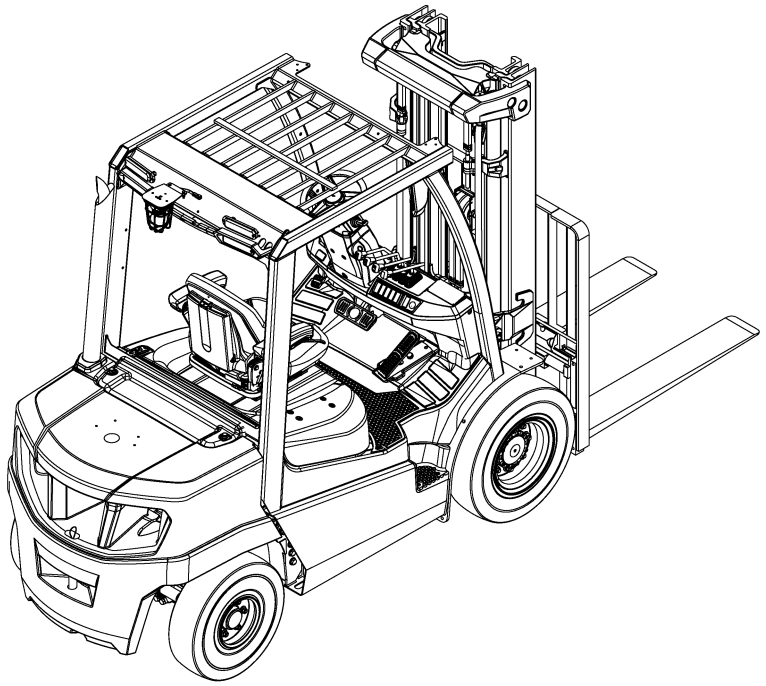
YANMAR ENGINES

H2.0A, H2.5A6, H2.5A, H3.0A, H3.5A (H40A, H50A6, H60A, H70A) [R177]



HYSTER

PART NO. 4277933

0600 SRM 2299

SAFETY PRECAUTIONS
MAINTENANCE AND REPAIR

- The Service Manuals are updated on a regular basis, but may not reflect recent design changes to the product. Updated technical service information may be available from your local authorized Hyster® dealer. Service Manuals provide general guidelines for maintenance and service and are intended for use by trained and experienced technicians. Failure to properly maintain equipment or to follow instructions contained in the Service Manual could result in damage to the products, personal injury, property damage or death.
- When lifting parts or assemblies, make sure all slings, chains, or cables are correctly fastened, and that the load being lifted is balanced. Make sure the crane, cables, and chains have the capacity to support the weight of the load.
- Do not lift heavy parts by hand; always use a lifting mechanism.
- Wear safety glasses.
- DISCONNECT THE BATTERY before doing any maintenance or repair on electric lift trucks. Disconnect the battery ground cable on internal combustion lift trucks.
- Always use correct blocks to prevent the unit from rolling or falling. See HOW TO PUT THE LIFT TRUCK ON BLOCKS in the **Operating Manual** or the **Periodic Maintenance** section of the service manual.
- Keep the unit clean and the working area clean and orderly.
- Use the correct tools for the job.
- Keep the tools clean and in good condition.
- Always use **HYSTER ® APPROVED** parts when making repairs. Replacement parts must meet or exceed the specifications of the original equipment manufacturer.
- Make sure all nuts, bolts, snap rings, and other fastening devices are removed before using force to remove parts.
- Always fasten a DO NOT OPERATE tag to the controls of the unit when making repairs, or if the unit needs repairs.
- Strictly follow all **WARNING** and **CAUTION** notes in the operating manual, safety labels, service manual, and other instructions.
- Gasoline, Liquid Petroleum Gas (LPG), Compressed Natural Gas (CNG), Hydrogen Gas (H2), and Diesel fuels are flammable and potentially explosive. Hydraulic, transmission, and other fluids and oils are also flammable. Be sure to follow the necessary safety precautions when handling these substances or working on systems containing these substances.
- Lead acid batteries generate flammable gas when they are being charged. Keep fire and sparks away from the area. Make sure the area is well ventilated.
- Lithium-ion batteries should only be used in working environments where the temperature is within the recommended operating range (typically between 0 - 45°C (32 - 113°F)). Extreme temperatures, moisture, improper charging or damage to the battery can cause a fire or explosion.
- Whenever Diagnostic tools are needed for engine, only licensed or certified persons can use Diagnostic tools.

NOTE: The following symbols and words indicate safety information in this manual:

WARNING

Indicates a hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION

Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury and property damage.

On the lift truck, the WARNING symbol (and word, if present) are on orange background. The CAUTION symbol (and word, if present) are on yellow background.

WARNING

Installing improper electrical accessories or installing an electrical accessory incorrectly can increase the risk of equipment damage, personal injury and fire. DO NOT install electrical accessories to the truck unless you have been trained and authorized to do so. Personnel installing the electrical accessories must document the changes made to the truck. DO NOT install accessories which affect the truck's compliance with standard ANSI/ITSDF B56.1, UL 558, or UL 583, or which otherwise affect the safe operation of the truck.

WARNING

Installing improper electrical accessories or installing an electrical accessory incorrectly can increase the risk of equipment damage, personal injury and fire. DO NOT install electrical accessories to the truck unless you have been trained and authorized to do so. Personnel installing the electrical accessories must document the changes made to the truck. DO NOT install accessories which affect the truck's compliance with standard EN 1175:2020.

WARNING

California Proposition 65 - Operating, servicing and maintaining a powered industrial truck can expose you to chemicals including engine exhaust, carbon monoxide, phthalates, and lead, which are known to the State of California to cause cancer and birth defects or other reproductive harm. For more information, go to www.P65Warnings.ca.gov.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

"THE QUALITY KEEPERS"

HYSTER APPROVED PARTS

Introduction

GENERAL
202001-001

NOTE: For any fasteners in this manual that feature standard torque specifications, please refer to **Metric and Inch (SAE) Fasteners** 8000SRM0231 for correct specifications.

DISCHARGING THE CAPACITORS

WARNING

DO NOT make repairs or adjustments unless you have been properly trained and authorized to do so. Improper repairs and adjustments can create dangerous operating conditions. DO NOT operate a lift truck that needs repairs. Report the need for repairs to your supervisor immediately. If repair is necessary, attach a DO NOT OPERATE tag on the steering wheel and disconnect the battery.

Disconnect the battery and discharge the capacitors before opening any compartment covers or inspecting or repairing the electrical system. DO NOT place tools on top of the battery. If a tool causes a short circuit, the high current flow form the battery can cause personal injury or property damage.

Some check and adjustments are performed with the battery connected. DO NOT connect the battery until the procedure instructs you to do so. Never wear any metallic items on your fingers, arms, or neck. Metal items can accidentally make an electrical connection and cause injury. Before performing any tests or adjustments, block the lift truck to prevent unexpected movement.

The capacitors in the transistor controller(s) can hold an electrical charge for about 10 minutes after the battery is disconnected. To prevent an electrical shock and personal injury, discharge the capacitor(s) before inspecting or repairing any component in the drive unit compartment. Make certain that the battery had been disconnected.

DO NOT short across the motor controller terminals with a screwdriver or jumper wire.

Make certain the Emergency-Stop Switch has not been activated. This will isolate the controller and prevent the capacitors from discharging properly. The proper way to disconnect the battery is by separating the battery connectors.

DISCHARGING THE CAPACITORS: For trucks with rapid-charge option, the horn cannot be used to discharge capacitors prior to service. Disconnect the battery, then wait five minutes before performing any service on the truck.

1. Ensure the capacitors are discharged by performing Step 2 through Step 6 below.
2. Turn the key or keyless switch to **OFF** position.
3. Disconnect the battery by separating the connector on the battery cable from the connector on the lift truck.
4. Block the drive wheels to prevent the lift truck from moving.
5. Make sure the Emergency-Stop Switch **HAS NOT** been activated. If the Emergency-Stop Switch is activated, rotate the switch to the right until it pops up.
6. Press the horn button on the steering column. Wait 30 seconds to be sure capacitors are fully discharged. If the horn does not sound when the switch is actuated, wait 10 minutes before proceeding with service.
   For lift trucks equipped with rapid-charge option, the horn cannot be used to discharge capacitors prior to service. Disconnect the battery, then wait five minutes before performing any service on the truck.

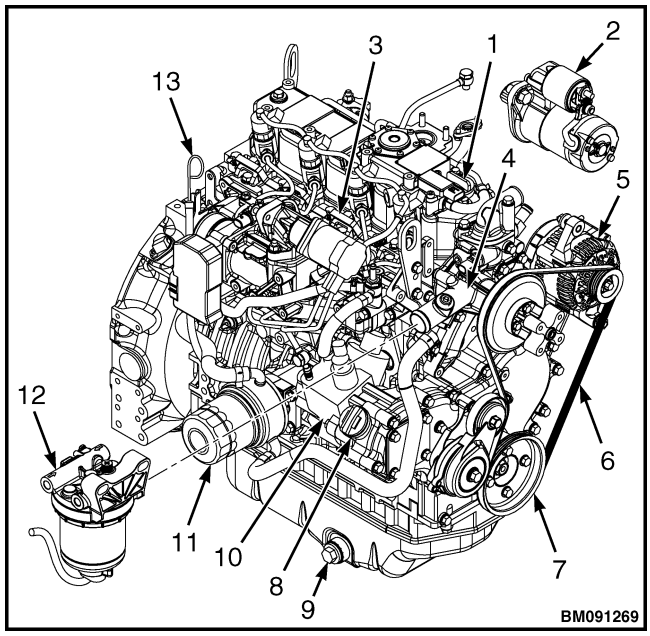
ENGINE IDENTIFICATION
202001-010

This section contains repair instructions for the following Yanmar engines:

Yanmar number	Hyster number	Description	Model
4TNV86CHT-XNHYG	4667918	2.1L engine Diesel CAC W/DPF	H2.0-3.5A, H2.5A6 (H40-70A) (R177)
4TNV86CT	4667873	2.1L engine Diesel	H2.0-2.5A (H40-50A) (R177)
4TNV86CHT	4667918		H2.5A6, H3.0-3.5A (H60-70A) (R177)
4TNE94L-BSHYG	4671891	3.0L engine Diesel	H2.0-3.5A, H2.5A6 (H40-70A) (R177)
4TNE98-BQHYG	4671892	3.3L engine Diesel	H2.0-3.5A, H2.5A6 (H40-70A) (R177)
4TN86DHT-XNHYG	4667872	2.1L engine Diesel CAC W/DOC	H2.0-3.5A, H2.5A6 (H40-70A) (R177)
4TNE94L-BSNMH	4713670	3.0L engine Diesel	H2.0-3.5A, H2.5A6 (H40-70A) (R177)
4TNE98L-BNMH	4713672	3.3L engine Diesel	H2.0-3.5A, H2.5A6 (H40-70A) (R177)
4TN88G	4667917	2.2L engine LPG	H2.0-3.5A, H2.5A6 (H40-70A) (R177)
4TN88GN-NHYG	4671902	2.2L engine LPG	H2.0-3.5A, H2.5A6 (H40-70A) (R177)
4TN888	4671903	2.2L engine Bi-Fuel	H2.0-3.5A, H2.5A6 (H40-70A) (R177)
4TN888N	4671959	2.2L engine Bi-Fuel	H2.0-3.5A, H2.5A6 (H40-70A) (R177)
TBD	4700608	2.2L engine CNG	H2.0-3.5A, H2.5A6 (H40-70A) (R177)

