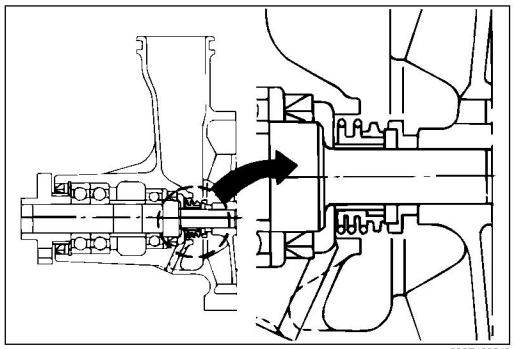
2. Oil seal (impeller side)
(1) Apply molybdenum disulfide grease to the inner periphery of the oil seal lip.
(2) Apply clean engine oil to the outer periphery of the oil seal.
(3) Press the oil seal into place with the lip facing the outside, and taking care not to deform the oil seal.

3. Water pump shaft (with bearings)
(1) Set the pump with the impeller mounting side facing down, and set on top of the base plates of a bench press.
(2) Apply engine oil to the outer periphery of the bearing outer face.
(3) Use the bench press to slowly press in the pump shaft (with bearings) from the pulley center side.

When pressing the pump shaft, take care not to damage the oil seal.

5. Oil seal (pulley-center side)
(1) Apply molybdenum disulfide grease to the inner periphery of the seal lip.
(2) Press in the oil seal with the lip facing the inside and taking care not to deform the seal.

6. Pulley center
Use a bench press to press in the pulley center, taking care not to damage the oil seal.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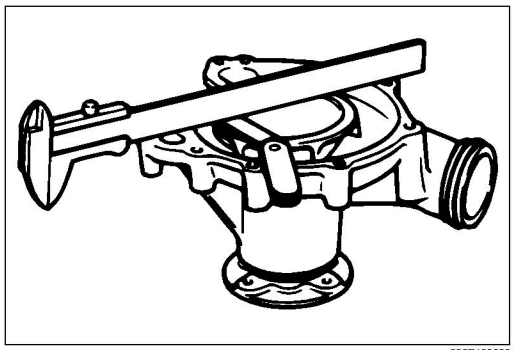
7. Seal unit

(1) Apply sealant to the pump body contact surface of the seal unit.

(2) Press in the seal unit fully until its collar strikes the pump body.

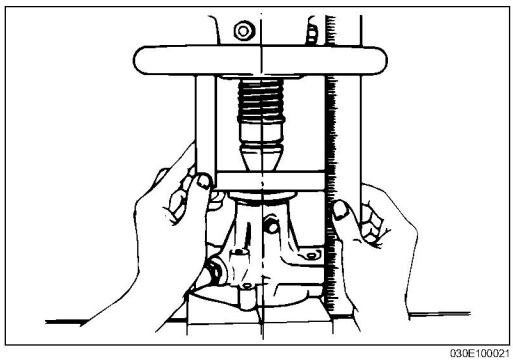
Take care not to damage the seal unit.


030E100020

8. Water pump impeller

Use a bench press to press in the impeller until the designated clearance exists between it and the pump body facing.

Pump body and impeller clearance	mm (in)
0.5 (0.020)	


030E100021

Note:

1. The fan center and impeller have been installed on the pump shaft with a press, and no attempt must be made to remove or reinstall them separately. Always replace the assembly as a single unit. Removing and installing the fan center and impeller alone may result in the failure of the water pump during engine operation, leading to serious overheating.

Note:

2. The water pump assembly must be replaced any time the fan center and impeller pressure can be pulled off with a force of less than falls below 1,960 N (200 kgf).

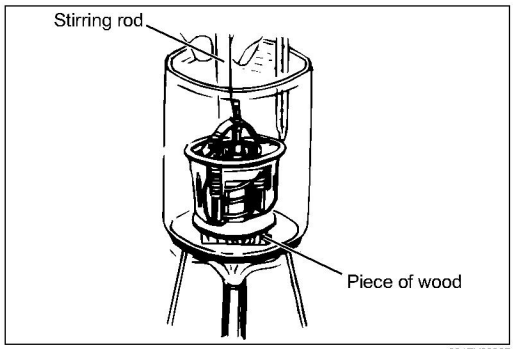
Note:

3. Do not strike bearings with a hammer to install, since damage may result.

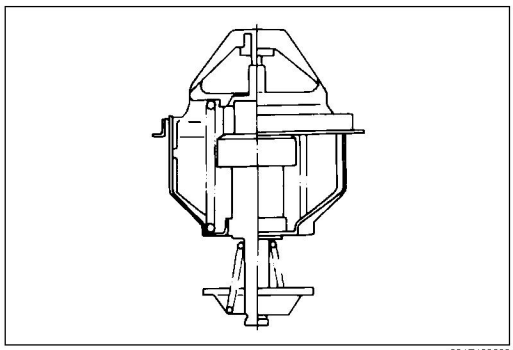
THERMOSTAT

INSPECTION AND REPAIR

If excessive wear or damage is discovered during inspection, the appropriate parts must be adjusted, repaired, or replaced.



031EY00027


031E100003

Operation test

1. Completely submerge the thermostat in water as shown.
2. Heat the water while constantly stirring so that the thermostat never come into contact with direct heat from the bottom.
3. Check the temperature at which the thermostat valve opens.

Thermostat valve operation temperature °C (°F)

74.5 ~ 78.5 (166 ~ 173)

4. Check the temperature at which the valve is fully open.

Thermostat full-open temperature °C (°F)

90 (194)

Valve lift when fully open mm (in)

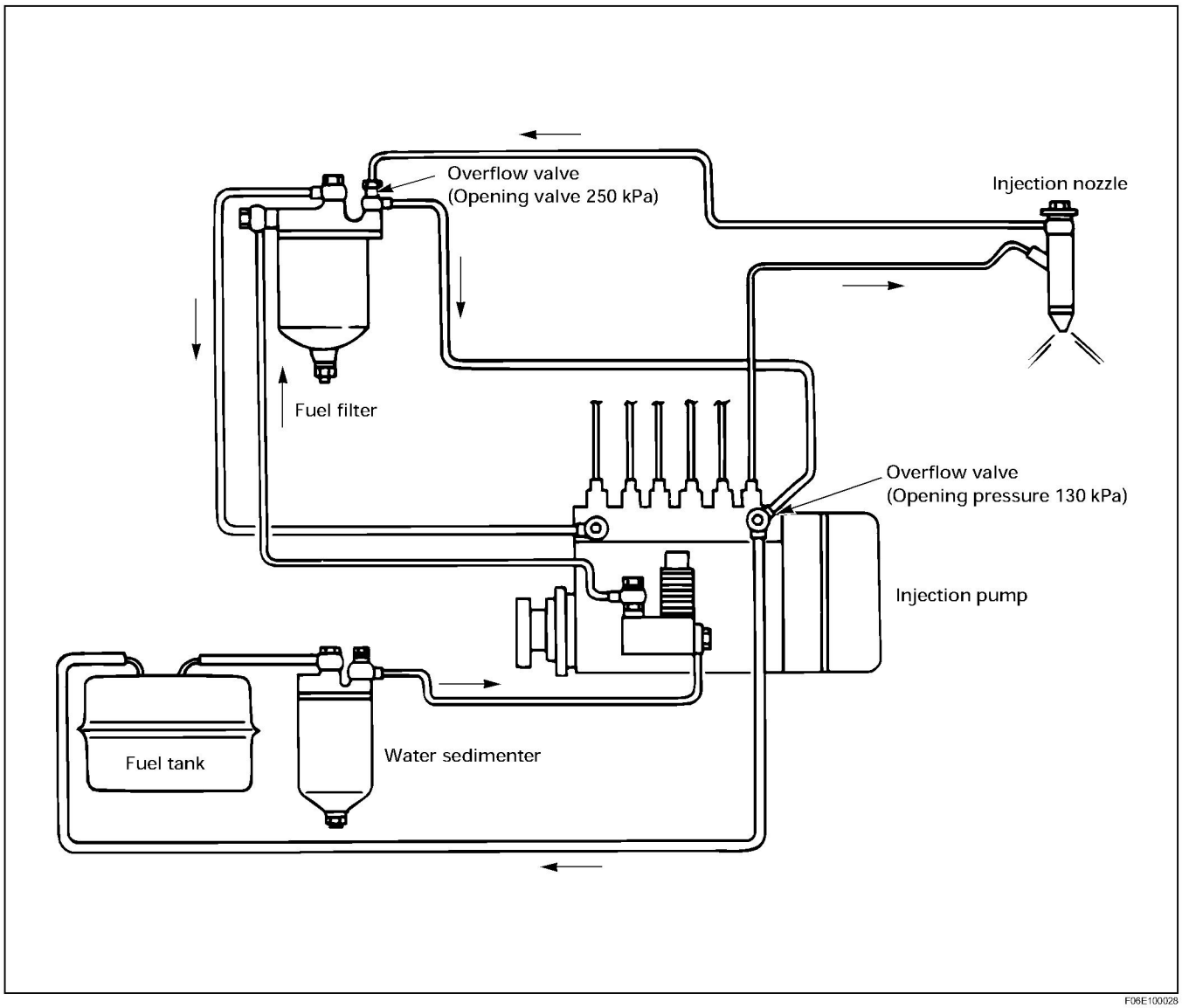
10 (0.39)

CHAPTER 8

FUEL SYSTEM

CONTENTS

INTRODUCTION



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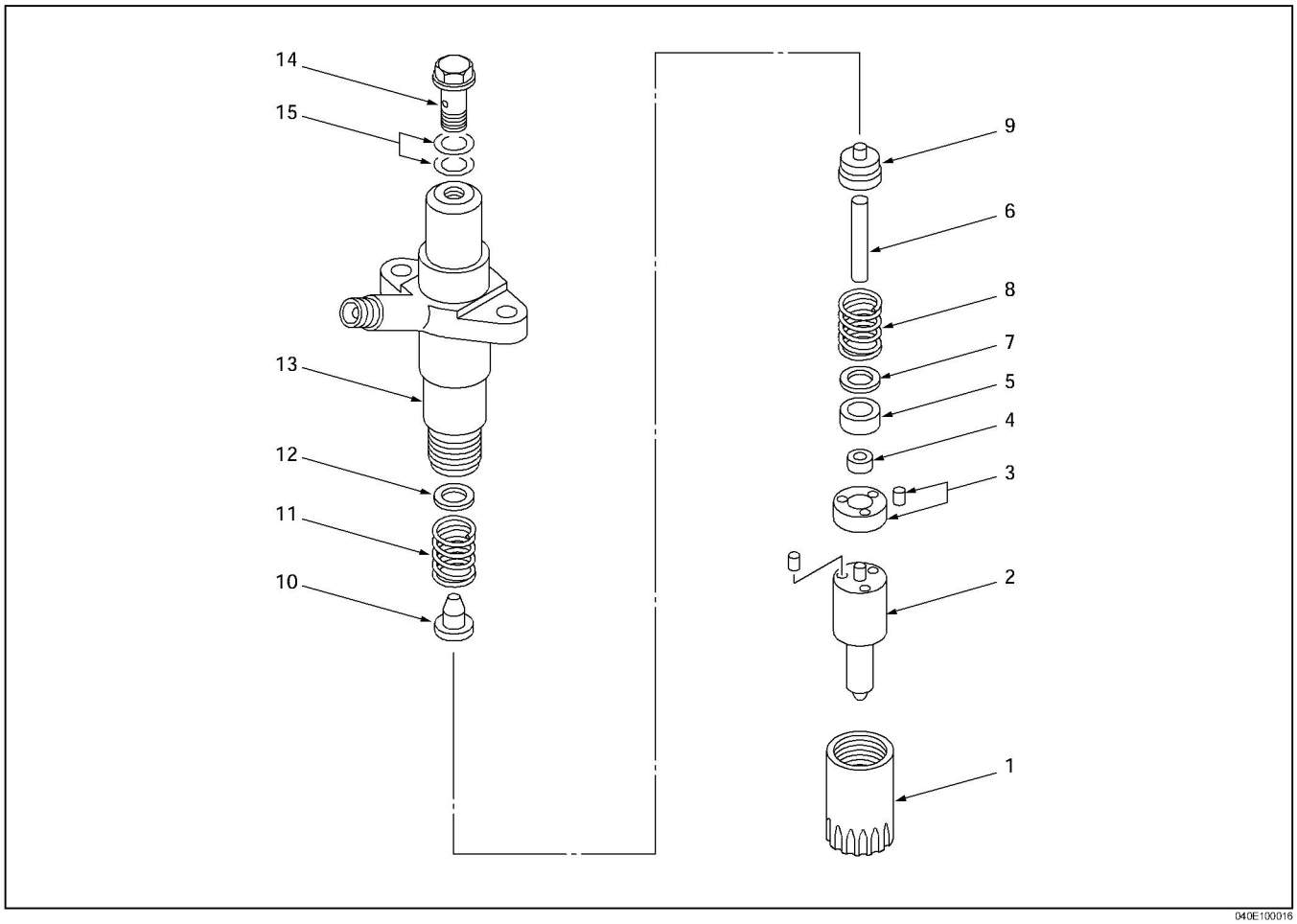
INJECTION NOZZLE – 2 Stage Injection Type

DISASSEMBLY

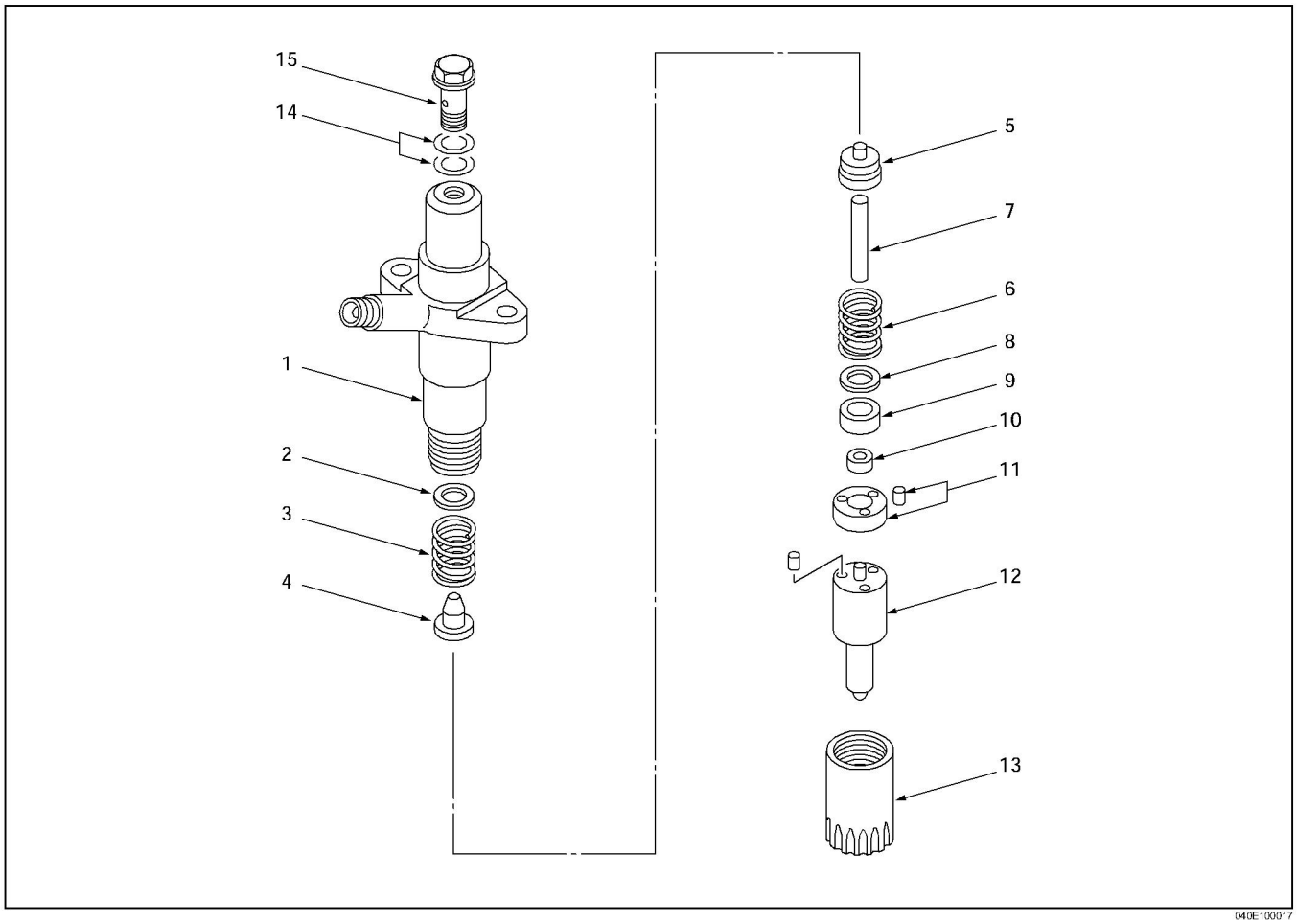


Disassembly sequence

1. Retaining nut
2. Nozzle & pin
3. Spacer & pin
4. Lift piece
5. Spring seat
6. Push rod
7. Shim (Second nozzle opening pressure adjustment)
8. Second spring
9. Collar
10. Spring seat
11. First spring
12. Shim (First nozzle opening pressure adjustment)
13. Nozzle holder body
14. Eye bolt
15. Gasket

(1) Before disassembly remove carbon deposit from nozzle and nozzle holder using a wire brush and wash the outside nozzle holder assembly.
Caution: Do not touch nozzle holes with the wire brush during cleaning it.
(2) Disassemble the nozzle holder assembly to numerical order.

REASSEMBLY AND OPENING PRESSURE ADJUSTMENT

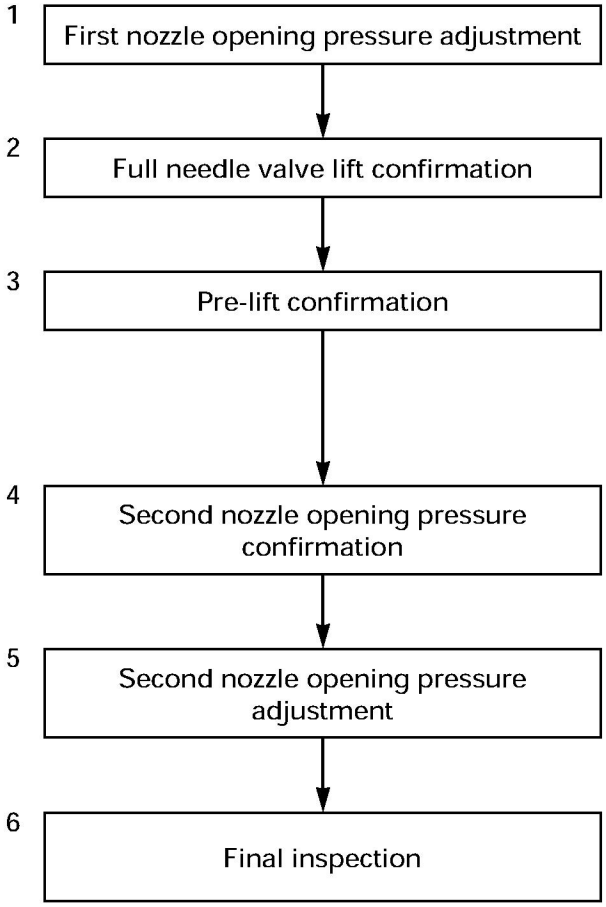


Reassembly sequence

1. Nozzle holder body
2. Shim (First opening pressure adjustment)
3. First spring
4. Spring seat
5. Collar
6. Second spring
7. Push rod
8. Shim (Second opening pressure adjustment)
9. Spring seat
10. Lift piece
11. Spacer & pin
12. Nozzle & pin
13. Retaining nut
14. Gasket
15. Eye bolt

The nozzle holder is adjusted as the components are reassembled in the sequence above.
As adjustment of the 2 stage injection type nozzle holder is made in hundredths of a millimeter, clean the parts thoroughly in light oil to completely remove any dirt or foreign matter.

REASSEMBLY AND ADJUSTMENT PROCEDURE



1 Adjust the first nozzle opening pressure using the shim.

2 Confirm the full needle valve lift in accordance with the closed method.

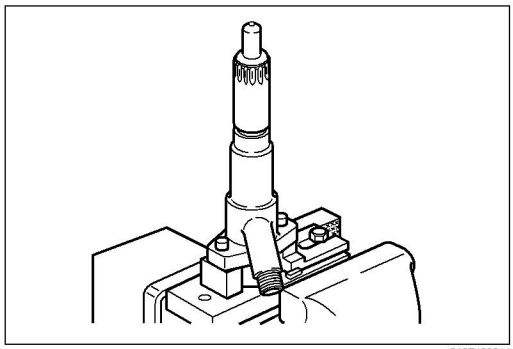
3 Confirm pre-lift in accordance with the closed method.

CAUTION:
If not as specified, replace the nozzle assembly, lift piece, pins and spacer using the nozzle service kit.

4 Confirm the second nozzle opening pressure in accordance with the closed method.

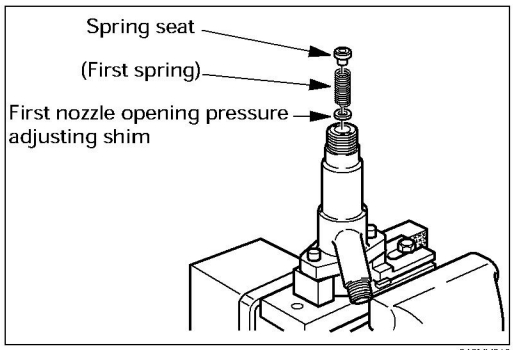
5 Adjust the second nozzle opening pressure using the shim.

6 Confirm the condition of the fuel spray with the nozzle and nozzle holder assembled.


040E100014

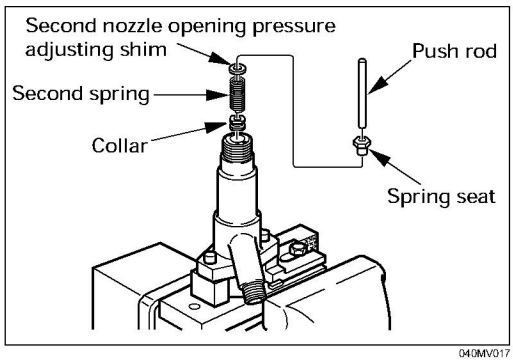
First nozzle opening pressure adjustment

1. Clamp the nozzle holder in a vise.



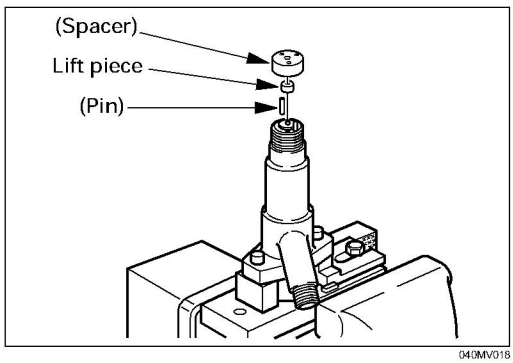
040MV016

2. Install the shim, first spring and spring seat in the nozzle holder.



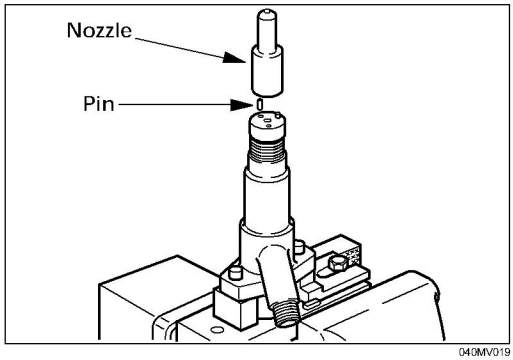
040MV017

3. Install the collar, second spring, shim, spring seat and push rod in the nozzle holder.



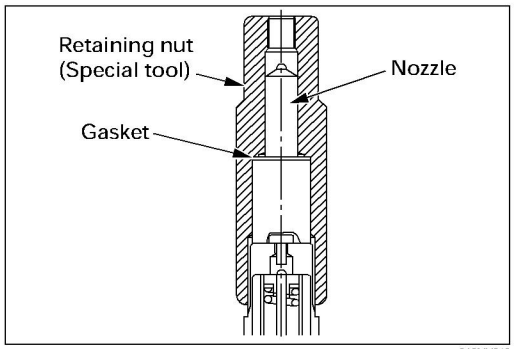
040MV018

4. Install the pins, lift piece and spacer in the nozzle holder.

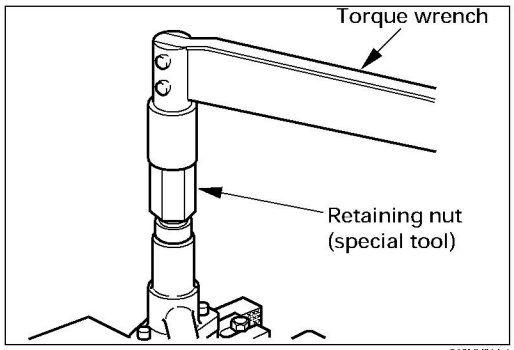


040MV019

5. Install the pins in the spacer.
6. Install the nozzle on the spacer.



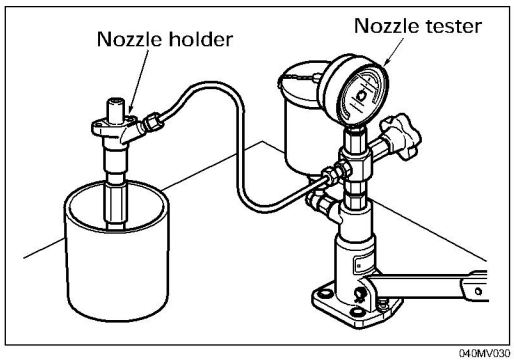
7. Hand-tighten the adjustment retaining nut together with the gasket to the nozzle holder.
   Retaining nut: 157892-4000 (ZEXEL)
   Gasket: 157892-1500 (ZEXEL)



8. Tighten the adjustment retaining nut to the specified torque.

Torque N·m (kg·m)

29 – 39 (3.0 – 4.0)



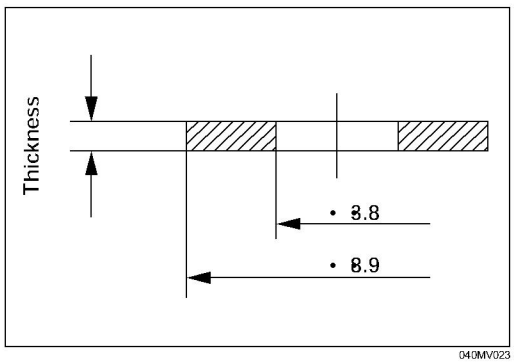
9. Set the nozzle holder to the nozzle tester.
10. Operate the nozzle tester and measure the first nozzle opening pressure.

MPa (psi)

Nominal	Adjustment
17.7 (2570)	18.1 – 18.9 (2630 – 2740)

11. If the first nozzle opening pressure is not as specified, disassemble the nozzle holder and replace the shim until the pressure is as specified.

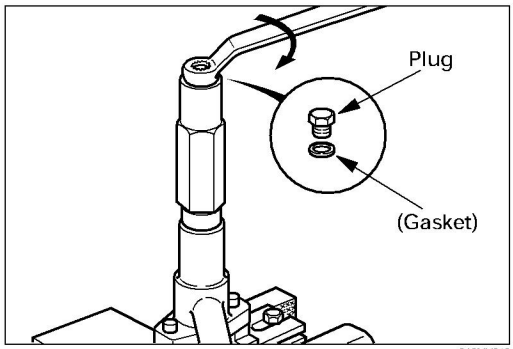
CAUTION:
Use a micrometer to measure shim thickness.



First nozzle opening pressure adjusting shim

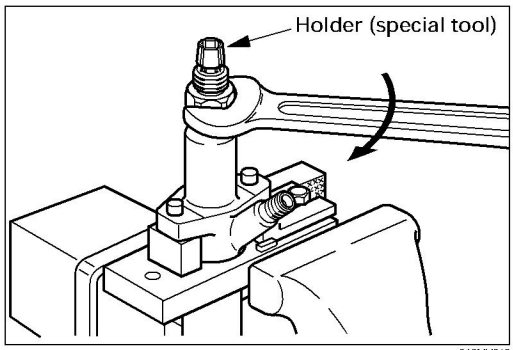
mm

Part No. (ZEXEL)	Thickness
150539-0700	0.40
150539-0800	0.50
150539-0900	0.52
150539-1000	0.54
150539-1100	0.56
150539-1200	0.58
150539-1300	0.60
150539-1400	0.70

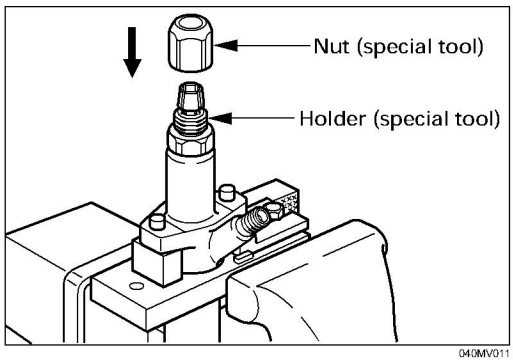


Full needle valve lift confirmation

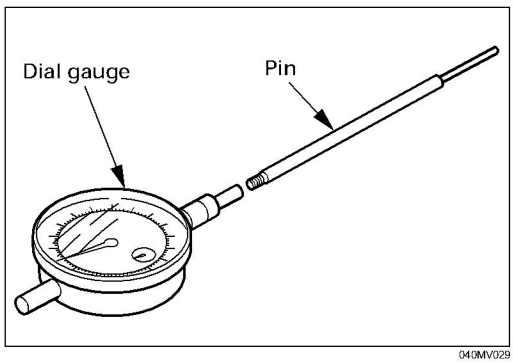
1. Install the gasket and plug on the adjustment retaining nut.
   Gasket: 026508-1140 (ZEXEL)
   Plug: 157892-1600 (ZEXEL)



2. Position the nozzle holder with the nozzle facing down and install the dial gauge holder on the nozzle holder.
   Dial gauge holder: 157892-5000 (ZEXEL)



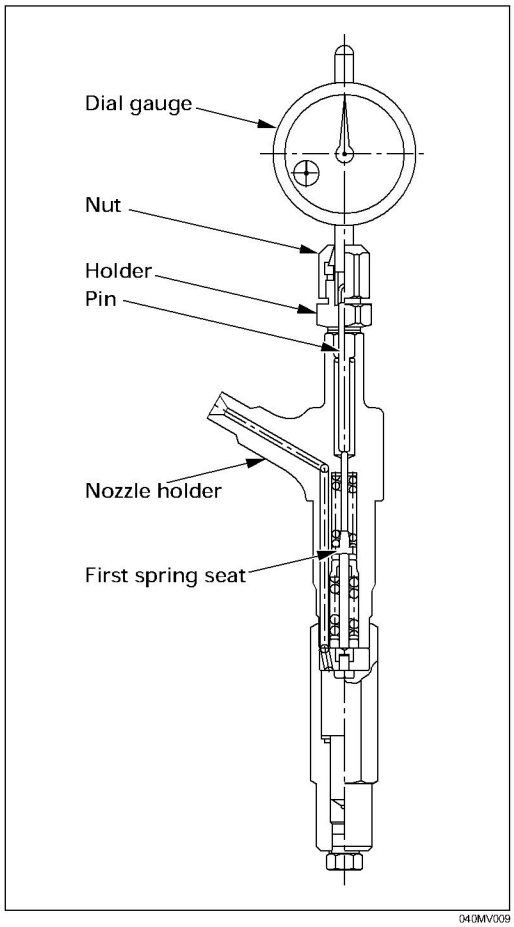
3. Install the nut on the dial gauge holder.
   Nut: 157892-1000 (ZEXEL)



4. Install the pin to the dial gauge.

Note:
The lengths of the pins do not include the threaded portions.

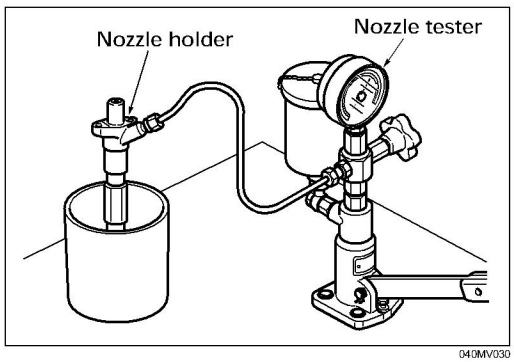
Pin (ℓ=85 mm): 157892-4700 (ZEXEL)
Dial gauge: 157954-3800 (ZEXEL)



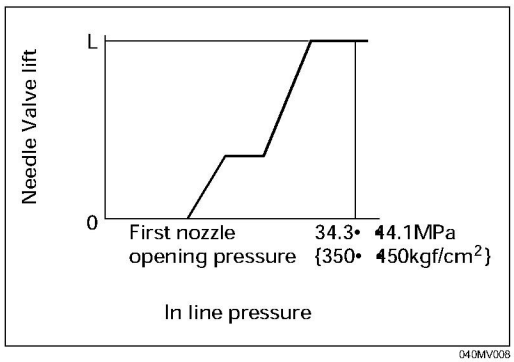
5. Secure the dial gauge to the nozzle holder using the nut so that the pin contacts the tip of the first spring seat.

