CATERPILLAR®

99709-68120

Service Manual

6D16 Diesel Engine

DP80
DP90
DP100
DP115
DP135
DP150

For use with Chassis & Mast
Service Manual

6D16

diesel engine

Shop Manual

FOREWORD

This Shop Manual is published for the information and guidance of personnel responsible for maintenance of 6D16 diesel engine, and includes procedures for adjustment and maintenance services.
We earnestly look forward to seeing that this manual is made full use of in order to perform correct service with no wastage.

For more details, please consult your nearest authorized Caterpillar® dealer or distributor.
Kindly note that the specifications and maintenance service figures are subject to change without prior notice in line with improvement which will be effected from time to time in the future.

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HOW TO READ THIS MANUAL

How This Manual Is Compiled

- This manual is compiled by classifying various systems into certain groups.
- Each group contains specifications; troubleshooting; maintenance service standards; ❶ tightening torque; ⚠ lubricant, fluid and sealant; 🔧 special tools; and service procedure.
- Page enumeration is independent by every group where first page is always 1.

Group No.	Group denomination	Contents
00	General	General specifications, engine No. and name plate, precautions for maintenance operations, table of standard tightening torques
11	Engine	Engine body
12	Lubrication	Lubrication system
13	Fuel and engine control	Fuel system
14	Cooling	Cooling system
15	Intake and exhaust	Intake and exhaust system, intercooler
54	Electrical system	Alternator, starter, preheating system, engine start system
61	Special equipment	Air compressor

General Explanation of This Manual

● **Specifications**

Particulars relative to maintenance service are made.

● **Structure and operation**

(1) Regarding conventional equipment, descriptions are made in brief.

(2) Regarding new equipment, descriptions of system and operating condition are made in detail.

● **Troubleshooting**

Symptoms of troubles and possible causes are described comparatively.

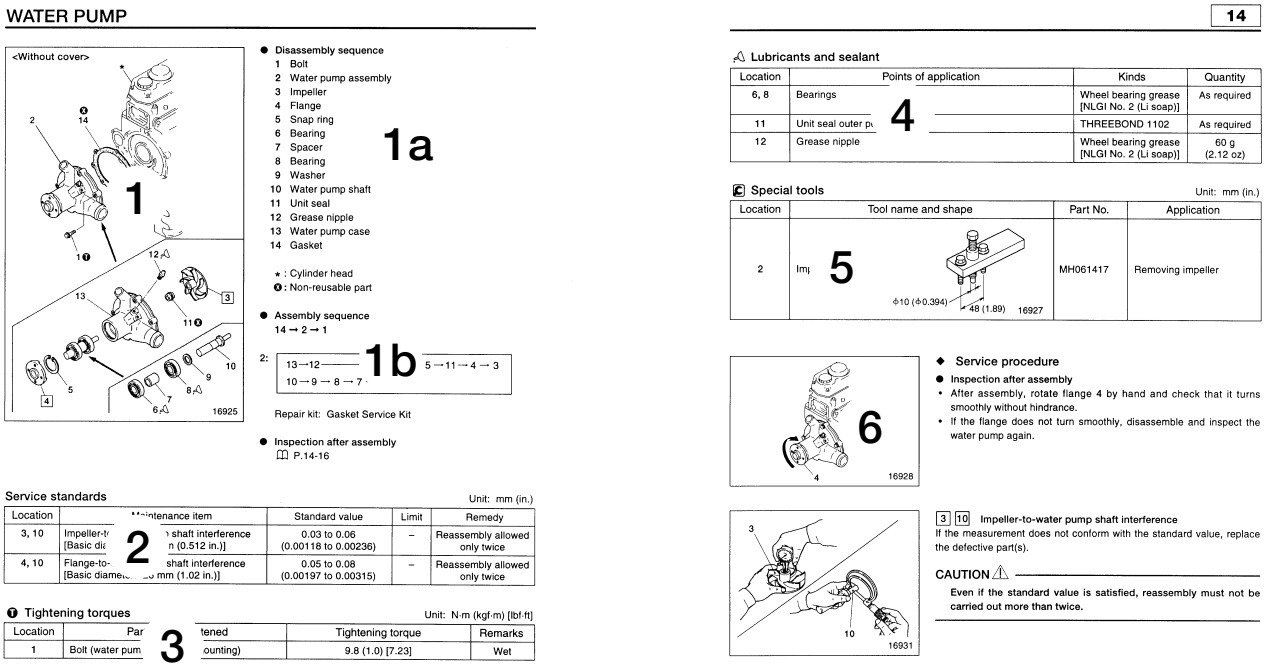
● **Inspection and adjustment mounted in vehicle**

Descriptions are made regarding inspection and adjustment of units mounted in vehicle.

● **Service procedure**

In principle, an explanation is given at the spread title page so that the service procedure can be understood. Servicing points are explained as a supplementary explanation.

Regarding the design of this manual

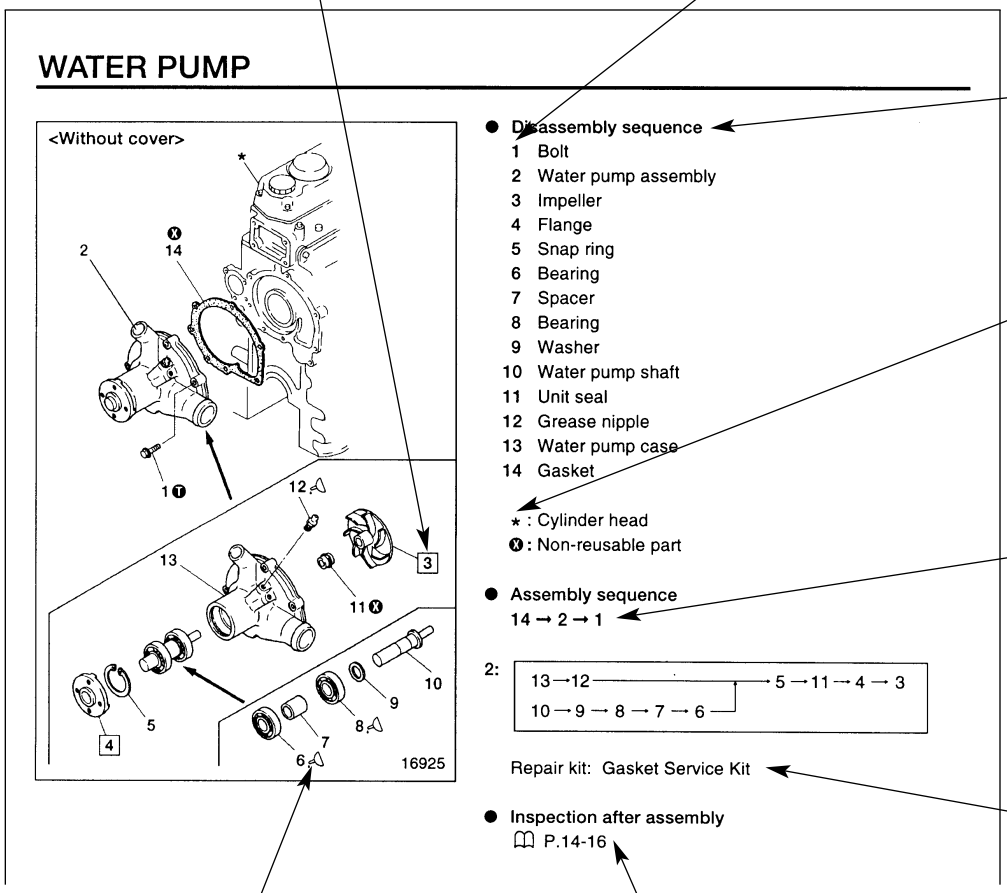


1. ..... Illustration for disassembly and assembly or removal and installation: 3-D exploded view of component parts is displayed.
   1a. ..... Names of parts show an example of the disassembly (removal) sequence.
   1b. ..... When the assembly (installation) sequence differs from the disassembly (removal) sequence, an example of the assembly (installation) sequence is shown.
2. ..... Service standards are shown collectively, classified by location.
3. ..... Tightening torques are shown collectively, classified by location.
4. ..... Points of lubricant, fluid and sealant application are shown collectively, classified by location.
5. ..... Special tools to be used are shown collectively, classified by location.
6. ..... When it is considered hard to understand the service procedure, just by the foregoing description, a supplementary description of the service procedure is given.

1. Illustration for disassembly and assembly or removal and installation

This shows that the appropriate service procedure is described in the text.

This shows the key No. of the part. In the text, this No. is referred to uniformly throughout.



This shows an example of the disassembly (removal) sequence.

No service procedure is referred to in this section, but the item can be an objective of various procedures.

This is shown when the assembly (installation) sequence is not the reverse of the disassembly (removal) sequence.

This shows that a repair kit is available.

Meaning of symbols

- Ⓣ : shows that the tightening torque is specified.
- : shows that application of lubricant, fluid or sealant is required.
- : shows that the part should not be reused.

This shows that the service procedure is described in another section.

- P○○-○○
  : shows reference page within the same group.
- Gr○○
  : shows reference group within the same book.

2. Service standards table

Only the relevant service standards are shown.

Service standards

Unit: mm (in.)

Location	Maintenance item	Standard value	Limit	Remedy
3, 10	Impeller-to-water pump shaft interference [Basic diameter: 13 mm (0.512 in.)]	0.03 to 0.06 (0.00118 to 0.00236)	–	Reassembly allowed only twice
4, 10	Flange-to-water pump shaft interference [Basic diameter: 26 mm (1.02 in.)]	0.05 to 0.08 (0.00197 to 0.00315)	–	Reassembly allowed only twice

This shows the key No. of the relevant part.

3. Tightening torque table

This shows specified tightening torque.

Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
1	Bolt (water pump assembly mounting)	9.8 (1.0) [7.23]	Wet

This shows the key No. of the relevant part.

This shows that the item is to be tightened wet.

4. Lubricants and sealant table

Only the relevant lubricants and sealant are shown.

This shows the application point.

Lubricants and sealant

Location	Points of application	Kinds	Quantity
6, 8	Bearings	Wheel bearing grease [NLGI No. 2 (Li soap)]	As required
11	Unit seal outer periphery	THREEBOND 1102	As required
12	Grease nipple	Wheel bearing grease [NLGI No. 2 (Li soap)]	60 g (2.12 oz)

This shows the key No. of the relevant part.

This shows the specified brand.

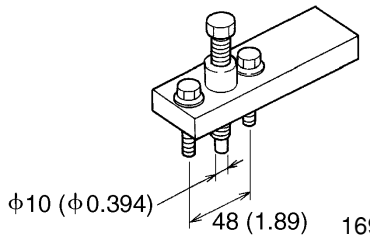
5. Special tools table

Only the relevant special tools are shown.

Purpose of special tools is shown.

Special tools

Unit: mm (in.)

Location	Tool name and shape	Part No.	Application
2	Impeller Puller 	MH061417	Removing impeller

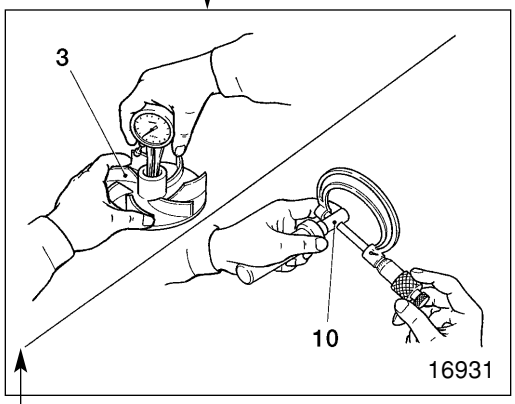
This shows the key No. of the relevant part.

Quote this number when placing an order for the part.

6. Service procedure

This indicates a special service tool.

This shows the key No. of the relevant part.



3 10 **Impeller-to-water pump shaft interference**

If the measurement does not conform with the standard value, replace the defective part(s).

CAUTION ⚠

Even if the standard value is satisfied, reassembly must not be carried out more than twice.

The key No. referred to in the text is always the same as the key No. shown in the illustration.

Servicing procedures of disassembly (removal), assembly (installation), inspection, adjustment, etc. are shown collectively.

Terms and Units

The terms and units in this manual are defined as follows.

- This service manual contains important cautionary instructions and supplementary information under the following four headings which identify the nature of the instructions and information:

DANGER ⚠ — Precautions that should be taken in handling potentially dangerous substances such as battery fluid and coolant additives.

WARNING ⚠ — Precautionary instructions, which, if not observed, could result in serious injury or death.

CAUTION ⚠ — Precautionary instructions, which, if not observed, could result in damage to or destruction of equipment or parts.

NOTE — Suggestions or supplementary information for more efficient use of equipment or a better understanding.

- **Front and rear**

The terms “front” is the fan side and “rear” the flywheels side of the engine.

- **Left and right**

The terms “right” and “left” shall be used to indicate the side as viewed from the flywheel side of the engine.

- **Terms of service standards**

(1) Standard value
Standard value dimensions in designs indicating: the design dimensions of individual parts, the standard clearance between two parts when assembled, and the standard value for an assembly part, as the case may be.

(2) Limit
When the value of a part exceeds this, it is no longer serviceable in respect of performance and strength and must be replaced or repaired.

- **Tightening torque**

Excessive or insufficient tightening torque has particular importance in respect of performance. Accordingly, tightening torque is specified in locations that are to be tightened.
Where there is no specified figure for tightening torque, follow the table covering standard tightening torques.
When the item is to be tightened in a wet state, wet is indicated. Where there is no indication, read it as dry, and tighten at specified torque.

- **Unit**

Length, weight, surface area and capacity are in SI units with foot-pound units are given in brackets.
Tightening torques and other parameters are given in SI units with metric and foot-pound units added in brackets ( ) and [ ].

Example: 390 N·m (40 kgf·m) [289 lbf·ft]
- 390 N·m — SI unit
- (40 kgf·m) — Metric unit
- [289 lbf·ft] — Foot-pound unit

Temperatures are given in degrees Celsius with degrees Fahrenheit given brackets.
For the conversion into the foot-pound system, refer to the following conversion table.

Unit	Sign of SI unit	Sign of foot-pound unit	Conversion rate
Mass quantity of matter	kg g	lb oz	1 kg = 2.2046 lb 1 g = 0.035274 oz
Dimension	m mm	ft. in.	1 m = 3.2808 ft. 1 mm = 0.03937 in.
Capacity	L cm^3 cm^3	gal. oz cu.in.	1 L = 0.2642 gal. (U.S.) 1 L = 0.220 gal. (Imp.) 1 cm^3 = 0.033814 oz (U.S.) 1 cm^3 = 0.035195 oz (Imp.) 1 cm^3 = 0.061023 cu.in.
Force	N (Newton)	lbf	1 N = 0.2248 lbf 1 N = 0.10197 kgf
Pressure	kPa (kilopascal) MPa (megapascal)	psi	1 kPa = 0.0102 kgf/cm^2 1 kPa = 0.145 psi 1 kPa = 0.2953 in. Hg 1 MPa = 10.197 kgf/cm^2 1 MPa = 145.0546 psi
Stress	N/cm^2	psi	1 N/cm^2 = 1.45 psi
Moment of force	N·m	lbf.ft	1 N·m = 0.7375 lbf.ft 1 N·m = 0.10197 kgf·m
Output	kW (kilowatt)	HP	1 kW = 1.34 HP
Temperature	°C	°F	t°C = (1.8t°C + 32)°F

GROUP 00 GENERAL

GENERAL SPECIFICATIONS 2
ENGINE NUMBER AND NAME PLATE 3
PRECAUTIONS FOR MAINTENANCE OPERATION 4
TABLE OF STANDARD TIGHTENING TORQUES 12

GENERAL SPECIFICATIONS

Item		Specifications
Engine model		6D16
Type		6-cylinder in-line, water-cooled 4-cycle diesel
Combustion chamber type		Direct injection type
Valve mechanism		Overhead valve (OHV) type
Bore × Stroke	mm (in.)	118 × 115 (4.65 × 4.53)
Total displacement	cc (cu. in.)	7545 (460.4)
Compression ratio		17.5
Empty mass	kg (lb)*	500 (1.102)

* Empty mass as measured according to Mitsubishi Motors Corporation standard.

Engine Output

6D16	kW (HP)/rpm	98 (131)/2200

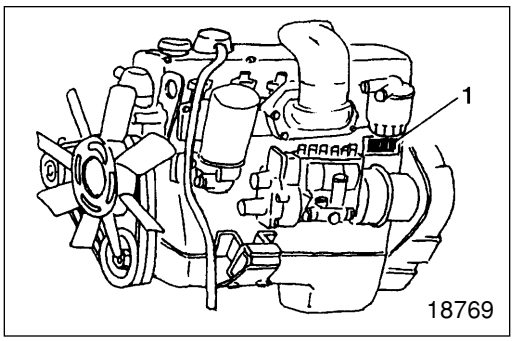
NOTE

The output (SAE, gross) is corrected to standard ambient conditions based on SAE J1349.

ENGINE NUMBER AND NAME PLATE

The serial number for engine is assigned to the respective engine in manufacturing sequence: every engine has its own number. This number is required for incidental inspection of the engine. Please do not fail to mention this number to the dealers when ordering spare parts.

Engine Number

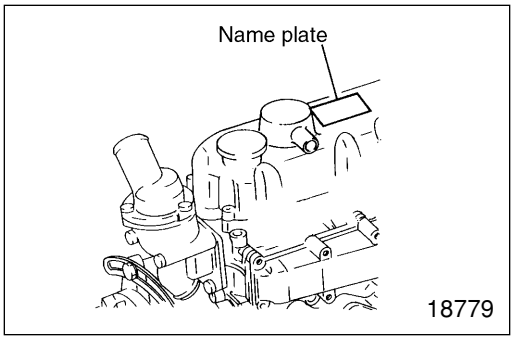


Engine number **1** is punch-marked on the left of the crankcase.

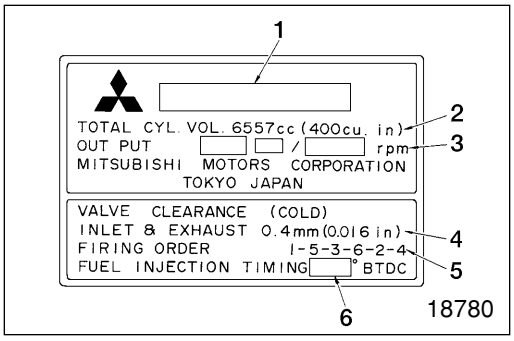
Example: 6D16–□□□□□□

- 6D16 – Engine model
- □□□□□□ – Engine number

Name Plate



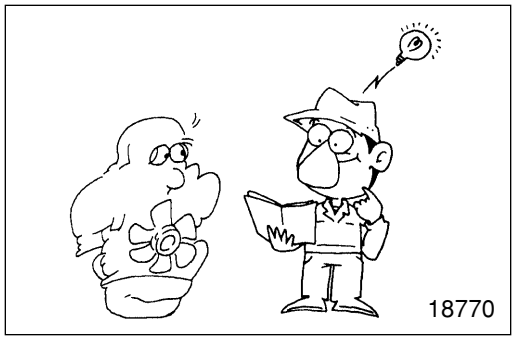
The name plate is attached to the portion shown in the illustration, and indicate the following items.



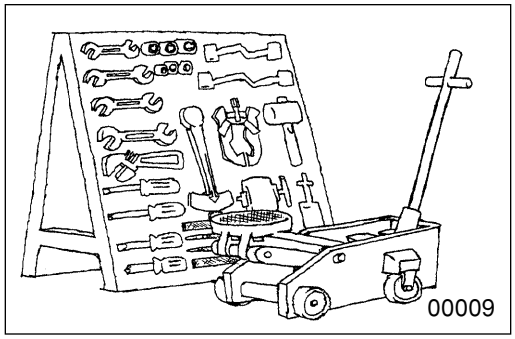
1. Engine model
2. Total displacement
3. Maximum output
4. Valve clearance
5. Firing order
6. Fuel injection timing

PRECAUTIONS FOR MAINTENANCE OPERATION

In order to determine the condition of the vehicle adequately, attend the vehicle beforehand to find and keep record of the accumulated hours, operating condition, what the customer's demand is, and other information that may be necessary.
Prepare the steps to be taken and perform efficient and wasteless maintenance procedure.



Determine where the fault exists and check for the cause to see whether removal or disassembly of the part is necessary. Then follow the procedure specified by this manual.

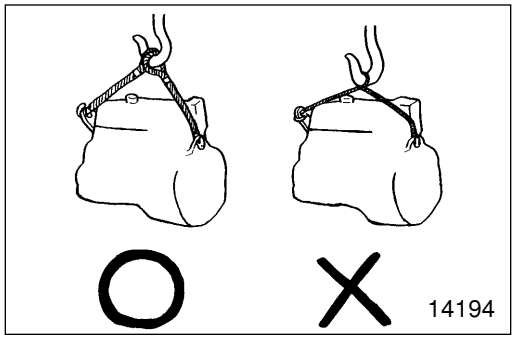


Perform maintenance work at a level area.
Prepare the following.

- Prepare general and special tools necessary for the maintenance work.

WARNING ⚠

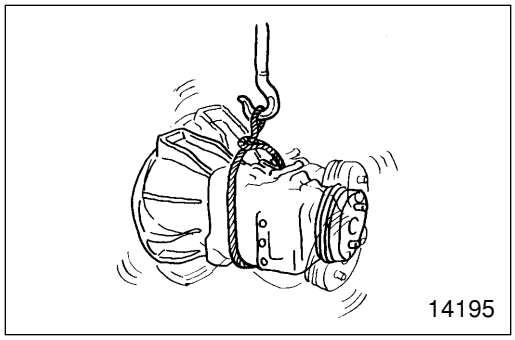
Do not attempt to use tools other than special tools where use of special tools is specified in this manual. This will avoid injury or damage.



Pay special attention to safety when removing or installing heavy items such as engines, transmissions.

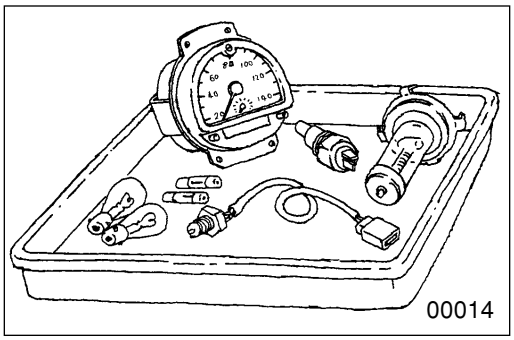
When lifting up heavy items using cables, pay special attention to the following points:

- Check the mass of the item to be lifted and use a cable capable of lifting that mass.

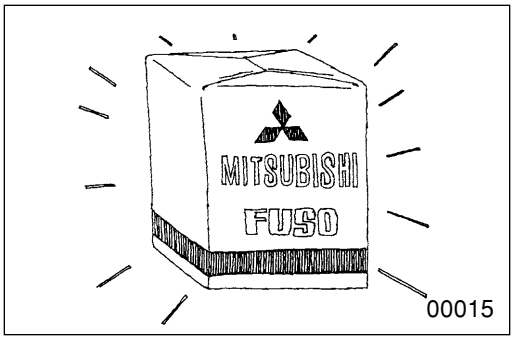


- If you do not have the specified lifting hanger, secure the item using cable taking the point-of-balance of the item into consideration.
- You must work in a position where you will not be injured even if the cable comes undone and the lifted item falls.

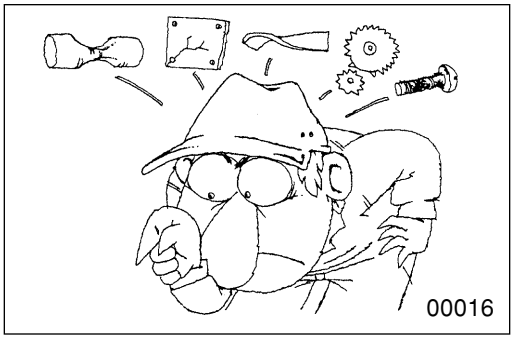
Be particularly careful not to work in shoes that have oily soles and are slippery. When working as a team of two or more, arrange signals in advance and keep confirming safety. Be careful not to accidentally bump switches or levers.



Check for oil leakage before cleaning the area having the fault otherwise you might miss detecting the leakage.
Prepare replacement part(s) beforehand.

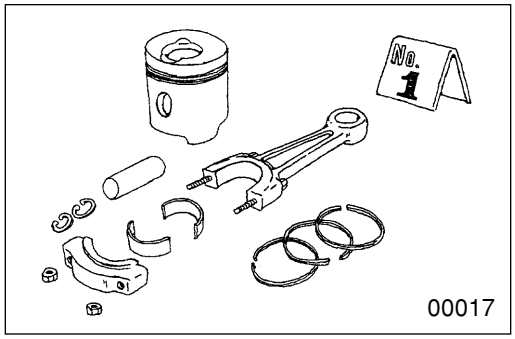


Replace oil seals, packing, O-rings and other rubber parts; gaskets and split pins with new parts whenever any of them has been removed. Use only genuine Caterpillar replacement parts.



On disassembly, visually inspect all parts for wear and tear, cracks, damage, deformation, degradation, rust, corrosion, smoothness in rotation, fatigue, clogging and any other possible defect.

PRECAUTIONS FOR MAINTENANCE OPERATION

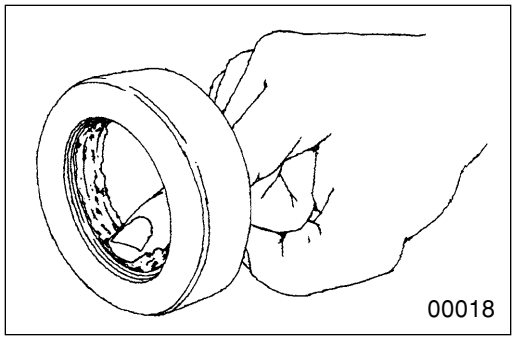


00017

Put alignment marks on part combinations before disassembly and arrange the disassembled parts neatly. This will help avoid mismating of the parts later.
Put the alignment marks, punch marks, etc. where performance and appearance will not be affected.
Cover the area left open after removal of parts to keep it free from dust.

CAUTION ⚠

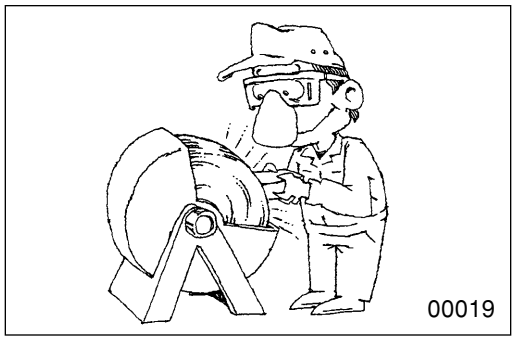
- **Take care to avoid mixing up numerous parts, similar parts, left and right, etc.**
- **Keep new parts for replacement and original (removed) parts separate.**


00018

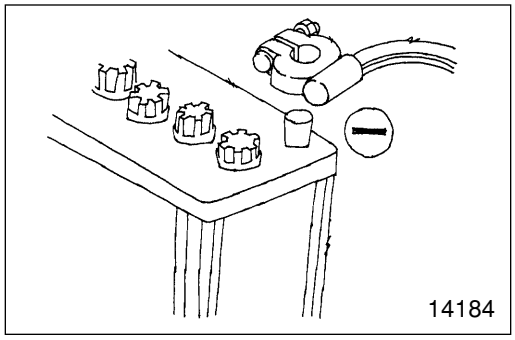
Apply the specified oil or grease to U-packings, oil seals, dust seals and bearings during assembly.
Use only the specified oil, grease, etc. for lubricant, remove the excess immediately after application with a piece of waste, etc.

CAUTION ⚠

When the specified lubricant, fluid and sealant is not available, you may use an equivalent.


00019

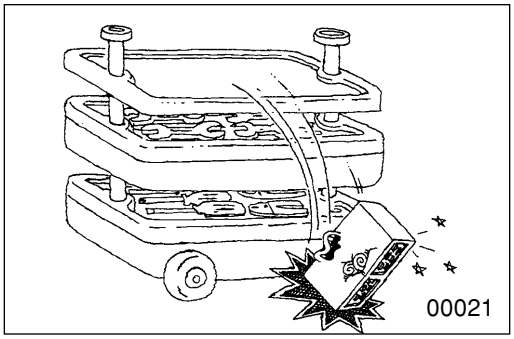
Wear goggles when using a grinder or welder. Pay full attention to safety by wearing gloves when necessary. Watch out for sharp edges, etc. that might injure your hands or fingers.


14184

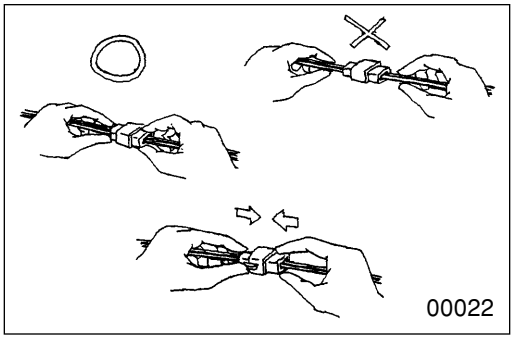
Before carrying out maintenance work on the electric system, disconnect the negative terminals of the batteries to prevent them from short-circuiting and burning-out.

CAUTION ⚠

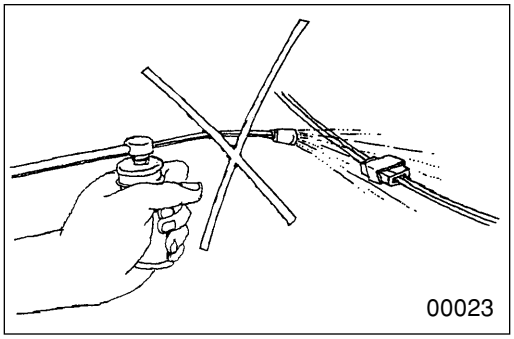
Be sure to turn starter and lighting switches, etc. off before disconnecting or connecting battery terminals, because the semiconductors can be damaged.



Take care when handling sensors, relays, etc. which are vulnerable to shock and heat. Do not attempt to remove the cover from, or apply paint to, the electronic control unit.



Pull the connector, and not the harness lead, to separate connectors. To separate a lock-type connector, first push toward arrow mark. To reconnect a lock-type connector, press the separated parts until they click together.

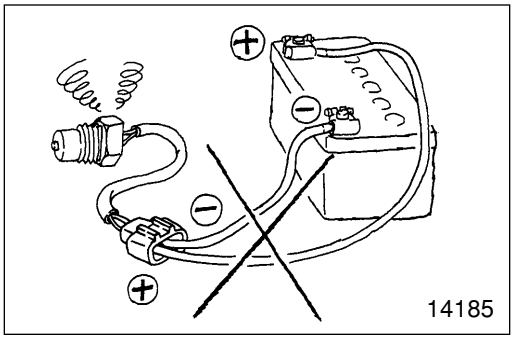


When washing the vehicle, cover the electric system parts and instruments with waterproof material beforehand (Cover with vinyl sheet or the like). Keep water away from harness wire connectors and sensors. If any of them should get wet, wipe them off immediately.

When using an electric welder, such electronic parts that are directly connected to the batteries might be damaged due to the flow of current from the welder that flows through the negative circuit. Parts that have switches might be subject to the same danger if the switches are left on.

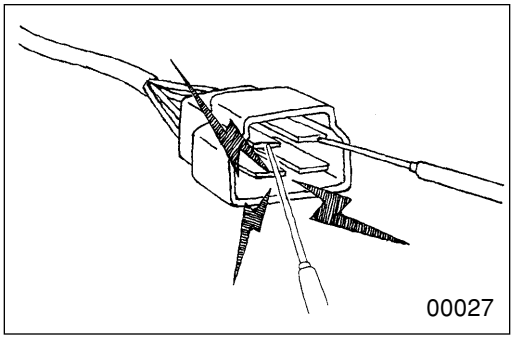
Therefore, do not fail to observe the following.

- Connect the negative terminal of the welder as near as possible to the area that is to be welded.
- Disconnect the negative terminals of batteries.



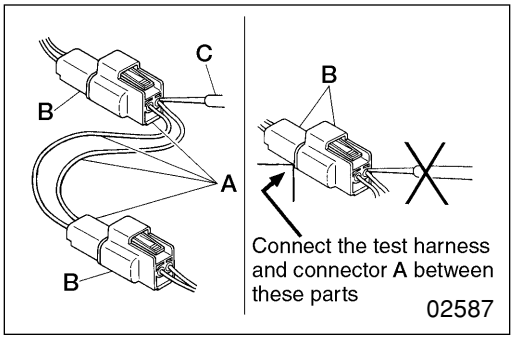
To apply voltage for testing, check that the positive and negative cables are connected properly, then increase voltage gradually from 0 volt. Do not apply voltage higher than the specified value.

In particular, pay close attention to the electronic control unit and sensors, since they are not always fed the battery voltage.

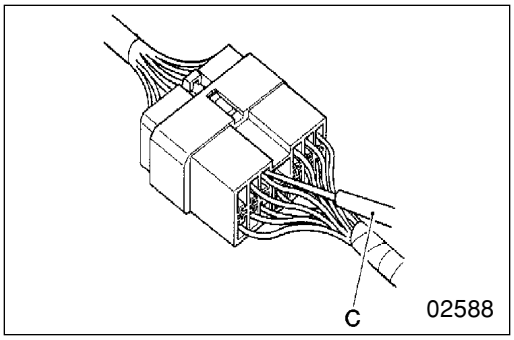


When using testers or the like for continuity tests, be careful not to allow test probes to touch the wrong terminals.

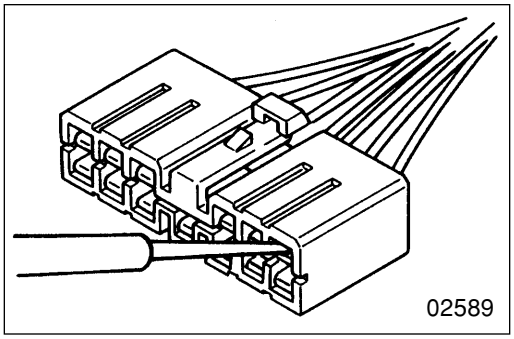
Measurement Procedures Using Connectors



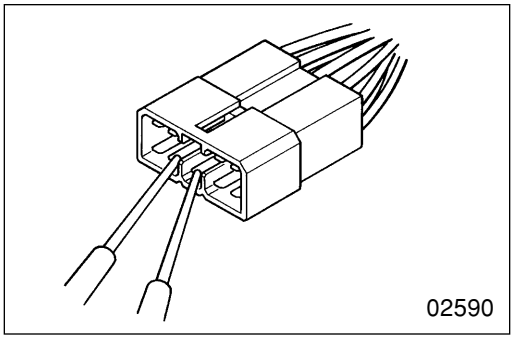
Test with connectors engaged (continuity through circuit obtained)
<Waterproof connector>
Prepare a test harness and connectors **A**, then connect if between the two parts of harness **B** that is to be tested. Check the circuit by touching test probe **C** to the test connector.
Never insert the test probe from the harness side of the waterproof connection, or waterproof performance might be diminished causing corrosion of the connector.



<Non-waterproof connector>
Insert test probe **C** from the harness side of the connector. Where control units, etc. have connectors that are too small to accept the test probe, do not force the test probe into them.



Test with connectors disengaged
Using female pins
Insert a test probe into a terminal. However, do not force the probe into the terminal, or it will cause a poor contact.

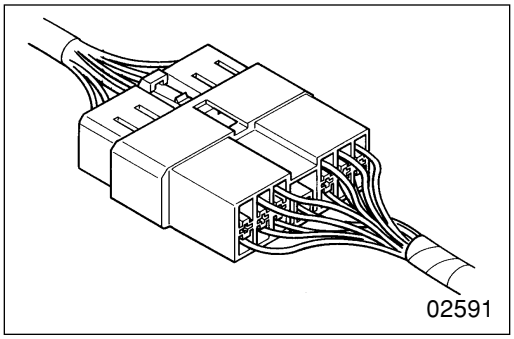


Using male pins
Touch the pins directly using test probes.

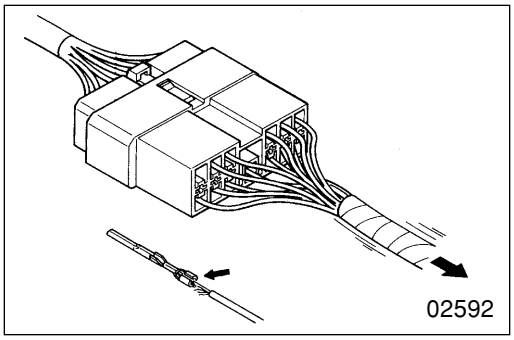
CAUTION ⚠

Be sure that you do not short circuit the connector pins when you use the test probe because this could damage the internal circuit of the electronic control unit.

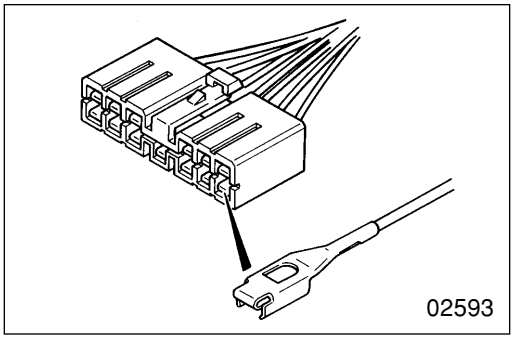
Connector Inspection Procedures



Visual inspection
Check for loose connection and poor engagement.

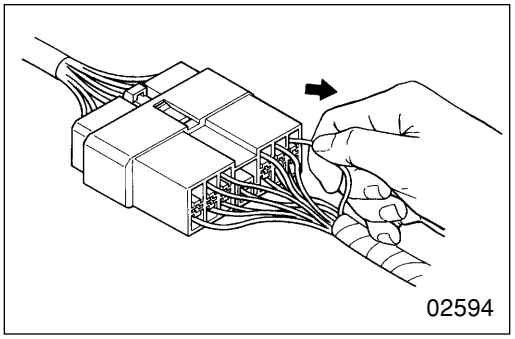


Check if harnesses are broken by pulling gently around the terminals.



Check for a decrease in contact pressure between the male and female terminals.

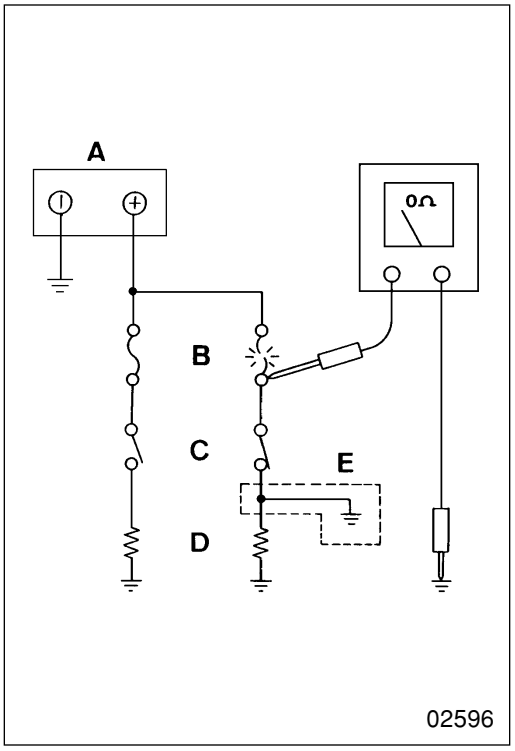
Check for poor contact caused by connector pins having fallen out, rusted terminals or foreign particles.



Connector pin fall out inspection

Damaged connector pin stoppers can cause poor engagement of the terminals (male and female pins) even if the connector body is secured, and might cause some pins to fall out. Check if the pins have fallen out from the connector by pulling each harness gently.

Inspection Procedures for Blown Fuses



Remove fuse B and measure resistance between the loaded side of the fuse and ground.

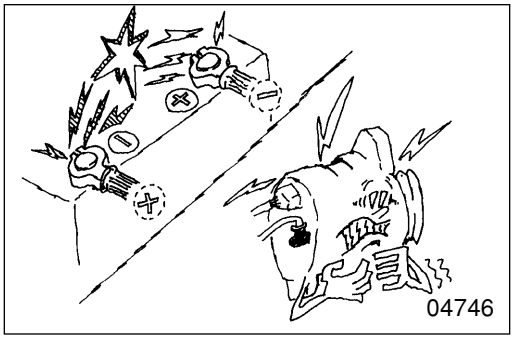
Turn on all circuit switches (connected to the fuse). If the resistance value reading is approximately 0, a short has occurred between the switch and the loaded point. A value of other than zero may indicate that the fuse was blown by a temporary short but the short is no longer present.

The major causes of a short circuit are as follows:

- Harness stuck onto the vehicle body.
- Harness sheath damaged by friction or heat.
- Water in connectors or circuits.
- Mistakes (accidental short circuits)

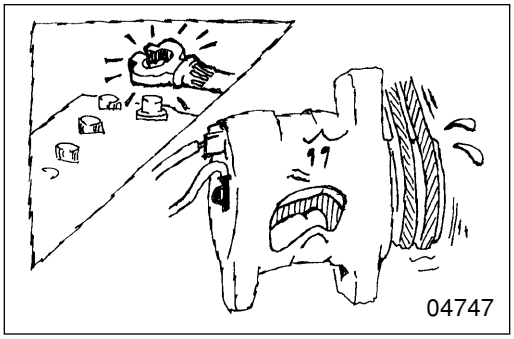
A: Battery
B: Fuse
C: Loaded switch
D: Load
E: Short circuit

Precautions for Handling Alternator

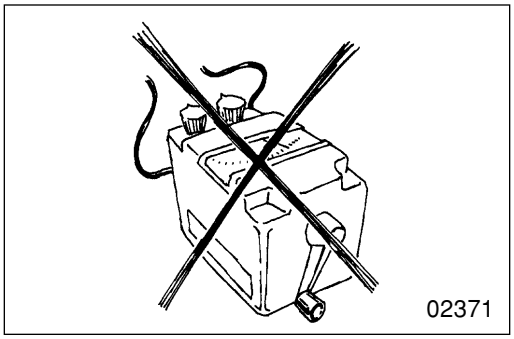


When servicing the alternator, pay attention to the following:

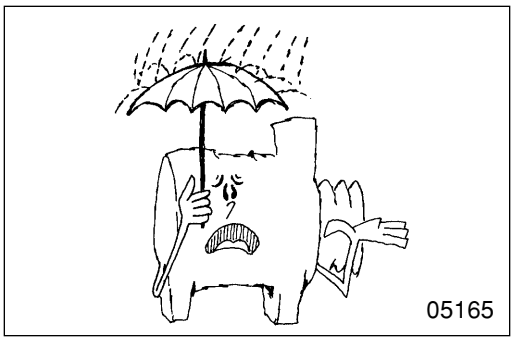
- Do not connect the alternator with battery polarities reversed.
  If the alternator is connected with reversed polarities, a large current flow from the battery to the alternator occurs, and the diode or regulator might be damaged.



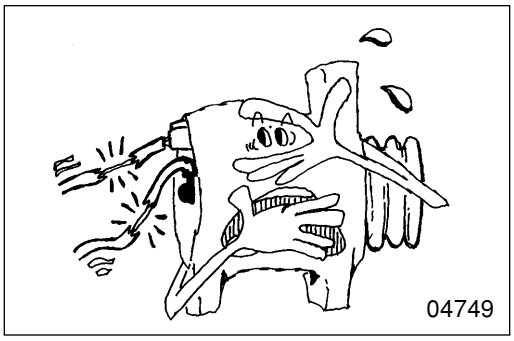
- While the engine is running, do not remove the battery terminals. If the battery terminals are removed at that time, a surge voltage is generated and the diode or regulator might be weakened.



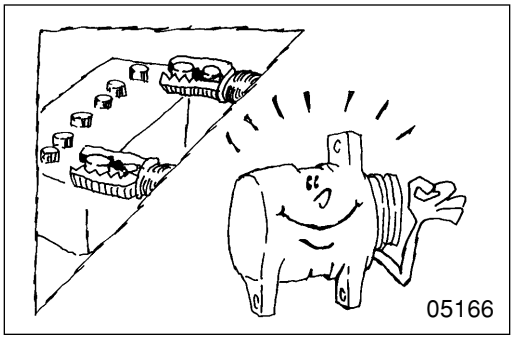
- Do not use a high-voltage tester such as a megger for inspection. If a high-voltage tester is used, the diode or regulator might be destroyed.



- Do not splash water over the alternator.
  If water is directly splashed over the alternator, individual components will be short-circuited and might be destroyed.



- Do not short-circuit terminal B and terminal L while running the alternator.
  If the terminals are short-circuited while the alternator is running, the diode trio might be destroyed.



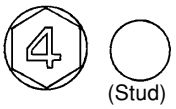
- Disconnect the battery terminals before quick-charging the battery. Quick-charging without disconnecting the battery terminals might damage the diode or regulator.

TABLE OF STANDARD TIGHTENING TORQUES

- Use specified bolts and nuts and tighten them at specified torques according to the following table, unless otherwise specified.
- Threads and contact seats shall be dry.
- Where there is a difference in strength classification between the nut and bolt (or stud bolt), the torque specified for the bolt shall apply.

Hex-head Bolt and Stud Bolt

Unit: N·m (kgf·m) [lbf·ft]

Strength classification	4T		7T		8T	
Repre-sentation / Diameter symbol	 (Stud)		 (Stud)		 (Stud)	 02154
M5	2 to 3 (0.2 to 0.3) [1.48 to 2.21]	–	4 to 6 (0.4 to 0.6) [2.95 to 4.43]	–	5 to 7 (0.5 to 0.7) [3.69 to 5.16]	–
M6	4 to 6 (0.4 to 0.6) [2.95 to 4.43]	–	7 to 11 (0.7 to 1.1) [5.16 to 8.11]	–	8 to 12 (0.8 to 1.2) [5.90 to 8.85]	–
M8	9 to 14 (0.9 to 1.4) [6.64 to 10.3]	–	17 to 26 (1.7 to 2.6) [12.5 to 19.2]	–	20 to 29 (2.0 to 3.0) [14.8 to 21.4]	–
M10	19 to 28 (1.9 to 2.8) [14.0 to 20.6]	18 to 26 (1.8 to 2.7) [13.3 to 19.2]	36 to 52 (3.5 to 5.5) [26.6 to 38.4]	33 to 49 (3.5 to 5.0) [24.3 to 36.1]	45 to 60 (4.5 to 6.0) [33.2 to 44.3]	41 to 59 (4.3 to 6.9) [30.2 to 43.5]
M12	35 to 50 (3.4 to 5.0) [25.8 to 36.9]	31 to 46 (3.1 to 4.7) [22.9 to 33.9]	70 to 95 (7.0 to 9.5) [51.6 to 70.1]	65 to 85 (6.5 to 8.5) [47.9 to 62.7]	85 to 110 (8.5 to 11) [62.7 to 81.1]	75 to 100 (7.5 to 10) [55.3 to 73.8]
M14	60 to 85 (6.0 to 8.5) [44.3 to 62.7]	55 to 75 (5.5 to 7.5) [40.6 to 55.3]	120 to 160 (12 to 16) [88.5 to 118]	110 to 140 (11 to 14) [81.1 to 103]	130 to 180 (13 to 18) [95.9 to 133]	120 to 160 (12 to 17) [88.5 to 118]
M16	90 to 130 (9.5 to 13) [66.4 to 95.9]	90 to 120 (9.0 to 12) [66.4 to 88.5]	180 to 240 (18 to 24) [133 to 177]	160 to 220 (16 to 22) [118 to 162]	200 to 270 (20 to 27) [148 to 199]	190 to 260 (19 to 26) [140 to 192]
M18	140 to 190 (14 to 19) [103 to 140]	120 to 160 (12 to 16) [88.5 to 118]	260 to 340 (25 to 35) [192 to 251]	220 to 290 (22 to 30) [162 to 214]	290 to 390 (30 to 40) [214 to 288]	260 to 340 (26 to 35) [192 to 251]
M20	190 to 260 (19 to 26) [140 to 192]	170 to 230 (17 to 23) [125 to 170]	350 to 470 (36 to 48) [251 to 347]	320 to 420 (32 to 43) [236 to 310]	410 to 550 (41 to 56) [302 to 406]	370 to 490 (37 to 50) [273 to 361]
M22	260 to 340 (26 to 35) [192 to 251]	230 to 300 (23 to 31) [170 to 221]	470 to 640 (48 to 65) [347 to 472]	430 to 570 (43 to 58) [317 to 420]	550 to 740 (56 to 75) [406 to 546]	490 to 670 (50 to 68) [361 to 494]
M24	340 to 450 (34 to 46) [251 to 332]	290 to 390 (29 to 40) [214 to 288]	630 to 840 (63 to 86) [465 to 620]	540 to 730 (55 to 74) [398 to 538]	730 to 980 (74 to 100) [538 to 723]	630 to 840 (64 to 86) [465 to 620]

Hex-head Flange Bolt

Unit: N·m (kgf·m) [lbf·ft]

Strength classification	4T		7T		8T	
Repre-sentation / Diameter symbol						 02154
M6	4 to 6 (0.4 to 0.6) [2.95 to 4.43]	–	8 to 12 (0.8 to 1.2) [5.90 to 8.85]	–	9 to 14 (0.9 to 1.4) [6.64 to 10.3]	–
M8	10 to 15 (1.0 to 1.5) [7.38 to 11.1]	–	19 to 28 (1.9 to 2.8) [14.0 to 20.6]	–	22 to 32 (2.2 to 3.3) [16.2 to 23.6]	–
M10	21 to 30 (2.1 to 3.1) [15.5 to 22.1]	20 to 28 (1.9 to 2.9) [14.8 to 20.6]	39 to 58 (3.9 to 6.0) [28.8 to 42.8]	37 to 53 (3.6 to 5.4) [27.3 to 39.1]	50 to 65 (5.0 to 6.5) [66.8 to 47.9]	45 to 65 (4.5 to 6.5) [33.2 to 47.9]
M12	38 to 54 (3.8 to 5.5) [28.0 to 39.8]	35 to 51 (3.4 to 5.2) [25.8 to 37.6]	80 to 110 (8.0 to 11) [59.0 to 81.1]	70 to 95 (7.0 to 9.5) [51.6 to 70.1]	90 to 120 (9.0 to 12) [66.4 to 88.5]	85 to 110 (8.5 to 11) [62.7 to 81.1]

TABLE OF STANDARD TIGHTENING TORQUES

Hex-head Nut

Unit: N·m (kgf·m) [lbf·ft]

Strength classification	4T		6T	
Representation / Diameter symbol			    02155	
	Standard screw	Coarse screw	Standard screw	Coarse screw
M5	2 to 3 (0.2 to 0.3) [1.48 to 2.21]	–	4 to 6 (0.4 to 0.6) [2.95 to 4.43]	–
M6	4 to 6 (0.4 to 0.6) [2.95 to 4.43]	–	7 to 11 (0.7 to 1.1) [5.16 to 8.11]	–
M8	9 to 14 (0.9 to 1.4) [6.64 to 10.3]	–	17 to 26 (1.7 to 2.6) [12.5 to 19.2]	–
M10	19 to 28 (1.9 to 2.8) [14.0 to 20.6]	18 to 26 (1.8 to 2.7) [13.3 to 19.2]	36 to 52 (3.5 to 5.5) [26.6 to 38.4]	33 to 49 (3.5 to 5.0) [24.3 to 36.1]
M12	35 to 50 (3.4 to 5.0) [25.8 to 36.9]	31 to 46 (3.1 to 4.7) [22.9 to 33.9]	70 to 95 (7.0 to 9.5) [51.6 to 70.1]	65 to 85 (6.5 to 8.5) [47.9 to 62.7]
M14	60 to 85 (6.0 to 8.5) [44.3 to 62.7]	55 to 75 (5.5 to 7.5) [40.6 to 55.3]	120 to 160 (12 to 16) [88.5 to 118]	110 to 140 (11 to 14) [81.1 to 103]
M16	90 to 130 (9.5 to 13) [66.4 to 95.9]	90 to 120 (9.0 to 12) [66.4 to 88.5]	180 to 240 (18 to 24) [133 to 177]	160 to 220 (16 to 22) [118 to 162]
M18	140 to 190 (14 to 19) [103 to 140]	120 to 160 (12 to 16) [88.5 to 118]	260 to 340 (25 to 35) [192 to 251]	220 to 290 (22 to 30) [162 to 214]
M20	190 to 260 (19 to 26) [140 to 192]	170 to 230 (17 to 23) [125 to 170]	350 to 470 (36 to 48) [251 to 347]	320 to 420 (32 to 43) [236 to 310]
M22	260 to 340 (26 to 35) [192 to 251]	230 to 300 (23 to 31) [170 to 221]	470 to 640 (48 to 65) [347 to 472]	430 to 570 (43 to 58) [317 to 420]
M24	340 to 450 (34 to 46) [251 to 332]	290 to 390 (29 to 40) [214 to 288]	630 to 840 (63 to 86) [465 to 620]	540 to 730 (55 to 74) [398 to 538]

Hex-head Flange Nut

Unit: N·m (kgf·m) [lbf·ft]

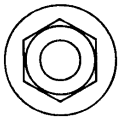
Strength classification	4T	
Repre-sentation / Diameter symbol	 02155	
	Standard screw	Coarse screw
M6	4 to 6 (0.4 to 0.6) [3.69 to 5.16]	–
M8	10 to 15 (1.0 to 1.5) [2.95 to 4.43]	–
M10	21 to 30 (2.1 to 3.1) [7.38 to 11.1]	20 to 28 (1.9 to 2.9) [28.0 to 39.8]
M12	38 to 54 (3.8 to 5.5) [15.5 to 22.1]	35 to 51 (3.4 to 5.2) [14.8 to 20.6]

TABLE OF STANDARD TIGHTENING TORQUES

Tightening torque for flare nut for general purpose

Unit: N·m (kgf·m) [lbf·ft]

Pipe diameter	ϕ4.76 mm (ϕ0.187 in.)	ϕ6.35 mm (ϕ0.250 in.)	ϕ8 mm (ϕ0.315 in.)	ϕ10 mm (ϕ0.394 in.)	ϕ12 mm (ϕ0.472 in.)	ϕ15 mm (ϕ0.591 in.)
Tightening torque	17 (1.7) [12.5]	25 (2.6) [18.4]	39 (4.0) [28.8]	59 (6.0) [43.5]	88 (9.0) [64.9]	98 (10.0) [72.3]

Tightening torque for air piping nylon tube for general purpose {DIN type}

Unit: N·m (kgf·m) [lbf·ft]

Standard diameter	6 × 1 mm (0.236 × 0.0394 in.)	10 × 1.25 mm (0.394 × 0.0492 in.)	12 × 1.5 mm (0.472 × 0.0591 in.)	15 × 1.5 mm (0.591 × 0.0591 in.)
Tightening torque	$20^{+5.9}_{-0}$ $\left(2.0^{+0.6}_{-0}\right)$ $\left[14.8^{+0.4}_{-0}\right]$	$29^{+9.8}_{-0}$ $\left(3.0^{+1.0}_{-0}\right)$ $\left[21.4^{+0.7}_{-0}\right]$	$49^{+9.8}_{-0}$ $\left(5.0^{+1.0}_{-0}\right)$ $\left[36.1^{+0.7}_{-0}\right]$	$54^{+4.9}_{-0}$ $\left(5.5^{+1.0}_{-0}\right)$ $\left[39.8^{+0.7}_{-0}\right]$

Tightening torque for air piping nylon tube for general purpose {SAE type}

Unit: N·m (kgf·m) [lbf·ft]

Standard diameter	1/4 in.	3/8 in.	1/2 in.	5/8 in.
Tightening torque	$13^{+3.9}_{-0}$ $\left(1.3^{+0.4}_{-0}\right)$ $\left[9.59^{+0.30}_{-0}\right]$	$29^{+4.9}_{-0}$ $\left(3.0^{+0.5}_{-0}\right)$ $\left[21.4^{+0.4}_{-0}\right]$	$49^{+4.9}_{-0}$ $\left(5.0^{+0.5}_{-0}\right)$ $\left[36.1^{+0.4}_{-0}\right]$	$64^{+4.9}_{-0}$ $\left(6.5^{+0.5}_{-0}\right)$ $\left[47.2^{+0.4}_{-0}\right]$

GROUP 11 ENGINE

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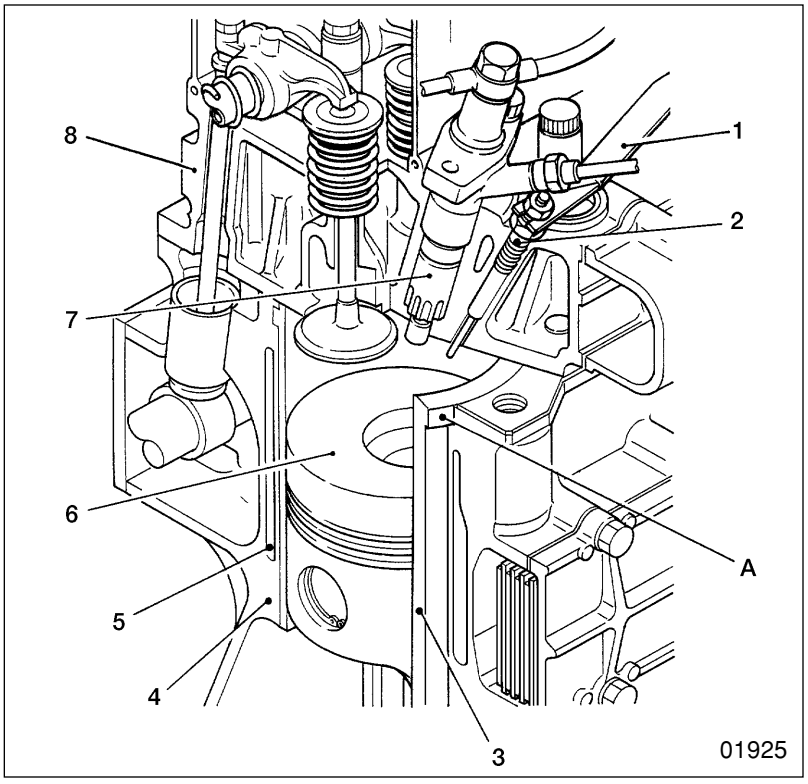
SPECIFICATIONS

Item	Specifications
Engine model	6D16
Type	6-cylinder, in-line, water-cooled, 4-cycle diesel
Combustion chamber type	Direct injection
Valve mechanism	Overhead valve
Cylinder bore × stroke mm (in.)	ϕ118 × 115 (ϕ4.65 × 4.53)
Total displacement cc (cu. in.)	7545 (460.4)
Compression ratio	17.5

Cylinder Head and Crankcase

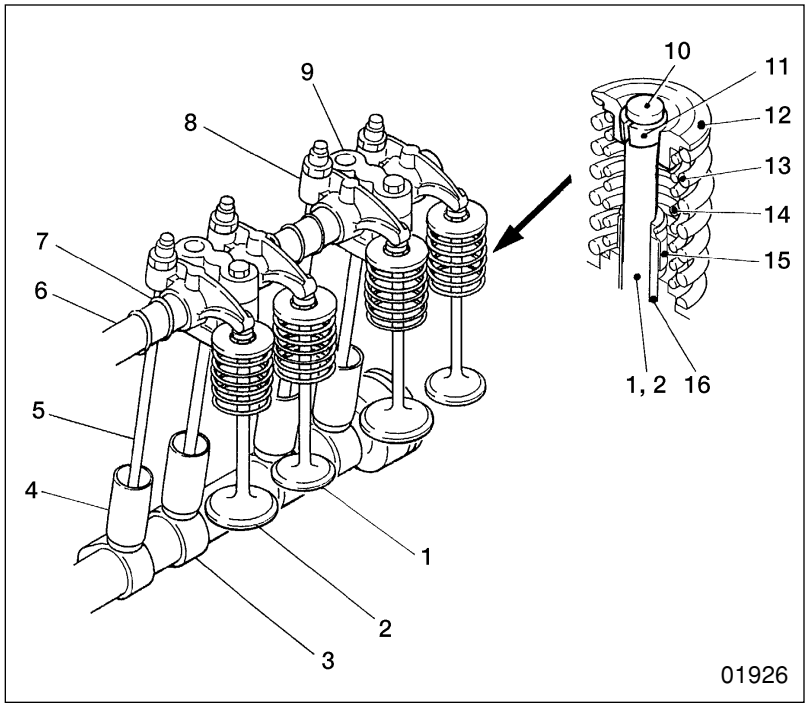


1 Connecting plate
2 Glow plug
3 Cylinder liner
4 Crankcase
5 Water jacket
6 Piston
7 Injection nozzle
8 Cylinder head

A: Cylinder liner size mark
Outer diameter mark: 1, 2, 3
Inner diameter mark: A, B

- The cylinder liners **3** are a dry type liners that are easier to remove than wet liners. Liners are press-fitted into the crankcase **4**.
- The cylinder liners **3**, crankcase **4**, and pistons **6** have size marks. They should be combined as specified according to the size marks. P.11-34

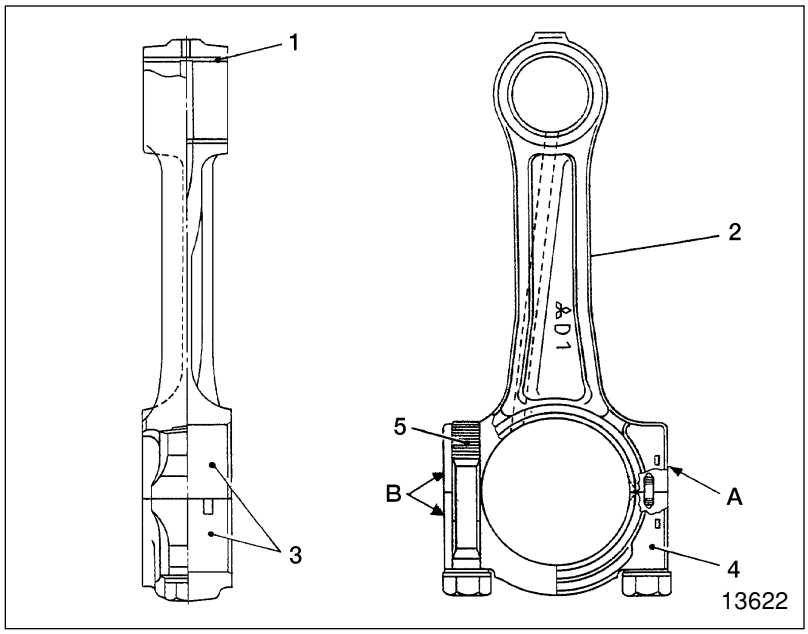
Valve Mechanism



1 Exhaust valve
2 Inlet valve
3 Camshaft
4 Tappet
5 Push rod
6 Rocker shaft
7 Rocker shaft spring
8 Rocker
9 Rocker shaft bracket
10 Valve cap
11 Valve cotter
12 Upper retainer
13 Outer valve spring
14 Inner valve spring
15 Valve stem seal
16 Valve guide

- The valve stem seals **15** are fitted onto the valves **1**, **2** to control the amount of lubricant flowing onto the sliding surfaces of the valves **1**, **2** and valve guides **16**.
- The valve springs **13**, **14** are unevenly pitched to prevent abnormal vibration at high speeds. To prevent the inner and outer springs from meshing with each other, the springs are wound in opposite directions.
- To facilitate removal and reinstallation of the camshaft from the rear end of the crankcase, the diameter of each bushing is smaller toward the front of the engine.

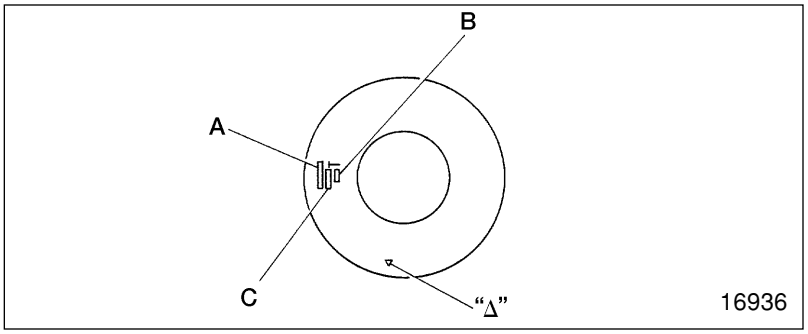
Connecting Rods



1 Connecting rod bushing
2 Connecting rod
3 Connecting rod bearing
4 Connecting rod cap
5 Connecting rod bolt

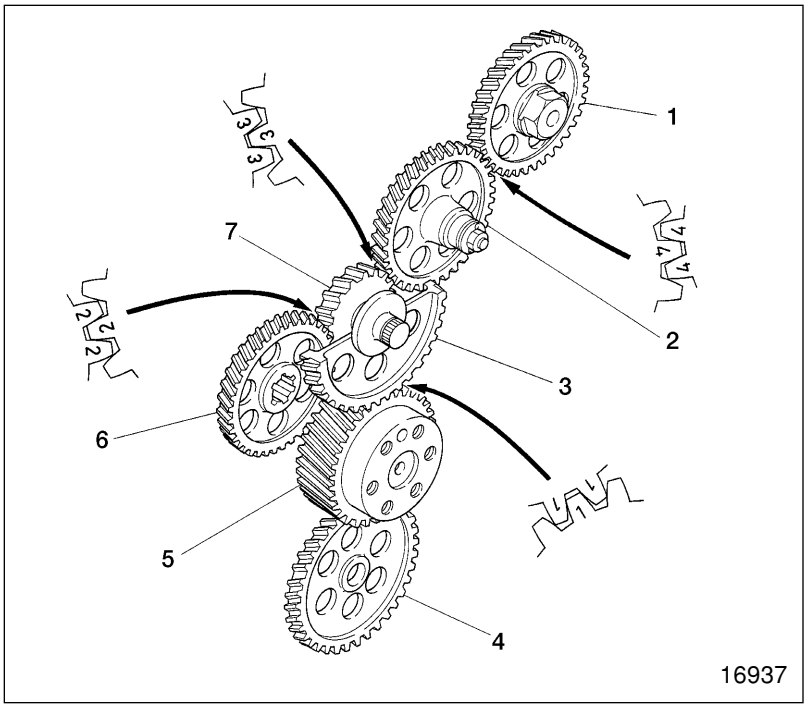
A: Alignment mark
B: Weight mark stamp
(A, B, C, D, E, F, G, H, I, V, W, X, Y, Z)

Pistons



A: Part number
B: Size mark (A, B)
C: Weight mark
Δ: Front mark

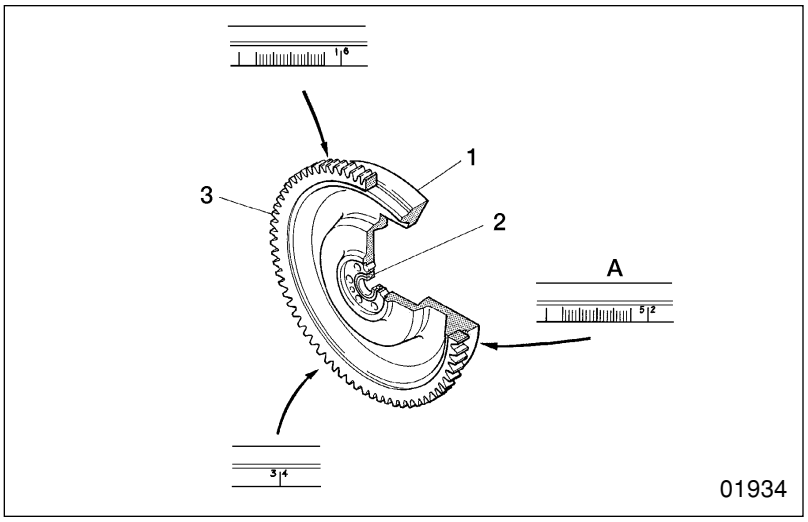
Timing Gears



1 Camshaft gear
2 No. 2 idler gear
3 No. 1 idler gear
4 Oil pump gear
5 Crankshaft gear
6 Air compressor drive gear or injection pump drive gear
7 No. 1 idler gear

Each gear is stamped with a timing gear alignment mark ("**1**", "**2**", "**3**", or "**4**") to facilitate reassembly.

Flywheel



1 Flywheel
2 Pilot bearing
3 Ring gear

A: Angle scale, cylinder number

Symptoms / Possible causes	Low power output	Abnormal engine noise	Remarks
Incorrect oil viscosity	○		🕮 Gr 11
Incorrect/defective fuel	○		🕮 Gr 13
Incorrect valve clearance	○		
Defective cylinder head gasket	○	○	
Worn valve/valve seat, and carbon deposits	○	○	
Weakened valve spring	○	○	
Worn/damaged piston ring(s)	○	○	
Worn/damaged piston ring groove(s)	○	○	
Incorrect injection timing	○	○	🕮 Gr 13
Defective injection pump	○	○	🕮 Gr 13
Defective cooling system	○		🕮 Gr 14
Defective injection nozzle(s)	○	○	🕮 Gr 13
Air trapped in fuel system	○		🕮 Gr 13
Clogged air cleaner	○		🕮 Gr 15
Clogged muffler	○		🕮 Gr 15
Defective turbocharger	○	○	🕮 Gr 15
Incorrectly fitted pipe(s)/hose(s)		○	🕮 Gr 13
Injection pump, alternator, or other auxiliary device(s) defective/incorrectly fitted		○	🕮 Gr 13, 54
Loose/damaged V-belt		○	🕮 Gr 14
Incorrectly fitted crankshaft pulley		○	
Defective air cleaner or muffler		○	🕮 Gr 15
Defective valve spring(s)		○	
Defective rocker shaft and bracket		○	
Incorrect lubrication of rocker shaft bracket		○	
Incorrect backlash in timing gears		○	
Incorrect lubrication of timing gear peripheries and idler shafts		○	
Worn connecting rod small end bushing and piston pin		○	
Worn/damaged crankshaft pin and connecting rod big end bearing		○	
Worn/damaged crankshaft journal and main bearing		○	
Excessive end play in crankshaft and camshaft		○	
Worn tappet(s) and camshaft		○	

M E M O

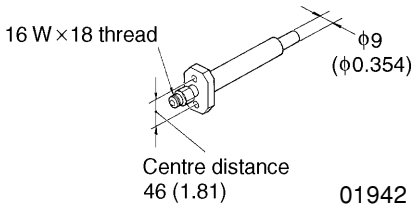
Measuring Compression Pressure

Service standards

Location	Maintenance item		Standard value	Limit	Remedy
–	Compression pressure	Each cylinder (at 200 rpm)	2550 kPa (26 kgf/cm²) [370 psi]	1960 kPa (20 kgf/cm²) [284 psi]	Inspect
		Cylinder-to-cylinder pressure difference	–	390 kPa (4 kgf/cm²) [56.6 psi]	Inspect

Special tools

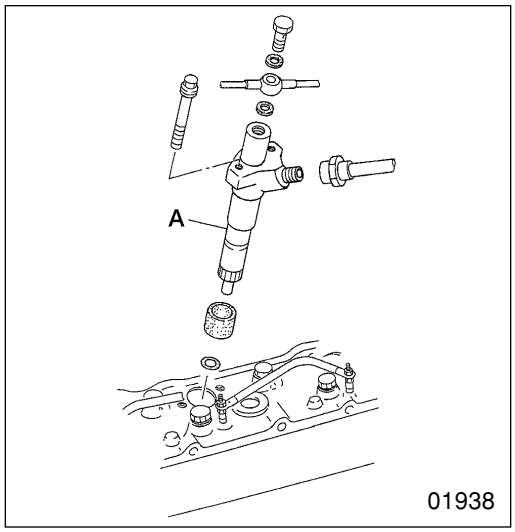
Unit: mm (in.)

Location	Tool name and shape	Part No.	Application
–	Compression Gauge Adapter 	MH061461	Measuring compression pressure

Reductions in compression pressure should be used as a guide in determining the timing of engine overhauls. Take measurements regularly and keep track of changes; an overview of pressure variations can be useful in fault diagnosis.

During the engine's run-in period and after parts have been replaced, the compression pressure will increase slightly as piston rings, valve seats, and other parts fit snugly in position. The pressure will then normalize as parts wear.

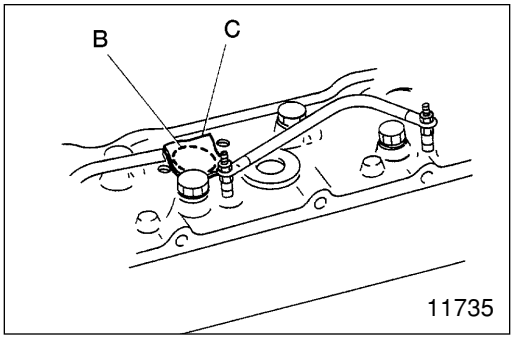
- Before inspections, check that the engine oil, starter, and battery are normal.
- Warm up the engine until the coolant temperature reaches 75 to 85°C (167 to 185°F).
- Turn off all lights and auxiliary devices.



- Remove the injection nozzle **A**.
  Gr 13

CAUTION ⚠

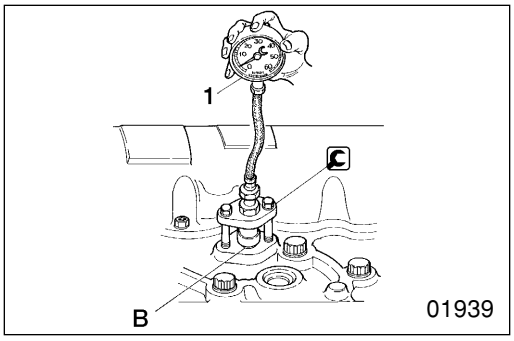
Cover the mounting holes and injection pipes to prevent the entry of dust and dirt.



- Cover the injection nozzle mounting hole **B** with a cloth **C**. Then, turn the engine over with the starter and check that no foreign matter adheres to the cloth.

WARNING ⚠

If any cylinder is cracked, coolant, engine oil, and fuel will enter the cylinder through the crack. When the engine is turned over, these substances will spray out of the nozzle mounting hole B at a high temperature. For safety, move away from the nozzle mounting hole before turning over the engine.



- Fit the 🄒 Compression Gauge Adapter onto an injection nozzle mounting hole **B** together with a nozzle gasket. Then, connect the compression gauge **1**.
- Turn the engine over and measure the compression pressure.
- Measure the compression pressure in every cylinder and determine the pressure differences between cylinders.
- If any compression pressure or cylinder-to-cylinder pressure difference exceeds the specified limit, pour a little engine oil into the cylinder via the injection nozzle mounting hole **B** then take the measurement again.
  - If the compression pressure increases, there may be wear or damage on piston rings and inner surfaces of cylinders.
  - If the compression pressure does not increase, valves may be seized or incorrectly seated, or the cylinder head gasket may be defective.

Inspecting and Adjusting Valve Clearances

Service standards

Unit: mm (in.)

