SERVICE MANUAL

MITSUBISHI DIESEL ENGINES

S6R, S6R2

MITSUBISHI HEAVY INDUSTRIES, LTD.

INTRODUCTION

This service manual is written to familiarize you with the maintenance of your Mitsubishi S6R Diesel Engine. If the engine is carefully maintained it will deliver a long productive life and efficient performance marked by power and economy.

Before you attempt to inspect, disassemble, or repair the engine, read this manual carefully to learn more about the engine and how to care for it properly. All descriptions, illustrations, specifications, and serial numbers in this manual are effective as of the date printing of this manual.

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

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What This Manual Covers

This service manual covers standard specifications for the Mitsubishi Diesel Engine, and describes

- Specifications
- Maintenance standards
- Adjustments
- Disassembly, inspection and repair
- Reassembly

The fuel injection pump, governor, and turbocharger are described in separate manuals. For non-standard engines, such as marine propulsion engines, etc., supplements have been published to be read with this manual.

In addition to the table of contents, a short summary of contents is found on the first page of each section of the manual.

Operation and periodical maintenance are described in the *Operation & Maintenance Manual*, component parts and ordering of service parts are described in the *Parts Catalogue*. Construction and function of the engine are described in the various training manuals.

How to Use This Manual

1. Parts in illustrations are numbered to correspond with references to these numbers in text.
2. Items or conditions to be inspected during disassembly are enclosed in a box in the disassembled views:

Clogged oil hole

3. Maintenance standards for inspection and repair are described in text where they are relevant. For a quick summary of maintenance standards refer to chapter 2 of this manual.
4. The sequence in which parts are to be reassembled is summarized below each assembled view.

   ⑤→②→④→③→①

5. Tightening torque under *wet* conditions is indicated as "(wet)" in text, drawings, and tables. When so indicated as (wet), apply engine oil to the threaded portion of the fastener. Unless indicated as such, the tightening torque is to be assumed in the dry condition.

6 Pay attention to the special notes, cautions, and warnings.

Notes, Cautions, and Warnings

Notes, cautions, and warnings are used in this manual to emphasize important or critical instructions or advice.

NOTE ..... An operating procedure, condition, etc. that will help you work more efficiently.

⚠CAUTION ..... Operating procedures or practices which if ignored could result in damage to the engine.

⚠WARNING ..... Operating procedures or practices which if ignored could result in injury or loss of life.

Terms Used in This Manual ..... Before you read this manual, note that the following special terms are used in dimensional and other specifications.

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

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

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

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

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

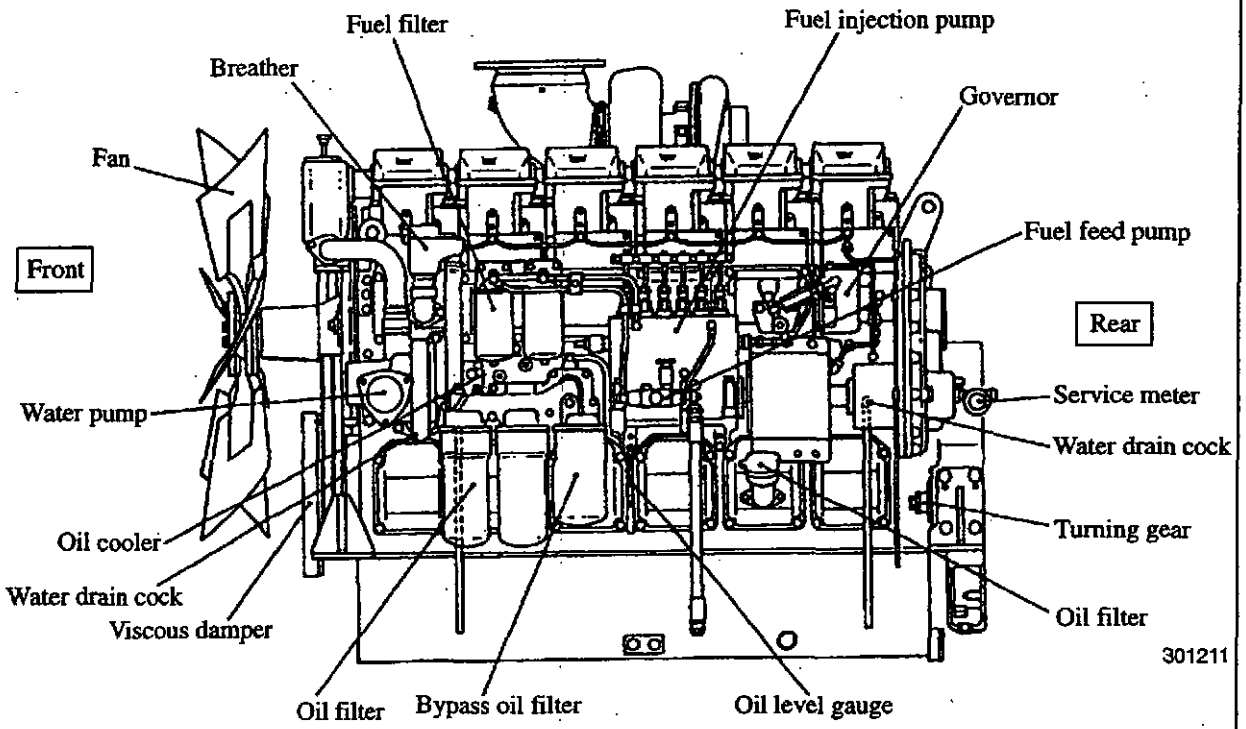
Summary of Manual Contents

Chapter	Contents
1. General	External views, engine serial number location, engine model and application codes, specifications, tips on disassembly and reassembly.
2. Maintenance standards	Maintenance standards, tightening torque, sealants and lubricants.
3. Special tools	A list of special tools required.
4. Overhaul instructions	Determining when to overhaul the engine, testing compression pressure.
5. Adjustments, Bench Testing, and Performance Tests	Adjustment of valve clearance and fuel system priming, fuel timing adjustment, bench testing, and performance tests.
6. Engine Accessory Removal and installation	Removal and installation of tubochargers, air coolers, fuel injection pumps, alternator, starters, etc.
7. Engine Proper	Disassembly, inspection, and reassembly of the engine proper, to include cylinder heads, valve mechanisms, pistons, flywheel, timing gears, camshaft, viscous damper, crankshaft.
8. Inlet and Exhaust Systems	Disassembly, inspection, and reassembly of inlet and exhaust systems, to include air cleaners, air coolers, exhaust manifolds, and air heater.
9. Lubrication System	Disassembly, inspection, and reassembly of lubrication system, to include the oil strainer, oil pump, relief valve, oil cooler,oil thermostats, oil filters, safety valve and oil filter alarm.
10. Cooling System	Disassembly, inspection, and reassembly of cooling system, to include water pump, thermostats, radiator and fan drive.
11. Fuel System	Disassembly, inspection, and reassembly of the fuel system, to include fuel filters, fuel injection nozzles, Woodward governor drive and governor linkage.
12. Electrical System	Disassembly, inspection, and reassembly of electrical system, to include starters and the alternator.
13. Air Start System	Disassembly, inspection and reassmbly of air start devices, to include air motor, air filter, distrbutor valve, starter valve, magnetic valve.
14. Workshop Tips	General precautions for disassembly and reassembly of parts: oil seals, O-rings, bearings, lock plates, and pins.

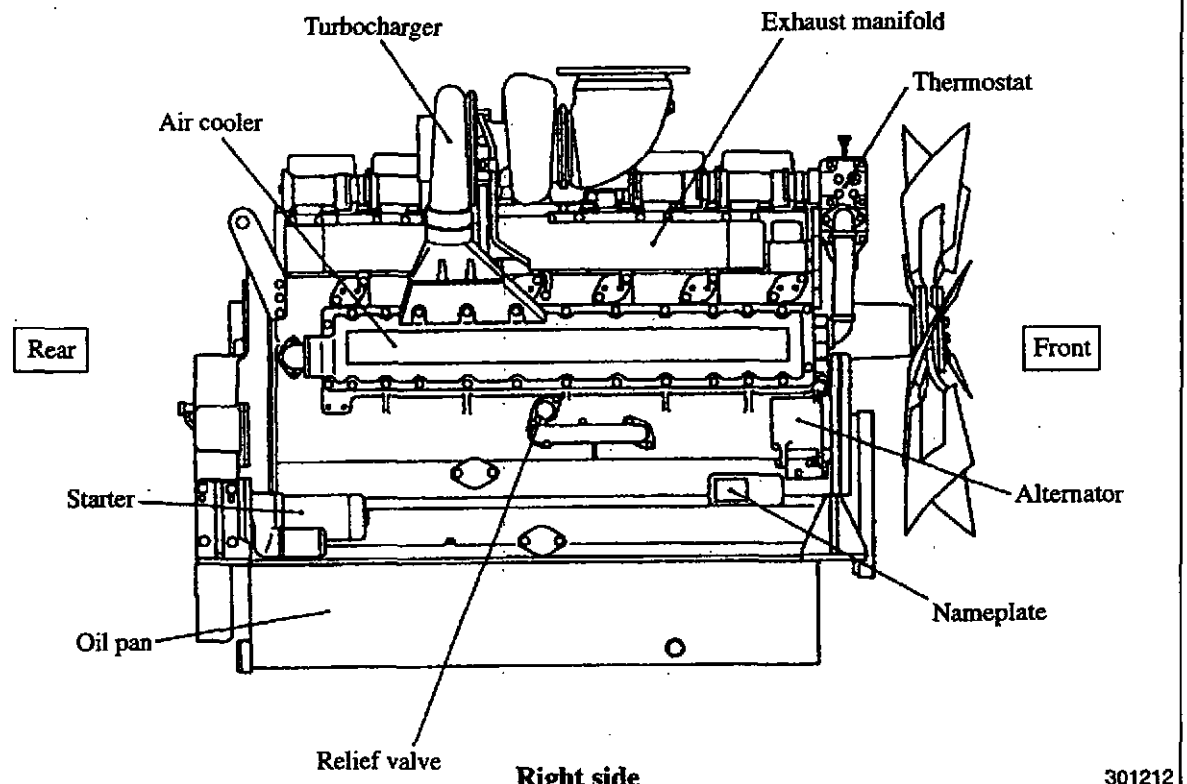
GENERAL

1. Outline

1.1 External View



Left side



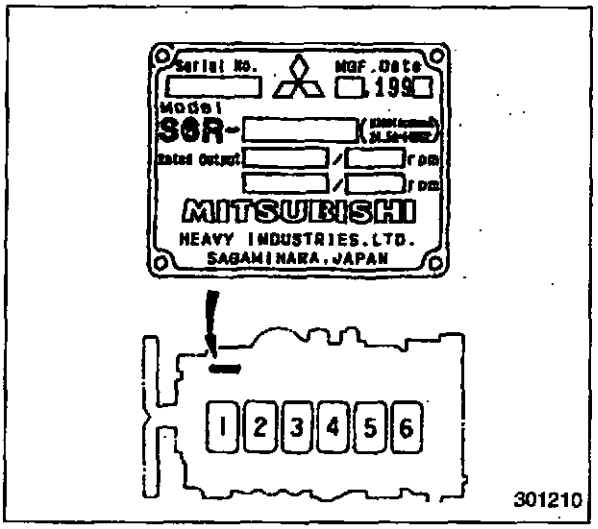
Right side

1.2 Engine Serial Number Location

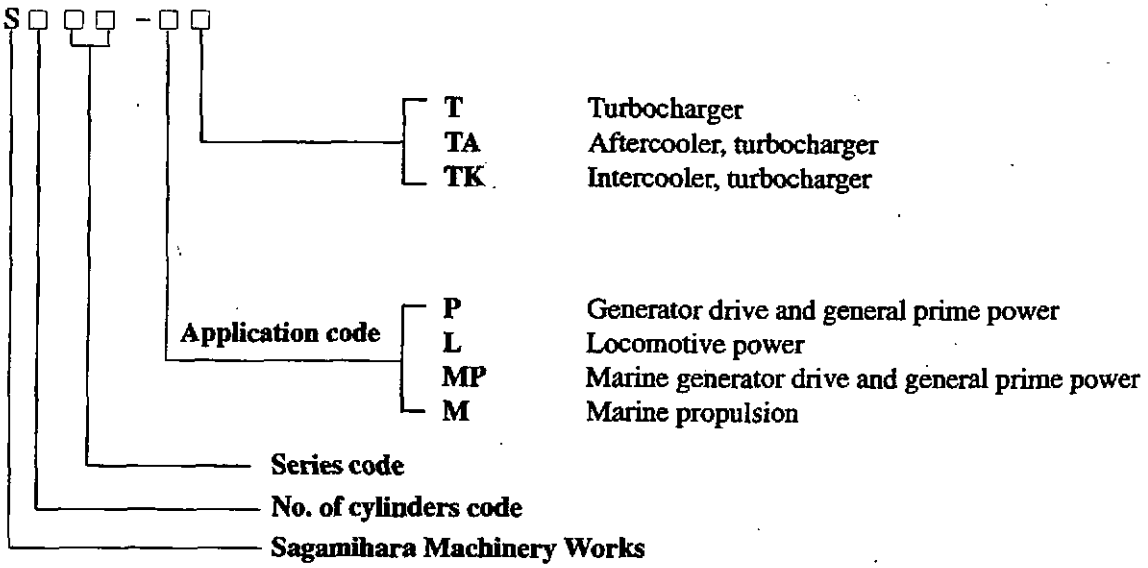
The engine serial number is stamped on the nameplate attached to the left lower side of the engine.

Example: Model Serial No.
S6R 10012

The rated output and speed are also stamped on the nameplate. Numbers in the illustration show cylinder numbers.



1.3 Engine Model and Application Codes



2. SPECIFICATIONS

Model designation				S6R			S6R2		
				T	TA	TK	T	TA	TK
General									
	Type			Water-cooled, 4-stroke cycle, tubocharged diesel					
				T=— TA=w/aftercooled TK=w/intercooled					
	No. of cylinder-arrangement			6—in—line					
	Combustion chamber type			Direct injection					
	Valve mechanism			Overhead					
	Cylinder diameter × stroke		mm (in.)	170 × 180 (6.693 × 7.087)			170 × 220 (6.693 × 8.661)		
	Piston displacement		ℓ (cu in.)	24.5 (1495)			30.0 (1831)		
	Compression ratio			14.0:1					
	Fuel			Light oil (JIS K2204 special No. 1-3) or A heavy oil (limited to big name brand)					
	Firing order			1-5-3-6-2-4					
	Rotation direction			Counterclockwise as viewed from flywheel side					
	Dimensions	Overall length	mm	1722 (67.8)					
		Overall width	mm	1050 (41.3)					
		Overall height	mm	1498 (59)			1578 (62.1)		
	Weight (Dry)		kg (lb)	2250 (4961)	2300 (5072)		2350 (5182)	2400 (5292)	
Engine proper									
	Cylinder liner	Type		Wet type					
	No. of piston rings	Compression rings		2					
		Oil ring (w/expander)		1					
	Valve timing (when warm)	Inlet valve	Open	B.T.D.C. 37°					
			Close	A.B.D.C. 44°					
		Exhaust valve	Open	B.B.D.C. 57°					
			Close	A.T.D.C 24°					
	Engine support			4 point support					
	Starting system			Electric-motor air motor or direct air inlet starting					
Inlet and exhaust systems									
	Air cleaner	Type		Paper element type or pre-cleaner type					
	Turbocharger	Type		TD15, TD13 or TD10					
		No. of units		1					
	Air cooler	Type		Laminated fin-plate type					

Model designation			S6R			S6R2		
			T	TA	TK	T	TA	TK
Lubrication system								
	Type		Pressure feed by gear pump					
	Engine oil	Specification	Class CD oil or class CF oil (API service classification)					
		Capacity (engine) liter (U.S.gal)	100 (26.4), approx.					
	Oil pump	Type	Gear pump					
		Delivery capacity liter (U.S.gal) min	140 (83.2) (at 800 rpm engine)					
	Relief valve	Type	Piston valve type					
		Valve opening pressure kgf/cm² (psi) [MPa]	4.7 (67) [0.46]					
	Oil cooler	Type	Water-cooled multi-plate type (housed in the crankcase)					
	Full-flow oil filter	Type	Paper element type (spin on)					
	Bypass oil filter	Type	Paper element type (spin on)					
	Oil filter alarm	Type	Piston valve type, built-in electric contact points					
		Lamp lighting and valve opening pressure (differential pressure) kgf/cm² (psi) [MPa]	$1.5\ ^{+0.3}_{0}$ ($21\ ^{+4}_{0}$) [$0.15\ ^{+0.03}_{0}$]					
	Oil thermostat	Type	Wax type					
		Valve opening temperature °C (°F)	80–84 (176–183)					
Cooling system								
	Type		Forced circulation					
	Capacity (Engine) liter (U.S.gal)		50 (13.2), approx.			55 (14.5), approx.		
	Water pump	Type	Centrifugal					
		Delivery capacity liter (U.S.gal)	800 (211.2) (at 1800 rpm engine)					
	Water pump and alternator drive belts	Type-No. of belts	Low-edge cog "C" –2					
		Outer circumference mm (in.)	1910 (75.2)					
	Thermostats	Type	Wax type					
		Valve opening temperature °C (°F)	69–73 (156.2–163.4)					
	Radiator	Type	Plate fin or corrugated fin					
	Cooling fan	Type	Steel-blade, circular arc type					
		No. of blades	8					
		Outside diameter mm (in.)	1010 (39.8)					

Model designation			S6R			S6R2		
			T	TA	TK	T	TA	TK
Fuel system								
	Injection pump	Model	PS 6 type					
		Manufacturer	Mitsubishi Heavy Industry					
		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 pump	Model	Bosch KD 22Z type					
		Manufacturer	Zexel Kiki					
		Cam lift	12 (0.47)					
	Governor	Control system	(Hydraulic) Zexel Kiki RHD Woodward PSG		(Electrical) Woodward EG-3P Barber-Coleman DYNA –8000			
	Injection nozzles	Type	Hole type					
		Manufacturer	Zexel Kiki					
		No. of spray orifice	10					
		Spray orifice inside diameter, mm (in.)	0.35 (0.0137) 0.325 (0.012), 0.31 (0.012) –160°					
		Spray angle	160°					
		Injection pressure kgf/cm^2 (psi) [MPa]	350 – 355 (4978 – 5049) [34.32 – 34.81]					
	Fuel Filter	Type	Paper element type (spin on)					

Model designation			S6R			S6R2		
			T	TA	TK	T	TA	TK
Electrical system								
	Voltage polarity		24V- Negative (–) ground					
	Starter	Model	8-23000-6641					
		Manufacturer	Nikko Electric Industry					
		Type	Pinion shift (Reduction type)					
		Out put V-kW	24-7.5					
		No. of starters	1 or 2					
		Pinion/ring gear ratio	11/182					
	Alternator	Type	3-Phase with built-in IC regulator					
		Manufacturer	Mitsubishi Electric					
		Output V-A	24-30					
		Rated output Generated rpm	5000 (at 27V, 30A)					
		Maximum speed rpm	8000					
		Regulator adjusting voltage V	28.5±0.5					
	Safety relay (for starter chattering)	Model	0–25000–7223					
		Manufacturer	Nikko Electric Industry					
		Mominal voltage V	24					
		Allowable temperature °C (°F)	-30 to +40 (-22 to 104.0)					
		Rating Seconds	30 minutes					
		Allowed contact current A	330 (momentary)					
			50 (30 seconds)					
		Ground	2-wire system					

3. Tips on Disassembly and Reassembly

This service manual covers recommended procedures to be followed when servicing Mitsubishi diesel engines. It also contains information on special tools required and basic safety precautions.

It is the responsibility of service personnel to be familiar with these requirements, precautions, and potential hazards and to discuss these points with their foreman or supervisor.

Study this manual carefully and observe the following general precautions to prevent serious personal injury and to avoid damage to the engine, equipment, and parts.

3.1 Disassembly

(1) Use the correct tools and instruments. Serious injury or damage to the engine can result from using the wrong 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 disassembled or cleaned parts in the order in which they were removed. This will save you time at reassembly.

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

(5) Carefully check each part for faults during removal or cleaning. Signs of abnormal wear will tell if parts or assemblies are functioning improperly.

(6) When lifting or carrying heavy parts, get someone to help you if the part is too awkward for one person to handle. Use jacks and chain blocks when necessary.

3.2 Reassembly

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

(2) Use only the correct tools and instruments.

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

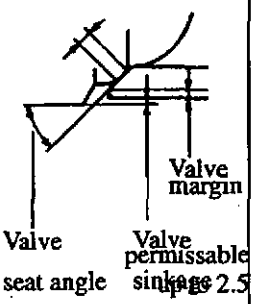
(4) Use a torque wrench to tighten parts when specified tightening torques are required. (Refer to 2, Group No.2)

(5) Replace all gaskets and packing. Apply only the proper amount of quick-drying cement to gaskets or packets when required.

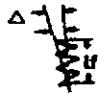
MAINTENANCE STANDARDS

1. Maintenance Standards Table

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
General	Maximum rpm		5-10% higher than rated rpm		Faulty if lower or 15% higher then rated rpm		Check governor setting.
	Minimum rpm		S6R: 600 to 650rpm S6R2: 500 to 550 rpm				
	Compression pressure kgf/cm² (psi) [MPa]		18.5 (263) [1.8] minimum (at 120 rpm)		Faulty if 13 (185) [1.3] or less		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) [0.5-0.64] (at rated rpm) 2 (28) [0.2] minimum (at idling)		Faulty if 5 (71) [0.4] or less Faulty if 1 (14) [0.1] or less		Oil temp. 60 to 70°C (140 to 158°F)
	Valve timing (with 2mm (0.08 in) clearance on valve side, cold)		Inlet valve opens B.T.D.C. 2.5° Inlet valve closes A.B.D.C. 13° Exhaust valve opens B.B.D.C. 26° Exhaust valve closes A.T.D.C. 10.5° ±2° (crank angle)				Valves are only for checking valve timing and are different from the 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	ø36 (1.42)	36.000 to 36.040 (1.41732 to 1.41889)		36.090 (1.42086)	
		Rocker diameter	ø36 (1.42)	35.966 to 35.991 (1.41598 to 1.41697)		35.940 (1.41496)	
	Valves	Valve stem diameter	ø10 (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	ø10 (0.39)	10.000 to 10.015 (0.39370 to 0.39429)		10.060 (0.39606)	The same for both inlet and exhaust valves.
	Valve seats and valves	Valve seat angle	30°				Seat width 
		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 (0.0840 to 0.0965)	2.8 (0.110)		
		Valve margin	3.0 (0.12)	2.8 to 3.2 (0.110 to 0.126)	Refacing (0.098)		

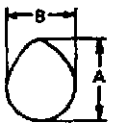
Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Engine proper	Valve seats and valves	Cylinder head bore inside diameter and valve seat diameter	ø60 (2.36)	(–0.070 to –0.130) ((–0.0028 to –0.0051))			– (minus) indicates the valve is closed.
	Valve springs	Free length		73 (2.87)		71 (2.80)	
		Squareness		θ=1.5° or less		Δ=2.2 (0.087) over the length	
		Length under test force (mm(in.)/kgf (lbf)[N])		66.0(2.598)/ 29.45 to32.55 (64.9 to 71.8) [289 to 319]			
	Valve push rods	Runout		0.5 (0.020) maximun			
	Cylinder heads	Warpage of gasketed surface		0.03 (0.0012) maximum	0.07 (0.0028)	0.50 (0.0197)	Regrind slightly.
	Cylinder liners	Inside diameter	ø170 (6.69)	170.000 to 170.040 (6.69290 to 6.69447)	170.200 (6.70588)	170.500 (6.75177)	
		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			
		Protrusion of cylinder liner flange above gasketed surface		0.11 to 0.20 (0.0043 to 0.0078)			
	Pistons	Outside diameter	ø170 (6.69)	169.76 to 169.80 (6.6835 to 6.6850)		169.66 (6.6795)	Measure diameter in the direction teansverse to pin at piston skirt.
		Variance in weight among pistons per engine		20 g (0.7 oz), maximum			
		Pin bore diameter	ø70 (2.76)	70.002 to 70.015 (2.75598 to 2.75649)		70.040 (2.75958)	
		Protrusion		0.06 to 0.65 (0.0024 to 0.0256)			
	Cylinder head gasket	As-installed thickness	1.8 (0.071)	1.77 to 1.83 (0.0697 to 0.0720)			

Unit: mm (in.)

Group	Inspection point			Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Engine proper	Piston and cylinder head	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, the general value can be obtained at the cylinder bore.
			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		ø70 (2.76)	69.987 to 70.000 (2.75539 to 0.75590)		69.970 (2.75472)	
	Connecting rods	Bushing inside diameter		ø70 (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)		67 (2.64)	(0.2 to 0.6) ((0.008 to 0.024))		(0.0394)	
		Variance in weight among connecting rods per engine			40g (1.4 oz), maximum			
		Big end bore diameter		131 (5.16)	131.000 to 131.025 (5.1547 to 5.15845)		130.950-131.050 (5.15551-5.15944)	To be used on combination with metal caps. Out-of-roundness (largest valve-smallest valve<0.1 (0.0039)
	Connecting rod metal	Thickness of center	STD	3.000 (0.11811)	2.972 to 2.985 (0.11701-0.11752)		2.930 (0.11535)	Replace metals if
			– 0.25 (–0.0098)	3.125 (0.12303)	3.097 to 3.110 (0.12193-0.12244)		3.055 (0.12028)	worn down to service
			– 0.50 (–0.0197)	3.250 (0.12795)	3.222 to 3.235 (0.12685-0.12736)		3.180 (0.12520)	limit. Regrind crank-
			– 0.75 (–0.0295)	3.375 (0.13287)	3.347 to 3.360 (0.13177-0.13228)		3.305 (0.13012)	pins and use under-
			– 1.00 (–0.0394)	3.500 (0.13780)	3.472 to 3.485 (0.13669-0.13720)		3.430 (0.13504)	beyond service limit.
	Flywheel	Face runout			0.285 (0.01122), maximum			
		Radial runout			0.127 (0.00500), maximum			
	Injection pump Accessory drive	Drive case bearing journal inside diameter		ø90 (3.54)	89.987 to 90.022 (3.54279 to 3.54417)			
				ø100 (3.94)	99.987 to 100.022 (3.93649 to 3.93787)			
		Bearing		ø90 (3.94)	89.985 to 90.000 (3.54272 to 3.54331)			
		Outside diameter		ø100 (3.94)	99.985 to 100.000 (3.93642 to 3.93701)			

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Engine proper	Injection pump Accessory drive	Inside diameter	ø45 (1.77)	44.988 to 45.000 (1.77118 to 1.77165)			
			ø50 (1.97)	49.985 to 50.000 (1.96791 to 1.96850)			
		Drive shaft bearing journal outside diameter	ø45 (1.77)	45.002 to 45.013 (1.77173 to 1.77216)			
			ø50 (1.97)	50.002 to 50.013 (1.96858 to 1.96901)			
	Viscous damper	Radial runout (at periphery)		0.5 (0.020) or less		1.5 (0.059)	Replace every 8000 hours
		Face runout		0.5 (0.020) or less		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
		Idle gear bushing inside diameter	ø50 (1.97)	50.000 to 50.025 (1.96850 to 1.96948)		50.060 (1.97086)	
		Idle gear shaft diameter	ø50 (1.97)	49.950 to 49.975 (1.96653 to 1.96752)		49.900 (1.96456)	
		Idle gear end play		(0.2 to 0.4) ((0.008 to 0.016))		(0.6) ((0.024))	
	Camshaft	Cam 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.

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Engine proper	Camshaft	Journal diameter	ø84 (3.31)	83.92 to 83.94 (3.3039 to 3.3047)		83.87 (3.3020)	
		Camshaft bushing inside diameter (as installed in crankcase)	ø84 (3.31)	84.000 to 84.035 (3.3071 to 3.3085)		84.10 (3.3110)	Replace bushings and *ream them, if necessary*, if worn beyond service limit.
		End play	8 (0.3)	(0.10 to 0.25) ((0.0039 to 0.0098))		(0.40) ((0.0016))	Replace thrust plate.
	Crankshaft	Crankpin diameter	ø125 (4.92)	–0.050 to –0.070 (–0.00197 to –0.00276)	–0.110 (–0.0043)		
		Crankpin journal diameter	140 (5.51)	–0.050 to –0.070 (–0.00197 to –0.00276)	–0.110 (–0.0043)		
		Center to center distance between journal and crankpin	S6R: 90 (3.54) S6R2: 110 (4.33)	±0.1 (±0.004)			
		Parallelism between journals and crankpins		0.01 (0.0004), maximum at pin length	0.03 (0.0012)		
		Out of roundness between 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 journals and crankpins	7	$7.0\ ^{0}_{-0.2}$			
		Hardness of journals and crankpins		Hv>620			
		Angular error of crankpins		±0°20'			
		Runout		0.04 (0.0016), maximum	0.10 (0.0039)		Repair or replace
		End play (shaft thrust width)	66 (2.60)	(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. +0.25 (+0.0098), +0.50 (+0.0197), +0.75 (+0.0295)

Unit: mm (in.)

Group	Inspection point			Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Engine proper	Main metals	Thickness of center	STD –0.25 (–0.0098) –0.50 (0.0197) –0.75 (–0.0295) –1.00 (–0.0394)	3.5 (0.138) 3.625 (0.14272) 3.750 (0.14764) 3.875 (0.15256) 4.000 (0.15748)	3.467 to 3.480 (0.13650-0.13701) 3.592 to 3.605 (0.14142-0.14193) 3.717 to 3.730 (0.14634-0.14685) 3.842 to 3.855 (0.15126-0.15177) 3.967 to 3.980 (0.15618-0.15669)		3.425 (0.13484) 3.550 (0.13976) 3.675 (0.14468) 3.800 (0.14961) 3.925 ((0.15453)	Replace bearings if worn down to service limit. Regrind crankpins and use undersize bearings if worn beyond service limit.
	Crankcase	Warpage of gasketed surface			0.1 (0.004), maximum	0.2 (0.008)		Regrind slightly.
		Main metal bore diameter		147 (5.79)	147.000 to 147.025 (5.78739 to 2.78837)		147.045 (5.78877)	
Lubrication system	Oil pump	Oil pump gear - to - idler gear backlash			(0.087-0.316)) ((0.0034 to 0.0124))		(0.3) ((0.012))	
		Drive and driven gear backlash		0.0079))	(0.10 to 0.20) ((0.0039 to		(0.4) ((0.016))	
		Radical clearance of gear in case		ø60 (2.36)	(0.100 to 0.196) ((0.00394 to 0.00772))		Tip clearance (0.35) ((0.0138))	
		End clearance of gears incase		34 (1.34)	(0.050 to 0.114) ((0.00197 to 0.00449))		(0.25) ((0.0098))	
		Shaft diameter		25 (0.98)	24.947 to 24.960 (0.98216 to 0.98268		24.900 (0.98031)	
		Bushing inside diameter			25.000 to 25.021 (0.98425 to 0.98503)		30.055 (1.18327)	
	Safety valve	Opening pressure			14±1kgf/cm² (199±14 psi) [1.37±0.10 MPa]			
		Spring installation length/ weight			67.2/384N (39.2 kgf)			
	Pump idler gear-to-crankshaft gear backlash				(0.11 to 0.38) ((0.0043 to 0.0150))			
	Relief valve	Opening pressure			4.7kgf/cm²(66.86psi) [0.46MPa]			
	Oil thermostat	Temperature at which valve starts opening			80 to 84°C (176 to 183°F)			
		Temperature at which valve lift is more than 11mm (0.43 in.)			95°C (203°F)			

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Lubrication system	Bypass alarm	Lamp lighting and valve opening pressure (differential pressure)		1.5 $^{+0.3}_{0}$ kgf/cm² (21 $^{+4}_{0}$ psi) [0.15 $^{+0.03}_{0}$ MPa]			1 mm (0.04 in.) shim changes 0.07 kgf/cm² (1 psi) [0.007 MPa].
	Oil jet nozzle	Opening pressure		2.7 to 3.3 kgf/cm² (38.4 to 45 psi) [0.26 to 0.32 MPa]			
Cooling system	Water pump	Bearing bore inside diameter	80 (3.15)	79.988 to 80.018 (3.14913 to 3.15031)		80.025 (3.15058)	
			90 (3.54)	89.987 to 90.022 (3.54279 to 3.54416)		90.025 (3.54428)	
		Bearing: Outside diameters	80 (3.15)	79.985 to 80.000 (3.14902 to 3.14961)			
			90 (3.54)	89.985 to 90.000 (3.54272 to 3.54331)			
		Bearing: Inside diameters	40 (1.57)	39.988 to 40.000 (1.57433 to 1.57480)			
		Diameter of shaft on which bearing inner race is fitted	40 (1.57)	40.002 to 40.013 (1.57488 to 1.57531)		39.995 (1.57492)	
		Vane front face clearance in pump case	0.72 (0.028)	(0.5 to 1.3) ((0.020 to 0.051))			
	Thermostat	Temperature at which valve *starts opening*		69 to 73°C (156.2 to 163.4°F)			Check at atmospheric pressure.
		Temperature at which valve lift is more than 11 mm (0.43 in.), minimum		85°C (185°F)			
	Fan drive	Inside diameters of bracket bore in which bearing outer races are fitted	100 (3.94)	99.987 to 100.022 (3.93649 to 3.93787)			
			110 (4.33)	109.987 to 110.022 (4.33019 to 4.33157)			
		Bearing: Outside diameters	100 (3.94)	99.985 to 100.000 (3.93642 to 3.93701)			
			110 (4.33)	109.985 to 110.000 (4.33012 to 4.33071)			
		Bearing: Inside diameters	45 (1.77)	44.988 to 45.000 (1.77118 to 1.77165)			
			50 (1.97)	49.985 to 50.000 (1.96791 to 1.96850)			
		Diameters of shaft on which bearing inner races are fitted	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)			
	Tension of water pump and alternator drive belt			10 to 15 (0.39 to 0.59)			Measure deflection by pushing belt midway between pulleys. 

Unit: mm (in.)

Group	Inspection point			Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Fuel system	Fuel injection nozzle	Valve opening pressure kgf/cm²(psi)[MPa]		350 (4977) [34.3]				
		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.
	PSG governor drive	Inside diameter of case bore in which drive shaft-side bearing outer race is fitted		52 (2.05)	51.988 to 52.018 (2.04677 to 2.04795)			
		Drive shaft-side bearing	Outside diameter	52 (2.05)	51.987 to 52.000 (2.04673 to 2.04724)			
			Inside diameter	25 (0.98)	24.990 to 25.000 (0.98386 to 0.98425)			
		Outside diameter of drive shaft on which bearing inner race is fitted		25 (0.98)	25.002 to 25.011 (0.98433 to 0.98468)			
		Inside diameter of case bore in which idler shaft-side bearing outer race is fitted		47 (1.85)	46.989 to 47.014 (1.84996 to 1.85094)			
		Drive shaft-side bearing	Outside diameter	47 (1.85)	46.988 to 47.000 (1.84992 to 1.85039)			
			Inside diameter	20 (0.79)	19.990 to 20.000 (0.78701 to 0.78740)			
		Outside diameter of idler shaft on which bearing inner race is fitted		20 (0.79)	20.002 to 20.011 (0.78749 to 0.78783)			

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Electrical system	Starter	Pinion shaft diameter and bushing inside diameter on front side	19 (0.75)	(18.90 - 18.94) (0.744 - 0.746)			
		Pinion shaft diameter on rear side	30 (1.18)	30.002 - 30.011 (1.18118 - 1.18153)			
		Armature shaft diameter on front side	25 (0.98)	25.002 - 25.011 (0.98433 - 0.98468)			
		Armature shaft diameter on rear side	14 (0.55)	13.941 - 13.968 (0.549 - 0.550)			
		Commutator diameter	43 (1.69)			42 (1.65)	
		Runout of commutator		0.06 (0.0024) maximum		0.100 (0.00394)	
		Mica depthhh in commutator		0.7-0.9 (0.028 - 0.035)	0.2 (0.008)		
		Height of brushes		21 to 22 (0.827 - 0.867)		13 (0.512)	
		Tension of brush springs (installed)	4.5 kgf (99 lbf) [44.13 N]	4.0 - 5.0 kgf (8.8 - 11 lbf) [3.92 - 49 N]		4.0 kgf (8.8 lbf) [39.23 N]	
	Bearings	Front bearing	19 (0.75)	19.000 - 19.033 (0.74815 - 0.74933)		0.25 (0.0098)	
		Pinion	19 (0.75)	19.000 - 19.033 (0.74815 - 0.74933)		0.25 (0.0098)	
		Rear bearing	14 (0.55)	14.000 - 14.027 (0.55118 - 0.55224)		0.25 (0.0098)	
	Thrust gap	Armature		0.3 - 0.7 (0.12 - 0.028)			
		Pinion shaft		0.2 - 0.8 (0.008 - 0.031)			
	Alternator	End play of armature		0.2 - 0.6 (0.0079 - 0.0236)			
		End play of pinion shaft		0.2 - 0.6 (0.0079 - 0.0236)			
		Diameter of spring	41 (1.61)	40.8 - 41.02 (1.606 - 1.6150)		40.6 (1.598)	
		Height of brushes	18.5 (0.729)			11.5 (0.453)	Up to wear limit line
		Tension of brush springs gf (lbf) [N]	380 (13.3) [3.7]	320 - 440 (11.2 - 15.4) [3.1 - 4.3]		200 (7) [1.96]	

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Electrical system	Alternator	Tension of alternator drive belt kgf (lbt) [N]					Push belt at midway between pulleys (force: approx. 10-15 (22-33) [98-147])
Air start system	Distributor valve	Valve height		21.5±0.1 (0.847±0.004)	20 (0.788)		
		Shaft clearance in bushing		(0.050 to 0.091) ((0.002 to 0.004))	(0.300) ((0.012))		
	Starter valve	Valve clearance in valve guide	ø15 (0.591)	(0.16 to 0.0520) ((0.0006 to 0.0204))		(0.100) ((0.004))	
		Valve spring free length		36 (1.418)		34 (1.3396)	

2. Tightening Torque Table

2.1 Important Bolts and Nuts

Description	Thread Dia × Pitch (M-thread)	Torque			Remarks
		kgf·m	lbf·ft	N·m	
Cylinder head	22 × 2.5	55	398	539	[Wet] 2-step tightening method Note (a)
Cylinder head nozzle glands (studs)	14 × 2.0	7 to 8	51 to 58	69 to 78	
Rocker case	12 × 1.25	11	80	108	
Rocker shaft	14 × 2	15	108	147	
Rocker arm lock nuts	12 × 1.25	6.5	47	64	
Bridge lock nuts	10 × 1.25	5.6	40	55	
Camshaft gear	12 × 1.25	13	94	127	
Camshaft thrust plate	12 × 1.25	6	43	59	
Main metal cap	22 × 2.5	50	362	490	[Wet]
Hanger	12 × 1.25	11	80	108	
Piston cooling nozzle	12 × 1.75	3.5	2.5	34	Note (c)
Timing gear case	16 × 1.5	22	159	216	
Rear plate	12 × 1.25	11	80	108	
Oil pan	12 × 1.25	6	43	59	
Mounting bracket (front)	12 × 1.25	11	80	108	
Mounting bracket (rear)	16 × 1.5	22	159	216	
Connecting rod metal cap	22 × 1.5	55	398	539	[Wet] 2-step tightening method Note (d)
Flywheel	22 × 1.5	55	398	539	[Wet]
Torsional vibration damper	22 × 1.5	50	362	490	
Rear idler shaft	12 × 1.25	11	80	108	
Rear idler shaft thrust plate	10 × 1.25	3	22	29	
Exhaust manifold V-clamp nuts	6 × 1.0	0.9	6.5	9	
Fuel injection pump /accessory drive case	12 × 1.25	11	80	108	
Fuel injection pump gears (nuts)	30 × 1.5	40	289	392	
Oil pump	12 × 1.25	11	80	108	Apply LOCTITE 262 to screw threads.
Oil pump idler gear (nut)	12 × 1.25	7	51	69	

Note: (a) To tighten cylinder head bolts according to the angle method, tighten to 30 kgf·m (217 lbf·ft) [294 N·m], then turn 60° more.

(b) Be sure to tighten main bearing caps and main bearing cap side bolts according to the specified sequence.

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

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

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

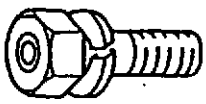
(c) To tighten check valves, be sure to use a torque wrench. Tightening without the use of a torque wrench can result in excessive tightening force, and this can cause valve malfunctions and lead to seizing of pistons due to insufficient lubricating oil during engine operation.

(d) To tighten connecting rod caps according to the angle method, tighten to 25 kgf·m (181 lbf·ft) [245 N·m], then turn 60° more.

(e) [Wet] indicates apply engine oil to the threads of the nuts and bolts.

Description	Thread Dia × Pitch (M-thread)	Torque			Remarks
		kgf·m	lbf·ft	N·m	
Water pump	12 × 1.25	6	43	59	
Water pump pulley (nut)	24 × 1.5	25	181	245	For alternator drive
Fan drive camshaft gear (nut)	12 × 1.25	11	80	108	
Fan drive shaft gear (nut)	30 × 1.5	40	289	392	
Fan plate	12 × 1.25	11	80	108	
Fuel injection pump bracket	12 × 1.25	11	80	108	
Fuel injection pump	12 × 1.25	11	80	108	
Fuel injection pump laminated plate	12 × 1.25	8.5 to 9.5	61 to 69	83 to 93	
Fuel injection pump flywheel (nut)	24 × 1.5	24 to 26	174 to 188	235 to 255	
Injection pump coupling shaft	14 × 1.5	17 to 18	123 to 130	167 to 177	
Plunger assembly	12 × 1.25	8 to 8.5	58 to 61	78 to 83	
Delivery valve holder	30 × 1.5	24 to 26	174 to 188	235 to 255	
Fuel injection nozzle gland (nut)	14 × 1.5	10	72	98	
Fuel injection nozzle tip retaining nut	28 × 1.5	18 to 20	130 to 145	177 to 196	
Nozzle bolder cap nuts	14 × 1.5	7 to 8	51 to 58	69 to 78	
Fuel injection nozzle holder set screw nut	14 × 1.5	4 to5	29 to 36	39 to 49	
Fuel injection nozzle inlet connector	16 × 1.5	6.5 to 7.5	47 to 54	64 to 74	
Injection pipes	18 × 1.5	5 to 7	36 to 51	49 to 69	
Fuel rack control lever	18 × 1.25	2.5	18	25	2-step tightening method
Governor drive case	12 × 1.25	11	80	108	
Starter	12 × 1.25	6	43	59	

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 automobile screw thread								
	8 × 1.25 (0.31 × 0.049)	12 (0.47)	1.7	12	17	3.1	22	30
	10 × 1.25 (0.39 × 0.049)	14 (0.55)	3.4	25	33	6.1	44	60
	12 × 1.25 (0.47 × 0.049)	17 (0.67)	6.1	44	60	11.0	80	108
	14 × 1.5 (0.55 × 0.059)	22 (0.87)	9.9	72	97	17.9	129	176
	16 × 1.5 (0.63 × 0.059)	24 (0.94)	14.8	107	145	26.7	193	262
	18 × 1.5 (0.71 × 0.059)	27 (1.06)	21.4	155	210	38.5	278	378
	20 × 1.5 (0.79 × 0.059)	30 (1.18)	29.7	215	291	53.4	386	524
	22 × 1.5 (0.87 × 0.059)	32 (1.26)	39.3	284	385	70.8	512	694
	24 × 1.5 (0.94 × 0.059)	36 (1.42)	49.7	359	487	89.5	647	878
	27 × 3 (1.06 × 0.12)		75.3	544	73.8	135.5	980	1328
Metric course screw threads								
	10 × 1.5 (0.39 × 0.059)	14 (0.55)	3.3	24	32	5.9	43	58
	12 × 1.75 (0.47 × 0.069)	17 (0.67)	5.8	42	57	10.4	75	102
	14 × 2 (0.55 × 0.079)	22 (0.87)	9.5	69	93	17.0	123	167
	16 × 2 (0.63 × 0.079)	24 (0.94)	14.2	103	139	25.6	185	251
	18 × 2.5 (0.71 × 0.098)	27 (1.06)	19.8	143	194	35.7	258	350
	20 × 2.5 (0.79 × 0.098)	30 (1.18)	27.7	200	272	49.9	361	489
	22 × 2.5 (0.87 × 0.098)	32 (1.26)	37.0	268	363	66.6	482	653
	24 × 3 (0.94 × 0.12)	36 (1.42)	47.7	345	468	86.0	622	843
	27 × 3 (1.06 × 0.12)	41 (1.61)	70.0	506	686	126.0	911	1236

Remarks: (a) This table lists the tightening torque for the standard nuts and bolts.
(b) The numerical values in this table are for when using spring washers.
(c) This table shows the standard values with a maximum tolerance value of +10%.
(d) Except for special tables, tightening torque should be done using this table.
(e) *Don't apply oil to screws (dry state).*

2.3 Standard Eyebolts

Threads Diameter × Pitch (mm)	Width across flats (mm)	Strength classification		
		4T		
		N·m	lbf·ft	kgf·m
M8 × 1.25	12	8±1	58±0.72	0.8±0.1
M10 × 1.25	14	15±2	10.8±1.45	1.5±0.2
M12 × 1.25	17	25±3	18.1±2.17	2.5±0.3
M14 × 1.5	22	34±4	25.3±2.89	3.5±0.4
M16 × 1.5	24	44±5	32.5±3.62	4.5±0.5
M18 × 1.5	27	74±5	54.2±3.62	7.5±0.5
M20 × 1.5	30	98±10	72.3±7.23	10.0±1.0
M24 × 1.5	36	147±16	108.5±10.8	15.0±1.5
M27 × 1.5	41	226±20	166.3±14.5	23.0±2.0

(Dry)

2.4 Standard Union Nuts

Nominal Diameter	Cap nut size	Width across flats	N·m	lbf·ft	kgf·m
63	M14 × 1.5	19	39	29	4
80	M16 × 1.5	22	49	36	5
100	M20 × 1.5	27	78	58	8
120	M22 × 1.5	30	98	72	10
150	M27 × 1.5	32	157	116	16
180	M30 × 1.5	36	196	145	20
200	M30 × 1.5	36	196	145	20
220	M33 × 1.5	41	245	181	25
254	M36 × 1.5	41	294	217	30

(Dry)

2.5 High-Pressure Fuel Injection Pipes

Cap nut size	N·m	lbf·ft	kgf·m
M12 × 1.5	39±5	29±3.6	4±0.5
M14 × 1.5	49±5	36±3.6	5±0.5
M18 × 1.5	59±1	43±7.2	6±1.0

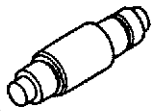
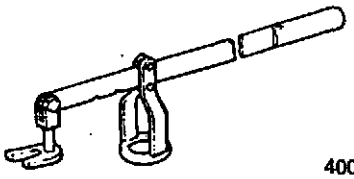
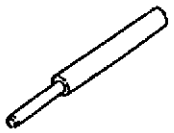
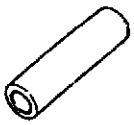
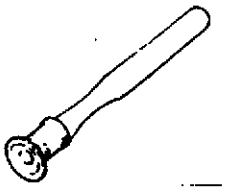
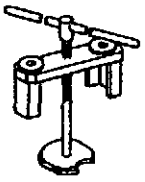
(Dry)

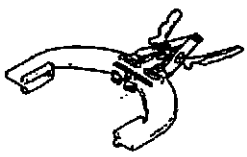
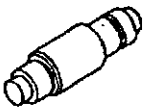
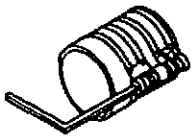
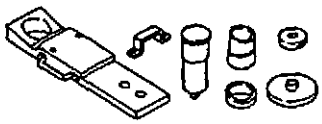
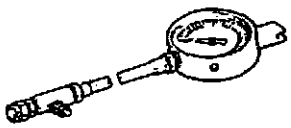
3. Sealants and Lubricants Table

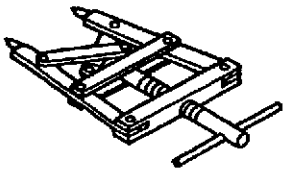
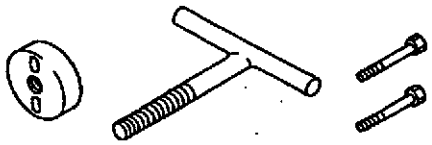
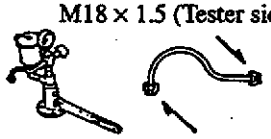
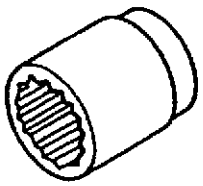
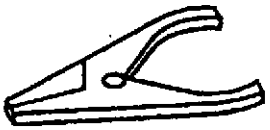
Group	Application point		Sealant or lubricant	How to use
Engine Proper	Cylinder head sealing caps		Hermeseal S-2	Coat holes in crankcase
	Water outlet connectors (Rocker case)		Grease	Grease O-ring joint
	Cylinder liners		Engine oil	Grease O-ring joint
	Front cover, gear case, oil pan, and crankcase		Herdite	Coat joint surfaces only
	Rear plate, gear case, oil pan, and crankcase		Herdite	Coat three-joint surfaces only
	Crankcase taper plugs		Sealock, Loctite (made by Three Bond)	Apply to threads
	Crankcase sealing cap		Three Bond 1104	
	Oil pan and crankcase		Herdite	Coat joint surfaces only of both sides of packing
	Oil seal		Engine oil	Coat lip of each oil seal
	Rear plate and timing gear case		Three Bond 1212	Coat both sides of packing
	Drive case		Three Bond 1212	Apply to flange surface
	Cylinder hhead gasket		Three Bond 1212	Apply to areas around tappet chambers
Lubrication system	Oil pump	Cover and case	Three Bond 1104	Coat both sides of packing
Cooling system	Water pump	Oil seal, unit seal	Engine oil	Coat lip of inner seal
	Fan drive	Oil seal	Engine oil	Coat lip of oil seal
Inlet system	Air cooler	Between the element and the both side of plate	Shin-Etsu Chemical Co., Ltd KE-45-W or a similar sealant or lubricant.	Fill the gap between the element and the plate.
Others	Taper plugs and cocks not precoated with Three Bond thread sealants.		Vulcanized tape sealing	Wrap threads with 2 turns of tape.

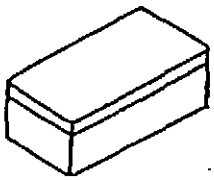
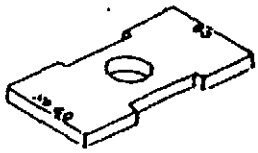
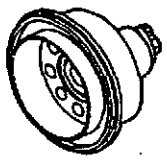
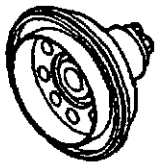
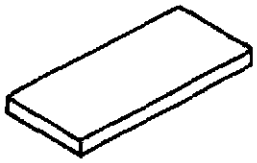
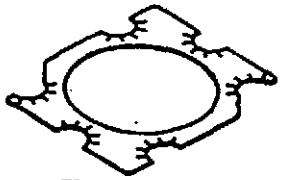
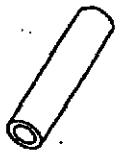
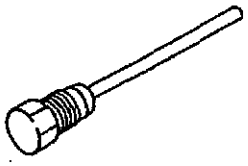
SPECIAL TOOLS

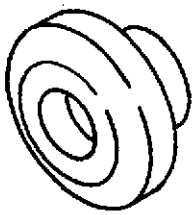
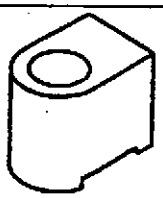
Special Tools

Tool name	Part No.	Shape	Use
Rocker bushing tool	37591 - 02600	 403390	Rocker bushing installation/ removal
Eye nut	37591 - 02400	 401178	Cylinder head suspension
Valve spring pusher	33591 - 04500	 400009	Valve spring removal/ installation
Valve guide remover	33591 - 04300	 400011	Valve guide removal
Valve guide and 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	 400018	Idler bushing removal/ installation
Piston installer	37191 - 07100	 400019	Piston installation
Connecting rod bushing installer	37591 - 01010	 400016	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	For removal/installation of fandrive shaft gear, pulley cap nut
Torque wrench	32191 - 03100	 400904	

Tool name	Part No.	Shape	Use
Piston remover	MM321420	 403210	Piston removal
Water pump pliers	37591 - 03100		For water pump cover snapring
Impeller remover	37591 - 03200		Water pump impeller removal
Adjustable wrench	F9611 - 15000	 400905	
Nozzle tester	41091 - 01500	Nozzle connection pipe M18 × 1.5 (Tester side)  M18 × 1.5 (Nozzle fitting side) 400907	Nozzle opening pressure measurement
Socket	37591-03500		
Plier	49160 - 90101		
Plier	49160 - 90201		

Tool name	Part No.	Shape	Use
Plier	49160 - 90301		
Tool box	49160 - 90501		
Injection coupling gauge	37951 - 06100		Flywheel and coupling clearance adjustment
Front seal installer assembly	37591 - 05010		Front oil seal installation
Rear seal installer assembly	37591 - 06010		Rear oil seal installation
Projection plate	37598 - 09201		Crankcase ridge depth measurement
Head bolt plate	37598 - 08900		For use in angle-method tightening of head bolts
Head bolt spacer	37598 - 09100		
Valve seat cutter shaft	37591 - 06400		Valve seat contact surface adjustment

Tool name	Part No.	Shape	Use
Valve seat cutter	37591 - 06430		
Liner pusher	37591 - 06200		Liner retainment
Bolt	37591 - 06300		

OVERHAUL INSTRUCTIONS

1. Determination of Overhaul Timing

In most cases the engine should be overhauled when the engine's compression pressure is low. Other factors that indicate an engine overhaul is required are as follows:

(a) Reduced power

(b) Increased fuel consumption

(c) Increased engine oil consumption

(d) Increased blow-by gas volume through the breather due to abrasion at the cylinder liner and the piston ring

(e) Gas leakage due to poorly adjusted seating of the suction and the discharge valves

(f) Starting problems

(g) Increased noise from engine parts

(h) Abnormal color of exhaust gas from engine after warm-up.

Any one or a combination of these symptoms may indicate that engine overhaul is required; they may also indicate other problems of non-related causes. Of the items listed above some directly relate to deterioration of the engine while others do not. Items (b) and (f) are more likely to be affected substantially by

- Injection volume of the fuel injection pump
- Fuel injection timing
- Abrasion at the plunger
- Fitting of the injection nozzle
- Condition of electrical equipment: battery, starter, or alternator.

Item (d) above, however, requires special consideration because decreased pressure due to abrasion at the cylinder liner and the piston ring is one of the most obvious signs that the engine requires overhauling.
The most effective way to make a determination is by testing the compression pressure; other factors are to be considered secondarily.

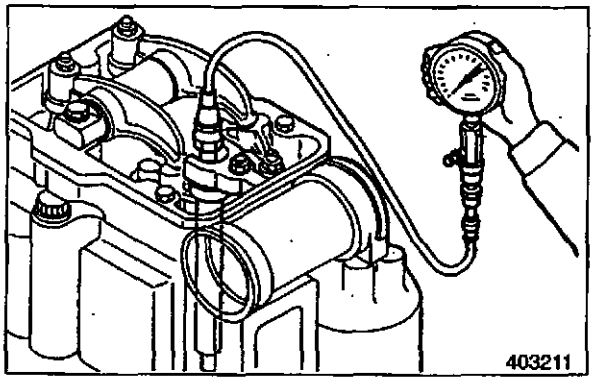
2. Testing the Compression Pressure

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

(2) Attach the adapter (3759-02200) to the cylinder and connect pressure gauge (33391 -02100) to the adaptor.

(3) Crank the engine with the starter, then read the compression gauge indication while the engine is running at the specified speed.

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



⚠CAUTION

(a) Measure the compression pressure on all cylinders. It is not a good practice to measure the compression pressure on only two or three cylinders, then make a judgment about the compression on the remaining cylinders.

(b) Compression pressure varies with changes in engine rpm's.
Check engine rpm when measuring compression pressure.

Unit: kgf/cm² (psi)[MPa]

Item	Assembly Standard	Repair Limit
Compression pressure	18.5 (263)[1.8] min.	13 (185)[1.3] max.

NOTE

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

⚠CAUTION

(a) Measure the compression pressure at regular intervals to obtain correct data.
(b) The compression pressure will be slightly higher in a new or overhauled engine due to the breaking in the piston rings, valve seats, etc. Pressure will drop slightly after the engine parts are broken in.

ADJUSTMENTS, BENCH TESTING, PERFORMANCE TESTS

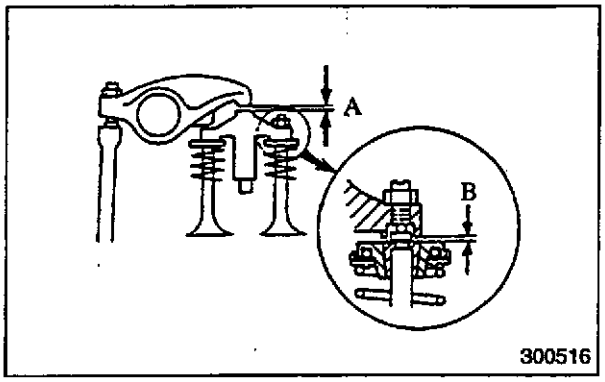
1. Adjustments

1.1 Valve Clearance

Valve clearance should be inspected and adjusted when the engine is cold.

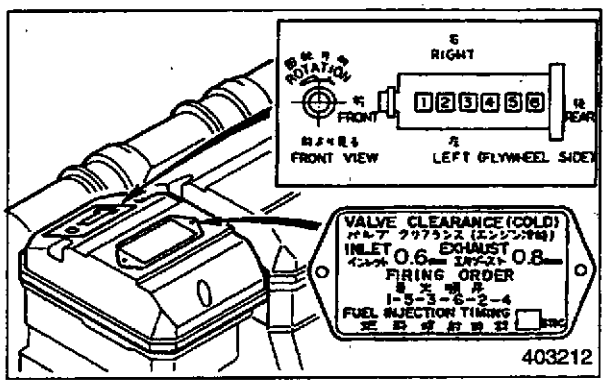
Unit: mm (in.)

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



NOTE

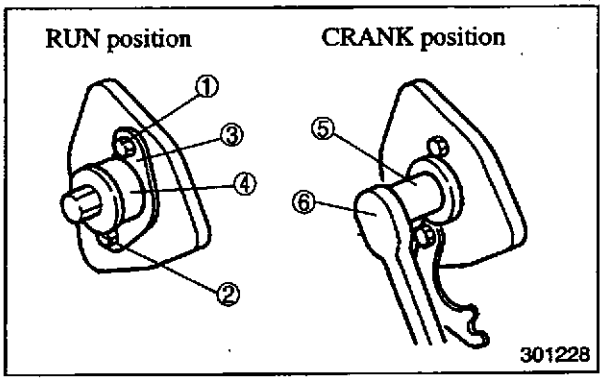
The bridge-to-valve rotator clearance (B) should be more than 1.5 mm (0.059 in.) after the front and rear valve heights have been adjusted. If the clearance is too small, grind the bridge to obtain the specified clearance.



(1) Inspecting valve clearance

(a) Inspect the valve clearance in the firing order by turning the crankshaft (120°) in the direction of normal rotation to bring the piston to top dead center of the compression stroke.

Firing order: 1-5-3-6-2-4



NOTE

Note these points when using the turning gear

(a) Loosen bolts ① and ②. Remove the plate ③ from the slot of the shaft ④.
Push the shaft ④ until it reaches its limit.

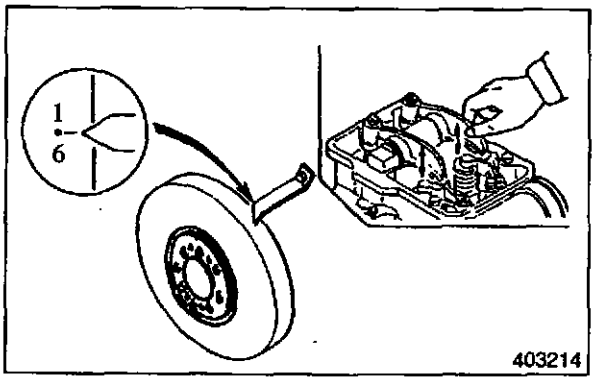
(b) Make the shaft ④ turn by rotating it with the socket ⑤ and the ratchet handle ⑥.

(c) After completing the turn, pull out the shaft ④. Insert the plate ③ into the slot of the shaft ④. Tighten the bolts ① and ②. Check and be sure the plate ③ is inserted into the slot of the shaft ④.

⚠CAUTION

Set the turning gear at the run time condition before you start the engine.

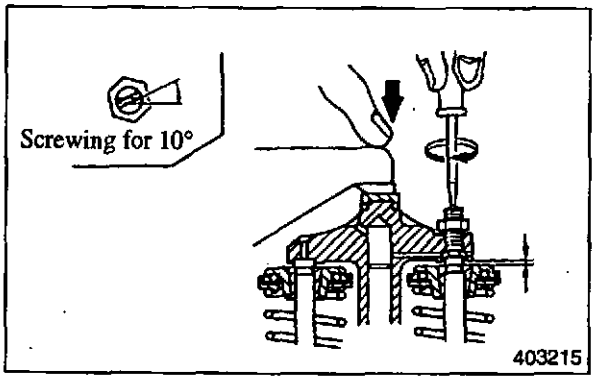
(b) The top dead center on the compression stroke of the piston is identified by the timing mark (provided on the torsional vibration damper), aligned with the pointer. With the piston so located, the inlet and exhaust valve rocker arms are not pushed up by their push rods.



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

(2) Adjusting front and rear valve heights by the valve bridge

(a) Before adjusting the valve clearance, adjust the front and rear valve heights by means of the bridge (bring the bridge into contact with the valves). If the valve seats are worn, valve heights will differ, causing variations between stem tops and bridges.



(b) To adjust valve height, loosen the lock nut, then back off the adjusting screw.

(c) Holding the rocker arm with your fingers, slowly screw in the adjusting screw until it touches the valve stem top. After looking into the hole of the bridge to check that the screw is in contact with the stem top, turn the screw about 10° of one turn, and tighten the lock nut.

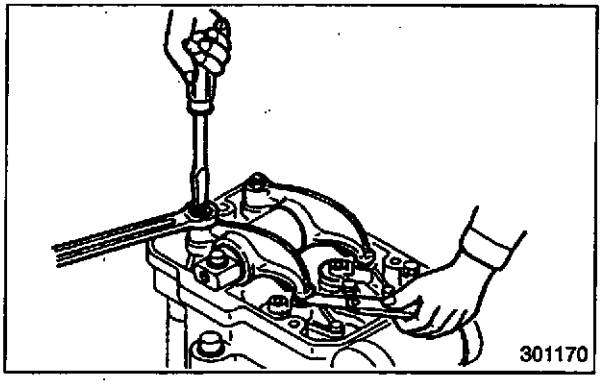
NOTE

If the valve clearance between the bridge and valve rotator is less than specified, the valve cotters may come off. Be sure to maintain the specified clearance (or more) between the two.

(3) Adjusting valve clearance

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

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



1.2 Fuel System Priming

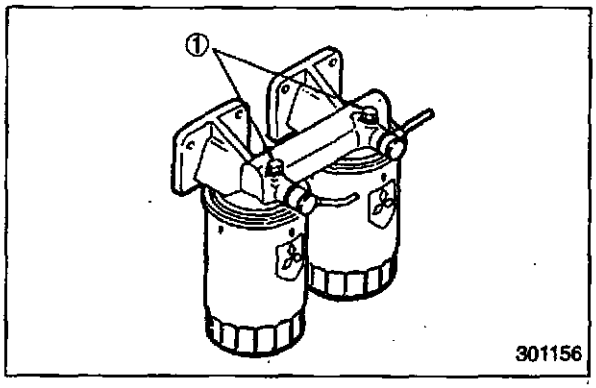
First prime the fuel filters, then prime the fuel injection pumps.

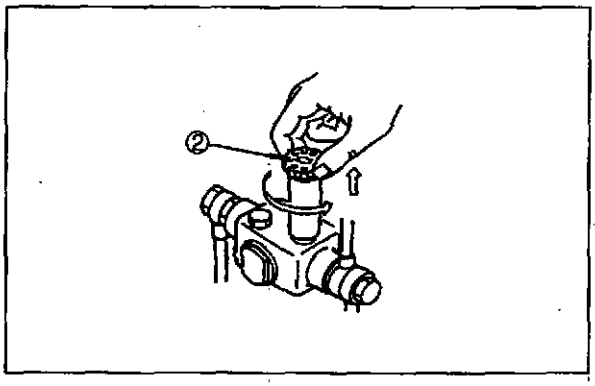
(1) Fuel filter

(a) Loosen the vent plug ① by turning it about 1.5 rotations.

(b) Unlock the priming pump handle ② by turning it counterclockwise. Operate the priming pump by moving the handle up and down.

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



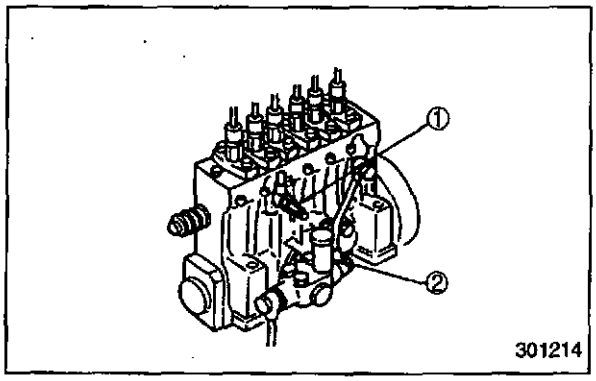


(2) Fuel injection pumps

(a) Loosen the air vent plug ① by turning it about 2 rotations.