CAUTION:

- **Secure the dial gauge so that a stroke of 2 mm can be measured.**
- **Do not over-tighten the nut as the dial gauge shaft may jam. (Confirm from the dial gauge that the shaft moves smoothly.)**

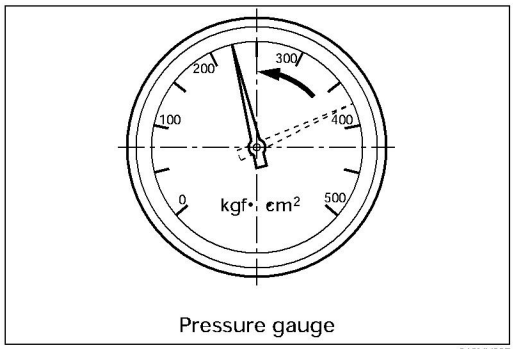


6. Set the nozzle holder to the nozzle tester and put needle to zero on the dial gauge.
7. Operate the nozzle tester to bleed any air from inside the retaining nut and to confirm that no fuel leaks.



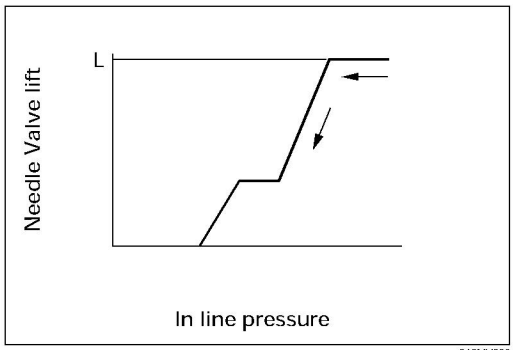
8. Operate the nozzle tester and increase the in-line pressure to 34.3 – 44.1 MPa (350 – 450 kg/cm^2) so that the nozzle's needle valve moves through its full lift.
   Record full lift 'L'. (Read dial gauge)

Note:
The above operation is used to determine whether the nozzle seat is worn and whether the nozzle assembly is in good condition.



Pressure gauge

040MV007



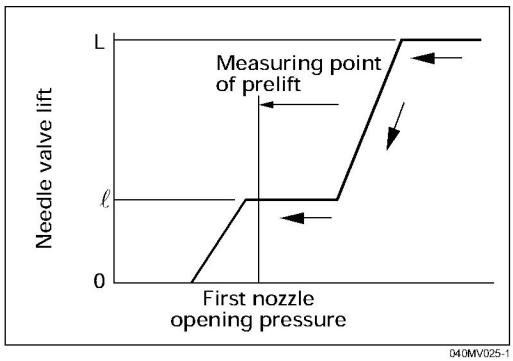
In line pressure

040MV006

Pre-lift confirmation

1. With the needle valve at full lift, release the nozzle tester handle.

Note:
The in-line pressure will decrease and needle valve lift (as indicated on the dial gauge) will also decrease a little.

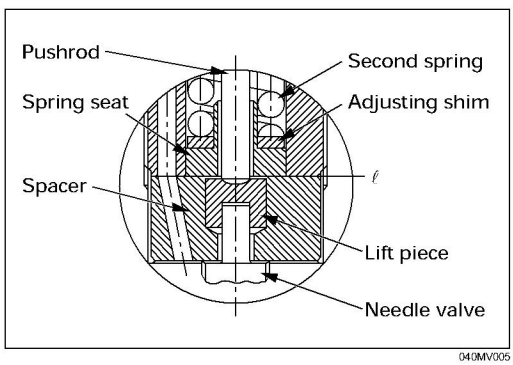


040MV025-1

2. Read the needle valve lift 'ℓ' from the dial gauge indication (once the needle valve has descended when the second spring has stopped operating). Refer to the pre-lift measuring point for 'ℓ'.

Pre-lift measuring point:
Read the dial gauge at first nozzle opening pressure +approx 1 MPa (10 kg/cm^2).

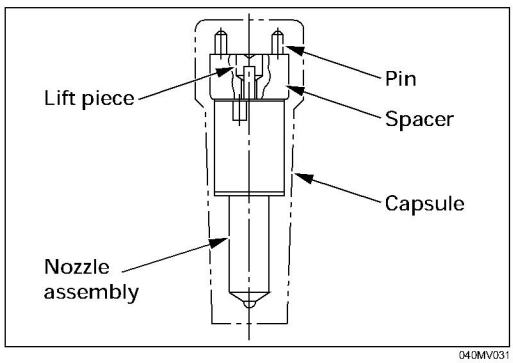
Note:
This point can be found while the pressure is decreasing.



040MV005

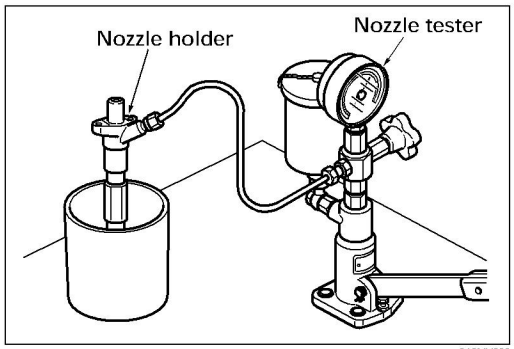
3. Confirm that pre-lift 'ℓ' is as specified.

Pre-lift	mm (in)
0.06 (0.0024)	



040MV031

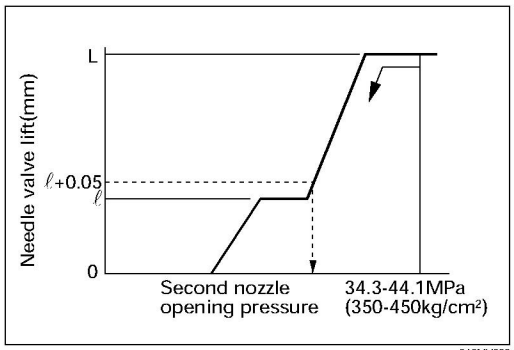
4. If pre-lift is not as specified, replace the pins, lift piece, spacer and nozzle assembly as a set with the service kit.
Service kit: 105019-0290 (ZEXEL)



Second nozzle opening pressure confirmation

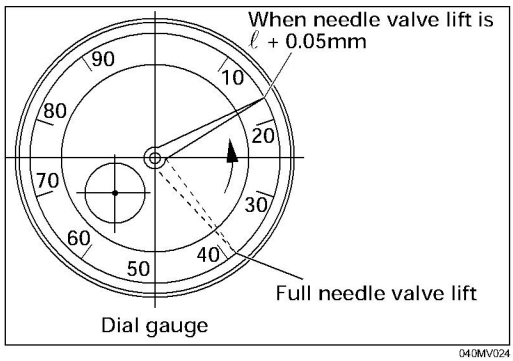
1. After pre-lift confirmation, operate the nozzle tester to increase in-line pressure to 34.3 – 44.1 MPa (350 – 450 kg/cm^2) so that the nozzle's needle valve moves through its full lift.

Full lift	mm (in)
0.4 (0.0157)	

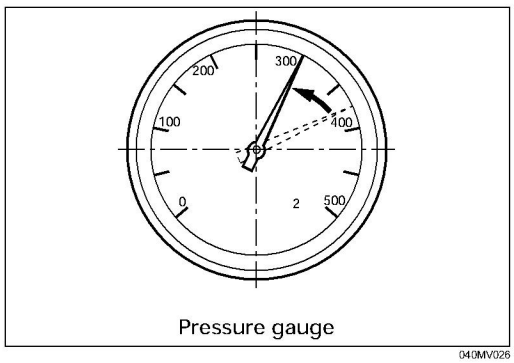


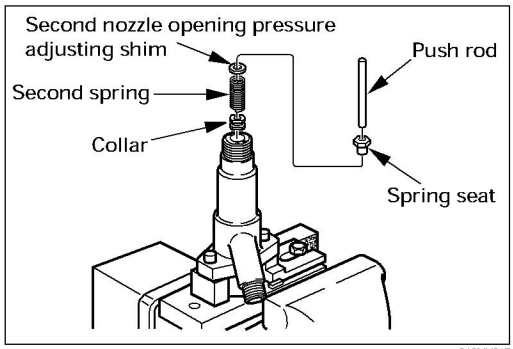
2. Release the nozzle tester handle so that in-line pressure decreases.

Note:
The in-line pressure will decrease and needle valve lift (as indicated on the dial gauge) will also decrease a little.



3. Then, read the pressure gauge indication (second nozzle opening pressure) the instant that the dial gauge indicates the specified needle valve lift (usually pre-lift ℓ + 0.05 mm).



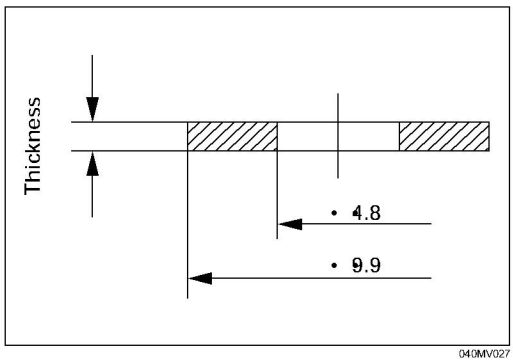


Second nozzle opening pressure adjustment
If the second nozzle opening pressure is not as specified, disassemble the nozzle from the nozzle holder and replace the shim until the pressure is as specified.

MPa (psi)

Nominal	Adjustment
22.1 (3200)	23.1 – 24.1 (3350 – 3500)

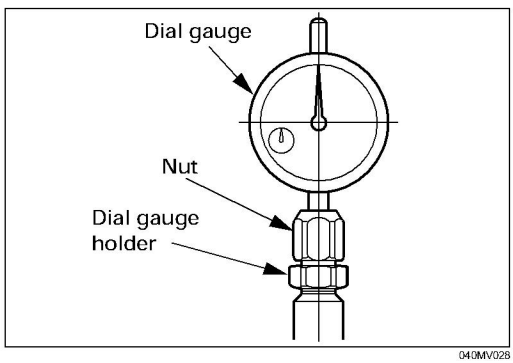
CAUTION:
- **Because the second opening pressure changes when the first opening pressure changes, the second opening pressure must be adjusted when the first opening pressure changes.**
- **Use a micrometer to measure shim thickness.**



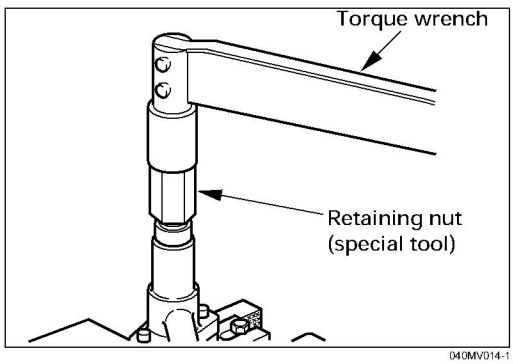
Second nozzle opening pressure adjusting shim

mm

Part No. (ZEXEL)	Thickness
150590-0600	0.40
150590-0700	0.50
150590-0800	0.52
150590-0900	0.54
150590-1000	0.56
150590-1100	0.58
150590-1200	0.60
150590-1300	0.70



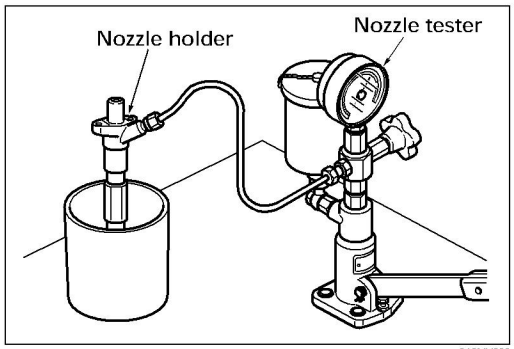
Final inspection
1. Remove the dial gauge, nut and dial gauge holder.



2. Remove the adjustment retaining nut and gasket.
3. Install the original retaining nut, confirm that the pins are inserted fully into the nozzle, and then hand-tighten the retaining nut. Then, tighten the original retaining nut to the specified torque.

Torque N·m (kg·m)

59 – 79 (6.0 – 8.0)



4. Set the nozzle holder to the nozzle tester and check first nozzle opening pressure, spray condition, seat oil tightness and each part for oil leaks.
5. When replacing the nozzle, replace the nozzle, lift piece, pins and spacer as a set with the nozzle service kit.

CAUTION:
Pre-lift will not be as specified if only the nozzle is replaced.

MEMO

CHAPTER 9

TURBOCHARGER

CONTENTS

TURBOCHARGER SERVICING

1. Refer to TROUBLESHOOTING in this Section to determine whether or not turbocharger repair or overhaul is required.
2. The following procedures should also be performed (either with the turbocharger on the equipment or removed from the equipment but not disassembled) to determine whether or not turbocharger repair or overhaul is required.
   * Visual checks
   * Clearance measurements
   * End play measurements
3. The turbocharger compressor and turbine housing may be removed from the center housing and rotating assembly for further visual inspection.

TROUBLESHOOTING

If the engine does not run well (insufficient output or irregular acceleration) -

1. Run the engine at idle.
2. Check for oil leakage from the turbocharger.
3. Listen for abnormal turbocharger noise.
4. Write down any abnormal conditions and their location.
5. Stop the engine.
6. Allow sufficient time for the turbocharger to cool.
7. Check the turbocharger air inlet hose and outlet hose. The bands attaching the hoses to the turbocharger must be tight. There must be no oil leakage.

WARNING: The turbocharger generates very high temperatures during operation. It will remain dangerously hot for some time after the engine is stopped. Allow sufficient time for the turbocharger to cool before touching it.

OIL LEAK

Leak point	Cause	Countermeasure
Turbine housing gas inlet and outlet tightening area	Bearing abrasion (Trouble in the oil supply system)	Check the turbocharger air inlet
Turbine and bearing housing mating surfaces		
Turbocharger oil inlet tightening area	Loose bolts	Tighten bolts
	O-ring damage	Replace O-ring
Compressor housing case	Oil leak from tightening area (Air compressor oil leak)	Turbocharger OK

ABNORMAL NOISE

Description	Cause	Countermeasure
Whistling sound	High-speed turbocharger operation	Normal sound of rotor rotation
Grinding sound	Foreign particles in turbocharger	Check the turbocharger air inlet
	Bearing abrasion (Trouble in the oil supply system)	
Hissing sound	Loose air or gas pipe	Tighten bolts, screws, and/or hose bands as required

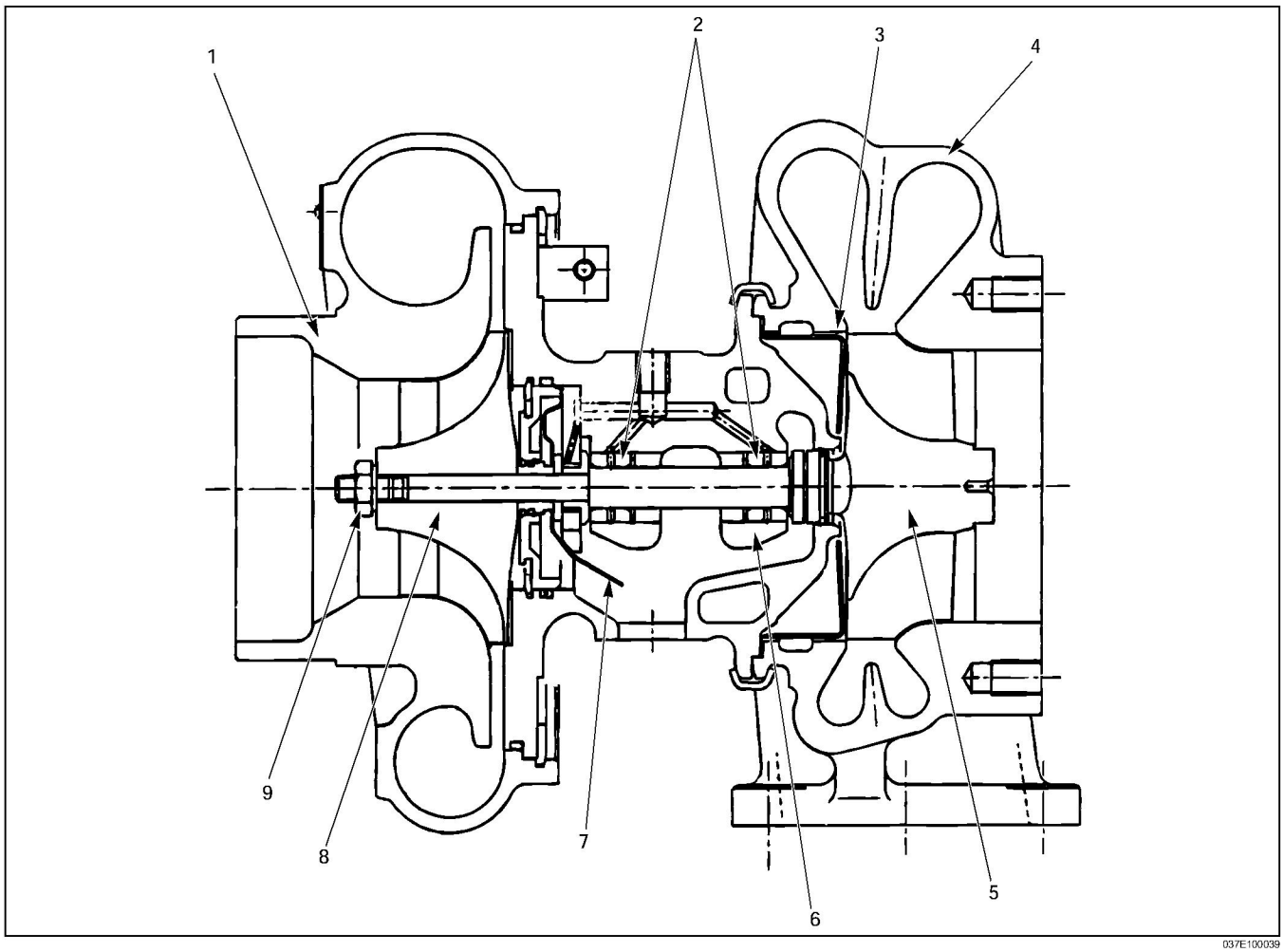
INSUFFICIENT OUTPUT OR IRREGULAR ACCELERATION

Problem	Cause	Countermeasure
Poor engine performance because of air and/or gas leakage	Loose air and/or gas pipes running to the turbocharger	Tighten bolts, screws, and/or hose bands as required

Disconnect the air inlet hose at the turbocharger to perform the following inspection.

Checkpoint	Problem	Countermesure
Air inlet	Oil on air inlet inside and outside surfaces resulting from oil leakage	Turbocharger OK
Shaft end nuts or blades	Loose or missing	Replace turbocharger
	Foreign particles in turbocharger	
	Bearing abrasion (Trouble in the oil supply system)	
Compressor housing	Blade and housing interference	
	Bearing abrasion (Trouble in the oil supply system)	
Oil feed pipe	Clogged	Remove restrictions

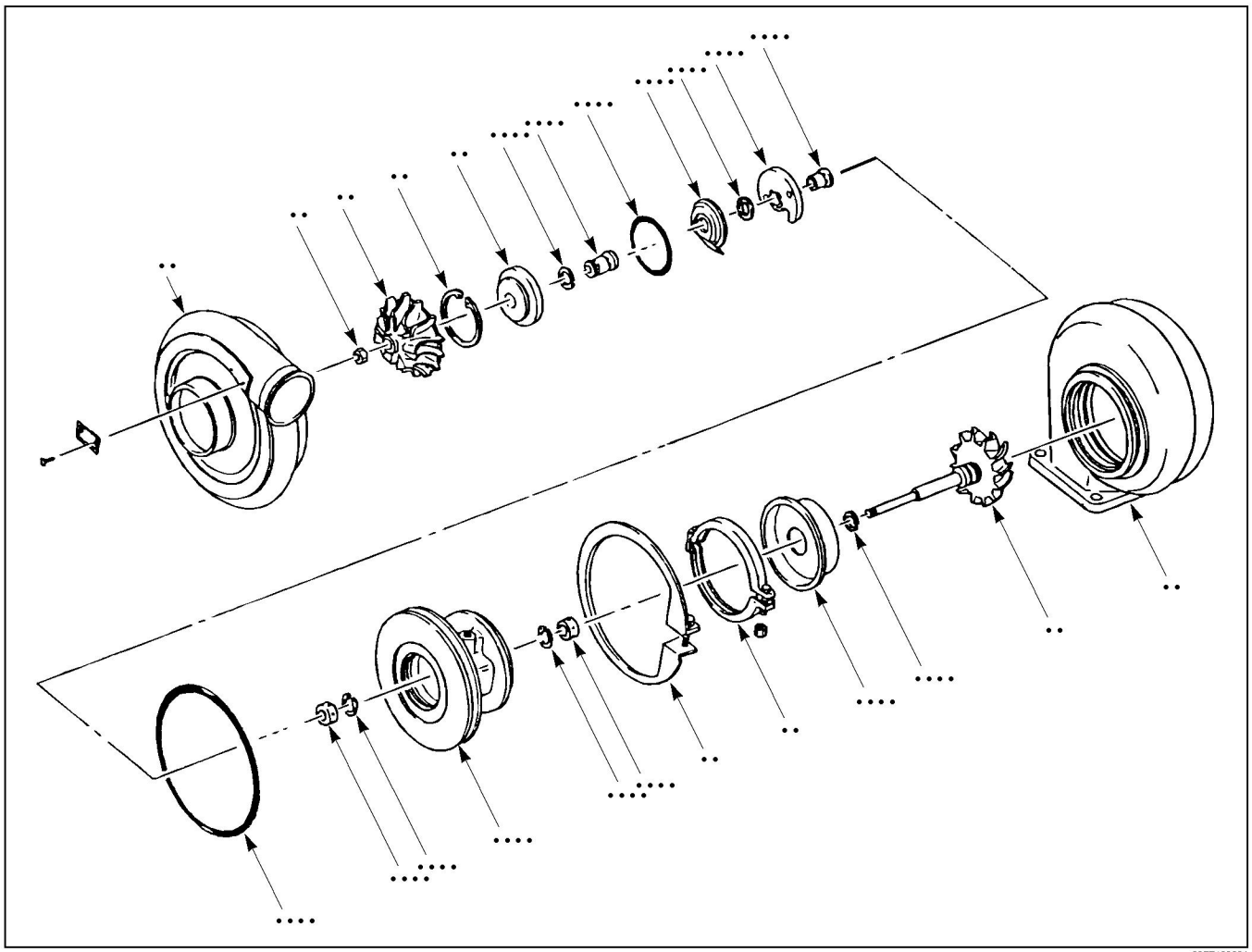
CONSTRUCTION



Legend

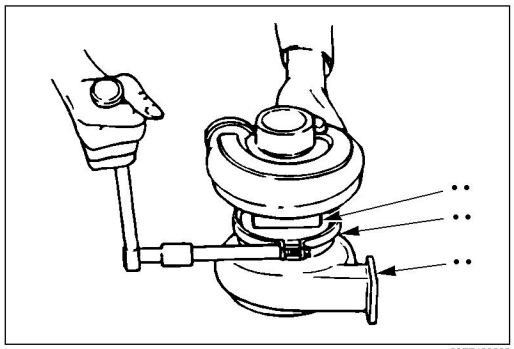
(1) Compressor cover
(2) Bearings
(3) Turbine back plate
(4) Turbine housing
(5) Turbine wheel
(6) Bearing housing
(7) Oil deflector
(8) Compressor wheel
(9) Nut

DISASSEMBLY



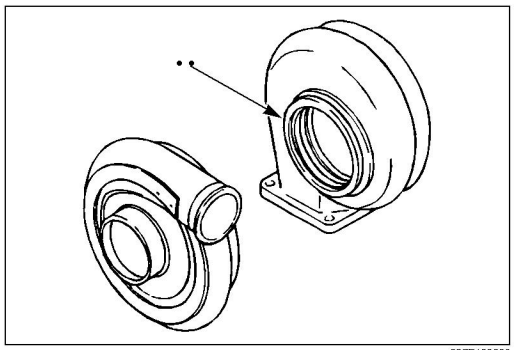
Legend

(1) Coupling ASM
(2) Turbine housing
(3) Snap ring
(4) Compressor cover
(5) Nut
(6) Compressor wheel
(7) Snap ring
(8) Shaft & turbine wheel
(9) Insert
(10) Thrust sleeve
(11) Piston ring
(12) Gasket
(13) Oil deflector
(14) Thrust ring
(15) Thrust bearing
(16) Thrust ring
(17) Piston ring
(18) Turbine back plate
(19) Bearings
(20) Snap ring
(21) Gasket
(22) Bearing housing

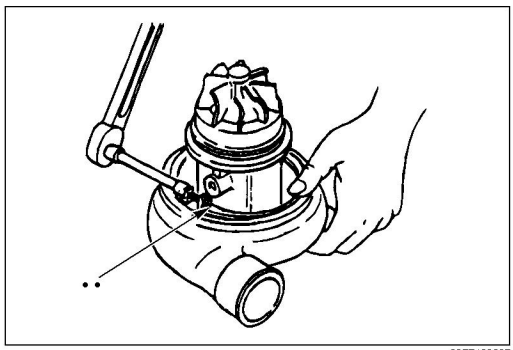

037E100005

1. Remove the coupling assembly (1).

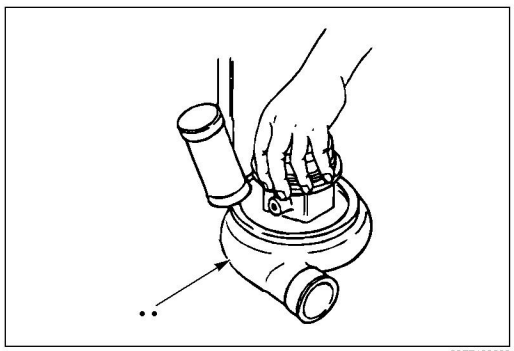
Note:
When you reassemble the turbocharger the exact positioning of the compressor cover, bearing housing (3), and turbine housing (2) are important. Before disassembly, use a felt-tip pen or punch to mark these parts so you can match them correctly at reassembly.


037E100006

2. Remove the turbine housing (1).

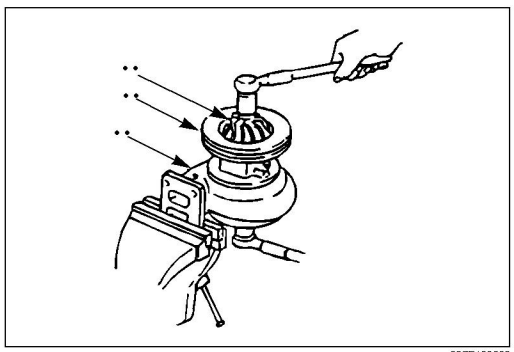

037E100007

3. Remove the snap ring (1).

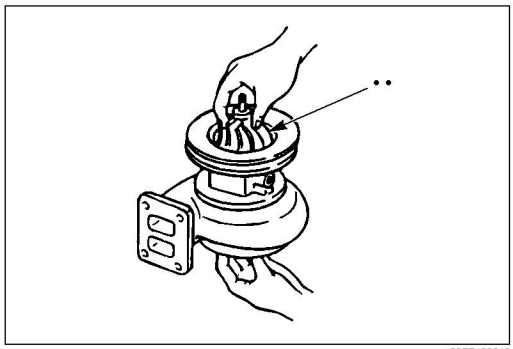

037E100008

4. Remove the compressor cover (1) by tapping around it lightly with a plastic hammer or wooden mallet.

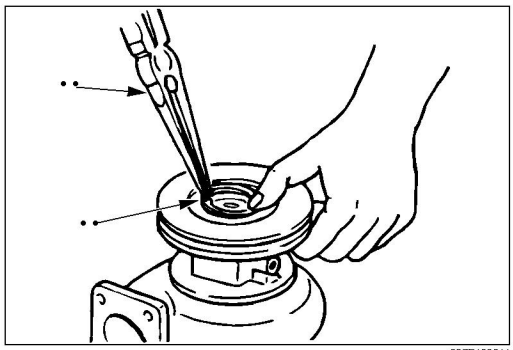
Note:
Do not bump the compressor wheel against the compressor cover.


037E100009

5. Fit bearing housing (3) to turbine housing (1) by clamping them in a vise.
   Fix the boss of the shaft & turbine wheel with the 17 mm box wrench. Remove the compressor wheel (2) and mounting lock nut with a 14 mm box wrench.

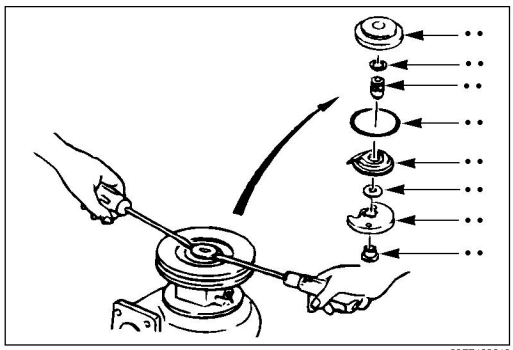

037E100010

6. Restrain the turbine wheel by hand, then turn the compressor wheel (1) to lift it off the shaft.


037E100011

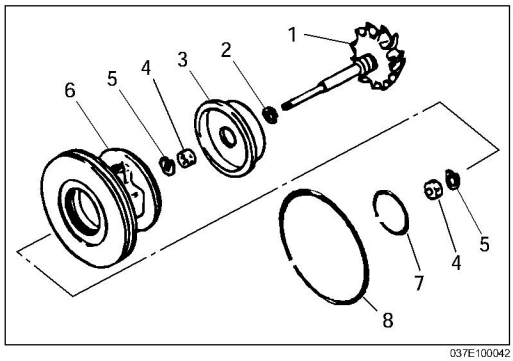
7. Remove snap ring (1) with a pair of snap ring pliers (2).

WARNING:
If the ring ends slip off the ends of the pliers, the ring may fly off. Use your hand to hold down the snap ring while you pinch the ring ends with the snap ring pliers.


037E100012

8. Use two screwdrivers to gently lift the insert (1) off the bearing housing.
   Remove the following parts after the insert is removed:

   (1) Insert
   (2) Piston ring
   (3) Thrust sleeve
   (4) Gasket
   (5) Oil deflector
   (6) Thrust ring
   (7) Thrust bearing
   (8) Thrust ring



037E100042

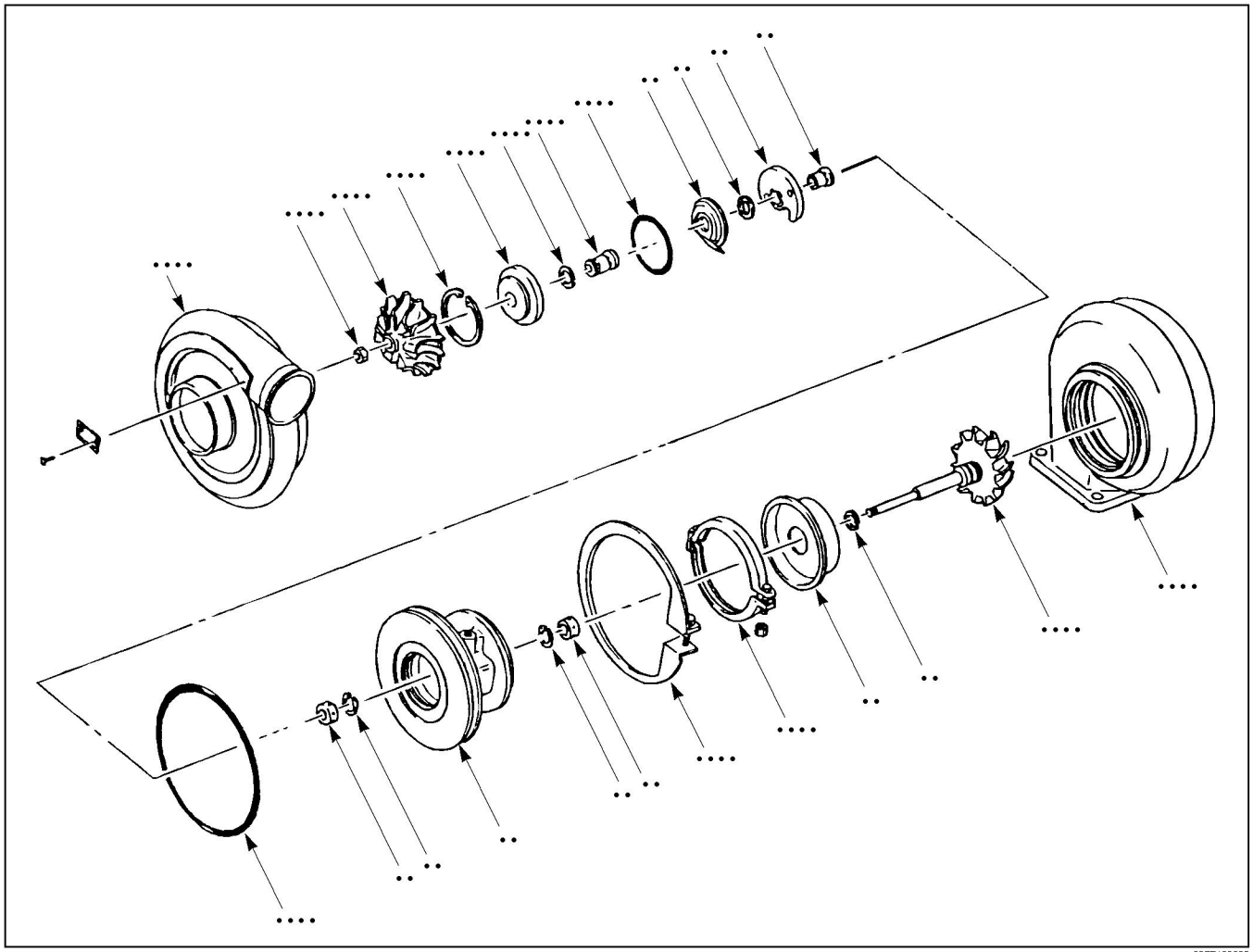
9. Remove the following parts from the bearing housing (6). Use snap ring pliers to remove the snap ring (5).

