SERVICE MANUAL

MITSUBISHI DIESEL ENGINE

S6A3

500KW

MITSUBISHI HEAVY INDUSTRIES, LTD.

INTRODUCTION

This Service Manual is written to familiarize you with the maintenance of your Mitsubishi S6A3 Diesel Engine.

Long productive life and efficient performance are the essential qualities required of the engine if it is to fulfil its function of rationalizing power economy. These qualities depend to a great extent on the care exercised in maintenance of the engine.

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

The description, illustrations and specifications contained in this manual were of the serial numbers of the engines manufactured at the time this manual was approved for printing.

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

SCOPE

This Service Manual covers the standard-specification model of Mitsubishi S6A2 Diesel Engine and describes, group by group, the specifications, maintenance standards, adjustments, disassembly, inspection and repair, and reassembly of the engine.

The fuel injection pump, governor and turbocharger are described in the separate volume of this manual.

For the non-standard-specification engines such as marine propulsion engines, etc., the supplement has been published to be read together with this manual.

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

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

HOW TO USE THIS MANUAL

1. The parts read in the texts or shown in the illustrations are numbered in the disassembling sequence prescribed for each system or assembly.
2. The item to be inspected during disassembly are indicated in ☐ in the disassembled view.
3. The maintenance standards to be referred to for inspection and repairs are indicated in easy-to-refer passages of the texts and also in GROUP No. 2 in a tabulated form.
4. The sequence in which the parts are to be reassembled are shown in the form of, for example, ⑤→②→④→③→① below the assembled view.
5. Marks are used in this manual to emphasize important and critical instructions as shown below:
6. Tightening torque in "wet" condition is indicated as [wet]. Unless indicated as such, the torque is to be considered in "dry" condition.

NOTES, CAUTIONS and WARNINGS

NOTES, CAUTIONS and WARNINGS are used in this manual to emphasize important and critical instructions. They are used for the following conditions:

NOTE ..... An operating procedure, condition, etc., which is essential to highlight.

⚠ CAUTION ..... Operating procedures, practices, etc., which if not strictly observed, will result in damage to or destruction of engine.

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

DEFINITION OF TERMS

In this manual, the following terms are used in the dimensional and other specifications:

NOMINAL VALUE	Indicates the standard dimension of a part.
ASSEMBLY STANDARD	Indicates the dimension of a part, the dimension to be attained at the time of reassembly or the standard performance. Its value is rounded to the nearest whole number needed for inspection and is different from the design value.
STANDARD CLEARANCE	Indicates the clearance to be obtained between mating parts at the time of reassembly.
REPAIR LIMIT	A part which has reached this limit must be repaired.
SERVICE LIMIT	A part which has reached this limit must be replaced.

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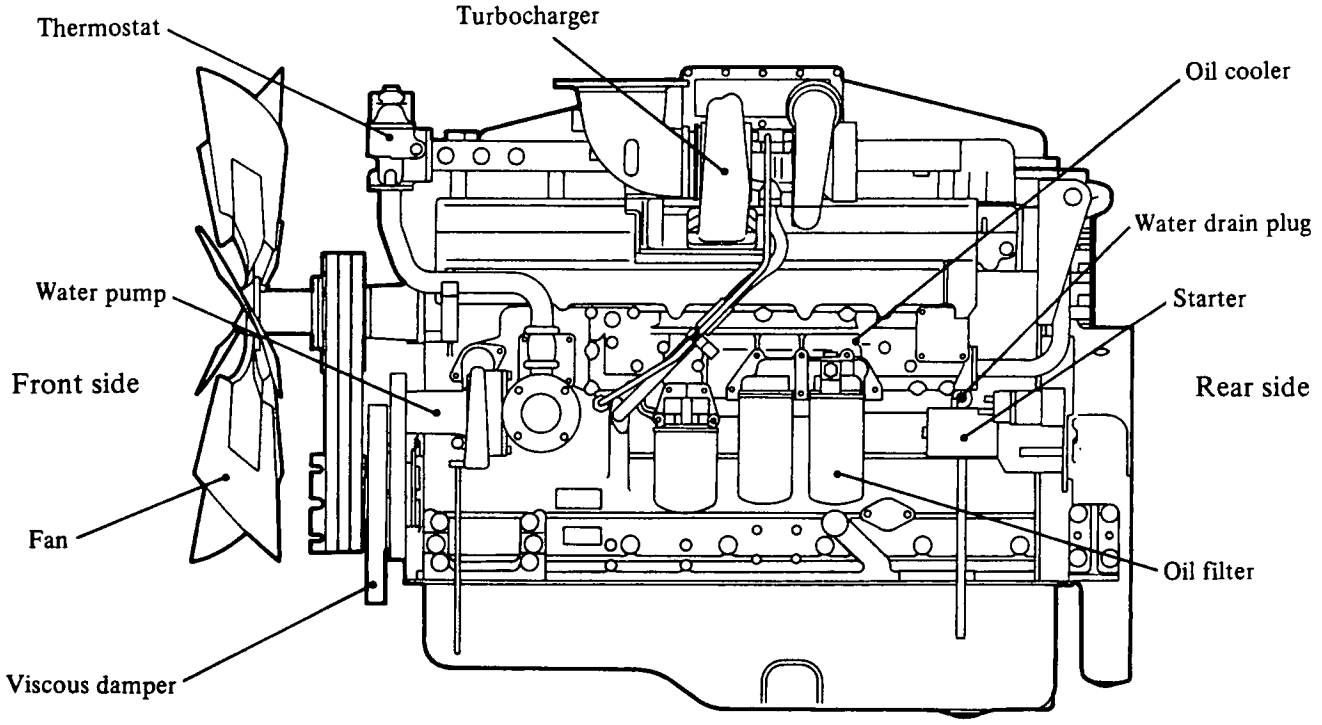
GENERAL

1. GENERAL

1.1 Nomenclature



Left side

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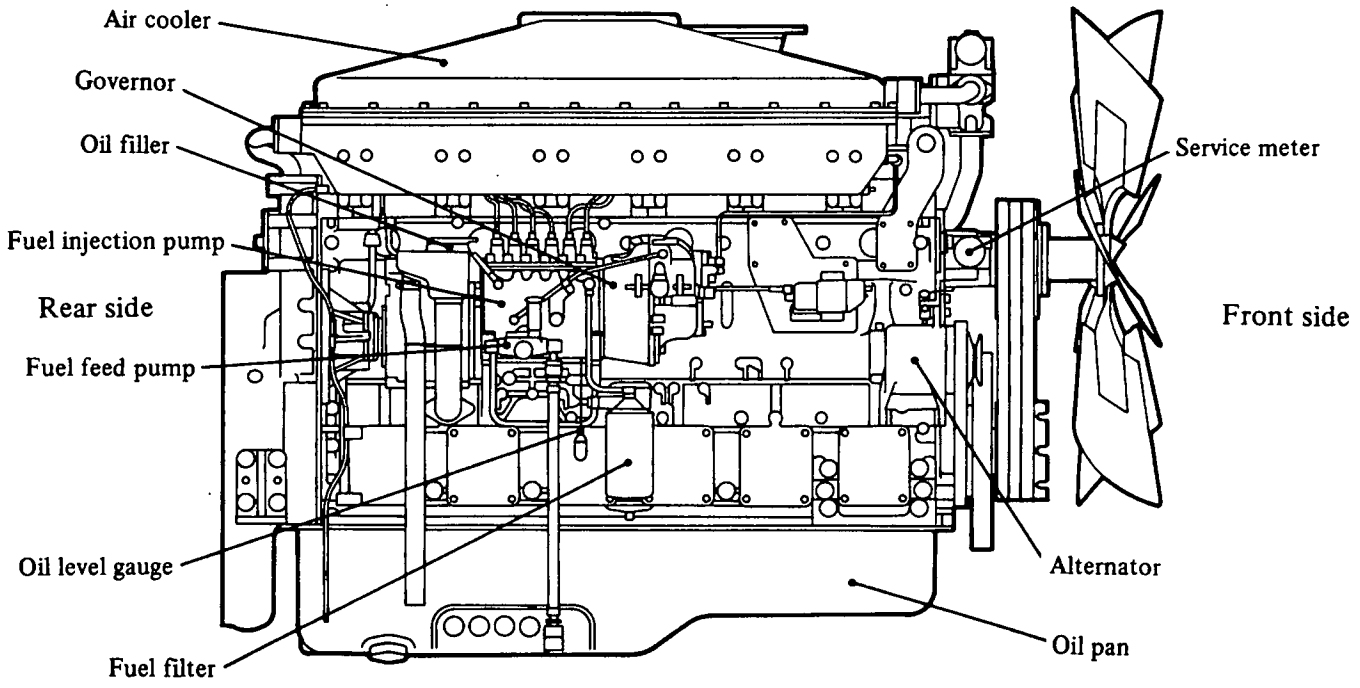

Right side

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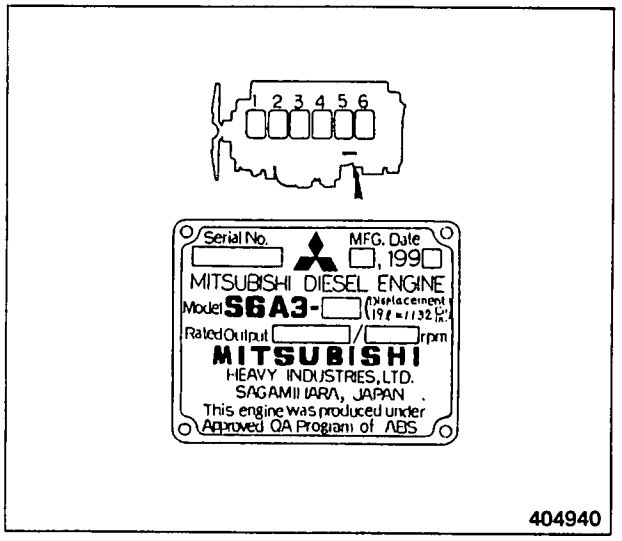
NOTE: Rotation is counterclockwise as seen from rear side.

1.2 Engine serial number location

The engine serial number is stamped on the nameplate attached to the left rear side of the engine.

Example: Model S6A3, Serial number 30125

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



1.3 Engine model and application codes

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- "T" stands for turbocharged unit.
- "TA" stands for turbocharged, aftercooled unit.
- "TK" stands for turbocharged, intercooled unit.

Application code:
- No code: Construction equipment drive
- P: Generator drive and prime power
- L: Locomotive drive
- MP: Marine generator drive and marine general mechanical drive
- M: Marine propulsion

Series code

No. -of-cylinders code

Sagamihara Machinery Works

2. SPECIFICATIONS

Model designation				S6A3	
				TA	TK
General	Type			Water-cooled, 4-stroke cycle diesel, turbocharged	
				w/aftercooler	w/intercooler
	No. of cylinders – arrangement			6 – in-line	
	Combustion chamber type			Direct injection	
	Valve mechanism			Overhead	
	Cylinder bore X stroke mm (in.)			150 x 175 (5.906 x 6.890)	
	Piston displacement liter (cu in.)			18.56 (1132.62)	
	Compression ratio			14.5 : 1	
	Fuel			Diesel fuel oils specified by ASTM	
	Firing order			1-5-3-6-2-4	
	Direction of rotation			Counterclockwise as viewed from flywheel side	
	Dimensions	Overall length mm (in.)		1877 (73.9) [without fan 1570 (61.8)]	1570 (61.8)
		Overall width mm (in.)		930 (36.6)	
		Overall height mm (in.)		1304 (51.3)	
	Weight (dry) kg (lb)			1720 (3793)	
Engine proper	Cylinder liners			Wet type	
	No. of piston rings	Compression rings		2	
		Oil ring		1 (w/spring expander)	
	Valve timing	Inlet valves	Open	55° B.T.D.C.	
			Close	65° A.B.D.C.	
		Exhaust valves	Open	65° B.B.D.C.	
			Close	55° A.T.D.C.	
	Engine support			4-point support	
	Starting system			Electric-starter, air-motor	
Inlet and exhaust systems	Air cleaner	Type		Paper element type or turbine silencer	
	Turbocharger	Type – No. of units		TD13 or TD10 – 1	
	Air cooler			Laminated fin-plate type	
Lubrication system	Method			Pressure feed by gear pump	
	Engine oil	Specification		Class CD oil (API Service Classification)	
		Capacity (engine) liter (U.S. gal)		80 (21.1)	

Model designation			S6A3	
			TA	TK
Lubrication system	Oil pump	Type	Gear pump	
		Delivery capacity liter (U.S. gal)/min	210 (55) (at 1500 engine rpm) 250 (66) (at 1800 engine rpm)	
	Relief valve	Type	Piston valve type	
		Valve opening pressure kgf/cm² (psi) [MPa]	5 to 6 (71 to 85) [0.5 to 0.6]	
	Oil cooler	Type	Water-cooled multi-plate type built in crankcase	
	Full-flow type oil filter	Type	Cartridge type paper element	
	Bypass type oil filter	Type	Cartridge type paper element	
	Oil filter alarm	Type	Piston valve with built-in electric contact points	
		Valve opening pressure kgf/cm² (psi) [MPa]	2.5 (35.6) [0.25] [Contact points close at 1.5 (21.3) [0.15]	
Cooling system	Type		Forced circulation	
	Capacity (engine) liter (U.S. gal)		40 (10.6)	
	Water pump	Type	Centrifugal	
		Delivery capacity liter (U.S. gal)	580 (153.1) (at 1500 engine rpm) 650 (171.6) (at 1800 engine rpm)	
	Water pump belt	Type	Low edge cog C belt	
		Manufacturer	Mitsuboshi Belt	
		Outside circumference mm (in.)	1710 (67.32)	
	Thermostats	Type	Wax	
		Valve opening temperature °C (°F)	65 ± 2 (149 ± 3.6) and 71 ± 2 (159.8 ± 3.6)	
	Radiator	Type	Plate fin or corrugated fin	
	Cooling fan	Type	Steel-blade, circular-arc type with spider	
	Fan belt	Type	Low edge cog belt (3-piece set)	
		Manufacturer	Mitsuboshi Belt	
		Outside circumference mm (in.)	1455 (57.3) (w/o automatic tensioner) 1490 (58.7) (w/ automatic tensioner)	
	Corrosion resistor (water filter)	Type	Cartridge	
		Manufacturer	Tsuchiya Seisakusho	
Fuel system	Injection pump	Model	Bosch PS7S	
		Manufacturer	Diesel Kiki	
		Plunger outside diameter mm (in.)	13 (0.51)	
		Plunger lead mm (in.)	Right-hand 40 (1.57)	
		Cam lobe lift mm (in.)	12 (0.47)	

Model designation				S6A3	
				TA	TK
Fuel system	Feed pump		Model	Bosch NP-FP/KD-P7S type	
			Manufacturer	Diesel Kiki	
			Cam lobe lift mm (in.)	4 (0.16)	
	Governor		Control system	⟨Mechanical⟩ All speed RSUV Constant speed RSUV-D	⟨Hydraulic⟩ Woodward PSG
					⟨Electrical⟩ Woodward EG-B2P Woodward EG-3P Barber-Colman DYNA 8000
	Injection nozzles		Type	Hole type	
			Manufacturer	Diesel Kiki	
			No. of spray orifice	8	
			Spray orifice inside diameter mm (in.)	0.28 (0.0110)	
			Spray angle	158°	
			Injection pressure kgf/cm² (psi) [MPa]	220 (3128) [21.6]	
	Fuel filter			Cartridge type paper element	
Electrical system	Voltage-polarity			24-V – Negative (–) ground	
	Starter		Model	0340 552 0121	
			Manufacturer	Sawafuji Electric	
			Type	Pinion shift	
			Output V – kW	24 – 6	
			No. of starter	1	
	Alternator		Type	3-phase with silicon-rectifier (add-on type)	
			Manufacturer	Mitsubishi Electric	
			Output V – A	24 – 35	
			Rated voltage generating rpm	800, minimum (at 28V)	
			Rated output generating rpm	2500, maximum (at 26V, 24A)	
			Maximum rpm	8000 (0.5 minute)	
	Safety relay	Manufacturer		Sawafuji Electric	
		Relay switch	Operating voltage V	16, maximum	
			Holding voltage V	8, maximum	
		Safety coil (b coil)	Operating voltage V	3, maximum	
			Holding voltage V	0.05 to 0.15	
		Safety coil (c coil)	Operating voltage V	23 to 25	
			Holding voltage V	4, maximum	

Model designation			S6A3	
			TA	TK
Air-starting systems	Air-motor starting	Model	FSM-100C-102	
		Manufacturer	Fuji-Kuki	
		Type	Pinion shift	
		Nominal output (PS)	10 at 6 kgf/cm² (85 psi) [0.6 MPa]	

3. SUGGESTIONS FOR DISASSEMBLY AND REASSEMBLY

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

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

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

3.1 Disassembly

(1) Use only right tools and instruments. Serious injury to the personnel and damage to the engine result from the wrong use of tools and instruments.

(2) Use an overhaul stand or work bench if necessary. Also, use assembly bins to keep the engine parts in order of removal.

(3) Lay down the disassembled and cleaned parts in the order in which they were removed to save time for reassembling work.

(4) Pay attention to marks on assemblies, components and parts for their positions or directions. Put on marks, if necessary, to aid reassembly.

(5) Carefully check each part for any sign of faulty condition during removal or cleaning. The part will tell you how it acted or what was abnormal about it more accurately during removal or cleaning.

(6) When lifting or carrying a part too heavy or too awkward for one person to handle, get another person's help and, if necessary, use a jack or chain block.

3.2 Reassembly

(1) Wash all engine parts, except for oil seals, O-rings, rubber sheets, etc., with cleaning solvent and dry them with pressure air.

(2) Use only right tools and instruments.

(3) Use only good-quality lubricating oils and greases. Be sure to apply a coat of oil, grease or sealant to parts as specified. (Refer to 3, Group No. 2.)

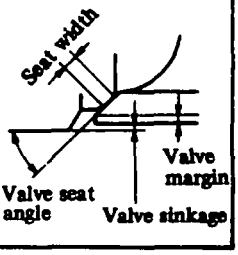
(4) Be sure to use a torque wrench to tighten parts for which tightening torque is specified. (Refer to 2. TIGHTENING TORQUES, Group 2.)

(5) Replace gaskets and packings with new ones. Apply a proper amount of quick-drying cement to gaskets or packings, if necessary.

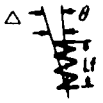
MAINTENANCE STANDARDS

1. MAINTENANCE STANDARDS

Unit: mm (in.)

Group	Inspection point		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
General	Maximum rpm		5 to 10% higher than rated rpm		Lower or 15% higher than rated rpm		Check governor setting.
	Minimum rpm		600 to 650 rpm				
	Compression pressure		25 kgf/cm² (356 psi) [2.5 MPa] at 120 to 200 rpm, minimum		20 kgf/cm² (284 psi) [2.0 MPa], minimum		Oil and water temp. 20 to 30°C (68 to 86°F)
	Lube oil pressure		5 to 6.5 kgf/cm² (71 to 92.4 psi) [0.5 to 0.64 MPa] (at rated rpm)		4 kgf/cm² (57 psi) [0.4 MPa], minimum		Oil temperature 60 to 70°C (140 to 158°F)
			2 to 3 kgf/cm² (28 to 43 psi) [0.2 to 0.3 MPa] (at idling rpm)		1 kgf/cm² (14 psi) [0.1 MPa], minimum		
	Valve timing [with 2-mm (0.08-in.) clearance on valve side, cold]		Inlet valve opens 11° B.T.D.C. Inlet valve closes 21° A.B.D.C. Exhaust valve opens 21° B.B.D.C. Exhaust valve closes 11° A.T.D.C. ±2° (crank angle)				Values are only for checking valve timing and are different from actual ones.
	Valve clearance (cold)	Inlet valves	0.4 (0.016) (±0.05 (±0.0020))				
		Exhaust valves	0.5 (0.020) (±0.05 (±0.0020))				
	Injection timing		B.T.D.C.	± 1° (crank angle)			Varies according to specifications. Refer to caution plate on No. 1 rocker cover.
	Belt tension	Fan Water pump and alternator		10 to 15 (0.4 to 0.6)			Measure sag at point indicated by arrows. 
Engine proper	Rockers	Rocker bushing inside diameter	32 (1.26)	32.000 to 32.040 (1.25984 to 1.26141)		32.100 (1.26378)	
		Rocker shaft diameter	32 (1.26)	31.975 to 31.991 (1.25886 to 1.25949)		31.950 (1.25787)	
	Valves	Valve stem diameter — Inlet valves	10 (0.39)	9.940 to 9.960 (0.39134 to 0.39213)		9.910 (0.39016)	
		Valve stem diameter — Exhaust valves	10 (0.39)	9.910 to 9.930 (0.39016 to 0.39094)		9.880 (0.38898)	
		Valve guide inside diameter	10 (0.39)	10.000 to 10.015 (0.39370 to 0.39429)		10.060 (0.39606)	The same for both inlet exhaust valves.
	Valve seats and valves	Valve seat angle	30°				
		Valve sinkage		0 ± 0.2 (0 ± 0.008)	0.5 (0.020)		
		Seat width — Inlet valves		2.08 ± 0.15 (0.0819 ± 0.0059)	2.5 (0.098)		
		Seat width — Exhaust valves		1.85 ± 0.15 (0.0728 ± 0.0059)	2.3 (0.091)		

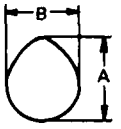
Unit: mm (in.)

Group	Inspection point			Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Valve seats and valves	Valve margin			3.0 ± 0.1 (0.118 ± 0.004)	Refacing is permissible up to 2.0 (0.079).		
		Cylinder head bore inside diameter and valve seat outside diameter	Inlet valves	58 (2.28)	(−0.07 to −0.13) ((−0.0028 to −0.0051))			(−0.07) ((−0.0028)) and (−0.13) ((−0.0051)) are interference.
			Exhaust valves	54 (2.13)				
	Valve springs	Free length			67.5 (2.657)		66.2 (2.606)	
		Squareness		ϕ θ = 1°, maximum 			△ = 1.5 (0.059) over the length	
		Length under test force/ test force			60.0 (2.362)/ 27.8 kgf ± 5% (61.3 lbf ± 5%) [272.6 N ± 5%]			
	Valve push-rods	Runout			0.5 (0.020), maximum			
	Cylinder heads	Warpage of gasketed surface			0.03 (0.0012), maximum	0.07 (0.0028)	0.50 (0.0197)	Regrind slightly.
	Cylinder liners	Inside diameter		150 (5.91)	150.00 to 150.04 (5.9055 to 5.9071)		150.14 (5.9110)	
		Out-of-roundness			0.02 (0.0008), maximum			
		Taper			0.02 (0.0008), maximum			
		Squareness with respect to lower face of flange			0.03 (0.0012), maximum			
		Projection of cylinder liner flange above gasketed surface			0.10 to 0.19 (0.0039 to 0.0075)			
	Pistons	Diameter		150 (5.91)	149.78 to 149.82 (5.8968 to 5.8984)		149.68 (5.8929)	Measure diameter in the direction transverse to pin at piston skirt.

Unit: mm (in.)

Group	Inspection point		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Pistons	Max. permissible difference between average weight of all pistons in one engine		±15 g (±0.53 oz), maximum			
		Piston ring side clearance — Top	3.00 (0.1181)	(0.08 to 0.11) ((0.0031 to 0.0043))		(0.20) ((0.0079))	Insert new rings into the grooves and measure the side clearance.
		Piston ring side clearance — Second	2.50 (0.0984)	(0.07 to 0.10) ((0.0028 to 0.0039))		(0.15) ((0.0059))	
		Piston ring side clearance — Oil	5.00 (0.1969)	(0.05 to 0.09) ((0.0020 to 0.0035))		(0.15) ((0.0059))	
		Piston pin bore diameter	58 (2.28)	58.002 to 58.012 (2.28354 to 2.28393)		58.020 (2.28425)	
		Projection		0.38 to 0.89 (0.0150 to 0.0350)			
	Cylinder head gasket	As-installed thickness	1.8 (0.071)	±0.03 (±0.0012)			
	Pistons and cylinder heads	Clearance between piston top and cylinder head		(0.88 to 1.45) ((0.0346 to 0.0571))			
	Piston rings	Gaps (Use 160 ± 0 (6.3 ± 0) gauge) — Top		(0.6 to 0.8) ((0.024 to 0.031))		(2.0) ((0.079))	If gauge is not available, check gaps by placing rings in a new cylinder liner.
		Gaps (Use 160 ± 0 (6.3 ± 0) gauge) — Second		(0.5 to 0.7) ((0.020 to 0.028))		(2.0) ((0.079))	
		Gaps (Use 160 ± 0 (6.3 ± 0) gauge) — Oil		(0.5 to 0.7) ((0.220 to 0.028))		(2.0) ((0.079))	
	Piston pins	Diameter	58 (2.28)	57.987 to 58.000 (2.28295 to2.28346)		57.970 (2.28228)	
	Connecting rods	Small end bushing inside diameter	58 (2.28)	58.020 to 58.040 (2.28425 to 2.28503)		58.070 (2.28622)	
		Bend and twist		0.05/100 (0.0020/3.9), maximum			
		End play (crankpin and big end widths)	61 (2.40)	(0.2 to 0.3) ((0.008 to 0.012))	(0.5) ((0.020))		(Indicated clearance) (0.4 – 0.6) ((0.016 – 0.024))
		Max. permissible difference between average weight of all pistons in one engine		±20 g (0.7 oz), maximum			
		Big-end bore diameter	110 (4.33)	110.000 to 110.022 (4.33070 to 4.33157)		110.047 (4.33255)	To be used in combination with bearing caps.
	Connecting rod bearings	Thickness of central part (STD)	3.0 (0.118)	2.987 to 3.000 (0.11760 to 0.11811)		2.950 (0.11614)	
	Flywheel	Face runout		0.28 (0.0110), maximum			
		Radial runout		0.13 (0.0051), maximum			

Unit: mm (in.)

Group	Inspection point			Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Accessary drive	Drive case bore inside diameter		80 (3.15)	79.987 to 80.022 (3.14909 to 3.15047)			
				100 (3.94)	99.989 to 100.014 (3.93657 to 3.93755)			
		Bearing	Diameter	80 (3.15)	79.983 to 80.004 (3.14893 to 3.14976)			
				100 (3.94)	99.980 to 100.005 (3.93621 to 3.93720)			
			Inside diameter	40 (1.57)	39.985 to 40.003 (1.57421 to 1.57492)			
				45 (1.77)	44.985 to 45.003 (1.77106 to 1.77177)			
		Drive shaft diameter		40 (1.57)	40.002 to 40.013 (1.57488 to 1.57531)			
				45 (1.77)	45.002 to 45.013 (1.77173 to 1.77216)			
	Viscous damper	Radial runout (at periphery)			0.5 (0.020), maximum		1.5 (0.059)	
		Face runout			0.5 (0.020), maximum		1.5 (0.059)	
	Timing gears	Backlash			(0.12 to 0.18) ((0.0047 to 0.0071))	(0.30) ((0.0118))	(0.50) ((0.0197))	Replace gears.
		Idler gear bushing inside diameter		50 (1.97)	50.000 to 50.025 (1.96850 to 1.96948)		50.060 (1.97086)	
		Idler gear shaft diameter		50 (1.97)	49.975 to 49.950 (1.96752 to 1.96653)		49.900 (1.96456)	
		Idler gear end play		53 (2.09)	(0.2 to 0.4) ((0.008 to 0.016))	(0.6) ((0.024))		
	Camshaft	Cam lift (A–B)			7.59 ± 0.05 (0.2988 ± 0.0020)		6.79 (0.2673)	
		Runout			0.05 (0.0020), maximum	0.08 (0.0031)		Runout at center bushing measured with both ends supported. Repair or replace.
		Diameter of journals		68 (2.68)	67.92 to 67.94 (2.6740 to 2.6748)		67.87 (2.6720)	
		Inside diameter of bushings (as-installed)		68 (2.68)	68.00 to 68.03 (2.6772 to 2.6783)		68.09 (2.6807)	Replace bushings if worn beyond service limit. Ream as necessary.
		End play			(0.10 to 0.25) ((0.0039 to 0.0098))	(0.40) ((0.0157))		Replace thrust plate.

Unit: mm (in.)

Group	Inspection point		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Crankshaft	Diameter of crankpins	104 (4.09)	-0.10 to -0.12 (-0.0039 to -0.0047)	-0.16 (-0.0063)		
		Diameter of journals	140 (5.51)	-0.05 to -0.07 (-0.0020 to -0.0028)	-0.10 (-0.0039)		
		Center-to-center distance between journal and crankpin	87.5 (3.44)	±0.10 (±0.0039)			
		Parallelism between journals and crankpins		Runout: 0.01 (0.0004), maximum (over crankpin length)			
		Out-of-roundness of journals and crankpins		0.01 (0.0004), maximum	0.03 (0.0012)		
		Taper of journals and crankpins		0.01 (0.0004), maximum	0.03 (0.0012)		
		Fillet radius of journals and crankpins		$7.0^{0}_{-0.2}$ ($0.276^{0}_{-0.008}$)			
		Hardness of journals and crankpins		Hv > 620			Hs > 75
		Angular error of crankpins		± 0°20′			
		Runout		0.04 (0.0016), maximum	0.10 (0.0039)		Repair or replace.
	Main bearings	End play (thrust journal length)	58 (2.28)	(0.20 to 0.395) ((0.0079 to 0.01555))	(0.50) ((0.0197))	+1.18 (+0.0465) (crankshaft length)	Replace thrust plate if worn down to repair limit. Use oversize thrust plate if worn beyond repair limit. Oversize thrust plates: +0.25, +0.50, +0.75 (+0.0098, +0.0197, +0.0295)
		Thickness of center (STD)	3.5 (0.138)	3.467 to 3.480 (0.13650 to 0.13701)		3.425 (0.13484)	Replace bearings if worn down to service limit. Regrind journals and use undersize bearings if bearings are worn beyond service limit. Undersize bearings: −0.25, −0.50, −0.75, −1.00 (−0.0098, −0.0197, −0.0295, −0.0394)
	Crankcase	Warpage of gasketed surface		0.05 (0.0020), maximum	0.20 (0.0079)		Regrind slightly.
		Main bearing — bore diameter	147 (5.79)	147.000 to 147.040 (5.78738 to 5.78896)		147.050 (5.78936)	

Unit: mm (in.)

Group	Inspection point		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Lubrication system	Oil pump	Gear backlash		(0.10 to 0.20) ((0.0039 to 0.0079))		(0.40) ((0.0157))	
		Gear radial clearance in case	84 (3.31)	(0.15 to 0.23) ((0.0059 to 0.0091))	(0.35) ((0.0138)) (Tip clearance)		
		Gear end clearance in case	63 (2.48)	(0.10 to 0.20) ((0.0039 to 0.0079))	(0.25) ((0.0098))		
		Shaft diameter	34 (1.34)	33.960 to 33.944 (1.33701 to 1.33638)		33.920 (1.33543)	
		Bushing inside diameter		34.000 to 34.025 (1.33858 to 1.33956)		34.055 (1.34075)	
	Relief valve	Opening pressure		5 to 6 kgf/cm² (71 to 85 psi) [0.5 to 0.6 MPa]			Adjust with shims.
	Oil filter alarm	Valve opening pressure (differential pressure)		2.5 ± 0.2 kgf/cm² (36 ± 2.8 psi) [0.2 ± 0.02 MPa]			Contact points should close at 1.5 kgf/cm² (21.3 psi) [0.15 MPa] on pressure rise.
Cooling system	Water pump	Inside diameter of pump case bore to which the bearing outer race is fitted	62 (2.44)	61.988 to 61.982 (2.44047 to 2.44023)			
			72 (2.83)	71.988 to 71.982 (2.83417 to 2.83393)			
		Bearing — Diameter	62 (2.44)	62.004 to 61.983 (2.44110 to 2.44027)			
			72 (2.83)	72.004 to 71.983 (2.83480 to 2.83397)			
		Bearing — Inside diameter	30 (1.18)	29.987 to 30.003 (1.18059 to 1.18122)			
		Diameter of shaft bearing journals	30 (1.18)	30.011 to 30.002 (1.18153 to 1.18118)			
		Rattle in radial direction		0.010 to 0.025 (0.00039 to 0.00098)		0.045 (0.00177)	Turn it slowly to check. Replace bearing if it fails to rotate smoothly.
		Rattle in axial direction				0.25 (0.0098)	
		Vane front face clearance in pump case		(0.5 to 1.3) ((0.020 to 0.051))			
		Vane rear face clearance in pump case		(1.0 to 1.3) ((0.039 to 0.051))			

Unit: mm (in.)

Group	Inspection point		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Cooling system	Thermostat	Temperature at which valve starts opening		65 or 71 ± 2°C (149 or 159.8 ± 3.6°F)			Check at atmospheric pressure.
		Temperature at which valve lift is more than 10 (0.4), minimum		80 or 85 ± 2°C (176 or 185 ± 3.6°F)			
Fuel system	Fuel injection nozzles	Valve opening pressure		220 kgf/cm² (3128 psi) [21.6 MPa]			Adjusting limit: 225 to 230 kgf/cm² (3200 to 3271 psi) [22.1 to 22.6 MPa]
		Spray angle	158°				Check spray performance with a hand tester [at fuel oil temperature 20° C (68° F)]. Replace the nozzle tip, if the spray pattern is still bad after washing in clean fuel oil.
		Oil tightness of needle valve seat	Needle valve shall hold a pressure 20 kgf/cm² (284 psi) [2 MPa] lower than opening pressure for 10 seconds.				
Electrical system	Starter	Commutator-side shaft outside diameter and end bushing inside diameter	18 (0.71)				
		Pinion stopper outside diameter and front bushing inside diameter	19 (0.75)				
		Pinion shaft diameter and pinion bushing inside diameter	19 (0.75)				
		Diameter of center-bracket part of shaft and center bushing inside diameter	22.5 (0.886)				
		Commutator outside diameter		53.5 (2.106)		50.5 (1.988)	
		Runout of commutator		0.03 (0.0012), maximum	0.2 (0.008)		
		Mica depth in commutator		0.5 to 0.8 (0.020 to 0.031)	0.2 (0.008)		

Unit: mm (in.)

Group	Inspection point		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Electrical system	Starter	Brush height		22 (0.87)		15 (0.59)	
		Brush spring tension		2000 gf (4.4 lbf) [19.6 N]			
	Alternator	Slip ring outside diameter		33 ± 0.2 (1.30 ± 0.008)		32.2 (1.268)	
		Brush height		18 (0.71)		8 (0.31)	Up to wear limit line
		Brush spring tension		390 gf (0.86 lbf) [3.82 N]		220 gf (0.49 lbf) [2.16 N]	

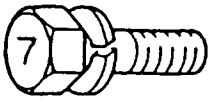
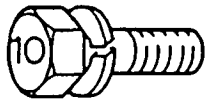
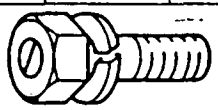
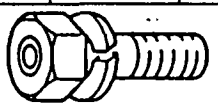
2. TIGHTENING TORQUES

2.1 Important bolts and nuts

Description	Thread Dia x Pitch (M-thread)	Width across flats, mm (in.)	Torque			Remarks
			kgf·m	lbf·ft	N·m	
Cylinder head bolts	20 x 2.5	30 (1.18)	40	290	392	[Wet]
Rocker shaft brackets	12 x 1.75	17 (0.67)	5	36	49	
Main bearing caps	24 x 3	36 (1.42)	60	435	588	[Wet]
Main bearing cap side bolts	16 x 1.5	22 (0.87)	15	108	147	[Wet]
Oil jets	12 x 1.75	17 (0.67)	3 to 4	22 to 29	29 to 39	
Timing gear case	12 x 1.25	17 (0.67)	15	108	147	
Oil pan	10 x 1.25	14 (0.55)	4	29	39	
Mounting brackets	18 x 1.5	24 (0.94)	25	181	245	
Connecting rod bearing caps	18 x 1.5	27 (1.06)	30	217	294	[Wet]
Crankshaft pulley and damper	22 x 1.5	32 (1.26)	40	290	392	
Flywheel	22 x 1.5	32 (1.26)	55	400	539	[Wet]
Exhaust manifolds	10 x 1.5	14 (0.55)	5 to 6	36 to 43	49 to 59	
Idler gears	10 x 1.25	14 (0.55)	4	29	39	
Camshaft gear	30 x 1.5	50 (1.97)	40	290	392	Left-hand screw thread
Fuel injection pump drive gear	30 x 1.5	46 (1.81)	40	290	392	
Idler shaft	12 x 1.25	17 (0.67)	5.5	40	54	
Oil pump drive gear	27 x 1.5	41 (1.61)	30	220	294	
Water pump pulley	24 x 1.5	36 (1.42)	25	180	245	
Water pump impeller	22 x 1.5	32 (1.26)	20	145	196	
Fuel injection pump coupling	10 x 1.5	19 (0.75)	8.5 to 9.5	60 to 69	83 to 93	
Fuel injection pump coupling shaft	12 x 1.75	17 (0.67)	8.5 to 9.5	60 to 69	83 to 93	
Gland (injection nozzle holder)	12 x 1.25	17 (0.67)	8	58	78	
Injection nozzle holder set screw cap nuts	16 x 1	22 (0.87)	4 to 5	29 to 36	39 to 49	
Injection nozzle tip retaining nuts	19 x 1	19 (0.75)	6 to 8	43 to 58	59 to 78	

Remarks: (a) Apply engine oil to threads of parts specified to be [Wet].
(b) For tightening of the main bearing cap bolts and side bolts, refer to page 114.
(c) Tighten the connecting rod bolts in two steps. Refer to page 86.

2.2 Standard bolts and nuts

	Thread Dia x Pitch, mm (in.)	Width across flats, mm (in.)	Strength classification					
			7T			10.9		
			kgf·m	lbf·ft	N·m	kgf·m	lbf·ft	N·m
Metric automotive thread								
	8 x 1.25 (0.31 x 0.049)	12 (0.47)	1.7	12	17	3.1	22	30
	10 x 1.25 (0.39 x 0.049)	14 (0.55)	3.4	25	33	6.1	44	60
	12 x 1.25 (0.47 x 0.049)	17 (0.67)	6.1	44	60	11.0	80	108
	14 x 1.5 (0.55 x 0.059)	22 (0.87)	9.9	72	97	17.9	129	176
	16 x 1.5 (0.63 x 0.059)	24 (0.94)	14.8	107	145	26.7	193	262
	18 x 1.5 (0.71 x 0.059)	27 (1.06)	21.4	155	210	38.5	278	378
	20 x 1.5 (0.79 x 0.059)	30 (1.18)	29.7	215	291	53.4	386	524
	22 x 1.5 (0.87 x 0.059)	32 (1.26)	39.3	284	385	70.8	512	694
	24 x 1.5 (0.94 x 0.059)	36 (1.42)	49.7	359	487	89.5	647	878
Metric coarse thread								
	10 x 1.5 (0.39 x 0.059)	14 (0.55)	3.3	24	32	5.9	43	58
	12 x 1.75 (0.47 x 0.069)	17 (0.67)	5.8	42	57	10.4	75	102
	14 x 2 (0.55 x 0.079)	22 (0.87)	9.5	69	93	17.0	123	167
	16 x 2 (0.63 x 0.079)	24 (0.94)	14.2	103	139	25.6	185	251
	18 x 2.5 (0.71 x 0.098)	27 (1.06)	19.8	143	194	35.7	258	350
	20 x 2.5 (0.79 x 0.098)	30 (1.18)	27.7	200	272	49.9	361	489
	22 x 2.5 (0.87 x 0.098)	32 (1.26)	37.0	268	363	66.6	482	653
	24 x 3 (0.94 x 0.12)	36 (1.42)	47.7	345	468	86.0	622	843

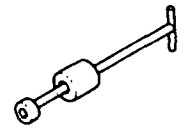
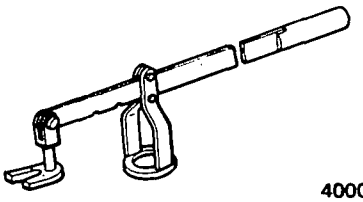
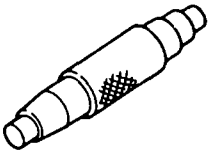
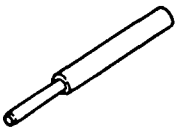
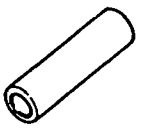
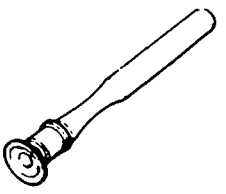
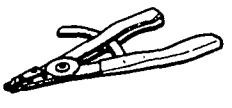
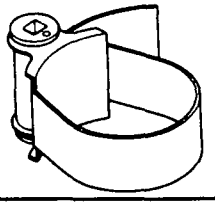
Remarks: (a) Use these torques for bolts and nuts with spring washers.
(b) The tolerance of these torques is ±10%.
(c) Do not coat threads with oil.

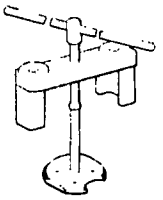
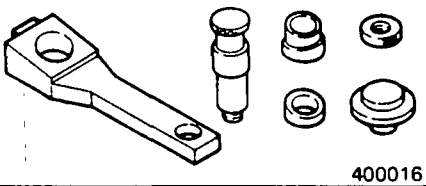
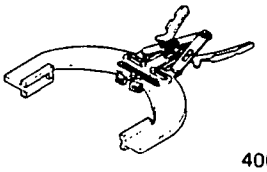
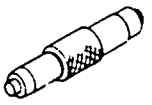
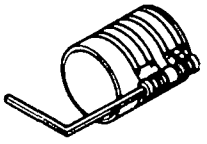
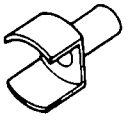
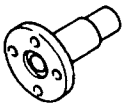
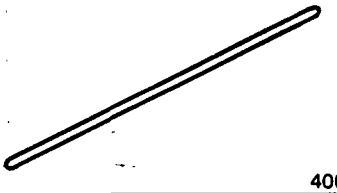
3. SEALANTS AND LUBRICANTS

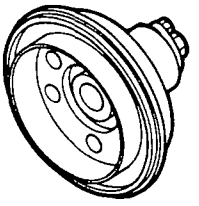
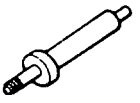
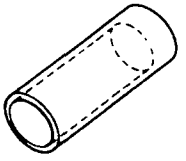
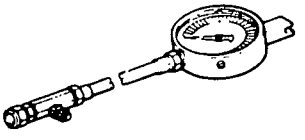
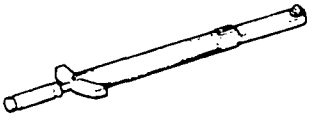
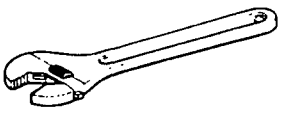
Group	Application point		Sealant or lubricant	How to use
Engine proper	Cylinder head sealing caps		ThreeBond 1215	Apply to holes in crankcase
	Rocker shaft taper plugs		Locktite	
	Cylinder liners		Hermeseal S-2	Apply to top (joint) of each liner
	Front cover, oil pan and crankcase		Herdite	Apply to joint surfaces
	Rear plate, gear case, oil pan and crankcase			Apply to three joint surfaces only of both sides of packings
	Crankcase taper plugs		Plugs precoated with ThreeBond thread sealant	
	Crankcase sealing caps		ThreeBond 1104	
	Oil pan and crankcase		Hermeseal S-2	Apply to joint surfaces only of both sides of packing
	Oil seals		Engine oil	Apply to lip of each oil seal.
Lubrication system	Oil pump	Cover and case	ThreeBond 1104	Apply to both sides of packing
Cooling system	Water pump	Oil seal, unit seal	Engine oil	Apply to lip of inner seal
	Fan drive	Oil seal	Engine oil	Apply to lip of oil seal
Others	Taper plugs and cocks not precoated with ThreeBond thread sealants		Vulcanized sealing tape	Wrap threads with 2 turns of tape

SPECIAL TOOLS

SPECIAL TOOL LIST

Tool name	Part No.	Shape	Use
Nozzle remover	32591 - 00201	 400007	Injection nozzle removal
Valve spring pusher	33591 - 04500	 400009	Valve spring removal/ installation
Rocker bushing puller	32591 - 02600	 400010	Rocker bushing removal/ installation
Valve guide remover	36291 - 04200	 400011	Valve guide removal
Valve guide & seal installer	32591 - 00300	 400012	Valve guide and valve stem seal installation
Valve lapper	30091 - 08800	 400013	Valve lapping
Ring pliers	45191 - 08400	 400014	Snap ring removal/ installation
Oil filter wrench	32591 - 22100	 404941	Oil filter cartridge, fuel filter cartridge and corrosion resistor cartridge removal

Tool name	Part No.	Shape	Use
Cylinder liner remover	32591 - 04100	 400015	Cylinder liner removal
Connecting rod bushing installer	32591 - 08010	 400016	Connecting rod bushing removal/installation
Piston ring pliers	37191 - 03200	 400017	Piston ring removal/ installation
Idler bushing puller	32591 - 02500	 400018	Idler bushing removal/ installation
Piston installer	37191 - 07100	 400019	Piston installation
Sleeve installer	32591 - 00500	 400020	Oil seal sleeve installation
Installer guide	32591 - 00600	 400021	To be used in combination with sleeve installer for oil seal sleeve installation
Turning bar	37491 - 03100	 400022	Enging cranking

Tool name	Part No.	Shape	Use
Oil seal installer	32591-07010	 404942	Rear oil seal installation
Compression gauge adaptor	32591 - 02200	 400023	Compression pressure measurement
Bearing installer	37191 - 06500	 400024	Water pump bearing installation
Unit seal installer	37191 - 06300	 400025	Water pump unit seal installation
Compression gauge	33391 - 02100	 400902	Compression pressure measurement
Socket	58309 - 73100	 400903	Removal/installation of fan pulley cap nut
Torque wrench	32191 - 03100	 400904	
Adjustable wrench	F9611 - 15000	 400905	

OVERHAUL INSTRUCTIONS

1. DETERMINING WHEN TO OVERHAUL THE ENGINE

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

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

The engine develops troubles of widely different varieties when the compression pressure drops in it. Following are the typical troubles caused by this compression pressure failure:

(a) Low power or loss of power

(b) Increase in fuel consumption

(c) Increase in lubricating oil consumption

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

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

(f) Hard starting

(g) Excessive abnormal noise

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

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

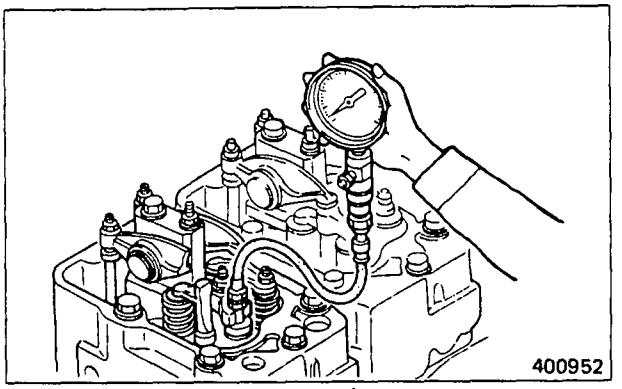
2. TESTING THE COMPRESSION PRESSURE

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

(2) Attach the adaptor (32591-02200) to the cylinder, and connect a compression gauge (33391-02100) to the adaptor.

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

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



Measuring compression pressure

⚠ CAUTION

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

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

Unit: kgf/cm^2 (psi) [MPa]

Item	Assembly standard	Repair limit
Compression pressure	25 (356) [2.5]	20 (284) [2.0]

NOTE

Measure the compression pressure with the engine running at 120 -200 rpm.

⚠ CAUTION

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

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

ADJUSTMENTS, BENCH TEST, PERFORMANCE TESTS

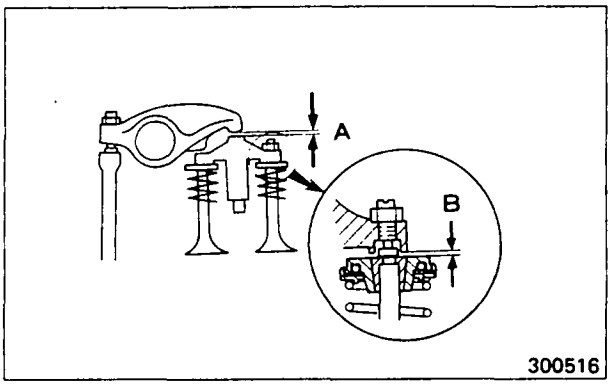
1. ADJUSTMENTS

1.1 Valve clearance

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

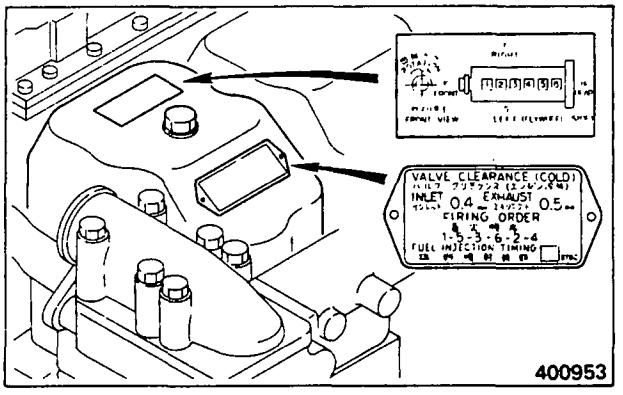
Unit: mm (in.)

Item		Assembly standard
Valve clearance (A) (cold)	Inlet valves	0.4 (0.016)
	Exhaust valves	0.5 (0.020)
Valve bridge-to-valve cotter clearance (B)		0.5 (0.020), minimum



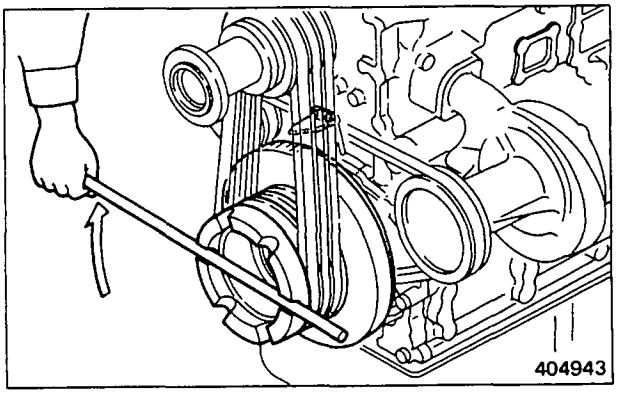
NOTE

Clearance B between the bridge and valve rotator should be more than 0.5 mm (0.020 in.) (assembly standard) after the front and rear valve heights have been adjusted. If the clearance is too small, grind the bridge to obtain the specified clearance.



(1) Inspection

(a) Check the valve clearance in the firing order, by turning the crankshaft in the normal direction (clockwise as seen from the front side) to bring each piston to its top dead center on compression stroke.

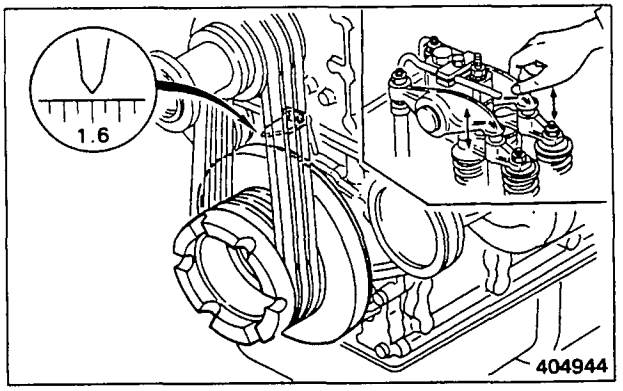


Firing order (injection sequence)

Cylinder No.	1–5–3–6–2–4

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

(c) Insert a feeler gauge into between the rocker arm and bridge cap, and check the valve clearance.

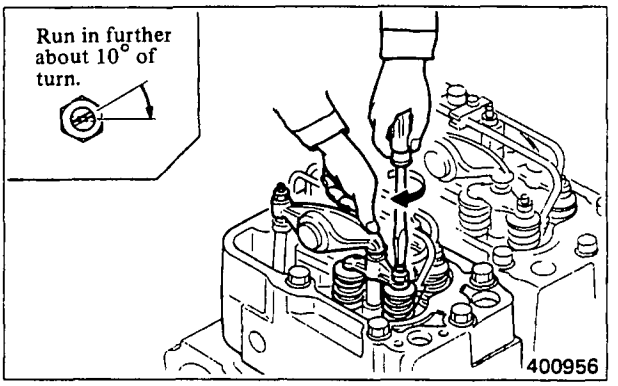


(2) Adjusting valve bridge (valve height)

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

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

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



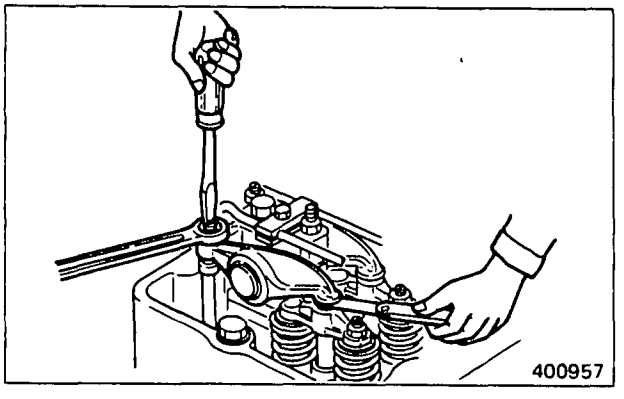
⚠ CAUTION

If the valve bridge-to-rotator clearance is too small, the valve cotters are apt to come off. Be sure to maintain specified clearance between the bridge and rotator.

(3) Adjustment

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

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



1.2 Fuel system priming

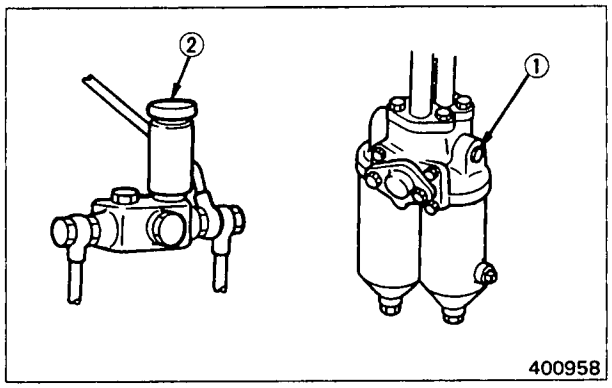
Prime the fuel filters and fuel injection pumps in that order.

(1) Fuel filters (wire-element type)

(a) Loosen air vent plugs (1) about 1.5 turns.

(b) Unlock the priming pump by turning its handle (2) counterclockwise, and operate the pump.

(c) Tighten the air vent plug when fuel flows from the vent holes without bubbles.

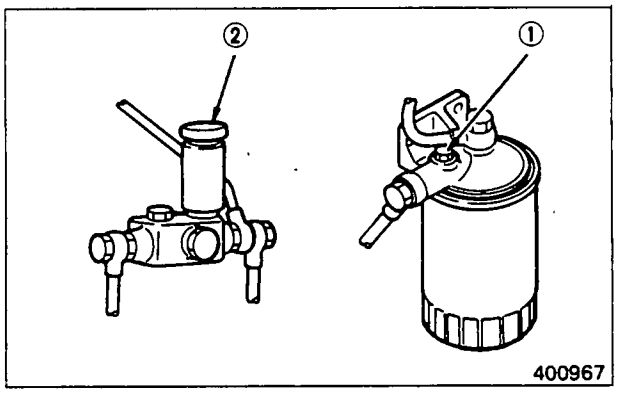


(2) Fuel filter (paper-element type)

(a) Loosen air vent plug (1) about 1.5 turns.

(b) Unlock priming pump handle (2) by turning it counterclockwise, and operate the priming pump.

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

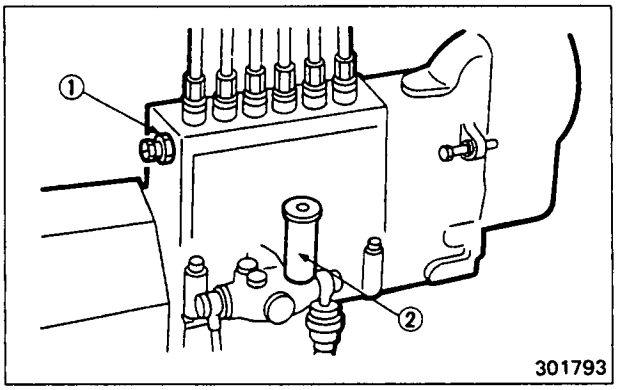


(3) Fuel injection pumps

(a) Loosen air vent plug (1) about 1.5 turns.

(b) Operate the priming pump handle (2).

(c) Tighten the air vent plug when fuel flows from the vent hole without bubbles. Lock the priming pump by turning its handle clockwise while pushing it down before tightening the last vent plug.



⚠ CAUTION

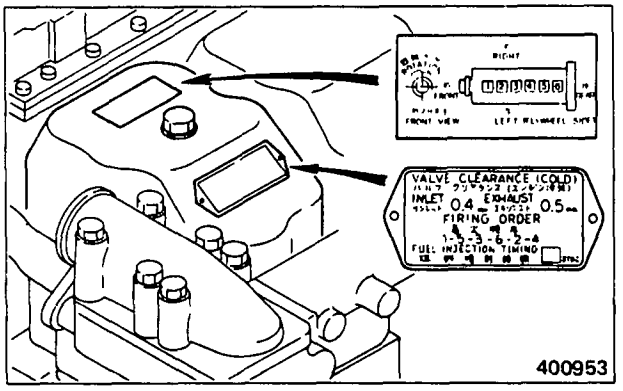
(a) If all vent plugs are tightened before the priming pump handle is locked, fuel pressure acts on the feed pump, making it impossible to restore the handle.

(b) Wipe off fuel spilt from the vent holes with cloth.

