Engine No. 10001–UP

SERVICE MANUAL

MITSUBISHI DIESEL ENGINE

S16R

1635/1825/2000kW

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 produlsion 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 disassembly 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→④→③→②→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:

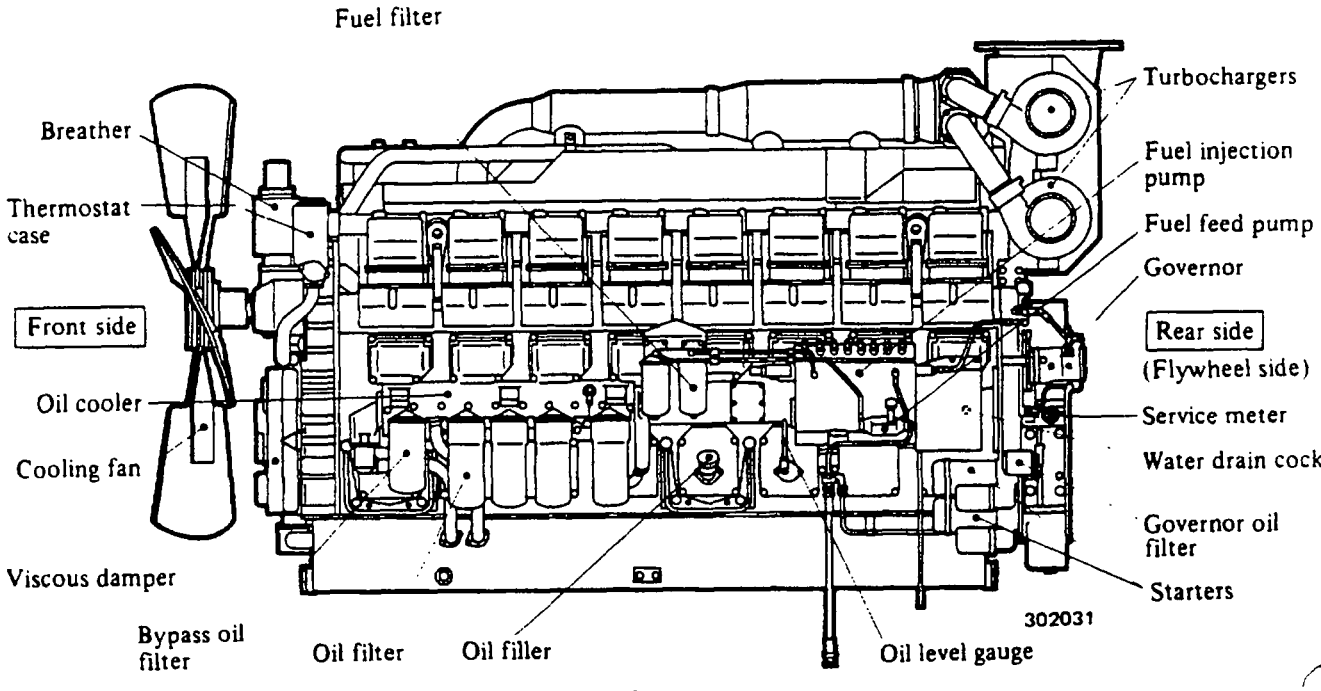
NOMINAL VALUE	Indicates the standard dimension of a part.
ASSEMBLY STANDARD	Indicates the dimension of a part, the dimension to be attained at the time of reassembly or the standard performance. Its value is rounded to the nearest whole number needed for inspection and is different from the design value.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

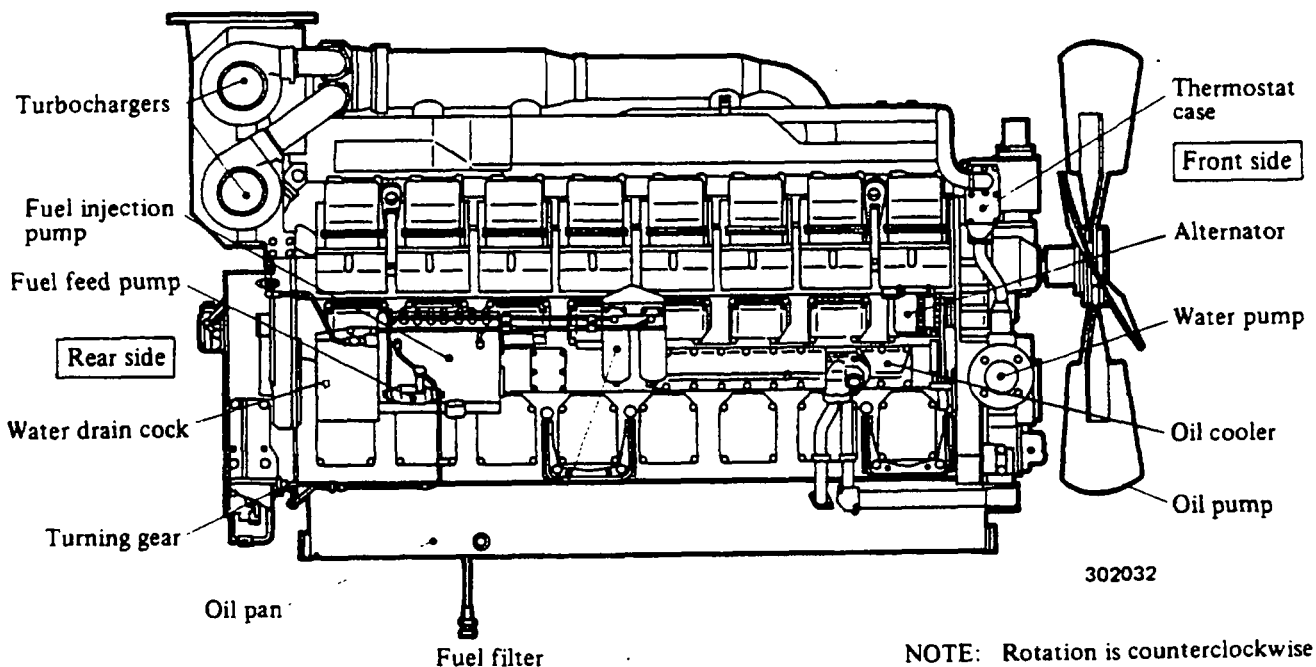
GENERAL

1. GENERAL

1.1 Nomenclature



Left side



NOTE: Rotation is counterclockwise as seen from rear side.

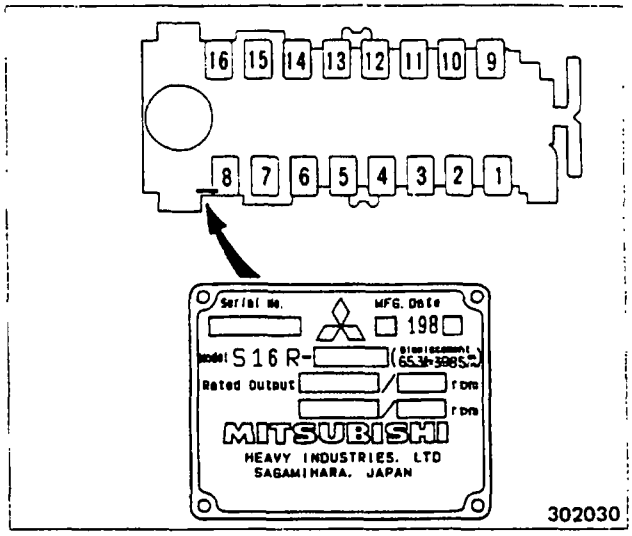
Right side

1.2 Engine serial number location

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

Example:	Model	Serial number
	S16R	10012

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:

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

Series code

No.-of-cylinders code

Sagamihara Machinery Works

2. SPECIFICATIONS

Model designation				S16R		
				T	TA	TK
General	Type			Water-cooled, 4-stroke cycle diesel, turbocharged		
				–	Aftercooled	Intercooled
	No. of cylinders – arrangement			16 – V		
	Combustion chamber type			Direct injection		
	Valve mechanism			Overhead		
	Cylinder bore x stroke, mm (in.)			170 x 180 (6.70 x 7.10)		
	Piston displacement, liter (cu in.)			65.3 (3985)		
	Compression ratio			14.0 : 1		
	Fuel			Diesel fuel oils specified by ASTM		
	Firing order (injection sequence)			1-9-6-14-2-10-4-12-8-16-3-11-7-15-5-13		
	Direction of rotation			Counterclockwise as from flywheel side		
	Dimensions, mm (in.)	Overall length		2875 (113.2)		
		Overall width		1360 (53.5)		
		Overall height		1810 (71.3)		
	Weight (dry), kg (lb)			6100 (13450)	6200 (13670)	
Engine proper	Cylinder liners			Wet type		
	No. of piston rings	Compression rings		2		
		Oil ring		1 (w/spring expander)		
	Valve timing	Inlet valves	Open	37° B.T.D.C.		
			Close	44° A.B.D.C.		
		Exhaust valves	Open	57° B.B.D.C.		
			Close	24° A.T.D.C.		
	Engine support			6-point support		
	Starting system			Electric starters, air-motor or air starting		
Inlet and exhaust systems	Air cleaner	Type		Paper element type or precleaner type		
	Turbo-chargers	Type – No. of units		TD13 or TD10 – 4		
	Air cooler			–	Laminated-fin plate type	
Lubrication system	Type			Forced lubrication by gear pump		
	Engine oil	Specification		Class CD oil (API Service Classification)		
		Capacity (engine), liter (U.S. gal)		230 (61), approx.		
	Oil pump	Type		Gear pump		
		Delivery capacity, liter (U.S. gal)/min		580 (153) (at 1800 engine rpm)		

Model designation			S16R		
			T	TA	TK
Lubrication system	Relief valve	Type	Piston valve type		
		Valve opening pressure, kgf/cm²(psi)[MPa]	4.7 (66.8) [0.5]		
	Oil cooler	Type	Water-cooled multi-plate type (built in crankcase)		
	Full-flow filter	Type	Paper element (spin-on type)		
	Bypass filter	Type	Paper element (spin-on type)		
	Oil filter alarm	Type	Piston valve with built-in electric contact points		
		Valve opening pressure (differential pressure), kgf/cm²(psi)[MPa]	2.3 to 2.7 (32.7 to 38.4) [0.2 to 0.3] (Contact points close at 1.5 to 1.8 (21.3 to 25.6) [0.1 to 0.2])		
	Oil thermostat	Type	Wax		
		Valve opening temperature, °C (°F)	91 to 95 (195.8 to 203.0)		
Cooling system	Type		Forced circulation		
	Capacity (engine), liter (U.S. gal)		170 (45), approx.		
	Water pump	Type	Centrifugal		
		Delivery capacity, liter (U.S. gal)	1850 (488) (at 1800 engine rpm)		
	Thermostat	Type	Wax		
		Valve opening temperature, °C (°F)	69 to 73 (156.2 to 163.4)		
	Radiator	Type	Plate fin or corrugated fin		
	Cooling fan	Type	With aluminum blades		
		No. of blades	6		
		Outside diameter, mm (in.)	1530 (60.3)		
Fuel system	Injection pumps	Model – manufacturer	PS8 – Mitsubishi Heavy Industries		
		Plunger outside diameter, mm (in.)	17 (0.67)		
		Plunger lead, mm (in.)	Left-hand 35 (1.38)		
		Cam lift, mm (in.)	15 (0.59)		
	Feed pumps	Model	Bosch KD22Z		
		Manufacturer	Diesel Kiki		
		Cam lift, mm (in.)	12 (0.47)		
	Governor	Type	<Hydraulic> Woodward PSG	<Electrical> Woodward EG-3P or EG-B2P Barber-Colman DYNA – 1	

Model designation			S16R		
			T	TA	TK
Fuel system	Injection nozzles	Type	Hole type		
		Manufacturer	Diesel Kiki		
		No. of spray orifice	10		
		Spray orifice inside diameter, mm (in.)	0.34 (0.0134)		
		Spray angle	160°		
		Injection pressure, kgf/cm²(psi) [MPa]	$350\,^{+5}_{0}$ ($4977\,^{+71}_{0}$) [$34.3\,^{+0.5}_{0}$]		
	Fuel filter		Paper element (spin-on type)		
Electrical system	Voltage-polarity		24-V – Negative (-) ground		
	Starter	Model	8-23000-1840		
		Manufacturer	Nikko Electric		
		Type	Pinion shaft (reduction)		
		Output, V – kW	24 – 7.5		
		No. of starters	2		
		No. of pinion teeth/No. of ring gear teeth	15/193		
	Alternator	Type	3-phase with built-in IC regulater		
		Manufacturer	Mitsubishi Electric		
		Output, V – A	24 – 30		
		Rated output generating speed, rpm	5000 (at 27V, 30A)		
		Regulated voltage, V	28.5 ± 0.5		
	Safety relay (for starter chattering)	Model	0-25000-7440		
		Manufacturer	Nikko Electric		
		Operating voltage range, V	24		
		Rating, second	30		
		Operating voltage, V	8 – 24		
		Operating interval (at 24V), second	SS-SW circuit ON-OFF cycle: 2.5 to 3.0		
		Permissible operating temperature range, °C (°F)	-20 to +50 (-4 to +122)		
		Ground	2-wire type		
	Alternator drive belt	Type	Low-edge cog C		
		Outer circumference, mm (in.)	1000 (39.4)		

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. SEALANTS AND LUBRICANTS, Group 2.)

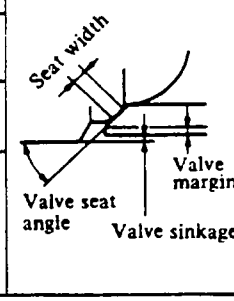
(4) Be sure to use a torque wrench to tighten parts for which tightening torque is specified. (Refer to 2. TIGHTENING TORQUES, Group 2.)

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

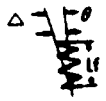
MAINTENANCE STANDARDS

1. MAINTENANCE STANDARDS

Unit: mm (in.)

Group	Item		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
General	Maximum rpm		5 to 10% higher than rated rpm		Lower or 15% higher than rated rpm		Check governor setting.
	Minimum rpm		600 to 650 rpm				
	Compression pressure, kgf/cm² (psi) [MPa]		18.5 (263) [1.8] at 120 rpm, minimum		13 (185) [1.3], minimum		Oil and water temp. 20 to 30°C (68 to 86°F)
	Lube oil pressure, kgf/cm² (psi) [MPa]		5 to 6.5 (71 to 92.4) [0.5 to 0.64] (at rated rpm)		5 (71) [0.5], 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-mm (0.08-in.) clearance on valve side, cold]		Inlet valve opens 2.5° B.T.D.C. Inlet valve closes 13° A.B.D.C. Exhaust valve opens 26° B.B.D.C. Exhaust valve closes 10.5° 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		0.6 (0.024)			
		Exhaust valves		0.8 (0.031)			
	Injection timing		B.T.D.C.	±1° (crank angle)			Varies according to specifications. Refer to caution plate on No. 1 rocker cover.
Engine proper	Rockers	Rocker bushing inside diameter	36 (1.42)	36.000 to 36.040 (1.41732 to 1.41889)		36.090 (1.42086)	
		Rocker shaft diameter	36 (1.42)	35.966 to 35.991 (1.41598 to 1.41697)		35.940 (1.41496)	
	Valves	Valve stem diameter	10 (0.39)	9.940 to 9.960 (0.39134 to 0.39213)		9.910 (0.39016)	The same for both inlet and exhaust valves.
		Valve guide inside diameter	10 (0.39)	10.000 to 10.015 (0.39370 to 0.39429)		10.060 (0.39606)	
	Valve seats and valves	Valve seat angle	30°				
		Valve sinkage	0	-0.2 to 0.2 (-0.0079 to 0.0079)	1.0 (0.039)		
		Seat width	2.3 (0.091)	2.15 to 2.45 (0.0846 to 0.0965)	2.8 (0.110)		
		Valve margin	3.0 (0.12)	2.8 to 3.2 (0.110 to 0.126)	Refacing is permissible up to 2.5 (0.098).		

Unit: mm (in.)

Group	Item		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Valve seats and valves	Cylinder head bore inside diameter and valve seat outside diameter	60 (2.36)	(-0.070 to -0.130) ((-0.00276 to -0.00512))			Minus (-) indicates interference.
	Valve springs	Free length		73 (2.87)		71 (2.80)	
		Squareness		$\phi\theta$ = 1.5°, maximum 		Δ = 2.2 (0.087) over the length	
		Length under test force/Test force, mm (in.)/ kgf (lbf) [N]		66.0 (2.60)/ 29.45 to 32.55 (64.9 to 71.8) [289 to 319]			
	Valve push-rods	Runout		0.5 (0.020), maximum		0.5 (0.020)	
	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	170 (6.69)	170.000 to 170.040 (6.69290 to 6.69447)	170.400 (6.70865)	171.500 (6.75196)	
		Out-of-roundness		0.02 (0.0008), maximum			
		Taper		0.02 (0.0008), maximum			
		Squareness with respect to lower face of flange		0.03 (0.0012), maximum			
		Projection of cylinder liner flange above gasketed surface		0.09 to 0.18 (0.0035 to 0.0071)			
	Pistons	Diameter	170 (6.69)	169.76 to 169.80 (6.6835 to 6.6850)		169.66 (6.6795)	Measure diameter in direction transverse to piston pin and at skirt.
		Max. permissible difference between average weight of all pistons in one engine		40 g (1.4 oz), maximum			
		Piston pin bore diameter	70 (2.76)	70.002 to 70.015 (2.75598 to 2.75649)		70.020 (2.75669)	
		Protrusion		0.06 to 0.65 (0.0024 to 0.0256)			

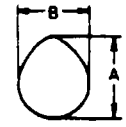
Unit: mm (in.)

Group	Item			Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Cylinder head gasket	As-installed thickness		1.8 (0.07)	1.77 to 1.83 (0.070 to 0.072)			
	Pistons and cylinder heads	Clearance between piston top and cylinder head			(1.22 to 1.95) ((0.0480 to 0.0768))			
	Piston rings	Gaps	Top		(0.6 to 0.8) ((0.024 to 0.031))		(2.0) ((0.079))	If gauge is not available, check gaps by placing rings in a new cylinder liner.
			Second		(0.6 to 0.8) ((0.024 to 0.031))		(2.0) ((0.079))	
			Oil		(0.3 to 0.45) ((0.012 to 0.018))		(2.0) ((0.079))	
	Piston pins	Diameter		70 (2.76)	69.987 to 70.000 (2.75539 to 2.75590)		69.970 (2.75472)	
	Connecting rods	Small end bushing inside diameter		70 (2.76)	70.020 to 70.040 (2.75669 to 2.75747)		70.070 (2.75866)	
		Bend and twist			0.05/100 (0.0020/3.9), maximum			
		End play (crankpin and big end widths)		60 (2.36) x 2	(0.4 to 0.9) ((0.016 to 0.035))		(1.4) ((0.055))	
		Max. permissible difference between average weight of all rods in one engine			40 g (1.4 oz), maximum			
		Big-end bore diameter		131 (5.16)	131.000 to 131.025 (5.15747 to 5.15845)		131.050 (5.15944)	To be used in combination with bearing caps.
	Connecting rods bearings	Thickness of central part	STD	3.000 (0.11811)	2.957 to 2.970 (0.11642 to 0.11693)		2.915 (0.11476)	Replace bearings if worn down to service limit. Regrind crankpins and use undersize bearings if worn beyond service limit.
			-0.25 (-0.0098)	3.125 (0.12303)	3.082 to 3.095 (0.12134 to 0.12185)		3.040 (0.11968)	
			-0.50 (-0.0197)	3.250 (0.12795)	3.207 to 3.220 (0.12626 to 0.12677)		3.165 (0.12461)	
			-0.75 (-0.0295)	3.375 (0.13287)	3.332 to 3.345 (0.13118 to 0.13169)		3.290 (0.12953)	
			-1.00 (-0.0394)	3.500 (0.13780)	3.457 to 3.470 (0.13610 to 0.13661)		3.415 (0.13445)	
	Flywheel	Axial runout			0.336 (0.013), maximum			
		Radial runout			0.13 (0.005), maximum			

Unit: mm (in.)

Group	Item		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Fuel injection pump drive	Inside diameter of bearing bore in case	90 (3.54)	89.987 to 90.022 (3.54279 to 3.54417)			
			100 (3.94)	99.987 to 100.022 (3.93649 to 3.93787)			
		Bearings — Outside diameter	90 (3.54)	89.980 to 90.005 (3.54251 to 3.54350)			
			100 (3.94)	99.980 to 100.005 (3.93621 to 3.93720)			
		Bearings — Inside diameter	45 (1.77)	44.985 to 45.003 (1.77106 to 1.77177)			
			50 (1.97)	49.985 to 50.003 (1.96791 to 1.96862)			
		Diameter of drive shaft bearing journals	45 (1.77)	45.002 to 45.013 (1.77173 to 1.77216)			
			50 (1.97)	50.002 to 50.013 (1.96858 to 1.96901)			
	Oil pump drive	Inside diameter of bearing bore in cover	110 (4.33)	110.000 to 110.035 (4.33070 to 4.33208)			
		Inside diameter of bearing bore in plate	110 (4.33)	109.987 to 110.022 (4.33019 to 4.33157)			
		Bearings — Outside diameter	110 (4.33)	109.980 to 110.005 (4.32991 to 4.33090)			
		Bearings — Inside diameter	50 (1.97)	49.985 to 50.003 (1.96791 to 1.96862)			
		Diameter of gear shaft bearing journals	50 (1.97)	49.993 to 50.013 (1.96822 to 1.96901)			
	Viscous dampers	Radial runout (at periphery)		0.5 (0.020), maximum		1.5 (0.059)	Replace after 8000 hours of operation.
		Axial runout		0.5 (0.020), maximum		1.5 (0.059)	
	Timing gears	Backlash		(0.12 to 0.18) ((0.0047 to 0.0071))	(0.30) ((0.0118))	(0.50) ((0.0197))	Replace gears.
		Inside diameter of idler gear bushing	50 (1.97)	50.000 to 50.025 (1.96850 to 1.96948)		50.060 (1.97086)	
		Diameter of idler gear shaft	50 (1.97)	49.950 to 49.975 (1.96653 to 1.96752)		49.900 (1.96456)	
		Cam idler gear end play		(0.1 to 0.5) ((0.0039 to 0.020))		(0.8) ((0.031))	
		Front idler gear end play		(0.2 to 0.4) ((0.008 to 0.016))		(0.6) ((0.024))	
		Fan drive idler gear end play		(0.25 to 0.75) ((0.0098 to 0.0295))		(1.2) ((0.047))	

Unit: mm (in.)

Group	Item		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Camshaft	Lobe lift (A – B)	9.247 (0.36405)	9.197 to 9.297 (0.36209 to 0.36602)		8.45 (0.3327)	
		Runout		0.05 (0.002), maximum	0.08 (0.0031)		Runout at center bushing measured with both ends supported. Repair or replace.
		Diameter of journals	84 (3.31)	83.92 to 83.94 (3.3039 to 3.3047)		83.87 (3.3020)	
		Inside diameter of bushings (as-installed)	84 (3.31)	84.000 to 84.035 (3.3071 to 3.3085)		84.10 (3.3110)	Replace bushings if worn beyond service limit. Ream as necessary.
		End play	8 (0.3)	(0.10 to 0.25) ((0.0039 to 0.0098))		(0.40) ((0.0157))	Replace thrust plate.
	Crankshaft	Diameter of crankpins	125 (4.92)	-0.050 to -0.070 (-0.00197 to -0.00276)	-0.110 (-0.00433)		
		Diameter of journals	170 (6.69)	-0.060 to -0.080 (-0.00236 to -0.00315)	-0.120 (-0.00472)		
		Center-to-center distance between journal and crankpin	90 (3.54)	±0.1 (±0.004)			
		Parallelism between journals and crankpins		Runout: 0.01 (0.0004), maximum (over crankpin length)	0.03 (0.0012)		
		Out-of-roundness of journals and crankpins		0.01 (0.0004), maximum	0.03 (0.0012)		
		Taper of journals and crankpins		0.02 (0.0008), maximum	0.03 (0.0012)		
		Fillet radius of crankpins	7 (0.28)	$7.0\ ^{0}_{-0.2}$ $(0.276\ ^{0}_{-0.008})$			
		Fillet radius of journals	8.5 (0.335)	$8.5\ ^{0}_{-0.2}$ $(0.335\ ^{0}_{-0.008})$			
		Hardness of journals and crankpins		Hv > 590			

Unit: mm (in.)

Group	Item			Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Engine proper	Crankshaft	Angular error of crankpins			±0°20′			
		Runout			0.04 (0.0016), maximum	0.10 (0.0039)		Repair or replace.
		End play (thrust journal length)		67 (2.64)	(0.20 to 0.40) ((0.0079 to 0.0157))		(0.50) ((0.0197)) +1.18 (+0.0465)	Replace thrust plate if worn down to repair limit. Use oversize thrust plate if worn beyond repair limit. Oversize thrust plates: +0.25 (+0.0098), +0.50 (+0.0197), +0.75 (+0.0295)
	Main bearings	Thickness of central part	STD	4.5 (0.177)	4.467 to 4.480 (0.17587 to 0.17638)		4.425 (0.17421)	Replace bearings if worn down to service limit. Regrind journals and use undersize bearings if bearings are worn beyond service limit.
			−0.25 (−0.0098)	4.625 (0.18209)	4.592 to 4.605 (0.18079 to 0.18130)		4.550 (0.17913)	
			−0.50 (−0.0197)	4.750 (0.18701)	4.717 to 4.730 (0.18571 to 0.18622)		4.675 (0.18405)	
			−0.75 (−0.0295)	4.875 (0.19193)	4.842 to 4.855 (0.19063 to 0.19114)		4.800 (0.18898)	
			−1.00 (−0.0394)	5.000 (0.19685)	4.967 to 4.980 (0.19555 to 0.19606)		4.925 (0.19400)	
	Crankcase	Warpage of gasket contact surface			0.1 (0.004), maximum	0.2 (0.008)		Regrind slightly.
		Diameter of main bearing bore		179 (7.05)	179.000 to 179.025 (7.04723 to 7.04821)		179.045 (7.04900)	
Lubrication system	Oil pump	Pump gear backlash			(0.10 to 0.20) ((0.0039 to 0.0079))		(0.4) ((0.016))	
		Clearance between gears and case		60 (2.36)	(0.200 to 0.296) ((0.00787 to 0.01165))		(0.35) ((0.0138))	
		Clearance between gears and cover		72.5 (2.854)	(0.040 to 0.116) ((0.00157 to 0.00457))		(0.21) ((0.0083))	Remove 0.04 (0.0016) packing when measuring clearance.
		Diameter of drive shaft			29.887 to 29.900 (1.17665 to 1.17716)		29.840 (1.17480)	
		Diameter of driven shaft		30 (1.18)	29.947 to 29.960 (1.17901 to 1.17953)		29.900 (1.17716)	
		Inside diameter of bushings			30.000 to 30.021 (1.18110 to 1.18193)		30.055 (1.18327)	

Unit: mm (in.)

Group	Item		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Lubrication system	Safety valve	Opening pressure, kgf/cm² (psi) [MPa]		12 (171) [1.2]			
		Spring – Length under test force/ test force, mm (in.)/kgf(lbf)[N]		66.4 (2.61)/ 34.8 (77) [341]		66.4 (2.61)/ 30.0 (66) [294]	
	Relief valve	Opening pressure, kgf/cm² (psi) [MPa]		4.7 (67) [0.5]			
	Oil thermostat	Temperature at which valve starts opening		93 ± 2°C (199.4 ± 3.6°F)			
		Temperature at which valve lift is more than 11 (0.43)		105°C (221°F)			
	Bypass alarm	Valve opening pressure (differential pressure), kgf/cm² (psi) [MPa]		2.5 ± 0.2 (36 ± 2.8) [0.2 ± 0.02]			Contact points should close at 1.5 to 1.8 (21 to 26) [0.1 to 0.2]. 1 (0.04) shim changes 0.07 (1) [0.007].
	Piston nozzles	Opening pressure, kgf/cm² (psi) [MPa]		2.7 to 3.3 (38 to 47) [0.26 to 0.32]			
Cooling system	Water pump	Inside diameter of bearing bore in case (bearing cover)	120 (4.72)	119.987 to 120.022 (4.72389 to 4.72527)			
			110 (4.33)	110.005 to 110.040 (4.33090 to 4.33227)			
		Bearings – Outside diameter	120 (4.72)	119.980 to 120.005 (4.72361 to 4.72460)			
			110 (4.33)	109.980 to 110.005 (4.32991 to 4.33090)			
		Bearings – Inside diameter	55 (2.17)	54.981 to 55.004 (2.16460 to 2.16551)			
		Diameter of shaft bearing journals	55 (2.17)	55.002 to 55.015 (2.16543 to 2.16594)			
		Vane front face clearance in pump case	1.3 (0.051)	(0.8 to 1.75) ((0.031 to 0.0689))			

Unit: mm (in.)

Group	Item			Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Cooling system	Thermostat	Temperature at which valve starts opening			71 ± 2°C (159.8 ± 3.6°F)			Check at atmospheric pressure.
		Temperature at which valve lift is more than 11 (0.43), minimum			85°C (185°F)			
	Fan drive	Inside diameter of bearing bore in case		140 (5.51)	139.986 to 140.026 (5.51125 to 5.51282)			
				120 (4.72)	119.987 to 120.022 (4.72389 to 4.72527)			
		Bearings	Outside diameter	140 (5.51)	139.976 to 140.006 (5.51086 to 5.51204)			
				120 (4.72)	119.980 to 120.005 (4.72361 to 4.72460)			
			Inside diameter	55 (2.17)	54.981 to 55.004 (2.16460 to 2.16551)			
		Diameter of shaft bearing journals		55 (2.17)	55.002 to 55.015 (2.16543 to 2.16594)			
Fuel system	Fuel injection nozzles	Valve opening pressure, kgf/cm² (psi) [MPa]		350 (4977) [34.3]	350 to 355 (4977 to 5048) [34.3 to 34.8]			
		Spray angle		160°				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.
	Governor drive	Inside diameter of drive shaft bearing bore in case		52 (2.05)	51.988 to 52.018 (2.04677 to 2.04795)			
		Drive shaft bearings	Outside diameter	52 (2.05)	51.983 to 52.004 (2.04657 to 2.04740)			
			Inside diameter	25 (0.98)	24.987 to 25.003 (0.98374 to 0.98437)			

Unit: mm (in.)

Group	Item		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Fuel system	Governor drive	Diameter of drive shaft bearing journal	25 (0.98)	25.002 to 25.011 (0.98433 to 0.98468)			
		Inside diameter of idler shaft bearing bore in case	47 (1.85)	46.989 to 47.014 (1.84996 to 1.85094)			
		Idler shaft bearings: Outside diameter	47 (1.85)	46.986 to 47.003 (1.84984 to 1.85051)			
		Idler shaft bearings: Inside diameter	20 (0.79)	19.987 to 20.003 (0.78689 to 0.78752)			
		Diameter of idler shaft bearing journal	20 (0.79)	20.002 to 20.011 (0.78748 to 0.78783)			
		Diameter of drive gear shaft	26 (1.02)	26.035 to 26.048 (1.02500 to 1.02551)			
		Inside diameter of drive gear	26 (1.02)	26.000 to 26.013 (1.02362 to 1.02413)			
		Diameter of drive gear shaft (EG-B2P)	29 (1.14)	28.959 to 28.980 (1.14012 to 1.14094)			
		Inside diameter of drive gear (EG-B2P)	29 (1.14)	29.00 to 29.04 (1.1417 to 1.1433)			
		Diameter of idler gear shaft	24 (0.94)	24.035 to 24.048 (0.94626 to 0.94677)			
		Inside diameter of idler gear	24 (0.94)	24.000 to 24.013 (0.94488 to 0.94539)			
Electrical system	Starters	Diameter of commutator	43 (1.69)			42 (1.65)	
		Runout of commutator		0.06 (0.0024), maximum		0.10 (0.0039)	
		Mica depth in commutator		0.7 to 0.9 (0.028 to 0.035)		0.2 (0.008)	
		Height of brushes		21 to 22 (0.83 to 0.87)		13 (0.51)	
		Tension of brush springs, kgf (lbf) [N]	4.5 (10) [44]	4.0 to 5.0 (9 to 11) [39 to 49]			Test when installing.

Unit: mm (in.)

Group	Item		Nominal value	Assembly standard (standard clearance)	Repair limit (clearance)	Service limit (clearance)	Remarks
Electrical system	Starters	Armature shaft diameter (rear)	14 (0.55)	13.941 to 13.968 (0.54886 to 0.54992)			
		Armature shaft diameter (front)	25 (0.98)	25.002 to 25.011 (0.98433 to 0.98468)			
		Pinion shaft diameter (rear)	30 (1.18)	30.002 to 30.011 (1.18118 to 1.18153)			
		Pinion shaft diameter (front)	19 (0.75)	18.90 to 18.94 (0.7441 to 0.7457)			
		Front bearing	19 (0.75)	19.00 to 19.033 (0.7480 to 0.7493)		0.25 (0.0098)	Clearance between shaft and bearing.
		Pinion					
		Rear bearing	14 (0.55)	14.00 to 14.027 (0.5512 to 0.5522)			
		End play of armature		0.3 to 0.7 (0.012 to 0.028)			
		End play of pinion shaft		0.2 to 0.8 (0.008 to 0.031)			
	Alternator	Diameter of spring	41 (1.61)	40.8 to 41.02 (1.606 to 1.6150)		40.6 (1.598)	
		Height of brushes	23 (0.91)			8 (0.31)	Up to wear limit line.
		Tension of brush springs, gf (ozf) [N]	380 (13) [3.7]	380 ± 60 (13 ± 2) [3.7 ± 0.6]		200 (7) [2.0]	
	Tension of alternator drive belt			10 to 15 (0.4 to 0.6)			Measure deflection by pushing belt midway between pulleys. 
Air start system	Distributor valve	Valve height		21.5 ± 0.1 (0.846 ± 0.004)	20 (0.79)		
		Shaft clearance in bushing		(0.050 to 0.091) ((0.00197 to 0.00358))	(0.300) ((0.01181))		
	Starter valves	Valve clearance in valve guide	15 (0.59)	(0.016 to 0.052) ((0.00063 to 0.00205))	(0.100) ((0.00394))		
		Valve spring free length		36 (1.4)		34 (1.3)	

2. TIGHTENING TORQUES

2.1 Major bolts and nuts

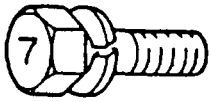
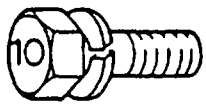
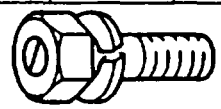
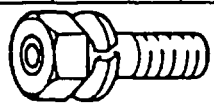
Description	Thread Dia x Pitch (M-thread)	Width across flats, mm (in.)	Torque			Remarks
			kgf·m	lbf·ft	N·m	
Cylinder heads	22 x 2.5	27 (1.06)	55	398	539	[Wet]
Rocker cases	12 x 1.25	17 (0.67)	11	80	108	
Rocker shafts	14 x 2	19 (0.75)	15	108	147	
Camshaft gears	12 x 1.25	17 (0.67)	11	80	108	
Camshaft thrust plates	12 x 1.25	17 (0.67)	6	43	59	
Main bearing caps	24 x 3	30 (1.18)	60	434	588	[Wet]
Main bearing cap side bolts	20 x 2.5	27 (1.06)	40	289	392	
Hanger	20 x 1.5	30 (1.18)	40	289	392	
	16 x 1.5	24 (0.94)	22	159	216	
Piston cooling nozzles	12 x 1.75	17 (0.67)	3.5	25	34	
Timing gear case	16 x 1.5	24 (0.94)	22	159	216	
Rear plate	12 x 1.25	17 (0.67)	6	43	59	
	16 x 1.5	24 (0.94)	22	159	216	
Oil pan	12 x 1.25	17 (0.67)	6	43	59	
Mounting brackets	20 x 1.5	30 (1.18)	40	289	392	
Connecting rod bearing caps	22 x 1.5	27 (1.06)	55	398	539	[Wet]
Balance weights	22 x 1.5	32 (1.26)	50	362	490	[Wet]
Flywheel	22 x 1.5	32 (1.26)	60	434	588	[Wet]
Ring gear	10 x 1.25	14 (0.55)	6	43	59	
Viscous damper	22 x 1.5	32 (1.26)	50	362	490	
Timing idler gears	12 x 1.25	17 (0.67)	11	80	108	
Idler shaft thrust collar	16 x 1.5	24 (0.94)	22	159	216	
Front gear case	12 x 1.25	17 (0.67)	6	43	59	
	16 x 1.5	24 (0.94)	22	159	216	

Description	Thread Dia x Pitch (M-thread)	Width across flats, mm (in.)	Torque			Remarks
			kgf·m	lbf·ft	N·m	
Front plate	12 x 1.25	17 (0.67)	6	43	59	
Idler shafts	12 x 1.25	17 (0.67)	11	80	108	
Idler gear thrust plates	10 x 1.25	14 (0.55)	3	22	29	
Oil pump and water pump mount plate	12 x 1.25	17 (0.67)	6	43	59	
Bearing covers	12 x 1.25	17 (0.67)	11	80	108	
Fuel injection pump drive cases	12 x 1.25	17 (0.67)	11	80	108	
Fuel injection pump gears (nuts)	30 x 1.5	46 (1.81)	40	289	392	
Fuel injection pump coupling shafts	14 x 1.5	22 (0.87)	17 to 18	123 to 130	167 to 177	Tighten slit portion.
Oil pump	12 x 1.25	17 (0.67)	11	80	108	
Oil pump cover	10 x 1.25	14 (0.55)	3.4	25	33	
Water pump	12 x 1.25	17 (0.67)	11	80	108	
Water pump shaft pulley (nut)	30 x 1.5	46 (1.81)	40	289	392	For alternator drive
Fan drive case	12 x 1.25	17 (0.67)	11	80	108	
Fan drive gear (nut)	30 x 1.5	46 (1.81)	40	289	392	
Fan drive coupling (nut)	30 x 1.5	46 (1.81)	40	289	392	
Fan drive hub	12 x 1.25	17 (0.67)	11	80	108	
Fan drive idler shaft	12 x 1.25	17 (0.67)	6	43	59	
Fuel injection pump brackets	12 x 1.25	17 (0.67)	11	80	108	
Fuel injection pumps	12 x 1.25	17 (0.67)	11	80	108	
Fuel injection pump laminated plates	12 x 1.25	17 (0.67)	8.5 to 9.5	61 to 69	83 to 93	
Fuel injection pump flywheels (nuts)	24 x 1.25	36 (1.42)	28 to 30	203 to 217	275 to 294	
Plunger assemblies	12 x 1.25	19 (0.75)	8 to 8.5	58 to 61	78 to 83	
Delivery valve holders	30 x 1.5	32 (1.26)	24 to 26	174 to 188	235 to 255	
Fuel injection nozzle glands (nuts)	14 x 1.5	22 (0.87)	10	72	98	
Fuel injection nozzle tips (nuts)	28 x 1.5	27 (1.06)	18 to 20	130 to 145	177 to 196	

Description	Thread Dia x Pitch (M-thread)	Width across flats, mm (in.)	Torque			Remarks
			kgf-m	lbf-ft	N·m	
Fuel injection nozzle adjusting screw nuts	14 x 1.5	22 (0.87)	4 to 5	29 to 36	39 to 49	
Fuel injection nozzle inlet connectors	16 x 1.5	19 (0.75)	6.5 to 7.5	47 to 54	64 to 74	
Governor drive cases	12 x 1.25	17 (0.67)	11	80	108	
Starters	12 x 1.25	17 (0.67)	6	43	59	

Remarks: Coat threads of parts specified to be [Wet].

2.2 Standard bolts and nuts

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

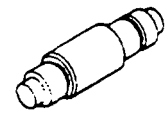
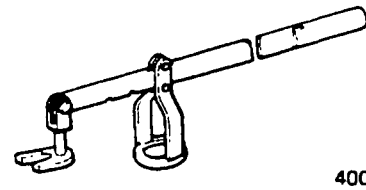
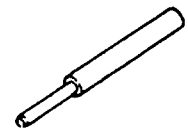
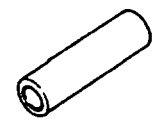
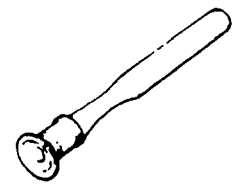
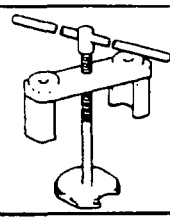
Remarks: (a) Use these torques for bolts and nuts with spring washers.
(b) The tolerance of these torques is ±10%.
(c) Do not coat threads with oil.

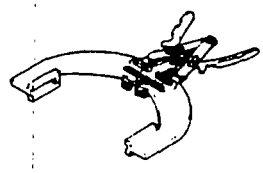
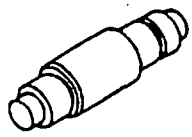
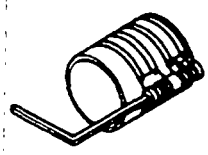
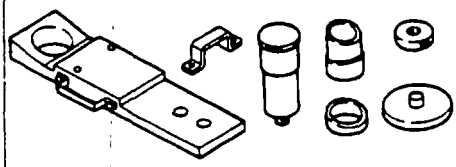
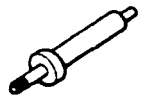
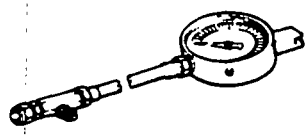
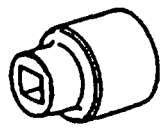
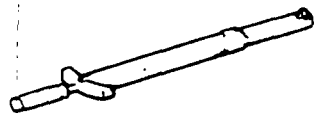
3. SEALANTS AND LUBRICANTS

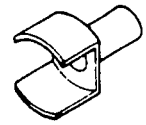
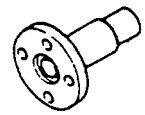
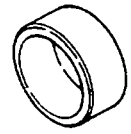
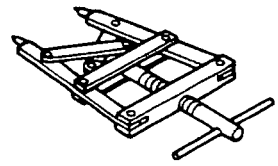
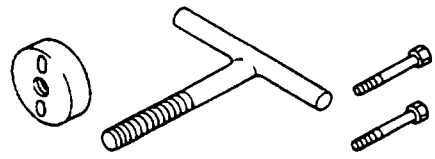
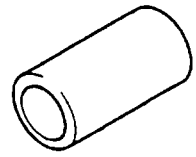
Group	Application point		Sealant or lubricant	How to use
Engine proper	Cylinder head sealing cap		HERMESEAL S-2	Apply to holes in crankcase.
	Water outlet connector (rocker case)		Grease	Apply to O-ring grooves.
	Cylinder liner		Engine oil	Apply to O-ring grooves.
	Front plate, gear case, oil pan and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

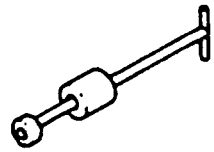
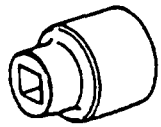
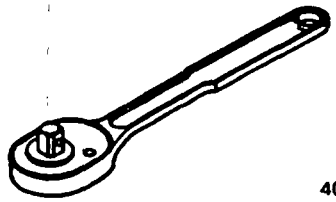
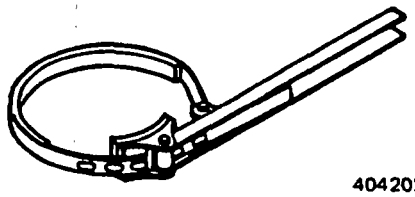
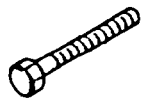
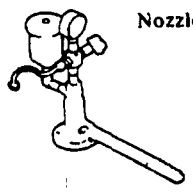
SPECIAL TOOLS

SPECIAL TOOL LIST

Tool name	Part No.	Shape	Use
Rocker bushing tool	37591-02600	 403390	Rocker bushing removal/ installation
Eye nut	37591-02400	 401178	Cylinder head lifting
Valve spring pusher	33591-04500	 400009	Valve spring removal/ installation
Valve guide remover	33591-04300	 400011	Valve guide removal
Valve guide & seal installer	37191-01500	 400012	Valve guide and valve stem seal installation
Valve lapper	30091-08800	 400013	Valve lapping
Ring pliers	45191-08400	 400014	Snap ring removal/ installation
Cylinder liner remover	37591-04100	 400015	Cylinder liner removal

Tool name	Part No.	Shape	Use
Piston ring tool	37191-03200	 400017	Piston ring removal/ installation
Idler bushing puller	32591-02500	 403390	Idler bushing removal/ installation
Piston installer	37191-07100	 400019	Piston installation
Connecting rod bushing installer	37591-01010	 404197	Connecting rod bushing removal/installation
Compression gauge adaptor	37591-02200	 400023	Compression pressure measurement
Compression gauge	33391-02100	 400902	Compression pressure measurement
Socket	58309-73100	 400903	Fan drive shaft gear and coupling, injection pump gear and water pump shaft pulley nut removal/ installation
Torque wrench	32191-03100	 400904	

Tool name	Part No.	Shape	Use
Piston remover	45815-32300	 403210	Piston removal
Slinger installer	37491-02100	 400020	Oil seal slinger installation (rear side of crankshaft)
Installer guide	37491-02200	 400021	Oil seal slinger installation (to be used in combination with slinger installer)
Unit seal installer	37191-06300	 400025	Water pump unit seal installation
Water pump pliers	37591-03100	 404198	For water pump cover snap ring
Impeller remover	37591-03200	 404199	Water pump impeller removal
Ring installer	37791-03300	 404200	Water pump unit seal ring installation
Ring remover	37791-03400	 404608	Water pump unit seal ring removal

Tool name	Part No.	Shape	Use
Nozzle remover	33591-10101	 400007	Injection nozzle removal
Socket	F9614-22000	 400903	For turning
Ratchet handle	37191-03300	 404201	For turning
Oil filter wrench	32591-02100	 404202	Oil filter/fuel filter removal/ installation
Adjustable wrench	F9611-15000	 400905	
Jacking bolt	64362-68500	 M12 × 1.25 – 95mm 404203	
Injection nozzle tester	41091-01500	 Nozzle connection pipe M18 x 1.5 (Tester side) M18 x 1.5 (Nozzle side) 400907	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

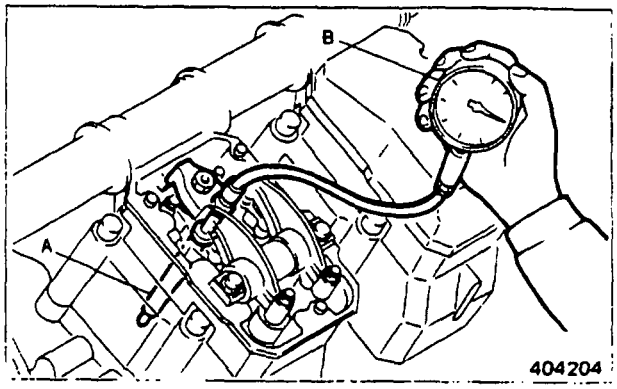
(f) Hard starting

(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 (A) (37591-02200) to the cylinder, and connect compression gauge (B) (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.

⚠ 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	18.5 (263) [1.8], minimum	13 (185) [1.3], maximum

NOTE

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

⚠ CAUTION

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

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

ADJUSTMENTS, BENCH TEST, PERFORMANCE TESTS

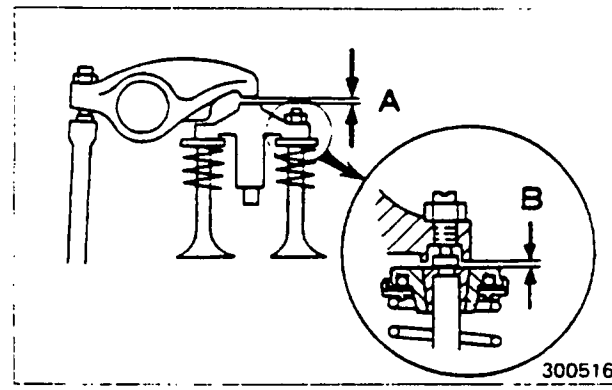
1. ADJUSTMENTS

1.1 Valve clearance

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

Unit: mm (in.)

Item		Assembly standard
Valve clearance (A)	Inlet valves	0.6 (0.024)
	Exhaust valves	0.8 (0.031)

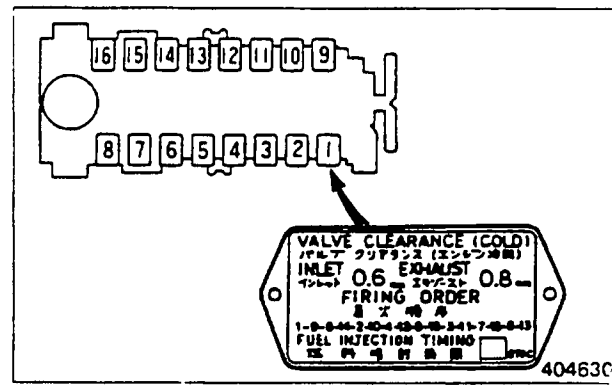


NOTE

(a) Clearance B between the bridge and valve rotator should be more than 1.5 mm (0.059 in.) (assembly standard) after the front and rear valve heights have been adjusted. If the clearance is too small, grind the bridge to obtain the specified clearance.

(b) The inlet valve is on the left side of the cylinder head and the exhaust valve on the right side as seen from aside the engine.

(c) The valve clearance is indicated on the caution plate attached to the No. 1 cylinder rocker cover.



(1) Inspection

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

Firing order (injection sequence)

Cylinder No.	1-9-6-14-2-10-4-12-8-16-3-11-7-15-5-13

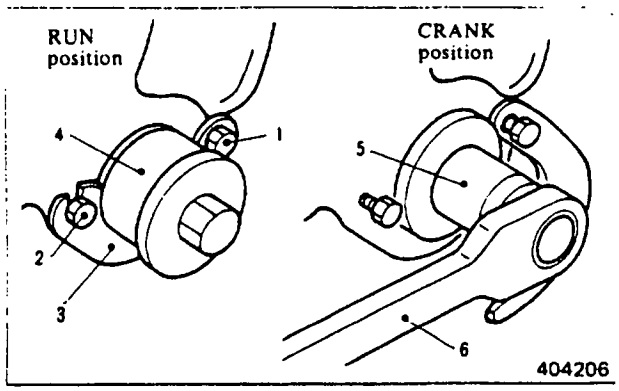
NOTE

How to use the turning gear

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

(b) Put socket (5) and ratchet handle (6) to the hexagonal end of shaft (4), and turn the shaft for cranking the engine.
The engine will be cranked in the normal direction if the handle is pushed down.

(c) After cranking the engine, pull out shaft (4), restore plate (3) to its original position, and tighten bolts (1) and (2), making sure that plate (3) is properly fitted in the groove of shaft (4).

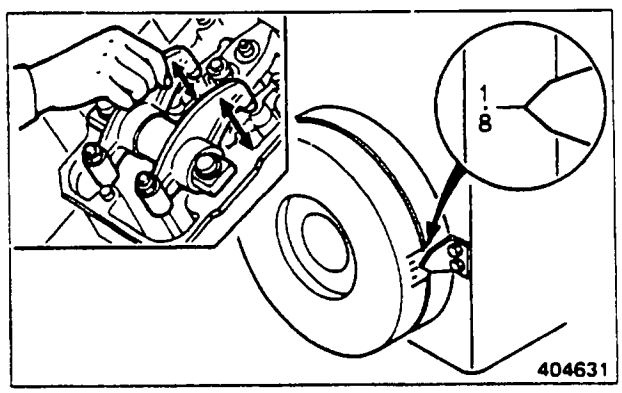


⚠ CAUTION

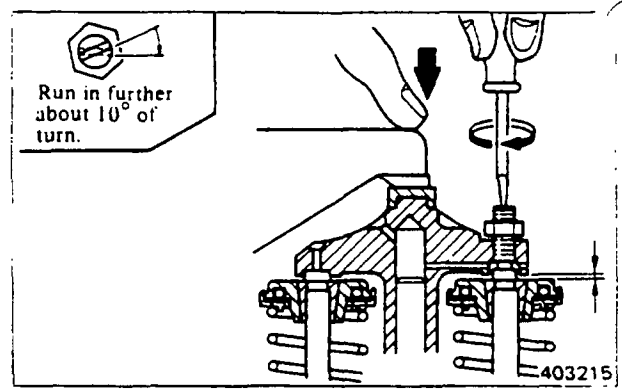
When starting the engine, make sure that the turning gear is in RUN position.

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

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



(2) Adjusting valve bridge (valve height)



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

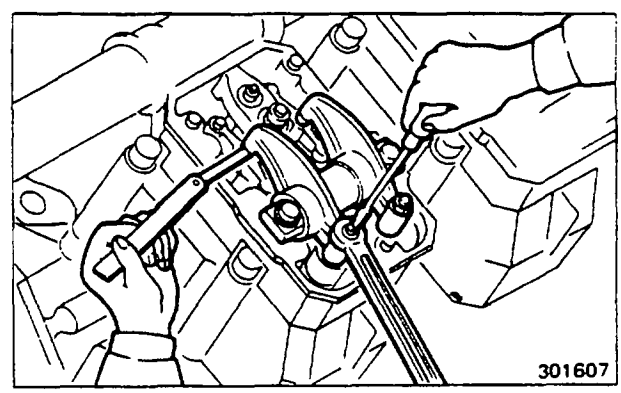
(b) Loosen lock nut for adjusting screw, and back off the screw.

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

⚠ CAUTION

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

(3) Adjustment



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

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

1.2 Fuel system priming

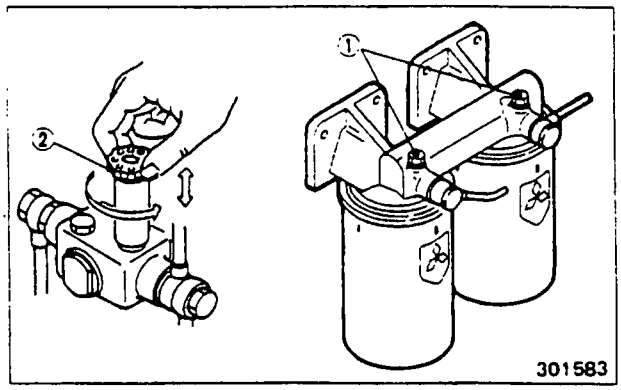
Prime the fuel filters and fuel injection pumps in that order.

(1) Fuel filters

(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 plugs when fuel flows from the vent holes without bubbles.



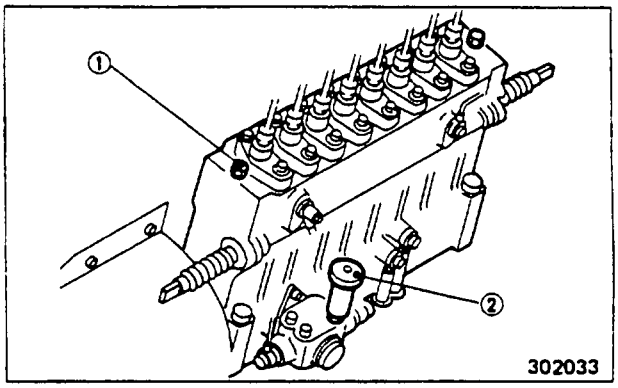
(2) Fuel injection pumps

(a) Loosen air vent plug about 2 turns.

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

(c) Tighten the air vent cock 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.

(d) Similarly prime the injection pump on the other side.



⚠ CAUTION

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

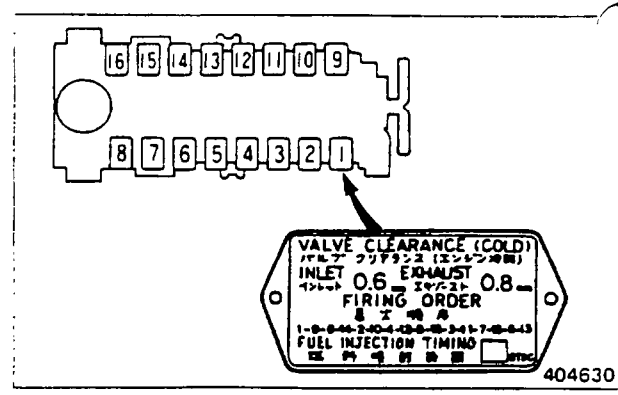
(b) Wipe off fuel spilt from the vent holes with cloth.

1.3 Fuel injection timing

(Right-hand fuel injection pump)

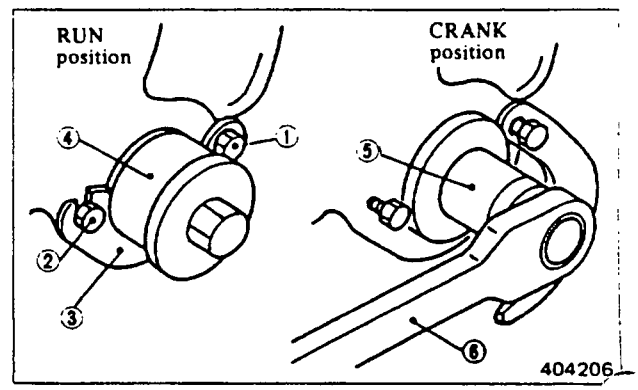
(1) Fuel injection timing and indication

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.



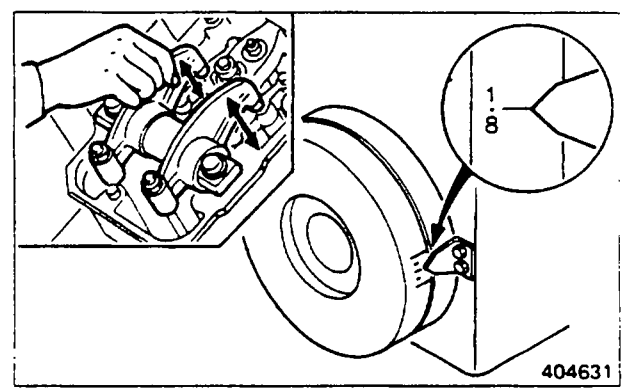
(2) Bringing No. 1 piston to top dead center on compression stroke

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



(b) Stop cranking the engine when the timing mark (1.8) on the viscous 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.

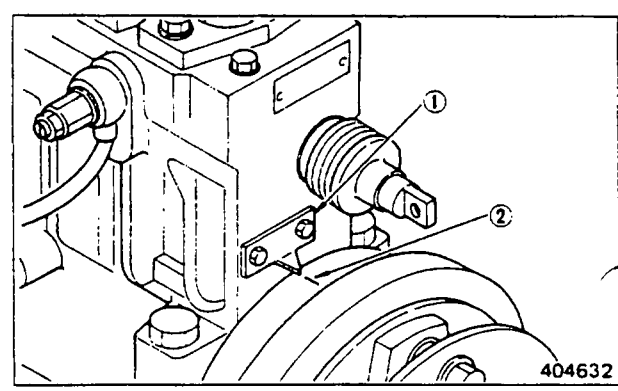


⚠ CAUTION

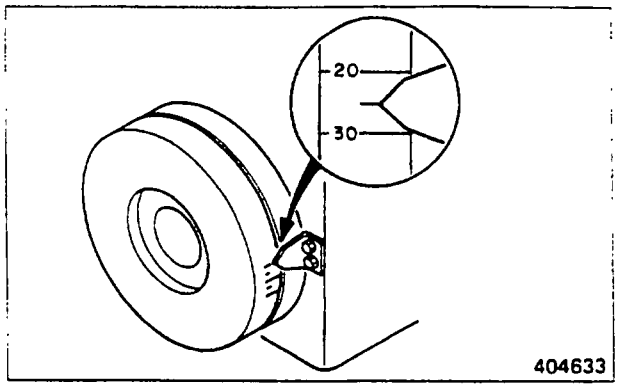
Do not confuse the top dead center on compression stroke for No. 1 cylinder with that for No. 8 cylinder.

(3) Inspection

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



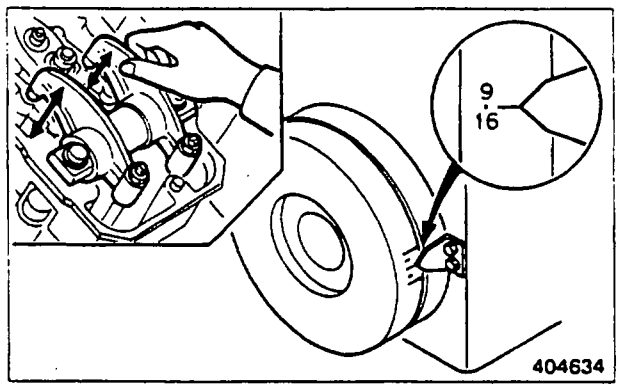
(b) Read the degrees of an angle (injection timing) on the scale on the damper, indicated by the pointer. Minus (-) mark on the scale and "B.T.D.C." on the caution plate mean "BEFORE" top dead center.



(4) Adjustment

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

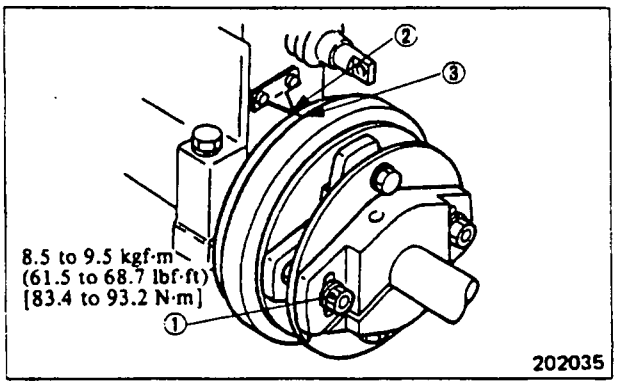
(b) Loosen two coupling (laminated plate) bolts (1), and displace the injection pump shaft to align pointer (2) on the pump case with timing mark (3) on the flywheel. Then, tighten one bolt to the specified torque and, after turning the crankshaft, similarly tighten the other.



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

(Left-hand fuel injection pump)

On this injection pump, the piston of No. 9 cylinder is at top dead center on compression stroke when the timing mark (9.16) on the damper is aligned with the pointer. At this time, the No. 9 cylinder inlet and exhaust valves should have a clearance. Adjust the injection timing as in case of the right-hand injection pump.



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

⚠ CAUTION

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

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

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

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

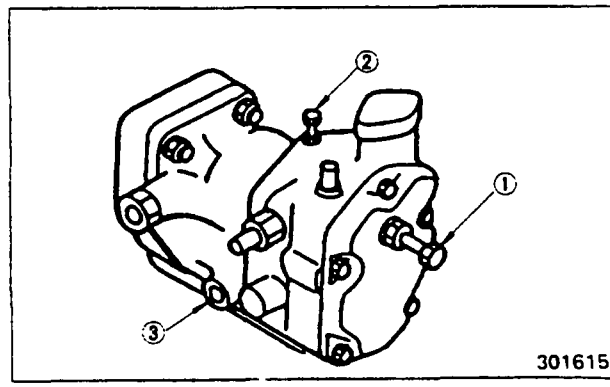
For inspection and adjustment, warm up the engine thoroughly until the coolant and oil temperature rises to 70°C (158°F).

PSG-type governor

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

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

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



(2) Adjusting no-load maximum speed setting

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

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

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

(3) Correcting hunting

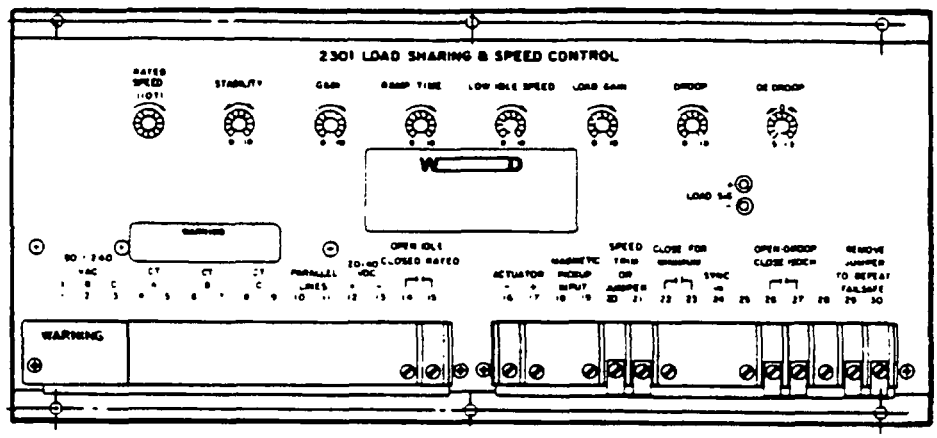
(a) If the engine hunts, reset needle valve (3). Open the needle valve by turning it counterclockwise (2 to 3 rotations) until the engine hunts. Keep the engine hunting for about 30 seconds until air is vented from the governor.

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

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

(d) Seal governor set bolt (2).

Woodward 2301 and 2301A load sharing & speed control devices (for EG-3P governor)



400912

(1) Adjusting idling speed setting

(a) Open the external lamp switch (between terminals 14 and 15). The engine speed will drop to the speed set by "LOW IDLE SPEED" potentiometer.

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

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

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

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

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

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

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

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

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

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

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

⚠ CAUTION

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

Barber-Colman Dyna 1-type governor

(1) Adjusting speed setting

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

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

"A"	.....	3 o'clock position
"GAIN"	...	9 o'clock position
"D"	.....	10 o'clock position
"I"	.....	8 o'clock position
"L"	.....	10 o'clock position

(set at factory)

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

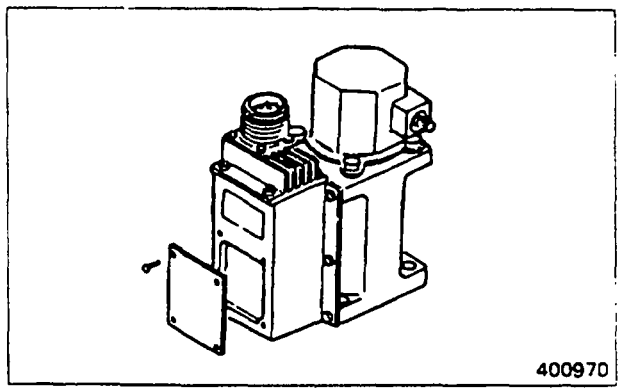
(d) Turn "SPEED" potentiometer within 20 rotations until the specified engine speed is obtained. This potentiometer can be turned clockwise to increase the speed or counterclockwise to decrease it, but it has no stopper for limiting the rotation in either direction.

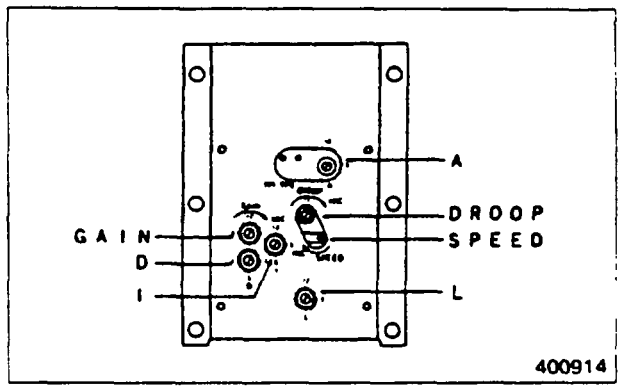
(e) Set the indicated horsepower by means of rack set bolt.