   (1) Shaft & turbine wheel
   (2) Piston ring
   (3) Turbine back plate
   (4) Bearing
   (5) Snap ring
   (7) Gasket
   (8) Gasket

Note:
1. **If you see the blades of the turbine wheel are bent or damaged, replace it.**
2. **Do not attempt to straighten the bent blades. Replace the part.**
3. **Use snap ring pliers to remove the snap ring.**

CLEANING

This section will show you how to clean the turbocharger without using blasting equilpment, a common practice at most maintenance factories and shops.

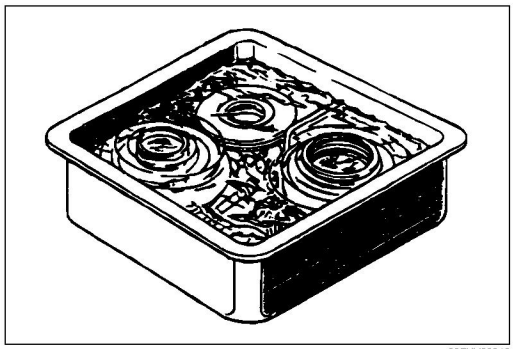


Legend

(1) Bearing housing
(2) Snap ring
(3) Bearings
(4) Thrust ring
(5) Thrust bearing
(6) Thrust ring
(7) Oil deflector
(8) Turbine back plate
(9) Piston ring
(10) Shaft & turbine wheel
(11) Piston ring
(12) Thrust sleeve
(13) Gasket
(14) Insert
(15) Snap ring
(16) Compressor wheel
(17) Nut
(18) Gasket
(19) Compressor cover
(20) Snap ring
(21) Turbine housing
(22) Coupling ASM

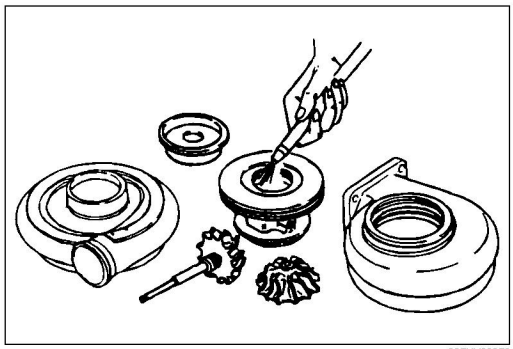
Note:

1. **Never blast the parts marked in the drawing above, the end surfaces of the compressor wheel (5), or the shaft of the shaft & turbine wheel (13).**
2. **If you use a household detergent, choose one that is chemically neutral (non-corrosive).**

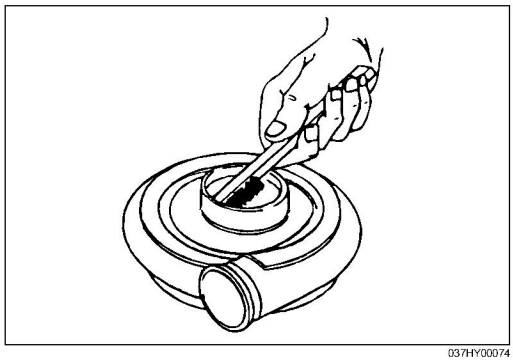

037HY00019

1. Before cleaning, visually inspect all parts for signs of wear or burning.
2. Soak the parts in a pan filled with solvent.
   Wash each part separately to remove all oil, grease, and carbon scale.

Note:
1. **Do not soak in solvent the gaskets, bearing, and thrust bearing.**
2. **Commercially available "Oil Clean", an alchol base organic solvent, should be diluted with water (5-10 parts water to 1 part solvent).**

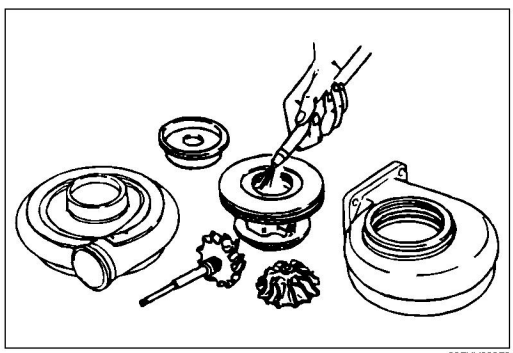

037HY00073

3. Blow compressed air on the parts to clean them.

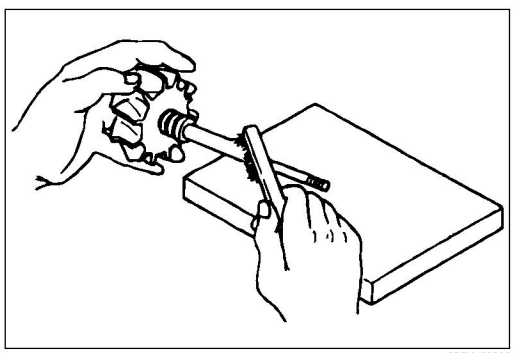

037HY00074

4. With a plastic scraper or wire brush, remove scale from the parts.

Note:
If shot blasting is used to clean parts, the surfaces of the compressor wheel, and the threads, rings and grooves of the shaft & turbine wheel should be covered to protect them.


037HY00073

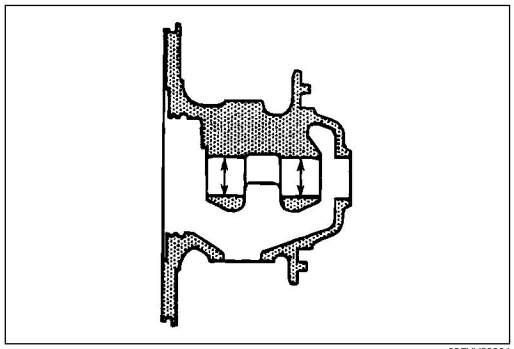
5. Blow compressed air on the parts to clean them.


037HY00023

6. Apply clean engine oil to all sliding surfaces. Buff to remove rust from screw threads, shaft, and ring grooves.

Note:
Do not use a file to clean the surfaces.

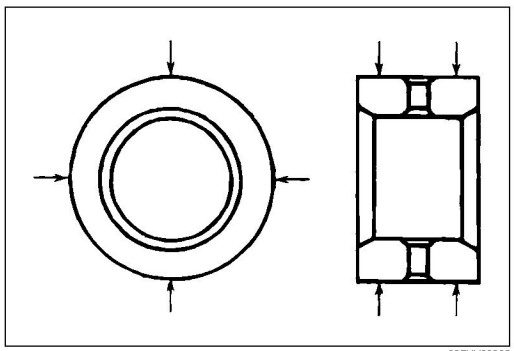
INSPECTION


037HY00024

Bearing housing

Measure the inside diameter of the bearing bores in the housing. If they exceed the service limit, replace the housing.

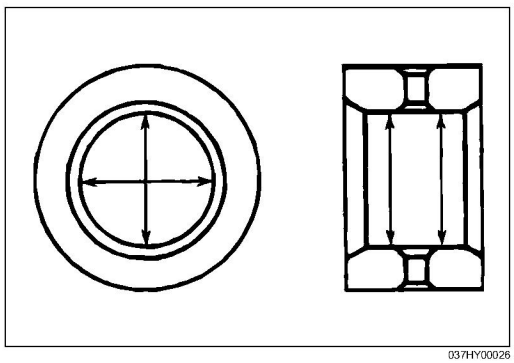
Limit	mm (in)
ø 20.506 (0.80732)	


037HY00025

Bearing

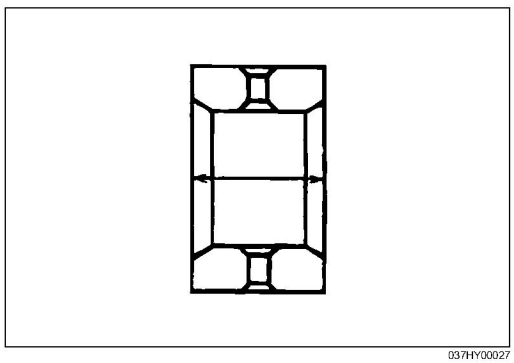
1. Measure the outside diameter of the bearing. If it is less than the service limit, replace the bearing.

Limit	mm (in)
ø 20.382 (0.80244)	


037HY00026

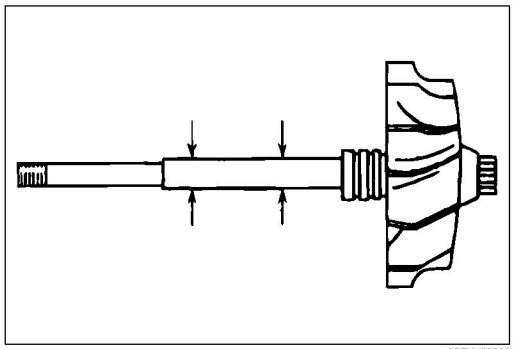
2. Measure the inside diameter of the bearing. If it exceeds the service limit, replace the bearing.

Limit	mm (in)
ø 12.042 (0.47409)	


037HY00027

3. Measure the length of the bearing. If it is less than the service limit, replace the bearing.

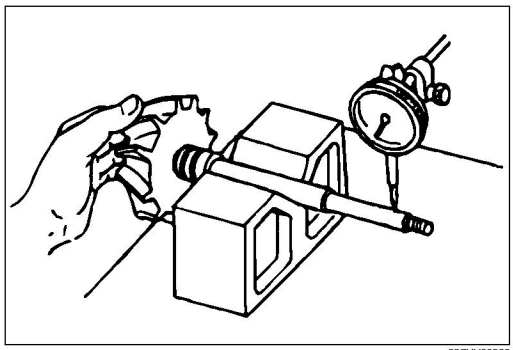
Limit	mm (in)
11.94 (0.4701)	


037HY00028

Shaft & turbine wheel

1. Measure the diameter of the shaft journals.
   If it is less than the service limit, replace the shaft & turbine wheel.

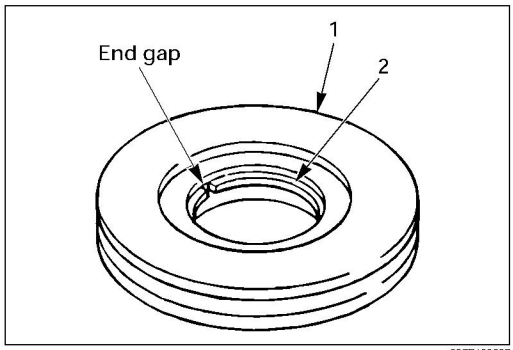
Limit	mm (in)
ø 11.996 (0.4722)	


037HY00029

2. Use a dial indicator and V-block to measure the runout of the shaft. If it exceeds the service limit, replace the shaft & turbine wheel.

Note:

1. **Replace the shaft & turbine wheel if it is bent. Never attempt to straighten a bent shaft.**
2. **Check the surfaces of the shaft journals. If they are rough, hold the shaft on a lathe by tightening it in the chucks at the center. Turn it at 300 to 600 rpm to lightly polish the journals with #400 (or finer) sandpaper and engine oil.**



037E100037

Insert

Place a new piston ring in the groove of the insert. Measure the end gaps of the ring. If the gap exceeds the standard clearance, replace the insert.

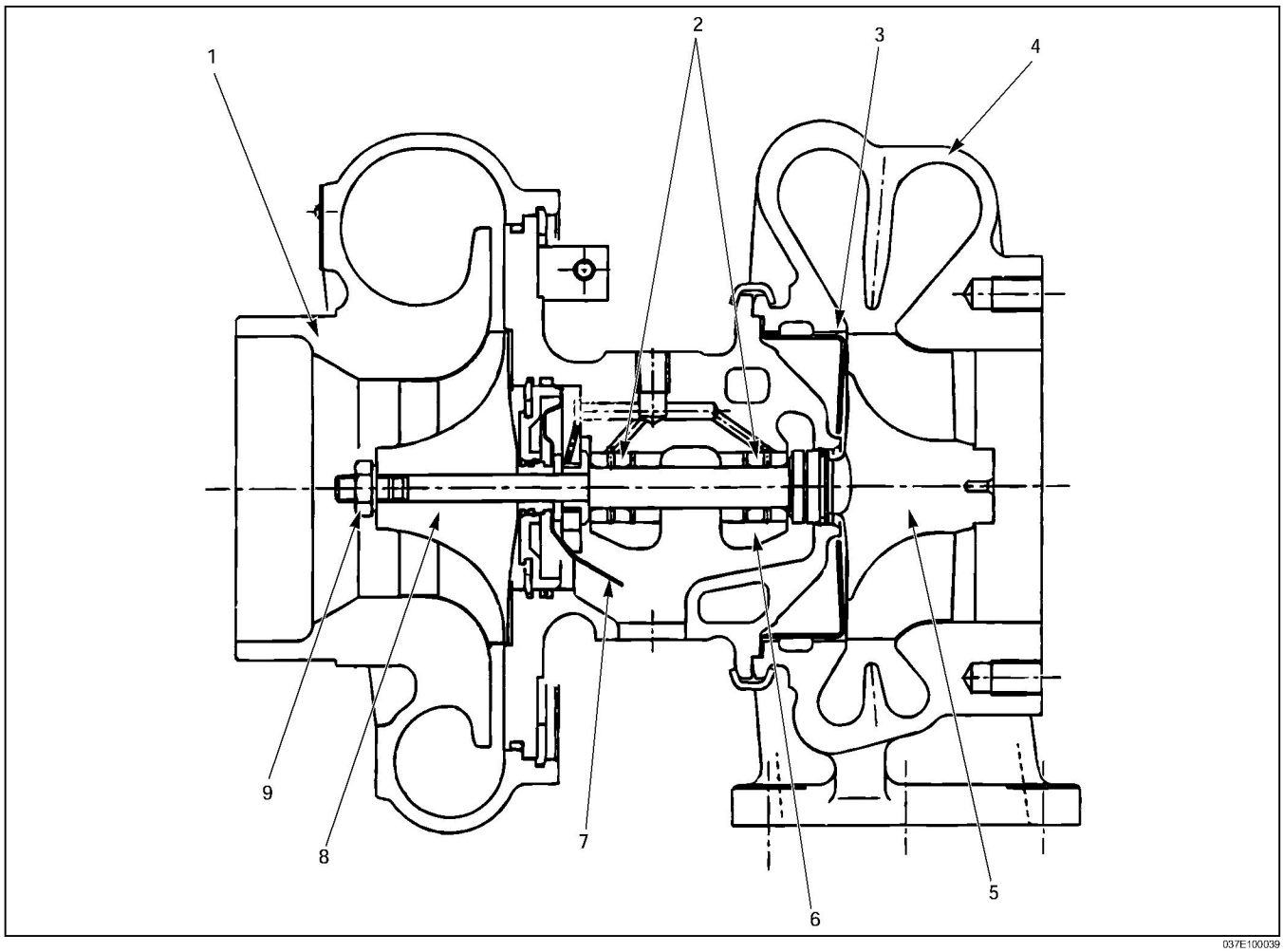
Standard clearance	mm (in)
0.05 – 0.25 (0.0020 – 0.0098)	

Replacement parts

The following parts should be replaced at disassembly:

(1) Piston rings
(2) Gaskets

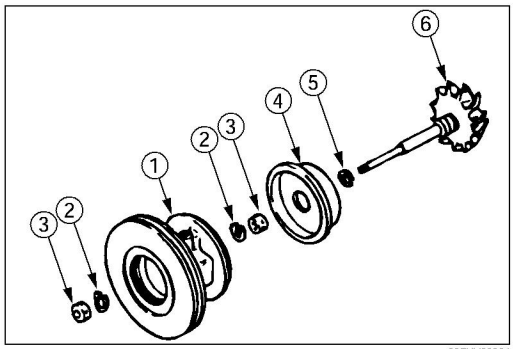
REASSEMBLY



Legend

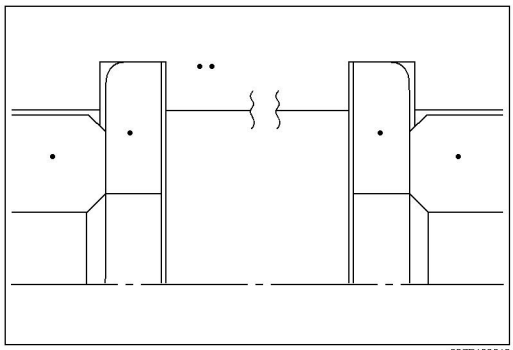
(1) Compressor cover
(2) Bearings
(3) Turbine back plate
(4) Turbine housing
(5) Turbine wheel
(6) Bearing housing
(7) Oil deflector
(8) Compressor wheel
(9) Nut

Note:
After installing an overhauled turbocharger on the engine, crank the engine with the starter to permit the engine oil to flow to the turbocharger.



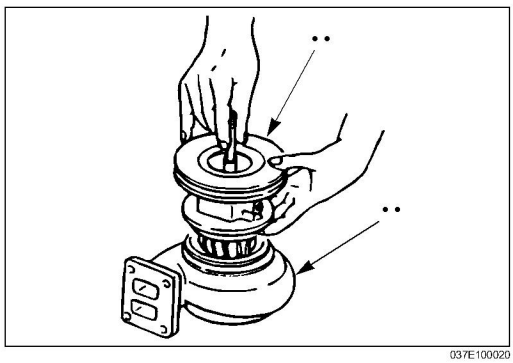
037HY00084

1. Reassemble the following parts.
   (1) Bearing housing
   (2) Snap ring
   (3) Bearing
   (4) Turbine back plate
   (5) Piston ring
   (6) Shaft & turbine wheel

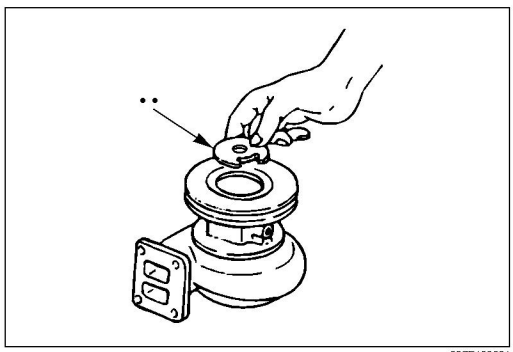

037E100019

Note:
1. **Use snap ring pliers (49160-90200) to attach snap ring (2). Insert the snap ring (2) into the bearing housing (3). The side with the round edge has to contact the bearing (1). Upon inserting the snap ring, do not compress it too much with the snap ring pliers.**
2. **After applying oil to the outer and inner surfaces of the bearing (1), install it.**
3. **Apply a light coat of oil to the piston ring of the shaft & turbine wheel.**
   Do not expand the ring more than necessary, and do not twist its end gap.
4. **Do push the shaft & turbine wheel unless it is aligned properly.**

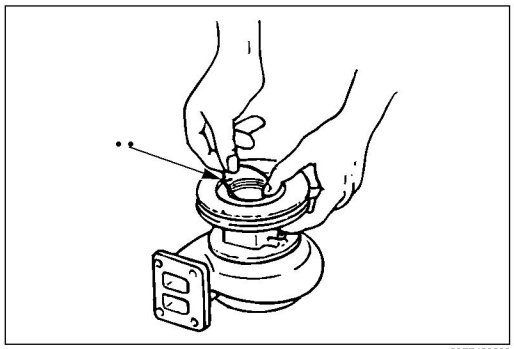
Do not damage the blades of the shaft & turbine wheel.
Align the shaft properly before you insert it.
Excessive force can bend the shaft if it is not properly aligned.


037E100020

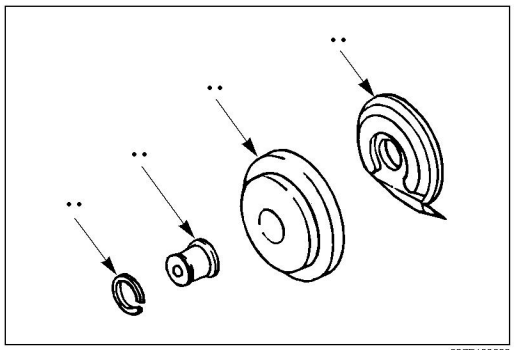
2. After the assembly above is completed, mount the bearing housing (1) on the turbine housing (2). Tighten temporaily with the coupling assembly (1).


037E100021

3. install the thrust bearing (1) after applying engine oil to its inside and outside surfaces. Wipe dust and oil from the shaft and end surfaces of the thrust ring.


037E100022

4. Apply engine oil to the O-ring (1) then install it.

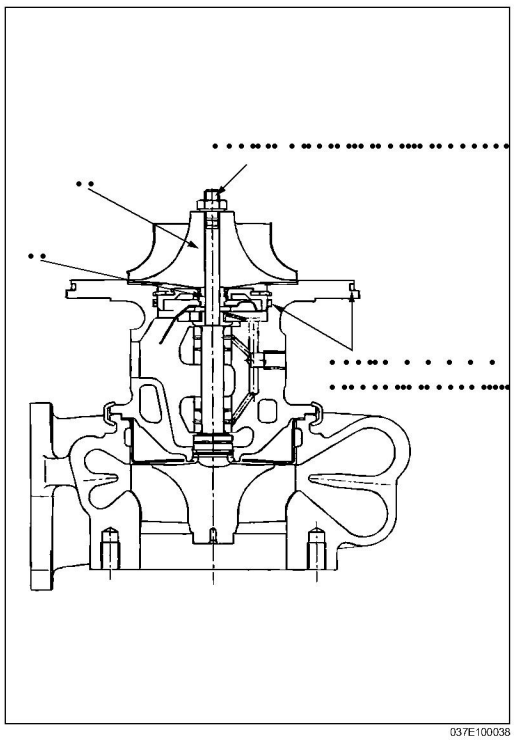

037E100023

5. Assemble the insert (2) sub-assembly parts in the following order.

   (1) Oil deflector
   (4) Thrust sleeve
   (3) Piston ring
   (2) Insert

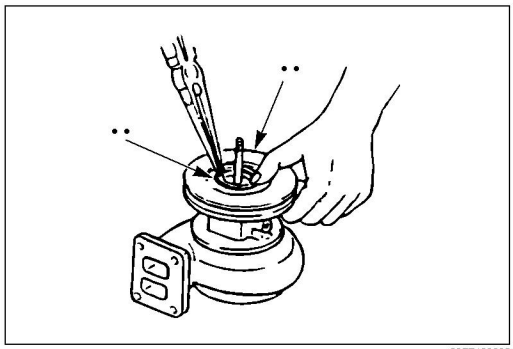
Note:

1. **When you install the piston ring (3) to the thrust sleeve (4), do not expand the ring more than necessary and do not twist is end gaps.**
2. **Apply engine oil to the piston ring (3) fitted to the thrust sleeve (4), then install the sleeve to the insert (2). To avoid damage to the ring, fit the ring gently, end gap first.**

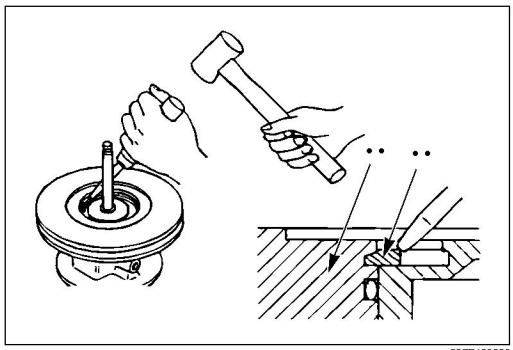

037E100038

After completing the above assembly, mount the sub-assembly to the bearing housing (2). Keep the end surface of the thrust ring and both ends of the thrust sleeve clean and free of dust and oil.

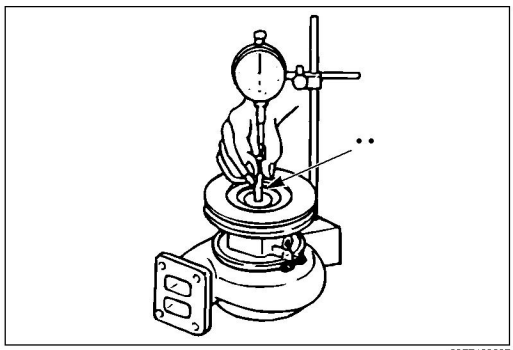
In the drawing shown on the right shows, apply Molykote, engine oil, or grease to the specified parts. Remove all oil from parts of thick line.


037E100025

6. Using snap ring pliers (49160-90100), install snap ring (1) to the bearing housing (2) with its tapered side facing up.

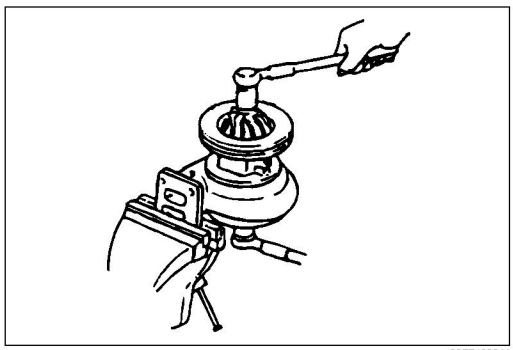

037E100026

Note:
1. **When you install the snap ring (2), position it in the specified direction.**
2. **Use a hammer and screwdriver to tap lightly the ends of the snap ring so it fits snugly in the groove of the bearing hausing (1).**
3. **When tapping the snap ring in position, do not damage the bearing housing with the screwdriver.**


037E100027

7. Set up a dial indicator on the shaft & turbine wheel (1). Move the shaft & turbine wheel in the axial direction to measure the clearance. If it is not within standard clearance, disassemble the parts and check for the cause.

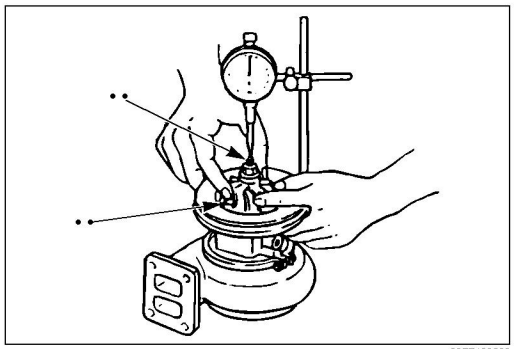
Standard clearance	mm (in)
0.39 – 1.00 (0.0154 – 0.0394)	


037E100044

8. Keep the ends of the thrust sleeve and both end surfaces of the compressor wheel clean and free of dust and oil.
9. Install the compressor wheel. Apply Molykote to the threads of lock nut.
   Tighten the nut to the specified torque

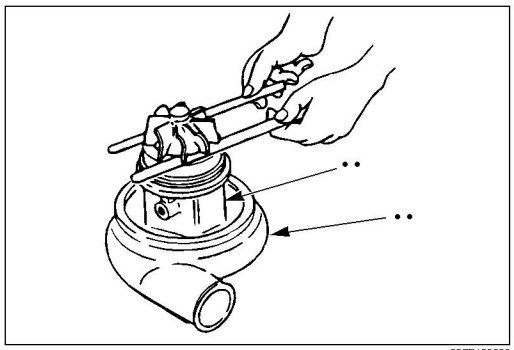
Tighten torque	N·m (kgf·m/lb·ft)
20 (2.0 / 14)	

Note:
(a) To tighten, set the turbocharger at a right angle with the wrench at a right angle to the shaft. Be careful not to bend the shaft.
(b) To tighten, hold down the commpressor wheel with your fingers to prevent it from rotating with the wrench.



10. Set up a dial indicator on the shaft and turbine wheel (2) as shown. Move the compressor wheel (1) in the axial direction to measure the play. If the play is not within standard clearance, disassemble the parts and check for the cause.

Standard clearance	mm (in)
0.075 – 0.155 (0.00295 – 0.00610)	

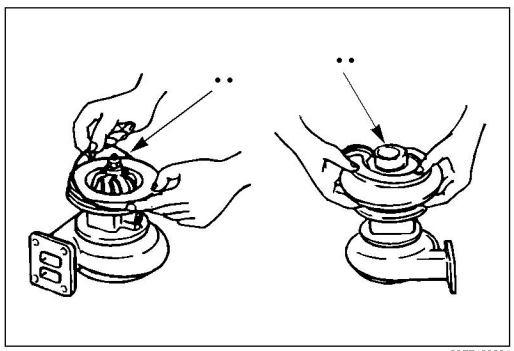


11. Remove the turbine housing from the bearing housing (1). Install the compressor cover (2).

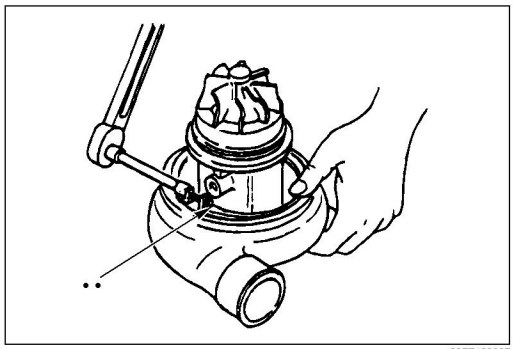
    With feeler gauges, measure the clearance between turbine back plate and turbine wheel. If the clearance is not within standard clearance, disassemble the parts and check for cause.

Note:
Measure the clearance with two feeler gauge from the tips of the vanes as shown.

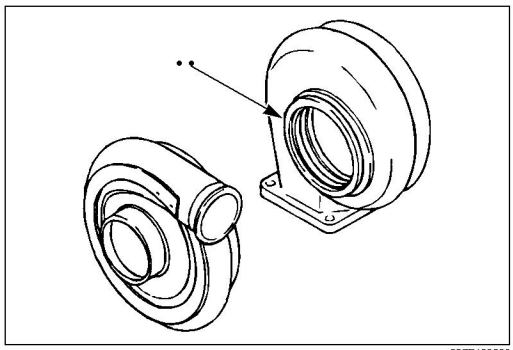
Standard clearance	mm (in)
0.48 – 0.92 (0.0199 – 0.0362)	



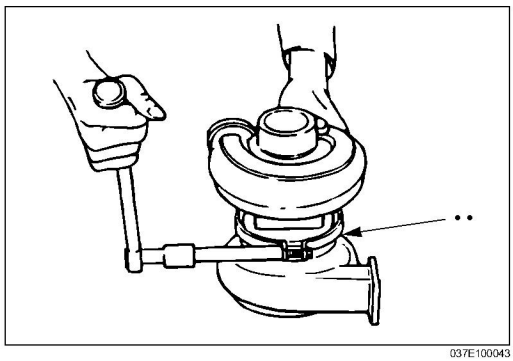
12. Install the compressor cover (2). Be sure that it is correctly positioned with respect to the turbine housing. Apply grease to O-ring (1) before you install it.



13. Install snap ring (1).



14. Be sure the turbine housing (1) is correctly positioned with the compressor housing.



15. Appy Molykote to the threads of the coupling assembly (1), then tighten it to the specified torque.

Tightening torque	N·m (kgf·m/lb·ft)
6 (0.6 / 4.3)	

SERVICE STANDARD

Units: mm (in.)

