SERVICE MANUAL

Engine No. 10001—UP

MITSUBISHI DIESEL ENGINE

S12R

1200/1350/1500kW

MITSUBISHI HEAVY INDUSTRIES, LTD.

Introduction

This service manual is written to familiarize you with the maintenance of your Mitsubishi S12A2 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 of 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 S12A2 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

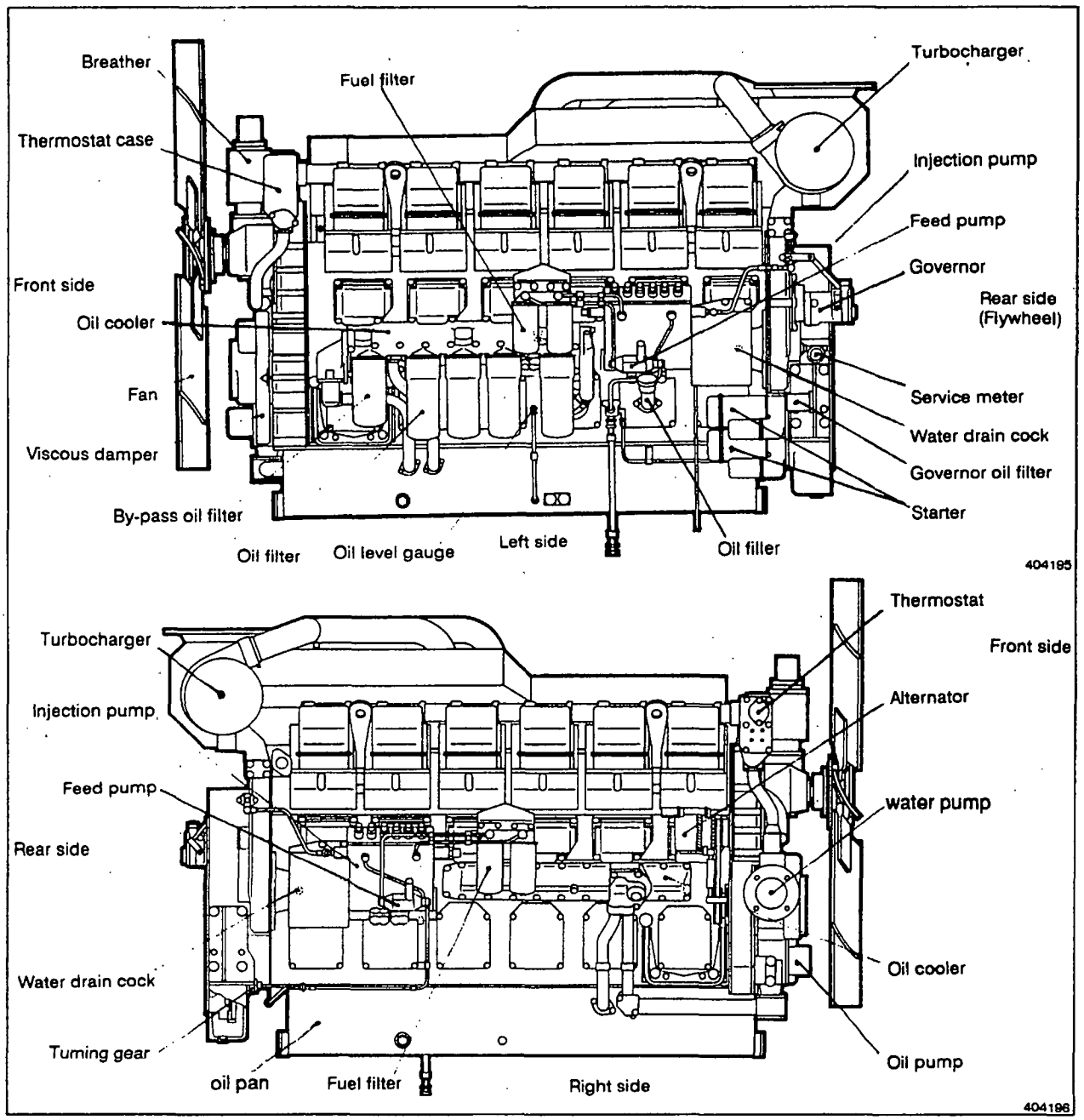
Chapter		Contents
1.	General	External views, sectional views, engine serial number location, engine model and application codes, specifications, tips on disassembly and reassembly
2.	Maintenance Standards	Maintenance standards, tightening torque, sealants and lubricants
3.	Special Tools	A list of special tools required
4.	Overhaul Instructions	Determining when to overhaul the engine, testing compression pressure
5.	Adjustments, Bench Testing, and Performance Tests	Adjustment of valve clearannce and fuel system priming, fuel timing adjustment, bench testing, and performance tests.
6.	Engine Accessory Removal and Installation	Removal and installation of turbochargers, 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, cylinder liners, pistons, connecting rods, flywheel, timing gears, camshaft, crankcase, crankshaft, main bearings.
8.	Inlet and Exhaust Systems	Disassembly, inspection, and reassembly of inlet and exhaust systems, to include air cleaners, inlet manifolds and air coolers, exhaust manifolds, and air heater
9.	Lubrication System	Disassembly, inspection, and resassembly of lubrication system, to include the oil strainer, oil pump, relief valve, oil cooler, and oil filters
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
12.	Electrical System	Disassembly, inspection, and reassembly of electrical system, to include starters and the alternator
13.	Air Start Systems	Disassembly, inspection, and reassembly of air start systems, to include the air motor, air filter, distributor valve, starter valves, and magnetic valves
14.	Workshop Tips	General precautions for disassembly and resassembly of parts: oil seals, O-rings, bearings, lock plates, and pins.

1. GENERAL

1. GENERAL

1. Outline

1.1 External View



NOTE

Direction of rotation when viewed from the rear is to the left (counterclockwise).

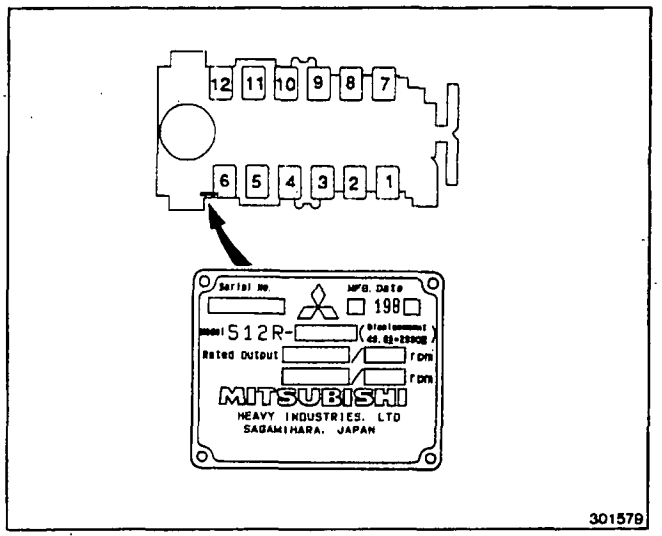
1.2 Engine Serial Number Location

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

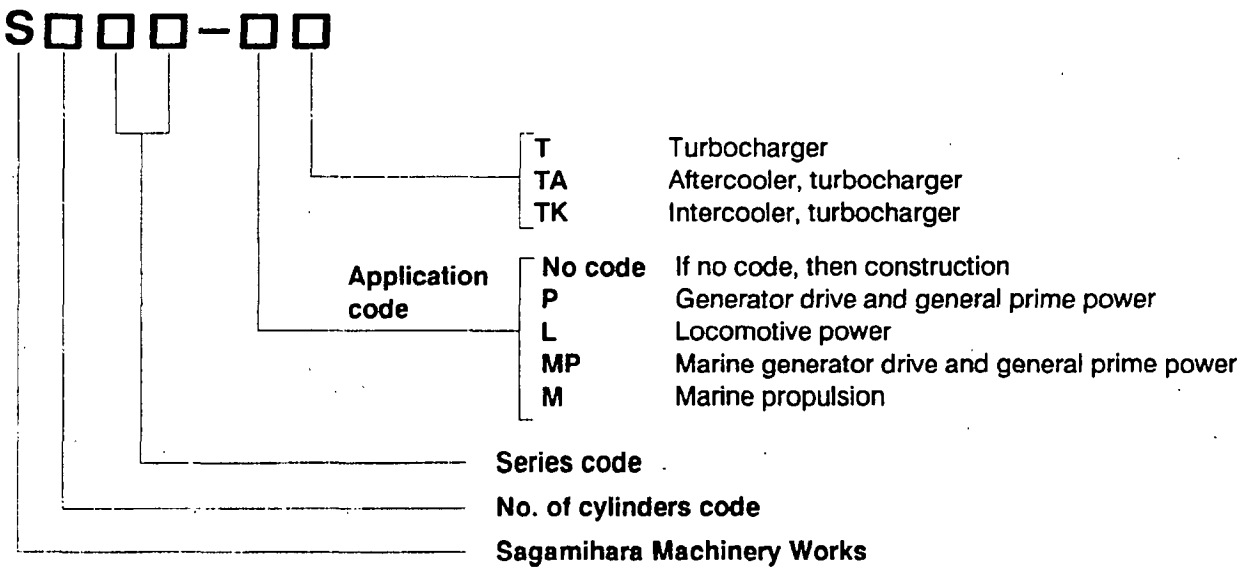
Example: Model Serial No.

SR12 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

Engine Type			S12 R [T,TA,TK]
Main specification			
Model			Water-cooled, 4-stroke cycle, turbocharged diesel T=— TA=w/aftercooler TK=w/intercooler
No. of cylinder-arrangement			12-V
Combustion type			Direct injection
Valve mechanism			Overhead
Cylinder diameter x stroke		mm	170 x 180
Displacement		l	49.0
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			1-12-5-8-3-10-6-7-2-11-4-9
Rotation direction			Counterclockwise as viewed from flywheel
Dimensions	Length	mm	2320
	Width	mm	1360
	Height	mm	1565
Weight (Dry)		kg	4700 4800
Engine proper			
Cylinder liner	Type		Wet type
Piston ring	No. of units		Compression rings: 2 Oil ring (w/expander): 1
Valve timing (when warm)	Inlet valve	Open Close	B.T.D.C. 37° A.B.D.C. 44°
	Exhaust valve	Open Close	B.B.D.C. 57° A.T.D.C. 24°
Engine support method			4 point support
Starting system			Starter, air motor or direct air inlet starting
Inlet and exhaust system			
Air cleaner	Type		Paper element type or pre-cleaner type
Turbocharger	Type		TD15 or TD13
	No. of units		2
Air cooler	Type		Laminated fin-plate type

Engine Type			S12 R [T,TA,TK]
Oil system			
	Lubricating type		Forced circulation type (Pressure feed by oil pump)
	Engine oil	Standard	Class CD oil (API service classification)
		Capasity (engine) l	180
	Oil pump	Type	Gear pump
		Delivery capacity l/mm	580 (at 1800 rpm engine)
	Relief valve	Type	Piston valve type
		Valve opening pressure kgf/cm^2	4 • 7
	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
		Valve opening pressure kgf/cm^2 (differential pressure)	2.3~2.7 (Contact point ON: 1.5~1.8kgf/cm^2
	Oil thermostat	Type	Wax type
		Valve opening temperature ℃	91~95
Cooling system			
	Cooling type		Water-cooled, forced circulation
	Capacity (Engine)		125 approx.
	Water pump	Type	Centrifugal
		Delivery capacity l/min.	1850 (at 1800 rpm engine)
	Thermostats	Type	Wax
		Valve opening temperature ℃	69~73
	Radiator	Type	Plate fin or corrugated fin
	Cooling fan	Type	Aluminum plated, circular arc type
		No. of blades	8
		Outside diameter mm	1524

Engine Type			S12 R [T,TA,TK]
Fuel system			
Injection pump	Model		PS6 type
	Manufacturer		Mitsubishi Heavy Industries
	Plunger outside diameter	mm	17
	Plunger lead	mm	Counterclockwise, Left-hand 35 lead
	Cam lift	mm	15
Feed pump	Model		Bosch KD 22Z type
	Manufacturer		Diesel Kiki
	Cam lift		12
Governor	Control system		(Hydraulic) Woodward PSG (Electrical) Woodward EG-3P or EG-B2P Barber-Coleman DYNA 1
Injection nozzles	Model		Hole type
	Manufacturer		Diesel Kiki
	No. of spray holes		10
	Spray hole diameter-Spray angle (deg.)	mm	ø0.35-160°
	Injection pressure	kgf/cm^2	350^{+5}_{0}
Fuel Filter	Type		Paper elememt type (spin on)

Engine Type			S12 R [T,TA,TK]
Electrical system			
Voltage polarity			24V- - ground
Starter	Model		Test production 0-23000 1840
	Manufacturer		Nikko Electric Industry
	Pinion mesh type		Pinion shift (Reduction type)
	Output	V-kW	24-7.5
	No. of starters		2
	No. of pinion tooth/ring gear tooth		15/193
Alternator	Type		3-phase alternating generator, Internal IC regulator
	Manufacturer		Mitsubishi Electric
	Output	V-A	24-30
	Rated output generated rpm		5000 (at 27V, 30 A)
	Regulated voltage	VV	28.5 ± 0.5
Safety relay (for starter chattering)	Model		0–25000–7440
Automatic contact relay	Manufacturer		Nikko Electric Industry
	Allowable temperature	℃	–20~+50
Alternator drive belt	Rating Seconds		30
	Operating voltage		8~24
	Operation interval for starter chattering (at 24V)	sec.	2.5~3.0 (SS–SW ON-OFF 1 cycle)
	Ground		2-wire system
	Nominal voltage		24
	Model		Low edge cog belt C type
	Outside circumference	mm	1000

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 enigine, 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 when required. Use assembly bins to keep engine parts in their 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 postions 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 section 3 of Chapter 2, "Maintenance Standards."

(4) Use a torque wrench to tighten parts when specified tightening torques are required. (Refer to section 2 of Chapter 2, "Maintenance Standards."

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

2. MAINTENANCE STANDARDS

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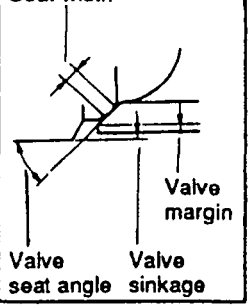
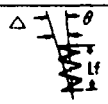
1. Maintenance Standards Table

Unit: mm

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 than rated rpm		The rated rpm is stamped on the nameplate. Check governor setting.
	Minimum rpm		600~650rpm				
	Compression pressure		18.5kgf/cm² minimum (at 120 rpm)		Faulty if 13kgf/cm² or less		Oil and water temp. 20~30°C
	Lube oil pressure		5~6.5kgf/cm² (at rated rpm) 2kgf/cm² minimum (at idling)		Faulty if 5kgf/cm² or less Faulty if 1kgf/cm² or less		Oil temp. 60~70°C
	Valve timing (with 2mm 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 B.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			
		Exhaust valves		0.8			
	Injection timing		BTDC	±1° (crank angle)			Varies according to specifications. Refer to caution plate on No.1 rocker cover.
Engine proper	Rockers	Rocker bushing inside diameter	ø36	36.000~ 36.040		36.090	
		Rocker shaft diameter	ø36	35.966~ 35.991		35.940	
	Valves	Valve stem diameter	ø10	9.940~ 9.960		9.910	The same for both inlet and exhaust valves.
		Valve guide inside diameter	ø10	10.000~ 10.015		10.060	The same for both inlet and exhaust valves.
	Valve seats and valves	Valve seat angle	30°				Seat width 
		Valve sinkage	0	-0.2~0.2	1.0		
		Seat width	2.3	2.15~2.45	2.8		
		Valve margin	3.0	2.8~3.2	Refacing permissable up to 2.5		

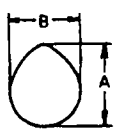
Unit: mm

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 outside diameter	ø60	(-0.070~ -0.130)			- (minus) Indicates the valve is closed.
	Valve springs	Free length		73		71	
		Squareness		θ=1.5 or less		Δ=2.2 over the length	
		Length under test force (mm/kgf)		66.0/29.45~ 32.55			
	Valve push rods	Runout		0.5 maximum		0.5	
	Cylinder heads	Warpage of gasketed surface		0.03 or less	0.07	0.50	Regrind slightly.
	Cylinder liners	Inside diameter	ø170	170.000~ 170.040	170.400	171.500	
		Out-of-roundness		0.02 or less			
		Taper		0.02 or less			
		Squareness with respect to lower face of flange		0.03 or less			
		Protrusion of cylinder liner flange above gasketed surface		0.09~0.18			
	Pistons	Outside diameter	ø170	169.76~ 169.80		169.66	Measure diameter in the direction transverse to pin at piston skirt.
		Variance in weight among pistons per engine		40g or less			
		Pin bore diameter	ø70	70.002~ 70.015		70.020	
		Protrusion		0.06~0.65			
	Cylinder head gasket	As-installed thickness	1.8	1.77~1.83			

Unit: mm

Group	Inspection Point			Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remarks
Engine proper	Pistons and cylinder head	Clearance between piston top and cylinder head			(1.22~1.95)			
	Piston rings	Gaps	Top		(0.6~0.8)		(2.0)	If gauge is not available, the general value can be obtained at the cylinder bore.
			Second		(0.6~0.8)		(2.0)	
			Oil		(0.3~0.45)		(2.0)	
	Piston pins	Diameter		ø70	69.987~ 70.000		69.970	
	Connecting rods	Bushing inside diameter		ø70	70.020~ 70.040		70.070	
		Bend and twist			0.05/100 or less			
		End play (rod and crankpin widths)		60 x 2	(0.4~0.9)		(1.4)	
		Variance in weight among connecting rods per engine			40g or less			
		Big end bore diameter		ø131	131.000~ 131.025		131.050	To be used in combination with bearing caps.
	Connecting rod bearings	Thickness of center	STD -0.25 -0.50 -0.75 -1.00	3.000 3.125 3.250 3.375 3.500	2.972~2.985 3.097~3.110 3.222~3.235 3.347~3.360 3.472~3.485		2.930 3.055 3.180 3.305 3.430	Replace bearings if worn down to service limit. Regrind crankpins and use undersize bearings if worn beyond service limit.
	Flywheel	Face runout			0.336 or less			
		Radial runout			0.13 or less			
	Injection pump accessory drive	Drive case bearing journal inside diameter		ø90	89.987~ 90.022			
				ø100	99.987~ 100.022			
		Bearing outside diameter		ø90	89.980~ 90.005			
				ø100	99.980~ 100.005			
		Bearing inside diameter		ø45	44.985~ 45.003			
				ø50	49.985~ 50.003			

Unit: mm

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remarks
Engine proper	Injection pump accessory drive	Drive shaft bearing journal outside diameter	ø45 ø50	45.002~45.013 50.002~50.013			
	Oil pump drive	Cover bearing journal inside diameter	ø110	110.000~110.035			
		Plate bearing journal inside diameter	ø110	109.987~110.022			
		Bearings Outside diameter	ø110	109.980~110.005			
		Inside diameter	ø50	49.985~50.003			
		Gear shaft bearing journal diameter	ø50	49.993~50.013			
	Vibration damper	Radial runout (at periphery)		0.5 or less		1.5	Replace every 8000 hours
		Face runout		0.5 or less		1.5	
	Timing and front gears	Backlash		(0.12~0.18)	(0.30)	(0.50)	Replace gears
		Idle gear bushing inside diameter	ø50	50.000~50.025		50.060	Same as the front oil pump idler, front fan drive idler, rear idler
		Idle gear shaft diameter	ø50	49.950~49.975		49.900	
		Idle gear end play		(0.1~0.5)		(0.8)	
		Front idle gear end play		(0.2~0.4)		(0.6)	
		Fan drive idle gear end play		(0.25~0.75)		(1.2)	
	Cam shaft	Cam lift (A-B)	9.247	9.197~9.297		8.45	
		Runout		0.05 or less	0.08		Runout at center bushing measured with both ends supported. Repair or replace.

Unit: mm

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remarks
Engine proper	Cam Shaft	Journal diameter	ø84	83.92~ 83.94		83.87	
		Camshaft bushing inside diameter (as installed in crank case)	ø84	84.000~ 84.035		84.10	Replace bushings and ream them, if necessary, if worn beyond service limit.
		End play	8	(0.10~0.25)		(0.40)	Replace thrust plate.
	Crankshaft	Crankpin diameter	ø125	-0.050~ -0.070	-0.110		
		Crank journal diameter	ø170	-0.060~ -0.080	-0.120		
		Center to center distance between journal and crankpin	90	±0.1			
		Parallelism between journals and crankpins		0.01 or less at pin length	0.03		
		Out of roundness between journals and crankpins		0.01 or less difference between diameters	0.03		
		Taper of journals and crankpins		0.02 or less difference between diameters	0.03		
		Fillet radius of crankpins	7	$7.0\ ^{0}_{-0.2}$			
		Fillet radius of journals	8.5	$8.5\ ^{0}_{-0.2}$			
		Hardness of journals and crankpins		Hv>590			
		Angular error of crankpins		±0°20'			
		Runout		0.04 or less	0.10		Repair or replace
		End play (Shaft thrust width)	67	(0.20~0.40)		(0.50) +1.18 for crank shaft width	Replace thrust plate if worn down to repair limit. Use oversize thrust plate if worn beyond repair limit. +0.25, +0.50, +0.75

Unit: mm

Group	Inspection Point			Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remarks
Engine proper	Main bearings	Thick-ness of center	STD -0.25 -0.50 -0.75 -1.00	4.5 4.625 4.750 4.875 5.000	4.467~4.480 4.592~4.605 4.717~4.730 4.842~4.855 4.967~4.980		4.425 4.550 4.675 4.800 4.925	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 or less	0.2		Regrind slightly.
		Main bearing bore diam-eter		ø179	179.000~ 179.025		179.045	
Lubrica-tion system	Oil pump	Oil pump gear and water pump gear backlash			(0.12~0.18)	(0.3)	(0.5)	
		Drive and driven gear backlash			(0.10~0.20)		(0.4)	
		Drive and driv-en gear clear-ance in case		ø60	(0.200~0.296) (0.040~0.116)		Tip clear-ance (0.35)	
		Gear end clearance in case		72.5			(0.21)	Remove the coverinstal-lation packing (width of 0.04) and measure.
		Shaft diameter		ø30	Drive shaft 29.887~ 29.900 Driven shaft 29.947~ 29.960		Drive shaft 29.840 Driven shaft 29.900	
		Bushing inside diame-ter			30.000~ 30.021		30.055	
	Safety valve	Valve opening pressure			12kgf/cm²			
		Spring instal-lation length/ weight (mm/kgf)			66.4/34.8			
	Relief valve	Valve opening pressure			4.7kgf/cm²			
	Oil thermostat	Temperature at which valve starts opening			93±2°C			
		Temperature at which valve lift is more than 11mm			105°C			

Unit: mm

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remarks
Lubrication system	Bypass alarm	Valve opening pressure		2.5±0.2kgf/cm²			Contact point ON should close at 1.5~1.8kgf/cm². Difference in oil pressure is 0.07kgf/cm² with a 1mm shim.
	Piston cooling nozzle	Valve opening pressure		3.0±0.3			
Cooling system	Water pump	Bearing bore inside diameter	ø120	119.987~120.022			
			ø110	110.005~110.040			Same as the bearing cover.
		Bearing Outside diameter	ø120	119.980~120.005			
			ø110	109.980~110.005			
		Inside diameter	ø55	54.981~55.004			
		Shaft bearing journal diameter	ø55	55.002~55.015			
		Vane front face clearance	1.3	(0.3~1.75)			
	Thermostat	Temperature at which valve starts opening		71±2°C			Check at atmospheric pressure
		Temperature at which valve lift is 0.1mm or more		85°C			
	Fan drive	Bearing bore inside diameter	ø140	139.986~140.026			
			ø120	119.987~120.022			
		Bearing Outside diameter	ø140	139.970~140.006			
			ø120	119.980~120.005			
		Inside diameter	ø55	54.981~55.004			
		Shaft bearing journal diameter	ø55	55.002~55.015			

Unit: mm

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remarks
Fuel system	Fuel injection nozzles	Valve opening pressure	350kgf/cm²	350~355kgf/cm²			
		Spray angle	160°				Check spray performance with a hand tester [at fuel oil temperature 20°C (68°F)]. Replace the nozzle tip if the spray pattern is still bad after washing in clean fuel oil.
	Governor drive	Case drive shaft side bearing bore inside diameter	ø52	51.988~52.018			
		Drive shaft side bearings Outside diameter	ø52	51.983~52.004			
		Inside diameter	ø25	24.987~25.003			
		Drive shaft bearing bore diameter	ø25	25.002~25.011			
		Case idler shaft side bearing journal inside diameter	ø47	46.989~47.014			
		Idler shaft side bearing Outside diameter	ø47	46.986~47.003			
		Inside diameter	ø20	19.987~20.003			
		Idler shaft bearing journal diameter	ø20	20.002~20.011			
		Drive shaft gear journal diameter	ø26	26.035~26.048			
		Drive gear inside diameter	ø26	26.000~26.013			
		EG-B2P drive shaft and gear journal diameter	ø29	28.959~28.080			

Unit: mm

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remarks
Fuel system	Governor drive	EG-B2P drive gear inside diameter	ø29	29.00~ 29.04			
		Idler shaft and gear journal outside diameter	ø24	24.035~ 24.048			
		Idler gear inside diameter	ø24	24.000~ 24.013			
Electri-cal system	Starter	Diameter of pinion shaft front side and inside diame-ter of metal	ø19	(0.045~ 0.138)		(0.25)	
		Diameter of pinion shaft rear side	ø30	30.002~ 30.011			
		Diameter of armature shaft front side	ø25	25.002~ 25.011			
		Diameter of armature shaft rear side	ø10	10.001~ 10.007			
		Commutator outside diameter	ø39			ø38	
		Armature shaft distor-tion		0.05			
		Runout of commutator		0.015 or less		0.100	
		Mica depth in commutator		0.5~0.8	0.2		
		Brush height		20		12	
		Brush spring tension (with brush installed)		4.0~5.0kgf			
		Armature end play		0.2~0.6			
		Pinion shaft end play		0.2~0.6			
	Alternator	Slip ring outside diameter	41	40.8~41.02		40.6	
		Brush height	23			8	Up to wear limit

Unit: mm

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remarks
Electrical system	Alternator	Brush spring tension	380gf	320~440gf		200gf	
	Alternator drive belt tension			10~15			Flexibility when pressed with thumb. 
Air start systems	Distributor valve	Valve height		21.5±0.1	20		
		Shaft clearance in bushing		(0.050~ 0.091)	(0.300)		
	Starter valve	Valve clearance in valve guide	ø15	(0.016~ 0.052)		(0.100)	
		Valve spring free length		36		34	

2. Tightening Torque Table

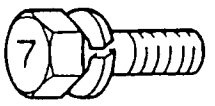
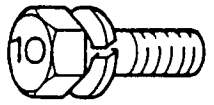
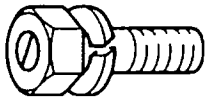
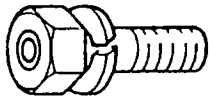
2.1 Important Bolts and Nuts

Secured part or component	M dia.x pitch (metric thread)	Width across flats (mm)	Tightening Torque kgf·m	lbf·ft	N·m	Remarks
Cylinder head	22 x 2.5	27	55	398	539	[Wet]
Rocker case	12 x 1.25	17	11	80	108	
Rocker shaft	14 x 2	19	15	108	147	
Cam shaft gear	12 x 1.25	17	11	80	108	
Cam shaft thrust plate	12 x 1.25	17	6	43	59	
Main bearing caps	24 x 3	30	60	434	588	[Wet]
Main bearing cap side bolts	20 x 2.5	27	40	289	392	
Hanger	20 x 1.5	30	40	289	392	
	16 x 1.5	24	22	159	216	
Piston cooling nozzle	12 x 1.75	17	3.5	21A	21A	
Timing gear case	16 x 1.5	24	22	159	216	
Rear plate	12 x 1.25	17	6	43	59	
	16 x 1.5	24	22	159	216	
Oil pan	12 x 1.25	17	6	43	59	
Mounting brackets	20 x 1.5	30	40	289	392	
Connecting rod bearing caps	22 x 1.5	27	55	398	539	[Wet]
Balance weight	22 x 1.5	32	50	362	490	[Wet]
Flywheel	22 x 1.5	32	60	434	588	[Wet]
Ring gears	10 x 1.25	14	6	43	59	
Vibration damper	22 x 1.5	32	50	362	490	
Timing idler gears	12 x 1.25	17	11	80	108	
Idler shaft thrust collar	16 x 1.5	24	22	159	216	
Front gear case	12 x 1.25	17	6	43	59	
	16 x 1.5	24	22	159	216	
Front plate	12 x 1.25	17	6	43	59	
Idler shaft	12 x 1.25	17	11	80	108	
Idler gear thrust plate	10 x 1.25	14	3	22	29	
Oil pump and water pump mounting plates	12 x 1.25	17	6	43	59	
Bearing cover	12 x 1.25	17	11	80	108	
Injection pump drive case	12 x 1.25	17	11	80	108	
Injection pump gears (nuts)	30 x 1.5	46	40	289	392	
Injection pump coupling shaft	14 x 1.5	22	17~18	123~130	167~177	Tighten the slit part.
Oil pump	12 x 1.25	17	11	80	108	
Oil pump cover	10 x 1.25	14	3.4	25	33	

Note: [Wet] indicates apply engine oil to the threads of the nuts and bolts.

Secured part or component	M dia.x pitch (metric thread)	Width across flats (mm)	Tightening Torque kgf•m	lbf•ft	N•m	Remarks
Water pump	12 x 1.25	17	11	80	108	
Water pump shaft pulley (nuts)	30 x 1.5	46	40	289	392	For alternator drive
Fan drive case	12 x 1.25	17	11	80	108	
Fan drive gear (nuts)	30 x 1.5	46	40	289	392	
Fan drive coupling (nuts)	30 x 1.5	46	40	289	392	
Fan drive hub	12 x 1.25	17	11	80	108	
Fan drive idler shaft	12 x 1.25	17	6	43	59	
Injection pump brackets	12 x 1.25	17	11	80	108	
Injection pump	12 x .25	17	11	80	108	
Injection pump laminate plate	12 x 1.25	17	8.5~9.5	61~69	83~93	
Injection pump flywheel (nuts)	24 x 1.5	36	28~30	203~217	275~294	
Plunger assembly	12 x 1.25	19	8~8.5	58~61	78~83	
Delivery valve holder	30 x 1.5	32	24~26	174~188	235~255	
Injection nozzle gland (nuts)	14 x 1.5	22	10	72	98	
Injection nozzle chip (nuts)	28 x 1.5	27	18~20	130~145	177~196	
Injection nozzle adjusting screw nut	14 x 1.5	22	4~5	29~36	39~49	
Injection nozzle inlet connector	16-1.5	19	6.5~7.5	47~54	64~74	
Governor drive case	12 x 1.25	17	11	80	108	
Starter	12 x 1.25	17	6	43	59	

2.2 General Bolts and Nuts

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

Note:
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)

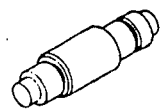
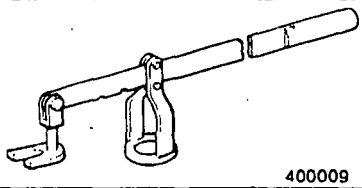
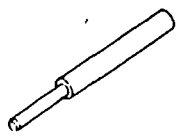
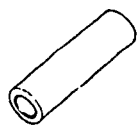
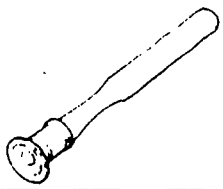
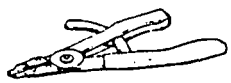
3. Sealants and Lubricants Table

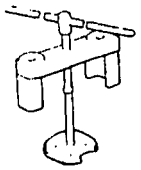
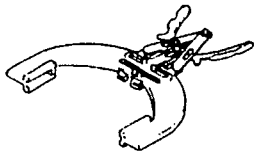
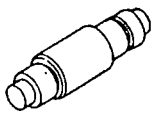
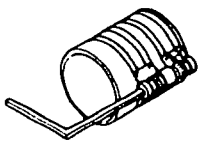
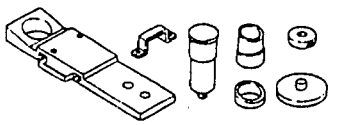
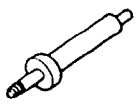
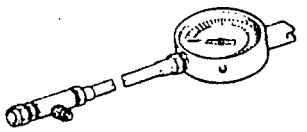
Group	Application Point	Sealant or Lubricant	How to Use
Engine Proper			
	Cylinder head sealing caps	Hermeseal S-2	Coat holes in crankcase
	Water outlet connectors (Rocker case)	Grease	Grease O-ring joint
	Cylinder liners	Engine oil	Grease O-ring joint
	Front plate, gear case, oil pan, and crankcase	Herdite	Coat three-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
	Oil pan and crankcase	Herdite	Coat joint surfaces only of both sides of packing
	Oil seals	Engine oil	Coat lip of each oil seal
Lubrication system			
	Oil pump Cover and case	Three Bond 1215	Coat both sides of packing
Cooling system			
	Water pump • Oil seal • Unit seal	Engine oil LLC solution (antifreeze)	Coat lip of inner seal only Coat floating seat
	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.

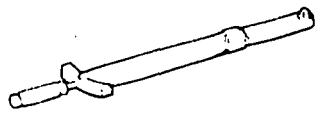
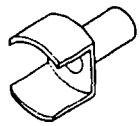
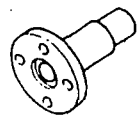
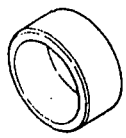
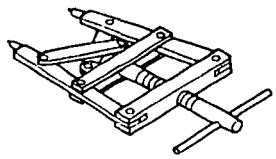
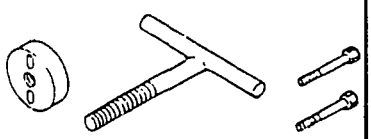
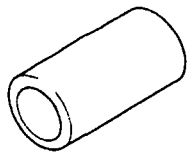
3. SPECIAL TOOLS

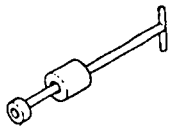
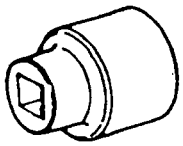
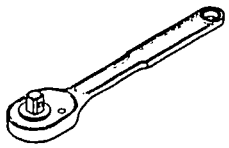
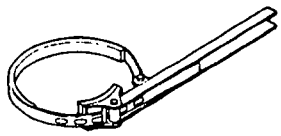
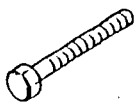
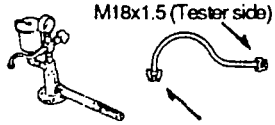
3. SPECIAL TOOLS

Special Tool List

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

Tool Name	Part No.	Shape	Use
Cylinder liner remover	37591-04100	 400015	Cylinder liner remova
Piston ring tool	37191-03200	 400017	Piston ring removal/installation
Idler bushing puller	32591-02500	 403390	Idler bushing removal/installation
Piston installer	37191-07100	 400019	Piston installation
Connecting rod bushing installer	37591-01010	 404197	Connecting rod bushing removal/ installation
Compression gauge adaptor	37591-02200	 400023	Compression pressure measurement
Compression gauge	33391-02100	 400902	Compression pressure measurement
Socket	58309-73100	 400903	For removal/installation of fandrive shaft gear, coupling, injection pump gear, and water pump shaft pulley nut.

Tool Name	Part No.	Shape	Use
Torgue wrench	32191-03100	 400904	
Piston remover	45815-32300	 403210	Piston removal
Slinger installer	37491-02100	 400020	Oil seal slinger installation (Crankshaft rear side)
Installer guide	37491-02200	 400021	To be used in combination with slinger installer for oil seal slinger installation (Rear side)
Unit seal installer	37191-06300	 400025	Water pump unit seal installation
Water pump pliers	37591-03100	 404198	For water pump cover snap ring
Impeller remover	37591-03200	 404199	Water pump impeller removal
Ring installer	37791-03300	 404200	Pressurized ring insertion for water pump unit seal

Tool Name	Part No.	Shape	Use
Ring remover	37791-03400	 404608	Water pump unit seal ring removal
Nozzle remover	33591-10101	 400007	Nozzle removal
Socket	F9614-22000	 400903	Engine cranking
Ratchet handle	37191-03300	 404201	Engine cranking
Oil filter wrench	32591-02100	 404202	Removal/installation of oil filter and fuel filter
Adjustable wrench	F9611-1500	 400905	
Jacking bolt	64362-68500	 404203 M12x1.25-95mm	
Nozzle tester	41091-01500	Nozzle connection pipe M18x1.5 (Tester side)  M18x1.5 (Nozzle fitting side) 400907	Nozzle opening pressure measurement

4. OVERHAUL INSTRUCTIONS

4. 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

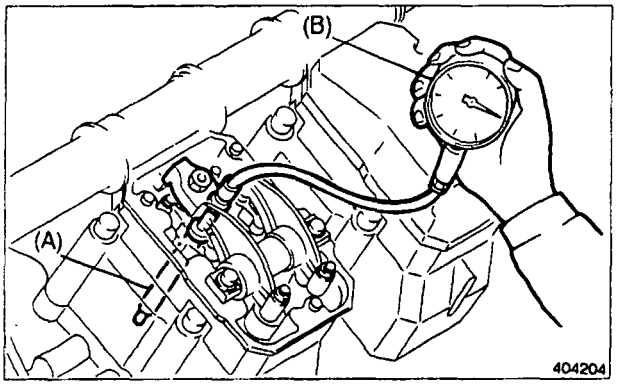
(g) Increased noise from engine parts

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 adapter and connect pressure gauge (33391-02100).

(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/cm^2

Item	Assembly Standard	Repair Limit
Compression pressure	18.5 min.	13 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.

5. ADJUSTMENTS, BENCH TESTING, AND PERFORMANCE TESTS

5. ADJUSTMENTS, BENCH TESTING, AND PERFORMANCE TESTS

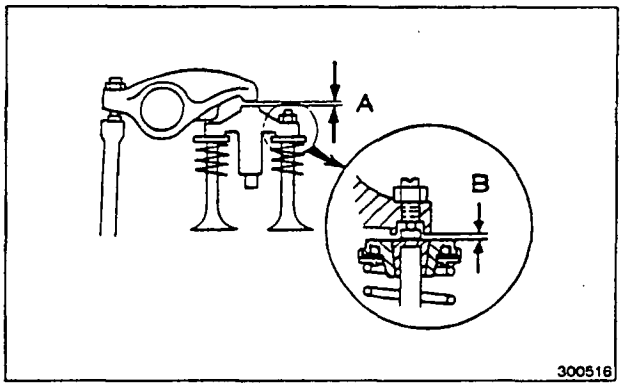
1. Adjustments

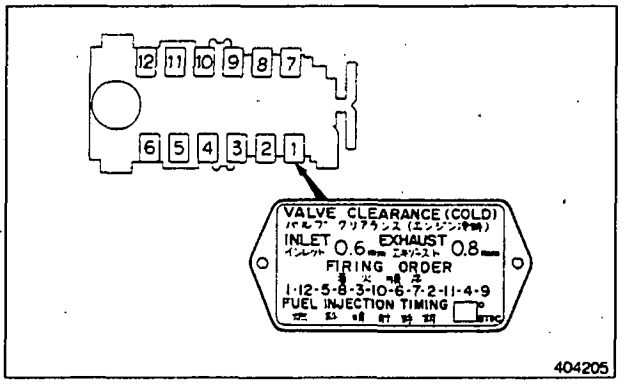
1.1 Valve Clearance

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

Unit: mm (in.)

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





NOTE

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

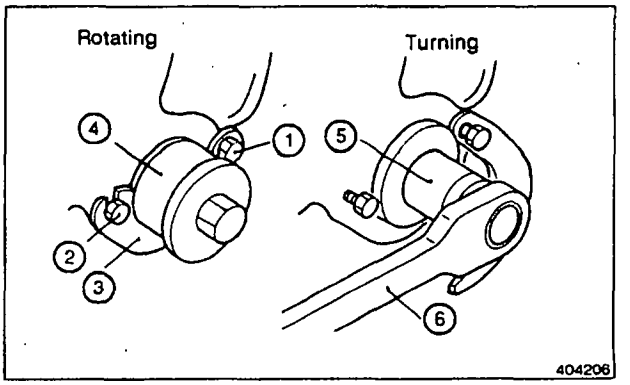
(b) Looking toward the cylinder head, the inlet valves are on the left, the exhaust valves on the right.

(c) The specified clearances for the valves are indicated on the caution plate fitted to the No. 1 cylinder rocker cover.

(1) Inspecting valve clearance

(a) Inspect the valve clearance in the firing order by turning the crankshaft (60°) in the direction of normal rotation to bring the piston to top dead center of the compression stroke.

Firing order: 1-12-5-8-3-10-6-7-2-11-4-9



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). Push down the ratchet handle (6) in the normal direction.

(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 viscous 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.

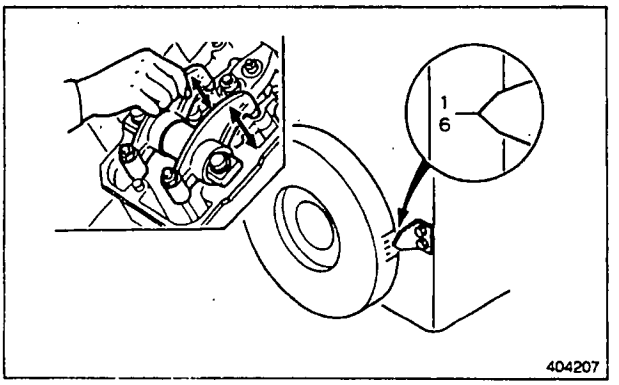
(c) Insert a feeler gauge in between the rocker arm and bridge cap, and inspect the valve clearance.

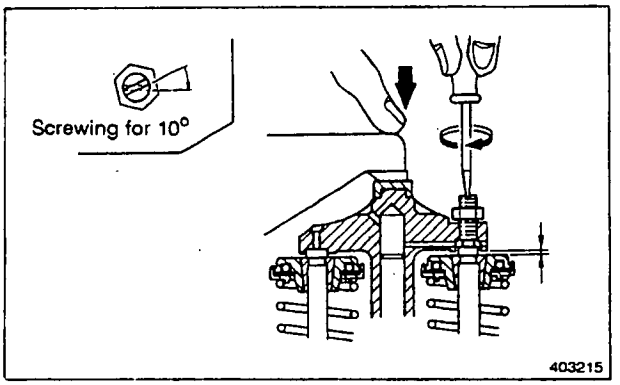
(2) Adjusting front and rear valve heights by the valve bridge

(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.





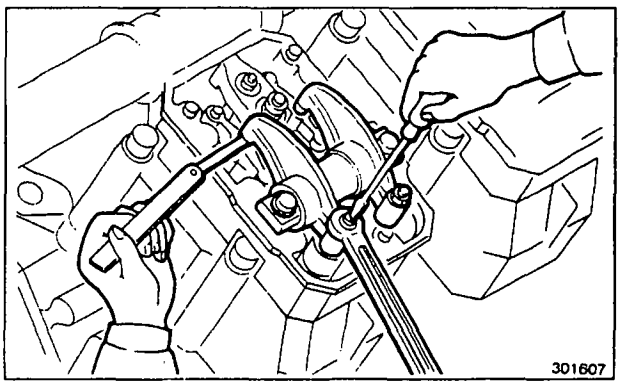
NOTE

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.

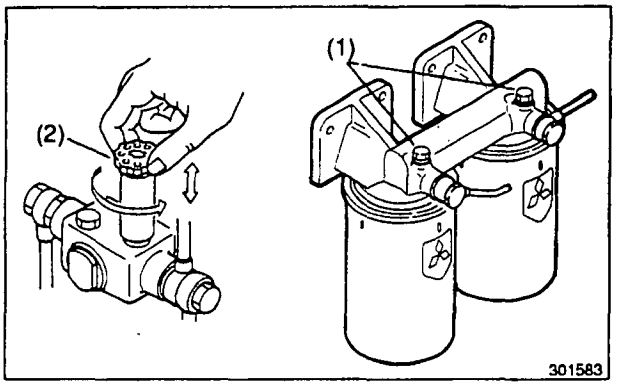
(1) Fuel filter

(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.

(d) Follow the same procedure for both right and left fuel filters.



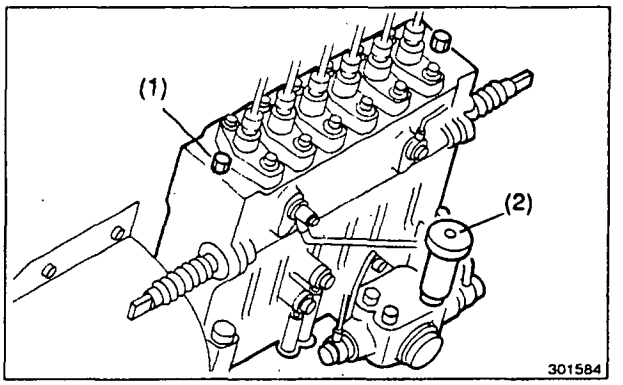
(2) Fuel injection pumps

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

(d) Follow the same procedure for both the right and left injection pumps.



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.

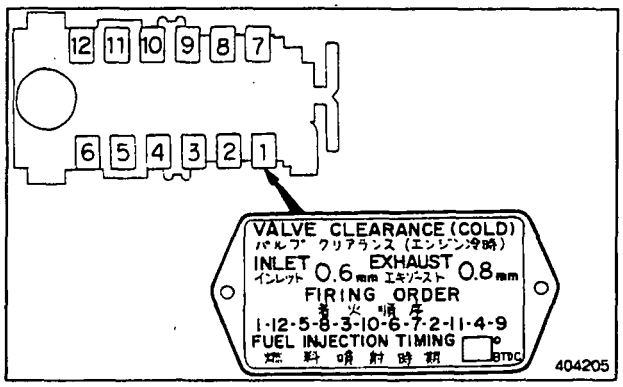
(b) Use a cloth to wipe off fuel spilled from the vent holes.

1.3 Fuel Injection Timing Adjustment

Right Hand Injection Pump

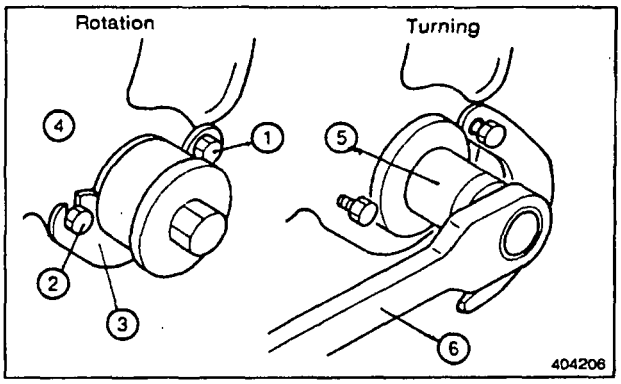
(1) Fuel injection timing and indication

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.



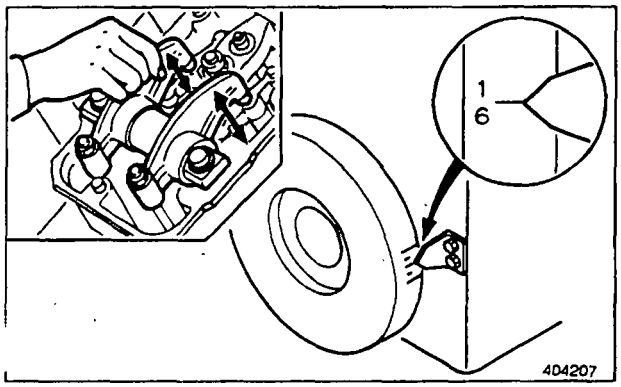
(2) Confirming the position of the No. 1 piston's top dead center on the compression stroke

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



(b) Stop turning when the timing mark (1•6) on the viscous damper is aligned with the pointer.

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

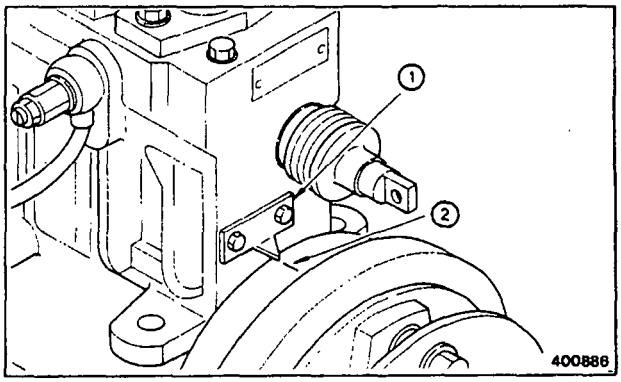


CAUTION!

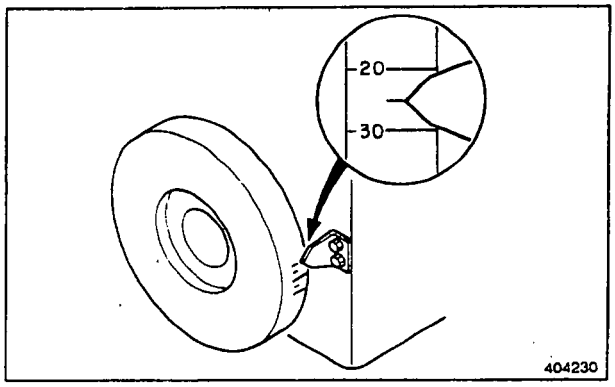
Do not confuse the top dead center on the compression stroke for No. 1 cylinder with that for the No. 6 cylinder.

(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 degree angle (injection timing) on the scale of the damper, indicated by the pointer minus (-) mark on the scale. **BTDC** on the caution plate means "Before Top Dead Center."

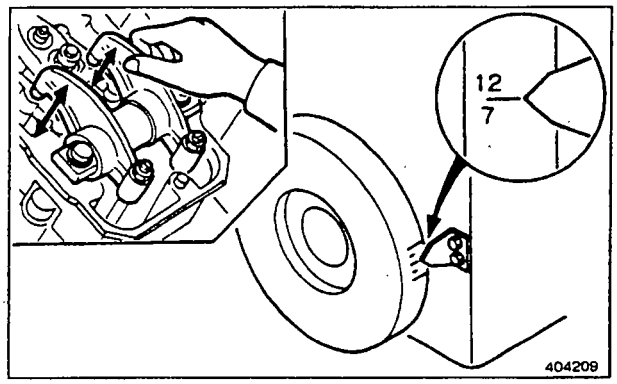


(4) Adjusting fuel injection timing

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

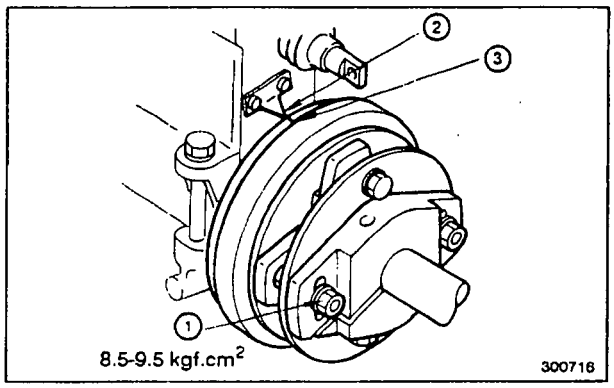
(b) Loosen the coupling bolts (1) , then displace the injection pump to align the pointer (2) on the pump case with the timing mark (3) on the coupling. Tighten one bolt to the specified torque. After turning the crankshaft, tighten the other bolt.

(c) Inspect the timing again by cranking the engine.



Left-hand Fuel Injection Pump

On this pump, the position where the pointer is aligned with the index numbers "7·12" on the damper is top dead center on the compression stroke of the No. 7 cylinder piston. At this position, both inlet and exhaust valves of that cylinder should have the specified clearance. For subsequent steps, follow the same procedure outlined for the right-hand injection pump.



1.4 Idling Speed and Maximum Speed Setting Inspection and Adjustment

CAUTION!

(a) The idling speed (no-load) and maximum speed are set for each engine at factory bench testing, then the set bolts are sealed. These settings are to be inspected and adjusted at Mitsubishi service shops only.

(b) After adjusting the governor, be sure to seal the stopper.

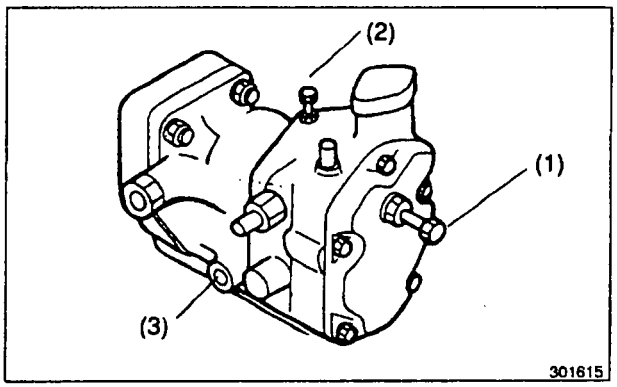
(c) The stoppers are specified to be sealed. Whether the seals are intact or not has important bearing on the validity of claims under the warranty.

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

NOTE

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

PSG Governor



(1) Inspecting and adjusting idling speed setting

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

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

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

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

(b) If the maximum speed is out of the specified range, reset it with the 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

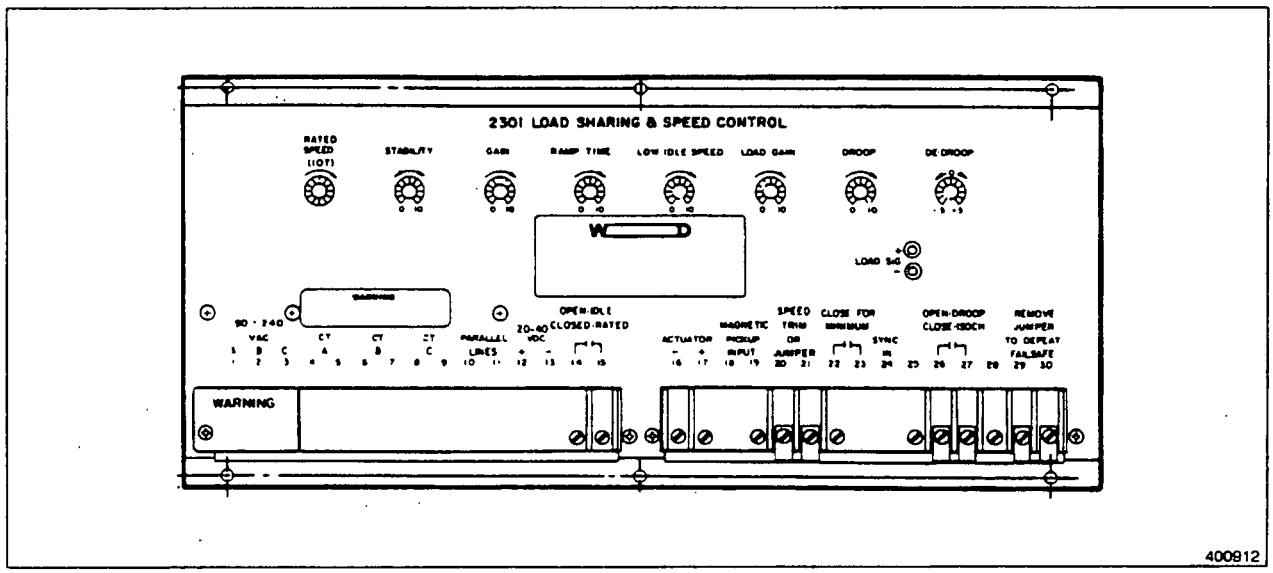
(a) If the engine hunts, adjust it with the needle valve (3) . Open the needle valve by turning it counterclockwise (2 to 3 rotations) until the engine hunts. Keep the engine hunting for about 30 seconds, until air is vented from the governor.

(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.

Woodward 2301 and 2301A Load Sharing & Speed Control Devices (for EG-3P Governors)



(1) Adjusting idling speed setting

(a) Open the external lamp switch (terminals 14-15). 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) Close the external lamp switch (terminals 14-15).

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

(c) 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.

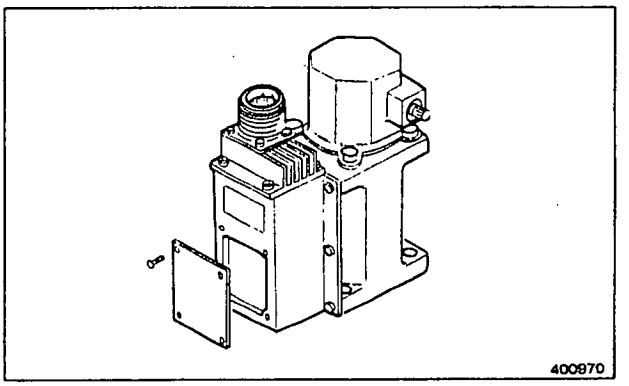
(b) Turn the "STABILITY" potentiometer clockwise or counter clockwise until the engine gains stability.

(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 1 Governor

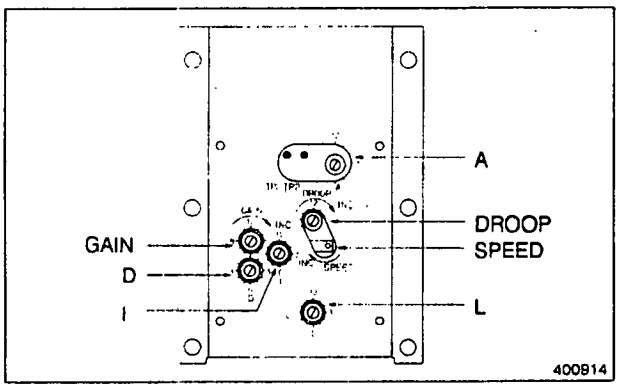


(1) Adjusting speed setting

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

(b) Remove the top cover from the controller, then make sure that the potentiometers are set as shown below.

Potentiometer	Position
A	3 o'clock
GAIN	9 o'clock
D	10 o'clock
I	8 o'clock
L	10 o'clock (adjusted at factory)



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

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

(e) Set the indicated horsepower with the rack set bolt.

(2) Correcting hunting

(a) The "A" potentiometer is to be set when the engine is in the no-load condition. Slowly turn this potentiometer clockwise until the actuator lever quickly vibrates (hunting occurs). Slowly turn it counterclockwise until hunting stops.

CAUTION!

If you fail to stop hunting, this can damage the actuator.

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

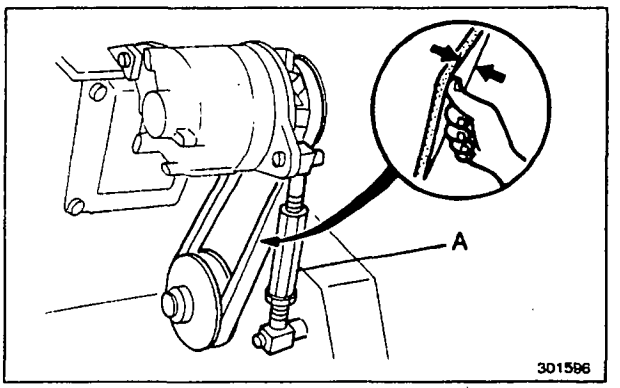
(c) After setting "GAIN", "A", and "D" potentiometers, turn the power source switch OFF. When engine speed is reduced to about 1/2, again turn the power source switch ON. If the engine speed overshoots (jumps) the setting, turn the "I" potentiometer counterclockwise. If the time required to restore the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

(d) After "A", "D", "DROOP", and "GAIN" the set speed will vary slightly. Use the "SPEED" potentiometer to set speed correctly. If "DROOP" has been turned in the speed direction (clockwise), turn "A" slightly counterclockwise and "GAIN" clockwise.

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

1.5 Inspecting and adjusting alternator drive belt

With your thumb apply pressure to the belt midway between the pulleys to inspect the belt tension. If the tension is incorrect, adjust it with the turnbuckle (A).



NOTE

Be sure the drive belt tension is not excessively tight.

Unit: mm

Item	Assembly Standard
Belt tension	10-15

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 10 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 at rated speed or over 2 kgf/cm^2 at idling speed.

(2) **Coolant temperature** should be 70-85°C.

(3) **Lubricating oil temperature** should be in the range of 60-95°C 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

(a) Adjusting valve clearance.

(b) Adjusting injection timing

(c) Tightening external bolts and nuts.

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
Atmospheric vapor pressure	11.4 mmHg

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

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

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

p_0 : Measured atmospheric pressure (mmHg)

p : Standard dry atmospheric pressure (743 mmHg, 99 KPa)

θ : Measured temperature (°C + 273)

θ_0 : Standard atmospheric temperature (298 K, 25°C)

fm, fm' : Main fuel consumption coefficient

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

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

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

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:

$600 \leq p \leq 825$ mmHg {$80 \leq p \leq 110$ KPa}

$10 \leq \theta - 273 \leq 40$°C {$283 \leq \theta \leq 313$ K}

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.

6. ENGINE ACCESSORY REMOVAL AND INSTALLATION

6. ENGINE ACCESSORY REMOVAL AND INSTALLATION

This section explains procedures and tips for removal and installation of the accessories, the preliminary procedures before overhauling the engine.

1. Preparation

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

(b) Loosen the drain cocks of both sides of the crank case and drain the coolant.

(c) Loosen the oil pan drain plug, and drain the engine oil.

Oil capacity: approx. 150 liters

WARNING!

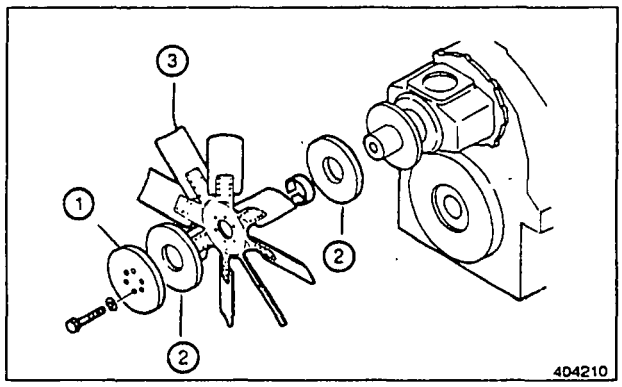
HOT ENGINE OIL CAN CAUSE SERIOUS BURNS. USE CAUTION WHEN YOU DRAIN THE OIL.

2. Removing Engine Accessories

(1) Removing the fan

(a) Unscrew the fan mounting bolts and the plate (1), then remove the fan (3) and friction rubbers (2).

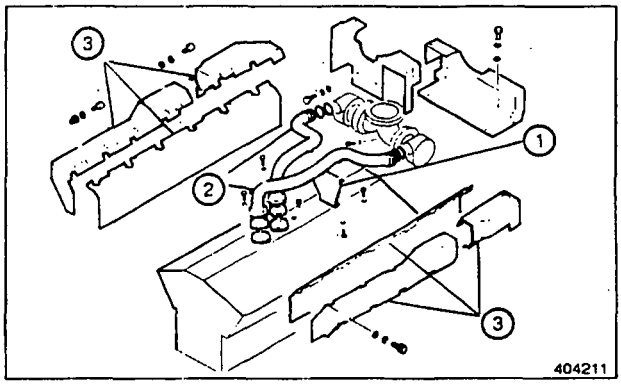
Weight: approx. 40 kg



(2) Removing the air duct and insulator

(a) Unscrew the air duct mounting bolts and stay (1), then remove the air ducts (2).

(b) Remove all insulators (3)



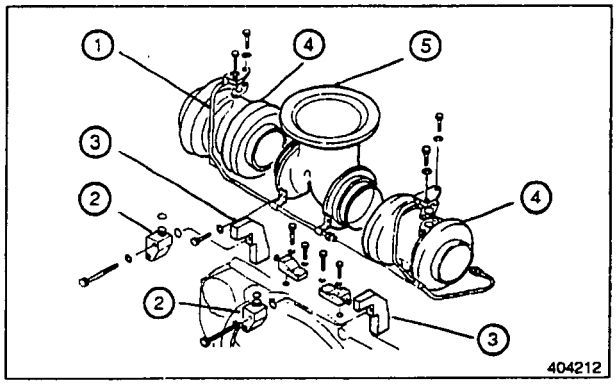
(3) Removing the turbocharger

(a) Disconnect the turbocharger lubricating oil pipes (1).

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

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

(d) Remove the turbocharger (4) and the exhaust pipe (5).