(2) Correcting hunting

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

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





Potentiometers

(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.

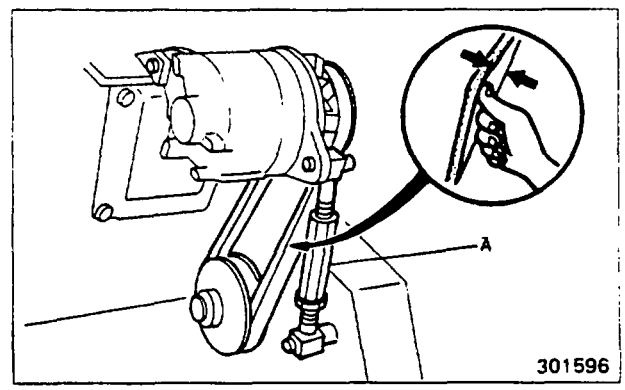
(e) Install the top cover to the controller, and seal the cover bolts.

1.5 Alternator drive belt tension

Apply thumb pressure to the belt midway between the pulleys to check the belt tension. If the tension is incorrect, make an adjustment by means turnbuckle (A).

Unit: mm (in.)

Item	Assembly standard
Belt tension	10 to 15 (0.4 to 0.6)



⚠ CAUTION

Do not adjust the belt too tight. If the belt is too tight, undue stresses are placed on the bearing and belt, which might shorten the life of both.

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 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 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 kgf/cm^2 (28 psi) [0.2 MPa] at idling speed.

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

(3) Lubricating oil temperature:
It should be 60°C to 95°C (140°F to 203°F) when measured in oil pan.

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

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

(6) Exhaust color and abnormal smell

2.3 Bench test (dynamometer test) conditions

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

2.4 Inspection and adjustment after bench test

(1) Adjustment of valve clearance

(2) Adjustment of injection timing

(3) Retightening of exhaust manifold mounting bolts

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. PREPARATORY STEPS

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

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

(c) Loosen the oil pan drain plug, and drain engine oil.
[Oil capacity: 200 liters (53 U.S. gal)]

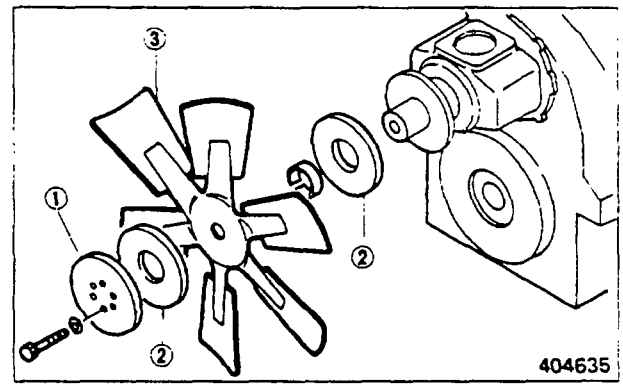
⚠ WARNING

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

2. ENGINE ACCESSORY REMOVAL

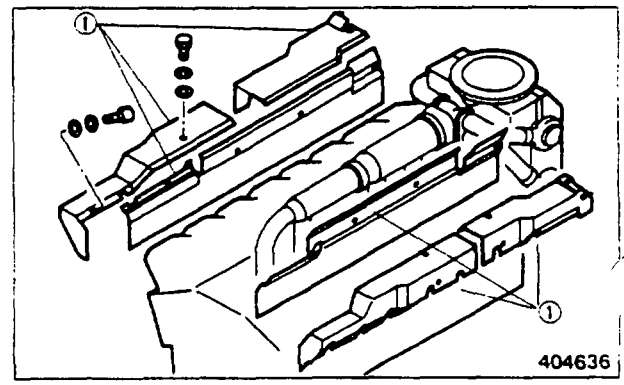
(1) Removing fan

Remove plate (1) by unscrewing mounting bolts. Remove friction rubber (2) and fan (3).
[Weight of fan: 40 kg (90 lb), approx.]

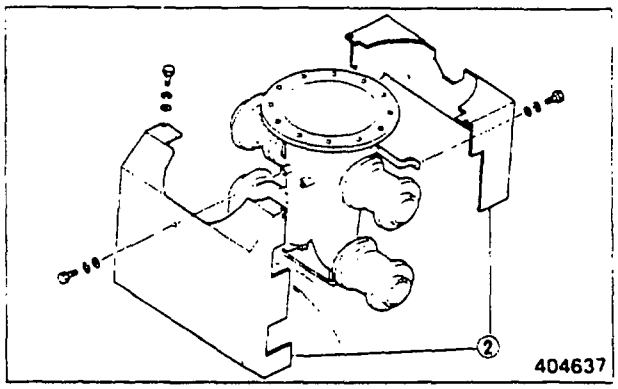


(2) Removing insulators

(a) Remove insulators (1) from the exhaust manifolds.

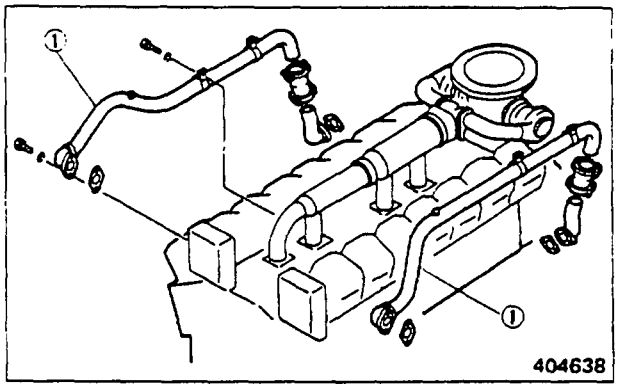


(b) Remove insulators (2) from the turbocharger.



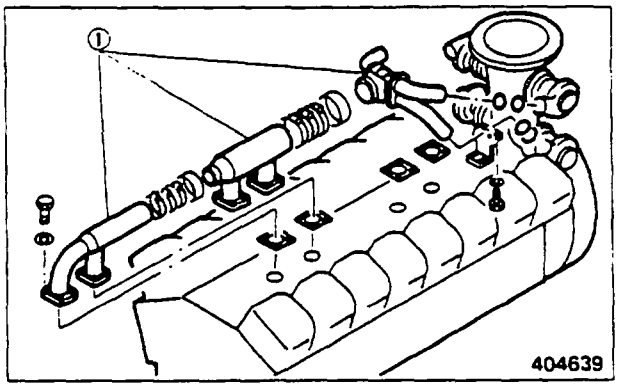
(3) Removing water pipes

Disconnect water pipes (1) from the air cooler by unscrewing mounting bolts.



(4) Removing air ducts

Remove air ducts (1) from the engine by unscrewing mounting bolts.



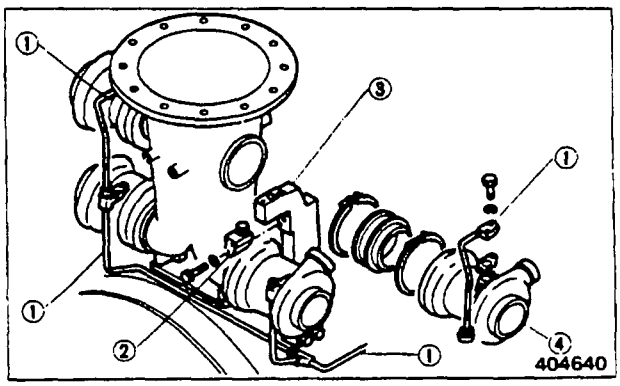
(5) Removing turbochargers

(a) Disconnect lube oil pipes (1) from the turbocharger.

(b) Unscrew exhaust manifold-side bolts of the turbocharger.

(c) Remove drain connector (2) and bracket (3) from the turbocharger.

(d) Remove turbocharger (4).
[Weight of turbocharger: 30 kg (66 lb), approx.]

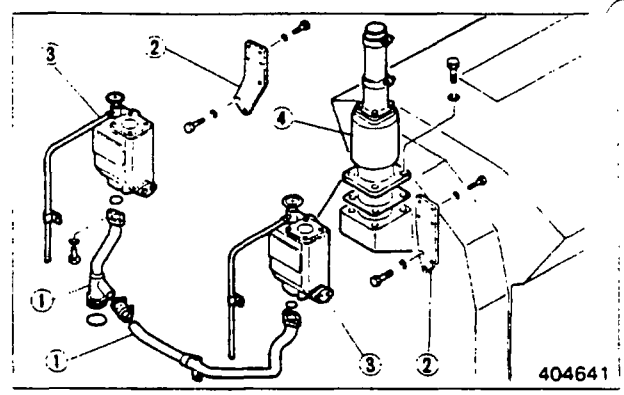


(6) Removing thermostat cases and breather

(a) Disconnect water bypass pipe (1) from the thermostat case.

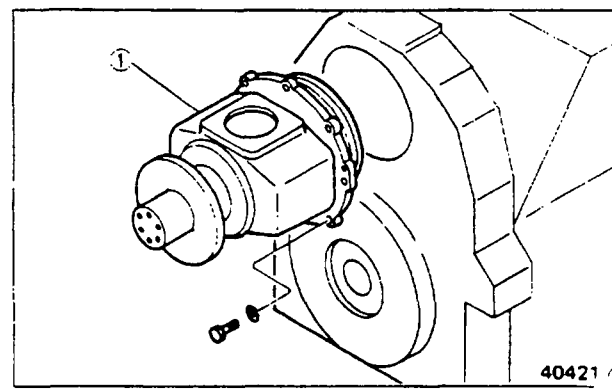
(b) Unscrew bolts securing thermostat case bracket (2), and remove thermostat case (3).

(c) Remove breather (4) by unscrewing mounting bolts.



(7) Removing fan drive

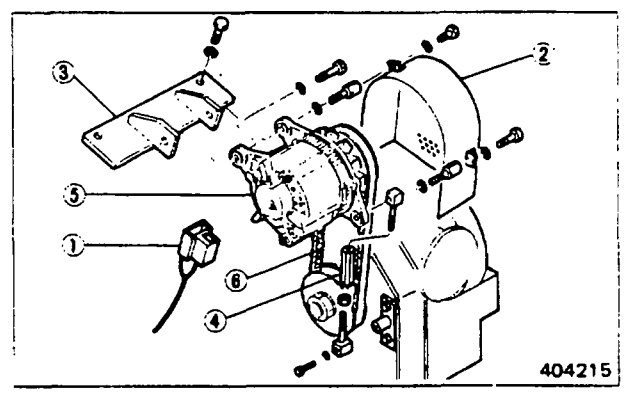
Remove fan drive (1) by unscrewing mounting bolts.
[Weight of fan drive: 45 kg (100 lb), approx.]



(8) Removing alternator

(a) Disconnect harness (1) from the alternator. Remove belt cover (2), bracket (3) and adjusting turnbuckle (4), then remove alternator (5).

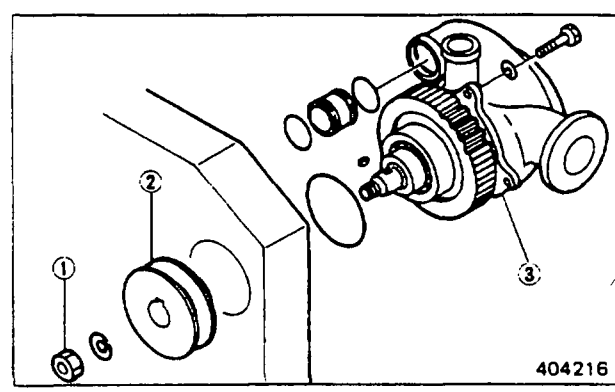
(b) Remove V-belt (6).



(9) Removing water pump

(a) Unscrew nut (1), and remove drive pulley (2).

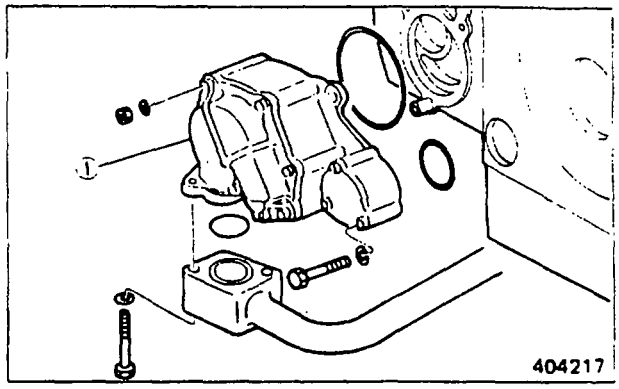
(b) Remove water pump (3) by unscrewing mounting bolts and nuts. [Weight of water pump: 33 kg (73 lb), approx.]



(10) Removing oil pump

(a) Unscrew bolts securing the oil pipe to the bottom of oil pump.

(b) Remove oil pump (1) by unscrewing mounting bolts and nuts.
[Weight of oil pump: 23 kg (51 lb), approx.]



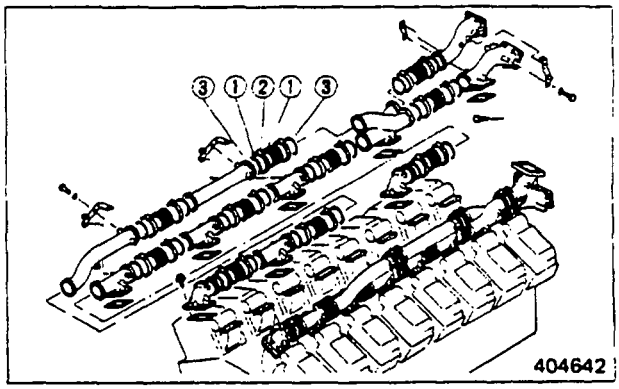
(11) Removing exhaust manifolds

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

(b) Remove manifold (4) and gaskets (5) by unscrewing mounting bolts.

NOTE

When installing the manifolds, put each gasket in place with its marking "MANIFOLD" facing the manifold.



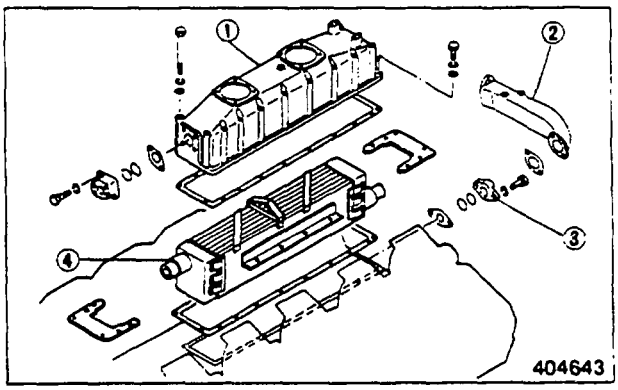
(12) Removing air cooler

(a) Remove air cooler case (1) by unscrewing mounting bolts.

(b) Disconnect water pipe (2) and connector (3) from the rear of air cooler.

(c) Fasten a hoist to the hook at the center of air cooler element (4). Remove the element while moving it forward.
[Weight of air cooler element: 38 kg (84 lb), approx.]

(d) Remove packing (5).

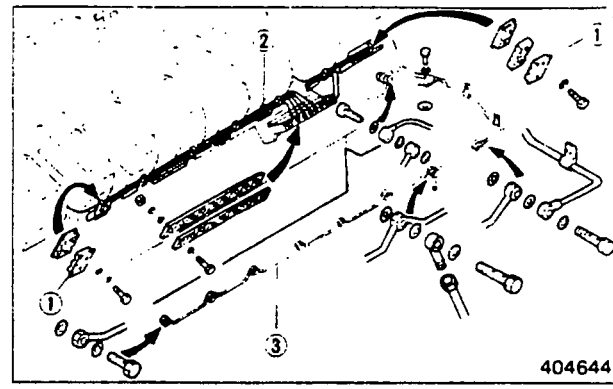


(13) Removing fuel injection pipes and fuel leak-off pipes

(a) Remove injection pipe clamps (1).

(b) Disconnect injection pipes (2).

(c) Disconnect fuel leak-off pipes (3).



⚠ CAUTION

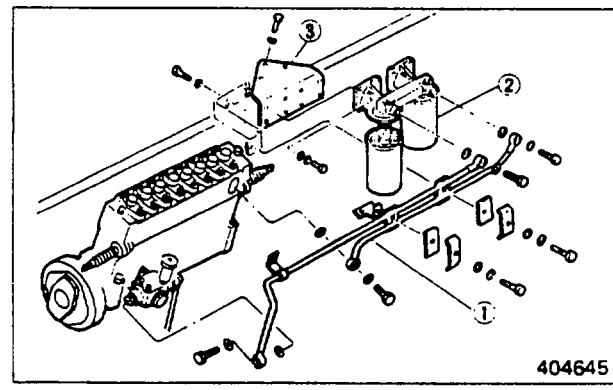
Be sure to fit rubber caps to the openings of injection pumps and nozzle inlet connectors to prevent dirt from getting inside the fuel system.

(14) Removing fuel filters

(a) Disconnect fuel pipes (1) from the filters.

(b) Remove fuel filters (2) by unscrewing mounting bolts.

(c) Remove filter bracket (3) by unscrewing mounting bolts.



(15) Removing fuel injection pumps

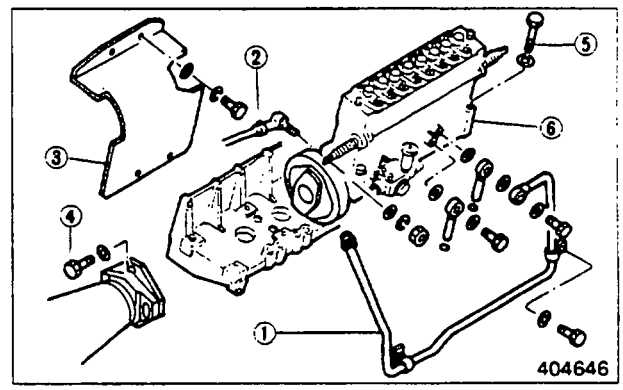
(a) Disconnect oil pipe (1) from the drive case.

(b) Unscrew the nut securing the ball joint, and disconnect link (2) from the governor.

(c) Removing coupling cover (3).

(d) Unscrew two bolts (4) securing the coupling.

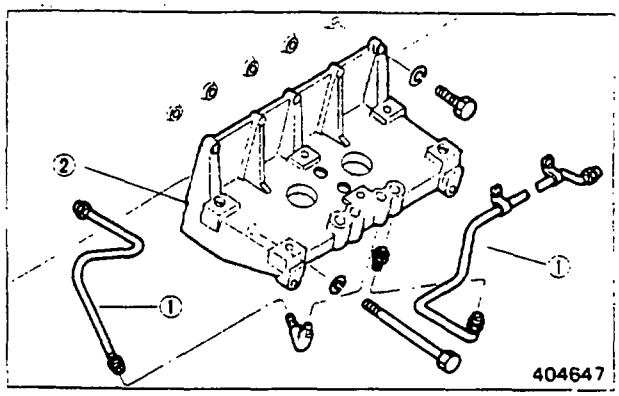
(e) Unscrew injection pump mounting bolts (5). Lift off injection pump (6) complete with coupling (leaving the drive shaft laminated plate on the drive shaft).
[Weight of fuel injection pump: 70 kg (155 lb), approx.]



(16) Removing injection pump brackets

(a) Disconnect lube oil pipe (1) from the bracket.

(b) Remove bracket (2) by unscrewing mounting bolts.



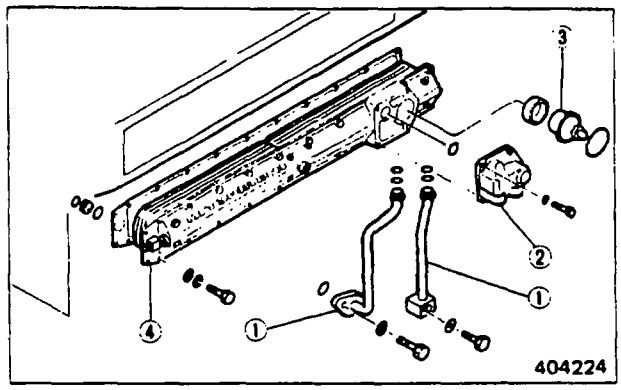
(17) Removing right-hand oil cooler

(a) Disconnect oil pipes (1) between the oil pan and oil cooler inlet connector.

(b) Remove oil cooler inlet connector (2) by unscrewing mounting bolts.

(c) Pull out oil thermostat (3) from the oil cooler.

(d) Remove oil cooler (4) by unscrewing mounting bolts.
[Weight of right-hand oil cooler: 20 kg (44 lb), approx.]



(18) Removing oil filters with left-hand oil cooler

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

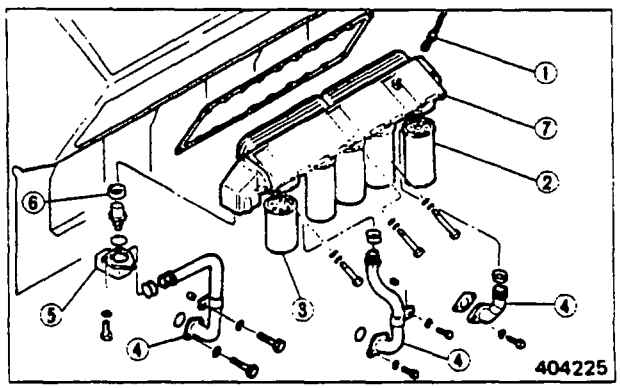
(b) Remove four oil filter elements (2) and one bypass filter element (3).

(c) Disconnect oil pipes (4).

(d) Remove oil cooler inlet connector (5) by unscrewing bolts.

(e) Remove oil thermostat (6).

(f) Remove oil filter bracket (7) complete with oil cooler.
[Weight of the complete: 45 kg (100 lb), approx.]

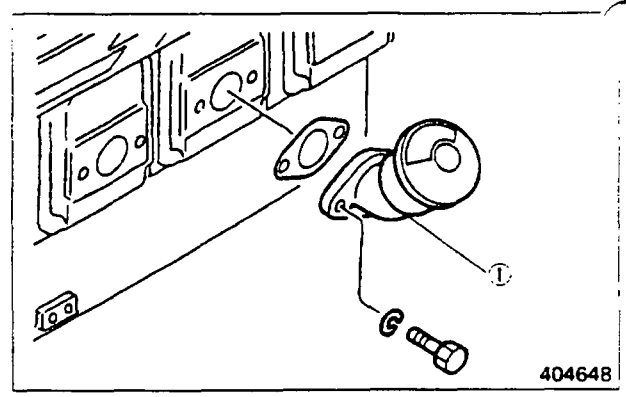


NOTE

Before removing oil filter elements (2) and bypass filter element (3), bore a hole in the bottom of each element to drain oil.

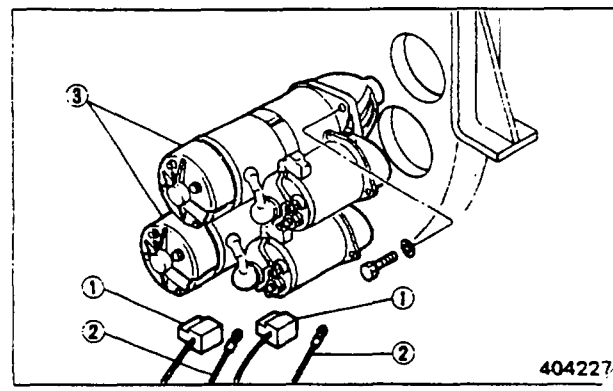
(19) Removing oil filler

Remove oil filler (1) by unscrewing mounting bolts.



(20) Removing starters

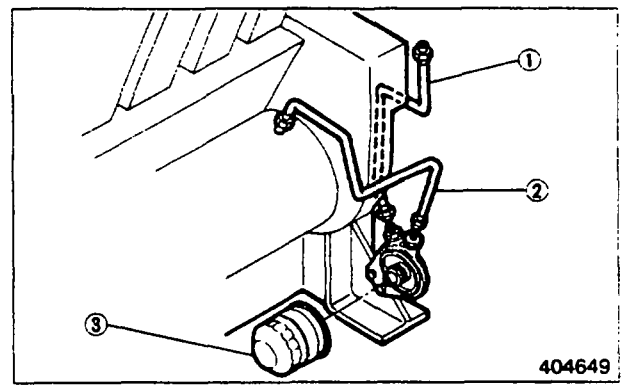
Disconnect harnesses (1) and (2) from the starters. Remove starters (3) by unscrewing mounting bolts.
[Weight of starter: 19 kg (42 lb), approx.]



(21) Removing governor oil filter (Woodward governor)

(a) Disconnect oil pipes (1) and (2).

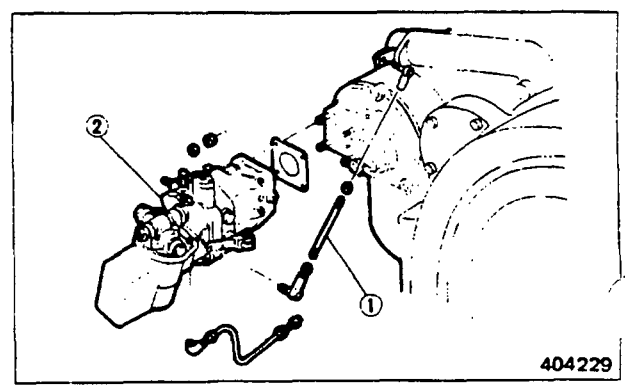
(b) Remove oil filter (3).



(22) Removing governor (Woodward governor)

(a) Remove governor link (1).

(b) Remove governor (2) by unscrewing mounting nuts.



3. ENGINE ACCESSORY INSTALLATION

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

(a) Refill the lubrication system.

(b) Refill the cooling system.

(c) Refill the governor oil filter with engine oil through air vent plug hole. This helps starting the engine easily.

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

(e) Prime the fuel system.

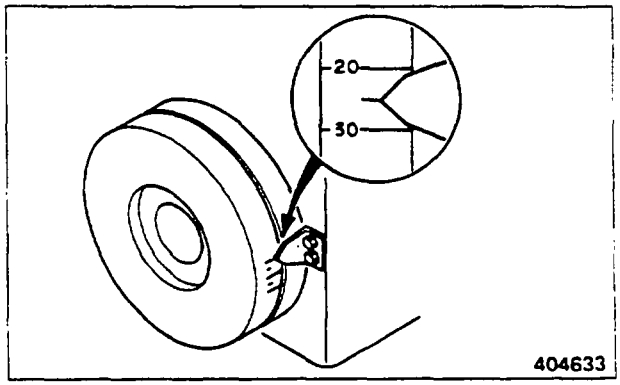
(f) To install the injection pumps, refer to FUEL INJECTION PUMP INSTALLATION which follows. After installing the injection pumps, check and adjust the injection timing.
(Refer to 1.3 Fuel injection timing, 1. ADJUSTMENT, Group 5.)

Fuel Injection Pump Installation

(a) Turn the crankshaft in normal direction to align No. 1·8 timing mark on the viscous damper with the pointer on the engine.

(b) Make sure that the No. 1 cylinder inlet and exhaust valve rocker arms are not being pushed up by their pushrods.

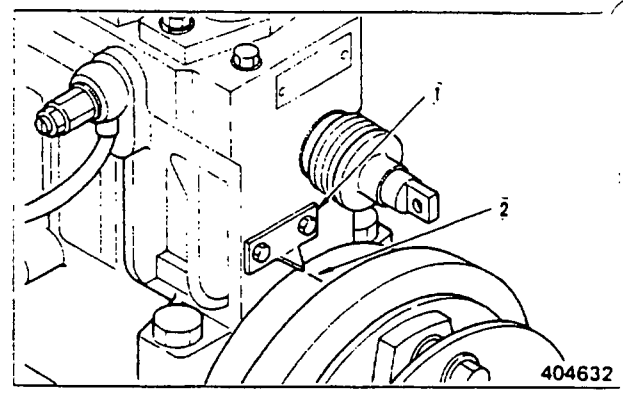
(c) Turn the crankshaft in the reverse direction about 60° once, then slowly turn it in the normal direction until the timing mark on the damper is aligned with the pointer.



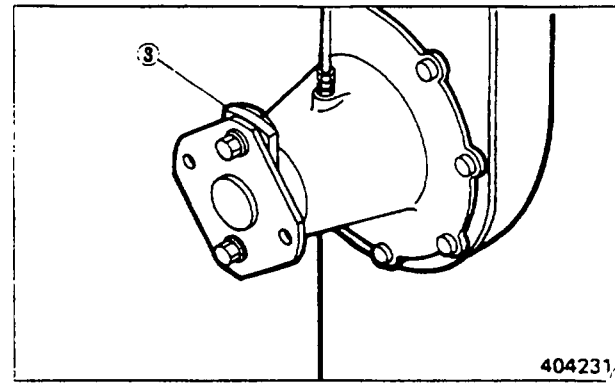
NOTE

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

(d) Before installing the injection pump, align mark (2) on the coupling with pointer (1) on the pump case.



(e) Install pump drive-side coupling half (3) to the drive shaft, leaving the securing bolts loose enough.



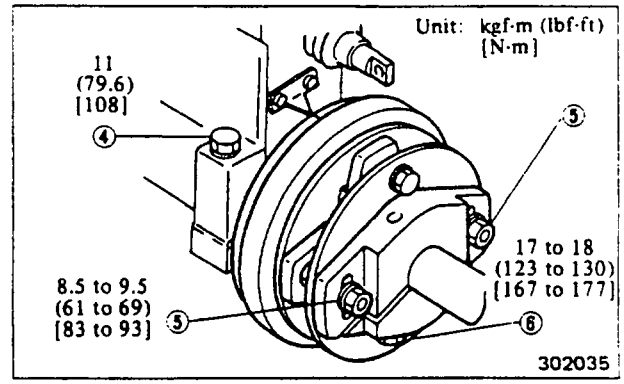
(f) Put the injection pump proper on the bracket, and temporarily tighten bolts (4).

(g) Connect the fuel pipe and lube oil pipe to the pump.

(h) Temporarily tighten coupling nuts (5) (2 places).

(i) After tightening bolts (4), make sure that mark (2) on the coupling is aligned with pointer (1) on the pump case, and tighten nuts (5) (2 places) to the specified torque.

(j) Tighten coupling shaft bolt (6) to the specified torque.



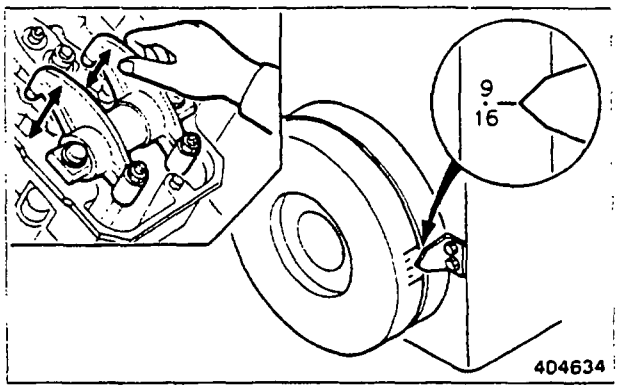
⚠ CAUTION

Tighten the coupling bolts evenly to the specified torque. Over- or under-tightening of the bolts will result in damage to various parts and mistiming of injection.

(Installing left-hand injection pump)

(a) Align the No. 9·16 timing mark on the viscous damper with the pointer. Make sure the No. 9 cylinder piston is at top dead center on compression stroke. With the No. 9 piston so located, the inlet and exhaust valve rocker arms are not being pushed up by the pushrods.

(b) Adjust the injection timing as in case of the right-hand injection pump, and install the pump, pipes and control linkage in place.

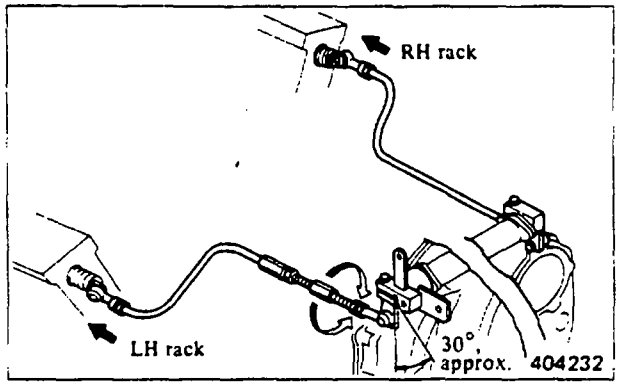


(Adjusting control rack position)

This adjustment is for equalizing the injection quantities of the right-hand and left-hand injection pumps.

(a) Push in the racks of the both pumps all the way toward the non-injection position, and turn the adjusting rod in the linkage of the left-hand pump.

(b) After adjusting the rack position, tighten the lock nut for the adjusting rod and seal it with wire.



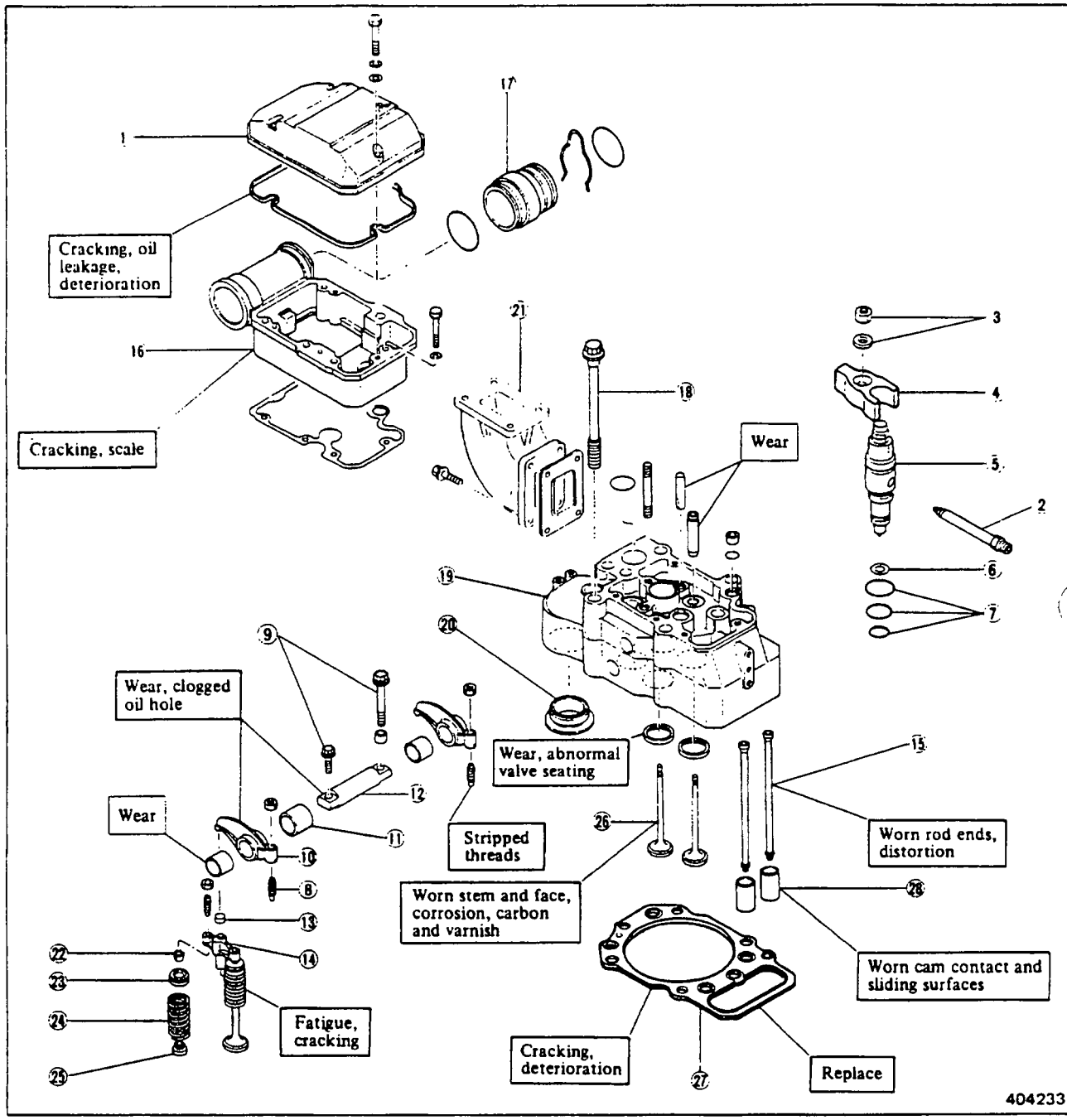
⚠ CAUTION

After adjusting the rack position, make sure the racks moves freely. If any rack fails to move freely, the governor will not work properly.

ENGINE PROPER

1. CYLINDER HEADS AND VALVE MECHANISM

1.1 Disassembly



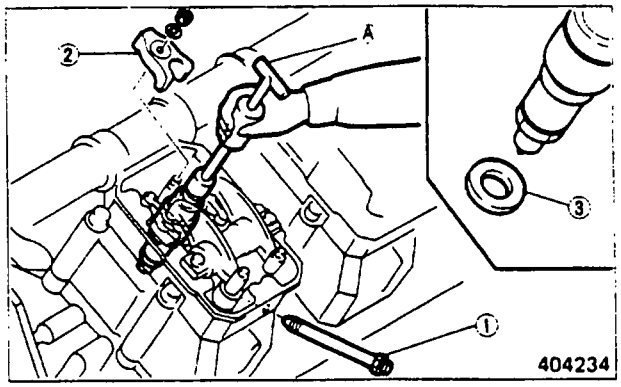
① Rocker cover
② Fuel inlet connector
③ Nut, washer
④ Injection nozzle gland
⑤ Injection nozzle
⑥ Gasket
⑦ O-ring
⑧ Adjusting screw
⑨ Bolt
⑩ Rocker
⑪ Spacer
⑫ Rocker shaft
⑬ Valve bridge cap
⑭ Valve bridge
⑮ Pushrod
⑯ Rocker case
⑰ Water outlet connector
⑱ Cylinder head bolt
⑲ Cylinder head
⑳ Inlet port packing
㉑ Exhaust connector
㉒ Valve cotter
㉓ Valve rotator
㉔ Valve spring
㉕ Stem seal
㉖ Valve
㉗ Cylinder head gasket
㉘ Tappet

(1) Removing injection nozzles

(a) Remove fuel inlet connector (1) and nozzle gland (2).

(b) Using injection nozzle remover (A) (33591-10101), remove each injection nozzle assembly. Take out gasket (3) left behind in the cylinder head.

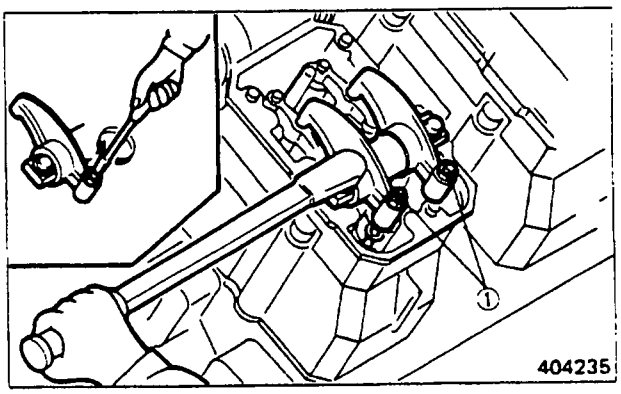
(c) Set the nozzles and inlet connectors in groups, each identified for its cylinder head. Be careful not to damage the nozzle tip.



(2) Removing rocker shaft assemblies

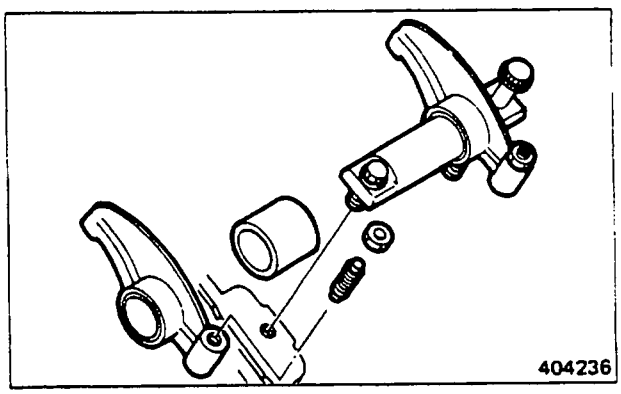
(a) Loosen adjusting screw (1) of each rocker in advance.

(b) Set the rocker shaft assemblies and mounting bolts in groups, each identified for its cylinder head.



(3) 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.



(4) Removing valve bridges

Remove the valve bridges and bridge caps.

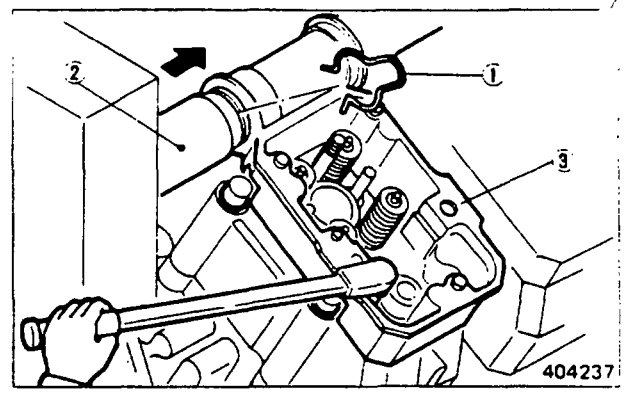
NOTE

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

(5) Removing rocker cases

(a) Remove snap ring (1) for water outlet connector (2), and shift the connector toward the snap ring groove side.

(b) Remove rocker case (3) from the cylinder head by unscrewing mounting bolts.



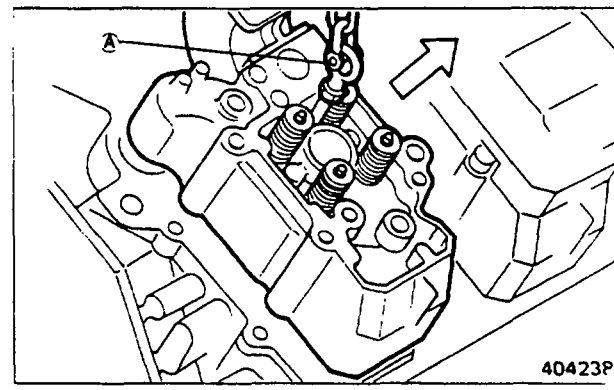
(6) Removing cylinder head assemblies

(a) Each cylinder head is located on the crankcase with dowel pins. Using eye nut (A) (37591-02400), lift the head off the crankcase.
[Weight of cylinder head: 35 kg (77 lb), approx.]

(b) Remove the cylinder head gasket.

⚠ CAUTION

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

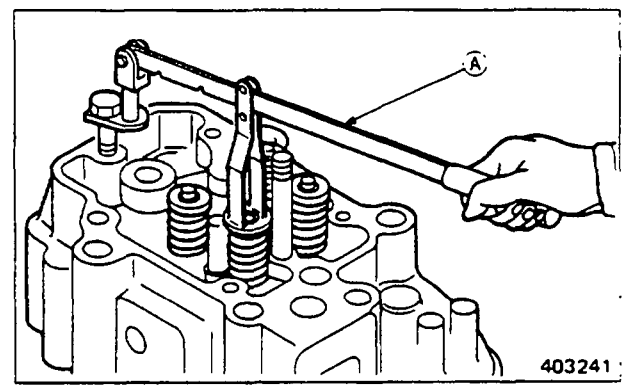


(7) Removing valves and valve springs

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

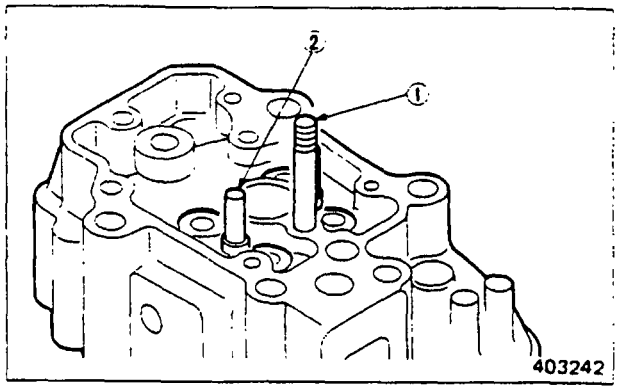
NOTE

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



(8) Removing studs and bridge guides

Do not remove studs (1) and bridge guides (2) securing the nozzle glands unless the removal is valid. If the studs and guides are removed during disassembly, use new studs and guides at the time of reassembly. Apply thread sealant to their cylinder head-side threads before installing them.



1.2 Inspection and repair

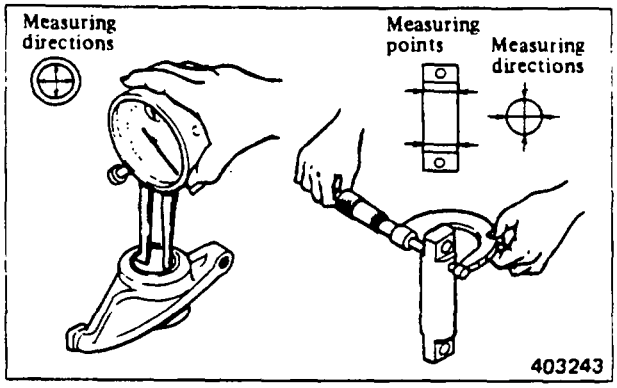
Rockers, rocker bushings and rocker shaft

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

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

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Inside diameter of rocker bushings	36 (1.42)	36.000 to 36.040 (1.41732 to 1.41889)	36.090 (1.42086)
Diameter of rocker shafts		35.966 to 35.991 (1.41598 to 1.41697)	35.940 (1.41496)



Measuring rcoker bushing and rocker shaft

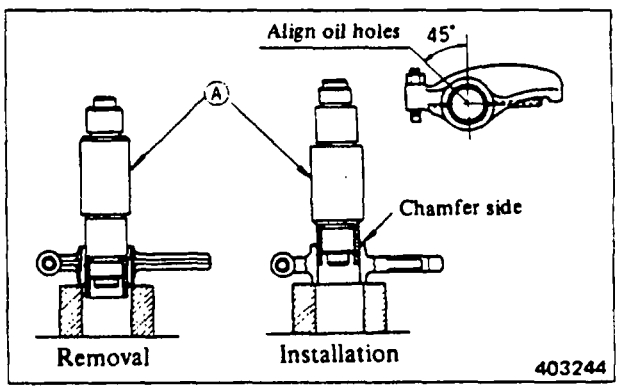
(2) Replacing rocker bushings

Using rocker bushing puller (A) (37591-02600), 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.



Replacing rocker bushing

(c) After installing the bushing, measure its inside diameter to make sure that it is 36 $^{+0.04}_{0}$ mm (1.42 $^{+0.00157}_{0}$ in.).
If the diameter is out of this tolerance, refinish it to 36 $^{+0.04}_{0}$ mm (1.42 $^{+0.00157}_{0}$ in.) $\frac{3.2S}{\nabla\nabla\nabla}$ by reaming.

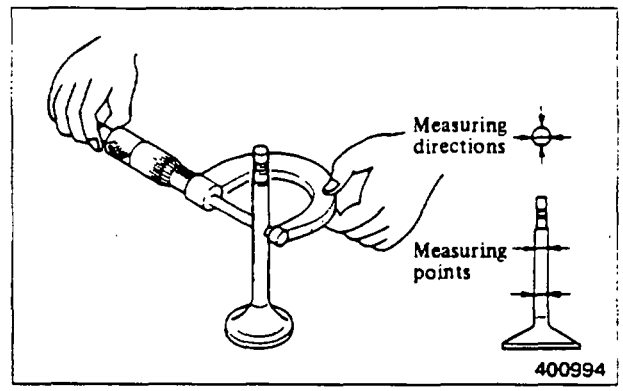
Valve guides and valve stems

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

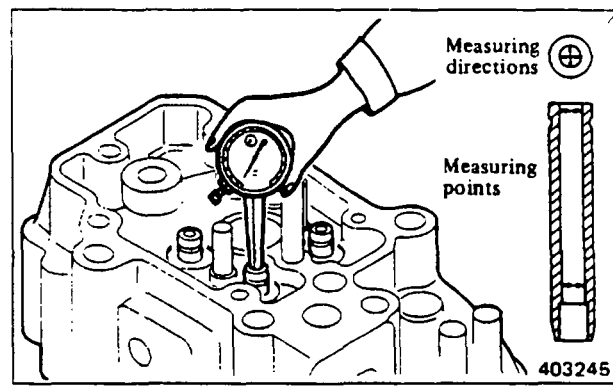
The valve guide is worn more rapidly at its both ends than at any other parts. Measure the inside diameter of the guide at its ends and at middle part in two directions. Replace the guides if they are worn in excess of the service limit.

Unit: mm (in.)

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



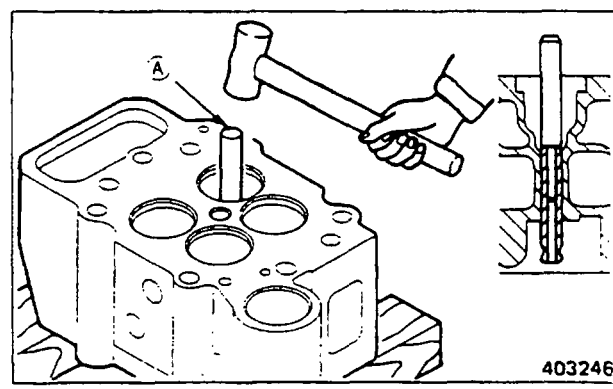
Measuring valve stem



Measuring valve guide

(2) Replacing valve guides and stem seals

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



Removing valve guide

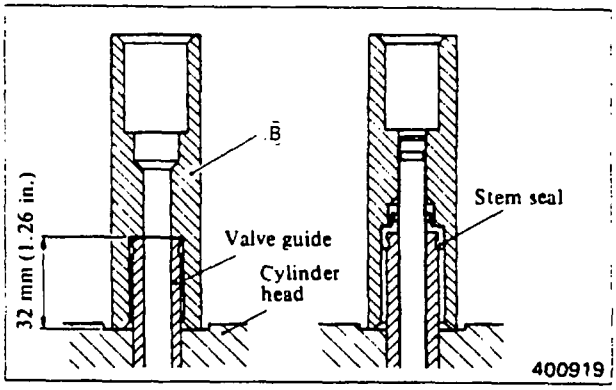
(b) To install a new valve guide, use valve guide & seal installer (B) (37191-01500) and a press.

CAUTION

(a) As-installed depth is specified for the valve guide; 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

Valves and valve seats

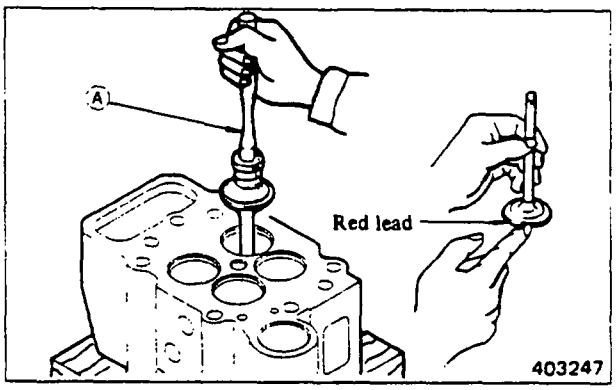
(1) Inspecting valve face

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

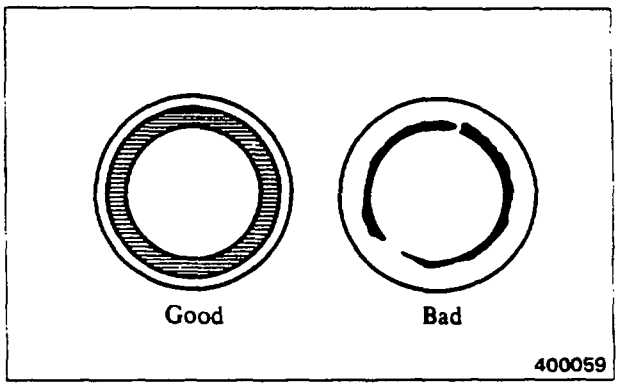
NOTE

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

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



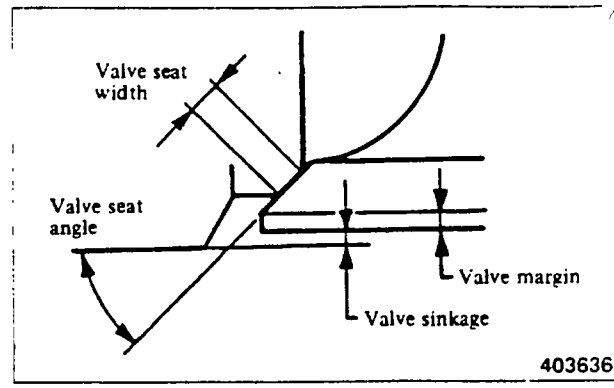
Checking valve face



Valve contact with its seat

Unit: mm (in.)

Item		Assembly standard	Repair limit
Valve seat	Angle	30°	
	Valve sinkage	-0.2 to 0.2 (-0.008 to 0.008)	1.0 (0.039)
	Width	2.15 to 2.45 (0.0846 to 0.0965)	2.8 (0.110)
Valve margin		2.8 to 3.2 (0.110 to 0.126)	2.5 (0.098) by refacing



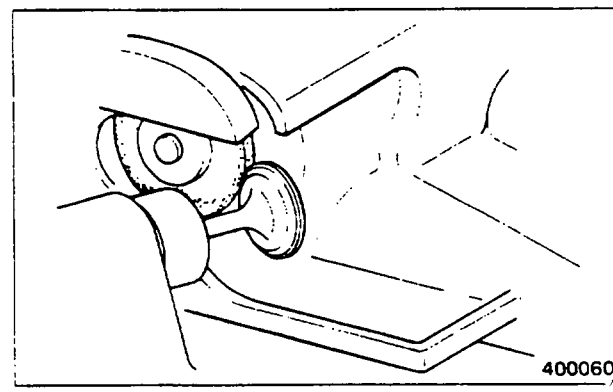
(2) Refacing valves

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

NOTE

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

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



Refacing valve

(3) Refacing valve seats

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

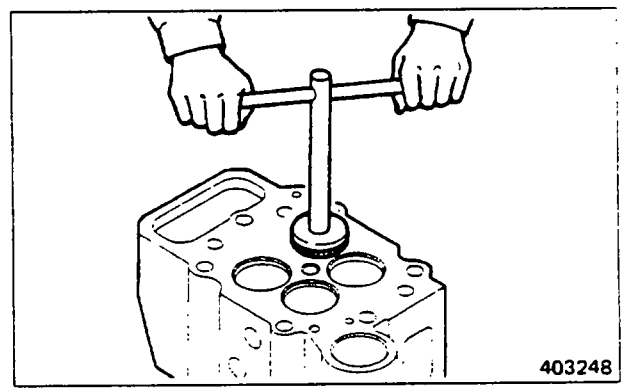
(b) Lap the valve in the valve seat.

NOTE

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

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

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



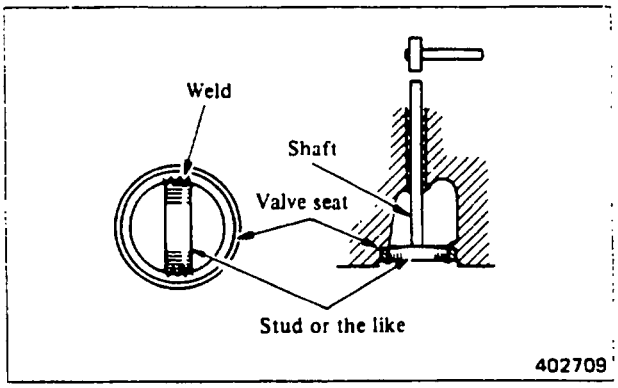
Refacing valve seat

(4) Replacing valve seats

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

NOTE

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

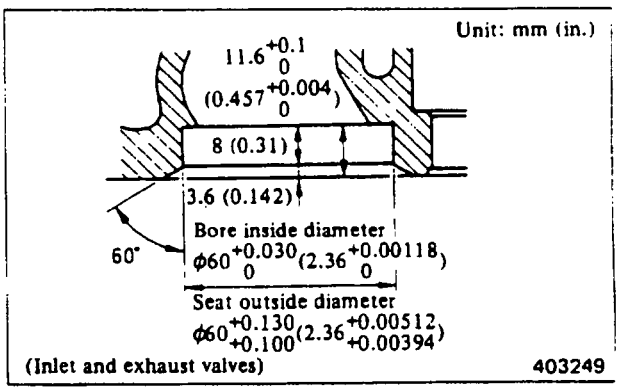


Removing valve seat

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

Unit: mm (in.)

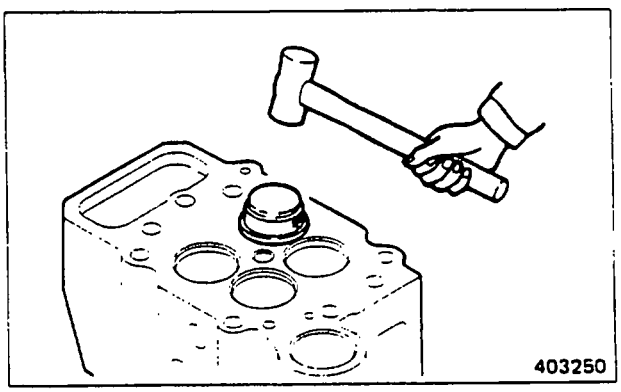
Item	Nominal value	Standard clearance
Cylinder head bore inside diameter and valve seat outside diameter	60 (2.36)	-0.070 to -0.130 (-0.00276 to -0.00512)



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 containing dry ice.

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

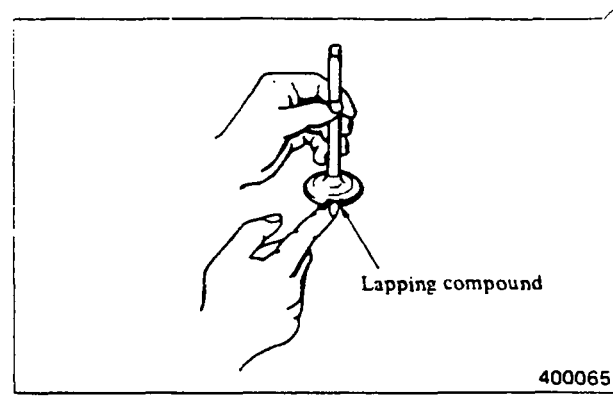


Installing valve seat

(5) Lapping valves in valve seats

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

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



Coating valve with lapping compound

NOTE

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

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

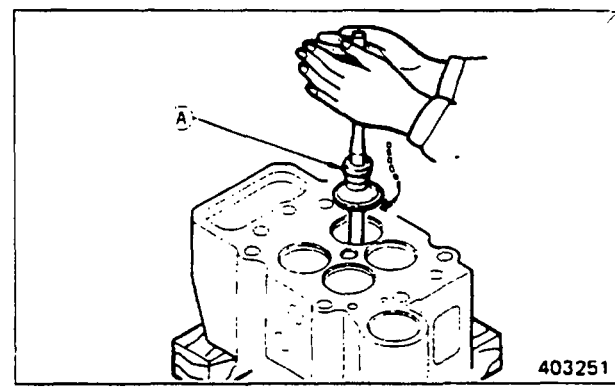
(c) Mixing the compound with a small amount of engine oil will facilitate coating.

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

(c) Wash off the compound with diesel fuel.

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

(e) Check the valve face for contact.

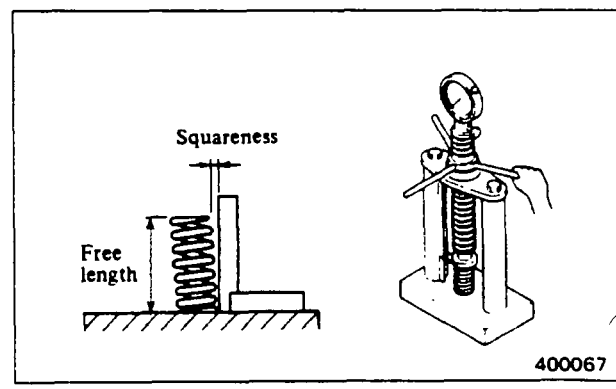


Lapping valve in valve seat

Valve springs

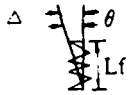
Measuring squareness and free length

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



Measuring valve spring

Unit: mm (in.)

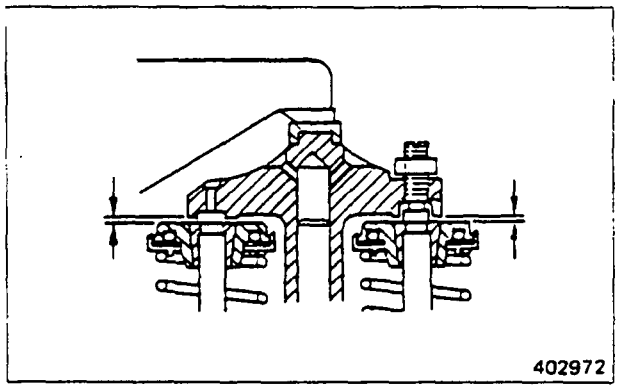
Item	Assembly standard	Service limit
Free length	73 (2.87)	71 (2.80)
Squareness	 θ=1.5°, maximum	Δ = 2.2 (0.087) over the length
Length under test force/test force, mm(in.)/ kgf (lbf) [N]	66.0 (2.6)/ 29.45 to 32.55 (65 to 72) [289 to 319]	

Valve bridges and bridge caps

Measuring clearance between bridge and rotators (cotters)

(1) If the clearance is less than 1.5 mm (0.059 in.), check he valve stem top for cupping. When the stem top is badly cupped, replace the valve to obtain more than 1.5 mm (0.059 in.) clearance.

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

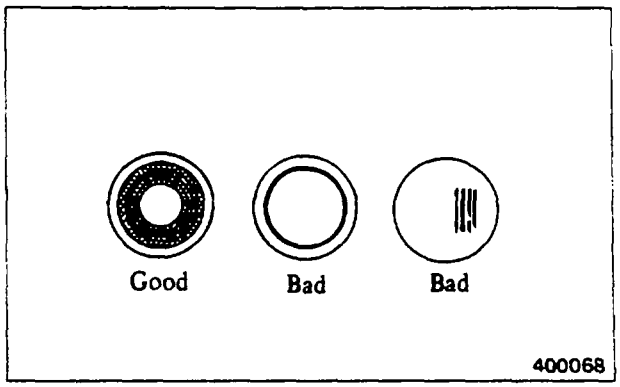


Inspecting bridge-to-rotator clearance

Tappets and valve pushrods

(1) Inspecting cam contact face of tappets

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



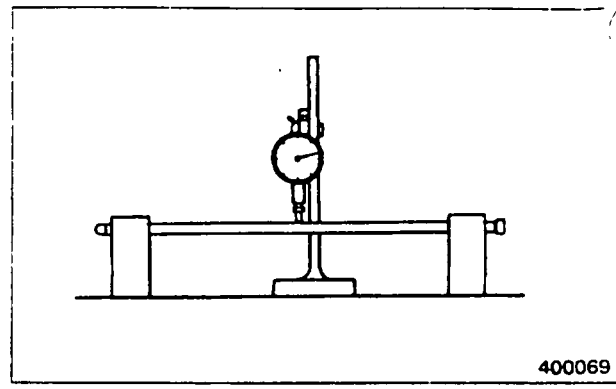
Cam contact face of tappet

(2) Measuring runout of valve pushrods

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

Unit: mm (in.)

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



Measuring valve pushrod runout

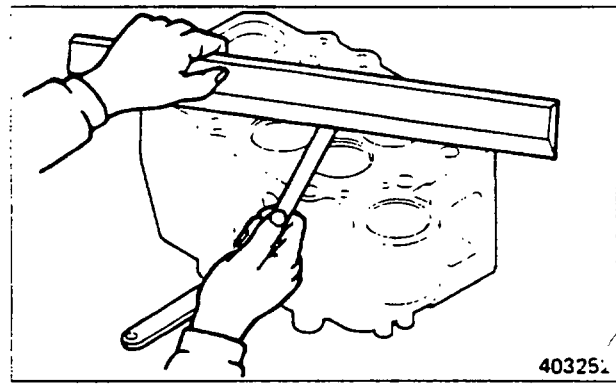
Cylinder heads

Measuring warpage of gasket contact surface

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

Unit: mm (in.)

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



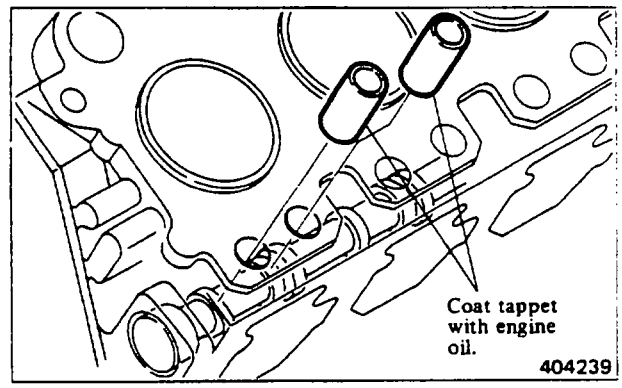
Measuring warpage of gasket contact surface of head

1.3 Reassembly

To reassemble, follow the reverse of disassembly procedure.

(1) Installing tappets

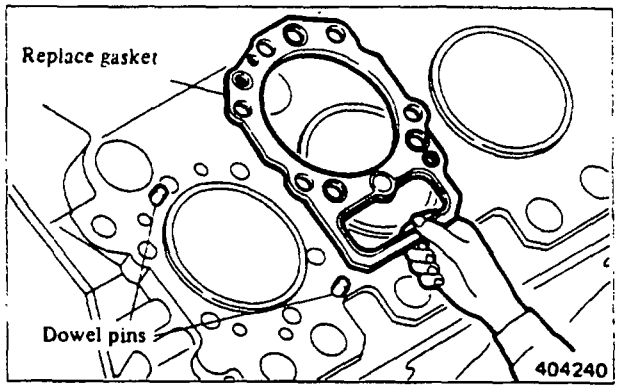
Coat the tappets with engine oil, and carefully put them on the camshaft.



(2) Installing cylinder head gaskets

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

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



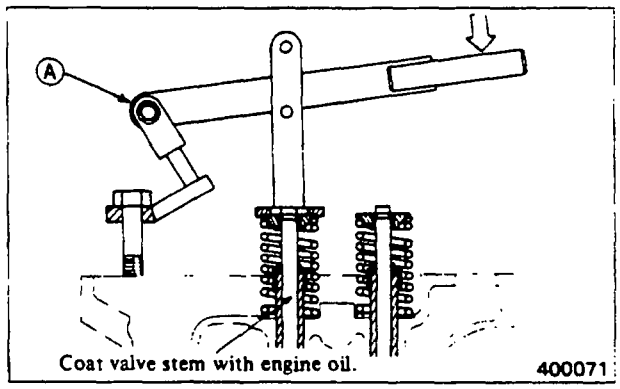
⚠ CAUTION

Do not apply any sealant to the gaskets.