1.3 Fuel injection timing

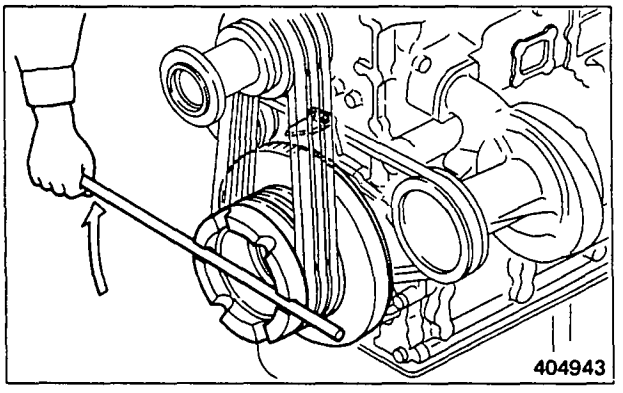
(1) Fuel injection timing and indication

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



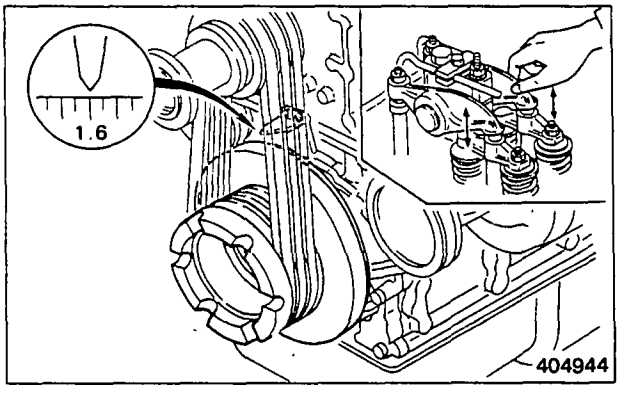
(2) Bringing No. 1 piston to top dead center on compression stroke

(a) Using turning bar (37491-03100) at the crankshaft pulley, turn the crankshaft in normal direction (clockwise as seen from the front side of the engine).



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

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

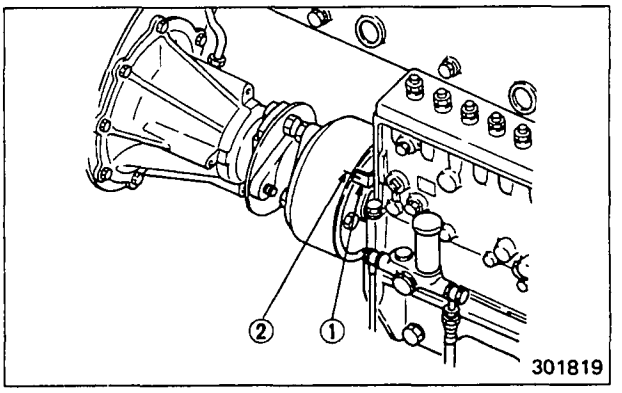


⚠ CAUTION

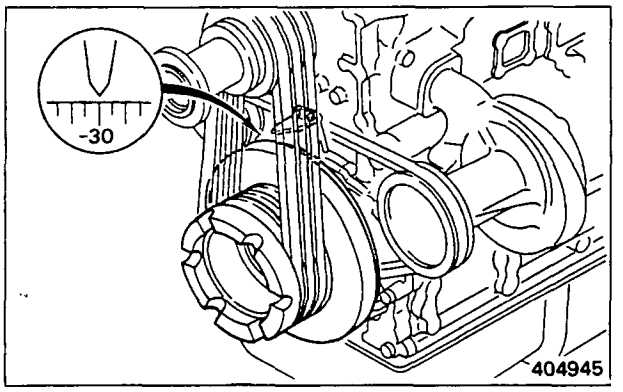
Do not confuse the top dead center on compression stroke for No. 1 cylinder with that for No. 6 cylinder.

(3) Inspection

(a) Once turn the crankshaft about 60° in the reverse direction. Then, turn it just a little at a time in the normal direction to align timing mark (2) on the pump drive coupling with pointer (1) on the pump case.



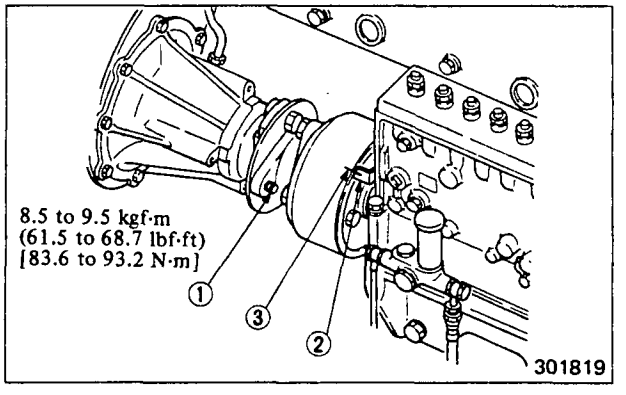
(b) Read the degrees of an angle (injection timing) on the scale on the damper, indicated by the pointer. Minus (-) mark on the scale and "B.T.D.C." on the caution plate mean "BEFORE" top dead center.



(4) Adjustment

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

(b) Loosen two coupling bolts (1), and displace the injection pump shaft to align pointer (2) on the pump case with timing mark (3) on the coupling. Then, tighten one bolt to the specified torque and, after turning the crankshaft, similarly tighten the other.



(c) Again check the timing by cranking the engine for verification.

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

⚠ CAUTION

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

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

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

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

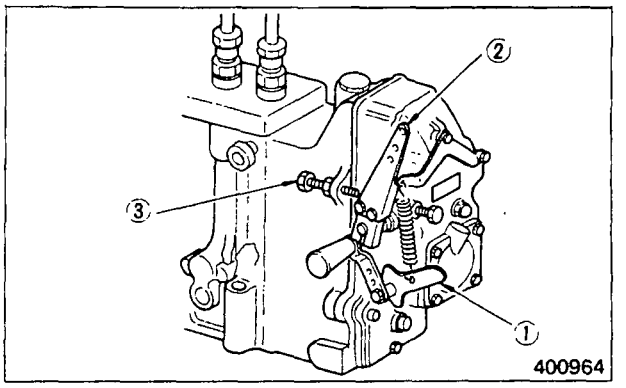
For inspection and adjustment, warm up the engine thoroughly until the coolant and oil temperature rises to 70°C (158°F).

RSUV-type governor

(1) Adjusting no-load minimum (idling) speed setting

(a) Make sure that load control lever (1) is in the idling position, and measure the engine speed (rpm).

(b) If the idling speed is out of the specified range, reset the idling position of load control lever. (Make reference to the separate volume, GOVERNOR.)



(2) Adjusting no-load maximum speed setting

(a) Move the load control lever and speed control lever (2) until they touch maximum stopper bolts (3) respectively.

⚠ CAUTION

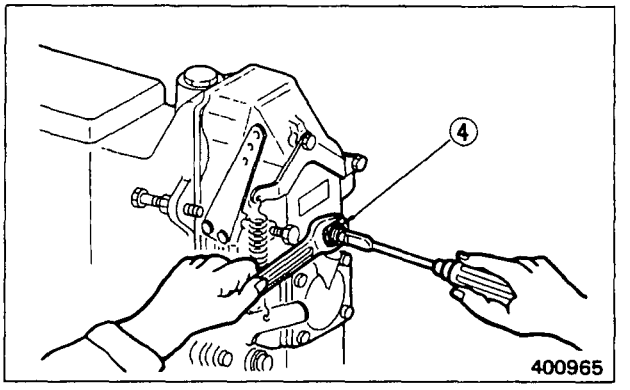
There is a possibility of the engine overrunning in some maximum stopper bolt position. With this possibility kept in mind, operate the control levers while observing the engine rpm.

(b) Measure the engine rpm. If it is out of the specified range, reset the speed control lever by repositioning its maximum stopper bolt.

(c) Make sure that the engine will neither stall nor hunt even if the speed control lever is quickly moved from the maximum speed to the minimum speed position.

(3) Adjusting governor and correcting hunting

(a) If the engine hunts during idling run, reset idling sub-spring (4) at the rear side of governor. Set this spring so that it does neither push tension lever nor be apart from it inside the governor.

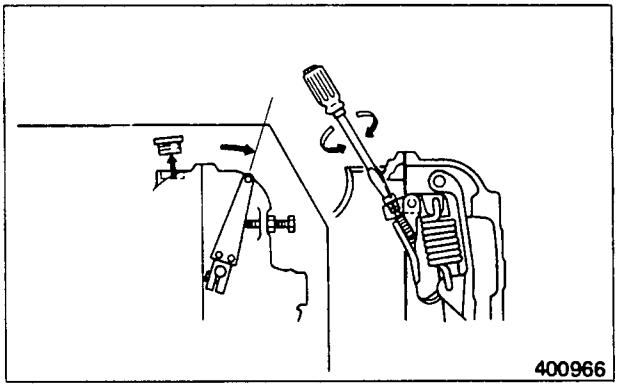


(b) If the engine still hunts after the idling sub-spring has been reset, inspect the control rack for binding.

⚠ CAUTION

If the idling sub-spring is over-corrected, the no-load maximum speed will fluctuate, possibly causing the engine to overrun.

(c) If the engine hunts during no-load maximum speed operation, it is an indication that the tension of main spring is weak. In such a case, tighten the adjusting screw of swivel lever to increase the tension of main spring. Do not over-tighten this screw; over-tightening will narrow the accuracy of speed regulation, causing the engine to hunt when idling. Set the screw within the specified speed regulation range.



(d) Seal each set bolt.

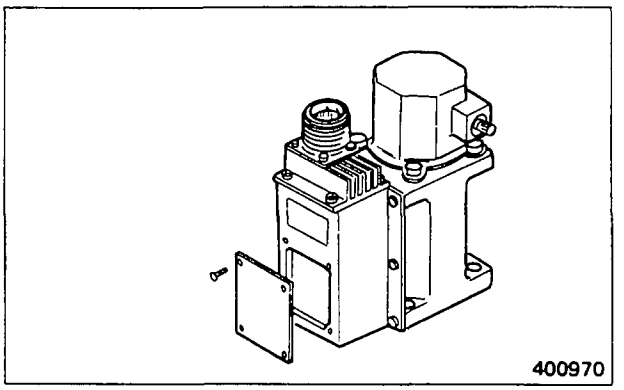
Barber-Colman Dyna 8000 type governor

(1) Adjusting speed setting

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

(b) Remove the top cover of controller, and make sure that the potentiometers are set as follows:

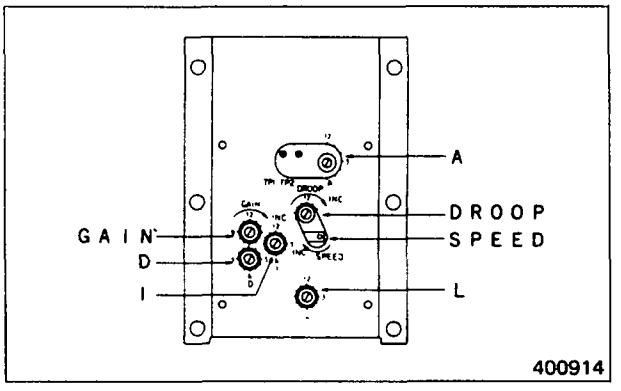
"A" ..... 3 o'clock position
"GAIN" ... 9 o'clock position
"D" ..... 10 o'clock position
"I" ..... 8 o'clock position
"L" ..... 10 o'clock position
(set at factory)



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

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

(e) Set the indicated horsepower by means of rack set bolt.



Potentiometer

(2) Correcting hunting

(a) "A" potentiometer is to be set under no-load condition of the engine. Slowly turn this potentiometer clockwise until the actuator lever quickly vibrates (hunting occurs). Then, slowly turn it counterclockwise until hunting stops. A failure to stop hunting will result in a damage to the actuator.

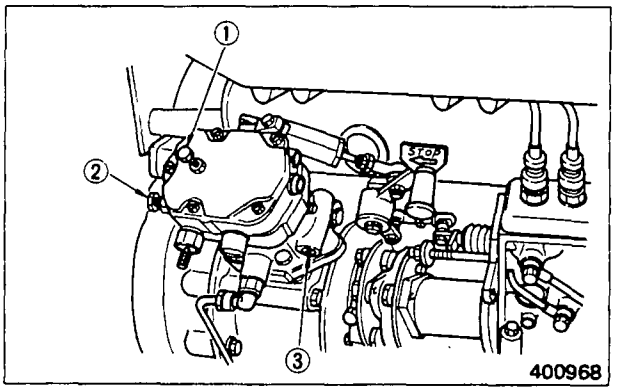
(b) If the actuator fails to gain stability (hunting does not stop), slowly turn "GAIN" potentiometer counterclockwise. If the actuator is in stable condition, slowly turn "GAIN" potentiometer clockwise until hunting occurs; then, slowly turn it counterclockwise until hunting stops.

(c) After setting "GAIN," "A" and "D" potentiometers, turn the power source switch OFF and, when the engine speed is reduced to about 1/2, again turn the power source switch ON. If the engine speed overshoots (jumps up beyond) the setting, turn "I" potentiometer counterclockwise. If the time required to restore to the set speed is too long, turn "I" potentiometer clockwise. Repeat this operation with the engine running under no-load condition.

(d) When "A," "D," "DROOP" and "GAIN" potentiometers are adjusted, the set speed will slightly vary. Set the speed correctly by means of "SPEED" potentiometer. If "DROOP" potentiometer has been turned in the direction of increasing the speed (clockwise), slightly turn "A" potentiometer counterclockwise, and similarly turn "GAIN" potentiometer clockwise.

(e) Install the top cover to the controller, and seal the cover bolts.

Woodward PSG-type governor



(1) Adjusting idling speed setting

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

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

(2) Adjusting no-load maximum speed setting

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

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

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

(3) Correcting hunting

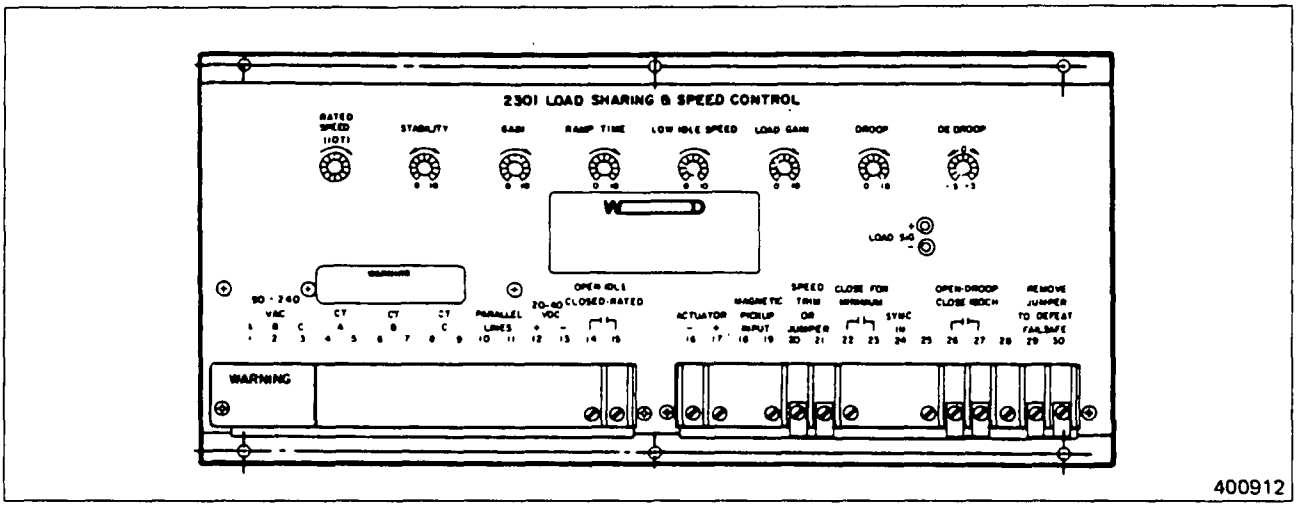
(a) If the engine hunts, reset needle valve (3). Open the needle valve by turning it counterclockwise (2 to 3 rotations) until the engine hunts. Keep the engine hunting for about 30 seconds until air is vented from the governor.

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

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

(d) Seal each set bolt.

Woodward 2301 load sharing & speed control (for EG-3P and EG-B2P governors)



(1) Adjusting idling speed setting

(a) Open the external lamp switch. The engine speed will drop to the speed set by "LOW IDLE SPEED" potentiometer.

(b) Set "LOW IDLE SPEED" potentiometer to obtain the specified idling speed.

(c) Make sure that the engine speed is above the "minimum injection quantity" position of control rack and is governed as was set by "LOW IDLE SPEED" potentiometer.

(d) If the engine speed fluctuates, reset "GAIN" and "STABILITY" potentiometers.

(2) Adjusting speed setting (no-load rated speed)

(a) Close the external lamp switch (between terminals 14 and 15).

(b) Set "RATED SPEED" potentiometer so that the engine runs at the rated speed.

(c) If the engine speed fluctuates, reset "GAIN" and "STABILITY" potentiometers.

(3) Setting "GAIN" and "STABILITY" potentiometers

(a) Speed of response of the governor can be increased by increasing the gain. To increase the gain for this purpose, turn "GAIN" potentiometer clockwise while observing the voltmeter, until the engine just lacks stability.

(b) Turn "STABILITY" potentiometer clockwise or counterclockwise until the engine gains stability.

(c) To verify the engine (governor) stability, change the load on the engine in steps, or quickly move the fuel control linkage. If the stability cannot be gained by turning "STABILITY" potentiometer, turn "GAIN" potentiometer counterclockwise. Turn "GAIN" potentiometer clockwise if low-pitch hunting occurs.

⚠ CAUTION

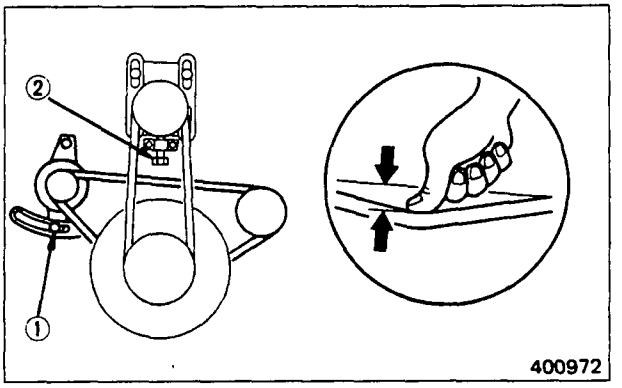
To obtain the optimum performance, turn "GAIN" potentiometer as clockwise as possible, and stop turning it just before the engine lacks stability.

1.5 Belt inspection and adjustment

Apply thumb pressure to the belt midway between the pulleys to check the belt tension. If the tension is incorrect, make an adjustment by means of adjusting bolts (1) (2).

Unit: mm (in.)

Item		Assembly standard
Belt tension	Fan	10 to 15 (0.4 to 0.6)
	Water pump and alternator	10 to 15 (0.4 to 0.6)



2. BENCH TEST

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

2.1 Starting up

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

(2) Crank the engine with the starter for about 15 seconds to permit lubricating oil to circulate through the engine. For this cranking, do not supply fuel to the engine.

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

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

2.2 Inspection after starting up

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

(1) Lubricating oil pressure:
It should be 5 to 6.5 kgf/cm^2 (71 to 92 psi) [0.5 to 0.6 MPa] at rated speed or 2 to 3 kgf/cm^2 (28 to 43 psi) [0.2 to 0.3 MPa] at idling speed.

(2) Coolant temperature: It should be 70°C to 85°C (158°F to 185°F).

(3) Lubricating oil temperature: It should be 80°C to 100°C (176°F to 212°F) when measured in oil pan.

(4) Leakage of oil, coolant and fuel, especially oil leakage from turbocharger lubricating oil pipe connections.

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

(6) Exhaust color and abnormal smell

2.3 Bench test (dynamometer test) conditions

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

2.4 Inspection and adjustment after bench test

(1) Retightening of cylinder head bolts

(2) Adjustment of valve clearance

(3) Adjustment of injection timing

3. PERFORMANCE TESTS

3.1 Standard equipment

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

3.2 Items to be tested

(1) Fuel consumption test

(2) No-load maximum speed test

(3) No-load minimum speed test

3.3 Test methods

(1) Fuel consumption test

(a) Engine speed (rpm)

(b) Fuel injection quantity

(c) Engine output

(2) No-load maximum speed test

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

(3) No-load minimum speed test

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

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

(4) Others

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

ENGINE ACCESSORY REMOVAL AND INSTALLATION

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

1. PREPARATORY STEPS

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

(b) Loosen the drain cocks on the left-hand side and of the rear of crankcase, and drain coolant.

(c) Loosen the oil pan drain plug, and drain engine oil.
[Oil capacity: 70 liters (18.5 U.S. gal.)]

⚠ WARNING

Hot engine oil can cause personal injury if it contacts the skin. Use caution when draining the oil.

2. ENGINE ACCESSORY REMOVAL

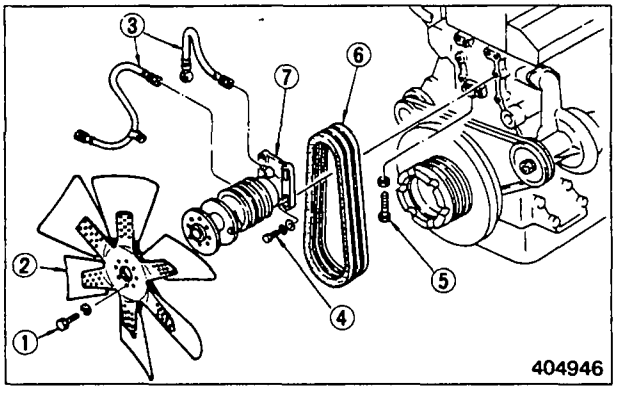
(1) Removing fan drive

(a) Remove fan (2) by unscrewing fan mounting bolts (1).

(b) Remove two flexible lubricating oil pipes (3).

(c) Loosen bracket mounting bolts (4) and back off belt tension adjusting bolts (5) to slacken V-belt (6).

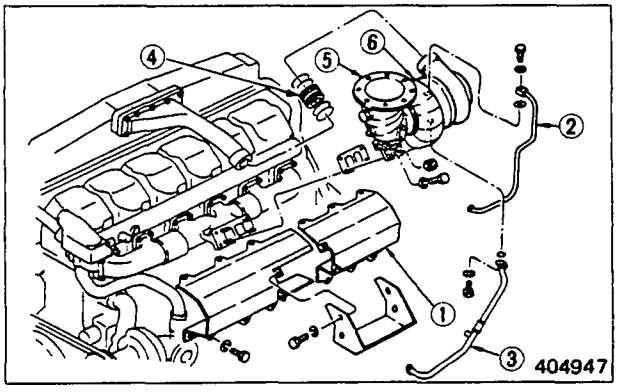
(d) Remove V-belt and fan drive (7) by unscrewing bracket mounting bolts.



(2) Removing turbocharger and insulator

(a) Remove 3-part insulator (1).

(b) Disconnect turbocharger lubricating oil pipe (2) and drain pipe (3).



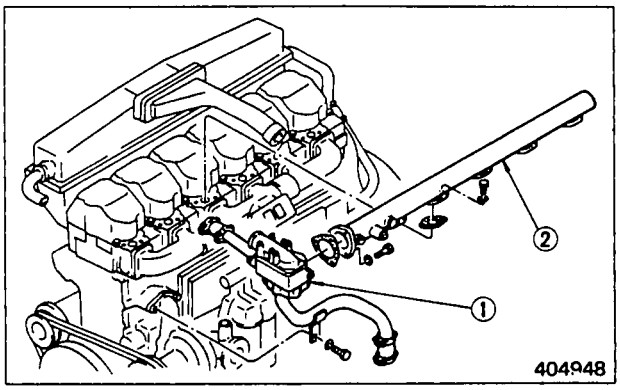
(c) Unscrew bolt (4) connecting air duct and turbocharger.

(d) Remove exhaust pipe (5) and turbocharger (6).

(3) Removing thermostat case and water pipes

(a) Removing thermostat case (1) complete with water pipe.

(b) Remove water outlet pipe (2) by unscrewing bolts.

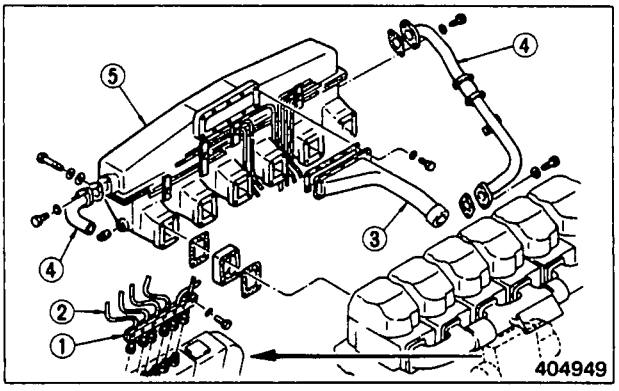


(4) Removing air cooler and fuel pipes

(a) Remove pipe clamp (1) and disconnect fuel injection pipes (2) at both ends.

(b) Disconnect air duct (3) and water pipes (4).

(c) Remove air cooler (5) with fuel injection pipes clamped on it.



NOTE

Coolant in the air cooler will be automatically drained by opening the drain cock on crankcase.

[Weight of air cooler:
54 kg (119 lb) approx.]

(d) Remove fuel leak-off pipes

⚠ CAUTION

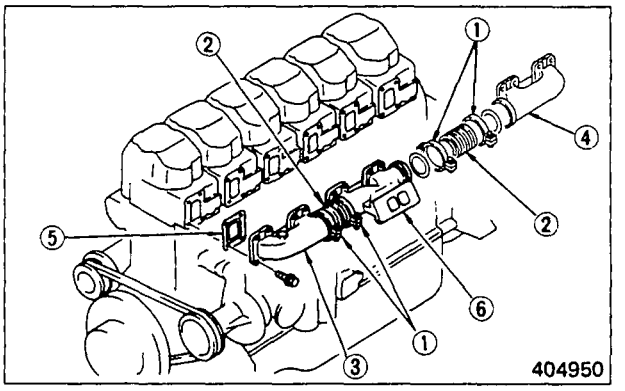
Be sure to fit rubber caps to the openings of the injection pump and nozzle holders from which fuel injection pipes were disconnected to prevent dust from getting inside the fuel system.

(5) Removing exhaust manifolds

(a) After removing couplings (1), remove joints (2) and gaskets (3).

(b) Remove manifolds (3) (4) and gaskets (5) by unscrewing bolts.

(c) Remove manifold (6) and gaskets.

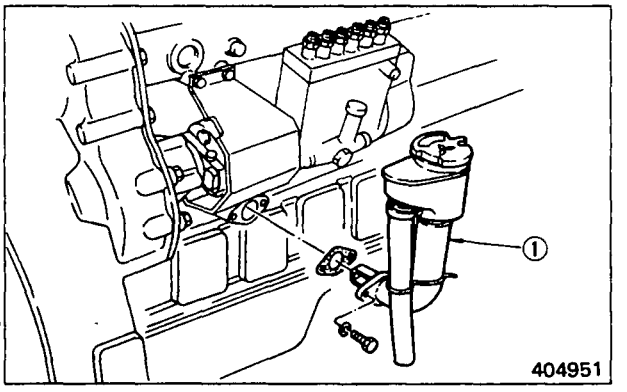


NOTE

When installing the manifolds, place each gasket with its side marked as "TOP" facing the mainfold.

(6) Removing oil filler

Remove oil filler (1) by unscrewing bolts.



(7) Removing fuel injection pump

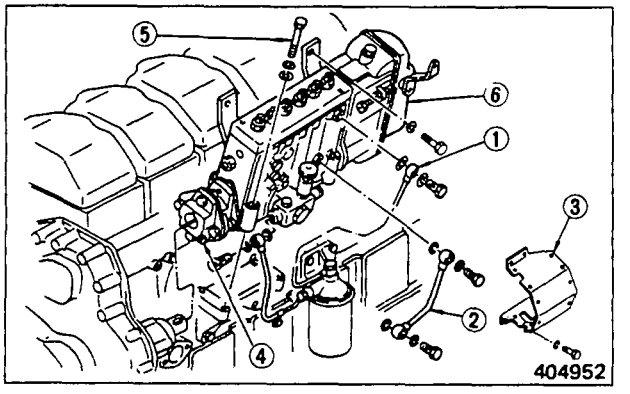
(a) Disconnect fuel pipe (1) and oil pipe (2) from the pump.

(b) Remove coupling cover (3) from the pump.

(c) Loosen bolts (4) securing the coupling to the shaft sufficiently.

(d) Unscrew bolts (5) securing the pump to the engine. Remove pump (6) complete with the coupling by prying it toward the front side of the engine with a bar.

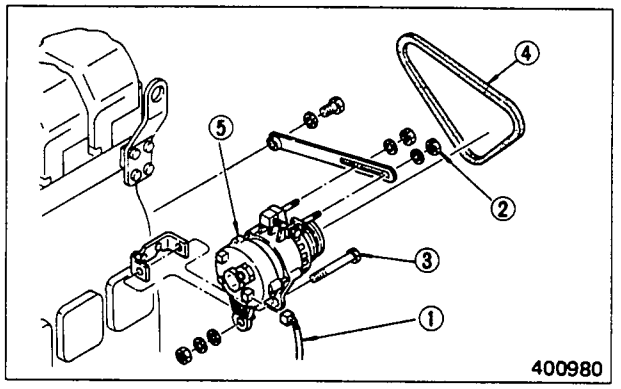
[Weight of injection pump: 25 kg (55 lb), approx.]



(8) Removing alternator

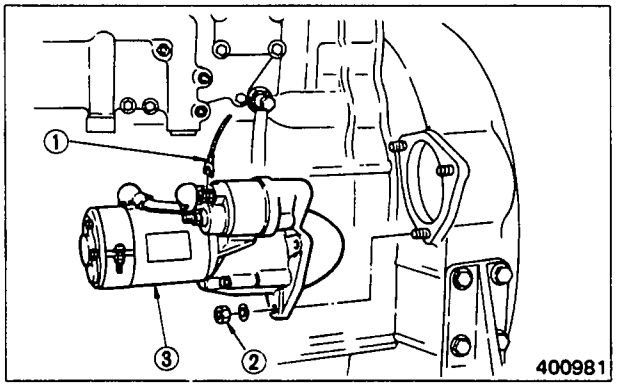
(a) Disconnect harness (1), and loosen nuts (2) for belt adjusting boss.

(b) Remove V-belt (4) and alternator (5) by unscrewing bolt (3).



(9) Removing starter

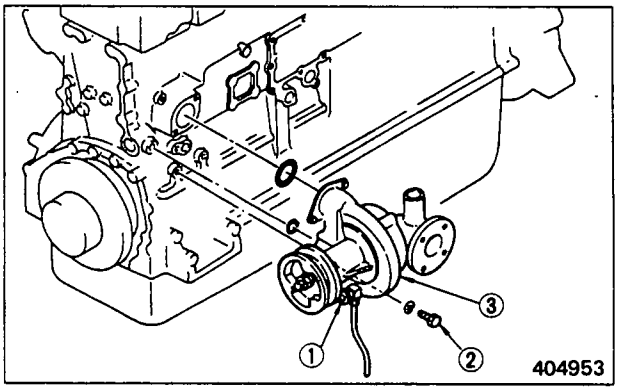
Disconnect harness (1), and remove starter (3) by unscrewing nuts (2). [Weight of starter: 15 kg (33 lb), approx.]



(10) Removing water pump

(a) Drain coolant from the water pump by loosening the drain valve (1).

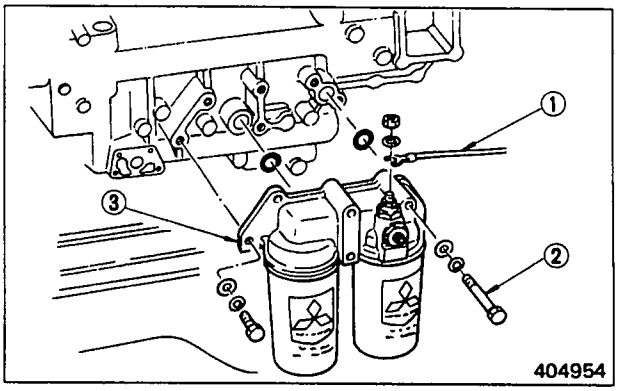
(b) Remove water pump (3) by unscrewing bolts (2).



(11) Removing oil filter

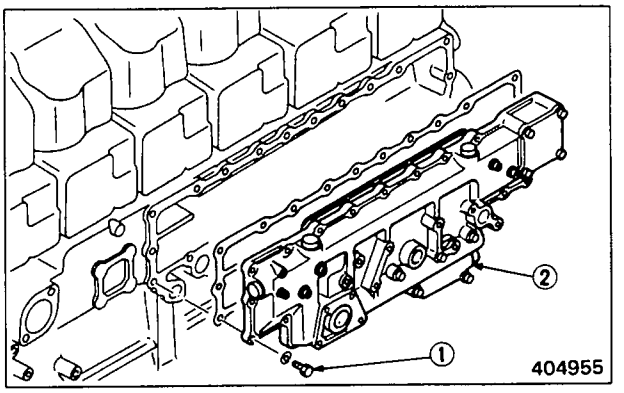
(a) Disconnect harness (1) for the oil filter alarm.

(b) Remove oil filter bracket (3) by unscrewing bolts (2).



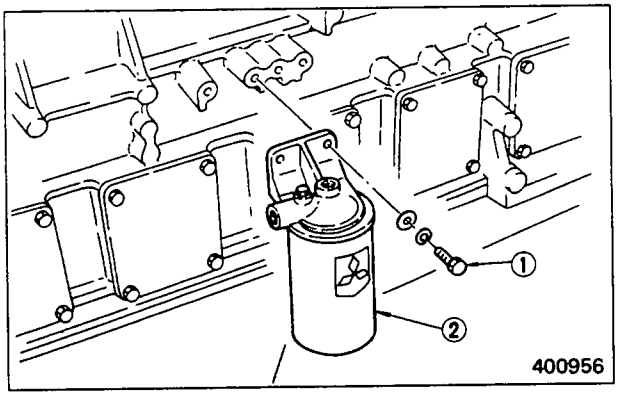
(12) Removing oil cooler

Remove oil cooler (2) by unscrewing bolts (1).



(13) Removing fuel filter

Remove fuel filter (2) by unscrewing mounting bolts (1).



3. ENGINE ACCESSORY INSTALLATION

To install the accessories, follow the reverse of removal procedures. After installing the accessories, service as follows:

(a) Refill the lubrication system.

(b) Refill the cooling system.

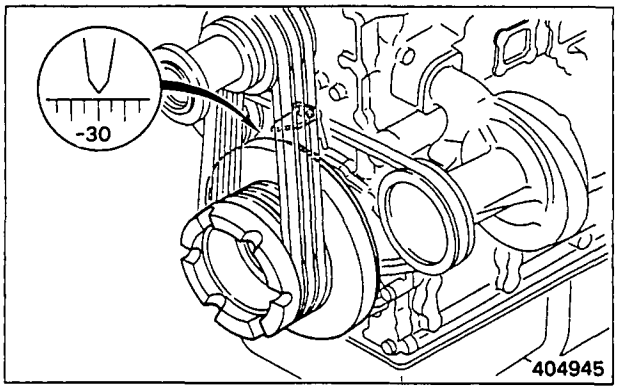
(c) Check each pipe connection for oil or coolant leaks.

(d) Prime the fuel system.

(e) To install the injection pumps, refer to FUEL INJECTION PUMP INSTALLATION which follows. After installing the injection pumps, check and adjust the injection timing. (Refer to 1.3 Fuel injection timing, 1. ADJUSTMENT, Group 5.)

4. INJECTION PUMP INSTALLATION

(a) Make sure the pointer on the engine is aligned with No. 1 cylinder injection timing.

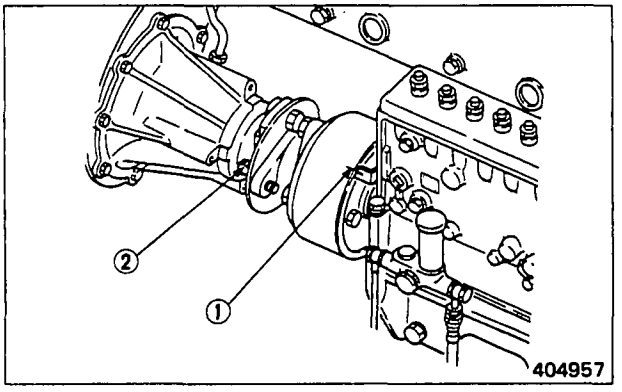


NOTE

Ascertain in advance the beginning-of-injection timing punched on the caution plate attached to No. 1 cylinder rocker cover.

(b) Install coupling to injection pump and align the pointer on the pump case with mark (1) on the coupling.

(c) Fit the key of drive shaft into the keyway in coupling, push in the injection pump toward the drive case. Tighten bolts (2) securing the coupling to the shaft to 8.5 to 9.5 kgf·m (61.5 to 68.7 lbf·ft) [83.4 to 93.2 N·m].

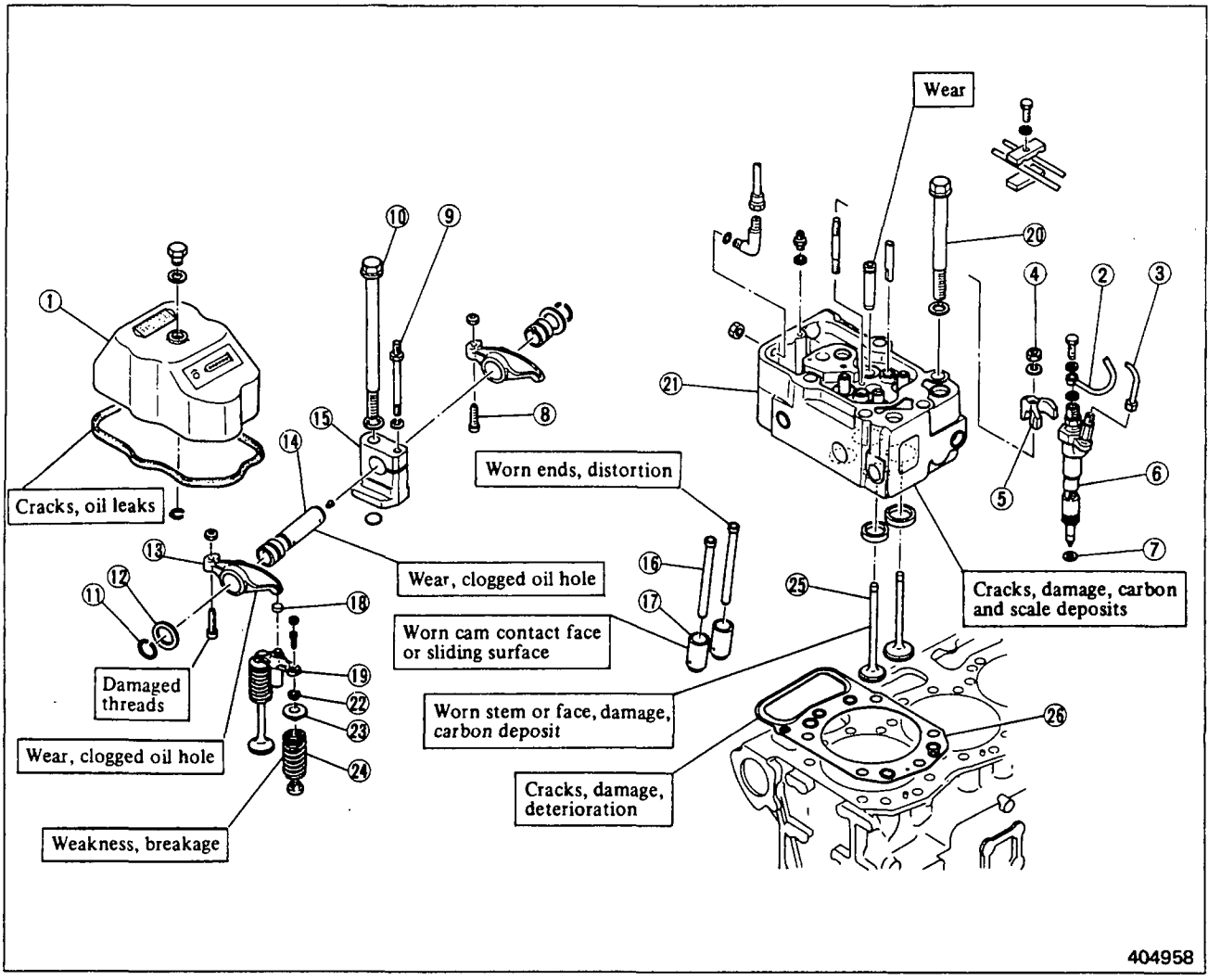


(d) Connect the fuel pipe and lubricating oil pipes to the pump.

ENGINE PROPER

1. CYLINDER HEADS AND VALVE MECHANISM

1.1 Disassembly

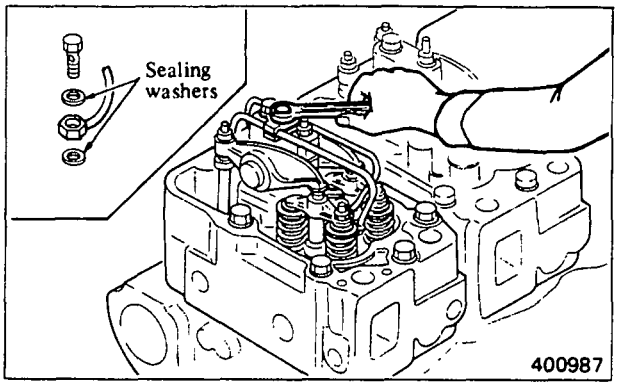


① Rocker cover
② Fuel leak-off pipe
③ Fuel pipe
④ Nut, washer
⑤ Injection nozzle gland
⑥ Injection nozzle
⑦ Packing
⑧ Adjusting screw
⑨ Bolt
⑩ Cylinder head bolt
⑪ Snap ring
⑫ Washer
⑬ Rocker
⑭ Rocker shaft
⑮ Rocker shaft bracket
⑯ Valve pushrod
⑰ Tappet
⑱ Valve bridge cap
⑲ Valve bridge
⑳ Cylinder head bolt
㉑ Cylinder head
㉒ Valve cotter
㉓ Valve rotator
㉔ Valve spring
㉕ Valve
㉖ Cylinder head gasket

(1) Removing fuel pipes

(a) Disconnect each fuel injection pipe and fuel leak-off pipe.

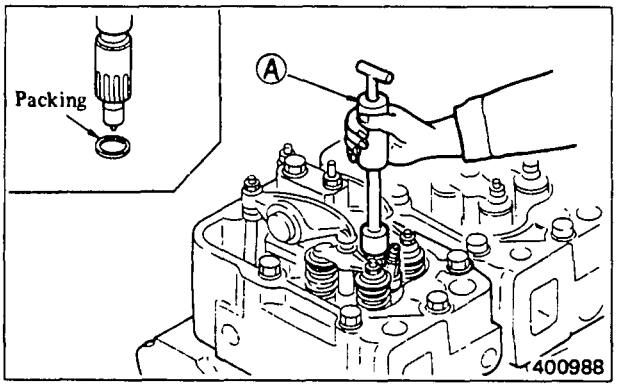
(b) Remove the nozzle-side sealing washers, and set them aside so as not to lose them.



(2) Removing injection nozzles

(a) Using injection nozzle remover (A) (32591-00201), remove each injection nozzle. Take out the packing left behind in the cylinder head.

(b) Be careful not to damage the nozzle tip.

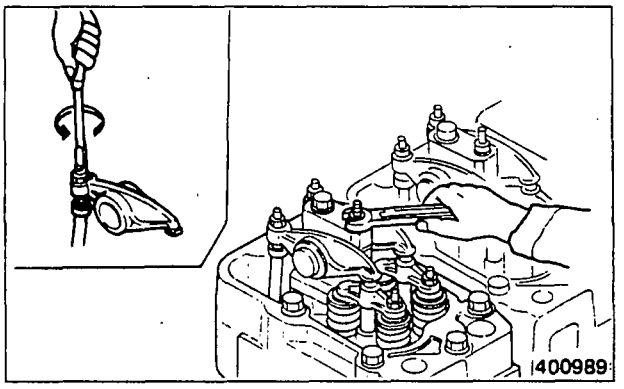


(3) Removing rocker shaft assemblies

(a) Loosen the adjusting screw of each rocker about one rotation in advance.

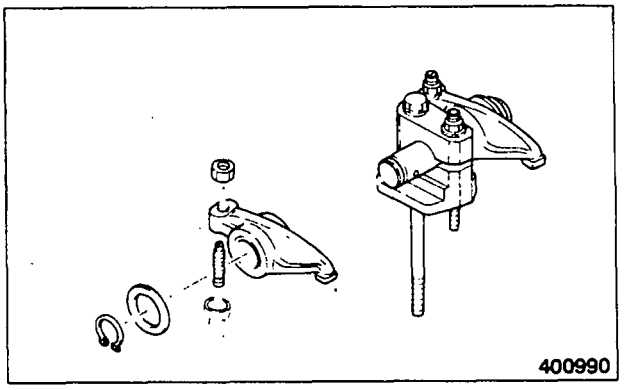
(b) Loosen the short rocker bracket mounting bolt about five rotations first; then remove the long bolt securing the cylinder head and rocker bracket with a torque wrench.

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



(4) Disassembling rocker shaft assemblies

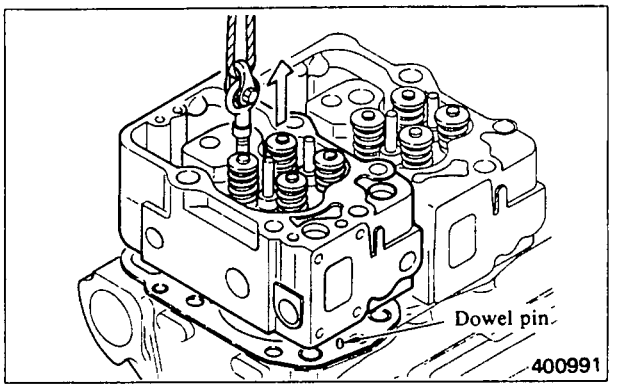
Lay the disassembled rockers in the order removed, and install them in that order at the time of reassembly. This is for insuring the same rocker shaft-to-rocker clearance as before.



(5) Removing cylinder head assemblies

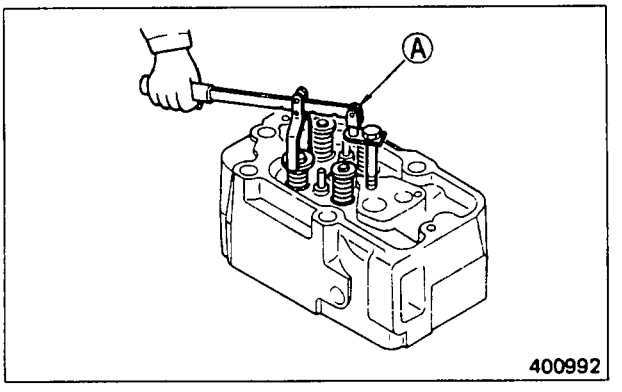
(a) Remove the cylinder head bolts.

(b) Each cylinder head is located relative to the crankcase with dowel pins. Lift the head off the crankcase.
[Weight of cylinder head:
29 kg (64 lb), approx.]



(6) Removing valves and valve springs

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



NOTE

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

1.2 Inspection and repair

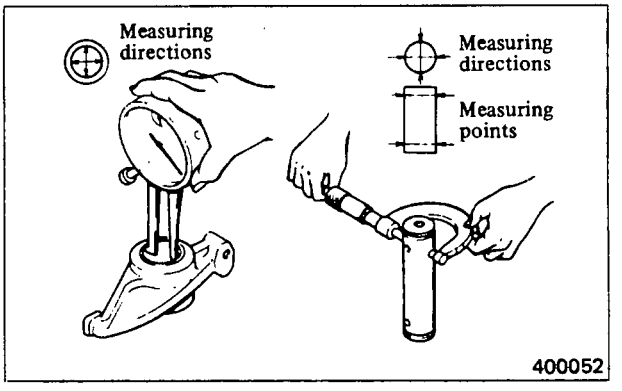
Rockers, rocker bushings and rocker shafts

(1) Measuring inside diameter of rocker bushings and diameter of rocker shafts

Replace the bushings and shafts if they are worn in excess of the service limit.

Unit: mm (in.)

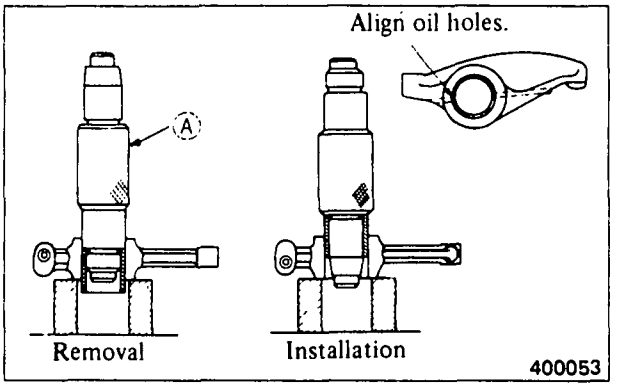
Item	Nominal value	Assembly standard	Service limit
Inside diameter of rocker bushings	32 (1.26)	32.000 to 32.040 (1.25984 to 1.26141)	32.100 (1.26378)
Diameter of rocker shafts		31.991 to 31.975 (1.25949 to 1.25886)	31.950 (1.25787)



Measuring rocker bushing and rocker shaft

(2) Replacing rocker bushings

Using rocker bushing puller (A) (32591-02600), remove the rocker bushings (worn) for replacement.



Replacing rocker bushing

NOTE

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

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

(c) After installing the bushing, measure its inside diameter to make sure that it is $32\ ^{+0.04}_{0}$ mm ($1.26\ ^{+0.00157}_{0}$ in.).
If the diameter is out of this tolerance, refinish it to $32\ ^{+0.04}_{0}$ mm ($1.26\ ^{+0.00157}_{0}$ in.) $\frac{3.2S}{\nabla\nabla\nabla}$ by reaming.

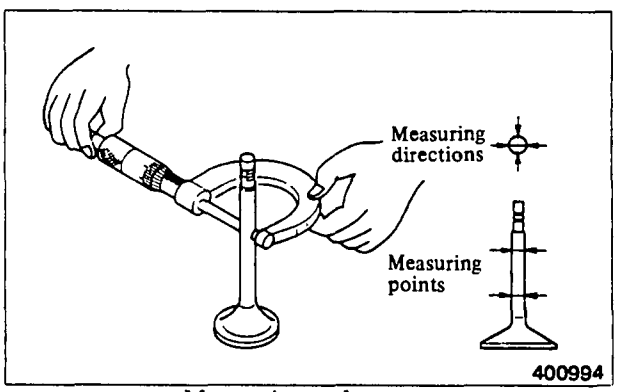
Valve guides and valve stems

(1) Measuring diameter of valve stems and inside diameter of valve guides

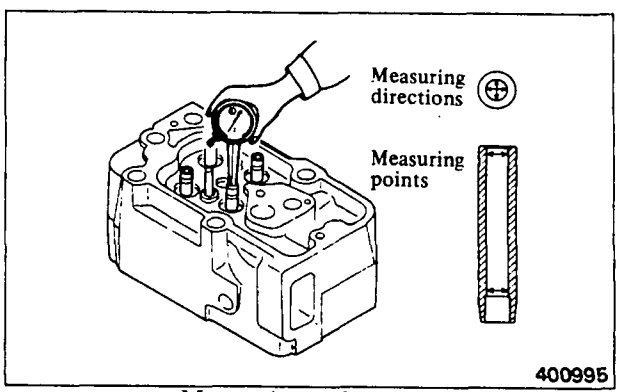
The valve guide is worn more rapidly at its both ends than at any other parts. Measure the inside diameter of the guide at its ends and at middle part in two directions. Replace the guides if they are worn in excess of the service limit.

Unit: mm (in.)

Item		Nominal value	Assembly standard	Service limit
Diameter of valve stems	Inlet	10 (0.39)	9.960 to 9.940 (0.39213 to 0.39134)	9.910 (0.39016)
	Exhaust		9.930 to 9.910 (0.39094 to 0.39016)	9.880 (0.38898)
Inside diameter of valve guides			10.000 to 10.015 (0.39370 to 0.39429)	10.060 (0.39606)



Measuring valve stem



Measuring valve guide

(2) Replacing valve guides and stem seals

(a) Using valve guide remover (A) (36291-04200), remove the valve guide (worn) for replacement.

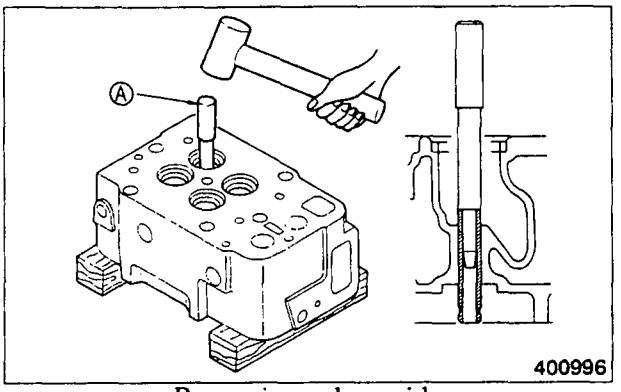
(b) To install a new valve guide, use valve guide & seal installer (B) (32591-00300) and a press.

⚠ CAUTION

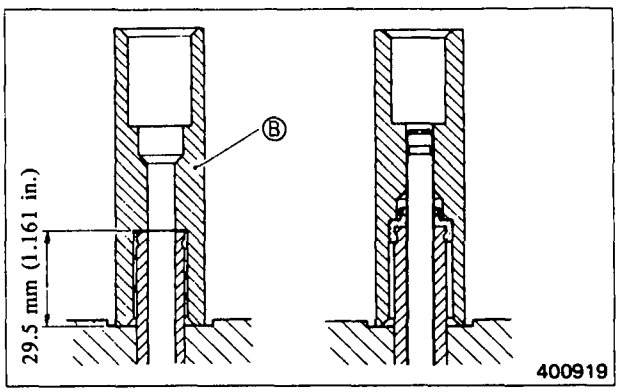
(a) As-installed depth is specified for the valve guide; be sure to use the vave guide & seal installer to secure this depth.

(b) Do not apply any oil or sealant to the surface of stem seal that comes in contact with the valve guide. When installing the stem seal, coat the seal rubbing surface of the stem with engine oil to insure initial lubrication of the stem seal lip.

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



Removing valve guide



Installing valve guide and stem seal

Valves and valve seats

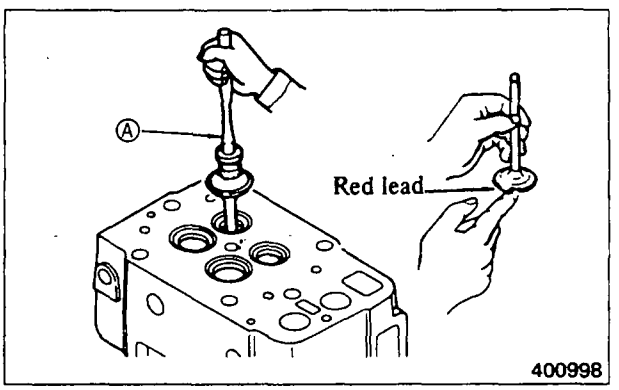
(1) Inspecting valve face

Coat the valve face lightly with red lead and, using valve lapper (A) (30091-08800), check the valve contact with its seat. If the contact is not uniform, or if the valve is defective or worn in excess of the Repair limit, repair or replace the valve and valve seat.

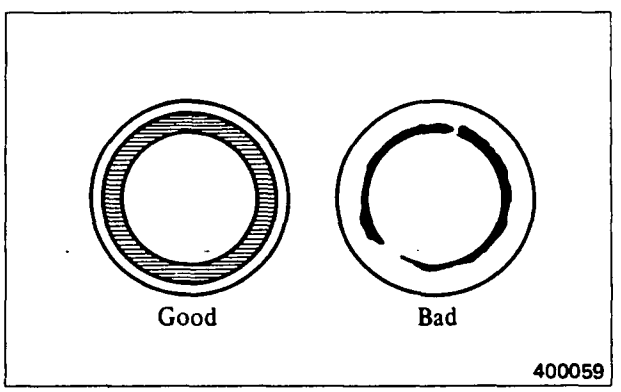
NOTE

(a) Check the valve face after checking or replacing the valve guide.

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



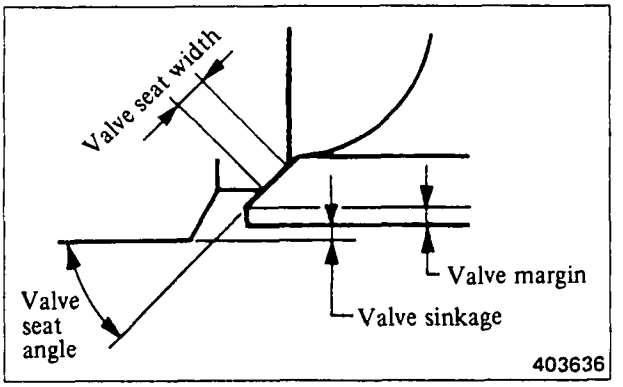
Checking valve face



Valve contact with its seat

Unit: mm (in.)