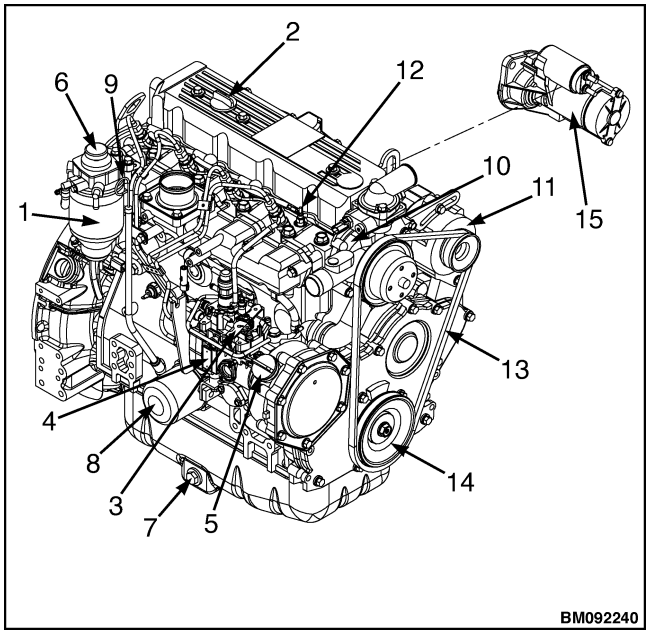
MAJOR ENGINE COMPONENT IDENTIFICATION

The following figure shows where the major engine components are located.



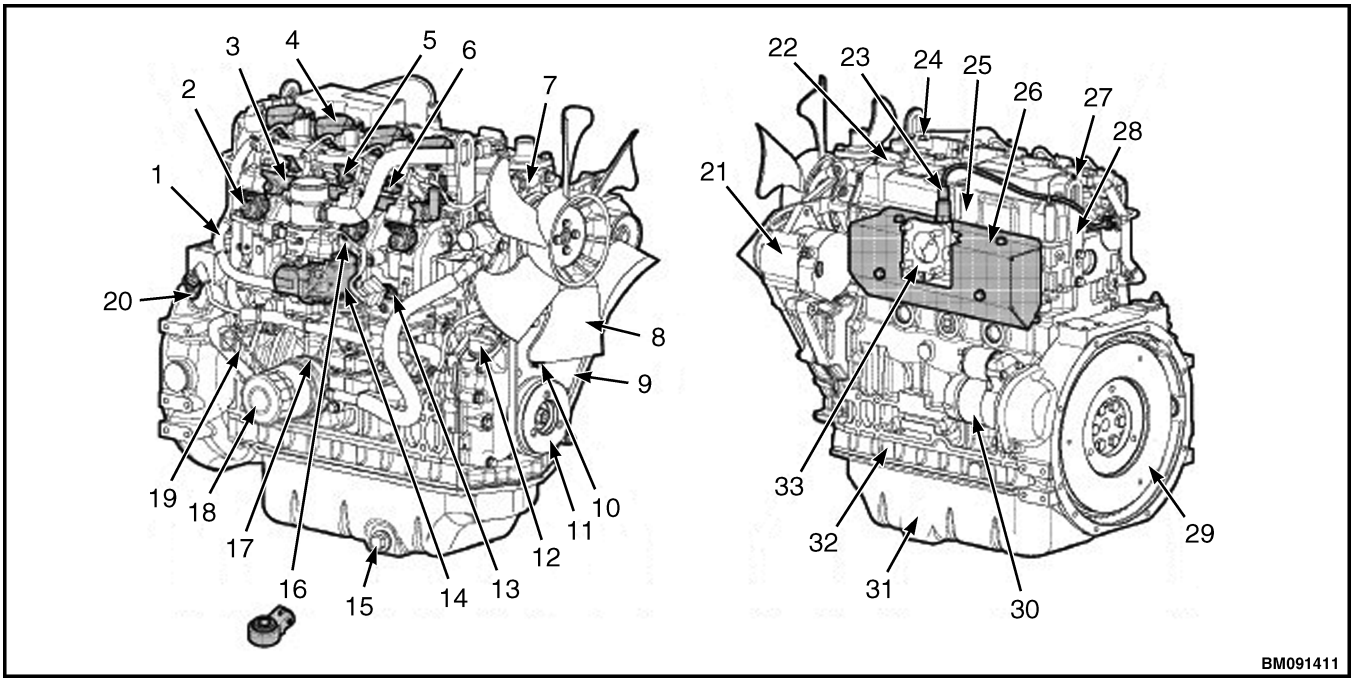
1. TOP FILLER PORT (ENGINE OIL)
2. STARTER MOTOR
3. GLOW PLUG
4. WATER PUMP
5. ALTERNATOR
6. V-BELT
7. CRANKSHAFT V-PULLEY
8. SIDE FILLER PORT (ENGINE OIL)
9. DRAIN PLUG (ENGINE OIL)
10. FUEL INJECTION PUMP
11. ENGINE OIL FILTER
12. WATER SEPARATOR/FUEL FILTER
13. DIPSTICK (ENGINE OIL)

Figure 1. Major engine components (Yanmar 2.1L diesel engines)



1. WATER SEPARATOR/FUEL FILTER
2. TOP FILLER PORT (ENGINE OIL)
3. GOVERNOR LEVER
4. FUEL INJECTION PUMP
5. SIDE FILLER PORT (ENGINE OIL)
6. FUEL PRIMING PUMP
7. DRAIN PLUG (ENGINE OIL)
8. ENGINE OIL FILTER
9. DIPSTICK (ENGINE OIL)
10. ENGINE COOLANT PUMP
11. ALTERNATOR
12. GLOW PLUG
13. V-BELT
14. CRANKSHAFT V-PULLEY
15. STARTER MOTOR

Figure 2. Major engine components (Yanmar 3.0 and 3.3L diesel engines)



NOTE: THE LPG ENGINE ILLUSTRATED IS AN EXAMPLE AND MAY NOT REFLECT THE LPG ENGINE IN YOUR TRUCK.

1. BREATHER HOSE
2. GAS INJECTORS
3. GAS FUEL RAIL
4. IGNITION COILS
5. SPARK PLUGS
6. FUEL TEMP. AND PRESSURE SENSOR
7. WATER PUMP
8. ENGINE COOLING FAN
9. V-BELT
10. CAM SPEED SENSOR
11. CRANKSHAFT V-PULLEY
12. SIDE FILLER PORT (ENGINE OIL)
13. INTAKE TEMP. AND PRESSURE SENSOR
14. INTAKE THROTTLE
15. DRAIN PLUG (ENGINE OIL)
16. KNOCK SENSOR
17. ENGINE LUBRICATING OIL COOLER
18. ENGINE LUBRICATING OIL FILTER
19. DIPSTICK (ENGINE OIL)
20. CRANK SPEED SENSOR
21. ALTERNATOR
22. TOP FILLER PORT (ENGINE OIL)
23. O^2 SENSOR
24. LIFTING EYE (ENGINE COOLING FAN END)
25. CYLINDER HEAD COVER
26. EXHAUST INSULATOR
27. PCV VALVE
28. LIFTING EYE (FLYWHEEL END)
29. FLYWHEEL
30. STARTER
31. OIL PAN
32. OIL PAN SPACER
33. EXHAUST MANIFOLD

Figure 3. Major engine components (LPG engines)

LOCATION OF LABELS

Diesel engine labels

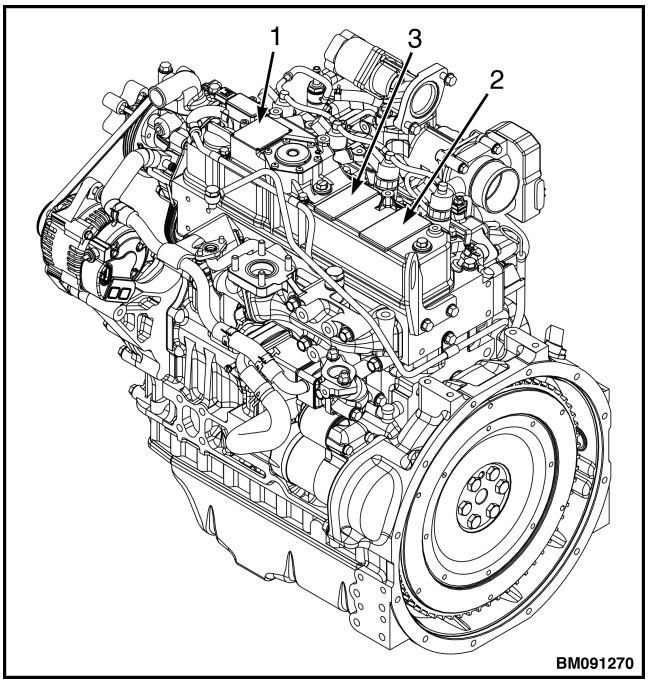


Figure 4. Diesel engine labels

Table 1. Legend for diesel engine labels

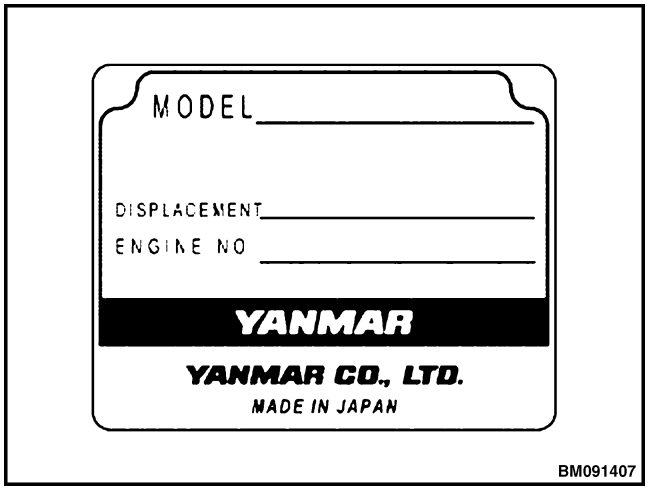
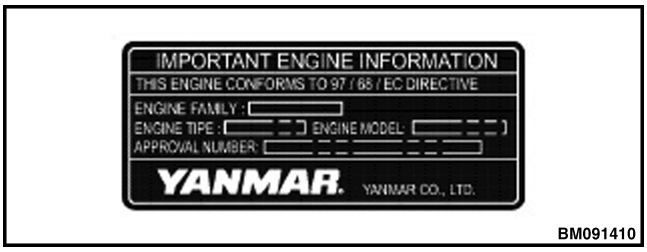
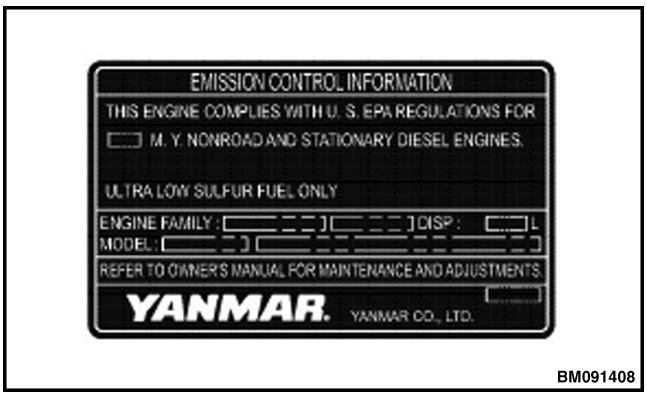
Item number	Name	Label	Description
1	Engine nameplate		Contains model information and unique engine serial number.