Weight:	Turbocharger approx. 50 kg
	Exhaust pipe approx. 18 kg

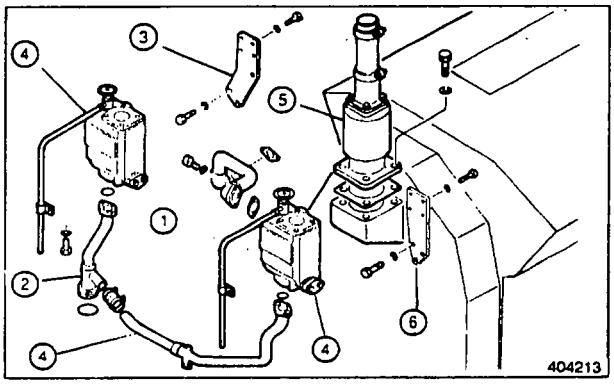
(4) Removing thermostat cases and breather

(a) Remove the water pipe (1).

(b) Remove the water by-pass pipe (2).

(c) Remove the thermostat case mounting bracket (3) and the thermostat case (4).

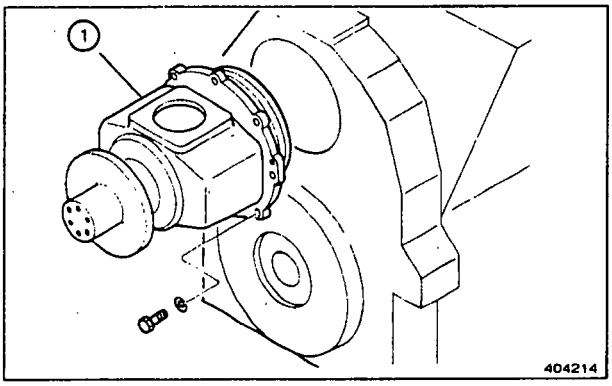
(d) Unscrew the breather mounting bolts and remove the breather (5).



(5) Removing the fan drive

Unscrew the fan drive case mounting bolt, then remove the fan drive (1).

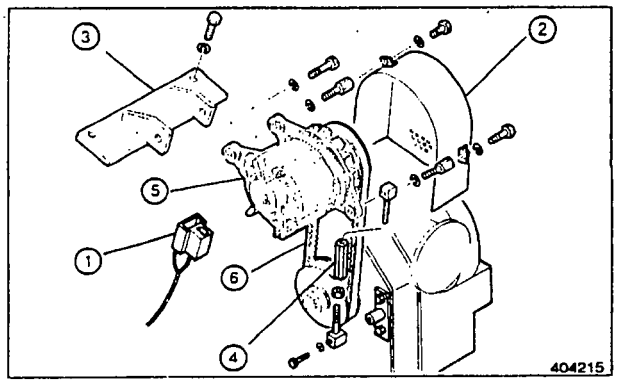
Weight: approx. 45 kg.



(6) Removing the alternator

(a) Disconnect the harness (1). Remove the belt cover (2), alternator mounting bracket (3), and the belt adjust turn buckle (4). Remove the alternator (5).

(b) Remove the V-belt (6).

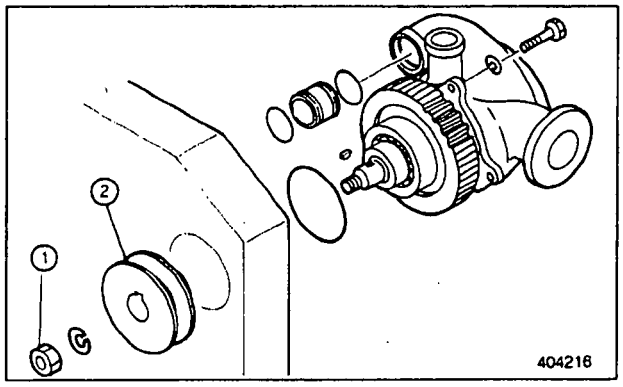


(7) Removing the water pump

(a) Remove the nut at the end of the water pump shaft. Remove the alternator driving pulley (2).

(b) Remove the water pump (3) by unscrewing the bolts and nuts.

Weight: approx. 33 kg

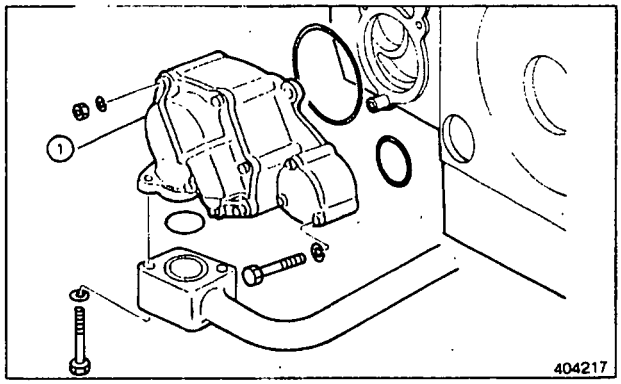


(8) Removing the oil pump

(a) Unscrew the connecting bolt the oil pipe under the oil pump.

(b) Unscrew the oil pump mounting bolt and nut, then remove the oil pump (1).

Weight: approx. 23 kg



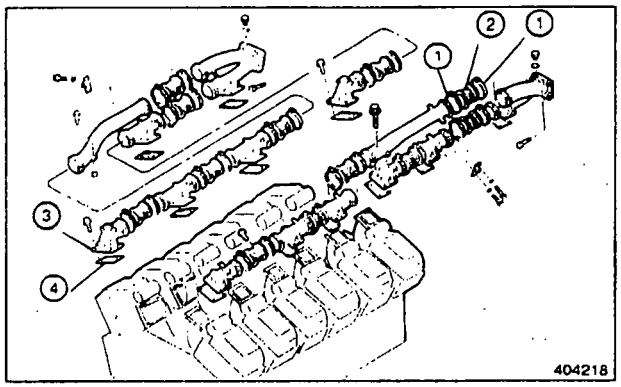
(9) Removing the exhaust manifold

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

(b) Unscrew the manifold mounting bolt, then remove the manifold (3) and the gasket (4).

NOTE

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



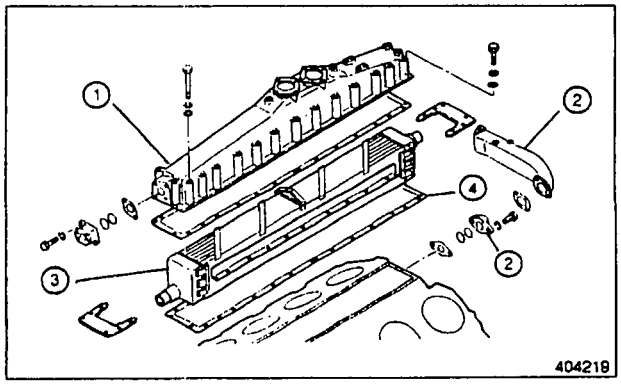
(10) Removing the air cooler

(a) Unscrew the air cooler case mounting bolts and the air cooler case (1).

(b) Disconnect the water pipe (2) and connector (3).

(c) Lift the air cooler element (4) and slide it out.

Weight: approx. 69 kg



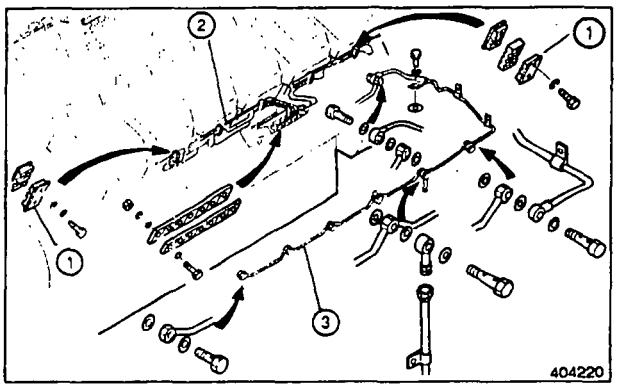
(d) Remove the packing (5).

(11) Removing the injection pipe and fuel leak-off pipe

(a) Remove the injection pipe clamp (1).

(b) Remove the injection pipe (2).

(c) Remove the fuel leak-off pipe (3).



NOTE

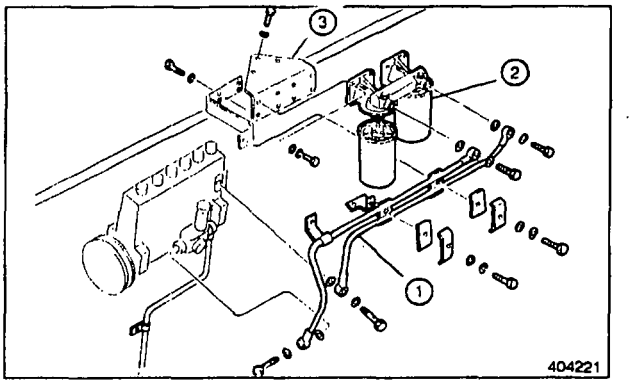
Cover the openings of the injection pump, the nozzle inlet connector, and the injection pipe with rubber caps to prevent dust from entering the fuel line.

(12) Removing the fuel filter

(a) Disconnect the fuel pipe (1).

(b) Unscrew the filter mounting bolts, then remove the filter bracket (3).

(c) Unscrew the filter bracket mounting bolts, then remove the fuel filter (2).



(13) Removing the left and right fuel injection pumps

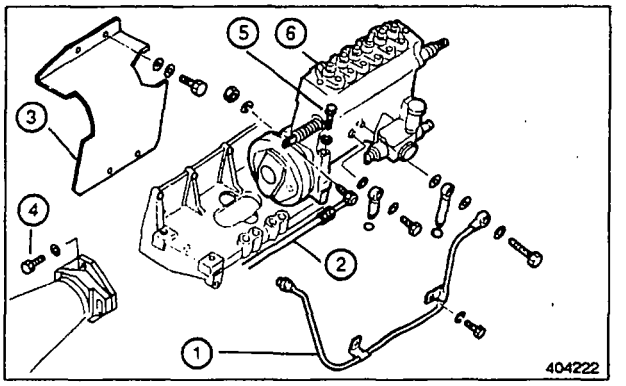
(a) Remove the injection pump drive case lubricant oil pipe (1).

(b) Remove the ball joint mounting nut, then disconnect the link (2) from the governor.

(c) Remove the coupling cover (3).

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

(e) Remove the pump mounting bolt (5). Remove the injection pump (6), complete with the coupling by lifting it up. Leave the laminate plate on the drive shaft.

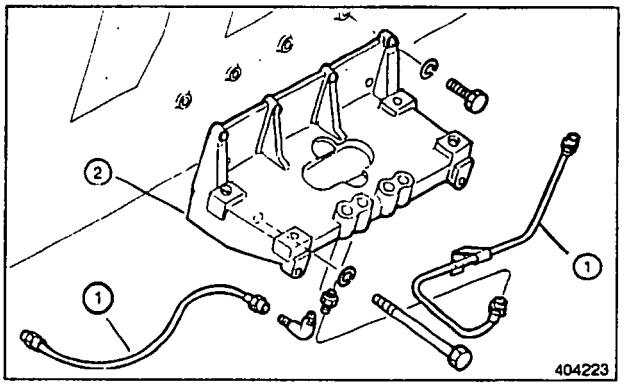


Weight: approx. 60 kg

(14) Removing the injection pump bracket

(a) Remove the lubrication oil pipe (1).

(b) Unscrew the bracket mounting bolts, and remove bracket (2).



(15) Removing the right oil cooler

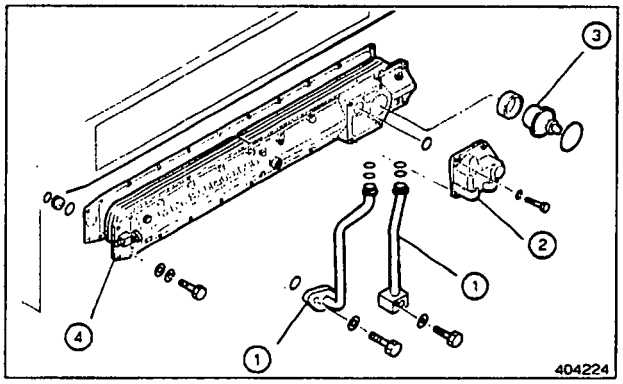
(a) Disconnect the oil pipe (1) from the oil pan and the oil cooler inlet connector.

(b) After unscrewing the oil cooler inlet connector mounting bolt, disconnect connector (2).

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

(d) Unscrew the oil cooler mounting bolt, then remove the oil cooler (4).

Weight: approx. 20 kg



(16) Removing the left oil filter and oil cooler

(a) Disconnect harness (1) from the oil filter alarm

(b) Remove the four oil filter elements (2) and the by- pass filter element (3).

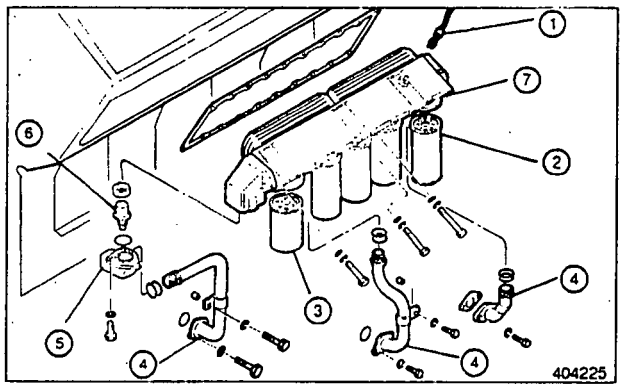
(c) Disconnect the oil pipe (4).

(d) Unscrew the oil cooler inlet connector mounting bolt, and disconnect the connector (5).

(e) Remove the oil thermostat (6).

(f) After unscrewing the oil filter bracket mounting bolt, remove the filter bracket (7) complete with the oil cooler.

Weight: approx. 45 kg

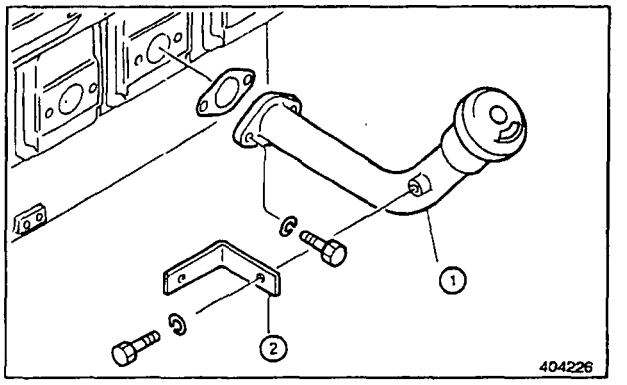


NOTE

Before removing the oil filter element (2) and the by-pass filter element (3), make a hole in the bottom of the filter to drain engine oil.

(17) Removing the oil filler

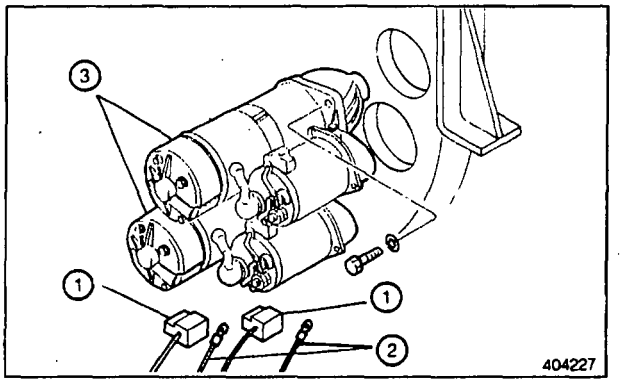
Unscrew the oil filler mounting bolt and the stay mounting bolt, then remove the oil filler (1).



(18) Removing the starter

Disconnect the harnesses (1) and the starter (2) by unscrewing the starter mounting bolts.

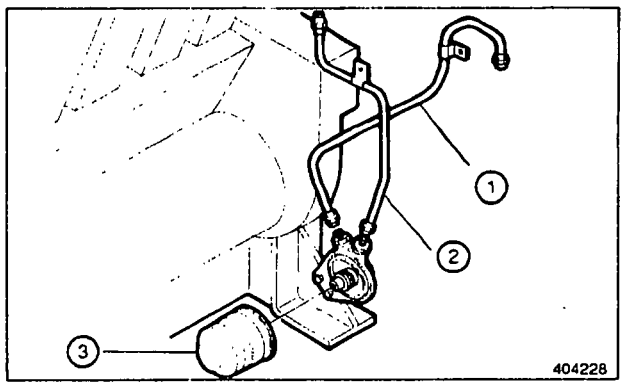
Weight:	approx. 19 kg



(19) Removing the oil filter for the Woodward governor

(a) Remove the lubricating oil pipes (1) and (2).

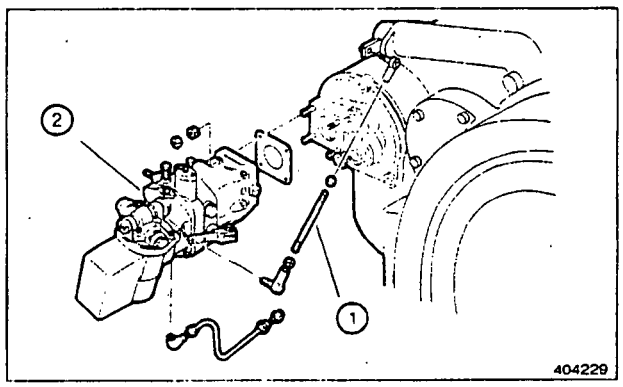
(b) Remove the oil filter (3).



(20) Removing the Woodward governor

(a) Unscrew the link from the Woodward governor.

(b) Unscrew the governor mounting nuts (1), then remove the Woodward governor (2).



3. Engine Accessory Installation

To install the engine accessories, follow the removal procedures in reverse order. After installation, service them as follows.

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

(b) Refill the cooling system with coolant.

(c) For easy engine starting, pour engine oil for the governor into the oil filter from its vent plug.

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

(e) Prime the fuel system.

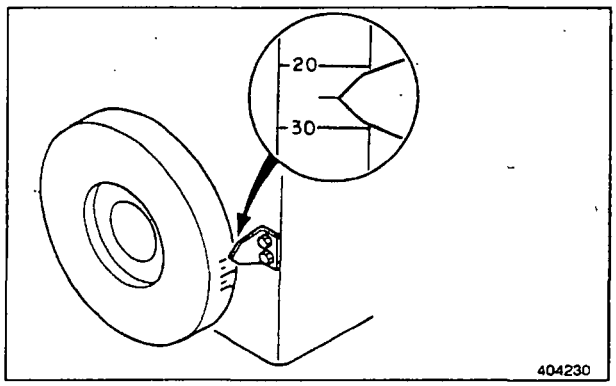
(f) Install the fuel injection pump. After installing the fuel injection pumps, be sure to inspect and adjust the injection timing. (Refer to Section 1.3 of Chapter 5, "Adjustments, Bench Testing, and Performance Tests."

Fuel Injection Pump Installation:
Left Injection Pump

(a) Turn the crankshaft in the normal direction to align the timing marks "1•6" on the viscous damper with the pointer.

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

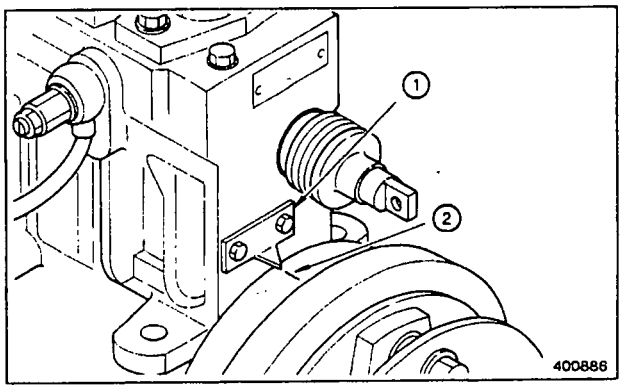
(c) Turn the crankshaft once about 60° in reverse. Turn it a little at a time in the normal direction to align the timing mark on the damper with the pointer.



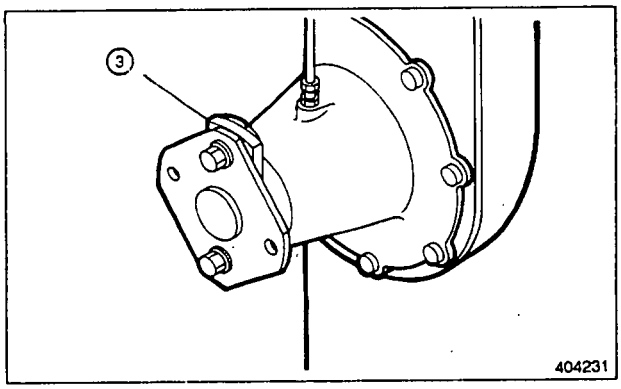
NOTE

Verify the injection timing by referring to the caution plate attached to the No. 1 rocker cover.

(d) Install the coupling to the injection pump, then align the pointer (1) on the pump case with mark (2) on the coupling.



(e) Connect the pump drive coupling (3) to the drive shaft. Loosen the coupling mounting bolts enough.



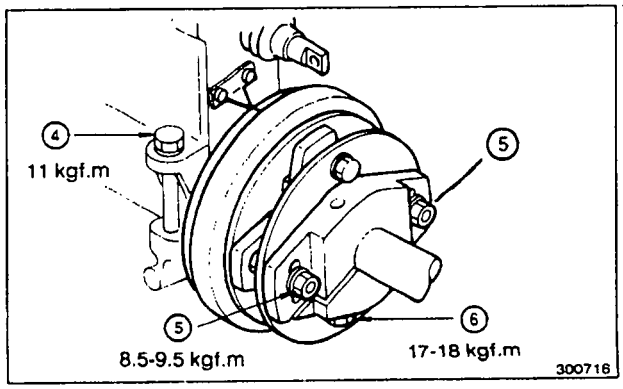
(f) Put the pump case on the pump bracket, then tighten the mounting bolts (4) temporarily.

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

(h) Tighten the two coupling bolts temporarily.

(i) Tighten the pump mounting bolt (4) firmly. Be sure that the coupling mark (2) aligns with the pump case pointer (1). Tighten the two connecting nuts (5) as specified.

(j) Tighten the shaft tightening bolt (6) of the coupling as specified.



NOTE

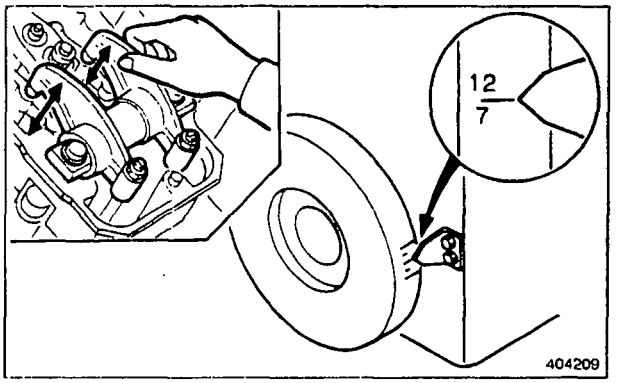
Apply equal and specified torques on each coupling bolt. Coupling damage or wrong injection timing can be caused by improper tightening of bolts.

Fuel Injection Pump Installation:

Left Injection Pump

(a) To install this pump, align the timing marks "7-12" on the viscous damper with the pointer. At this position make sure that both inlet and exhaust valves of the No. 7 cylinder piston is at top dead center of the compression stroke.

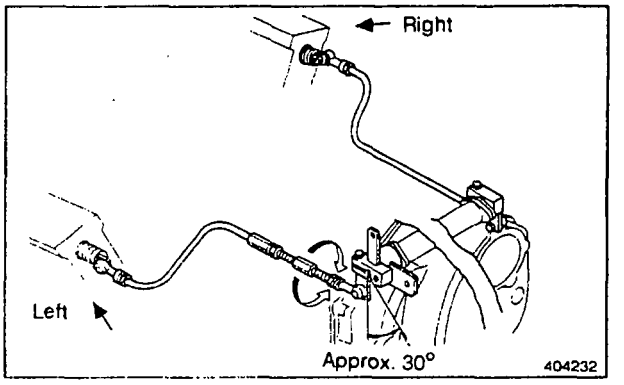
(b) For subsequent steps, follow the procedures described for the right injection pump above.



Adjusting Injection Quantities of Left and Right Pumps

(a) To adjust, push in the racks of the pumps all the way to the non-injection position, then turn the adjusting rod of the linkage of the left injection pump.

(b) After adjusting, tighten the lock nut of the adjusting rod and seal it with a wire.



NOTE

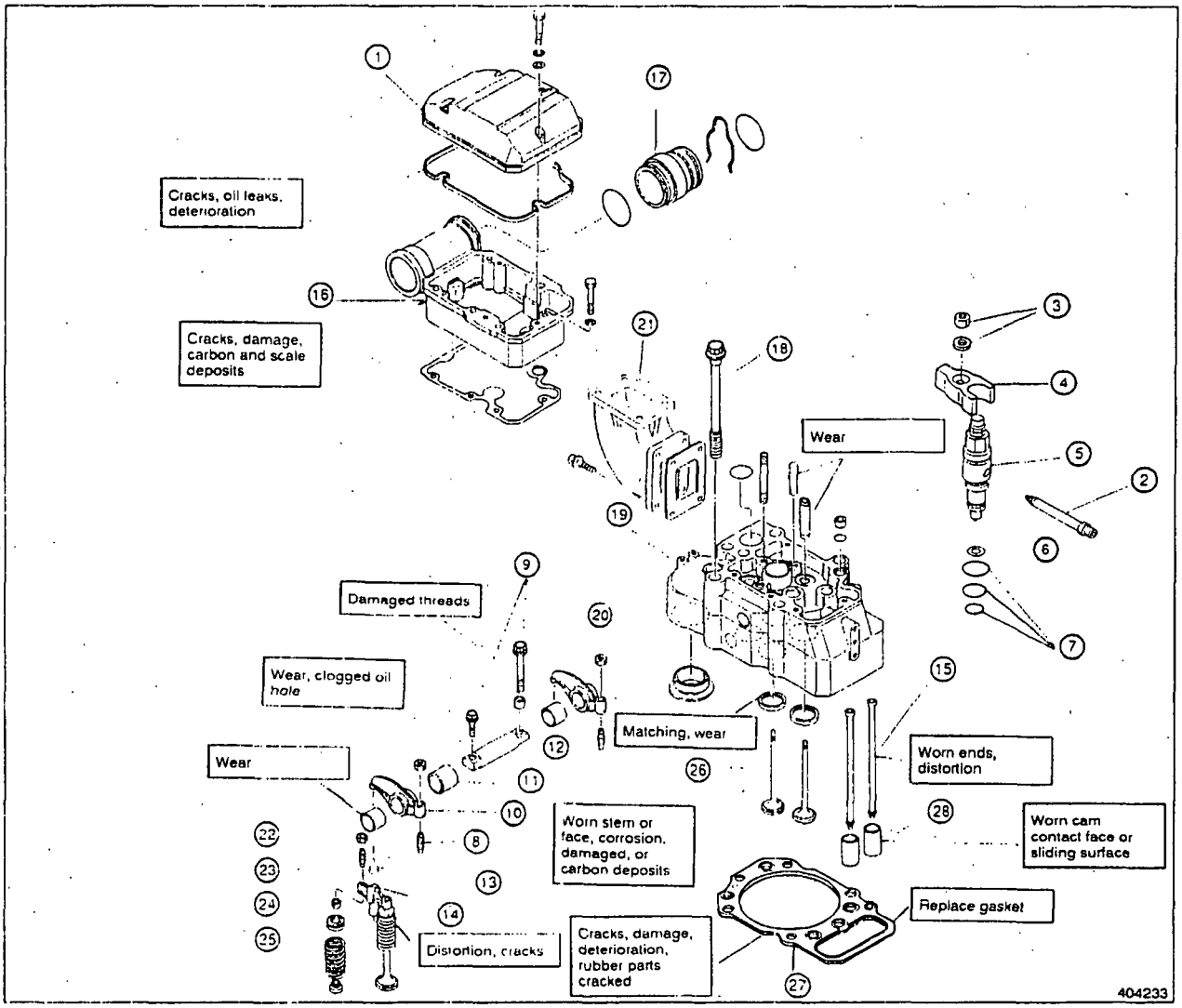
When you turn the adjusting rod, be sure that the rack slides smoothly without any sign of sticking. If the rack fails to move smoothly, the governor will not function properly.

7. THE ENGINE PROPER

7. THE ENGINE PROPER

1. Cylinder Heads and Valve Mechanism

1.1 Disassembly



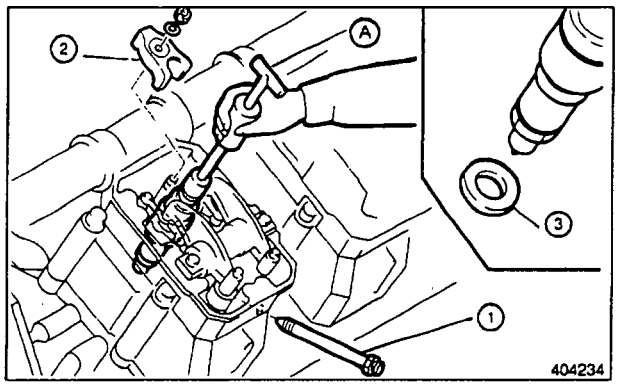
①	Rocker cover	⑪	Spacer	㉑	Exhaust connector
②	Fuel inlet connector	⑫	Rocker shaft	㉒	Valve cotter
③	Nut, washer	⑬	Bridge cap	㉓	Valve rotator
④	Injection nozzle gland	⑭	Valve bridge	㉔	Valve spring
⑤	Injection nozzle	⑮	Push rod	㉕	Stem seal
⑥	Gasket	⑯	Rocker case	㉖	Valve
⑦	O-ring	⑰	Water outlet connector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

(1) Removing fuel injection nozzles

(a) Remove the fuel inlet connection (1) and the nozzle gland.

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

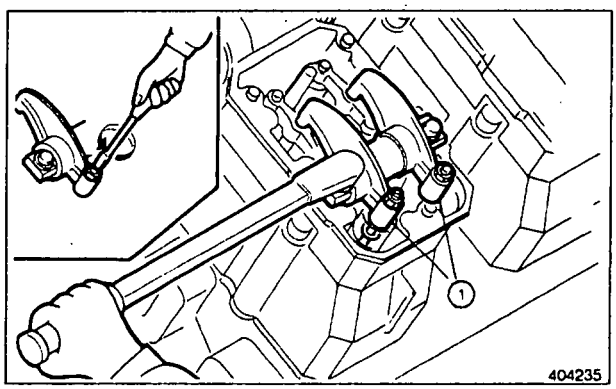
(c) Put away the nozzle and the inlet connector where you can find them later. Do not damage the nozzle tip.



(2) Removing the rocker shaft assemblies

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

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



(3) Disassembling rocker shaft assemblies

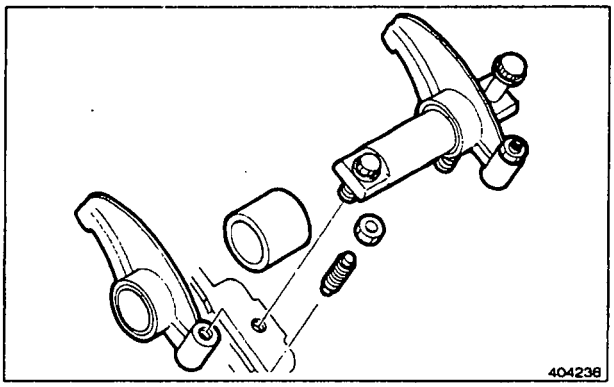
Arrange the disassembled rockers in the order removed, so you can install them in that order at reassembly. This will ensure the same rocker-shaft clearance as before.

(4) Removing the valve bridge

Remove the valve bridge and bridge cap.

NOTE

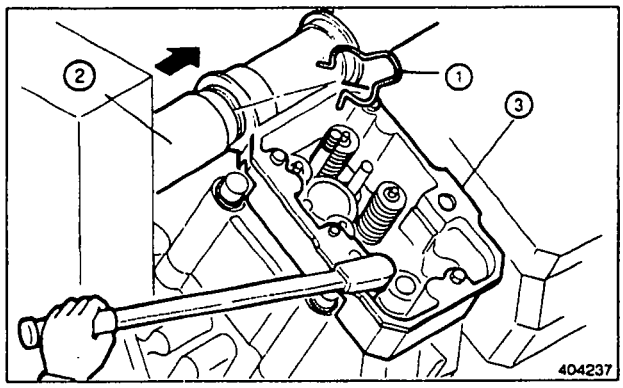
Do not drop the bridge cap or other parts into the crankcase through the push rod hole.



(5) Removing the locker case

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

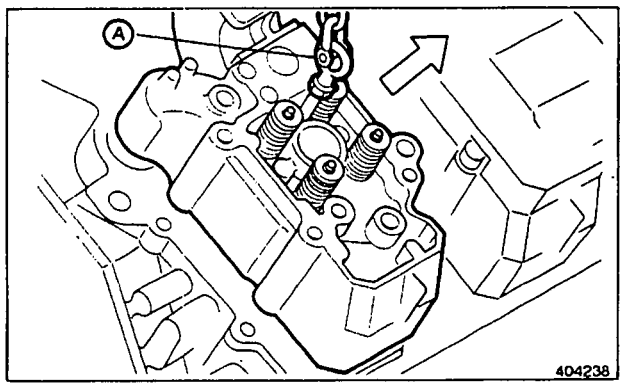
(b) Unscrew the locker case mounting bolts, then remove the locker case (3) from the cylinder head.



(6) Removing cylinder head assemblies

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

Cylinder head weight: approx. 35 kg



(b) Remove the cylinder head gasket

CAUTION!

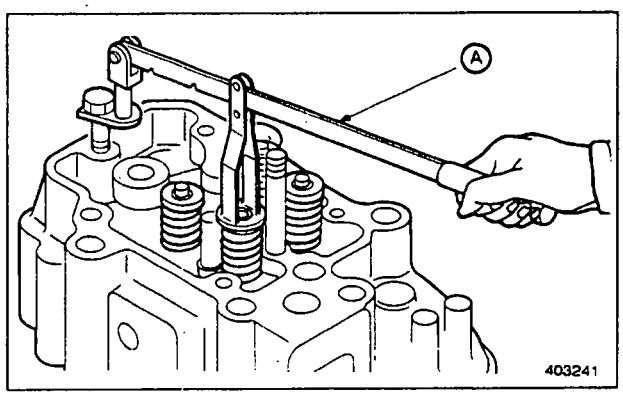
Do not damage the cylinder head or crankcase surfaces when you remove the gasket with a screwdriver or other tool.

(7) Removing valves and valve springs

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

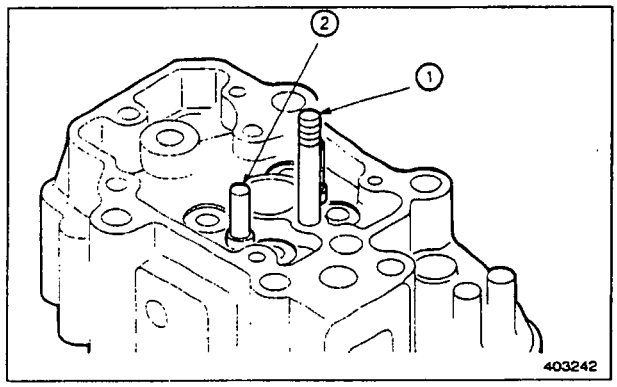
NOTE

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 (1) 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

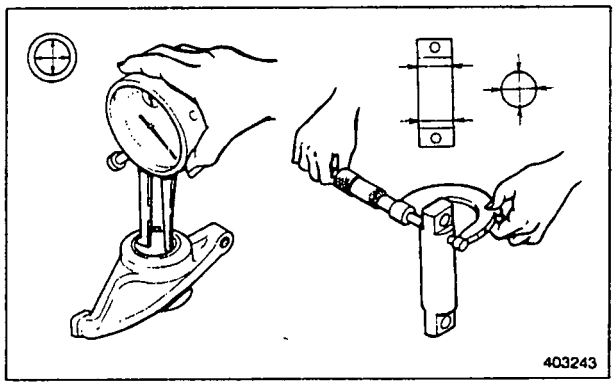
Rockers, Rocker Bushings, Rocker Shafts

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

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

Unit: mm

Item	Nominal Value	Assembly Standard	Service Limit
Rocker bushing inside diameter	ϕ36	36.00-36.040	36.090
Rocker shaft diameter	ϕ36	35.966-35.991	35.940



Measuring rocker bushing and rocker shaft

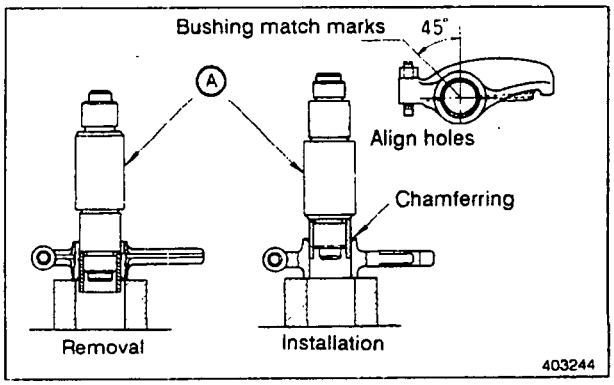
(2) Replacing rocker bushings

Use a rocker busing puller (A) (34591-02600) 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 $\phi 36^{+0.04}_{0}$. If the diameter is not within this tolerance, refinish to standard tolerance by reaming ($\phi 36^{+0.04}_{0}$ 3.25).



Replacing the rocker bushing

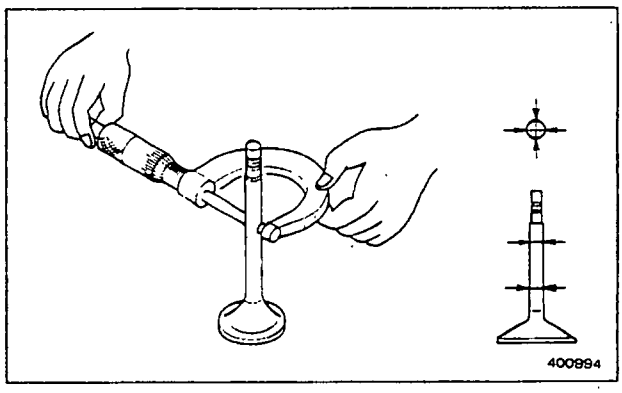
Valve Guide and Valve Stems

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

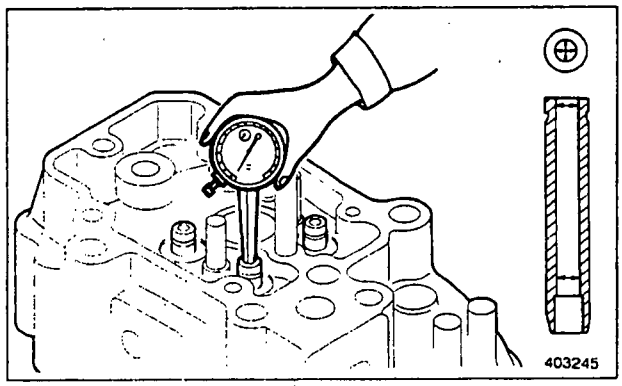
The valve guide wears more rapidly at its tooth end than at any other location. Measure the inside diameter of the guide at its ends and at the middle in two directions. If the service limit is exceeded, replace the guide.

Unit: mm

Item	Nominal Value	Assembly Standard	Service Limit
Valve stem diameter	ϕ10	9.940-9.960	9.910
Valve guide inside diameter	ϕ10	10.000-10.015	10.060



Measuring valve stems



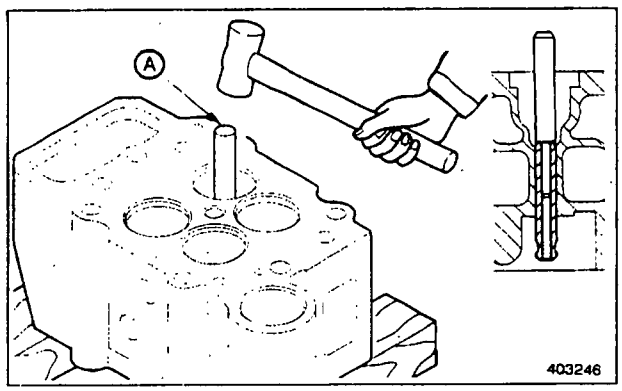
Measuring valve guide inside diameter

(2) Replacing valve guides and stem seals

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

NOTE

Use a new stem seal at reassembly.



Removing valve guide

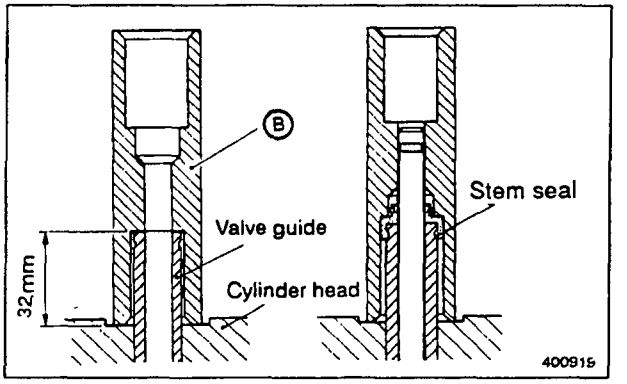
(b) Use a valve guide seal installer (B) (37191-01500) to install slowly a new guide with a press.

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.

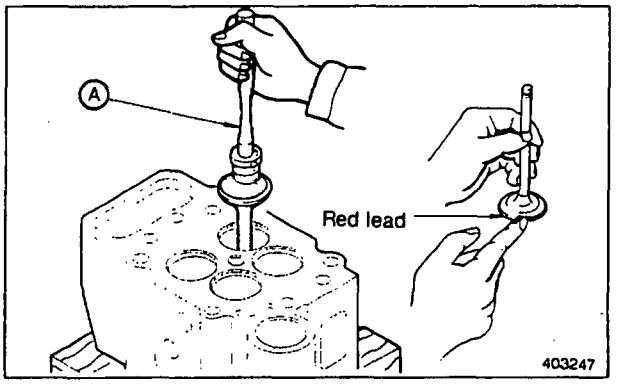


Installing valve guide and stem seal

Valves and Valve Seats

(1) Inspecting the valve face

Coat the valve face lightly with red lead. Use valve lapper (A) (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.

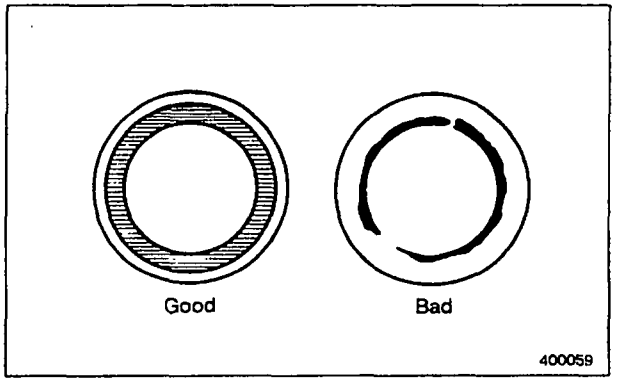


Inspecting a valve face

NOTE

(a) **Inspect the valve face after the inspection or replacement of the valve guide.**

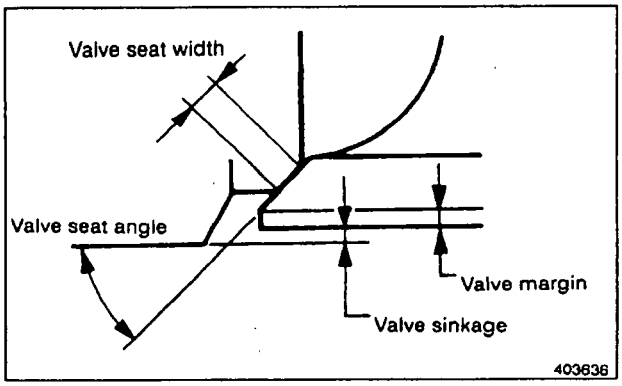
(b) **When you press the valve coated with red lead into the valve seat, do not rotate the valve.**



Valve contact with its seat

Unit: mm

Item		Assembly Standard	Repair Limit
Valve seat	Angle	30°	
	Valve sinkage	-0.2-0.2	1.0
	Width	2.15-2.45	2.8
Valve margin		2.8-3.2	2.5 by refacing



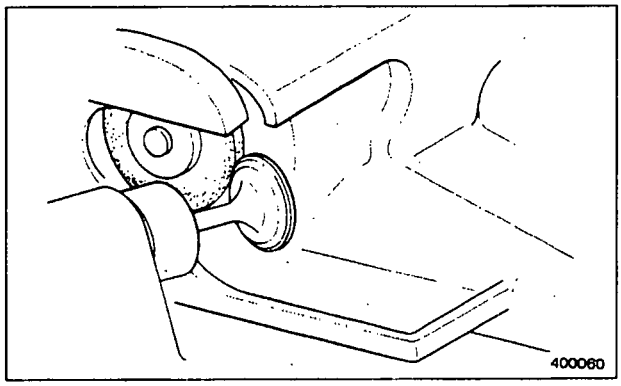
(2) Refacing the valve face.

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.

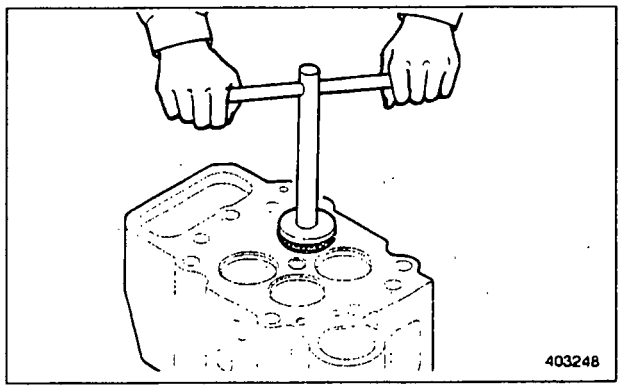
(b) Lap the valve in the valve seat.

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.

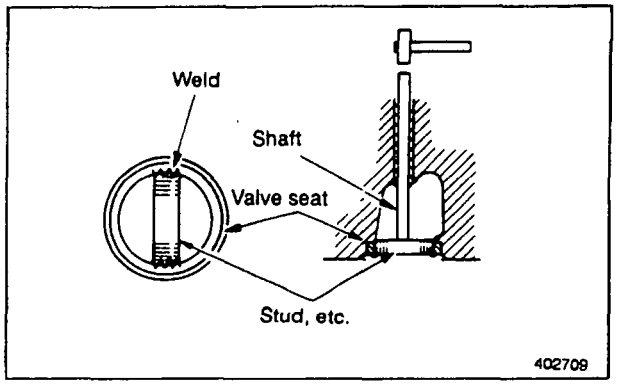
(c) Replace the valve seat if the valve sinkage exceeds the repair limit after refacing.



Refacing a valve seat

(4) Replacing 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

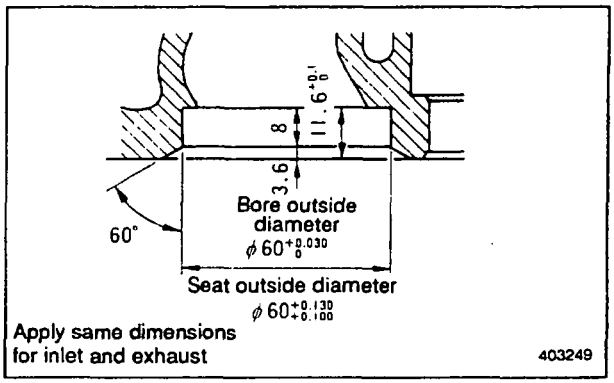
CAUTION!

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

Item	Nominal Value	Standard Clearance
Cylinder head bore inside diameter and valve seat outside diameter	ϕ60	-0.070 to -0.130



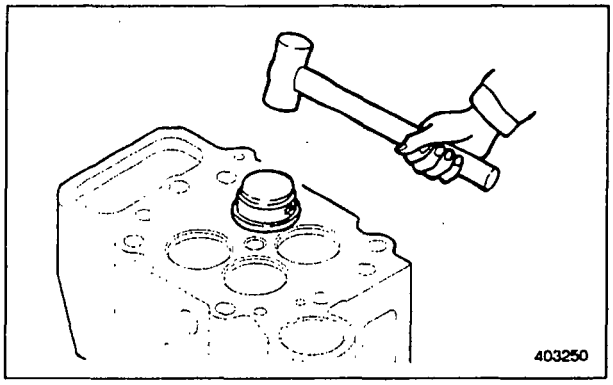
Valve seat dimensions

NOTE

A minus (-) indicates interference.

(c) Chill the valve seat in liquid nitrogen (about -170°C for more than 4 minutes with the cylinder head kept at normal temperature, or heat the cylinder head to 80°C or 100°C 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 have been replaced.

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

NOTE

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

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

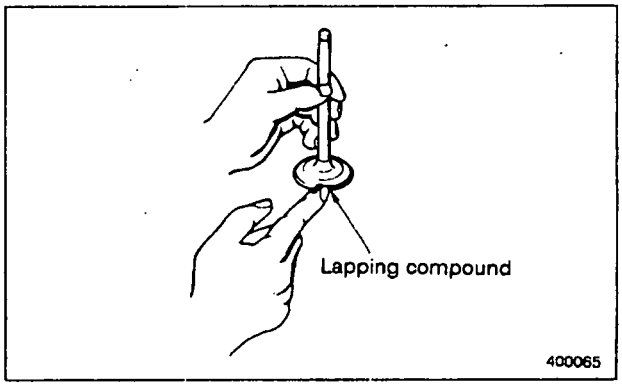
(c) Mixing the compound with a small amount of engine oil will facilitate coating.

(b) Use the valve lapper (A) (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.

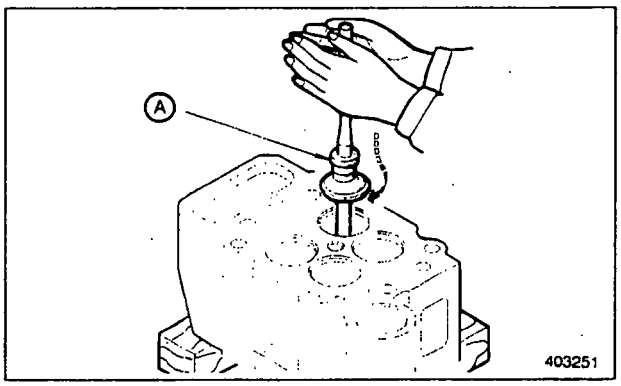
(c) Wash off the compound with diesel fuel.

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

(e) Check the valve face for contact.



Coating valve with lapping compound

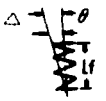


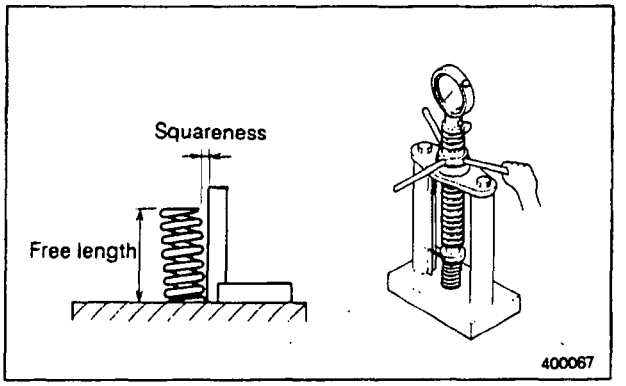
Lapping a valve in its valve seat

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

Item	Assembly Standard	Repair Limit
Free length	73	71
Squareness	$\theta = 1.5^{\circ}$ max. 	Δ = 2.2 over the length
Length under test force/test forces (mm/kgf)	66.0/29.45-32.55	



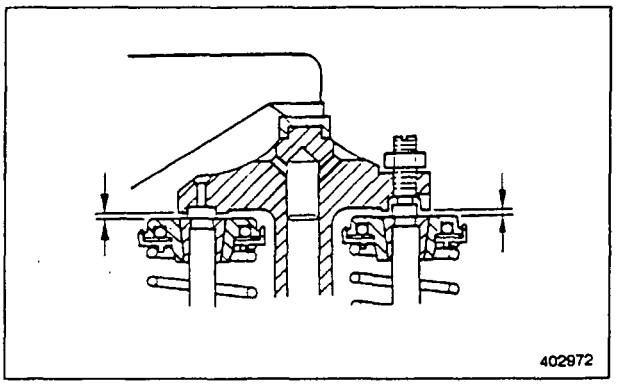
Measuring a valve spring

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, check the valve stem top for cupping. When the stem top is badly cupped, replace the valve to obtain more than 1.5 mm clearance.

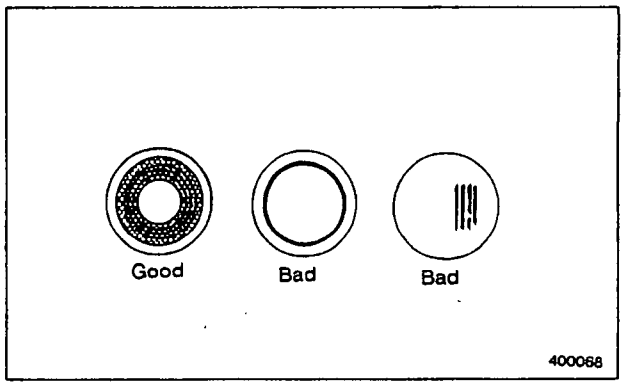
(b) Check the condition of the bridge cap. Replace it if it is badly worn.



Checking bridge-to-rotor clearance

Tappets and Push Rods

(1) Inspect cam contacts if the cam faces are excessively worn.



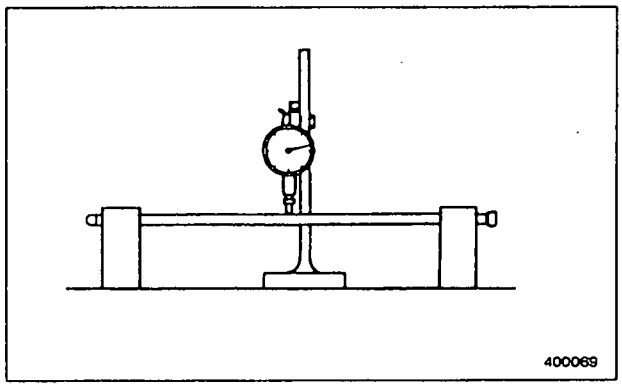
Tappet cam contact face

(2) Inspecting valve push rods for runout.

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

Unit: mm

Item	Assembly Standard
Push rod runout	Less than 0.5 max.



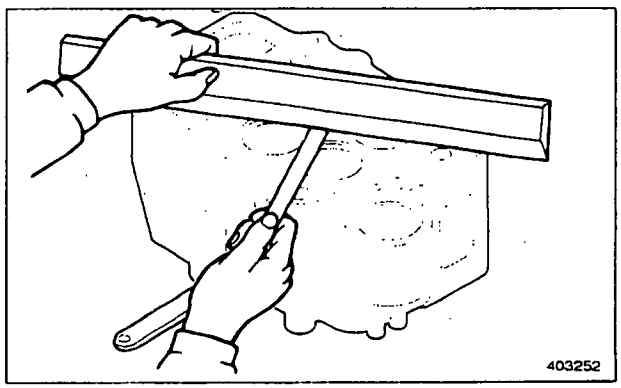
Measuring valve pushrod runout

Cylinder Head

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

Units: mm

Item	Assy. Stand.	Repair Limit	Service Limit
Head warp	< 0.03	0.07	0.05

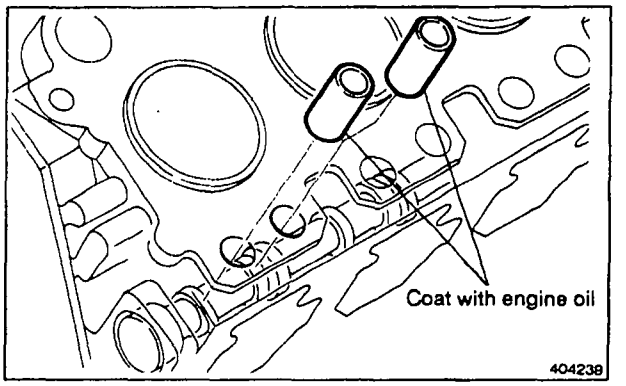


Measuring head gasket warpage

1.3 Reassembly

(1) Installing tappets

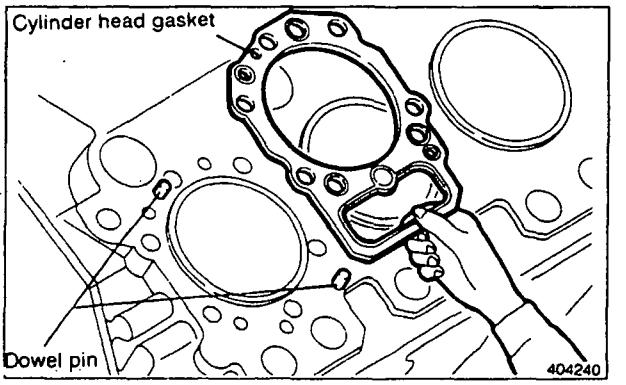
Insert tappets coated with engine oil into the tappet holes and make them seat softly on the cam shaft.



(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.



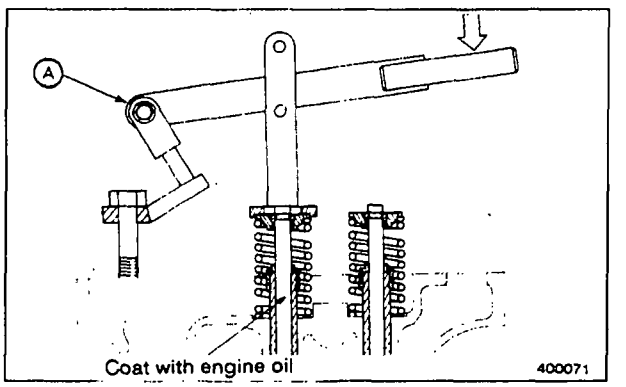
CAUTION!

Do not apply any sealant to the gaskets.

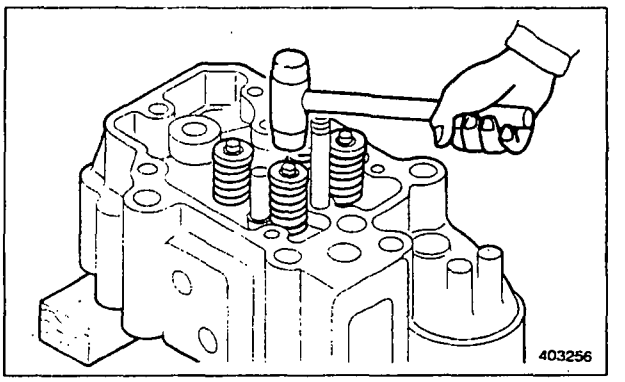
(3) Reassembling the cylinder heads

(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 (A) (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 the exhaust connector to the cylinder head, while pushing down the exhaust connector so it touches the edge of the bolt hole.

NOTE

Place the gasket so its "MANIFOLD" printed side aligns with the connector side.

(b) Install eye nut (A) (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 so the head is slightly separated. Screw the head bolts coated with engine oil.

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

CAUTION!

(a) The cylinder head bolts should be screwed down after wiping off the coating of engine oil.

(b) Before you install the cylinder head assembly, measure the protrusion of each piston. Make sure that the protrusion is correct. (Refer to (4), "Pistons", 2.2, of this chapter.)

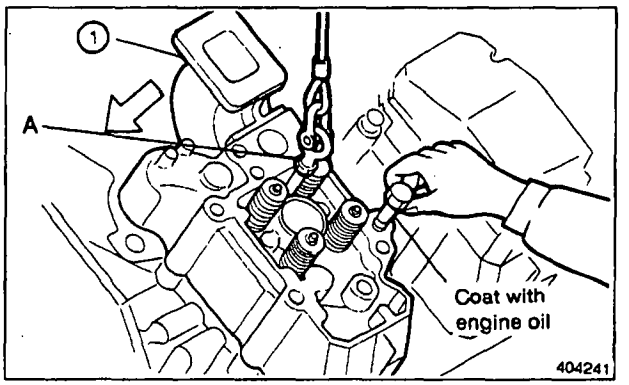
(5) Installing the locker case

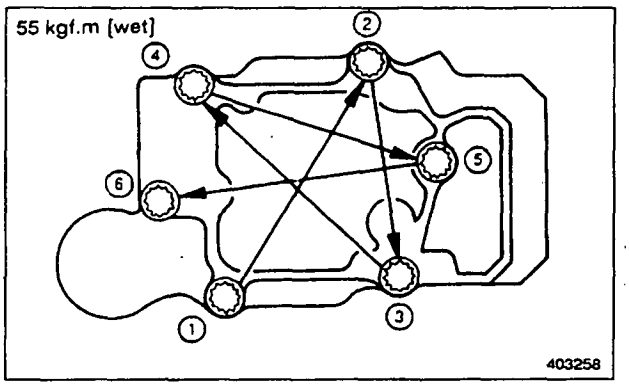
(a) Insert the water outlet connector fully into the locker case.

(b) Install the locker case so it meets the dowel pins.

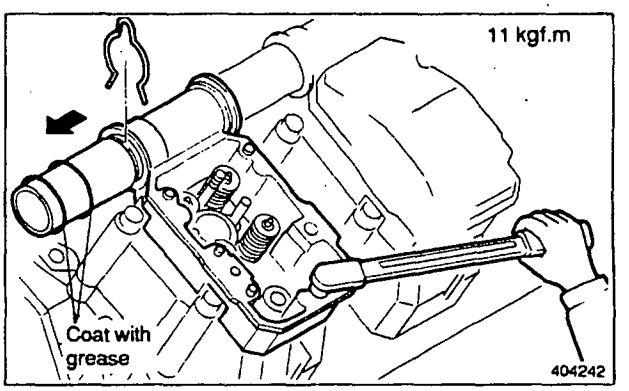
(c) Insert the water outlet connector by sliding it from the next locker case after coating the O-ring with grease. Install the snap ring.

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





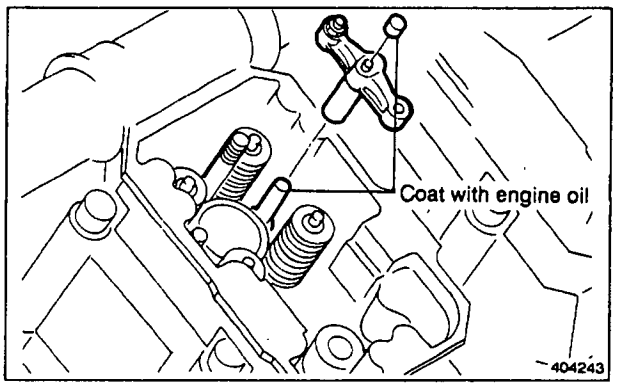
Head bolt tightening sequence



(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.

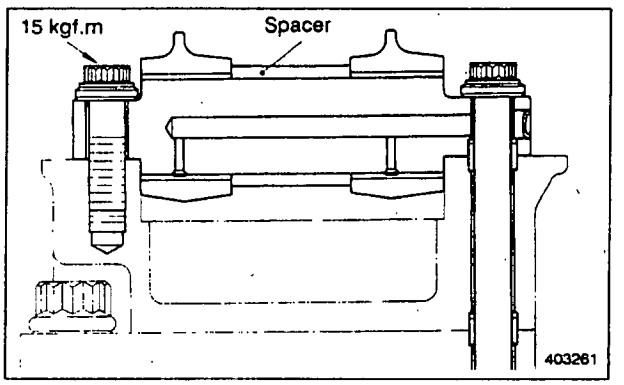
(b) Coat the bridge contact face of the bridge caps with engine oil. Install the caps in position, being careful not to let them fall into the crankcase through the push rod holes.



(7) Installing rocker shaft assemblies

(a) Align the notch of the rocker shaft with the bolt hole of the rocker shaft 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

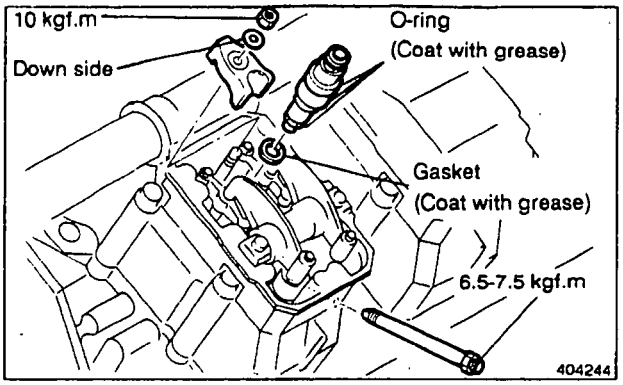
(a) Disconnect the fuel inlet connector from the nozzle assemblies.

(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 to the specified torque.

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



NOTE

(a) Maintain equal distances between the fuel inlet connector and the cylinder head before tightening to the specified torque.