(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.



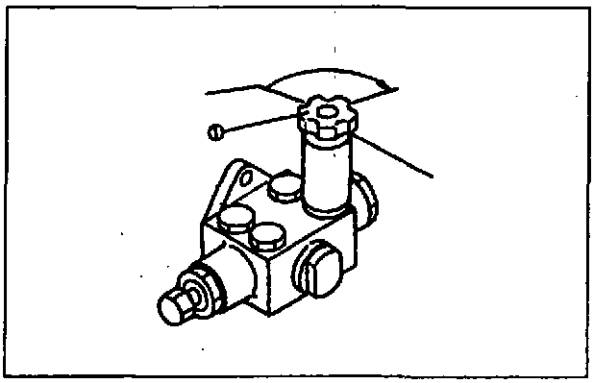
NOTE

(a) If the 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) Use a cloth to wipe off fuel spilled from the vent holes.

(3) Tightening priming pump cap

(a) Tighten the priming pump cap by hand, and stop turning immediately after the tightening force suddenly increases.

(b) After step (a), further turn the priming pump cap by 120° to 150° using a wrench.



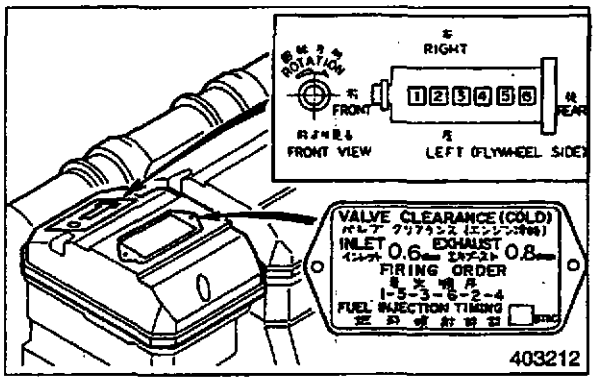
⚠CAUTION

Be sure to tighten the priming pump cap according to the specified angle (Θ = 120° to 150°).
If the priming pump cap is not tightened firmly, engine operations can result in the wear of internal threads. This can cause the priming pump cap to eject and fuel to flow out.
If the priming pump cap is tightened with excessive force (Θ = 240° or more), the head section of the priming pump can become damaged.

1.3 Fuel Injection Timing Adjustment

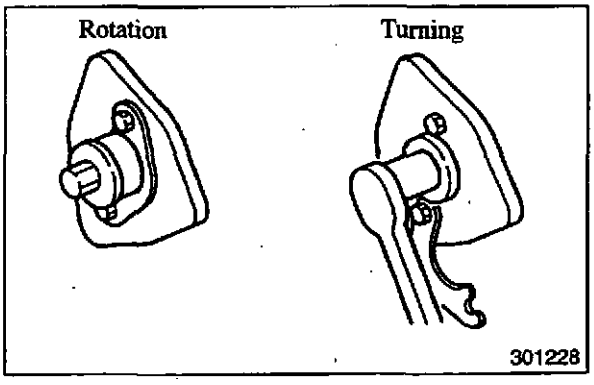
(1) Fuel injection timing and indication

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



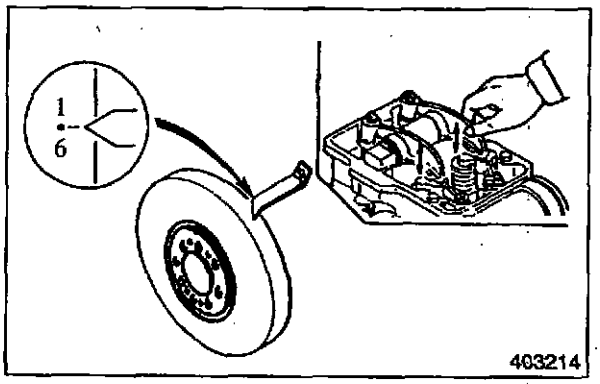
(2) Confirming the position of the No. 1 piston's top dead center on the compression stroke

(a) Use the ratchet handle to turn in the normal direction.



(b) Stop turning when the timing mark (1-6) on the torsional vibration damper is aligned with the pointer.

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

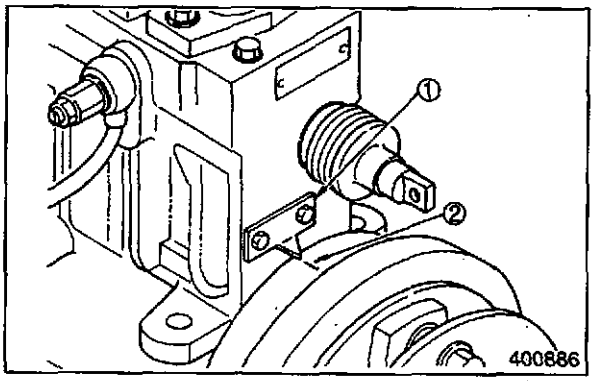


⚠CAUTION

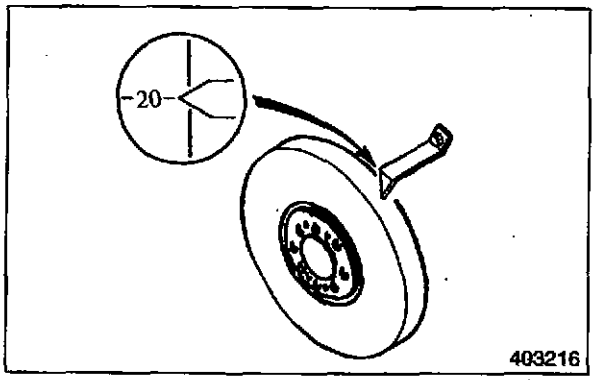
Do not confuse the top dead center on the compression stroke for No. 1 cylinder with that for the No. 6 cylinder.

(3) Inspecting fuel injection timing

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



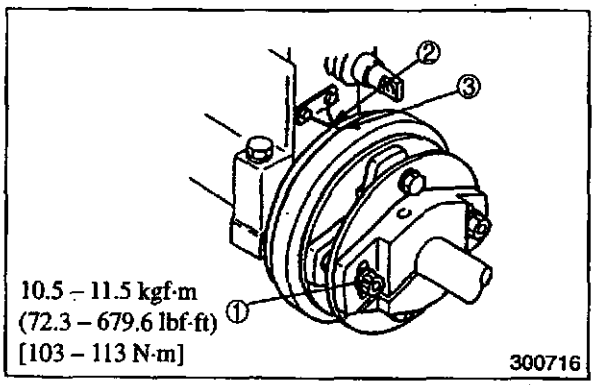
(b) Read the degrees of an angle (injection timing) on the scale on the vibration damper, indicated by pointer. Minus (–) mark on the scale and caution plate means "BEFORE" top dead center.



(4) Adjusting fuel injection timing

(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 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 inspect the timing by cranking the engine for verification.

1.4 Idling Speed and Maximum Speed Setting Inspection and Adjustment

⚠CAUTION

(a) No-load minumum (idling speed and maximum speed are set for each engine on the test bench at the factory and the set bolts are sealed. These setting are to be inspected 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 are specified to be sealed. Whether the seals are intact or not has important bearing on the validity of claims under the warranty.

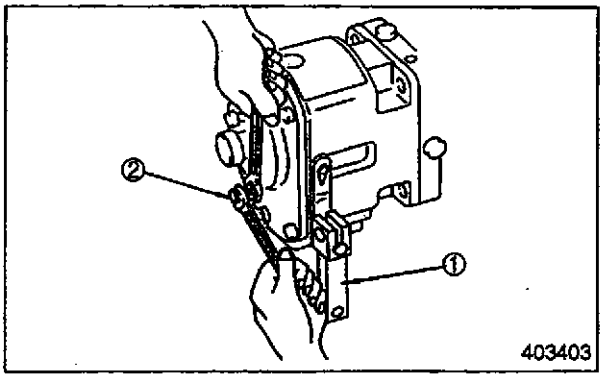
(d) When inspecting and adjusting these settings, be ready to operate the engine stop lever manually if the engine overrun.

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

RHD-type governor

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

(a) Hold speed control lever ① at the position for permitting the engine to run at the specified idling speed, and set low idle set bolt ② there.



⚠CAUTION

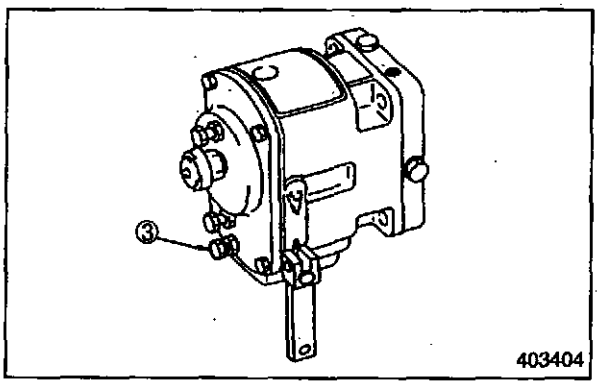
If a critical speed (the speed at which the engine exhibits excessive vibration due to torsional resonance) might exist, shift the idling speed setting to a lower or higher idling level.

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

(2) Inspecting and adjusting governor set (setting for limiting maximum engine speed)

(a) Hold the speed control lever at the indicated maximum speed position.

(b) With the speed control lever held in that position, run in governor set bolt (maximum speed set bolt) ③ until its forward end comes in contact with the speed control lever held as above. Secure the bolt right there by tightening its lock nut.



(3) Correcting hunting

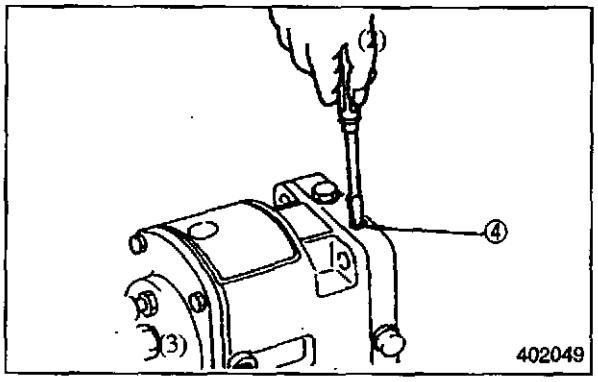
(a) If the engine hunts, reset needle valve ④. Open the needle valve by turning it counterclockwise (2 to 3 rotations) until the engine hunts. Keep the engine hunting for about 30 seconds until air is vented from the governor.

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

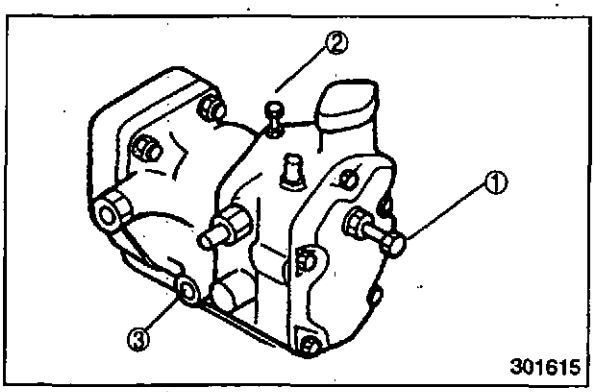
(c) Over-closing the needle valve will delay speed regulation with respect to changes in load.

(d) Move the speed control lever a little to check for governor response, making sure that the speed will increase once and settle at the steady level.

(e) Seal each set bolt.



PSG type governor



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

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

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

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

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

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

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

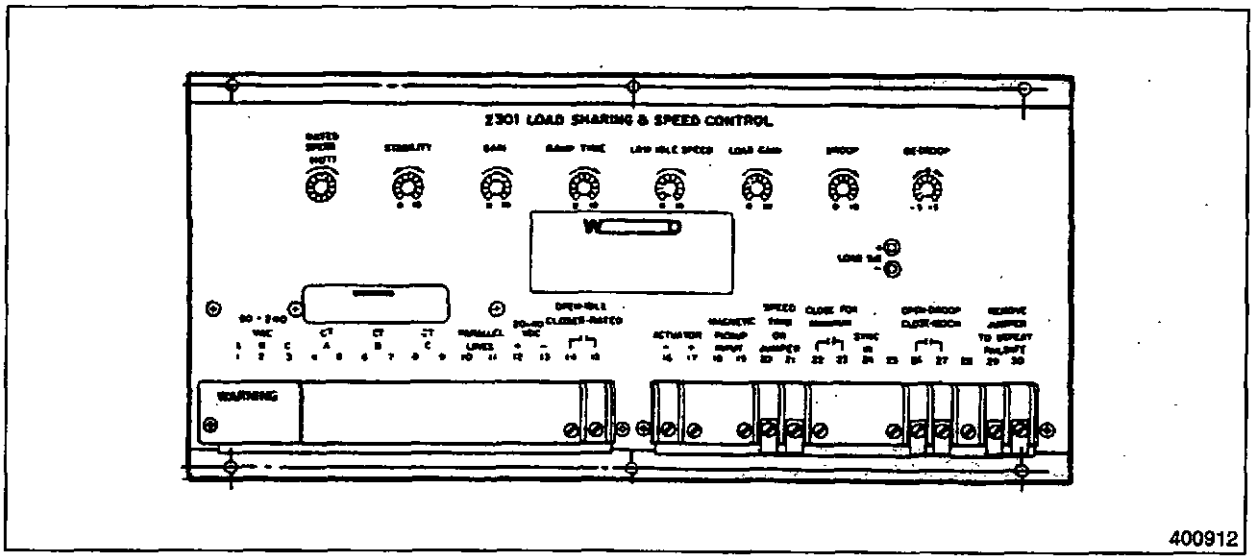
(3) Correcting hunting

(a) If the engine hunts, adjust it with the 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) If the needle is closed too far, this will delay speed regulation with respect to changes in load. Keep the valve backed off at least 1/4 rotation from the fully closed position.

(d) Seal each set bolt.



(1) Adjusting idling speed setting

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

(b) Set the "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 the control rack, and is governed as set by the "LOW IDLE SPEED" potentiometer.

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

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

(a) Set "RATED SPEED" with the potentiometer so the engine runs at the rated speed.

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

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

(a) Response time of the governor can be increased with larger gain. To increase the gain for this purpose, turn the "GAIN" potentiometer clockwise while you observe the voltmeter until the engine just lacks stability.

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

(c) To verify 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 the "STABILITY" potentiometer, turn "GAIN" counterclockwise. If low pitch hunting occurs, turn the "GAIN" potentiometer clockwise.

⚠CAUTION

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

Barber-Colman DYNA 8000-type Governor

(1) Adjusting speed setting

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

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

"I" potentiometer.....
"1" position
"GAIN" potentiometer.....
"3" position
"DROOP" potentiometer...
Turn all the way counterclockwise for isochronuous operation. Set in the desired position for droop operation (12% of 35° operation).

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

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

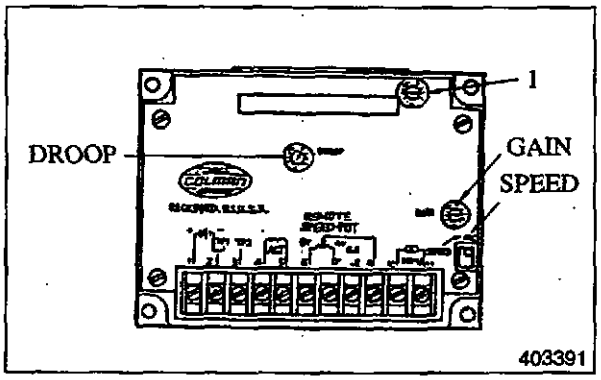
(e) Set "SPEED" potentiometer for idling speed or so.

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

(2) Correcting hunting

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

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



Potentiometer

(3) Correcting overshooting

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

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

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

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

(4) Changing droop setting

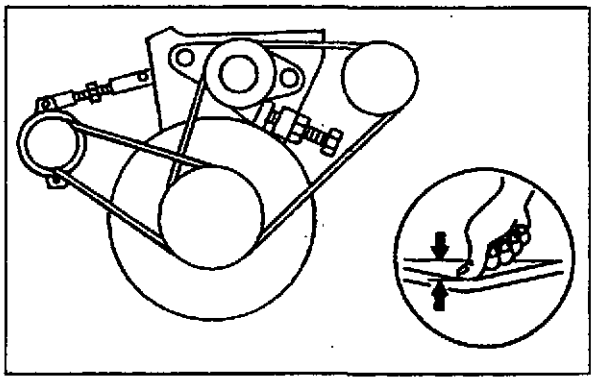
The governor would become unstable if "DROOP" potentiometer is turned clockwise from the set position after "GAIN" potentiometer of the controller has been adjusted. This can be corrected by turning "GAIN" potentiometer clockwise just a little.

1.5 Inspecting and Adjusting Water Pump and Alternator Drive Belt

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

Unit: mm (in.)

Item	Assembly standard
Belt tension	10–15 (3·8–5·8)



⚠CAUTION

Be sure the drive belt tension is excessively tight.

2. Bench Testing

An overhauled engine should be tested for performance on a dynamometer. This test is also for breaking in the major running parts of the engine. To test the engine, follow the procedures described below.

2.1 Starting Up

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

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

(3) Move the speed control lever slightly in the direction of increasing fuel injection, then turn the starter switch to START to start the engine. Do not move the control lever to the "fuel injection" position.

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

2.2 Inspection After Starting Up

After starting up the engine, check the following points. If you find anything wrong, immediately stop the engine, then investigate the cause.

(1) Lubricating oil pressure should be 5 to 6.5 kgf/cm^2 (71 to 92.4 psi) [490 to 637 KPa] at rated speed or over 2 to 3 kgf/cm^2 (28 to 42 pis) [196 to 294 kPa] at idling speed.

(2) Coolant temperature should be 70-90°C (158°F to 194 °F).

(3) Lubricating oil temperature should be in the range of 70-90°C (158° to 194°F) when measured in the oil pan.

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

(5) Knocking should die away as coolant temperature rises. No other defects should be found.

(6) Exhaust color, abnormal odors

2.3 Bench Testing (Dynamometer) Conditions

Here is a summary table of bench testing 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	25%	10
5	"	50%	10
6	"	75%	30
7	"	100%	20

Rated: Varies according to specifications.

2.4 Inspection and Adjustments After Bench Testing

(1) Adjusting valve clearance

(2) Adjusting injection timing

(3) Retightening of exhaust manifold mounting bolts

3. Performance Tests

There are various performance test procedures, and here the procedures for construction machinery [JISD1005 (1986)] are described. Other test items may be required on application. Engine performance is judged with integrated test results.

3.1 Standard Equipment

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

3.2 Test Items

(1) Fuel consumption test

(2) No-load maximum speed test

(3) No-load minimum speed test

3.3 Test Methods

(1) Fuel consumption test

(a) Engine speed (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. "Stable minimum speed" means minimum speed at which the engine rpm's can be quickly dropped from maximum rpm's without stalling.

(b) The no-load minimum speed is the specified rpm.

(4) During performance testing, inspect for leakage of gas, coolant, lubricating oil, or fuel, and for noise or hunting. Make adjustments as needed.

(5) Adjusting engine output

Diesel engine output is affected by atmospheric pressure, temperature, and humidity. Therefore, the engine output should be set for standard atmospheric conditions.

Item	Condition
Atmospheric pressure	750 mmHg
Temperature	25°C (77°F)
Atmospheric vapor pressure	11.4 mmHg

Measured axis output and axis torque should be calibrated by the coefficient obtained from the following formula.

$$k = \left\{ \left(\frac{p_0}{p}\right) \cdot \left(\frac{\theta}{\theta_0}\right)^{0.7} \right\}^{fm} \qquad \text{(Non-charged)}$$

$$k = \left\{ \left(\frac{p_0}{p}\right)^{0.7} \cdot \left(\frac{\theta}{\theta_0}\right)^{1.5} \right\}^{fm} \qquad \text{(Turbocharged)}$$

Po : Measured atmospheric pressure (mmHg)
p : Standard dry atmospheric pressure (743 mmHg, 99 KPa)
θ : Measured temperature (°C)
θ_0 : Standard atmospheric temperature (298 K, 25°C)
fm, fm' : Main fuel consumption coefficient

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

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

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

q : Fuel supply volume per stroke volume, single stroke (mg/ℓ-cycle)

r : Compression ratio of charger (r=1 for non-charged) where k is in the range:
$600 \le p \le 825$ mmHg {$80 \le p \le 110$ KPa}
$10 \le \theta - 273 \le 40$°C {$283 \le \theta \le 313$ K}
$0.9 \le k \le 1.1$

If k is out of the above range, and p and θ are within the range, then the calibrated output value is recorded along with relative test conditions.

ENGINE ACCESSORY REMOVAL AND INSTALLATION

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

1. Preparation

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

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

(c) Loosen the oil pan drain plug, and drain engine oil.
[Oil capacity: 100 liters (26.4 U.S.gals)]

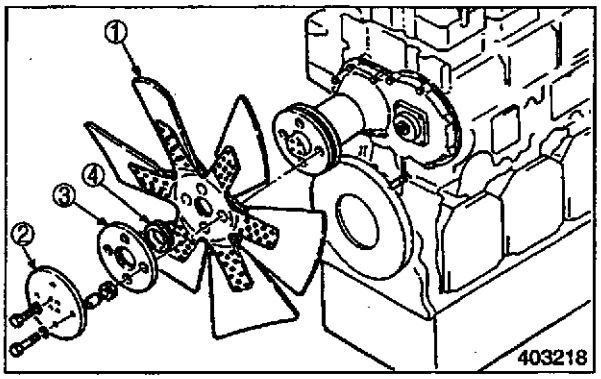
⚠WARNING

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

2. Engine Accessory Removal

(1) Removing fan

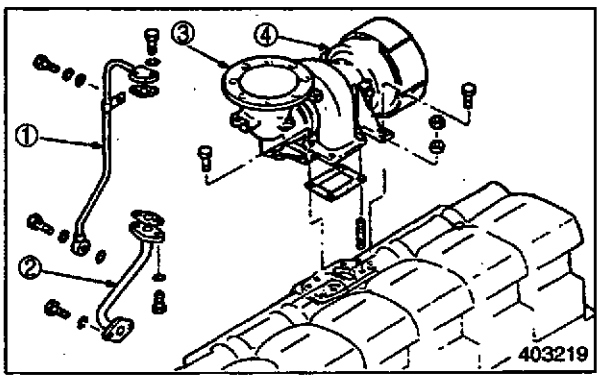
Unscrew fan mounting bolts, and remove fan ①, plate ②, friction rubber ③ and spacer ④.



(2) Removing turbocharger

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

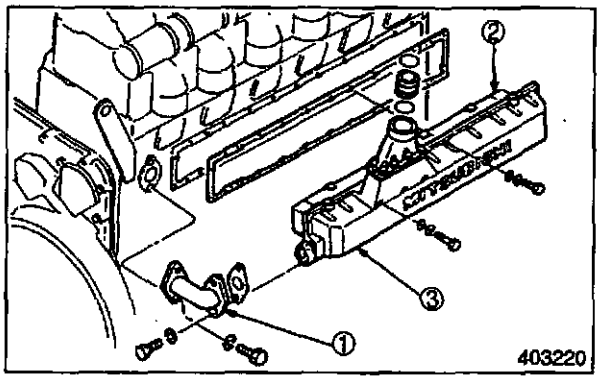
(b) Remove turbocharger ④ complete with exhaust pipe ③.



(3) Removing air cooler

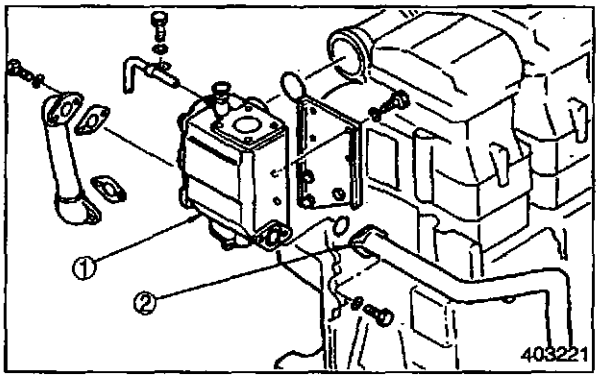
(a) Disconnect water pipes ①.

(b) Remove air cooler ② complete with air cooler cover ③.



(4) Removing thermostat case

Remove thermostat case ① complete with water bypass pipe ②.



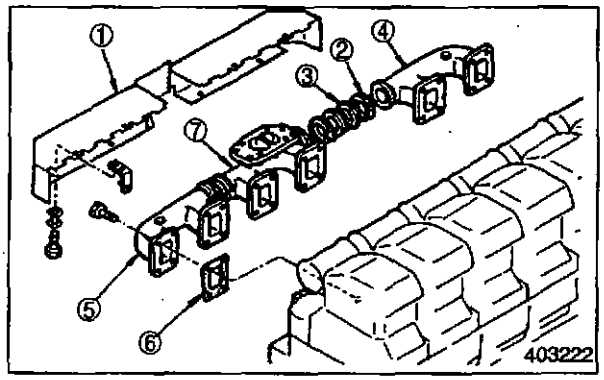
(5) Removing exhaust manifolds

(a) Remove insulator ①.

(b) Remove couplings ② and joints ③.

(c) Unscrew the bolts securing manifolds ④ ⑤, and remove the manifolds complete with gaskets ⑥.

(d) Remove manifold ⑦ complete with gasket.



NOTE

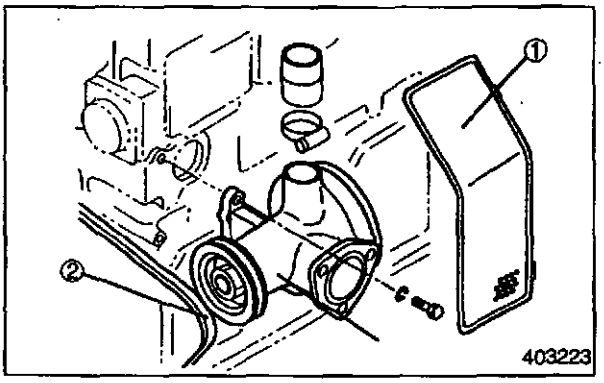
When installing the manifolds, place each gasket with its side marked as "MANIFOLD" facing the manifold.

(6) Removing water pump

(a) Remove belt cover ①.

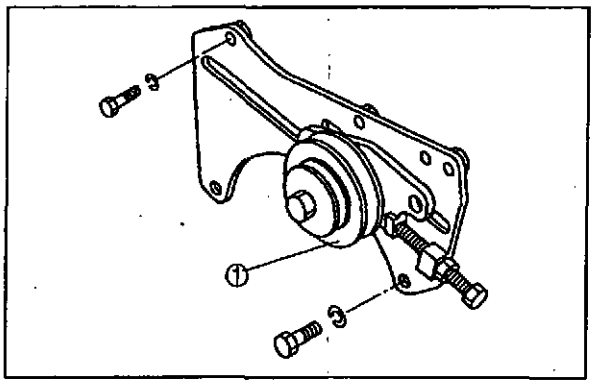
(b) Loosen the tension pulley, then remove water pump drive belt ②.

(c) Remove water pump ③ by unscrewing mounting bolts.



(7) Removing tension pulley

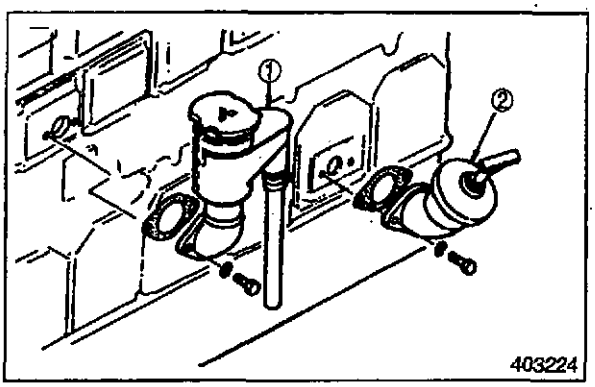
Remove the tension pulley mounting bolts, and remove tension pulley ①.



(8) Removing breather and oil filler

(a) Remove breather ① by unscrewing mounting bolts.

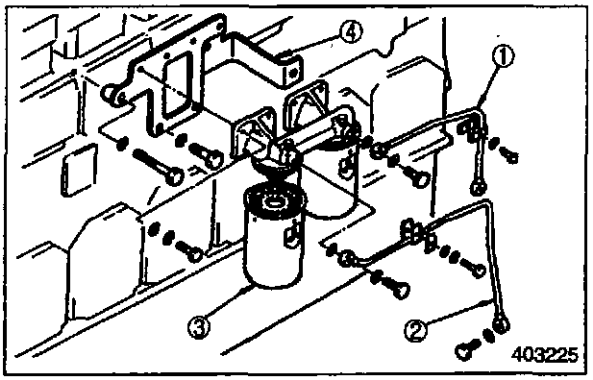
(b) Remove oil filler ② by unscrewing mounting bolts.



(9) Removing fuel filters

(a) Disconnect fuel pipes ① and ②.

(b) Remove fuel filter ③ and filter bracket ④.

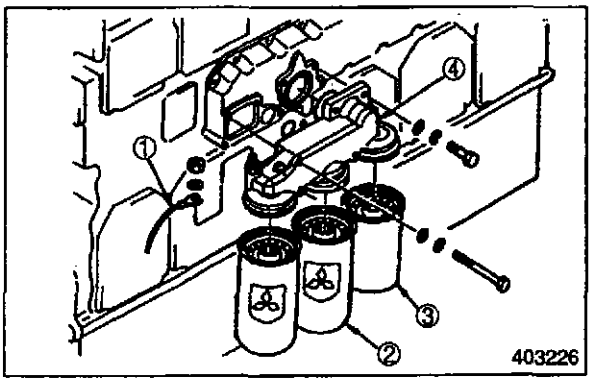


(10) Removing the exhaust manifold

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

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

(c) Remove oil filter bracket ④ by unscrewing mounting bolts.



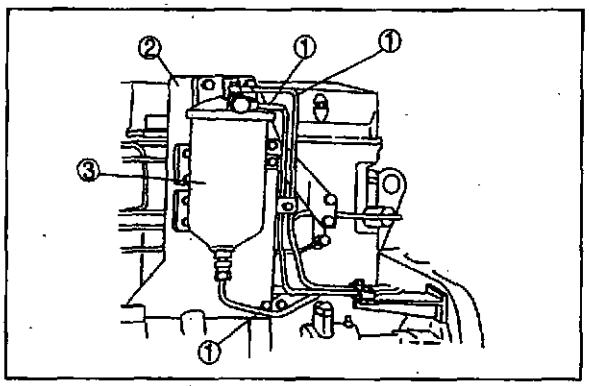
NOTE

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

(11) Removing oil filter of governor (woodward governor)

(a) Remove oil pipe ①.

(b) Remove oil filter mounting bracket ② and oil filter ③.



(12) Removing governor

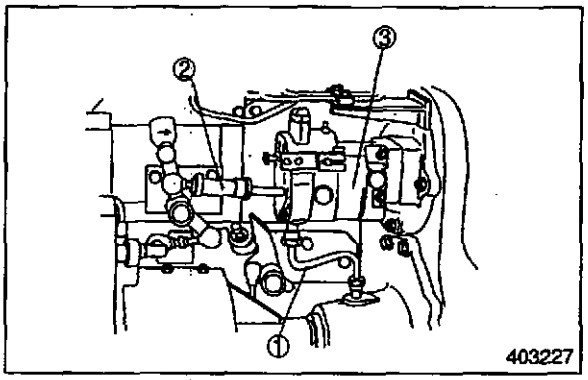
(a) Disconnect lube oil pipe ① from the governor.

(b) Remove control link ② as an assembly.

(c) Remove governor ③ by unscrewing mounting nuts.

NOTE

Record the sealed portions of control link ② before removing the link to aid reinstallation.

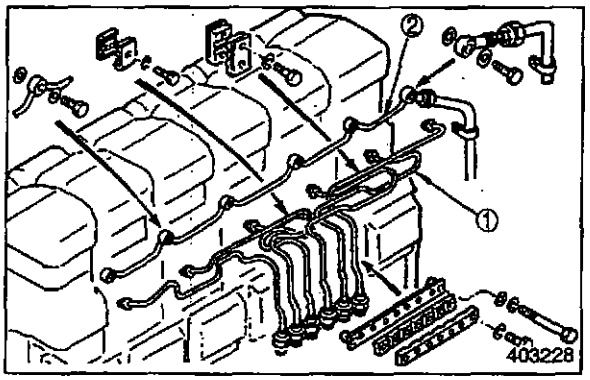


(13) Disconnecting fuel pipes

Disconnect fuel pipes ① (6 pcs) and leak-off pipes ② (2 pcs).

⚠CAUTION

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



(14) Removing fuel injection pump

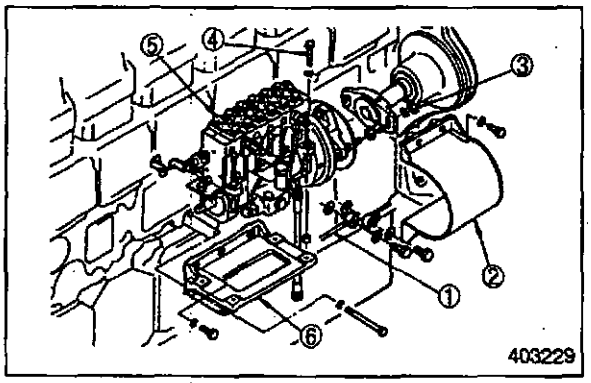
(a) Disconnect lube oil pipe ①.

(b) Remove coupling cover ②.

(c) Unscrew nut ③ securing the coupling.

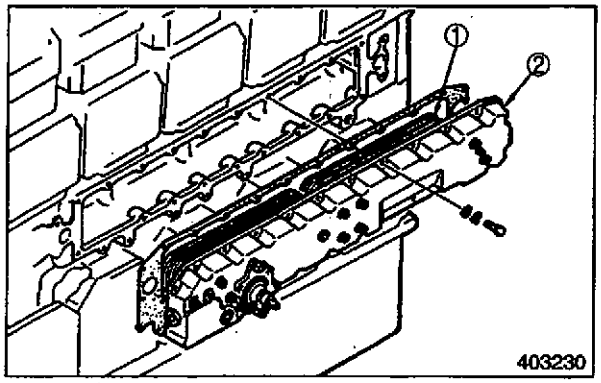
(d) Unscrew bolts ④ securing injection pump ⑤ to the engine. Remove the pump complete with coupling by prying it toward the front side of the engine with a bar. [Weight: 60 kg (132 lb)]

(e) Remove bracket ⑥ by unscrewing mounting bolts.



(15) Removing oil cooler

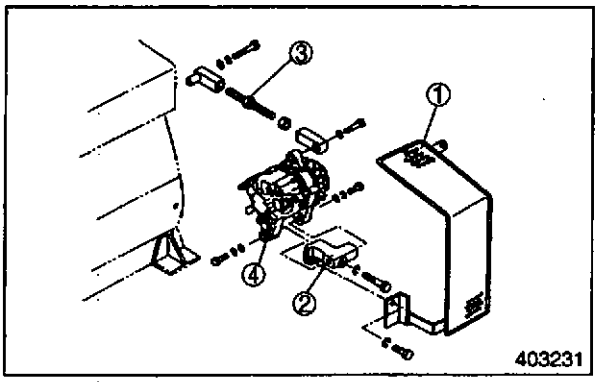
Remove oil cooler ① complete with cover ②.



(16) Removing alternator

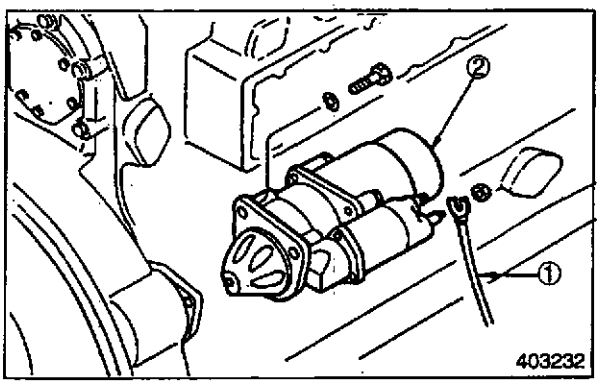
(a) Remove belt cover ①.

(b) Disconnect harness ②. Remove alternator mounting bracket ③ and belt adjusting turnbuckle ④, and take off alternator ⑤.



(15) Removing starter

Disconnect harness ① and remove starter ② by unscrewing mounting bolts.



3. Engine Accessory Installation

To install the engine accessories, use reverse of the removal procedures. After installing them, service them follows:

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

(b) Refill the cooling system with coolant.

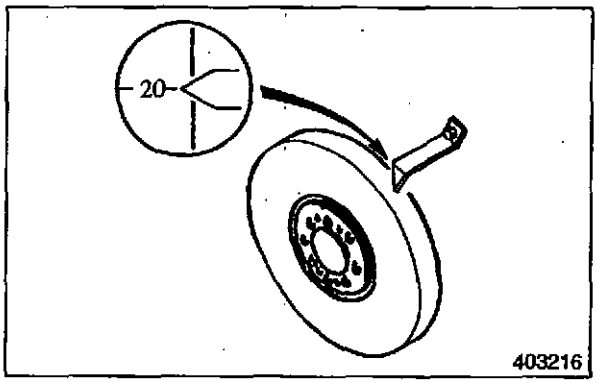
(c) Check each pipe connection for oil or coolant leaks.

(d) Prime the fuel system.

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

FUEL INJECTION PUMP INSTALLATION

(a) Turn the crankshaft in normal direction to align No. 1.6 timing mark on the torsional viscous damper with the pointer on the engine.



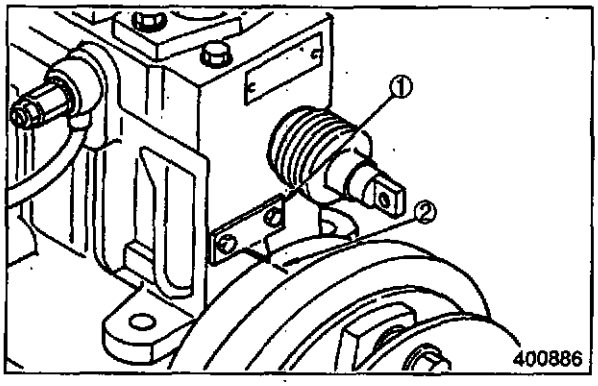
(b) Make sure that the inlet and exhaust valve rocker arms are not being pushed up by their pushrods.

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

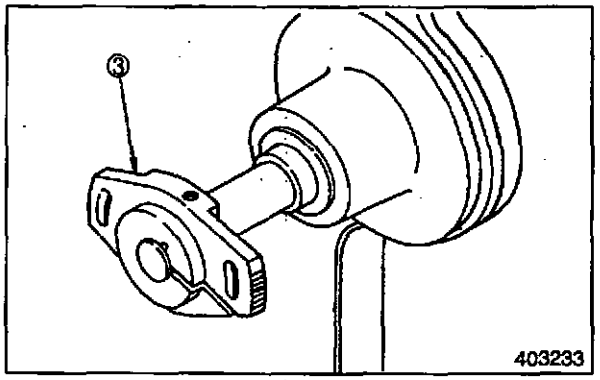
NOTE

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 flywheel with pointer ① on the pump case.



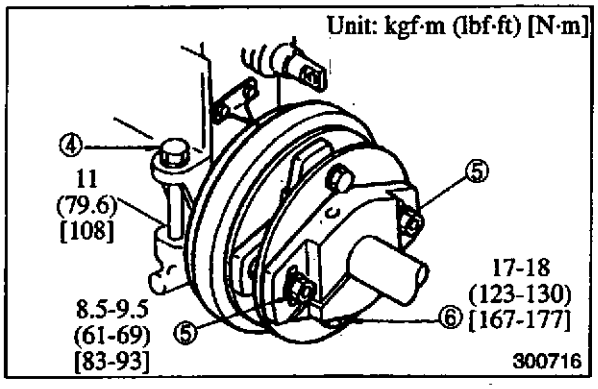
(e) Install one half ③ of the pump drive-side coupling to the drive shaft, leaving the securing bolts loose enough.



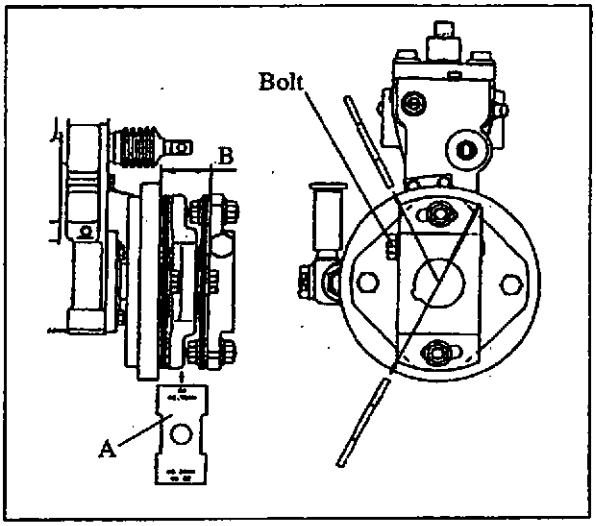
(f) Place the injection pump proper on the bracket, and temporarily tighten bolts ④.

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

(h) Temporarily tighten coupling nuts ⑤.



(i) Using injection coupling gauge (A) (37591-16100), adjust the clearance between the flywheel and coupling.
   1) Insert the side of the gauge marked with "GO" to determine clearance (B) between the flywheel and coupling, then tighten the bolt.
   2) Make sure the side of the gauge marked with "NO GO" does not enter the gap. Only the side marked with "GO" should fit into the gap.
   (Clearance between flywheel and coupling: 49±0.25 mm)
   3) If the inspection in step 2) shows that the clearance is not 49±0.25 mm, loosen the bolt and readjust the clearance.



(j) After firmly tightening pump mounting bolt (4), check to make sure pointer (1) on the pump case end face is aligned with line (2) on the coupling. Then, tighten two connecting nuts (5) to the specified torque.

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

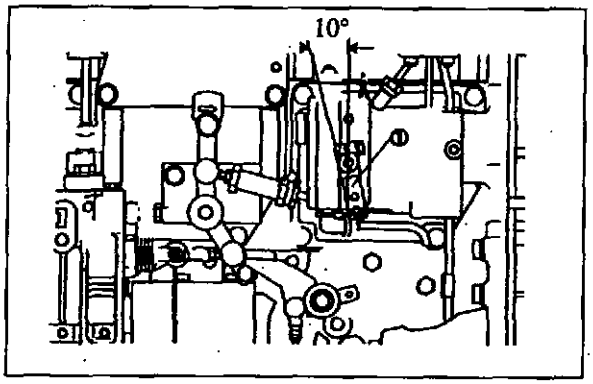
⚠CAUTION

Tighten the bolts of the coupling evenly to the specified torque to ensure secure mounting.
If the bolts are tightened with excessive force or insufficient force, parts damage and/or incorrect injection timing can result.

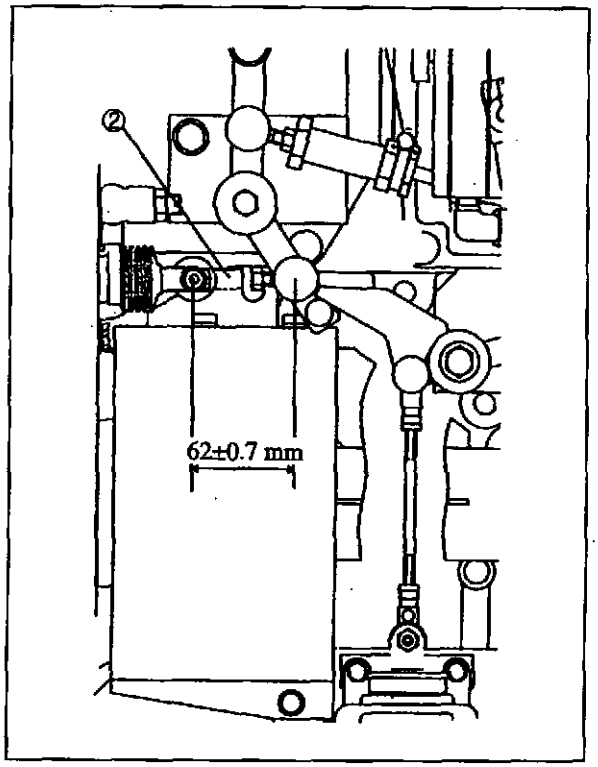
(2) Installing governor link

(a) Check to make sure the output shaft of the governor is positioned on the side marked with "0" (no-injection side).

(b) Install governor lever ① at the angle shown in the diagram on the right.



(c) Install links ② on the right- and left-hand banks, making sure that the installation length is 62±07 mm.

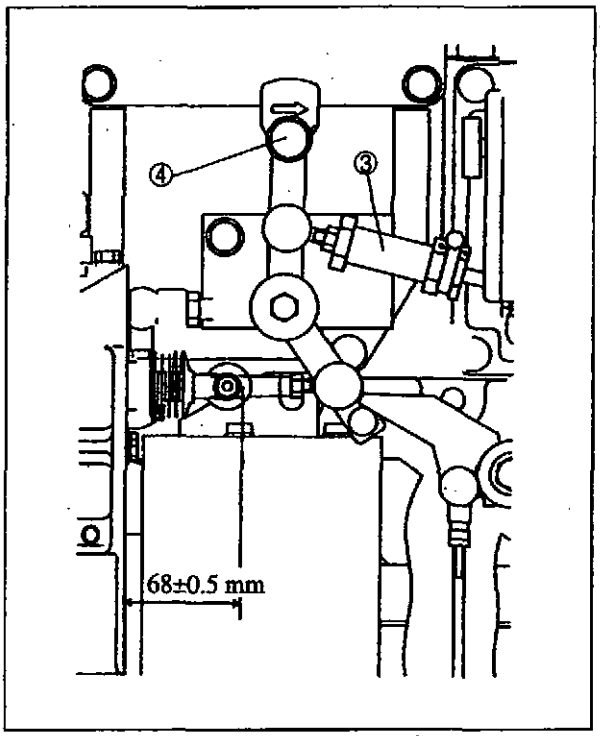


(d) Install rod ③ while adjusting the length of the rod to achieve a distance of 68±0.5 mm (2.68±0.020 in.) between the rack end surface and the pump case end surface.

NOTE

Make sure more than 8 mm of threads of the rod and ball joint are engaged on both ends.

(e) Check to make sure the rack stroke is approximately 2 mm when stopper lever ④ is pulled fully to the STOP side.



(3) Adjusting and inspecting stop solenoid and start rack limit solenoid

[RUN-OFF solenoid]

< Adjustment >

(a) Supply electric current to solenoid ① (contracted condition).

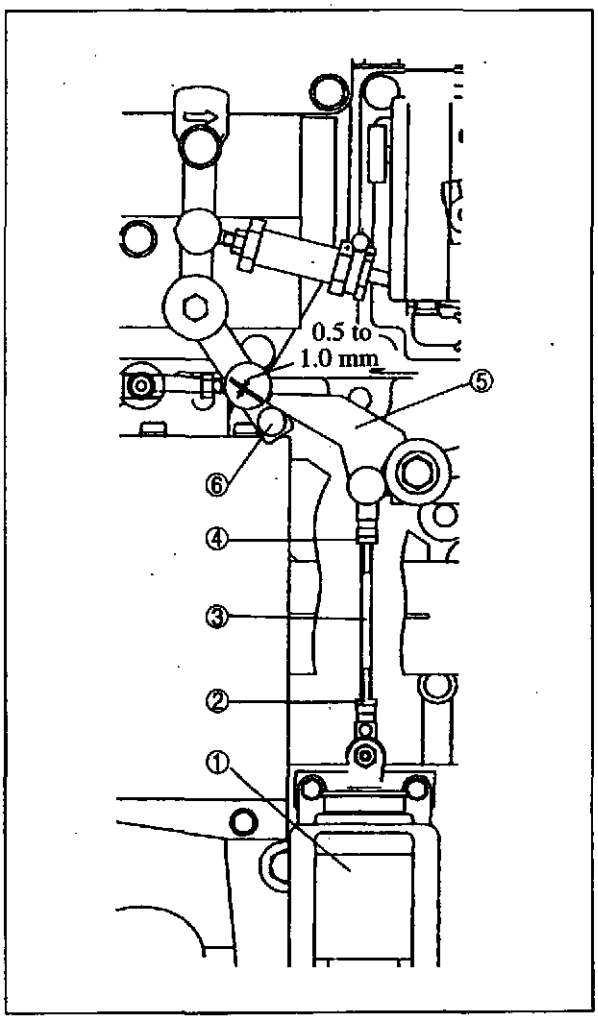
(b) Loosen nuts ② and ③.

(c) Rotate rod ④ to adjust the clearance between lever ⑤ and follower ⑥ to between 0.5 and 1.0 mm.

(d) Tighten nuts ② and ③.

< Inspection >

(e) Cut off electric current to solenoid ① (extended condition).



RUN-OFF Solenoid

(f) After adjusting the exhaust temperature for the right- and left-hand banks, operate the engine at high idling speed.

(g) Supply electric current to solenoid ① (contracted condition).

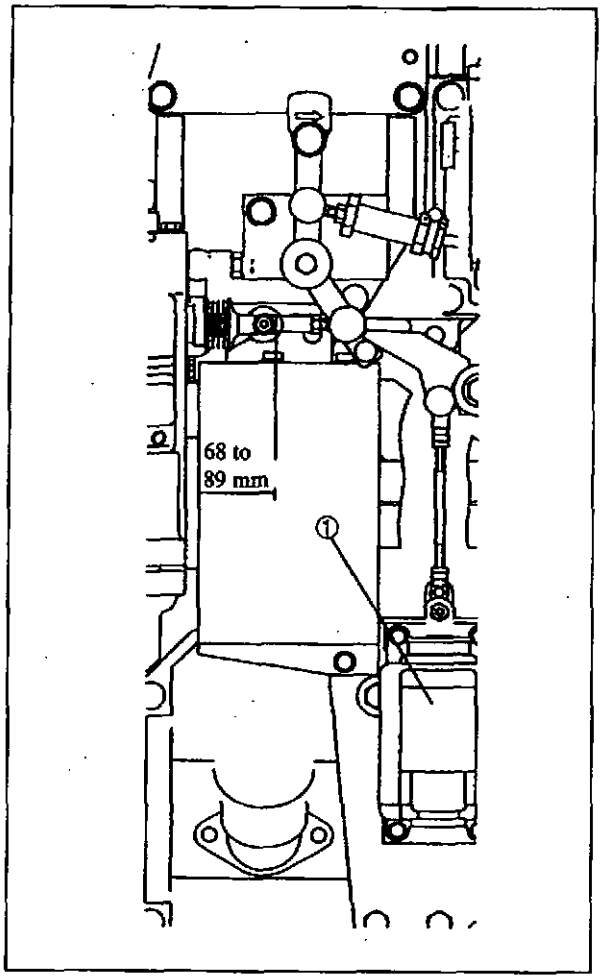
(h) After the engine stops completely, check to make sure the distance between the rack end surface and pump case end surface is 68 to 69 mm on both banks.

NOTE

It should be noted that the engine may not stop if the distance between the rack end surface and pump case is more than 70 mm.

⚠CAUTION

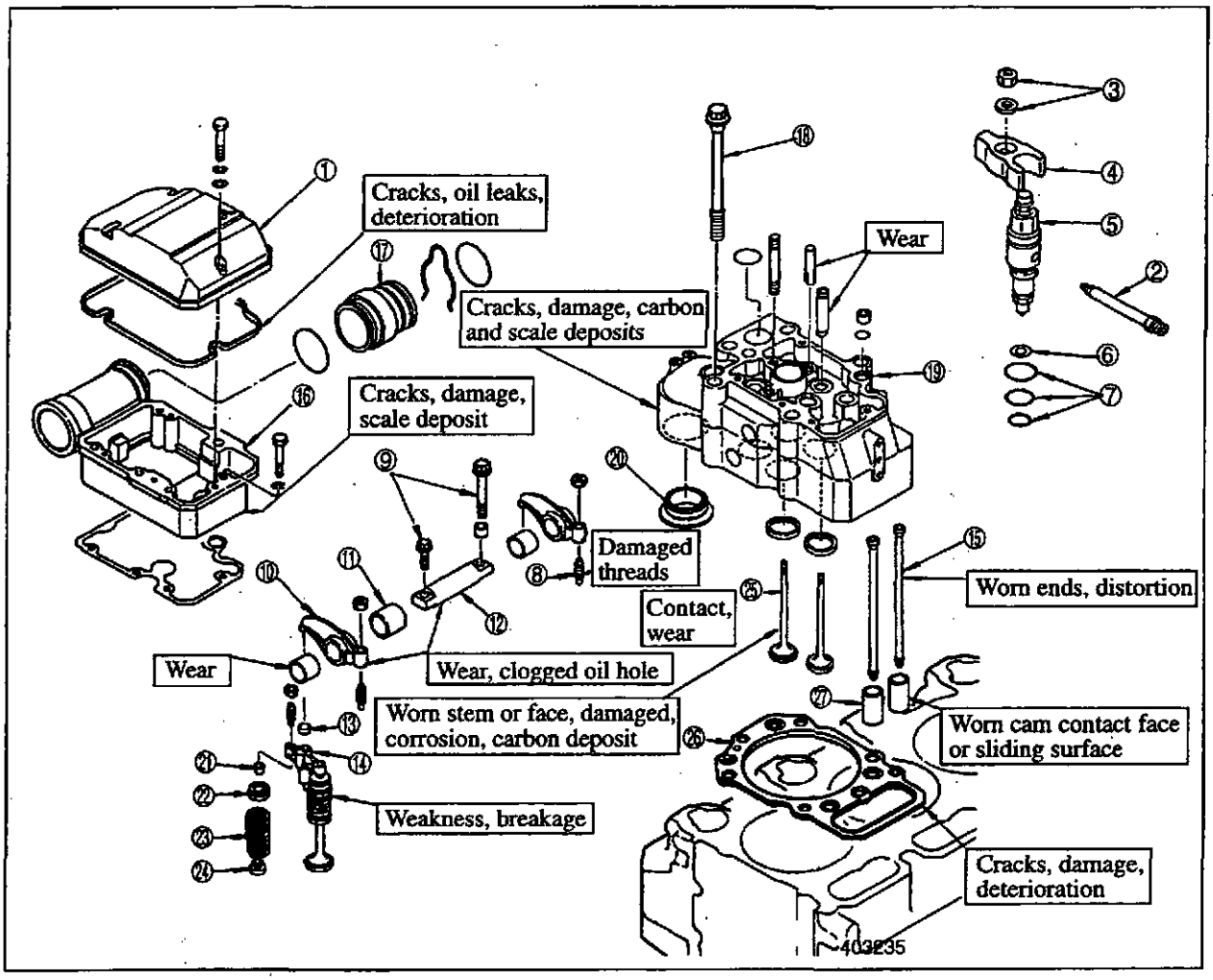
When adjusting the adjusting rod, make sure the rack moves without interference. If the rack does not move smoothly, the governor cannot operate properly.



THE ENGINE PROPER

1. Cylinder Heads and Valve Mechanism

1.1 Disassembly



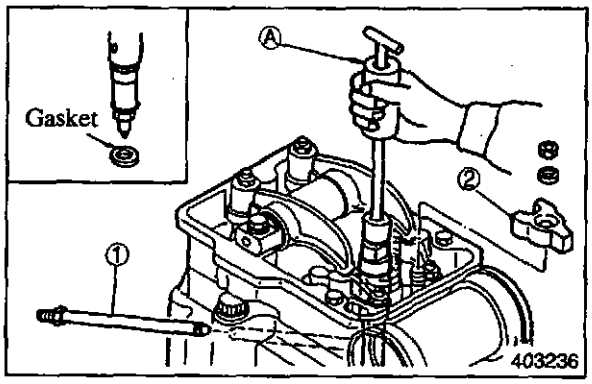
① Rocker cover
② Fuel inlet connector pipe
③ Nut, washer
④ Injection nozzle gland
⑤ Injection nozzle
⑥ Gasket
⑦ O-ring
⑧ Adjusting screw
⑨ Bolt
⑩ Rocker
⑪ Spacer
⑫ Rockershaft
⑬ Bridge cap
⑭ Valve bridge
⑮ Push rod
⑯ Rocker case
⑰ Water outlet connector
⑱ Cylinder head bolt
⑲ Cylinder head
⑳ Inlet port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

(1) Removing fuel injection nozzles

(a) Remove the fuel inlet connector pipe and the nozzle gland.

(b) Use the nozzle remover Ⓐ (33591-10101), to remove the nozzle assembly. Take out the gasket left behind in the cylinder head.

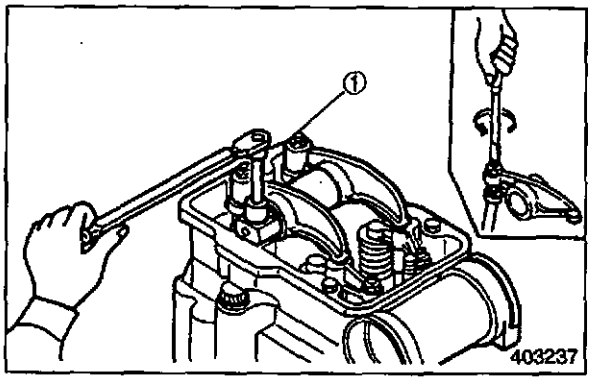
(c) Put away the nozzle and the inlet connector pipe where you can find the m later. Do not damage the nozzle tip.



(2) Removing the rockershaft assemblies

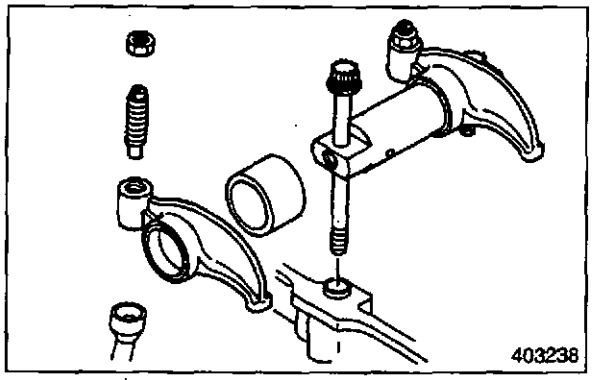
(a) Loosen the adjusting screw (1) of each rocker.

(b) Keep the shaft assembly and mounting bolts together as a set.



(3) Disassembling rockershaft assemblies

Arrange the disassembled rockers in the order removed, so you can install them in that order at reassembly. This will ensure the same rockershaft clearance as before.



(4) Removing the valve bridge

Remove the valve bridge and bridge cap.

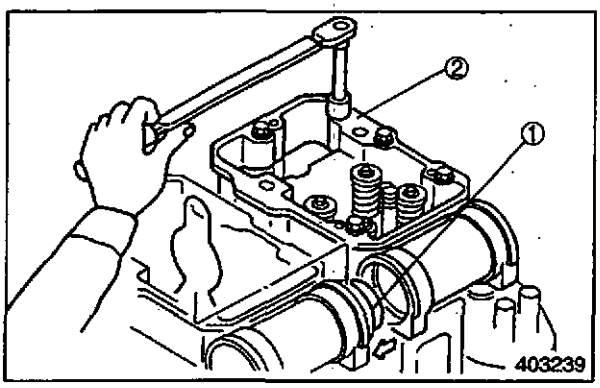
NOTE

Do not drop the bridge cap or other parts into the crankcase through the push rod hole.

(5) Removing the rocker case

(a) Remove the snap ring of the water outlet connector. Slide the connector ① towards the snap ring.

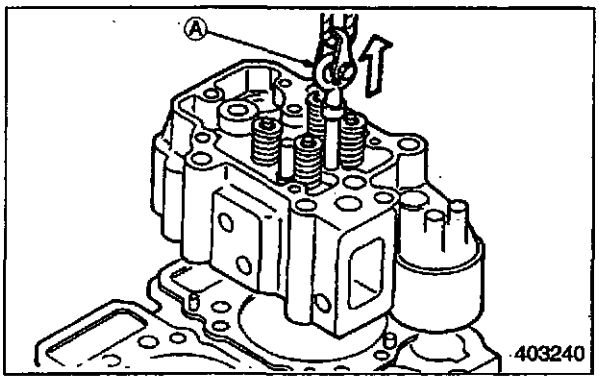
(b) Unscrew the rocker case mounting bolts, then remove the rocker case ② from the cylinder head.



(6) Removing cylinder head assemblies

(a) Each cylinder head is located relative to the crankcase with the dowel pins. Use the eye nut Ⓐ (37591-02400) to lift the head off the crankcase.

Cylinder head weight: approx. 35kg (77 lb).



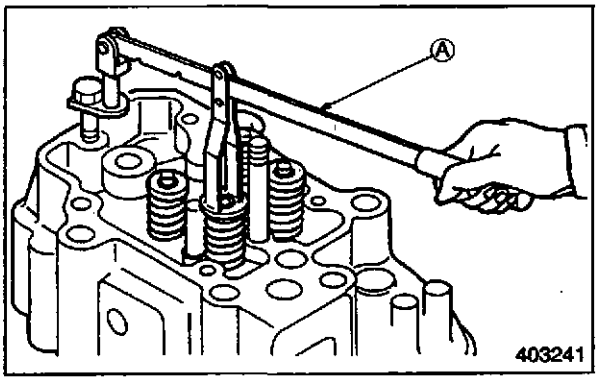
⚠CAUTION

Do not damage the cylinder head or crankcase surfaces when you remove the gasket with a screwdriver or other tool.

(b) Remove the cylinder gasket.

(7) Removing valves and valve springs

Use a valve spring pusher Ⓐ (33591-04500) to compress the valve spring squarely, then remove the valve cotters.

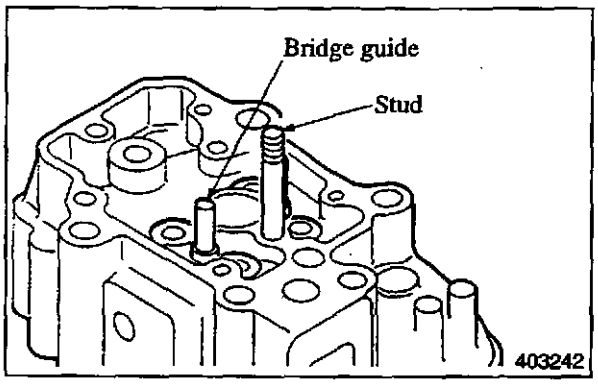


NOTE

If the valves are to be reversed, do not change the combination of the valve seat and valve guide.

(8) Removing studs, guides, etc.

Do not remove the nozzle gland mounting studs or the bridge guide from the cylinder head unless absolutely necessary. If any of these parts have been removed, apply sealant to the studded side threads of the part when installing it to the cylinder head, or install a new part.



1.2 Inspection and Repair

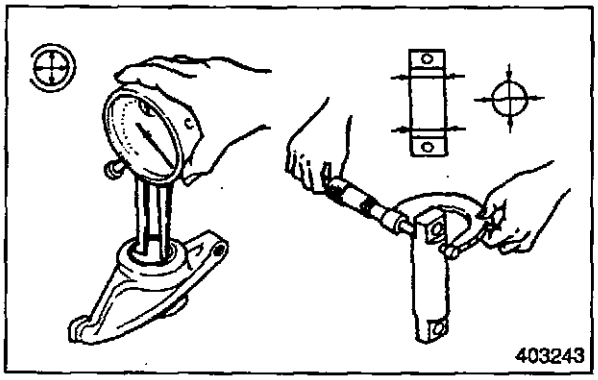
Rockers, Rocker Bushings, Rockershafts

(1) Measuring rocker bushing inside diameter and rockershaft diameter

If the measurement exceeds the service limit, replace the bushing or shaft.

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Rocker bushing inside diameter	ø36 (1.42)	36.00-36.040 (1.41732-1.41889)	36.090 (1.42086)
Rocker shaft diameter	ø36 (1.42)	35.966-35.991 (1.41598-1.41697)	35.940 (1.41496)



Measuring rocker bushing and lockershaft

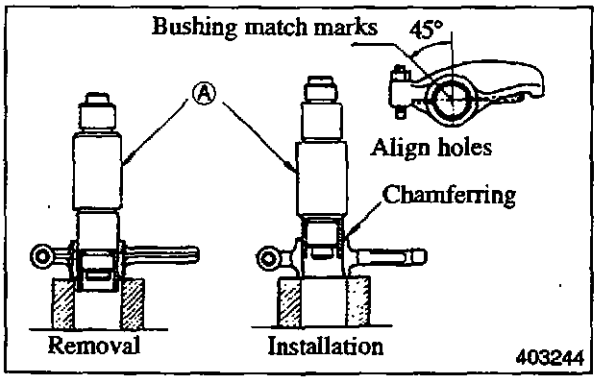
(2) Replacing rocker bushings

Use a rocker bushing puller Ⓐ (37951-02600) to remove the rocker bushings for replacement.

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

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

(c) After installing the bushing, measure its inside diameter to make sure that it is ø36 $^{+0.04}_{0}$ m. If the diameter is not within this tolerance, refinish to standard tolerance by reaming (ø36 $^{+0.04}_{0}$ 3.2S).