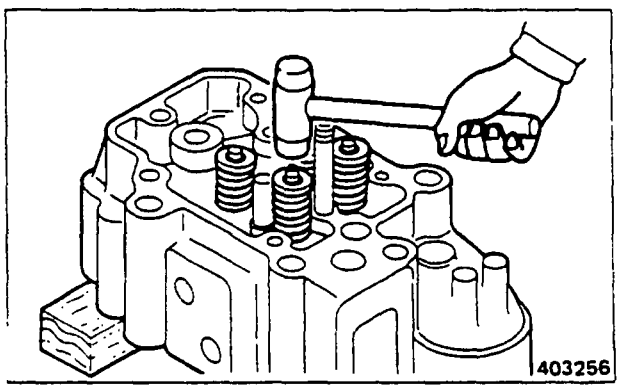
(3) Reassembling cylinder heads

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

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

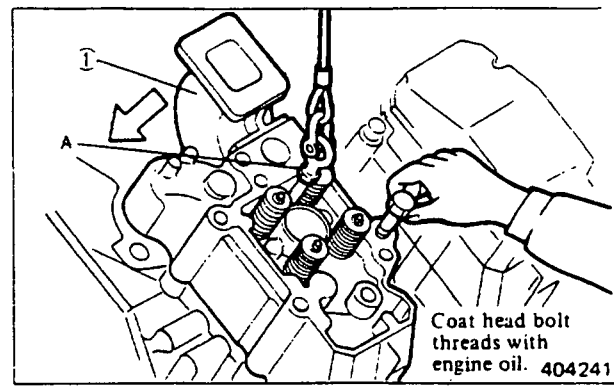


(c) Lightly tap on the top of each valve stem with a soft hammer to make sure that the valve spring and cotters are properly installed.



(4) Installing cylinder head assemblies

(a) Install exhaust connector (1) to the cylinder head. When installing the connector, push it down as far as it will go in order to align it with the exhaust manifold.

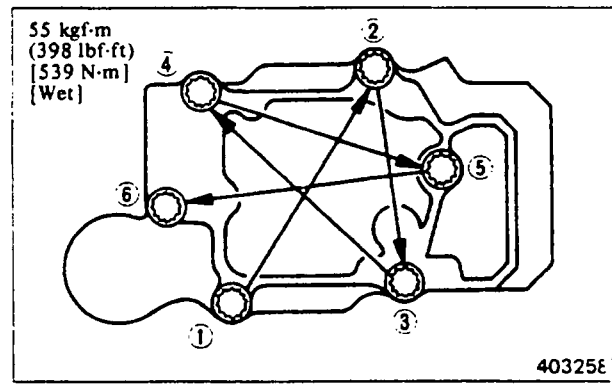


NOTE

Put the connector gasket in position with its side marked as "MANIFOLD" facing the connector.

(b) Attach eye nut (A) (37591-02400) to the stud bolt. Fasten a hoist to the eye nut with shackle, and lift the cylinder head assembly. Keep the head assembly slightly lifted with the dowel pins entering their holes. Put engine oil on the threads of cylinder head bolts and bolt seats, and put the bolts into the head assembly.

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



Cylinder head bolt tightening sequence

⚠ CAUTION

(a) Put the cylinder head bolts after engine oil has drained away.

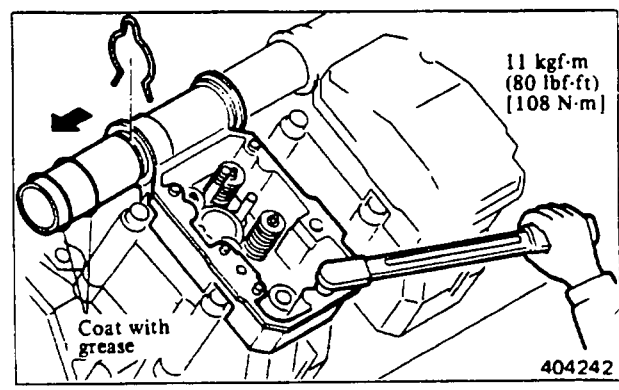
(b) Before installing the cylinder head assemblies, measure the projection of pistons, making sure the projection is correct. (Refer to (4), 2.2.)

(5) Installing rocker cases

(a) Put the water outlet connector all the way into the rocker case.

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

(c) Coat the O-rings of water outlet connector with grease, install the connector by putting it from the adjacent rocker case, and fit the snap ring.

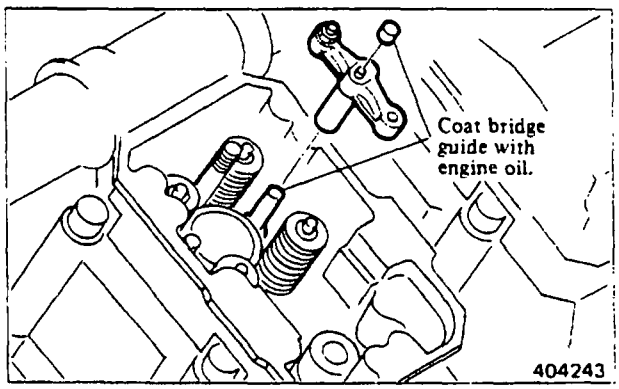


(d) Tighten the rocker case mounting bolts to the specified torque.

(6) 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.

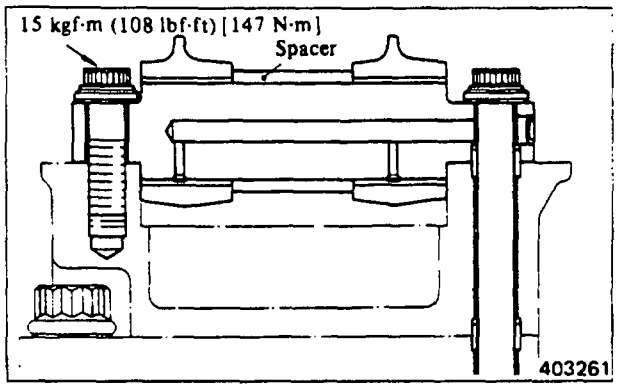
(b) Coat the bridge contact face of bridge caps with engine oil, and put the caps in position, being careful not to drop them into the crankcase through pushrod holes.



(7) Installing rocker shaft assemblies

(a) Put the rocker interposed between spacers on each end of the rocker shaft.

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



⚠ CAUTION

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

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

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

(8) Installing injection nozzle assemblies

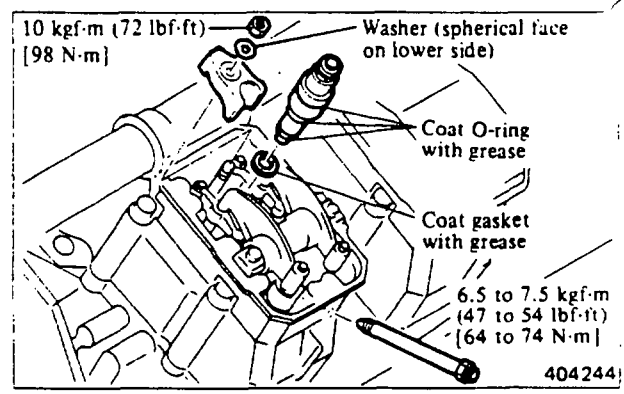
(a) Remove the fuel inlet connector from the nozzle assembly.

(b) Fit three O-rings to the nozzle, and apply grease to the rings.

(c) Apply a small amount of grease to the gasket, and put the gasket to the nozzle. Insert the nozzle assembly into the cylinder head while observing the center of connector mounting hole.

(d) Put and tighten the fuel inlet connector to the specified torque.

(e) Tighten the nozzle gland nut to the specified torque.



NOTE

(a) When tightening the fuel inlet connector, leave an equal space around it to prevent its interference with the cylinder head.

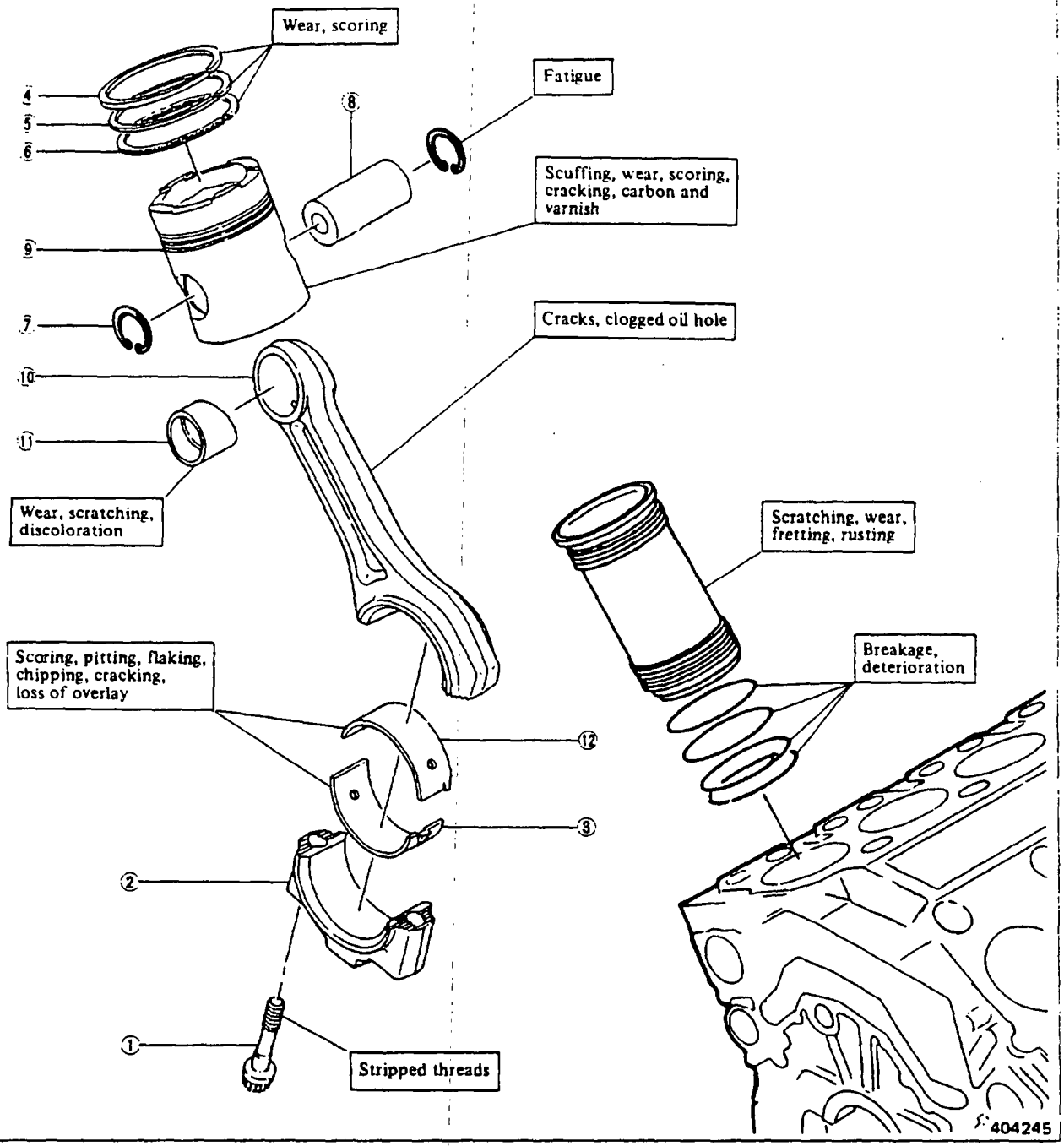
(b) Be sure to fit the gasket when installing the nozzle assembly.

(9) Adjusting valve clearance

Refer to 1.1, Group No. 5.

2. CYLINDER LINERS, PISTONS AND CONNECTING RODS

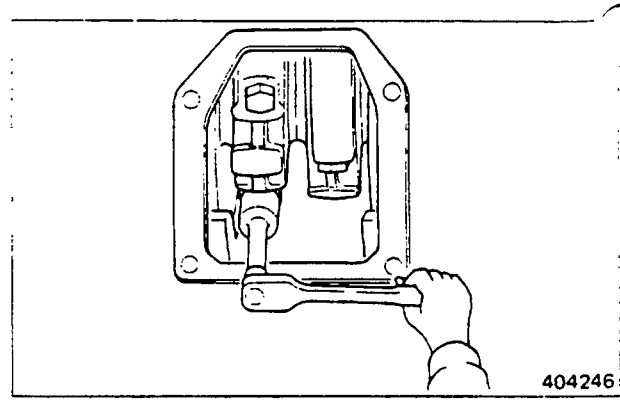
2.1 Disassembly



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

(1) Removing connecting rod caps

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



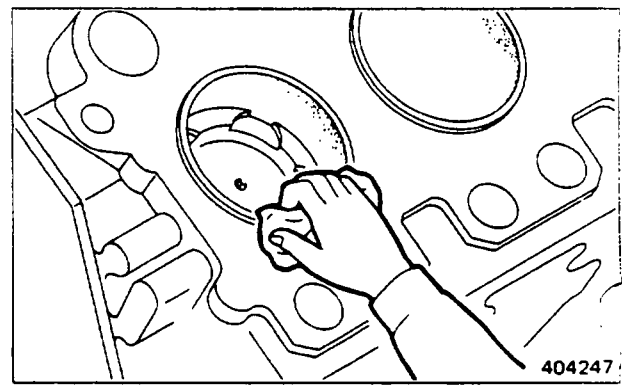
NOTE

(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

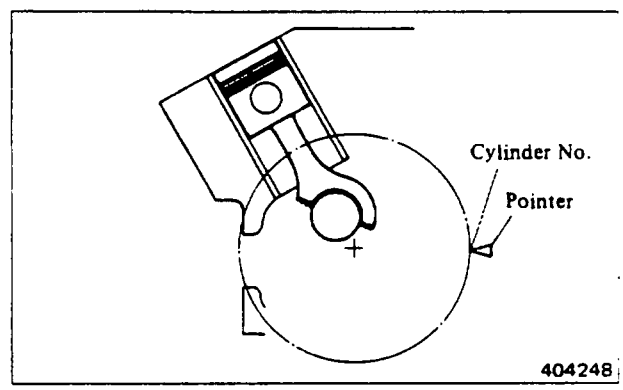
Remove all carbon and varnish from the upper areas of cylinder liners with rag or oil paper. Carbon or varnish, if any, will make it difficult to pull the pistons upward.



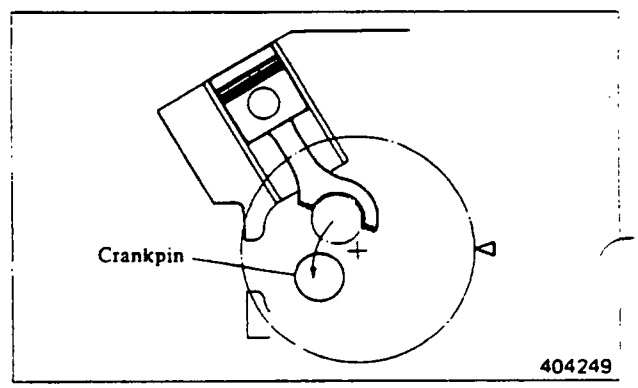
(3) Removing pistons

(Right-hand bank cylinders)

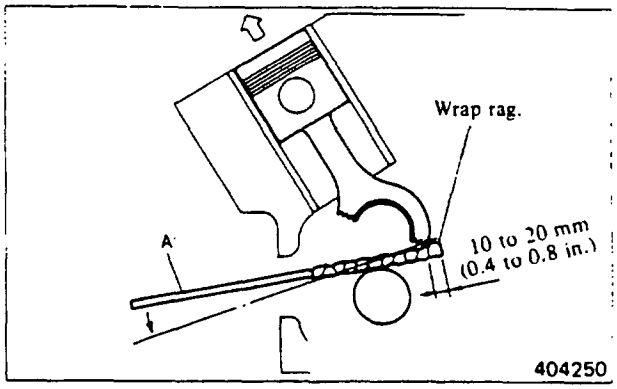
(a) Bring the piston assembly (from which the connecting rod bearing cap has been removed) to top dead center by turning the crankshaft.



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



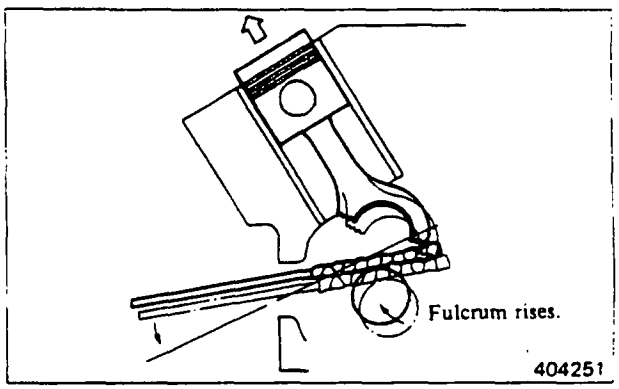
(c) Wrap rag over bar (A). Insert one end of the bar into the bolt hole in the connecting rod big end, and raise the piston assembly just a little by making use of the crankpin as a fulcrum.



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.

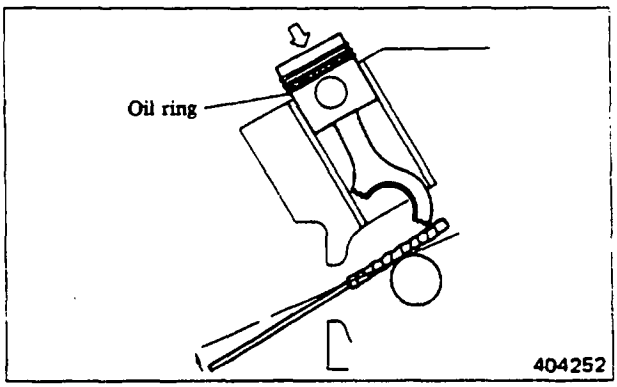
(d) Turn the crankshaft in the normal direction just a little at a time to raise the crankpin (fulcrum) while pushing down on the outer end of the bar to raise the piston assembly.



NOTE

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.

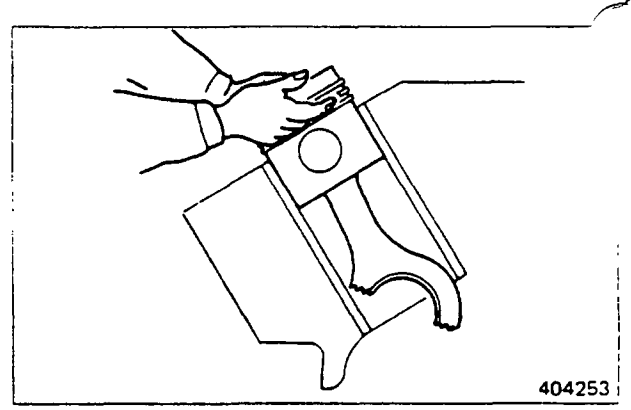


⚠ CAUTION

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

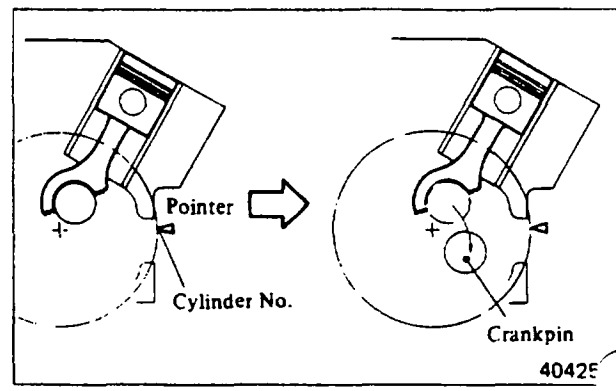
(f) Hold the compression ring portion of the piston by hands, carefully pull the piston from the cylinder liner, and rest its skirt on the top of crankcase.

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



(Left-hand bank cylinders)

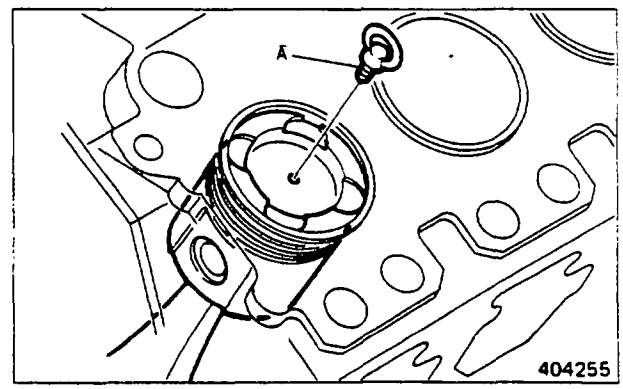
The pistons in the left-hand bank cylinders can be removed in the same procedure as for removal of those in the right-hand bank cylinders, but the crankpin positions and the crankshaft turning direction are reverse.



(Removing pistons with piston remover)

(a) In the right-hand bank, position the crank of a piston to be removed at about 50° before top dead center. In the left-hand bank, position it at about 50° after top dead center.

(b) Attach piston remover (A) (45815-32300) to the top of the piston, and lift off the piston and connecting rod.



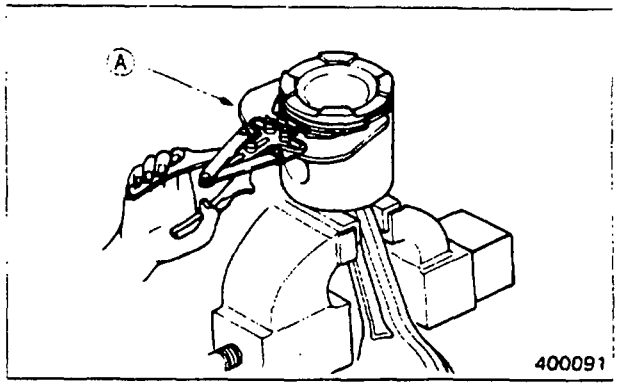
⚠ CAUTION

(a) The piston will swing when it comes out of the cylinder. Hold the piston to prevent its skirt from hitting against the connecting rod.

(b) Hold the connecting rod properly to prevent it from damaging the liner.

(4) Removing piston rings

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

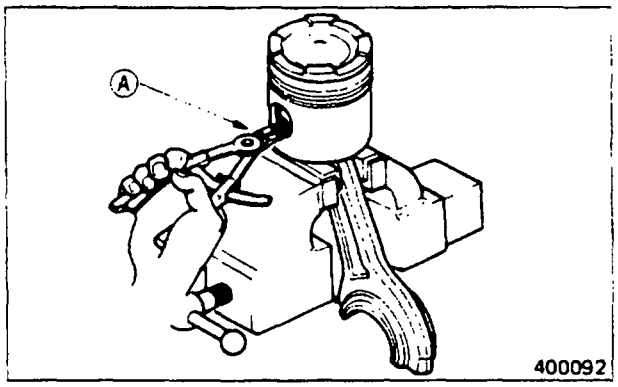


(5) Removing piston pin

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

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

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



2.2 Inspection and repair

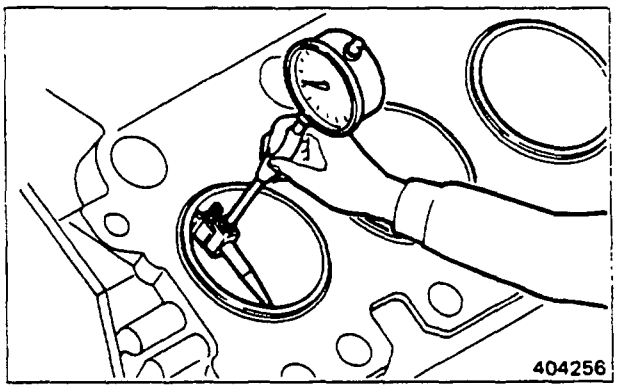
Cylinder liners

(1) Measuring inside diameter

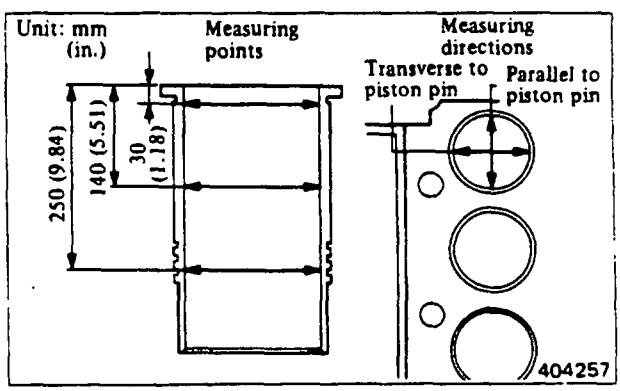
Measure the inside diameter of each liner in two directions, parallel and transverse to the piston pin, at three positions, top (ridged area), middle and bottom as shown. Replace the liner if it is worn in excess of the service limit.

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Inside diameter of cylinder liners	170 (6.69)	170.000 to 170.040 (6.69290 to 6.69447)	171.500 (6.75196)



Measuring cylinder liner



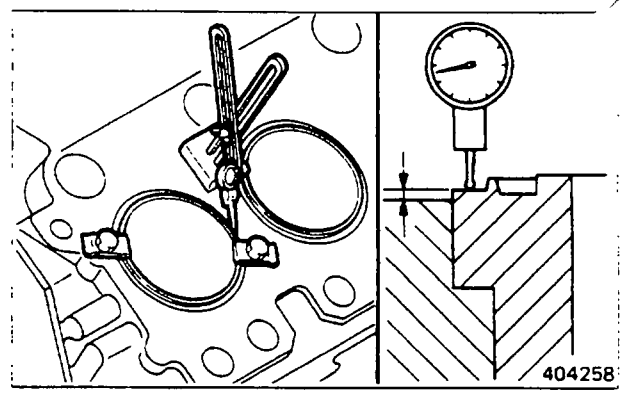
Cylinder liner measuring diagram

(2) Measuring projection

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

Unit: mm (in.)

Item	Assembly standard
Projection of cylinder liners	0.09 to 0.18 (0.0035 to 0.0071)



Measuring cylinder liner projection

⚠ CAUTION

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

(a) Clean the gasket contact surface of the crankcase and the top of the liners.

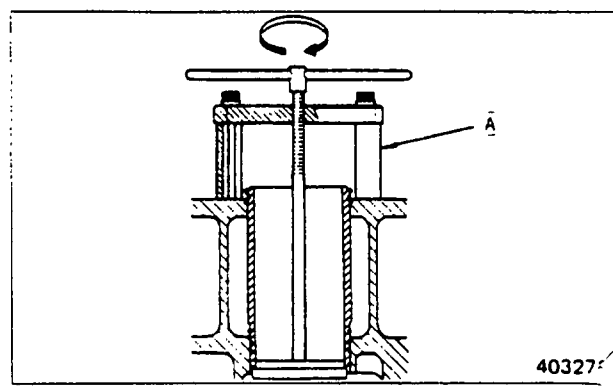
(b) Secure the top of the liner uniformly at two places with clamps and bolts (M22 x 2.5).

(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

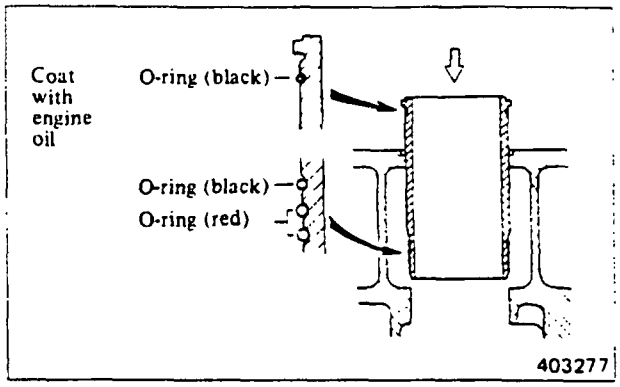
(a) Using cylinder liner remover (A) (37591-04100), remove the cylinder lines from the crankcase for replacement.



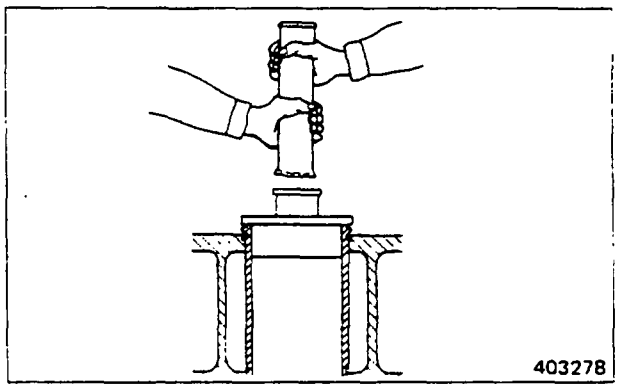
(b) Attach O-rings to each new cylinder liner, and carefully put the liner into the bore of the crankcase.

⚠ CAUTION

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



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



NOTE

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

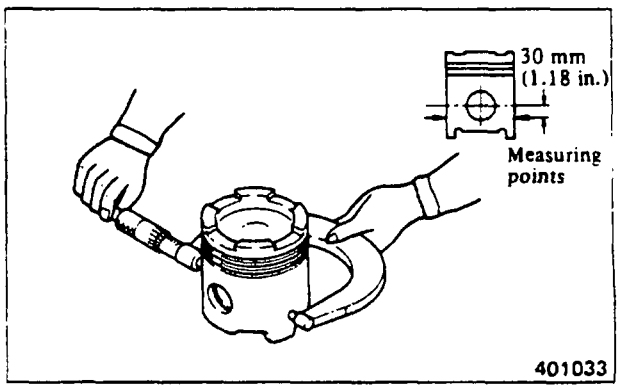
(b) Check to make sure the projection of each liner is within the assembly standard range.

Pistons

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

(1) Measuring diameter

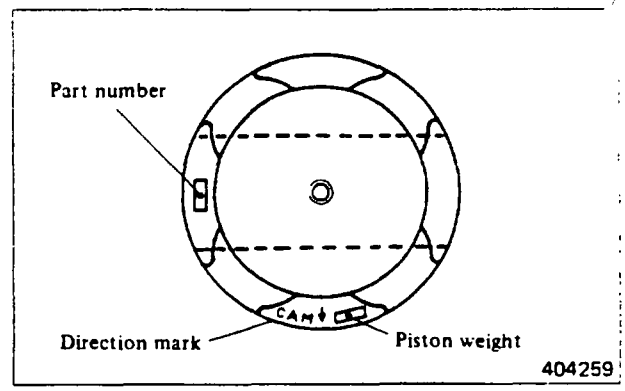
(a) Using a micrometer, measure the diameter of each piston in the direction transverse to the piston pin, at the position shown. Replace the piston if it (outside diameter) is worn in excess of the service limit. If any pistons have to be replaced, select new pistons so that the difference between average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



Measuring piston diameter

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Diameter of pistons	170 (6.69)	169.76 to 169.80 (6.6835 to 6.6850)	169.66 (6.6795)
Maximum permissible difference between average weight of all pistons in one engine	–	40 g (1.4 oz). maximum	–

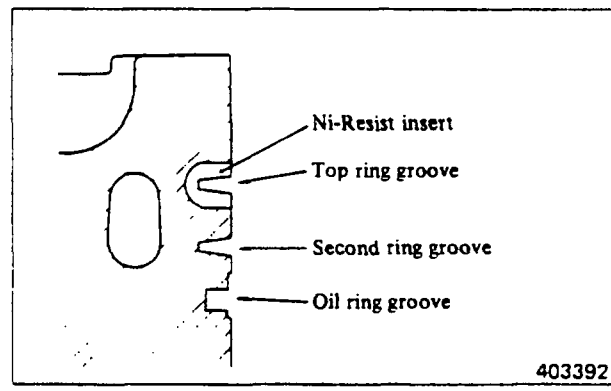


Piston weight stamp location

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

(2) Inspecting piston ring grooves

Check the piston ring grooves for wear and damage, and replace the piston if necessary.
Check the Ni-Resist insert for cracks, and replace the piston if the insert is cracked.



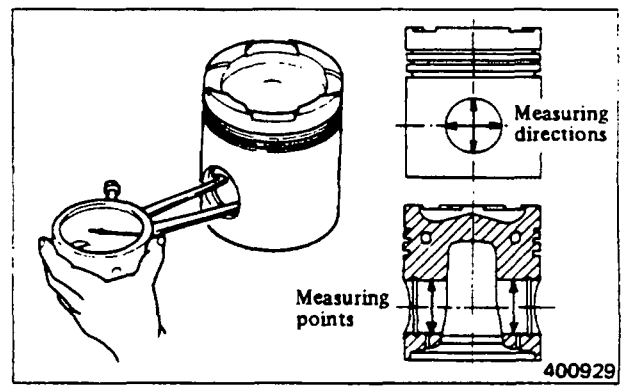
Piston ring grooves to be inspected

(3) Measuring inside diameter of piston pin bore

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

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Inside diameter of piston pin bore	70 (2.76)	70.002 to 70.015 (2.75598 to 2.75649)	70.020 (2.75669)



Measuring piston pin bore diameter

(4) Measuring piston projection

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

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

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

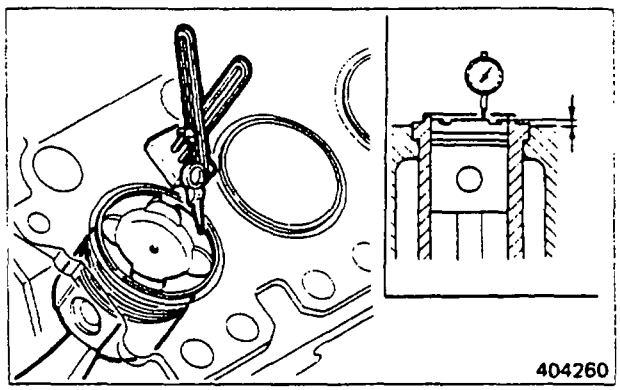
(c) Measure the projection at four places on the piston head, and average the four measurements to determine the projection. Subtract the piston projection from the asinstalled thickness of cylinder head gasket to determine the clearance between the piston top and cylinder head.

Unit: mm (in.)

Item	Assembly standard
Projection of pistons	0.06 to 0.65 (0.0024 to 0.0256)
As-installed thickness of cylinder head gasket	1.77 to 1.83 (0.0697 to 0.0720)
Clearance between piston top and cylinder head	1.22 to 1.95 (0.0480 to 0.0768)

⚠ CAUTION

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



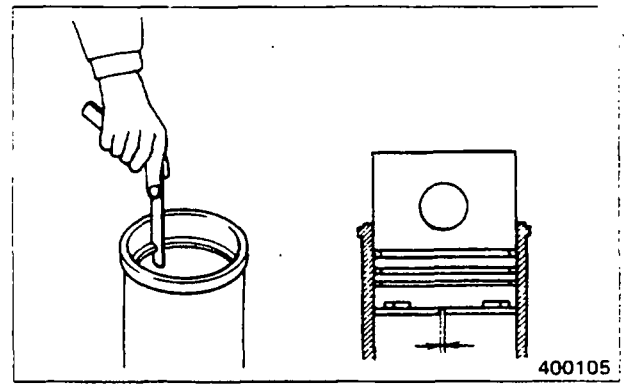
Measuring piston protrusion

(5) Measuring piston ring gaps

Put the rings in the 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: 170 ± 0 mm (6.69 ± 0 in.).

NOTE

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



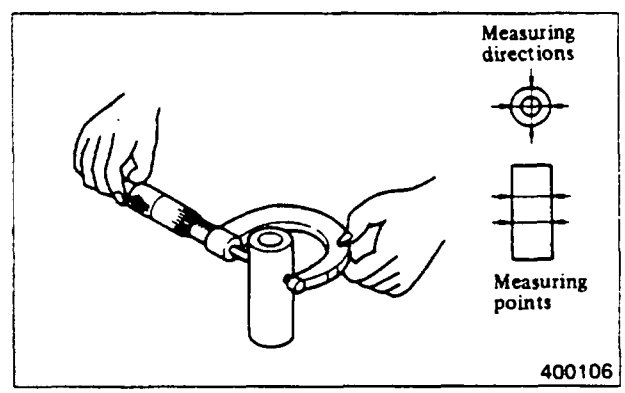
Measuring piston ring gap

Unit: mm (in.)

Item		Standard clearance	Service limit
Piston ring gaps	Top	0.6 to 0.8 (0.024 to 0.031)	2.0 (0.079)
	Second	0.6 to 0.8 (0.024 to 0.031)	
	Oil	0.3 to 0.45 (0.012 to 0.018)	

(6) Measuring diameter of piston pins

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



Measuring piston pin diameter

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Diameter of piston pins	70 (2.76)	69.987 to 70.000 (2.75539 to 2.75590)	69.970 (2.75472)

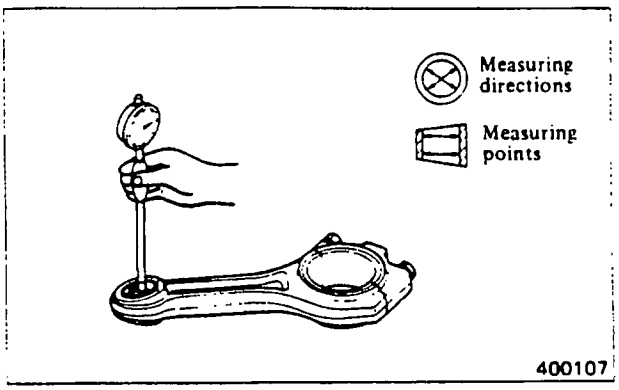
Connecting rods, connecting rod bearings and small-end bushings

(1) Measuring inside diameter of bushings

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

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Inside diameter of connecting rod bushings	70 (2.76)	70.020 to 70.040 (2.75669 to 2.75747)	70.070 (2.75866)



Measuring connecting rod small-end bushing inside diameter

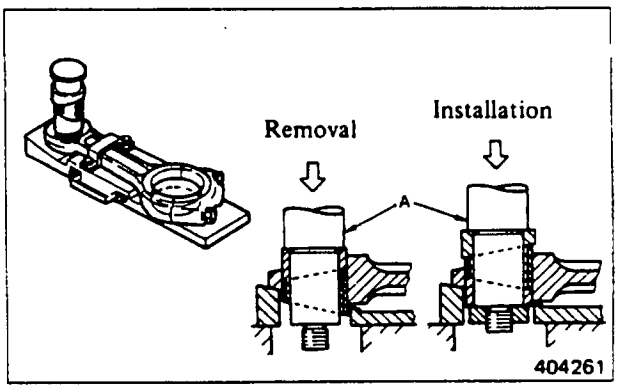
(2) Replacing bushings

(a) Using connecting rod bushing installer (A) (37591-01010), remove the bushing, as shown, for replacement.

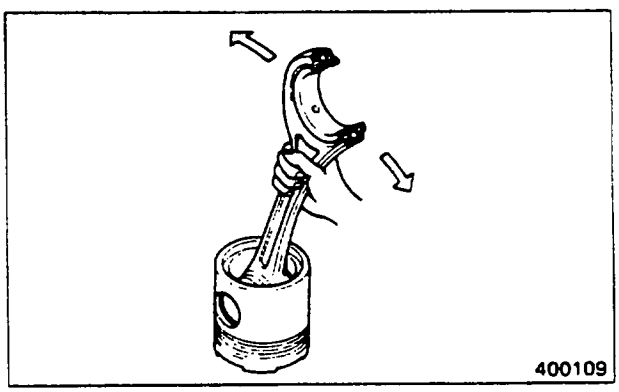
(b) When installing a replacement bushing, align oil holes in the bushing and connecting rod.

(c) After installing the bushing, ream its inside diameter to $70^{+0.040}_{+0.020}$ mm ($2.76^{+0.00157}_{+0.00079}$ in.) $\frac{1.6S}{\nabla\nabla\nabla}$ and its parallelism relative to the 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

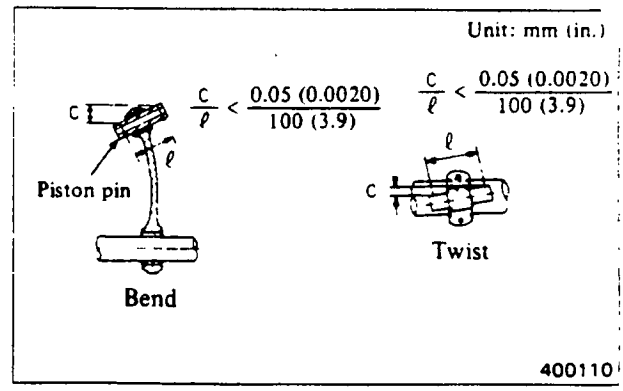


(3) Inspecting connecting rods for bend and twist

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

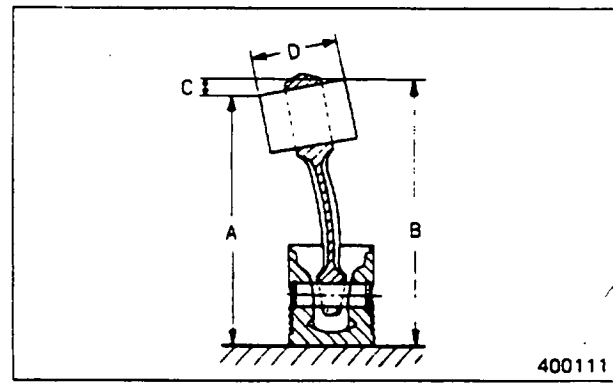


Inspecting connecting rod

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

Unit: mm (in.)

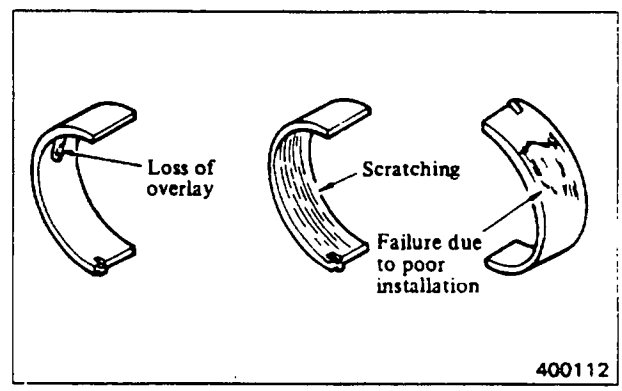
Item	Assembly standard
Connecting rod bend and twist (C/D)	0.05/100 (0.0020/3.9), maximum



Inspecting connecting rod installed to piston

(4) Inspecting connecting rod big-end bearings

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

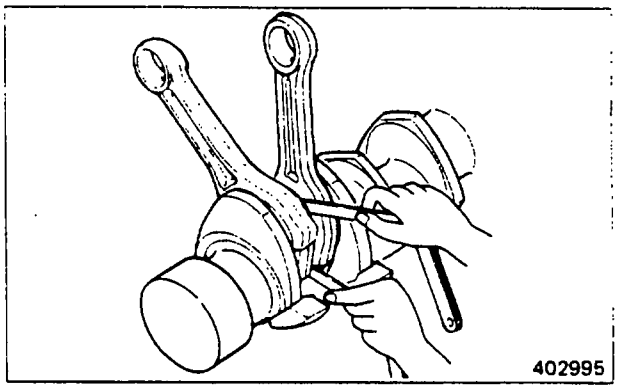


(5) Measuring connecting rod end play

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

Unit: mm (in.)

Item	Nominal value	Standard clearance	Service limit
End play of connecting rod (crankpin and big end widths)	60 x 2 (2.36x2)	(0.4 to 0.9) ((0.016 to 0.035))	(1.4) ((0.055))



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.

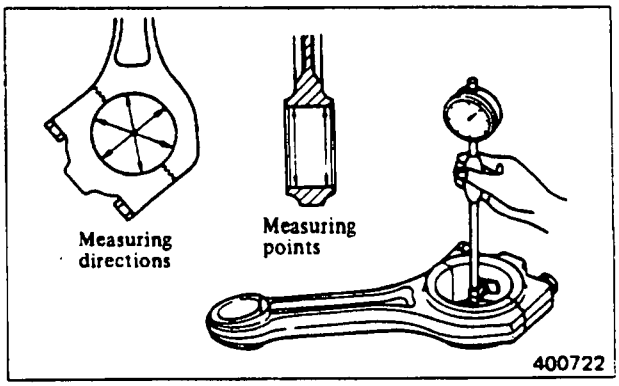
Item	Assembly standard
Max. permissible difference between average weight of all connecting rods in one engine	40 g (1.4 oz), maximum

(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	131 (5.16)	131.000 to 131.025 (5.15747 to 5.15845)	131.050 (5.15944)



Measuring connecting rod big-end bore diameter

(8) Measuring connecting rod bearing thickness

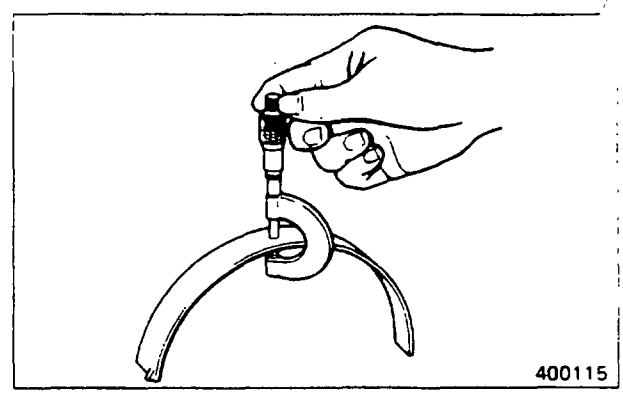
Using a ball-point type micrometer, measure the center of each bearing shell. If the thickness exceeds the service limit, on either upper or lower shell, replace both shells as a set.

Unit: mm (in.)

Item		Nominal value	Assembly standard	Service limit
Connecting rod bearing thickness	STD	3.000 (0.11811)	2.957 to 2.970 (0.11642 to 0.11693)	2.915 (0.11476)
	-0.25 (-0.0098)	3.125 (0.12303)	3.082 to 3.095 (0.12134 to 0.12185)	3.040 (0.11968)
	-0.50 (-0.0197)	3.250 (0.12795)	3.207 to 3.220 (0.12626 to 0.12677)	3.165 (0.12461)
	-0.75 (-0.0295)	3.375 (0.13287)	3.332 to 3.345 (0.13118 to 0.13169)	3.290 (0.12953)
	-1.00 (-0.0394)	3.500 (0.13780)	3.457 to 3.470 (0.13610 to 0.13661)	3.415 (0.13445)

NOTE

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



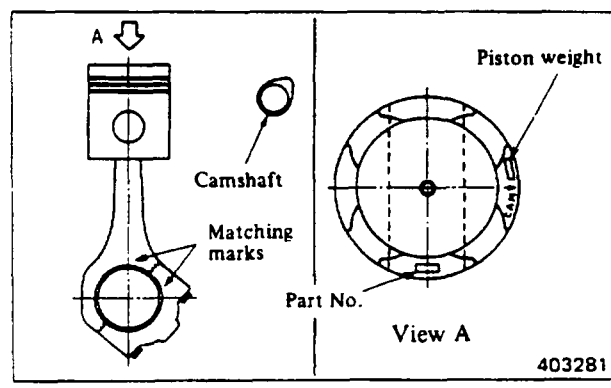
Measuring connecting rod bearing thickness

2.3 Reassembly

To reassemble, follow the reverse of disassembly procedure.

(1) Installing pistons to connecting rods

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

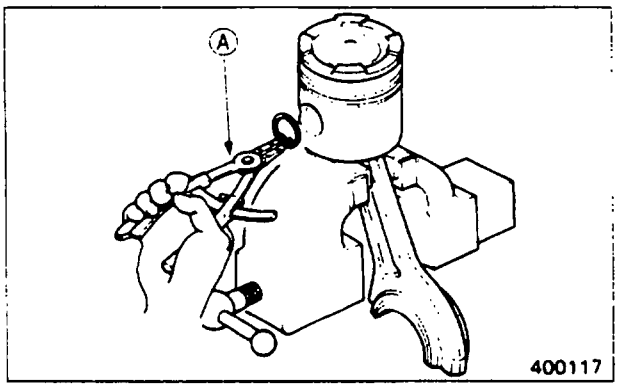


Matching marks on connecting rod

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

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

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



NOTE

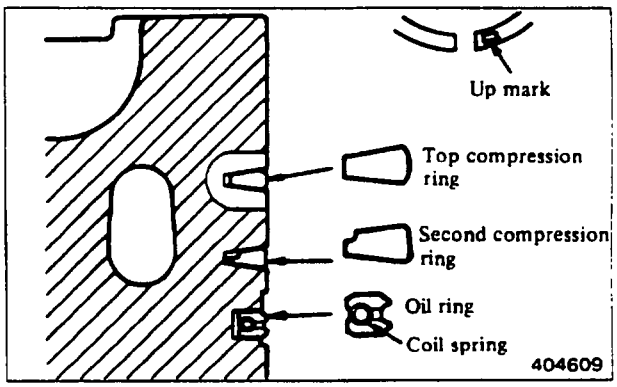
Positon the ends of both snap rings at the bottom of pin bore.

(2) Installing piston rings

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

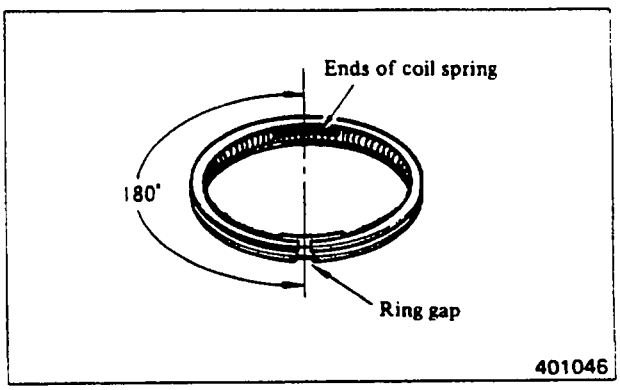
⚠ CAUTION

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



Piston and piston rings

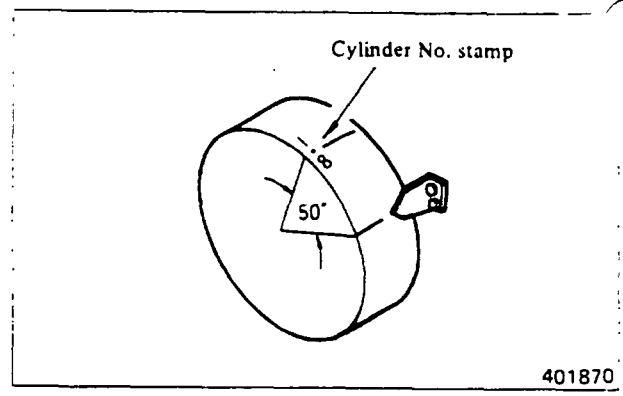
(b) Install the oil ring with its gap positioned at 180° to that of coil spring.



(3) Preparatory steps for installing pistons

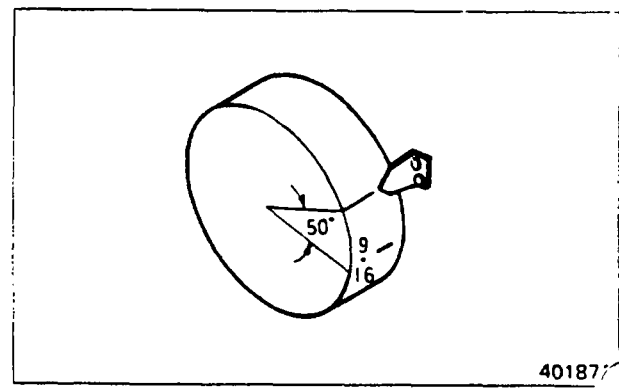
(a) Right-hand bank cylinders

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.

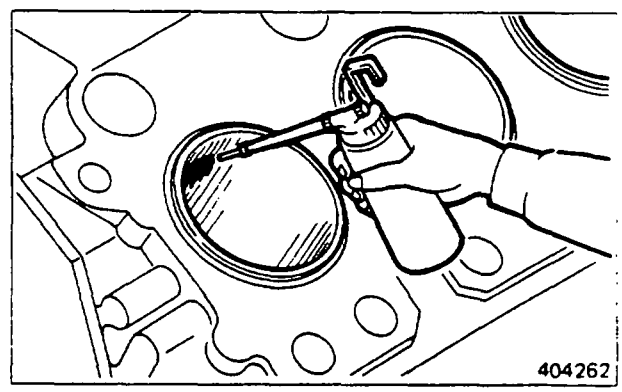


(b) Left-hand bank cylinders

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° after top dead center.

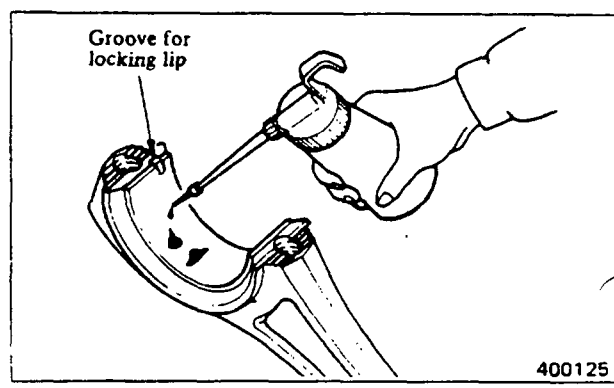


(c) Clean the cylinder liner bore surface and crankpin by wiping with rag, and coat it with engine oil.



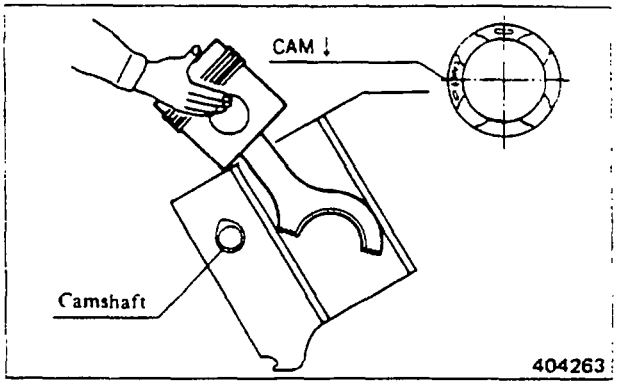
(4) Installing connecting rod bearings (upper shells)

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



(5) Installing pistons

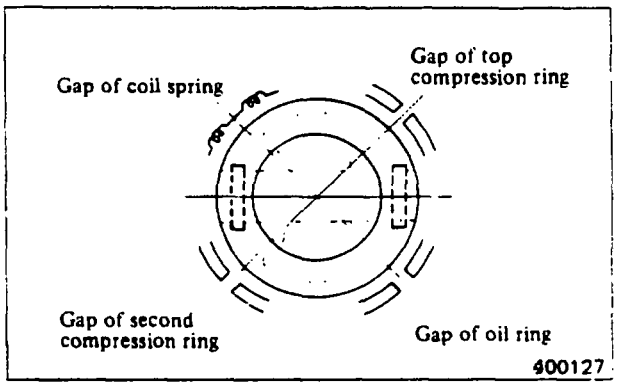
(a) Put the connecting rod in the cylinder liner, and carefully rest the piston on the top of crankcase.



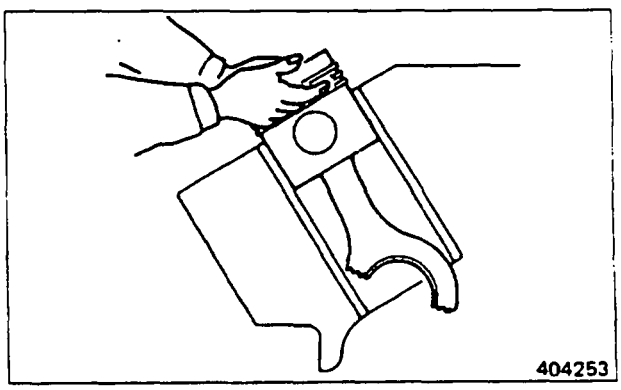
⚠ CAUTION

When inserting the piston assembly into the cylinder liner, make sure that CAM (arrow mark) points the camshaft side, and keep the connecting rod away from the piston cooling nozzle by looking into the inspection hole of crankcase. Do not attempt to rotate the piston.

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



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

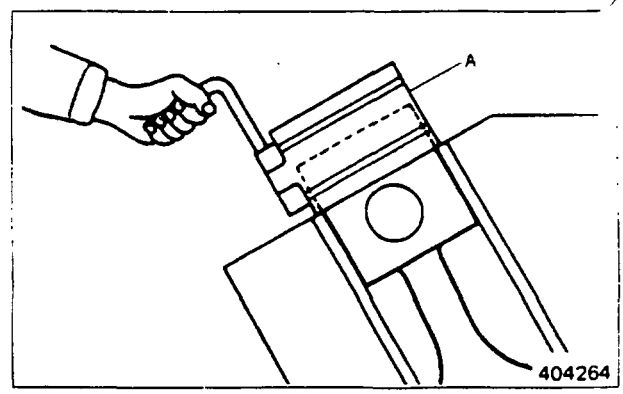


NOTE

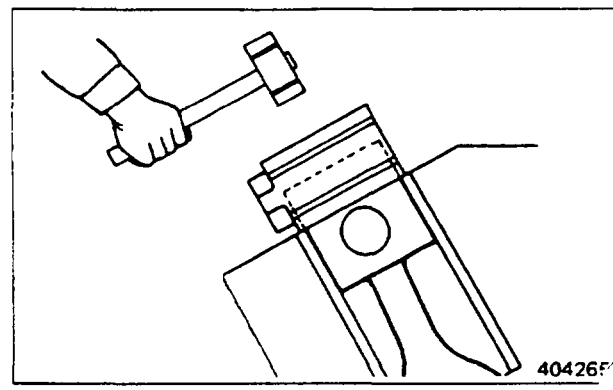
(a) Be careful not to get your little finger pinched between the oil ring and cylinder liner.

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

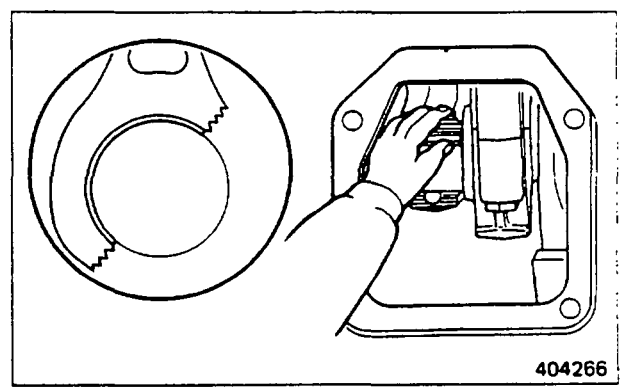
(d) After making sure that the piston ring gaps are positioned properly, coat the rings with engine oil, and clamp them with piston installer (A) (37191-07100). At this time, coat the inside surface of the installer with engine oil.



(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.



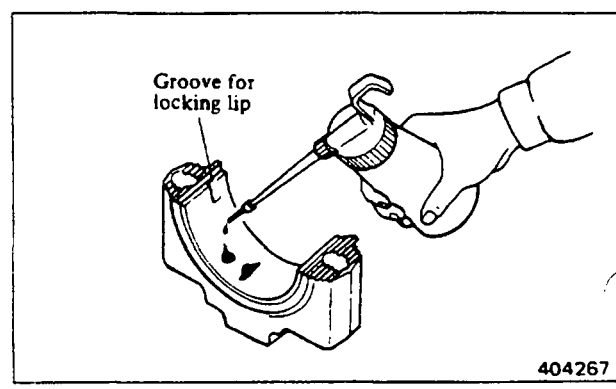
(f) Make sure the upper shell of the bearing is properly positioned in place in the connecting rod big end, by inserting the hand through the inspection hole of crankcase.
If the bearing shell is slightly out of place, reposition it by lightly pushing it by the palm of a hand.



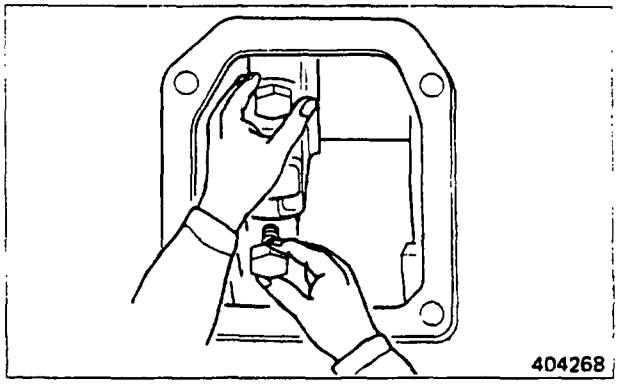
(6) Installing connecting rod caps

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

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



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

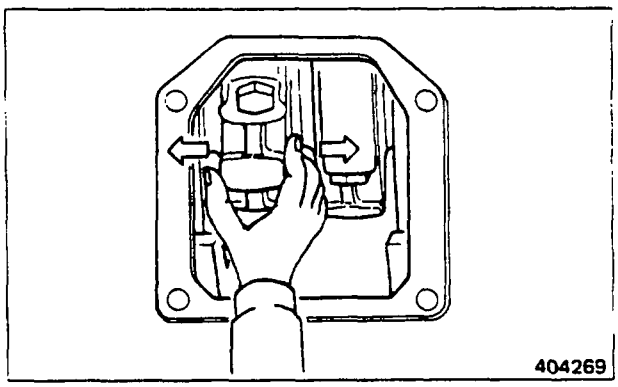


(d) With the bolts tightened temporarily, touch the joint between the cap and rod, making sure that the cap and rod surfaces are flush with each other, and tighten the bolts to the specified torque.

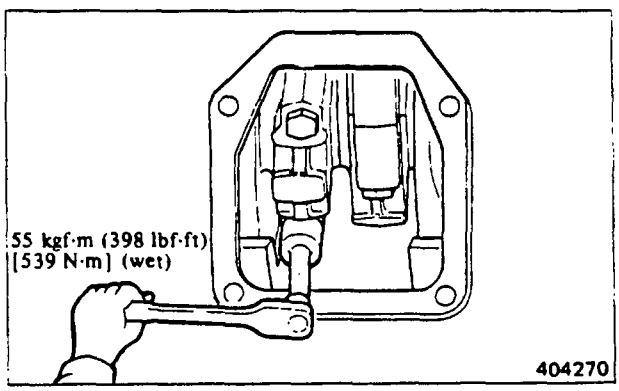
⚠ CAUTION

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

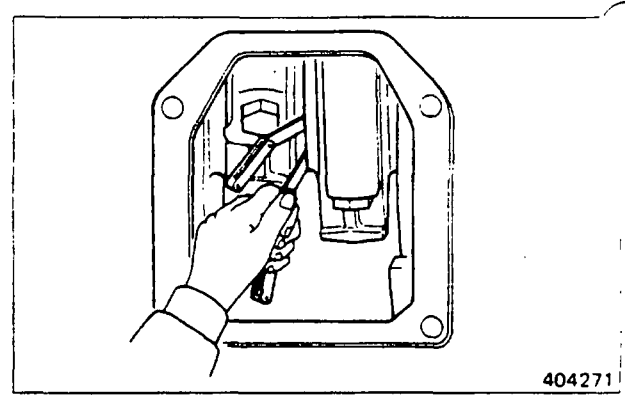
(e) Move the big end of each rod in the thrust direction, making sure that the rod has correct end play.



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



(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.)

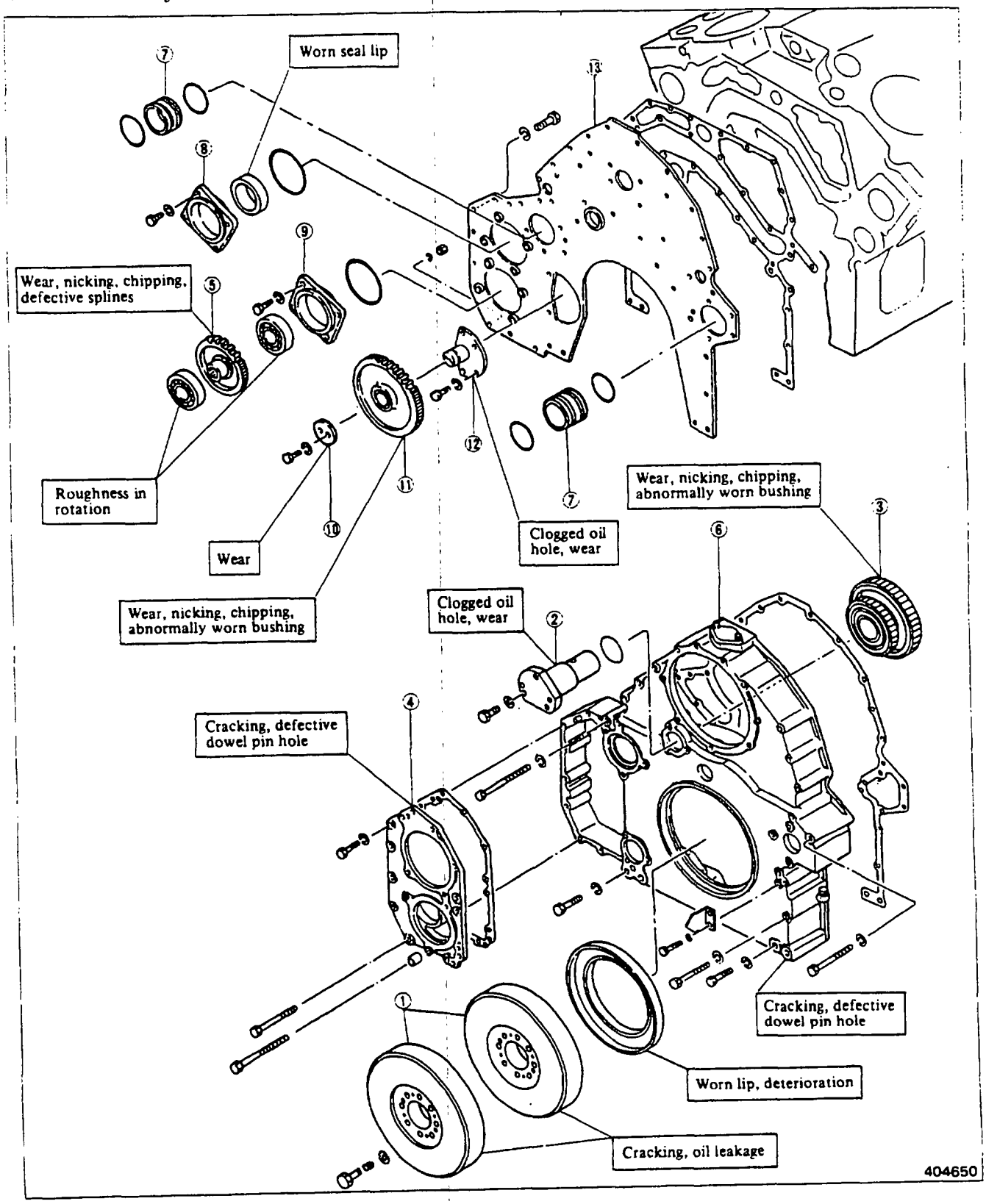


⚠ CAUTION

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

3. VISCOUS DAMPERS AND FRONT GEARS

3.1 Disassembly

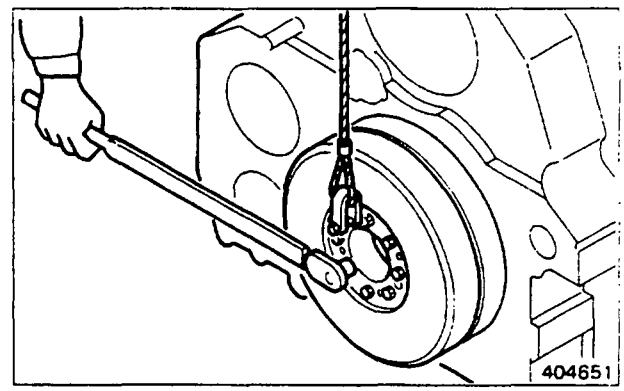


① Viscous dampers
② Fan drive idler gear shaft
③ Fan drive idler gear
④ Plate
⑤ Oil pump gear
⑥ Front gear case
⑦ Water coupling
⑧ Water pump bearing cover
⑨ Oil pump bearing cover
⑩ Thrust plate
⑪ Idler gear
⑫ Idler gear shaft
⑬ Front plate

(1) Removing viscous dampers

(a) Fasten a hoist to the viscous dampers. Unscrew the damper mounting bolts.

