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14.6 LITER

DIESEL

Mitsubishi

S6B3

ENGINE SERVICE MANUAL

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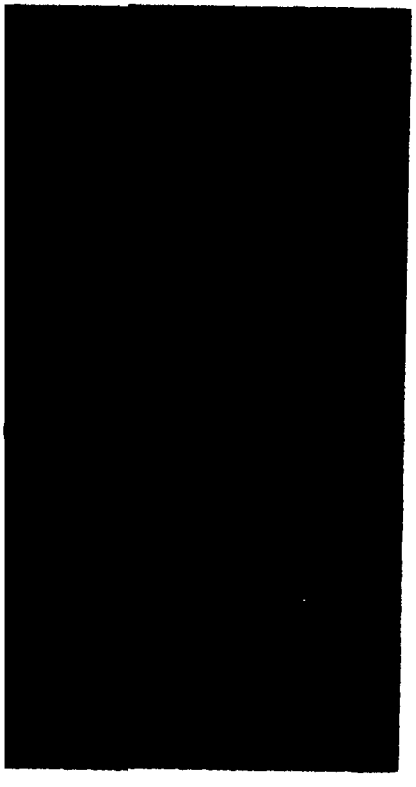
SERVICE MANUAL



MITSUBISHI DIESEL ENGINE

S6B3

400KW

MITSUBISHI HEAVY INDUSTRIES, LTD.

INTRODUCTION

This Service Manual is written to familiarize you with the maintenance of your Mitsubishi 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 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 GROUP INDEX and the contents of each group in the first page of the group.

For the operation and periodic maintenance of the engine, refer to OPERATION & MAINTENANCE MANUAL. For the component parts and ordering of the service parts, refer to PARTS CATALOGUE. For the construction and function of the engine, refer to 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.

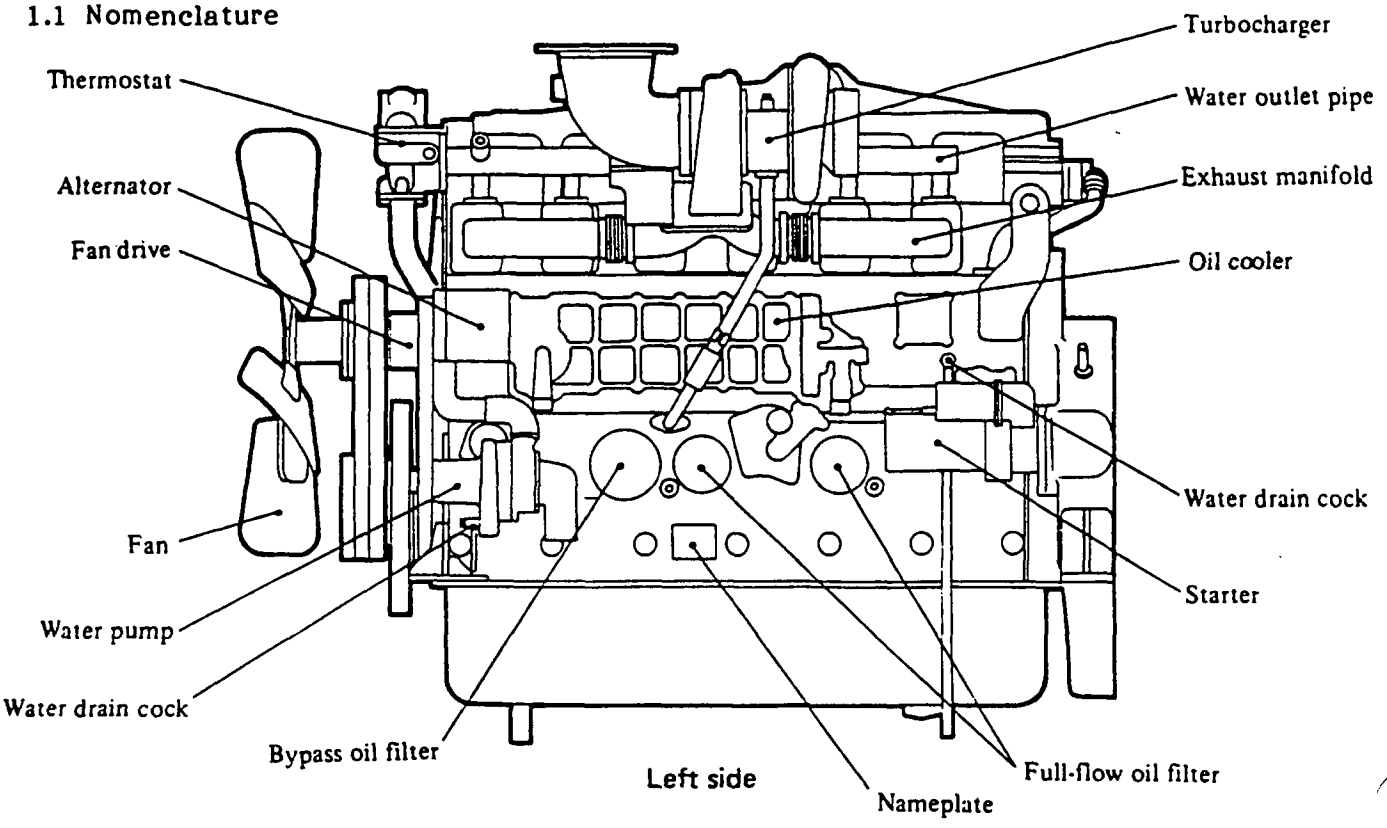
SERVICE LIMIT ..... A part which has reached this limit must be replaced.

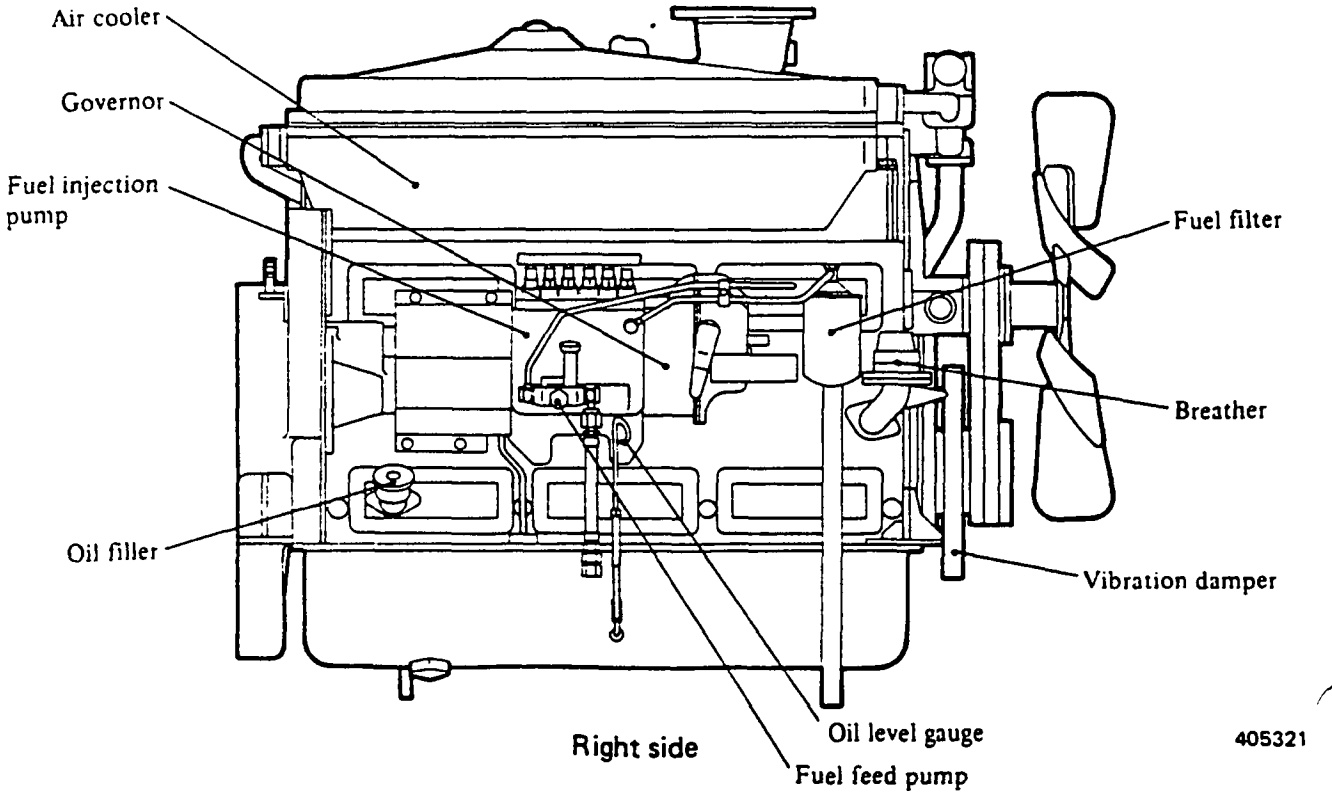
GROUP INDEX

GENERAL

1. GENERAL

1.1 Nomenclature



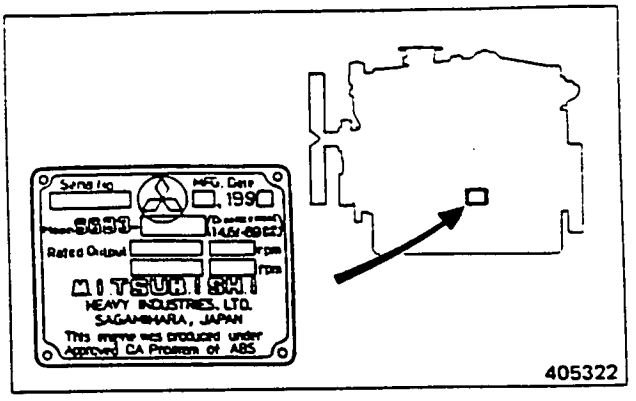


1.2 Engine serial number location

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

Example: Model S6B3 Serial number 30125

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



1.3 Engine model and application codes

S□□□-□□

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

Application code:
- Not coded: 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				S6B3	
				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.)			135 x 170 (5.31 x 6.69)	
	Piston displacement, liter (cu in.)			14.60 (891)	
	Compression ratio			14.2 : 1	
	Fuel			Diesel fuel oils specified by ASTM	
	Firing order (injection sequence)			1-5-3-6-2-4	
	Direction of rotation			Counterclockwise as seen from flywheel side	
	Dimensions, mm (in.)	Overall length		1400 (55.1)	
		Overall width		885 (34.8)	
		Overall height		1270 (50.0)	
	Weight (dry), kg (lb)			1200 (2646)	
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 or air motor	
Inlet and exhaust systems	Air cleaner	Type		Paper element type or turbine silencer	
	Turbocharger	Type – No. of units		TD10 type – 1 unit	
	Air cooler			Laminated fin-plate type	
Lubrication system	Type			Forced feed by gear pump	
	Engine oil	Specification		Class CD oil (API Service Classification)	
		Capacity, liter (U.S. gal)		Oil pan 40 (10.6) approx. engine 50 (13.2) (standard specification)	

Model designation			S6B3	
			TA	TK
Lubrication system	Oil pump	Type	Gear pump	
		Delivery capacity, liter (U.S. gal)/min	250 (66) (at 2000 engine rpm)	
	Relief valve	Type	Piston valve	
		Valve opening pressure, kgf/cm^2 (psi) [MPa]	5.4 to 6.4 (77 to 91) [0.5 to 0.6]	
	Oil cooler	Type	Water-cooled multi-plate type (built in crankcase)	
	Full-flow type oil filter	Type	Paper element (cartridge type)	
	Bypass type oil filter	Type	Paper element (cartridge type)	
	Oil filter alarm	Type	Piston valve with built-in electric contact points	
		Valve opening pressure (differential pressure), kgf/cm^2 (psi) [MPa]	2.3 to 2.7 (33 to 38) [0.2 to 0.3]	
Cooling system	Type		Forced circulation	
	Capacity (engine), liter (U.S. gal)		30 (7.9)	
	Water pump	Type	Centrifugal	
		Delivery capacity, liter (U.S. gal)/min	310 (81.8) (at 2000 engine rpm)	
	Water pump belt	Type	Low edge cog belt type C	
		Manufacturer	Mitsuboshi Belt	
		Outside circumference, mm (in.)	1535 (60.43)	
	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 type C (2-piece set)	
		Manufacturer	Mitsuboshi Belt	
		Outside circumference, mm (in.)	1305 (51.38)	
Fuel system	Injection pump	Model	Bosch P type	
		Manufacturer	Nippon Denso	
		Plunger diameter, mm (in.)	13 (0.51)	
		Plunger lead, mm (in.)	Double lead 22 + 55 (0.87 + 2.17)	
		Cam lift, mm (in.)	12 (0.47)	

Model designation			S6B3	
			TA	TK
Fuel system	Feed pump	Model	KD22	
		Manufacturer	Nippon Denso	
		Cam lift, mm (in.)	4 (0.16)	
	Governor	Control system	⟨Mechanical⟩ All-speed RSUV Constant-speed RSUV-D	⟨Hydraulic⟩ Woodward PSG ⟨Electrical⟩ Woodward EG-3P Barber-Colman DYNA 8000
	Injection nozzles	Type	Hole type	
		Manufacturer	Nippon Denso	
		No. of spray orifice	8	
		Spray orifice diameter, mm (in.)	0.28 (0.0110)	
		Spray angle	158°	
		Injection pressure, kgf/cm² (psi) [MPa]	$250\ ^{+5}_{0}$ $(3555\ ^{+71}_{0})$ $[24.5\ ^{+0.5}_{0}]$	
	Fuel filter		Paper-element (cartridge type)	
Electrical system	Voltage – polarity		24-V – Negative (–) ground	
	Starter	Model	0350-620-0050	
		Manufacturer	Sawafuji Electric	
		Type	Pinion shift	
		Output, V – kW	24 – 6	
	Alternator	Model	A004T57670	
		Type	3-phase	
		Manufacturer	Mitsubishi Electric	
		Output, V – A	24 – 35	
		Rated output generating speed, rpm	5000, maximum (at 27V, 25A)	
		Maximum speed, rpm	8000	
	Safety relay	Model	0590-001-0510	
		Manufacturer	Sawafuji Electric	
		Relay switch — Operating voltage, V	16, maximum	
		Relay switch — Holding voltage, V	8, maximum	
		Safety coil (b coil) — Operating voltage, V	3, maximum	
		Safety coil (b coil) — Holding voltage, V	0.05 to 0.15	
		Safety coil (c coil) — Operating voltage, V	10.5 to 11.5	
		Safety coil (c coil) — Holding voltage, V	4, maximum	

Model designation			S6B3	
			TA	TK
Air-start system	Air-motor starting	Model	FSM-100C-102	
		Manufacturer	Fuji Kuki	
		Type	Pinion shift	
		Nominal output, (PS)	10 at 6 kgf/cm^2 (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, Group No. 2.)

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

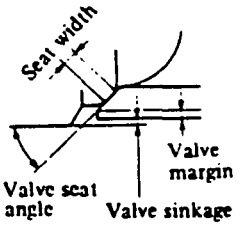
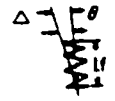
MAINTENANCE STANDARDS

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 700 rpm				
	Compression pressure, kgf/cm² (psi) [MPa]			28 (398.2) [2.7] at 160 rpm, minimum		19 (270) [1.9], minimum		Oil and water temp. 20 to 30°C (68 to 86°F)
	Lube oil pressure, kgf/cm² (psi) [MPa]			5 to 7 (71 to 99.5) [0.5 to 0.7] (at rated rpm)		4 (57) [0.4], minimum		Oil temperature 60 to 70°C (140 to 158°F)
				2 (28) [0.2], minimum (at idling rpm)		1 (14) [0.1], minimum		
	Valve timing [with 2 (0.08) clearance on valve side, cold]			Inlet valve opens 10° B.T.D.C. Inlet valve closes 20° A.B.D.C. Exhaust valve opens 20° B.B.D.C. Exhaust valve closes 10° 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)				
	Injection timing			B.T.D.C.	± 1° (crank angle)			Varies according to specifications. Refer to caution plate on No. 1 rocker cover.
	Belt tension (sag)	Fan			20 to 25 (0.8 to 1)			Measure sag at point indicated by arrows. 
		Water pump and alternator						
Engine proper	Rockers	Rocker bushing inside diameter		28 (1.10)	28.070 to 28.090 (1.10512 to 1.10590)		28.150 (1.10827)	
		Rocker shaft diameter		28 (1.10)	27.972 to 27.993 (1.10126 to 1.10208)		27.930 (1.09960)	
	Valves	Valve stem diameter	Inlet valves	10 (0.39)	9.940 to 9.960 (0.39134 to 0.39213)		9.910 (0.39016)	
			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 and exhaust valves.

Unit: mm (in.)

Group	Inspection point			Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Valves and valve seats	Valve seat angle		30°			 * Refacing is permissible up to	
		Valve sinkage			0 ± 0.2 (0 ± 0.0079)	0.5 (0.0197)		
		Seat width	Inlet valves		2.6 ± 0.15 (0.102 ± 0.0059)	3.1 (0.122)		
			Exhaust valves		1.85 ± 0.15 (0.073 ± 0.0059)	2.35 (0.0925)		
		Valve margin	Inlet valves		3.0 ± 0.1 (0.12 ± 0.004)	*2.5 (0.098)		
			Exhaust valves		2.5 ± 0.1 (0.098 ± 0.004)	*2.0 (0.079)		
		Cylinder head bore inside diameter and valve seat outside diameter	Inlet valves	50 (1.97)	(–0.075 to –0.130) ((–0.00295 to –0.00512))			- (minus) indicates interference.
			Exhaust valves	46 (1.81)	(–0.065 to –0.120) ((–0.00256 to –0.00472))			
	Valve springs	Free length			67.5 (2.657)		66.2 (2.606)	
		Squareness		$\phi\theta$ = 1°, maximum 			Δ = 1.5 (0.059) over the length	
		Length under test force			60.0 (2.362)			
		Test force, kgf (lbf) [N]			27.8 (61.3) [273] ±5%			
	Valve push-rods	Runout			0.5 (0.020), maximum			
	Cylinder heads	Warpage of gasket contact surface			0.03 (0.0012), maximum	0.07 (0.0028)	0.50 (0.0197)	Regrind slightly.
	Cylinder liners	Inside diameter		135 (5.31)	135.000 to 135.040 (5.31495 to 5.31652)		135.140 (5.32046)	
		Out-of-roundness			0.02 (0.0008), maximum			
		Taper						
		Squareness with respect to lower face of flange			0.03 (0.0012), maximum			
		Projection			0.10 to 0.19 (0.0039 to 0.0075)			

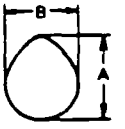
Unit: mm (in.)

Group	Inspection point			Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Pistons	Diameter		135 (5.31)	134.810 to 134.855 (5.30747 to 5.30924)		134.700 (5.30314)	Measure diameter in the direction transverse to pin at piston skirt.
		Max. permissible difference between average weight of all pistons in one engine			20 g (0.7 oz), maximum			
		Side clearance	Top	4.27 (0.1681)	(0.077 to 0.087) ((0.00303 to 0.00343))		(0.20) ((0.0079))	Measure side clearance with new piston rings installed.
			Second	3.23 (0.1272)	(0.046 to 0.051) ((0.00181 to 0.00201))			
			Oil	4.00 (0.1575)	(0.030 to 0.070) ((0.00118 to 0.00276))			
		Piston pin bore diameter		55 (2.17)	55.000 to 55.012 (2.16543 to 2.16582)		55.015 (2.16594)	
		Projection			0.45 to 1.15 (0.0177 to 0.0453)			
	Cylinder head gasket	As-installed thickness		1.8 (0.071)	±0.1 (±0.004)			
	Pistons and cylinder heads	Clearance between piston top and cylinder head			(0.75 to 1.63) ((0.0295 to 0.0642))			
	Piston rings	Gaps	Top		(0.4 to 0.6) ((0.016 to 0.024))		(1.0) ((0.039))	If gauge is not available, check gaps by placing rings in a new cylinder liner.
			Second					
			Oil		(0.4 to 0.65) ((0.016 to 0.026))		(1.2) ((0.047))	
	Piston pins	Outside diameter		55 (2.17)	54.987 to 55.000 (2.16484 to 2.16535)		54.980 (2.16456)	
	Connecting rods	Small end bushing inside diameter		55 (2.17)	55.020 to 55.040 (2.16614 to 2.16692)		55.070 (2.16811)	
		Bend and twist			0.05/100 (0.0020/3.9), maximum			
		End play (crankpin and big end widths)		56 (2.20)	(0.2 to 0.4) ((0.008 to 0.016))	(0.8) ((0.031))		
		Max. permissible difference between average weight of all rods in one engine			30 g (1.1 oz), maximum			
		Big-end bore diameter		95 (3.74)	95.000 to 95.022 (3.74015 to 3.74102)		95.047 (3.74200)	To be used in combination with bearing caps.

Unit: mm (in.)

Group	Inspection point			Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Connecting rod bearings	Thickness of central part	Standard	2.500 (0.098)	2.482 to 2.500 (0.09772 to 0.09843)		2.450 (0.09646)	Replace bearings if worn down to service limit.
			Undersizes 0.25 (0.0098)	2.625 (0.10335)	2.607 to 2.625 (0.10264 to 0.10335)		2.575 (0.10138)	
			Undersizes 0.50 (0.0197)	2.750 (0.10827)	2.732 to 2.750 (0.10756 to 0.10827)		2.700 (0.10630)	
			Undersizes 0.75 (0.0295)	2.875 (0.11319)	2.857 to 2.875 (0.11248 to 0.11319)		2.825 (0.11122)	
			Undersizes 1.00 (0.0394)	3.000 (0.11811)	2.982 to 3.000 (0.11740 to 0.11811)		2.950 (0.11614)	
	Fly-wheel	Face runout			0.28 (0.0110), maximum			
		Radial runout			−0.13 (0.0051), maximum			
	Acces-sary drive	Drive case bearing bore inside diameter		80 (3.15)	79.988 to 80.018 (3.14913 to 3.15031)			
				100 (3.94)	99.987 to 100.022 (3.93649 to 3.93787)			
		Bearing	Outside diameter	80 (3.15)	79.983 to 80.004 (3.14893 to 3.14976)			
			Outside diameter	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)			
			Inside diameter	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)			
	Vibra-tion damper	Radial runout (at periphery)			0.5 (0.020), maximum		1.5 (0.059)	
		Face runout						
	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		40 (1.57)	40.000 to 40.025 (1.57480 to 1.57578)		40.100 (1.57874)	
		Idler gear shaft diameter			39.959 to 39.975 (1.57319 to 1.57382)		39.900 (1.57086)	
		Idler gear end play		49 (1.93)	(0.10 to 0.28) ((0.0039 to 0.0110))	(0.60) ((0.0236))		

Unit: mm (in.)

Group	Inspection point		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Camshaft	Lobe 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.
		Journal diameter	68 (2.68)	67.91 to 67.93 (2.6736 to 2.6744)		67.88 (2.6724)	
		Bushing inside diameter (as installed)		67.98 to 68.05 (2.6764 to 2.6791)		68.17 (2.6839)	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.
	Crankshaft	Crankpin diameter	90 (3.54)	-0.07 to -0.09 (-0.0028 to -0.0035)	-0.13 (-0.0051)		Regrind and use undersize connecting rod bearings if worn beyond repair limit.
		Journal diameter	130 (5.12)	-0.100 to -0.120 (-0.00394 to -0.00472)	-0.160 (-0.00630)		Regrind and use undersize main bearings if worn beyond repair limit.
		Center-to-center distance between journal and crankpin	85 (3.35)	±0.10 (±0.004)			
		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					
		Fillet radius of journals and crankpins		$6\ ^{0}_{-0.2}$ ($0.24\ ^{0}_{-0.008}$)			
		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.

Unit: mm (in.)

Group	Inspection point			Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Main bearings	End play (thrust journal length)		52 (2.05)	(0.20 to 0.39) ((0.0079 to 0.0154))	(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.
		Thickness of central part	Standard	3.5 (0.138)	3.482 to 3.500 (0.13709 to 0.13780)		3.450 (0.13583)	Replace bearings if worn down to service limit.
			Undersizes 0.25 (0.0098)	3.625 (0.14272)	3.607 to 3.625 (0.14201 to 0.14272)		3.575 (0.14075)	
			Undersizes 0.50 (0.0197)	3.750 (0.14764)	3.732 to 3.750 (0.14693 to 0.14764)		3.700 (0.14567)	
			Undersizes 0.75 (0.0295)	3.875 (0.15256)	3.857 to 3.875 (0.15185 to 0.15256)		3.825 (0.15059)	
			Undersizes 1.00 (0.0394)	4.000 (0.15748)	3.982 to 4.000 (0.15677 to 0.15748)		3.950 (0.15551)	
	Thrust bearings	Thickness	Standard	5.000 (0.19685)	4.830 to 4.900 (0.19016 to 0.19291)		4.775 (0.18799)	
			Oversizes 0.25 (0.0098)	5.250 (0.20669)	5.080 to 5.150 (0.20000 to 0.20276)		5.025 (0.19783)	
			Oversizes 0.50 (0.0197)	5.500 (0.21654)	5.330 to 5.400 (0.20984 to 0.21260)		5.275 (0.20768)	
			Oversizes 0.75 (0.0295)	5.750 (0.22638)	5.580 to 5.650 (0.21968 to 0.22244)		5.525 (0.21752)	
	Crank-case	Warpage of gasket contact surface			0.1 (0.004), maximum	0.20 (0.0079)		Regrind slightly.
		Main bearing bore diameter		137 (5.39)	137.000 to 137.025 (5.39369 to 5.39467)		137.350 (5.40747)	
Lubrication system	Oil pump	Backlash between oil pump drive gear and idler gear			(0.11 to 0.24) ((0.0043 to 0.0094))		(0.40) ((0.0157))	
		Backlash between oil pump drive gear and driven gear			(0.10 to 0.20) ((0.0039 to 0.0079))			
		Pump gear radial clearance		60 (2.36)	(0.120 to 0.233) ((0.00472 to 0.00917))		(0.30) ((0.0118))	
		Pump gear end clearance		71 (2.80)	(0.060 to 0.134) ((0.00236 to 0.00528))	(0.20) ((0.0079))		
		Shaft diameter		25 (0.98)	24.947 to 24.960 (0.98216 to 0.98268)		24.900 (0.98031)	
		Bushing inside diameter			25.000 to 25.021 (0.98425 to 0.98508)		25.100 (0.98819)	
		Idler gear shaft diameter			24.947 to 24.960 (0.98216 to 0.98268)		24.910 (0.98071)	
		Idler gear shaft bushing inside diameter			25.000 to 25.021 (0.98425 to 0.98508)		25.100 (0.98819)	

Unit: mm (in.)

Group	Inspection point			Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Lubrication system	Safety valve	Setting, kgf/cm² (psi) [MPa]			13 ± 1 (185 ± 14) [1.3 ± 0.1]			
		Spring	Length under test force		66.8 (2.630)			
			Test force, kgf (lbf) [N]		33.6 (74) [330]		30 (66) [294]	
	Backlash between oil pump idler gear and crankshaft gear				0.24 to 0.38 (0.0094 to 0.0150)			
	Relief valve	Setting, kgf/cm² (psi) [MPa]			5.9 ± 0.5 (84 ± 7) [0.6 ± 0.05]			Shim adjust.
	Oil cooler bypass valve	Setting, kgf/cm² (psi) [MPa]			4.5 (64) [0.4]			Replace if out of standard.
	Oil filter alarm switch	Closing pressure, kgf/cm² (psi) [MPa]			$1.5^{+0.3}_{0}$ $(21.3^{+4.3}_{0})$ $[0.1^{+0.03}_{0}]$			Differential pressure
		Bypass valve opening pressure, kgf/cm² (psi) [MPa]			2.5 ± 0.2 (35.6 ± 2.8) [0.2 ± 0.02]			
	Oil jet nozzles	Setting, kgf/cm² (psi) [MPa]			3 ± 0.3 (42.7 ± 4.3) [0.3 ± 0.03]			
Cooling system	Water pump	Pump case bearing bore inside diameter		52 (2.05)	51.998 to 52.018 (2.04677 to 2.04795)		52.025 (2.04822)	
				62 (2.44)	61.988 to 62.018 (2.44047 to 2.44165)		62.025 (2.44192)	
		Bearings	Outside diameter	52 (2.05)	51.983 to 52.004 (2.04657 to 2.04740)			
				62 (2.44)	61.983 to 62.004 (2.44027 to 2.44110)			
			Inside diameter	25 (0.98)	24.987 to 25.003 (0.98374 to 0.98437)			
		Pump shaft bearing journal diameter		25 (0.98)	25.002 to 25.015 (0.98433 to 0.98484)		24.995 (0.98405)	
		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))			

Unit: mm (in.)

Group	Inspection point			Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Cooling system	Water pump	Vane rear face clearance in pump case			(1.0 to 1.3) ((0.039 to 0.051))			
	Thermostat	Temperature at which valve starts opening			65 or 71 ± 2°C (149 or 160 ± 3.6°F)			Check at atmospheric pressure.
		Temperature at which valve lift is more than 10 (0.39), minimum			80 or 85 ± 2°C (176 or 185 ± 3.6°F)			
Fuel system	Fuel injection nozzles	Injection pressure (valve opening pressure), kgf/cm² (psi) [MPa]			250^{+5}_{0} (3555^{+71}_{0}) – [$24.5^{+0.5}_{0}$]			
		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		No leakage shall occur when a pressure 20 kgf/cm² (284 psi) [2 MPa] lower than valve opening pressure is applied to needle valve for 10 seconds.				
Electrical system	Starters	Bracket	Inside diameter of bearing	Front	19 (0.75)			19.2 (0.756)	
				Center	28 (1.10)			28.2 (1.110)	
			Bore for bearing	Gear case	52 (2.05)			52.1 (2.051)	
				Rear of bracket	32 (1.26)			32.1 (1.264)	
		Commutator diameter			40 (1.57)			38 (1.50)	
		Commutator runout				0.05 (0.0020)		0.10 (0.0039)	
		Mica depth				0.5 to 0.8 (0.020 to 0.031)		0.20 (0.0079)	
		Brush height				20 (0.79)		14 (0.55)	
		Brush spring tension, kgf (lbf) [N]				1.4 (3.1) [13.7]		1.0 (2.2) [9.8]	

Unit: mm (in.)

Group	Inspection point			Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Electrical system	Starters	Engage switch	Resistance in P coil		0.1 to 0.3Ω			
			Resistance in h coil		1.5 to 2.5Ω			
			Deflection of contactor spring		1.0 to 2.0 (0.04 to 0.08)			
			Thickness of contact piece: M, B		7 (0.28)		6.7 (0.26)	Replace every 3 years.
			Thickness of contact piece: Main		5 (0.20)		4.7 (0.19)	Replace every 3 years.
		Pinion	Clutch slipping torque, kgf·cm (lbf·ft)[N·m]	—	6 to 8 (0.4 to 0.6) [0.6 to 0.8]		9(0.7)[0.9], minimum 5(0.4)[0.5], maximum	
			Inside diameter of bearing	19.1 (0.752)			19.3 (0.760)	
		Output shaft	Outside diameter (bearings): At center	28 (1.10)			27.90 (1.098)	
			Outside diameter (bearings): At pinion	19 (0.75)			18.92 (0.745)	
			Outside diameter (bearings): At front	19 (0.75)			18.92 (0.745)	
			Runout		0.05 (0.0020)		0.10 (0.0039)	
			Thrust gap		0.1 to 0.3 (0.004 to 0.012)			Adjust at assembly.
		Insulation resistance	Armature and field		1MΩ		0.5MΩ	Measure with a 500 V megger.
			Brush holder		1MΩ		0.5MΩ	Measure with a 500 V megger.
		Pinion gap			0.5 to 1.5 (0.020 to 0.059)			
	Alternator	Slip ring outside diameter		41 (1.61)			40.4 (1.59)	
		Brush height			23 (0.91)		8 (0.31)	Up to wear limit line
		Brush spring tension, kgf (lbf) [N]			0.32 to 0.44 (0.7 to 1.0) [3 to 4]		0.20 (0.4) [2]	

2. TIGHTENING TORQUES

2.1 Major bolts and nuts

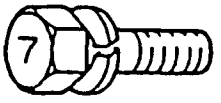
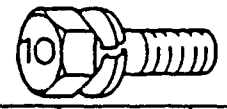
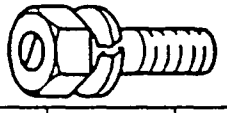
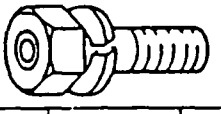
Description	Thread dia. x pitch, mm	Width across flats, mm	Torque			Remarks
			kgf-m	lbf-ft	N-m	
Cylinder head bolt	18 x 2.5	24	36	260	353	[Wet]
Rocker shaft brackets	10 x 1.5	14	6	43	59	
Main bearing cap bolts	22 x 2.5	32	56	405	549	[Wet]
Main bearing cap side bolts	16 x 1.5	22	15	108	147	[Wet]
Oil jet	12 x 1.75	17	3.5	25	34	
Timing gear case	12 x 1.25	17	7.6	55	75	
Oil pan	10 x 1.25	14	3.6	26	35	
Mounting brackets	12 x 1.25	17	7.6	55	75	
Connecting rod bearing caps	16 x 1.5 -	26	28	203	275	[Wet]
Crankshaft pulley, damper	22 x 1.5	32	40	290	392	
Flywheel	22 x 1.5	32	55	398	539	[Wet]
Exhaust manifolds	10 x 1.5	14	6 to 8	43 to 58	59 to 78	
Camshaft gear	30 x 1.5	50	30	217	294	
Fuel injection pump gear	24 x 1.5	41	22	159	216	
Idler gear shaft (bolt)	16 x 1.5	24	12	87	118	
Idler gear shaft (nut)	16 x 1.5	24	10	72	98	
Oil pump idler gear	12 x 1.25	17	6 to 8	43 to 58	59 to 78	Apply LOCTITE 262 to threads
Oil pump cover	10 x 1.25	14	3.4	25	33	[Wet]
Water pump pulley	22 x 1.5	32	16	116	157	
Water pump cover	10 x 1.25	14	3.3	24	32	
Fuel injection pump coupling	12 x 1.5	17	9 to 9.5	65 to 69	88 to 93	
Fuel injection pump coupling shaft	12 x 1.5	10	9 to 9.5	65 to 69	88 to 93	Hex socket
Gland (injection nozzle holder)	10 x 1.25	14	3.7	27	36	
Injection nozzle holder set screw cap nuts	14 x 1.0	19	4 to 5	29 to 36	39 to 49	
Injection nozzle tip retaining nuts	19 x 0.75	19	6 to 8	43 to 58	59 to 78	
Injection nozzle inlet connector	14 x 1.5	14	6 to 7	43 to 51	59 to 69	

Note: (a) Apply engine oil to threads of parts specified to be [Wet].

(b) Tighten main bearing cap bolts and side bolts as described in page 122.

(c) Tighten connecting rod bolts in two steps as described in page 92.

2.2 Standard bolts and nuts

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

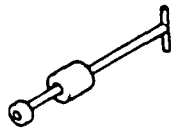
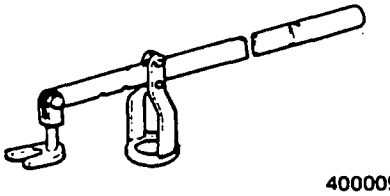
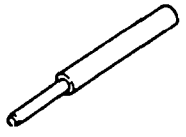
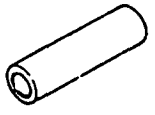
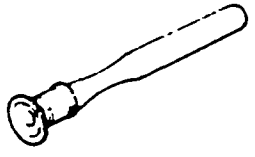
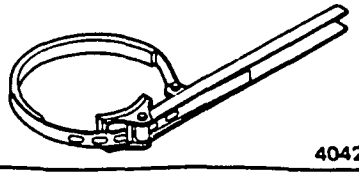
Remarks: (a) Use these torques for bolts and nuts with spring washers.
(b) The tolerance of these torques is ±10%.
(c) Do not coat threads with oil.

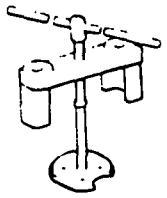
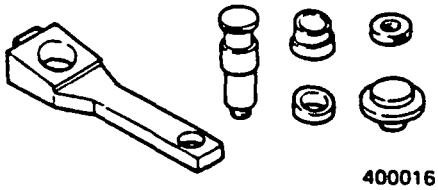
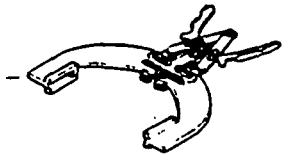
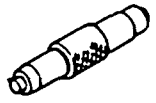
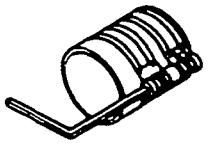
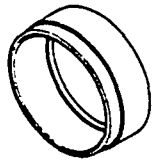
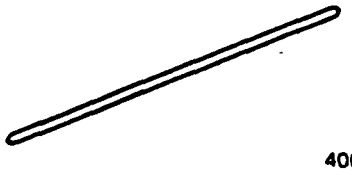
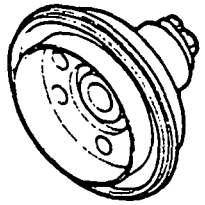
3. SEALANTS AND LUBRICANTS

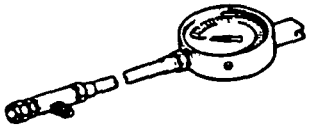
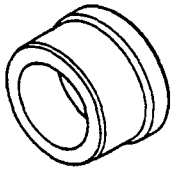
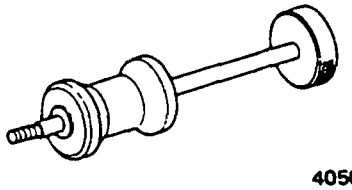
Group	Application point		Sealant or lubricant	How to use
Engine proper	Cylinder head sealing caps		HERMESEAL S-2	Apply to holes in crankcase.
	Cylinder liners		Three Bond 1104	Apply to top of each liner and joint surfaces of crankcase.
			Liquid soap	Apply to O-ring.
	Front cover		Three Bond 1104	Apply to joint surfaces of crankcase.
	Rear plate, gear case, oil pan and crankcase		HERDITE	Apply to three joint surfaces. (Oil pan packing)
	Front cover, crankcase and oil pan			
	Crankcase sealing caps		Three Bond 1104	
	Oil pan packing		HERDITE	Apply to joint surfaces only of packings.
	Oil seals		Engine oil	Apply to lip of each oil seal.
Lubrication system	Oil pump	Pump idler gear shaft and nut	LOCTITE 262	Apply to threads.
		Relief valve plug and connector		
Cooling system	Water pump	Unit seal	Three Bond 1102	Apply to periphery.
		Oil seal	Engine oil	Apply to lip only of inner seal.
Others	Taper plugs and cocks not precoated with Three Bond thread sealants		Vulcanized sealing tape	Wrap threads with 2 turns of tape.

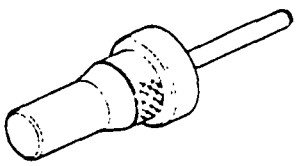
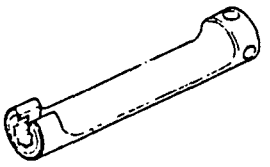
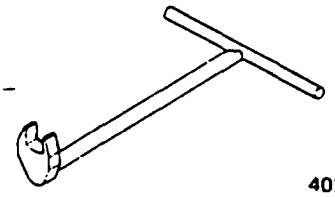
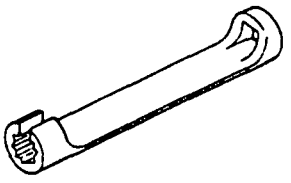
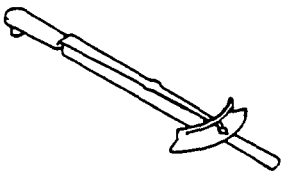
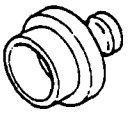
SPECIAL TOOLS

SPECIAL TOOL LIST

Tool name	Part No.	Shape	Use
Nozzle remover	36291-00900	 400007	Injection nozzle removal
Valve spring pusher	33591-04500	 400009	Valve spring removal/ installation
Rocker bushing puller	MH061236	 402655	Rocker bushing removal/ installation
Valve guide remover	36291-04200	 400011	Valve guide removal
Valve guide & seal installer	32591-10300	 400012	Valve guide and valve stem seal installation
Valve lapper	30091-07500	 400013	Valve lapping
Snap ring pliers	45191-08400	 400014	Snap ring removal/ installation
Oil filter wrench	32591-02100	 404201	Oil filter cartridge, fuel filter cartridge and corrosion resistor cartridge removal

Tool name	Part No.	Shape	Use
Cylinder liner remover	36291-03100	 400015	Cylinder liner removal
Connecting rod bushing installer	37191-08000	 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
Oil seal slinger installer	34A91-04100	 405704	Front oil seal slinger installation
Turning bar	32091-01500	 400022	Engine turning
Oil seal installer	34A91-04020	 404942	Rear oil seal installation

Tool name	Part No.	Shape	Use
Compression gauge adaptor	36291-02200	 400023	Compression pressure measurement
Compression gauge	33391-02100	 400902	Compression pressure measurement
Socket	58309-73100	 400903	Fan pulley cap nut removal/installation
Cam bushing installer	34A91-02100	 405705	Cam bushing removal/ installation
Adjustable wrench	F9611-15000	 400905	
Slide hammer	40691-03100	 405094	Main bearing cap removal

Tool name	Part No.	Shape	Use
Valve seat calking tool	Inlet 36291-05010 Exhaust 36291-05020	 670232	Valve seat installation and calking
Socket wrench	36291-00401	 402664	Fuel pipe removal/ installation
T wrench	36291-00700	 402665	Fuel pipe removal/ installation (injection nozzle side)
Socket wrench	36291-00800	 402666	Leak-off pipe removal/ installation
Torque wrench	32191-03200	 402667	
Cylinder liner installer	36291-03200	 402662	Cylinder liner installation
Injection nozzle tester	04329-00012 or 04329-00050	 402669	Nozzle valve opening pressure measurement

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.

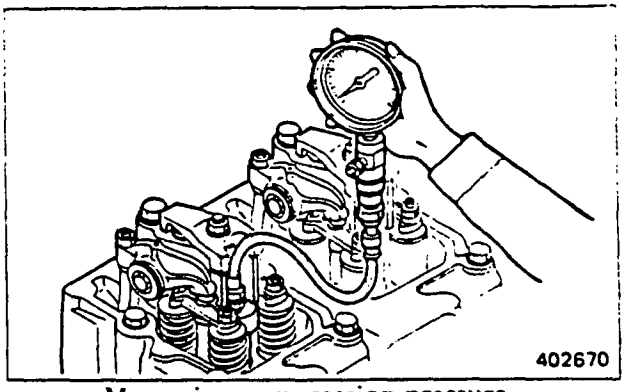
2. TESTING THE COMPRESSION PRESSURE

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

(2) Attach adaptor (36291-02200) to the cylinder, and connect 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/cm² (psi) [MPa]

Item	Assembly standard	Repair limit
Compression pressure	28 (398) [2.7]. minimum	19 (270) [1.9]. maximum

NOTE

Measure the compression pressure with the engine running at 160 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

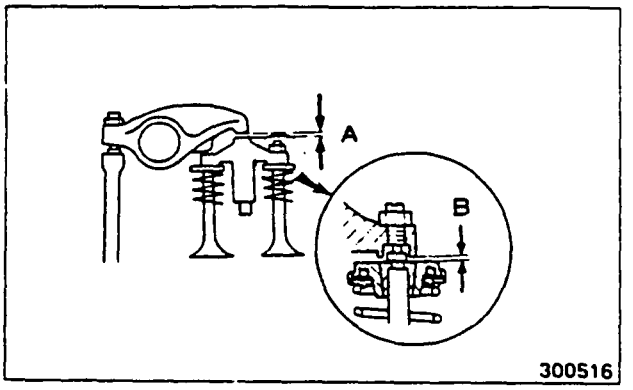
1. ADJUSTMENTS

1.1 Valve clearance

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

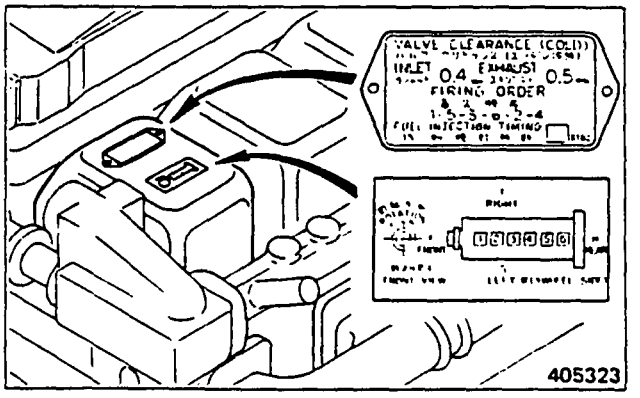
Unit: mm (in.)

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



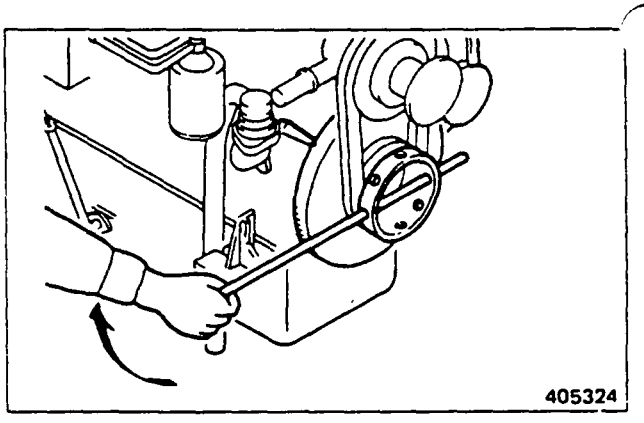
NOTE

If the bridge-to-valve rotator clearance (B) is less than the assembly standard, grind the bridge and valve rotator to obtain a clearance of more than 0.5 mm (0.020 in.) between the two.



(1) Inspection

(a) Check the valve clearance in the firing order (injection sequence), by turning the crankshaft (120°) in the normal direction at a time to bring the piston to its top dead center on compression stroke.

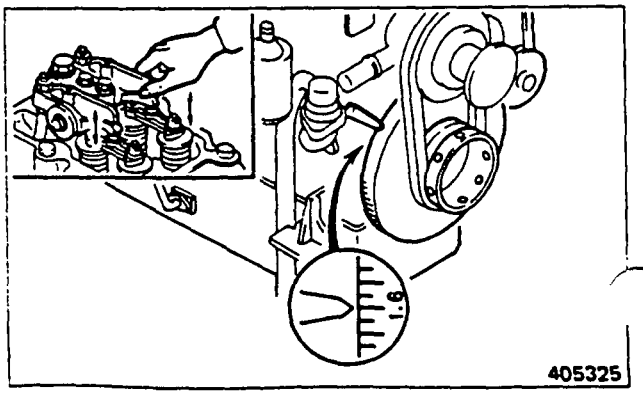


Firing order (injection sequence)

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 vibration damper) being aligned with the pointer. With the piston so located, the inlet and exhaust valve rocker arms are not being pushed up by their pushrods.

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

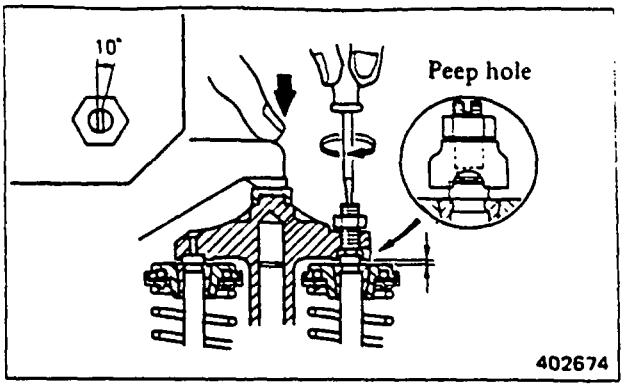


(2) Adjusting valve heights by means of valve bridge

(a) Before adjusting the valve clearance, adjust and equalize the heights of the two valves by bringing the bridge into contact with the tops of their stems. If the seat for one valve is more worn than that for the other, for example, the valve heights become unequal to produce some clearance between the bridge and the stem of a less worn valve, resulting in difference in height (clearance) between the two valves. This is the reason why the valve heights should be equalized in advance. It is not necessary to make this adjustment often. To adjust, proceed as follows:

(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, making sure that the screw comes in contact with the valve stem top by looking into the peep hole. From that position, further turn in the screw about 10° of rotation, and tighten the lock nut.



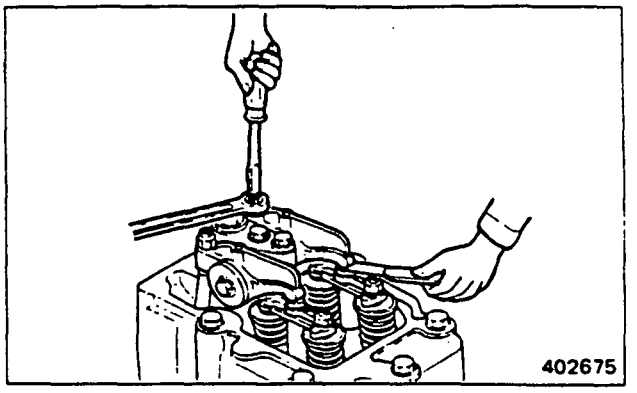
⚠ CAUTION

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

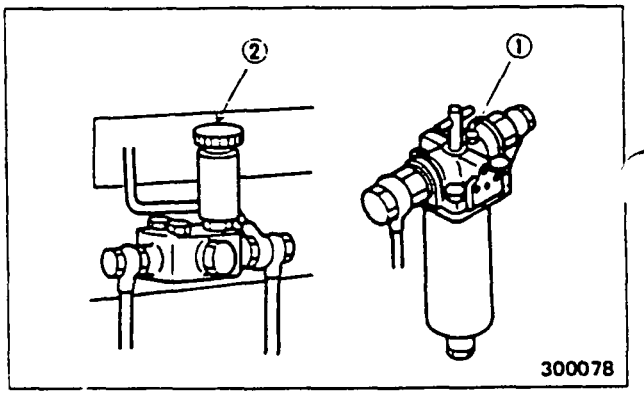
Prime the fuel filters and fuel injection pump in that order.

(1) Fuel filter (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 hole without bubbles.

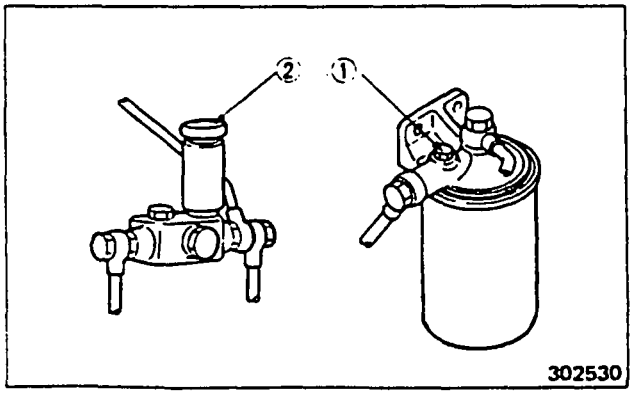


(2) Fuel filter (paper-element type)

(a) Loosen air vent plug (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 hole without bubbles.

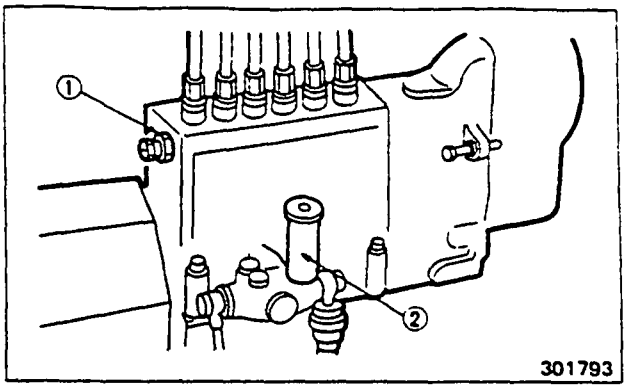


(3) Fuel injection pump

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

(b) Operate the priming pump (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

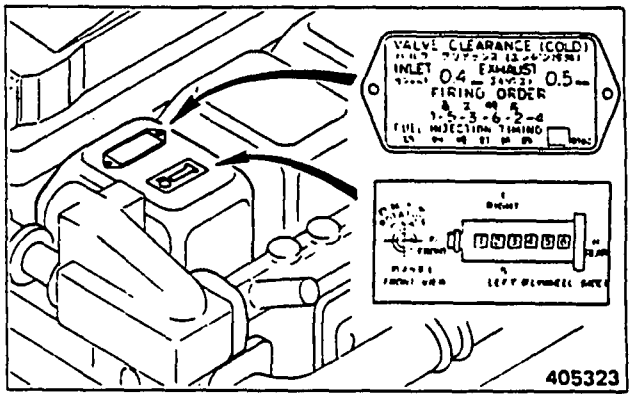
(a) If all vent plugs are tightened before the priming pump is locked, fuel pressure acts on the feed pump, making it impossible to restore the pump to the original position.

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

1.3 Fuel injection timing

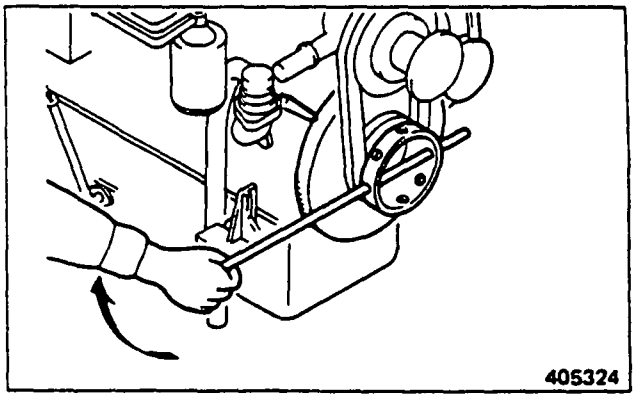
(1) Fuel injection timing and indication

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.

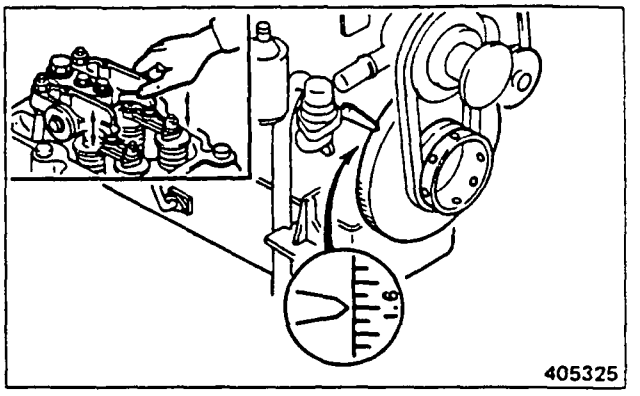


(2) Bringing No. 1 piston to top dead center on compression stroke

(a) Put the turning bar (32091-01500) to the crank pulley, and 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.



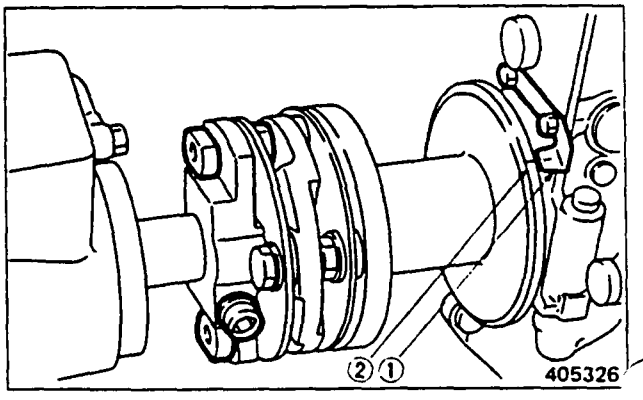
(c) Move the No. 1 cylinder inlet and exhaust valve rocker arms up and down to make sure that they are not being pushed up by their pushrods.

⚠ CAUTION

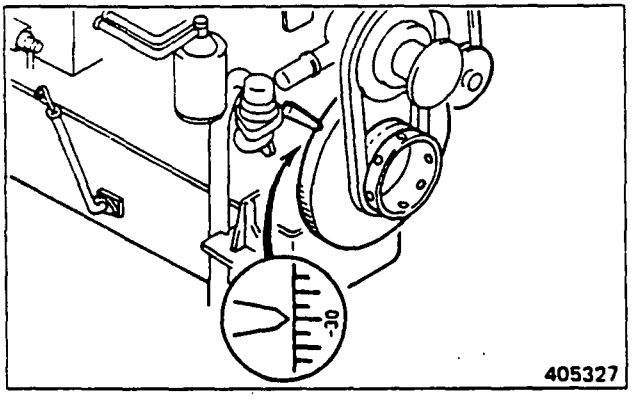
Do not confuse the top dead center on compression stroke for No. 1 cylinder with that for No. 6 cylinder.

(3) Inspection

(a) Once turn the crankshaft about 60° in the reverse direction. Then, turn it 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.

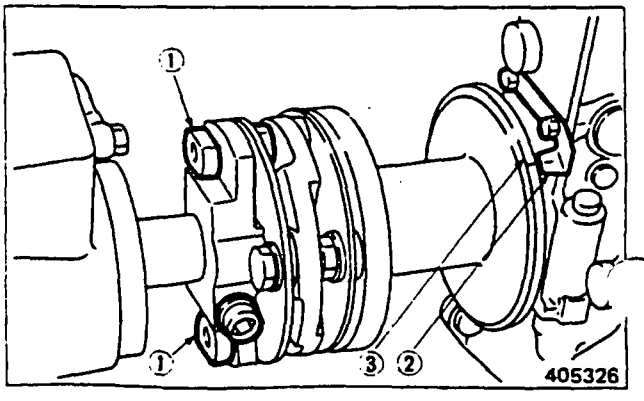


(b) Read the degrees of an angle (injection timing) on the scale on the vibration damper, indicated by the pointer. Minus (-) mark on the scale and "B.T.D.C." on the caution plate mean "BEFORE" top dead center.



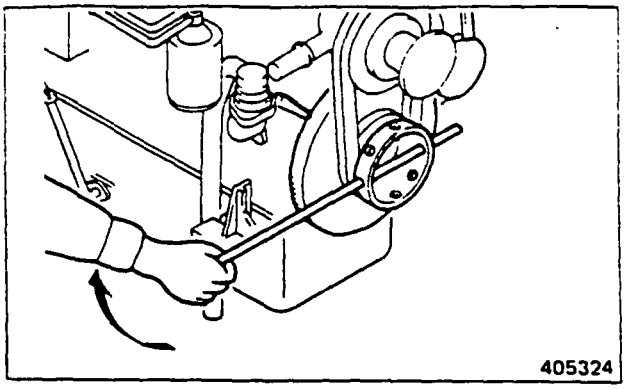
(4) Adjustment

(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 (idle) speed and maximum speed setting

⚠ CAUTION

(a) No-load minimum (idle) 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 external 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).

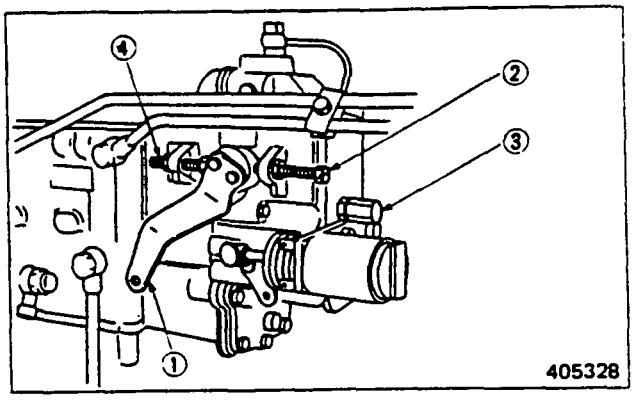
RSUV-type governor

(1) Engine starting

(a) Pull speed control lever (1) to high-speed side. Operate starter switch to crank the engine.

(b) At about 150 rpm of cranking speed, the engine will fire up to pick up speed. Immediately after the engine fires, move the speed control lever back to hold the speed anywhere between 800 to 1000 rpm.

(c) When the engine is noted to be running with a steady speed, move the speed control lever back to the low idle speed position.

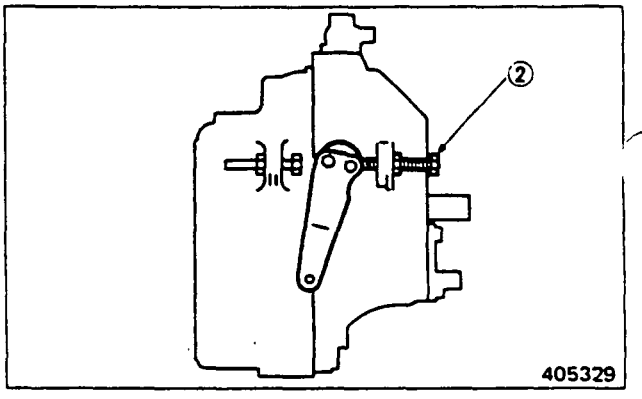


(2) Idle speed setting (setting for keeping the no-load minimum engine speed)

(a) Hold the speed control lever at the position for permitting the engine to run at 600 to 700 rpm, and set the low idle speed set bolt (2).