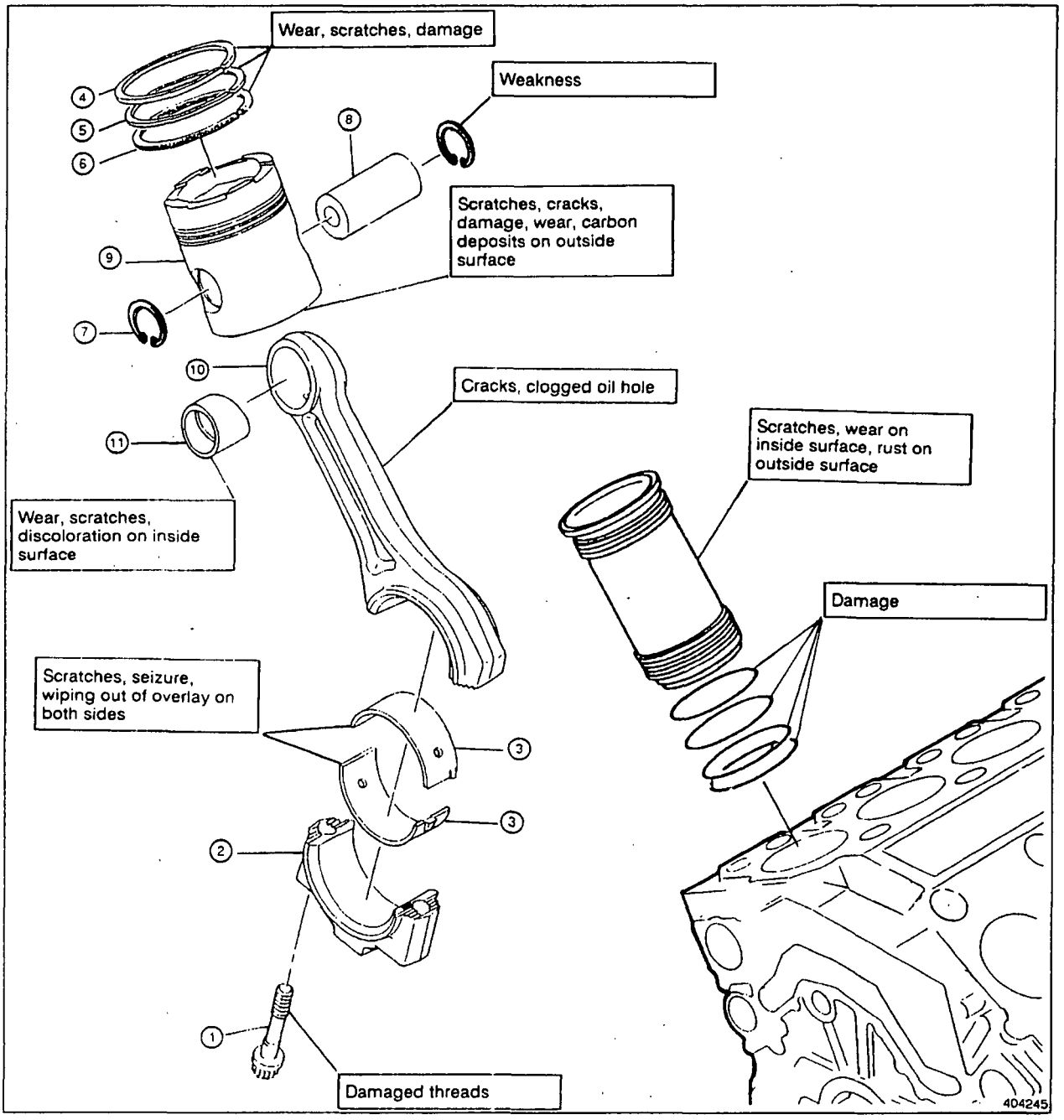
(b) Be sure to install the gasket when installing the nozzle assemblies.

(9) Adjusting valve clearance

Refer to section 1.1, Chapter 5, "Adjustments, Bench Testing, and Performance Tests."

2. Cylinder Liners, Pistons, and Connecting Rods

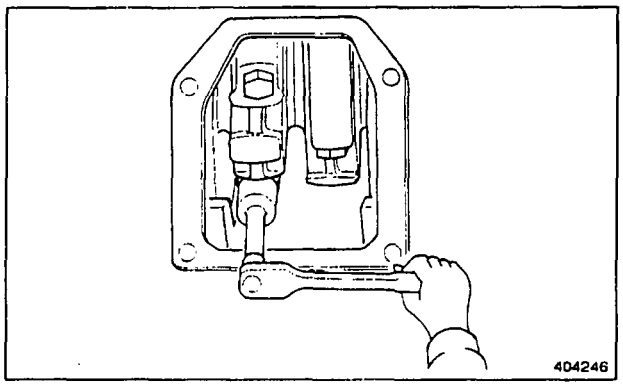
2.1 Disassembly



① Bolt
② Connecting rod cap
③ Connecting rod bearing
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

(1) Removing connecting rod caps

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



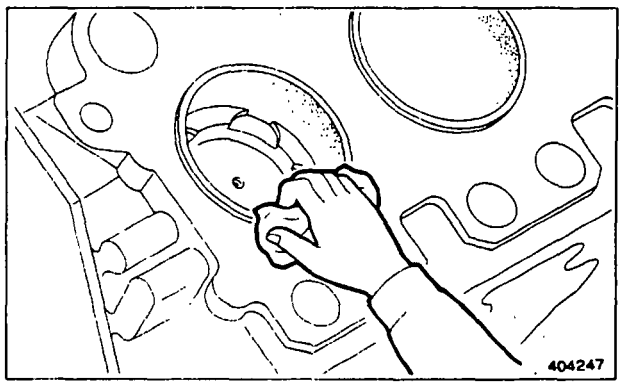
NOTE

(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

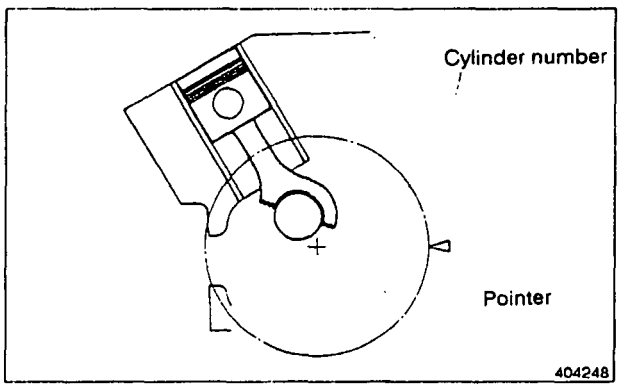
Use a cloth or oil paper to remove all carbon deposits from the upper areas of the cylinder liner. If any carbon deposits are present, this will make it difficult to pull a piston up.



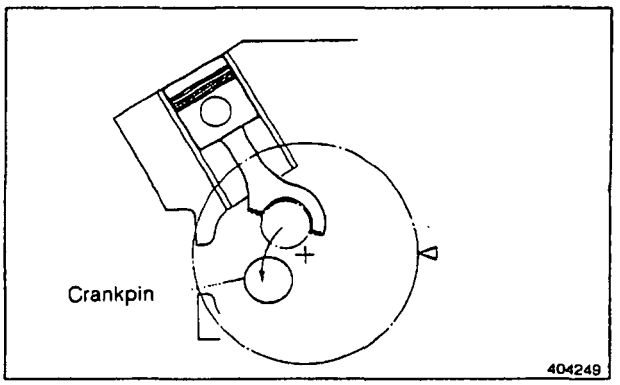
(3) Removing pistons

Pistons for Right Bank Cylinders

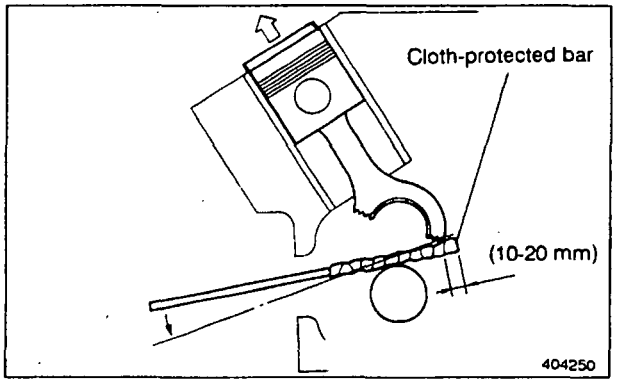
(a) Turn the crankshaft to bring the piston assembly (from which the connecting rod has been removed) to top dead center.



(b) Turn the crankshaft in reverse 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.



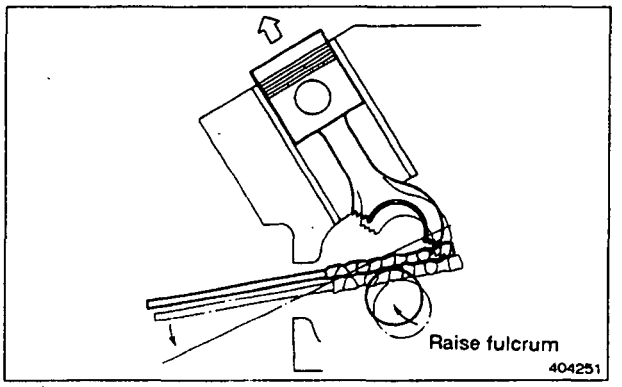
(c) Cover the turning bar (A) with a cloth to protect it. Put the tip of the bar under the bottom of the large end of the connecting rod, then pry up the piston assembly a small amount by making using the crank pin as a fulcrum.



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 mm from the bottom end of the large end.

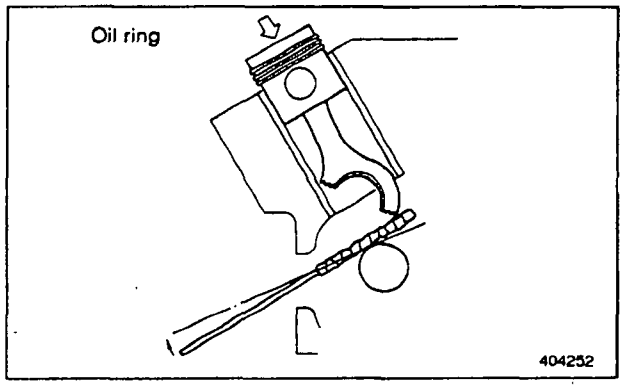
(d) Turn the crankshaft in the normal direction just a little at a time to raise the crank pin (fulcrum) while pushing down on the outer end of the bar to raise the piston assembly.



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.

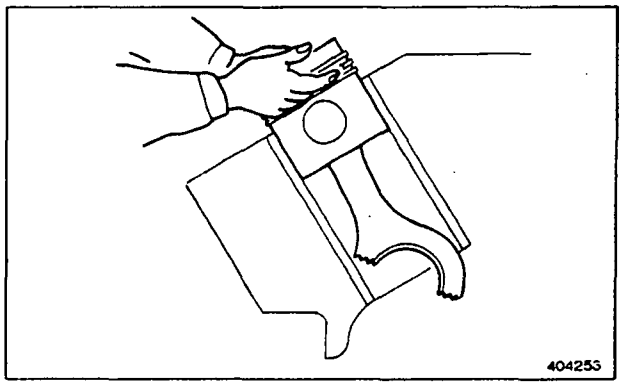


CAUTION!

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

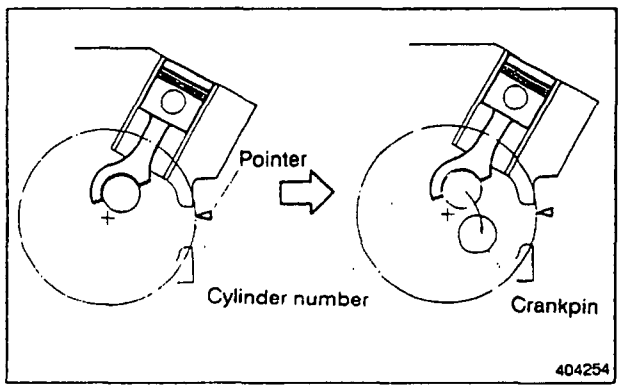
(f) While holding the compression ring portion of the piston with your hands, carefully pull the piston from the cylinder liner, then rest its skirt on the top of the crankcase.

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



Pistons for Left Bank Cylinders

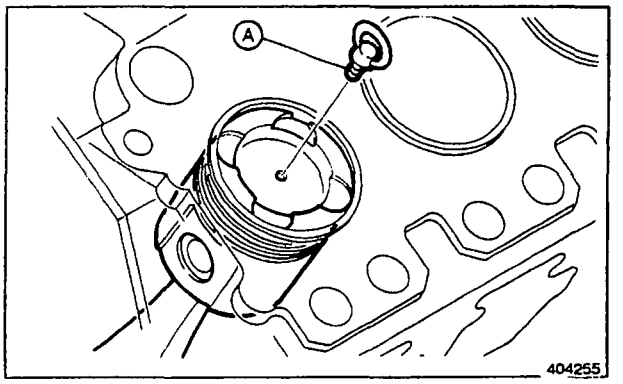
Removal procedure is the same as that for removing pistons for right bank cylinders. The only difference is that the position of the crank pin and the direction of the crankshaft rotation for removal are reversed.



Using the Piston Remover

(a) Turn the crankshaft to bring the piston assembly to be removed to 50° before top dead center for the right bank. For the left bank, turn the crankshaft to 50° past top dead center.

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



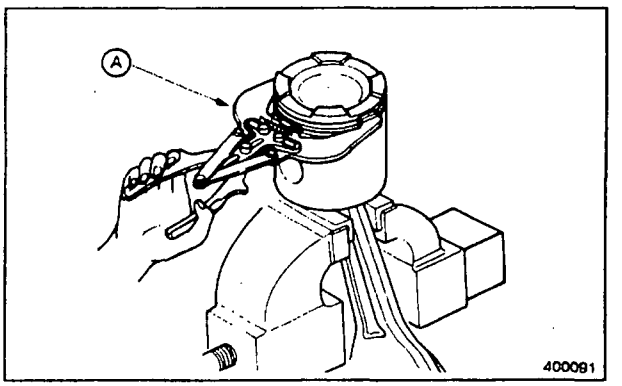
CAUTION!

(a) Do not damage the piston when you pull it out from the cylinder liner. Do not let it hit the connecting rod with its skirt.

(b) Do not damage the cylinder liner bore with the connecting rod.

(4) Removing the piston ring

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

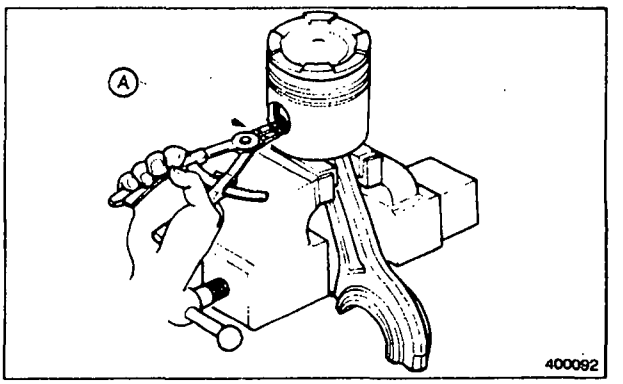


(5) Removing piston pins from a piston

(a) Use ring pliers (A) (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

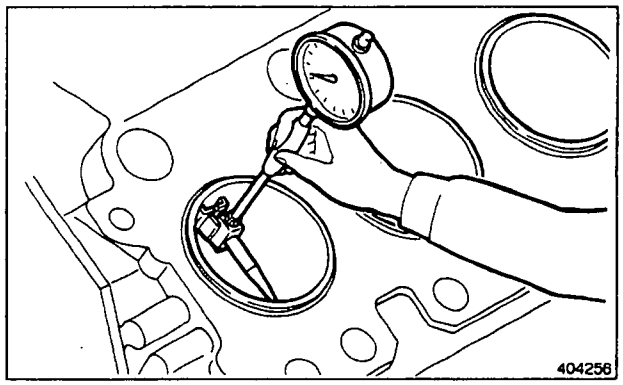
Cylinder Liners

(1) Measuring cylinder liner inside diameter

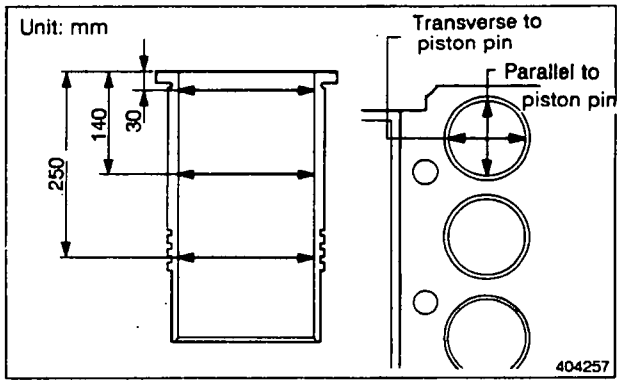
Measure the inside diameter of each liner in two directions, parallel and transverse to the piston pin, at three positions on the top (ridged area). If measurements exceed the service limit, replace the liner.

Unit: mm

Item	Nominal Value	Assembly Standard	Service Limit
Cylinder liner inside diameter	ϕ170	170.000-170.040	171.500



Measuring cylinder liner



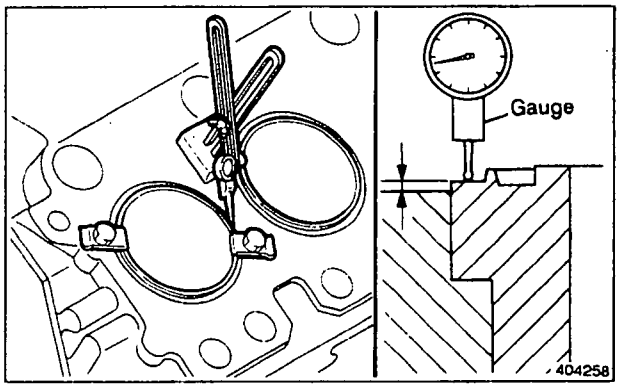
Cylinder liner measuring diagram

(2) Measuring cylinder liner protrusion

Measure the protrusion of each liner at its flange with a 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

Item	Assembly Standard
Cylinder liner protrusion at flange	0.09-0.18



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.

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

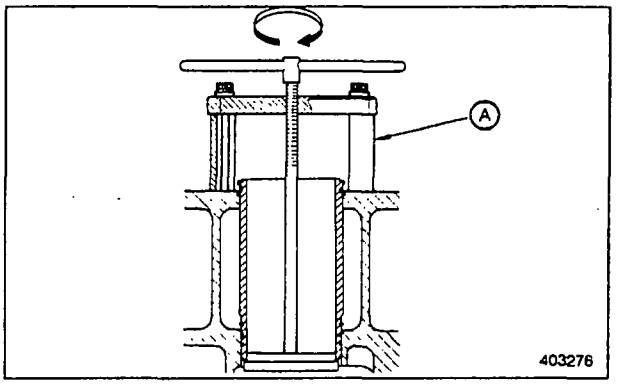
(b) Secure the top of the liner uniformly at two places with the clamps and bolts (M22 x 2.5)

(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

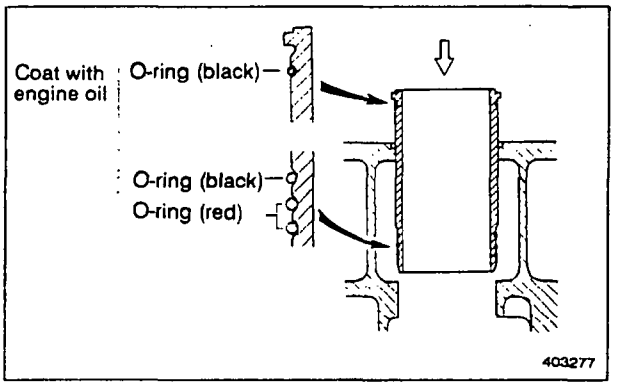
(a) Use the cylinder liner remover (A) (37591-04100) to remove the cylinder liner from the crankcase for replacement.



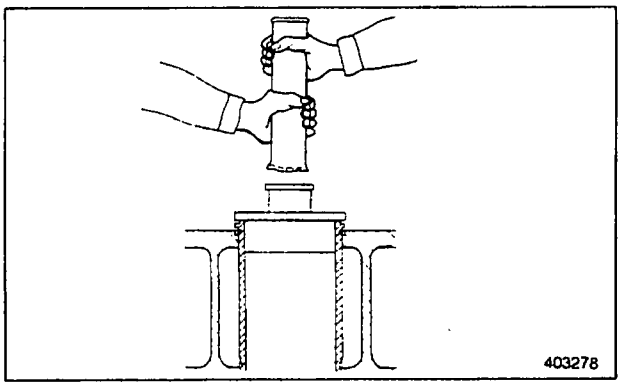
(b) Attach O-rings to the new cylinder liner, then carefully insert the liner into the bore of the crankcase.

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.

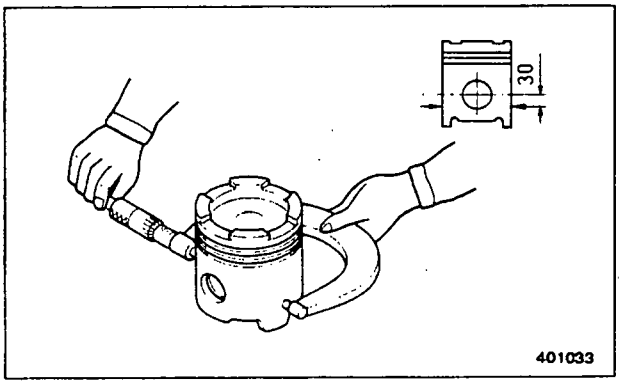
(b) Check each liner to be sure its protrusion is within assembly standards.

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.

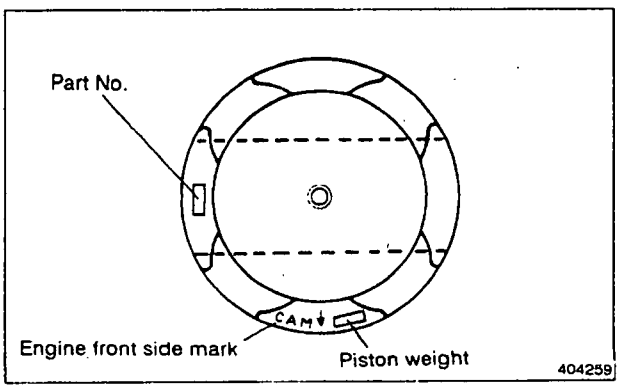


Measuring piston diameter

Unit: mm

Item	Nominal Value	Assembly Standard	Service Limit
Piston diameter	ϕ170	169.76-169.80	169.66
Weight variance among pistons		40 g max.	

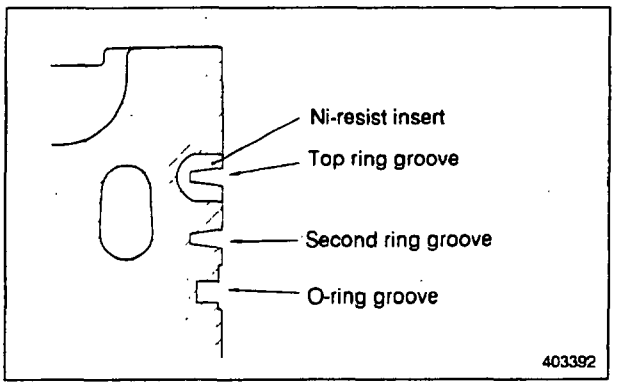
(b) The piston weight is stamped on the top of each piston.



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.



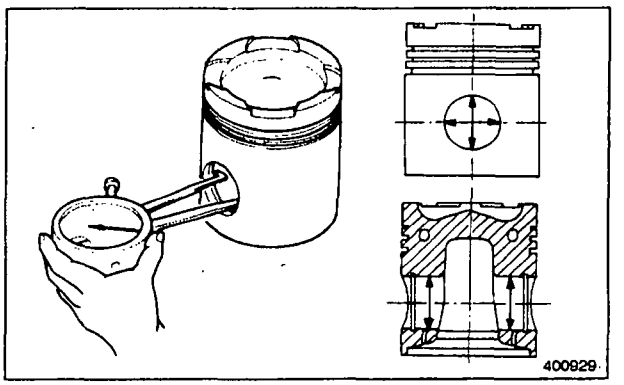
Inspecting piston ring grooves

(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

Item	Nominal Value	Assembly Standard	Service Limit
Piston pin bore diameter	ϕ70	70.002-70.015	70.020



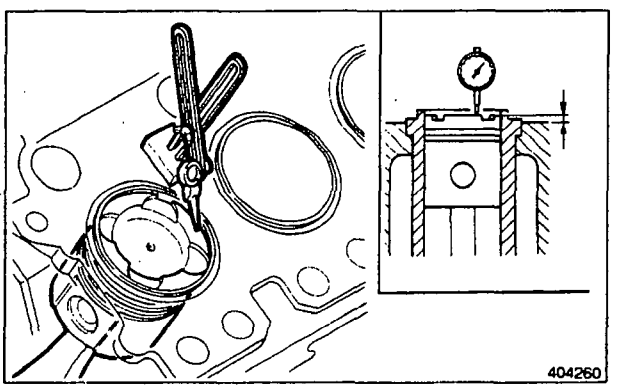
Measuring piston bore diameter

(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

Item	Assembly Standard
Piston protrusion	0.06-0.65
Installed thickness of cylinder head gasket	1.77-1.83
Clearance between piston top and cylinder head	1.22-1.95

CAUTION!

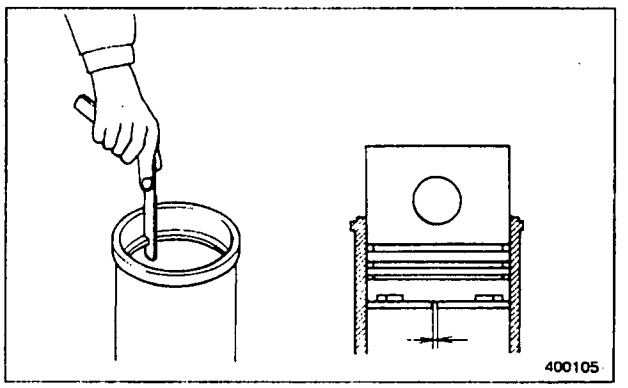
Keep the piston protrusion with assembly standard range to maintain high engine performance and to prevent the valves from interfering with the piston.

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



Measuring piston ring gap

NOTE

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

Unit: mm

Item		Standard Clearance	Service Limit
Piston ring gaps	Top	0.6-0.8	
	Second	0.6-0.8	2.0
	Oil	0.3-0.45	

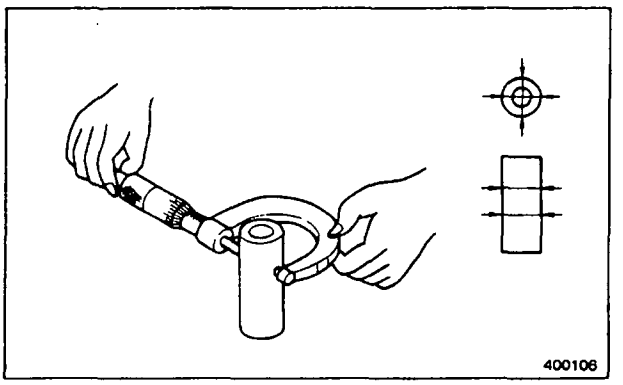
Piston Pins

(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

Item	Nominal Value	Assembly Standard	Service Limit
Piston pin outside diameter	ϕ70	69.987-70.000	69.970



Measuring piston pin diameter

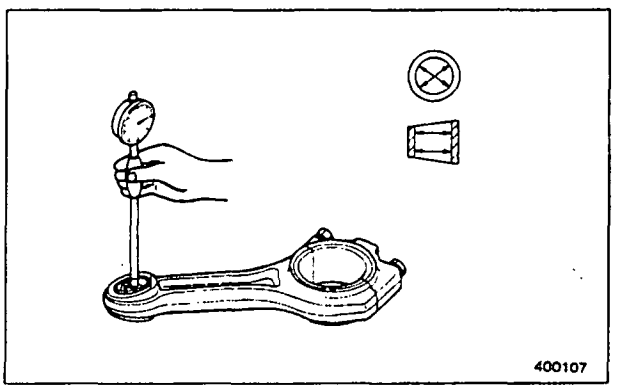
Connecting Rods, Connecting Rod Bearings, and Bushings

(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

Item	Nominal Value	Assembly Standard	Service Limit
Connecting rod bushing inside diameter	ϕ70	70.020-70.040	70.070



Measuring connecting rod bushing inside diameter

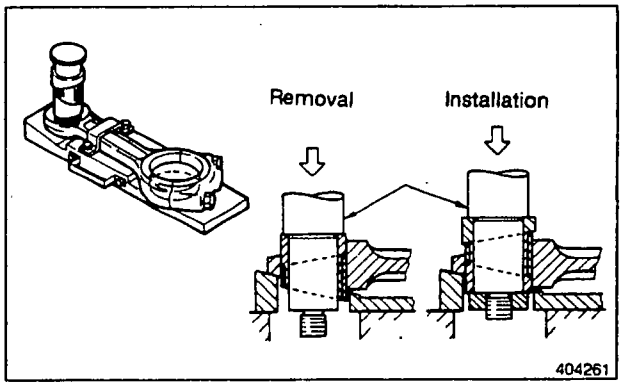
(2) Replacing connecting rod bushings

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

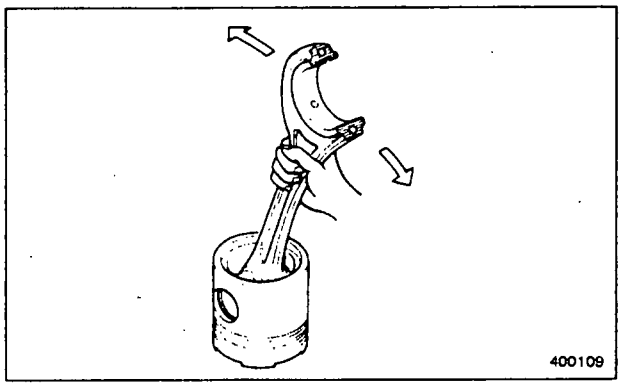
(b) When installing a new bushing, align the oil holes in the bushing and connecting rod.

(c) After installing the bushing, finish its inside diameter to $\phi 70^{+0.040}_{+0.020}$ 1.6S and its parallel bushing with respect to the large-end bearing to 0.05 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

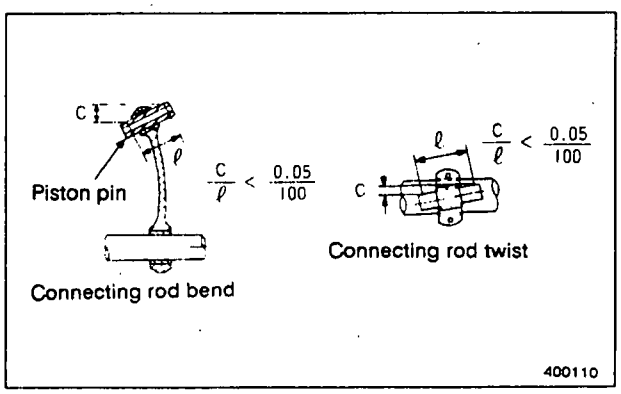


(3) Inspecting connecting rods for bend and twist.

(a) Measure *C* and *l*. If the measurement at *C* is larger than 0.05 mm per 100 mm 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.

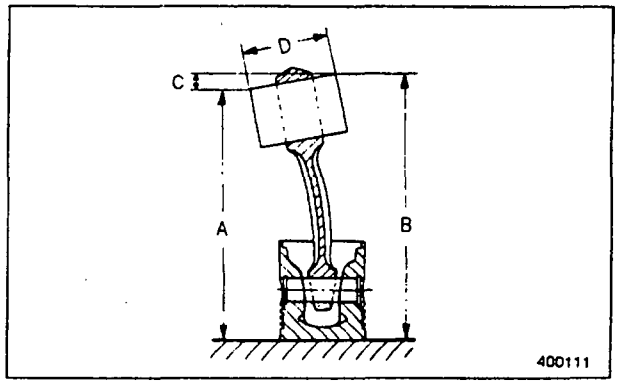


Inspecting connecting rod

(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

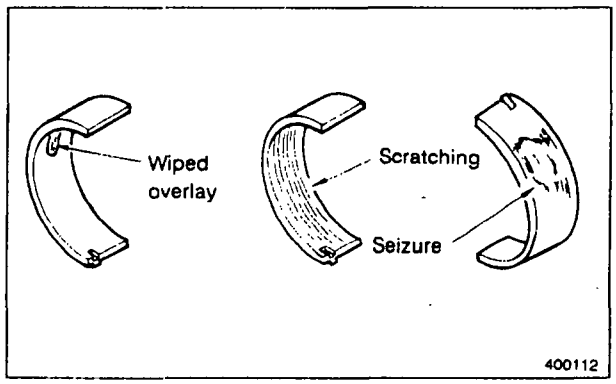
Item	Assembly Standard
Connecting rod bend and twist (C/D)	0.05/100 max.



Inspecting connecting rod installed on piston

(4) Inspecting connecting rod large-end bearings

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



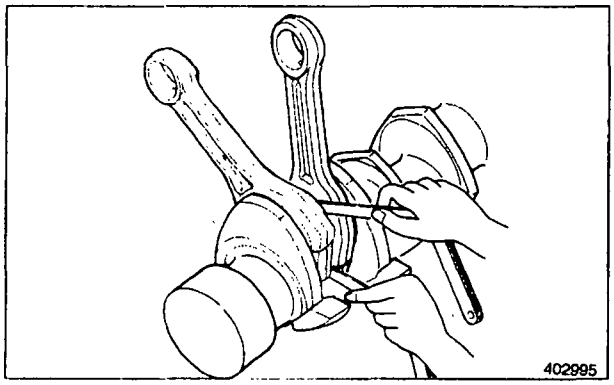
(5) Measuring connecting rod end play

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

Item	Nominal Value	Standard Clearance (Nominal)	Service Limit
Connecting rod end play*	60 x 2	0.4-0.9	1.4

*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.

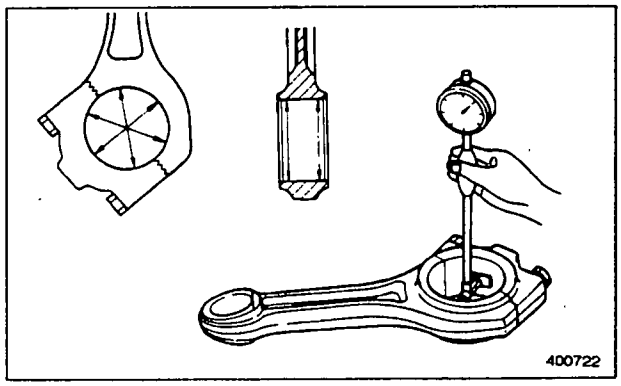
Item	Assembly Standard
Variance in weight among connecting rods per engine	40 g max.

(7) Measuring connecting rod large-end bore diameter

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

Unit: mm

Item	Nominal Value	Assembly Standard	Service Limit
Connecting rod large-end bore diameter	ϕ131	131.000-131.025	131.050



Measuring connecting rod large-bore diameter

(8) Measuring connecting rod bearing thickness

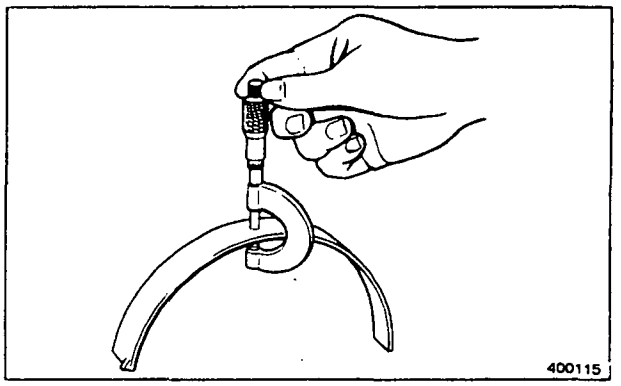
Use a ball-point micrometer to measure the center of each bearing shell. If the thickness exceeds the service limit on the upper or lower shell, replace both shells as a set.

Units: mm

Item		Nominal Value	Assembly Standard	Service Limit
Connecting rod bearing thickness	STD	3.000	2.972-2.985	2.930
	-0.25	3.125	3.097-3.110	3.055
	-0.50	3.250	3.222-3.235	3.180
	-0.75	3.375	3.347-3.360	3.305
	-1.00	3.500	3.472-3.485	3.430

NOTE

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



Measuring connecting rod bearing thickness

2.3 Reassembly

Reassembly is done in the reverse order of disassembly.

(1) Reassembling pistons on connecting rods

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

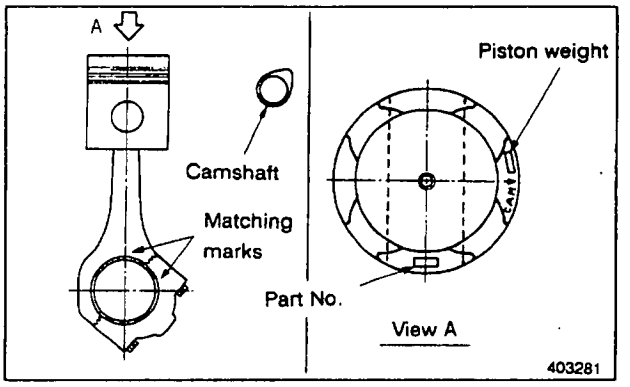
(b) Coat the piston pin with engine oil, then insert it in position through the connecting rod.

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

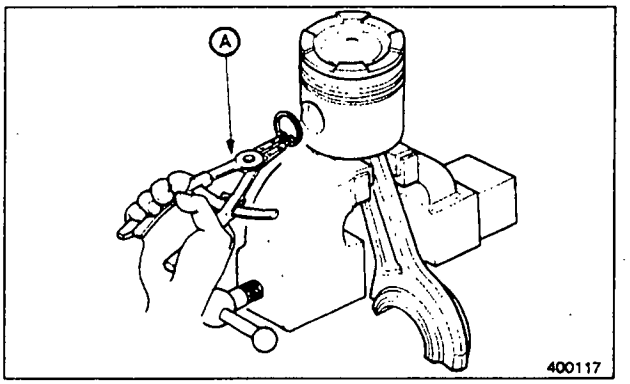
(d) Use ring pliers (A) (45191-08400) to install the snap rings in the grooves of the pistons. Make sure that the rings are not fatigued and that they fit in the grooves properly.

NOTE

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



Matching marks on connecting rod

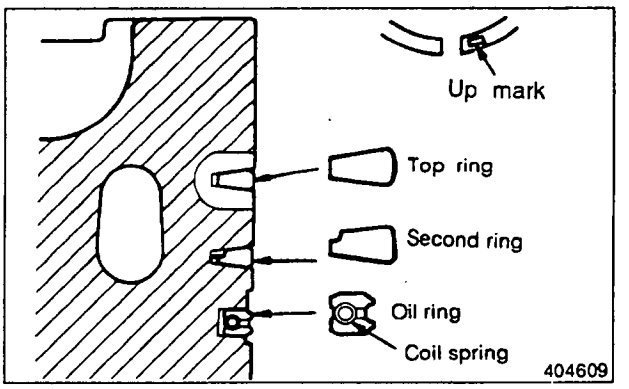


(2) Installing piston rings

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

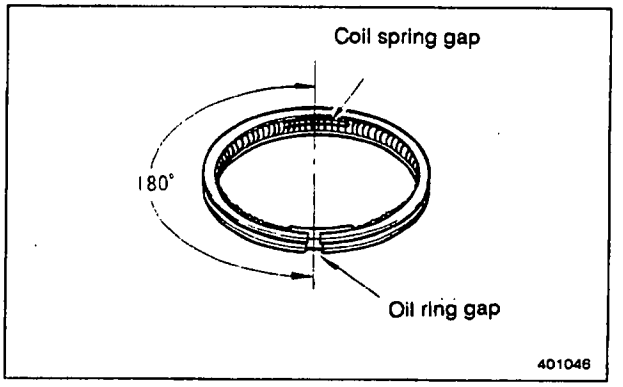
CAUTION!

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 ring arrangement

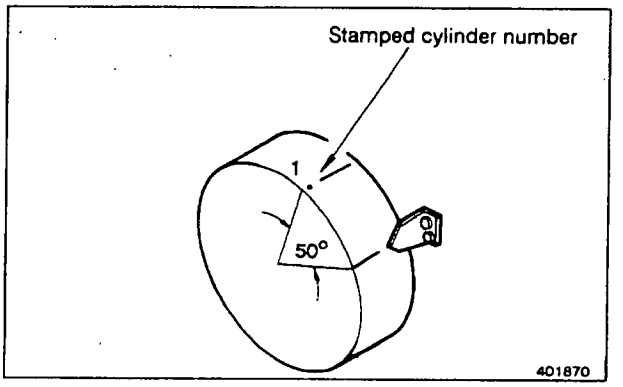
(b) Install the oil ring with its gap positioned at 180° to the coil spring.



(3) Preparation before installing pistons

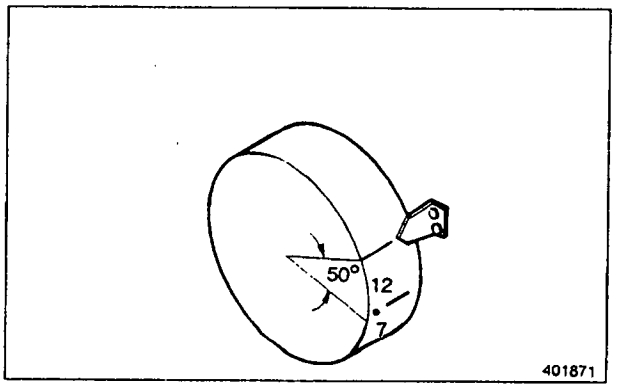
(a) Pistons for right bank cylinders

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.

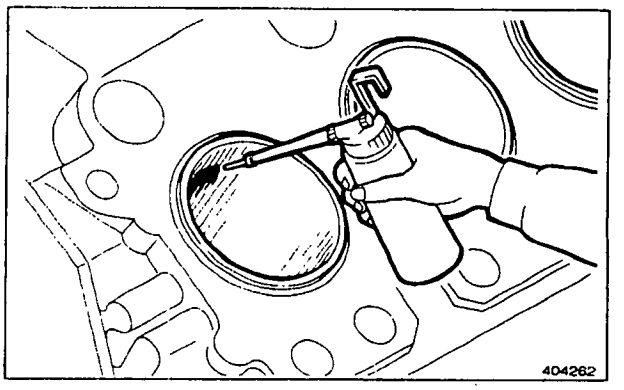


(b) Pistons for left bank cylinders

Turn the crankshaft in the normal direction until the number of the cylinder to which the piston is to be installed is at the position of about 50° after top dead center.

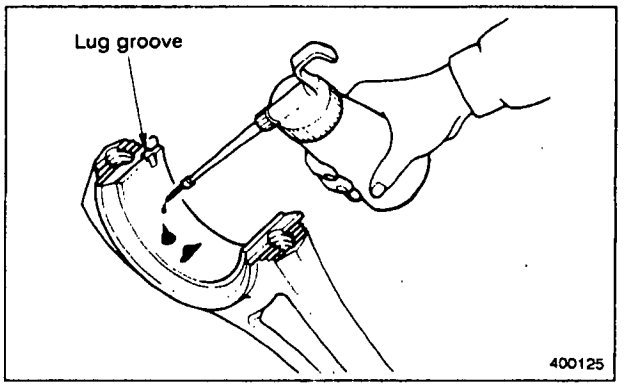


(c) Clean the cylinder liner bore surface and crank pin by wiping with a cloth, then coat it with engine oil.



(4) Installing connecting rod bearing upper shells

Install the upper shell of the bearing 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 bearing are aligned.



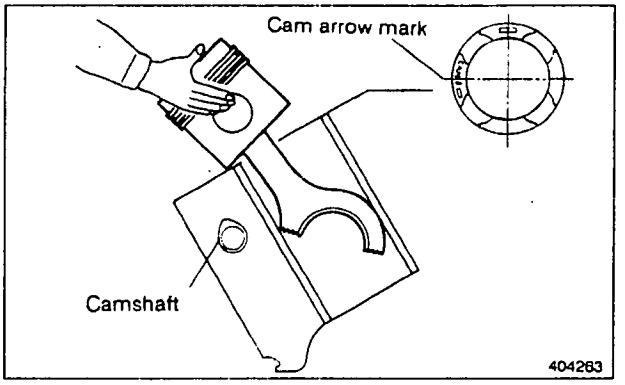
(5) Inserting pistons

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

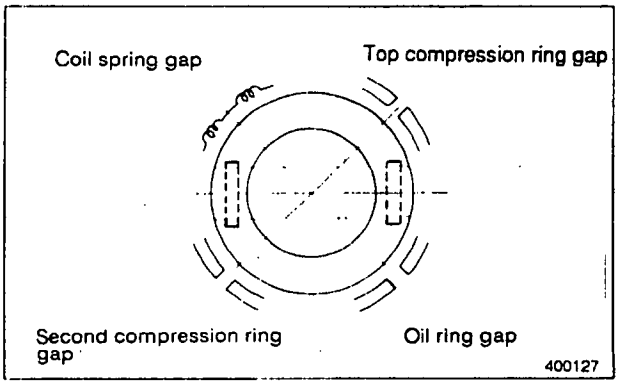
CAUTION!

(a) Make sure the arrow mark above the "F" on top of the piston points forward.

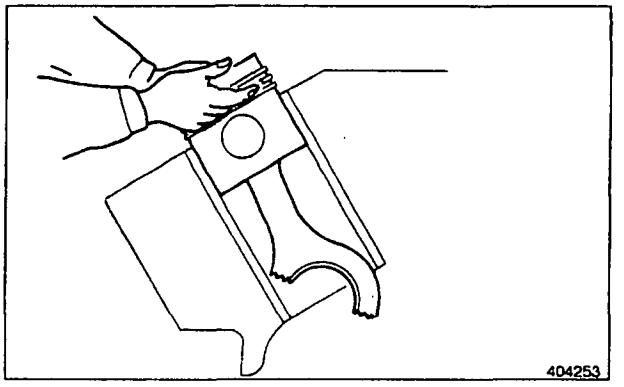
(b) When placing the connecting rod in the liner, keep it away from the oil jet nozzle by observing the rod through the inspection hole of the crankcase. Do not rotate the piston.



(b) Coat the piston rings with engine oil, then position the ring gaps as shown.



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



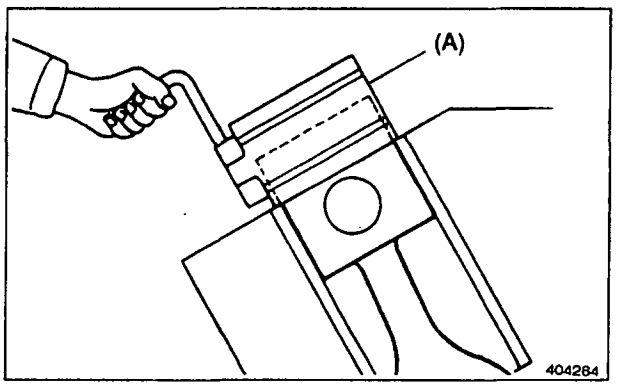
WARNING!

DO NOT PINCH YOUR FINGER BETWEEN THE OIL RING AND CYLINDER LINER.

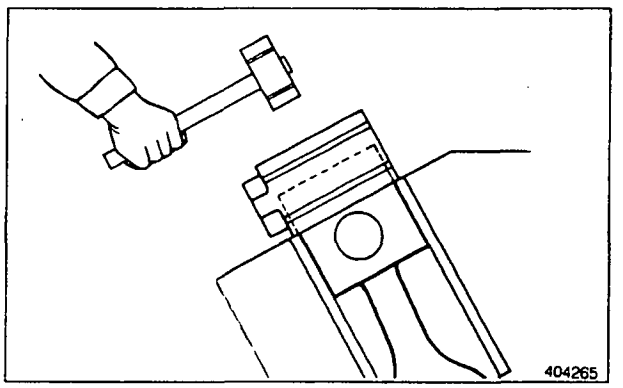
NOTE

Slowly insert the piston to avoid damaging it.

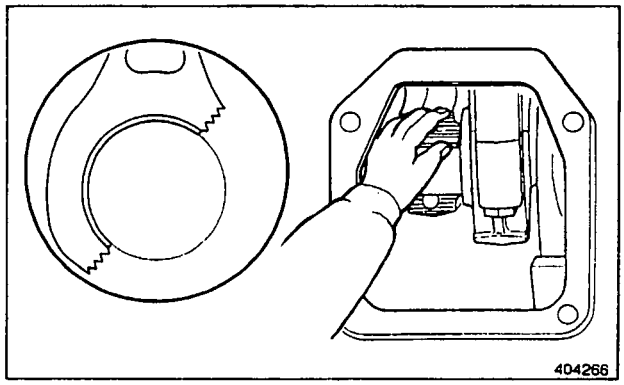
(d) After making sure that the piston ring gaps are positioned properly, coat the rings with engine oil, then clamp them, using the piston installer (A) (37191-07100). At this time, coat the inside surface of the installer with engine oil.



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



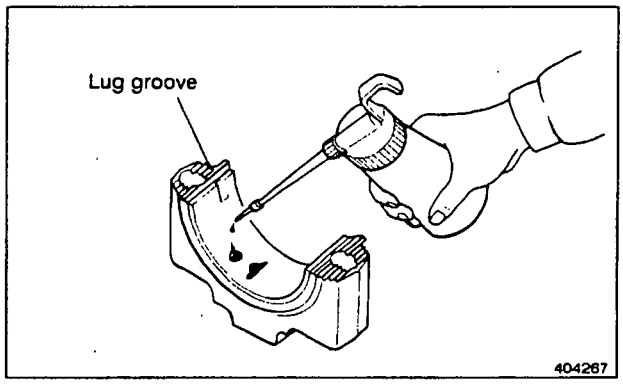
(f) By inserting your hand through the crankcase inspection hole, make sure that the upper shell of the bearing is properly positioned in the large end of the connecting rod.



(6) Installing connecting rod cap bolts

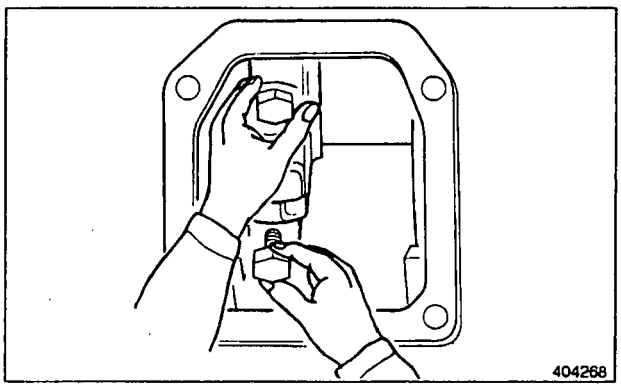
(a) Insert the connecting rod bearing into the connecting rod cap along the ring groove.

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



(c) Install each cap in position. With you 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.

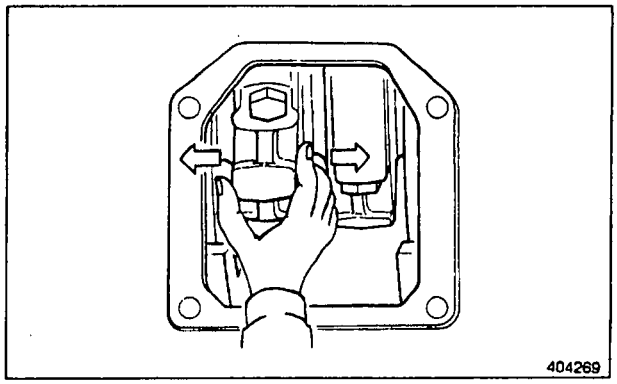
(d) With the cap bolts tightened temporarily, touch the joint between the cap and rod. Make sure that the cap is normally held in place, and tighten the bolts to the specified torque.



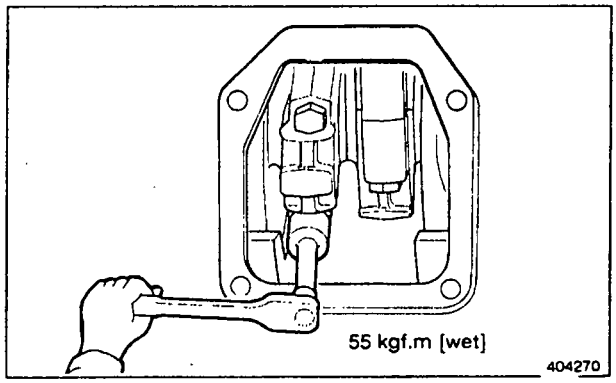
CAUTION!

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

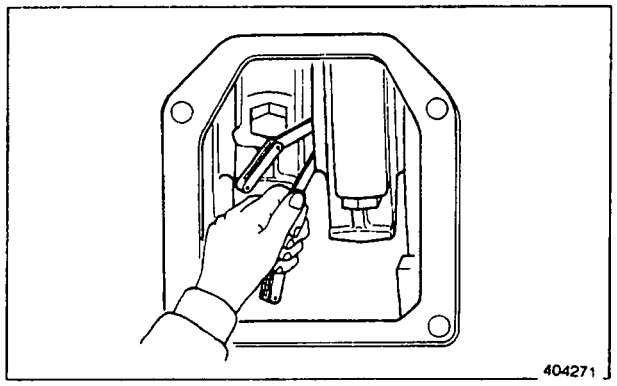
(e) Temporarily tighten the cap bolts of the rod installed later, then press it squarely toward the rod already installed by tapping. Move the large end of this rod in the thrust direction. Make sure that the rod has correct end play.



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



(g) 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 section 2.2 of chapter 7, "Adjustments, Bench Testing, and Performance Tests.")

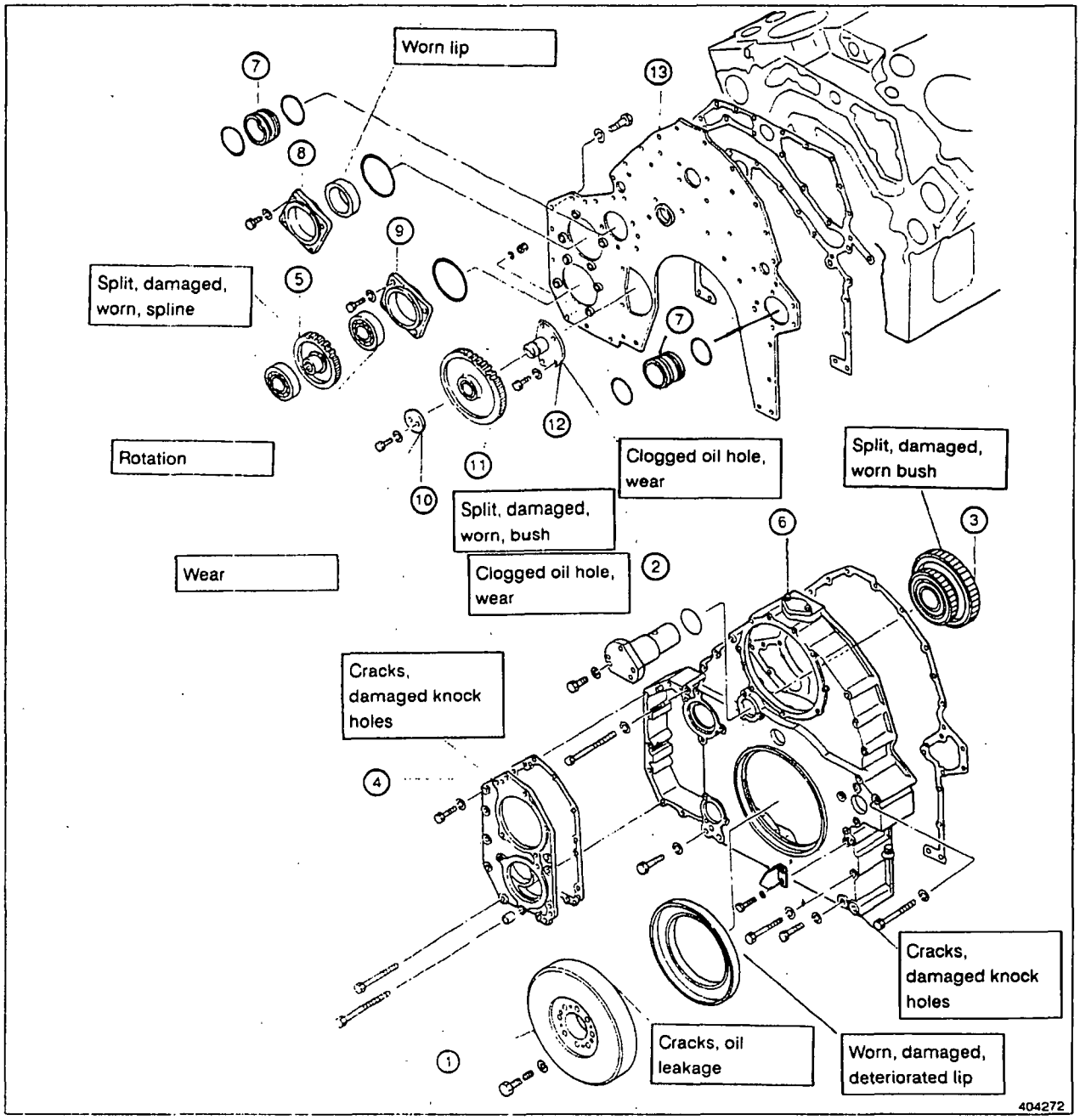


NOTE

Before installing the cylinder head, measure the protrusion of the piston. Make sure that the measurement is correct. (Refer to (4), "Pistons", 2.2 of this chapter.)

3. Viscous Damper and Front Gear

3.1 Disassembly



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

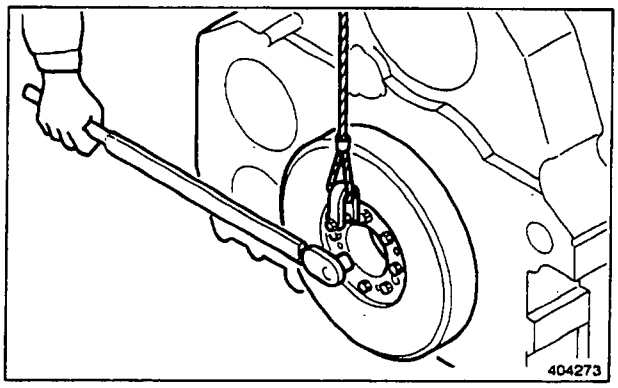
(1) Removing the viscous damper

(a) Attach a sling to the viscous damper.

(b) Unscrew the mounting bolts.

(c) Screw the jacking bolts (M14 x 1.5-40 mm) into the holds uniformly, then remove the viscous damper.

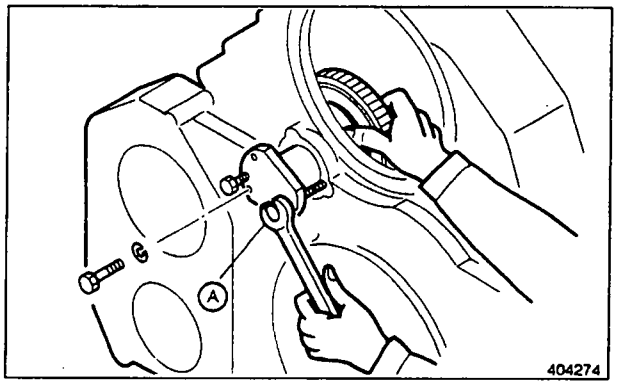
Weight: approx. 50 kg



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

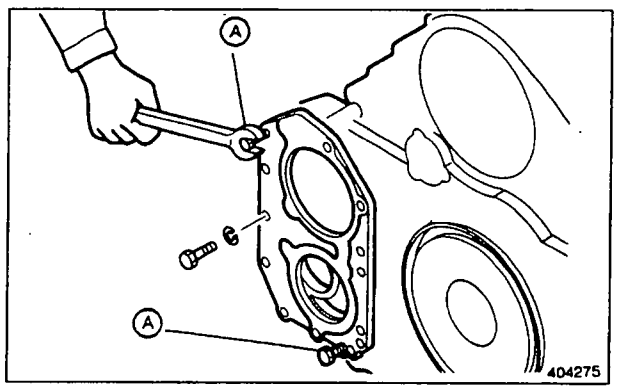
(a) Unscrew the 3 idler shaft mounting bolts.

(b) Screw the 2 jacking bolts (A) (64362-68500: M12 x 1.25) into the idler shaft, then pull it out. When pulling it, grip the idler gear inside by hand to hold it. After pulling the shaft out, remove the idler gear through the drive case mounting hole.



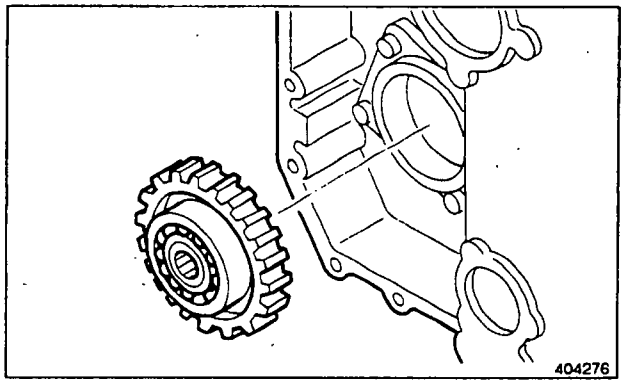
(3) Removing the oil pump and water pump mounting plate

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



(4) Removing the oil pump gear

Remove the oil pump gear, complete with the bearing.

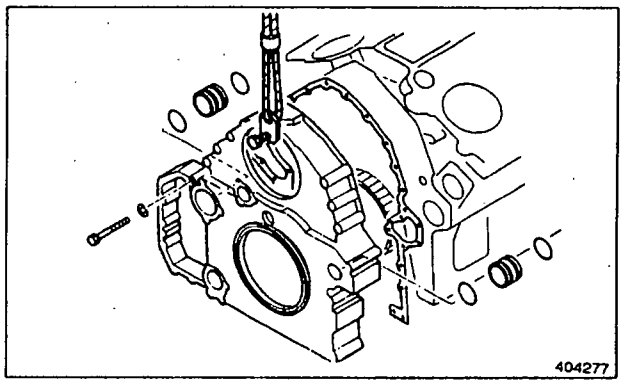


(5) Removing the front gear case

(a) Attach a sling to the front gear case.

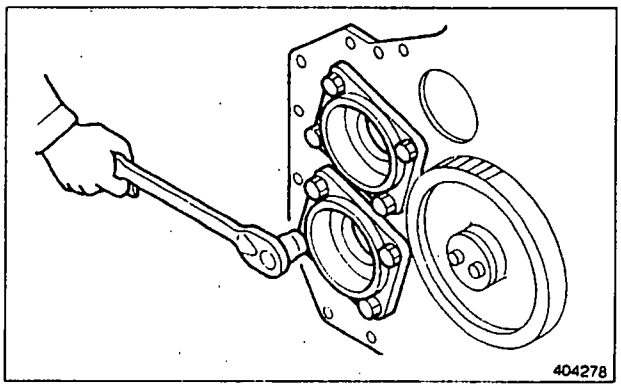
(b) Unscrew the front gear case mounting bolts. Remove the lifted gear case by sliding it until the gear case comes apart from the positioning dowel pin. Be careful not to damage the oil seal, or bend the pointer by hitting it.

Weight: 70 kg approx.



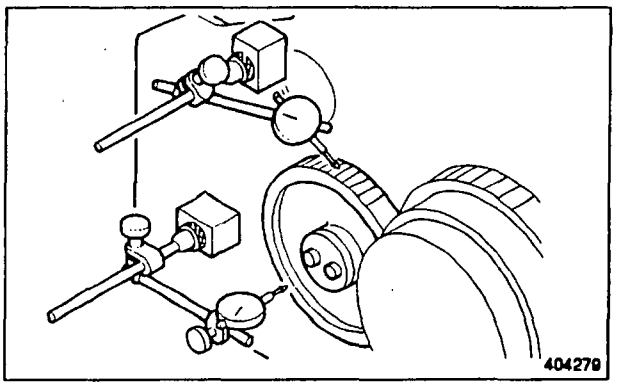
(6) Removing the oil pump and water pump bearing cover

Unscrew the bearing cover mounting bolts, and remove the bearing cover.