Item			Assembly standard	Repair limit
Valve seat	Angle		30°	–
	Valve sinkage		0 ± 0.2 (0 ± 0.008)	0.5 (0.020)
	Width	Inlet	2.08 (0.0819)	2.5 (0.098)
		Exhaust	1.85 (0.0728)	2.3 (0.091)
Valve margin			3.0 ± 0.1 (0.118 ± 0.004)	2.0 (0.079) by refacing



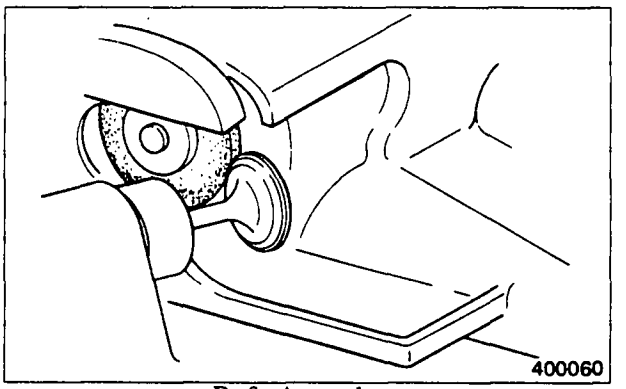
(2) Refacing valves

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

NOTE

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

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

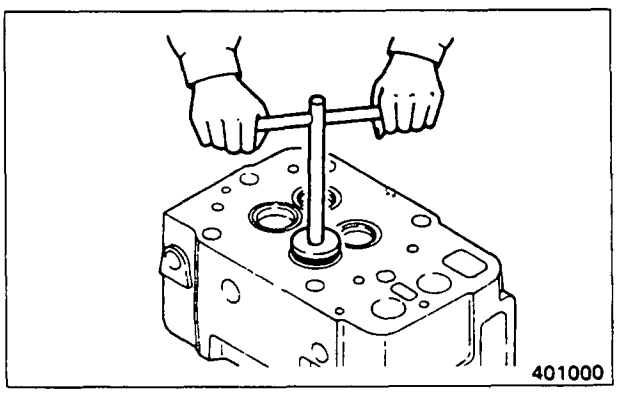


Refacing valve

(3) Refacing valve seats

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

(b) Lap the valve in the valve seat.



Refacing valve seat

NOTE

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

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

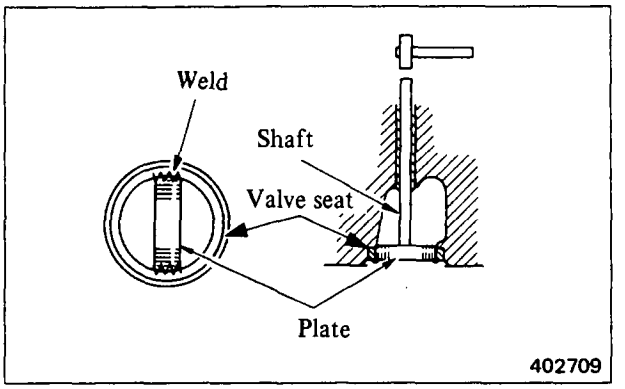
(c) Replace the valve seat if the valve sinkage is more than the Repair limit after refacing.

(4) Replacing valve seats

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

NOTE

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

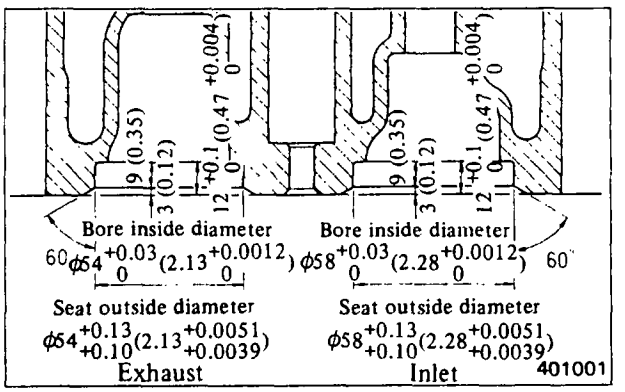


Removing valve seat

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

Unit: mm (in.)

Item		Nominal value	Standard clearance
Cylinder head bore inside diameter and valve seat outside diameter	Inlet	58 (2.28)	-0.07 to -0.13 (-0.0028 to -0.0051)
	Exhaust	54 (2.13)	



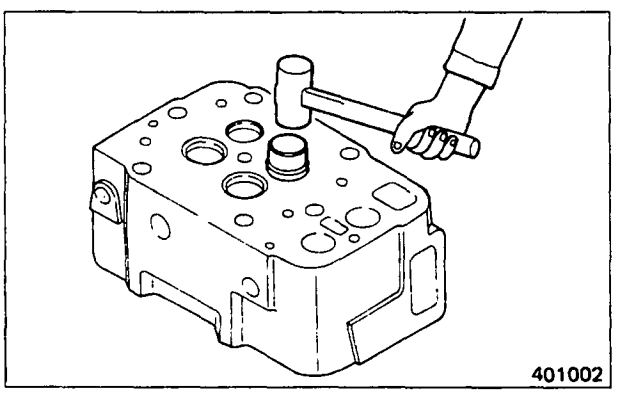
Valve seat dimensions

NOTE

Minus (-) sign of the standard clearance values indicates interference.

(c) Chill the valve seat in liquid nitrogen [about -170°C (-274°F)] for more than 4 minutes with the cylinder head kept at normal temperature, or heat the cylinder head to 80°C to 100°C (176°F to 212°F) with the valve seat chilled in ether containing dry ice.

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



Installing valve seat

(5) Lapping valves in valve seats

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

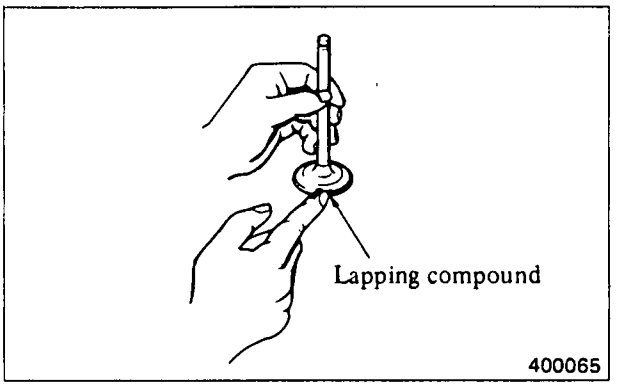
(a) Coat the valve face lightly with a lapping compound.

NOTE

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

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

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



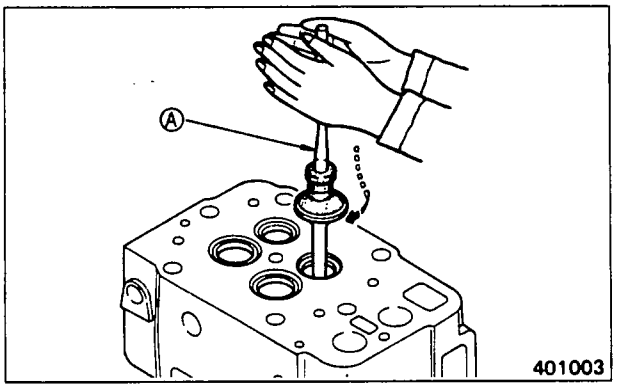
Coating valve with lapping compound

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

(c) Wash off the compound with diesel fuel.

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

(e) Check the valve face for contact.



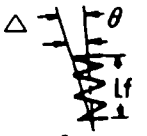
Lapping valve in valve seat

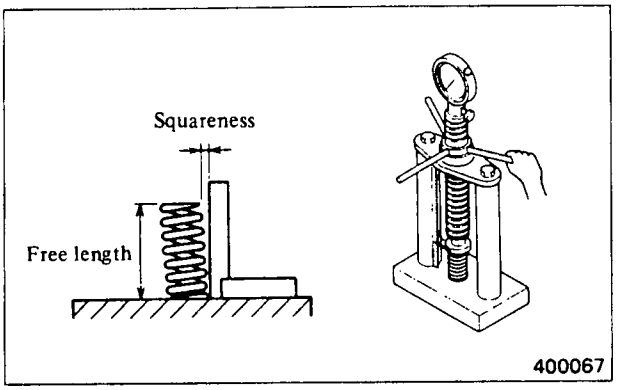
Valve springs

Measuring squareness and free length

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

Unit: mm (in.)

Item	Assembly standard	Service limit
Free length	67.5 (2.657)	66.2 (2.606)
Squareness	 θ = 1°, maximum	Δ = 1.5 (0.059) over the length
Length under test force/test force, mm (in.)/ kgf (lbf) [N]	60.0 (2.362)/ 27.8±5% (61.3±5%) [272.6±5%]	

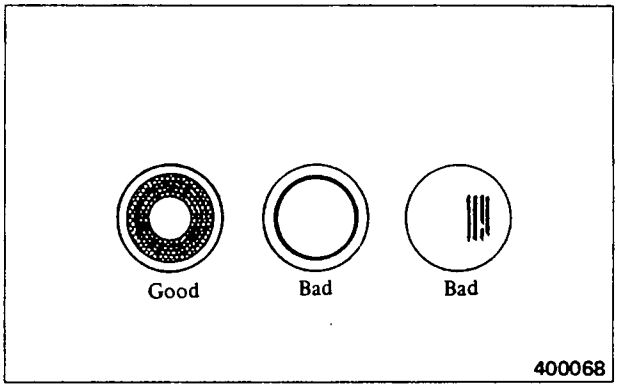


Measuring valve spring

Tappets and valve pushrods

(1) Inspecting cam contact face of tappets

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



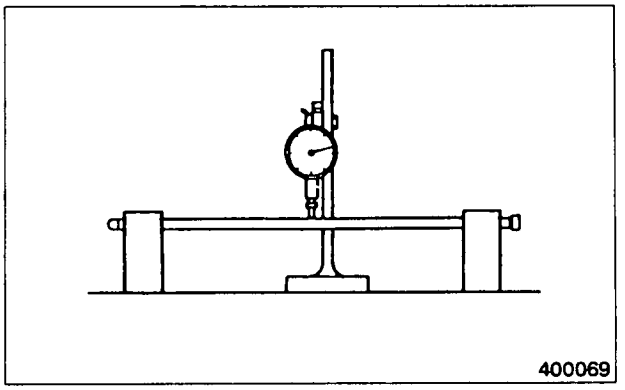
Cam contact face of tappet

(2) Measuring runout of valve pushrods

If the runout exceeds the Assembly standard, replace the pushrods.

Unit: mm (in.)

Item	Assembly standard
Runout of valve pushrods	0.5 (0.020), maximum



Measuring valve pushrod runout

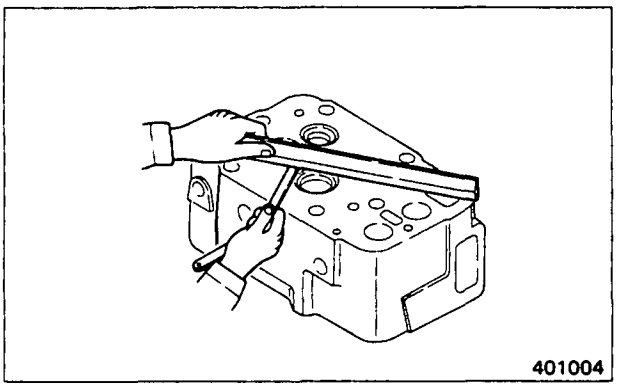
Cylinder heads

Measuring warpage of gasket contact surface

Measure the warpage of gasket contact surface of each head with straight edge and feeler gauge. If the warpage is in excess of the repair limit, reface the surface with a surface grinder.

Unit: mm (in.)

Item	Assembly standard	Repair limit	Service limit
Warpage of gasket contact surface	0.03 (0.0012), maximum	0.07 (0.0028)	0.50 (0.0197)



Measuring warpage of gasket contact surface of head

1.3 Reassembly

To reassemble, follow the reverse of disassembly procedure.

(1) Installing cylinder head gaskets

(a) Clean the gasket contact surfaces of cylinder heads and crankcase with a rag.

(b) Put the cylinder head gaskets in position on the crankcase, making sure that dowel pins enter their holes in the gaskets.

⚠ CAUTION

Do not apply any sealant to the gaskets.

(2) Reassembling cylinder heads

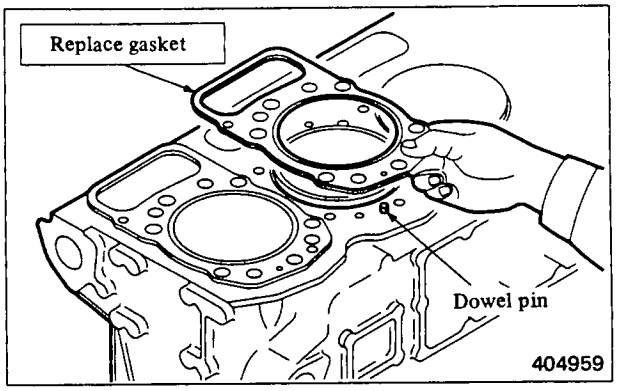
(a) Coat the valve stems with engine oil, and put them into the valve guides.

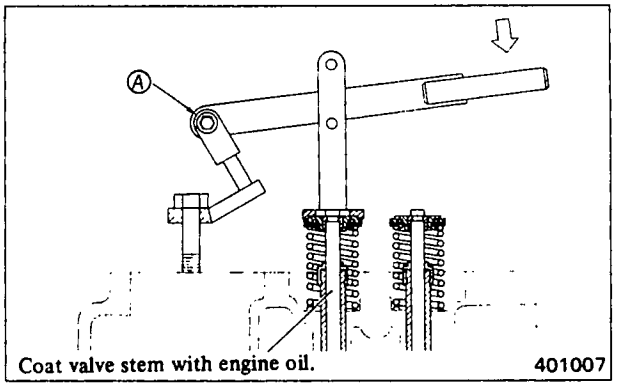
(b) Put the valve springs and rotators in position on the valve guides. Compress each valve spring with valve spring pusher (A) (33591-04500), and install the valve cotters to the valve stem.

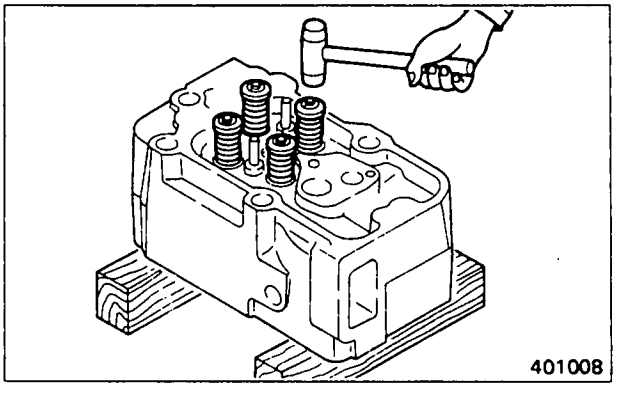
(c) Lightly tap on the top of each valve stem with a soft hammer to make sure that the valve spring and cotters are properly installed.

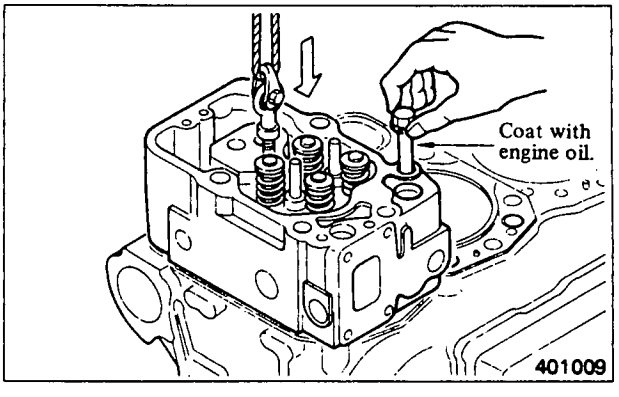
(3) Installing cylinder head assemblies

Keep the head assembly slightly lifted with the dowel pins entering their holes. Put engine oil on the threads of cylinder head bolts (except for those securing the rocker brackets), and put the bolts into the head assembly.









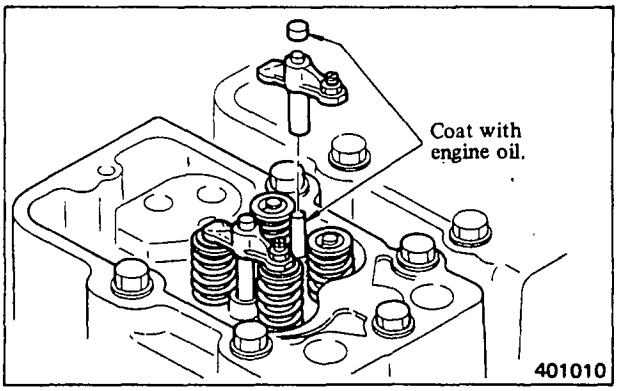
⚠ CAUTION

Before installing the cylinder head assembly, measure the projection of each piston, making sure that the projection is correct. (Refer to (4), Pistons, 2.2, 2, Group No. 7.)

(4) Installing valve bridges and caps

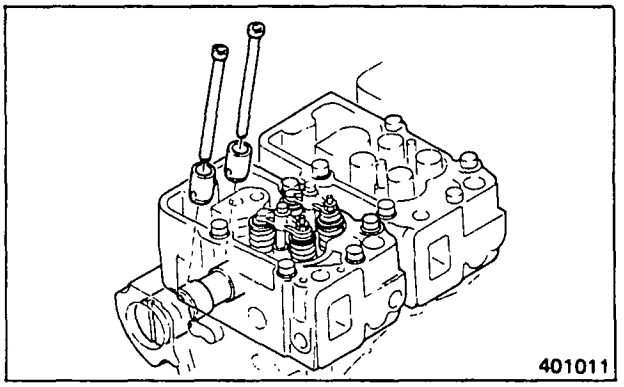
(a) Put engine oil on the bridge guides, and install the bridges to the guides with the adjusting screw positioned on the inlet manifold side.

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



(5) Installing tappets and pushrods

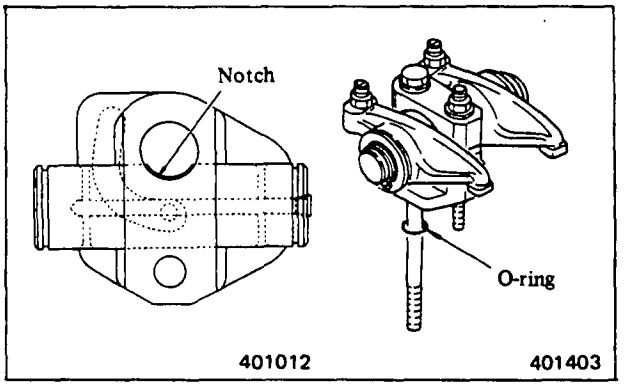
Put engine oil on the tappets, and carefully put them on the camshaft. After that, install the pushrods.



(6) Installing rocker shaft assemblies

(a) Align the notch of rocker shaft with the bolt hole of rocker shaft bracket, and put the bolt into the bolt hole.

(b) Put the long bolt for securing the head and rocker bracket with O-ring through the bolt hole of the rocker bracket into the cylinder head.



⚠ CAUTION

(a) Try to move the rocker arm up and down to make sure that it is free.

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

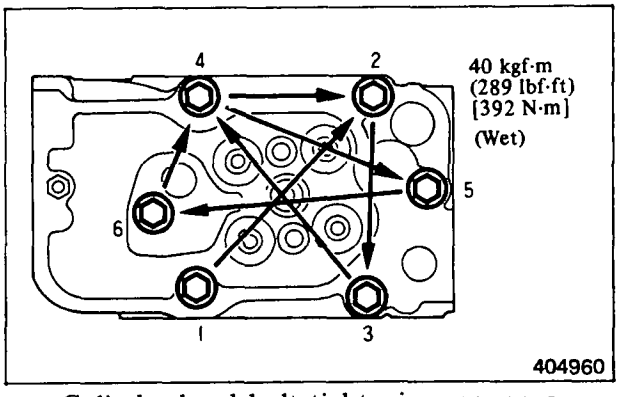
(c) Tighten the long bolt securing the head and rocker bracket first; then tighten the short bolt to the specified torque.

(7) Tightening cylinder head bolts

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

⚠ CAUTION

To prevent gas leakage past the cylinder head gasket, retighten bolts 2 and 4 after tightening bolts 1 thru 6.



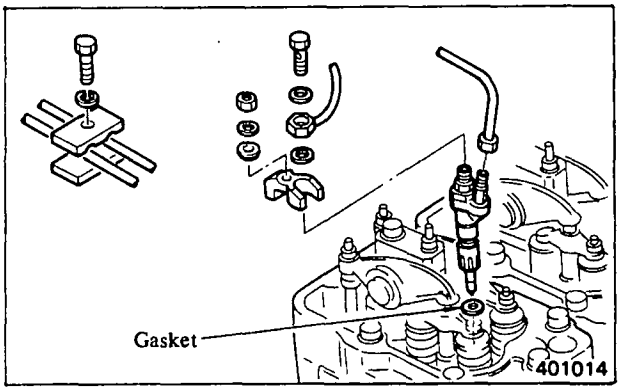
Cylinder head bolt tightening sequence

(8) Installing injection nozzle assemblies

Tighten the nozzle gland nuts to the specified torque. Be sure to put the gaskets.

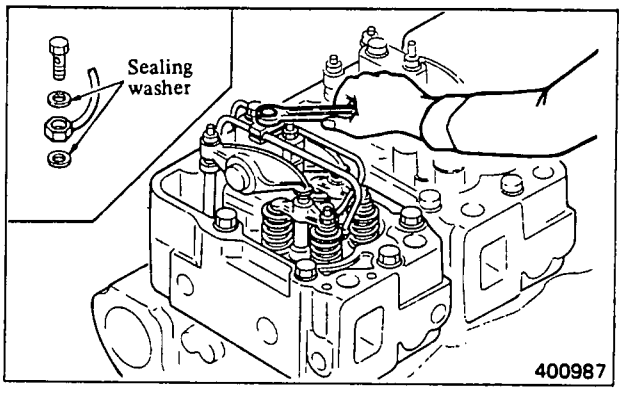
NOTE

When tightening each nozzle gland, install the fuel injection pipe and fuel leak-off pipe in position temporarily by leaving equal space around to prevent interference of the pipe with the collar.



(9) Installing fuel pipes

Put the sealing washers on the connection of each leak-off pipe, and tighten the connector securely to prevent fuel leakage.

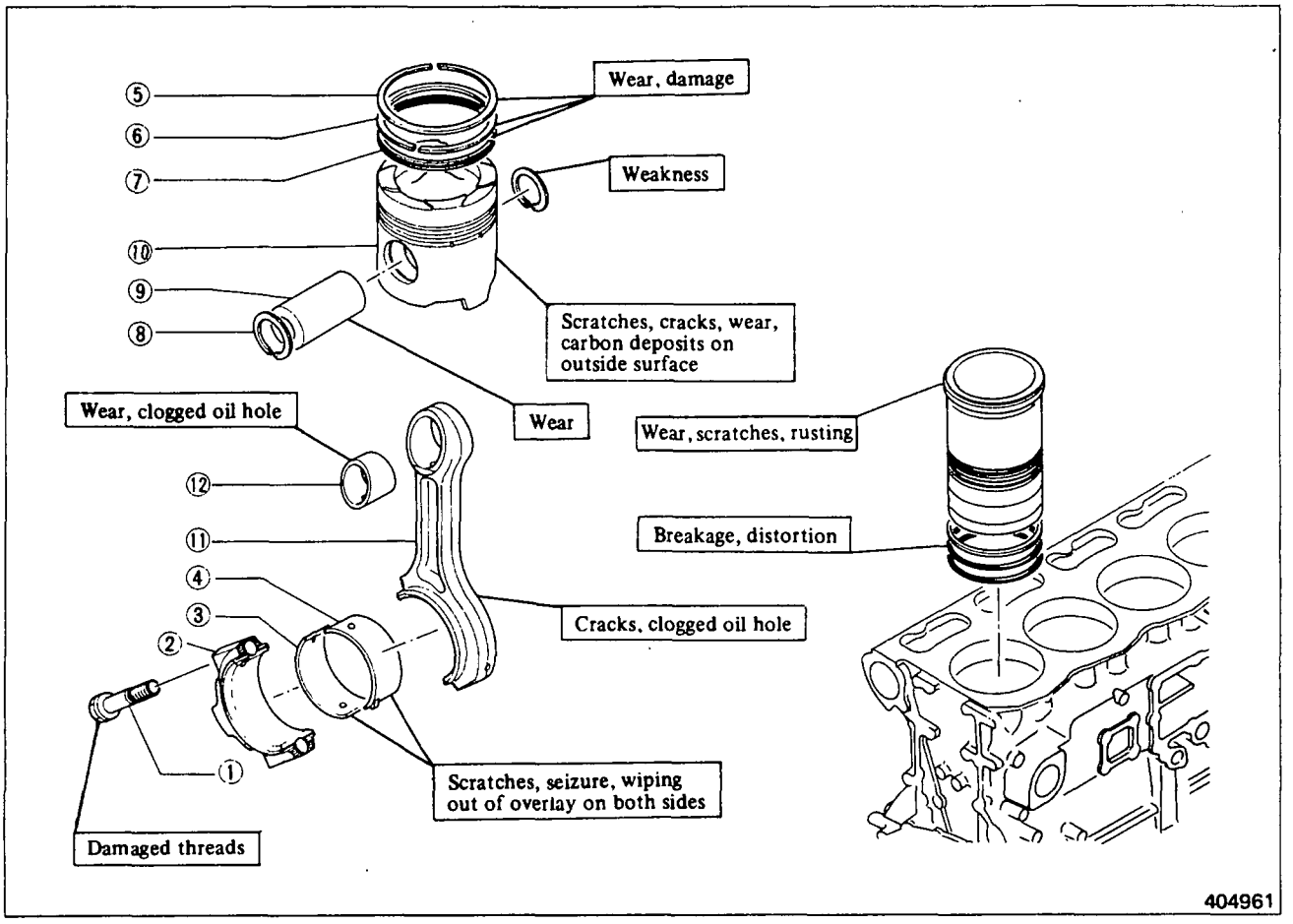


(10) Adjusting valve clearance

Refer to 1.1, Group No. 5.

2. CYLINDER LINERS, PISTONS AND CONNECTING RODS

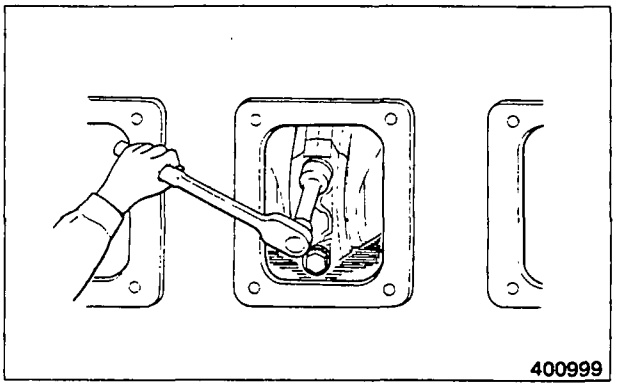
2.1 Disassembly



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

(1) Removing connecting rod caps

Unscrew the cap bolts, and remove the caps.



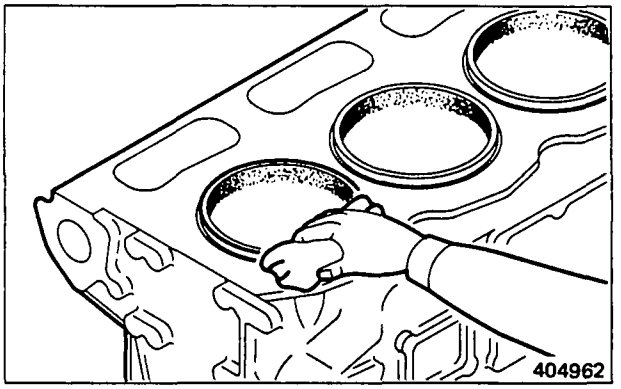
NOTE

(a) Be careful not to let the bearings fall into the oil pan.

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

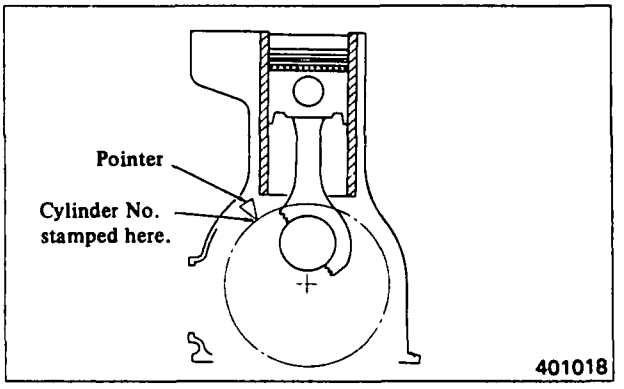
(2) Preparatory step for removing pistons

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

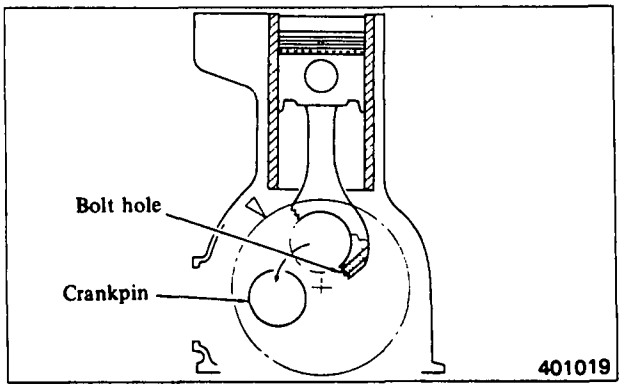


(3) Removing pistons

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



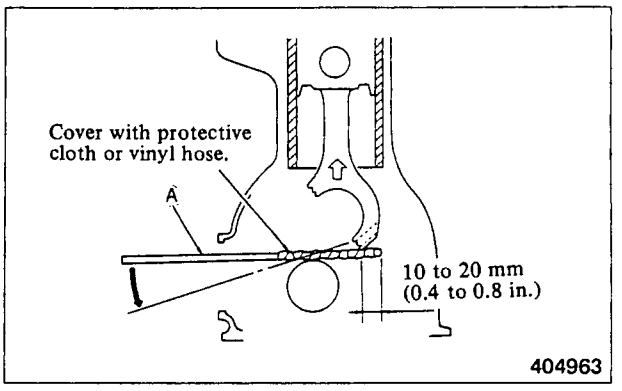
(b) Turn the crankshaft in the reverse direction until the crankpin comes off the connecting rod and the bolt hole is visible in the inspection hole on the side of crankcase.



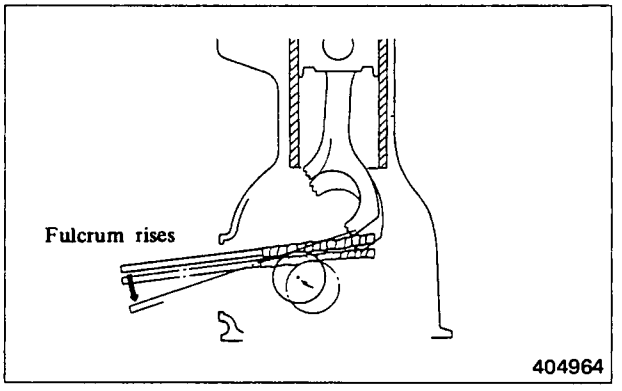
(c) Wrap rag over turning bar (A) (37491-03100). Insert one end of the bar into the bolt hole in the connecting rod big end, and raise the piston assembly just a little by making use of the crankpin as a fulcrum.

⚠ CAUTION

Do not insert the bar too deep, or it will hit the liner, making it difficult to remove the piston assembly. Insert the bar so that it projects 10 to 20 mm (0.4 to 0.8 in.) from the connecting rod big end.



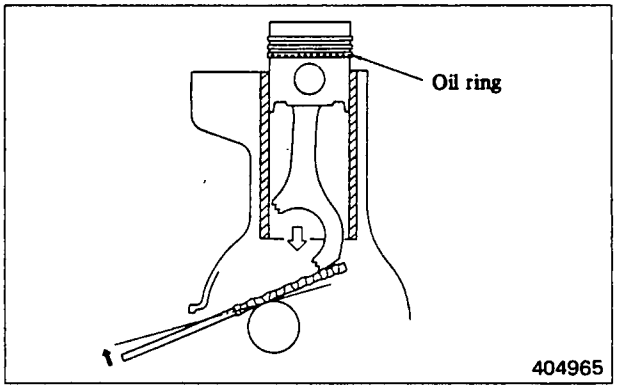
(d) Turn the crankshaft in normal direction just a little at a time to raise the crankpin (fulcrum) while pushing down on the outer end of the bar to raise the piston assembly.



⚠ CAUTION

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

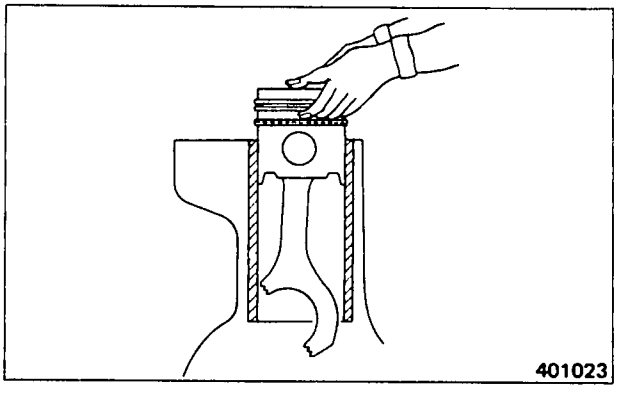
(e) When the oil ring just comes out of the cylinder liner, lower the piston carefully until the oil ring rests on the edge of the liner.



⚠ CAUTION

Lower the piston slowly and carefully, or the oil ring will suffer damage. Do not attempt to rotate the piston.

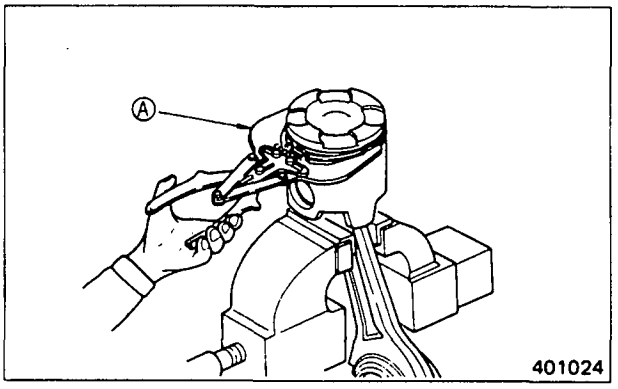
(f) Hold the compression ring portion of the piston by hands, carefully pull the piston from the cylinder liner, and rest its skirt on the top of crankcase.



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

(4) Removing piston rings from piston

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

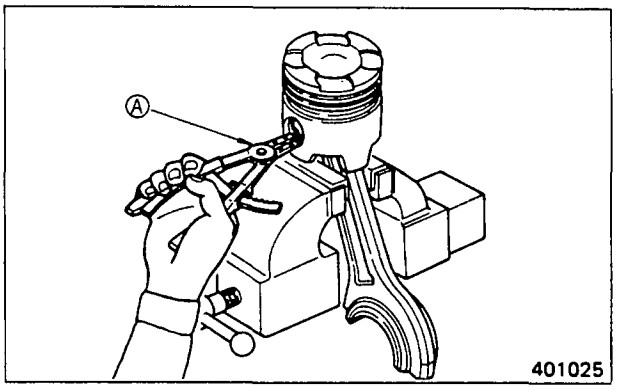


(5) Removing piston pin

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

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

(c) If it is difficult to pull out the pin, heat the piston with a piston heater or in hot water to expand the pin bore.

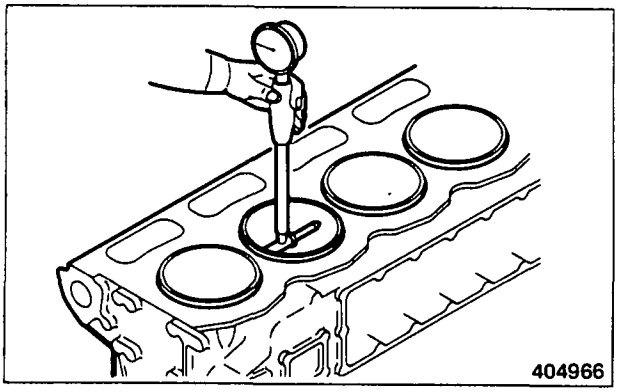


2.2 Inspection and repair

Cylinder liners

(1) Measuring inside diameter

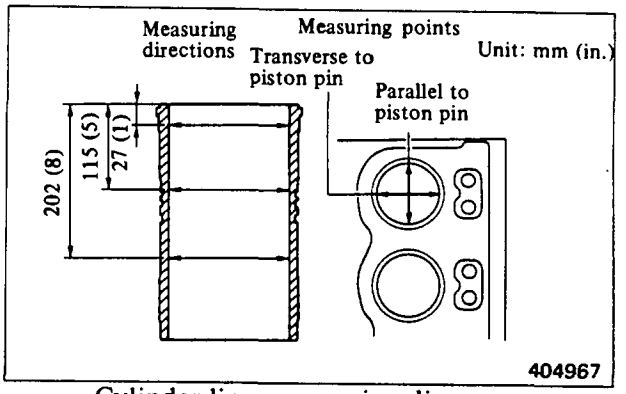
Measure the inside diameter of each liner in two directions, parallel and transverse to the piston pin, at three positions, top (ridged area), middle and bottom as shown. Replace the liner if it is worn in excess of the Service limit.



Measuring cylinder liner

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Inside diameter of cylinder liners	150 (5.91)	150.00 to 150.04 (5.9055 to 5.9071)	150.14 (5.9110)



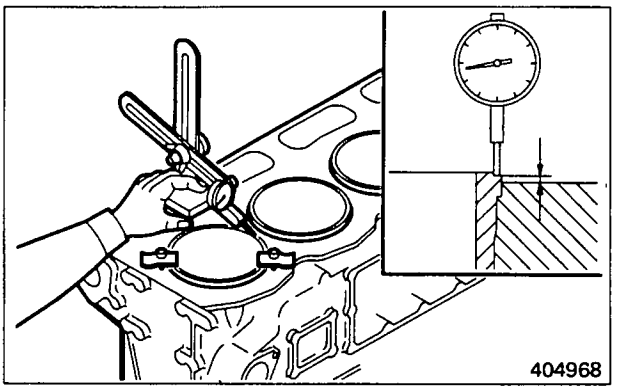
Cylinder liner measuring diagram

(2) Measuring projection

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

Unit: mm (in.)

Item	Assembly standard
Cylinder liner projection at flange	0.10 to 0.19 (0.0039 to 0.0075)



Measuring cylinder liner projection

⚠ CAUTION

If the projection is less than the Assembly standard, the gasket will not exert sufficient sealing force around the bore, causing exhaust gas leakage.

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

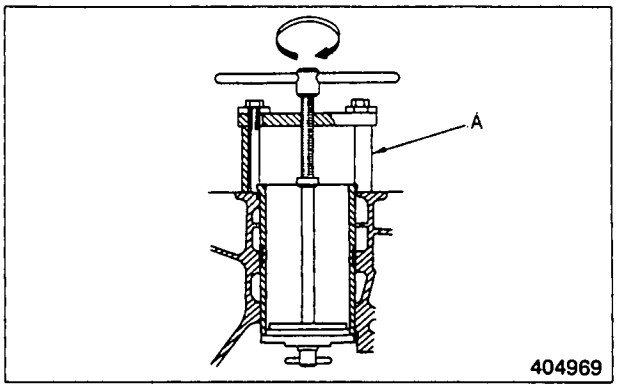
(b) Secure the top of the liner uniformly at two places with clamps and bolts (M20 x 2.5).

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

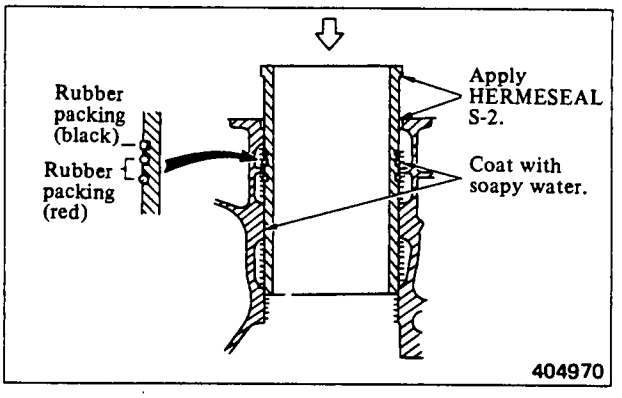
(d) Measure projection at four places on the top of the liner. Take the average from the four measurements.

(3) Replacement

(a) Using cylinder liner remover (A) (33591-04100), remove the cylinder liners from the crankcase for replacement.



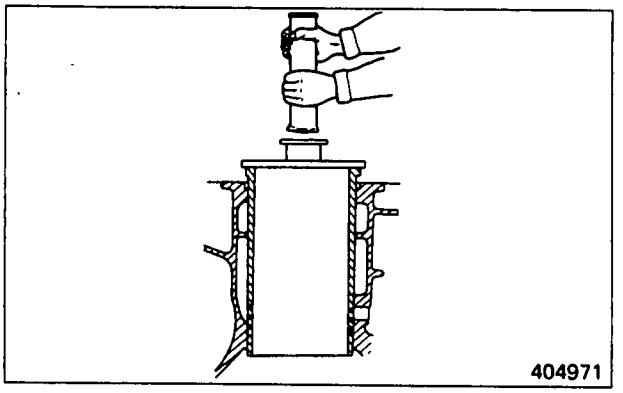
(b) Attach rubber packings to each new cylinder liner, and carefully put the liner into the bore of the crankcase.



⚠ CAUTION

Apply HERMESEAL S-2 to the joints of cylinder liner and crankcase. When putting the liner, coat the rubber packings with soapy water to prevent them from twisting.

(c) After putting the liner into the bore, lightly tap on its top, using installer, to rest its flange in the counterbore formed of the crankcase.



NOTE

(a) When tapping on the liner top, keep the liner pressed downward.

(b) After putting the liners to all bores, test the liner joints for water-tightness by applying pressure water.

(c) Check to make sure the projection of each liner is within the Assembly standard range.

Pistons

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

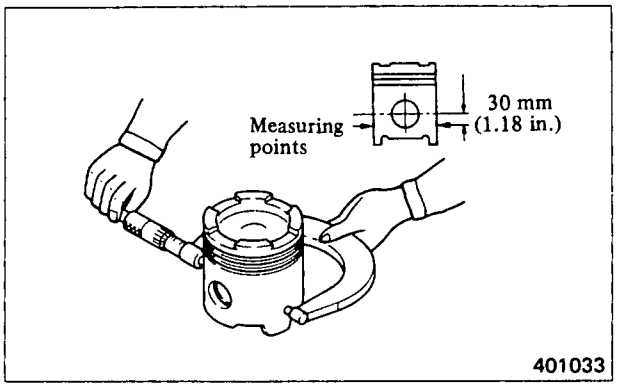
(1) Measuring diameter

(a) Using a micrometer, measure the diameter of each piston in the direction transverse to the piston pin, at the position shown. Replace the piston if it (outside diameter) is worn in excess of the Service limit. If any pistons have to be replaced, select new pistons so that the difference between average weight of all pistons in one engine is within the Assembly standard.

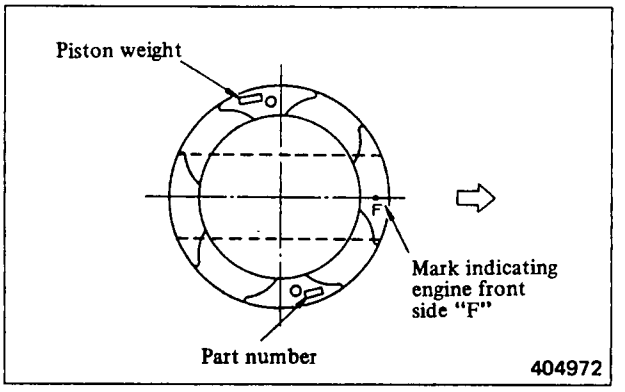
Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Diameter of pistons	150 (5.91)	149.82 to 149.78 (5.8984 to 5.8968)	149.68 (5.8929)
Maximum permissible difference between average weight of all pistons in one engine	–	±15 g (±0.53 oz), maximum	–

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



Measuring piston diameter



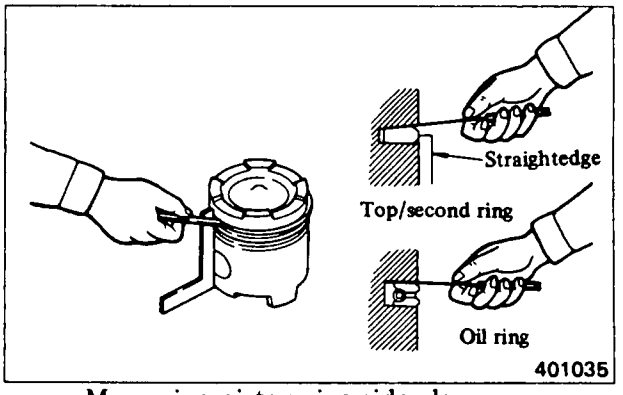
Piston weight stamp location

(2) Measuring piston ring side clearance

Put new piston rings into the ring grooves in the piston, and measure the side clearance of each ring with a feeler gauge, as shown. To measure the clearance on the top and second rings, press in the ring with a straightedge until its face is flush with the piston. If the side clearance exceeds the Service limit, replace the piston.

⚠ CAUTION

Remove carbon, and measure the side clearance all the way around the piston.



Measuring piston ring side clearance

Unit: mm (in.)

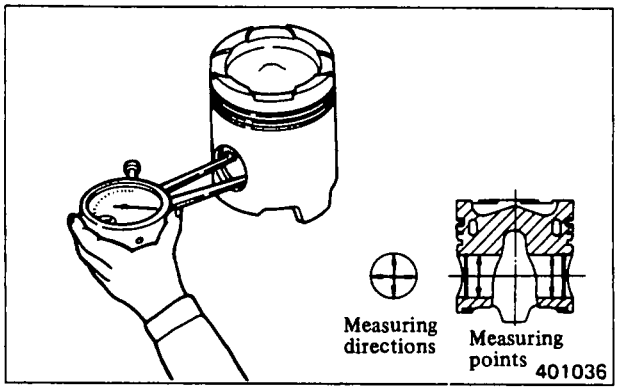
Item		Nominal value	Standard clearance	Service limit
Piston ring side clearance (with new rings in grooves)	Top	3.00 (0.1181)	0.08 to 0.11 (0.0031 to 0.0043)	0.20 (0.0079)
	Second	2.50 (0.0984)	0.07 to 0.11 (0.0028 to 0.0043)	0.10 (0.0039)
	Oil	5.00 (0.1969)	0.05 to 0.09 (0.0020 to 0.0035)	0.15 (0.0059)

(3) Measuring inside diameter of piston pin bore

Using caliper gauge or cylinder gauge, measure the inside diameter of piston pin bore of the piston. Replace the piston if the bore is worn in excess of the Service limit.

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Inside diameter of piston pin bore	58 (2.28)	58.002 to 58.012 (2.28354 to 2.28393)	58.020 (2.28425)



Measuring piston pin bore diameter

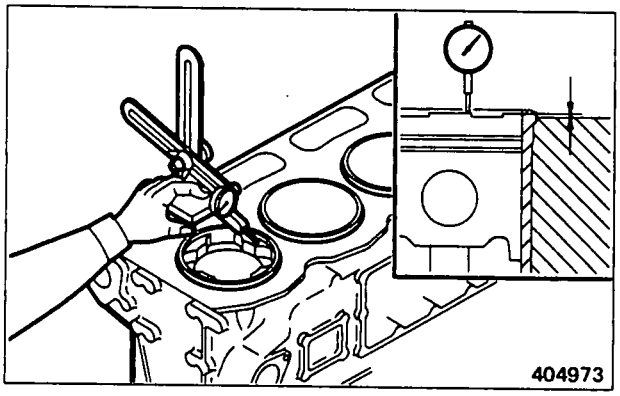
(4) Measuring piston projection

Measure the projection of each piston and, if it is not within the Assembly standard range, check the various parts for clearance.

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

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

(c) Measure the projection at four places on the piton head, and average the four measurements to determine the projection. Subtract the piston projection from the asinstalled thickness of cylinder head gasket to determine the clearance between the piston top and cylinder head.



Measuring piston projection

Unit: mm (in.)

Item	Assembly standard (Standard clearance)
Projection of pistons	0.38 to 0.89 (0.0150 to 0.0350)
As-installed thickness of cylinder head gasket	1.8 ± 0.03 (0.071 ± 0.0012)
Clearance between piston top and cylinder head	(0.88 to 1.45) ((0.0346 to 0.0571))

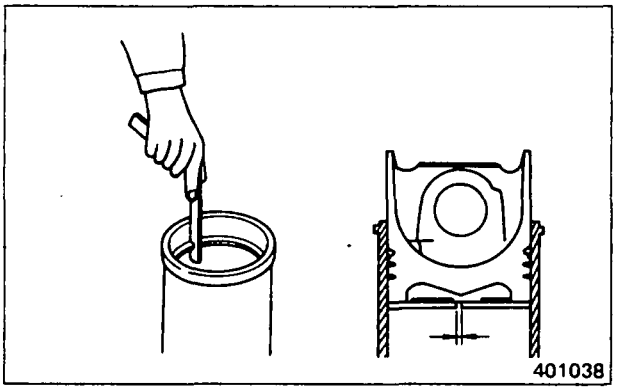
⚠ CAUTION

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

(5) Measuring piston ring gaps

Put the rings in a new or master cylinder liner, and measure the gap of each ring. If the gap of any ring exceeds the Service limit, replace all rings as a set.

Inside diameter of master cylinder liner: 150 + 0 mm (5.91 + 0 in.).



Measuring piston ring gap

NOTE

Put the piston rings in the master cylinder liner by pushing them squarely with the piston.

Unit: mm (in.)

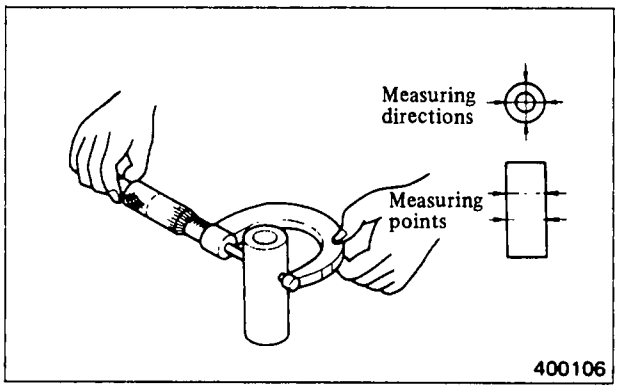
Item		Standard clearance	Service limit
Piston ring gaps	Top	0.6 to 0.8 (0.024 to 0.031)	2.0 (0.079)
	Second	0.5 to 0.7 (0.020 to 0.028)	
	Oil	0.5 to 0.7 (0.020 to 0.028)	

(6) Measuring diameter of piston pins

Using a micrometer, measure the diameter of each piston pin. Replace the pin if it is worn in excess of the Service limit.

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Diameter of piston pins	58 (2.28)	58.000 to 57.987 (2.28346 to 2.28295)	57.970 (2.28228)



Measuring piston pin diameter

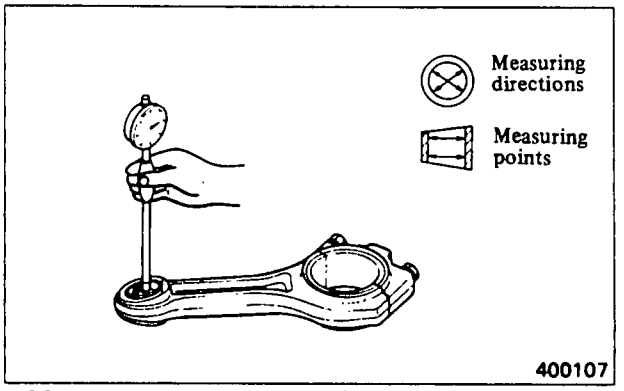
Connecting rods, connecting rod bearings and small-end bushings

(1) Measuring inside diameter of bushings

Using a cylinder gauge, measure the inside diameter of each bushing. Replace the bushing if it is worn in excess of the Service limit.

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Inside diameter of connecting rod bushings	58 (2.28)	58.020 to 58.040 (2.28425 to 2.28504)	58.070 (2.28622)



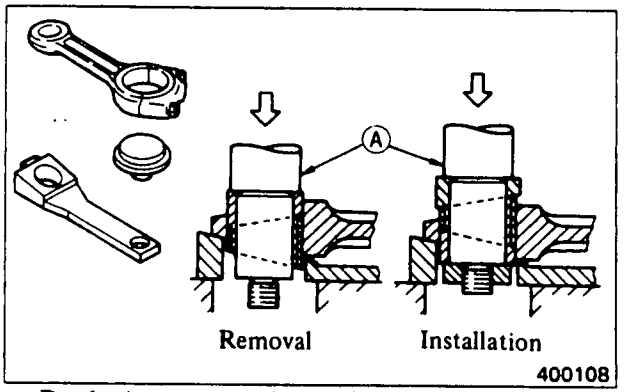
Measuring connecting rod small-end bushing inside diameter

(2) Replacing bushings

(a) Using connecting rod bushing installer (A) (32591-08010), remove the bushing, as shown, for replacement.

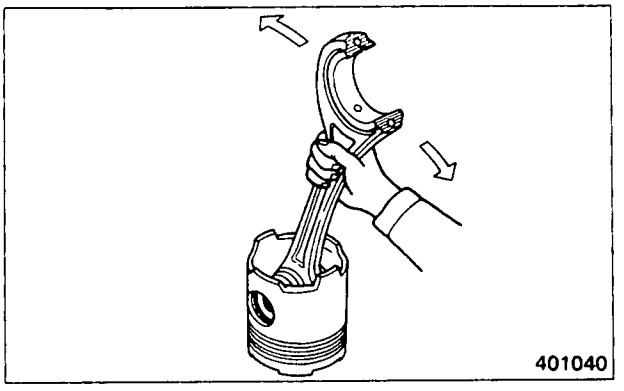
(b) When installing a replacement bushing, align oil holes in the bushing and connecting rod.

(c) After installing the bushing, ream its inside diameter to $58^{+0.040}_{+0.020}$ mm ($2.28^{+0.00157}_{+0.00079}$ in.) 1.6S and its parallelism relative to the big end bearing to 0.05 mm (0.0020 in.).



Replacing connecting rod small-end bushing

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

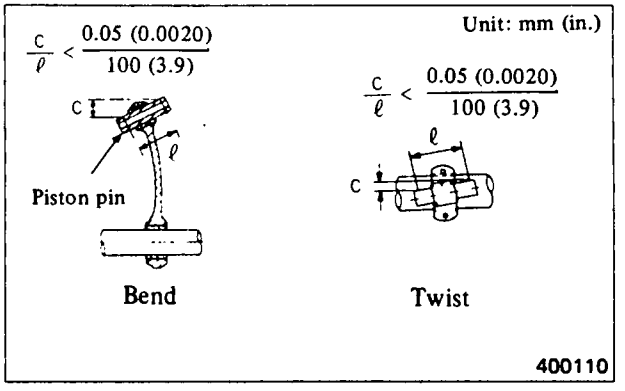


(3) Inspecting connecting rods for bend and twist

(a) Measure "C" and "ℓ." If the measurement at "C" is larger than 0.05 mm (0.0020 in.) per 100 mm (3.9 in.) of "ℓ," straighten the rod with a press.

NOTE

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

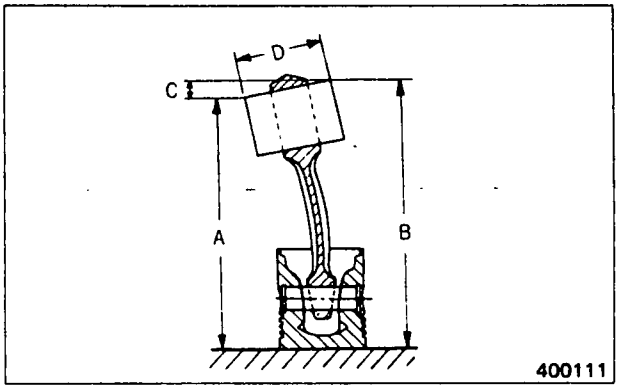


Inspecting connecting rod

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

Unit: mm (in.)

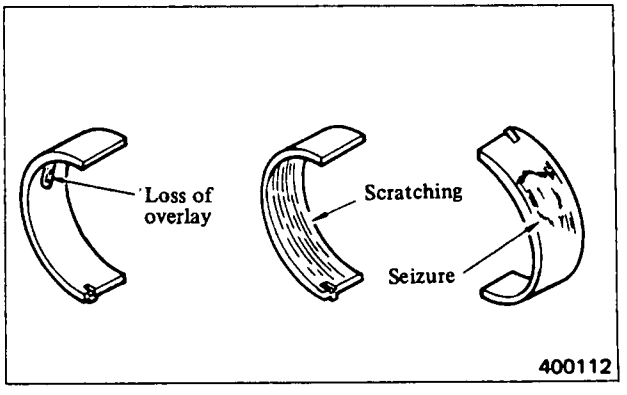
Item	Assembly standard
Connecting rod bend and twist	0.05/100 (0.0020/3.9), maximum



Inspecting connecting rod installed to piston

(4) Inspecting connecting rod big-end bearings

Check each bearing shell for loss of overlay, scratching, pitting and failure due to poor installation. If any of these defects is present, replace the shell.

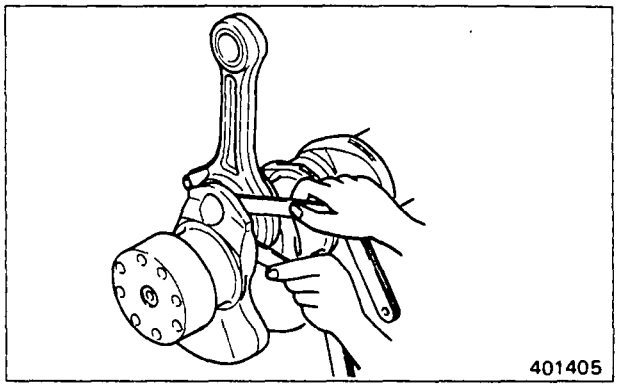


(5) Measuring connecting rod end play

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

Unit: mm (in.)