Replacing the rocker bushing

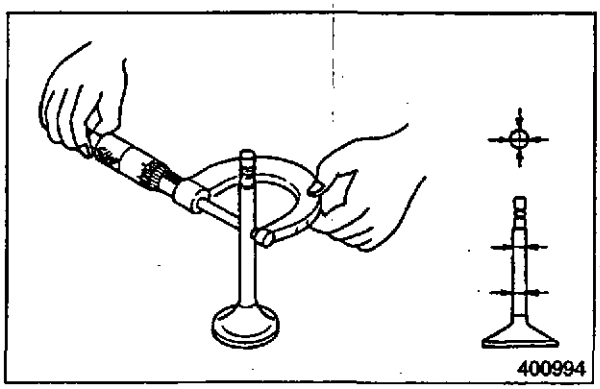
Valve guide and Valve Stems

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

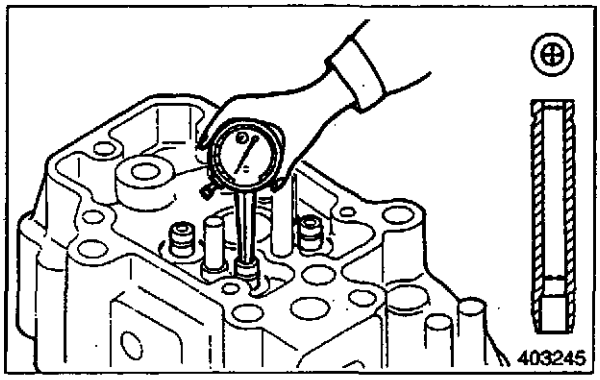
The valve guide wears more rapidly at its tooth end than at any other location. Measure the inside diameter of the guide at its ends and at the middle in two directions. If the service limitis exceeded, replace the guide.

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Valve stem diameter	ø10 (0.39)	9.940-9.960 (0.39213 -0.39134)	9.910 (0.39016)
Valve guide inside diameter	ø10 (0.39)	10.000-10.015 (0.39370 -0.39429)	10.060 (0.39606)



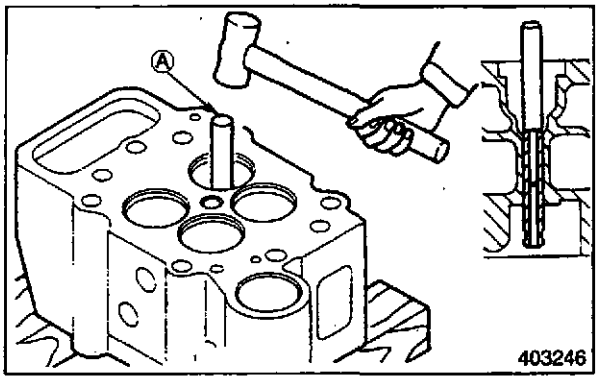
Measuring valve stems



Measuring valve guide inside diameter

(2) Replacing valve guides and stem seals

(a) Use the valve guide remover Ⓐ (33591-04300) to remove the valve guide for replacement.

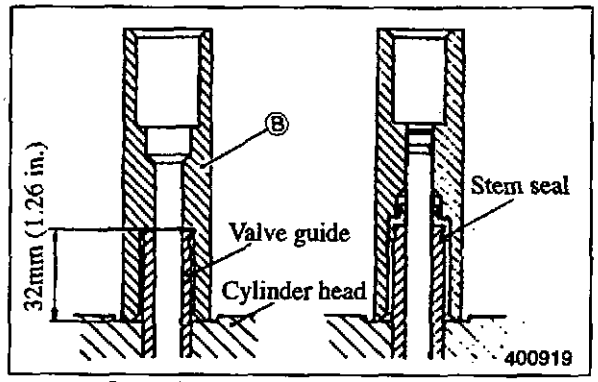


Removing valve guide

(b) Use a valve guide seal installer Ⓑ (37191-01500) to install slowly a new guide with a press.

⚠CAUTION

(a) The installation depth for the valve guide is specified, so use the valve guide seal installer to secure the correct depth.
(b) Do not apply any oil or sealant to the surface of the stem seal that comes in contact with the valve guide. When installing the stem seal, coat the seal rubbing surface of the stem with engine oil to ensure initial lubrication of the stem seal lip.
(c) Use a new stem seal.



Installing valve guide and stem seal

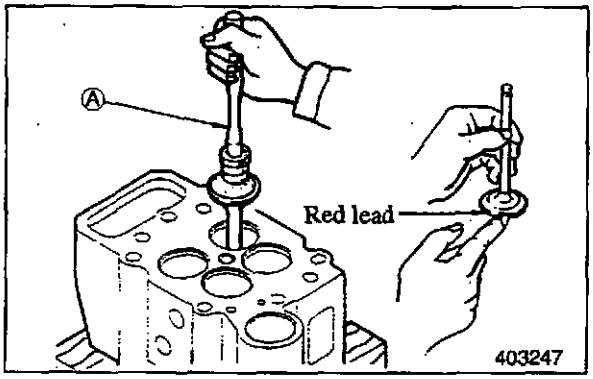
Valves and Valve Seats

(1) Inspecting the valve face

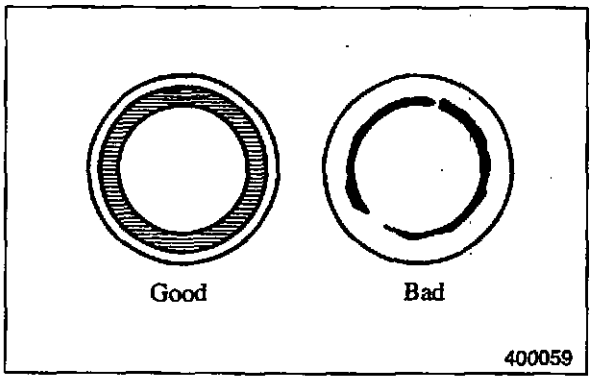
Coat the valve face lightly with red lead. Use valve lapper Ⓐ (30091-08800) to inspect the valve contact with its seat. If the contact is not uniform, or if the valve is defective, or if the repair limit is exceeded, repair or replace the valve and valve seat.

NOTE

(a) Inspect the valve face after the inspection or replacement of the valve guide.
(b) When you press the valve coated with red lead into the valve seat, do not rotate the valve.



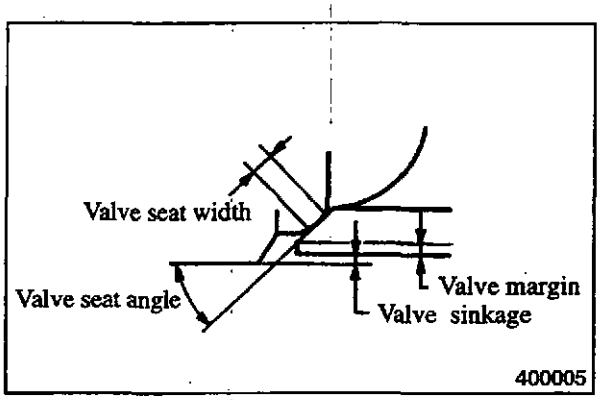
Inspecting a valve face



Valve contact with its seat

Unit: mm (in.)

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

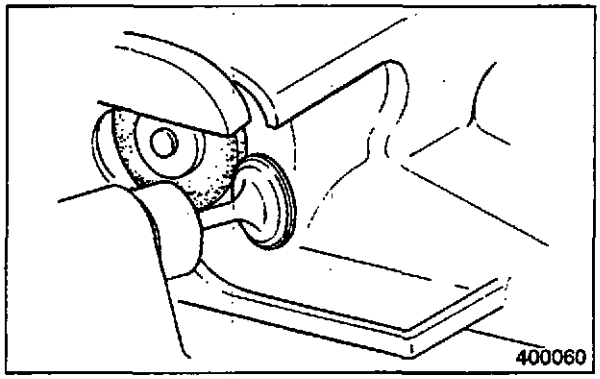


(2) Refacing the valve face

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

NOTE

(a) Set a valve refacer at an angle of 30°.
(b) Grind the valve stock to a minimum. If the margin seems to exceed the repair limit as a result of grinding, replace the valve.

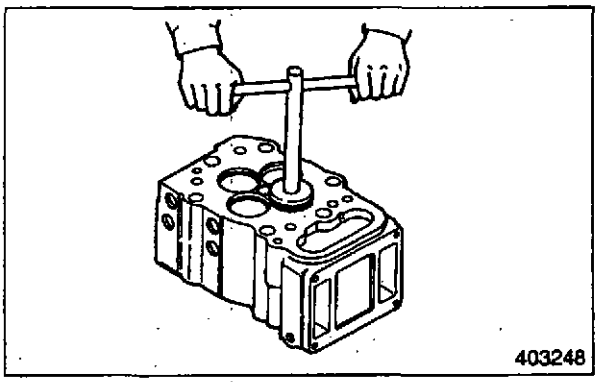


Refacing a valve

(3) Refacing valve seats

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

(b) Lap the valve in the valve seat.



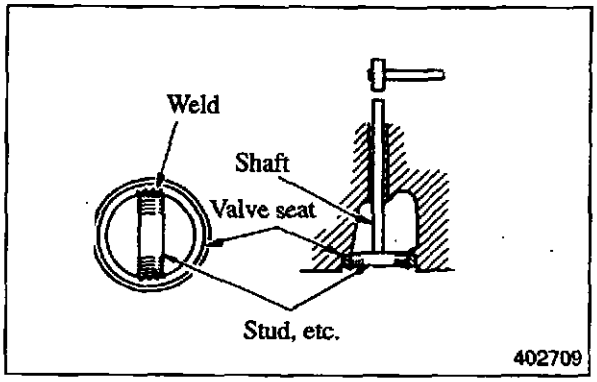
Refacing a valve seat

NOTE

(a) Cut or grind the valve seat only as needed 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 exceeds the repair limit after refacing.

(4) Repairing valve seats

(a) Weld a stud to the valve seat. Insert a shaft into the valve guide holder from the upper side of the cylinder head. Drive the seat off the head as shown.



Removing a valve seat

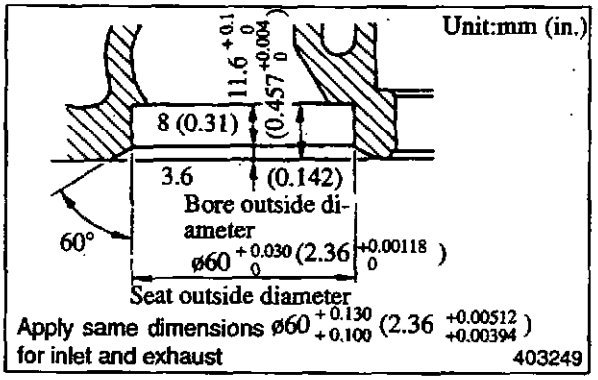
⚠CAUTION

When you weld the stud, do not permit splatter to come in contact with the machined surfaces of the cylinder head.

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

Unit: mm (in.)

Item	Nominal Value	Standard Clearance
Cylinder head bore inside diameter and valve seat outside diameter	ø60 (2.36)	–0.070 to –0.130 (–0.00276 to –0.00512)
		(176°F to 212°F)



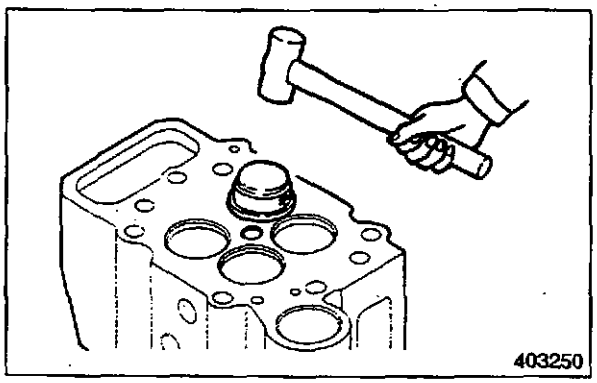
Valve seat dimensions

NOTE

Negative (–) clearance valves indicate interferences.

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

(d) Use the installer to install the valve seat.

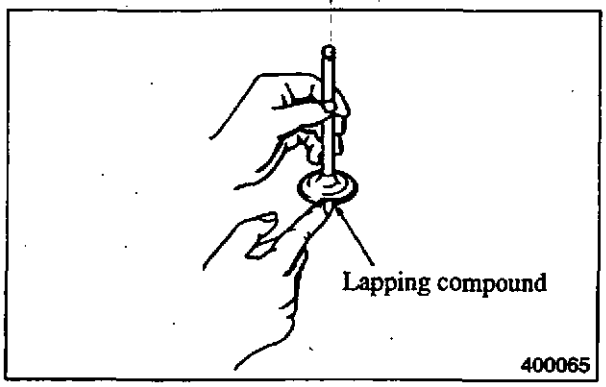


Installing a valve seat

(5) Lapping valves in valve seats

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

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



Coating valve with lapping compound

NOTE

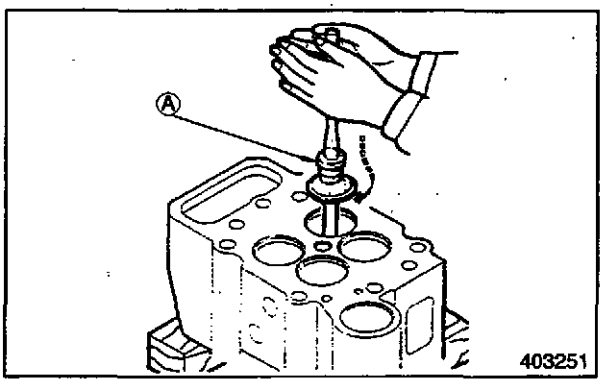
(a) Do not permit the compound to come in contact with the valve stem.
(b) Use a compound of 120 to 150 mesh for initial lapping and a compound finer than 200 mesh for finish lapping.
(c) Mixing the compound with a small amount of engine oil will facilitate coating.

(b) Use the valve lapper Ⓐ (30091-08800) to lap the valve in the seat. To lap, raise the valve off the seat, then rotate the valve only a partial turn and strike it against the seat.

(c) Wash off the compound with diesel fuel.

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

(e) Check the valve face for contact.



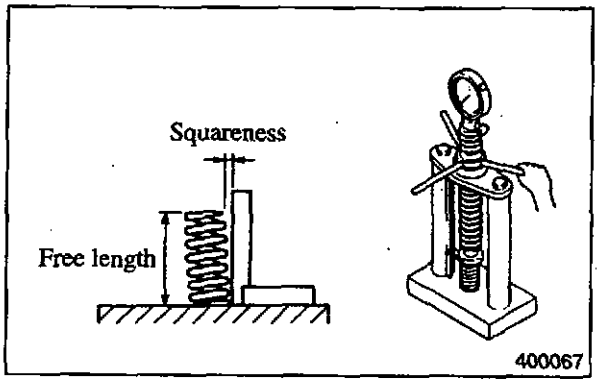
Lapping a valve in its valve seat

Valve Springs: Measuring Squareness and Free Length

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

Unit: mm (in.)

Item	Assembly Standard	Repair Limit
Free length	73 (2.87)	71 (2.80)
Squareness	θ=1.5° max. 	Δ=2.2 (0.087) over the length
Length under test force/test forces mm(in.)/kgf(lbf)[N]	66.0 (2.598)/29.45-32.55 (65-71.8) [289-319]	



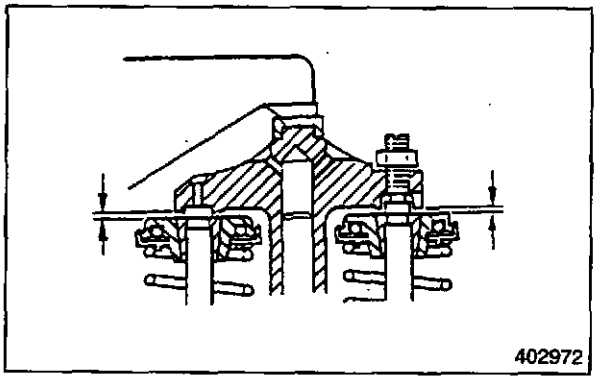
Measuring a valve spring

Valve Bridges and Bridge Caps

Check the clearance between the bridge and the rotator (cotter).

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

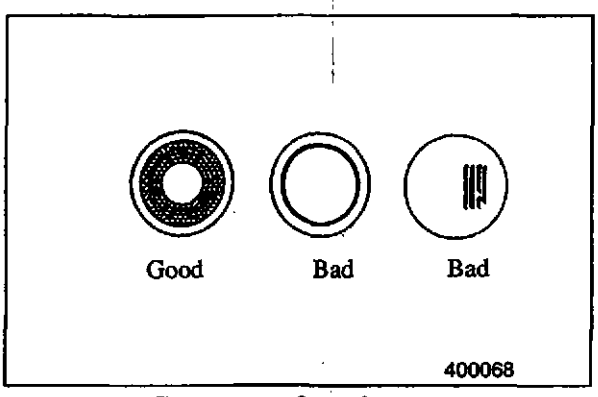
(b) Check the condition of the bridge cap. Replace it if it is badly worn.



Checking bridge-to-rotor clearance

Tappets and Push Rods

(1) Inspecting cam contact face of tappets. Replace the tappets if their cam contact faces are abnormally worn.



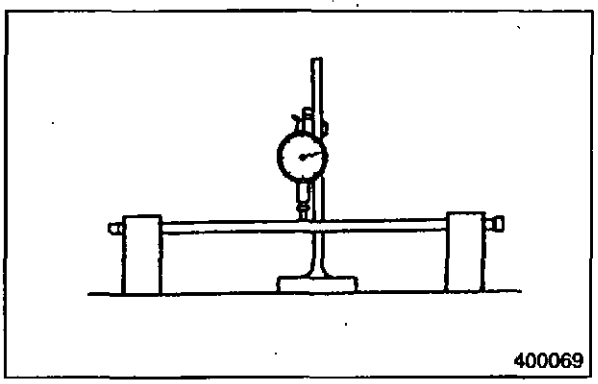
Cam contact face of tappet

(2) Inspecting valve push rods for runout

If the runout exceeds the assembly standard, replace the push rods.

Unit: mm (in.)

Item	Assembly Standard
Push rod runout	0.5 (0.020) max.



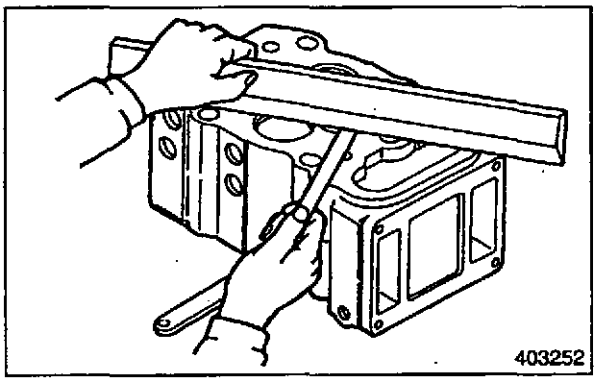
Measuring valve pushrod runout

Cylinder Head

Use a straight edge and feeler gauge to measure warpage on each cylinder head. If warpage exceeds the repair limit, reface the gasket surface with a surface grinder.

Unit: mm (in.)

Item	Assy. Stand.	Repair Limit	Service Limit
Head warpage	< 0.03 (0.0012)	0.07 (0.0028)	0.50 (0.0197)

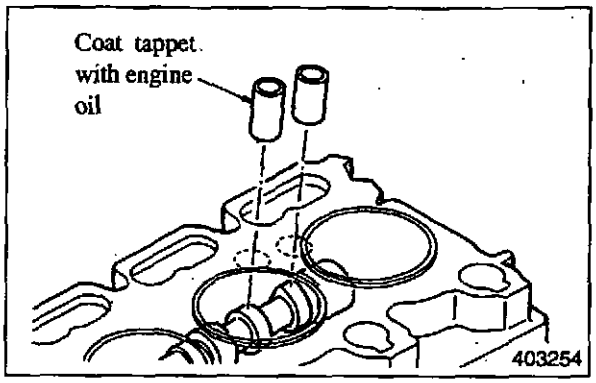


Measuring head gasket warpage

1.3 Reassembly

(1) Installing tappets

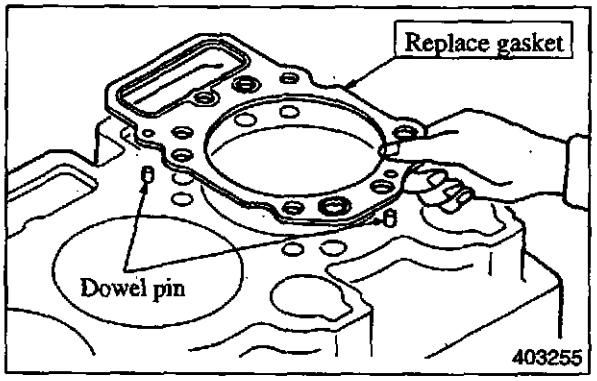
Coat the tappets with engine oil and make them seat softly on the camshaft.



(2) Installing cylinder head gaskets

(a) Clean the gasketed surfaces of the cylinder head and crankcase thoroughly with a solvent or degreasing solution.

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



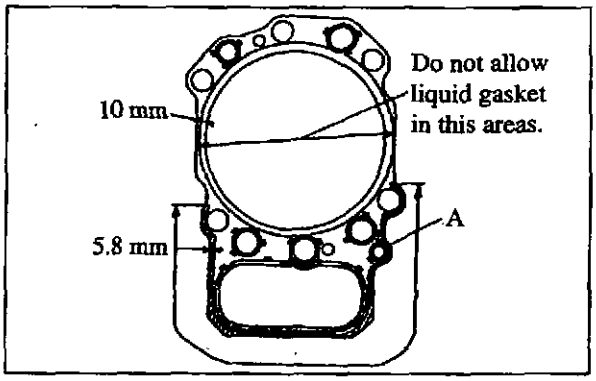
- Application of liquid gasket

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

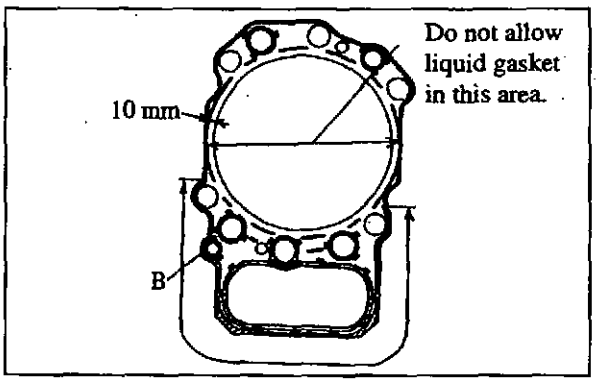
  Do not apply an excessive amount of liquid gasket, since it can press the head gasket O-ring and cause deformation. Do not allow liquid gasket to adhere around the bore; otherwise, gas leakage can occur.

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

  The diagrams on the right show the areas and amounts of liquid gasket application.



Application of liquid gasket on head-facing side



Application of liquid gasket on crankcase-facing side

NOTE

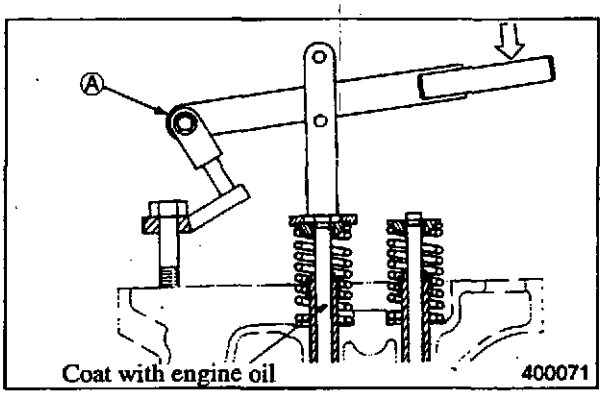
(a) Apply liquid gasket (37594-01300) to areas 5 to 8 mm from the periphery of the head gasket.
(b) Liquid gasket should be applied to areas indicated in the diagrams on the right.
(c) Apply liquid gasket to both sides of the head gasket. Spread the liquid gasket with a finger to a thickness of 0.2 to 0.5 mm.
(d) Sections (A) and (B) are very close to O-rings. Make sure there is no large amount of liquid gasket on the edge at these sections.

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

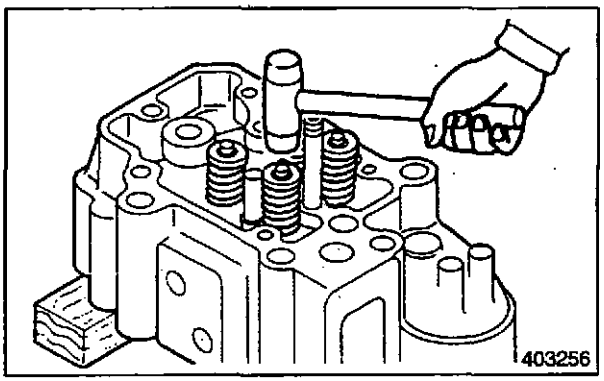
(3) Reassembling the cylinder heads

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

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

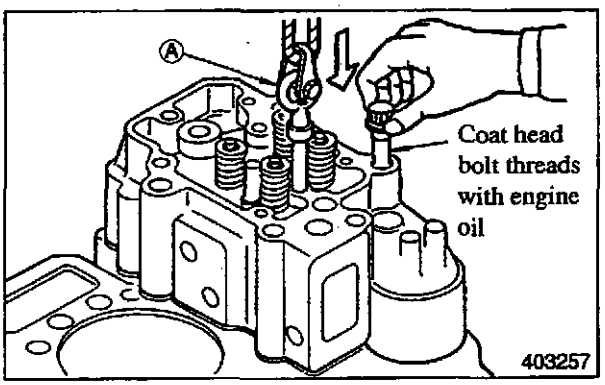


(c) Lightly tap on the top of each valve stem with a soft hammer to make sure that the valve spring and cotters are properly installed.



(4) Installing cylinder head assemblies

(a) Install eye nut Ⓐ (37591-02400) to the stud bolt, and lift up the cylinder head assembly. Set the head position to coincide with the position of the dowel pin. Screw the head bolts coated with engine oil.

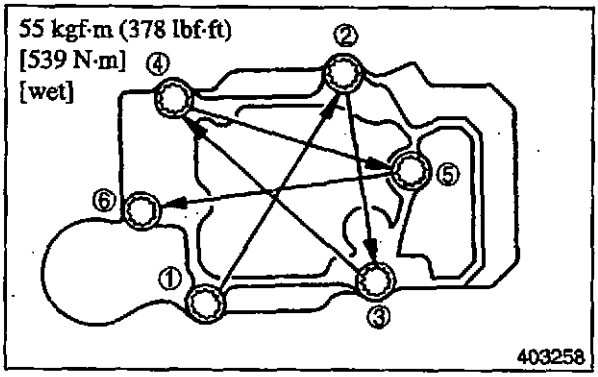


NOTE

When installing the connector, make sure the "MANIFOLD" mark on the gasket faces the connector.

(b) Install eye nut (A) (37591-02400) on the stud bolt. Attach a shackle and wire rope to the eye nut and lift the cylinder head assembly. Align the holes on the cylinder head with the dowel pins, and keep the head assembly slightly lifted. Apply engine oil to the threads of the head bolts and the bolt seats, and install the bolts into the head assembly.

(c) Tighten the cylinder head bolts with the specified torque in the order shown in the drawing.



Head bolt tightening sequence

NOTE

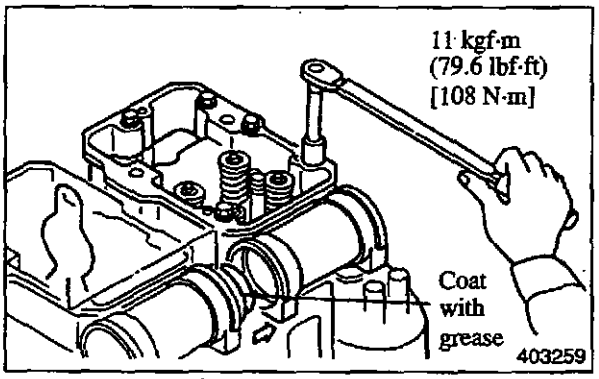
To tighten cylinder head bolts according to the angle method, tighten to 30 kgf·m (217 lbf·ft) [294 N·m], then turn 60° more.

⚠CAUTION

(a) Remove excess engine oil from the cylinder head bolts before installing.
(b) Before installing the cylinder head assemblies, measure the projection of pistons and make sure the amount of projection is correct.

(5) Installing the rocker case

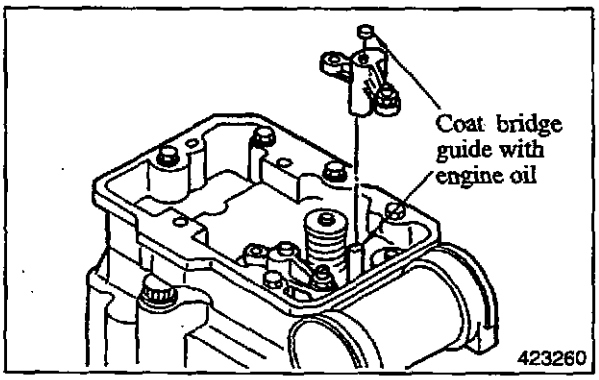
(a) Insert the water outlet connector fully in to the rocker case.
(b) Install the rocker case so it meets the dowel pins.
(c) Insert the water outlet connector by sliding it from the next rocker case after coating the O-ring with grease. Install the snap ring.
(d) Tighten the rocker case mounting bolts to the specified torque.



(6) Installing valve bridges and caps

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

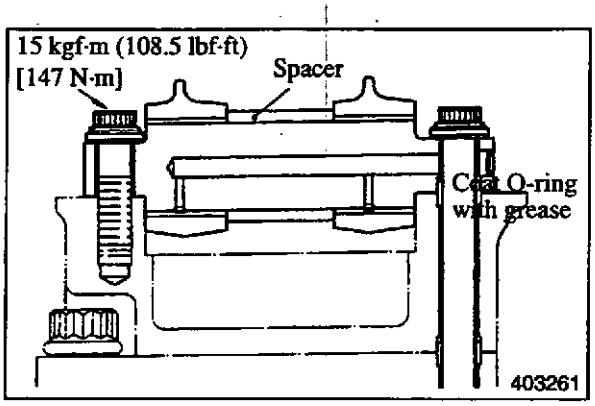
(b) Coat the bridge contact face of the bridge caps with engine oil. Install the caps in position, being careful not to let them fall into the crankcase through the push rod holes.



(7) Installing rockershaft assemblies

(a) Align the notch of the rocker shaft with the bolt hole of the rockershaft bracket, then insert the bolt into the bolt hole.

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



⚠CAUTION

(a) Move the rocker arm up and down to make sure that the arm is free.
(b) While tightening the bracket mounting bolts temporarily, install the bracket in place so the rocker tip comes in contact with the bridge caps evenly.
(c) Tighten the long bolt securing the head and rocker bracket first, then tighten the short bolt to the specified torque.

(8) Installing injection nozzle assemblies

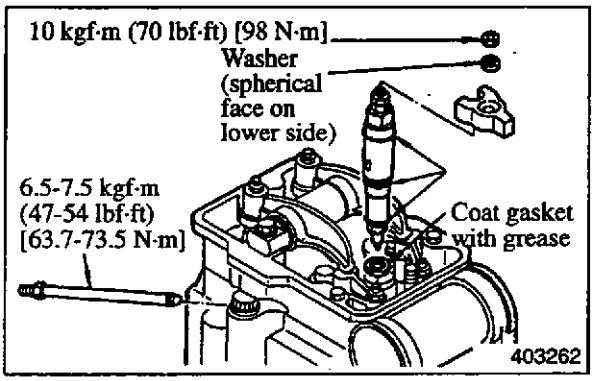
(a) Disconnect the fuel inlet connector pipe from the nozzle assemblies.

(b) Install 3 O-rings to the nozzle and coat with grease.

(c) Coat the gasket with grease then install the gasket to the nozzle. Insert the nozzle assembly into the cylinder head. Watch the center of the connector installation hole.

(d) Tighten the fuel inlet connector pipe to the specified torque.

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



NOTE

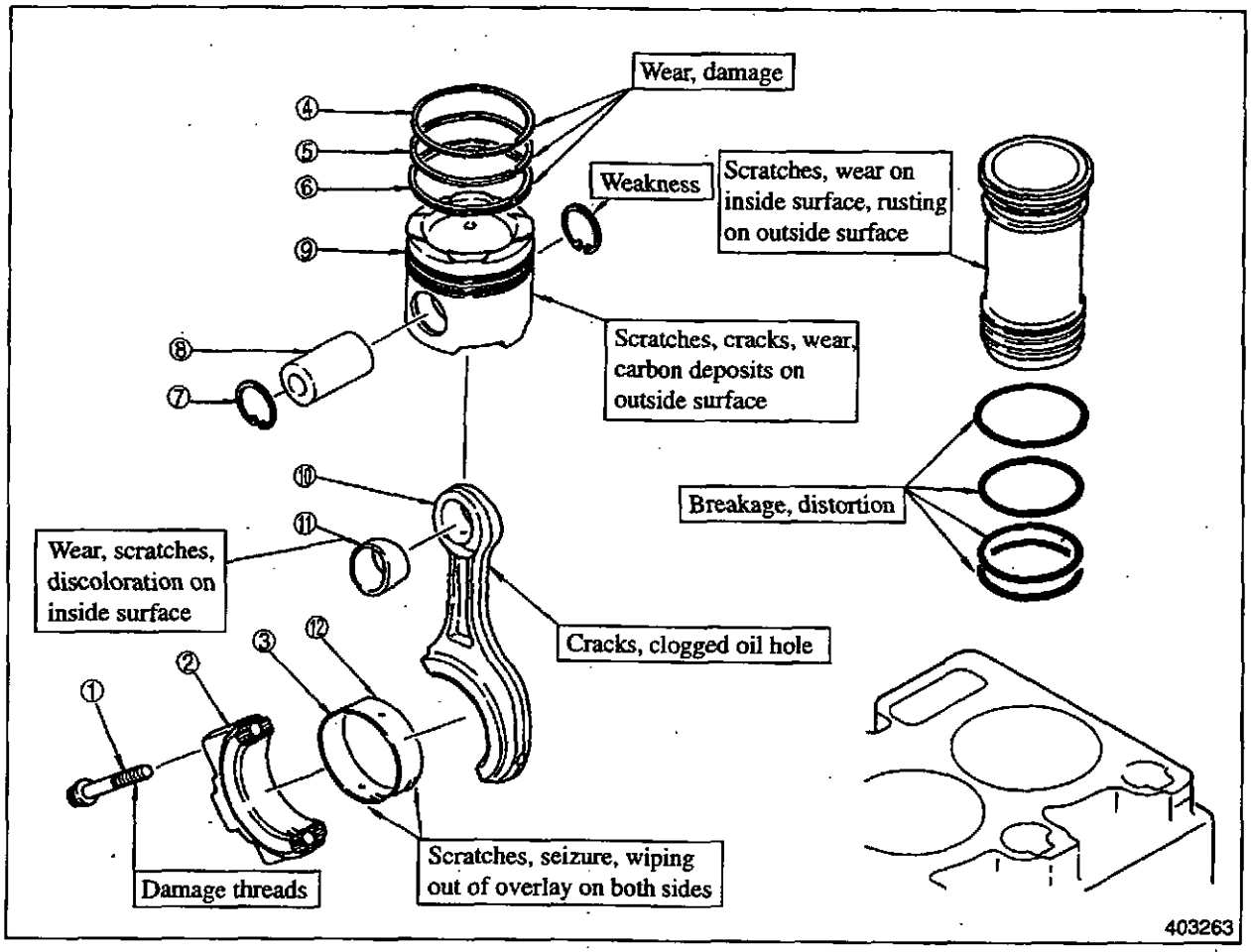
(a) Maintain equal distances between the fuel inlet connector pipe and and the cylinder head before tightening to the specified torque.
(b) Be sure to install the gasket when installing the nozzle assemblies.

(9) Adjusting valve clearance

Refer to section 1.1, Group No. 5.

2. Cylinder Liners, Pistons, and Connecting Rods

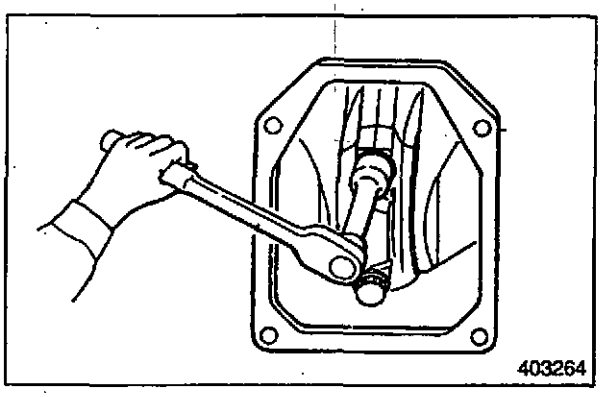
2.1 Disassembly



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

(1) Removing connecting rod caps

Unscrew the cap bolts from the inspection wind, then remove the cap.

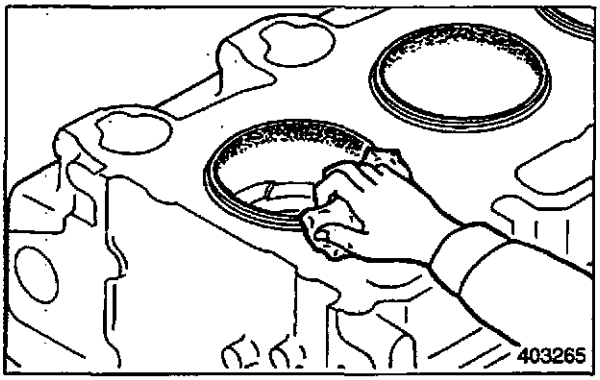


NOTE

(a) Do not damage the bearings or drop them into the oil pan.
(b) Mark the removed connecting rod bearings for identification of cylinder numbers and for upper and lower shells.

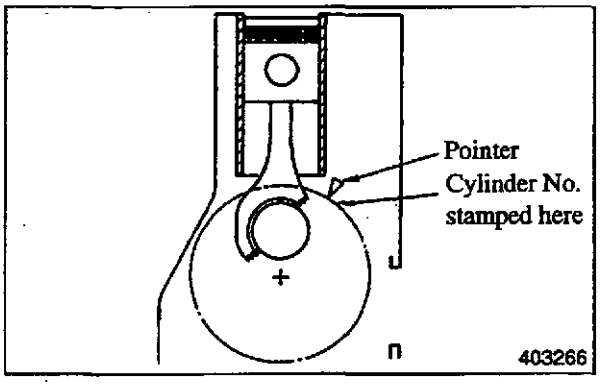
(2) Preparation before removing pistons

Use a cloth or oil paper to remove all carbon deposits from the upper areas of the cylinder liner. If any carbon deposits are present, this will make it difficult to pull a piston up.

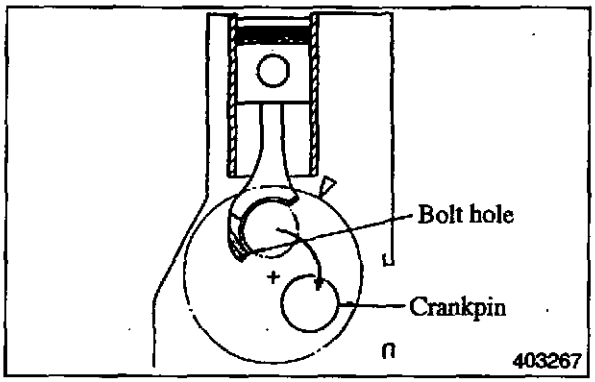


(3) Removing pistons
(By the use of a bar)

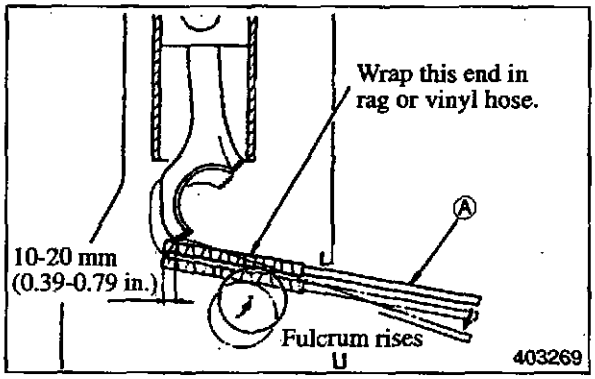
(a) Turn the crankshaft to bring the piston assembly (from which the connecting rod has been removed) to top dead center.



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



(c) Cover the turning bar Ⓐ with a cloth to protect it. Put the tip of the bar under the bottom of the large end of the connecting rod, then pry up the piston assembly a small amount by making using the crank pin as a fulcrum.



⚠CAUTION

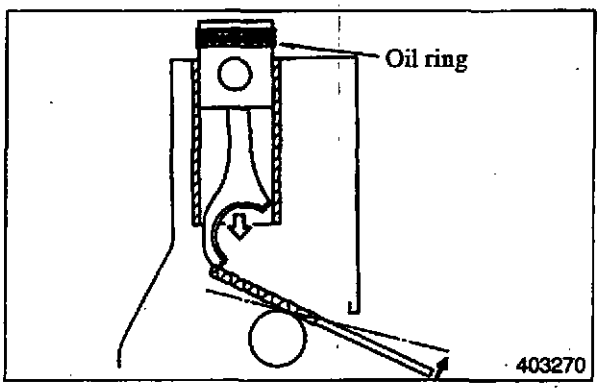
If you force the turning bar, you may not be able to remove the piston assembly. Insert the bar so it protrudes about 10-20 (0.39 to 0.79 in.) mm from the bottom end of the large end.

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

⚠CAUTION

Raise the piston assembly carefully so that the connecting rod will not interfere with the piston cooling oil jet nozzle.

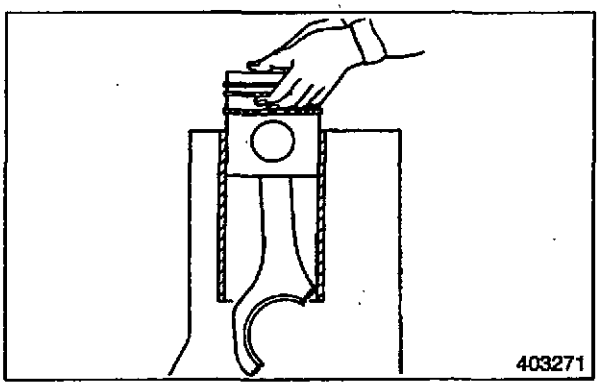
(e) When the oil ring of the piston comes out of the cylinder liner, lower the piston a little and carefully rest the oil ring on the edge of the liner.



⚠CAUTION

To avoid damage to the oil ring, lower the piston slowly and carefully. Do not rotate the piston.

(f) While holding the compression ring portion of the piston with your hands, carefully pull the piston from the cylinder liner, then rest its skirt on the top of the crankcase.

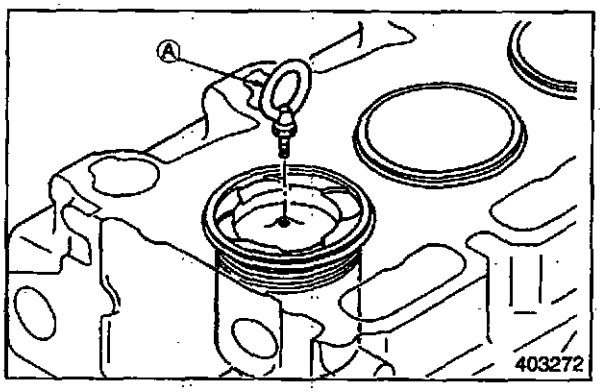


(g) With your hands holding the piston pin portion of the piston, and lift the piston assembly off the liner.

(4) Using the piston remover

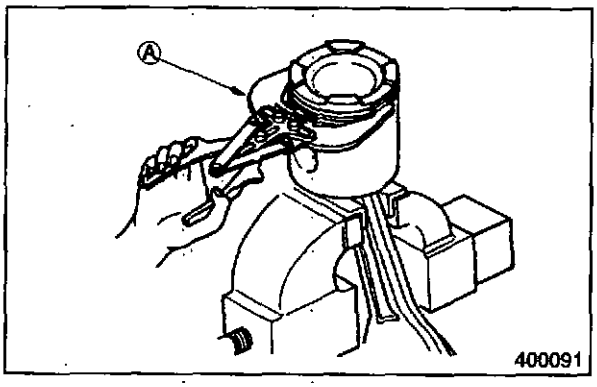
(a) Turn the crankshaft to bring the piston assembly to be removed to 50° before top dead center.

(b) Attach piston remover Ⓐ (MM321420) to the top of the piston. Grip the handle of the remover, then lift the piston and the connecting rod off the liner.



(5) Removing the piston ring

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

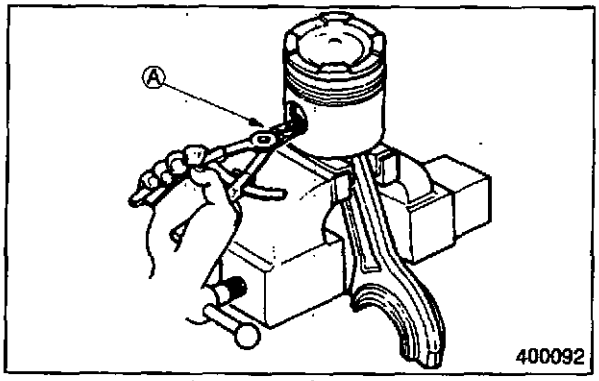


(6) Removing piston pins from a piston

(a) Use ring pliers Ⓐ (45191-08400) to 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

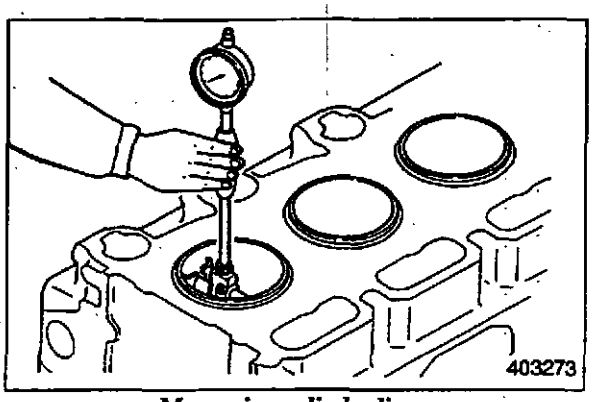
Cylinder Liners

(1) Measuring cylinder liner inside diameter

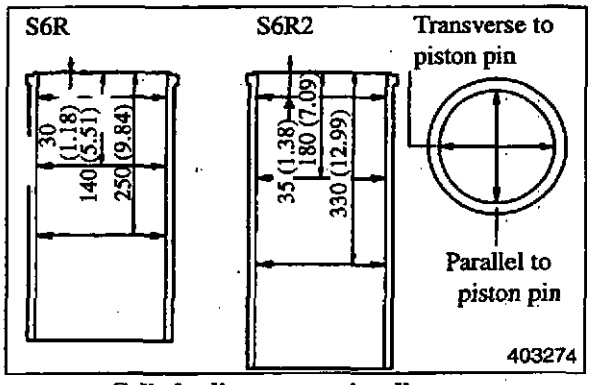
Measure the inside diameter of each liner in two directions, parallel and transverse to the piston pin, at three positions on the top (ridged area). If measurements exceed the service limit, replace the liner.

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service limit
Cylinder liner inside diameter	ø170 (6.69)	170.000-170.040 (6.69290-6.69447)	170.500 (6.7177)



Measuring cylinder liner



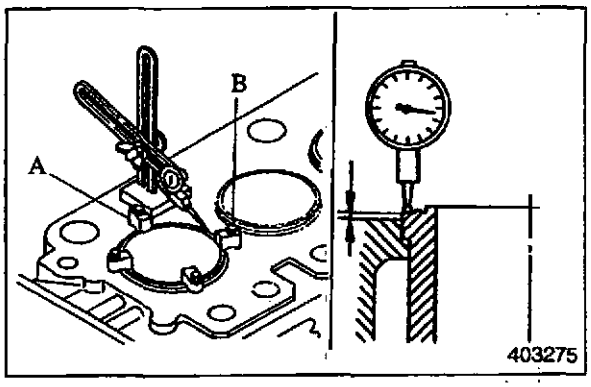
Cylinder liner measuring diagram

(2) Measuring cylinder liner protrusion

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

Unit: mm (in.)

Item	Assembly Standard
Cylinder liner protrusion at flange	0.11-0.20 (0.0043-0.0079)



Measuring cylinder liner protrusion

⚠CAUTION

If the protrusion is less than the assembly standard, the gasket will fail to seal the bore resulting in gas leakage.

- When cylinder head has just been removed

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

  (b) Secure the top of the liner uniformly at four places with liner pusher Ⓐ (37591-06200) and bolt Ⓑ (37591-06300).

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

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

  (e) If the average is less than the assembly standard, insert a shim under the collar of the cylinder liner.

- When cylinder liner is replaced (See section (3).)

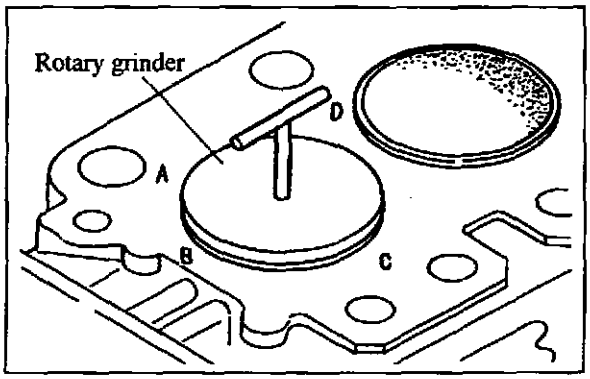
  (a) Remove the cylinder liner, and study the cylinder liner contacting surface of the crankcase.

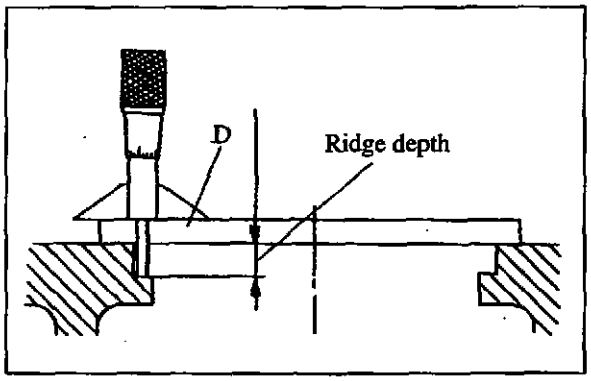
  (b) If the cylinder liner contacts the crankcase only on one side, use a rotary grinder to grind the surface to keep the differences of depth in four directions A, B, C and D within 0.05 mm.

  (c) Measure the ridge depth of the crankcase. Since the top surface of the crankcase may be slightly distorted, use projection plate (D) (37598-09201) to obtain accurate measurements.

  (d) Measure at four locations A, B, C and D, and obtain the average.

  (e) Measure the thickness (standard measurement: 15 mm) of the projection plate using a micrometer. Subtract the projection plate thickness from the measured ridge depth to obtain the actual ridge depth from the top surface of the crankcase.





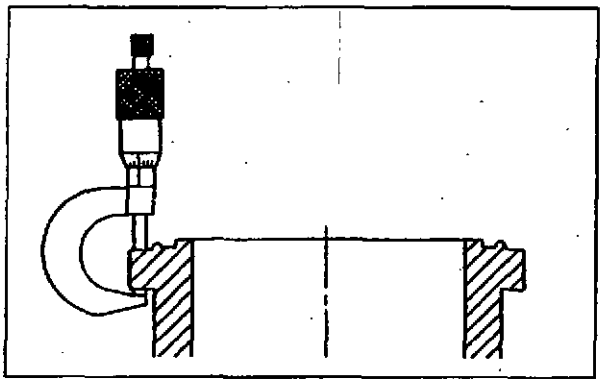
Unit: mm (in.)

	Assembly standard
Crankcase ridge depth	$14\ ^{+0.05}_{0}$

(f) Measure the thickness of the cylinder liner collar.

Unit: mm (in.)

	Assembly standard
Thickness of cylinder liner collar	$14^{+0.20}_{+0.16}$



(g) Subtract the crankcase ridge depth from the cylinder liner collar thickness. This value is the cylinder liner projection.

(h) If the value is less than the assembly standard, insert a shim under the collar of the cylinder liner.

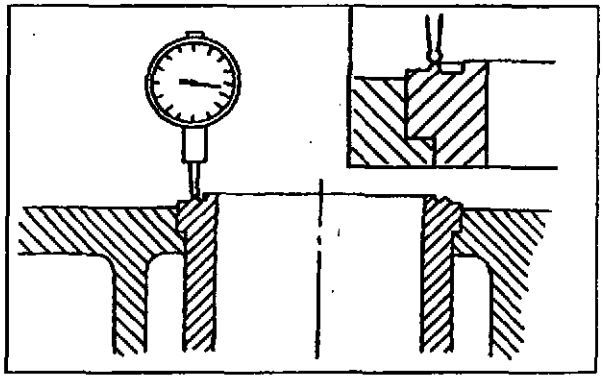
- Measuring cylinder liner projection

(a) Place a dial gauge on the top surface of the cylinder liner, and set the indicator to 0 (zero).

(b) Measure the cylinder liner protrusion at four locations, and obtain the average.

Unit: mm (in.)

	Assembly standard
Cylinder liner projection	0.2±0.04



Measuring cylinder liner projection

(c) If the average is less than the assembly standard or if the protrusion has sectional chipping, replace the cylinder liner. (See section (3).)

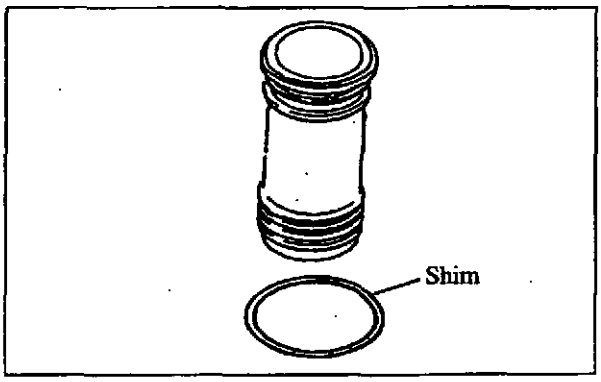
- Inserting cylinder liner shim

(a) Remove the cylinder liner. Insert a shim between the cylinder liner and crankcase.

NOTE

From the table below, select the appropriate shim thickness that achieves the largest protrusion within the assembly standard range.

Thickness of shim	Part No.
0.05 mm	37507-02510
0.10 mm	37507-02500
0.15 mm	37507-02520



Inserting cylinder liner shim

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

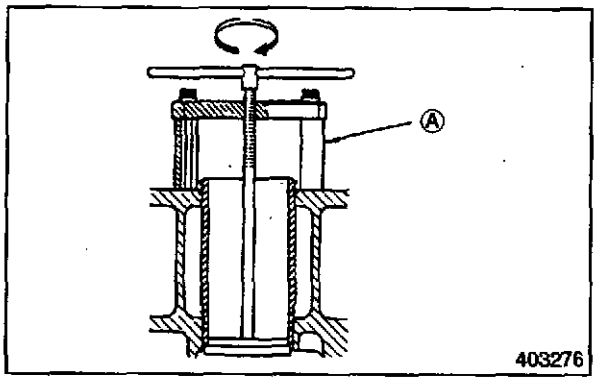
(b) Secure the top of the liner uniformly at two places with the clamps and bolts (M22 × 2.5).

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

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

(3) Replacing cylinder liners

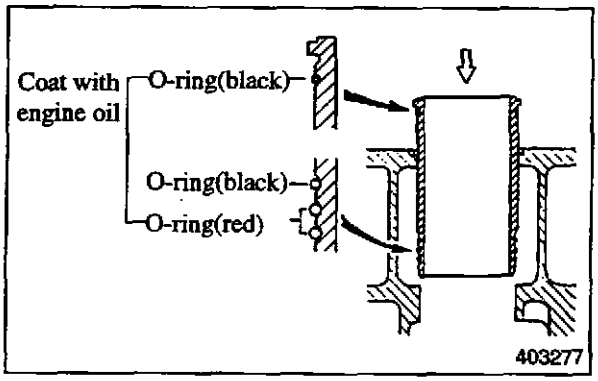
(a) Use the cylinder liner remover Ⓐ (37591-04100) to remove the cylinder liner from the crankcase for replacement.



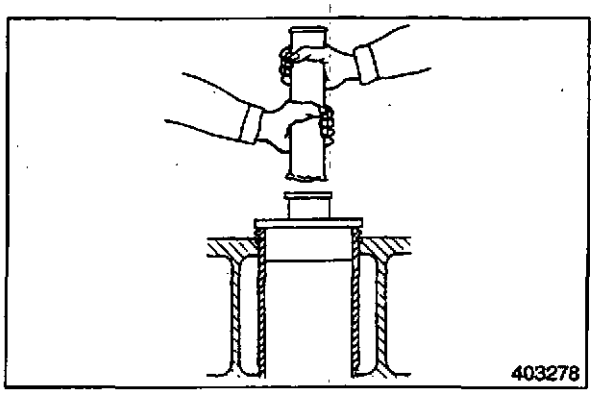
(b) Attach O-rings to the new cylinder liner, then carefully insert the liner into the bore of the crankcase.

⚠CAUTION

Before you insert the liner, coat the O-rings with engine oil to prevent them from twisting.



(c) After inserting the liner into the bore, lightly tap it on the top with the installer so it rests on its flange in the counterbore formed by the crankcase. After seating the liner, tap on it several times to be sure that it is properly installed.



NOTE

(a) After installing the liners on all bores, test the liner joints for water tightness by applying water under pressure.
(b) Check each liner to be sure its protrusion is within assembly standards.

Pistons

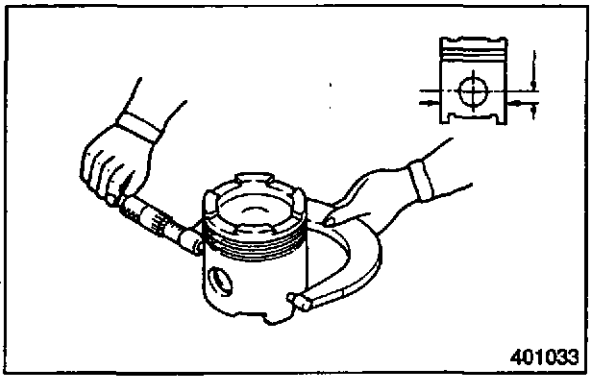
Check the combustion chamber and inside surfaces of the piston bosses. Replace the piston if any defects are found.

(1) Measuring piston diameter

(a) Using a micrometer, measure the diameter of each piston in the transverse direction to the piston pin (at the position shown). If the diameter exceeds the service limit, replace the piston. If any pistons have to be replaced, select new pistons so the variance in weight among pistons per engine is within assembly standards.

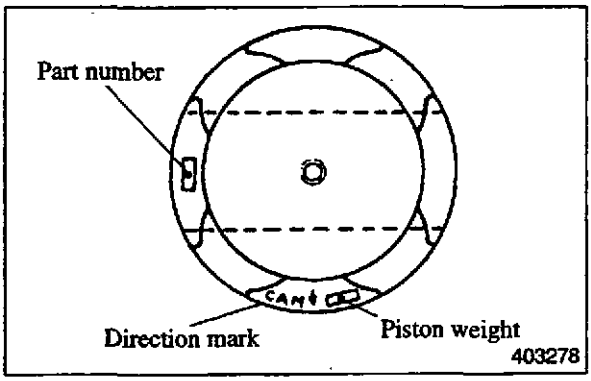
Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service limit
Piston diameter	ø170 (6.69)	169.76-169.80 (6.6885 -6.6850)	169.66 (6.6795)
Weight Variance among pistons		20 g (0.7oz) max.	



Measuring piston diameter

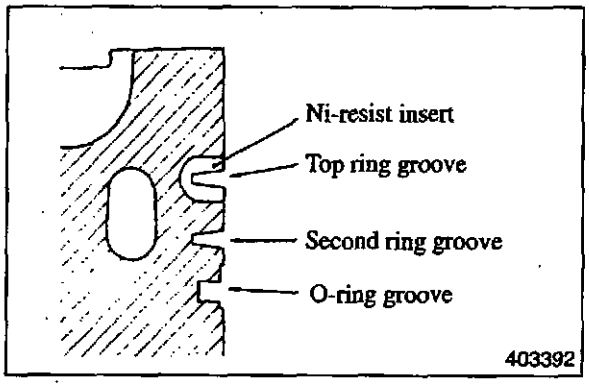
(b) The piston weight is stamped on the top of each piston.



Piston weight stamp location

(2) Inspecting piston ring grooves

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



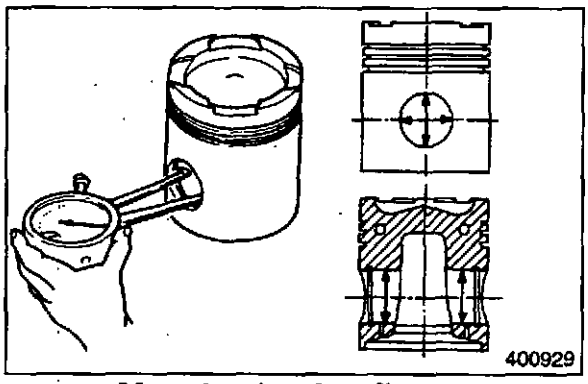
Inspecting piston ring grooves

(3) Measuring piston pin bore diameter

Using calipers or a cylinder gauge, measure the piston pin bore diameter. If the diameter exceeds the service limit, replace the piston.

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Piston pin bore diameter	ø 70 (2.76)	70.002-70.015 (2.75598 -2.75649)	70.020 (2.75669)



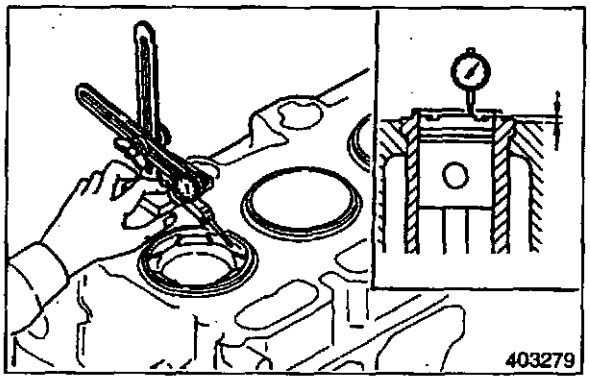
Measuring piston bore diameter

(4) Measuring piston protrusion

Measure the protrusion of each piston. If it is not within standards for piston protrusion measurement, inspect the clearance of the parts.

(a) Measure the top dead center of the pistons with a dial gauge.

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



Measuring piston protrusion

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

Unit: mm (in.)

Item	Assembly Standard
Piston protrusion	0.06-0.65 (0.0024-0.0256)
Installed thickness of cylinder head gasket	1.77-1.83 (0.0697-0.0720)
Clearance between piston top and cylinder head	1.22-1.95 (0.0480-0.0768)

⚠CAUTION

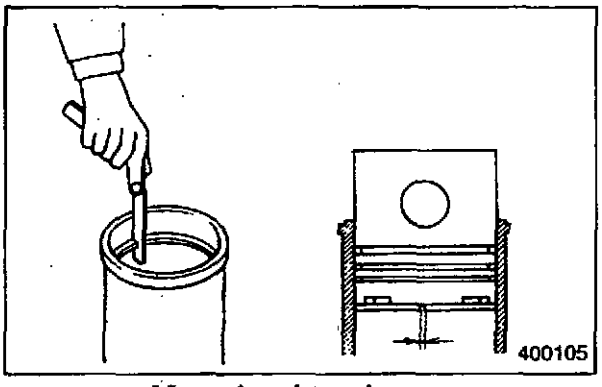
Keep the piston protrusion with assembly standard range to maintain high engine performance and to prevent the valves from interfering with the piston.

Piston Rings

(1) Measuring gaps

Place the rings for the new master cylinder liner, then measure the gap of each ring. If the gap of any ring exceeds the service limit, replace all the rings as a set.

Master cylinder liner inside diameter : 170 ± 0 mm (6.70±0 in.)



Measuring piston ring gap

NOTE

Use a piston to place the piston ring in the liner by pushing it squarely.

Unit: mm (in.)