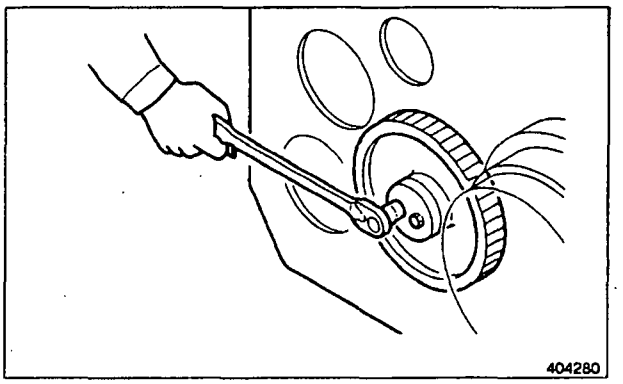
(7) Measuring backlash and end play of the idler gear

Measure the backlash and end play of the idler gear to obtain the data for replacement. (Refer to 3.2 of this chapter.)



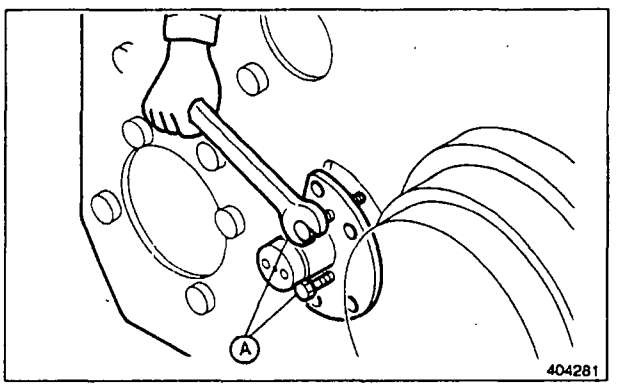
(8) Removing the idler gear

Unscrew the thrust plate mounting bolt and remove the idler gear.



(9) Removing the idler shaft

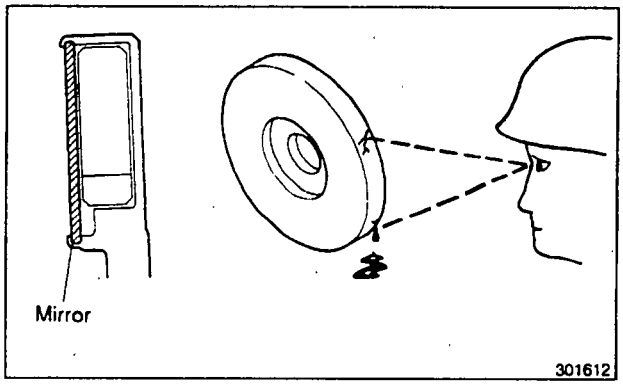
Do not remove the idler shaft unless it is needed. When needed, remove it by unscrewing the mounting bolts and screwing the two jacking bolts (A) (M10 x 1.25) uniformly.



3.2 Inspection and Repair

Viscous Damper Inspection

Check the viscous damper for cracks, deformations or cracks in the mirror plate, leakage of silicon oil, discolored or peeling paint due to excessive heat. Replace it with a new one after 8000 hours of service.



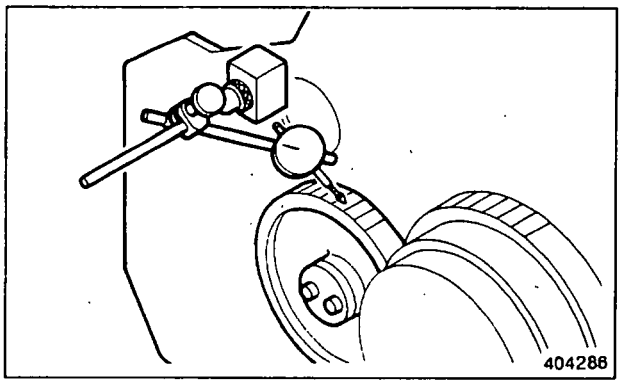
Viscous damper inspection

Measuring Backlash

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

Unit: mm

Item	Standard Clearance	Repair Limit	Service Limit
Backlash	0.12-0.18	0.30	0.50

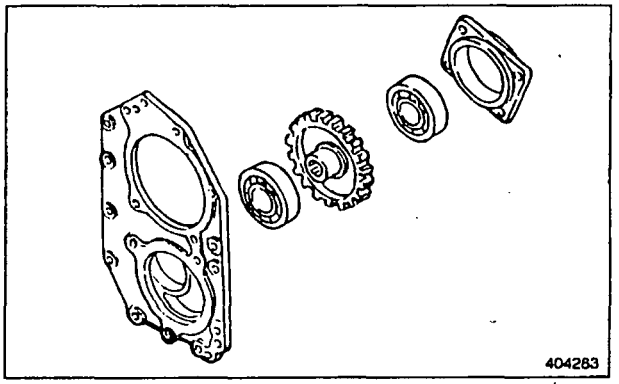


Measuring gear backlash

Oil Pump Drive: Bearing Bore Diameters

Rotate the bearing, and replace it if it is not smooth. Check the following items and replace them if you find any evidence of excessive wear.

- Drive shaft and bearing
- Drive case and bearing
- Drive shaft and oil seal



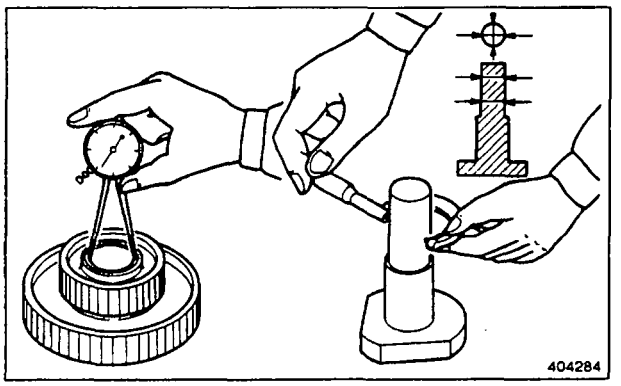
Unit: mm

Item		Nominal Value	Assembly Standard
Cover bearing bore		ϕ110	110.000-110.035
Plate bearing bore		ϕ110	109.987-110.022
Bearing	Outside dia.	ϕ110	109.980-110.005
	Inside dia.	ϕ50	49.95-50.003
Gear shaft bearing bore		ϕ50	49.993-50.013

Idler Gears, Idler Gear Bushings, and Idler Gear Shafts

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

If the diameter exceeds the service limit, replace the bushing or shaft (whichever is worn).



Measuring inside diameters for idler bushing and shaft

Unit: mm

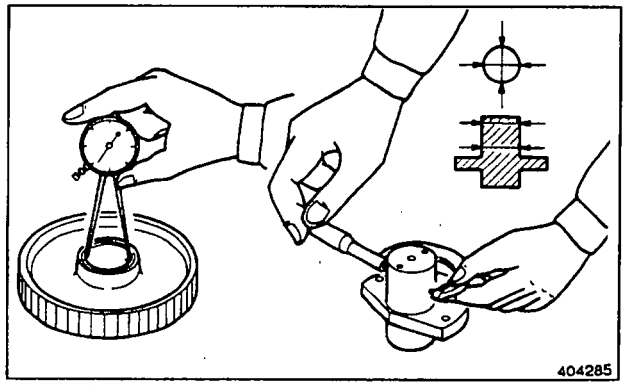
Item	Nominal Value	Assembly Standard	Service Limit
Idler gear bushing inside diameter	ϕ50	50.000-50.025	50.060
Idler gear shaft diameter	ϕ50	49.950-49.975	49.900

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

If the diameter exceeds the service limit, replace the bushing or shaft (whichever is worn).

Unit: mm

Item	Nominal Value	Assembly Standard	Service Limit
Idler gear bushing inside diameter	ϕ50	50.00–50.025	50.060
Idler gear shaft diameter	ϕ50	49.950–49.975	49.900



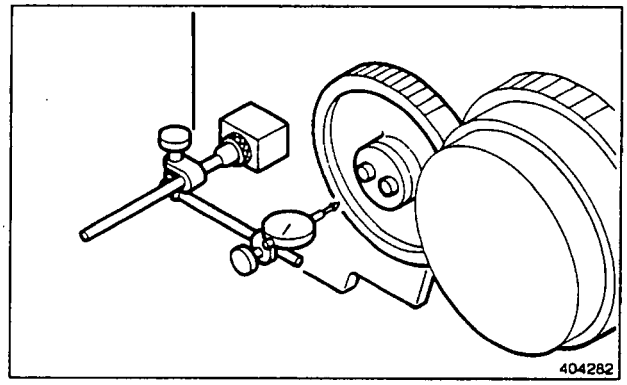
Measuring inside diameters for idler bushing and shaft

(3) 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

Item	Standard Clearance	Repair Limit
Idler gear end play	0.2-0.4	0.6
Fan drive idler gear end play	0.25-0.75	1.2



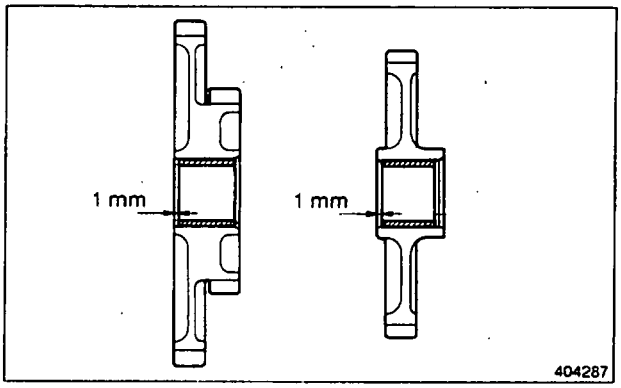
Measuring idler gear end play

(4) Replacing idler bushing

(a) Use the idler bushing puller (32591-0002500) to remove the existing bushing.

(b) Install a new bushing to the gear by pressing it until the end face of the bushing is 1 mm deeper than that of the gear boss.

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



Replacing idler bushing

3.3 Reassembly

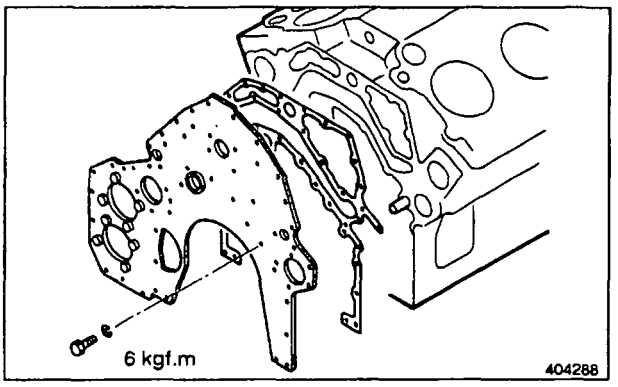
Reassembly is the reverse procedure of disassembly.

(1) Installing the front plate

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

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

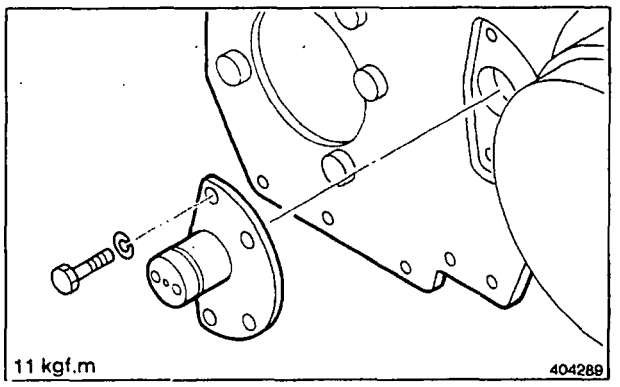
(c) Make sure that the lower end of the front plate is flush with the bottom of the crankcase. Cut off the excess of the packing neatly along the edge of the plate.



(2) Installing the idler shaft

(a) Insert the idler shaft using the guide bolts.

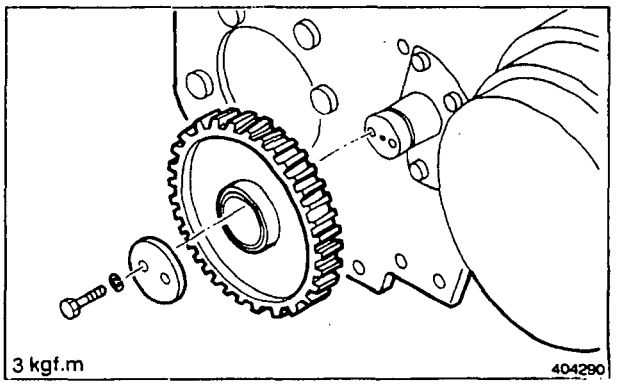
(b) Tighten the shaft mounting bolts to the specified torque.



(3) Installing the idler gear

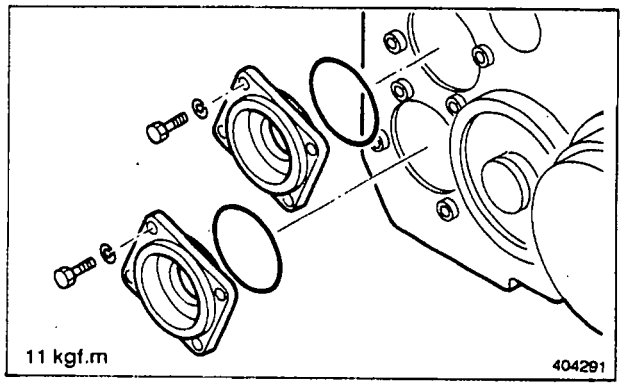
(a) Insert the idler gear into the shaft, and install the thrust plate.

(b) Install the thrust plate, then tighten the mounting bolts to the specified torque.



(4) Installing the oil pump and water pump drive bearing cover

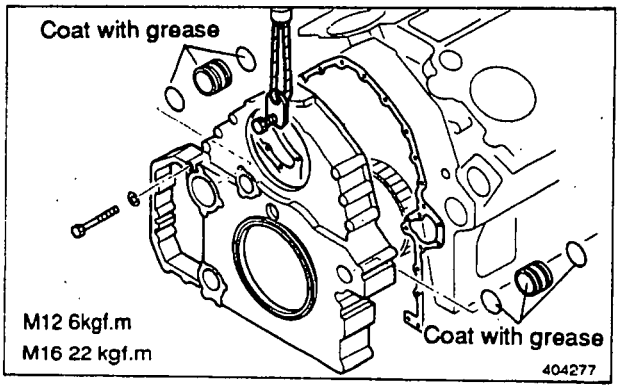
(a) Insert the bearing cover into the front plate, then tighten the cover mounting bolts to the specified torque.



(5) Installing the front gear case and pointer

(a) Apply a sealant (HERDITE) to the front gear case packing mounting surface, then place the packing in position. Apply sealant in the same manner to the packing, then install the front gear case.

(b) Now mount the water coupling of the crankcase and the gear case to the crankcase. Apply grease to the O-rings and O- ring grooves.



CAUTION

Do not damage the O-rings when installing the gear case.

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

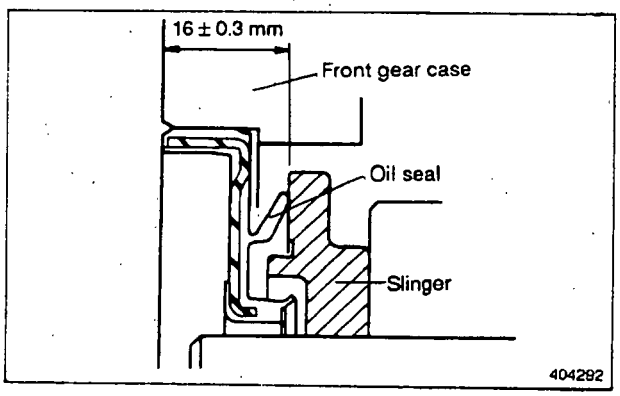
(d) Tighten the front cover mounting bolts uniformly to the specified torque.

(e) Make sure that the lower end of the front cover is flush with the bottom of the crankcase. Cut off the excess packing neatly along the edge of the cover.

(f) Install the oil seal to the front gear case.

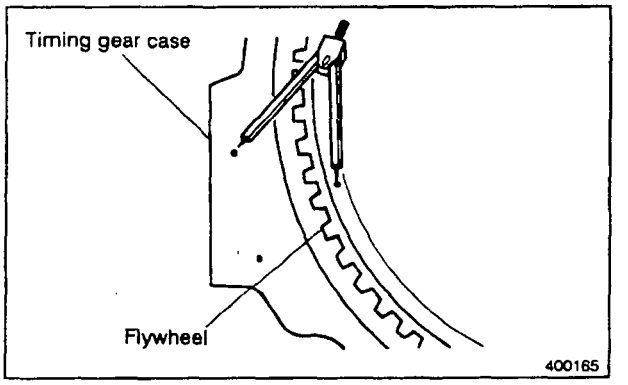
(g) Apply engine oil to the lip of the oil seal.

(h) Insert the oil seal to the slinger using the jig in position as shown in the figure (404292).



When the Pointer Is Out of Place

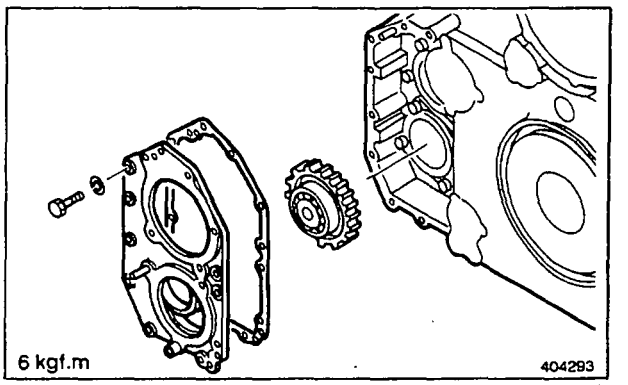
To determine the top dead center on the compression stroke of No. 1 cylinder, for example, bring the mark on the flywheel to where it is at an equal distance between the marks stamped on the timing gear case.



(6) Installing the oil pump gear and mounting plate for the oil pump and water pump

(a) Insert the oil pump gear.

(b) Install the plate, then tighten the bolts to the specified torque.



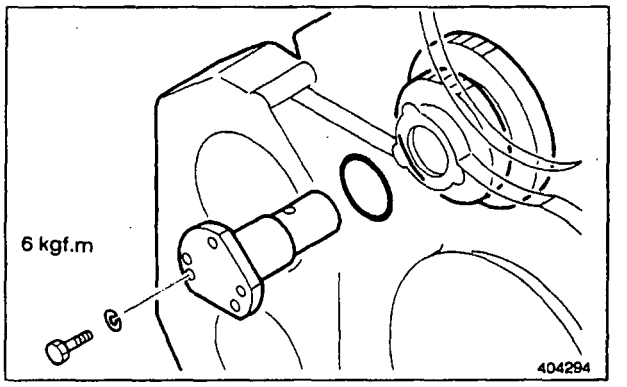
(7) Installing fan drive idler gear and shaft

(a) Install the idler gear through the drive case mounting hole with its smaller gear toward the front side.

(b) Insert the idler shaft. During installation, hold the gear center to align it with the center of the idler shaft hole.

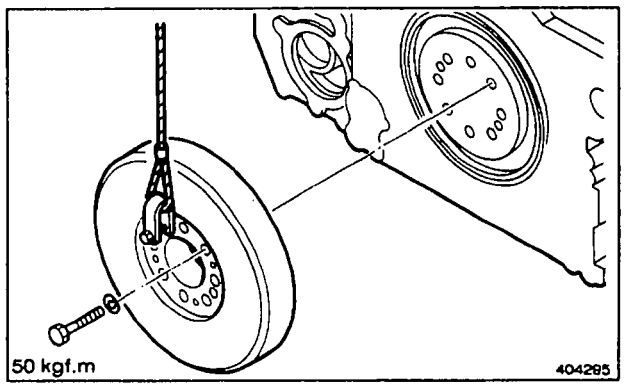
(c) Tighten the idler shaft mounting bolts to the specified torque.

(d) Make sure that there is end play and backlash for the gear.



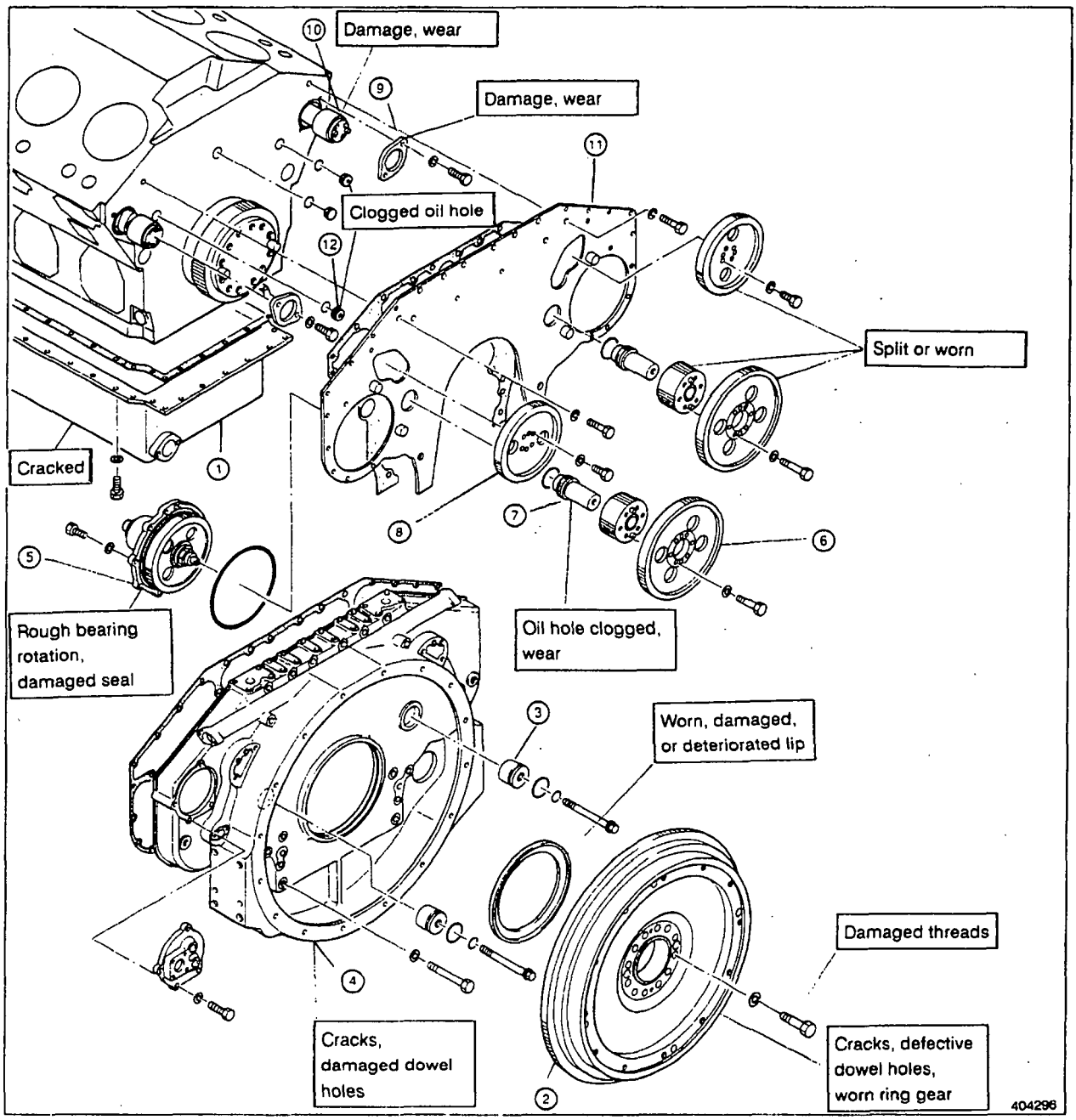
(8) Installing the viscous damper

Tighten the damper mounting bolts to the specified torque.



4. Flywheel, Timing Gears, and Camshaft

4.1 Disassembly



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

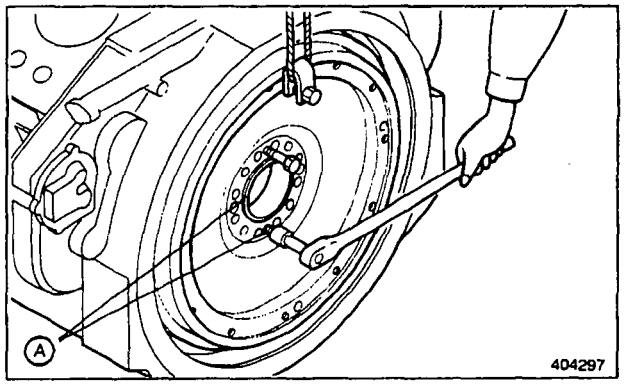
(1) Removing the flywheel

(a) Attach a sling to the flywheel.

(b) Unscrew the mounting bolts.

(c) Screw the two jacking bolts (A) (64362-68500: M12 X 1.25) into the holes in the flywheel evenly, then remove the flywheel.

Weight: approx. 138 kg



CAUTION!

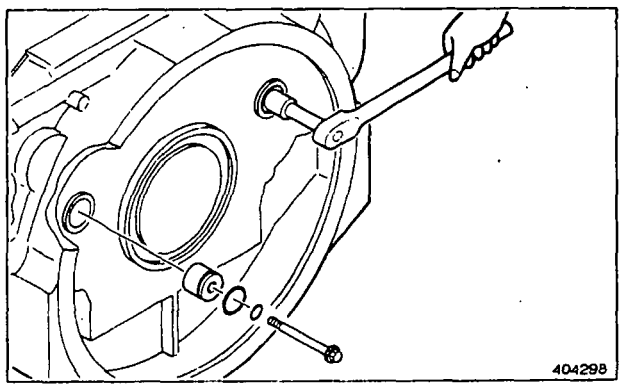
(a) When you remove the flywheel, do not drop it or bump it against a hard object.

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

(2) Removing the idler shaft collar

(a) Unscrew the idler shaft thrust collar mounting bolts. Mark the collar at its position.

(b) Screw the bolt (M18 X 1.5) through the thrust collar mounting bolt hole and pull the thrust collar from the gear case.



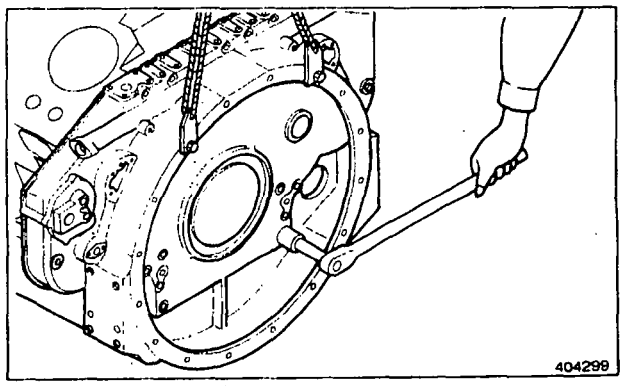
(3) Removing the timing gear case

(a) Attach slings to the timing gear case.

(b) Unscrew the mounting bolts.

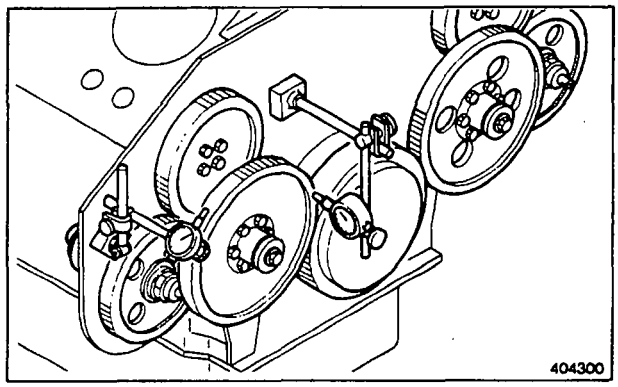
(c) Remove the timing gear case by lifting it up until it separates from the dowel pin. Do not damage the oil seal.

Weight: approx. 150 kg



(4) Measuring backlash and end play

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

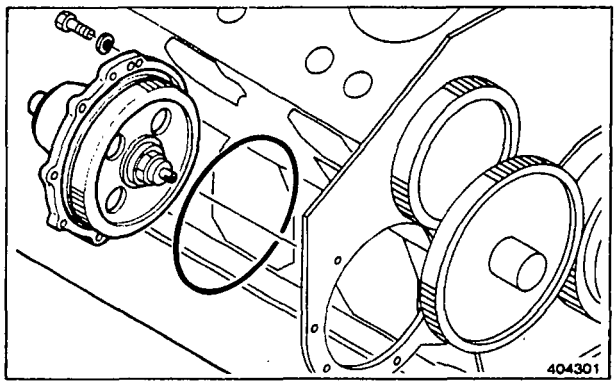


(5) Removing the fuel injection pump drive gears (left and right)

Unscrew the injection pump drive case mounting bolts, then remove the pump drive. Do not damage the gear teeth.

NOTE

Remove the No. 12 cylinder cam cover before removing the pump drive case of the left side.



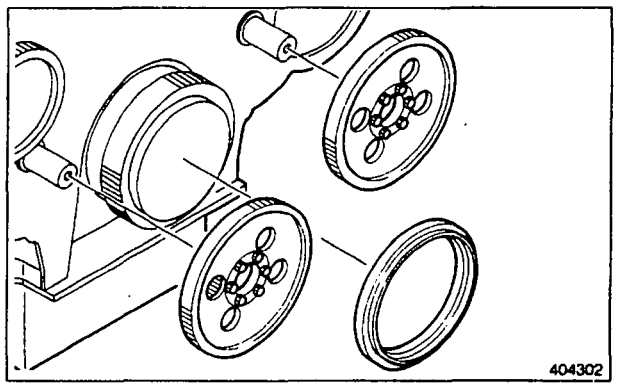
(6) Removing idler gears

(a) Remove the slinger of the crankshaft. (Refer to section 5.2 of this chapter.)

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

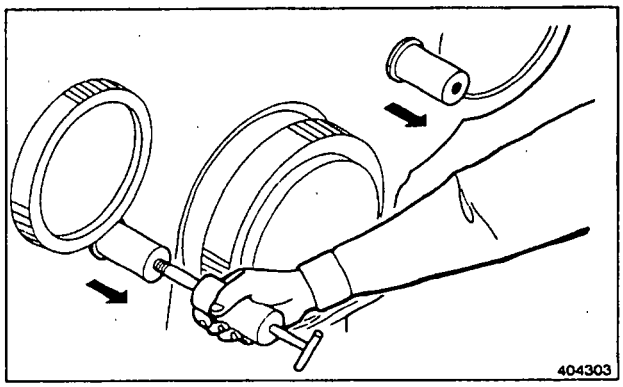
NOTE

If you want to remove the idler gear without removing the slinger, unscrew the assembly bolt of the idler gear.



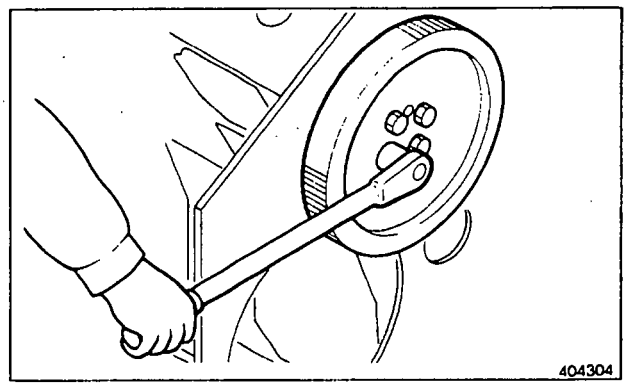
(7) Removing the idler shaft

Do not remove the idler shaft unless you need to repair it. To remove, install the sliding hammer to the idler shaft removing screw hole.



(8) Removing camshaft gears

Unscrew the camshaft gear mounting bolts, then remove the camshaft gear.



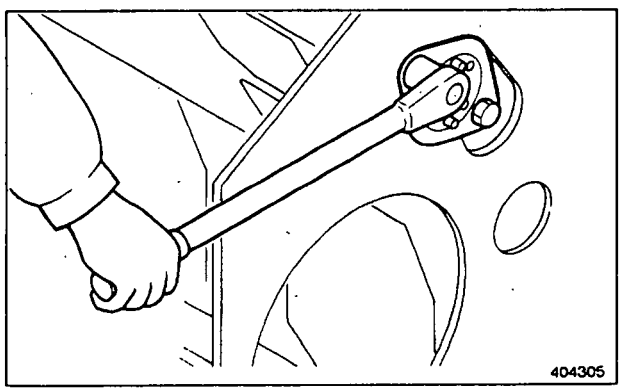
(9) Removing camshafts

Unscrew the thrust plate mounting bolts, then pull out the camshaft from the crankcase.

Weight: approx. 35 kg

CAUTION!

When pulling out the camshaft, support it with a bar inserted through the inspection hole of the crankcase to prevent damage to the cam surfaces and bushings.

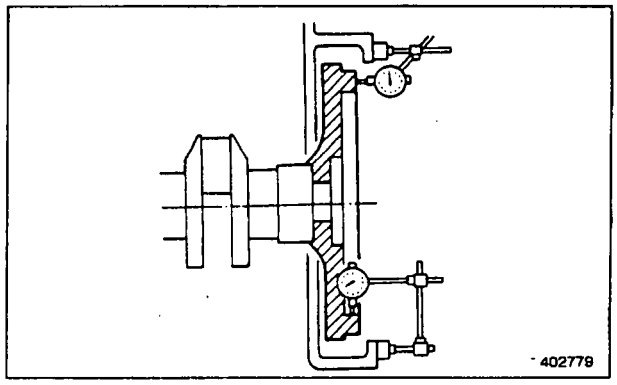


4.2 Inspection and Repair

Flywheel and Ring Gear

Measure 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.



Measuring flywheel runout

Unit: mm

Item		Assembly Standard
Flywheel	Face runout	0.336 max.
	Radial runout	0.13 max.

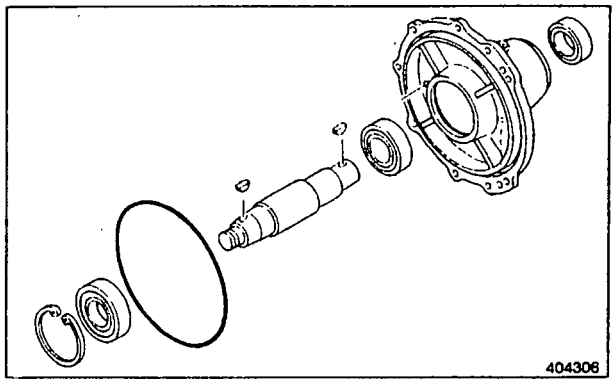
Injection Pump Drive Diameter and Inside Diameter of Bearings

(1) Check the bearing for smooth rotation. Replace the bearing if it rotates erratically or hums.

(2) Check the fit of the drive shaft in the bearing. Replace excessively worn parts.

(3) Check the fit of the bearing in the drive case. Replace excessively worn parts.

(4) Check the drive shaft and oil seal. Replace any defective parts.



Unit: mm

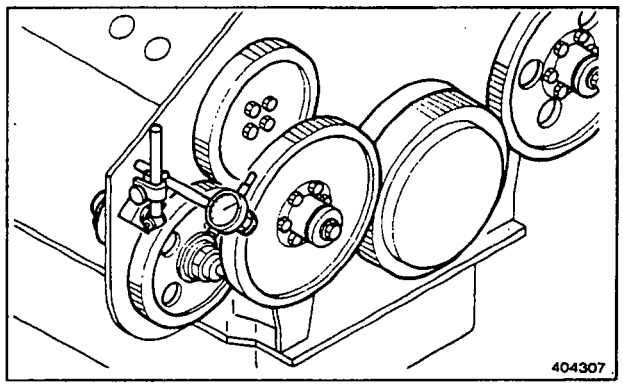
Item		Nominal Value	Assembly Standard
Case bearing bore inside diameter		ϕ90	89.987-90.022
		ϕ100	99.987-100.022
Bearing	Outside dia.	ϕ90	89.980-90.005
		ϕ100	99.980-100.005
	Inside dia.	ϕ45	44.985-45.003
		ϕ50	49.985-50.003
Drive shaft bearing dia.		ϕ45	45.002-45.013
		ϕ50	50.002-50.013

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

Item	Standard Clearance	Repair Limit	Service Limit
Timing gear backlash	0.12-0.18	0.30	0.50



Measuring timing gear backlash

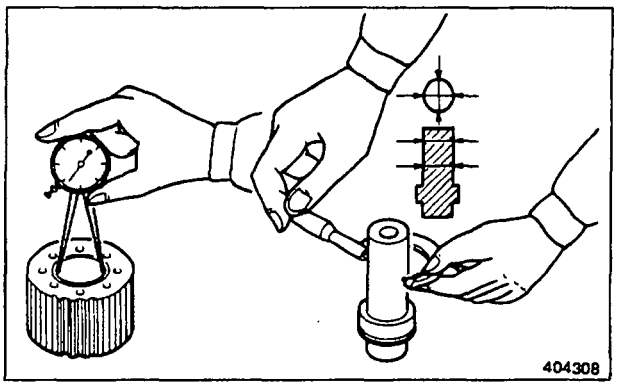
Idler Gears, Idler Gear Bushing, and Idler Gear Shafts

(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

Item	Nominal Value	Assembly Standard	Service Limit
Idler gear bushing inside dia.	ϕ50	50.000-50.025	50.060
Idler gear shaft dia.	ϕ50	49.950-49.975	49.900



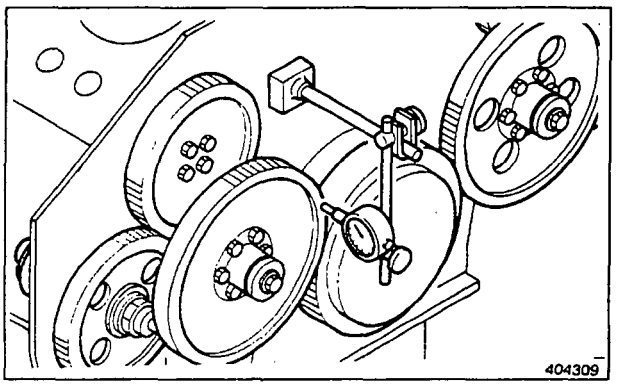
Measuring idler gear bushing and shaft

(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

Item	Standard Clearance	Repair Limit
Idler gear end play	0.1-0.5	0.8



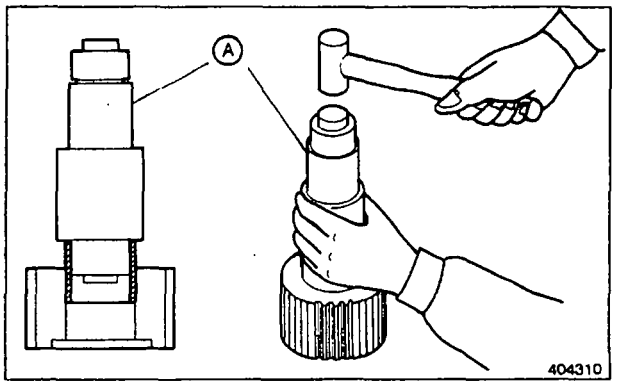
Measuring ilder gear end play

(3) Replacing idler bushings

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

(b) Install a new bushing to the gear by pressing it until the end face of the bushing 1 mm deeper than 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 $\phi 50\ ^{+0.025}_{0}$ 1.6S



Replacing the idler gear bushing

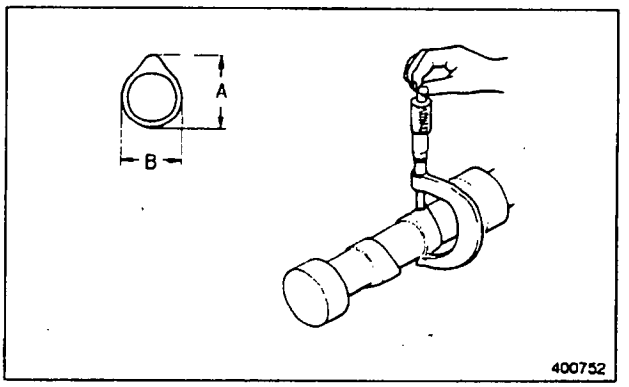
Camshafts and Camshaft Bushings

(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

Item	Assembly Standard	Service Limit
Cam lift (A-B)	9.197-9.297	8.45



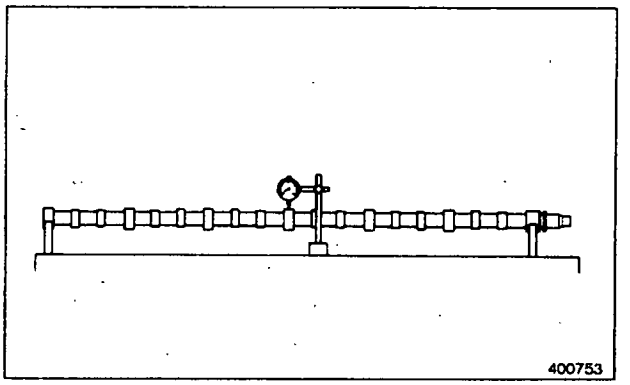
Measuring cam lift

(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

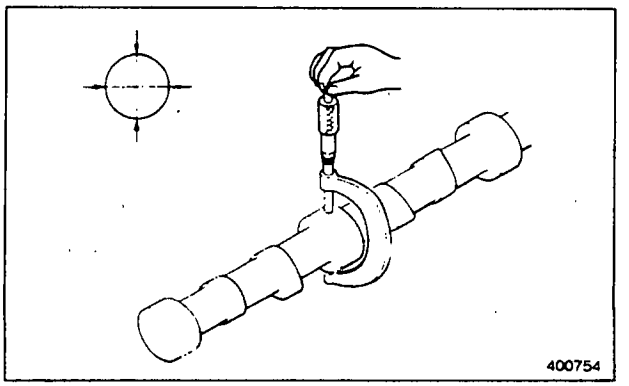
Item	Assembly Standard	Repair Limit
Camshaft runout	0.05 max.	0.08

(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

Item	Nominal Value	Assembly Standard	Service Limit
Camshaft journal dia.	ϕ84	83.92-83.94	83.87



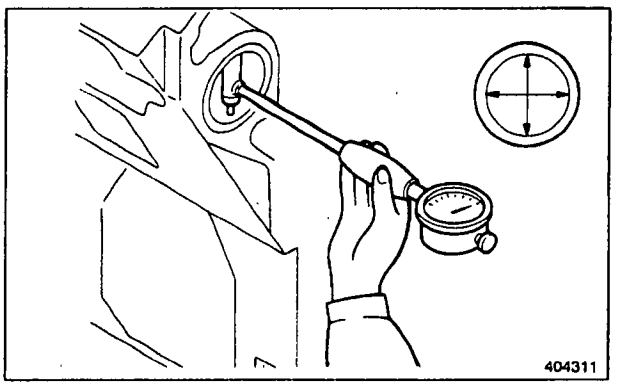
Measuring cam shaft journal diameter

(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

Item	Nominal Value	Assembly Standard	Service limit
Camshaft bushing inside dia.	ϕ84	84.000-84.035	84.10



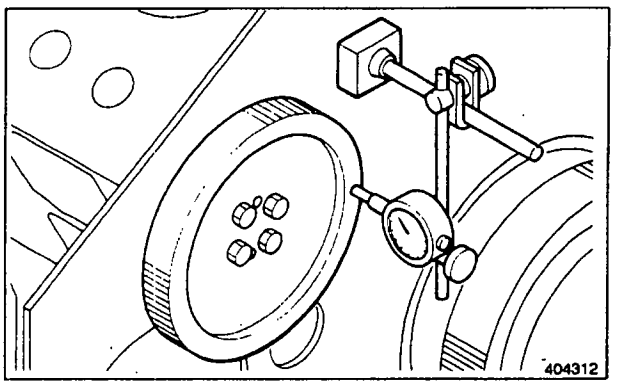
Measuring cam shaft inside diameter

(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

Item	Standard Clearance	Service Limit
Camshaft end play	0.10-0.25	0.40

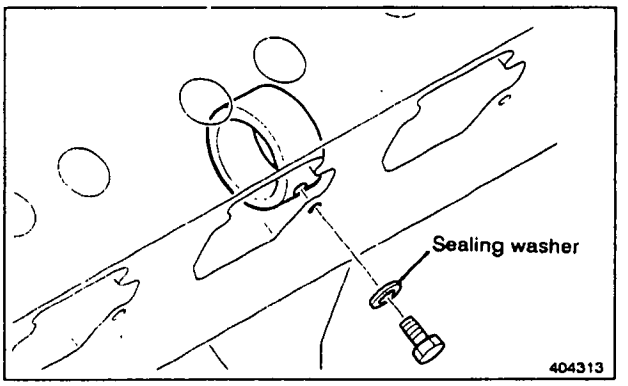


Measuring cam shaft end play

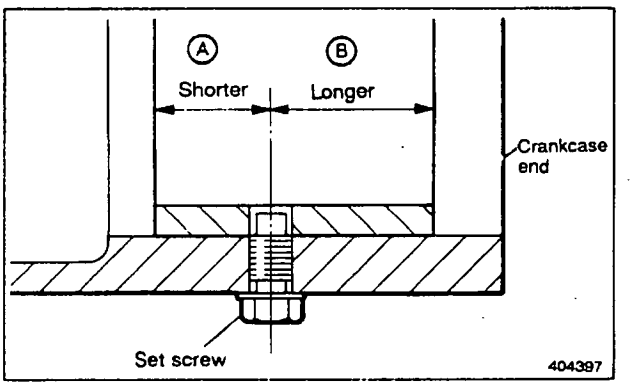
(6) Replacing camshaft bushings

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.



Replacing a cam shaft bushing



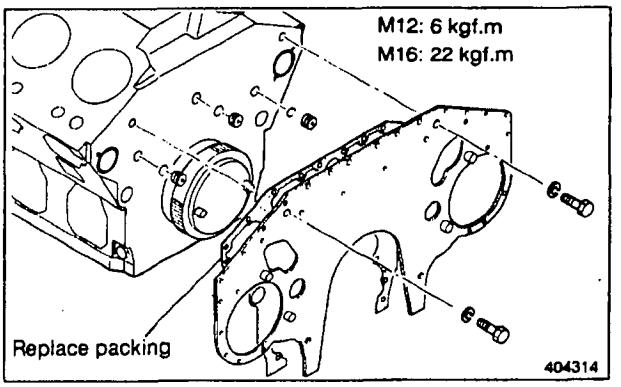
4.3 Reassembly

(1) Installing the rear plate

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

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

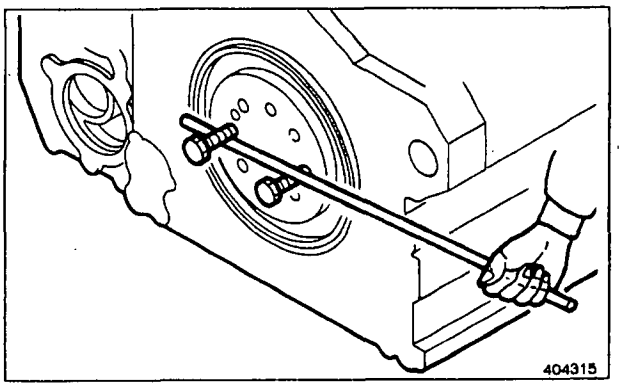
(c) Make sure that the lower end of the rear plate is flush with the bottom of the crankcase. Cut off the excess of the packing neatly along the edge of the plate.



(2) Cranking the engine

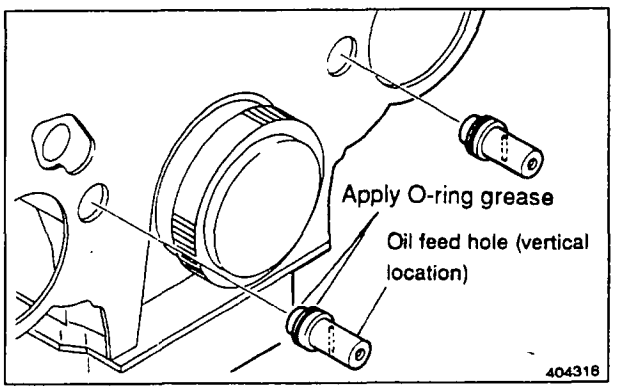
(a) Install the bolt to the viscous damper mounting hole.

(b) Using this bolt, turn the crankshaft with a bar to bring the No. 1 cylinder piston to the top dead center on the compression stroke.



(3) Installing idler gear shafts

Fit the O-ring to the idler shaft. Apply grease to the O-ring to insert the idler shaft into the crankcase. At this time, set the oil feeding hole to the bushing at the vertical position.



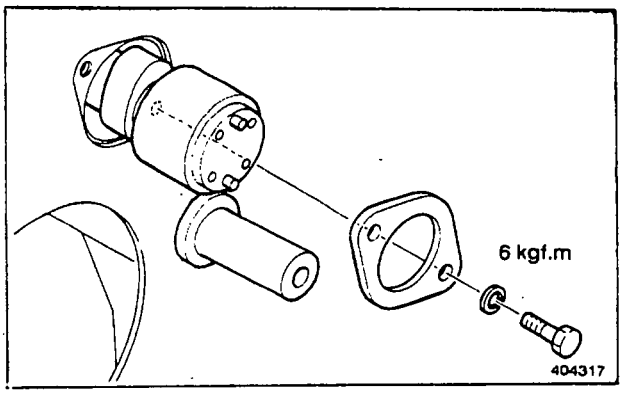
(4) Installing the camshafts (left and right)

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

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

NOTE

Do not mix the two different camshafts when you reassemble the engine.

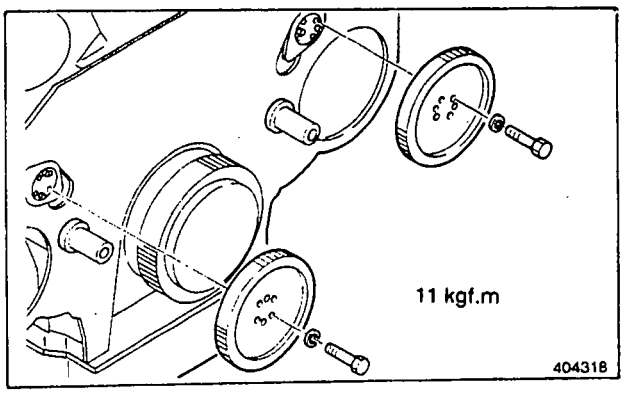


(5) Installing camshaft gears

(a) Install the camshaft gears to meet the dowel pin.

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

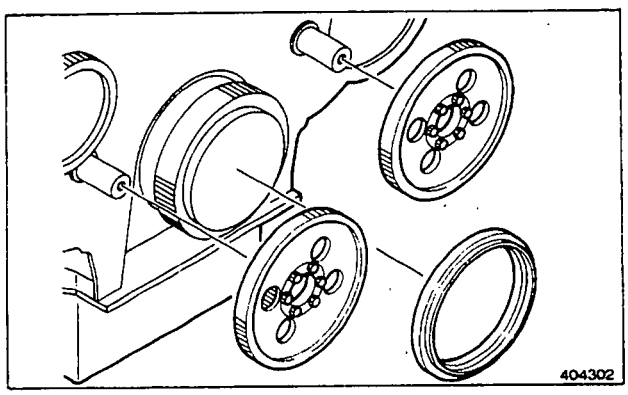
(c) After installing the camshaft gear, check that the gear rotates smoothly.



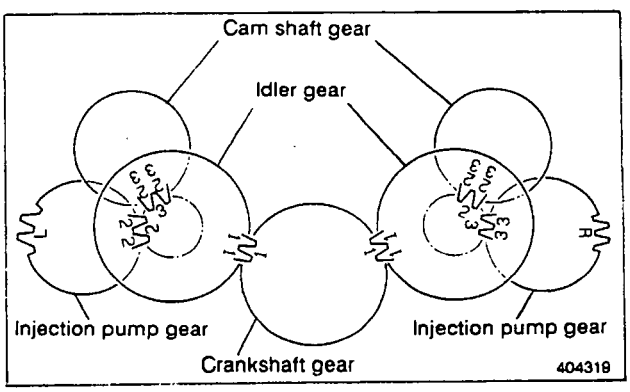
(6) Installing idler gears

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

(b) Insert the slinger to the crankshaft. (Refer to section 5.2, of this chapter.)



(c) Confirm that the matching marks of the timing gear coincide with the figure shown on the right.



Timing gear train

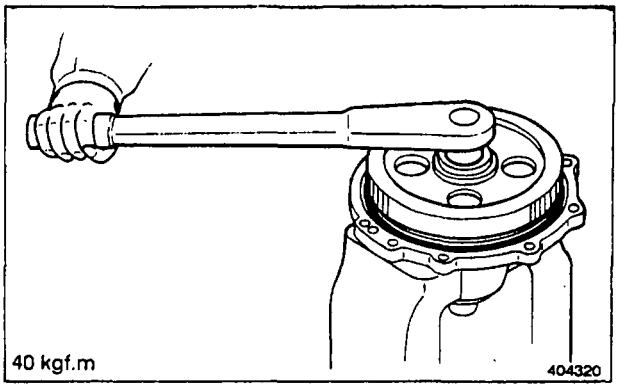
(7) Installing the injection pump drive

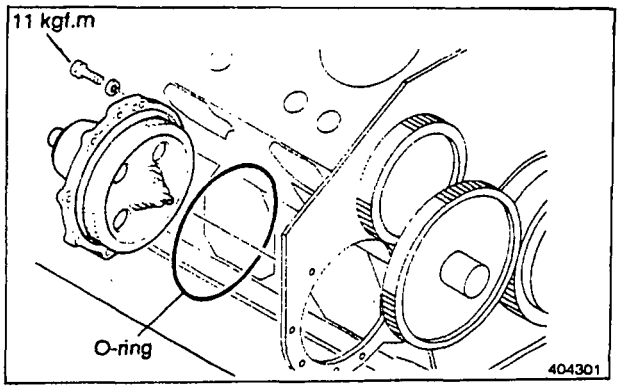
(a) Install the injection pump gear to the drive shaft, then tighten it to the specified torque.

(b) Fit the O-ring to the installation surface of the drive case.

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

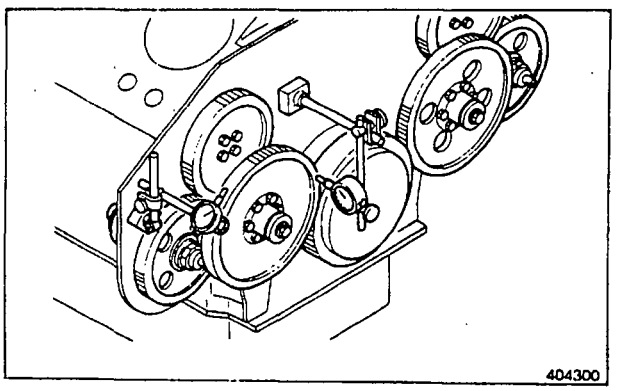
(d) Tighten the drive case mounting bolts to the specified torque.





(8) Inspecting and adjusting timing gears after installation

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



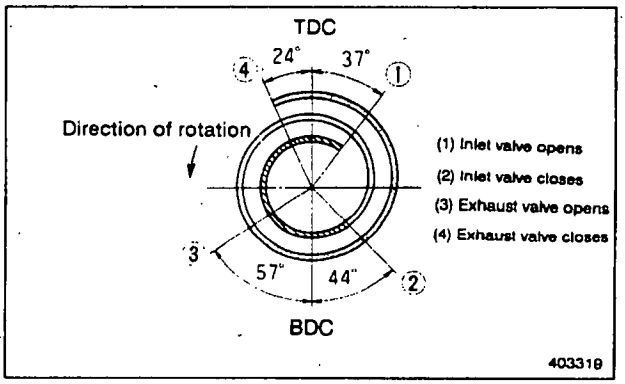
Inspecting Timing Gear Backlash and End Play

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

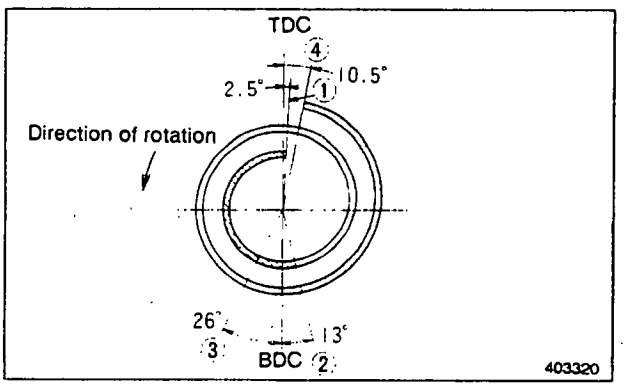
Inspecting Valve Timing

It is not necessary to inspect the valve timing, provided that all match marks on the timing gears are aligned. Inspect the timing for verification as explained here.

Using a 2 mm feeler gauge, add 2 mm clearance to the inlet and exhaust valves of the No. 1 cylinder. Then insert a 0.05 mm feeler gauge between to top of the bridge cap and rocker. Slowly turn the crankshaft to find the position where the feeler gauge is firmly gripped (the valve starts opening) and the position where the gauge is released (the valve starts closing). Check that these positions coincide with the angular positions shown in the valve timing diagram with 2 mm clearance added to the valves.



Valve timing diagram



(9) Installing the timing gear case

(a) 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.

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

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

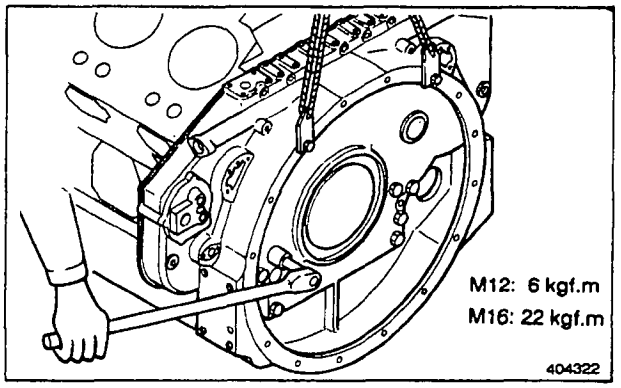
(d) Apply engine oil to the oil seal lip. Insert the oil seal into the timing gear case.

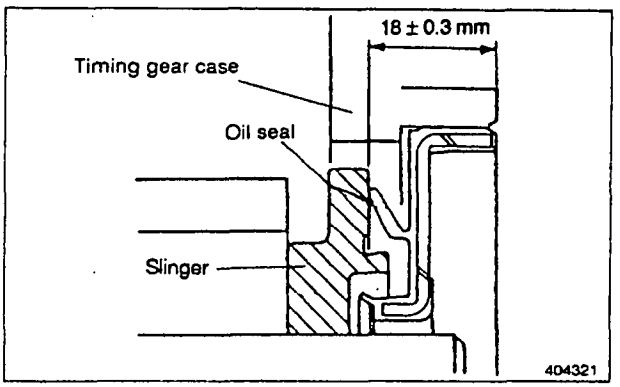
(e) Fit the oil seal to the slinger using the jig in the position shown in the figure (404321).

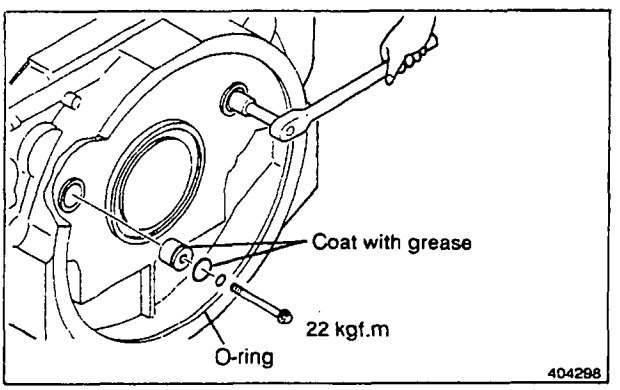
(10) Installing the idler shaft thrust collar

(a) Fit the O-ring to the thrust collar. Apply grease, then insert it in the timing gear case.

(b) Fit the O-ring to the thrust collar mounting bolts, then tighten to the specified torque.





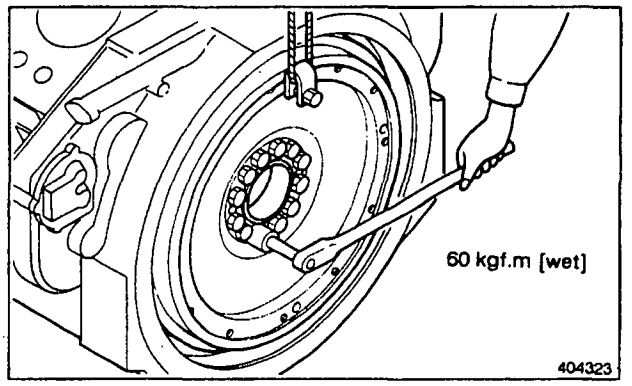


(11) Installing the flywheel

(a) Install the flywheel. Check that all dowel pins enter their holes.

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

(c) Inspect the face and radial runouts of the flywheel. (Refer to section 4.2 of this chapter.)



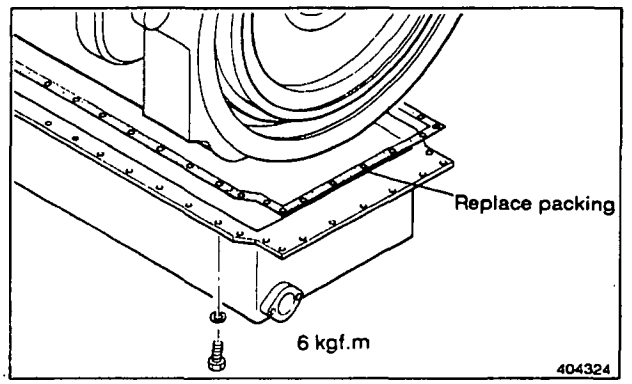
(12) Installing the oil pan

(a) Fit the O-ring to the oil passage of the oil pan mounting surface.

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

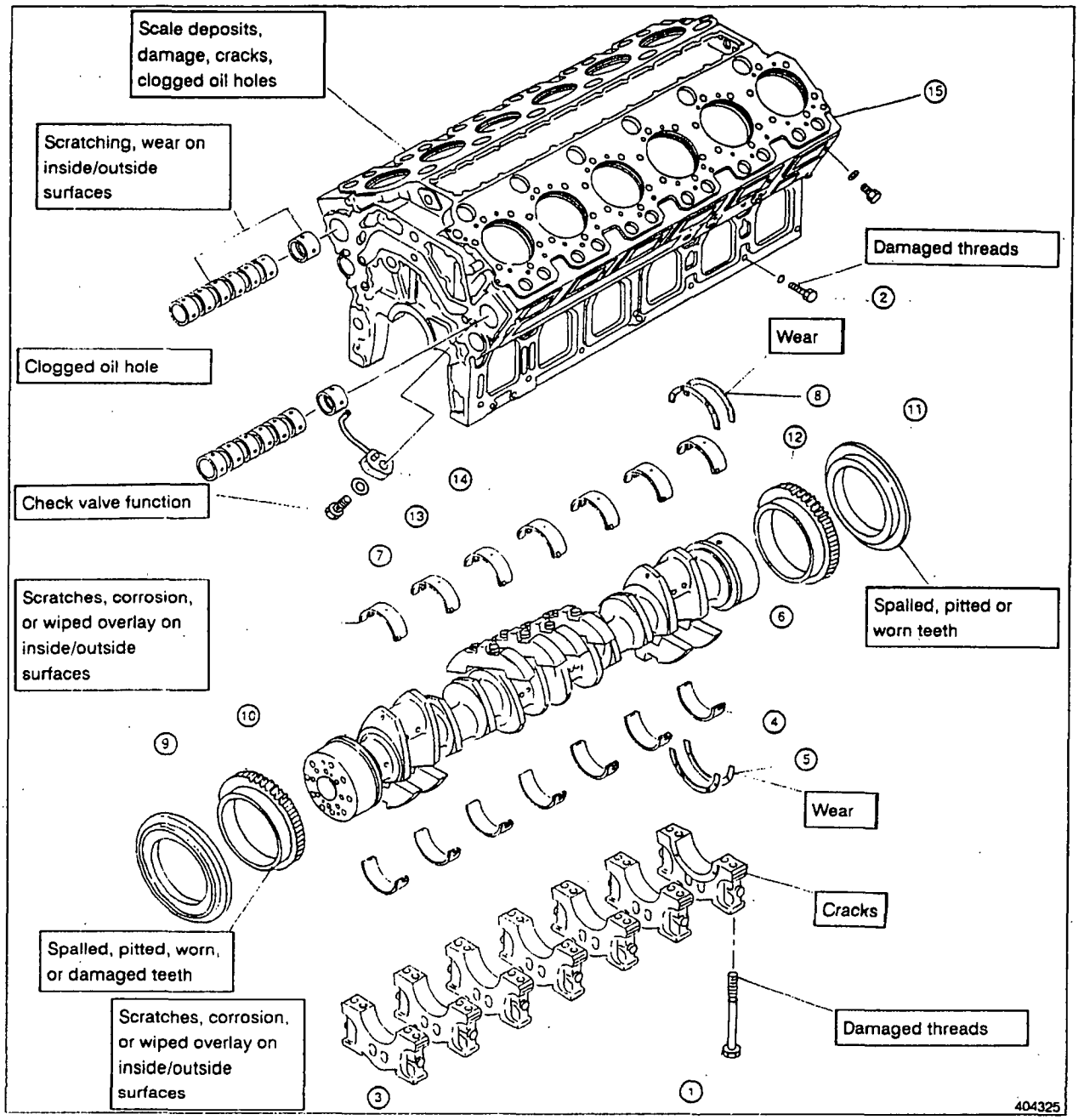
(c) Screw two guide bolts into the crankcase, then install the oil pan.