Table 1. Legend for diesel engine labels (Continued)

Item number	Name	Label	Description
2	97/68/EC Directive Certified Engines 4TNV86CT or 4TNV86CHT		Contains information stating that the engines described in this manual have been certified by the 97/68/EC Directive.
3	EPA certification label 4TNV86CT		Contains information certifying compliance with United States Environmental Protection Agency (EPA) emission control regulations, as well as California Air Resources Board (ARB) regulations. Only engines that conform to ARB regulations can be sold in the state of California.

LPG engine

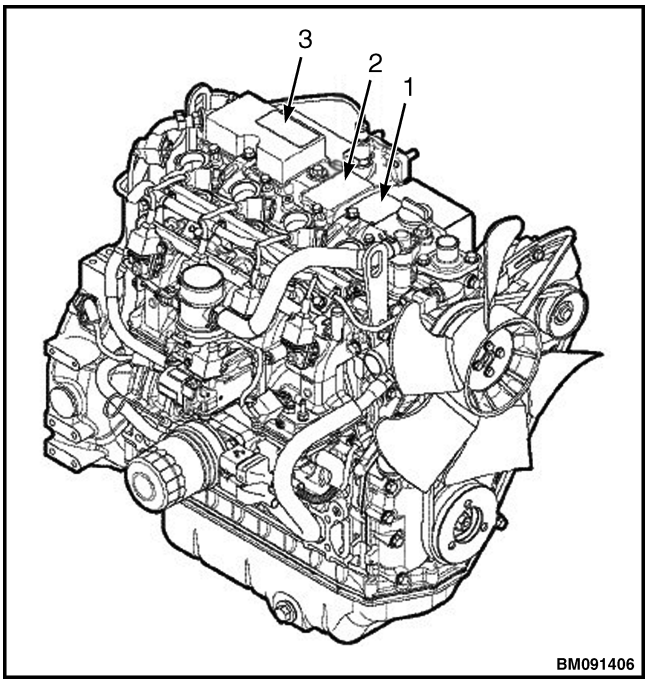


Figure 5. LPG engine labels

Table 2. Legend for LPG engine labels

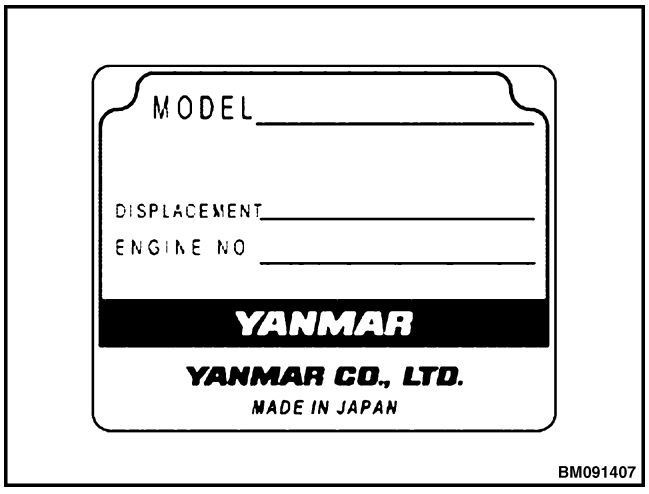
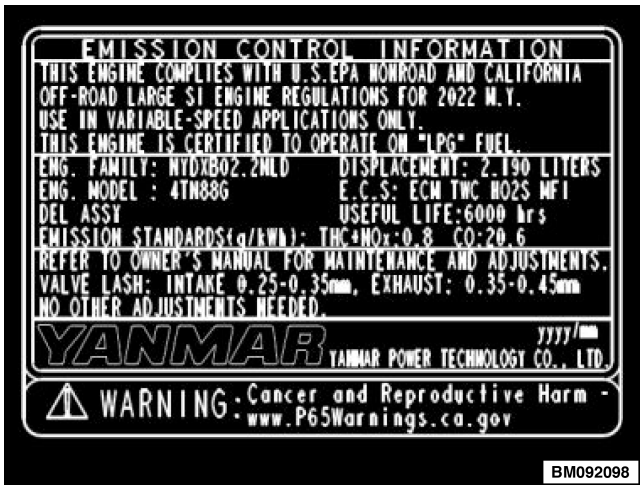
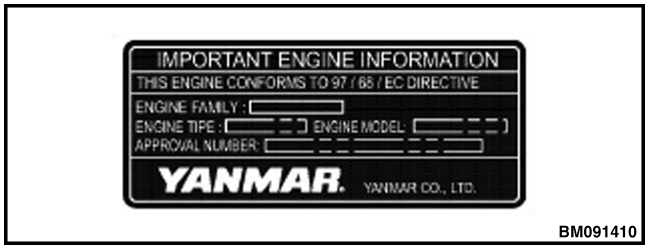
Item number	Name	Label	Description
1	Engine nameplate		Contains model information and unique engine serial number.

Table 2. Legend for LPG engine labels (Continued)

Item number	Name	Label	Description
2*	EPA/ARB certification label		Contains information certifying compliance with United States Environmental Protection Agency (EPA) emission control regulations, as well as California Air Resources Board (ARB) regulations. Only engines that conform to ARB regulations can be sold in the state of California.
3	EU Stage V emission control label		Contains information stating that the engines described in this manual have been certified under EU Stage V regulations.
*Optional			

Diesel engine repair (Yanmar 2.1L)

DIESEL ENGINE SPECIFICATIONS 202001-011

GENERAL ENGINE DATA

Table 3. Yanmar 2.1L diesel engines

Specification type	Engine type		
	4TNV86CT (w/DPF)	4TNV86CHT (w/DPF and CAC)	4TNV86DHT (w/DOC and CAC)
Number of cylinders	4	4	4
Aspiration/combustion type	Turbocharged, DI	Turbocharged, DI	Turbocharged, DI
Minimum idle speed	865-885 rpm	865-885 rpm	865-885 rpm
Maximum idle speed	2520-2540 rpm	2520-2540 rpm	2520-2540 rpm
Cold low idle speed	990-1010 rpm	990-1010 rpm	990-1010 rpm
Bore x stroke	86 x 90 mm (3.4 x 3.5 in.)	86 x 90 mm (3.4 x 3.5 in.)	86 x 90 mm (3.4 x 3.5 in.)
Displacement	2091 cm^3	2091 cm^3	2091 cm^3
Compression ratio	19.2	19.2	17.3
Firing order	1-3-4-2	1-3-4-2	1-3-4-2
Starting aid	Glow plug	Glow plug	Glow plug
EGR	Yes	Yes	Yes
Aftertreatment	DPF	DPF	DOC
Peak torque	161.5 N•m (119.12 lbf ft)	193.3 N•m (142.6 lbf ft)	193.3 N•m (142.6 lbf ft)
Peak torque speed	1625 rpm	1625 rpm	1625 rpm
Rated output	37 kW (49.6 hp)	44 kW (59 hp)	44 kW (59 hp)
Rated speed	2500 rpm	2500 rpm	2500 rpm
CO_2 value, Hot NRTC (g/kWh)	837	756	N/A
Oil consumption @Rated Power (g/hr.)	TBD		
Speed fluctuation (RPM)	TBD		
Overspeed-Instantaneous (RPM)	TBD		
Overspeed-Continuous (RPM)	TBD		
Thrust load (dynamic) (N)	1372	1372	1372
Thrust load (static) (N)	2842	2842	2842

Table 3. Yanmar 2.1L diesel engines (Continued)

Specification type	Engine type		
	4TNV86CT (w/DPF)	4TNV86CHT (w/DPF and CAC)	4TNV86DHT (w/DOC and CAC)
Allowable bending moment	1770 N•m (1305 lbf ft)	1770 N•m (1305 lbf ft)	1770 N•m (1305 lbf ft)
Allowable gradeability (fore and aft)	25° Continuous		
Allowable gradeability (right and left)	25° Continuous		

INTAKE AIR SYSTEM

Table 4. Yanmar 2.1L diesel engines

Specification type	Engine type		
	4TNV86CT (w/DPF)	4TNV86CHT (w/DPF and CAC)	4TNV86DHT (w/DOC and CAC)
Air cleaner size (recommended)	7 in. diameter, radial flow		
Intake air volume @Rated Power (m3 / min.)	3.70	4.15	6.35
Inlet restriction (EGR closed)– new filter (Pa)	-2900	-2900	-3900
Inlet Restriction (EGR closed)– limit (Pa)	-6200	-6200	-6200

EXHAUST SYSTEM

Table 5. Yanmar 2.1L diesel engines

Specification type	Engine type		
	4TNV86CT (w/DPF)	4TNV86CHT (w/DPF and CAC)	4TNV86DHT (w/DOC and CAC)
Exhaust gas volume @Rated Power (kg/h)	240.76	250.59	275.42
Exhaust restriction (EGR closed)– limit (Pa)	16	16	17