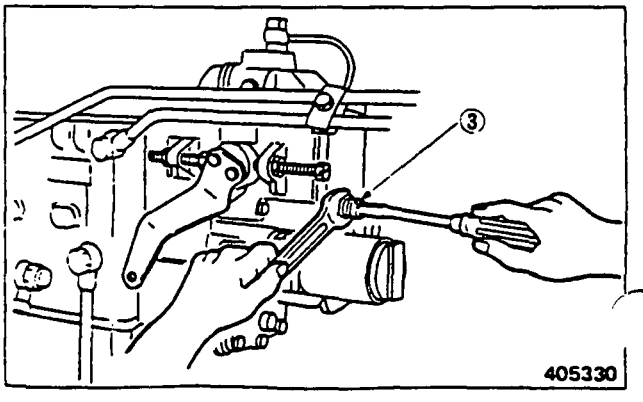
⚠ CAUTION

If a critical speed (the speed at which the engine exhibits excessive vibration due to torsional resonance) might exist, shift the idle speed setting to a lower or higher idle speed level.



(b) Turning the low idle speed set bolt clockwise increases the idle speed.

(c) If engine speed tends to fluctuate, turn the idle sub-spring adjusting screw (3) clockwise to push in this spring, making it come in slight contact with tension lever. With idle sub-spring exerting some force to the lever, the speed will rise slightly but will stop fluctuating.



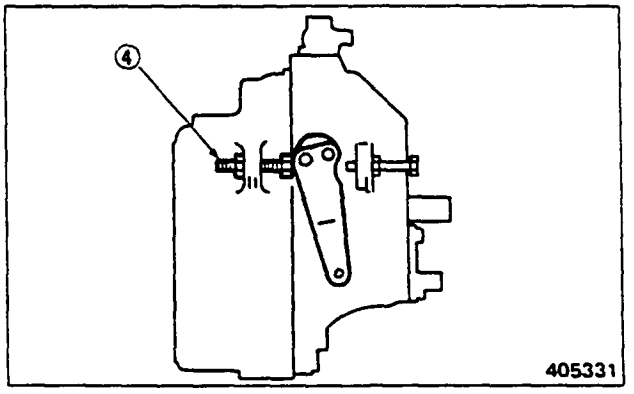
⚠ CAUTION

Tightening the idle sub-spring adjusting screw is likely to result in engine overspeeding when, during duty operation, the load is dumped. When tightening the adjusting screw, be sure to tighten it just enough to eliminate the unstable condition.

(3) Governor setting (setting for limiting maximum engine speed)

(a) Hold the speed control lever at the indicated maximum speed position while applying full load to the engine.

(b) Run in governor set bolt (maximum speed set bolt) (4) slowly until its forward end comes in contact with the speed control lever held as above. Secure the bolt right there by tightening its lock nut.

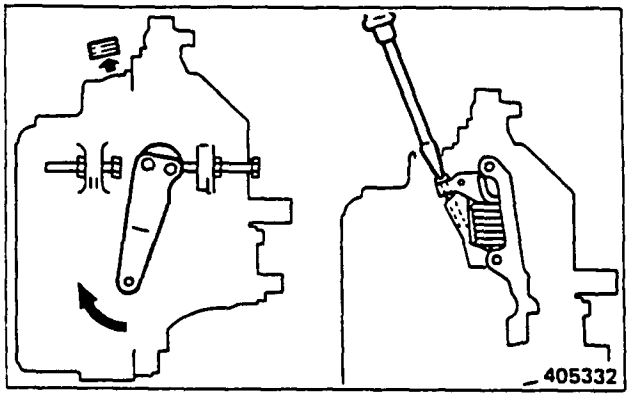


(4) Adjustment of speed regulation (governor notch)

(a) This adjustment is to be made by turning the adjusting screw for swivel lever to increase or decrease the pre-tension of governor spring.

(b) To gain access to the adjusting screw, remove the plug at the top of governor housing, and turn the speed control lever all the way to the low idle speed set bolt: this will turn up the swivel lever, pointing the head of the adjusting screw toward the plug hole. Insert a flat-tip screwdriver through the hole to catch the screw head.

(c) Tightening the adjusting screw increases the pre-tension of governor spring to narrow the speed regulation; loosening it decreases the governor spring pre-tension to widen the regulation.



One notch corresponds to 1/4 turn of adjusting screw and to 3 to 5 rpm change of engine speed.

(d) Changing the setting of this adjusting screw changes the governor setting (for limiting the maximum engine speed). After making a governor notch adjustment, be sure to re-adjust the governor setting.

(e) Tightening the adjusting screw, mentioned above, will increase the maximum speed, and vice versa.

⚠ CAUTION

The adjustable range is 20-notch (5 turns) long. Never loosen the screw by more than 20 notches from the fully tightened position or the control action of the governor will become hazardous.

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.

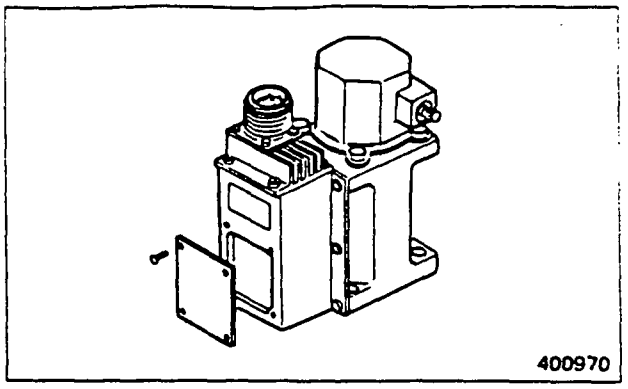
(d) Turn "SPEED" potentiometer within 20 turns until the specified engine speed is obtained. This potentiometer can be turned clockwise to increase the speed or counterclockwise to decrease it, but it has no stopper for limiting the rotation in either direction.

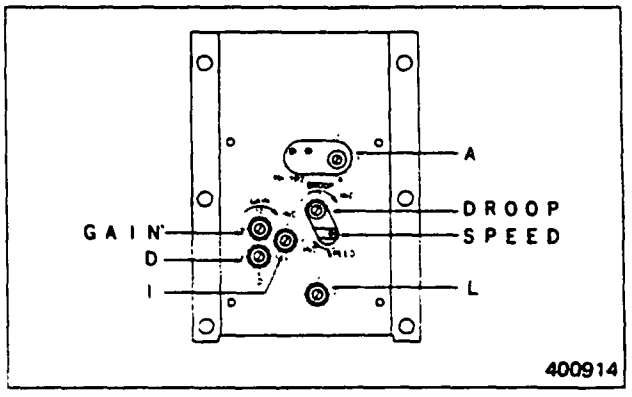
(e) Set the indicated horsepower by means of the rack set bolt.

(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 counter-clockwise 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 counter-closckwise. If the actuator is in stable condition, slowly turn "GAIN" potentiometer clockwise until hunting occurs; then, slowly turn it counterclockwise until hunting stops.





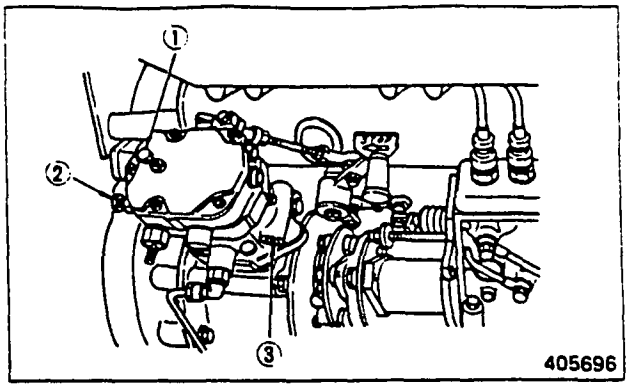
Potentiometer

(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) Inspecting and adjusting idle speed

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

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

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

(a) Move the speed control lever to 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

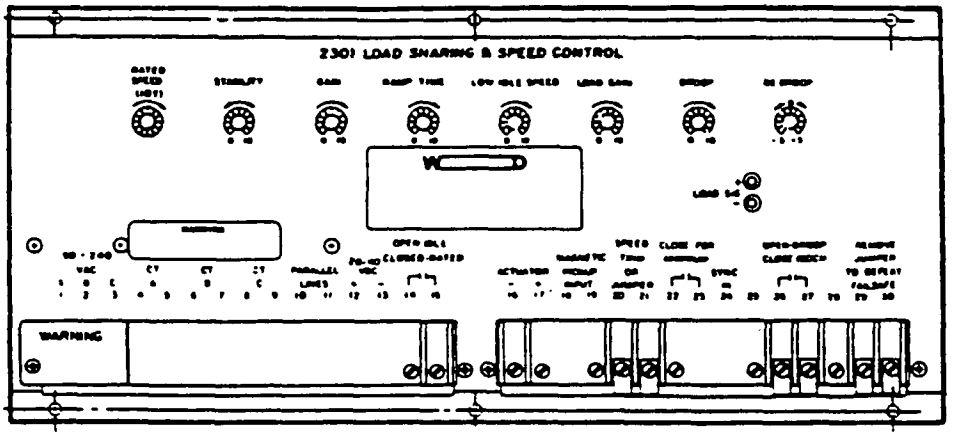
(a) If the engine hunts, reset needle valve (3). Open the needle valve by turning it counterclockwise (2 to 3 turns) until the engine hunts. Keep the engine hunting for about 30 seconds until air is vented from the governor.

(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 turn from the fully closed position.

(d) Seal each set bolt.

Woodward 2301 load sharing & speed control device (for EG-3P governor)



400912

(1) Adjusting idle 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 idle 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.

(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.

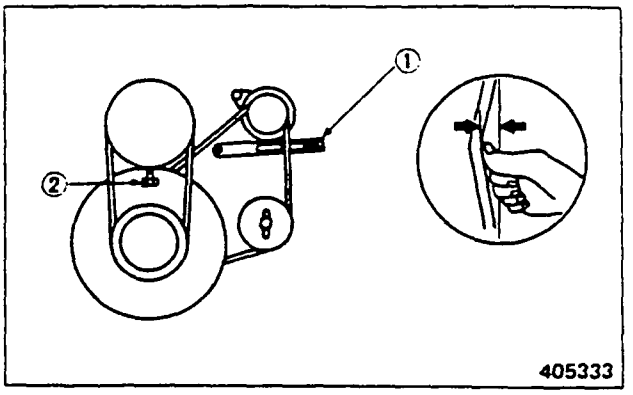
(c) To verify the engine (governor) stability, change the load on the engine in steps, or quickly move the fuel control linkage. If the stability cannot be gained by turning "STABILITY" potentiometer, turn "GAIN" potentiometer counterclockwise. Turn "GAIN" potentiometer clockwise if low-pitch hunting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

Apply thumb pressure to the belt midway between the pulleys to inspect 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	20 to 25 (0.8 to 1)
	Water pump and alternator	

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 "full injection" position.)

(4) After the engine starts, let it idle under no-load condition by operating the speed 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], minimum at idle speed.

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

(3) Lubricating oil temperature:
It should be 60°C to 80°C (140°F to 176°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	Idle speed	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

(2) No-load maximum speed

(3) No-load minimum speed

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. START BY:

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

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

(c) loosen the oil pan drain plug, and drain engine oil.
[Oil capacity: 40 liters (10.6 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

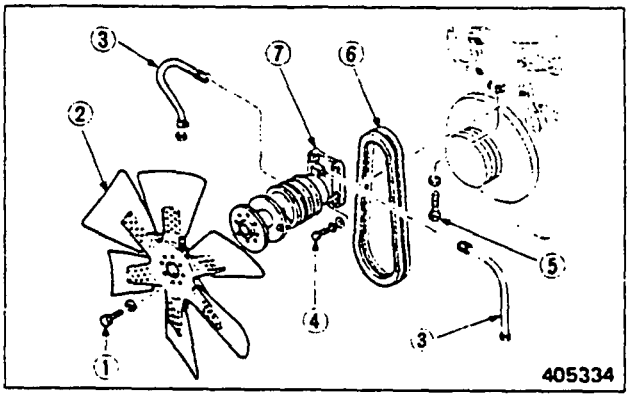
(1) Removing fan drive

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

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

(c) Loosen bracket mounting bolt (4). Back off adjusting bolt (5) to slacken belt (6).

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

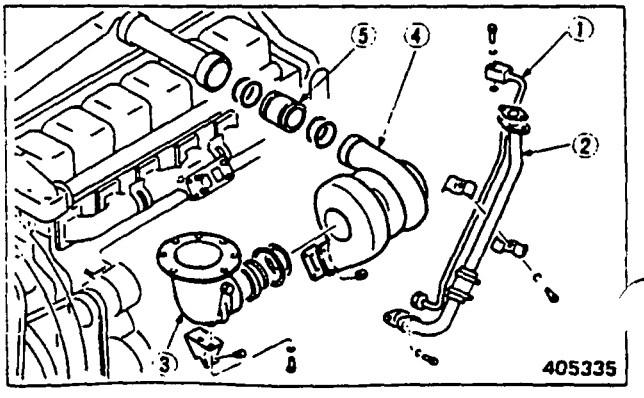


(2) Removing turbocharger

(a) Disconnect lubricating oil pipe (1) and drain pipe (2) from the turbocharger.

(b) Remove exhaust pipe (3) and turbocharger (4).

(c) Remove joint (5) connecting air duct and turbocharger.

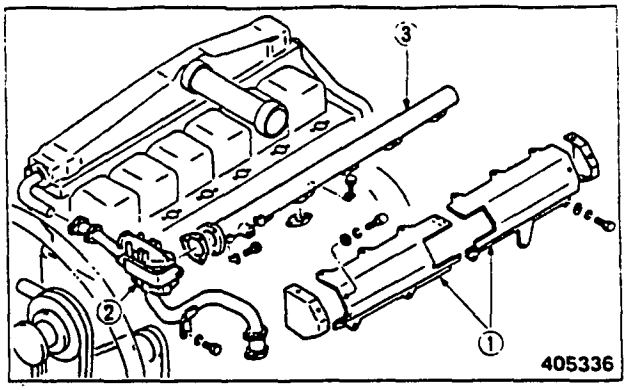


(3) Removing insulator, thermostat case and water pipes

(a) Remove 2-piece type insulator (1).

(b) Remove thermostat case (2).

(c) Remove water outlet pipe (3) by unscrewing its mounting bolts.

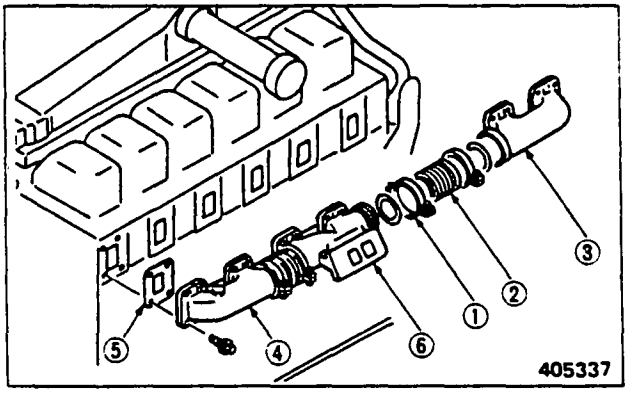


(4) Removing exhaust manifolds

(a) Remove coupling (1) and joint (2).

(b) Unscrew the manifold mounting bolts, and remove manifolds (3) (4) and gaskets (5).

(c) Remove manifold (6) and gasket.



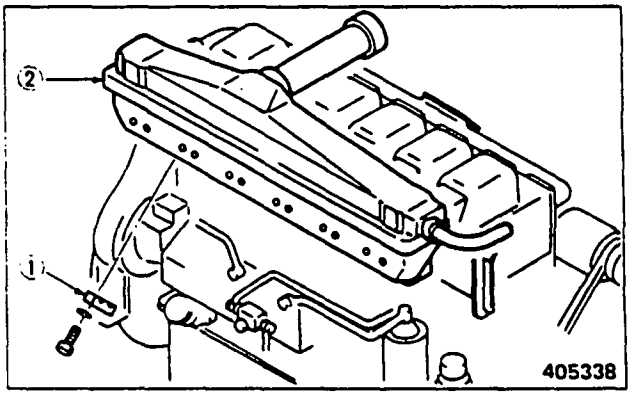
NOTE

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

(5) Removing air cooler

(a) Remove pipe clamp (1).

(b) Unscrew air cooler mounting bolts, and remove air cooler (2).



NOTE

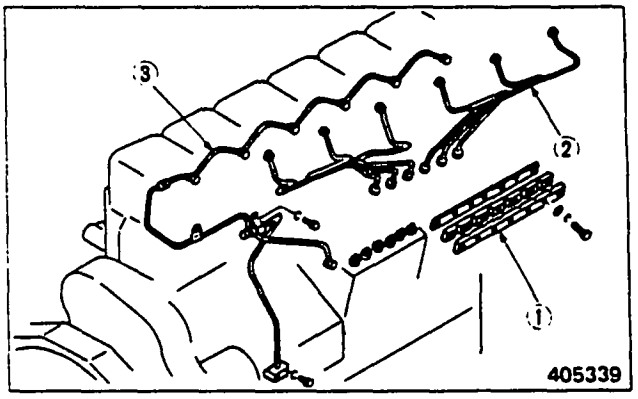
Coolant in the air cooler will be drained by opening the drain cock on the crankcase.

[Air cooler weight: 34 kg (75 lb)] approx.]

(6) Removing fuel pipes and fuel leak-off pipe

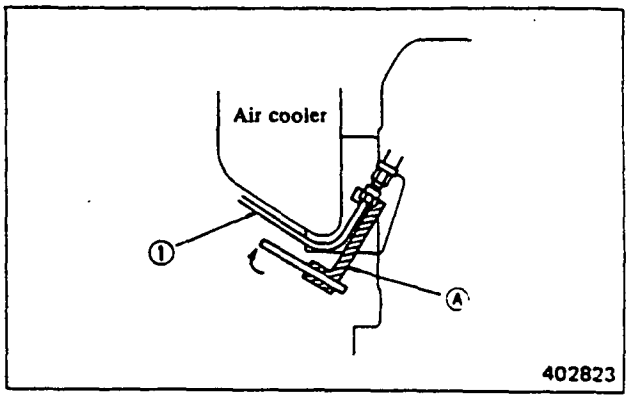
(a) Remove pipe clamp (1).

(b) Disconnect and remove six fuel pipes (2) and fuel leak-off pipe (3).



NOTE

When removing fuel pipes (1) with the air cooler mounted on the engine, use socket (A) (36291-00401).

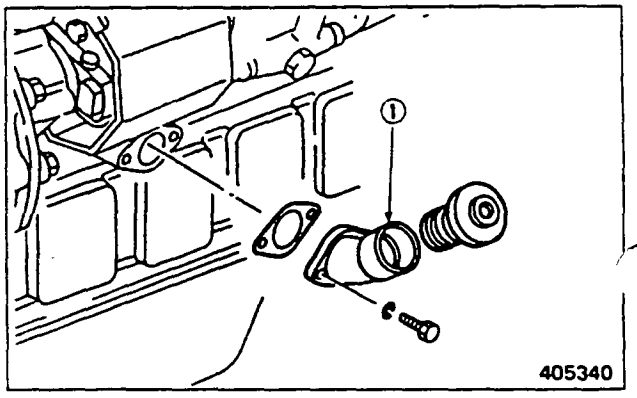


⚠ CAUTION

After disconnecting the injection pipes, be sure to fit rubber caps to the openings of the injection pump and nozzle holders to prevent dust from getting inside the fuel system.

(7) Removing oil filler

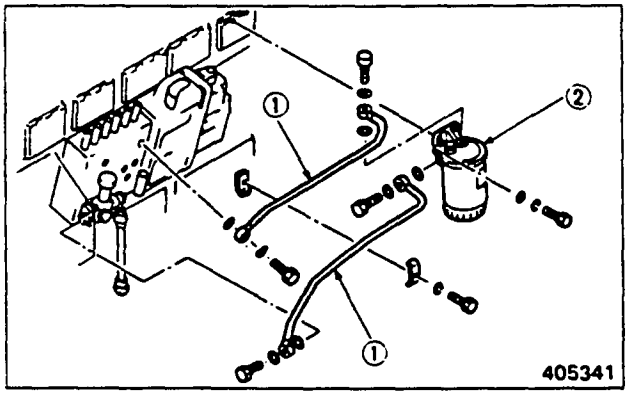
Remove oil filler (1) by unscrewing its mounting bolts.



(8) Removing fuel filter

(a) Disconnect fuel pipes (1) from filter (2).

(b) Remove fuel filter (2) by unscrewing its mounting bolts.



(9) Removing fuel injection pumps

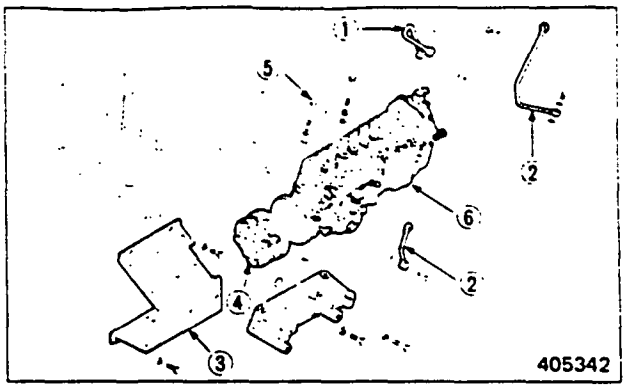
(a) Remove boost control pipe (1).

(b) Disconnect oil pipes (2) from the pump.

(c) Remove coupling cover (3).

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

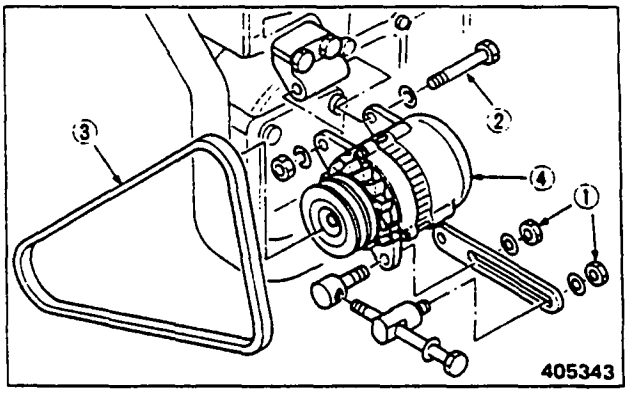
(e) Unscrew bolts (5) securing pump (6) to the engine. Remove the pump complete with the coupling by prying it toward the front side of the engine with a bar. [Weight: 25 kg (55 lb), approx.]



(10) Removing alternator

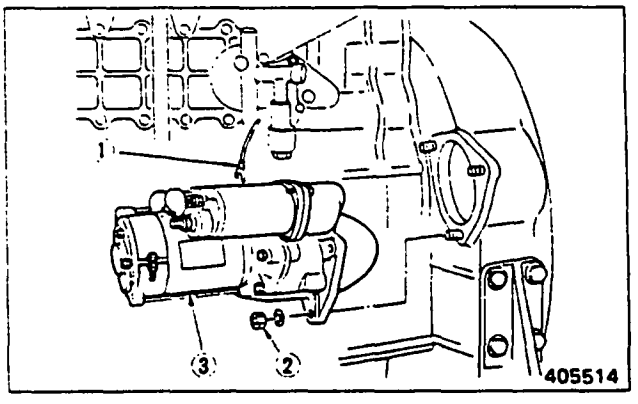
(a) Loosen nuts (1).

(b) Remove belt (3) and alternator (4) by unscrewing mounting bolts (2).



(11) Removing starter

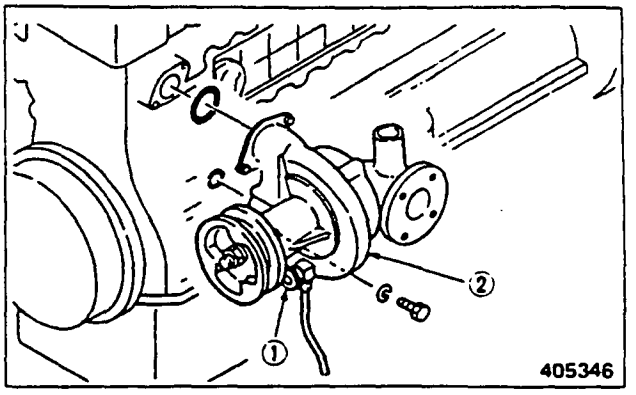
Disconnect harness (1), and remove starter (3) by unscrewing nuts (2). [Starter weight: 15 kg (33 lb), approx.]



(12) Removing water pump

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

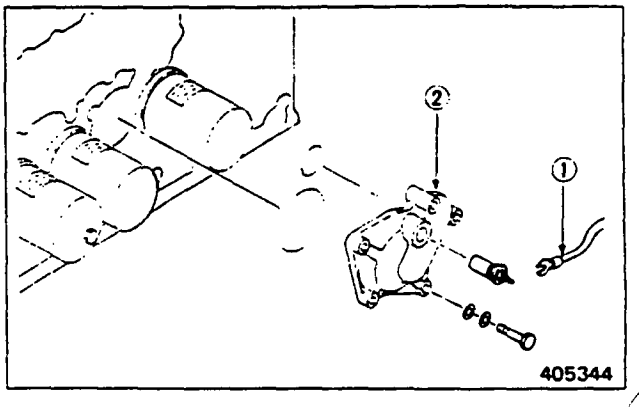
(b) Remove water pump (2) by unscrewing its mounting bolts.



(13) Removing oil filter cover

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

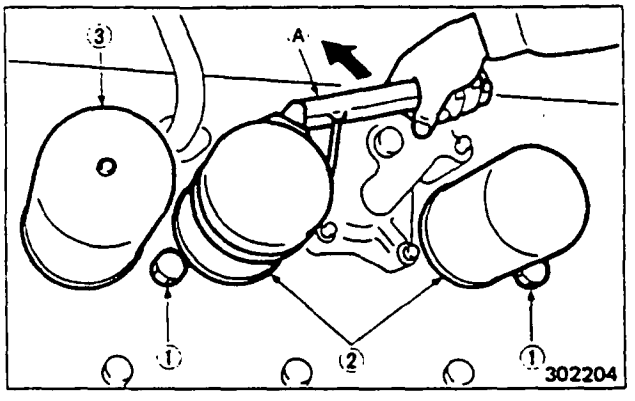
(b) Remove oil filter cover (2) by unscrewing its mounting bolts.



(14) Removing oil filters and bypass oil filter

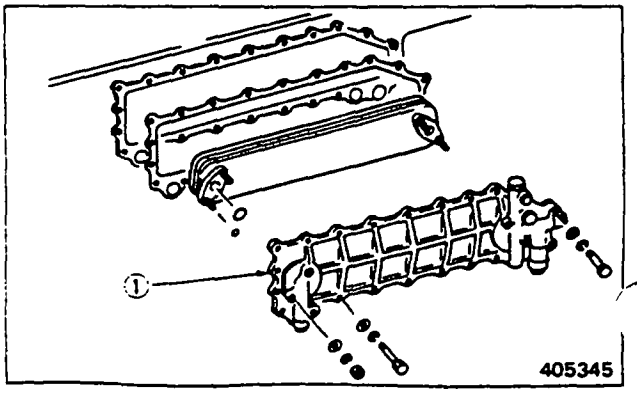
(a) Drain engine oil from the crankcase by removing drain plugs (1).

(b) Remove oil filters (2) and bypass oil filter (3) using oil filter wrench (A) (32591-02100).



(15) Removing oil cooler

Remove oil cooler (1) by unscrewing its mounting bolts.



3. ENGINE ACCESSORY INSTALLATION

Following the reverse of removal procedure.

END BY:

(a) refill the engine with recommended oil up to the specified level.

(b) refill the cooling system with coolant.

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

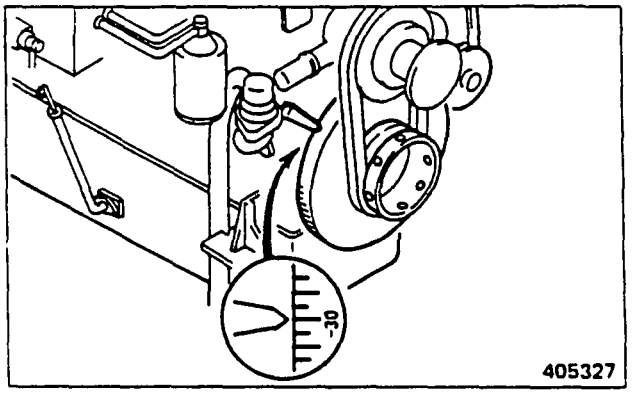
(d) prime the fuel system.

(e) after installing the fuel injection pump, check and adjust the injection timing. (Refer to 1.3, Group No. 5.)

Fuel Injection Pump Installation

To install the injection pump, proceed as follows:

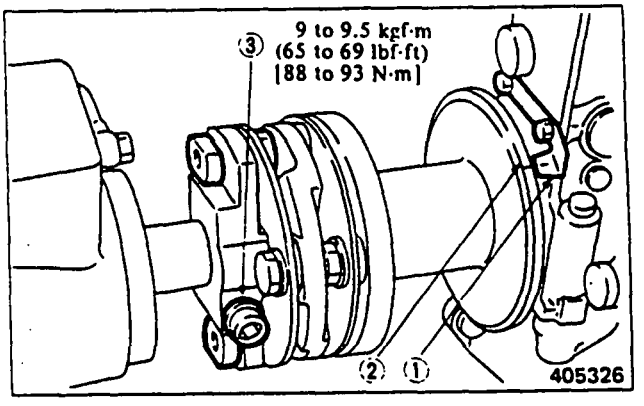
(a) Make sure the pointer on the engine is aligned with No. 1 cylinder injection timing (beginning-of-injection) mark on vibration damper.



NOTE

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

(b) Install the coupling to the injection pump and align the pointer (1) on the pump case with mark (2) on the coupling.



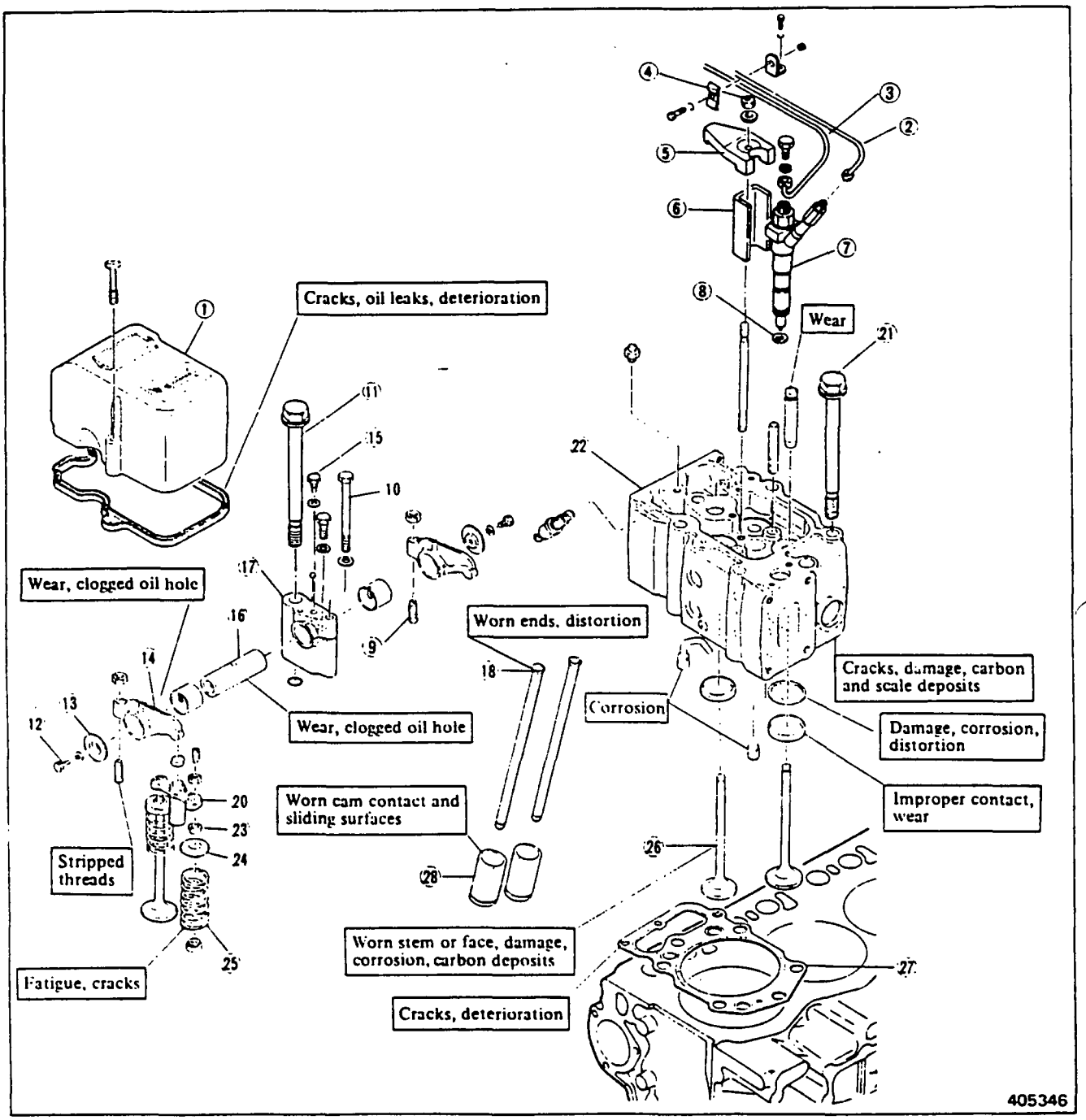
(c) Fit the key of drive shaft into the keyway in the coupling, push in the injection pump toward the drive case and install it to the bracket. Tighten bolts (3) securing the coupling to the shaft to the specified torque.

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

ENGINE PROPER

1. CYLINDER HEADS AND VALVE MECHANISM

1.1 Disassembly

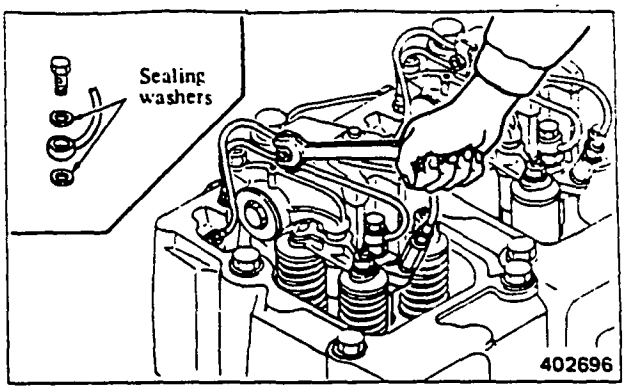


① Rocker cover
② Fuel pipe
③ Fuel leak-off pipe
④ Nut, washer
⑤ Injection nozzle gland
⑥ Spacer
⑦ Injection nozzle
⑧ Packing
⑨ Adjusting screw
⑩ Bolt
⑪ Cylinder head bolt
⑫ Bolt, washer
⑬ Thrust plate
⑭ Rocker
⑮ Set screw
⑯ Rocker shaft
⑰ Rocker shaft bracket
⑱ Valve pushrod
⑲ Valve bridge cap
⑳ Valve bridge
㉑ Cylinder head bolt
㉒ Cylinder head
㉓ Valve cotter
㉔ Valve rotator
㉕ Valve spring
㉖ Valve
㉗ Cylinder head gasket
㉘ Tappet

(1) Removing fuel pipes

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

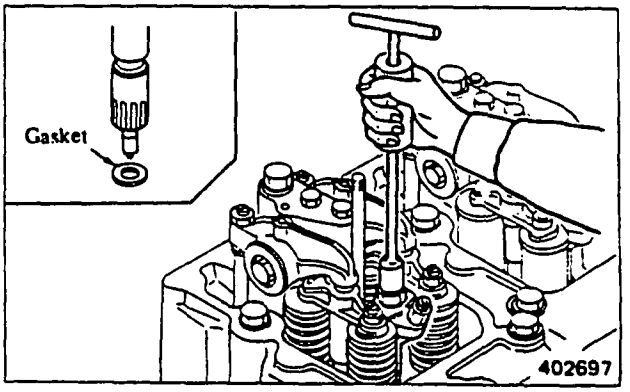
(b) Remove the nozzle-side sealing washers, and set them aside so as not to lose them.



(2) Removing injection nozzles

(a) Using injection nozzle remover (A) (36291-00900), remove each injection nozzle. Take out the gasket left behind in the cylinder head.

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

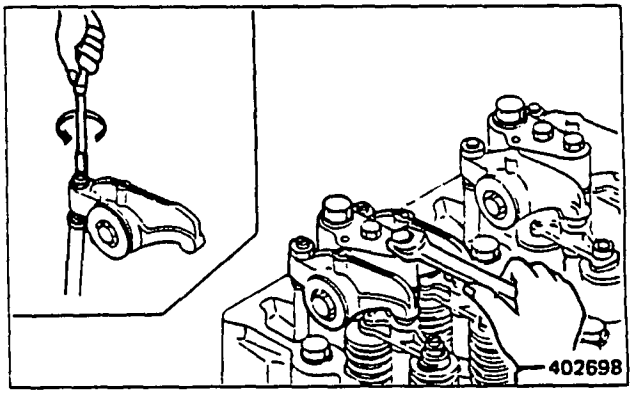


(3) Removing rocker shaft assemblies

(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.

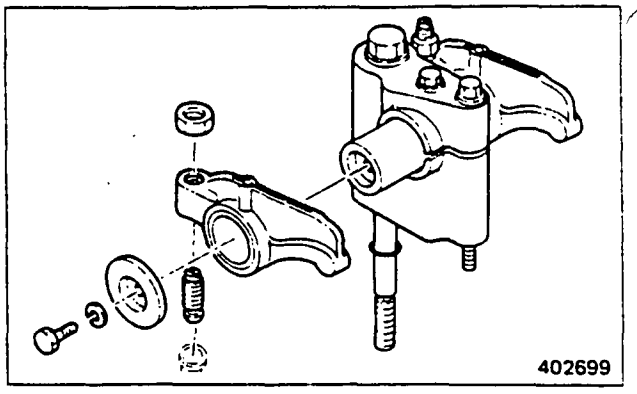


NOTE

Be careful not to let any valve bridge cap or lower O-ring for rocker bracket fall into crankcase through valve pushrod hole.

(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.

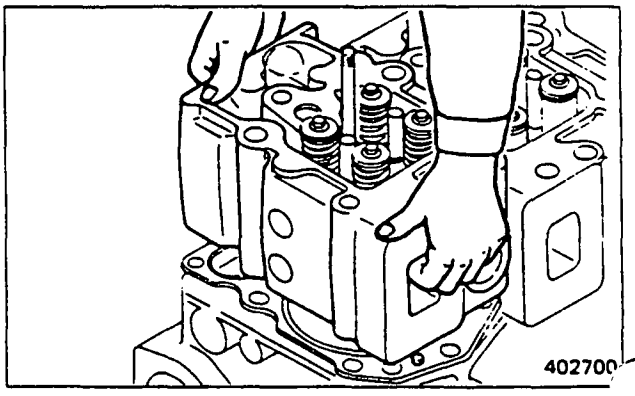


(5) Removing cylinder head assemblies

Each cylinder head is located on the crankcase with dowel pins. Lift the head off the crankcase.
[Cylinder head weight: 20 kg (44 lb), approx.]

⚠ CAUTION

Be careful not to damage the cylinder head and crankcase surfaces when removing the gasket.

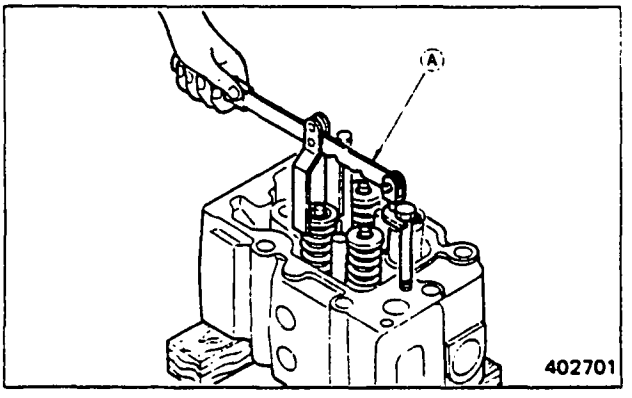


(6) Removing valves and valve springs

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



(7) Removing studs, connectors, etc.

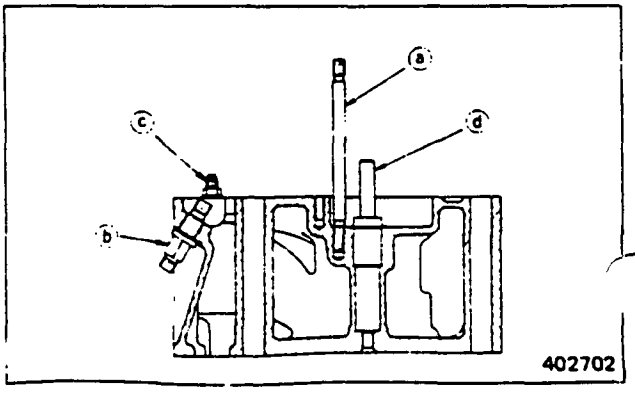
Do not remove the following parts from the cylinder head unless absolutely necessary. If any of these parts has been removed, apply sealant to the studded-side threads of the part when installing it to the cylinder head, or install a new part.

(a) Stud for injection nozzle holder

(b) Connector for high-pressure fuel pipe

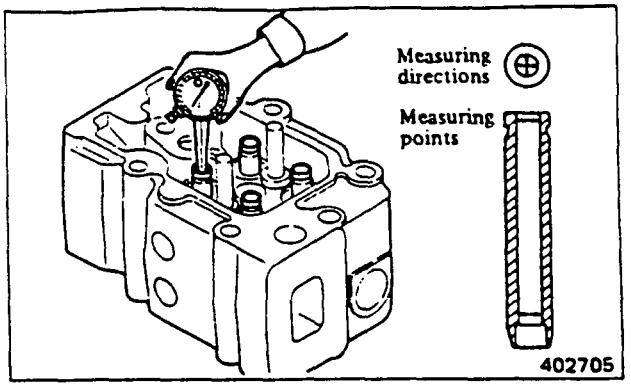
(c) Connector for return fuel pipe

Do not remove bridge guide (d) except when replacing the valve guide.



Unit: mm (in.)

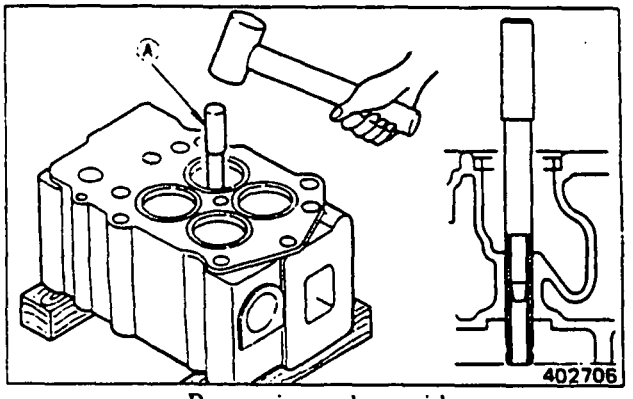
Item		Nominal value	Assembly standard	Service limit
Valve stem diameter	Inlet	10 (0.39)	9.940 to 9.960 (0.39134 to 0.39213)	9.910 (0.39016)
	Ex-haust		9.910 to 9.930 (0.39016 to 0.39094)	9.880 (0.38898)
Valve guide inside diameter			10.000 to 10.015 (0.39370 to 0.39429)	10.060 (0.39606)



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.



Removing valve guide

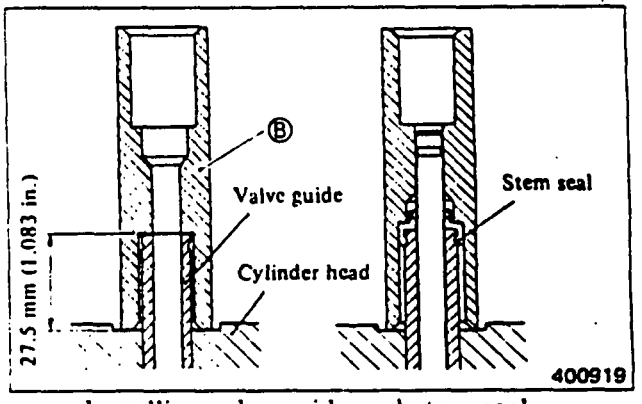
(b) Using valve guide & seal installer (B) (32591-10300), install a new guide slowly with a press.

⚠ CAUTION

(a) The height to top of valve guide is specified; be sure to use the valve 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.



Installing valve guide and stem seal

1.2 Inspection and repair

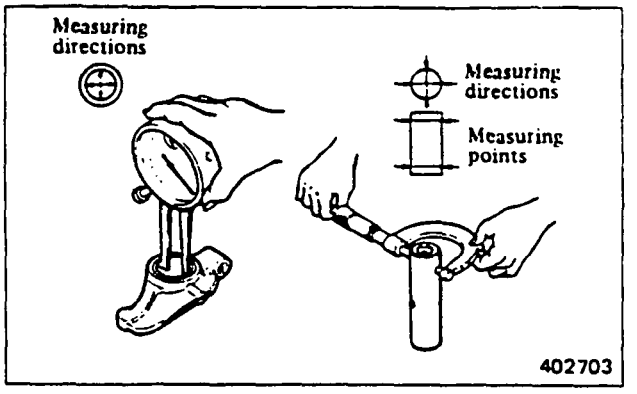
Rockers, rocker bushings and rocker shafts

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

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

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Rocker bushing inside diameter	28 (1.10)	28.070 to 28.090 (1.10512 to 1.10590)	28.150 (1.10827)
Rocker shaft diameter		27.972 to 27.993 (1.10126 to 1.10208)	27.930 (1.09960)



Measuring rocker bushing and rocker shaft

(2) Replacing rocker bushings

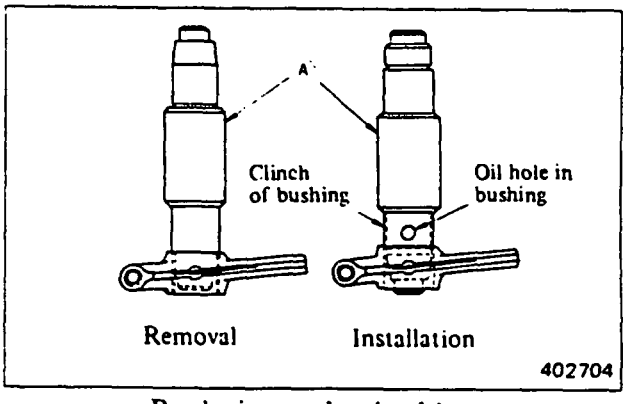
Using rocker bushing puller (A) (MH061236), remove the rocker bushings (worn) for replacement.

NOTE

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

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

(c) After installing the bushing, measure its inside diameter to make sure that it is $28^{+0.09}_{+0.07}$ mm ($1.10^{+0.0035}_{+0.0028}$ in.).
If the diameter is out of this tolerance, refinish it to $28^{+0.09}_{+0.07}$ mm ($1.10^{+0.0035}_{+0.0028}$ in.) 3S by reaming.

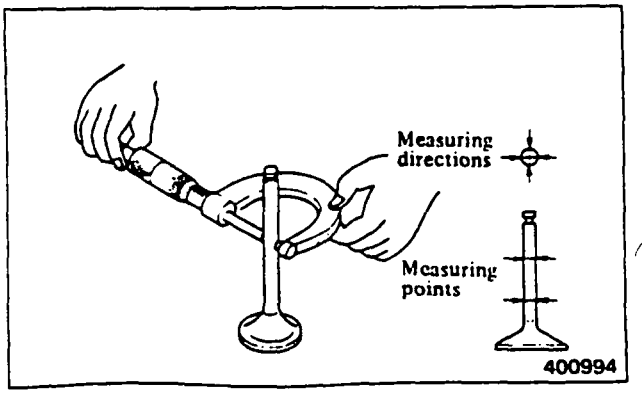


Replacing rocker bushing

Valve guides and valve stems

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

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



Measuring valve stem

Valves and valve seats

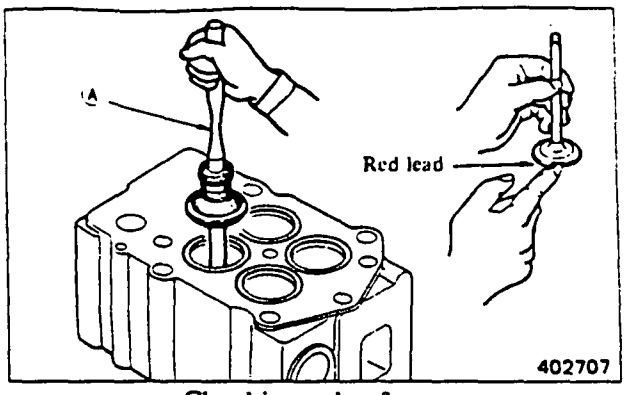
(1) Inspecting valve face

Coat the valve face lightly with red lead and, using valve lapper (A) (30091-07500), 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.

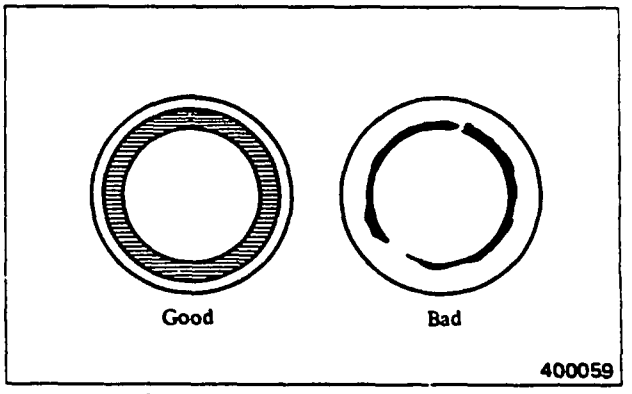
NOTE

(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.



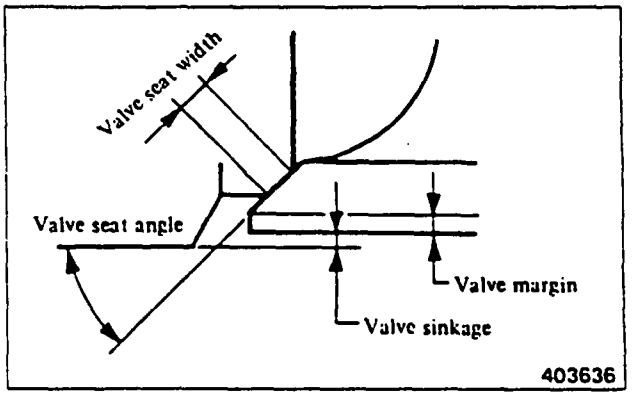
Checking valve face



Valve contact with its seat

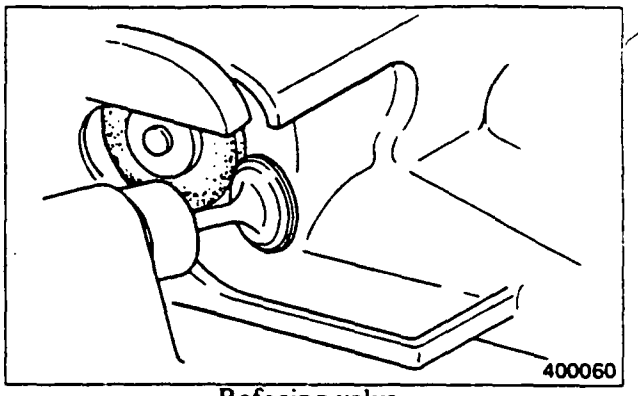
Unit: mm (in.)

Item			Assembly standard	Repair limit
Valve seat	Angle		30°	
	Valve sinkage		0 ± 0.2 (0 ± 0.008)	0.5 (0.020)
	Width	Inlet	2.45 to 2.75 (0.0965 to 0.1083)	3.1 (0.122)
		Exhaust	1.70 to 2.00 (0.0669 to 0.0787)	2.3 (0.091)
Valve margin		Inlet	3.0 ± 0.1 (0.118 ± 0.0039)	2.5(0.098) by refacing
		Exhaust	2.5 ± 0.1 (0.098 ± 0.0039)	2.0(0.079) by refacing



(2) Refacing valves

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



Refacing valve

NOTE

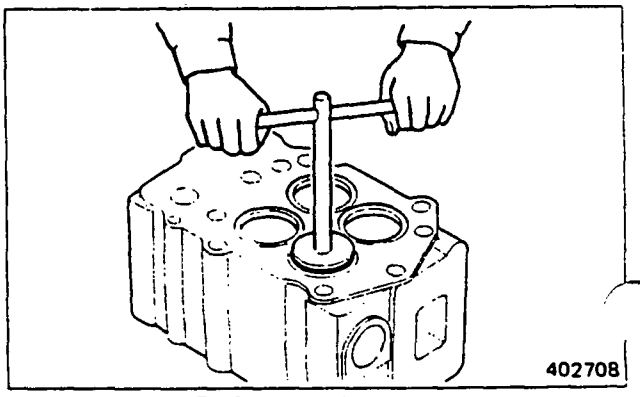
(a) Set a valve refacer at an angle of 30°.

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

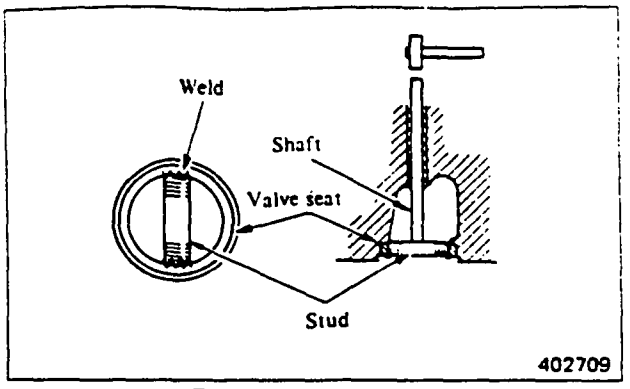
(a) Cut or grind the valve seat only as necessary for refacing.

(b) Replace the valve seat if the seat width is more than 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 stud 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.



Removing valve seat

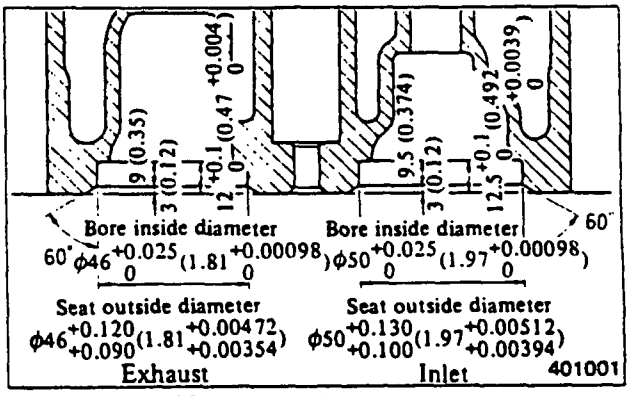
NOTE

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

(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.)

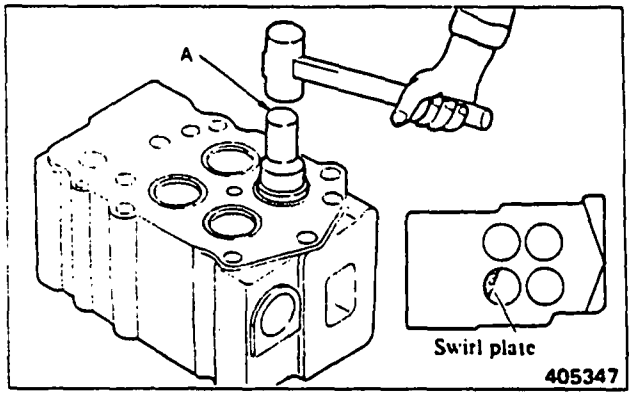
Item		Nominal value	Standard clearance
Cylinder head bore inside diameter and valve seat outside diameter	Inlet	50 (1.97)	-0.075 to -0.130 (-0.00295 to -0.00512)
	Exhaust	46 (1.81)	-0.065 to -0.120 (-0.00256 to -0.00472)



Valve seat dimensions

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

(d) Using valve seat calking tool (A) (36291-05020), install the valve seat.



Installing valve seat

NOTE

On the inlet valve side, install the swirl plates in the cylinder head before inserting the valve seats. Locate each swirl plate in place by aligning its locking lip with the hole in the head.

(5) Lapping valves in valve seats

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

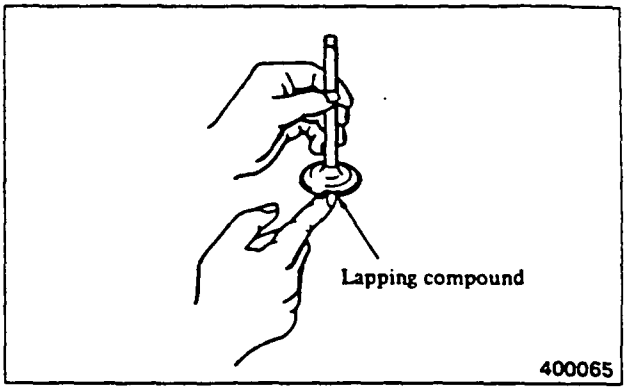
(a) Coat the valve face lightly with a lapping compound.

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.



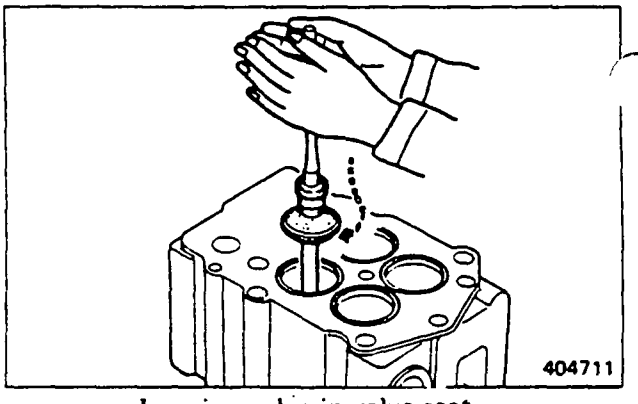
Coating valve with lapping compound

(b) Using valve lapper (A) (30091-07500), 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.



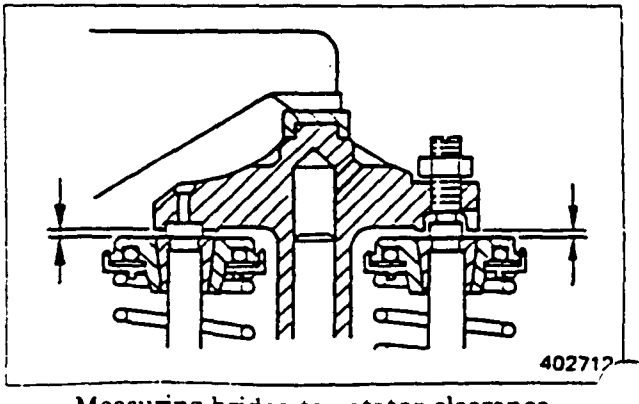
Lapping valve in valve seat

Valve bridges and bridge caps

Measuring the clearance between bridge and rotator (cotters).

(1) If the clearance is less than 0.5 mm (0.020 in.), check the valve stem top for cupping. When the stem top is badly cupped, replace the valve to obtain more than 0.5 mm (0.020 in.) clearance.

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



Measuring bridge-to-rotator clearance

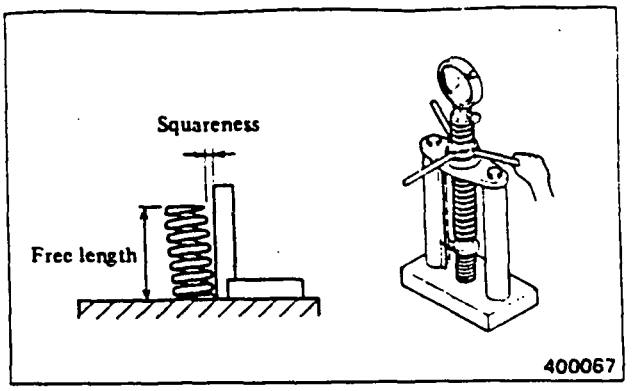
Valve springs

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 (2.66)	66.2 (2.61)
Squareness	 $\theta = 1°$, maximum	$\Delta = 1.5$ (0.059) over the length ℓ
Test force, kgf (lbf) [N]	27.8 ± 5% (61 ± 5%) [273 ± 5%]	
Length under test force	60.0 (2.362)	

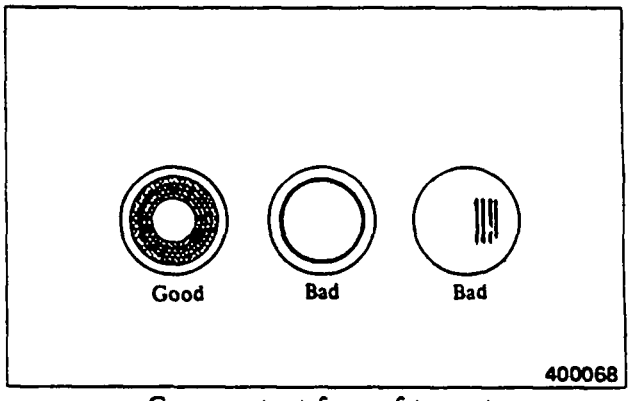


Measuring valve spring

Tappets and valve pushrods

(1) Inspecting cam contact face of tappets

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



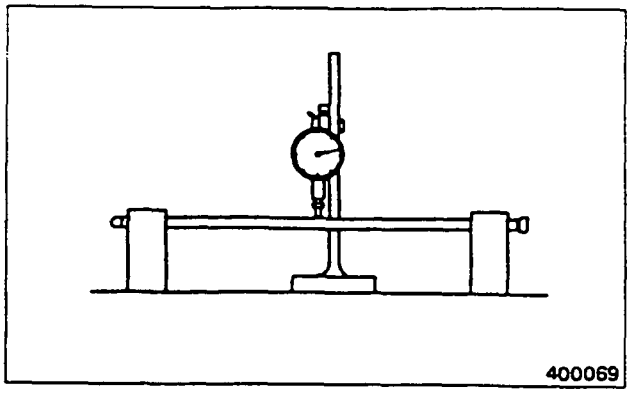
Cam contact face of tappet

(2) Measuring runout of valve pushrods

If the runout is in excess of the assembly standard, replace the pushrods.