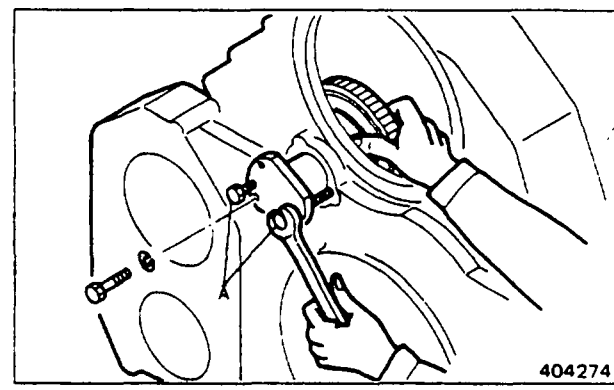
(b) Lift off the dampers by screwing two jacking bolts [M14 x 1.5 - 40 mm (1.57 in.)] into the front damper evenly.
[Weight of two dampers: 50 kg (110 lb), approx.]



(2) Removing fan drive idler gear and idler gear shaft

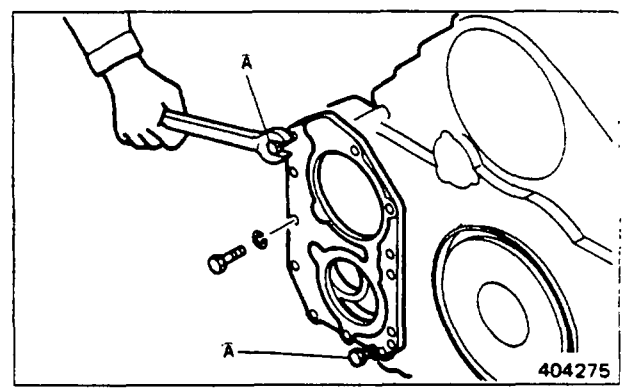
(a) Unscrew three bolts securing the idler gear shaft.

(b) Remove the idler gear shaft by screwing two jacking bolts (A) (64362-68500, M12 x 1.25) into the shaft evenly. At this time, hold the idler gear inside the drive case by hand put through the access hole.



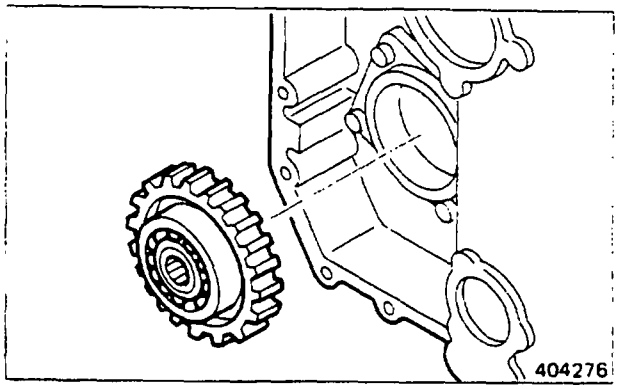
(3) Removing oil pump and water pump mounting plate

Unscrew the plate mounting bolts. Remove the plate by screwing two jacking bolts (A) (64362-68500, M12 x 1.25) into the plate evenly.



(4) Removing oil pump gear

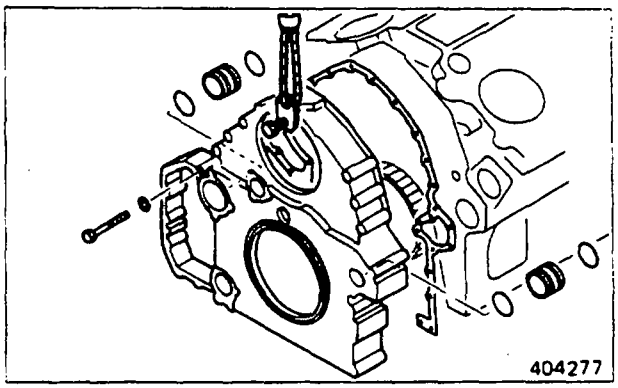
Remove the oil pump gear complete with the bearing.



(5) Removing front gear case

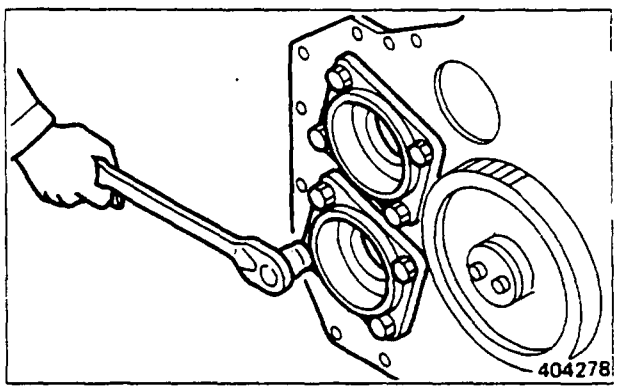
(a) Fasten a hoist to the front gear case.

(b) Unscrew the bolts securing the front gear case. Withdraw the gear case until the dowel pins come out and lift it off. When removing the gear case, be careful not to damage the oil seal or pointer.
[Weight of front gear case: 70 kg (154 lb), approx.]



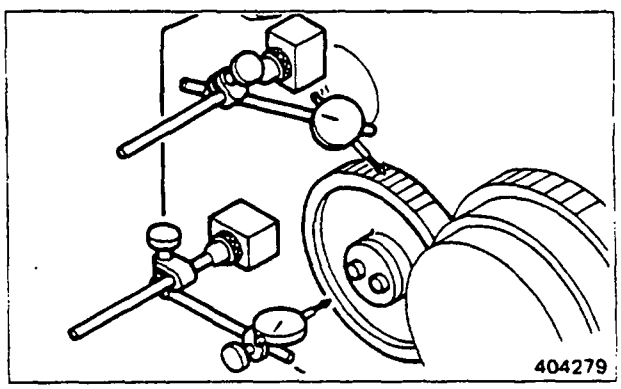
(6) Removing oil pump and water pump bearing covers

Remove the bearing covers by unscrewing the mounting bolts.



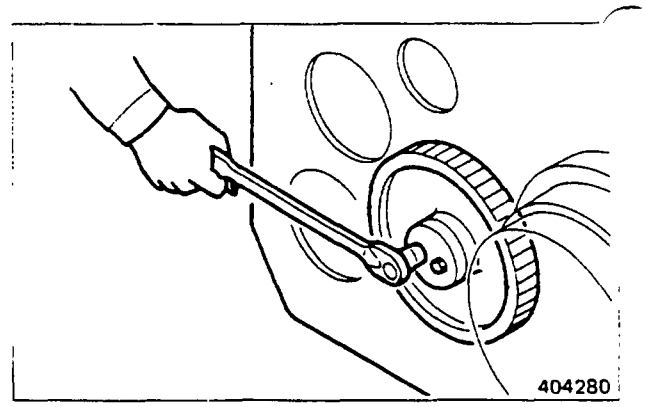
(7) Measuring idler gear backlash and end play

Measure the idler gear backlash and end play and make a record of these measurements.
(Refer to 3.2 Inspection and repair.)



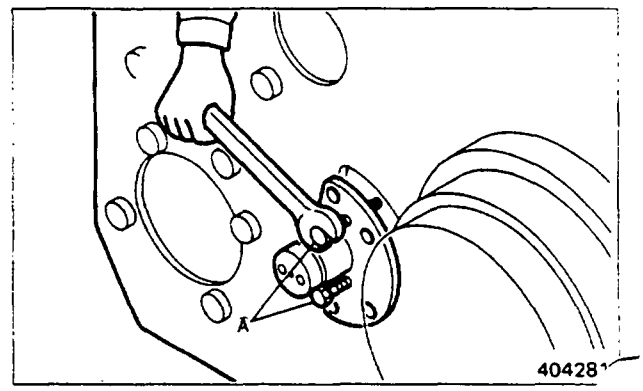
(8) Removing idler gear

Unscrew the bolts securing the thrust plate, and remove the idler gear from the shaft.



(9) Removing idler gear shaft

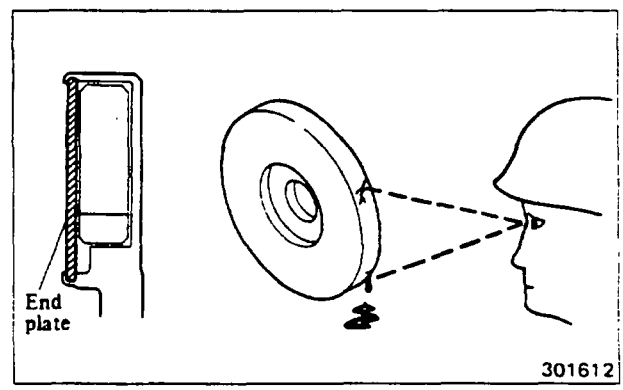
Do not try to remove the idler gear shaft unless replacement of the shaft is needed. To remove the shaft, unscrew the mounting bolts, and remove the shaft by screwing two jacking bolts (A) (M10 x 1.25) into the shaft evenly.



3.2 Inspection and repair

Inspecting viscous dampers

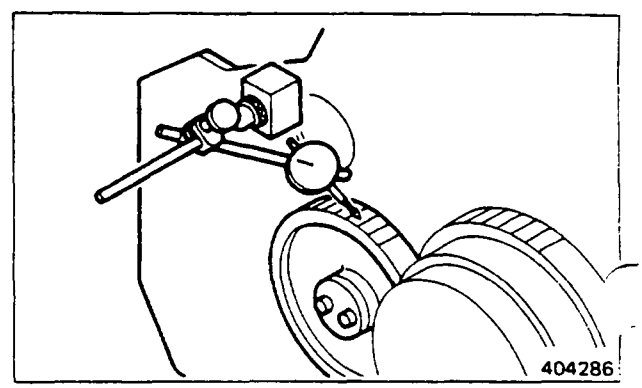
Visually check for cracks in the casing, swelling of the end plate, leakage of silicone fluid, discoloration of painted surface and flaking or blistering of painted surface. Replace the dampers every 8000 service hours because it is difficult to determine by visual inspection whether or not the dampers have expired in safe service life.



Inspecting viscous damper

Measuring gear backlash

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



Measuring gear backlash

Unit: mm (in.)

Item	Assembly standard	Repair limit	Service limit
Gear backlash	0.12 to 0.18 (0.0047 to 0.0071)	0.30 (0.0118)	0.50 (0.0197)

Oil pump drive

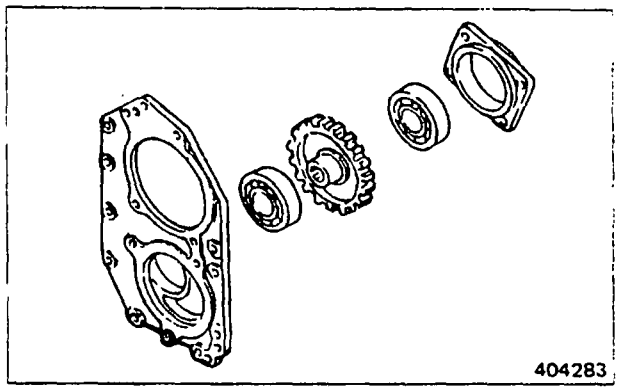
Diameter of bearing journals and inside diameter of bearing bores

Check each bearing for smooth rotation. Replace the bearing if it rotates roughly or hums.

Check the fit of the bearing inner race on the drive shaft, and replace a part whichever is badly worn.

Check the fit of the bearing outer race in the drive case, and replace a part whichever is badly worn.

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



Unit: mm (in.)

Item		Nominal value	Assembly standard
Inside diameter of bearing bore in cover		110 (4.33)	110.000 to 110.035 (4.33070 to 4.33208)
Inside diameter of bearing bore in plate			109.987 to 110.022 (4.33019 to 4.33157)
Bearings	Outside diameter	110 (4.33)	109.980 to 110.005 (4.32991 to 4.33090)
	Inside diameter	50 (1.97)	49.985 to 50.003 (1.96791 to 1.96862)
Diameter of gear shaft bearing journals		50 (1.97)	49.993 to 50.013 (1.96822 to 1.96901)

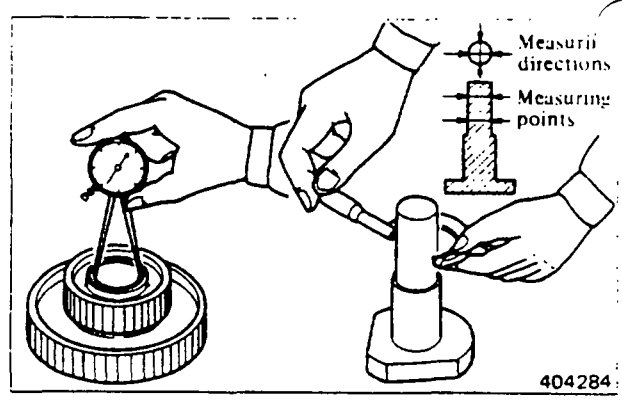
Idler gears, idler gear shafts and bushings

(1) Measuring diameter of fan drive idler gear shaft and inside diameter of bushing

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

Unit: mm (in.)

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



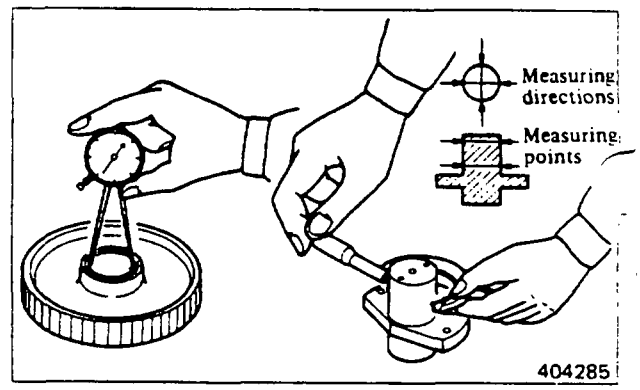
Measuring fan drive idler gear shaft and bushing

(2) Measuring diameter of idler gear shaft and inside diameter of idler gear bushing

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

Unit: mm (in.)

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



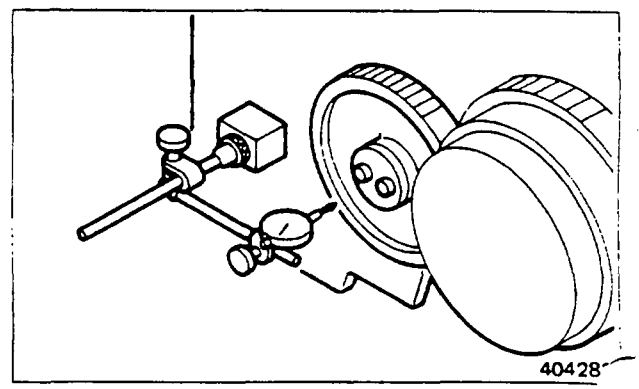
Measuring idler gear shaft and bushing

(3) Measuring end play of idler gears

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

Unit: mm (in.)

Item		Assembly standard	Service limit
End play	Idler gear	0.2 to 0.4 (0.008 to 0.016)	0.6 (0.024)
	Fan drive idler gear	0.25 to 0.75 (0.0098 to 0.0295)	1.2 (0.047)



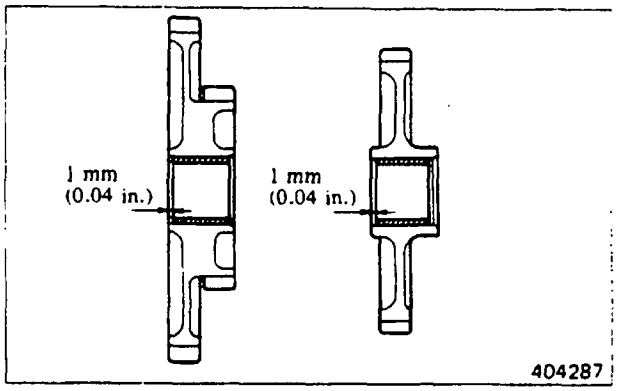
Measuring idler gear end play

(4) Replacing idler gear bushings

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

(b) Install a new bushing in the idler gear until its end face is 1 mm (0.04 in.) below the end face of the gear boss.

(c) After installing the bushing, make sure that its inside diameter is within the assembly standard. If it is less than the assembly standard, ream the bushing to finish its inside diameter to 50 $^{+0.025}_{0}$ mm (1.97 $^{+0.00098}_{0}$ in.) 1.6S.



Installing bushing

3.3 Reassembly

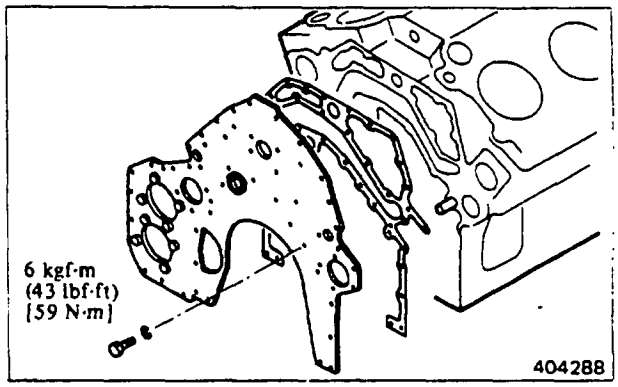
To reassemble, follow the reverse of disassembly procedure.

(1) Installing front plate

(a) Apply sealing compound to the front plate packing contact surface of the crankcase. Put the packing in position and, after applying the same compound to the packing, put the front plate in position.

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

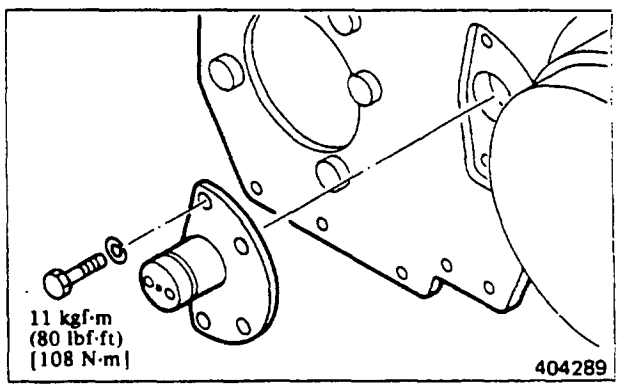
(c) Make sure the bottom end of the front plate is flush with the bottom of the crankcase.



(2) Installing idler gear shafts

(a) Using a guide bolt, drive the idler gear shaft into position.

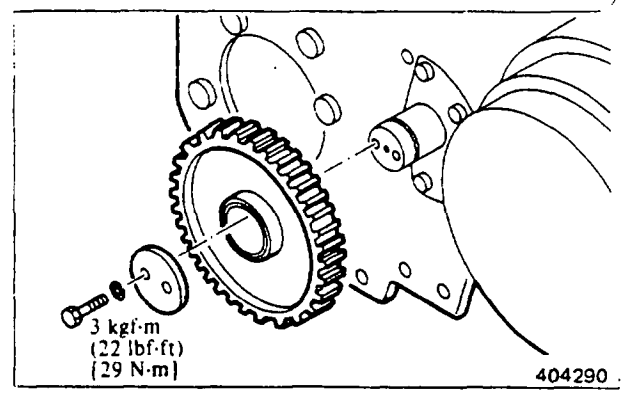
(b) Tighten the mounting bolts to the specified torque.



(3) Installing idler gears

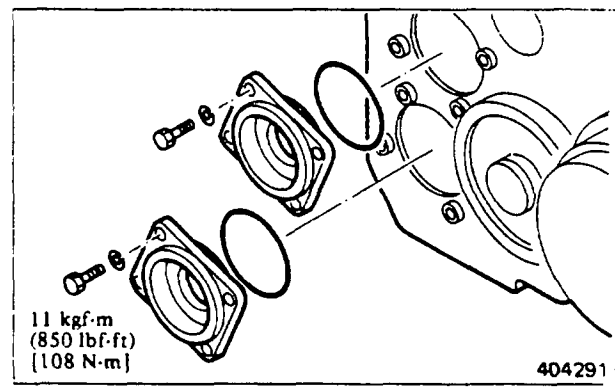
(a) Put the idler gear on the shaft, and install the thrust plate.

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



(4) Installing oil pump and water pump bearing covers

Put each bearing cover in position in the front plate, and tighten the mounting bolts to the specified torque.



(5) Installing front gear case and pointer

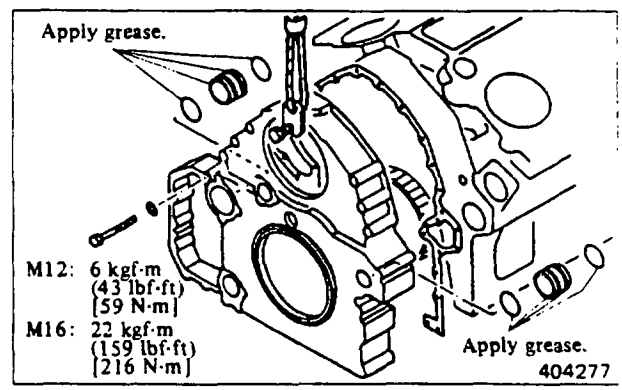
(a) Apply sealing compound to the front gear case packing contact surface of the crankcase. Put the packing in position and, after applying the same compound to the packing, put the front gear case in position.

(b) Fit the water coupling to the crankcase, and apply grease to the O-rings and O-ring holes. Install the gear case, using care not to damage the O-rings.

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

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

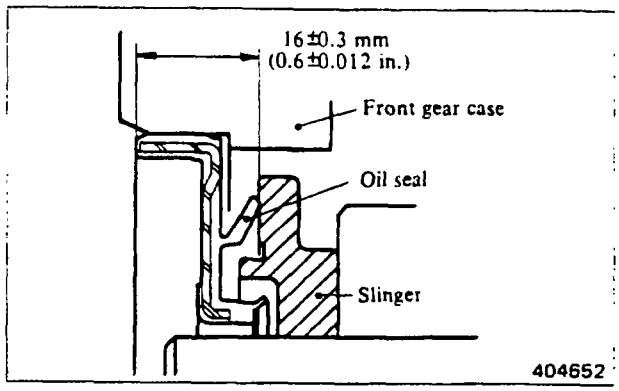
(e) Make sure the bottom face of the gear case is flush with the bottom of the crankcase. Cut off the excess of the packing neatly along the edge of the cover.



(f) Put the oil seal in position in the gear case.

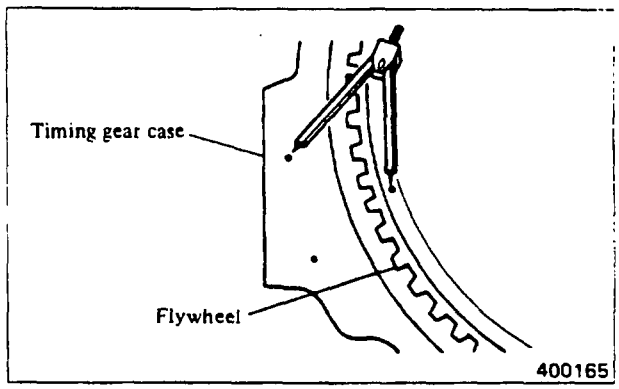
(g) Apply engine oil to the lip of the oil seal.

(h) Put the oil seal so that it is 16 ± 0.3 mm (0.6 ± 0.012 in.) from the slinger, as shown.



(When the pointer has been out of place)

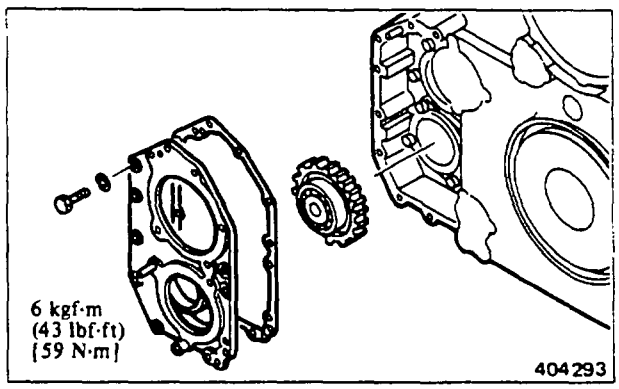
To determine the top dead center on compression stroke of No. 1 cylinder, for example, bring the mark on the flywheel to the position where it is at the equal distances from the two marks punched on the timing gear case.



(6) Installing oil pump and water pump mounting plate

(a) Put the oil pump gear in position.

(b) Put the plate in position, and tighten its mounting bolts to the specified torque.



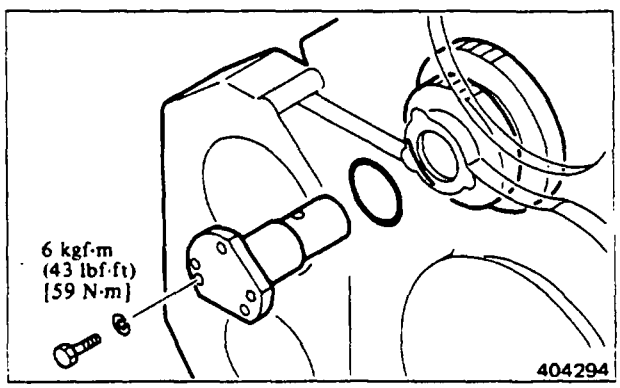
(7) Installing fan drive idler gear and shaft

(a) Put the idler gear in position through the hole, with the smaller gear on this side.

(b) Hold the shaft in alignment with the idler gear, and insert the shaft into position.

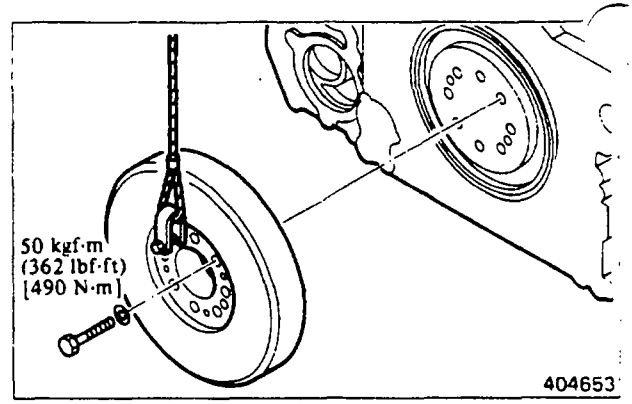
(c) Tighten the idler gear shaft mounting bolts to the specified torque.

(d) Make sure the end play and backlash of the gear are correct.



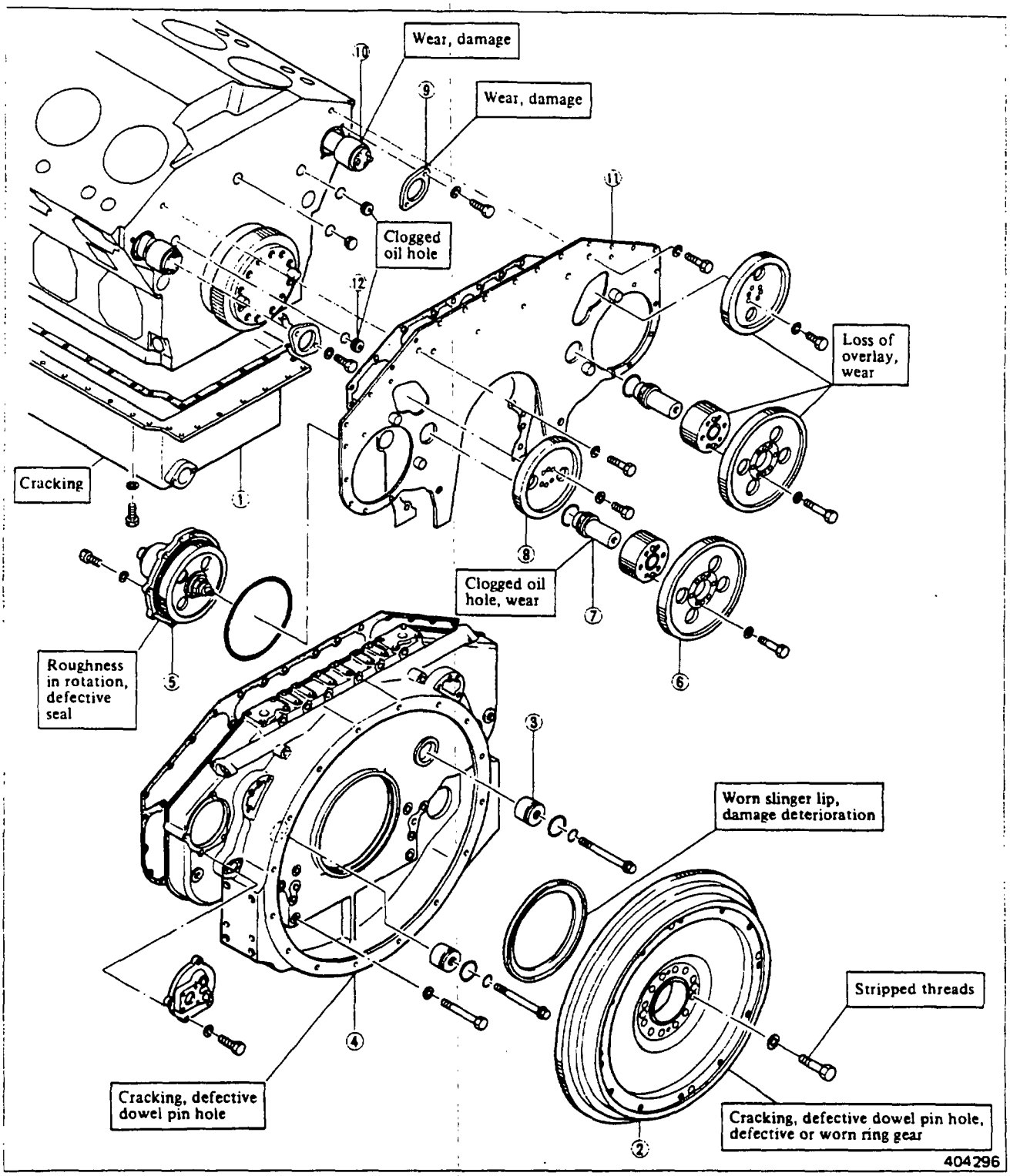
(8) Installing viscous dampers

Tighten the damper mounting bolts to the specified torque.



4. FLYWHEEL, TIMING GEARS AND CAMSHAFTS

4.1 Disassembly



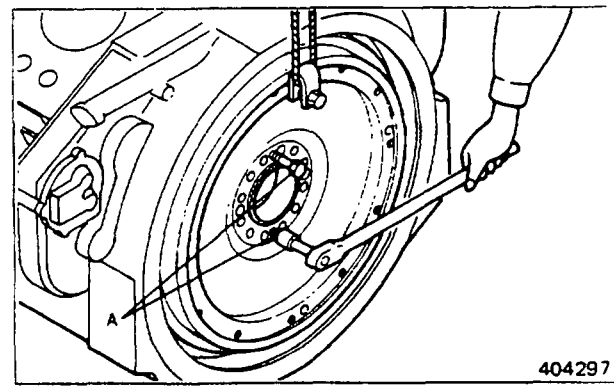
① Oil pan
② Flywheel
③ Idler gear shaft thrust collar
④ Timing gear case, oil seal
⑤ Fuel injection pump drive
⑥ Idler gear
⑦ Idler gear shaft
⑧ Camshaft gear
⑨ Thrust plate
⑩ Camshaft
⑪ Rear plate
⑫ Nozzle plate

(1) Removing flywheel

(a) Fasten a hoist to the flywheel.

(b) Unscrew the flywheel mounting bolts.

(c) Screw two jacking bolts (64362-68500, M12 x 1.25) into the holes in the flywheel evenly, and remove the flywheel.
[Weight of flywheel: 138 kg (304 lb), approx.]



⚠ CAUTION

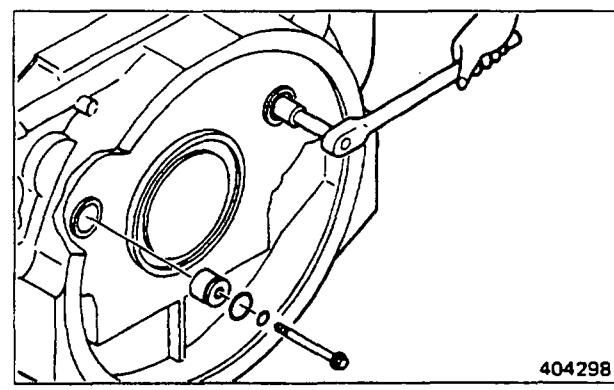
(a) When removing the flywheel, be careful not to drop or bump it against a hard object.

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

(2) Removing idler gear shaft thrust collars

(a) Unscrew the bolt securing each idler gear shaft thrust collar to the rear of timing gear case. Before removing the collar, put a mark on it for identification of idler gear to which it is to be installed.

(b) Remove the collar by screwing the bolt (M18 x 1.5) into its bolt hole.

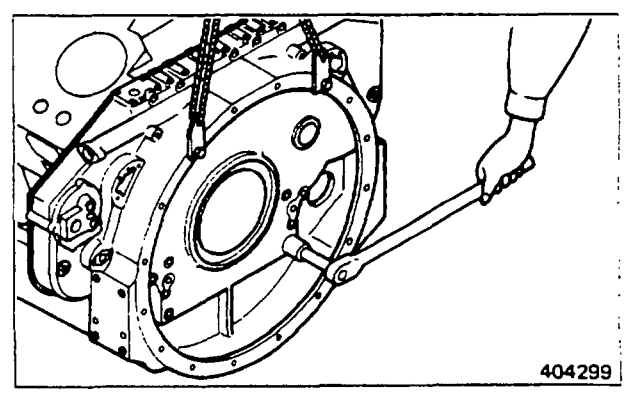


(3) Removing timing gear case

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

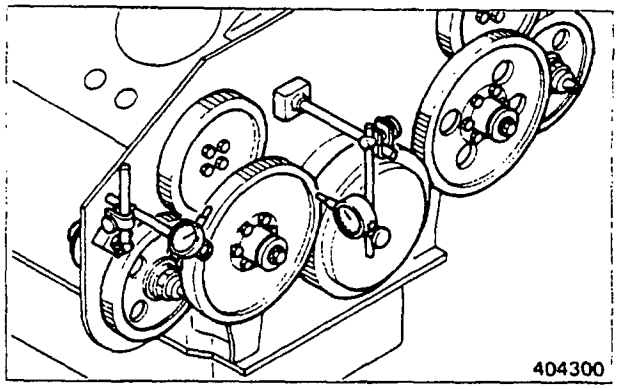
(b) Unscrew the mounting bolts.

(c) Pull out the case in suspended state until the dowel pins come out of the holes. Be careful not to damage the oil seal.
[Weight of timing gear case: 150 kg (330 lb), approx.]



(4) Measuring backlash and end play

Measure the backlash and end play of each gear to obtain the data for parts replacement.
(Refer to 4.2.)

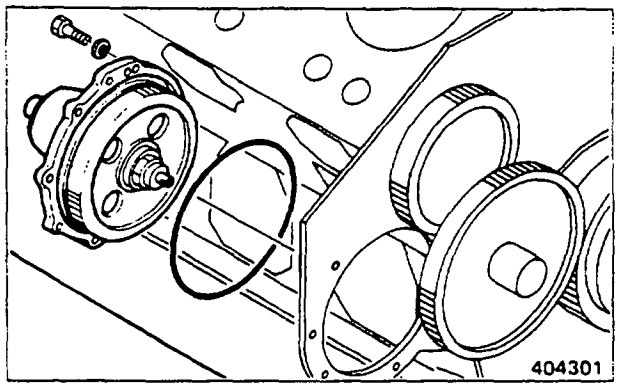


(5) Removing fuel injection pump drive cases (right-hand and left-hand)

Remove the right-hand drive case by unscrewing its mounting bolts. Be careful not to damage the gear teeth when removing the case.

NOTE

To remove the left-hand drive case, remove the No. 16 cylinder cam cover in advance.



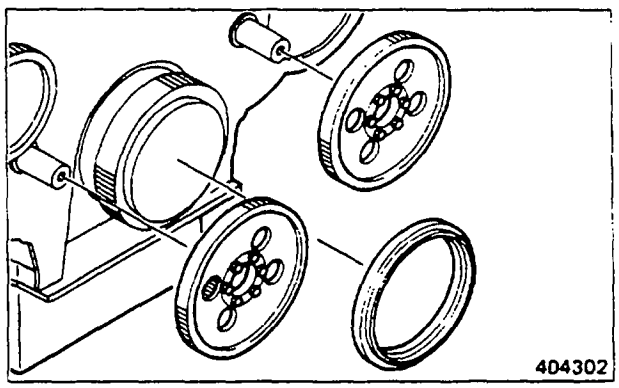
(6) Removing idler gears

(a) Remove the slinger from the crankshaft.
(Refer to (5), 5.2.)

(b) Remove the right-hand and left-hand idler gears.

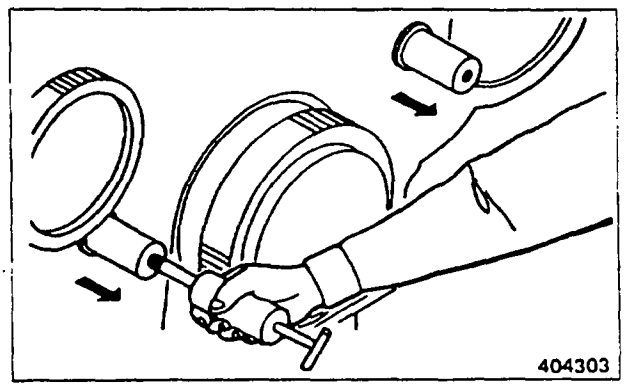
NOTE

To remove the idler gear without removing the slinger, unscrew six bolts holding the two gears.



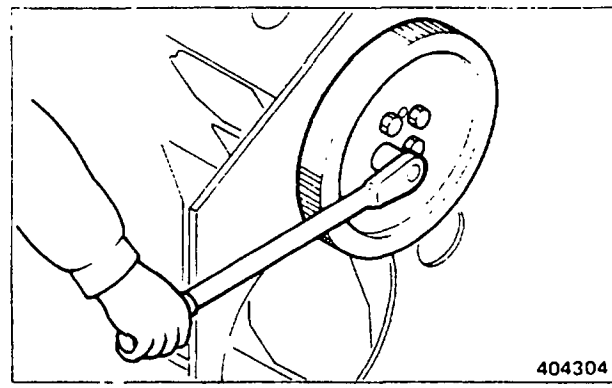
(7) Removing idler gears shafts

Do not attempt to remove the idler gear shafts unless replacement of the shafts is needed.
To remove each shaft, screw a sliding hammer into the jacking hole (M18 x 1.5) in the shaft.



(8) Removing camshaft gears

Remove the gear from each camshaft by unscrewing its mounting bolts.

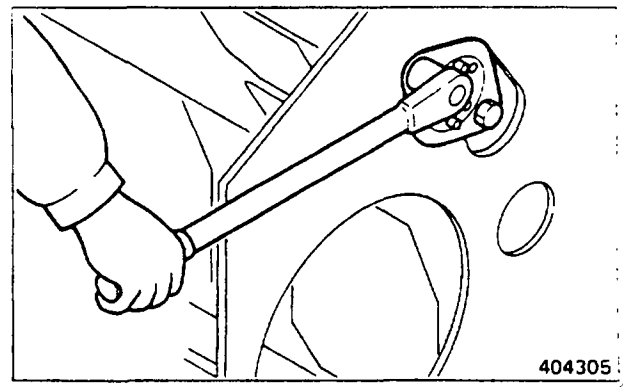


(9) Removing camshafts

Unscrew the bolts securing the thrust plate, and remove each camshaft from the crankcase.
[Weight of camshaft: 45 kg (100 lb), approx.]

⚠CAUTION

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

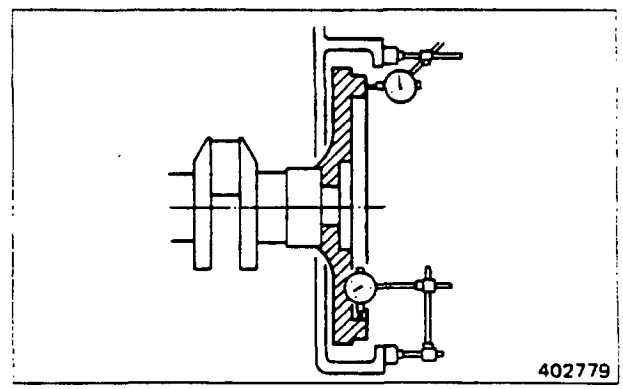


4.2 Inspection and repair

Flywheel and ring gear

Measuring axial and radial runouts 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
Axial runout	0.336 (0.0132), maximum
Radial runout	0.13 (0.0051), maximum

Fuel injection pump drives

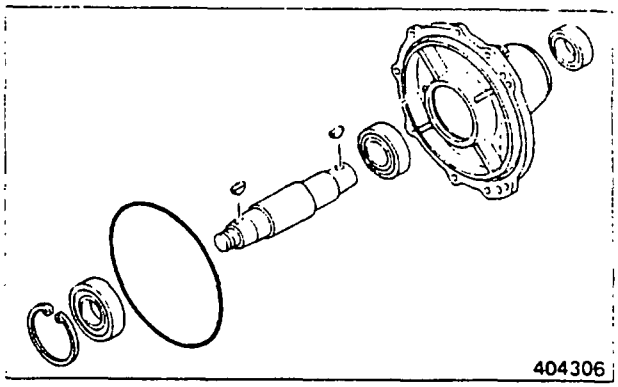
Inspecting fit of bearings

Check each bearing for smooth rotation. Replace the bearing if it rotates roughly or hums.

Check the fit of the bearing inner race on the drive shaft, and replace a part whichever is badly worn.

Check the fit of the bearing outer race in the drive case, and replace a part whichever is badly worn.

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



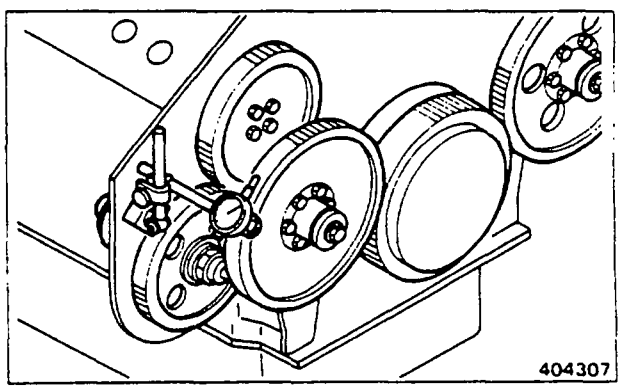
Unit: mm (in.)

Item		Nominal value	Assembly standard
Drive case bore inside diameter		90 (3.54)	89.987 to 90.022 (3.54279 to 3.54417)
		100 (3.94)	99.987 to 100.022 (3.93649 to 3.93787)
Bearings	Outside diameter	90 (3.54)	89.980 to 90.005 (3.54251 to 3.54350)
		100 (3.94)	99.980 to 100.005 (3.93621 to 3.93720)
	Inside diameter	45 (1.77)	44.985 to 45.003 (1.77106 to 1.77177)
		50 (1.97)	49.985 to 50.003 (1.96791 to 1.96862)
Drive shaft diameter		45 (1.77)	45.002 to 45.013 (1.77173 to 1.77216)
		50 (1.97)	50.002 to 50.013 (1.96858 to 1.96901)

Timing gears

Measuring backlash

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



Measuring timing gear backlash

Unit: mm (in.)

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

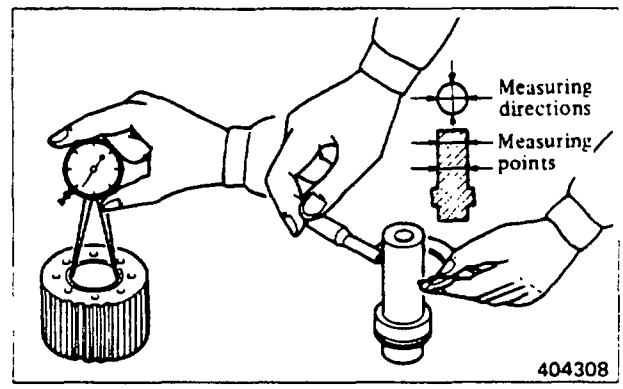
Idler gears, idler gear bushings and idler gears shafts

(1) Measuring diameter of idler gear shafts and inside diameter of bushings

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

Unit: mm (in.)

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



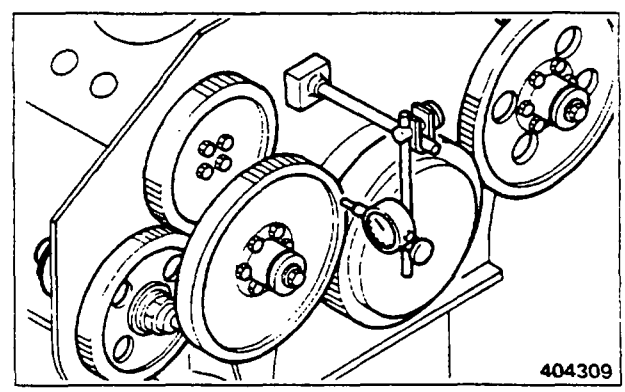
Measuring idler gear bushings and shafts

(2) Measuring end play of idler gears

Measure the end play of each idler gear with feeler gauge or dial indicator. Replace the thrust collar if the end play exceeds the service limit.

Unit: mm (in.)

Item	Standard clearance	Service limit
End play of idler gears	0.1 to 0.5 (0.004 to 0.020)	0.8 (0.031)



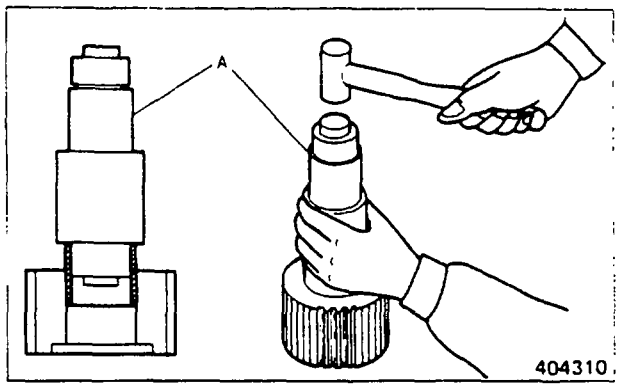
Measuring idler gear end play

(3) Replacing idler gear bushing

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

(b) Put a new bushing in the gear by pressing it from the boss side of the gear until the end face of the bushing is 1 mm (0.04 in.) below that of gear boss.

(c) After installing the bushing, make sure that its inside diameter is within the assembly standard. If it is less than the assembly standard, ream the bushing to finish its inside diameter to $50\ ^{+0.025}_{0}$ mm ($1.97\ ^{+0.00098}_{0}$ in.) 1.6S



Replacing idler gear bushing

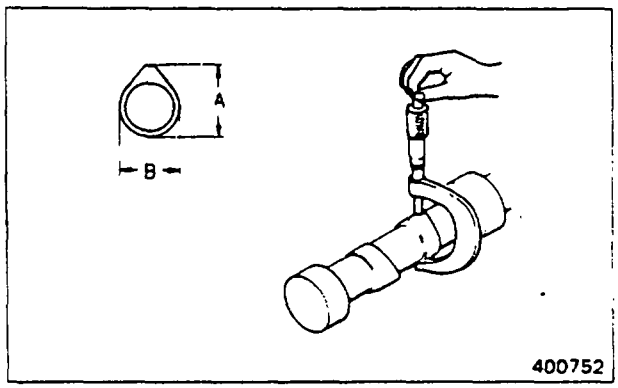
Camshafts and camshaft bushings

(1) Measuring cam lift

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

Unit: mm (in.)

Item	Assembly standard	Service limit
Lobe lift (A - B)	9.197 to 9.297 (0.36209 to 0.36602)	8.45 (0.3327)



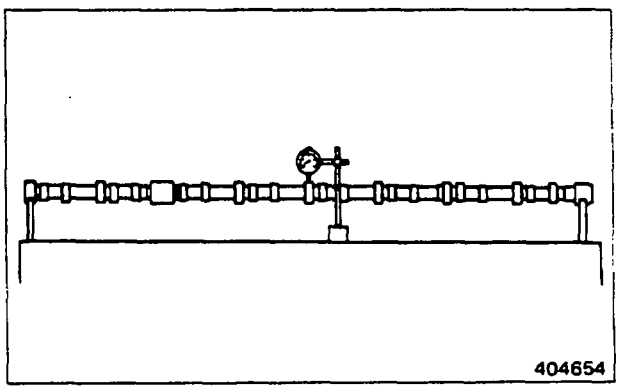
Measuring lobe lift

(2) Measuring camshaft runout

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

⚠ CAUTION

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



Measuring camshaft runout

Unit: mm (in.)

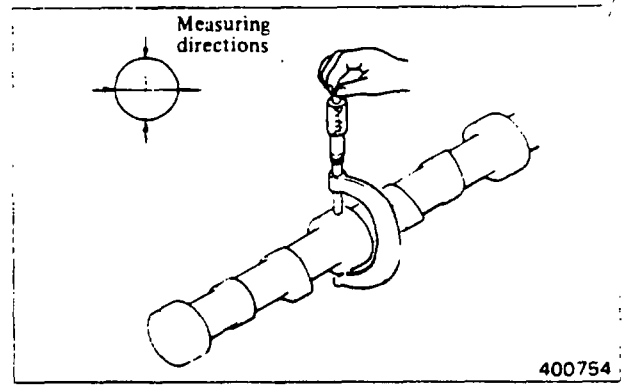
Item	Assembly standard	Repair limit
Camshaft runout	0.05 (0.0020), maximum	0.08 (0.0031)

(3) Measuring diameter of camshaft journals

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

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Diameter of camshaft journals	84 (3.31)	83.92 to 83.94 (3.3039 to 3.3047)	83.87 (3.3020)



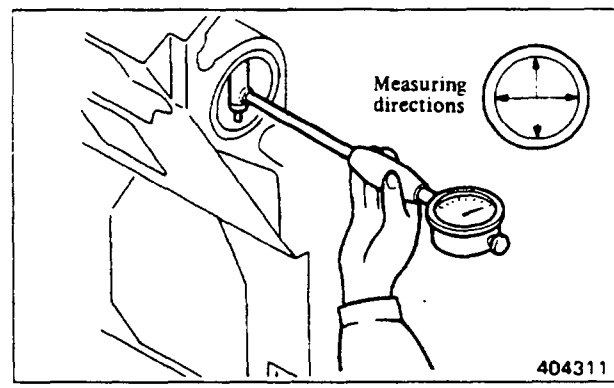
Measuring camshaft journal diameter

(4) Measuring inside diameter of camshaft bushings

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

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Inside diameter of camshaft bushings	84 (3.31)	84.000 to 84.035 (3.30708 to 3.30846)	84.10 (3.3110)



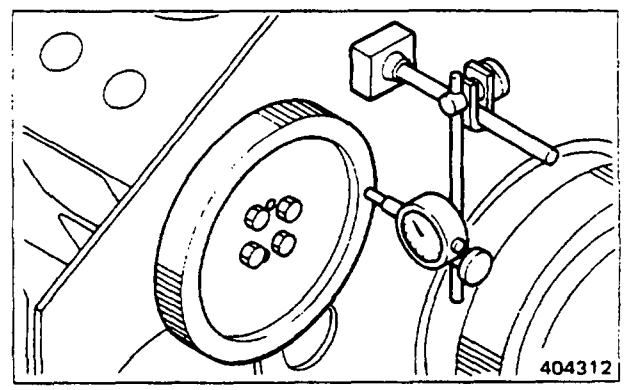
Measuring camshaft bushing inside diameter

(5) Measuring end play of camshafts

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

Unit: mm (in.)

Item	Standard clearance	Repair limit
End play of camshafts	0.10 to 0.25 (0.0039 to 0.0098)	0.40 (0.0157)

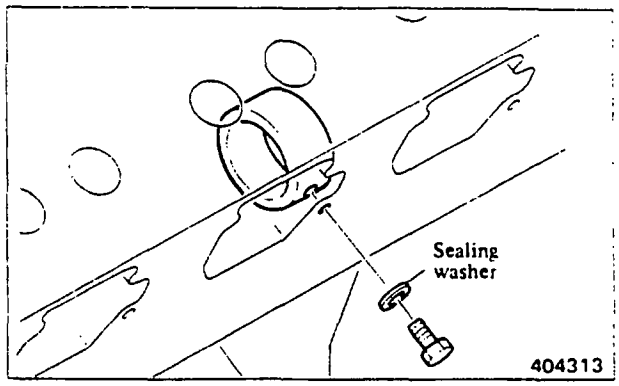


Measuring camshaft end play

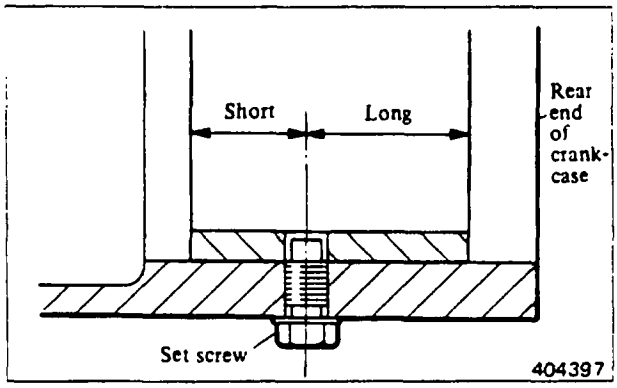
(6) Replacing camshaft bushings

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

Install the wide bushing at the rearmost journal correctly.



Replacing camshaft bushings



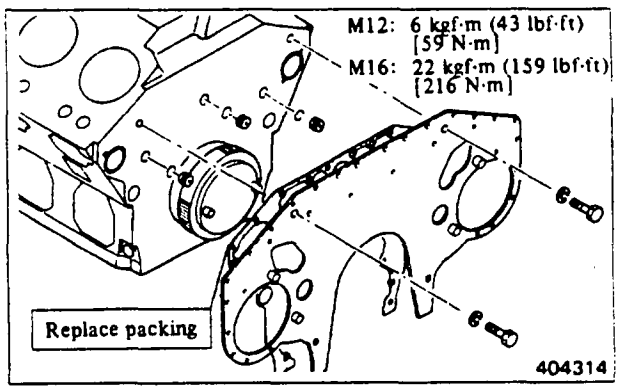
4.3 Reassembly

(1) Installing rear plate

(a) Apply sealing compound to the rear plate contact surface of crankcase, and put the packing in position. Apply the same compound to the packing, and install the rear plate in position.

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

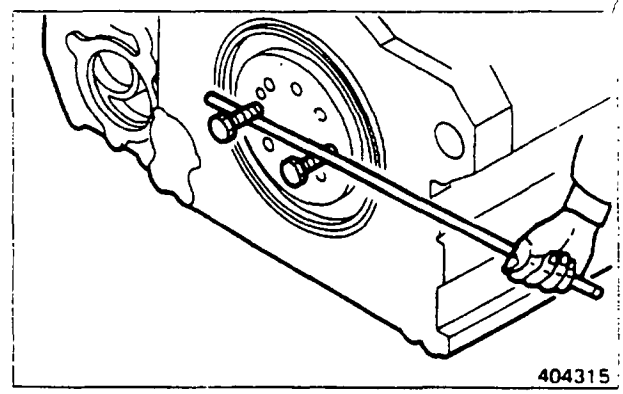
(c) Make sure that the lower end of rear plate is flush with the bottom of crankcase. Cut off the excess of the packing neatly along the edge of the plate.



(2) Cranking engine

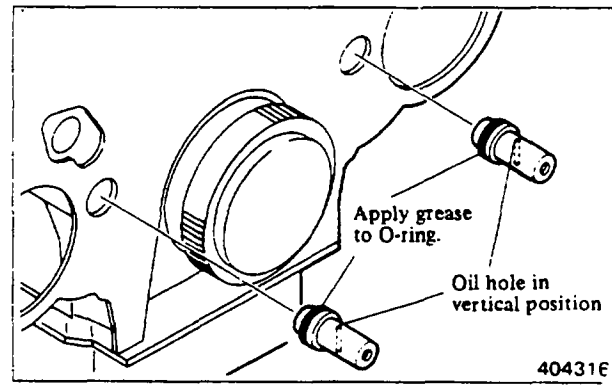
(a) Screw two bolts (M22 x 1.5) into the bolt holes in the viscous damper.

(b) Put a bar to the crankshaft, using the two bolts, turn over the crankshaft to bring No. 1 cylinder piston to top dead center on compression stroke.



(3) Installing idler gear shafts

Put the O-ring on the idler gear shaft. Apply grease to the O-ring, and drive the shaft into the crankcase. Make sure the oil hole in the shaft is in vertical direction.

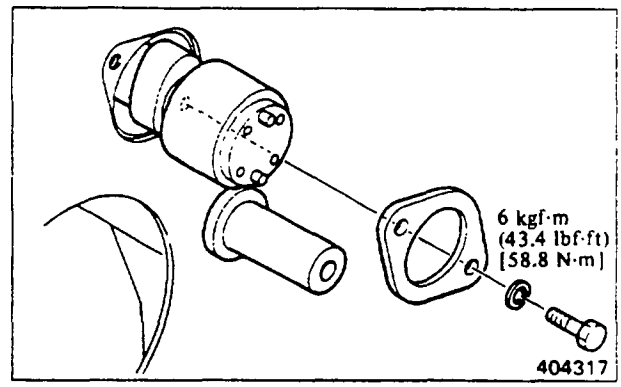


(4) Installing camshafts (right-hand and left-hand)

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

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

(c) Make sure that the camshaft rotates lightly.



NOTE

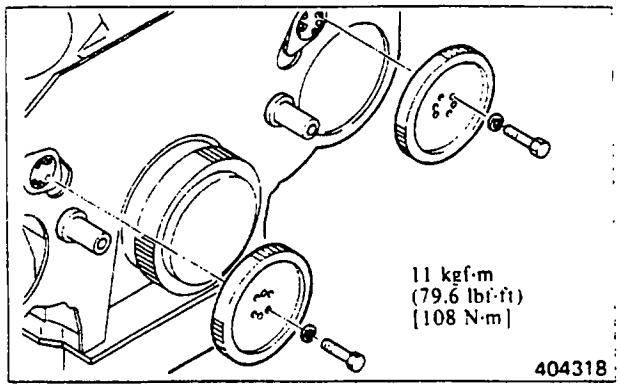
Identify the right-hand and left-hand camshafts when installing them.

(5) Installing camshaft gears

(a) Put the camshaft gear on the camshaft with the dowel pin entering its hole.

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

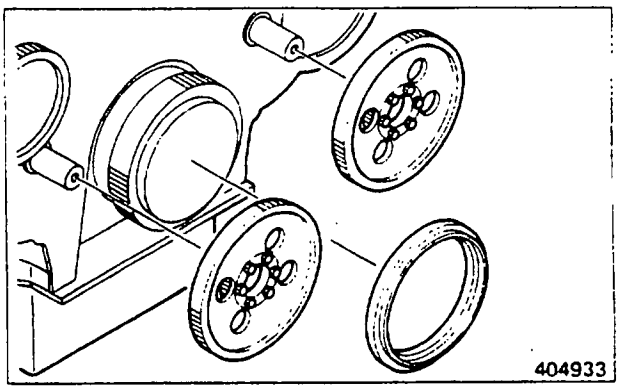
(c) Make sure that the camshaft rotates lightly.



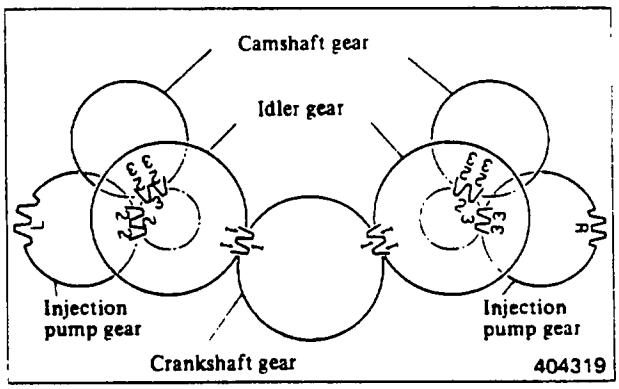
(6) Installing idler gears

(a) Install the idler gear in position by aligning its matching mark with those on the crankshaft gear and camshaft gear.

(b) Install the slinger to the crankshaft. (Refer to (5), 5.2.)



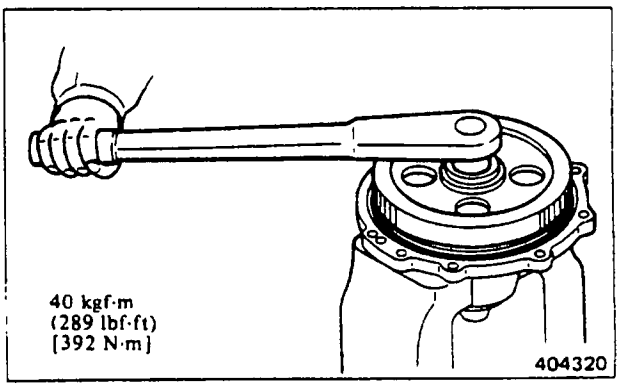
(c) Align the matching marks on the timing gears as shown at right.



Timing gear train

(7) Installing fuel injection pump drives

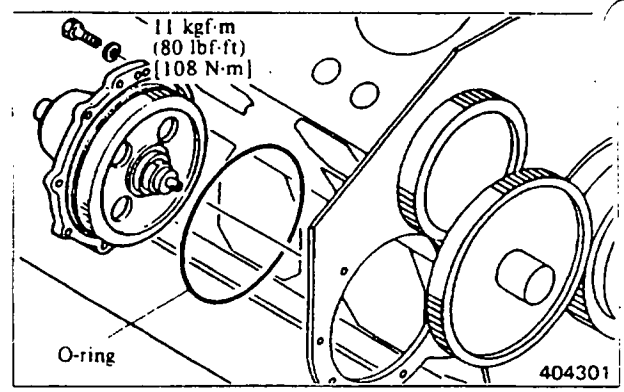
(a) Install the injection pump drive gear to the drive shaft, and tighten the mounting nut to the specified torque.



(b) Put the O-ring on the mounting flange of drive case.

(c) Install the injection pump drive to the rear plate by aligning its matching mark with that on the idler gear.

(d) Tighten the drive case mounting bolts to the specified torque.

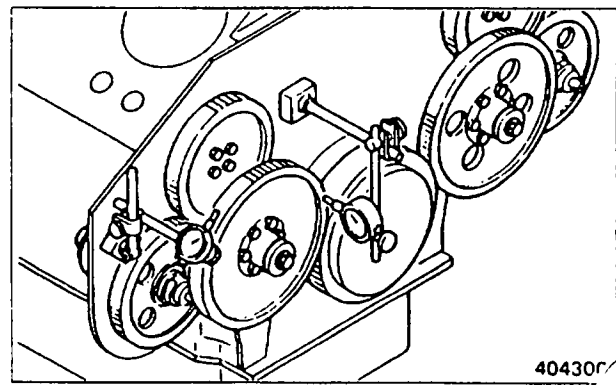


(8) Inspecting and adjusting timing gears after installation

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

(Inspecting backlash and end play)

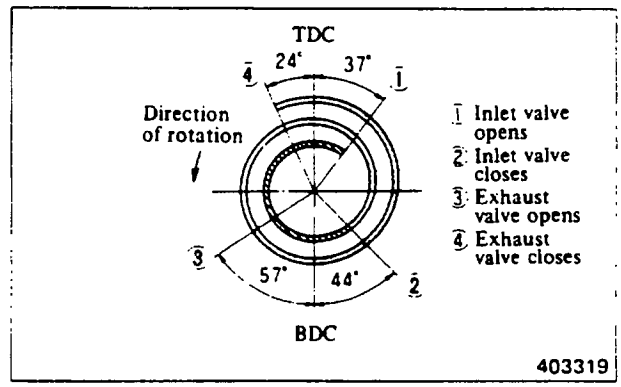
After installing the timing gears, check the backlash between the gears in mesh and the end play of each gear. (Refer to 4.2.)



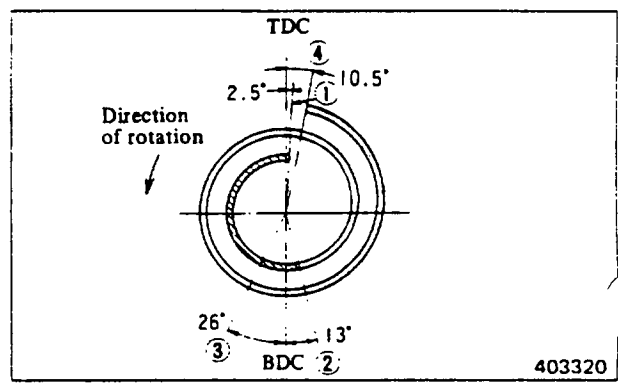
(Inspecting valve timing)

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

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



Valve timing diagram



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

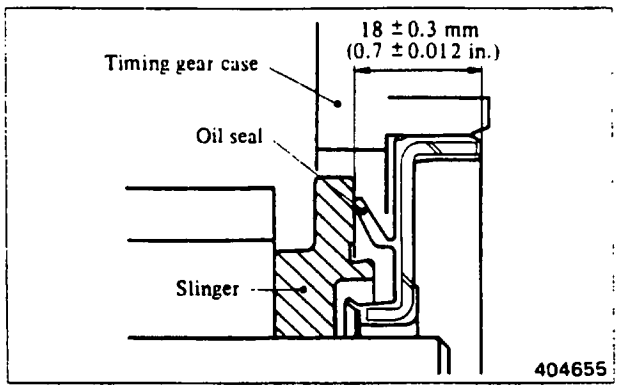
(9) Installing timing gear case

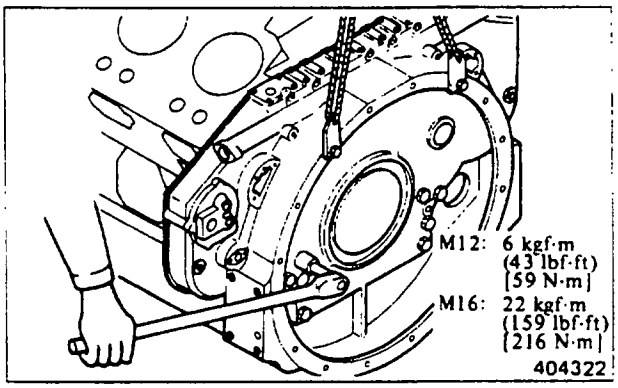
(a) Apply sealing compound to the packing contact surface of rear plate, and put the packing in position. Apply the same compound to the packing, and install the timing gear case to the rear plate. Cut off the excess of packing neatly along the bottom edge of crankcase.