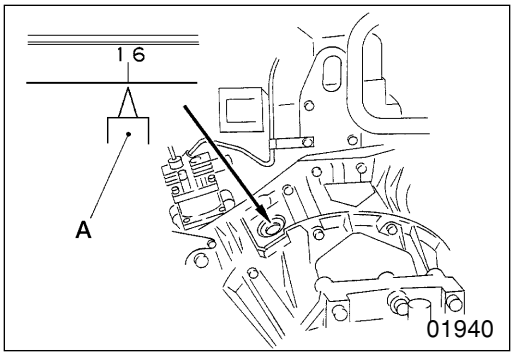
Location	Maintenance item	Standard value	Limit	Remedy
–	Valve clearance (when cold)	0.4 (0.0158)	–	Adjust

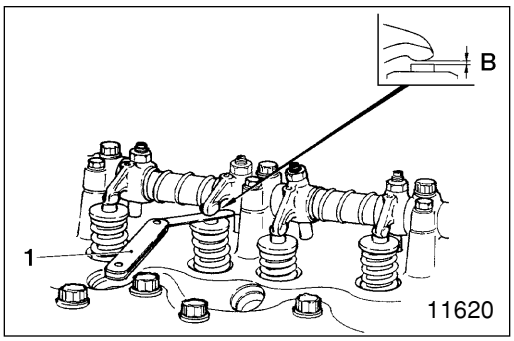
Ⓣ Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
2, 3	Rocker arm adjusting screw lock nut	34 (3.5) [25.1]	–

Valve clearances should be checked and adjusted when the engine is cold.





[Inspection]

- Bring piston No. 1 or piston No. 6 to the top-dead-centre (TDC) position of its compression stroke. To do this, crank the engine until the "**1.6**" mark inscribed on the flywheel is aligned with the pointer **A** in the flywheel housing inspection window.

NOTE

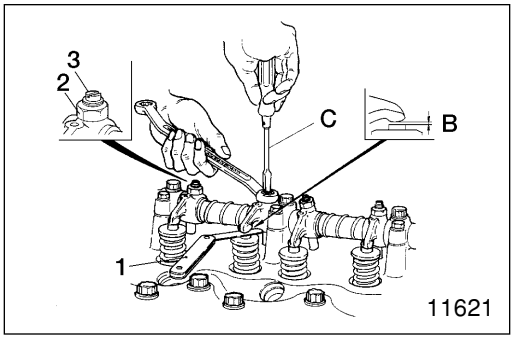
Pistons whose push rods are not pushing up their rockers are at top-dead-centre (TDC) of their compression strokes.

- When piston No. 1 or piston No. 6 is at the TDC position of its compression stroke, measure the clearance **B** of every valve marked "○" in the following table.

Piston No.	1		2		3		4		5		6	
Valve arrangement	In.	Ex.	In.	Ex.	In.	Ex.	In.	Ex.	In.	Ex.	In.	Ex.
No. 1 piston at TDC of compression stroke	○	○	○	×	×	○	○	×	×	○	×	×
No. 6 piston at TDC of compression stroke	×	×	×	○	○	×	×	○	○	×	○	○

NOTE

To measure the clearance, insert a feeler gauge 1. The gauge should be able to move in the gap, albeit not loosely. Accurate measurements cannot be taken if the gauge moves loosely in the gap.

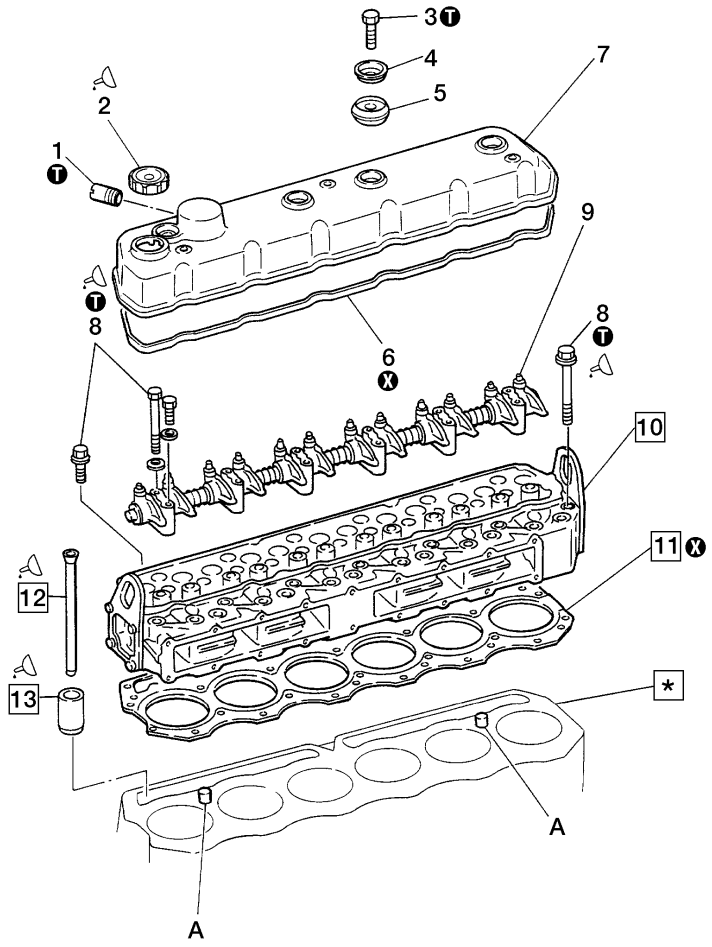


- If any measurement is out of specification, make adjustments as follows:

[Adjustment]

- To adjust the valve clearance **B**, loosen the lock nut **2** and turn the adjusting screw **3** until the feeler gauge **1** moves more stiffly in the gap.
- After adjusting the clearance, tighten the lock nut **2**. At this time, use a screwdriver **C** to stop the adjusting screw **3** from turning. Next, insert the feeler gauge **1** once more to confirm that the clearance **B** is correct.

CYLINDER HEAD AND VALVE MECHANISM



● **Disassembly sequence**

1 Joint
2 Oil filler cap
3 Bolt
4 Plate
5 Rubber
6 Rocker cover gasket
7 Rocker cover
8 Cylinder head bolt
9 Rocker and bracket assembly 📖 P.11-16
10 Cylinder head and valve assembly 📖 P.11-20
11 Cylinder head gasket
12 Push rod
13 Tappet

*: Crankcase 📖 P.11-62
A: Locating pin
X: Non-reusable part

● **Assembly sequence**

Follow the disassembly sequence in reverse.

Service standards

Unit: mm (in.)

Location	Maintenance item	Standard value	Limit	Remedy
12	Push rod runout	–	0.4 (0.0157)	Replace
13, *	Tappet-to-crankcase clearance [Basic diameter: 31 mm (1.220 in.)]	0.06 to 0.10 (0.00237 to 0.00394)	0.2 (0.00787)	Replace tappet

Tightening torques

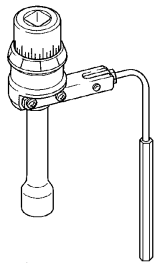
Unit: N·m (kgf·m) [lbf·ft]

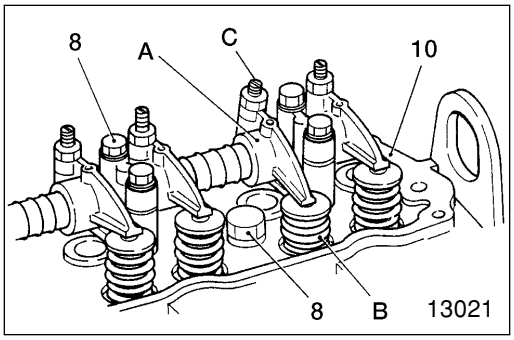
Location	Parts to be tightened		Tightening torque	Remarks
1	Joint		29 (3.0) [21.4]	–
3	Rocker cover bolt		3.9 (0.4) [2.88]	–
8	Cylinder head bolt (installation of rocker and bracket assembly and cylinder head and valve assembly)	M14 bolt	78 (8) [57.5] + 180°	• Wet • Can be reused up to 3 times
		M10 bolt	17 (1.75) [12.5] + 34 (3.5) [25.1]	–

Oils

Location	Points of application	Kinds	Quantity
2	Rubber seal of oil filler cap	Engine oil	As required
8	Threads of cylinder head bolts	Engine oil	As required
12	Both ends of push rods	Engine oil	As required
13	Outer surfaces of tappets	Engine oil	As required

Special tools

Location	Tool name and shape	Part No.	Application
10	Socket Wrench  01984	MH061560	Tightening cylinder head bolts (M14 bolt only)

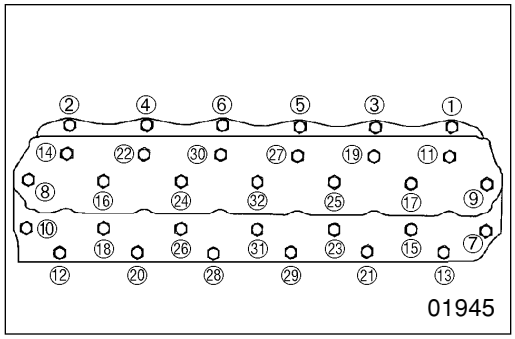


◆ Service procedure

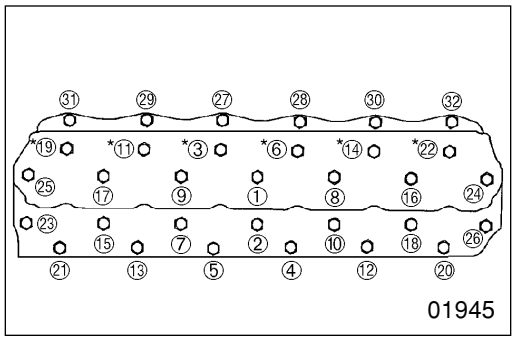
10 Cylinder head and valve assembly

[Removal]

- Before loosening the cylinder head bolts **8**, loosen the adjusting screw **C** on every rocker **A** that is compressing its valve spring **B**.



- Loosen and remove the cylinder head bolts **8** in the sequence shown. Each cylinder head bolt should be loosened a little at a time.



[Fitting]

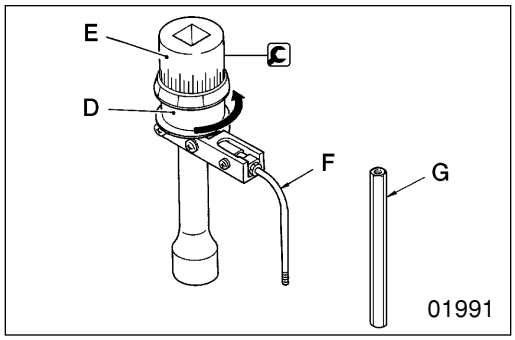
- The M14 cylinder head bolts **8** can be reused only three times. Before refitting the cylinder head bolts, make a punch mark on the head of each one to indicate times of reuse.

CAUTION ⚠

If any bolt already has three punch marks, it must not be reused any more; replace it with a new one.

- Tighten the cylinder head bolts **8** to the specified torque {M14 bolts: 78 N·m (8 kgf·m) [57.5 lbf·ft]; M10 bolts: 17 N·m (1.75 kgf·m) [12.5 lbf·ft]} in the sequence shown. Then, turn the bolts further in accordance with the following procedure.

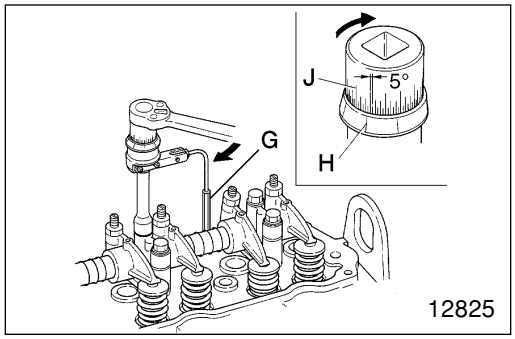
∗: Tighten together with rocker and bracket assembly
① to ㉖ : M14 bolt (wet)
㉗ to ㉜ : M10 bolt



<M14 Bolts>

- Before fitting the Socket Wrench over a cylinder head bolt, turn the holder **D** counter-clockwise to tension the built-in spring.

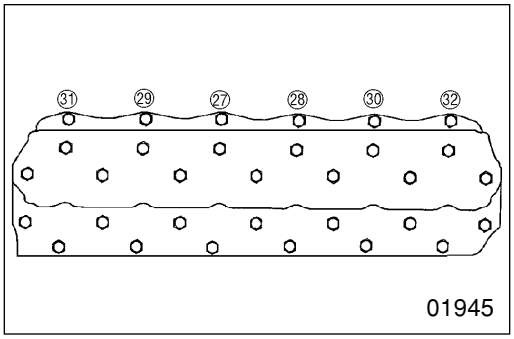
E: Socket
F: Rod
G: Rod (extension)



- Set the socket such that the built-in spring force forces the rod **G** against the rocker shaft bracket, an injection pipe, or another nearby part.
- On the holder **D**, select the inscribed line **H** that is easiest to see.
- Using the selected line as a reference, turn the socket **E** 180° clockwise. (One gradation on the scale **J** represents 5°.)

CAUTION ⚠

Since the M14 cylinder head bolts 8 utilize the plastic region tightening method, they must not be tightened further after this procedure.



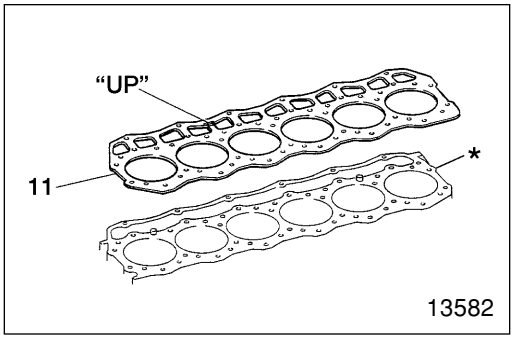
<M10 Bolts>
- After fitting the M14 cylinder head bolts 8, tighten the M10 bolts to the specified torque {34 N·m (3.5 kgf·m) [25.1 lbf·ft]} in the sequence shown.

11 Cylinder head gasket

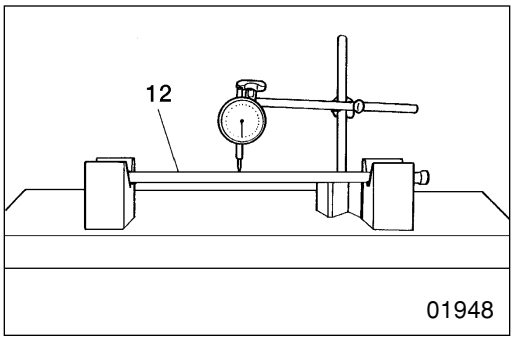
[Removal]

CAUTION ⚠

When removing the cylinder head gasket 11, be careful not to scratch the cylinder head and valve assembly 10 and the crankcase ∗.

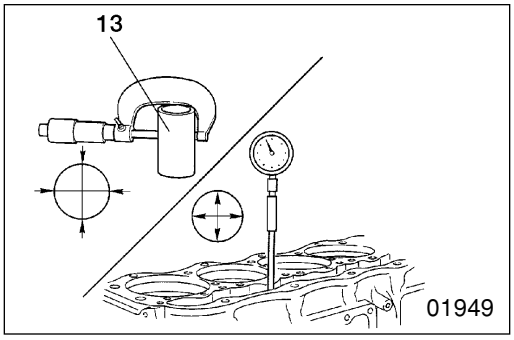


[Fitting]
- Fit the cylinder head gasket 11 onto the crankcase ∗ as shown.



12 Push rod runout

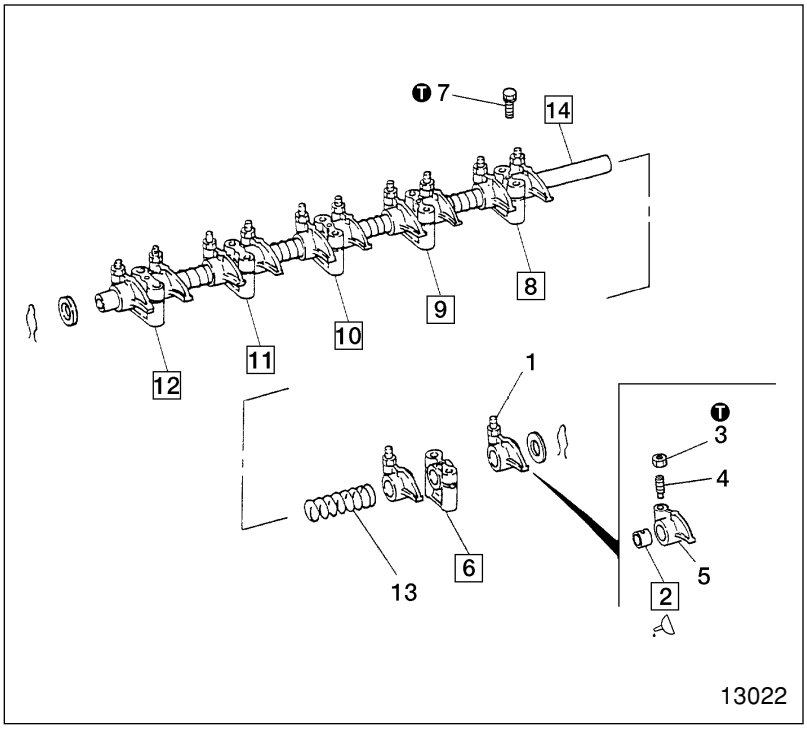
If any measurement exceeds the specified limit, replace the defective part(s).



13 ∗ Tappet-to-crankcase clearance

If any measurement exceeds the specified limit, replace the defective part(s).

Rocker and Bracket Assembly



● **Disassembly sequence**

1 Rocker assembly
2 Rocker bushing
3 Lock nut
4 Adjusting screw
5 Rocker
6 No. 6 rocker shaft bracket
7 Set screw
8 No. 5 rocker shaft bracket
9 No. 4 rocker shaft bracket
10 No. 3 rocker shaft bracket
11 No. 2 rocker shaft bracket
12 No. 1 rocker shaft bracket
13 Rocker shaft spring
14 Rocker shaft

● **Assembly sequence**

Reverse the order of disassembly.

Service standards

Unit: mm (in.)

Location	Maintenance item	Standard value	Limit	Remedy
2, 14	Rocker bushing-to-rocker shaft clearance [Basic diameter: 24 mm (0.945 in.)]	0.01 to 0.08 (0.000394 to 0.00315)	0.12 (0.00472)	Replace

Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

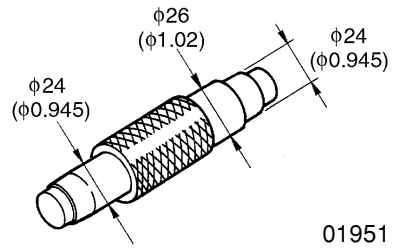
Location	Parts to be tightened	Tightening torque	Remarks
3	Adjusting screw lock nut	34 (3.5) [25.1]	–
7	Rocker shaft set screw	3.9 (0.4) [2.88]	–

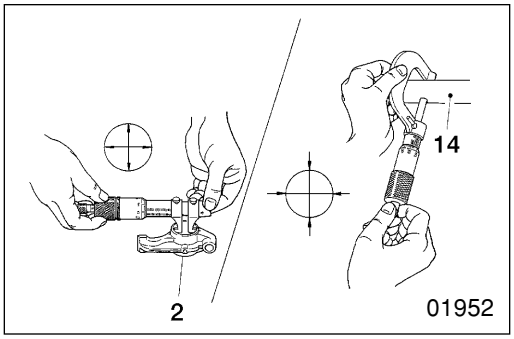
Oils

Location	Points of application	Kinds	Quantity
2	Rocker bushing inner surface	Engine oil	As required

Special tools

Unit: mm (in.)

Location	Tool name and shape	Part No.	Application
2	Rocker Bushing Puller 	MH061777	Removing and installing rocker bushings

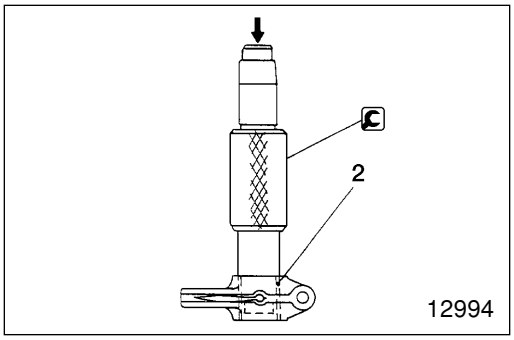


◆ Service procedure

2 14 Rocker bushing and rocker shaft

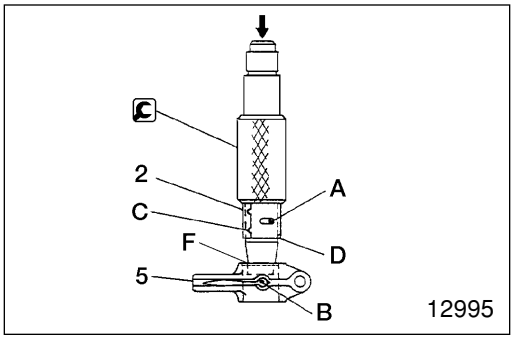
[Inspection]

If any clearance exceeds the specified limit, replace the defective part(s).



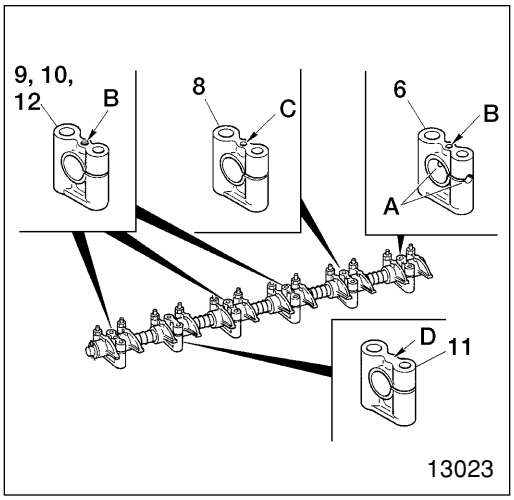
Rocker bushing

[Removal]



[Installation]

- Align the oil hole **A** in the rocker bushing **2** with the oil hole **B** in the rocker **5**.
- Position the notch **C** and seam **D** on the rocker bushing **2** as shown.
- Install the rocker bushing **2** into the rocker **5** from the chamfered side **F**.

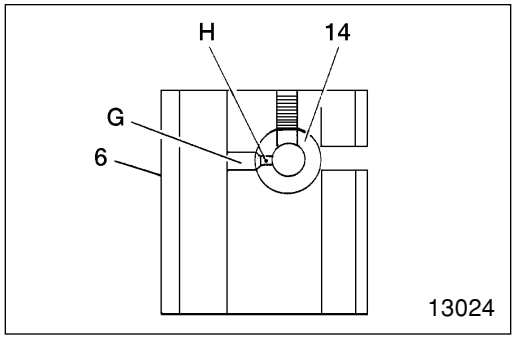


6 8 to 12 14 Installing rocker shaft brackets and rocker shaft

Rocker shaft brackets

Be sure to fit the rocker shaft brackets **6**, **8**, **12** in their correct positions.

A: Oil hole
B: Threaded hole (for M8 rocker cover bolt)
C: Threaded hole (for M6 set screw)
D: No threaded hole

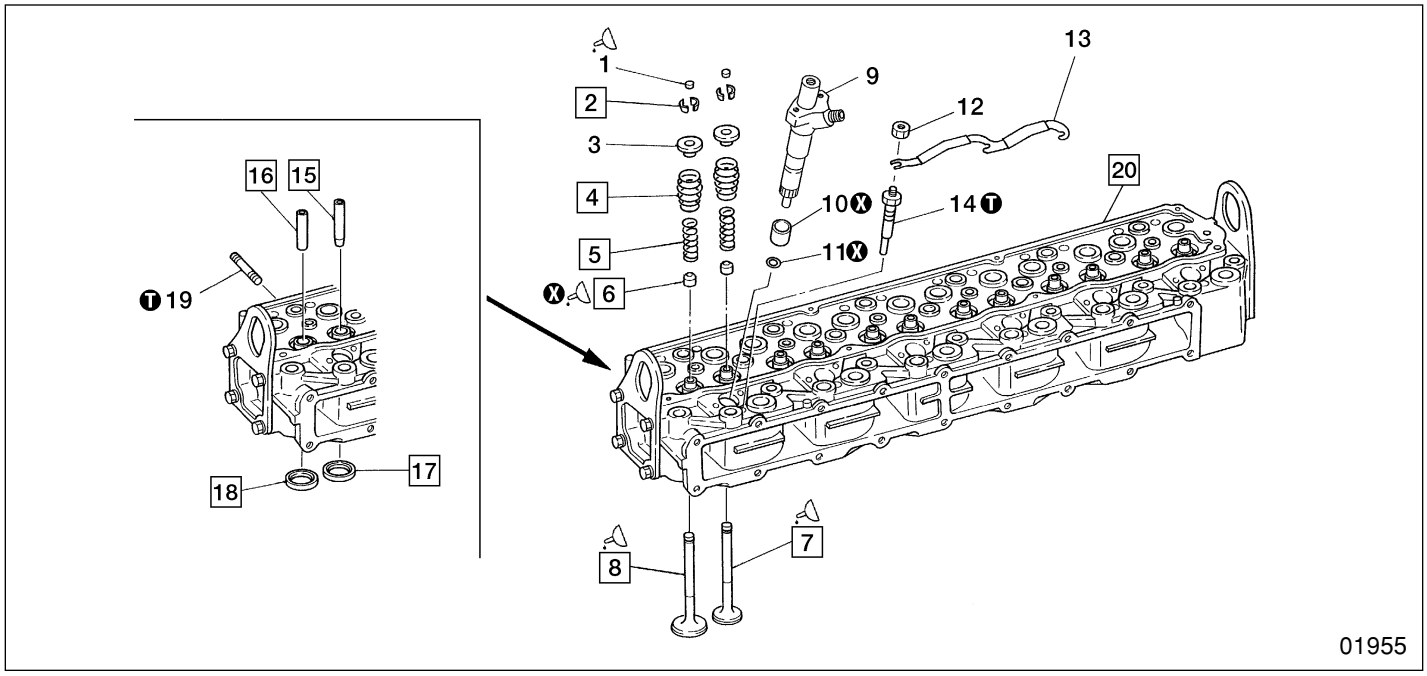


Rocker shaft

Align the oil hole **G** in the No. 6 rocker shaft bracket **6** with the oil hole **H** in the rocker shaft **14**.

M E M O

Cylinder Head and Valve Mechanism



● **Disassembly sequence**

1 Valve cap
2 Valve cotter
3 Upper retainer
4 Outer valve spring
5 Inner valve spring
6 Valve stem seal
7 Exhaust valve
8 Inlet valve
9 Injection nozzle 🕮 Gr 13
10 Dust seal
11 Nozzle tip gasket
12 Nut
13 Connecting plate
14 Glow plug 🕮 Gr 54
15 Exhaust valve guide
16 Inlet valve guide
17 Exhaust valve seat
18 Inlet valve seat
19 Stud
20 Cylinder head

Ⓧ: Non-reusable part

CAUTION ⚠

The injection nozzles 9 and glow plugs 14 project from the bottom surface of cylinder head 20. Take care not to damage them.

● **Assembly sequence**

Follow the disassembly sequence in reverse.

NOTE

Any valve stem seal 6 removed from an exhaust valve 7 or inlet valve 8 must be replaced.

Service standards

Unit: mm (in.)

Location	Maintenance item		Standard value	Limit	Remedy
4	Outer valve spring	Free length	67.0 (2.64)	64.0 (2.52)	Replace
		Installed load [at 47.8 mm (1.88 in.) installed length]	330 N (33.5 kgf) [74.5 lbf]	290 N (29.7 kgf) [65.2 lbf]	Replace
		Squareness	–	2.5 (0.0984)	Replace
5	Inner valve spring	Free length	55.1 (2.17)	52.1 (2.05)	Replace
		Installed load [at 40.5 mm (1.59 in.) installed length]	92 N (94 kgf) [20.7 lbf]	78 N (8.0 kgf) [17.5 lbf]	Replace
		Squareness	–	2.0 (0.0787)	Replace
7	Exhaust valve	Stem outside diameter	ϕ8.93 to 8.94 (ϕ0.3516 to 0.3520)	ϕ8.85 (ϕ0.348)	Replace
		Sinkage from cylinder head bottom surface	1.3 to 1.7 (0.0512 to 0.0670)	2.0 (0.0787)	Inspect every location
		Valve margin	1.5 (0.0591)	1.2 (0.0472)	Reface or replace
		Seat angle	45°	–	Correct
8	Inlet valve	Stem outside diameter	ϕ8.96 to 8.97 (ϕ0.3528 to 0.3531)	ϕ8.85 (ϕ0.348)	Replace
		Sinkage from cylinder head bottom surface	1.1 to 1.5 (0.0433 to 0.0591)	1.8 (0.0709)	Inspect every location
		Valve margin	1.5 (0.0591)	1.2 (0.0472)	Reface or replace
		Seat angle	45° ± 15’	–	Correct
7, 15	Exhaust valve stem-to valve guide clearance [Basic diameter: 9 mm (0.354 in.)]		0.07 to 0.10 (0.00276 to 0.00394)	0.2 (0.00787)	Replace
8, 16	Inlet valve stem-to-valve guide clearance [Basic diameter: 9 mm (0.354 in.)]		0.04 to 0.06 (0.00157 to 0.00236)	0.15 (0.00591)	Replace
17	Exhaust valve seat width		1.8 to 2.2 (0.0709 to 0.0866)	2.8 (0.110)	Correct or replace
18	Inlet valve seat width		1.8 to 2.2 (0.0709 to 0.0866)	2.8 (0.110)	Correct or replace
20	Cylinder head	Bottom surface distortion	0.08 (0.00315) or less	0.2 (0.00787)	Correct or replace
		Height from top to bottom surface	94.9 to 95.1 (3.736 to 3.744)	94.5 (3.72)	Replace

Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

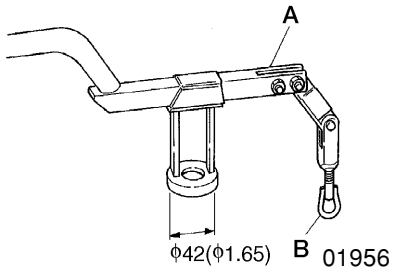
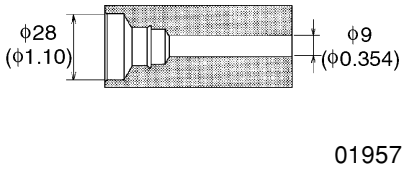
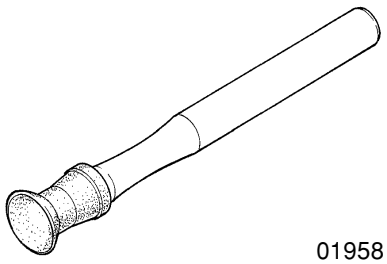
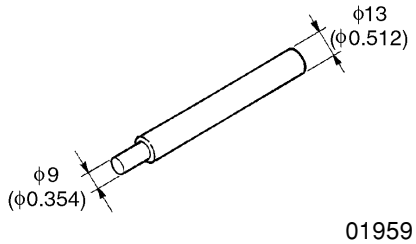
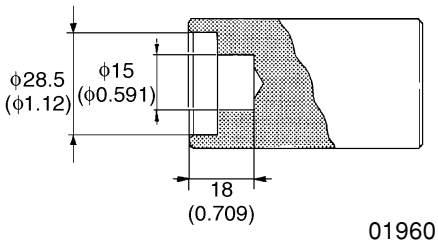
Location	Parts to be tightened	Tightening torque	Remarks
14	Glow plug	15 to 20 (1.5 to 2.0) [11.1 to 14.8]	–
19	Exhaust manifold mounting stud	29 (3) [21.4]	–

Oils

Location	Points of application	Kinds	Quantity
1	Rocker contact surface on valve cap top	Engine oil	As required
6	Lip of valve stem seal	Engine oil	As required
7, 8	Valve stem	Engine oil	As required

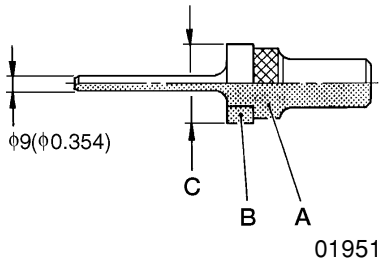
Special tools

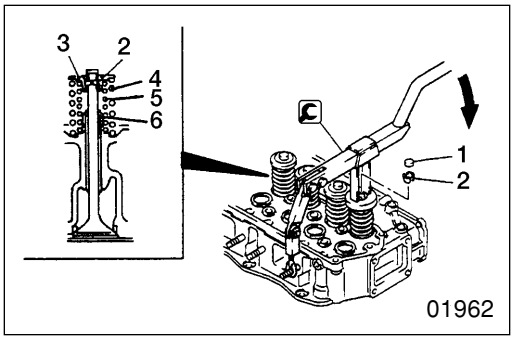
Unit: mm (in.)

Location	Tool name and shape	Part No.	Application
2	A: Valve Lifter B: Valve Lifter Hook 	A: MH061668 [with ϕ42 (ϕ1.65) valve lifter seat] B: MH061679	Removing and installing valve cotters
6	Valve Stem Seal Installer 	MH061293	Installing valve stem seals
7, 8	Valve Lapper 	30091-07500 (inlet, exhaust)	Lapping valves and valve seats
15, 16	Valve Guide Remover 	MH061066 (inlet, exhaust)	Removing valve guides
	Valve Guide Remover 	MH061998	Installing inlet and exhaust valve guides

Special tools

Unit: mm (in.)

Location	Tool name and shape	Part No.	Application
17, 18	A: Caulking Tool Body B: Installer Ring C dimension: MH061693 φ51 (φ2.01); MH061694 φ44 (φ1.73) 	A: MH061067 B: MH061693 (Inlet) MH061694 (Exhaust)	Installing valve seats



◆ Service procedure

2 Valve cotters

[Removal]

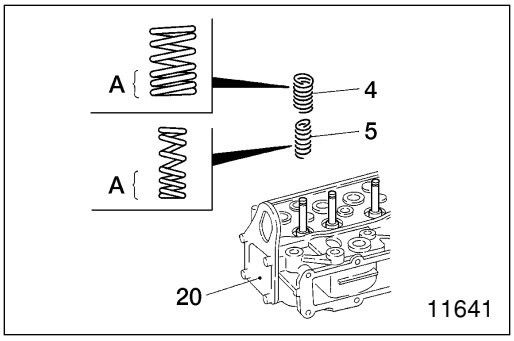
To remove the valve cotter **2**, use the Valve Lifter to evenly compress the valve springs **4**, **5**.

[Installation]

To install valve cotters, follow the removal instructions in reverse.

CAUTION

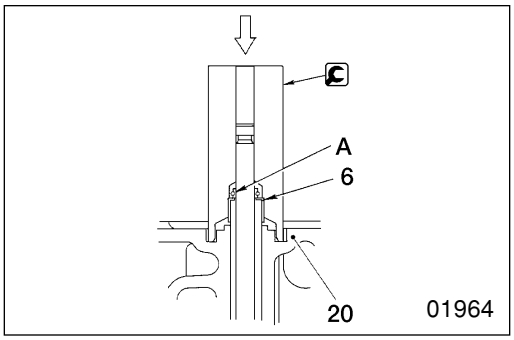
Do not compress the valve springs 4, 5 more than is necessary. If the valve springs are compressed excessively, the upper retainer 3 can touch the valve stem seal 6 and be damaged.



4 5 Installing outer and inner valve springs

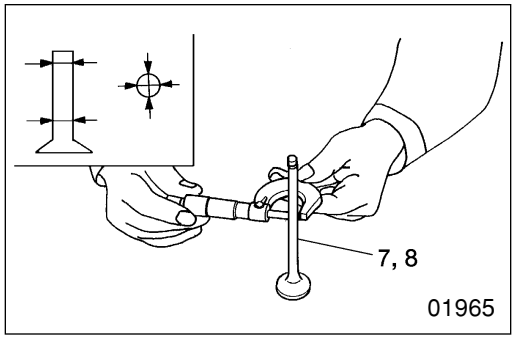
Fit the outer and inner valve springs **4**, **5** onto the cylinder head **20** with their painted ends downward.

A: Painted end



6 Installing valve stem seals

- Apply engine oil to the lip **A** of the valve stem seal **6**.
- Install the valve stem seal **6** using the Valve Stem Seal Installer. Strike the Valve Stem Seal Installer until it sits snugly on the cylinder head **20**.



7 8 **Valves**

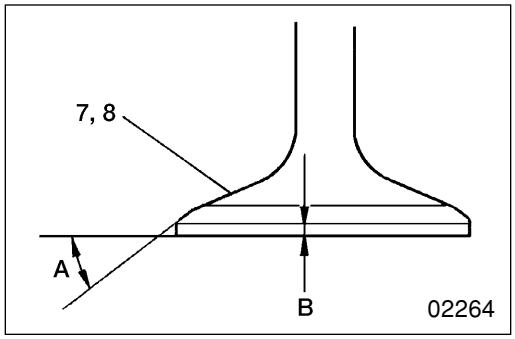
[Inspection]

(1) Valve stem outside diameter

Replace the valves **7**, **8** if its stem's outside diameter is below specification or severely worn.

CAUTION ⚠

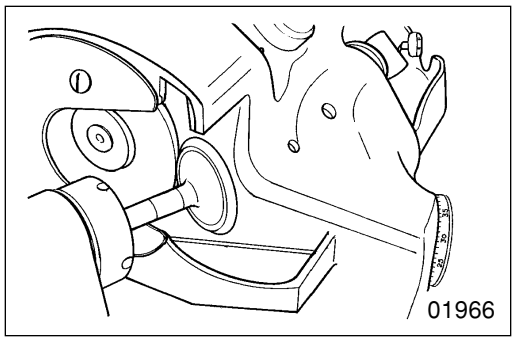
Whenever the valves 7, 8 are replaced, be sure to lap the valves and valve seats 17, 18. 🕮 **P.11-25.**



(2) Valve seat angle and valve margin

Reface or replace the valves **7**, **8** if the valve seat angle or valve margin exceeds the specified limits.

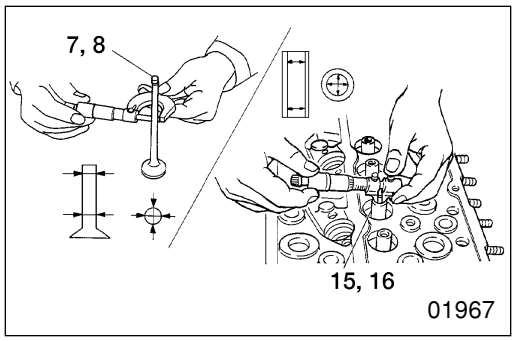
A: Valve seat angle
B: Valve margin



[Rectification]

NOTE

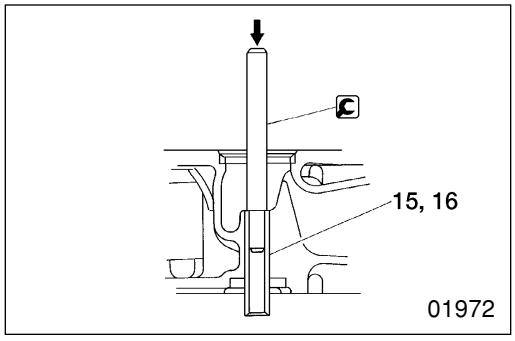
- **Keep grinding to a minimum.**
- **If the valve margin is below specification after grinding, replace the valves 7, 8.**
- **After grinding, be sure to lap the valves 7,8 and valve seats 17, 18.** 🕮 **P.11-25**



7 8 15 16 **Valves and valve guides**

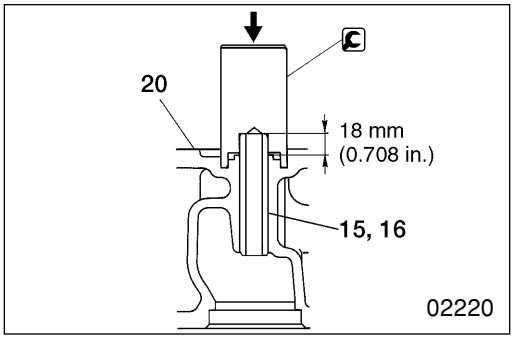
[Inspection]

If any clearance exceeds the specified limit, replace the defective part(s).



Valve guides

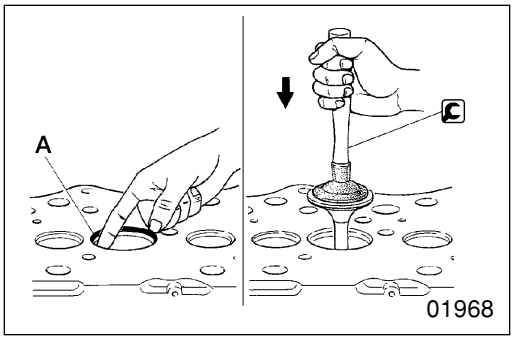
[Removal]



[Installation]
Install the valve guides **15**, **16** using the Valve Guide Installer. Strike the Valve Guide Installer until it sits snugly on the cylinder head **20**.

CAUTION

- **The valve guides 15, 16 must be pressed in to the specified depth. Be sure to use the Valve Guide Installer for this operation.**
- **Exhaust valve guides 15 are longer than inlet valve guides 16. Be sure to install the correct type of guide in each location.**



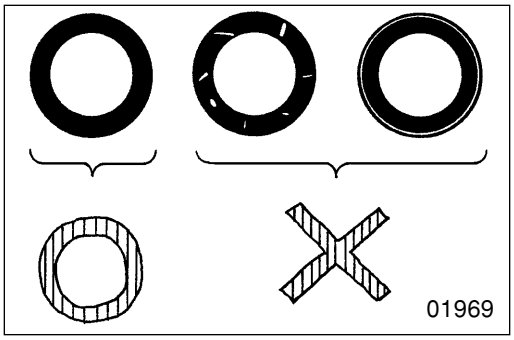
7 8 17 18 Valves and valve seats

[Inspection]

- Apply an even coat of minimum to the valve seats **17**, **18** surface **A** that makes contact with the valves **7**, **8**.
- Using the Valve Lapper, strike the valves **7**, **8** against the valve seats 17, 18 once. Do not rotate the valve during this operation.

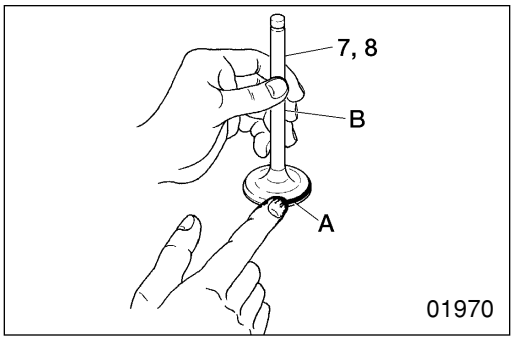
NOTE

Carry out these inspections after inspecting the valves and valve guides.



- If the minimum deposited on the valves **7**, **8** indicate a poor contact pattern, rectify the contact pattern as follows:

Contact	Corrective action
Minor defect	Lapping
Serious defect	Reface or replace valve and valve seat



[Refacing]
Lap the valve in accordance with the following procedure:

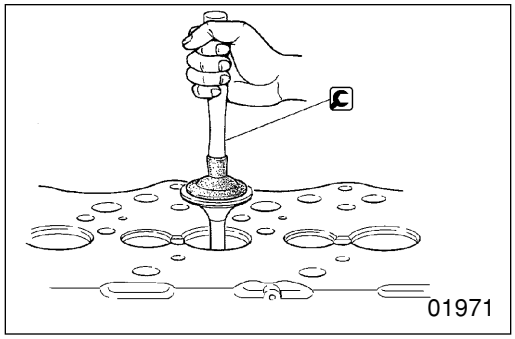
- Apply a thin, even coat of lapping compound to the surface **A** of the valves **7**, **8** that makes contact with the valve seats **17**, **18**.

CAUTION

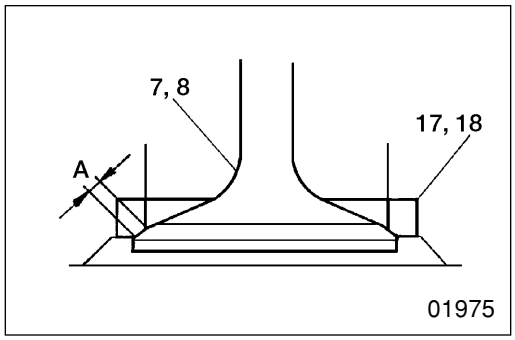
Ensure that no compound adheres to the stem B of the valves 7, 8.

NOTE

- **Start with intermediate-mesh compound (120 to 150 mesh) and finish with fine-mesh compound (200 mesh or more).**
- **The addition of a small amount of engine oil makes lapping compound easier to apply.**



- Using the C Valve Lapper, lightly strike the valves **7**, **8** against the valve seats **17**, **18** while turning it little by little.
- Wash away the compound with gas oil or a similar fluid.
- Apply engine oil to the contact surfaces of the valve seats **17**, **18** and rub it in so that the contact surfaces are lubricated and mate together snugly.
- Inspect the contact pattern of the valves **7**, **8** and valve seats **17**, **18** once more.
- If the contact pattern is still defective, replace the valve seats 17, 18.



17 **18** **Valve seats**

[Inspection]

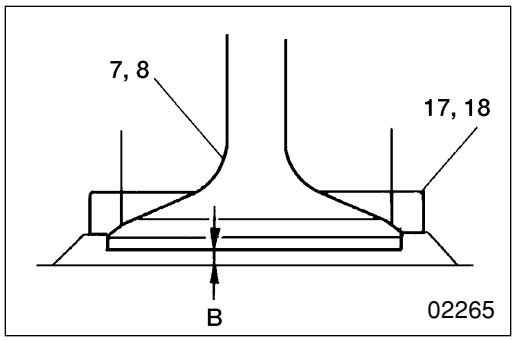
(1) Valve seat width

If the measurement exceeds the specified limit, rectify or replace the valve seats **17**, **18**.

A: Valve seat width

NOTE

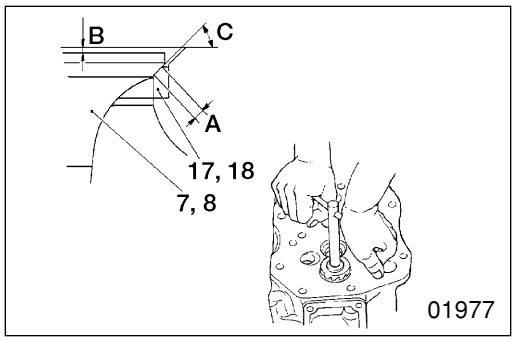
Whenever the valve seats 17, 18 are rectified or replaced, be sure to lap the valve seats 17, 18 and valves 7, 8. 🕮 **P.11-25**



(2) Valve sinkage from cylinder head bottom surface

If any measurement exceeds the specified limit, rectify or replace the defective part(s).

B: Valve sinkage



[Rectification]

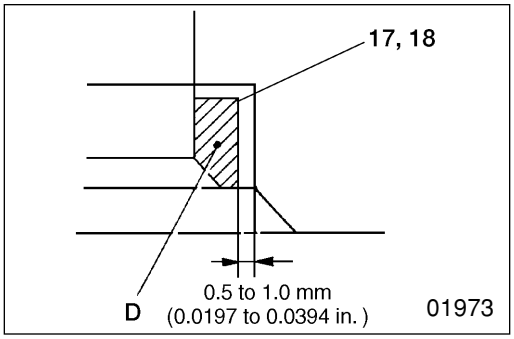
- Grind the valve seats **17**, **18** using a valve seat cutter or valve seat grinder.
- After grinding, put some sandpaper of around #400 grade between the cutter and valve seat and grind the valve seat lightly.
- Use a 15° or 17° cutter to achieve the specified valve seat width **A**.

C: Valve seat angle

CAUTION ⚠

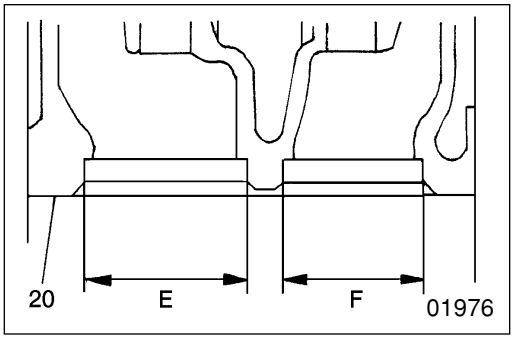
Ensure that grinding does not cause the valve sinkage B to exceed the specified limit.

- After rectification, lap the valves **7**, **8** and valve seats **17**, **18**.
  🕮 P.11-25



[Removal]
Valve seats **17**, **18** are installed by expansion fitting. To remove a valve seat, grind the inside surface to reduce its thickness, then remove the valve seat at room temperature.

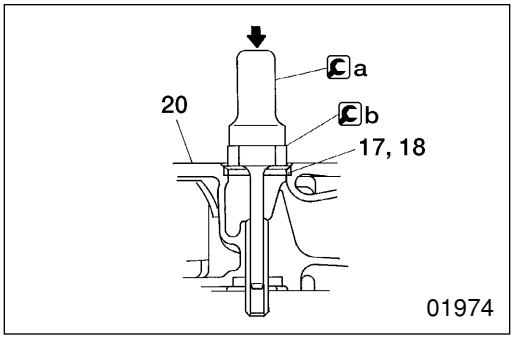
D: Material to remove



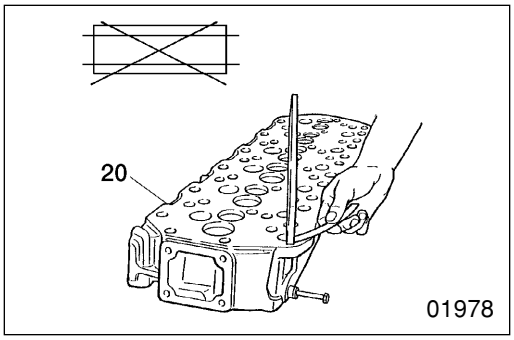
[Installation]
- Check that the valve seat hole diameters **E**, **F** in the cylinder head **20** conform with the values shown below.

Unit: mm(in.)

	Dimension
Inlet valve seat hole (**E**)	$\phi 51\ ^{+0.03}_{0}$ ($\phi 2.01\ ^{+0.001}_{0}$)
Exhaust valve seat hole (**F**)	$\phi 44\ ^{+0.025}_{0}$ ($\phi 1.73\ ^{+0.001}_{0}$)



- Cool the valve seats **17**, **18** by immersing it in liquid nitrogen.
- Install the valve seats **17**, **18** in the cylinder head **20** using the a Caulking Tool Body and b Installer Ring.
- After installing the valve seats **17**, **18**, lap the valve seats and valves **7**, **8**. P.11-25

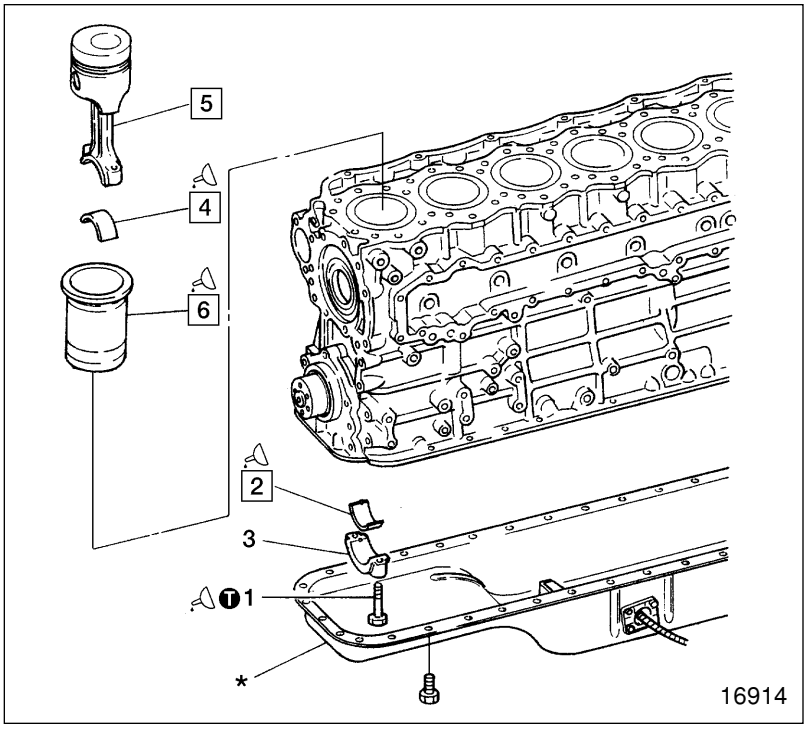


20 Inspecting cylinder head
- Measure the extent of distortion in the cylinder head's bottom surface.
- If the degree of distortion exceeds the specified limit, rectify the distortion with a surface grinder.

CAUTION ⚠

Ensure that grinding does not cause the cylinder head's top surface-to-bottom surface distance to fall below the specified limit.

PISTONS, CONNECTING RODS, AND CYLINDER LINERS



● **Pre-disassembly inspection**
📖 P.11-30

● **Removal sequence**
1 Bolt
2 Lower connecting rod bearing
3 Connecting rod cap
4 Upper connecting rod bearing
5 Piston and connecting rod assembly
📖 P.11-36
6 Cylinder liner

*: Oil pan 📖 Gr 12

● **Installation sequence**
Reverse the order of removal.

Service standards

Unit: mm (in.)

Location	Maintenance item		Standard value	Limit	Remedy
–	Piston projection		0.85 to 1.06 (0.0335 to 0.0417)	–	Inspect each location
	Connecting rod end play		0.15 to 0.45 (0.00591 to 0.0177)	0.6 (0.236)	Replace
2, 4	Connecting rod end play	Oil clearance [Basic diameter: 65 mm (2.56 in.)]	0.04 to 0.09 (0.00157 to 0.00354)	0.2 (0.00787)	Replace
		Span when free	–	Less than 69.5 (2.74)	
5, 6	Piston and connecting rod assembly-to-cylinder liner clearance [Basic diameter: 118 mm (4.65 in.)]		0.075 to 0.105 (0.00395 to 0.00413)	–	Replace
6	Cylinder liner	Flange projection	0.03 to 0.10 (0.00118 to 0.00394)	–	Replace
		Inside diameter	ϕ118 to 118.03 (ϕ4.646 to 4.647)	ϕ118.25 (ϕ4.656)	Replace
		Cylindricity	0.03 (0.00118) or less	–	Replace or grind to oversize

Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

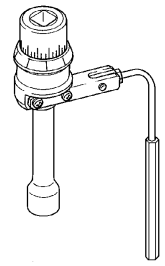
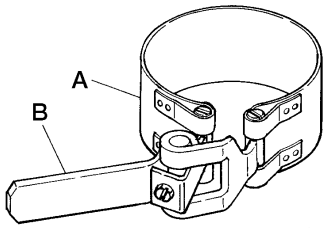
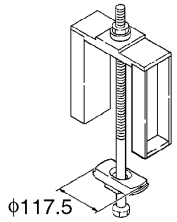
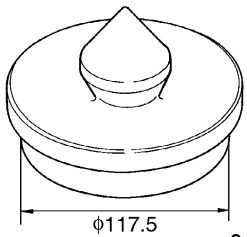
Location	Parts to be tightened	Tightening torque	Remarks
1	Bolt (connecting rod installation)	29 (3) [21.4] + 90° ± 5°	Wet

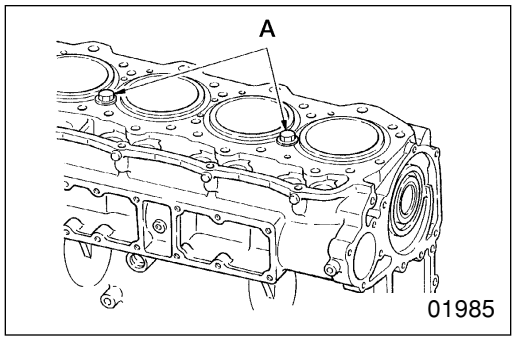
Oils

Location	Points of application	Kinds	Quantity
1	Both threads	Engine oil	As required
2, 4	Connecting rod bearing inside surface	Engine oil	As required
6	Cylinder liner outside surface	Engine oil	As required

Special tools

Unit: mm (in.)

Location	Tool name and shape	Part No.	Application
5	Socket Wrench  01984	MH061560	Installing piston and connecting rod assembly
5	A: Piston Guide Clamp B: Piston Guide Lever  01981	A: MH061760 B: MH061658	Installing piston and connecting rod assembly
6	Cylinder Liner Extractor  01982	MH061761	Removing cylinder liners
	Cylinder Liner Installer  01983	MH061771	Installing cylinder liners (dry type)



◆ Service procedure

● **Pre-disassembly inspection**

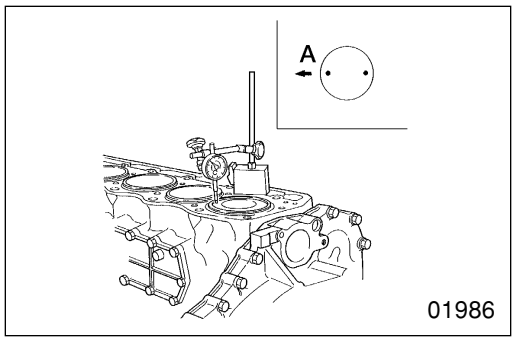
(1) Piston projection from crankcase top surface

NOTE

The piston projections affect engine performance and must therefore be checked.

WARNING ⚠

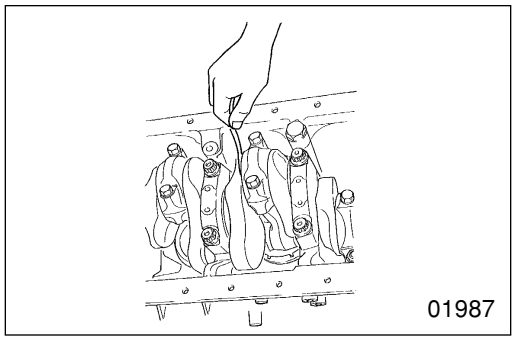
The cylinder liners may rise out of position when the crankcase is turned over or the crankshaft is turned. Hold their flanges down using bolts and washers A.



- Measure the projection of each piston at two points and calculate the average of the two values.

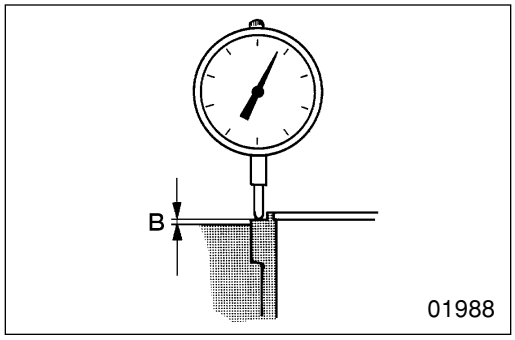
  A: Front of engine

- If the average value is out of specification, check the clearances between all relevant parts.



(2) Connecting rod end play

- Measure the end play of every connecting rod.
- If any measurement exceeds the specified limit, replace the defective part(s).



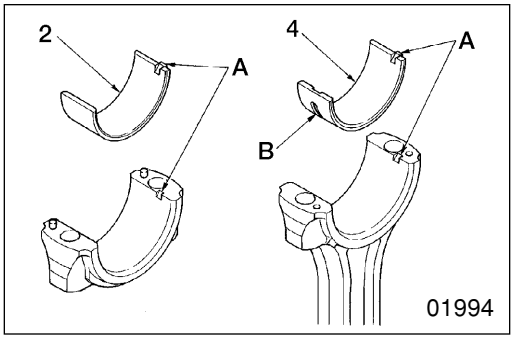
(3) Cylinder liner flange projection

- If any measurement is out of specification, replace the defective part(s).

  B: Flange projection

CAUTION ⚠

If the cylinder liner 6 flange projection is insufficient, bearing pressure on the cylinder head gasket will be too low in the region of the bore, possibly causing gas to leak.



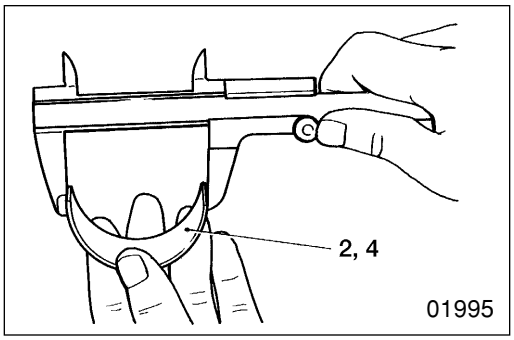
2 4 Connecting rod bearings

[Installation]

Install the connecting rod bearings 2, 4 by fitting the lugs A into their respective grooves.

CAUTION ⚠

The upper connecting rod bearing has an oil hole B. The lower connecting rod bearing has no oil hole. Take care not to confuse the upper and lower parts.



[Inspection]

CAUTION ⚠

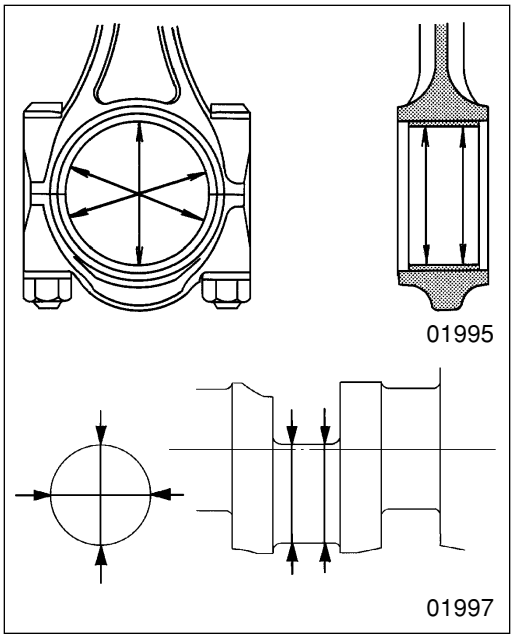
- **Do not attempt to manually expand a connecting rod bearings 2, 4 if its span is insufficient.**
- **Upper and lower connecting rod bearings 2, 4 must be replaced as a set.**

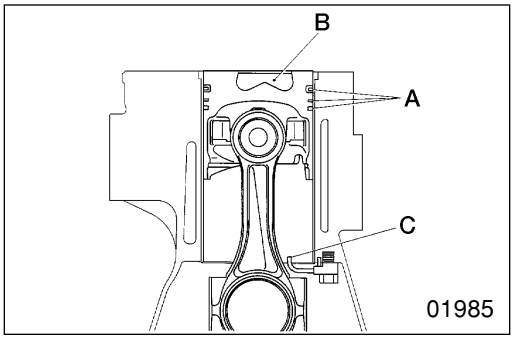
(1) Span when free

If the span is less than the specified requirement, replace the upper and lower connecting rod bearings 2, 4 as a set.

(2) Connecting rod bearing-to-crankshaft pin clearance

If the connecting rod bearing-to-crankshaft pin clearance exceeds the specified limit, replace the defective part(s).

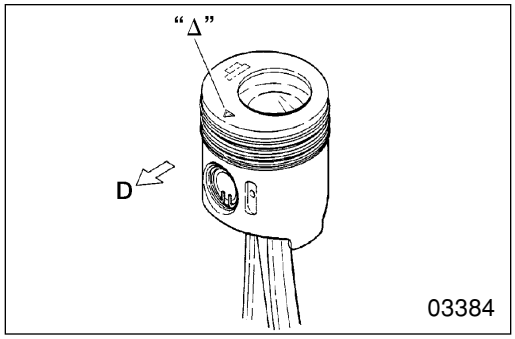




5 Installing piston and connecting rod assembly

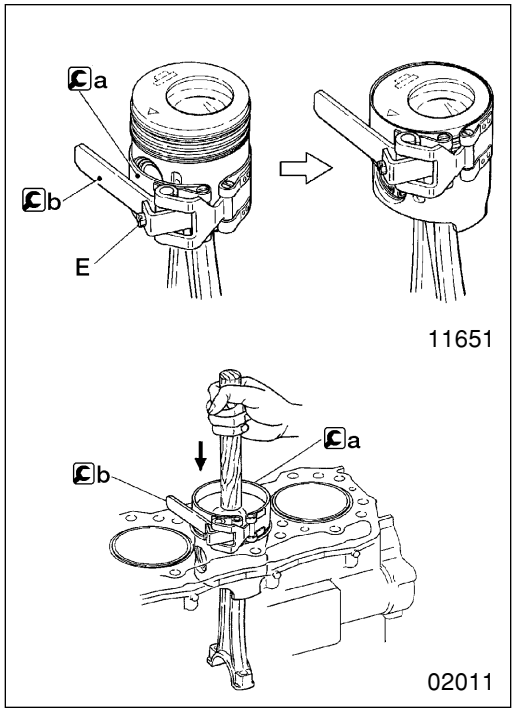
CAUTION ⚠

- **Ensure that the piston ring gaps A remain in their correct positions. 🕮 P.11-40**
- **Take care not to damage the piston crown B (the area that forms part of the combustion chamber).**
- **Ensure that the connecting rod does not touch the oil jet C.**

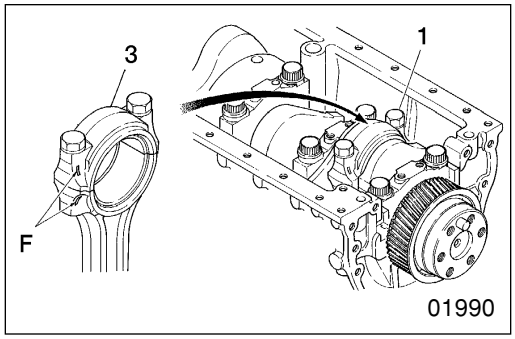


- With the piston's "Δ" front mark facing the front of the engine, install the piston and connecting rod assembly in accordance with the following procedure.

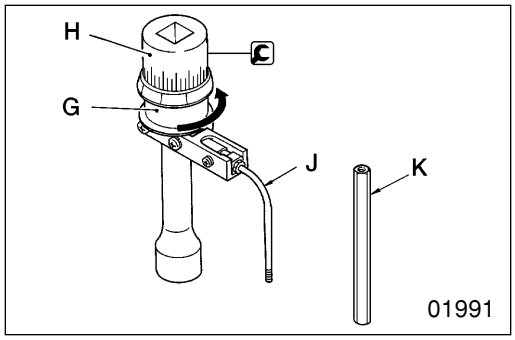
  D: Front of engine



- Fit the a Piston Guide Clamp over the piston skirt. Using the bolt **E** of the b Piston Guide Lever, adjust the clamp's inside diameter such that it matches the piston's outside diameter.
- Move the c Piston Guide Clamp and b Piston Guide Lever to the top of the piston.

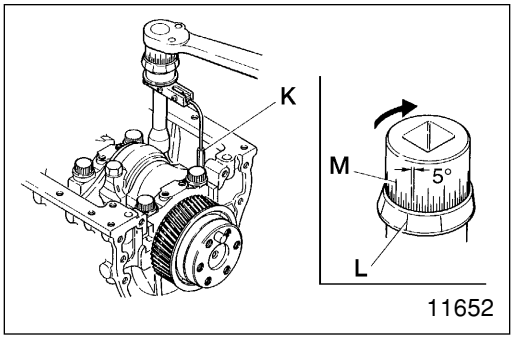


- With the piston installed, align the mating marks **F** on the connecting rod and connecting rod cap **3** and tighten the bolts to the specified torque. Then, tighten the bolts **1** further in accordance with the following procedure.



- Before fitting the Socket Wrench over a bolt, turn the holder **G** counter-clockwise to tension the built-in spring.

  H: Socket
  J: Rod
  K: Rod (extension)



- Set the socket wrench such that the built-in spring force forces the rod **K** against the crankshaft.
- On the holder **G**, select the inscribed line **L** that is easiest to see.
- Using the selected line as a reference, turn the socket **H** 90° ± 5° clockwise. (One gradation on the scale **M** represents 5°.)

NOTE

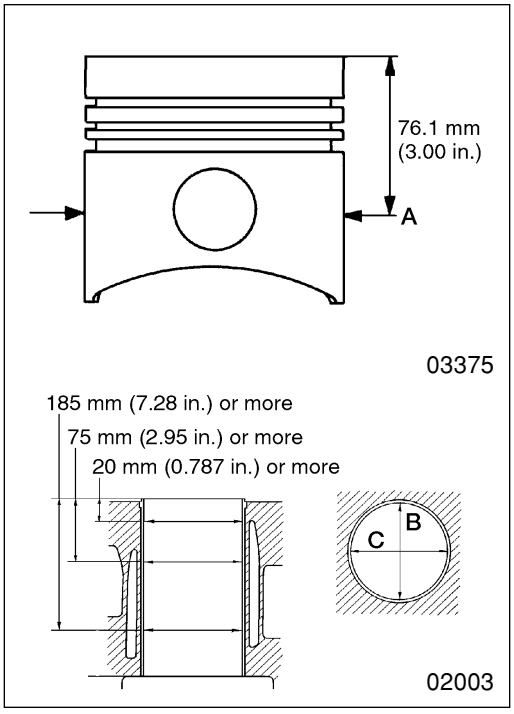
After fitting the connecting rod caps 3, inspect the following items:

- **Connecting rod end play (🕮 P.11-30)**
- **Piston projections (🕮 P.11-30)**

5 6 Piston-and-connecting rod assembly and cylinder liners

[Inspection]

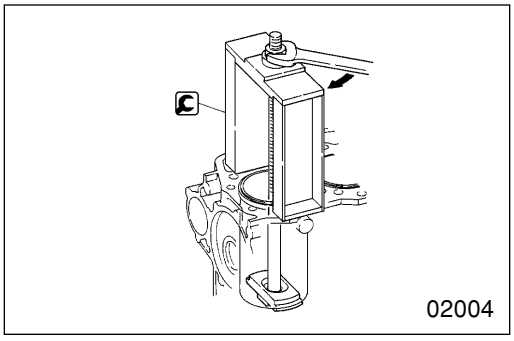
If any clearance is out of specification, replace the defective part(s).



A: Outside diameter measurement position
B: Direction of crankshaft axis
C: Perpendicular to crankshaft axis

NOTE

The cylinder liners are of a thin design and cannot be bored to oversize dimensions. To prevent deformation of the cylinder liners, do not remove them except for replacement.

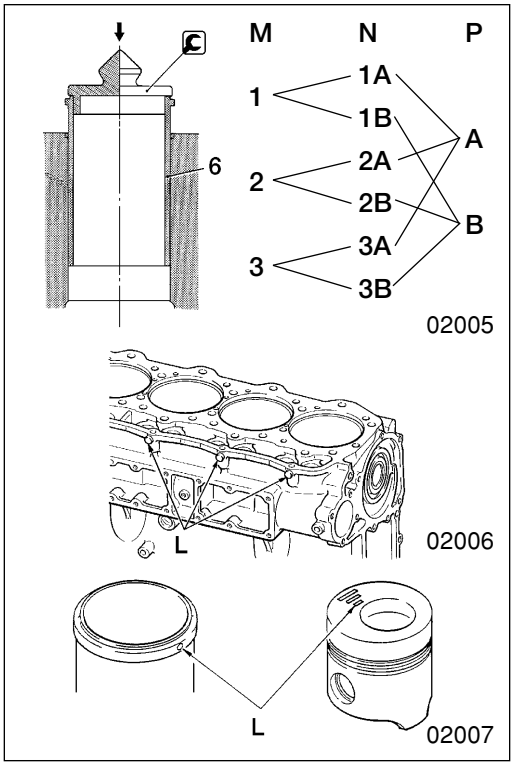


Cylinder liners

[Removal]

NOTE

If any cylinder liner 6 must be reused after removal, make an alignment mark with paint and use this mark to reinstall the cylinder liner in its original position.



[Installation]

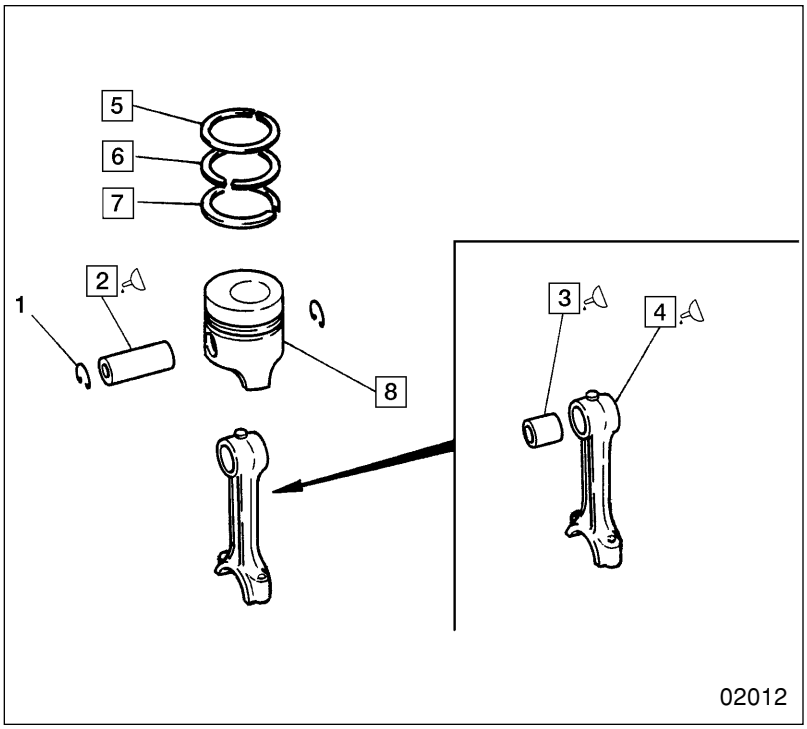
- Apply engine oil to the outside surface of the cylinder liner **6**.
- Insert the cylinder liner into the crankcase and press it into position using the Cylinder Liner Installer. Push down evenly on the entire upper surface of the Cylinder Liner Installer.

CAUTION ⚠

- **Size marks L are provided on the cylinder liner 6, piston, and crankcase (6 places). When the cylinder liner is replaced, select the proper one according to the size marks on the crankcase and the piston, as shown in the illustration.**
  M: Crankcase size mark
  N: Cylinder liner size mark
  P: Piston size mark
- **The cylinder liners are of a thin design. Handle them with care, and do not subject them to hammer blows or other severe shocks.**

M E M O

Piston and Connecting Rod Assembly



- **Disassembly sequence**
  1 Snap ring
  2 Piston pin
  3 Connecting rod bushing
  4 Connecting rod
  5 1st compression ring
  6 2nd compression ring
  7 Oil ring
  8 Piston

- **Assembly sequence**

Reverse the order of disassembly.

Service standards

Unit: mm (in.)