COOLING SYSTEM

Table 6. Yanmar 2.1L diesel engines

Specification type	Engine type		
	4TNV86CT (w/DPF)	4TNV86CHT (w/DPF and CAC)	4TNV86DHT (w/DOC and CAC)
Coolant type	LLC		
Coolant temp (max)	110°C (230°F)		
Coolant volume (engine only)	2.0 liter (2.11 qt)		
Thermostat start to full open temp	71-85°C (160-185°F)		
Radiator cap pressure	88.3 kPa (12.8 psi)		
Heat rejection @Rated Power(kW)	32.7 kW (43.9 hp)	31.3 kW (42 hp)	32.9 kW (44.1 hp)
CAC	No	Yes	Yes
CAC heat rejection	N/A	8.2 kW (11 hp)	8.2 kW (11 hp)
Maximum CAC pressure drop (kPa)	N/A	9.1 kPa (1.32 psi)	8.5 kPa (1.23 psi)
Maximum CAC outlet temperature, 25C ambient	N/A	52°C (125.6°F)	52°C (125.6°F)
Air Mass Flow (kg/h)	N/A	201	282

ENGINE PERFORMANCE

Table 7. Yanmar 2.1L diesel engine: 4TNV86CT

Speed (RPM)	Torque	Power
875	143.3 N•m (105.7 lbf ft)	13.1 kW (17.6 hp)
1000	148.1 N•m (109.2 lbf ft)	15.5 kW (20.8 hp)
1200	154.9 N•m (114.2 lbf ft)	19.5 kW (26.1 hp)
1300	158.0 N•m (116.5 lbf ft)	21.5 kW (26.1 hp)
1400	161.0 N•m (118.7 lbf ft)	23.6 kW (28.8 hp)
1500	163.5 N•m (120.6 lbf ft)	25.7 kW (34.5 hp)
1575	165.2 N•m (121.8 lbf ft)	27.2 kW (36.5 hp)
1625	167.1 N•m (123.2 lbf ft)	28.4 kW (38.1 hp)
1675	166.2 N•m (122.6 lbf ft)	29.2 kW (39.2 hp)
1700	165.5 N•m (122.1 lbf ft)	29.5 kW (39.7 hp)
1800	162.8 N•m (120.1 lbf ft)	30.7 kW (41.2 hp)
1900	160.9 N•m (118.7 lbf ft)	32.0 kW (42.9 hp)
1950	159.6 N•m (117.7 lbf ft)	32.6 kW (43.9 hp)

Table 7. Yanmar 2.1L diesel engine: 4TNV86CT (Continued)

Speed (RPM)	Torque	Power
2000	158.3 N•m (116.8 lbf ft)	33.2 kW (44.5 hp)
2100	154.6 N•m (114.0 lbf ft)	34.0 kW (45.6 hp)
2200	152.3 N•m (112.3 lbf ft)	35.1 kW (47.1 hp)
2300	147.5 N•m (108.8 lbf ft)	35.5 kW (47.6 hp)
2400	142.4 N•m (105.0 lbf ft)	35.8 kW (48 hp)
2450	140.7 N•m (103.8 lbf ft)	36.1 kW (48.4 hp)
2500	140.1 N•m (103.3 lbf ft)	36.7 kW (49.2 hp)
2530	139.1 N•m (102.6 lbf ft)	36.9 kW (49.5 hp)

Table 8. Yanmar 2.1L diesel engine: 4TNV86CHT

Speed (RPM)	Torque	Power
875	158.1 N•m (116.6 lbf ft)	14.5 kW (19.4 hp)
1000	164.4 N•m (121.3 lbf ft)	17.2 kW (23.1 hp)
1200	185.9 N•m (137.1 lbf ft)	23.4 kW (31.4 hp)
1300	189.4 N•m (139.7 lbf ft)	25.8 kW (34.6 hp)
1400	192.9 N•m (142.3 lbf ft)	28.3 kW (38 hp)
1500	196.5 N•m (144.4 lbf ft)	30.9 kW (41.3 hp)
1575	199.5 N•m (147.1 lbf ft)	32.9 kW (44.1 hp)
1625	202.0 N•m (149.0 lbf ft)	34.4 kW (46.1 hp)
1675	201.6 N•m (148.7 lbf ft)	35.4 kW (47.5 hp)
1700	201.0 N•m (148.3 lbf ft)	35.8 kW (48 hp)
1800	196.9 N•m (145.2 lbf ft)	37.1 kW (49.8 hp)
1900	194.4 N•m (143.4 lbf ft)	38.7 kW (51.9 hp)
1950	192.5 N•m (142 lbf ft)	39.3 kW (52.7 hp)
2000	190.7 N•m (140.7 lbf ft)	39.9 kW (53.5 hp)
2100	187.1 N•m (138 lbf ft)	41.1 kW (55.1 hp)
2200	182.8 N•m (134.8 lbf ft)	42.1 kW (56.5 hp)
2300	178.3 N•m (131.5 lbf ft)	42.9 kW (57.9 hp)
2400	173.8 N•m (128.2 lbf ft)	43.7 kW (58.6 hp)
2450	171.2 N•m (126.3 lbf ft)	43.9 kW (58.9 hp)
2500	167.9 N•m (123.8 lbf ft)	44.0 kW (59.0 hp)
2530	165.4 N•m (122 lbf ft)	43.8 kW (58.7 hp)

Table 9. Yanmar 2.1L diesel engine: 4TNV86DHT

Speed (RPM)	Torque	Power
800	145.3 N•m (107.2 lbf ft)	12.2 kW (16.4 hp)
1000	162.9 N•m (120.1 lbf ft)	17.1 kW (22.9 hp)
1200	184.4 N•m (136.0 lbf ft)	23.2 kW (31.1 hp)
1300	188.8 N•m (139.3 lbf ft)	25.7 kW (34.5 hp)
1400	192.0 N•m (141.6 lbf ft)	28.2 kW (37.8 hp)
1500	195.7 N•m (144.3 lbf ft)	30.7 kW (41.2 hp)
1625	201.1 N•m (148.3 lbf ft)	34.2 kW (45.9 hp)
1700	198.3 N•m (146.3 lbf ft)	35.0 kW (46.9 hp)
1800	194.0 N•m (143.1 lbf ft)	36.6 kW (49.1 hp)
1900	190.7 N•m (140.7 lbf ft)	37.9 kW (50.8 hp)
2000	187.0 N•m (137.9 lbf ft)	39.2 kW (52.6 hp)
2100	184.3 N•m (135.9 lbf ft)	40.5 kW (54.3 hp)
2200	180.1 N•m (132.8 lbf ft)	41.5 kW (55.7 hp)
2300	176.2 N•m (130.0 lbf ft)	42.4 kW (56.9 hp)
2400	170.9 N•m (126.0 lbf ft)	43.0 kW (57.7 hp)
2500	168.0 N•m (123.9 lbf ft)	44.0 kW (59.0 hp)

Cylinder head specifications

Table 10. Adjustment specifications

Model	Valve clearance
4TNV86CT, 4TNV86CHT, 4TNV86DHT	0.15-0.25 mm (0.006-0.010 in.)

Table 11. Cylinder head

Inspection item			Standard	Limit	Reference page
Combustion surface distortion (flatness)			0.05 mm (0.0020 in.)	0.15 mm (0.0059 in.)	See Valve recession section, in Diesel cylinder head repair
Valve recession	4TNV86CT, 4TNV86CHT, 4TNV86DHT	Intake	0.30-0.50 mm (0.0118-0.0197 in.)	0.8 mm (0.0315 in.)	
		Exhaust	0.30-0.50 mm (0.0118-0.0197 in.)	0.8 mm (0.0315 in.)	
Valve seat	Seat angle	Intake	120°	-	See Valve face and valve seat section, in Diesel cylinder head repair
		Exhaust	90°	-	
	Seat correction angle		40°, 150°	-	

Table 12. Intake/Exhaust valve guard

Inspection item			Standard	Limit	Reference page
4TNV86CT, 4TNV86CHT, 4TNV86DHT	Intake	Guide inside diameter	8.010-8.025 mm (0.3154-0.3159 in.)	8.10 mm (0.3189 in.)	See Inspection of valve guides section, in Diesel cylinder head repair
		Valve stem outside diameter	7.960-7.975 mm (0.3134-0.3140 in.)	7.90 mm (0.3110 in.)	
		Valve stem bend	0.035-0.070 mm (0.0014-0.0028 in.)	0.18 mm (0.0071 in.)	
	Exhaust	Guide inside diameter	8.015-8.030 mm (0.3156-0.3161 in.)	8.10 mm (0.3189 in.)	
		Valve stem outside diameter	7.965-7.970 mm (0.3136-0.3138 in.)	7.90 mm (0.3110 in.)	
		Valve stem bend	0.045-0.075 mm (0.0018-0.0030 in.)	0.18 mm (0.0071 in.)	
Valve guide projection from cylinder head		4TNV86CT, 4TNV86CHT	14.71-15.00 mm (0.5791-0.5905 in.)		See Reassembly of intake and exhaust valves, in Diesel cylinder head repair
Valve guide installation method			Cold-fitted		

Table 13. Push rod

Inspection item	Standard	Limit	Reference page
Push rod bend (all models)	Less than 0.03 mm (0.0012 in.)	0.03 mm (0.0012 in.)	See Push rod bend section, in Diesel cylinder head repair

Table 14. Rocker arm and shaft

Model	Inspection item	Standard	Limit	Reference page
4TNV86CT, 4TNV86CHT, 4TNV86DHT	Arm shaft hole diameter	16.000-16.020 mm (0.6299-0.6307 in.)	16.07 mm (0.6327 in.)	See Inspection of Rocker Arm Assembly section, in Diesel cylinder head repair
	Shaft outside diameter	15.966-15.984 mm (0.6286-0.6293 in.)	15.94 mm (0.6276 in.)	
	Oil clearance	0.016-0.054 mm (0.0006-0.0021 in.)	0.13 mm (0.0051 in.)	

Table 15. Valve spring

Model	Inspection item	Standard	Limit	Reference page
4TNV86CT, 4TNV86CHT, 4TNV86DHT	Free length	42 mm (1.6535 in.)	41.5 mm (1.6339 in.)	See Inspection of Valve Springs section, in Diesel cylinder head repair
	Squareness	-	47.0 mm (1.8504 in.)	

Camshaft and timing gear train specifications

Table 16. Camshaft

Inspection item			Standard	Limit	Reference page
End play			0.05-0.20 mm (0.0020-0.0079 in.)	0.030 mm (0.0118 in.)	See Removal of camshaft section, in Diesel cylinder head repair
Bend (1/2 the dial gauge reading)			0-0.2 mm (0-0.0008 in.)	0.05 mm (0.0020 in.)	See Inspection of camshaft section, in Diesel cylinder head repair
Cam lobe height		4TNV86CT, 4TNV86CHT, 4TNV86DHT	38.600-38.800 mm (1.5197-1.5276 in.)	38.350 mm (1.5098 in.)	
Shaft outside diameter/bearing inside diameter					
Model: 4TNV86CT, 4TNV86CHT, 4TNV86DHT	Gear end	Bore inside diameter	44.990-45.055 mm (1.7713-1.7738 in.)	45.130 mm (1.7768 in.)	See Inspection of camshaft section, in Diesel cylinder head repair
		Camshaft outside diameter	44.925-45.950 mm (1.7687-1.7697 in.)	44.890 mm (1.7673 in.)	
		Oil clearance	0.040-0.130 mm (0.0016-0.0051 in.)	0.240 mm (0.0094 in.)	