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



5. Crankcase, Crankshaft, and Main Bearings

5.1 Disassembly

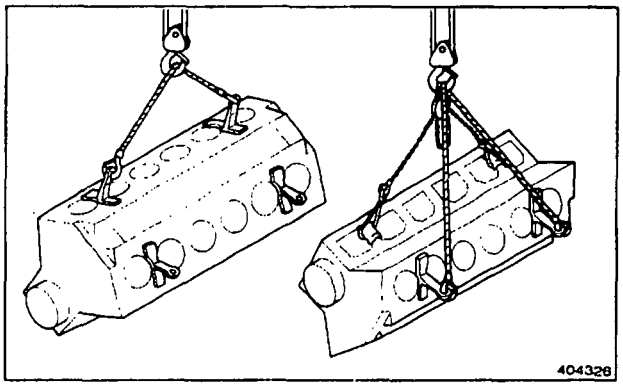


①	Main bearing cap bolt	⑥	Crankshaft	⑪	Slinger (rear)
②	Side bolt	⑦	Main bearing (upper)	⑫	Crankshaft gear (rear)
③	Main bearing cap	⑧	Thrust plate	⑬	Check valve
④	Main bearing (lower)	⑨	Slinger (front)	⑭	Piston cooling nozzle
⑤	Thrust plate	⑩	Crankshaft gear (front)	⑮	Crankcase

(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.

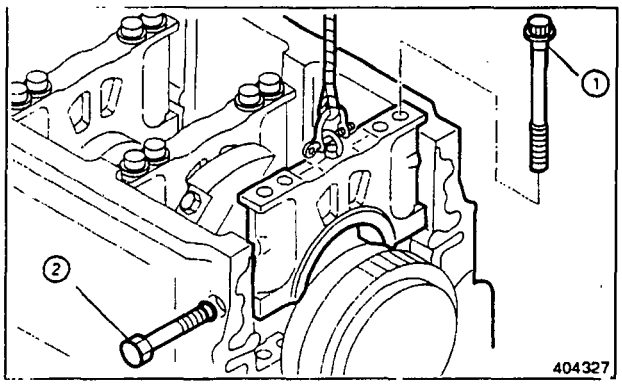
Crankcase and crankshaft weight: approx. 1800 kg



(2) Removing the main bearing caps

(a) Unscrew the cap bolts (1) and side bolts (2). Use a cap remover or a crane (eye bolt M12 x 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.

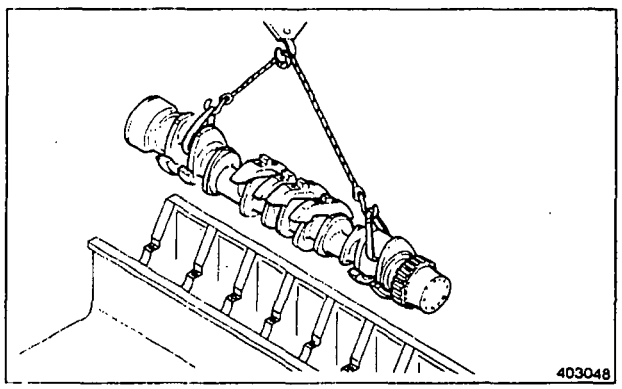


(3) Removing the crankshaft

(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.

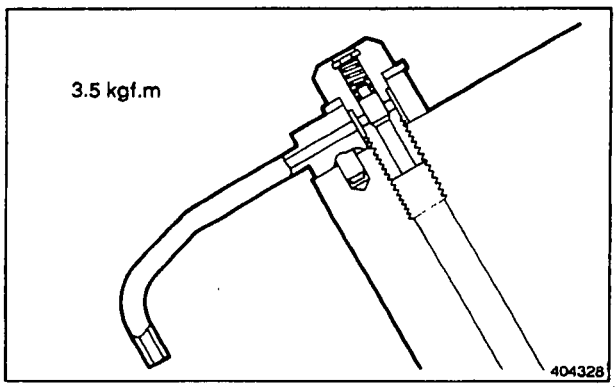


(4) Removing the piston cooling nozzles

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

NOTE

Tighten the piston cooling nozzle to the specified torque when reassembling.



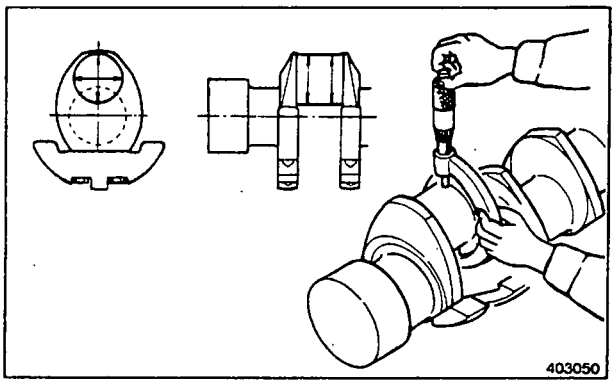
5.2 Inspecting and Repairing the Crankshaft

(1) Measuring crank pin and journal diameters.

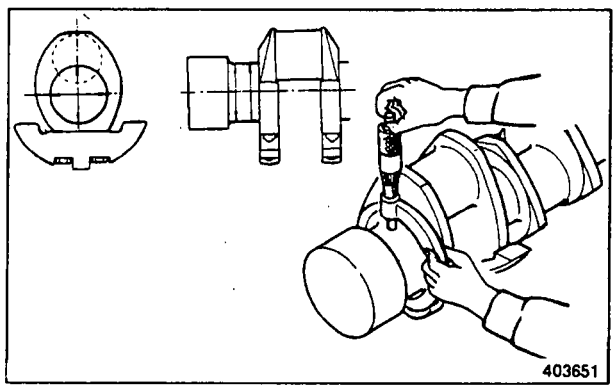
(a) Using a micrometer, measure the crank pin and journal diameters. If the diameter exceeds the repair limit, grind them to the next lower size: -0.25 mm, -0.5 mm, -0.75 mm, or -1.00 mm.

(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 crank pin diameter



Measuring crank journal diameter

Units: mm

Item			Nominal value	Assembly standard	Repair Limit
Crank pin dia.			ϕ125	-0.050 to -0.070	-0.110
Journal dia.			ϕ170	-0.060 to -0.080	-0.120
Pin journal	Out of roundness			Dia. difference 0.01 max.	0.03
	Taper			Dia. difference 0.02 max.	0.03
	Fillet radius	Pin	7	7.0 -0.2	
		Journal	8.5	8.5 -0.2	
	Hardness			Hv >590	

Grinding dimensions for an undersize crankshaft

Units: mm

	Undersize	Finishing Dimension	Out of Roundness	Taper
Crankpin dia.	0.25	124.68-124.70	Dia. difference 0.01 max.	Dia. difference 0.02 max.
	0.50	124.43-124.45		
	0.75	124.18-124.20		
	1.00	123.93-123.95		
Journal dia.	0.25	169.67-169.69	Dia. difference 0.01 max.	Dia. difference 0.02 max.
	0.50	169.42-169.44		
	0.75	169.17-169.19		
	1.00	168.92-168.94		

(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 590 (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 $\phi^{0.85}$.

(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.

(a) 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

+0.50 mm

+0.75 mm

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.

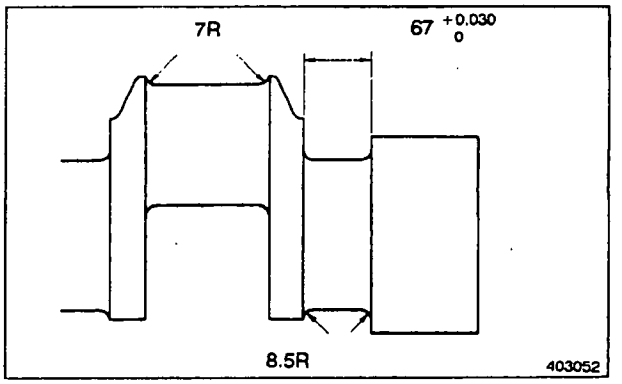
Unit: mm

Item	Standard Clearance	Repair Limit
Crankshaft end play	0.20-0.40	0.50

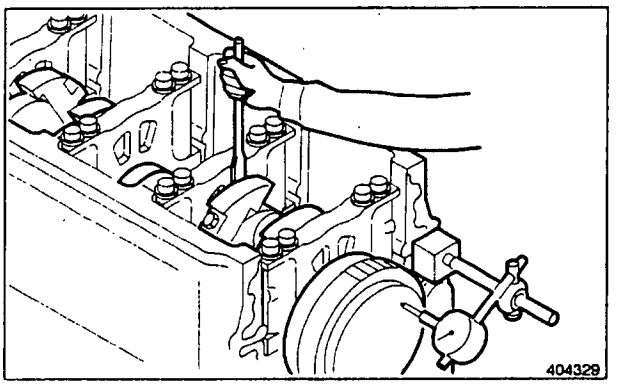
Crankshaft Journal Grinding Dimensions for Oversize Thrust Plates

Unit: mm

Item	Oversizes for Journal or Thrust Plates	Oversizes for Journal and Thrust Plates	Tolerance
+0.25 O.S	67.25	67.50	+0.03 0
+0.50 O.S	67.50	68.00	
+0.75 O.S	67.75	68.50	



Measuring thrust bearing journal length



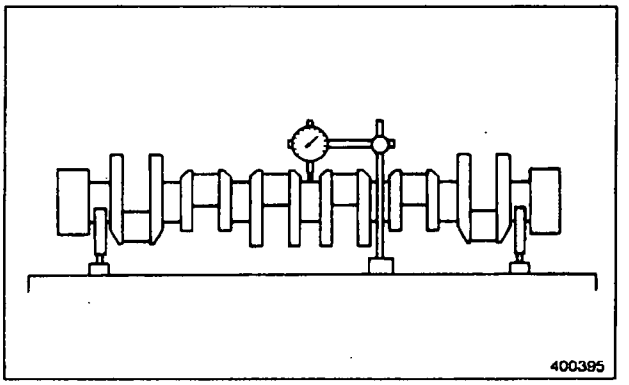
Measuring crankshaft end play

(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

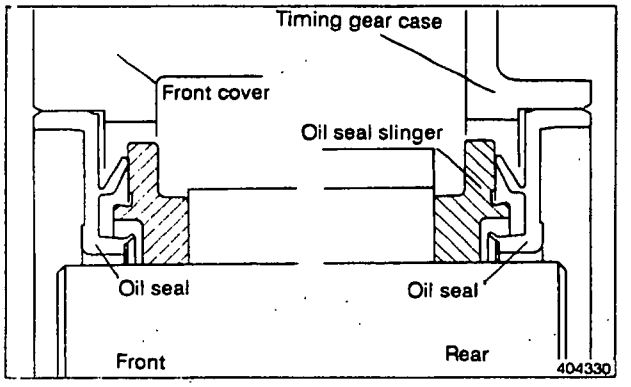
Item	Assembly Standard	Repair Limit
Crankshaft runout	0.04 max.	0.10



Measuring crankshaft runout

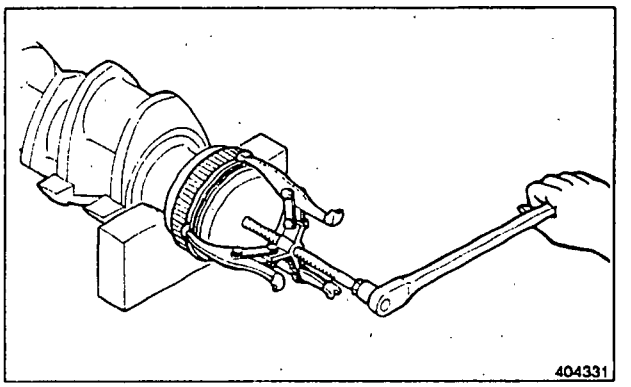
(5) Replacing the oil seal slinger

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



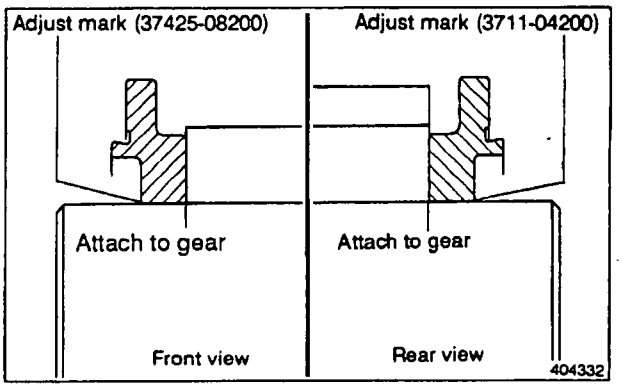
Removing the Slinger

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



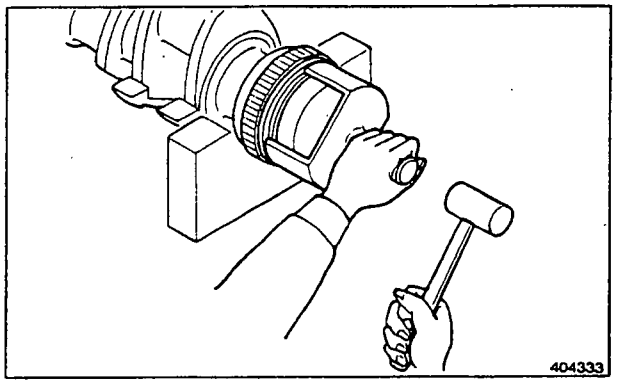
Slinger Installation

(a) Identify the front slinger and the rear slinger.



(b) Use a slinger installer to install the slinger heated above 110° to the crankshaft until it touches the gear.

If the slinger has stopped before it touches the gear, tap the center or shoulder of the installer with a copper hammer.



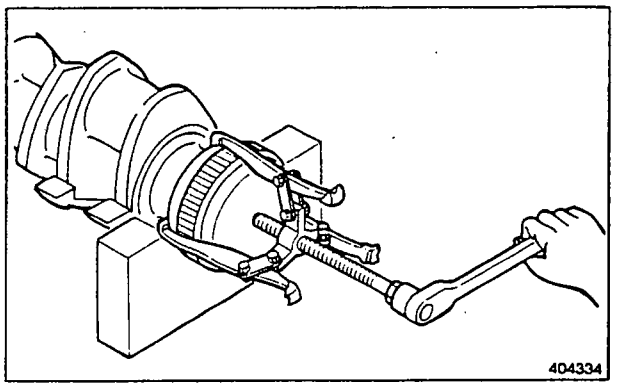
(6) Replacing the crankshaft gear

Removing the Gear

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 within the specified value

Front side:	0.106-0.171 mm
Rear side:	0.274-0.358

(b) Heat the gear to the range 180°-200°C

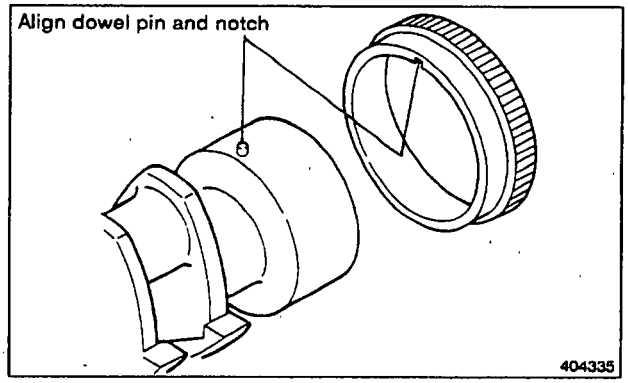
(c) Drive the rear crankshaft gear onto the crankshaft by tapping the end face of the gear lightly with a copper hammer. Be sure the crankshaft dowel pin enters the notch in the gear.

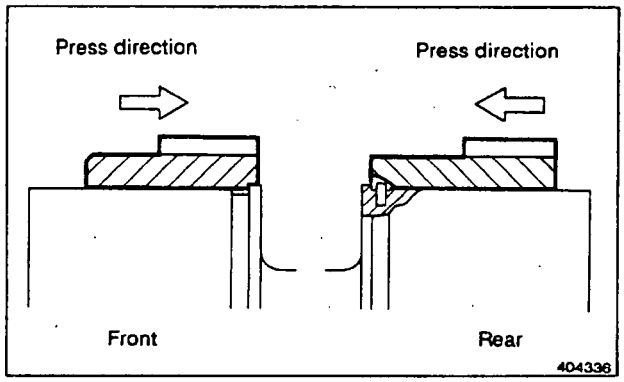
NOTE

(a) The front crankshaft gear has no notch for alignment, so it can be driven on to the crankshaft at any position.

(b) Install the gear to the crankshaft until it touches the collar.

(c) Do not mistake the direction of gear installation.

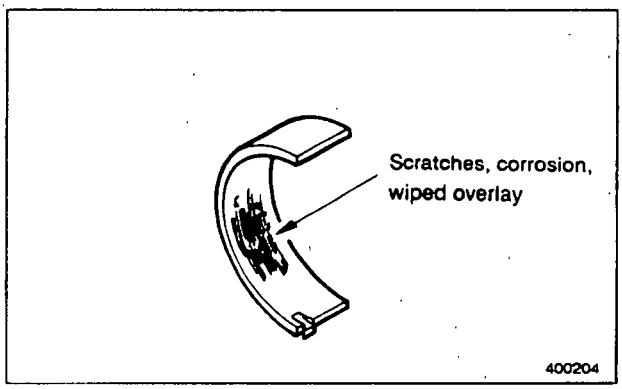




Main Bearing

(1) Inspection

Inspect each bearing 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 bearing cap.

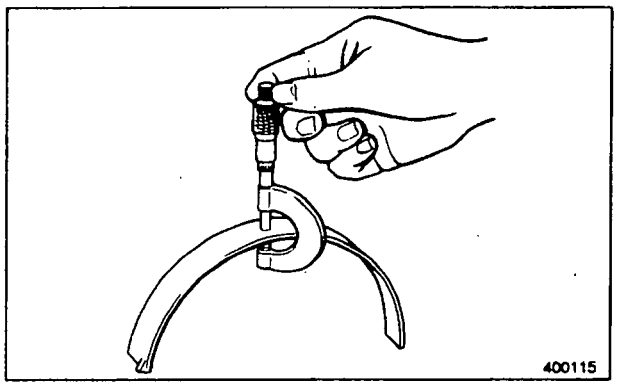


(2) Measuring bearing thickness

Use a ball point micrometer to measure the center of each bearing 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.

Units: mm

Item		Nominal Value	Assembly Standard	Service Limit
Main bearing thickness (center)	STD	4.5	4.467-4.480	4.425
	-0.25	4.625	4.592-4.605	4.550
	-0.50	4.75	4.717-4.730	4.675
	-0.75	4.875	4.842-4.855	4.800
	-1.00	5.000	4.967-4.980	4.925



Measuring main bearing thickness

(3) Replacing main bearings

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

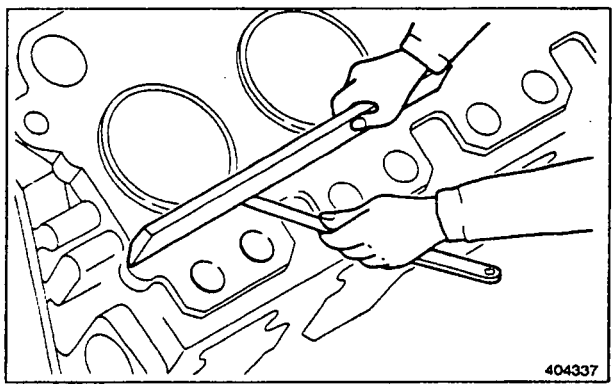
Crankcase

(1) Measuring gasketed surface warp

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

Item	Assembly Standard	Repair Limit
Crankcase gasketed surface warpage	0.1 max.	0.20



Measuring crankcase gasketed surfaces

NOTE

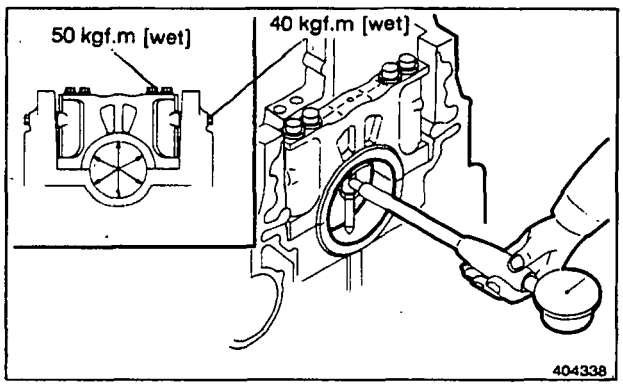
Do not grind the crankcase more than necessary to remove warpage. Excessive grinding can cause the piston protrusion to exceed assembly standard. (Refer to (4) for section 2.2, "Pistons" in this chapter.)

(2) Measuring main bearing bore diameter

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

Unit: mm

Item	Nominal Value	Assembly Standard	Service Limit
Main bearing bore dia.	ϕ179	179.000-179.025	179.045



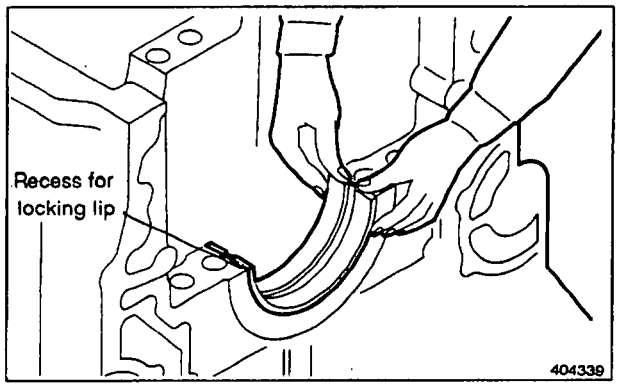
Measuring main bearing bore diameter

5.3 Reassembly

Reassembly is the reverse procedure of disassembly.

(1) Installing the main bearing

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

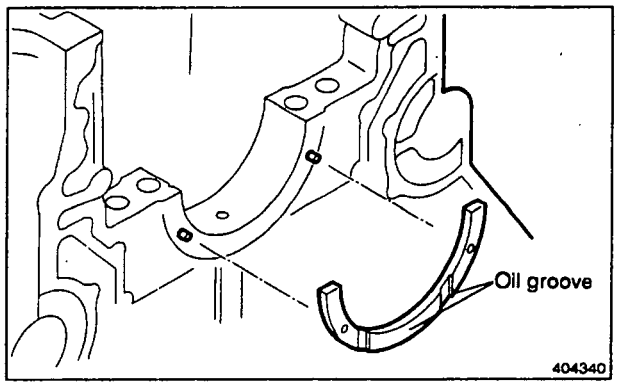


(b) Lightly coat the inside surface of the shells with engine oil.

(2) Installing thrust plates

(a) Install the thrust plates to the No. 7 bearing 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.

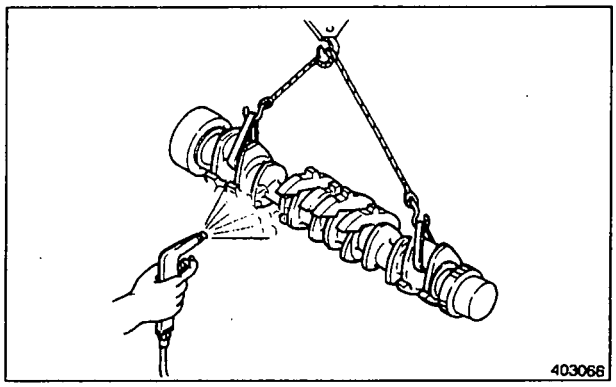


(3) Installing the crankshaft

(a) Wash the crank shaft 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 bearing caps

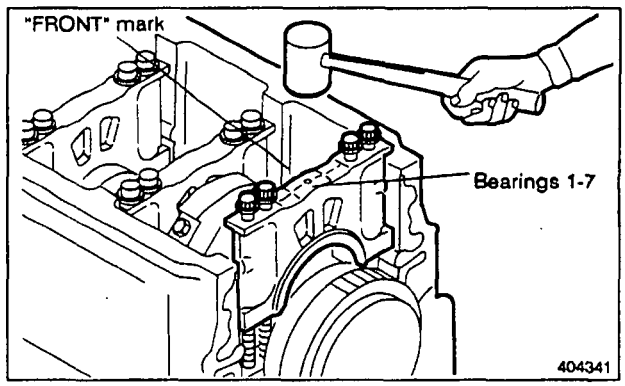
(a) Fit the lower shell of the bearing to each bearing cap.

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

(c) From the front side of the crankcase, bearings 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 bearing cap bolts with engine oil, then temporarily install the bolts.

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

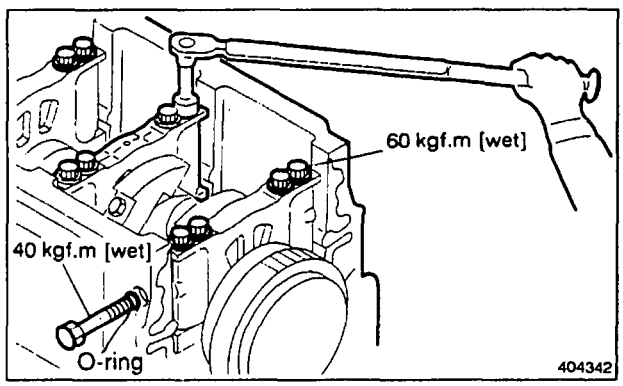


(5) Installing bearing cap bolts

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

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

(c) Make sure that the crankshaft rotates smoothly.

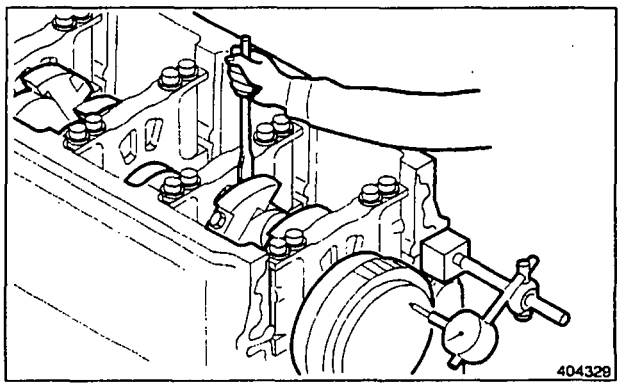


*(6) Measuring crankshaft end play

(a) Tighten No. 1 through No. 6 bearing cap bolts, mounting bolts, and side 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.

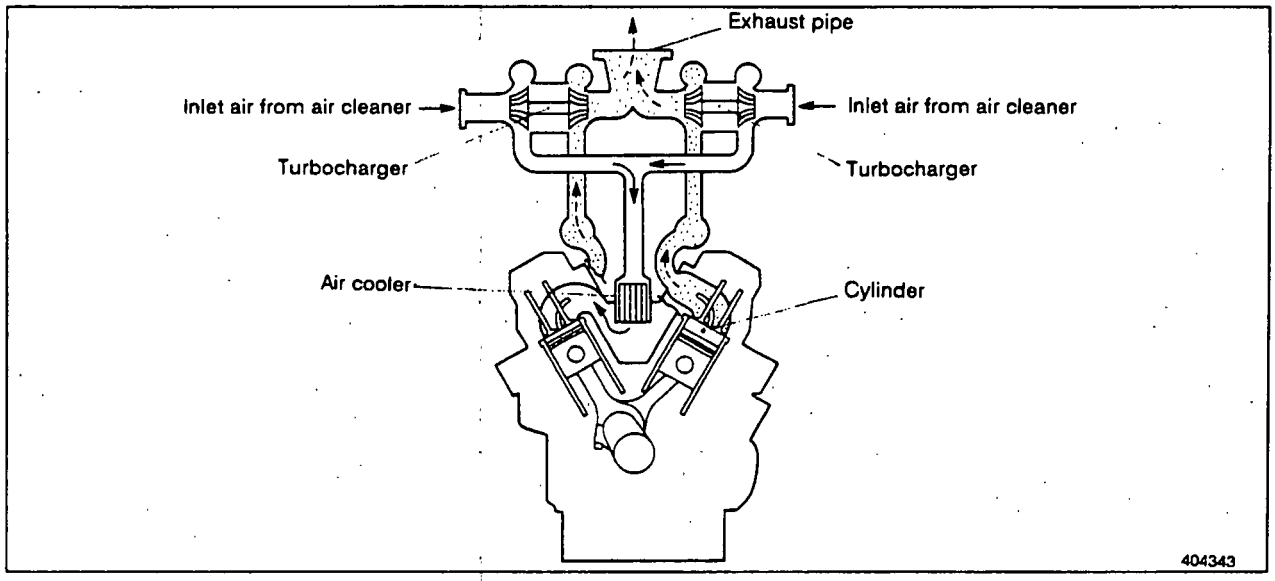
(c) Confirm that all cap bolts and side bolts are tightened to the specified torque. (Refer to section 4.2 of this chapter.)



8. INLET AND EXHAUST SYSTEMS

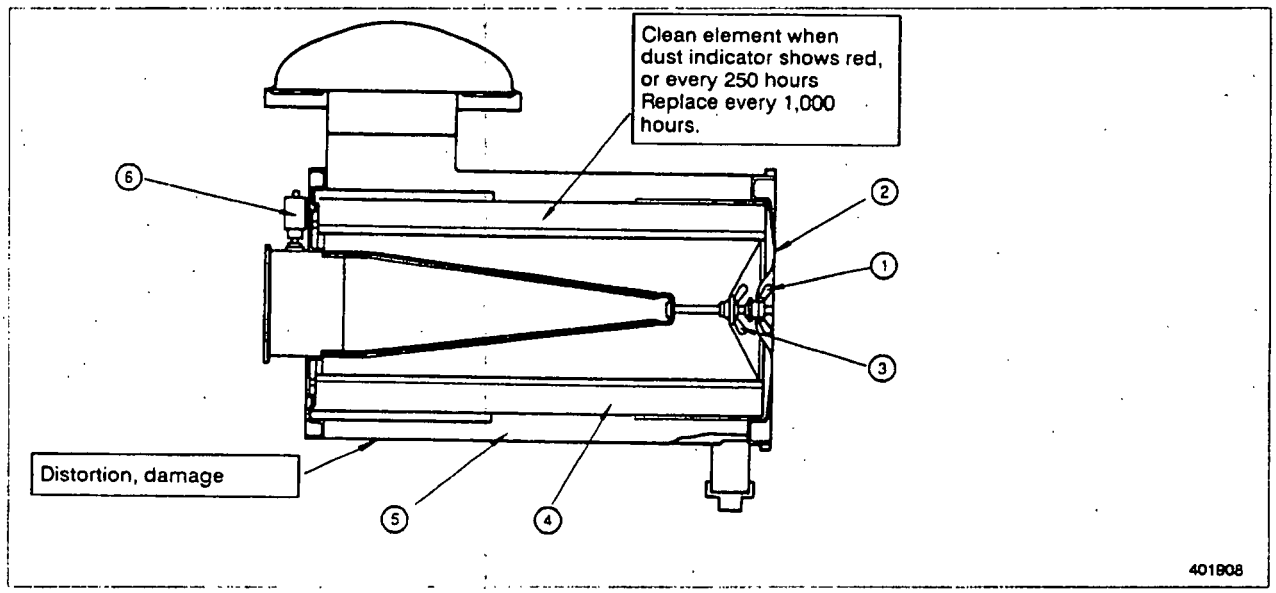
8. INLET AND EXHAUST SYSTEMS

1. Description



2. Air cleaners

Disassembly and Inspection



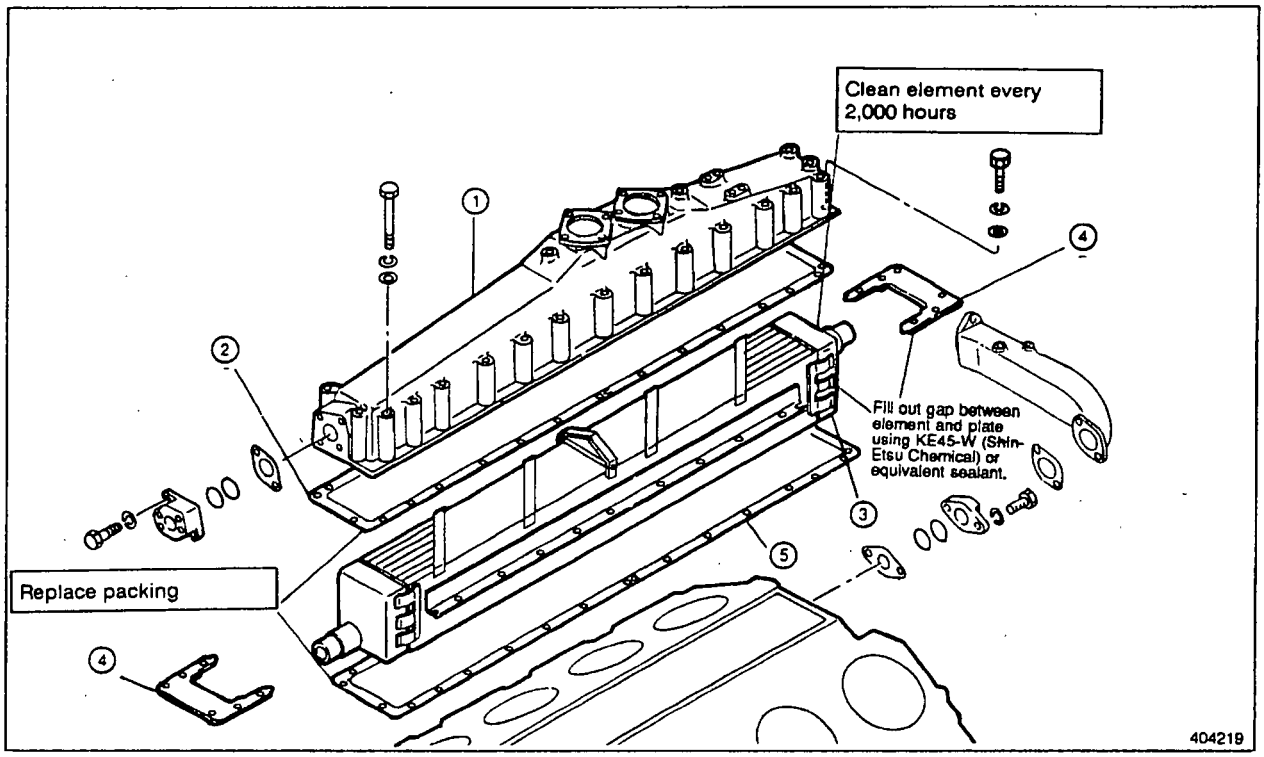
①	Wing nut	③	Wing nut	⑤	Air cleaner body
②	Cover	④	Element	⑥	Dust indicator

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



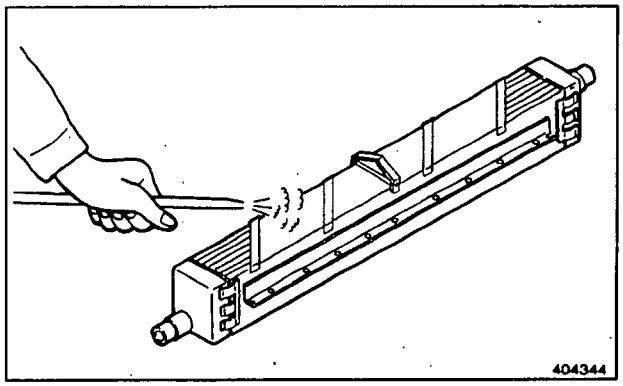
① Air cooler case
② Packing
③ Element
④ Plate
⑤ Packing

3.2 Inspection

(1) Cleaning air coolers

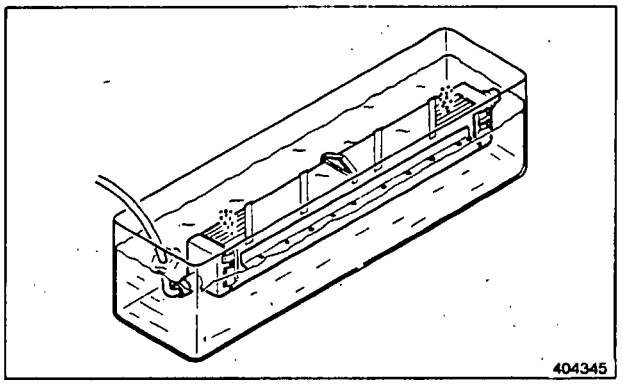
(a) Remove dirt built up from the air cooler by directing high pressure air of 3 to 5 kgf/cm^2 (maximum) in the direction opposite to air flow. Inspect the cooler for corrosion and cracks.

(b) Wash the fresh water or salt water pipes in water and caustic soda or soda lime, then remove scale deposits by inserting a 3 mm (1/8 in.) bar into each pipe.



(2) Inspecting air coolers for air tightness

Immerse the air cooler in water, then apply high pressure air of 4 kgf/cm^2 to the coolant side to inspect for air leaks.

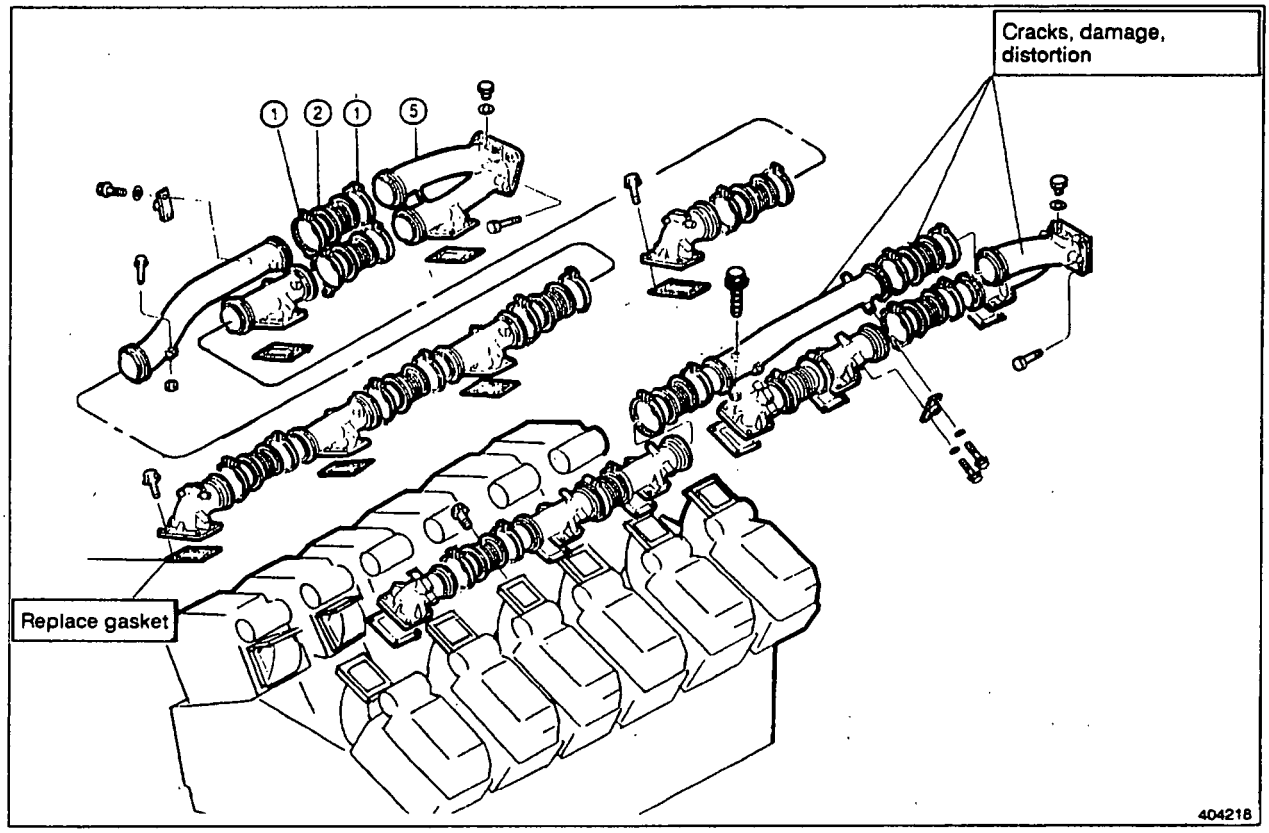


CAUTION!

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 Coupling
② Flexible joint
③ Exhaust manifold
④ Gasket

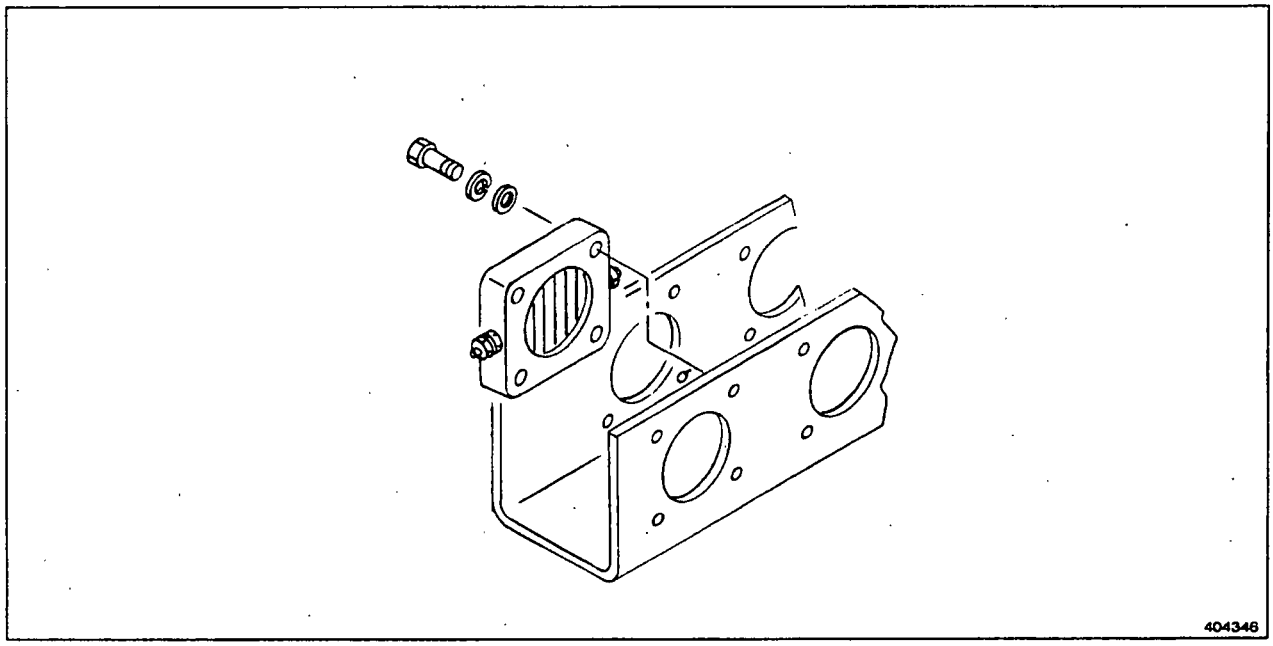
NOTE

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

(b) If any of the gaskets requires replacement, replace all the gaskets together.

5. Air Heater

5.1 Disassembly



1 Air heater assembly

5.2 Inspection

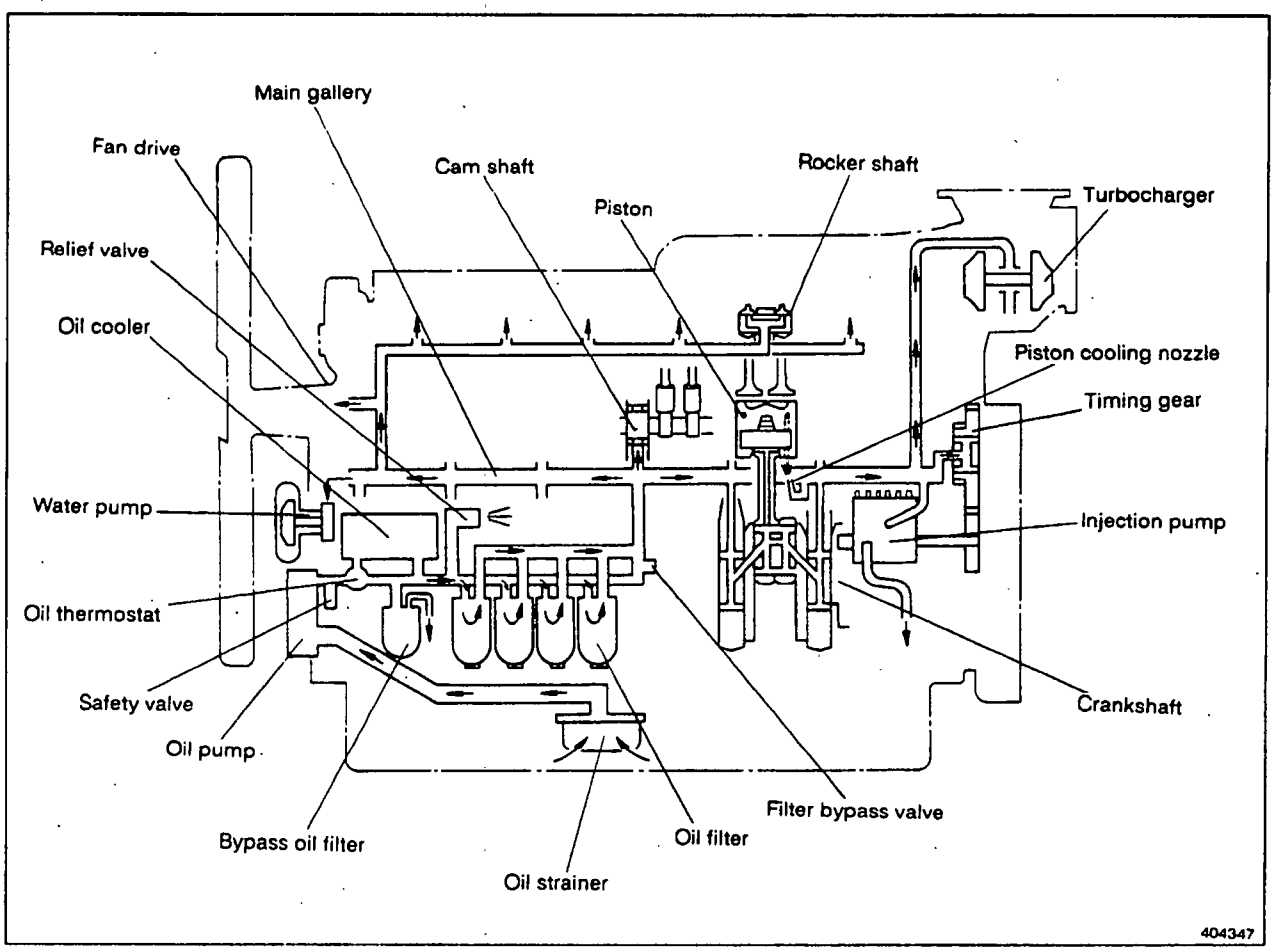
(a) When the starter switch is set to "HEAT", use a galvanometer or an inspection lamp to check that electricity is flowing through the indicator, the relay switch, and air heater.

(b) Confirm that it takes 40-5- 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.

9. LUBRICATION SYSTEM

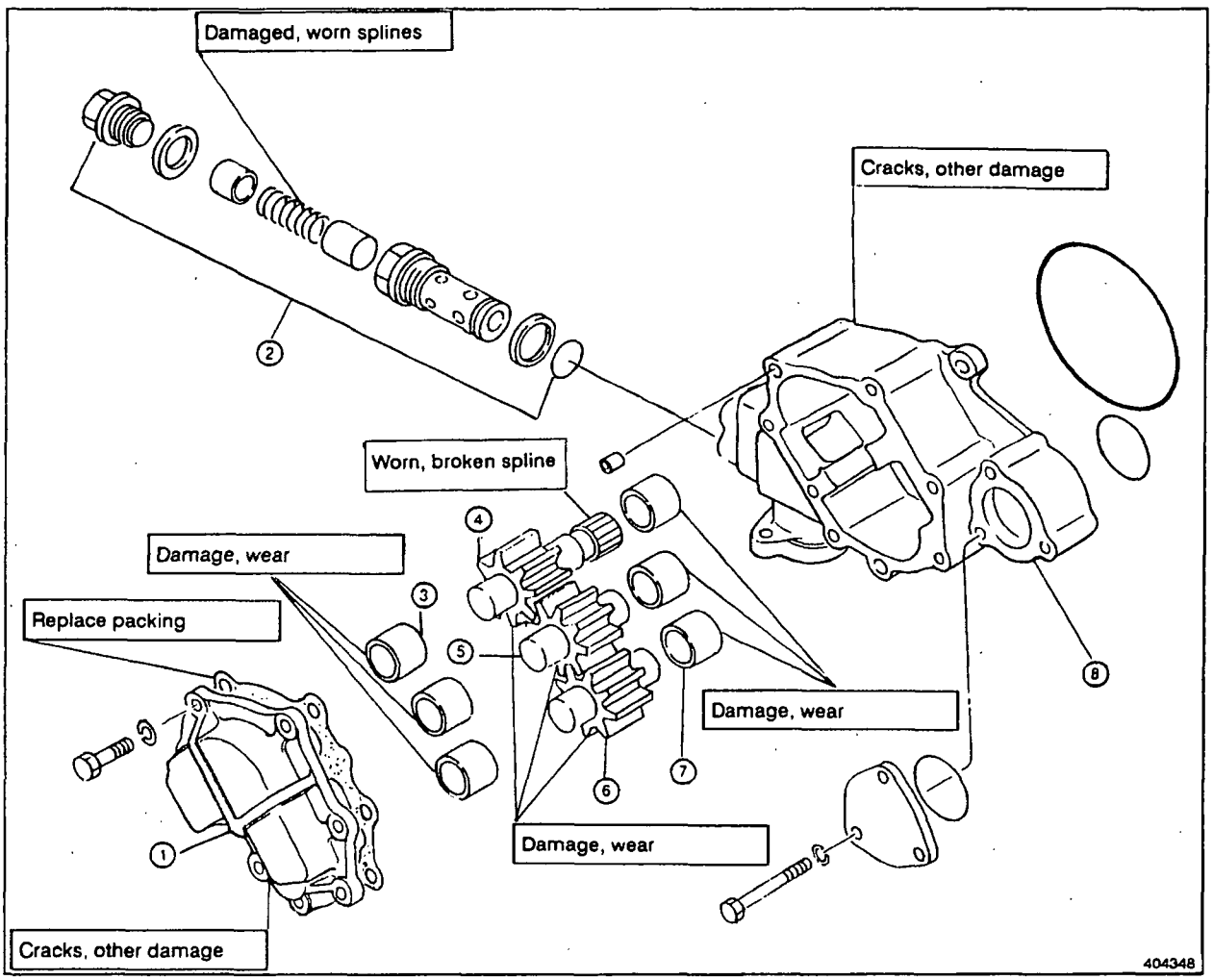
9. LUBRICATION SYSTEM

1. Description



2. Oil Pump and Safety Valve

2.1 Disassembly



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

2.2 Inspection

(1) Measuring drive gear and driven gear backlash

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

Unit: mm

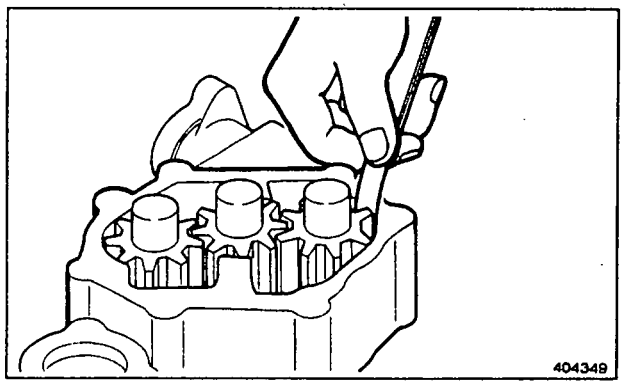
Item	Standard Clearance	Service Limit
Drive gear and driven gear backlash	0.10-0.20	0.4

(2) Measuring pump gear tip clearance

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

Unit: mm

Item	Nominal Value	Standard Clearance	Service Limit
Drive gear and driven gear clearance	ϕ60	0.200-0.296	Tip clearance: 0.35



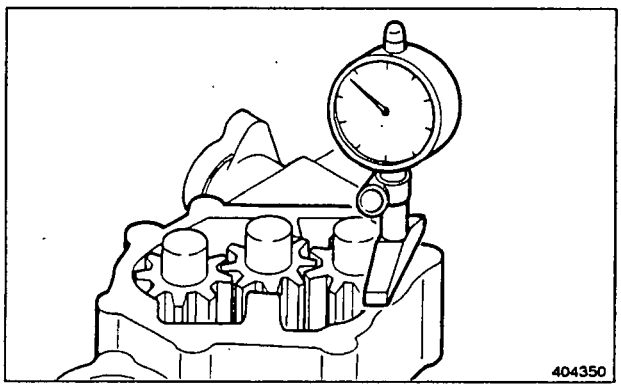
Measuring drive gear tip clearance

(3) Measuring pump gear end clearance

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

Unit: mm

Item	Nominal Value	Standard Clearance	Service Limit
Pump gear end clearance	72.5	0.040-0.116	0.21



Measuring drive gear end clearance

NOTE

Remove the cover mounting packing (0.04 mm thick) when you measure.

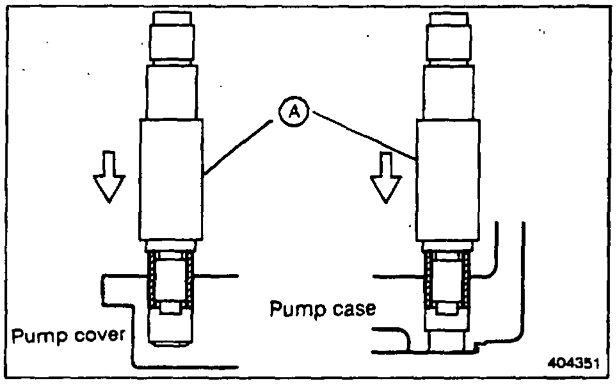
(4) Measuring drive and driven gear shaft and bushing diameters

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

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

Unit: mm

Item	Nominal Value	Assembly Standard	Service Limit
Shaft diameter	ϕ30	29.947-29.960	29.920
Bushing inside diameter	ϕ30	30.000-30.021	30.055

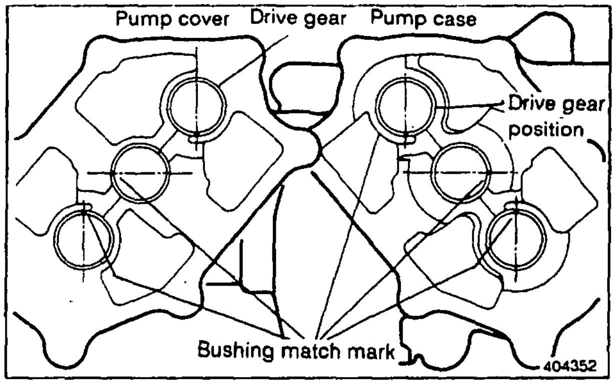


Oil pump bushing match mark positions

(5) Replacing oil pump bushings

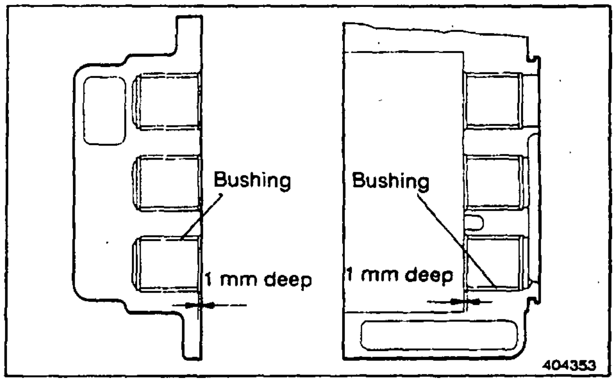
(a) Remove the oil pump bushing as needed. If the oil pump busing insertion is too tight to remove it, replace it with the case or cover assembly.

(b) When you install the pump cover bushing, take the bushing joint position as shown in the right figure. (Do not align with the lubrication oil groove.



(c) Using the oil pump bushing installer, insert the bushing to the position shown in the right figure.

(d) After you press a new bushing into position, finish its inside diameter to $30H7^{+0.021}_{0}$ ᴡᴡ.

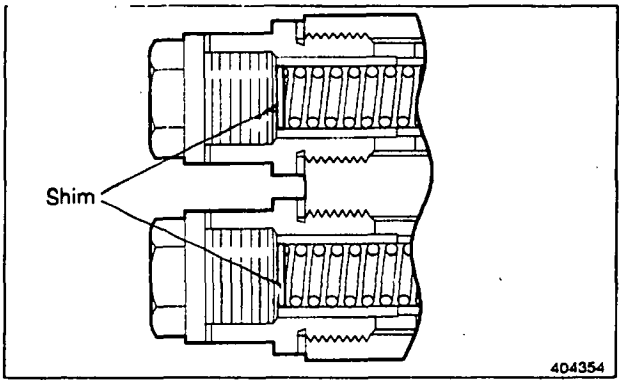


Installing oil pump bushing

(6) Inspecting the safety valve

(a) Check the valve spring of the oil pump safety valve for deterioration. If excessive deterioration or wear is found, replace the valve spring.

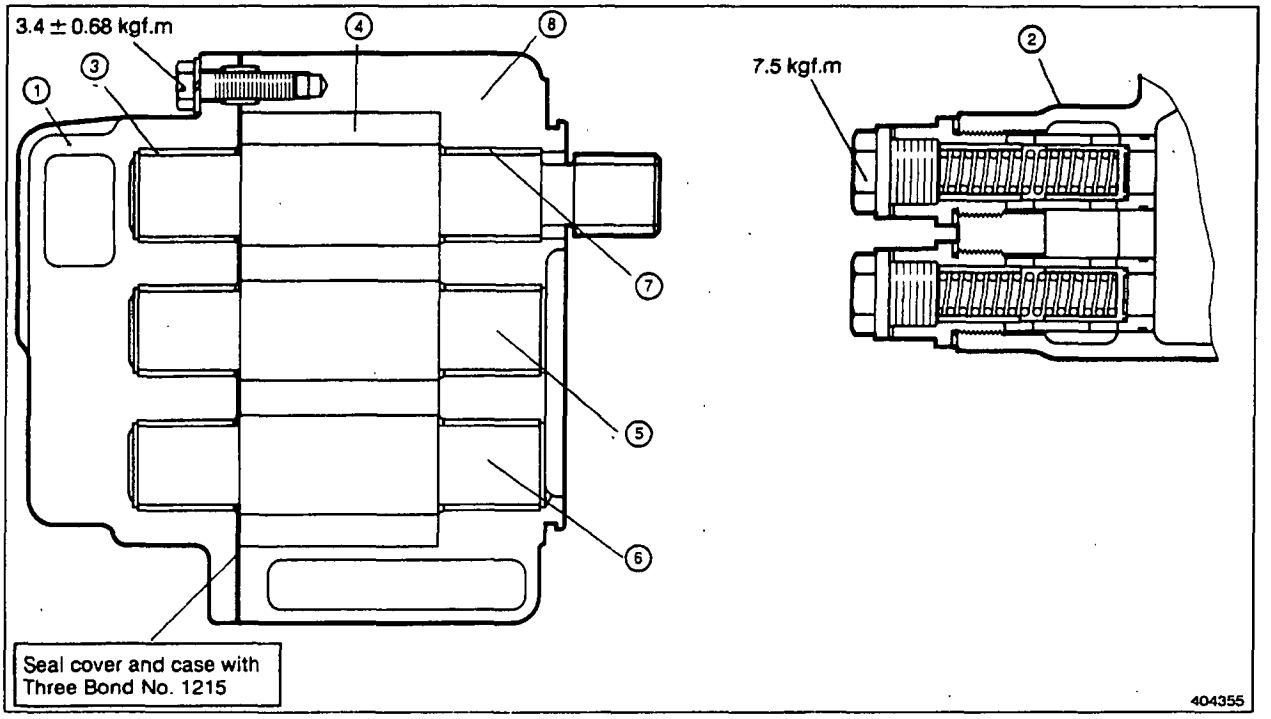
(b) Measure the valve opening pressure. If the pressure is higher or lower than the assembly standard, increase or decrease the thickness of the shim inserted between the spring and spring cap nut. The thickness of the shim will vary 1 mm for every 1 kgf/cm^2



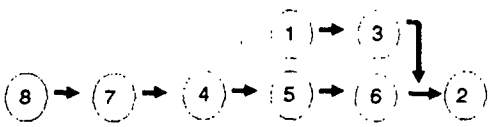
Unit: mm

Item	Assembly Standard	Service Limit
Safety valve opening pressure (kgf/cm^2)	12	
Safety valve spring length under test force /test force (mm/kgf)	66.4/34.8	66.4/30.0

2.3 Reassembly



Reassembly Order

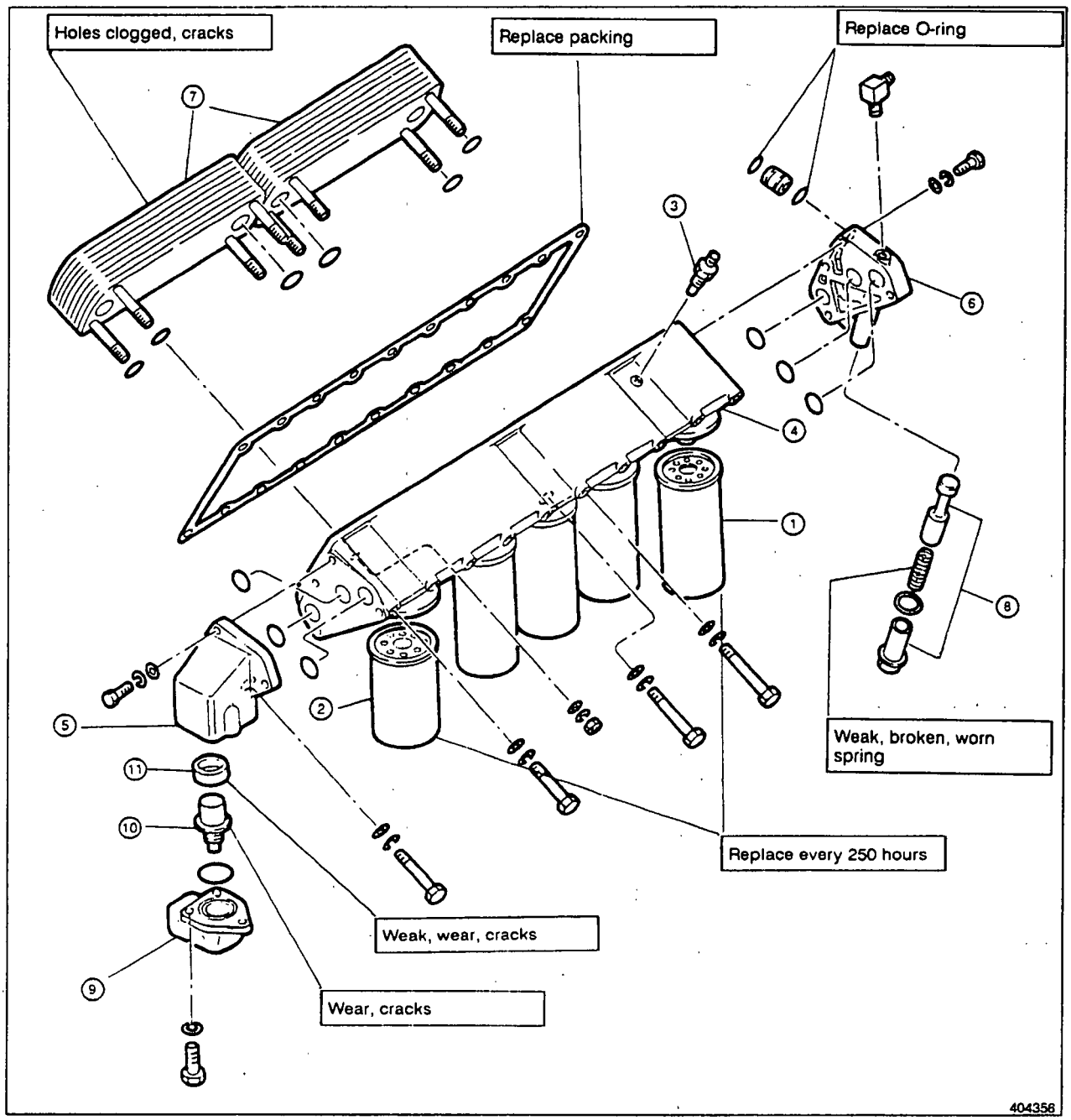


NOTE

Coat the pump parts with oil before installation.