Unit: mm (in.)

Item	Assembly standard
Pushrod runout	0.5 (0.020), maximum



Measuring valve pushrod runout

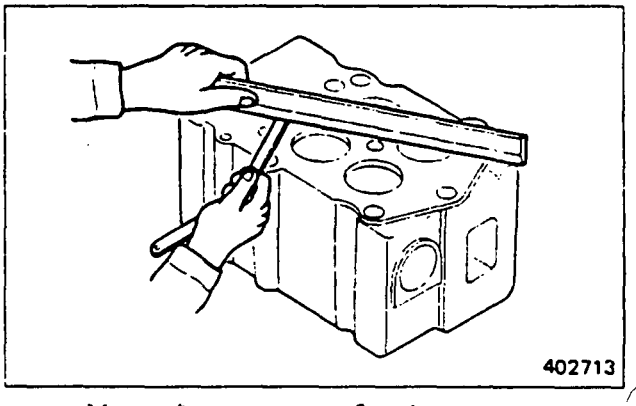
Cylinder heads

(1) Measuring warpage of gasket contact surface

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

Unit: mm (in.)

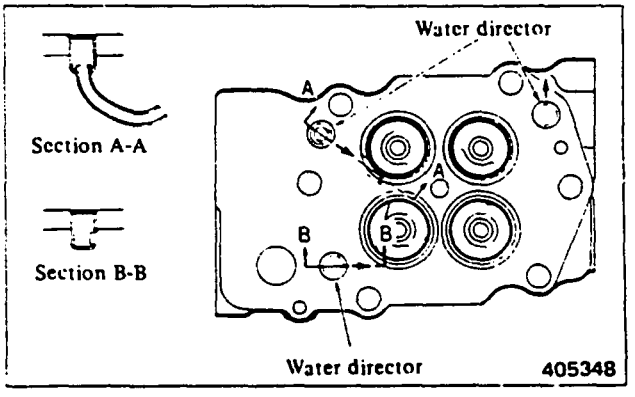
Item	Assembly standard	Repair limit	Service limit
Warpage of gasket contact surface	0.03 (0.0012), maximum	0.07 (0.0028)	0.50 (0.0197)



Measuring warpage of gasket contact surface of head

(2) Inspecting water directors

Check each water director for corrosion, and replace it if necessary. Using a soft hammer, drive a new director into the cylinder head until it measures 1.0 mm (0.04 in.) from the gasket contact surface of the head, with its window positioned as shown.



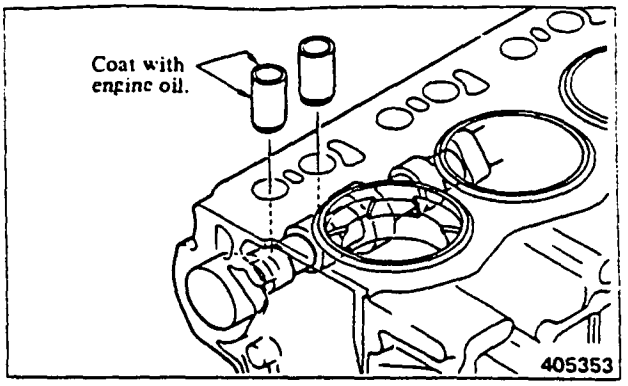
Installing water directors

1.3 Reassembly

Follow the reverse of disassembly procedure.

(1) Installing tappets

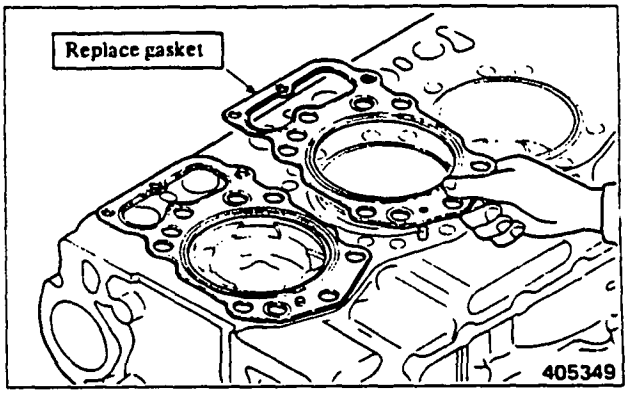
Coat the tappets with engine oil, and carefully put them on the camshaft.



(2) Installing cylinder head gaskets

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

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



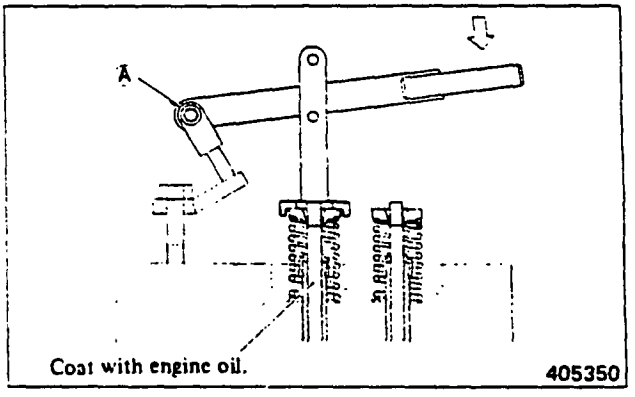
⚠ CAUTION

Do not apply any sealant to the gaskets.

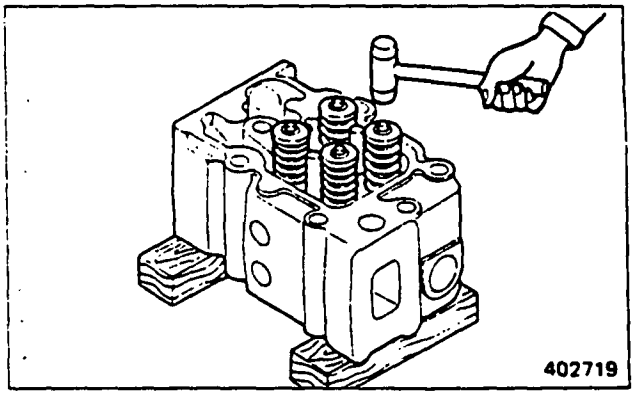
(3) Reassembling cylinder heads

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

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

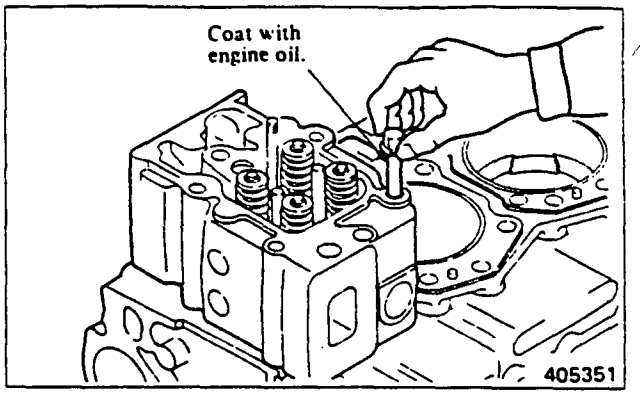


(c) Lightly tap on the top of each valve stem with a soft hammer to make sure that the valve spring and cotters are properly installed.



(4) Installing cylinder head assemblies

Keep the head assembly slightly lifted with the dowel pins entering their holes. Coat with engine oil the threads of head bolts (except those for securing the head and rocker bracket), put the bolts in the head assembly, and tighten them temporarily.



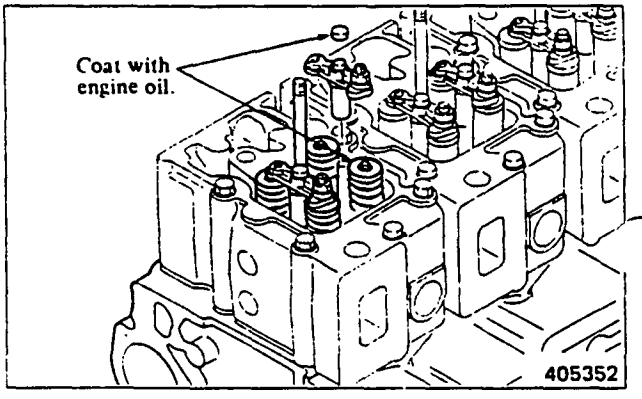
⚠ CAUTION

Before installing the cylinder head assembly, measure the projection of each piston, making sure that the projection is correct. (Refer to Pistons, 2.2.)

(5) Installing valve bridges and caps

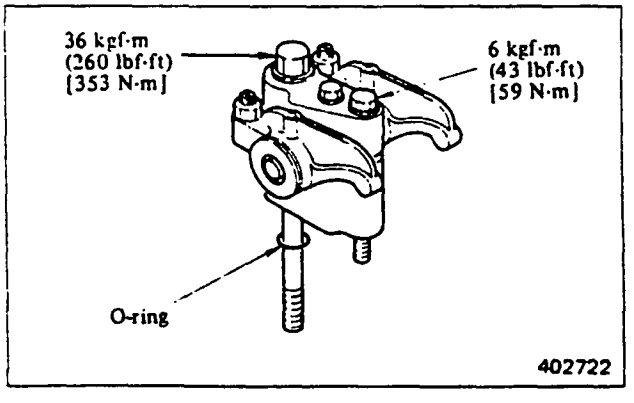
(a) Coat the bridge guides with engine oil, and install the bridges to the guides with the adjusting screw on the exhaust manifold side.

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



(6) Installing rocker shaft assemblies

Insert 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) Move the rocker arm up and down to make sure that the arm is free.

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

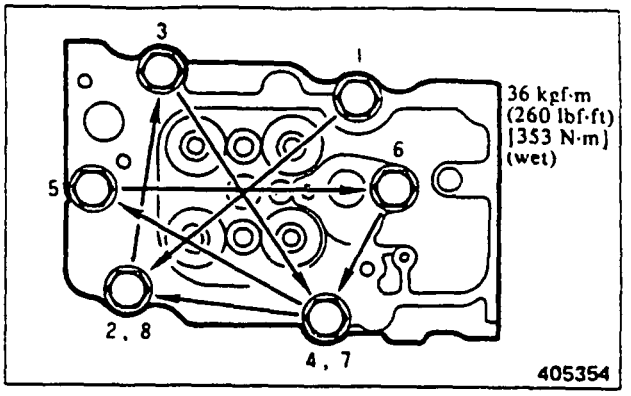
(c) Tighten the long bolt securing the head and rocker bracket first; then tighten the short bolt to the specified torque.

(7) Tightening cylinder head bolts

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

⚠ CAUTION

Tighten bolts 1 thru 6 first, then retighten bolts 4 and 2 only to prevent gas leakage.



Cylinder head bolt tightening sequence

(8) Installing injection nozzle assemblies

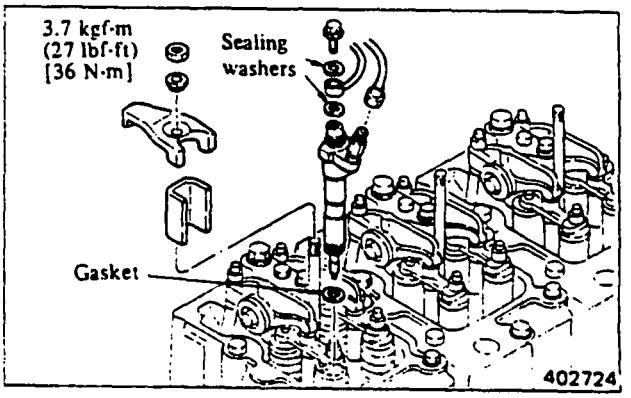
(a) Install the nozzle assemblies to the cylinder heads, and connect the injection pipe and leak-off pipe to each assembly.

(b) Tighten the nozzle gland and spacer to the specified torque.

NOTE

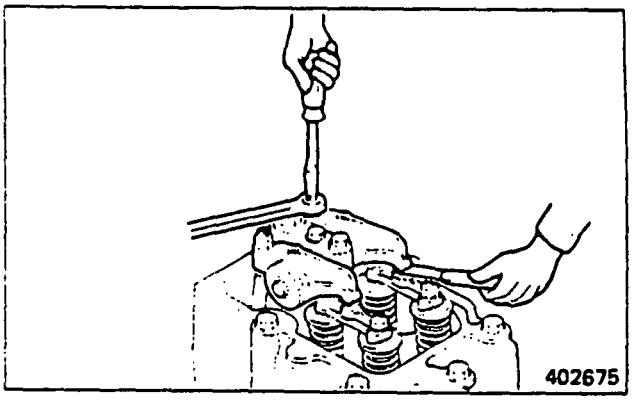
(a) When connecting the leak-off pipe, be sure to install the sealing washer to the connection of the pipe.

(b) When installing each nozzle assembly, be sure to install the gasket.



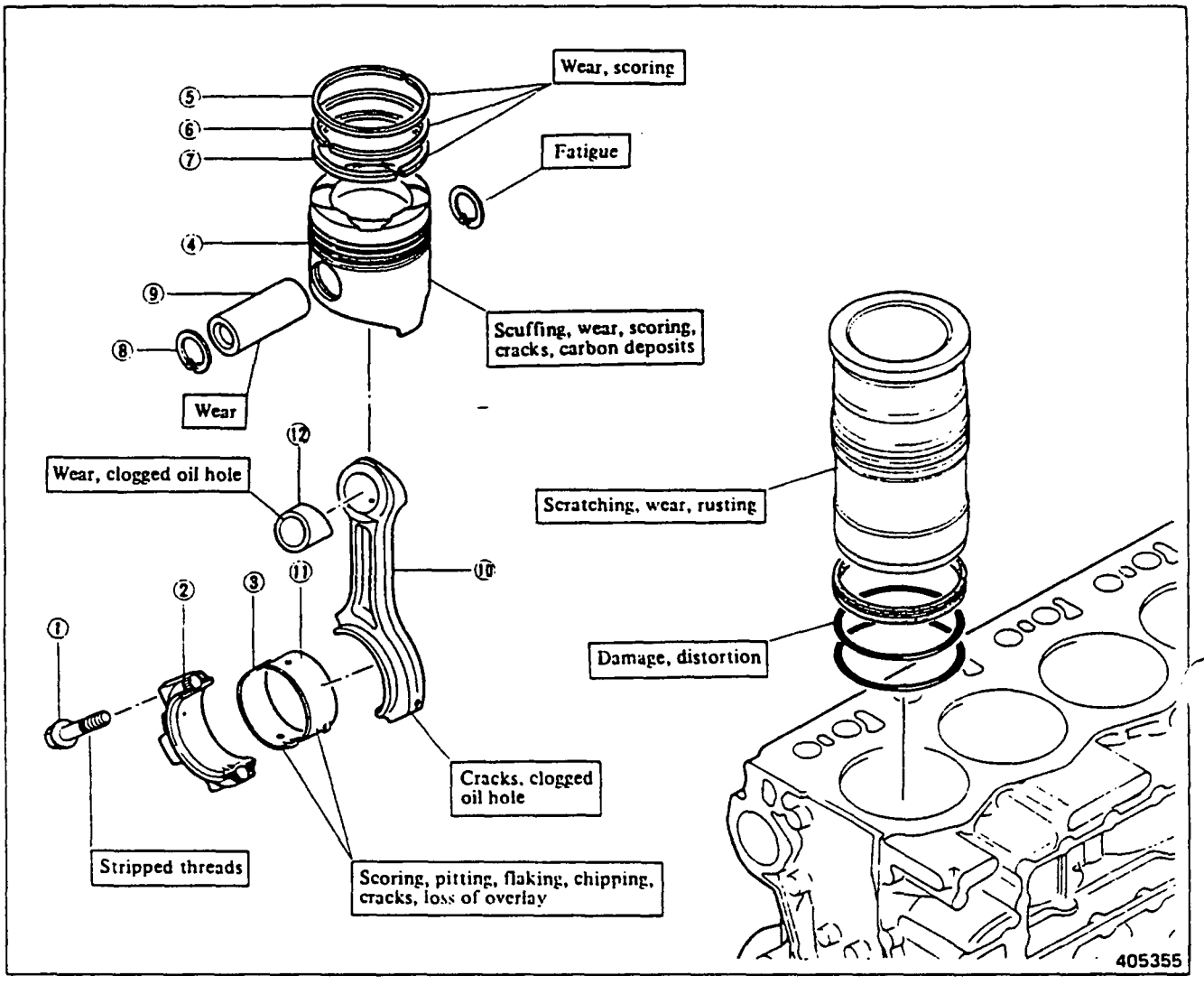
(9) Adjusting valve clearance

Refer to 1.1, Group No. 5.



2. CYLINDER LINERS, PISTONS AND CONNECTING RODS

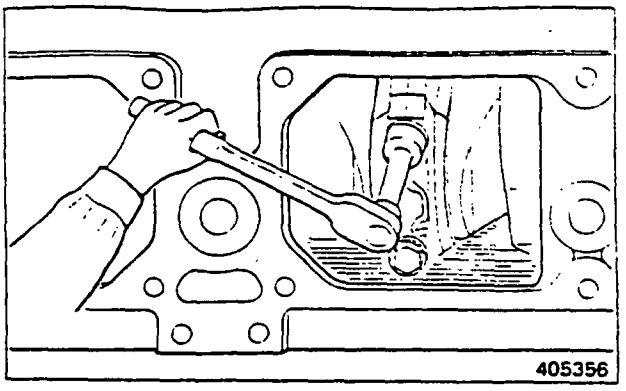
2.1 Disassembly



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

(1) Removing connecting rod caps

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



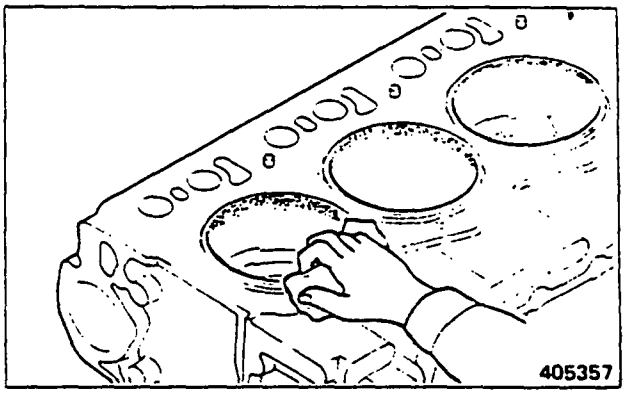
NOTE

(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.

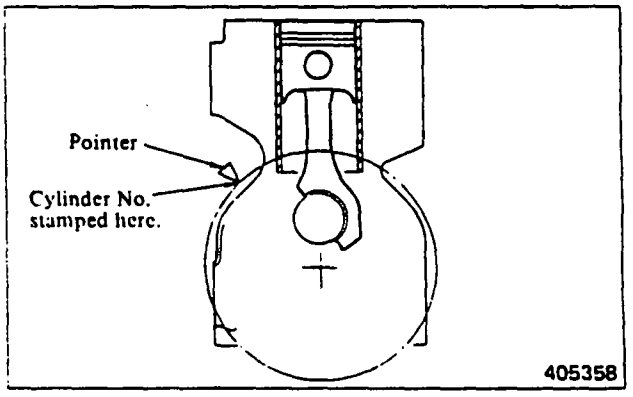
(2) Preparatory step for removing pistons

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

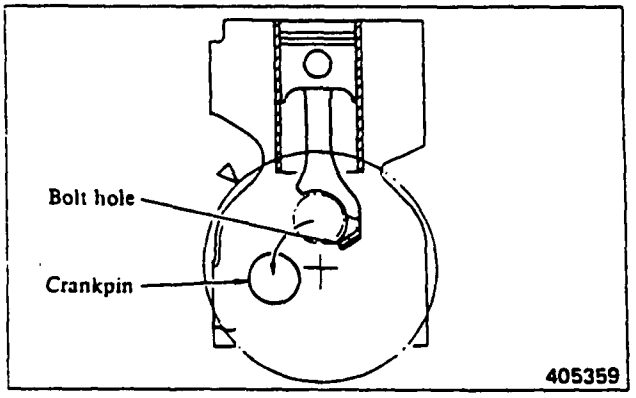


(3) Removing pistons

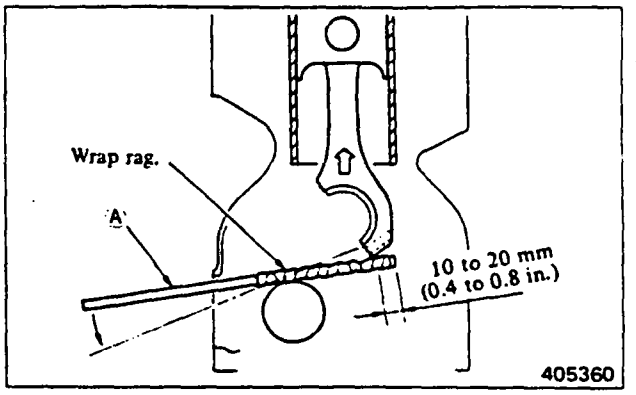
(a) Bring the piston assembly (from which the connecting rod bearing cap has been removed) to top dead center by turning the crankshaft.



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



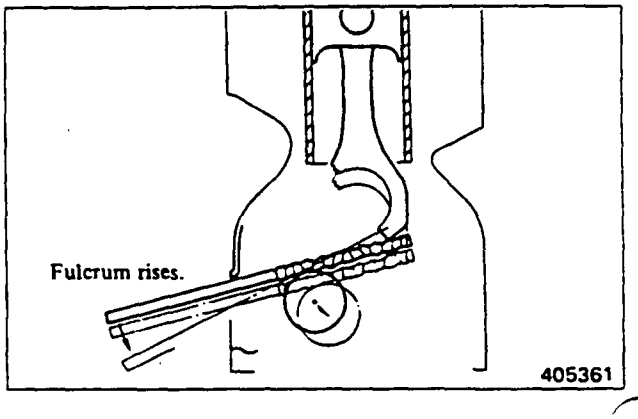
(c) Wrap rag over turning bar (A) (32091-01500). Insert one end of the bar into the bolt hole in the connecting rod big end, and raise the piston assembly just a little by making use of the crankpin as a fulcrum.



NOTE

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

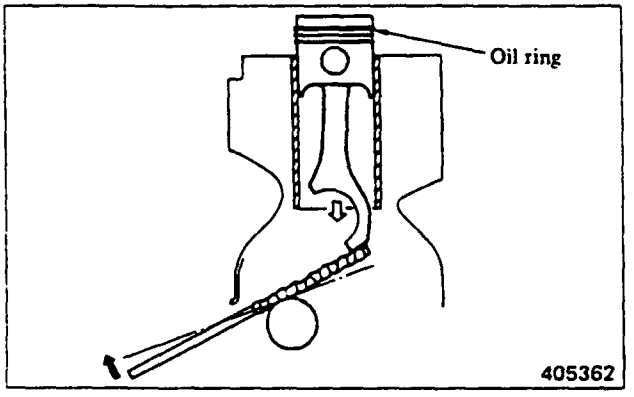
(d) Turn the crankshaft in the normal direction just a little at a time to raise the crankpin (fulcrum) while pushing down on the outer end of the bar to raise the piston assembly.



⚠ 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.

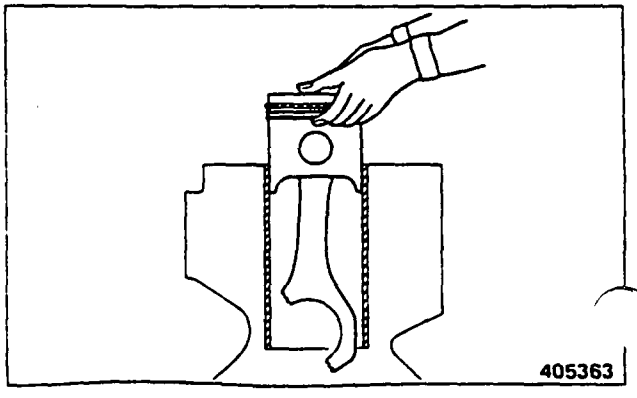
(e) When the oil ring of the piston comes out of the cylinder liner, lower the piston just a little, and carefully rest the oil ring on the edge of the liner.



⚠ CAUTION

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

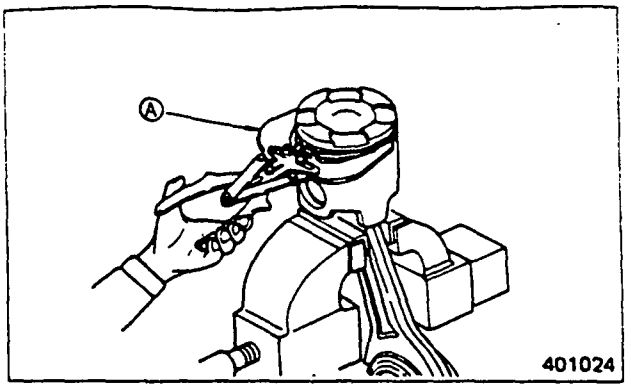
(f) Hold the compression ring portion of the piston by hands, carefully pull the piston from the cylinder liner, and rest its skirt on the top of crankcase.



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

(4) Removing piston rings

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

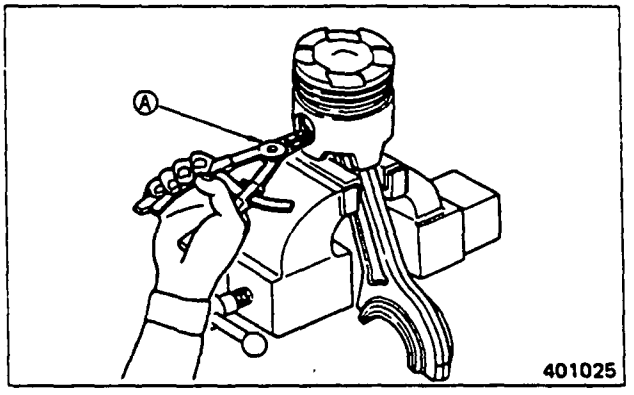


(5) Removing piston pin

(a) Using snap 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.

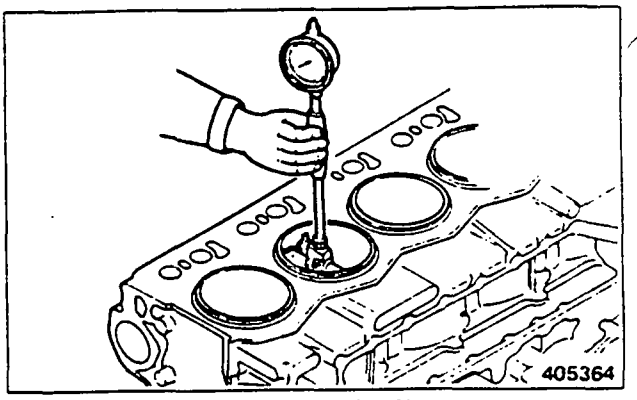


2.2 Inspection and repair

Cylinder liners

(1) Measuring inside diameter

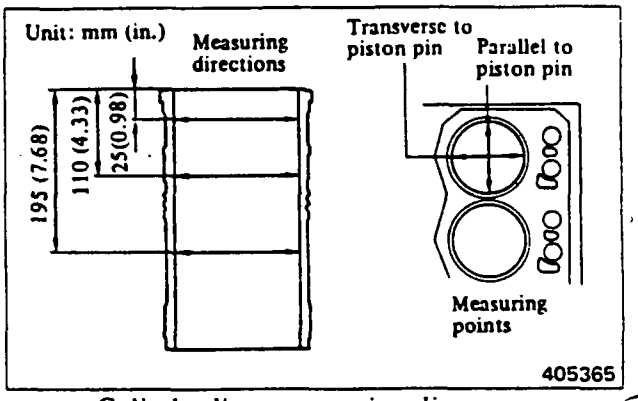
Measure the inside diameter of each liner in two directions, parallel and transverse to the piston pin, at three positions, top (ridged area), middle and bottom as shown. Replace the liner if it is worn in excess of the service limit.



Measuring cylinder liner

Unit: mm (in.)

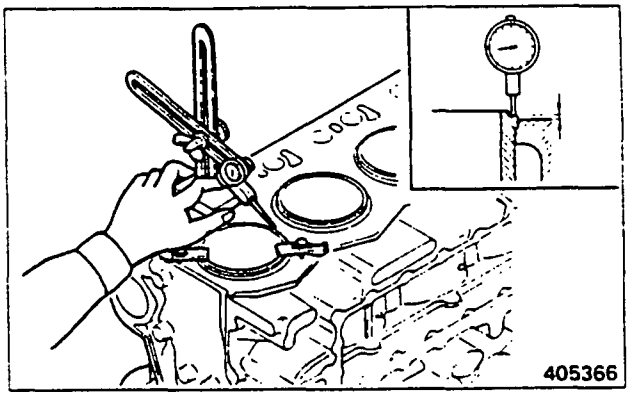
Item	Nominal value	Assembly standard	Repair limit
Cylinder liner inside diameter	135 (5.31)	135.000 to 135.040 (5.31495 to 5.31652)	135.140 (5.32046)



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.



Measuring cylinder liner projection

Unit: mm (in.)

Item	Assembly standard
Projection	0.10 to 0.19 (0.0039 to 0.0075)

⚠ 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 gasket contact surface of the crankcase and the top of the liners.

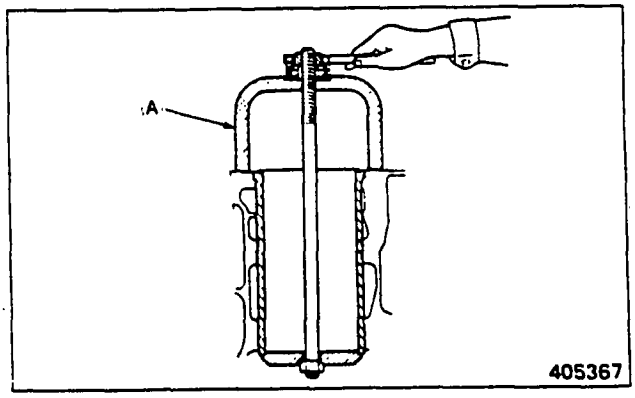
(b) Secure the top of the liner uniformly at two places with clamps and bolts (M18 x 2.5).

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

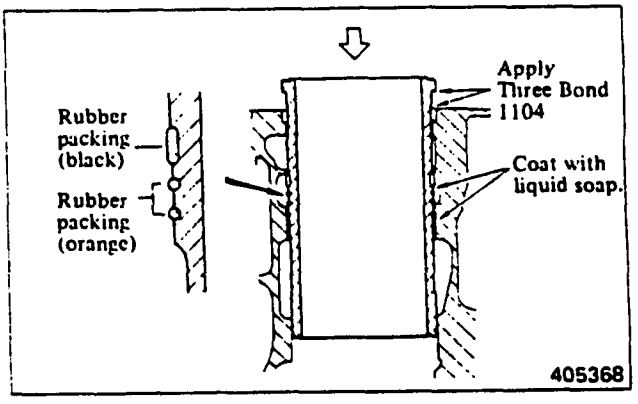
(d) Measure the projection at four places on the top of the liner. Take the average from the four measurements.

(3) Replacement

(a) Using cylinder liner remover (A) (36291-03100), remove the cylinder liners from the crankcase for replacement.



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



⚠ CAUTION

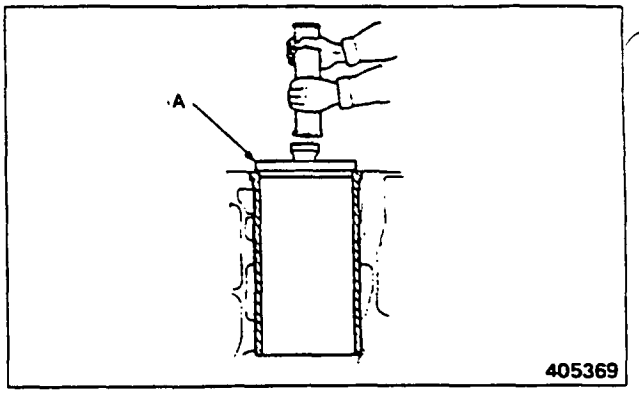
Apply Three Bond 1104 to the joints of cylinder liner and crankcase. When inserting the liner, coat the rubber packings with liquid soap to prevent them from twisting.

(c) After inserting the liner into the bore, lightly tap on its top, using cylinder liner installer (A) (36291-03200), to rest its flange in the counterbore formed of the crankcase. After installing, lightly tap on the liner several time to make sure that it is rested properly.

NOTE

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

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

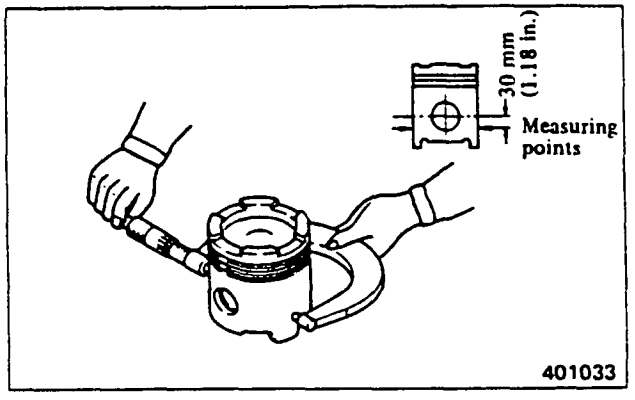


Pistons

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

(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.

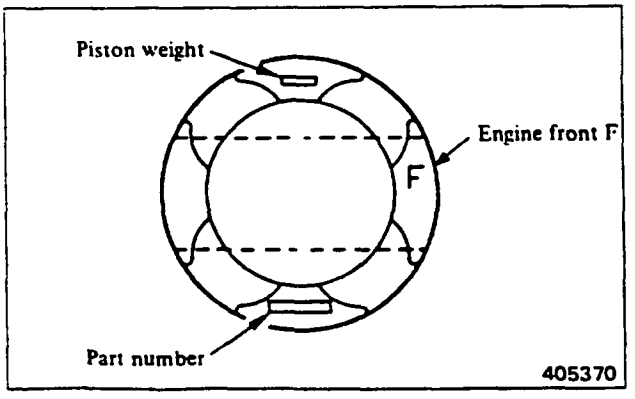


Measuring piston diameter

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Piston diameter	135 (5.31)	134.810 to 134.855 (5.30747 to 5.30924)	134.700 (5.30314)
Maximum permissible difference between average weight of all pistons in one engine	–	±20 g (±0.7 oz). maximum	–

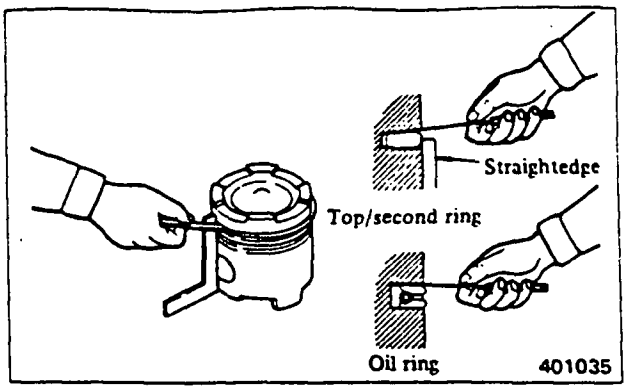
(b) The piston weight is stamped on the top of each piston.



Piston weight stamp location

(2) Measuring piston ring side clearance

Put new piston rings in 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 is in excess of the service limit, replace the piston.



Measuring piston ring side clearance

Piston ring side clearance
(with new rings in grooves) Unit: mm (in.)

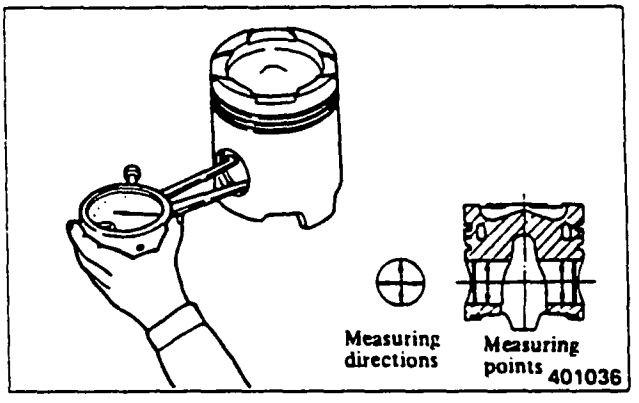
Item	Nominal value	Standard clearance	Service limit
Top	4.27 (0.1681)	0.077 to 0.087 (0.00303 to 0.00343)	–
Second	3.23 (0.1272)	0.046 to 0.051 (0.00181 to 0.00201)	0.20 (0.0079)
Oil	4.00 (0.1575)	0.030 to 0.070 (0.00118 to 0.00276)	

⚠ CAUTION

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

(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 in excess of the service limit.



Measuring piston pin bore diameter

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Inside diameter of piston pin bore	55 (2.17)	55.002 to 55.012 (2.16543 to 2.16582)	55.015 (2.16594)

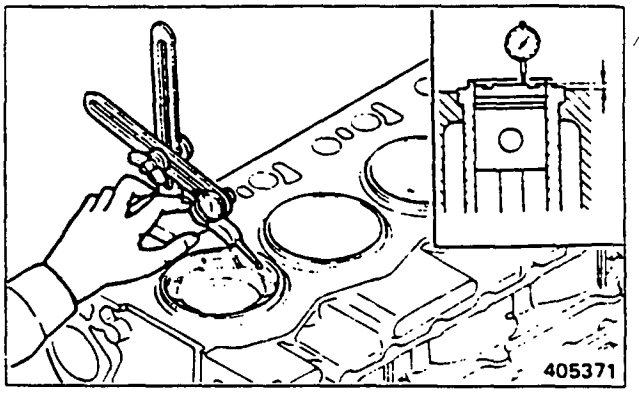
(4) Measuring piston projection

Measure the projection of each piston and, if it is not within the assembly standard, 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 piston head, and average the four measurements to determine the projection. Subtract the piston projection from the as-installed 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)
Piston projection	0.45 to 1.15 (0.0177 to 0.04528)
As-installed thickness of cylinder head gasket	1.8 ± 0.1 (0.071 ± 0.004)
Clearance between piston top and cylinder head	0.75 to 1.63 (0.0295 to 0.0642)

⚠ CAUTION

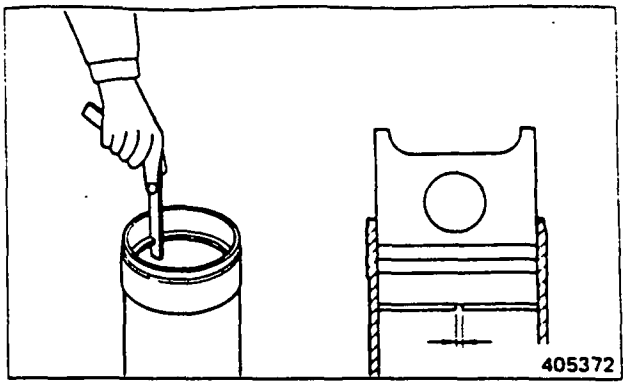
Keeping the piston projection within the assembly standard is important not only for engine performance but also for prevention of interference of the valves with the pistons.

Piston rings

(1) Measuring gaps

Place 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: 135 + 0 mm (5.31 + 0 in.).



Measuring piston ring gap

NOTE

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

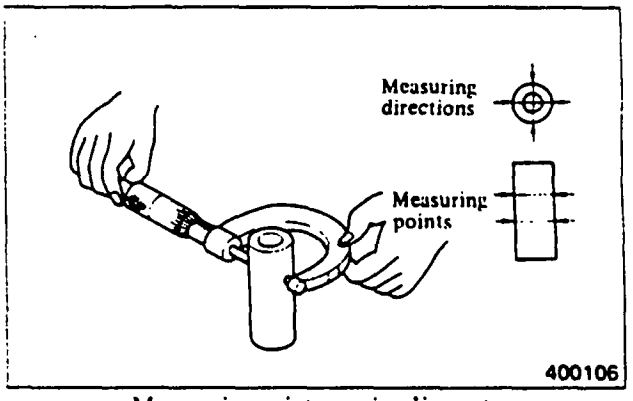
Unit: mm (in.)

Item		Standard clearance	Service limit
Piston ring gaps	Top	0.4 to 0.6 (0.016 to 0.024)	1.0 (0.039)
	Second		1.0 (0.039)
	Oil	0.4 to 0.65 (0.016 to 0.0256)	1.2 (0.047)

Piston pins

Measuring diameter of piston pins

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



Measuring piston pin diameter

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Piston pin outside diameter	55 (2.17)	54.987 to 55.000 (2.16484 to 2.16535)	54.980 (2.16456)

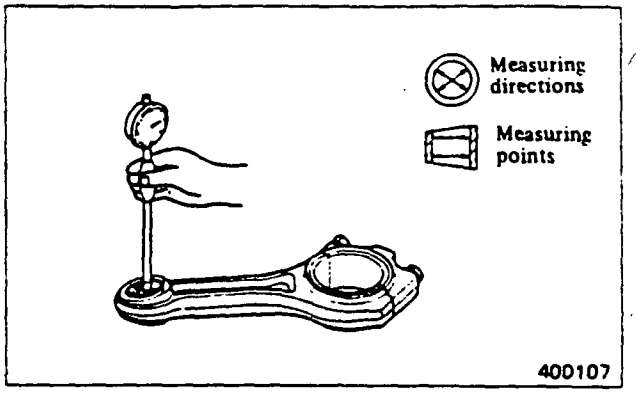
Connecting rods, connecting rod bearings and small-end bushings

(1) Measuring inside diameter of bushings

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

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Connecting rod small end bushing inside diameter	55 (2.17)	55.020 to 55.040 (2.16614 to 2.16692)	55.070 (2.16811)



Measuring connecting rod small-end bushing inside diameter

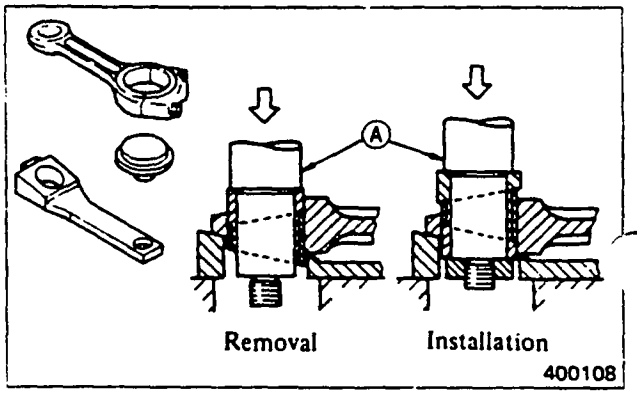
(2) Replacing bushings

(a) Using connecting rod bushing puller (A) (37191-08000), remove the bushing, as shown, for replacement.

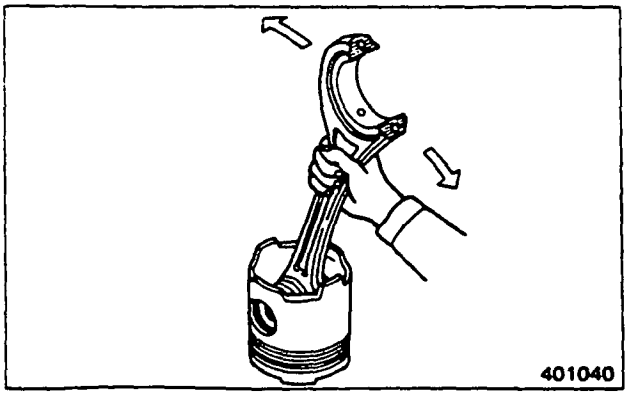
(b) When installing a replacement bushing, align oil holes in the bushing and connecting rod.

(c) After installing the bushing, ream its inside diameter to finish it to 55 $^{+0.040}_{+0.020}$ mm (2.17 $^{+0.00157}_{+0.00079}$ in.) $\frac{1.5S}{\nabla\nabla\nabla}$ and finish the parallelism between the bushing and big-end bearing to 0.05 mm (0.0020 in.).

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



Replacing connecting rod small-end bushing

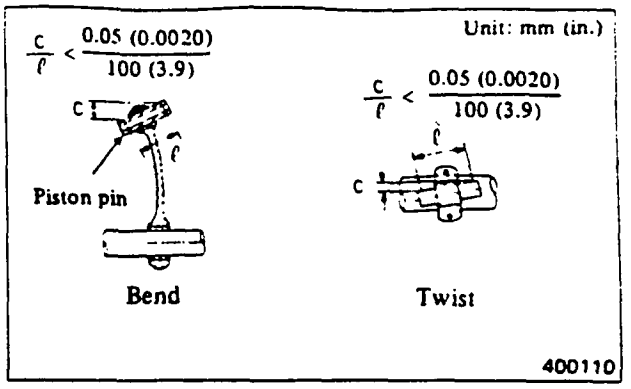


(3) Inspecting connecting rods for bend and twist

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

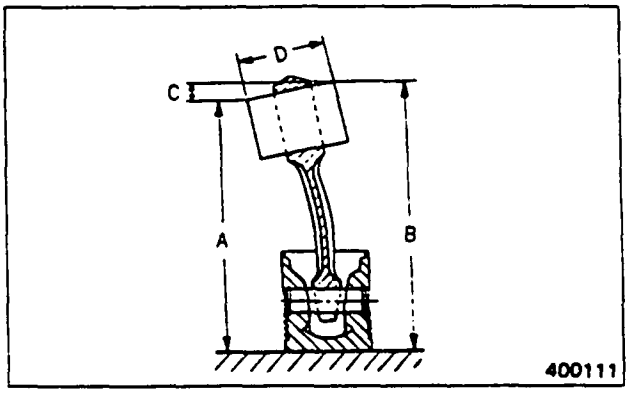


Inspecting connecting rod

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

Unit: mm (in.)

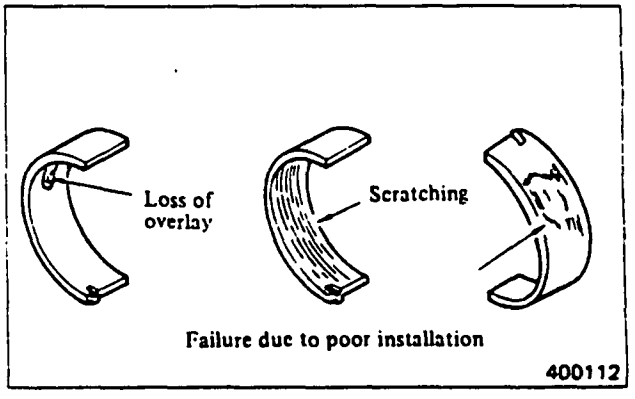
Item	Assembly standard
Connecting rod bend and twist C/D	0.05/100 (0.0020/3.9), maximum



Inspecting connecting rod installed to piston

(4) Inspecting connecting rod bearings

Inspect 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.

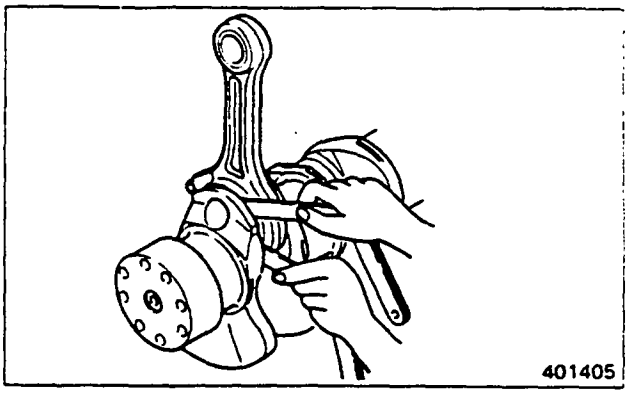


(5) Measuring connecting rod end play

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 repair limit, replace the connecting rod.

Unit: mm (in.)

Item	Nominal value	Standard clearance [Nominal]	Repair limit
Connecting rod end play [widths of connecting rod and crank-pin]	56 (2.20)	0.2 to 0.4 (0.008 to 0.016)	0.8 (0.031)



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.

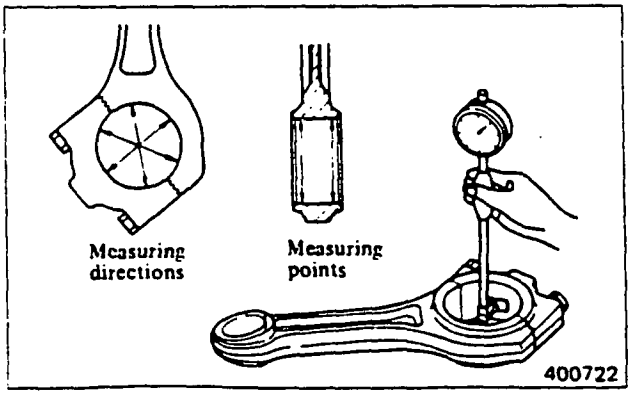
Item	Assembly standard
Max. permissible difference between average weight of all connecting rods in one engine	±30 g (±1.1 oz), maximum

(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.)

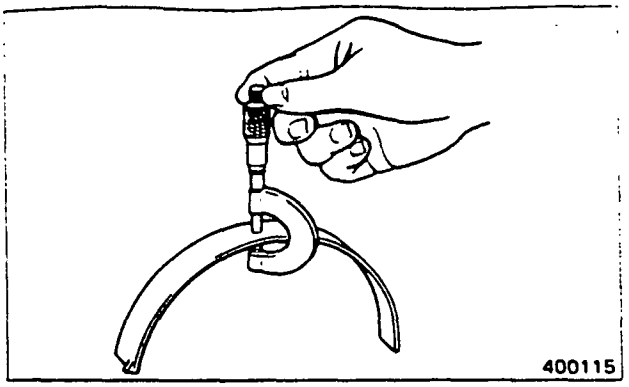
Item	Nominal value	Assembly standard	Service limit
Connecting rod big-end bore diameter	95 (3.74)	95.000 to 95.022 (3.74015 to 3.74102)	95.047 (3.74200)



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.



Measuring connecting rod bearing thickness

Unit: mm (in.)

Item		Nominal value	Assembly standard	Service limit
Connecting rod bearing thickness	STD	2.5 (0.098)	2.482 to 2.500 (0.09772 to 0.09843)	2.450 (0.09646)
	-0.25 (-0.0098)	2.625 (0.10335)	2.607 to 2.625 (0.10264 to 0.10335)	2.575 (0.10138)
	-0.50 (-0.0197)	2.750 (0.10827)	2.732 to 2.750 (0.10756 to 0.10827)	2.700 (0.10630)
	-0.75 (-0.0295)	2.875 (0.11319)	2.857 to 2.875 (0.11248 to 0.11319)	2.825 (0.11122)
	-1.00 (-0.0394)	3.000 (0.11811)	2.982 to 3.000 (0.11740 to 0.11811)	2.950 (0.11614)

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.).

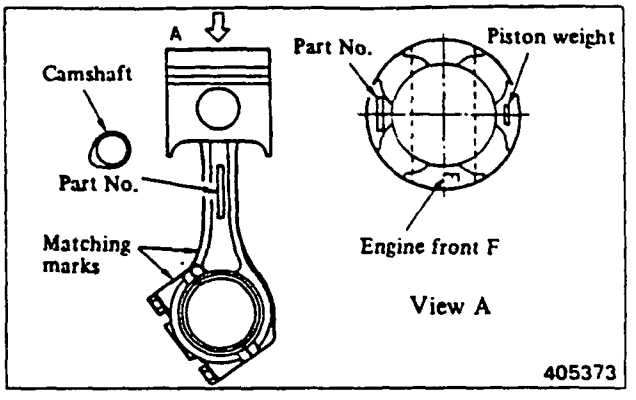
2.3 Reassembly

Follow the reverse of disassembly procedure.

(1) Installing pistons to connecting rods

(a) The piston pin is to be clearance-fitted to the piston. Heat the piston with a piston heater or in hot water and coat the piston pin with engine oil, then put the pin into position through the connecting rod small end to connect the rod to the piston.

(b) Install the connecting rod to the piston, making sure that the matching marks on its big end and the piston part number are on the camshaft side.

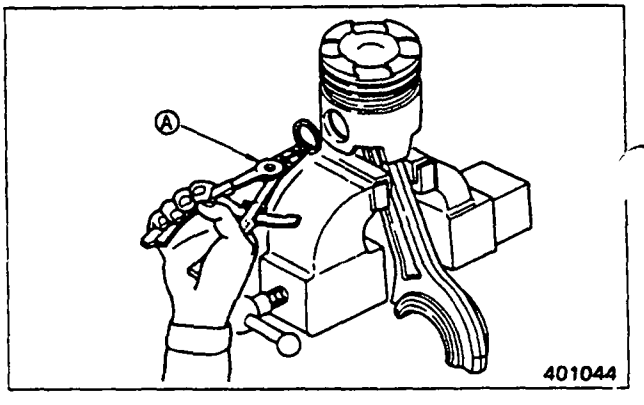


Matching marks on connecting rod

(c) Using snap 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.

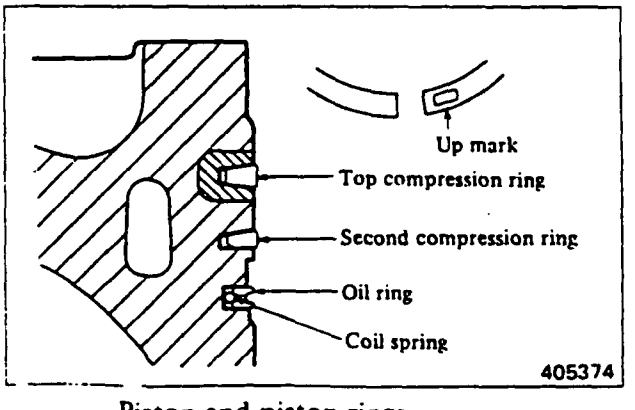


(2) Installing piston rings

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

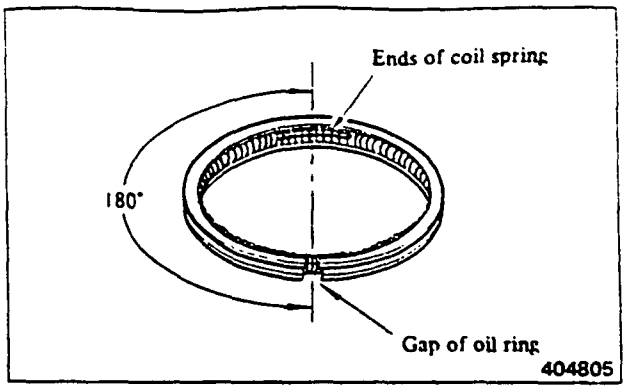
⚠ CAUTION

Top piston ring is marked "RN" and second piston ring "2R" near the gap on the side to be up when installed on the piston. If the ring is installed with this mark down, excessive oil consumption or overheating will occur.



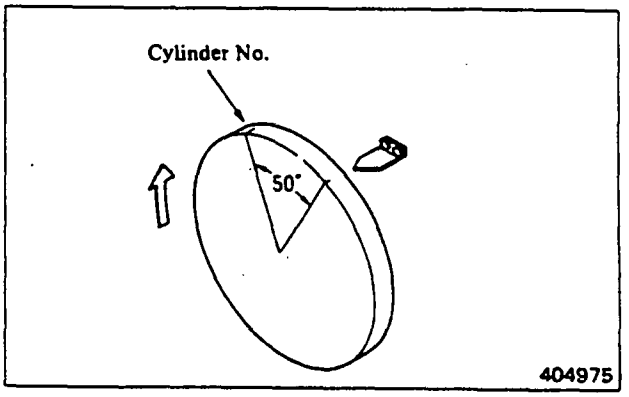
Piston and piston rings

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

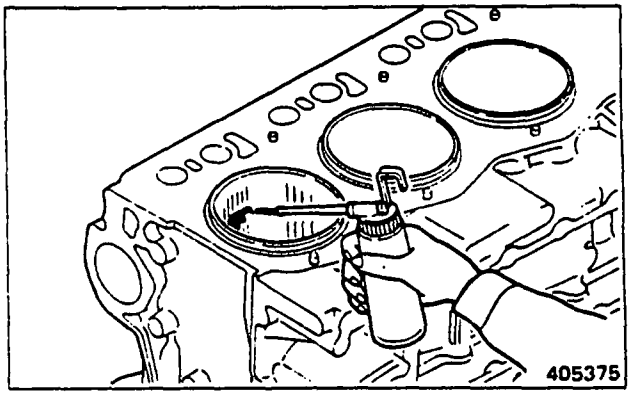


(3) Preparatory steps for installing pistons

(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.

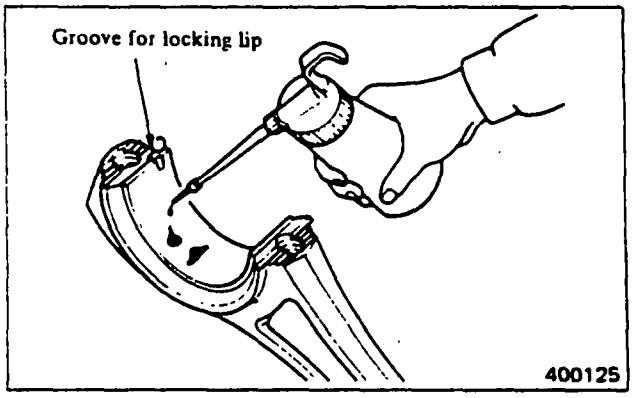


(b) Clean the cylinder liner bore surface and crankpin by wiping with rag, and coat it with engine oil.



(4) Installing connecting rod bearings (upper shells)

Install 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 the oil holes in the rod and bearing are aligned.

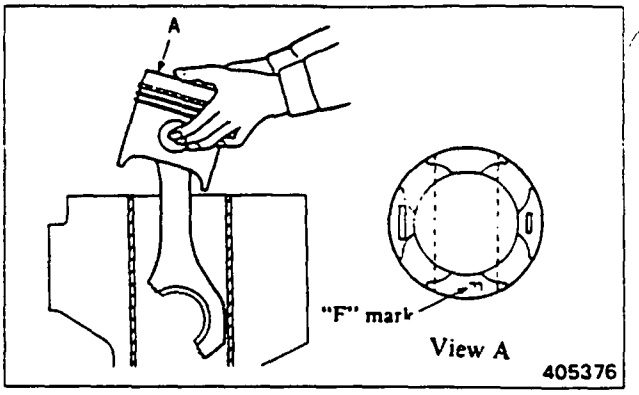


(5) Installing pistons

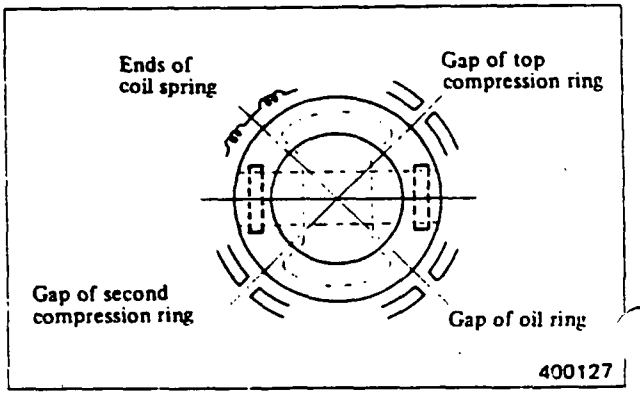
(a) Put the connecting rod in the cylinder liner, and carefully rest the piston on the top of crankcase.

⚠ CAUTION

When putting the piston assembly in the cylinder liner, make sure that F mark points the camshaft side, and keep the connecting rod away from the oil jet by looking into the inspection hole of the crankcase. Do not attempt to rotate the piston.



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

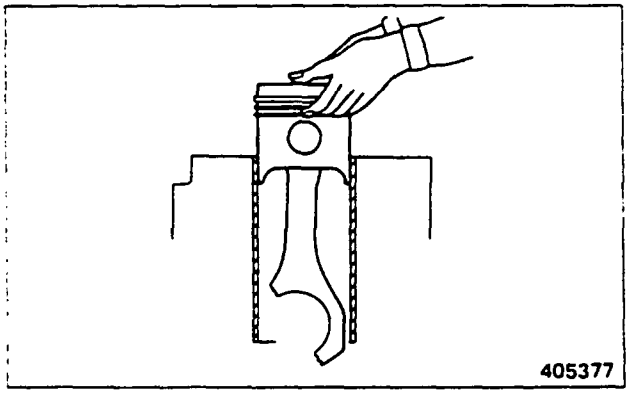


(c) Hold the compression ring portion of the piston by hands, and carefully insert the piston into the cylinder liner.