Table 16. Camshaft (Continued)

Inspection item			Standard	Limit	Reference page
	Intermediate	Bore inside diameter	45.000-45.025 mm (1.7716-1.7726 in.)	45.100 mm (1.7756 in.)	
		Camshaft outside diameter	44.910-44.935 mm (1.7681-1.7691 in.)	44.875 mm (1.7667 in.)	
		Oil clearance	0.065-0.115 mm (0.0026-0.0045 in.)	0.225 mm (0.0089 in.)	
	Flywheel end	Bore inside diameter	45.000-45.025 mm (1.7716-1.7726 in.)	45.100 mm (1.7756 in.)	
		Camshaft outside diameter	44.925-45.950 mm (1.7687-1.7697 in.)	44.890 mm (1.7673 in.)	
		Oil clearance	0.050-0.100 mm (0.0020-0.0039 in.)	0.210 mm (0.0083 in.)	

Table 17. Idler gear shaft and bushing

Model	Inspection item		Standard	Limit	Reference page
4TNV86CT, 4TNV86CHT, 4TNV86DHT	Idler gear A	Shaft outside diameter	45.950-45.975 mm (1.8091-1.8100 in.)	45.900 mm (1.8071 in.)	-
		Bushing inside diameter	46.000-46.025 mm (1.8110-1.8120 in.)	46.075 mm (1.8140 in.)	
		Oil clearance	0.025-0.075 mm (0.0010-0.0030 in.)	0.175 mm (0.0068 in.)	
	Idler gear B	Shaft outside diameter	42.950-42.975 mm (1.6909-1.6919 in.)	42.900 mm (1.6890 in.)	-
		Bushing inside diameter	43.000-43.025 mm (1.6929-1.6939 in.)	43.075 mm (1.6959 in.)	
		Oil clearance	0.025-0.075 mm (0.0010-0.0030 in.)	0.175 mm (0.0068 in.)	

Table 18. Timing gear backlash

Model	Inspection item	Standard	Limit	Reference page
All models	Crank gear, cam gear, idler gear fuel injection pump gear and PTO gear	0.08-0.14 mm (0.0031-0.0055 in.)	0.16 mm (0.0063 in.)	See Checking timing gear backlash section, in Diesel cylinder head repair

Crankshaft and piston specifications

NOTE: Check appropriate parts catalog for various sizes of replacement main bearing inserts.

Table 19. Crankshaft

Inspection item			Standard	Limit	Reference page
Bend (1/2 the dial gauge reading)			-	0.02 mm (0.0008 in.)	See Inspection of crankshaft section, in Diesel cylinder head repair
Model: 4TNV86CT, 4TNV86CHT, 4TNV86DHT	Connecting rod journals	Journal outside diameter	47.952-47.962 mm (1.8879-1.8883 in.)	47.902 mm (1.8859 in.)	
		Bearing inside diameter	48.000-48.026 mm (1.8898-1.8909 in.)	-	
		Bearing insert thickness	1.492-1.500 mm (0.0587-0.0591 in.)	-	
		Oil clearance	0.038-0.074 mm (0.0015-0.0029 in.)	0.150 mm (0.0059 in.)	
	Main bearing journal	Journal outside diameter	49.952-49.962 mm (1.9666-1.9670 in.)	57.902 mm (2.2796 in.)	See Inspection of crankshaft section, in Diesel cylinder head repair
		Bearing inside diameter	50.000-50.020 mm (1.9685-1.9693 in.)	-	
		Bearing insert thickness	1.995-2.010 mm (0.0785-0.0791 in.)	-	
		Oil clearance	0.038-0.068 mm (0.0015-0.0027 in.)	0.150 mm (0.0059 in.)	

Table 20. Thrust bearing

Inspection item	Standard	Limit	Reference page
Crankshaft end play-all models	0.13-0.23 mm (0.0051-0.0091 in.)	0.28 mm (0.0110 in.)	See Removal of crankshaft section, in Diesel cylinder head repair

Table 21. Piston

Inspection item		Standard	Limit	Reference page
Model: 4TNV86CT, 4TNV86CHT, 4TNV86DHT	Piston outside diameter (Measure at 90° to the piston pin)	85.940-85.970 mm (3.3835-3.3846 in.)	85.895 mm (3.3817 in.)	See Inspection of pistons, piston rings and wrist pin section, in Diesel cylinder head repair
	Piston diameter measure location (Upward from the bottom of the piston)	24 mm (0.9449 in.)	-	

Table 21. Piston (Continued)

Inspection item			Standard	Limit	Reference page
	Piston pin	Hole inside diameter	26.000-26.009 mm (1.0236-1.0240 in.)	26.039 mm (1.0252 in.)	See Inspection of pistons, piston rings and wrist pin section, in Diesel cylinder head repair
		Pin outside diameter	25.995-26.000 mm (1.0234-1.0236 in.)	25.965 mm (1.0222 in.)	
		Oil clearance	0.000-0.014 mm (0.000-0.0006 in.)	0.074 mm (0.0029 in.)	

Table 22. Piston ring

Model	Inspection item		Standard	Limit	Reference page
4TNV86CT, 4TNV86CHT, 4TNV86DHT	Top ring	Ring groove width	2.065-2.080 mm (0.0813-0.0819 in.)	-	See Inspection of pistons, piston rings and wrist pin section, in Diesel cylinder head repair
		Ring width	1.970-1.990 mm (0.0776-0.0783 in.)	1.950 mm (0.0768 in.)	
		Side clearance	0.075-0.110 mm (0.0030-0.0043 in.)	-	
		End gap	0.200-0.400 mm (0.0079-0.0157 in.)	0.490 mm (0.193 in.)	
	Second ring	Ring groove width	2.035-2.050 mm (0.0801-0.0807 in.)	2.150 mm (0.0846 in.)	
		Ring width	1.950-1.970 mm (0.0768-0.0776 in.)	1.930 mm (0.0760 in.)	
		Side gap	0.045-0.100 mm (0.0018-0.0039 in.)	0.200 mm (0.0079 in.)	
		End gap	0.30-0.50 mm (0.0118-0.0197 in.)	0.590 mm (0.0232 in.)	
4TNV86CT, 4TNV86CHT, 4TNV86DHT	Oil ring	Ring groove width	4.015-4.030 mm (0.1581-0.1587 in.)	4.130 mm (0.1626 in.)	See Inspection of pistons, piston rings and wrist pin section, in Diesel cylinder head repair
		Ring width	3.970-3.990 mm (0.1563-0.1571 in.)	3.950 mm (0.01555 in.)	
		Side clearance	0.025-0.060 mm (0.0010-0.0024 in.)	0.180 mm (0.0071 in.)	
		End gap	0.200-0.400 mm (0.0079-0.0157 in.)	0.490 mm (0.0193 in.)	

Table 23. Connecting rod

Model	Inspection item	Standard	Limit	Reference page
4TNV86CT, 4TNV86CHT, 4TNV86DHT	**Connecting rod small end**			
	Wrist pin bushing inside diameter	26.025-26.038 mm (1.0234-1.0251 in.)	26.068 mm (1.0263 in.)	See Inspection of connecting rod section, in Diesel cylinder head repair
	Wrist pin outside diameter	25.995-26.000 mm (1.0234-1.0236 in.)	25.967 mm (1.0223 in.)	
	Oil clearance	0.025-0.043 mm (0.0010-0.0017 in.)	0.101 mm (0.0040 in.)	
	Connecting rod big end			
	Side clearance	0.20-0.40 mm (0.0079-0.0157 in.)	-	

Table 24. Tappet

Model	Inspection item	Standard	Limit	Reference page
4TNV86CT, 4TNV86CHT, 4TNV86DHT	Tappet bore (block) inside diameter	12.000-12.025 mm (0.4724-0.4734 in.)	12.045 mm (0.4742 in.)	See Inspection of tappets section, in Diesel cylinder head repair
	Tappet stem outside diameter	11.975-11.990 mm (0.4715-0.4720 in.)	11.955 mm (0.4707 in.)	
	Oil clearance	0.010-0.050 mm (0.0004-0.0020 in.)	0.090 mm (0.0035 in.)	

Cylinder block specifications

Table 25. Cylinder block

Model	Inspection item	Standard	Limit	Reference page
4TNV86CT, 4TNV86CHT, 4TNV86DHT	Cylinder inside diameter	86.000-86.030 mm (3.3858-3.3870 in.)	86.200 mm (3.3937 in.)	See Inspection of cylinder block section, in Diesel cylinder head repair
	Cylinder bore	0.01 mm (0.0004 in.) or less	0.03 mm (0.0012 in.)	

Special torque chart

Table 26. Torque for bolts and nuts

Model	Component	Thread diameter and pitch	Torque	Lubricating oil application (Thread portion and seat surface)
4TNV86CT, 4TNV86CHT, 4TNV86DHT	Cylinder head bolt	M10 x 1.25 mm	92-98 N•m (68-72 lbf ft)	Applied
	Connecting rod bolt	M9 x 1.0 mm	44.1-49 N•m (33-36 lbf ft)	Applied
	Flywheel bolt	M10 x 1.25 mm	83.3-88.2 N•m (61-65 lbf ft)	Applied
	Main bearing cap bolt	M12 x 1.5 mm	96.0-100 N•m (70.8-73.8 lbf ft)	Applied
	Crankshaft pulley bolt	M14 x 1.5 mm	Cast metal (FC300) 83.3-93.1 N•m (62-69 lbf ft)	Applied
			Steel metal (S45C) 112.7-122.7 N•m (83-91 lbf ft)	
	Fuel injector retainer bolt	M8 x 1.25 mm	24.4-28.4 N•m (18-21 lbf ft)	Not Applied
	Supply pump drive gear nut	M18 x 1.5 mm	75-85 N•m (55-63 lbf ft)	Not Applied
	High-pressure fuel line nut	M12 x 1.5 mm (Common rail)	29.4-34.3 N•m (21.7-25.3 lbf ft)	Not Applied
		M12 x 1.5 mm (Injector)	26.5-34.3 N•m (19.5-25.3 lbf ft)	
		M16 x 1.0 mm (Supply pump)	29.4-34.3 N•m (21.7-25.3 lbf ft)	
	Crank rotation sensor	M6 x 1.0 mm	6-10 N•m (4.4-7.4 lbf ft)	Not Applied
4TNV86CT, 4TNV86CHT, 4TNV86DHT	Cam speed sensor	M6 x 1.0 mm	7.5-8.5 N•m (5.5-6.3 lbf ft)	Not Applied
	Pipe, EGR valve	M8 x 1.25 mm	18.9-24.7 N•m (14.0-18.2 lbf ft)	Not Applied
	New air temperature sensor	M6 x 1.0 mm	3.0-4.0 N•m (2.2-3.0 lbf ft)	Not Applied
	Intake temperature sensor	M14 x 1.5 mm	11.0-17.0 N•m (8.1-12.5 lbf ft)	Not Applied
	Exhaust temperature sensor	M12 x 1.25 mm	25.0-40.0 N•m (18.4-29.5 lbf ft)	Not Applied
	DPF inlet temperature sensor	M14 x 1.5 mm	45.0-55.0 N•m (33.2-40.6 lbf ft)	Not Applied