Part or Item		Nominal Value	Assembly Standard (Standard Clearance)	Service Limit (Clearance)	Remarks
Inside diameter of bearing housing bores		ø20.5 (0.807)		ø20.506 (0.80732)	
Bearing	Outside diameter			ø20.382 (0.80244)	
	Inside diameter			ø12.042 (0.47409)	
	Length			11.94 (0.4701)	
Shaft & turbine wheel	Diameter of journals	ø12.0 (0.47)		ø11.996 (0.47228)	
	Runout of shaft			0.015 (0.00059)	
End gap of piston ring			0.05 – 0.25 (0.0020 – 0.0098)		With ring fitted in the insert
Clearance between shaft & turbine wheel and turbine housing			0.39 – 1.00 (0.0154 – 0.0394)		
Axial play of shaft & turbine wheel			0.075 – 0.155 (0.00295 – 0.00610)		
Clearance between turbine back plate and turbine wheel			0.48 – 0.92 (0.0189 – 0.0362)		

MEMO

CHAPTER 10

ENGINE ELECTRICAL

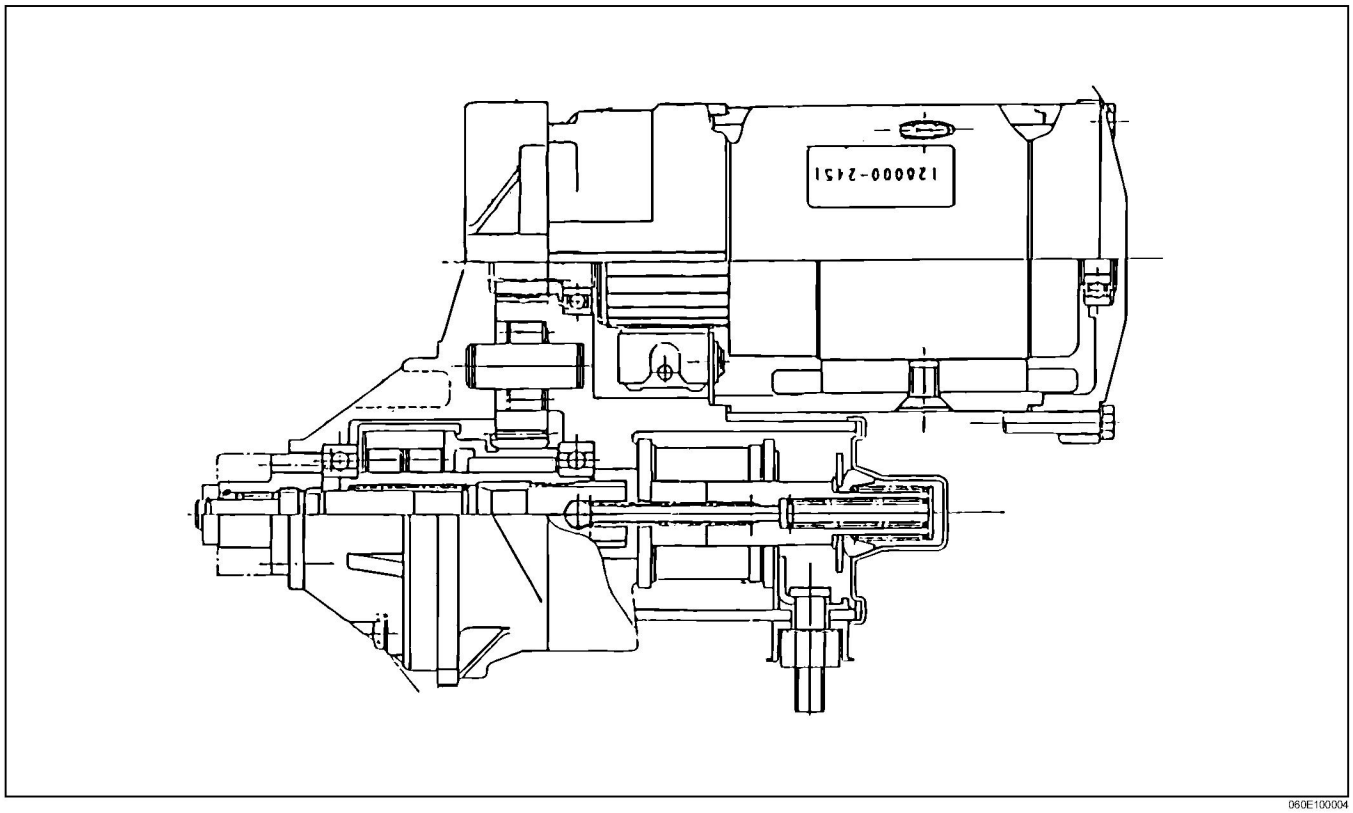
CONTENTS

STARTER

MAIN DATA AND SPECIFICATIONS

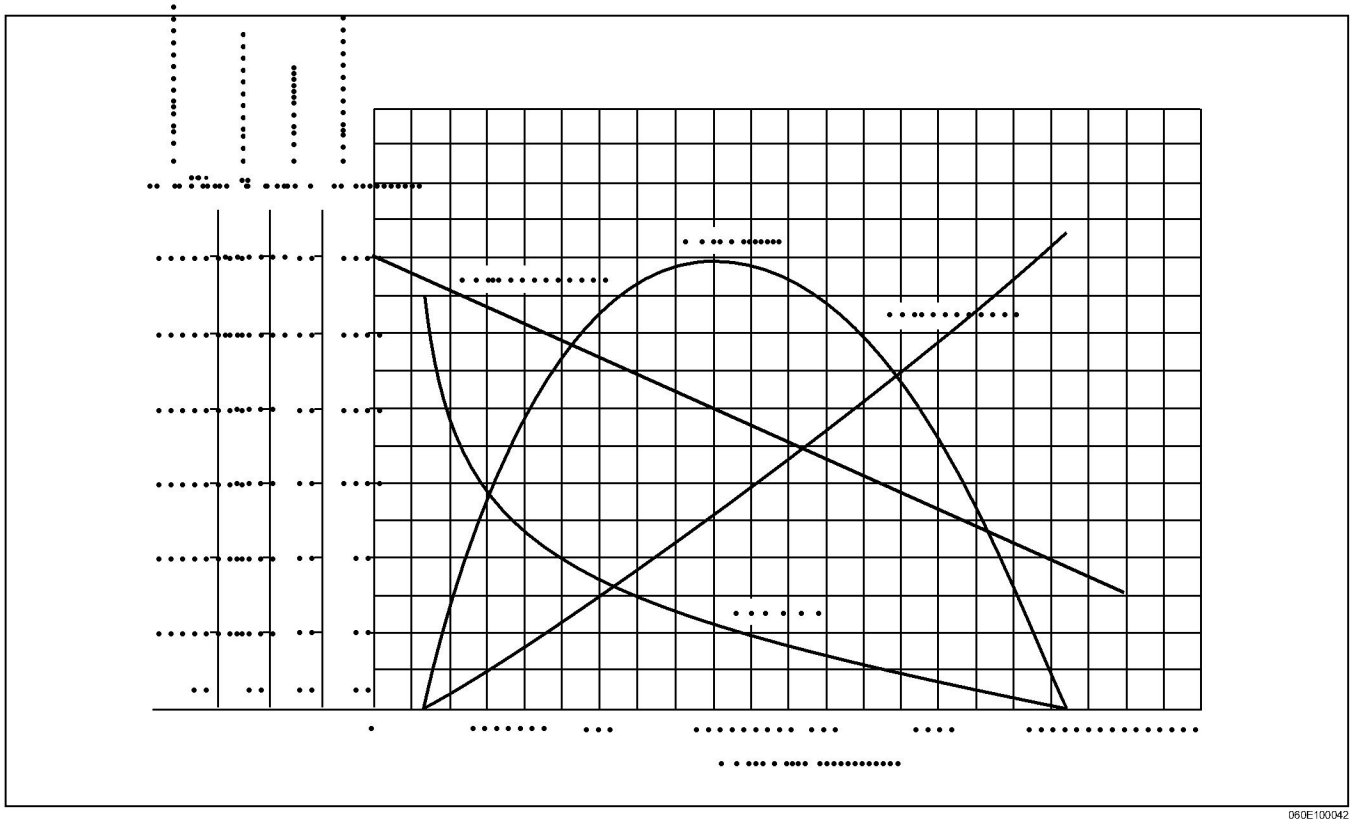
Isuzu Part No.		1 – 81100 – 230 – 1
Nippon Denso Code No.		1 – 28000 – 245 – 0
Rated voltage	(V)	24
Rated output	(kW)	5.5
Rating	(Sec)	30
Direction of rotation (Viewed from the pinion side)		Clockwise
Clutch type		Roller
Terminal voltage (No Load)	(V)	24
Minimum current (No Load)	(A)	120
Minimum operating speed (No Load)	(rpm)	4100
Pinion gear		
Modules		3
Number of teeth		11
Outside diameter	mm (in.)	40.5 (1.6)
Travel distance	mm (in.)	0.82 (0.032)
Yoke outside diameter	mm (in.)	100 (3.94)
Number of poles		4
Magnetic switch (at 20°C [68°F])		
Series coil resistance	(Ω)	0.76 – 0.84
Shunt coil resistance	(Ω)	2.42 – 2.64
Brush length		
Standard	mm (in.)	20 (0.79)
Limit	mm (in.)	13 (0.51)
Brush spring standard fitting load	kg (lbs.)	3.3 (7.3)
Commutator		
Outside diameter		
Standard	mm (in.)	43 (1.69)
Limit	mm (in.)	42 (1.65)
Difference between the largest and smallest diameters		
Standard	mm (in.)	0.02 (0.0008)
Limit	mm (in.)	0.05 (0.0020)
Depth of undercut mica		
Standard	mm (in.)	0.5 – 0.8 (0.02 – 0.03)
Limit	mm (in.)	0.2 (0.008)

SECTIONAL DRAWING



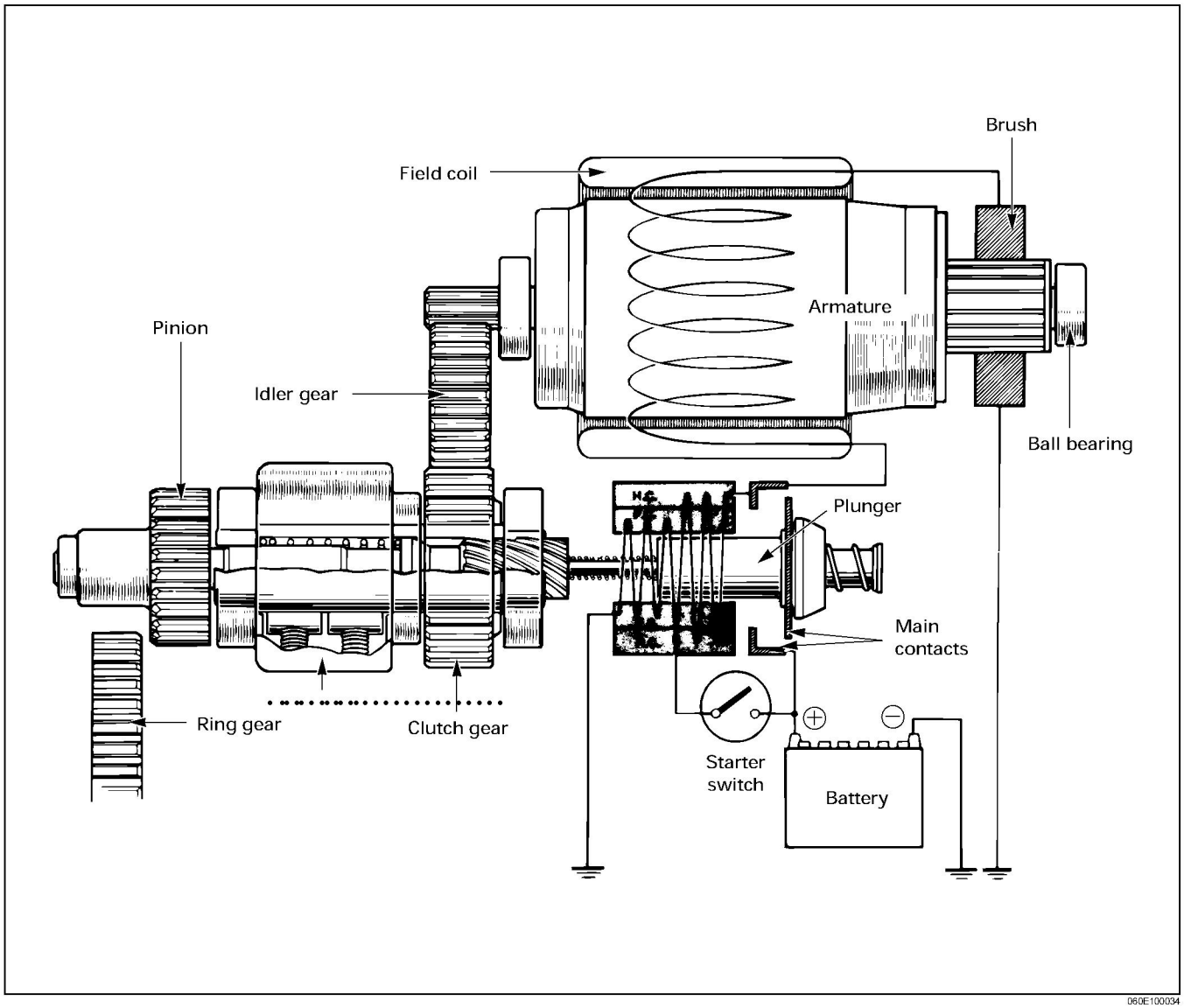
060E100004

OUTPUT CHARACTERISTICS

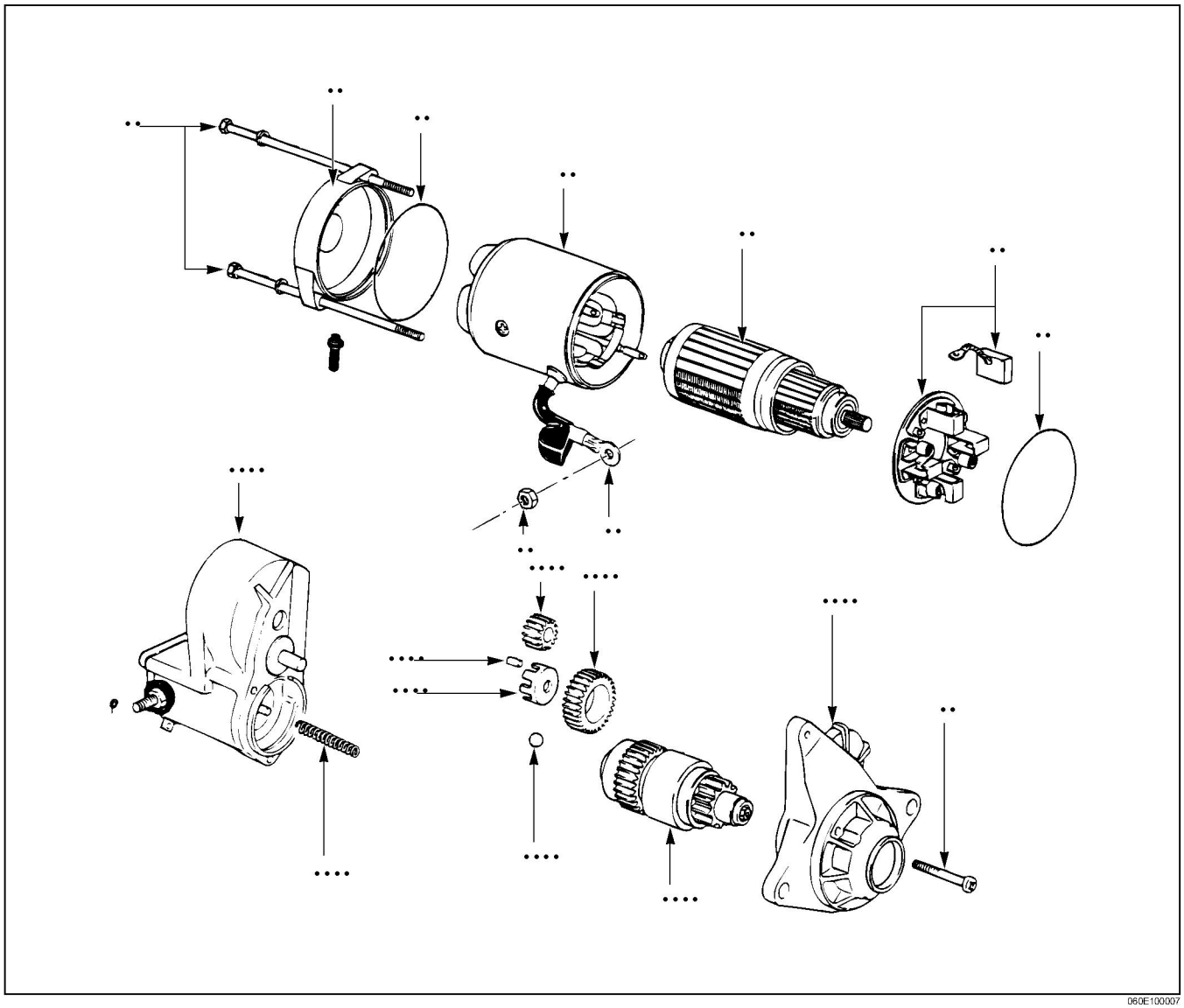


060E100042

CIRCUIT ARRANGEMENT



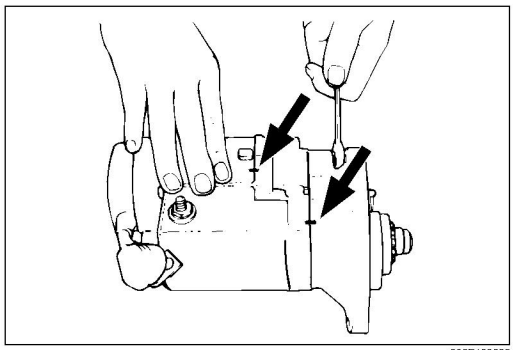
DISASSEMBLY



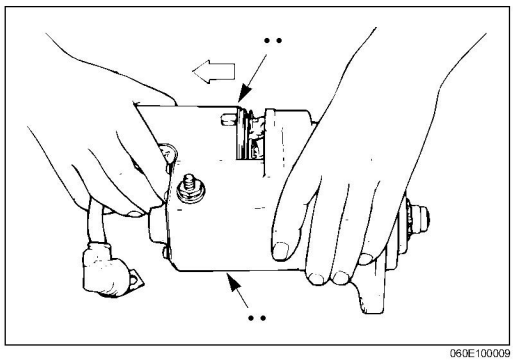
Disassembly sequence

1. Hexagon nut
2. Connecting lead wire
3. Through bolts
▲4. End frame
5. Starter seal
▲6. Yoke
▲7. Brushes and brush holder
▲8. Armature
9. Screw
▲10. Starter housing
▲11. Pinion clutch
▲12. Steel ball
▲13. Starter pinion
▲14. Idler gear
▲15. Retainer
▲16. Clutch roller
17. Compression return spring
▲18. Magnetic switch body

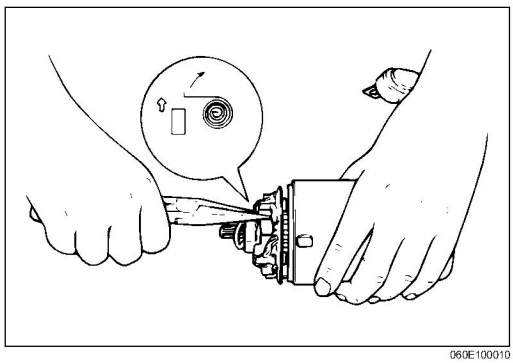
IMPORTANT OPERATIONS


060E100035

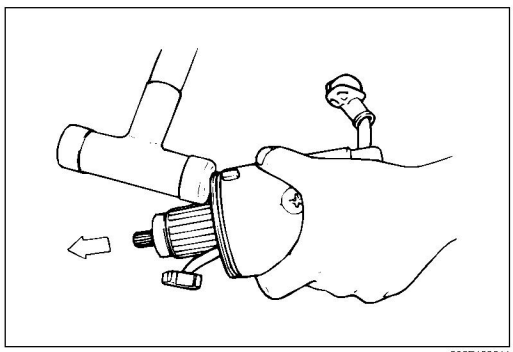
4. End frame
6. Yoke
10. Starter housing
18. Magnetic switch body
Apply setting marks across the end frame, the yoke, and the magnetic switch body.
This will ensure reassembly of the parts in their original positions.


060E100009

6. Yoke
Remove the yoke ① from the magnetic switch ②.

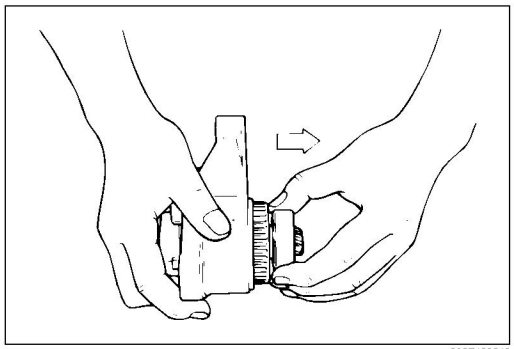

060E100010

7. Brushes and brush holder
Use a long nose pliers to remove the brushes and pull out the brush holder.


060E100011

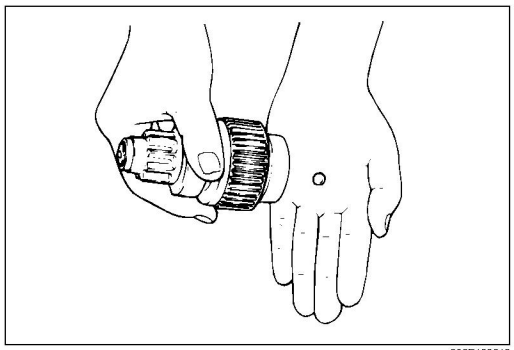
8. Armature
Remove the armature from the yoke.

Note:
If necessary, tap the yoke end with a plastic hammer to remove the armature.

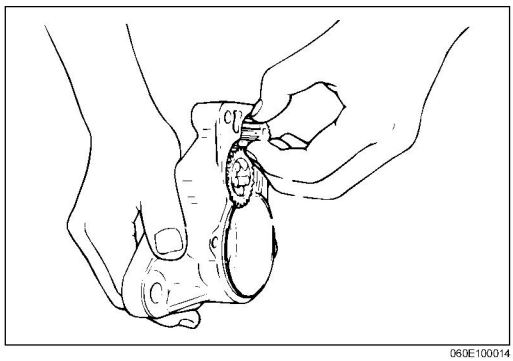

060E100012

11. Pinion clutch
Remove the magnetic sub-switch from the starter housing.

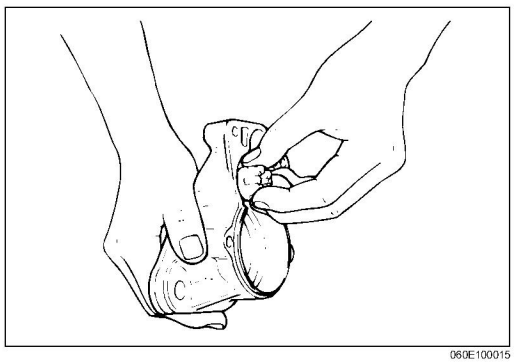
Note:
If the pinion is installed to the starter housing (externally attached to the magnetic sub-switch shaft, it must be removed before the magnetic sub-switch.


060E100013

12. Steel ball
Remove the steel ball from the pinion clutch.


060E100014

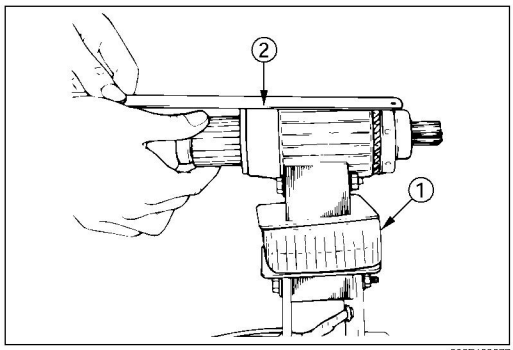
13. Starter pinion
14. Idler gear
Remove the starter pinion and the idler gear from the starter housing.


060E100015

15. Retainer
16. Clutch roller
Remove the retainer and the clutch roller from the starter housing.

INSPECTION AND REPAIR

Make the necessary adjustments, repairs, and part replacements if excessive wear or damage is discovered during inspection.

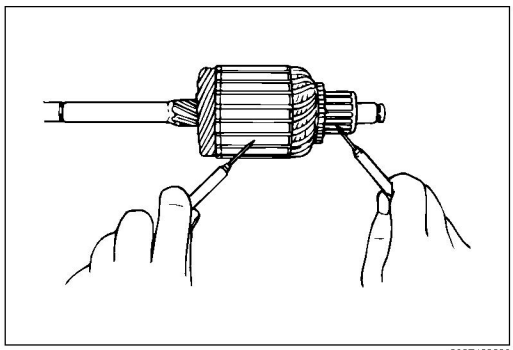


060E100077

ARMATURE

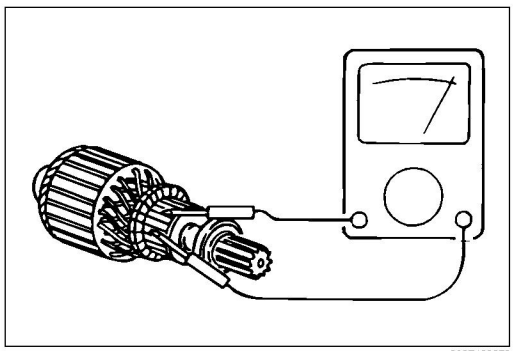
Armature short circuit test

1. Place the armature on a growler tester ①.
2. Hold a hacksaw blade ② against the armature core while slowly rotating the armature.
   If the armature is short circuited, the hacksaw blade will vibrate and will be attracted to the armature core.
   A short circuited armature must be replaced.


060E100036

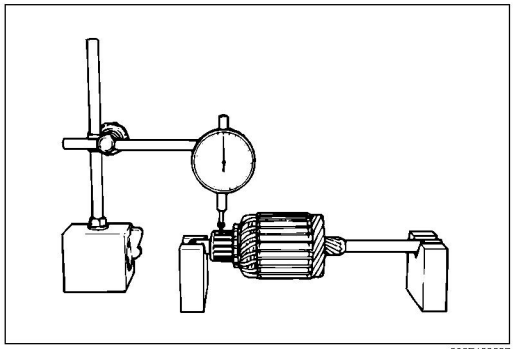
Armature winding ground test

Check for continuity across the commutator segments and the core.
If there is continuity, the armature is internally grounded due to insulation failure and must be replaced.


060E100078

Armature winding continuity test

Check for continuity across the commutator segment.
If there is no continuity, the armature coil is open and must be replaced.

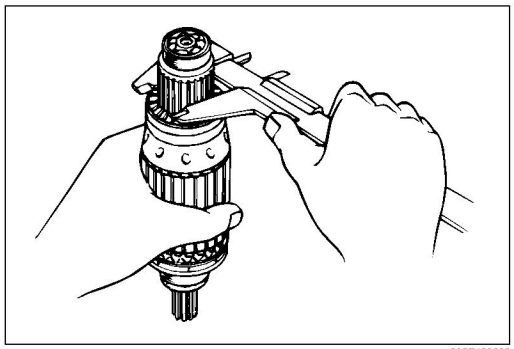

060E100037

Commutator run-out test

Use a dial indicator and a V-block to measure the commutator runout.
If the measure value exceeds the limit, the commutator must be replaced.

Commutator run-out mm (in.)

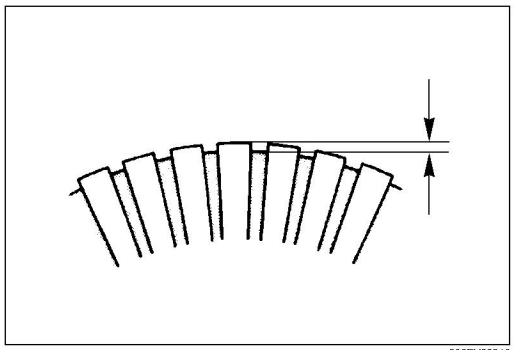
Standard	Limit
0.02 (0.0008)	0.05 (0.002)


060E100020

Commutator outside diameter measurement
Use a vernier caliper to measure the commutator outside diameter.
If the measured value exceeds the limit, the armature must be replaced.

Commutator outside diameter mm (in.)

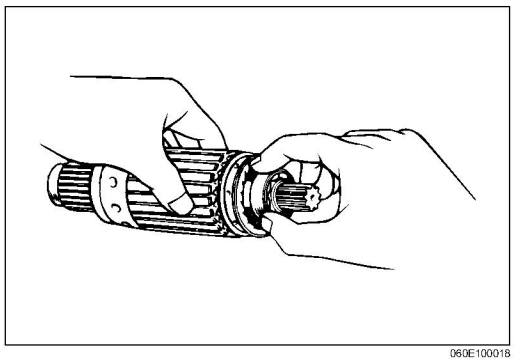
Standard	Limit
43.0 (1.7)	42.0 (1.65)


060EY00016

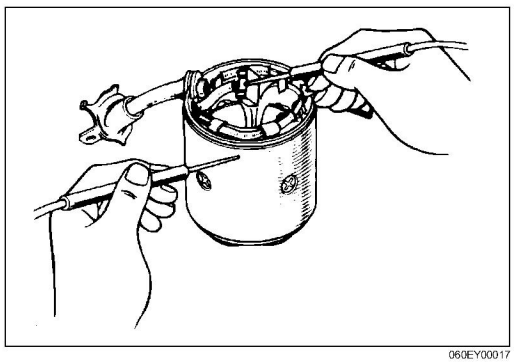
Segment mica depth measurement
Use a depth gauge to measure the segment mica depth.
If the measured value exceeds the limit, the segment mica must be undercut.

Segment mica depth mm (in.)

Standard	Limit
0.7 – 0.9 (0.028 – 0.035)	0.2 (0.008)

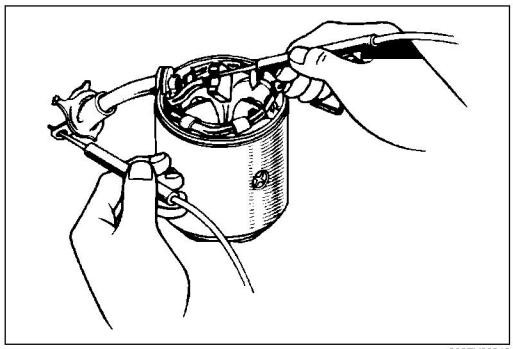

060E100018

Bearing inspection
Visually inspect the bearing.
If the bearing is worn or damaged, it must be replaced.

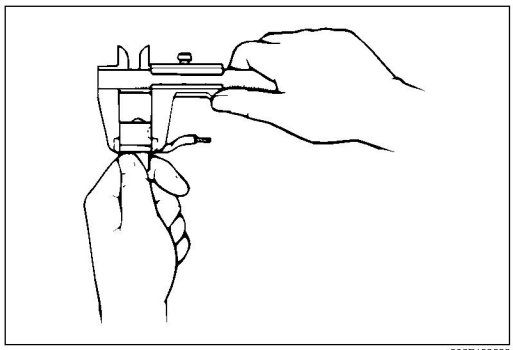

060EY00017

YOKE

Field winding ground test
Use a circuit tester to check the field winding ground.
1. Touch one probe to the brush field winding end.
2. Touch the other probe to the bare surface of the yoke body.
   There should be no continuity.
   If there is continuity, the field windings are grounded.
   Repair or replace the field windings.


060EY00018

Field winding continuity test
Use a circuit tester to check the field winding continuity.
1. Touch one probe to the field winding lead wire.
2. Touch the other probe to the brush.
   There should be continuity.
   If there is no continuity, the field windings are open.
   Repair or replace the field windings.


060E100038

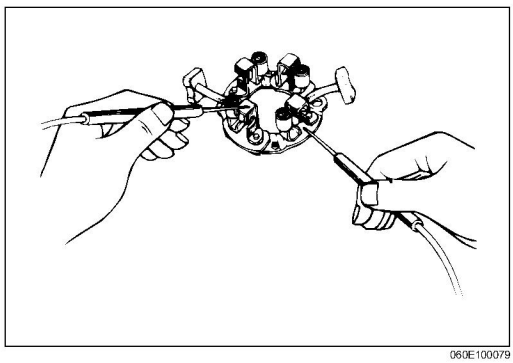
BRUSH AND BRUSH HOLDER

Brush length measurement
Measure the brush length to check for wear.
If the measured value exceeds the limit, the brush and/or the yoke must be replaced.

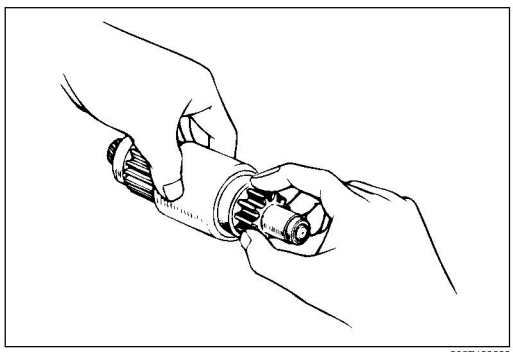
Brush length (H) mm (in.)

Standard	Limit
20.0 (0.79)	13.0 (0.51)

Brush spring inspection
Visually check te brush spring for weakness and rusting.
Replace the brush spring if it is weak or rusted.


060E100079

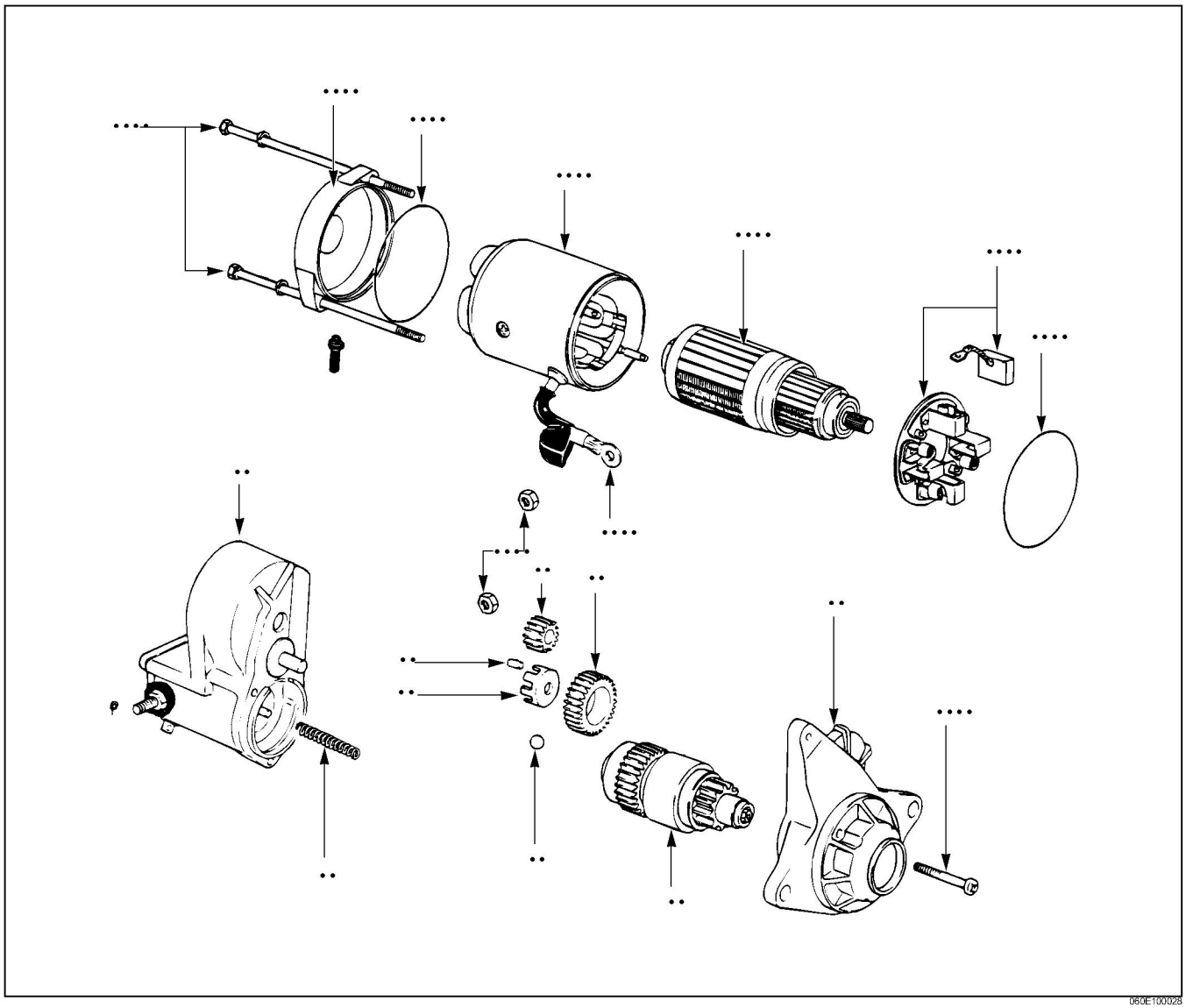
Brush holder insulation test
Use a circuit tester to check the brush holder insulation.
1. Touch one probe to the field winding lead wire.
2. Touch the other probe to the brush.
   There should be continuity.
   If there is continuity, the brush holder must be repaired or replaced.