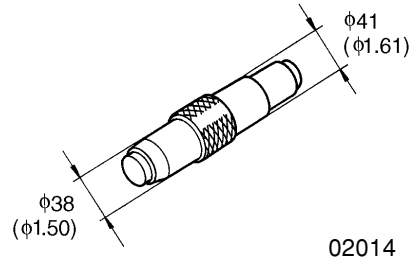
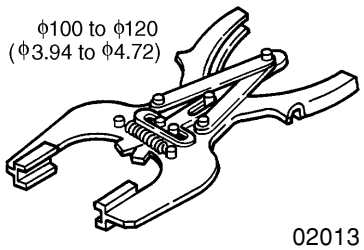
Location	Maintenance item		Standard value	Limit	Remedy
2, 3	Piston pin-to-connecting rod small end bushing clearance [Basic diameter: 38 mm (1.50 in.)]		0.02 to 0.05 (0.000787 to 0.00197)	0.1 (0.00394)	Replace
2, 8	Piston pin-to-piston clearance [Basic diameter: 38 mm (1.50 in.)]		0.004 to 0.02 (0.000157 to 0.000787)	0.05 (0.00197)	Replace
4	Connecting rod bend and torsion		–	0.05 (0.00197)	Replace
5 to 7	Piston ring end gap	1st compression ring	0.35 to 0.55 (0.0138 to 0.0217)	1.5 (0.0591)	Replace
		2nd compression ring	0.35 to 0.55 (0.0138 to 0.0217)	1.5 (0.0591)	Replace
		Oil ring	0.35 to 0.55 (0.0138 to 0.0217)	1.5 (0.0591)	Replace
5 to 8	Piston ring-to-piston ring groove clearance	1st compression ring	0.11 to 0.15 (0.00433 to 0.00591)	0.2 (0.00787)	Replace
		2nd compression ring	0.05 to 0.08 (0.00197 to 0.00315)	0.15 (0.0591)	Replace
		Oil ring	0.03 to 0.06 (0.00118 to 0.00236)	0.15 (0.0591)	Replace

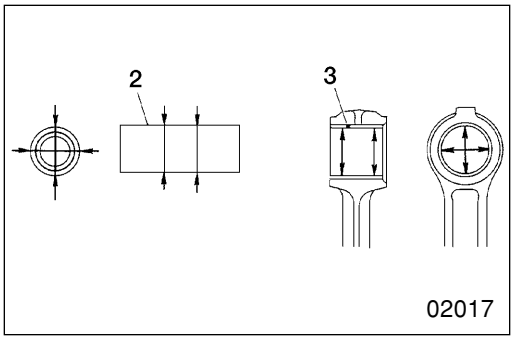
Oils

Location	Points of application	Kinds	Quantity
2	Piston pin outer surface	Engine oil	As required
3	Connecting rod bushing outer surface	Engine oil	As required
4	Bushing installation surface of connecting rod	Engine oil	As required

Special tools

Unit: mm (in.)

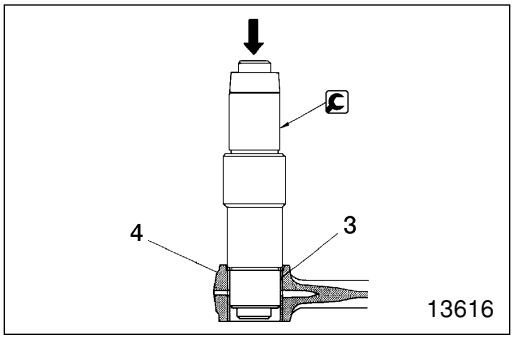
Location	Tool name and shape	Part No.	Application
3	Connecting Rod Bushing Puller 	MH061778	Removing and installing connecting rod bushings
5 to 7	Piston Ring Tool 	30091-07100	Removing and installing piston rings



◆ Service procedure

2 3 Rocker bushing and rocker shaft

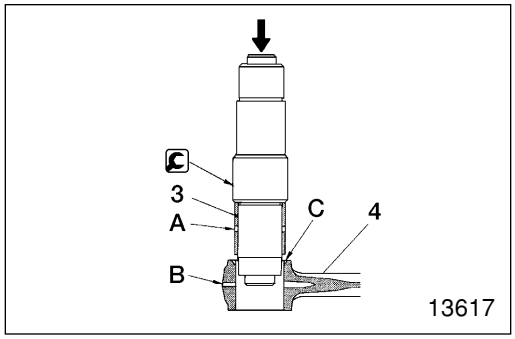
If the clearance exceeds the specified limit, replace the defective part(s).



Connecting rod bushing

[Removal]

Apply the Connecting Rod Bushing Puller to the connecting rod bushing 3. Using a press, apply pressure of approximately 49 kN (5,000 kgf) [11,015 lbf] such that the bushing is pressed out of the connecting rod 4.

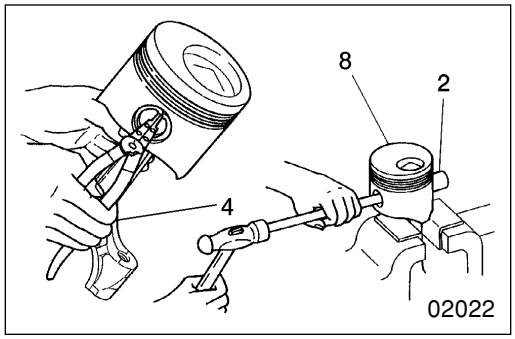


[Installation]

- Align oil hole **A** in the connecting rod bushing **3** with oil hole **B** in the connecting rod **4**.
- Apply the Ⓒ Connecting Rod Bushing Puller to the connecting rod bushing **3**. Using a press, apply pressure of approximately 49 kN (5,000 kgf) [11,015 lbf] such that the bushing is pressed into the connecting rod **4** from the chamfered side **C**.

NOTE

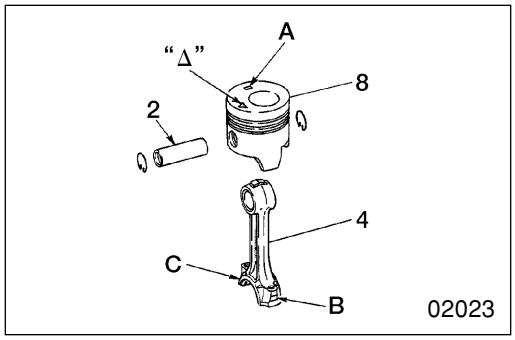
After installing the connecting rod bushing 3, insert the piston pin 2 and check that it turns smoothly and without play.



2 4 8 Piston pin, connecting rod, and piston

[Removal]

- Tap out the piston pin **2** using a rod and hammer.
- If the piston pin **2** is difficult to remove, heat the piston **8** in hot water or using a piston heater.



[Installation]

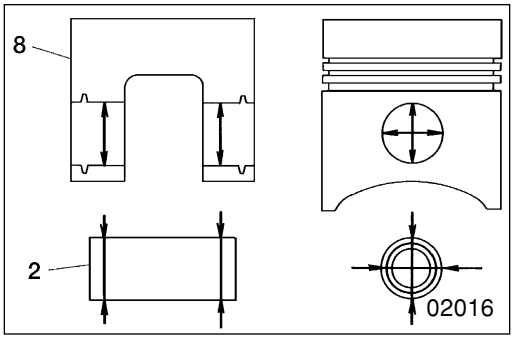
- Apply engine oil to the piston pin **2**. With the connecting rod **4** and piston **8** aligned as illustrated, insert the piston pin to hold these components together.

  A: Weight mark
  B: Weight mark (A, B, C, D, E, F, G, H, I, V, W, X, Y, Z)
  C: Alignment mark for connecting rod cap
  Δ: Front mark

- If the piston pin **2** is difficult to insert, heat the piston **4** in hot water or using a piston heater.

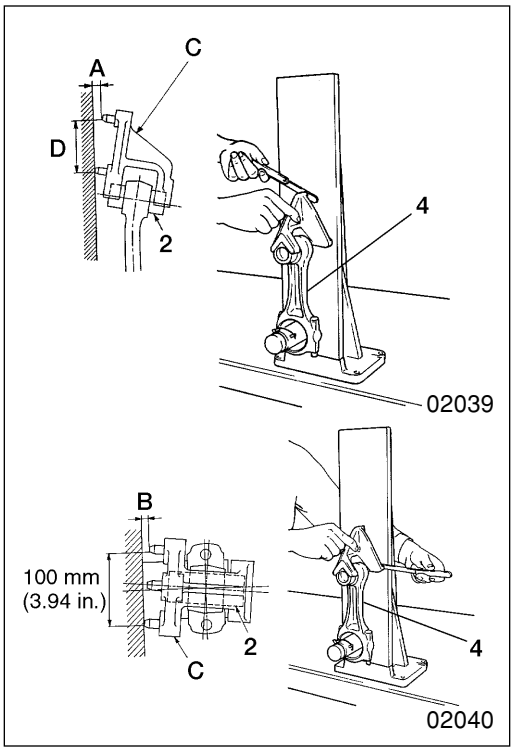
CAUTION ⚠

- **No piston should differ from any other piston by a weight of more than log.**
- **The connecting rods must all have the same weight mark.**
- **After inserting the piston pin 2, check that it turns smoothly and without play.**



2 8 **Piston pin-to-piston clearance**

If the clearance exceeds the specified limit, replace the defective part(s).



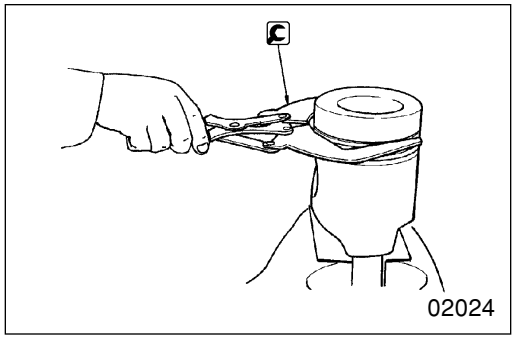
4 **Connecting rod bend and twist**

- Fit the connecting rod bushing **3** and piston **2** in their respective positions of the connecting rod **4**.
- Measure the extent of bending **A** and twisting **B** in the connecting rod **4**.
- If either measurement exceeds the specified limit, replace the connecting rod **4** or rectify it.

C: Connecting rod **4** aligner (measurement device)

NOTE

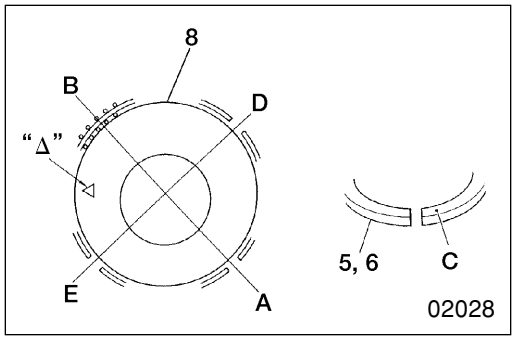
- **Before mounting the connecting rod 4 on the connecting rod aligner C, install the upper and lower connecting rod bearings in their respective positions.**
- **Measurements must be made with the connecting rod cap mounting nuts tightened to their specified torque.** **P.11-29**



5 to 8 Piston rings and piston

Piston rings

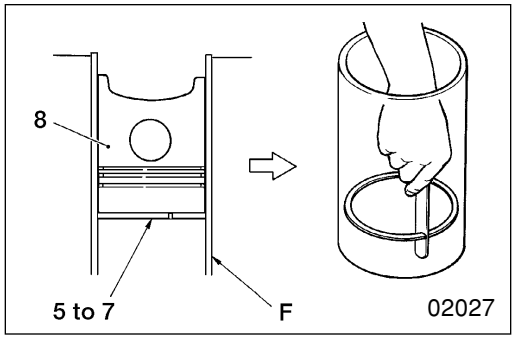
[Removal]



[Installation]

- Fit the oil ring **7** onto the piston **8** with its side rail gaps **A** and the expander spring gap **B** in the positions illustrated.
- Fit the compression rings **5**, **6** onto the piston such that the manufacturer's marks **C** near the gaps face upward.
- Align the compression ring gaps **D**, **E** as illustrated.

D: 1st compression ring gap
E: 2nd compression ring gap
Δ: Front mark



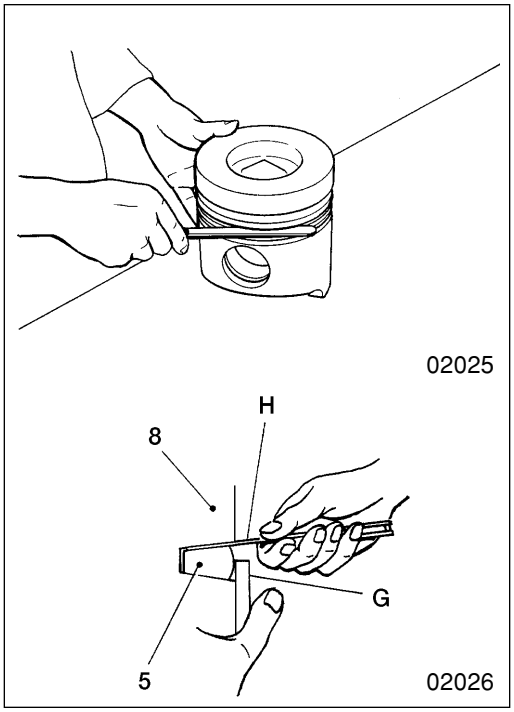
[Inspection]

(1) Piston ring end gap

- Using the crown of a piston **8**, push the piston ring **5**, **6 or 7** horizontally into a cylinder liner **F** for measurement.
- Taking care not to move the piston ring **5**, **6 or 7**, measure the end gap. Replace all the rings of a piston if any gap exceeds the specified limit.

NOTE

- **To keep the piston ring 5, 6 or 7 horizontal, be sure to insert them into the cylinder liner F using a piston 8.**
- **Push the piston ring 5, 6 or 7 down to the bottom of cylinder liner F; the bottom should be less worn than the top.**
- **Piston ring 5, 6 or 7 must be replaced as a set. Never replace piston rings individually.**



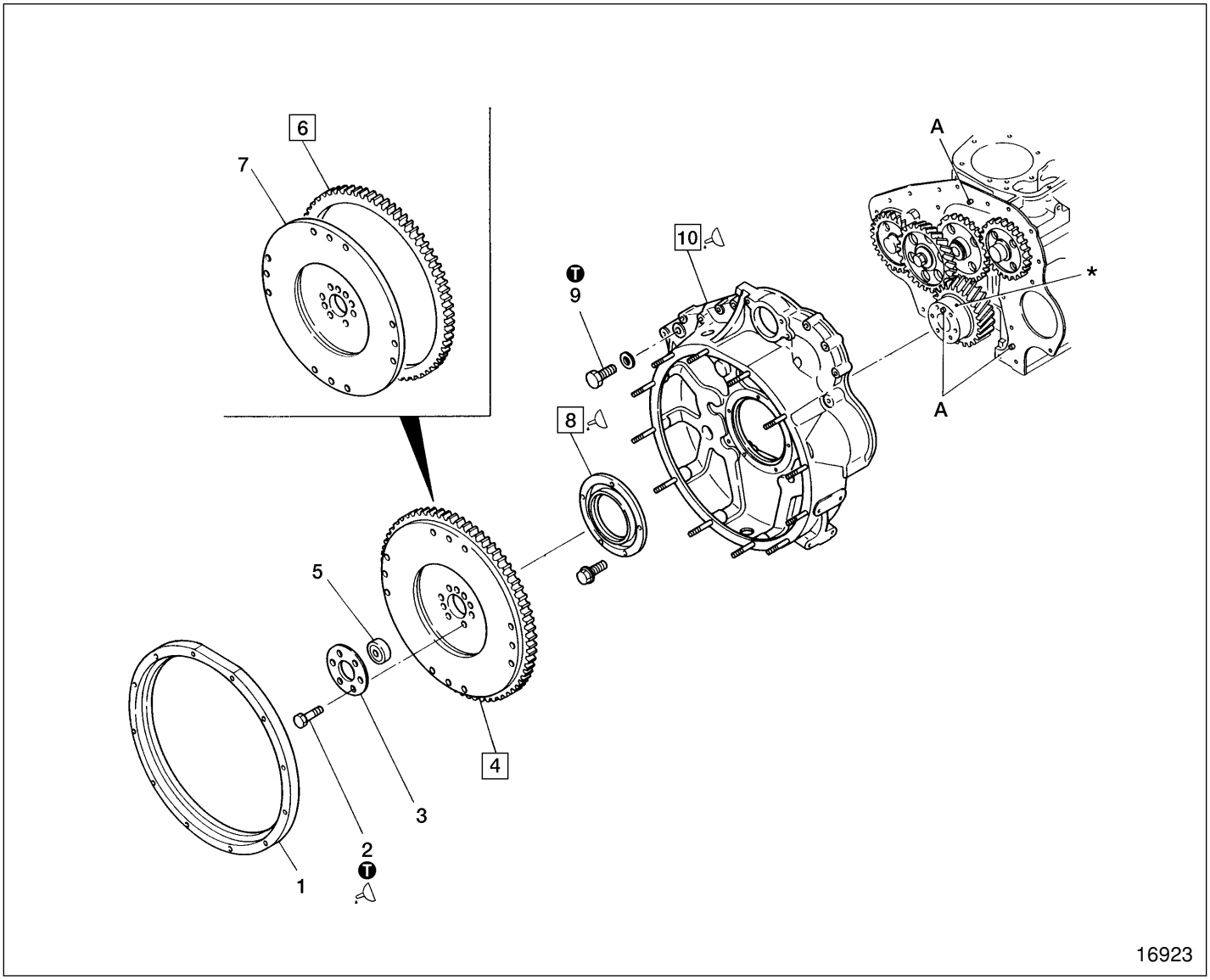
(2) Piston ring-to-piston ring groove clearance

- If any measurement exceeds the specified limit, replace the defective part(s).
- Measure the 1st compression ring **5** clearance with a thickness gauge **H** while pressing the ring against the piston **8** with a straight edge **G**.

NOTE

- **Remove any carbon deposits from the ring groove of the piston 8 and measure the clearance around the piston's entire periphery.**
- **Piston rings 5, 6, 7 must be replaced as a set. Never replace piston rings individually.**

FLYWHEEL



● **Disassembly sequence**

1 Spacer
2 Bolt
3 Washer plate
4 Flywheel assembly
5 Pilot bearing
6 Ring gear
7 Flywheel
8 Rear oil seal
9 Plug
10 Flywheel housing

∗: Crankcase 🕮 P.11-62
A: Locating pin
Ⓧ: Non-reusable part

● **Assembly sequence**

Reverse the order of disassembly.

Service standards

Unit: mm (in.)

Location	Maintenance item		Standard value	Limit	Remedy
4	Flywheel assembly	Friction surface distortion	0.05 (0.00197) or less	0.2 (0.00787)	Correct or replace
		Height of friction surface	20 (0.787)	19 (0.748)	Replace
		Friction surface runout (when fitted)	–	0.2 (0.00787)	Correct or replace
3	Eccentricity of joint		–	0.2 (0.00787)	Inspect or replace

Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

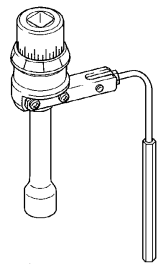
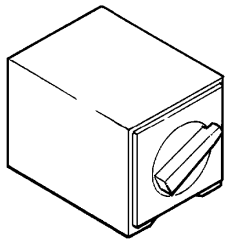
Location	Parts to be tightened	Tightening torque	Remarks
8	Flywheel mounting bolt	98 (10) [72.3] + 150°	• Wet • Can be reused up to 3 times
9	Plug	88 (9) [64.9]	–

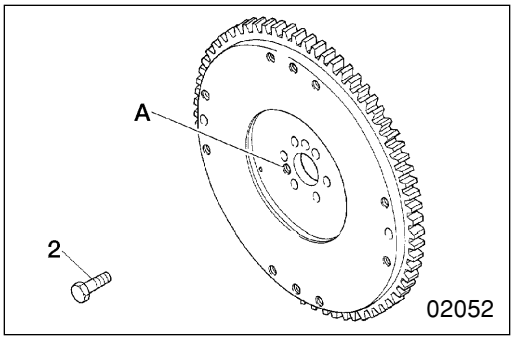
Oils and sealants

Location	Points of application	Kinds	Quantity
2	Bolt threads	Engine oil	As required
8	Rear oil seal lip	Engine oil	As required
	Flywheel mounting surface of rear oil seal	Threebond 1207C	As required
10	Engine mounting surface of flywheel housing	Threebond 1207C	As required

Special tools

Unit: mm (in.)

Location	Tool name and shape	Part No.	Application
4	Socket Wrench  01984	MH062354	**Fitting flywheel**
	Magnetic Base  00471	MH062356	

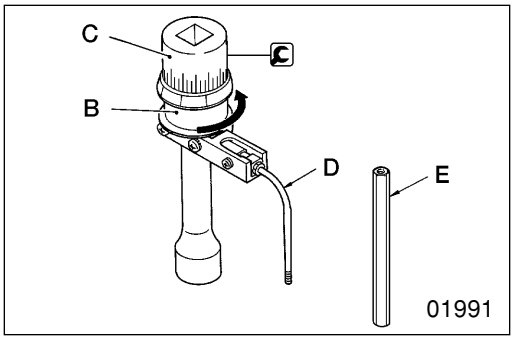


◆ Service procedure

4 Flywheel assembly

[Removal]

To remove the flywheel assembly **4**, screw the mounting bolts **2** into the removal holes **A**.



[Installation]

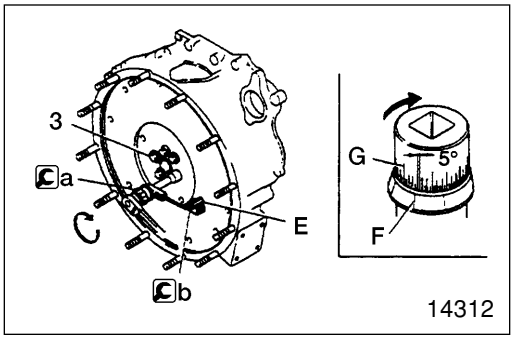
- The bolts **2** can be used only three times. Before refitting the bolts, make a punch mark on the head of each one to indicate times of reuse.

CAUTION ⚠

If any bolt already has three punch marks, it must not be reused any more; replace it with a new one.

- Tighten the bolts **2** to their specified torque, then tighten them further in accordance with the following procedure:
- Turn the holder **B** of the 🔧 Socket Wrench counter-clockwise to tension the built-in spring.

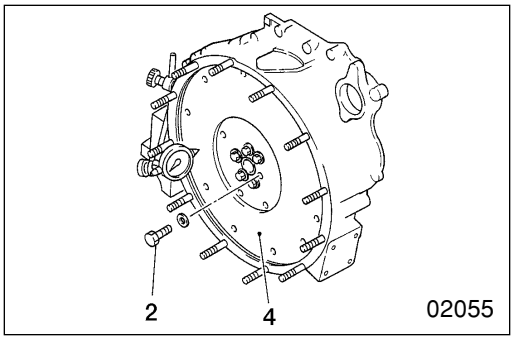
C: Socket
D: Rod
E: Rod (extension)



- Set the 🔧a Socket Wrench such that the built-in spring forces the rod **E** against the 🔧b Magnetic Base.
- On the holder **B**, select the inscribed line **F** that is easiest to see.
- Using the selected line as a reference, turn the socket 150° clockwise. (One gradation on the scale **G** represents 5°.)

CAUTION ⚠

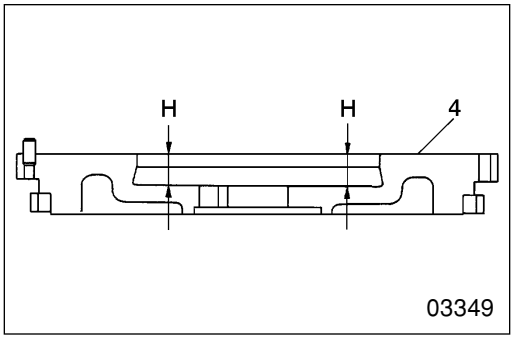
Since the bolts 2 utilize the plastic region tightening method, they must not be tightened further after this procedure.



[Inspection]

(1) Runout

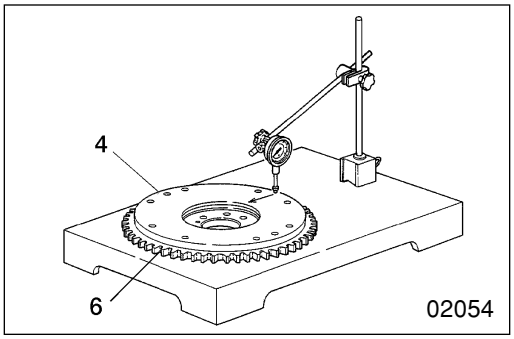
- Tighten the bolts **2** to their specified torque.
- If runout exceeds the specified limit, check that the bolts **2** are tightened correctly and inspect the crankshaft * mounting surface. Then, rectify or replace the flywheel assembly **4** as required.



(2) Height of friction surface

If the measurement is below the specified value, rectify or replace the flywheel assembly **4**.

H: Height of friction surface

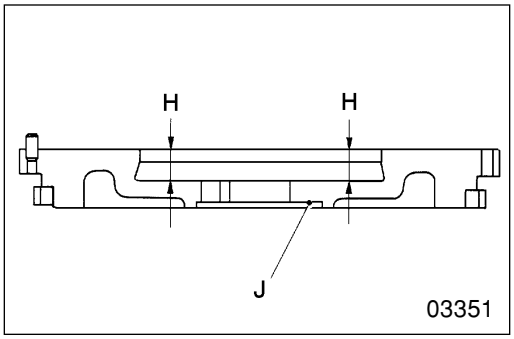


(3) Distortion of friction surface

If distortion exceeds the specified limit, rectify or replace the flywheel assembly **4**.

NOTE

If any abnormality is evident on the ring gear 6, replace the ring gear before making inspections.



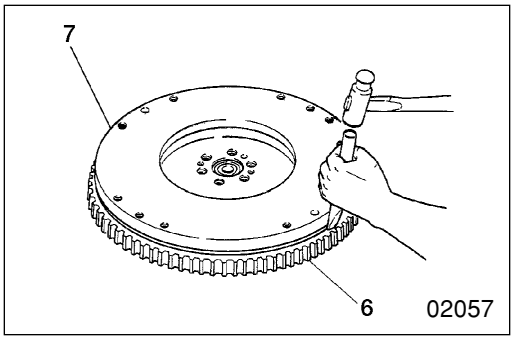
[Rectification]

Grind the friction surface such that its height **H** remains greater than the specified minimum. The friction surface must remain parallel with surface **J** with a tolerance of 0.1 mm (0.00394 in.).

6 Ring gear

[Inspection]

Inspect the ring gear **6** for damage and abnormal wear. If any defect is evident, the ring gear must be replaced.



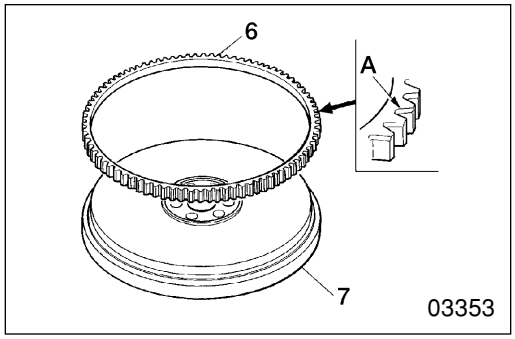
[Removal]

- Heat the ring gear **6** evenly with an acetylene torch or the like.

CAUTION ⚠

Be careful not to get burned.

- Remove the ring gear **6** from the flywheel **7** by tapping around its entire periphery.



[Installation]

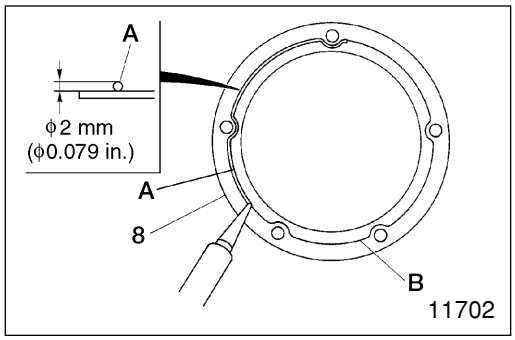
- Using a piston heater or the like, heat the ring gear **6** to approximately 100°C (212°F) for 3 minutes.

CAUTION ⚠

Be careful not to get burned.

- Fit the ring gear **6** with the non-chamfered side of its teeth toward the flywheel **7**.

A: Chamfered side of ring gear

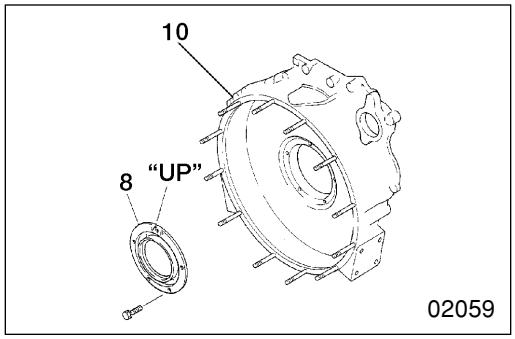


8 **Fitting rear oil seal**

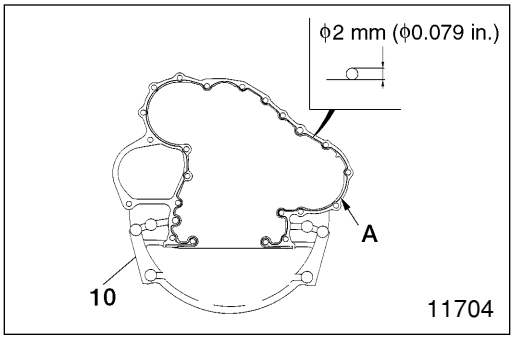
- Apply an even, unbroken bead of sealant **A** to the rear oil seal **8** in the position illustrated **B**.
- Fit the rear oil seal 9 onto the flywheel housing **10** within 3 minutes of applying the sealant **A**.

CAUTION ⚠

- **Ensure that the sealant application position B on the oil seal 8 is clean before applying sealant.**
- **When fitting the rear oil seal 8, hold it firmly in position to prevent spreading the sealant.**
- **After fitting the rear oil seal 8, wait at least 30 minutes before starting the engine.**
- **Apply a new bead of sealant A whenever the mounting bolts of the rear oil seal 8 have been loosened.**



- Apply engine oil to the lip of the rear oil seal **8**.
- Fit the rear oil seal **8** onto the flywheel housing **10** in the direction illustrated.



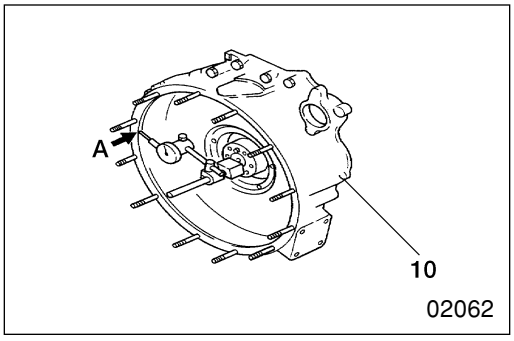
10 **Flywheel housing**

[Installation]

- Apply an even, unbroken bead of sealant **A** to the crankcase mounting surface of the flywheel housing **10**.
- Fit the flywheel housing **10** onto the crankcase within 3 minutes of applying the sealant **A**.

CAUTION ⚠

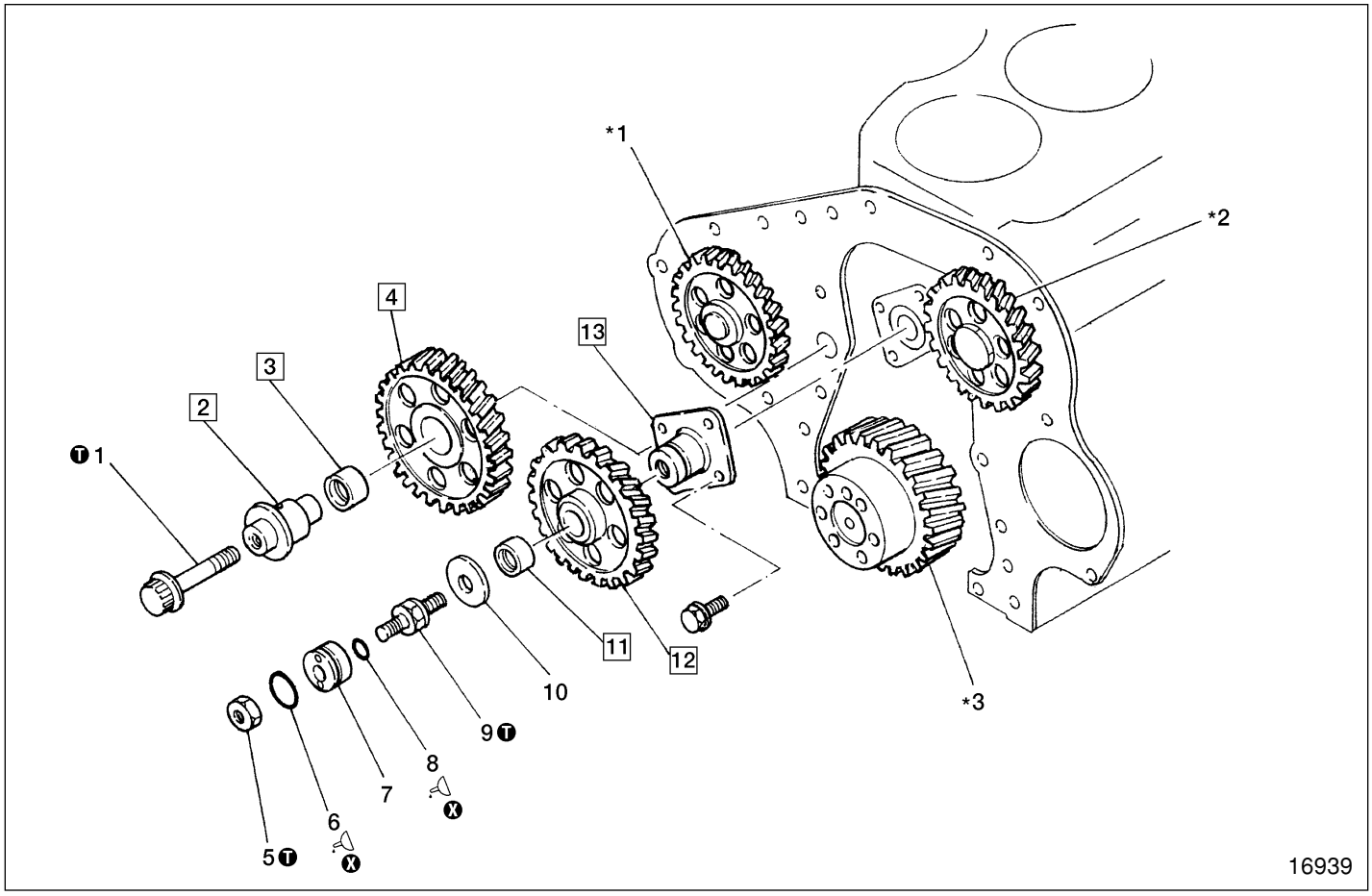
- **Ensure that the sealant application position on the flywheel housing 10 is clean before applying sealant.**
- **When fitting the flywheel housing 10, hold it firmly in position to prevent spreading the sealant.**
- **After fitting the flywheel housing 10, wait at least an hour before starting the engine.**
- **Apply a new bead of sealant A whenever the mounting bolts of the flywheel housing 10 have been loosened.**



[Inspection]

- Rotate the crankshaft and check the extent of eccentricity at the joint **A** of the flywheel housing **10**.
- If eccentricity exceeds the specified limit, carry out reassembly.
- If eccentricity still exceeds the specified limit after reassembly, replace the defective part(s).

TIMING GEARS



● **Pre-disassembly inspection**

📖 P.11-50

● **Disassembly sequence**

1 Bolt
2 No. 1 idler shaft
3 No. 1 idler gear bushing
4 No. 1 idler gear
5 Nut
6 O-ring
7 Collar
8 O-ring
9 Bolt
10 Thrust washer
11 No. 2 idler gear bushing
12 No. 2 idler gear
13 No. 2 idler shaft

*1: Drive gear
*2: Camshaft gear 📖 P.11-54
*3: Crankshaft gear 📖 P.11-62

X: Non-reusable part

CAUTION ⚠

Since the No. 1 idler gear 4 is supported by the No. 1 idler shaft 2, these parts must be removed as a single unit.

● **Assembly sequence**

Reverse the order of disassembly.

Service standards

Unit: mm (in.)

Location	Maintenance item		Standard value	Limit	Remedy
–	Gear backlash	Between No. 1 idler gear and crankshaft gear	0.08 to 0.15 (0.00315 to 0.00591)	0.35 (0.0138)	Replace
		Between No. 1 idler gear and No. 2 idler gear	0.07 to 0.15 (0.00276 to 0.00591)	0.35 (0.0138)	Replace
		Between No. 1 idler gear and drive gear	0.07 to 0.15 (0.00276 to 0.00591)	0.35 (0.0138)	Replace
		Between No. 2 idler gear and camshaft gear	0.08 to 0.16 (0.00315 to 0.00630)	0.35 (0.0138)	Replace
2. 3	No. 1 idler shaft-to-gear bushing clearance [Basic diameter: 37 mm (1.46 in.)]		0.01 to 0.05 (0.000394 to 0.00197)	0.2 (0.00787)	Replace
4, 12	Idler gear end play		0.05 to 0.15 (0.00197 to 0.00591)	0.3 (0.0118)	Replace
11, 13	No. 2 idler gear bushing-to-shaft clearance [Basic diameter: 32 mm (1.26 in.)]		0.01 to 0.05 (0.000394 to 0.00197)	0.2 (0.00787)	Replace

Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

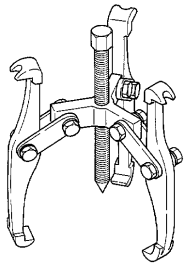
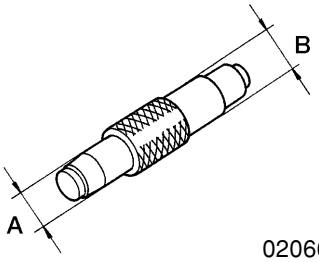
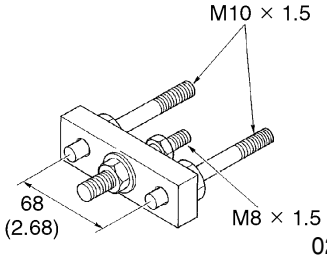
Location	Parts to be tightened	Tightening torque	Remarks
1	No. 1 idler gear mounting bolt	88 (9) [64.9]	–
5	Collar mounting nut	82 (8.4) [60.5]	–
9	No. 2 idler gear mounting bolt	95 (9.7) [70.1]	–

Oils

Location	Points of application	Kinds	Quantity
6, 8	O-ring	Engine oil	As required

Special tools

Unit: mm (in.)

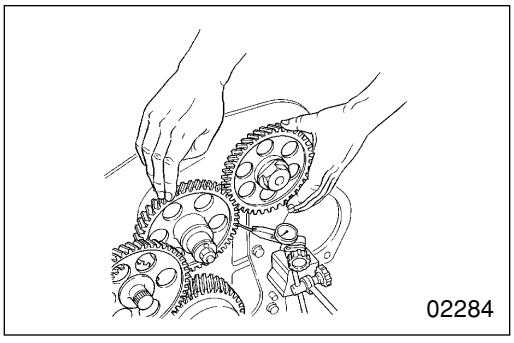
Location	Tool name and shape	Part No.	Application
2, 4	Gear Puller  02065	MH061326	Removing No. 1 idler shaft and gear
3, 11	Idler Gear Bushing Puller A: No. 1 idler gear bushing: ϕ37 (ϕ1.46); No. 2 idler gear bushing: ϕ32 (ϕ1.26) B: No. 1 idler gear bushing: ϕ40 (ϕ1.57); No. 2 idler gear bushing: ϕ35 (ϕ1.38)  02066	<No. 1> MH062601 <No. 2> MH061779	Removing and fitting idler gear bushings
13	Idler Shaft Puller  02067	MH062405	Removing No. 2 idler gear shaft

◆ Service procedure

● Pre-disassembly inspection

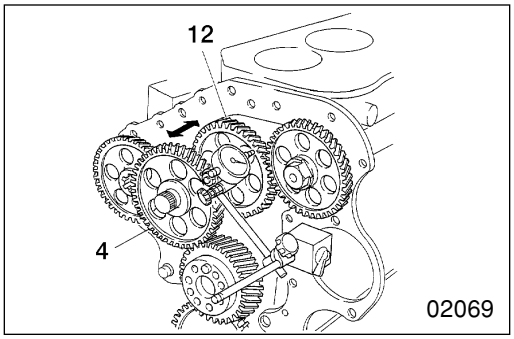
(1) Gear backlash

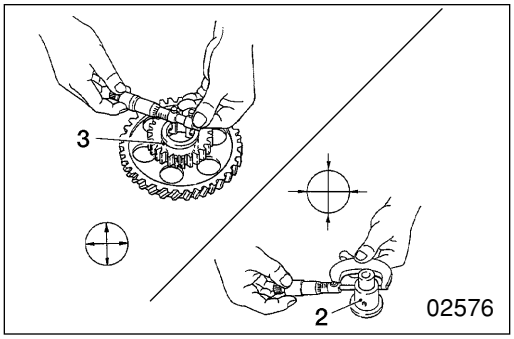
For each gear pair, measure backlash at three or more points. If any measurement exceeds the specified limit, replace the defective part(s).


02284

(2) Idler gear end play

If the measurement exceeds the specified value, replace the defective part(s).

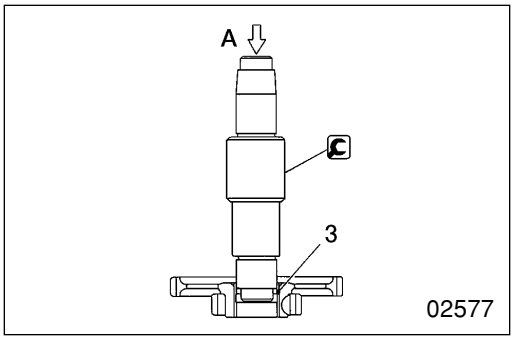

02069



2 3 **No. 1 idler shaft and No. 1 idler gear bushing**

[Inspection]

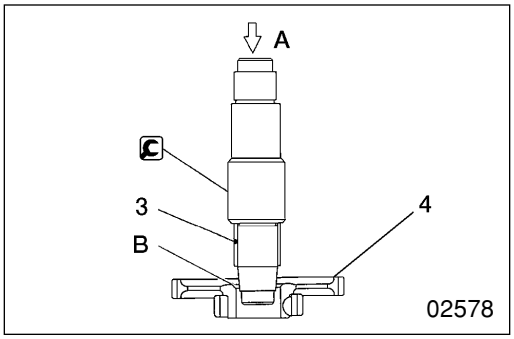
If the clearance exceeds the specified limit, replace the defective part(s).



No. 1 idler gear bushing

[Removal]

A: Press

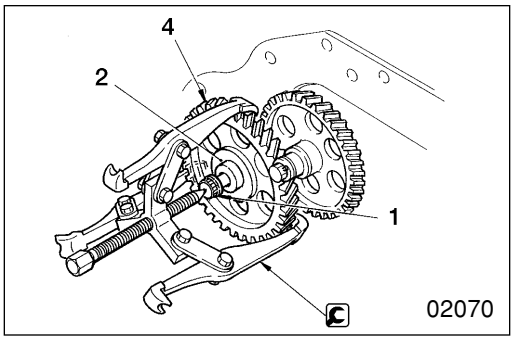


[Installation]

- Using the Idler Gear Bushing Puller, press the No. 1 idler gear bushing **3** into the No. 1 idler gear **4** from the side of the gear whose internal diameter is chamfered B.

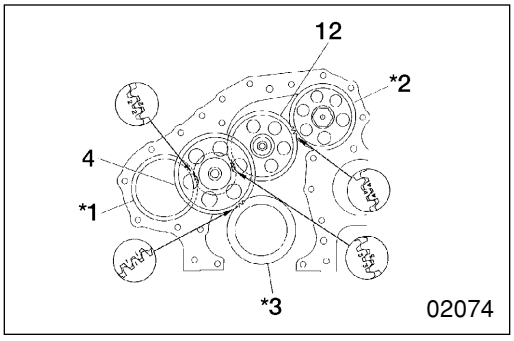
  A: Press

- After installation, measure the clearance again. If the measurement is below the nominal value range, ream the bushing **3**.



2 4 **Removing No. 1 idler shaft and No. 1 idler gear**

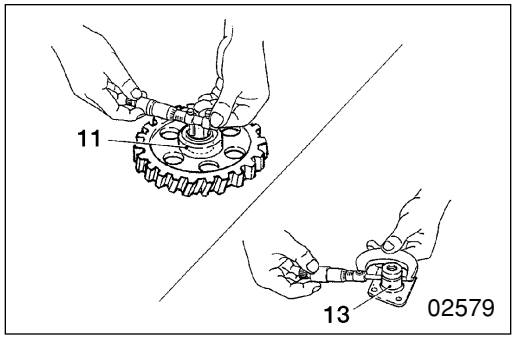
Loosen the bolt **1** by approximately 15 mm (0.591 in.), then remove the No. 1 idler shaft **2** and No. 1 idler gear **4** as a single unit.



4 12 **Installing No. 1 and No. 2 idler gears**

Fit the No. 1 and No. 2 idler gears **4**, **12** such that their alignment marks ("**1**", "**2**", "**3**", "**4**") are aligned with those on the gears with which they mate.

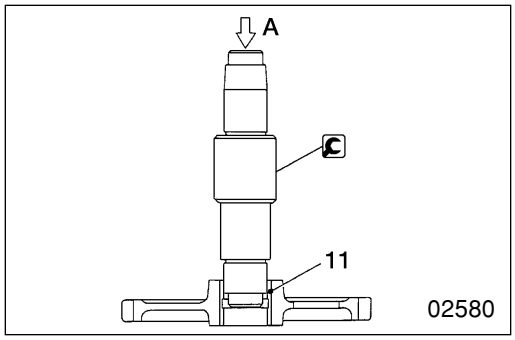
***1**: Drive gear
***2**: Camshaft gear
***3**: Crankshaft gear



11 **13** **No. 2 idler gear bushing and No. 2 idler shaft**

[Inspection]

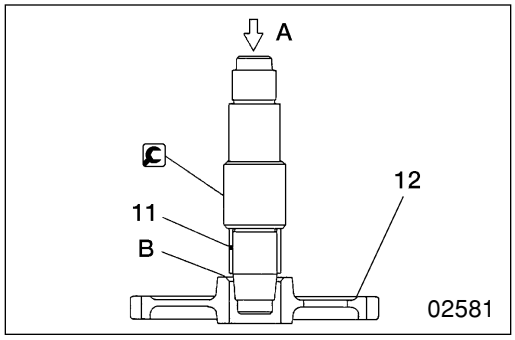
If the clearance exceeds the specified limit, replace the defective part(s).



No. 2 idler gear bushing

[Removal]

A: Press

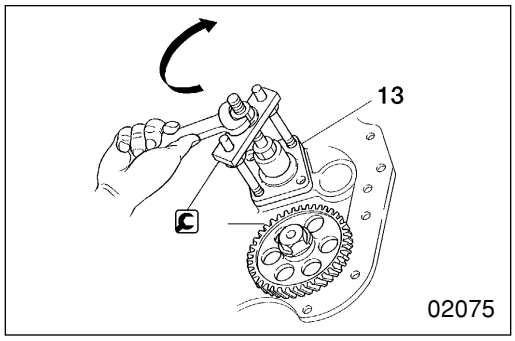


[Installation]

- Using the Idler Gear Bushing Puller, press the No. 2 idler gear bushing **11** into the No. 2 idler gear **12** from the side of the gear whose internal diameter is chamfered **B**.

  A: Press

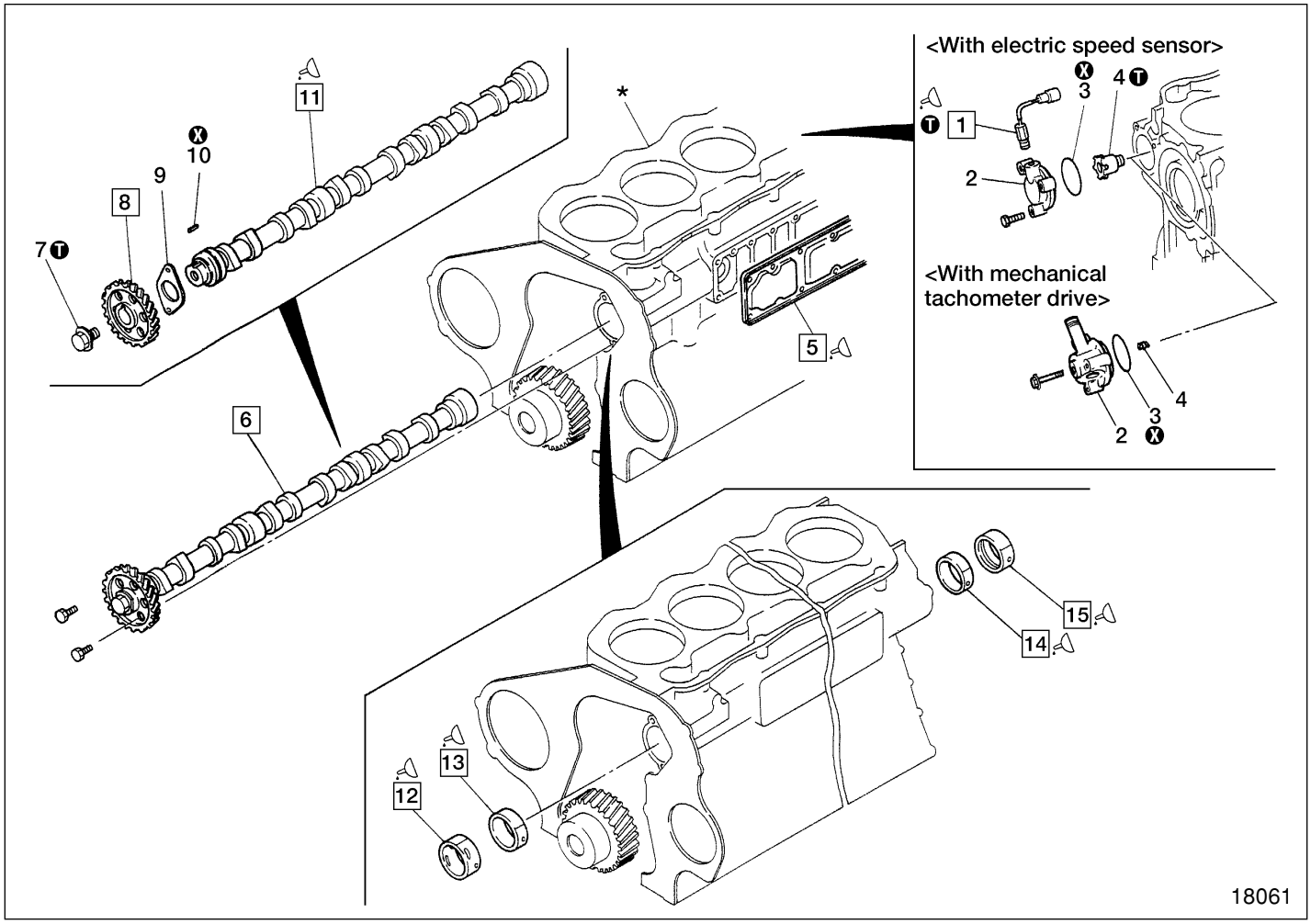
- After installation, measure the clearance again. If the measurement is below the nominal value range, ream the bushing **11**.



13 **Removing No. 2 idler shaft**

M E M O

CAMSHAFT



● **Pre-disassembly inspection**

P.11-56

● **Disassembly sequence**

1 Engine speed sensor <models with electric speed sensor>
2 Adapter <models with electric speed sensor>
Tachometer drive case <models with mechanical tachometer>
3 O-ring
4 Pulse rotor <models with electric speed sensor>
Tachometer drive coupling <models with mechanical tachometer>
5 Side cover
6 Camshaft assembly
7 Bolt
8 Camshaft gear
9 Thrust plate
10 Key
11 Camshaft
12 No. 4 camshaft bushing
13 No. 3 camshaft bushing
14 No. 2 camshaft bushing
15 No. 1 camshaft bushing

∗: Crankcase P.11-62
Ⓧ: Non-reusable part

NOTE

- **Do not remove the engine speed sensor 1 unless defects are evident.**
- **Do not remove the camshaft gear 8 unless defects are evident.**

● **Assembly sequence**

Reverse the order of disassembly.

Service standards

Unit: mm (in.)

Location	Maintenance item			Standard value	Limit	Remedy
1	Resistance of engine speed sensor [at 25°C (77°F)]			2.3 ± 0.2 kΩ	–	Replace
6	Camshaft assembly end play			0.05 to 0.22 (0.00197 to 0.00866)	0.4 (0.0157)	Inspect each part
11	Camshaft	Cam lift	Inlet	6.901 (0.272)	6.40 (0.252)	Lobe height: 49.011 (1.930) Base circle diameter: 41.627 (1.659)
			Exhaust	7.680 (0.302)	7.18 (0.283)	Lobe height: 49.307 (1.941) Base circle diameter: 41.627 (1.659)
		Bend		0.02 (0.000787) or less	0.04 (0.00157)	Replace
11, 12 to 15	Camshaft journal-to-camshaft bushing clearance	No. 1 journal [Basic diameter: 57.75 mm (2.27 in.)]		0.05 to 0.10 (0.00197 to 0.00394)	0.25 (0.00984)	Replace
		No. 2 journal [Basic diameter: 58.00 mm (2.28 in.)]		0.05 to 0.10 (0.00197 to 0.00394)		
		No. 3 journal [Basic diameter: 58.25 mm (2.29 in.)]		0.13 to 0.18 (0.00512 to 0.00709)		
		No. 4 journal [Basic diameter: 58.50 mm (2.28 in.)]		0.05 to 0.10 (0.00197 to 0.00394)		

Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

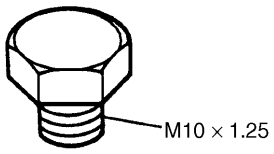
Location	Parts to be tightened	Tightening torque	Remarks
1	Engine speed sensor <models with electric speed sensor>	29 ± 5.9 (3.0 ± 0.6) [21.4 ± 4.4]	–
4	Pulse rotor <models with electric speed sensor>	98 (10) [72.3]	–
7	Camshaft gear mounting bolt	175 (18) [129]	–

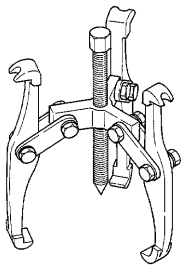
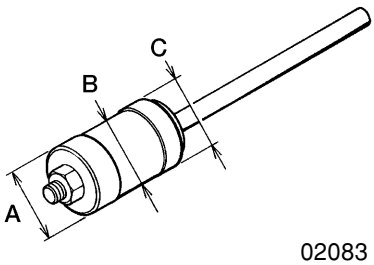
Oils and sealants

Location	Points of application	Kinds	Quantity
1	Engine speed sensor threads <models with electric speed sensor>	Threebond 1104J	As required
5	Crankcase mounting surface of side cover	Threebond 1207C	As required
11	Camshaft journals	Engine oil	As required
12 to 15	Inside surfaces of camshaft bushings	Engine oil	As required

Special tools

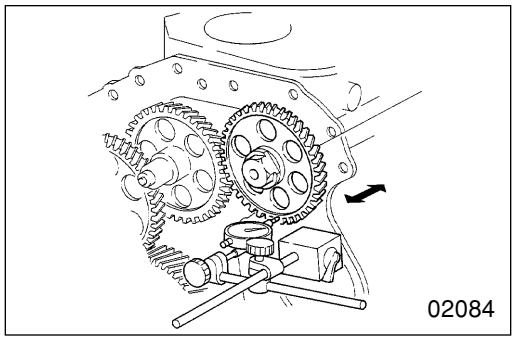
Unit: mm (in.)

<table>
<tr><th>Location</th><th>Tool name and shape</th><th>Part No.</th><th>Application</th></tr>
<tr><td rowspan="2">8</td><td>Plug
 

02082</td><td>MF665007</td><td>Blanking plug for use when removing camshaft gear</td></tr>
<tr><td>Gear Puller
 
02065</td><td>MH061326</td><td>Removing camshaft gear</td></tr>
<tr><td>12 to 15</td><td>Camshaft Bushing Installer and Extractor
<table><tr><th></th><th>A, C dimension</th><th>B dimension</th></tr><tr><td>No. 1</td><td>ϕ62.00 (ϕ2.44)</td><td>ϕ57.75 (ϕ2.27)</td></tr><tr><td>No. 2</td><td>ϕ62.25 (ϕ2.45)</td><td>ϕ58.00 (ϕ2.28)</td></tr><tr><td>No. 3</td><td>ϕ62.50 (ϕ2.46)</td><td>ϕ58.25 (ϕ2.29)</td></tr><tr><td>No. 4</td><td>ϕ62.75 (ϕ2.47)</td><td>ϕ58.50 (ϕ2.30)</td></tr></table> 

02083</td><td>MH062025</td><td>Removing and installing camshaft bushings</td></tr>
</table>

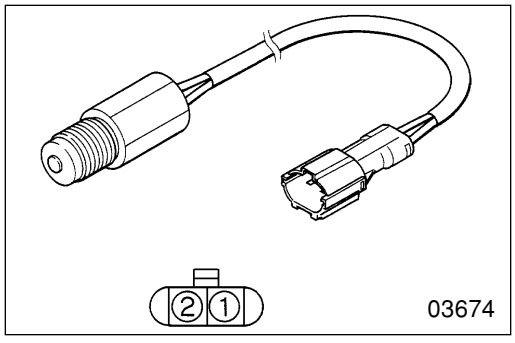
◆ Service procedure


02084

● **Pre-disassembly inspection**

Camshaft end play

If the end play measurement exceeds the specified limit, replace the defective part(s).



03674

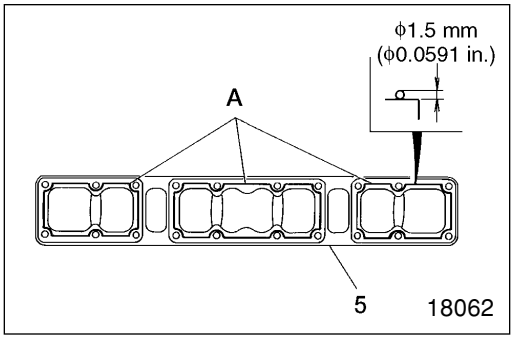
1 Inspecting engine speed sensor

<Models with electric speed sensor>

- Measure the electrical resistance between terminals ① and ②.
- If the measurement is out of specification, replace the speed sensor 1. 📖 P.11-55

CAUTION ⚠

Check the tightening torque of the engine speed sensor 1. If the sensor is insufficiently tightened, it may not produce signals.

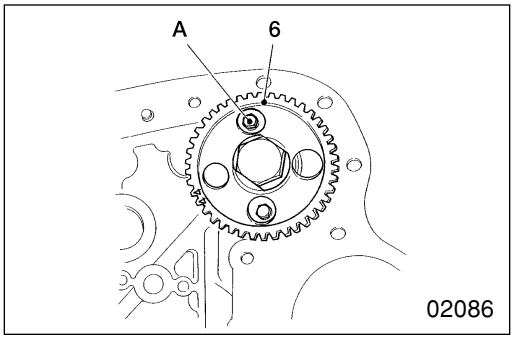


5 Fitting side cover

- Apply an even, unbroken bead of sealant **A** to the side cover **5**.
- Fit the side cover **5** onto the crankcase within **3** minutes of applying the sealant **A**.

CAUTION ⚠

- **Ensure that the sealant application surface of the side cover 5 is clean before applying sealant.**
- **When fitting the side cover 5, hold it firmly in position to prevent spreading the sealant.**
- **After fitting the side cover 5, wait at least an hour before starting the engine.**
- **Apply a new bead of sealant A whenever the mounting bolts of the side cover 5 have been loosened.**



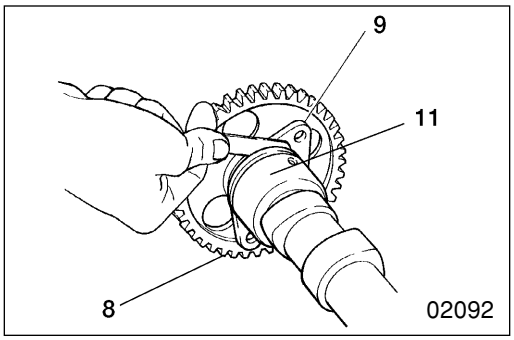
6 Camshaft assembly

[Removal]

- When removing the camshaft assembly **6**, take off the side cover **5** and support the camshaft by hand.
- Remove the bolts **A** from the camshaft gear holes, then slowly remove the camshaft assembly **6**.

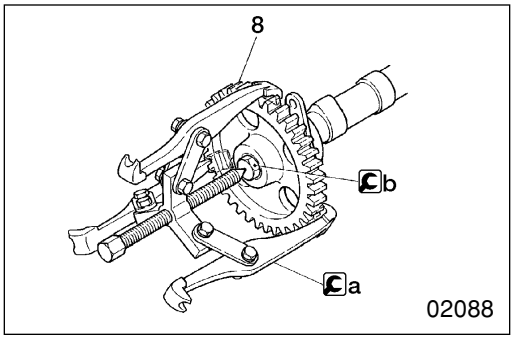
CAUTION ⚠

Take care not to damage the camshaft bushings 12 to 15 when removing the camshaft assembly 6.



[Installation]

- Before installing the camshaft assembly **6**, measure the end play between the thrust plate **9** and camshaft **11**.
- If the measurement exceeds the specified limit, replace the defective part(s).
- With the alignment marks lined up on the camshaft gear **8** and No. 2 idler gear, fit the camshaft assembly.



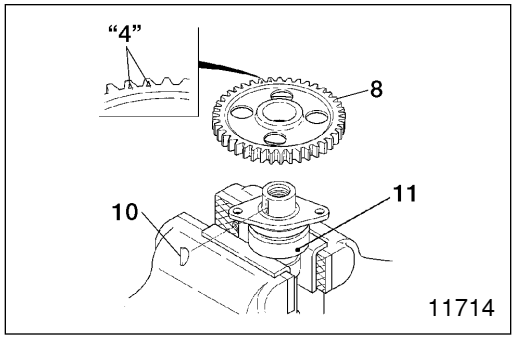
8 Camshaft gear

[Removal]

CAUTION ⚠

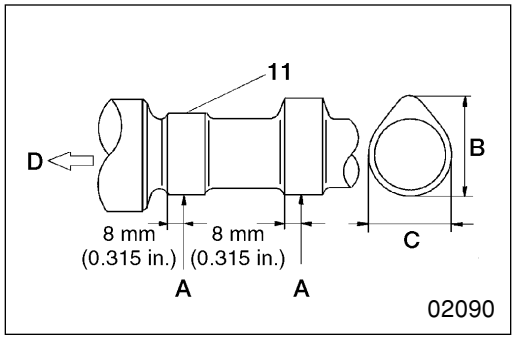
The camshaft gear 8 must be removed with the appropriate special tools. Do not tap off the camshaft gear since this would damage it.

a : Gear Puller
b : Plug



[Installation]

- Fit the camshaft gear **8** onto the camshaft **11** in the direction illustrated.
- Do not forget to fit the key **10**.



11 Inspecting camshaft

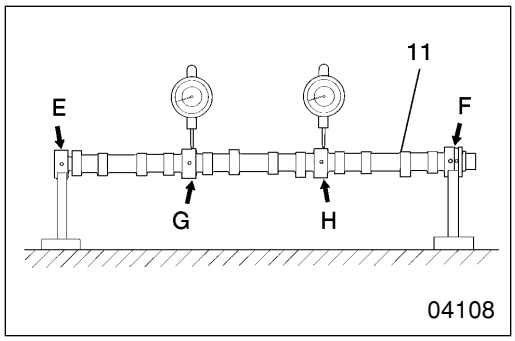
(1) Cam lift

If any base circle-to-lobe height difference is less than the required value, replace the camshaft **11**.

NOTE

Since the cams are tapered, they must be measured at the position A shown in the diagram.

B: Lobe height
C: Base circle diameter
D: Front of engine

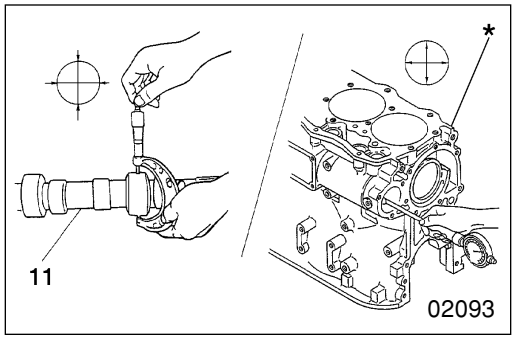


(2) Camshaft bend

Support the camshaft **11** at its No. 1 journal **E** and No. 4 journal **F**, then take measurements at the No. 2 journal **G** and No. 3 journal **H**. If either measurement exceeds the specified limit, replace the camshaft.

NOTE

Turn the camshaft 11 through one revolution. One-half of the dial indicator reading represents the camshaft's bend.



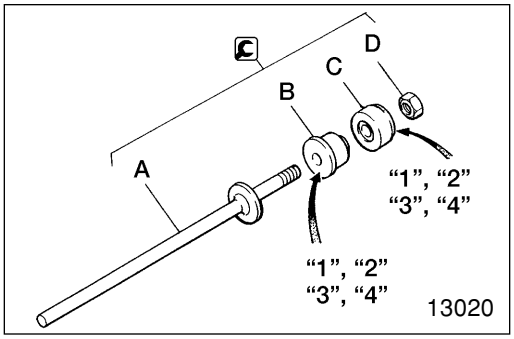
11 to 15 Camshaft and camshaft bushings

[Inspection]

If any clearance exceeds the specified limit, replace the defective part(s).

NOTE

Measure the camshaft bushings 12 to 15 with the camshaft installed in the crankcase ∗.



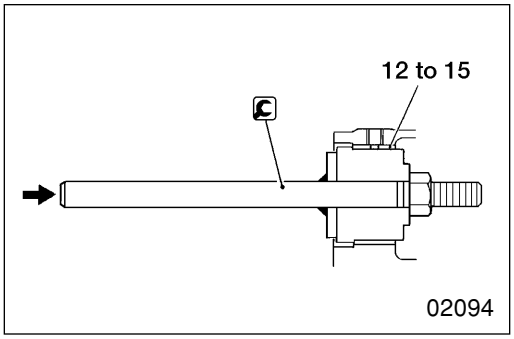
Camshaft bushings

Removal and installation of camshaft bushings should be carried out using the Camshaft Bushing Installer and Extractor. Each guide of the tool is stamped with an identification mark ("**1**", "**2**", "**3**", "**4**") in the position shown. Use correct adapter and/or guide piece to remove and install a bushing according to the table below.

Bushing No. (from front of engine)	Identification mark
No. 1	1
No. 2	2
No. 3	3
No. 4	4

<Components of Camshaft Bushing Installer and Extractor>

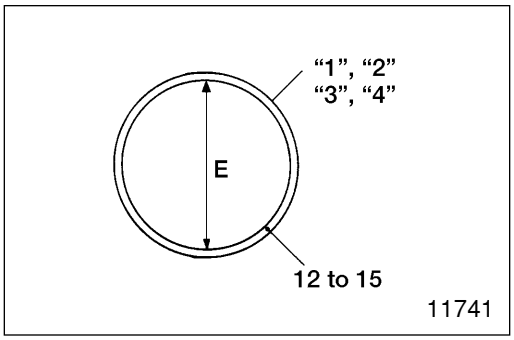
A: Rod
B: Camshaft bushing adapter
C: Guide piece
D: Nut



[Removal]

Remove the No. 4 and No. 3 camshaft bushings **12**, **13** from the rear of the engine. Remove the No. 2 and No. 1 camshaft bushings **14**, **15** from the front of the engine.

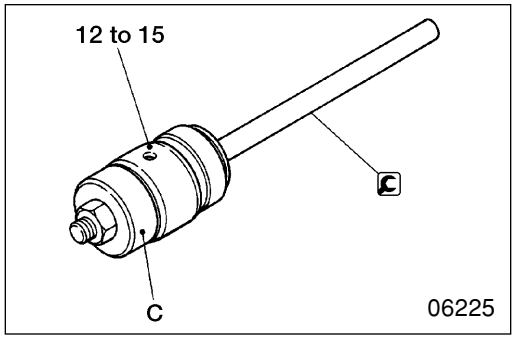
: Camshaft Bushing Installer and Extractor



[Installation]

- Identify the No. 1 to No. 4 camshaft bushings **12** to **15** from their identification marks ("**1**", "**2**", "**3**", "**4**") in accordance with the table below. If any bushing's identification mark is unclear, identify the bushing from its internal diameter **E**.

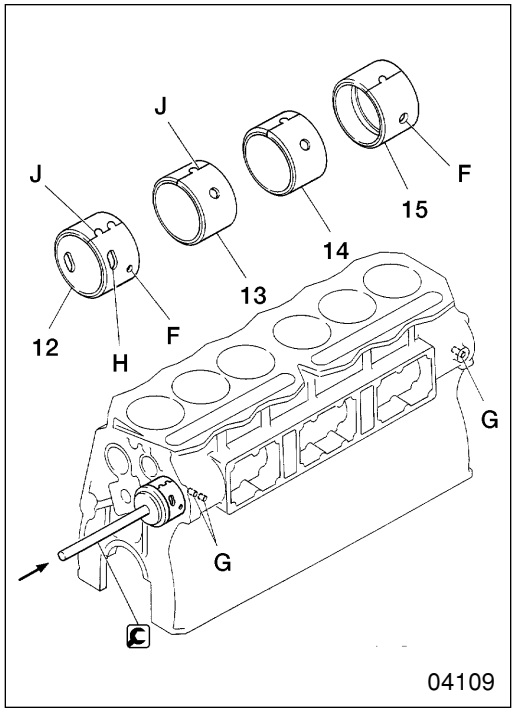
Bushing No. (from front of engine)	Identification mark	Internal diameter [mm (in.)]
No. 1	1	ϕ57.75 (ϕ2.27)
No. 2	2	ϕ58.00 (ϕ2.28)
No. 3	3	ϕ58.25 (ϕ2.29)
No. 4	4	ϕ58.50 (ϕ2.30)



- Install the bushings **12 to 15** by using all components of the Camshaft Bushing Installer and Extractor (rod **A**, camshaft bushing adapter **B**, guide piece **C** and nut **D**).
- Install the camshaft bushings **12 to 15** in the following order: No. 3, No. 4, No. 2 and No. 1.

NOTE

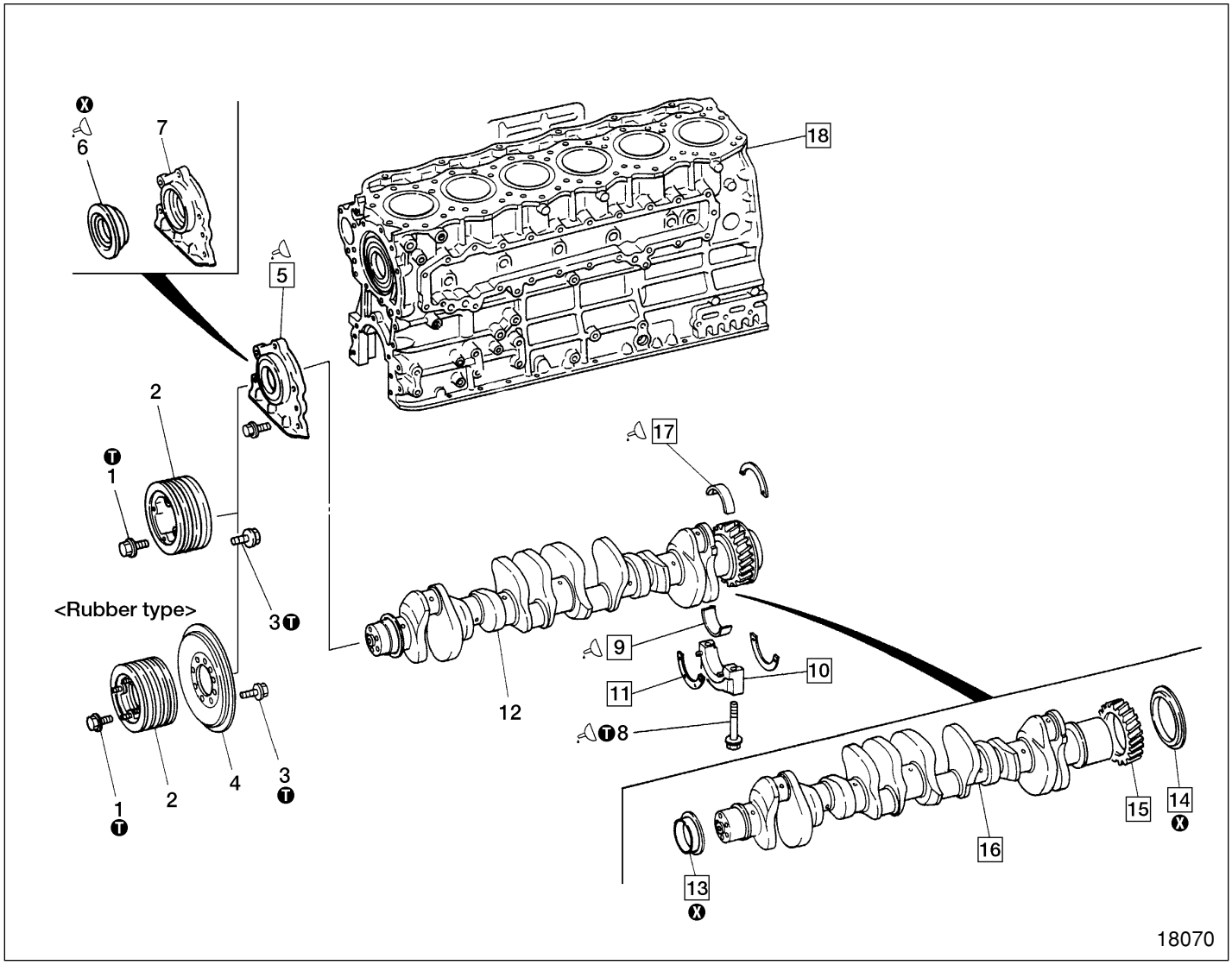
Install the No. 3 and No. 4 camshaft bushings 12, 13 from the rear of the engine. Install the No. 1 and No. 2 camshaft bushings 14, 15 from the front of the engine.



- Ensure that the oil holes **F** in the No. 1 and No. 4 camshaft bushings **15**, **12** are aligned with the oil holes **G** in the crankcase. With the No. 4 camshaft bushing, ensure also that the longer oil hole **H** is toward the rear of the engine.

J: Bushing clinch joint
: Camshaft Bushing Installer and Extractor

M E M O



● **Pre-disassembly inspection**

P.11-65

● **Disassembly sequence**

1 Bolt
2 Crankshaft pulley
3 Bolt
4 Torsional damper
5 Front cover assembly
6 Front oil seal
7 Front cover
8 Bolt
9 Lower main bearing
10 Main bearing cap
11 Thrust plate
12 Crankshaft assembly
13 Front oil seal slinger
14 Rear oil seal slinger
15 Crankshaft gear
16 Crankshaft
17 Upper main bearing
18 Crankcase

Ⓧ: Non-reusable part

● **Assembly sequence**

Reverse the order of disassembly.