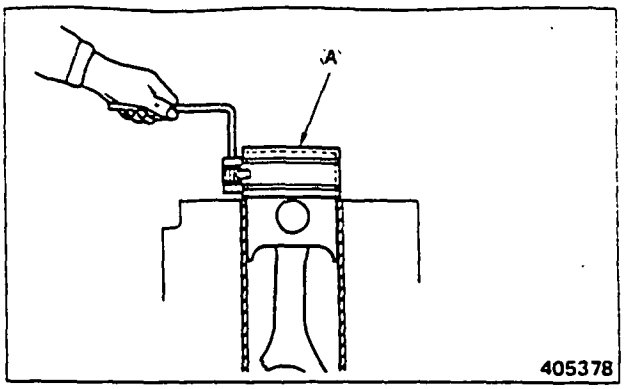
NOTE

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

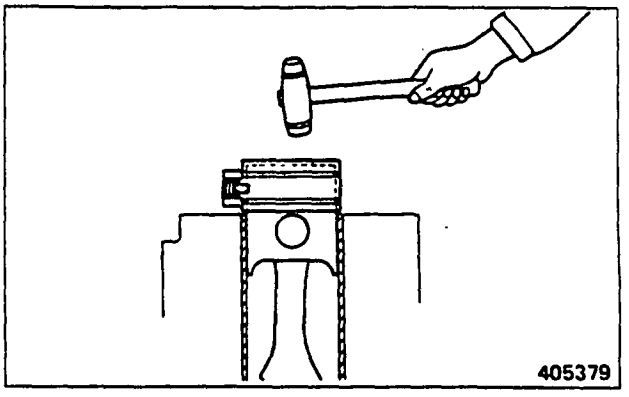
(b) Slowly insert the piston, being careful not to damage the oil ring.



(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.

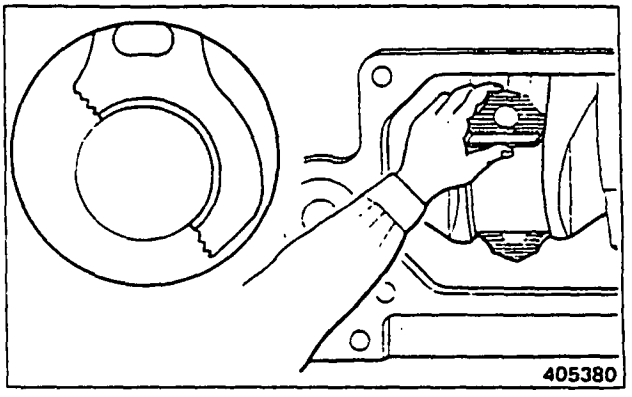


(e) Lightly tap on the piston head with a soft hammer to insert the piston into the cylinder liner. If the piston will not go into the liner, move the big end of connecting rod back and forth through the inspection hole of crankcase.



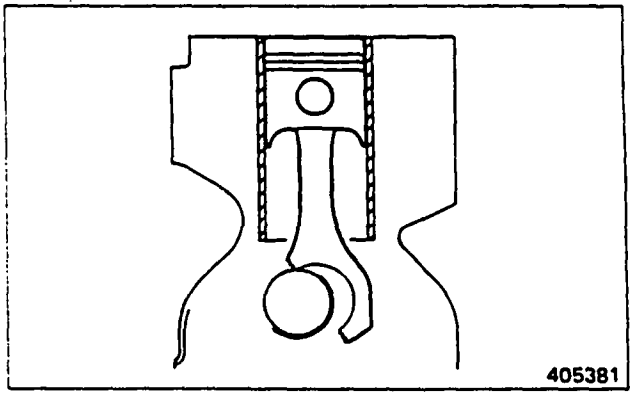
(f) Make sure the upper shell of the bearing is properly positioned in place in the connecting rod big end, by inserting the hand through the inspection hole of crankcase.

If the bearing shell is slightly out of place, reposition it by lightly pushing it by the palm of a hand.



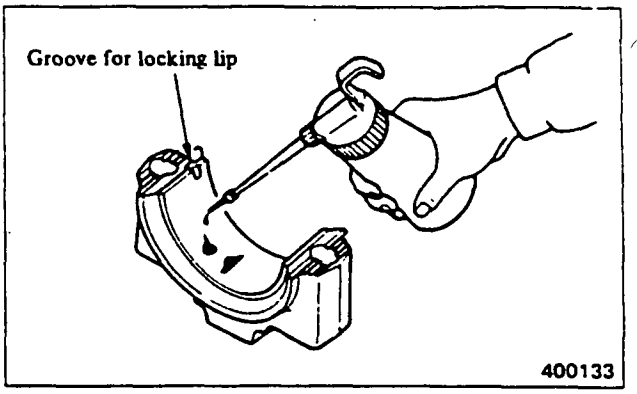
(If the bearing is off connecting rod big end)

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.



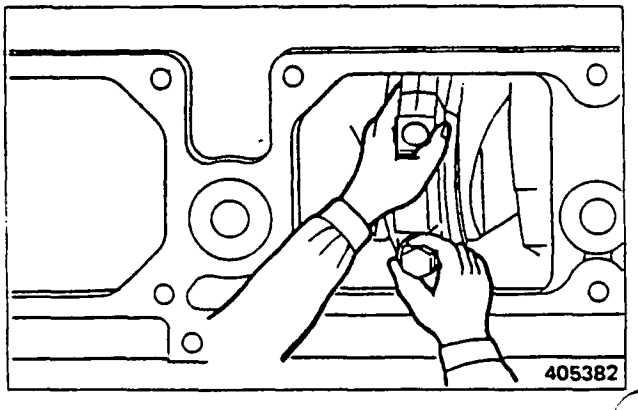
(6) Installing connecting rod caps

(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 lower shells of connecting rod bearings 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.

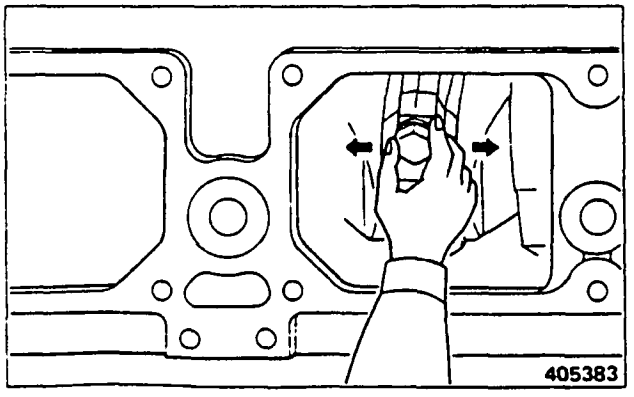


(d) With the bolts tightened temporarily, touch the joint between the cap and rod, making sure that the cap and rod surfaces are flush with each other, and tighten the bolts to the specified torque.

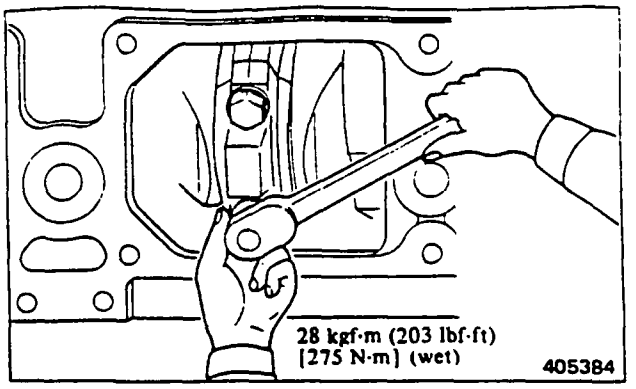
⚠ CAUTION

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

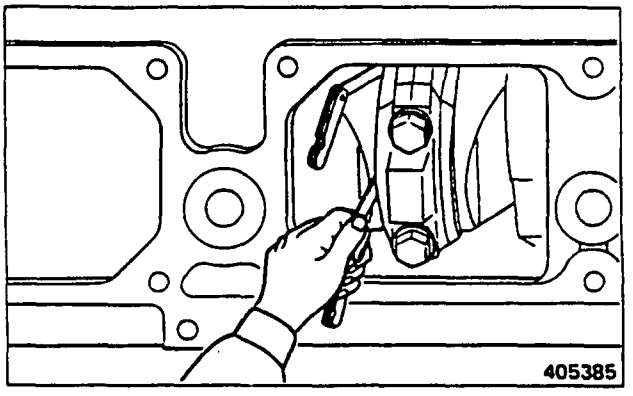
(e) Move the big end of each rod in the thrust direction, making sure that the rod has correct end play.



(f) Tighten the cap bolts to the specified torque. Then loosen the bolts completely and retighten them to the specified torque.



(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 (5), Connecting rods, connecting rod bearings and small-end bushings, 2.2.)



Measuring connecting rod end play

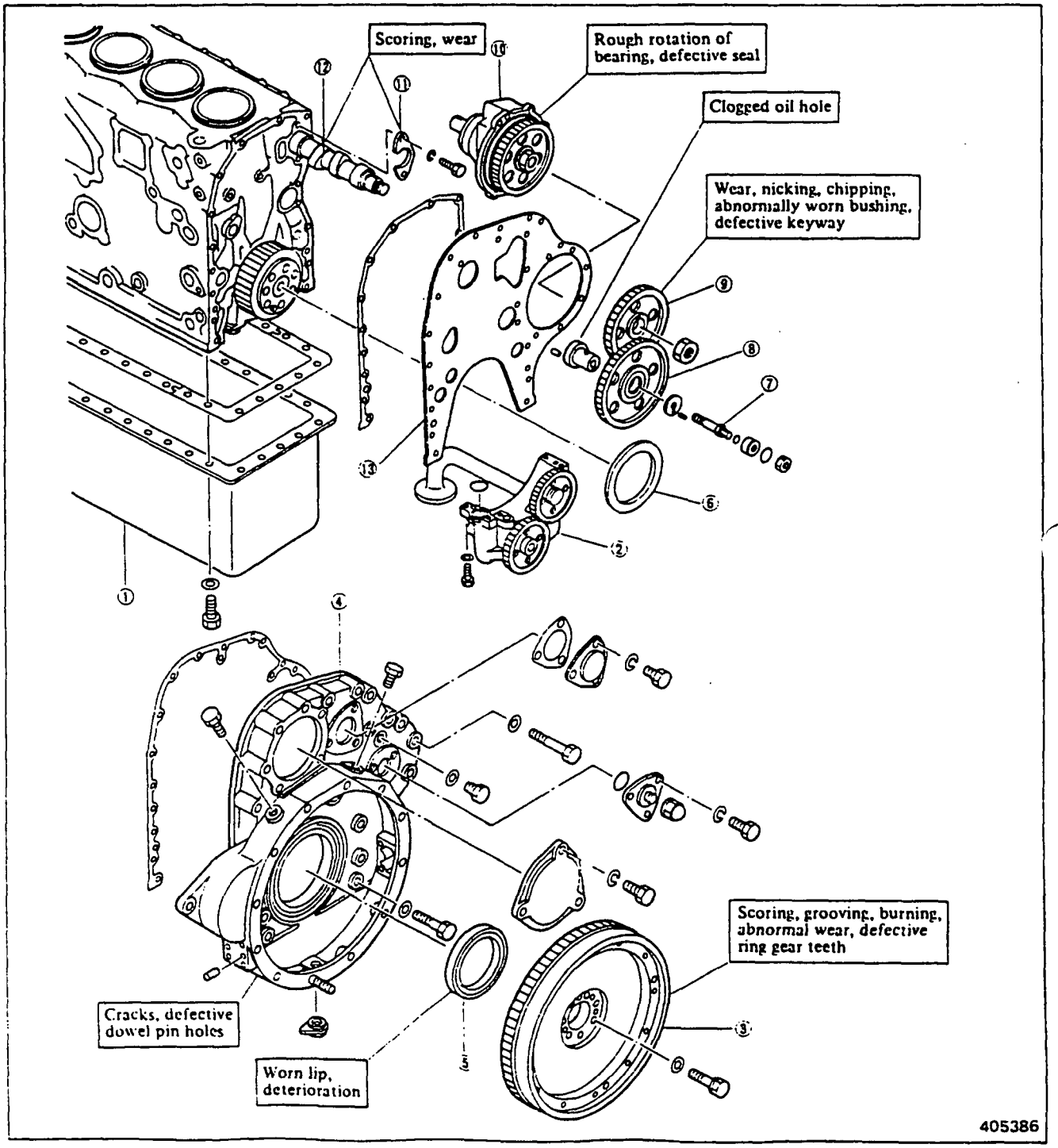
⚠ CAUTION

Before installing the cylinder head, measure the projection of piston, making sure that it is correct.
(Refer to (4), Pistons, 2.2.)

3. FLYWHEEL, TIMING GEARS AND CAMSHAFT

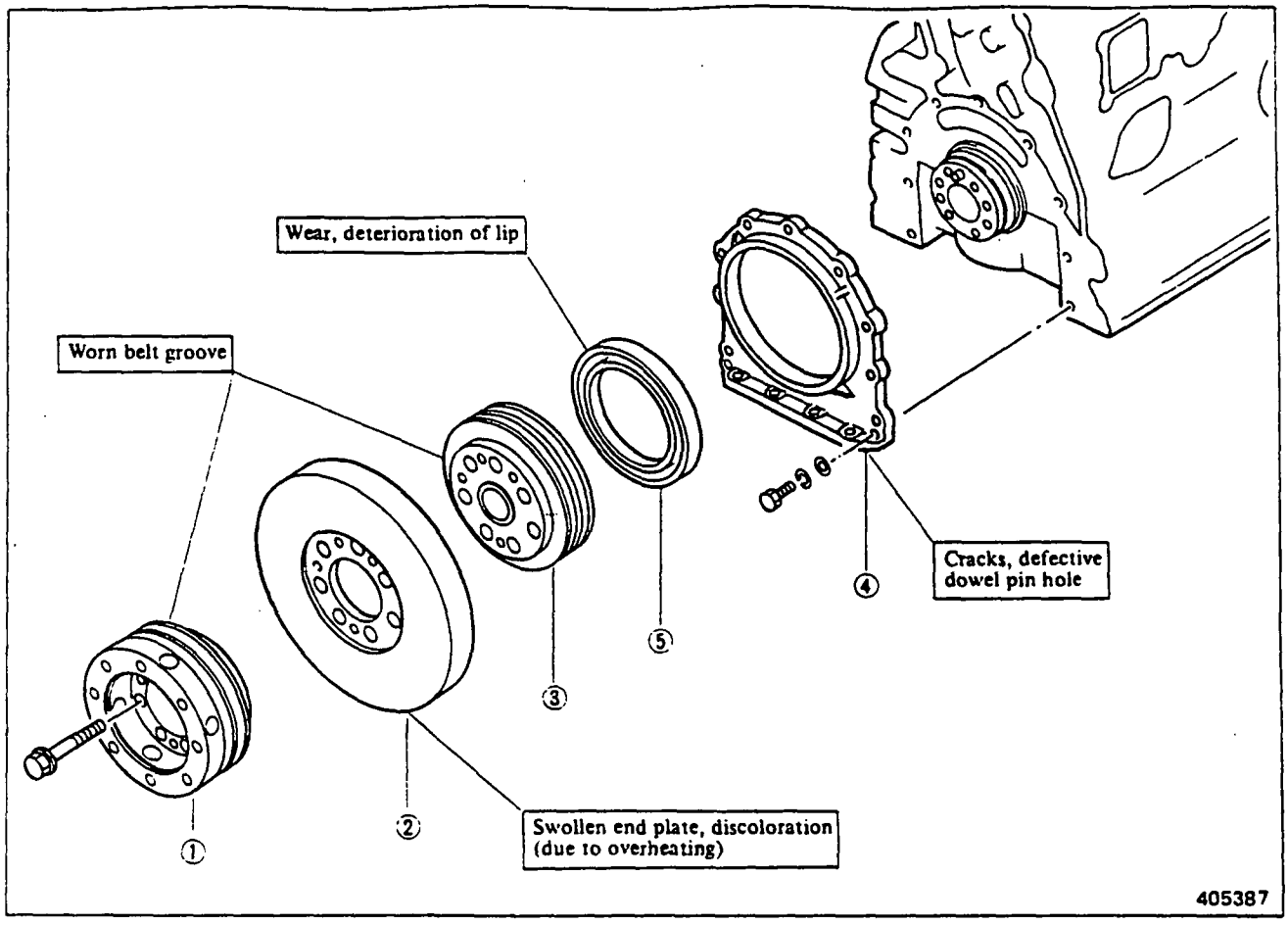
3.1 Disassembly

Flywheel side



① Oil pan
② Oil pump, oil strainer
③ Flywheel
④ Timing gear case
⑤ Oil seal
⑥ Oil seal slinger
⑦ Collar, idler gear shaft bolt
⑧ Idler gear
⑨ Camshaft gear
⑩ Accessory drive
⑪ Thrust plate
⑫ Camshaft
⑬ Rear plate

Viscous damper side



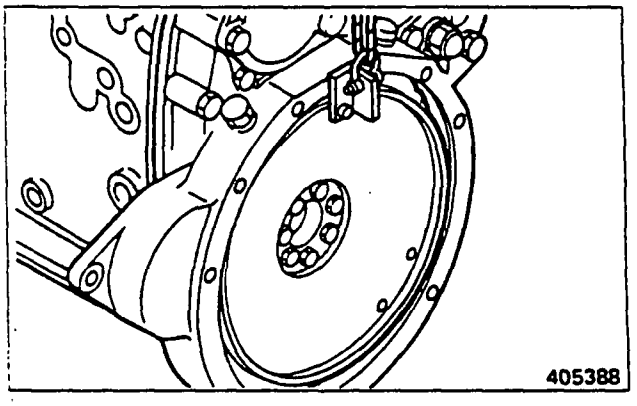
1 Pulley (for fan)
2 Viscous damper
3 Pulley (for water pump and alternator)
4 Front cover
5 Oil seal

(1) Removing flywheel

(a) Fasten a hoist to the flywheel.

(b) Unscrew the flywheel mounting bolts.

(c) Screw jacking bolts (M10 x 1.25) into the holes in the flywheel uniformly, and remove the flywheel. [Flywheel weight: 30 kg (66 lb), approx.]



⚠ CAUTION

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

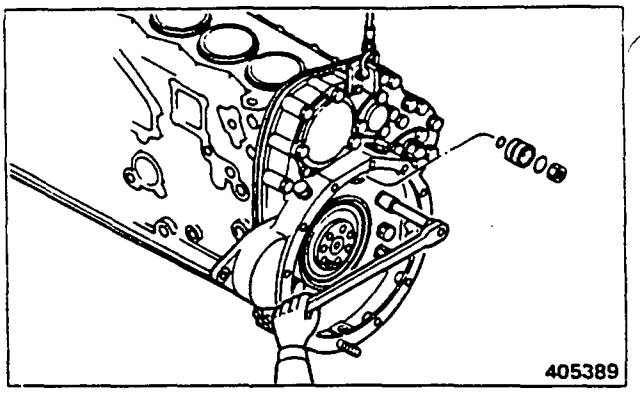
(b) The ring gear is shrinkage-fitted to the flywheel. Do not remove the gear except when it has to be replaced.

(2) Removing timing gear case and idler gear shaft collar

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

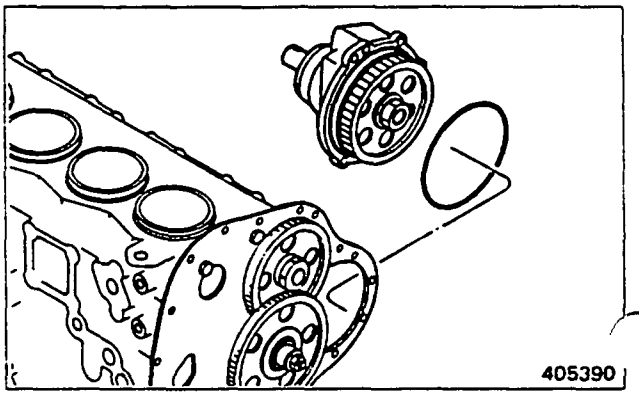
(b) Unscrew the idler gear shaft collar mounting nut, and remove the collar and two O-rings.

(c) Unscrew the mounting bolts, and remove the timing gear case.
[Timing gear case weight: 40 kg (88 lb), approx.]



(3) Removing accessory drive

Remove the accessory drive from the rear plate by loosening its mounting bolts (four bolts on the timing gear case side and two bolts on the rear plate side).

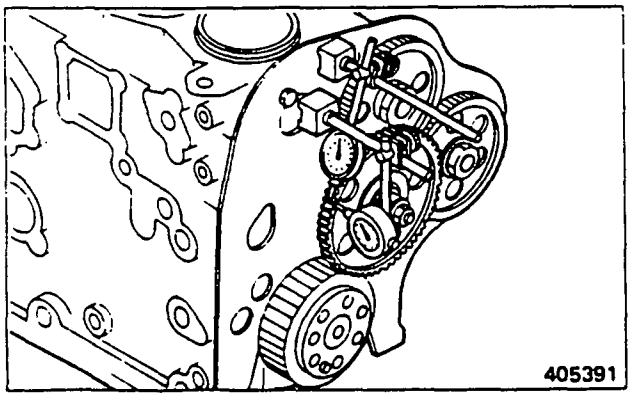


(4) Measuring backlash and end play

Measure the backlash and end play of the gears to obtain the data for parts replacement. To measure the backlash and end play of the injection pump gear, temporarily install the accessory drive.

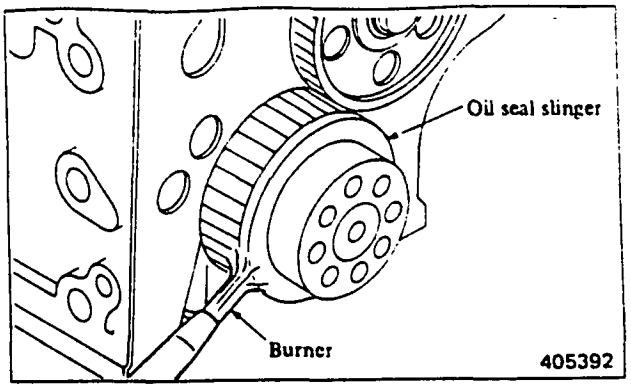
Unit: mm (in.)

Item	Standard clearance	Repair limit
Backlash	0.12 to 0.18 (0.0047 to 0.0071)	0.50 (0.0197)
Idler gear end play	0.10 to 0.28 (0.0039 to 0.0110)	0.60 (0.0236)
Camshaft end play	0.10 to 0.25 (0.0039 to 0.0098)	0.40 (0.0157)



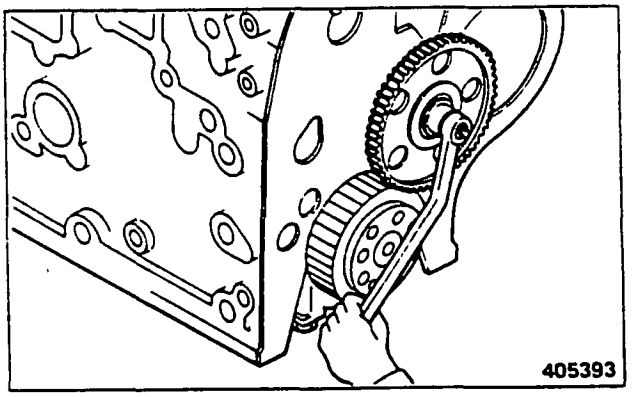
(5) Removing oil seal slinger

Remove the oil seal slinger from the crankshaft by heating it with a burner.



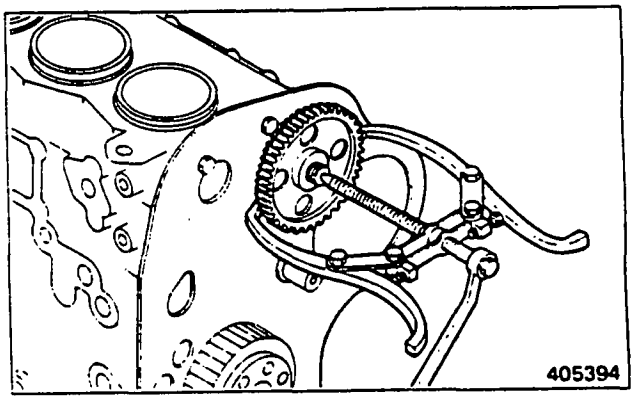
(6) Removing idler gear

To remove the idler gear and plate, unscrew the idler gear shaft bolt.



(7) Removing camshaft gear

Unscrew the camshaft gear mounting nut and, using a gear puller, remove the gear.

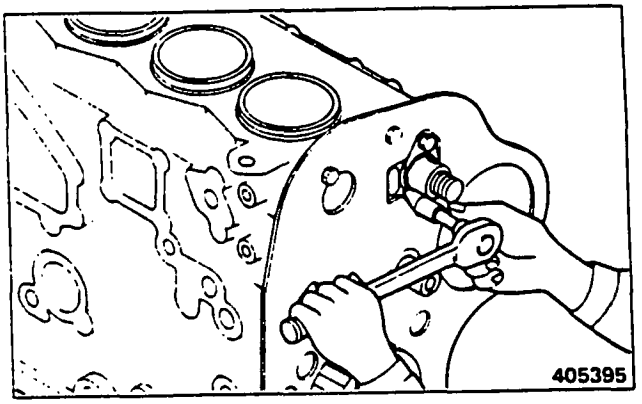


(8) Removing camshaft

Remove the thrust plate by unscrewing its mounting bolts, and pull out the camshaft from the crankcase.

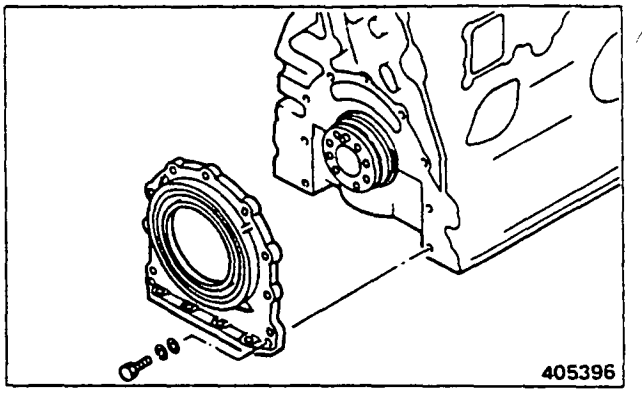
⚠ CAUTION

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



(9) Removing front cover

Unscrew the front cover mounting bolts and remove the cover, being careful not to damage the oil seal.

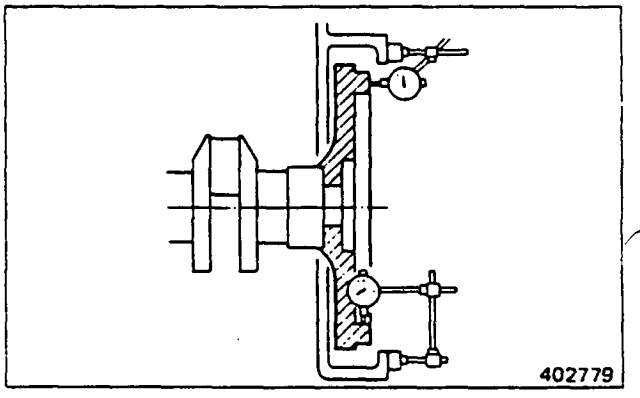


3.2 Inspection and repair

Flywheel and ring gear

Measuring face runout (axial eccentricity) and bore runout (radial eccentricity) of flywheel

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.)

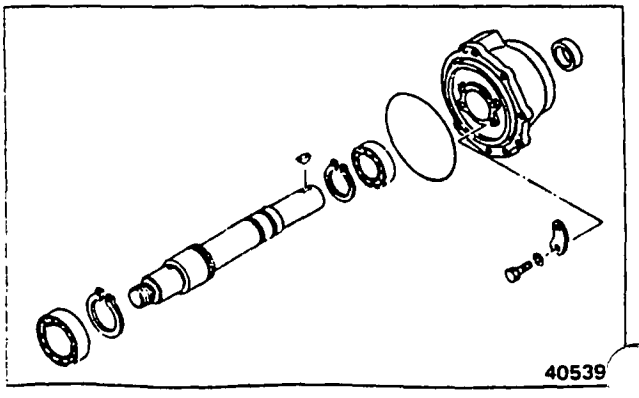
Item		Assembly standard
Flywheel	Face runout	0.28 (0.0110), maximum
	Bore runout	0.13 (0.0051), maximum

Accessory drive

(1) Check the bearing by the hand. Replace the bearing if it rotates erratically or hums.

(2) Check the fit of drive shaft in the bearing, and replace an excessively worn part.

(3) Check the fit of the bearing in the drive case, and replace an excessively worn part.



(4) Check the drive shaft and oil seal, and replace a defective part.

Unit: mm (in.)

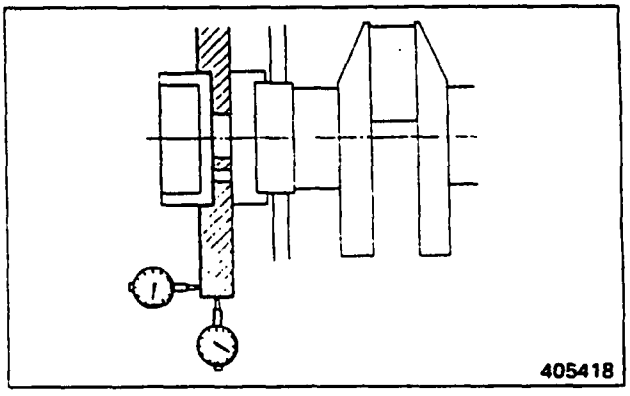
Item		Nominal value	Assembly standard
Drive case bearing bore inside diameter		80 (3.15)	79.988 to 80.018 (3.14913 to 3.15031)
		100 (3.94)	99.987 to 100.022 (3.93649 to 3.93787)
Bearing	Outside diameter	80 (3.15)	79.983 to 80.004 (3.14893 to 3.14976)
		100 (3.94)	99.980 to 100.005 (3.93621 to 3.93720)
	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)
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 and crankshaft pulley

(1) Inspecting viscous damper

(a) Visually check for cracked or swollen end plate, leakage of silicone (damping) fluid, discoloration due to overheating and other defects.

(b) With the damper installed to the crankshaft, measure the radial and face runouts of the damper by turning the crankshaft slowly, with a dial indicator set up on the periphery of the damper as shown. If the runouts are in excess of the service limit, replace the damper. The damper should be replaced every 8000 operating hours even if there is no evidence of defects.



Measuring damper runouts

Unit: mm (in.)

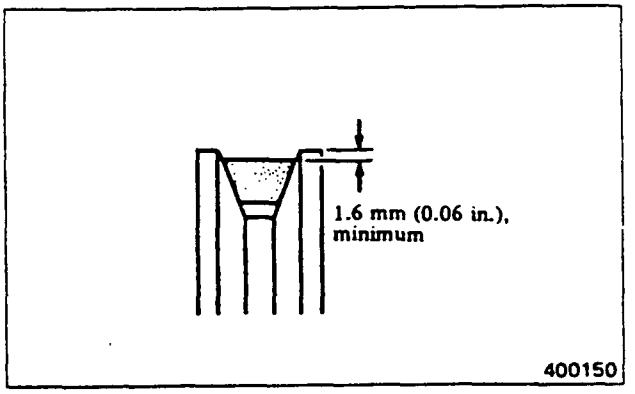
Item		Assembly standard	Service limit
Viscous damper	Radial runout	0.5 (0.020). maximum	1.5 (0.059)
	Face runout		

(2) Inspecting crankshaft pulley

Inspect 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 (0.06 in.), replace the pulley.

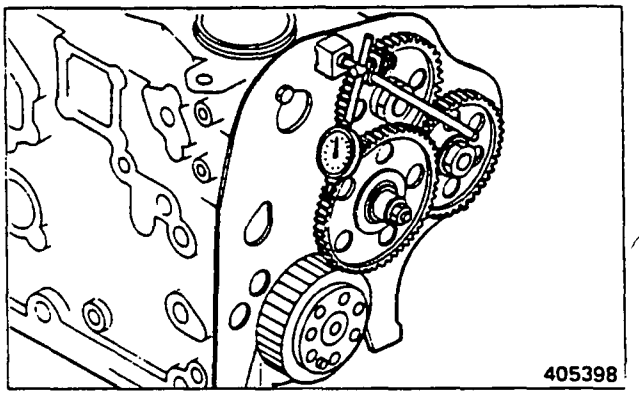


Inspecting V-belt groove in crankshaft pulley

Timing gears

Measuring backlash

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



Measuring timing gear backlash

Unit: mm (in.)

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

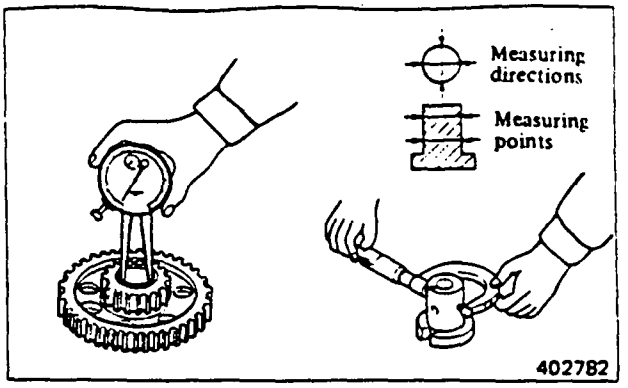
Idler gear, idler gear bushing and idler gear shaft

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

Replace the shaft and/or bushing if they are in excess of the service limit.

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Idler gear bushing inside diameter	40 (1.57)	40.000 to 40.025 (1.57480 to 1.57578)	40.100 (1.57874)
Idler gear shaft diameter		39.959 to 39.975 (1.57319 to 1.57382)	- 39.900 (1.57086)



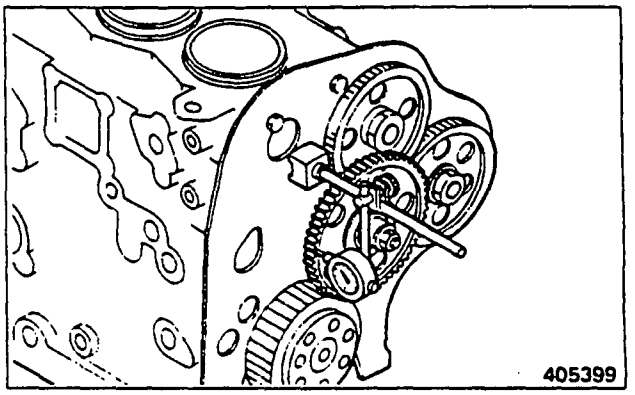
Measuring idler gear bushing and shaft

(2) Measuring idler gear end play

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

Unit: mm (in.)

Item	Standard clearance	Repair limit
Idler gear end play	0.10 to 0.28 (0.0039 to 0.0110)	0.60 (0.0236)

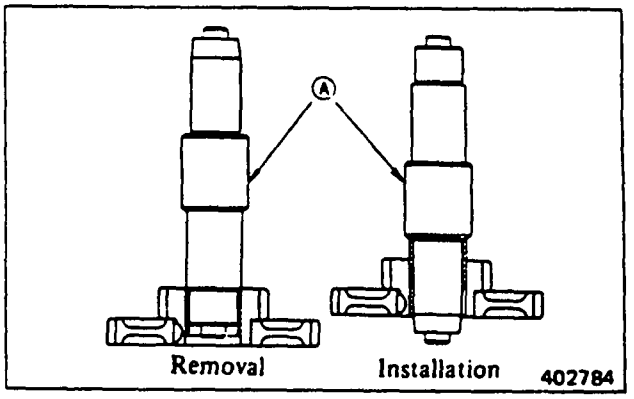


Measuring idler gear end play

(3) Replacing idler gear bushing

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

(b) To install a new bushing, press it from the smaller-gear side of the idler gear until the end face of the bushing is flush with that of the gear boss.



Replacing idler gear bushing

(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 $40\ ^{+0.025}_{0}$ mm ($1.57\ ^{+0.00098}_{0}$ in.) $\frac{3.2S}{\nabla\nabla\nabla}$.

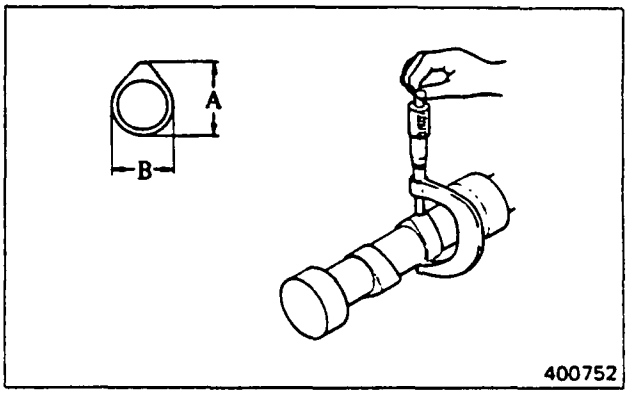
Camshaft and camshaft bushings

(1) Measuring lobe lift

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

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

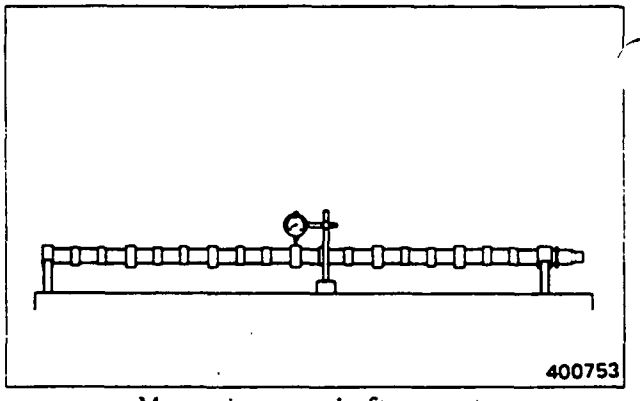
If the runout is in excess of the repair limit, straighten the camshaft by means of a press, or replace it with a new one.

⚠ 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.

Unit: mm (in.)

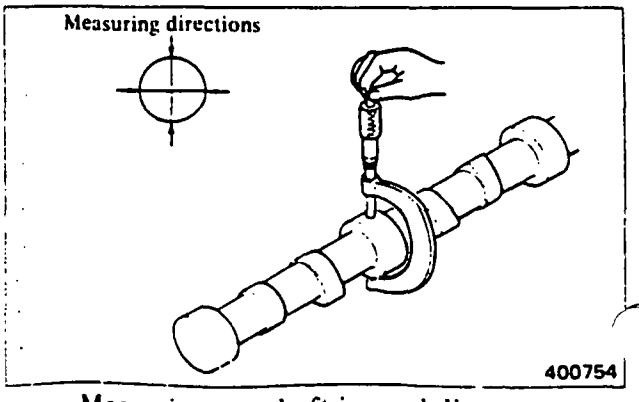
Item	Assembly standard	Repair limit
Camshaft runout	0.05 (0.0020), maximum	0.08 (0.0031)



Measuring camshaft runout

(3) Measuring camshaft journal diameter

Using a micrometer, measure each camshaft journal in two directions at right angles to each other. Replace the camshaft if the journal is in excess of the service limit.



Measuring camshaft journal diameter

Unit: mm (in.)

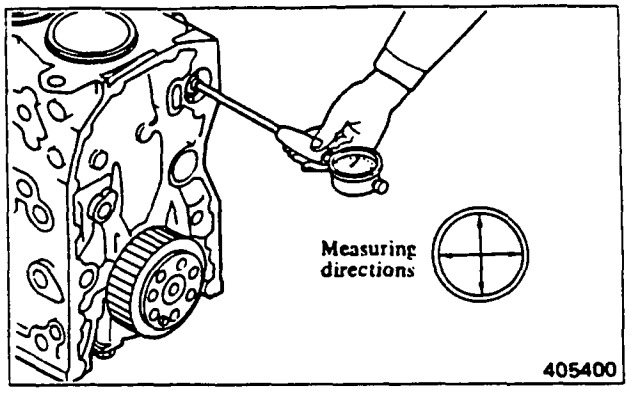
Item	Nominal value	Assembly standard	Service limit
Comshaft journal diameter	68 (2.68)	67.91 to 67.93 (2.6736 to 2.6744)	67.88 (2.6724)

(4) Measuring camshaft bushing inside diameter

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

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Camshaft bushing inside diameter	68 (2.68)	67.98 to 68.05 (2.6764 to 2.6791)	68.17 (2.6839)



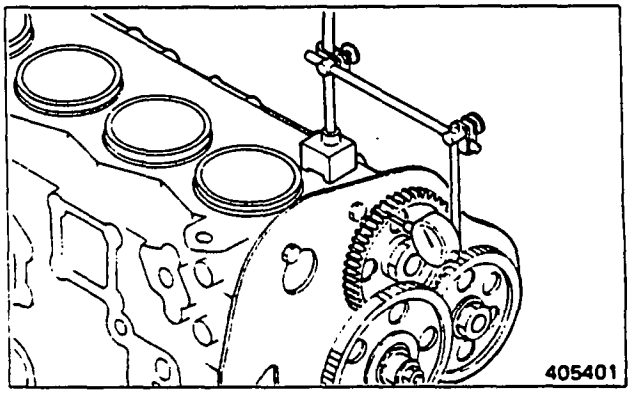
Measuring camshaft bushing inside diameter

(5) Measuring camshaft end play

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

Unit: mm (in.)

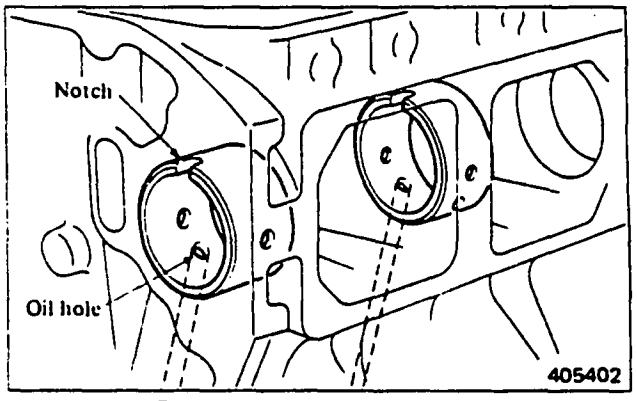
Item	Standard clearance	Repair limit
Camshaft end play	0.10 to 0.25 (0.0039 to 0.0098)	0.40 (0.0157)



Measuring camshaft end play

(6) Replacing camshaft bushings

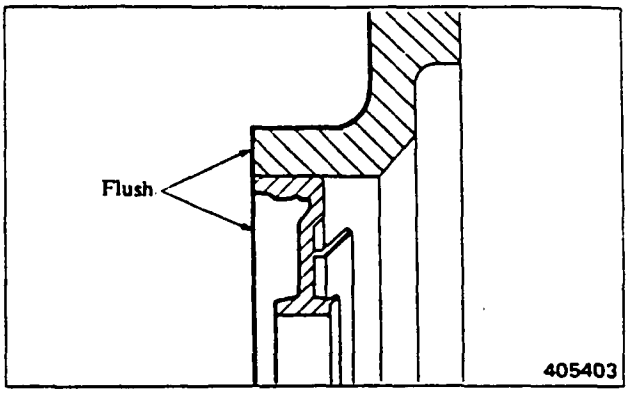
Chill the bushings with liquid nitrogen for 5 minutes and put them in the crankcase with bushing installer (A) (34A91-02100). Make sure the oil holes of the crankcase and bushings are aligned. Install the rearmost (No. 7) bushing with its notched side facing the rear of the crankcase.



Replacing camshaft bushings

Replacing front oil seal

Using a hammer, remove the oil seal from the front cover. To install a new oil seal, press it into the cover with a plate until it is flush with the cover. Do not apply any oil or sealant to the periphery of the oil seal.



NOTE

Do not attempt to reuse the oil seal which has been removed during disassembly.

3.3 Reassembly

Follow the reverse of disassembly procedure.

(1) Installing front cover

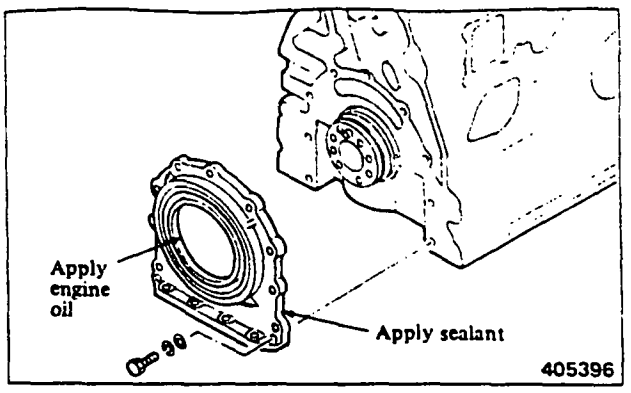
(a) Put the oil seal in the front cover and apply engine oil to the lip of the seal.

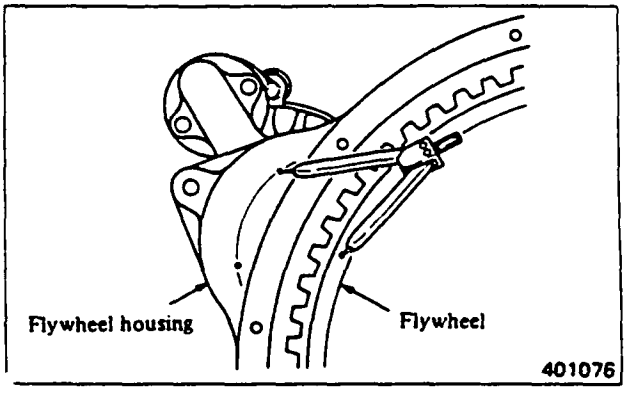
(b) Apply sealant (Three Bond 1104) to the front cover mounting surface of crankcase, and place the packing in position.

(c) Install the front cover to the crankcase, using care not to twist or fold the oil seal.

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

(e) Tighten the front cover mounting bolts uniformly.





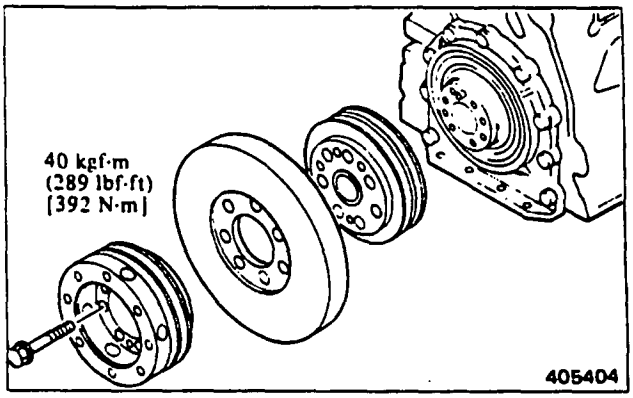
(When the pointer has been out of place)

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 equal distances from two marks punched on the flywheel housing.

(2) Installing pulley and viscous damper

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

(b) Check the damper for radial and face runouts.
(Refer to Viscous damper and crankshaft pulley, 3.2.)



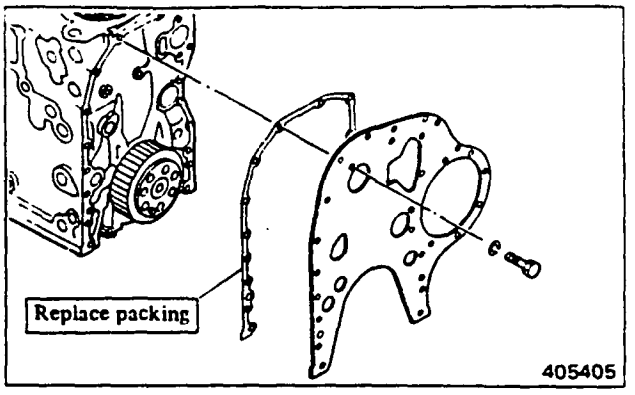
(3) Installing rear plate

(a) Put the packing on the crankcase, making sure the dowel pin enters its hole in the packing.

(b) Install the rear plate, making sure the dowel pin enters its hole in the plate.

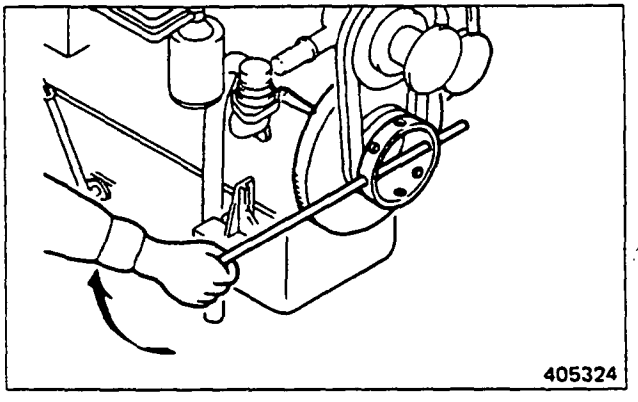
(c) Replace the dowel pin if worn, or if the rear plate has been replaced.

(d) Make sure that the lower end of rear plate is flush with the bottom of crankcase.



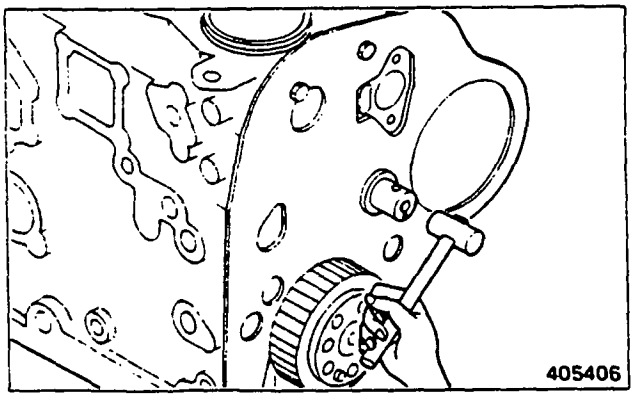
(4) Turning engine

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



(5) Installing idler gear shaft

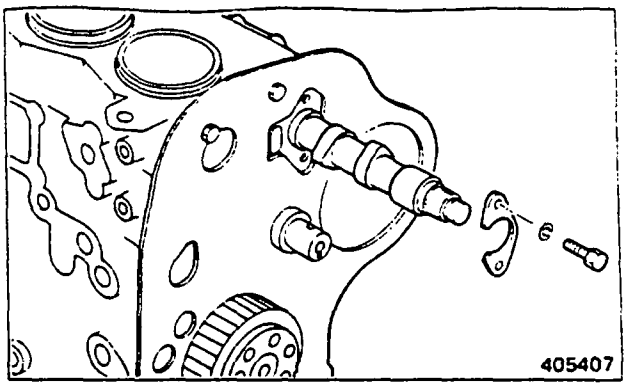
Drive in the idler gear shaft into position with the dowel pin aligned with the shaft groove.



(6) Installing camshaft

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

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

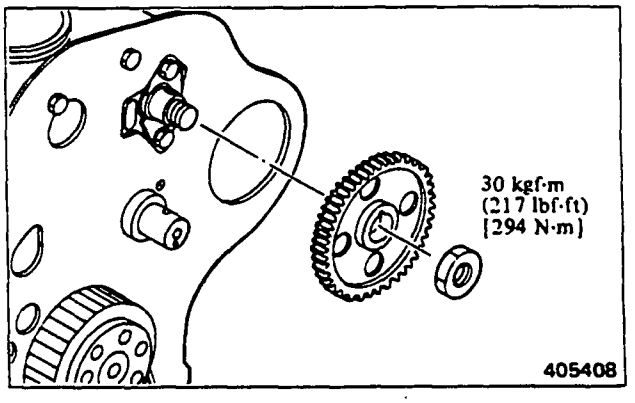


⚠ CAUTION

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

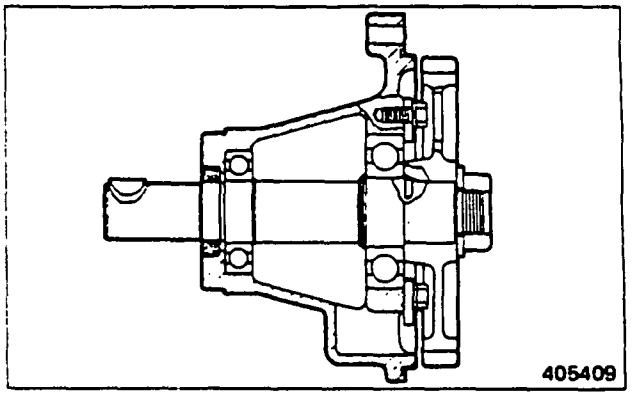
(7) Installing camshaft gear

Install the camshaft gear to the camshaft by aligning the keyway of the gear with woodruff key. Tighten the nut to the specified torque.



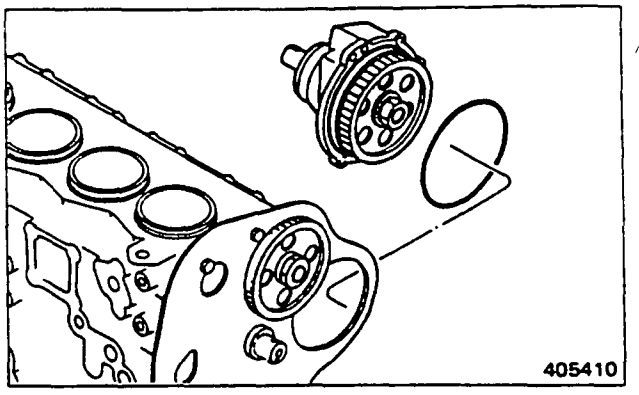
(8) Reassembling accessory drive

Put the gear on the drive shaft, making sure the dowel pin of the shaft enters the notch of the gear, and drive the gear onto the shaft with a copper hammer.



(9) Installing accessory drive

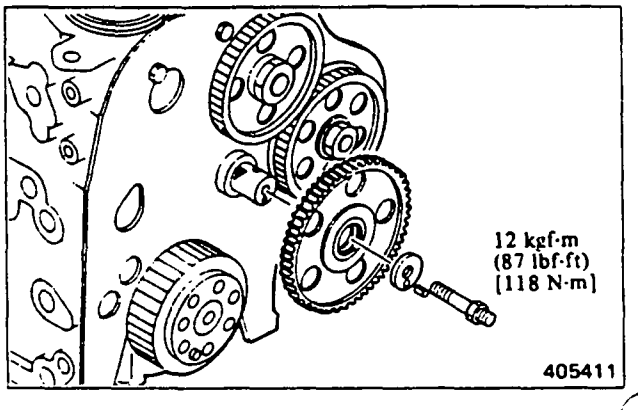
Put O-ring in the groove in the mounting flange of accessory drive to which the injection pump drive gear and guide plate have been installed, and install the drive to the rear plate.



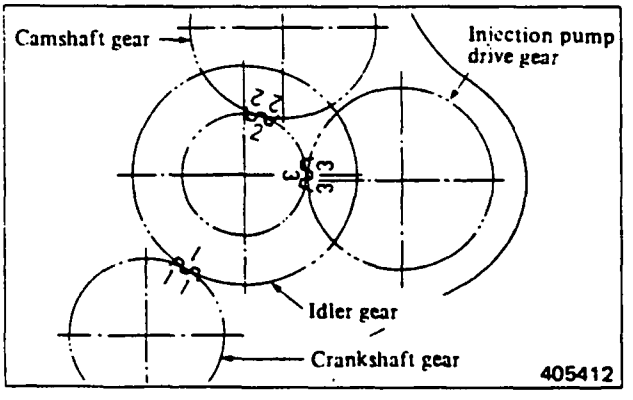
(10) Installing idler gear

(a) Put the idler gear on its shaft by aligning its timing marks with those on the crankshaft gear, injection pump gear and camshaft gear. Install the thrust plate to the gear.

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



(c) After installing the idler gear, make sure the timing marks of this gear are properly aligned with those of the other gears in the train.

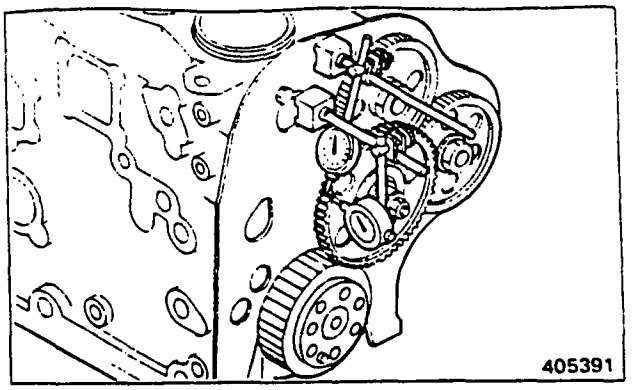


(11) Inspecting and adjusting timing gears after installation.

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, inspect the backlash between the gears in mesh and the end play of each gear. (Refer to Measuring backlash and Measuring idler gear end play, 3.2.)

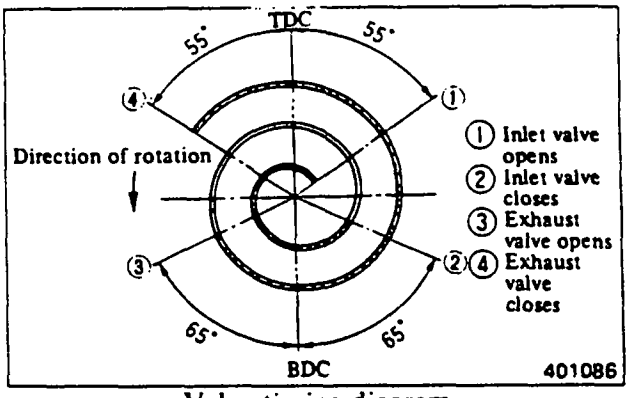


Inspecting timing gear backlash and end play

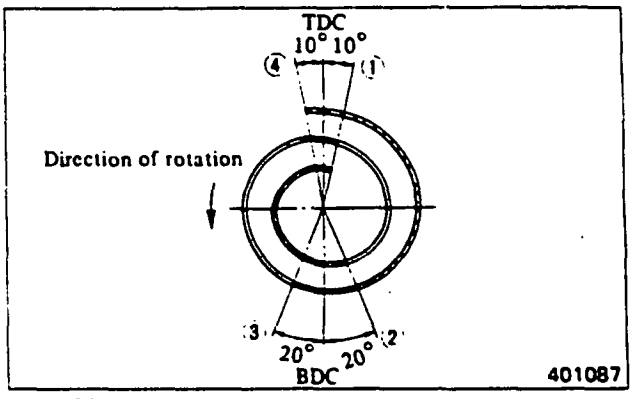
(Inspecting valve timing)

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

Adjust the clearance of inlet and exhaust valves of No. 1 cylinder to 2 mm (0.08 in.) by inserting a 2 mm (0.08 in.) feeler gauge into between the bridge cap top and rocker. Pull out the 2 mm (0.08 in.) feeler gauge, insert a 0.05 mm (0.0020 in.) feeler gauge there, and slowly turn the crankshaft in normal direction, trying to find a position where the 0.05 mm (0.0020 in.) feeler gauge is firmly gripped (the valve starts opening) and a position where that gauge is just ungripped (the valve starts closing). Check to make sure that these positions coincide with the angular positions shown in the valve timing diagram with 1.95 mm (0.0768 in.) valve clearance.



Valve timing diagram



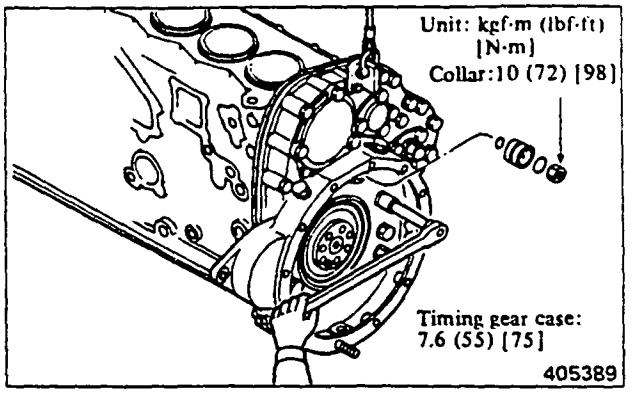
Valve timing diagram with 1.95 mm (0.0768 in.) clearance added to valves

(12) Installing timing gear case and idler gear shaft collar

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

(b) Put O-ring in the gooves in the idler gear shaft and collar. Install the collar to the shaft through the hole in the case, and tighten the collar mounting nut to the specified torque.

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



(13) Installing rear oil seal

To install the rear oil seal, use oil seal installer (34A91-04020).

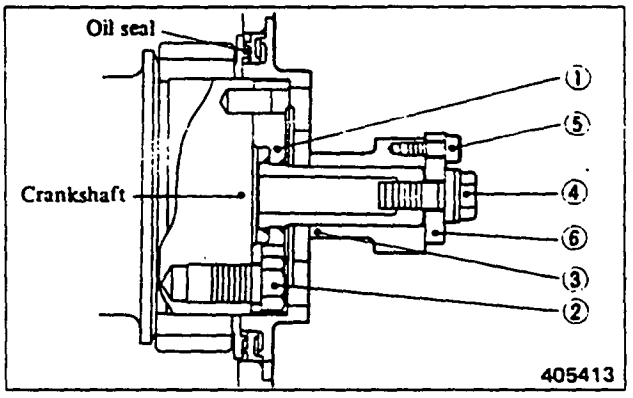
(a) Install guide (1) to the rear end of the crankshaft with insert bolts (2).