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

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

(d) Apply engine oil to the oil seal lip, and put the seal in the bore of timing gear case with a special tool. Put the seal so that it is 18 ± 0.3 mm (0.7 ± 0.012 in.) from the slinger, as shown.

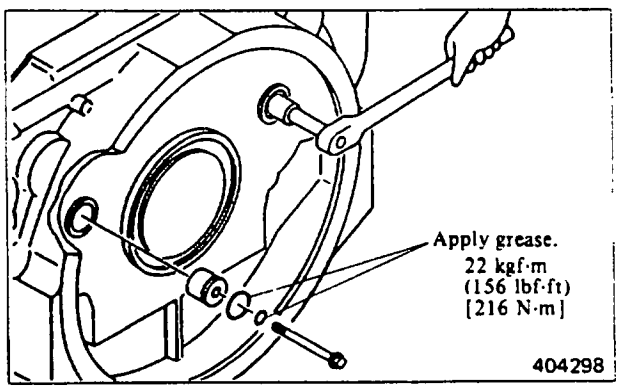




(10) Installing idler shaft thrust collars

(a) Put the O-ring on the thrust collar. Apply grease to the O-ring, and put the collar in the timing gear case.

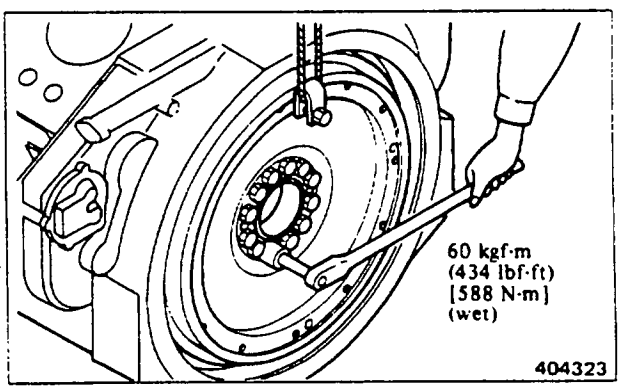
(b) Put the O-ring on the thrust collar mounting bolt, and tighten the bolt to the specified torque.



(11) Installing flywheel

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

(b) Apply engine oil to the threads and seats of flywheel mounting bolts, and tighten the bolts to the specified torque. Check the axial and radial runouts of the flywheel. (Refer to 4.2.)



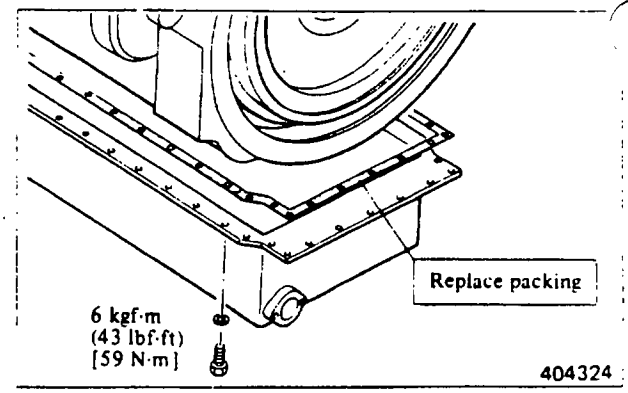
(12) Installing oil pan

(a) Put the O-ring to the oil port in the oil pan flange.

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

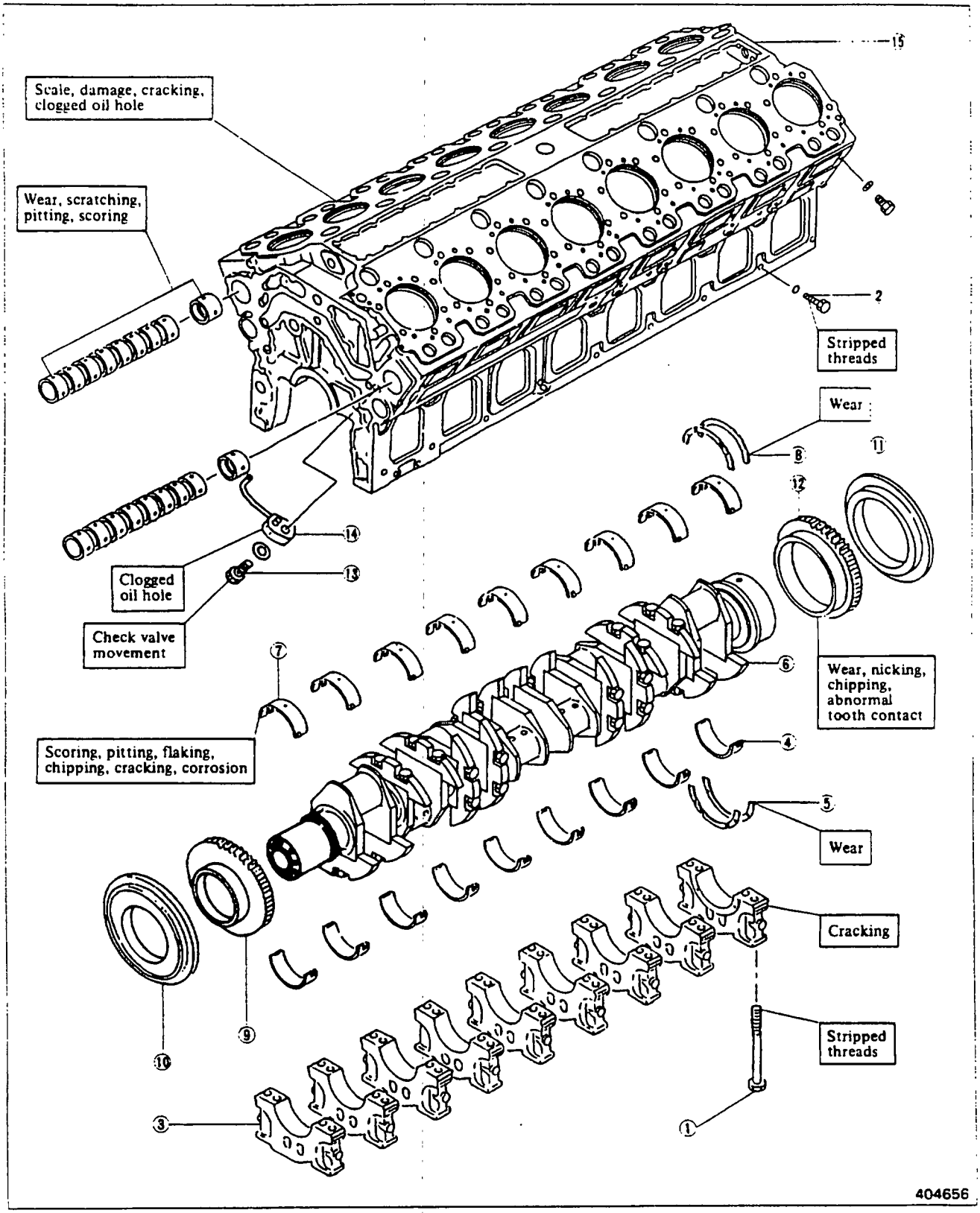
(c) Screw two guide bolts into the crankcase, and install the oil pan in position.

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



5. CRANKCASE, CRANKSHAFT AND MAIN BEARINGS

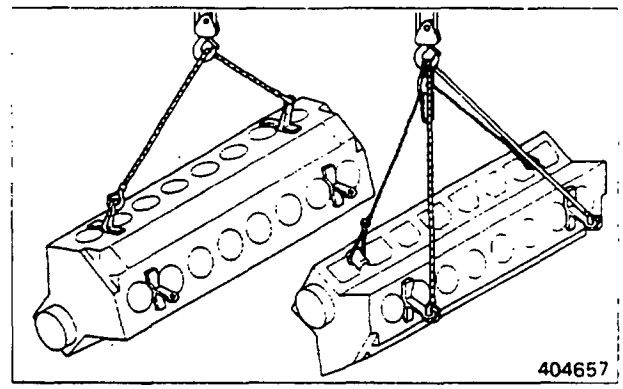
5.1 Disassembly



① Main bearing cap bolt
② Side bolt
③ Main bearing cap
④ Main bearing (lower shell)
⑤ Thrust plate
⑥ Crankshaft
⑦ Main bearing (upper shell)
⑧ Thrust plate
⑨ Slinger (front)
⑩ Crankshaft gear (front)
⑪ Slinger (rear)
⑫ Crankshaft gear (rear)
⑬ Check valve
⑭ Piston cooling nozzle
⑮ Crankcase

(1) Turning crankcase upside down

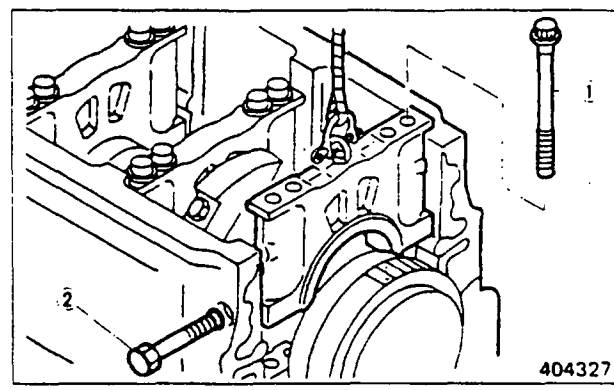
Using a chain block and shackles, lay the crankcase by its side. Then, attach wire ropes to the crankcase, and turn it upside down.
[Weight of crankcase and crankshaft: 2500 kg (5513 lb), approx.]



(2) Removing main bearing caps

(a) Unscrew bolts (1) and side bolt (2) for each main bearing cap. Using a cap remover or a combination of hoist and eye bolt (M12 x 1.25), remove the cap.

(b) Remove the thrust plates from the No. 9 bearing cap. Be careful not to damage the plates during removal.

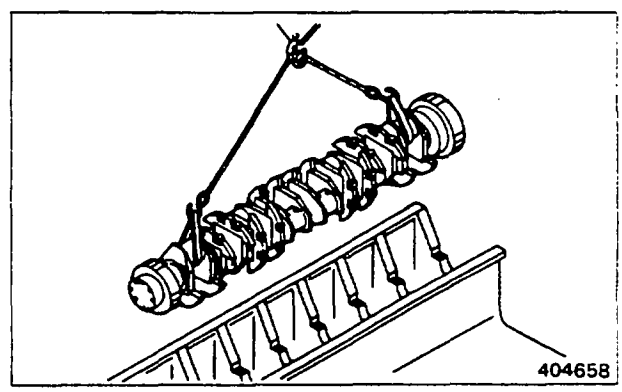


(3) Removing crankshaft

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

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

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

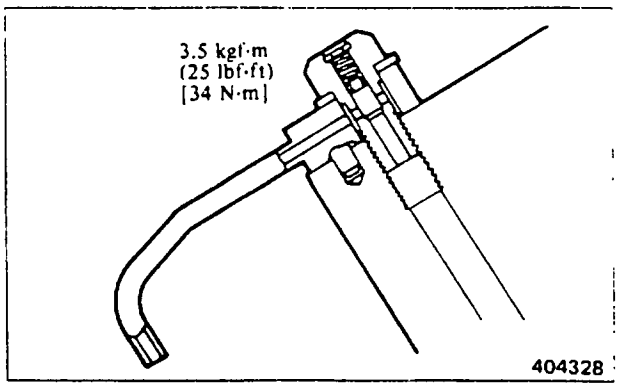


(4) Removing piston cooling nozzles

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

NOTE

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



5.2 Inspection and repair

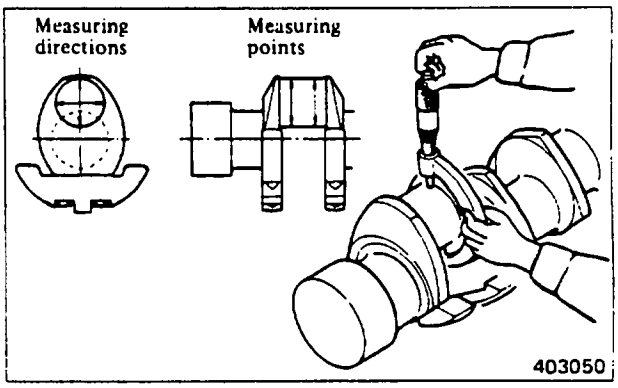
Crankshaft

(1) Measuring diameter of crankpins and journals

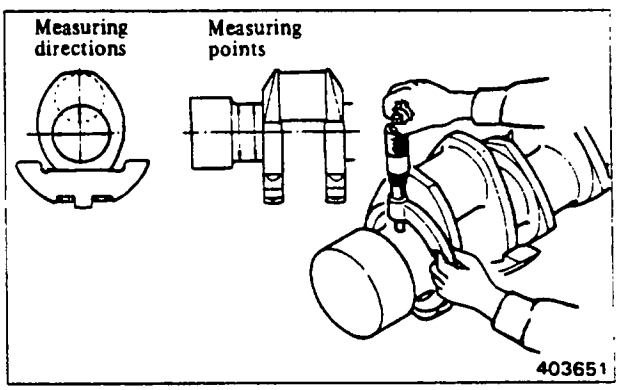
(a) Using a micrometer, measure the crankpins and journals. If they are worn in excess of the repair limit, grind them to the next undersize [-0.25 mm (-0.0098 in.), -0.50 mm (-0.0197 in.), -0.75 mm (-0.0295 in.) or -1.00 mm (-0.0394 in.)].

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

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



Measuring crankpin diameter



Measuring journal diameter

Unit: mm (in.)

Item			Nominal value	Assembly standard	Repair limit
Crankpin diameter			125 (4.92)	-0.050 to -0.070 (-0.00197 to -0.00276)	-0.110 (-0.00433)
Journal diameter			170 (6.69)	-0.060 to -0.080 (-0.00236 to -0.00315)	-0.120 (-0.00472)
Crankpins and journals	Out of roundness			0.01 (0.0004), maximum	0.03 (0.0012)
	Taper			0.02 (0.0008), maximum	0.03 (0.0012)
	Fillet radius	Crankpins	7 (0.28)	$7.0\ ^{0}_{-0.2}$ ($0.276\ ^{0}_{-0.008}$)	
		Journals	8.5 (0.33)	$8.5\ ^{0}_{-0.2}$ ($0.335\ ^{0}_{-0.008}$)	
Hardness				Hv > 590	

(2) Grinding crankshaft

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

When grinding the crankpins and journals, be sure to produce the same fillet radius as the original one. They should have a hardness of 590 or more in terms of Vickers Hardness Number. If necessary, reharden the crankpins and journals, and inspect them for cracks by conducting a magnalux (magnetic particle) test.

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

Crankshaft refinishing dimensions

Unit: mm (in.)

	Undersize	Finishing dimension	Out-of-roundness	Taper
Diameter of crankpins	0.25 (0.0098)	124.68 to 124.70 (4.9087 to 4.9094)	0.01 (0.0004), maximum	0.02 (0.0008), maximum
	0.50 (0.0197)	124.43 to 124.45 (4.8988 to 4.8996)		
	0.75 (0.0295)	124.18 to 124.20 (4.8890 to 4.8898)		
	1.00 (0.0394)	123.93 to 123.95 (4.8791 to 4.8799)		
Diameter of journals	0.25 (0.0098)	169.67 to 169.69 (6.6799 to 6.6807)		
	0.50 (0.0197)	169.42 to 169.44 (6.6701 to 6.6709)		
	0.75 (0.0295)	169.17 to 169.19 (6.6602 to 6.6610)		
	1.00 (0.0394)	168.92 to 168.94 (6.6504 to 6.6512)		

(3) Measuring end play

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

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

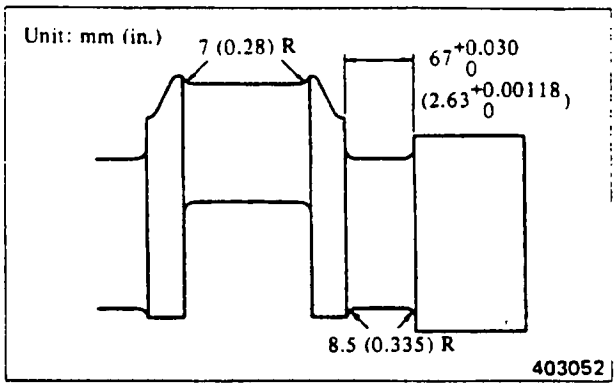
Unit: mm (in.)

Item	Standard clearance	Service limit
End play of crankshaft	0.20 to 0.40 (0.0079 to 0.0157)	0.50 (0.0197)

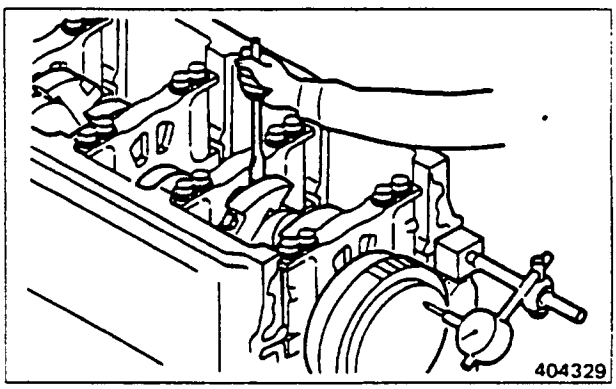
Crankshaft journal grinding dimensions for oversize thrust plates

Unit: mm (in.)

Item	Oversizes for journal or thrust plates	Oversizes for journal and thrust plates	Tolerance
+0.25 (+0.0098) oversize	67.25 (2.6476)	67.50 (2.6575)	$+0.03$ 0 $(^{+0.0012}_{0})$
+0.50 (+0.0197) oversize	67.50 (2.6575)	68.00 (2.6772)	
+0.75 (+0.0295) oversize	67.75 (2.6673)	68.50 (2.6968)	



Measuring thrust bearing journal length



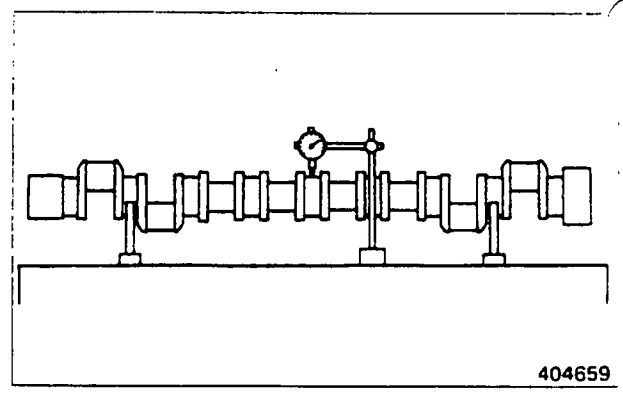
Measuring crankshaft end play

(4) Measuring runout

Support the crankshaft on its No. 2 and No. 8 journals in V-blocks, and measure the runout at the center journal with a dial indicator. Depending on the amount of runout, repair the crankshaft by grinding or straightening with a press. If the runout exceeds the repair limit, replace the crankshaft.

Unit: mm (in.)

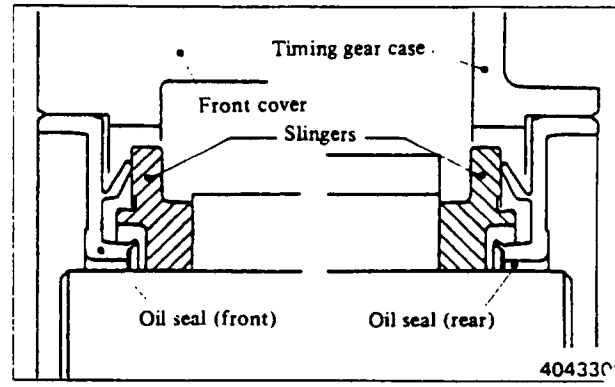
Item	Assembly standard	Repair limit
Runout of crankshaft	0.04 (0.0016), maximum	0.10 (0.0039)



Measuring crankshaft runout

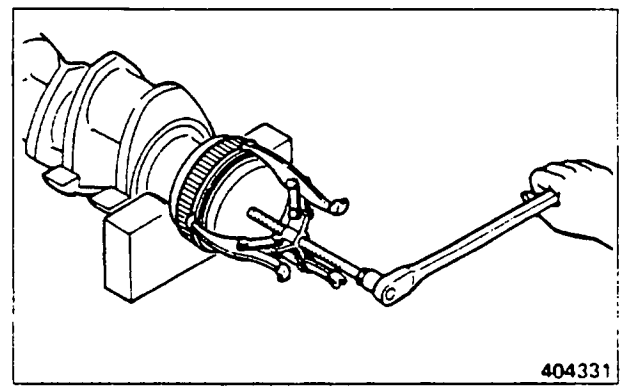
(5) Replacing oil seal slingers

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



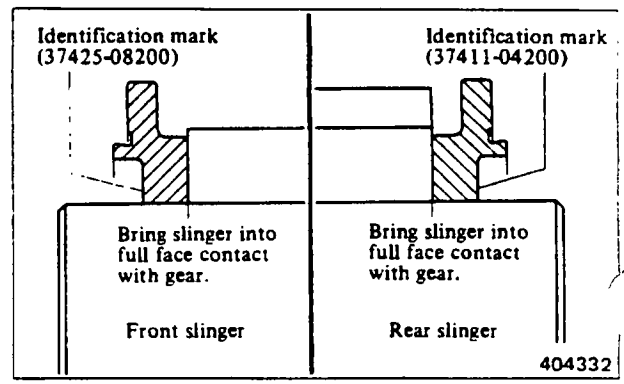
(Removal)

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

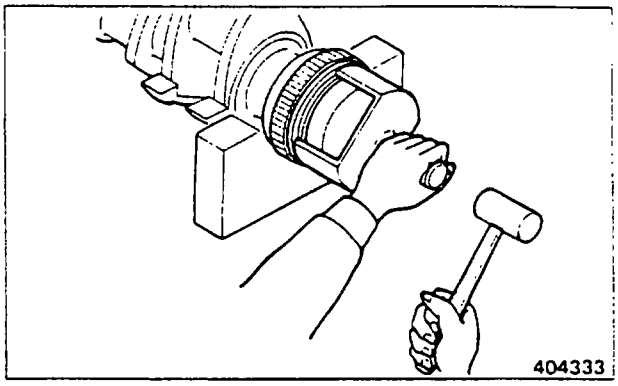


(Installation)

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



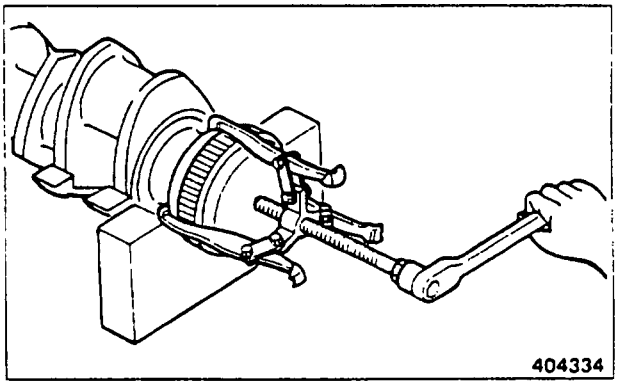
(b) Using an installer, drive the slinger heated above 110°C (230°F) onto the crankshaft until it is in full face contact with the crankshaft gear. If the installer gets fast halfway, give blows of a copper hammer to the center or shoulder of the installer.



(6) Replacing crankshaft gears

(Removal)

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



NOTE

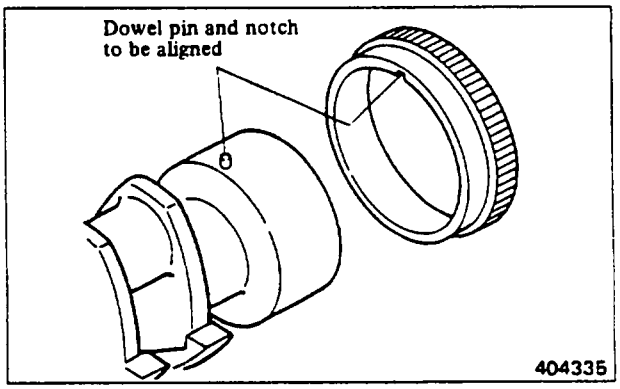
Do not remove the gears by driving with a hammer.

(Installation)

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

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

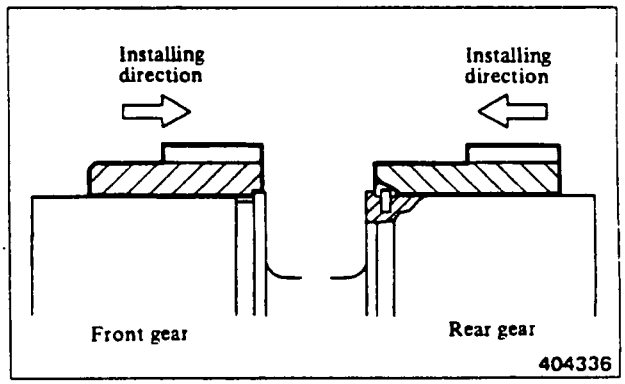
(c) Drive the gear onto the crankshaft by giving light blows of a copper hammer to the end face of the gear, making sure that the crankshaft dowel pin enters the notch in the gear. No relationship is specified for the front gear and crankshaft.



⚠ CAUTION

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

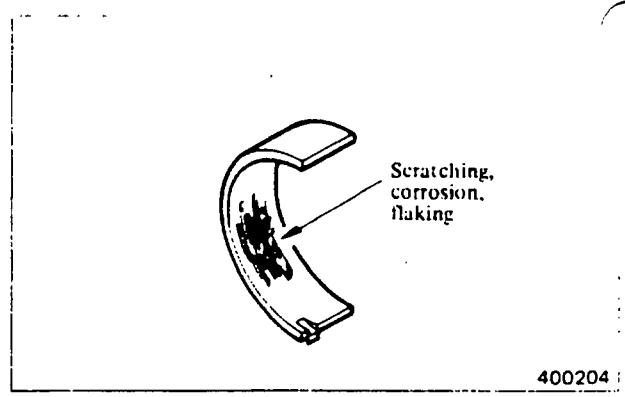
(b) Be sure to install the gear correctly in direction.



Main bearings

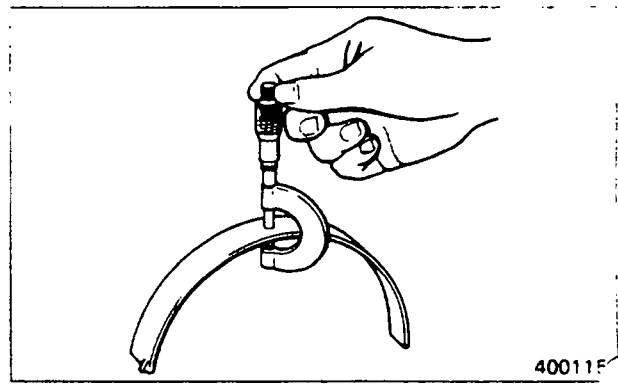
(1) Inspection

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



(2) Measuring bearing thickness

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



Measuring main bearing thickness

Unit: mm (in.)

	Item	Nominal value	Assembly standard	Service limit
Main bearing thickness (standard size)	STD	4.5 (0.177)	4.467 to 4.480 (0.17587 to 0.17638)	4.425 (0.17421)
	-0.25 (-0.0098)	4.625 (0.18209)	4.592 to 4.605 (0.18079 to 0.18130)	4.550 (0.17913)
	-0.50 (-0.0197)	4.75 (0.1870)	4.717 to 4.730 (0.18571 to 0.18622)	4.675 (0.18405)
	-0.75 (-0.0295)	4.875 (0.19193)	4.842 to 4.855 (0.19063 to 0.19114)	4.800 (0.18898)
	-1.00 (-0.0394)	5.000 (0.19685)	4.967 to 4.980 (0.19555 to 0.19606)	4.925 (0.19390)

NOTE

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

(3) Replacing main bearings

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

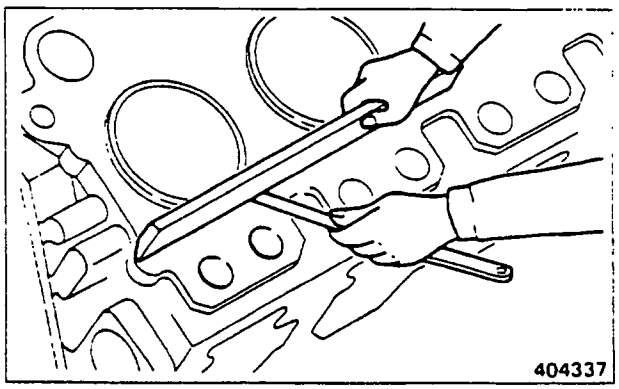
Crankcase

(1) Measuring warpage of gasket contact surface

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

Unit: mm (in.)

Item	Assembly standard	Repair limit
Warpage of gasket contact surface	0.1 (0.004), maximum	0.2 (0.008)



Measuring gasket contact surface

NOTE

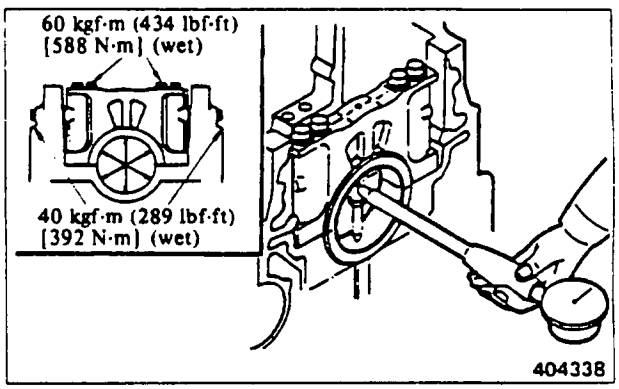
Do not grind the surfaces more than are necessary for removing warpage to prevent the piston projection from exceeding the assembly standard. (Refer to (4), Pistons, 2.2.)

(2) Measuring inside diameter of main bearing bore

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

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Main bearing bore diameter	179 (7.05)	179.000 to 179.025 (7.04723 to 7.04821)	179.045 (7.04900)



Measuring main bearing bore diameter

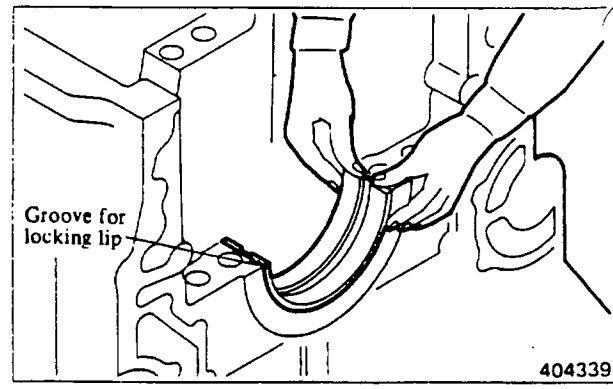
5.3 Reassembly

To reassemble, follow the reverse of disassembly sequence.

(1) Installing main bearings

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

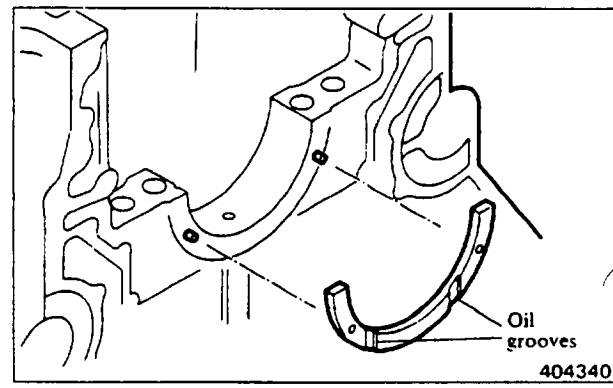
(b) Lightly coat the inside surface of the shells with engine oil.



(2) Installing thrust plates

(a) Install the thrust plate to No. 9 bearing seat outside the crankcase, with the oil groove side the plate facing outside.

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

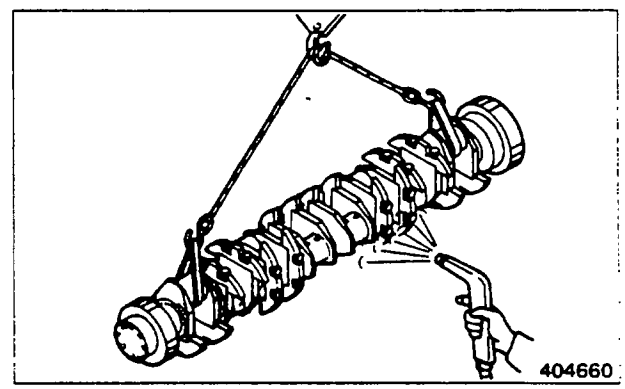


(3) Installing crankshaft

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

NOTE

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



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

(c) Lightly coat the journals with engine oil.

(4) Installing main bearing caps

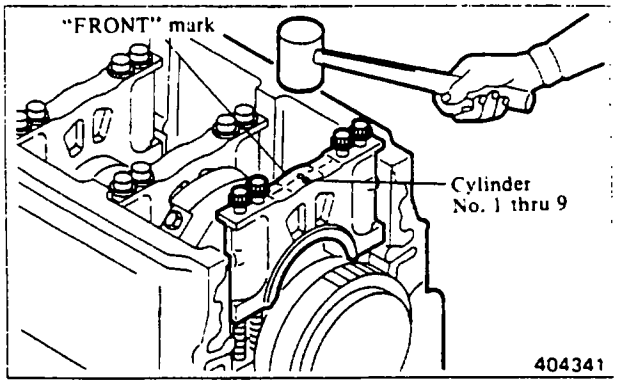
(a) Put the lower shell of the bearing in each bearing cap.

(b) Install the thrust plates to No. 9 bearing cap with the oil groove side of the plates facing outside.

(c) Bearing numbers "1" thru "9" (from the front side of crankcase) are punched on the caps. Install the caps with these numbers and "FRONT" mark on the front side of crankcase.

(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.

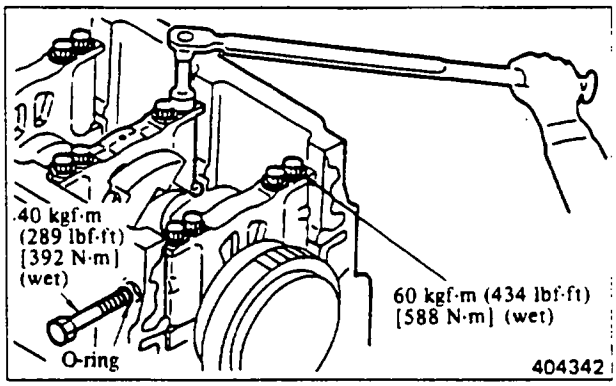


(5) Installing bearing cap bolts

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

(b) Tighten side bolts alternately to the specified torque.

(c) Make sure that the crankshaft rotates smoothly.

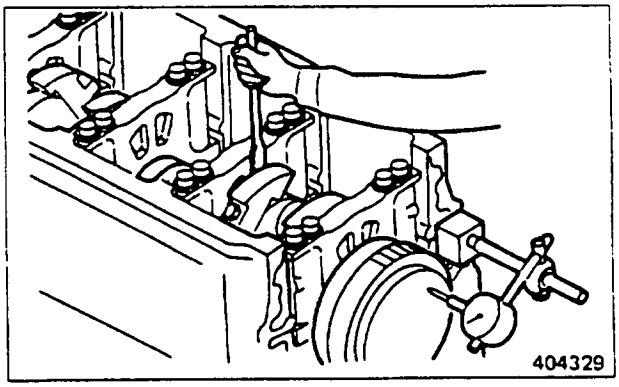


(6) Measuring crankshaft end play

(a) Tighten No. 1 thru No. 8 bearing cap bolts and side bolts to the specified torque, with No. 9 cap bolts being temporarily tightened, and measure the end play.

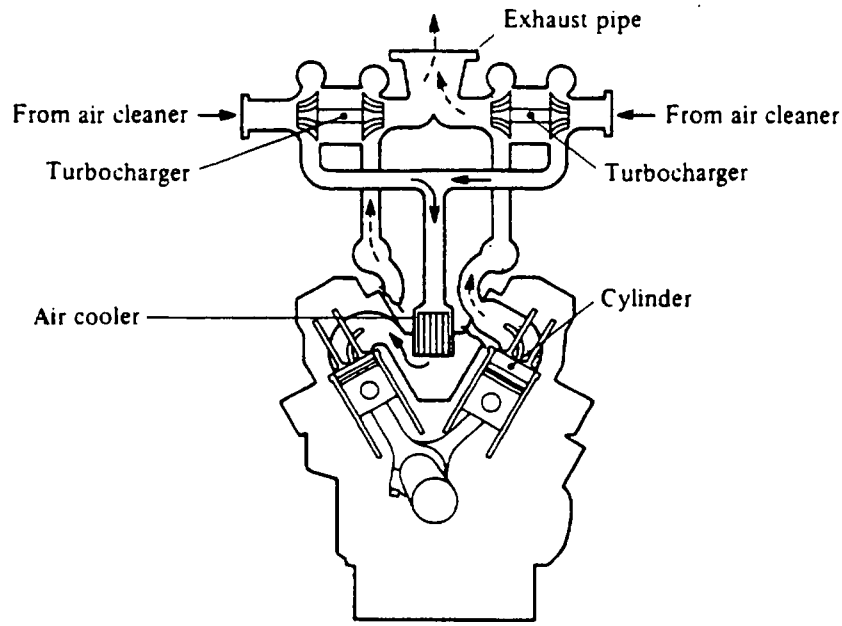
(b) After tightening the No. 9 cap bolts, make sure that the end play is correct.

(c) Again make sure that all cap bolts and side bolts are tightened to the specified torque.
(Refer to (3), 5.2.)



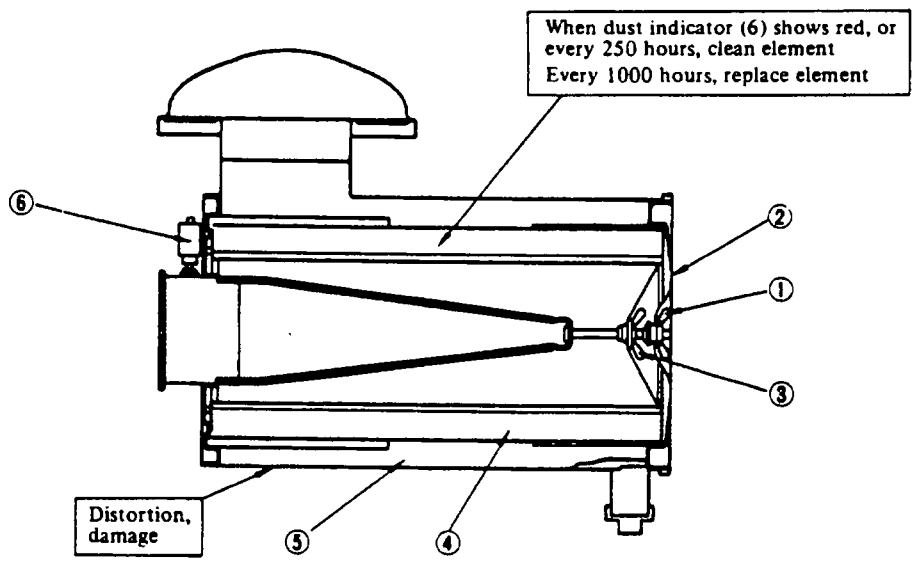
INLET AND EXHAUST SYSTEMS

1. DESCRIPTION



2. AIR CLEANER

Disassembly and inspection



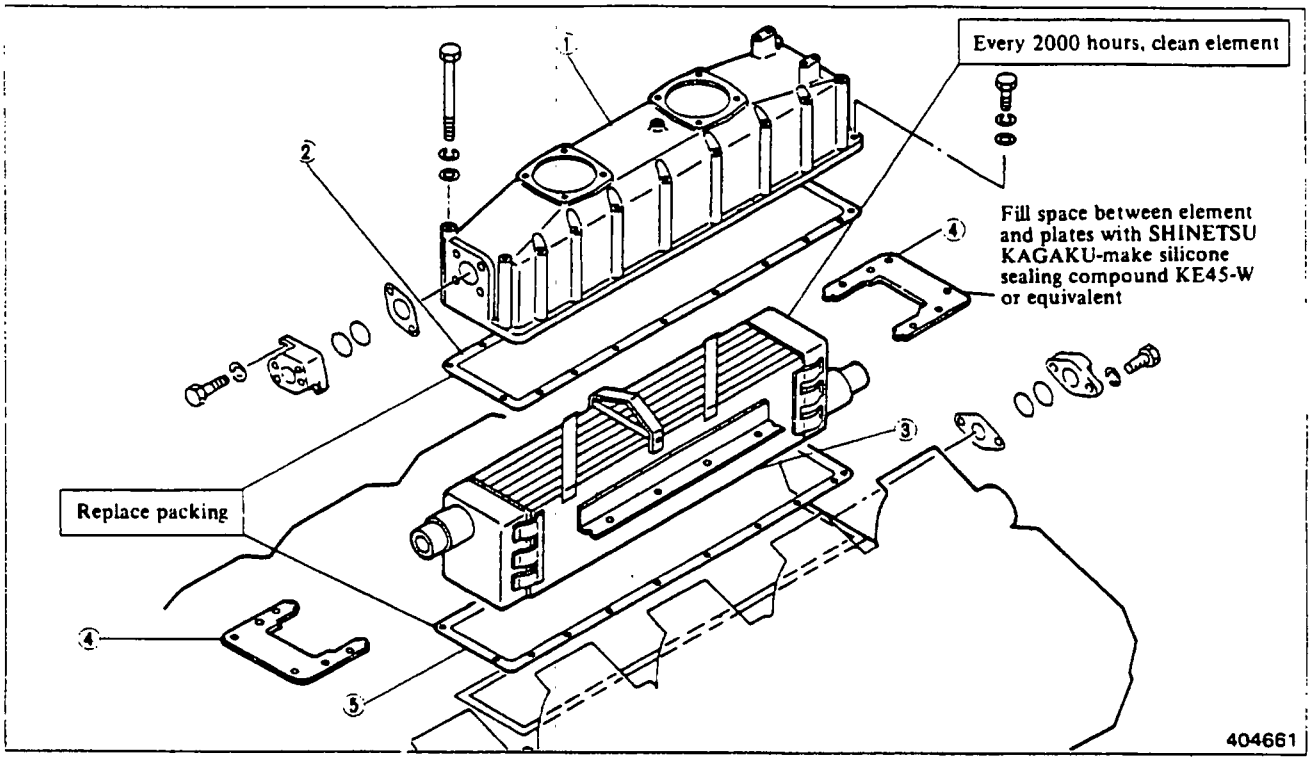
① Wing nut
② Cover
③ Wing nut
④ Element
⑤ Air cleaner body
⑥ Dust indicator

⚠ CAUTION

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

3. AIR COOLER

3.1 Disassembly



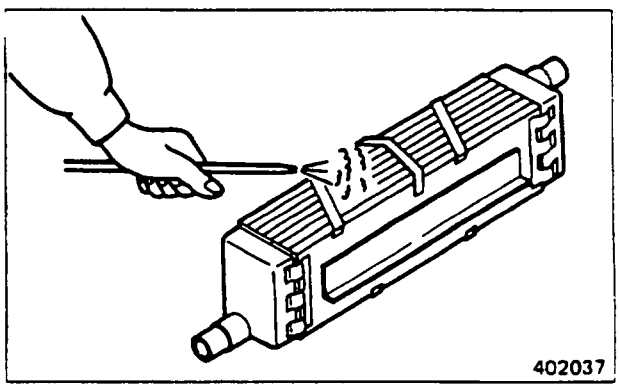
① Air cooler case
② Packing
③ Element
④ Plate
⑤ Packing

3.2 Inspection

(1) Cleaning air cooler

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

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

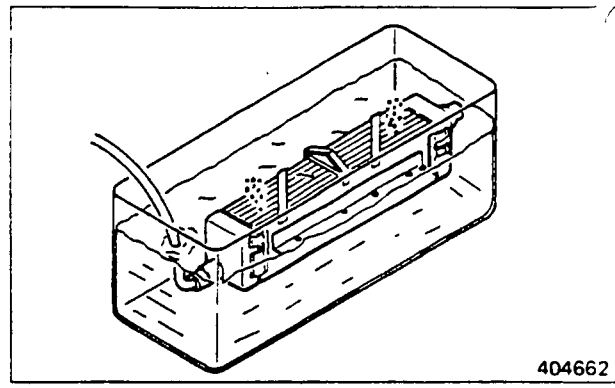


⚠ WARNING

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

(2) Inspecting air cooler for airtightness

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

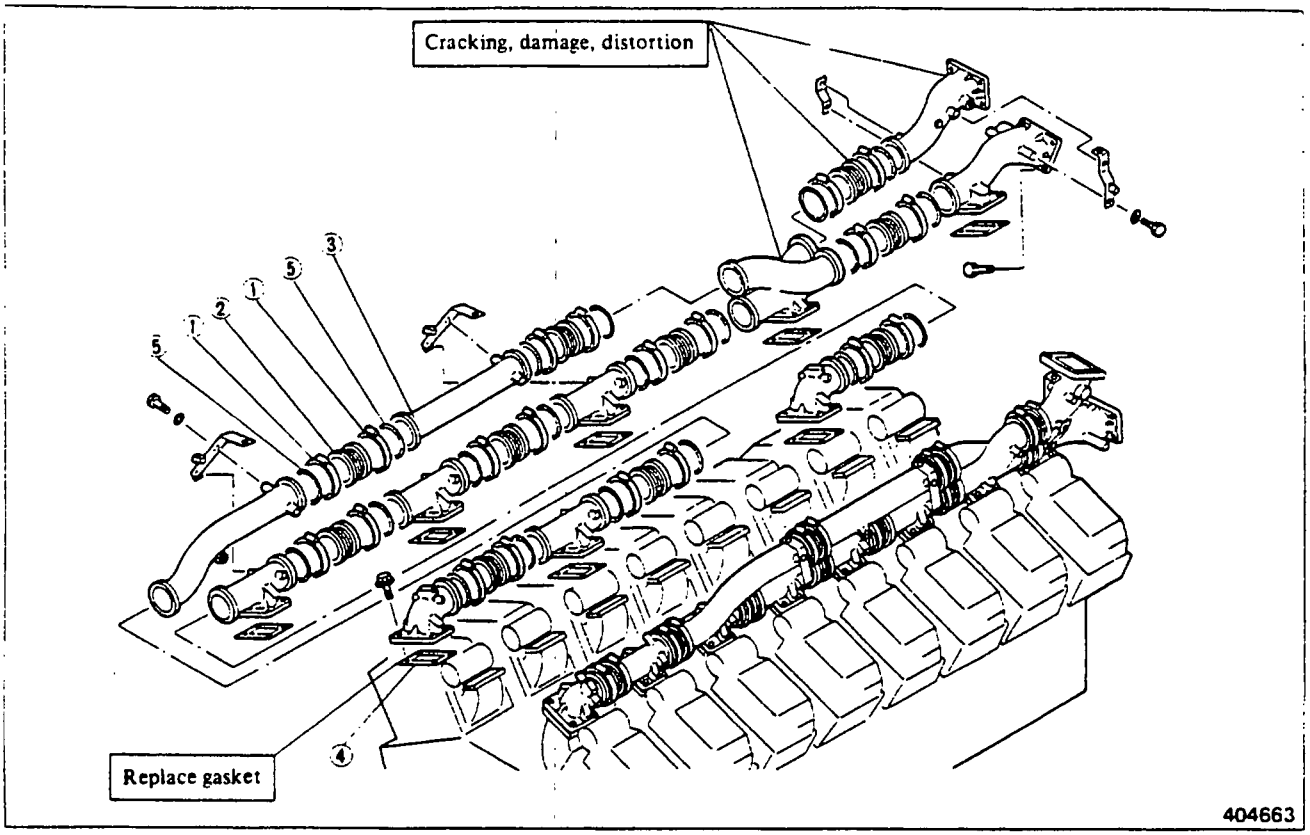


⚠ CAUTION

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

4. EXHAUST MANIFOLDS

Disassembly and inspection



① Coupling
② Flexible joint
③ Exhaust manifold
④ Gasket
⑤ Gasket

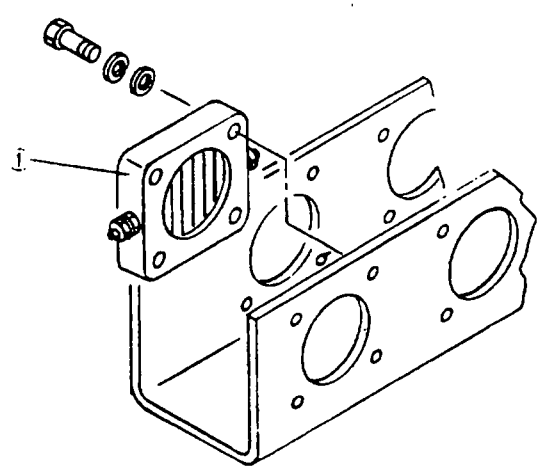
NOTE

(a) Gaskets (4) are marked "MANIFOLD" on the side to be on the manifold side when put in position on the air cooler.

(b) Use new gaskets (4) during reassembly.

5. AIR HEATER

5.1 Disassembly



① Air heater assembly

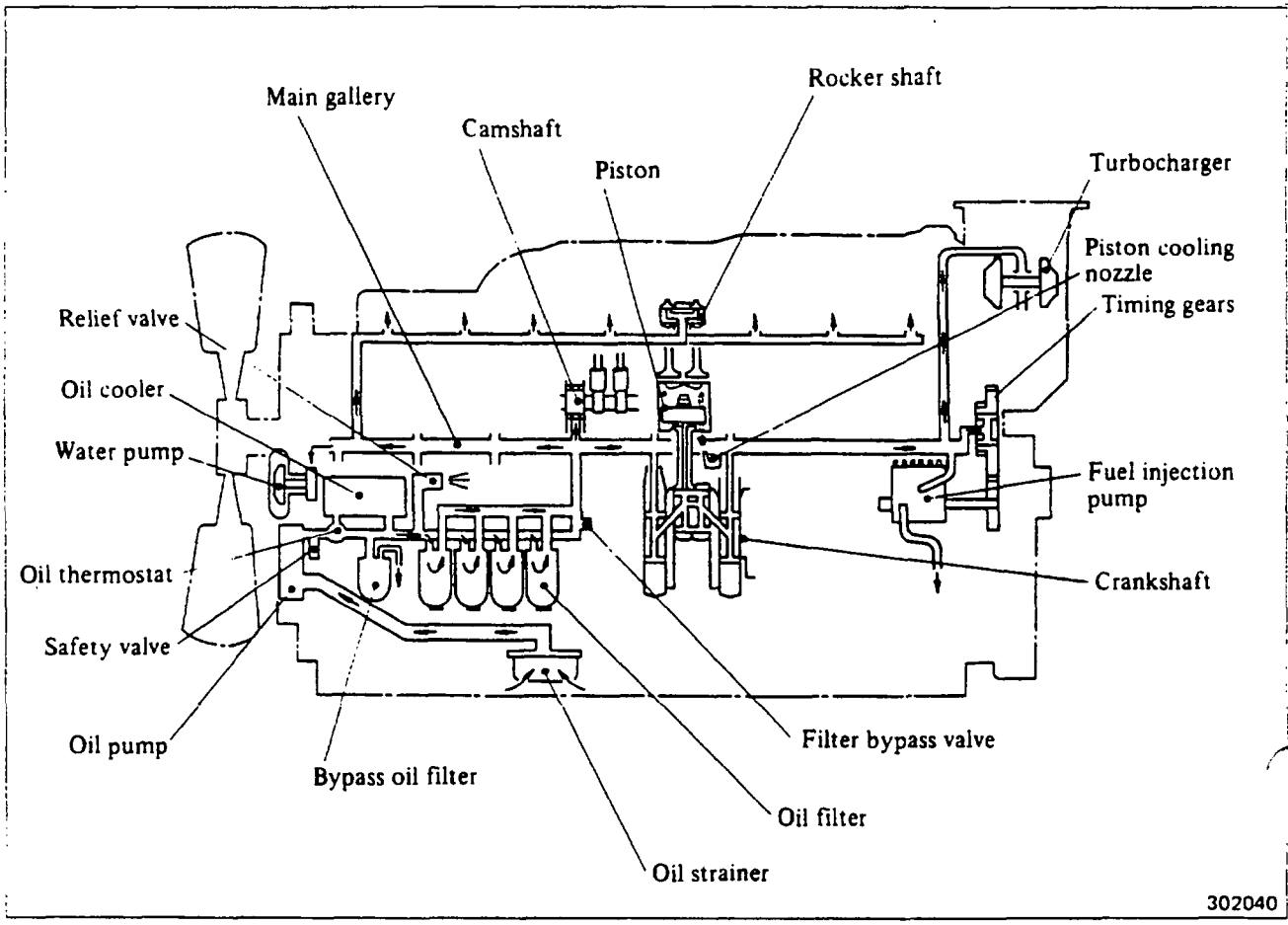
5.2 Inspection

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

(b) Check to make sure that the indicator takes 40 to 50 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.

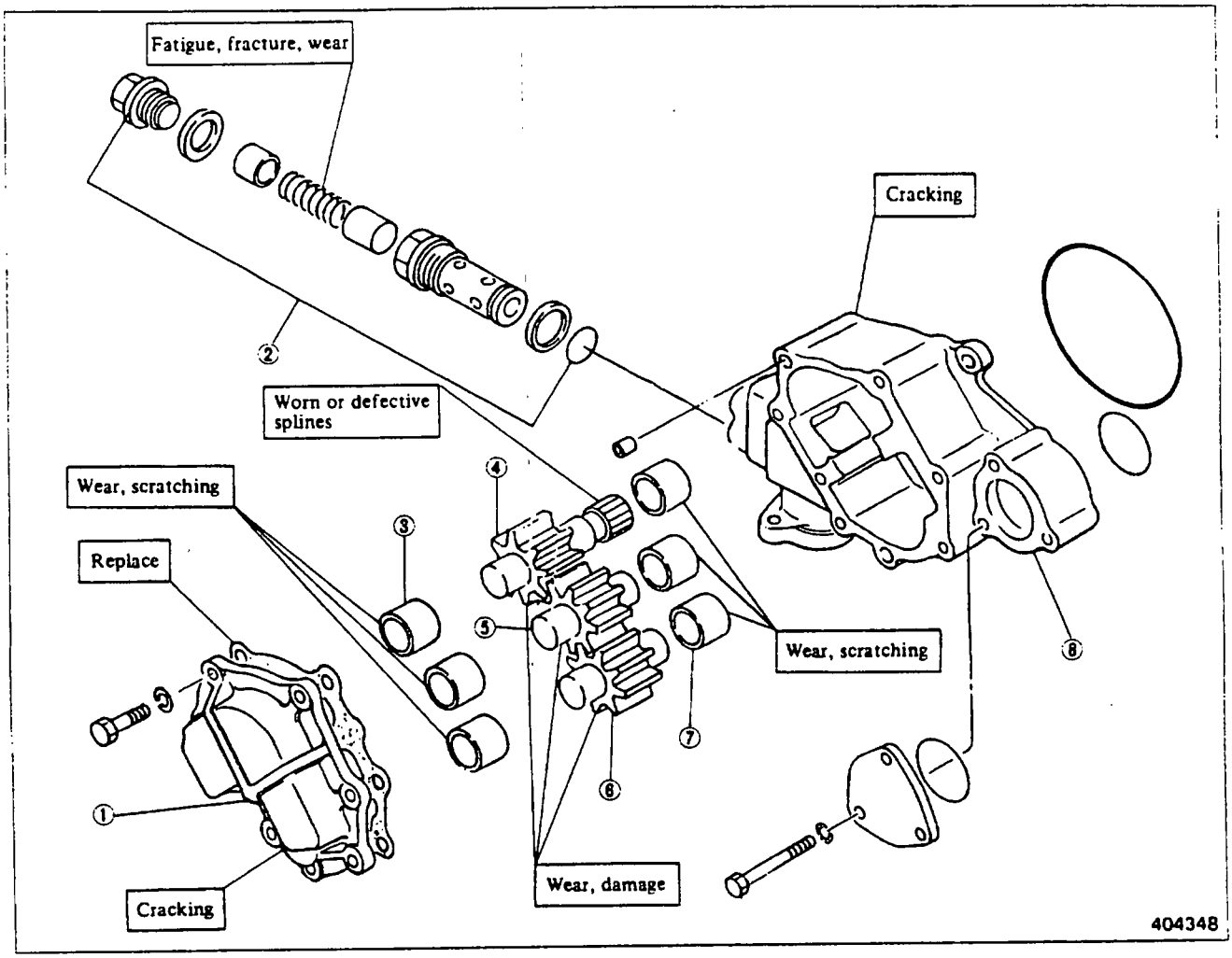
LUBRICATION SYSTEM

1. DESCRIPTION



2. OIL PUMP AND SAFETY VALVE

2.1 Disassembly



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

2.2 Inspection

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

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

Unit: mm (in.)

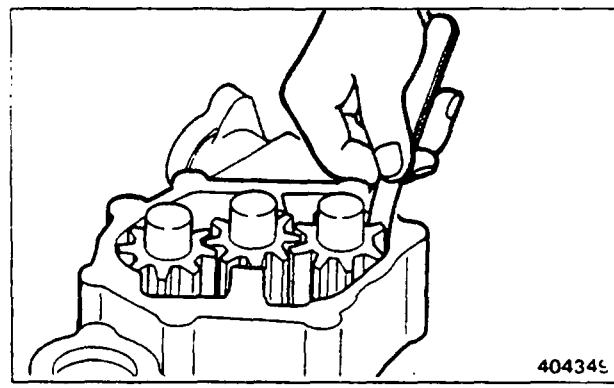
Item	Standard clearance	Service limit
Backlash between drive gear and driven gear	0.10 to 0.20 (0.0039 to 0.0079)	0.4 (0.016)

(2) Measuring clearance between oil pump gears and case

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

Unit: mm (in.)

Item	Nominal value	Standard clearance	Service limit
Clearance between gears and case	60 (2.36)	0.200 to 0.296 (0.00787 to 0.01165)	0.35 (0.0138)



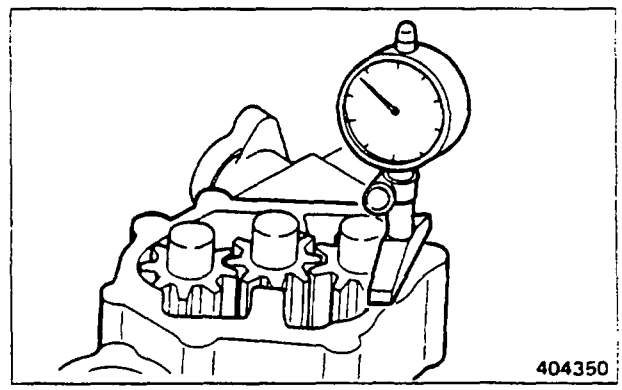
Measuring clearance between gears and case

(3) Measuring clearance between oil pump gears and cover

Using a dial indicator, measure the clearance. If the clearance exceeds the service limit, replace the gears or cover whichever is badly worn.

Unit: mm (in.)

Item	Nominal value	Standard clearance	Service limit
Clearance between gears and cover	72.5 (2.854)	0.040 to 0.116 (0.00157 to 0.00457)	0.21 (0.0083)



Measuring clearance between gears and cover

NOTE

Remove the cover packing which is 0.04 mm (0.0016 in.) in thickness when measuring the clearance.

(4) Measuring diameter of oil pump gear shafts and inside diameter of bushings

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

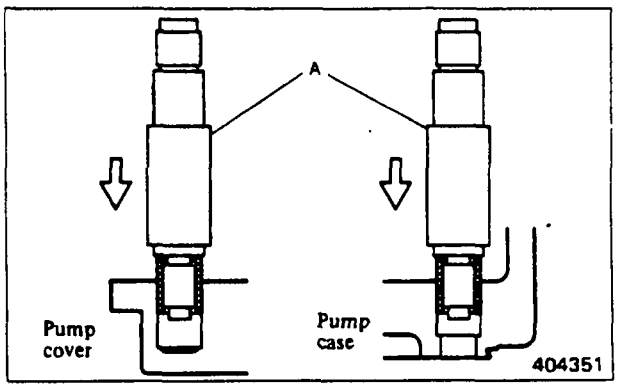
(b) Measure the gear shafts and bushings. Replace them if worn in excess of the service limit.

Unit: mm (in.)

Item	Nominal value	Assembly standard	Service limit
Diameter of gear shafts	30 (1.18)	29.947 to 29.960 (1.17901 to 1.17953)	29.920 (1.17795)
Inside diameter of bushings		30.000 to 30.021 (1.18110 to 1.18193)	30.055 (1.18327)

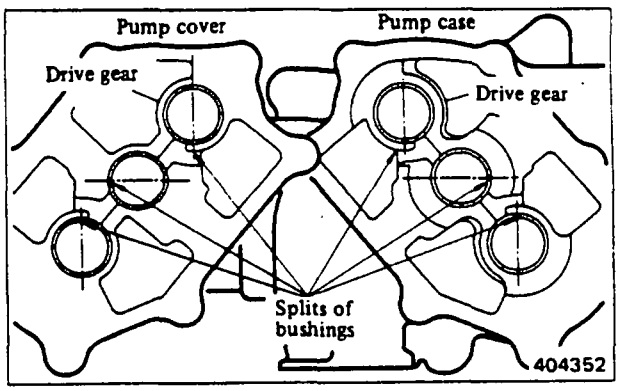
(5) Replacing oil pump bushings

(a) If it is difficult to remove the bushings, replace the bushings and case or cover as an assembly.



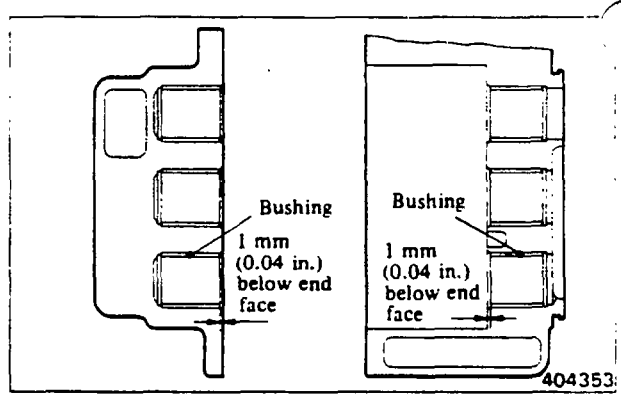
Installing oil pump bushings

(b) When installing the bushings in the cover, position their splits as shown. (The splits are not in alignment with the oil grooves.)



(c) Use oil pump bushing installer (A) to install the bushings.

(d) After installing the bushings, ream the inside diameter of each bushing to 30H7 $^{+0.021}_{0}$ mm (1.18 $^{+0.00083}_{0}$ in.) ▽▽▽.

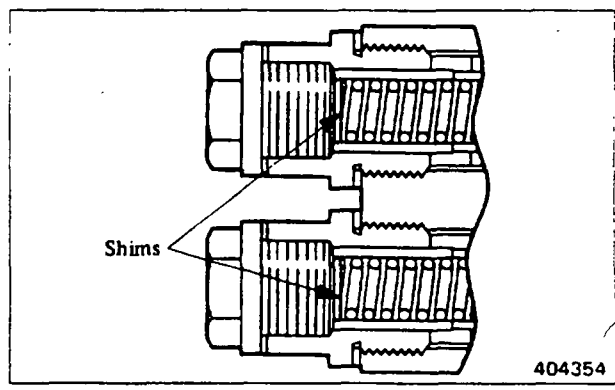


Positioning bushing splits

(6) Inspecting safety valve

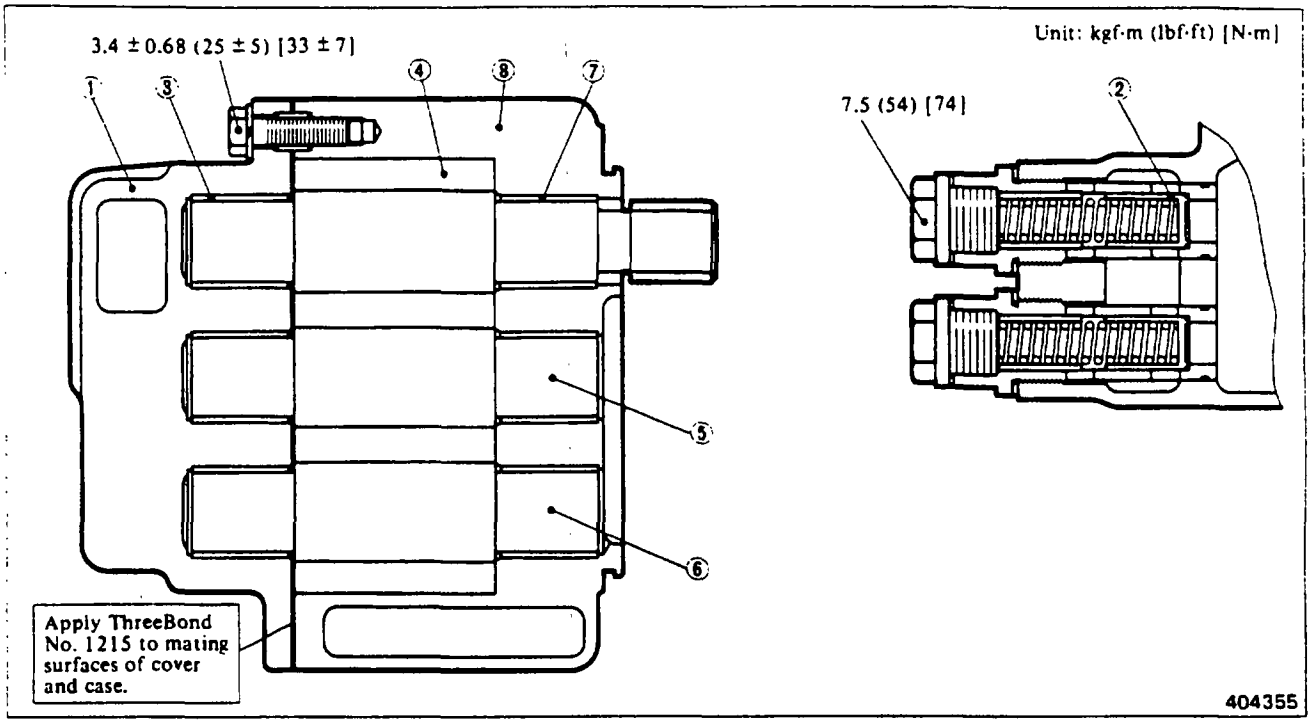
(a) Replace the valve spring if it is fatigued, worn or fracture.

(b) Measure the oil pressure at idling speed and at maximum speed. If the pressure is below the assembly standard, make an adjustment by inserting shims into between the spring and plug. 1 mm (0.04 in.) thickness of shim will change the pressure by about 1 kgf/cm^2 (14 psi) [0.1 MPa].