Item		Standard Clearance	Service Limit
Piston ring gaps	Top	0.6-0.8 (0.024-0.031)	2.0 (0.079)
	Second	0.6-0.8 (0.024-0.031)	
	Oil	0.3-0.45 (0.012-0.018)	

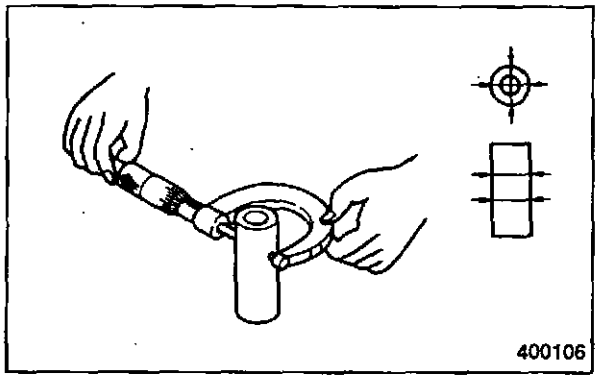
Piston Pins

(1) Measuring piston pin diameter

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

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Piston pin outside diameter	ø70 (2.76)	69.987-70.000 (2.75590 -2.75539)	69.970 (2.75472)



Measuring piston pin diameter

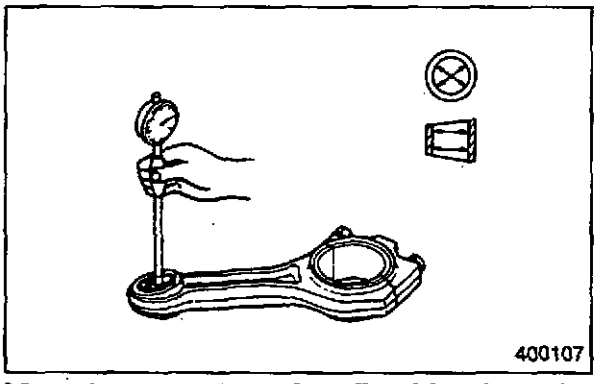
Connecting Rods, Connecting Rod Bearings, and small-end Bushings

(1) Measuring small-end bushing inside diameter

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

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Connecting rod bushing inside diameter	ø70 (2.76)	70.020-70.040 (2.75669 -2.75747)	70.070 (2.75866)



Measuring connecting rod small-end bushing inside diameter

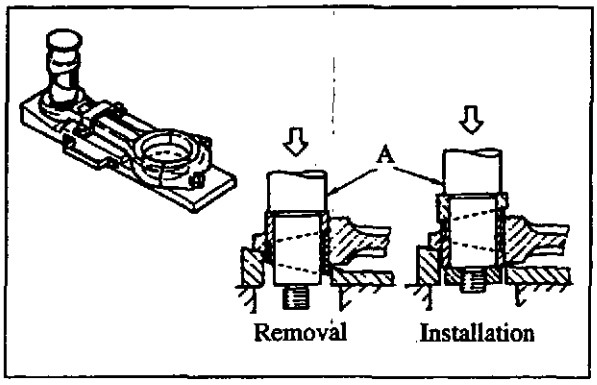
(2) Replacing connecting rod small-end bushings

(a) Use a connecting rod small-end bushing installer Ⓐ (37591-01010) to remove the bushing for replacement as shown.

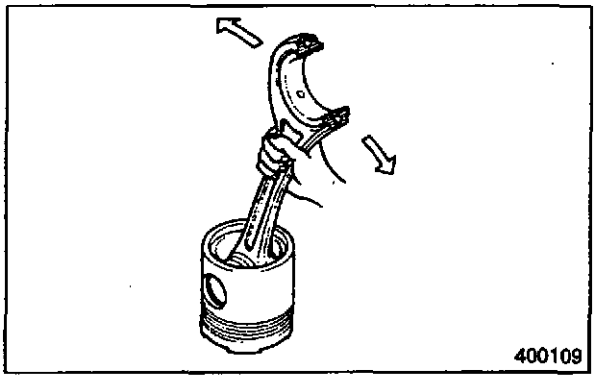
(b) When installing a new bushing, align the oil holes in the bushing and connecting rod.

(c) After installing the bushing, finish its inside diameter to ø70 $^{+0.040}_{+0.020}$ (2.76 $^{+0.00157}_{+0.00079}$ in.) $\frac{1.6S}{\nabla\nabla\nabla}$ and its parallel bushing with respect to the large-end bearing to 0.05 (0.0020 in.) mm by reaming.

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



Replacing connecting rod bushing

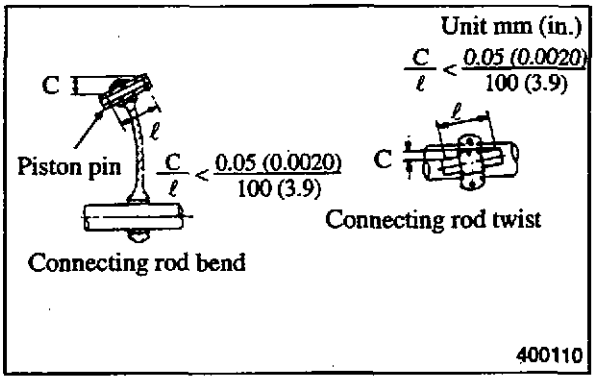


(3) Inspecting connecting rods for bend and twist.

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

NOTE

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

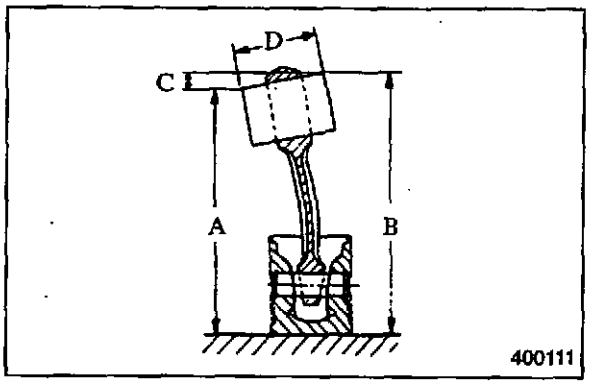


Inspecting connecting rod

(b) To inspect the rod installed to the piston, place the piston on a surface plate, insert a round bar the same diameter as the crank pin into the large end bore, then measure heights (A) and (B) of the bar.

Unit: mm (in.)

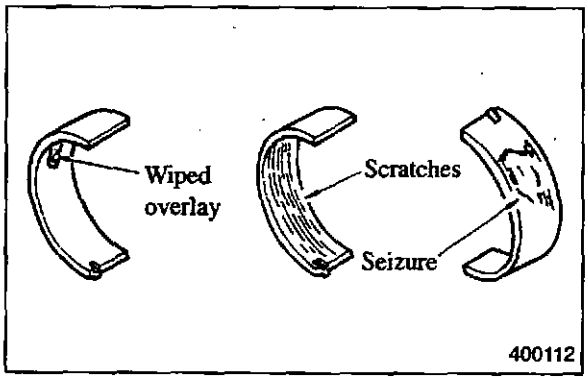
Item	Assembly Standard
Connecting rod bend and twist (C/D)	0.05/100 (0.0020/3.9) max.



Inspecting connecting rod installed on piston

(4) Inspecting connecting rod large-end metals

metal shell for wiped overlay, scratching, seizure, pitting, and other defects. If any defect is found, replace the shell.



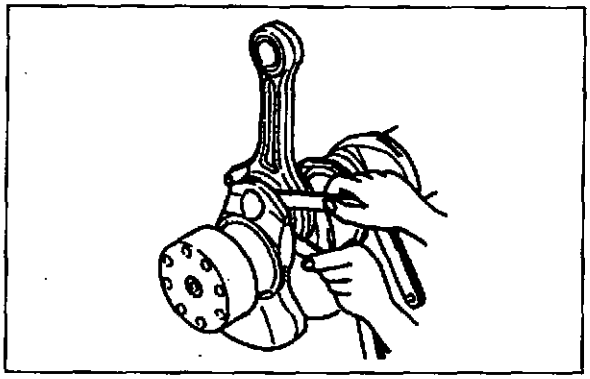
(5) Measuring connecting rod end play

Install the connecting rod to its crank pin, then tighten its cap bolts to the specified torque. Use a feeler gauge to measure the end play. If the end play exceeds the service limit, replace the connecting rod.

Unit: mm (in.)

Item	Nominal Value	Standard Clearance (Nominal)	Service Limit
Connecting rod end play*	67 (2.64)	0.2 to 0.6 (0.008 to 0.024)	1.0 (0.039)

*Widths of connecting rod and crank pin



Measuring connecting rod end play

(6) Variance in weight among connecting rods per engine

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

Unit: mm (in.)

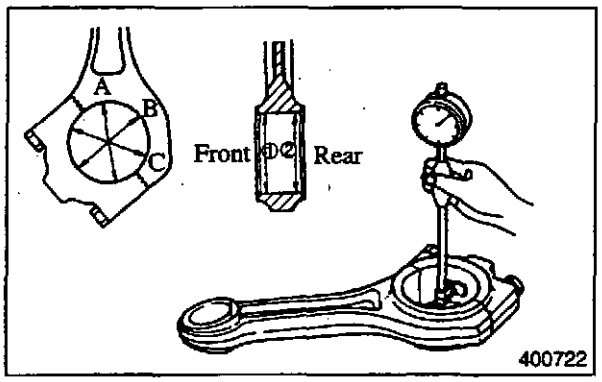
Item	Assembly Standard
Variance in weight among connecting rods per engine	40 g (1.4 oz) max.

(7) Measuring connecting rod large-end bore diameter

Measure the connecting rod big-end bore diameter in directions A, B and C and at front and rear positions ① and ②, as shown in the diagram. To obtain the out-of-roundness valve, substract the smallest measured value from the largest measured value.
If the diameter exceeds the service limit, replace the connecting rod.

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Connecting rod large-end bore diameter	ø131 (5.16)	131.050 (5.16337)	0.100 (0.004)



Measuring connecting rod large-bore diameter

(8) Inspecting serration on connecting rod big-end bore

Inspect the serration on connecting rod big-end bore by conducting a magnalux (magnetic particle) test. It cracking or damage is found, replace the connecting rod.

(9) Measuring connecting rod metal thickness

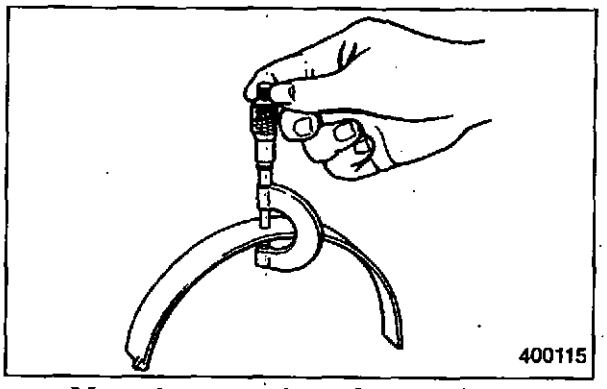
Use a ball-point micrometer to measure the center of each metal shell. If the thickness exceeds the service limit on the upper or lower shell, replace both shells as a set.

Unit: mm (in.)

Item		Nominal Value	Assembly Standard	Service Limit
Connecting rod metal thickness	STD	3.000 (0.11811)	2.972-2.985 (0.11701 -0.11752)	2.930 (0.11535)
	-0.25 (-0.0098)	3.125 (0.12303)	3.097-3.110 (0.12193 -0.12244)	3.055 (0.12028)
	-0.50 (0.0197)	3.250 (0.12795)	3.222-3.235 (0.12685 -0.12736)	3.180 (0.12519)
	-0.75 (-0.0295)	3.375 (0.13287)	3.347-3.360 (0.13177 -0.13228)	3.305 (0.13012)
	-1.00 (-0.0394)	3.500 (0.13780)	3.472-3.485 (0.13669 -0.13720)	3.430 (0.13504)

NOTE

Four sizes are available for the connecting rod metals (see column 2 of the table above).



Measuring connecting rod metal thickness

2.3 Reassembly

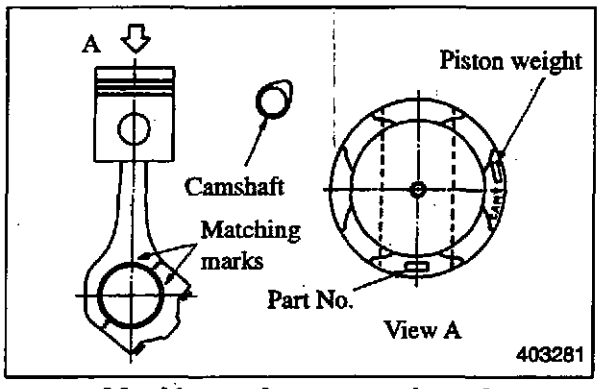
(1) Reassembling pistons on connecting rods

(a) Head the piston with a piston heater or with hot water.

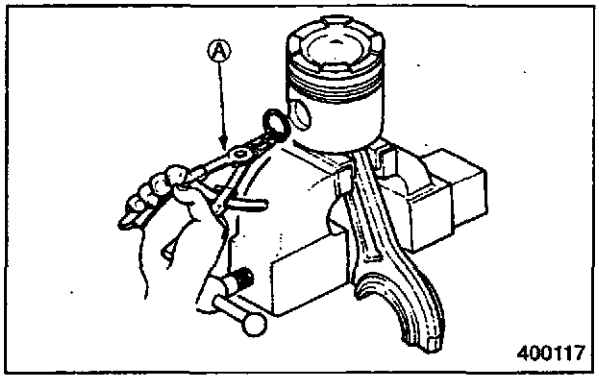
(b) Coat the piston pin with engine oil, then insert it in position through the connecting rod.

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

(d) Use ring pliers Ⓐ (45191-08400) to install the snap rings in the grooves of the pistons. Make sure that the rings are not fatigued and that they fit in the grooves properly.



Matching marks on connecting rod



NOTE

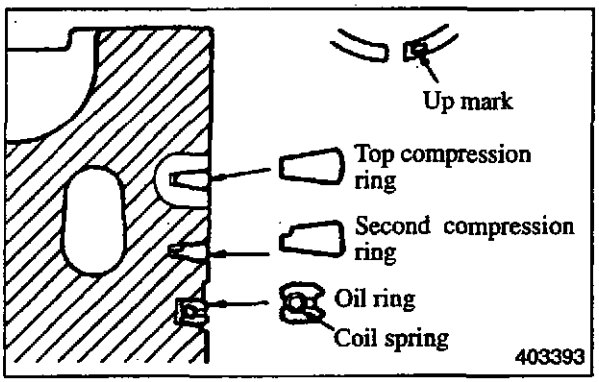
Position the ends of both snap rings at the bottom of the pin bore.

(2) Installing piston rings

(a) Use the piston ring tool (37191-03200) to install the piston rings on the piston.

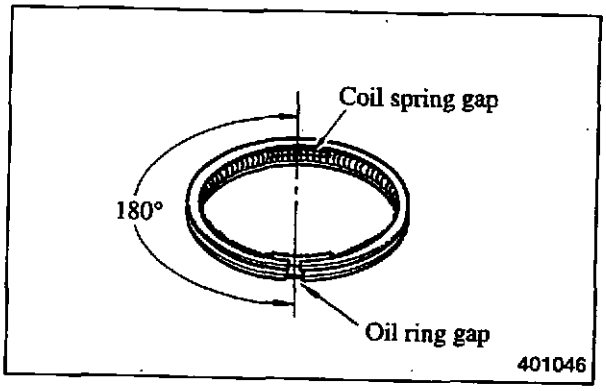
⚠CAUTION

The top piston ring and second piston ring are marked "RH", and the oil ring is marked "R" near the gap on the side to be up when installed with this mark down. Install them this way to avoid excessive oil consumption and overheating.



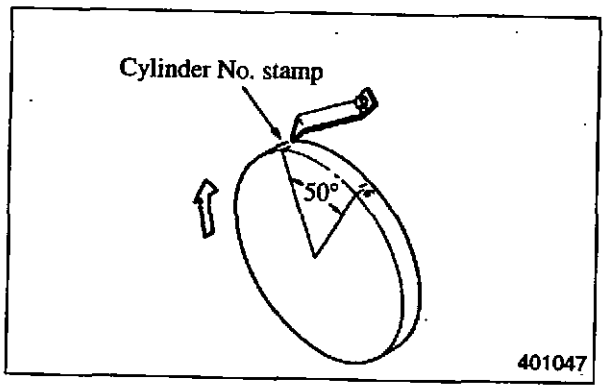
Piston and piston rings

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

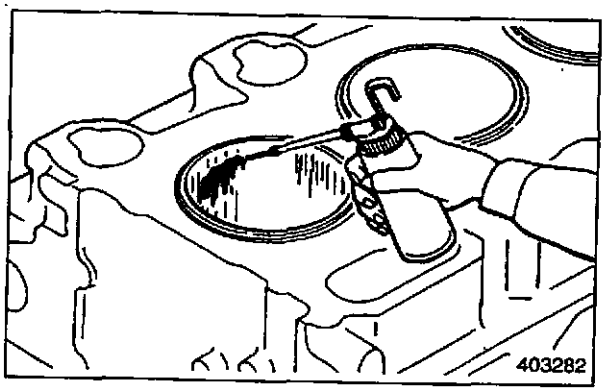


(3) Preparation before installing pistons

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

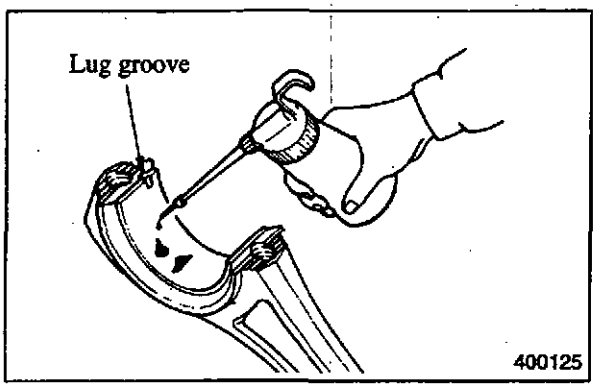


(b) Clean the cylinder liner bore surface and crank pin by wiping with a cloth, then coat it with engine oil.



(4) Installing connecting rod metal upper shells

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

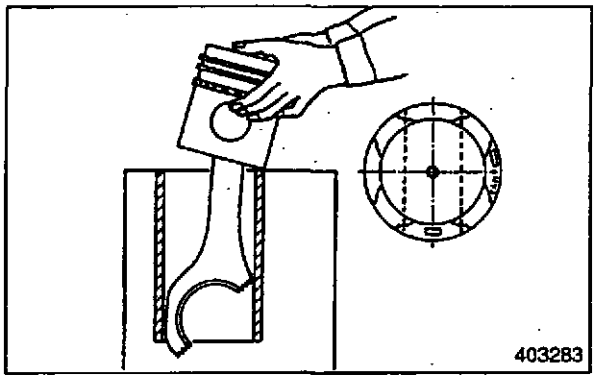


(5) Inserting pistons

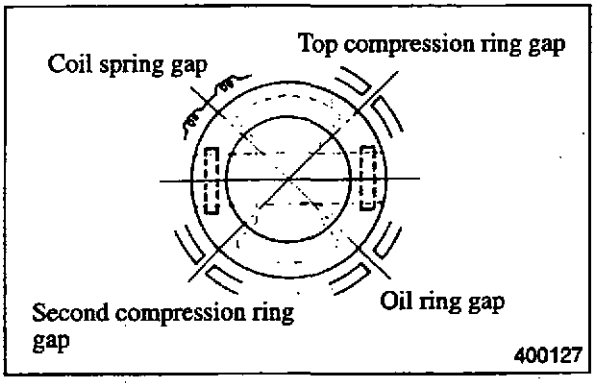
(a) Put the connecting rod in the cylinder liner, and carefully rest the piston on top of the crankcase.

⚠CAUTION

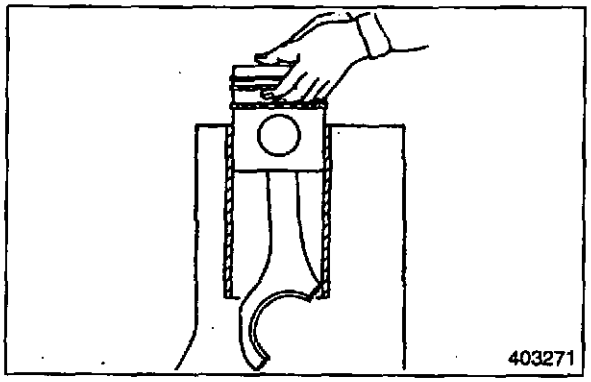
Make sure the arrow mark "CAM" on top of the piston points the camshaft side.
When placing the connecting rod in the liner, keep it away from the oil jet nozzle by observing the rod through the inspection hole of the crankcase. And do not rotate the piston.



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



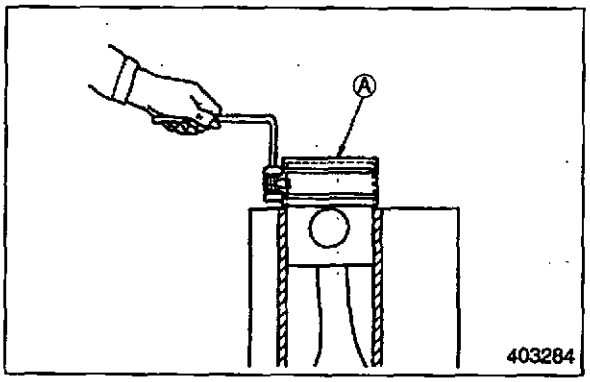
(c) With your hands, hold the compression ring portion of the piston, then carefully insert the piston into the cylinder liner.



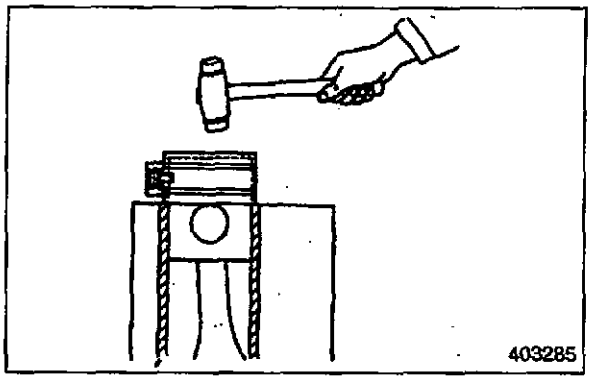
NOTE

(a) Do not pinch your finger between the oil ring and cylinder liner.
(b) Slowly insert the piston to avoid damaging it.

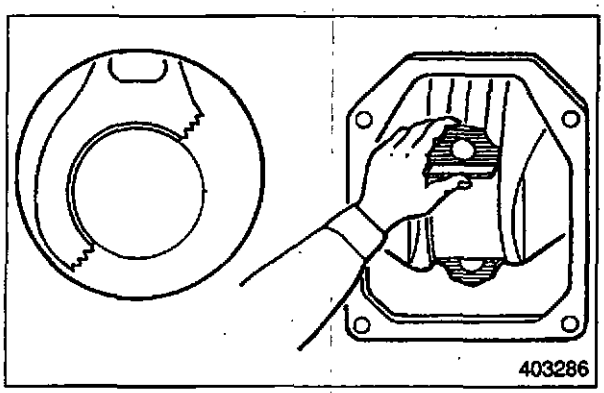
(d) After making sure that the piston ring gaps are positioned properly, coat the rings with engine oil, then clamp them, using the piston installer Ⓐ (37191-07100). At this time, coat the inside surface of the installer with engine oil.



(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 large end of the connecting rod back and forth through the crankcase inspection hole.

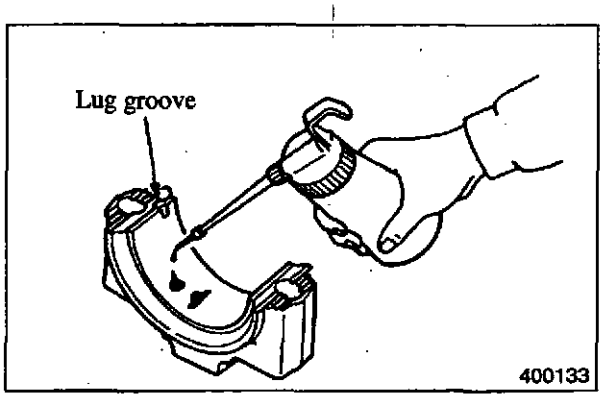


(f) By inserting your hand through the crankcase inspection hole, make sure that the upper shell of the metal is properly positioned in the large end of the connecting rod.



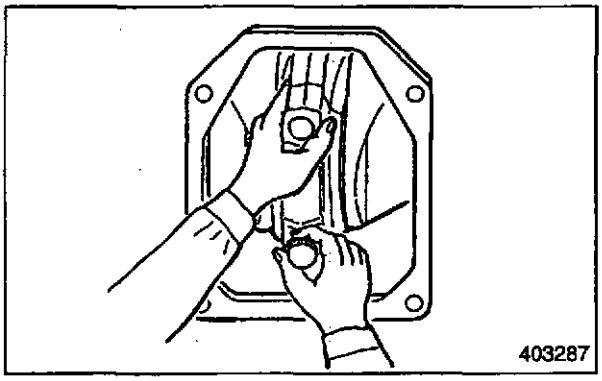
(6) Installing connecting rod cap bolts

(a) Coat the threads of the cap bolts and the inside surface of the lower shells of the connecting rod metal with engine oil.



(b) Install each cap in position. With your hand, hold the upper end of the cap, then tighten the bolt at the lower end first. This will help prevent dropping the cap into the oil pan. Coat the threads of the bolts with engine oil, then tighten the bolts temporarily.

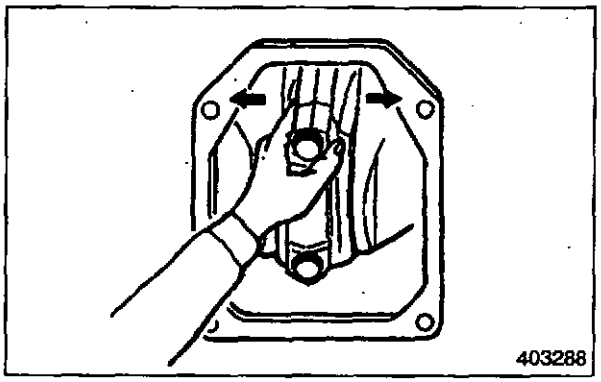
(c) With the cap bolts tightened temporarily, touch the joint between the cap and rod. Make sure that the cap is normally held in place, and tighten the bolts to the specified torque.



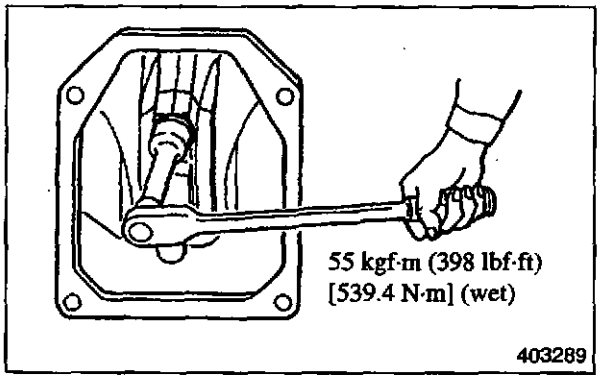
⚠CAUTION

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

(d) Move the large end of this rod in the thrust direction. Make sure that the rod has correct end play.



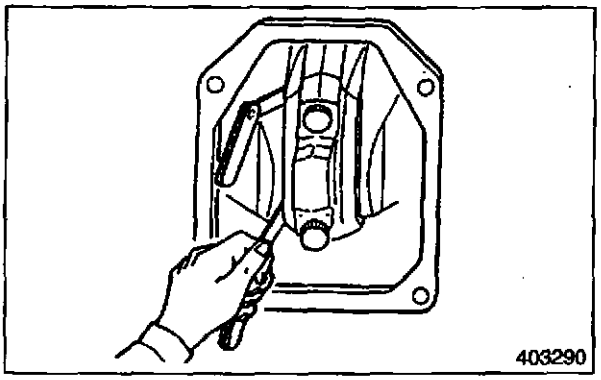
(e) Tighten the cap bolts to the specified torque.



(f) Use a feeler gauge to measure the end play of the connecting rod. Make sure that the end play is equal on both top and bottom sides of the crank pin. (Refer to 2.2 Group No. 7.)

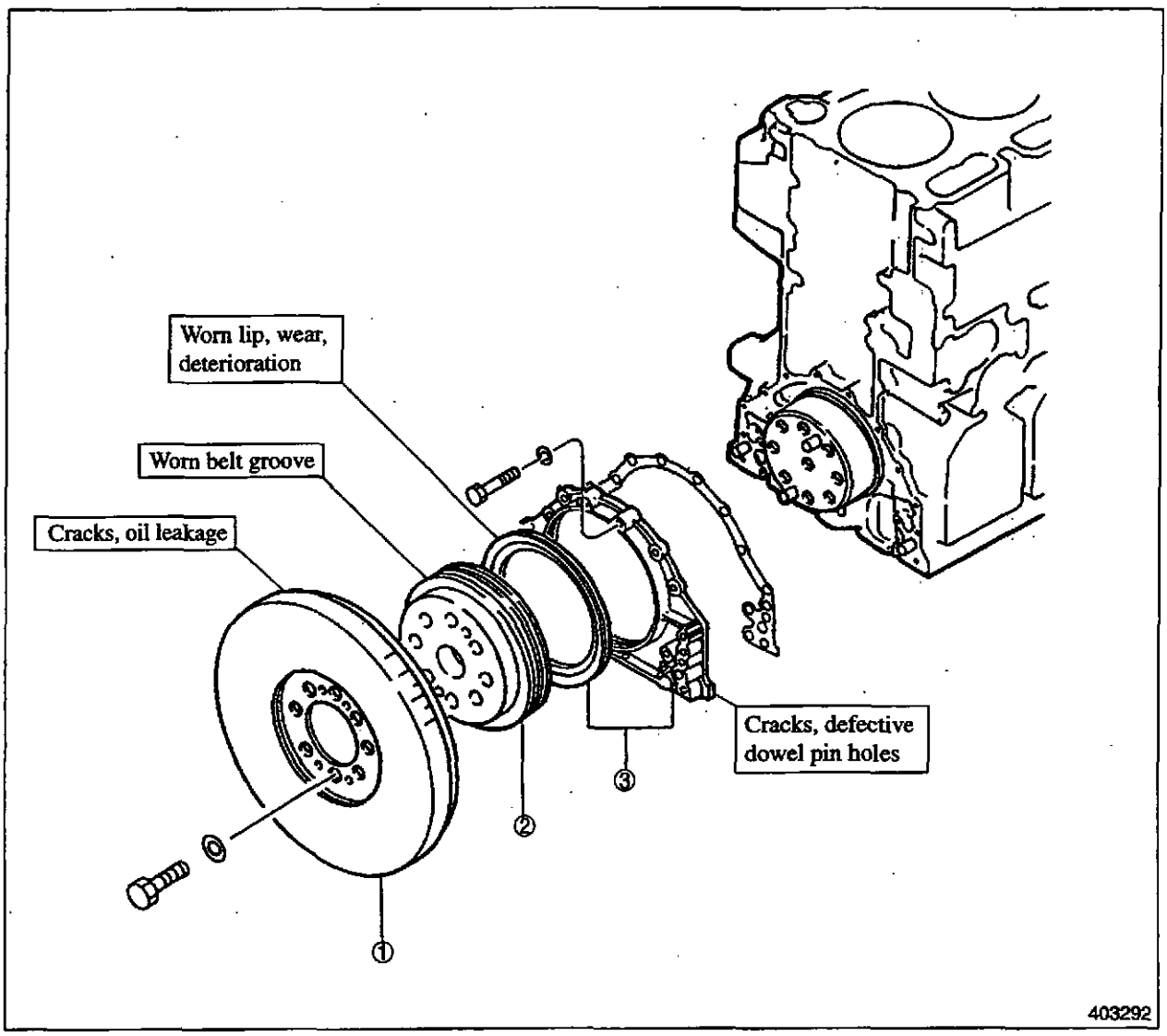
NOTE

To tighten connecting rod cap bolts according to the angle method, tighten to 25 kgf·m (181 lbf·ft) [245 N·m], then turn 60° more.



3. Viscous Damper

3.1 Disassembly

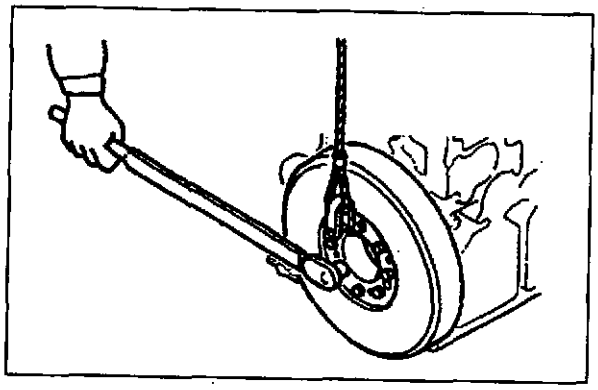


① Viscous damper
② Pulley (water pump and alternator drive)
③ Front cover, oil seal

(1) Removing the viscous damper

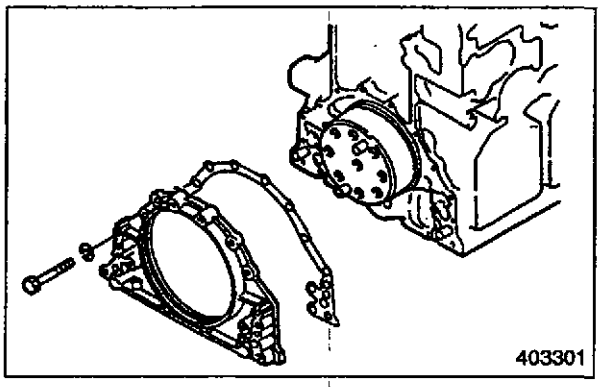
(a) Attach a sling to the viscous damper. Remove the damper mounting bolts.

(b) To remove the damper, install two jack bolts (M12 × 1.24 - 40 mm) in bolt holes and screw the bolts evenly while lifting the damper. (Weight: approx. 50 kg)



(2) Removing front cover

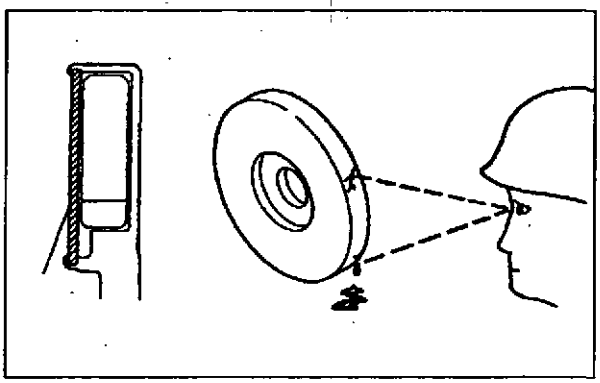
Unscrew the front cover mounting bolts, and remove the cover, being careful not to damage the oil seal.



3.2 Inspection and repair

(1) Inspecting viscous damper

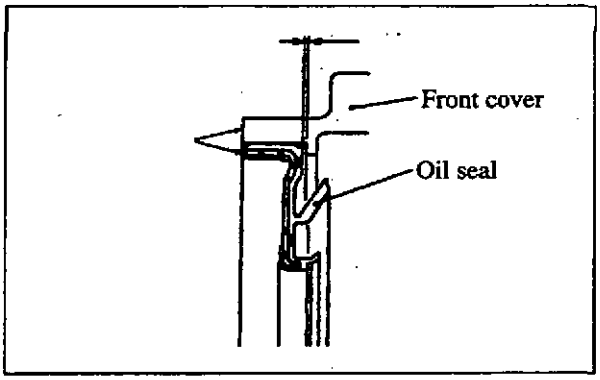
(a) Check the viscous damper for surface cracking, mirror plate swelling and cracking, silicone oil leakage, paint discoloration caused by excess heating, and surface peeling. Replace the viscous damper after 8,000 hours of operation regardless of whether the damper has surface flaw.



3.3 Reassembly

(1) Installing front cover

(a) Apply engine oil to the lip section of the oil seal. Install the oil seal in the front cover, making sure that the oil seal is flush with the end face of the oil seal installation hole of the front cover.

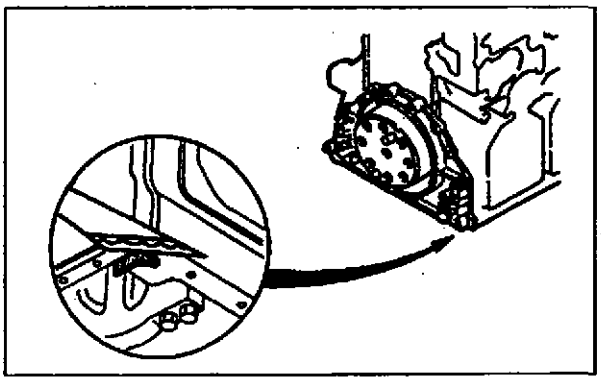


(b) Apply sealant (HERDITE) to the front cover packing mounting surface of the crankcase, position the packing on the surface, then apply sealant on the packing. Install the front cover.

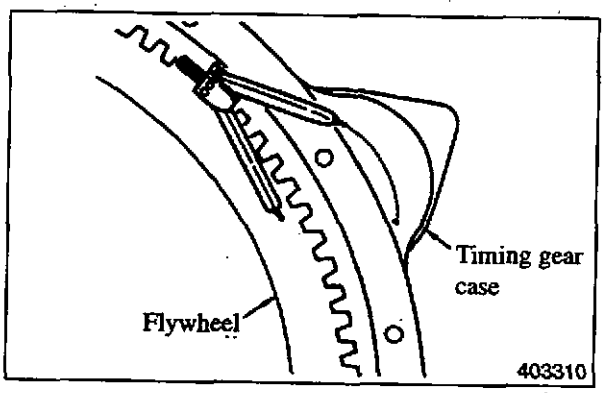
(c) If the dowel pins are worn or the cover has been replaced, install new dowel pins.

(d) Tighten the case mounting bolts evenly.

(e) Check to make sure the bottom surfaces of the front cover and crankcase are flush. Carefully remove excess packing protrusion from the joined surfaces.

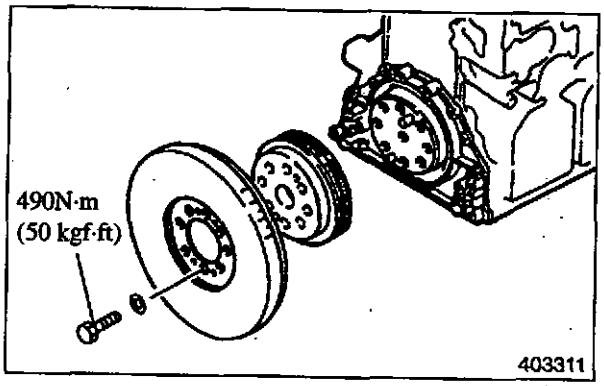


(When the pointer was removed or dislocated accidentally)
To determine the top dead center of No. 1 piston in compression stroke, bring the mark on the flywheel to the position where it is at the equal distances from the two marks punched on the timing gear case. When these mark are positioned at the equal distance from one another, No. 1 and No. 6 pistons are at the top dead center.



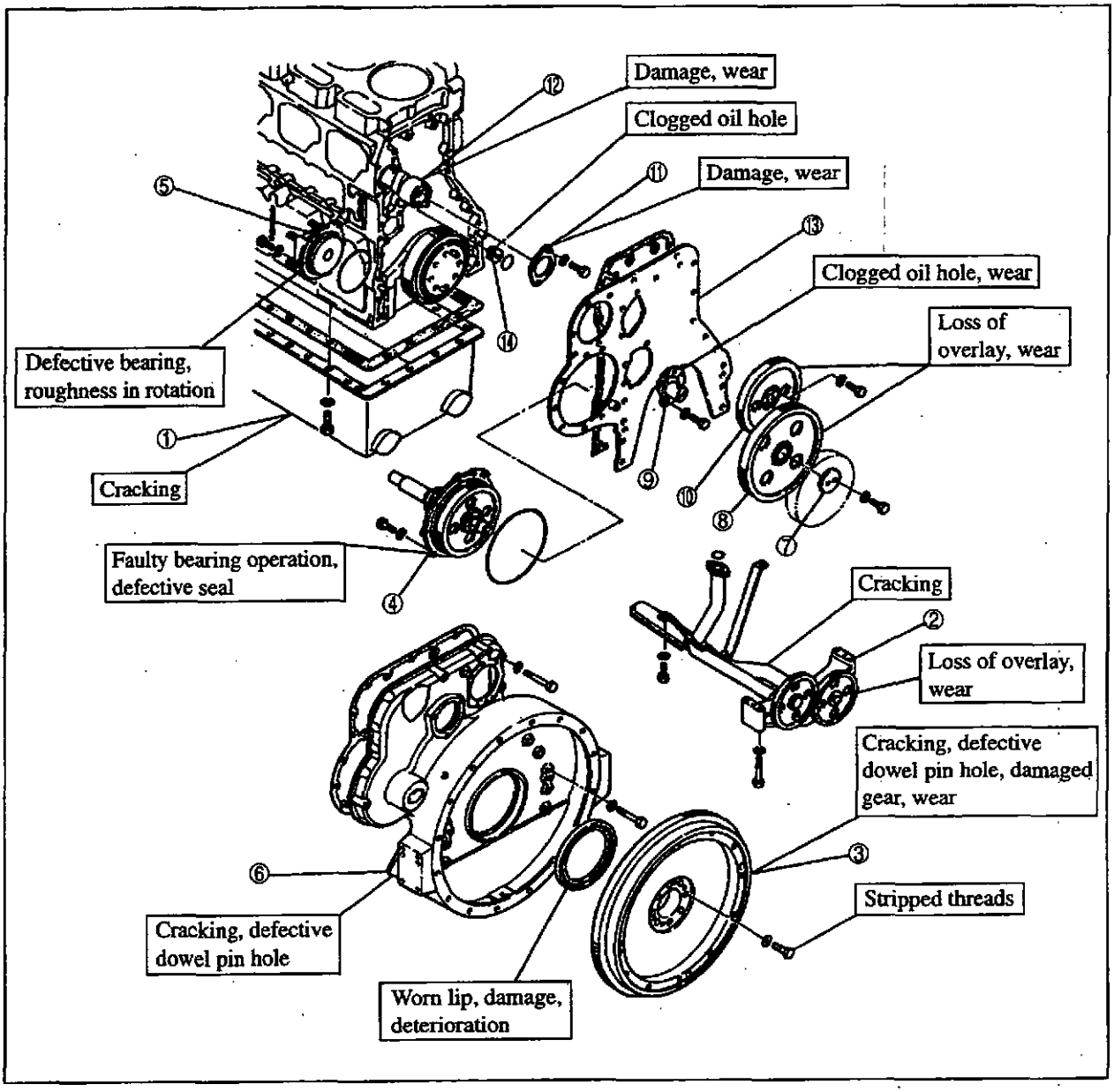
(2) Installing pulley and torsional damper

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



4. FLYWHEEL, TIMING GEARS AND CAMSHAFTS

4.1 Disassembly



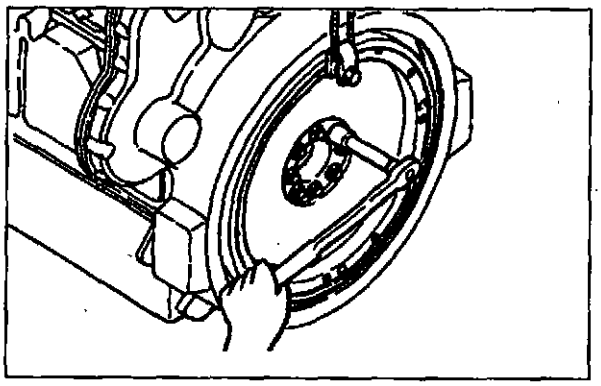
① Oil pan
② Oil strainer, oil pipe, oil pump
③ Flywheel
④ Injection pump accessory drive
⑤ Governor drive
⑥ Timing gear case, oil seal
⑦ Thrust plate
⑧ Idler gear
⑨ Idler shaft
⑩ Camshaft gear
⑪ Thrust plate
⑫ Camshaft
⑬ Rear plate
⑭ Nozzle plate

(1) Removing flywheel

(a) Attach a sling on the flywheel.

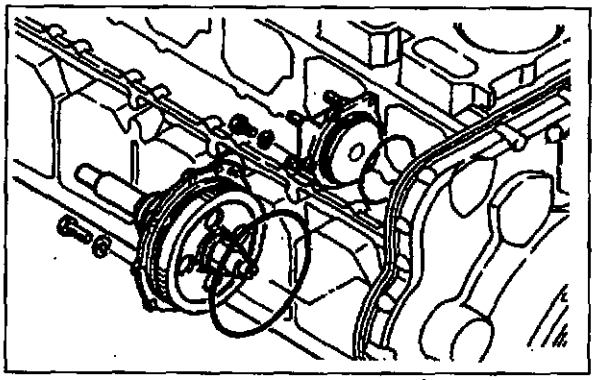
(b) Remove the flywheel mounting bolts.

(c) Install two jack bolts (A) (64362-68500: M12 × 1.25) in the holes provided for flywheel removal, and screw the bolts evenly to remove the flywheel.
(Weight: approx. 140 kg)



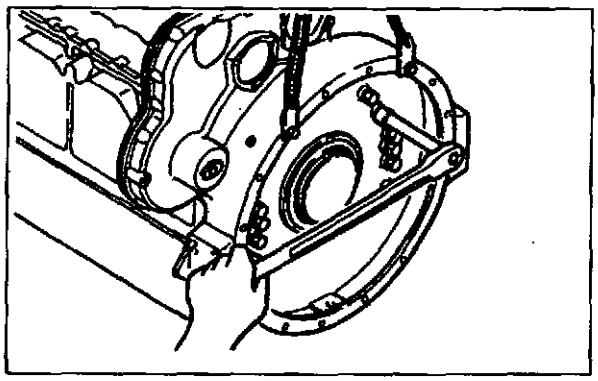
⚠CAUTION

(a) Do not drop or hit the flywheel against a hard object during the removal process.
(b) The ring gear is bolted to the flywheel. Do not remove the ring gear from the flywheel unless it is replaced.



(2) Removing governor drive and injection pump accessory drive

Remove the mounting bolts from the governor drive and injection pump accessory drive case. Remove the governor drive and injection pump accessory drive. Be careful not to damage the gear teeth.



(3) Removing timing gear case

(a) Attach slings to the timing gear case.

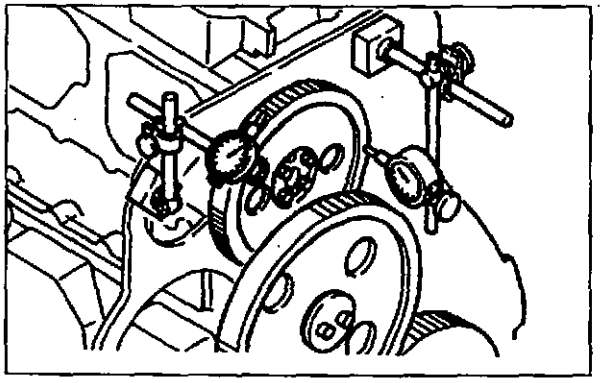
(b) Remove the timing gear case mounting bolts.

(c) Remove the timing gear case by pulling it away from the engine block until the dowel pins are out of the holes.

In this step, be sure to keep the timing gear case suspended, and be careful not to damage the oil seal.
(Timing gear case weight: approx. 85 kg)

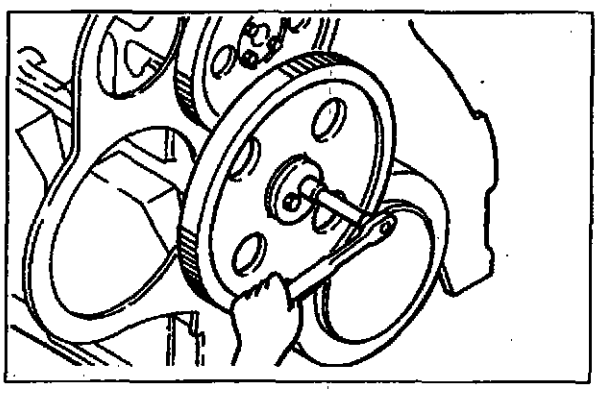
(4) Measuring backlash and end play

Measure the backlash and end play of each gear to obtain data to evaluate part replacement needs.



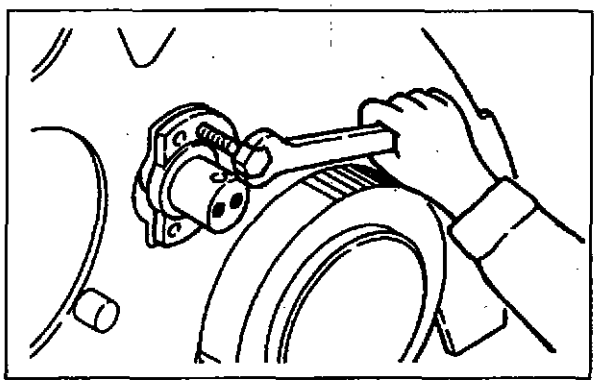
(5) Removing idler gear

Align the pointer with the mark for top dead center of piston No. 1 in compression stroke. Remove the thrust plate mounting bolts, and remove the idler gear.



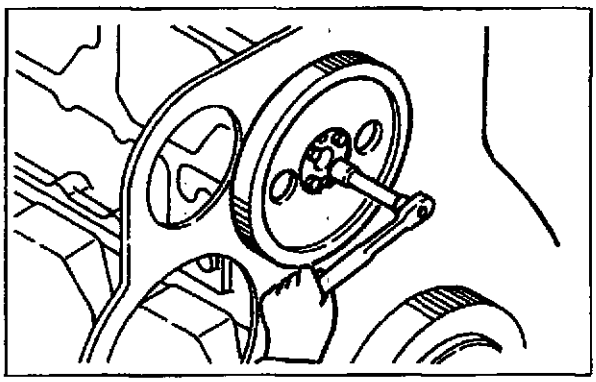
(6) Removing idler shaft

Remove the idler shaft mounting bolts. Install two jack bolts (M10 x 1.25) in the holes provided for shaft removal, and screw the bolts evenly to remove the idler shaft.



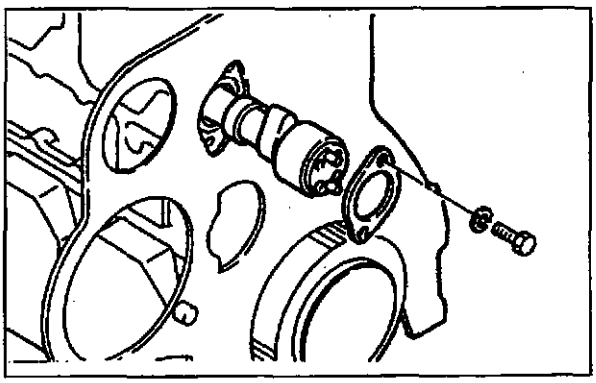
(7) Removing camshaft gear

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



(8) Removing camshaft

Remove the thrust plate mounting bolts. Remove the camshaft from the crankcase.
(Camshaft weight: approx. 32 kg)



⚠CAUTION

When pulling out the camshaft, support it with a bar-like tool inserted through the side cover mounting section of the crankcase to prevent damaging the cam surfaces and shaft bushings.

4.2 Inspection and Repair

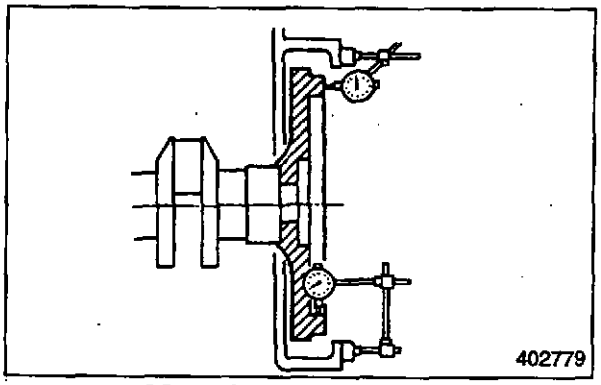
Flywheel and Ring Gear

Measuring the flywheel face and radial runouts.

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

Unit: mm (in.)

Item		Assembly Standard
Flywheel	Face runout	0.285 (0.0112) max.
	Radial runout	0.127 (0.0050) max.



Measuring flywheel runout

Fuel injection pump accessory drive

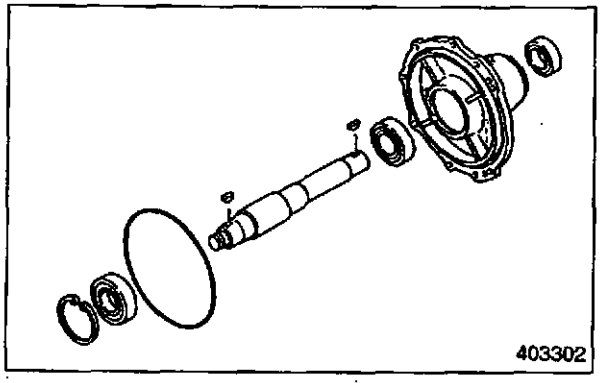
Inspecting fit of bearings

Inspect each bearing for smooth rotation. Replace the bearing if it rotates erratically or hums.

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

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

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



Unit: mm (in.)

Item		Nominal Value	Assembly Standard
Case bearing bore inside diamter		ø90 (3.54)	89.987-90.022 (3.54279 -3.54417)
		ø100 (3.94)	99.987-100.022 (3.93365 -3.93787)
Bearing	Outside dia.	ø90 (3.54)	89.985-90.000 (3.54272 -3.54331)
		ø100 (3.94)	99.985-100.000 (3.93642 -3.93701)
	Inside dia.	ø45 (1.77)	44.988-45.000 (1.77118 -1.77165)
		ø50 (1.97)	49.985-50.000 (1.96791 -1.96850)
Drive shaft bearing dia.		ø45 (1.77)	45.002-45.013 (1.77173 -1.77216)
		ø50 (1.97)	50.002-50.013 (1.96858 -1.96901)

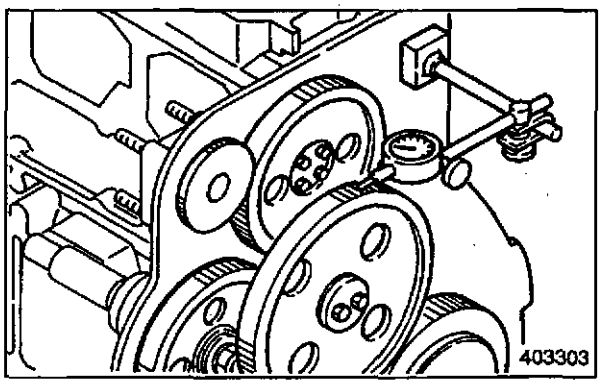
Timing Gears: Measuring Backlash

To measure the backlash between the gears, set up a dial gauge so that it contacts the pitch circle of the gear to measure. If a dial gauge is not available, measure the backlash by inserting a feeler gauge between the gear teeth. If the backlash exceeds the service limit, replace the worn gear.

Unit: mm (in.)

Item	Standard Clearance	Repair Limit	Service Limit
Timing gear backlash	0.12-0.18 (0.11-0.38) [0.11-0.38 (0.0043-0.0150)]	0.30 (0.0118)	0.50 (0.0197)

Shown in [ ] is the backlash between the crankshaft gear and oil pump idler gear.



Measuring timing gear backlash

NOTE

The injection pump accessory drive and governor drive are to be bolted together with the timing gear case.
This makes it necessary to install them to the rear plate temporarily with bolts and nuts when measuring the backlash.

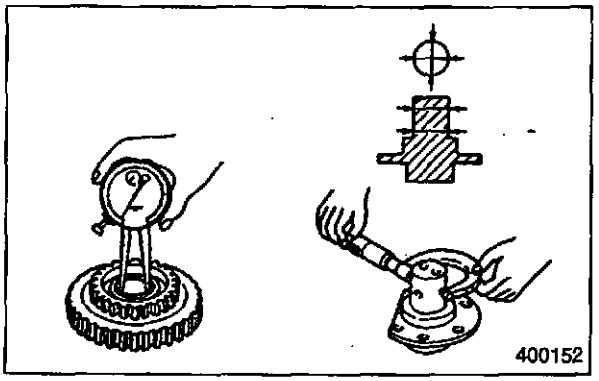
Idler Gears, Idler Gear Bushing, and Idler Gear Shafts

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

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

Unit: mm (in.)

Item	Norminal Value	Assembly Standard	Service Limit
Idler gear, bushing inside dia.	ø50 (1.97)	50.000-50.025 (1.96850 -1.96948)	50.060 (1.97086)
Idler gear shaft dia.	ø50 (1.97)	49.950-49.975 (1.96653 -1.96752)	49.900 (1.96456)



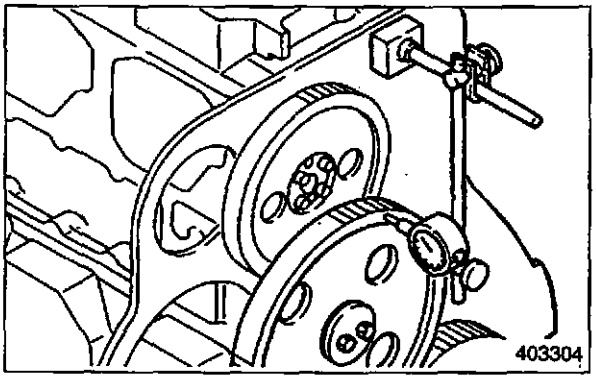
Measuring idler gear bushing and shaft

(2) Measuring idler gear end play

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

Unit: mm (in.)

Item	Standard Clearance	Service Limit
Idler gear end play	0.2-0.4 (0.008-0.016)	0.6 (0.024)



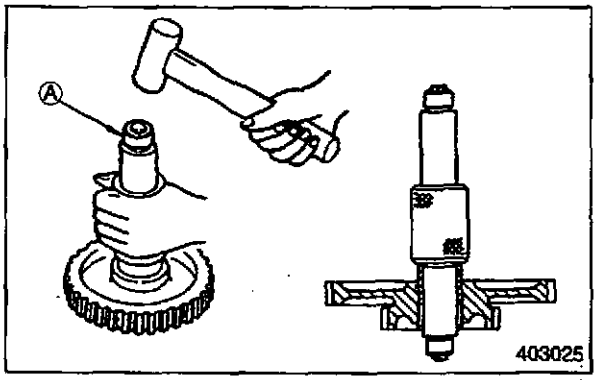
Measuring idler gear end play

(3) Replacing idler bushings

(a) Use an idler bushing puller Ⓐ (32591-02500) to remove the existing bushing.

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

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



Replacing the idler gear bushing

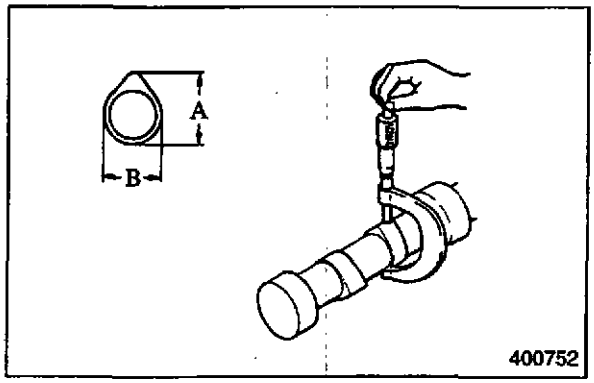
Camshafts and Camshaft Bushings

(1) Measuring cam lift

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

Unit: mm (in.)

Item	Assembly standard	Service Limit
Cam lift (A-B)	9.197-9.297 (0.36209-0.36602)	8.45 (0.3327)



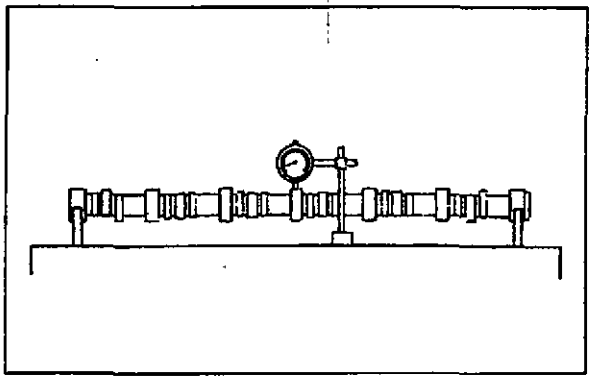
Measuring cam lift

(2) Measuring camshaft runout

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

⚠CAUTION

Set up a dial gauge on the camshaft, then turn the camshaft. Take one-half of the gauge indication as the runout.



Measuring camshaft runout

Unit: mm (in.)

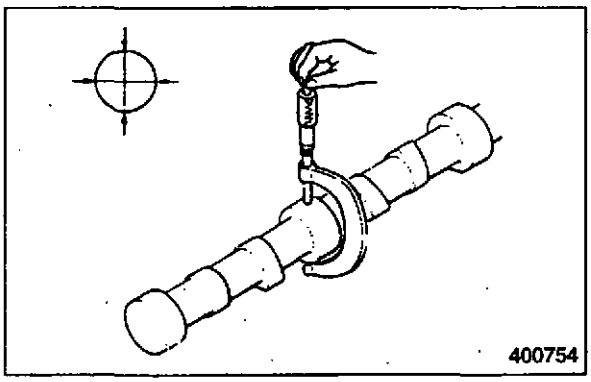
Item	Assembly Standard	Repair Limit
Camshaft runout	0.05 (0.0020) max.	0.08 (0.0031)

(3) Measuring camshaft journal diameter

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

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Camshaft journal dia.	ø84 (3.31)	83.92-83.94 (3.3039 -3.3047)	83.87 (3.3031)



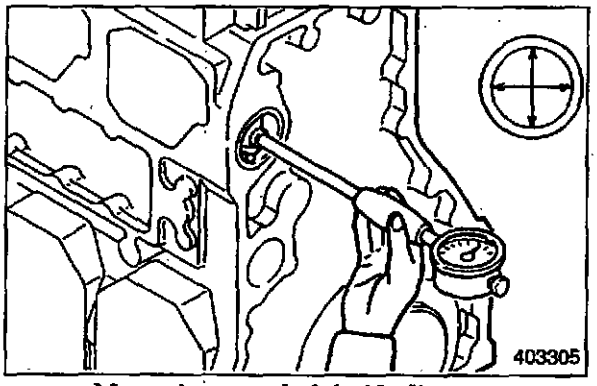
Measuring camshaft journal diameter

(4) Measuring camshaft bushing inside diameter

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

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Camshaft bushing inside dia.	ø84 (3.31)	84.000-84.035 (3.3071 -3.3085)	84.10 (3.3110)



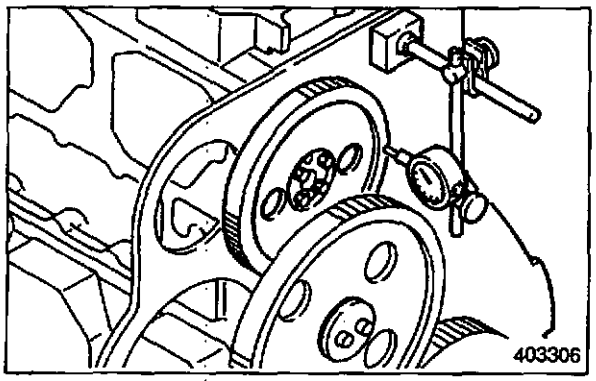
Measuring cam shaft inside diameter

(5) Measuring camshaft end play

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

Unit: mm (in.)

Item	Standard Clearance	Service Limit
Camshaft end play	0.10-0.25 (0.0039-0.0098)	0.40 (0.016)

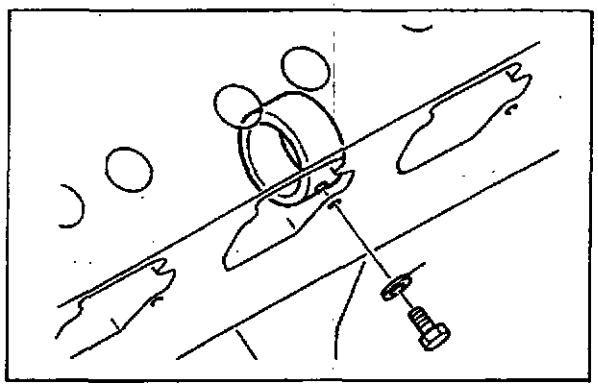


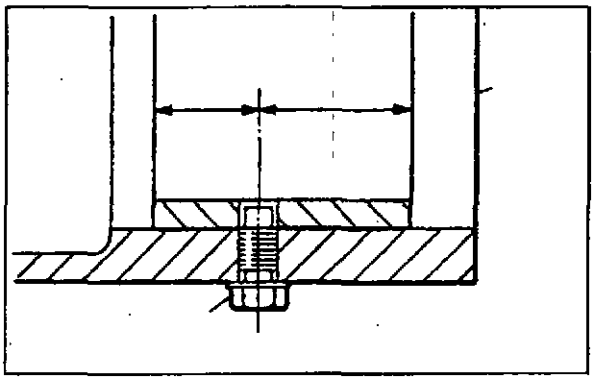
Measuring camshaft end play

(6) Replacing camshaft bushings

Install the bushings in the crankcase, then secure them in place with the set screws.
Before tightening the screws, be 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.

Use a wide bushing as the bearing for the rear section, and insert it in the correct direction.





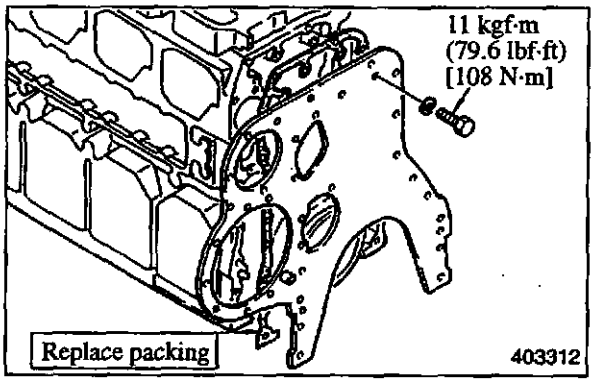
4.3 Reassembly

(1) Installing rear plate

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

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

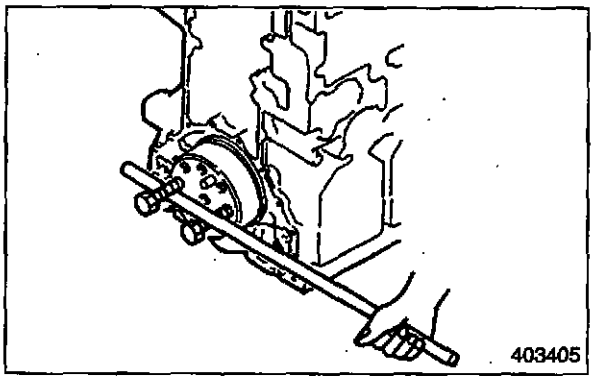
(c) Make sure that the lower end of rear plate is flush with the bottom of crankcase. Cut off the excess of the packing neatly along the edge of the plate.