Table 26. Torque for bolts and nuts (Continued)

Model	Component	Thread diameter and pitch	Torque	Lubricating oil application (Thread portion and seat surface)
	DPF inside temperature sensor	M12 x 1.25 mm	45.0-55.0 N•m (33.2-40.6 lbf ft)	Not Applied
	DPF differential pressure sensor	M6 x 1.0 mm	5.6-8.4 N•m (4.1-6.2 lbf ft)	Not Applied
	Bolt, DPF differential pressure sensor pipe joint	M12 x 1.25 mm	24.5-34.3 N•m (18.1-25.3 lbf ft)	Burning prevention medicine
	Knob, cylinder head cover	M8 x 1.5 mm	12.0-15.0 N•m (8.9-11.0 lbf ft)	Not Applied
	Glow plug	M10 x 1.25 mm	15-20 N•m (11.1-14.8 lbf ft)	Not Applied
	Glow connector nut	M4 x 0.7 mm	1-1.5 N•m (0.7-1.1 lbf ft)	Not Applied
	Piston cooling nozzle banjo bolt	M8 x 1.25 mm	12.7-16.7 N•m (9.4-12.3 lbf ft)	Not Applied

DIESEL CYLINDER HEAD REPAIR
202001-012

DISASSEMBLY OF CYLINDER HEAD

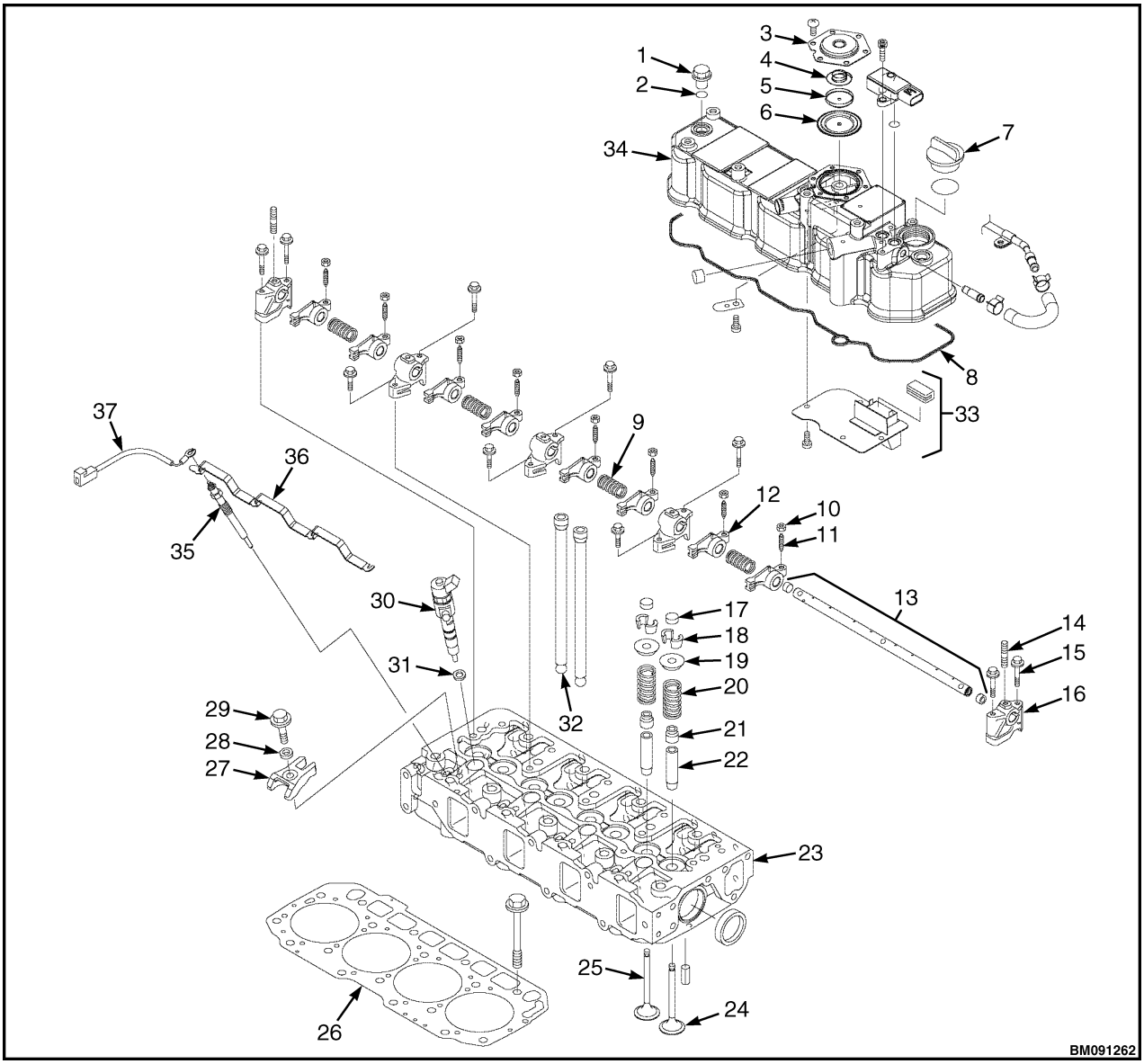


Figure 6. Cylinder head components (Yanmar 2.1L diesel engines)

Legend for Figure 6.

1. VALVE COVER KNOB
2. VALVE COVER KNOB O-RING
3. CRANKCASE BREATHER COVER
4. DIAPHRAGM SPRING
5. DIAPHRAGM PLATE
6. BREATHER DIAPHRAGM
7. OIL FILL CAP
8. VALVE COVER GASKET
9. ROCKER ARM SHAFT SPRING
10. VALVE ADJUSTING SCREW LOCK NUT
11. VALVE ADJUSTING SCREW
12. ROCKER ARM
13. ROCKER ARM SHAFT
14. ROCKER ARM SHAFT ALIGNING STUD
15. SUPPORT BOLT
16. ROCKER ARM SHAFT SUPPORT
17. VALVE CAP
18. VALVE STEM COTTER
19. SPRING RETAINER
20. VALVE SPRING
21. VALVE STEM SEAL
22. VALVE GUIDE
23. CYLINDER HEAD
24. INTAKE VALVE
25. EXHAUST VALVE
26. CYLINDER HEAD GASKET
27. FUEL INJECTOR RETAINER
28. WASHER
29. FUEL INJECTOR RETAINER BOLT
30. FUEL INJECTOR
31. FUEL INJECTOR GASKET
32. PUSH ROD
33. CRANKCASE BREATHER COMPONENTS
34. VALVE COVER
35. GLOW PLUG
36. GLOW PLUG BRACKET
37. GLOW PLUG WIRE HARNESS

NOTE: Locate and identify all components prior to disassembly, to ensure all components are returned to the same position during reassembly.

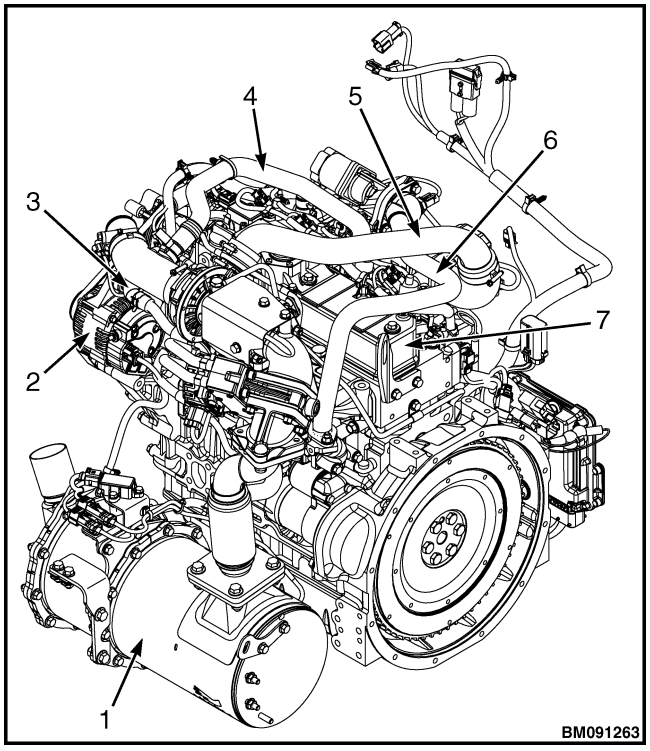
Prior to disassembly, prepare a clean, flat surface on a workbench large enough to accomodate the cylinder head assembly. Discard all gaskets, O-rings and seals. New gaskets, O-rings and seals are required when reassembling the cylinder head.

1. Drain all coolant from the engine into a suitable container.

NOTE: Perform Step 2 through Step 8 ONLY if your engine is equipped with DPF and EGR. For other engines, skip to Step 9.

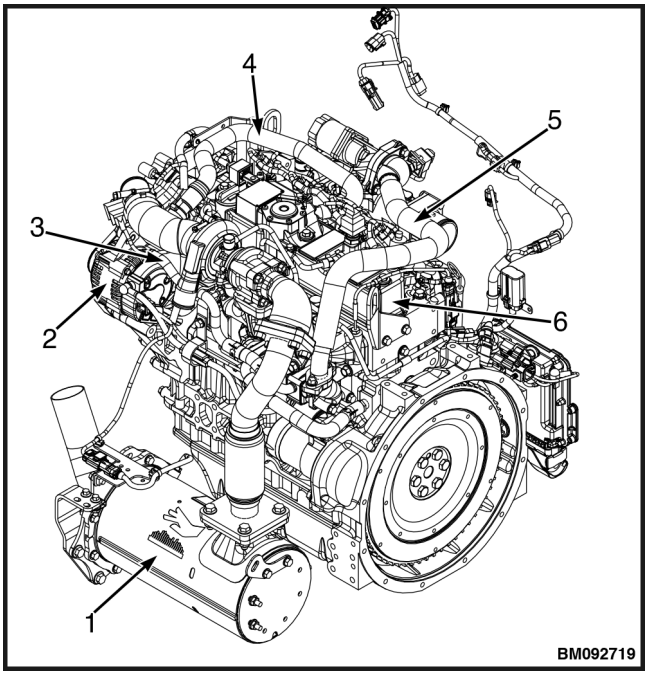
2. For engine options equipped with DPF, disconnect the exhaust pipe that connects the DPF to the exhaust throttle body. See, Figure 7.