Item	Nominal value	Standard clearance [Nominal]	Repair limit
End play of connecting rod (crackpin and big end widths)	61 (2.40)	0.2 to 0.3 (0.008 to 0.012) [0.4 to 0.6 (0.016 to 0.024)]	0.5 (0.020)



Measuring connecting rod end play

(6) Maximum permissible difference between average weight of all connecting rods in one engine

When replacing the connecting rods, make sure the difference between average weight of all connecting rods in one engine is within the Assembly standard.

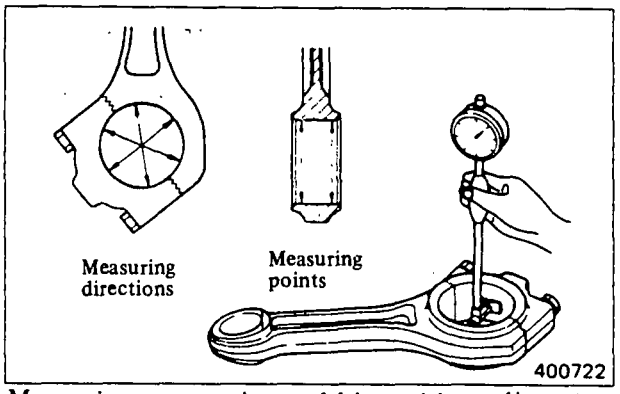
Item	Assembly standard
Max. permissible difference between average weight of all connecting rods in one engine	±20 g (±0.7 oz), maximum

(7) Measuring connecting rod big-end bore diameter

Measure the bore in two positions, front and rear, and in two directions. If the diameter exceeds the Service limit, replace the connecting rod.

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Connecting rod big-end bore diameter	110 (4.33)	110.000 to 110.022 (4.33070 to 4.33157)	110.047 (4.33255)



Measuring connecting rod big-end bore diameter

(8) Measuring connecting rod bearing thickness

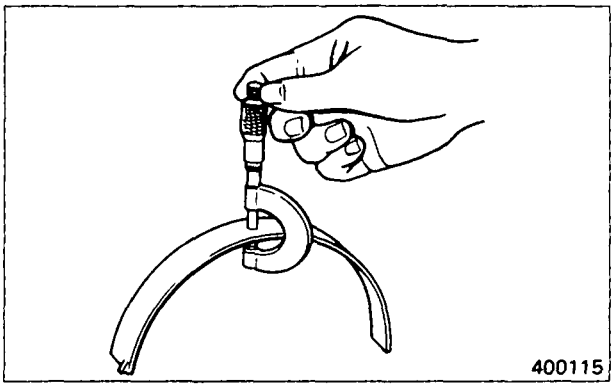
Using a ball-point type micrometer, measure the center of each bearing shell. If the thickness exceeds the Service limit, on either upper or lower shell, replace both shells as a set.

Unit: mm (in.)

Item		Nominal value	Assembly standard	Service limit
Connecting rod bearing thickness	STD	3.000 (0.11811)	2.987 to 3.000 (0.11760 to 0.11811)	2.950 (0.11614)
	-0.25 (-0.0098)	3.125 (0.12303)	3.112 to 3.125 (0.12252 to 0.12303)	3.075 (0.12106)
	-0.50 (-0.0197)	3.250 (0.12795)	3.237 to 3.250 (0.12744 to 0.12795)	3.200 (0.12598)
	-0.75 (-0.0295)	3.375 (0.13287)	3.362 to 3.375 (0.13236 to 0.13287)	3.325 (0.13091)
	-1.00 (-0.0394)	3.500 (0.13780)	3.487 to 3.500 (0.13728 to 0.13780)	3.450 (0.13583)

NOTE

Four undersizes are available for the connecting rod bearings; namely, -0.25 mm (-0.0098 in.), -0.50 mm (-0.0197 in.), -0.75 mm (-0.0295 in.) and -1.00 mm (-0.0394 in.).



Measuring connecting rod bearing thickness

2.3 Reassembly

To reassemble, follow the reverse of disassembly procedure.

(1) Installing pistons to connecting rods

(a) Though the piston pin is to be clearance-fitted in the piston, heat the piston with a piston heater or in hot water. Coat the piston pin with engine oil, and put it into position through the connecting rod.

(b) Install the connecting rod to the piston with the matching marks on its big end on the camshaft side.

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

NOTE

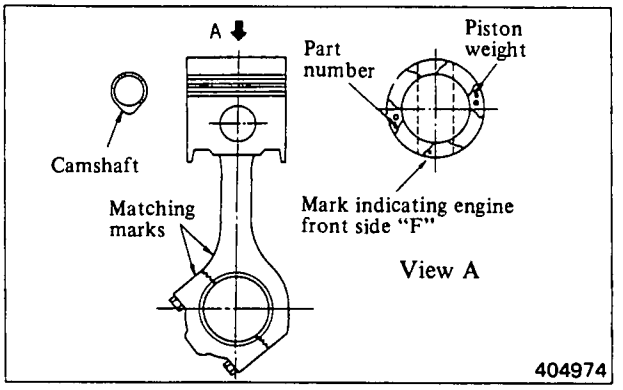
Position the ends of both snap rings at the bottom of pin bore.

(2) Installing piston rings

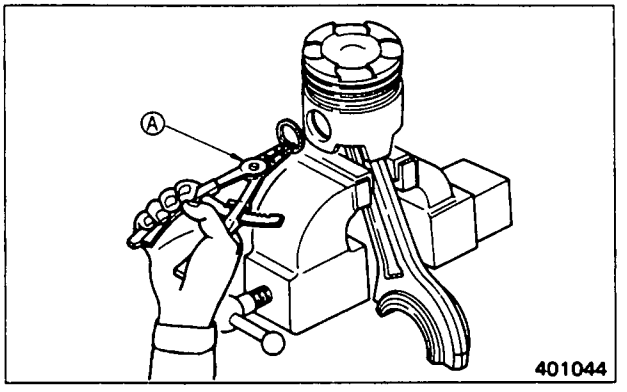
(a) Using piston ring pliers (37191-03200), install the piston rings to the piston.

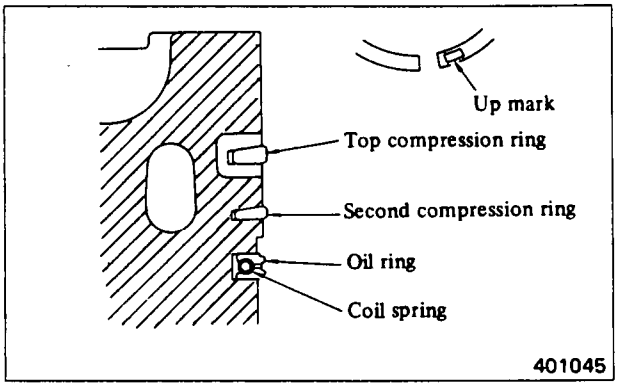
⚠ CAUTION

The top and second rings are marked "RH" and the oil ring "R" on the side to be up when installed on the piston, at one end. If the ring is installed with the mark down, excessive oil consumption or piston seizure will result.



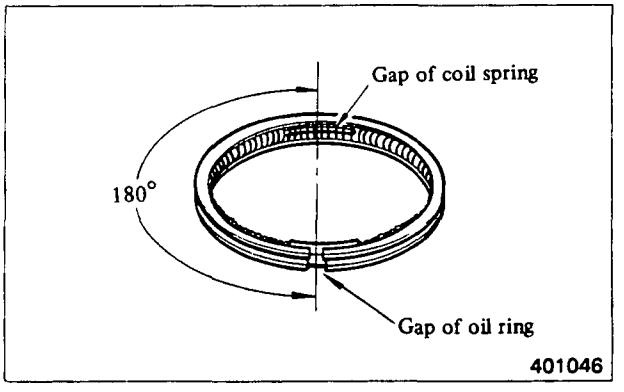
Matching marks on connecting rod





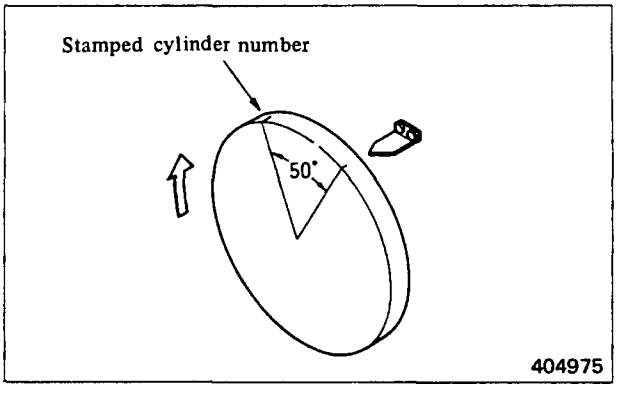
Piston and piston rings

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

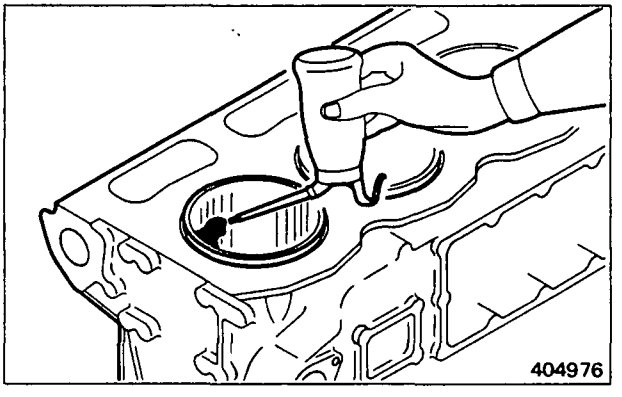


(3) Preparatory steps for installing pistons

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

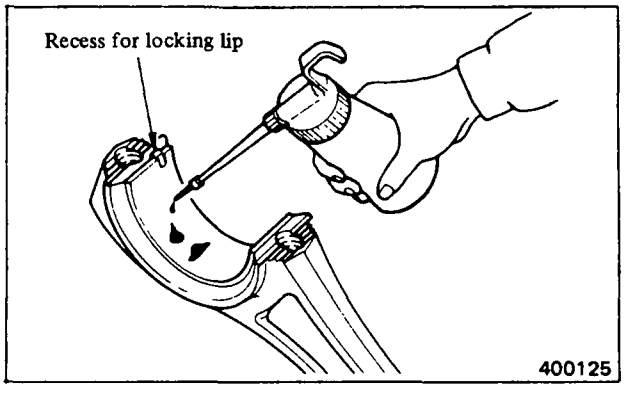


(b) Clean the cylinder liner bore surface and crankpin by wiping with rag, and coat it with engine oil.



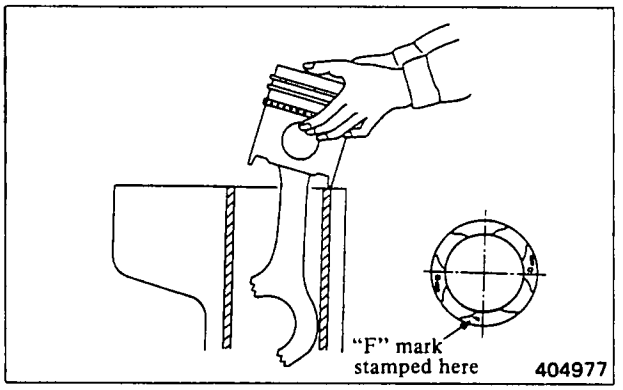
(4) Installing connecting rod bearings (upper shells)

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



(5) Inserting pistons

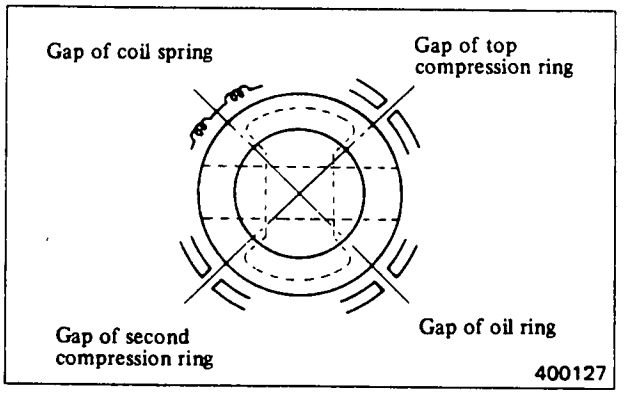
(a) Put the connecting rod in the cylinder liner, and carefully rest the piston on the top of crankcase.



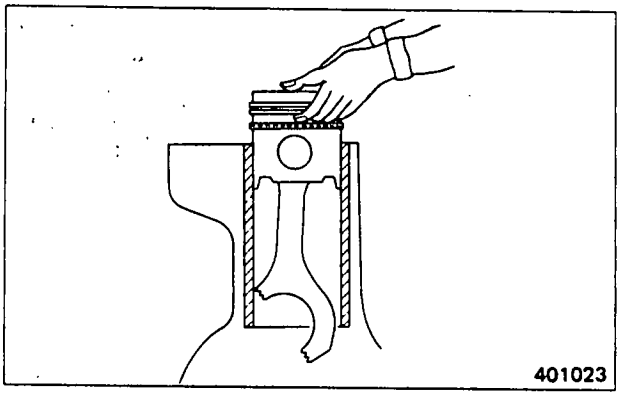
⚠ CAUTION

Make sure that "F" mark on the top of piston points forward. Keep the connecting rod away from the piston cooling nozzle by looking into the inspection hole of crankcase. Do not attempt to rotate the piston.

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



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

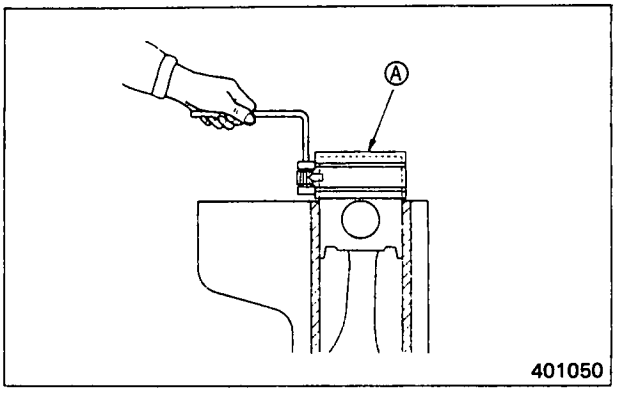


NOTE

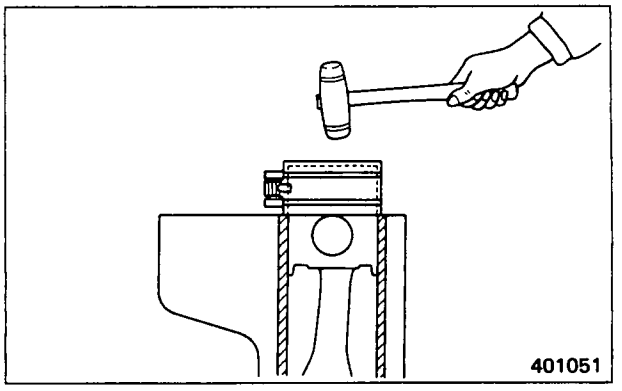
(a) Be careful not to get your finger pinched between the oil ring and cylinder liner.

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

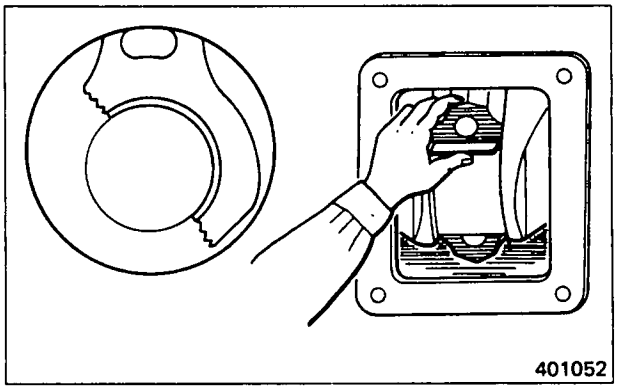
(d) After making sure that the piston ring gaps are positioned properly, coat the rings with engine oil, and clamp them, using piston installer (A) (37191-07100). At this time, coat the inside surface of the installer with engine oil.



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

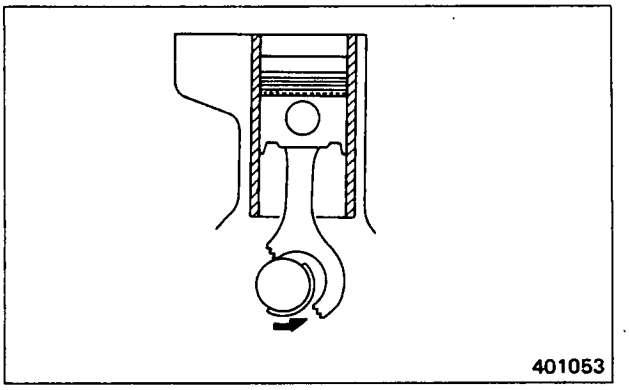


(f) Make sure the upper shell of the bearing is properly positioned in place in the connecting rod big end, by inserting the hand through the inspection hole of crankcase.
If the bearing shell is slightly out of place, reposition it by lightly pushing it by the palm of a hand.



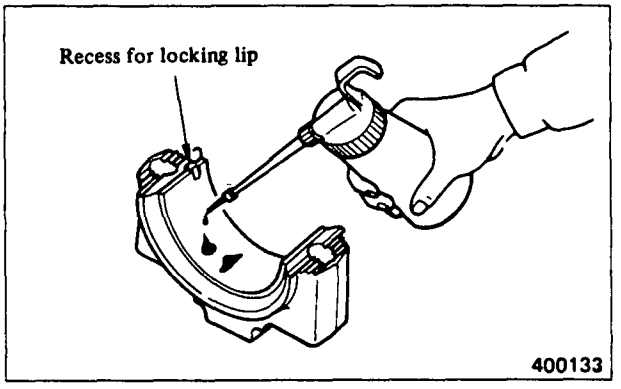
(If the bearing is off connecting rod big end)

Turn the crankshaft to produce a space between the connecting rod big end and crankpin, and insert the bearing into position while sliding it along the crankpin surface.



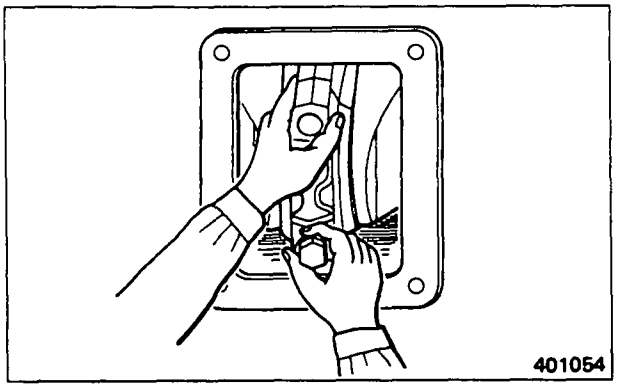
(6) Installing connecting rod caps

(a) Put the lower shell of connecting rod bearing in the cap by fitting its locking lip in the groove in the cap.



(b) Coat the threads of cap bolts and the inside surface of the bolt with engine oil.

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

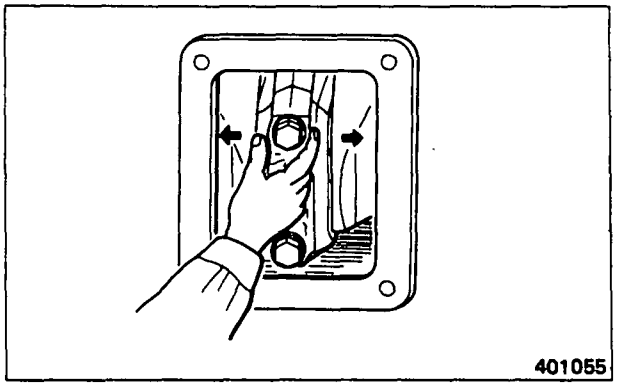


(d) With the bolts tightened temporarily, touch the joint between the cap and rod, making sure that the cap and rod surfaces are flush with each other, and tighten the bolts to the specified torque.

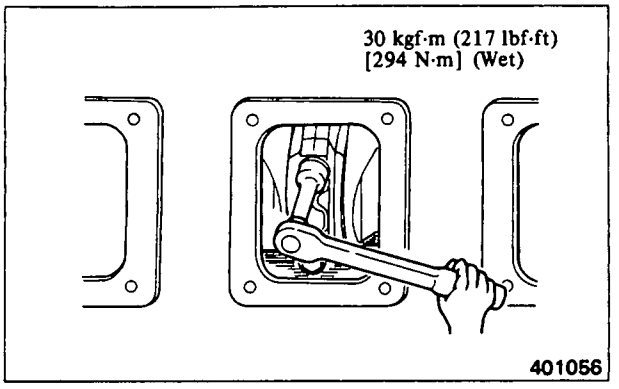
⚠ CAUTION

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

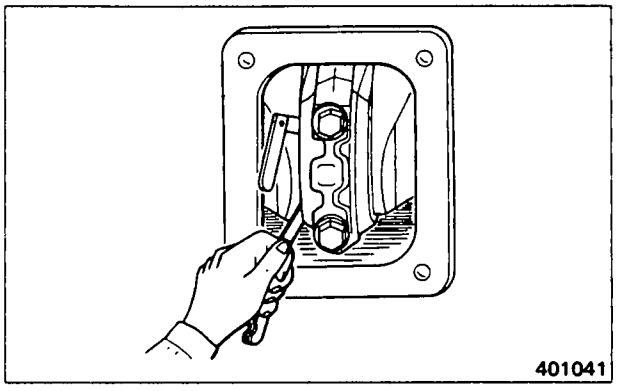
(e) Move the big end of each rod in the thrust direction, making sure that the rod has correct end play.



(f) Tighten the cap bolts to the specified torque in two steps.



(g) Using a feeler gauge, measure the end play of connecting rod, making sure that the end play is equal on both top and bottom sides of the crankpin. (Refer to 2.2, Group No. 7.)



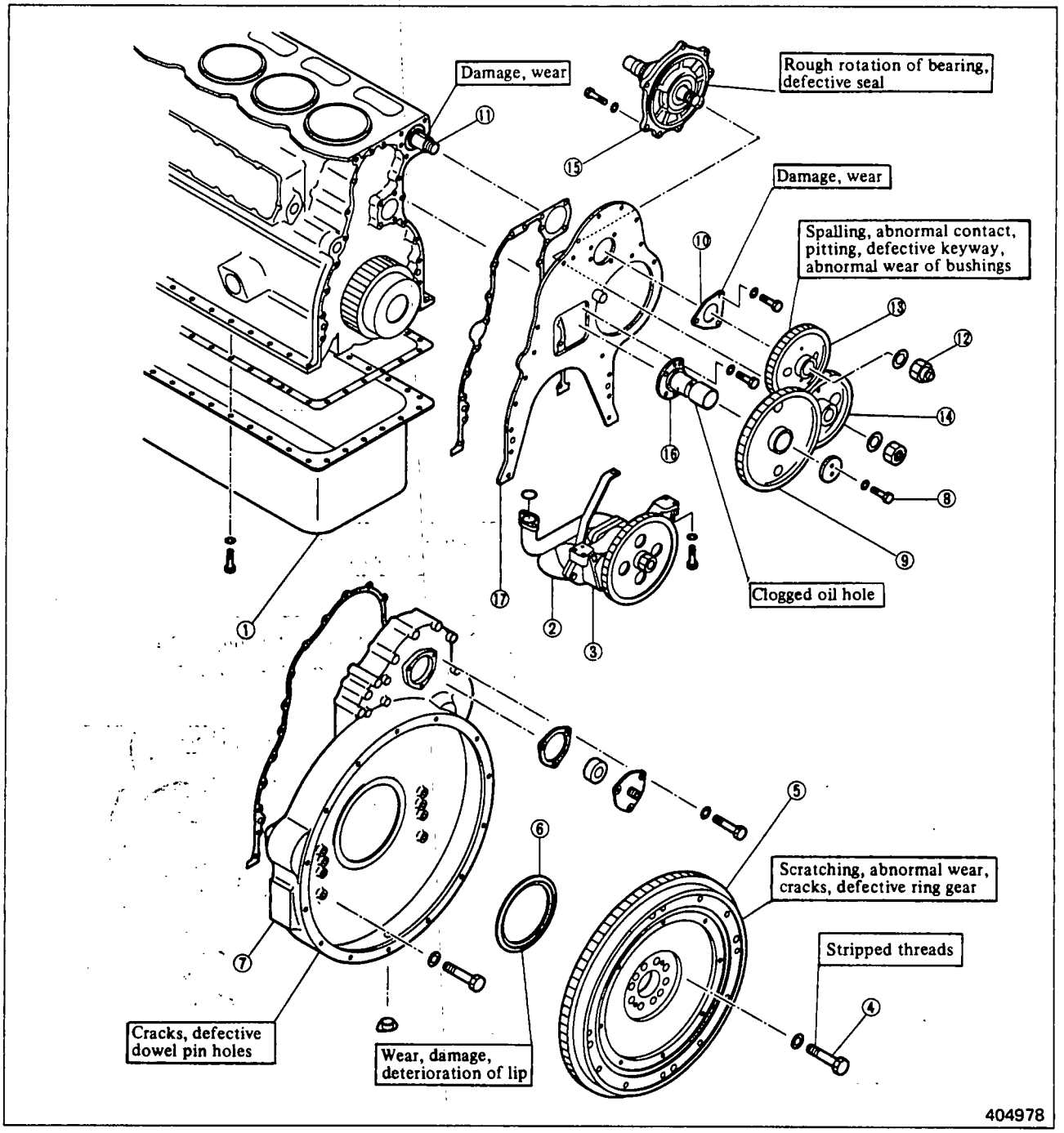
NOTE

Before installing the cylinder head, measure the protrusion of piston, making sure that it is correct. (Refer to (4), Pistons, 2.2, Group No. 7.)

3. FLYWHEEL, TIMING GEARS AND CAMSHAFT

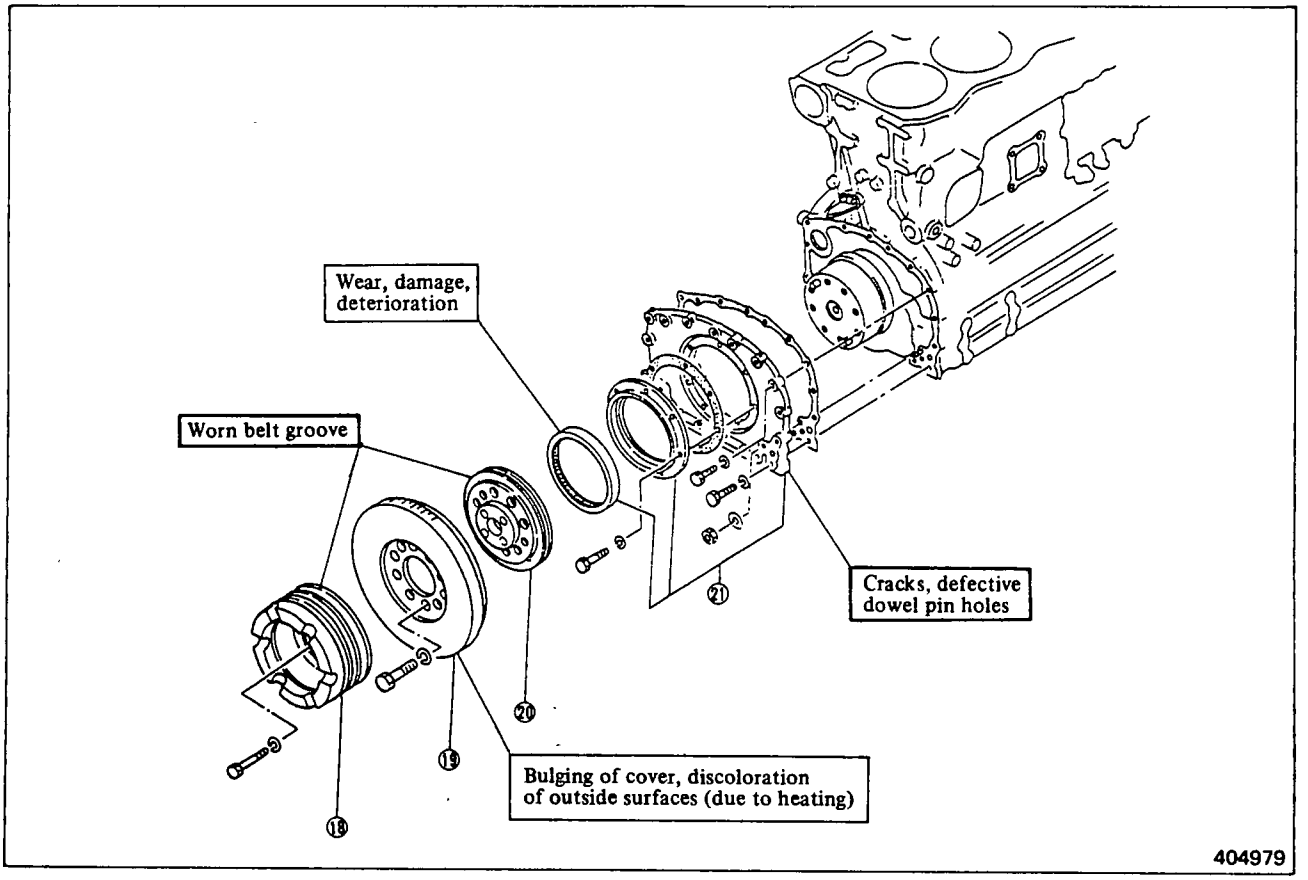
3.1 Disassembly

Flywheel side



① Oil pan
② Oil strainer, oil pipe
③ Oil pump
④ Bolt
⑤ Flywheel
⑥ Oil seal
⑦ Timing gear case
⑧ Bolt, thrust plate
⑨ Idler gear
⑩ Bolt, thrust plate
⑪ Camshaft
⑫ Connector
⑬ Camshaft gear
⑭ Injection pump drive gear
⑮ Accessory drive
⑯ Idler gear shaft
⑰ Rear plate

Vibration damper side



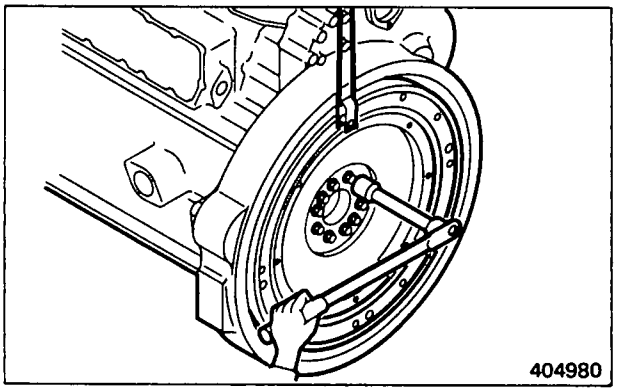
⑱ Fan pulley
⑲ Viscous damper
⑳ Pulley (for water pump and alternator)
㉑ Front cover, oil seal case, oil seal

(1) Removing flywheel

(a) Fasten a hoist to the flywheel.

(b) Unscrew the flywheel mounting bolts.

(c) Screw jacking bolts [M20 x 1.5 -60 mm (2.36 in.)] into the holes in the flywheel evenly, and remove the flywheel.
[Weight of flywheel: 50 kg (110 lb)]



⚠ CAUTION

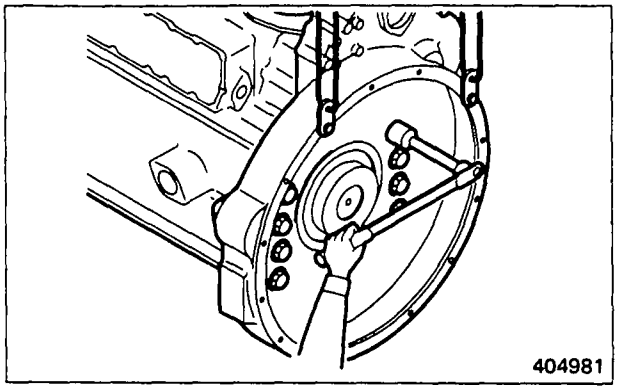
(a) When removing the flywheel, be careful not to drop or bump it against a hard object.

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

(2) Removing timing gear case

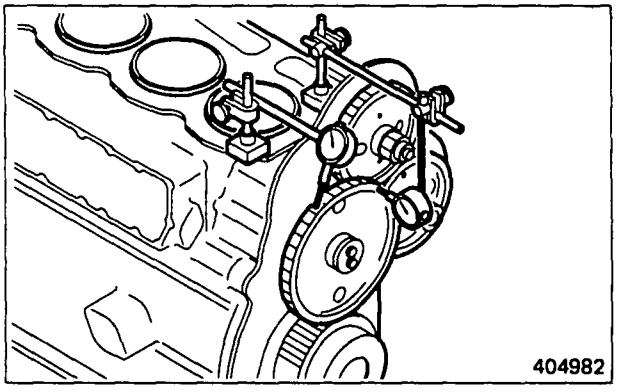
(a) Fasten a hoist to the timing gear case.

(b) Unscrew the mounting bolts, and remove the timing gear case. [Weight of timing gear case: 65 kg (143 lb)]



(3) Measuring backlash and end play

Measure the backlash and end play of each gear to obtain the data for parts replacement.
(Refer to 3.2, Group No. 7.)

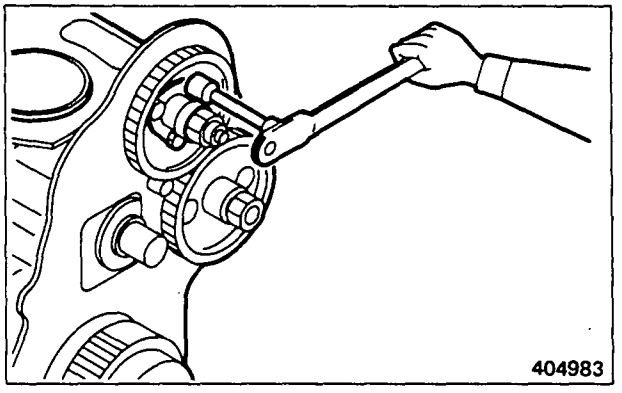


(4) Removing camshaft

After removing the idler gear, unscrew the bolts securing the thrust plate, and remove the camshaft from the crankcase.

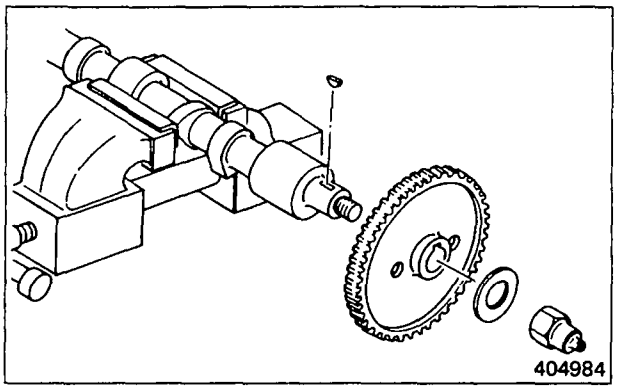
⚠ CAUTION

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



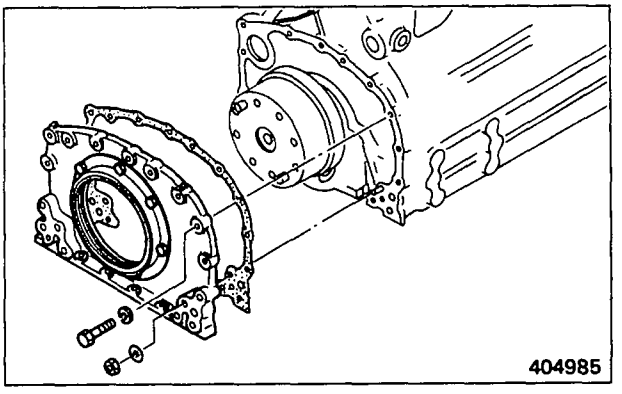
(5) Removing camshaft gear from camshaft

Grip the camshaft in a vise with aluminum or copper protective jaws. Loosen the connector, and remove the camshaft gear, using a puller.



(6) Removing front cover

Unscrew the front cover mounting bolts and nuts. Screw jacking bolts (two of the cover mounting bolts) into the holes in the cover uniformly, and remove the cover, being careful not to damage the oil seal.

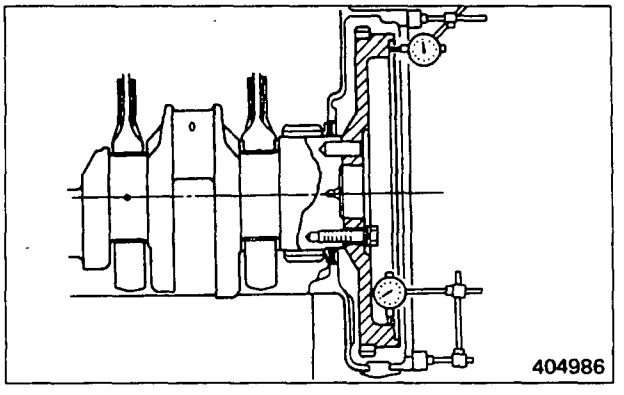


3.2 Inspection and repair

Flywheel and ring gear

Measuring flywheel face and radial runouts

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



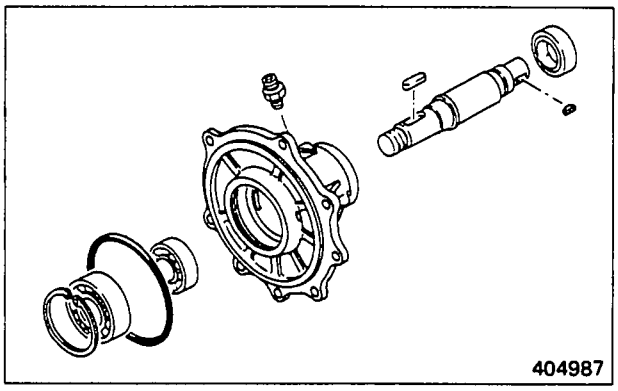
Measuring flywheel runouts

Unit: mm (in.)

Item		Assembly standard
Flywheel	Face runout	0.28 (0.0110), maximum
	Radial runout	0.13 (0.0051), maximum

Accessory drive

Check the bearing by spinning it by hand. Replace the bearing if it rotates erratically or hums.
Check the fit of drive shaft in the bearing, and replace an excessively worn part.
Check the fit of the bearing in the drive case, and replace an excessively worn part.
Check the drive shaft and oil seal, and replace a defective part.



Unit: mm (in.)

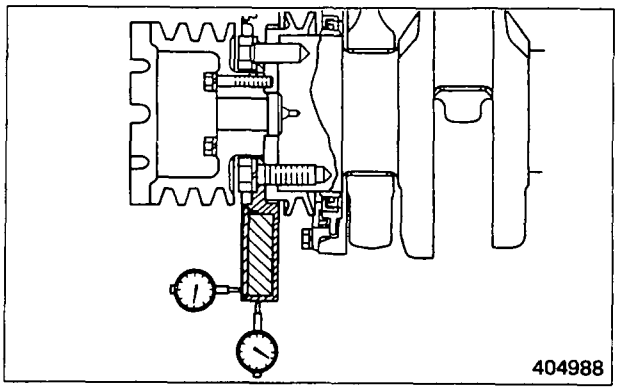
Item		Nominal value	Assembly standard
Inside diameter of bore in drive case		80 (3.15)	79.987 to 80.022 (3.14909 to 3.15047)
		100 (3.94)	99.989 to 100.014 (3.93657 to 3.93755)
Bearings	Outside diameter	80 (3.15)	79.983 to 80.004 (3.14893 to 3.14976)
		100 (3.94)	99.980 to 100.005 (3.93621 to 3.93720)
	Inside diameter	40 (1.57)	39.985 to 40.003 (1.57421 to 1.57492)
		45 (1.77)	44.985 to 45.003 (1.77106 to 1.77177)
Diameter of bearing surface of drive shaft		40 (1.57)	40.002 to 40.013 (1.57488 to 1.57531)
		45 (1.77)	45.002 to 45.013 (1.77173 to 1.77216)

Viscous damper and crankshaft pulley

(1) Inspecting viscous damper

(a) Visually check for cracks in the casing, swelling of the end plate, leakage of silicone fluid, discoloration of painted surface and flaking or blistering of painted surface.

(b) With the damper installed to the engine, measure the radial and face runouts of the inertia mass of the damper by turning the crankshaft slowly, with a dial gauge set up on the periphery of the damper as shown. If the runouts exceed the Service limit, replace the damper. Replace the damper every 8000 service hours because it is difficult to determine by visual inspection whether or not the damper has expired in safe service life.



Measuring damper runouts

Unit: mm (in.)

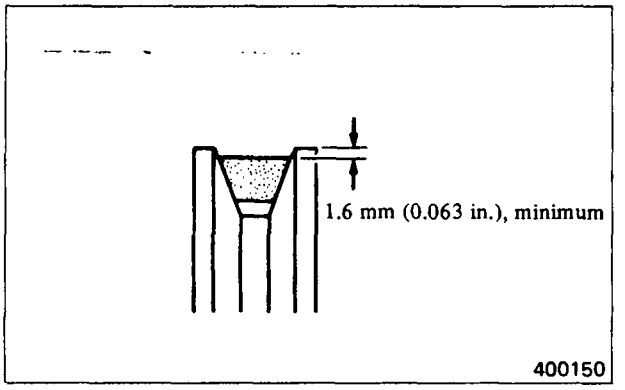
Item		Assembly standard	Service limit
Viscous damper	Radial runout	0.5 (0.020), max.	1.5 (0.059)
	Face runout		

(2) Inspecting crankshaft pulley

Check the V-belt groove for wear. Wrap a new belt around the pulley, pressing it in the groove as far as it goes, and see if the top surface of the belt is above the top of the pulley.

If the top surface of the belt (or the belts for the pulleys having two or more grooves) is uniformly above the top of the pulley all the way around, it is not necessary to replace the pulley.

If the top surface of the belt sinks into the groove more than 1.6 mm (0.063 in.), replace the pulley.



Inspecting V-belt groove in crankshaft pulley

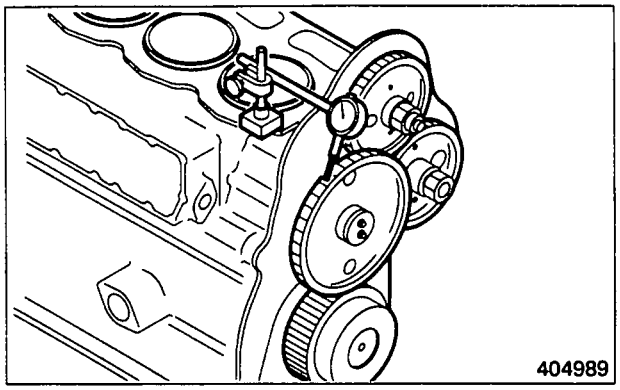
Timing gears

Measuring gear backlash

Set a dial indicator against the pitch circle of one of the mating gears, and try to move the gear back and forth to measure the backlash. If the dial indicator is not available, measure the backlash by inserting a feeler gauge between the teeth of the gears. Replace a worn gear if the backlash exceeds the Service limit.

Unit: mm (in.)

Item	Standard clearance	Repair limit	Service limit
Timing gear backlash	0.12 to 0.18 (0.0047 to 0.0071)	0.30 (0.0118)	0.50 (0.0197)



Measuring timing gear backlash

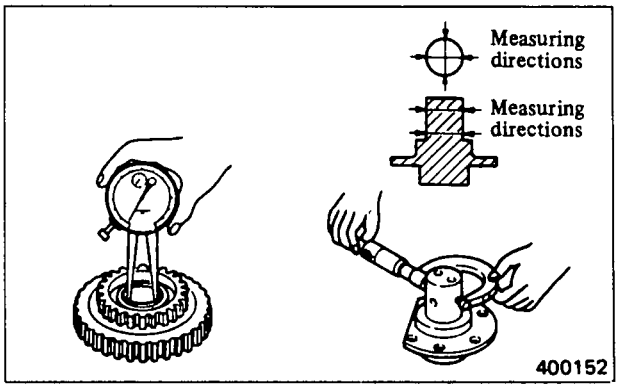
Idler gear, idler gear bushing and idler gear shaft

(1) Measuring diameter of idler gear shaft inside diameter of idler gear bushing

Replace the shaft and bushing if they are worn in excess of the Service limit.

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Inside diameter of idler gear bushing	50 (1.97)	50.000 to 50.025 (1.96850 to 1.96948)	50.060 (1.97086)
Diameter of idler gear shaft		49.975 to 49.950 (1.96752 to 1.96653)	49.900 (1.96456)



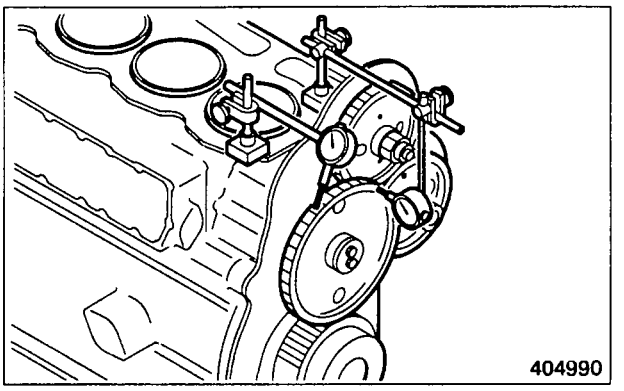
Measuring idler gear bushing and shaft

(2) Measuring end play of idler gears

Measure the end play of the idler gears with feeler gauge or dial indicator. Replace the thrust plate if the idler gear end play exceeds the Service limit.

Unit: mm (in.)

Item	Standard clearance	Repair limit
Idler gear end play	0.2 to 0.4 (0.008 to 0.016)	0.6 (0.024)



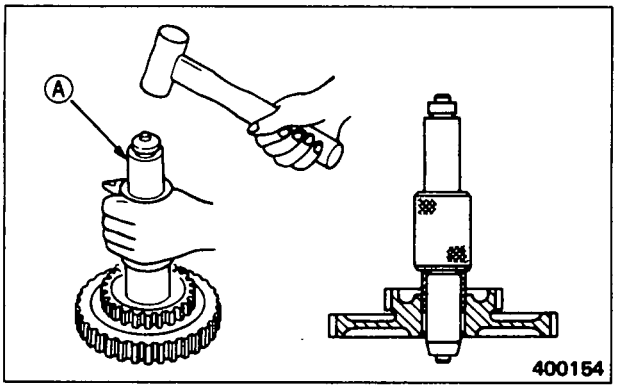
Measuring idler gear end play

(3) Replacing idler gear bushings

(a) To remove the bushing for replacement, use idler bushing puller (A) (32591-02500).

(b) Install a new bushing to the gear by pressing it from the boss side of the gear until the end face of the bushing is flush with that of gear boss.

(c) After installing the bushing, make sure that its inside diameter is within the Assembly standard. If it is less than the Assembly standard, ream the bushing to finish its inside diameter to $50^{+0.025}_{0}$ mm ($1.97^{+0.00098}_{0}$ in.) 1.5S.



Replacing idler gear bushing

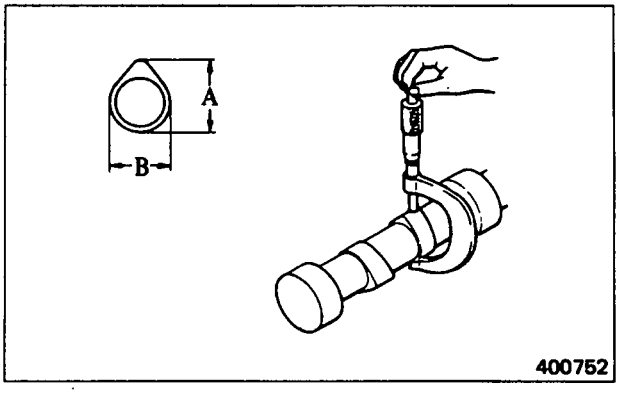
Camshafts and camshaft bushings

(1) Measuring cam lift

Using a micrometer, measure lobe height "A" and base circle "B" of each cam to determine the loss of lobe lift. Replace the camshaft if the lobe lift is smaller than the Service limit.

Unit: mm (in.)

Item	Assembly standard	Service limit
Lobe lift (A – B)	7.59 ± 0.05 (0.2988 ± 0.0020)	6.79 (0.2673)



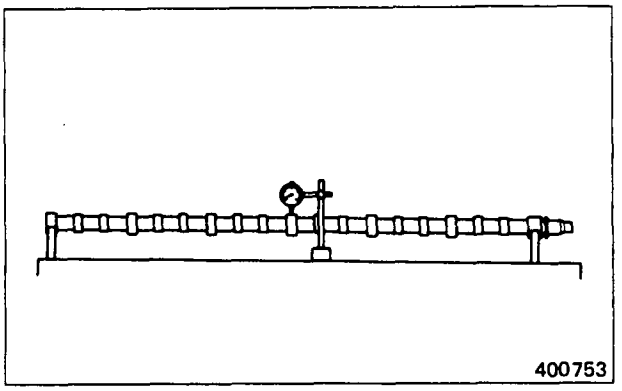
Measuring lobe lift

(2) Measuring camshaft runout

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

CAUTION

Set up a dial indicator on the camshaft, and turn the camshaft. Take one half (1/2) of the indicator reading as the runout.



Measuring camshaft runout

Unit: mm (in.)

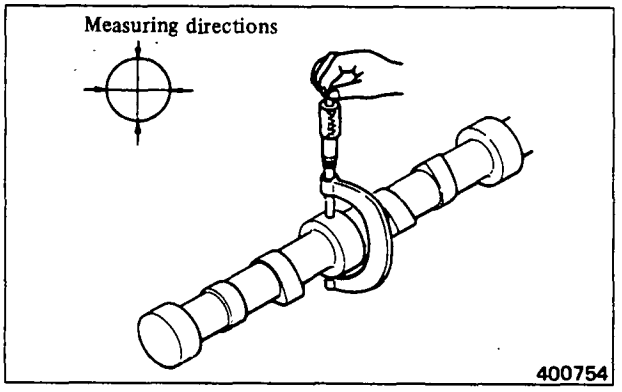
Item	Assembly standard	Repair limit
Camshaft runout	0.05 (0.0020), maximum	0.08 (0.0031)

(3) Measuring diameter of camshaft journals

Using a micrometer, measure each camshaft journal in two directions at right angles to each other. Replace the camshaft if the journals are worn in excess of the Service limit.

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Camshaft journal diameter	68 (2.68)	67.94 to 67.92 (2.6748 to 2.6740)	67.87 (2.6720)



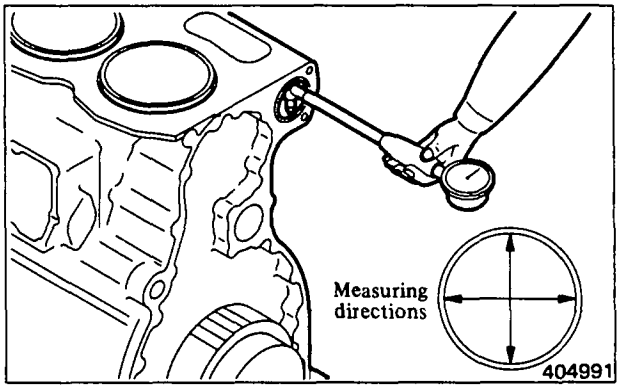
Measuring camshaft journal diameter

(4) Measuring inside diameter of camshaft bushings

Using a cylinder gauge, measure the inside diameter of camshaft bushings fitted to the crankcase. Replace the bushings if they are worn in excess of the Repair limit.

Unit: mm (in.)

Item	Nominal value	Assembly standard	Repair limit
Camshaft bushing inside diameter	68 (2.68)	68.00 to 68.03 (2.6772 to 2.6783)	68.09 (2.6807)



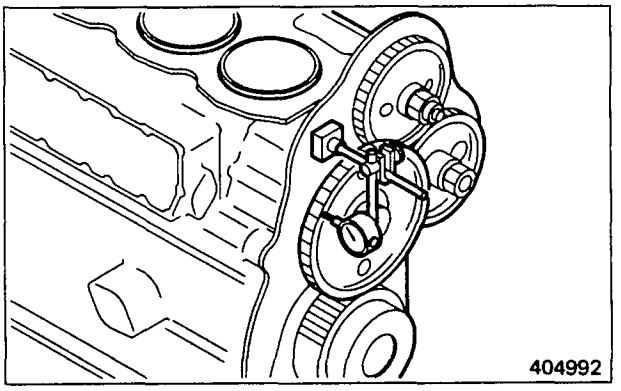
Measuring camshaft bushing inside diameter

(5) Measuring end play of camshaft

Using a dial gauge, measure the end play of each camshaft to which the camshaft gear is installed. Replace the thrust plate if the end play exceeds the Repair limit.

Unit: mm (in.)

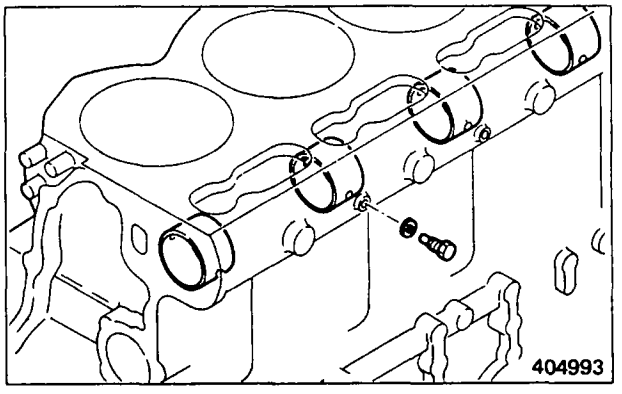
Item	Standard clearance	Repair limit
Camshaft end play	0.10 to 0.25 (0.0039 to 0.0098)	0.40 (0.0157)



Measuring camshaft end play

(6) Replacing camshaft bushings

Install the bushings in the crankcase, and secure them in place with set screws. Before tightening the screws, make sure that the screw holes in the bushings and crankcase are aligned and that the oil holes in the bushings are aligned with those leading to the oil gallery in the crankcase.



Replacing camshaft bushings

3.3 Reassembly

To reassemble, follow the reverse of disassembly procedure.

(1) Installing front cover

(a) Put the oil seal to the front cover.

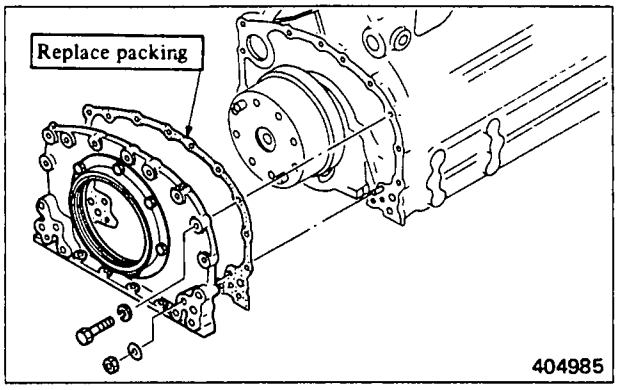
(b) Apply sealant (HERDITE) to the front cover mounting surface of crankcase, and place the packing in position. Apply the same sealant to the packing, and put the front cover.

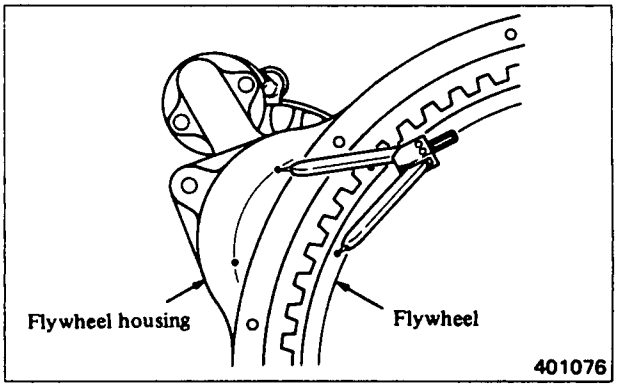
(c) Replace the dowel pins if worn, or if the front cover has been replaced.

(d) Tighten the front cover mounting bolts uniformly.

(When the pointer has been out of place)

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

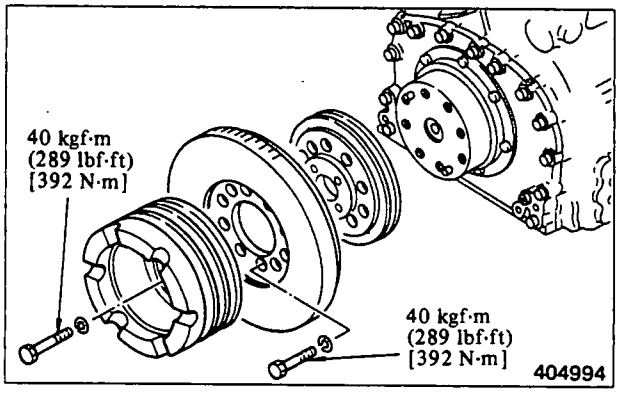




(2) Installing pulley and viscous damper

(a) Tighten the pulley and damper mounting bolts to the specified torque.

(b) Inspect the damper for radial and face runouts.
(Refer to 3.2, Group No. 7.)

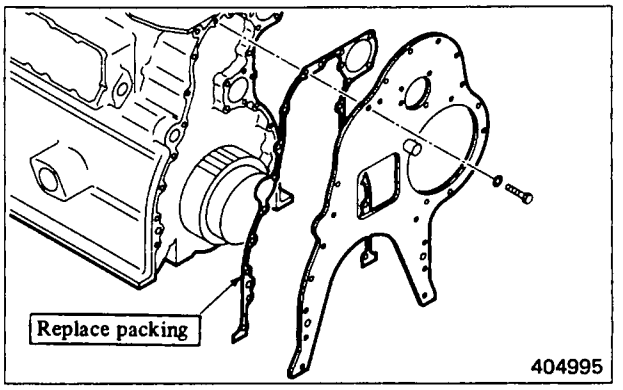


(3) Installing rear plate

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

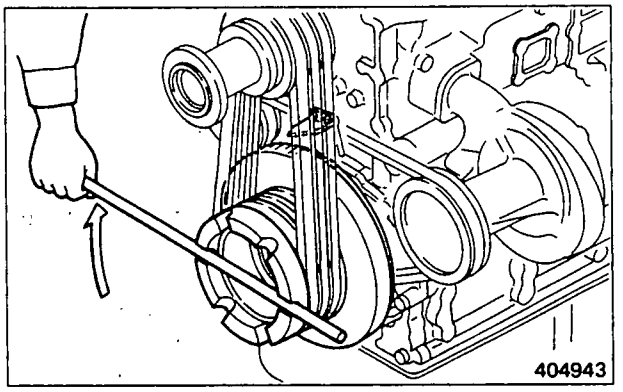
(b) Replace the dowel pins if worn, or if the rear plate has been replaced.