Item	Assembly standard	Service limit
Safety valve opening pressure	12 kgf/cm^2 (171 psi) [1.2 MPa]	–
Safety valve spring – Length under test force/test force, mm (in.)/kgf (lbf)[N]	66.4 (2.61)/ 34.8 (77) [341]	66.4 (2.61)/ 30.0 (66) [294]

2.3 Reassembly



Reassembly sequence

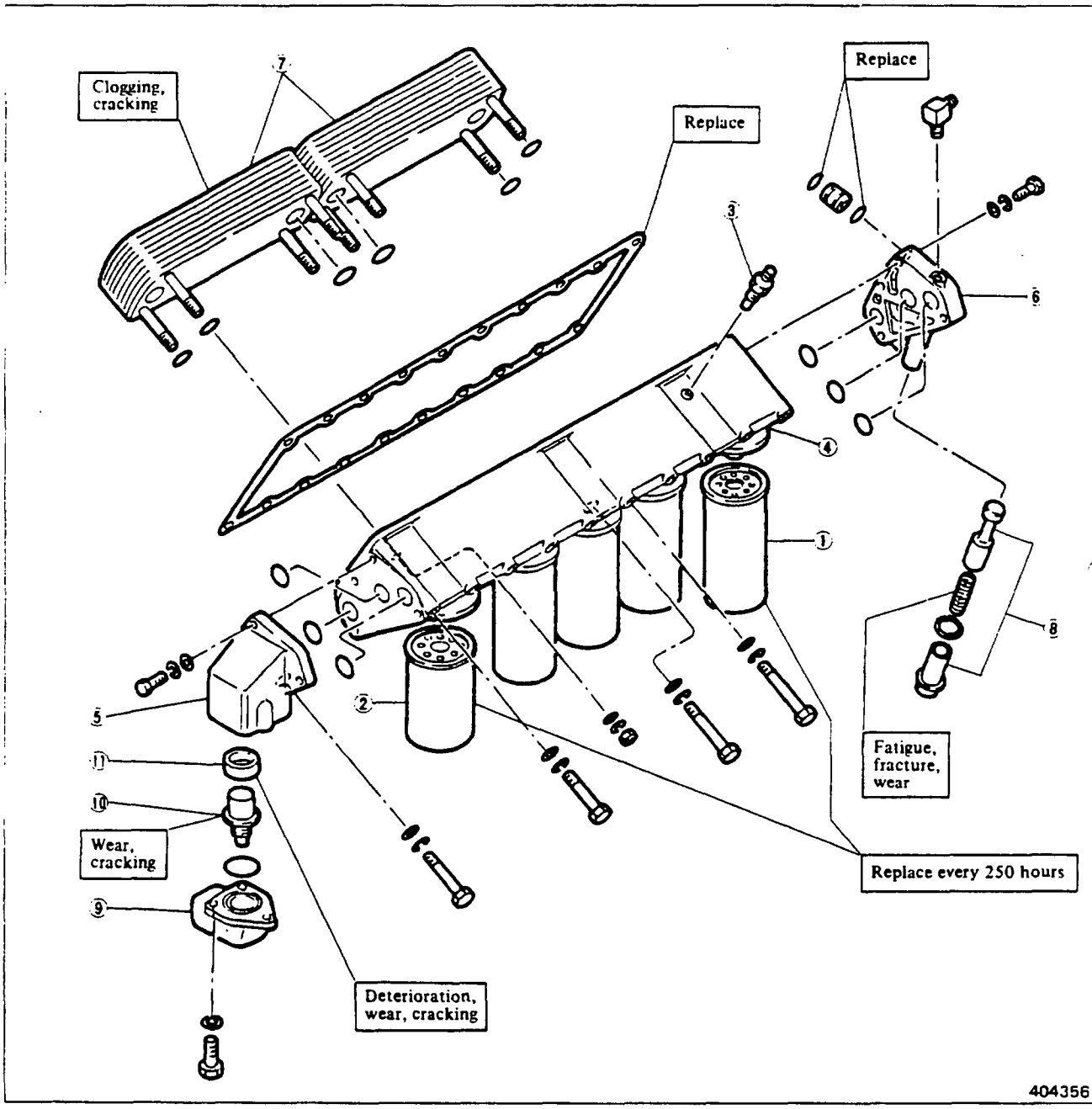
①→③
⑧→⑦→④→⑤→⑥→②

NOTE

Apply engine oil to the parts during reassembly.

3. OIL FILTERS, OIL FILTER ALARM, RELIEF VALVE, AND LEFT-HAND OIL COOLER AND OIL THERMOSTAT

3.1 Disassembly

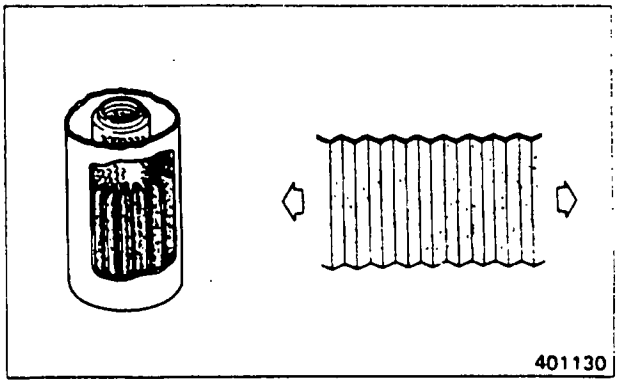


① Full-flow oil filter element
② Bypass oil filter element
③ Oil filter alarm
④ Filter bracket assembly
⑤ Adaptor (A) assembly
⑥ Adaptor (B) assembly
⑦ Oil cooler element
⑧ Relief valve assembly
⑨ Connector
⑩ Oil thermostat
⑪ Thermostat seal

3.2 Inspection

(1) Inspecting oil filters

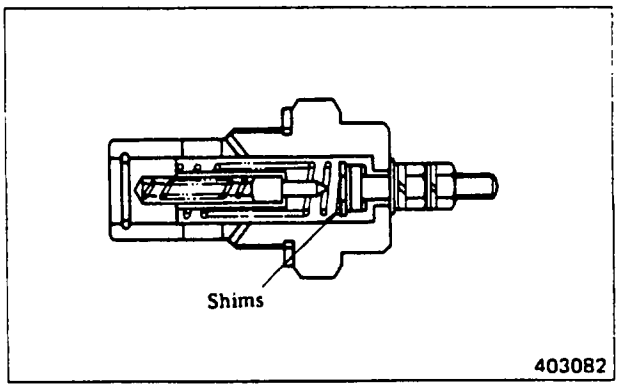
When replacing the paper element, investigate by sampling about 500 cm^3 (30.5 in^3.) of the oil. If any metallic particles or other foreign matter is found, unfold the pleats of the removed element and check for color and shape of metallic particles trapped in the pleats to locate the cause.



(2) Inspecting oil filter alarm

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

(b) If the valve opening pressure is out of the assembly standard, adjust it by inserting shims. 1 mm (0.04 in.) thickness of shim corresponds to a change in pressure of 0.07 kgf/cm^2 (1.00 psi) [0.007 MPa].



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

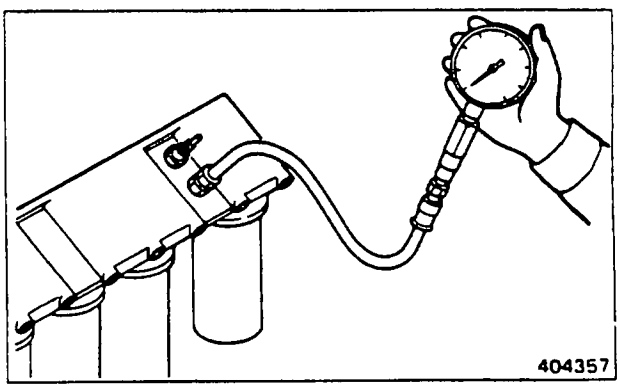
Item	Assembly standard
Pressure difference across oil filter alarm that makes its valve open	2.3 to 2.7 (33 to 38) [0.2 to 0.3]
Pressure difference across oil filter alarm that makes its contacts close	1.5 to 1.8 (21 to 26) [0.1 to 0.2]

(3) Testing relief valve setting

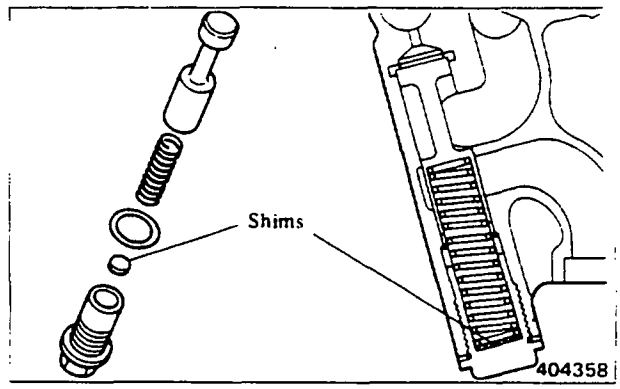
(a) Remove the taper plug (PT 1/8) at the top of oil filter bracket, and attach a pressure gauge.

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

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



(d) If the relief valve setting is below the assembly standard, remove the oil pipe, and adjust the setting by inserting shims into between the oil pipe and spring. 1 mm (0.04 in.) thickness of shims will change the pressure by about 1 kgf/cm^2 (14 psi) [0.1 MPa].



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

Item	Assembly standard
Relief valve setting (at maximum speed)	5 to 6.5 (71 to 92) [0.5 to 0.6]
Relief valve opening pressure	4.7 (67) [0.5]

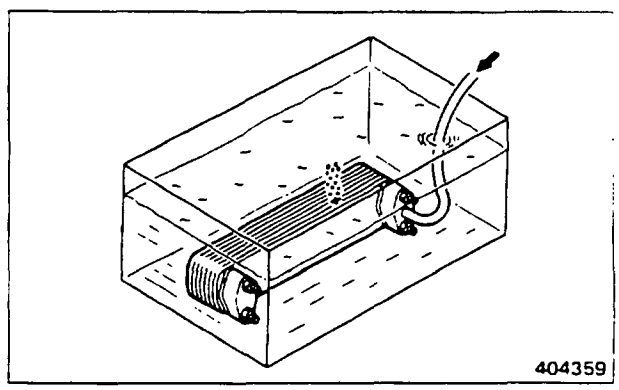
NOTE

The oil pressure may rise beyond the assembly standard when the oil temperature is low put it will come down to the assembly standard as the temperature rises.

(e) If the setting does not vary after the adjustment has been made, replace the relief valve and spring.

(4) Inspecting left-hand oil cooler

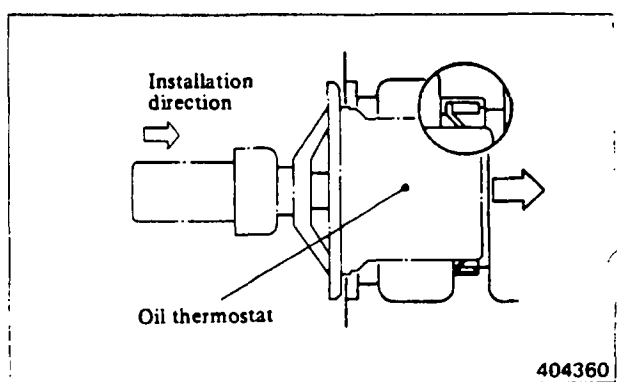
Test the element for tears or other defects by applying an air pressure of 15 kgf/cm^2 (213 psi) [1.5 MPa], and replace it if leakage occurs.



(5) Inspecting left-hand oil thermostat

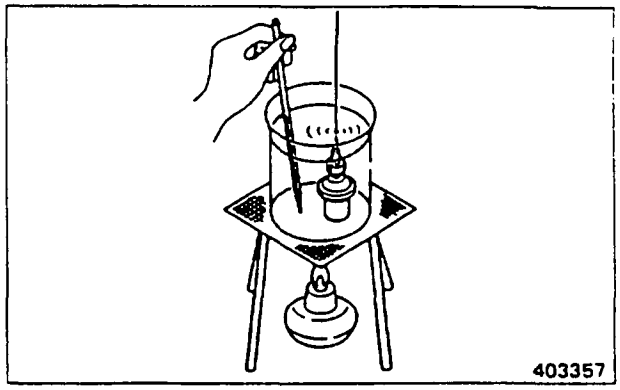
(a) Check the oil thermostat seal for deterioration or tears, and replace it if defective.

(b) Install the seal correctly as shown.



Installing thermostat seal

(c) Put each thermostat in a glass jar filled with engine oil, 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 11 mm (0.43 in.). If these measurements are out of the assembly standard, replace the thermostat.



Unit: °C (°F)

Item	Assembly standard
Temperature at which valve starts opening	93 ± 2 (199 ± 3.6)
Temperature at which valve lift is more than 11 mm (0.43 in.), minimum	105 (221)

⚠ CAUTION

(a) Stir the oil 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 the side face of the thermostat valve at reassembly.

3.3 Reassembly

To reassemble, follow the reverse of disassembly sequence.

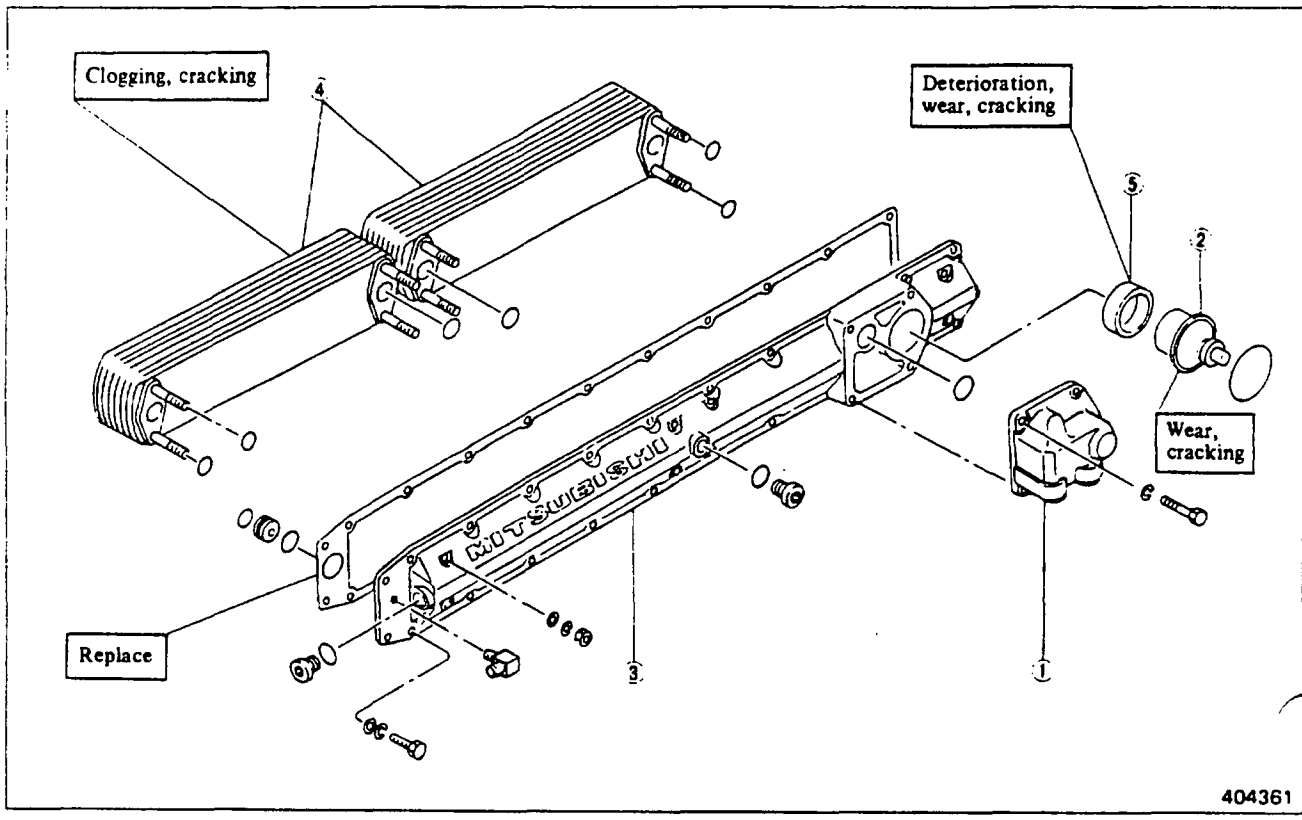
(1) Replace packings and O-rings during reassembly.

(2) Wash oil passages clean with washing solvent and blow dry thoroughly before installation.

(3) Install oil filter elements after installing filter bracket assembly.

4. RIGHT-HAND OIL COOLER AND OIL THERMOSTAT

4.1 Disassembly



① Connector
② Oil thermostat
③ Oil cooler cover
④ Oil cooler element
⑤ Thermostat seal

4.2 Inspection

Check the oil cooler and oil thermostat as in case of the left-hand cooler and thermostat.

4.3 Reassembly

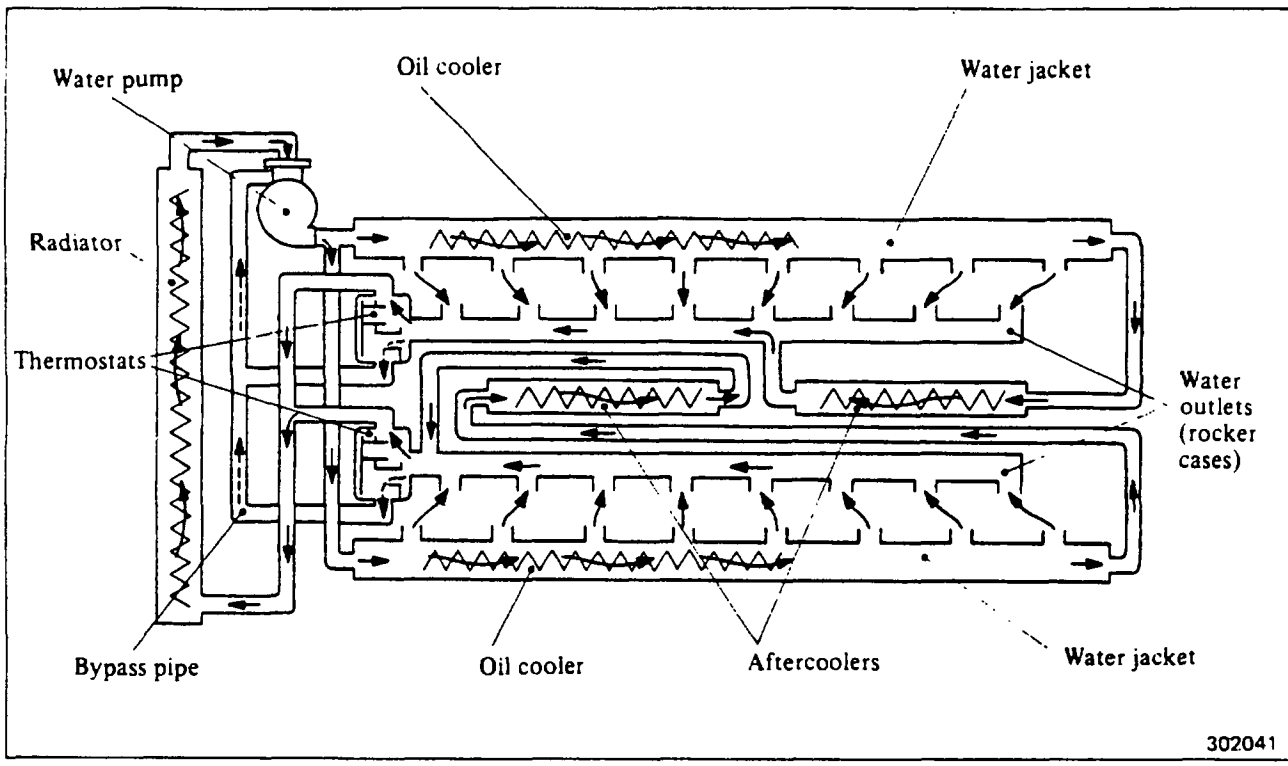
To reassemble, follow the reverse of disassembly procedure.

(1) Replace packings and O-rings during reassembly.

(2) Wash oil passages clean with washing solvent and blow dry before installing the oil cooler and thermostat.

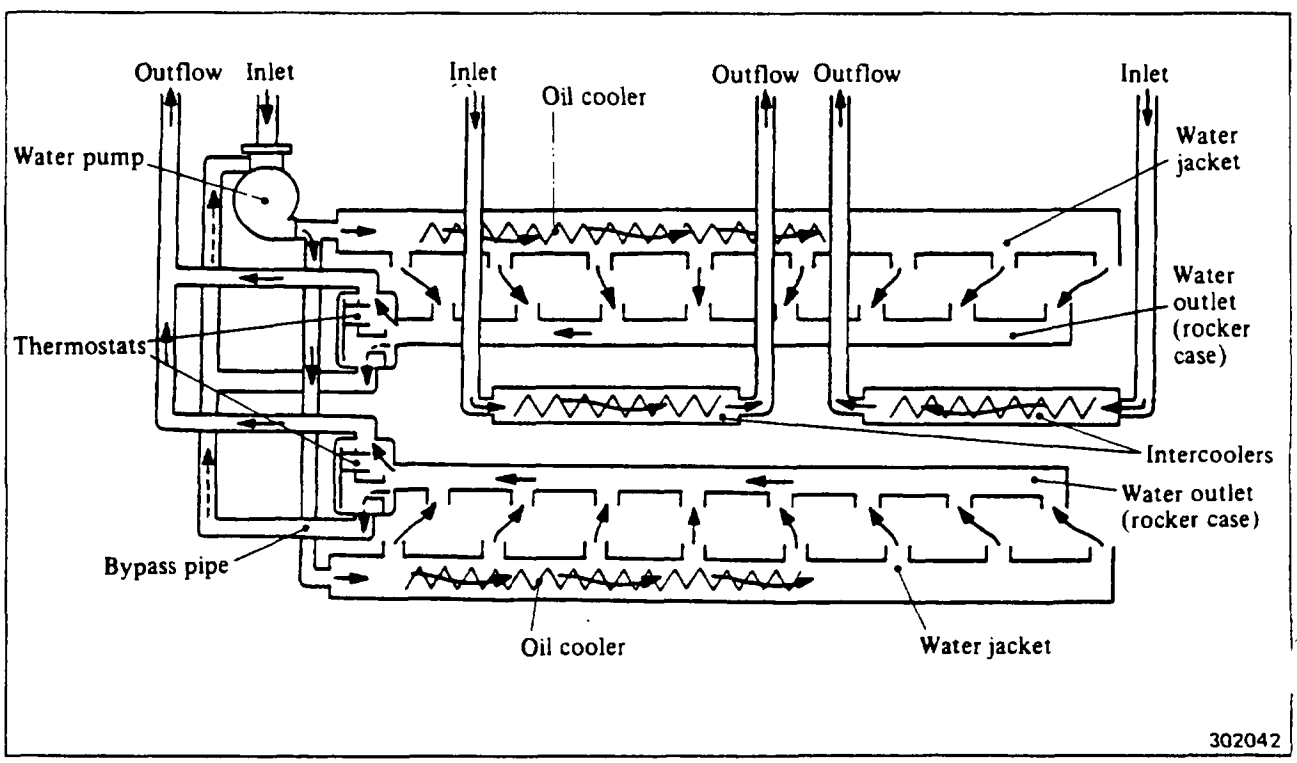
COOLING SYSTEM

1. CLOSED COOLING SYSTEM WITH RADIATOR



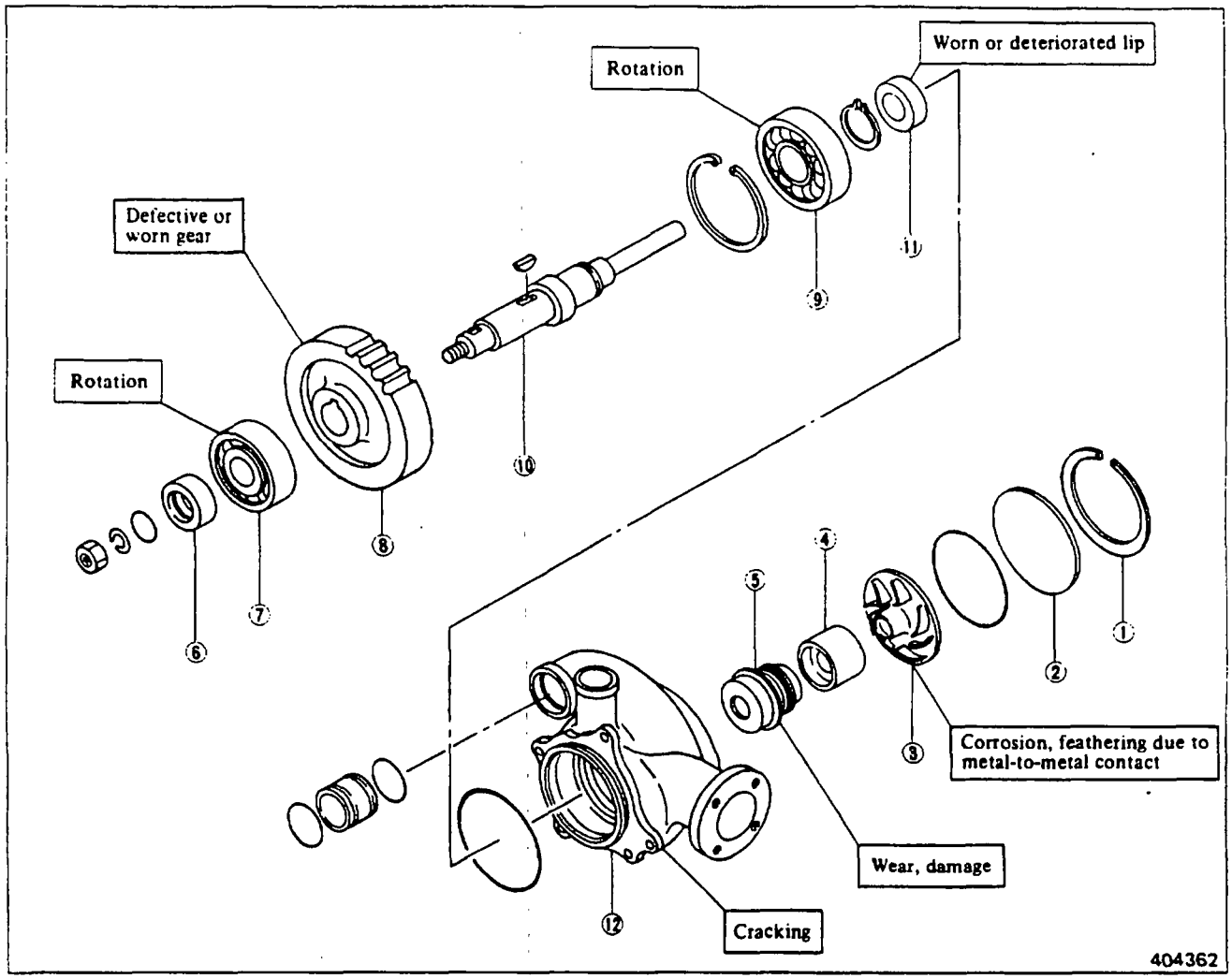
2. OPEN COOLING SYSTEM TWO WATER CIRCUITS

PTK



3. WATER PUMP

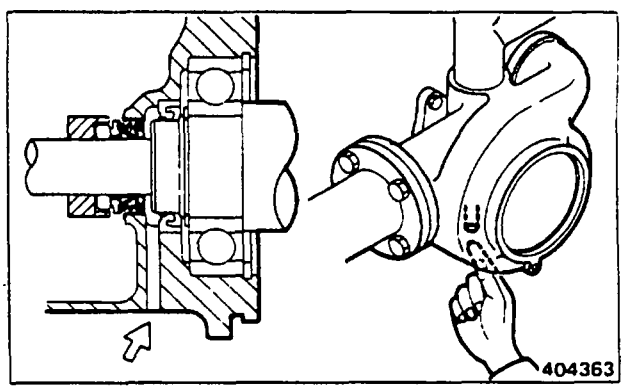
3.1 Disassembly



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

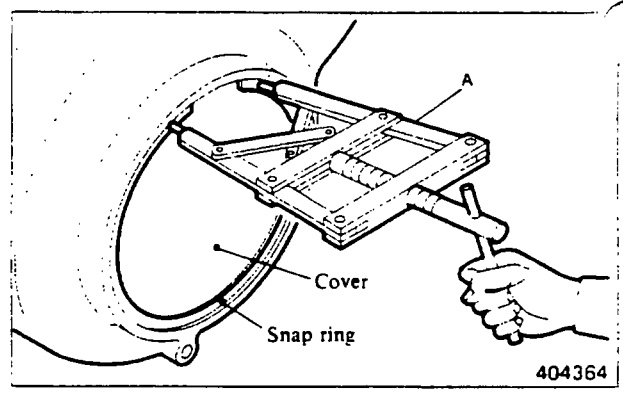
(1) Inspecting water pump on engine

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

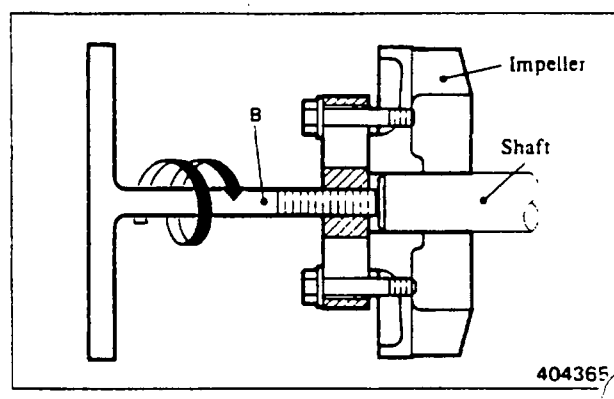


(2) Removing impeller

(a) Remove the snap ring securing the cover, and remove the cover with water pump pliers (A) (37591-03100).



(b) Remove the impeller with impeller remover (B) (37591-03200).



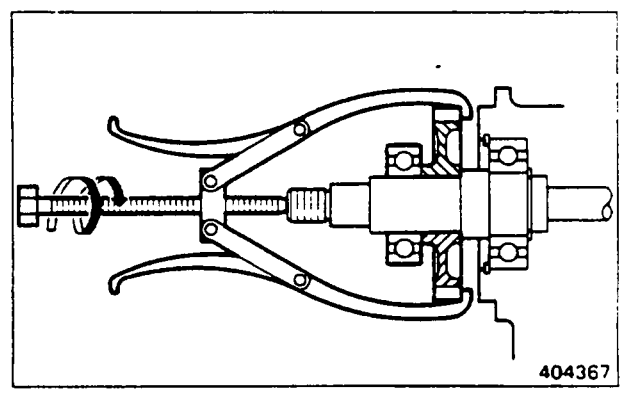
Removing impeller

(3) Removing water pump shaft

(a) Remove the oil seal sleeve.

(b) Using gear puller, remove the gear complete with the ball bearing.

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

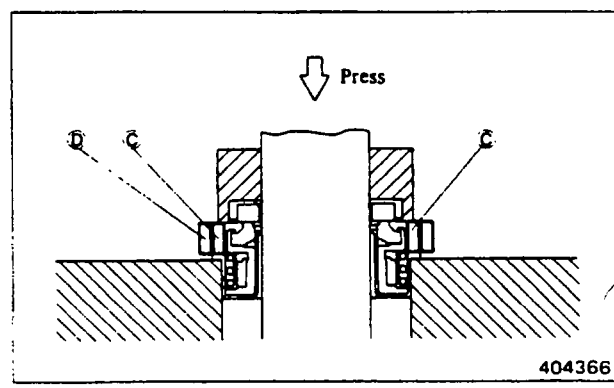


Removing gear

(d) Put two halves (C) of the ring of ring remover (37791-03400) between the unit seal and pump case.

(e) Put outer ring (D) over the two halves (C) of the ring.

(f) Support the pump case, and press the shaft off the case with an arbor press by pushing the impeller side end of the shaft.



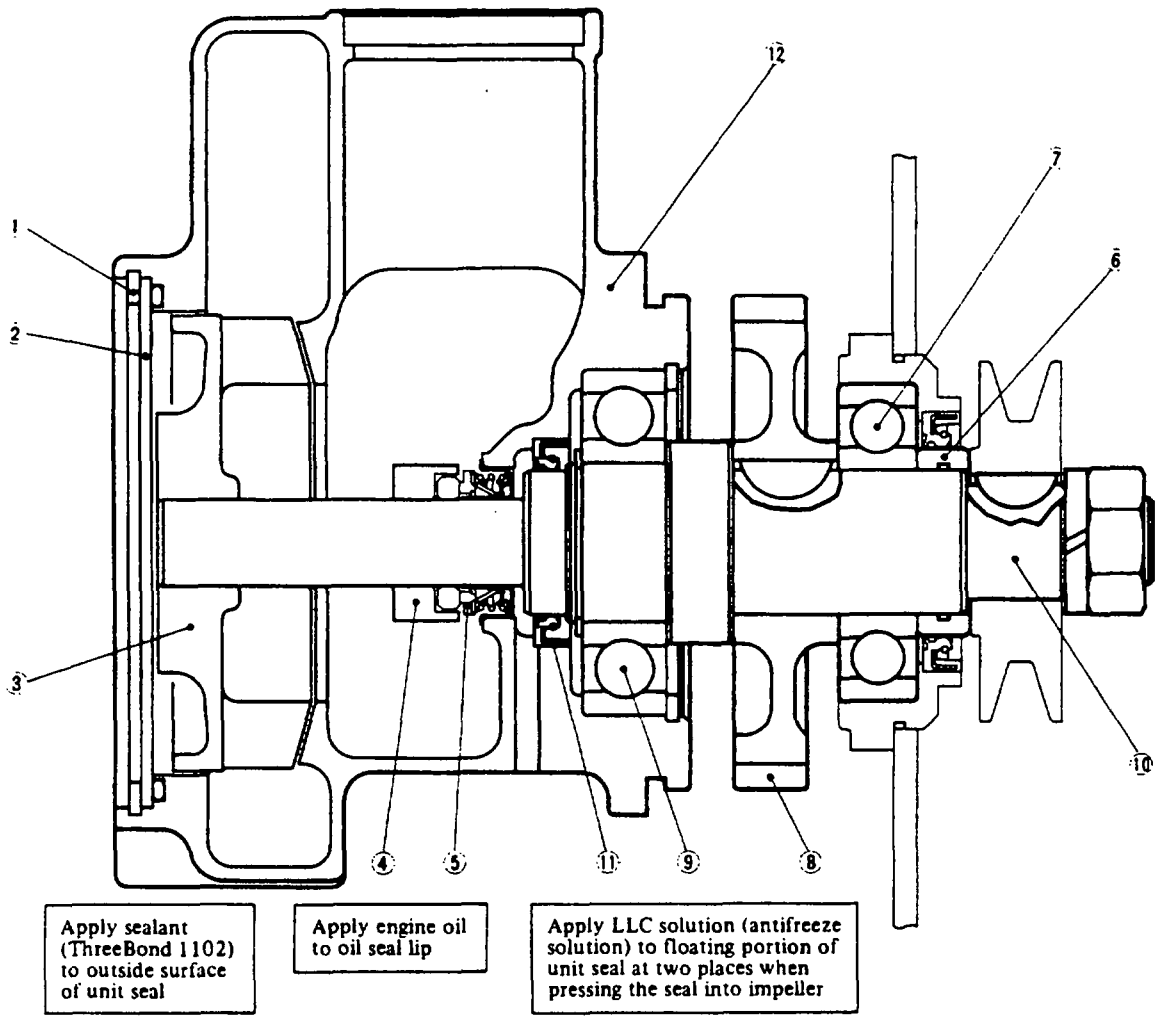
3.2 Inspection

Measure the inside diameter of bearing bores in the pump case and bearing cover and the diameter of bearing journals of the shaft, and replace a badly worn part, if any.

Unit: mm (in.)

Item		Nominal value	Assembly standard
Inside diameter of bearing bore in case		120 (4.72)	119.987 to 120.022 (4.72389 to 4.72527)
Inside diameter of bearing bore in bearing cover		110 (4.33)	110.005 to 110.040 (4.33090 to 4.33227)
Bearings	Outside diameter	120 (4.72)	119.980 to 120.005 (4.72361 to 4.72460)
		110 (4.33)	109.980 to 110.005 (4.32991 to 4.33090)
	Inside diameter	55 (2.17)	54.981 to 55.004 (2.16460 to 2.16551)
		50 (1.97)	49.981 to 50.004 (1.96775 to 1.96866)
Diameter of bearing journals of shaft		55 (2.17)	55.002 to 55.015 (2.16543 to 2.16594)
		50 (1.97)	50.002 to 50.013 (1.96858 to 1.96901)

3.3 Reassembly



Reassembly sequence

⑫→⑪→⑤
⑩→⑨
→⑧→⑦→⑥→④→③→②→①

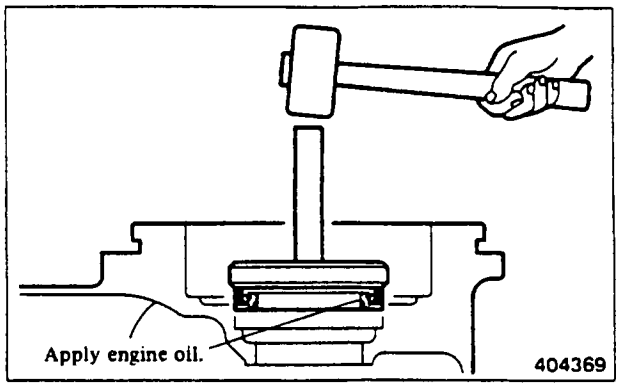
⚠ CAUTION

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

(1) Install the oil seal in position in the pump case with oil seal installer.

NOTE

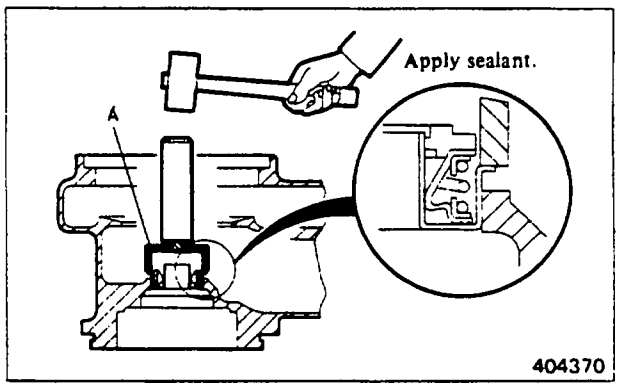
Apply engine oil to the lip of oil seal.



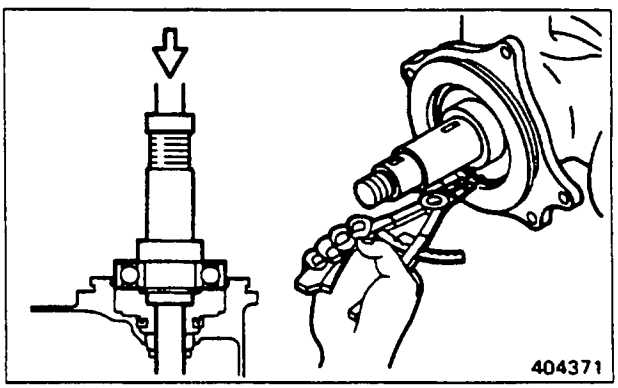
(2) Install the unit seal in position in the pump case with unit seal installer (A) (37191-06300). Be sure to replace the unit seal if it has been removed from the pump case during disassembly.

NOTE

Apply sealant (ThreeBond No. 1102) to the outside of the unit seal.



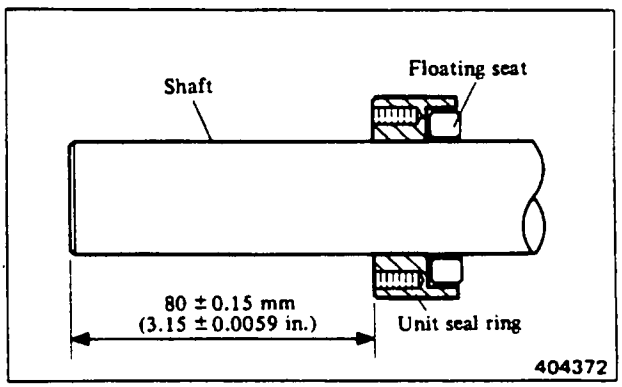
(3) Press the pump shaft complete with impeller-side ball bearing into the pump case with an arbor press, with the snap ring side of the case down.



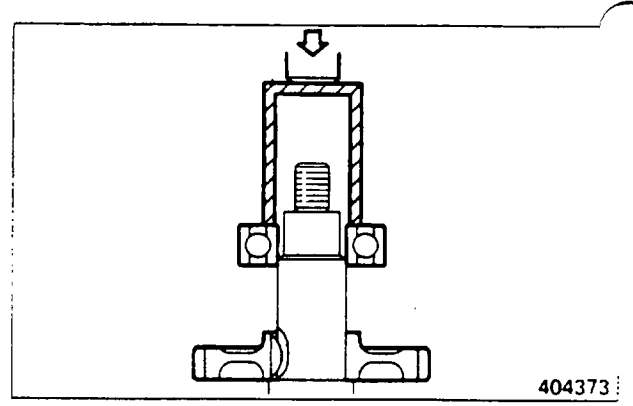
(4) Press the unit seal ring fitted with the floating seat onto the shaft with ring installer (37791-03300) until the end face of the ring is 80 ± 0.15 mm (3.15 ± 0.0059 in.) from the end of the shaft, as shown.

NOTE

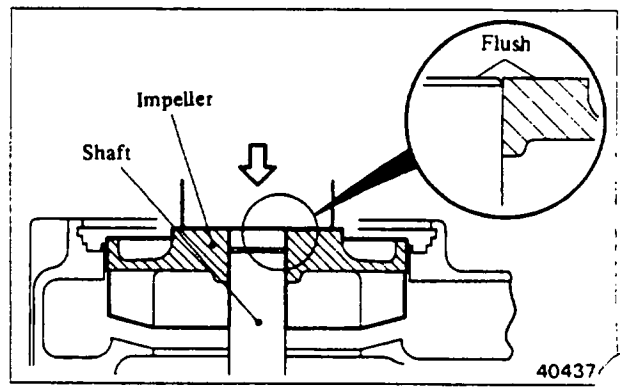
Apply LLC solution (antifreeze solution) to the floating seat at two places.



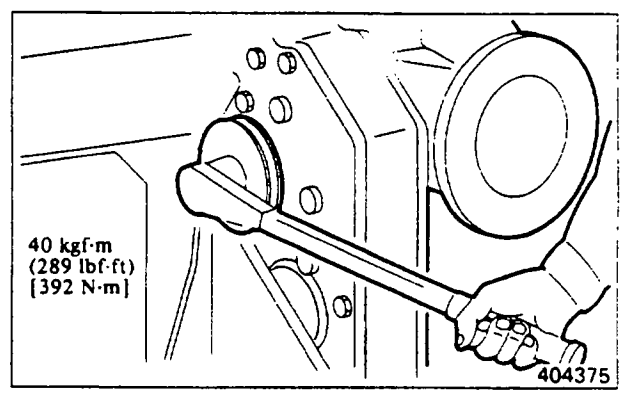
(5) Press the gear onto the shaft with an arbor press by aligning the shaft key with the keyway in the gear bore.



(6) Press the impeller onto the shaft with an arbor press until the end face of impeller boss is flush with the end of the shaft.

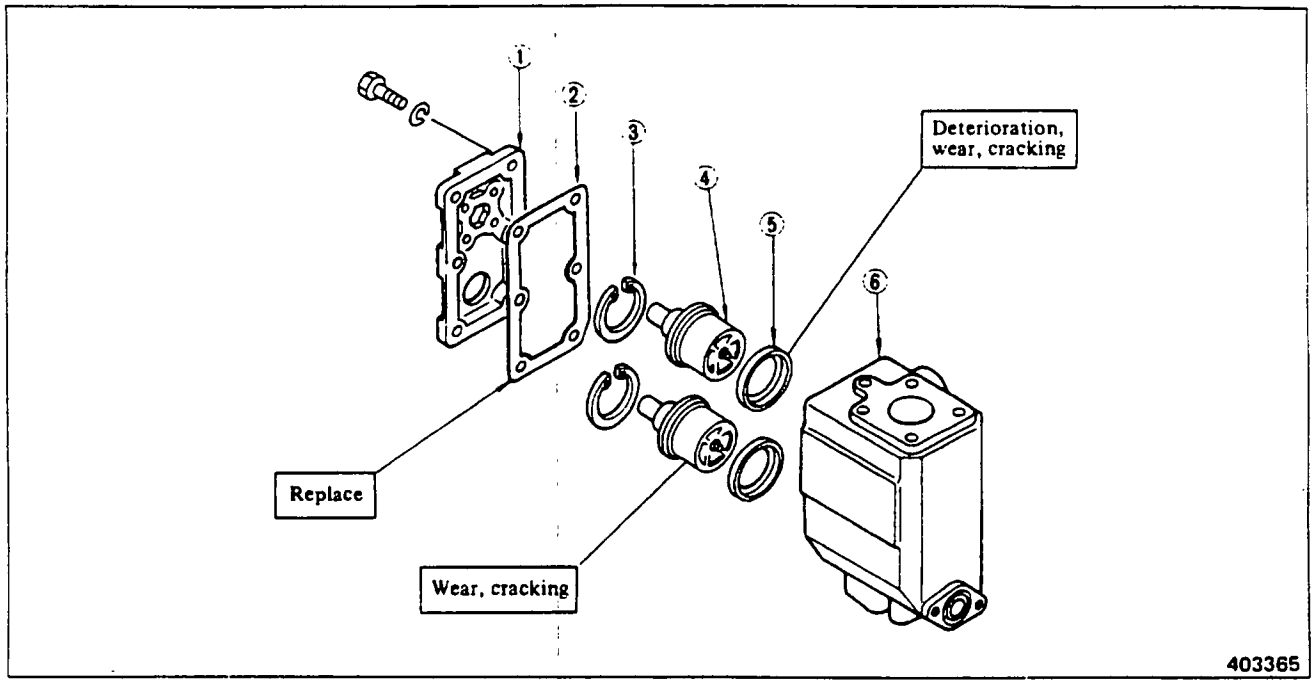


(7) Install the water pump assembly in position on the engine. Put the alternator pulley on the rear of the shaft, and tighten it to the specified torque.



4. THERMOSTATS

4.1 Disassembly



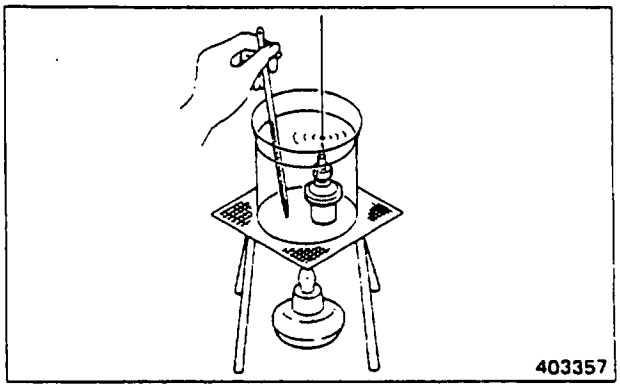
① Thermostat cover
② Packing
③ Snap ring
④ Thermostat
⑤ Thermostat seal
⑥ Thermostat case

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 11 mm (0.43 in.). If these measurements are out of the assembly standard, replace the thermostat.

Unit: °C (°F)

Item	Assembly standard
Temperature at which valve starts opening	71 ± 2 (160 ± 3.6)
Temperature at which valve lift is more than 11 mm (0.43 in.), minimum	85 (185)



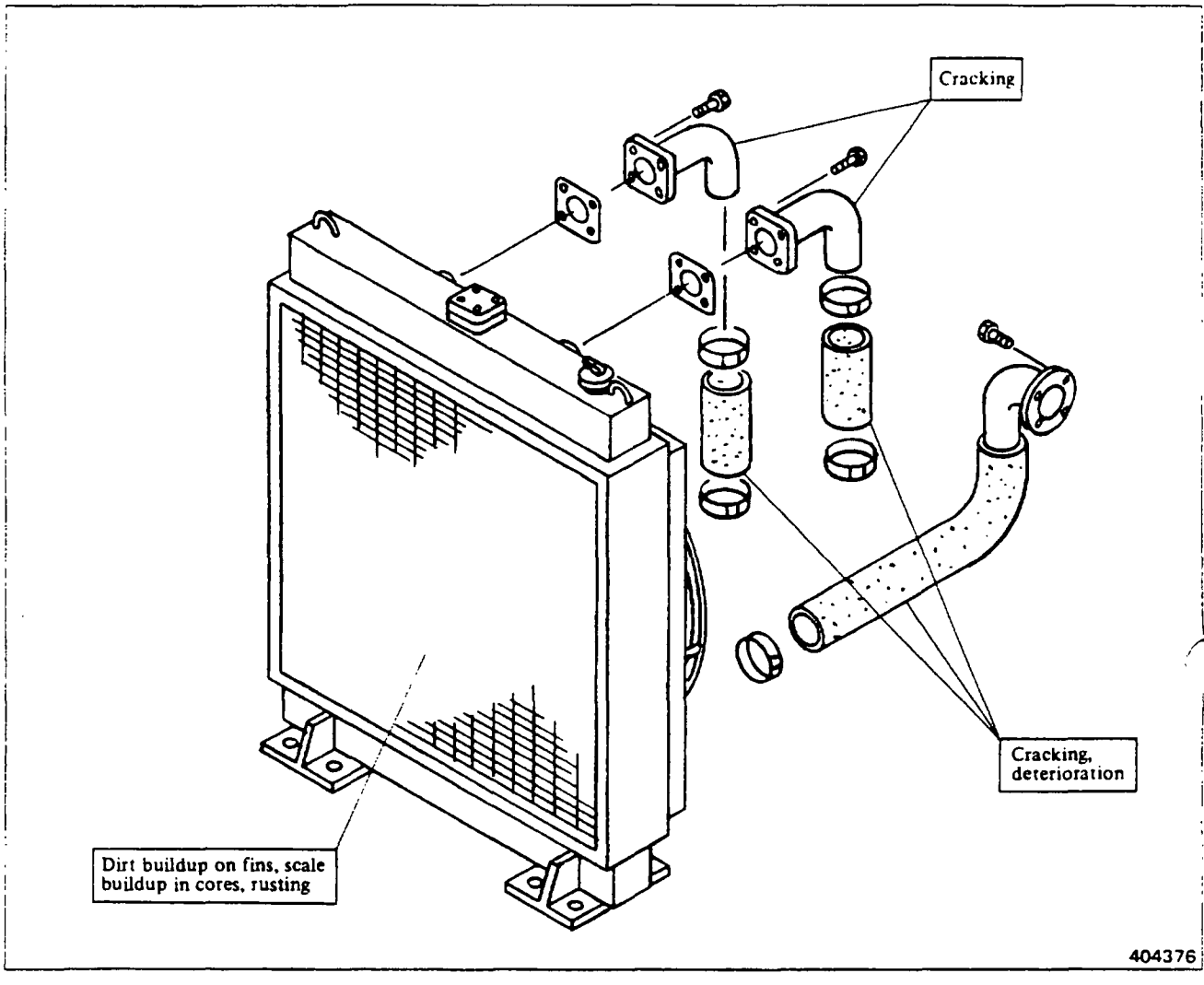
⚠ CAUTION

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

(b) Be sure to place each thermostast in correct position by ascertaining the valve opening temperature stamped on the side face of the thermostat valve at reassembly.

5. RADIATOR

Inspection

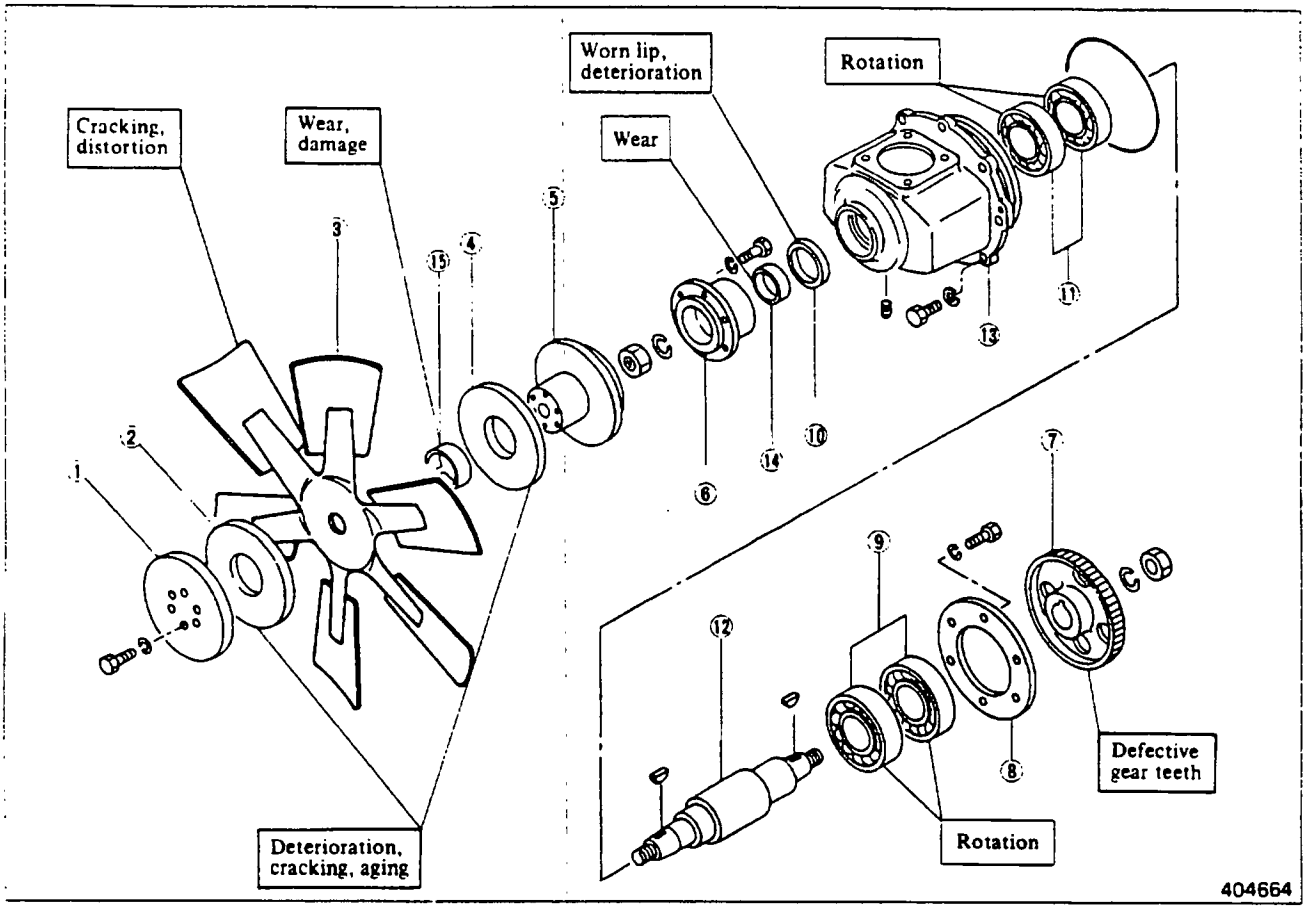


(1) Check the radiator fins for trash buildup. Also check the core interior for scale buildup and rusting. Clean the radiator as recommended.

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

6. FAN DRIVES

6.1 Disassembly



① Plate
② Friction rubber
③ Fan
④ Friction rubber
⑤ Fan hub
⑥ Coupling
⑦ Fan drive gear
⑧ Thrust plate
⑨ Bearings
⑩ Oil seal
⑪ Bearings
⑫ Drive shaft
⑬ Fan drive case
⑭ Oil seal sleeve
⑮ Fan bushing

⚠ 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.

6.2 Inspection

(1) Measure the inside diameter of bearing bore in the drive case and the diameter of bearing journals of the shaft, and replace a badly worn part if any.

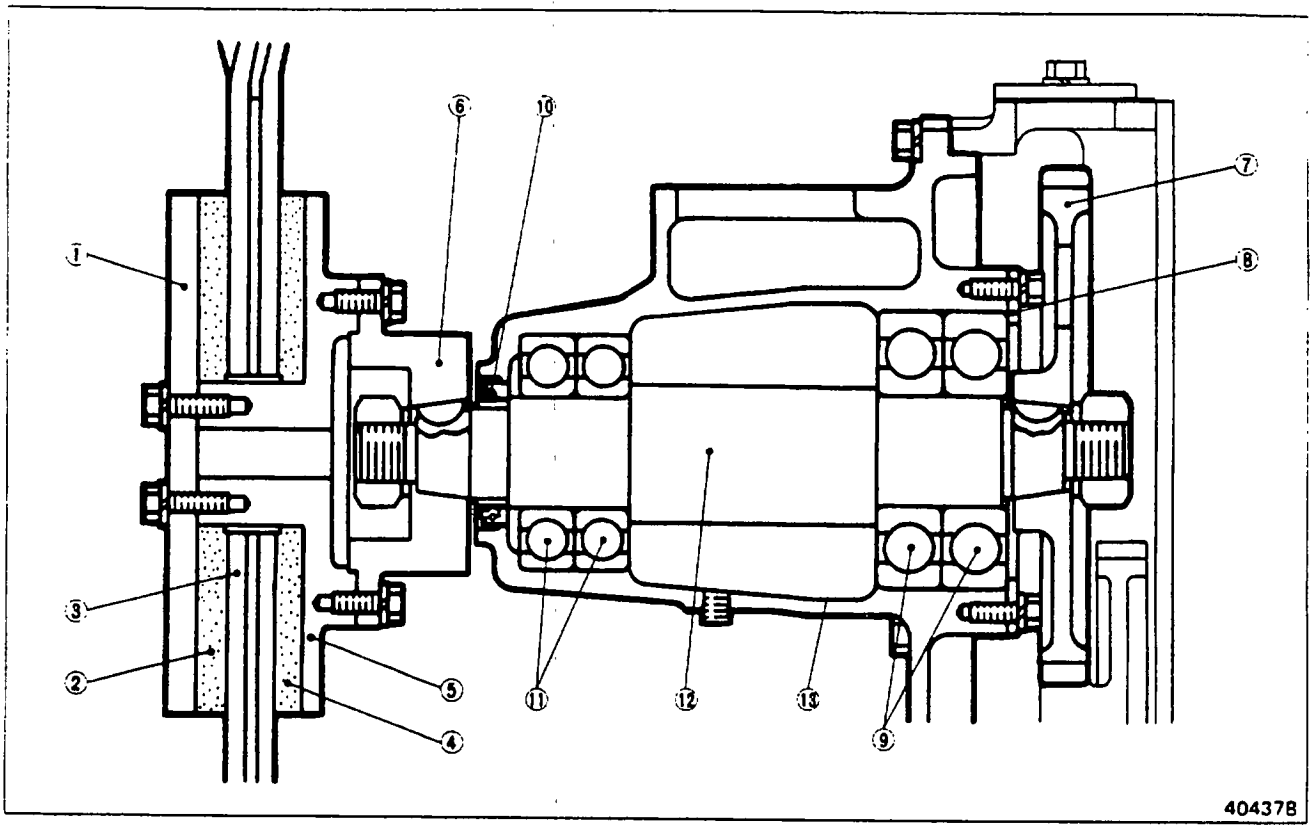
Unit: mm (in.)

Item		Nominal value	Assembly standard
Inside diameter of bearing bore in case		140 (5.51)	139.986 to 140.026 (5.51125 to 5.51282)
		120 (4.72)	119.987 to 120.022 (4.72389 to 4.72527)
Bearings	Outside diameter	140 (5.51)	139.976 to 140.006 (5.51086 to 5.51204)
		120 (4.72)	119.980 to 120.005 (4.72361 to 4.72460)
	Inside diameter	55 (2.17)	54.981 to 55.004 (2.16460 to 2.16551)
Diameter of shaft bearing journals		55 (2.17)	55.002 to 55.015 (2.16543 to 2.16594)

(2) Check the fan bushing for wear or damage, and replace it if defective.

(3) Check the friction rubber for deterioration, fatigue, cracks or other defects, and replace it if defective.

6.3 Reassembly



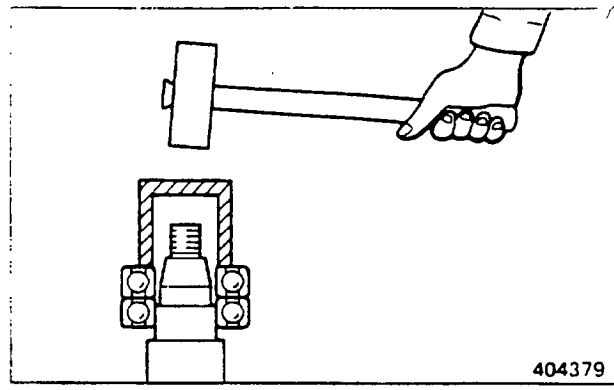
Reassembly sequence

⑬→⑩
⑫→⑪
→⑨→⑧→⑦→⑥→⑤→④→③→②→①

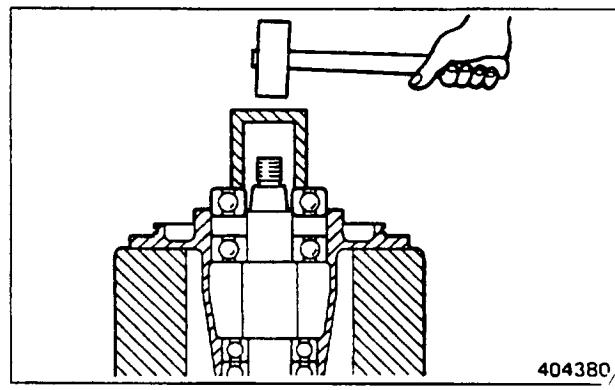
(1) Press the fan-side bearings onto the shaft with bearing installer. Press the oil seal into the case.

NOTE

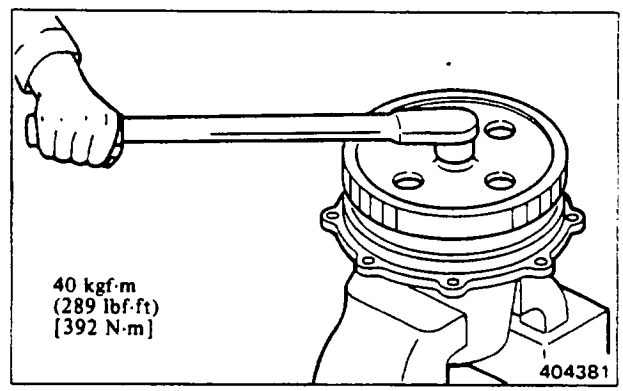
Apply engine oil to the lip of oil seal before installing the seal.



(2) Install the shaft in the bracket. Then, press the gear-side bearings onto the shaft and into the case with bearing installer, and put the thrust plate.



(3) Put the gear on the shaft by aligning the shaft key with the keyway in the gear, and tighten the nut to the specified torque.

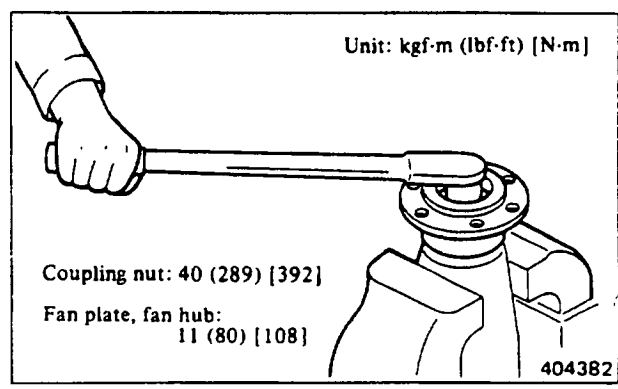


(4) Installing fan

(a) Put the coupling on the shaft by aligning shaft key with the keyway in the coupling, and tighten the nut to the specified torque.

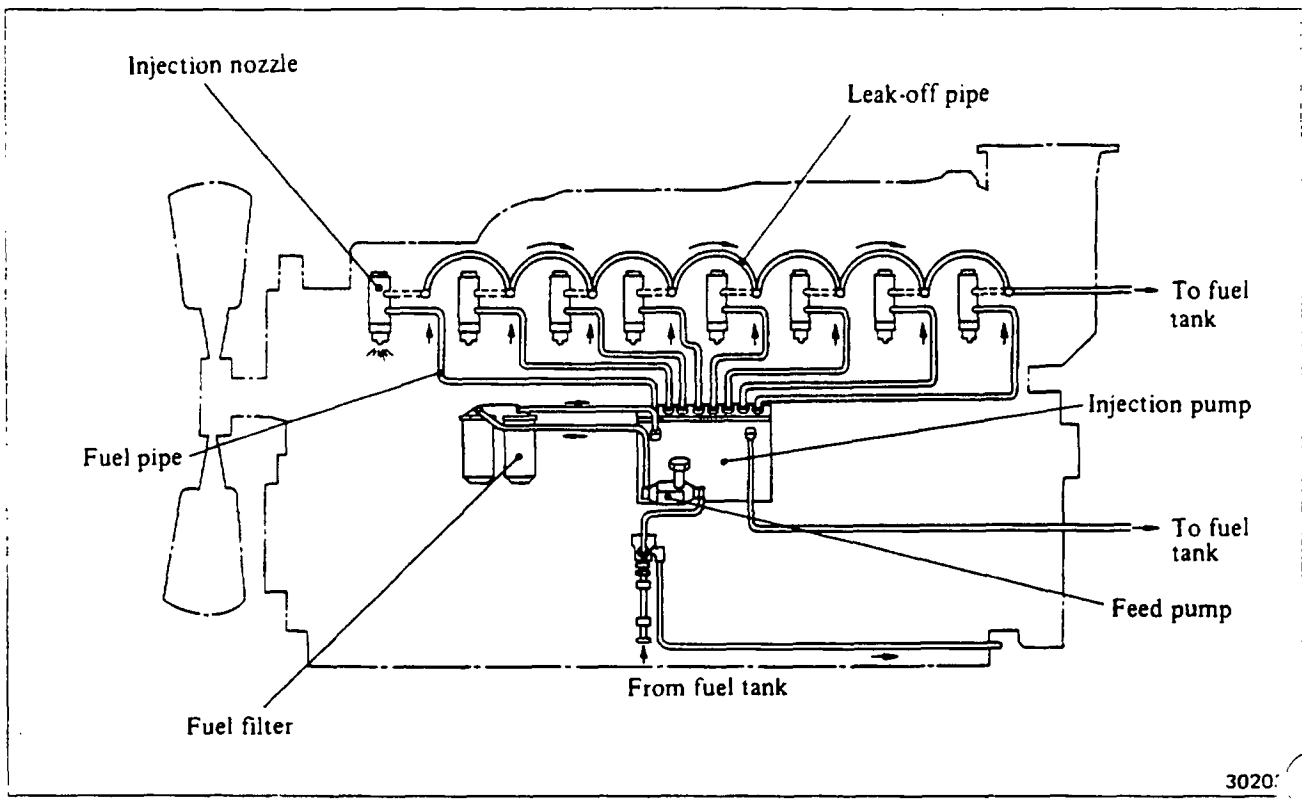
(b) Tighten the bolts securing the coupling and fan hub to the specified torque.

(c) Put friction rubber, fan bushing and fan on the shaft. Put fan plate in position, and tighten its mounting bolts to the specified torque.