3. Oil Filter Assembly

3.1 Disassembly

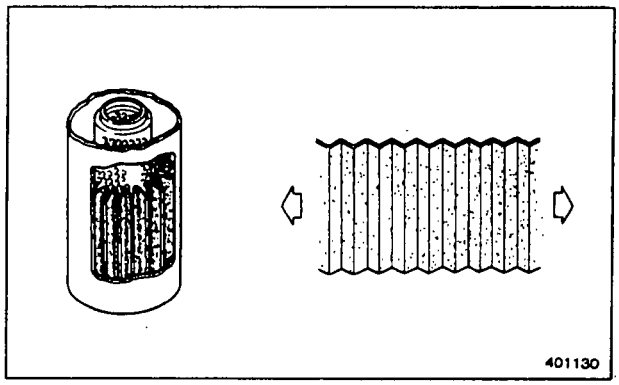


① Full flow oil filter element
② Bypass oil filter element
③ Oil filter alarm
④ Filter bracket assy.
⑤ Adaptor A assy.
⑥ Adaptor B assy.
⑦ Air cooler element
⑧ Relief valve assy.
⑨ Connector
⑩ Oil thermostat
⑪ Thermostat seal

3.2 Inspection

(1) Inspecting the oil filter

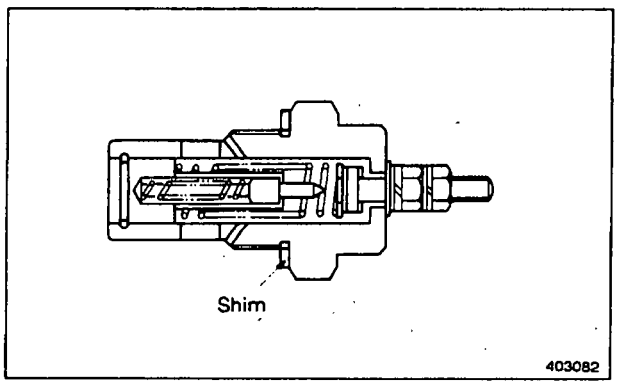
When you replace the paper element, sample about 500 cm^3 of oil and check for metal particles. If any metal particles are found, unfold the pleats of the element and check the color and shape of the particles trapped in the pleats to identify the cause.



(2) Inspecting the oil filter alarm

(a) Use a tester to check the alarm for insulation and continuity. If the alarm is found defective, disassemble and repair it. Replace the alarm if the bakelite or rubber insulators are deteriorated or damaged.

(b) If the valve opening pressure is not within the assembly standard, adjust it by inserting shims. For the thickness of a shim, 1 mm corresponds to a change in pressure of 0.07 kgf/cm^2.



Unit: kgf/cm^2

Item	Assembly Standard
Pressure difference across oil filter alarm that makes its valve open	2.3-2.7
Pressure difference across oil filter alarm that makes its contacts close	1.5-1.8

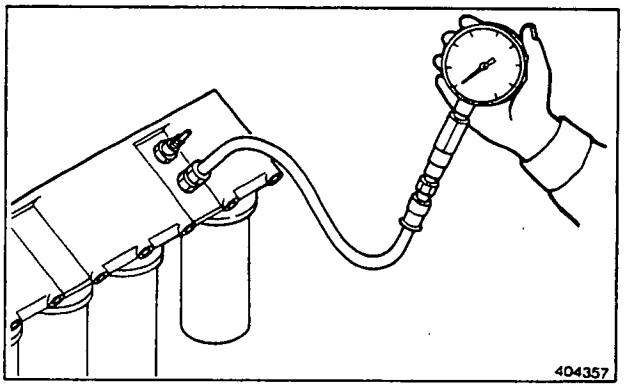
(3) Measuring relief valve pressure

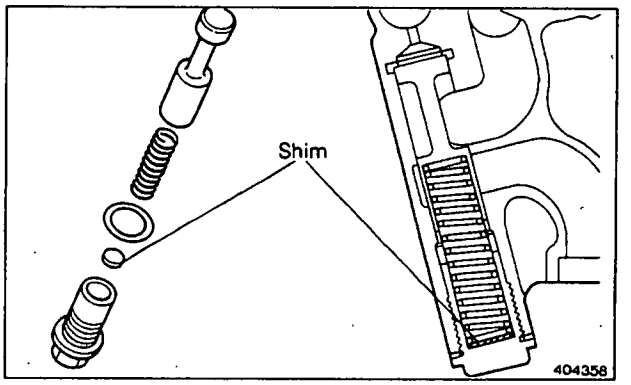
(a) Remove the taper plug (PT 1/8) on the upper side of the filter bracket, and attach a pressure gauge.

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

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

(d) If the measured oil pressure is lower than the specified value, adjust the valve opening pressure by inserting shims. For shim thickness, 5 mm corresponds to a change in pressure of approximately 1 kg/m^2.





Unit: kgf/cm^2

Item	Assembly Standard
Set pressure (max. speed)	5-6.5
Relief valve opening pressure	4.7

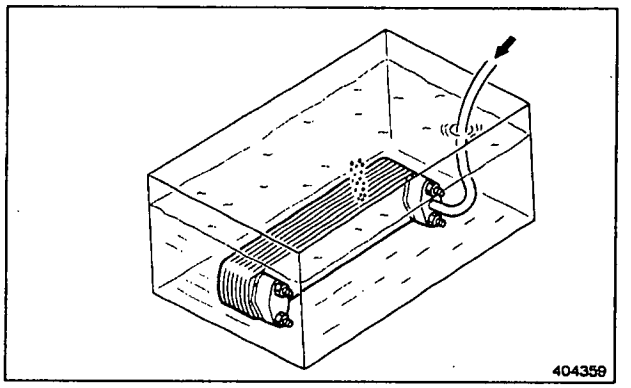
NOTE

The measured oil pressure might be above the set pressure when oil temperature is low, but it returns to the set pressure when oil temperature rises.

(e) If adjustment with shims is not effective, replace the relief valve and spring.

(4) Inspecting the left side oil cooler

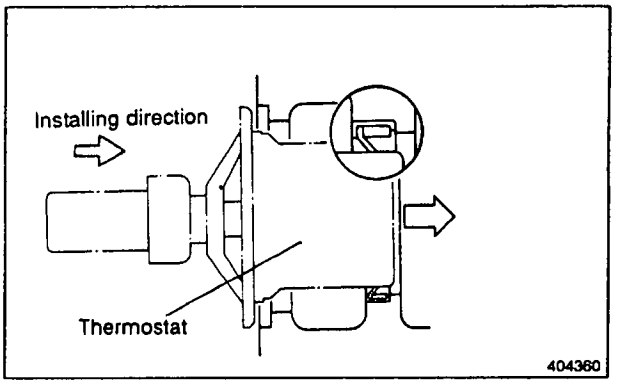
Test the oil path with compressed air (15 kgf/cm^2) for damage or cracks in the element. If there is any leakage, replace the element.



(5) Inspecting the left side thermostat

(a) Inspect the oil thermostat seal for weakness and cracks. If any are found, replace the seal.

(b) Refer to the figure on the right that shows the correct direction for seal installation.

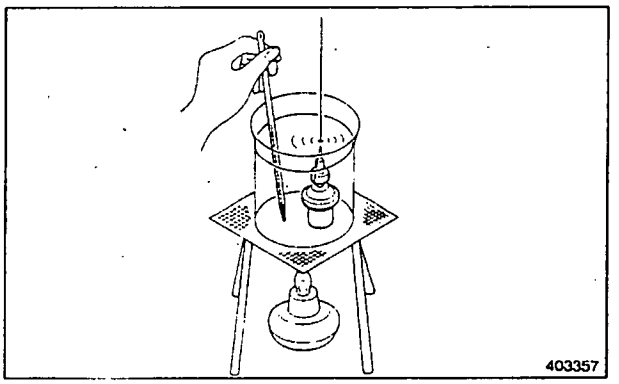


Installing seal for thermostat

(c) Operation testing

Immerse the thermostat in engine oil, then measure the temperature where the valve opens, then measure it again when the valve lift is 11 mm. Replace the thermostat if temperatures are not within standard.

Item	Assembly Standard
Temperature for valve opening	93 ± 2°C
Temperature for 11 mm valve lift	105°C



NOTE

(a) Stir the oil in the beaker with a stick to maintain an even temperature during the test.

(b) At reassembly, be sure to place the thermostat in the correct position by ascertaining the valve opening temperature stamped on its mounting flange.

3.3 Reassembly

Reassembly is the reverse procedure of disassembly.

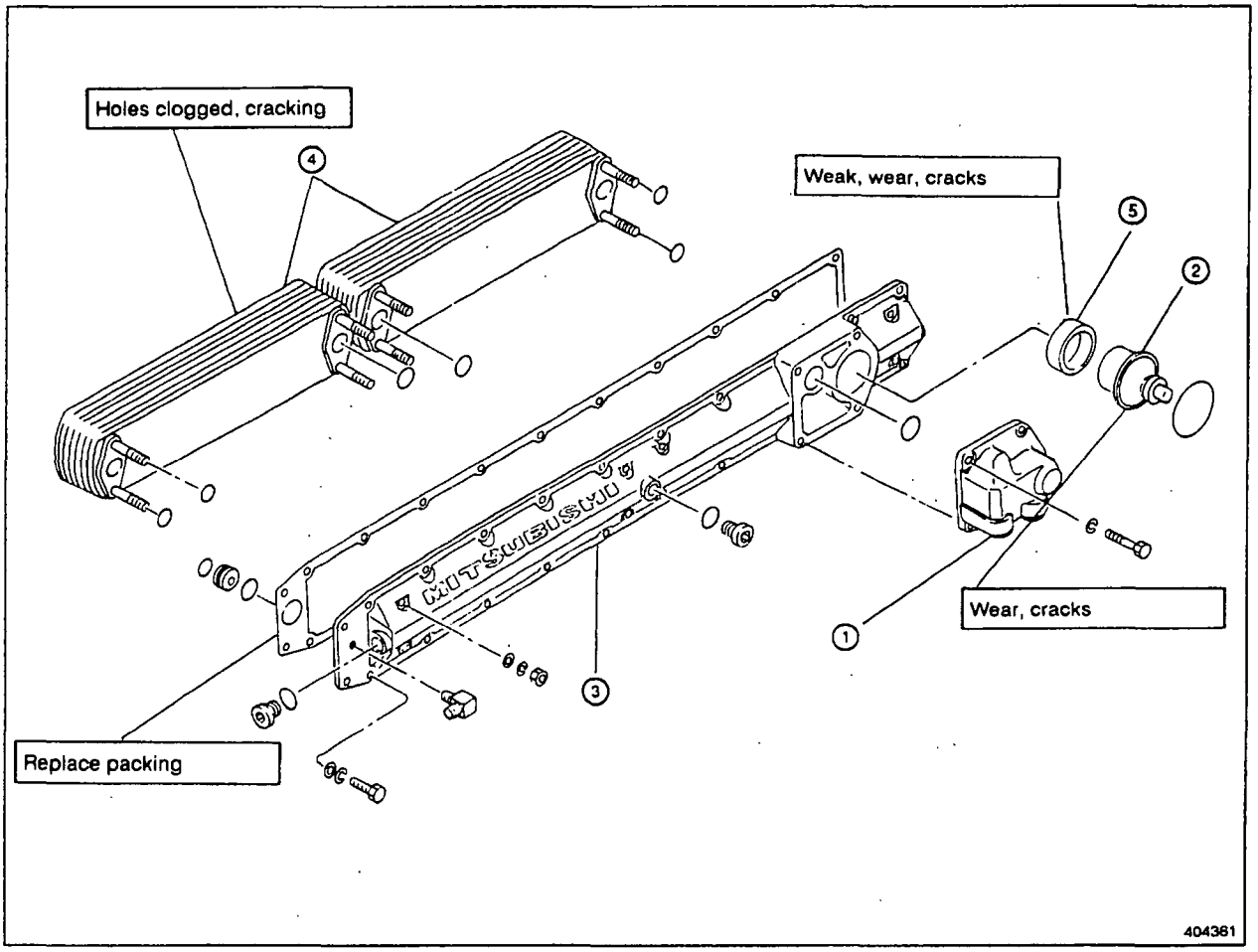
(1) Replace packing and O-rings during reassembly.

(2) Before reassembly, clean the oil paths of the oil filter bracket, etc. by flushing them with oil and blowing them with air.

(3) Install the oil filter element complete with its bracket.

4. Right Side Oil Cooler and Oil Thermostat

4.1 Disassembly



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

4.2 Inspecting the oil cooler element and oil thermostat

Follow the same inspection procedure as that for the left side oil cooler and oil thermostat. If you find any deterioration, replace them.

4.3 Reassembly

Reassembly is the reverse procedure of disassembly.

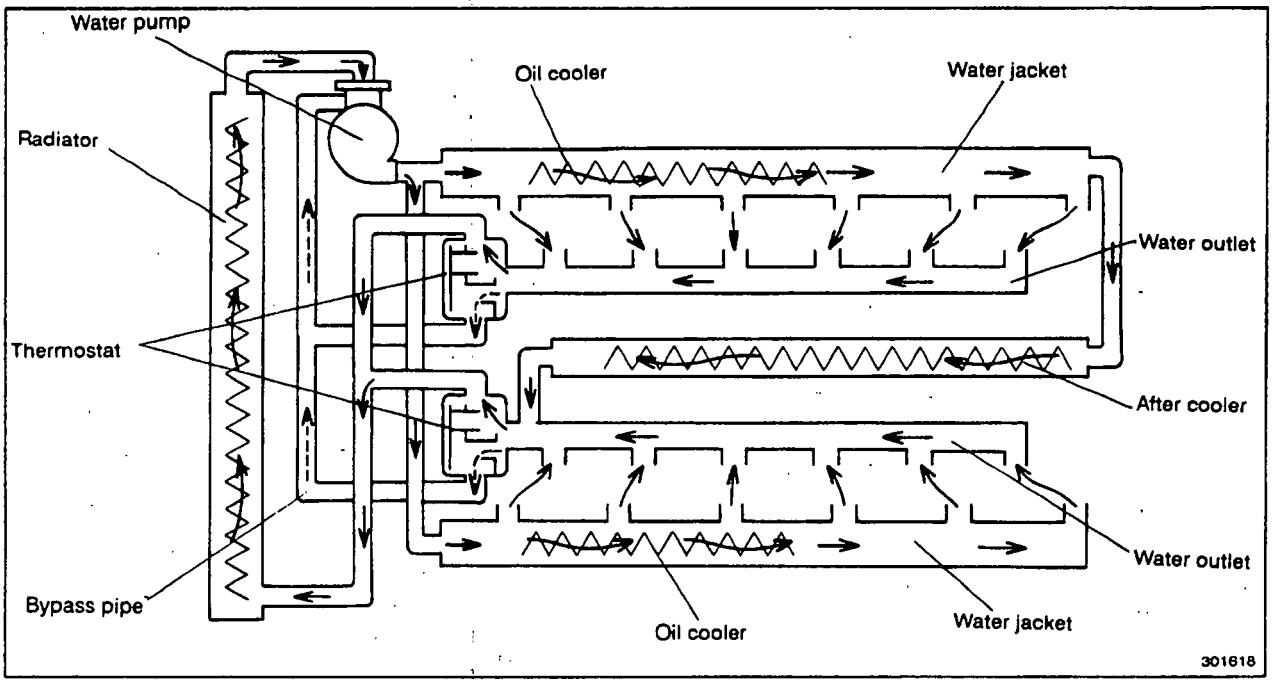
(1) Replace packing and O-rings at reassembly.

(2) Before reassembly, clean the oil paths of the oil cooler cover, etc. by flushing them with oil then blowing them with compressed air.

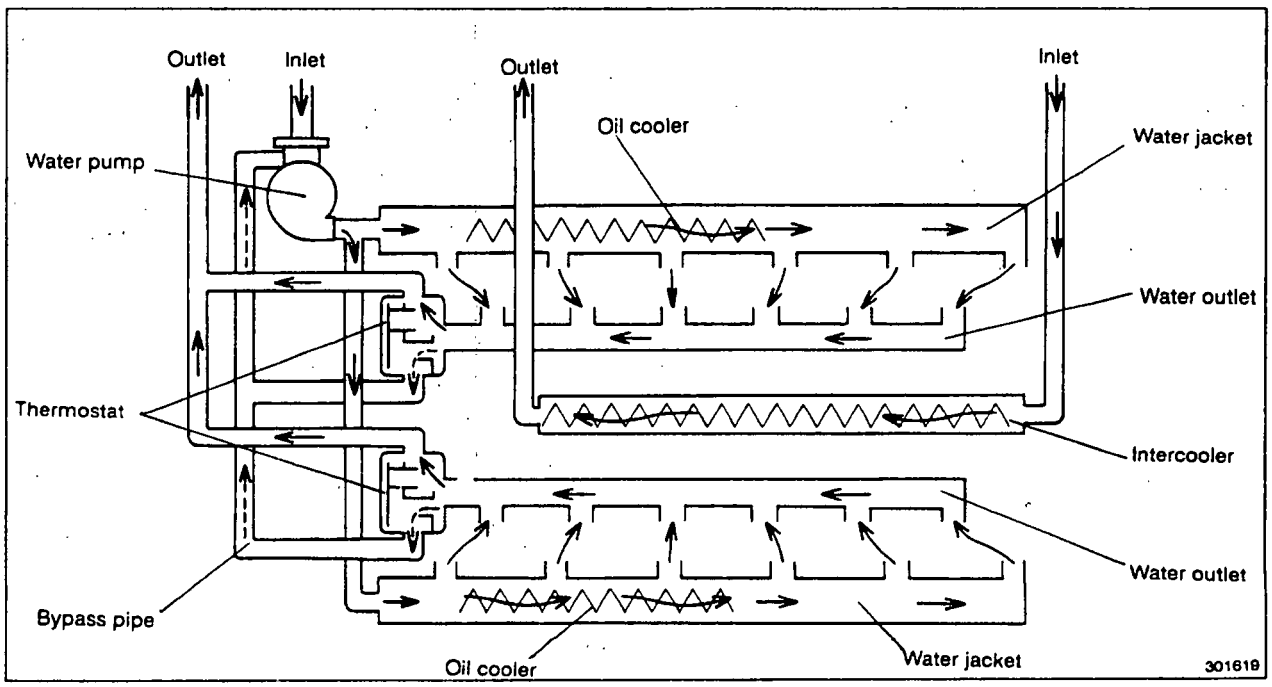
10. COOLING SYSTEM

10. COOLING SYSTEM

1. Cooling System With a Radiator

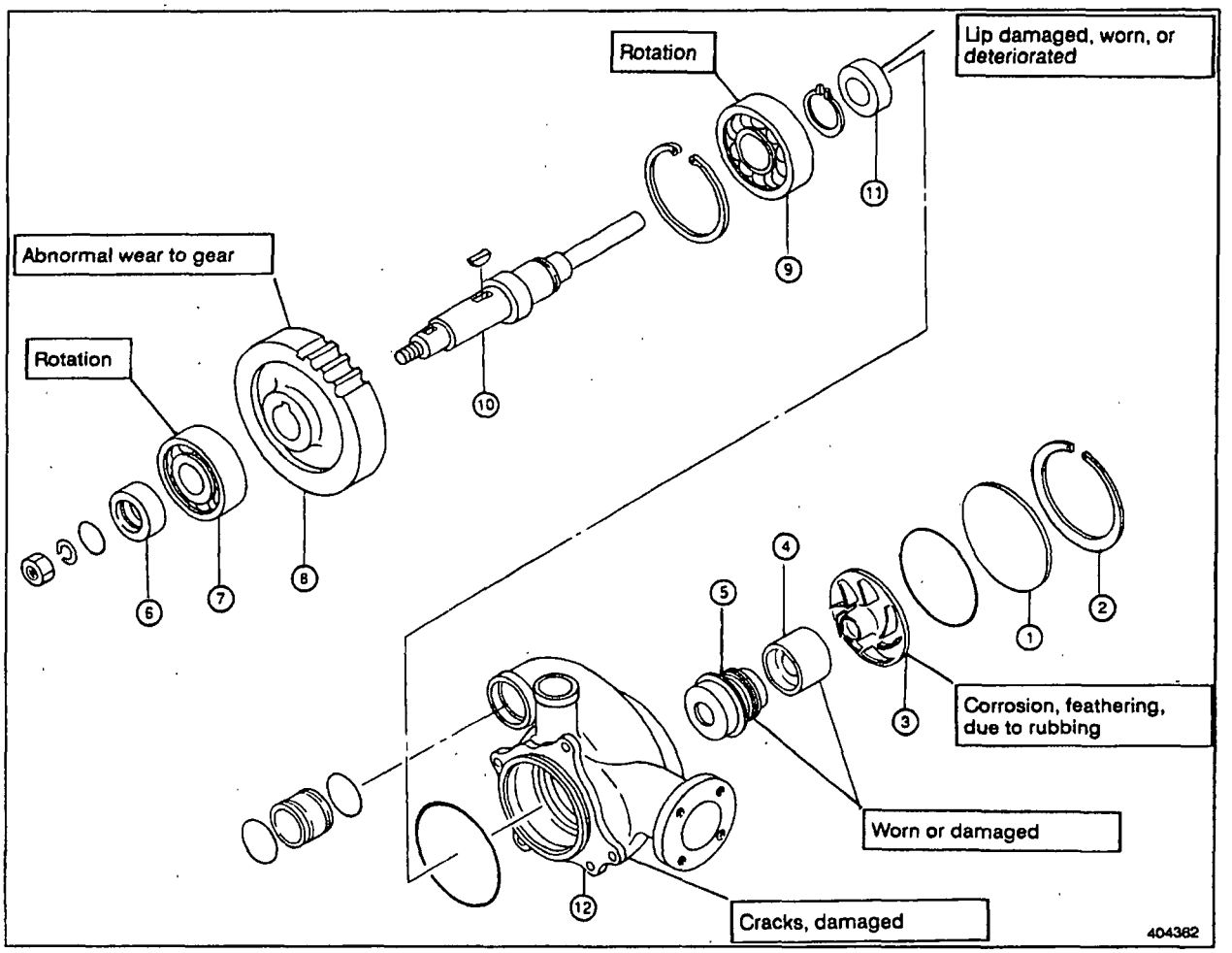


2. Cooling System With a Remote Water Supply



3. Water Pump

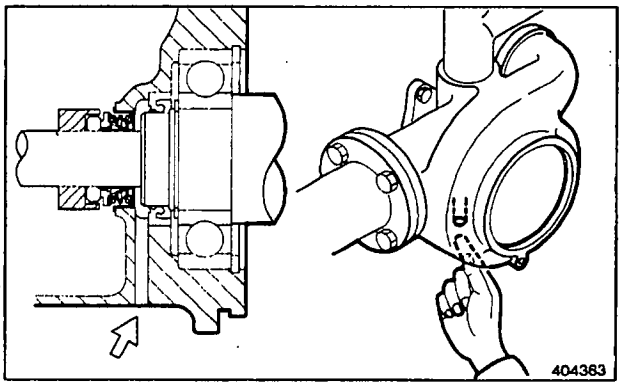
3.1 Disassembly



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

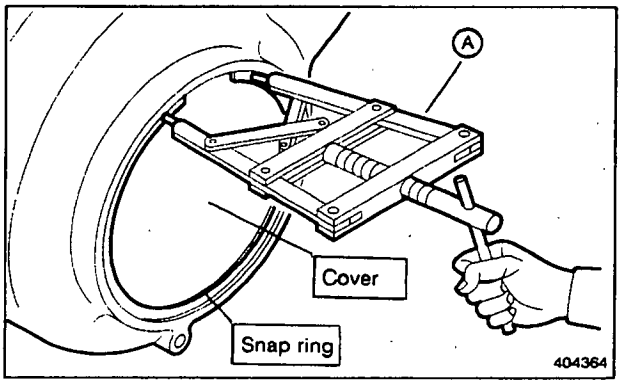
(1) Inspecting the water pump on the engine

Touch the drain port located at the bottom of the pump with your finger. If the port is leaking water, check the condition of the unit seal. If it is leaking oil, the oil seal is defective.

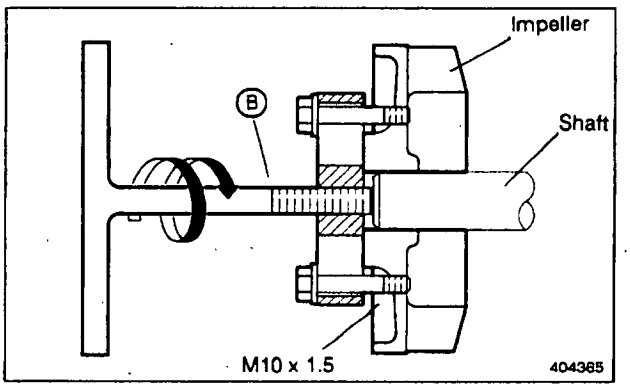


(2) Removing the impeller

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



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



Removing the impeller

(3) Removing the water pump shaft

(a) Remove the oil seal sleeve.

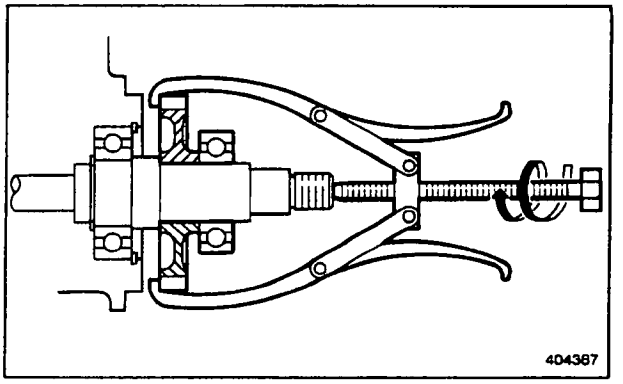
(b) Remove the gear, complete with the bearing with the gear puller.

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

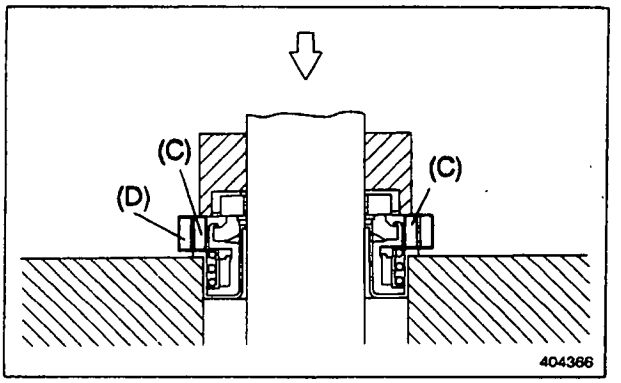
(d) Insert the two half rings (C) of the ring remover (37791-03400) between the unit seal and the pump case as shown in the figure (404366).

(e) Fit the outer ring (D) to the outside of the half rings in such a way that they do not fall free.

(f) Receive the pump case and pull out the edge face on the side of the shaft impeller by pushing with a hand press in the direction of the arrow mark as shown in the figure (404366).



Removing the gear



3.2 Inspection

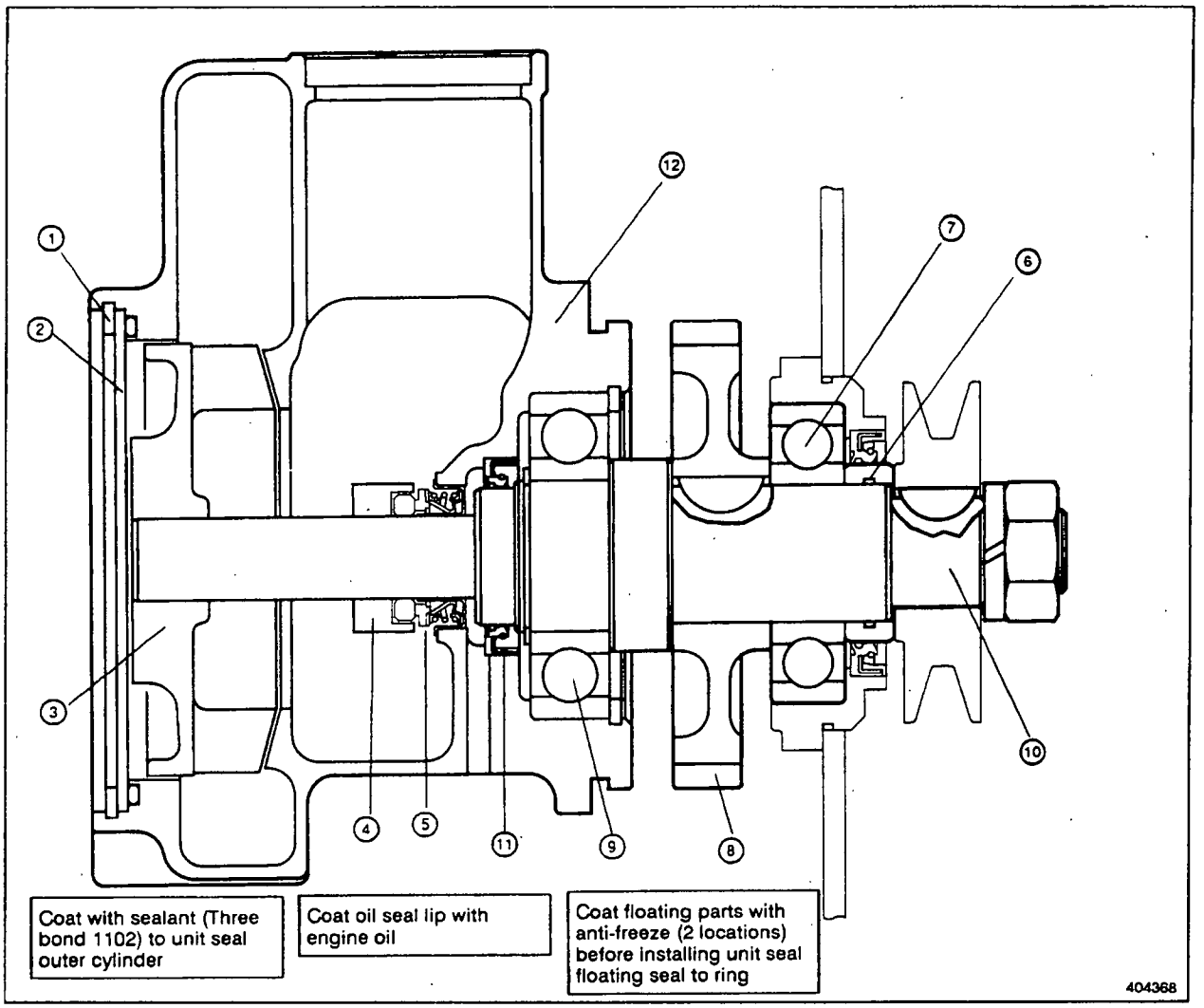
Water Pump

Measure the inside diameter of the pump case bore to which the bearing outer race is fitted. Measure the diameter of the pump shaft on which the bearing inner race is fitted. If the bearing, case, or shaft is worn, replace it.

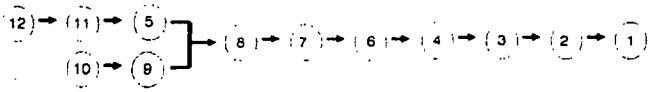
Unit: mm

Item		Nominal Value	Assembly Standard
Inside diameter of pump case bearing		ϕ120	119.987-120.022
Inside diameter of cover to which the bearing outer race is fitted		ϕ110	110.005-110.040
Bearing	Diameter	ϕ120	119.980-120.005
		ϕ110	109.980-110.005
	Inside diameter	ϕ55	54.981-55.004
		ϕ50	49.981-50.004
Diameter of pump shaft on which bearing inner race is fitted		ϕ55	55.002-55.015
		ϕ50	50.002-50.013

3.3 Reassembly



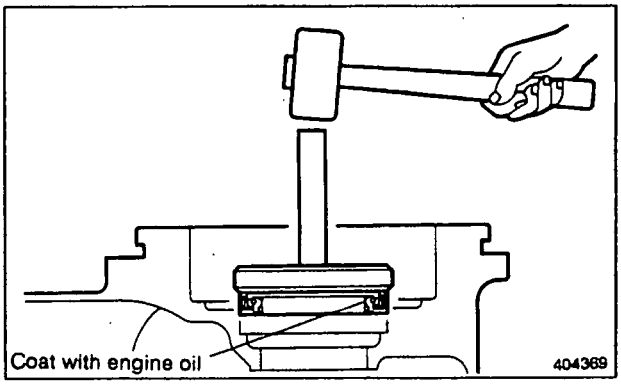
Reassembly Sequence



NOTE

Replace all O-rings and oil seals at reassembly.

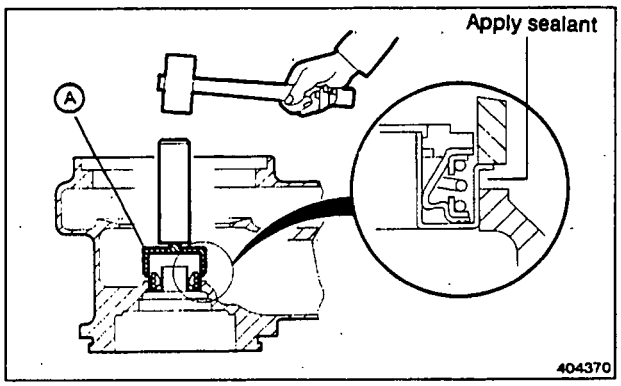
(1) With the oil seal installer, press in the oil seal. Apply engine oil to the oil seal lip.



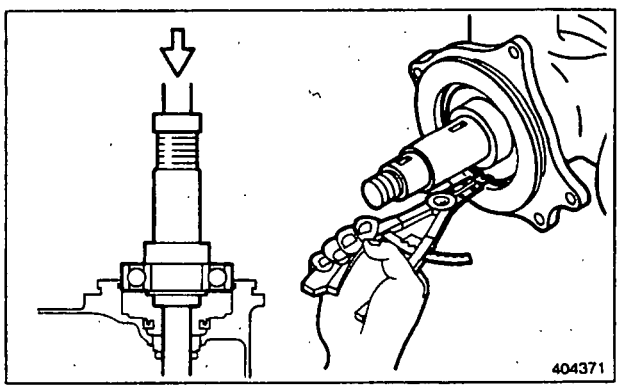
(2) Use the unit seal installer (A) (37191-06300) to press in the unit seal. Replace the unit seal if it has been removed during reassembly.

NOTE

Install the unit seal after coating with sealant (three-bond 1102) to seal the outer ring.



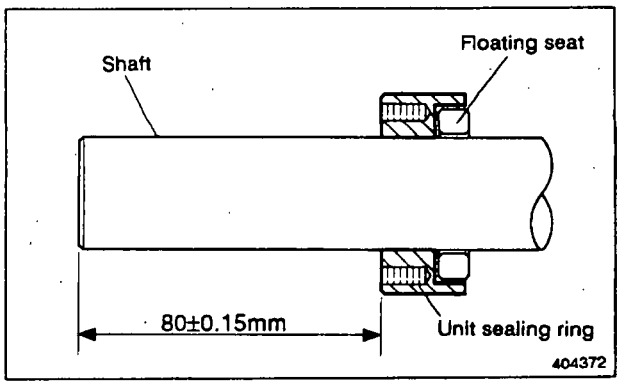
(3) Use a press to press in the impeller-side pump shaft, complete with ball bearings into the case. Install the snap ring with its gap down.



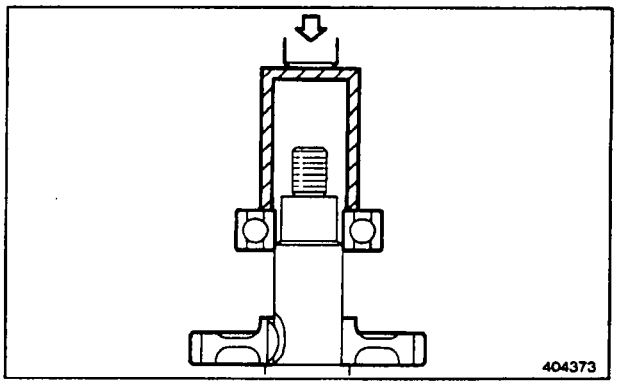
(4) With a press, press in the unit seal ring, complete with the unit seal floating seat using the ring installer (37791- 03300).

NOTE

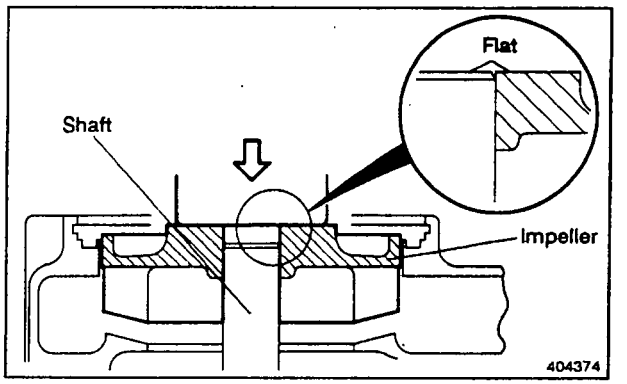
Before installation, coat with anti-freeze the floating parts at two locations.



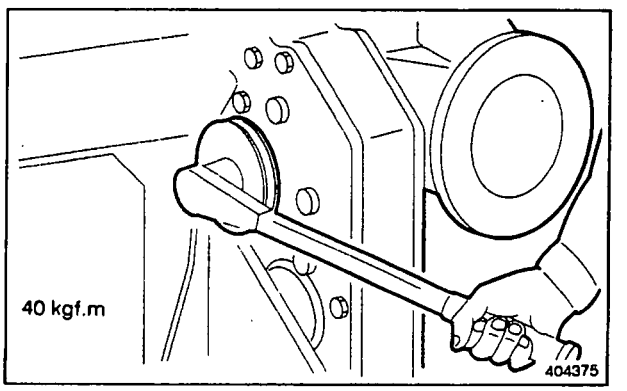
(5) Insert the gear into the shaft by matching the key. Press in the nut side of the ball bearing.



(6) Press in the impeller. The impeller's boss end and pump shaft end should form a flat surface.

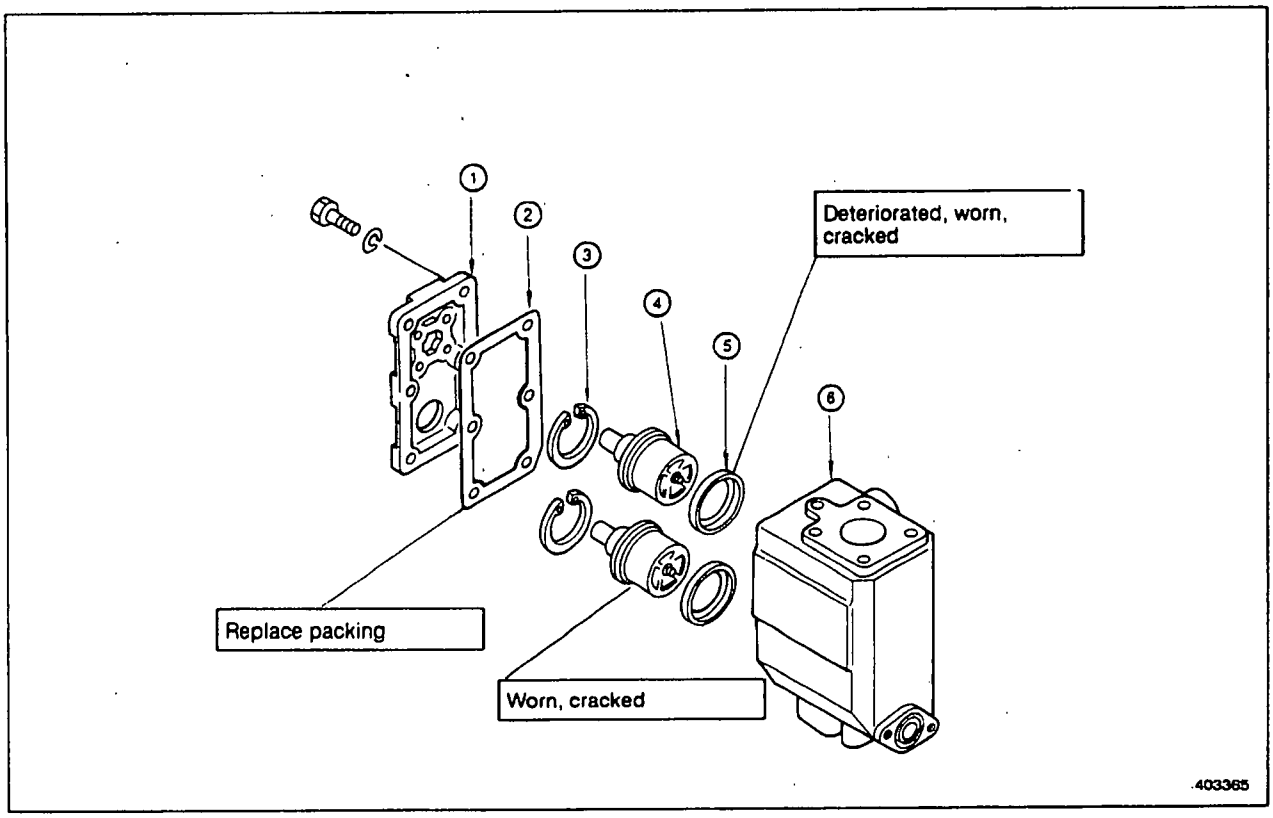


(7) After installing the water pump assembly, install the alternator pulley and tighten the nut to the specified torque.



4. Thermostats

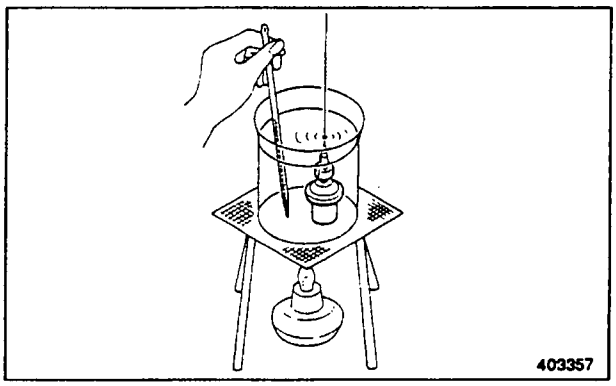
4.1 Disassembly



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

4.2 Inspection

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 or more. If the valve fails to operate properly, replace the thermostat.



Unit: mm

Item	Assembly Standard
Temperature where valve should start opening	71 ± 2°C
Valve lift of 11 mm	85°C

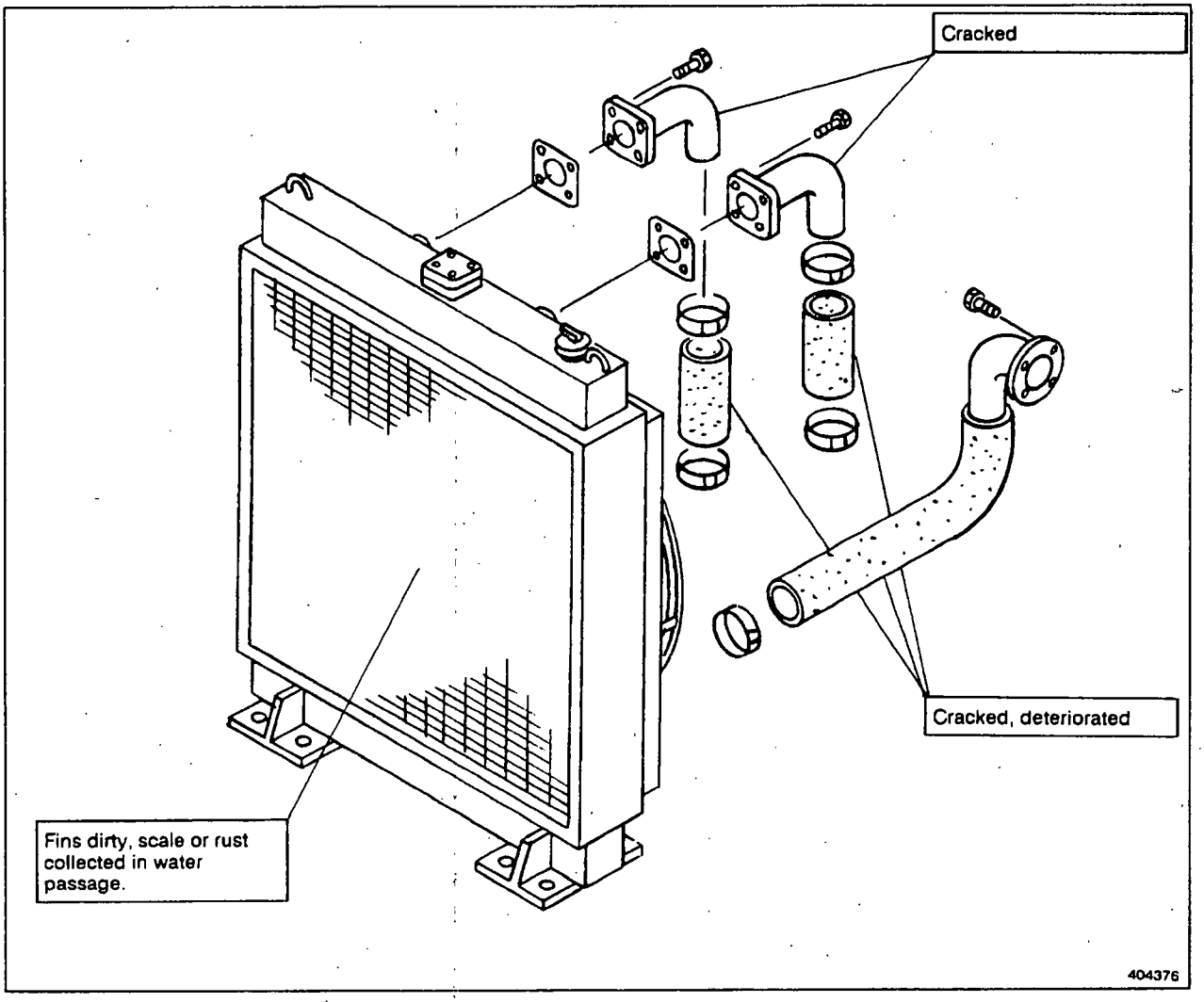
NOTE

(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 its mounting flange.

5. Radiator

Inspection

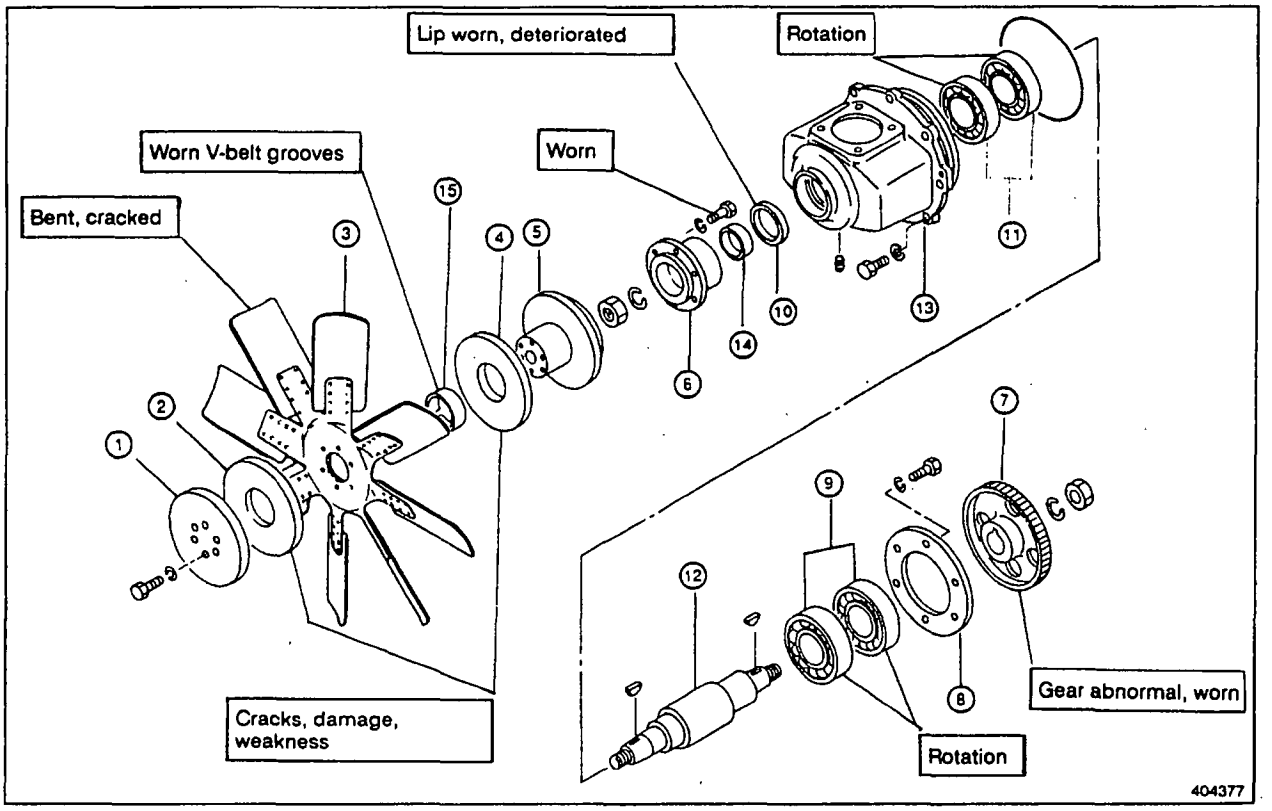


(1) Inspect the radiator for dirt, scale, or rust in the water passages, then clean if necessary...

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

CAUTION!

If one of the fan blades is broken, this can cause excessive vibration and weaken the opposite blade. Carefully inspect each blade for cracks or warping.

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, shaft, or bracket is worn, replace it.

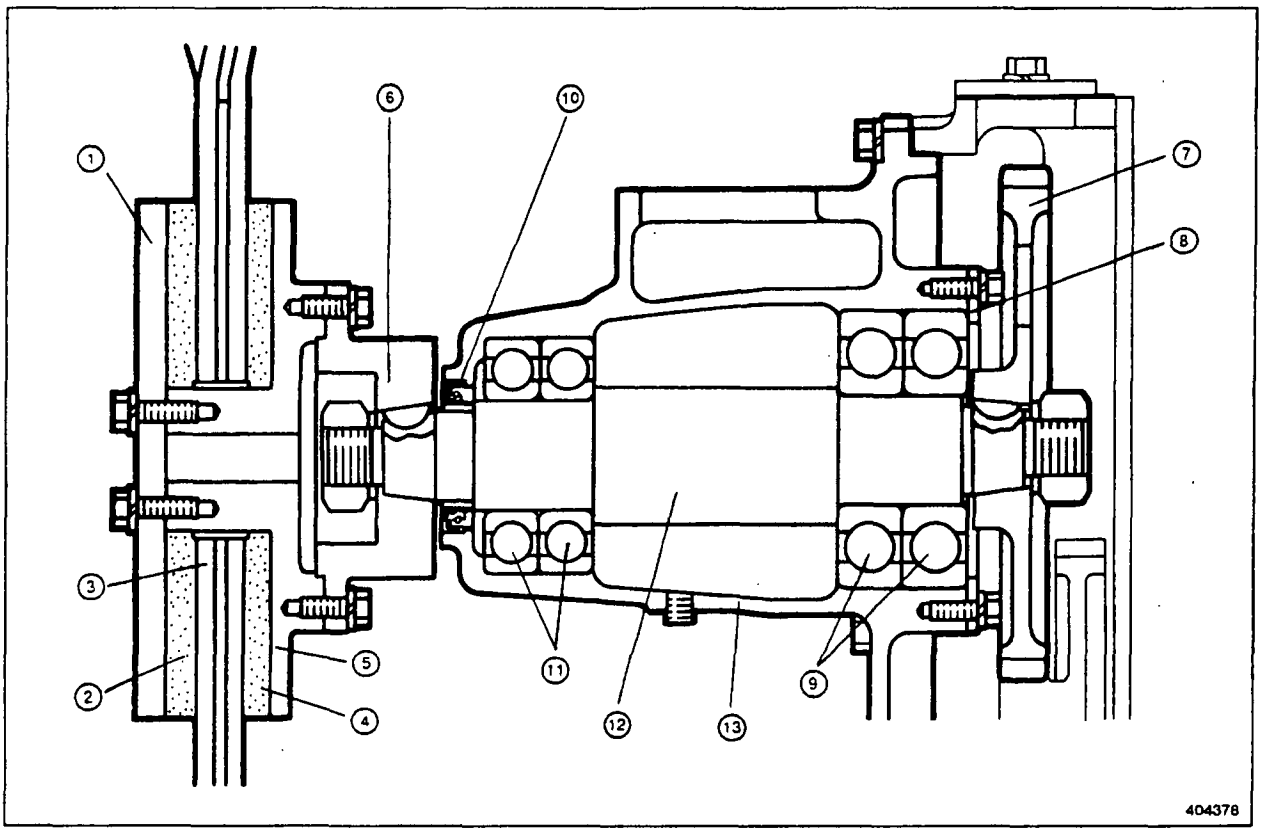
(2) Check the fan bushing for wear and damage and replace it anything abnormal is found.

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

Unit: mm

Item		Nominal Value	Assembly Standard
Inside diameter of bracket bore to which bearing outer race is fitted		ϕ140 ϕ120	139.986-140.026 119.987-120.022
Bearing	Diameter	ϕ140	139.976-140.006
		ϕ120	119.980-120.005
	Inside diameter	ϕ55	54.981-55.004
Diameter of shaft on which bearing inner race is fitted		ϕ55	55.002-55.015

6.3 Reassembly



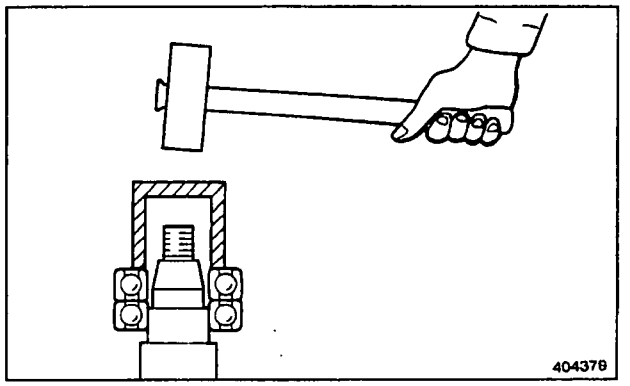
Reassembly Sequence

(13) → (10)
(12) → (11)
] → (9) → (8) → (7) → (6) → (5) → (4) → (3) → (2) → (1)

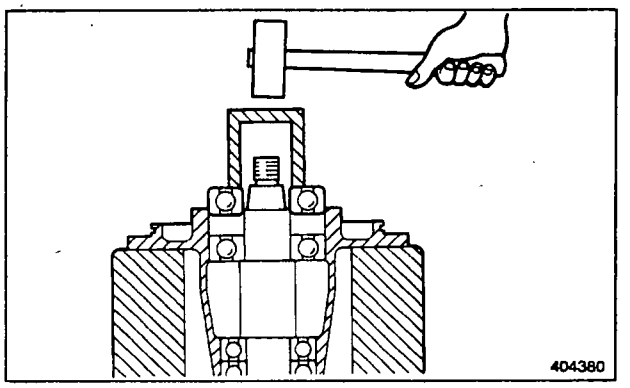
(1) Use a bearing installer to press the bearing onto the shaft. Press the oil seal to the case.

NOTE

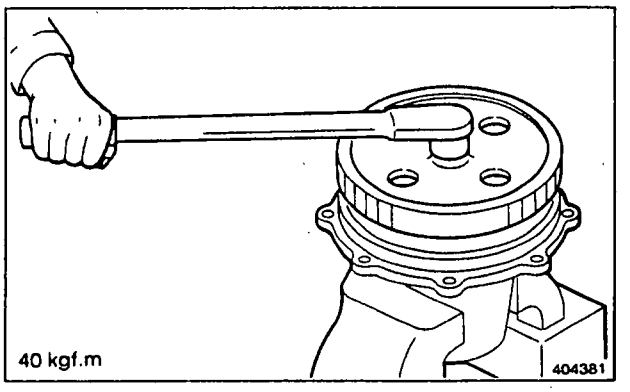
Apply engine oil to the oil seal lip before installation.



(2) Press the shaft into the bracket. Use a bearing installer to press the bearings to the shaft and bracket. Install the thrust plate.



(3) Insert the gear onto the shaft, then tighten the nut to the specified torque.

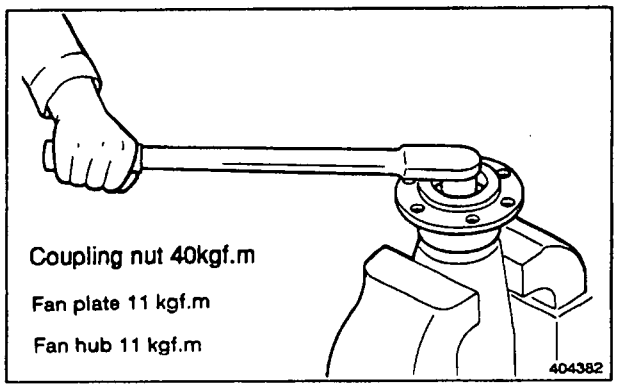


(4) Installing the fan

(a) Match the key to insert the coupling to the shaft, then tighten the nut to the specified torque.

(b) Tighten the coupling and the fan hub mounting bolt to the specified torque.

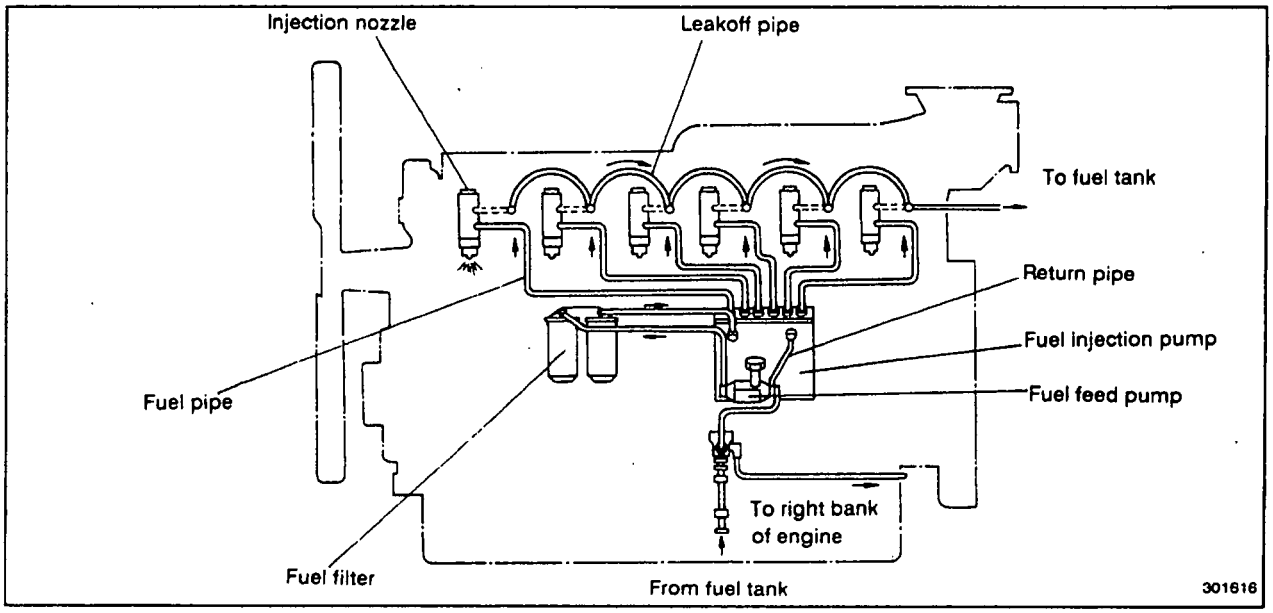
(c) Insert the friction rubber, the fan bushing, and the fan to the shaft, then tighten the fan plate mounting bolt to the specified torque.