For engine options equipped with DOC, disconnect the exhaust pipe that connects the DPF to the turbo assembly. See, Figure 7.



1. DPF
2. ALTERNATOR
3. COOLING HOSES
4. BREATHER HOSE
5. INTAKE DUCT
6. EGR PIPE
7. CYLINDER HEAD COVER

Figure 7. Engine assembly with DPF



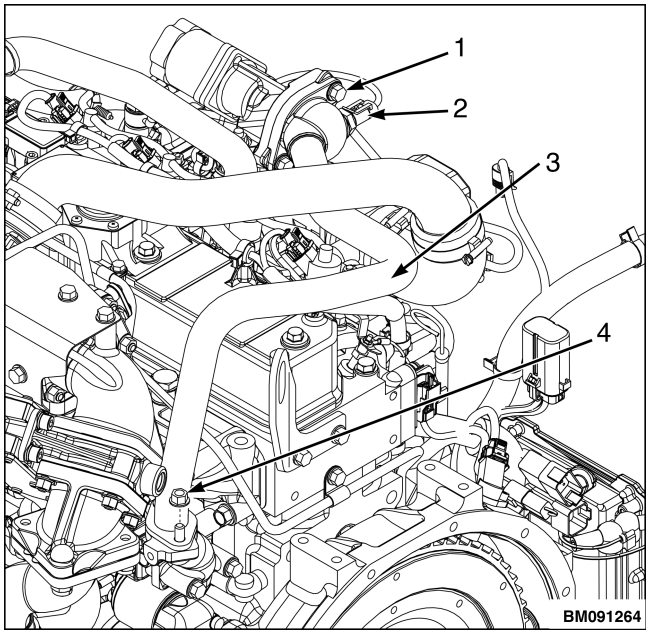
1. DOC
2. ALTERNATOR
3. COOLING HOSES
4. BREATHER HOSE
5. EGR TUBE
6. CYLINDER HEAD COVER

Figure 8. Engine assembly with DOC

3. Remove the breather hose (item 4) from the cylinder head cover. See Figure 7 or Figure 8.

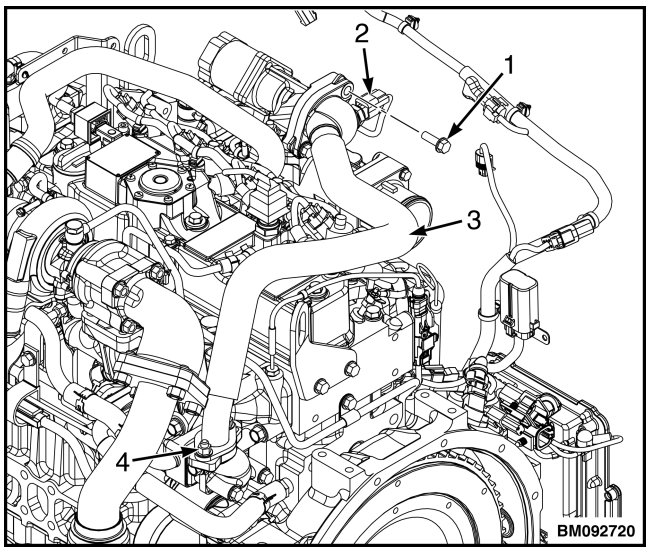
4. For engine option with DPF, remove the intake duct. See Figure 7.

5. Disconnect the electrical connector from the EGR sensor. See Figure 9 or Figure 10.



1. BOLT
2. EGR SENSOR ELECTRICAL CONNECTOR
3. EGR PIPE
4. NUT

Figure 9. EGR sensor pipe with DPF



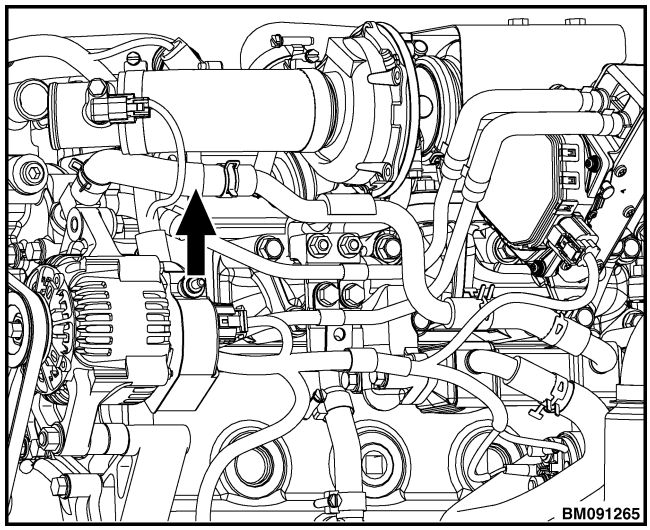
1. BOLT
2. EGR SENSOR ELECTRICAL CONNECTOR
3. EGR PIPE
4. NUT

Figure 10. EGR sensor pipe with DOC

6. Loosen the two bolts attaching the EGR pipe. See item 1 on, Figure 9 or Figure 10.

7. Loosen the two nuts attaching the EGR pipe. See item 4 on, Figure 9 or Figure 10.

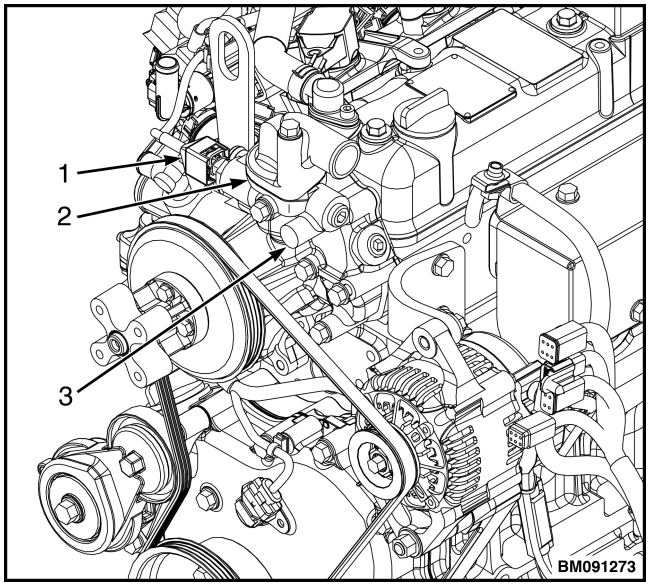
8. Place a cloth under the EGR to collect water spillage. Disconnect and remove the cooling pipes. See Figure 11.



NOTE: ENGINE WITH DPF SHOWN. OTHER OPTIONS APPEAR SIMILAR.

Figure 11. Cooling pipes

9. Disconnect the electrical connector from the coolant temperature sensor, attached to the coolant pump. See Figure 12.



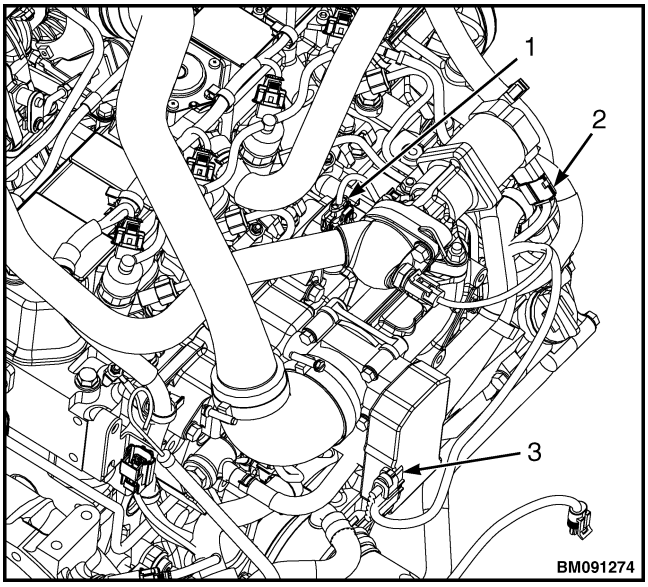
1. COOLANT TEMPERATURE SENSOR ELECTRICAL CONNECTOR
2. COOLANT TEMPERATURE SENSOR
3. WATER PUMP

Figure 12. Water pump and temperature sensor

10. Remove the cooling fan and the water pump. See Water pump repair in the **Cooling system** 0700SRM2300 manual.

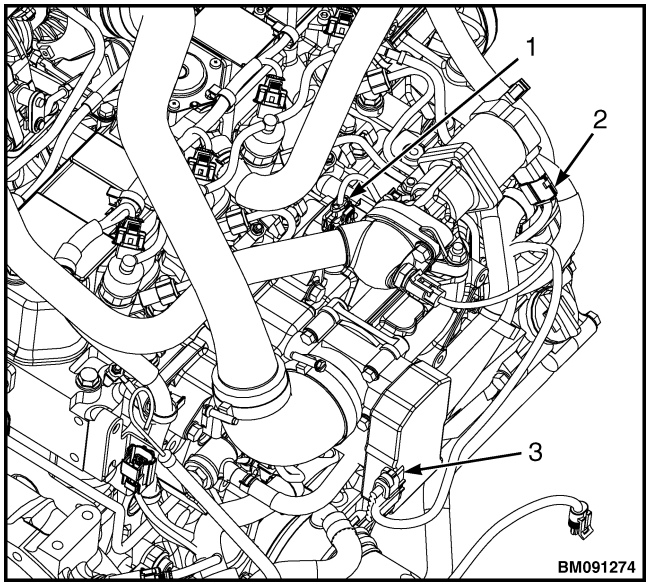
11. For engine options equipped with DPF, disconnect the connectors from the EGR valve, intake throttle, and ambient air temperature sensor. See Figure 13.

    For engine options equipped with DOC, disconnect the connectors from the EGR valve and ambient air temperature sensor. See Figure 13.



1. INTAKE TEMPERATURE SENSOR CONNECTOR
2. EGR VALVE CONNECTOR
3. INTAKE THROTTLE CONNECTOR

Figure 13. Intake throttle and EGR valve connectors



1. INTAKE TEMPERATURE SENSOR CONNECTOR
2. EGR VALVE CONNECTOR

Figure 14. EGR valve connectors

12. For engine options equipped with DPR, remove the intake throttle and EGR valve. See Figure 15.

For engine options equipped with DOC, remove the EGR valve. See Figure 16.