060E100080

PINION CLUTCH

Pinion inspection
Use your hand to turn the pinion in the direction of starter motor rotation. The pinion should turn freely.
Try to turn the pinion in the opposite direction. The pinion should lock.

REASSEMBLY



Reassembly sequence

1. Magnetic switch body
▲2. Compression return spring
▲3. Clutch roller
▲4. Retainer
5. Idler gear
6. Starter pinion
7. Steel ball
8. Pinion clutch
9. Starter housing
10. Screw
11. Armature
▲12. Brushes and brush holder
▲13. Yoke
14. Starter seal
▲15. End frame
▲16. Through bolt
17. Connecting lead wire
18. Hexagon nut

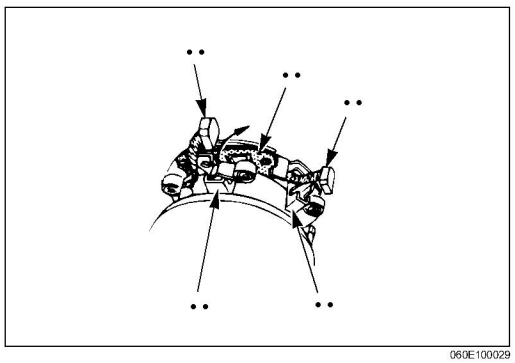
IMPORTANT OPERATIONS

2. Compression return spring

Apply a coat of engine oil to the compression return spring.

3. Clutch roller
4. Retainer

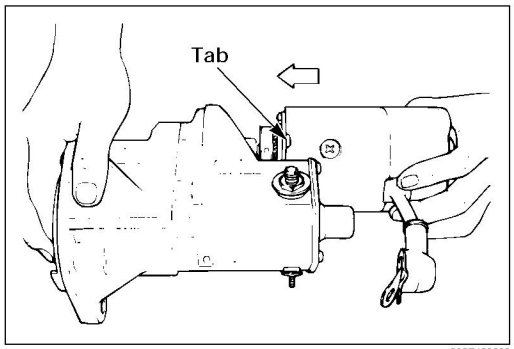
Apply a coat of engine oil to the clutch roller and the retainer.



060E100029

12. Brushes and brush holder

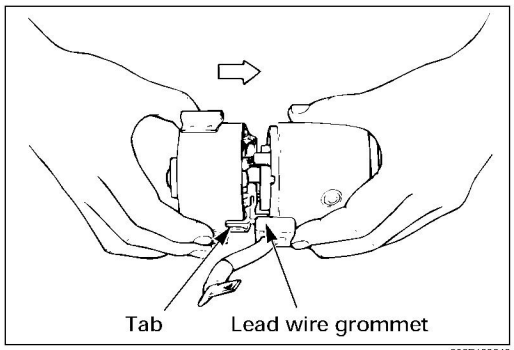
1) Install the negative brush (1) on the brush holder side to the brush holder negative hole (2).
   The brush holder negative hole is not insulated.
2) Install the positive brush (3) on the yoke side to the brush holder positive hole (4).
   The brush holder positive hole is separated from the plate with the insulator (5).
3) Check that the positive brush lead wires are not grounded.
4) Install the brush holder to the yoke.
   Take care not to damage the brush holder or the yoke.
   Do not spill oil on the brush holder or the yoke.



060E100039

13. Yoke

1) Install the yoke to the magnetic switch.
   The yoke must engage the notch on the magnetic switch.
2) Securely set the rubber boot to the magnetic switch C-terminal.



060E100040

15. End frame

Install the end frame to the yoke.
The end frame tab engage the yoke lead wire grommet.

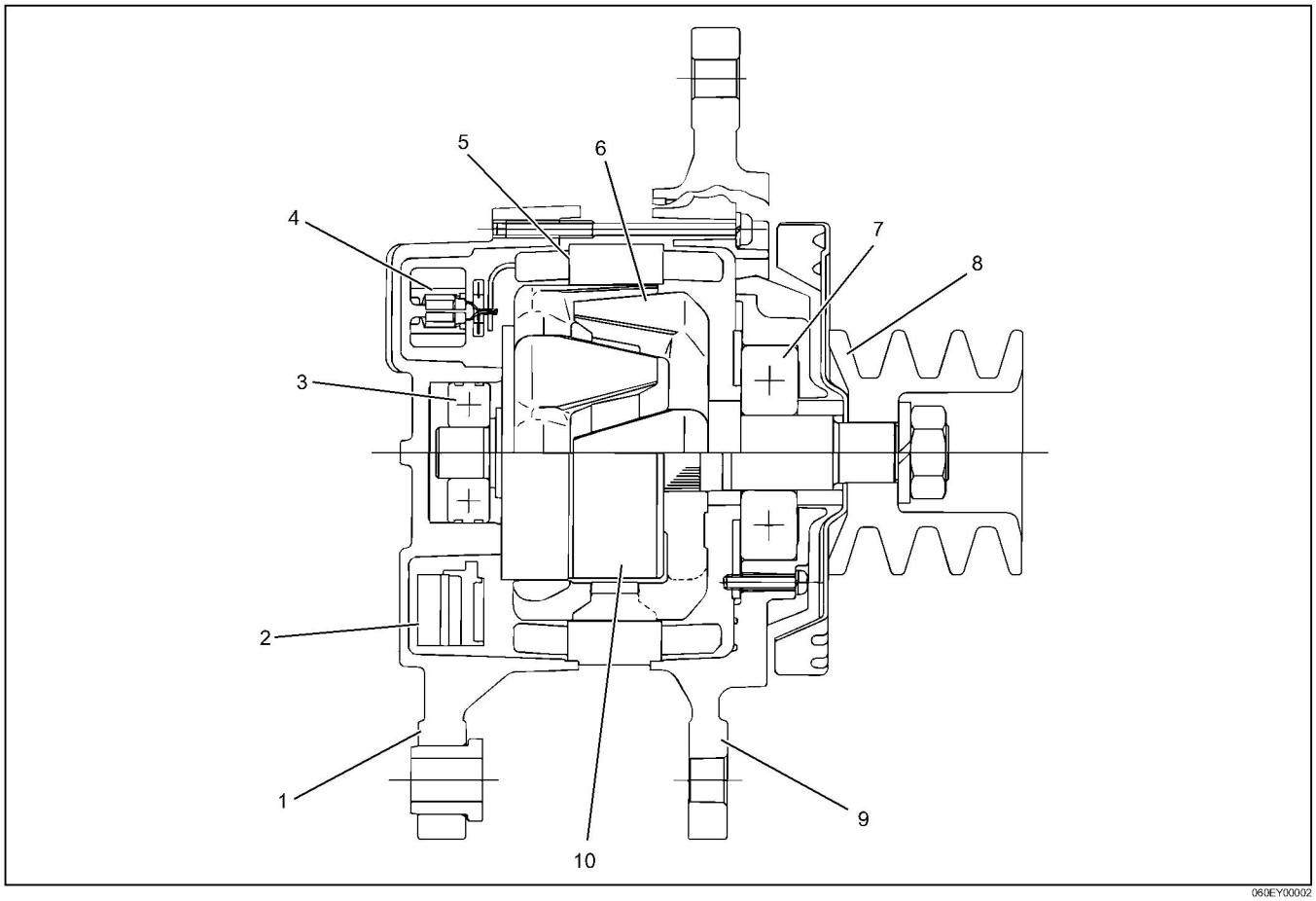
16. Through bolt

Tighten the through bolt to the specified torque.

Through bolt torque	kg·m (lb·ft/N·m)
1.0 ± 0.2 (7.1 ± 1.4 / 9.8 ± 2.0)	

ALTERNATOR

GENERAL DESCRIPTION



Legend

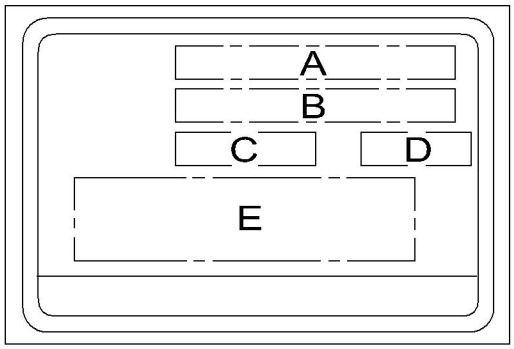
(1) Rear bracket
(2) IC regulator
(3) Bearing
(4) Rectifier
(5) Stator
(6) Rotor
(7) Bearing
(8) Pulley
(9) Front bracket
(10) Field coil assembly

The engine uses a brushless alternator.
Main alternator components are the rotor, the stator, the rectifier, the front and rear brackets, the IC regulator, the bearings, and the pulley.
Moving parts include the rotor and the pulley.
The field coil is installed to the rear bracket.
6 main diodes (3 positive and 3 negative) in conjunction with 2 sub-diodes provide 3-phase rectification. The diodes are installed to the stator coil.
An additional 3 diodes (diode trio) are used to provide field current.
The alternator has 3 terminals.

a. Terminal B: DC power output
b. Terminal L: Exciting current input
c. Terminal R: Exciting current input

Terminal R is active only until the alternator begins to generate electricity.
Terminal L also serves as a voltage output terminal. When the voltage across terminal L is equal to the battery voltage, the indicator lamp (no charging) turns off.
Sealed bearings requiring no lubrication are used throughout the alternator.
The IC regulator is a solid-state device and is serviced as a unit. It cannot be disassembled.

MITSUBISHI IDENTIFICATION PLATE



A: Isuzu part number
B: Manufacturer's abbreviated name
C: System voltage output
D: Manufacturer's lot No.
E: Bar code

IDENTIFICATION

The alternator identification plate is attached to the alternator rear bracket. The ISUZU part number, the manufacturer's code number, and other important information are stamped on the plate.

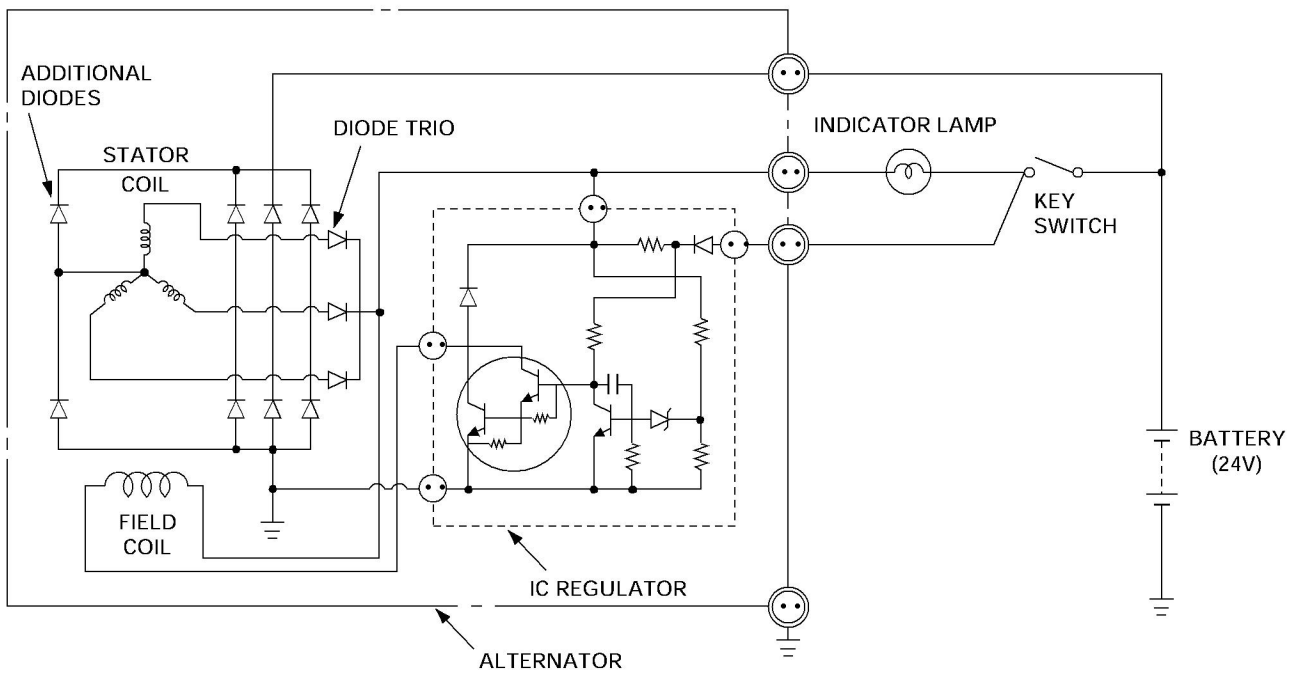
Refer to the identification plate together with the "Main Data and Specifications" Tables and accompanying charts in this Manual when requesting service assistance from a qualified electrical repair shop.

If you are unable to locate the data applicable to your engine, please contact ISUZU MOTORS LIMITED through your machine supplier.

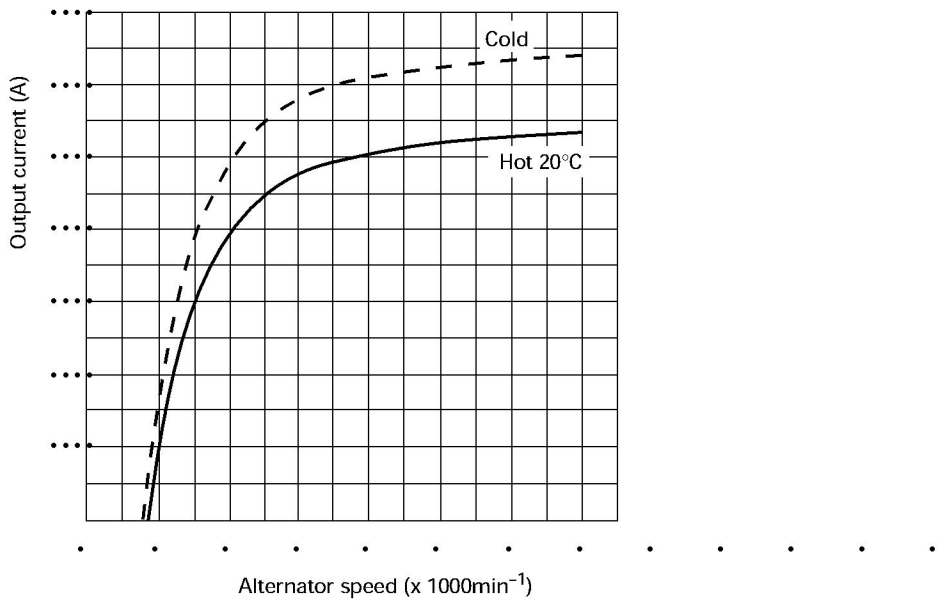
MAIN DATA AND SPECIFICATIONS

Isuzu Part No.		181200-6031
Manufacturer's code No. (MITSUBISHI)		A004T06285
Rated voltage	(V)	24
Rated output	(A)	50
Rated speed	(min^{-1})	5000
Rated output	(Amp./Volt/min^{-1})	50/27/5000
No-load output at 0 Amp.	(Volt/min^{-1})	24/900
Direction of rotation as viewed from pulley side		Clockwise
Ground polarity		(–)
Pulley diameter	mm (in.)	80 (3.15)
Coil resistance at 20°C		
Field coil	(Ω)	4.5 – 5.2

CHARGING CIRCUIT



ALTERNATOR OUTPUT PERFORMANCE



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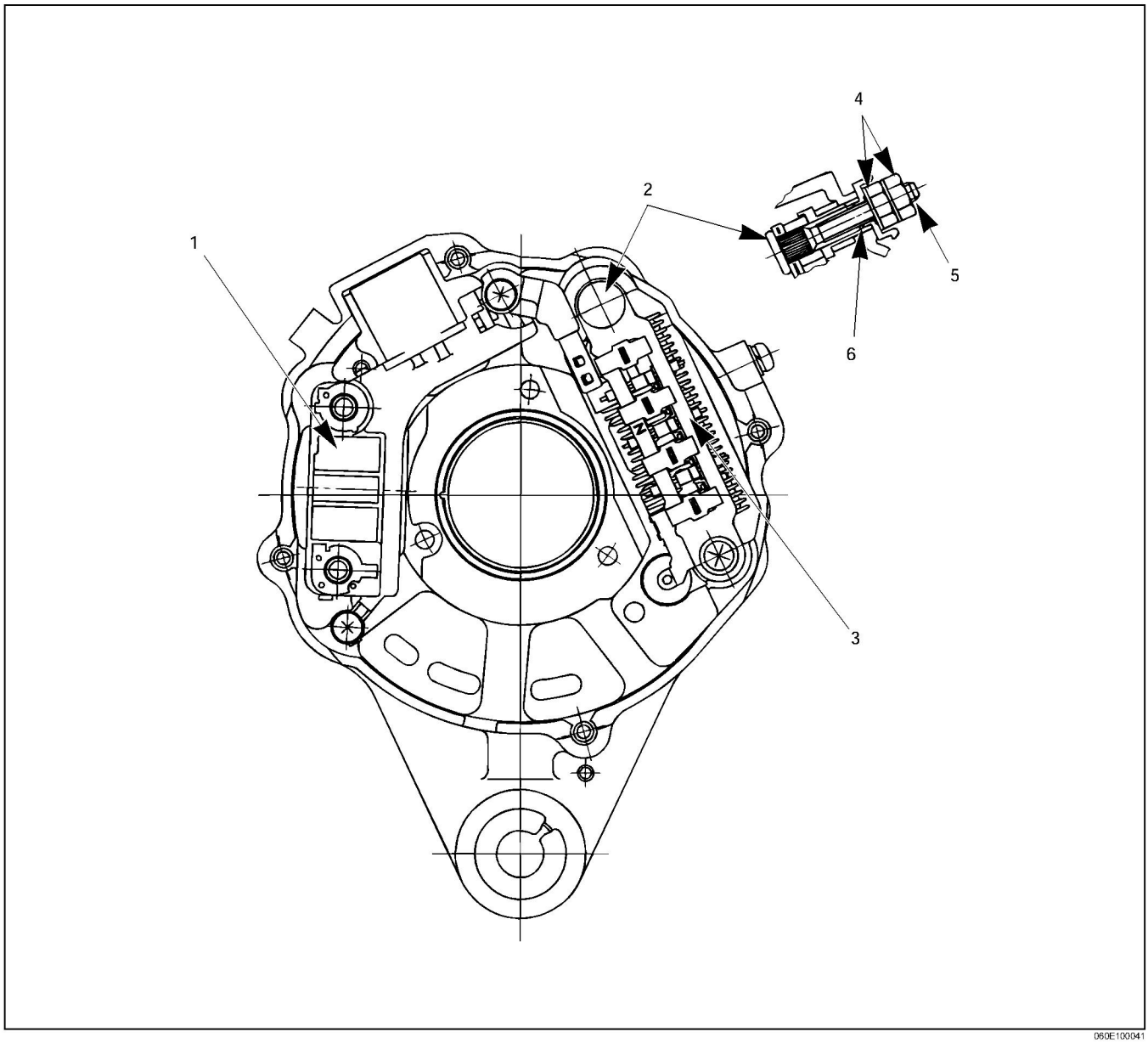
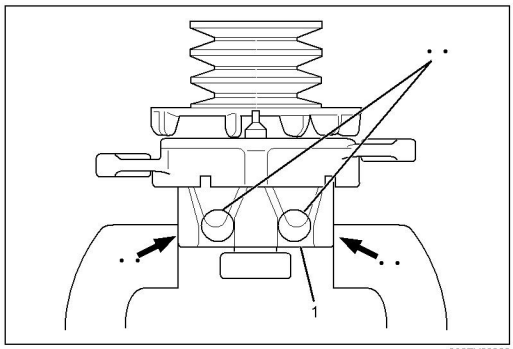
DISASSEMBLY



060E100041

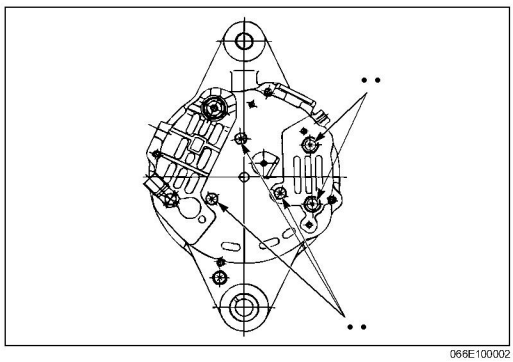
(1) IC regulator
(2) Terminal stud
(3) Rectifier assembly
(4) Nut
(5) Terminal B
(6) Tube



060EY00030

1. Scratch setting marks between the front and rear brackets and the alternator body (2 locations). This will ensure installation to its original position.
2. Remove the 4 through bolts.
3. Use the blade of a screwdriver to pry the front bracket and the stator apart.
4. Carefully separate the front bracket, pulley, and rotor from the stator and rear bracket.

Note:
- **Do not push the screwdriver blade too deeply into the stator. Coil damage will result.**
- **A vise may be used to secure the rotor. Be sure to clamp the vise at points A (see illustration below). Do not clamp the vise at points B. Damage to the rotor will result.**


066E100002

5. Remove the 2 screws (A) attaching the coil terminal plate to the IC regulator.
6. Hold the coil assembly in your hand. Be careful not to damage the terminal plate.
7. Remove the 3 screws (B) and the coil assembly.
8. Remove the clame.

Note:
It is very important that Steps 5, 6 and 7 be performed in that order. If Step 6 is performed before Step 5, terminal damage will result.

9. Remove the cap and nut from the rectifier terminal stud.

Note:
The tube will remain in the rear bracket. Take care not to lose it.

10. Remove the rectifier retaining screw and the 2 IC regulator retaining screws.
11. Remove the stator and rectifier assembly (as a single unit) from the rear bracket.
12. Remove the IC regulator.
13. Unsolder the 4 stator coil leads from the rectifier terminals.
14. Remove the stator from the rectifier.

Note:
High temperature solder with a melting point of 230°C connects the stator coil leads to the rectifier. Use a 180~280 watt soldering iron to free the leads as quickly as possible. Do not apply the soldering iron for more than 5 seconds. Diode damage will result.

BEARING REMOVAL

Note:
Bearings are not normally removed. If they are removed, they must be replaced with new ones.

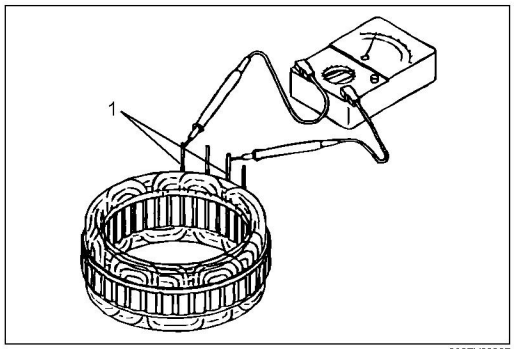
- **Front bracket bearing**

Remove the 4 retainer screws. Press out the bearing with a suitable tool.

- **Rotor bearing**

Use an ordinary bearing puller.

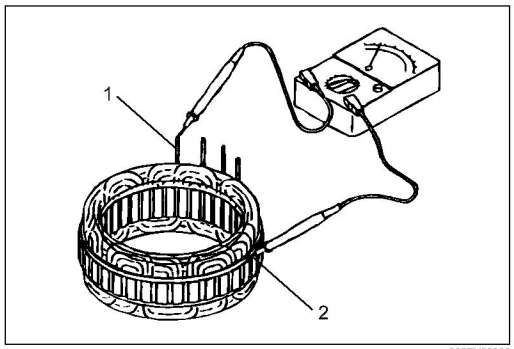
INSPECTION AND REPAIR



060EY00007

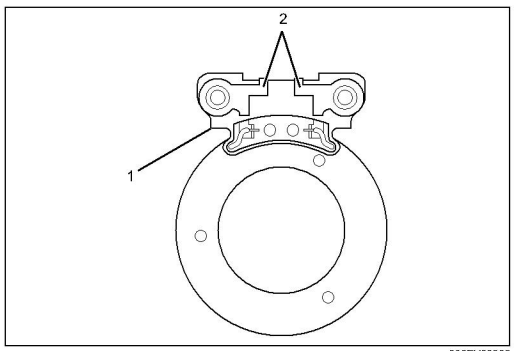
Startor

1. Check the stator for damage, loose connections, and discolored windings.
2. Use a circuit tester to check for continuity between each pair of stator coil leads (1). Replace the stator if there is no continuity.



060EY00008

3. Use a circuit tester to check for continuity between each of the stator coil leads (1) and the stator core (2). Replace the stator if there is no continuity.



060EY00005

Rotor

1. Turn the rotor. Listen for bearing noise (a scraping sound). Feel for rough rotation. Replace the rotor if either of these conditions is present.
2. Check for grease leakage. If leakage is minimal, wipe it away. If leakage is excessive, replace the rotor.

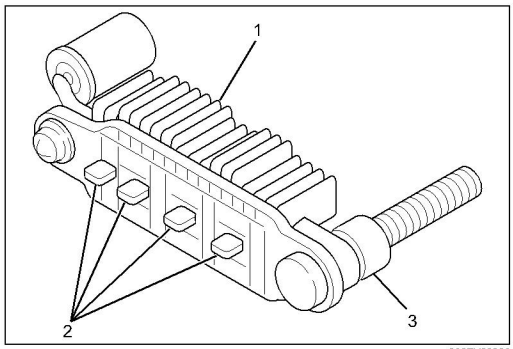
Note:
It is recommended that inspection be made with the bearing fitted to the rotor shaft.Coil Assembly

Coil

Use an ohmmeter to measure the coil resistance between both terminals (1) and the terminal plate (2). Replace the coil assembly if the resistance is outside the specifications.

Coil resistance at 20°C

4.5 – 5.2 ohms



Rectifier

(1) Positive diode
(2) Diode terminals
(3) A part of negative diode

1. Use a circuit tester to test for continuity between each diode terminal (2) and the positive heat sink. Test in both directions.
   If there is continuity and/or an open circuit in both directions, the rectifier must be replaced.
2. Use a circuit tester to test for continuity between each diode terminal (2) and the negative heat sink. Test in both directions.
   If there is continuity and/or an open circuit in both directions, the rectifier must be replaced.
3. Check the diode trio for continuity in both directions.
   If there is continuity and/or an open circuit in both directions, the rectifier must be replaced.

Front bracket

Turn the bracket. Listen for bearing noise (a scraping sound). Feel for rough rotation. Replace the bracket if either of these conditions is present.
Check for grease leakage. If leakage is minimal, wipe it away. If leakage is excessive, replace the bracket.

Regulator

The regulator cannot be checked in the absence of the other components. Check regulator operation after alternator reassembly.

REASSEMBLY

Follow the disassembly steps in the reverse order.
Note the following precautions.

- No lubrication is required. Bearings are prelubricated.
- Wipe away any grease leakage from the bearing area.
- Use high-temperature solder (melting point of 230°C).
- Use a 180 – 280 watt soldering iron to solder the leads as quickly as possible. Do not apply the soldering iron for more than 5 seconds. Diode damage will result.
- Bracket, rotor, and stator reassembly is difficult because of the tight fit of the components. To make reassembly easier, heat the area around the rear bracket bearing box to approximately 55°C.
- Check that the rotor turns smoothy after alternator reassembly.

Tightening torques

Pulley fixing nut: 147 N·m (15 kgm/108 lbft)

Through bolts: 5.1 N·m (0.52 kgm/3.8 lbft)

Bearing retainer screws: 3.6 N·m (0.37 kgm/ 2.7 lbft)

Coil retaining screws: 3.6 N·m (0.37 kgm/2.7 lbft)

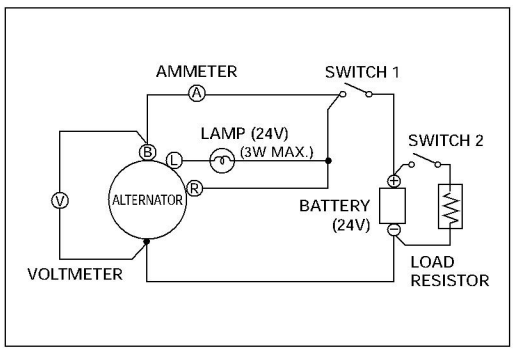
Rectifier retaining screws: 3.6 N·m (0.37 kgm/ 2.7 lbft)

Regulator retaining screws: 3.4 N·m (0.35 kgm/ 2.5 lbft)

Nuts for stud bolts: 8.8 N·m (0.9 kgm/6.5 lbft)

Bench testing

Perform bench tests on the reassembled alternator.



Voltage regulation

1. Make connections as shown in the illustration on the following page. Use an ammeter with a scale of 0 – 100 amperes and voltmeter with a scale of 0 – 30 volts.
2. Close switch 1 and open switch 2. The lamp should light.
   If the lamp does not light, check the voltage at terminal-L.
   If the voltage is nearly equal to battery voltage (24V), check the alternator.
   If the voltage is low, check for an open lamp and related circuitry.
3. Slowly increase alternator speed.
   The lamp should turn off as alternator speed approaches 1,300 min^{-1}.
4. Check the voltage as alternator speed increases.
   If the voltage fluctuates wildly during alternator speed increase and rises above 30 volts, the IC regulator is probably defective.
   If the voltage does not exceed battery voltage (24V), the alternator is defective (no generation of electricity). Check alternator components again.

5. Increase alternator speed to approximately 5000 min^{-1}.
6. Note the ammeter reading.
   If the reading is 5 amperes or less, note the voltmeter reading (be sure that alternator speed remains constant). This is the regulated voltage.
   If the reading is more than 5 amperes, continue to operate the ammeter at 5000 min^{-1} until the reading falls to 5 amperes or less.
   If the reading does not fall, replace the battery.
   If the reading still does not fall, the alternator is defective and must be repaired or replaced.

Current output

1. Operate the alternator at minimum speed.
2. Close switch 1. Check that the lamp lights.
3. Set the load resistor to its maximum resistance (minimum current).
4. Close switch 2.
5. Increase the alternator speed to a constant 5,000 min^{-1}.
6. Adjust the load resistor for maximum current output.
7. Allow the alternator to run for 15 minutes. Output should increase as alternator temperature increases.
8. Once again, adjust the load resistor for maximum current output.
   The maximum current output must equal the specified value. If it does not, the alternator must be rechecked.