Service standards

Unit: mm (in.)

Location	Maintenance item			Standard value	Limit	Remedy
9, 17	Main bearing	Oil clearance [Basic diameter: 80 mm (3.15 in.)]		0.05 to 0.10 (0.00197 to 0.00394)	0.15 (0.00591)	Replace
		Span when free		–	Less than 85.5 (3.37)	Replace
16	Crankshaft bearing	End play		0.10 to 0.25 (0.00394 to 0.00984)	0.4 (0.0157)	Replace
		Bend		0.05 (0.00197) or less	0.1 (0.00394)	Contact or replace
		Pin and journal	Roundness	0.01 (0.000394) or less	0.03 (0.00118)	Contact or replace
			Cylindricity	0.006 (0.000236) or less	–	Contact or replace
18	Distortion of crankcase top surface			0.07 (0.000276) or less	0.2 (0.00787)	Replace

❶ Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

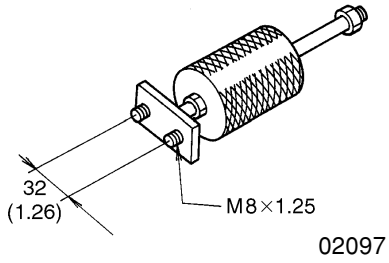
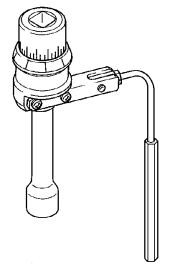
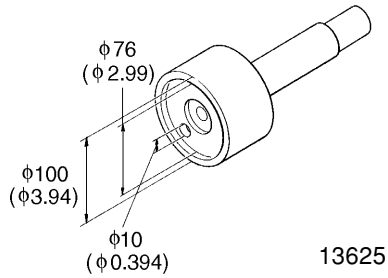
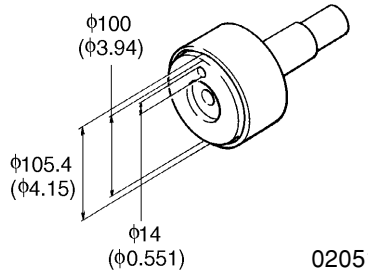
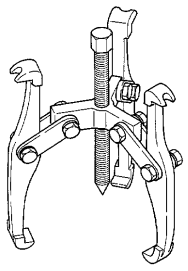
Location	Parts to be tightened	Tightening torque	Remarks
1	Crankshaft pulley mounting bolt	185 (19) [136]	–
3	Torsional damper mounting bolt	67 (8) [49.4]	–
8	Main bearing cap mounting bolt	67 (8) [49.4] + 90°	• Wet • Can be reused up to 3 times

Oils and sealants

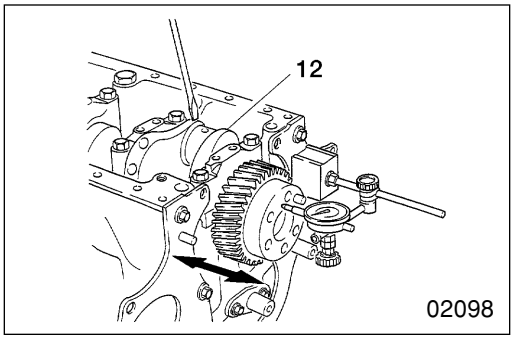
Location	Points of application	Kinds	Quantity
5	Crankcase mounting surface of front cover assembly	Threebond 1207C	As required
6	Front oil seal lip	Engine oil	As required
8	Bolt threads	Engine oil	As required
9, 17	Main bearing inside surfaces	Engine oil	As required

Special tools

Unit: mm (in.)

Location	Tool name and shape	Part No.	Application
10	Main Bearing Cap Extractor  02097	MH061189	Removing main bearing caps
	Socket Wrench  01984	MH061560	Fitting main bearing caps
13	Front Oil Seal Slinger Installer  13625	MH062710	Installing front oil seal
14	Rear Oil Seal Slinger Installer  02051	MH061470	Installing rear oil seal slinger
15	Gear Puller  02065	MH061326	Removing crankshaft gear

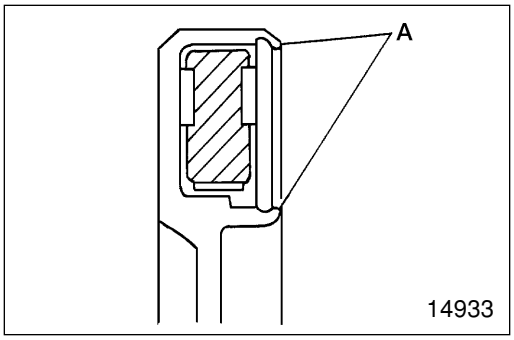
◆ Service procedure



● Pre-disassembly inspection

Crankshaft assembly end play

If the measurement exceeds the specified limit, replace the defective part(s).

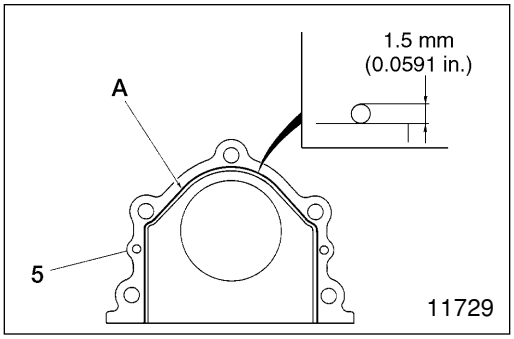


4 Torsional damper <Viscous type>

CAUTION ⚠

Leakage of silicon oil from the caulked seam A can cause the viscous-type torsional damper to stop functioning. Note the following points:

- **Check that the caulked seam is free of gouges and other damage.**
- **Do not submit the torsional damper to shock by striking it with a hammer or dropping it.**
- **Do not roll the torsional damper or stack it with other units.**

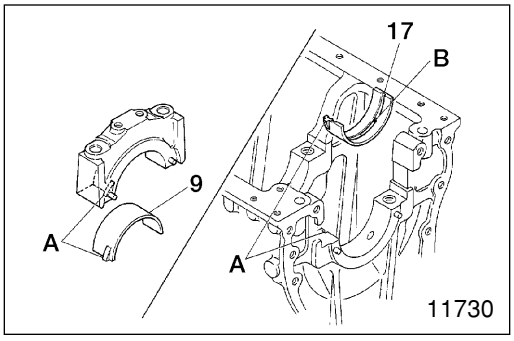


5 Installing front cover assembly

- Apply an even, unbroken bead of sealant **A** to the mating surface of the front cover assembly **5** to be mounted to the crankcase **18**.
- Fit the front cover assembly **5** onto the crankcase **18** within 3 minutes of applying the sealant **A**.

CAUTION ⚠

- **Ensure that the sealant application surface of the front cover assembly 5 is clean before applying sealant.**
- **When fitting the front cover assembly 5, hold it firmly in position to prevent spreading the sealant.**
- **After fitting the front cover assembly 5, wait at least an hour before starting the engine.**
- **Apply a new bead of sealant A whenever the mounting bolt of the front cover assembly 5 have been loosened.**



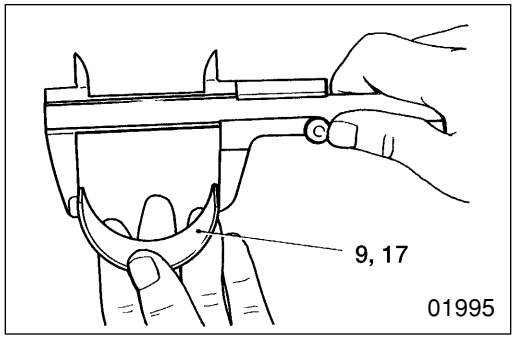
9 17 Main bearings

[Installation]

Install the main bearings **9**, **17** such that their lugs **A** fit into the corresponding grooves.

CAUTION ⚠

The upper main bearing 17 has an oil hole B. The lower main bearing 9 has no oil hole. Take care not to confuse the upper and lower parts.



[Inspection]

CAUTION ⚠

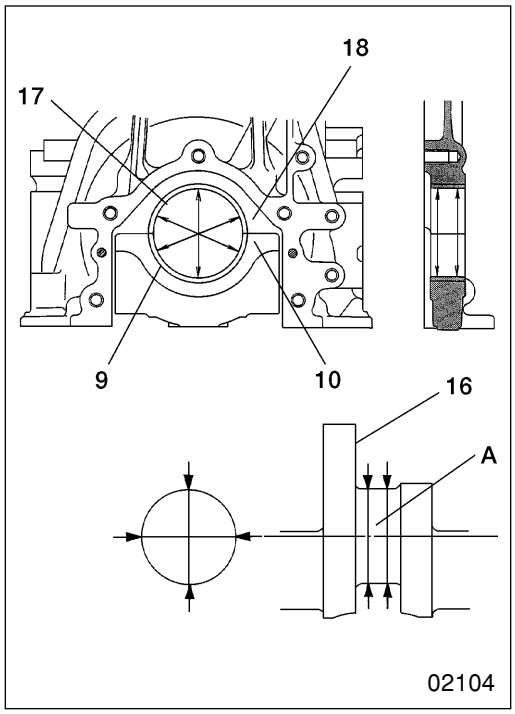
- **Do not attempt to manually expand either bearing 9, 17 if its span is insufficient.**
- **Upper and lower bearings 9, 17 must be replaced as a set.**

(1) Span when free

If either bearing's span when free exceeds the specified limit, the bearings **9**, **17** must be replaced.

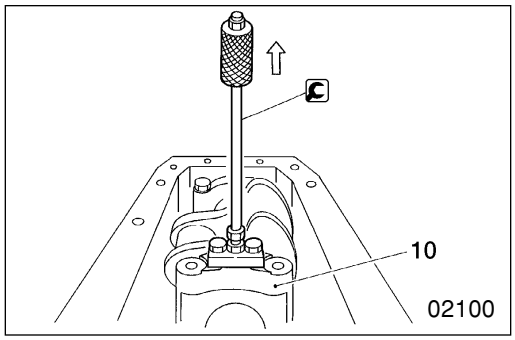
(2) Main bearing-to-crankshaft clearance

- Fit the upper main bearing **17** into the crankcase **18** and the lower main bearing **9** into the main bearing cap **10**. Then, tighten the bolts 8 to their specified torque.
- Measure the internal diameters of the main bearings **9**, **17** and the outside diameter **A** of the crankshaft journal. If the clearance exceeds the specified limit, replace the defective part(s).



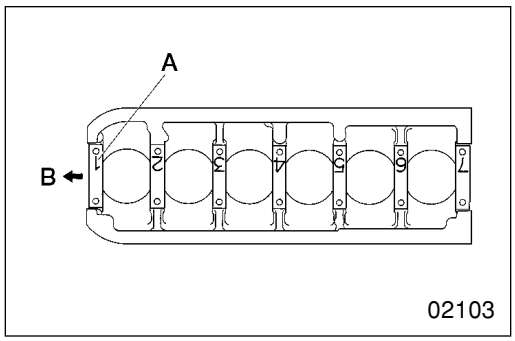
10 Main bearing caps

[Removal]



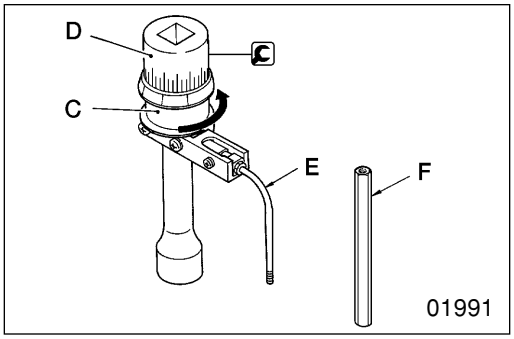
[Installation]

- Starting at the front of the engine **B**, fit the main bearing caps 10 in the order of the numbers **A** embossed on them and such that the numbers are in the positions illustrated.
- The bolts **8** can be reused only three times. Before fitting the bolts, make a punch mark on the head of each bolt to indicate times of reuse.



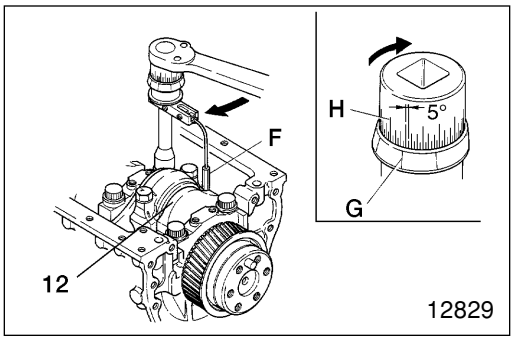
CAUTION ⚠

If any bolt already has three punch marks, it must not be reused any more; replace it with a new one.



- Tighten the bolts **8** to the specified torque. Then, turn the bolts further in accordance with the following procedure:
- Turn the holder **C** of the 🔧 Socket Wrench counter-clockwise to tension the built-in spring.

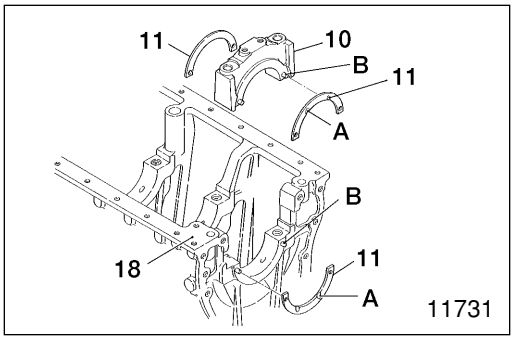
D: Socket
E: Rod
F: Rod (extension)



- Set the socket wrench such that the built-in spring force forces the rod **F** against the crankshaft assembly **12**.
- On the holder **C**, select the inscribed line **G** that is easiest to see.
- Using the selected line as a reference, turn the socket **D** 90° clockwise. (One gradation on the scale **H** represents 5°.)

CAUTION ⚠

Since the bolts utilize the plastic region tightening method, they must not be tightened further after this procedure.



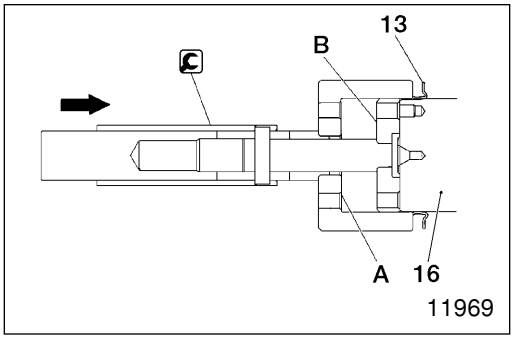
11 Installing thrust plates

Fit a thrust plate **11** on each side of the main bearing caps **10** and at the rear end of the crankcase **18** such that the oil grooves **A** are on the outside.

B: Locating pin

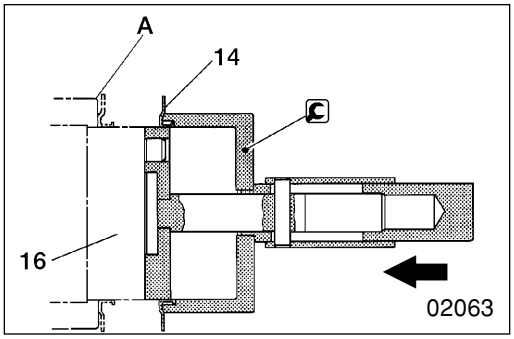
NOTE

If oversize thrust plates 11 are used, they must be fitted on both sides of the bearing caps 10. Ensure that the bearing cap rear thrust plates and the rearmost thrust plate in the crankcase 18 are the same size. Note, however, that the front and rear thrust plates on each bearing cap may be of different sizes.



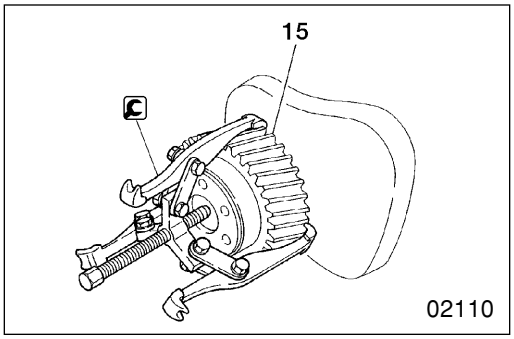
13 Installing front oil seal slinger

Using the 🔧 Front Oil Seal Slinger Installer, drive the front oil seal slinger **13** onto the crankshaft **16** until the tool's end face **A** is pressed firmly against the guide **B**.



14 Installing rear oil seal slinger

Using the Rear Oil Seal Slinger Installer, drive the rear oil seal slinger **14** onto the crankshaft **16** until it is pressed firmly against the end face **A** of the crankshaft gear **15**.



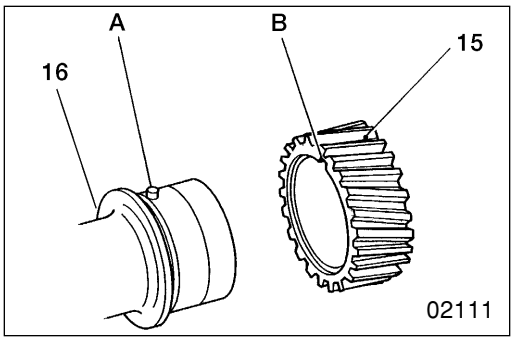
15 Removing and fitting crankshaft gear

[Removal]

CAUTION

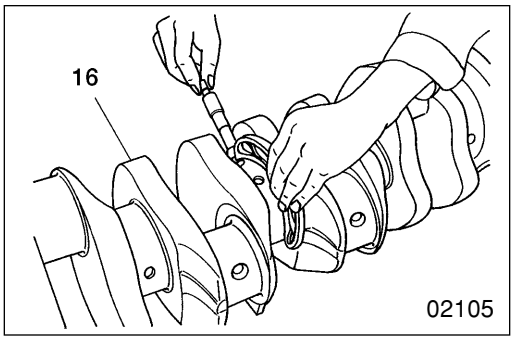
Do not tap off the crankshaft gear 15 since this could damage it.

: Gear Puller



[Installation]

- Using a piston heater or the like, heat the crankshaft gear 15 to a temperature of approximately 100°C (212°F).
- Align the locating pin **A** on the crankshaft **16** with the notch **B** in the crankshaft gear **15**. Then, drive the gear into position by striking its end face with a plastic mallet.

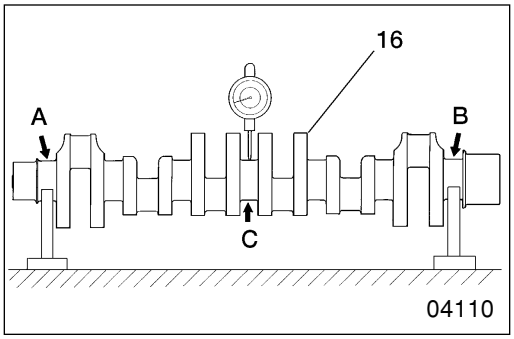


16 Crankshaft

[Inspection]

(1) Roundness and cylindricity of crankshaft journal and pin

If either measurement exceeds the specified limit, replace the crankshaft **16** or grind it to undersize.

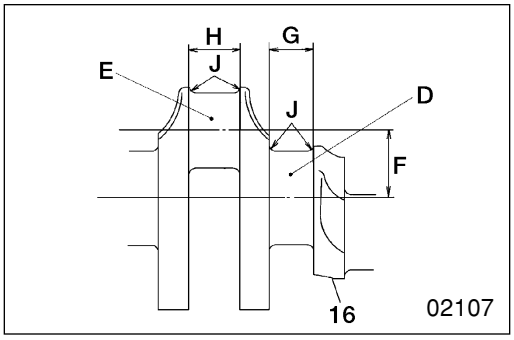


(2) Bend

- Support the crankshaft **16** at its No. 1 journal **A** and No. 7 journal B. Measure the extent of bending in the crankshaft at the centre of the No. 4 journal **C**.
- If the measurement exceeds the specified limit, replace the crankshaft.

NOTE

With the dial indicator applied to the centre journal, turn the crankshaft 16 through one revolution. One-half of the dial indicator reading represents the extent of bending.



[Rectification]

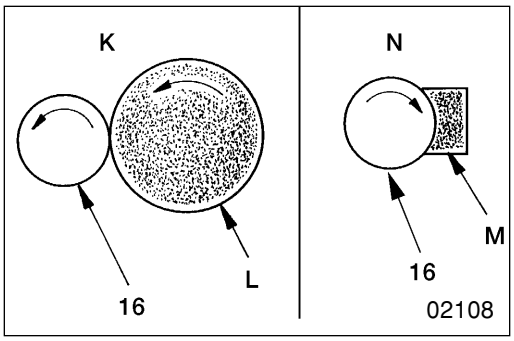
NOTE

If the crankshaft 16 is rectified by grinding, the main bearings 9, 17 must be replaced with undersized ones.

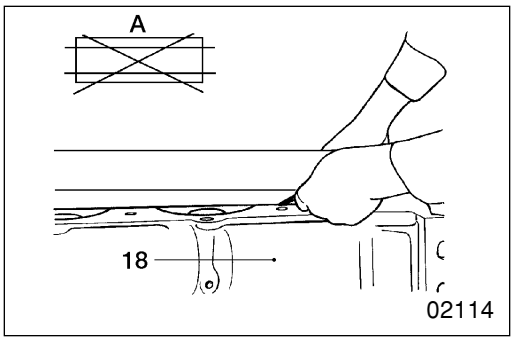
- Grind such that the centre-to-centre distance **F** between the journal **D** and pin **E** does not change.
  F: 57.5 $^{+0.025}_{-0.075}$ mm (2.26 $^{+0.001}_{-0.003}$ in.)
- Grind such that the journal width **G** and pin width **H** do not change.
  G: 37 mm (1.46 in.)
  H: 42 $^{+0.2}_{0}$ mm (1.65 $^{+0.008}_{0}$ in.)
- Finish the corner fillet smoothly and to the specified radius **J**.
  J: Radius 4 ± 0.2 mm (Radius 0.157 ± 0.008 in.)
- Carry out a magnetic inspection to check for cracks caused by grinding. Also, check that the Shore hardness of the surface has not dropped below Hs 75.

Crankshaft undersize dimensions — Unit: mm (in.)

	Degree of undersize			
	0.25 (0.00984)	0.50 (0.0197)	0.75 (0.0295)	1.00 (0.0394)
Finished journal diameter	79.685 to 79.705 (3.137 to 3.138)	79.435 to 79.455 (3.127 to 2.537)	79.185 to 79.205 (3.117 to 3.118)	78.935 to 78.955 (3.107 to 3.108)
Finished pin diameter	64.67 to 64.69 (2.546 to 2.547)	64.42 to 64.44 (2.536 to 2.537)	64.17 to 64.19 (2.526 to 2.527)	63.92 to 63.94 (2.516 to 2.517)
Roundness	0.01 (0.000394) or less			
Cylindricity	0.006 (0.000236) or less			



- When grinding **K**, turn the crankshaft **16** counter-clockwise as viewed from its front end. The grinder **L** should rotate in the same direction.
- When finishing **N** the crankshaft **16** with sandpaper or a whetstone **M**, rotate the crankshaft clockwise.



18 Distortion of crankcase top surface

If distortion exceeds the specified limit, correct it with a surface grinder.

A: Measurement positions

CAUTION ⚠

When grinding the crankcase 18, take care that the piston projections stay within specification.

GROUP 12 LUBRICATION

SPECIFICATIONS 2

STRUCTURE AND OPERATION 3

TROUBLESHOOTING 9

ON-VEHICLE INSPECTION AND ADJUSTMENT 10
- Oil Filter Replacement 10
- Engine Oil Replacement 12
- Oil Pressure Measurement 13

OIL PAN, OIL JET, AND OIL LEVEL SENSOR 14

OIL PUMP AND OIL STRAINER 16

OIL FILTER 20
<Spin-on Type> 20

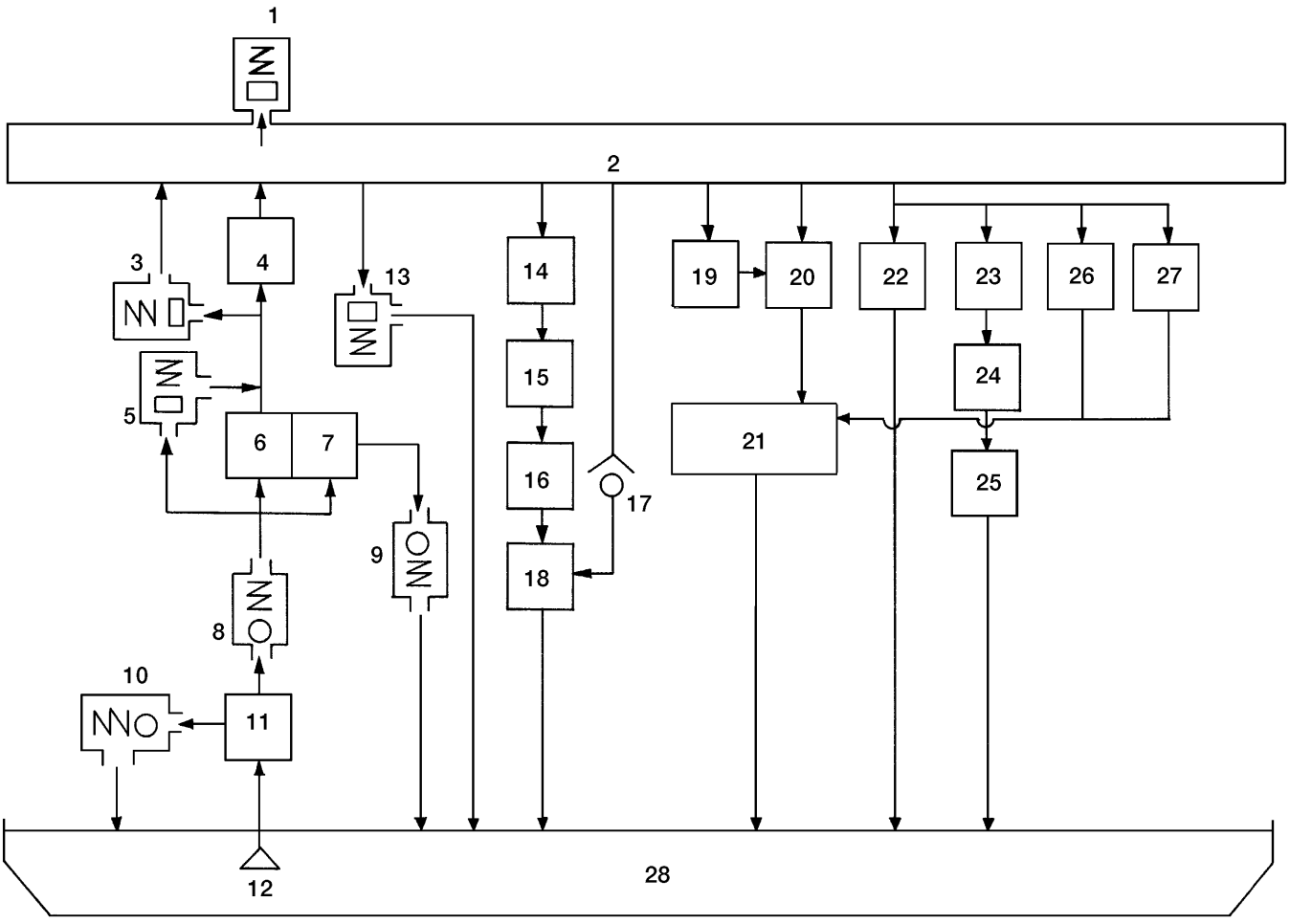
OIL COOLER 22

REGULATOR VALVE 24

SPECIFICATIONS

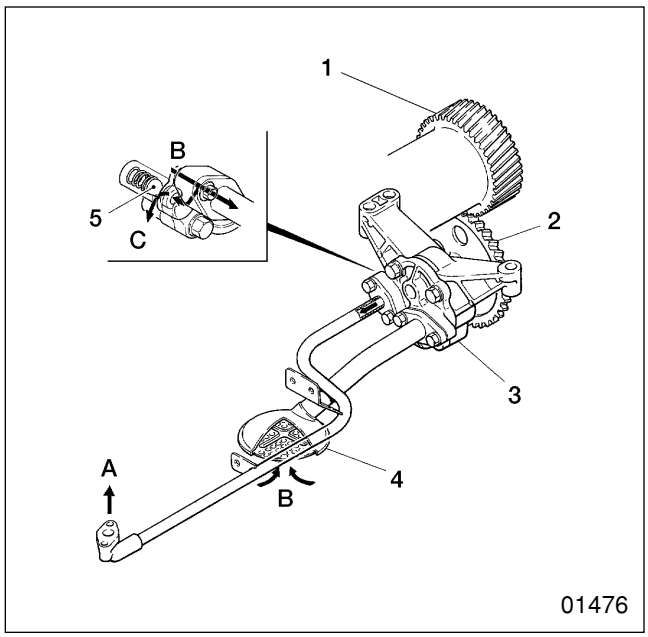
Item			Specifications
Mode of lubrication			Oil pump type
Oil filter type			Spin-on paper-filter type or replaceable-element type
Oil cooler type			Shell and plate type (multi-plate type)
Engine oil			API CC or above
Oil quantity L (U.S.gal.)	Oil pan	General power applications	Approx. 9.5 (2.51)
		Construction machinery applications	Approx. 16 (4.23)
	Oil filter	Spin-on type	2.1 (0.555)
		Replaceable-element type	2.3 (0.608)

Lubrication System (Oil Flow)



1 Engine oil pressure gauge unit
2 Main oil gallery
3 Bypass valve
4 Oil cooler
5 Engine oil bypass alarm switch
6 Full-flow filter element
7 Bypass filter element
8 Check valve (built into oil filter)
9 Bypass check valve (built into oil filter)
10 Relief valve (built into oil pump)
11 Oil pump
12 Oil strainer
13 Regulator valve
14 Crankshaft main bearing
15 Connecting rod bearing
16 Connecting rod bushing
17 Check valve for oil jet
18 Piston
19 Injection pump
20 Air compressor (or injection pump drive)
21 Timing gears
22 Camshaft bushing
23 Rocker bushing
24 Push rod
25 Tappet
26 Idler gear shaft No. 1
27 Idler gear shaft No. 2
28 Oil pan

Oil Pump



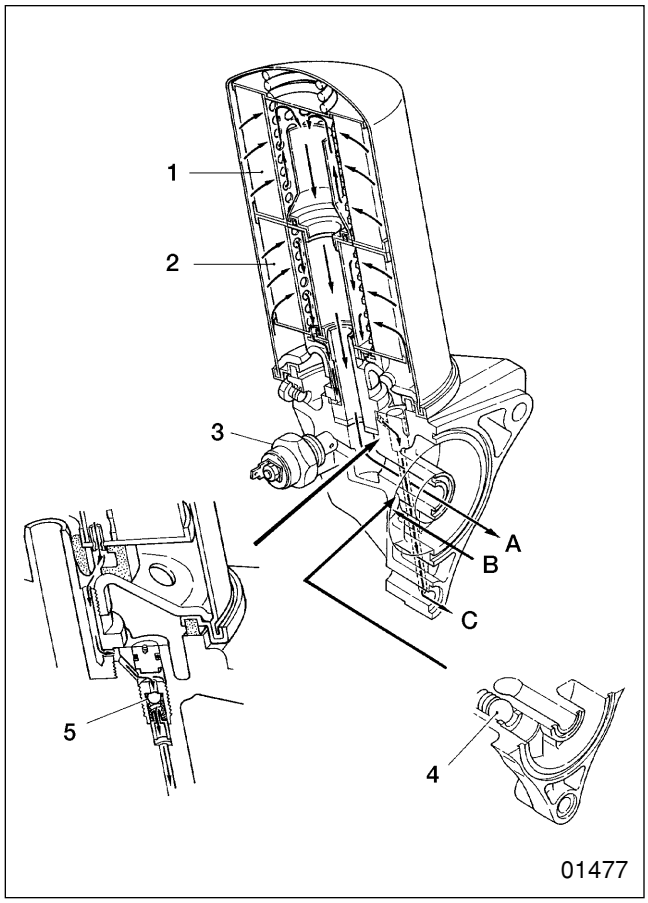
1 Crankshaft gear
2 Oil pump gear
3 Oil pump
4 Oil strainer
5 Relief valve

A: To oil filter
B: From oil pan
C: To oil pan

Oil pump **3** is a gear type. It is driven by rotation of the crankshaft via crankshaft gear **1** and oil pump gear **2**.
Relief valve **5** is fitted to the oil pump. When the oil pump discharge pressure exceeds a specified level, the relief valve returns some of the engine oil to the oil pan, thus protecting the lubrication system from excessive oil pressure.

Oil Filter

<Spin-on type>

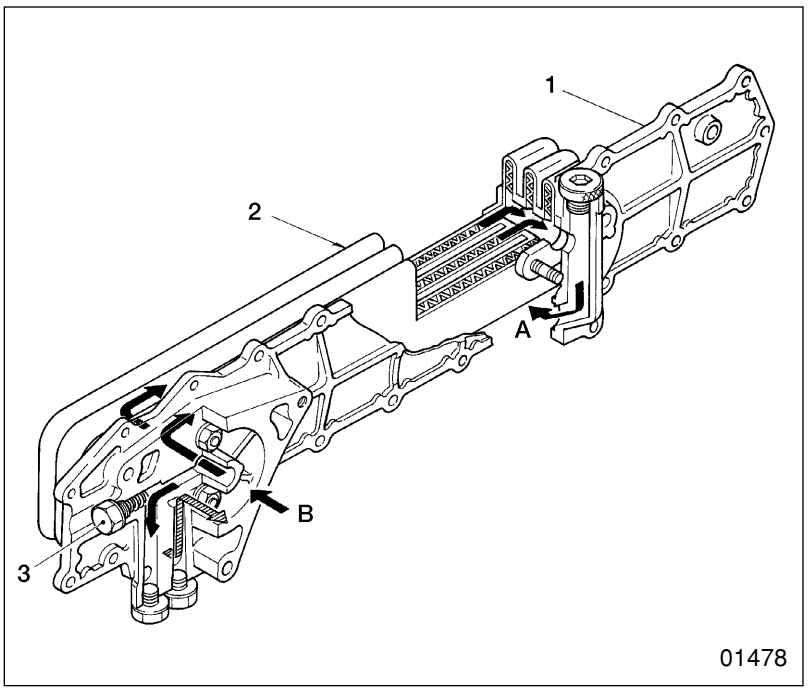


1 Full-flow filter element
2 Bypass filter element
3 Engine oil bypass alarm switch
4 Check valve
5 Bypass check valve

A: To oil cooler
B: From oil pump
C: To oil pan

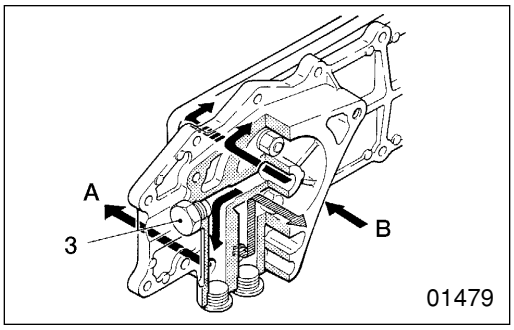
This oil filter is a spin-on paper-filter type incorporating full-flow filter element **1** and bypass filter element **2**.
Engine oil bypass alarm switch **3** is fitted to the oil filter bracket. If clogging causes the pressure difference before and after the element to exceed a specified level, a valve inside the switch opens to allow oil to flow directly to the oil cooler.
Check valve **4** is fitted to the inlet to prevent a reverse flow of oil out of the filter when the engine is stationary. In conjunction with this, bypass check valve **5** opens only when oil pressure in the bypass arrangement exceeds a specified level. As a result, the oil level in the filter is kept constant and oil reaches all parts of the lubrication system quickly when the engine is started.

Oil Cooler



1 Oil cooler cover
2 Oil cooler element
3 Bypass valve

A: To main oil gallery
B: From oil filter

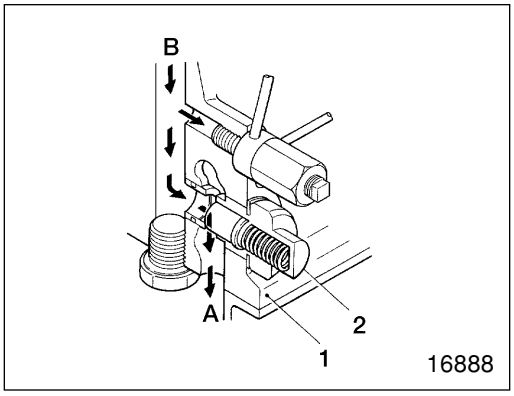


● **Bypass valve**

When oil viscosity is high at low temperatures or the element is clogged, flow resistance increases. When this happens, bypass valve **3** opens to allow engine oil to return to the main oil gallery without passing through the cooler.

A: To main oil gallery
B: From oil filter

Regulator Valve



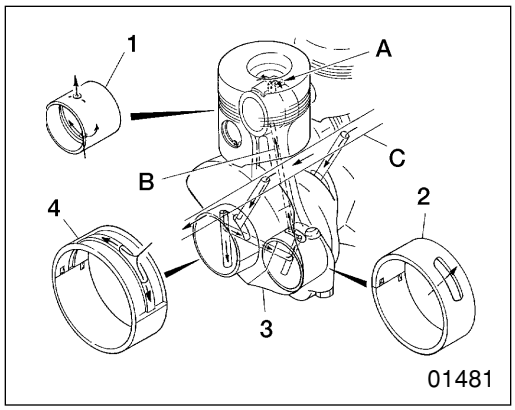
1 Crankcase
2 Regulator valve

A: To oil pan
B: Main oil gallery

● **Regulator valve**

When the pressure of oil going to main oil gallery **B** drops below a specified level, regulator valve **2** opens, allowing some of the oil to return to oil pan **A**. The oil pressure is thus constantly regulated.

Lubrication of Related Parts



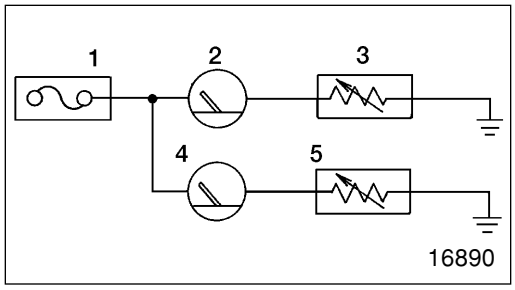
Engine oil fed to the main oil gallery lubricates the following related parts:

- **Main Bearing and Connecting Rod Bearing**
  - **1** Connecting rod bushing
  - **2** Connecting rod bearing
  - **3** Crankshaft
  - **4** Main bearing

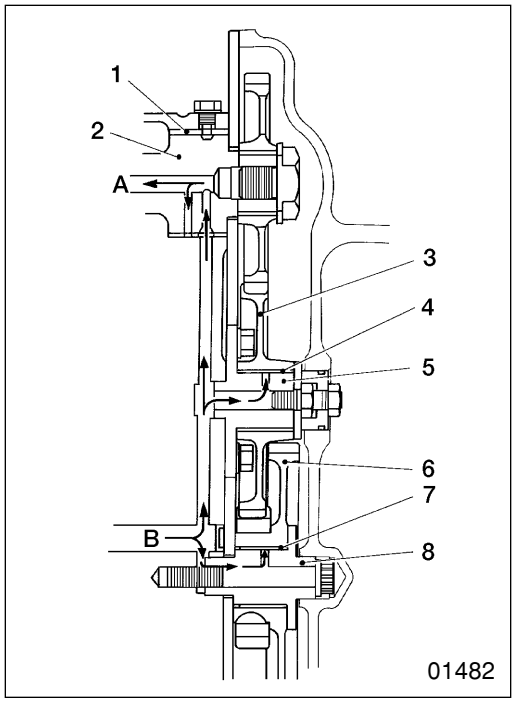
  - **A:** Oil jet
  - **B:** Connecting rod oil passage
  - **C:** Main oil gallery

Oil supplied via the oil passage in crankshaft **3** flows through connecting rod oil passage **B** to lubricate the connecting rod's small end. The oil then sprays out of oil jet **A** at the top of the connecting rod to cool the piston.

Lubrication System Electric Circuit



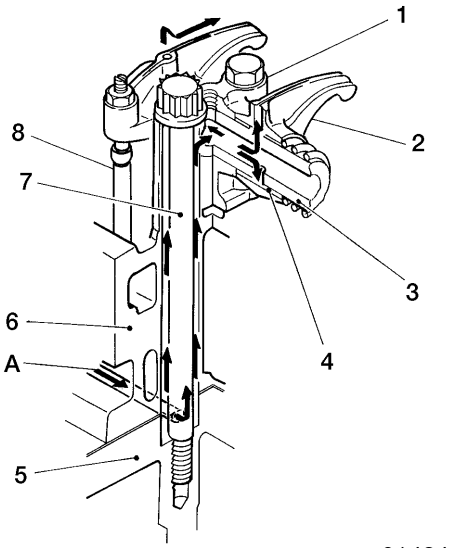
- **Oil pressure gauge/temperature gauge circuit**
  - **1** Fuse box
  - **2** Oil pressure gauge
  - **3** Engine oil pressure gauge unit
  - **4** Oil temperature gauge
  - **5** Engine oil temperature sensor

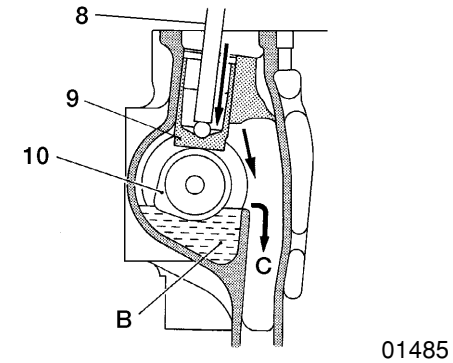


- **Timing gear and camshaft**
  - **1** Camshaft bushing No. 4
  - **2** Camshaft
  - **3** Idler gear No. 2
  - **4** Idler gear bushing
  - **5** Idler shaft No. 2
  - **6** Idler gear No. 1
  - **7** Idler gear bushing
  - **8** Idler gear shaft No. 1

  - **A:** To rocker bushing
  - **B:** From main oil gallery

Engine oil flows through the inside of camshaft **2** and lubricates each camshaft bushing.



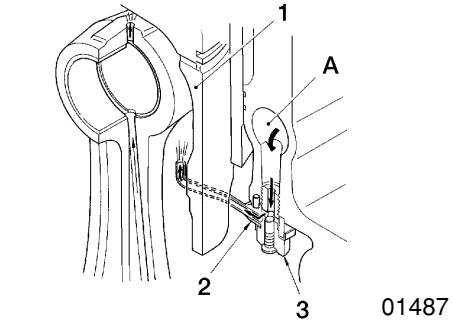


● **Valve mechanism**

1 Rocker shaft bracket
2 Rocker
3 Rocker shaft
4 Rocker bushing
5 Crankcase
6 Cylinder head
7 Cylinder head bolt
8 Push rod
9 Tappet
10 Camshaft

A: From camshaft bushing No. 4
B: Oil reservoir
C: To oil pan

After lubricating rocker **2**, the camshaft bushings, and other components, oil enters oil reservoir **B** to lubricate the cams.

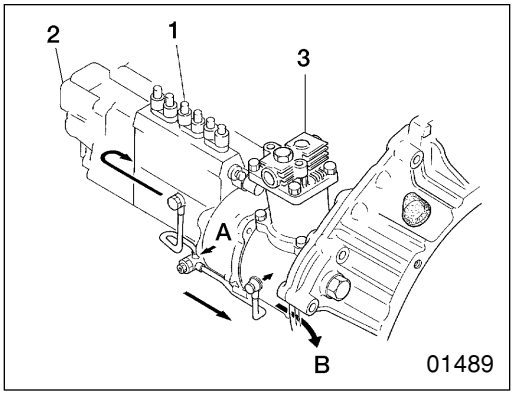


● **Check valve and oil jet**

1 Piston
2 Oil jet
3 Check valve

A: Main oil gallery

An oil jet **2** is fitted in the lower part of the main oil gallery **A** for each piston. These oil jets cool the pistons **1** by injecting oil into them. Each oil jet is fitted with a check valve that opens and closes at specified oil pressure levels. At low engine speeds, these check valves **3** close to maintain the required volume of oil in the lubrication system and prevent reductions in oil pressure.

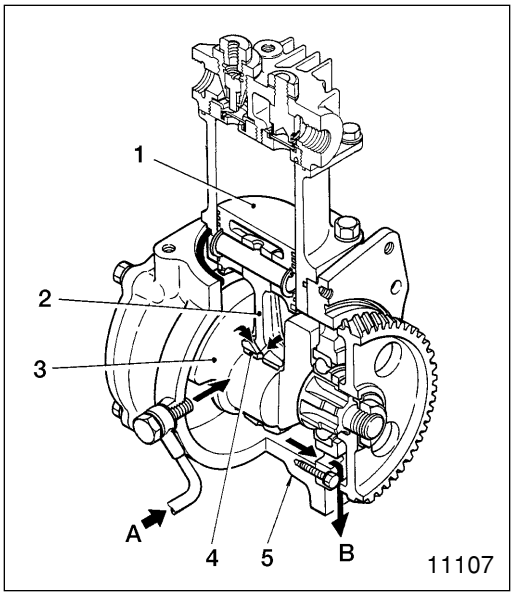


● **Injection pump**

1 Injection pump
2 Governor
3 Air compressor (or injection pump drive)

A: From main oil gallery
B: To oil pan

Engine oil that has lubricated injection pump **1** and governor **2** returns to the oil pan via the timer case, air compressor **3** (or injection pump drive), and timing gear train.

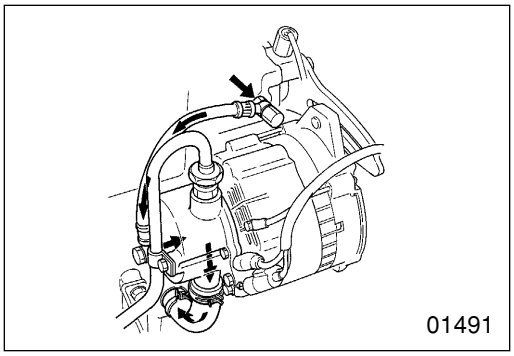


● **Air compressor**

1 Piston
2 Connecting rod
3 Crankshaft
4 Connecting rod bushing
5 Crankcase

A: From main oil gallery
B: To oil pan

Engine oil from the main oil gallery splashes onto connecting rod **2** and lubricates connecting rod bushing **4**. Piston **1** and the connecting rod's small end are lubricated by oil that is splashed onto them by the rotation of the crankshaft **3**.



● **Vacuum pump**

Some of the oil used to lubricate the camshaft bushings is fed to the vacuum pump housing via a flexible hose. After lubricating the vacuum pump vanes, this oil leaves via an outlet at the bottom of the housing and returns to the oil pan.

Possible causes \ Symptoms		Engine hard to start	Overheating	Low oil pressure	Excessive oil consumption (oil leakage)	Remarks
Oil cooler	Oil cooler element installed poorly		○	○	○	
	Gasket defective		○	○	○	
	O-ring defective		○	○	○	
	Oil cooler element clogged		○	○		
	Oil cooler element damaged		○	○	○	
	Fatigue in bypass valve spring		○			
Oil pump	Oil pump malfunctioning		○	○		
	Interference between oil pump gear and oil pump case or cover	○		○		
	Oil pipe poorly fitted		○	○		
	Oil strainer clogged		○	○		
	Fatigue in relief valve spring			○		
Oil filter	Oil filter fitted poorly				○	
	Element clogged		○	○		
	Fatigue in check valve and bypass check valve springs			○		
	O-ring defective			○		
Front cover assembly timing gear case	Front oil seal defective				○	🕮 Gr 11
	Front cover assembly fitted poorly				○	🕮 Gr 11
Flywheel housing	Rear oil seal defective				○	🕮 Gr 11
	Gasket fitted poorly				○	🕮 Gr 11
Fatigue in regulator valve spring				○		
Piston cooling oil jet(s) defective			○			
Oil working its way up into combustion chamber(s)					○	🕮 Gr 11
Oil working its way down into combustion chamber(s)					○	🕮 Gr 11
Oil viscosity too high		○				
Unsuitable oil quality			○			
Deterioration in oil			○			
Fuel mixed with oil			○			

Oil Filter Replacement

<Spin-on type>

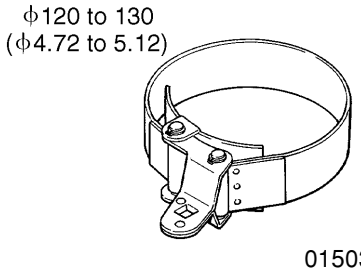
Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

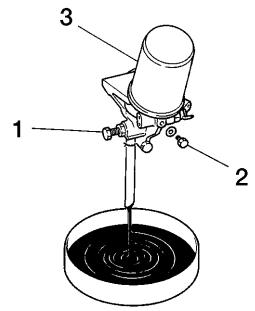
Location	Parts to be tightened	Tightening torque	Remarks
1	Oil filter drain valve <Upward-facing type>	30 ± 4.9 (3 ± 0.5) [22.1 ± 3.6]	–

Special tools

Unit: mm (in.)

Location	Tool name and shape	Part No.	Application
3	Oil Filter Wrench  01503	MH061537	Oil filter removal

<Upward-facing type>



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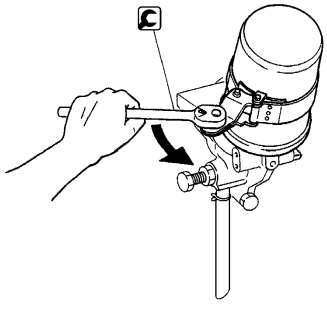
WARNING ⚠

- **Wipe up any spilled engine oil since it can cause a fire.**
- **Do not touch oil when the engine is hot since it can inflict severe burns.**

CAUTION ⚠

When pouring oil into the engine, take care not to spill any on the V-belts. Contact with oil could make the V-belts slip, rendering the cooling system less effective.

<Upward-facing type>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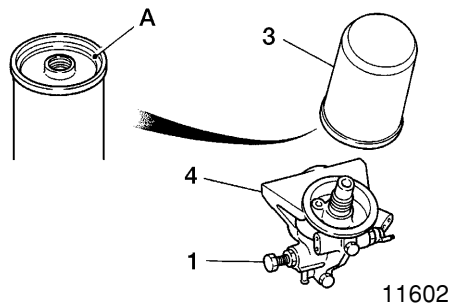
With an upward-facing oil filter, loosen drain plug **1** and air plug **2** in that order, then drain the oil out of filter **3**.

[Removal]

<Upward-facing type>



[Installation]

- Clean the surface on oil filter head **4** that makes contact with oil filter **3**.
- Apply a film of engine oil to gasket area **A** of filter **3**.
- Screw oil filter **3** into oil filter head **4** until gasket area **A** touches the oil filter head.
- Tighten filter **3** by a further 1 1/8 to 1 3/8 of a turn.
- Fit oil filter drain valve **1**.
- Start the engine and check that no oil leaks from gasket area **A**.
- Check the engine oil level and add oil if necessary.

Engine Oil Replacement

Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

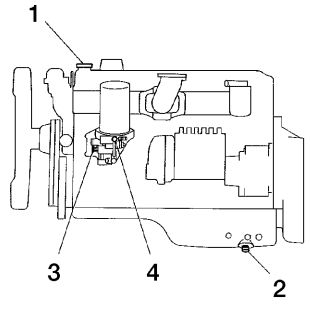
Location	Parts to be tightened	Tightening torque	Remarks
2	Oil pan drain plug	7	–
3	Oil filter drain valve	30 ± 4.9 (3 ± 0.5) [22.1 ± 3.6]	–

Lubricants

Unit: L (U.S.gal.)

Location	Points of application		Kinds	Quantity
–	Oil pan	General power applications	API CC or above	Approx. 9.5 (2.51)
		Construction machinery applications		Approx. 16 (4.23)
–	Oil filter	Spin-on type	API CC or above	Approx. 2.1 (0.555)
		Replaceable-element type		Approx. 2.3 (0.608)

<Upward-facing spin-on type>



WARNING

- **Wipe up any spilled engine oil since it can cause a fire.**
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CAUTION

When pouring oil into the engine, take care not to spill any on the V-belts. Contact with oil could make the V-belts slip, rendering the cooling system less effective.

[Draining]

- Warm up the engine, then remove oil filler cap **1**.
- Remove oil pan drain plug **2**, oil filter drain valve **3**, and air plug **4**. Then, drain the engine oil.

[Filling]

Tighten oil pan drain plug **2** and oil filter drain valve **3** to their specified torques, then pour the specified quantity of engine oil into the engine.

Oil Pressure Measurement

Service standards

Unit: MPa (kgf/cm²) [psi]

Location	Maintenance item		Standard value	Limit	Remedy
–	Oil pressure [at oil temperature 70 to 905 °C (158 to 194 °F)]	At no-load minimum speed	0.1 (1.0) [14.5] or higher	Up to 0.1 (1.0) [14.5]	Adjust
		At no-load maximum speed	0.2 to 0.6 (2.0 to 6.1) [29.0 to 87.0]	Up to 0.2 (2.0) [29.0]	

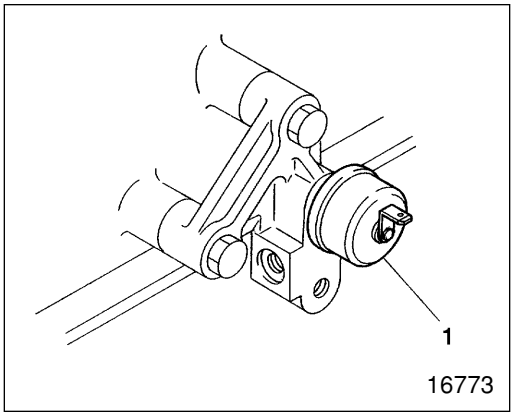
Tightening torque

Unit: N·m (kgf·m) [lbf·ft]

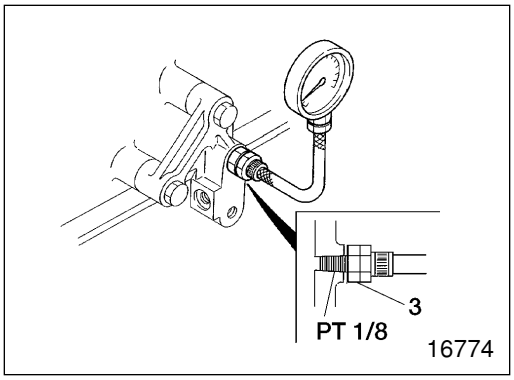
Location	Parts to be tightened	Tightening torque	Remarks
1	Engine oil pressure gauge unit	15 to 22 (1.5 to 2.2) [11.1 to 16.2]	Check with engine cold

Sealant

Location	Points of application	Kinds	Quantity
1	Wrap around thread of engine oil pressure gauge unit	Teflon tape	3 1/2 turns



- Remove engine oil pressure gauge unit **1**.

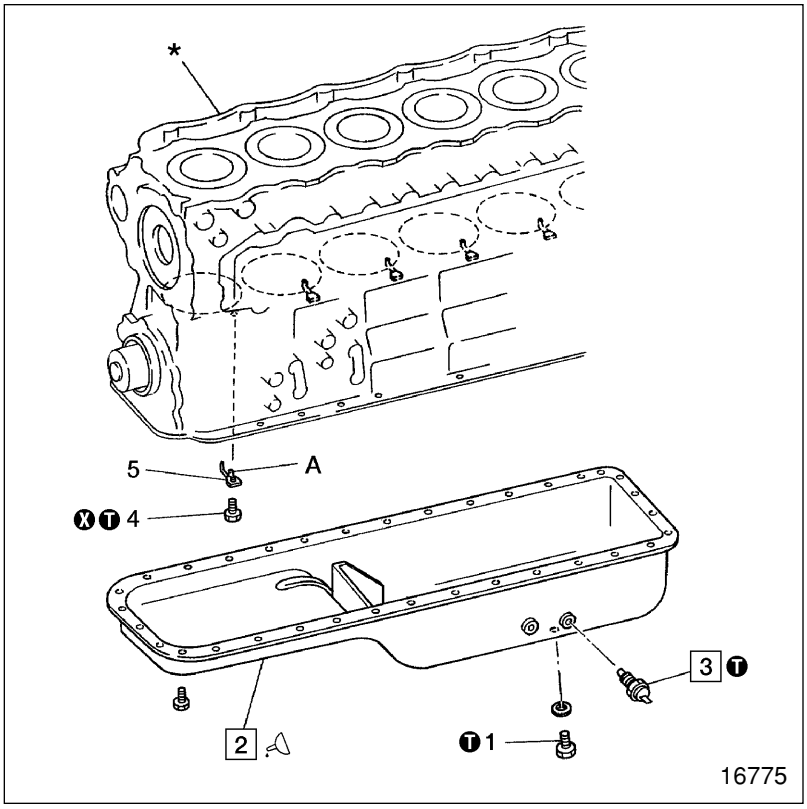


- Fit adapter **3** onto the engine oil pressure gauge unit mounting, then fit the oil pressure gauge onto the adapter.
- Warm up the engine until the oil temperature reaches 70 to 90°C (158 to 194°F).
- Measure the oil pressure at no-load minimum speed and at no-load maximum speed. If the measured values are below the specified standard values, overhaul the lubrication system.
- After taking measurements, fit oil pressure gauge unit **1** and tighten it to the specified torque.

NOTE

Oil pressure gauge unit 1 must be fitted with the engine cold.

OIL PAN, OIL JET, AND OIL LEVEL SENSOR



● **Disassembly sequence**

1 Drain plug
2 Oil pan
3 Engine oil temperature sensor
4 Check valve
5 Oil jet

*: Crankcase 🕮 Gr 11
A: Locating pin
: Non-reusable part

● **Assembly sequence**

Reverse the order of disassembly.

CAUTION ⚠

Do not tighten check valve 4 in excess of the specified torque. Excessive tightness can cause defective operation, resulting in scorching of the engine.

Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
1	Drain plug	69 (7) [50.9]	–
3	Engine oil temperature sensor	34 ± 6.9 (3.5 ± 0.7) [25.1 ± 5.1]	–
4	Check valve	34 (3.5) [25.1]	–

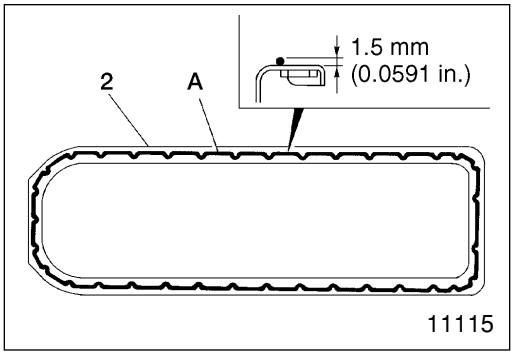
Sealant

Location	Points of application	Kinds	Quantity
2	Crankcase mounting surface of oil pan	THREEBOND 1207C	As required

Service standards

Location	Maintenance item		Standard value	Limit	Remedy
3	Resistance of engine oil temperature sensor (between terminal ① and body)	50°C (122°F)	(136 Ω)	–	Replace
		80°C (176°F)	48 ± 5 Ω	–	
		100°C (212°F)	27.2 ± 2 Ω	–	

Figures in parentheses are approximate.



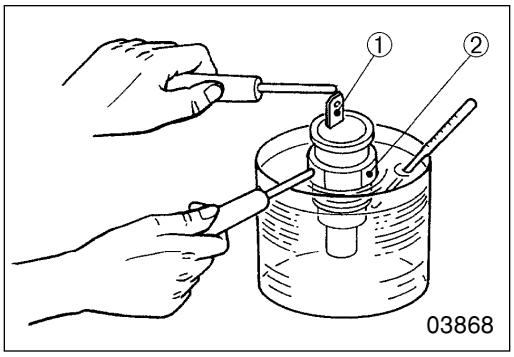
◆ Service procedure

2 Fitting oil pan

- Apply sealant **A** to the mounting surface of oil pan **2** as illustrated. Apply the sealant evenly and without breaks.
- Within three minutes of applying sealant **A**, fit oil pan **2** onto the crankcase*.

CAUTION ⚠

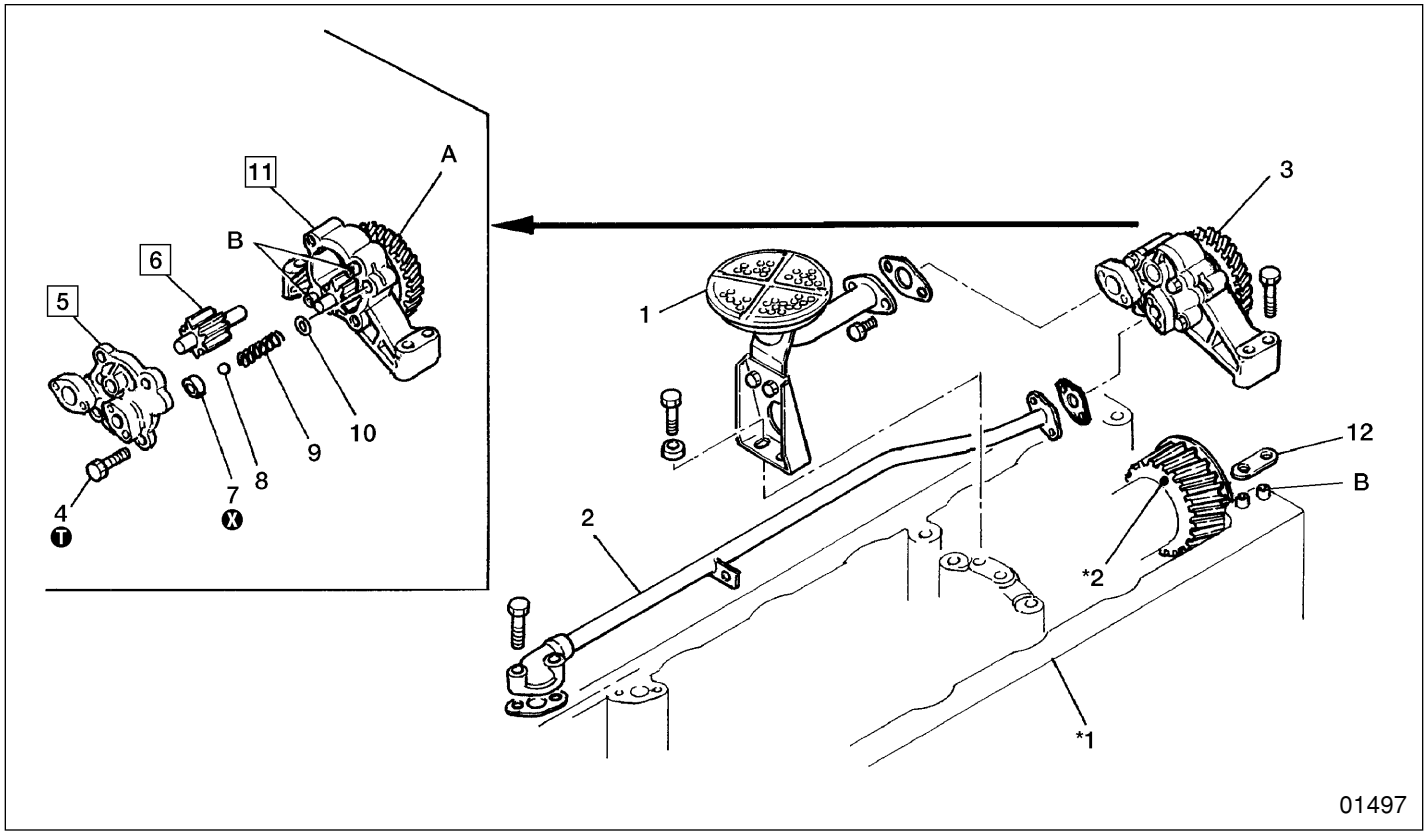
- **Clean the oil pan mounting surface and ensure it is free of oily substances before applying sealant A.**
- **Carefully mount oil pan 2 exactly in the correct position. Ensure that sealant A does not spread to other areas.**
- **After fitting oil pan 2, wait at least one hour before starting the engine.**
- **Reapply sealant A whenever the oil pan mounting bolts have been loosened.**



3 Engine oil temperature sensor

- Place engine oil temperature sensor **3** in a container of engine oil.
- Heat the engine oil until it reaches each of the temperatures in the service standards table.
- At each of the given temperatures, measure the electrical resistance between the engine oil temperature sensor's terminal ① and body ②.
- If the resistance values do not match those in the service standards table, replace the engine oil temperature sensor **3**.

OIL PUMP AND OIL STRAINER



● **Inspection before disassembly**
📖 P.12-17

● **Disassembly sequence**

1 Oil strainer
2 Oil pipe
3 Oil pump assembly
4 Bolt
5 Cover
6 Driven gear assembly
7 Ring
8 Relief valve
9 Relief valve spring
10 Washer
11 Gear and case assembly
12 Shim

***1:** Crankcase 📖 Gr 11
***2:** Crankshaft gear 📖 Gr 11

A: Oil pump gear
B: Locating pin
X : Non-reusable part

NOTE

- **Do not remove parts #7 to 10 unless they are defective.**
- **Gear and case assembly 11 is an integrated unit and cannot be disassembled. If any defect is apparent, replace the whole unit.**
- **Do not remove oil strainer 1 and oil pipe 2 from oil pump assembly 3 unless they are defective. Remove those three as a unit.**

● **Assembly sequence**

Reverse the order of disassembly.

Service standards

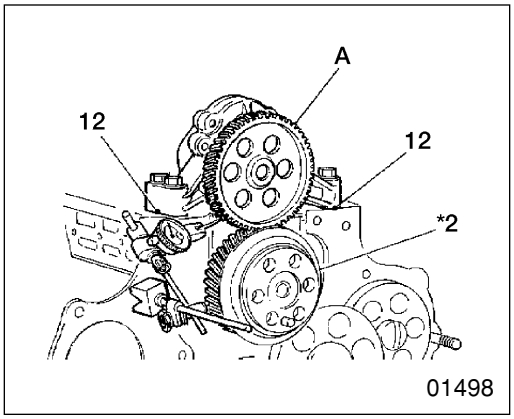
Unit: mm (in.)

Location	Maintenance item	Standard value	Limit	Remedy
5, 11	Clearance between drive gear shaft and inner diameter of cover [Basic diameter: 20 mm (0.787 in.)]	0.04 to 0.07 (0.00157 to 0.00276)	0.15 (0.00591)	Replace
5, 6, 11	Clearance between drive gear shaft and inner diameter of case and cover [Basic diameter: 20 mm (0.787 in.)]	0.04 to 0.07 (0.00157 to 0.00276)	0.15 (0.00591)	Replace
6, 11	Clearance between case and tooth tips of each gear	0.10 to 0.19 (0.00394 to 0.00748)	0.2 (0.00787)	Replace
	Difference between height of each gear and depth of case	0.06 to 0.11 (0.00236 to 0.00433)	0.15 (0.00591)	
8	Relief valve opening pressure	980 to 1175 kPa (10 to 12 kgf/cm^2) [142 to 170 psi]	–	Replace
9	Relief valve spring load [Installed length = 30 mm (1.18 in.)]	84 N (8.6 kgf) [18.9 lbf]	–	Replace
*2, A	Backlash between oil pump gear and crankshaft gear	0.08 to 0.18 (0.00315 to 0.00709)	0.35 (0.0138)	Adjust with shims

Ⓣ Tightening torque

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
4	Oil pump cover mounting bolt	25 ± 4.9 (2.5 ± 0.5) [18.4 ± 3.6]	–



◆ Service procedure

● Inspection before disassembly

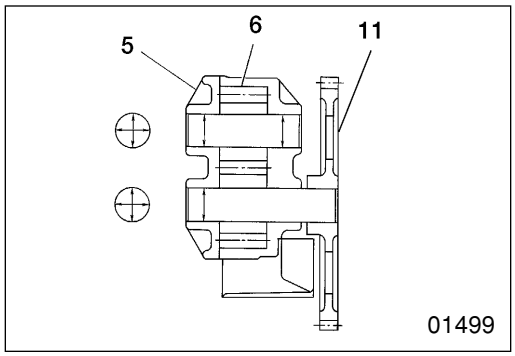
Measure the backlash between oil pump gear **A** and crankshaft gear ***2**. If the amount of backlash exceeds the specified limit, adjust it with shims **12**.

Unit: mm (in.)

Shim thickness	Change in amount of backlash
0.1 (0.00394)	0.073 (0.00287)
0.2 (0.00787)	0.146 (0.00575)

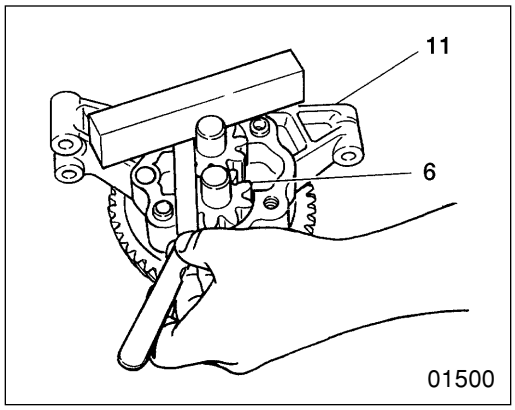
NOTE

Shim 12 must have the same thickness on the left and right sides.



5 6 11 Inspection of cover, driven gear assembly, and gear and case assembly

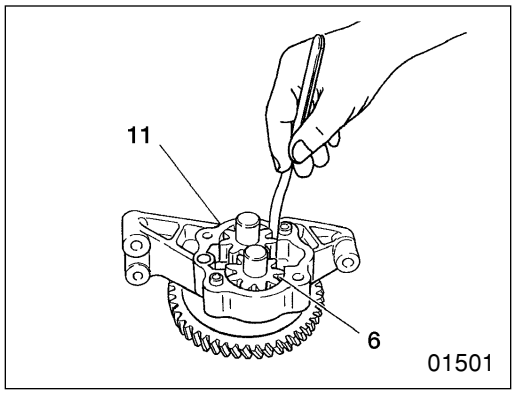
Measure the clearance between each gear shaft and the internal diameters of the cover and case.



6 11 Inspection of driven gear assembly and of gear and case assembly

(1) Differences between gear heights and case depth

Replace any component whose measurement is out of specification.



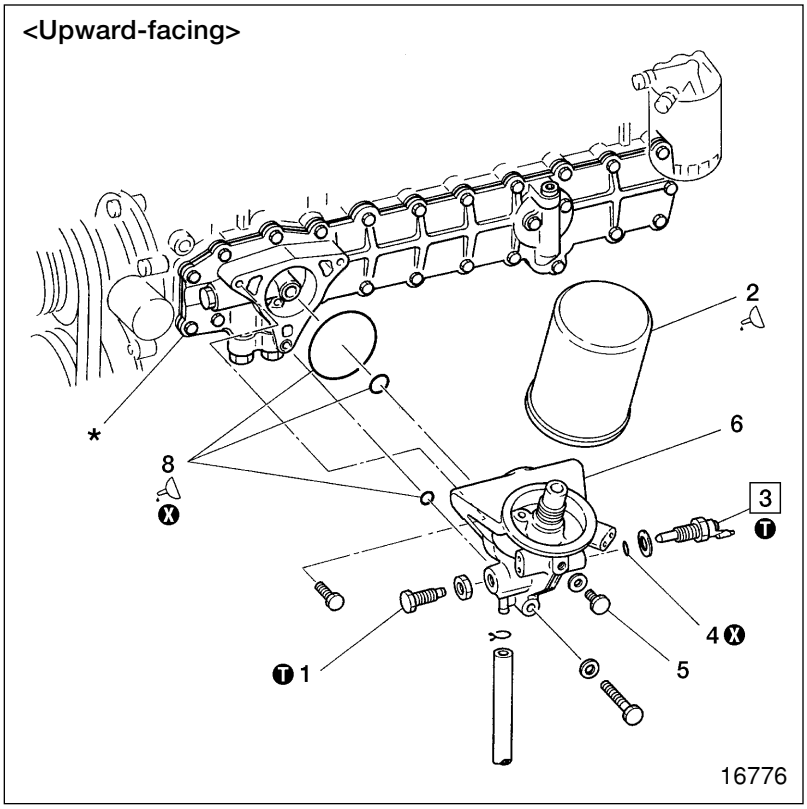
(2) Clearance between gear teeth and case

Replace any component whose measurement is out of specification.

M E M O

OIL FILTER

<Spin-on type>



● **Disassembly sequence**

1 Oil filter drain plug
2 Oil filter 📖 P.12-10
3 Engine oil bypass alarm switch
4 O-ring
5 Air plug
6 Oil filter head
7 Spacer (downward-facing filter only)
8 O-ring

*: Oil cooler 📖 P.12-22
Ⓧ: Non-reusable part

● **Assembly sequence**

Reverse the order of disassembly.

WARNING ⚠

- **Wipe up any spilled engine oil since it can cause a fire.**
- **Do not touch oil when the engine is hot since it can inflict severe burns.**

CAUTION ⚠

When pouring oil into the engine, take care not to spill any on the V-belts. Contact with oil could make the V-belts slip, rendering the cooling system less effective.