11. FUEL SYSTEM

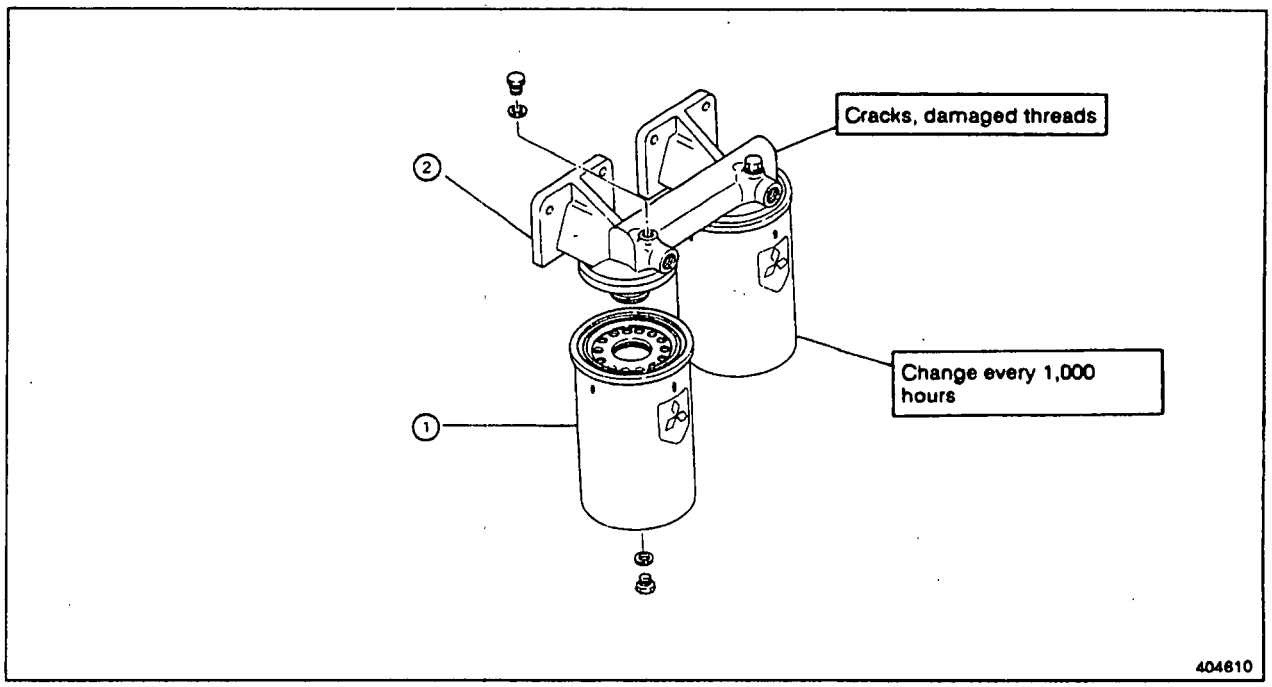
11. FUEL SYSTEM

1. Description



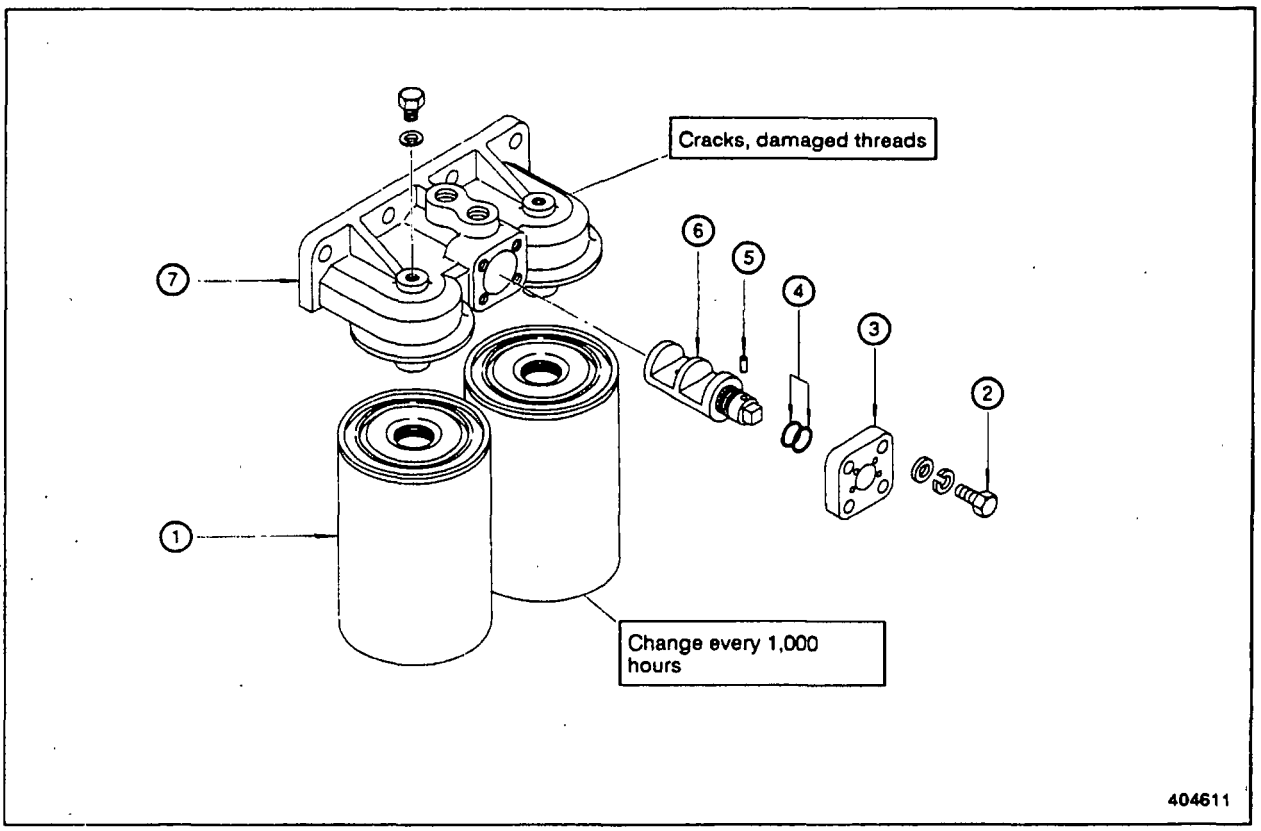
2. Fuel Filters

2.1 Disassembly and Inspection



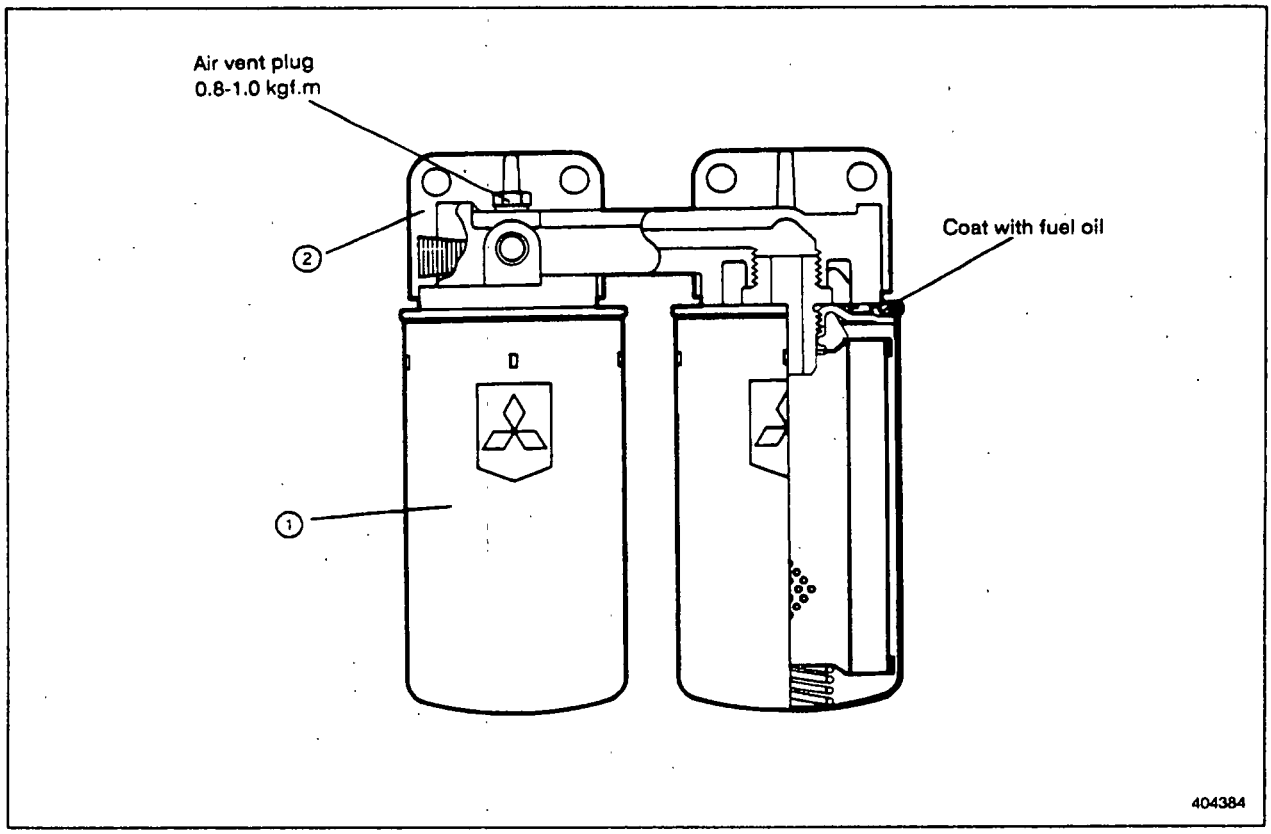
① Element ② Fuel filter bracket

Switchable Type



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

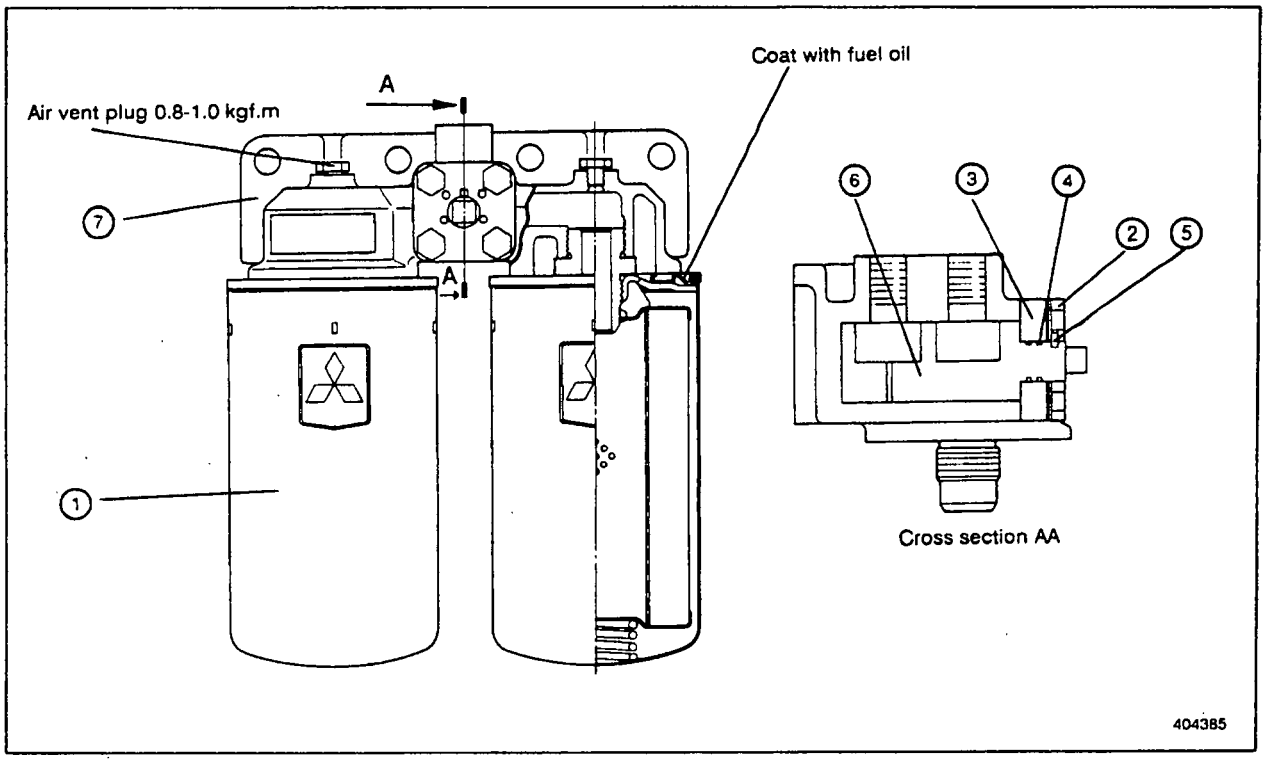
2.2 Reassembly



Reassembly Sequence

(2) → (1)

Switchable Type



Reassembly Sequence

(7) → (5) → (4) → (6) → (3) → (2) → (1)

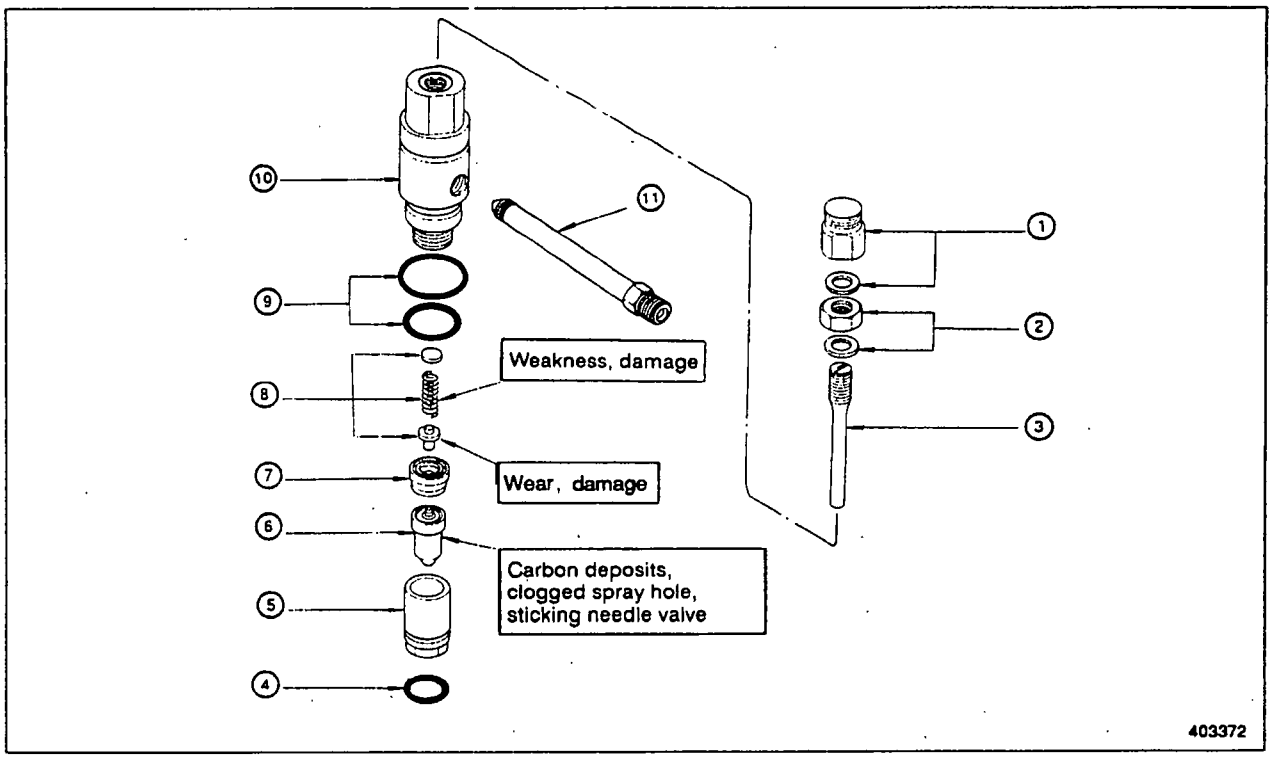
To install the cartridge, clean the mounting surface and apply fuel oil to the gasket. After bringing the gasket into contact with the sealing surface of the bracket, tighten the cartridge with your hand about one-half to three quarters of a turn.

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

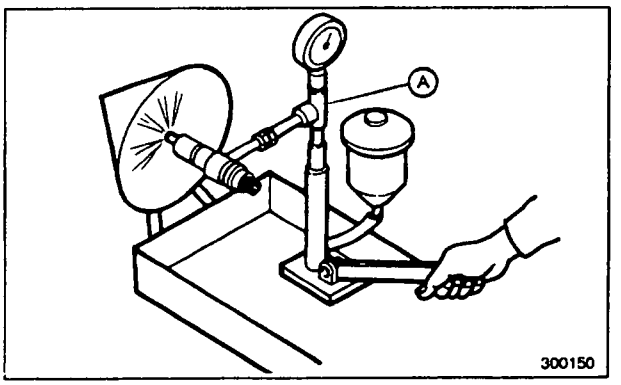


① Cap nut, gasket
② Jam nut, gasket
③ Adjusting screw
④ O-ring
⑤ Retaining nut
⑥ Nozzle tip
⑦ Spacer
⑧ Pushrod, nozzle spring, spring seat
⑨ O-ring
⑩ Nozzle holder
⑪ Fuel inlet connector

3.2 Inspection and Adjustment

(1) Injection Pressure

(a) Install the nozzle on the tester (A) (41091-01500). Operate the handle of the tester at a rate of about 1 stroke per second to observe the pressure at which fuel is being injected. If the pressure is out of standard, adjust the pressure of the nozzle.



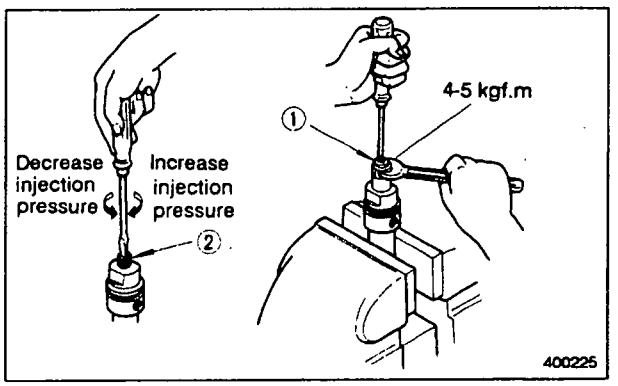
Unit: mm

Item	Assembly Standard
Injection pressure (Valve opening pressure)	350-355

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.

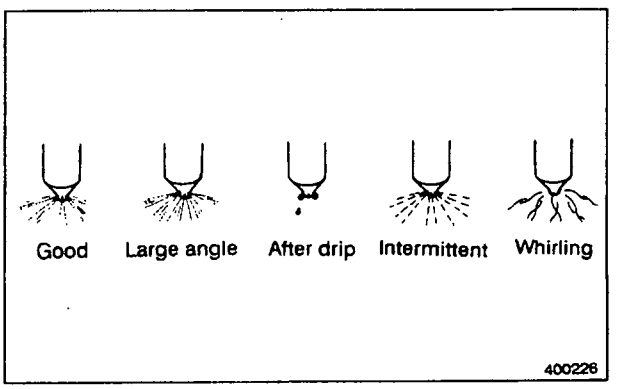


(c) After completing the adjustment, tighten the jam nut and the cap nut to the specified torque.

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

(2) Spray pattern

(a) When you are testing the injection pressure, inpsect 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.

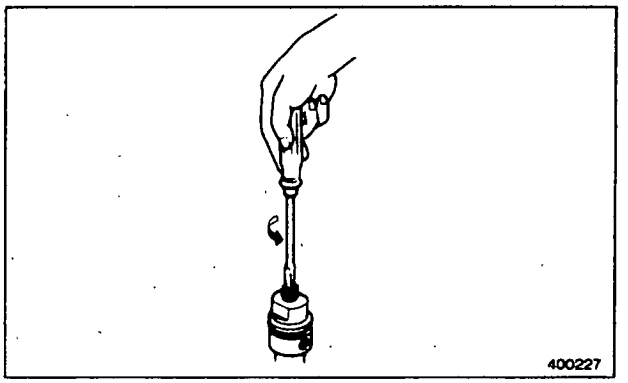


Spray patterns

(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

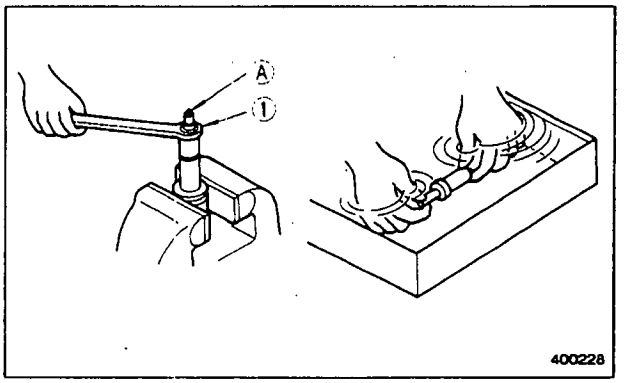
(a) The nozzle tip is spring loaded. Remove the cap nut and with a screwdriver, loosen the adjusting screw until it can be loosened by hand.



(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 (A).

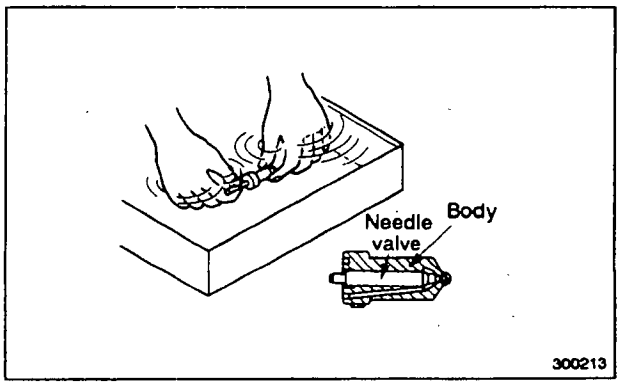


(c) Wash the nozzle tip in clean gasoline. After washing, assemble the needle valve and body in clean diesel fuel.

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.

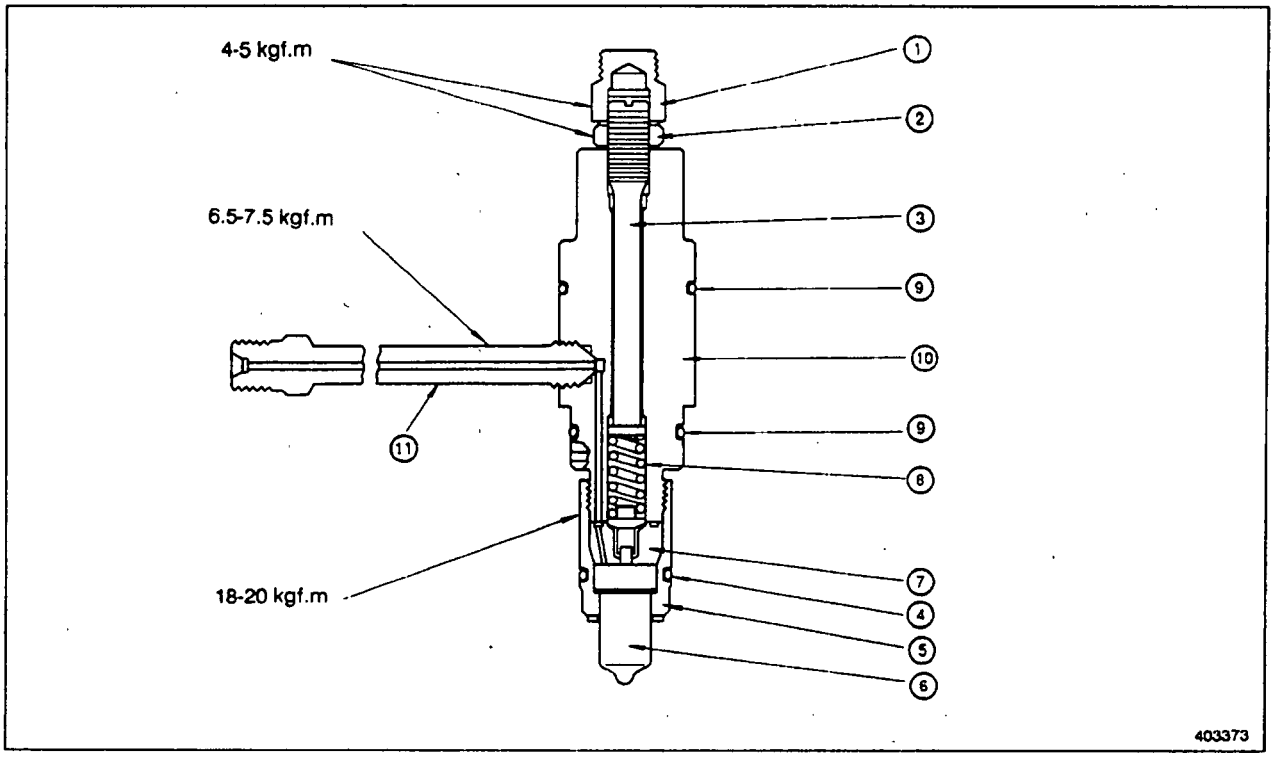


(e) If the spray pattern is still bad after the nozzle has been adjusted and cleaned, replace the nozzle tip.

NOTE

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

3.3 Reassembly



Reassembly Sequence

(10) → (9) → (3) → (8) → (7) → (6) → (5) → (4) → (11) → (2) → (1)

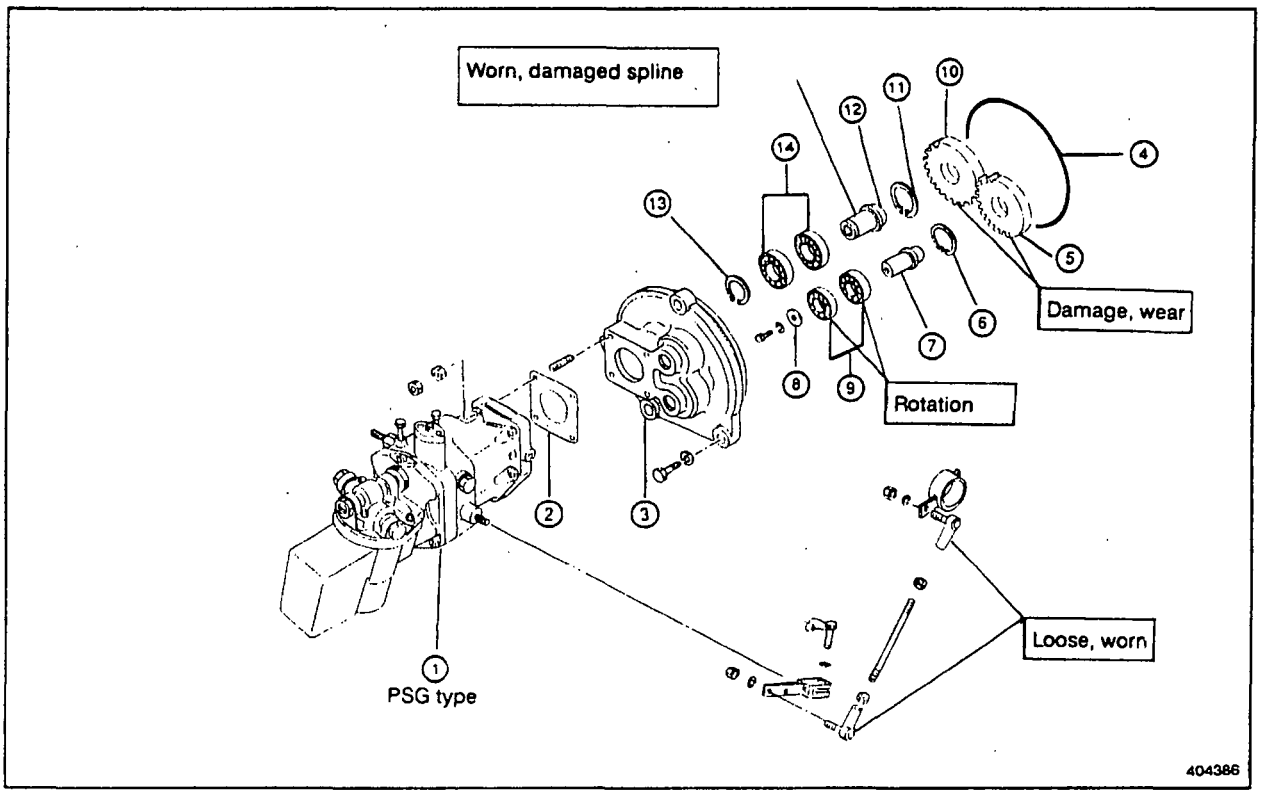
CAUTION!

Tighten the retaining nut 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. Woodward Governor Drive and Governor Link

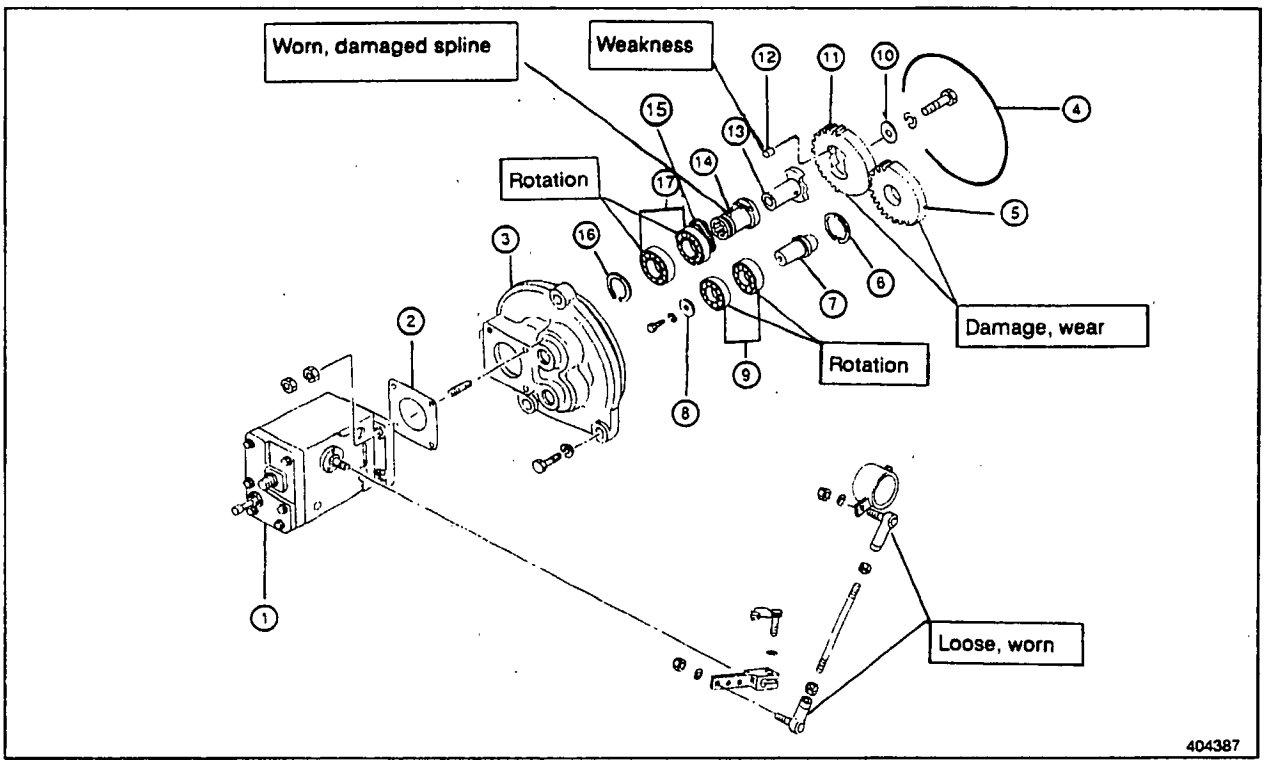
4.1 Disassembly

PSG, EG-3P Governors



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

EG-B2P Governors



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

4.2 Inspection

Rotate each bearing to check rotation. Replace the bearing if its rotation is not smooth.

Check the fit of the bearings on the drive shaft, and idler shaft. Replace the shaft or bearings if they are worn.

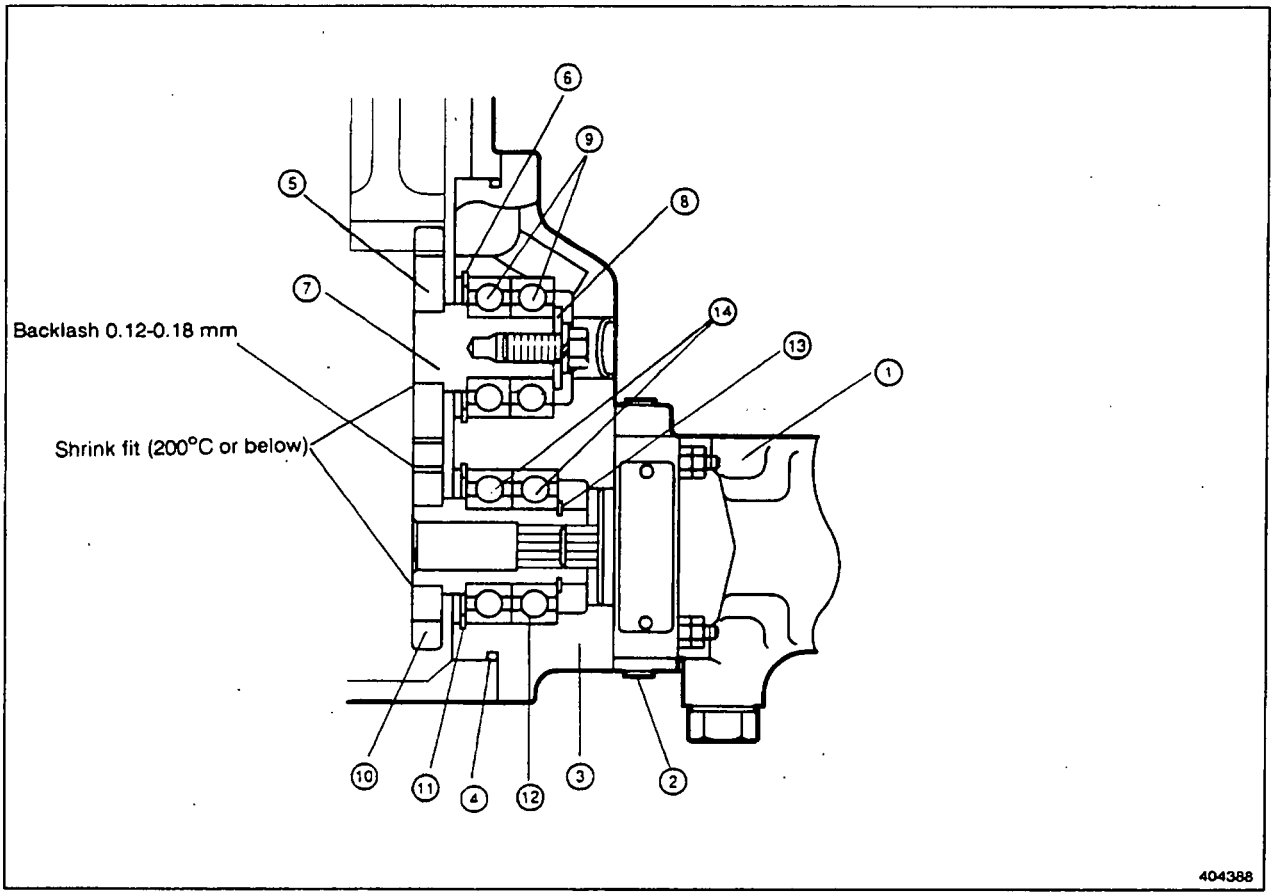
Check the fit of the bearings in the drive case and drive cover. Replace worn parts.

Unit: mm

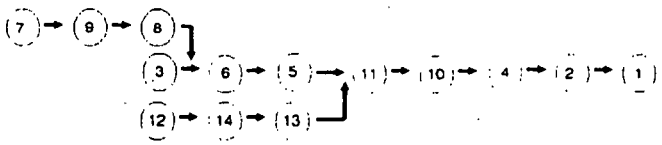
Item		Nominal Value	Assembly Standard
Bearing inside diameter for case drive shaft		ϕ52	51.988-52.018
Bearing for drive shaft	Outside dia.	ϕ52	51.983-52.004
	Inside dia.	ϕ25	24.987-25.003
Drive shaft outside dia. for bearing		ϕ25	25.002-25.011
Bearing inside dia. for case idler shaft		ϕ47	46.989-47.014
Bearing for idler shaft	Outside dia.	ϕ47	46.986-47.003
	Inside dia.	ϕ20	19.987-20.003
Idler shaft outside dia. for bearing		ϕ20	20.002-20.011
Drive shaft outside dia. for bearing		ϕ26	26.035-26.048
Drive gear inside dia.		ϕ26	26.000-26.013
EG-B2P drive shaft outside dia. for gear		ϕ29	28.959-28.980
EG-B2P drive gear inside dia.		ϕ29	29.00-29.04
Idler shaft outside dia. for gear		ϕ24	24.035-24.048
Idler gear inside dia.		ϕ24	24.000-24.013

4.3 Reassembly

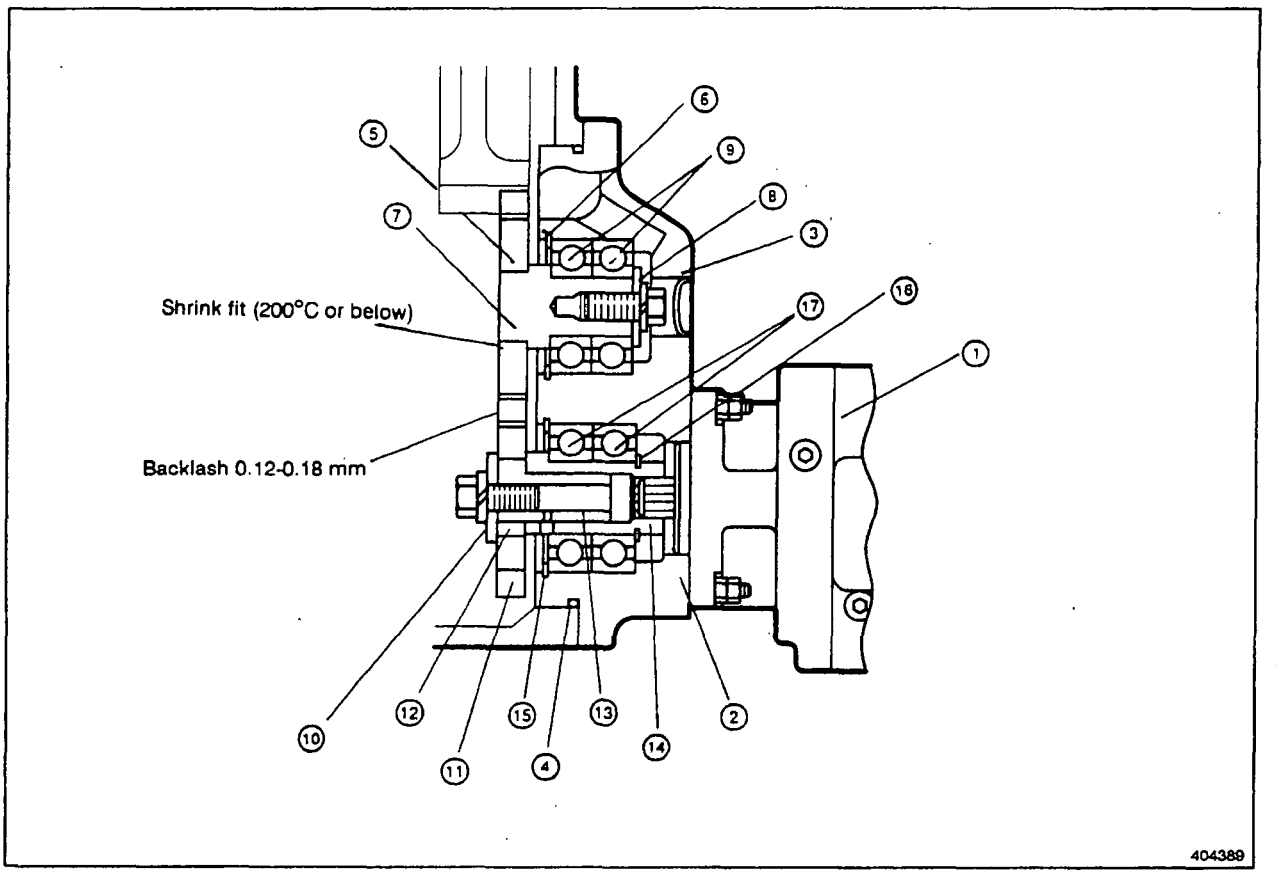
PSG, EG-3P Governor



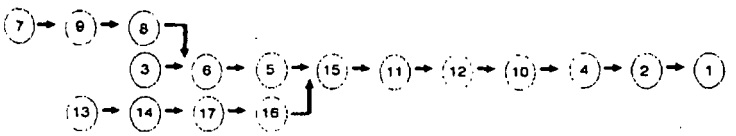
Reassembly Sequence



EG-B2P Governor



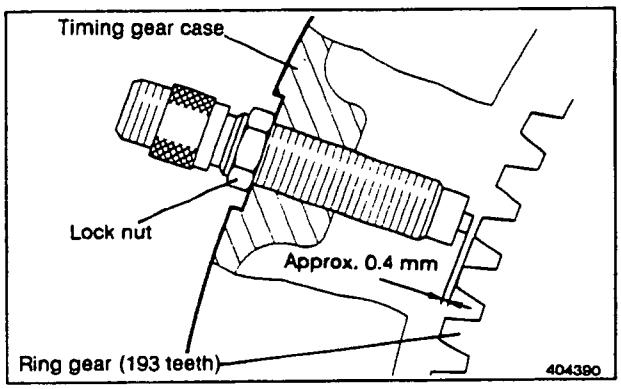
Reassembly Sequence



Installing Pick-up

(a) Rotate the engine with the turning gear and position a tooth of the ring gear at the center of the pick-up.

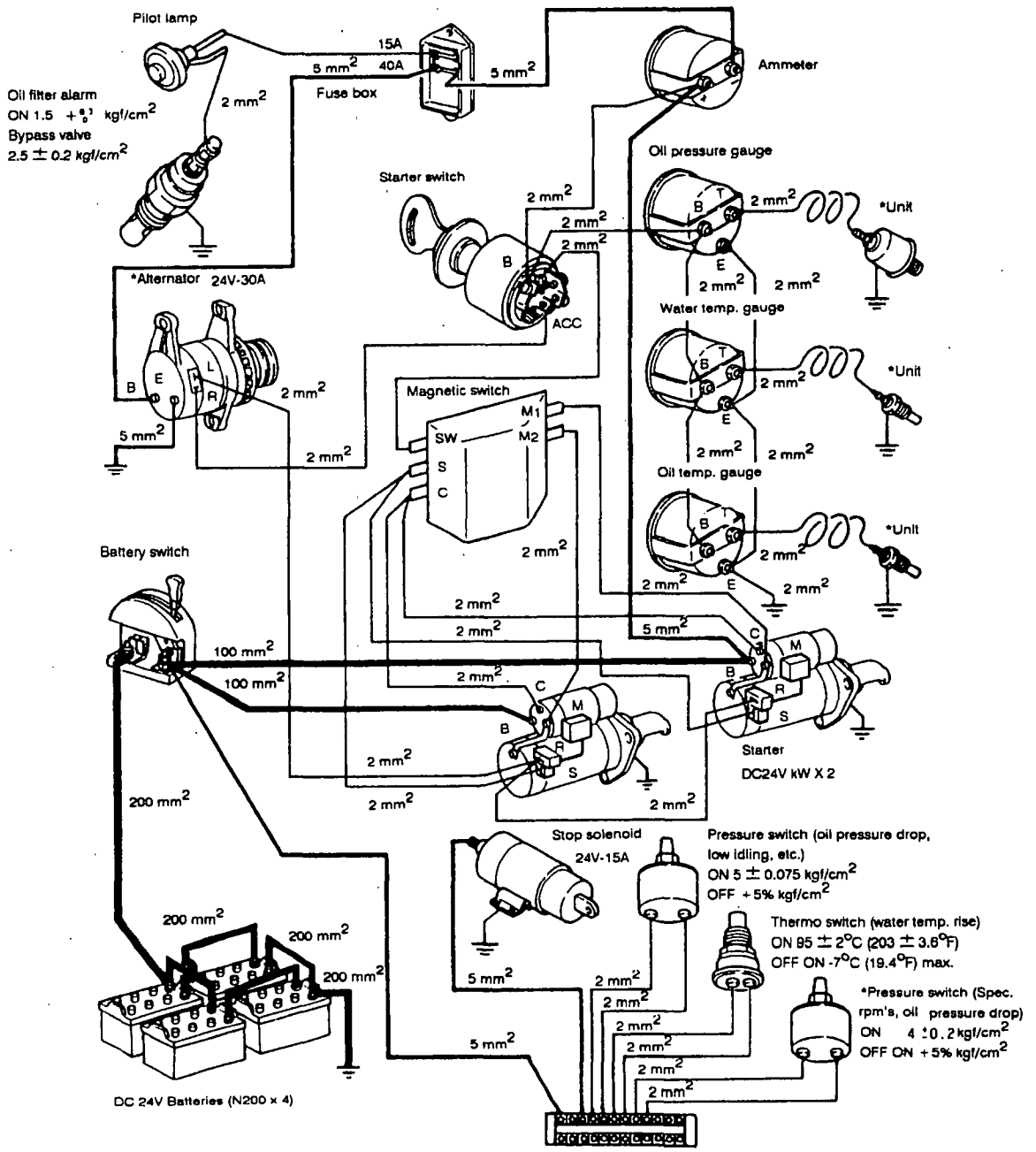
(b) Screw in the pick-up gently untll the tip of the pick- up touches the tooth of the gear. Draw it back about 1/4 of a rotation then fix the lock nut.



12. ELECTRICAL SYSTEM

12. ELECTRICAL SYSTEM

1. Electrical System Outline



Remarks:

(a) Circuit above is for the standard model. However, specifications and applications may vary with the type of engine.

(b) Circuit wiring is to be prepared in the field.

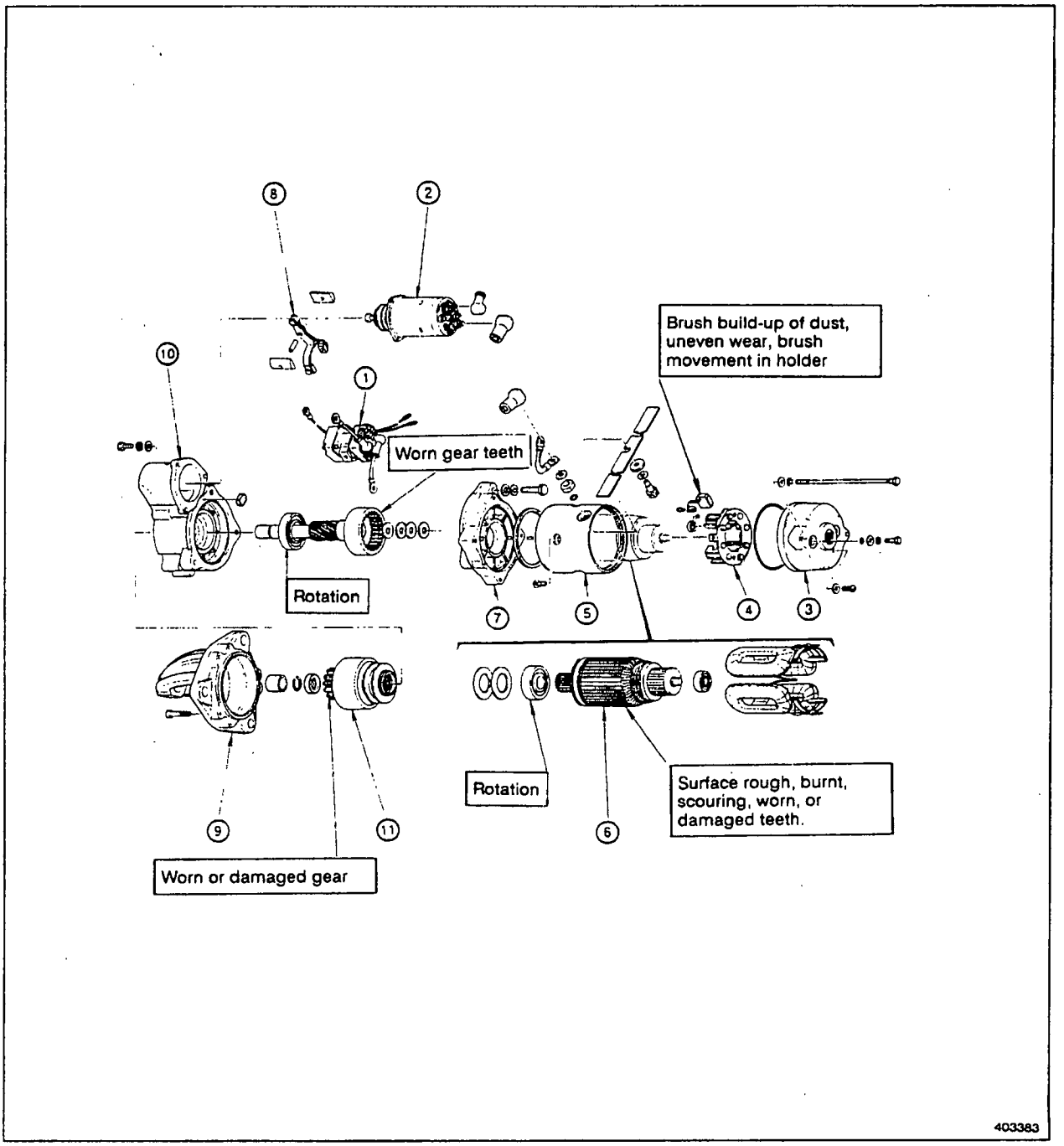
(c) Items marked with an asterisk (*) belong to the engine. Unmarked items are to be supplied individually.

301620

Wiring Diagram

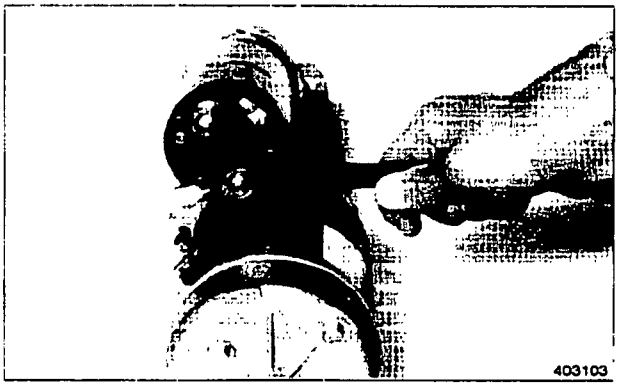
2. The Starter

2.1 Disassembly

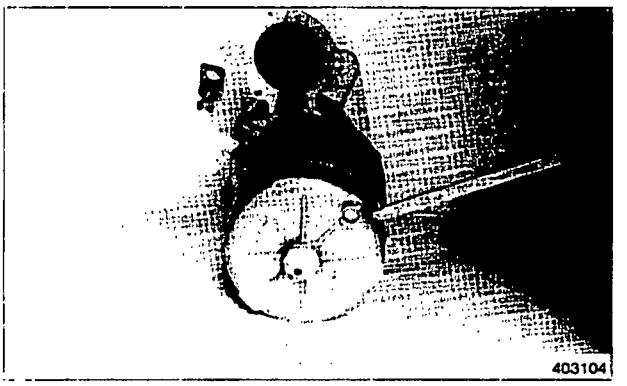


① Safety magnetic switch
② Magnetic switch assy.
③ Rear bracket
④ Brush holder assy.
⑤ Yoke assy.
⑥ Armature assy.
⑦ Center bracket
⑧ Lever assy.
⑨ Front bracket
⑩ Pinion case
⑪ Pinion clutch assy.

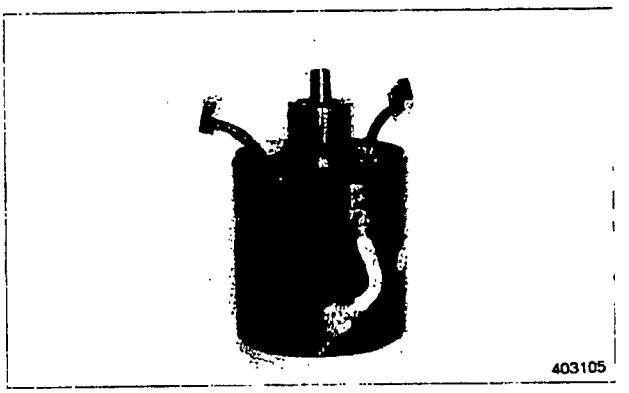
(1) After removing the safety switch, remove the lead wire, and then the magnetic switch assembly.



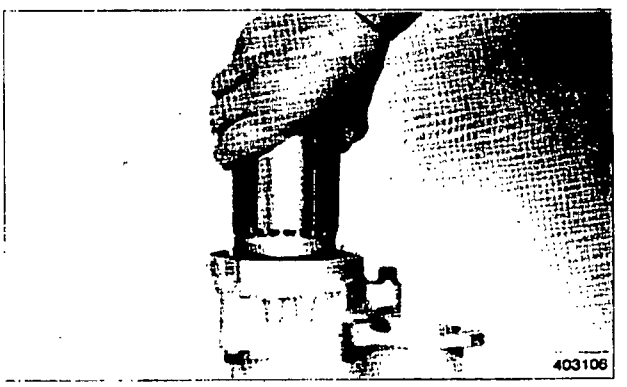
(2) Unscrew the through bolts and the brush holder mounting screws, then remove the rear bracket.



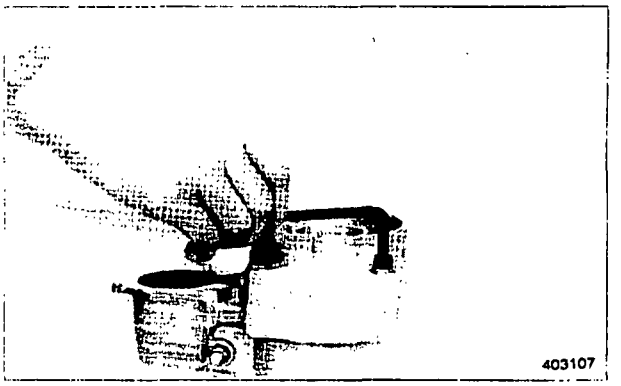
(3) Remove the brushes from the brush holder assembly, then remove the yoke.



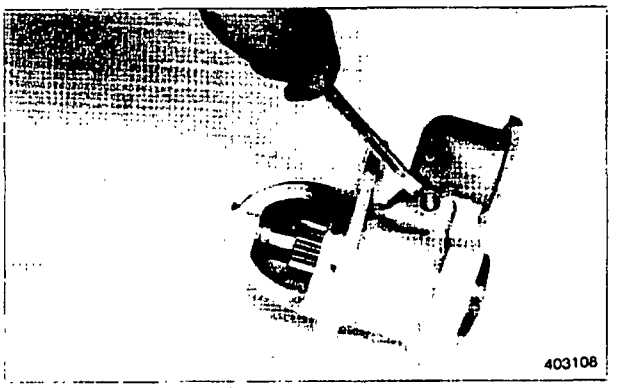
(4) Pull out the armature assembly.



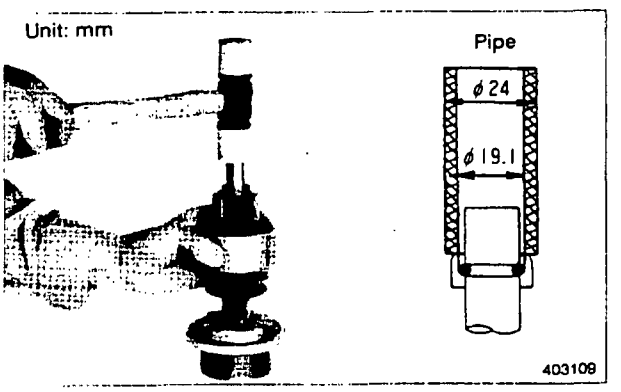
(5) Remove the center bracket.



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

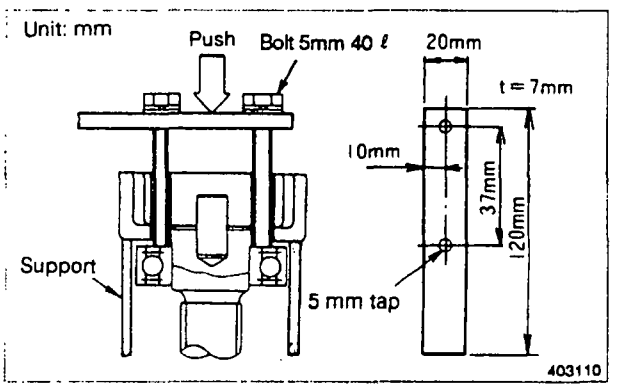


(7) Using a jig, remove the pinion stopper, then remove the overrunning clutch from the pinion shaft.



NOTE

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



Pinion shaft bearing puller

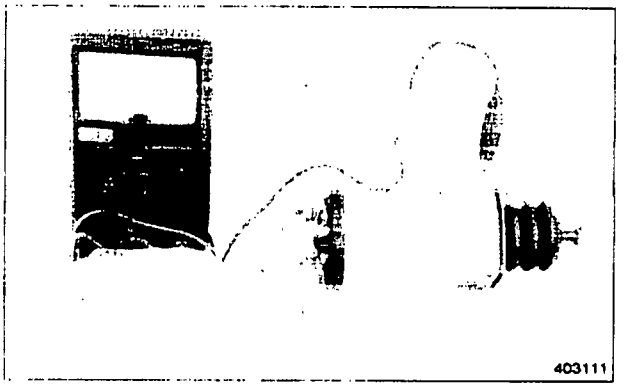
2.2 Inspection and Repair

Magnetic Switch

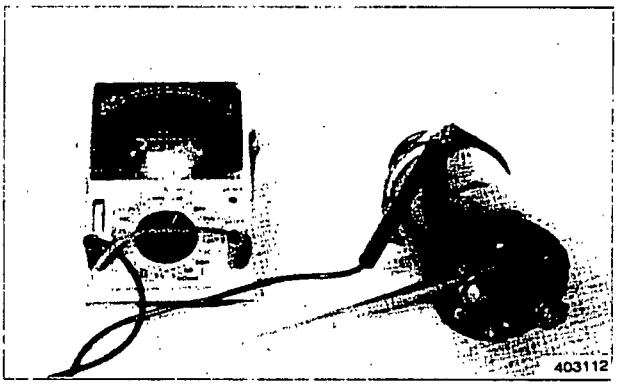
(1) Testing the magnetic switch coil

(a) Test the pressure coil and holding coil for an open ciruit. 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.

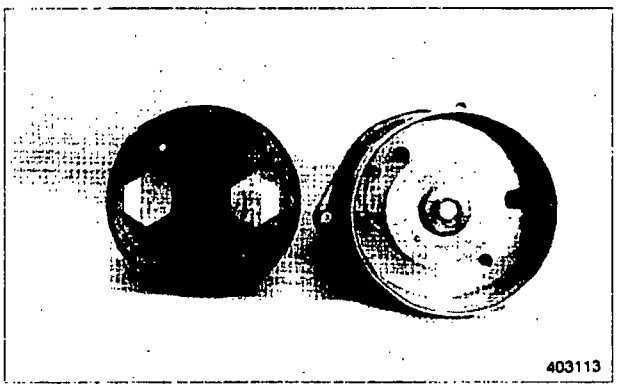


(2) Testing magnetic switch contact points

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.

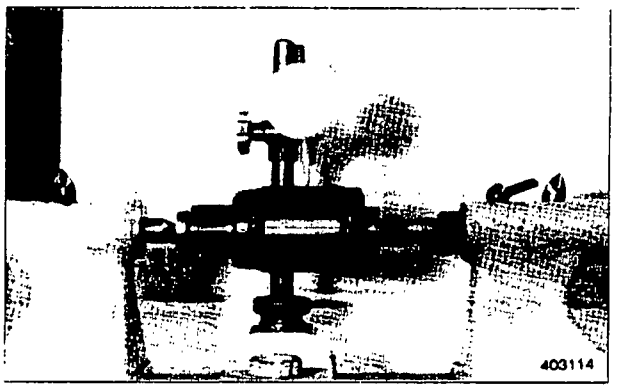
Armature

(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

Item	Assembly Standard
Armature shaft runout	0.05



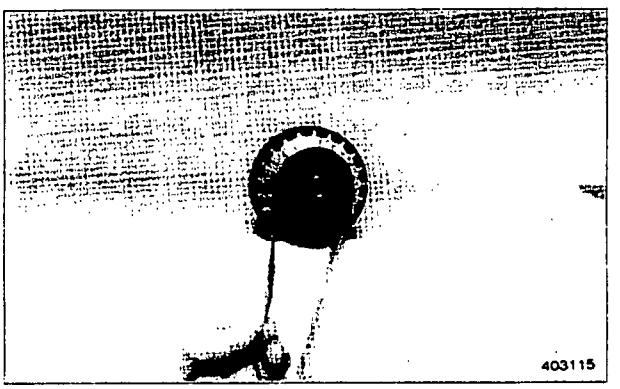
(2) Inspecting the commutator

(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

Item	Assembly Standard	Service Limit
Commutator runout	0.015	0.100

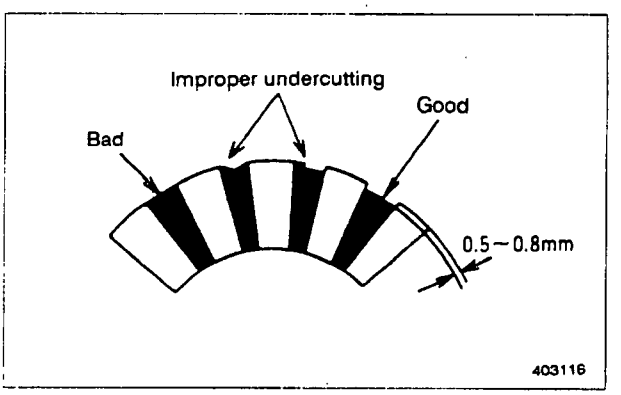


(b) Measuring the mica depth

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

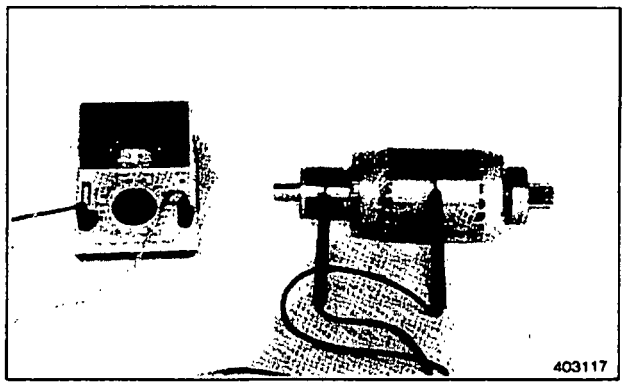
Item	Assembly Standard	Repair Limit
Commutator mica depth	0.5-0.8	0.2



(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.

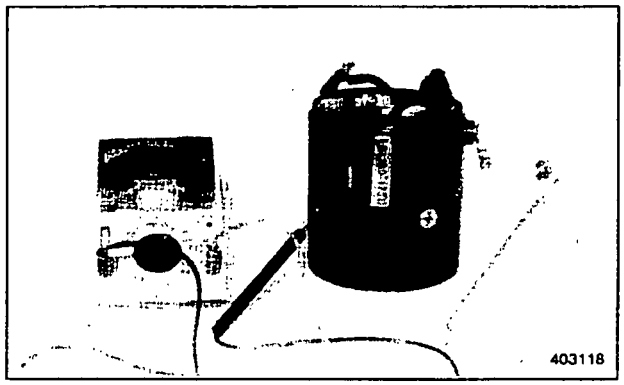
(b) If there is continuity between the commutator and shaft, replace the armature.



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.



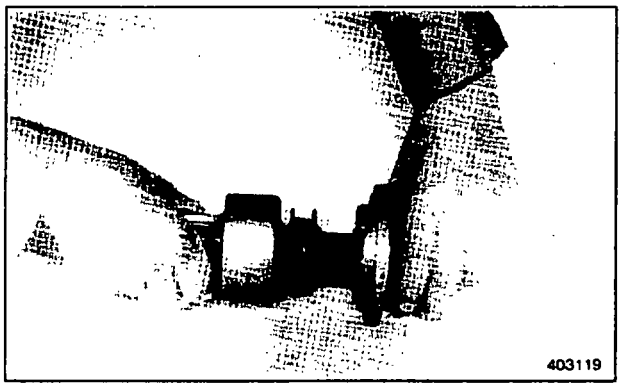
Overruning Clutch

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.

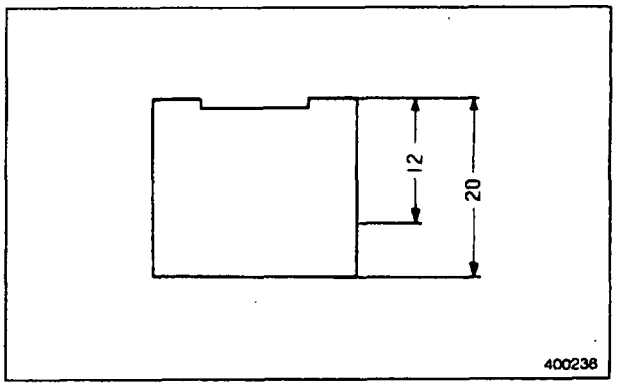


Brushes

(1) Inspecting for wear.

Unit: mm

Item	Assembly Standard	Service Limit
Brush height	20	12



(2) Testing brush spring tension

Unit: kgf

Item	Assembly Standard
Brush spring tension	4.0-5.0

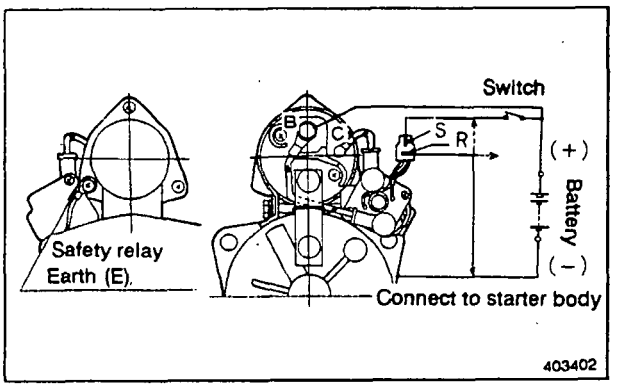
Safety Switch

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.

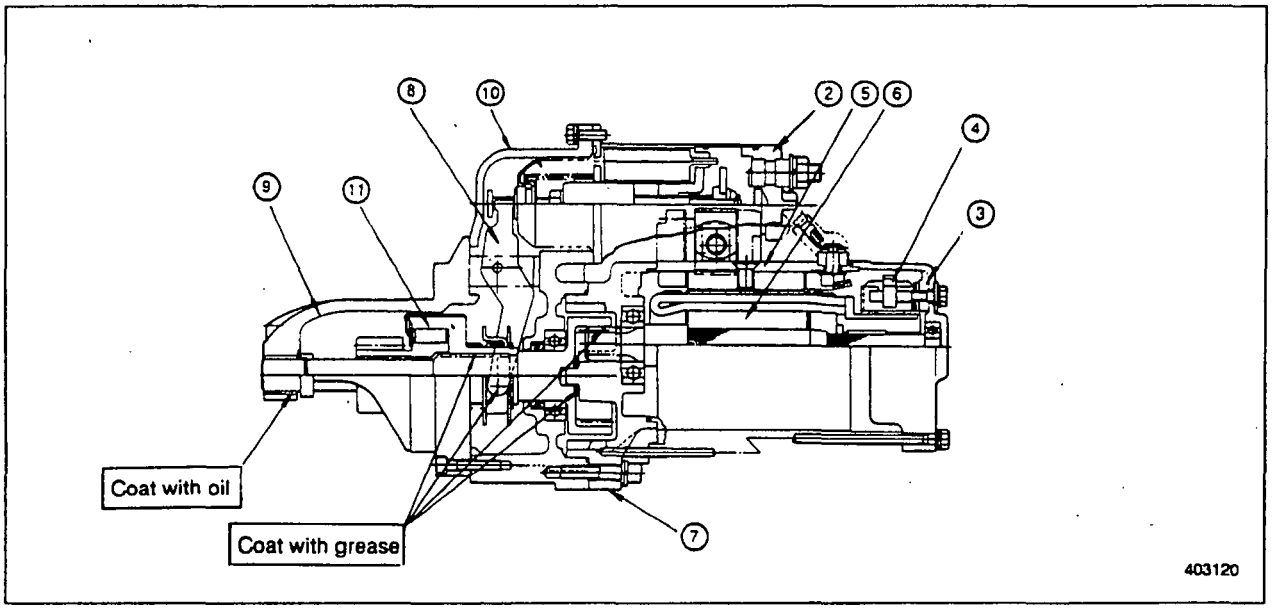


CAUTION!