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



(4) Cranking engine

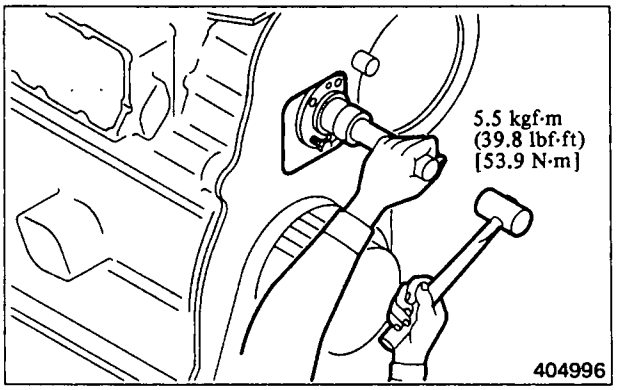
Turn the crankshaft to bring No. 1 cylinder piston to top dead center on compression stroke.



(5) Installing idler gear shaft

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

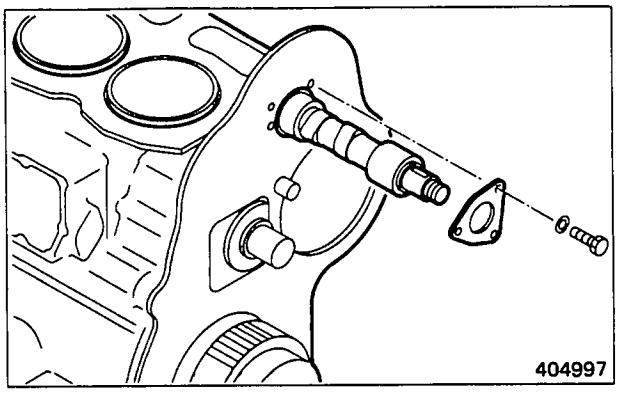
(b) Tighten the idler gear shaft mounting bolts to the specified torque.



(6) Installing camshaft

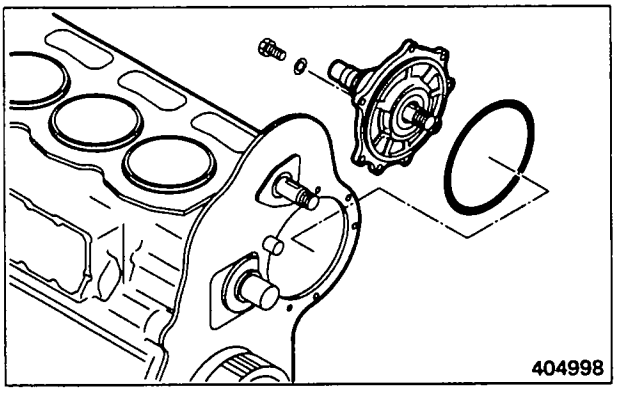
(a) Put the camshaft into the crankcase, and install the thrust plate.

(b) Check and make sure that the camshaft turns smoothly.



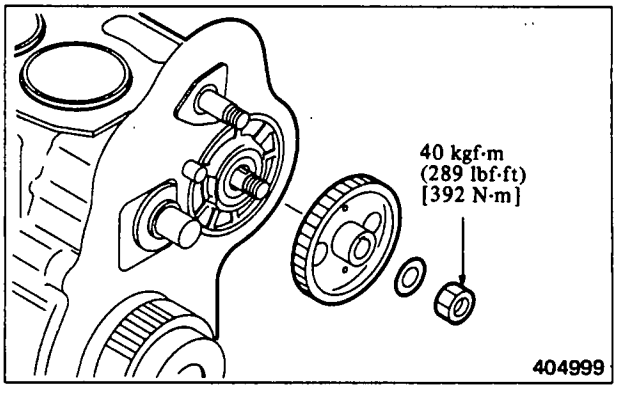
(7) Installing accessory drive

Fit O-ring in the groove in the mounting flange of drive case, and put the case to the rear plate.



(8) Installing fuel injection pump drive gear

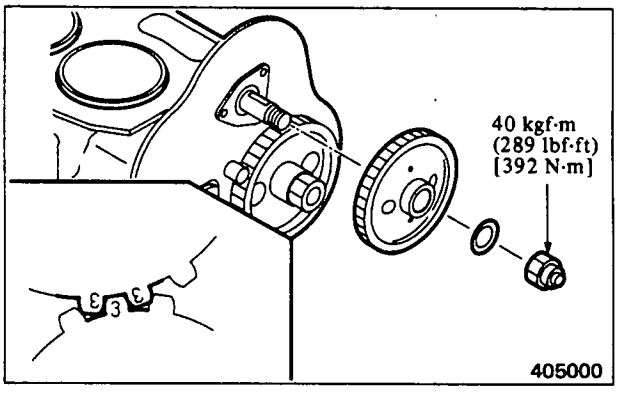
Place the injection pump drive gear on the drive shaft fitted with woodruff key, and tighten the nut to the specified torque.



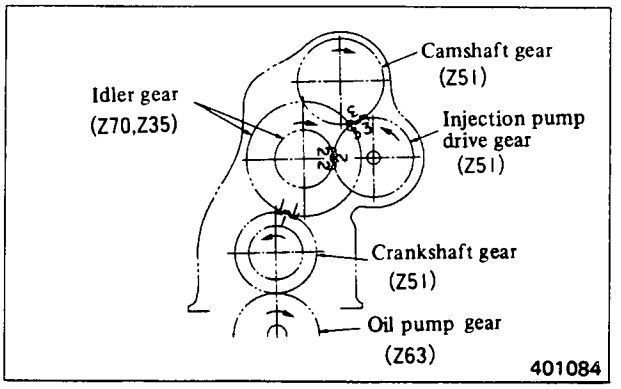
(9) Installing camshaft gear on camshaft

(a) Put the camshaft gear to the camshaft by aligning its matching mark with that on the injection pump drive gear.

(b) Tighten the nut to the specified torque, and bend the lock washer against the flat of the nut.



(c) Align the matching marks on the timing gears as shown at right.

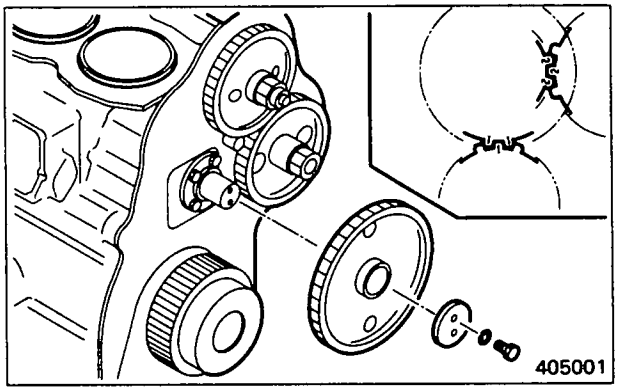


Timing gear train

(10) Installing idler gear

(a) Install the idler gear by aligning its matching mark with that on the crankshaft gear and injection pump drive gear, and install the thrust plate.

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

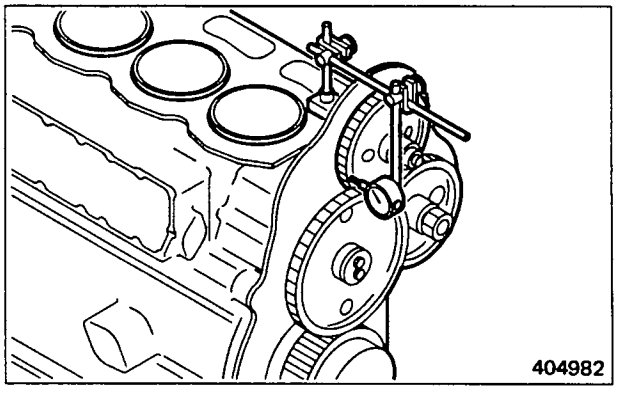


(11) Inspecting and adjusting timing gears after installation.

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

(Inspecting timing gear backlash and end play)

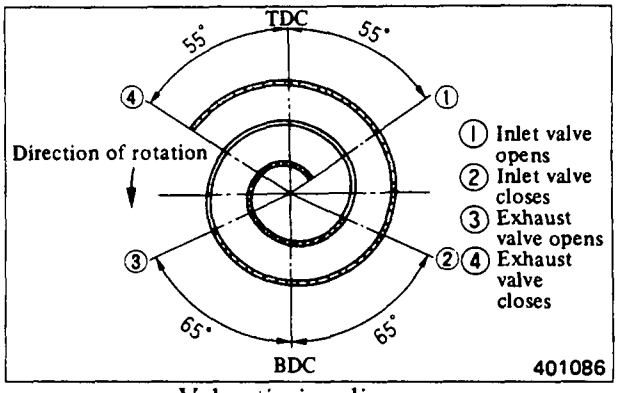
After installing the timing gears, check the backlash between the gears in mesh and the end play of each gear. (Refer to 3.2, Group No. 7.)



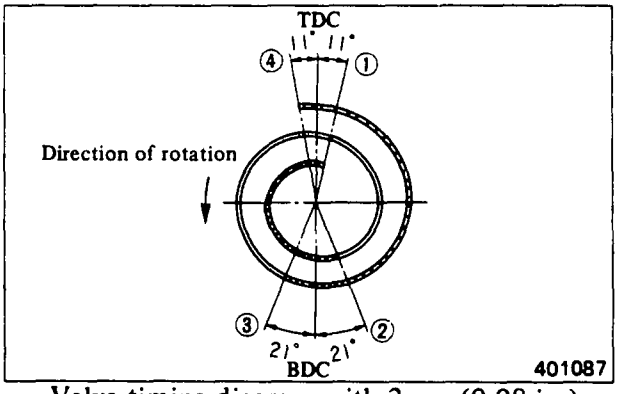
(Inspecting valve timing)

It is not necessary to check the valve timing, provided that all matching marks on the timing gears are aligned. Check the timing for verification as follows:

Using a 2 mm (0.08 in.) feeler gauge, set the clearance of the inlet and exhaust valves of No. 1 cylinder to 2 mm (0.08 in). Then, insert a 0.05 mm (0.0020 in.) feeler gauge into between the bridge cap and rocker, and slowly turn the crankshaft, trying to find a position where the feeler gauge is firmly gripped (the valve starts opening) and that where the gauge just becomes free (the valve starts closing). Check to make sure that these positions coincide with the angular positions shown in the valve timing diagram with 2 mm (0.08 in.) clearance added to the valves.



Valve timing diagram

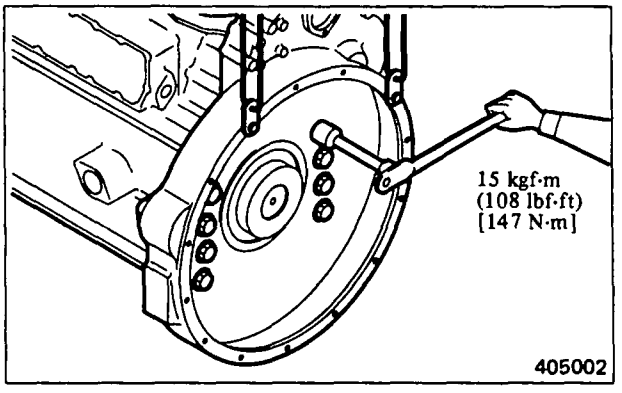


Valve timing diagram with 2mm (0.08 in.) clearance added to valves

(12) Installing timing gear case

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

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

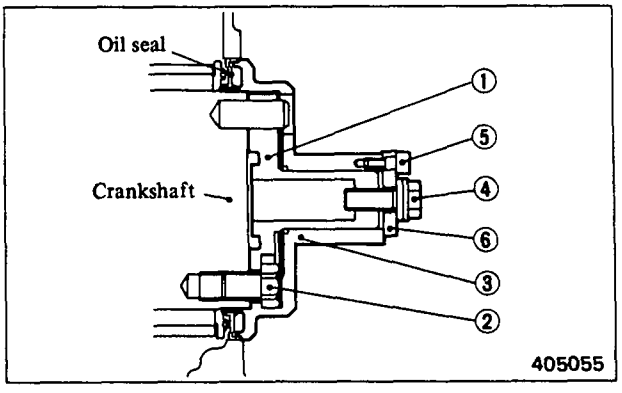


(13) Installing oil seal case

To install the oil seal, use the oil seal installer.

(a) Put guide (1) on the rear end of crankshaft with insert bolt (2).

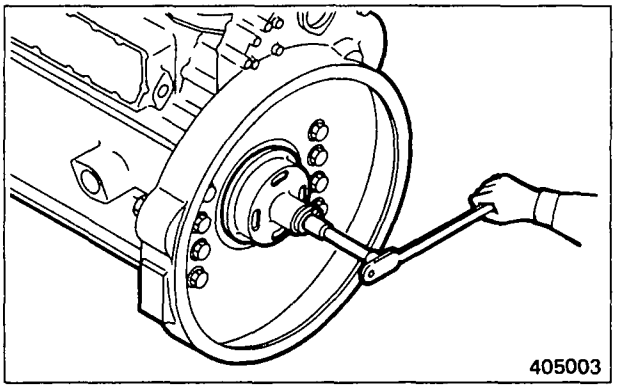
(b) Put the oil seal in installer (3), and put the installer on the shaft portion of guide (1).

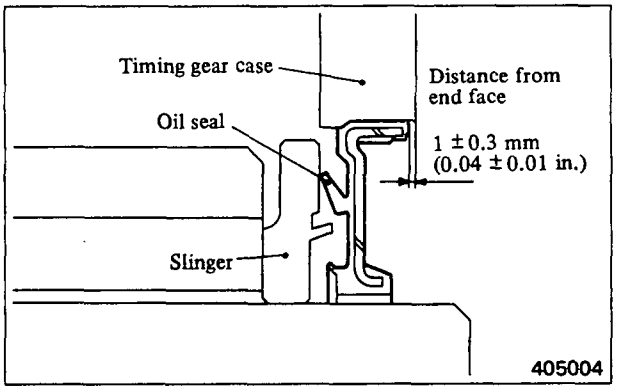


(c) Tighten bolt (4) of installer (3) to install the oil seal to the gear case.

(d) Loosen socket bolt (5). Slip swing washer (6) off bolt (4), and withdraw installer (3).

(e) Loosen insert bolt (2), and remove guide (1) from the crankshaft.



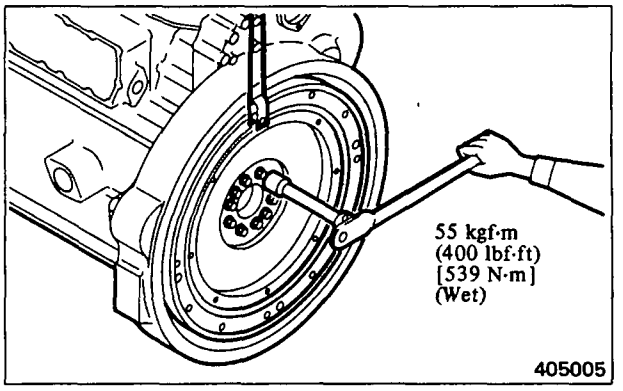


(14) Installing flywheel

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

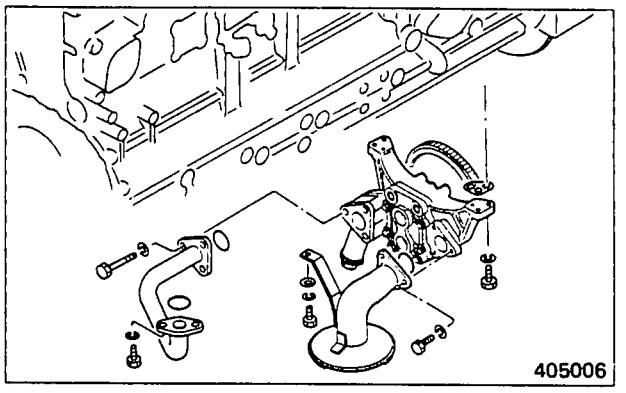
(b) Apply engine oil to the threads and seats of flywheel mounting bolts, and tighten the bolts to the specified torque. Check the axial and radial runouts of the flywheel.

(c) Inspect the face and radial runouts of the flywheel.
(Refer to 3.2, Group No. 7.)



(15) Installing oil pump and oil strainer

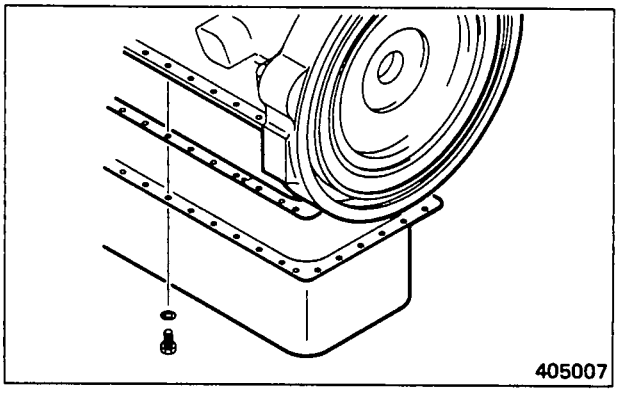
Measure the backlash between crankshaft gear and oil pump drive gear. If the backlash is too small, adjust it by fitting shims to the pump gear mounting face.



(16) Installing oil pan

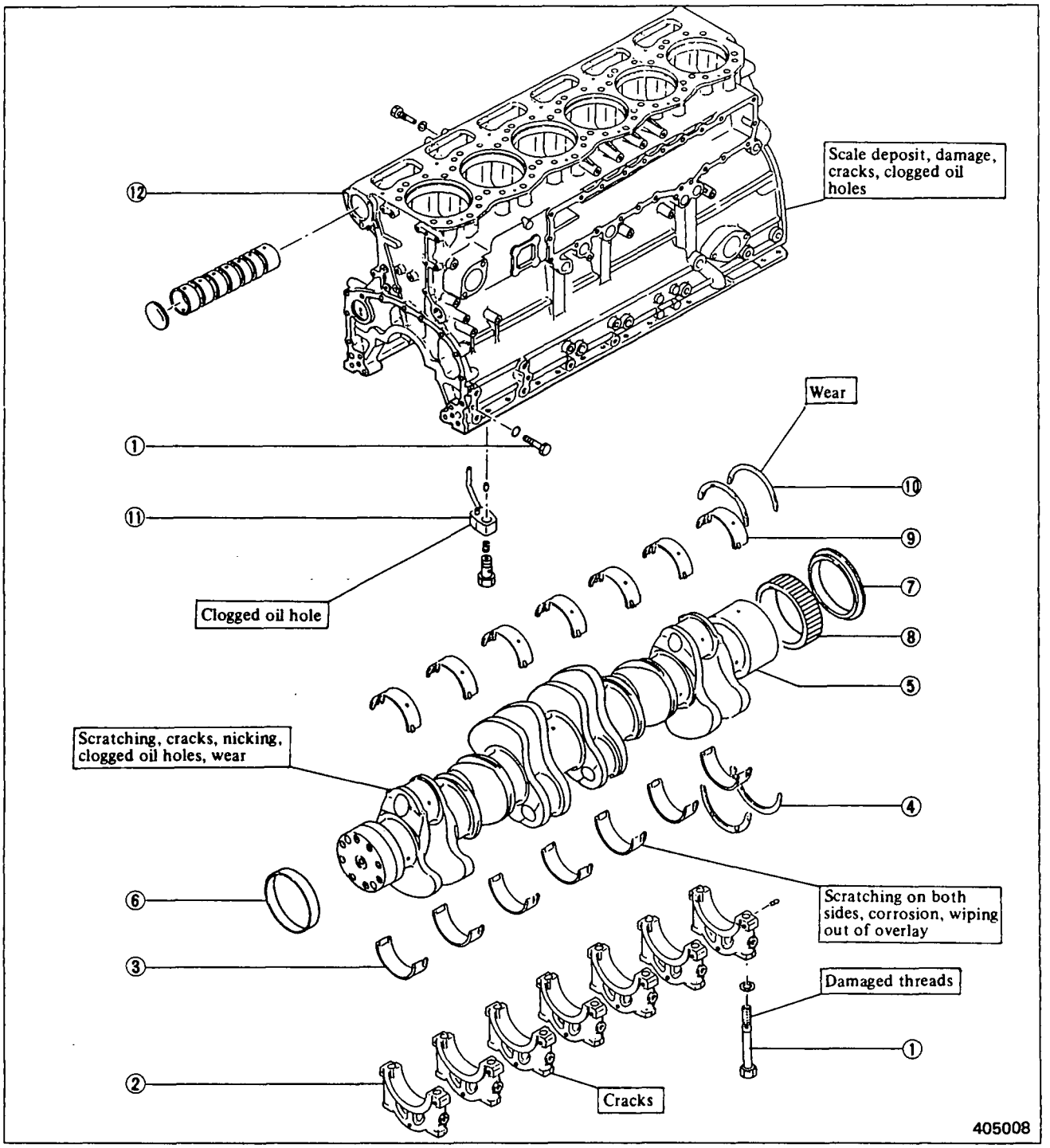
(a) Apply sealing compound (HERDITE) to the contact surfaces of packings (4 places), and put the packings.

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



4. CRANKCASE, CRANKSHAFT AND MAIN BEARINGS

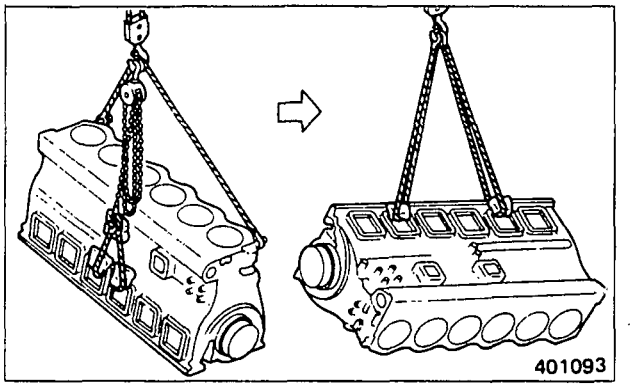
4.1 Disassembly



① Bolt, side bolt
② Main bearing cap
③ Main bearing (lower shell)
④ Thrust plate
⑤ Crankshaft
⑥ Sleeve
⑦ Slinger
⑧ Crankshaft gear
⑨ Main bearing (upper shell)
⑩ Thrust plate
⑪ Oil jet
⑫ Crankcase

(1) Turning crankcase upside down

Using a chain block and shackles, lay the crankcase by its side. Then, fasten a hoist to the crankcase, and turn it upside down.
[Weight of crankcase and crankshaft: 700 kg (1544 lb)]

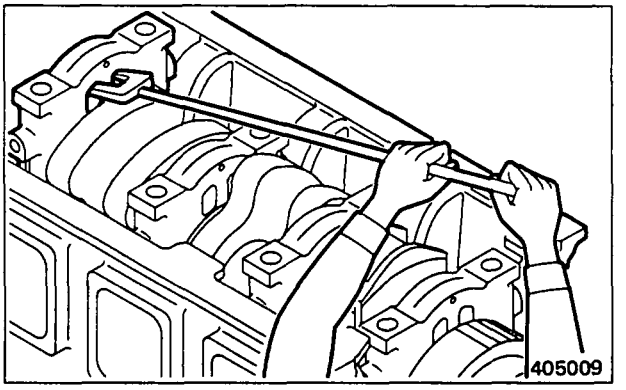


(2) Removing main bearing caps

(a) Unscrew the bolts and side bolt for each main bearing cap.

(b) Remove the cap, using a cap remover.

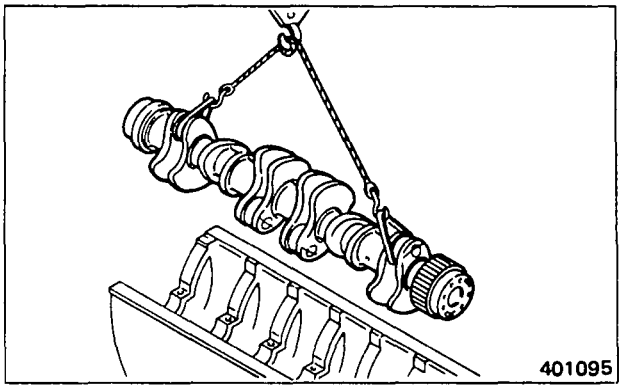
(c) Remove the thrust plates from the No. 7 bearing cap. Be careful not to damage the thrust plates.



(3) Removing crankshaft

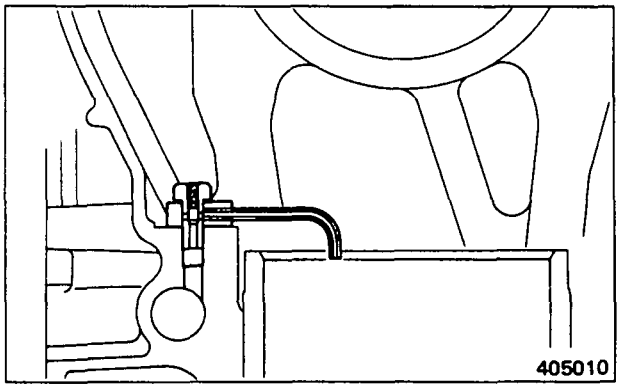
(a) Remove the upper halves of thrust plates while turning the crankshaft slowly.

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



(4) Removing oil jet nozzles

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



4.2 Inspection and repair

Crankshaft

(1) Measuring diameter of crankpins and journals

(a) Using a micrometer, measure the crankpins and journals. If they are worn in excess of the Repair limit, grind them to the next undersize [-0.25 mm (-0.0098 in.), -0.50 mm (-0.0197 in.), -0.75 mm (-0.0295 in.) or -1.00 mm (-0.0394 in.)].

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

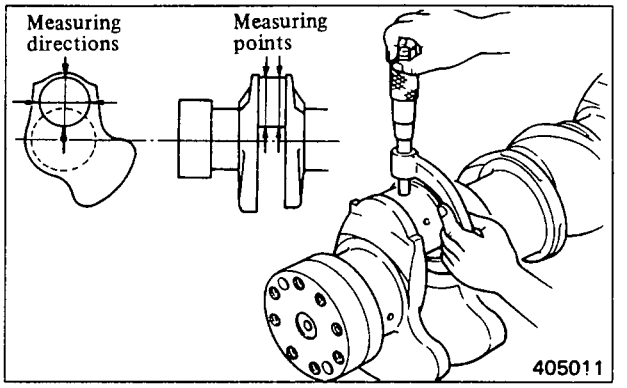
(c) If the -1.00 mm (0.0394 in.) undersize journals and crankpins are worn in excess of the Repair limit, replace the crankshaft.

Unit: mm (in.)

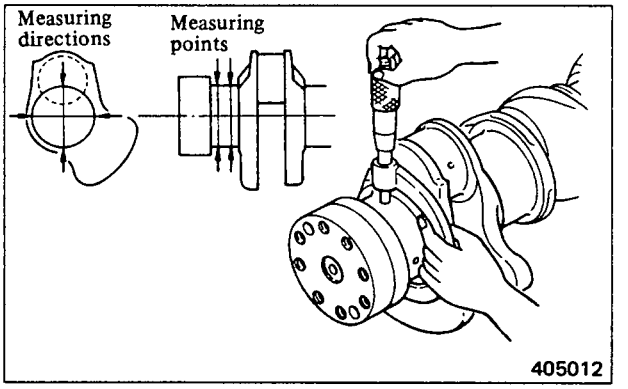
Item	Nominal value	Assembly standard	Repair limit
Crankpin diameter	104 (4.09)	-0.10 to -0.12 (-0.0039 to -0.0047)	-0.16 (-0.0063)
Journal diameter	140 (5.51)	-0.05 to -0.07 (-0.0020 to -0.0028)	-0.10 (-0.0039)
Out-of-roundness and taper of crankpins and journals		0.01 (0.0004), maximum	0.03 (0.0012)
Fillet radius		$7.0^{0}_{-0.2}$ ($0.276^{0}_{-0.008}$)	
Hardness		Hv > 620	

(2) Grinding crankshaft

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



Measuring crankpin diameter



Measuring journal diameter

Crankshaft refinishing dimensions

Unit: mm (in.)

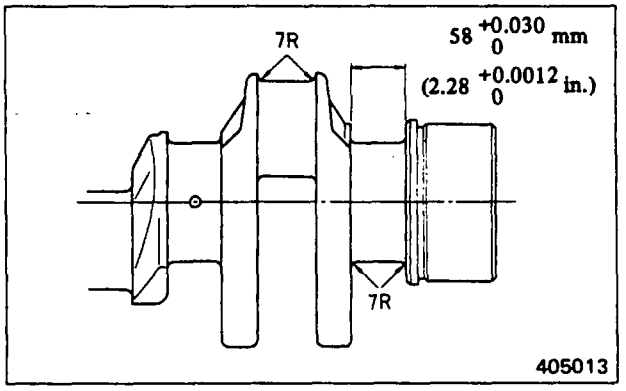
	Undersize	Finishing dimension	Out-of-roundness	Taper
Crankpin diameter	0.25 (0.0098)	103.63 to 103.65 (4.0799 to 4.0807)	0.01 (0.0004), maximum	0.01 (0.0004), maximum
	0.50 (0.0197)	103.38 to 103.40 (4.0701 to 4.0709)		
	0.75 (0.0295)	103.13 to 103.15 (4.0602 to 4.0610)		
	1.00 (0.0394)	102.88 to 102.90 (4.0504 to 4.0512)		
Journal diameter	0.25 (0.0098)	139.68 to 139.70 (5.4992 to 5.5000)		
	0.50 (0.0197)	139.43 to 139.45 (5.4894 to 5.4901)		
	0.75 (0.0295)	139.18 to 139.20 (5.4795 to 5.4803)		
	1.00 (0.0394)	138.93 to 138.95 (5.4697 to 5.4705)		

When grinding the crankpins and journals, be sure to produce the same fillet radius as the original one. They should have a hardness of 620 or more in terms of Vickers Hardness Number. If necessary, reharden the crankpins and journals, and inspect them for cracks by conducting a magnalux (magnetic particle) test.
After grinding the crankpins and journals, finish them to $\underset{\nabla\nabla\nabla}{0.8S}$.

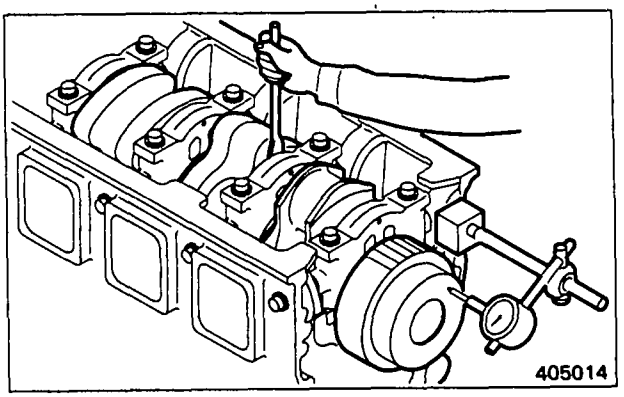
(3) Measuring end play

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

(b) If the end play still exceeds the Repair limit even after new thrust plates have been installed, replace the plates with the next oversize ones. There are three oversizes for the thrust plates; namely, +0.25 mm (+0.0098 in.), +0.50 mm (+0.0197 in.) and +0.75 mm (+0.0295 in.). Generally, the rear journal is likely to be worn more rapidly than the front journal. This means that replacement of the rear thrust plates will, in most cases, gains the purpose.



Measuring thrust bearing journal length



Measuring crankshaft end play

Unit: mm (in.)

Item	Standard clearance	Repair limit
End play of crankshaft	0.20 to 0.365 (0.0079 to 0.01437)	0.50 (0.0197)

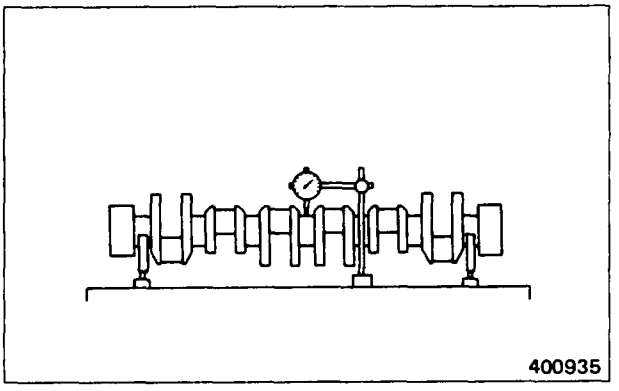
Crankshaft journal grinding dimensions for oversize thrust plates

Unit: mm (in.)

Item	Oversizes for journal or thrust plates	Oversizes for journal and thrust plates	Tolerance
Standard size	–	58 (2.28)	+0.03 0 ($^{+0.0012}_{0}$)
+0.25 (+0.0098) oversize	58.25 (2.2933)	58.50 (2.3031)	
+0.50 (+0.0197) oversize	58.50 (2.3031)	59.00 (2.3228)	
+0.75 (+0.0295) oversize	58.75 (2.3130)	59.50 (2.3425)	

(4) Measuring runout

Support the crankshaft on its No. 1 and No. 7 journals in V-blocks, and measure the runout at the center journal with a dial indicator. Depending on the amount of runout, repair the crankshaft by grinding or straightening with a press. If the runout exceeds the Repair limit, replace the crankshaft.



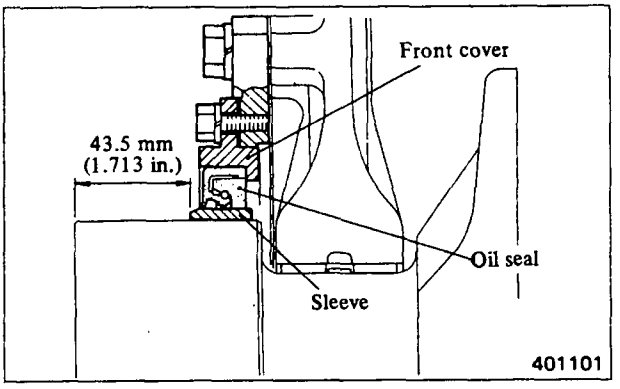
Measuring crankshaft runout

Unit: mm (in.)

Item	Assembly standard	Repair limit
Runout of crankshaft	0.04 (0.0016), maximum	0.10 (0.0039)

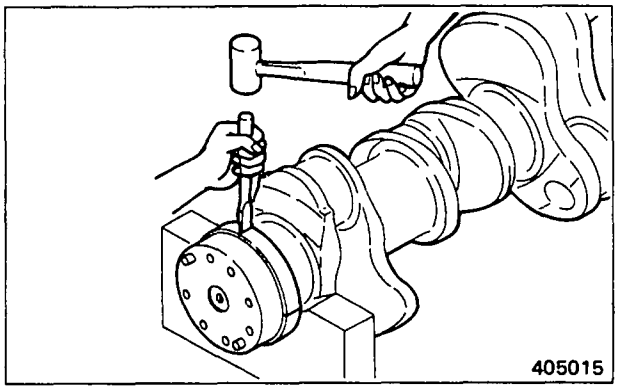
(5) Replacing front oil sleeve

If the sleeve is pitted, scratched or distorted to such an extent as to cause oil leakage, replace it with a new one as follows:



(Removal)

Give hammer blows to the sleeve at three places by holding a chisel at right angles to the sleeve surface and, when the sleeve loses tension, remove it from the crankshaft.



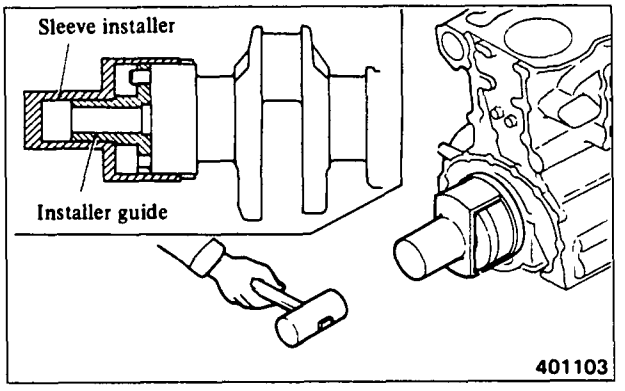
⚠ CAUTION

Be careful not to damage the crankshaft by the chisel.

(Installation)

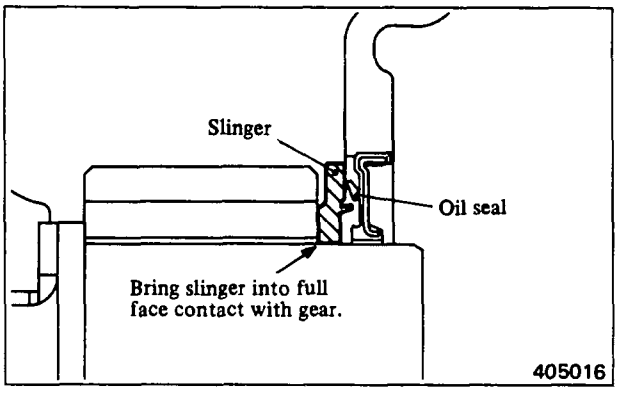
Coat the inside surface of a new sleeve with oil or MOLYKOTE, and install the sleeve, using a sleeve installer.

Tool name	Part number
Sleeve installer	32591-00500
Installer guide	32591-00600



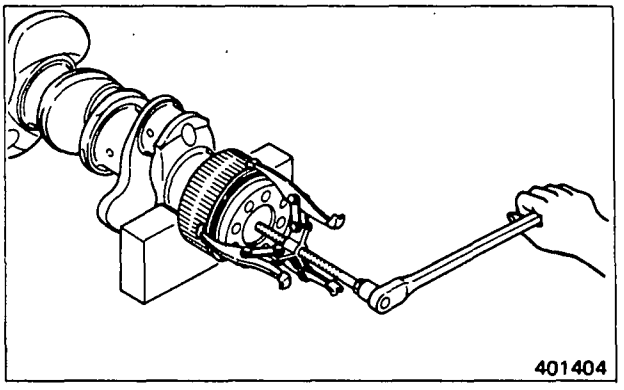
(6) Replacing rear oil seal slinger

If the slinger is pitted, scratched or distorted to such an extent as to cause oil leakage, replace it with a new one as follows:



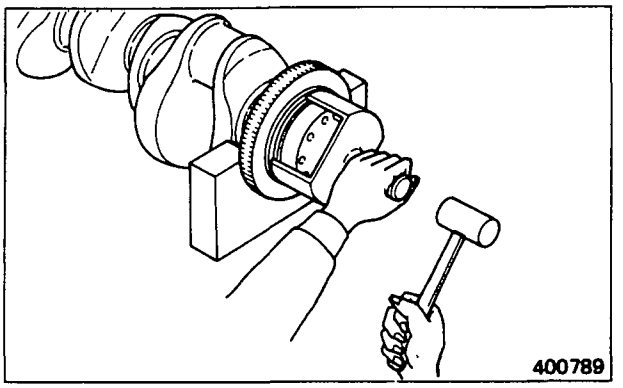
(Removal)

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



(Installation)

Fit the slinger heated up to 110°C (230°F) or more to the tip of the installer. Press the slinger until it touches the gear.
If the installer gets fast halfway, give the blows of a copper hammer to the center or shoulder of the installer.
Apply engine oil to the lip of the seal.



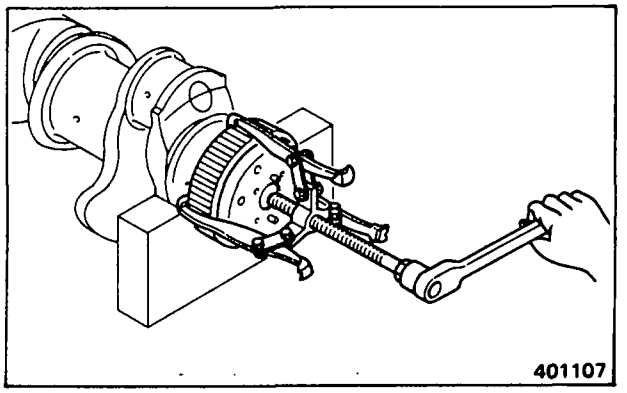
(7) Replacing (removing) crankshaft gear

(Removal)

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

NOTE

Do not remove the gear by driving with a hammer.

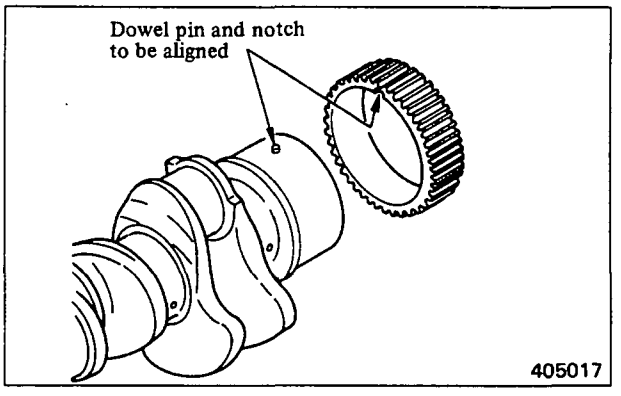


(Installation)

(a) Measure the diameter of crankshaft and the inside diameter of gears to make sure the fit of front gear is 0.106 to 0.171 mm (0.00417 to 0.00673 in.) and that of rear gear is 0.274 to 0.358 mm (0.01079 to 0.01409 in.).

(b) Heat the gear up to about 100°C (212°F).

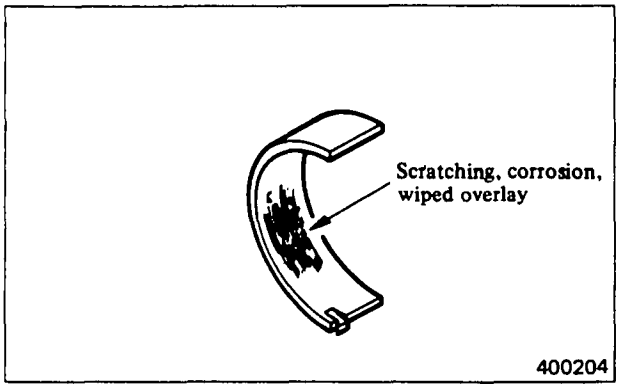
(c) Drive the gear onto the crankshaft by giving light blows of a copper hammer to the end face of the gear, making sure that the crankshaft dowel pin enters the notch in the gear.



Main bearings

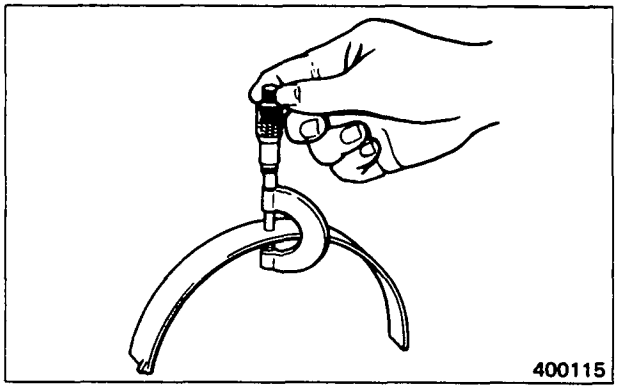
(1) Inspection

Check each bearing shell for abnormal contact, scratching, corrosion, flaking and other defects. Also check for a sign of poor seating in the bore of the crankcase or bearing cap.



(2) Measuring bearing thickness

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



Unit: mm (in.)

Item		Nominal value	Assembly standard	Service limit
Main bearing thickness	STD	3.500 (0.13780)	3.467 to 3.480 (0.13650 to 0.13701)	3.425 (0.13484)
	-0.25 (-0.0098)	3.625 (0.14272)	3.592 to 3.605 (0.14142 to 0.14193)	3.550 (0.13976)
	-0.50 (-0.0197)	3.750 (0.14764)	3.717 to 3.730 (0.14634 to 0.14685)	3.675 (0.14468)
	-0.75 (-0.0295)	3.875 (0.15256)	3.842 to 3.855 (0.15126 to 0.15177)	3.800 (0.14961)
	-1.00 (-0.0394)	4.000 (0.15748)	3.967 to 3.980 (0.15618 to 0.15670)	3.925 (0.15453)

NOTE

Four undersizes are available for the main bearings; namely, -0.25 mm (-0.0098 in.), -0.50 mm (-0.0197 in.). -0.75 mm (-0.0295 in.) and -1.00 mm (-0.0394 in.).

(3) *Replacing main bearings*

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

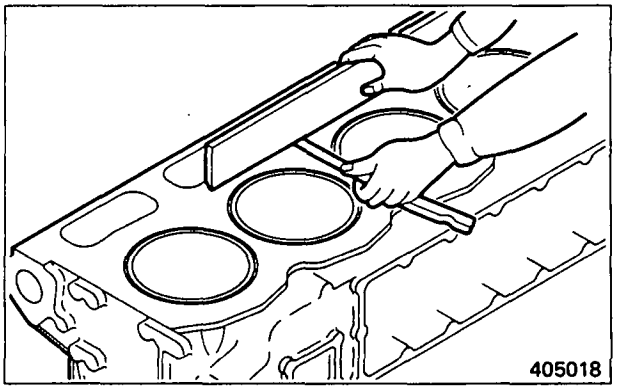
Crankcase

(1) Measuring warpage of gasket contact surface

Measure warpage with a straightedge and feeler gauge. If the warpage exceeds the Assembly standard, reface the gasket contact surface with a surface grinder.

Unit: mm (in.)

Item	Assembly standard	Repair limit
Warpage of gasket contact surface	0.05 (0.0020), maximum	0.20 (0.0079)



Measuring crankcase gasketed surfaces

NOTE

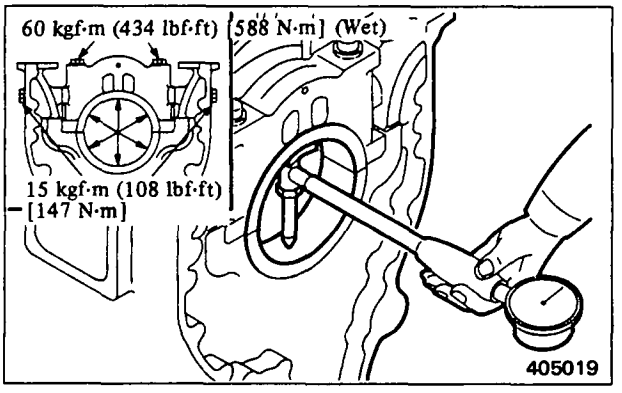
Do not grind the surfaces more than are necessary for removing warpage to prevent the piston projection from exceeding the Assembly standard. (Refer to (4), Pistons, 2.2, Group No. 7.)

(2) Measuring inside diameter of main bearing bore

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

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Main bearing bore diameter	137 (5.39)	137.000 to 137.035 (5.39369 to 5.39507)	137.045 (5.39546)



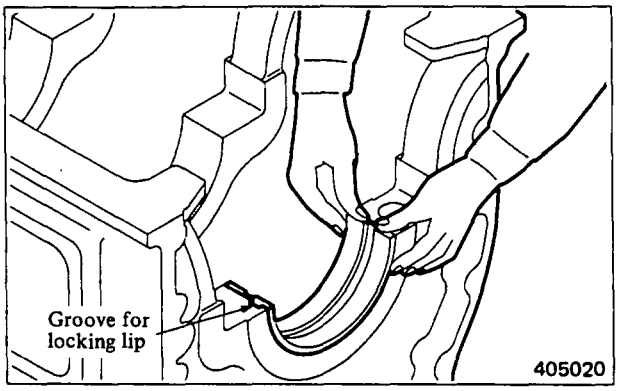
Measuring main bearing bore diameter

4.3 Reassembly

To reassemble, follow the reverse of disassembly sequence.

(1) Installing main bearings

(a) Put each upper shell of main bearing in the crankcase by fitting its locking lip in its groove. The oil holes in the bearings and crankcase will be aligned when the bearings are so installed.



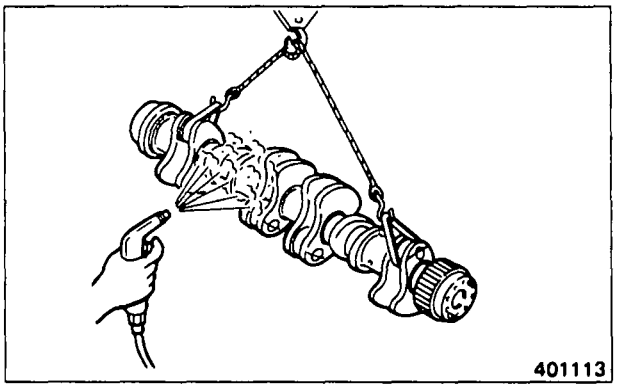
(b) Lightly coat the inside surface of the shells with engine oil.

(2) Installing crankshaft

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

NOTE

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

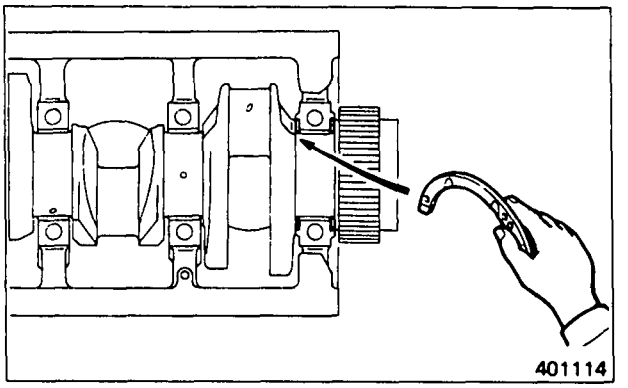


(b) Hold the crankshaft in a horizontal position by using a hoist, and carefully put it in the crankcase.

(c) Lightly coat the journals with engine oil.

(3) Installing thrust plates

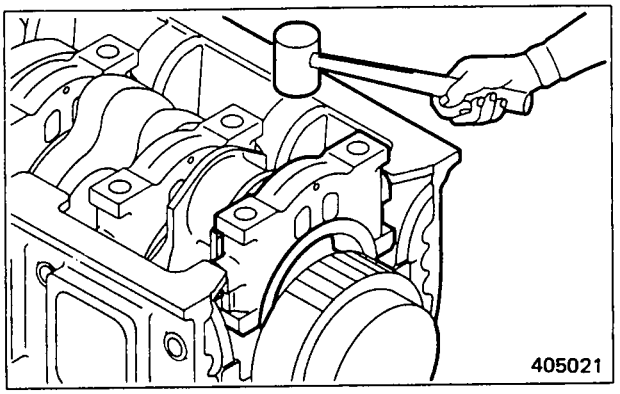
Install the thrust plates to No. 7 bearing seat of the crankcase with the oil groove side of the plates facing outside.



(4) Installing main bearing caps

(a) Put the lower shell of the bearing in each bearing cap.

(b) Install the bearing caps to the crankcase by matching the mark (figure) stamped on each cap with that stamped on the front side of crankcase.



NOTE

Whether or not the caps have been properly installed can be confirmed by observing the part numbers indicated on the caps. The part numbers should face rearward when the caps are installed.

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

(d) Using a soft hammer, drive in the bearing cap evenly.

(5) Installing bearing cap bolts

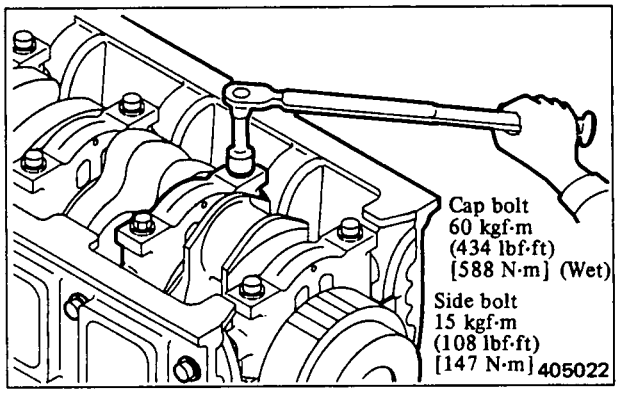
(a) Put engine oil on all bearing cap bolts and side bolts.

(b) Tighten the cap bolts to the specified torque.

(c) Tighten the right-side (camshaft-side) side bolts to the specified torque.

(d) Tighten the left-side (oil cooler-side) side bolts to the specified torque.

(e) Make sure that the crankshaft rotates freely.

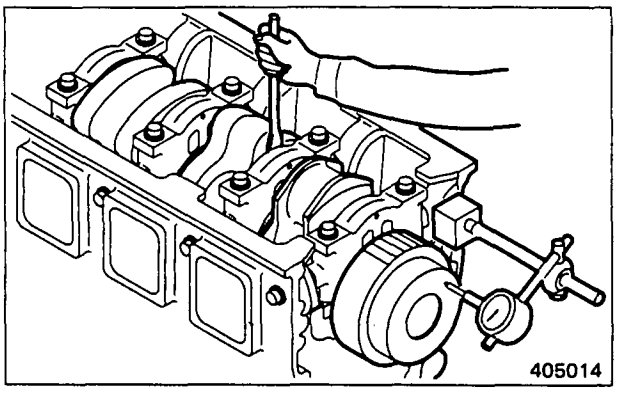


(6) Measuring crankshaft end play

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

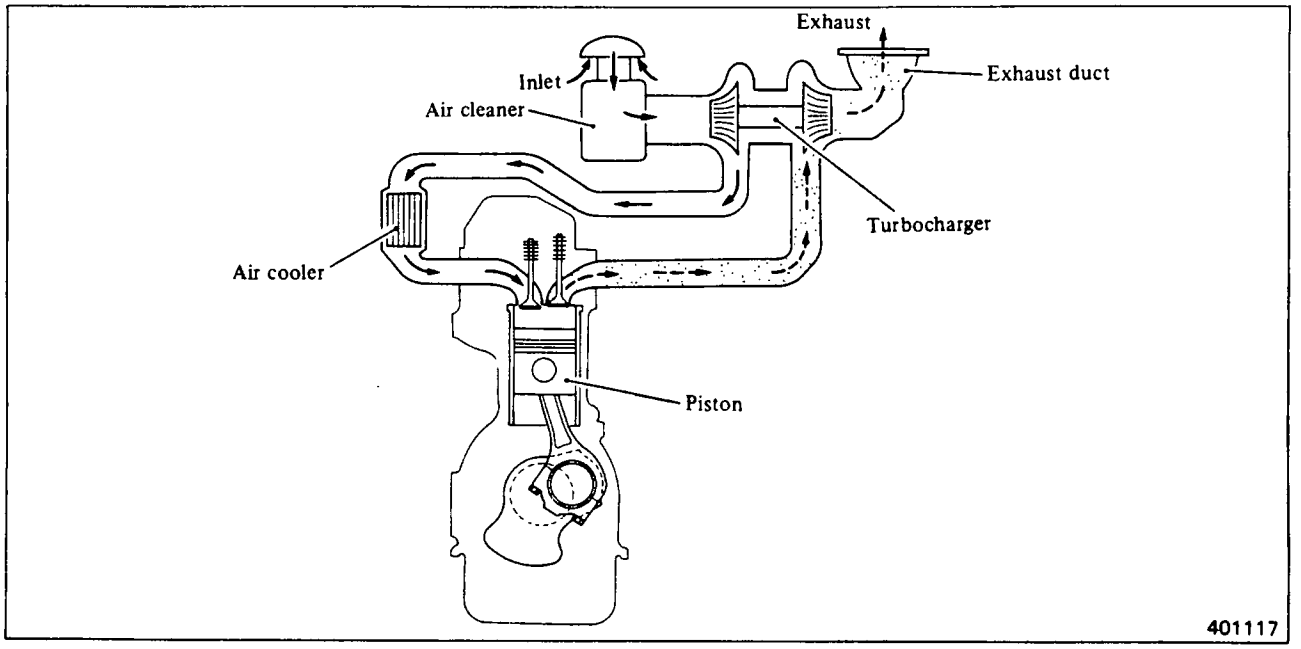
(b) After tightening the No. 7 cap bolts, make sure that the end play is correct.

(c) Again make sure that all cap bolts are tightened to the specified torque.
(Refer to 4.2, Group 7.)