Service standards

Unit: MPa (kgf/cm²) [psi]

Location	Maintenance item	Standard value	Limit	Remedy
3	Engine oil bypass alarm switch valve opening pressure	0.19 $^{+0.05}_{-0}$ (1.9 $^{+0.5}_{-0}$) [27.6 $^{+7.3}_{-0}$]	–	Replace

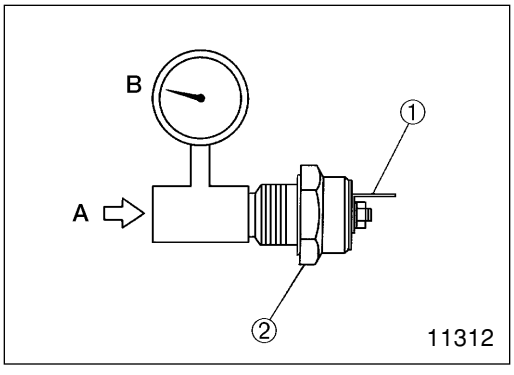
Ⓣ Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
1	Oil filter drain valve (Upward-facing)	30 ± 4.9 (3.0 ± 0.5) [22.1 ± 3.6]	–
3	Engine oil bypass alarm switch	49 ± 4.9 (5.0 ± 0.5) [36.1 ± 3.6]	–

Lubricant

Location	Points of application	Kinds	Quantity
2	Apply thin film to oil filter gasket area 🕮 P.12-10	Engine oil	As required
7	Apply to O-rings	Engine oil	As required



◆ Service procedure

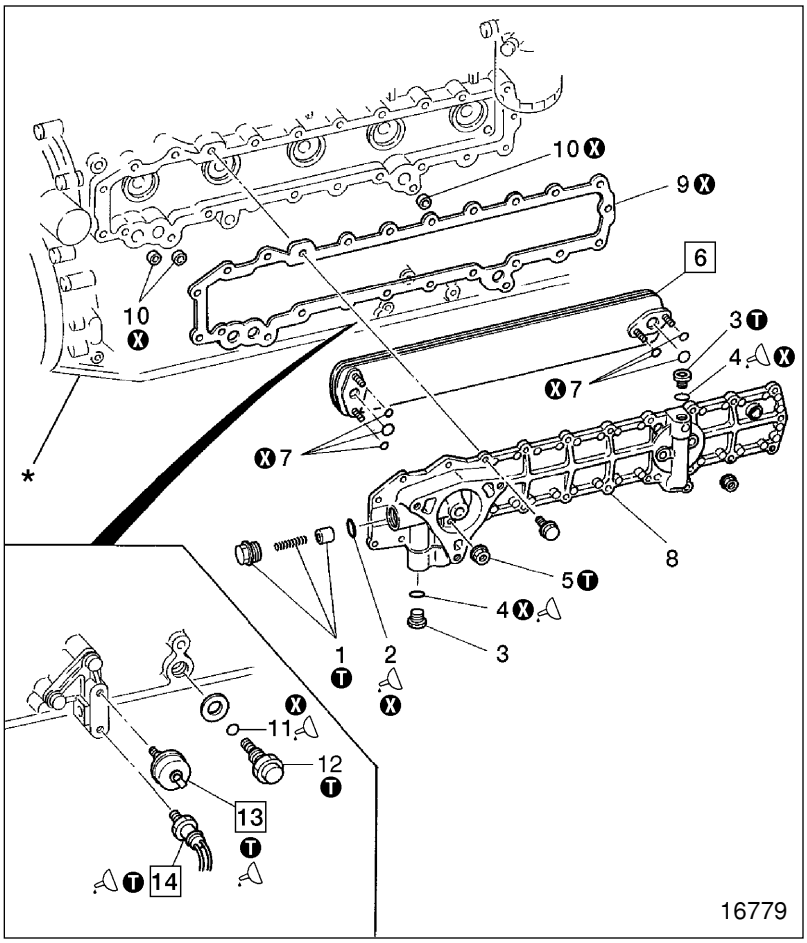
3 Inspection of engine oil bypass alarm switch

Carry out the following inspections and replace the engine oil bypass alarm switch **3** if the results are unsatisfactory:

- With no air pressure **A** applied to engine oil bypass alarm switch **3**, check that there is no electrical continuity between the terminal ① and body ② of the engine oil bypass alarm switch.
- Starting with pressure of 0 kPa (0 kgf/cm²) [0 lbf/in.²], gradually increase the air pressure **A** on engine oil bypass alarm switch **3**. Note the air pressure when electrical continuity appears between the terminal ① and body ②. Verify that this pressure conforms with the specified standard value.

B: Air pressure gauge

OIL COOLER



● **Disassembly sequence**

1 Bypass valve
2 O-ring
3 Oil cooler plug
4 O-ring
5 Nut
6 Oil cooler element
7 O-ring
8 Oil cooler cover
9 Gasket
10 O-ring
11 O-ring
12 Regulator valve 🕮 P.12-24
13 Engine oil pressure gauge unit
14 Engine oil pressure switch

*: Crankcase assembly 🕮 Gr 11
X : Non-reusable part

● **Assembly sequence**

Reverse the order of disassembly.

Service standards

Unit: kPa (kgf/cm²) [psi]

Location	Maintenance item	Standard value	Limit	Remedy
1	Oil cooler bypass valve opening pressure	295 ± 20 (3.0 ± 0.2) [42.8 ± 2.9]	–	–
6	Oil cooler element air leakage (air pressure of 980 kPa (10 kgf/cm²) [142 psi] for 15 seconds)	0 cc (0 cu.in.)	–	Replace
14	Operating pressure of engine oil pressure switch	19 ± 9.8 (0.5 ± 0.1) [7.11 ± 1.42]	–	Replace

T Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
1	Bypass valve	20 ± 4.9 (2.0 ± 0.5) [14.8 ± 3.6]	–
3	Oil cooler plug	25 ± 4.9 (2.5 ± 0.5) [18.4 ± 3.6]	–
5	Nut (oil cooler element mounting)	20 ± 4.9 (2.0 ± 0.5) [14.8 ± 3.6]	–
12	Regulator valve	105 ± 9.8 (11 ± 1) [77.4 ± 7.2]	–
13	Engine oil pressure gauge unit	15 ± 22 (1.5 ± 2.2) [11.1 ± 16.2]	–
14	Engine oil pressure switch	15 ± 22 (1.5 ± 2.2) [11.1 ± 16.2]	–

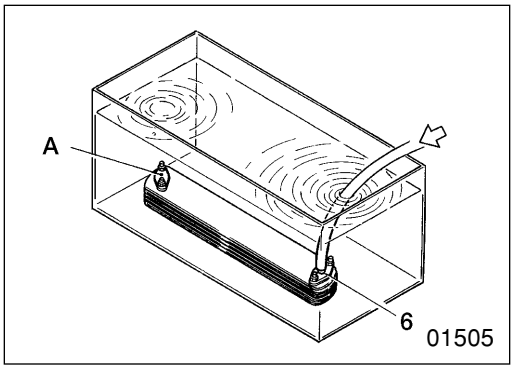
Lubricant and sealant

Location	Points of application	Kinds	Quantity
2, 4, 11	Apply to O-rings	Engine oil	As required
13, 14	Wrap around thread of engine oil pressure gauge unit and engine oil pressure switch	Teflon tape	3 1/2 turns

◆ Service procedure

● **Cleaning**

- Check whether carbon deposits or sludge have accumulated in the oil passages of oil cooler element **6** and oil cooler cover **8** or in the oil cooler's bypass arrangement. Remove any deposits with cleaning sealant.
- Clean out any water scale or fur that has accumulated in the oil cooler element **6** or oil cooler cover **8**. 🕮 Gr 14

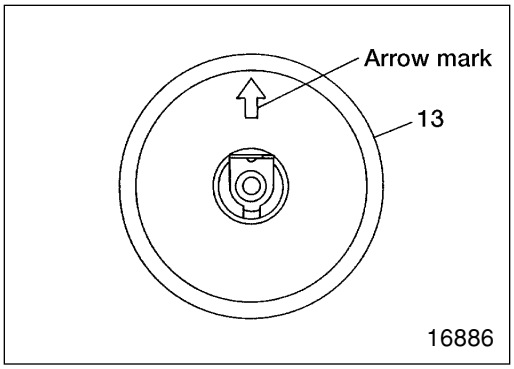


6 Inspection of oil cooler element

Plug outlet **A** of oil cooler element **6** and connect a hose to the oil inlet. Then, immerse the oil cooler element in a tank of water.

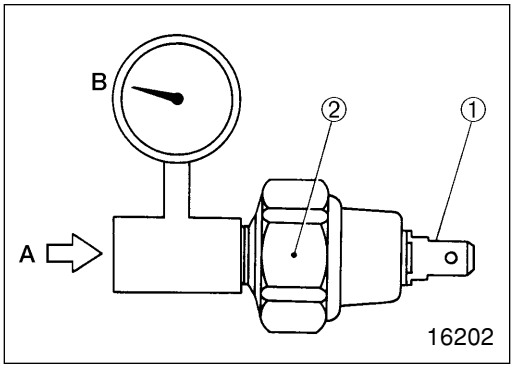
Apply the specified air pressure via the hose and check that no air leaks from the oil cooler element.

If any air leaks, replace the oil cooler element.



13 Engine oil pressure gauge unit

If the engine oil pressure gauge unit **13** is installed horizontally, it must be fitted with its arrow pointing upward.



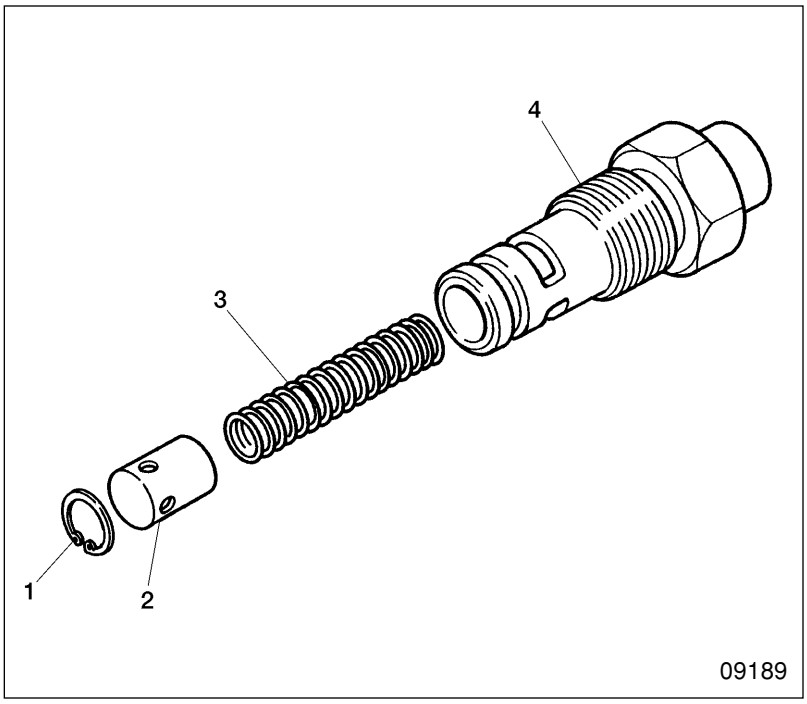
14 Inspection of engine oil pressure switch

Carry out the following inspections and replace the engine oil pressure switch **14** if the results are unsatisfactory.

- With no air pressure applied to the engine oil pressure switch **14**, check that there is continuity between the terminal ① and body ②.
- Starting from 0 kPa (0 kgf/cm^2) [0 lbf/in.^{2}], gradually apply the air pressure **A** and check that the air pressure when the continuity between the terminal ① and body ② disappears is within the specification.

B: Air pressure gauge

REGULATOR VALVE



● **Disassembly sequence**
1 Snap ring
2 Valve
3 Spring
4 Body

● **Assembly sequence**
Reverse the order of disassembly.

[Installation]
🕮 P.12-22

Service standards

Location	Maintenance item	Standard value	Limit	Remedy
3	Regulator valve spring load [Installed length = 48.3 mm (1.90 in.)]	76 to 80 N (7.8 to 8.2 kgf) [17.1 to 18.0 lbf]	–	–
–	Regulator valve opening pressure	390 ± 29 kPa (4.0 ± 0.3 kgf/cm^2) [56.6 ± 4.2 psi]	–	–

GROUP 13 FUEL AND ENGINE CONTROL

SPECIFICATIONS 2

STRUCTURE AND OPERATION 4

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- Checking and Adjusting Injection Timing 16
- Checking and Adjusting Minimum and Maximum No-load Speeds 18
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FUEL FILTER 20

INJECTION PUMP 22

INJECTION PUMP DRIVE 24

INJECTION NOZZLE 28

SPECIFICATIONS

Injection Pump

Item \ Engine model	6D16
Model	Bosch AD
Governor type	RSV-type all-speed mechanical governor
Feed pump type	KE
Automatic timer type	–
Manufacturer	Zexel

Injection Nozzle

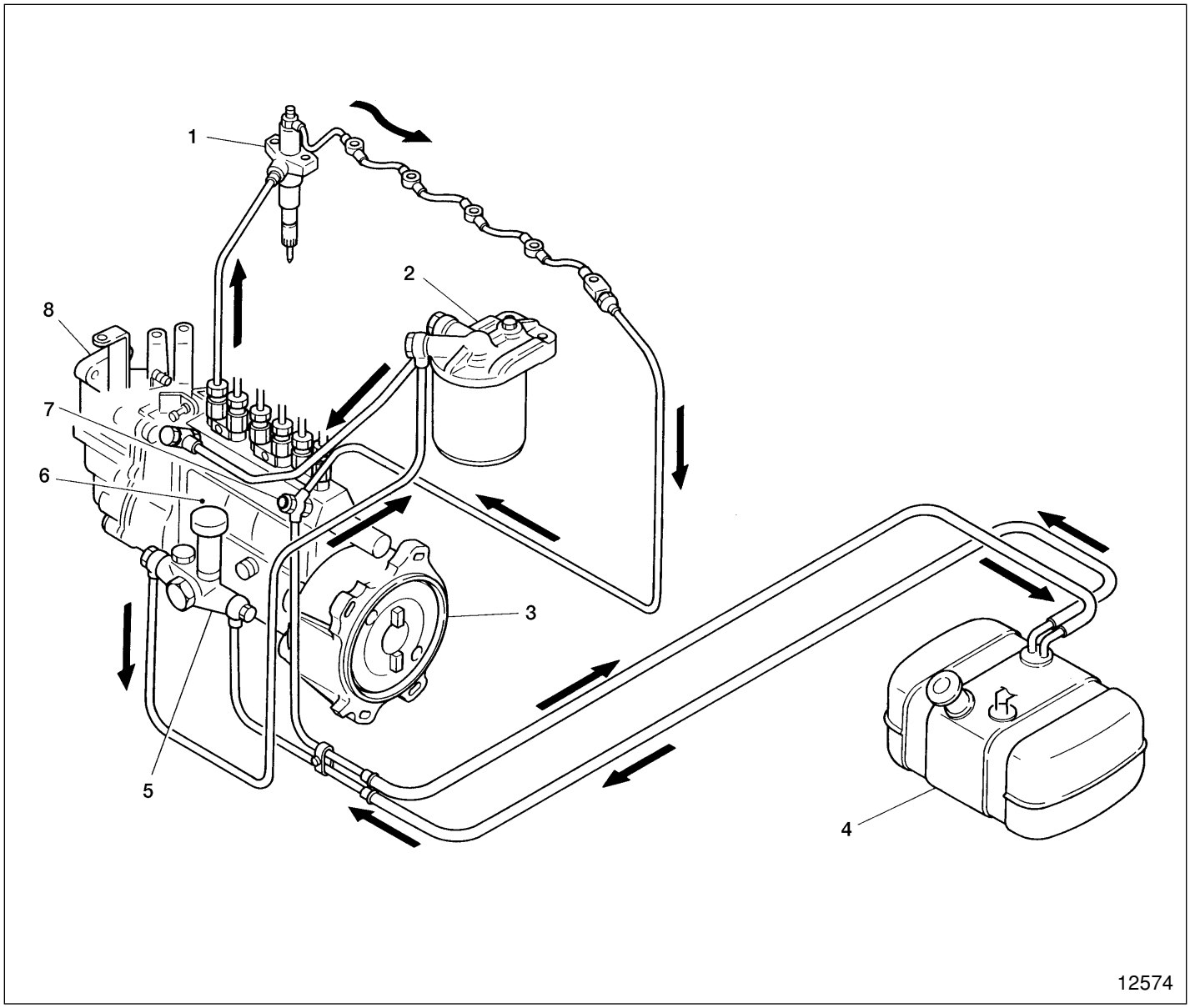
Item \ Engine model	6D16	
	Up to '96 model	From '97 model
Model	Hole-type (1-spring)	
No. of holes	5	
Hole diameter mm (in.)	0.31 (0.0122)	0.29 (0.0114)
Manufacturer	Zexel	

Other Items

Item	Specifications
Fuel filter type	Spin-on type (paper filter)

M E M O

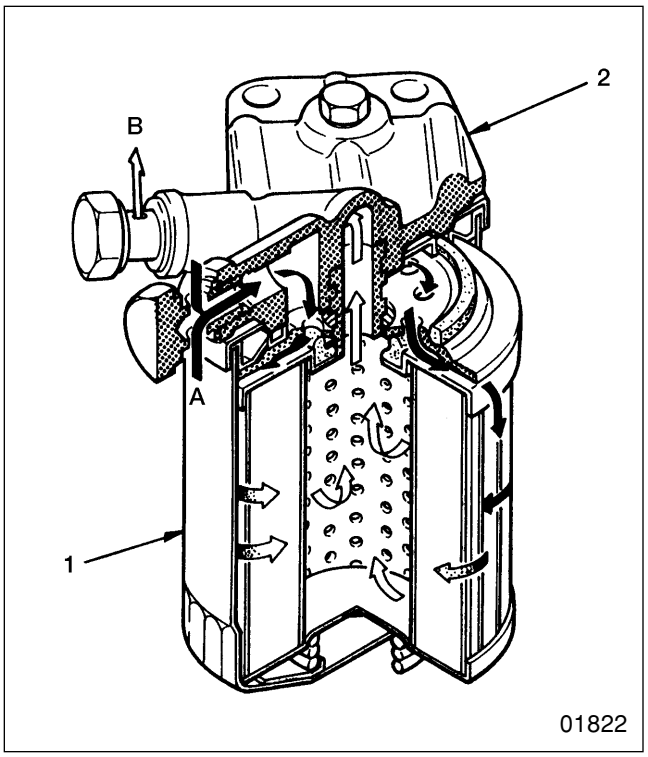
Fuel System



1 Injection nozzle
2 Fuel filter
3 Automatic timer
4 Fuel tank
5 Feed pump
6 Injection pump
7 Overflow valve
8 Governor

- Fuel from the fuel tank **4** is drawn up by the feed pump **5** and strained by the fuel filter **2**. The feed pump is driven by a cam in the injection pump **6**.
- After filtration, fuel is fed to the injection pump **6**. From there, it is fed under high pressure to the injection nozzles **1**. The injection nozzles spray the fuel into the combustion chambers.
- If the fuel pressure in the injection pump **6** exceeds a preset level, the overflow valve **7** opens to allow excess fuel to return to the fuel tank **4**.

Fuel Filter

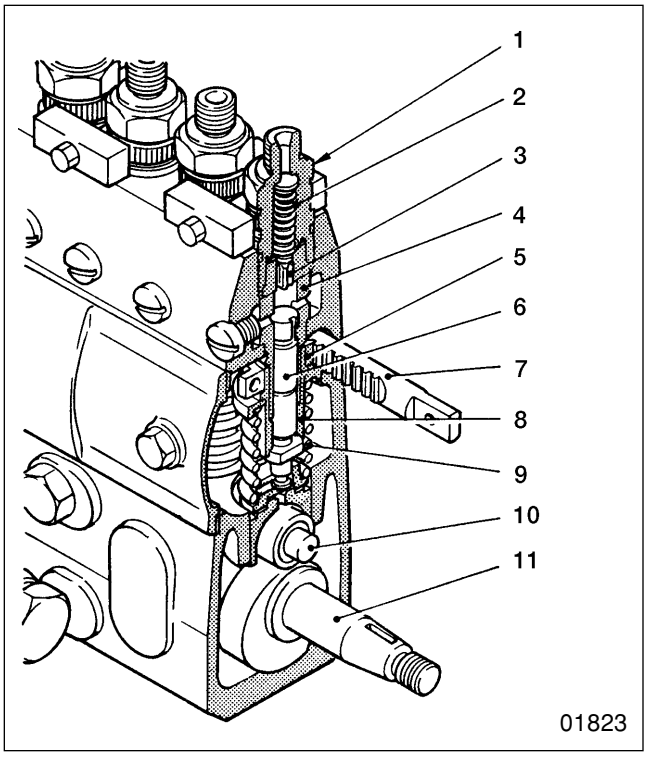


1 Fuel filter
2 Fuel filter head

A: From feed pump
B: To injection pump

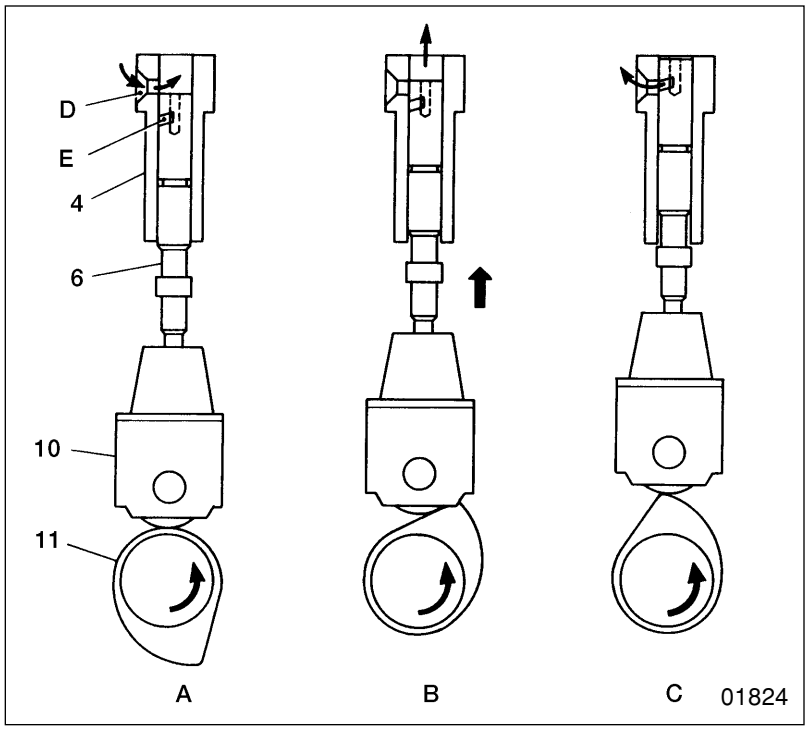
The fuel filter separates any water content out of fuel fed from the injection pump's feed pump, and its element removes any impurities.

Injection Pump

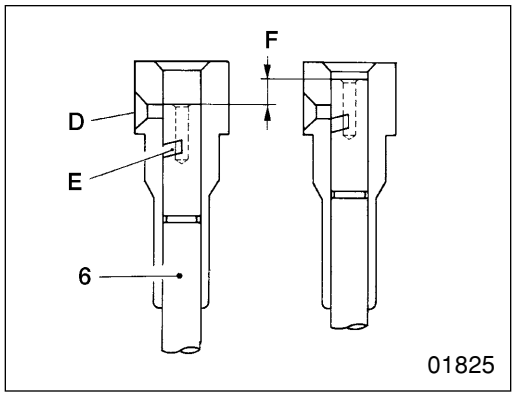


1 Delivery valve holder
2 Delivery valve spring
3 Delivery valve
4 Plunger barrel
5 Control pinion
6 Plunger
7 Control rack
8 Control sleeve
9 Plunger spring
10 Tappet
11 Camshaft

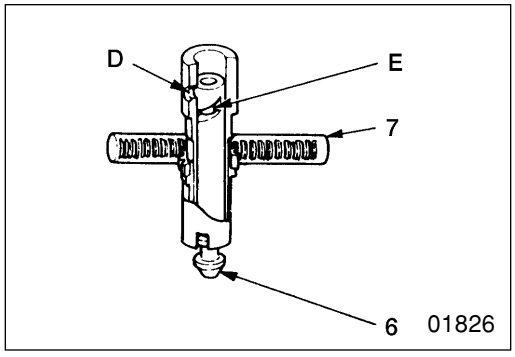
The injection pump feeds fuel to the injection nozzles under high pressure and incorporates a mechanism for increasing and decreasing the fuel flow.



● **Fuel feed action**
- **A:** Fuel drawn in
- **B:** Start of pressure feed
- **C:** End of pressure feed
- **D:** Inlet/outlet hole
- **E:** Lead

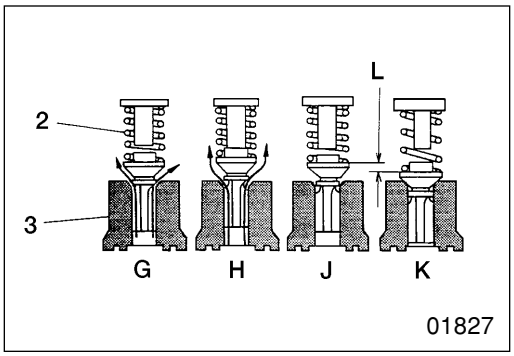


As the plunger **6** rises and its lead **E** meets the fuel inlet/outlet hole **D**, fuel flows through the center of the plunger and is expelled from the inlet/outlet hole. Regardless of how much further the plunger rises, no fuel feed takes place thereafter.
The stroke length **F** of the plunger **6** during which pressure feed takes place is known as the “effective stroke.”



● **Injection volume adjustment mechanism**

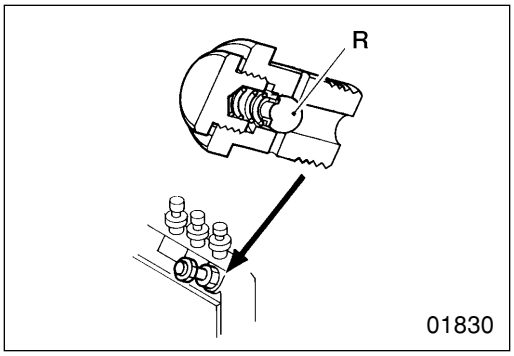
To match changes in engine loading, an adjustment mechanism controls the amount of fuel injected. This mechanism turns the plunger **6** by a given angle, thereby altering the point at which the fuel inlet/outlet hole **D** meets the lead **E**. Simply stated, the effective stroke is made longer or shorter. A single control rack **7** is used to rotate every plunger in the engine, so the plungers rotate simultaneously and by the same angle.



● **Delivery valve**

G: Pressurization starts
H:: Injection
J: Pressurization ends (Starting suction)
K: Suction ends
L: Suction stroke

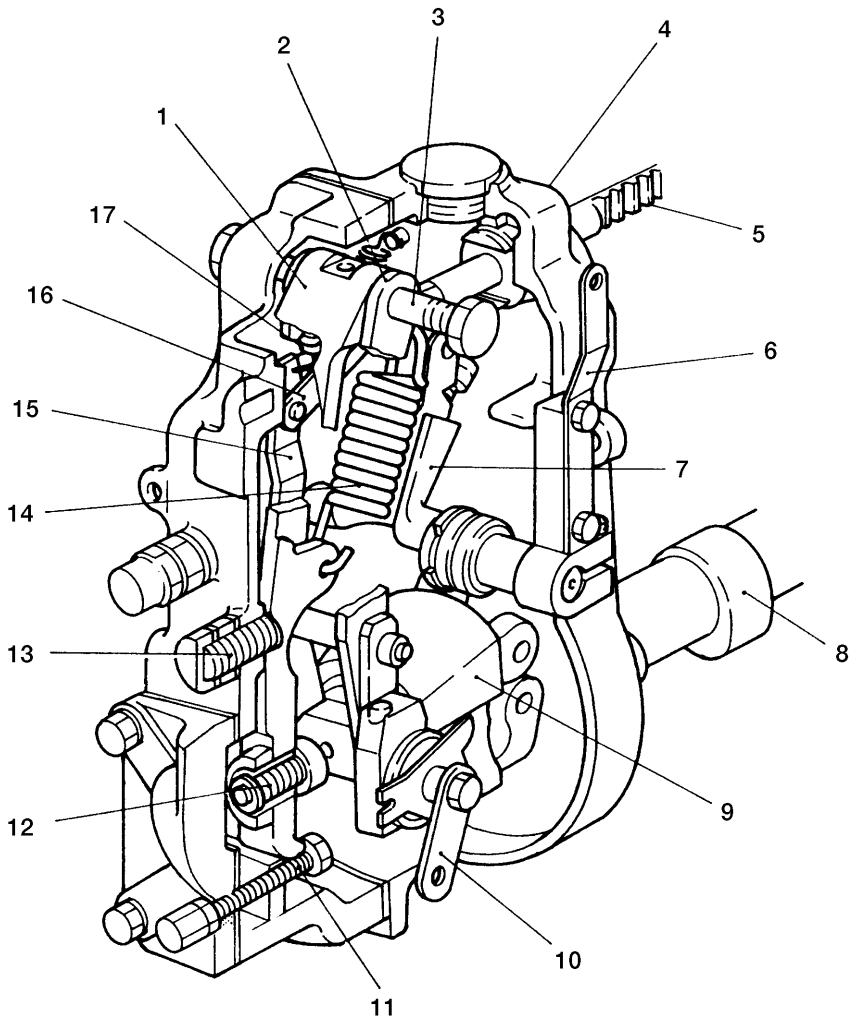
Fuel highly pressurized by plunger pushes up delivery valve **3** for injection, and when delivery of pressurized fuel ends, delivery valve returns by the force of delivery valve spring to close fuel passage, thus avoiding reverse flow of fuel. Delivery valve lowers further to rest at its seat, and for this stroke **L**, residual pressure between delivery valve and injection nozzle is for an instant lowered. This return suction makes fuel-cutting at nozzles effective and avoids post-injection dripping.



● **Overflow valve**

When the fuel pressure in the injection pump exceeds a preset level, the steel ball **R** is pushed up, allowing fuel to flow out from the injection pump and return to the fuel tank. This stabilizes the fuel temperature and temperature distribution in the injection pump and keeps the injection rate constant in each cylinder.

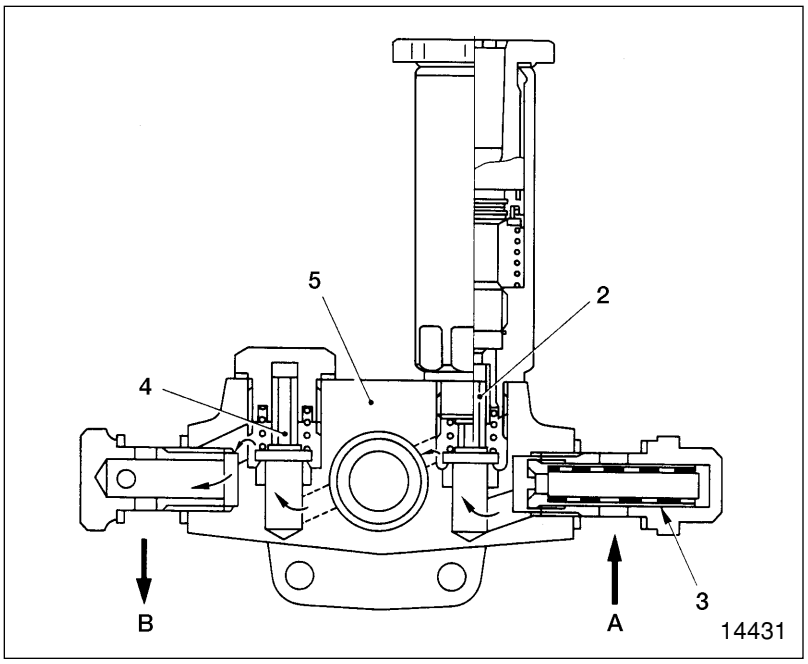
Governor



18225

1 Tension lever
2 Guide lever
3 Supporting lever shaft
4 Governor housing
5 Control rack
6 Adjusting lever
7 Swivel lever
8 Camshaft
9 Flyweight
10 Stop lever
11 Full-load stopper bolt
12 Ungleich spring or idling spring
13 Idling subspring
14 Governor spring
15 Control lever
16 Shackle
17 Start spring

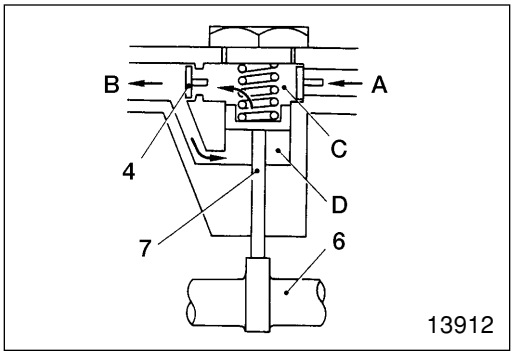
Feed Pump



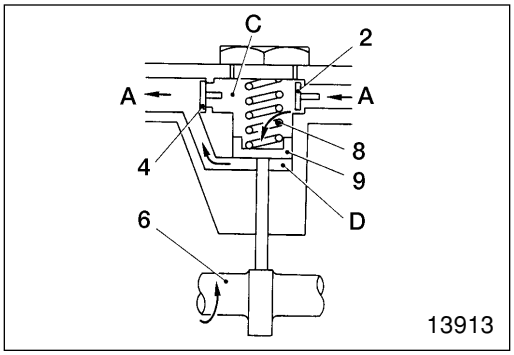
1 Priming pump
2 Inlet check valve
3 Gauze filter
4 Outlet check valve
5 Feed pump housing

A: From fuel tank
B: To fuel filter

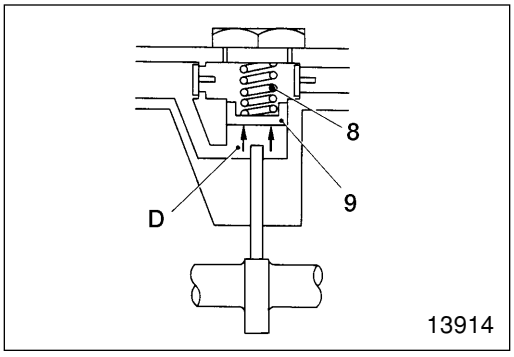
The feed pump is driven by the camshaft in the injection pump. The priming pump **1** enables fuel to be drawn up manually when the injection pump is stationary. It is particularly useful for air bleeding.
The gauze filter **3** removes large impurities from fuel drawn up from the fuel tank and thus prevents clogging of the feed pump. It must be washed regularly in gas oil.



● **Suction stroke**
When the injection pump camshaft **6** forces up the push rod **7**, fuel in the suction chamber **C** is compressed and opens the outlet check valve **4**. Most of the fuel forced out is drawn into the pressure chamber **D** below the piston.



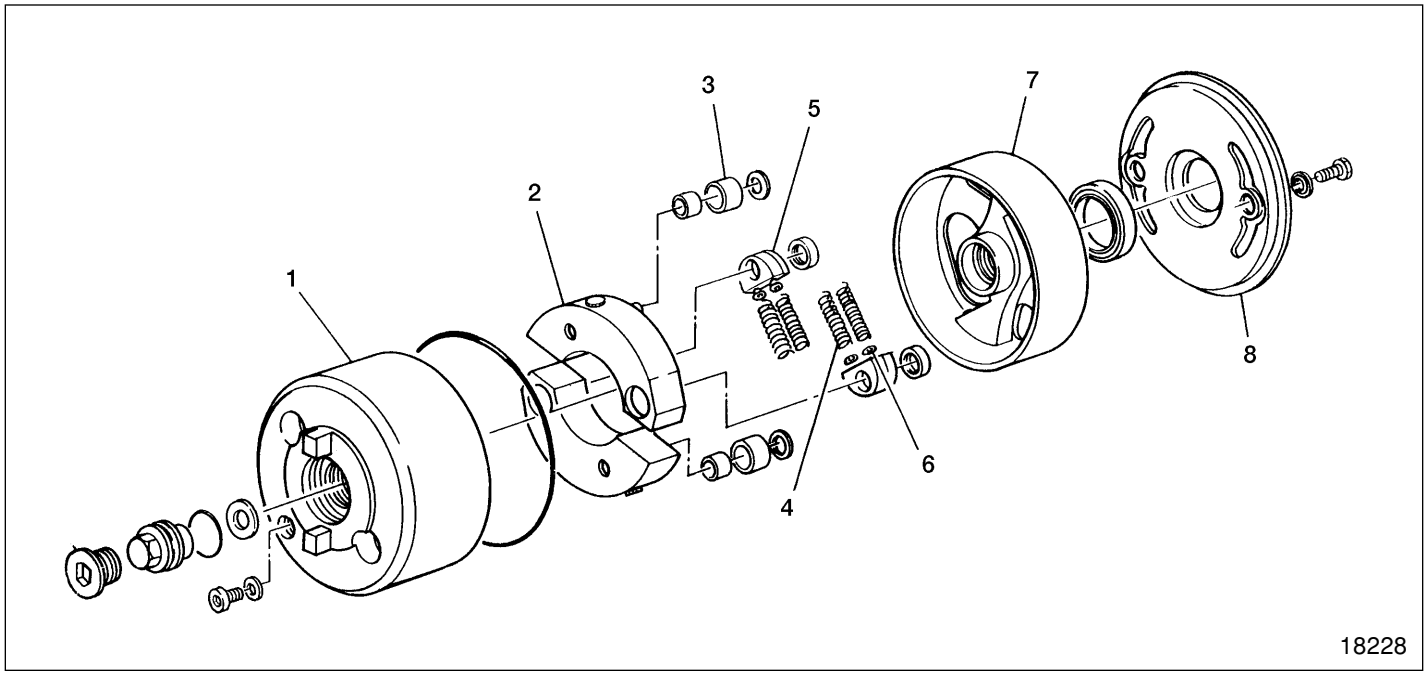
● **Pressure feed stroke**
As the camshaft **6** turns and the cam loses its lift, the piston **9** is pushed down by the piston spring **8**. The fuel in the pressure chamber **D** is thus forced out and fed toward the fuel filter.
At the same time, the outlet check valve **4** closes and the inlet check valve **2** opens. As a result, fuel is again drawn into the suction chamber **C**.



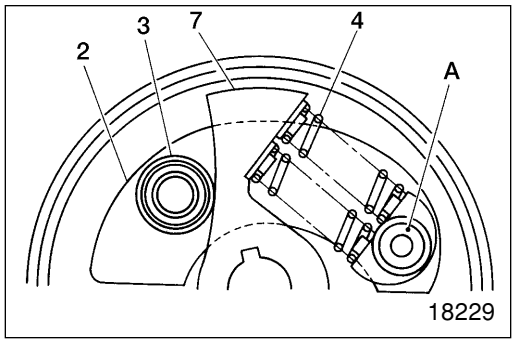
● **Stoppage**
When pressure in the pressure chamber **D** exceeds a preset level, the piston spring **8** cannot push back the piston **9**. The pump therefore stops operating, preventing pressure in the fuel filter from rising more than necessary.

Automatic Timer

The automatic timer utilizes a mechanical arrangement to adjust the injection timing in accordance with the engine speed. The automatic timer is mounted on the injection pump camshaft using a round nut. Via a driving disk, it is driven by the air compressor crankshaft or pump drive shaft.

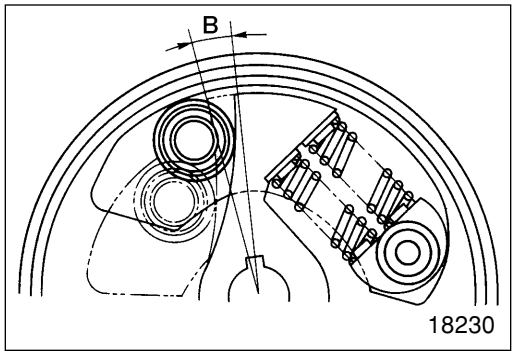


1 Timer housing
2 Flyweight
3 Roller
4 Timer spring
5 Spring seat
6 Shim
7 Flange
8 Cover



● **With engine stationary**

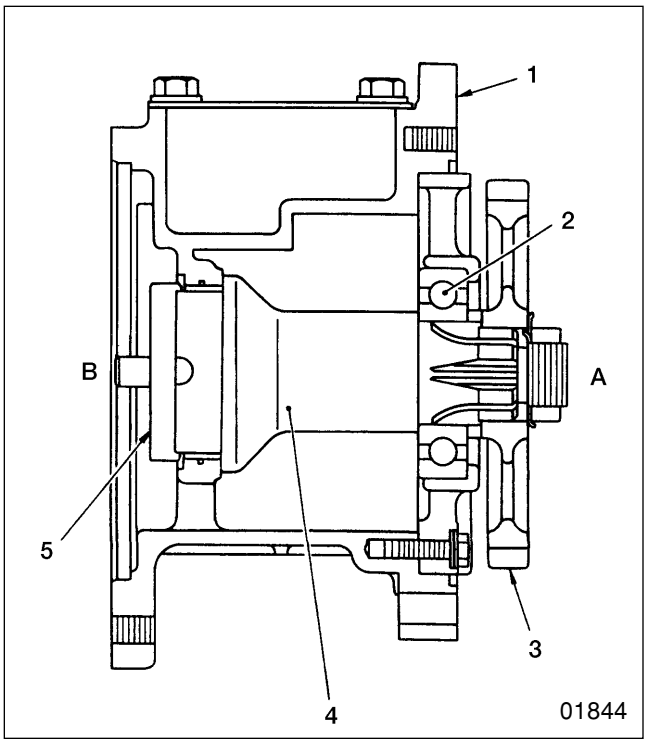
When the engine is stationary, the timer spring **4** overcomes the centrifugal force acting on the flyweight **2**. The flyweight roller is therefore held down by the flange **7**, and the injection timing arrangement is not advanced.



● **With engine running**

As the engine speed rises, the centrifugal force on the flyweight **2** increases. With the timer housing pin **A** as the fulcrum, the flyweight roller **3** thus moves outward while pushing the curved surface of the flange **7**, causing the flange to compress the timer springs **4**. As a result, the roller **3** of the flyweight **2** moves the flange **7** in the rotating directing and the injection timing is advanced.

Injection Pump Drive

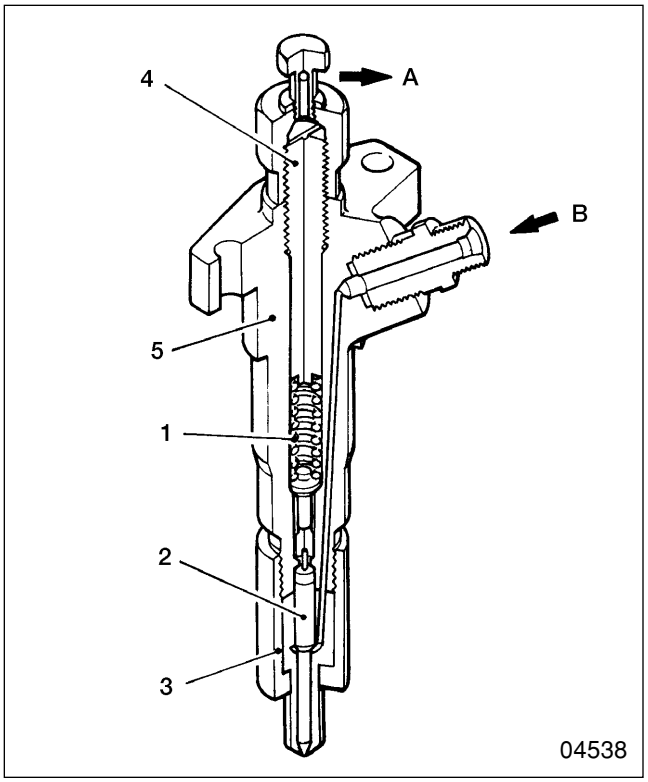


1 Pump drive case
2 Bearing
3 Pump drive gear
4 Pump drive shaft
5 Coupling

A: Timing gear side
B: Timer side

The injection pump drive is fitted onto the flywheel housing on the left of the engine. It is driven by the engine timing gear at half the engine speed.
The pump drive shaft **4** drives the injection pump via the coupling **5** on its timer side.

Injection Nozzles



1 Nozzle spring
2 Needle valve
3 Nozzle
4 Adjusting screw
5 Nozzle holder

A: To leak-off pipe
B: From injection pump

Fuel fed from the injection pump enters the nozzle holder **5**. When the fuel pressure in the nozzle holder exceeds a preset pressure, it overcomes the nozzle spring **1**, pushes up the needle valve **2**, and the fuel is sprayed into the cylinder from the orifice at the end of the nozzle **3**.
Some of the high-pressure fuel lubricates the needle valve **2** and returns to the fuel tank via the leak-off pipe.

Possible causes \ Symptoms		Engine will not start	Engine difficult to start	Engine knocks	Unstable engine output	Insufficient engine output	Engine maximum speed too high	Unstable engine idling	Engine stops soon after starting	Engine does not reach maximum speed	Engine will not stop	Accelerator pedal too stiff	Defective fuel supply
Injection pump proper	Sticky plunger	○											
	Sticky control rack	○											
	Sticky delivery valve	○											
	Worn tappet	○											
	Worn camshaft	○											
	Poorly adjusted injection timing		○		○	○		○					
	Worn plunger					○		○					
	Defective delivery valve seat					○							
	Excessively advanced injection timing			○									
	Insufficient plunger slide stroke				○								
	Broken plunger spring				○			○					
	Defective sliding action in control rack		○		○		○	○					
	Tappet worn or not sliding correctly				○								
	Broken delivery valve spring				○	○							
	Poor airtightness due to loose delivery valve holder				○	○							
	Defective delivery valve operation				○								
	Loose control pinion							○					
	Plunger spring not seating correctly							○					
	Delivery valve holder too tight							○					
	Uneven injection volume to cylinders		○					○					
Fuel feed pump	Gauze filter clogged	○						○	○				
	Check valve not operating	○											
	Sticky piston	○											
	Sticky push rod	○											
	Worn tappet	○											
	Defective check valve operation		○		○			○					
	Piston worn		○		○			○					

Possible causes \ Symptoms		Engine will not start	Engine difficult to start	Engine knocks	Unstable engine output	Insufficient engine output	Engine maximum speed too high	Unstable engine idling	Engine stops soon after starting	Engine does not reach maximum speed	Engine will not stop	Accelerator pedal too stiff	Defective fuel supply
Governor	Insufficient full-load stopper position					○							
	Weak governor spring					○				○			
	Incorrectly adjusted control lever				○	○				○			
	Flyweights not operating effectively						○						
	Weak idling spring							○					
	Bent links							○					
	Excessive friction or play in links							○					
	Loose round nut							○					
	Poorly adjusted idling set bolt							○					
	Defective sliding action in control lever											○	
	Stop mechanism damaged										○		
Automatic timer	Defective advancing action					○		○					
Injection nozzles	Sticky needle valve	○											
	Valve opening pressure too low	○								○			
	Blocked injection orifice	○		○		○		○		○			
	Poor airtightness in nozzle	○		○		○		○		○			
	Valve opening pressure too high			○									
	Broken spring				○	○							
	Defective sliding action in needle valve				○								
	Defective valve opening pressure				○								
	Weakness/deterioration in spring							○					
Fuel filter	Filter (and/or secondary filter) clogged	○			○			○	○				
Fuel tank empty		○											
Fuel pipes blocked and/or fuel leaking from connections		○											
Air or water in fuel system		○			○			○	○				
Low-quality fuel in use			○	○		○		○					
Cracked fuel pipe													○
Leaky fuel tank													○

Possible causes \ Symptoms		Engine will not start	Engine difficult to start	Engine knocks	Unstable engine output	Insufficient engine output	Engine maximum speed too high	Unstable engine idling	Engine stops soon after starting	Engine does not reach maximum speed	Engine will not stop	Accelerator pedal too stiff	Defective fuel supply
Incorrect oil viscosity	🕮 Gr. 12		○										
Incorrect valve clearance	🕮 Gr. 11		○				○						
Defective head gasket	🕮 Gr. 11		○				○						
Wear and/or carbon deposits on valve and valve seat	🕮 Gr. 11		○				○						
Weakness/deterioration in valve spring	🕮 Gr. 11		○				○						
Worn/damaged piston ring(s)	🕮 Gr. 11		○					○					
Worn/damaged piston ring groove(s)	🕮 Gr. 11		○					○					
Worn piston and cylinder liner	🕮 Gr. 11		○										
Cooling system malfunctioning	🕮 Gr. 14		○					○					
Defective starter switch	🕮 Gr. 54		○										
Defective glow relay	🕮 Gr. 54		○										

M E M O

Checking and Adjusting Injection Timing

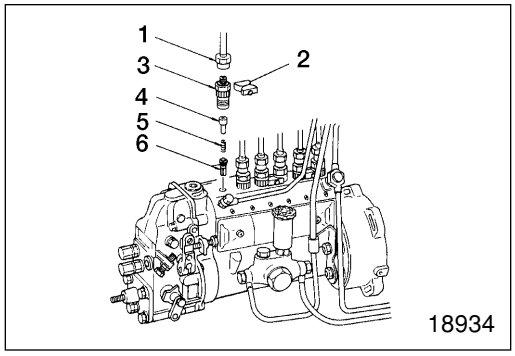
Service standards

Location	Maintenance item		Standard value	Limit	Remedy
–	Fuel injection timing (BTDC)	8, 9 ton models	11°	–	Adjust
		10 to 15 ton models	13°	–	Adjust

❶ Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened		Tightening torque	Remarks
1	Union nut (injection pipe mounting)		25 (2.5) [18.4]	–
2	Bolt (injection pipe lock plate)	Zexel, AD-type	3.4 to 4.9 (0.35 to 0.5) [2.88 to 3.61]	–
3	Delivery valve holder	Zexel, AD-type	49 to 54 (5 to 5.5) [36.1 to 39.8]	–

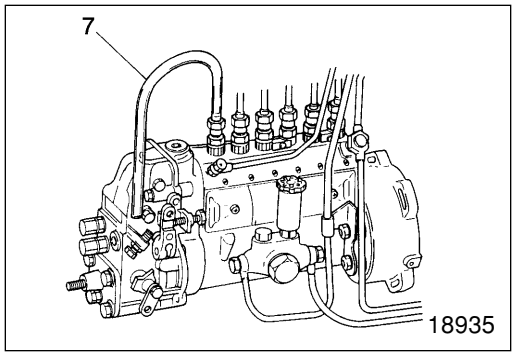


[Inspection]

- From the injection pump's No. 1 cylinder, remove the injection pipe **1**, lock plate **2**, delivery valve holder **3**, stopper **4**, delivery valve spring **5**, and delivery valve **6**.
- Fit the delivery valve holder **3**.

CAUTION ⚠

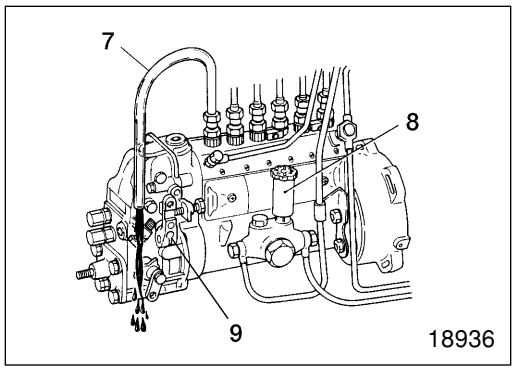
Place all parts in gas oil after removal to keep them free of dust.



- Fit an injection pipe **7** onto cylinder No. 1. Point the pipe's other end downward such that fuel flowing out can be seen clearly.
- Rotate the crankshaft pulley clockwise (as seen from the front of engine) by at least 180° and bring cylinder No. 1 to approximately 30° BTDC on its compression stroke.

NOTE

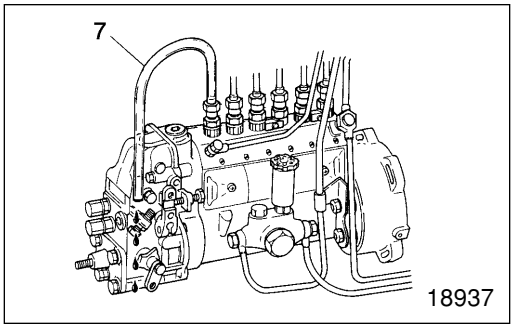
If the engine is turned in its reverse direction (when stopping the engine or by cranking), the automatic timer may stay in an advanced condition. This may not be cancelled by a slight forward rotation of the engine. Be sure to crank the engine forward manually by at least 180°.



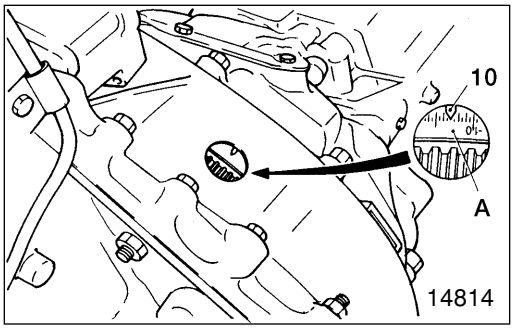
- Feed fuel into the injection pump using the priming pump **8**. With fuel flowing out of the injection pipe **7**, crank the engine slowly clockwise (as seen from the front of engine).

NOTE

Ensure that the stop lever 9 at the side of the governor is not in its STOP position.



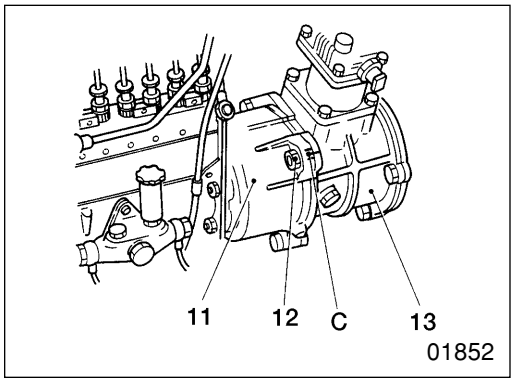
- When the flow of fuel from the injection pipe **7** diminishes, crank the engine more slowly. When the flow of fuel stops completely, stop cranking the engine.



- Check that the pointer **10** on the flywheel housing or torsional damper **B** indicates the value 1° earlier than the correct fuel injection timing.
  A: Flywheel

NOTE
- **The injection timing in this measurement becomes 15 earlier than the correct injection timing due to the inactivation of the delivery valve spring.**
- **The correct injection timing is indicated on the plate attached on the rocker cover.**

- If the injection timing should be measured in a dusty location, perform as follows:
  - Rotate the crankshaft pulley clockwise (as seen from the front of engine) and bring the No. 1 cylinder to 30° BTDC on its compression stroke.
  - Disconnect the injection pipe **1** with a little amount of fuel remained at the top of the delivery valve holder **3**.
  - Slowly rotate the crankshaft pulley clockwise. When the injection timing is reached, the fuel at the top of the delivery valve holder **3** starts to move.
- If the injection timing is out of the specification, adjust as follows:

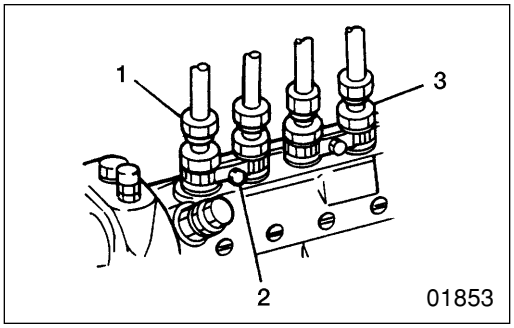


[Adjustment]
- Loosen the nuts **12** that hold the timer case **11** onto the pump drive or air compressor **13**.
- If the fuel injection timing is overly retarded, incline the injection pump toward the crankcase.
- If the fuel injection timing is overly advanced, incline the injection pump away from the crankcase.

NOTE
Turning the injection pump by one of the gradations inscribed on the timer case flange C causes a 6° change in the injection timing.

- Tighten the nuts **12**, then check the fuel injection timing again.

NOTE
If the fuel injection timing is so far out of specification that adjustment with the injection pump is not possible, the engine timing gear and injection pump drive gear may not be meshing correctly. If this occurs, remove and refit the air compressor or injection pump drive.
- **Air compressor: 🕮 Gr. 61**
- **Injection pump drive: 🕮 P.13-24**
- **After checking that the fuel injection timing is up to specification, fit the delivery valve 6, delivery valve spring 5, and stopper 4.**



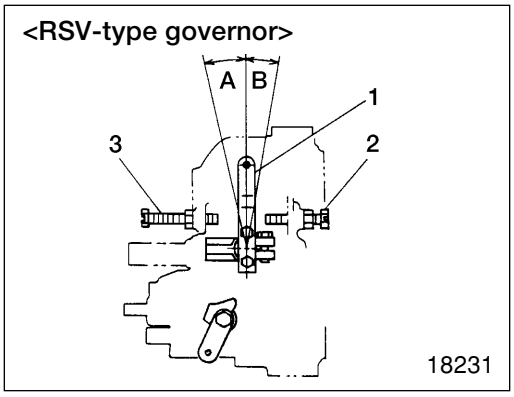
- Tighten each part to its specified torque.

Checking and Adjusting Minimum and Maximum No-load Speeds

Service standards

Location	Maintenance item	Standard value	Limit	Remedy
–	No-load minimum speed	690 $^{+30}_{0}$ rpm	–	Adjust
–	No-load maximum speed	2350 $^{+100}_{0}$ rpm	–	Adjust

Start the engine and allow it to warm up before carrying out the following inspections.



● **No-load minimum speed**

[Inspection]

Confirm that the control lever **1** is touching the idling set bolt **3**. Then check that the minimum speed is up to specification.

A: Idling position

[Adjustment]

If the minimum speed is out of specification, adjust it using the idling set bolt **3**.

● **No-load maximum speed**

[Inspection]

Confirm that the control lever **1** is touching the full-speed set bolt **2**. Then, check that the maximum speed is up to specification.

B: Full-speed position

[Adjustment]

If the maximum speed is out of specification, adjust it using the full-speed set bolt **2**.

NOTE

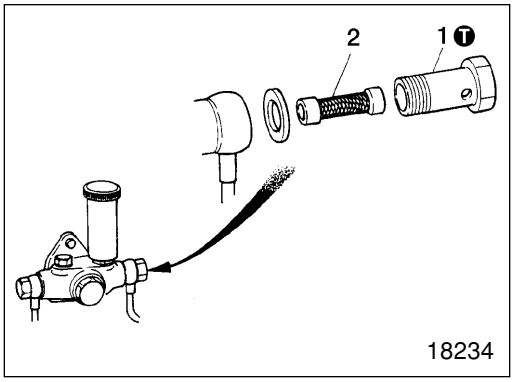
Check that the engine does not stall and that no hunting occurs when the control lever 1 is moved quickly from the full-speed position to the idling position. If any abnormality is apparent, make adjustments within the specified range.

Cleaning Fuel Feed Pump Gauze Filter

❶ Tightening torques

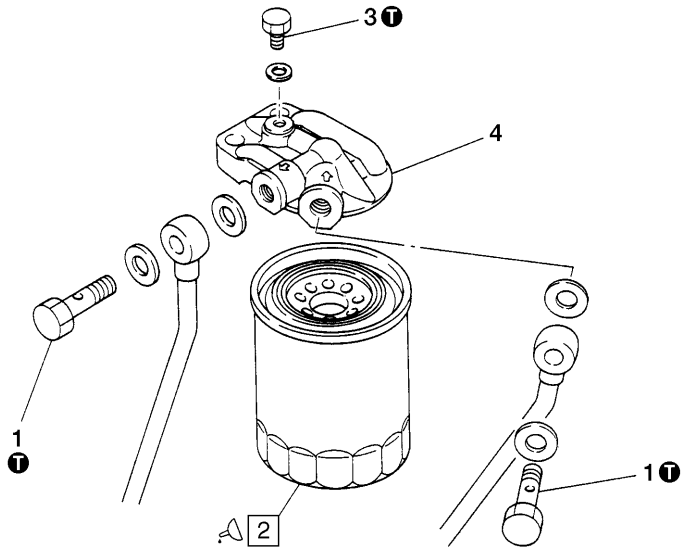
Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
1	Eyebolt	20 to 29 (2 to 3) [14.8 to 21.4]	–



- Remove the eyebolt **1** from the suction port side of the fuel feed pump.
- Remove the gauze filter **2** from the eyebolt **1**.
- Clean the gauze filter **2**.
- Refit the gauze filter **2** and eyebolt **1** in the opposite order to their removal.
- Bleed all air out of the fuel system.
- Start the engine and check for fuel leaks.

FUEL FILTER



18235

● **Disassembly sequence**

1 Eyebolt
2 Fuel filter
3 Air vent plug
4 Fuel filter head

● **Assembly sequence**

Reverse the order of disassembly.

T Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

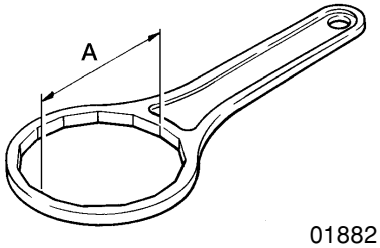
Location	Parts to be tightened	Tightening torque	Remarks
1	Eyebolt	34 (3.5) [25.1]	–
3	Air vent plug	9.8 ± 2.0 (1 ± 0.2) [7.23 ± 1.48]	–

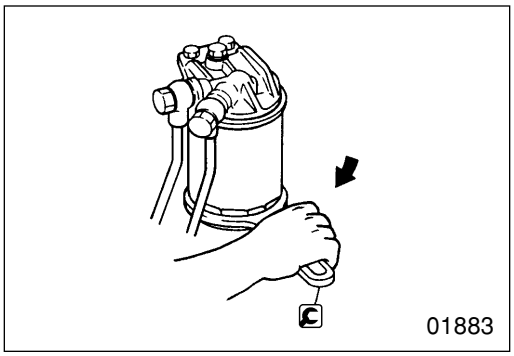
Oils

Location	Points of application	Kinds	Quantity
2	Gasket between fuel filter and fuel filter head	Engine oil	As required

Special tools

Unit: mm (in.)

Location	Tool name and shape	Part No.	Application
2	Filter Wrench Part No. / A MH061509 / 90.2 (3.55) MH061572 / 94.2 (3.71)  01882	MH061509 MH061572	Removing fuel filter



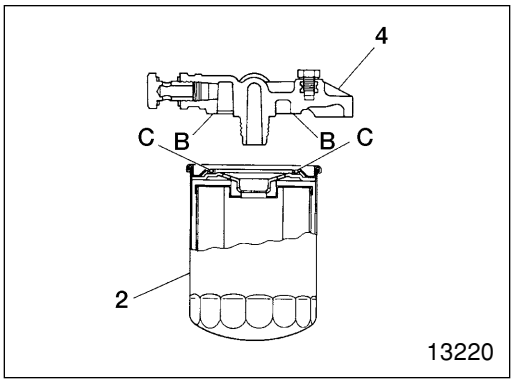
◆ Service procedure

2 Fuel filter

[Removal]

WARNING ⚠

- **Fuel is highly flammable; keep it away from flames and sources of heat.**
- **To minimize the risk of fire, wipe up any spilled fuel.**



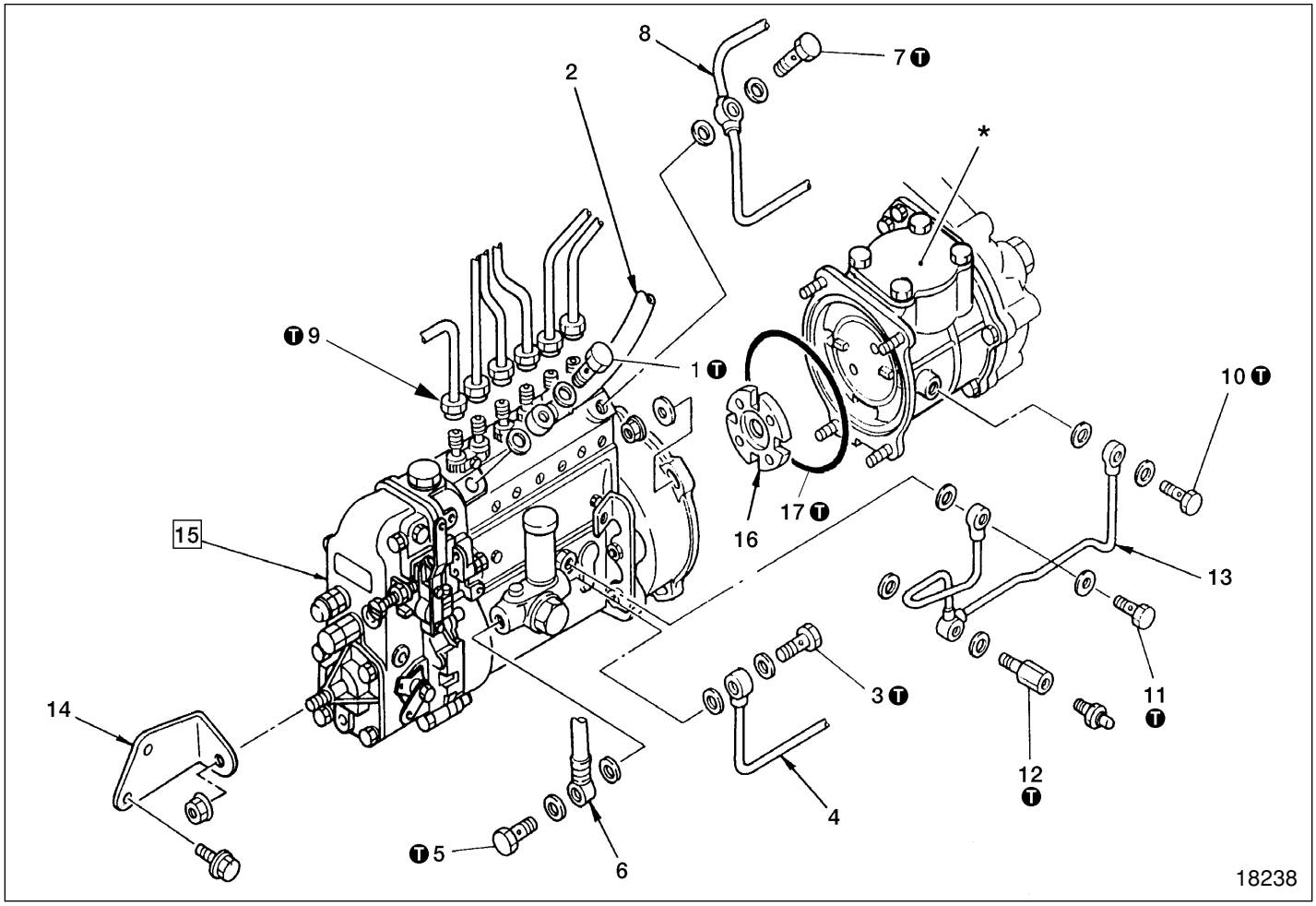
[Installation]

WARNING ⚠

Use of an unsuitable fuel filter 2 can lead to fuel leaks and fires. Be sure to use a genuine Mitsubishi filter.

- To fit the fuel filter **2**, turn it until the gasket **C** touches surface **B** of the fuel filter head **4**. Then, tighten the filter by 3/4 to 1 turn. Be sure to turn the filter by hand.
- Start the engine and check for fuel leaks.

INJECTION PUMP



● **Disassembly sequence**

1 Eyebolt
2 Fuel feed hose
3 Eyebolt
4 Fuel suction pipe
5 Eyebolt
6 Fuel feed hose
7 Eyebolt
8 Fuel return pipe
9 Injection pipe
10 Eyebolt
11 Eyebolt
12 Connector
13 Oil pipe
14 Injection pump stay
15 Injection pump assembly
16 Driving disk
17 O-ring
*: Air compressor 🕮 Gr. 61, or injection pump drive 🕮 P.13-24
Ⓧ: Non-reusable part

● **Assembly sequence**

Reverse the order of disassembly.

WARNING ⚠

- **Fuel is highly flammable; keep it away from flames and sources of heat.**
- **To minimize the risk of fire, wipe up any spilled fuel.**

CAUTION ⚠

Dirt particles in the injection pump assembly 15 can seriously detract from engine performance. To prevent the ingress of dirt, cover all pipes, hoses, and other parts after removal.

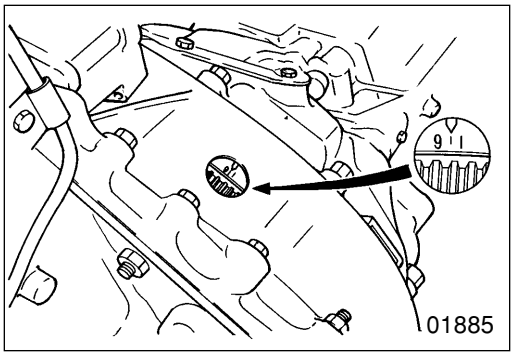
NOTE

For maintenance of the injection pump assembly 15, please contact a Zexel service station.

❶ Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

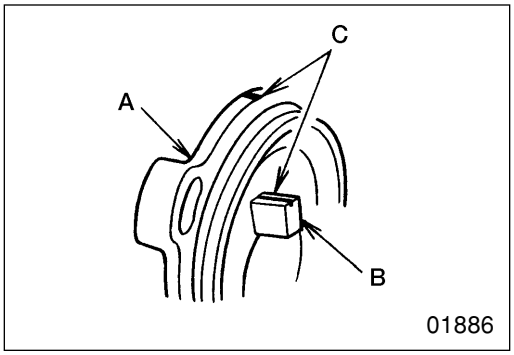
Location	Parts to be tightened		Tightening torque	Remarks
1, 7	Eyebolt (fuel feed hose, fuel return pipe)	Zexel	20 to 29 (2 to 3) [14.8 to 21.4]	–
3, 5	Eyebolt (fuel suction pipe, fuel feed hose)	Zexel	20 to 25 (2 to 2.5) [14.8 to 18.4]	–
9	Injection pipe union nut		25 (2.5) [18.4]	–
10	Eyebolt (oil pipe; air compressor or pump drive side)		21 (2.1) [15.5]	–
11	Eyebolt (oil pipe; injection pump side)	Zexel	10 to 13 (1 to 1.3) [7.38 to 9.59]	–
12	Connecter (oil pipe)		21 (2.1) [15.5]	–



◆ Service procedure

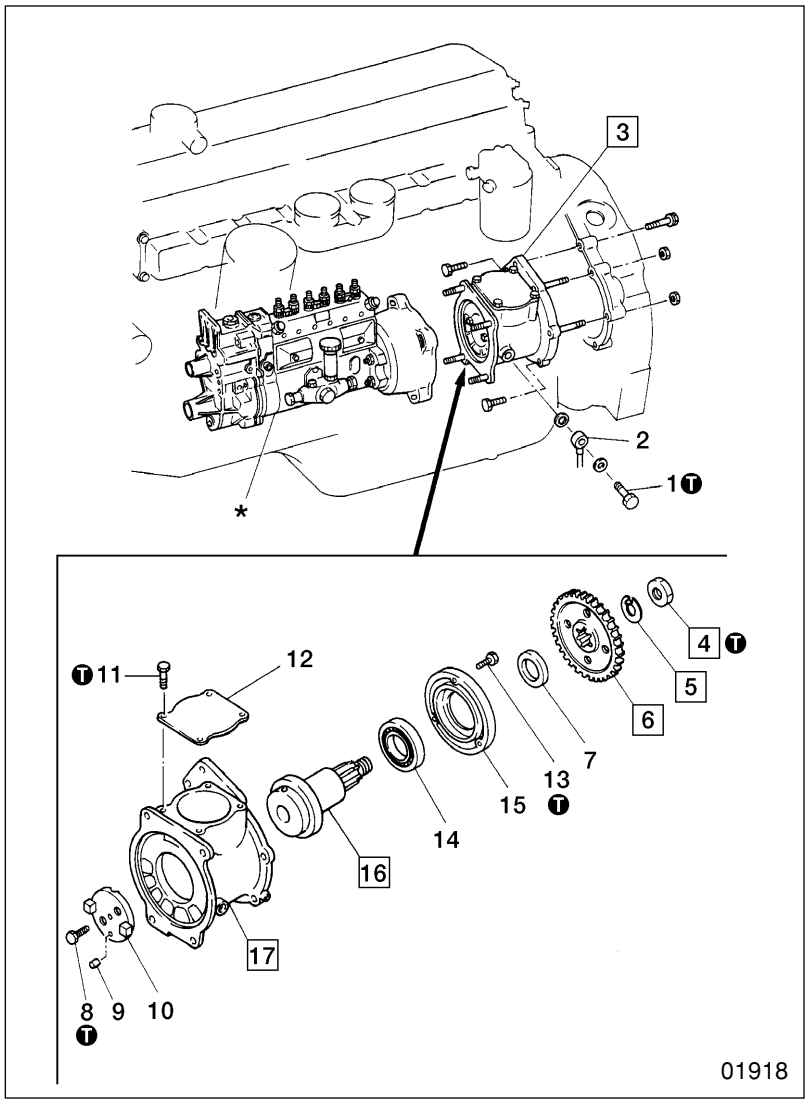
15 Installing injection pump assembly

- Bring cylinder No. 1 of the engine to the TDC position of its compression stroke.



- Align the inscribed lines **C** on the timer case **A** and timer **B**. Then, fit the injection pump assembly **15** onto the air compressor or injection pump drive.

INJECTION PUMP DRIVE



● **Disassembly sequence**

1 Eyebolt
2 Oil pipe
3 Injection pump drive assembly
4 Nut
5 Lock washer
6 Drive gear
7 Collar
8 Bolt
9 Pin
10 Coupling
11 Bolt
12 Cover
13 Bolt
14 Bearing
15 Bearing holder
16 Pump drive shaft
17 Pump drive case

*: Injection pump assembly P.13-22

● **Assembly sequence**

Reverse the order of disassembly.

Service standards

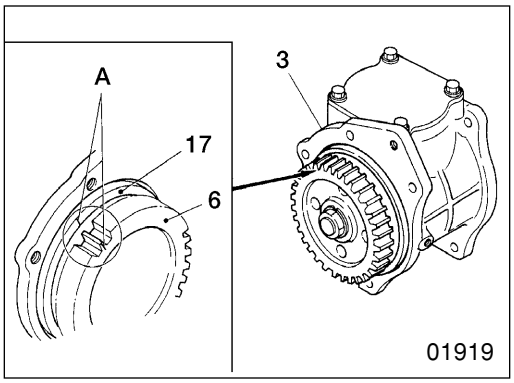
Unit: mm (in.)

Location	Maintenance item	Standard value	Limit	Remedy
16	Pump drive shaft end play	–	0.59 (0.0232)	Replace
16, 17	Pump drive shaft-to-pump drive case clearance	–	0.12 (0.00474)	Replace pump drive case

T Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

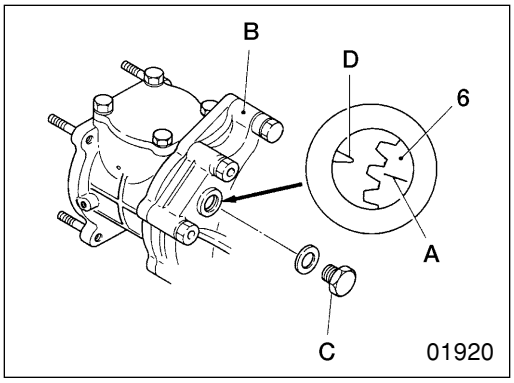
Location	Parts to be tightened	Tightening torque	Remarks
1	Eyebolt	21 (2.1) [15.5]	–
4	Nut (drive gear mounting)	167 to 211 (17 to 21.5) [123 to 156]	–
8	Bolt (coupling mounting)	30 to 36 (3.1 to 3.7) [22.1 to 26.6]	–
11	Bolt (cover mounting)	25 to 29 (2.5 to 3) [18.4 to 21.4]	–
13	Bolt (bearing holder mounting)	5.9 to 6.9 (0.6 to 0.75) [4.35 to 5.09]	–



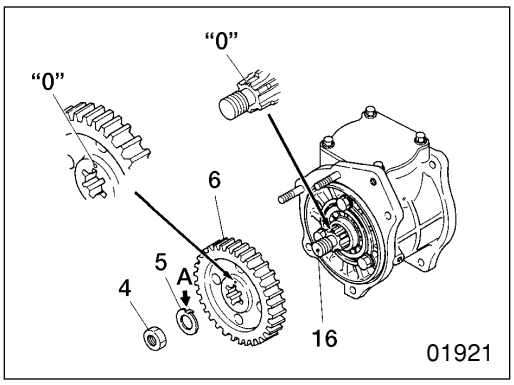
◆ Service procedure

3 Installing injection pump drive assembly

- Bring cylinder No. 1 of the engine to the TDC position of its compression stroke. 🕮 Gr. 11
- Align the inscribed line **A** on the drive gear 6 of the injection pump drive assembly **3** with the inscribed line **A** on the pump drive case **17**.