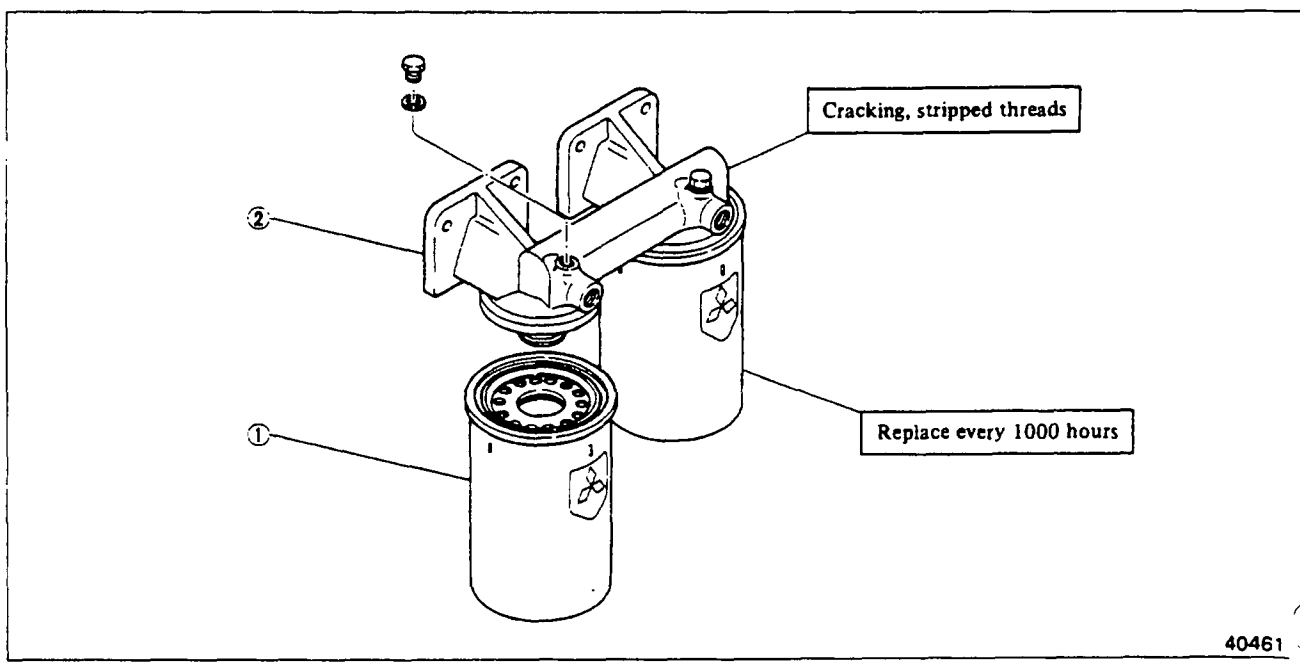
FUEL SYSTEM

1. DESCRIPTION



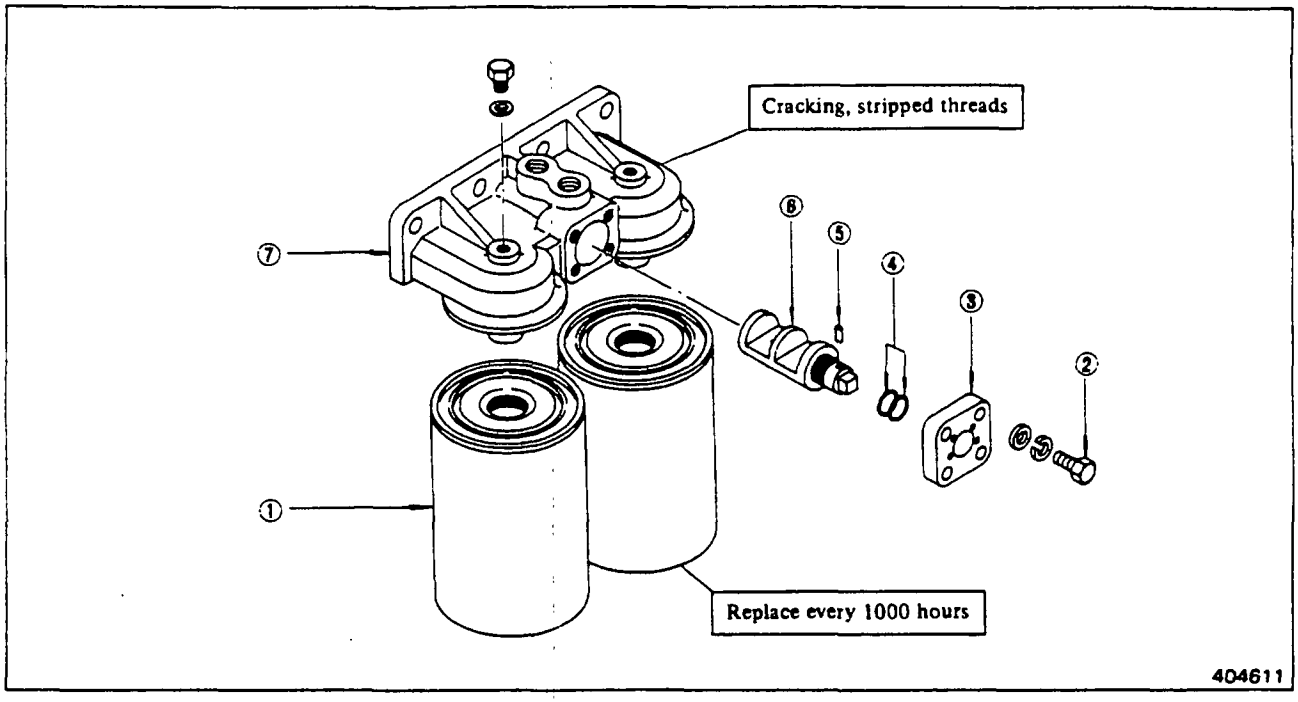
2. FUEL FILTERS

2.1 Disassembly and inspection



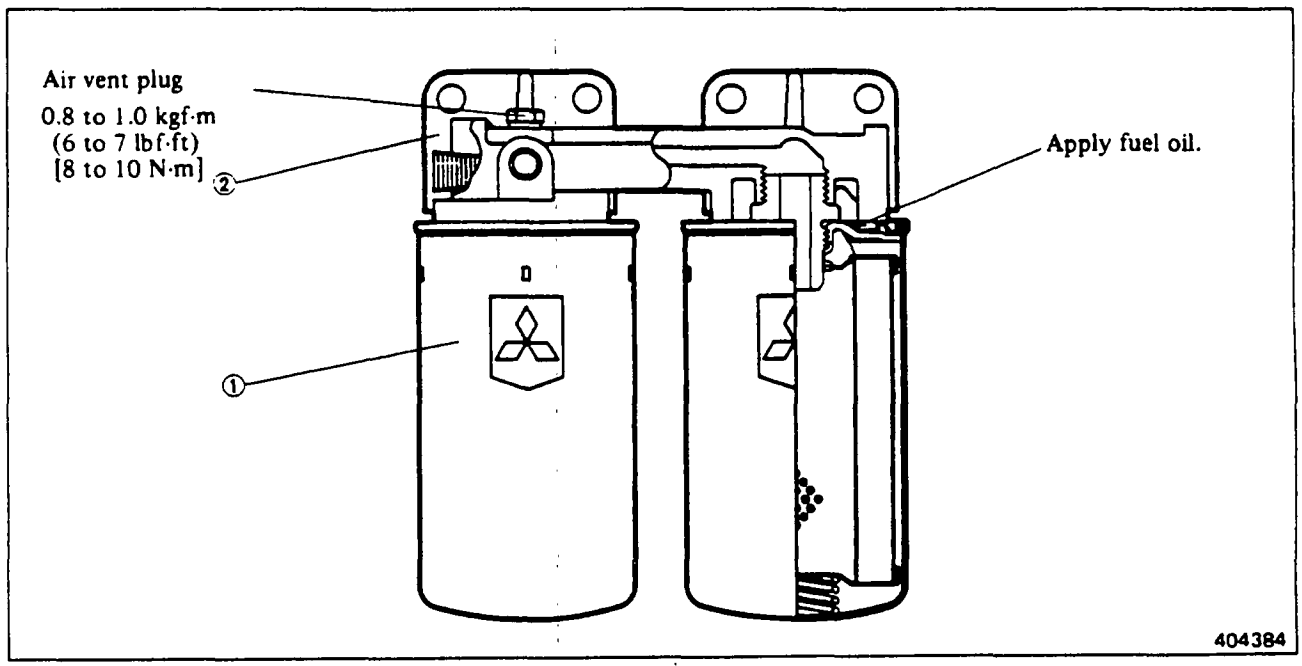
① Element ② Fuel filter bracket

(Fuel filter with selector cock)



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

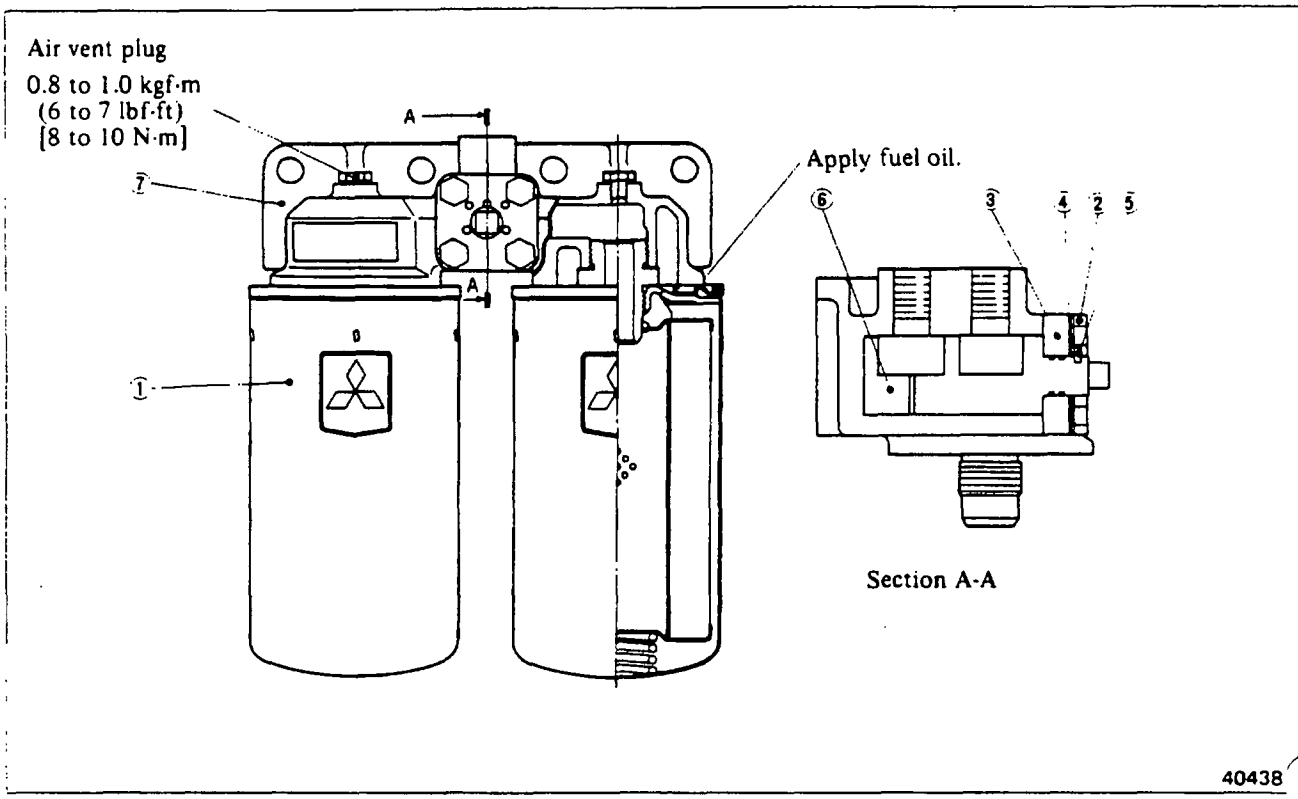
2.2 Reassembly



Reassembly sequence

②→①

(Fuel filter with selector cock)



Reassembly sequence

⑦→⑤→④→⑥→③→②→①

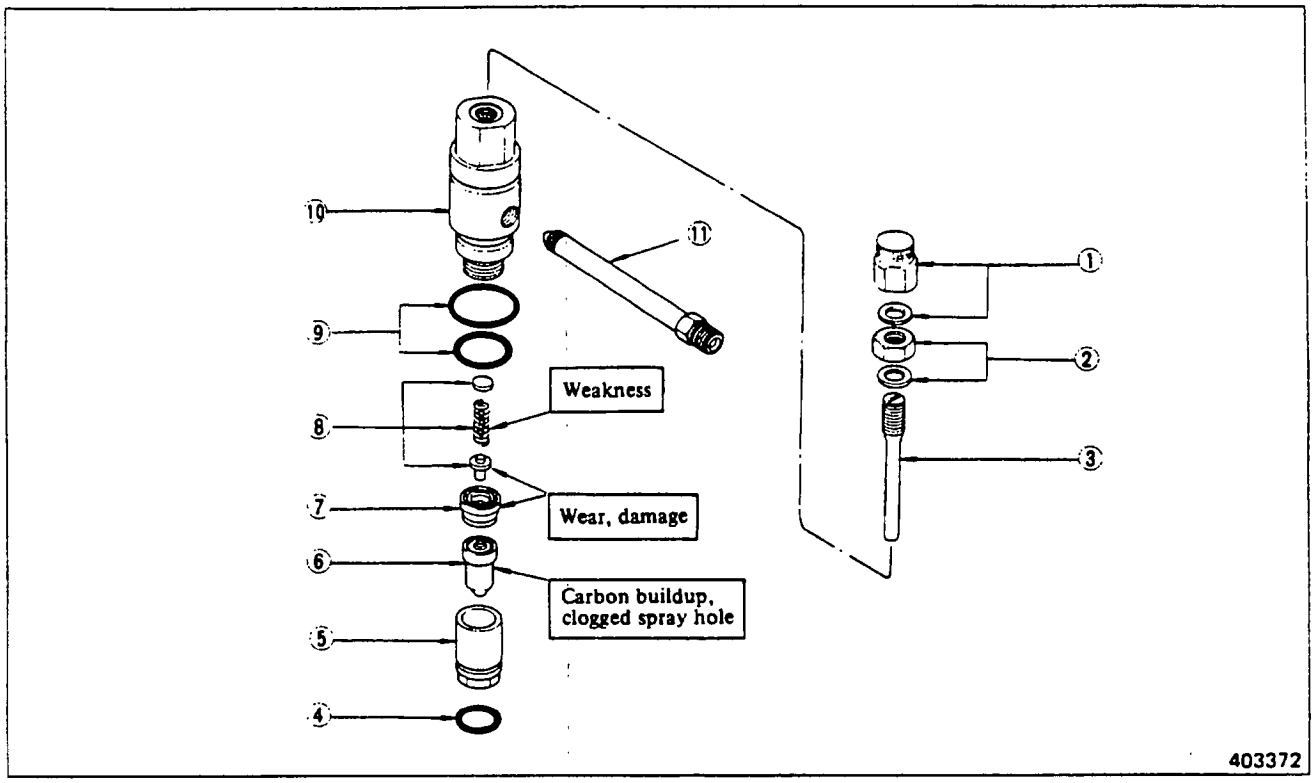
When installing cartridge, clean its mounting seat, and coat its gasket with clean fuel oil. After bringing gasket into contact with sealing surface of bracket, hand-tighten cartridge 1/2 to 3/4 turn.

⚠ 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 INJECTION NOZZLES

3.1 Disassembly

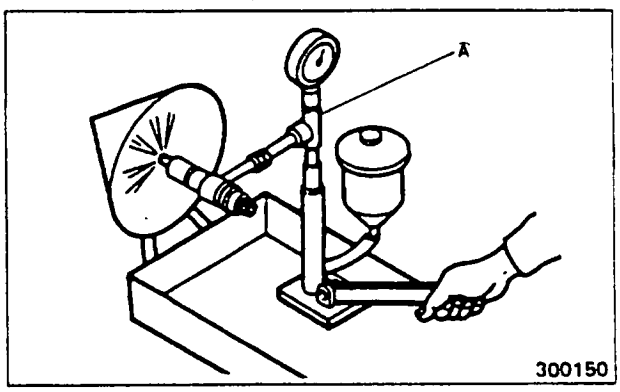


① Cap nut, gasket
② Jam nut, gasket
③ Adjusting screw
④ O-ring
⑤ Retaining nut
⑥ Nozzle tip
⑦ Spacer
⑧ Pushrod, nozzle spring, spring seat
⑨ O-ring
⑩ Nozzle holder
⑪ Fuel inlet connector

3.2 Inspection and adjustment

(1) Injection pressure

(a) Install the nozzle on the tester (A) (41091-01500). 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
Injection pressure (valve opening pressure)	350 to 355 (4977 to 5048) [34 to 35]

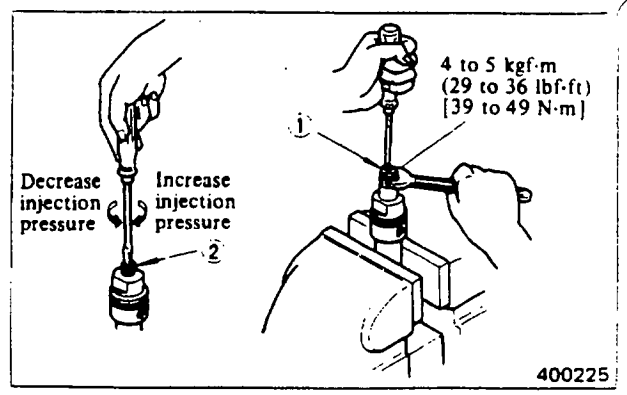
⚠ WARNING

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, loosen the jam nut, and turn adjusting screw (2) in either direction with a screwdriver.

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

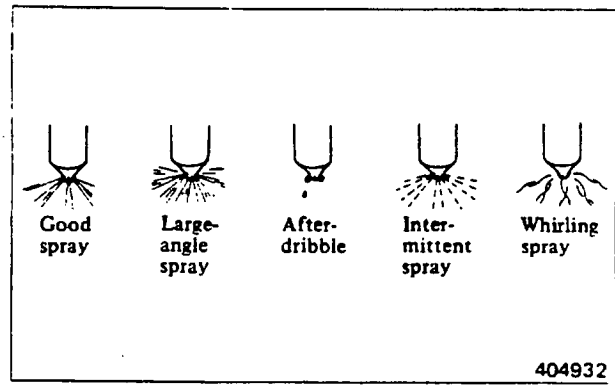
(d) Recheck the injection pressure, making sure that it meets the assembly standard.



(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.

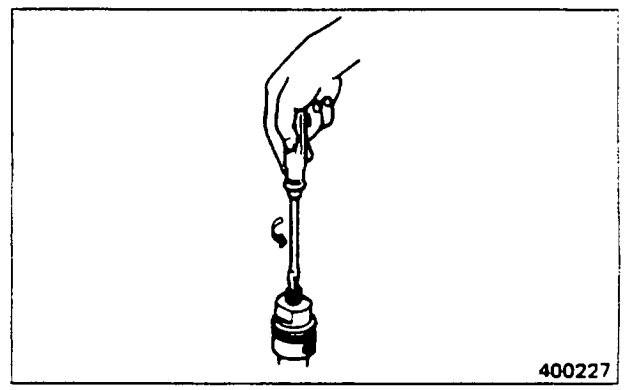
(b) When tested on the nozzle tester, the nozzle should spray fuel from its ten orifices at the same time in a good straight cone of 160 degrees, consisting of finely atomized fuel particles without any large droplets, and should terminate with no dribble at the tip.



Possible spray patterns

(3) Washing or replacing nozzle tip

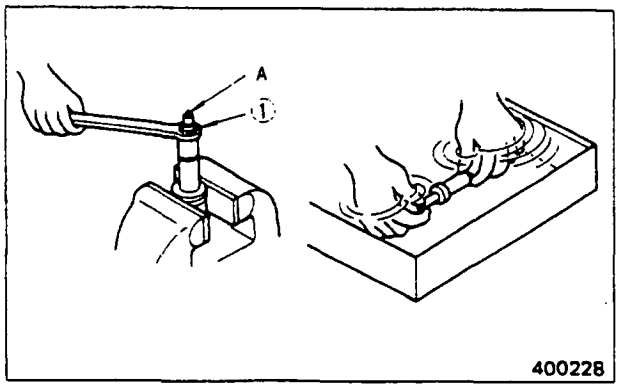
(a) The nozzle tip is spring loaded. Remove the cap nut and, with a screwdriver, loosen the adjusting screw to such an extent that it can be loosened by the hand.



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

⚠ CAUTION

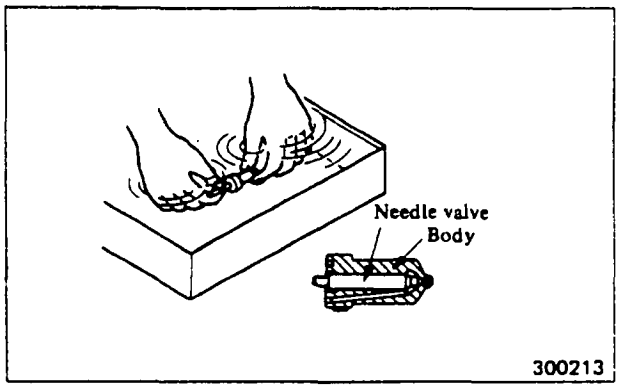
When pulling out the nozzle tip, be careful not to damage its tip (A).



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

NOTE

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



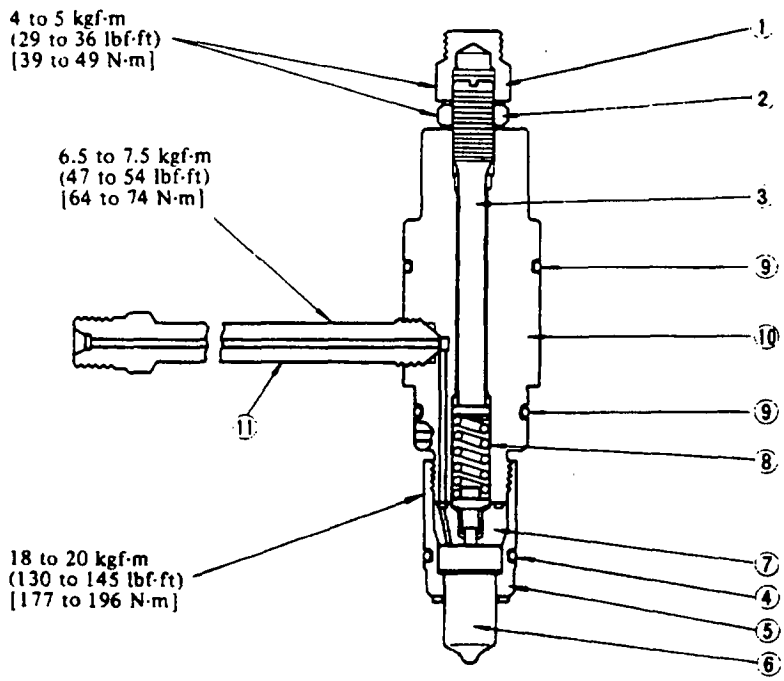
(d) Tighten the retaining nut to the specified torque.

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

NOTE

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

3.3 Reassembly



4033

Reassembly sequence

⑩→⑨→③→⑧→⑦→⑥→⑤→④→⑪→②→①

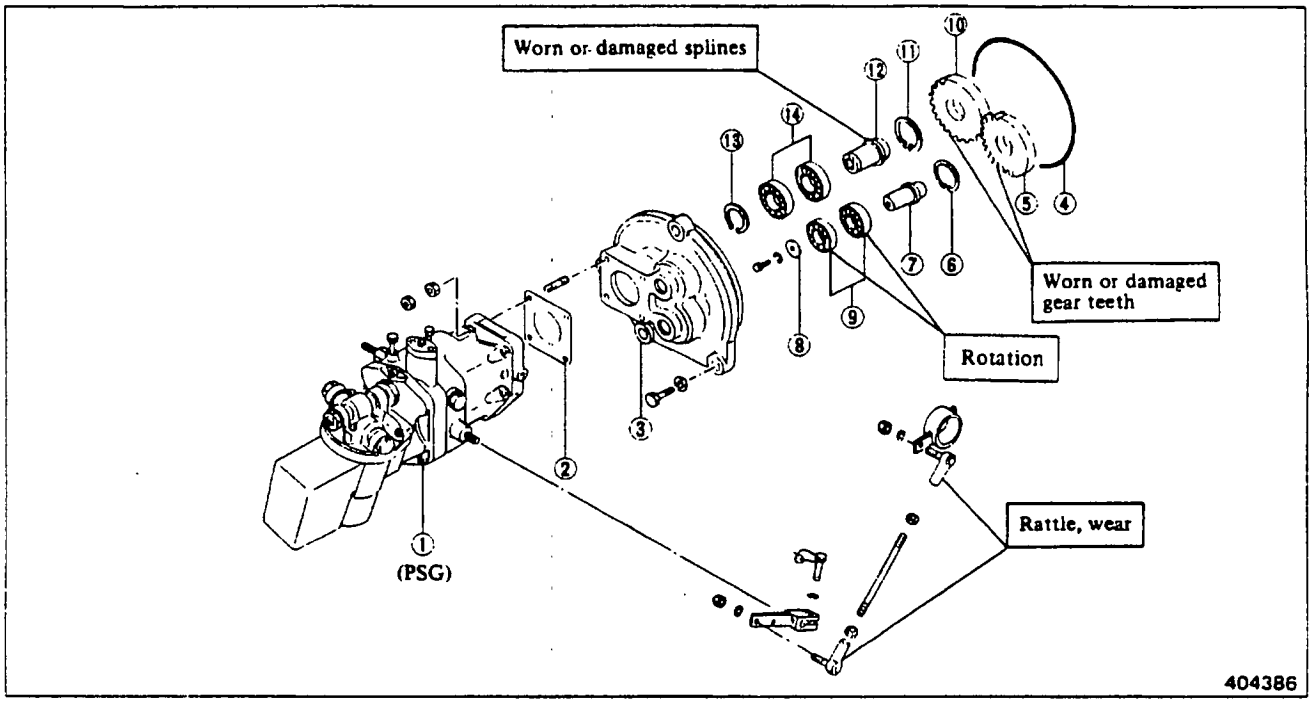
⚠ CAUTION

If retaining nut (5) is over-tightened, the needle valve will fail to move freely, resulting in exhaust smoke failure or sticking. With this kept in mind, be sure tighten the nut to the specified torque.

4. GOVERNOR DRIVE AND GOVERNOR LINK

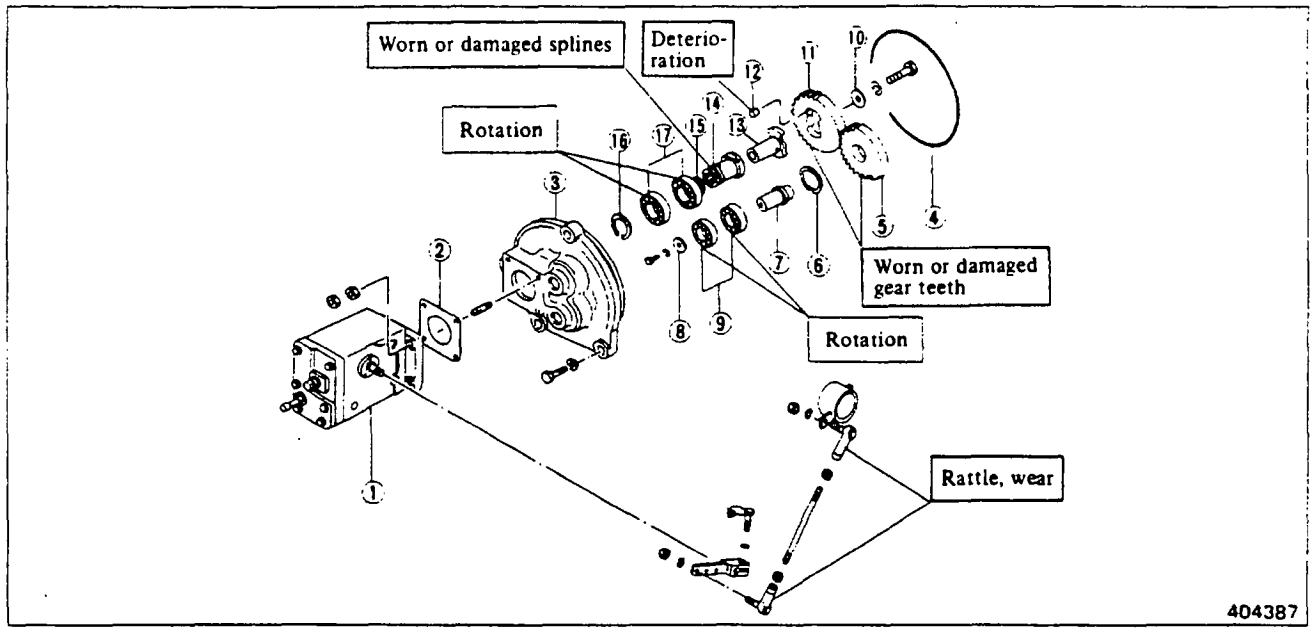
4.1 Disassembly

(PSG and EG-3P governors)



① Governor (PSG)
② Packing
③ Drive case
④ O-ring
⑤ Idler gear
⑥ Snap ring
⑦ Idler shaft
⑧ Washer
⑨ Bearings
⑩ Drive gear
⑪ Snap ring
⑫ Drive shaft
⑬ Snap ring
⑭ Bearings

(EG-B2P governor)



① Governor (EG-B2P)
② Packing
③ Drive case
④ O-ring
⑤ Idler gear
⑥ Snap ring
⑦ Idler shaft
⑧ Washer
⑨ Bearings
⑩ Washer
⑪ Drive gear
⑫ Gear rubber
⑬ Drive shaft
⑭ Drive shaft
⑮ Snap ring
⑯ Snap ring
⑰ Bearings

4.2 Inspection

Inspecting fits of bearings

Rotate each bearing to check for rotation. Replace a bearing which fails to rotate smoothly.

Check the fits of bearings on the drive shaft and idler shaft. Replace the shaft or bearings whichever are badly worn.

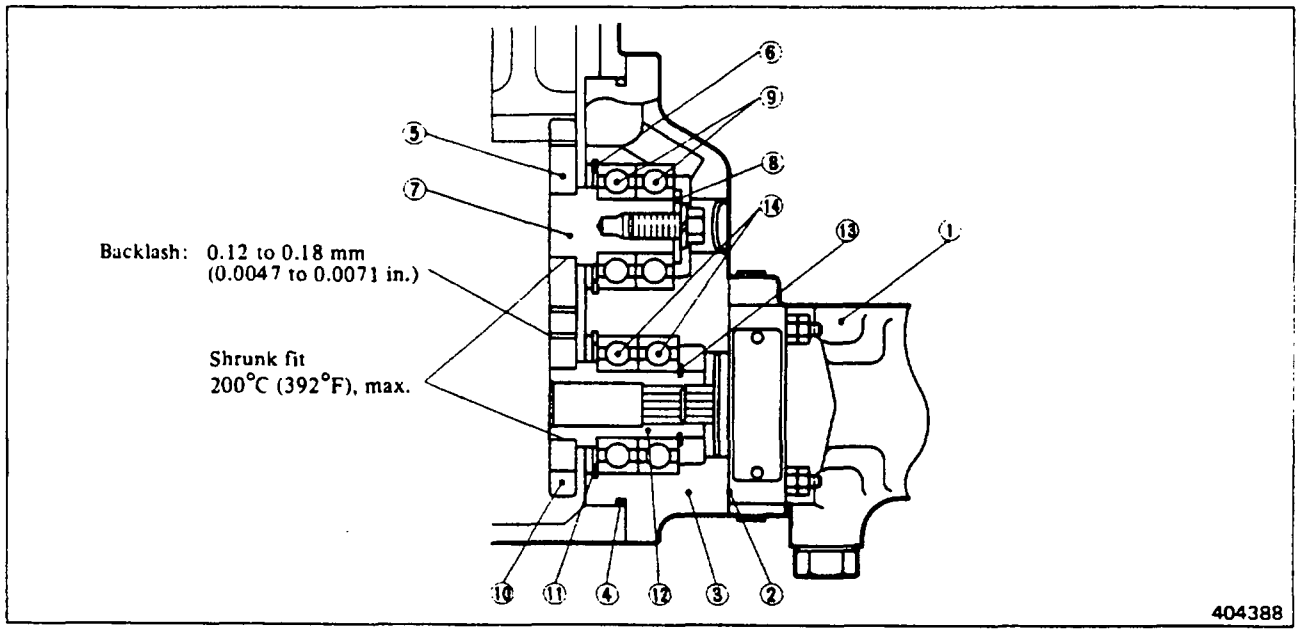
Check the fit of bearings in the drive case, and replace a worn part.

Unit: mm (in.)

Item		Nominal value	Assembly standard
Inside diameter of drive shaft bearing bore in case		52 (2.05)	51.988 to 52.018 (2.04677 to 2.04795)
Drive shaft bearings	Outside diameter	52 (2.05)	51.983 to 52.004 (2.04657 to 2.04740)
	Inside diameter	25 (0.98)	24.987 to 25.003 (0.98374 to 0.98437)
Diameter of drive shaft bearing journal		25 (0.98)	25.002 to 25.011 (0.98433 to 0.98468)
Inside diameter of idler shaft bearing bore in case		47 (1.85)	46.989 to 47.014 (1.84996 to 1.85094)
Idler shaft bearings	Outside diameter	47 (1.85)	46.986 to 47.003 (1.84984 to 1.85051)
	Inside diameter	20 (0.79)	19.987 to 20.003 (0.78689 to 0.78752)
Diameter of idler shaft bearing journal		20 (0.79)	20.002 to 20.011 (0.78748 to 0.78783)
Diameter of drive gear shaft		26 (1.02)	26.035 to 26.048 (1.02500 to 1.02551)
Inside diameter of drive gear		26 (1.02)	26.000 to 26.013 (1.02362 to 1.02413)
Diameter of drive gear shaft (EG-B2P)		29 (1.14)	28.959 to 28.980 (1.14012 to 1.14094)
Inside diameter of drive gear (EG-B2P)		29 (1.14)	29.00 to 29.04 (1.1417 to 1.1433)
Diameter of idler gear shaft		24 (0.94)	24.035 to 24.048 (0.94626 to 0.94677)
Inside diameter of idler gear		24 (0.94)	24.000 to 24.013 (0.94488 to 0.94539)

4.3 Reassembly

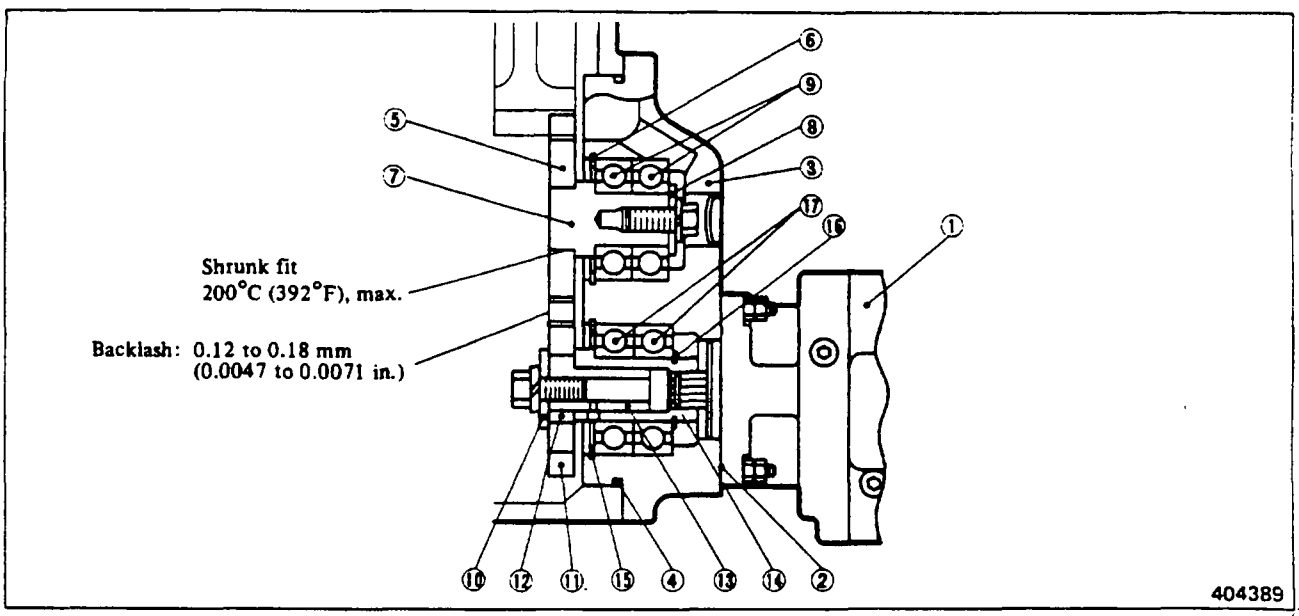
(PSG and EG-3P governors)



Reassembly sequence

⑦→⑨→⑧
③→⑥→⑤→⑪→⑩→④→②→①
⑫→⑭→⑬

(EG-B2P governor)



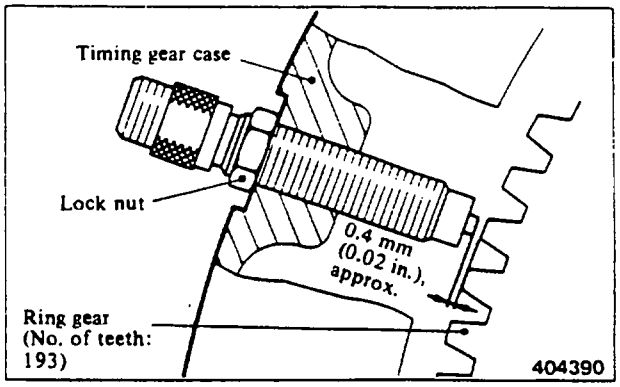
Reassembly sequence

⑦→⑨→⑧
③→⑥→⑤→⑮→⑪→⑫→⑩→④→②→①
⑬→⑭→⑰→⑯

Installing engine speed pickup

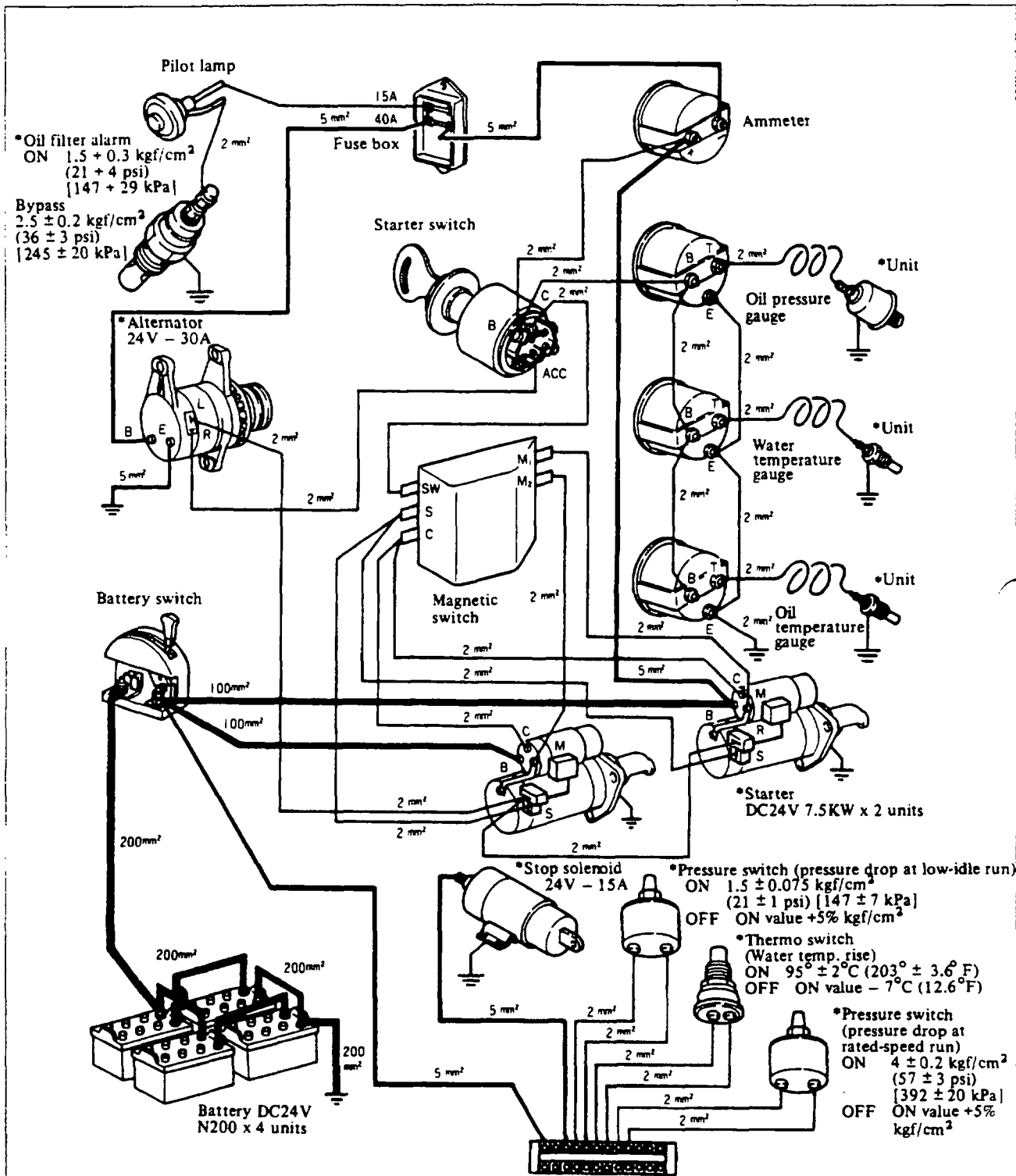
(a) Turn over the crankshaft with turning gear to align one of the ring gear teeth with the center of pickup installation hole in the timing gear case.

(b) Carefully screw the pickup into the hole until its tip touches the ring gear tooth. From that position, back off the pickup, and lock it there. (The clearance between the tip of pickup and ring gear tooth will be approximately 0.4 mm (0.02 in.).)



ELECTRICAL SYSTEM

1. DESCRIPTION



Remarks: (a) The schematic shown above is for the standard model. The circuit varies according to specifications and application of the engine.

(b) Wiring involved in the circuit is to be prepared in field.

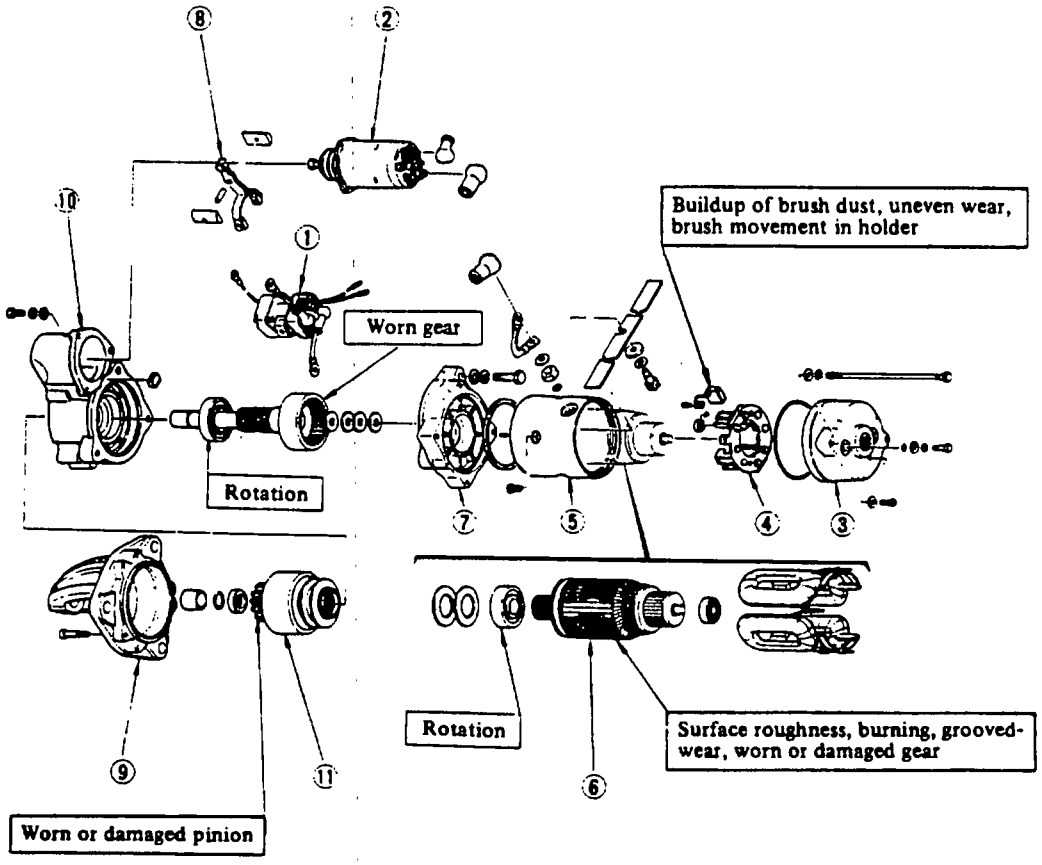
(c) Items bearing asterisk (*) are furnished with the engine. Items bearing no mark are to be supplied individually.

301620

Schematic

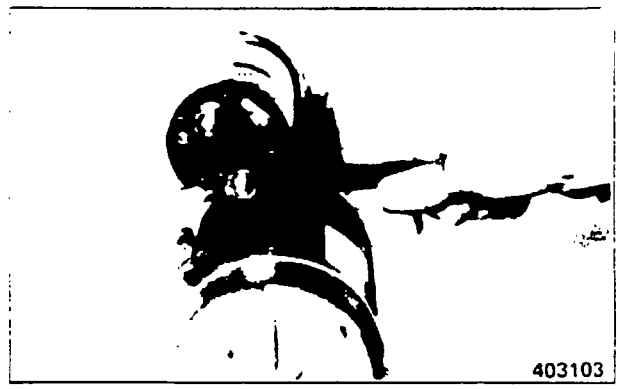
2. STARTER

2.1 Disassembly

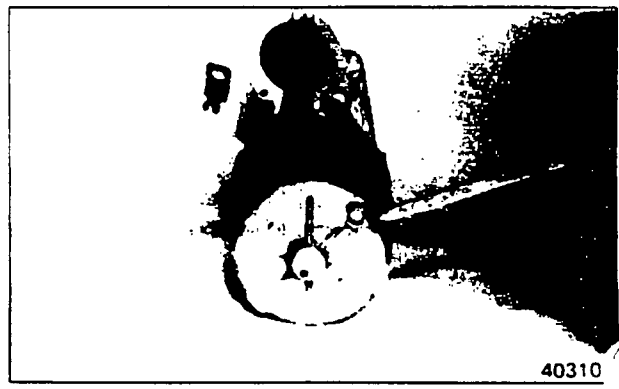


① Safety switch
② Magnetic switch assembly
③ Rear bracket
④ Brush holder assembly
⑤ Yoke assembly
⑥ Armature assembly
⑦ Center bracket
⑧ Lever assembly
⑨ Front bracket
⑩ Pinion case
⑪ Pinion clutch assembly

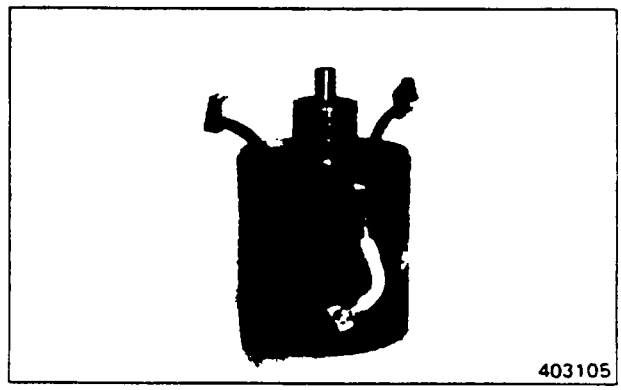
(1) After removing safety switch, disconnect lead wire, and remove magnetic switch.



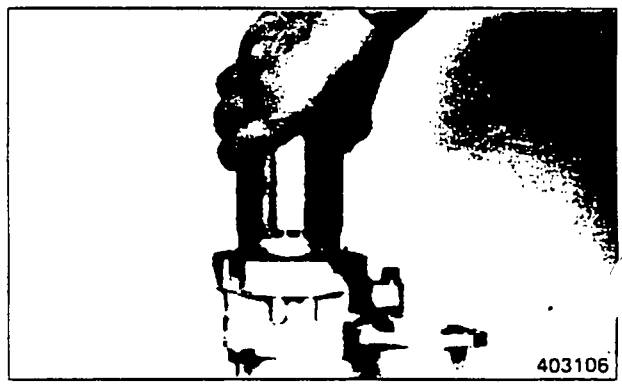
(2) Unscrew through bolts and brush holder mounting screws, and remove rear bracket.



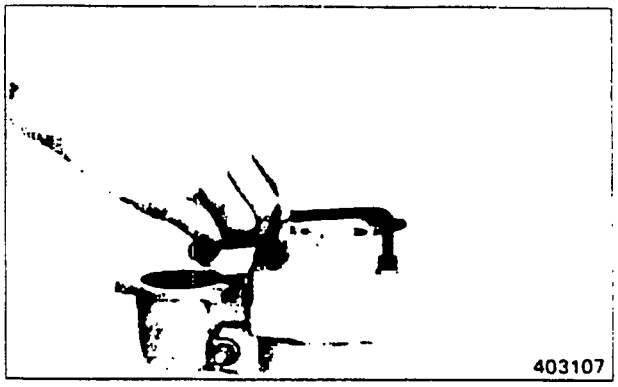
(3) Remove brushes from brush holder assembly, and take off yoke.



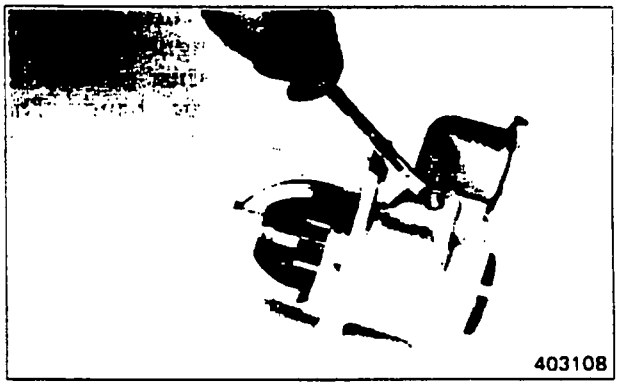
(4) Withdraw armature assembly.



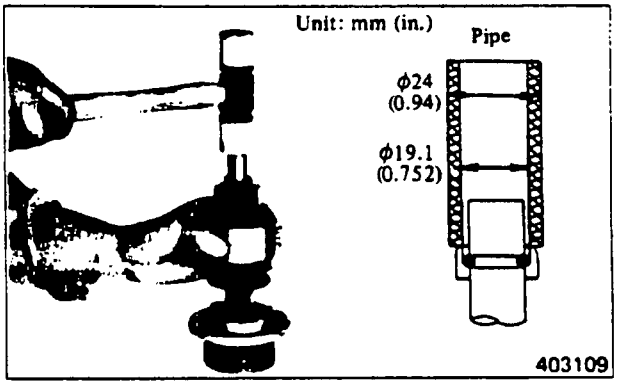
(5) Remove center bracket.



(6) Remove lever pin, inner housing and shift lever from pinion case.

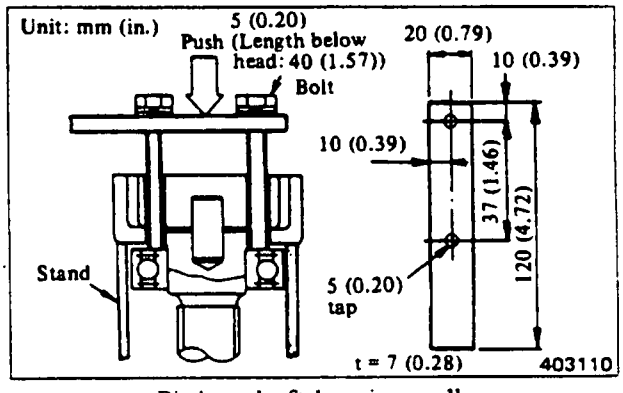


(7) Using a jig, remove pinion stopper, then, remove overrunning clutch from pinion shaft.



NOTE

Use a bearing puller of the type shown to remove pinion shaft bearing for replacement.



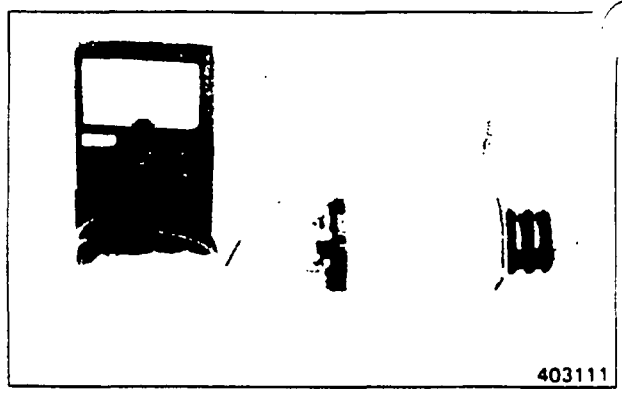
Pinion shaft bearing puller

2.2 Inspection and repair

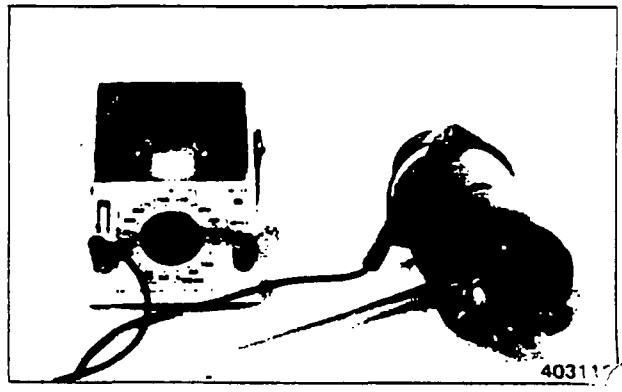
Magnetic switch

(1) Testing magnetic switch coil

(a) Test the pressure coil and holding coil for open circuit. The coils are open-circuited if there is no continuity between the terminal "M" of magnetic switch and the case. (Resistance: 1.16 ohms, approx.)

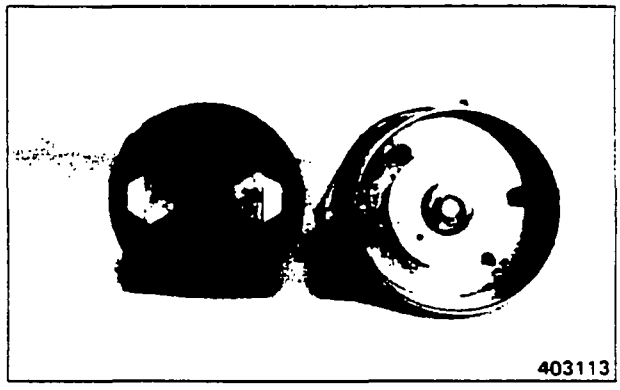


(b) Apply a voltage of 24 volts between the terminal "M" of magnetic switch and the case. Under this condition, push in the plunger by hand. The plunger should be attracted when the hand is released.



(2) Testing magnetic switch contact points

Measure the load current flowing through the starter. If the voltage drop between the terminals "B" and "M" exceeds 0.3 volt per 100 amperes of current, polish or replace the contact points.



NOTE

If the starter switch is turned to OFF during voltage measurement, the battery voltage is directly applied to the voltmeter and damage it. With this kept in mind, be sure to turn the starter switch to ON before measuring the voltage and turn it to OFF after measuring the voltage.

⚠ CAUTION

Under no circumstances should only the magnetic switch be tested.

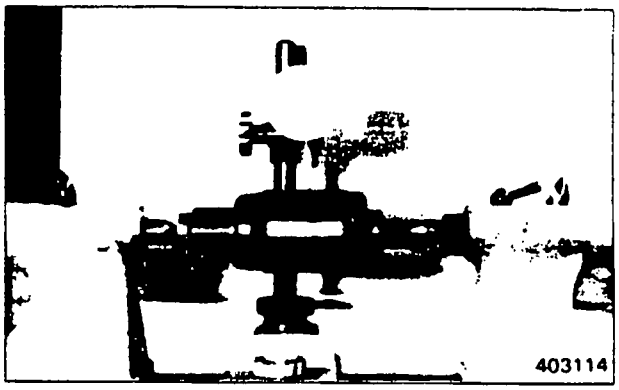
Armature

(1) Inspecting armature shaft for runout

Measure the runout with a dial indicator. If the runout exceeds the assembly standard, repair or replace the armature.

Unit: mm (in.)

Item	Assembly standard
Armature shaft runout	0.05 (0.0020)

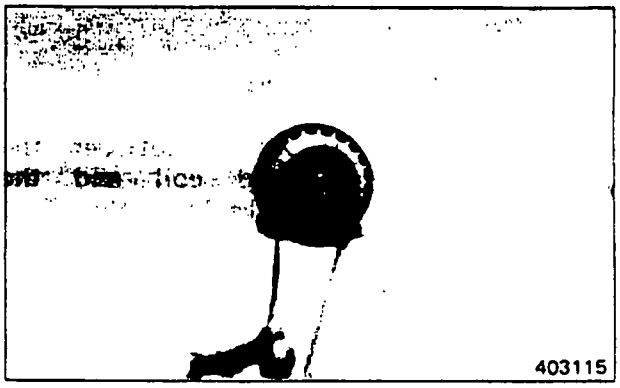


(2) Inspecting commutator

(a) Check the commutator surface for condition. If the surface is rough, polish it with #400 to #600 sandpaper.
Also check the commutator for runout with a dial indicator. Replace the commutator if the runout exceeds the service limit.

Unit: mm (in.)

Item	Assembly standard	Service limit
Commutator runout	0.06 (0.002), maximum	0.10 (0.004)

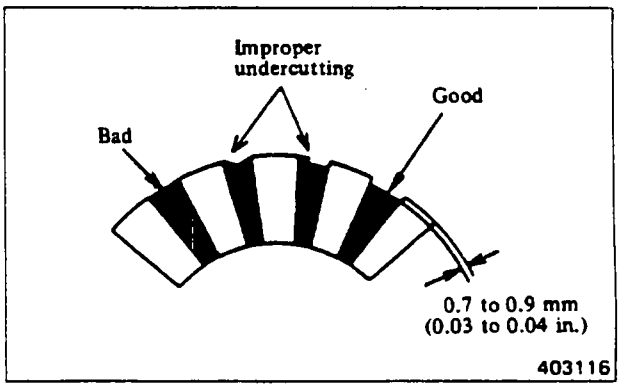


(b) Measuring mica depth

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

Unit: mm (in.)

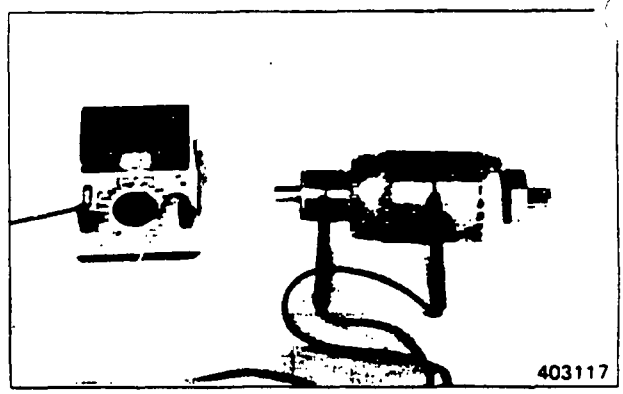
Item	Assembly standard	Repair limit
Commutator mica depth	0.7 to 0.9 (0.03 to 0.04)	0.2 (0.008)



(3) Testing armature

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

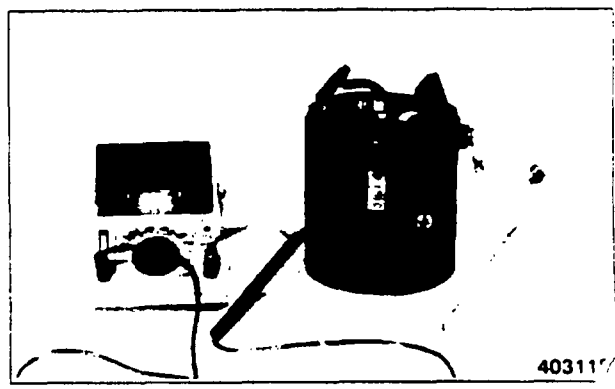
(b) If there is continuity between the commutator and shaft, replace the armature.



Field coil

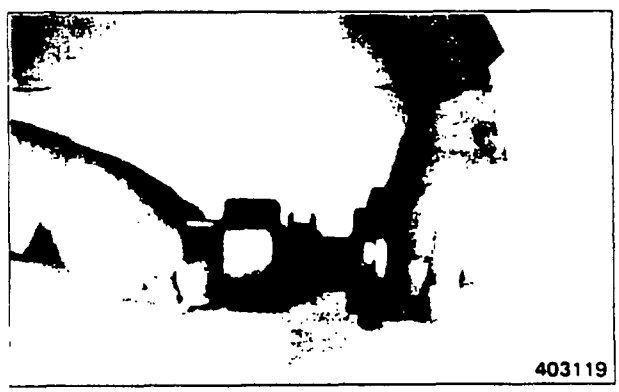
Testing for open circuits

If there is no continuity between the terminal "M" of field coil and the brush-side lead wire, replace the field coil. If there is continuity between the field coil and yoke, replace the field coil.



Overrunning clutch

The clutch is in good condition if it rotates freely in one direction when turned by hand.
Check the pinion teeth for wear or damage, and replace the pinion if they are damaged.



⚠ CAUTION

Do not immerse the overrunning clutch in cleaning solvent when cleaning the clutch. This will cause grease to flow out from inside the clutch, resulting in seizure of clutch parts.

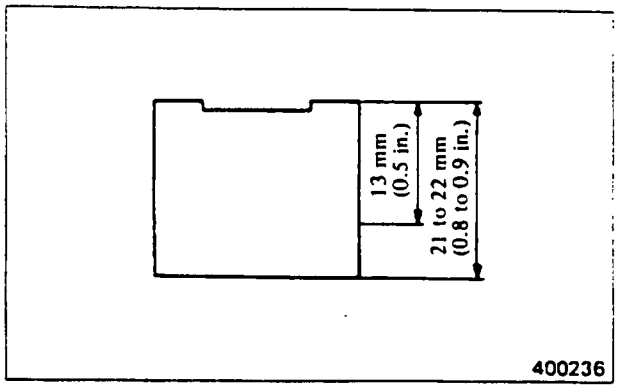
Brushes

(1) Inspecting for wear

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

Unit: mm (in.)

Item	Assembly standard	Service limit
Brush height	21 to 22 (0.8 to 0.9)	13 (0.5)



(2) Testing brush spring tension

Unit: kgf (lbf) [N]

Item	Assembly standard	Service limit
Test force of brush springs	4.0 to 5.0 (8.8 to 11.0) [39 to 49]	4.0 (8.8) [39], maximum

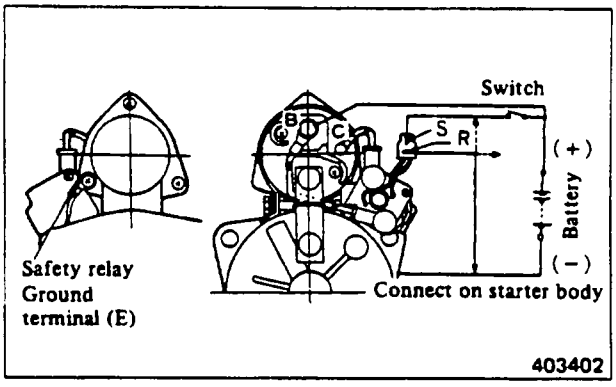
Safety switch

Connect the wires as shown, and test the starter and safety switch.

(1) Connect the terminal "R" to the negative (-) terminal of the battery.

(2) Close the switch to make sure that the starter runs.

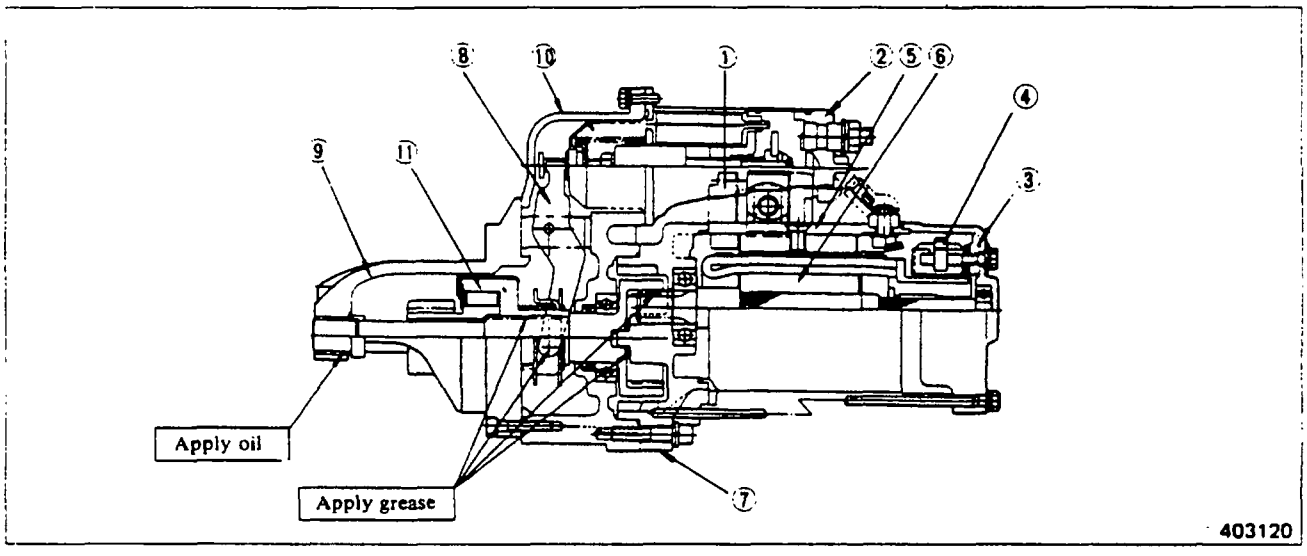
(3) Make sure that the starter stops running when the terminal "R" is disconnected from the negative (-) terminal of the battery, or when it is reconnected to the positive (+) terminal of the battery after disconnecting it.



CAUTION

Make sure that the polarity of each battery cable is correct when connecting the wires.