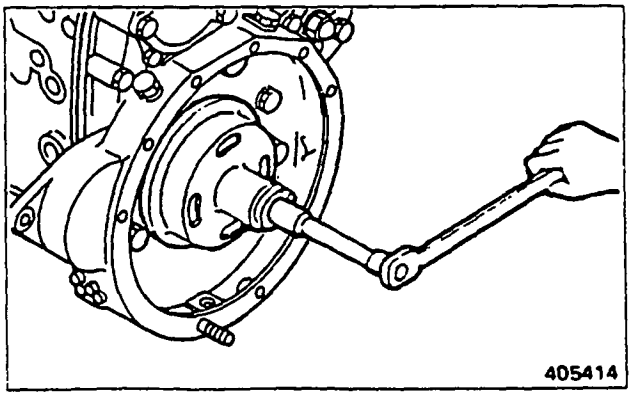
(b) Put the oil seal on installer (3), and put the installer on the shaft portion of the guide.

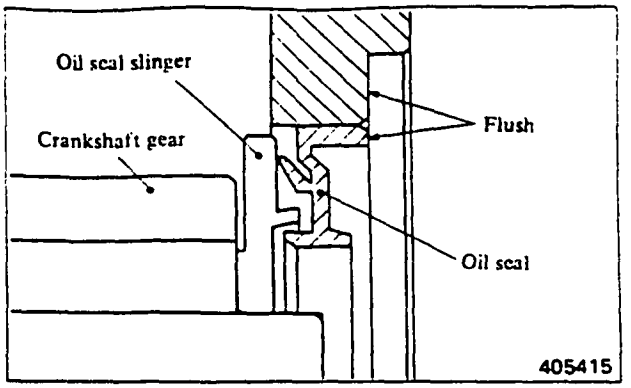
(c) Tighten bolt (4) of the installer to install the oil seal to the gear case.

(d) Loosen socket bolts (5). Remove swing washer (6) from bolt (4), and pull off the installer.

(e) Loosen the insert bolts, and remove the guide from the crankshaft.





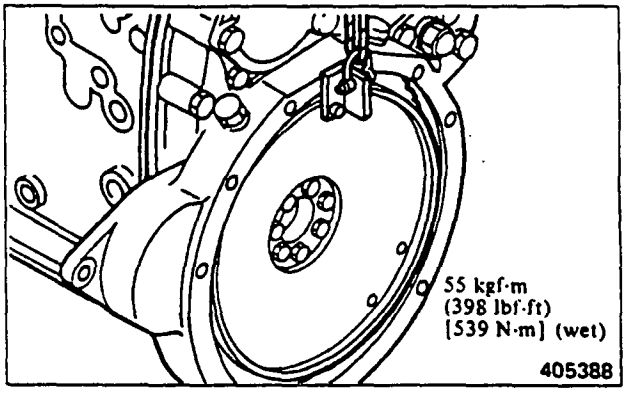


(14) Installing flywheel

(a) Install the flywheel, making sure that the dowel pin enters its hole in the flywheel.

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

(c) Inspect the face and radial runouts of the flywheel.
(Refer to Flywheel and ring gear, 3.2.)

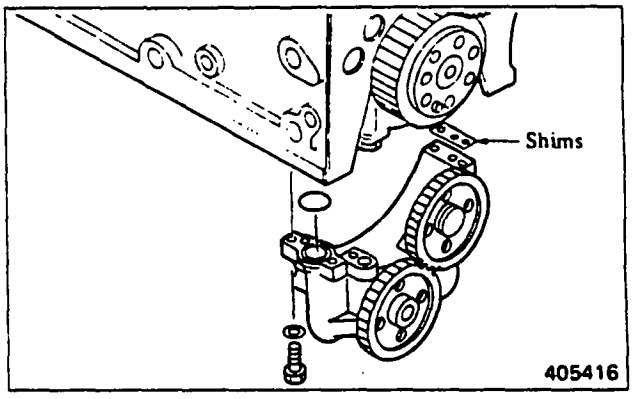


(15) Installing oil pump and oil strainer

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

Unit: mm (in.)

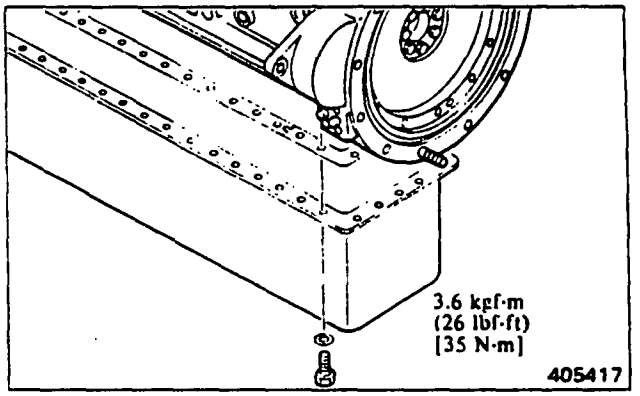
Item	Assembly standard
Backlash between crankshaft gear and oil pump gear	0.24 to 0.38 (0.0094 to 0.0150)



(16) Installing oil pan

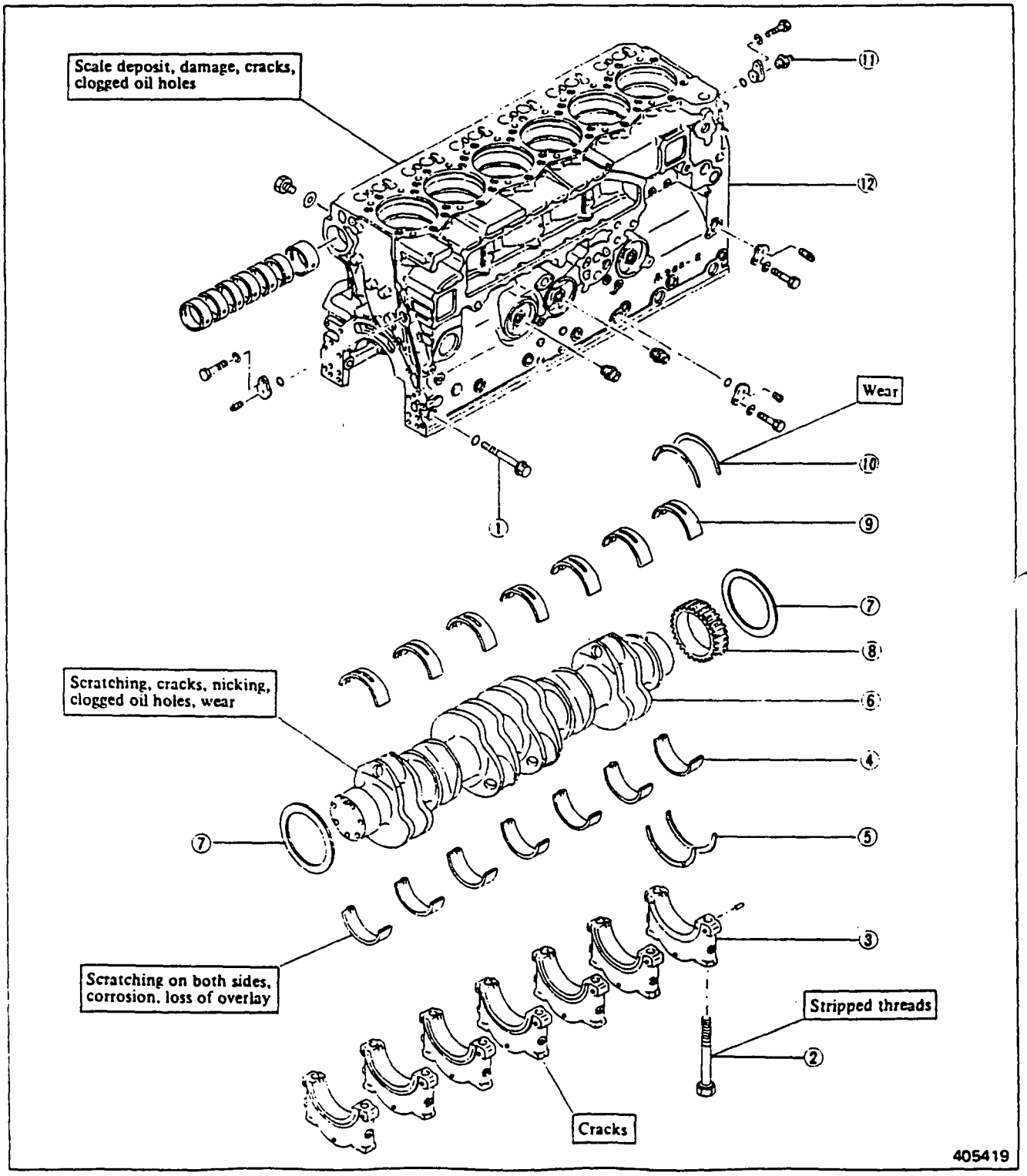
(a) Fit the packing to the oil pan by applying sealant (HERDITE) to the separated portions (4 places).

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



4. CRANKCASE, CRANKSHAFT AND MAIN BEARINGS

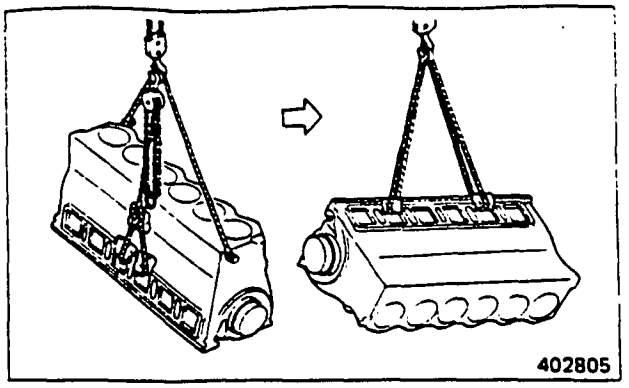
4.1 Disassembly



① Side bolt
② Bolt
③ Main bearing cap
④ Main bearing (lower shell)
⑤ Thrust plate
⑥ Crankshaft
⑦ Oil seal slinger
⑧ Crankshaft gear
⑨ Main bearing (upper shell)
⑩ Thrust plate
⑪ Oil spray plug
⑫ Crankcase

(1) Turning crankcase upside down

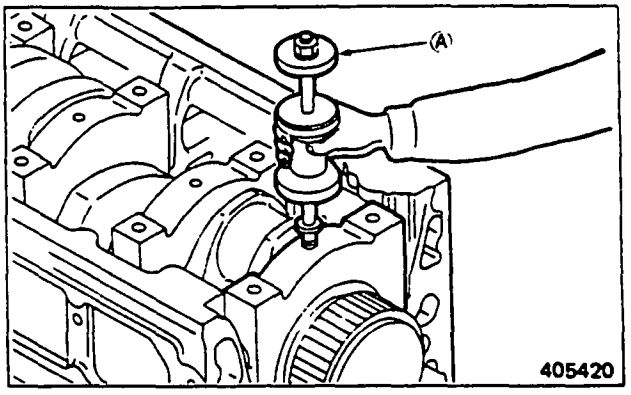
Using a hoist and shackles, lay the crankcase on its side. Then, attach slings to the crankcase, and turn it upside down.
[Crankcase and crankshaft weight: 400 kg (882 lb), approx.]



(2) Removing main bearing caps

(a) Using slide hammer (A) (40691-03100), remove the main bearing caps.

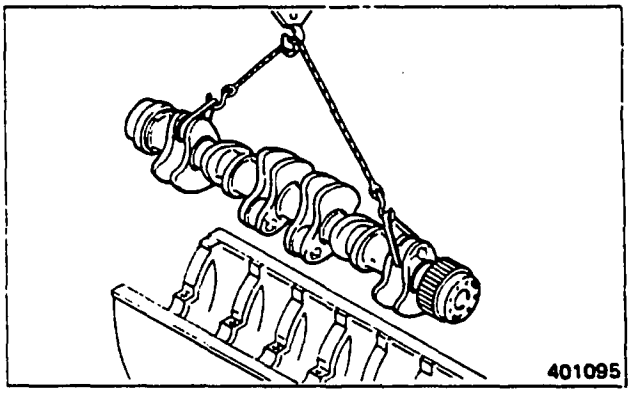
(b) Remove the thrust plates from the No. 7 bearing cap, being careful not to damage the thrust plates.



(3) Removing crankshaft

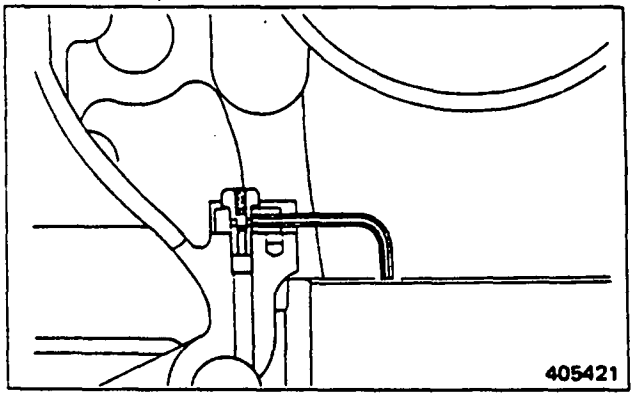
(a) Remove the upper halves of thrust plates while rotating the crankshaft slowly.

(b) Carefully lift the crankshaft off the crankcase, keeping it horizontal.



(4) Removing oil jet nozzles

Do not remove the oil jet nozzles unless their spray holes are clogged or spray direction is improper.



4.2 Inspection and repair

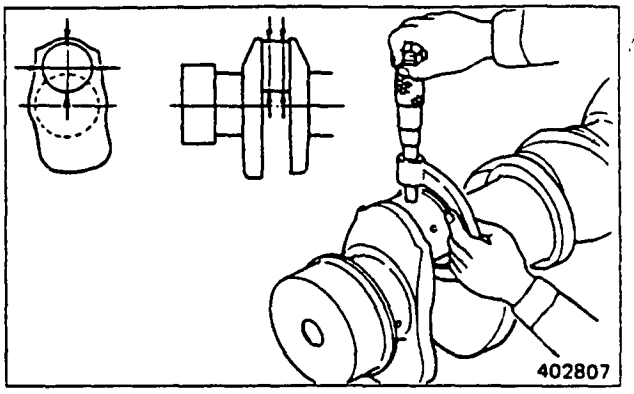
Crankshaft

(1) Measuring crankpin and journal diameters

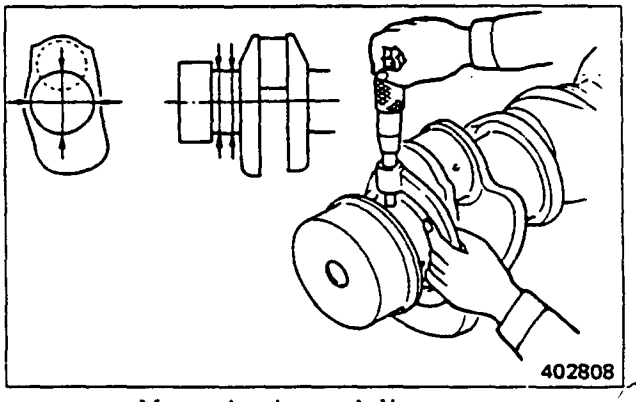
(a) Using a micrometer, measure the crankpin and journal diameters. If the diameters are in excess of the repair limit, grind them to the next undersize [-0.25 mm (-0.0098 in.), -0.50 mm (-0.0197 in.), -0.75 mm (-0.0295 in.) or -1.00 mm (-0.0394 in.)].

(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 in excess of the repair limit, replace the crankshaft.



Measuring crankpin diameter



Measuring journal diameter

Unit: mm (in.)

Item		Nominal value	Assembly standard	Repair limit
Crankpin diameter		90 (3.54)	-0.07 to -0.09 (-0.0028 to -0.0035)	-0.13 (-0.0051)
Journal diameter		130 (5.12)	-0.100 to -0.120 (-0.00394 to -0.00472)	-0.160 (-0.00630)
Crankpins and journals	Parallelism		0.01 (0.0004), maximum	0.03 (0.0012)
	Out-of-roundness			
	Taper			
	Fillet radius		$6.0^{\ 0}_{-0.2}$ ($0.236^{\ 0}_{-0.008}$)	
	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.

Crankshaft refinishing dimensions

Unit: mm (in.)

	Undersize	Finishing dimension	Out-of-roundness	Taper
Crankpin diameter	0.25 (0.0098)	89.66 to 89.68 (3.5299 to 3.5307)	0.01 (0.0004), maximum	0.01 (0.0004), maximum
	0.50 (0.0197)	89.41 to 89.43 (3.5201 to 3.5209)		
	0.75 (0.0295)	89.16 to 89.18 (3.5102 to 3.5110)		
	1.00 (0.0394)	88.91 to 88.93 (3.5004 to 3.5012)		
Journal diameter	0.25 (0.0098)	129.63 to 129.65 (5.10353 to 5.10432)		
	0.50 (0.0197)	129.38 to 129.40 (5.09370 to 5.09448)		
	0.75 (0.0295)	129.13 to 129.15 (5.08385 to 5.08464)		
	1.00 (0.0394)	128.88 to 128.90 (5.07401 to 5.07480)		

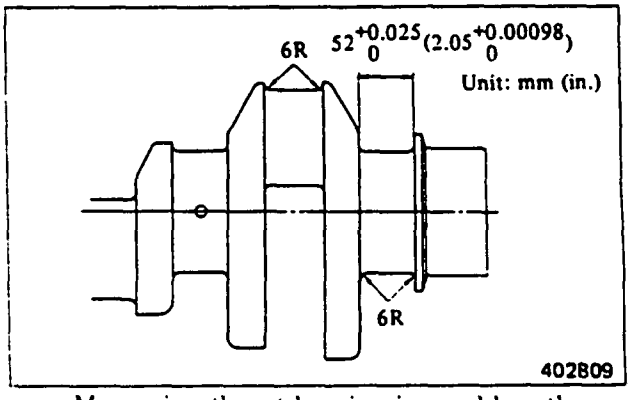
When grinding the crankpins and journals, be sure to produce the same fillet radius as the original one. They should have a hardness of 620 or more in terms of Vickers Hardness Number. If necessary, reharden the crankpins and journals, and inspect them for cracks by conducting a magnalux (magnetic particle)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

The journals and crankpins should be finished to $\underset{\nabla\nabla}{0.8S}$ after grinding.

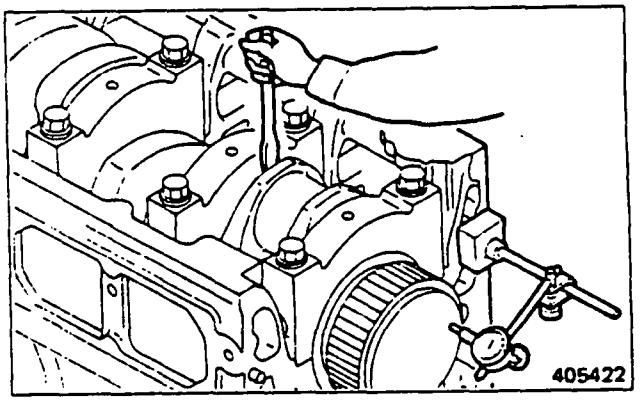
(3) Measuring crankshaft end play

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

(b) If the end play still exceeds the repair limit even after new thrust plates have been installed, replace the plates with the next oversize ones. There are three oversizes for the thrust plates; namely, +0.25 mm (+0.0098 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, gain the purpose.



Measuring thrust bearing journal length



Measuring crankshaft end play

Unit: mm (in.)

Item	Standard clearance	Repair limit
Crankshaft end play	0.20 to 0.39 (0.0079 to 0.0154)	0.50 (0.0197)

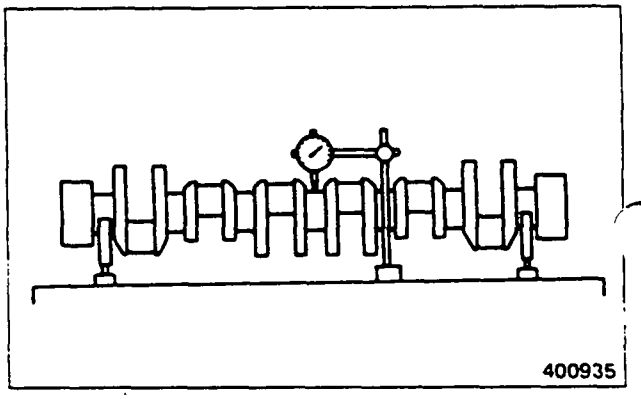
Crankshaft journal grinding dimensions for oversize thrust plates

Unit: mm (in.)

Item	Oversizes for journal or thrust plates	Oversizes for journal and thrust plates	Tolerance
+0.25 (+0.0098) oversize	52.25 (2.0571)	52.50 (2.0669)	+0.03 0 (+0.0012 0)
+0.50 (+0.0197) oversize	52.50 (2.0669)	53.00 (2.0866)	
+0.75 (+0.0295) oversize	52.75 (2.0768)	53.50 (2.1063)	–

(4) Measuring crankshaft runout

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



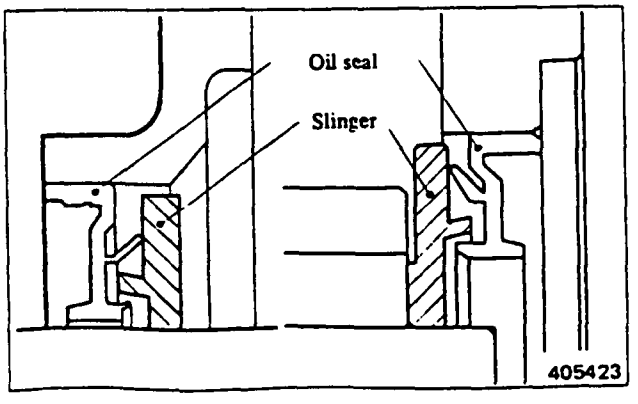
Measuring crankshaft runout

Unit: mm (in.)

Item	Assembly standard	Repair limit
Crankshaft runout	0.04 (0.0016), maximum	0.10 (0.0039)

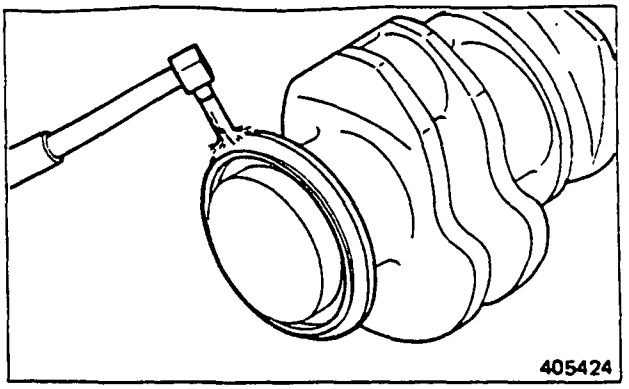
(5) Replacing slingers

Replace the slingers if they are pitted, scratched or distorted to such an extent of causing oil leaks.



(Removing the slingers)

To remove the slingers from the crankshaft, heat them with a burner.

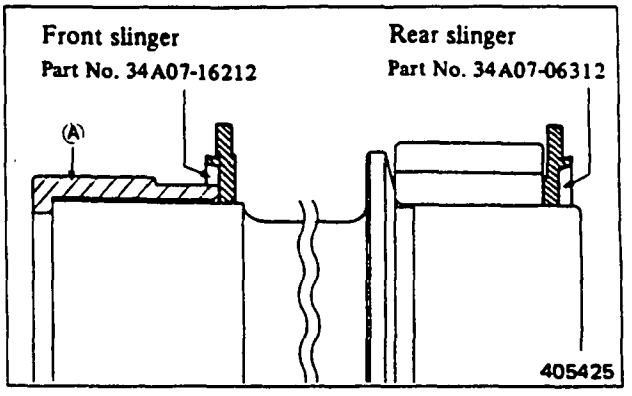


(Installing new slingers)

(a) Check the part numbers of the front and rear slingers for discrimination.

⚠ CAUTION

Install the front slinger on the front side of the crankshaft and the rear slinger on the rear side. A failure to follow this precaution will result in oil leaks.



(b) Heat new slingers to over 110°C (212°F), and drive them onto the crankshaft.

(c) Drive the rear slinger until it touches the gear. Position the front slinger with oil seal slinger installer (A) (34A91-04100).

(d) If the slinger cannot be installed by this means, hit its center or shoulder portion with a copper hammer.

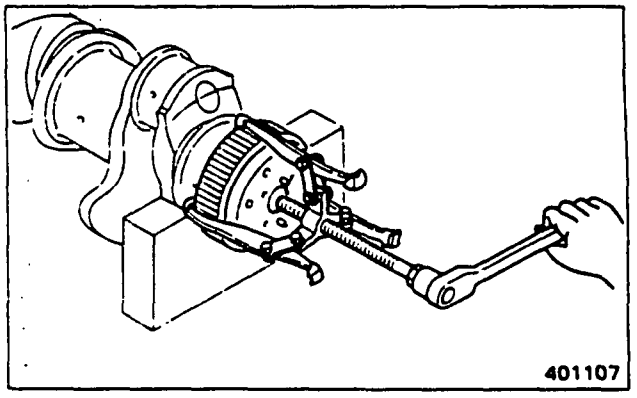
(6) Replacing crankshaft gear

(Removing the gear)

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

NOTE

Do not remove the gear by driving with a hammer.

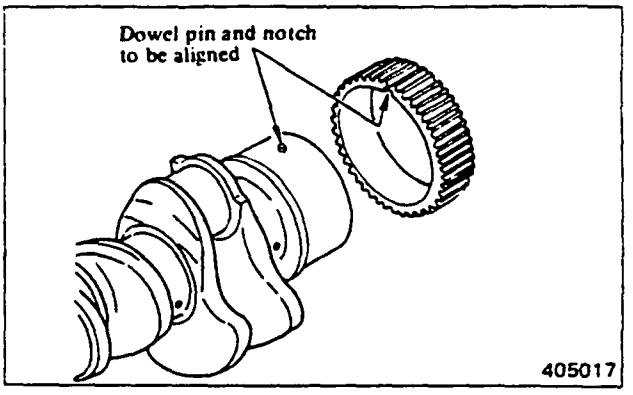


(Installing a new gear)

(a) Measure the inside diameter of a new gear and the outside diameter of the portion of the crankshaft to which the gear is to be installed to make sure that the interference is 0.101 to 0.161 mm (0.00398 to 0.00634 in.).

(b) Heat the gear up to 100°C to 200°C (212°F to 392°F) with a heater.

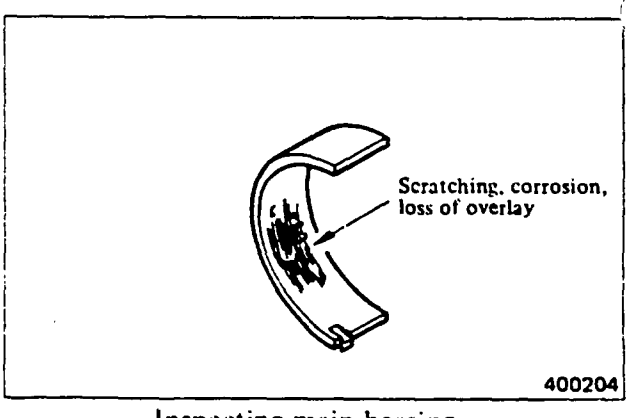
(c) Place the gear on the crankshaft by aligning the dowel pin with the notch of the gear, and hit the end face of the gear with a copper hammer.



Main bearings

(1) Inspection

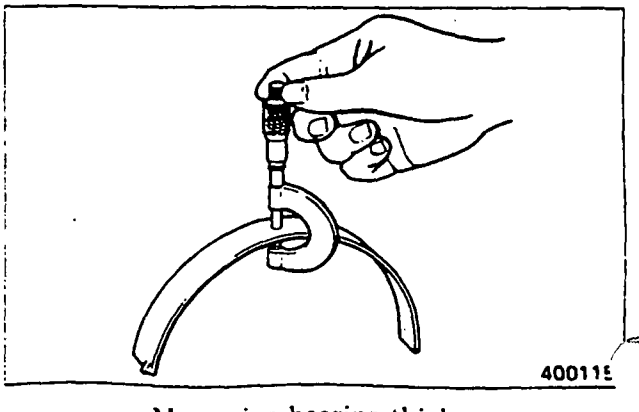
Inspect each bearing shell for abnormal contact, scratching, corrosion, loss of overlay and other defects. Also check for a sign of poor seating in the bore of the crankcase or bearing cap.



Inspecting main bearing

(2) Measuring bearing thickness

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



Measuring bearing thickness

Unit: mm (in.)

Item		Nominal value	Assembly standard	Service limit
Thickness of the center of main bearing	STD	3.500 (0.13780)	3.482 to 3.500 (0.13709 to 0.13780)	3.450 (0.13583)
	-0.25 (-0.0098)	3.625 (0.14272)	3.607 to 3.625 (0.14201 to 0.14272)	3.575 (0.14075)
	-0.50 (-0.0197)	3.750 (0.14764)	3.732 to 3.750 (0.14693 to 0.14764)	3.700 (0.14567)
	-0.75 (-0.0295)	3.875 (0.15256)	3.857 to 3.875 (0.15185 to 0.15256)	3.825 (0.15059)
	-1.00 (-0.0394)	4.000 (0.15748)	3.982 to 4.000 (0.15677 to 0.15748)	3.950 (0.15551)

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 is in excess of 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.

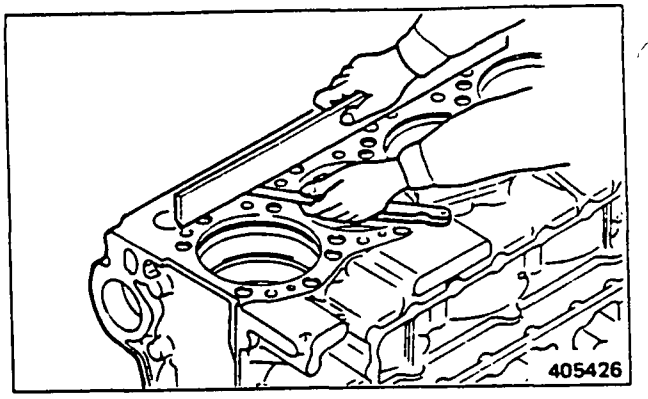
Crankcase

(1) Measuring warpage of gasket contact surface

Measure warpage with a straightedge and a feeler gauge. If the warpage is in excess of the assembly standard, reface the gasket contact surface with a surface grinder.

Unit: mm (in.)

Item	Assembly standard	Repair limit
Warpage	0.07 (0.0028), maximum	0.20 (0.0079)



Measuring warpage

NOTE

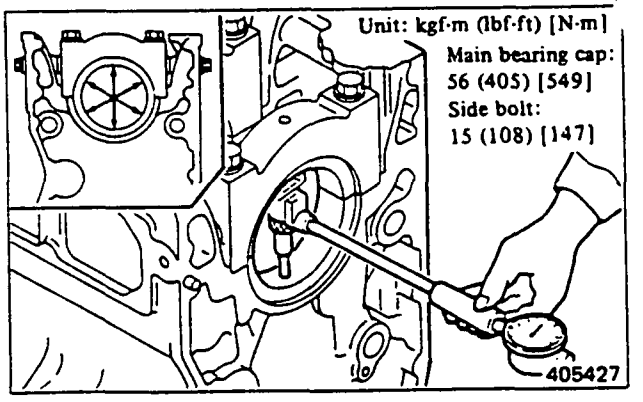
Do not grind the surfaces more than are necessary for removing warpage to prevent the piston projection from exceeding the assembly standard. (Refer to (4), Pistons, 2.2.)

(2) Measuring main bearing bore diameter

Secure each bearing cap to the specified torque, and measure the bore diameter 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 137.025 (5.39369 to 5.39467)	137.035 (5.39507)



Measuring main bearing bore diameter

NOTE

For tightening of the main bearing cap bolts, refer to (4), 4.3.

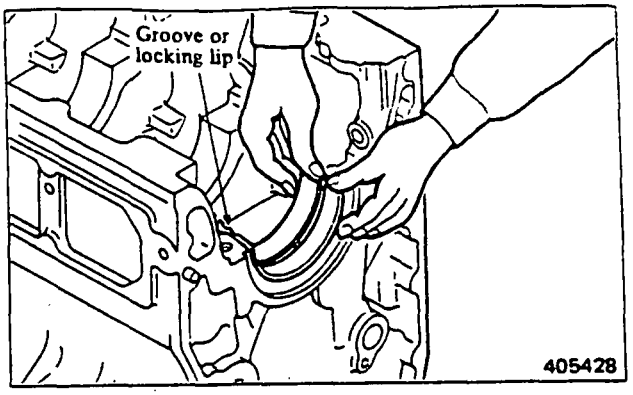
4.3 Reassembly

Follow the reverse of disassembly procedure.

(1) Installing main bearings

(a) Put each upper shell of main bearing in the crankcase by fitting its locking lip in the 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.

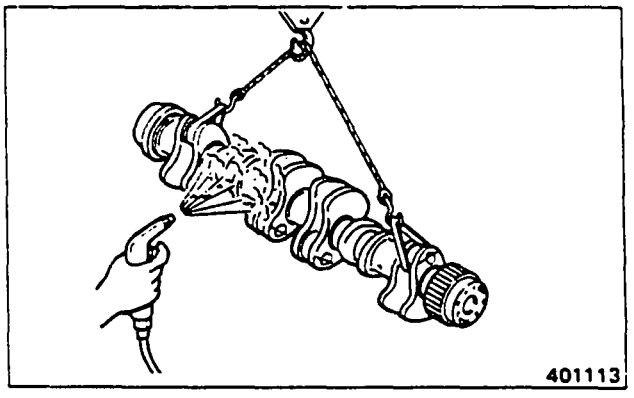


(2) Installing crankshaft

(a) Wash the crankshaft with cleaning solvent, and blow dry with compressed air. After washing the crankshaft, make sure that the oil holes are clean and free from dirt or foreign matter.

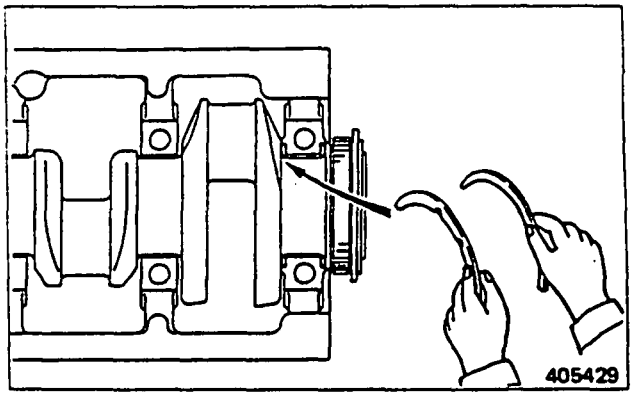
(b) Hold the crankshaft in a horizontal position by using a hoist, and carefully put it on the crankcase.

(c) Lightly coat the journals with engine oil.



(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

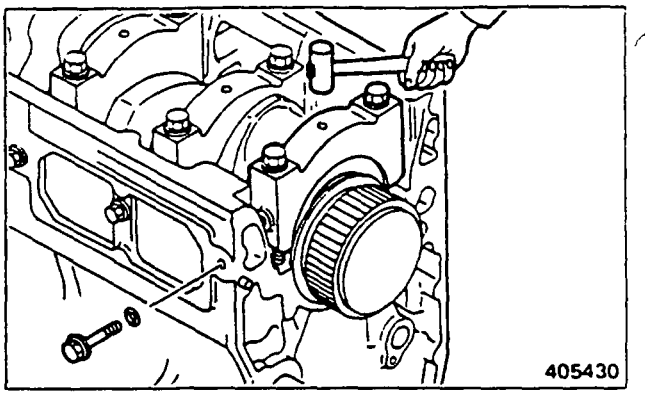
(a) Put the lower shell of the bearing to each bearing cap.

(b) Install the thrust plates to No. 7 bearing cap with their oil grooves outside.

(c) The bearing caps have bearing numbers stamped on them. Install the caps No. 1 thru No. 7 in that order from the front side of the engine.

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

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



(5) Installing bearing cap bolts

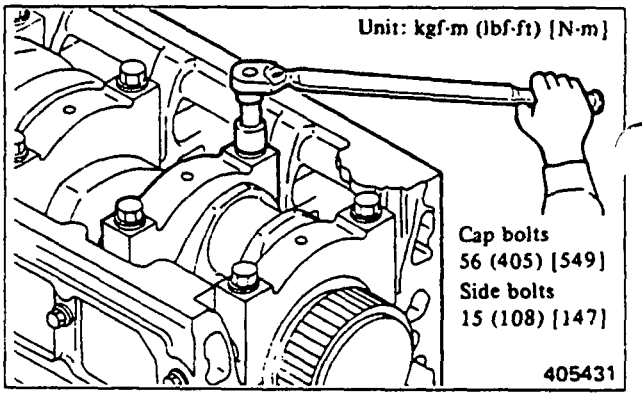
(a) Coat the threads of all cap bolts and side bolts.

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

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

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

(e) Make sure the crankshaft rotates smoothly and freely.

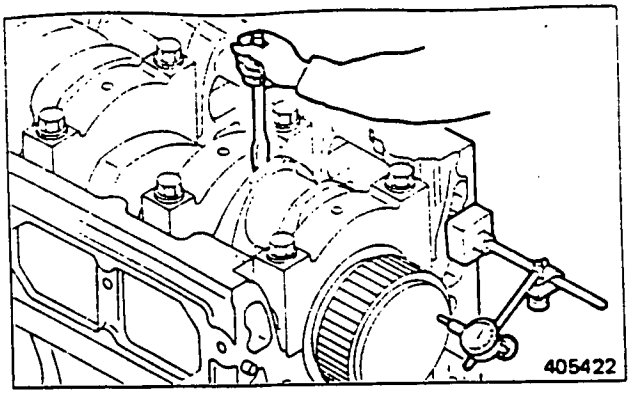


(6) Measuring crankshaft end play

(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.

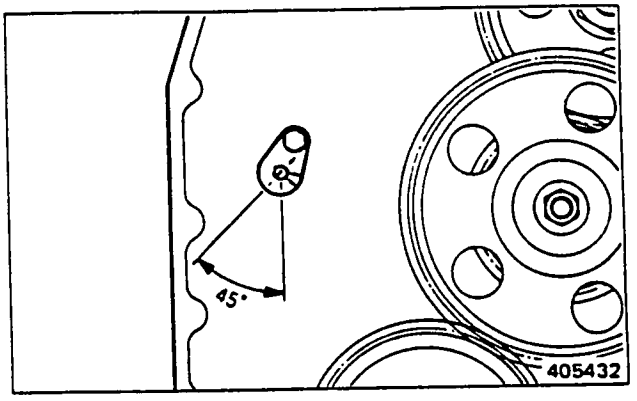
(b) After tightening the No.7 cap bolts, make sure that the end play is correct.

(c) Again make sure that all cap bolts are tightened to the specified torque.



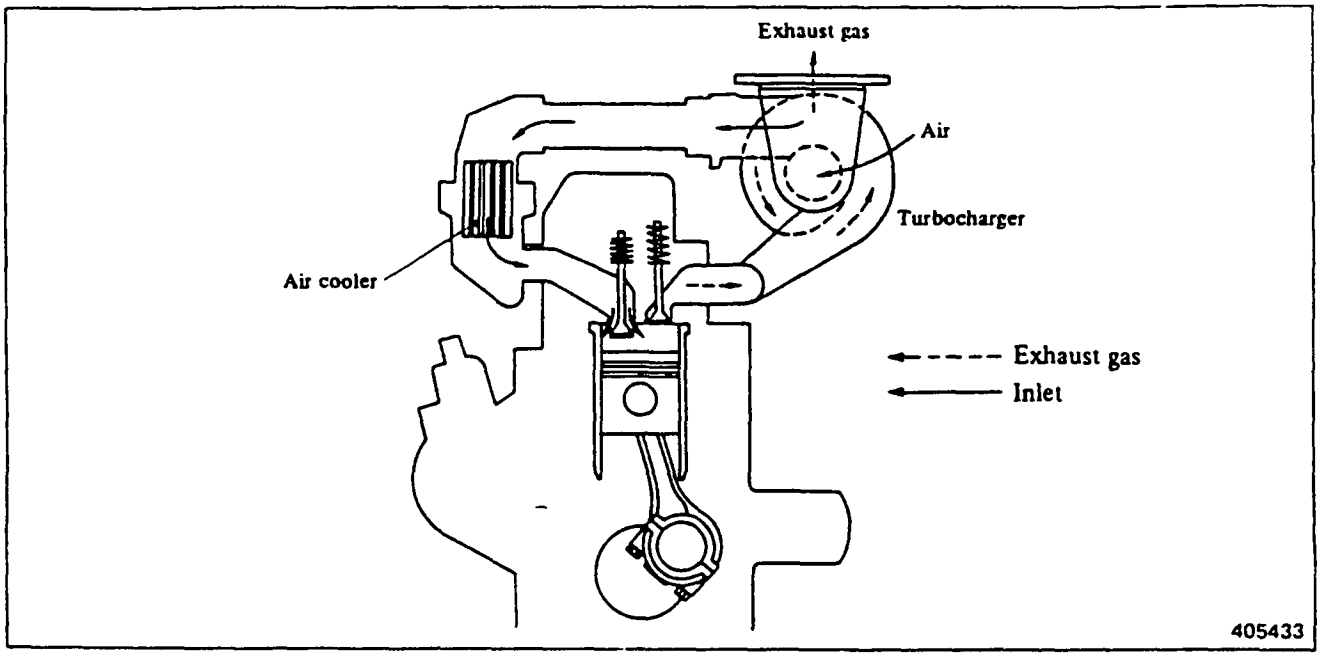
(7) Installing oil spray plug

Install the plug so that its arrow mark points in the direction of 45° to the left of the bottom (as seen from the rear side of the engine).



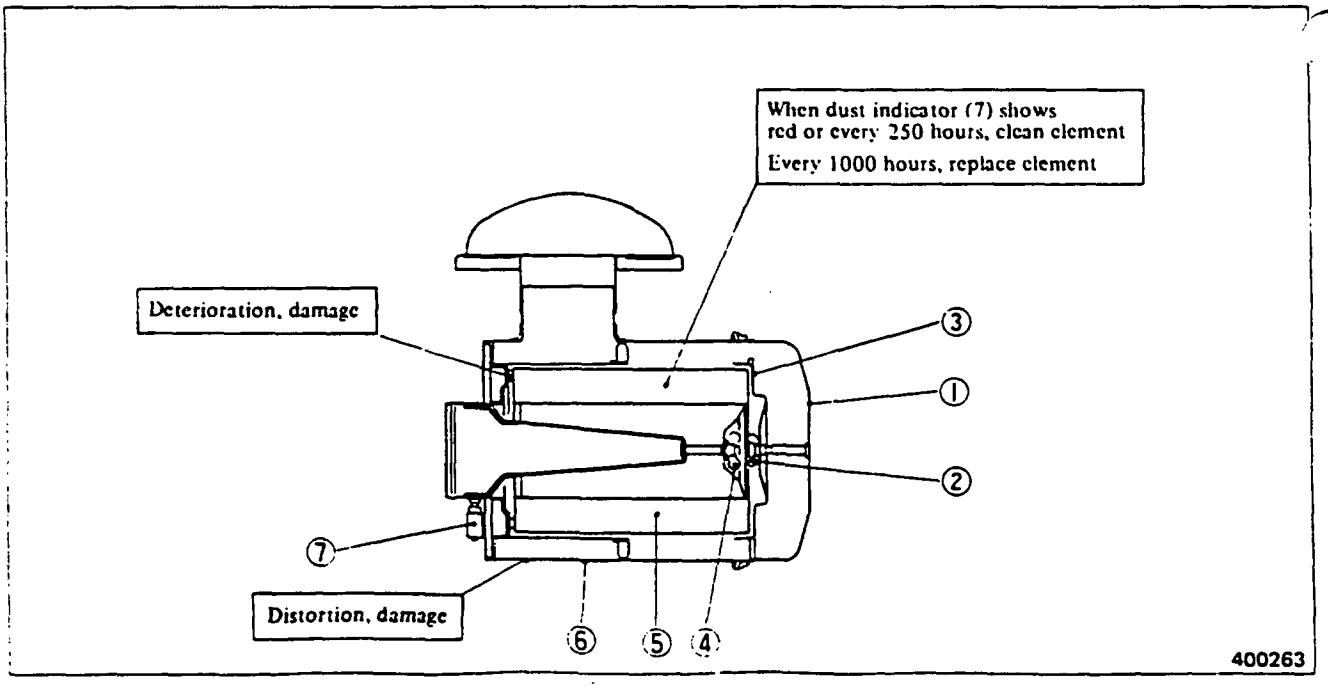
INLET AND EXHAUST SYSTEMS

1. DESCRIPTION



2. PAPER-ELEMENT TYPE AIR CLEANER

Disassembly and inspection



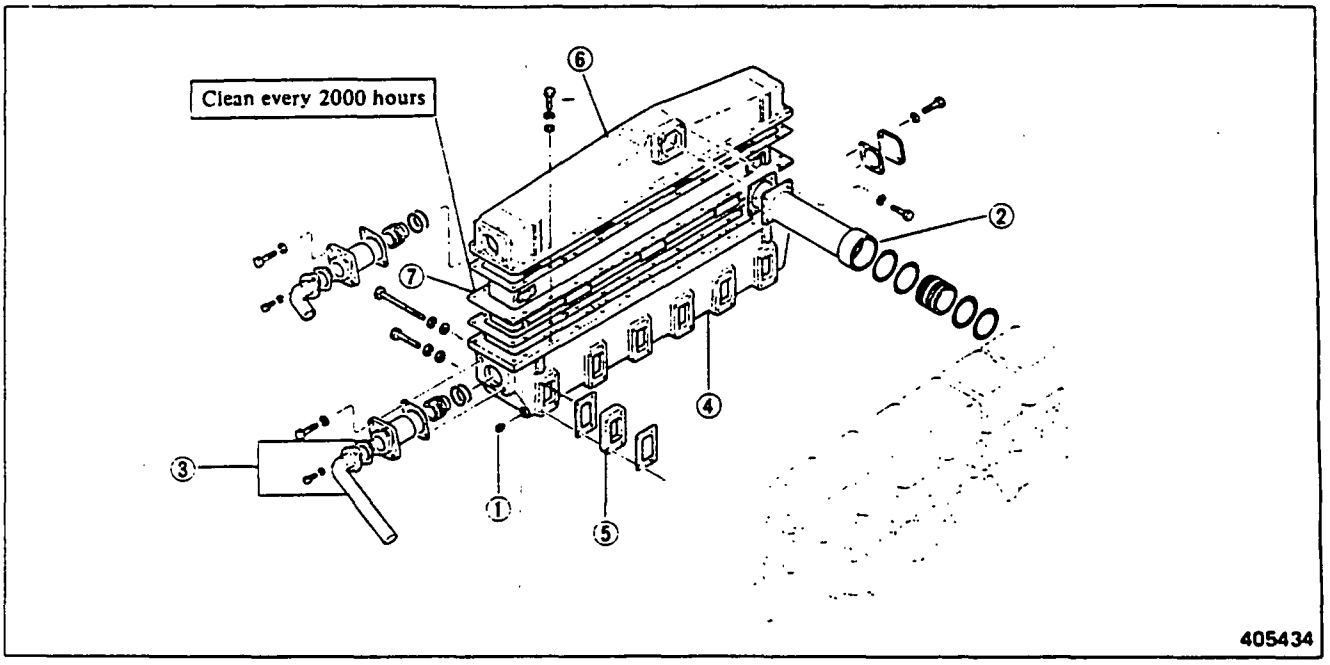
① Air cleaner cap
② Wing nut
③ Cover
④ Wing nut
⑤ Element
⑥ Air cleaner body
⑦ Dust indicator

⚠ 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 MANIFOLD AND AIR COOLER

3.1 Disassembly



① Taper plug
② Air duct
③ Water pipe, packing
④ Inlet manifold
⑤ Spacer
⑥ Inlet manifold cover
⑦ Element, gasket

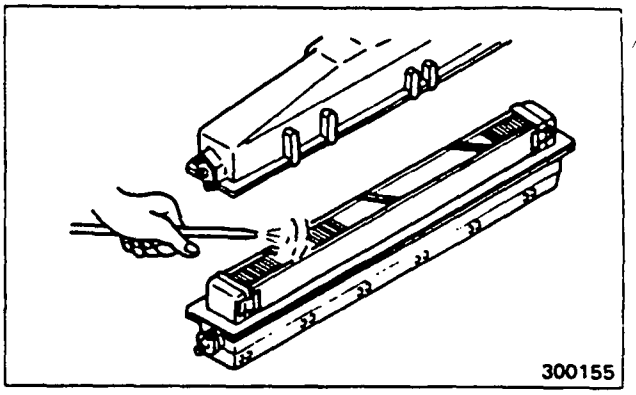
3.2 Inspection

(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 cracks.

(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.

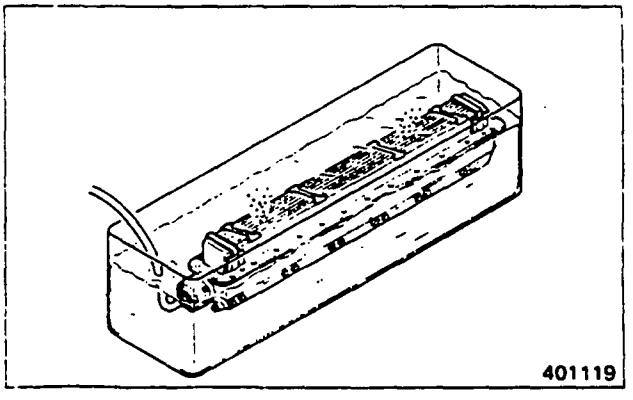


⚠ WARNING

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

(2) Inspecting air cooler for leakage

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.

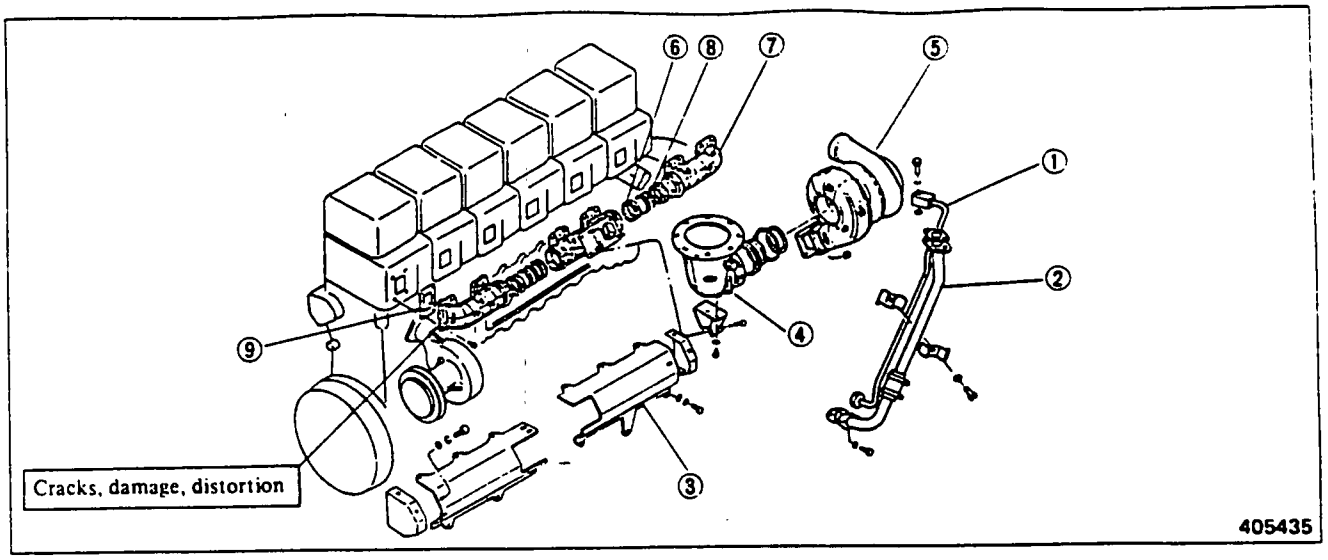


⚠ CAUTION

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

4. EXHAUST MANIFOLD

Disassembly and inspection



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

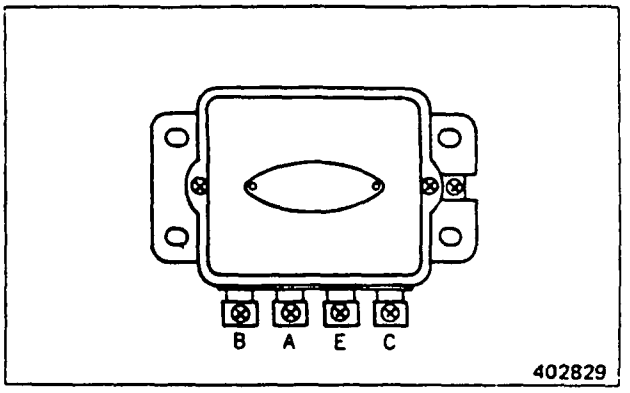
NOTE

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

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

5. AIR HEATER (HEATER RELAY)

Inspection



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

(2) Check to make sure that the indicator takes 40 to 60 seconds to glow red after the starter switch is turned to HEAT position. If the indicator glows red too early, or it fails to glow red, check the indicator and air heater for short or open circuit. The ohmic values of the air heater circuit components are as shown below:

Unit: Ohm

Item		Assembly standard
Resistance	Indicator	12.2
	Air heater	0.134 ± 10%

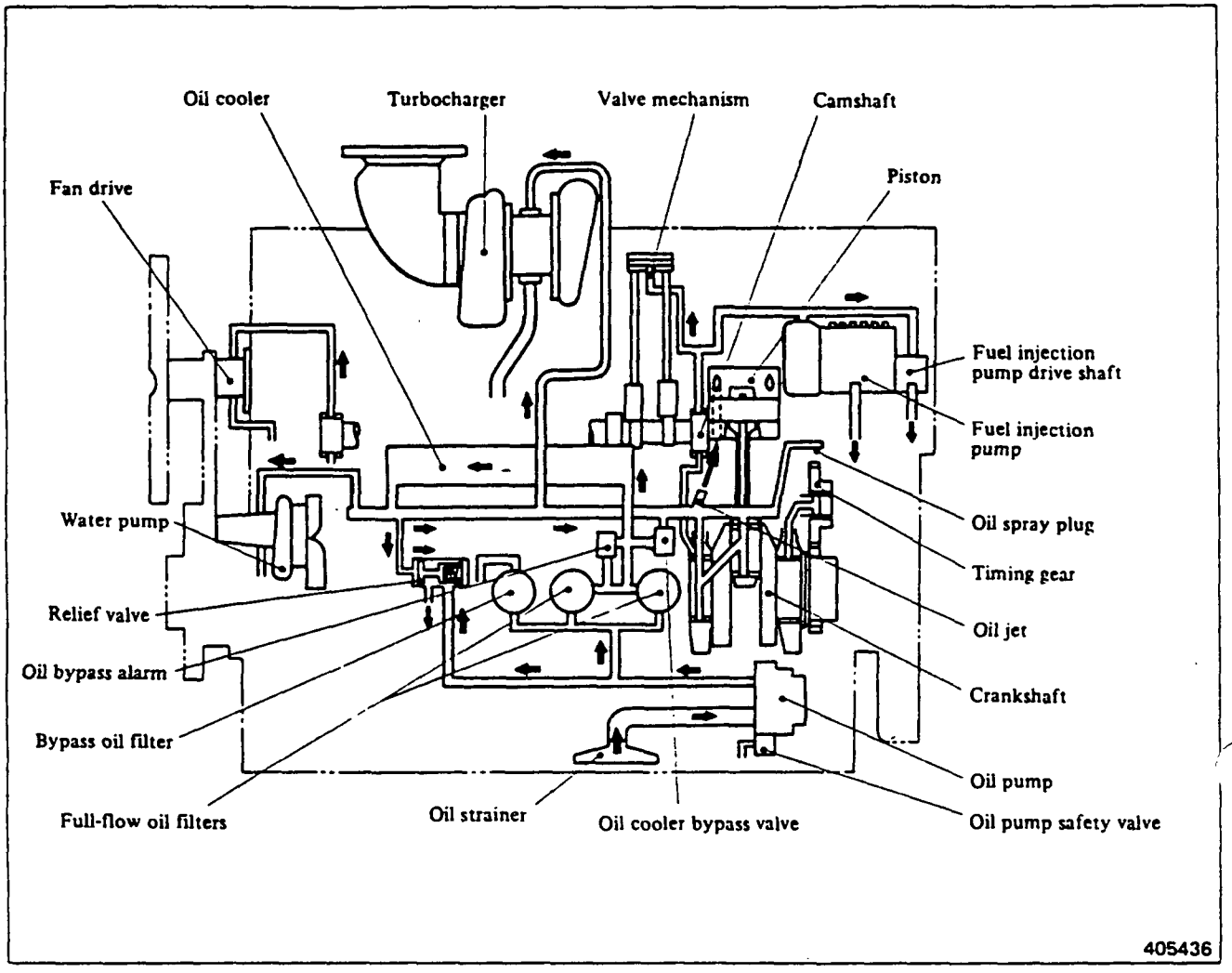
(3) Apply a test voltage (16 volts) between the terminals A and E of heater relay and check for continuity between the terminals B and C. Replace the relay if there is no continuity.

⚠ CAUTION

Do not apply the test voltage to the relay for more than 60 seconds.

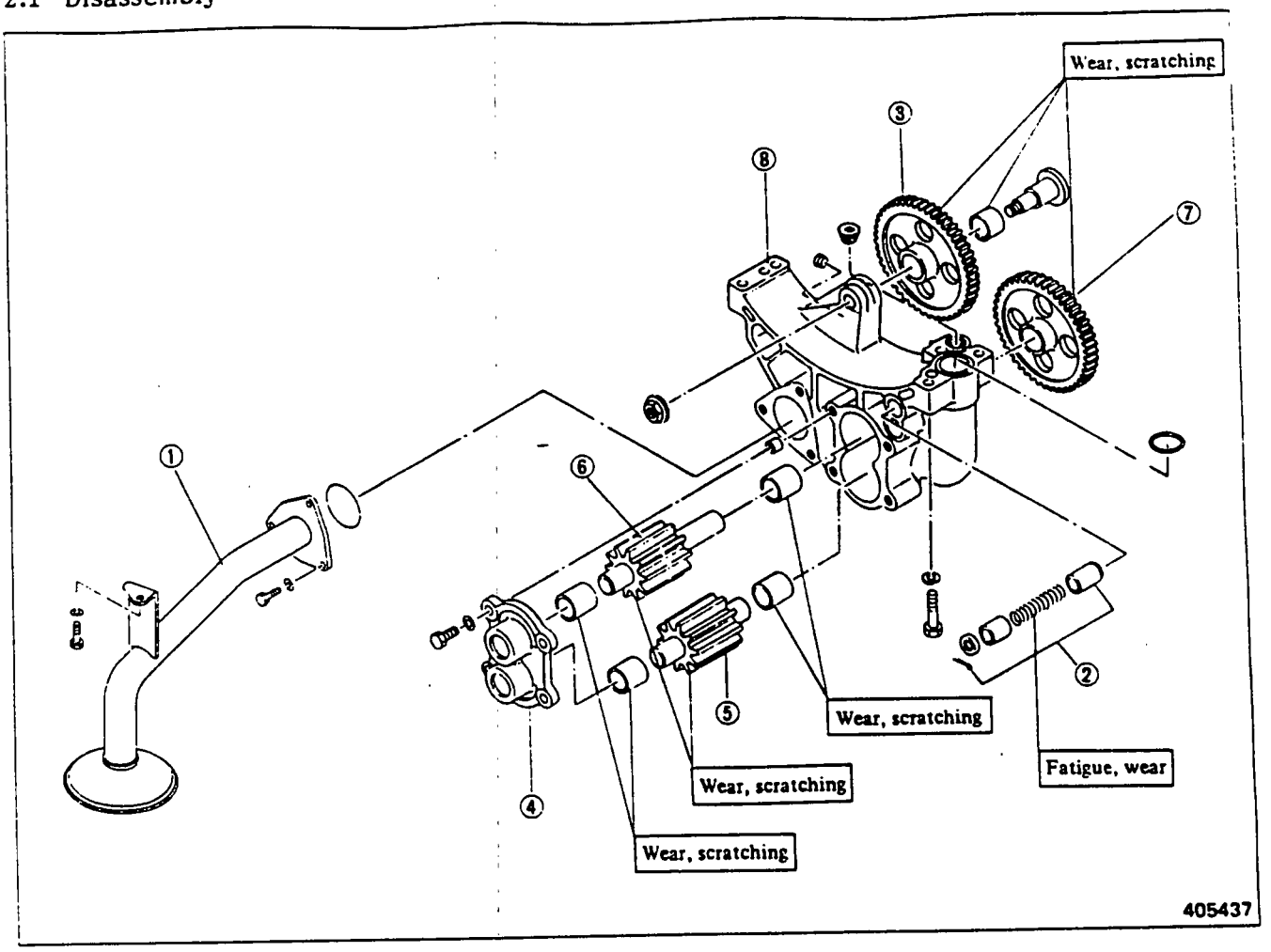
LUBRICATION SYSTEM

1. DESCRIPTION



2. OIL PUMP, OIL STAINER AND SAFETY VALVE

2.1 Disassembly



① Oil strainer
② Safety valve
③ Oil pump idler gear
④ Oil pump cover
⑤ Driven gear assembly
⑥ Drive gear assembly
⑦ Oil pump gear
⑧ Oil pump case

2.2 Inspection

(1) Measuring backlash between oil pump drive gear and driven gear

If the backlash is in excess of the service limit, replace the gears.