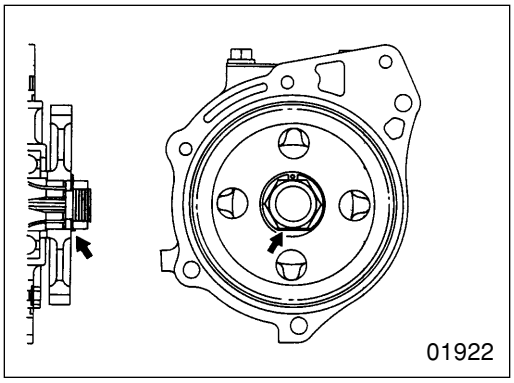


- Remove the plug C from the flywheel housing **B**, then check that the inscribed line **A** on the drive gear 6 is aligned with the pointer **D**. If the line and pointer are not aligned, remove and refit the injection pump drive assembly.

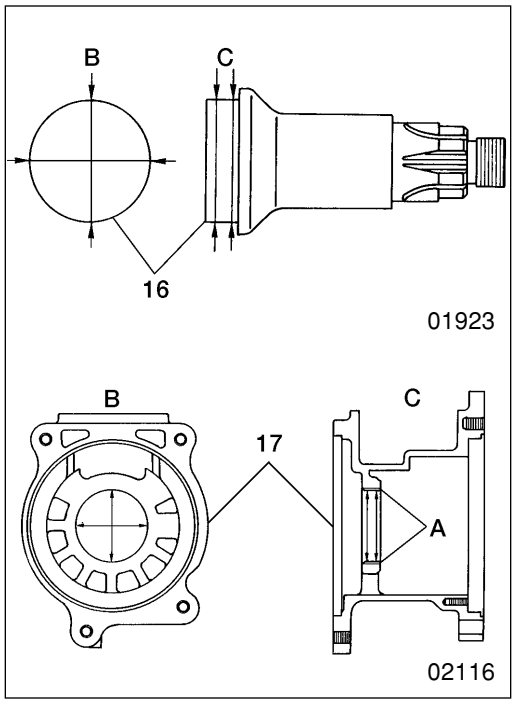


4 to 6 Installing drive gear

- Fit the drive gear **6** such that its "0" alignment mark is aligned with the "0" alignment mark on the pump drive shaft **16**. Then, fit the lock washer **5** such that its notch **A** is aligned with the drive gear alignment mark, and tighten the nut **4** to the specified torque.



- When the assembly is complete, bend the lock washer **5** down onto the nut **4**.



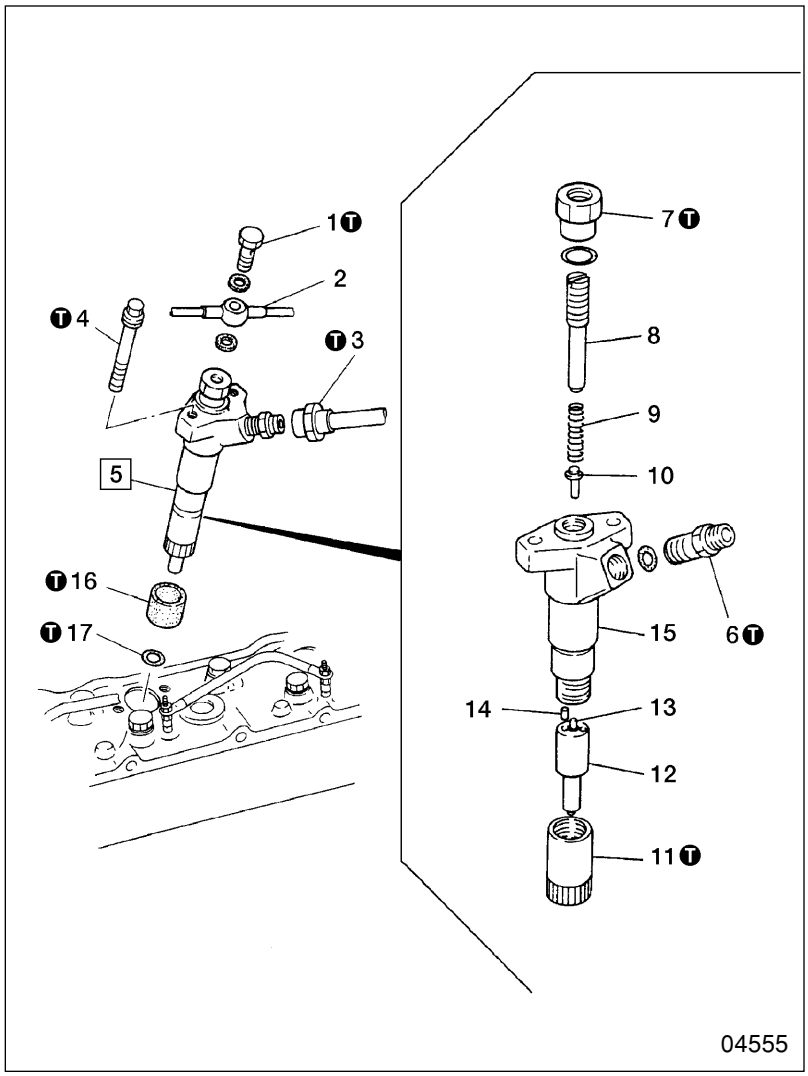
16 **17** **Pump drive shaft-to-pump drive case clearance**

If the clearance exceeds the specified limit, replace the pump drive case **17**.

A: Bushing
B: Measurement directions
C: Measurement positions

M E M O

INJECTION NOZZLE



● **Inspection before disassembly**
P.13-29

● **Disassembly sequence**

1 Eyebolt
2 Fuel leak-off pipe
3 Injection pipe
4 Bolt
5 Injection nozzle assembly
6 Connector
7 Cap nut
8 Adjusting screw
9 Spring
10 Push rod
11 Retaining nut
12 Nozzle
13 Needle valve
14 Pin
15 Nozzle holder
16 Dust seal
17 Gasket

X: Non-reusable part
Repair kit: Nozzle Service Kit

● **Assembly sequence**

Reverse the order of disassembly.

WARNING

To minimize the risk of fire, wipe up any spilled fuel.

CAUTION

Under no circumstances change the needle valve 13 and nozzle 12 combination used in each injection nozzle assembly 5.

NOTE

- **Clean off any carbon deposits before disassembling, reassembling, or adjusting the injection nozzle assembly 5. Before disassembly, check the pressure and shape of the spray and inspect the assembly for fuel leaks. If no abnormality is apparent, do not commence disassembly.**
- **When fitting the injection nozzle assembly 5, tighten each of the two bolts 4 a little at a time.**

Service standards

Location	Maintenance item	Standard value	Limit	Remedy
5	Injection pressure	17.7 MPa (180 kg/cm²) [2,567 psi]	–	Adjust

Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
1	Eyebolt (fuel leak-off pipe mounting)	9.8 to 15 (1.0 to 1.5) [7.23 to 11.1]	–
3	Injection pipe union nut	25 (2.5) [18.4]	–
4	Bolt (injection nozzle mounting)	15 (1.5) [11.1]	–
6	Connector	69 to 78 (7 to 8) [50.9 to 57.5]	–
7	Cap nut	29 to 39 (3 to 4) [21.4 to 28.8]	–
11	Retaining nut	59 to 78 (6 to 8) [43.3 to 57.5]	–

Special tools

Location	Tool name and shape	Part No.	Application
–	Nozzle Cleaning Tool	*105789-0010	Cleaning nozzles

*: Zexel part number

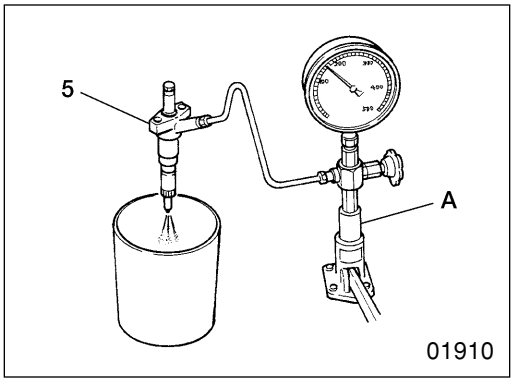
◆ Service procedure

● **Pre-disassembly inspection**

Fit the injection nozzle assembly **5** onto the nozzle tester **A** ready for inspection.

NOTE

Before commencing inspection, operate the lever on the nozzle tester A two or three times to bleed all air out of the arrangement.

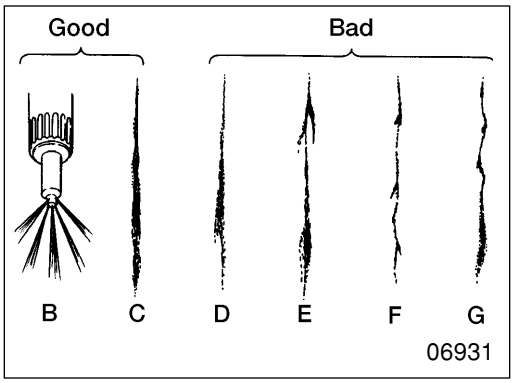


(1) Checking valve opening pressure

- Push down the lever on the nozzle tester **A** at a rate of 1-2 seconds per stroke. The pressure gauge reading will gradually rise, then the needle will suddenly deflect. Note the pressure when the needle starts to deflect.
- If the measurement is out of specification, disassemble the nozzle, clean it, and make adjustments using the adjusting screw **8**.
- If the measurement is still out of specification after adjustment, replace the injection nozzle assembly **5**.

WARNING ⚠

Do not touch the spray that comes out of the nozzle.



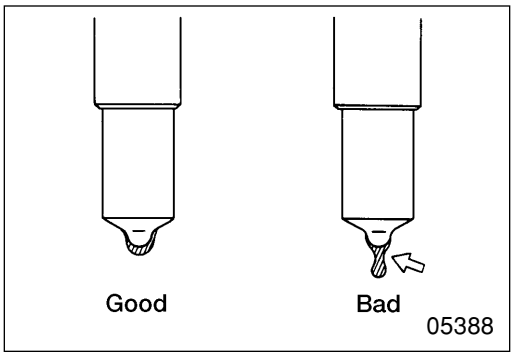
(2) Inspecting spray condition

- Pump the lever on the nozzle tester **A** at a rate of about 1-2 seconds per stroke, and maintain a continuous spray.
  B: Even spray from all five injection orifices (Good)
  C: Even and symmetrical spray (Good)
  D: Asymmetrical spray (Bad)
  E: Branched spray (Bad)
  F: Thin spray (Bad)
  G: Irregular spray (Bad)

- If the spray is unsatisfactory, disassemble and clean the injection nozzle assembly **5**, then inspect the spray again. If the spray is still unsatisfactory, replace the injection nozzle assembly **5**.
- Check that no fuel drips from the nozzle after the spray is complete.

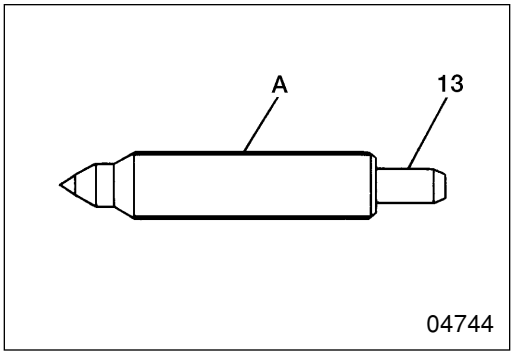
WARNING ⚠

Do not touch the spray that comes out of the nozzle.



(3) Inspecting for leaks

- Slowly increase the nozzle pressure to 1.96 MPa (20 kgf/cm^2) [284.3 psi] below the specified valve opening pressure. Maintain this pressure for 10 seconds and check that no fuel drips from the end of the nozzle.
- If the injection nozzle assembly **5** appears defective, disassemble and clean it, then inspect it again. If the injection nozzle assembly **5** still appears defective, it must be replaced.

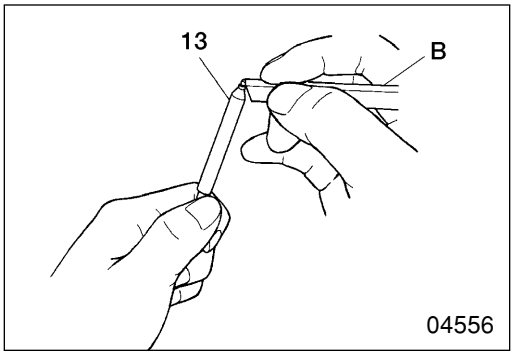


5 Injection nozzle assembly

[Disassembly]

CAUTION ⚠

- **Do not touch the sliding parts A of the needle valve 7.**
- **Do not change the needle valve 13 and nozzle 12 combination on each cylinder.**



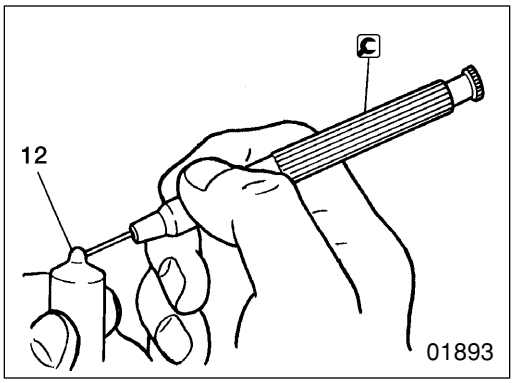
[Cleaning]

Wash the needle valve **13** and nozzle **12** in gas oil, then use the 🔧 Cleaning Tool Set to remove any carbon deposits in accordance with the following procedure.

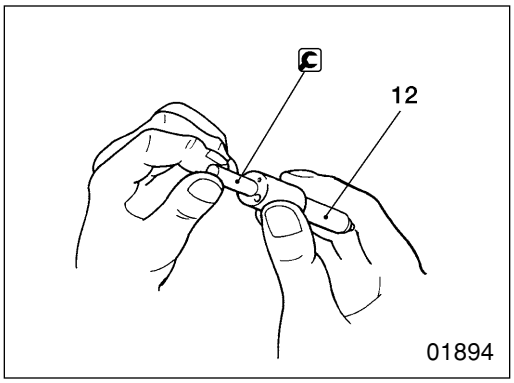
- Remove carbon from the end of the needle valve **13** using the Cleaning Bar of the 🔧 Cleaning Tool Set.

CAUTION ⚠

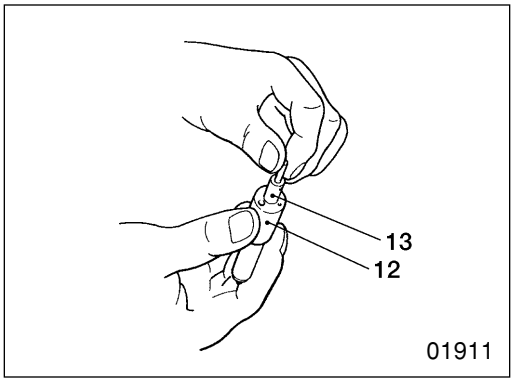
Do not use a wire brush or any hard metallic object for cleaning.



- Remove carbon from the injection orifice of the nozzle **12** using the Needle Cleaner of the Cleaning Tool Set. Insert the Needle Cleaner and rotate it to dislodge the carbon.



- Clean the seat of the nozzle **12** using the Cleaning Scraper of the Cleaning Tool Set.
- To remove burned and hardened carbon, use FUSO Carbon Remover.



[Inspection]

- Wash the needle valve **13** and nozzle **12** in gas oil, then fit them together.
- Pull up the needle valve **13** by approximately 1/3 of its entire stroke, then check that it drops under its own weight. Repeat this test several times, turning the needle valve each time.
- If the needle valve **13** does not drop as required, wash it in gas oil and carry out this test again. If the needle valve is still defective, replace the needle valve and nozzle **12** as a set.

NOTE

Whenever a nozzle 12 is replaced, the nozzle and needle valve 13 must be replaced as a set using Nozzle Service Kit. (This applies to Zexel products only.)

GROUP 14 COOLING

SPECIFICATIONS 2

STRUCTURE AND OPERATION 3

TROUBLESHOOTING 5

ON-VEHICLE INSPECTION AND ADJUSTMENT 6
- Replacing Coolant and Cleaning Coolant System 6
- Air Bleeding of Cooling System 8
- Gas Leak Testing 8

RADIATOR 10

COOLING FAN AND V-BELT 12

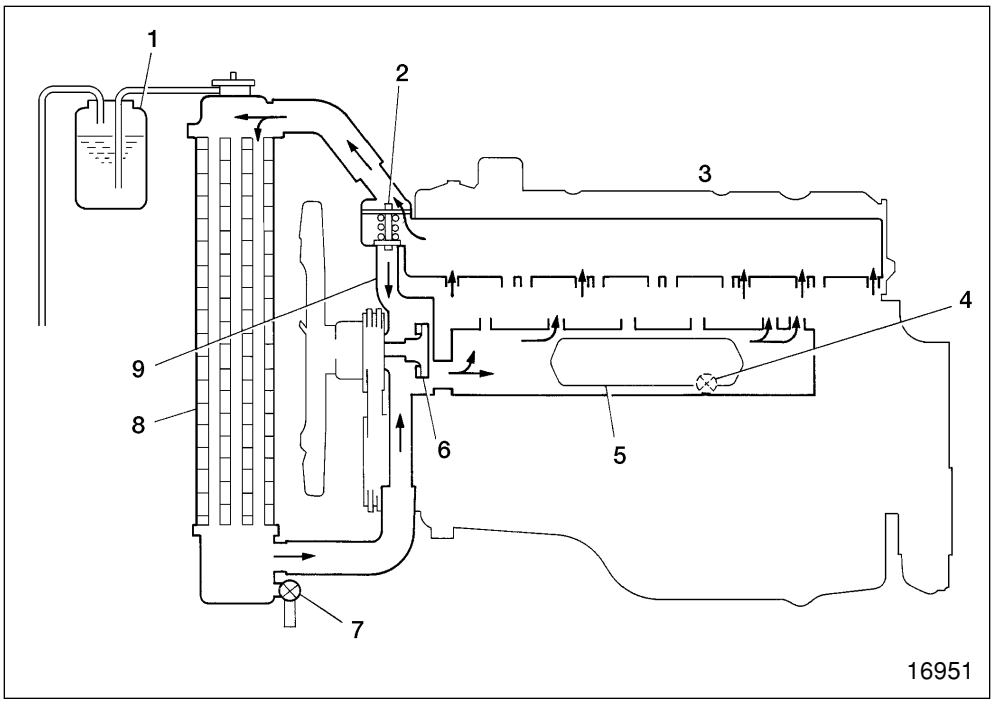
WATER PUMP 14

THERMOSTAT 18

SPECIFICATIONS

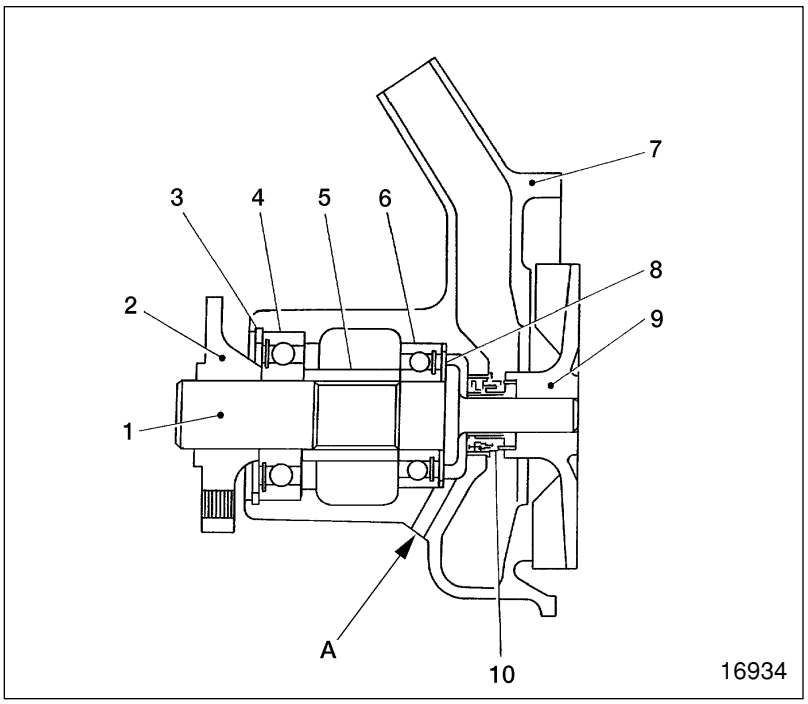
Item	Specifications
Cooling system	Forced water circulation type
Water pump type	Belt-driven involute type
Thermostat type	Wax pellet, bottom bypass type (with jiggle valve)
Automatic cooling fan coupling type	Constant control type
Radiator type	Tube and corrugated fin type
Coolant capacity (engine main body only) L (U.S.gal.)	13 (3.43)

Cooling System (Water Flow)



1 Reservoir tank
2 Thermostat
3 Cylinder head
4 Drain plug
5 Oil cooler
6 Water pump
7 Drain cock
8 Radiator
9 Bypass hose

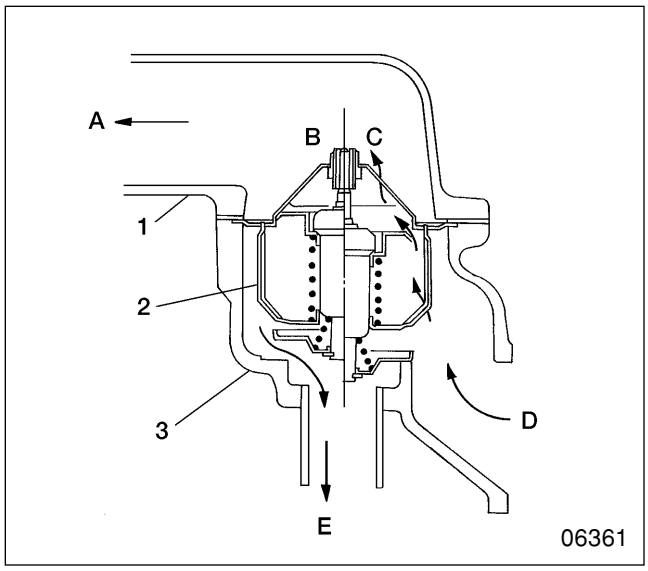
Water Pump



1 Water pump shaft
2 Flange
3 Snap ring
4 Bearing
5 Spacer
6 Bearing
7 Water pump case
8 Washer
9 Impeller
10 Unit seal

A: Drain hole

Thermostat

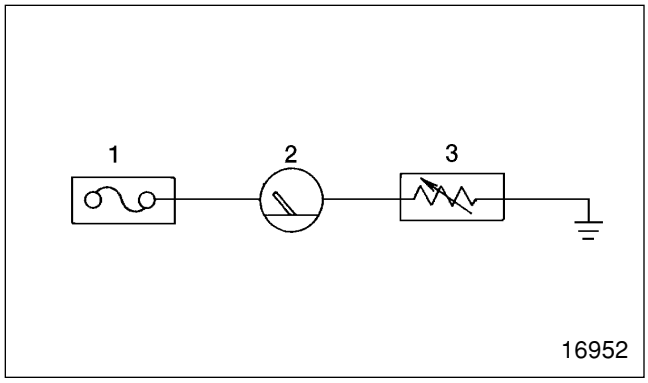


1 Thermostat cover
2 Thermostat
3 Thermostat case

A: To radiator
B: With low coolant temperature
C: With high coolant temperature
D: From cylinder head
E: To water pump

Thermostat **2** is a bottom bypass type that uses wax-charged pellets as its regulating element. As the wax changes from solid to liquid in line with temperature increases, the total wax volume changes. As a result, the position of the valve, changed by the coolant temperature, regulates the flow of coolant to the radiator and water pump (bypass side) and controls the coolant temperature.

Cooling System Electric Circuit

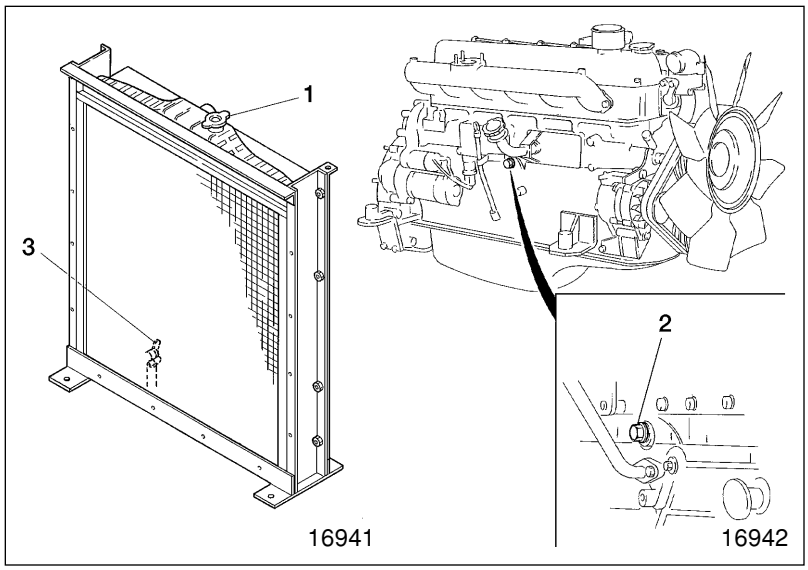


● **Water temperature gauge circuit**
1 Fuse box
2 Water temperature gauge
3 Water temperature sensor

In this circuit, the water temperature is determined according to the electrical resistance of water temperature sensor **3** and displayed on water temperature gauge **2**.

Possible causes / Symptoms		Overheating (insufficient cooling)	Overcooling	Abnormal noise	Excessive coolant loss	Remarks
V-belt	Loose or damaged	○		○		
	Excessive tension			○		
	Oil on belt	○				
Water pump	Water pump fitted poorly	○			○	
	Gasket defective	○			○	
	Bearing defective	○		○		
	Impeller defective	○				
	Unit seal defective	○			○	
	Loose fit between shaft and flange and/or shaft and impeller	○		○		
Thermostat	Case fitted poorly	○			○	
	Gasket defective	○			○	
	Valve opening temperature too high; valve remains closed	○				
	Valve opening temperature too low; valve remains open		○			
	Water leaking from water temperature sensor	○			○	
Radiator	Space between core and fins clogged	○				
	Core cracked and/or separation of soldered joints	○			○	
	Pressure cap not sufficiently airtight	○				
Cooling fan	Fan shroud fitted poorly	○		○		
Automatic cooling fan coupling	Bearing defective	○		○		
	Bimetal damaged	○				
	Bimetal contaminated with foreign particles	○	○			
	Silicon oil leaking	○		○		
Oil cooler	Oil cooler fitted poorly	○			○	🕮 Gr 12
	Gasket defective	○			○	
Cylinder head	Cylinder head fitted poorly	○			○	🕮 Gr 11
	Gasket defective	○			○	
Coolant quantity insufficient and/or coolant dirty		○				
Coolant passages dirty and/or clogged		○				
Hoses fitted poorly		○			○	
Ambient temperature extremely low			○			

Replacing Coolant and Cleaning Coolant System



1 Pressure cap
2 Crankcase drain plug
3 Radiator drain cock

Ⓣ Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
2	Crankcase drain plug	115 (12) [84.8]	–

Using the radiator for extended periods without cleaning the cooling system will cause overheating since rust and scale deposits will accumulate. The cooling system must be cleaned periodically.

● **Draining coolant**

Before draining the coolant, loosen pressure cap **1** to reduce the pressure in the cooling system.

WARNING ⚠

- **To avoid being scalded, ensure that the coolant has cooled sufficiently before draining it out.**
- **Unless care is exercised, opening pressure cap 1 when the coolant is hot can cause the coolant to spray out. Cover the pressure cap with a cloth, and loosen the cap slowly to bleed off the pressure before opening it fully.**

● **Cleaning procedure**

- Run the engine and keep the coolant at a temperature of approximately 90°C (194°F) so that the thermostat valve remains open and the coolant continues to circulate in the radiator.
- To increase the coolant temperature quickly, cover the front of the radiator with cardboard or a similar material.
- If cleaning is carried out after a large amount of rust has accumulated, the radiator may start to leak. Carefully examine the radiator for leaks after cleaning the cooling system.
- Soft water to be used should have the following properties.

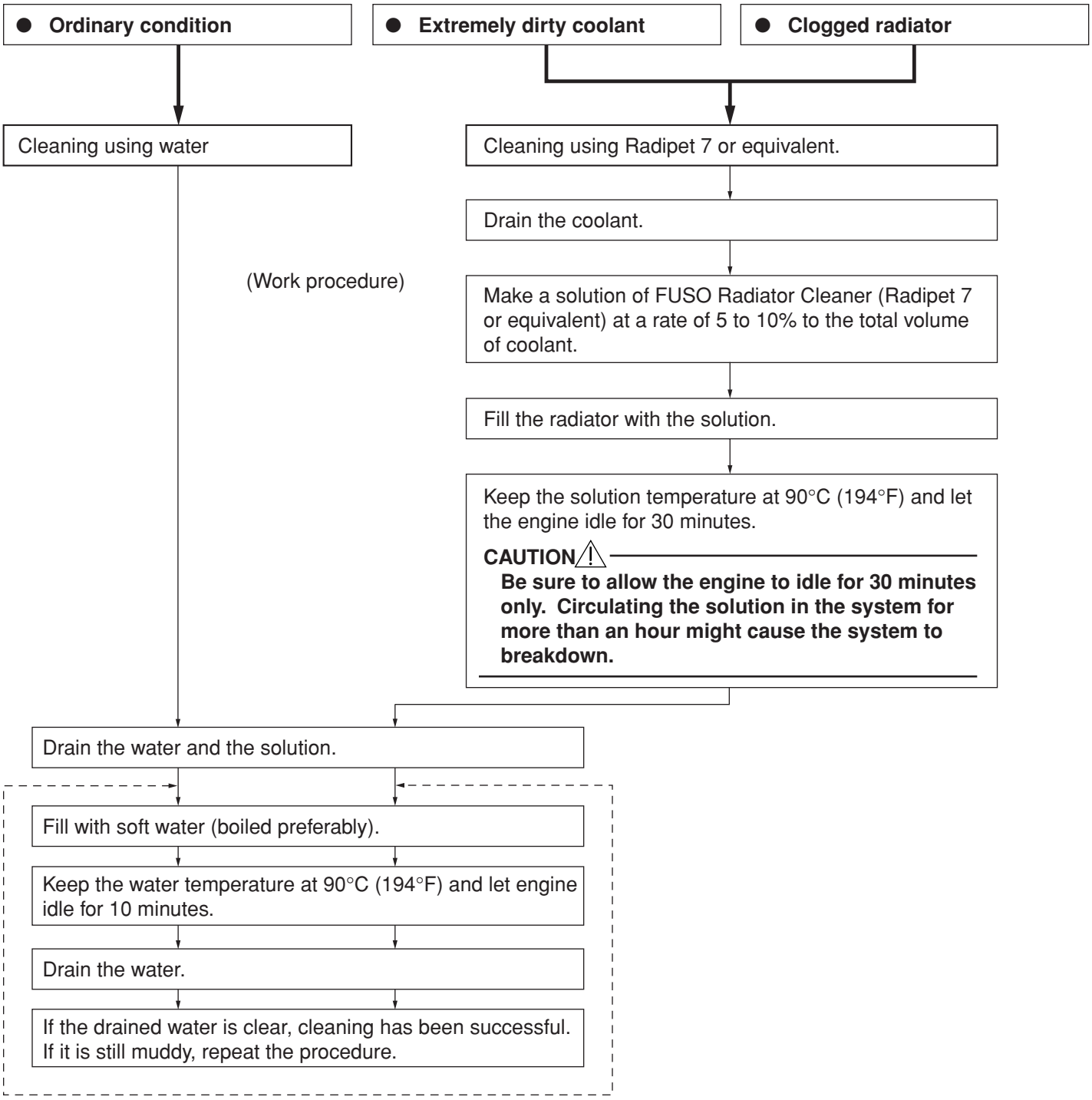
CAUTION ⚠

Do not use hard water as it causes scale and rust.

Required propertiies of soft water

Total hardness	300 ppm or less	Total dissolved solids	500 ppm or less
Sulfate SO_4^-	100 ppm or less	pH	6 to 8
Chloride Cl^-	100 ppm or less	–	–

Method of cleaning the cooling system depends on its condition.



NOTE

- **After cleaning with solution, fill with coolant as quickly as possible.**
- **To prevent freezing of the coolant and corrosion of the cooling system, use specified coolant solution of FUSO Diesel Long Life Coolant, FUSO Antifreeze or Radiator Antirust (Radipet 9).**

Air Bleeding of Cooling System

- Remove the pressure cap. Keeping the coolant temperature at 90°C (194°F), let the engine idle until the cooling system is completely bled of air. While the engine is idling, keep the heater controller's adjustment lever at its maximum-temperature position so that coolant flows freely in the heater piping.
- After bleeding the cooling system of air, add coolant to the radiator and reservoir tank as required.

Gas Leak Testing

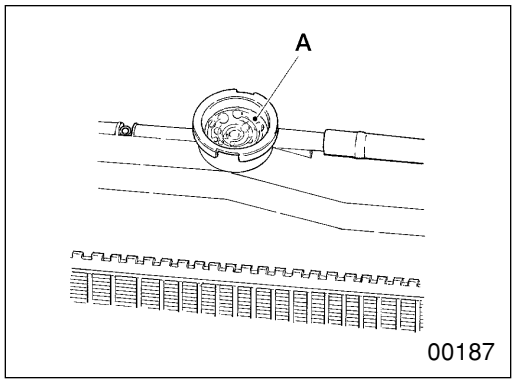
The presence of air or exhaust gas in the coolant increases corrosion and rust in the cooling system. Check for air or exhaust gas in the coolant using the following procedure:

- Remove pressure cap **1**.

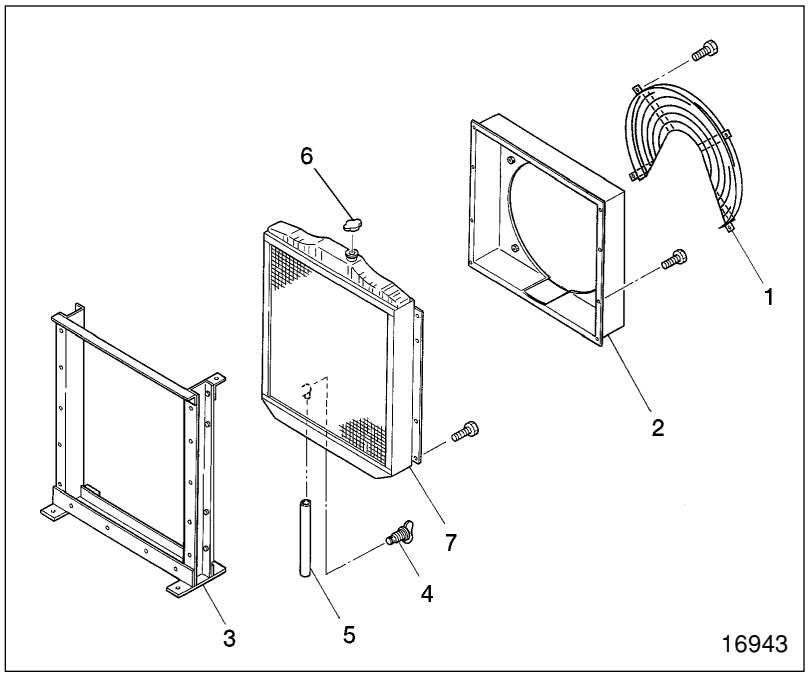
WARNING ⚠

Make sure the coolant is sufficiently cool before loosening the pressure cap. If the coolant is hot, it will spray out.

- Run the engine until the coolant temperature reaches approximately 90°C (194°F).
- If bubbles **A** appear continuously, there is air or exhaust gas in the coolant.
- If the coolant contains air, the cylinder head bolts, water pump mounting bolts, or hose connections may be loose. Alternatively, the hoses may be damaged.
- If the coolant contains exhaust gas, it is possible that the cylinder head gasket is damaged or that the cylinder head is cracked.



M E M O



● **Disassembly sequence**

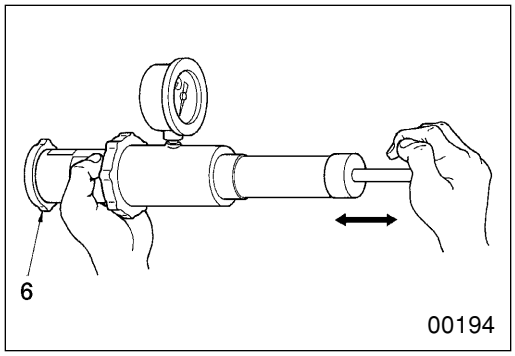
1 Wire net
2 Shroud
3 Frame
4 Drain cock
5 Drain hose
6 Pressure cap
7 Radiator

● **Assembly sequence**

Reverse the order of disassembly.

Service standards

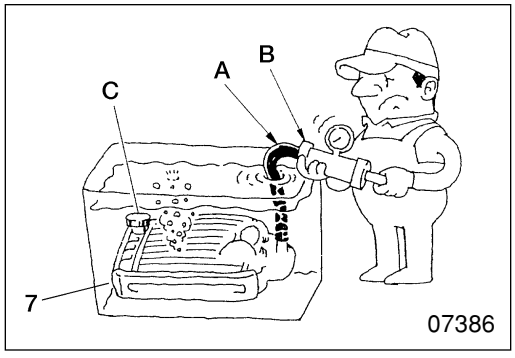
Location	Maintenance item	Standard value	Limit	Remedy
6	Pressure valve opening pressure	69 ± 15 kPa (0.7 ± 0.15 kg/cm²) [10.0 ± 2.2 psi]	–	Replace
7	Radiator air leakage {with air pressure of 150 kPa (1.5 kgf/cm²) [21.8 psi]}	0 cc (0 cu.in.)	–	Correct or replace



◆ Service procedure

6 Pressure cap inspection

Measure the pressure valve's opening pressure. If the measurement does not conform with the standard value, replace pressure cap **6**.

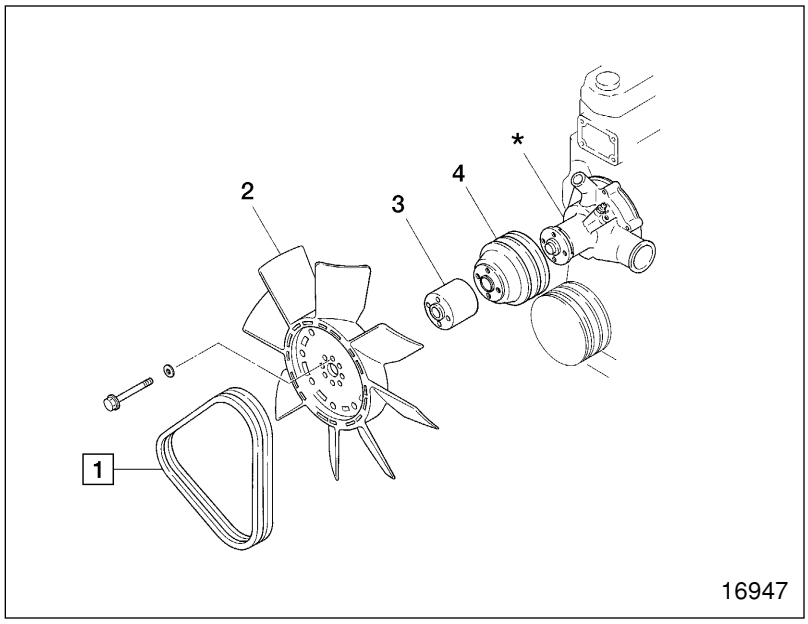


7 Radiator inspection

- Fit hose **A** and radiator cap tester **B** to the radiator upper tank.
- Fit plug **C** to the lower tank, then immerse the radiator in a tank of water.
- Using radiator cap tester **B**, apply the specified air pressure of 150 kPa (1.5 kgf/cm²) [21.8 psi], and check for air leakage.
- If air leakage is apparent, correct or replace radiator **7**.

M E M O

COOLING FAN AND V-BELT



● **Disassembly sequence**
1 V-belt
2 Cooling fan
3 Spacer
4 Water pump pulley

*: Water pump assembly
📖 P.14-14

● **Assembly sequence**
Reverse the order of disassembly.

CAUTION ⚠

When replacing V-belts 1, be sure to replace them as a set to maintain even tension between them.

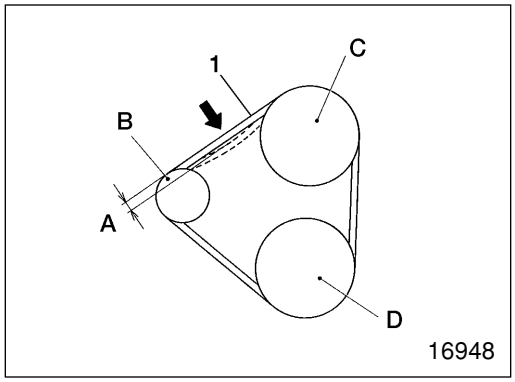
Service standards

Unit: mm (in.)

Location	Maintenance item	Standard value	Limit	Remedy
1	V-belt tension	10 to 15 (0.394 to 0.591)	–	Adjust

Special tools

Location	Tool name and shape	Part No.	Application
1	Belt Tension Gauge  03612	MH062345	V-belt tension measurement



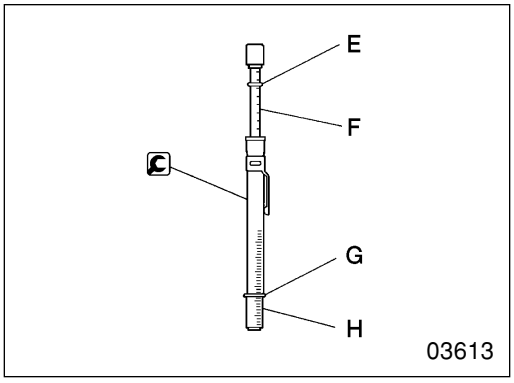
◆ Service procedure

1 V-belt

[Inspection]

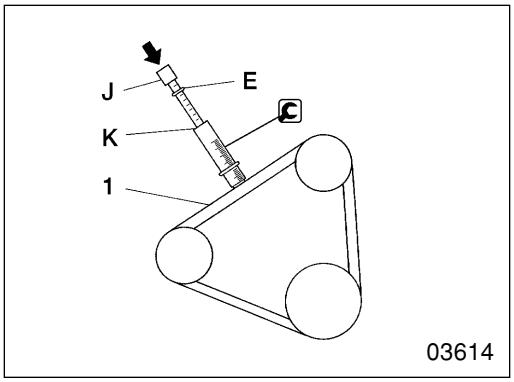
Apply force of approximately 98 N (10 kgf) [22.0 lbf] to the center of the V-belt **1** and measure the extent of V-belt deflection **A**.

B: Alternator pulley
C: Water pump pulley
D: Crankshaft pulley

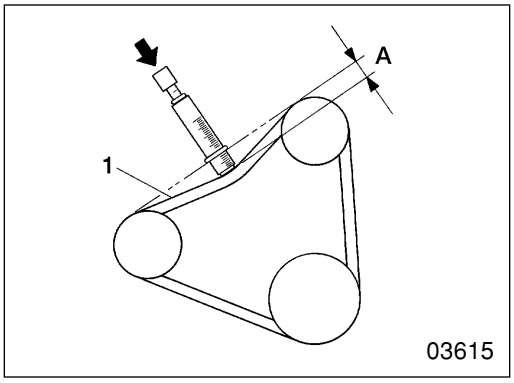


● **Use of belt tension gauge**

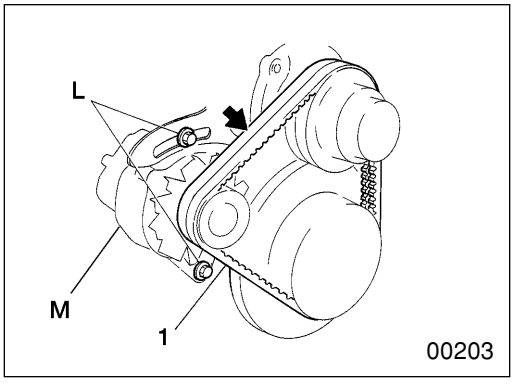
- Set upper O-ring **E** of Belt Tension Gauge to 8 N (10 kgf) [1.80 lbf] (push load) on scale **F**.
- Set lower O-ring **G** of Belt Tension Gauge to the V-belt's correct maximum deflection value on scale



- Apply the Belt Tension Gauge to the center of V-belt **1** and push until O-ring **E** reaches the flange **K**.



- Measure the extent of V-belt **1** deflection **A**. If the measurement does not conform with the standard value, adjust the V-belt as shown below.



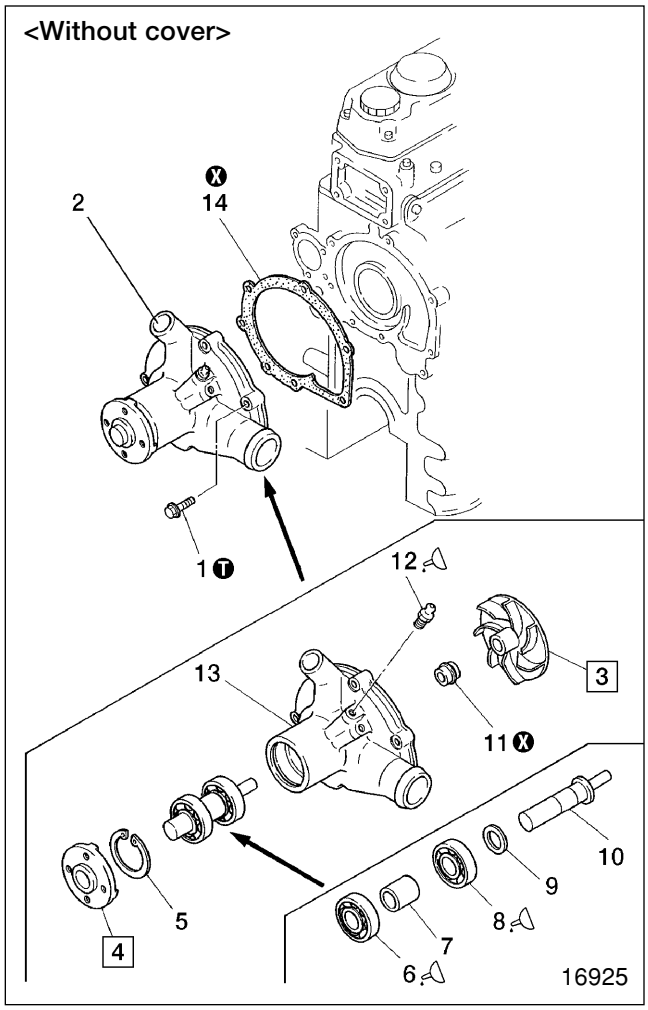
[Adjustment]
Adjust the V-belt tension as follows:

- Loosen alternator mounting bolts **L** (2 places) and adjust the V-belt tension by moving alternator **M** to the left or right.
- When the adjustment is complete, tighten the bolts and nuts securely.

CAUTION ⚠

- **Excessive tension in V-belt 1 may damage the belt and related bearings.**
- **Be sure to replace the V-belts 1 as a set to maintain even tension between them.**
- **Keep V-belt 1 free of oil. If the belt becomes oily, it will slip, resulting in overheating of the engine and insufficient charging of the battery.**

WATER PUMP



● **Disassembly sequence**

1 Bolt
2 Water pump assembly
3 Impeller
4 Flange
5 Snap ring
6 Bearing
7 Spacer
8 Bearing
9 Washer
10 Water pump shaft
11 Unit seal
12 Grease nipple
13 Water pump case
14 Gasket

Ⓧ : Non-reusable part

● **Assembly sequence**

14 → 2 → 1

2: 13 → 12 → 5 → 11 → 4 → 3
10 → 9 → 8 → 7 → 6

● **Inspection after assembly**

📖 P.14-16

Service standards

Unit: mm (in.)

Location	Maintenance item	Standard value	Limit	Remedy
3, 10	Impeller-to-water pump shaft interference [Basic diameter: 13 mm (0.512 in.)]	0.03 to 0.06 (0.00118 to 0.00236)	–	Reassembly allowed only twice
4, 10	Flange-to-water pump shaft interference [Basic diameter: 26 mm (1.02 in.)]	0.05 to 0.08 (0.00197 to 0.00315)	–	Reassembly allowed only twice

Ⓣ Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

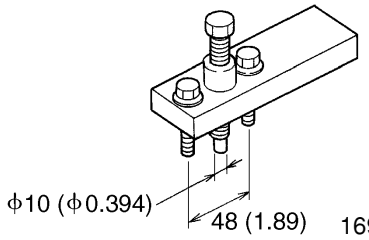
Location	Parts to be tightened	Tightening torque	Remarks
1	Bolt (water pump assembly mounting)	9.8 (1.0) [7.23]	–

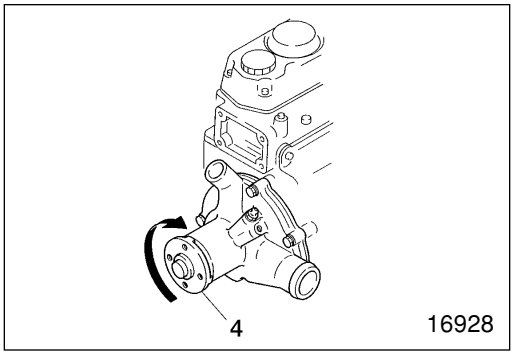
Lubricants and sealant

Location	Points of application	Kinds	Quantity
6, 8	Bearings	Wheel bearing grease [NLGI No. 2 (Li soap)]	As required
11	Unit seal outer periphery	THREEBOND 1102	As required
12	Grease nipple	Wheel bearing grease [NLGI No. 2 (Li soap)]	60 g (2.12 oz)

Special tools

Unit: mm (in.)

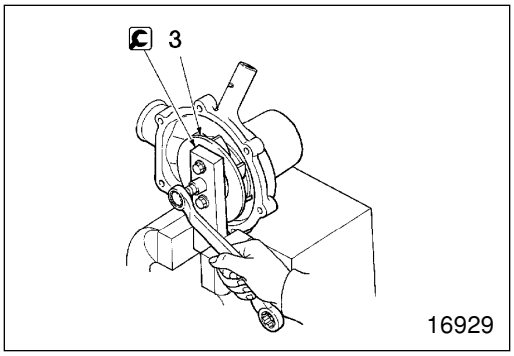
Location	Tool name and shape	Part No.	Application
2	Impeller Puller 	MH061417	Removing impeller



◆ Service procedure

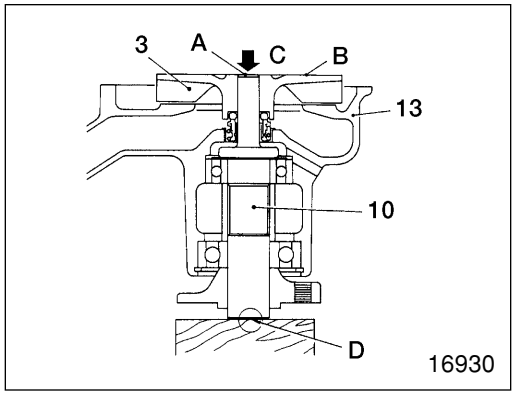
● **Inspection after assembly**

- After assembly, rotate flange **4** by hand and check that it turns smoothly without hindrance.
- If the flange does not turn smoothly, disassemble and inspect the water pump again.



3 **Impeller**

[Removal]

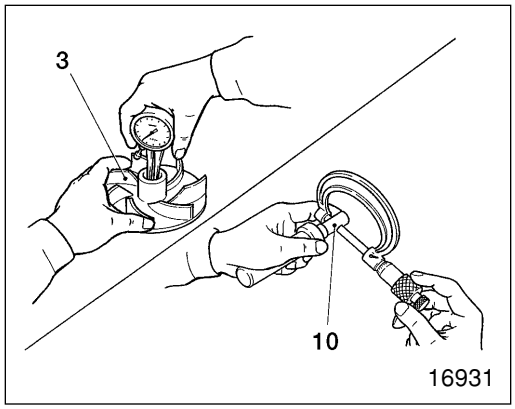


[Press-fitting]
Press-fit impeller **3** until its end face **B** is in line with end face **A** of water pump shaft **10**.

C: Press

NOTE

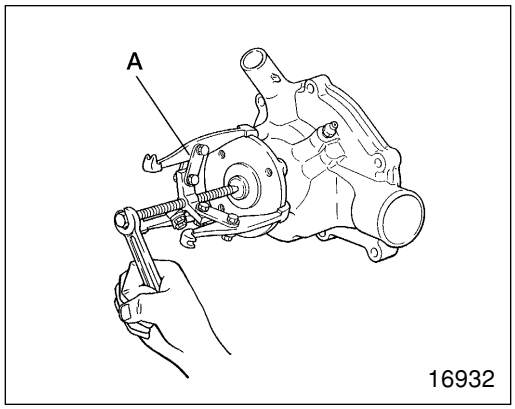
Press-fit the impeller such that flange side D of water pump shaft 10 is the load receiving surface.



3 **10** **Impeller-to-water pump shaft interference**
If the measurement does not conform with the standard value, replace the defective part(s).

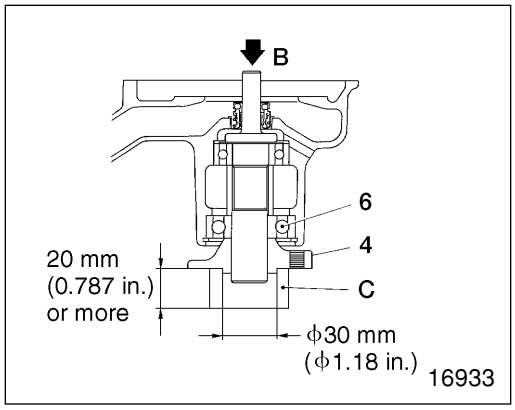
CAUTION ⚠

Even if the standard value is satisfied, reassembly must not be carried out more than twice.



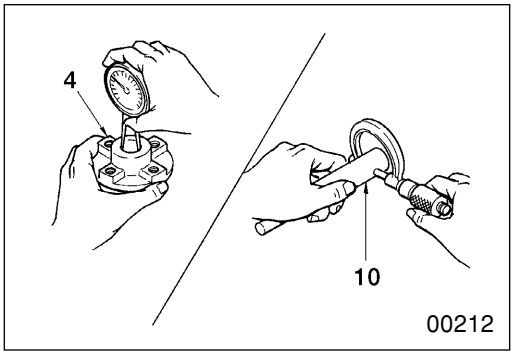
4 **Flange**
[Removal]

A: Gear puller



[Press-fitting]
With a load of 9,810 N (4,000 kgf) [2,205 lbf], press-fit flange **4** until it touches bearing **6**.

B: Press
C: Cylindrical jig



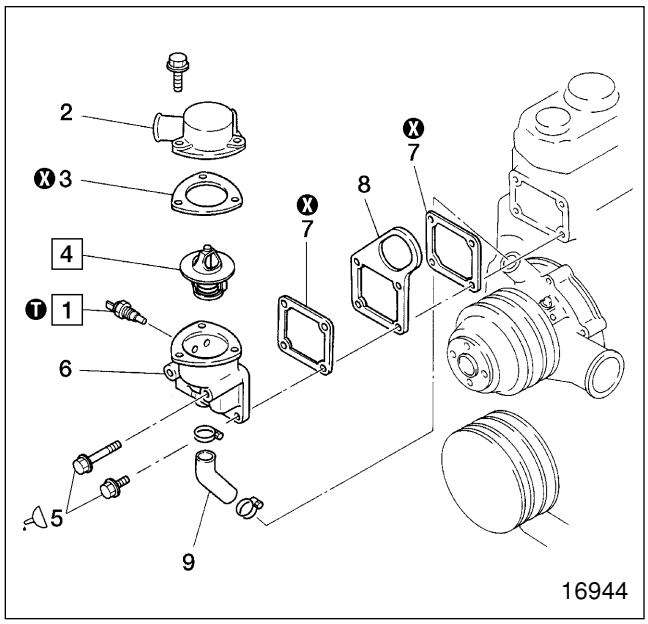
4 **10** **Flange-to-water pump shaft interference**

If the measurement does not conform with the standard value, replace the defective part(s).

CAUTION ⚠

Even if the standard value is satisfied, reassembly must not be carried out more than twice.

THERMOSTAT



● **Disassembly sequence**

1 Water temperature sensor
2 Thermostat cover
3 Gasket
4 Thermostat
5 Bolt
6 Thermostat case
7 Gasket
8 Front hanger
9 Bypass hose

**: Non-reusable part

NOTE

Do not remove thermostat case 6 and front hanger 8 unless they are leaking water or otherwise defective.

● **Assembly sequence**

Reverse the order of disassembly.

Service standards

Location	Maintenance item		Standard value	Limit	Remedy
1	Water temperature sensor resistance (Between terminal ① and body)	50°C (122°F)	(136 Ω)*	–	Replace
		80°C (176°F)	48 ± 5 Ω	–	
		100°C (212°F)	27.2 ± 2 Ω	–	
4	Thermostat	Valve opening temperature	76.5 ± 2°C (170 ± 36°F)	–	Replace
		Valve lift/temperature	10 mm (0.394 in.) or more at 90°C (194°F)	–	

*: Figures in parenthesis are approximate.

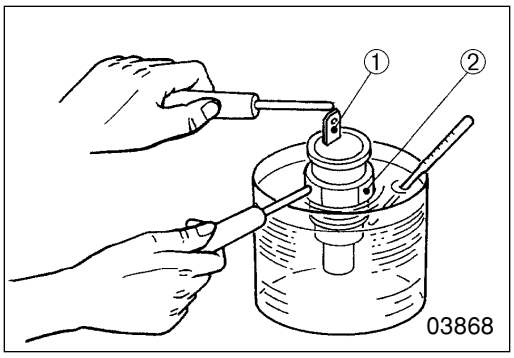
Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
1	Water temperature sensor	34 ± 6.9 (3.5 ± 0.7) [25.1 ± 5.1]	–

Lubricants and sealant

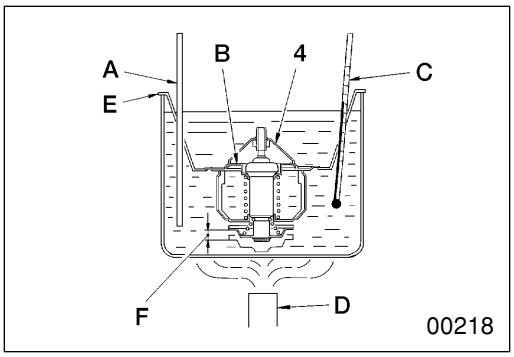
Location	Points of application	Kinds	Quantity
5	Threads of bolts (thermostat case mounting)	THREEBOND 2302	As required



◆ Service procedure

1 Water temperature sensor inspection

- Place water temperature sensor **1** in a container of engine oil.
- Heat the oil until it reaches the specified temperatures. Stir the oil to ensure that it heats up evenly.
- Measure the resistance between terminal ① and body ② of the water temperature sensor.
- If the measurements do not conform with the specified values, replace the water temperature sensor **1**.



4 Thermostat inspection

Place the thermostat in a container of water. While stirring the water with a rod **A** to ensure that it is heated evenly, carry out the following inspection procedure. If the measurements do not conform with the standard values, replace the thermostat **4**.

(1) Valve opening temperature

- Support thermostat **4** with wire **E** to keep it away from heat source **D**.
- Gradually heat the water until it reaches the valve opening temperature.
- Maintain this temperature for **5** minutes and check that valve **B** is open.
- When the water temperature drops below 65°C (149°F), check that valve **B** is completely closed.

C: Thermometer

(2) Valve lift

Heat the water to slightly higher than the valve opening temperature. With valve **B** fully open, maintain this water temperature for **5** minutes. Measure the extent of valve lift **F**.

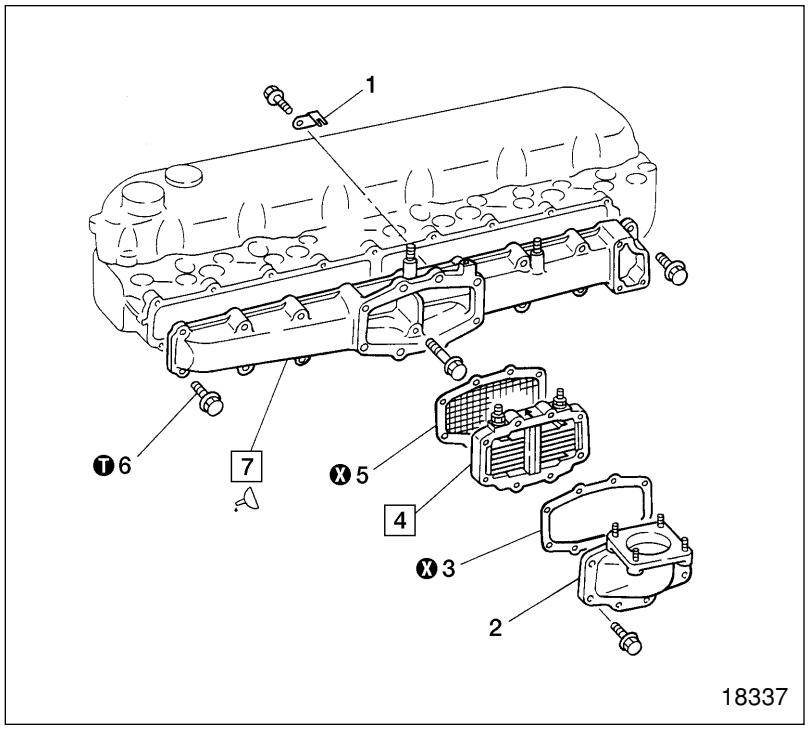
GROUP 15 INTAKE AND EXHAUST

TROUBLESHOOTING 2
INTAKE MANIFOLD 4
EXHAUST MANIFOLD 6

Symptoms / Possible causes	Engine hard to start	Back exhaust gas	White exhaust gas	Insufficient engine output	Excessive oil consumption	Strange sound or vibration in intake and Exhaust system	Remarks
Deformed front pipe, muffler, tail pipe						○	
Improperly mounted front pipe, muffler, tail pipe						○	
Incorrect valve clearance		○					🕮 Gr 11
Defective head gasket		○					🕮 Gr 11
Worn valve and valve seat and deposited carbon		○					🕮 Gr 11
Sagging valve spring		○					🕮 Gr 11
Worn or damaged piston ring			○		○		🕮 Gr 11
Worn or damaged piston ring groove of piston			○		○		🕮 Gr 11
Malfunctioning cooling equipment		○					🕮 Gr 14
Excessive engine oil			○				🕮 Gr 12
Seizure of major moving parts		○					🕮 Gr 11
Uneven or excessive fuel injection		○					🕮 Gr 13

M E M O

INTAKE MANIFOLD



● **Disassembly sequence**

1 Earth plate
2 Coupler
3 Gasket
4 Air heater
5 Gasket
6 Bolt
7 Intake manifold

X : Non-reusable part

● **Reassembly sequence**

Reverse the order of removal.

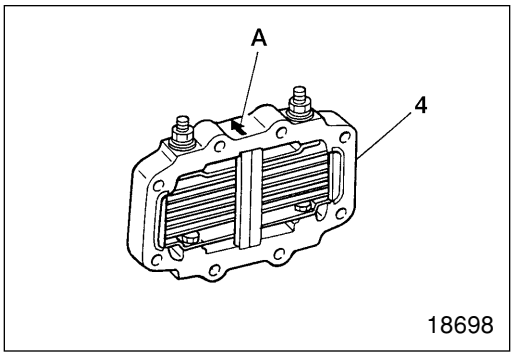
T Tightening torque

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
6	Bolt (for mounting intake manifold)	23 (2.37) [17.0]	–

Sealant

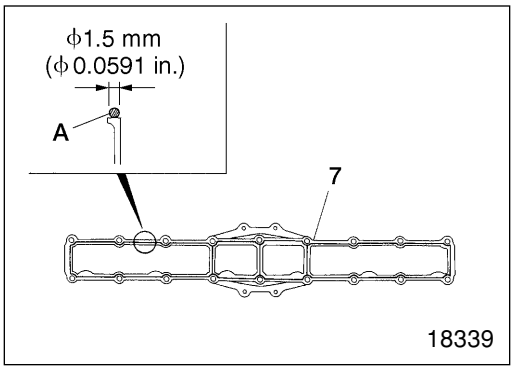
Location	Points of application	Kinds	Quantity
7	Apply to cylinder head mounting surface of the intake manifold	THREE BOND 1207B	As required



◆ Service procedure

4 Installation of air heater

The air heater **4** should be installed with its arrow mark **A** directed toward the intake manifold **7**.



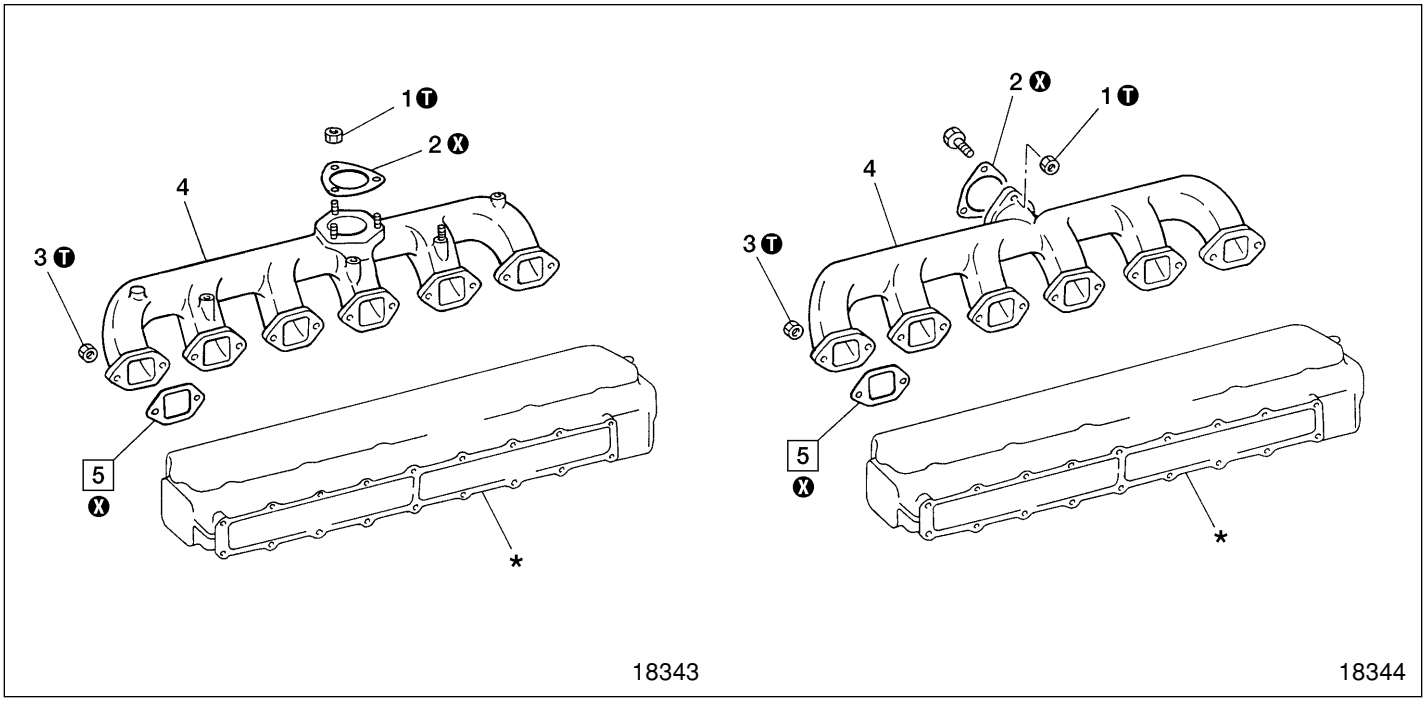
7 Installation of intake manifold

- The intake manifold is installed by use of either a seat gasket or sealant. This section describes the procedures for installation by use of a sealant.
- Apply sealant **A** evenly without a break to the cylinder head mounting surface of the intake manifold **7**.
- Install the intake manifold on the cylinder head in less than three minutes after application of sealant **A**.

CAUTION ⚠

- **Thoroughly clean the sealant applying surface of the intake manifold 7 beforehand.**
- **When the intake manifold 7 is installed, make sure that it is not out of alignment.**
- **When the manifold mounting bolt 6 was loosened, be sure to re-apply sealant A to the intake manifold 7.**
- **Do not start the engine in less than an hour after installation.**

EXHAUST MANIFOLD



● **Disassembly sequence**

1 Nut
2 Gasket
3 Nut
4 Exhaust manifold
5 Gasket

*: Cylinder head 🕮 Gr.11
Ⓧ: Non-reusable part

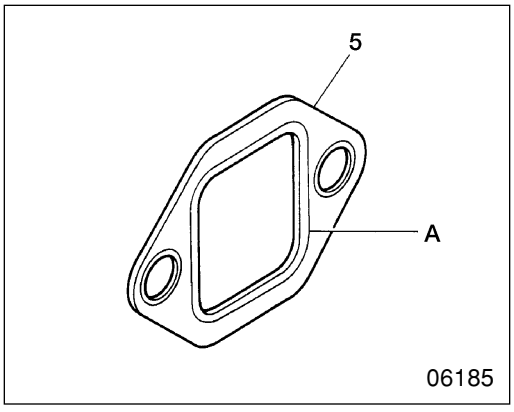
● **Reassembly sequence**

Reverse the order of disassembly.

Ⓣ Tightening torque

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
1	Nut (for mounting exhaust pipe)	41 (4.2) [30.2]	–
3	Nut (for mounting exhaust manifold)	41 (4.2) [30.2]	–



◆ Service procedure

5 Installation of gasket

Install the gasket **5** with the grommet fold-back portion **A** toward the cylinder head.