(2) Cranking engine

(a) Install bolts (M22 x 1.5) in viscous damper mounting holes.

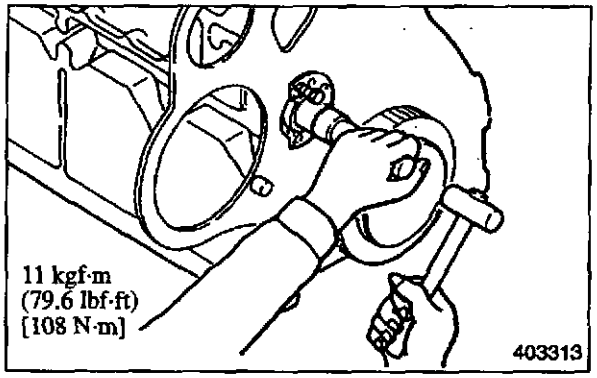
(b) Put the bar to the crankshaft, using the crankshaft pulley mounting bolts, and turn the crankshaft to bring No. 1 cylinder piston to top dead center on compression stroke.



(3) Installing idler gear shaft

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

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

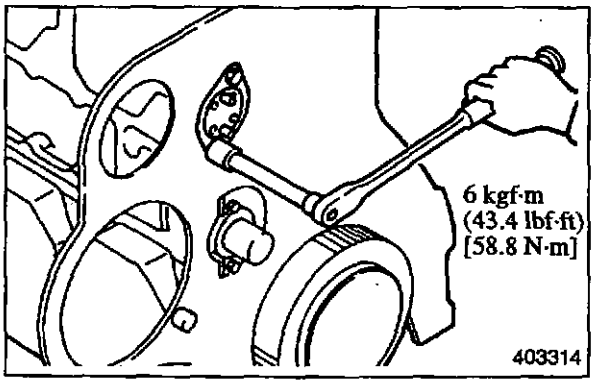


(4) Installing camshafts

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

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

(c) Make sure that the camshaft rotates lightly.

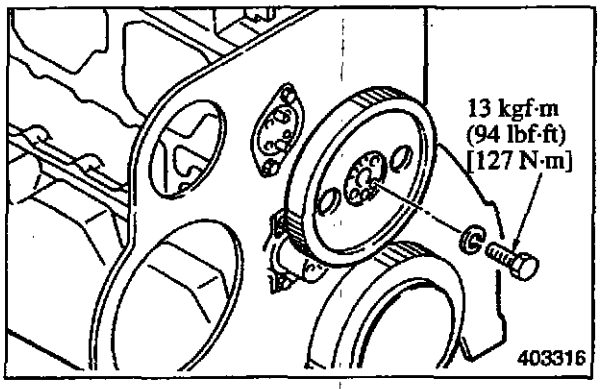


(5) Installing camshaft gear

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

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

(c) Make sure that the camshaft rotates lightly.

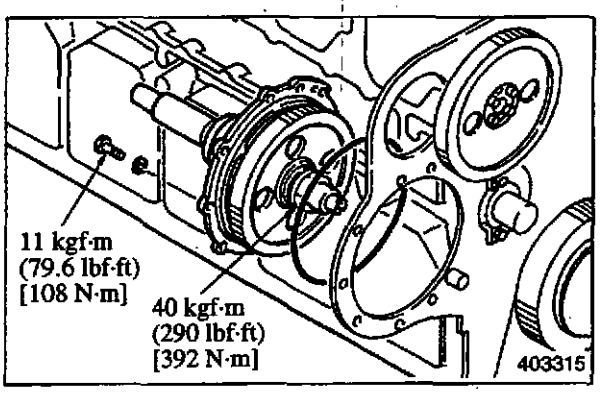


(6) Installing fuel injection pump accessory drive

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

(b) Fit the O-ring to the mounting flange of drive case, and install the case to the rear plate.

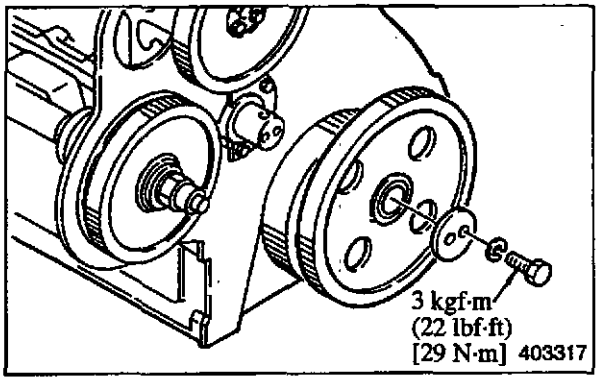
(c) Tighten the drive case mounting bolts to the specified torque.



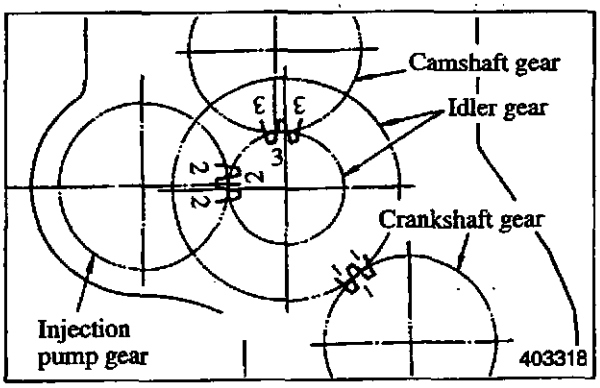
(7) Installing idler gear

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

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



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



Timing gear train

(8) Inspecting and adjusting timing gears after installation

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

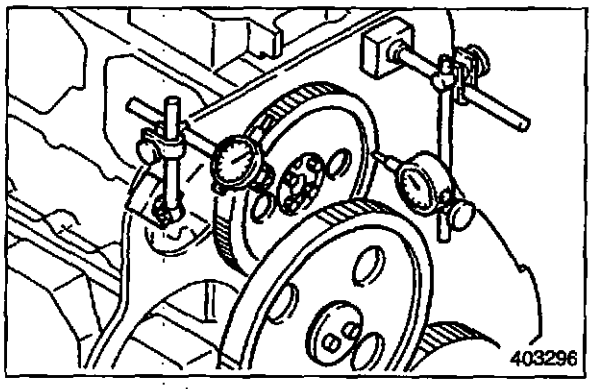
(Inspecting timing gear backlash and end play)

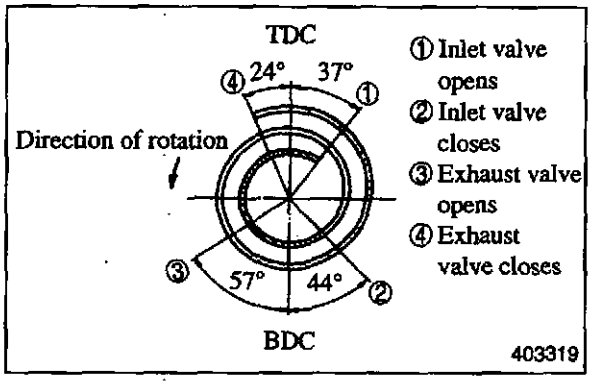
After installing the timing gears, inspect the backlash between the gears in mesh and the end play of each gear. (Refer to 3.2, Group No. 7.)

(Inspecting valve timing)

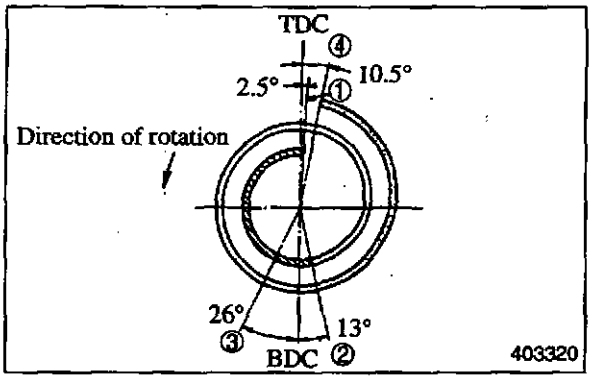
It is not necessary to inspect the valve timing, provided that all matching marks on the timing gears are aligned. Inspect the timing for verification as follows:

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





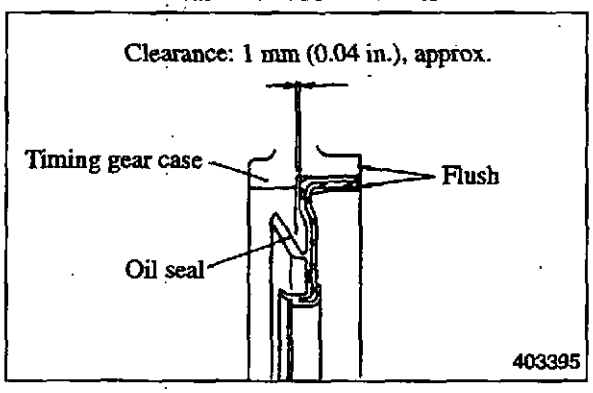
Valve timing diagram



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

(9) Installing timing gear case

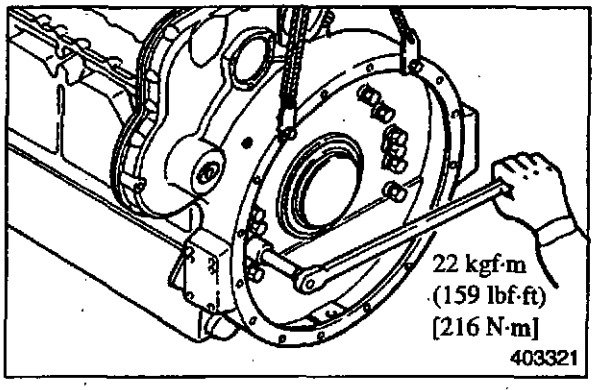
(a) Coat the oil seal lip with engine oil, and insert the seal into the bore of timing gear case until it is flush with the end face of the case.



(b) Apply sealant (HERDITE) to the timing gear case surface. Place the packing in position. Apply the sealant on the placed packing. Cut off the excess of the packing neatly along the bottom surface of the crankcase.

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

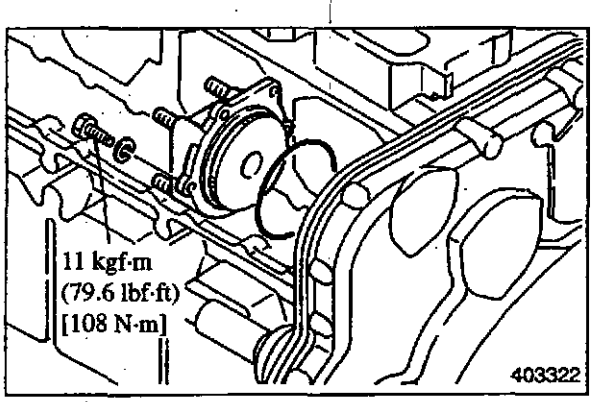
(d) Tighten the gear case mounting bolts evenly to the specified torque.



(10) Installing governor drive

(a) Fit the O-ring to the mounting flange of drive case (to which the drive shaft and gear have been installed), and install the case to the rear plate.

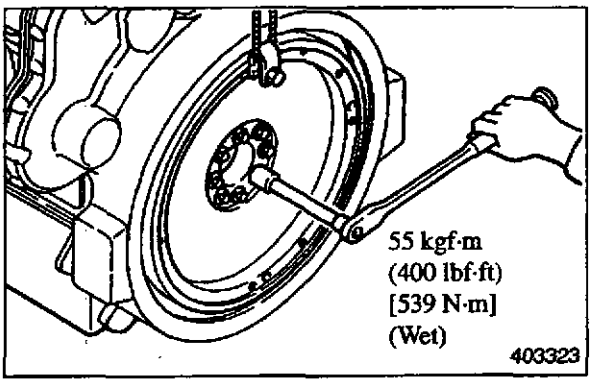
(b) Tighten the case mounting bolts to the specified torque.



(11) Installing flywheel

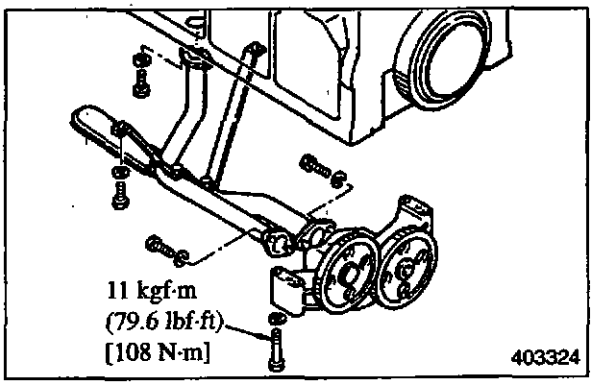
(a) Install the flywheel, making sure that the dowel pins enter their holes.

(b) Coat the threads and seats of flywheel mounting bolts with engine oil, and tighten the bolts to the specified torque. Inspect the face and radial runouts of the flywheel. (Refer to 3.2, Group No. 7.)



(12) Installing oil pump and oil strainer

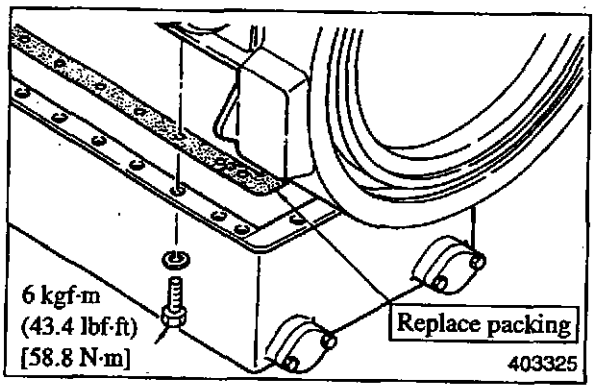
Measure the backlash between crankshaft gear and oil pump drive gear, and if it is not enough, make a shim adjustment.



(13) Installing oil pan

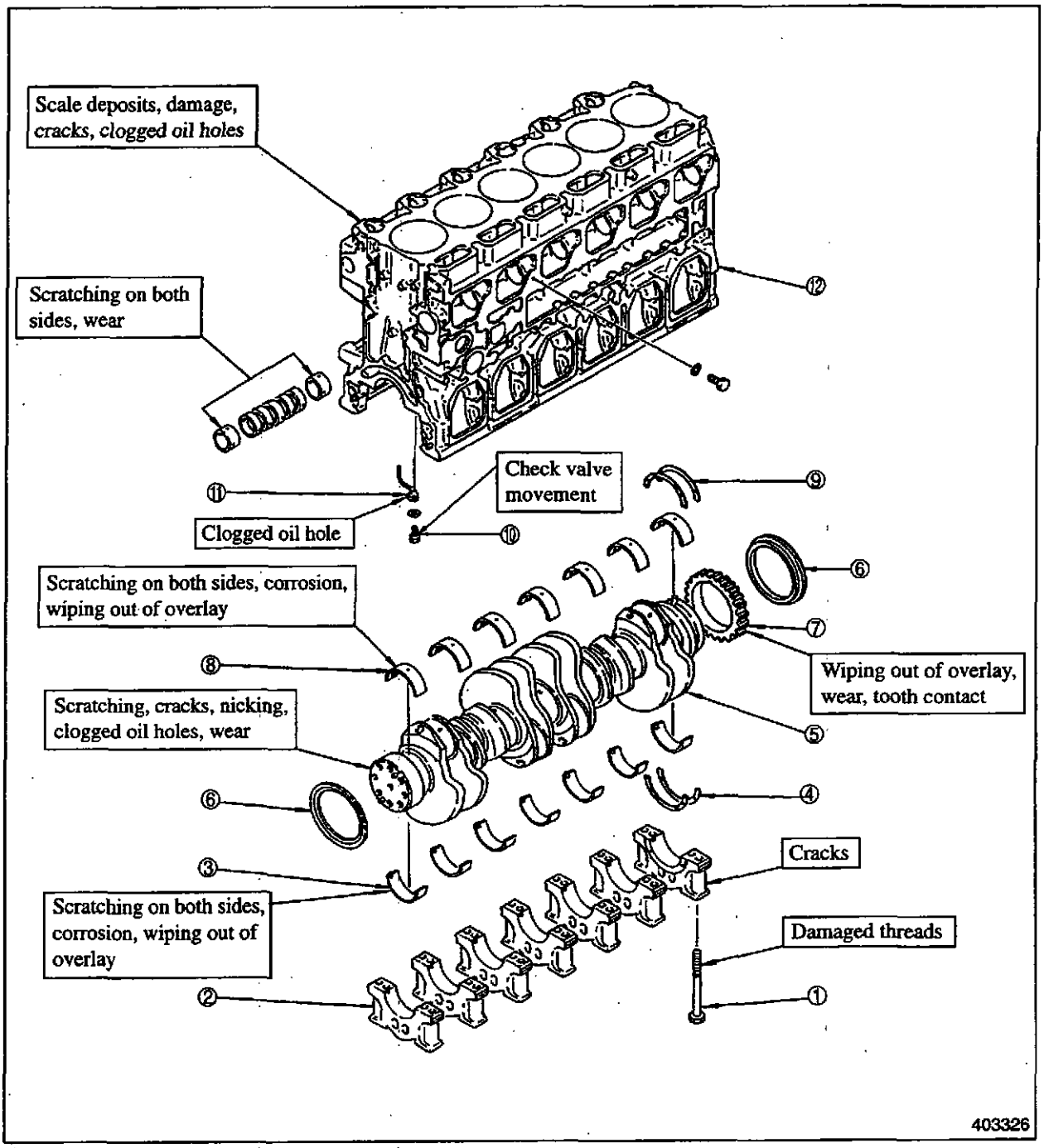
(a) Apply sealant (HERMESEAL S-2) to the joint surface of oil pan, and place the packing on the oil pan. Apply the same sealant to the packing, and install the oil pan to the crankcase.

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



5. Crankcase, Crankshaft, and Main Metals

5.1 Disassembly

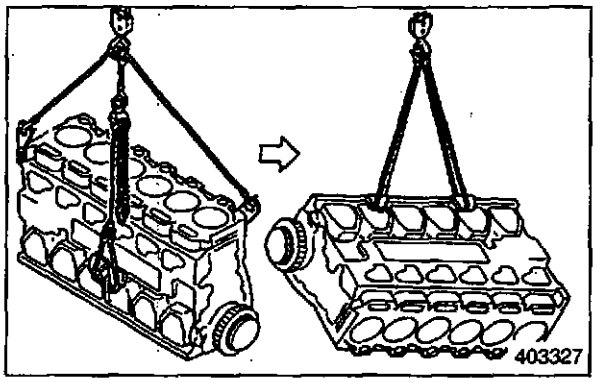


① Bolt
② Main metal cap
③ Main metal (lower shell)
④ Thrust plate
⑤ Crankshaft
⑥ Slinger
⑦ Crankshaft gear
⑧ Main metal (upper shell)
⑨ Thrust plate
⑩ Check valve
⑪ Piston cooling nozzle
⑫ Crankcase

(1) Turning the crankcase upside down

Use a block and tackle to lay the crankcase on its side. Attach wire ropes to the crankcase, then turn it upside down.

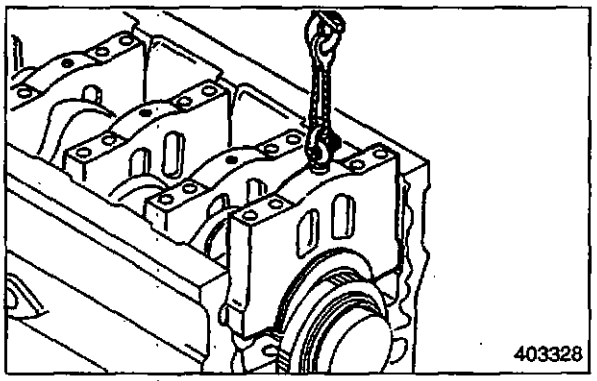
Crankcase and crankshaft weight:
S6R: 1000 kg (2205 lb), approx.
S6R2: 1100 kg (2426 lb), approx.



(2) Removing the main metal caps

(a) Unscrew the cap bolts ①. Use a cap remover or a crane (eye bolt M12 × 1.25) to remove the main bearing caps.

(b) Remove the thrust plates from the No. 7 bearing cap. Do not damage the thrust plates.

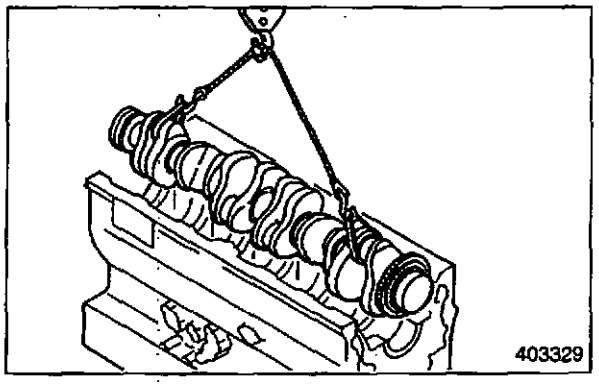


(3) Removing the crankshaft

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

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

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

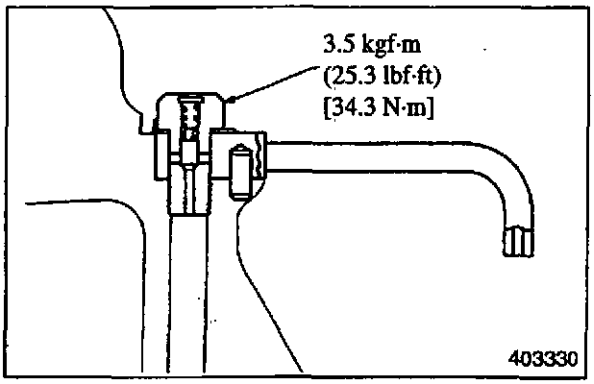


(4) Removing the oil jet nozzles

Remove the nozzles only when the oil holes are clogged or defective.

NOTE

Tighten the oil jet nozzle to the specified torque when reassembling.



5.2 Inspection and Repair

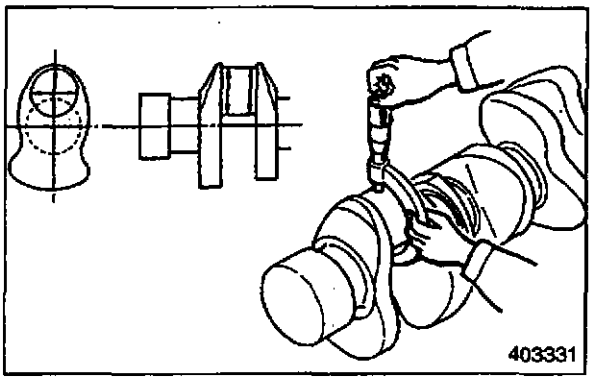
Crankshaft

(1) Measuring crank pin and journal diameters

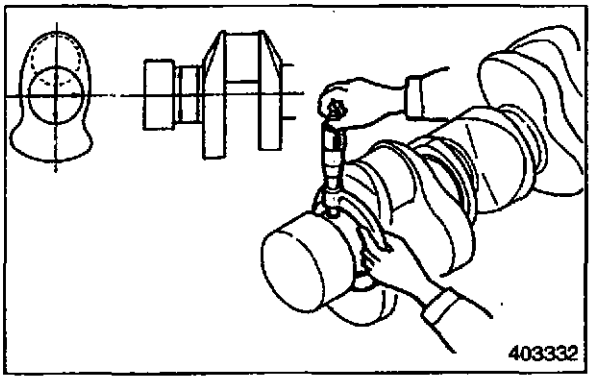
(a) Using a micrometer, measure the crank pin and journal diameters. If the diameter exceeds the repair limit, grind them to the next lower size: -0.25 mm (-0.0098 in.), -0.5 mm (-0.0197 in.), -0.75 mm (-0.0295 in.), or-1.00 mm (-0.0394 in.).

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

(c) If the -1.00 mm (0.0394 in.) undersize journals and crank pins exceed the repair limit, replace the crankshaft.



Measuring crankpin diameter



Measuring journal diameter

Unit: mm (in.)

Item		Nominal Value	Assembly Standard	Repair Limit
Crank pin dia.		ø125 (4.92)	–0.050 to –0.070 (–0.0020 to –0.0028)	–0.110 (–0.0043)
Journal dia.		ø140 (5.51)	–0.050 to –0.070 (–0.0020 to –0.0028)	–0.110 (–0.0043)
Pin, journal	Out of roundness		Dia. difference 0.01 max.	0.03 (0.0012)
	Taper		Dia. difference 0.02 max.	0.03 (0.0012)
	Fillet radius	7	$7.0\,^{0}_{-0.2}$ ($0.276\,^{0}_{-0.008}$)	
	Hardness		Hv >620	

Grinding dimensions for an undersize crankshaft

Unit: mm (in.)

	Undersize	Finishing Dimension	Out of roundness	Taper
Crankpin diameter	0.25 (0.0098)	124.68-124.70 (4.9087-4.9094)	0.01 (0.0004), maximum	0.02 (0.0008), maximum
	0.50 (0.0197)	124.43-124.45 (4.8988-4.8996)		
	0.75 (0.0295)	124.18-124.20 (4.8890-4.8898)		
	1.00 (0.0394)	123.93-123.95 (4.8791-4.8799)		
Journal diameter	0.25 (0.0098)	139.68-139.70 (5.4992-5.5000)		
	0.50 (0.0197)	139.43 139.45 (5.4894-5.4901)		
	0.75 (0.0295)	139.18-139.20 (5.4795-5.4803)		
	1.00 (0.0394)	138.93-138.95 (5.4697-5.4705)		

(2) Grinding the crankshaft

If the crankshaft is refinished in compliance with any grinding dimensions of the undersizes of the main bearing and the connecting rod bearing, and if the bearings are replaced by undersized bearings, it is not necessary to check the bearing contact pattern.

When grinding the crank pins and journals, be sure to produce the same fillet radius as the original. They should have a hardness of 620 (Vickers Hardness Number). If necessary, re-harden the crank pins and journals, and inspect them for cracks by conducting a magnalux (magnetic particle) test. After grinding, finish the journals and crank pins to $\frac{0.8S}{\nabla\nabla\nabla}$.

(3) Measuring crankshaft end play

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

(b) If the end play still exceeds the repair limit even after the new thrust plates have been installed, replace the plates with the next oversize plates. There are three sizes for the thrust plates:

+ 0.25 mm (+0.0098 in.)

+ 0.50 mm (+0.0197 in.)

+ 0.75 mm (+0.0295)

Generally the rear journal is likely to wear more rapidly than the front journal. This means that replacement of the rear thrust plates will generally be sufficient.

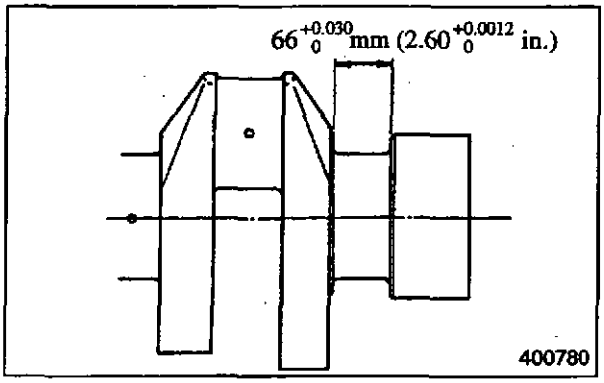
Unit: mm (in.)

Item	Standard Clearance	Service Limit
Crankshaft end play	0.20-0.40 (0.0079 to –0.0157)	0.50 (0.0197)

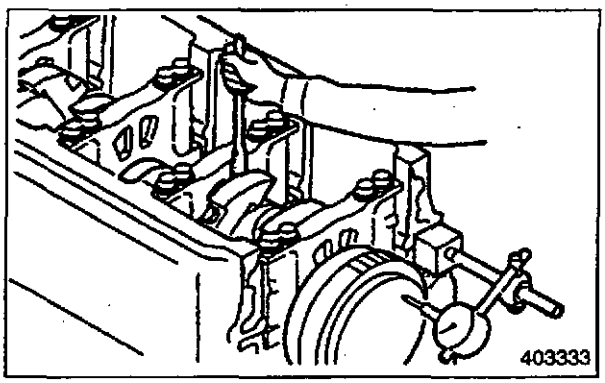
Crankshaft Journal Grinding Dimensions for Oversize Thrust Plates

Unit: mm (in.)

Item	Oversizes for Journal or Thrust Plates	Oversizes for Journal and Thrust Plates	Tolerance
+0.25 (+0.0098) O.S	66.25 (2.6083)	66.50	+0.03 0 ($^{+0.0012}_{0}$)
+0.50 (+0.0197) O.S	66.50 (2.6181)	67.00	
+0.75 (+0.0295) O.S	66.75 (2.6279)	67.50	



Measuring thrust bearing journal length



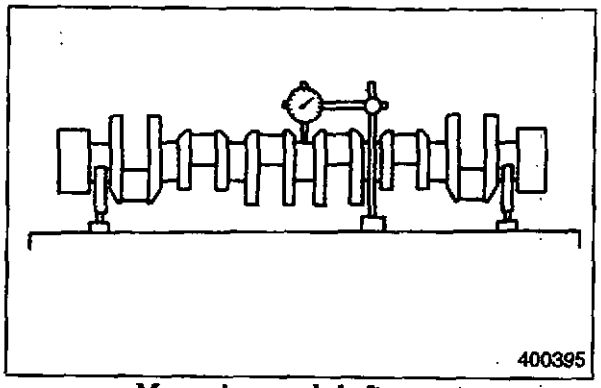
Measuring crankshaft end play

(4) Measuring crankshaft runout

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

Unit: mm (in.)

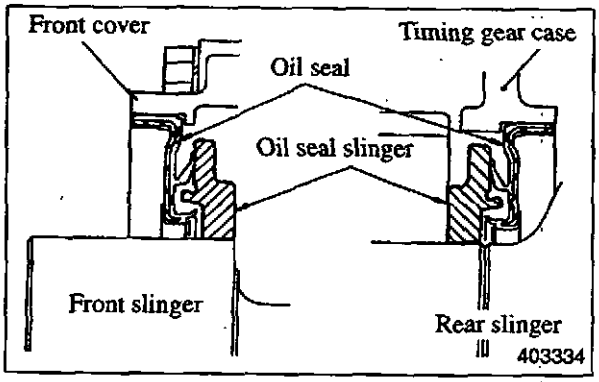
Item	Assembly Standard	Repair Limit
Crankshaft runout	0.04 (0.0016) max.	0.10 (0.0039)



Measuring crankshaft runout

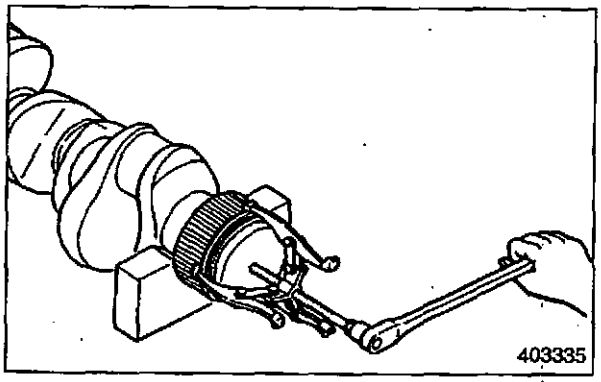
(5) Replacing the oil seal slinger

Replace the slinger if it is pitted, scratched, or distorted enough to cause oil leaks.



(Removing the Slinger)

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

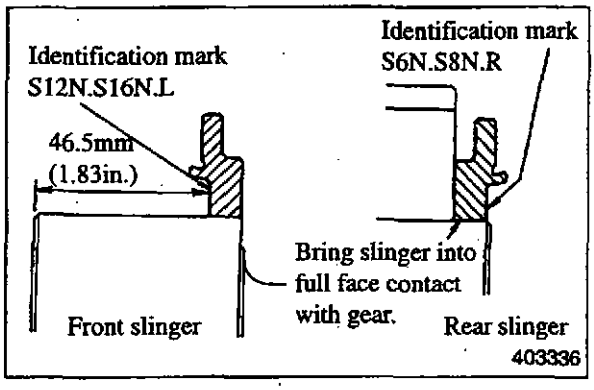


(Installing the slingers)

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

NOTE

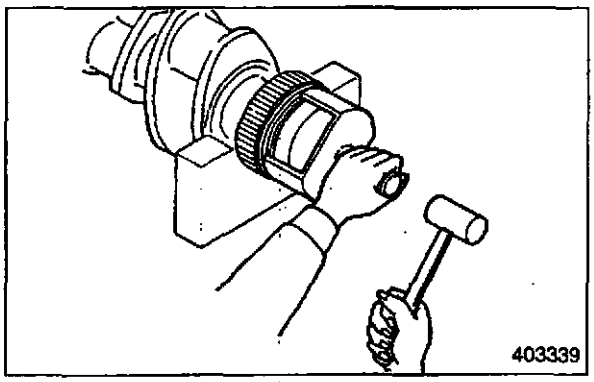
Be sure to install the front and rear slingers to the front and rear sides of crankshaft respectively, or oil leakage will occur.



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

(c) Drive the rear slinger until it touches the gear. Drive the front slinger until the dimension shown at right is obtained.

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



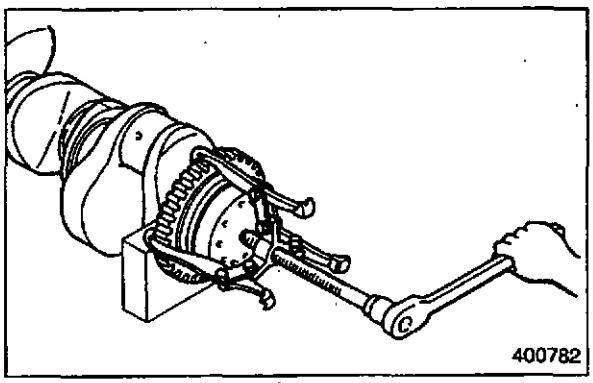
(6) Replacing the crankshaft gear

(Removing the Gear)

(a) Use a gear puller to remove the gear from the crankshaft.

NOTE

Do not remove the gear by hitting it with a hammer.

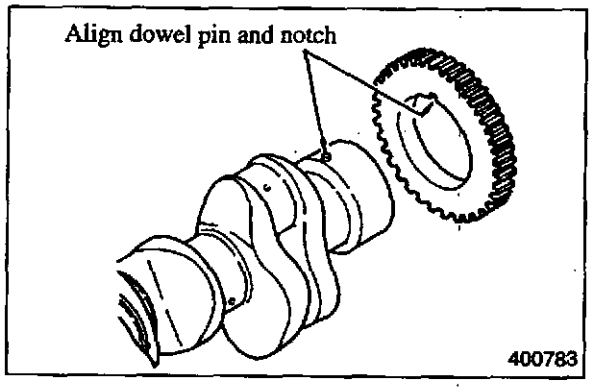


(Installing the Gear)

(a) Before installing the crankshaft gear, measure the inside diameter of the crankshaft gear to be sure that the fit is 0.0106 - 0.171 mm (0.00417 - 0.00673 in.).

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

(c) Drive the rear crankshaft gear onto the crankshaft by tapping the end face of the gear lightly with a copper hammer. Be sure the crankshaft dowel pin enters the notch in the gear.



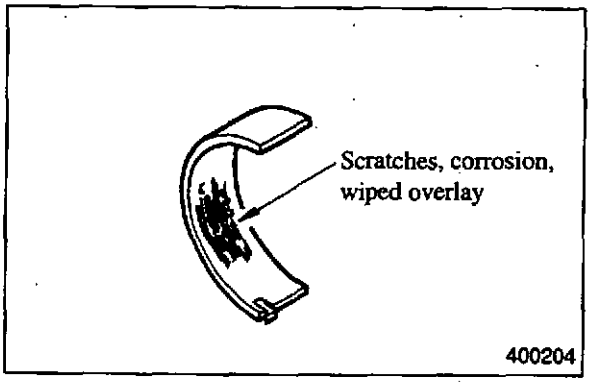
NOTE

(a) Install the gear to the crankshaft until it touches the collar.
(b) Do not mistake the direction of gear installation.

Main Metal

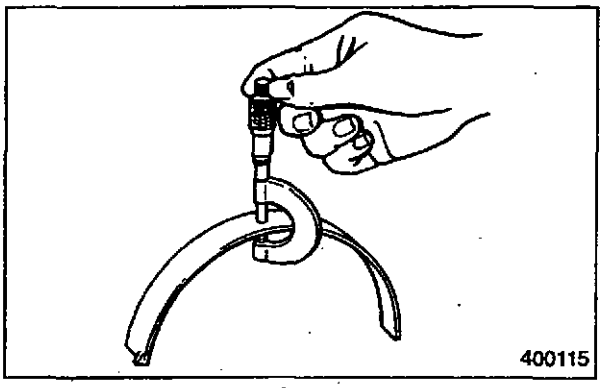
(1) Inspection

Inspect each metal shell for abnormal contact such as scratching, corrosion, wiped overlay, etc. Also check for signs of poor seating in the bore of the crankcase or metal cap.



(2) Measuring metal thickness

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



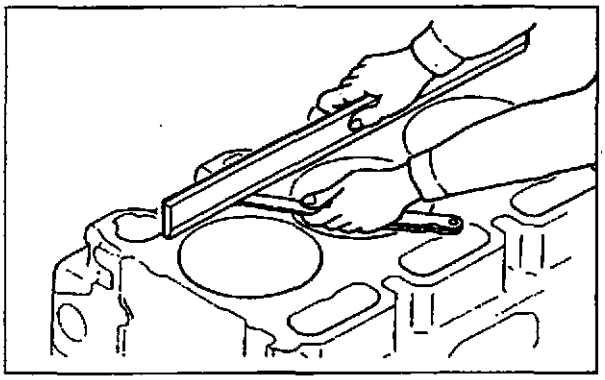
Measuring main metal thickness

Unit: mm

Item		Nominal Value	Assembly Standard	Service Limit
Main metal thickness (center)	STD	4.5 (0.138)	3.467-3.480 -(0.13650-0.13701)	4.425 (0.13484)
	-0.25 (-0.0098)	3.625 (0.14272)	3.592-3.605 -(0.14142-0.14193)	3.550 (0.13976)
	-0.50 (-0.0197)	3.75 (0.14764)	3.717-3.730 -(0.14634-0.14685)	3.675 (0.14468)
	-0.75 (-0.0295)	3.875 (0.15256)	3.842-3.855 -(0.15126-0.15177)	3.800 (0.14961)
	-1.00 (-0.0394)	4.000 (0.15748)	3.967-3.980 -(0.15618-0.15669)	3.925 (0.15453)

(3) Replacing main metals

If the thickness exceeds the service limit, either replace the main metals as above, or refinish the crankshaft and use undersize bearings. If the crankshaft is refinished in compliance with any of the undersizes, it is not necessary to check the metal contact pattern.


Measuring crankcase gasketed surfaces

Crankcase

(1) Measuring gasketed surface warpage

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

Unit: mm (in.)

Item	Assembly Standard	Repair Limit
Crankcase gasketed surface warpage	0.1 (0.004) max.	0.2 (0.0079)

NOTE

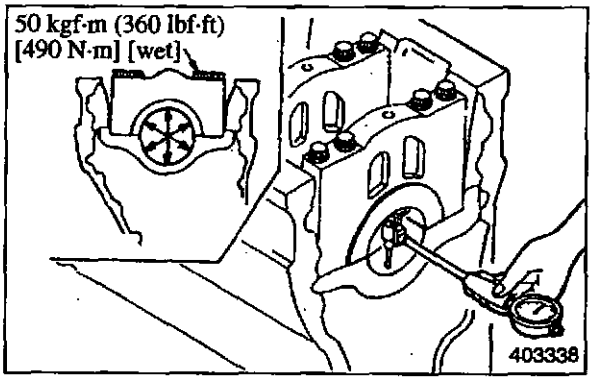
Do not grind the crankcase more than necessary to remove warpage. Excessive grinding can cause the piston protrusion to exceed assembly standard. (Refer to (4) for section 2.2, "Pistons" Group No.7.)

(2) Measuring main metal bore diameter

Secure the end metal cap to the specified torque, and measure the bore diameter in the cross direction.

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Main metal bore dia.	ø147 (5.79)	147.000-147.025 (5.78739-5.78837)	147.035 (5.78877)



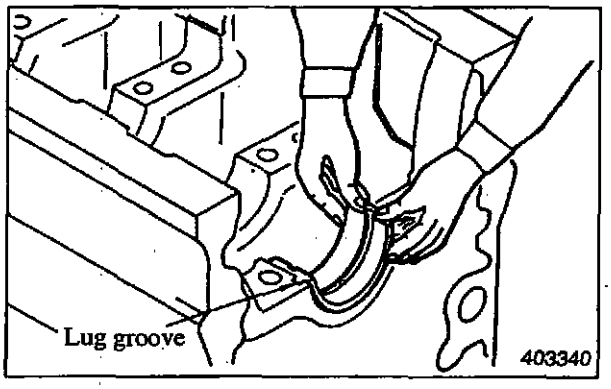
Measuring main metal bore diameter

5.3 Reassembly

(1) Installing the main metal

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

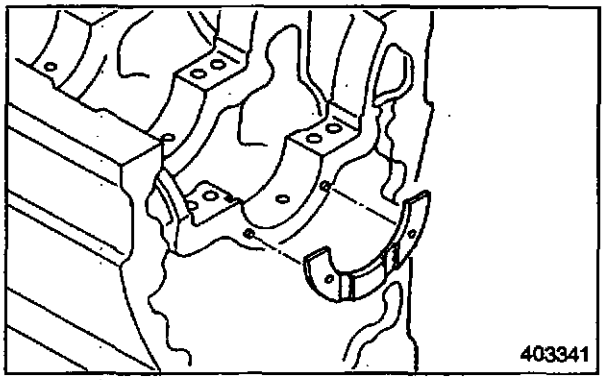
(b) Lightly coat the inside surface of the shells with engine oil.



(2) Installing thrust plates

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

(b) After installing the crankshaft, install the inner thrust plate with the oil groove facing inside the crankcase.

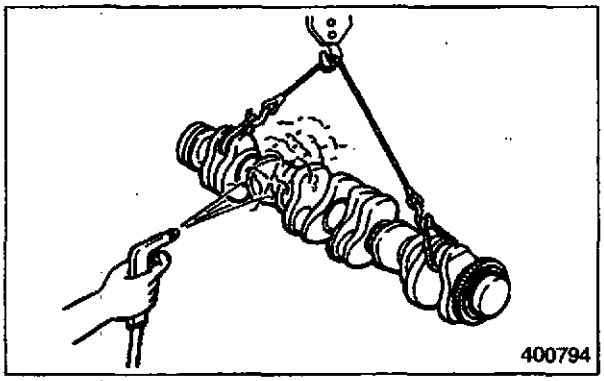


(3) Installing the crankshaft

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

NOTE

After washing the crankshaft, make sure that the oil holes are clean and not clogged.



(b) Hold the crankshaft horizontally with a hoist, then carefully put it on the crankcase.

(c) Lightly coat the journals with engine oil.

(4) Installing main metal caps

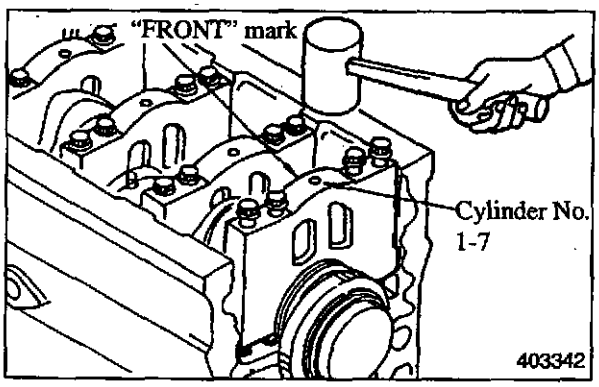
(a) Fit the lower shell of the metal to each metal cap.

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

(c) From the front side of the crankcase, metals 1 to 7 are stamped on the caps. Install the caps with these numbers on the front of the crankcase.

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

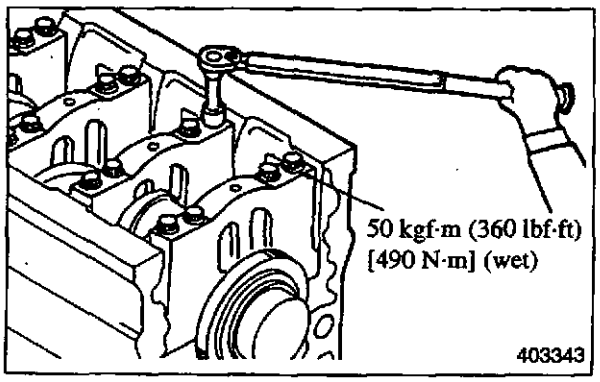
(e) Use a soft hammer to drive in the bearing caps evenly.



(5) Installing bearing cap bolts

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

(b) Make sure that the crankshaft rotates smoothly.

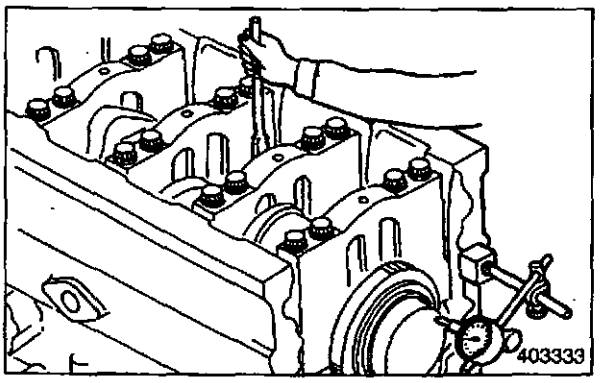


(6) Measuring crankshaft end play

(a) Tighten No. 1 through No. 6 metal cap bolts, mounting bolts to the specified torque, with the No. 7 cap bolt temporarily tightened, then measure the end play.

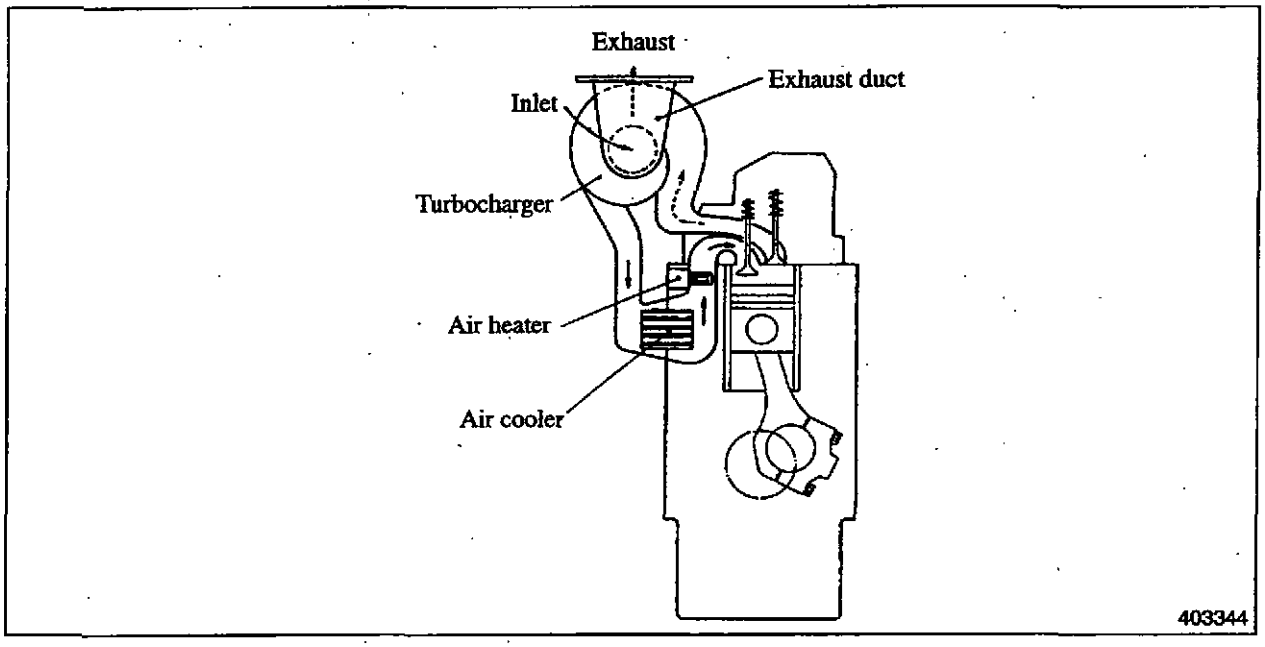
(b) After tightening the No. 7 cap bolts, make sure that the end play is correct.

(c) Confirm that all cap bolts are tightened to the specified torque.
(Refer to section 4.2 Group No. 7.)



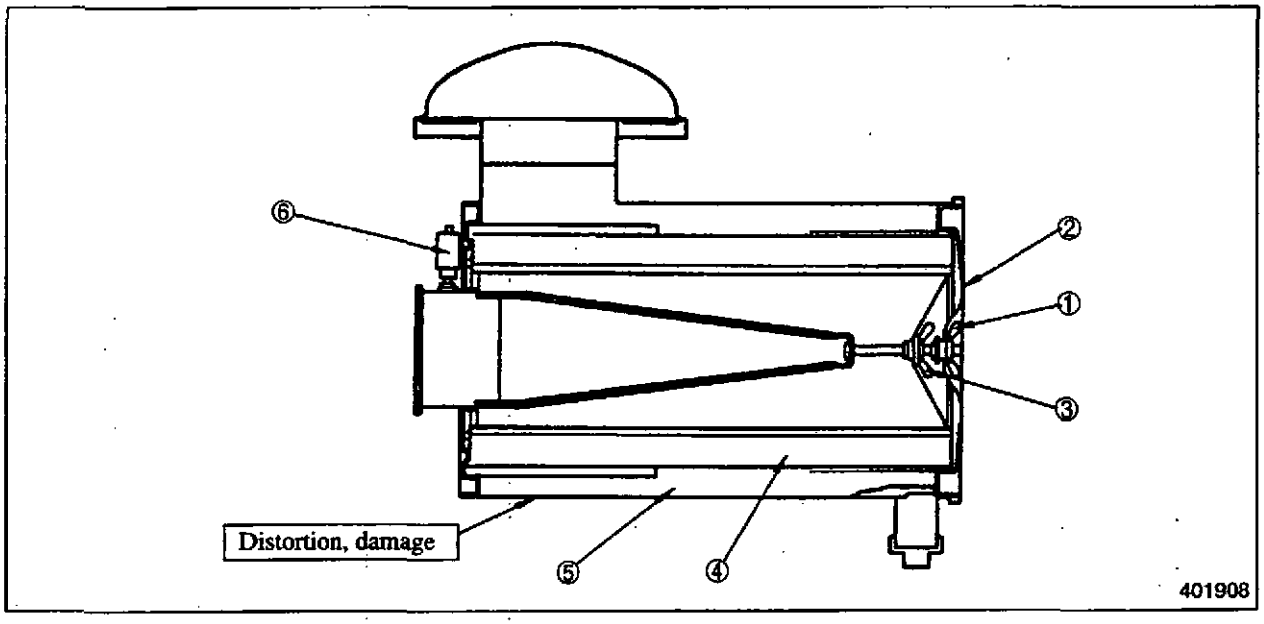
INLET AND EXHAUST SYSTEMS

1. Description



2. Air cleaner

Disassembly and Inspection



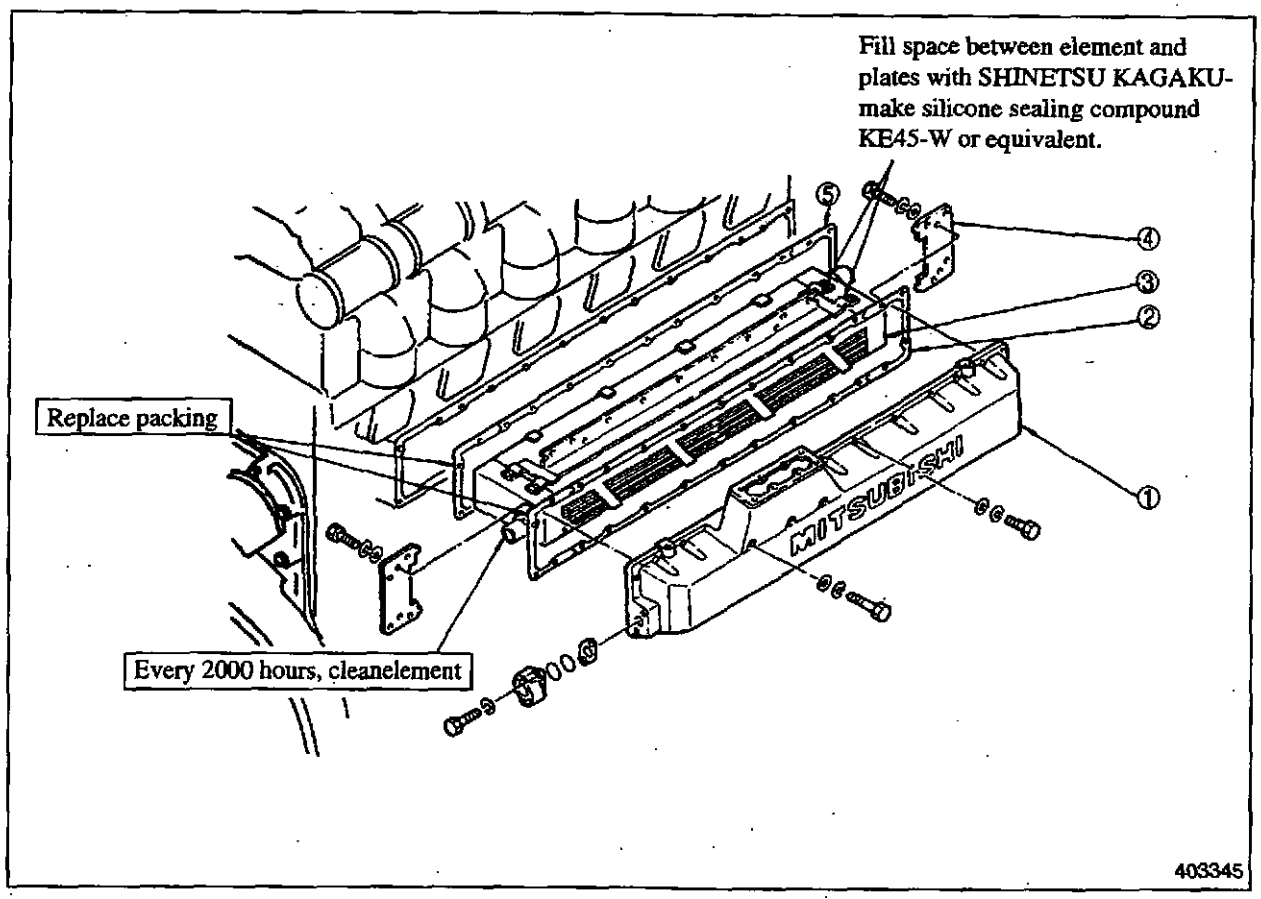
① Wing nut
② Cover
③ Wing nut
④ Element
⑤ Air cleaner body
⑥ Dust indicator

NOTE

When you remove 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



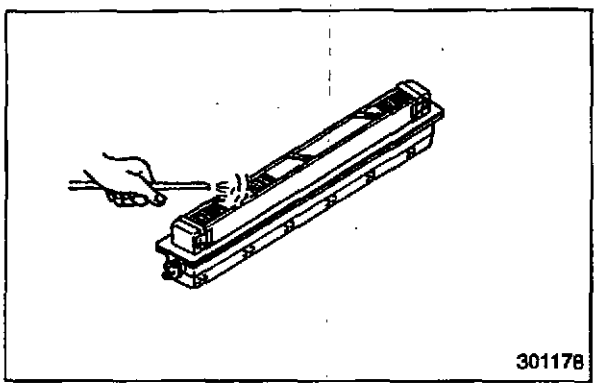
① Air cooler case
② Packing
③ Element
④ Plate
⑤ Packing

3.2 Inspection

(1) Cleaning air coolers

(a) Remove dirt built up from the air cooler by directing high pressure air of 3 to 5kgf/cm^2 (43 to 71 psi) [0.3 to 0.5 MPa] (maximum) in the direction opposite to air flow. Inspect the cooler for corrosion and cracks.

(b) Wash the fresh water or salt water pipes in water and caustic soda lime, then remove scale deposits.

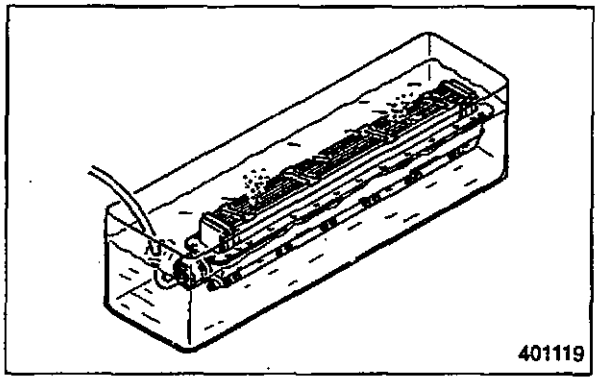


(2) *Inspecting air coolers for air tightness*

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

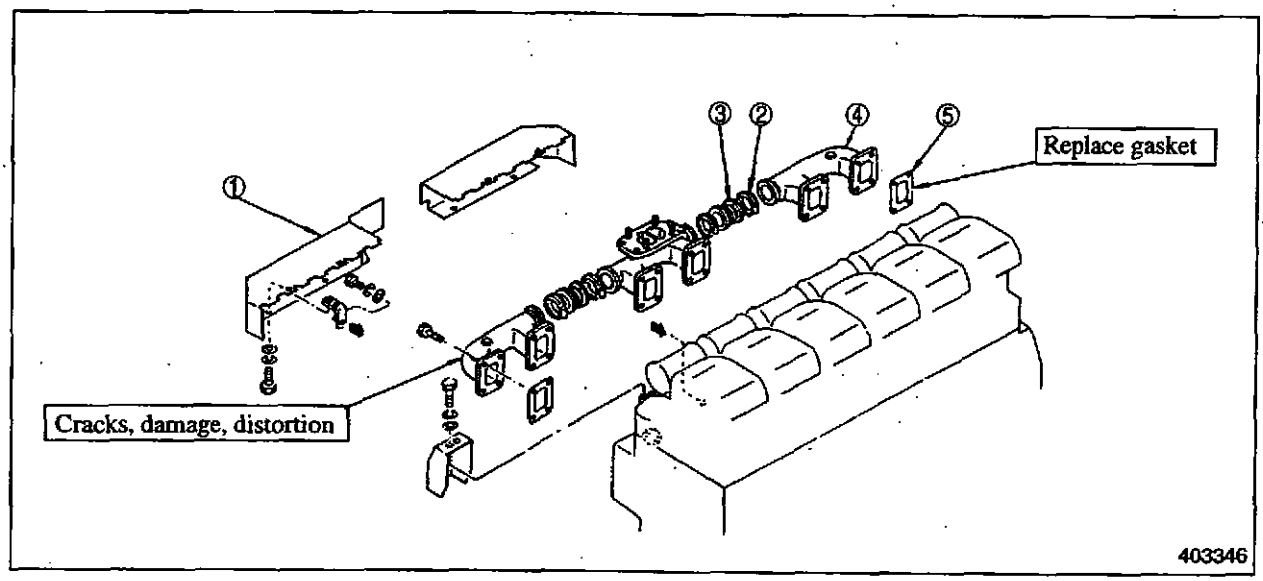
⚠CAUTION

A fresh water air cooler differs from a salt water type in construction and material. Keep this in mind when you handle a cooler.



4. Exhaust Manifold

Disassembly and Inspection



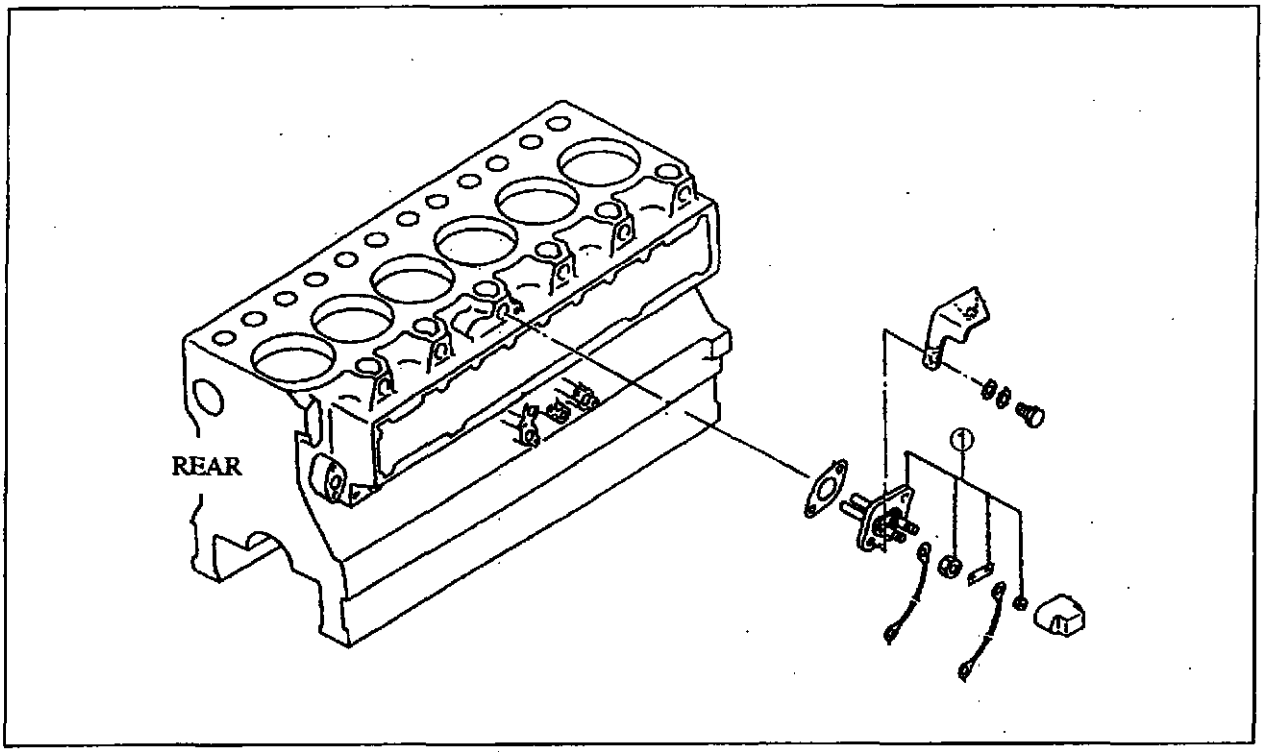
① Insulator
② Coupling
③ Flexible joint
④ Exhaust manifold
⑤ Gasket

NOTE

(a) Place each gasket with the "MANIFOLD" mark on the exhaust manifold side.
(b) If any of the gaskets requires replacement, replace all the cylinder together.

5. Air Heater

5.1 Disassembly



① Air heater assembly

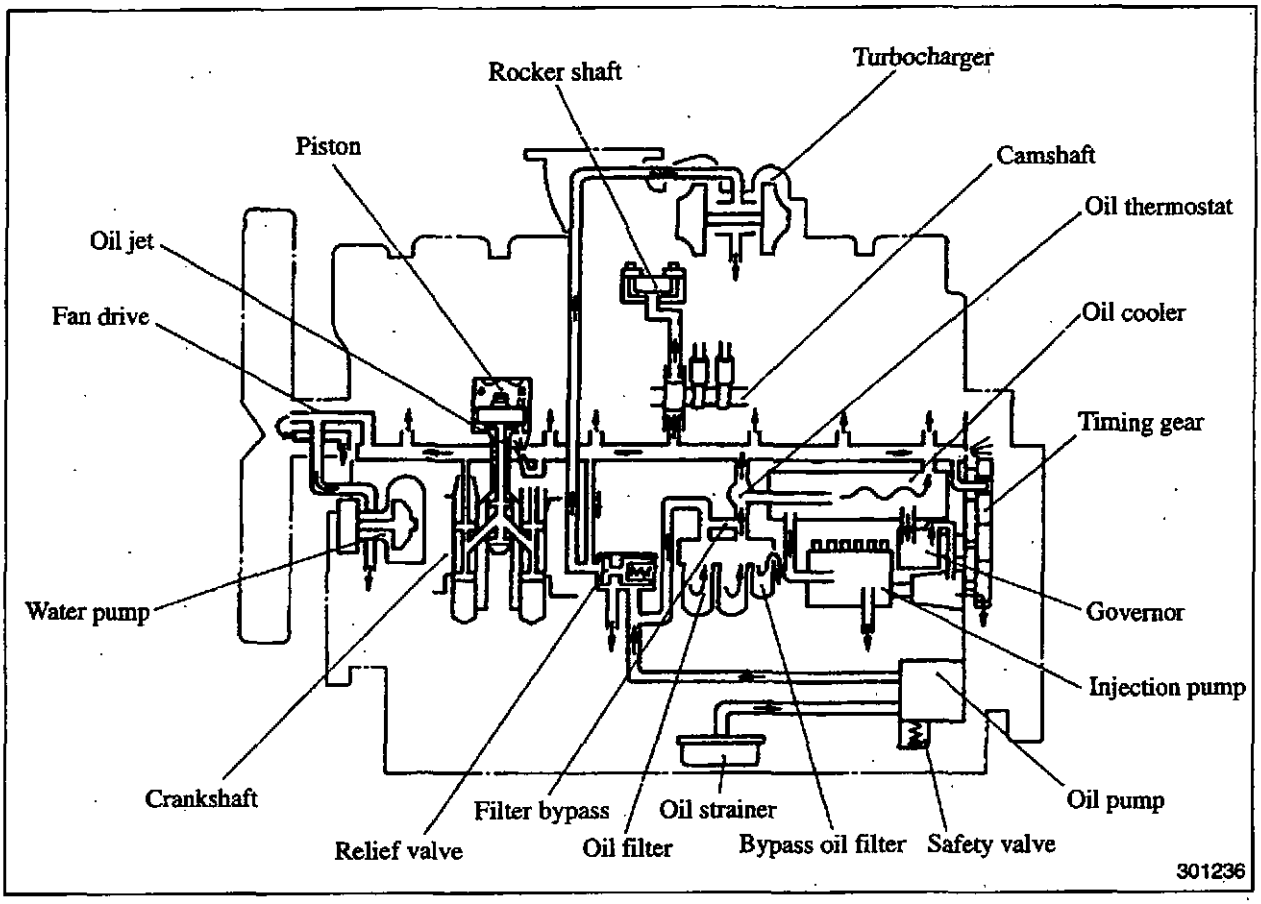
5.2 Inspection

(a) When the starter switch is set to "HEAT", use a galvanometer or an inspection lamp to check that electricity is flowing through the indicator, the heater relay switch, and air heater.