Unit: mm (in.)

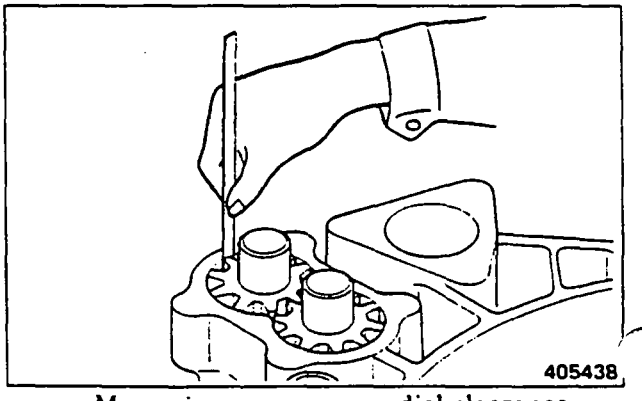
Item	Standard clearance	Service limit
Backlash between oil pump drive gear and idler gear	0.11 to 0.24 (0.0043 to 0.0094)	0.40 (0.016)
Backlash between oil pump drive gear and driven gear	0.10 to 0.20 (0.0039 to 0.0079)	

(2) Measuring pump gear radial clearance

Using a feeler gauge, measure the radial clearance. If the clearance is in excess of 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	60 (2.36)	0.120 to 0.233 (0.00472 to 0.00917)	0.30 (0.0118)



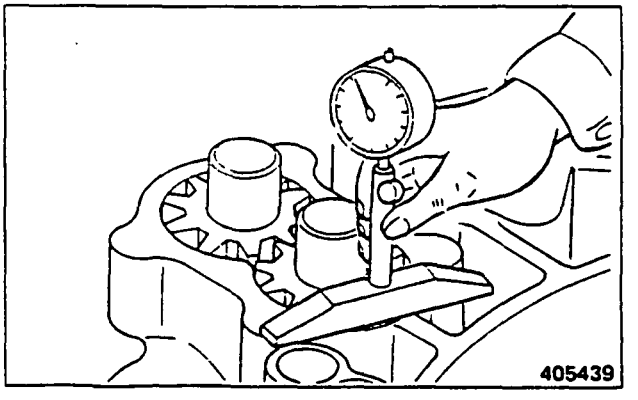
Measuring pump gear radial clearance

(3) Measuring pump gear end clearance

Using a dial indicator, measure the end clearance. If the clearance is in excess of 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	71 (2.80)	0.060 to 0.134 (0.00236 to 0.00528)	0.20 (0.0079)



Measuring pump gear end clearance

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

(a) Check the teeth of the gears and replace the gears if the teeth are defective.

(b) Measure the diameter of the drive and driven gear shafts and the inside diameter of their bushings. Replace the gears and bushings if the shafts and bushings are in excess of the service limit.

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Shaft diameter	25 (0.98)	24.947 to 24.960 (0.98216 to 0.98268)	24.900 (0.98031)
Bushing inside diameter		25.000 to 25.021 (0.98425 to 0.98508)	25.100 (0.98819)

(5) Measuring idler gear shaft diameter and bushing inside diameter

Measure the diameter of the idler gear shaft and the inside diameter of the bushing to determine the clearance. If the clearance is in excess of the service limit, replace the bushing.

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Shaft diameter	25 (0.98)	24.947 to 24.960 (0.98216 to 0.98268)	24.910 (0.98071)
Bushing inside diameter		25.000 to 25.021 (0.98425 to 0.98508)	25.100 (0.98819)

(6) Inspecting safety valve

Replace the valve spring if it is fatigued, worn or broken.

Unit: kgf/cm² (psi) [MPa]

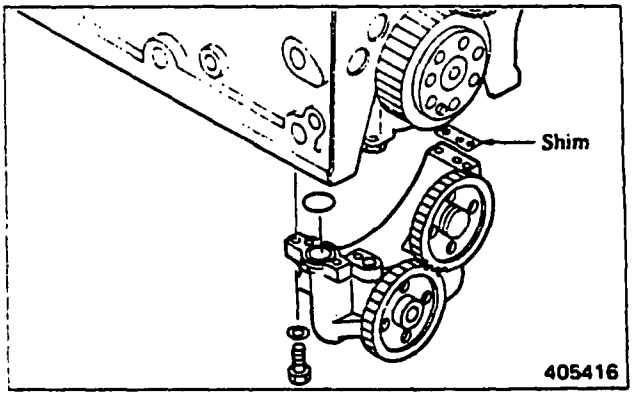
Item		Assembly standard	Service limit
Safety valve setting		13 ± 1 (185 ± 14) [1.3 ± 0.1]	
Spring	Length under test force, mm (in.)	66.8 (2.630)	
	Test force	33.6 (74) [330]	30 (66) [294]

(7) Adjusting backlash between oil pump idler gear and crankshaft gear

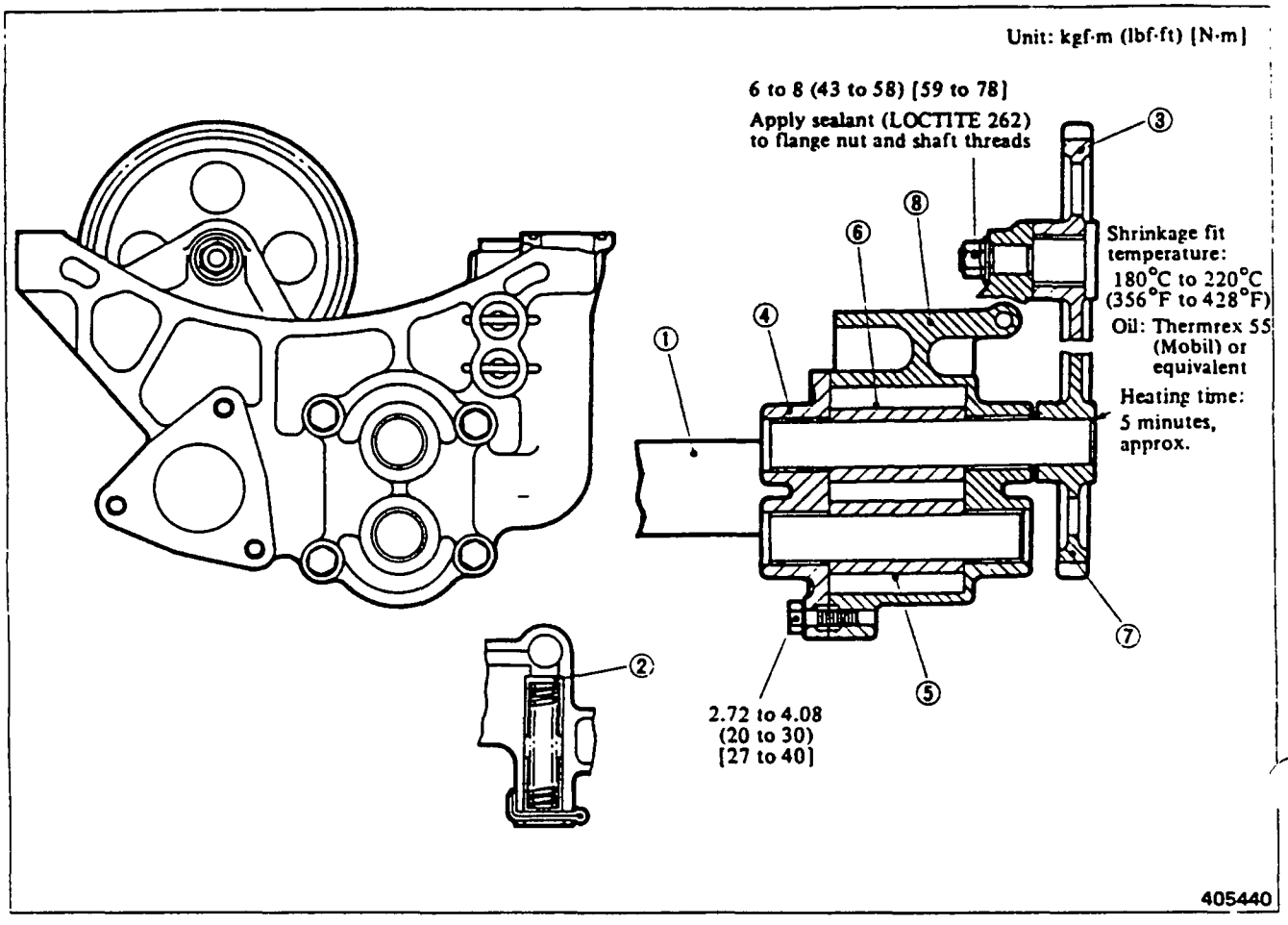
After installing the oil pump to the crankcase, measure the backlash. If the backlash is in excess of the assembly standard, shim adjust it.

Unit: mm (in.)

Item	Assembly standard
Backlash between oil pump idler gear and crankshaft gear	0.24 to 0.38 (0.0094 to 0.0150)



2.3 Reassembly



Reassembly sequence

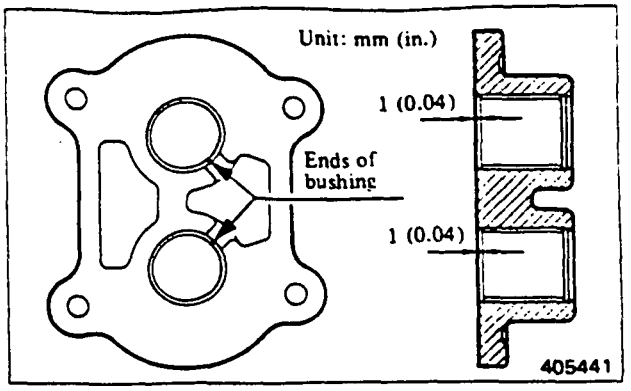
⑨→⑧→⑤→⑥→③→②→①
④→⑦→

NOTE

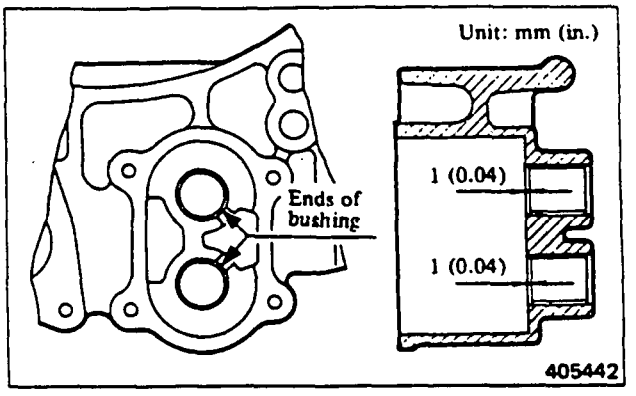
(a) Apply engine oil to the parts during reassembly.

(b) When replacing the pump bushings, press new bushings into position until they are recessed by 1 mm (0.04 in.) from the end face of the case or cover, and ream it to finish its inside diameter to $25H7^{+0.021}_{0}$ mm ($0.98H7^{+0.00083}_{0}$ in.) $\frac{1.6S}{\nabla\nabla}$.

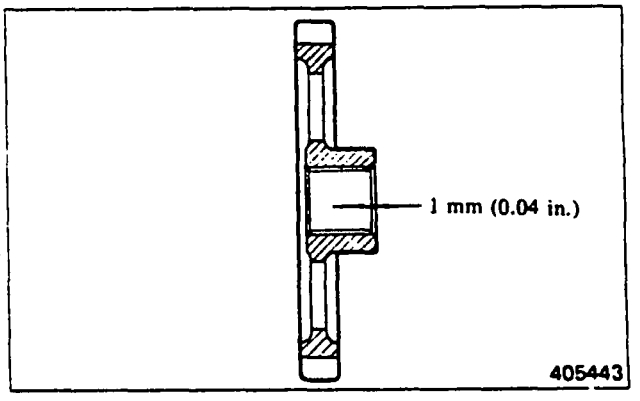
(c) When replacing the idler gear bushing, press a new bushing into position until it is recessed by 1 mm (0.04 in.), and ream it to finish its inside diameter to $20H7^{+0.021}_{0}$ mm ($0.79H7^{+0.00083}_{0}$ in.) $\frac{3.2S}{\nabla\nabla}$.



Installing oil pump cover bushing

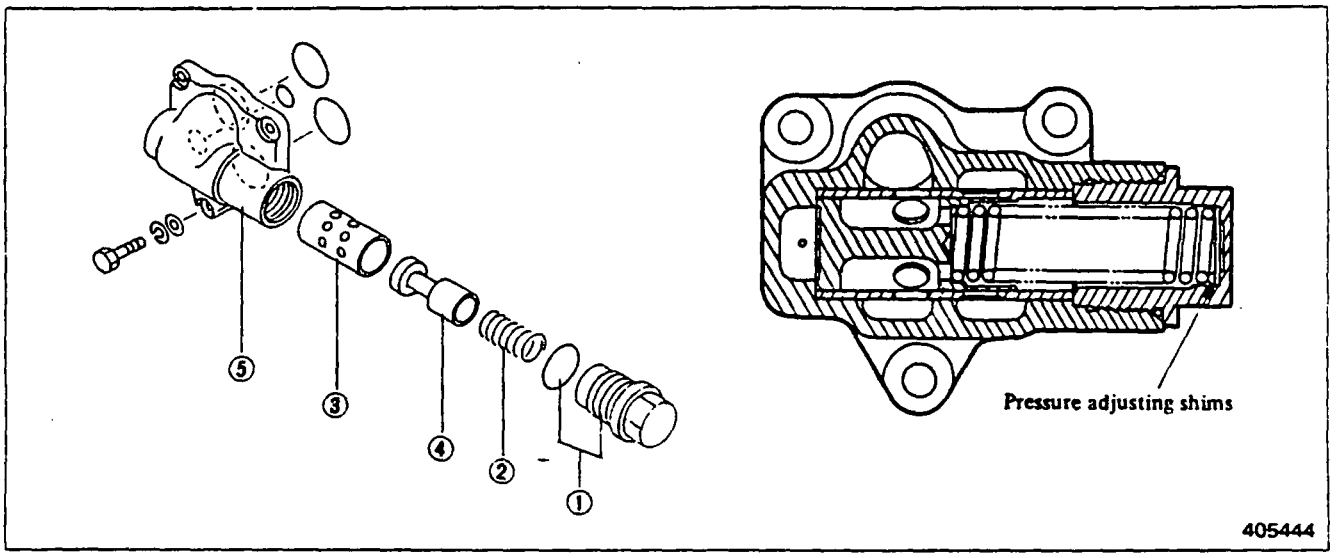


Installing oil pump cover bushing



3. RELIEF VALVE

3.1 Disassembly



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

3.2 Inspection

Measuring relief valve setting

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

(b) Measure the setting at idle speed and at maximum speed.

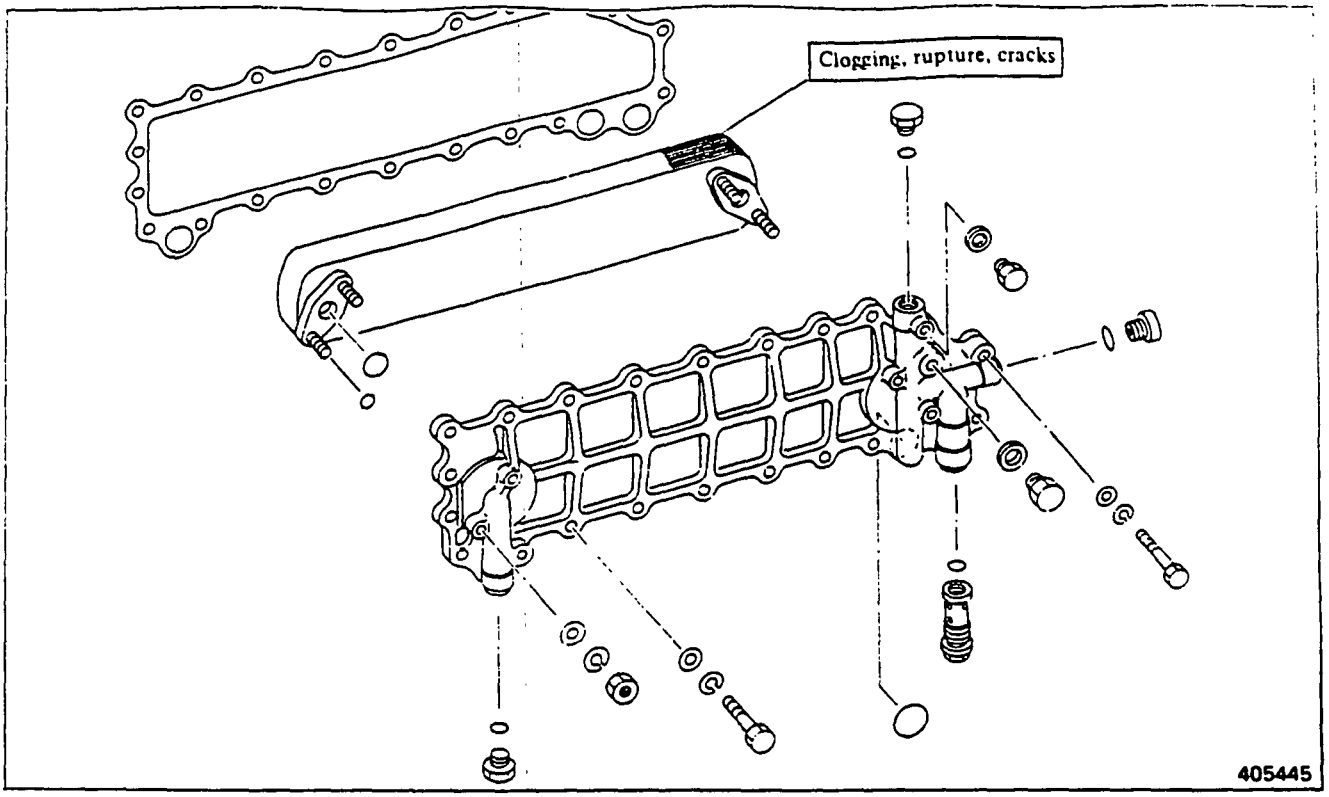
(c) If the setting is below the assembly standard, insert washer(s) into between the spring and plug. 2 mm (0.08 in.) thickness of the washer will vary the setting by 0.4 kgf/cm^2 (5.7 psi) [0.04 MPa].

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

Item	Assembly standard
Relief valve setting	5.9 ± 0.5 (84 ± 7) [0.6 ± 0.05]

4. OIL COOLER

4.1 Disassembly



⚠ CAUTION

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

4.2 Inspection

(a) Test the element by applying an air pressure of 15 kgf/cm^2 (213 psi) [1.5 MPa], and replace it if leakage occurs.

(b) Test the bypass valve for opening pressure, and replace it if the pressure exceeds the assembly standard.

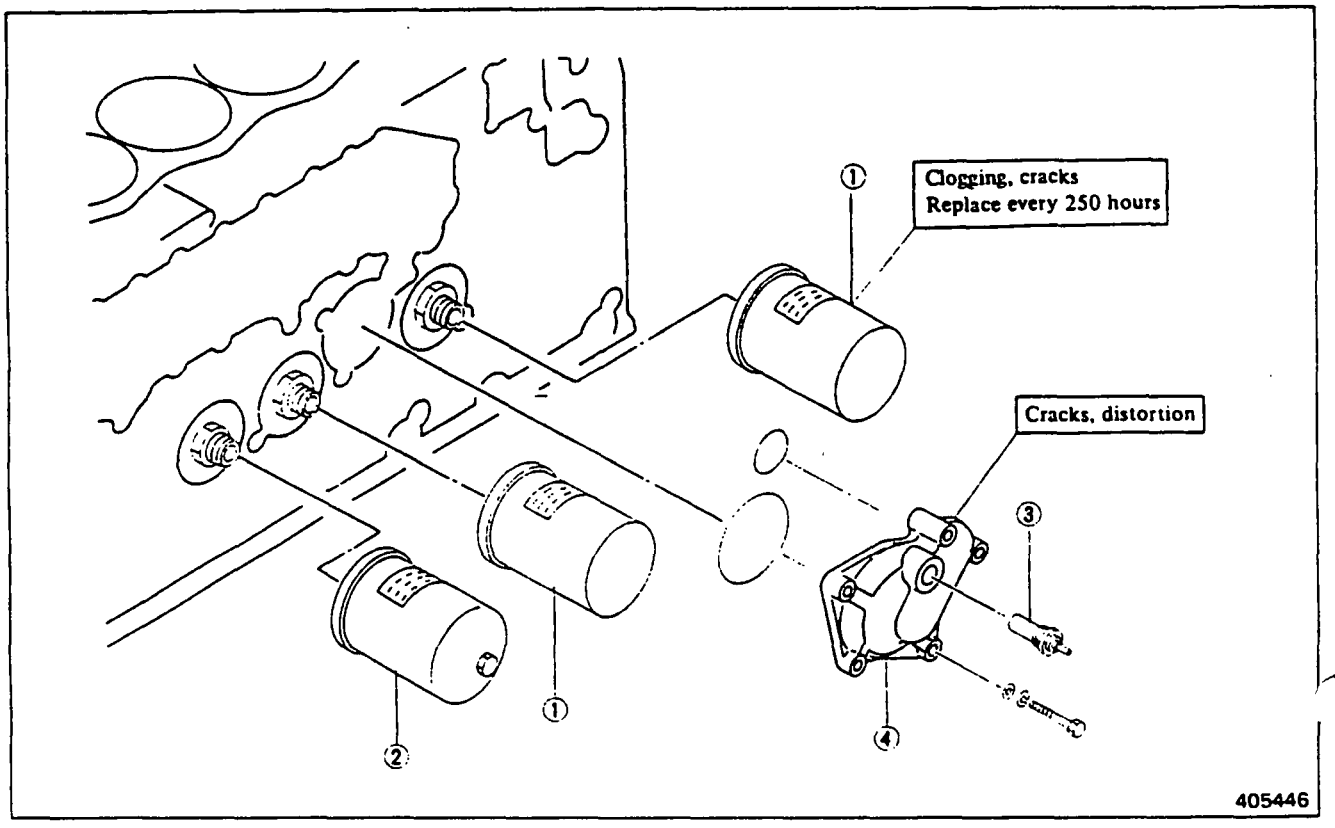
Unit: kgf/cm^2 (psi) [MPa]

Item	Assembly standard
Bypass valve setting (differential pressure)	4.5 (64) [0.4]

5. OIL FILTERS

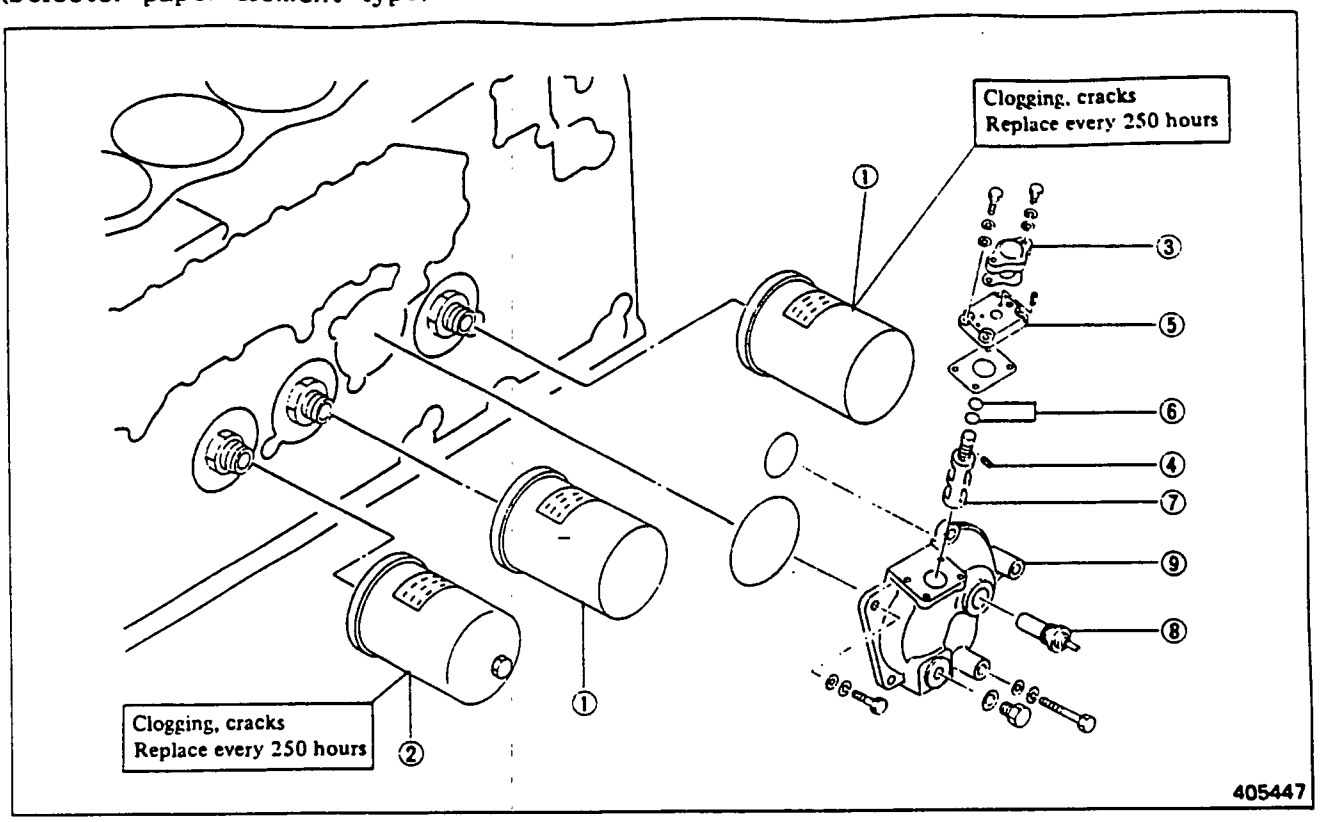
5.1 Disassembly

(Cartridge paper-element type)



① Oil filter
② Bypass oil filter
③ Oil filter alarm
④ Oil filter cover

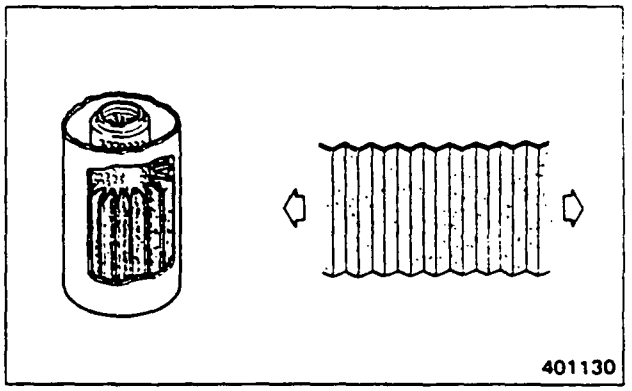
(Selector paper-element type)



① Spin-on filter assembly
② Bolt
③ Cover
④ Straight pin
⑤ Cover, gasket
⑥ O-ring
⑦ Cock
⑧ Oil filter alarm
⑨ Oil filter cover

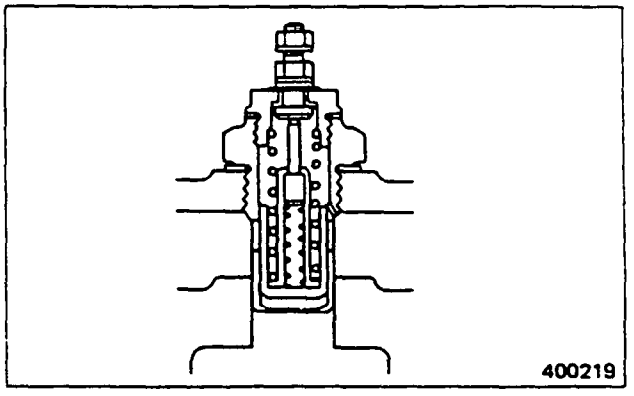
5.2 Inspection

(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 for color and shape of metallic particles trapped in the pleats to locate the cause.



(2) Inspecting oil filter alarm switch

(a) Using a tester, test the alarm switch 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.



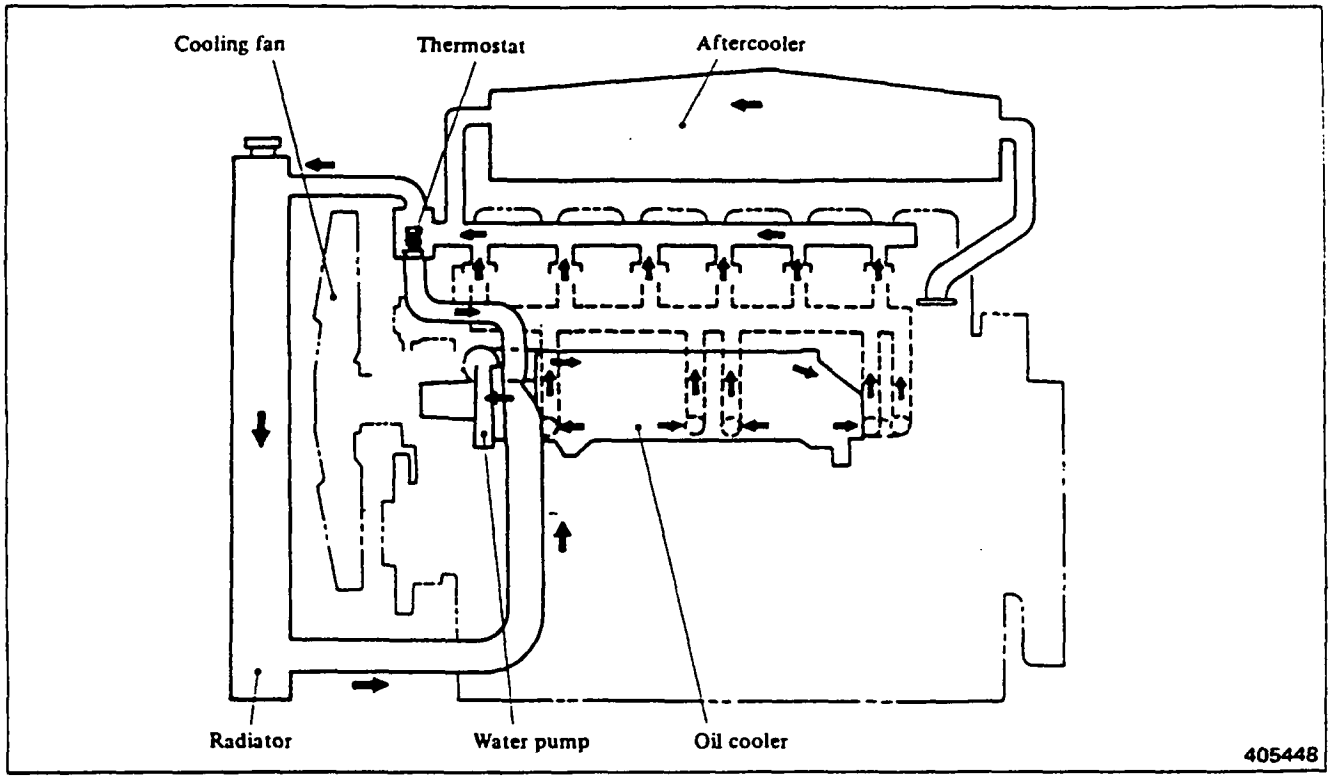
(b) If the setting for opening bypass valve is in excess of the assembly standard, adjust the switch by inserting shim(s). 1 mm (0.04 in.) thickness of the shim will vary the setting by 0.07 kgf/cm^2 (1.0 psi) [0.007 MPa].

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

Item	Assembly standard
Alarm switch closing pressure	$1.5\ ^{+0.3}_{0}$ $(21.3\ ^{+4.3}_{0})$ $[0.1\ ^{+0.03}_{0}]$
Bypass valve opening pressure	2.5 ± 0.2 (35.6 ± 2.8) $[0.2 \pm 0.02]$

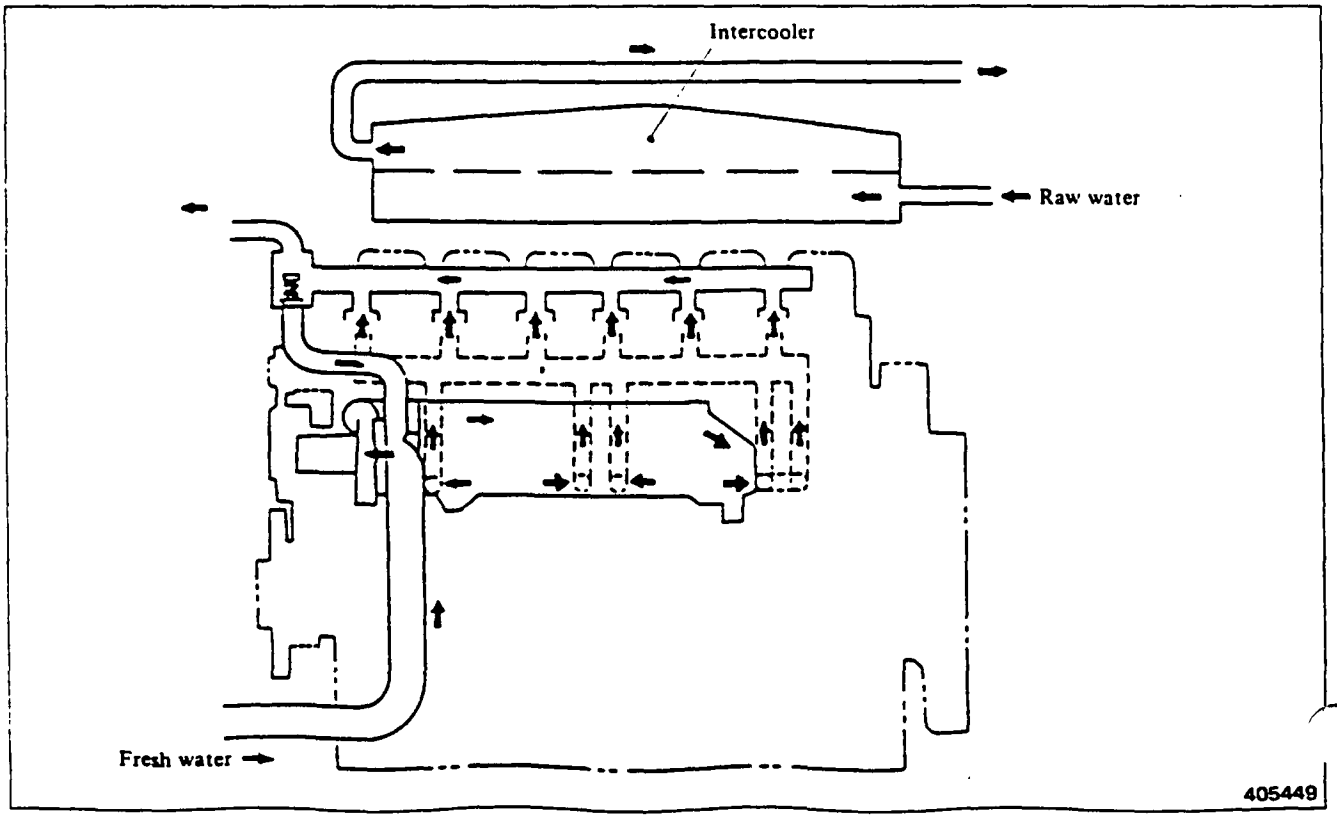
COOLING SYSTEM

1. COOLING SYSTEM WITH RADIATOR

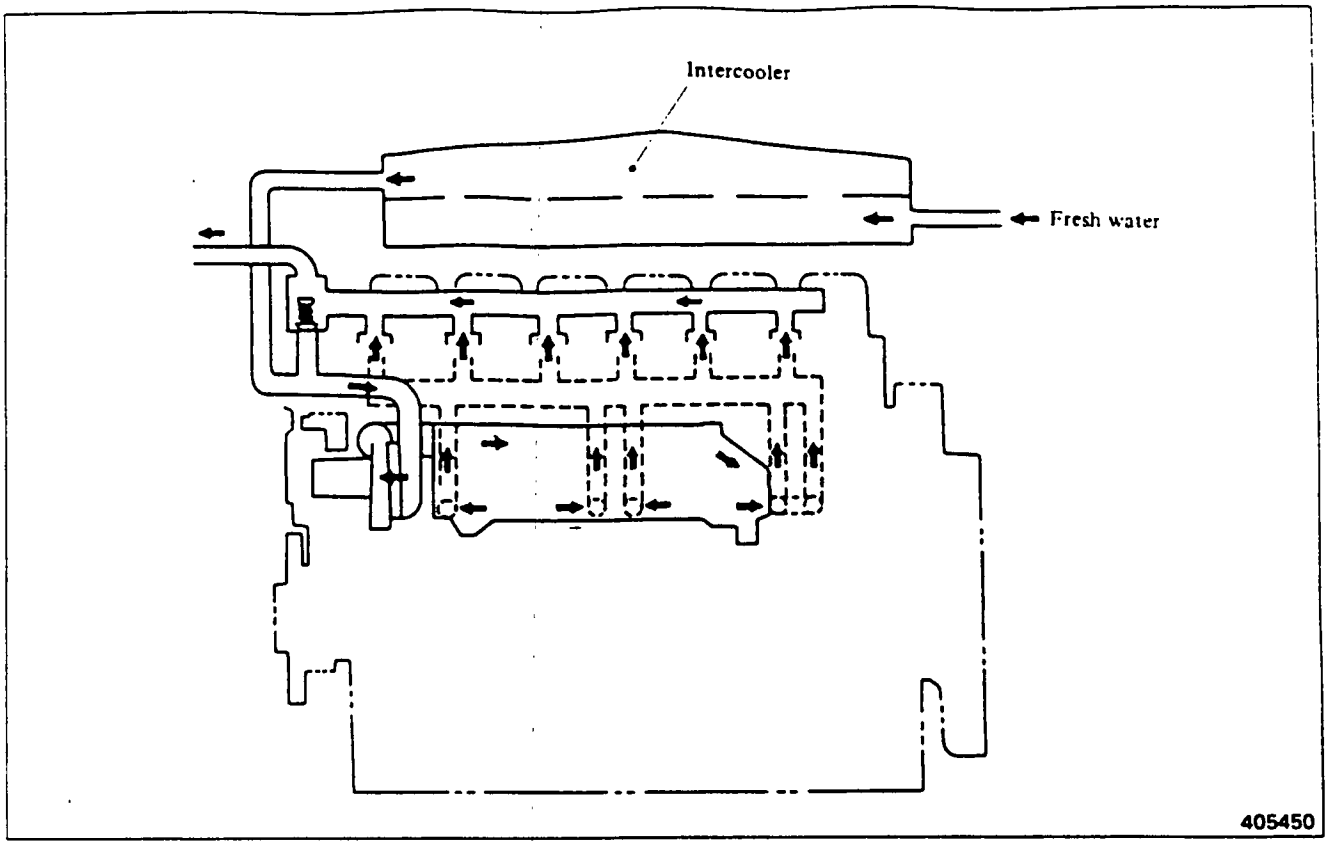


2. COOLING SYSTEM WITH A REMOTE WATER SUPPLY

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

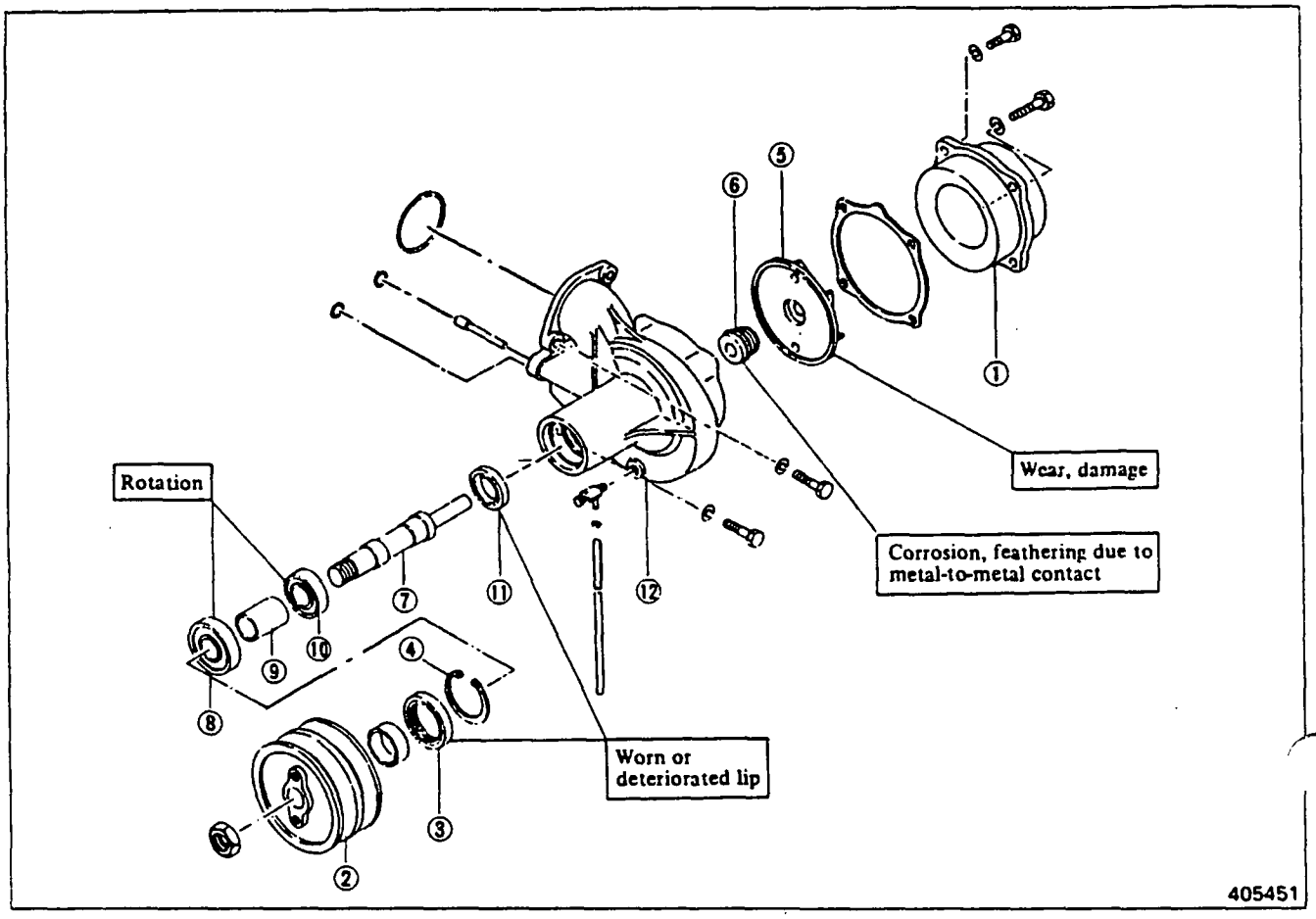


(2) Series type using fresh water (PTK)



3. WATER PUMP

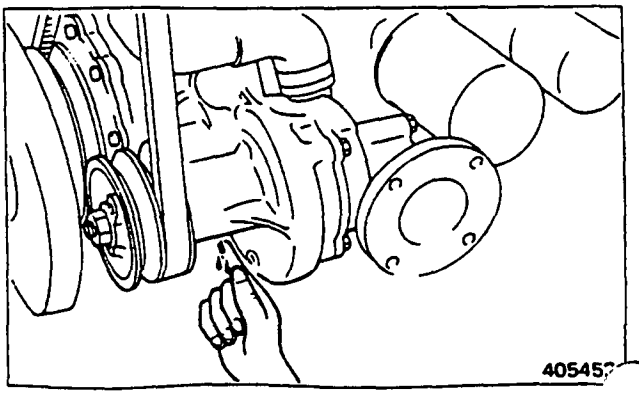
3.1 Disassembly



① Water pump cover, gasket
② Nut, pulley assembly
③ Oil seal
④ Snap ring
⑤ Impeller
⑥ Unit seal
⑦ Shaft
⑧ Ball bearing
⑨ Spacer
⑩ Ball bearing
⑪ Oil seal
⑫ Water pump case assembly

On-engine inspection

Touch the drain port located at the bottom of the pump 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.



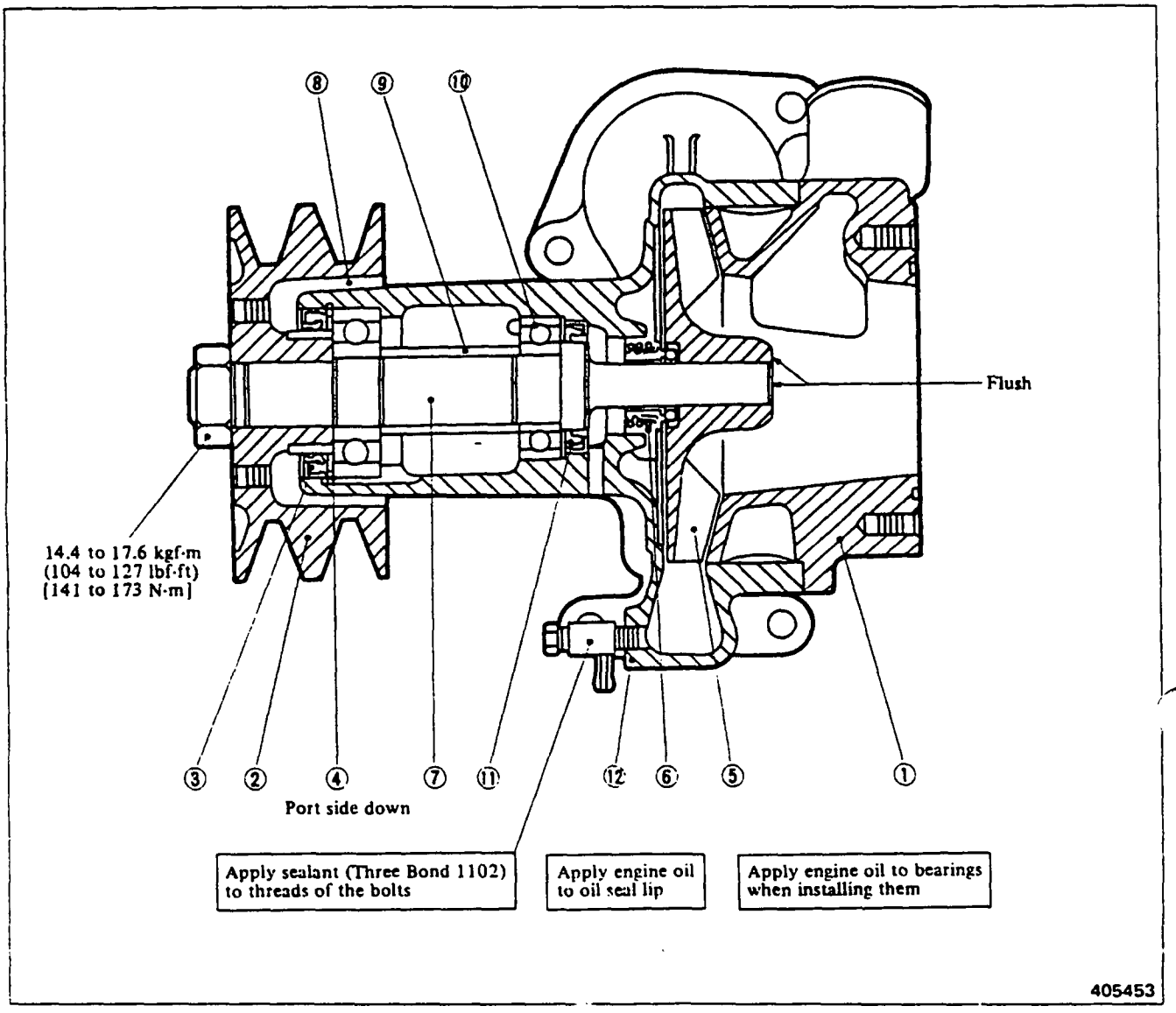
3.2 Inspection

Measure the inside diameter of pump case bearing bore and the diameter of shaft bearing journal. Replace the case, shaft or bearing whichever is badly worn.

Unit: mm (in.)

Item		Nominal value	Assembly standard	Service limit
Pump case bearing bore inside diameter		52 (2.05)	51.988 to 52.018 (2.04677 to 2.04795)	52.025 (2.04822)
		62 (2.44)	61.988 to 62.018 (2.44047 to 2.44165)	62.025 (2.44192)
Bearings	Outside diameter	52 (2.05)	51.983 to 52.004 (2.04657 to 2.04740)	
		62 (2.44)	61.983 to 62.004 (2.44027 to 2.44110)	
	Inside diameter	25 (0.98)	24.987 to 25.003 (0.98374 to 0.98437)	
Pump shaft bearing journal diameter		25 (0.98)	25.002 to 25.015 (0.98433 to 0.98484)	24.995 (0.98405)

3.3 Reassembly

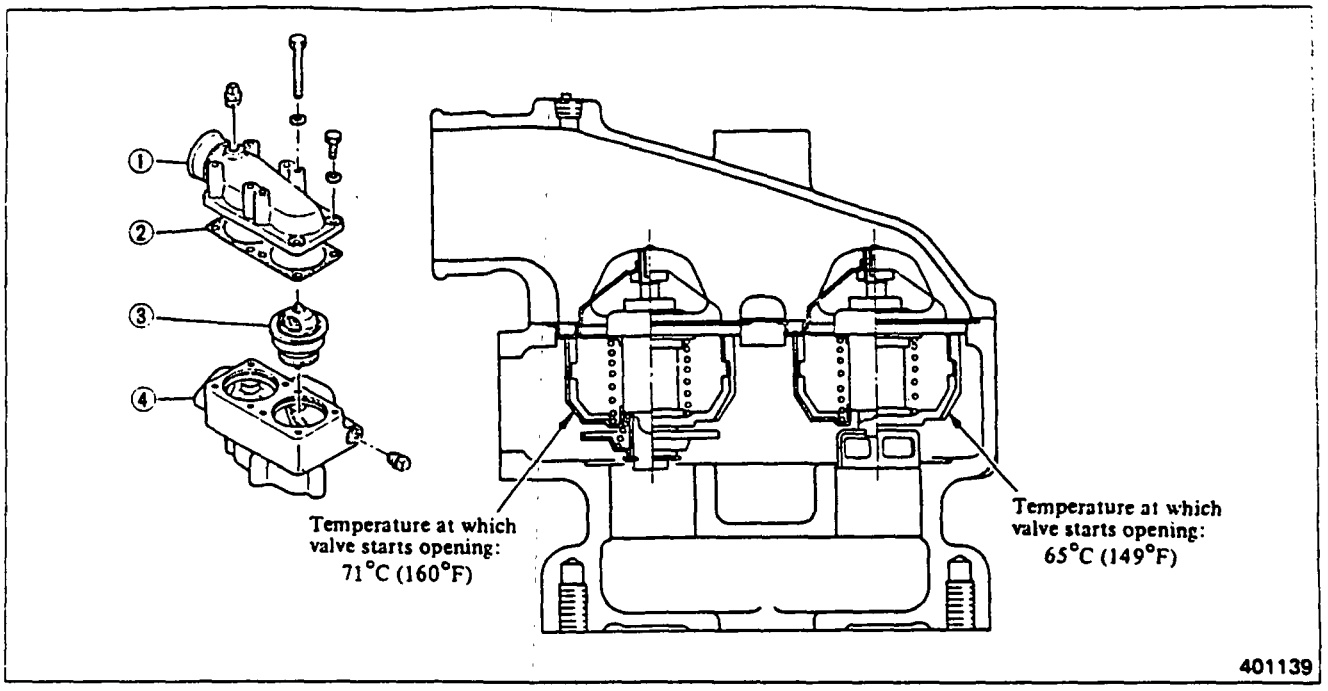


Reassembly sequence

⑫→⑪→④→③→②→⑥→⑤→①
⑦→⑩→⑨→⑧

4. THERMOSTAT

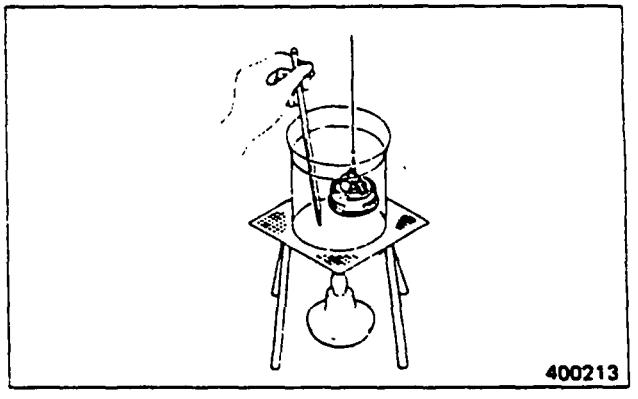
4.1 Disassembly



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 (0.39 in.). If these measurements are out of the assembly standard, replace the thermostat.



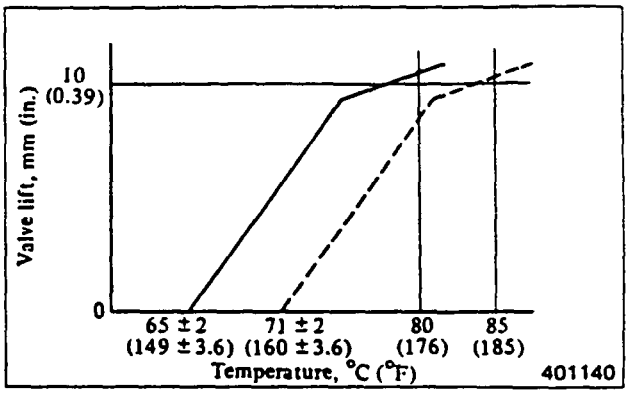
Unit: °C (°F)

Item	Assembly standard	
	A	B
Temperature at which valve starts opening	65 ± 2 (149 ± 3.6)	71 ± 2 (160 ± 3.6)
Temperature at which valve lift reaches 10 mm (0.39 in.), minimum	80 ± 2 (176 ± 3.6)	85 ± 2 (185 ± 3.6)

⚠ CAUTION

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

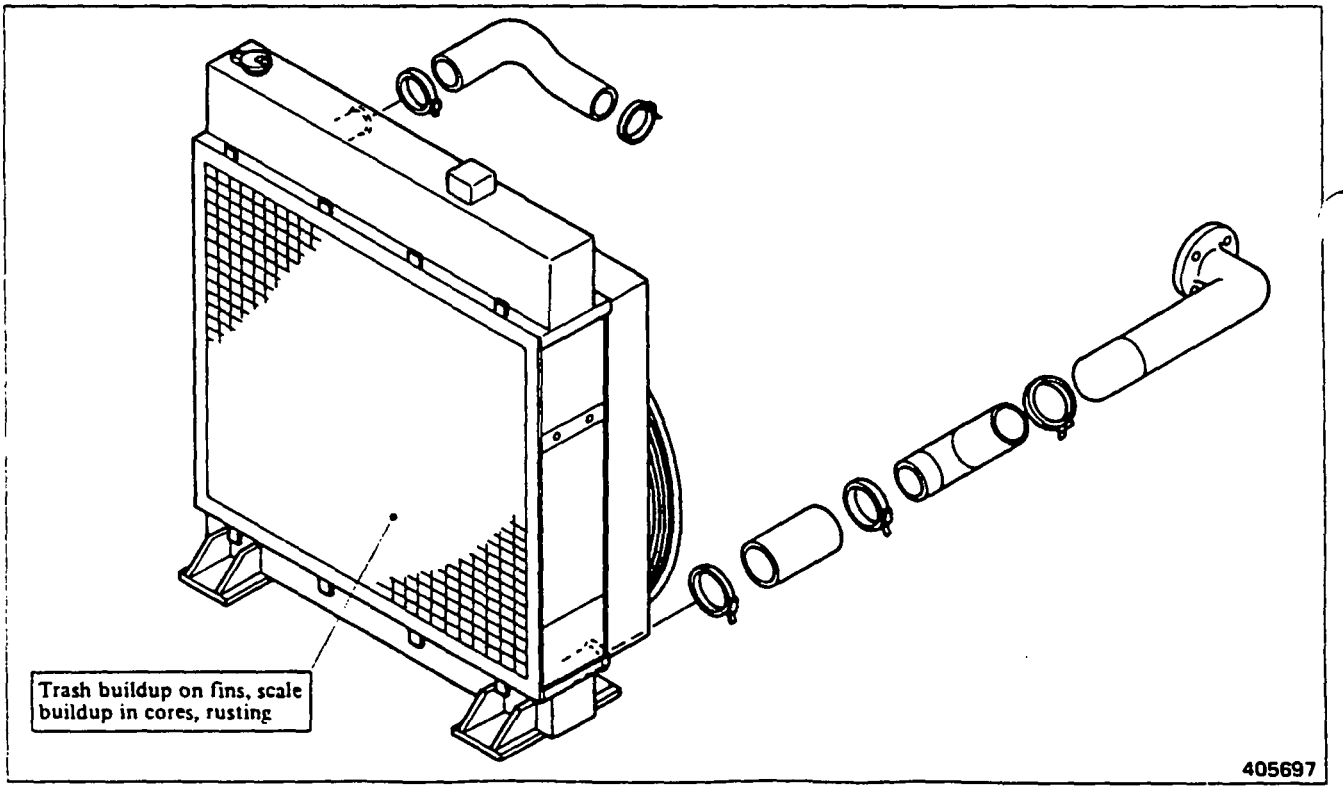
(b) Be sure to place each thermostat in correct position by ascertaining the valve opening temperature stamped on its mounting flange at reassembly.



Thermostat performance curve

5. RADIATOR

Inspection



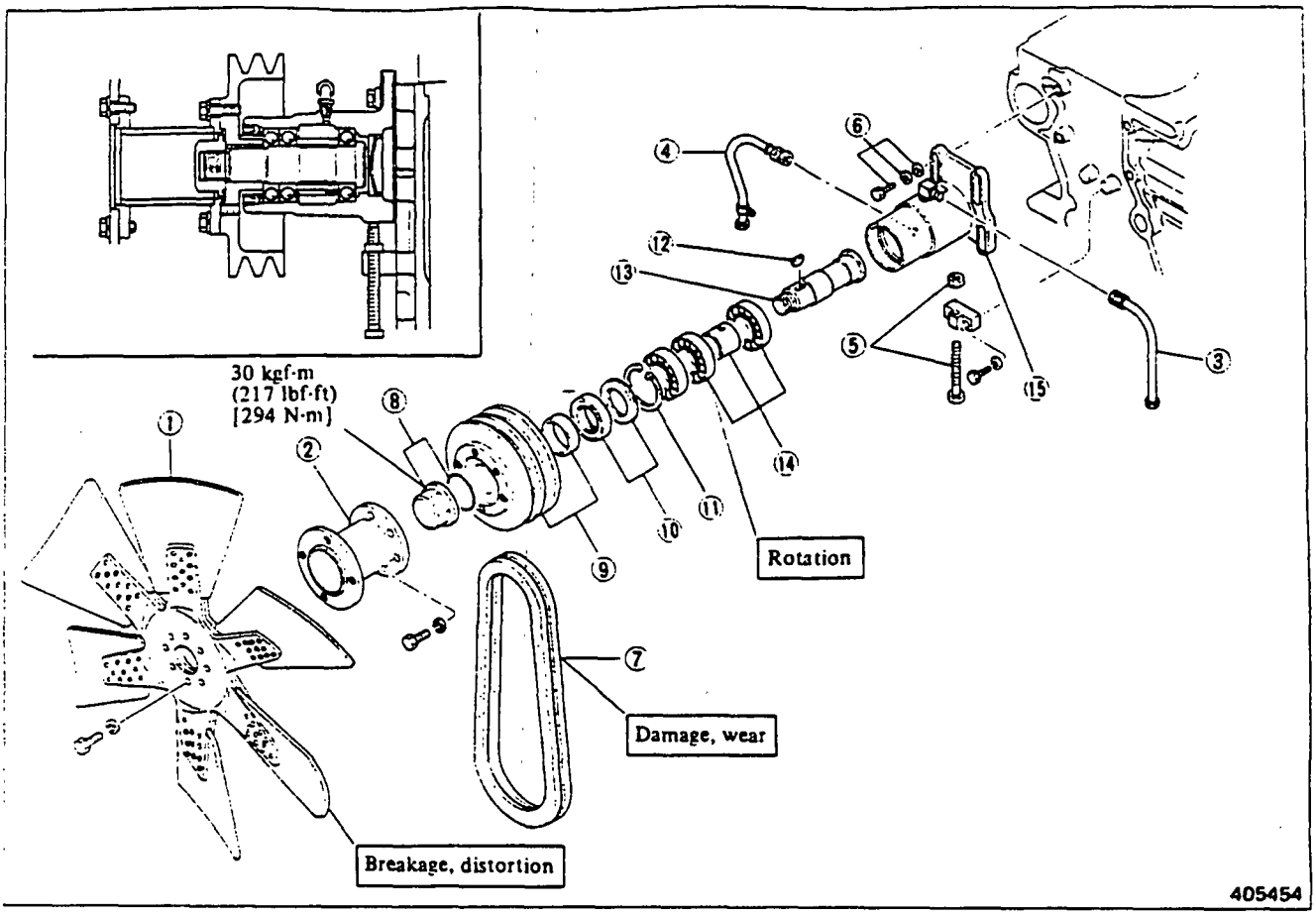
(1) Check the radiator fins for trash buildup. Also check the core interior for scale buildup and rusting. Clean the radiator if necessary.