GROUP 54 ELECTRICAL SYSTEM

SPECIFICATIONS 2

STRUCTURE AND OPERATION 3

TROUBLESHOOTING 12

ON-VEHICLE INSPECTION AND ADJUSTMENT 14
- Inspection of Preheater System 14

ALTERNATOR 16
<24V–40A> (with vacuum pump) 16
<24V–40A> (without vacuum pump) 24

STARTER 30

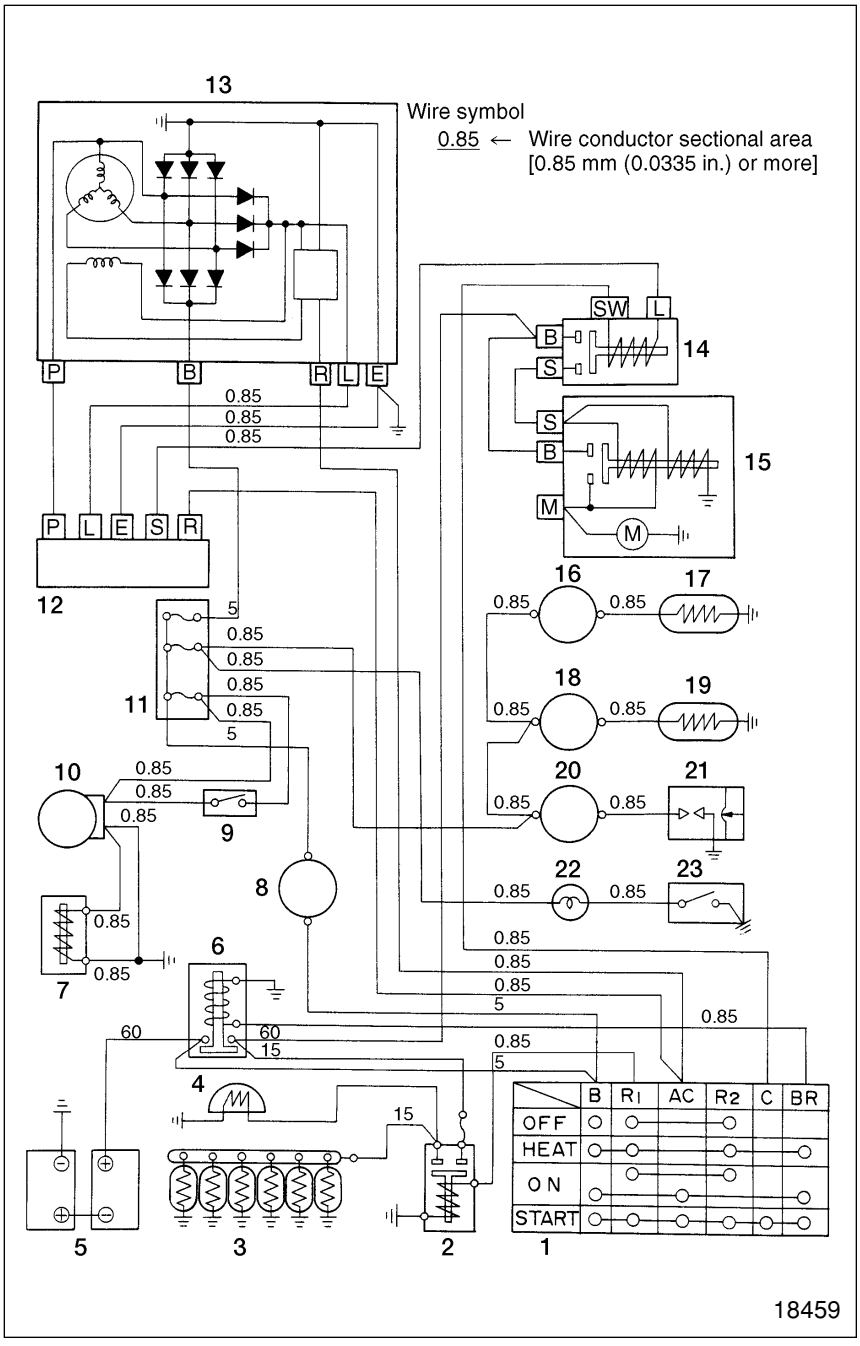
PREHEATER CIRCUIT 44

ENGINE STARTER CIRCUIT 46

SPECIFICATIONS

Item		Specifications		
Alternator	Manufacturer	MITSUBISHI ELECTRIC CORP.		
	Type	Alternator with built-in regulator, fan externally mounted type		
		Brushless		
	Vacuum pump	Provided	Not provided	
	Model	A4TU 3186	A4T4 0286	A4T4 0299
	Output V–A	24–40		
Starter	Manufacturer	MITSUBISHI ELECTRIC CORP.		
	Model	M8T60071		
	Output V–kW (HP)	24–5 (6.7)		
	Magnet switch operating voltage V	16 or less		
Starter relay	Model	U001T35383		
	Exciting current V–A	24–2.3		
	Closed magnetic voltage V	16 or less		
	Opened magnetic voltage V	4 or less		
	Allowable breaking voltage V	200		
Glow plug	Type	Sheathed type		
	Voltage – current V–A	23–3		
Glow relay	Model	U1T06670		
	Voltage – current V–A	24–2.3		
	Fuse capacity A	127		

Circuit Diagram <24V (Glow Plug) Specification>

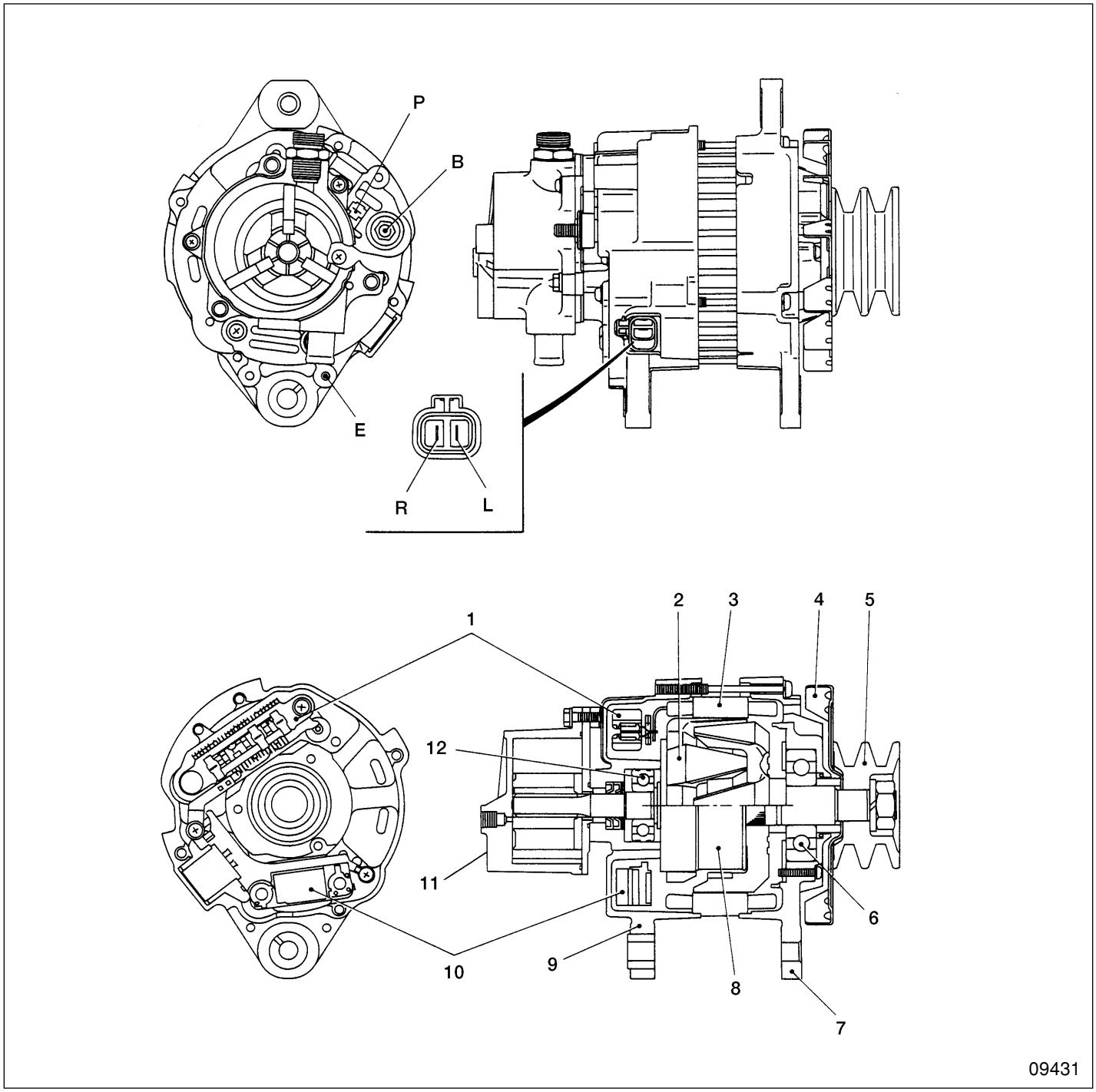


1 Starter switch
2 Glow relay
3 Glow plug
4 Glow indicator
5 Battery
6 Battery relay
7 Tachometer sensor
8 Ammeter
9 Lamp switch
10 Tachometer
11 Fuse box
12 Safety relay
13 Alternator
14 Starter relay
15 Starter
16 Thermometer (for oil)
17 Thermo sending unit
18 Thermometer (for coolant)
19 Thermo sending unit
20 Oil pressure gauge
21 Oil pressure gauge unit
22 Warning lamp
23 Oil bypass alarm switch

B: Terminal B
E: Terminal E
L: Terminal L
M: Terminal M
P: Terminal P
R: Terminal R
S: Terminal S
SW: Terminal SW

Alternator

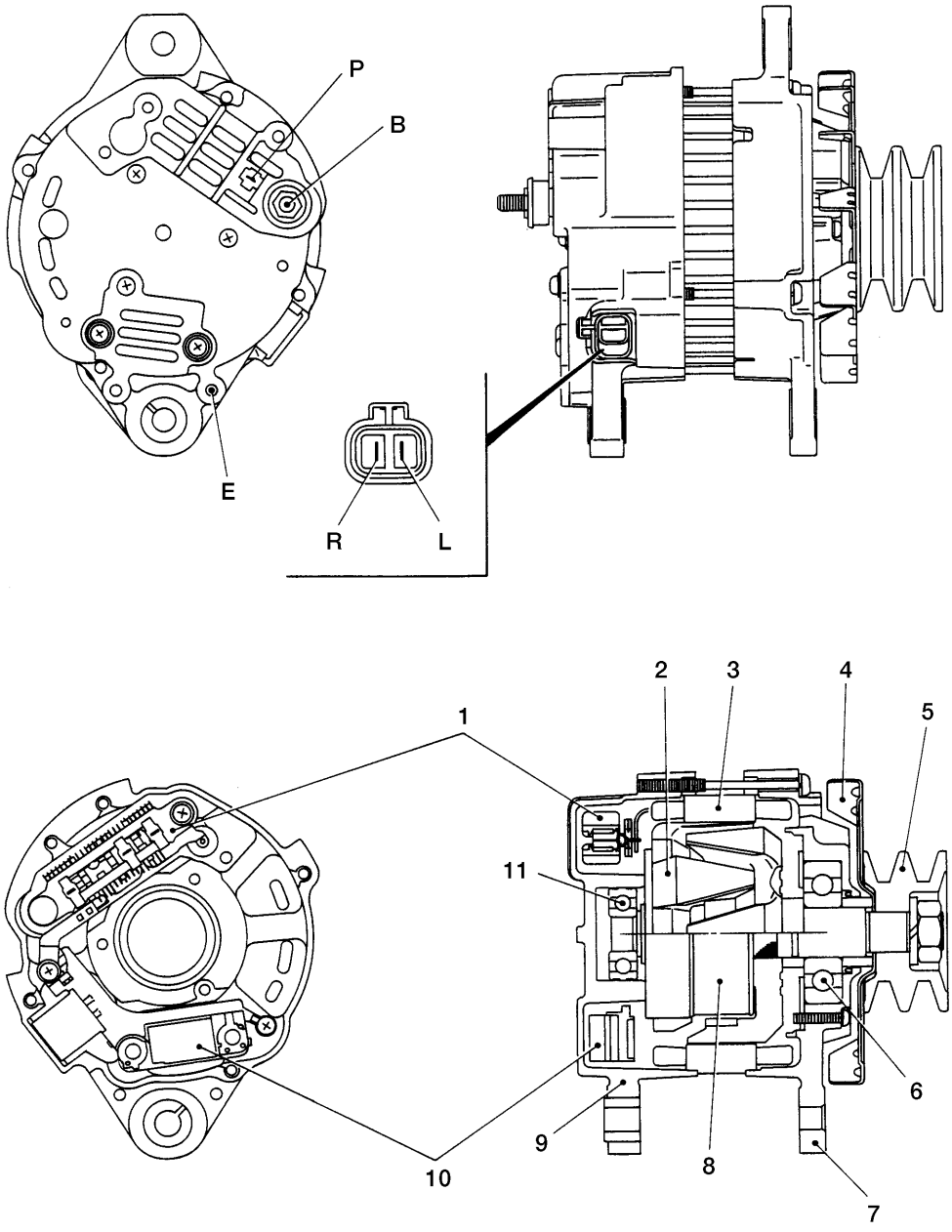
<24V–40A (with vacuum pump)>



1 Rectifier
2 Rotor assembly
3 Stator assembly
4 Fan
5 Pulley
6 Front bearing
7 Front bracket
8 Field coil
9 Rear bracket
10 Regulator
11 Vacuum pump
12 Rear bearing

B: Terminal B
E: Terminal E
L: Terminal L
P: Terminal P
R: Terminal R

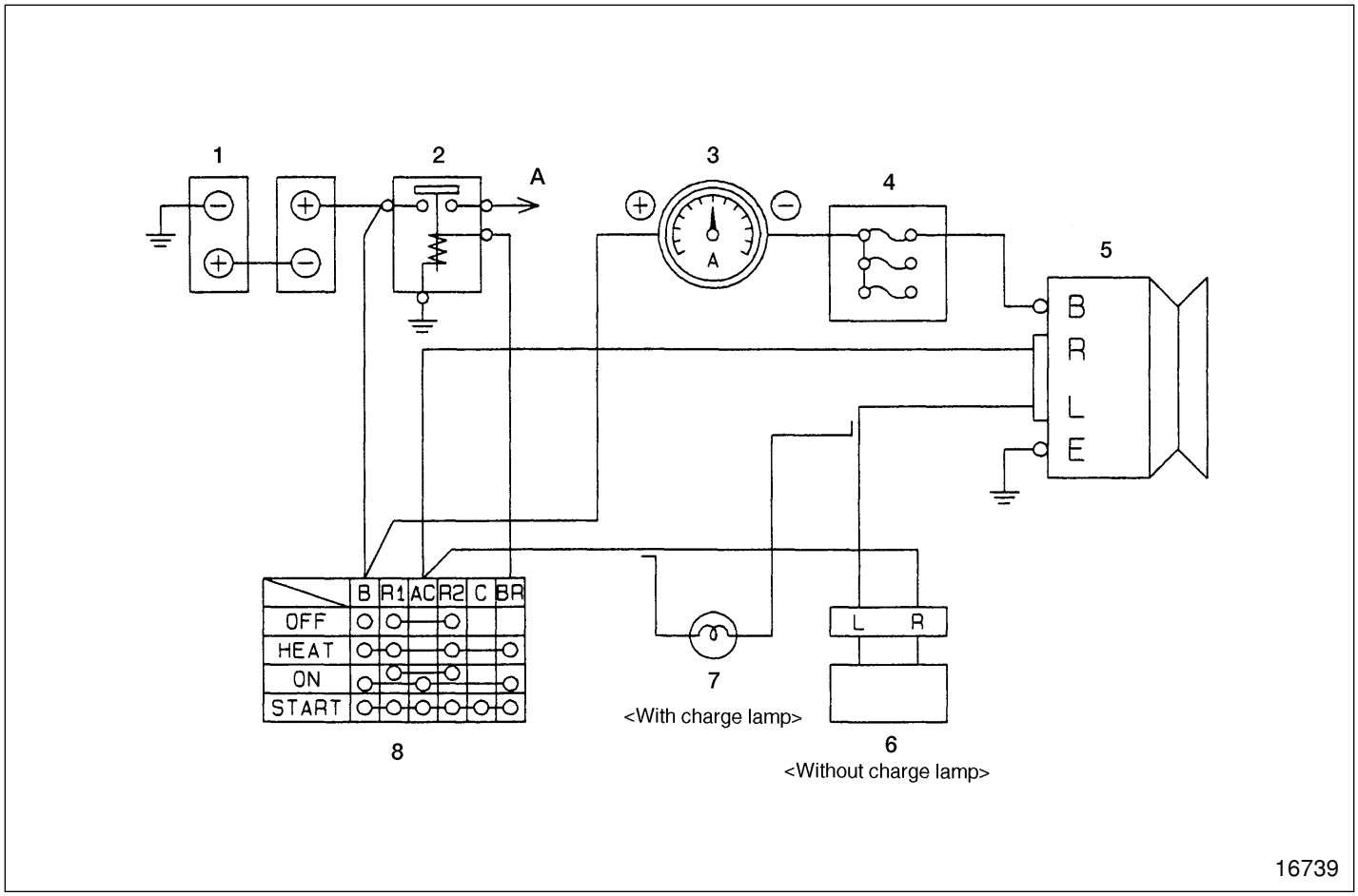
<24V–40A (without vacuum pump)>



1 Rectifier
2 Rotor assembly
3 Stator assembly
4 Fan
5 Pulley
6 Front bearing
7 Front bracket
8 Field coil
9 Rear bracket
10 Regulator
11 Rear bearing

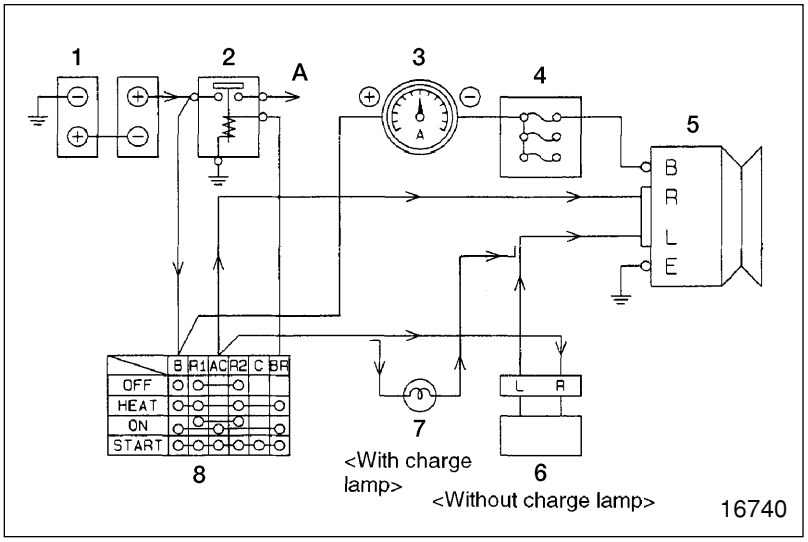
B: Terminal B
E: Terminal E
L: Terminal L
P: Terminal P
R: Terminal R

Charging Circuit



1 Battery
2 Battery relay
3 Ammeter
4 Fuse box
5 Alternator
6 Safety relay <Circuit without charge lamp>
7 Charge lamp <Circuit with charge lamp>
8 Starter switch

A: To starter relay terminal B
B: Terminal B
E: Terminal E
L: Terminal L
R: Terminal R



When engine is stationary

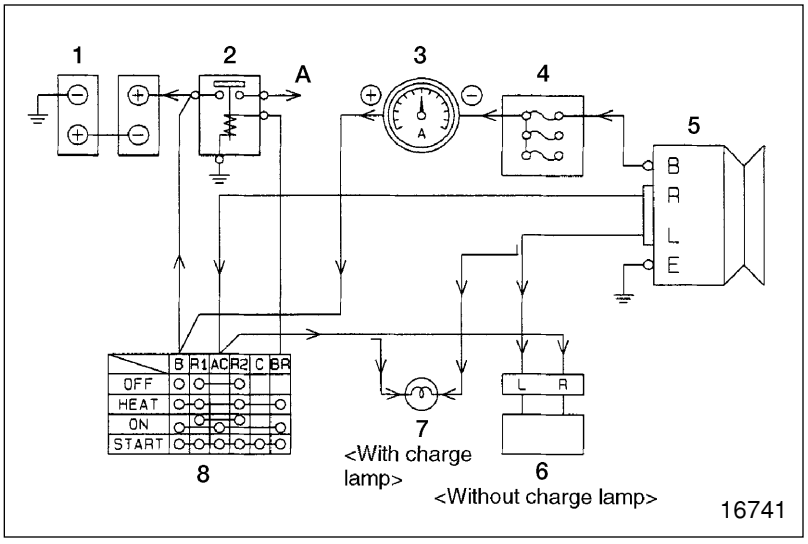
Position of starter switch **8**: ON

- To improve the performance of the alternator **5** in starting power generation at a low speed immediately after the engine has been started, current is set flowing to terminal **R**.

1 → **2** → **8** → **5 (R → E)** → Ground
6 (R → L) → **5 (L → E)** → Ground

- In the circuit with **A** charge lamp **7**, current flows as shown below.

1 → **2** → **8** → **5 (R → E)** → Ground
7 → **5 (L → E)** → Ground



After engine has been started

Position of starter switch **8**: ON

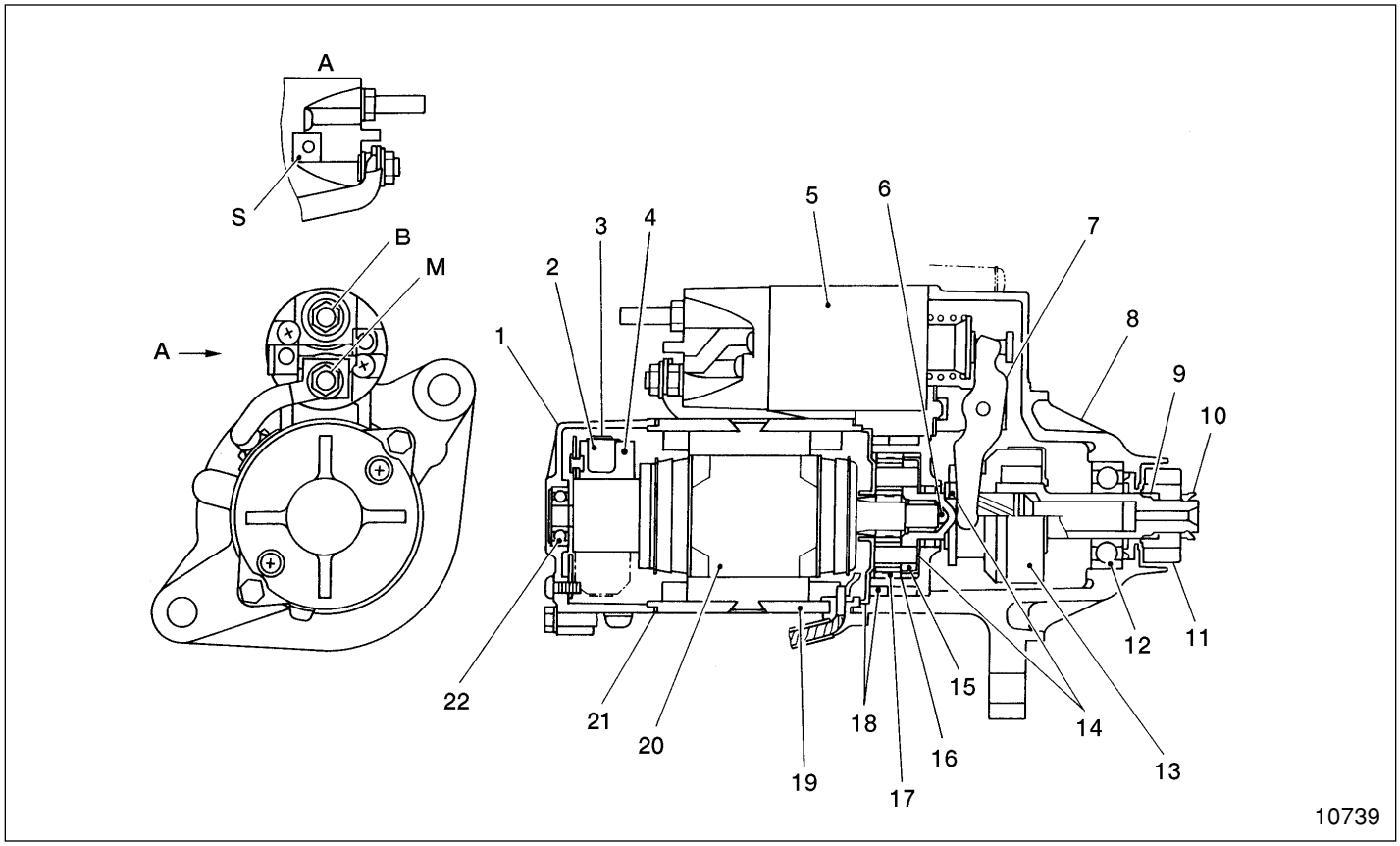
- The alternator **5** starts generating power.
- The output voltage at terminal **B** of the alternator **5** becomes higher than the voltage of the battery **1**.
- The alternator **5** starts charging the battery **1**.

5 (B) → **4** → **3** → **8** → **2** → **1**

- In the case of the circuit with the charge lamp **7**, the charge lamp goes out, as there is no potential difference between the voltage at terminal **L** of the alternator **5** and the battery voltage.

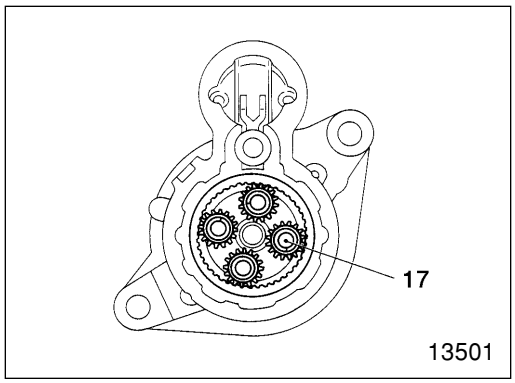
Starter

<24V–5kW (6.7 HP)>



1 Rear bracket
2 Brush
3 Brush spring
4 Brush holder assembly
5 Magnet switch
6 Ball
7 Lever
8 Front bracket
9 Spring
10 Pinion stopper
11 Pinion
12 Front bearing
13 Overrunning clutch
14 Washer
15 Gearshaft assembly
16 Internal gear assembly
17 Planetary gear
18 Packing
19 Yoke assembly
20 Armature assembly
21 Packing
22 Rear bearing

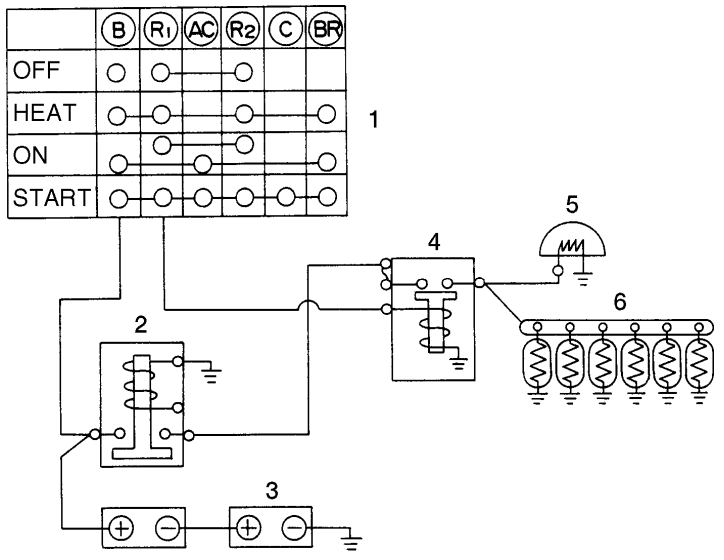
B: Terminal B
M: Terminal M
S: Terminal S



This starter uses planetary gear **17** in the reduction gear mechanism.

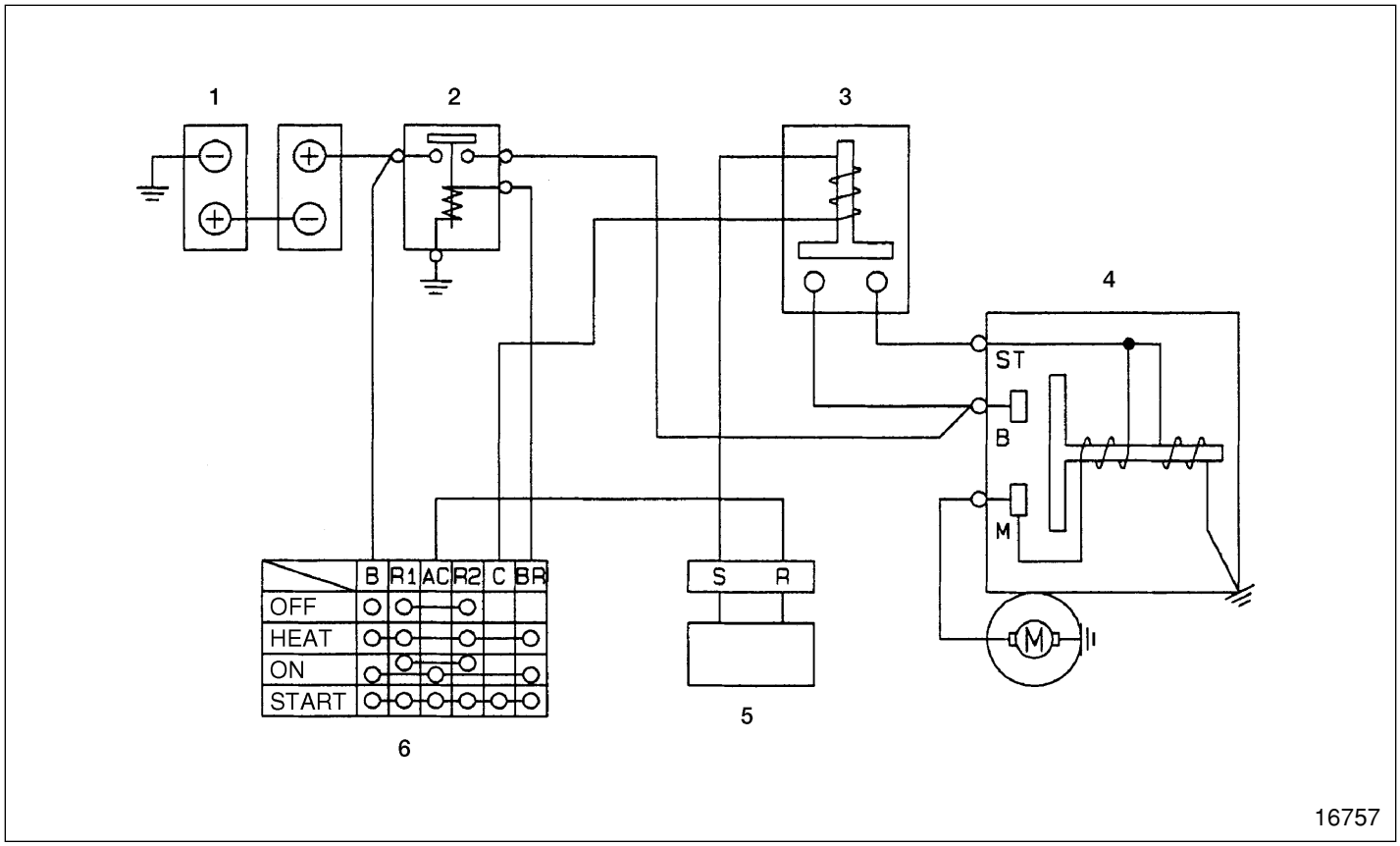
Preheating Circuit

<Glow Plug>



1 Starter switch
2 Battery relay
3 Battery
4 Heater relay
5 Glow indicator
6 Glow plug

Engine Starter Circuit



1 Battery
2 Battery relay
3 Starter relay
4 Starter
5 Safety relay
6 Starter switch

M E M O

Alternator

Possible causes \ Defective conditions		Battery fluid decreases in a short time	Battery temperature high	Battery is normal but is over-discharged.	With the engine stationary (the starter switch at ON), the charge lamp does not come on.	Alternator is in order but battery is over-discharged	Remarks
Connector incorrectly connected, harness open-circuited, defective grounding				○		○	
Blown fuse				○	○	○	
Weak tension of V-belt				○		○	🕮 Gr 14
Broken V-belt				○		○	🕮 Gr 14
Defective battery		○				○	
Alternator	Stator coil open-circuited			○			
	Stator coil and core short-circuited			○			
	Field coil defective			○			
	Rectifier defective			○			
	Regulator defective		○	○	○		
	Brush worn (if brush is provided)			○			
	Sagging brush spring (if brush is provided)			○			
	Defective wiring			○			

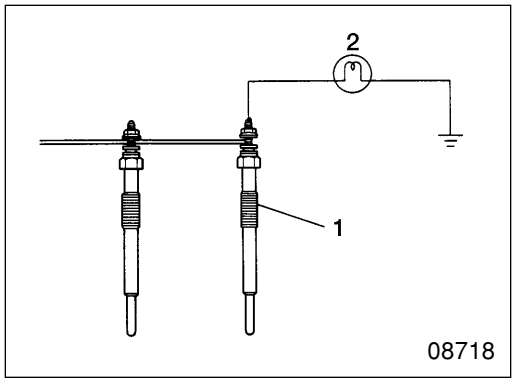
Starter

Possible causes \ Defective condition		Starter does not start	Starter starts but engine does not start: Pinion does not come in mesh with ring gear	Starter starts but engine does not start: Pinion comes in mesh with ring gear but does not rotate	Starter starts but engine does not start: Flywheel rotates but engine does not start	Engine does not stop	Engine cannot be preheated	Engine is hard to start	Remarks
Connector incorrectly connected, harness open-circuited, defective grounding		○			○	○	○	○	
Blown fuse		○							
Insufficient capacity of battery		○		○					
Starter	Contact of magnet switch binding or deposited	○							
	Coil of magnet switch open-circuited	○							
	Overrunning clutch in defective operation		○						
	Worn or damaged pinion		○						
Defective starter relay		○							
Defective starter switch		○				○			
Worn or damaged ring gear of flywheel			○						🕮 Gr 11

Starter, Preheater

Possible causes \ Defective condition	Engine is hard to start	Engine cannot be preheated	Remarks
Defective heater relay or glow relay wiring	○	○	
Defective battery wiring	○	○	
Defective glow plug wiring	○	○	
Defective glow plug	○	○	
Defective coolant temperature sensor	○		🕮 Gr 14
Defective coolant temperature sensor wiring	○		

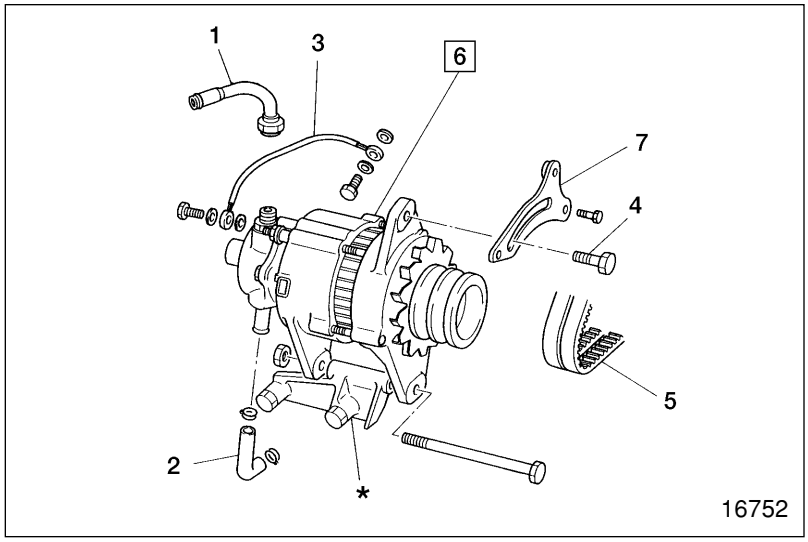
Inspection of Preheater System <Glow Plug Specification>



- Set the starter switch to OFF.
- Connect the inspection lamp **2** (24V–1.8W or thereabouts) to the glow plug **1**.
- Set the starter switch to the HEAT position.
- If the inspection lamp **2** does not come on, check the glow plug or heater relay.

M E M O

ALTERNATOR <24V–40A (with vacuum pump)>



● **Removal sequence**
1 Vacuum pipe
2 Oil return hose
3 Oil inlet hose
4 Adjust plate
5 V-belt
6 Alternator assembly 🕮 P.54-18
7 Adjust plate

*: Alternator bracket

WARNING ⚠

Before removing the alternator 6, be sure to disconnect the negative ⊖ terminal of the battery and insulate it with a tape or something else. If the negative ⊖ terminal is not disconnected, the battery voltage is always available at terminal B and is dangerous.

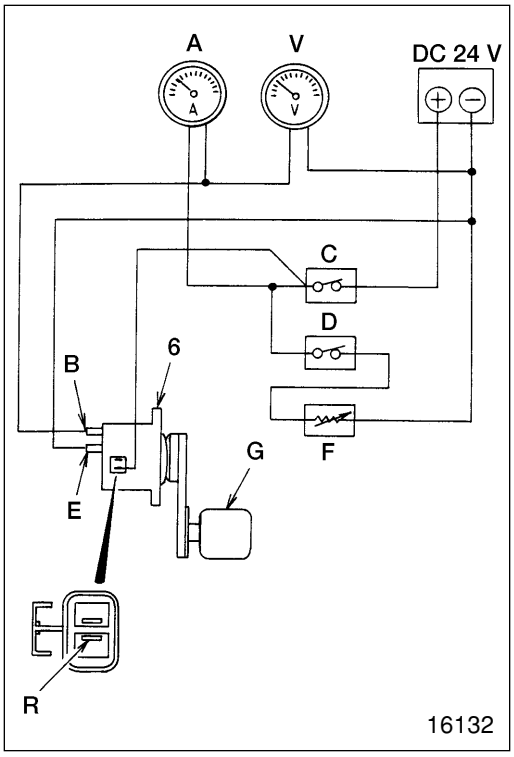
● **Installation sequence**
Reverse the order of removal.

● **Adjustment after installation**
Adjust the tension of the V-belt 5. 🕮 Gr 14

Service standards

Location	Maintenance item		Standard value	Limit	Remedy
6	Alternator output current (* When hot, when 27V is generated)	1500 rpm	24A or more	–	Check
		2500 rpm	33A or more	–	
		5000 rpm	37A or more	–	
	Regulator regulated voltage (5000 rpm, loads 5A or less)		28.5 ± 0.5V	–	Replace

*: "When hot" refers to the state of the engine after 30 minutes of maximum output operation at 5000 rpm at a normal ambient temperature.



◆ Service procedure

6 Inspection of alternator

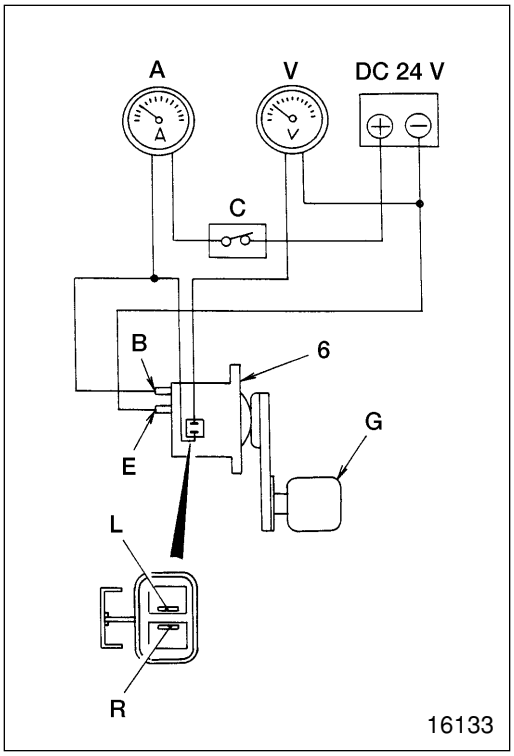
(1) Inspection of performance of alternator

(Inspection by test bench)

- Wire the alternator **6** as shown.
  - **A:** Ammeter
  - **B:** Alternator terminal B
  - **C:** Switch
  - **D:** Switch
  - **E:** Alternator terminal E
  - **F:** Load resistance (variable resistance)
  - **G:** Alternator drive motor
  - **V:** Voltmeter
  - **R:** Alternator terminal R

- Increase the load resistance **F** to a maximum (where practically no load current flows).
- Set the switch **C** and switch **D** to ON.
- Let the alternator **6** rotate at 5000 rpm.
- Adjust the load resistance **F** so that the current will have the nominal value.

  Nominal value of alternator current: 24V–40A
- Measure the current with the alternator **6** at each of the specified speeds.
- If the reading is out of the standard value, disassemble and check the alternator **6**. P.54-18



(2) Inspection of performance of regulator

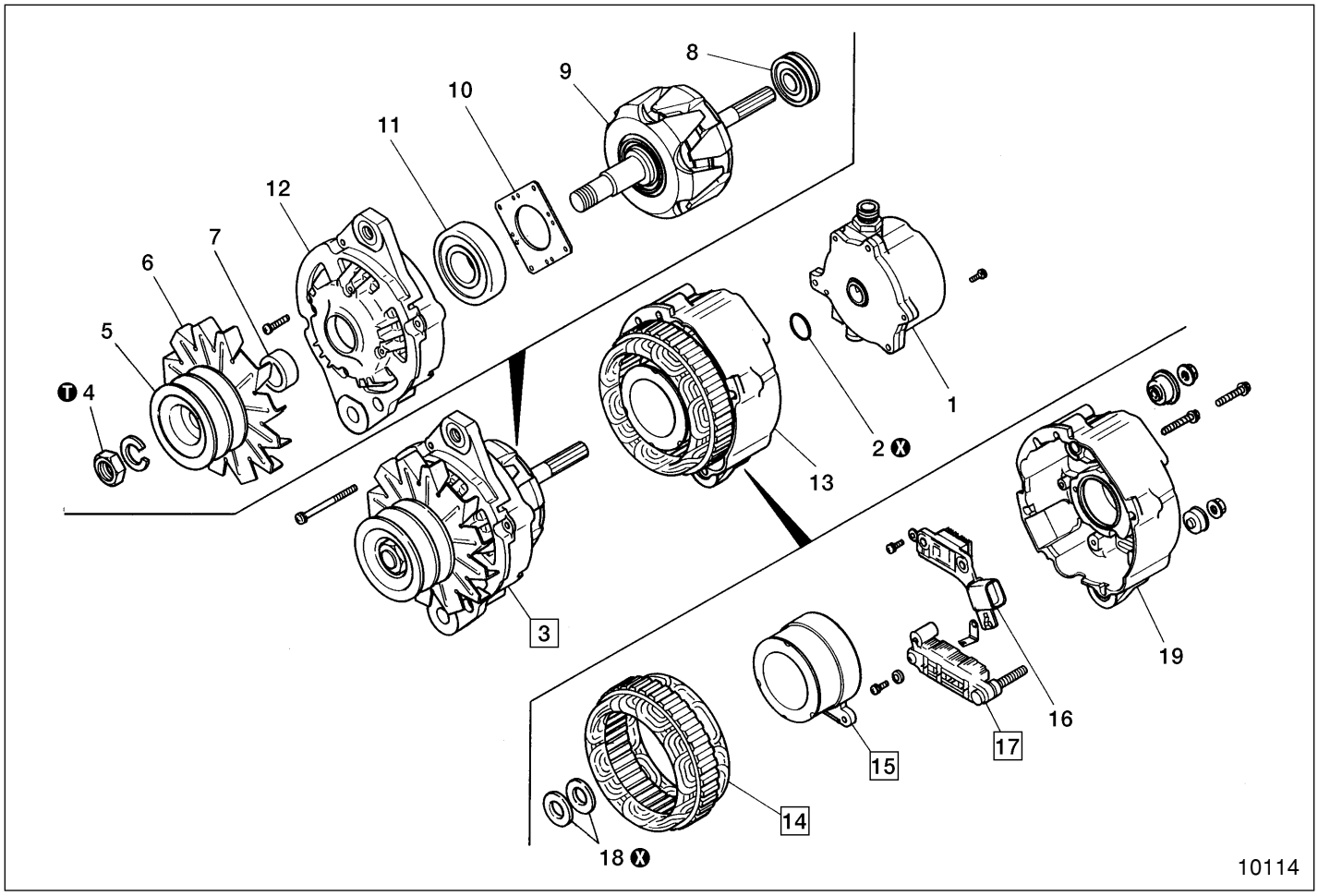
(Inspection by test bench)

- Wire the alternator **6** as shown.
  - **A:** Ammeter
  - **B:** Alternator terminal B
  - **C:** Switch
  - **E:** Alternator terminal E
  - **G:** Alternator drive motor
  - **L:** Alternator terminal L
  - **R:** Alternator terminal R
  - **V:** Voltmeter

- Set the switch **C** to ON.
- Let the alternator **6** rotate at a low speed.
- Increase the rotating speed of the alternator **6** to 5000 rpm and measure the voltage (regulated voltage). At the same time, check to ensure that the current value is 5A or less.
- If the readings are out of the standard values, proceed as described below.
  - If the readings exceed the standard values, replace the regulator (built in the alternator **6**).
  - If the readings are below the standard values, check all the parts of the alternator before replacing the regulator.

ALTERNATOR <24V–40A (with vacuum pump)>

Alternator Assembly



● **Disassembly sequence**

1 Vacuum pump assembly
📖 P.54-22
2 O-ring
3 Rotor & front bracket assembly
4 Nut
5 Pulley
6 Fan
7 Spacer
8 Rear bearing
9 Rotor assembly
10 Cover
11 Front bearing
12 Front bracket
13 Stator & rear bracket assembly
14 Stator assembly
15 Field coil
16 Regulator
17 Rectifier
18 Oil seal
19 Rear bracket

X : Non-reusable part

NOTE

Do not remove parts 8, 11 and 14 unless they are found to be defective.

● **Reassembly sequence**

13 → 3 → 2 → 1

13: 19 → 18, 16 → 17 → 15 → 14

3: 12 → 11 → 10, 9 → 8 → 7 → 6 → 5 → 4

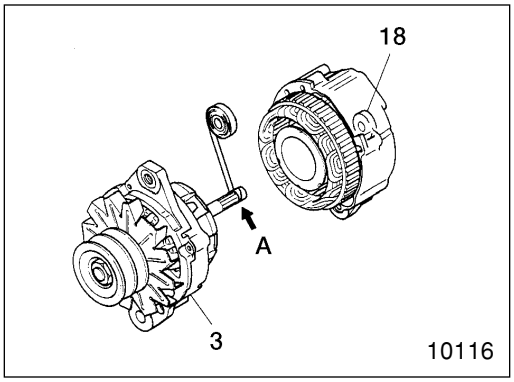
Service standards

Location	Maintenance item	Standard value	Limit	Remedy
15	Field coil resistance [at 20°C (68°F)]	Approx. 6.2 Ω	–	Replace

Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
4	Nut (to mount pulley)	132 to 162 (13.5 to 16.5) [97.4 to 119]	–



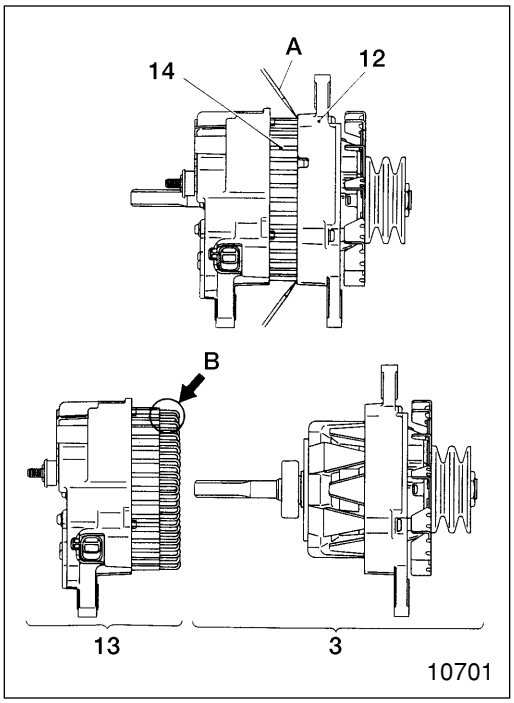
Service procedure

3 Rotor & front bracket assembly

[Removal]

CAUTION

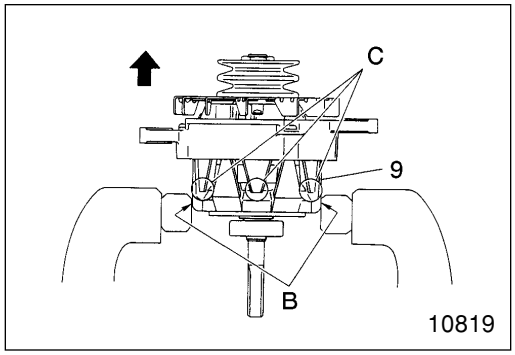
Wind a tape around the spline portion A of the shaft of the rotor & front bracket assembly 3 to prevent damage to the oil seal 18 at the time of removal.



- Insert a plain screwdriver **A** between the front bracket **12** and stator assembly **14**.
- While wrenching the plain screwdriver **A**, remove the rotor & front bracket assembly **3** from the stator & rear bracket assembly **13**.

CAUTION

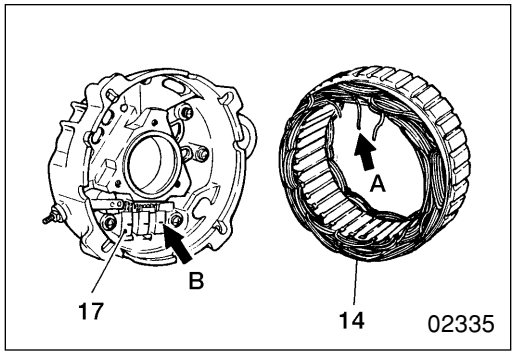
If the plain screwdriver A is inserted too far, the coil B of the stator assembly 14 might be damaged and short-circuited.



[Disassembly]

CAUTION ⚠

When the rotor assembly 9 is held in a vice, make sure that the base E of the lugs of the core is held.
If the lugs F of the core are held, they will be broken or damaged.



14 Stator assembly

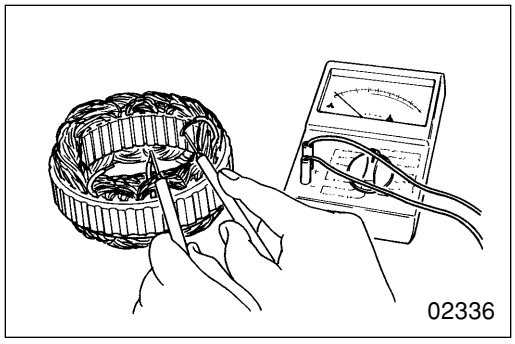
[Removal]

- Disconnect the leads **A** and remove the stator assembly **14** from the rectifier **17**.
  The leads are soldered to the diode leads **B** of the rectifier. (Three places)

CAUTION ⚠

De-soldering should be done quickly (in about 5 seconds or less). The diodes will be damaged if heated for a longer time.

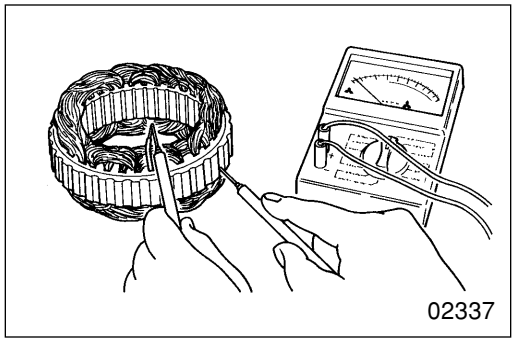
- For installation, reverse the order of removal.



[Inspection]

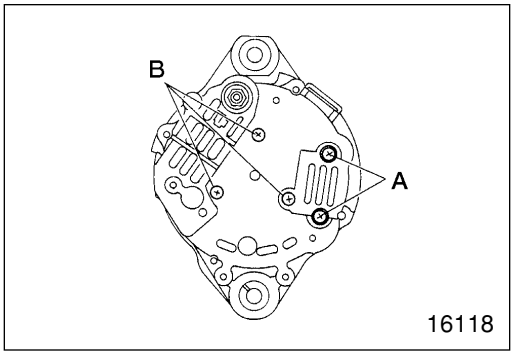
(1) Continuity between leads

- Check to ensure that there is continuity between each lead.
- If there is no continuity, the leads are open-circuited. Replace the stator assembly **14**.



(2) Continuity between each lead and core

- Check to ensure that there is no continuity between each lead and the core.
- If there is continuity, it means a short circuit. Replace the stator assembly **14**.



15 Field coil

[Removal]

- Remove the two screws **A**.

CAUTION ⚠

If the screws B are removed first, the weight of the field coil 15 will act on the lead portion secured by the screws A, and damage to the lead portion may result. Therefore, make sure that the screws A are removed first.

- Remove the three screws **B**.

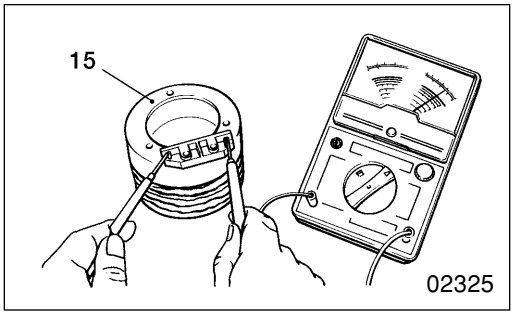
CAUTION ⚠

When the screws B are removed, the field coil 15 will fall under its own weight. Therefore, hold the field coil by hand beforehand.

- Remove the field coil **15**.

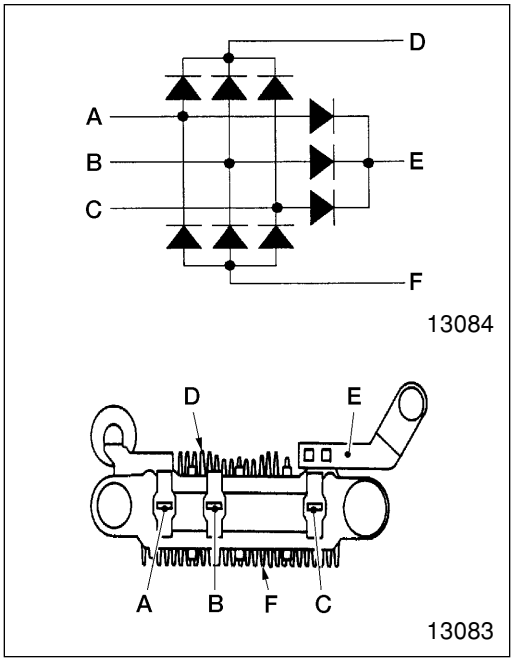
CAUTION ⚠

When the field coil 15 is taken out, the coil lead portion may be caught by the stator coil. Don't pull it out with undue force.



[Inspection]

- Measure the resistance between the terminals of the field coil **15**.
- If the reading is out of the standard value, replace the field coil **15**.



17 Inspection of rectifier

- Check the rectifier **17** to see if the internal diodes function properly, and replace if defective.

  Resistance infinite in both cases....Open
  Resistance close to V in both cases...Short

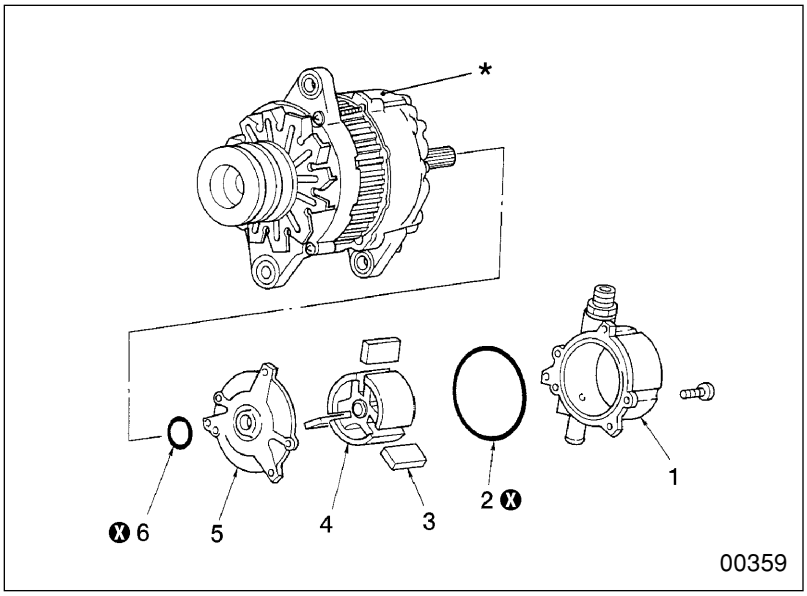
  A, B, C: Leads of stator coil connected
  D, F: Heat sink portion
  E: Regulator connected

- Exchange the ⊕ and ⊖ sides of the tester and perform checks in both cases.

CAUTION ⚠

When a tester is used for the checks, the current that flows out from the tester is feebler than the current that normally flows through the rectifier 17, so the tester may indicate a questionable resistance value. In a low range, this tendency will be stronger. Therefore, it is advisable to use the highest possible range.

Vacuum Pump Assembly



● **Disassembly sequence**
1 Vacuum housing
2 O-ring
3 Vane
4 Rotor
5 Plate
6 O-ring

*: Alternator 📖 P.54-18
X : Non-reusable part

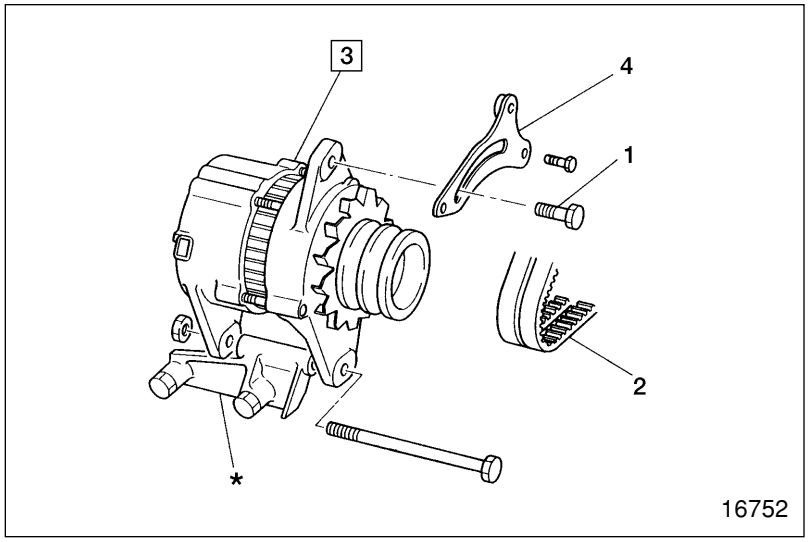
● **Reassembly sequence**
Reverse the order of removal.

Service standards

Location	Maintenance item	Standard value	Limit	Remedy
–	Attainable vacuum pressure (when alternator speed is 1500 rpm)	93 kPa (0.95 kgf/cm²) [13 psi]	–	–

M E M O

ALTERNATOR <24V–40A (without vacuum pump)>



● **Removal sequence**
1 Adjust bolt
2 V-belt
3 Alternator assembly 📖 P.54-26
4 Adjust plate

*: Alternator bracket

WARNING ⚠

Before removing the alternator 3, be sure to disconnect the negative ⊖ terminal of the battery and insulate it with a tape or something else. If the negative ⊖ terminal is not disconnected, the battery voltage is always available at terminal B and is dangerous.

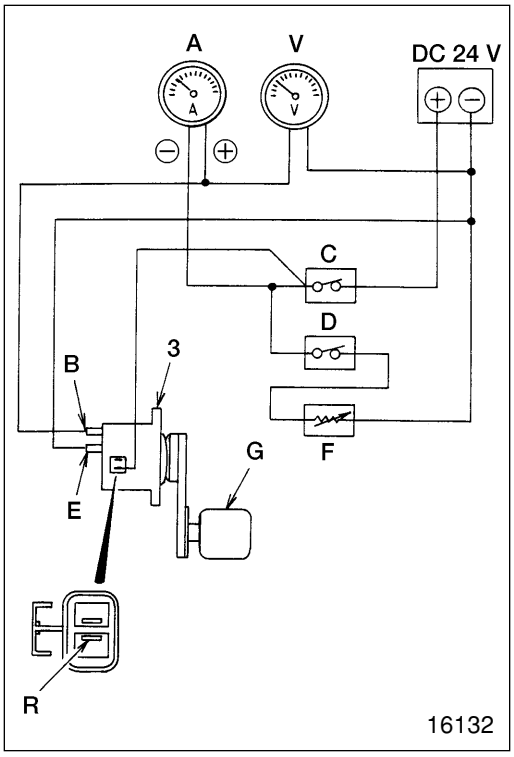
● **Installation sequence**
Reverse the order of removal.

● **Adjustment after installation**
Adjust the tension of the V-belt 2. 📖 Gr 14

Service standards

Location	Maintenance item		Standard value	Limit	Remedy
3	Alternator output current (* When hot, when 27V is generated)	1500 rpm	24A or more	–	Check
		2500 rpm	33A or more	–	
		5000 rpm	37A or more	–	
	Regulator regulated voltage (5000 rpm, loads 5A or less)		28.5 ± 0.5V	–	Replace

*: "When hot" refers to the state of the engine after 30 minutes of maximum output operation at 5000 rpm at a normal ambient temperature.



◆ Service procedure

3 Inspection of alternator

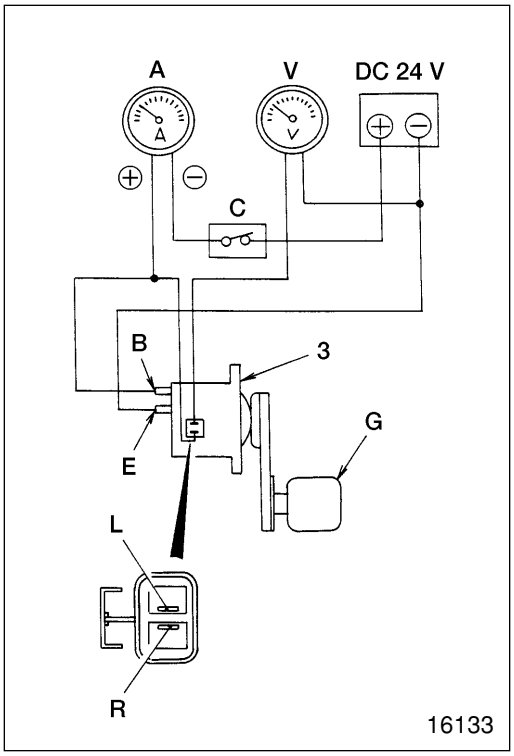
(1) Inspection of performance of alternator

(Inspection by test bench)

- Wire the alternator **3** as shown.
  - **A:** Ammeter
  - **B:** Alternator terminal B
  - **C:** Switch
  - **D:** Switch
  - **E:** Alternator terminal E
  - **F:** Load resistance (variable resistance)
  - **G:** Alternator drive motor
  - **V:** Voltmeter
  - **R:** Alternator terminal R

- Increase the load resistance **F** to a maximum (where practically no load current flows).
- Set the switch **C** and switch **D** to ON.
- Let the alternator **3** warm up at 5000 rpm for 30 minutes.
- Adjust the load resistance **F** so that the current will have the nominal value.

  Nominal value of alternator current: 24V–40A
- Measure the current with the alternator **3** at each of the specified speeds.
- If the reading is out of the standard value, disassemble and check the alternator **3**. P.54-26



(2) Inspection of performance of regulator

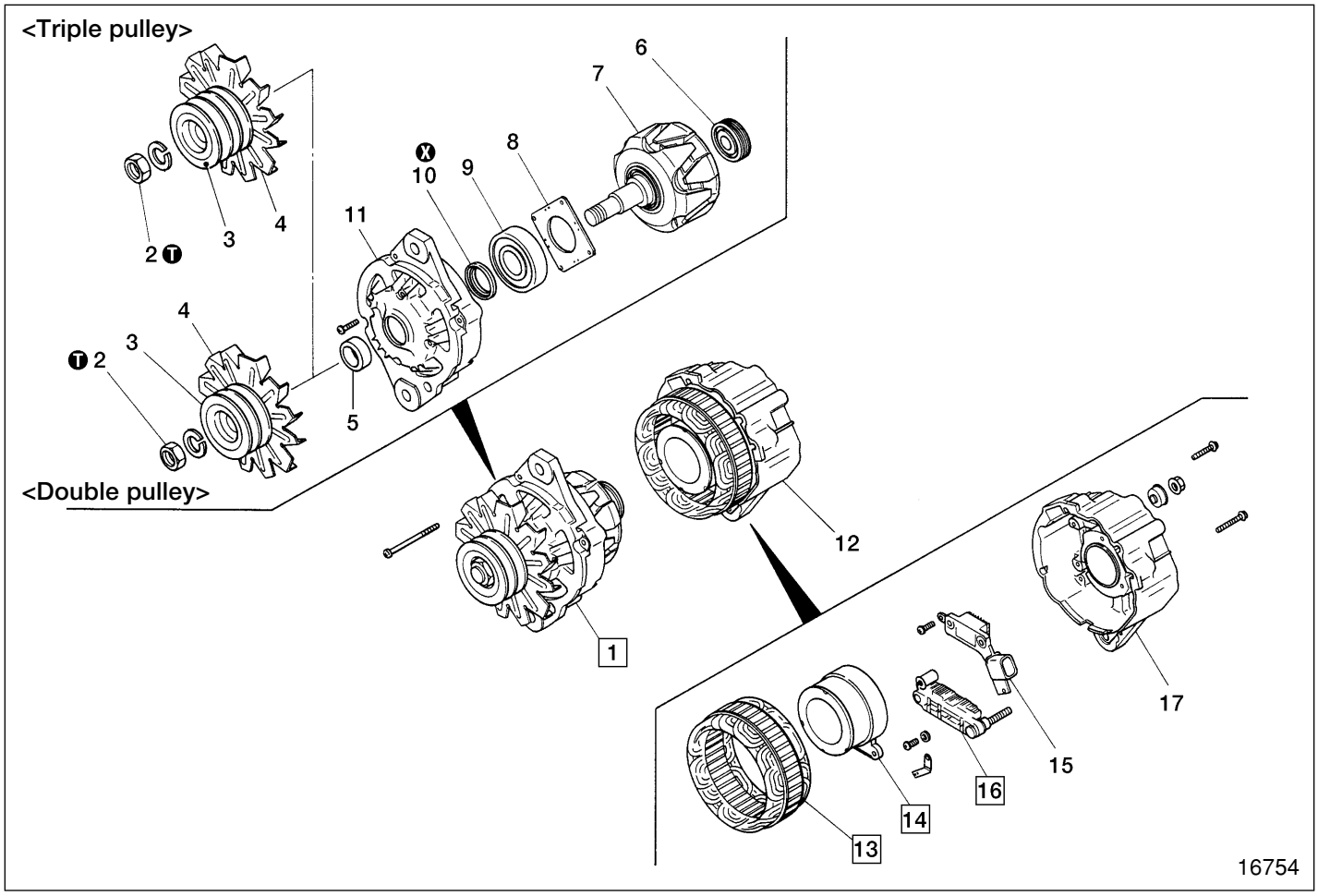
(Inspection by test bench)

- Wire the alternator **3** as shown.
  - **A:** Ammeter
  - **B:** Alternator terminal B
  - **C:** Switch
  - **E:** Alternator terminal E
  - **G:** Alternator drive motor
  - **L:** Alternator terminal L
  - **R:** Alternator terminal R
  - **V:** Voltmeter

- Set the switch **C** to ON.
- Let the alternator **3** rotate at a low speed.
- Increase the rotating speed of the alternator **3** to 5000 rpm and measure the voltage (regulated voltage). At the same time, check to ensure that the current value is 5A or less.
- If the readings are out of the standard values, proceed as described below.
  - If the readings exceed the standard values, replace the regulator (built in the alternator **3**).
  - If the readings are below the standard values, check all the parts of the alternator before replacing the regulator.

ALTERNATOR <24V–40A (without vacuum pump)>

Alternator Assembly



● Disassembly sequence

1 Rotor & front bracket assembly
2 Nut
3 Pulley
4 Fan
5 Spacer
6 Rear bearing
7 Rotor assembly
8 Cover
9 Front bearing
10 Oil seal
11 Front bracket
12 Stator & rear bracket assembly
13 Stator assembly
14 Field coil
15 Regulator
16 Rectifier
17 Rear bracket

X : Non-reusable part

NOTE

Do not remove parts 6, 9 and 13 unless they are found to be defective.

● Reassembly sequence

12 → 1

12: 17 → 16 → 15 → 14 → 13

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

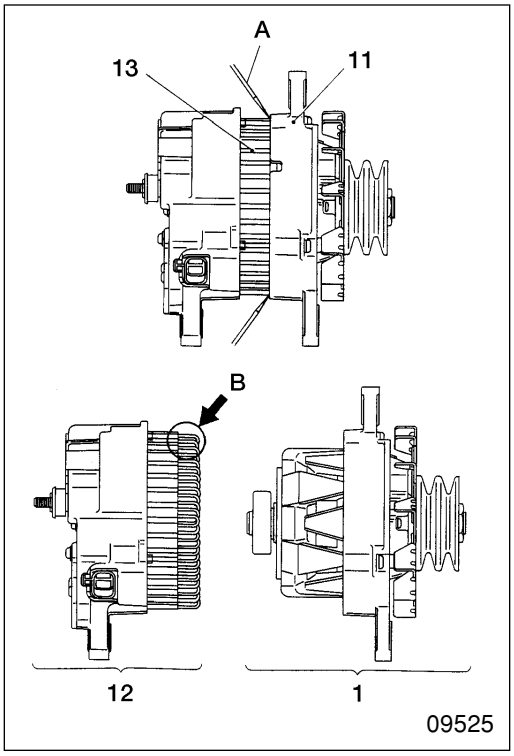
Service standards

Location	Maintenance item	Standard value	Limit	Remedy
14	Field coil resistance [at 20°C (68°F)]	5.8 to 6.6 Ω	–	Replace

Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
2	Nut (to mount pulley)	132 to 162 (13.5 to 16.5) [97.4 to 119]	–



Service procedure

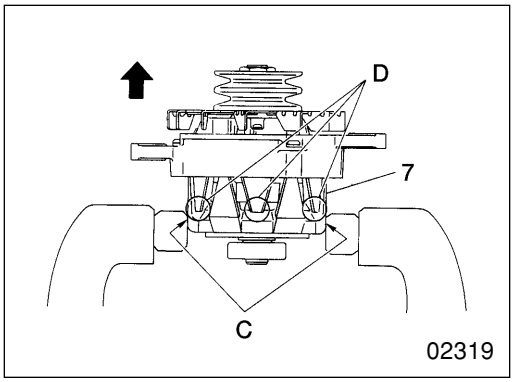
1 Rotor & front bracket assembly

[Removal]

- Insert a plain screwdriver **A** between the front bracket **11** and stator assembly **13**.
- While wrenching the plain screwdriver **A**, remove the rotor & front bracket assembly **1** from the stator & rear bracket assembly **12**.

CAUTION

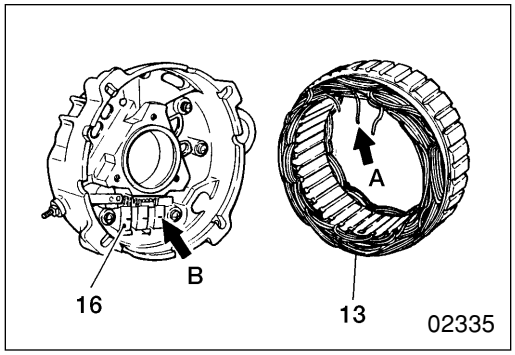
If the plain screwdriver A is inserted too far, the coil B of the stator assembly 13 might be damaged and short-circuited.



[Disassembly]

CAUTION

When the rotor assembly 7 is held in a vice, make sure that the base E of the lugs of the core is held.
If the lugs D of the core are held, they will be broken or damaged.



13 Stator assembly

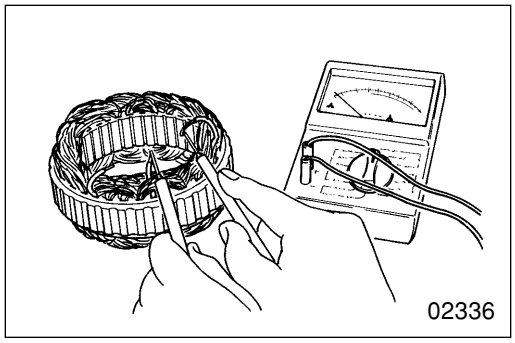
[Removal]

- Disconnect the leads **A** and remove the stator assembly **13** from the rectifier **16**.
  The leads are soldered to the diode leads **B** of the rectifier. (Three places)

CAUTION ⚠

De-soldering should be done quickly (in about 5 seconds or less). The diodes will be damaged if heated for a longer time.

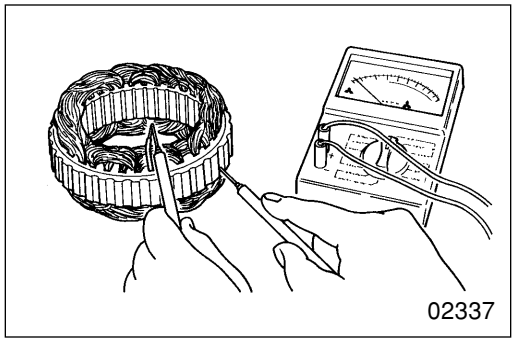
- For installation, reverse the order of removal.



[Inspection]

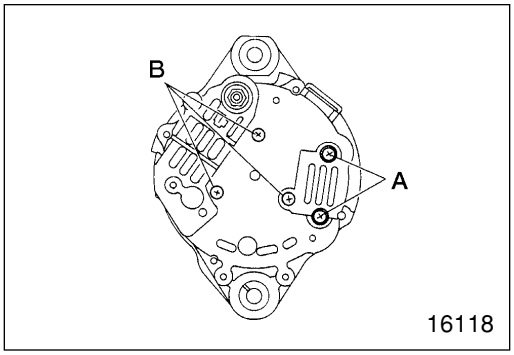
(1) Continuity between leads

- Check to ensure that there is continuity between each lead.
- If there is no continuity, the leads are open-circuited. Replace the stator assembly **13**.



(2) Continuity between each lead and core

- Check to ensure that there is no continuity between each lead and the core.
- If there is continuity, it means a short circuit. Replace the stator assembly **13**.



14 Field coil

[Removal]

- Remove the two screws **A**.

CAUTION ⚠

If the screws B are removed first, the weight of the field coil 14 will act on the lead portion secured by the screws A, and damage to the lead portion may result. Therefore, make sure that the screws A are removed first.

- Remove the three screws **B**.

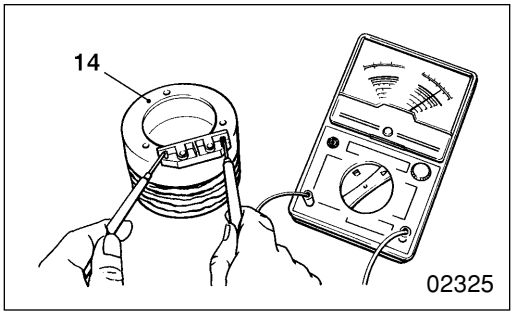
CAUTION ⚠

When the screws B are removed, the field coil will fall under its own weight. Therefore, hold the field coil by hand beforehand.

- Remove the field coil **14**.

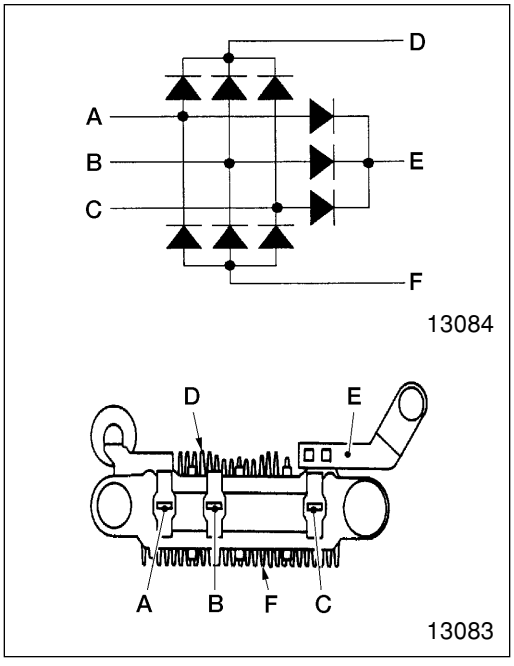
CAUTION ⚠

When the field coil is taken out, the coil lead portion may be caught by the stator coil. Don't pull it out with undue force.



[Inspection]

- Measure the resistance between the terminals of the field coil **14**.
- If the reading is out of the standard value, replace the field coil **14**.



16 Inspection of rectifier

- Check the rectifier **16** to see if the internal diodes function properly, and replace if defective.

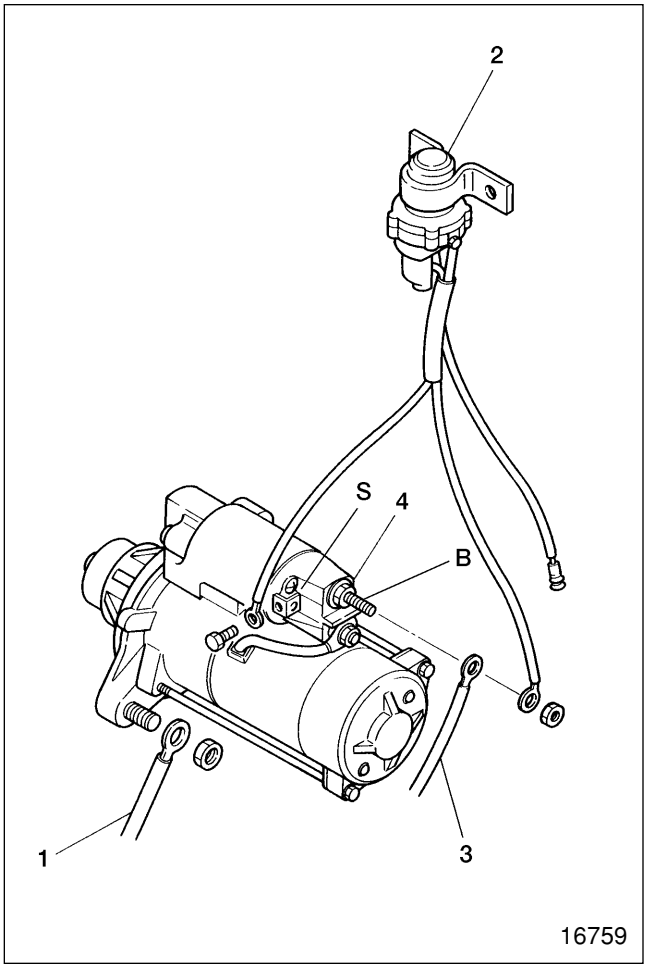
  Resistance infinite in both cases....Open
  Resistance close to V in both cases...Short

  A, B, C: Leads of stator coil connected
  D, F: Heat sink portion
  E: Regulator connected

- Exchange the ⊕ and ⊖ sides of the tester and perform checks in both cases.

CAUTION ⚠

When a tester is used for the checks, the current that flows out from the tester is feebler than the current that normally flows through the rectifier 16, so the tester may indicate a questionable resistance value. In a low range, this tendency will be stronger. Therefore, it is advisable to use the highest possible range.