(b) Confirm that it takes 50-60-seconds for the indicator lamp to come on after setting the starter switch to "HEAT". If the interval is too short, or the indicator lamp does not come on, use a tester to check the indicator and the air heater for a short or broken connection.

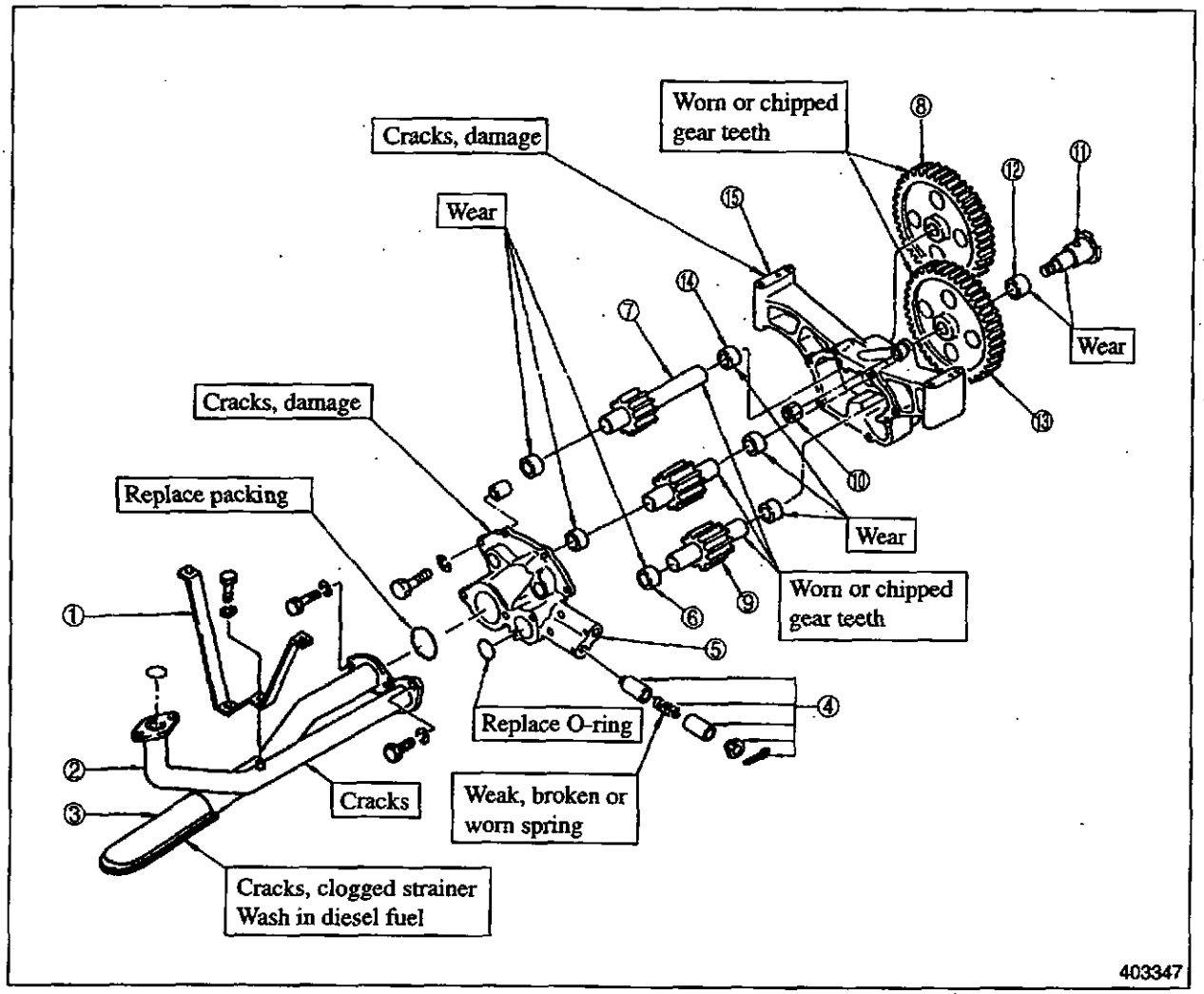
LUBRICATION SYSTEM

1.Description



2. Oil Pump and Safety Valve

2.1 Disassembly



① Support
② Oil pipe
③ Oil strainer
④ Safety valve
⑤ Pump cover
⑥ Bushing
⑦ Drive gear
⑧ Oil pump gear
⑨ Driven gear
⑩ Nut
⑪ Spindle
⑫ Bushing
⑬ Idler gear
⑭ Bushing
⑮ Pump case

NOTE

Before removing the gears, measure the backlash of each pair of gears. If the measurement exceeds the service limit, replace the gears.

2.2 Inspection

(1) Inspecting oil pump gear backlash

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

Unit: mm (in.)

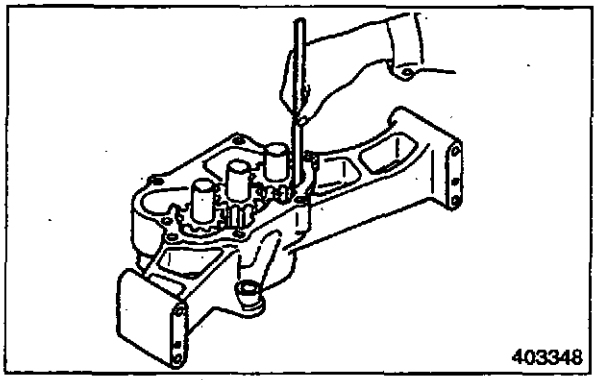
Item	Standard Clearance	Service Limit
Backlash between oil pump gear and idler gear	0.087-0.316 (0.0034 -0.0124)	0.3 (0.012)

(2) Measuring pump gear radial clearance

Use a feeler gauge, measure the radial 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
Pump gear radial clearance	60 (2.36)	0.100-0.196 (0.0039 -0.0077)	(Tip clearance) 0.35 (0.0138)



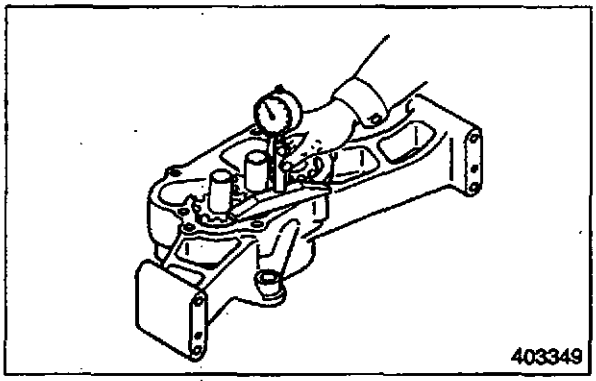
Measuring pump gear radial clearance

(3) Measuring pump gear end clearance

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

Unit: mm (in.)

Item	Nominal Value	Standard Clearance	Service Limit
Pump gear end clearance	34 (1.34)	0.050-0.114 (0.00197 -0.00449)	0.25 (0.0098)



Measuring pump gear end clearance

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

(a) Check the gear teeth. Replace gears if they are defective.

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

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Shaft diameter	25 (0.98)	24.947-24.960 (0.98216 -0.98268)	24.900 (0.98031)
Bushing inside diameter		25.000-25.021 (0.98425 -0.98508)	25.100 (0.98819)

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

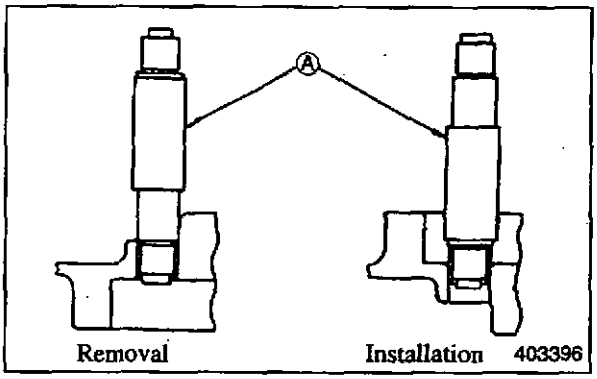
Measure the diameter of the spindle and the inside diameter of the bushing to determine the clearance. If the clearance exceeds the Service limit, replace the bushing.

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Spindle diameter	25 (0.98)	24.947-24.960 (0.98216 -0.98268)	24.900 (0.98031)
Bushing inside diameter		25.000-25.021 (0.98425 -0.98508)	25.100 (0.98819)

(6) Replacing oil pump bushings

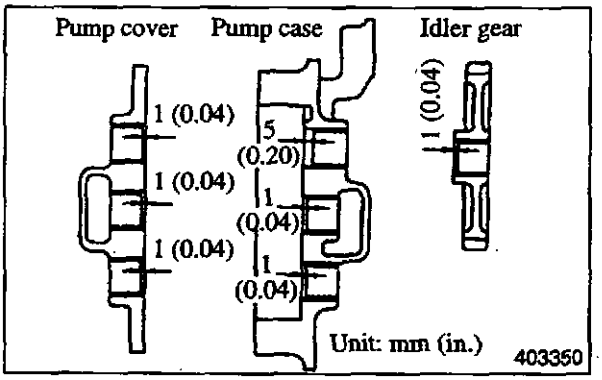
(a) Use oil pump bushing tool Ⓐ to remove the bushings for removal. If it is difficult to remove the bushings, replace the bushings and related parts as an assembly.



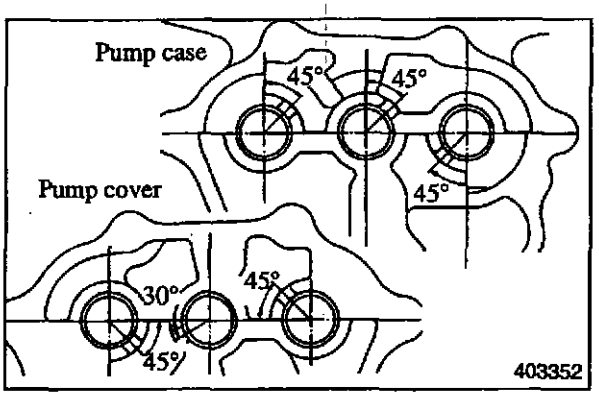
Replacing oil pump case bushing

(b) The press-in depths of the bushings are as shown at right.

(c) After installing each bushings, ream its inside diameter to $25H7^{+0.021}_{0}$ mm ($0.98H7^{+0.00083}_{0}$ in.).



(d) When installing the bushings to the pump case and pump cover, align the bushing ends with oil grooves.



Oil pump bushing end gap position

(7) Inspecting the safety valve

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

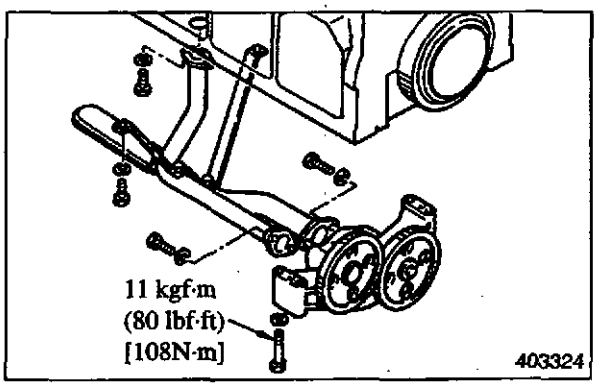
Item	Assembly Standard
Safety valve opening pressure	14±1 kgf/cm² (199±14) [1.37±0.10 MPa]
Safety valve spring length under test force/test force, mm (in.)/kgf (lbf) [N]	67.2 (2.64)/39.2 (86.4) [384.4]

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

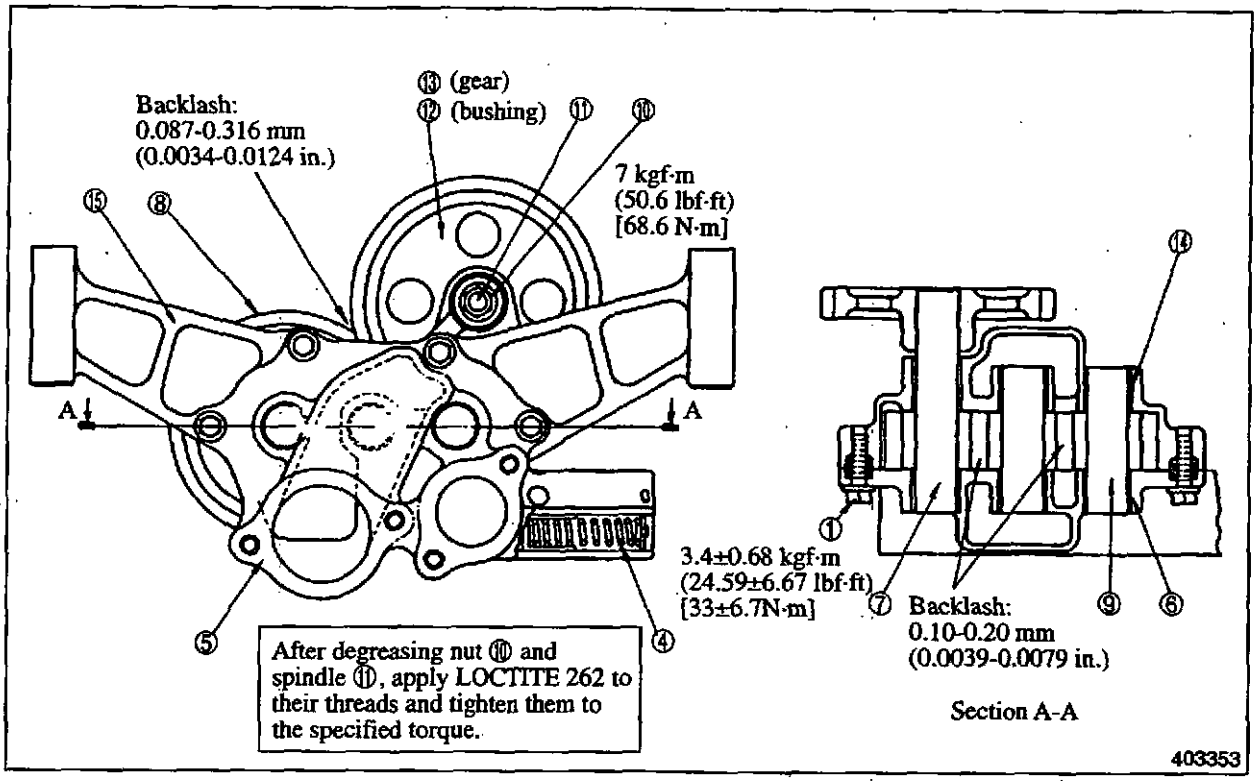
After installing the oil pump to the crankcase, measure the backlash. If the measurement exceeds the assembly standard, adjust the backlash by inserting shim(s).

Unit:mm (in.)

Item	Assembly Standard
Backlash between oil pump idler gear and crankshaft gear	0.11-0.38 (0.0043-0.0150)



2.3 Reassembly



Reassembling Order

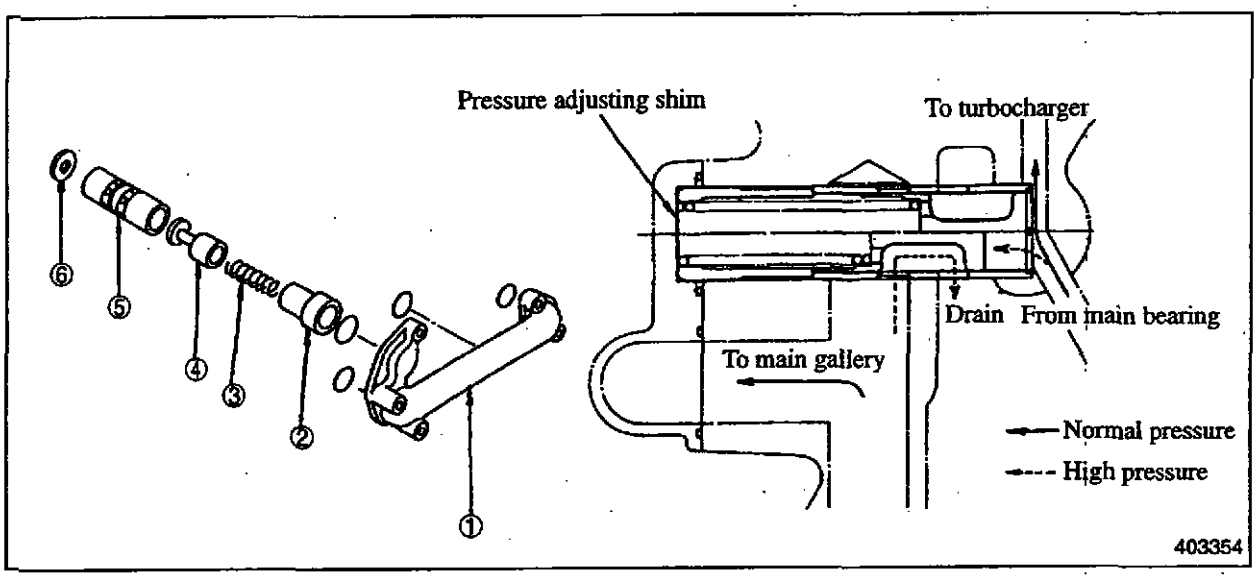
⑤→⑥
⑮→⑭→⑦→⑧→⑨→①→②→⑩
⑬→⑫→⑪

NOTE

Coat the pump parts with engine oil before installing them. Apply a thick coat of engine oil to the threads and seating faces of nuts (except for flange nuts) and bolts when thightening them.

3. Relief Valve

3.1 Disassembly



① Oil pipe, O-ring
② Stopper
③ Spring
④ Relief valve
⑤ Sleeve
⑥ Plate

3.2 Inspection

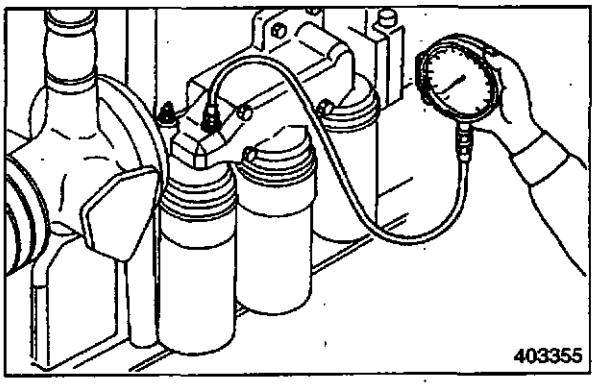
(1) Testing relief valve setting

(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.



Testing relief valve setting

Unit: kgf/cm² (psi) [MPa]

Item	Assembly Standard
Relief valve setting (at maximum speed)	5-6.5 (71.1-92.4) [0.49-0.64]
Relief valve opening pressure	4.2 (59.7) [0.41]

NOTE

The oil pressure may rise beyond the assembly standard when the oil temperature is low but 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.

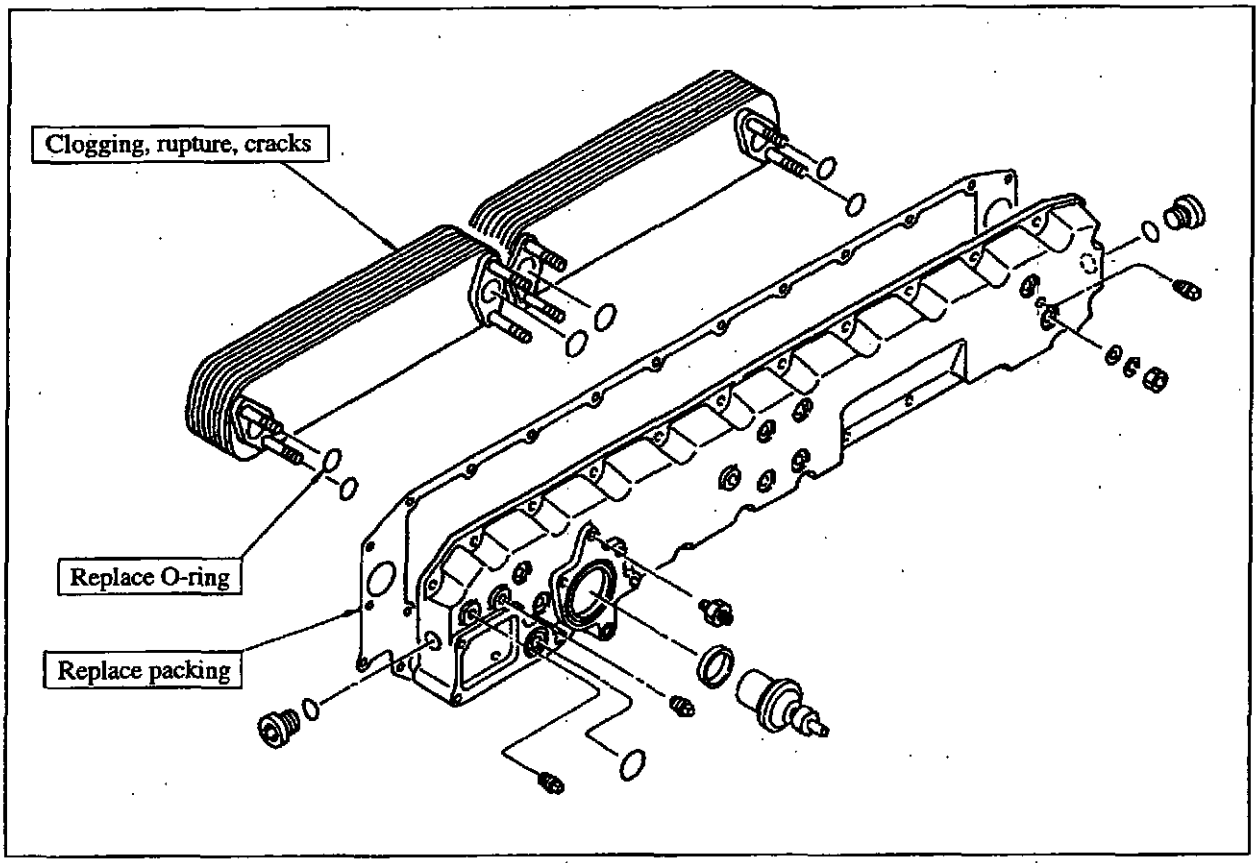
3.3 Reassembly

To reassemble, follow the disassembly sequence in reverse.

(1) Install new O-rings during reassembly.

4. Oil Cooler and Oil Thermostat

4.1 Disassembly



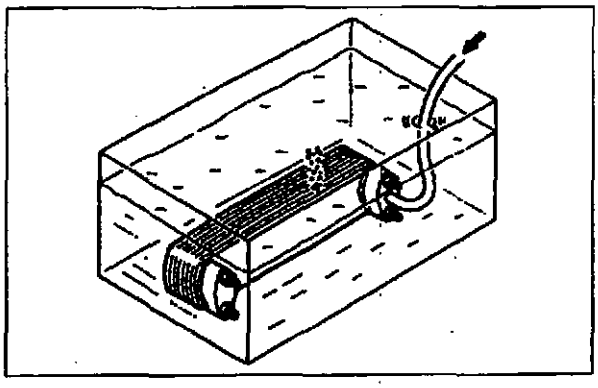
⚠CAUTION

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

4.2 Inspection

(1) *Inspecting oil cooler element*

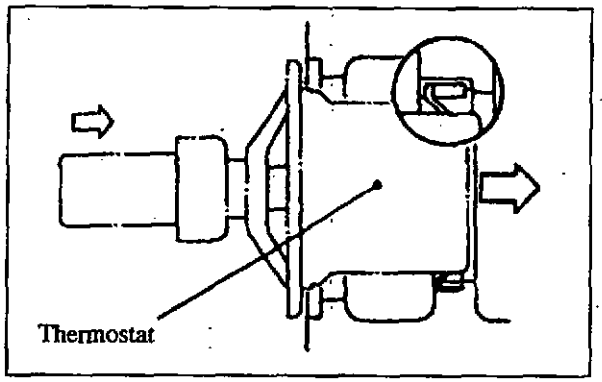
Test the element for tears or other defects by applying an air pressure of 15 kgf/cm² (213 psi) [1.5 MPa], and replace it if leakage occurs.



(2) Inspecting oil thermostat

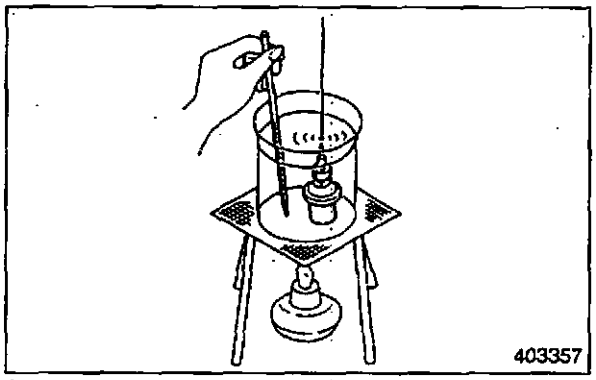
(a) Inspect the oil thermostat seal for deterioration or tears, and replace it if defective.

(b) Install the seal correctly as shown.



(3) Testing oil thermostat

Place the thermostat in a water tub, and test it for thermostat action by heating the tube to raise the water temperature. In the test, measure the temperature at which the valves starts opening and that at which the valve lift is more than 10 mm (0.39 in.). If these temperature measurements are out of the assembly standard, replace the thermostat.



Unit: °C (°F)

Item	Assembly Standard
Temperature at which valve starts opening	80-84 (176-183)
Temperature at which valve lift reaches 10 mm (0.93 in.) minimum	95 (203)

NOTE

(a) Stir the water in the tub 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.

4.3 Reassembly

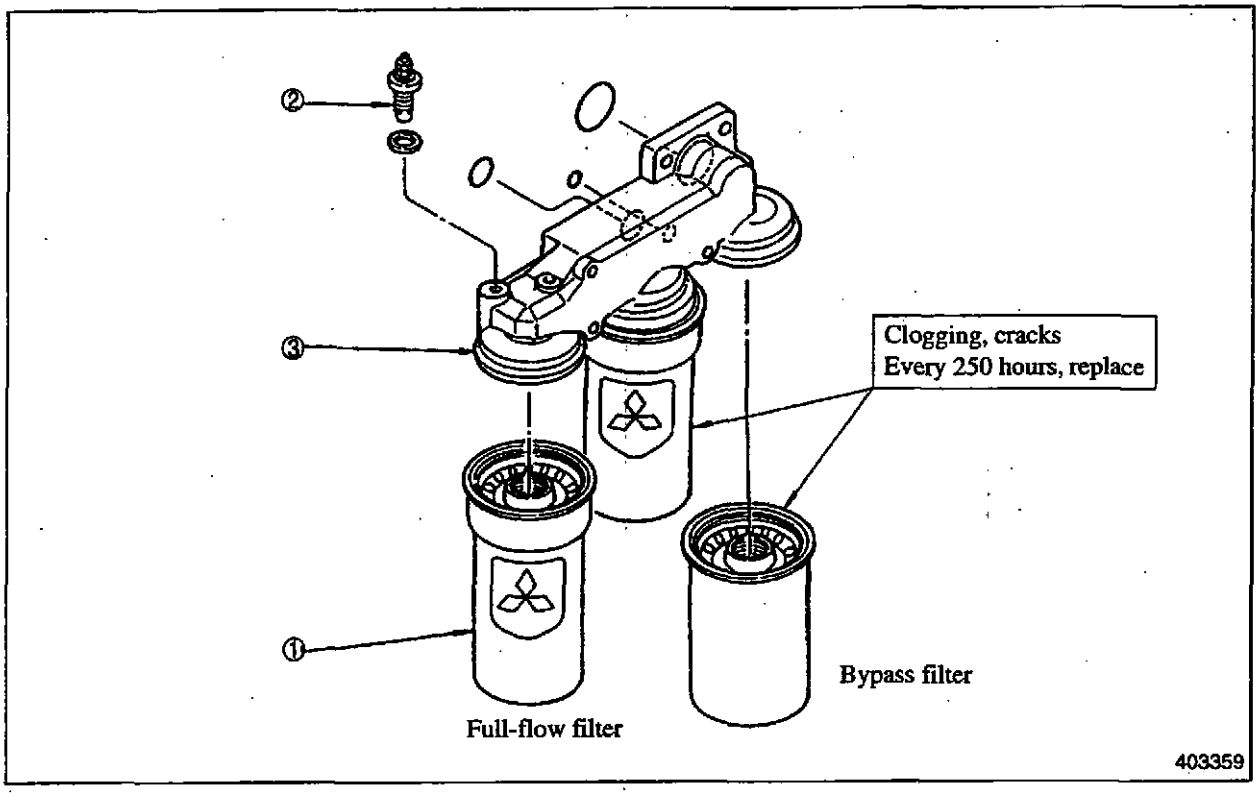
To reassemble, follow the disassembly sequence in reverse.

(1) Install new packings and O-rings during reassembly.

(2) Clean oil passages in the oil cooler cover and other parts with cleaning solution. Blow compressed air to remove dust and cleaning solution before reassembly.

5. Oil Filters

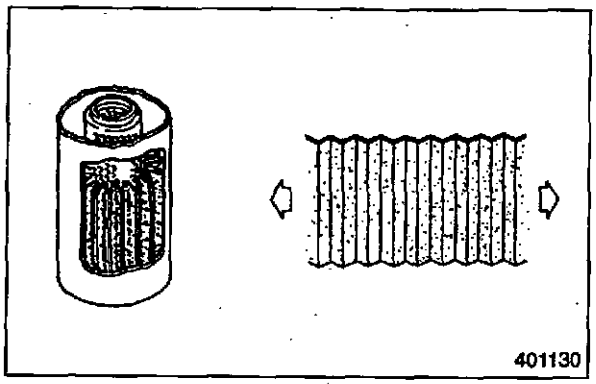
5.1 Disassembly



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

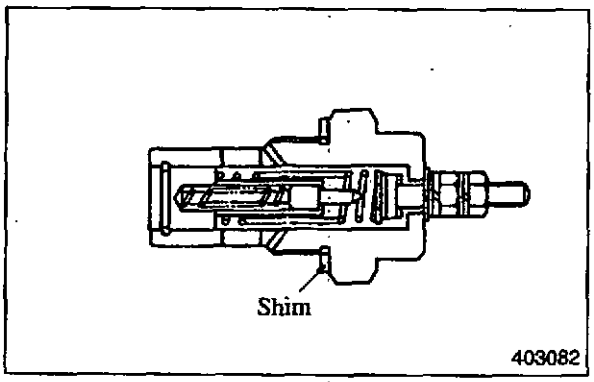
5.2 Inspection

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



(2) Inspecting oil filter alarm

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



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

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

Item	Assembly Standard
Oil filter alarm lamp lighting pressure	$1.5\ ^{+0.3}_{0}$ (21.3^{+4}_{+0}) $[1.5\ ^{+0.3}_{0}]$

5.3 Reassembly

To reassemble, follow the disassembly sequence in reverse.

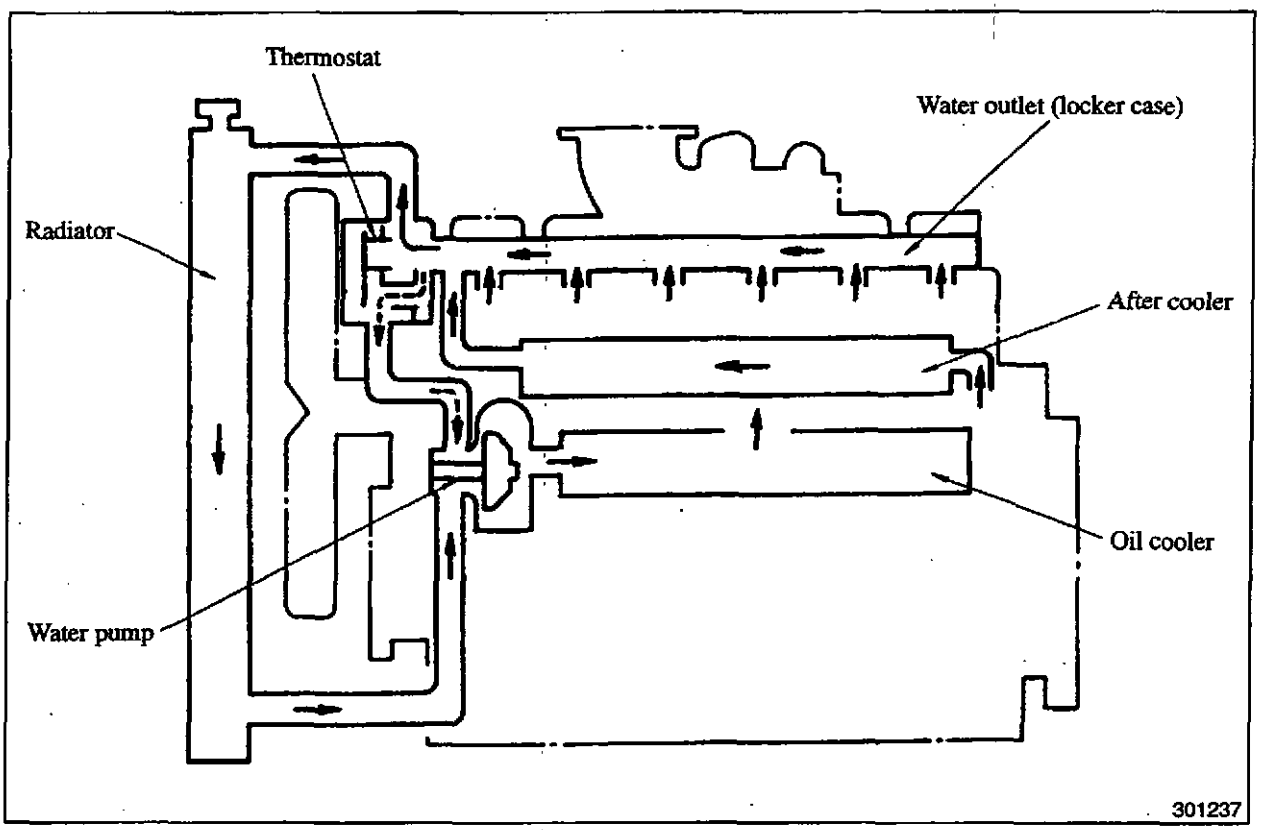
(1) Install new packings and O-rings during reassembly.

(2) Clean oil passages in the oil filter bracket and other parts with cleaning solution. Blow compressed air to remove dust and cleaning solution before reassembly.

(3) Mount the oil filter element on the bracket before installation.

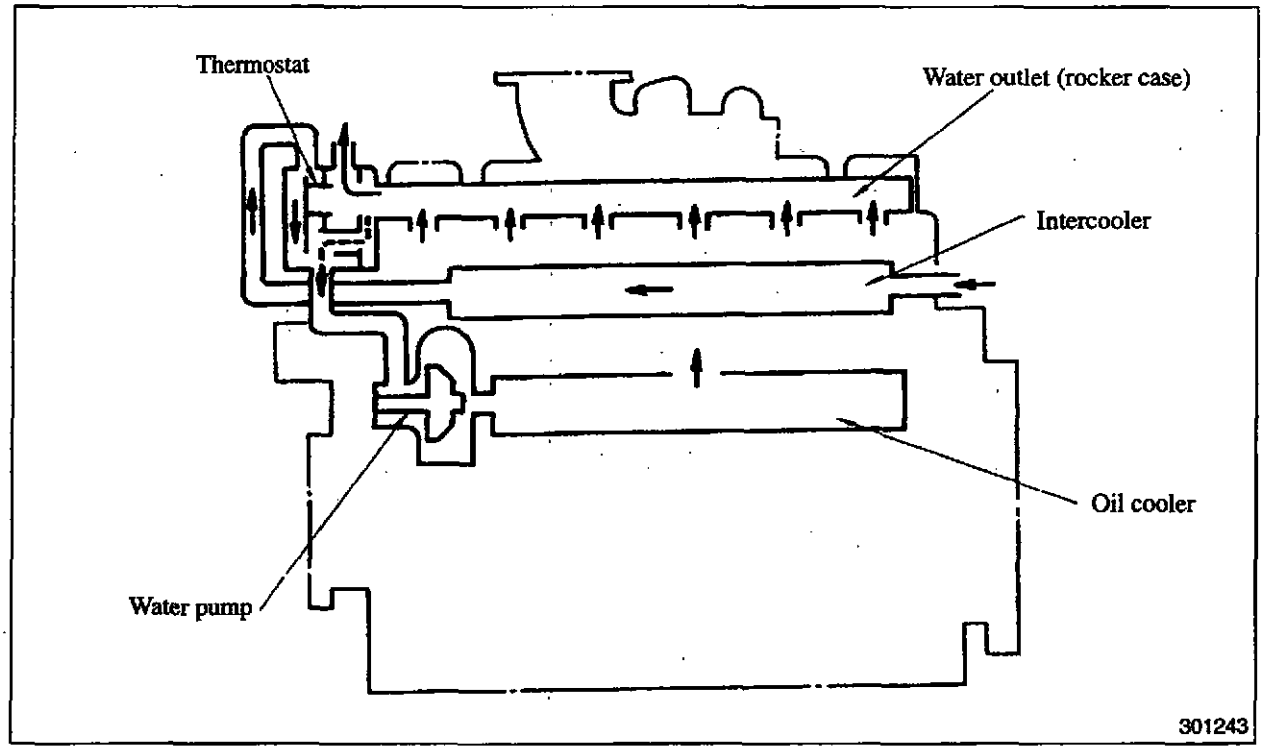
COOLING SYSTEM

1. Cooling System with Radiator



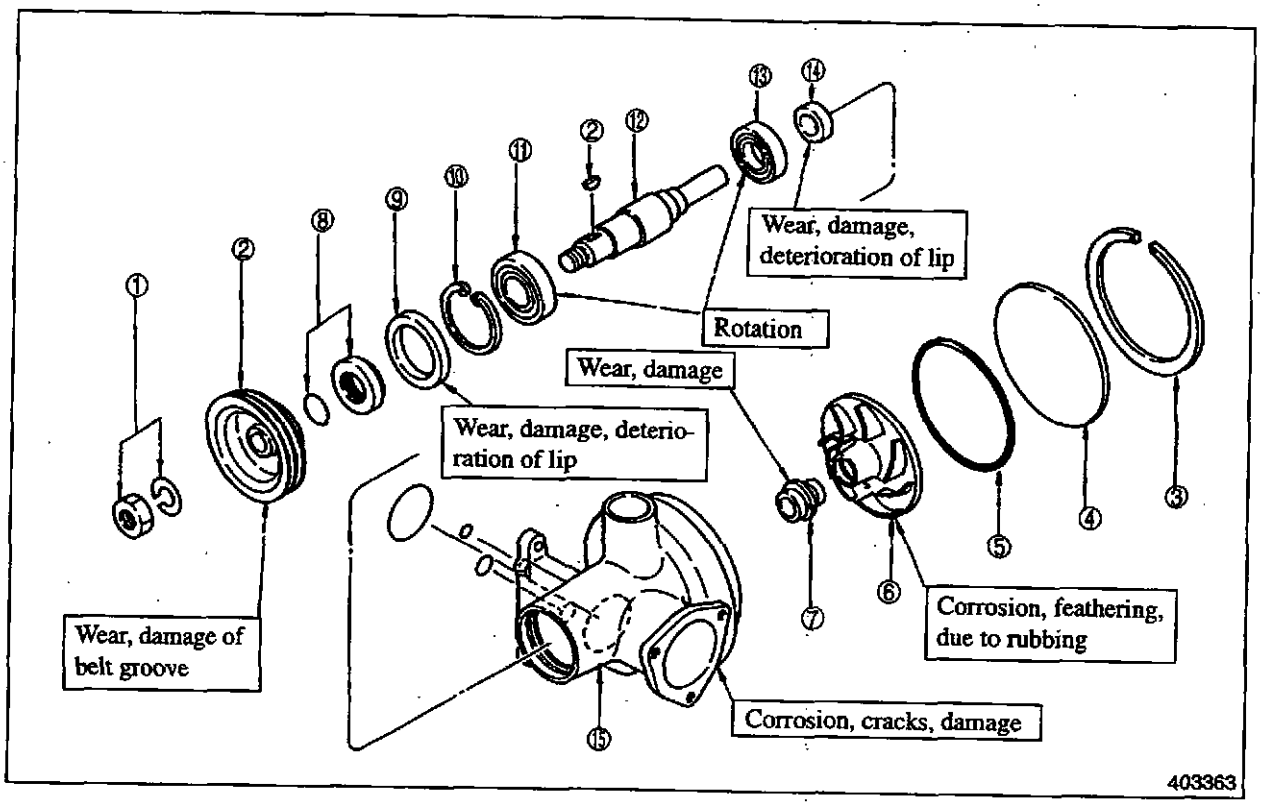
2. Cooling System with a Remote Water Supply

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



3. Water Pump

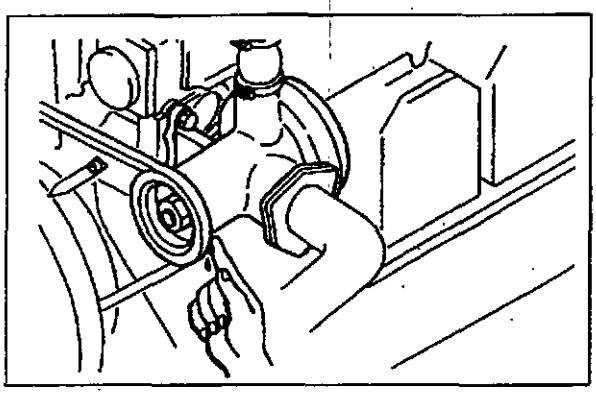
3.1 Disassembly



① Nut, washer
② Water pump pulley, key
③ Snap ring
④ Cover
⑤ O-ring
⑥ Impeller
⑦ Unit seal
⑧ Spacer, O-ring
⑨ Oil seal
⑩ Snap ring
⑪ Bearing
⑫ Water pump shaft
⑬ Bearing
⑭ Oil seal

(1) Inspecting the wear pump on engine

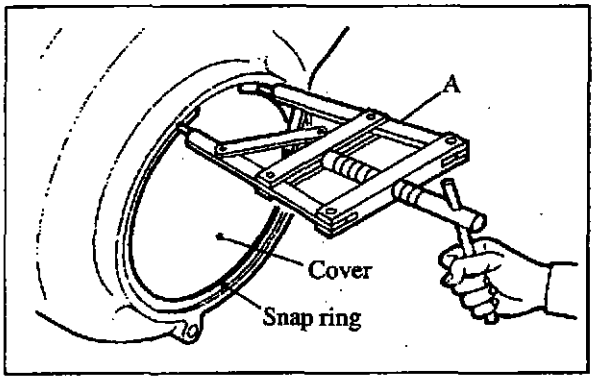
Touch the drain port located at the bottom of the center of pump with the finger. If the port is oozing inspect the unit seal for condition. If it is oozing oil, the oil seal would be defective.



(2) Removing impeller

(a) Remove the snap ring, cover and from the rear of the water pump.

(b) Using jacking bolts and a puller, draw out the impeller from the shaft.

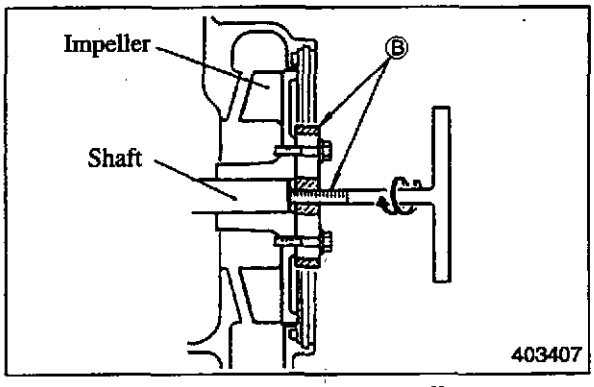


(3) Removing water pump shaft

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

⚠CAUTION

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



Removing water pump impeller

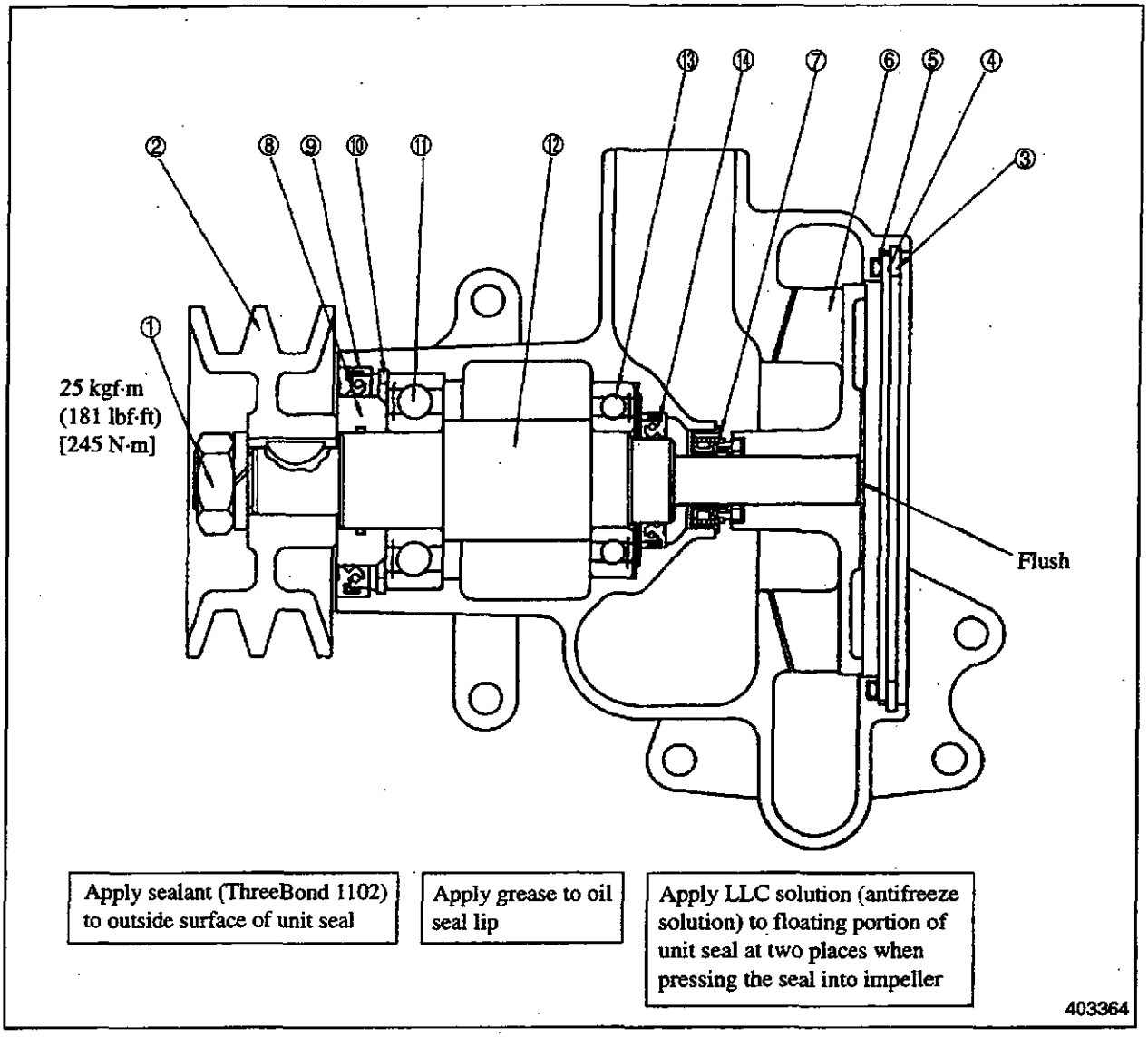
3.2 Inspection

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

Unit:mm (in.)

Item		Nominal Value	Assembly Standard
Inside diameter of pump case bearing		80 (3.15)	79.988 to 80.018 (3.14913 to 3.15031)
Inside diameter of cover to which the bearing outer race is fitted		90 (3.54)	89.987 to 90.022 (3.54279 to 3.54417)
Bearing	Diameter	80 (3.15)	79.985 to 80.000 (3.14902 to 3.14961)
		90 (3.54)	89.985 to 90.000 (3.54272 to 3.54331)
	Inside diameter	40 (1.57)	39.988 to 40.000 (1.57433 to 1.57480)
Diameter of pump shaft on which bearing inner race is fitted		40 (1.57)	40.002 to 40.013 (1.57488 to 1.57531)

3.3 Reassembly



Reassembling Sequence

⑭→⑬→⑫→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

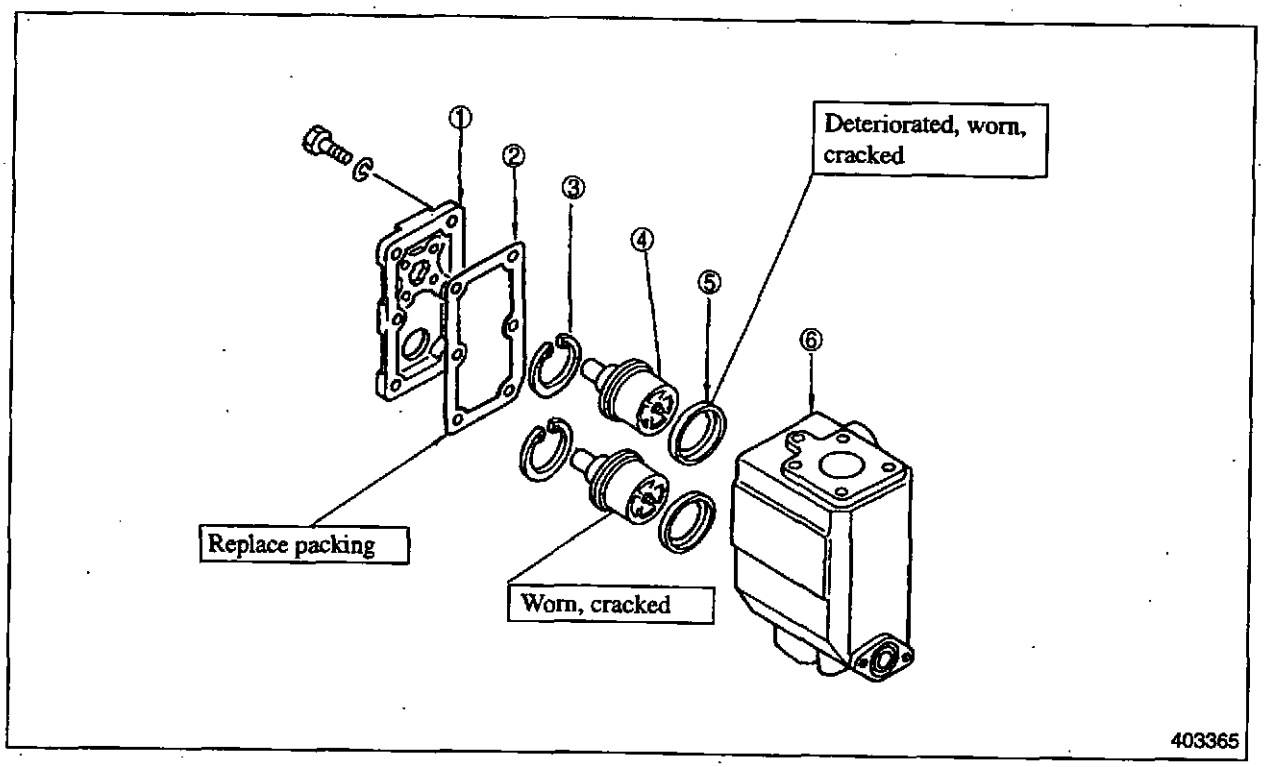
NOTE

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

(b) Install the ball bearings to the pump shaft with their sideplates on the oil seal side.

4. Thermostats

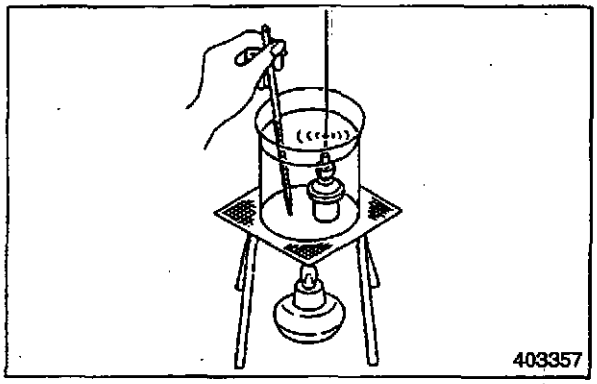
4.1 Disassembly



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

4.2 Inspection

Place the thermostat in a water tub, and test it for by heating the water to raise the water temperature. Test the temperature where the valve should start opening and where the valve shaft should be 11 mm (0.3 in.) or more. If the valve falls to operate properly, replace the thermostat.



Unit: °C (°F)

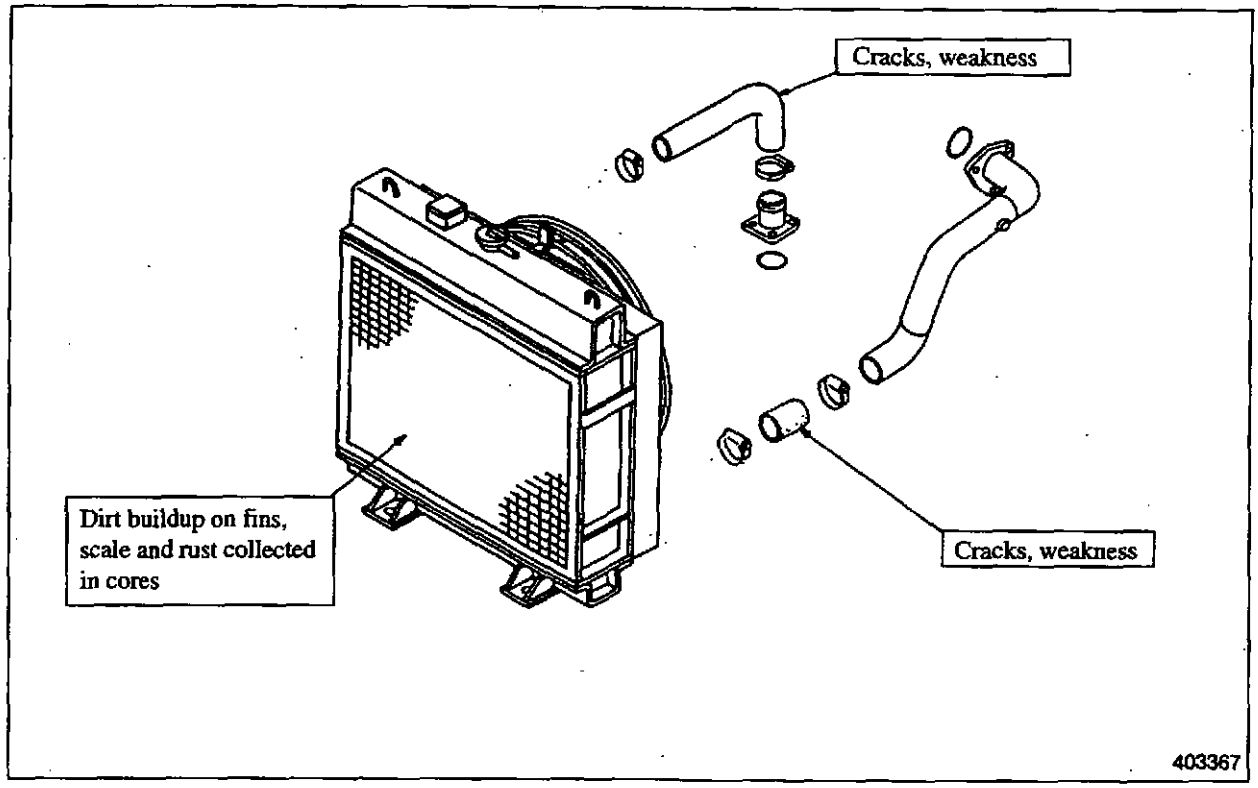
Item	Assembly Standard
Temperature where valve should start opening	69-73 (156.2-163.4)
Valve lift of 11 mm (0.43 in.), minimum	83-87 (181.4-188.6)

NOTE

(a) Stir the heated water during the test to maintain an even temperature.
(b) At reassembly, place the thermostat in the correct position by ascertaining the valve opening temperature stamped on it mounting flange.

5. Radiator

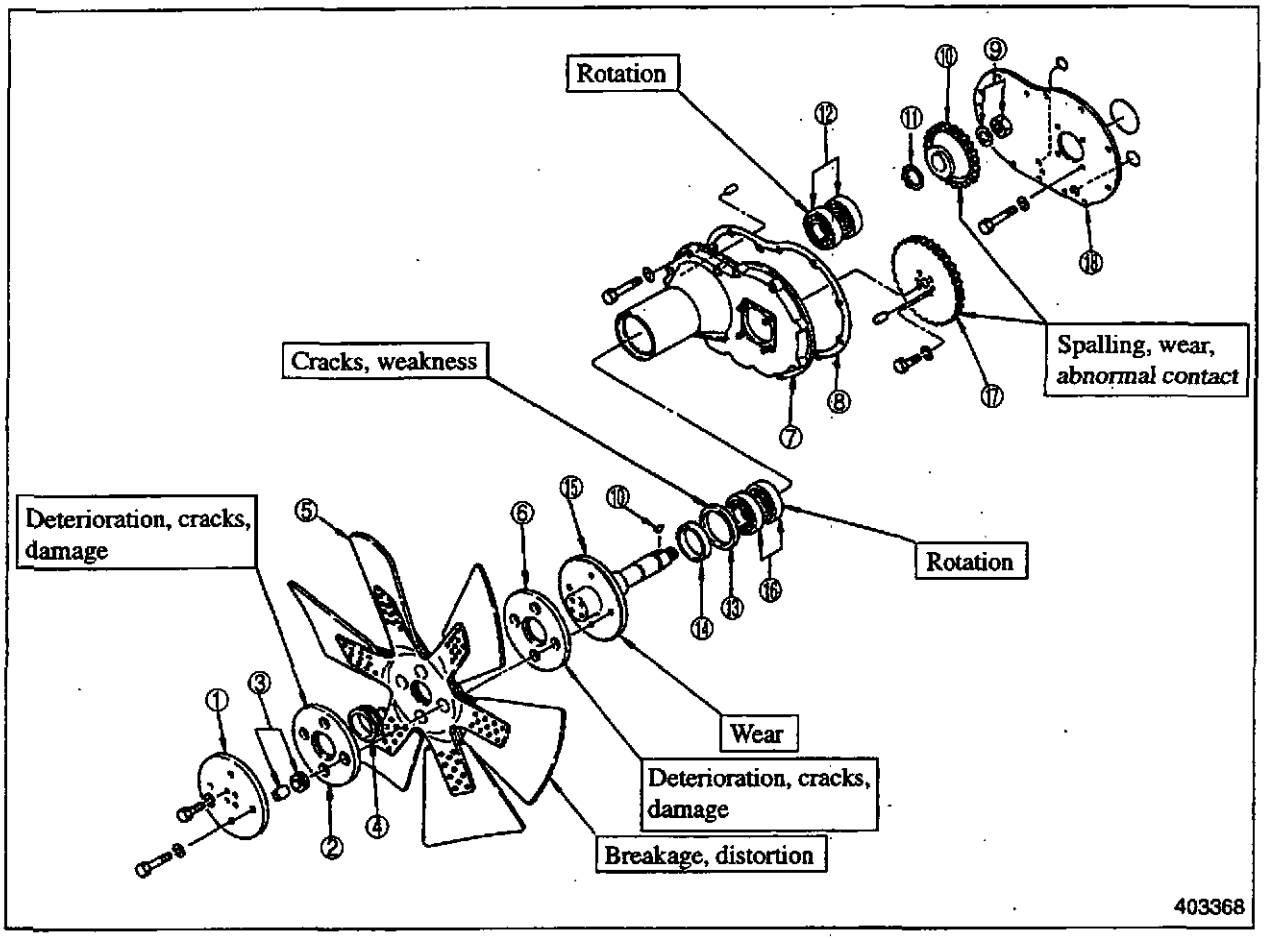
Inspection



(1) Inspect the radiator for dirt, scale, or rust in the water passages, the clean if necessary.
(2) Check the rubber hose and hose clamp. Replace them if any damage or deterioration is found.

6. Fan drive

6.1 Disassembly



① Plate
② Friction rubber
③ Spacer, grommet
④ Busing
⑤ Fan
⑥ Friction rubber
⑦ Fan drive case
⑧ Packing
⑨ Nut, washer
⑩ Fan drive gear, key
⑪ Snap ring
⑫ Bearings
⑬ Oil seal
⑭ Sleeve
⑮ Fan drive shaft
⑯ Bearings
⑰ Camshaft gear
⑱ Plate

⚠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 inspect each blade for cracks and distortion.

6.2 Inspection

(1) Measure the inside diameter of the bracket to which the bearing outer race is fitted.
Measure the diameter of the shaft to which the bearing inner race is fitted. If the bearing inner race is fitted. If the bearing, shaft, or bracket is worn, replace it.

(2) Check the fan bushing for wear and damage and replace if anything abnormal is found.

(3) Check the friction rubber for deterioration, cracks, or damage. Replace it if necessary.

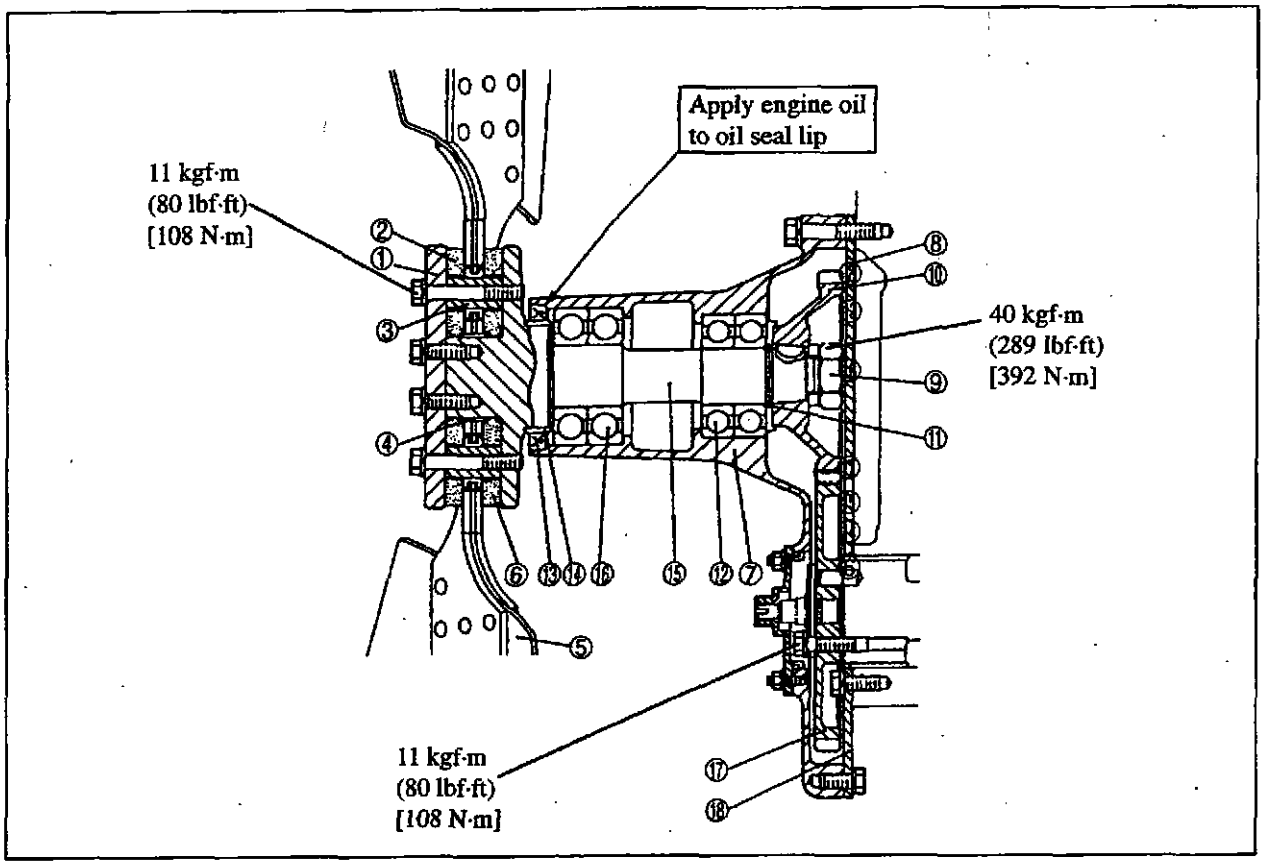
Unit: mm (in.)