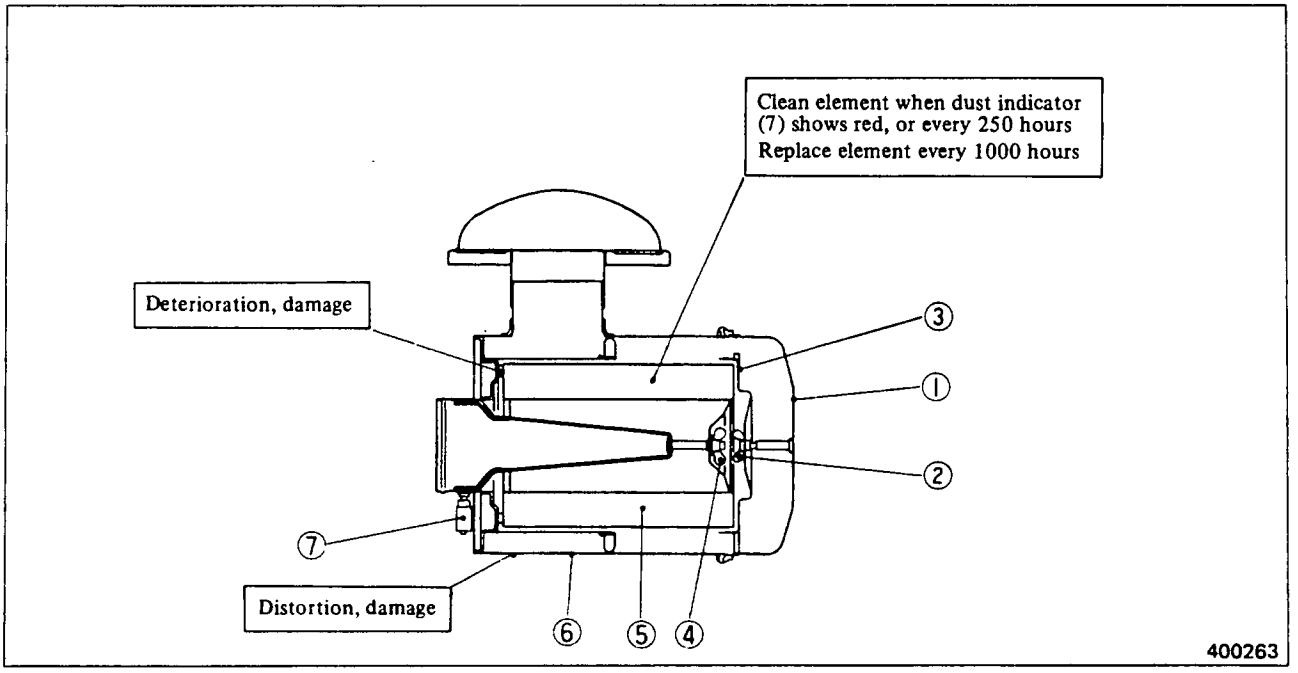
INLET AND EXHAUST SYSTEMS

1. DESCRIPTION



2. PAPER-ELEMENT TYPE AIR CLEANER

Disassembly and inspection



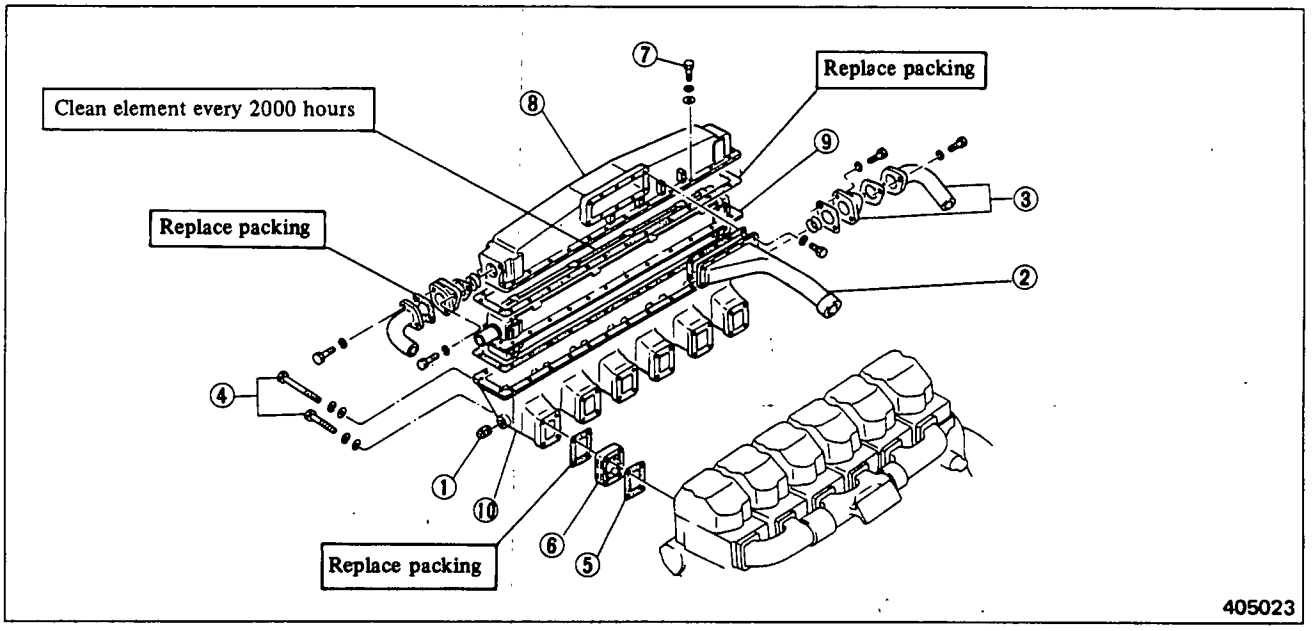
① Air cleaner cap
② Wing nut
③ Cover
④ Wing nut
⑤ Element
⑥ Air cleaner body
⑦ Dust indicator

⚠ CAUTION

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

3. INLET MANIFOLDS AND AIR COOLER

3.1 Disassembly

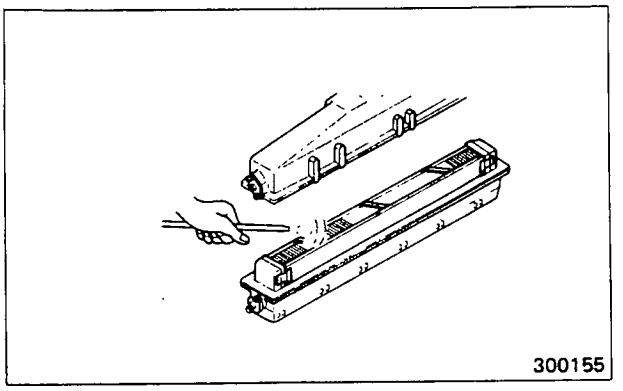


① Taper plug
② Air duct
③ Water pipe, packing
④ Bolts
⑤ Packing
⑥ Spacer
⑦ Bolt
⑧ Inlet manifold cover
⑨ Element, gasket
⑩ Inlet manifold

3.2 Inspection

(1) Cleaning air cooler

(a) Remove dirt buildup from the element by directing pressure air of 3 to 5 kgf/cm^2 (43 to 71 psi) [0.3 to 0.5 MPa] maximum in the direction opposite to the air flow. Then, check the element for corrosion and cracking.


300155

(b) Wash the fresh-water or sea-water pipes in water and caustic soda or soda lime, and remove scale deposits by inserting a 5 mm (0.2 in.) diameter bar into each pipe.

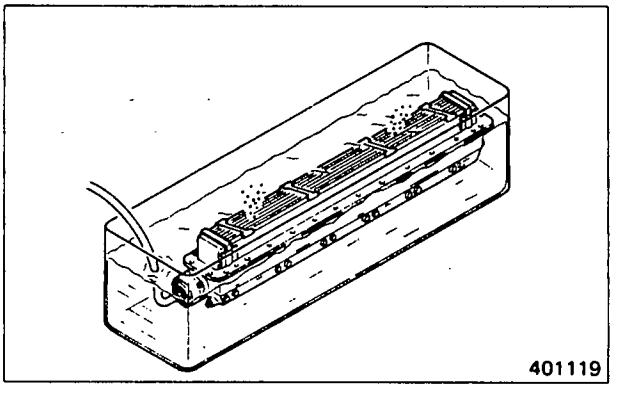
(c) Every 500 hours, replace the zinc rods if sea water is used in the cooler.

⚠ WARNING

When handling caustic soda or soda lime, be sure to wear rubber gloves to protect hands.

(2) Inspecting air cooler for airtightness

Immerse the air cooler in water, and apply pressure air of 4 kgf/cm^2 (57 psi) [0.4 MPa] to the coolant side to check for air leakage.

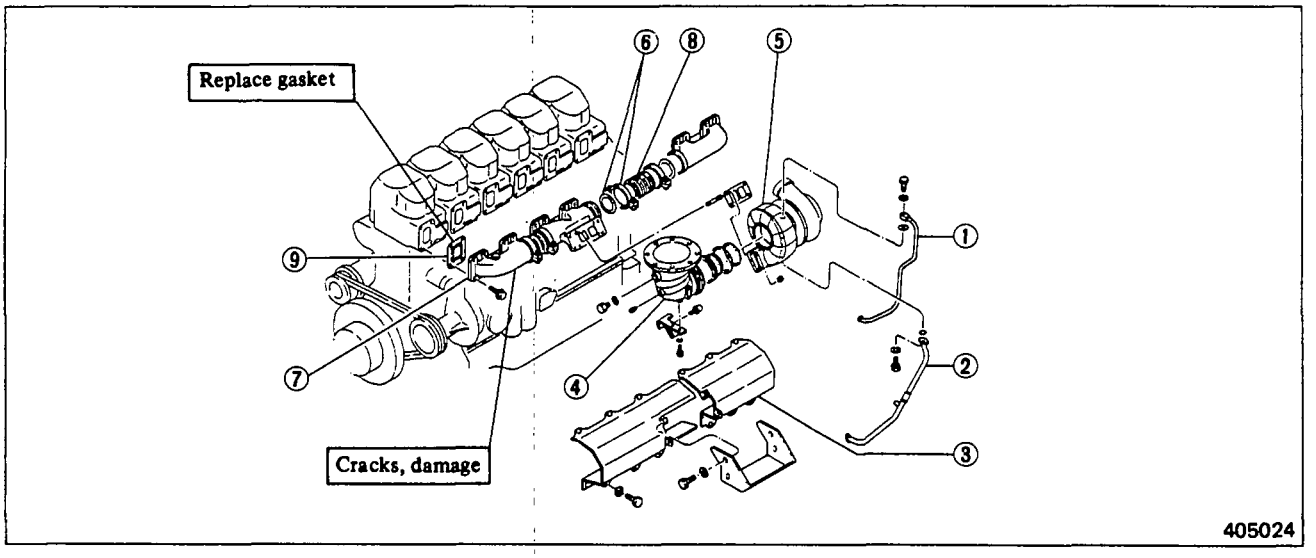

401119

⚠ CAUTION

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

4. EXHAUST MANIFOLDS

Disassembly and inspection



① Oil pipe
② Drain pipe
③ Insulator
④ Exhaust pipe
⑤ Turbocharger
⑥ Coupling, shims
⑦ Exhaust manifold
⑧ Flexible joint
⑨ Gasket

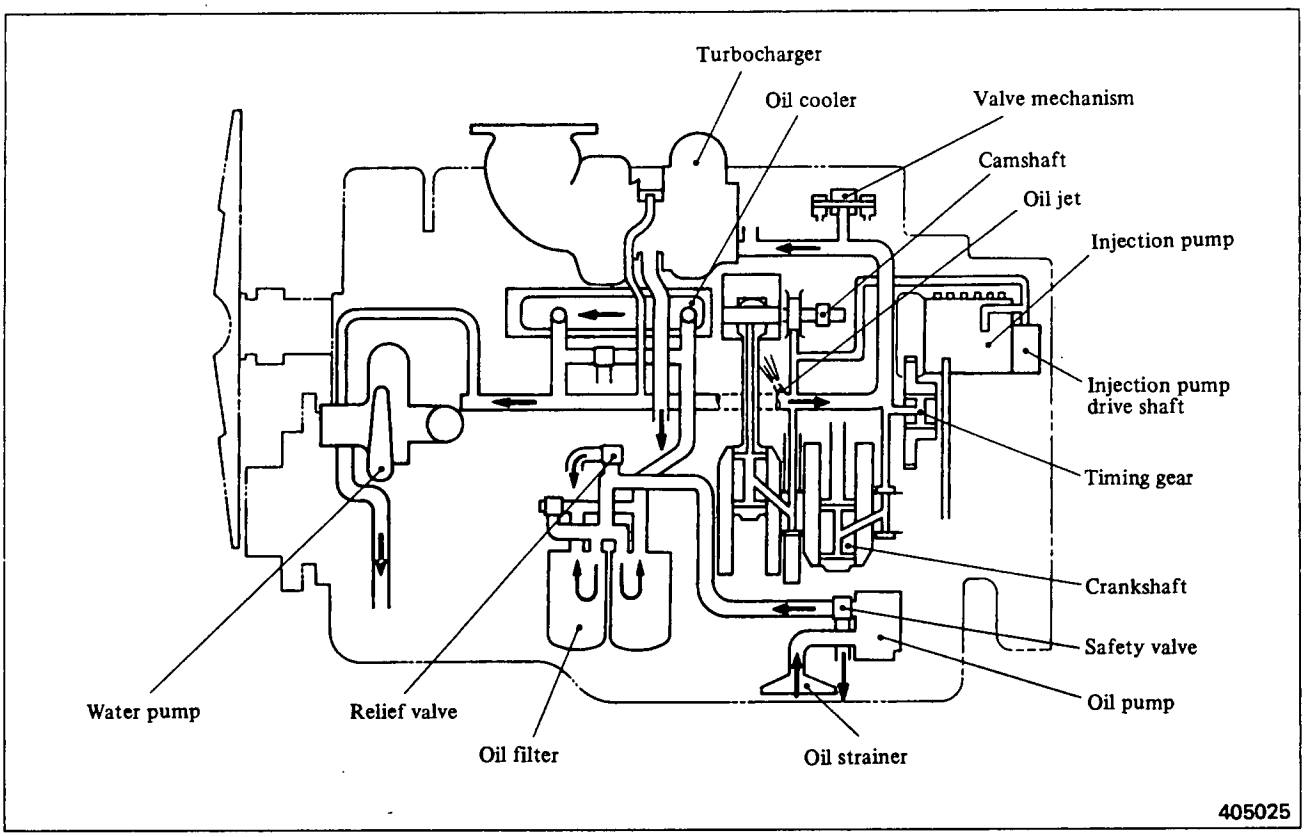
NOTE

(a) Put each gasket with "TOP" mark on the exhaust manifold side.

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

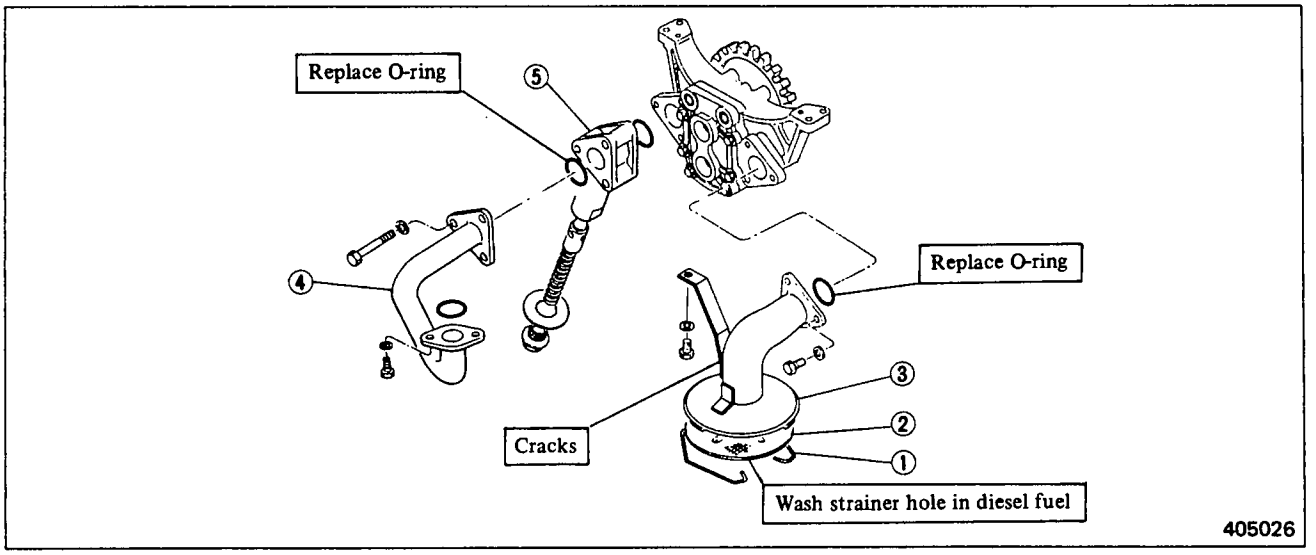
LUBRICATION SYSTEM

1. DESCRIPTION



2. OIL STRAINER AND SAFETY VALVE

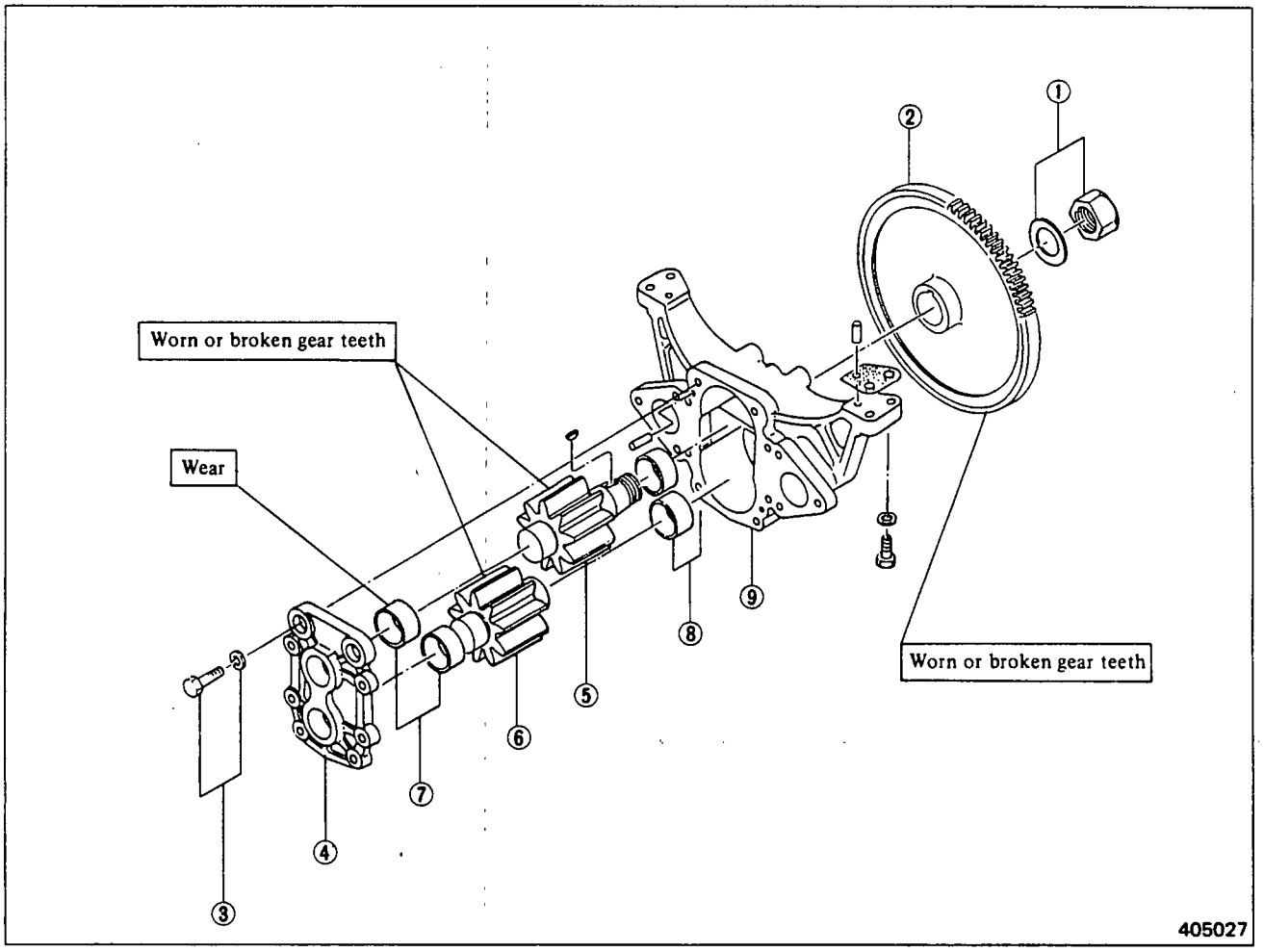
Disassembly and inspection



① Cilp
② Oil strainer
③ Oil strainer pipe
④ Oil pipe
⑤ Safety valve

3. OIL PUMP

3.1 Disassembly



① Nut, plain washer
② Oil pump gear, key
③ Bolt, spring washer
④ Pump cover
⑤ Pump drive gear
⑥ Pump driven gear
⑦ Bushing
⑧ Bushing
⑨ Pump case

3.2 Inspection

(1) Measuring oil pump gear backlash

If the backlash exceeds the Service limit, replace the gears.

Unit: mm (in.)

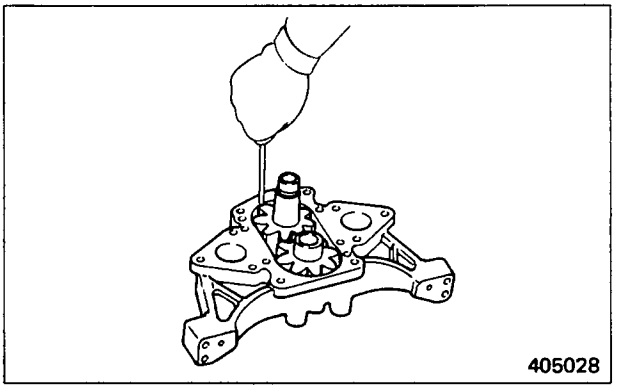
Item	Standard clearance	Service limit
Oil pump gear backlash	0.10 to 0.20 (0.0039 to 0.0079)	0.40 (0.0157)

(2) Measuring pump gear radial clearance

Using a feeler gauge, measure the radial clearance. If the clearance exceeds the Repair limit, replace the gears or case whichever is badly worn.

Unit: mm (in.)

Item	Nominal value	Standard clearance	Repair limit
Pump gear radial clearance	84 (3.31)	0.15 to 0.23 (0.0059 to 0.0091)	(Tip clearance) 0.35 (0.0138)



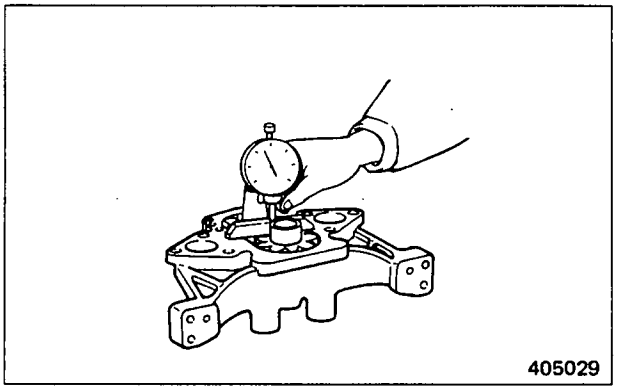
Measuring pump gear radial clearance

(3) Measuring pump gear end clearance

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

Unit: mm (in.)

Item	Nominal value	Standard clearance	Repair limit
Pump gear end clearance	63 (2.48)	0.10 to 0.20 (0.0039 to 0.0079)	0.25 (0.0098)



Measuring pump gear end clearance

(4) Measuring drive and driven gear shaft and bushing diameters

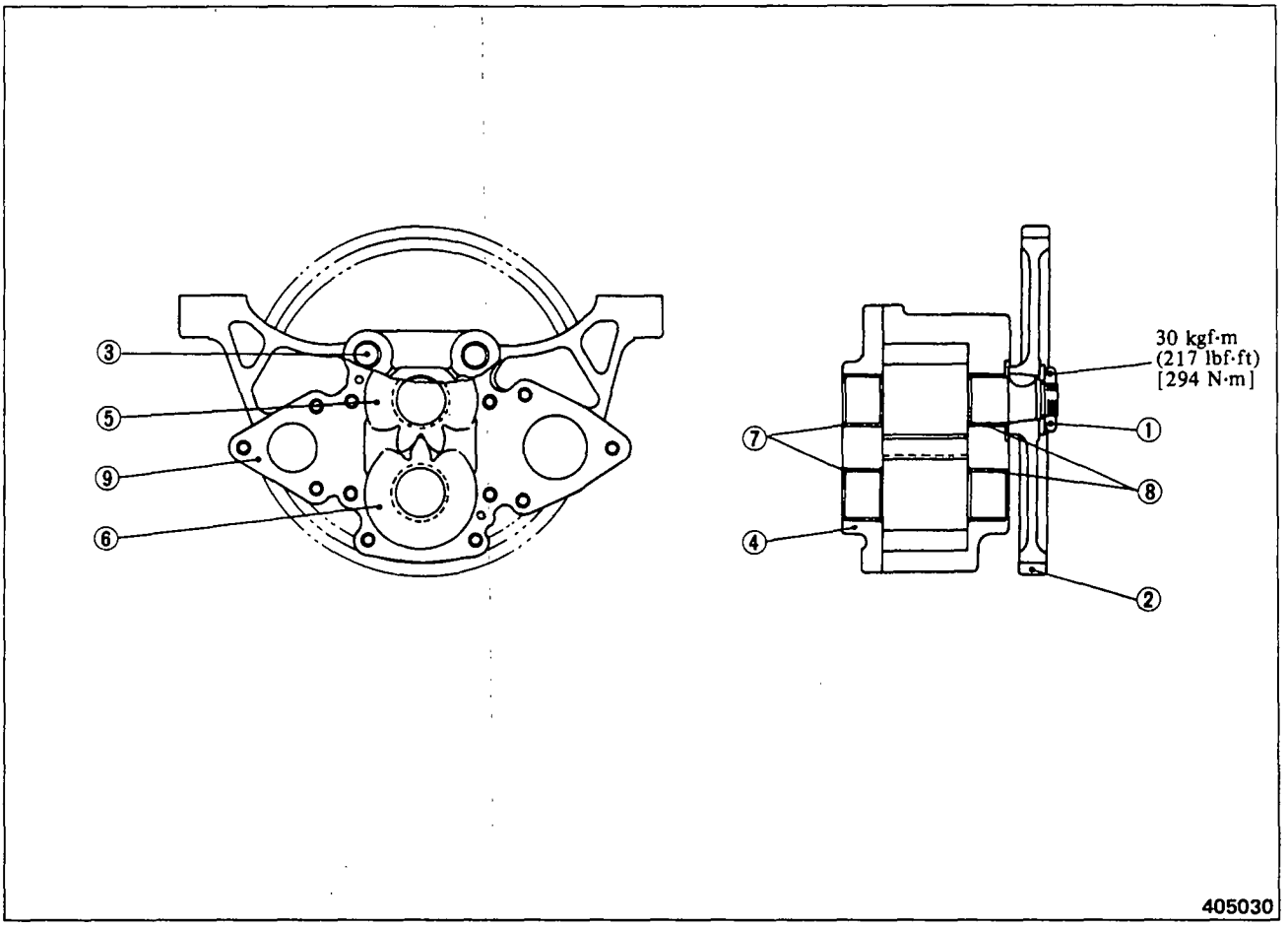
(a) Check the gear teeth, and replace the gears if defective.

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

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Shaft diameter	34 (1.34)	33.960 to 33.944 (1.33701 to 1.33638)	33.920 (1.33543)
Bushing inside diameter		34.000 to 34.025 (1.33858 to 1.33956)	34.055 (1.34075)

3.3 Reassembly



Reassembly sequence

⑨→⑧→⑤→⑥→③→②→①
④→⑦→③

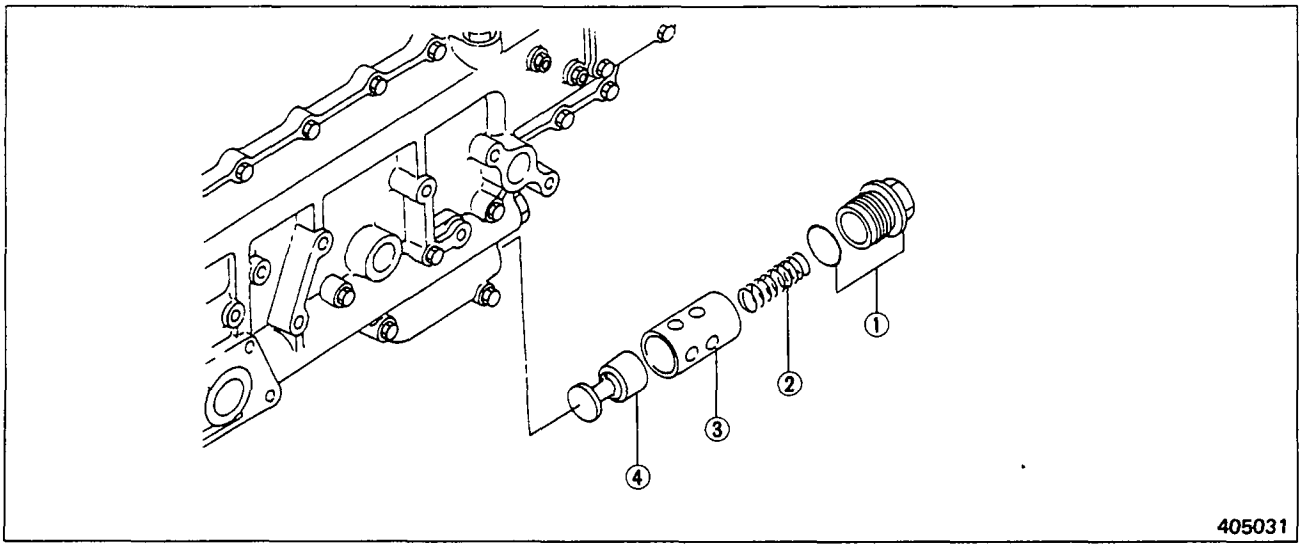
NOTE

(a) Apply engine oil to the parts during reassembly.

(b) When replacing the bushings only, finish them to 34H7 $^{+0.025}_{0}$ mm (1.34H7 $^{+0.00098}_{0}$ in.) after pressing them into the holes of pump case and cover.
The inside surface finish of the bushing is $\frac{1.6S}{\nabla\nabla\nabla}$.

4. RELIEF VALVE

4.1 Disassembly



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

4.2 Inspection

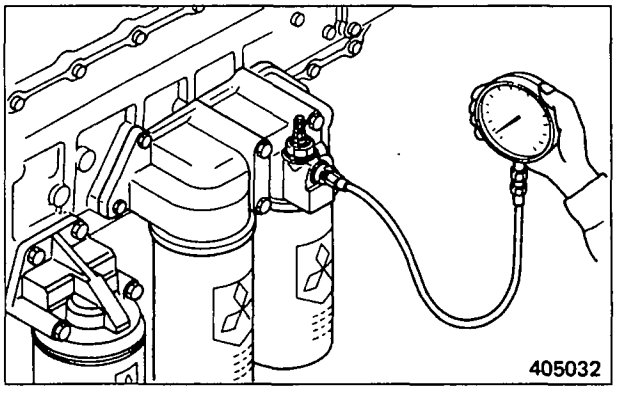
Testing relief valve pressure

(a) Remove the taper plug, and attach a pressure gauge.

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

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

(d) If the pressure is below the Assembly standard, make an adjustment by inserting washer into between the spring and plug. 2 mm (0.08 in.) thickness of washer will change the pressure by about 0.4 kgf/cm^2 (5.7 psi) [0.04 MPa].



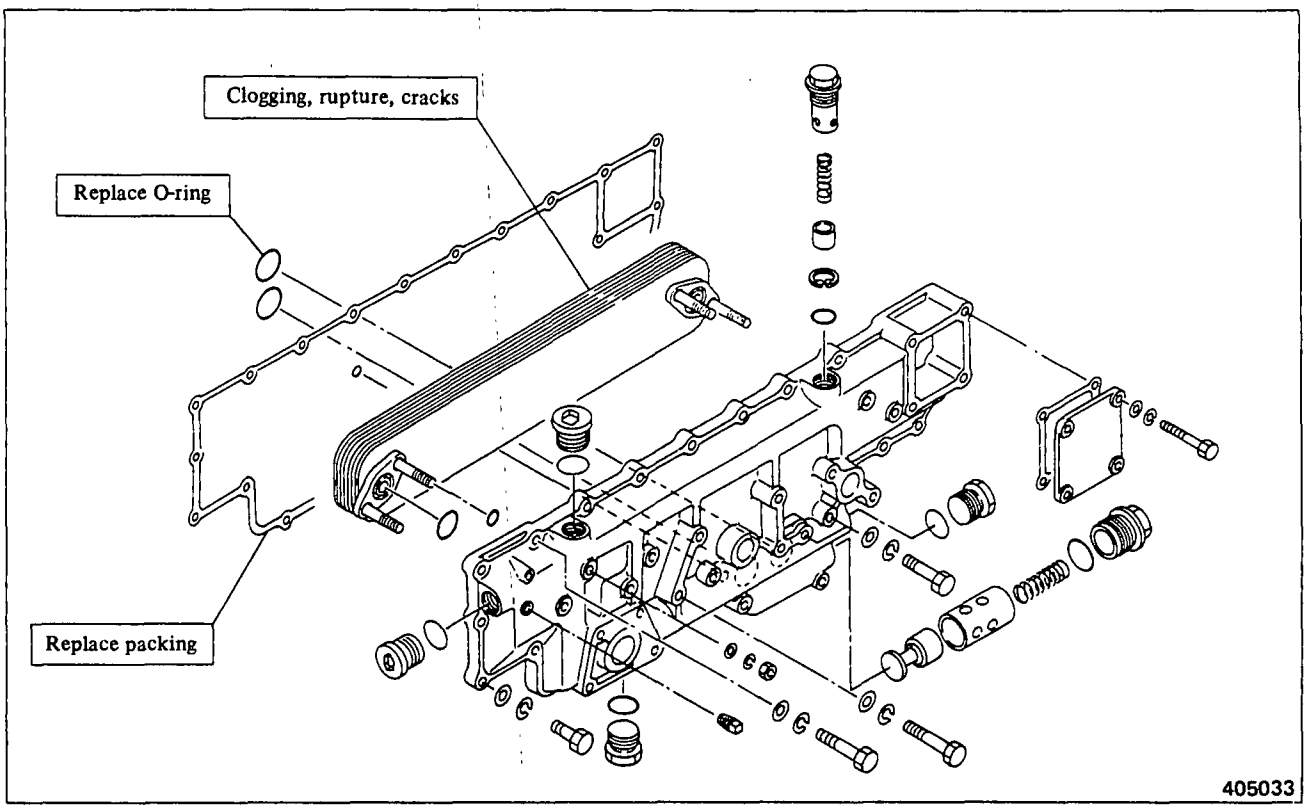
Relief pressure tap

Unit: kgf/cm^2(psi) [MPa]

Item	Assembly standard
Relief valve opening pressure	5 to 6 (71 to 85) [0.5 to 0.6]

5. OIL COOLER

Disassembly and inspection



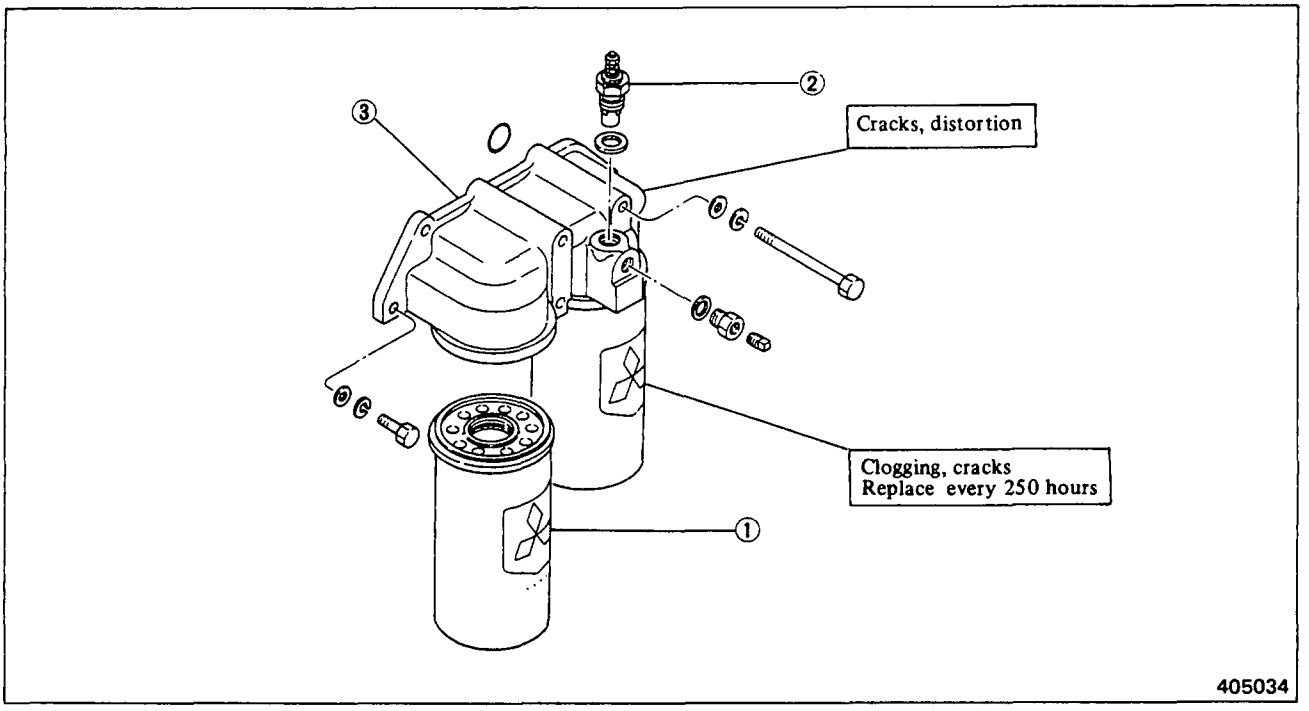
⚠ CAUTION

Replace packings and O-rings with new ones at reassembly.

6. FULL-FLOW OIL FILTER (PAPER-ELEMENT TYPE)

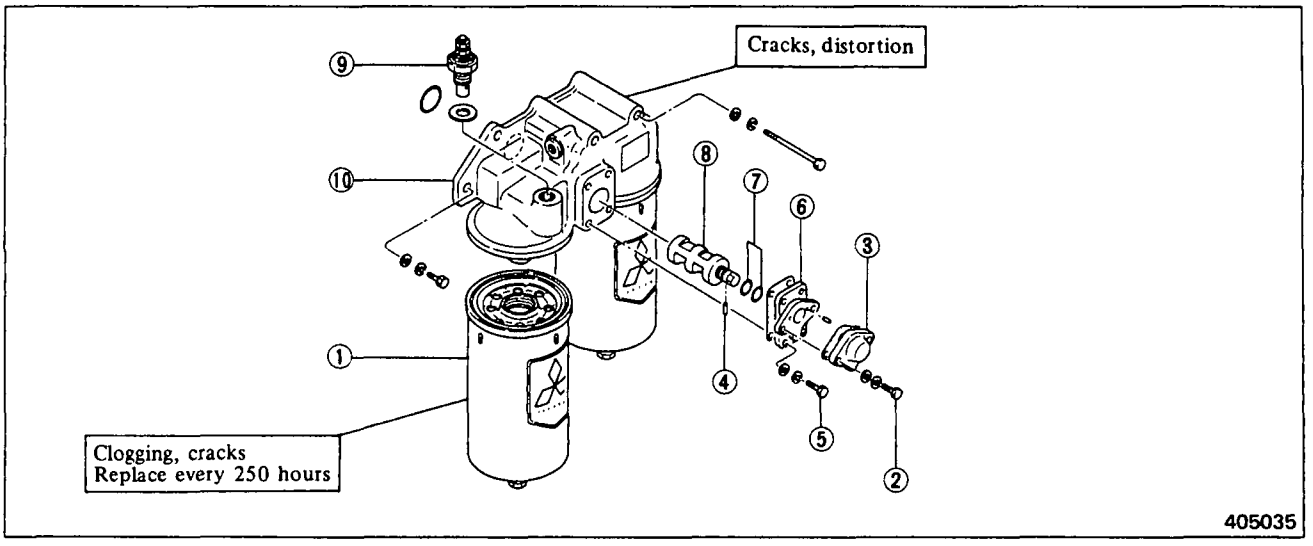
6.1 Disassembly

(Paper-element type)



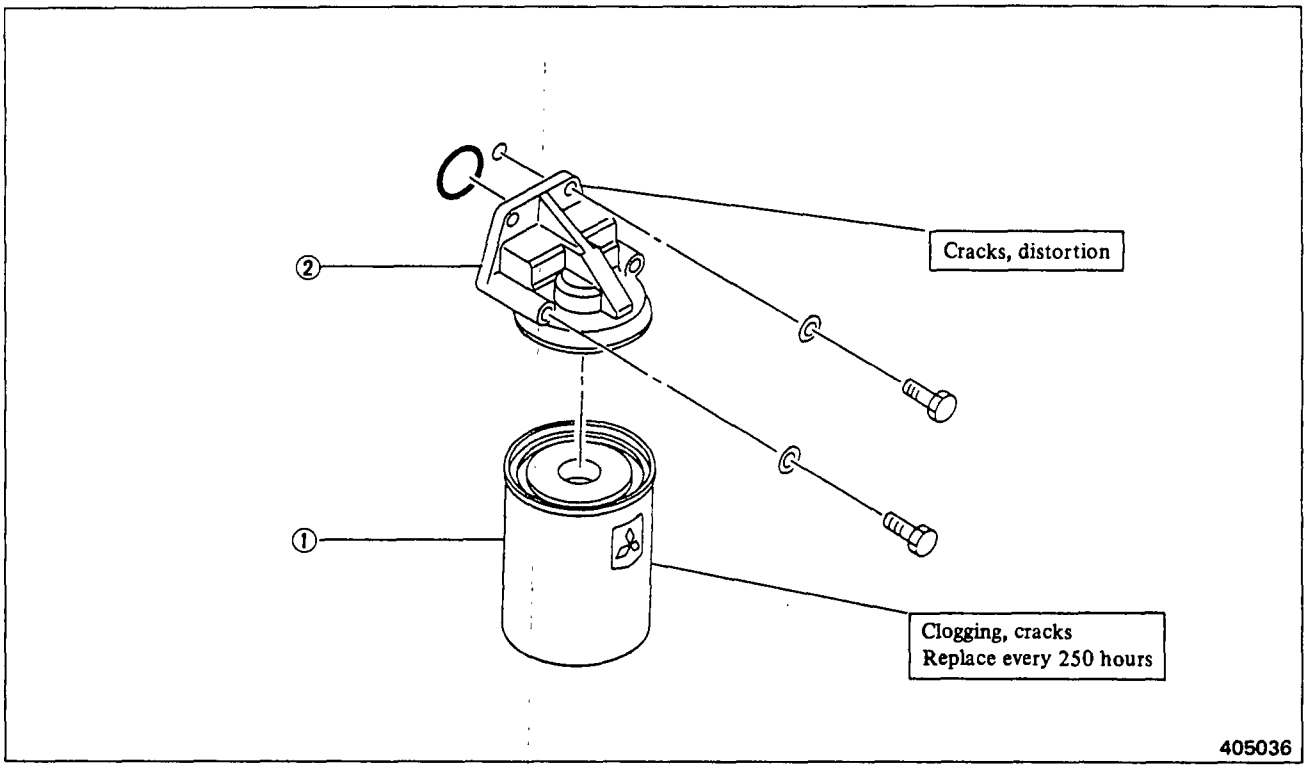
① Oil filter element (cartridge type)
② Oil filter alarm
③ Oil filter bracket

(Selector paper-element type)



① Cartridge (spin-on type)
② Bolt
③ Cover
④ Straight pin
⑤ Bolt
⑥ Cover, gasket
⑦ O-ring
⑧ Cock
⑨ Oil filter alarm
⑩ Oil filter bracket

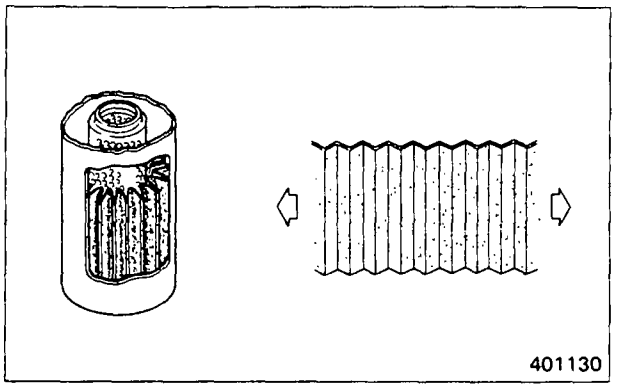
(Bypass oil filter)



① Oil filter element
② Oil filter bracket

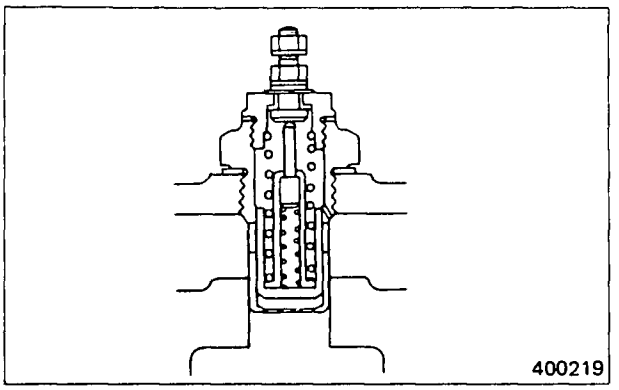
6.2 Inspection

(1) When replacing the paper element, investigate by sampling about 500 cm^3 (30.5 in^3.) of the oil. If any metallic particles or other foreign matter is found, unfold the pleats of the removed element and check the element for colors and shapes of metallic particles trapped in the pleats to locate the cause.



(2) Inspecting oil filter alarm

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



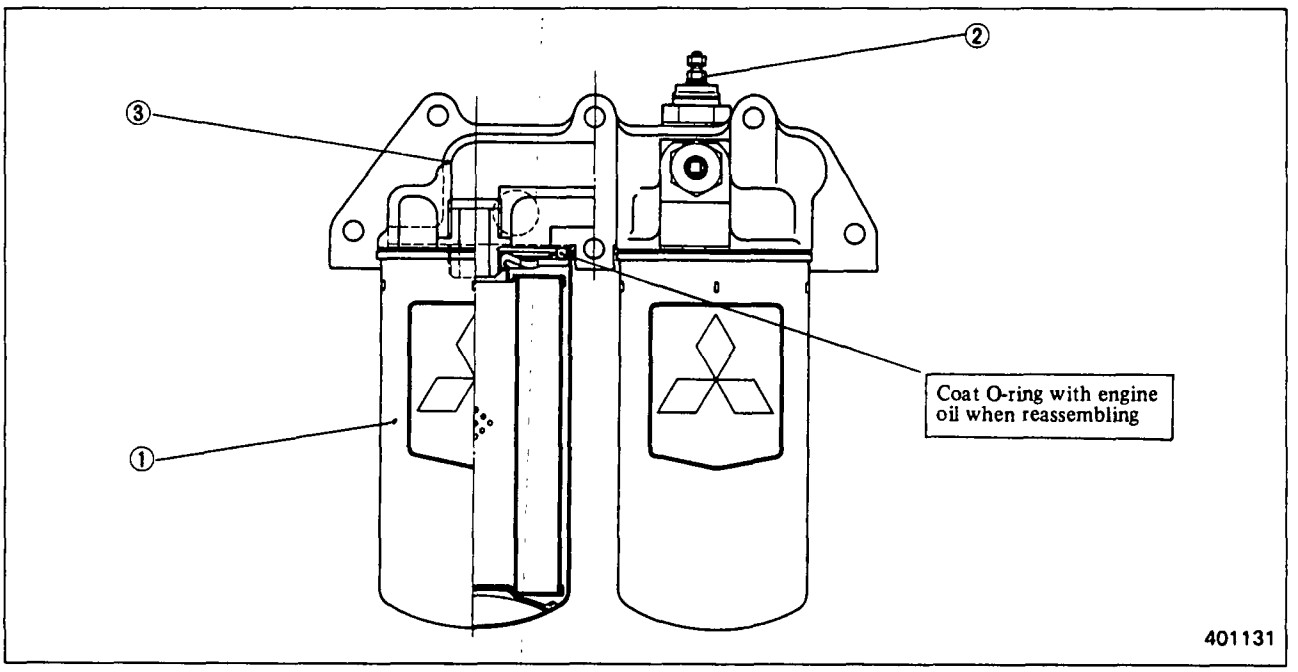
(b) If the valve opening pressure is out of the Assembly standard, adjust it by inserting shims. 1 mm (0.04 in.) thickness of shim corresponds to a change in pressure of 0.07 kgf/cm^2 (1.00 psi) [6.9 kPa].

Unit: kgf/cm^2 (psi) [MPa]

Item	Assembly standard
Pressure difference across oil filter alarm that makes its valve open	2.5 ± 0.2 (35.6 ± 2.84) [0.25 ± 0.02]
Pressure difference across oil filter alarm that makes its contacts close	1.5 (21.3) [0.15]

6.3 Reassembly

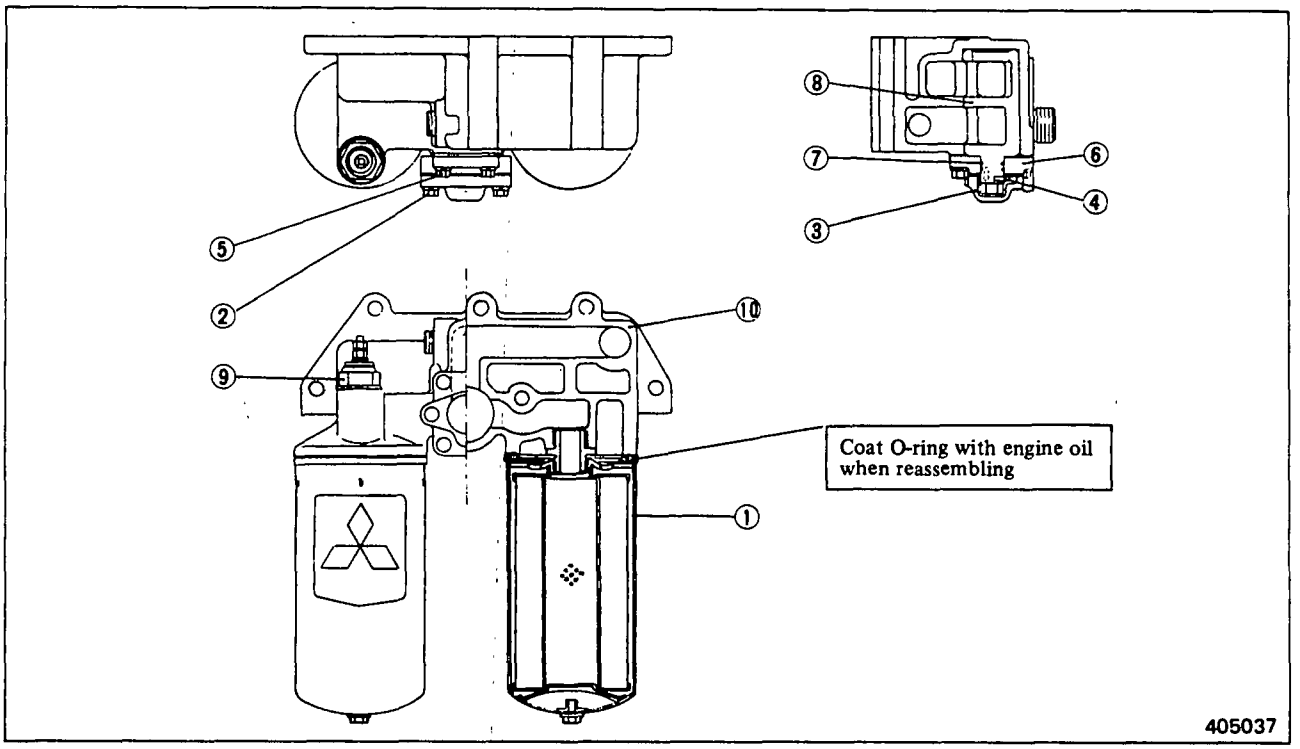
(Paper-element type)



Reassembly sequence

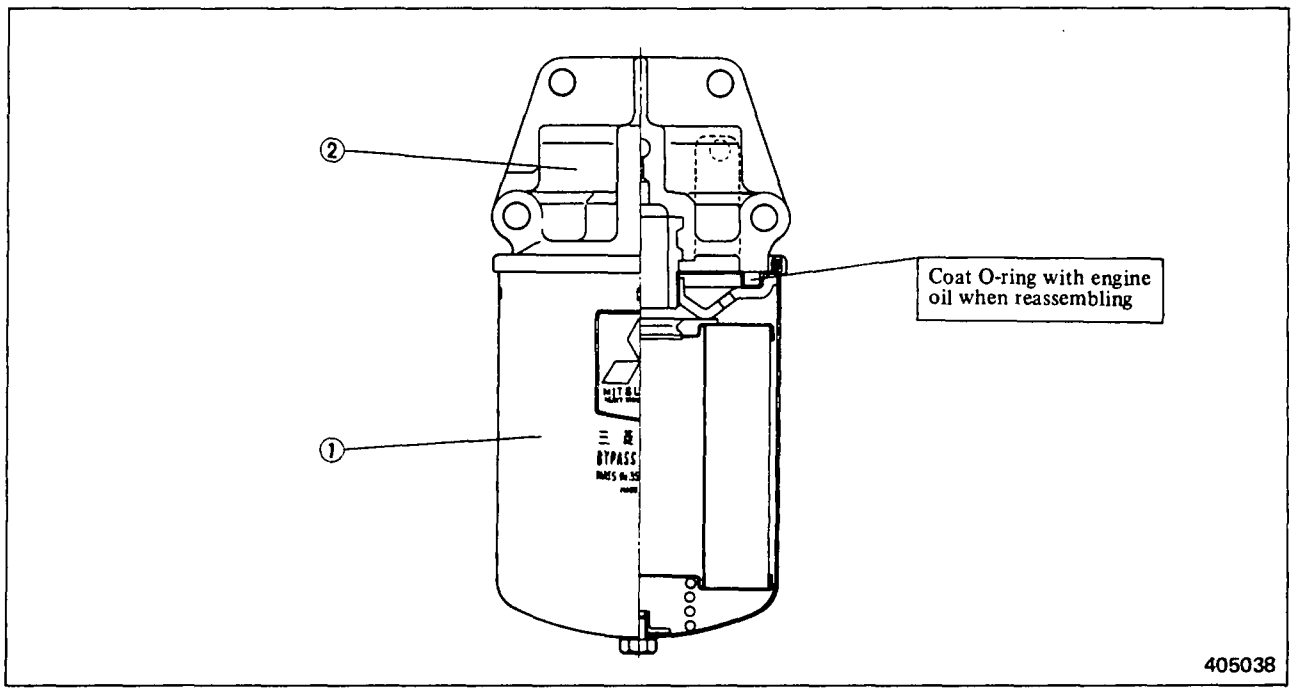
③→②→①

(Selector paper-element type)



Reassembly sequence ⑧→⑦→⑥→④→⑩→⑤→③→②→①→⑨

(Bypass oil filter)