Alternator output

50 amp/27 volt/5,000min^{-1}

TROUBLESHOOTING

Condition	Possible Cause	Correction
No output	Bad terminal connection	Repair
	Open or shorted circuit	Repair
	Open field coil	Replace
	Defective diode	Replace
	Defective IC regulator	Replace
Low output	Loose terminal connection	Tighten
	Loose cooling fan belt	Adjust belt tension
	Defective diode	Replace
	Shorted field coil	Replace
	Shorted stator coil	Replace
	Defective regulator	Replace
	Defective battery	Replace
	Poor terminal contact	Repair
Overcharging	Defective regulator	Replace
	Defective battery	Replace
Unstable current	Poor terminal contact	Repair
	Loose cooling fan belt	Adjust belt tension
	Short field coil	Replace
	Shorted stator coil	Replace
	Intermittent contact in wiring	Replace
	Poor terminal contact	Repair
	Defective regulator	Replace
Abnormal noise	Improper alternator installation	Correct
	Defective bearing	Replace
	Contact between the rotor core and stator core	Replace the rotor core and/or stator core
	Defective diode	Replace
	Shorted stator coil	Replace

MEMO

CHAPTER 11

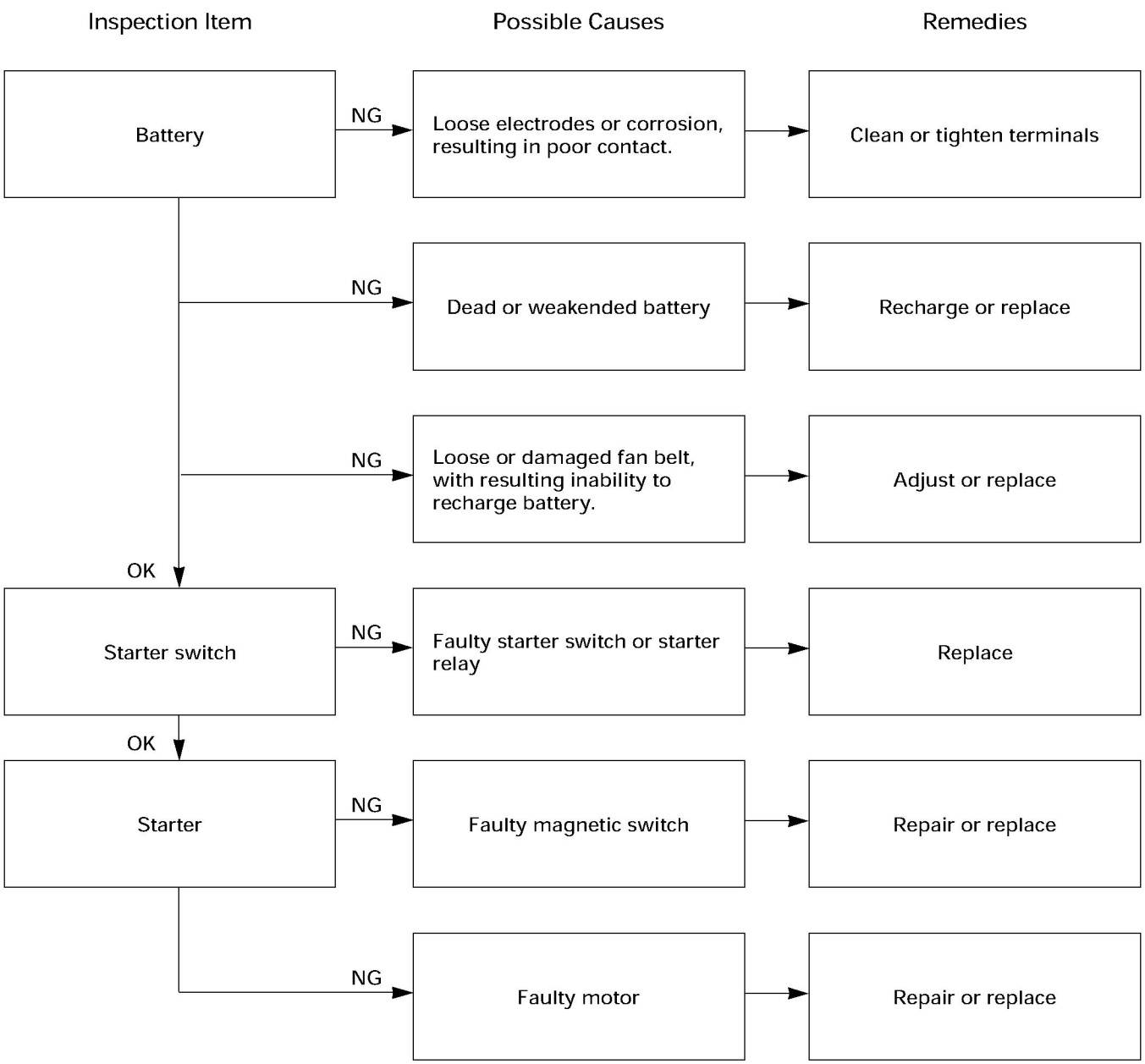
TROUBLESHOOTING

CONTENTS

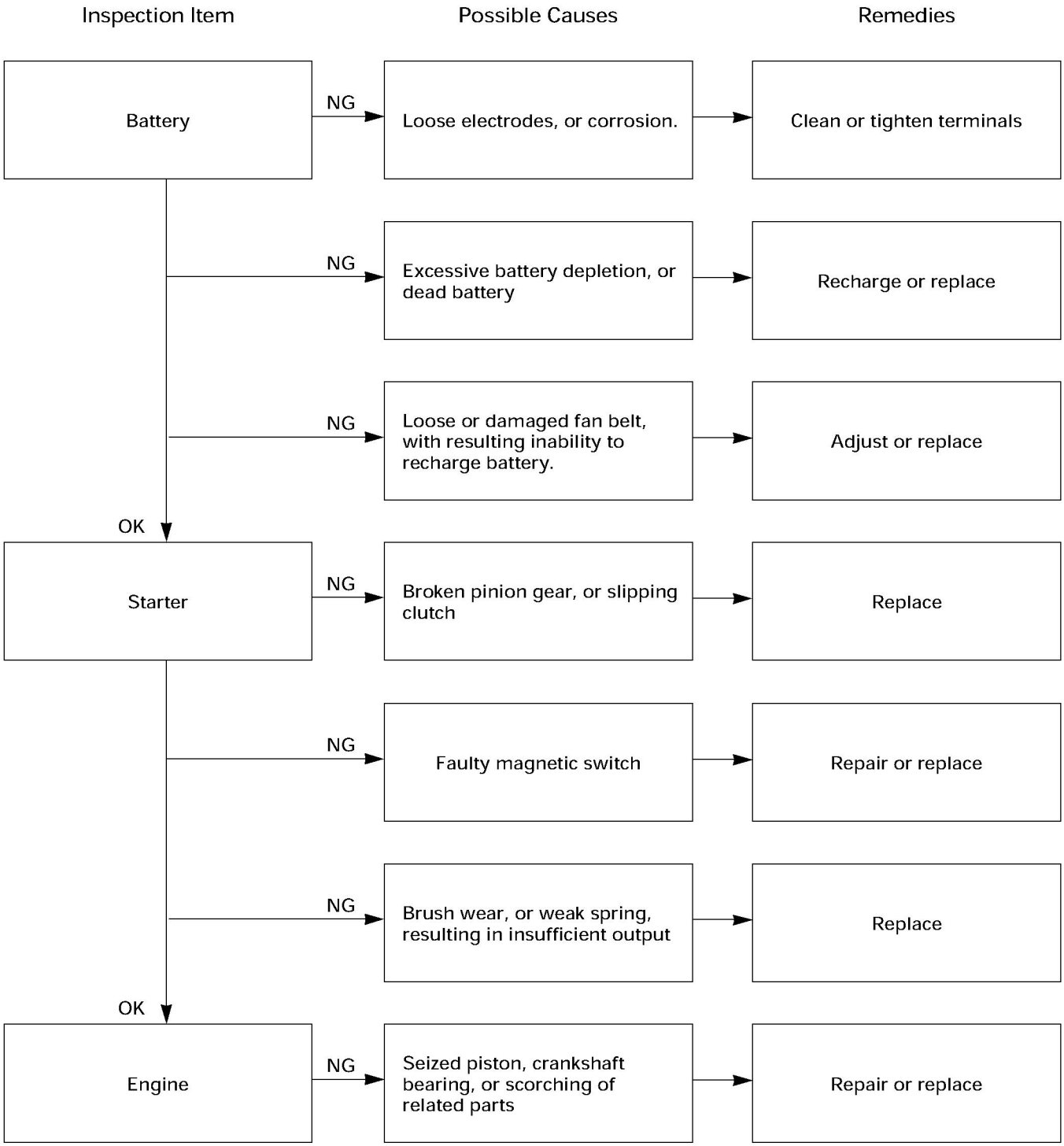
Comments:
This chapter has been prepared to provide quick guidance for responding to common engine problems. Each troubleshooting column is explained in the following topical order, from left to right:
(1) Inspection items (2) Possible Causes (3) Remedies

STARTING DIFFICULTIES

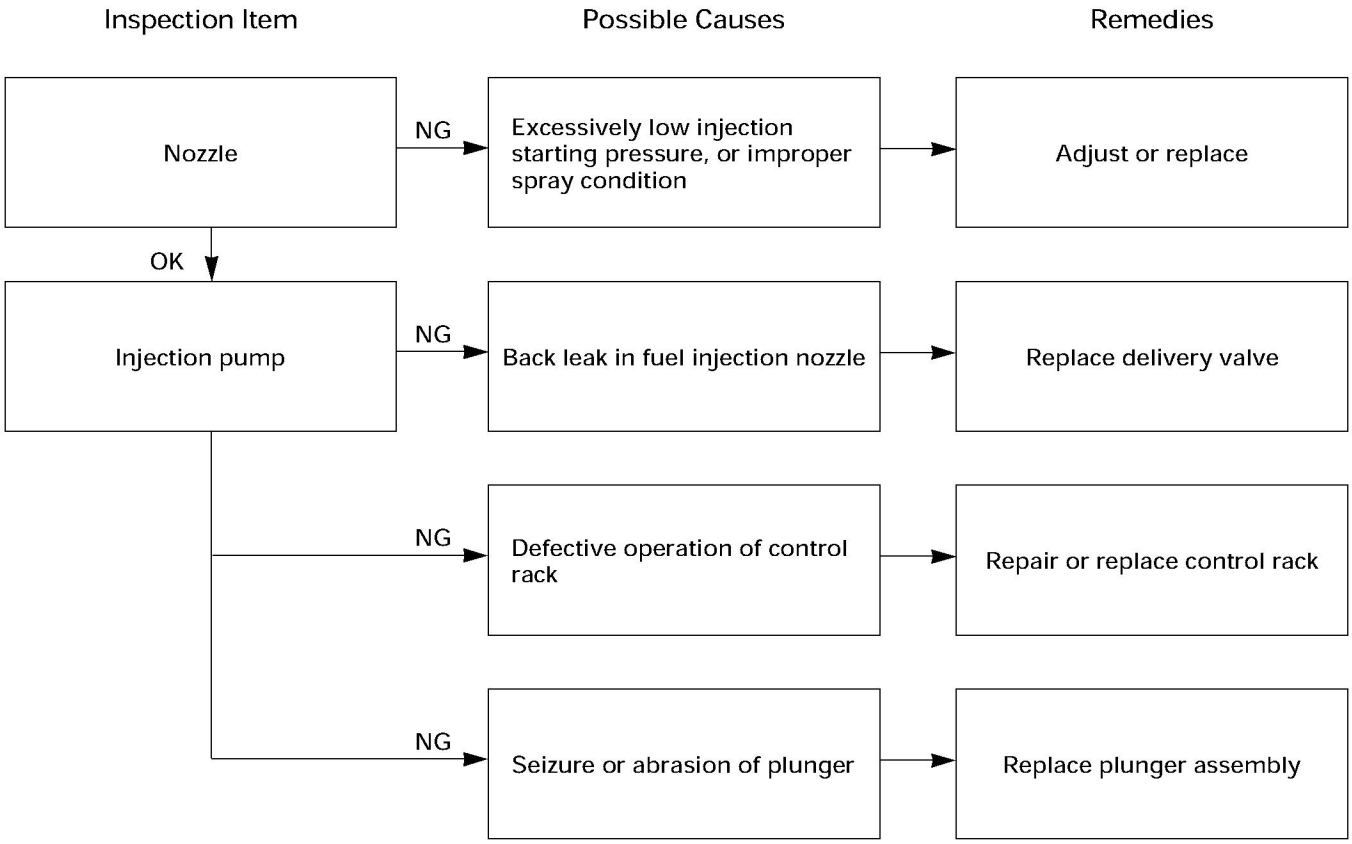
1. Starter doesn't turn



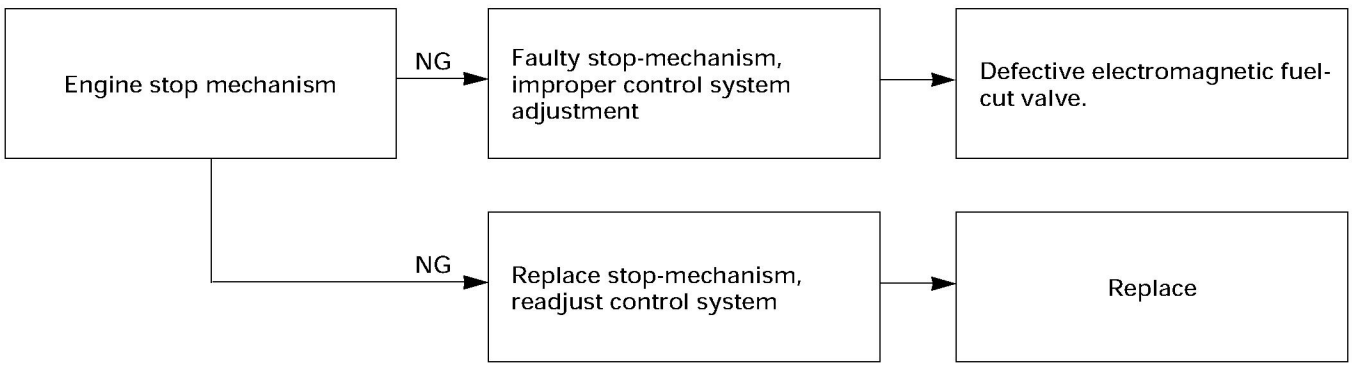
2. Starter turns, but engine doesn't turn



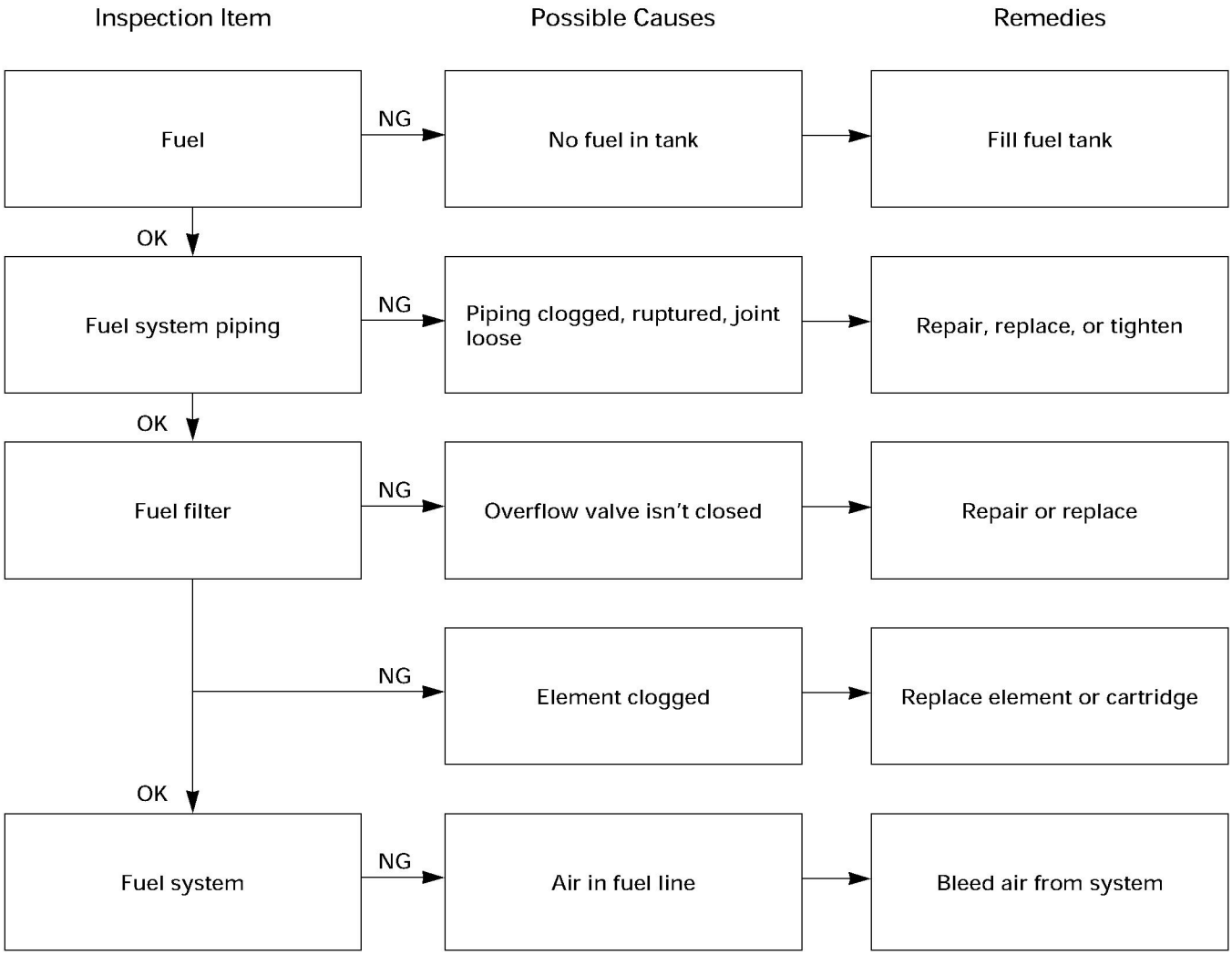
3. The engine turns and fuel reaches the injection pump, but it doesn't start



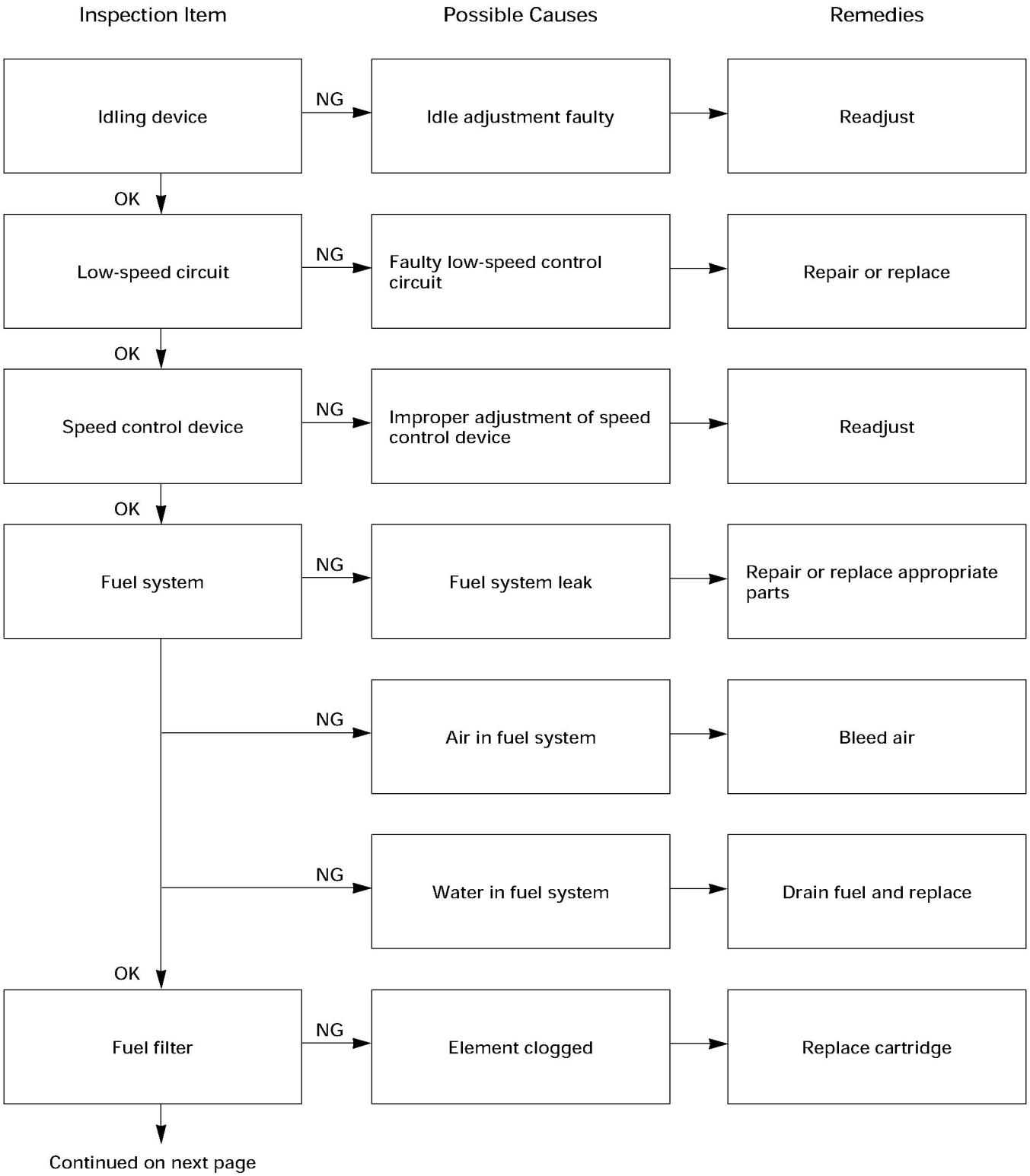
4. The engine turns, but doesn't start

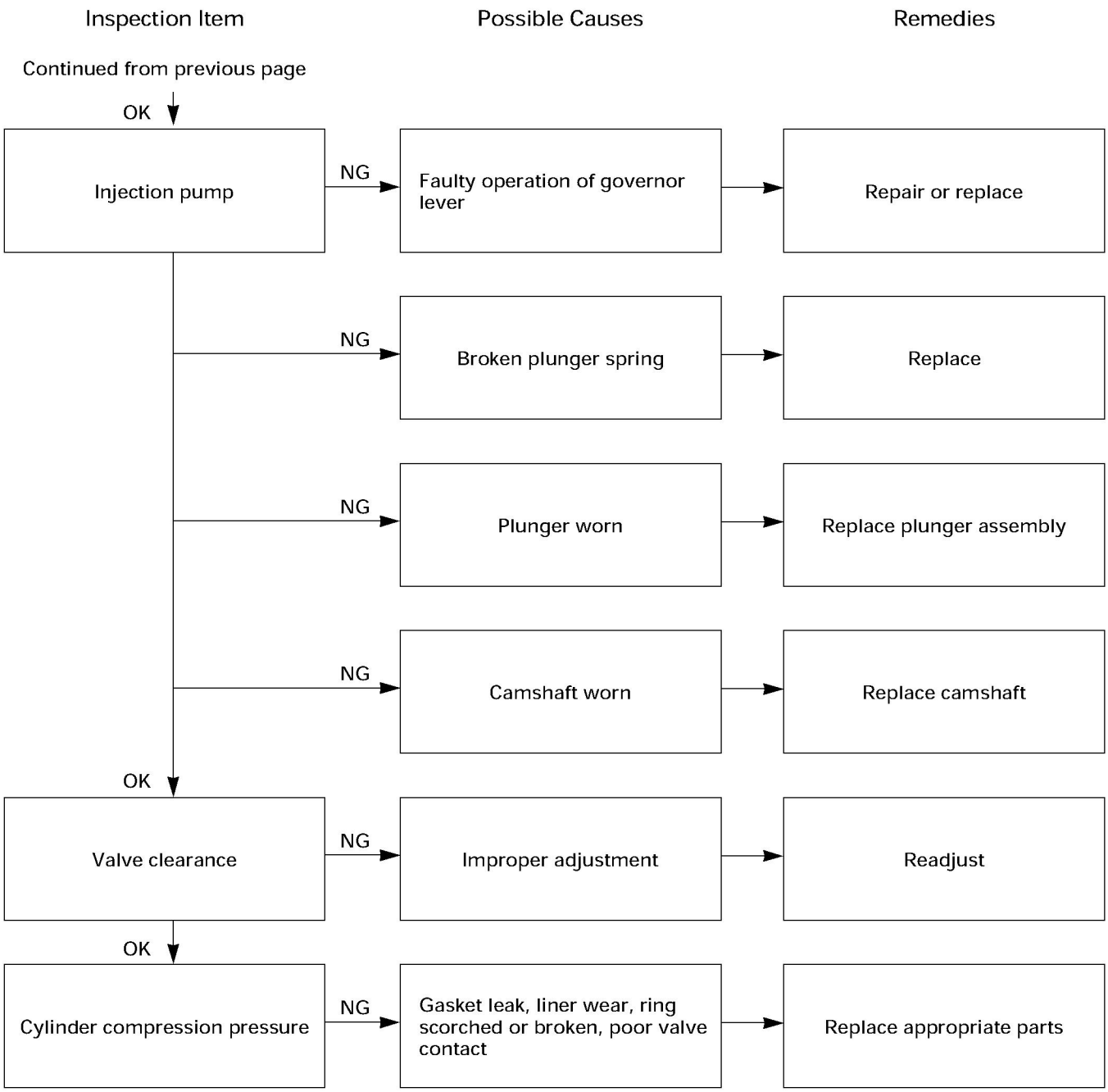


5. Fuel isn't supplied to the injection pump

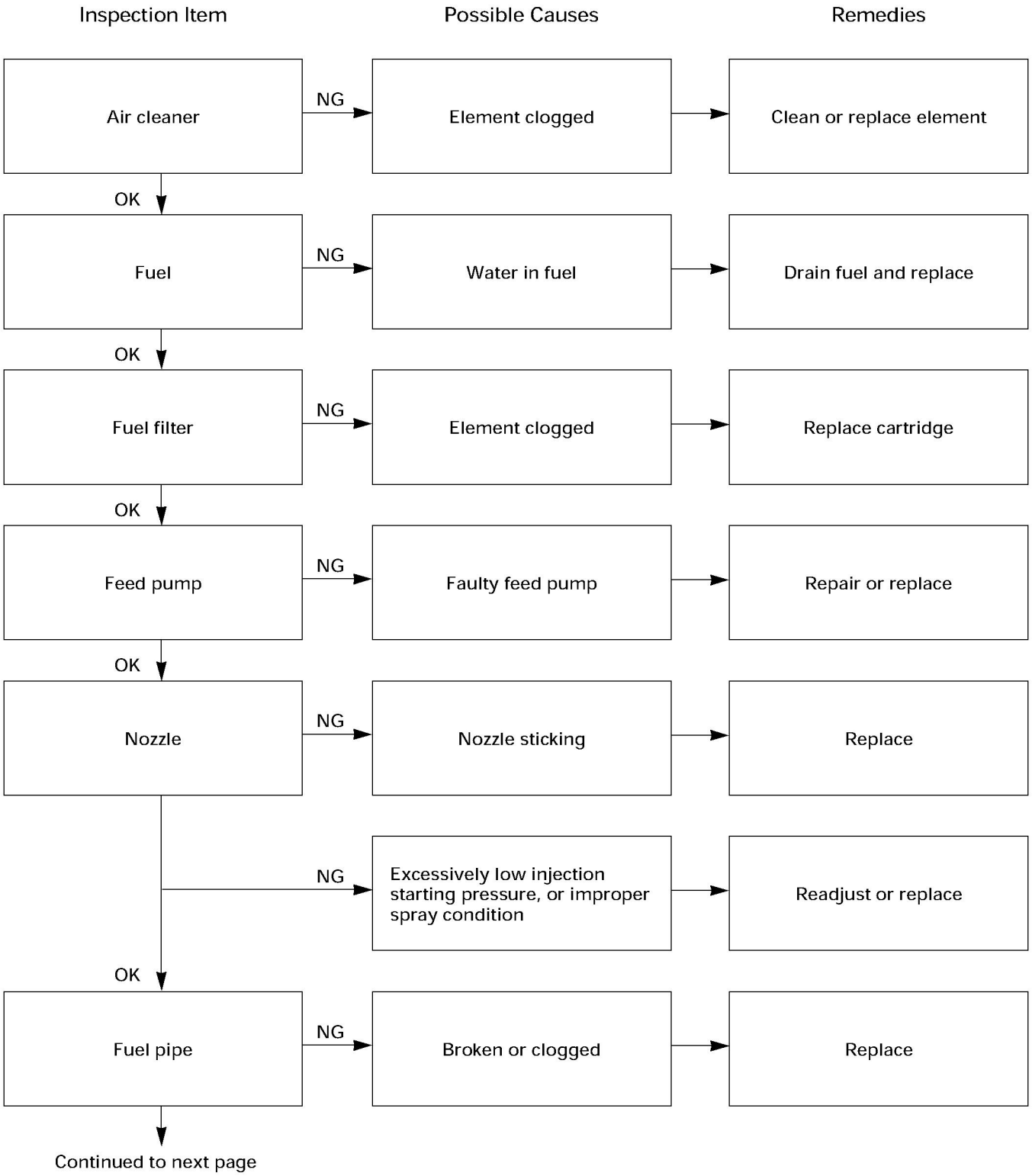


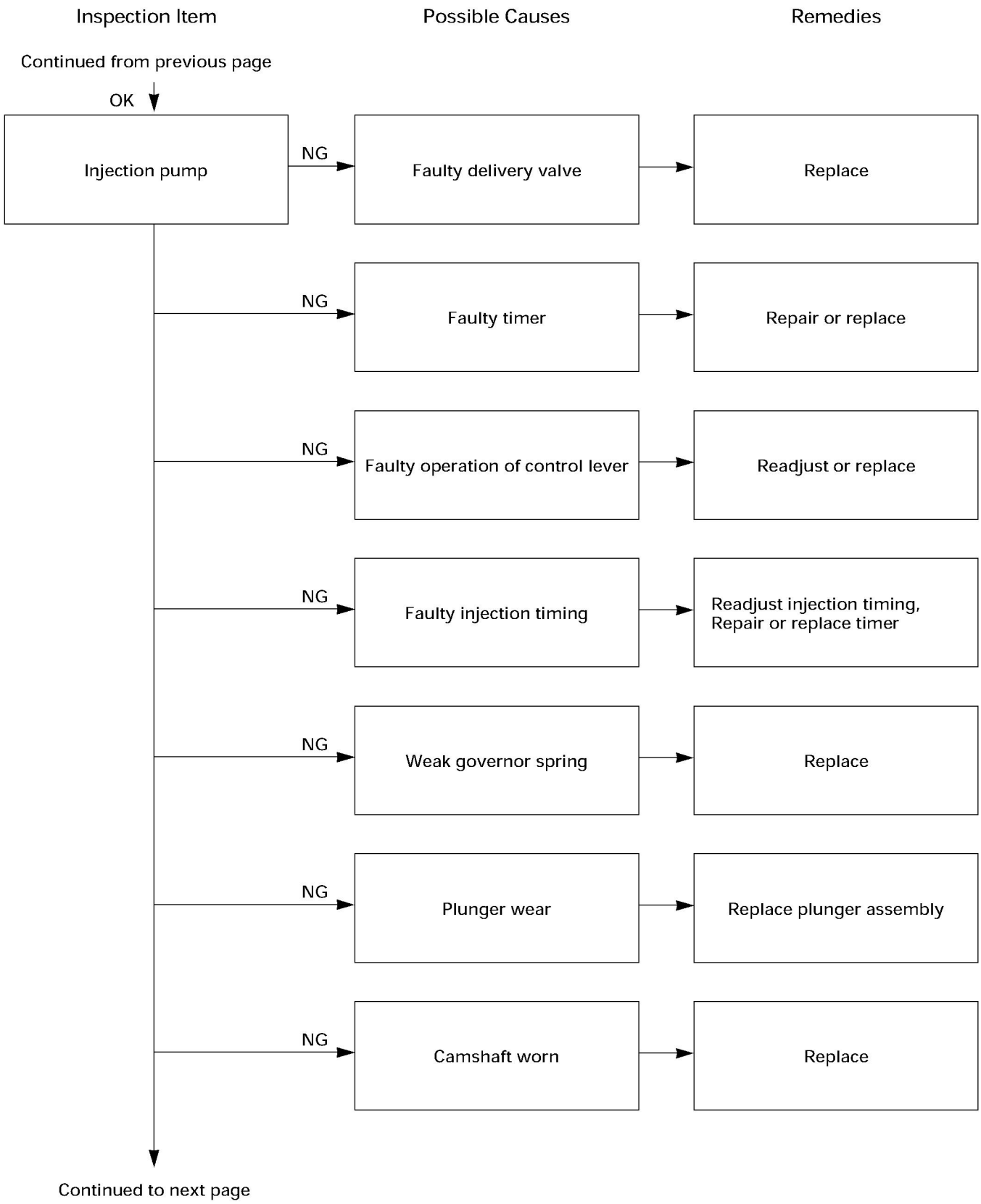
UNSTABLE IDLING RPM

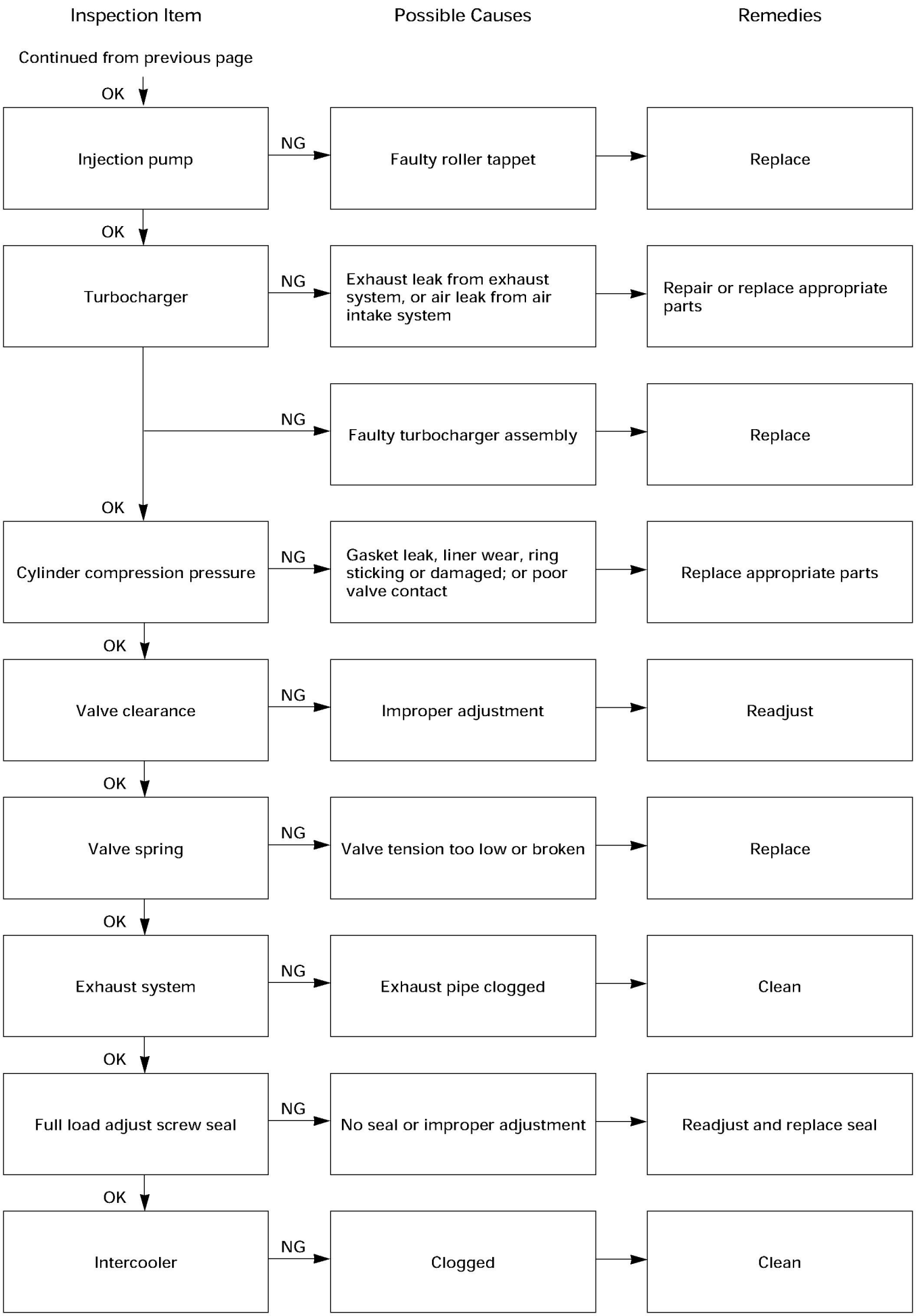



Inspection Item
Possible Causes
Remedies
Continued from previous page
OK
Injection pump
NG
Faulty operation of governor lever
Repair or replace
NG
Broken plunger spring
Replace
NG
Plunger worn
Replace plunger assembly
NG
Camshaft worn
Replace camshaft
OK
Valve clearance
NG
Improper adjustment
Readjust
OK
Cylinder compression pressure
NG
Gasket leak, liner wear, ring scorched or broken, poor valve contact
Replace appropriate parts