Item		Nominal Value	Assembly Standard
Inside diameter of fan drive case bore to which bearer outer race is fitted		100 (3.94)	99.987-100.022 (3.93649-3.93787)
		110 (4.33)	109.987-110.022 (4.33019-4.33157)
Bearing	Diameter	100 (3.94)	99.980-100.005 (3.93621-3.93720)
		110 (4.33)	109.980-110.005 (4.32991-4.33090)
	Inside diameter	45 (1.77)	44.985-45.003 (1.77106-1.77177)
		50 (1.97)	49.985-50.003 (1.96791-1.96862)
Diameter of pump shaft on which bearing inner race is fitted		45 (1.77)	45.002-45.013 (1.77173-1.77216)
		50 (1.97)	50.002-50.013 (1.96858-1.96901)

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

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

6.3 Reassembly

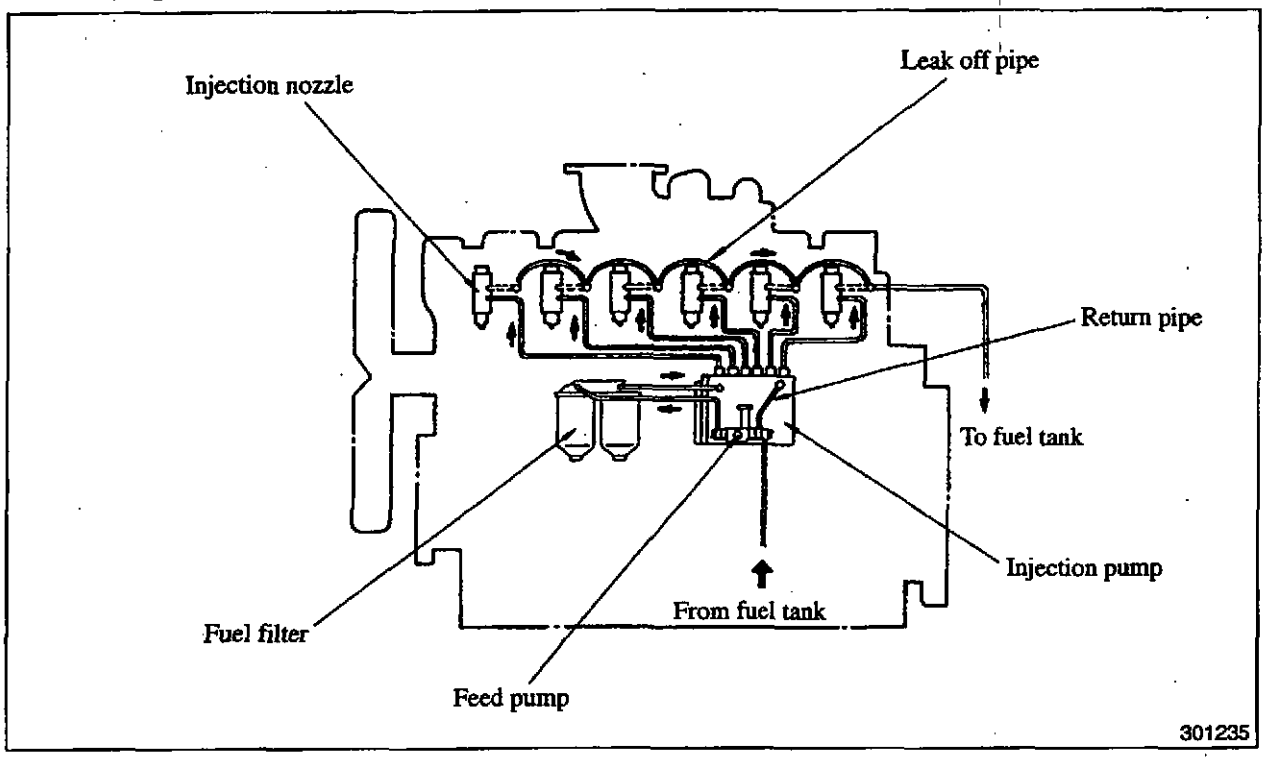


Reassembling Sequence

⑦ → ⑯ → ⑲ → ⑫ → ⑪ → ⑪ → ⑨ → ⑧ → ⑥ → ④ → ③ → ② → ①
⑮ → ⑭
⑱ → ⑰

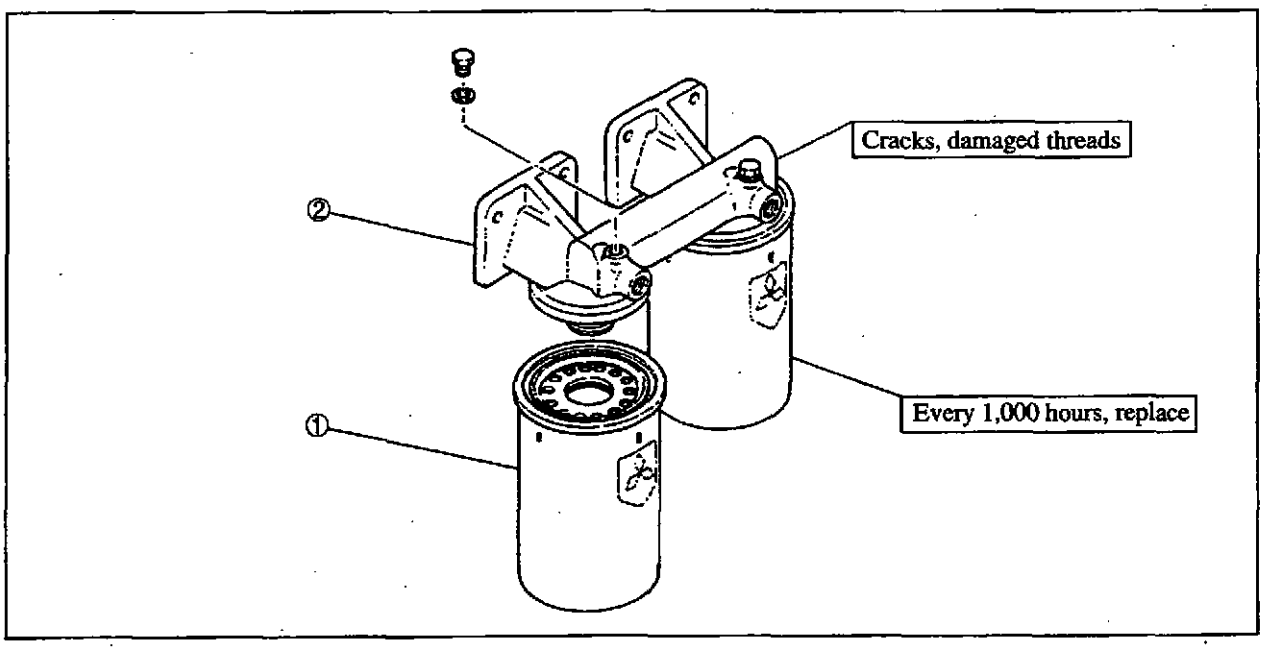
FUEL SYSTEM

1. Description



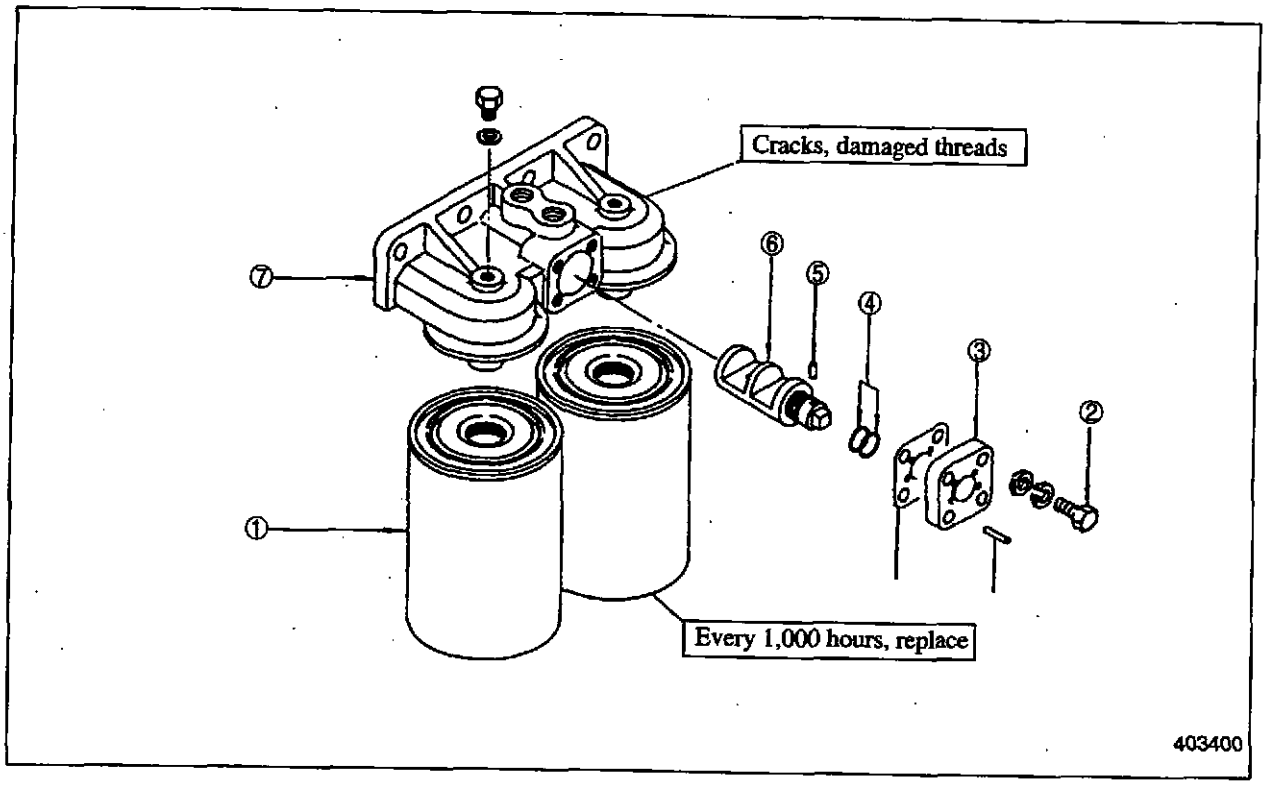
2. Fuel Filters

2.1 Disassembly and Inspection



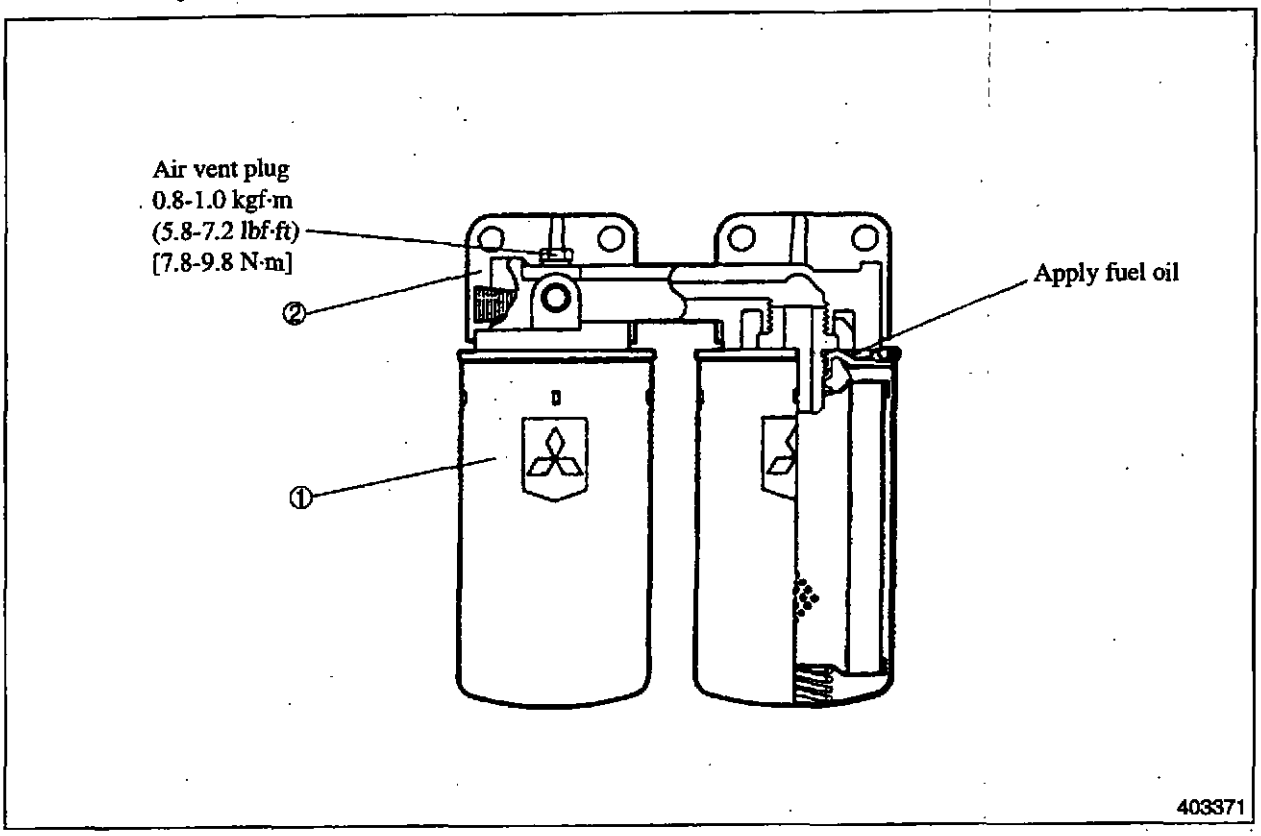
① Element ② Fuel filter bracket

(Selector type)



① Element
② Bolt
③ Cover
④ O-ring
⑤ Pin
⑥ Cock
⑦ Fuel filter bracket
⑧ Gasket

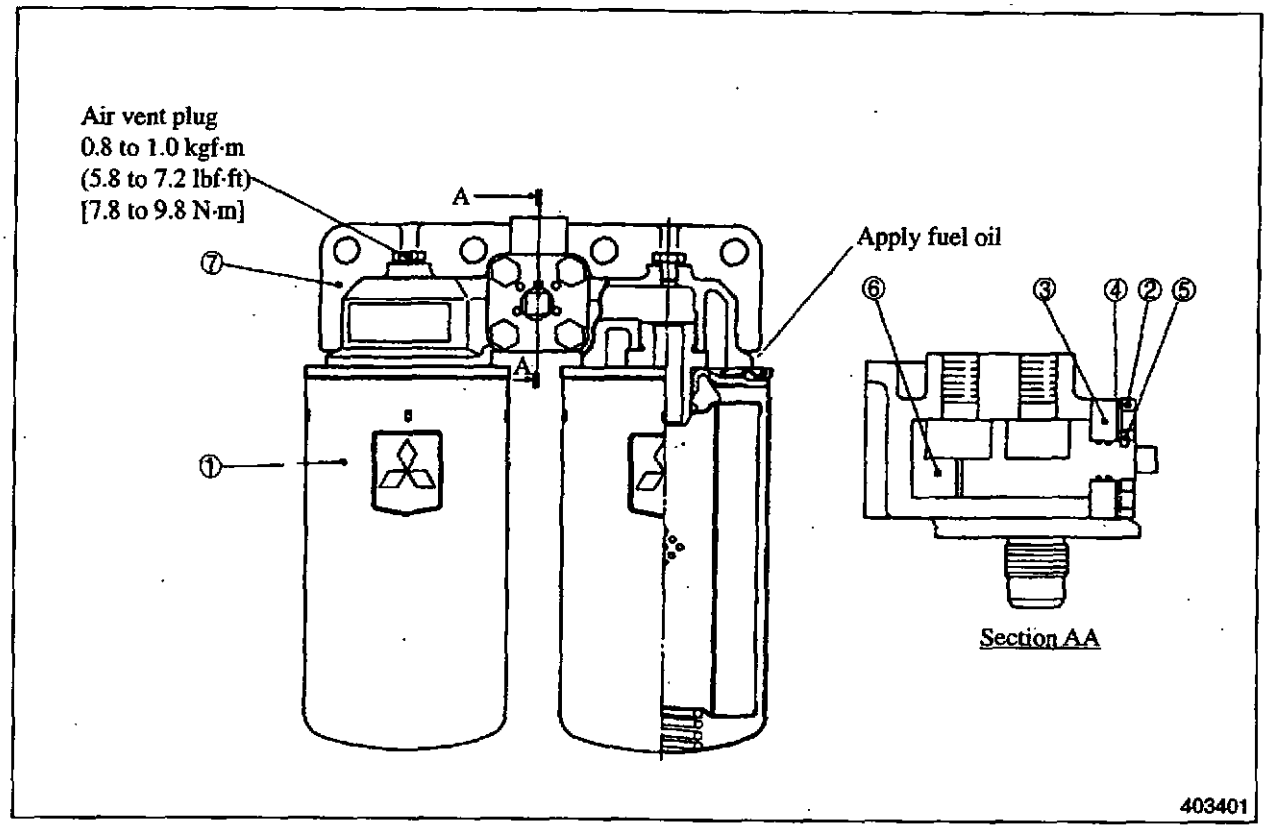
2.2 Reassembly



Reassembly Sequence

②→①

(Switchable Type)



Reassembly Sequence

⑦→⑤→④→⑥→③→②→①

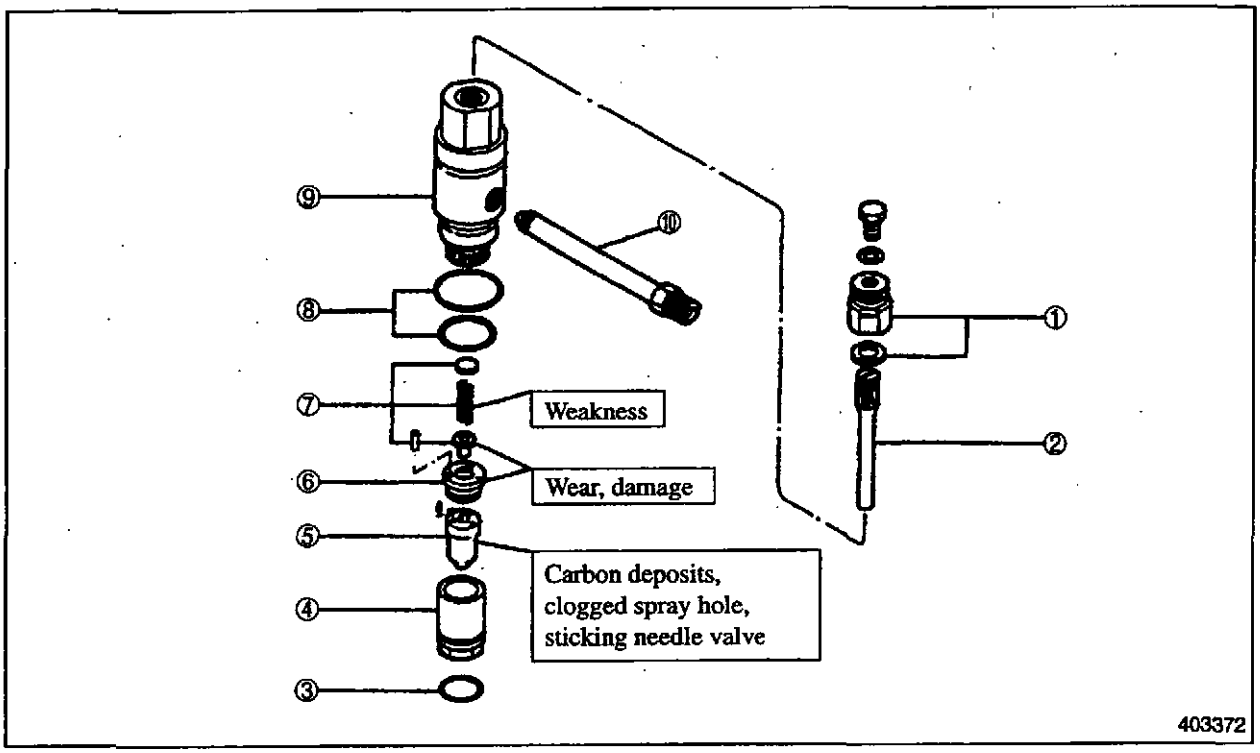
To install the cartridge, clean the mounting surface and apply fuel oil to the gasket. After bringing the gasket into contact with the sealing surface of the bracket, tighten the cartridge with your hand about one-half to three quarters of a turn.

⚠CAUTION

After installing the fuel filter on the engine, start the engine, then confirm that the filters are not leaking.

3. Fuel Injection Nozzles

3.1 Disassembly

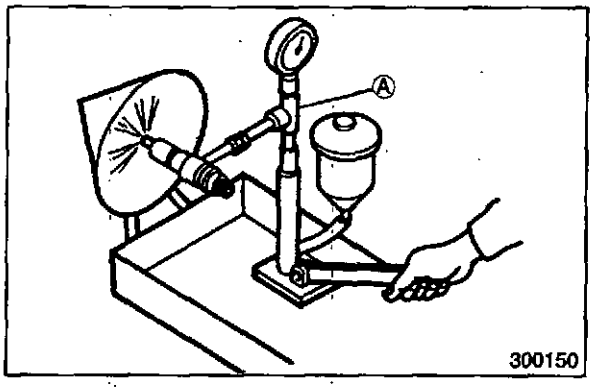


① Cap nut, gasket
② Adjusting screw
③ O-ring
④ Retaining nut
⑤ Nozzle tip
⑥ Spacer
⑦ Pushrod, nozzle spring, spring seat
⑧ O-ring
⑨ Nozzle holder
⑩ Fuel inlet connector

3.2 Inspection and Adjustment

(1) Injection Pressure

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



Unit: kgf/cm² (psi) [MPa]

Item	Assembly Standard
Injection pressure (Valve opening pressure)	350-355 (4977-5048) [34.3-34.8]

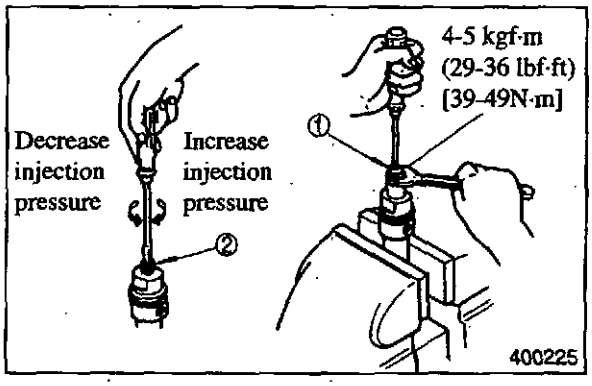
⚠ WARNING

During injection testing, never attempt to touch the spray hole of the injection nozzle.

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

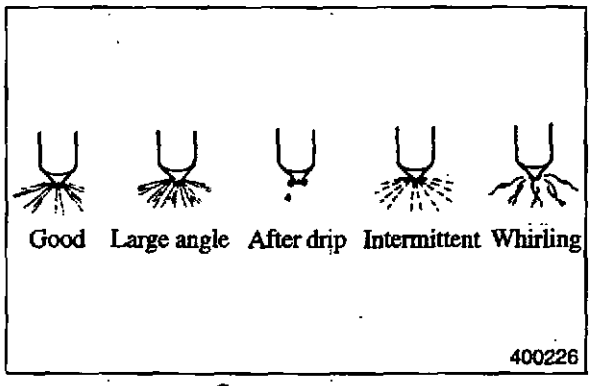
(c) After completing the adjustment, tighten the jam nut and the cap nut to the specified torque.

(d) Re-check the injection pressure to be sure that it is correct.



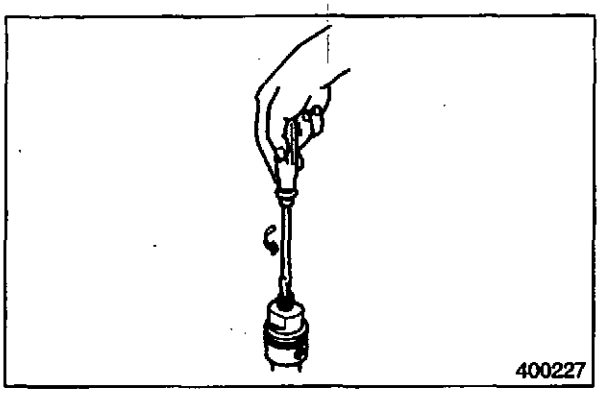
(2) Spray pattern

(a) When you are testing the injection pressure, inspect each nozzle for clogged spray holes and fuel leaks from the holes.
Also examine the spray pattern. If the nozzle is faulty, wash or replace the nozzle tip.



Spray patterns

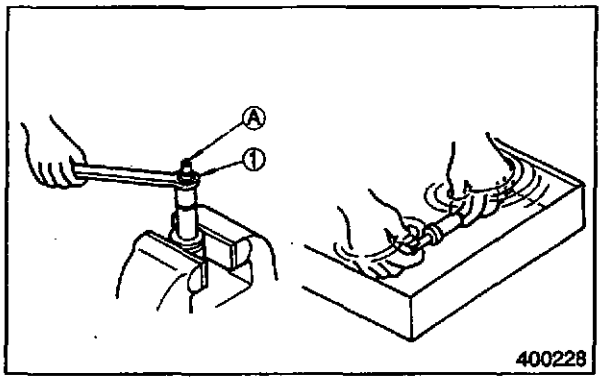
(b) When tested on the nozzle tester, the nozzle should spray fuel from its ten holes at the same time in a straight cone of 160 degrees. The spray should consist of finely atomized fuel particles without any large droplets. The spray should terminate with no dripping at the top.



(3) Washing or replacing the nozzle tip

(a) The nozzle tip is spring loaded. Remove the cap nut and with a screwdriver, loosen the adjusting screw until it can be loosened by han.

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



⚠CAUTION

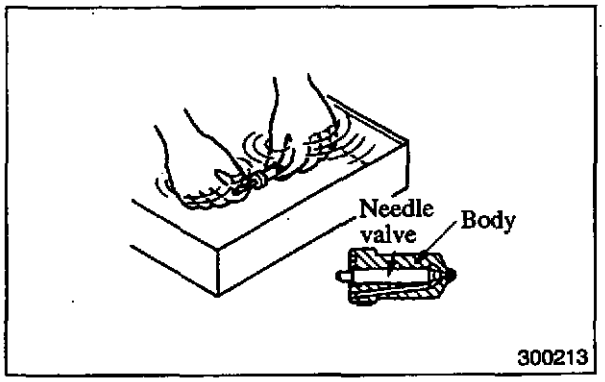
When pulling out the nozzle tip, do not damage the tip Ⓐ.

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

⚠CAUTION

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

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

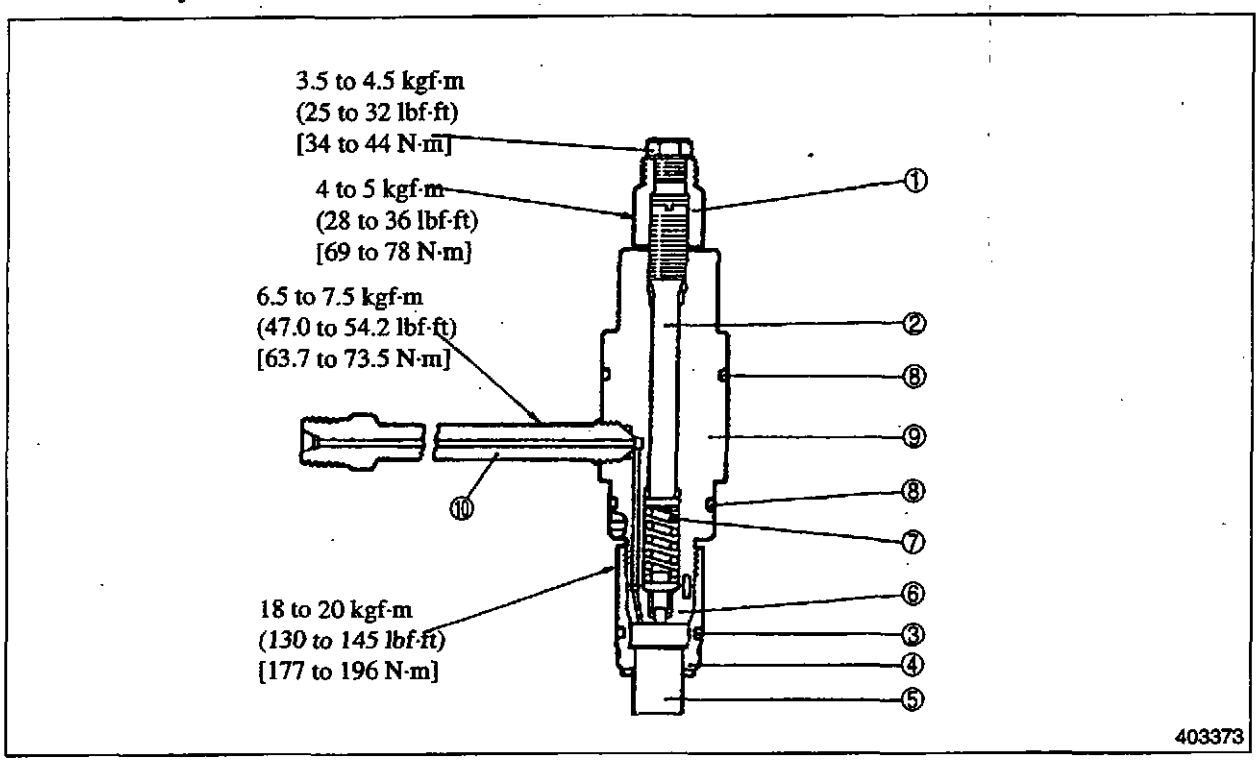


(e) If the spray pattern is still bad after the nozzle has been adjusted and cleaned, replace the nozzle tip.

NOTE

New nozzle tips are coated with vaseline to preserve them. Wash them twice, first in gasoline then in diesel fuel before you inslall them.

3.3 Reassembly



Reassembling Sequence

⑨→③→⑥→⑩

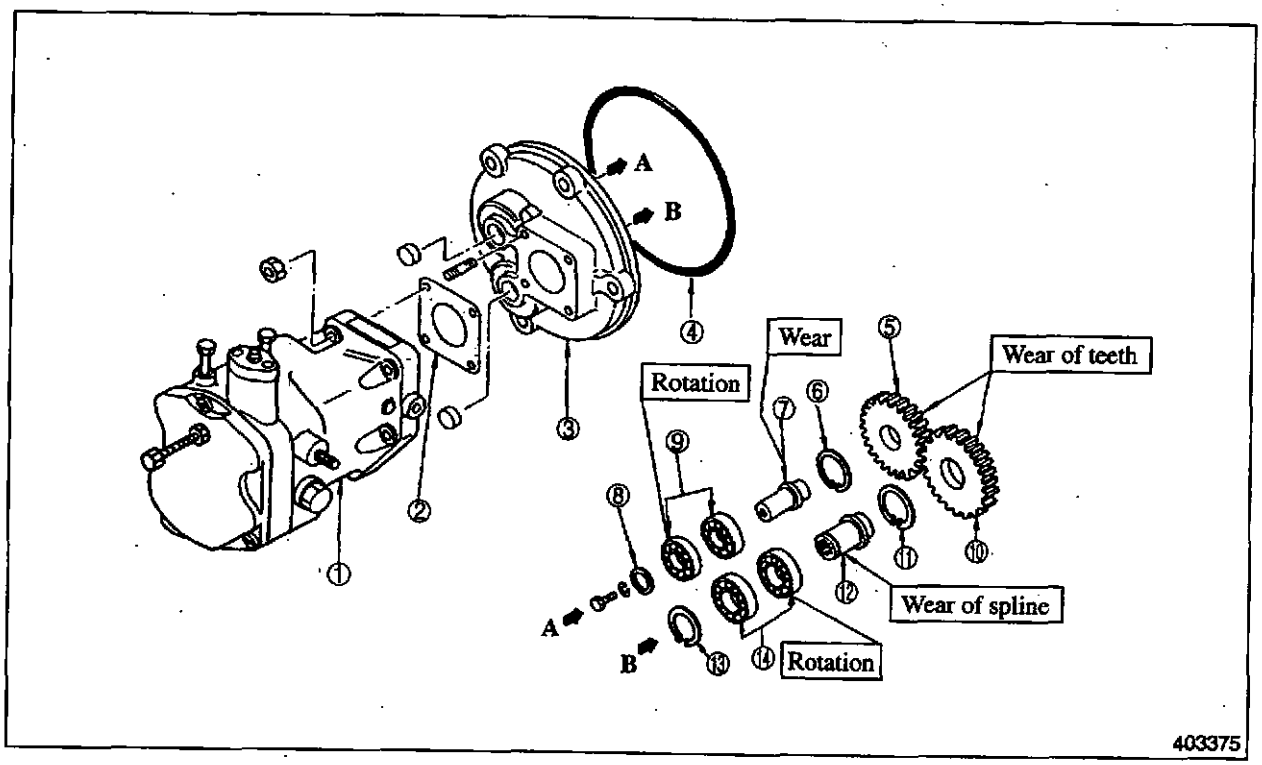
⚠CAUTION

Tighten the retaining nut ④ only as far as the specified torque. Excessive torque on the retaining nut, the needle will not operate smoothly, causing discoloration of exhaust gas and sticking.

4. Governor Drive

4.1 Disassembly

(PSG governor)



① PSG governor
② Packing
③ Drive case
④ O-ring
⑤ Idler gear
⑥ Snap ring
⑦ Idler shaft
⑧ Washer, bolt
⑨ Bearings
⑩ Drive gear
⑪ Snap ring
⑫ Drive shaft
⑬ Snap ring
⑭ 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 fit 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.

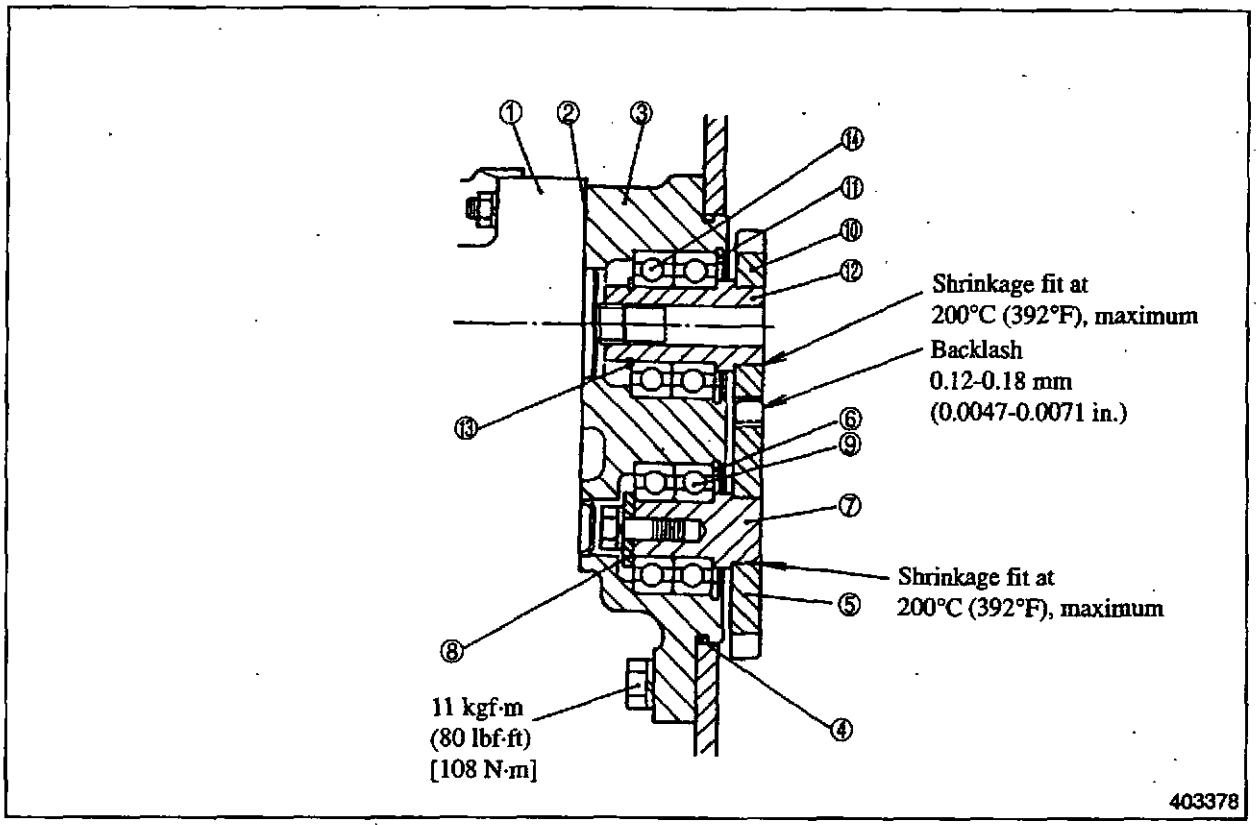
(PSG governor)

Unit: mm (in.)

Item		Nominal Value	Assembly Standard
Inside diameter of drive case bore in which drive shaft side bearing outer race is fitted		52 (2.05)	51.988 to 52.018 (2.04677 to 2.04795)
Drive shaft side bearing	Outside diameter	52 (2.05)	51.987 to 52.000 (2.04673 to 2.04742)
	Inside diameter	25 (0.98)	24.990 to 25.000 (0.98386 to 0.98425)
Diameter of drive shaft on which bearing inner race is fitted		25 (0.98)	25.002 to 25.011 (0.98433 to 0.98468)
Inside diameter of drive case bore in which idler shaft side bearing outer race is fitted		47 (1.85)	46.989 to 47.014 (1.84996 to 1.85094)
Idler shaft side bearing	Outside diameter	47 (1.85)	46.988 to 47.000 (1.84992 to 1.85039)
	Inside diameter	20 (0.79)	19.990 to 20.000 (0.78701 to 0.78740)
Diameter of idler shaft on which bearing inner races are fitted		20 (0.79)	20.002 to 20.011 (0.78748 to 0.78783)

4.3 Reassembly

(PSG governor)



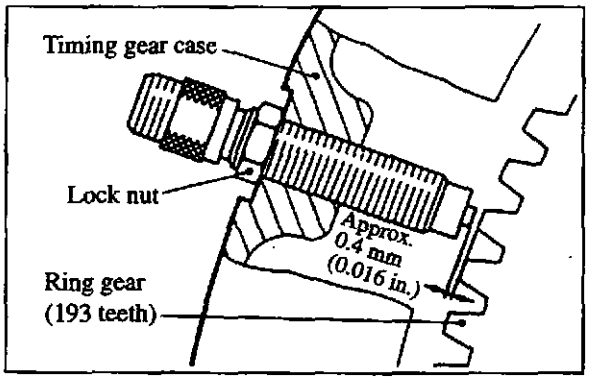
Reassembling Sequence

③→⑨→⑦→⑧→⑥→⑤→⑭→⑫→⑬→⑪→⑩→②→①→④

Installing pickup

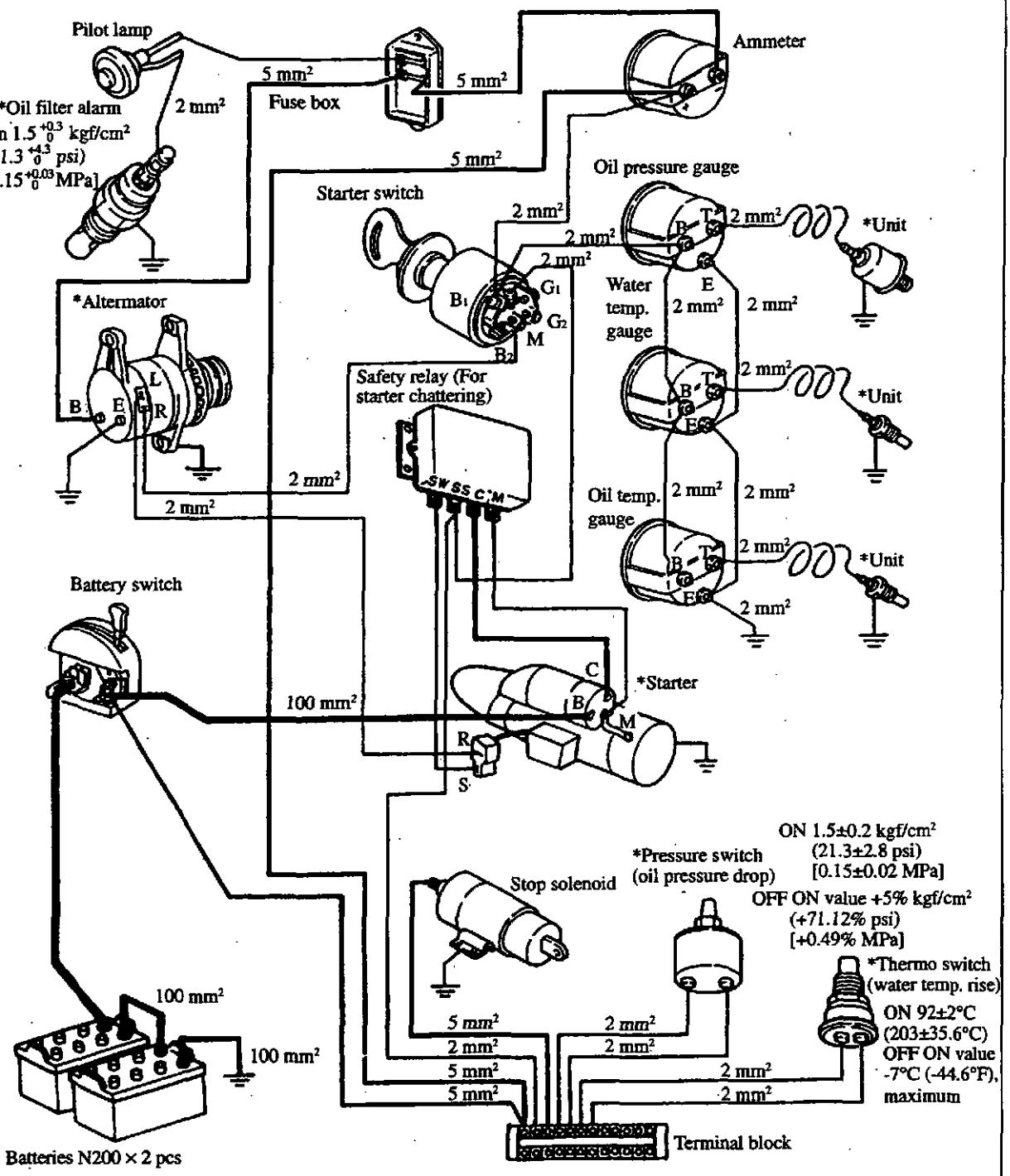
(a) Using the turning gear, turn the engine until one tooth of the ring gear aligns with the center of the pickup mounting hole.

(b) Gently screw the pickup. When the tip of the pickup contacts the tooth of the ring gear, unscrew the pickup slightly by turning 1/4 turn and secure it in position using the lock nut.



ELECTRICAL SYSTEM

1. Electrical System Outline



Remarks: (a) The circuit shown above is for standard model. The circuit varies from one specification and application of the engine to another.

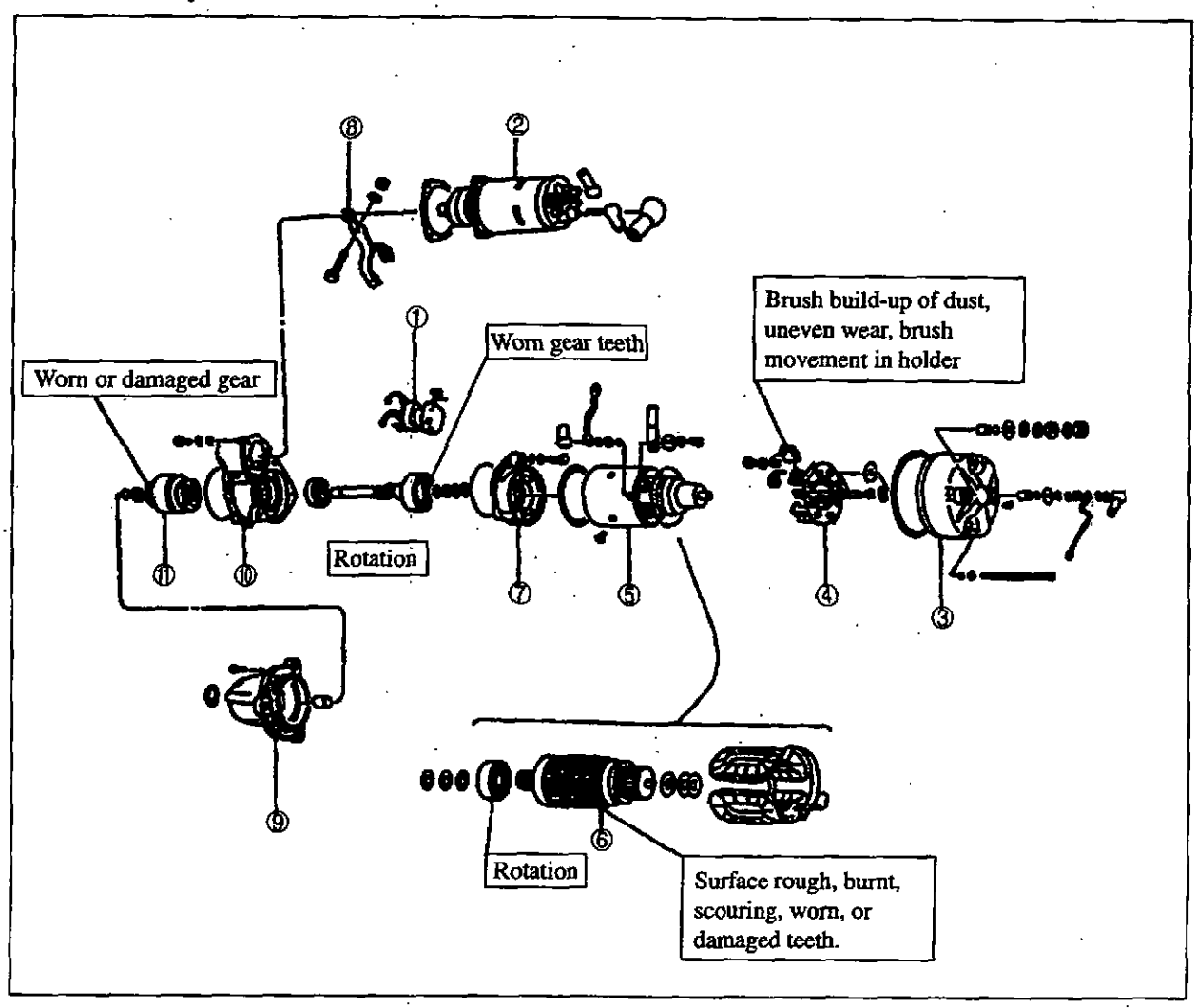
(b) Wiring involved in the circuit is to be prepared in field.

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

301239

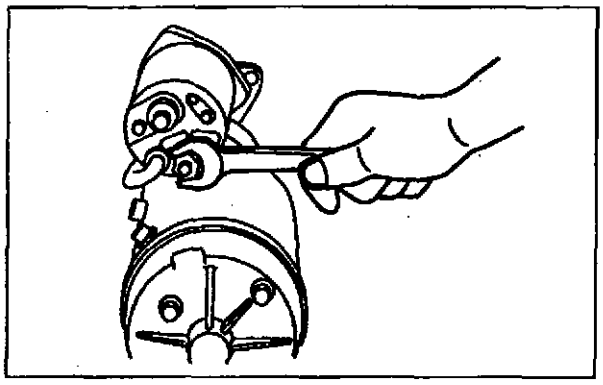
2. The Starter

2.1 Disassembly

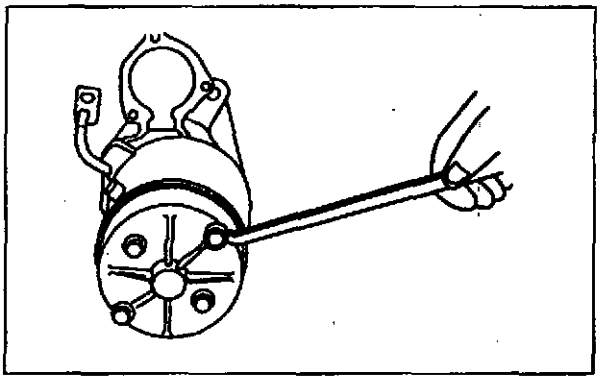


① Safety switch
② Magnetic switch assy.
③ Rear bracket
④ Brush holder assy.
⑤ Yoke assy.
⑥ Armature assy.
⑦ Center bracket
⑧ Lever assy.
⑨ Front bracket
⑩ Pinion case
⑪ Pinion clutch assy.

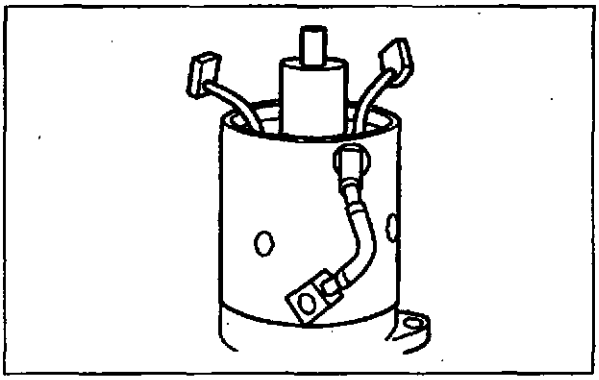
(1) After removing the safety switch, remove the lead wire, and then the magnetic switch assembly.



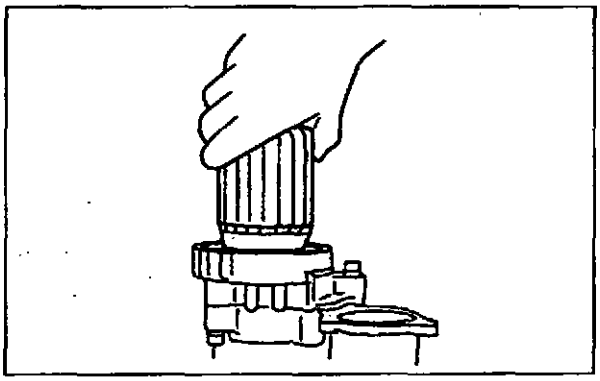
(2) Unscrew the through bolts and the brush holder mounting screws, then remove the rear bracket.



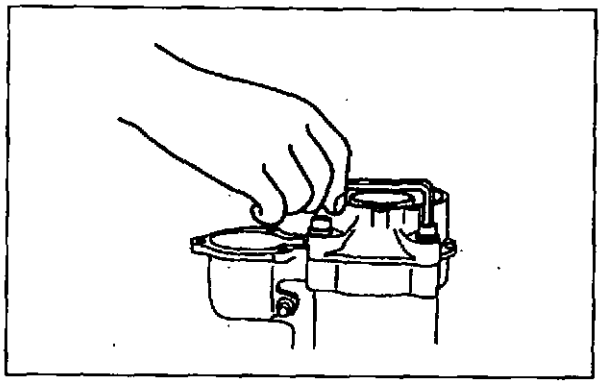
(3) Remove the brushes from the brush holder assembly, then remove the yoke.



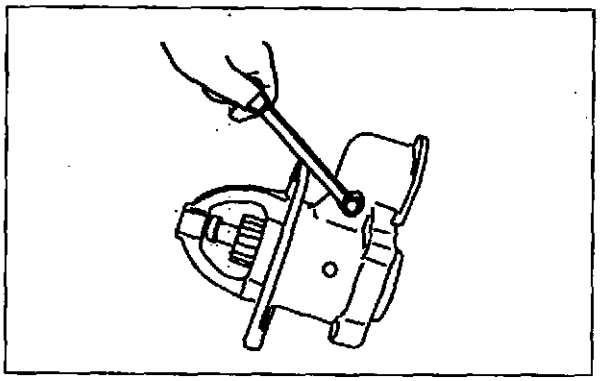
(4) Pull out the armature assembly.



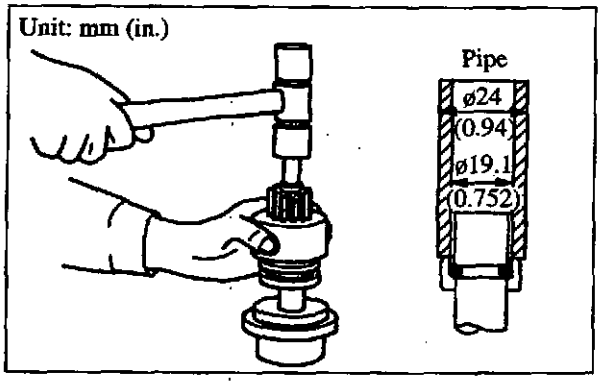
(5) Remove the center bracket.



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

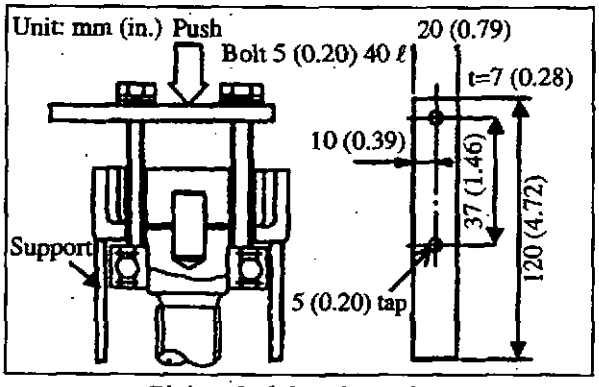


(7) Using a jig, remove the pinion stopper, then remove the overrunning clutch from the pinion shaft.



NOTE

To remove the shaft bearing for replacement, use a bearing puller like the one shown in the illustration.



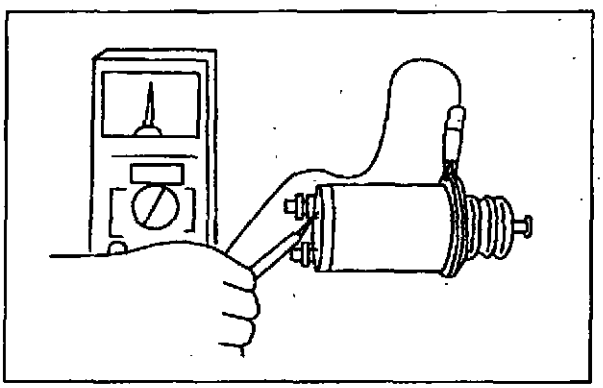
Pinion shaft bearing puller

2.2 Inspection and Repair

Magnetic Switch

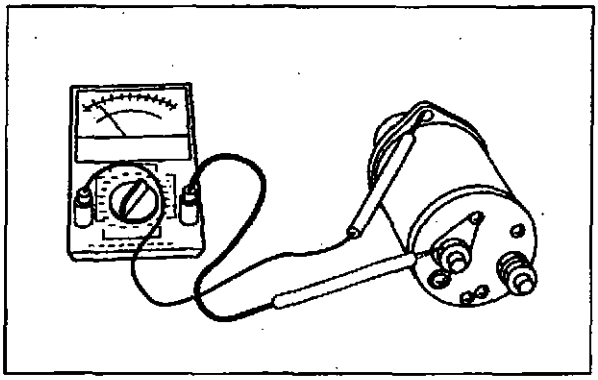
(1) Testing the magnetic switch coil

(a) Test the pressure coil and holding coil for an open circuit. The coils are open-circuited if there is no continuity between the M terminal of the magnetic switch and the case.



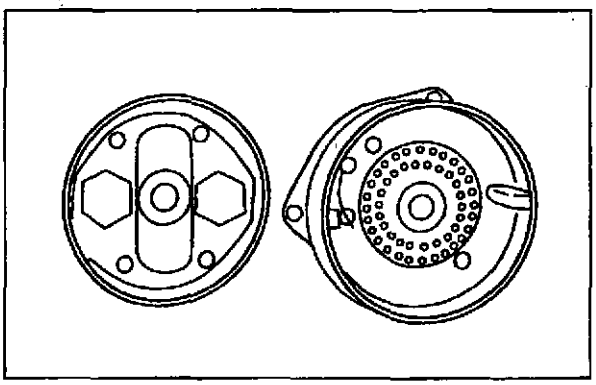
Resistance: 1.16 ohms (approx.)

(b) Apply voltage of 24 volts between the M terminal of the magnetic switch and the case. Now push in the plunger by hand. When you release your hand, the plunger should not be attracted.



(2) Testing magnetic switch contact points

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



⚠CAUTION

If the starter switch is turned to OFF during voltage measurement, the battery voltage is directly applied to the voltmeter. This can damage the voltmeter. Always turn the starter switch to ON before measuring the voltage, then turn it OFF after measuring the voltage.

⚠CAUTION

Under no circumstances should only the magnetic switch be tested.

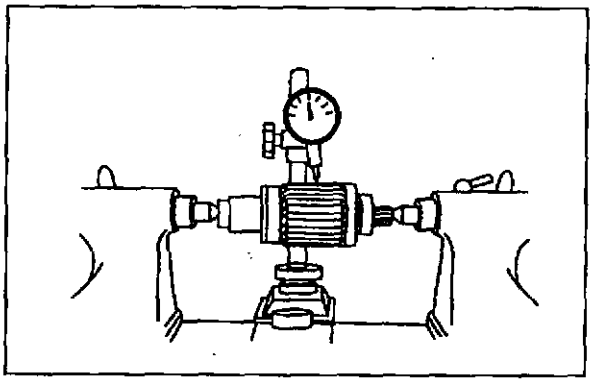
Armature

(1) Measuring the armature shaft for runout

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

Unit: mm (in.)

Item	Assembly Standard
Armature shaft runout	0.05 (0.0020)

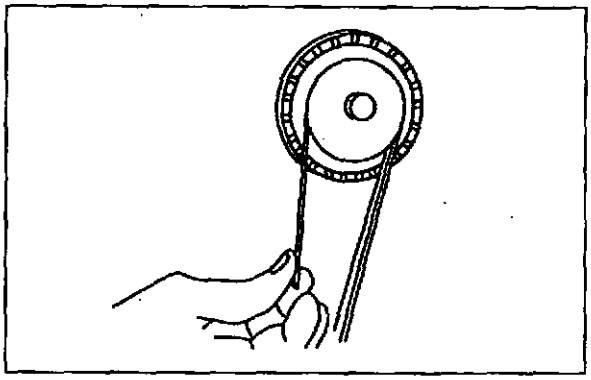


(2) Inspecting the commutator

(a) Check the condition of the commutator surface. If it is rough, polish it with #400-#600 sandpaper.
Check the commutator for runout with a dial gauge. 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	0.100 (0.00394)

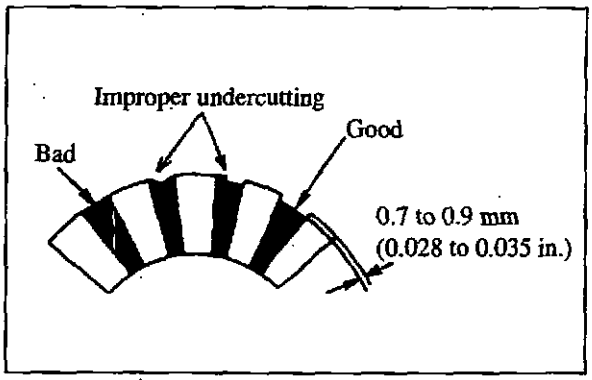


(b) Measuring the mica depth

Use a depth gauge to measure the depth of each mica undercut. If the depth exceeds the repair limit, re-condition the mica.

Unit: mm (in.)

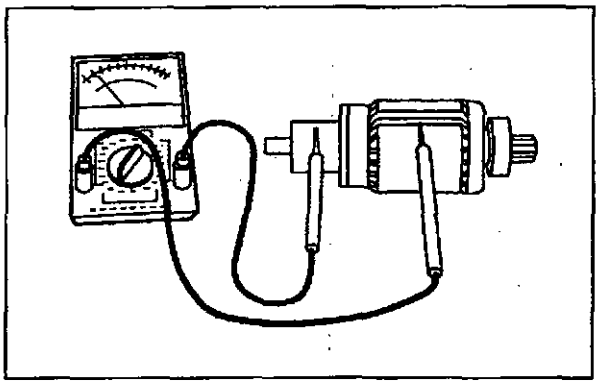
Item	Assembly Standard	Repair Limit
Commutator mica depth	0.7 to 0.9 (0.028 to 0.035)	0.2 (0.008)



(3) Testing the armature

(a) Use a growler to test the armature for short circuits. If the hacksaw blade vibrates against the core, replace the armature.

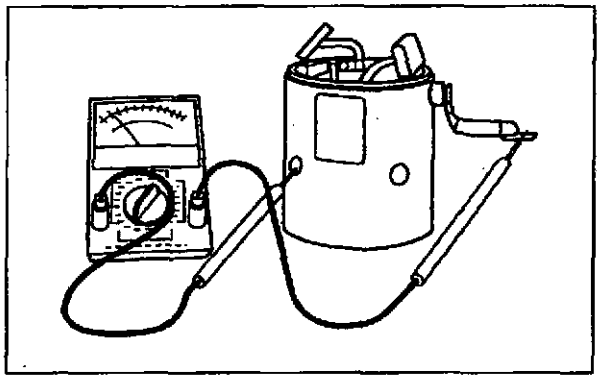
(b) If there is continuity between the commutator and shaft, replace the armature.



Field coil

(1) Testing for open circuits

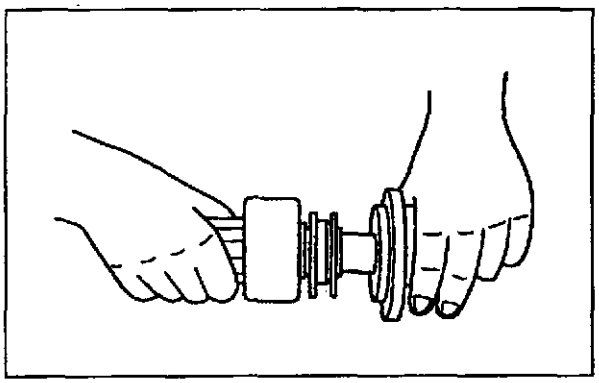
If there is no continuity between the M terminal of the field coil and the lead wire on the brush side, replace the field coil.



Overruning 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. If they are damaged, replace the pinion.



⚠CAUTION

Do not immerse the overruning clutch in cleaning solvent to clean it. Immersion in cleaning solvent will cause grease inside the clutch to run out, causing clutch parts to seize when operating.

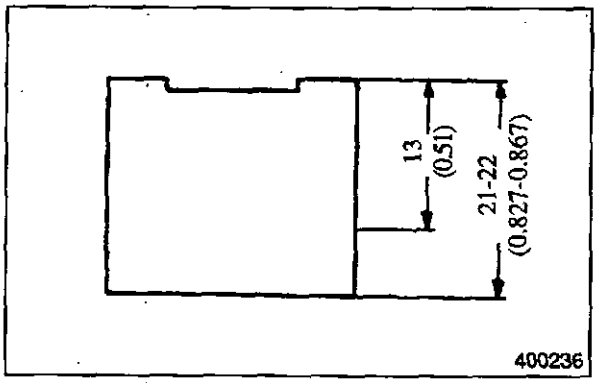
Brushes

(1) Inspecting for wear

Unit: mm (in.)

Item	Assembly Standard	Service Limit
Brush height	21 to 22 (0.827 to 0.867)	13 (0.51)

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



(2) Testing brush spring tension

Unit: kgf (lbf) [N·m]

Item	Assembly Standard	Service Limit
Brush spring tension	4.0 to 4.5 (8.8 to 9.9) [39.3 to 49.03]	less than 4.0 (8.8) [39.23]

Safety Switch

Connect the safety switch shown in the illustration, and check the starter and safety switch operations.

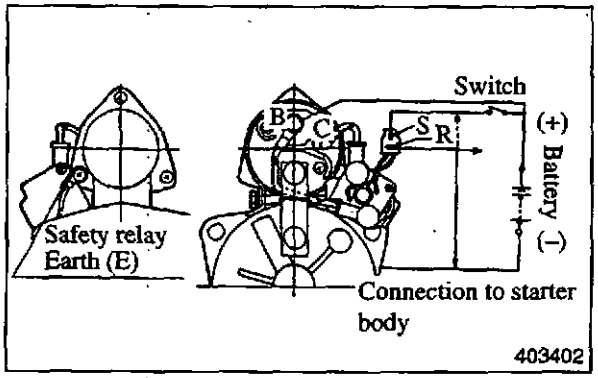
(1) Connect the R terminal to the battery minus (–) side.

(2) Turn the switch on, and check that the starter turns.

(3) After step (2) above is completed, if you remove the R terminal from the battery minus (–) side, or if you connect the terminal to the battery plus (+) side after removal, make sure you stop the starter operation.