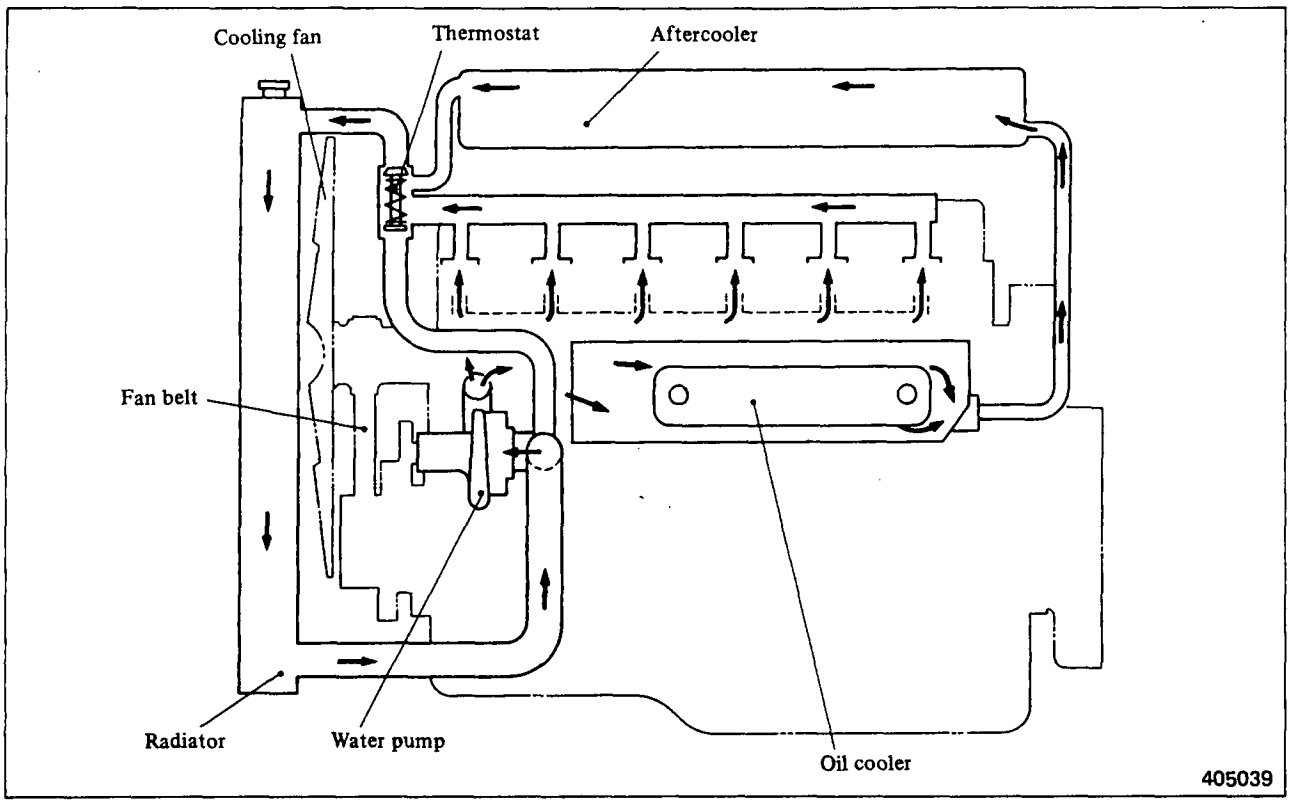


Reassembly sequence

②→①

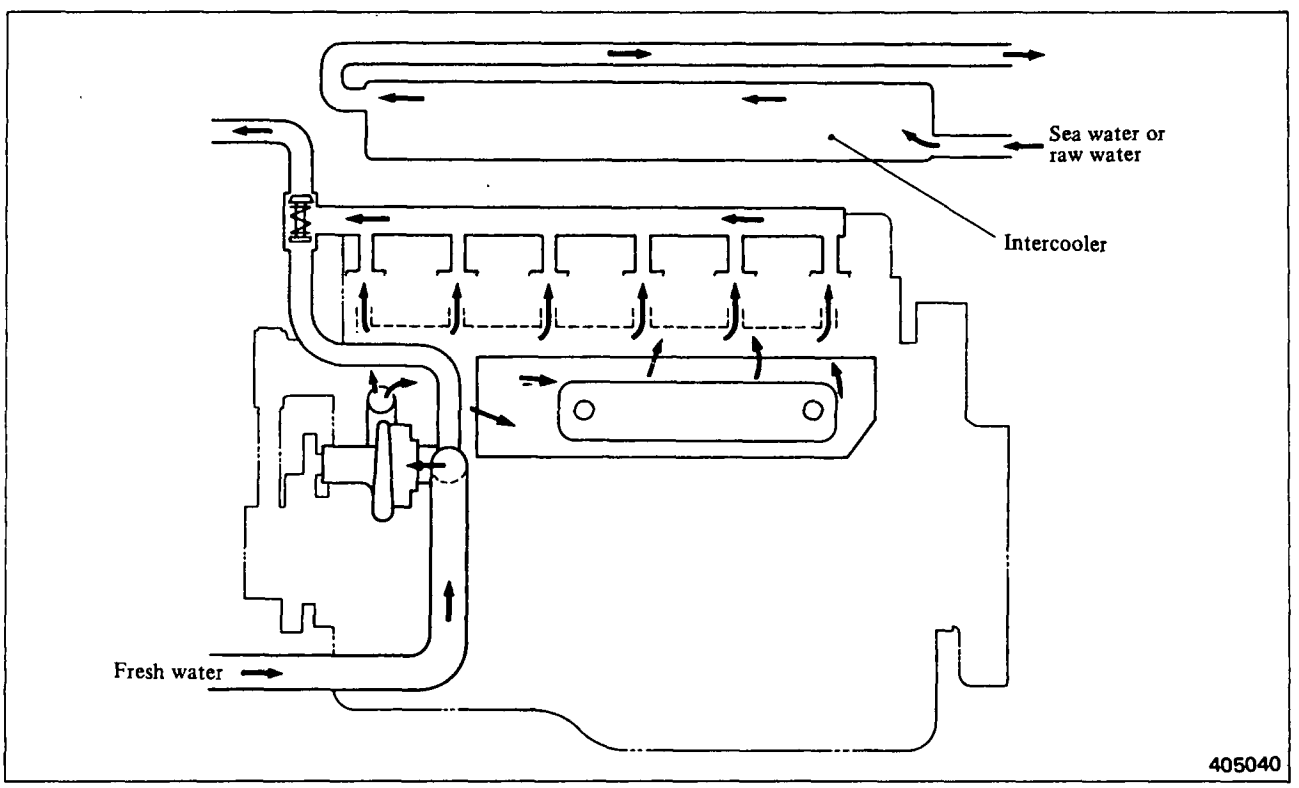
COOLING SYSTEM

1. COOLING SYSTEM WITH RADIATOR

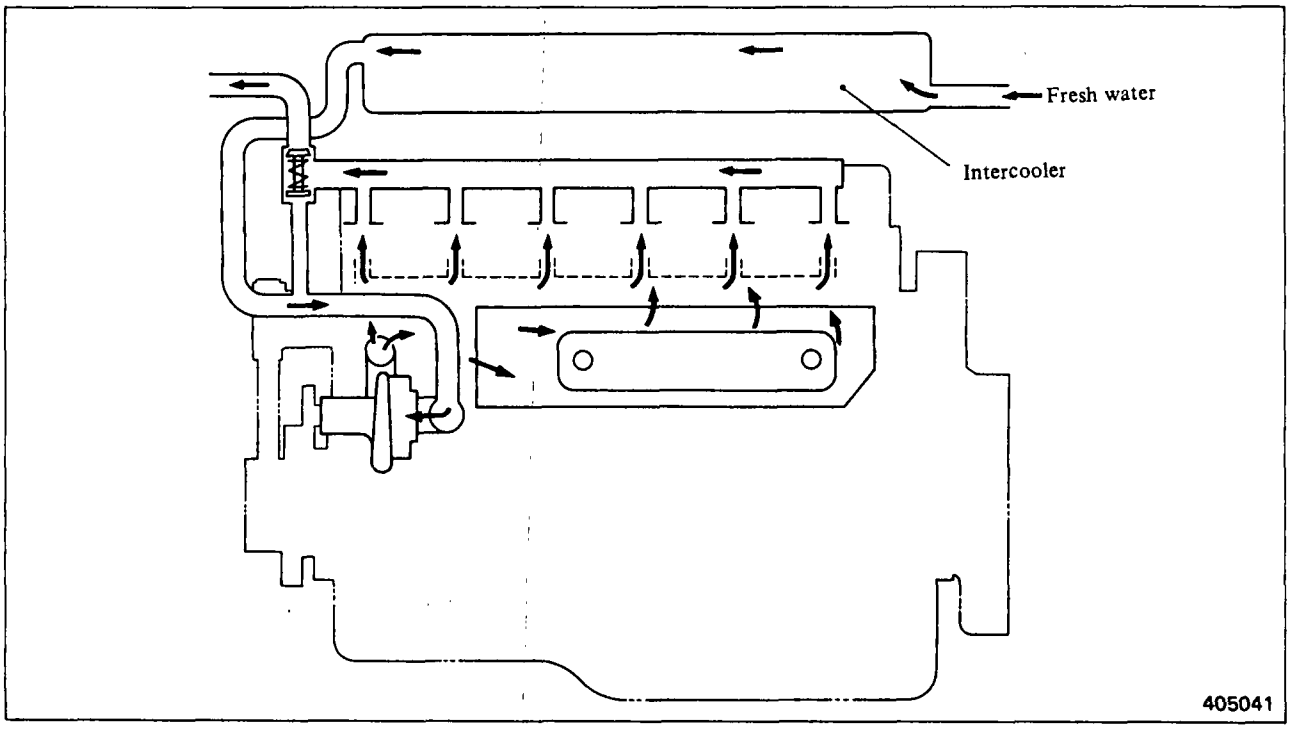


2. COOLING SYSTEM WITH A REMOTE WATER SUPPLY

(1) Parallel type using sea water or raw water and fresh water (PTK)

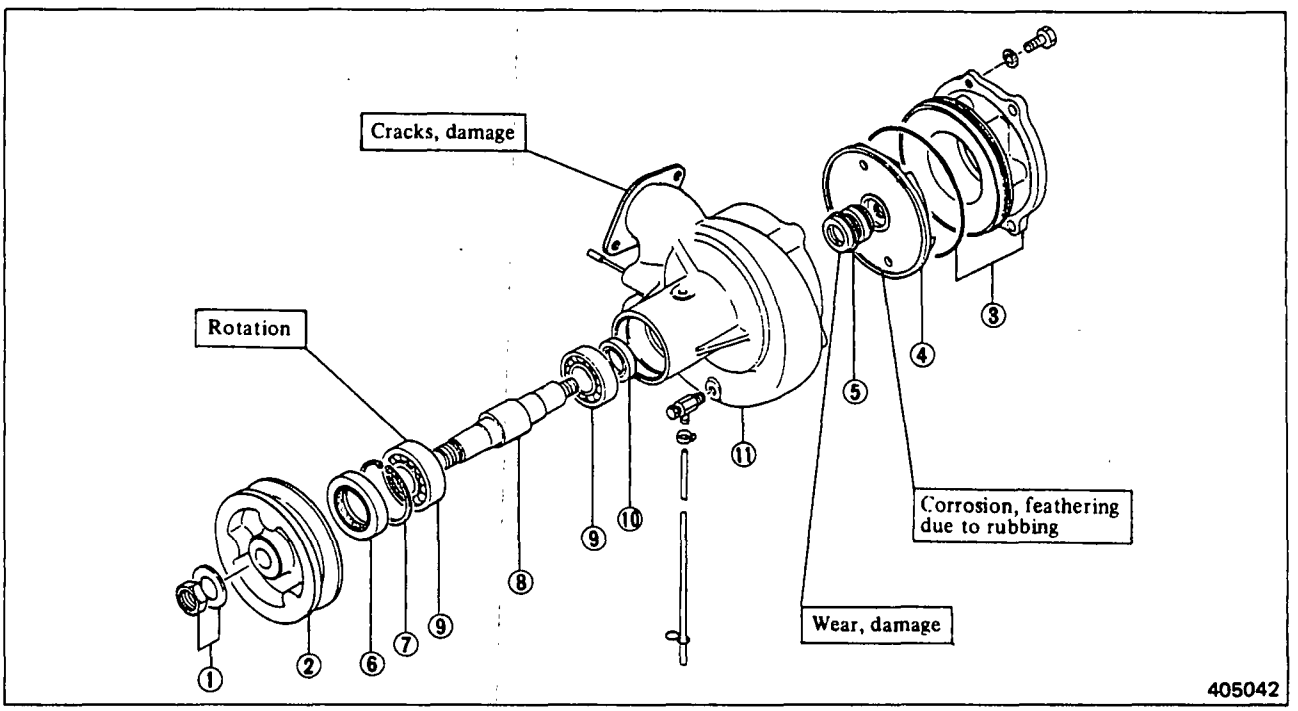


(2) Series type using fresh water (PTK)



3. WATER PUMP

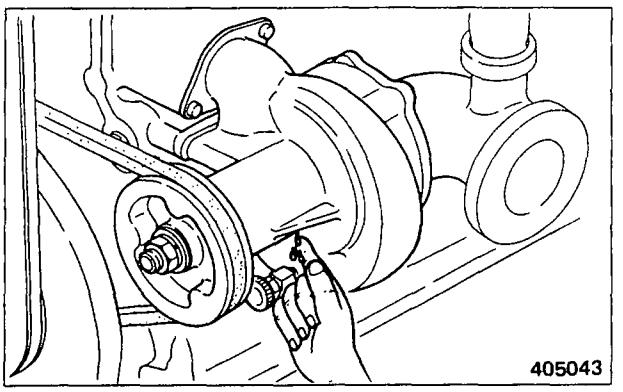
3.1 Disassembly



① Nut, washer
② Water pump pulley
③ Water pump cover, O-ring
④ Impeller
⑤ Unit seal
⑥ Oil seal
⑦ Snap ring
⑧ Water pump shaft
⑨ Ball bearing
⑩ Oil seal
⑪ Water pump case

(1) Inspecting water pump on engine

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



(2) Removing water pump shaft

Remove the snap ring from the front bearing. Using a press or soft hammer, drive out the pump shaft complete with the bearing toward the gear side.

⚠ CAUTION

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

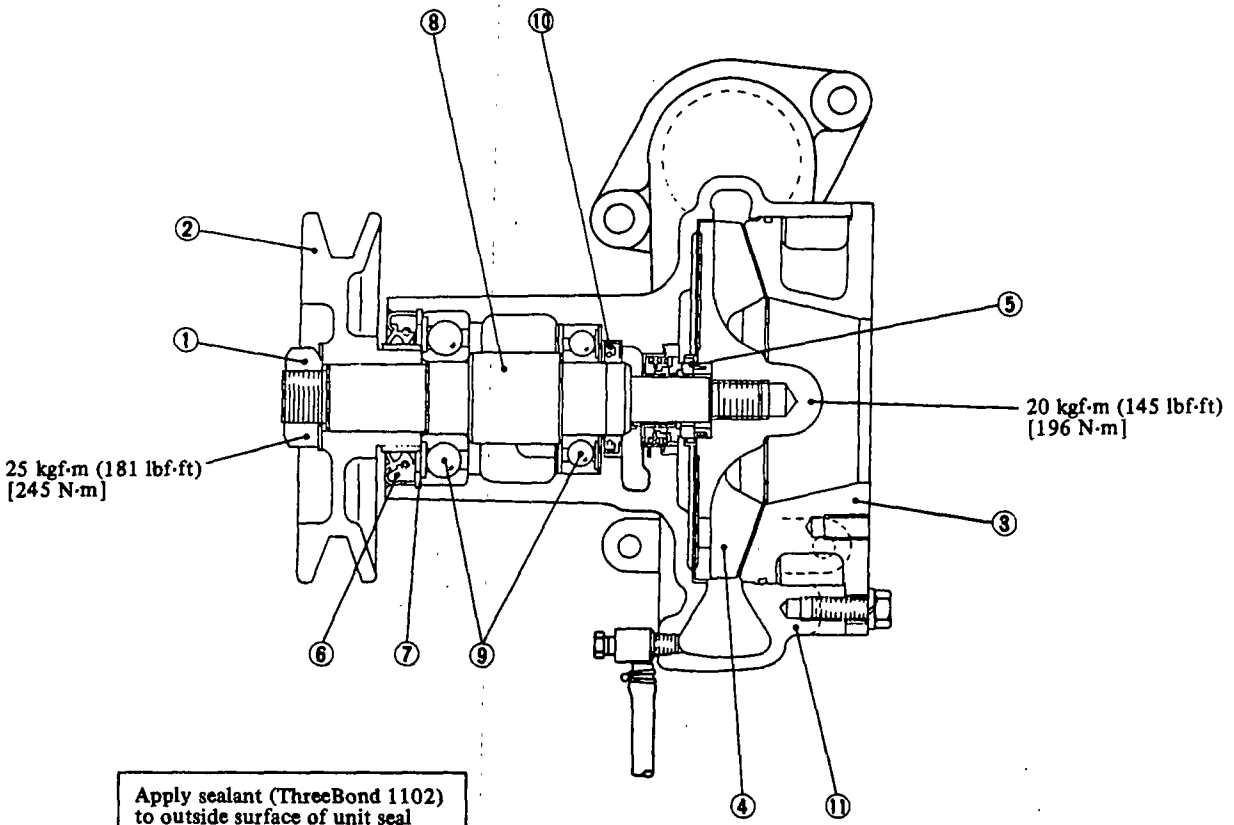
3.2 Inspection

Using a cylinder gauge, measure the inside diameter of the pump case bore to which the bearing outer race is fitted. If the case is badly worn or damaged, replace the case or the bearing.

Unit: mm (in.)

Item		Nominal value	Assembly standard
Inside diameter of bore in pump case		62 (2.44)	61.988 to 61.982 (2.44047 to 2.44023)
		72 (2.83)	71.988 to 71.982 (2.83417 to 2.83393)
Bearings	Outside diameter	62 (2.44)	62.004 to 61.983 (2.44110 to 2.44027)
		72 (2.83)	72.004 to 71.983 (2.83480 to 2.83397)
	Inside diameter	30 (1.18)	29.987 to 30.003 (1.18059 to 1.18122)
Diameter of bearing surface of pump shaft		30 (1.18)	30.011 to 30.002 (1.18153 to 1.18118)

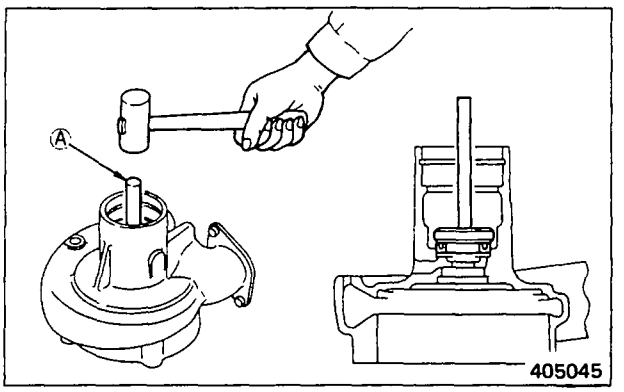
3.3 Reassembly



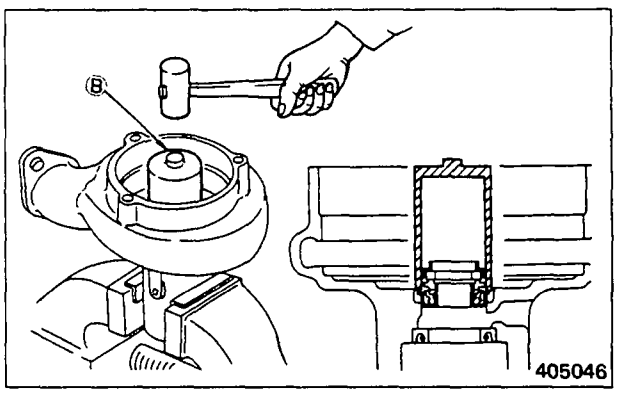
Reassembly sequence

⑪→⑩→⑤→⑨→⑧→⑦→④→③→⑥→②→①

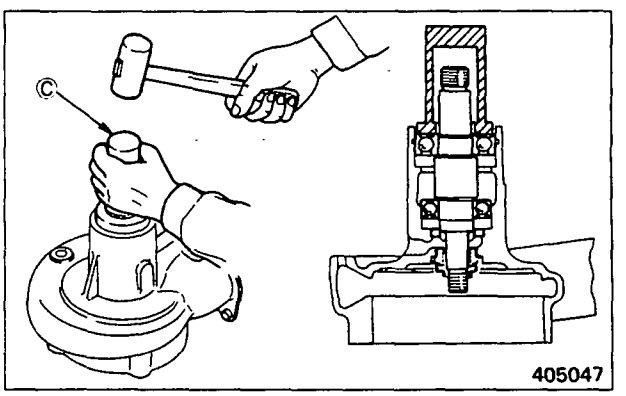
(1) Install the oil seal in position in the pump case with oil seal installer (A) (32591-03200).



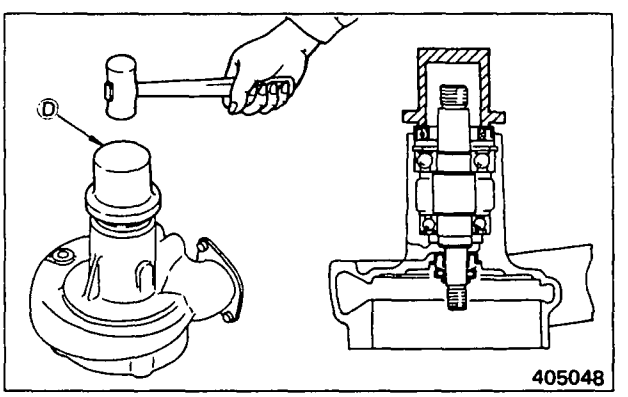
(2) Install the unit seal in position in the pump case with unit seal installer (B) (32591-03300). Be sure to replace the unit seal if it has been removed from the pump case during disassembly.



(3) Install the pump shaft in position complete with ball bearing into the pump case with installer (C) (32591-03600).

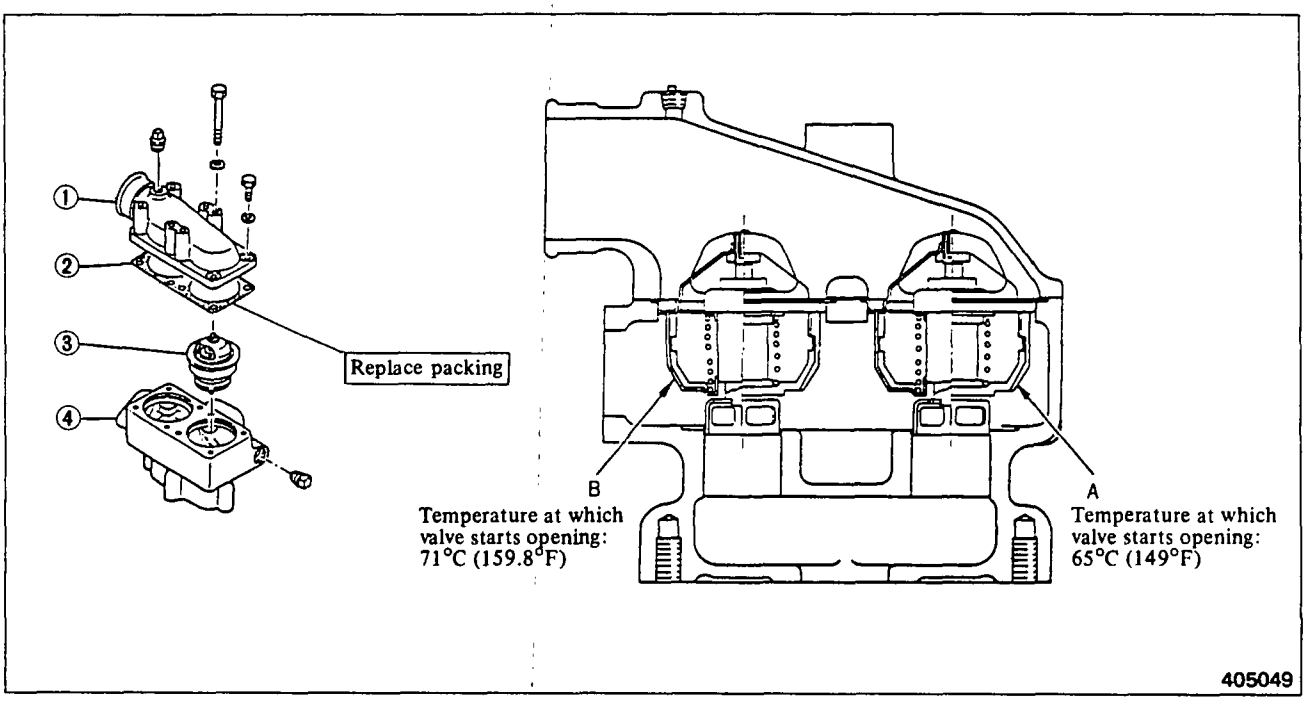


(4) Install the outer oil seal in position in the pump case with oil seal installer (D) (32591-03100).



4. THERMOSTATS

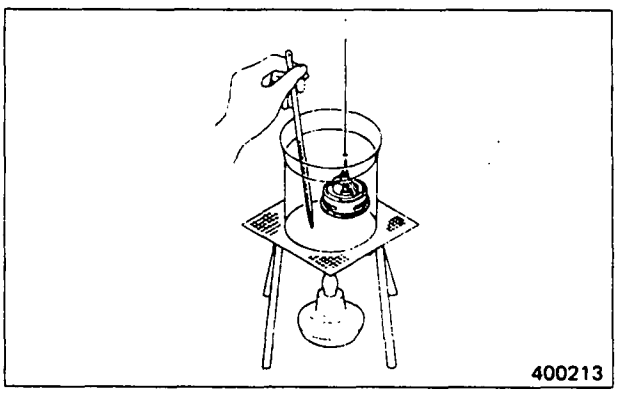
4.1 Disassembly



① Case cover
② Packing
③ Thermostat
④ Thermostat case

4.2 Inspection

Put each thermostat in a glass jar filled with water, and test it for thermostatic action by heating the jar to raise the water temperature. In the test, measure the temperature at which the valve starts opening and that at which the valve lift is more than 10 mm (0.4 in.). If these measurements are out of the Assembly standard, replace the thermostat.



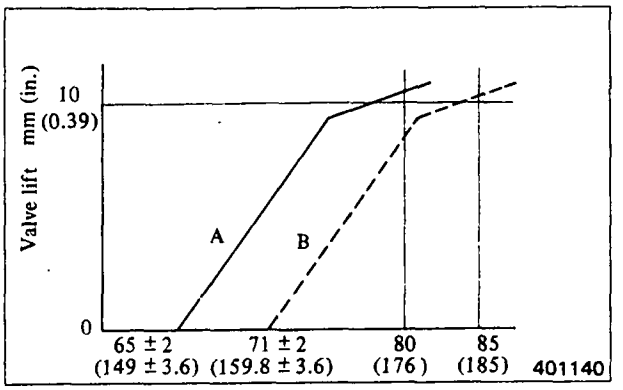
Unit: mm (in.)

Item	Assembly standard	
	A	B
Temperature at which valve starts opening	65 ± 2°C (149 ± 3.6°F)	71 ± 2°C (159.8 ± 3.6°F)
Temperature at which valve opens fully	80 ± 2°C (176 ± 3.6°F)	85 ± 2°C (185 ± 3.6°F)
Valve lift	10 (0.39), minimum	

NOTE

(a) Stir the water in the jar with a stick to maintain its temperature uniform during test.

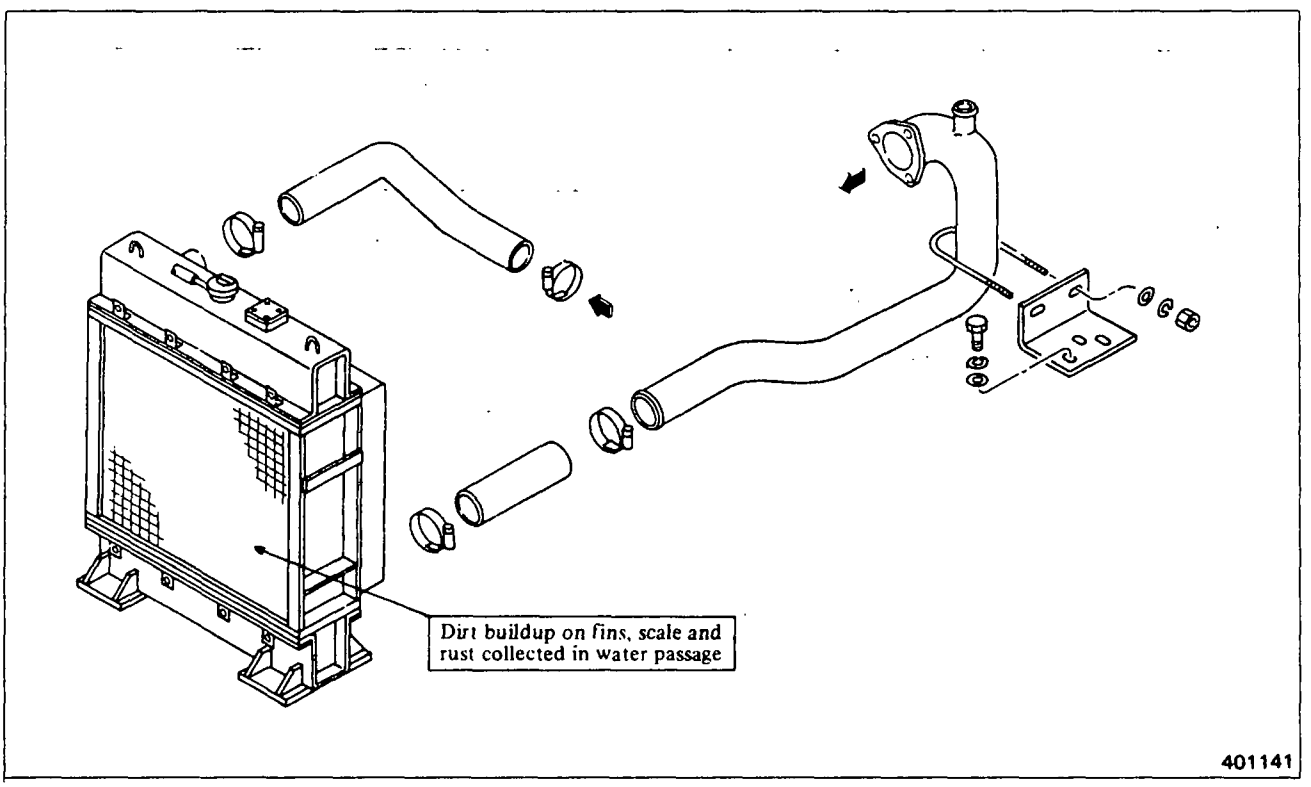
(b) Be sure to place each thermostat in correct position by ascertaining the valve opening temperature stamped on its mounting flange at reassembly.



Thermostat performance curve

5. RADIATOR

Inspection



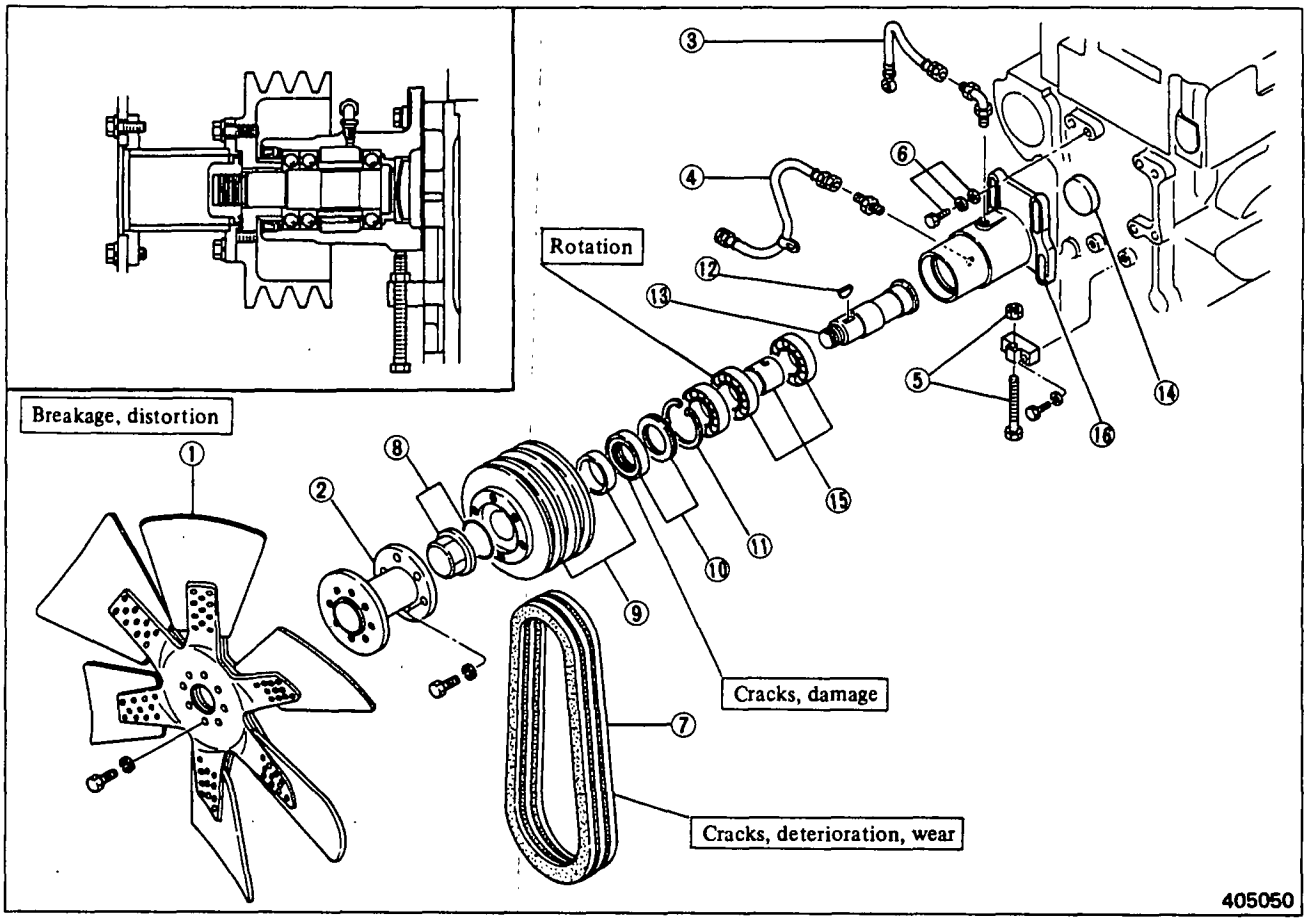
(1) Check the radiator fins for trash buildup. Also check the core interior for scale buildup and rusting. Clean the radiator as recommended.

(2) Check the rubber hoses and clamps, and replace defective parts if any.

6. FAN DRIVES

Disassembly and inspection

〈Pressure-lubricated type〉



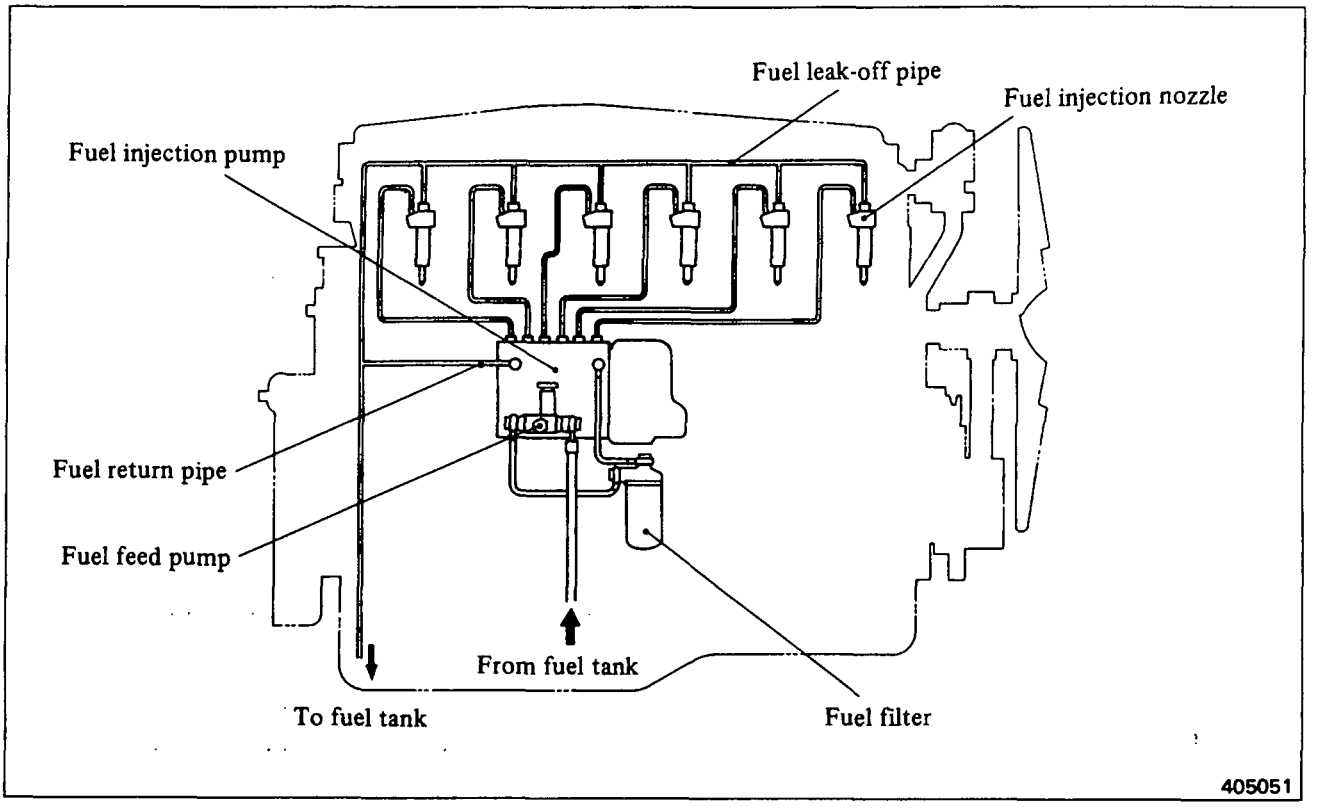
① Fan
② Spacer
③ Flexible pipe
④ Flexible pipe
⑤ Adjusting bolt, nut
⑥ Bolt, spring washer, plain washer
⑦ Belt
⑧ Cap nut, O-ring
⑨ Pulley, sleeve
⑩ Oil seal
⑪ Snap ring
⑫ Key
⑬ Shaft
⑭ Sealing cap
⑮ Ball bearing, spacer, bearings
⑯ Bracket

⚠ CAUTION

If any one of the fan blades is broken, the fan vibrates excessively, making the opposite blade fragile. With this kept in mind, carefully check each blade for cracks and distortion.

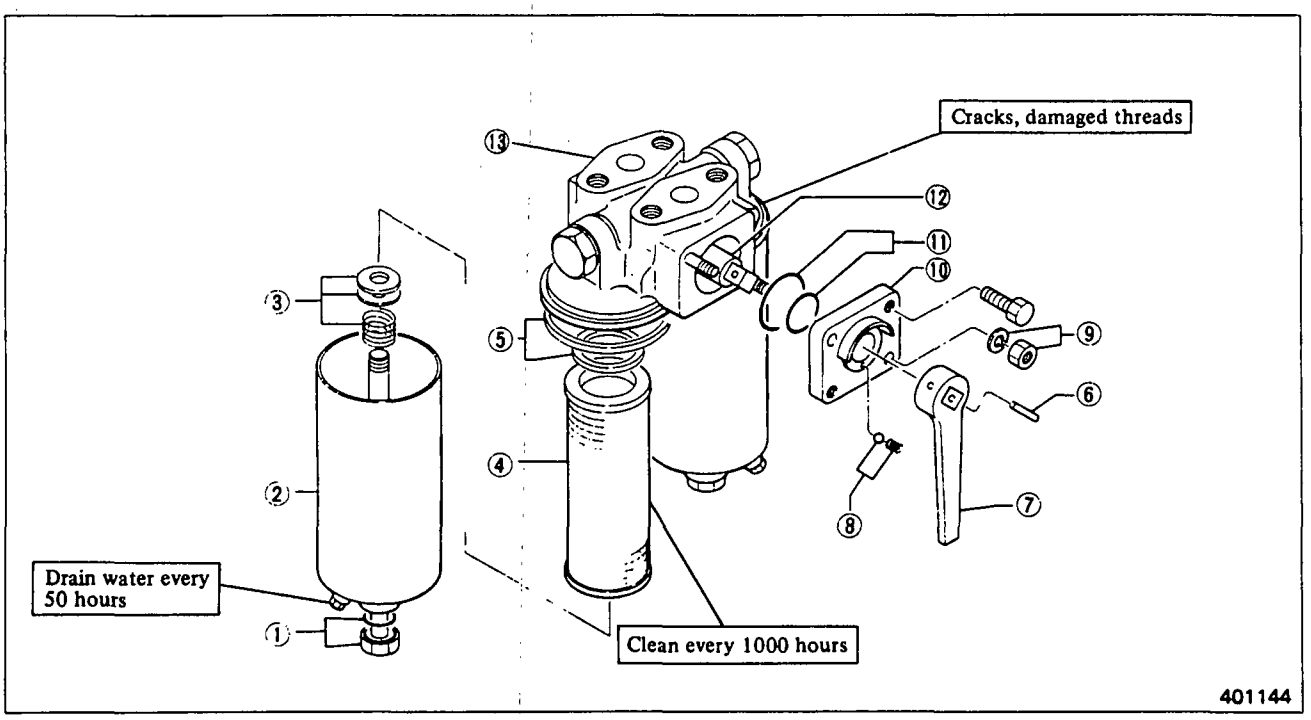
FUEL SYSTEM

1. DESCRIPTION



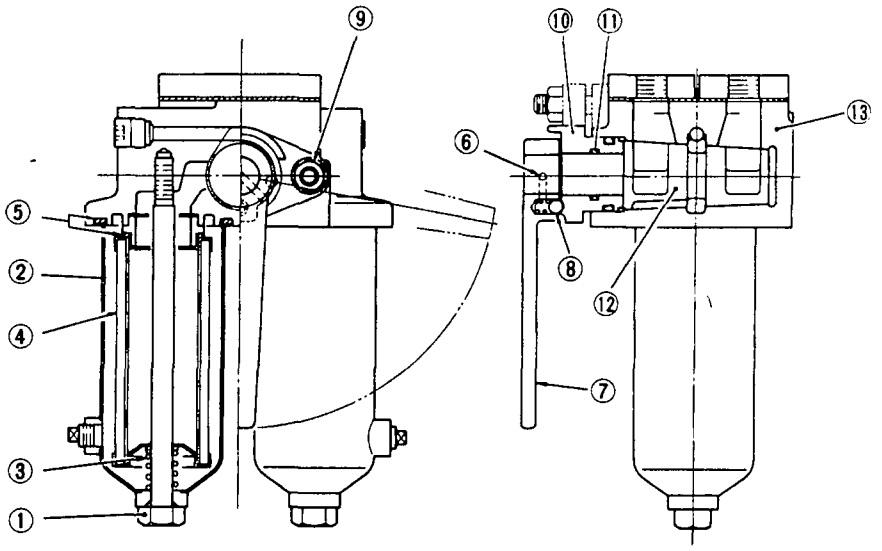
2. FUEL FILTER (WIRE-ELEMENT TYPE)

2.1 Disassembly and inspection



① Center bolt, O-ring
② Case
③ Spring, plate, packing
④ Element
⑤ Packing
⑥ Spring pin
⑦ Handle
⑧ Spring, steel ball
⑨ Nut, spring washer
⑩ Flange
⑪ O-ring
⑫ Cock
⑬ Filter case

2.2 Reassembly



Reassembly sequence

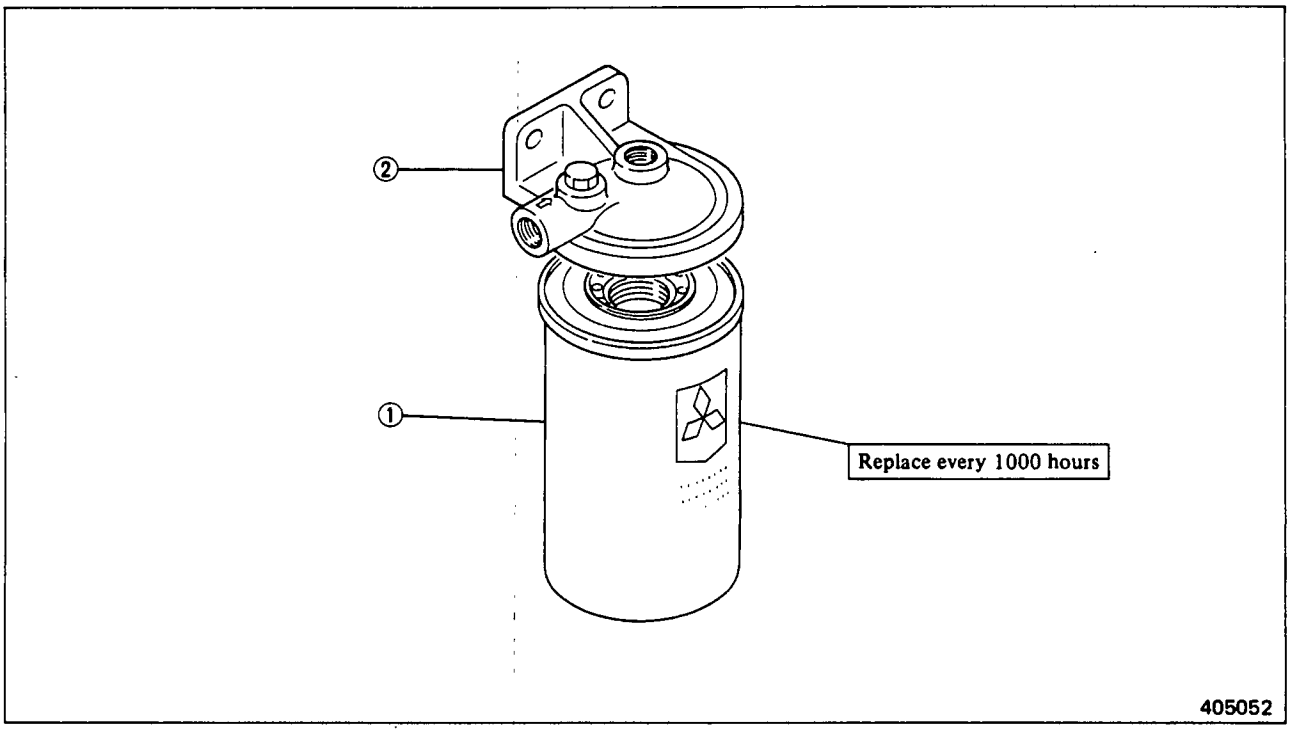
⑫→⑪→⑩→⑬→⑨→⑧→⑦→⑥→⑤→④→③→②→①

⚠ CAUTION

After installing the fuel filter on the engine, start the engine, and make sure that the filter is free from fuel leakage.

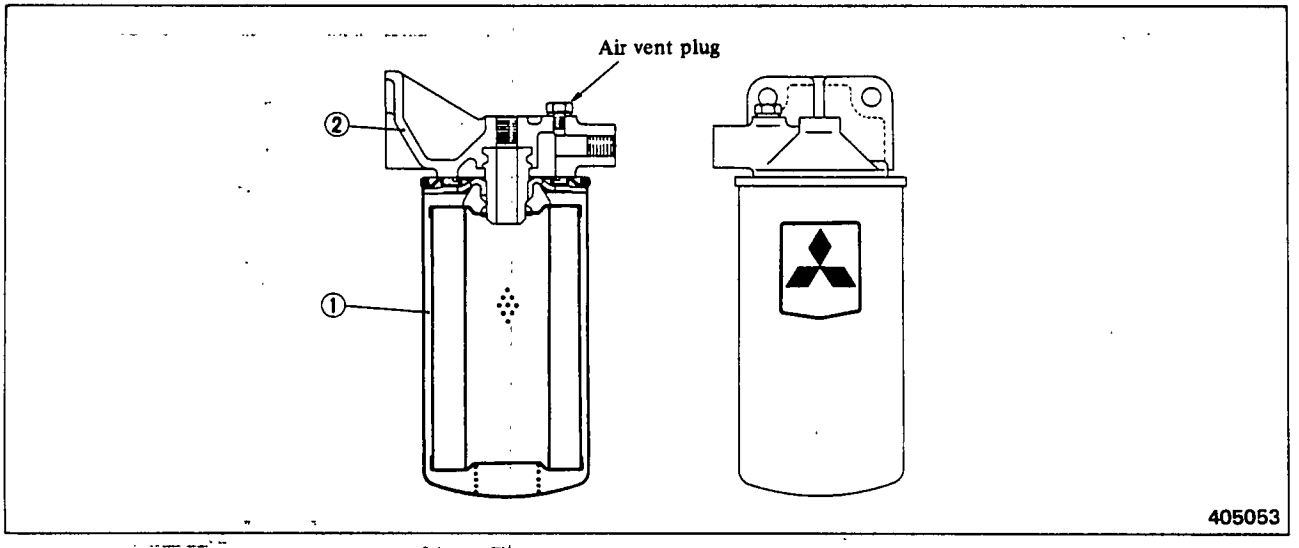
3. FUEL FILTER (PAPER-ELEMENT TYPE)

3.1 Disassembly and inspection



① Cartridge filter
② Filter bracket

3.2 Reassembly

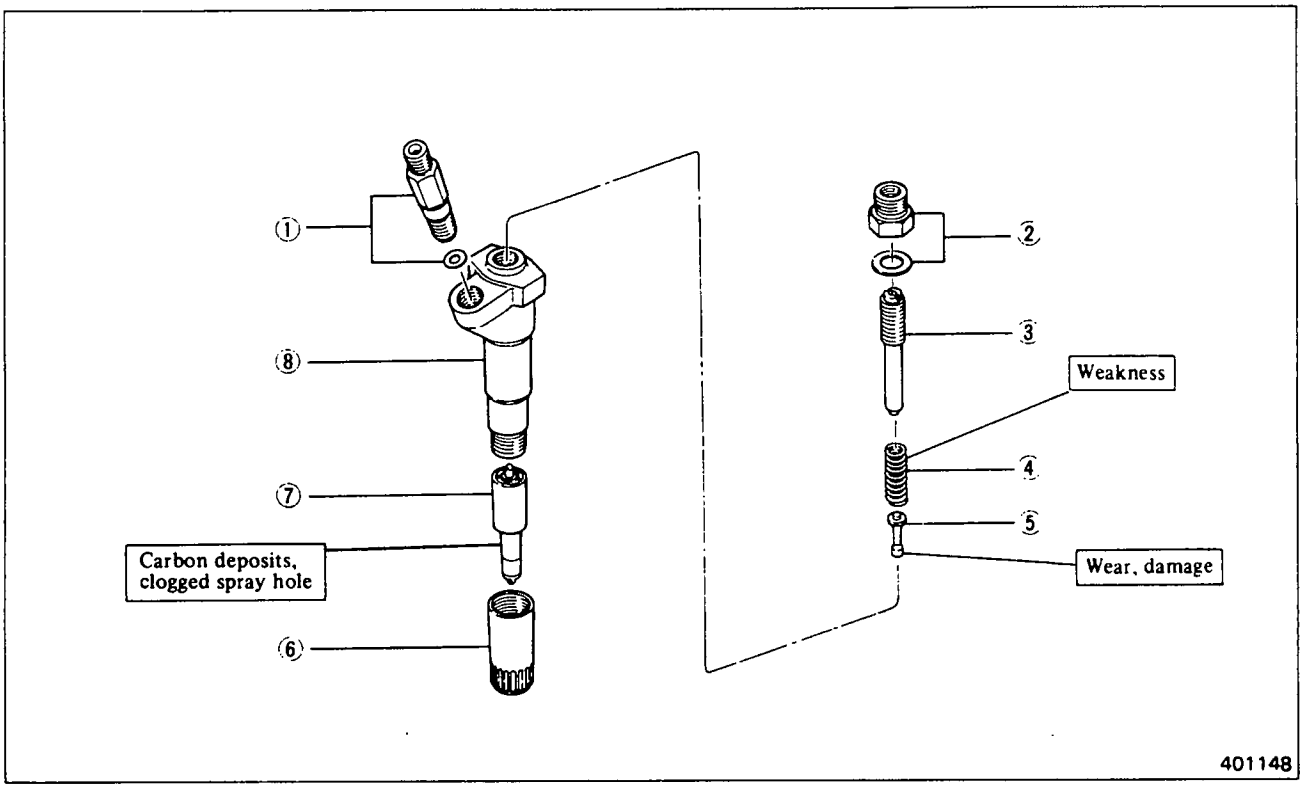


Reassembly sequence

②→①

4. FUEL INJECTION NOZZLES

4.1 Disassembly



① Inlet connector, gasket
② Cap nut, gasket
③ Adjusting screw
④ Nozzle spring
⑤ Pushrod
⑥ Retaining nut
⑦ Nozzle tip
⑧ Nozzle holder

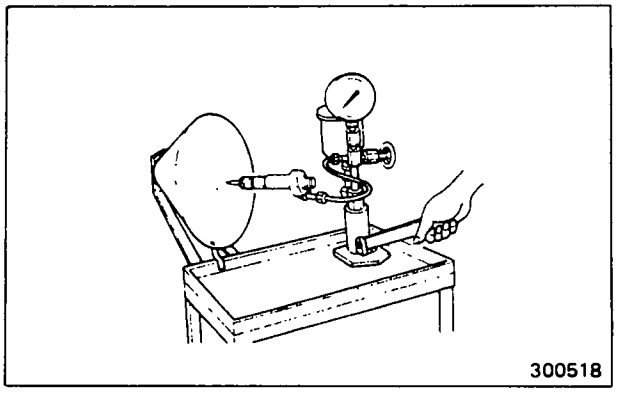
4.2 Inspection and adjustment

(1) Injection pressure

(a) Install the nozzle on the tester. Operate the handle of the tester at a rate of about 1 stroke per second to observe the pressure at which fuel injection begins. If the pressure is out of the assembly standard, adjust it.

Unit: kgf/cm² (psi) [MPa]

Item	Assembly standard	Adjusting limit
Injection pressure (valve opening pressure)	220 (3128) [21.6]	225 to 230 (3200 to 3271) [22.1 to 22.6]



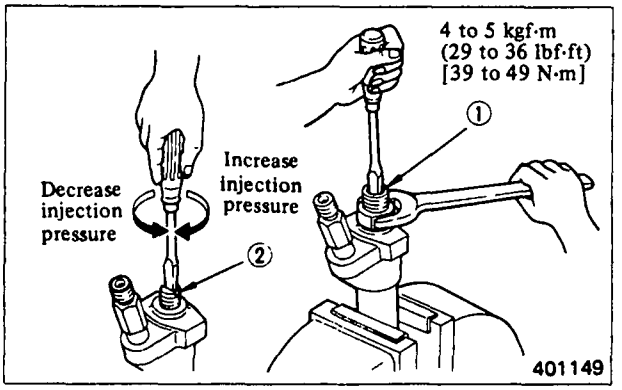
⚠ WARNING

Never attempt to touch the spray hole of injection nozzle during injection pressure testing.

(b) To adjust the injection pressure, remove cap nut (1) from the nozzle holder, and turn adjusting screw (2) in either direction with a screwdriver.

(c) After completing the adjustment, tighten the cap nut to the specified torque.

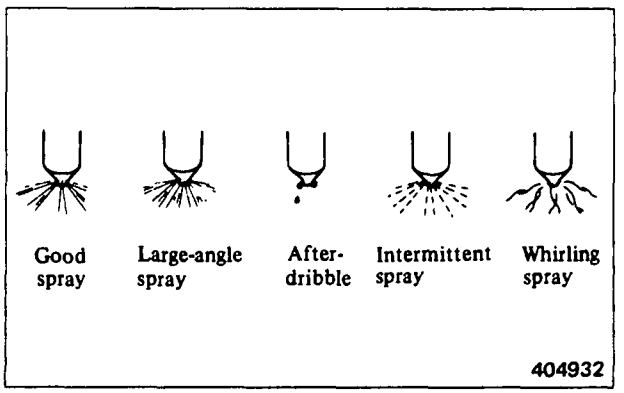
(d) Recheck the injection pressure, making sure that it is correct.



(2) Spray pattern

(a) At the time of testing the injection pressure, inspect each nozzle for clogged spray hole and fuel leaks from the hole. Also examine spray pattern. If the nozzle is faulty, wash or replace the nozzle tip.

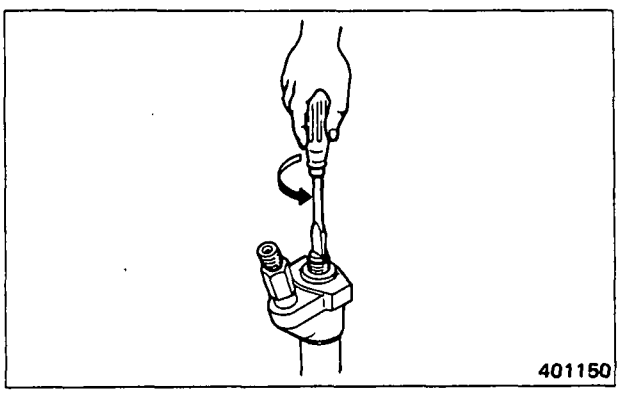
(b) When tested on the nozzle tester, the nozzle should spray fuel from its eight orifices at the same time in a good straight cone of 158 degrees, consisting of finely atomized fuel particles without any large droplets, and should terminate with no dribble at the tip.



Possible spray patterns

(3) Washing or replacing nozzle tip

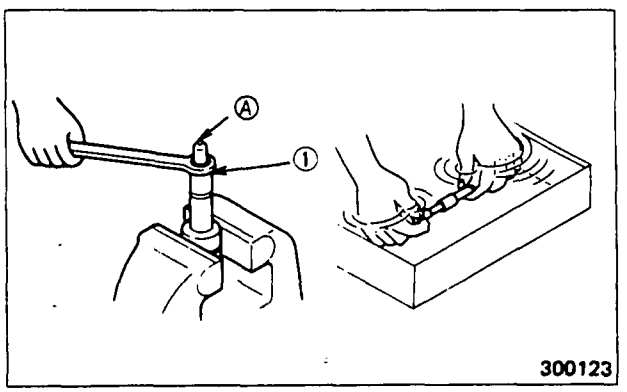
(a) The nozzle tip is spring loaded. Remove the cap nut and, with a screwdriver, loosen the adjusting screw to such an extent that it can be loosened by the hand.



(b) Loosen retaining nut (1), remove the nozzle tip and wash the needle valve and body.

⚠ CAUTION

When pulling out the nozzle tip, be careful not to damage its tip (A).



(c) Wash the nozzle tip in clean gasoline. After washing, assemble the needle valve and body in clean diesel fuel.

NOTE

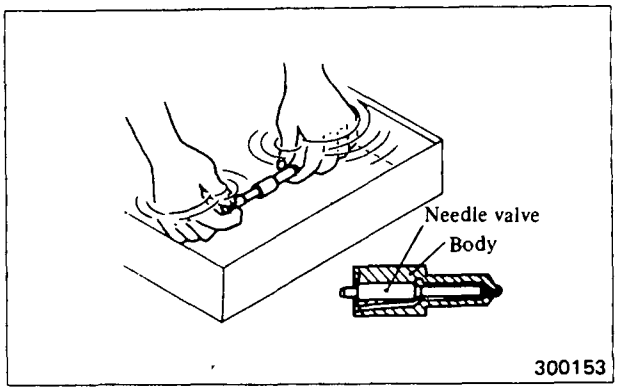
The needle valve and body are finely finished. Do not change the combination or set of the valve and body.

(d) Tighten the retaining nut to the specified torque.

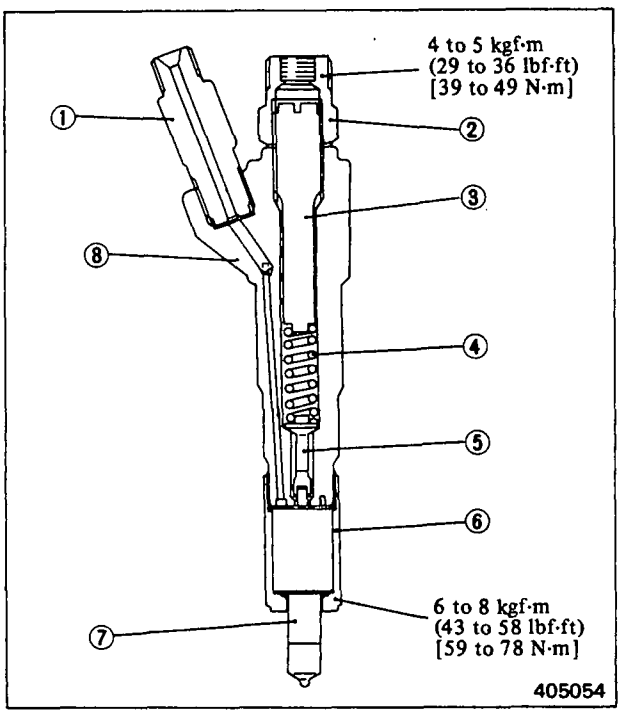
(e) If the spray pattern is still bad after the nozzle has been adjusted and cleaned, replace the nozzle tip.