● **Removal sequence**

1 Earth strap
2 Starter relay
3 Battery cable ⊕
4 Starter assembly 📖 P.54-32

B: Terminal B
S: Terminal S

WARNING ⚠

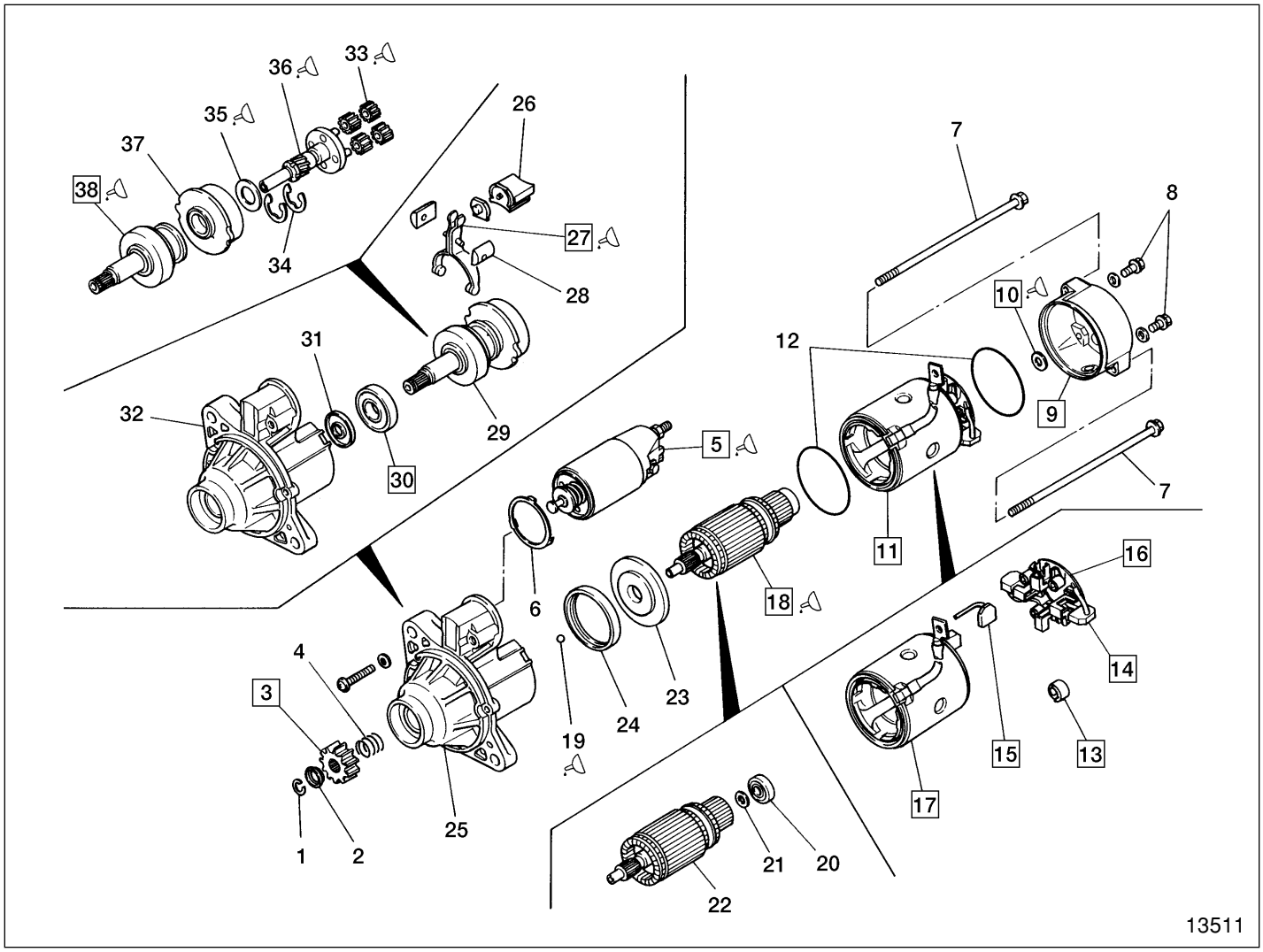
Before removing the starter 4, be sure to disconnect the negative ⊖ terminal of the battery and insulate it with a tape or something else. If the negative ⊖ terminal is not disconnected, the battery voltage is always available at terminal B and is dangerous.

● **Installation sequence**

Reverse the order of removal.

M E M O

Starter Assembly



● **Disassembly sequence**

1 Stopper ring
2 Pinion stopper
3 Pinion
4 Spring
5 Magnet switch
6 Shim
7 Bolt
8 Screw
9 Rear bracket
10 Conical washer
11 Yoke & brush holder assembly
12 Rubber packing
13 Brush spring
14 Brush ⊖
15 Brush ⊕
16 Brush holder assembly
17 Yoke assembly
18 Armature assembly
19 Ball
20 Rear bearing
21 Washer
22 Armature
23 Cover
24 Rubber packing
25 Front bracket assembly
26 Rubber packing
27 Lever
28 Bushing
29 Gearshaft & overrunning clutch assembly
30 Front bearing
31 Dust seal
32 Front bracket
33 Planetary gear
34 Washer
35 Washer
36 Gearshaft
37 Internal gear
38 Overrunning clutch

CAUTION ⚠

- To remove the yoke & brush holder assembly 11, first raise the brushes 14 and 15 from the brush holder assembly 16 to prevent damage to the commutator of the armature 22.
- Do not remove the bearings 20 and 30 unless they are found to be defective.
- When the yoke & brush holder assembly 11 is removed from the front bracket assembly 25, be careful not to allow the armature assembly 18 to fall.
- When the armature assembly 18 is removed, the ball 19 may simultaneously come out. Be careful not to lose it.
- When the motor section only is to be disassembled and checked like when the brushes and surrounding areas are to be checked, the pinion 3 need not be removed.
- Except in the above case, the pinion 3 must be removed before disassembly of the individual portions.

● **Reassembly sequence**

Reverse the order of disassembly.

CAUTION ⚠

When the magnet switch 5 was replaced, be sure to adjust the pinion gap.

● **Inspection after reassembly**

🕮 P.54-34

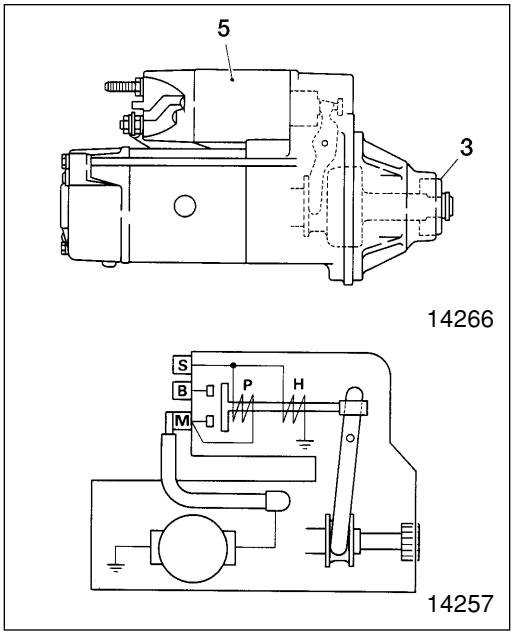
Service standards

Unit: mm (in.)

Location	Maintenance item			Standard value	Limit	Remedy
–	Pinion gap			0.5 to 2.0 (0.0197 to 0.0787)	–	Adjust
–	No-load characteristics	During 23V supply	Current	85A or less	–	Check
			Rotating speed	3300 rpm or more	–	
13	Spring pressure of brush spring			29 to 39 N (3 to 4 kgf) [6.52 to 8.77 lbf]	20 N (2 kgf) [4.50 lbf]	Replace
14, 15	Brush length			18 (0.709)	11 (0.433)	Replace
18	Outside diameter of commutator			32 (1.26)	31.4 (1.24)	Replace
	Commutator outer circumferential runout			–	0.05 (0.00197) or more	
	Depth of mica between segments			–	0.2 (0.00787) or less	Repair or replace

Lubricant

Location	Points of application	Kinds	Quantity
5	Apply to lever contacting portion of magnet switch	MULTEMP PS-2	As required
10	Apply to conical washer	MULTEMP PS-2	As required
19	Apply to ball	MOLYCOAT ® AG650	As required
18, 33	Apply to teeth of gears of amature assembly and planetary gears	MOLYCOAT ® AG650	As required
27	Apply to overrunning clutch sliding surfaces of lever	MULTEMP PS-2	As required
35	Apply to washer	MOLYCOAT ® AG650	As required
36, 38	Apply to sliding surfaces of gearshaft assembly and overrunning clutch assembly	MULTEMP PS-2	As required
18, 36	Apply to sliding surfaces of gearshaft and armature assembly	MOLYCOAT ® AG650	As required
38	Apply to splined portion of overrunning clutch	MULTEMP PS-2	As required



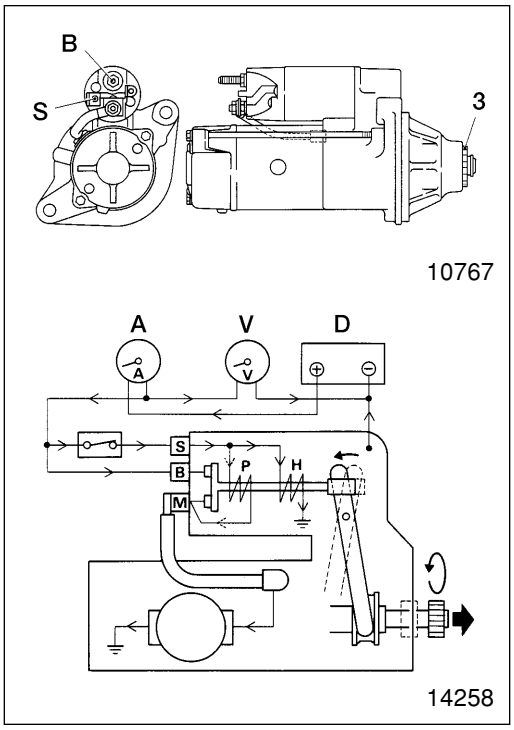
◆ Service procedure

● Inspection after reassembly

After reassembly, check the starter by supplying current.

CAUTION ⚠

- **When current is supplied to the starter, the pinion 3 will spring out and rotate. Be careful not to touch it by hand.**
- **The magnet switch 5 may be very hot after the end of inspection. Be careful when you touch it.**
- **The time during which current is supplied to the starter should be limited to 10 seconds or less on the pull-in coil P side and 30 seconds or less on the holding coil H side. If current is supplied to the coils for a longer period, the coils will be overheated and baked.**
- **When current is supplied to the starter, a large current that exceeds 100A will flow. When the starter is inspected, therefore, use thick cables like booster cables. Check to ensure that all the connections are tight and secure.**



(1) Performance test

- Wire the starter as shown.
  - **A:** Ammeter
  - **B:** Starter terminal B
  - **C:** Switch
  - **D:** DC power supply
  - **S:** Starter terminal S
  - **V:** Voltmeter
- Set the voltage at 23V DC.

CAUTION ⚠

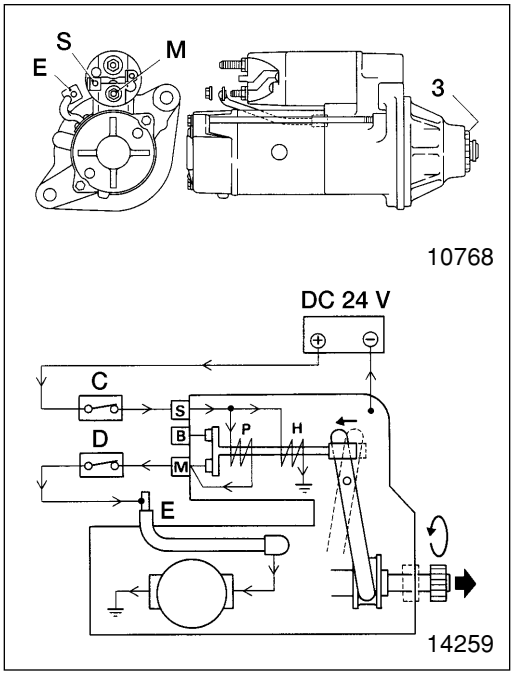
The voltage that is applied should be limited to 24V maximum.

- The following operations are performed by supplying current to the starter. It is therefore necessary that the series of operations ranging from measuring the current that flows through the starter to measuring the rotating speed are completed in less than 30 seconds.
- Set the switch **C** to ON to supply current to the starter. At the time, the pinion **3** will spring out and rotate.

CAUTION ⚠

When the switch C is set to ON, current is supplied to both the pull-in coil P and holding coil H. When the large current from the DC power supply D is supplied from terminal B of the starter to terminal M, the current to the pull-in coil is interrupted, and current flows to the holding coil only.
To prevent baking the holding coil, therefore, all the operations must be completed in less than 30 seconds.

  - Measure the current and rotating speed of the starter. Measure the rotating speed of the starter by illuminating the pinion 3 with a stroboscope.
  - Set the switch C to OFF to stop supplying current to the starter.
- If the reading is out of the standard value, disassemble and check the starter.

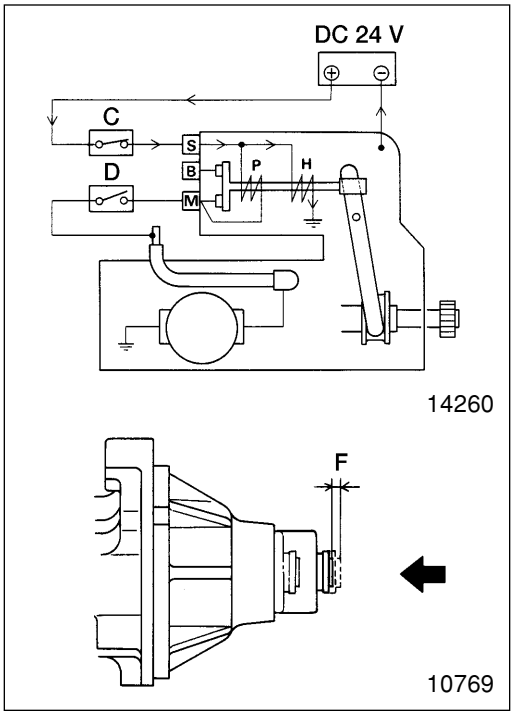


(2) Pinion gap

[Inspection]

- Wire the starter as shown.
  C: Switch
  D: Switch
  E: Cable
  M: Starter terminal M
  S: Starter terminal S

- The following operations are performed by supplying current to the starter. It is therefore necessary that the series of operations up to completion of measurement of the pinion gap is completed in less than 30 seconds.
- Set the switch **C** and switch **D** to ON to supply current to the starter. At the time, the pinion **3** will spring out and rotate.



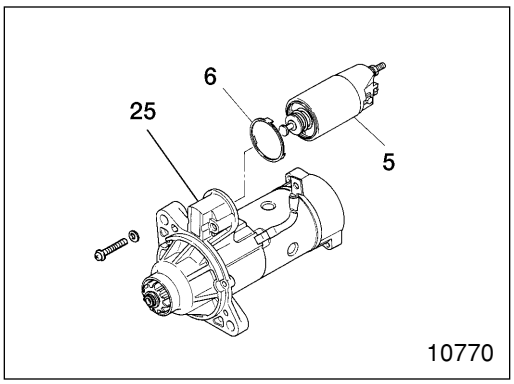
- Immediately (in less than 5 seconds) after the pinion has started rotation, set the switch **D** to OFF stop rotation of the pinion.

CAUTION ⚠

When the switch C and switch D are set to ON, current is supplied to both the pull-in coil P and holding coil H. Since wiring is such that no voltage is applied to terminal B of the starter, current flows to the pull-in coil during rotation of the pinion 3.

To prevent baking the pull-in coil, therefore, it is necessary that the switch E is set to OFF immediately (in less than 5 seconds) after the pinion has started rotating.

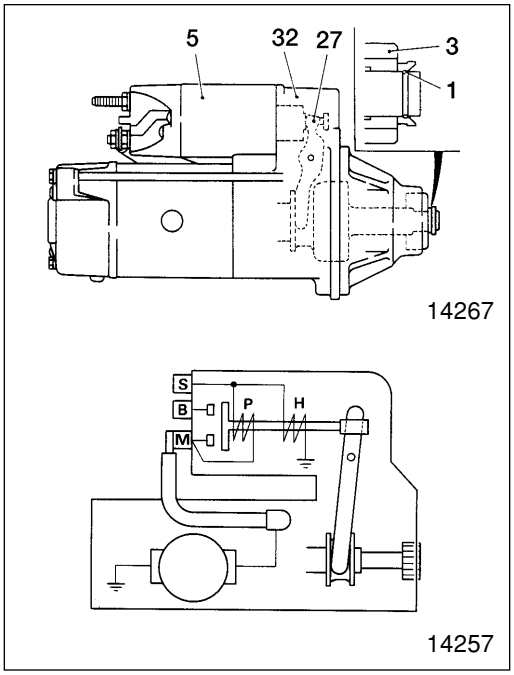
- Lightly push the end of the overrunning clutch **38** in and measure the amount **F** the clutch moves in the axial direction (pinion gap).
- Set the switch **C** to OFF to stop supplying current to the starter.
- If the reading is out of the standard value, adjust by the following procedures.



[Adjustment]

- Remove the magnet switch **5** from the front bracket assembly **25**.
- Adjust by changing the thickness of shim **6**.
  Increasing the number of shims reduces the pinion gap **F**.

  Types of shims: 0.25 mm (0.00984 in.),
  0.5 mm (0.0197 in.)



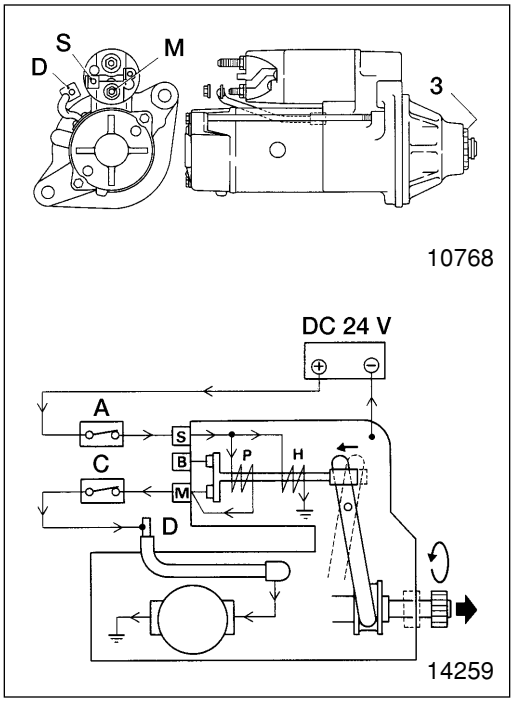
3 Pinion

[Removal]

To remove the pinion **3**, it is necessary to supply current to the starter and let the pinion spring out.

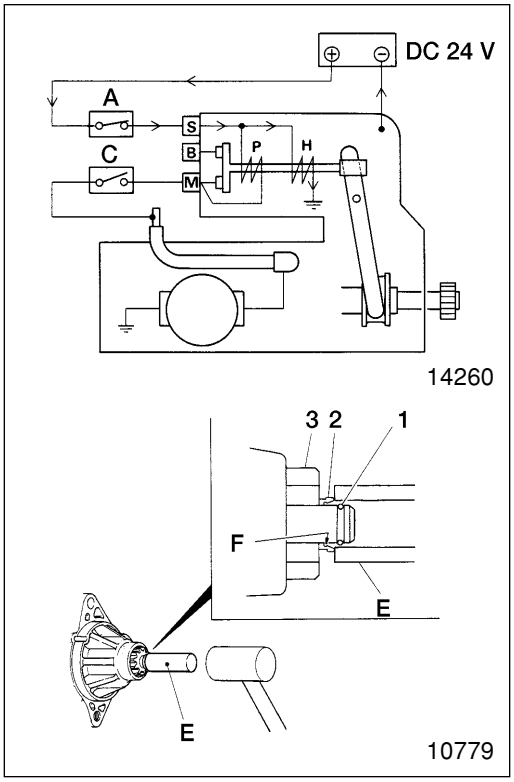
CAUTION ⚠

- **When current is supplied to the starter, the pinion 3 will spring out and rotate. Be careful not to touch it by hand.**
- **The magnet switch 5 may be very hot after the end of inspection. Be careful when you touch it.**
- **The time during which current is supplied to the starter should be limited to 10 seconds or less on the pull-in coil P side and 30 seconds or less on the holding coil H side. If current is supplied to the coils for a longer period, the coils will be overheated and baked.**
- **Make sure that the pinion 3 is made to spring out by supplying current to the starter. If the pinion is forced out by pulling the lever 27 without supplying current to the starter, the front bracket 32 and lever could be damaged by the impact produced when the stopper ring 1 is removed.**
- **When current is supplied to the starter, a large current that exceeds 100A will flow. When the starter is inspected, therefore, use thick cables like booster cables. Check to ensure that all the connections are tight and secure.**



- Wire the starter as shown.
  A: Switch
  B: Starter terminal B
  C: Switch
  D: Cable
  M: Starter terminal M
  S: Starter terminal S

- The following operations are performed by supplying current to the starter. It is therefore necessary that the series of operations up to removal of the pinion **3** is completed in less than 30 seconds.
- Set the switch **A** and switch **C** to ON to supply current to the starter. At the time, the pinion **3** will spring out and rotate.



- Immediately (in less than 5 seconds) after the pinion **3** has started rotating, set the switch **C** to OFF to stop rotation of the pinion.

CAUTION ⚠

When the switch A and switch C are set to ON, current is supplied to both the pull-in coil P and holding coil H. Since wiring is such that no voltage is applied to terminal B of the starter, current flows to the pull-in coil during rotation of the pinion 3.

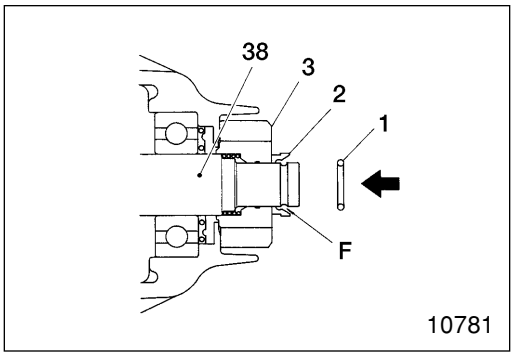
To prevent baking the pull-in coil, therefore, it is necessary that the switch C is set to OFF immediately (in less than 5 seconds) after the pinion has started rotating.

- Set the pipe-like tool **E** on the pinion stopper **2**.
- Lightly strike the tool **E** with a hammer to remove the stopper ring **1** from the ring groove **F** of the pinion stopper **2**.
- Remove the stopper ring **1** and remove the pinion **3**.
- Set the switch **A** to OFF to stop supplying current to the starter.

CAUTION ⚠

When the power supply to the starter is stopped, the pinion 3 may move in and the stopper ring 1 may fit in the ring groove F of the pinion stopper 2 again.

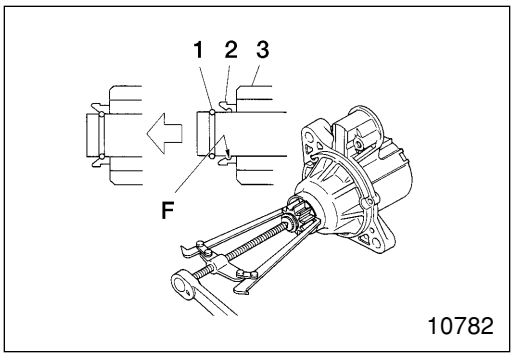
In this case, repeat the operations by supplying current to the starter.



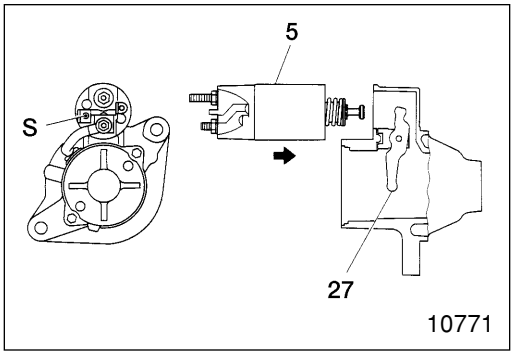
[Installation]

To install the pinion **3**, it is not necessary to supply current to the starter.

- Install the pinion stopper **2** and pinion **3** on the overrunning clutch **38** in the direction shown.
- Set the stopper ring **1** in the ring groove **F** of the overrunning clutch **38**.



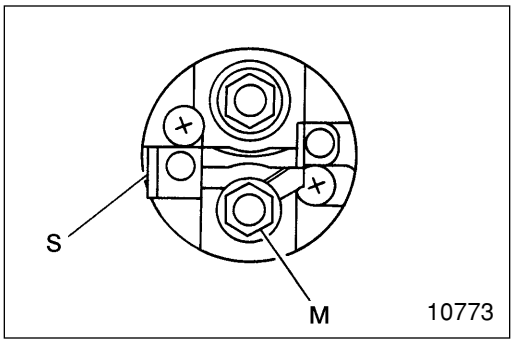
- Pull the pinion **3** strongly to make sure that the stopper ring **1** securely fits in the ring groove **F** of the pinion stopper **2**.



5 **Magnet switch**

[Installation]

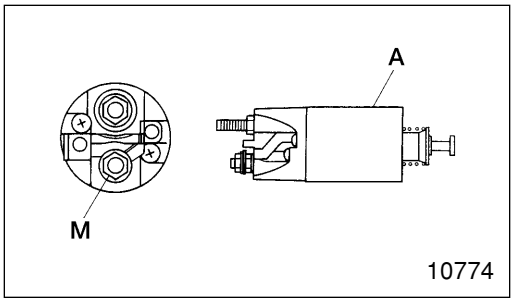
Install the magnet switch **5** on the lever **27** with terminal **S** in the direction shown.



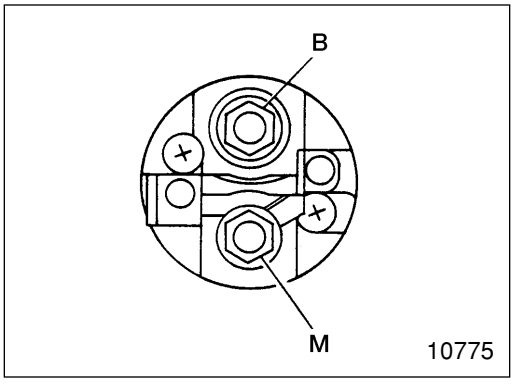
[Inspection]

(1) Open circuit test on coil

- Check to ensure that there is continuity between terminals **S** and **M**.
- If there is no continuity, replace the magnet switch **5**.

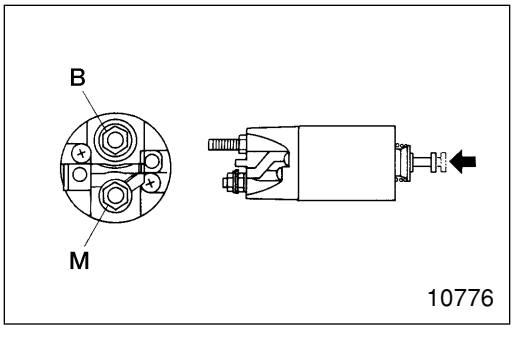


- Check to ensure that there is continuity between terminal **M** and body **A**.
- If there is no continuity, replace the magnet switch **5**.



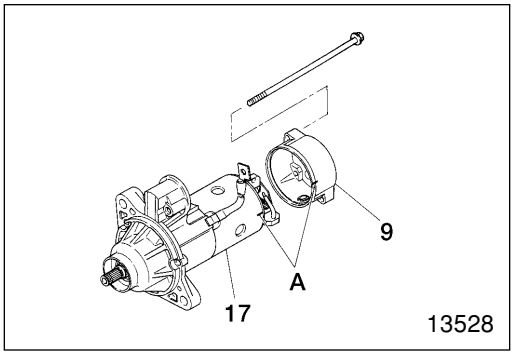
(2) Contact fusion check

- Check to ensure that there is no continuity between terminals **B** and **M**.
- If there is continuity, replace the magnet switch **5**.



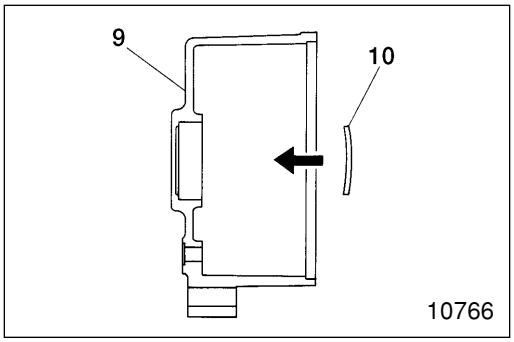
(3) Contact contacting check

- Push the end of the magnet switch **5** in to close the internal contact. In this state, check to ensure that there is continuity between terminals **B** and **M**.
- If there is no continuity, replace the magnet switch **5**.



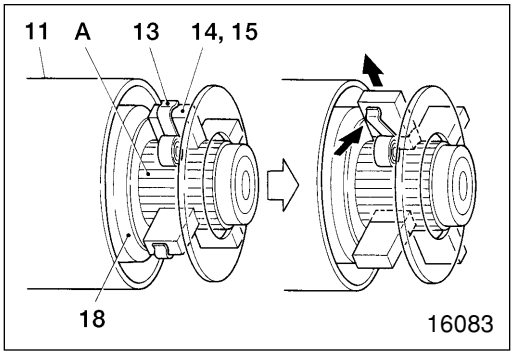
9 **Installation of rear bracket**

A: Alignment marks



10 **Installation of conical washer**

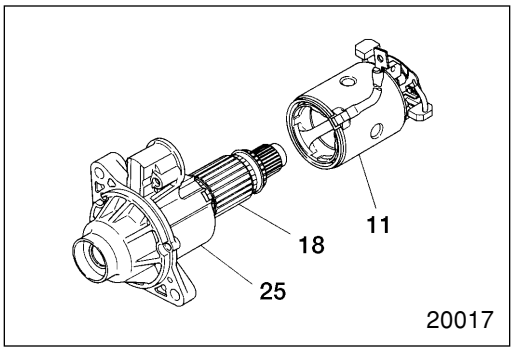
Install the conical washer **10** in the illustrated direction in the rear bracket **9**.



11 **Removal of yoke & brush holder assembly**

To remove the yoke & brush holder assembly, proceed as described below, while using care to prevent damage to the commutator **A** of the armature assembly **17** by the brushes **14** and **15**.

- Keep the brushes **14** and **15** apart from the commutator **A** and hold the brush spring **13** alongside the brushes.

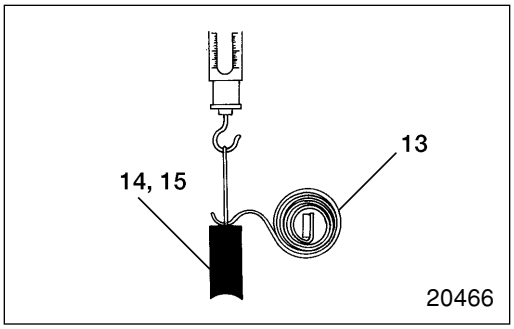


- Remove the yoke & brush holder assembly **11** from the front bracket assembly **25**.

CAUTION ⚠

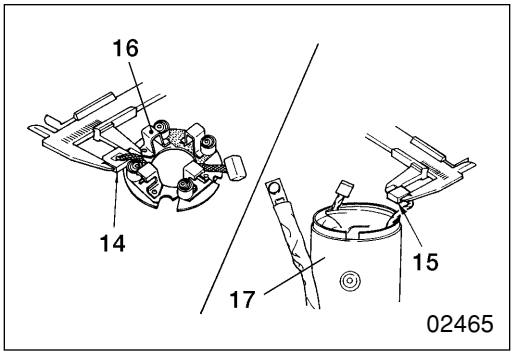
When the yoke & brush holder assembly 11 is removed, do not tilt it downward. Otherwise, the armature assembly 18 may fall down.

- For installation, reverse the order of removal.



13 **Inspection of brush spring**

- Use new brushes **14** and **15** and measure the load at the moment the brush spring **13** leaves the brushes as shown.
- If the reading is less than the limit, replace the brush spring **13**.



14 15 Inspection of brush

(1) Length of brush

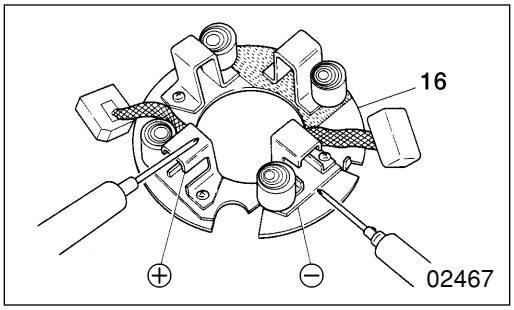
If the reading is less than the limit, replace the brushes **14** and **15**.

CAUTION ⚠

To replace the brush ⊖ 14, replace the brush holder assembly 16.

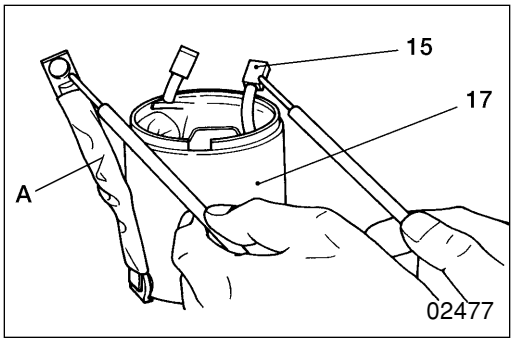
(2) Commutator contacting surfaces

If the contacting surfaces are rough or unevenly worn, repair with emery paper (#300 to 500).



16 Inspection of brush holder assembly

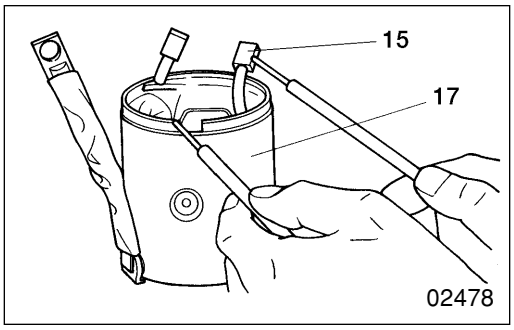
- Check to ensure that there is no continuity between the ⊕ side brush holder and ⊖ side holder plate.
- If there is continuity, it means a short circuit. Replace the brush holder assembly **16**.



17 Inspection of yoke assembly

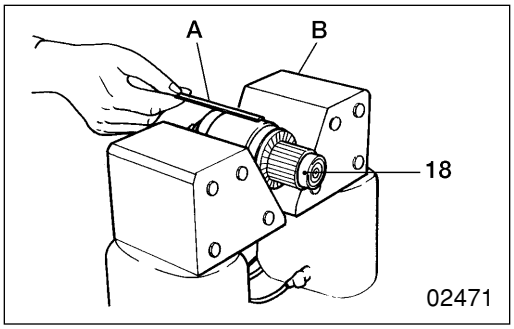
(1) Open circuit test on coil

- Check to ensure that there is continuity between cable **A** and brush ⊕ **15**.
- If there is no continuity, it means an open circuit. Replace the brush ⊕ **15** or yoke assembly **17**.



(2) Ground test on coil

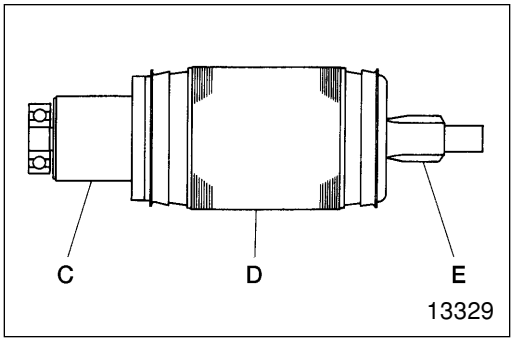
- Check to ensure that there is no continuity between the yoke assembly **17** and brush ⊕ **15**.
- If there is continuity, it means a short circuit. Check the insulation. If repair is impossible, replace the brush⊕ **15** or yoke assembly **17**.



18 Inspection of armature assembly

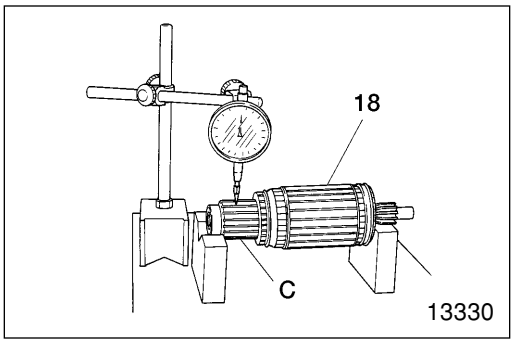
(1) Short circuit test on coil

- Bring the iron piece **A** close to the armature assembly **18**, keeping it in parallel.
- Slowly rotate the armature assembly **18** by hand.
- If the iron piece **A** is attracted or vibrates, it means a short circuit. Replace the armature assembly **18**.



(2) Ground test on coil

- Check to ensure that there is no continuity between the commutator **C** and core **D** (or shaft portion **E**).
- If there is continuity, it means a short circuit. Replace the armature assembly **18**.

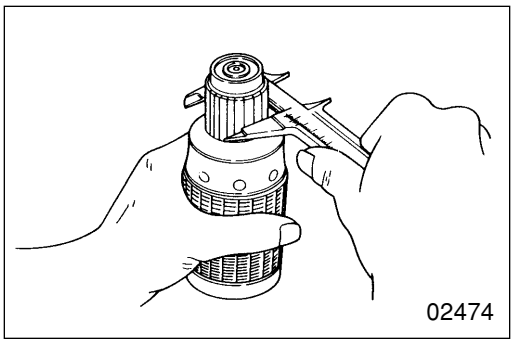


(3) Runout of commutator

If the reading is more than the limit, repair the outside diameter of the commutator portion **C** of the armature assembly **18** within the limit.

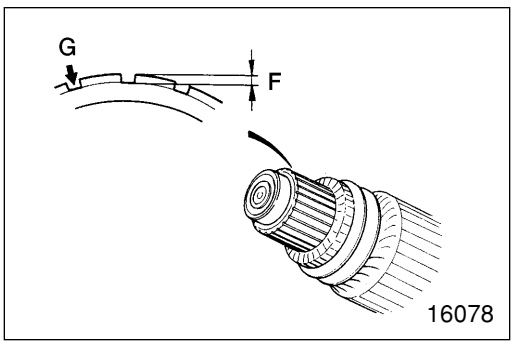
(4) Condition of commutator surface

- If the surface is rough or unevenly worn, repair with emery paper (#300 to 500).
- After the repair, be sure to check the runout of the commutator portion **C**.



(5) Outside diameter of commutator

If the reading is more than the limit, replace the armature assembly **18**.



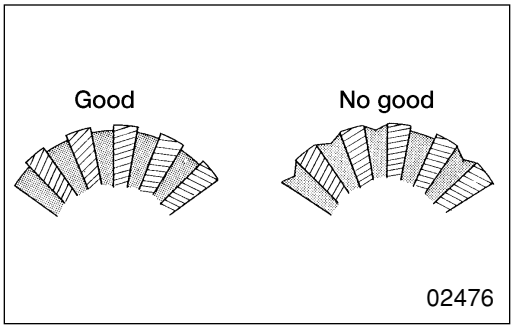
(6) Depth of mold between segments

Before inspection, clean the mold portions.

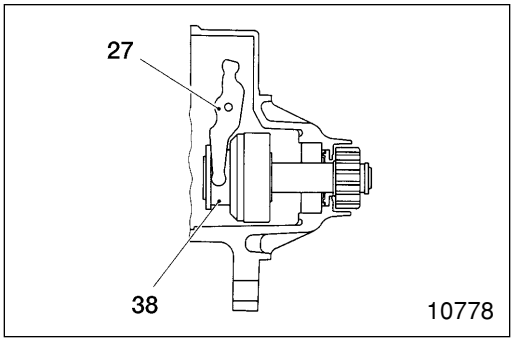
- If the reading is less than the limit, repair or replace the armature assembly **18**.

  F: Depth of mold

- Make repairs by grinding the illustrated portion **G**.

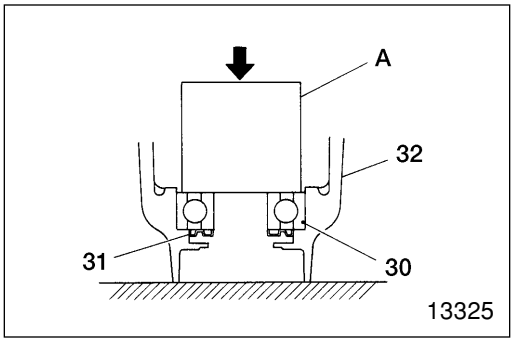


- If the mold portion is as shown, repair or replace the armature assembly **18**.



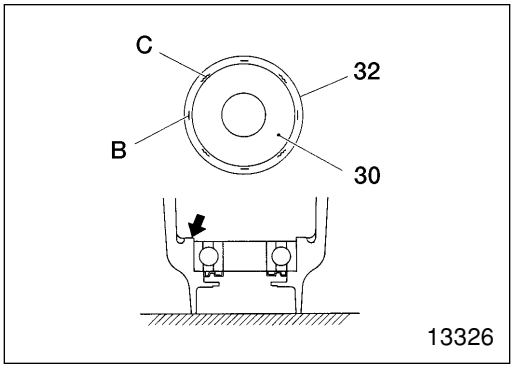
27 Installation of lever

Install the lever **27** in the illustrated direction on the overrunning clutch **38**.



30 Installation of front bearing

- Before the front bearing **30** is press-fitted, install the dust seal **31**.
- Press-fit the front bearing **30** in the front bracket with a press, using the pipe-like tool **A**.

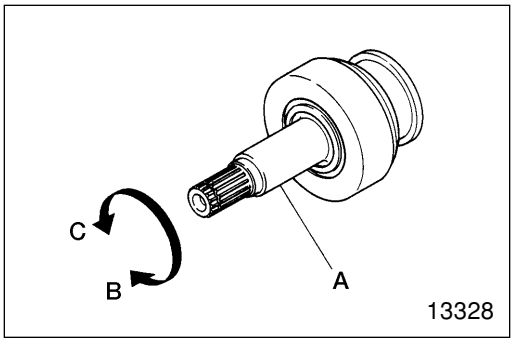


- Stake the front bracket **32** side.

CAUTION

Avoid staking the previously staked points B.

C: Staking points (4 places)



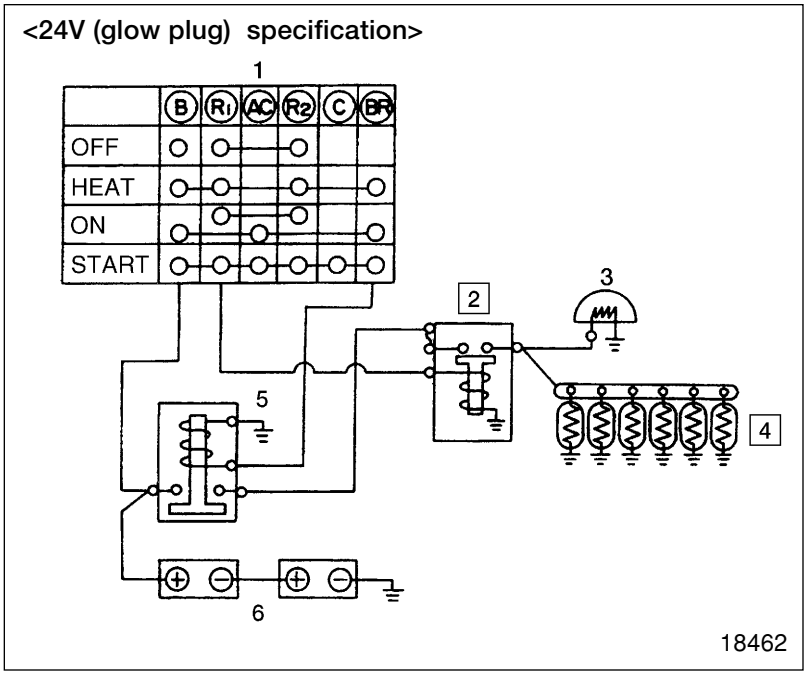
38 Inspection of overrunning clutch

Perform the following checks. If there is anything wrong, replace the overrunning clutch **38**.

- Check to ensure that when the shaft **A** is made to rotate in the direction **B**, it rotates smoothly.
- Check to ensure that when the shaft **A** is made to rotate in the direction **C**, it is locked.

M E M O

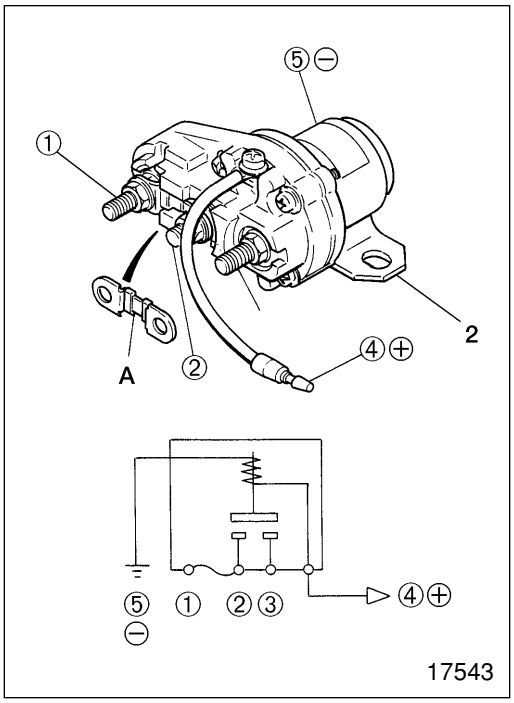
PREHEATER CIRCUIT



1 Starter switch
2 Glow relay
3 Glow plug indicator
4 Glow plug
5 Battery relay
6 Battery

Service standards

Location	Maintenance item	Standard value	Limit	Remedy
4	Resistance of glow plug at normal temperature	3.8 Ω	–	Replace



◆ Service procedure

2 Inspection of glow relay

Inspection of main body

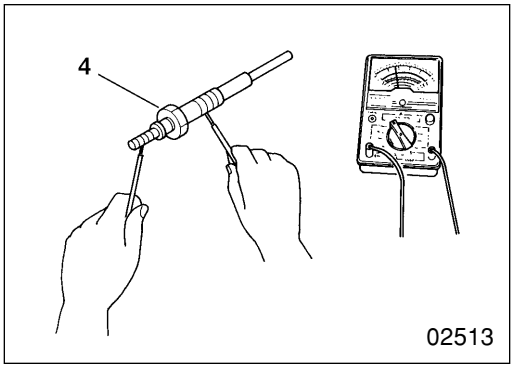
- Perform continuity checks according to the following table.

	①	②	③	④	⑤ (Body ground)
When no current is supplied	○——○			○——○	
When current is supplied	○——○——○			⊕——⊖	

○——○ There is continuity between terminals.
⊕——⊖ Terminals to which 24V DC is applied

A: Fuse

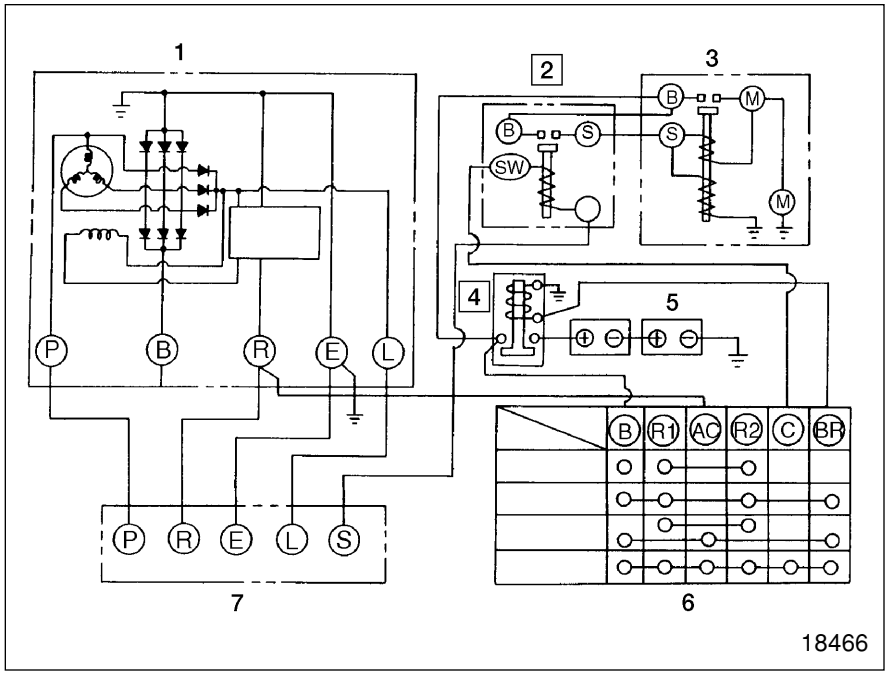
- If there is anything wrong, replace the glow relay **2**.



4 Inspection of glow plug

- Measure the resistance of the glow plug **4** as shown.
- If the reading is out of the standard value, replace the glow plug **6**.
  🕮 Gr 11

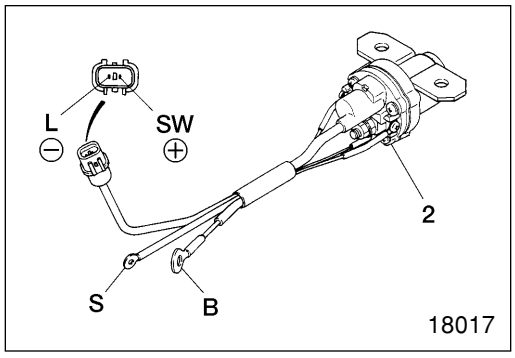
ENGINE STARTER CIRCUIT



1 Alternator
2 Starter relay
3 Starter
4 Battery relay (24V)
5 Battery
6 Starter switch
7 Safety relay

Service standards

Location	Maintenance item	Standard value	Limit	Remedy
7	Safety relay	Approx. 200 V	–	Replace



◆ Service procedure

2 Inspection of starter relay

- Perform continuity checks according to the following table.

	B	S	SW	L
When no current is supplied			○——○	
When current is supplied	○——○		⊕——⊖	

○——○ There is continuity between terminals.
⊕——⊖ Terminals to which 24V DC is applied

- If there is anything wrong, replace the starter relay **2**.

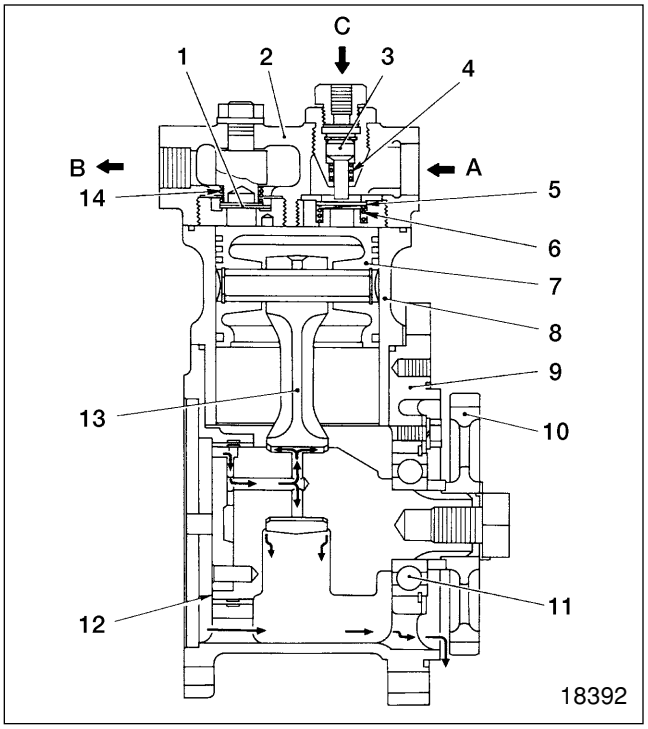
GROUP 61 SPECIAL EQUIPMENT

SPECIFICATIONS 2
STRUCTURE AND OPERATION 3
AIR COMPRESSOR 6

SPECIFICATIONS

Item		Specifications
Air compressor	Type	Air-cooled, single-cylinder
	Cylinder bore × stroke mm (in.)	ϕ80 × 40 (ϕ3.15 × 1.57)
	Cylinder displacement L (U.S.gal.)	201 (0.0531)
	Manufacturer	SANWA SEIKI MFG. CO., LTD

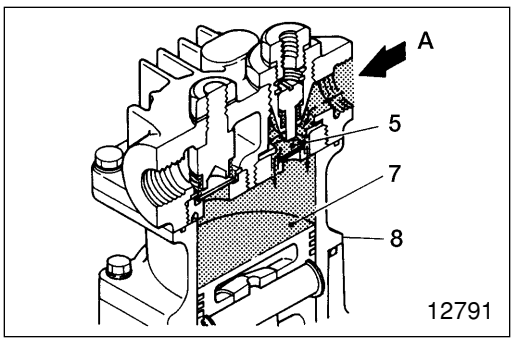
Air Compressor



1 Delivery valve
2 Cylinder head
3 Unloader valve
4 Unloader valve spring
5 Suction valve
6 Suction valve spring
7 Piston
8 Cylinder liner
9 Crankcase
10 Drive gear
11 Bearing
12 Crankshaft
13 Connecting rod
14 Delivery valve spring

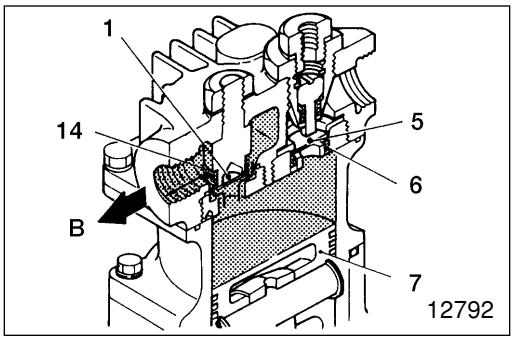
A: From air cleaner
B: To air tank
C: From pressure governor

- The air compressor is driven by drive gear **10** which is in mesh with the timing gear of the engine.
- Cylinder head **2** is provided with fins that prevent it from being overheated by the compression heat generated by the air compressor.



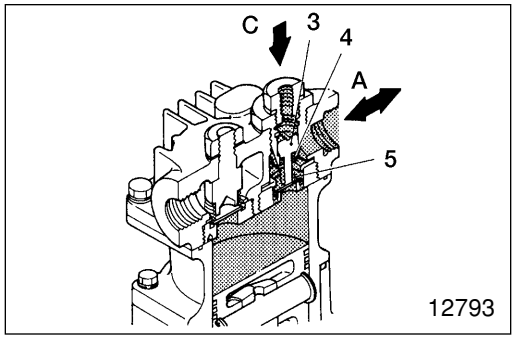
When air is taken in

- When drive gear **10** is turned, crankshaft **12** in mesh with the drive gear lowers piston **7**.
- The vacuum generated at this time opens suction valve **5**, allowing air **A** from the air cleaner to be drawn into cylinder liner **8**.



When air is sent under pressure

- When piston **7** goes up on the compression stroke, suction valve spring **6** closes suction valve **5**.
- The compressed-air pressure overcomes the force of delivery valve spring **14**, pushing to open delivery valve **1**, which results in the air **B** being sent under pressure to the air tank.

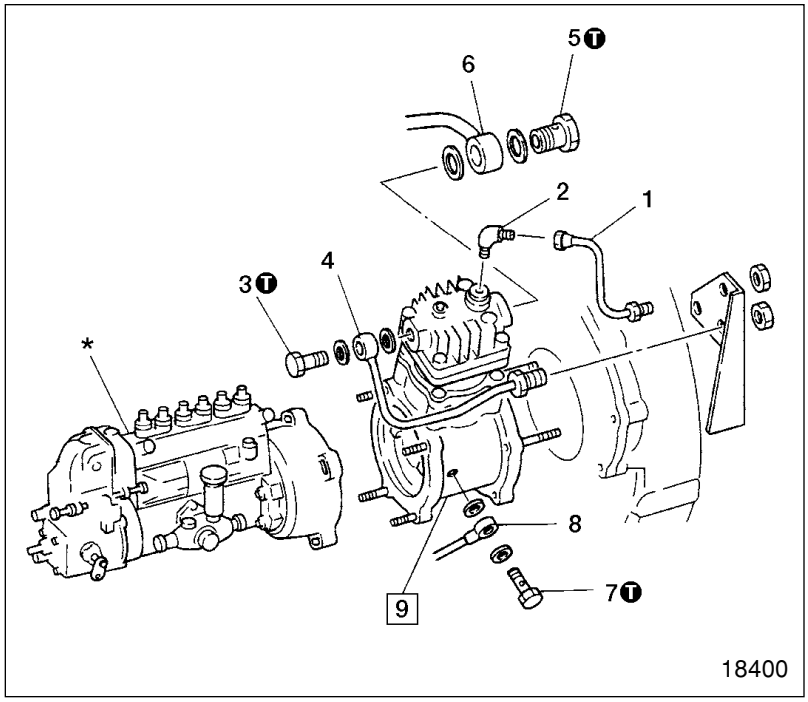


When the unloader valve operates

- When the pressure of the air in the air tank builds up to exceed the predetermined level, the air pressure governor operates and compressed air **C** is sent to unloader valve **3**, pushing down the unloader valve. At the same time, the air keeps suction valve **5** open, which means that the pressure of air **A** is not compressed and the air compressor runs under no load.
- As the air pressure of the air tank drops below the predetermined level, the air pressure governor is operated again to discharge compressed air **C** above unloader valve **3**. As a result, the unloader valve is returned to its original position by unloader valve spring **4**.

M E M O

AIR COMPRESSOR



● **Removal sequence**

1 Unloader pipe
2 Connector
3 Eye bolt
4 Air outlet pipe
5 Eye bolt
6 Air inlet pipe
7 Eye bolt
8 Oil pipe
9 Air compressor assembly 🕮 P61-8

*: Injection pump assembly 🕮 Gr. 13

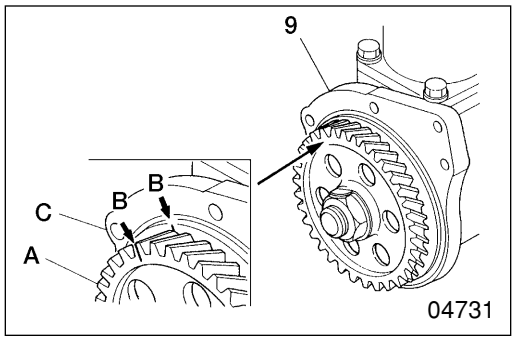
● **Installation sequence**

Reverse the order of removal.

T Tightening torques

Unit: N·m (kgf·m) [lbf·ft]

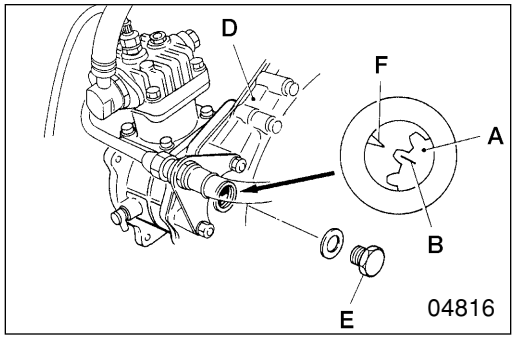
Location	Parts to be tightened	Tightening torque	Remarks
3	Eye bolt	125 (13) [92.2]	–
5	Eye bolt	180 (18) [133]	–
7	Eye bolt	21 (2.1) [15.5]	–



◆ Service procedure

9 Installation of air compressor assembly

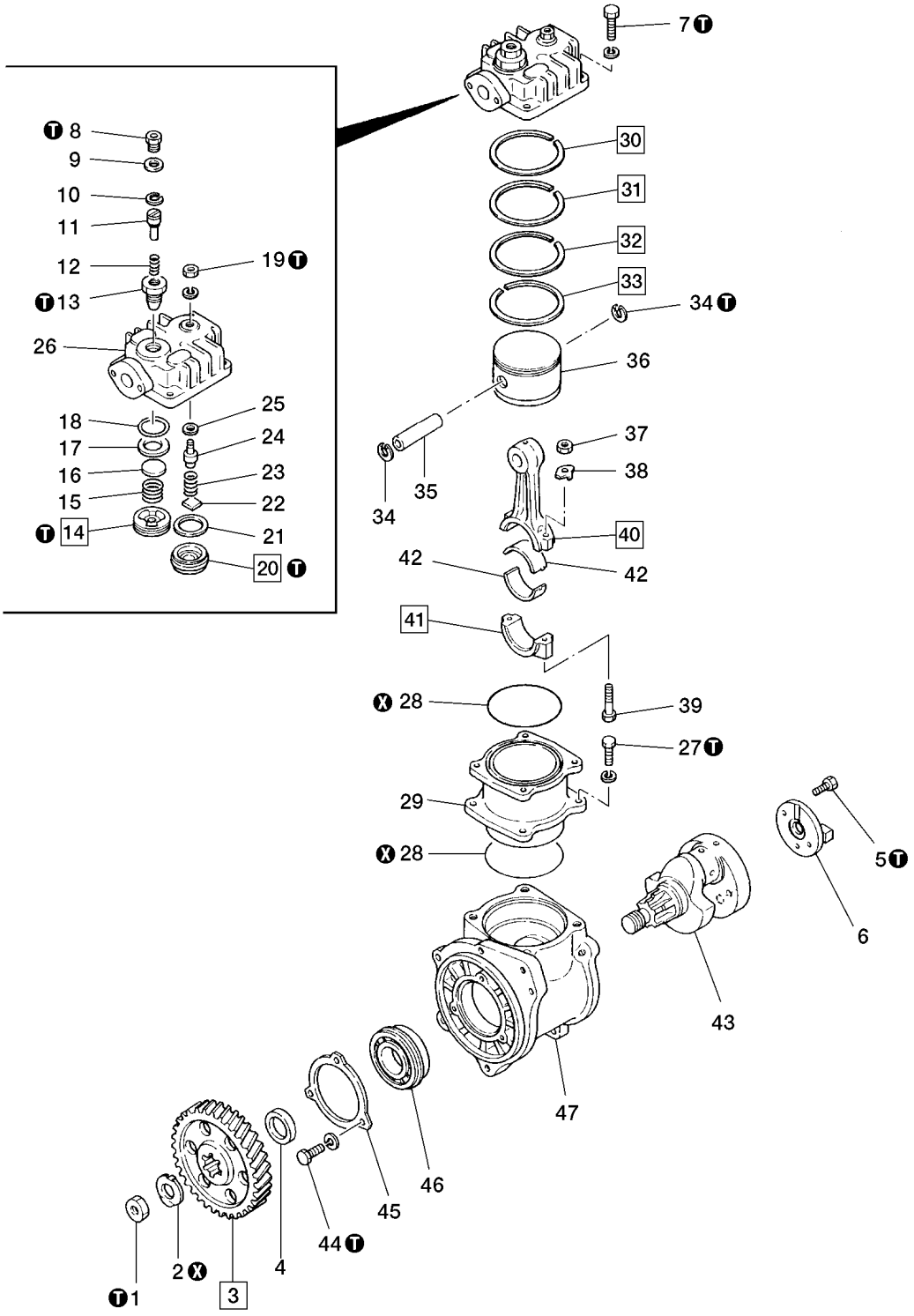
- Bring No. 1 cylinder of the engine to TDC on the compression stroke 🕮 Gr. 11.
- Align line **B** of drive gear **A** of air compressor assembly **9** with line **B** of crankcase **C**.



- Remove inspection plug **E** from flywheel housing **D** and check that line **B** on drive gear **A** is aligned with pointer **F**. If they are not aligned, reinstall.

M E M O

Air Compressor Assembly



18401

● **Disassembly sequence**

1 Nut
2 Lock washer
3 Drive gear
4 Spacer
5 Bolt
6 Coupling
7 Bolt
8 Connector
9 Gasket
10 Snap ring
11 Unloader valve
12 Unloader valve spring
13 Unloader valve guide
14 Suction valve holder
15 Suction valve spring
16 Suction valve
17 Suction valve seat
18 Suction valve gasket
19 Nut
20 Delivery valve holder
21 Suction valve gasket
22 Delivery valve
23 Delivery valve spring
24 Spring holder
25 Gasket
26 Cylinder head
27 Bolt
28 O-ring
29 Cylinder liner
30 1st compression ring
31 2nd compression ring
32 3rd compression ring
33 Oil ring
34 Snap ring
35 Piston pin
36 Piston
37 Nut
38 Lock washer
39 Bolt
40 Connecting rod
41 Connecting-rod cap
42 Bearing
43 Crankshaft
44 Bolt
45 Plate
46 Bearing
47 Crankcase

Ⓧ: Non-reusable part

● **Reassembly sequence**

Reverse the order of disassembly.

Service standards

Unit: mm (in.)

Location	Maintenance item		Standard value	Limit	Remedy
15	Suction valve spring load [Installed length: 9 mm (0.354 in.)]		2.3 N (0.23 kgf) [0.52 lbf]	1.3 N (0.13 kgf) [0.29 lbf]	Replace
23	Suction valve spring load		3.2 N (0.33 kgf) [0.72 lbf]	2.4 N (0.24 kgf) [0.54 lbf]	Replace
29, 36	Clearance between piston and cylinder liner [Basic diameter: 80 mm (3.15 in.)]	Top	0.27 to 0.33 (0.016 to 0.0130)	0.35 (0.0138)	Replace cylinder liner
		Skirt	0.11 to 0.17 (0.00433 o 0.00670)	0.19 (0.00748)	
30 to 33	Piston ring gap (as measured inside cylinder liner)	Compression ring	–	1.0 (0.0394)	Replace
		Oil ring	–	1.0 (0.0394)	
30 to 33, 36	Clearance between piston ring and piston groove	Compression ring	–	0.08 (0.00315)	Replace
		Oil ring	–	0.08 (0.00315)	
35, 36	Clearance between piston pin and piston [Basic diameter: 16 mm (0.630 in.)]		–	0.08 (0.00315)	Replace piston pin
35, 40	Clearance between piston pin and connecting-rod small end [Basic diameter: 16 mm (0.630 in.)]		–	0.07 (0.00276)	Replace connecting rod
40	Connecting rod end play		–	0.5 (0.0197)	Replace connecting rod
42, 43	Clearance between connecting-rod bearing and crankshaft [Basic diameter: 34 mm (1.34 in.)]		–	0.1 (0.0394)	Replace
43	Crankshaft end play and crankshaft		–	1.0 (0.0394)	Replace crankshaft
43, 47	Clearance between crankshaft and crankcase bushing I.D. [Basic diameter: 76.5 mm (3.01 in.)]		–	0.12 (0.00472)	Replace crankshaft

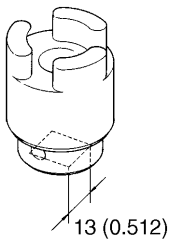
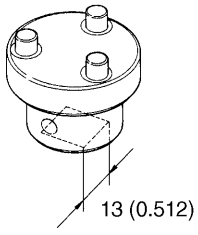
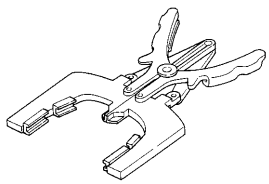
Tightening torques

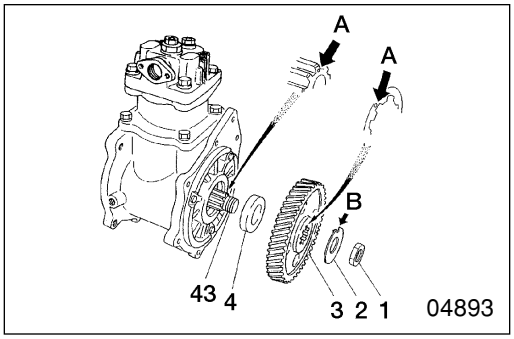
Unit: N·m (kgf·m) [lbf·ft]

Location	Parts to be tightened	Tightening torque	Remarks
1	Nut (for drive gear installation)	165 to 211 (17 to 21.5) [122 to 156]	–
5	Bolt (for coupling installation)	30 to 36 (3.1 to 3.7) [22.1 to 26.6]	–
7	Bolt (for installation of cylinder head and cylinder liner)	25 to 29 (2.5 to 3.0) [18.4 to 21.4]	–
8	Connector	29 to 34 (3.0 to 3.5) [21.4 to 25.1]	–
13	Unloader valve guide	98 to 118 (10 to 12) [72.3 to 87.0]	–
14	Suction valve holder	98 to 118 (10 to 12) [72.3 to 87.0]	–
20	Delivery valve holder	98 to 118 (10 to 12) [72.3 to 87.0]	–
27	Bolt (for installation of cylinder liner and crankcase)	25 to 29 (2.5 to 3.0) [18.4 to 21.4]	–
37	Nut (for installation of connecting rod and connecting-rod cap)	23 to 25 (2.3 to 2.6) [17.0 to 18.4]	–
45	Bolt (for plate installation)	14 to 18 (1.4 to 1.8) [10.3 to 13.3]	–

Special tools

Unit: mm (in.)

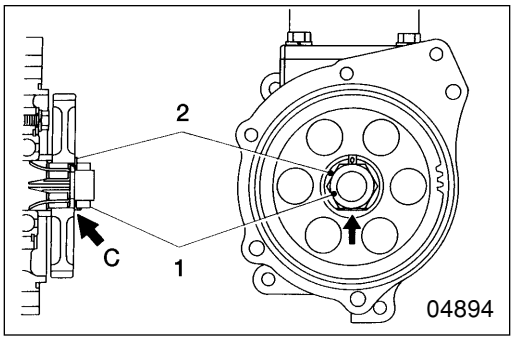
Location	Tool name and shape	Part No.	Application
14	Suction Valve Tool  01730	MH062013	For removal and installation of suction valve holder
20	Delivery Valve Tool  04813	MH062014	For removal and installation of delivery valve holder
30 to 33	Piston Ring Tool  01732	MH060014	For removal and installation of piston rings



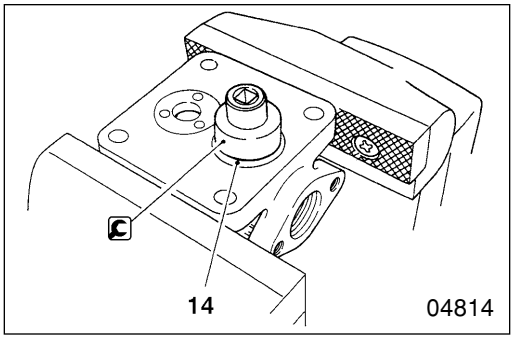
◆ Service procedure

3 Installation of drive gear

- Mount drive gear **3** so that alignment mark **A** "0" on crankshaft **43** is aligned with alignment mark **A** "0" on the drive gear.
  Align the alignment mark on the drive gear with cutout **B** in lock washer **2** and tighten nut **1** to specification.

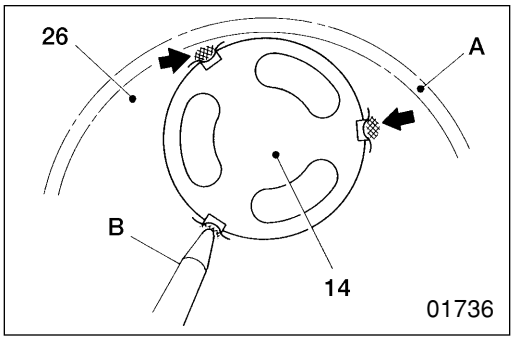


- After installation, bend the lock washer **2** onto **C** on the nut 1 side.



14 Suction valve holder

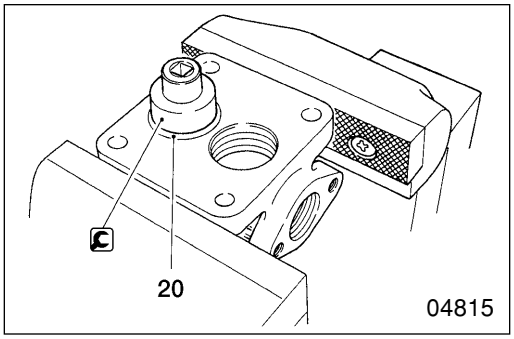
[Removal and Installation]



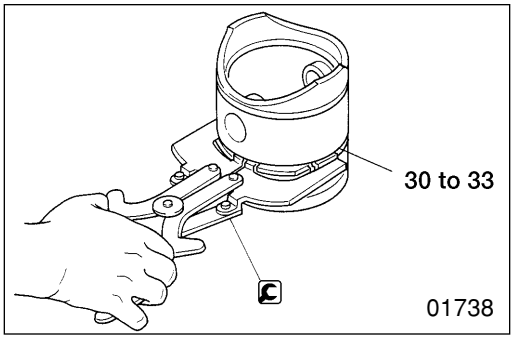
[Staking]

Stake cylinder head **26** at points not corresponding to O-ring's sealing surface **A**.

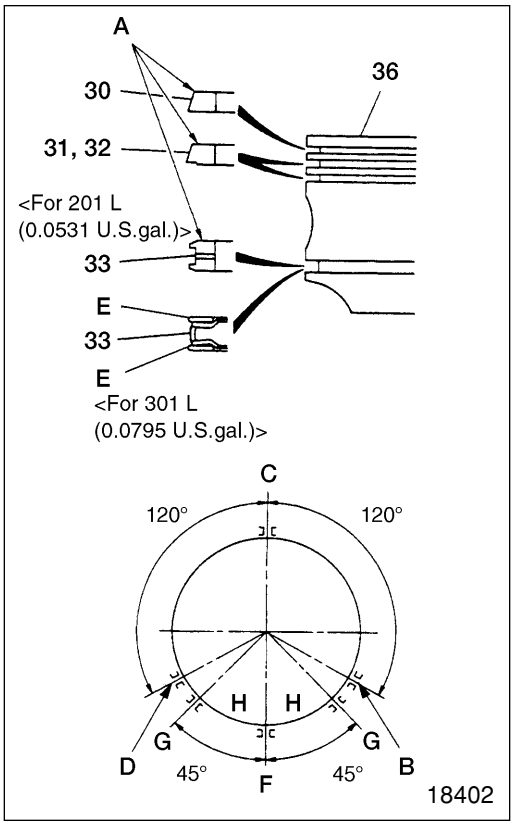
B: Punch



20 Removal and installation of delivery valve holder



30 to **33** **Piston rings**
[Removal and Installation]

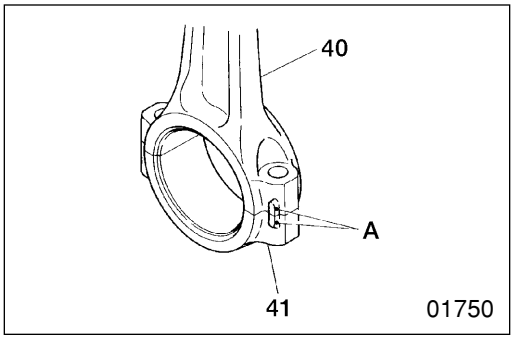


[Installation positions]

- Make sure that compression rings **30** to **32** and oil ring **33** are installed at the correct positions. Face the side on which the letter "**A**" has been stamped to the head of piston **36**.
- Locate each of compression ring ends **B** to **D** 120° apart from each other.

  B: 1st compression ring ends
  C: 2nd compression ring ends
  D: 3rd compression ring ends
  E: Side rail <For 301 L (0.0795 U.S.gal.)>

- Position oil ring ends **F** at the center of the compression ring ends **B**, **D**.
- Install the side rail with its ends **G** 45° away from oil rings ends **F**.



40 **41** **Installation of connecting rod and connecting-rod cap**
Align alignment marks **A** on connecting rod **40** and connecting-rod cap **41**.

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