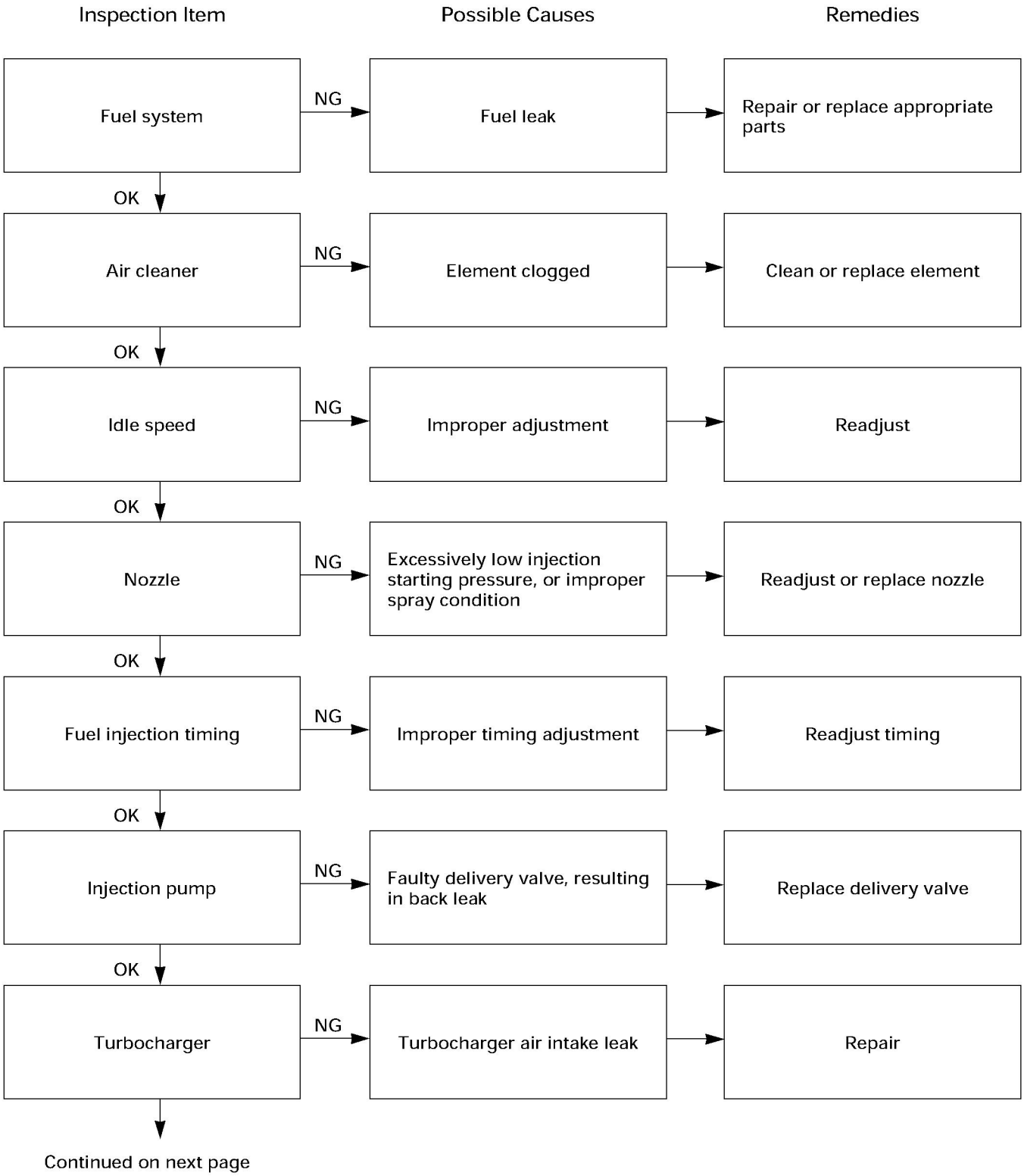
LACK OF POWER




Inspection Item
Possible Causes
Remedies
Continued from previous page
OK
Injection pump
NG
Faulty delivery valve
Replace
NG
Faulty timer
Repair or replace
NG
Faulty operation of control lever
Readjust or replace
NG
Faulty injection timing
Readjust injection timing,
Repair or replace timer
NG
Weak governor spring
Replace
NG
Plunger wear
Replace plunger assembly
NG
Camshaft worn
Replace
Continued to next page


Inspection Item
Possible Causes
Remedies
Continued from previous page
OK
Injection pump
NG
Faulty roller tappet
Replace
OK
Turbocharger
NG
Exhaust leak from exhaust system, or air leak from air intake system
Repair or replace appropriate parts
NG
Faulty turbocharger assembly
Replace
OK
Cylinder compression pressure
NG
Gasket leak, liner wear, ring sticking or damaged; or poor valve contact
Replace appropriate parts
OK
Valve clearance
NG
Improper adjustment
Readjust
OK
Valve spring
NG
Valve tension too low or broken
Replace
OK
Exhaust system
NG
Exhaust pipe clogged
Clean
OK
Full load adjust screw seal
NG
No seal or improper adjustment
Readjust and replace seal
OK
Intercooler
NG
Clogged
Clean

EXCESSIVE FUEL CONSUMPTION



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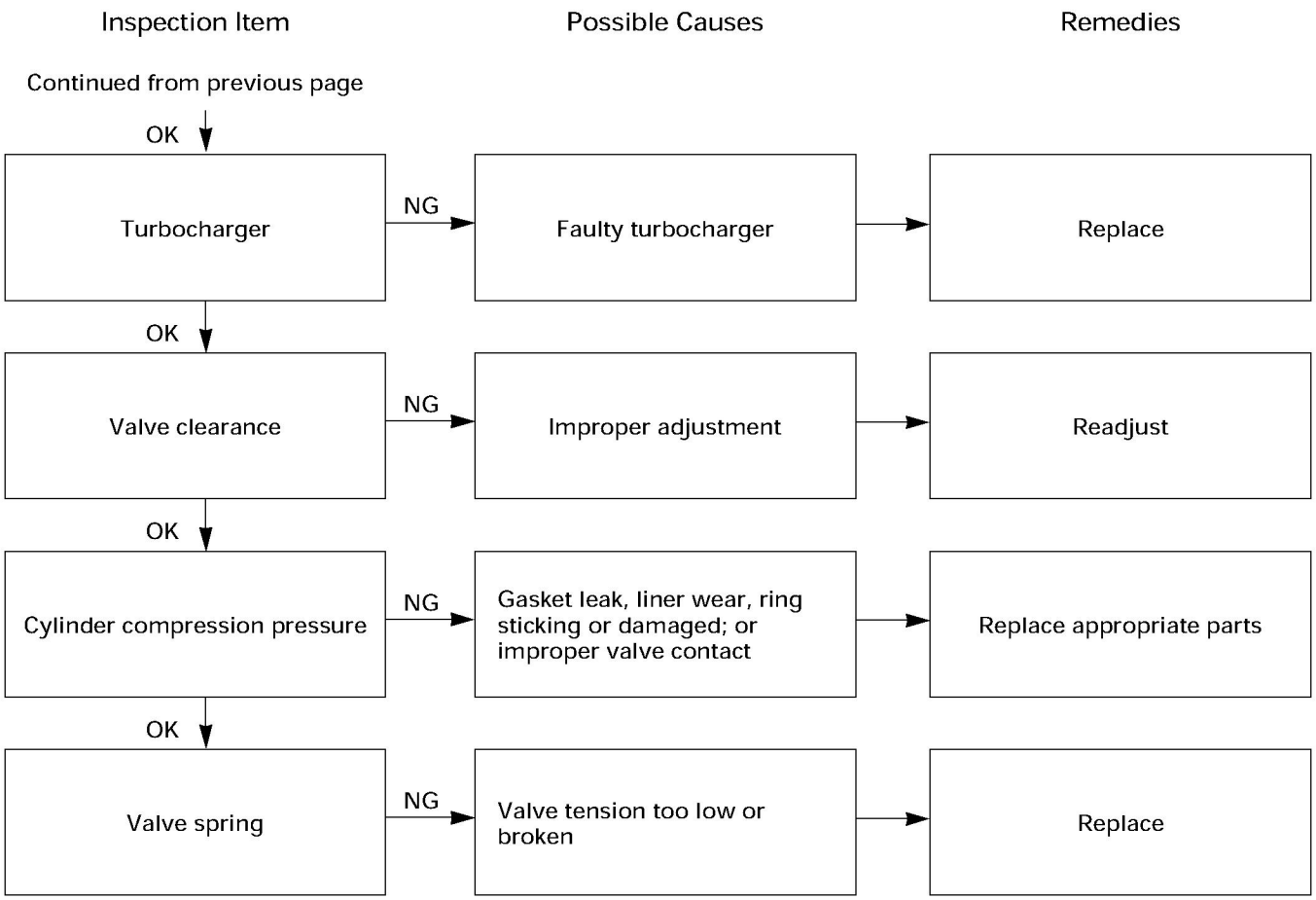
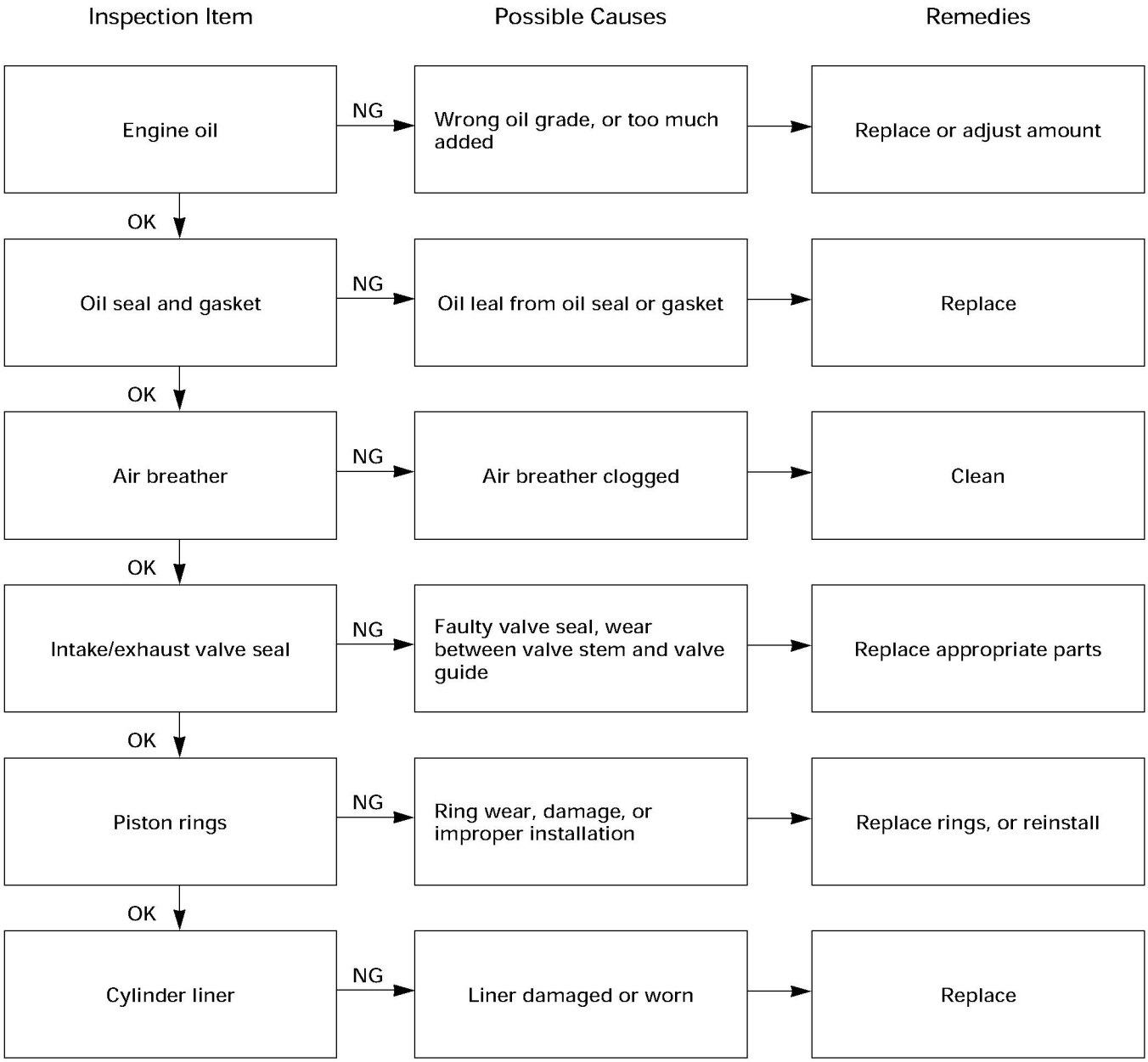
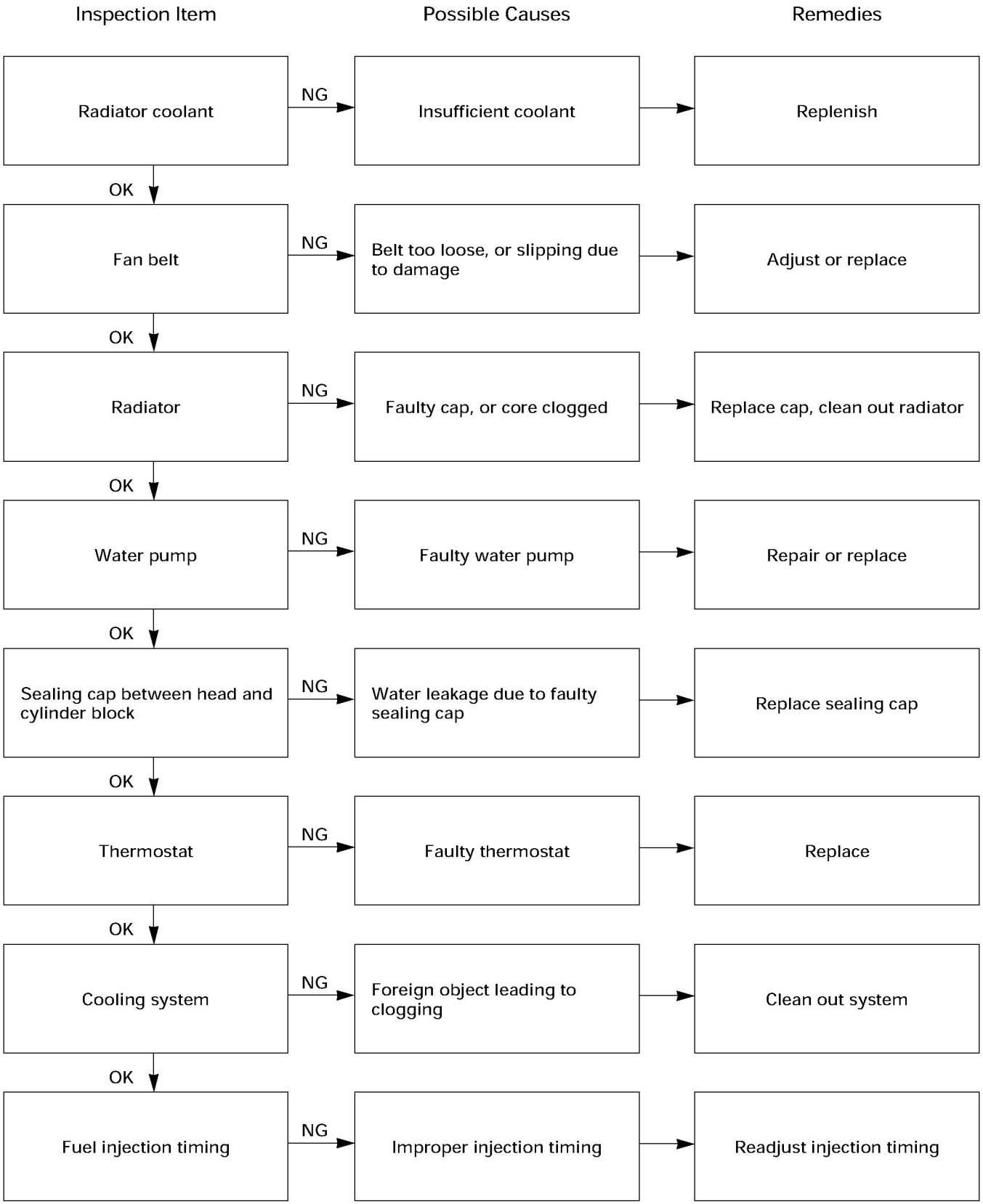

Inspection Item
Possible Causes
Remedies
Continued from previous page
OK
Turbocharger
NG
Faulty turbocharger
Replace
OK
Valve clearance
NG
Improper adjustment
Readjust
OK
Cylinder compression pressure
NG
Gasket leak, liner wear, ring sticking or damaged; or improper valve contact
Replace appropriate parts
OK
Valve spring
NG
Valve tension too low or broken
Replace

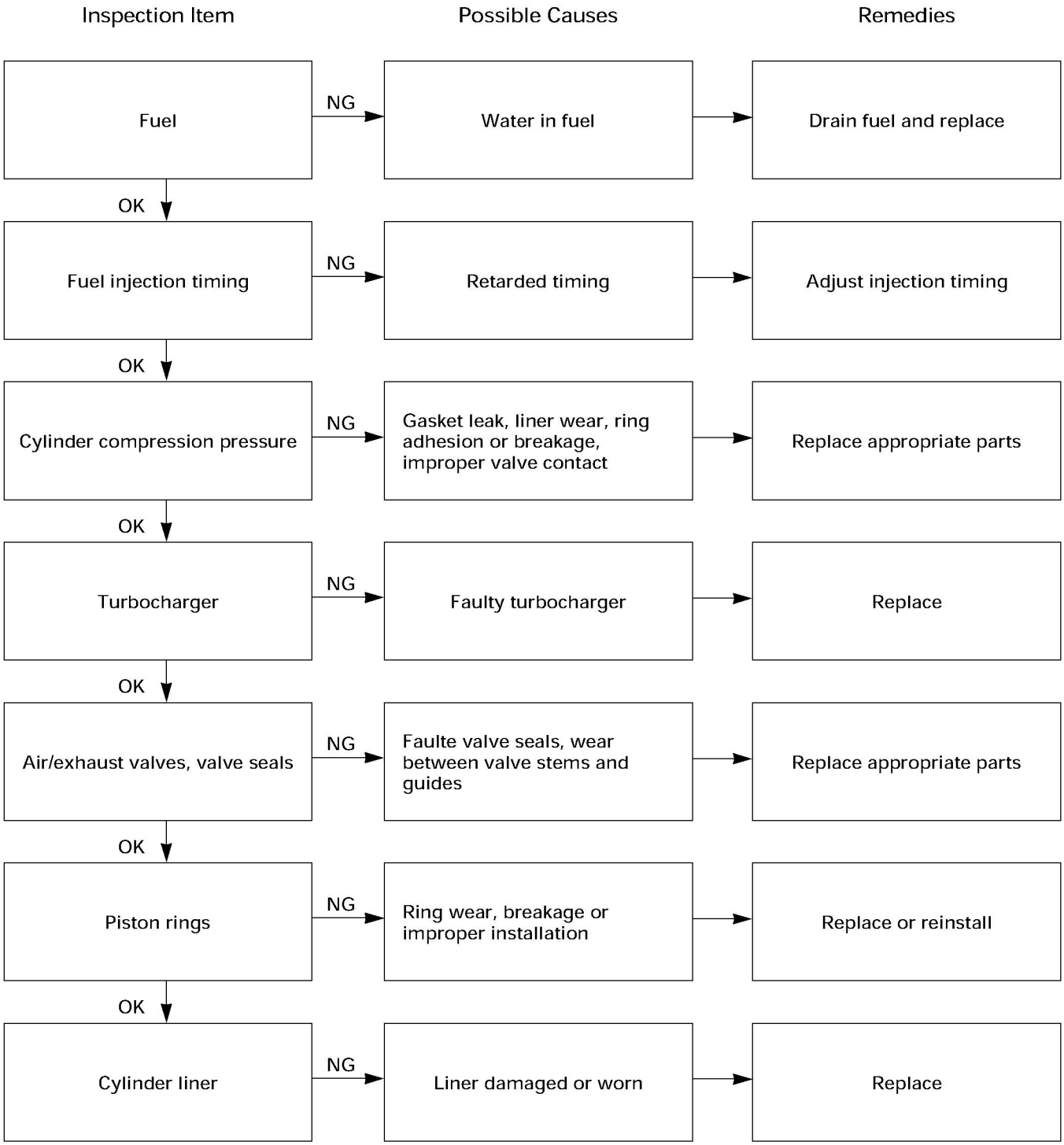
EXCESSIVE OIL CONSUMPTION



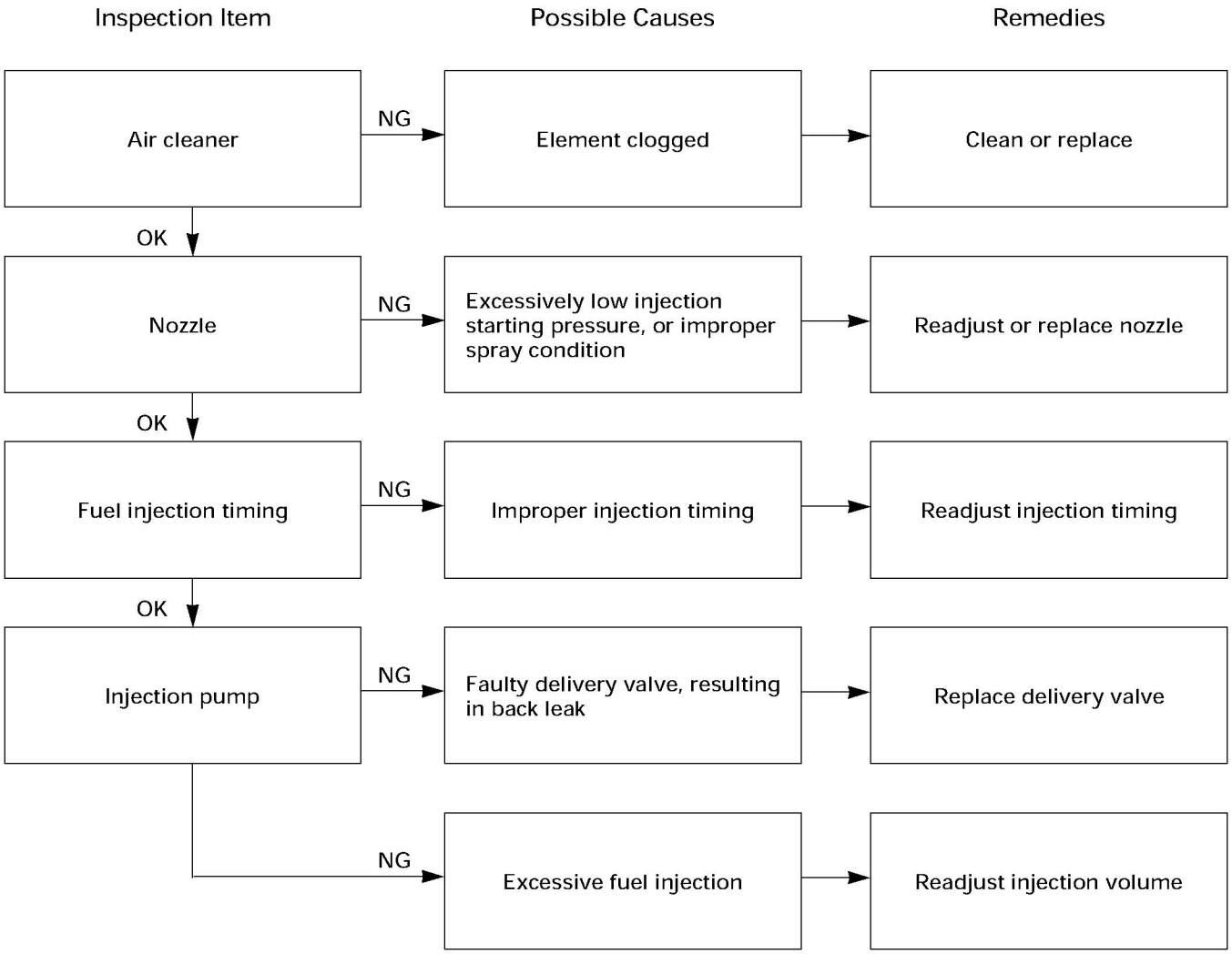
OVERHEATING



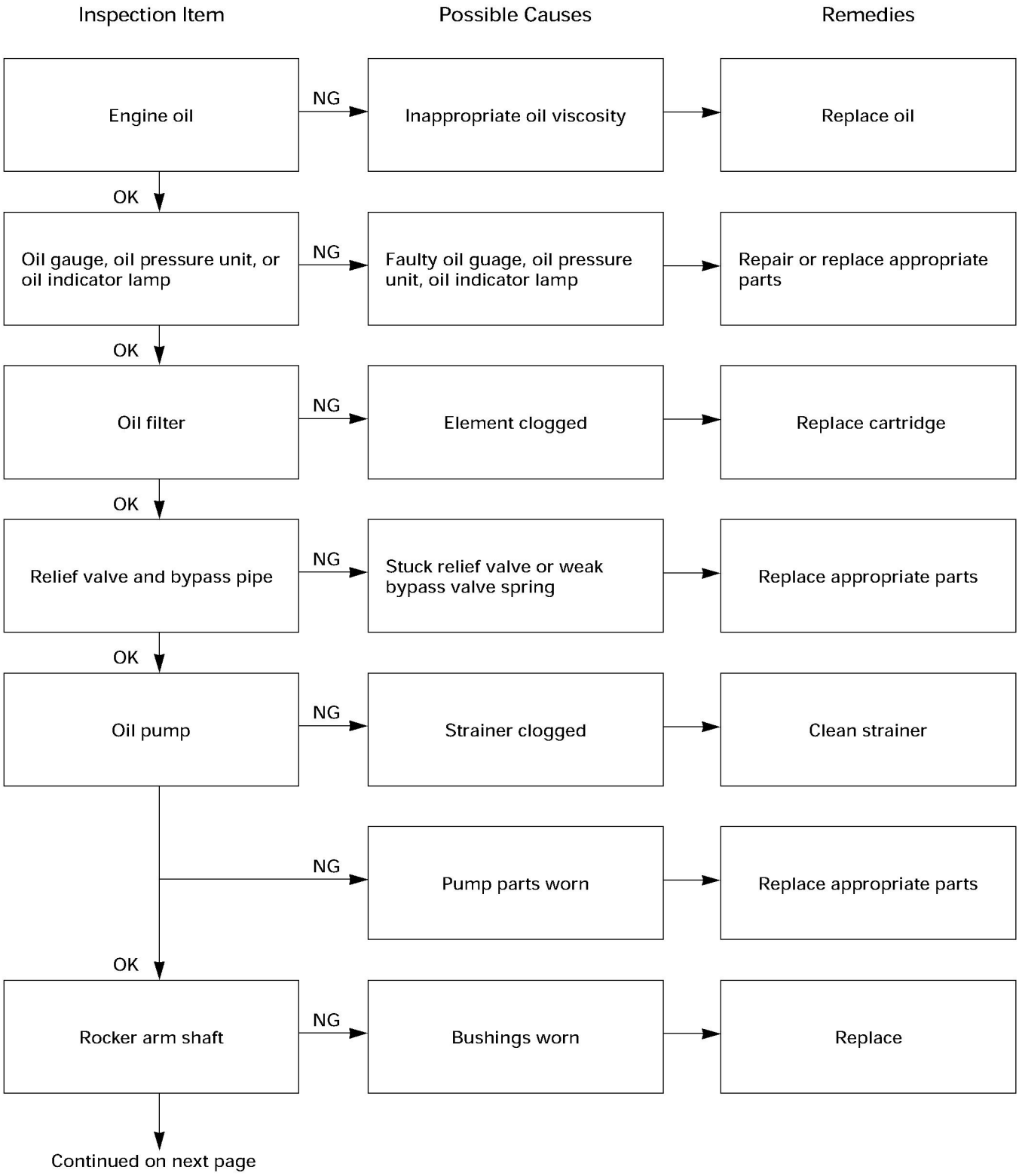
WHITE SMOKE IN EXHAUST

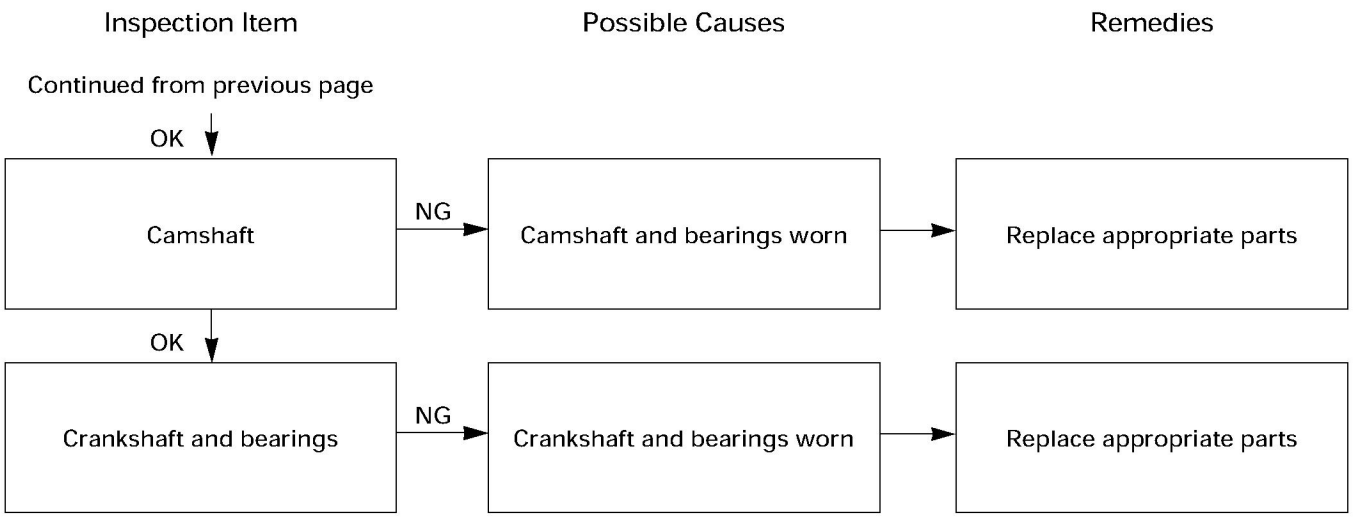


BLACK SMOKE IN EXHAUST



LOW OIL PRESSURE



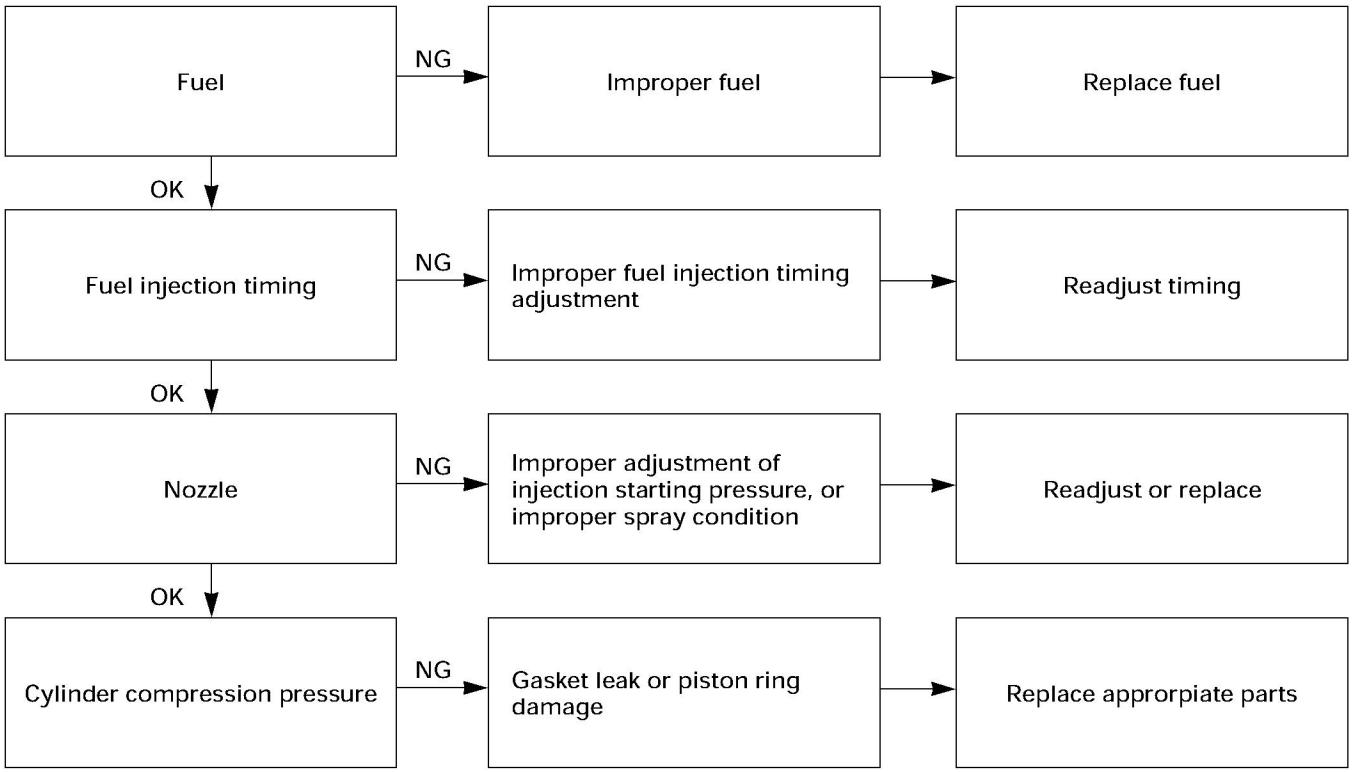

Inspection Item
Possible Causes
Remedies
Continued from previous page
OK
Camshaft
NG
Camshaft and bearings worn
Replace appropriate parts
OK
Crankshaft and bearings
NG
Crankshaft and bearings worn
Replace appropriate parts