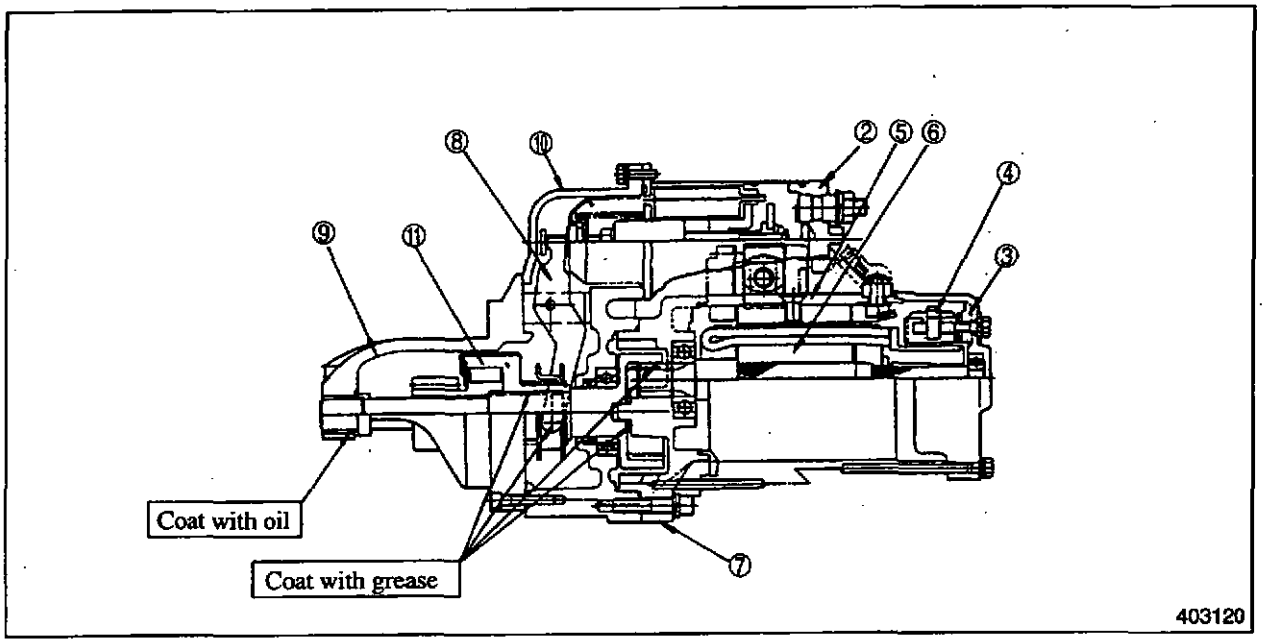
⚠CAUTION

When you are making connections, pay special attention to the battery's polarity (+) (–).



2.3 Reassembly

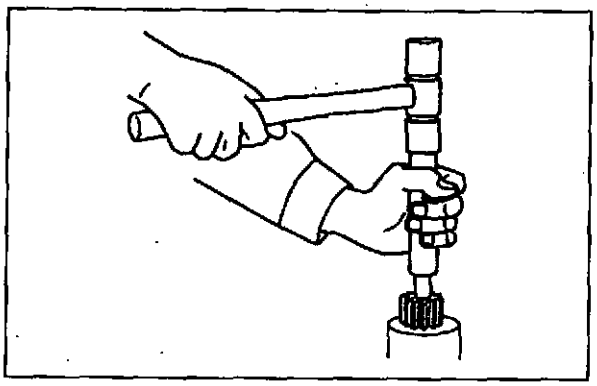
Reassembling Order



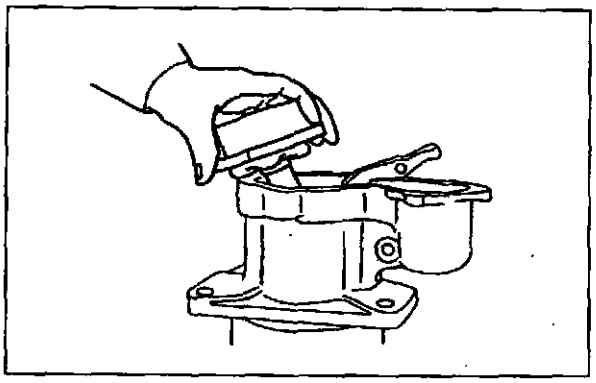
Reassembling Sequence

⑩→⑨→⑪→⑧→⑦→⑥→⑤→④→③→②→①

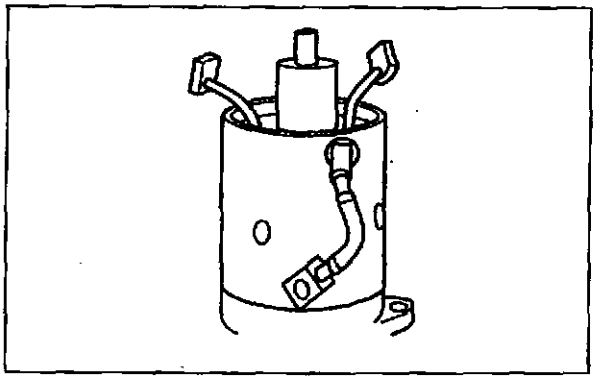
(1) Install the center bracket, overrunning clutch, and pinion stopper to the pinion shaft. Insert the shaft in position by tapping it with a plastic hammer.



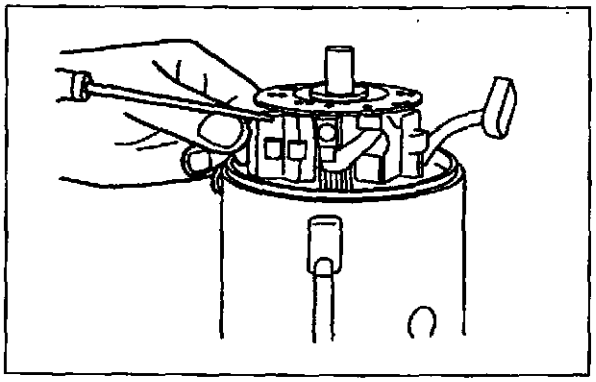
(2) Install the shift lever and pinion shaft to the front bracket by aligning the matching mark on the shift lever.



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

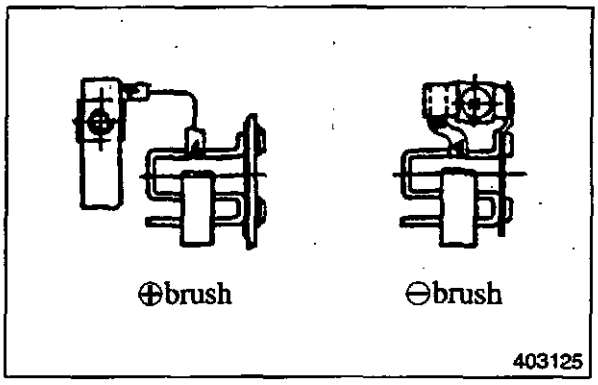


(4) Install the brushes and brush holders.

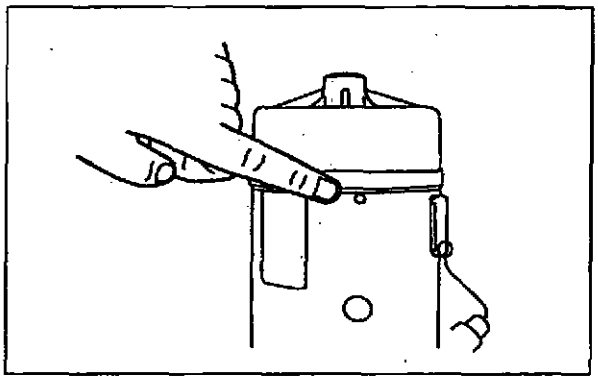


NOTE

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



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

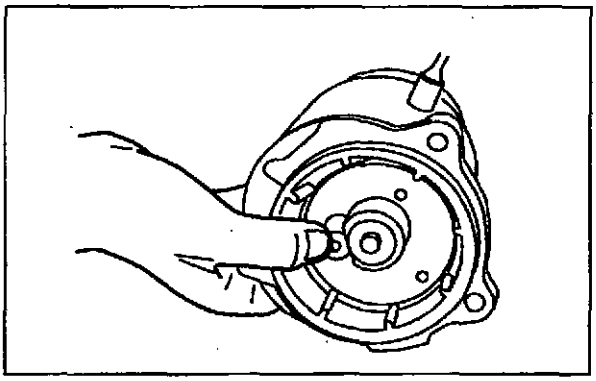


(6) Measure the end play of the armature. If the end play exceeds the assembly standard, adjust it on the rear side.

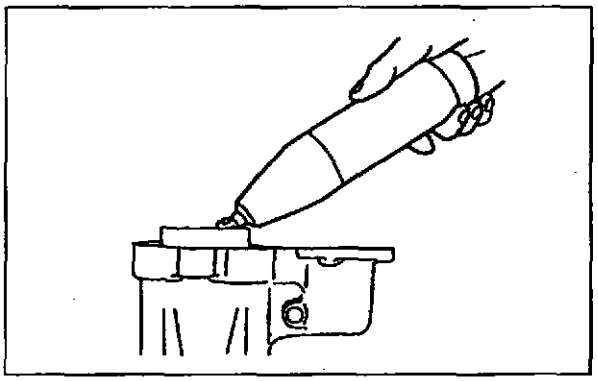
Test the motor to make sure that the voltage is below 24 volts and the current below 90 amperes.

Unit: mm (in.)

Item	Assembly Standard
Armature end play	0.2-0.6 (0.008-0.024)



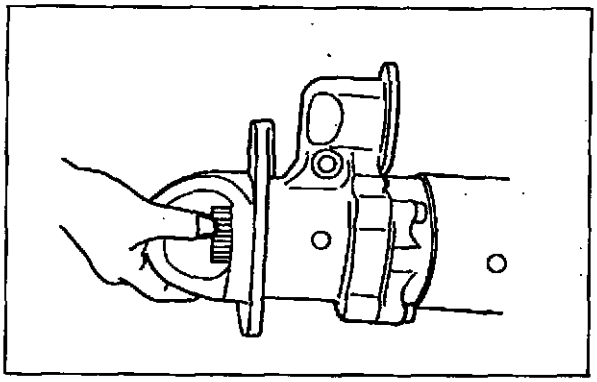
(7) Liberally coat the internal gear with grease, then install the pinion shaft to the gear.



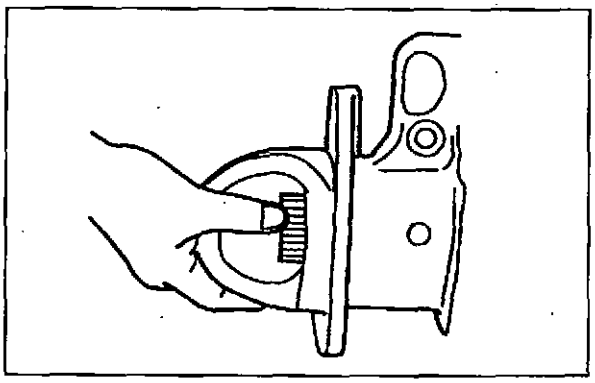
(8) Measure the end play of the pinion shaft. If the end play exceeds the assembly standard, adjust it on the internal gear side.

Unit: mm (in.)

Item	Assembly Standard
Pinion shaft end play	0.2-0.6 (0.008-0.024)

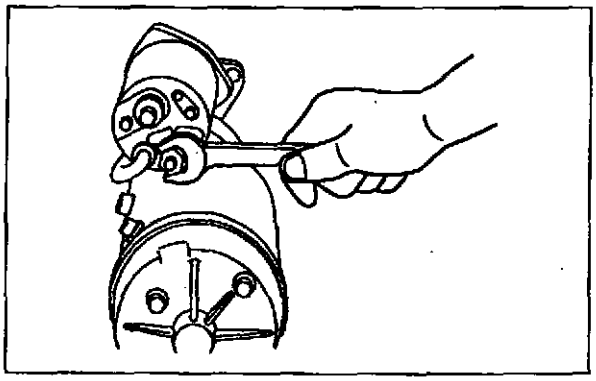


(9) Install the magnetic switch. Apply a voltage of 24 volts between the C and E terminals. Connect the lead wire and energize the circuit between the M and E terminals (within 1 second). After the pinion has shifted, measure how much the pinion returns. If the measurement is not 1.5 to 5 mm (0.06 to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



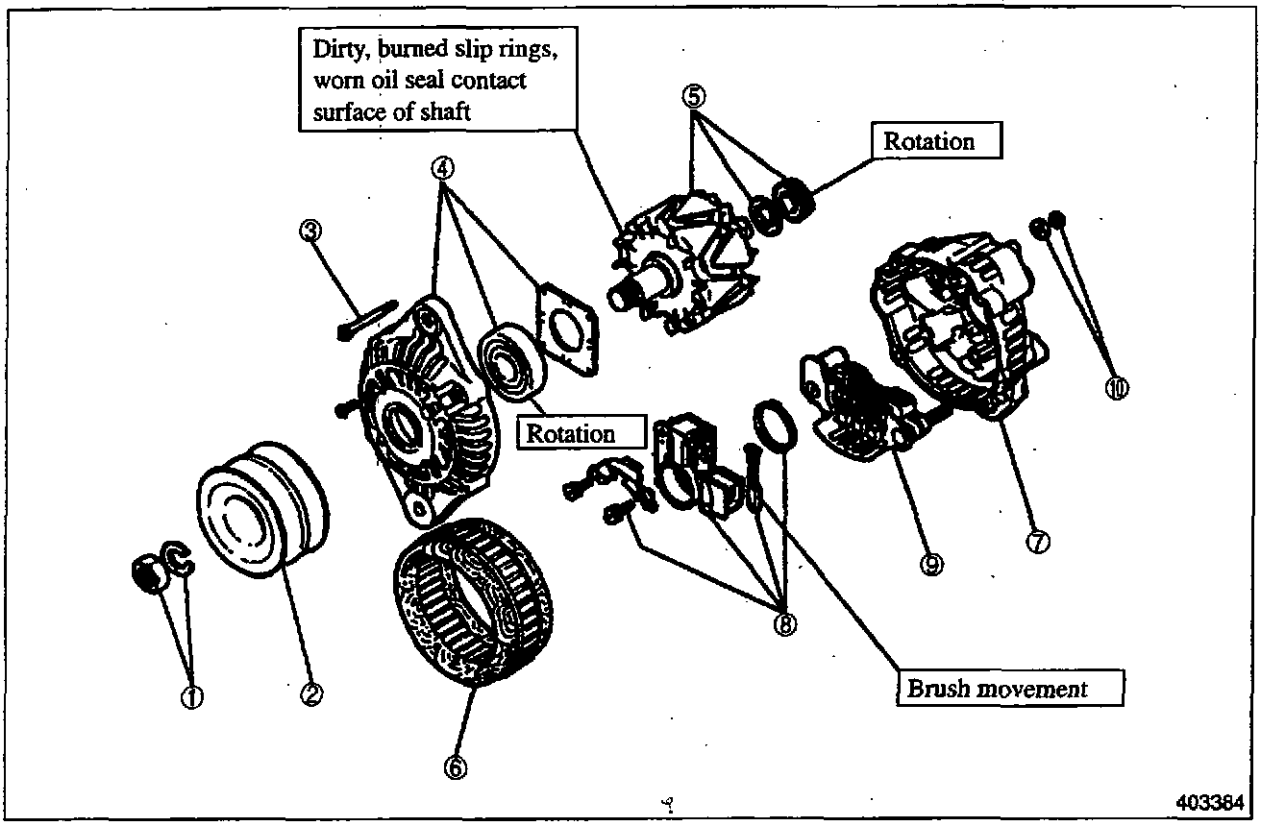
(10) Secure the lead wire.

(11) Install the safety switch.



3. The Alternator

3.1 Disassembly



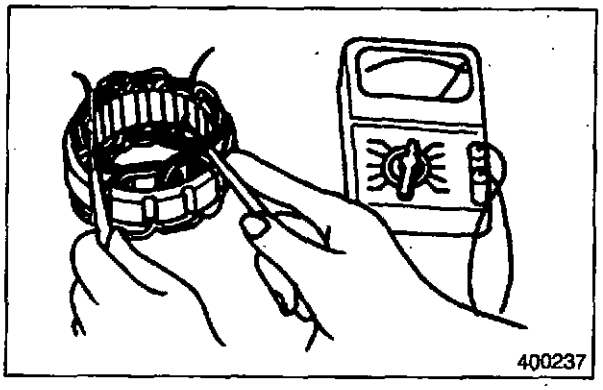
① Nut, washer
② Pulley
③ Screw
④ Front bracket assembly
⑤ Rotor assembly
⑥ Stator
⑦ Rear bracket
⑧ Regulator assembly
⑨ Rectifier assembly
⑩ Nut set

3.2 Inspection and repair

(1) Stator

(a) Testing the stator coil for open circuits
If there is no continuity among the four lead wires, replace the stator.

(b) Testing the stator coil for grounding
If there is continuity between the coil and core, replace the stator.

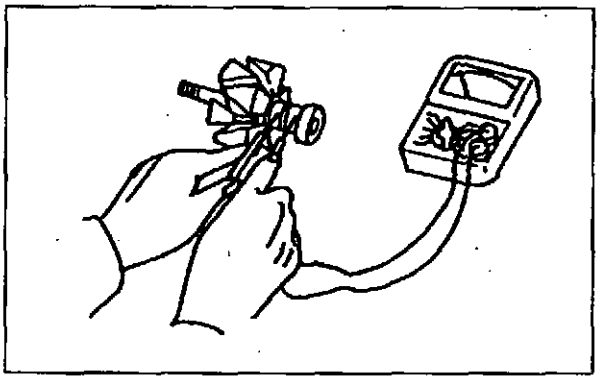


(2) Rotor

(a) Testing the rotor coil for open circuits
If there is no continuity between the slip rings, replace the rotor.

(b) Testing the rotor coil for grounding
If there is continuity between the slip rings and shaft (or core), replace the rotor.

(c) Measure the slip ring outside diameter
Using calipers, measure the outside diameter of each slip ring. If the diameter exceeds the service limit, replace the slip ring.



Unit: mm (in.)

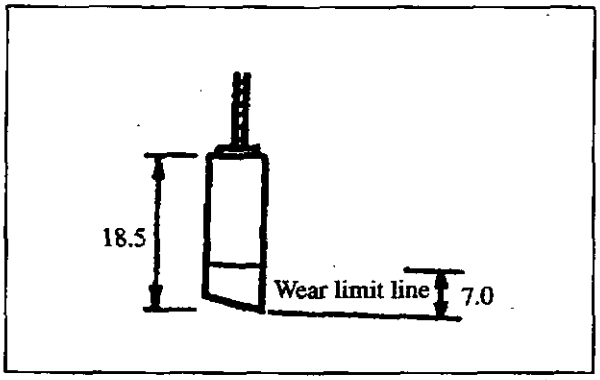
Item	Assembly Standard	Service Limit
Slip ring outside diameter	40.8 to 41.2 (1.606 to 1.622)	40.6 (1.598)

(3) Brushes

(a) Inspecting for wear

Unit: mm (in.)

Item	Assembly Standard	Service Limit
Brush height	18.5 (0.728)	11.5 (0.453)



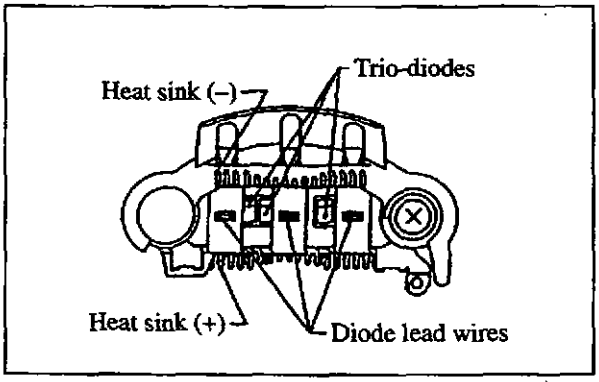
Inspecting brush

(b) Testing spring tension

Unit: gf (lbf) [N]

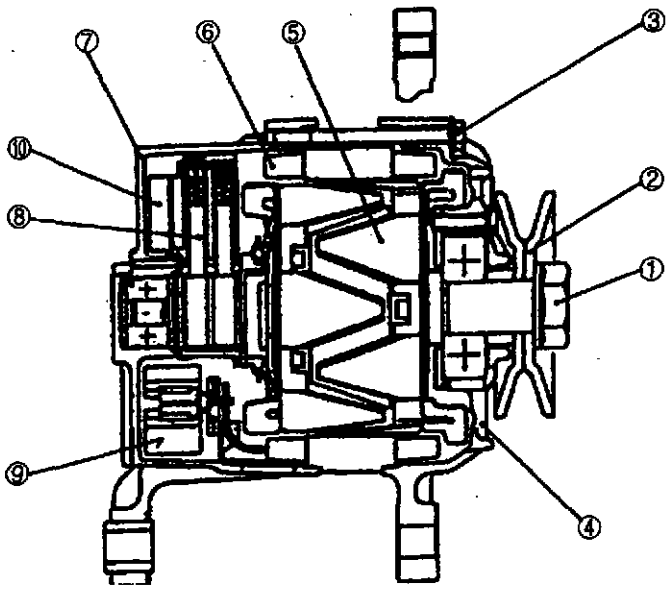
Item	Assembly Standard	Service Limit
Spring tension	320 to 440 (0.70 to 0.97) [3.1 to 4.3]	200 (0.45) [2.0]

(4) To check individual diodes, measure resistance between the diode lead wire and heat sink. Connect the positive (+) test lead wire to the diode and measure resistance. Then, connect the negative (-) test lead wire to the diode to measure resistance again. If both measured values are infinite, the diode circuit is open. If both measured values are close to 0 (zero), the circuit is shorted.
If the diode has an open circuit or is shorted, it is defective, and the rectifier must be replaced.



Inspecting rectifier

3.3 Reassembly

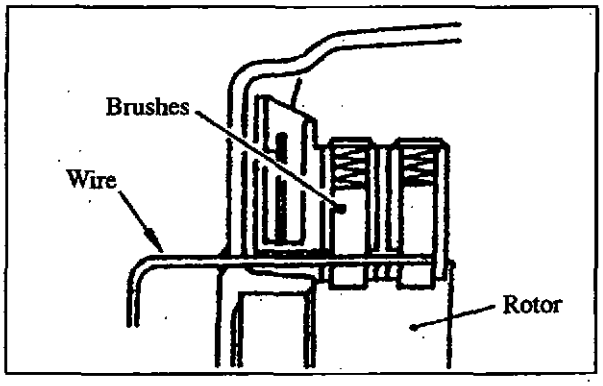


Reassembling Sequence

⑦→⑩→⑨→⑧→⑥→⑤→④→③→②→①

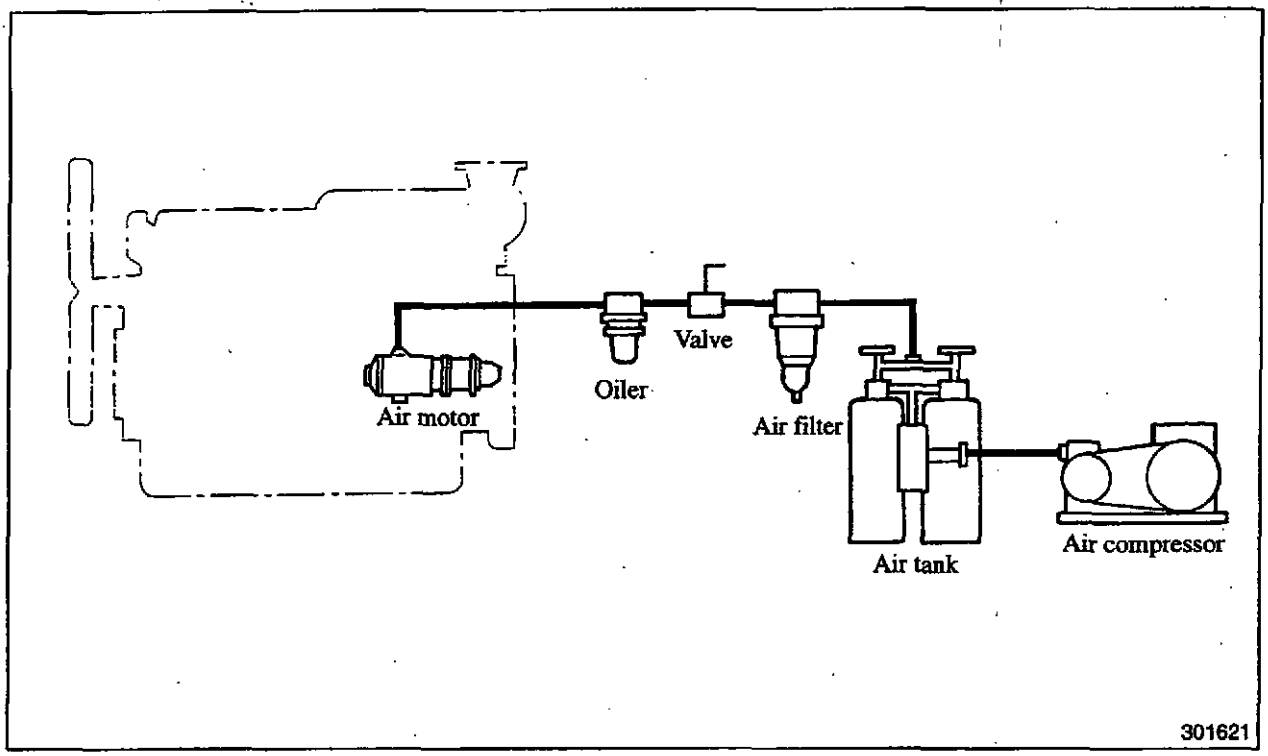
(1) Installing the brushes

Use a push wire to install the brushes in the brush holder as shown in the figure on the right. Install the rotor. Be sure to remove the push wire when you are finished.



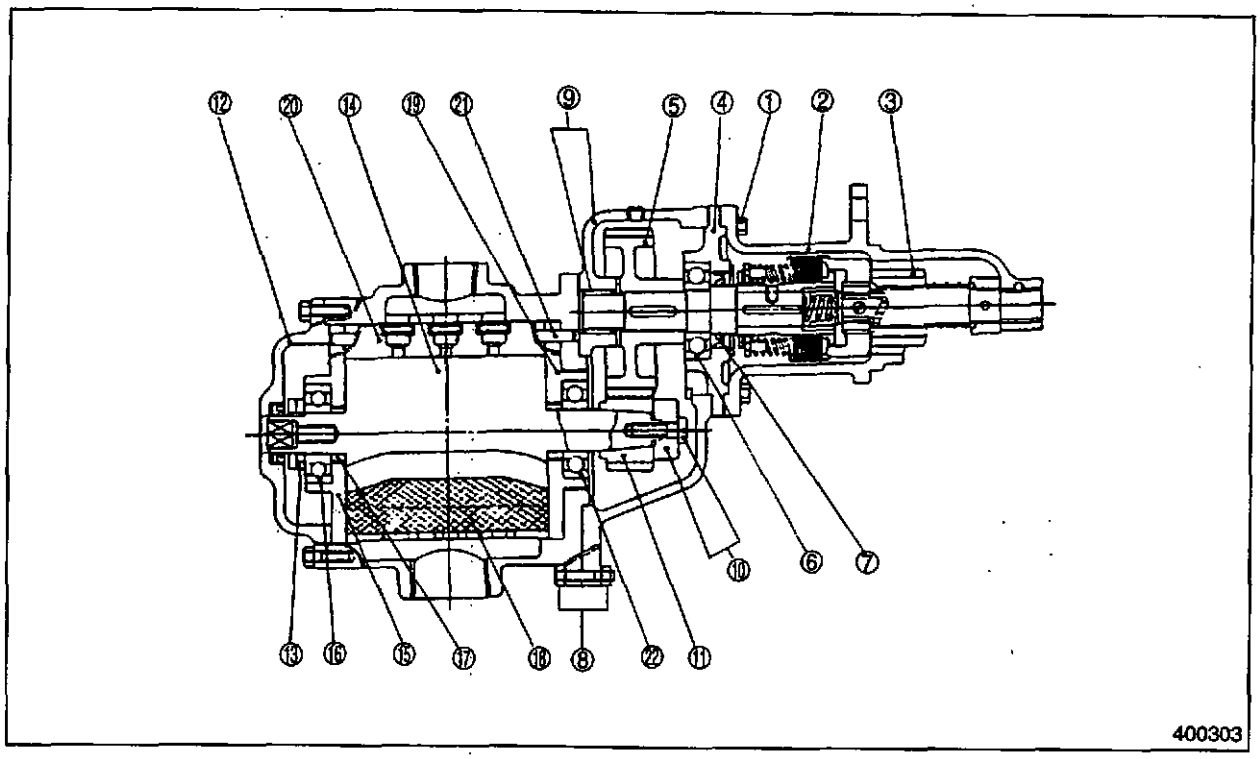
AIR START SYSTEMS

1. Air Motor System



2. Air Motor

2.1 Disassembly and Reassembly



① Bolt
② Pinion case
③ Clutch assy.
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.

Reassembling Sequence

⑲ → ㉒ → ⑭ → ⑱ → ⑰ → ⑳ → ⑮ → ⑯ → ⑬ → ㉑ → ⑫ → ⑪ → ⑩ → ⑨ → ⑧ → ①

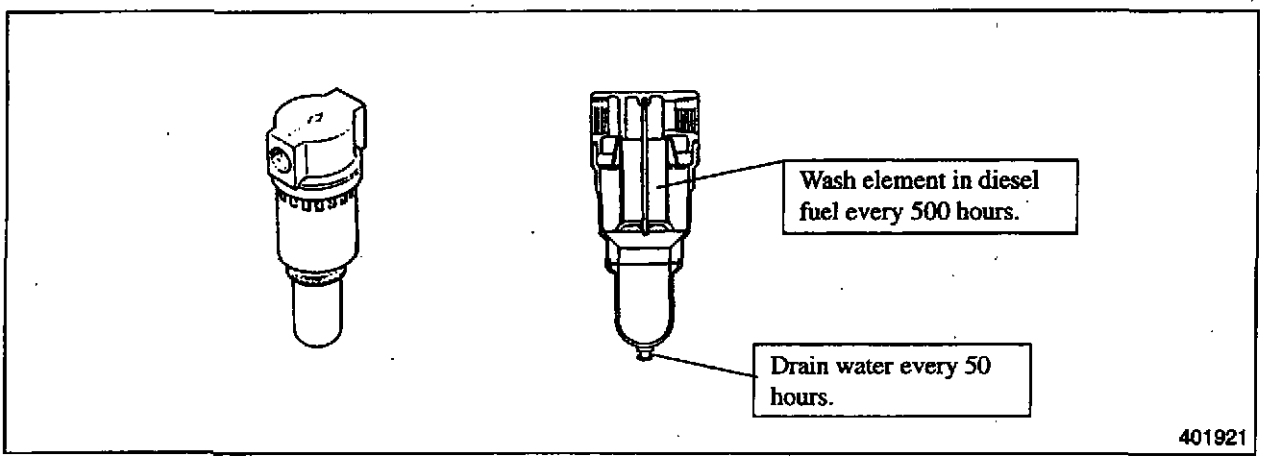
④ → ⑥ → ⑦ → ③ → ⑤ → ②

Inspection

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

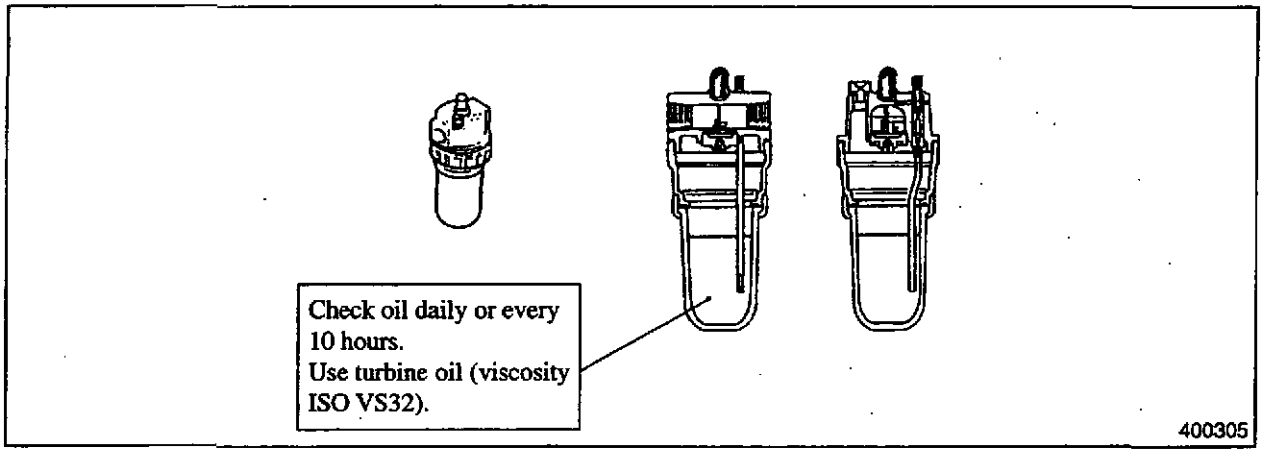
3. Air Filter

Inspection



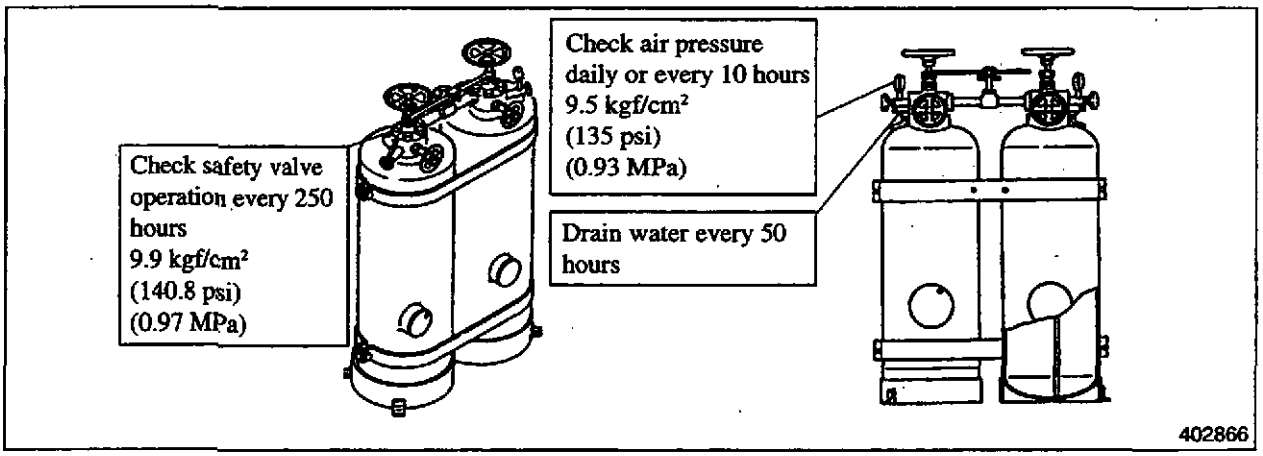
4. Oiler

Inspection

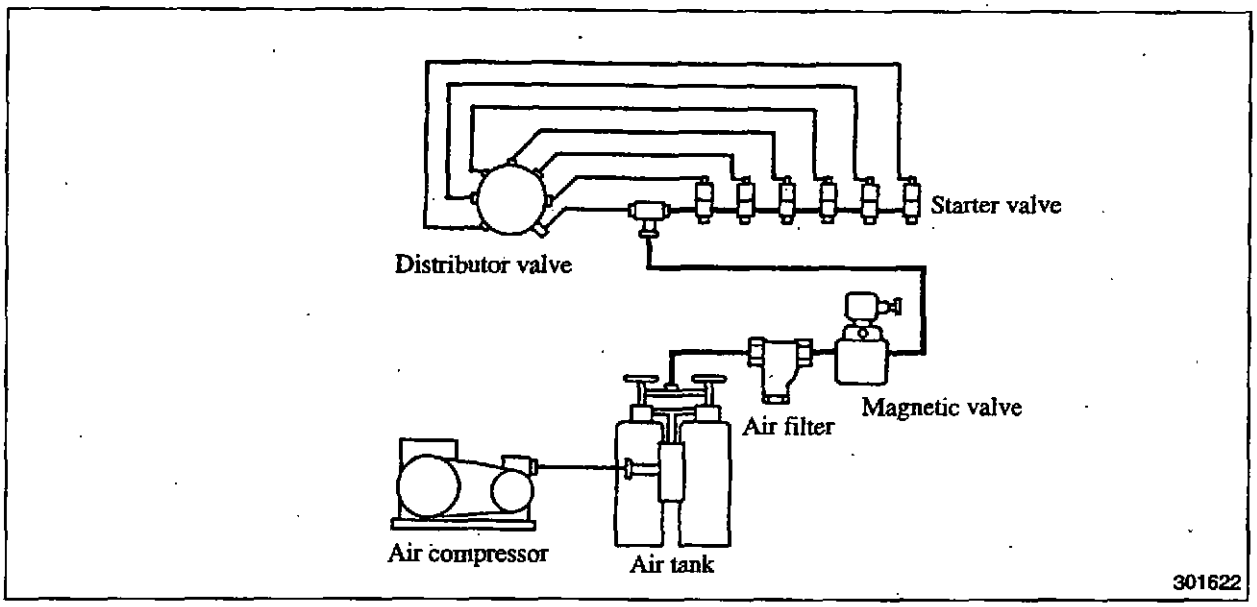


5. Air Tank (For Air Motor System)

Inspection

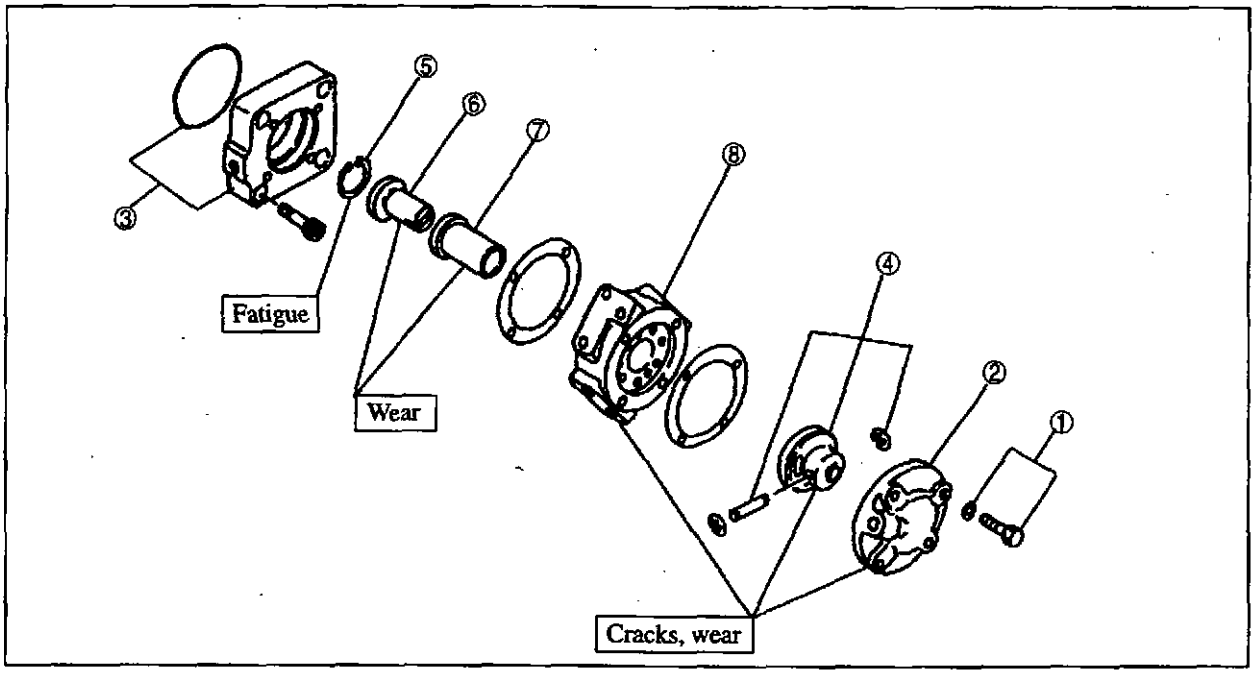


6. Direct Air Start System



7. Distributor Valve

7.1 Disassembly



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

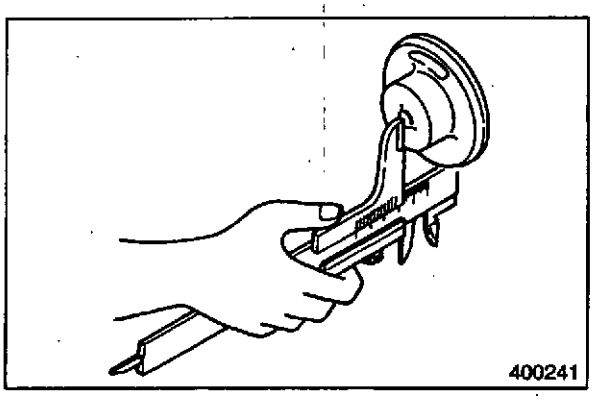
7.2 Inspection

(1) Measuring distributor valve height

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

Unit: mm (in.)

Item	Assembly Standard	Service Limit
Distributor valve height	21.5±0.1	21

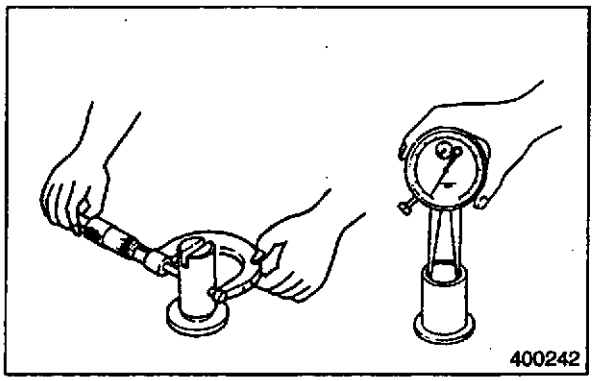


(2) Measuring distributor shaft clearance in the bushing

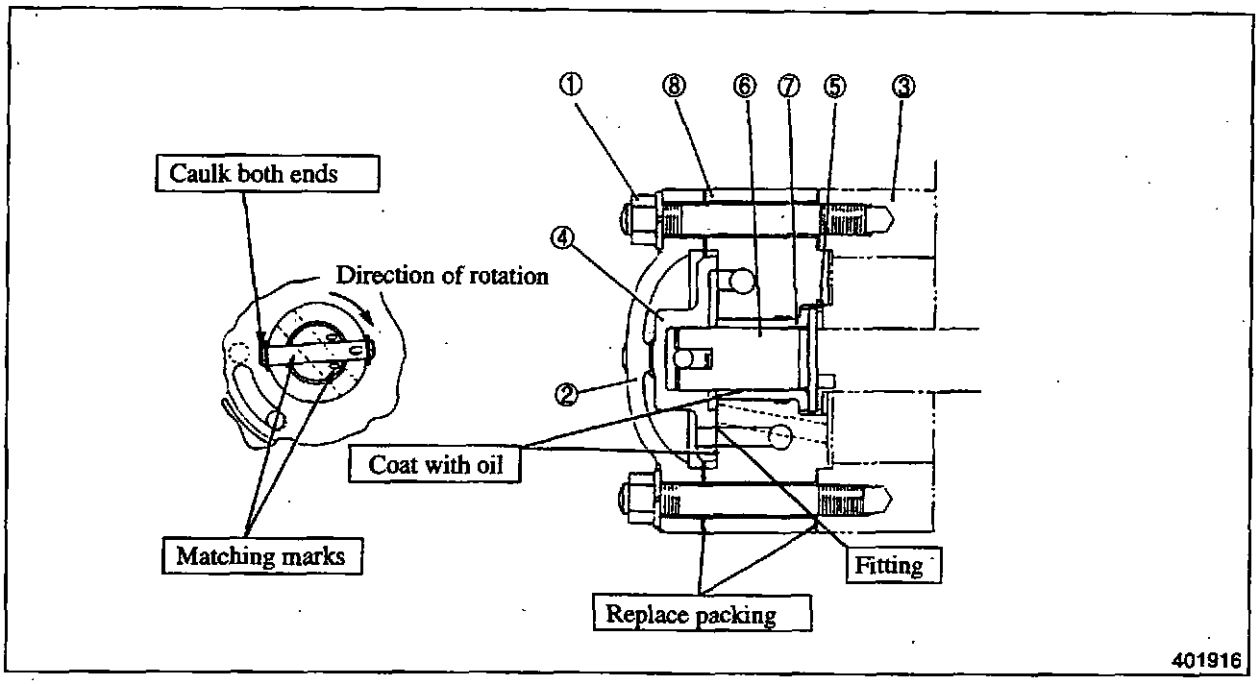
Measure the diameter of the shaft and the inside diameter of the bushing to determine the clearance. If the clearance exceeds the service limit, replace the bushing.

Unit: mm (in.)

Item	Assembly Standard	Service Limit
Distributor shaft clearance in bushing	0.050-0.091	0.300



7.3 Reassembly

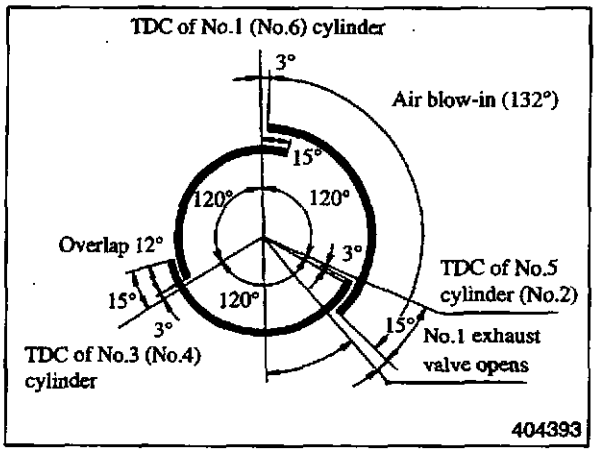


Reassembling Sequence

⑧→⑦→⑥→⑤→④→③→②→①

NOTE

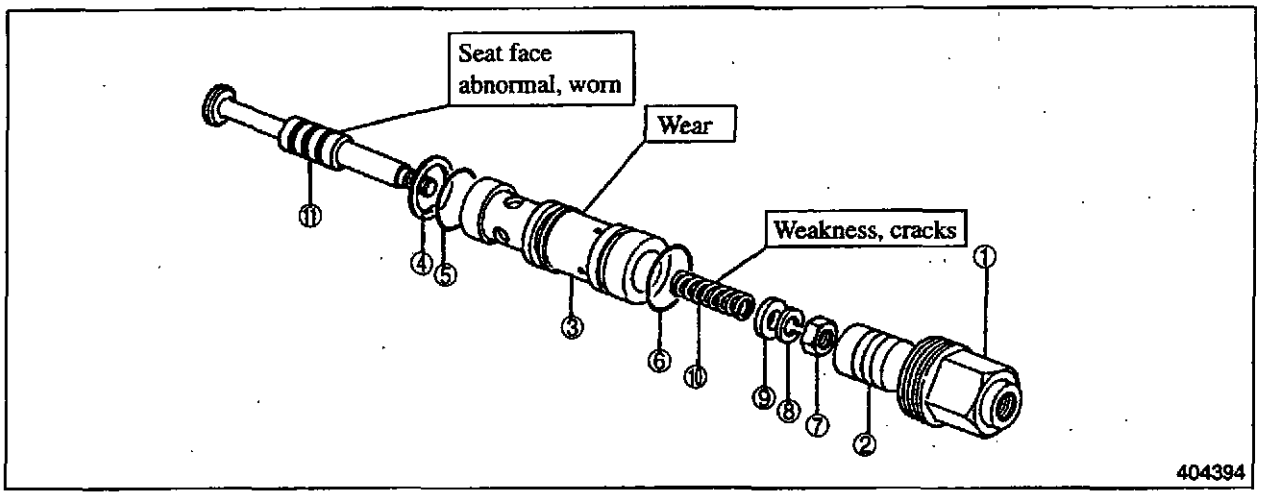
When reassembling and installing the distributor valve, be sure to align the matching marks. If the marks are not aligned, the valve timing (at which air is blown into the cylinders) could be off by 360°, resulting in a failure to start the engine.



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

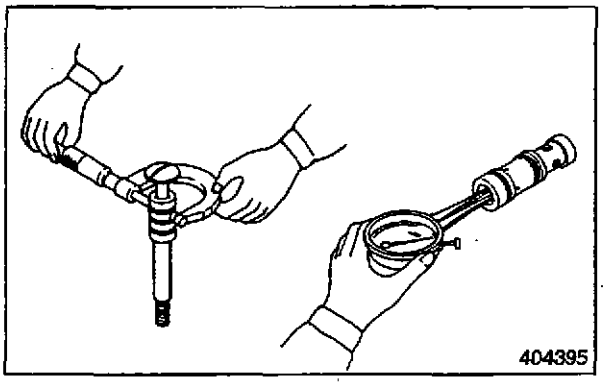
8.2 Inspection

(1) Measuring starter valve clearance in the guide

Using a micrometer and dial caliper gauge, measure the clearance. If the clearance exceeds the service limit, replace the parts.

Unit: mm (in.)

Item	Nominal Value	Standard Clearance	Service Limit
Starter valve clearance in guide	ø15	0.016-0.052	40.6

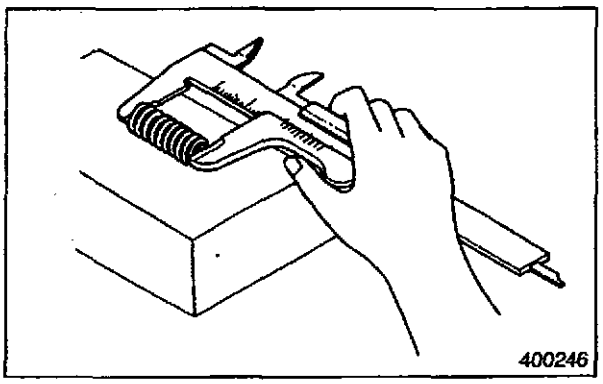


(2) Measuring valve spring length

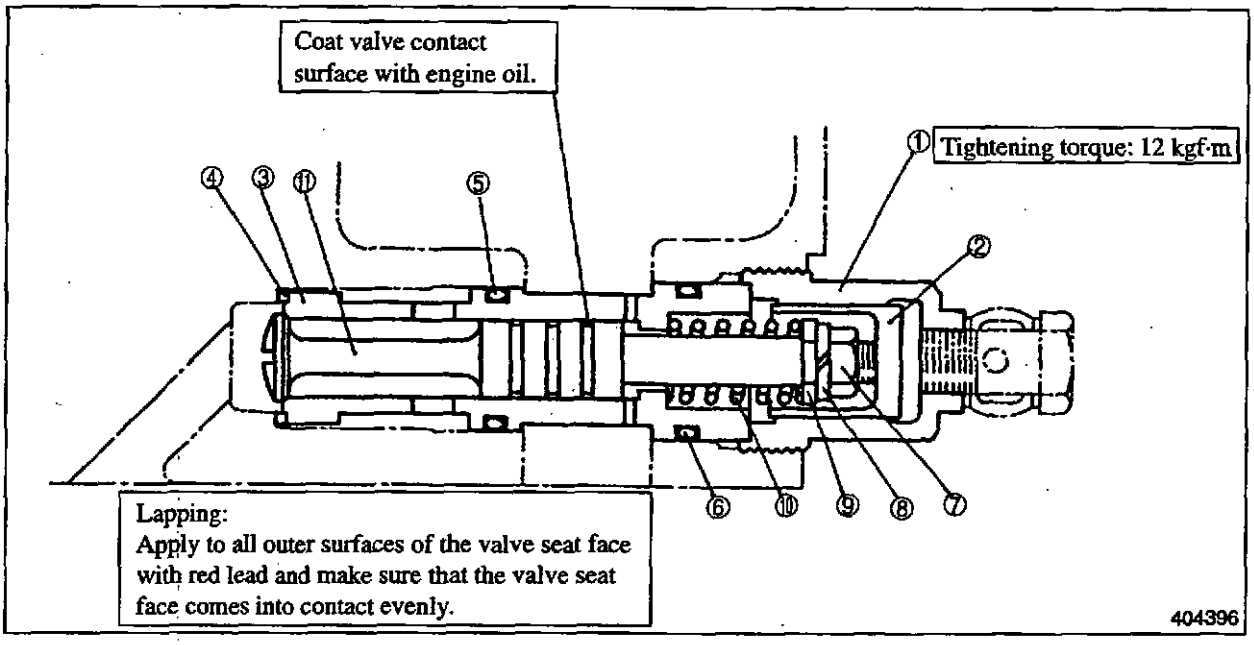
Use calipers to measure the free length. If the free length exceeds the service limit, replace the spring.

Unit: mm (in.)

Item	Assembly Standard	Service Limit
Valve spring free length	36	34



8.3 Reassembly

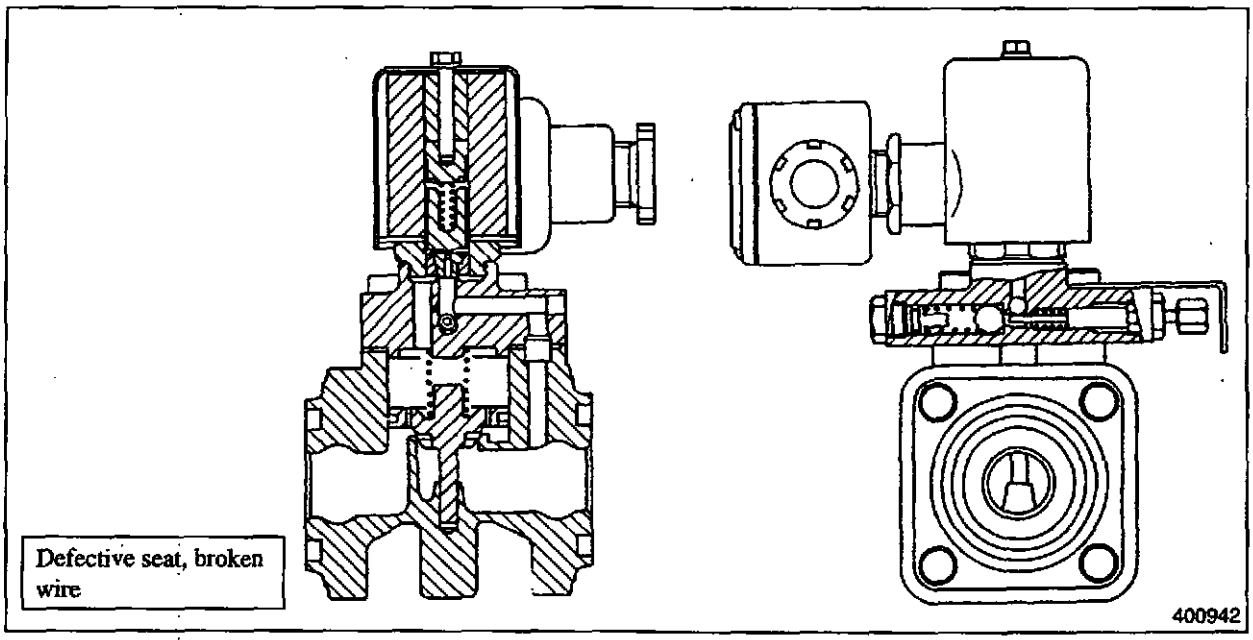


Reassembly Sequence

③→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

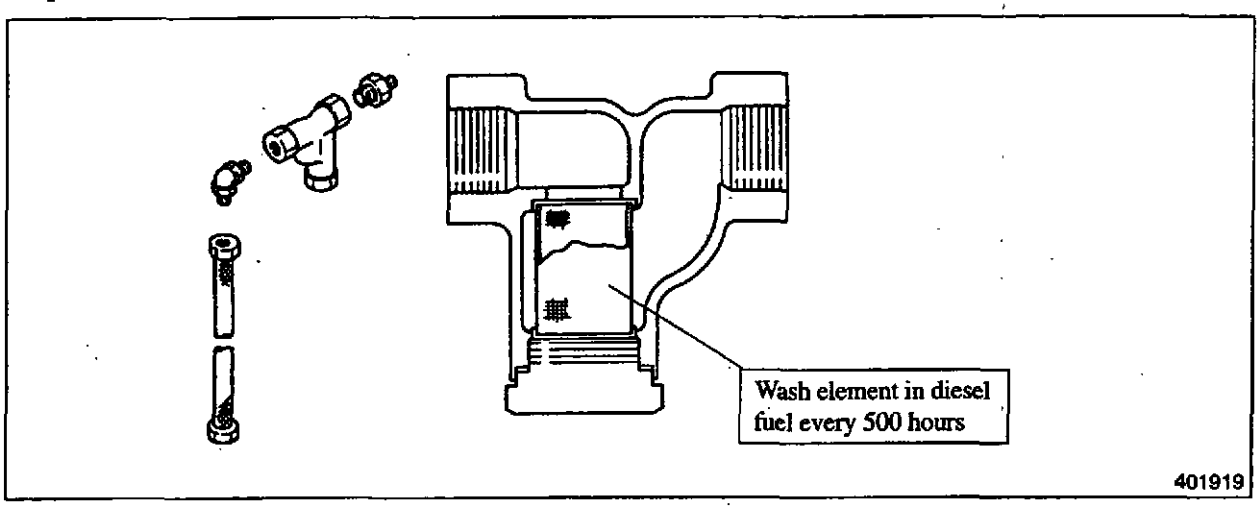
9. Magnetic Valve

Inspection



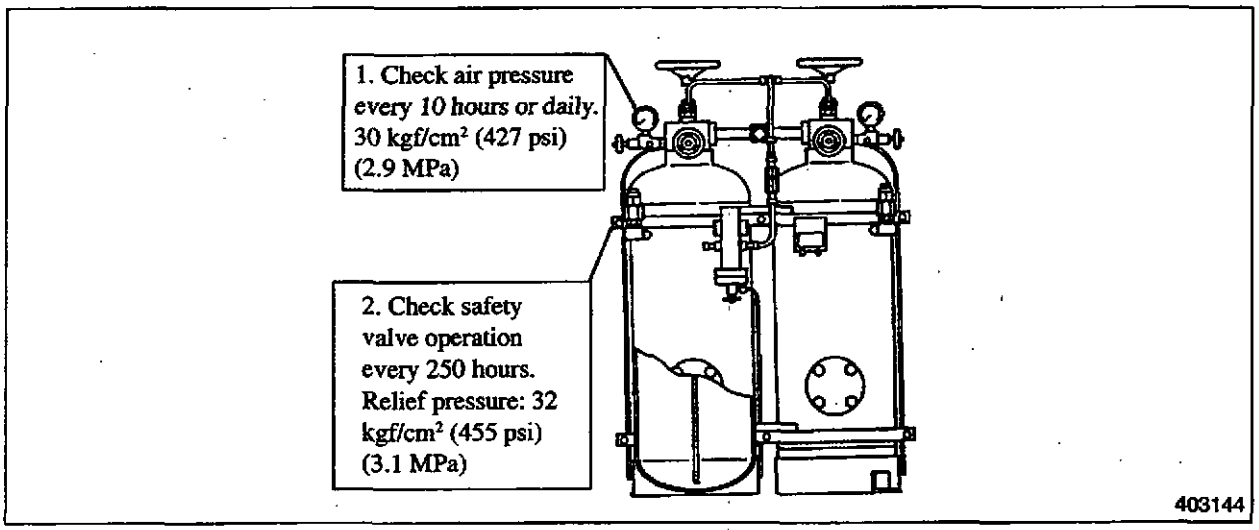
10. Air Filter

Inspection



11. Air Tank (For a Direct Air Start System)

Inspection



WORKSHOP TIPS

1. Precautions for Disassembly and Reassembly

1.1 Oil Seals

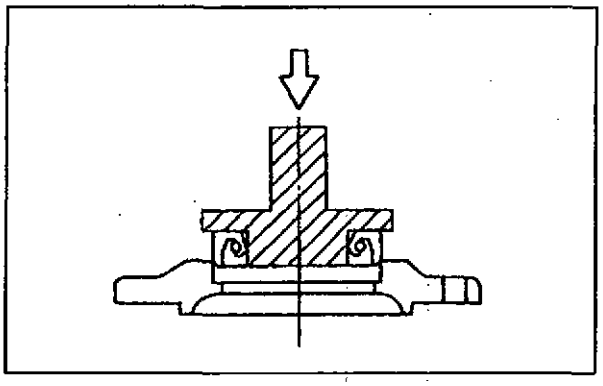
When installing oil seals, carefully observe the following points.

Driving oil seals into housings

(a) Check the seal lip for damage, and be sure to position correctly with respect to the oil compartment.

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

(c) Use an oil seal driver to guide the seal lip squarely. To avoid damage to the oil seal and leaking, never hammer on it directly.

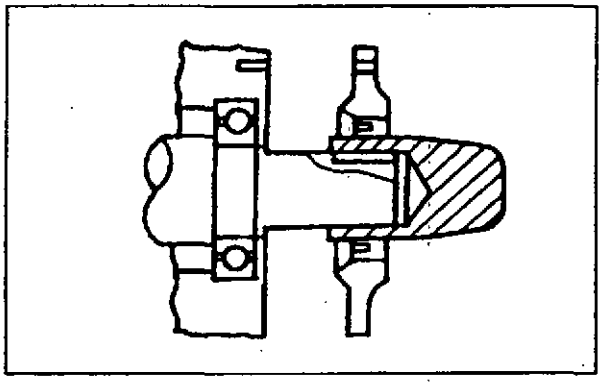


Oil seal driver

Driving oil seals onto shafts

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

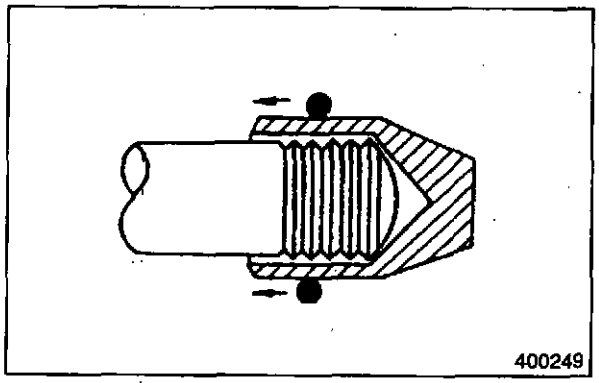
(b) Use an oil seal guide of the type shown when driving the oil seal over the stepped portion, splines, threads, or key way to prevent damage to the oil seal lip.



Oil seal guide

1.2 O-Rings

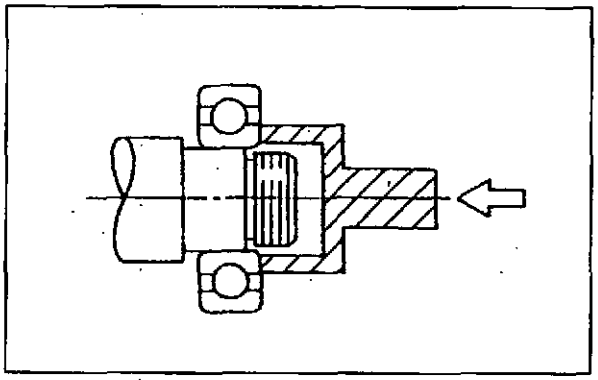
Use an O-ring guide to install an O-ring over stepped parts, splines, threads, or key way to prevent damage to the ring. Apply a thin coat of grease to the O-ring before installation.



O-ring guide

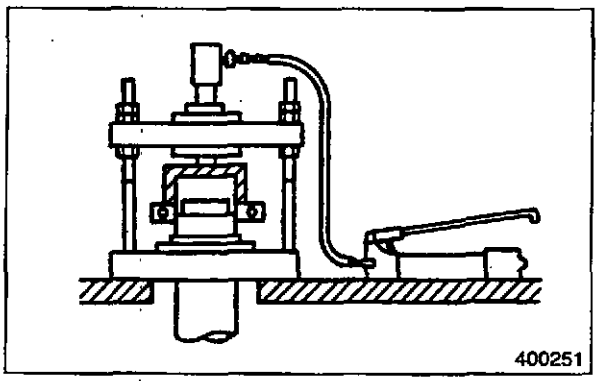
1.3 Bearings

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



Bearing driver

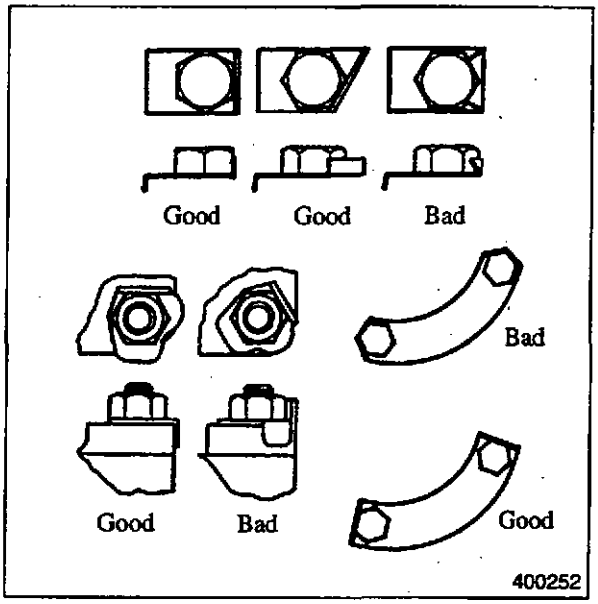
(2) Whenever possible, use a press to minimize shock to the bearing and to assure proper installation.



Bearing installation with a press

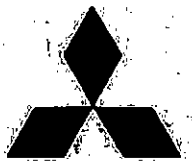
1.4 Lock Plates

Bend lock plates against the flats of the nuts or bolt heads as shown.



1.5 Split pins and spring pins

Generally, split pins are to be replaced at disassembly. Insert the pin fully and spread it properly. Drive each spring pin into position to hold it in place after later installation of parts has been completed.



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