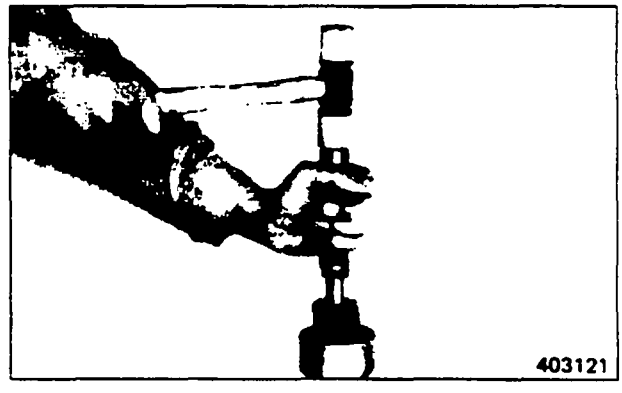
2.3 Reassembly



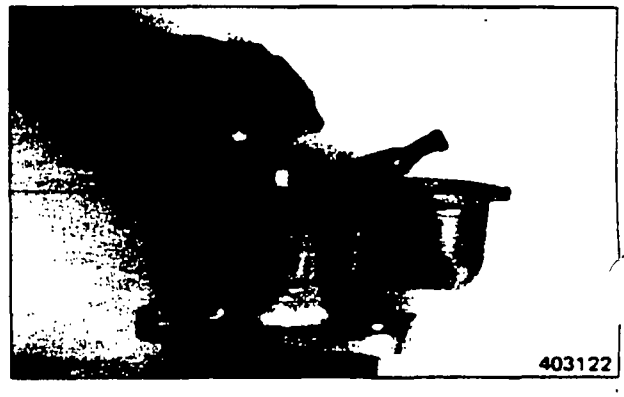
Reassembly sequence

⑩→⑨→⑪→⑧→⑦→⑥→⑤→④→③→②→①

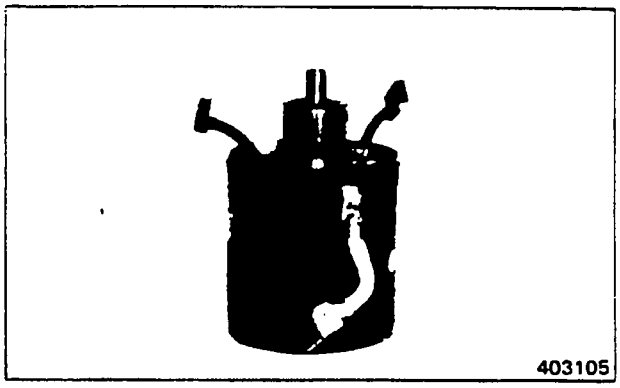
(1) Install center bracket, overrunning clutch and pinion stopper to pinion shaft, and insert the shaft into position by tapping with a plastic hammer.



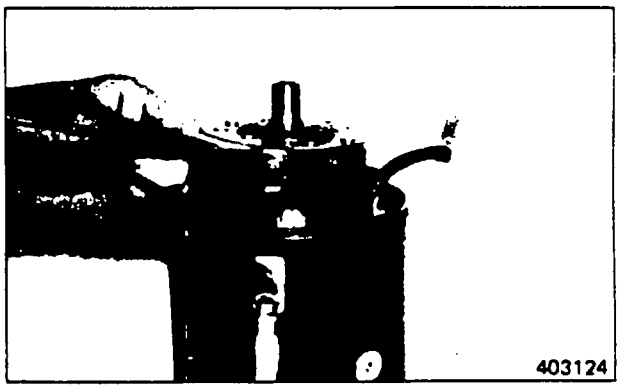
(2) Install shift lever and pinion shaft to front bracket by aligning matching mark on shift lever.



(3) Install armature and yoke to center bracket, making sure that dowel pin enters its hole.

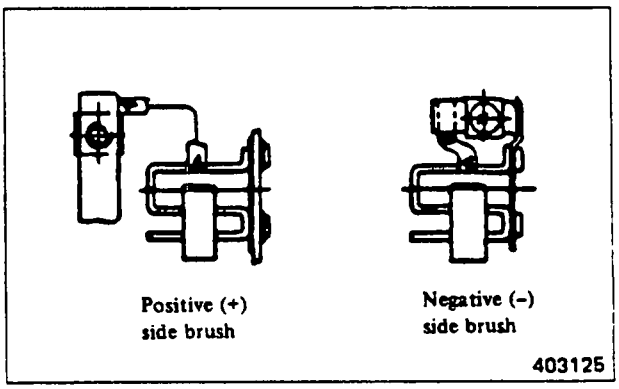

403105

(4) Install brushes and brush holders.


403124

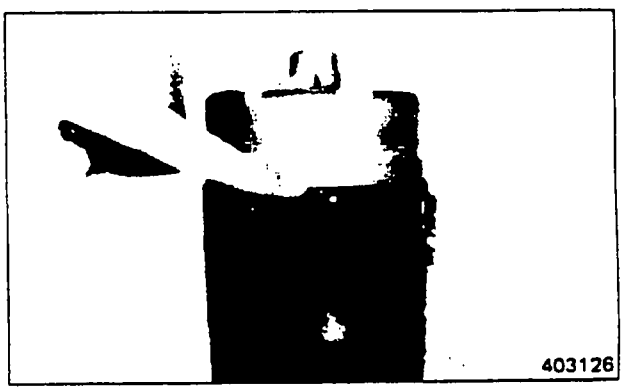
NOTE

Install positive (+) side brush and negative (-) side brush as shown.



403125

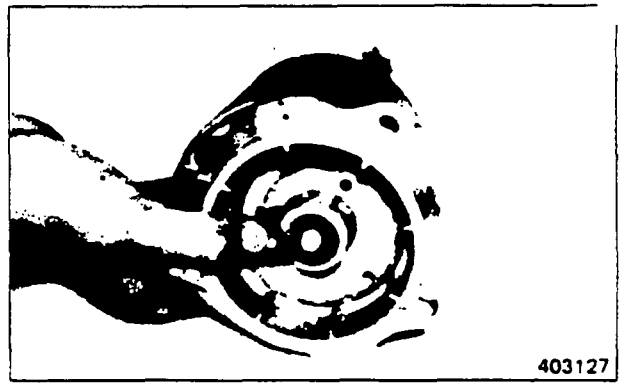
(5) Install rear bracket to yoke by aligning matching marks, secure brush holders with bolts, and tighten through bolts.


403126

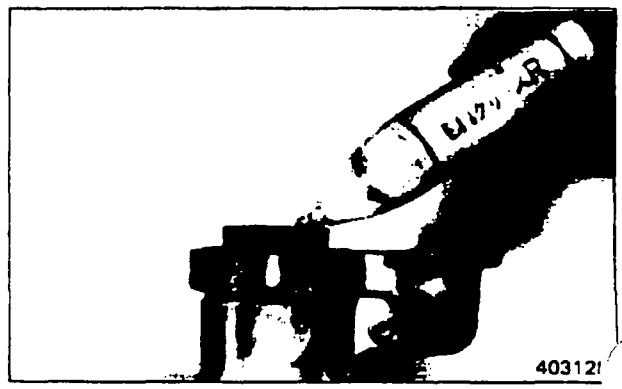
(6) Measure the end play of armature. If the end play exceeds the assembly standard, adjust it on the rear side. Test the motor to make sure that the voltage and current are below 24 volts and 90 amperes respectively.

Unit: mm (in.)

Item	Assembly standard
Armature end play	0.2 to 0.6 (0.008 to 0.024)



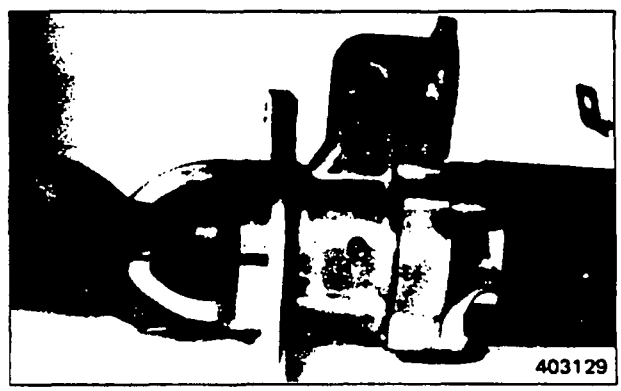
(7) Liberally coat internal gear with grease, and install pinion shaft to the gear.



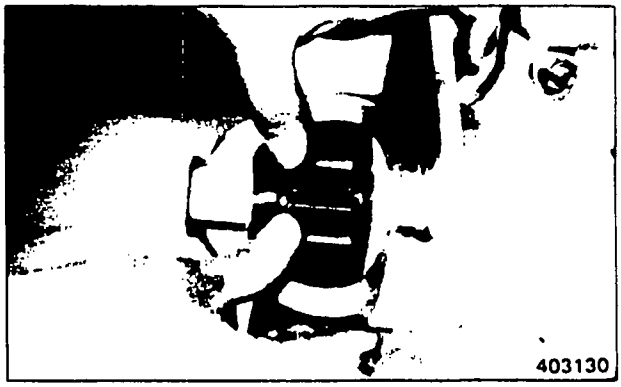
(8) Measure the end play of pinion shaft. If the end play exceeds the assembly standard, adjust it on the internal gear side.

Unit: mm (in.)

Item	Assembly standard
Pinion shaft end play	0.2 to 0.6 (0.008 to 0.024)



(9) Install magnetic switch. Apply a voltage of 24 volts between the terminals "C" and "E," connect lead wire and energize the circuit between the terminals "M" and "E" (within 1 second). After the pinion has shifted, measure how much the pinion returns. If the measurement is not 1.5 to 5 mm (0.06 to 0.20 in.), make an adjustment by means of magnetic switch adjusting screw.

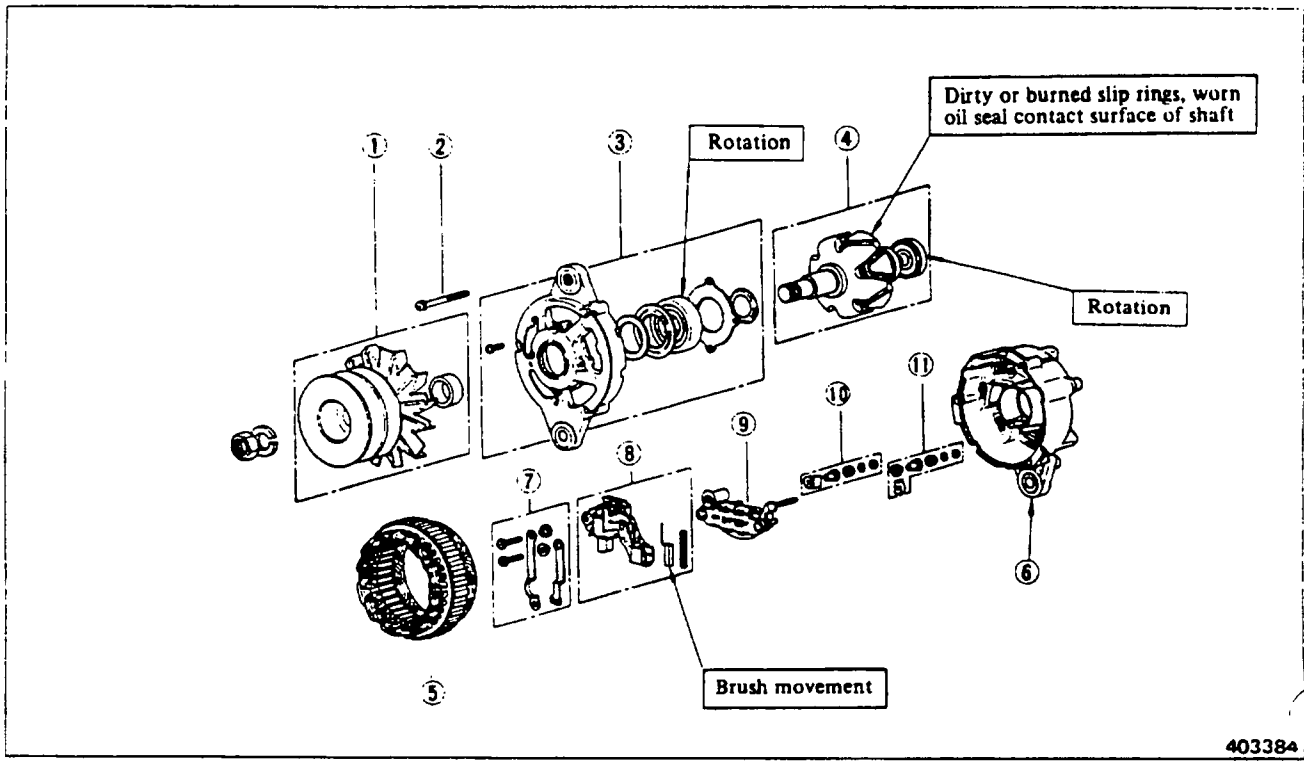


(10) Secure lead wire.

(11) Install safety switch.

3. ALTERNATOR

3.1 Disassembly



① Pulley assembly
② Through bolt
③ Front bracket assembly
④ Rotor assembly
⑤ Stator
⑥ Rear bracket
⑦ Terminal set
⑧ Regulator assembly
⑨ Rectifier assembly
⑩ Set nut
⑪ Set nut

⚠ CAUTION

(a) 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.

(b) Before disassembling the alternator, heat the bearing portion of rear bracket with a soldering iron or the like.

3.2 Inspection and repair

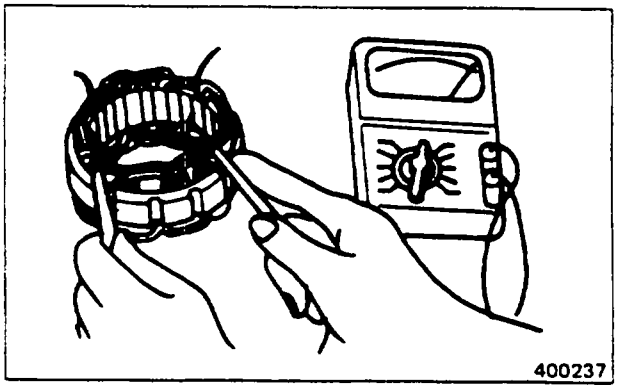
(1) Stator

(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.


400237

(2) Rotor

(a) Testing rotor coil for open circuits

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

(b) Testing rotor coil for grounding

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

(c) Measure slip ring outside diameter

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

Unit: mm (in.)

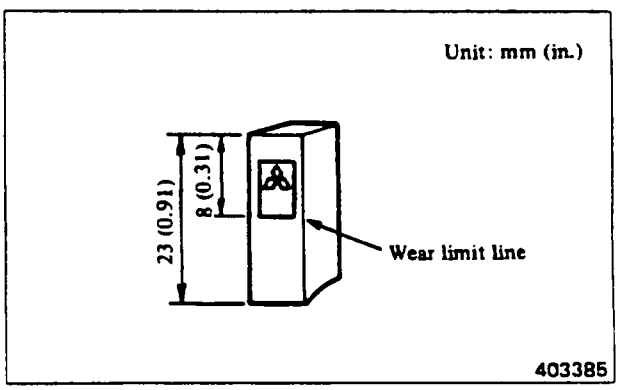
Item	Assembly standard	Service limit
Slip ring outside diameter	41 ± 0.2 (1.61 ± 0.008)	40.6 (1.598)

(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

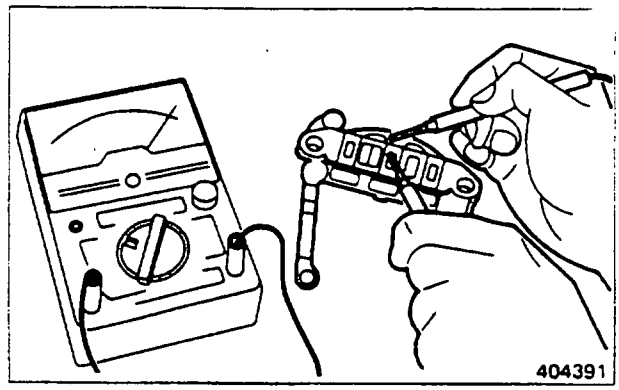
Unit: gf (lbf) [N]

Item	Assembly standard	Service limit
Brush spring tension	380 ± 60 (0.8 ± 0.1) [3 ± 0.6]	200 (0.4) [2]

(4) Diodes

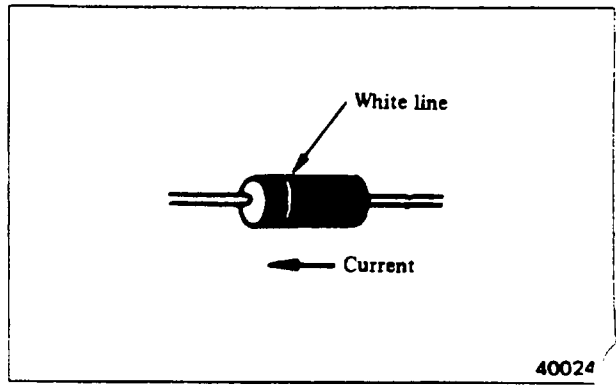
(a) Main diode

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

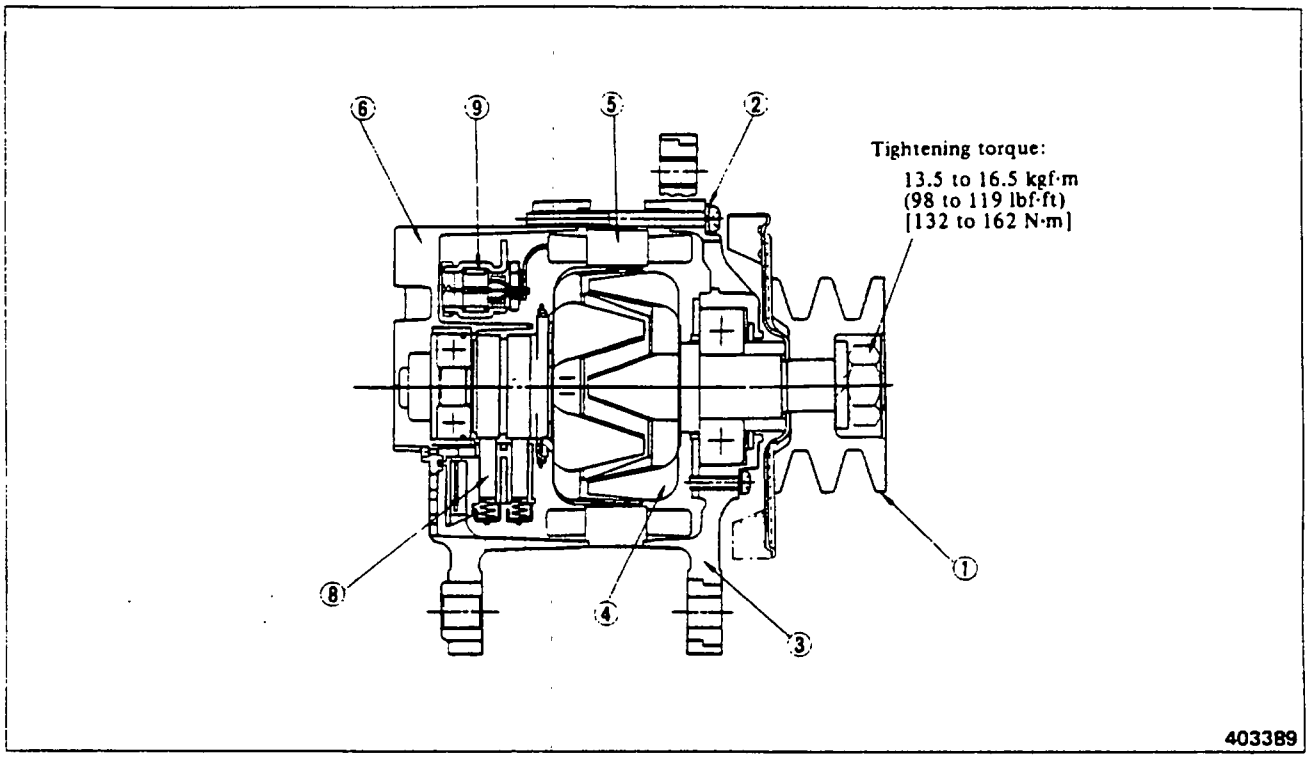


(b) Auxiliary diode

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



3.3 Reassemby

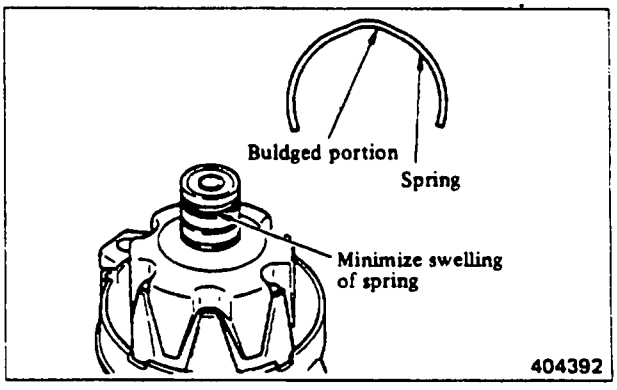


Reassembly sequence

⑥→⑨→⑧→⑤→②→①
④→③

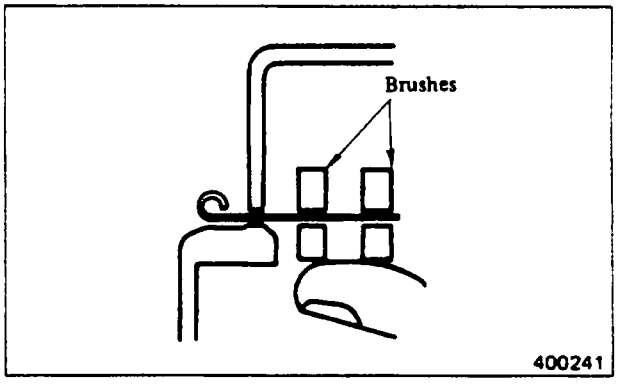
(1) Installing spring

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 at right. Then, install the rotor. Be sure to remove the wire after installing the rotor.

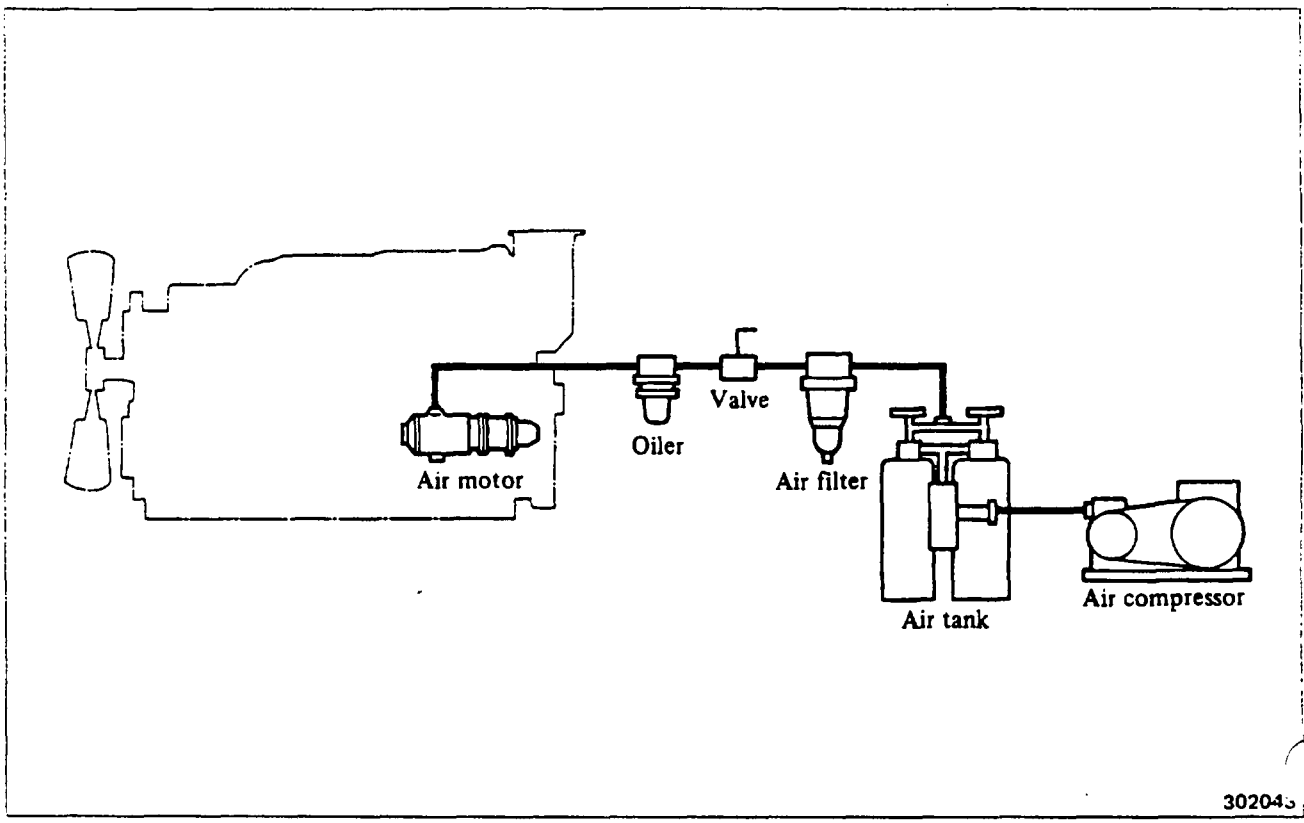


(3) Tightening pulley nut

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

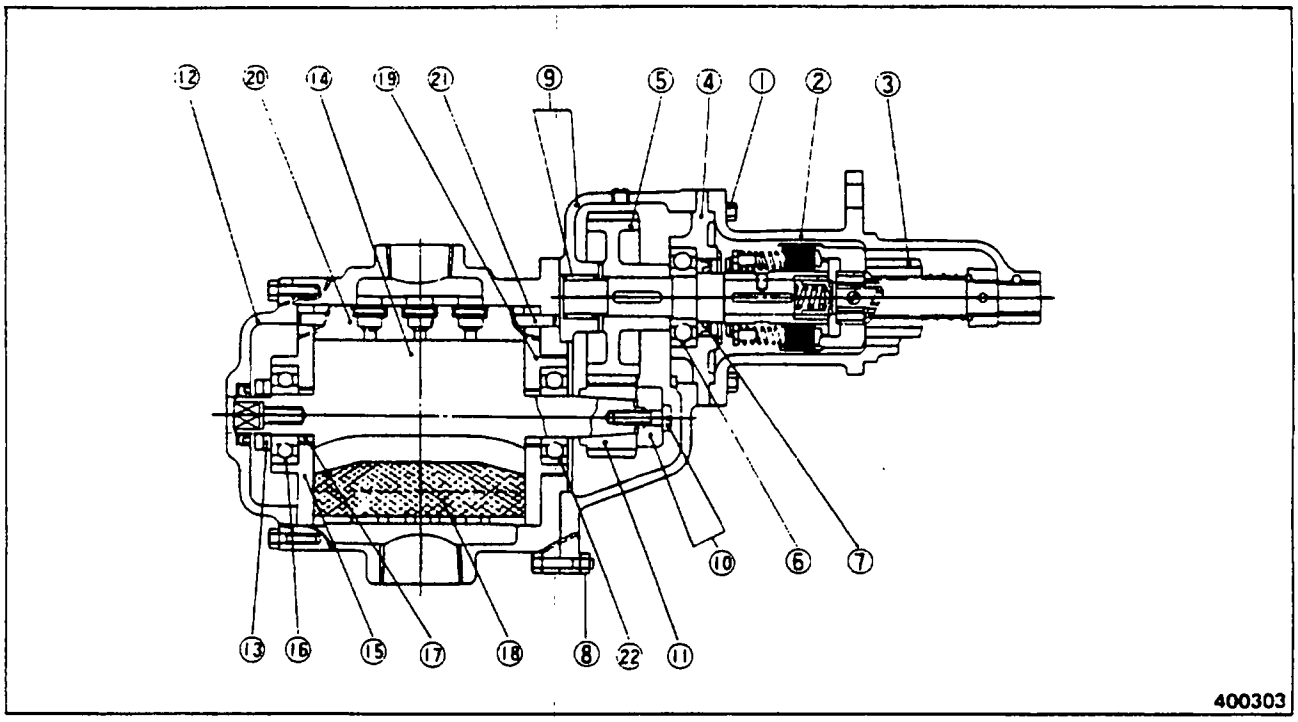
AIR START SYSTEMS

1. AIR MOTOR SYSTEM



2. AIR MOTOR

2.1 Disassembly and reassembly



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

NOTE

Do not remove the rotor adjusting ring from the rotor.

Reassembly sequence

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

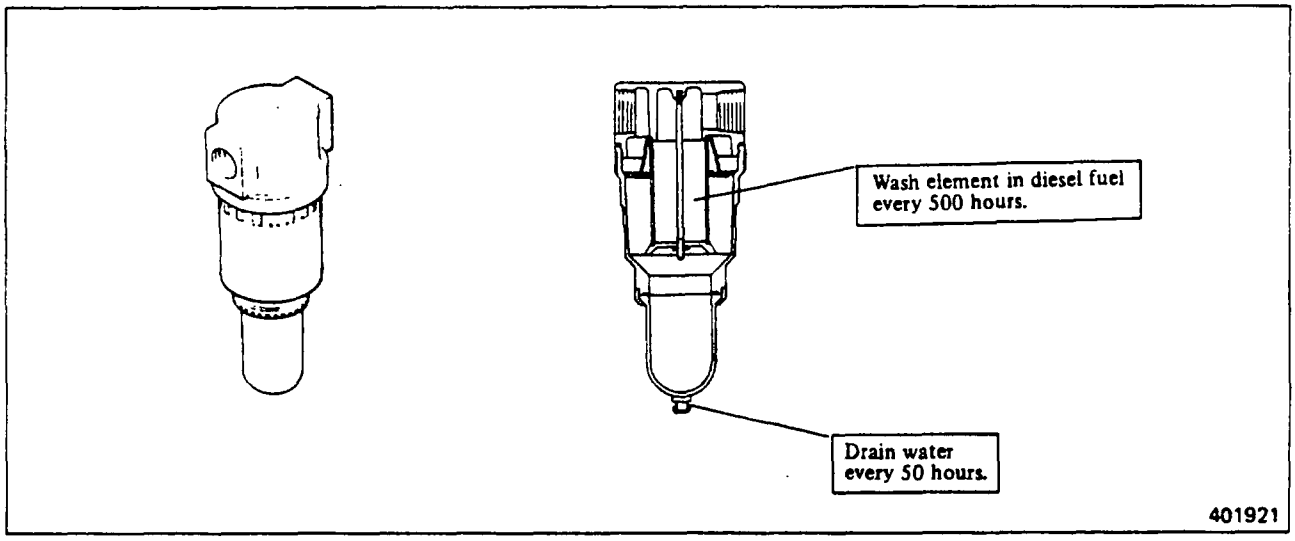
2.2 Inspection

Inspecting air motor

Wash and check 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.

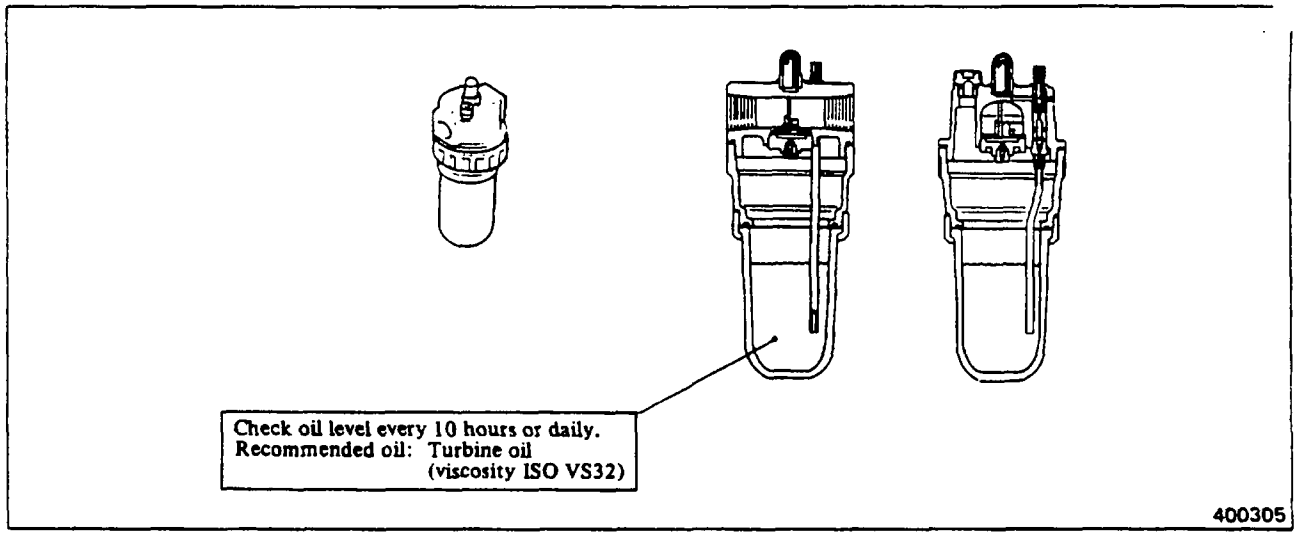
3. AIR FILTER

Inspection



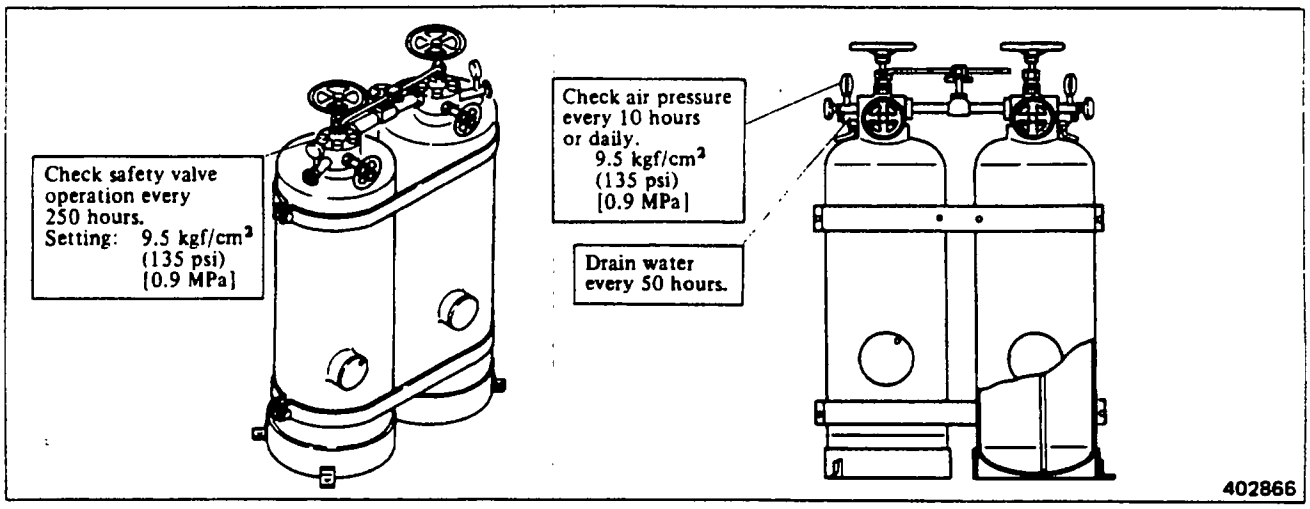
4. OILER

Inspection

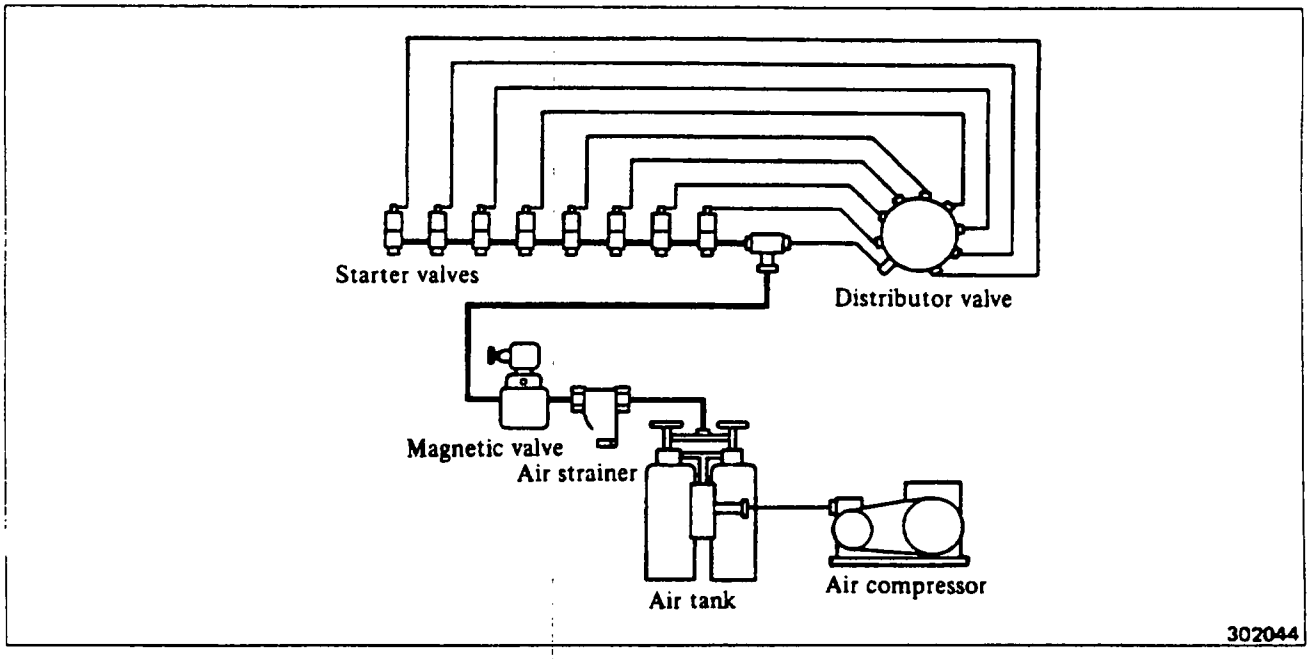


5. AIR TANK (FOR AIR MOTOR START SYSTEM)

Inspection

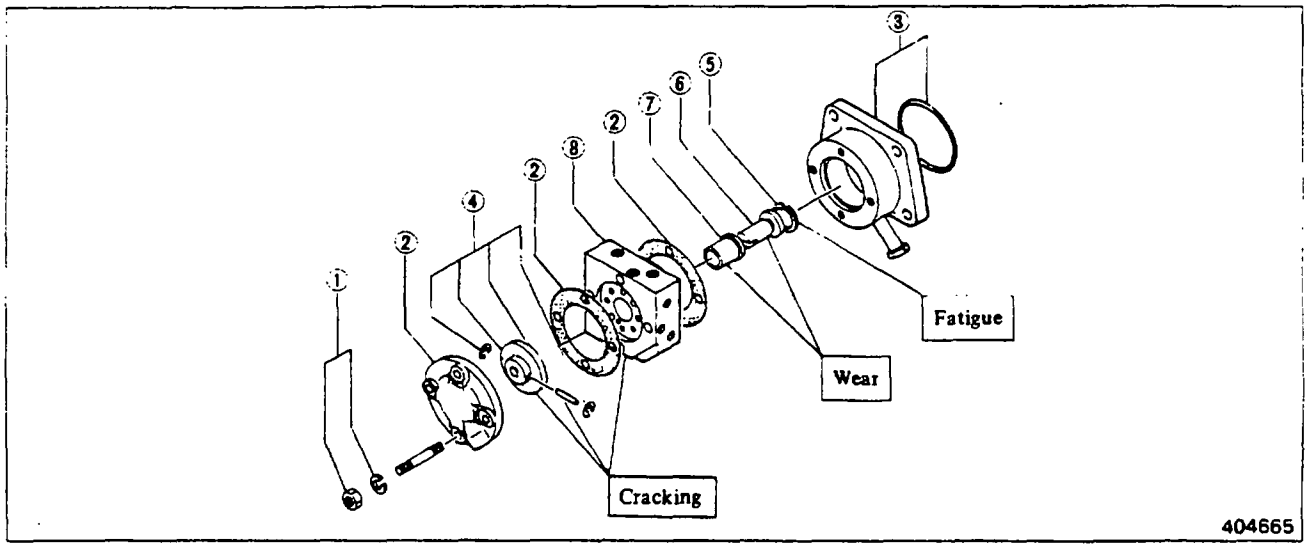


6. AIR START SYSTEM



7. DISTRIBUTOR VALVE

7.1 Disassembly



① Nut, spring washer
② Case cover, packing
③ Case bracket, O-ring
④ Lock pin, distributor valve, E-ring
⑤ Snap ring
⑥ Distributor shaft
⑦ Bushing
⑧ Distributor case

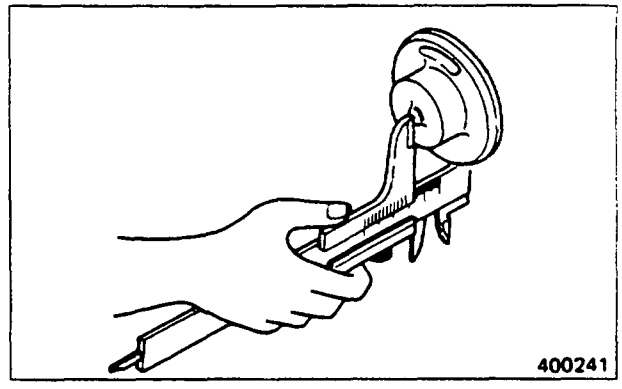
7.2 Inspection

(1) Measuring distributor valve height

If the height exceeds the repair limit, replace the valve.

Unit: mm (in.)

Item	Assembly standard	Repair limit
Height of distributor valve	21.5 ± 0.1 (0.846 ± 0.004)	21 (0.83)

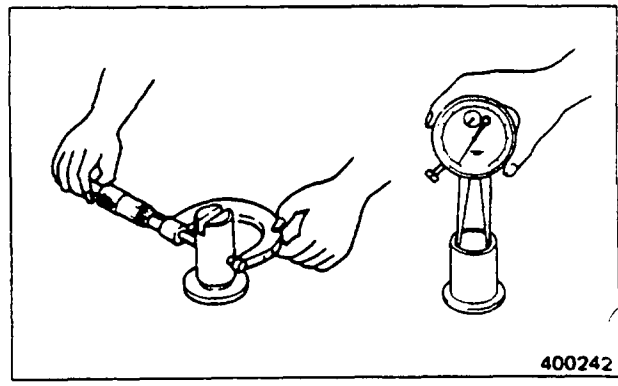


(2) Measuring distributor shaft clearance in bushing

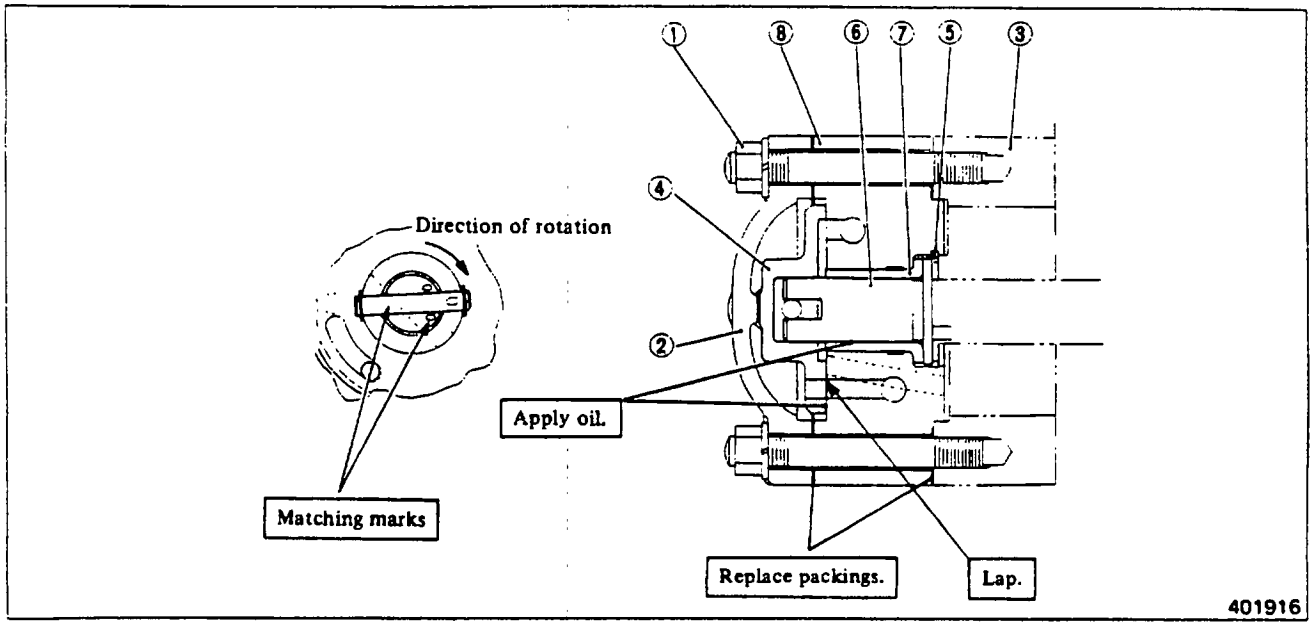
Measure the diameter of the shaft and the inside diameter of the bushing to determine the clearance. If the clearance exceeds the repair limit, replace the bushing.

Unit: mm (in.)

Item	Standard clearance	Repair limit
Clearance between shaft and bushing	0.050 to 0.091 (0.00197 to 0.00358)	0.300 (0.01181)



7.3 Reassembly

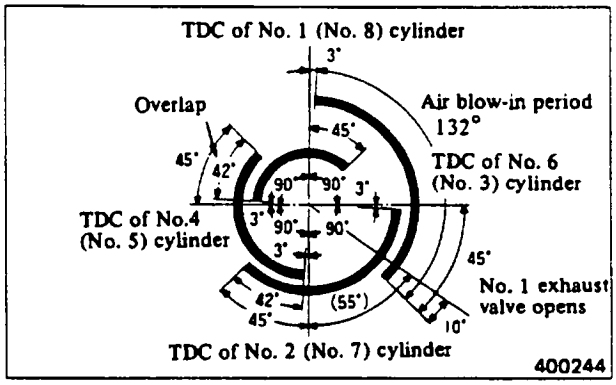


Reassembly sequence

⑧→⑦→⑥→⑤→④→③→②→①

NOTE

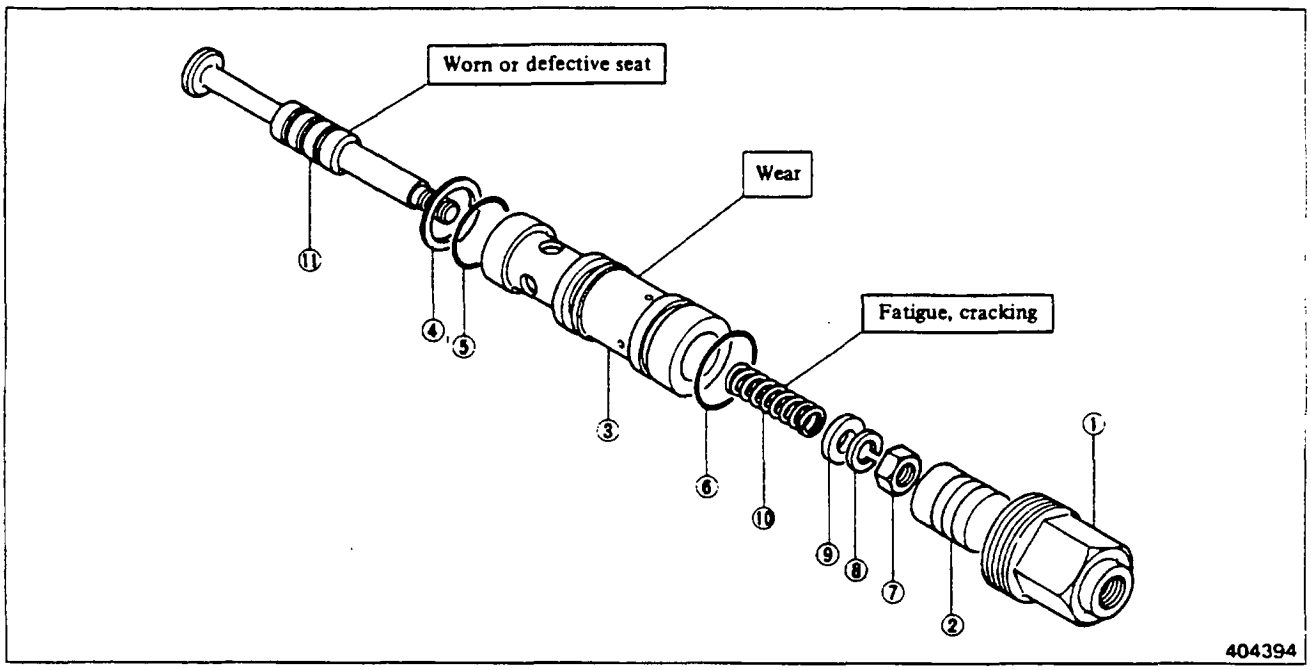
When reassembling and installing the distributor valve, be sure to align the matching marks. If the marks are not aligned, the valve timing (at which the air is blown into the cylinders) could be off by 360°, resulting in a failure to start.



Start air blow-in timing (crank angle)

8. STARTER VALVES

8.1 Disassembly

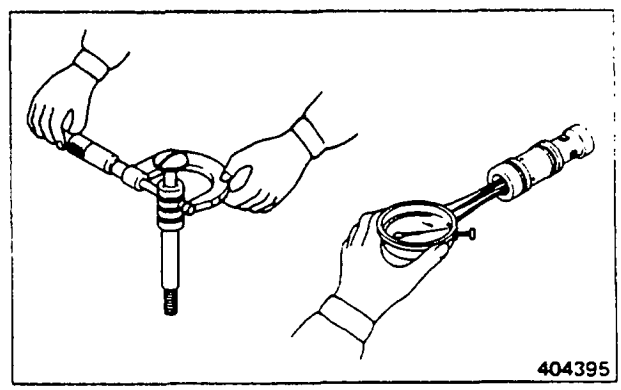


① Cap nut
② Starter valve piston
③ Starter valve guide
④ Starter valve gasket
⑤ O-ring
⑥ O-ring
⑦ Nut
⑧ Spring washer
⑨ Retainer
⑩ Spring
⑪ Starter valve

8.2 Inspection

(1) Measuring starter valve and guide

Measure the diameter of starter valve with a micrometer caliper. Measure the inside diameter of guide with a dial indicator caliper. If the clearance exceeds the service limit, replace the valve or guide whichever is badly worn.



Unit: mm (in.)

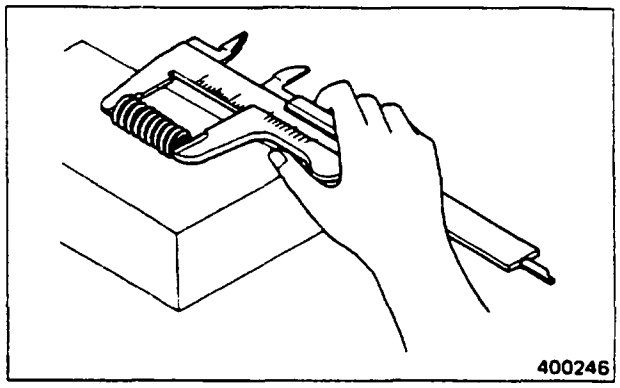
Item	Nominal value	Standard clearance	Service limit
Clearance between starter valve and guide	15 (0.59)	0.016 to 0.052 (0.00063 to 0.00205)	0.100 (0.00394)

(2) Measuring free length of valve springs

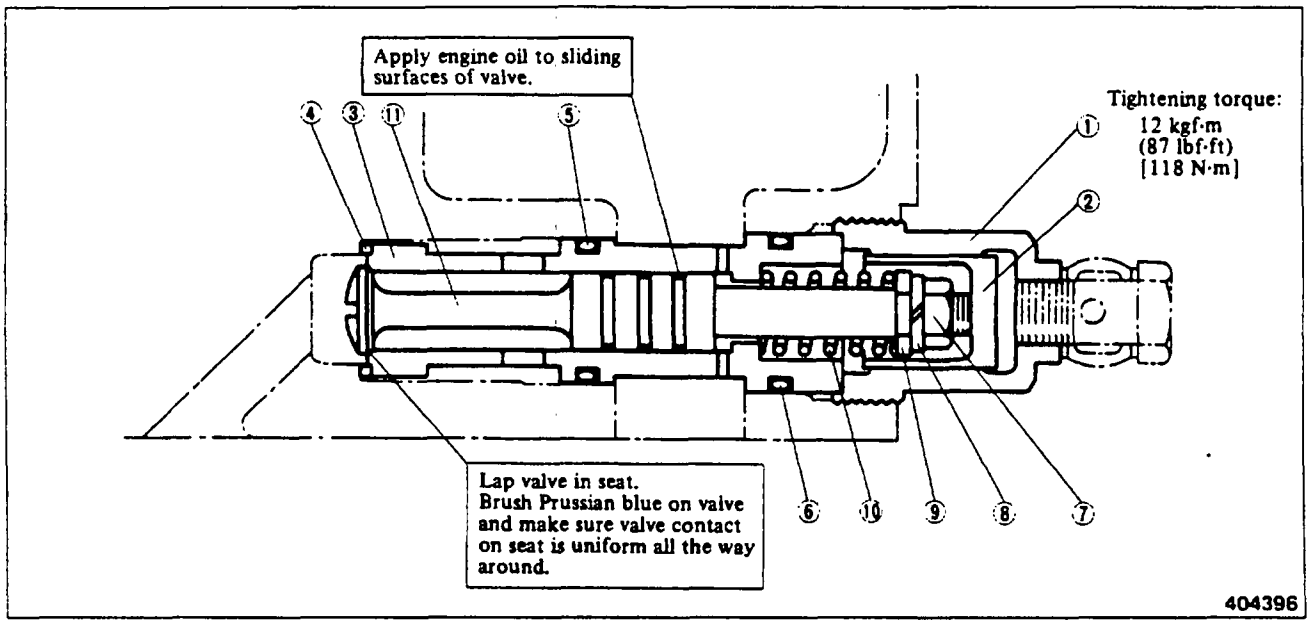
Using a caliper, measure the free length. If the free length exceeds the service limit, replace the spring.

Unit: mm (in.)

Item	Assembly standard	Service limit
Free length of valve spring	36 (1.42)	34 (1.34)



8.3 Reassembly

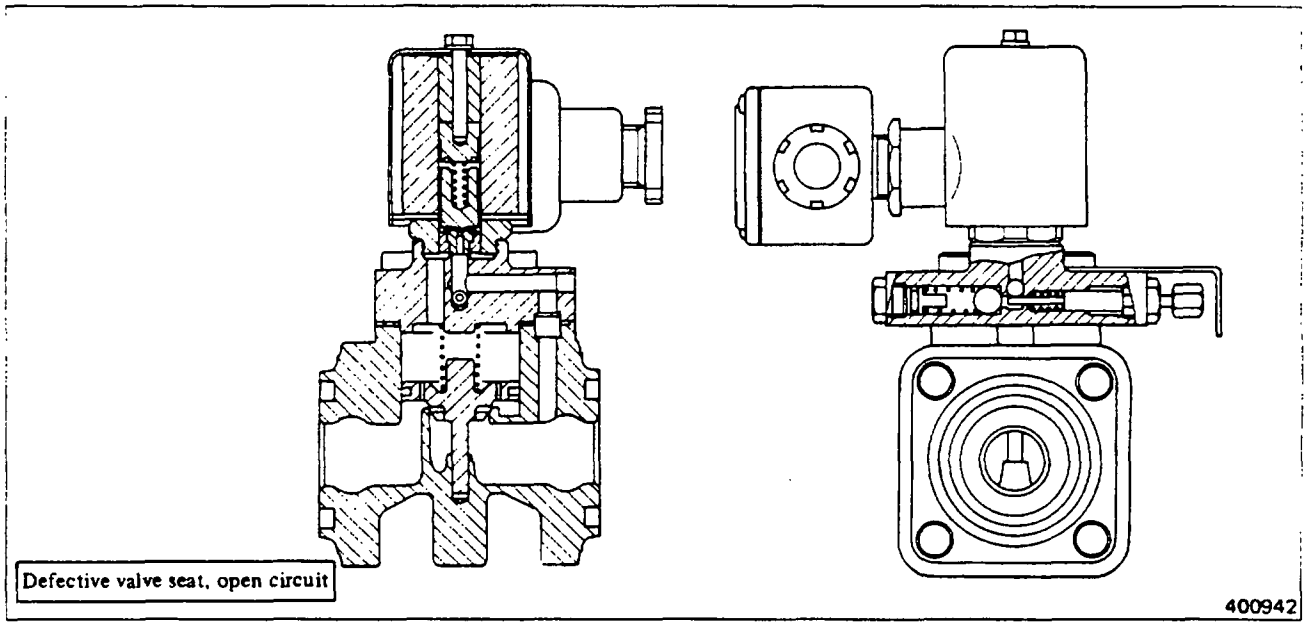


Reassembly sequence

③→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→②→①

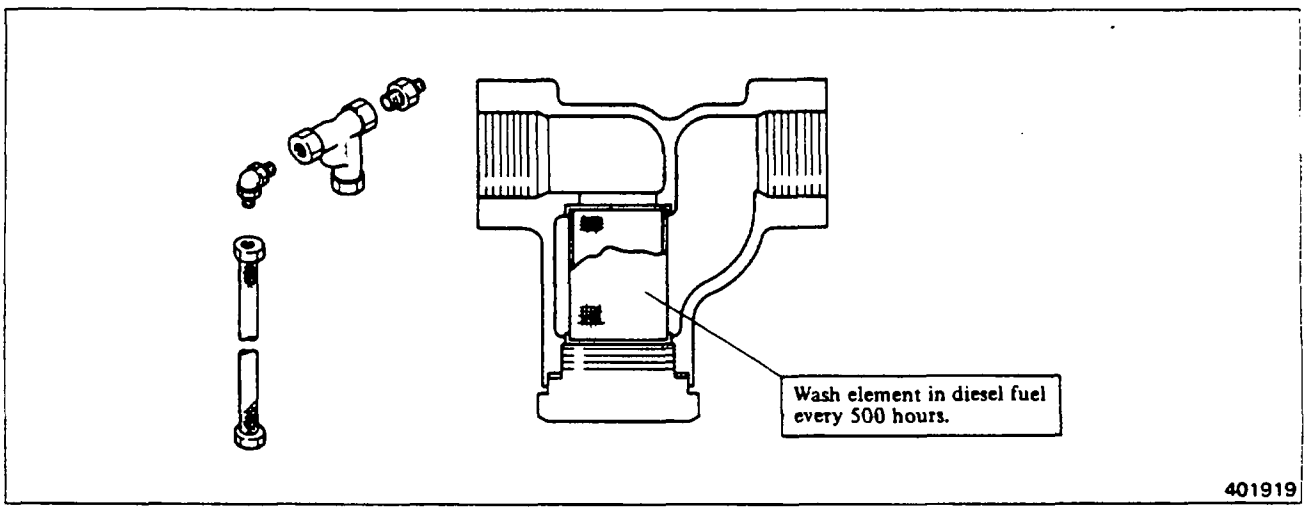
9. MAGNETIC VALVE

Inspection



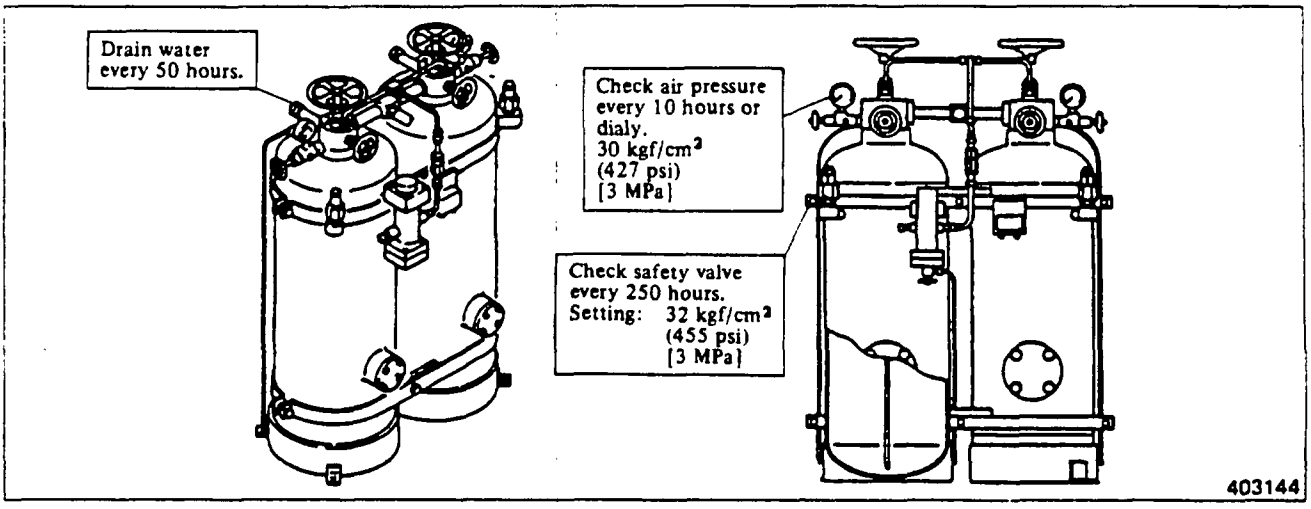
10. AIR STRAINER

Inspection



11. AIR TANK (FOR AIR START SYSTEM)

Inspection



WORKSHOP THEORY

1. PRECAUTIONS FOR DISASSEMBLY AND REASSEMBLY

1.1 Oil seals

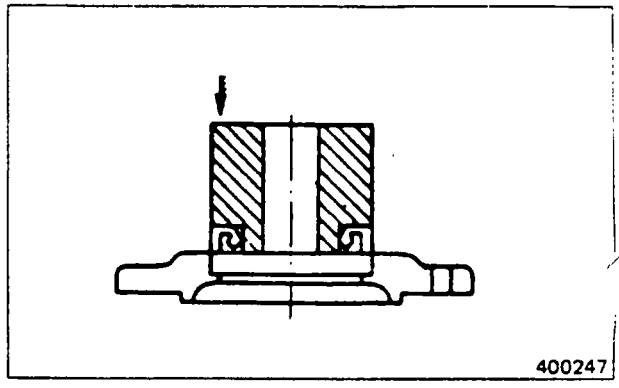
When installing oil seals, carefully observe the following points:

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.

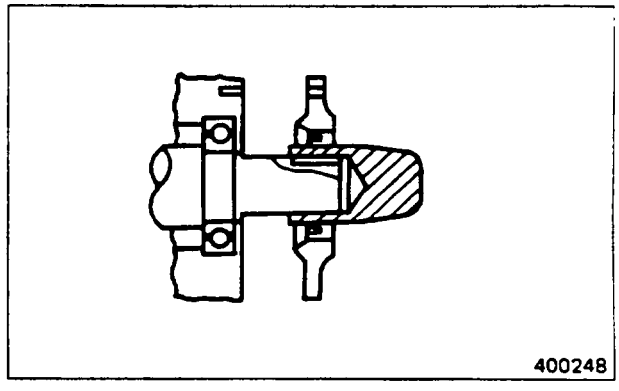


Oil seal driver

Driving oil seals onto shafts

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

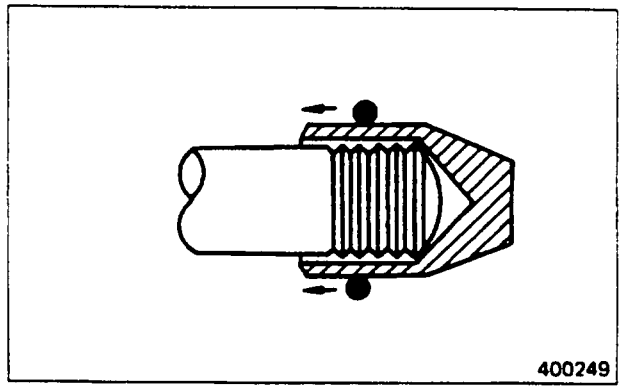
(b) Use an oil seal guide of the type shown when driving oil seal over stepped portion, splines, threads or keyway to prevent damage to seal lip.



Oil seal guide

1.2 O-rings

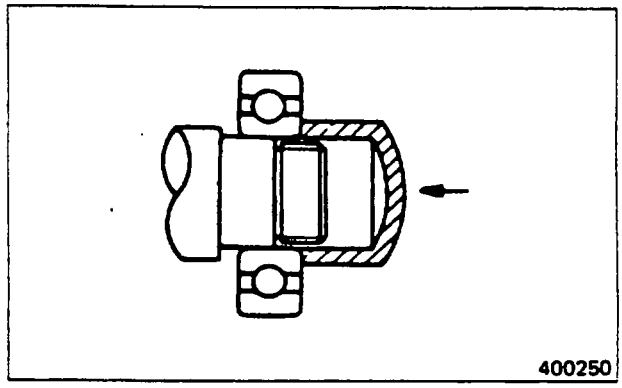
Use an O-ring guide of the type shown when installing O-ring over stepped portion, splines, threads or keyway to prevent damage to the ring. Apply a thin coat of grease to O-ring.



O-ring guide

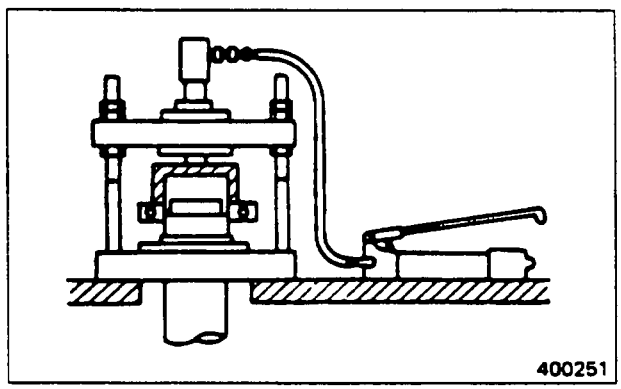
1.3 Bearings

(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

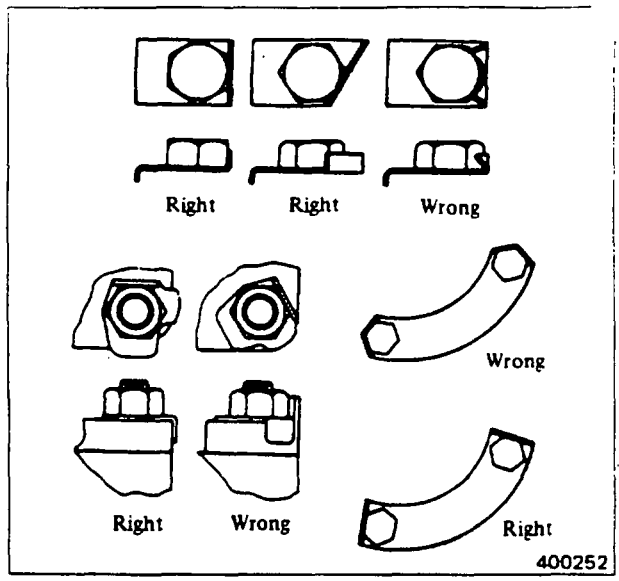
(2) Use a press whenever possible to minimize shock to bearing and to assure proper installation.



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.