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

6. FAN DRIVE

Disassembly

〈Pressure-lubricated type〉



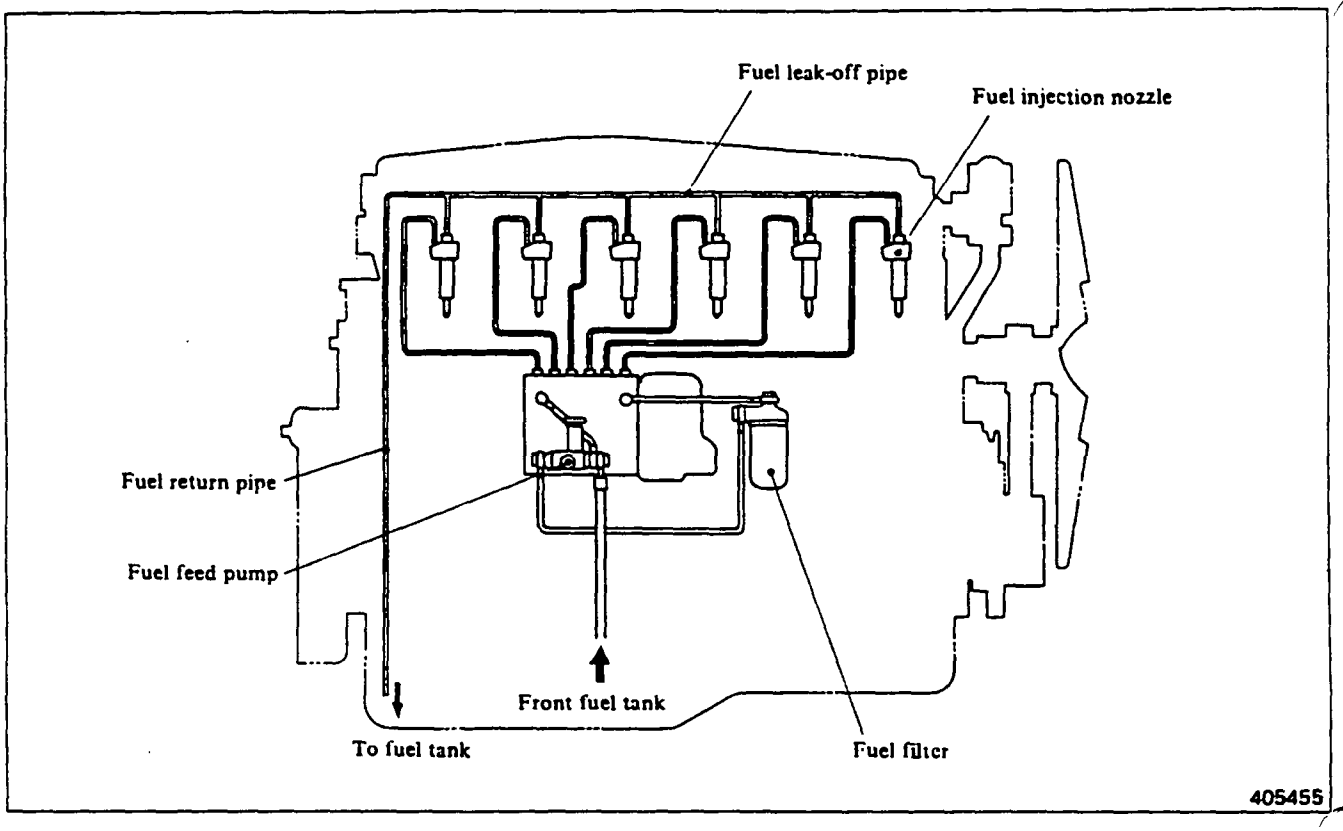
① Fan
② Spacer
③ Flexible pipe
④ Flexible pipe
⑤ Adjusting bolt, nut
⑥ Bolt, spring washer, plain washer
⑦ Belt
⑧ Cap nut, O-ring
⑨ Pulley, sleeve
⑩ Oil seal
⑪ Snap ring
⑫ Key
⑬ Shaft
⑭ Bearing, spacer, bearing
⑮ Bracket

⚠ 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.

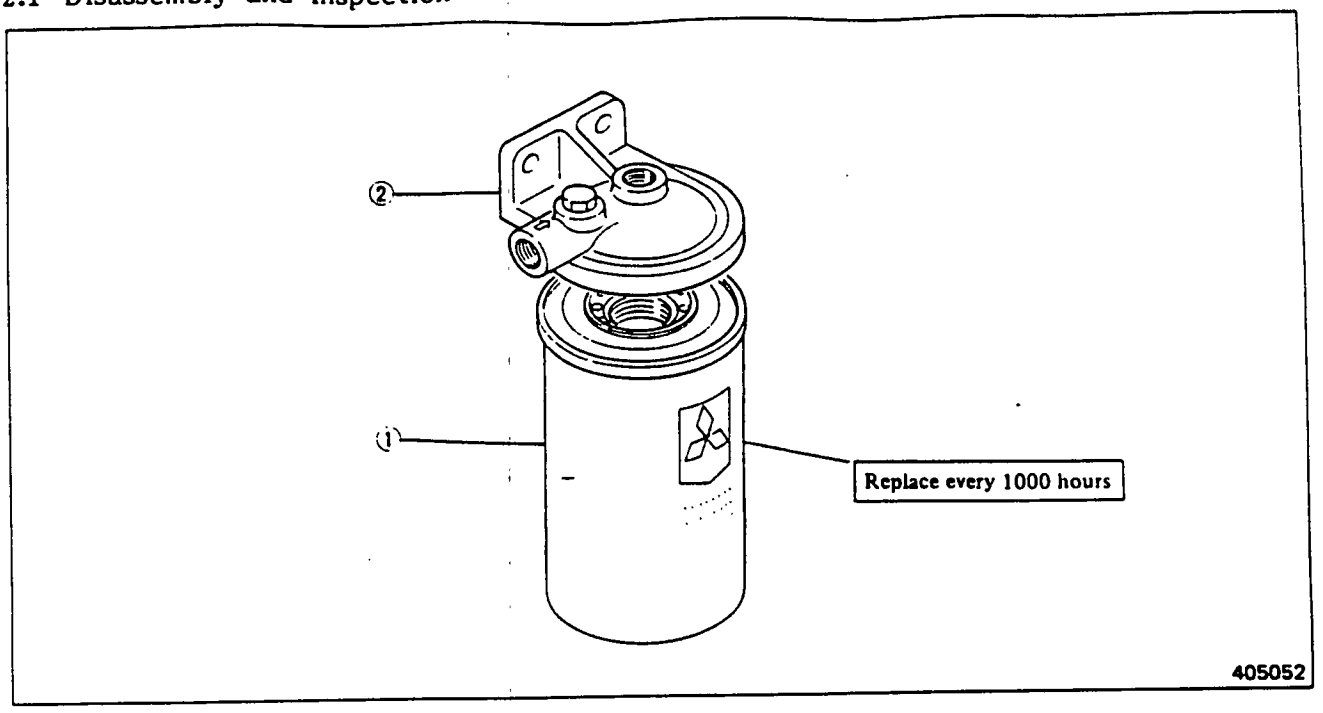
FUEL SYSTEM

1. DESCRIPTION



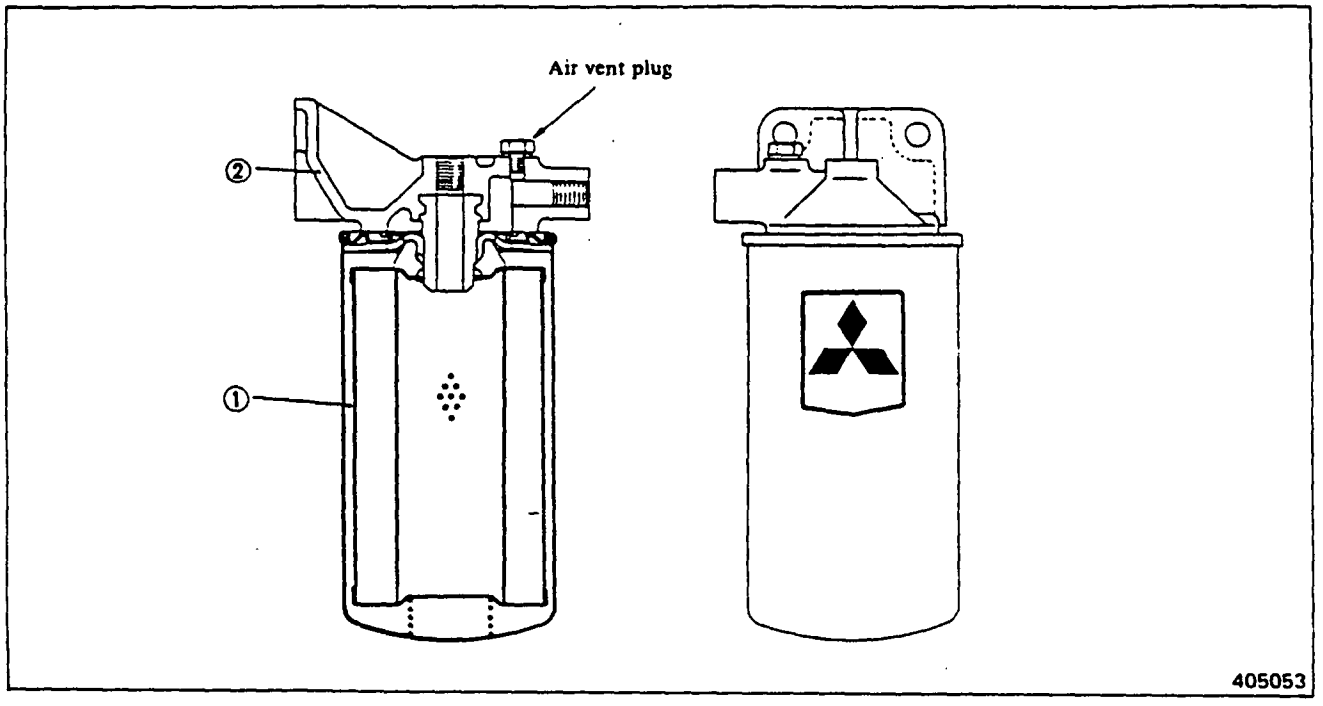
2. FUEL FILTERS

2.1 Disassembly and inspection



① Fuel filter ② Filter bracket

2.2 Reassembly



Reassembly sequence

②→①

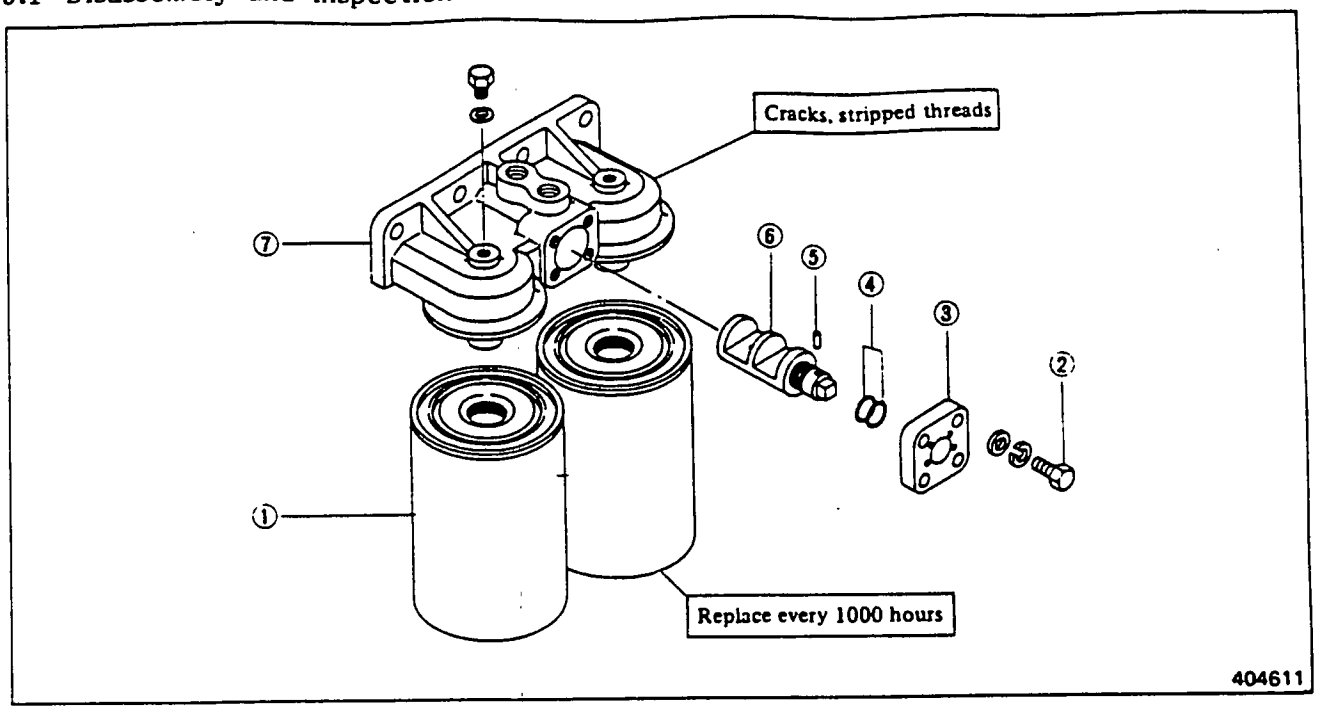
When installing the cartridge, clean its mounting seat, and coat its gasket with clean fuel oil. After bringing the gasket into contact with the sealing surface of the bracket, hand-tighten the cartridge 1/2 to 3/4 turn.

⚠ CAUTION

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

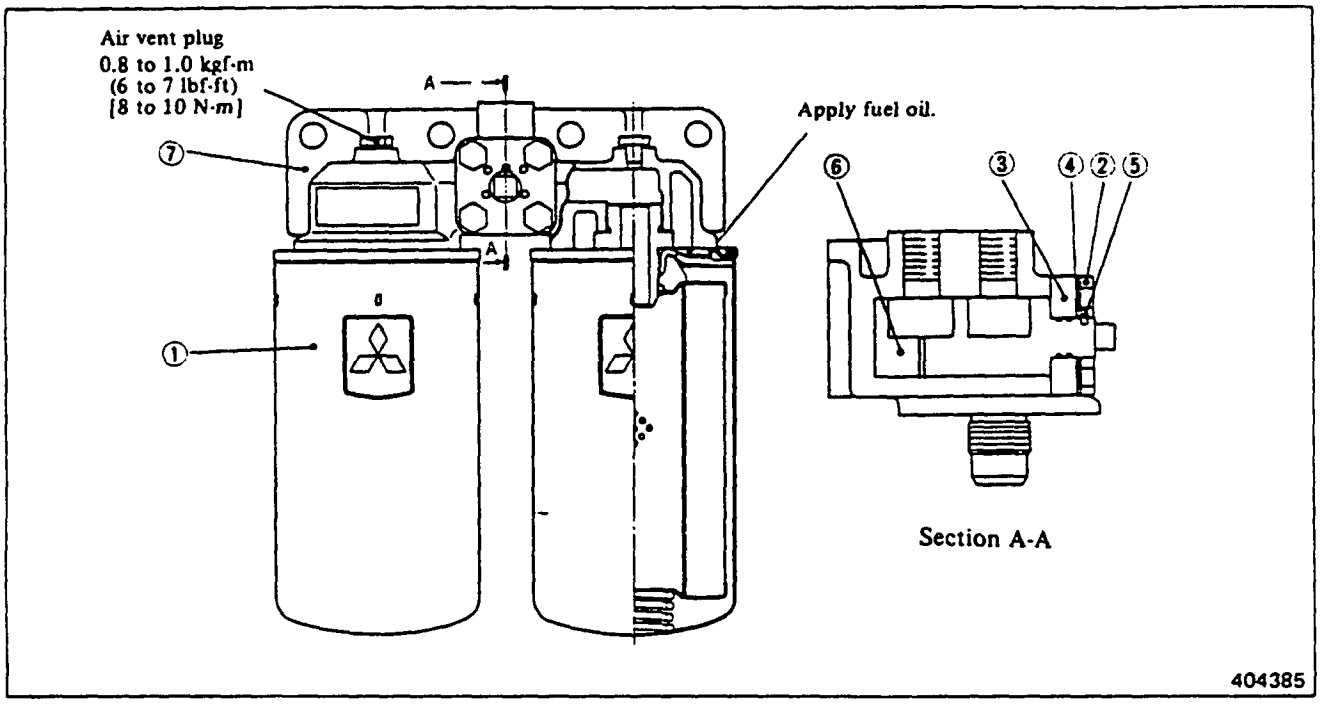
3. FUEL FILTERS (SELECTOR TYPE)

3.1 Disassembly and inspection



① Element
② Bolt
③ Cover
④ O-ring
⑤ Pin
⑥ Cock
⑦ Fuel filter bracket

3.2 Reassembly



Reassembly sequence

⑦→⑤→④→⑥→③→②→①

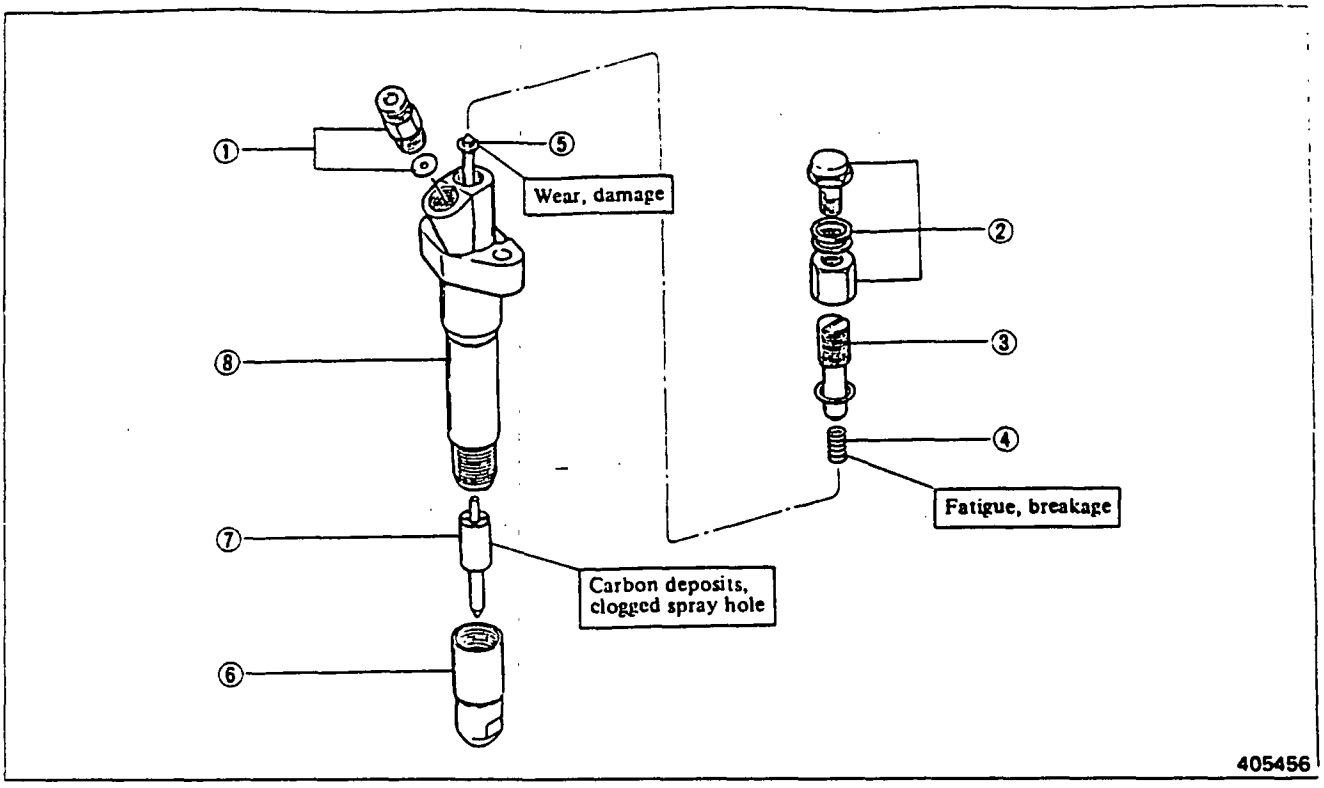
When installing the cartridge, clean its mounting seat, and coat its gasket with clean fuel oil. After bringing the gasket into contact with the sealing surface of the bracket, hand-tighten the cartridge 1/2 to 3/4 turn.

⚠ CAUTION

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

4. FUEL INJECTION NOZZLES

4.1 Disassembly



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

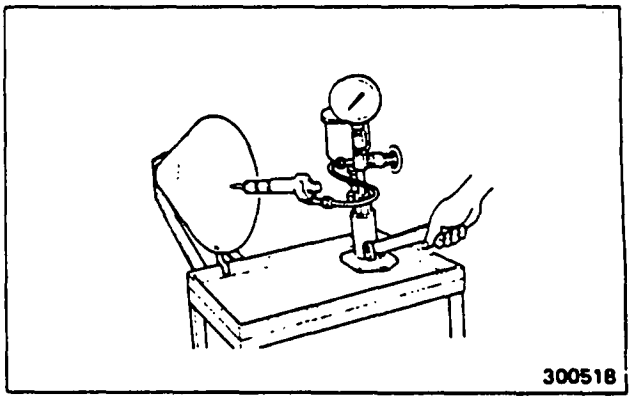
4.2 Inspection and adjustment

(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)	250 (3555) [24.5]	250 to 255 (3555 to 3626) [24.5 to 25.0]



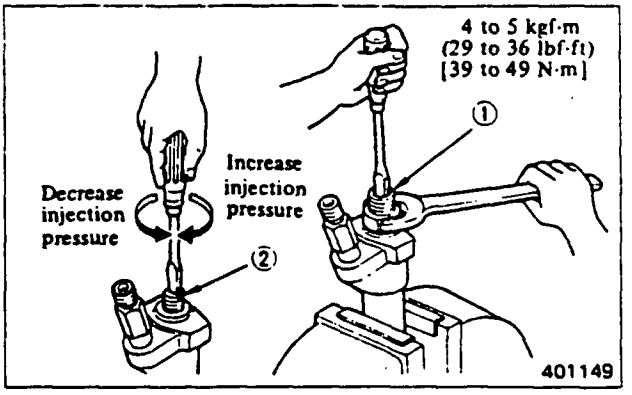
⚠ WARNING

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.

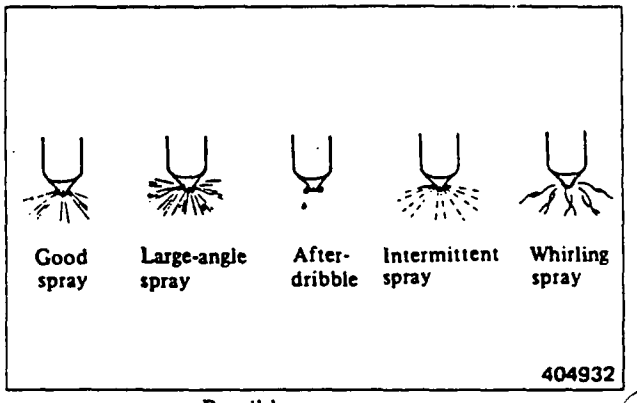
(d) Recheck the injection pressure, making sure that it is correct.



(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.

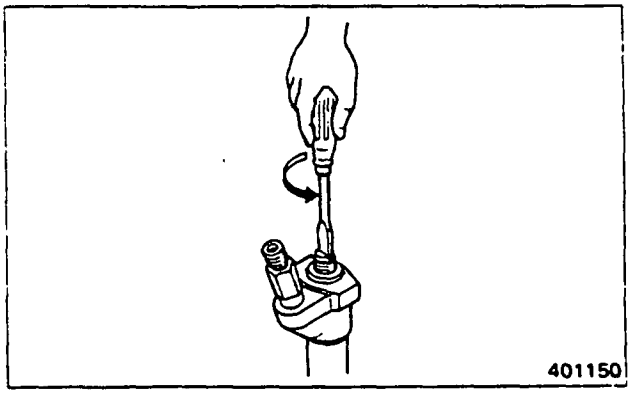
(b) When tested on the nozzle tester, the nozzle should spray fuel from its eight orifices at the same time in a good straight cone of 158°, consisting of finely atomized fuel particles without any large droplets, and should terminate with no dribble at the tip.



Possible spray patterns

(3) Washing or replacing nozzle tip

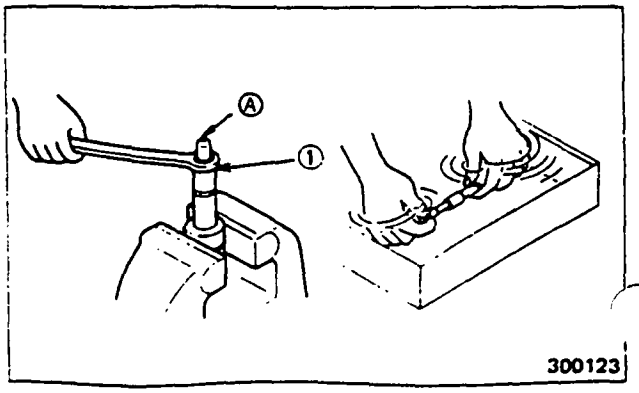
(a) The nozzle tip is spring loaded. Remove the cap nut and, with a screwdriver, loosen the adjusting screw to such an extent that it can be loosened by hand.



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

⚠ CAUTION

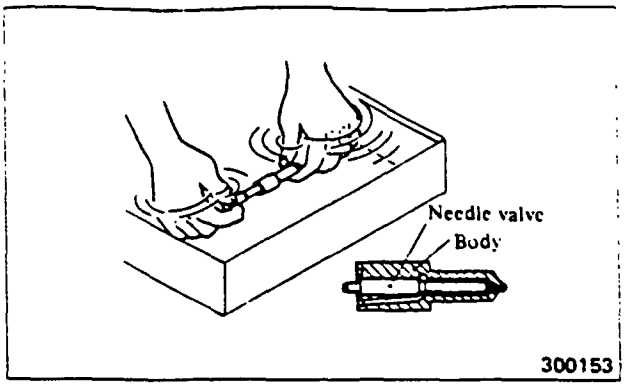
When pulling out the nozzle tip, be careful not to damage its tip (A).



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

⚠ CAUTION

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



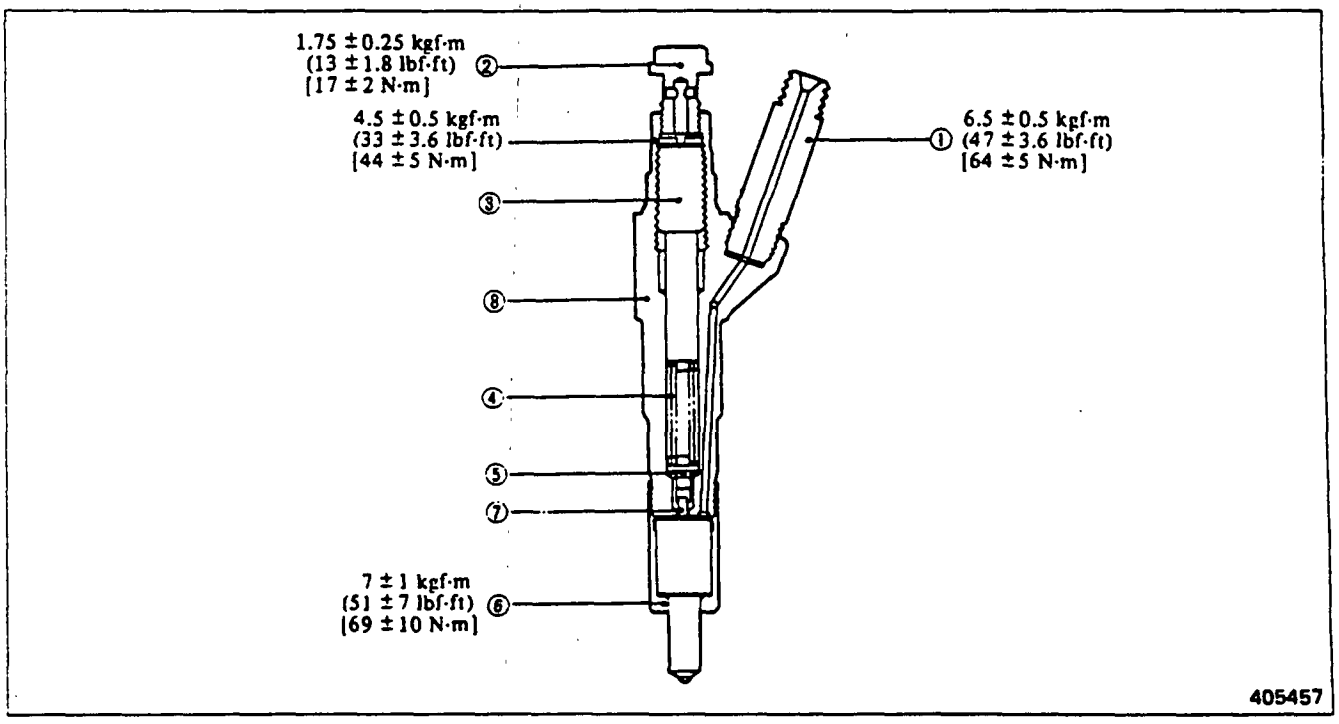
(d) Tighten the retaining nut to the specified torque.

(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 kerosene and then in diesel fuel to be used, before assembling them.

4.3 Reassembly



Reassembly sequence

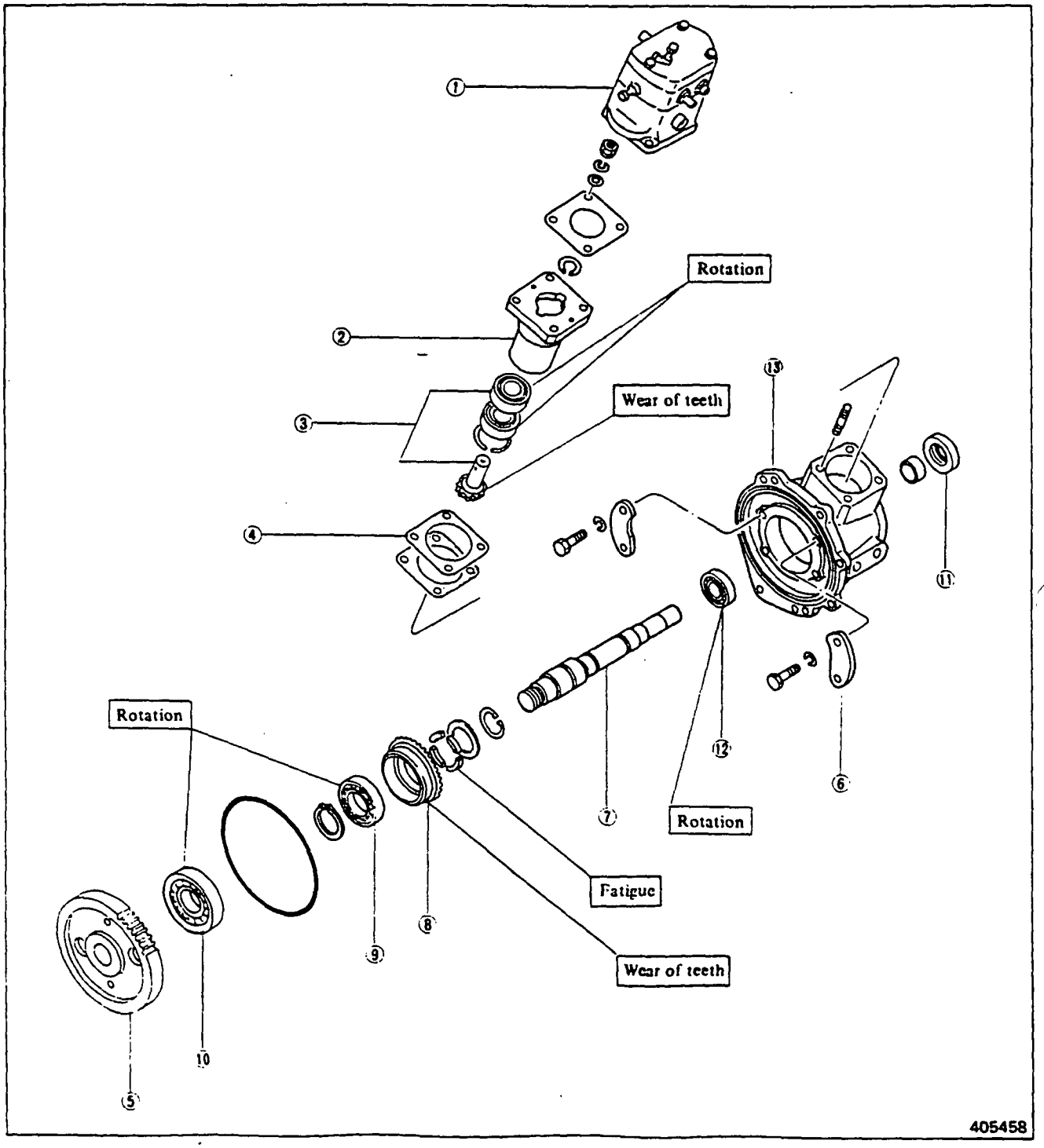
⑧→⑦→⑥→⑤→④→③→②→①

NOTE

When installing the nozzle tip to the nozzle holder, make sure that the locating pin of the tip enters the hole in the holder.

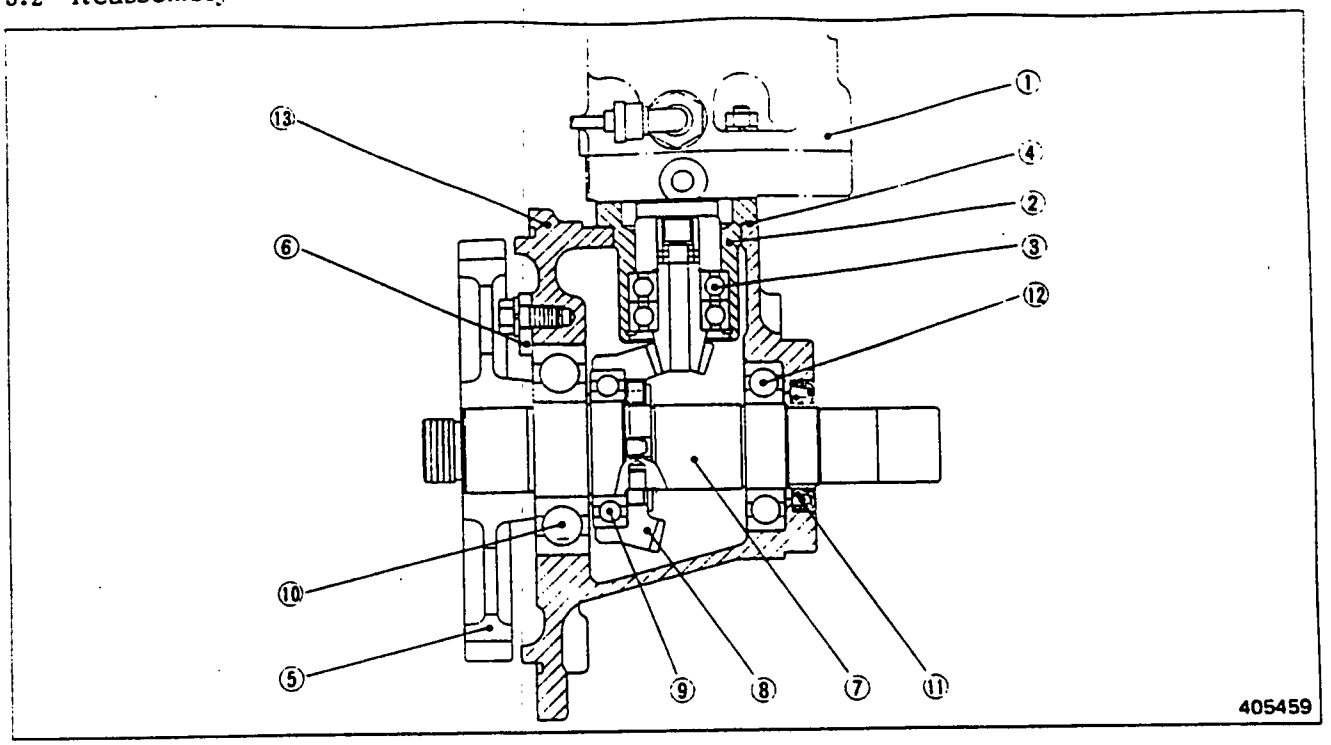
5. HYDRAULIC GOVERNOR DRIVE

5.1 Disassembly and inspection



① PSG governor
② Bearing case
③ Drive gear, ball bearing, snap ring
④ Shim
⑤ Injection pump drive gear
⑥ Thrust plate
⑦ Drive shaft
⑧ Drive gear
⑨ Ball bearing
⑩ Ball bearing
⑪ Oil seal
⑫ Ball bearing
⑬ Drive case

5.2 Reassembly

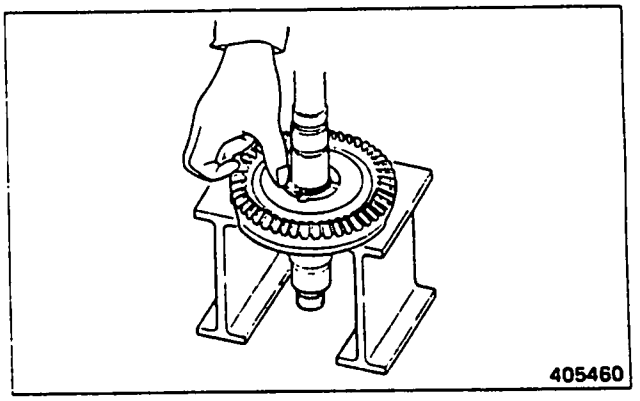


Reassembly sequence

②→③→④→①
⑬→⑫→⑪→⑥→⑤
⑦→⑨→⑧→⑩

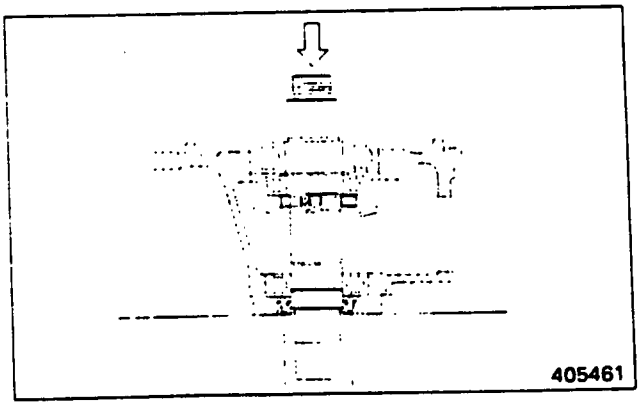
(1) Installing rubber

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



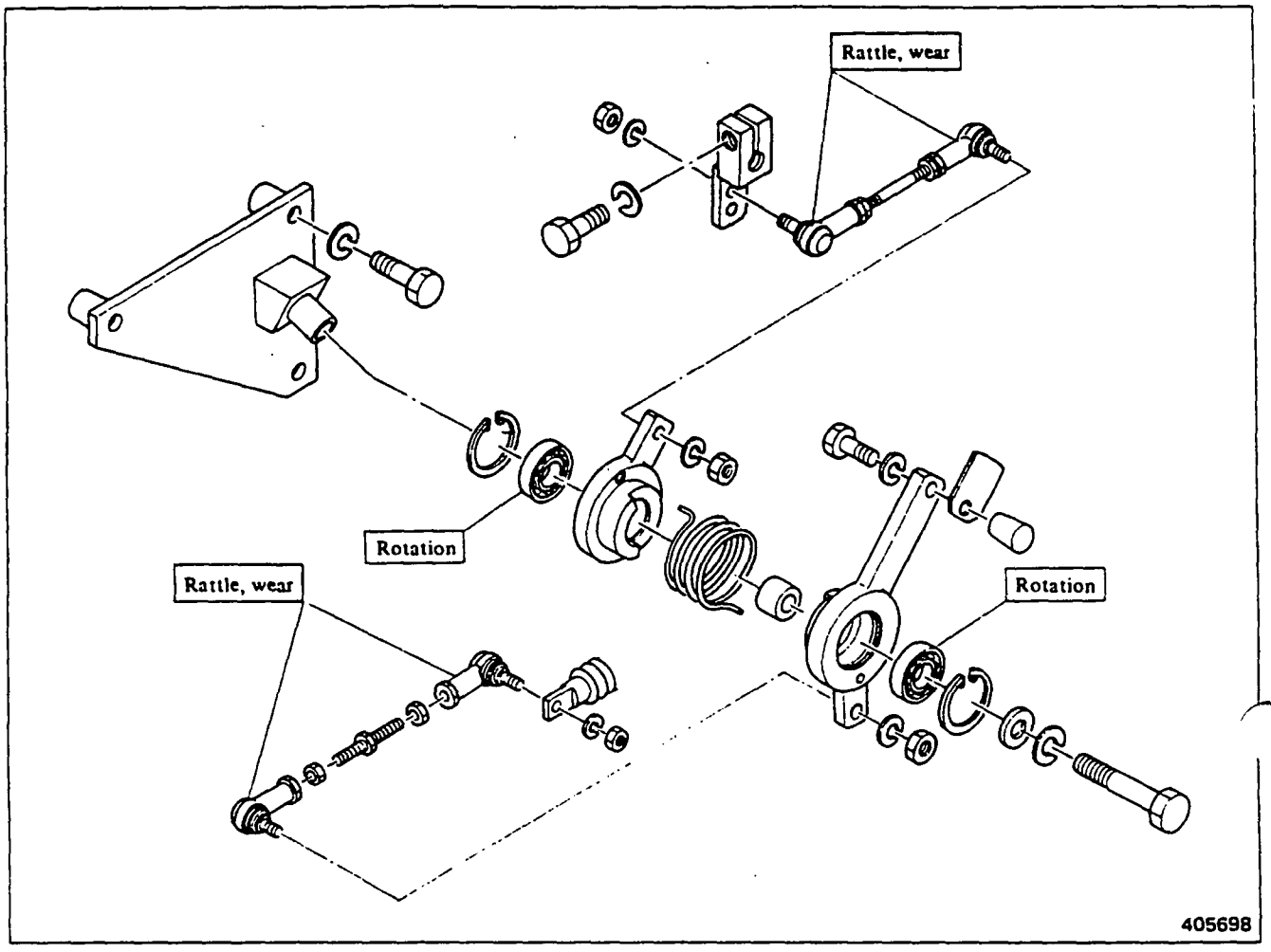
(2) Installing drive gear

Press the drive gear assembly into the drive case.

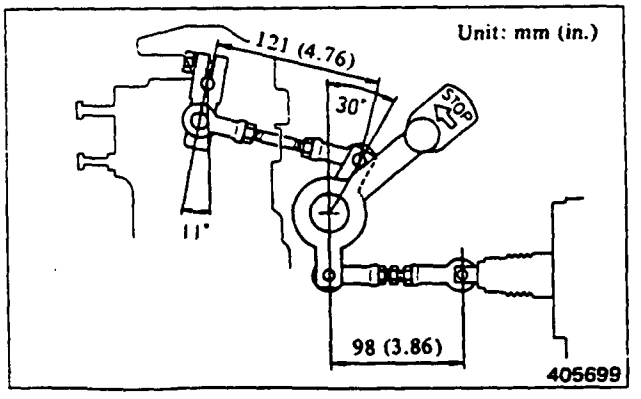


6. HYDRAULIC GOVERNOR LINKAGE

Inspection

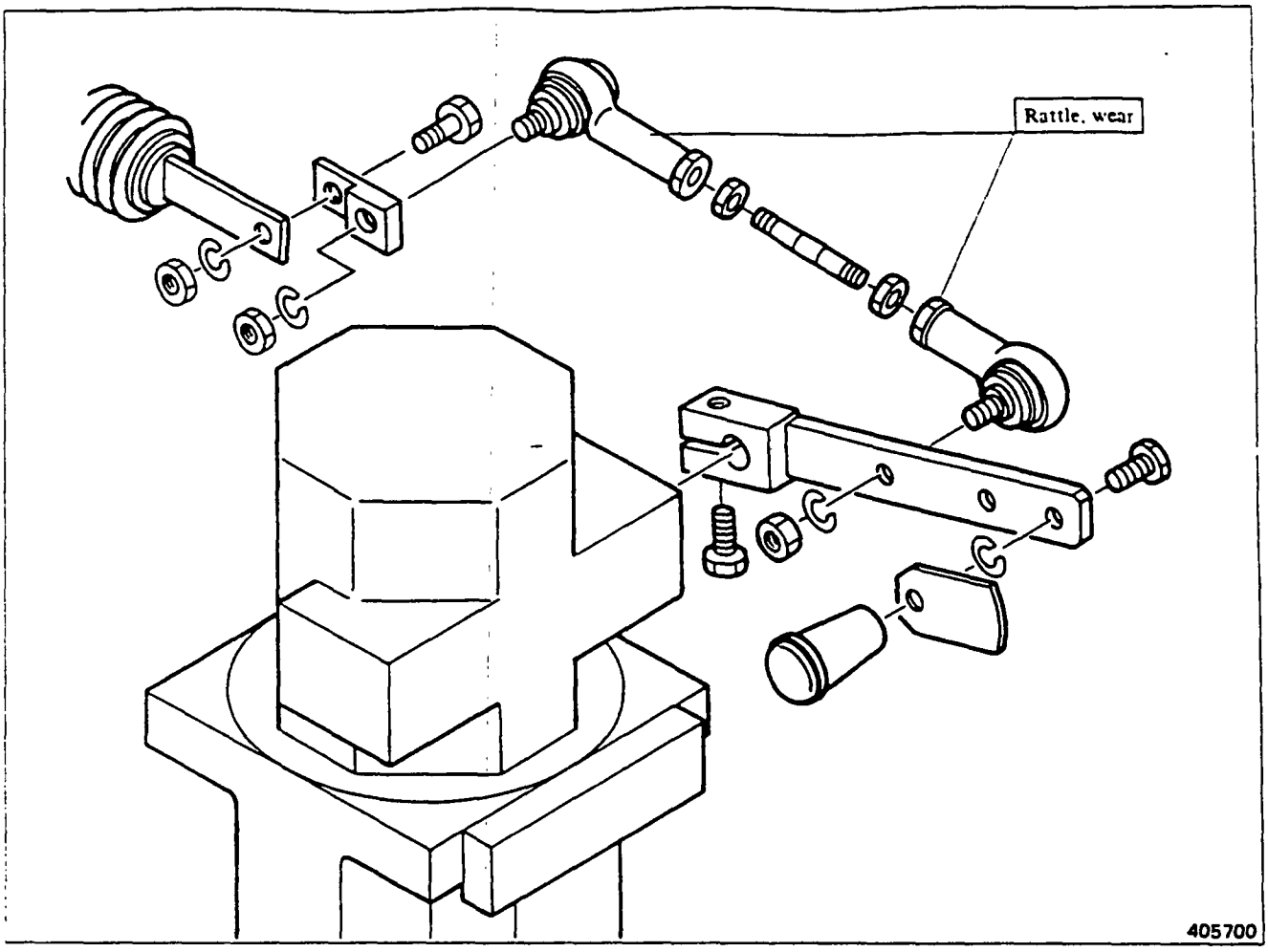


Replace the ball joints if they rattle excessively or are badly worn. When installing new ball joints, adjust them to the dimensions shown and, after adjusting the governor, seal the joints.

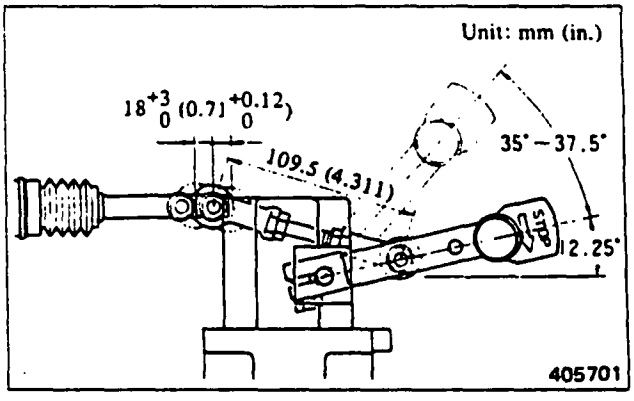


7. ELECTRIC GOVERNOR LINKAGE

Inspection

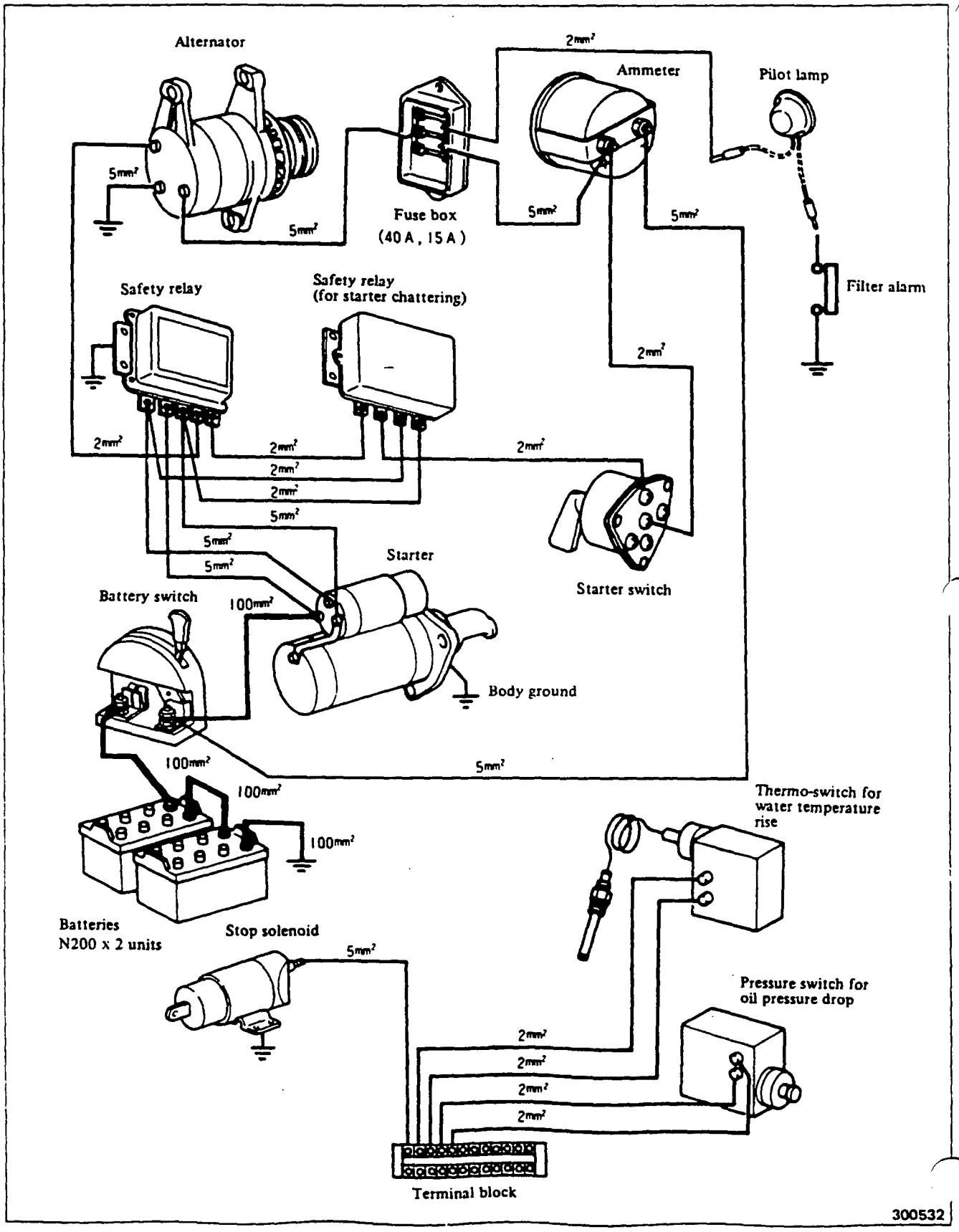


Replace the ball joints if they rattle excessively or are badly worn. When installing new ball joints, adjust them to the dimensions shown and, after adjusting the governor, seal the joints.



ELECTRICAL SYSTEM

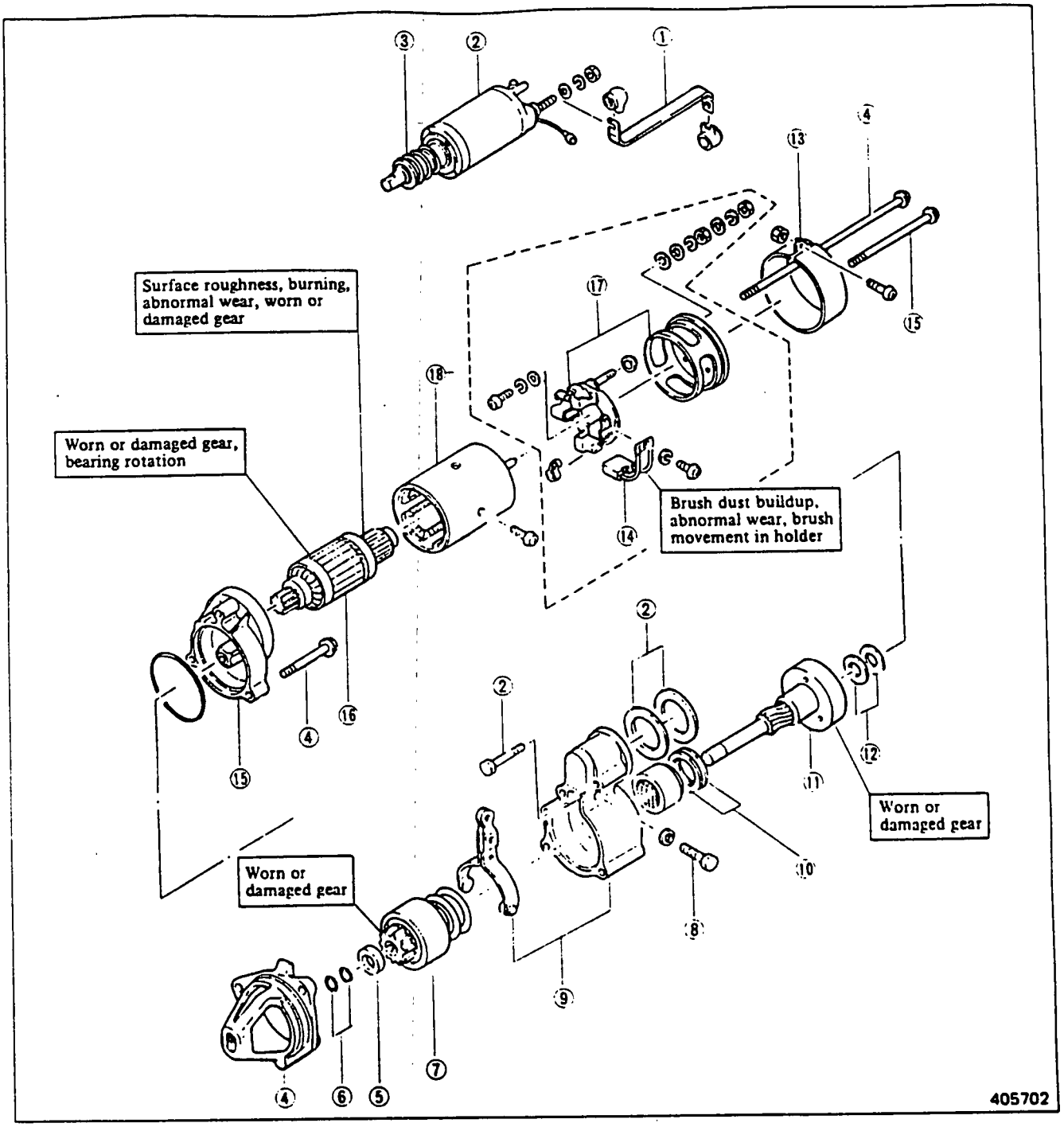
1. DESCRIPTION



Wiring diagram

2. STARTER

2.1 Disassembly

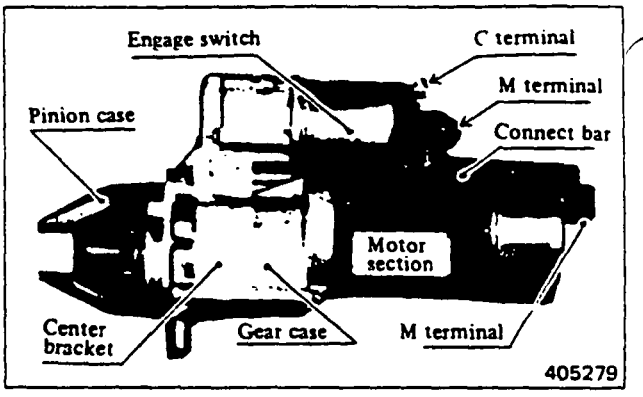


1 Connect bar
2 Engage switch assembly, plate, engage switch set bolt
3 Moving core
4 Pinion case set bolts
5 Pinion stopper
6 Hook, clip
7 Pinion clutch assembly
8 Lock plate, bolt
9 Center bracket, lever assembly
10 Shim, washer
11 Shaft
12 Shim, washer
13 Band assembly
14 Brush, set screw
15 Bolts, gear case
16 Armature assembly
17 Rear bracket, brush holder
18 Yoke assembly

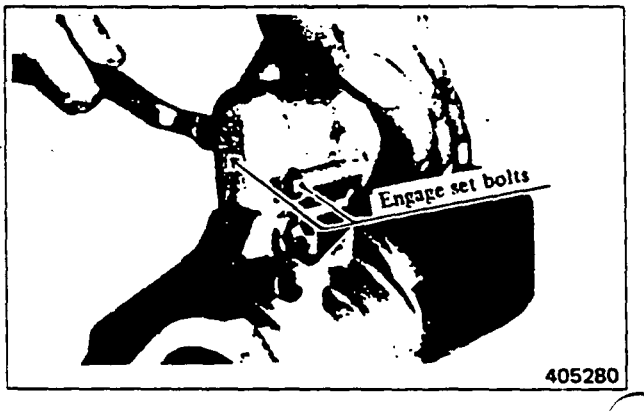
(1) Removing engage switch

(a) Remove the nuts from the M terminals of the engage switch and motor section.

(b) Remove the connect bar.

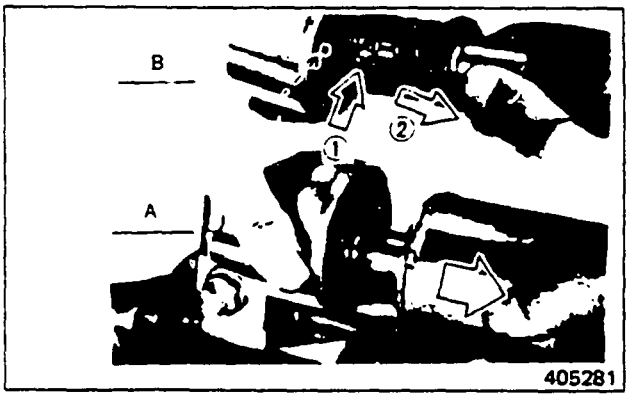


(c) Remove the engage switch set bolts.



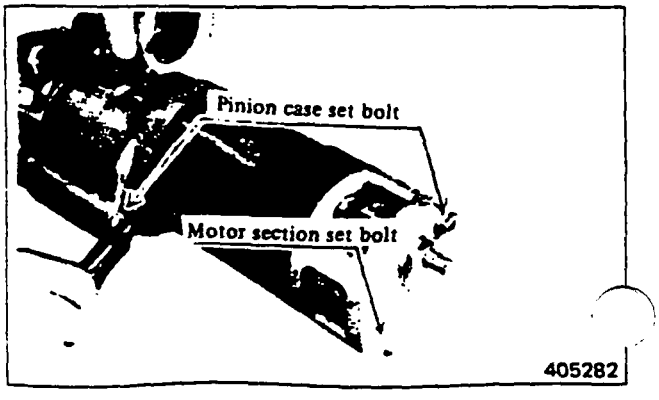
(d) Pull out the engage switch in the direction of arrow (A).

(e) Remove the moving core by moving it in directions (1) and (2) of (A) in that order.