ENGINE SOUNDS

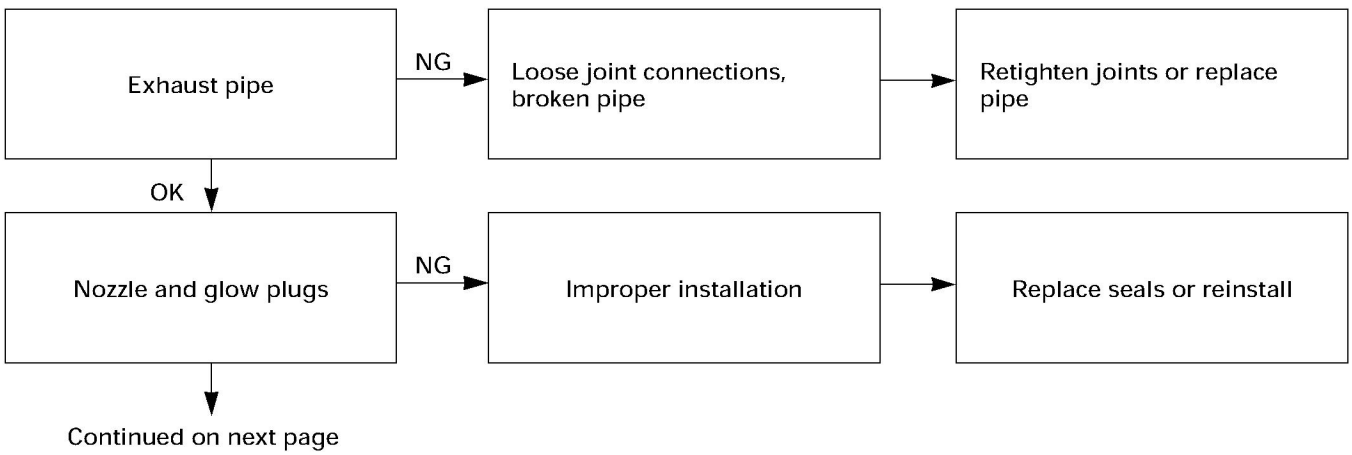
1. Knocking

Inspection Item | Possible Causes | Remedies

Before beginning inspections and repairs, be sure the engine is fully warmed up



2. Gas leak sounds



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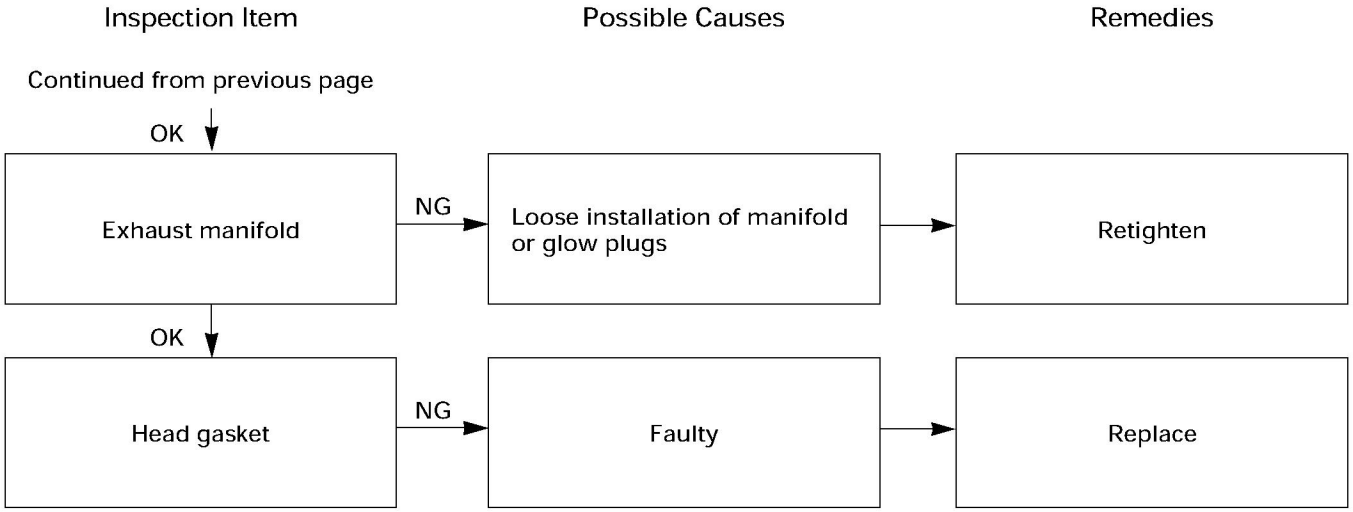
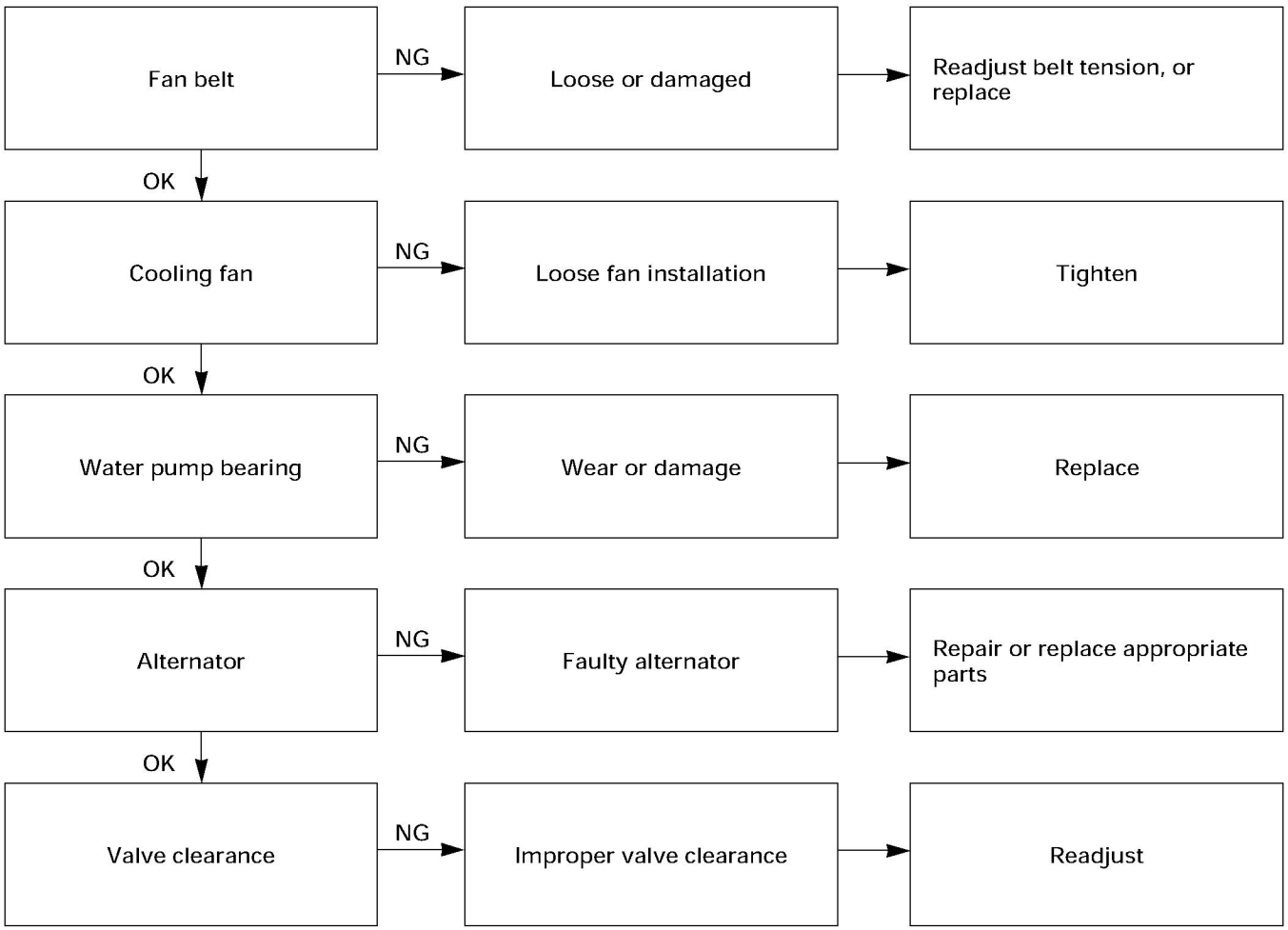
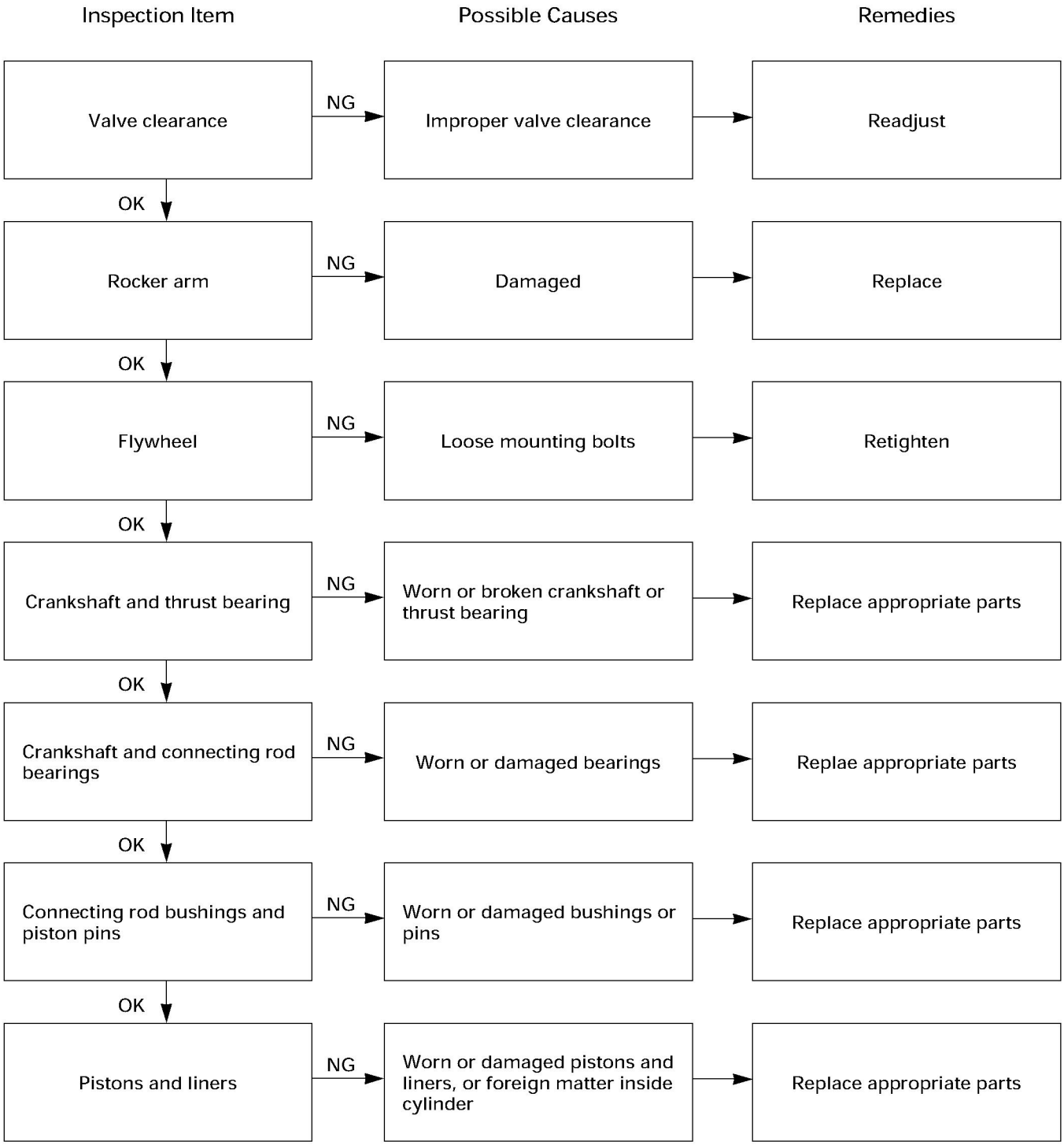


3. Continuous sounds



4. Clanking sounds



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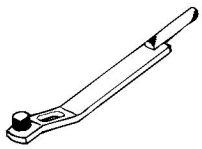
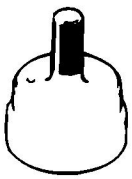
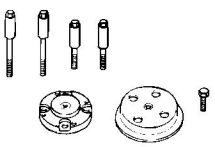
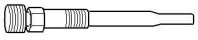
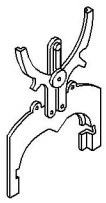
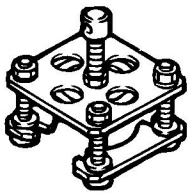
CHAPTER 12

SPECIAL TOOLS

CONTENTS

SPECIAL TOOLS LIST

Item No.	Illustration	Part Number	Part Name	Page
1		1-85235-007-0	Valve spring compressor	50
2		9-8523-1202-2	Valve guide remover	57
3	 901LX053	1-85231-016-0	Cylinder liner remover	67
4		1-85221-073-0	Cylinder liner installer	69
5		1-85221-072-0	Crankshaft gear installer	82
6		1-85220-052-0	Oil seal remover	83 84
7		1-85220-057-0	Oil seal installer	83 84
8	 901HY00127	5-85317-001-0	Compression gauge adapter	34

Item No.	Illustration	Part Number	Part Name	Page
9		1-85221-029-0	Piston ring replacer	53 93
10	 901HY00148	1-85221-075-0	Drive gear installer	82
11		1-85210-051-0	Crank gear remover	82

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CHAPTER 13

REPAIR STANDARDS

General Rules

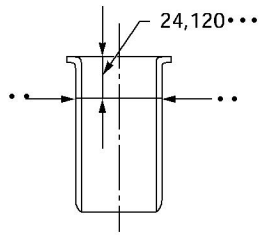
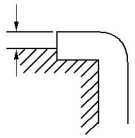
1. These tables provide standards relating the repair of the following diesel engine;

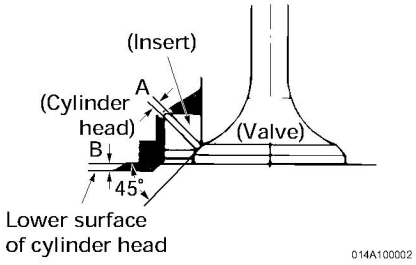
   Model AA-6SD1T (turbocharged)

2. These Repair Standards are based on inspection items, together with dimensions, assembly standards, limit values, and repair procedures.
   (1) Nominal dimensions are the standard production values.
   (2) Assembly standards considered to be the values used as objectives during the assembly procedures which follow repairs; as a result, they may be somewhat at variance with the assembly dimensions of a new engine.
   (3) Limit values refer to the measured values resulting from wear, etc., beyond which a part must not be used. If a measured value falls beyond the limit value, the part involved must be repaired or replaced.
   (4) "Repair Procedures" indicates normal repair methods.
   (5) Unless otherwise stated, the unit of numerical values in tables should be taken to refer to millimeters (mm).

3. Explanation of Terms Used in Tables
   (1) The dimension of "wear" refers to the difference between the dimensions of a part which is not worn (or the "nominal dimension" of a part without wear) and the dimension of the part suffering from the most wear (the dimension of the worn part).
   (2) Uneven wear means the difference between the maximum and minimum wear values.

4. When repairs are requested on the overall engine, first perform bench tests to determine what parts require repairs, then perform the minimum disassembly and repairs required to correct the problems. When repairs on a specific engine part are requested, repairs to be made in reference to the relevant items in accordance with the repair standards listed in this manual.

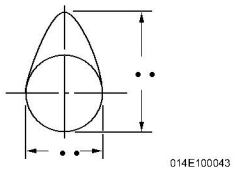
Major Category	Name of Part	Inspection Item	Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Time for engine disassembly and repair		Cylinder compression pressure MPa (kgf/cm^2)	2.84 (29) or more		2.06 (21) or less	Disassemble and repair engine	Water temperature 70 – 85°C, engine speed 220 rpm (varies depending on altitude)
		Fuel consumption ℓ/h	100%		140%		New engine performance is assumed 100%
		Lubricating oil consumption cc/h	100%		200%		
Engine Body	Cylinder Block	Wear on liner bore Measured at A–A  012E100029	Dia. 120		Dia 120.3	Upper step wear must be repaired, or replace with standard dimension liner	(Ref) Cylinder & liner interference 0.011 – 0.029
		Liner projection  012E100030		0.106 – 0.134		Some projection must be present	Difference in liner projection between neighboring cylinders not to exceed 0.02
		Cylinder block upper face warpage		0.05 or less	0.2 or more	Not repairable; must be replaced	
		Pressure test: 3 minutes kPa (kgf/cm^2)		490 (5)		Leaks require repair or replacement	

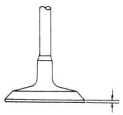
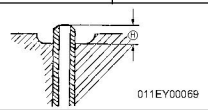
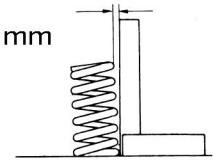
Major Category	Name of Part	Inspection Item	Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Engine Body	Cylinder Head	Valve seat depression: B (both inlet and exhaust)  		Inlet side 0.48	1.48 or more	Replace insert	Valve seat angle: α Inlet side 30° Exhaust side 45°
				Exhaust side 1.60	2.60 or more		
		Contact width with valve seat: A		Inlet side 2.7	3.5 or more	Repair with valve seat cutter	After repair, be sure to lap contact surfaces
				Exhaust side 2.4	3.2 or more		
		Warpage and flatness of cylinder head lower face (mounting surface)		0.05 or less	0.2 or more	Cannot be repaired: must replace cylinder head	
		Warpage of manifold mounting surface		0.05 or less	0.4 or more	repair	
		Water-pressure test, 3 minutes kPa (kgf/cm^2)		490 (5)		Leaks require repair or replacement	
		Cylinder head bolts tightening torque (angular tightening method) N·m (kgf-m)		M10 bolts 31 – 45 (3.2 – 4.6)		• Clean bolt mounting surfaces and threads, and apply molybdenum disulfide grease. • Never tighten again after using angular tightening method. • Reuse bolts max. 2 times	Tighten M14 bolts to 98.0 N·m (10 kgf·m) then to 147 N·m (15 kgf·m). Next, use angular method to additionally tighten to 30°– 60° rotation.

Major Category	Name of Part	Inspection Item		Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Main Operating Parts	Pistons	Clearance with cylinder: grade position from upper face 98 mm			Clearance with major axis 0.131 – 0.175			
		Piston pin and piston pin hole clearance			0.004 – 0.017	0.05 or more	Replace piston or piston pin	
		Pin wear		Dia. 43		Dia. 42.98 or less	Replace piston pin	
	Cylinder Head	Piston Ring Gap	No. 1 compression ring		0.35 – 0.50	1.0 or more	Replace rings when performing engine disassembly and repair	Gauge inner standard diameter 120
			No. 2, 3 compression ring		0.35 – 0.50			
			Oil ring		0.25 – 0.45	0.8 or more		
		Tension N (kgf)	No. 1 compression ring		24.1 – 31.8 (2.46 – 3.24)	14.7 or less (1.5)	Replace	Measure with ring compressed to standard ring gap.
			No. 2 compression ring		15.4 – 21.3 (1.57 – 2.17)	9.8 (1.0) or below		
			No. 3 compression ring		17.7 – 24.5 (1.80 – 2.50)	11.8 (1.2) or below		
			Oil ring		53.9 – 73.5 (5.5 – 7.5)	37.3 (3.8) or below	Replace	Measure with expander attached
		Clearance between piston ring and ring groove	No. 1 compression ring		0.105 – 0.14	0.20 or more	Replace rings or piston	When assembling compression rings on piston, be sure ring's marked surface is up. Backwards installation will result in excessive oil consumption. No top/bottom to oil ring.
			No. 2 compression ring		0.105 – 0.14	0.20 or more		
			No. 3 compression ring		0.085 – 0.120	0.20 or more		
			Oil ring		0.02 – 0.06	0.15 or more		
		Ring gap orientation					At 120° intervals	

Major Category	Name of Part	Inspection Item	Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Main Operating Parts	Crankshaft	Uneven wear on journal and pins	Dia. 90 Dia. 80	0.001	0.05 or more	Replace	Do not attempt to grind: always replace with new parts
		Journal wear	Dia. 90		Dia. 89.909 or less	Replace	
		Pin wear	Dia. 80		Dia. 79.894 or less	Replace	
		Journal and pin finish precision (taper and ellipse)		Ellipse and taper 0.007			
		Journal and bearing spread			96 or less	Use those with projection and proper arc; take care with back side fit	Load 9807 [1000] N[Kgf] Projection 0.03 – 0.07 mm
		Clearance between journal and bearing		0.045 – 0.11	0.16 or more	Replace bearing	
		Journal bearing undersize				Undersize bearings cannot be used	
		Crankshaft end play		0.15 – 0.33	0.4 or more	Replace thrust bearings	Measure at crankshaft's No. 4 bearing thrust surface
		Crankshaft runout		0.08 or less	0.15 or more	Replace	
		Ring gear				Perform lapping on gears with burrs; in cases of severe damage, replace.	
		Crankshaft balance (g-cm)		36 or less		Check dynamic balance	(Ref. value) At ends of journal
		Lower crankcase bolts tightening torque (angular tightening method) N·m (kgf-m)		M14 bolts 98 (10) ↓ 147 (15) ↓ 30 — 60° M10 bolts 38 (3.9)	0.15 or more	Apply molybdenum disulfide grease to threads and seating areas of bolts before tightening	Do not catch foreign matter in bolts
		Crankshaft rear oil seal wear				In case of oil leak, replace oil seal	Check for oil seal collapse (liberally apply oil when installing)

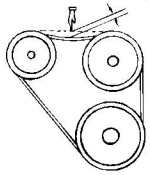
Major Category	Name of Part	Inspection Item	Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Main Operating Parts	Connecting Rods	Connecting rod bearing runout			85 or less	Use those with projection and proper arc; take care work back side fit	Load 9807 (1000 N (Kgf) Projection 0.03 – 0.07 mm
		Clearance between connecting rod bearing and crankpin		0.04 – 0.106	0.16 or more	Replace bearing or crankshaft	Take special care with crankpin precision
		Contact between connecting rod bearing and crankpin				Replace parts with poor contact or abrasions	
		Clearance between smallend bushing and piston pin		0.12 – 0.027	0.10 or more	Replace bushing or pin	Sufficient gap to allow smooth rotation when holding big end
		Connecting rod bearing undersize	Dia. 80				Crank must not be ground (no undersizes available)
		Connecting rod and crankpin end play		0.17 – 0.28	0.35 or more	Replace connecting rod	
		Center distance between big end and small end (mm)	223.5				Reference value
		Big end to small end hole twist (per 100 mm)		0.03 or less	0.1 or more	Repair or replace	
		Big end to small end hole parallelism (per 100 mm)		0.03 or less	0.1 or more	Repair or replace	
		Piston weight difference after assembly g		20 or less		Repair or replace	
		Bearing cap bolt tightening torque (angular tightening method) N·m (kgf-m)		39 (4.0) alternately (One side) (Other side) 60° → 120° ↙ 60°		Apply molybdenum disulfide grease to bolts before tightening	After tightening to 39 N·m (4.0 kgf·m), use angular tightening to tighten alternately first side 90°, other side 120°–150°, first side 30°–90°.

Major Category	Name of Part	Inspection Item	Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Main Operating Parts	Camshaft	Journal uneven wear				Replace camshaft	
		Clearance between journal and bearing		0.06 – 0.11	0.16 or more	Replace camshaft or bearing	
		Journal wear	Dia. 40	Dia. 39.915 – 39.940	Dia. 39.89 or less	Replace camshaft	
		Cam height: A – B  014E100043	5.92		5.56 or less	Replace camshaft	Minor step wear on cams can be repaired
		Camshaft runout		0.05	0.10 or more	Replace camshaft	Measure with dial gauge at No. 3 or No. 4 journal, runout during one rotation.
		Camshaft play (front-back direction)		0.055 – 0.205	0.4 or more		

Major Category	Name of Part	Inspection Item		Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Valve System	Valves	Inlet valve stem wear		Dia. 10		Dia. 9.92	Replace valve and valve guide together	Measure valve stem at three positions
		Exhaust valve stem wear		Dia. 10		Dia. 9.90		
		Clearance between inlet valve stem and valve guide			0.040 – 0.077	0.15 or more	Replace valve and valve guide together	
		Clearance between exhaust valve stem and guide			0.065 – 0.102	0.20 or more		
		Interference between valve guide and cylinder head			0.024			Apply oil to valve guide and press in
		Valve thickness 	Inlet	2.50		2.00 or less	Replace valve and valve guide together	
			Exhaust	2.35		1.85 or less		
		Height of valve guide above cylinder head 		22				Reference value
		Valve stem oil seal lip		Dia. 9.5		Dia. 9.8 or more	Replace oil seal	Don't damage lip.
		Valve spring	Tension N (kgf) (When compressed to installed length) Inner 46.2 mm Outer 48.7 mm	Inlet	Inner [11.4]		Inner [10.2 or less]	Replace oil seal	
					Outer [29.8]		Outer [26.8 or less]		
				Exhaust	Inner [29.0]		Inner [26.1 or less]		
					Outer [51.0]		Outer [45.9 or less]		
			Free height mm	Inlet	Inner [62.5]		Inner [60.5 or less]		
					Outer [59.3]		Outer [57.3 or less]		
				Exhaust	Inner [69.2]		Inner [67.2 or less]		
					Outer [80.7]		Outer [78.7 or less]		
			Inclination mm 				Inner 3.0 or more		
							Outer 3.5 or more		

Major Category	Name of Part	Inspection Item	Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Valve System	Valves	Valve clearance (inlet & exhaust) (cold)		0.4		Adjust	
		Clearance between rocker arm shaft and bushing		0.01 – 0.05	0.2 or more	Replace bushing or shaft	
		Rocker arm shaft wear	Dia. 19		Dia. 18.85 or less	Replace	
Intake System	Air cleaner	Air cleaner element condition					Special order item from manufacturer

Major Category	Name of Part	Inspection Item		Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Lubricating System	Oil pressure	Lubricating oil pressure kPa (kg/cm^2)						
	Oil Ipump and Relief valve	Clearance between pump body inner wall and gear teeth mm			0.10 – 0.196	0.15	Replace bushing, gear or body	
		Pumping rate ℓ/min (2486 rpm, SAE #30, pumping pressure 7.8 x 10^2(8) kPa (kgf/cm^2) / cm^2, oil temp. 80°C)			90.0			
		End gap between pump cover and gear			0.040 – 0.093	0.15	Replace gear or cover	
		Clearance between drive shaft and pump body			0.032 – 0.070	0.15		
		Clearance between drive shaft and bushing			0.045 – 0.078	0.15	Replace bushing	
		Diameter of drive shaft		Dia. 16		Dia 15.9 or less	Replace shaft	
		Initial operating pressure of relief valve kPa (kgf/cm^2)	Oil gallery		539 (5.5)			Reference value
			Oil pump		$1.08x10^3$ (11.0)			
	Oil filter	Clogging and damage to oil filter					Replace	Replace cartridge every 500 hours of operation
		Initial operating pressure of main oil filter relief valve kPa (kgf/cm^2)			196 (2.0)			

Major Category	Name of Part	Inspection Item	Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Cooling System	Water pump	Water pump ball bearing chatter (radial direction)		0.008 – 0.010	0.2	Replae	#6305 (2) #6205 (1)
		Pumping rate ℓ/min (pumping speed 2000 rpm, water temp 30°C Total head 8.6 m or more)		265			
		Clearance between pump impeller and pump body mm		0.5		Repair or replace if impeller and pump body are touching	
		Fan belt deflection mm Press with finger  033E100007		About 7 – 9		Adjust	(Reference) 10 kg/each
		Initial thermostat operating temperature (at sea level)		74.5 – 78.5°C			Replace thermostat if operation is incorrect.
		Thermostat full-open temperature (at sea level)		90°C		Temperature at which thermostat lift reaches 13 mm or more.	
		Fan center and bearing shaft interference		0.07 – 0.11	Press-in load 600 kg or less		Maximum 2 disassemblies. From 3rd time, replace shaft assembly.
		Bearing shaft and impeller interference		0.020 – 0.060			
		Pulley and fan center clearance		0.14 or less			

Major Category	Name of Part	Inspection Item	Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Fuel System	Piping, etc.	Clogged, cracked, loose fuel pipes, injection pipes, nozzle holders; defective seals.				Repair or replace	
		Fuel filter element clogging or damage				Replace	Cartridge type
	Fuel feed pump	Pumping performance (with hand primer pump, speed 60 – 100 times/minutes 1m head, pipe internal diameter x length (8mm x 2m))		Pumped up within 25 strokes or less	120 times or more	Repair or replace	
		Pumping capacity (cc) (Pump speed 1000 rpm. 15 seconds duration, Inlet head : 1m Outlet head : 0.3m)		530 or more	400 or less	Repair or replace	
		Air tightness 196 kPa (2.0 kgf/cm^2)		Bubbles from pushrod less than rice-grain size, not to exceed 30 cc/min		Other leaks require or replacement	
	Injection pump	Delivery valve: Delivery valve wear				Inspect for damage to valve's piston and seat; replace in case of severe vertical cracks on piston or impact scars on seat with loss of finish gloss. Immerse delivery valve in clean diesel fuel, then lightly press lower part of valve seat with finger and release; replace assembly if valve does not return to original state when finger is released.	

Major Category	Name of Part	Inspection Item	Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Fuel system	Injection Nozzle	Technology Needle valve seat: 7.84MPa (80 kgf/cm^2)				Repair or replace parts with leaks from seat area	
		Needle valve shaft seat: seconds (Impress fuel pressure of 29.4 MPa (300 kgf/cm^2) (nozzle starting pressure) and measure time required for pressure to drop from 24.5 MPa (250 kgf/cm^2) to 19.6 MPa (200 kgf/cm^2).)		5.0 or more		Replace	Fuel used: diesel fuel; clay (Redwood); 37 – 40 seconds 120°C
		Fuel spray and injection (Impress fuel pressure of Adjust needls valve opening pressure to 1st stage: 17.7 MPa (180 kg/cm^2/2570 psi) 2nd stage: 22.1 MPa (225 kg/cm^2/3200 psi))	① Visually inspect, no relatively large drops scattered. ② No drops scattered to one side. ③ No unevenness of spray from jets.			Replace faulty parts	
Electrical	Charge/ Discharge indication	Warning lamp indication				If warning indicator lights when engine is operating at normal speeds, check and repair electrical system.	
	Wiring	Check for looseness, cuts or damaged insulation to wiring.				Repair	
	Alternator 24V, 50A	Performance: Rated output current 27 V (5000 rpm)		50A			

Major Category	Name of Part	Inspection Item		Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Electrical	Starter 24V, 5.5 kW	Loose mount					Repair	
		Brush height			20	13 or less	Replace	
		Magnetic switch	Series coil resistance value (Ω)		0.76 – 0.84 (20°C)			If coil resistance value is severely abnormal, replace switch.
			Shunt coil resistance value (Ω)		2.42 – 2.62 (20°C)			
		Commutator	O.D.		Dia. 43	Dia. 42	Replace armature	
			Undercut depth		0.5 – 0.8	0.2	Repair	
		Performance	Unloaded characteristics (24V, 120A or less)		4100 rpm			Smooth pinion operation without noise
	Preheater	Control register, glow plug					Replace if cut wiring or shorts are found	
	Battery	Battery terminals						Special order from original manufacturer; manufacturer's specs.
		Plates, separator plates, container, etc.						
		Electrolyte turbidity						

Major Category	Name of Part	Inspection Item	Nominal Dimension	Assembly Standard Value	Limit	Repair Procedure	Comments
Electrical	Battery	Electrolyte specific gravity (at recharging, 20°C)					Special order from original manufacturer
		Capacity (20 hours)					
		Electrode voltage					
		Electrolye surface height					
Final Inspection		Engine run-in operation				30 minutes or more	
		Cylinder compression pressure MPa (kgf/ cm^2) (water temp. 70 – 85°C, about 220 rpm)		2.84 (29)	2.6 (21) or less	Inspect	Warm engine
		Difference in compression between cylinders kPa (kgf/cm^2) (water temp. 70 – 85°C, about 220 rpm)			196 (2 or more)	Inspect	Warm engine
		Lubricating oil pressure kPa (kgf/cm^2)		539 (5.5)	196 or less (2.0)	Adjust	
		Output check		85% or more			When new engine output is 100%
		Fuel consumption check		110% or less			

MEMO

WORKSHOP MANUAL
DIESEL ENGINE

MODEL AA-6SD1T

IDE-2392

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