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

2.3 Reassembly

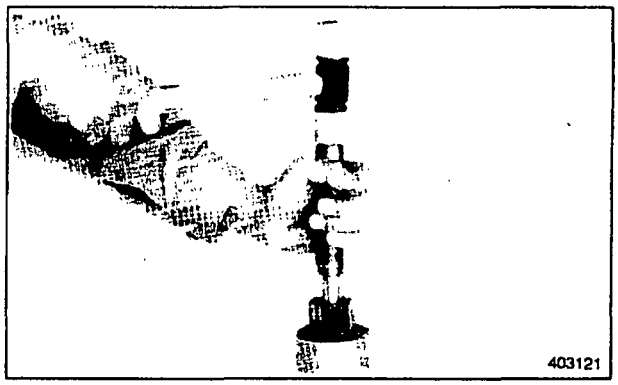
Reassembly Order



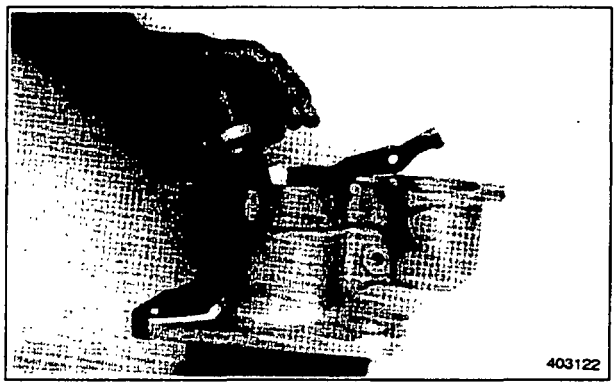
Reassembly Sequence

(10) → (9) → (11) → (8) → (7) → (6) → (5) → (4) → (3) → (2) → (1)

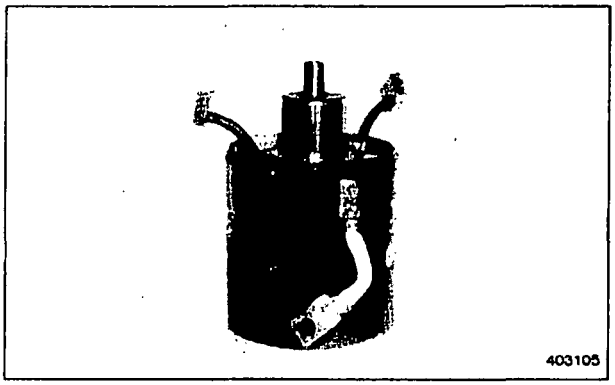
(1) Install the center bracket, overrunning clutch, and pinion stopper to the pinion shaft. Insert the shaft in position by tapping it with a plastic hammer.



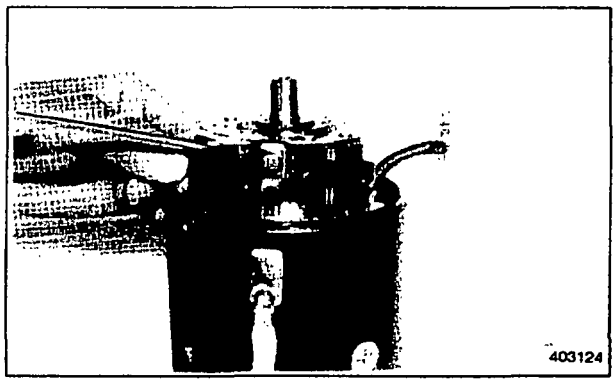
(2) Install the shift lever and pinion shaft to the front bracket by aligning the matching mark on the shift lever.



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

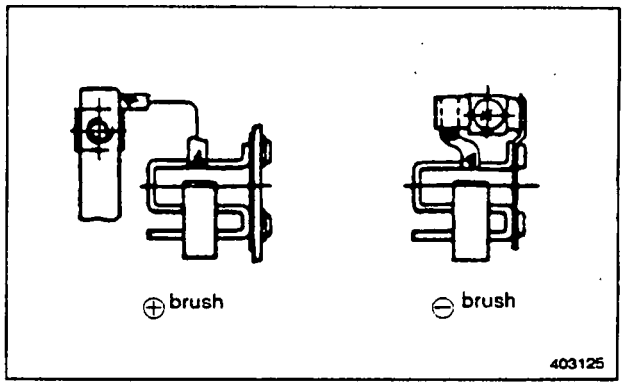


(4) Install the brushes and brush holders.

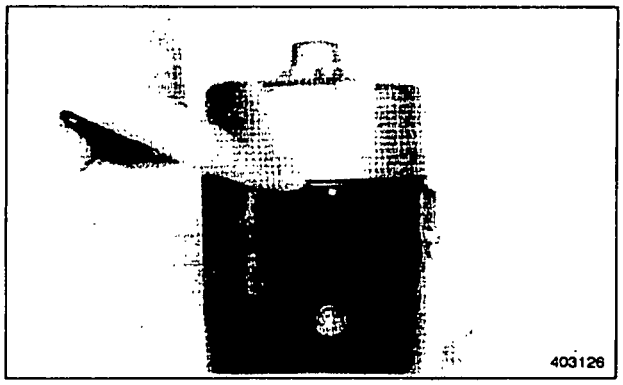


NOTE

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.

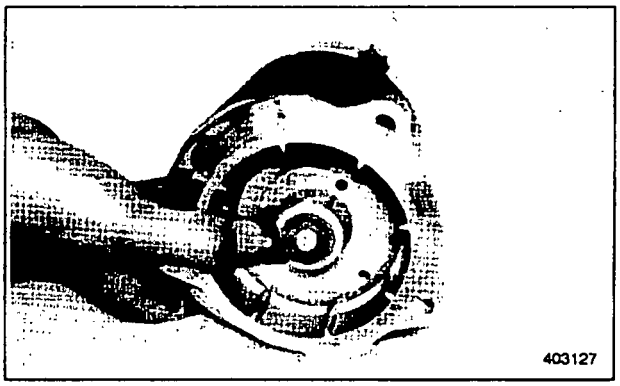


(6) Measure the end play of the armature. If the end play exceeds the assembly standard, adjust it on the rear side.

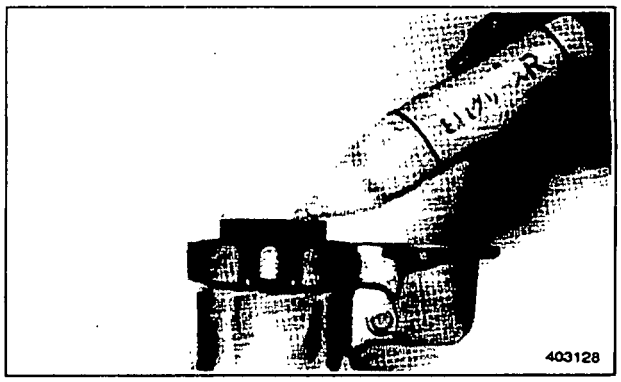
Test the motor to make sure that the voltage is below 24 volts and the current below 90 amperes.

Unit: mm

Item	Assembly Standard
Armature end play	0.2-0.6



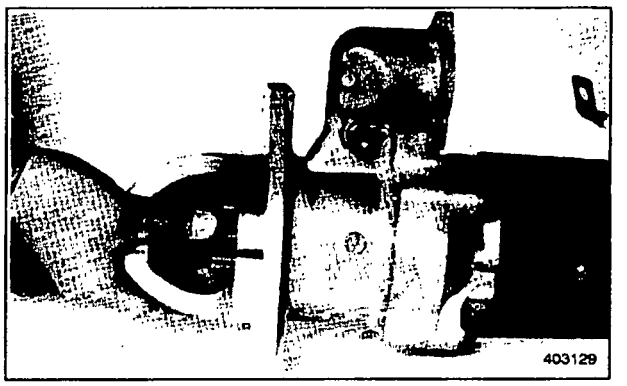
(7) Liberally coat the internal gear with grease, then install the pinion shaft to the gear.



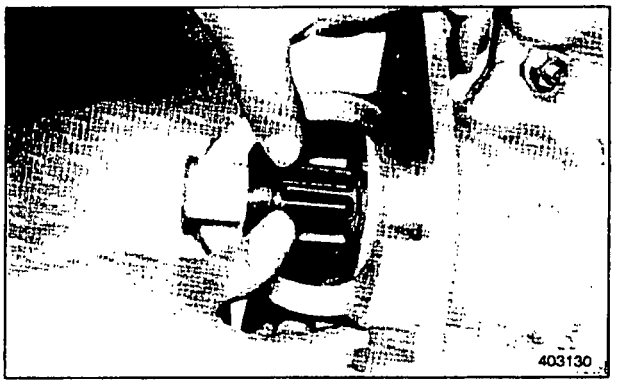
(8) Measure the end play of the pinion shaft. If the end play exceeds the assembly standard, adjust it on the internal gear side.

Unit: mm

Item	Assembly Standard
Pinion shaft end play	0.2-0.6

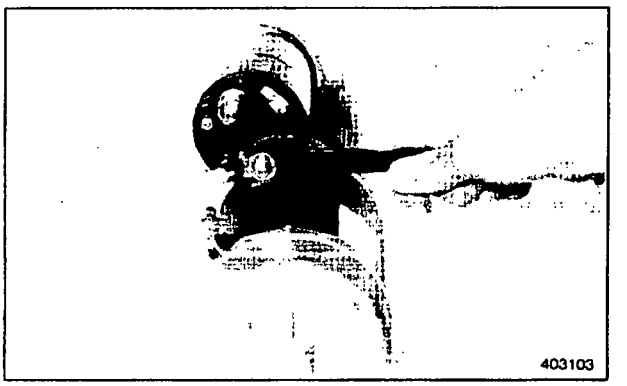


(9) Install the magnetic switch. Apply a voltage of 24 volts between the C and E terminals. Connect the lead wire and energize the circuit between the M and E terminals (within 1 second). After the pinion has shifted, measure how much the pinion returns. If the measurement is not 1.5 to 5 mm (0.06 to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



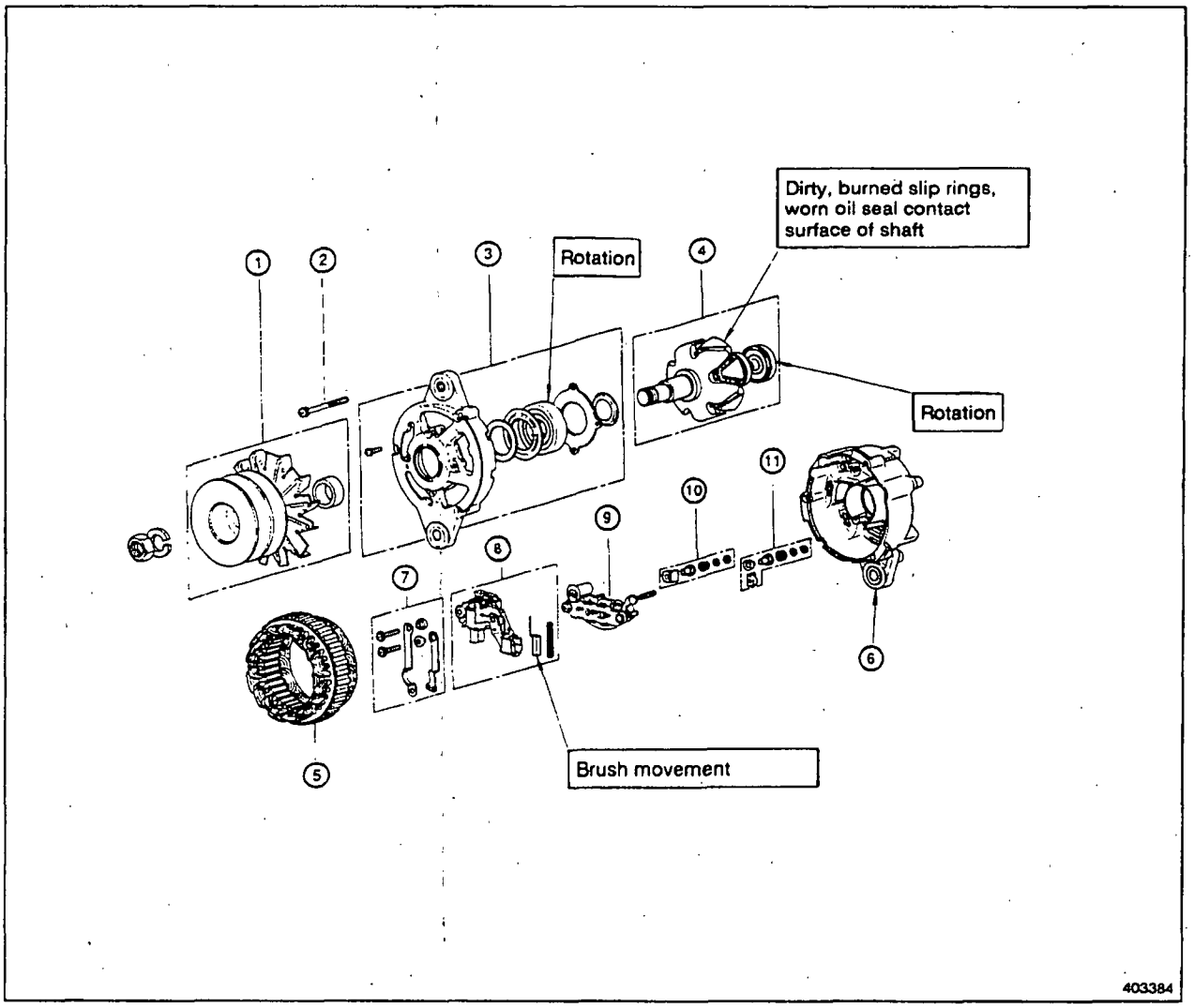
(10) Secure the lead wire.

(11) Install the safety switch.



3. The Alternator

3.1 Disassembly



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

NOTE

(a) To prevent the diode from overheating when you remove the solder on the stator coil lead wire, cut the diode lead wire with radio cutting pliers.

(b) Pre-heat the rear bracket bearing with a soldering iron or similar tool before disassembly.

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

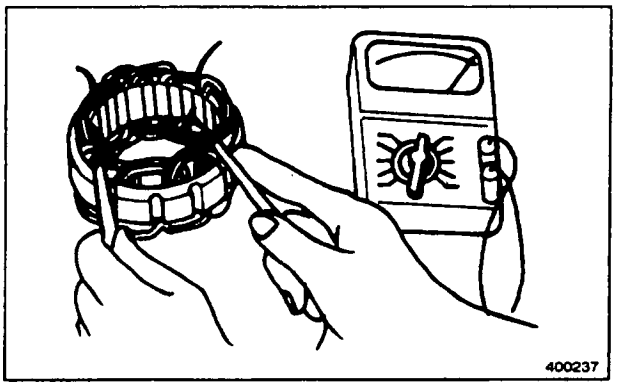
If there is no continuity between the slip rings, replace the rotor.

(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

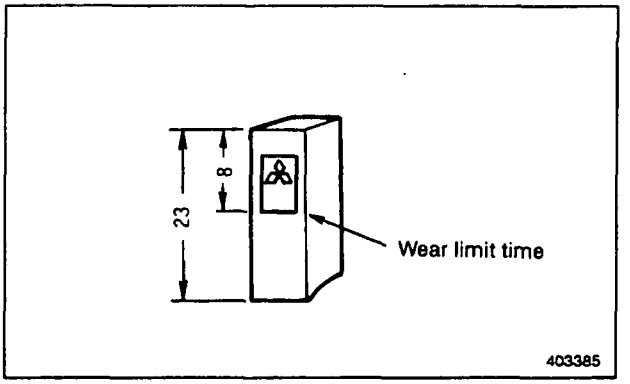
Item	Assembly Standard	Service Limit
Slip ring outside diameter	41 ± 0.2	40.6

(3) Brushes and brush springs

(a) Brush wear

Unit: mm

Item	Assembly Standard	Service Limit
Brush height	23	8



(b) Brush spring tension

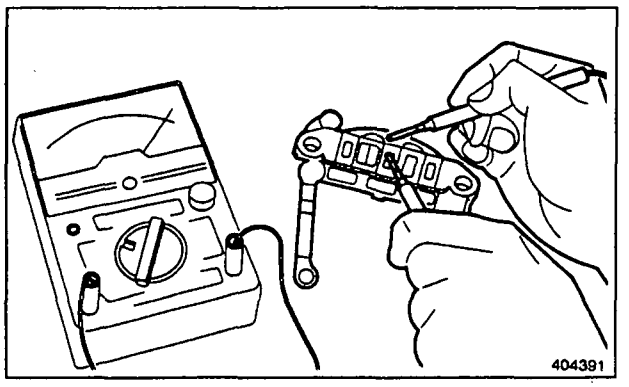
Unit: gf

Item	Assembly Standard	Service Limit
Brush spring tension	380 ± 60	200

(4) Diodes

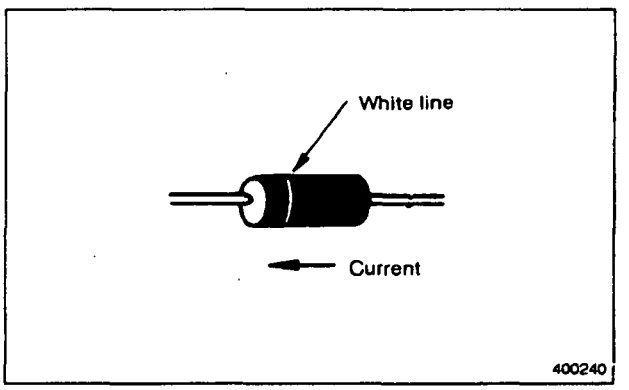
(a) Main diode

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

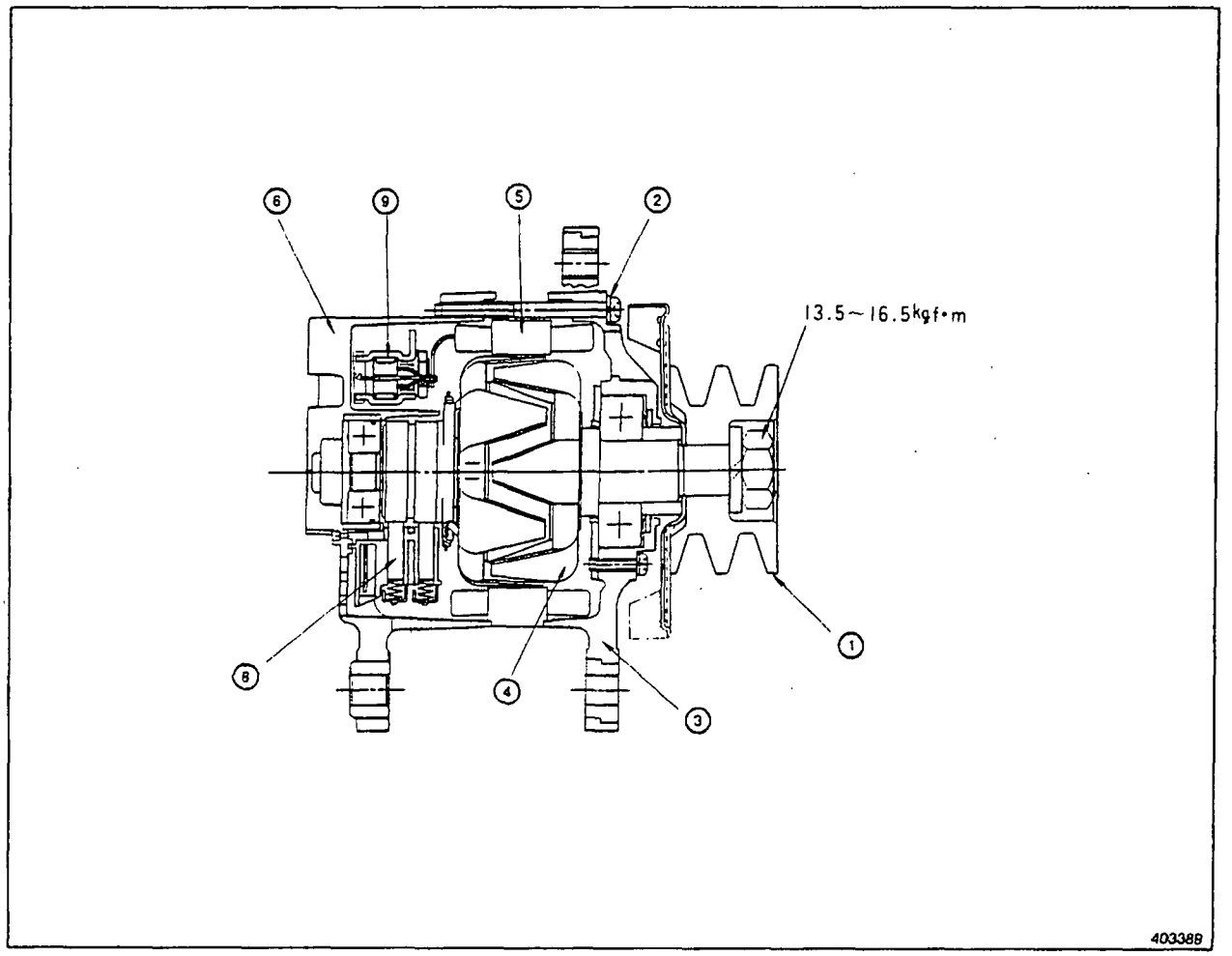


(b) Auxiliary diode

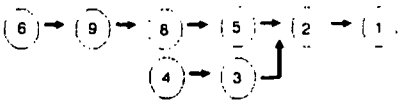
If the diode is short or open circuited, replace the heat sink assembly.



3.3 Reassembly

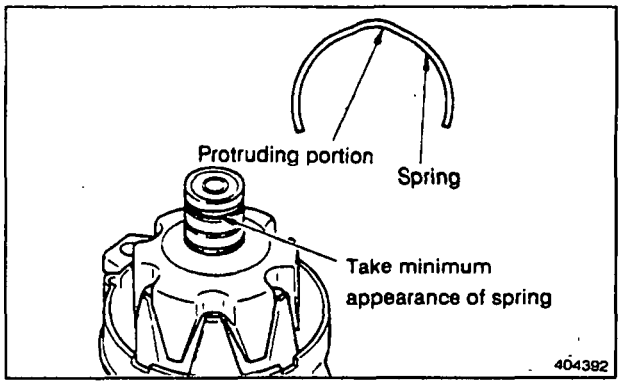


Reassembling Sequence



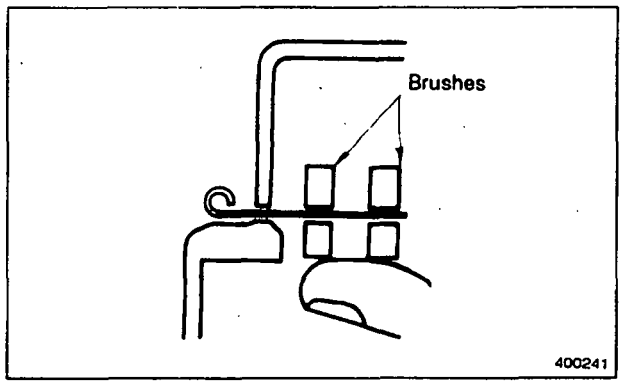
(1) Setting the springs

When setting the baffle spring in the off-center groove of the rear bearing circumference, be sure to move the protruding part to the deepest part of the groove.



(2) 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.



(3) Tightening the pulley

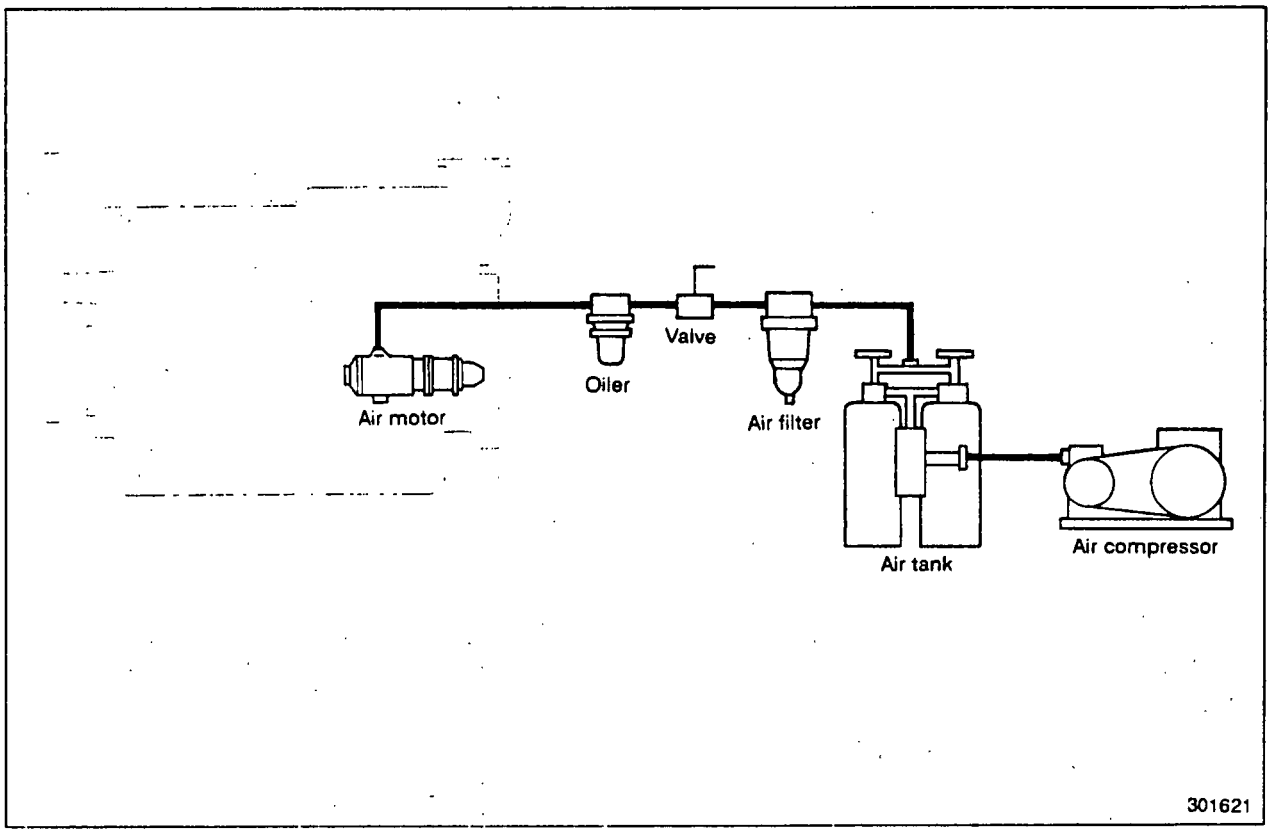
Tighten the pulley to the specified torque.

Tightening torque: 13.5-16.5 kgf.m

13. AIR START SYSTEMS

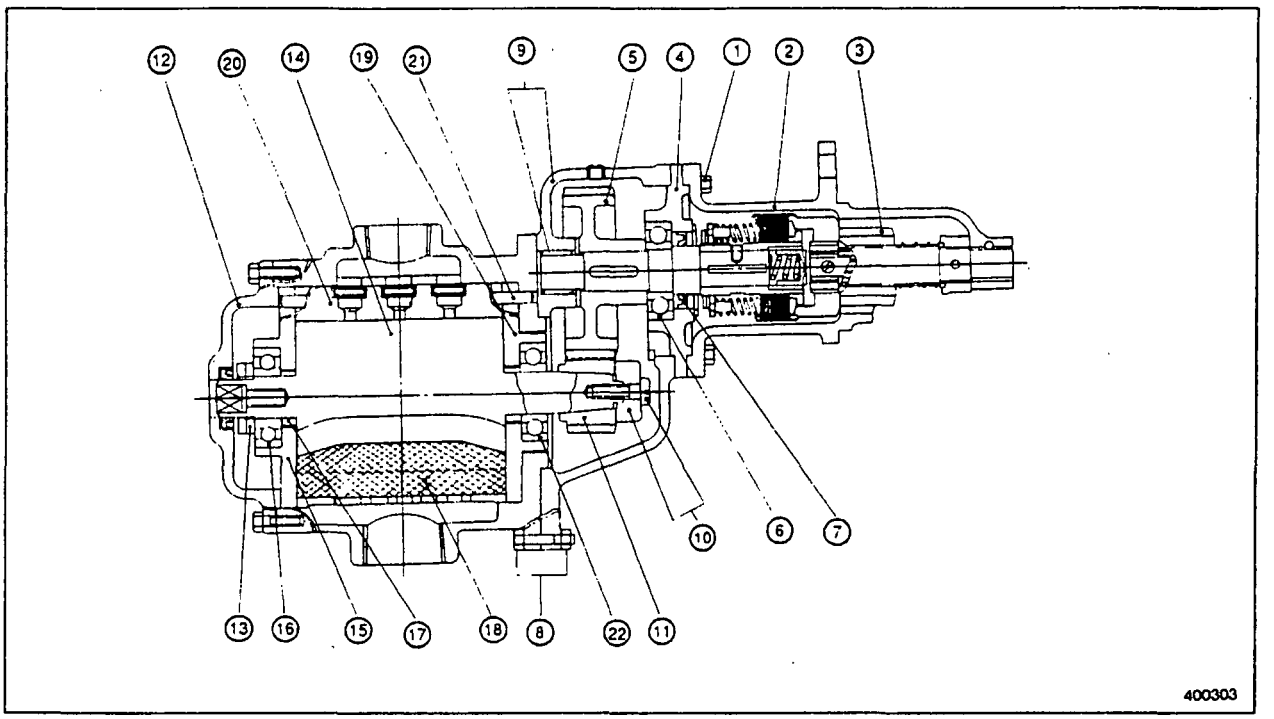
13. AIR START SYSTEMS

1. Air Motor System



2. Air Motor

2.1 Disassembly and Reassembly



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

NOTE

Do not remove the rotor adjusting ring from the rotor.

Reassembly Sequence

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

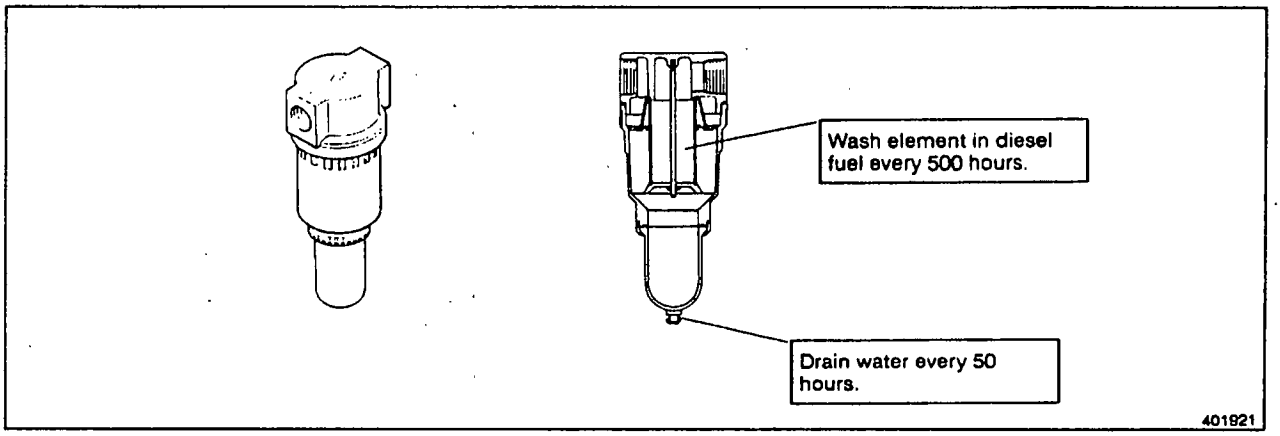
(4) → (6) → (7) → (3) → (5) → (2) → (1)

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.

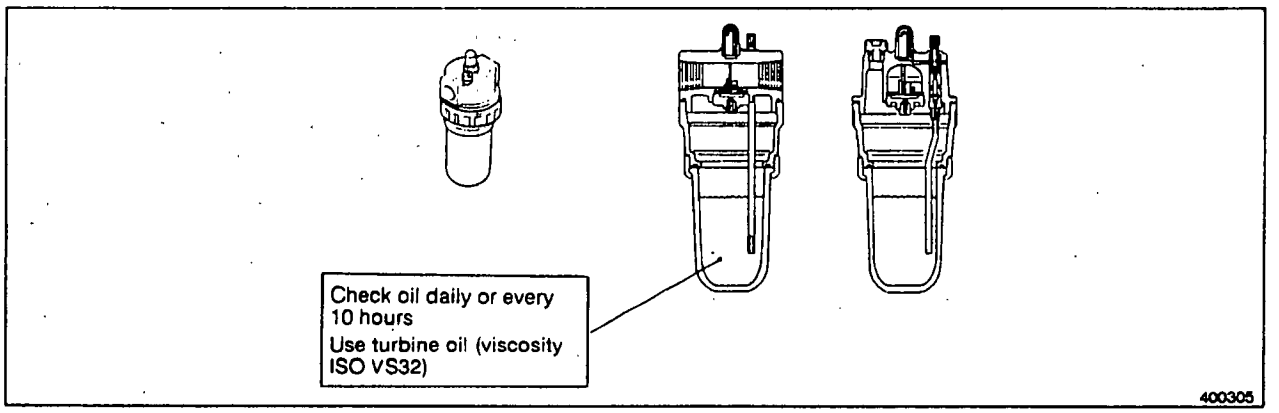
3. Air Filter

Inspection



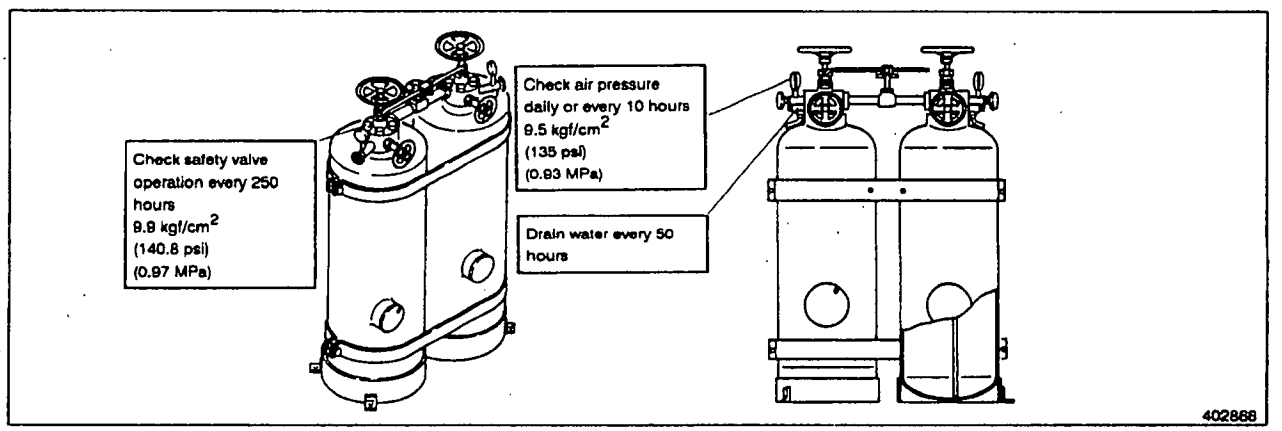
4. Oiler

Inspection

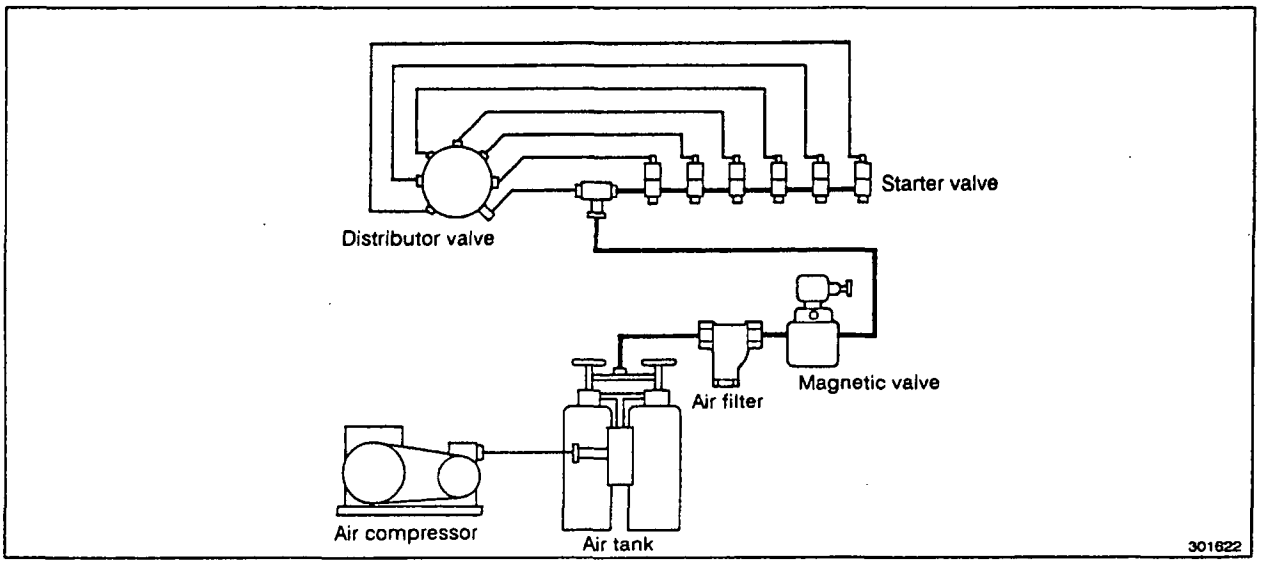


5. Air Tank (For Air Motor System)

Inspection

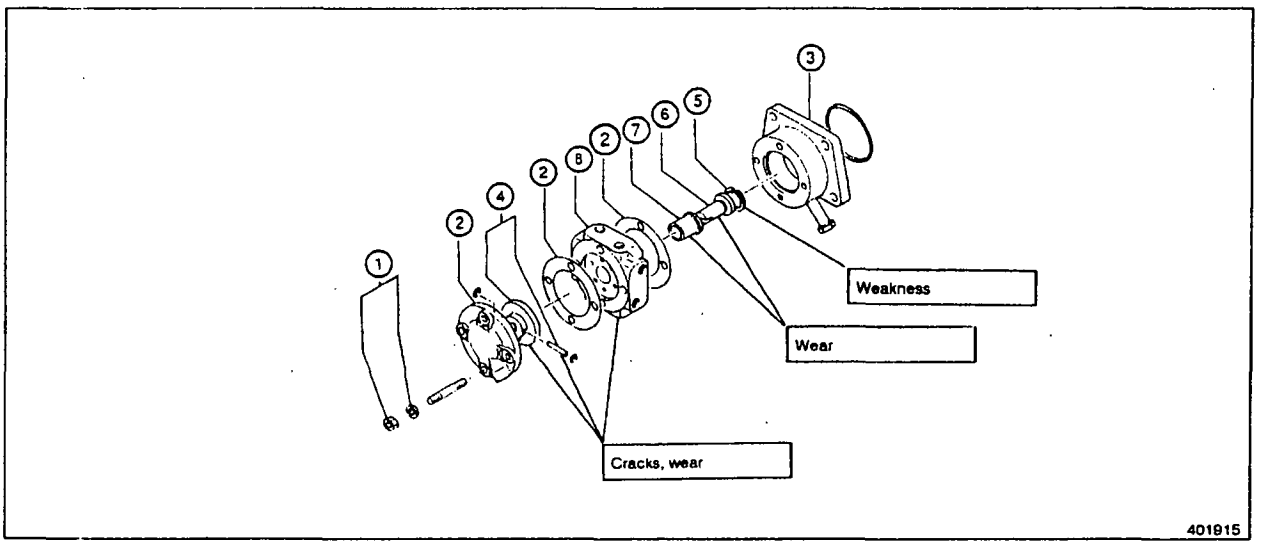


6. Direct Air Start System



7. Distributor Valve

7.1 Disassembly



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

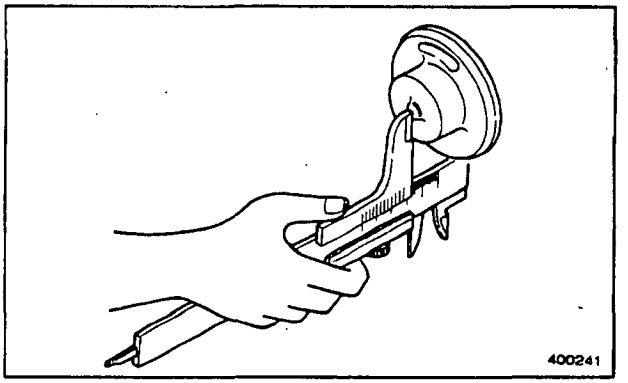
7.2 Inspection

(1) Measuring distributor valve height

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

Unit: mm

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

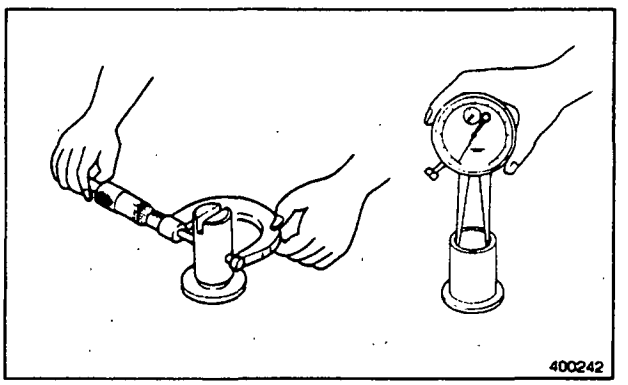


(2) Measuring distributor shaft clearance in the bushing

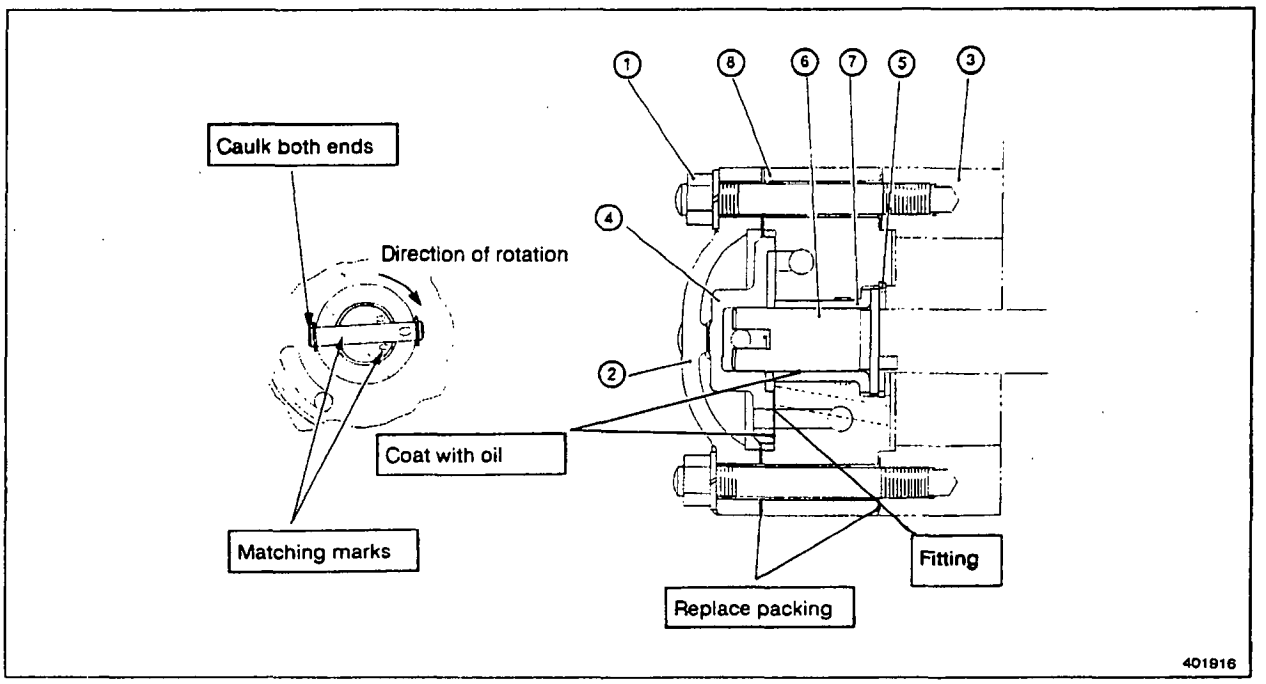
Measure the diameter of the shaft and the inside diameter of the bushing to determine the clearance. If the clearance exceeds the service limit, replace the bushing.

Unit: mm

Item	Standard Clearance	Repair Limit
Distributor shaft clearance in bushing	0.050-0.091	0.300



7.3 Reassembly

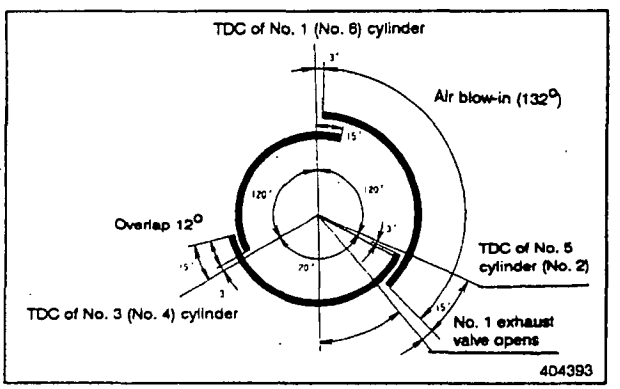


Reassembly Sequence

(8) → (7) → (6) → (5) → (4) → (3) → (2) → (1)

NOTE

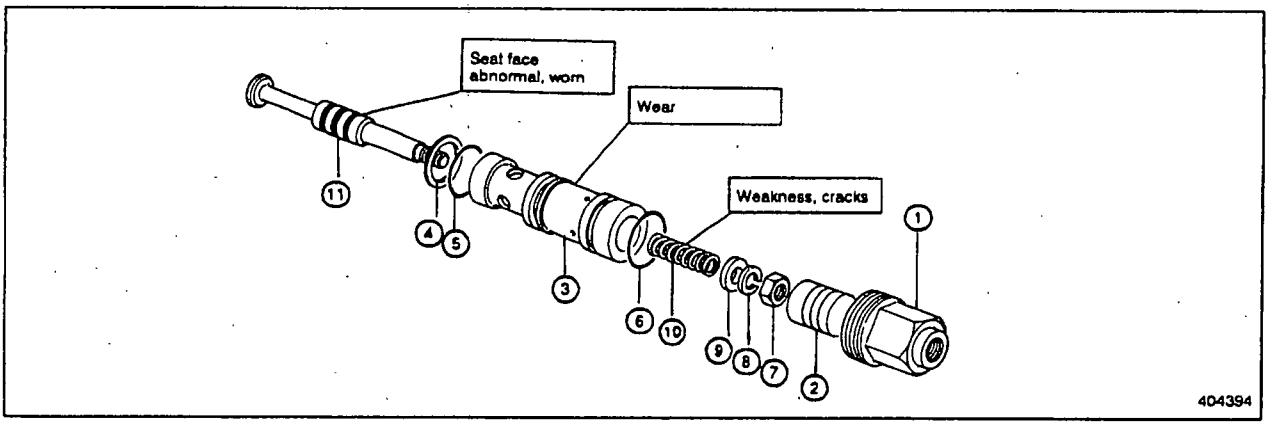
When reassembling and installing the distributor valve, be sure to align the matching marks. If the marks are not aligned, the valve timing (at which air is blown into the cylinders) could be off by 360°, resulting in a failure to start the engine.



Crank angle

8. Starter Valves

8.1 Disassembly

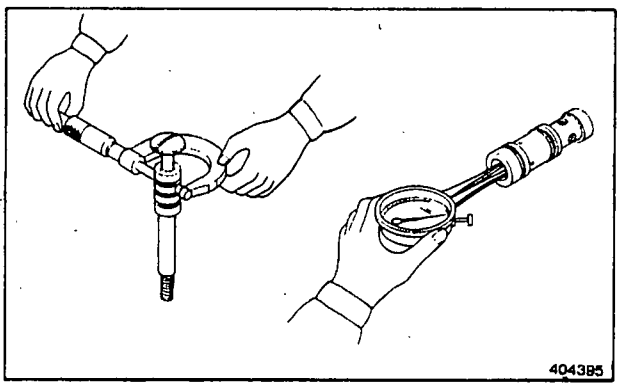


①	Eye bolt	⑤	Piston	⑨	Starter valve
②	Nut	⑥	Gasket, main air pipe	⑩	Starter valve guide
③	Connector	⑦	Retainer, cotter	⑪	O-ring
④	Cap nut	⑧	Valve spring, retainer		

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.

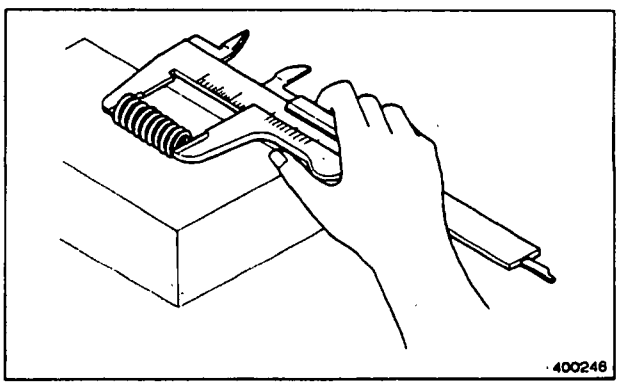


Unit: mm

Item	Nominal Value	Standard Clearance	Service Limit
Starter valve clearance in guide	ϕ15	0.016-0.052	0.100

(2) Measuring valve spring length

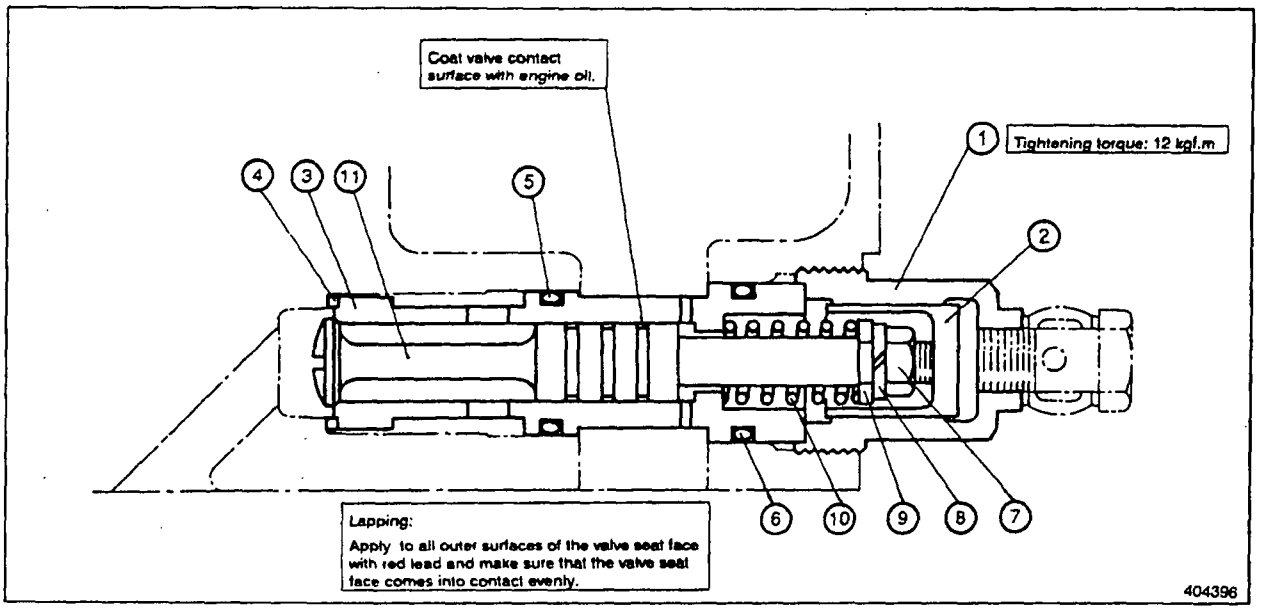
Use calipers to measure the free length. If the free length exceeds the service limit, replace the spring.



Unit: mm

Item	Assembly Standard	Service Limit
Valve spring free length	36	34

8.3 Reassembly

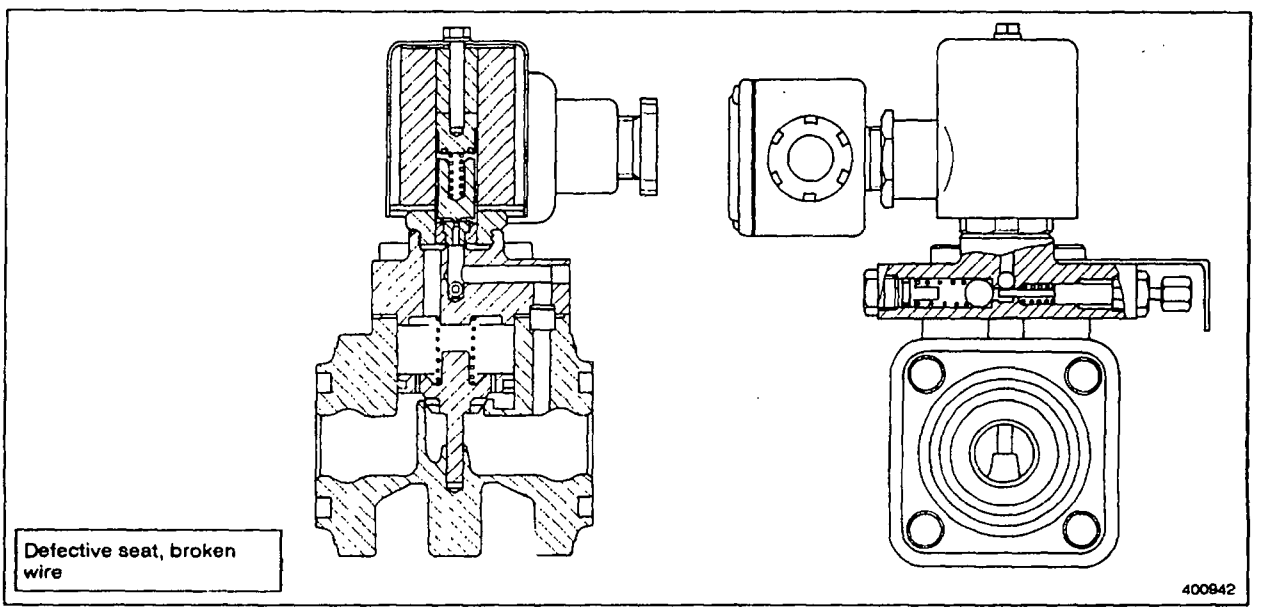


Reassembly Sequence

(3) → (11) → (10) → (9) → (8) → (7) → (6) → (5) → (4) → (2) → (1)

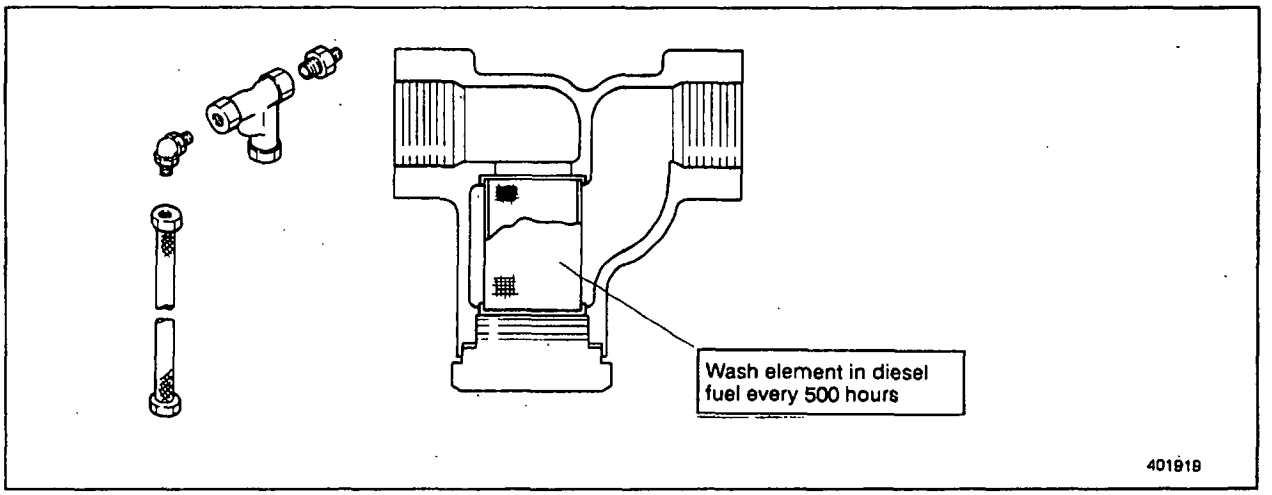
9. Magnetic Valve

Inspection



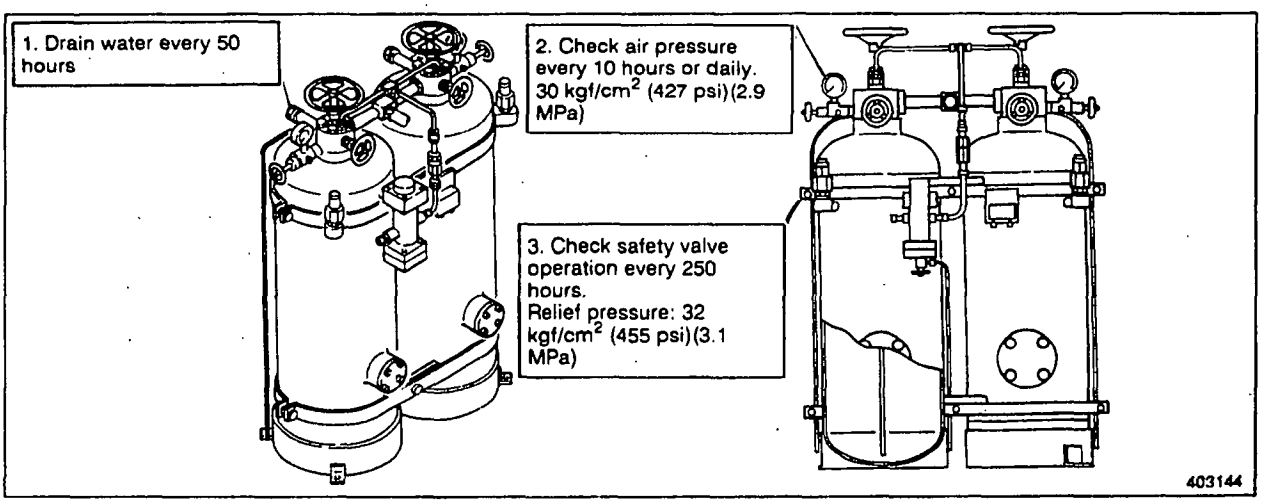
10. Air Filter

Inspection



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

Inspection



14. WORKSHOP TIPS

14. WORKSHOP TIPS

1. Precautions for Disassembly and Reassembly

1.1 Oil Seals

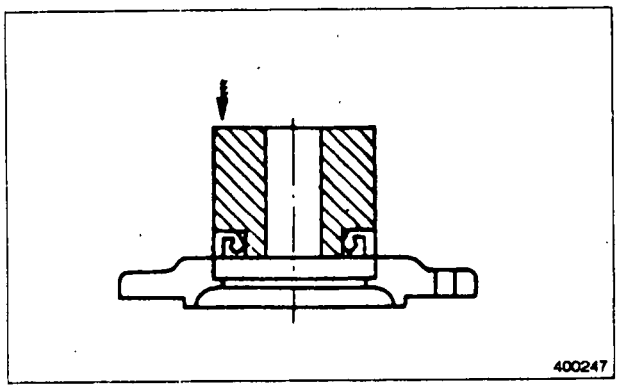
When installing oil seals, carefully observe the following points.

(1) 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.

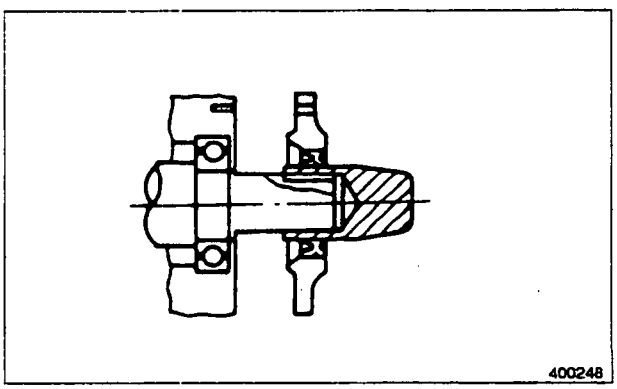


Oil seal driver

(2) Driving oil seals onto shafts

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

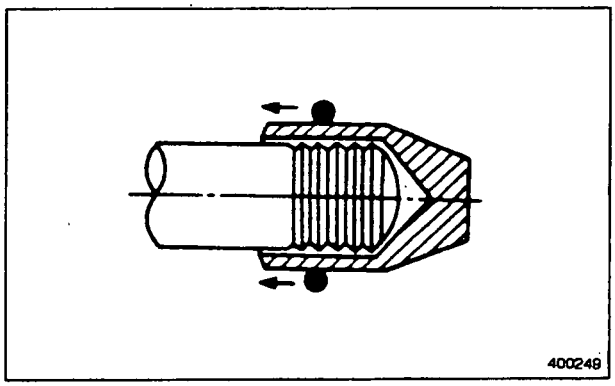
(b) Use an oil seal guide of the type shown when driving the oil seal over the stepped portion, splines, threads, or key way to prevent damage to the oil seal lip.



Oil seal guide

1.2 O-Rings

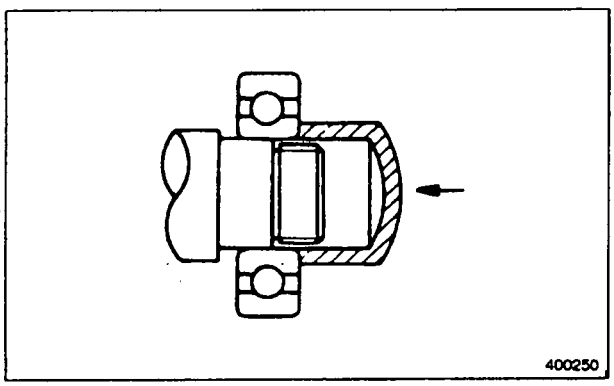
Use an O-ring guide to install an O-ring over stepped parts, splines, threads, or key way to prevent damage to the ring. Apply a thin coat of grease to the O-ring before installation.



O-ring guide

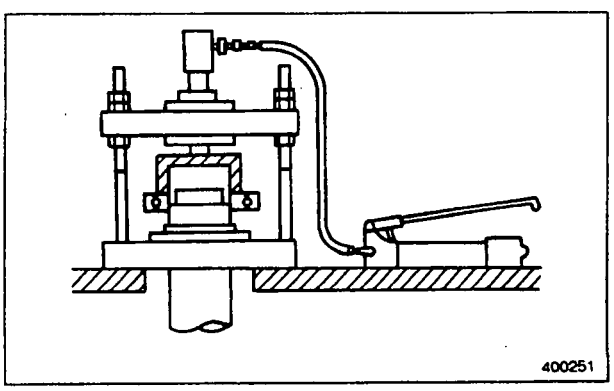
1.3 Bearings

(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

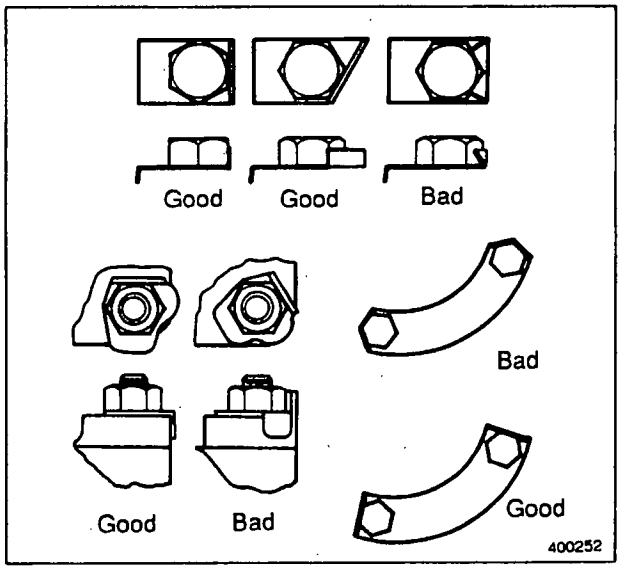
(2) Whenever possible, use a press to minimize shock to the bearing and to assure proper installation.



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.