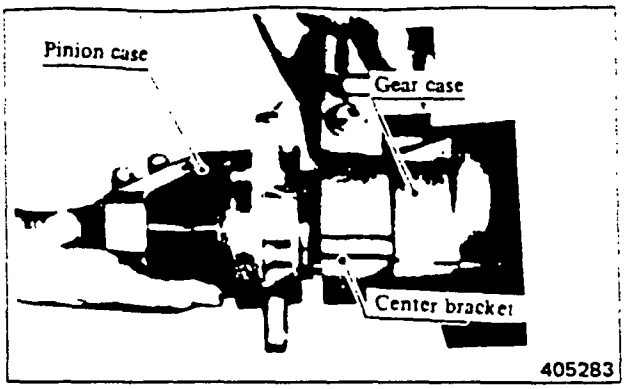


(2) Removing pinion clutch

(a) Remove the pinion case set bolt.

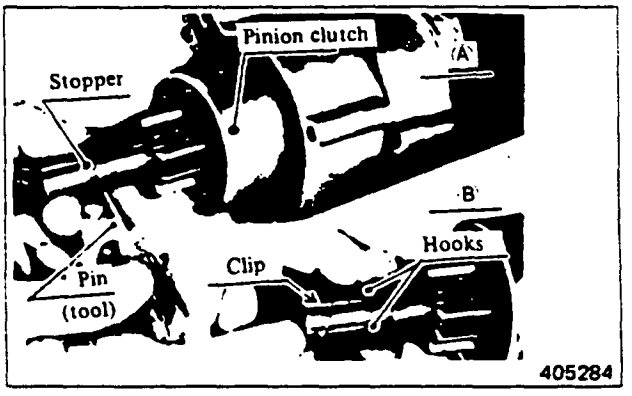


(b) Remove the pinion case.

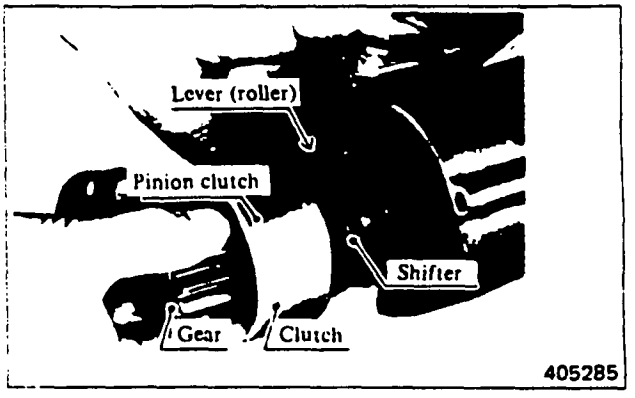


(c) Press a pin into the hole (or groove) of the stopper as shown in (A) and remove the clip as shown in (B).

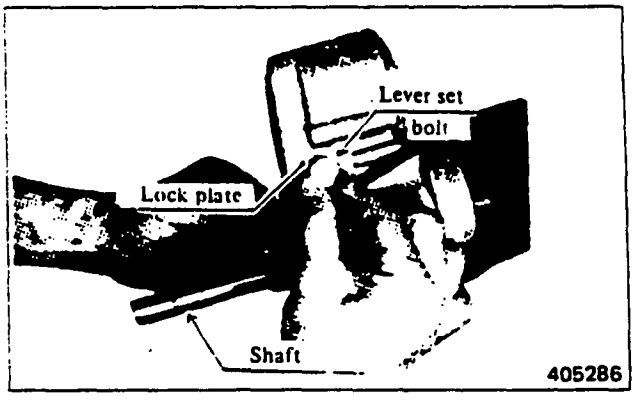
(d) Push the stopper toward the pinion side and remove the hooks (2 pcs) from the shaft.



(e) Push up the lever and remove the pinion clutch.

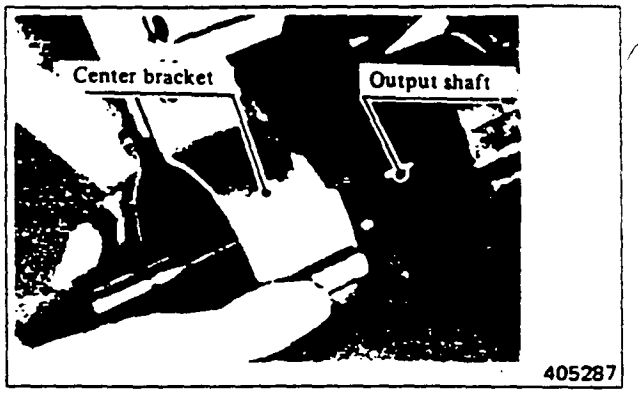


(f) Straighten the lock plate and remove the lever set bolt.



(3) Removing shaft

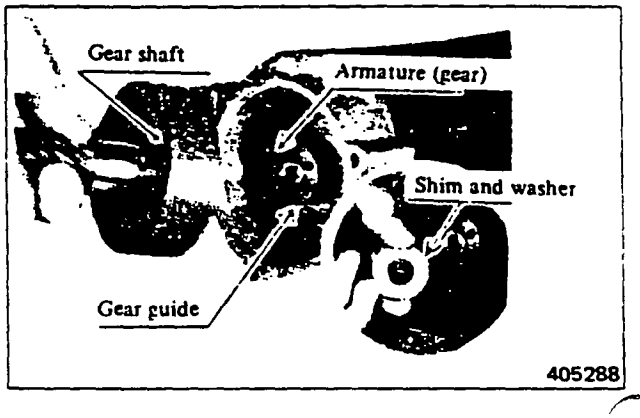
(a) Remove the center bracket.



(b) Remove the shim and washer from the shaft.

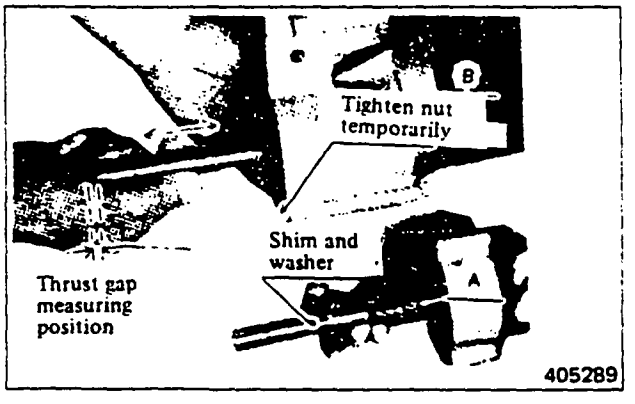
NOTE

Be careful not to lose the shim and washer.



(c) Remove the shaft.

(d) Remove the shim and washer.



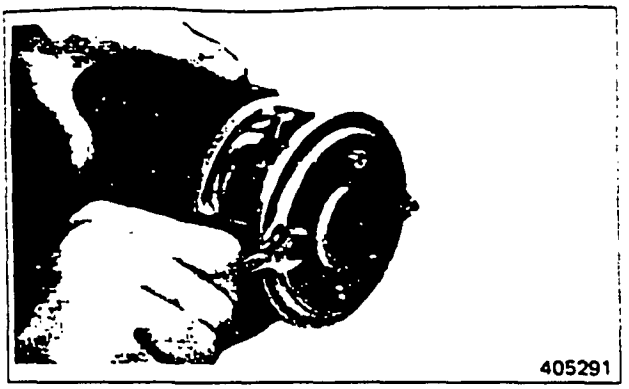
(4) Disassembling motor section

(a) Remove the band assembly.

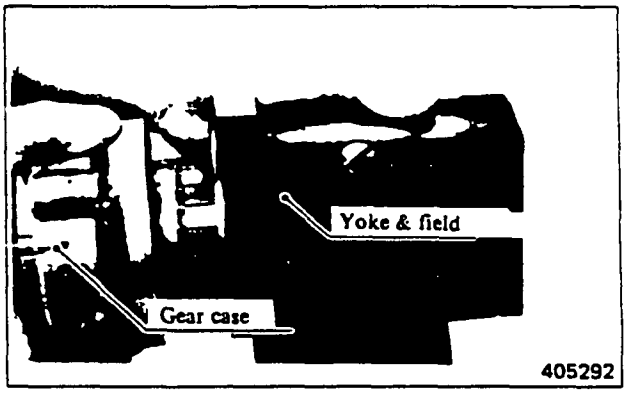
(b) Remove the brush set screws (4 pcs).

(c) Lift the brush spring and remove the brush.

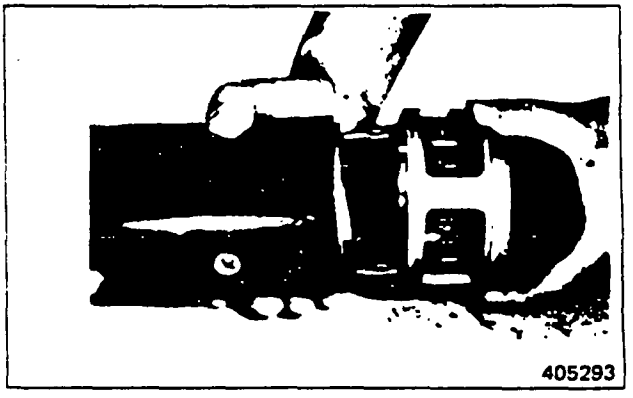
(d) Remove the bolts.



(e) Separate the gear case from the armature.



(f) Separate the rear bracket from the yoke assembly.

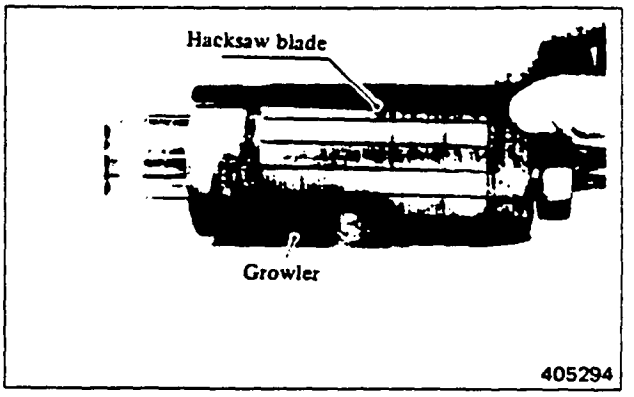


2.2 Inspection and repair

(1) Armature

(a) Testing armature coil for short circuits

Test the armature for short circuits on a growler. If the hacksaw blade vibrates against the core, replace the armature.



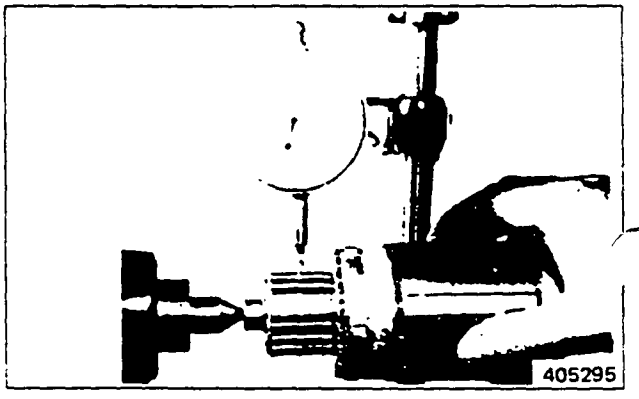
Testing armature for short circuits

(b) Testing insulation resistance

Using a megger, test the insulation resistance between the core and coil. The resistance should be more than 1 MΩ.

(c) Measuring commutator runout

Support the commutator in V-blocks, and measure the runout with a dial indicator. If the runout is in excess of the service limit, replace the armature.



Measuring commutator runout

Unit: mm (in.)

Item	Assembly standard	Service limit
Commutator runout	0.05 (0.0020)	0.10 (0.0039)

(d) Measuring commutator diameter

If the commutator is out of round, or worn, or if it has high mica, turn it in a lathe. After turning, measure the commutator diameter.

Unit: mm (in.)

Item	Nominal value	Service limit
Commutator diameter	40 (1.57)	38 (1.50)

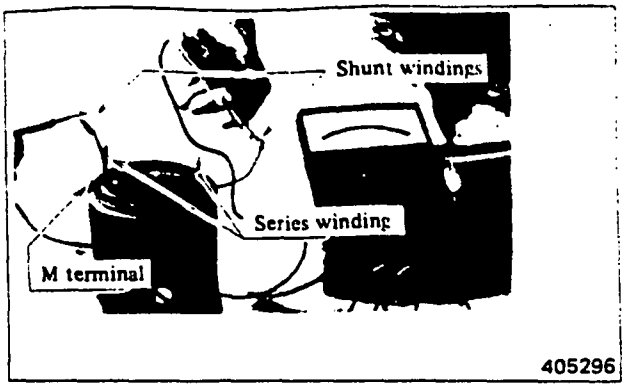
(2) Field coil

(a) Testing continuity

Using a tester, check for continuity between the series coil terminal and body. If there is no continuity, replace the field coil.

(b) Measuring insulation resistance

Using a megger, measure the insulation resistance between the coil terminal and body. To test, remove the ground screw and keep the terminal and body free. The insulation resistance should be more than 1 MΩ.



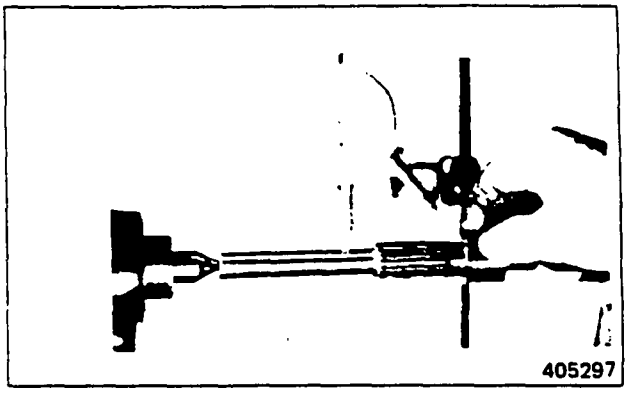
Testing field coil

(3) Shaft

Using a dial indicator, measure the runout of the shaft at its center.

Unit: mm (in.)

Item	Assembly standard	Service limit
Shaft runout	0.05 (0.0020)	0.10 (0.0039)



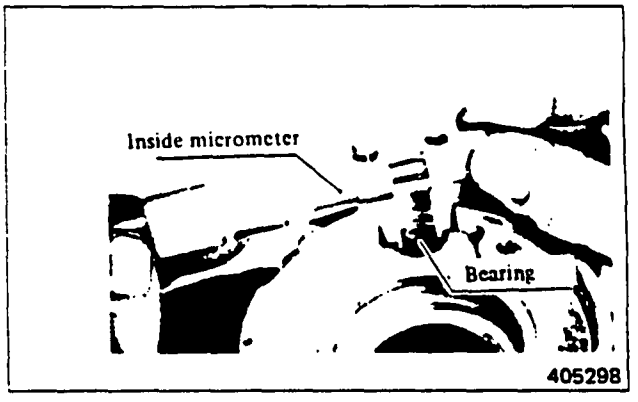
Measuring shaft runout

(4) Bearings

Using a micrometer, measure the inside diameter of the bearings.

Unit: mm (in.)

Item	Nominal value	Service limit
Front bearing	19 (0.75)	19.2 (0.756)
Center bearing	28 (1.10)	28.2 (1.110)

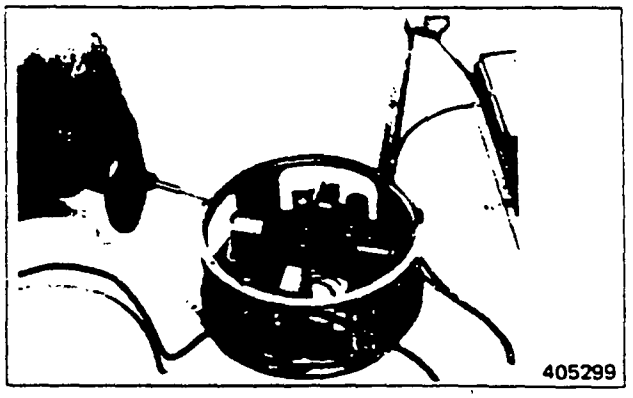


Measuring bearings

(5) Brushes and brush holders

(a) Testing insulation resistance

Using a megger, measure the insulation resistance between the positive (+) side holder (insulated) and bracket. The insulation resistance should be more than 1 MΩ.



Testing brush holder insulation

(b) Measuring brush spring tension

Using a spring gauge, measure the tension of each brush spring. Replace the spring if the tension is in excess of the service limit.

Unit: kgf (lbf) [N]

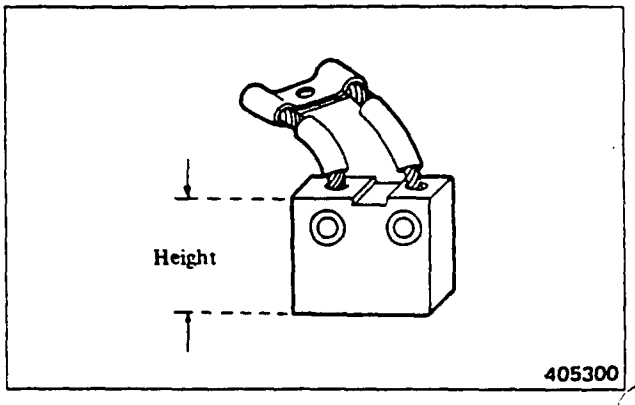
Item	Nominal value	Service limit
Brush spring tension	1.4 (3.1) [13.7]	1.0 (2.2) [9.8]

(c) Measuring brush height

Replace the brush if the height is in excess of the service limit.

Unit: mm (in.)

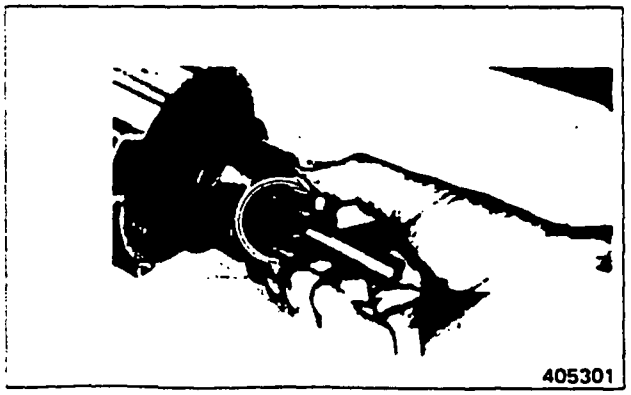
Item	Assembly standard	Service limit
Brush height	20 (0.79)	14 (0.55)



Measuring brush height

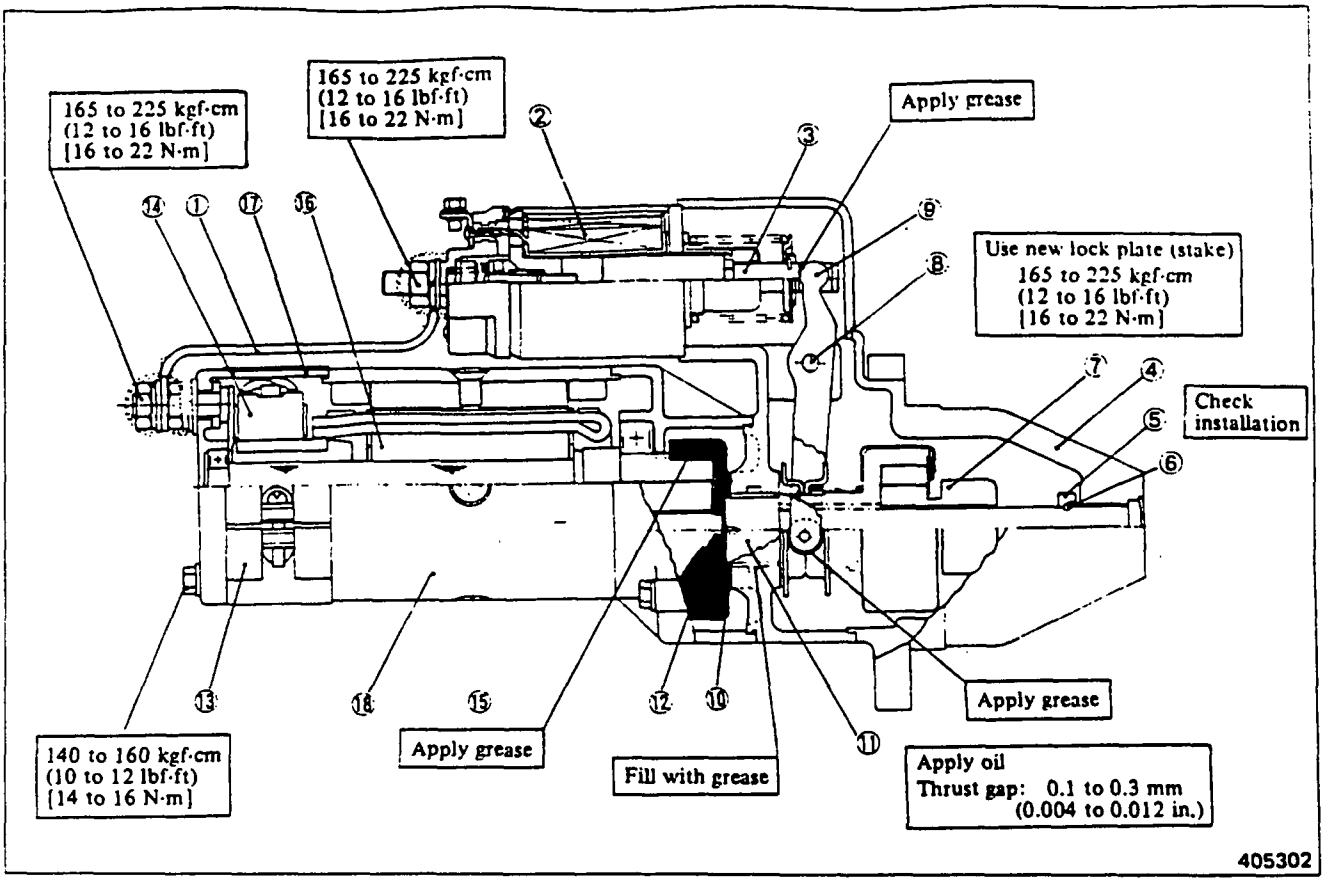
(6) Overrunning clutch

The clutch is in good condition if it rotates freely in the direction of arrow when turned by hand. The clutch slipping torque should be 6 to 8 kgf·cm (0.4 to 0.6 lbf·ft) [0.6 to 0.8 N·m].
Check the pinion teeth for wear or damage. Replace the pinion if damaged.



Testing pinion clutch

2.3 Reassembly



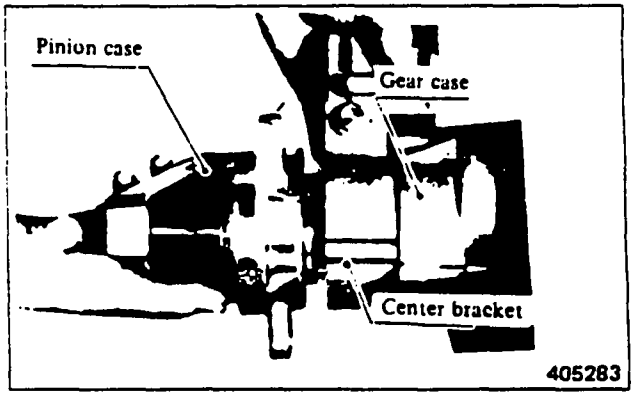
Reassembly sequence

⑱→⑰→⑯→⑭→⑬→⑮→⑫→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

Suggestions

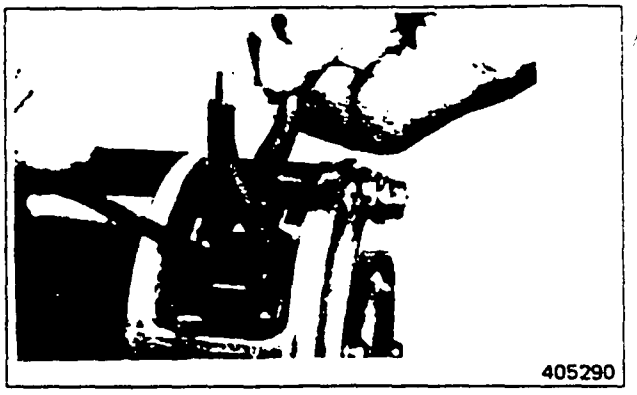
(1) Installing pinion case

First tighten the pinion case set bolt (through bolt securing the pinion case to the rear bracket). This will facilitate reassembling work.



(2) Installing brushes

When tightening the set screw of the brushes, cross the lead-in wires.



Inspection after reassembly

Measuring and adjusting pinion gap _

Energize the engage switch to cause the pinion to be shifted. Under this condition, measure the clearance between the pinion and pinion case, or the clearance between the pinion and pinion stopper.

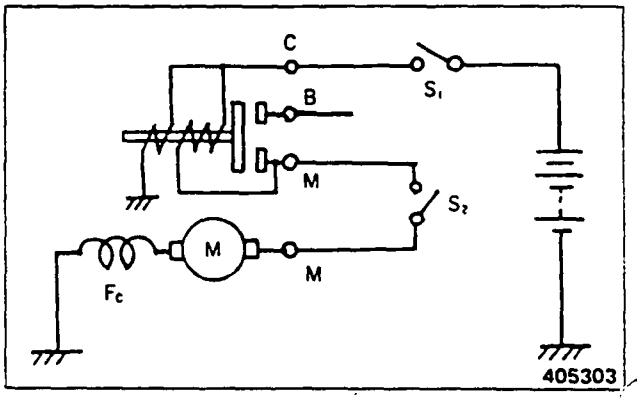
(a) Put switch (S1) in the circuit between the C terminal of the switch and battery. Put switch (S2) in the circuit between the M terminals of the switch and motor.

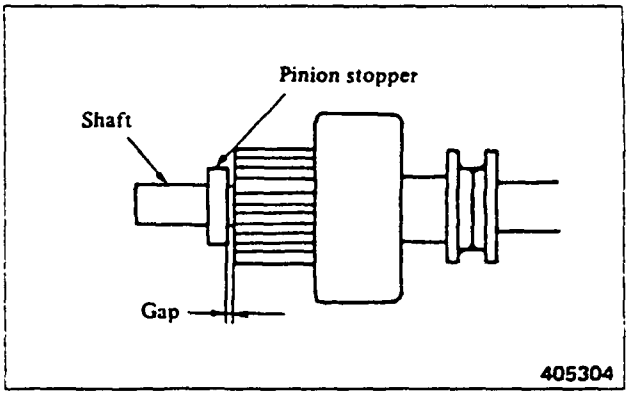
(b) Close switch (S1) and switch (S2) in that order.

(c) After the pinion has shifted, open switch (S2).

(d) Push the pinion back lightly.

(e) Under this condition, measure the gap.

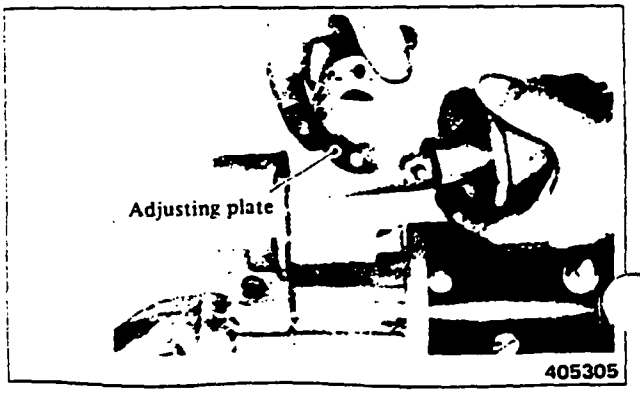




Unit: mm (in.)

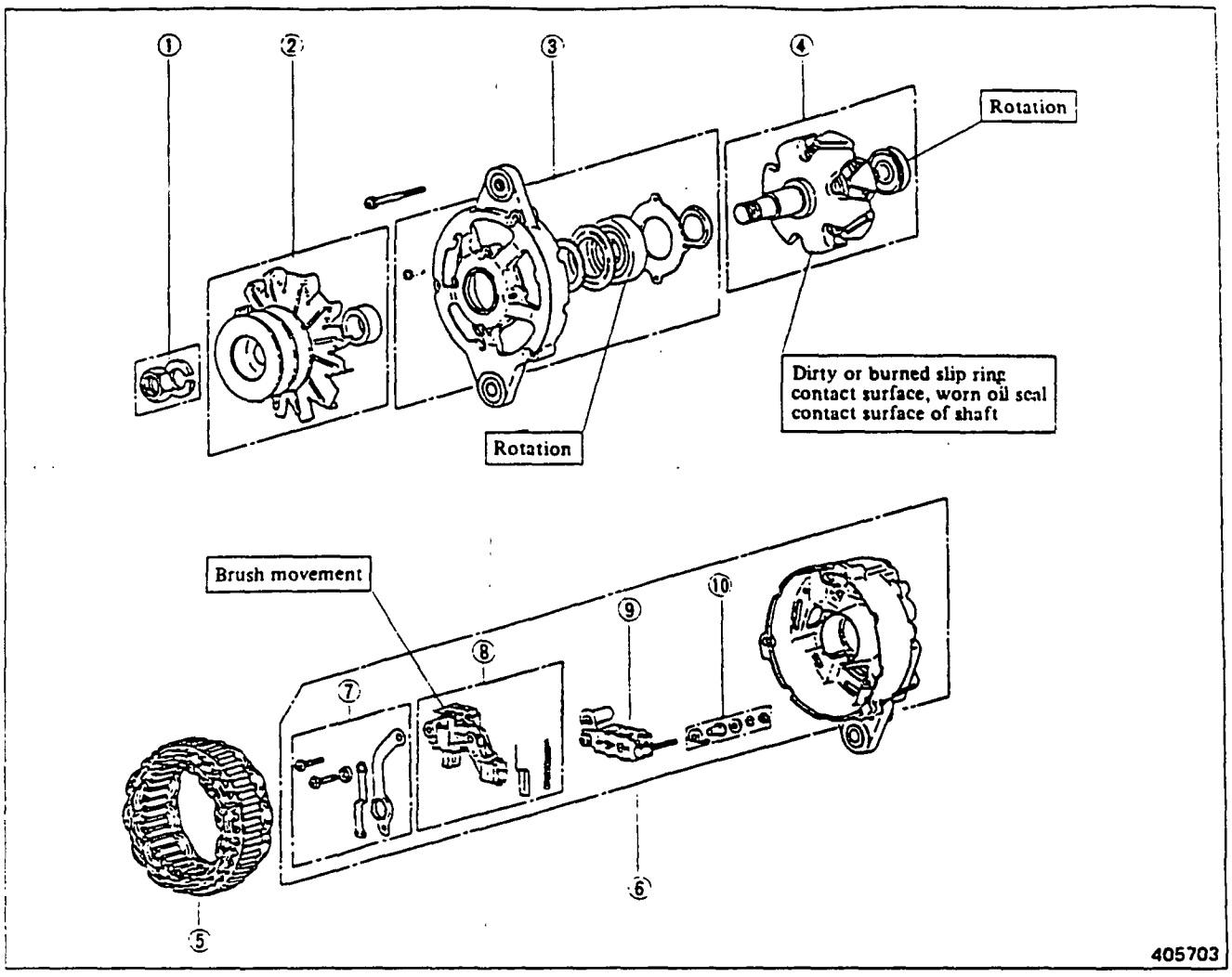
Item	Assembly standard
Pinion gap	1 to 2 (0.04 to 0.08)

To adjust the gap, put or remove the adjusting plate from the switch.



3. ALTERNATOR

3.1 Disassembly



① Nut, washer
② Pulley assembly
③ Bracket assembly
④ Rotor assembly
⑤ Stator
⑥ Bracket assembly
⑦ Terminal set
⑧ Regulator assembly
⑨ Rectifier assembly
⑩ Nut set

⚠ CAUTION

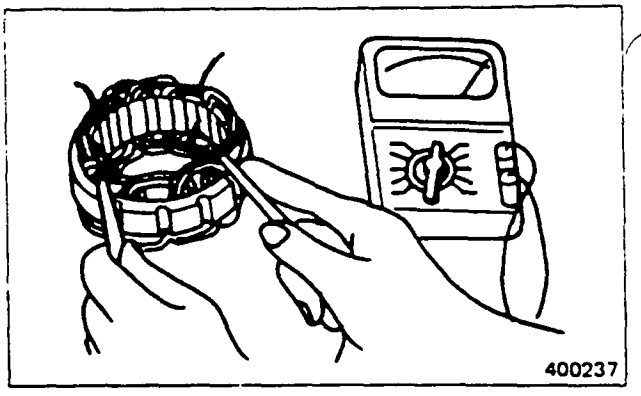
When undoing the soldered connections of lead wires extending from the stator coil, using a soldering iron, make it quickly by gripping the wires with a needle-nose pliers to prevent heating the diode rectifier.

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) Measuring 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.)

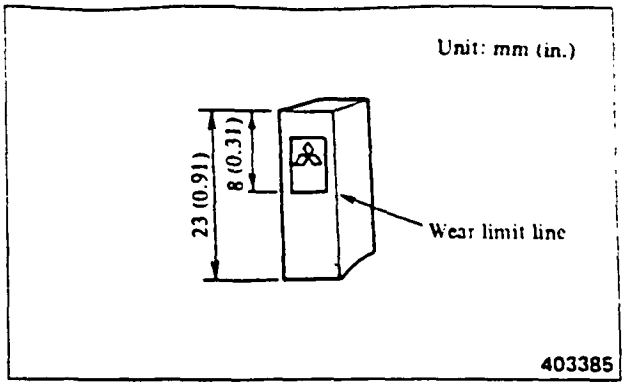
Item	Nominal value	Service limit
Slip ring outside diameter	41 (1.61)	40.4 (1.59)

(3) Brushes and brush springs

(a) Wear of brushes

Unit: mm (in.)

Item	Assembly standard	Service limit
Brush height	23 (0.91)	8 (0.31)



(b) Brush spring tension

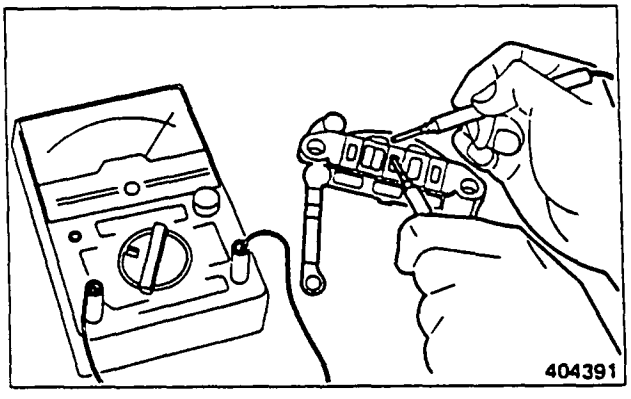
Unit: kgf (lbf) [N]

Item	Assembly standard	Service limit
Brush spring tension	0.32 to 0.44 (0.7 to 1.0) [3 to 4]	0.20 (0.4) [2]

(4) Diodes

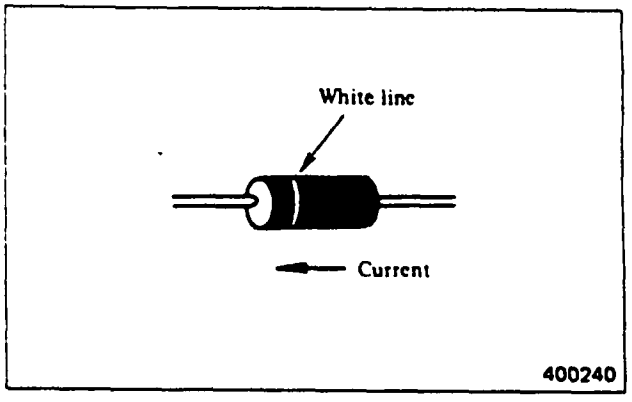
(a) Main diode

If there is continuity between the lead-in wire of diode and the heat sink in both direction (in case of infinity), or if there is no continuity, replace the rectifier assembly.

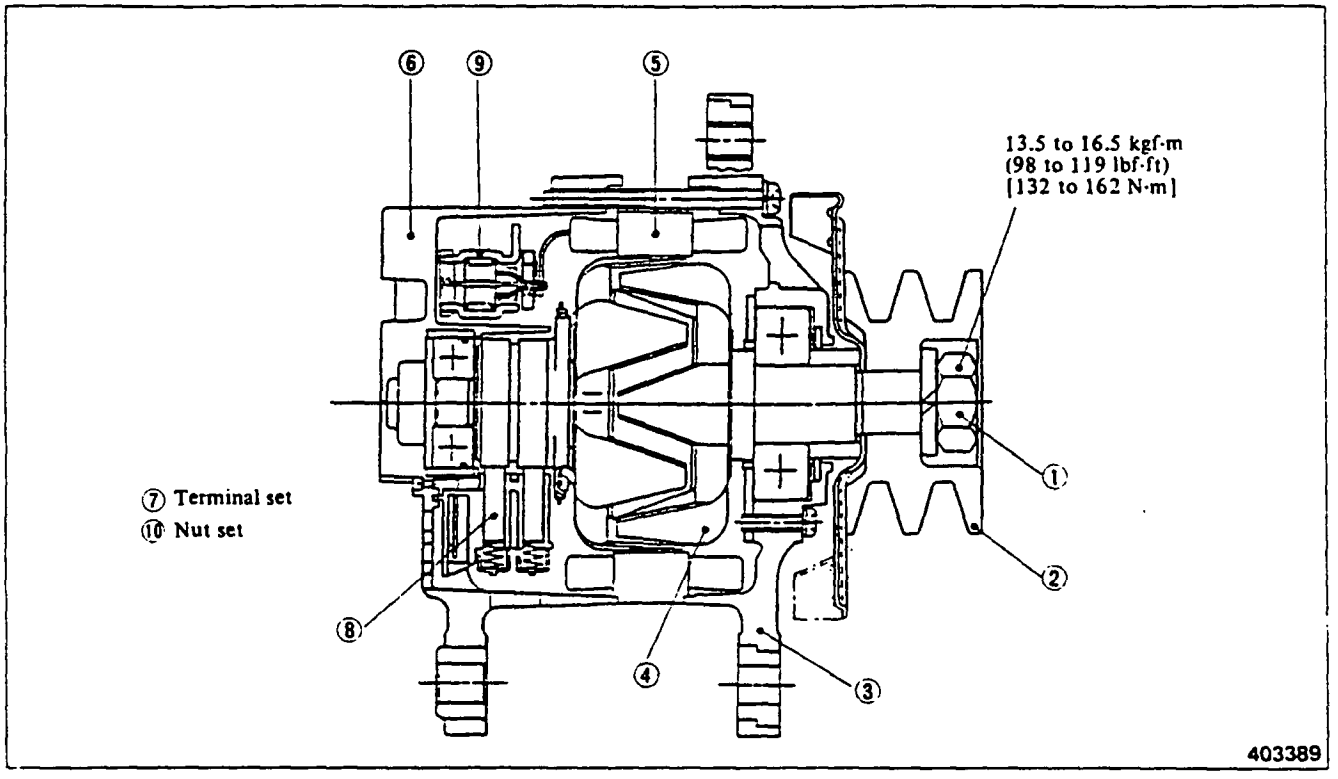


(b) Auxiliary diode

If there is continuity between the lead-in wires of the diode (in case of infinity), or if there is no continuity, replace the heat sink assembly.



3.3 Reassemby

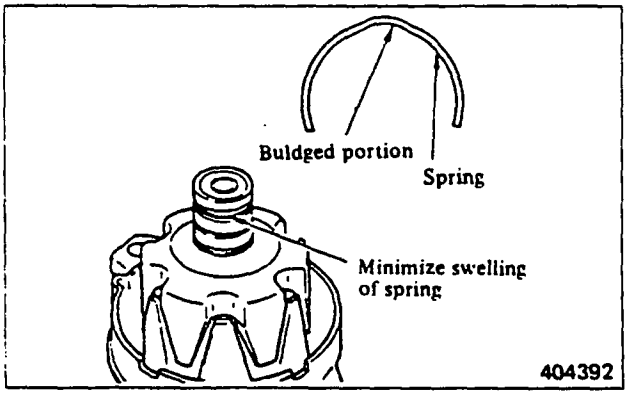


Reassembly sequence

⑥→⑩→⑨→⑧→⑦→⑤→②→①
③→④

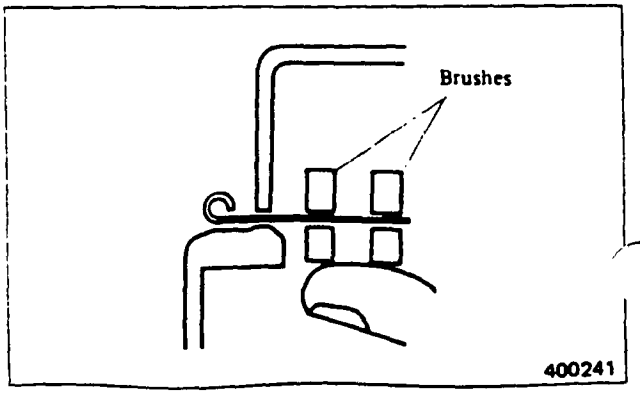
(1) Installing spring

When putting spring in the groove of the rear bearing, position its buldged portion at the deepest part of the groove.



(2) Holding brush for installing rotor

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

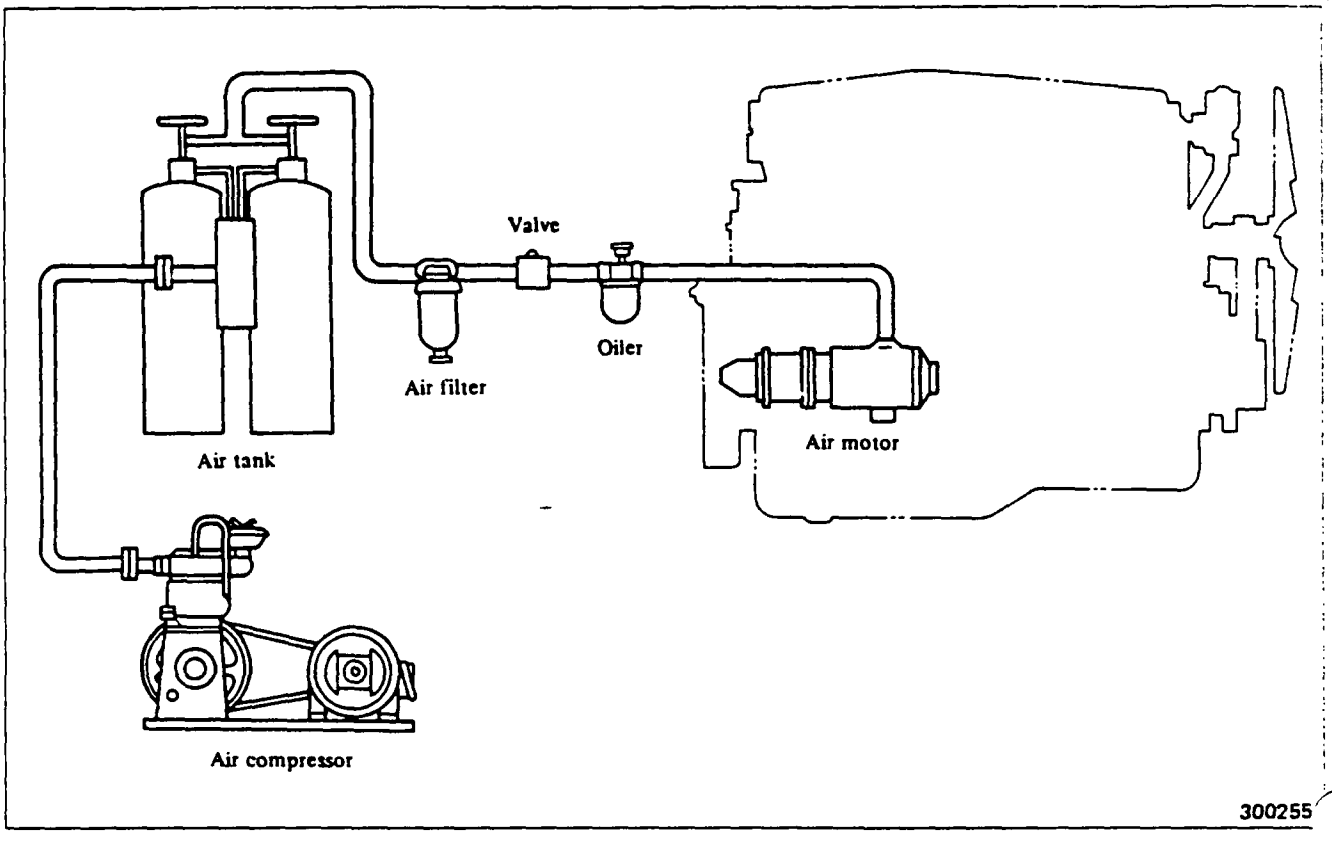


(3) Tightening pulley nut

Tighten the pulley nut to 13.5 to 16.5 kgf·m (98 to 119 lbf·ft) [132 to 162 N·m].

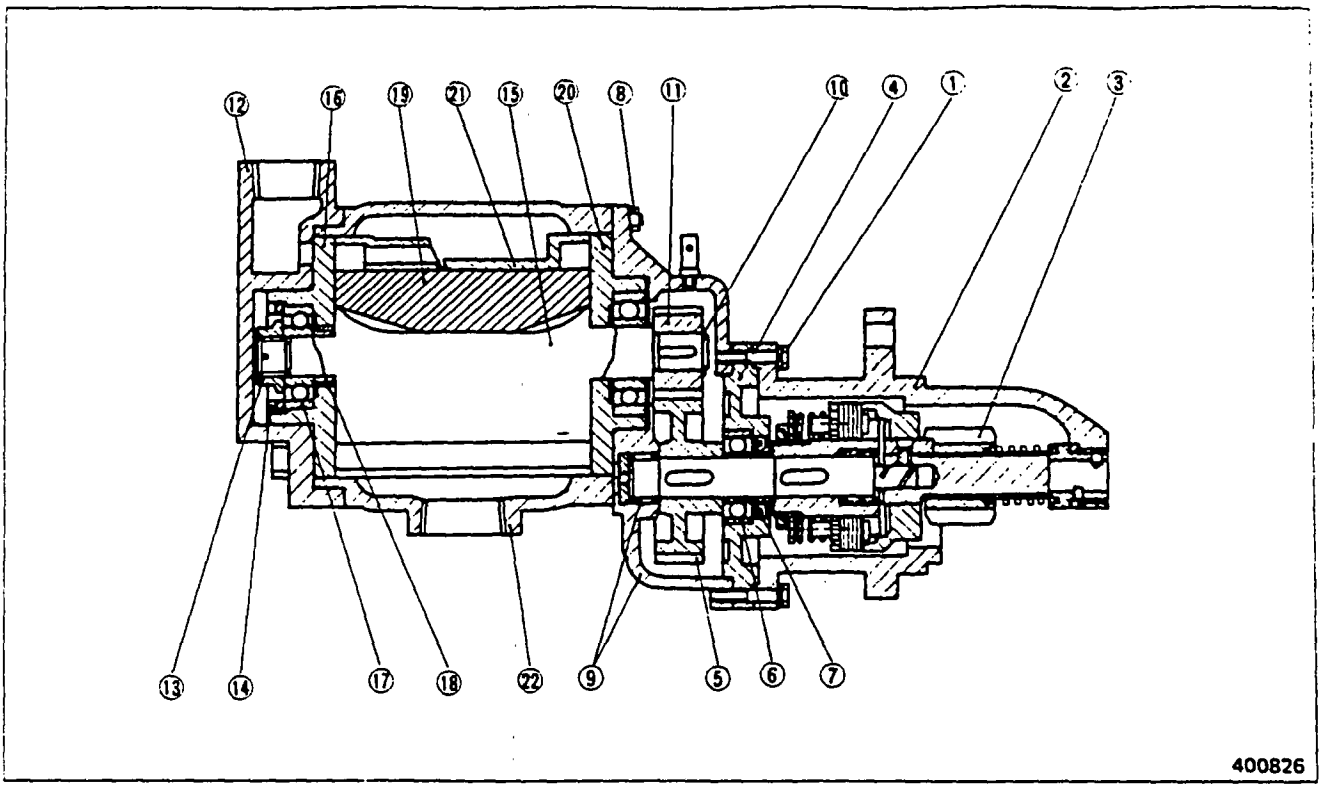
AIR START SYSTEM

1. DESCRIPTION



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

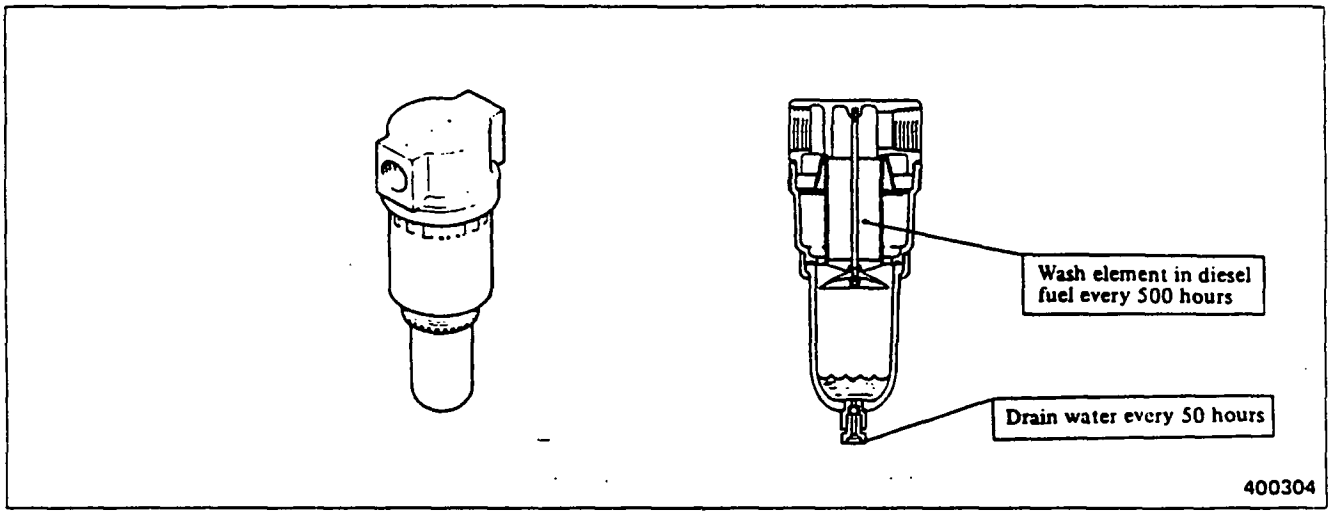
Wash and inspect the air motor parts for wear or damage. Replace the defective parts if any. The clutch assembly and pinion assembly should be replaced as an assembly.

Reassembling sequence

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

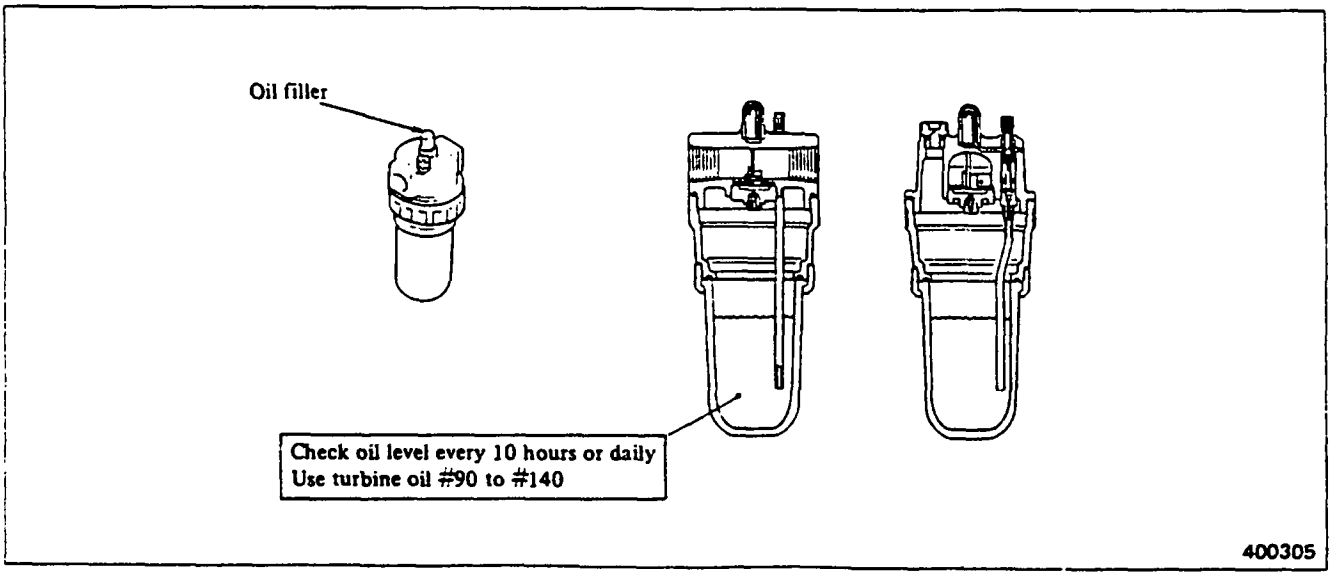
3. AIR FILTER

Inspection



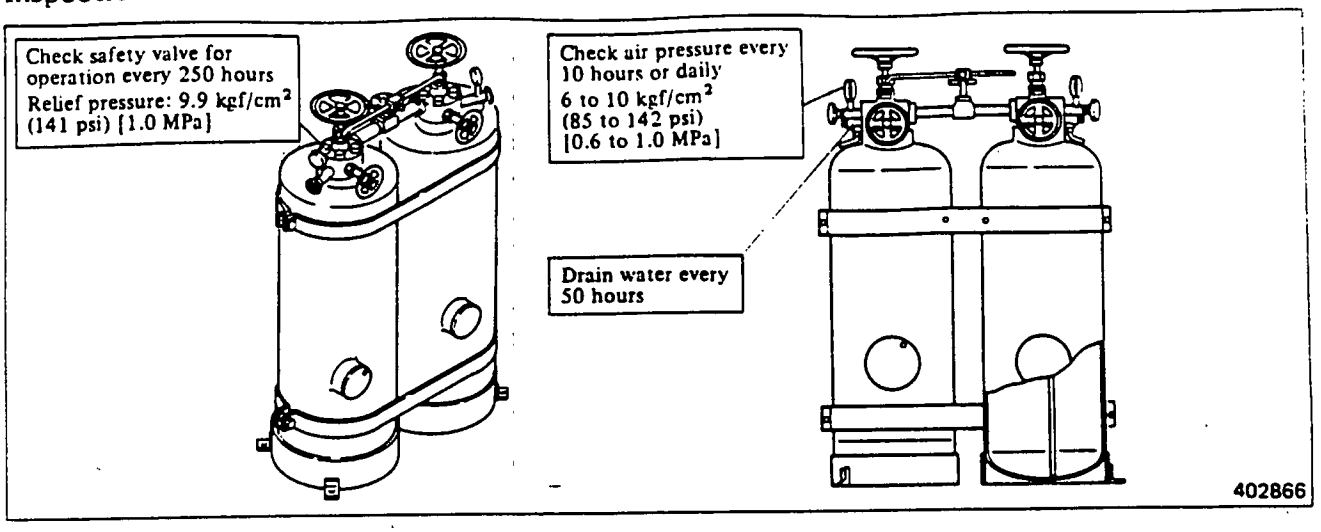
4. OILER

Inspection



5. AIR TANK

Inspection



WORKSHOP THEORY

1. PRECAUTIONS FOR DISASSEMBLY AND REASSEMBLY

1.1 Oil seals

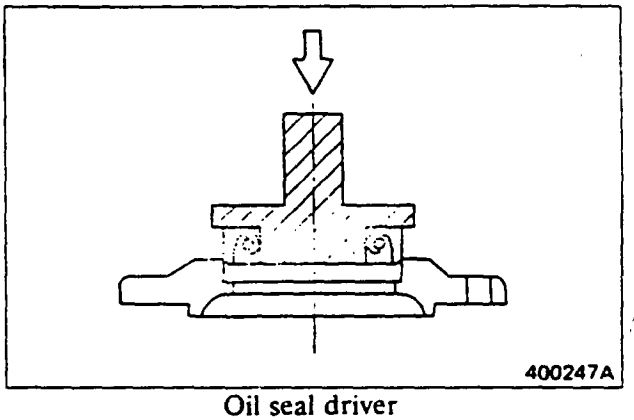
When installing oil seals, carefully observe the following points:

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.

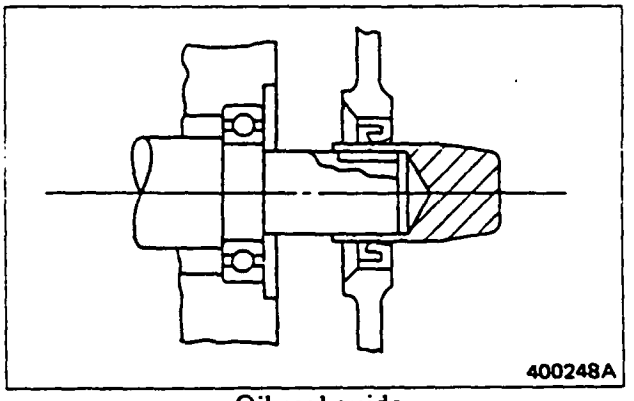


Oil seal driver

Driving oil seals onto shafts

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

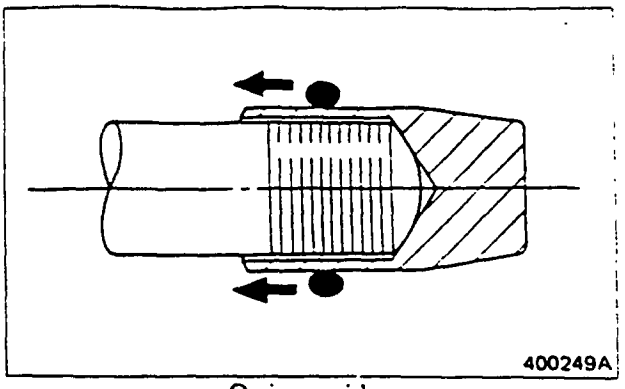
(b) Use an oil seal guide of the type shown when driving oil seal over stepped portion, splines, threads or keyway to prevent damage to seal lip.



Oil seal guide

1.2 O-rings

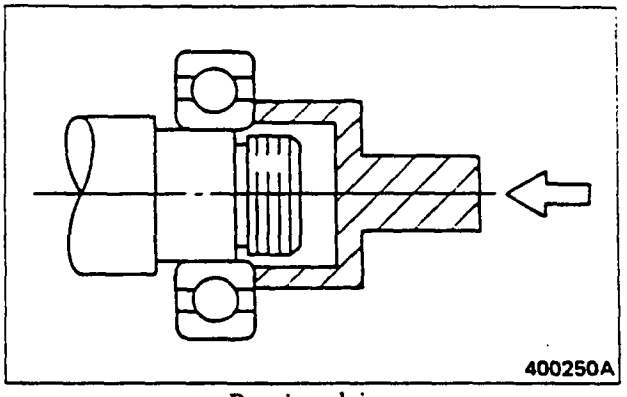
Use an O-ring guide of the type shown when installing O-ring over stepped portion, splines, threads or keyway to prevent damage to the ring. Apply a thin coat of grease to O-ring.



O-ring guide

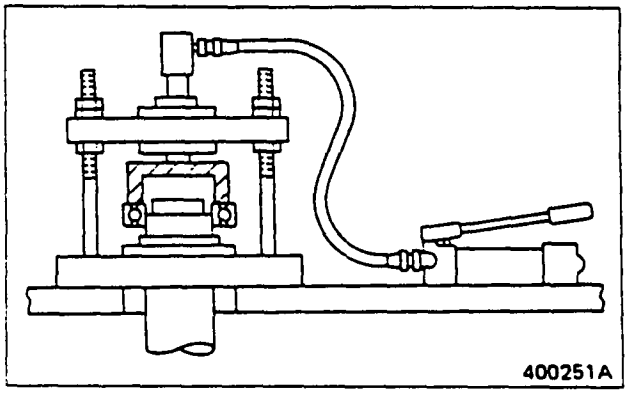
1.3 Bearings

(1) 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

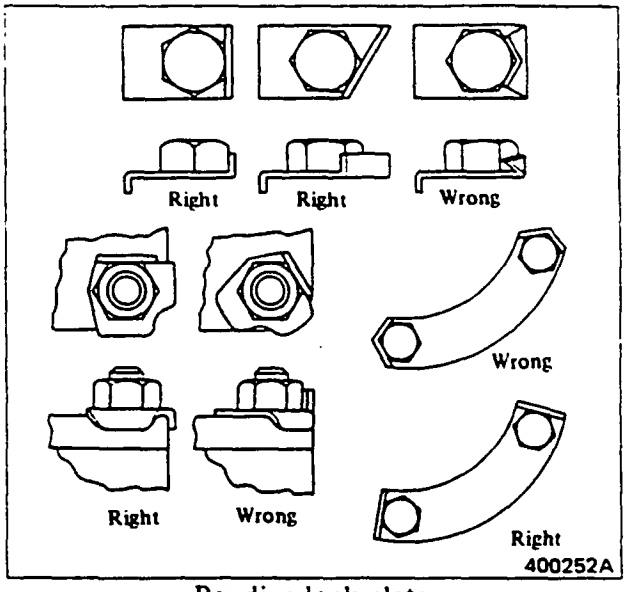
(2) Use a press whenever possible to minimize shock to bearing and to assure proper installation.



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 and bent properly 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.

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