NOTE

New nozzle tips are coated with vaseline for preservation. Be sure to wash them two times, first in gasoline and then in diesel fuel to be used, before assembling them.



4.3 Reassembly



NOTE

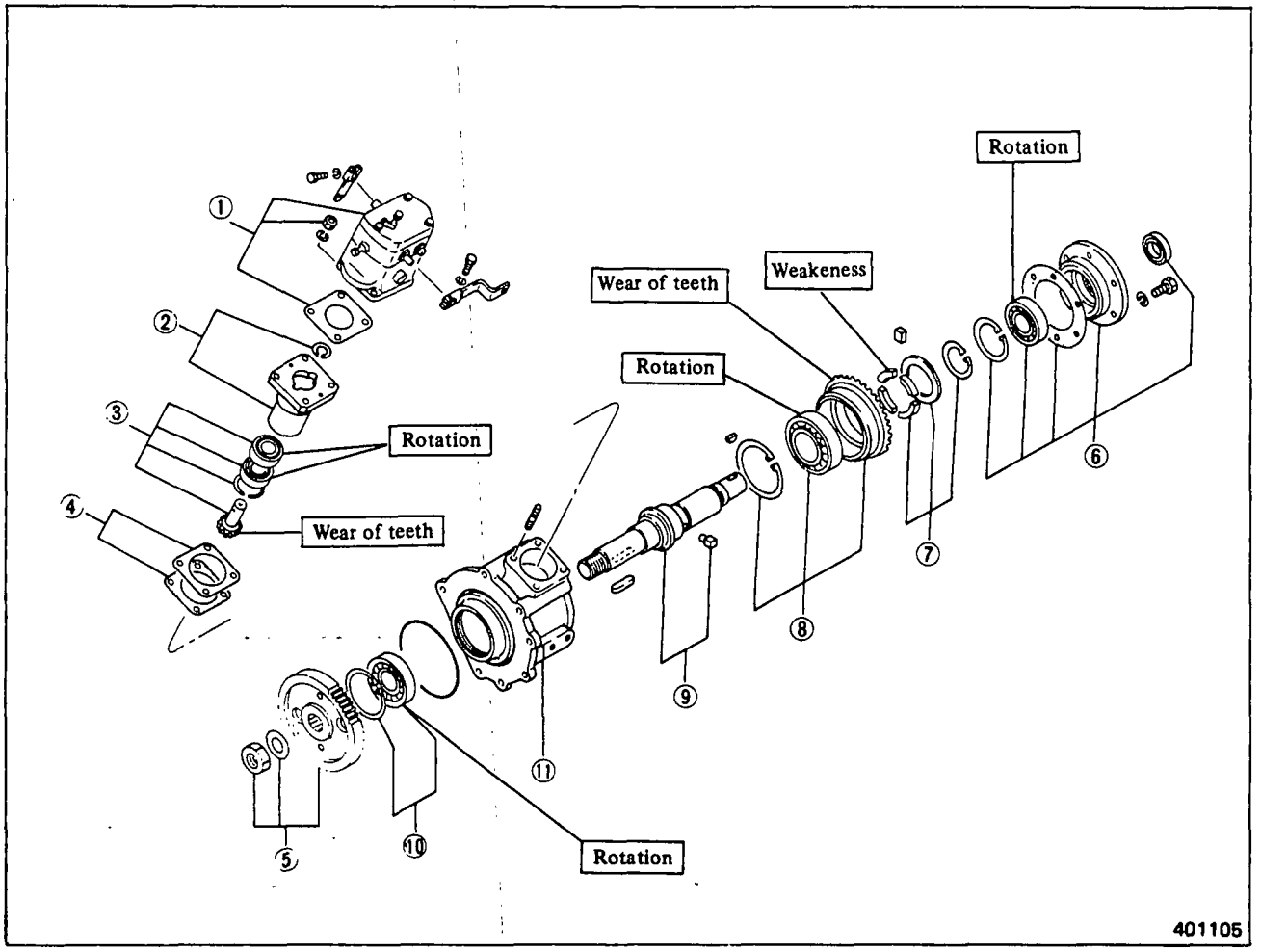
When putting the nozzle tip in the nozzle holder, make sure that the tip locating pin enters its hole in the holder.

Reassembly sequence

⑧→⑦→⑥→⑤→④→③→②→①

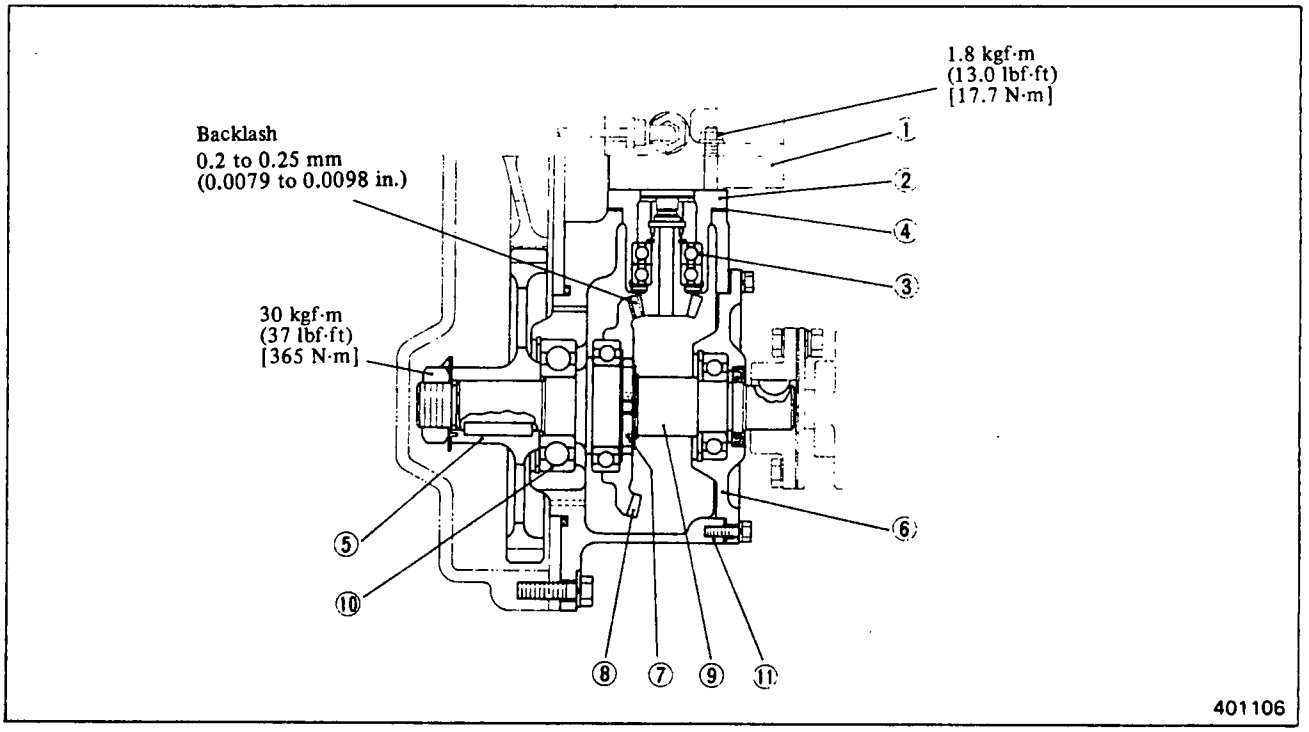
5. WOODWARD GOVERNOR DRIVE

5.1 Disassembly and inspection



① PSG governor, nut, packing
② Bearing case, snap ring
③ Drive gear, ball bearing, snap ring
④ Shim, packing
⑤ Nut, lock washer, injection pump drive gear
⑥ Bearing case, oil seal, snap ring, ball bearing, packing
⑦ Snap ring, washer, rubber, pin
⑧ Snap ring, ball bearing, drive gear
⑨ Drive shaft, pin
⑩ Snap ring, ball bearing
⑪ Drive case, O-ring

5.2 Reassembly

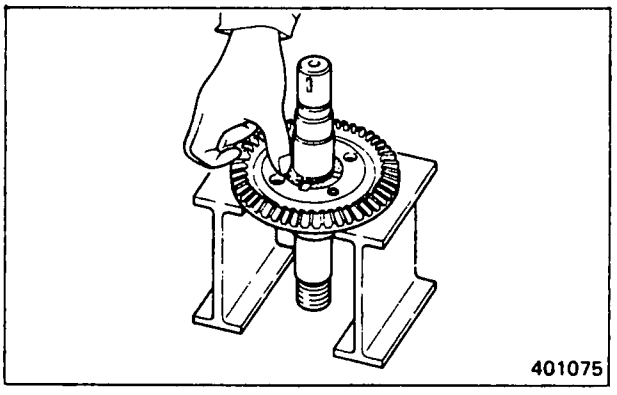


Reassembly sequence

⑨→⑧→⑦→⑪→⑩→⑥→③→②→④→⑤→①

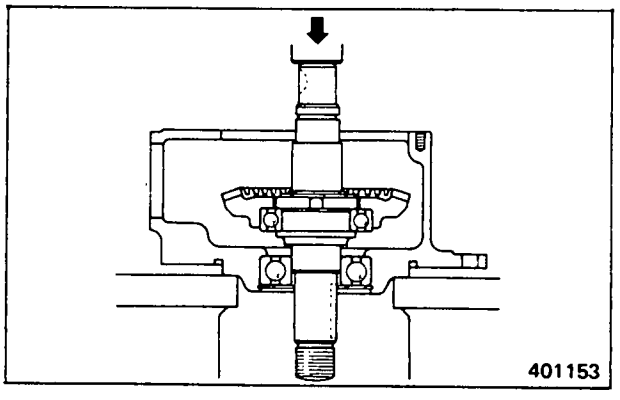
(1) Installing rubber

After pressing drive gear onto the drive shaft, install pin and rubber.



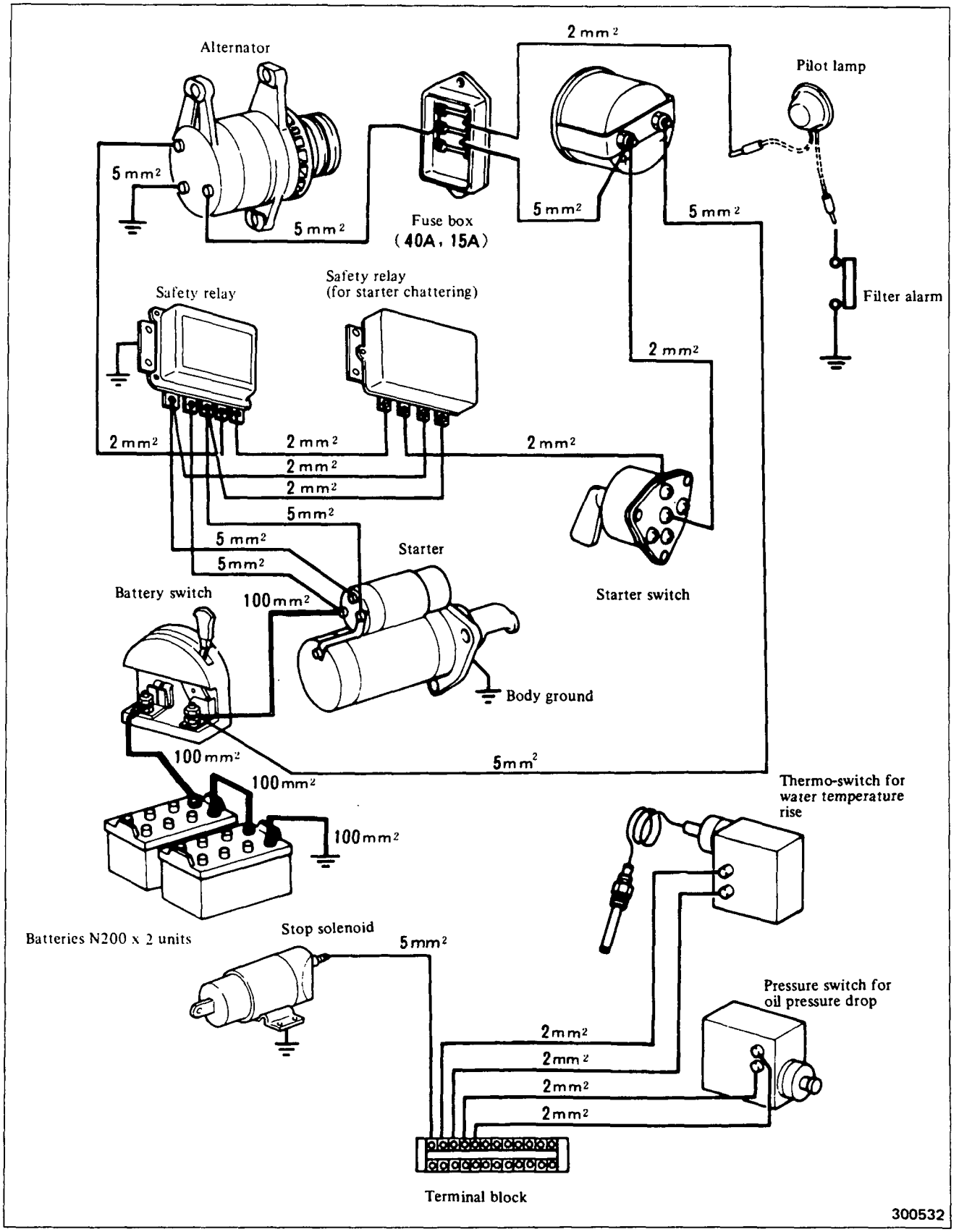
(2) Installing drive gear

Press the drive gear assembly into the drive case.



ELECTRICAL SYSTEM

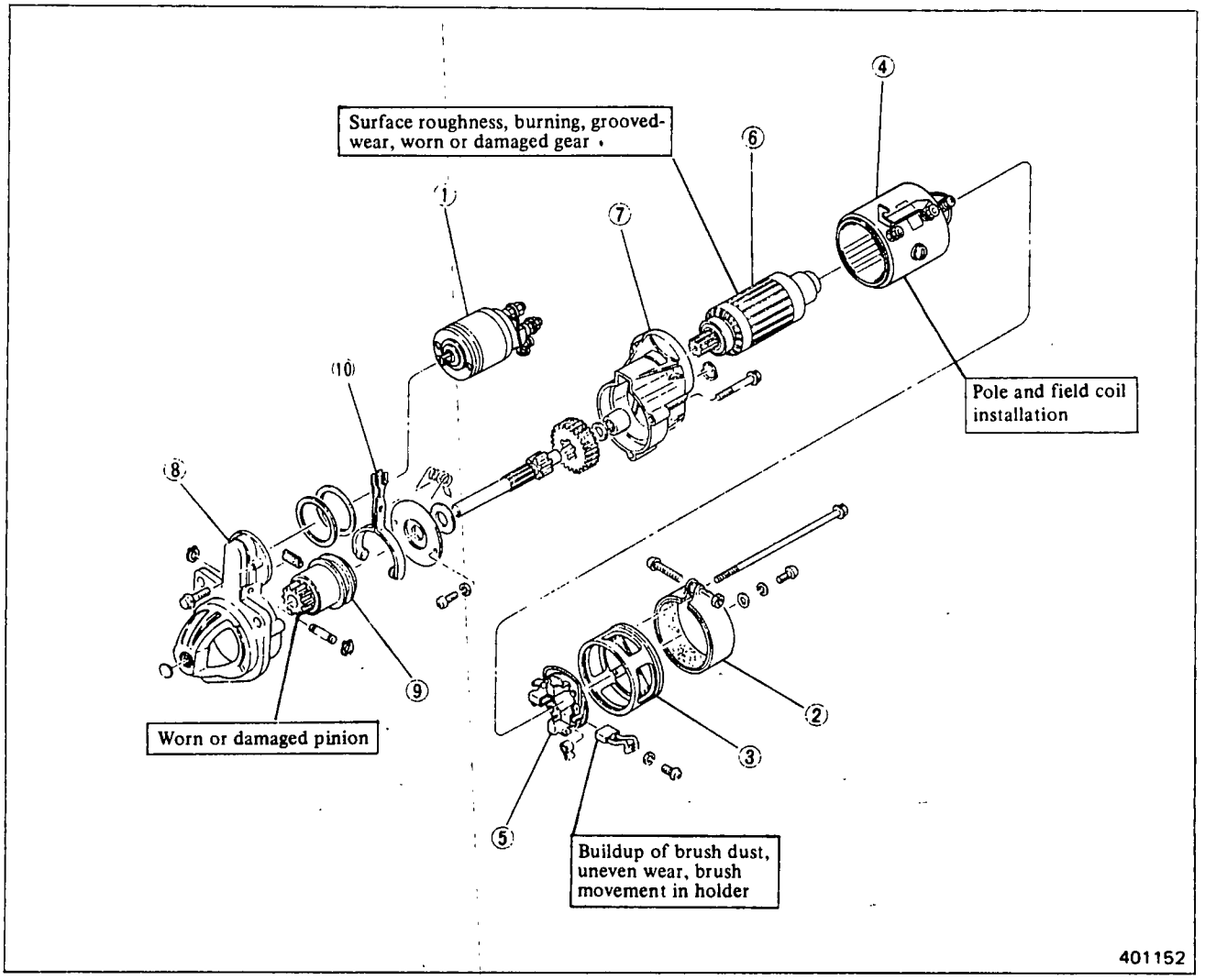
1. DESCRIPTION



Wiring diagram

2. STARTER

2.1 Disassembly



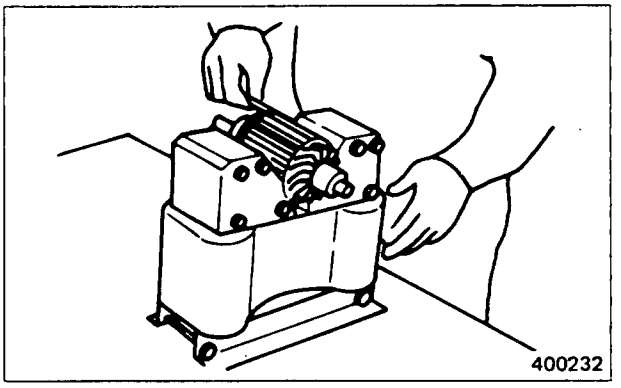
① Engage switch assembly
② Band assembly
③ Rear bracket
④ Yoke assembly
⑤ Brush holder assembly
⑥ Armature assembly
⑦ Center bracket
⑧ Pinion case
⑨ Pinion clutch assembly
⑩ Lever assembly

2.2 Inspection and repair

(1) Armature

(a) Testing armature coil for short circuits

Test the armature coil for short circuits on a growler. If the coil is short-circuited, replace the armature.



(b) Testing armature coil for grounding

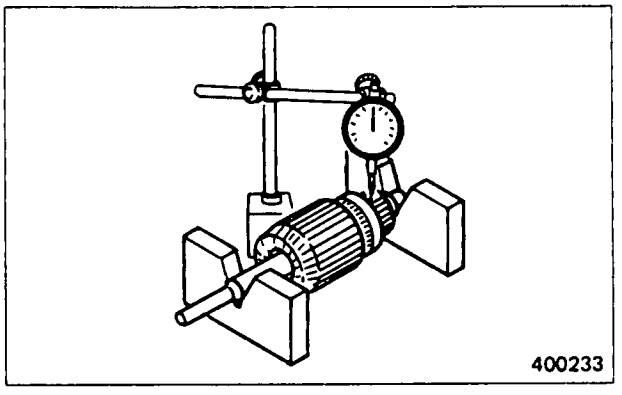
If there is continuity between the commutator and shaft (or core), replace the armature.

(c) Measuring commutator runout

Support the commutator in V-blocks, and measure the runout with a dial indicator. If the runout exceeds the Assembly standard, repair or replace the armature.

Unit: mm (in.)

Item	Assembly standard	Repair limit
Commutator runout	0.03 (0.0012), maximum	0.20 (0.0078)

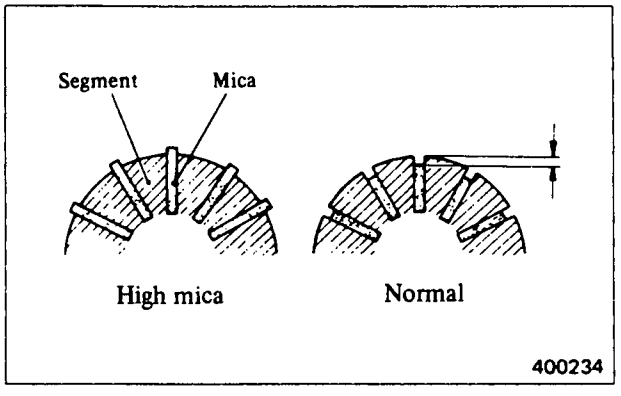


(d) Measuring commutator mica depth

Using a depth gauge, measure the depth of each mica undercut. If the depth exceeds the Repair limit, recondition the mica.

Unit: mm (in.)

Item	Assembly standard	Repair limit
Commutator mica depth	0.5 to 0.8 (0.020 to 0.031)	0.2 (0.008)



(e) Measuring commutator diameter

Using a calipers, measure the commutator diameter. If the diameter exceeds the Service limit, replace the commutator.

Unit: mm (in.)

Item	Assembly standard	Service limit
Commutator outside diameter	53.5 (2.106)	50.5 (1.988)

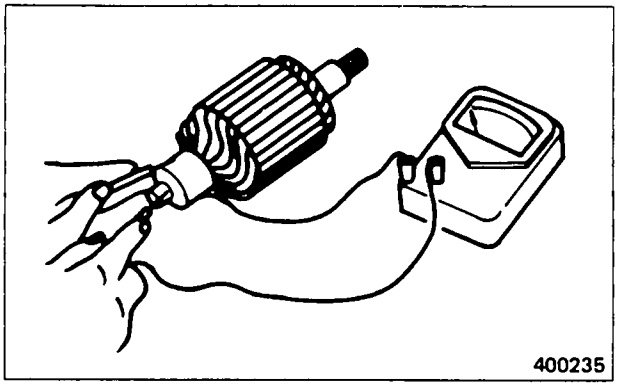
(2) Field coil

(a) Testing field coil for open circuits

If there is no continuity across the coil (between the brushes), replace field coil.

(b) Testing field coil for grounding

If there is continuity between the connector (or brush) and yoke, replace field coil.



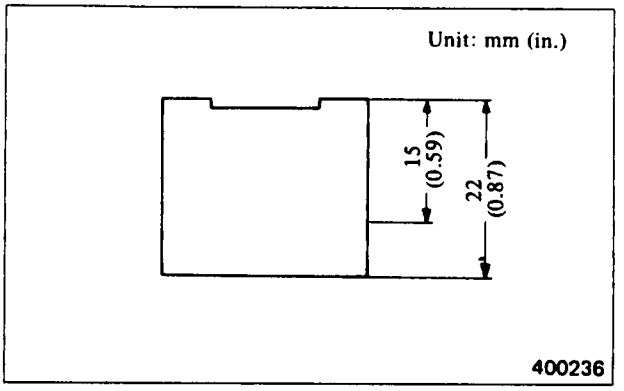
(3) Brushes and holders

(a) Wear of brushes

Unit: mm (in.)

Item	Assembly standard	Service limit
Brush height	22 (0.87)	15 (0.59)

If the brushes are unevenly worn or roughened, recondition them.



(b) Brush spring tension

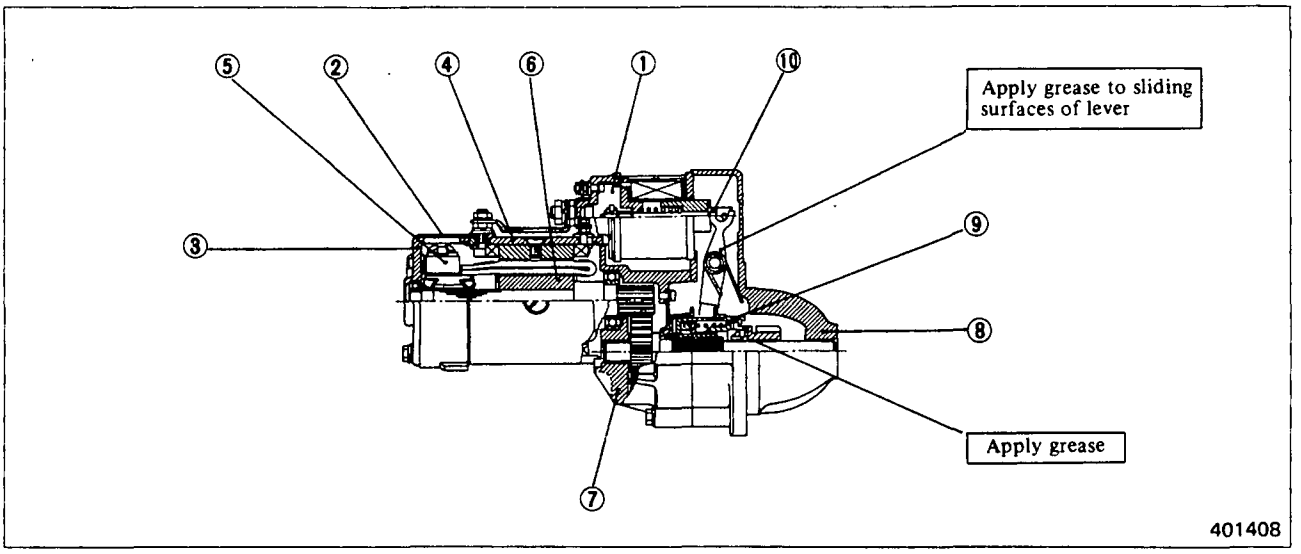
Unit: kgf (lbf) [N]

Item	Assembly standard
Brush spring tension	2 (4.4) [19.6]

(c) Testing brush holders for insulation

If there is continuity between the insulated brush holder and plate, replace the brush holder assembly.

2.3 Reassembly

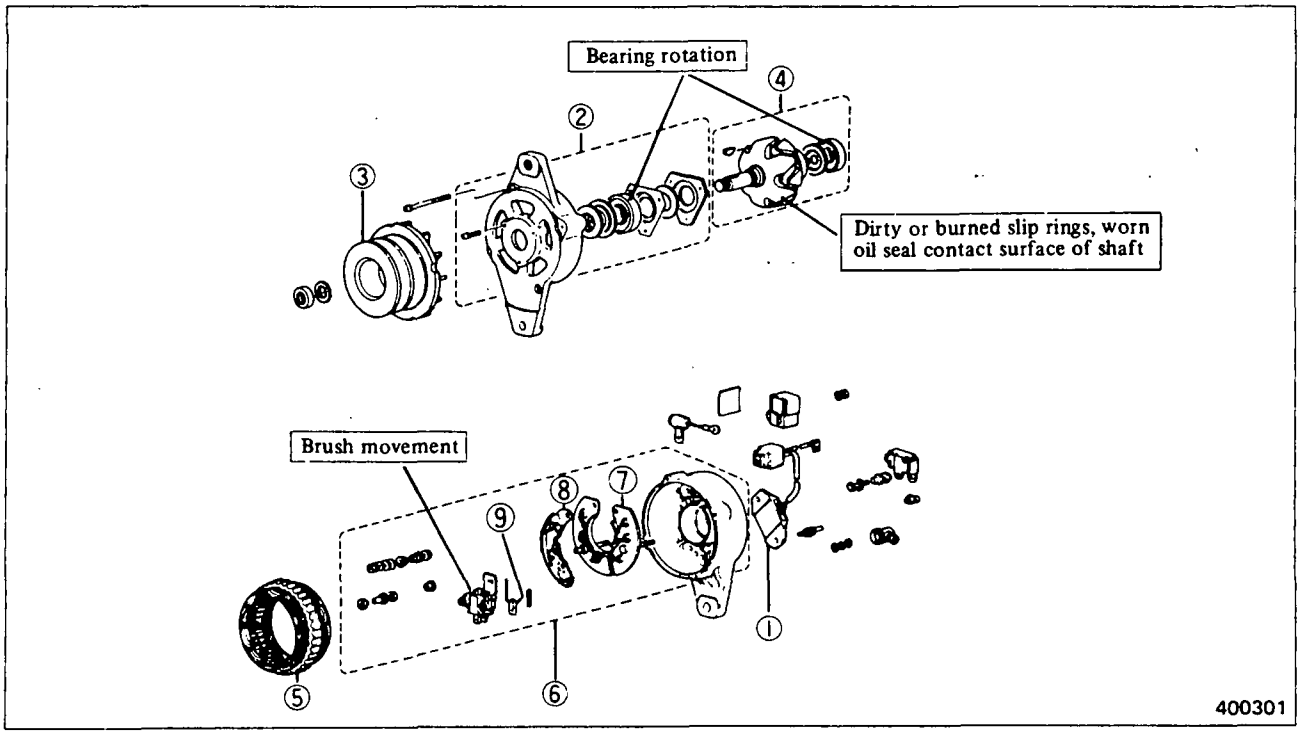


Reassembly sequence

⑨→⑧→⑩→⑦→⑥→⑤→④→③→②→①

3. ALTERNATOR

3.1 Disassembly



① Regulator assembly
② Front bracket assembly
③ Pulley
④ Rotor assembly
⑤ Stator
⑥ Rear bracket assembly
⑦ Rectifier assembly
⑧ Heat sink assembly
⑨ Brush

⚠ CAUTION

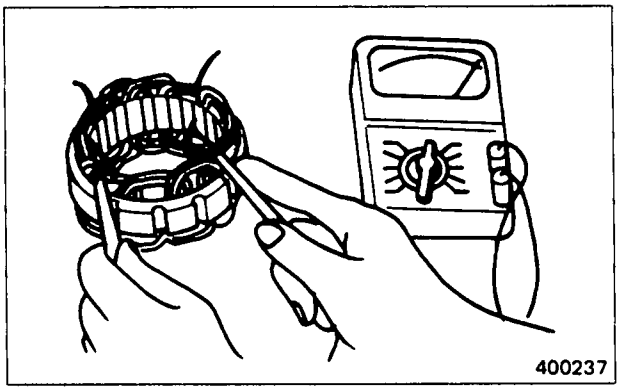
When undoing the soldered connections of lead wires extending from the stator coil, using a soldering iron, make it quickly by gripping the wires with a needle-nose pliers to prevent heating the diode rectifier.

3.2 Inspection and repair

(1) Stator

(a) Testing stator coil for open circuits

If there is no continuity among four lead wires, replace the stator.



(b) Testing stator coil for grounding

If there is continuity between the coil and core, replace the stator.

(2) Rotor

(a) Testing rotor coil for open circuits

If there is no continuity between the slip rings, replace the rotor.

(b) Testing rotor coil for grounding

If there is continuity between the slip rings and shaft (or core), replace the rotor.

(c) Measure slip ring outside diameter

Using a calipers, measure the outside diameter of each slip ring. If the diameter exceeds the Service limit, replace the slip ring.

Unit: mm (in.)

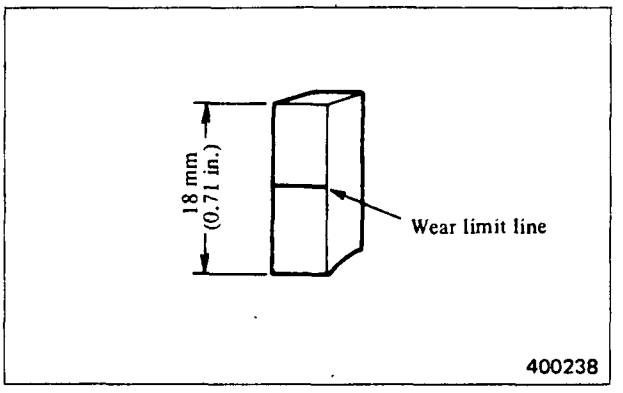
Item	Assembly standard	Service limit
Slip ring outside diameter	33 ± 0.2 (1.30 ± 0.008)	32.2 (1.268)

(3) Brushes and brush springs

(a) Wear of brushes

Unit: mm (in.)

Item	Assembly standard	Service limit
Brush height	18 (0.71)	8 (0.31)



(b) Brush spring tension

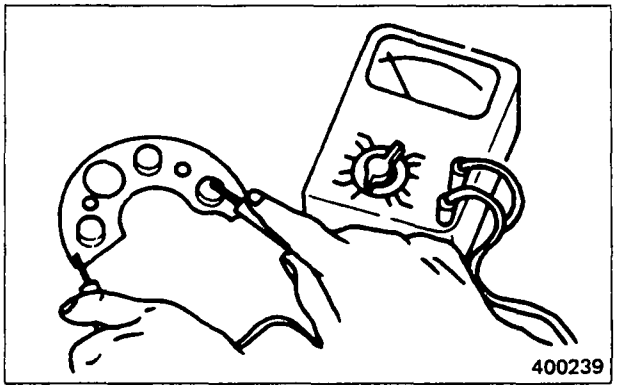
Unit: gf (lbf) [N]

Item	Assembly standard	Service limit
Brush spring tension	390 (0.86) [3.82]	220 (0.49) [2.16]

(4) Diodes

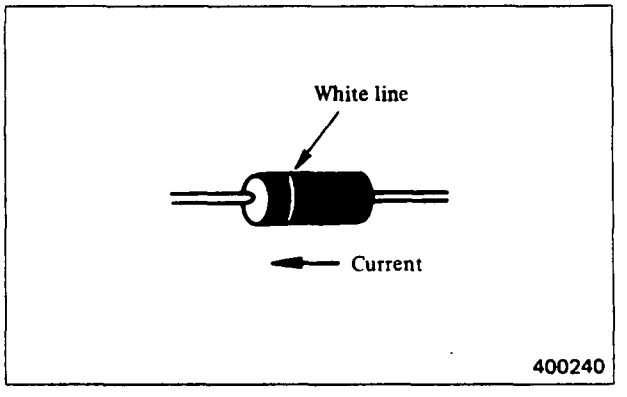
(a) Main diode

If there is continuity between the diode lead wire and heat sink in both directions, replace the rectifier assembly.

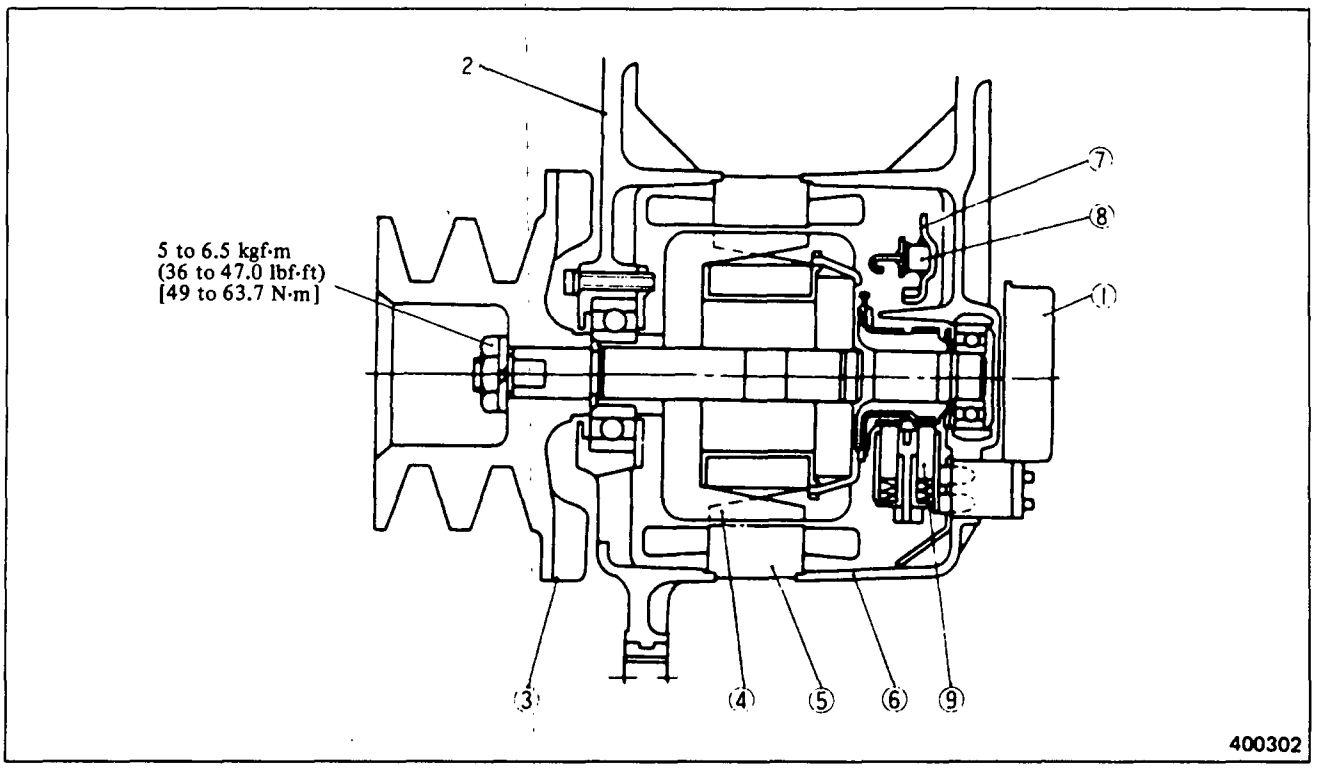


(b) Auxiliary diode

If the diode is short- or open-circuited, replace the heat sink assembly.



3.3 Reassembly



Reassembly sequence

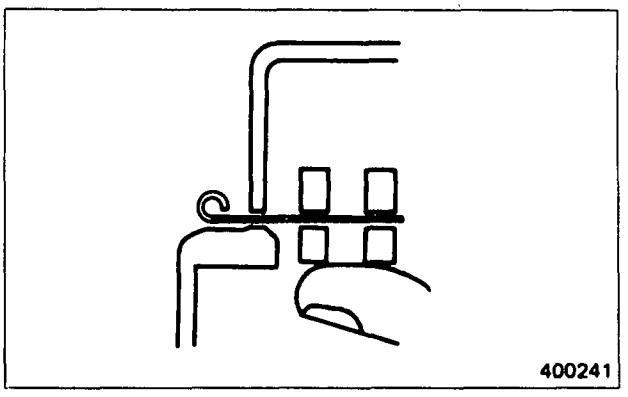
⑨→⑥→⑦→⑧→⑤→①
②→④→③

(1) Tightening pulley nut

Tighten the nut to 5 to 6.5 kgf·m (36 to 47.0 lbf·ft) [49 to 63.7 N·m] torque. After tightening the nut, hold the rotor, and apply 3.5 kgf·m (25.3 lbf·ft) [34.3 N·m] torque to the fan to make sure that the fan is secured properly.

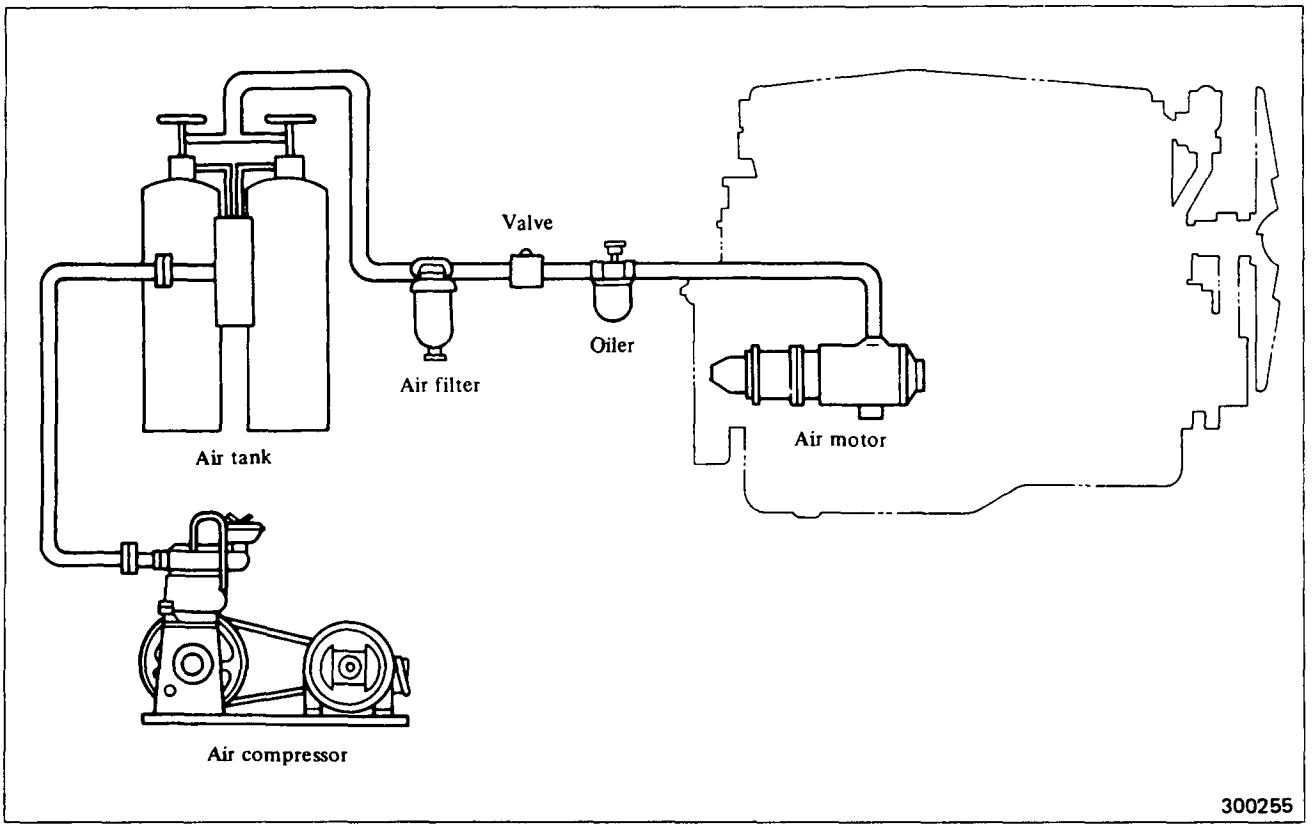
(2) Holding brush for installing rotor

Push the brush into the holder, and hold it there, using a piece of wire as shown at right. Then, install the rotor. Be sure to remove the wire after installing the rotor.



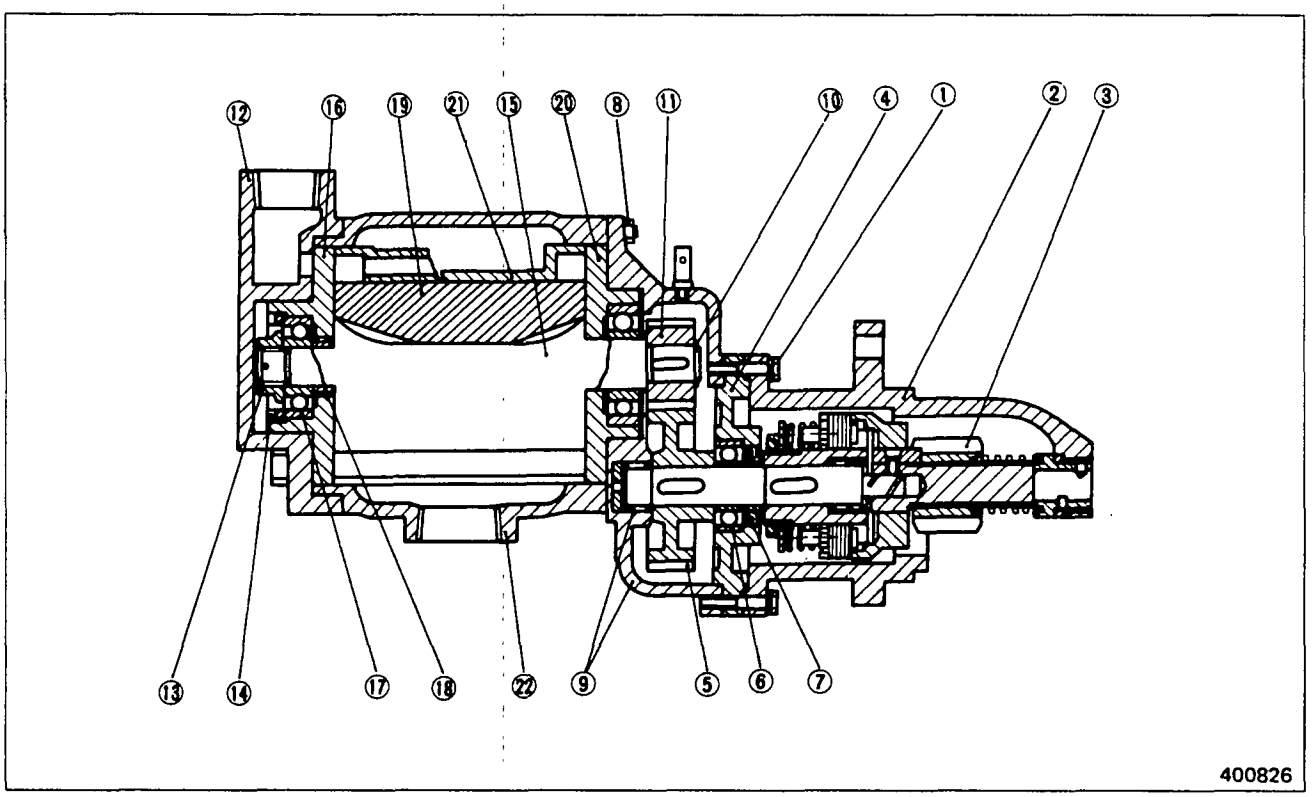
AIR START SYSTEMS

1. AIR MOTOR SYSTEM



2. AIR MOTOR

2.1 Disassembly and reassembly



① Bolt
② Pinion case
③ Clutch assembly
④ Gear case cover
⑤ Driven gear
⑥ Bearing
⑦ Oil seal
⑧ Nut
⑨ Gear case, needle roller bearing
⑩ Snap ring
⑪ Drive gear
⑫ Upper cover
⑬ Bearing retaining nut
⑭ Bearing retaining nut
⑮ Rotor
⑯ Cylinder upper cover
⑰ Ball bearing
⑱ Rotor adjusting ring
⑲ Vane
⑳ Cylinder lower cover
㉑ Cylinder
㉒ Cylinder case

NOTE

Do not remove the rotor adjusting ring from the rotor.

2.2 Inspection

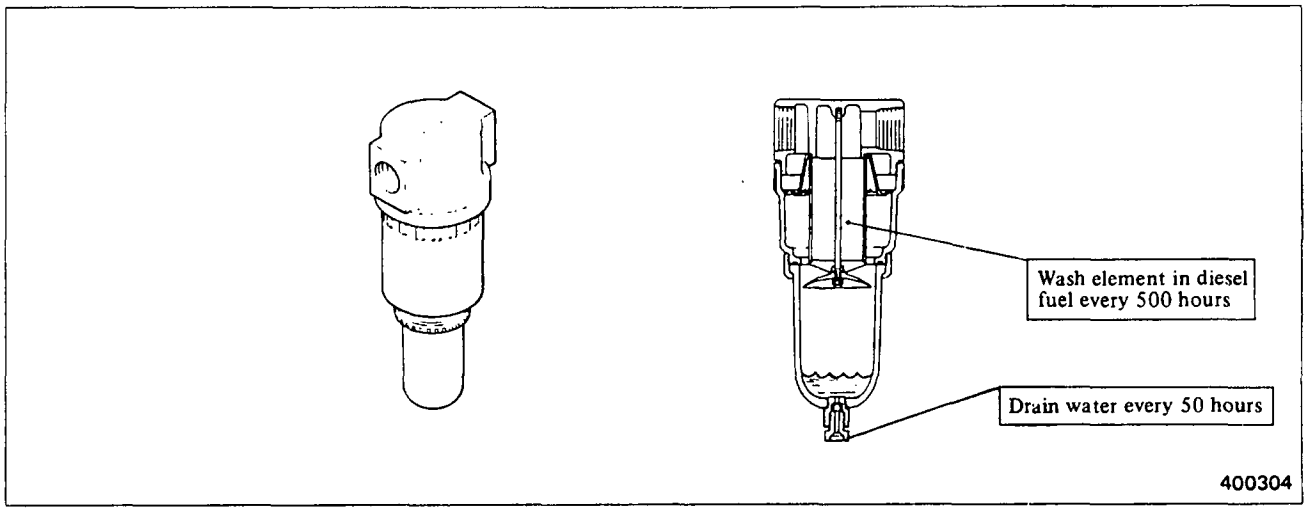
Wash and inspect the air motor parts for wear or damage. Replace the defective parts if any. The clutch assembly and pinion assembly should be replaced as an assembly.

Reassembling sequence

⑳→⑮→⑱→⑲→㉑→⑯→⑰→⑬→⑭→㉒→⑫→⑪→⑩→⑨→⑧→①
④→⑥→⑦→③→⑤→②→①

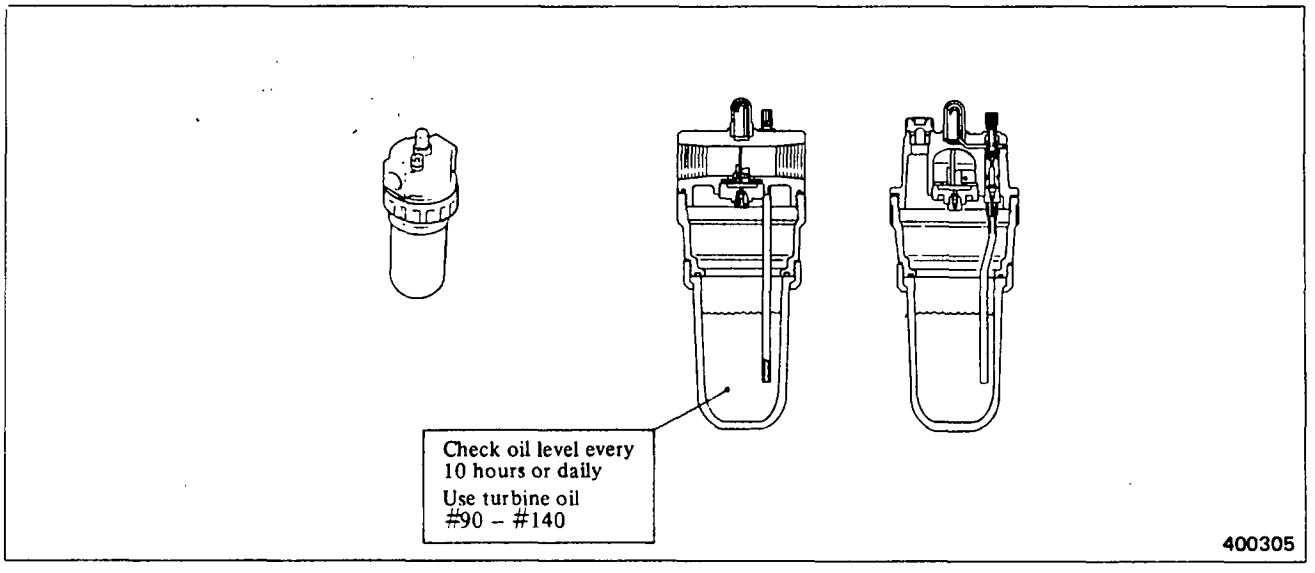
3. AIR FILTER

Inspection



4. OILER

Inspection



WORKSHOP THEORY

1. PRECAUTIONS FOR DISASSEMBLY AND REASSEMBLY

1.1 Oil seals

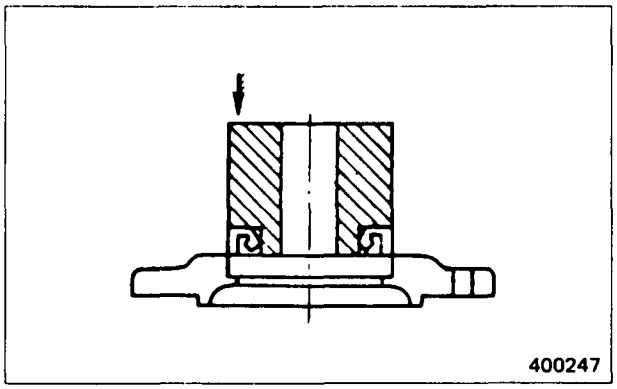
When installing oil seals, carefully observe the following points:

Driving oil seals into housings

(a) Make sure that seal lip is not damaged, and position it correctly with respect to oil compartment.

(b) Apply a small amount of grease to the surface of oil seal to be fitted into housing bore.

(c) Using a tool of the type shown to guide seal lip, drive oil seal squarely. Never give any hammer blows directly to oil seal since this will damage the seal, resulting in oil leakage.

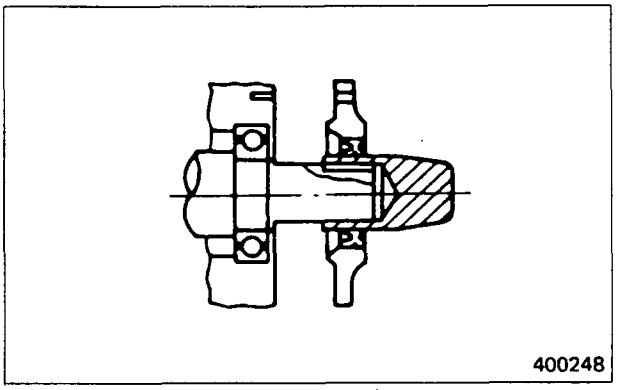


Oil seal driver

Driving oil seals onto shafts

(a) Apply a thin coat of grease to oil seal lip.

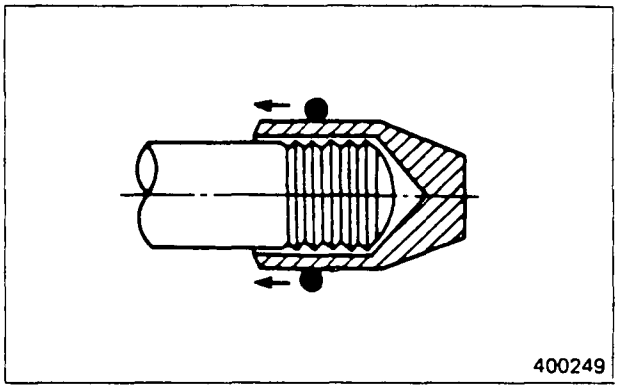
(b) Use an oil seal guide of the type shown when driving oil seal over stepped portion, splines, threads or keyway to prevent damage to seal lip.



Oil seal guide

1.2 O-rings

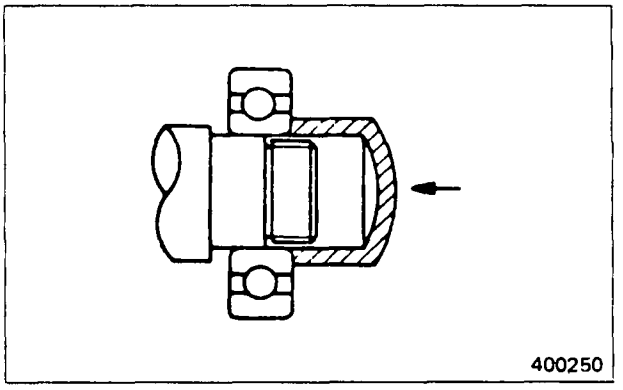
Use an O-ring guide of the type shown when installing O-ring over stepped portion, splines, threads or keyway to prevent damage to the ring. Apply a thin coat of grease to O-ring.



O-ring guide

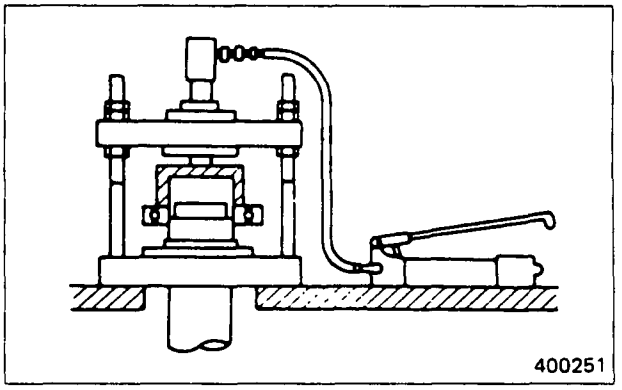
1.3 Bearings

(a) When installing a rolling bearing, be sure to give a push to the race, inner or outer, by which the bearing is fitted. Be sure to use a bearing driver of the type shown.



Bearing driver

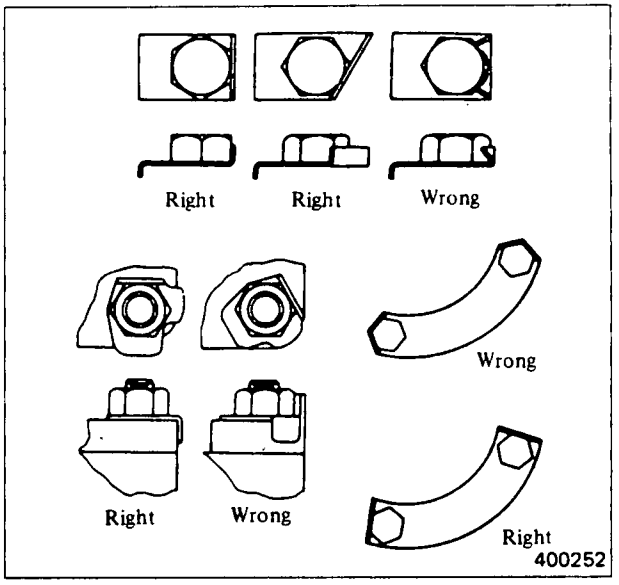
(b) Use a press whenever possible to minimize shock to bearing and to assure proper installation.



Bearing installation by a press

1.4 Lock plates

Bend lock plate against one of the flats of nut or bolt head as shown.



Bending lock plates

1.5 Split pins and spring pins

Generally, split pins are to be replaced at the time of disassembly. Drive each spring pin into position so that it may not get out of place after subsequent installation of parts has been completed.