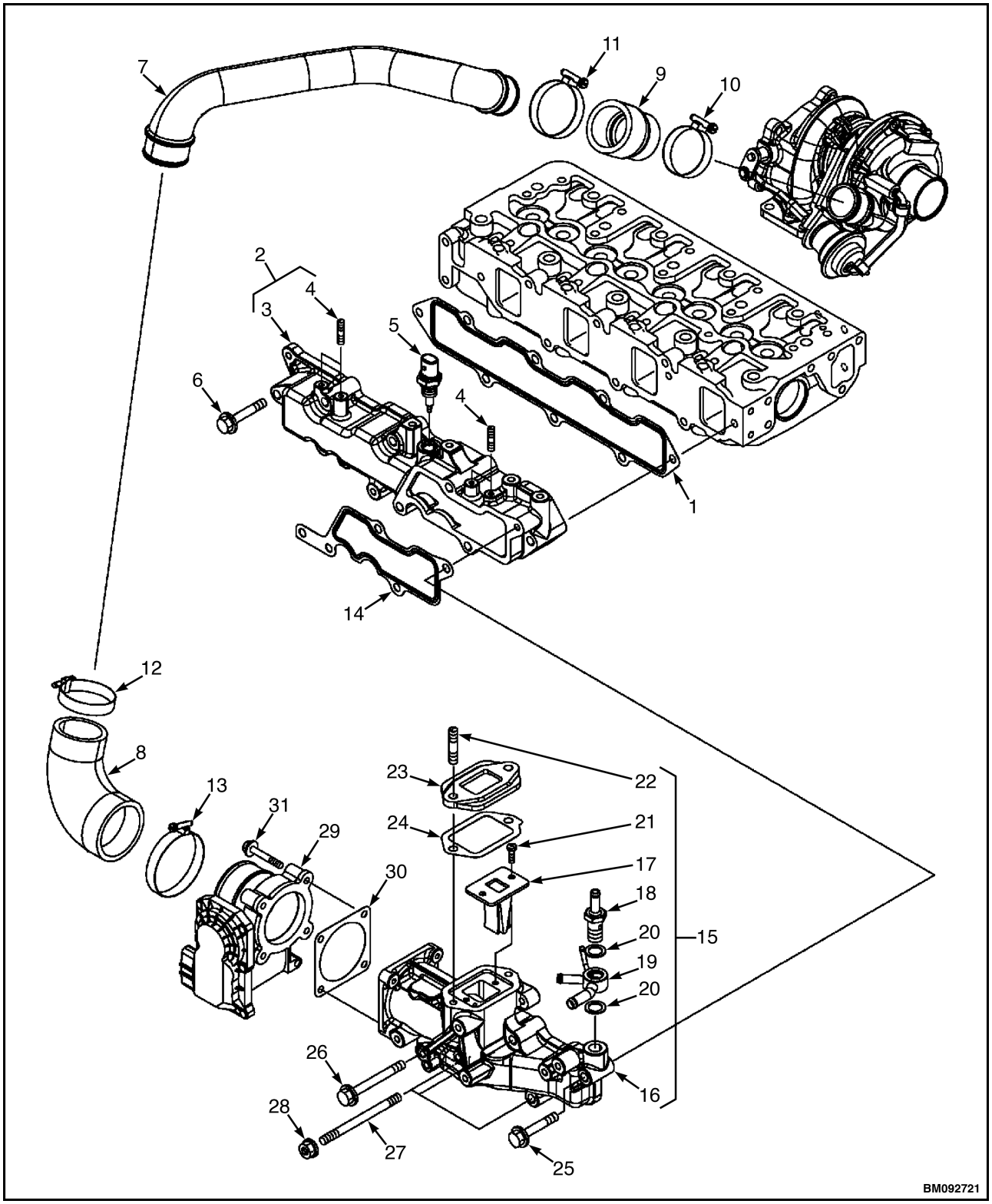


Figure 15. Intake manifold (2.1L diesel engine with DPF)

Legend for Figure 15.

1. INTAKE MANIFOLD GASKET
2. INTAKE MANIFOLD ASSEMBLY
3. INTAKE MANIFOLD
4. STUD
5. AIR TEMPERATURE SENSOR
6. INTAKE MANIFOLD MOUNTING BOLT
7. AIR DUCT
8. RUBBER ELBOW HOSE
9. RUBBER JOINT HOSE
10. CLAMP
11. CLAMP
12. CLAMP
13. CLAMP
14. GASKET
15. INTAKE COLLECTOR ASSEMBLY
16. INTAKE COLLECTOR
17. REED VALVE
18. JOINT HOSE
19. JOINT HOSE
20. WASHER SEAL
21. SCREW
22. STUD
23. EGR VALVE SPACER
24. EGR VALVE SPACER GASKET
25. BOLT
26. BOLT
27. STUD
28. NUT
29. INTAKE THROTTLE
30. INTAKE THROTTLE GASKET
31. BOLT

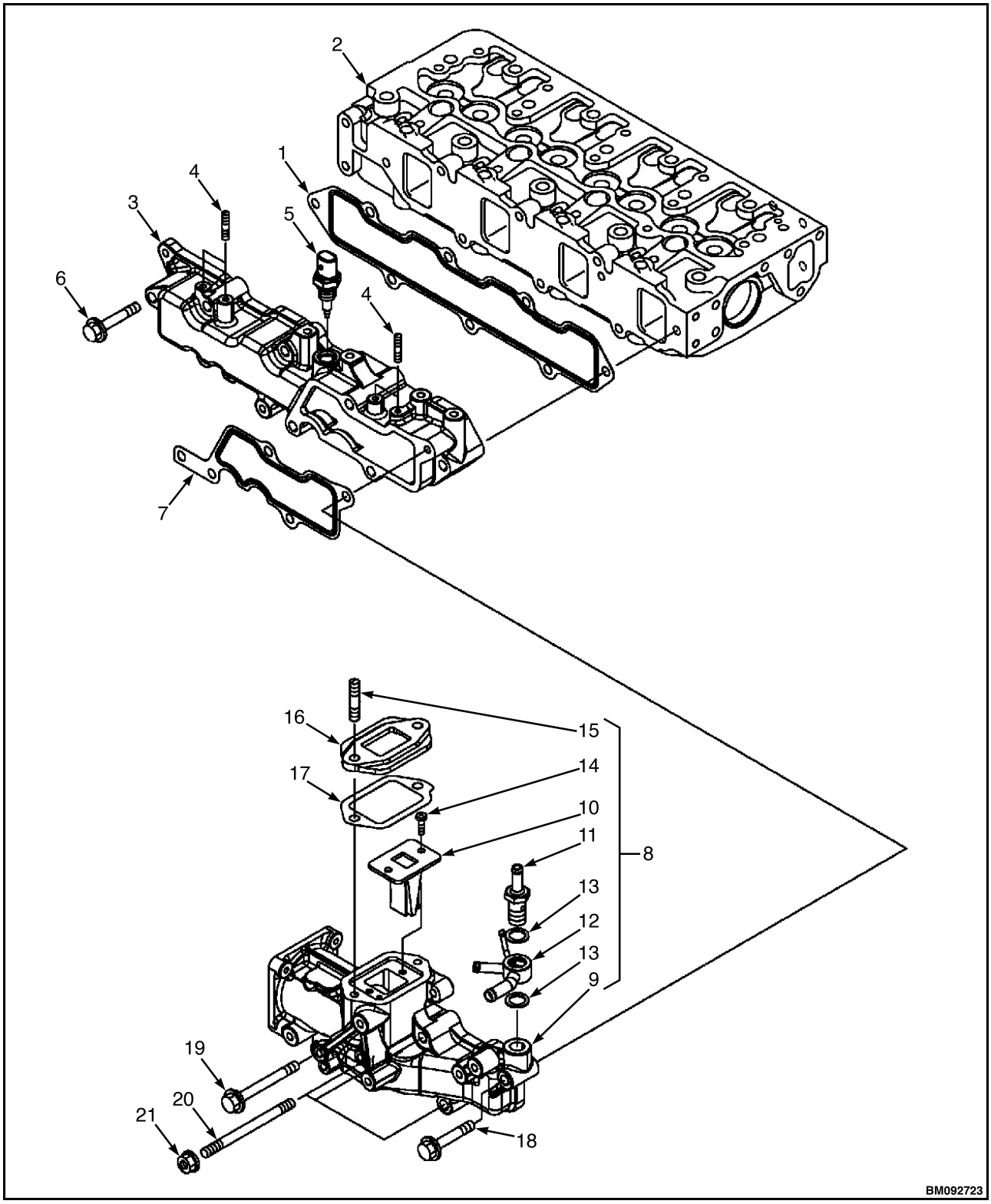
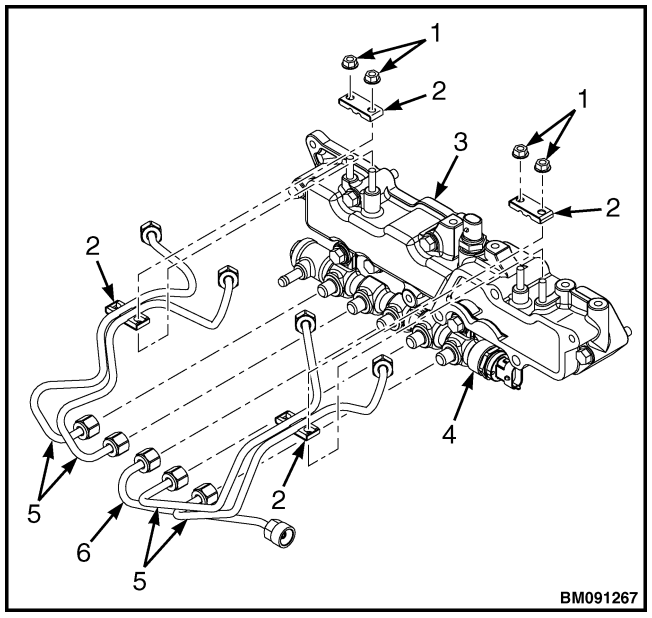


Figure 16. Intake manifold (2.1L diesel engine with DOC)

Legend for Figure 16.

1. INTAKE MANIFOLD GASKET
2. CYLINDER BLOCK
3. INTAKE MANIFOLD
4. STUD
5. AIR TEMPERATURE SENSOR
6. INTAKE MANIFOLD MOUNTING BOLT
7. INTAKE COLLECTOR GASKET
8. INTAKE COLLECTOR ASSEMBLY
9. INTAKE COLLECTOR
10. REED VALVE
11. JOINT HOSE
12. JOINT HOSE
13. WASHER SEAL
14. SCREW
15. STUD
16. EGR VALVE SPACER
17. EGR VALVE SPACER GASKET
18. BOLT
19. BOLT
20. STUD
21. NUT

13. Remove the nuts and hose clamps retaining the high-pressure fuel injection lines to the intake manifold. See Figure 17.



1. NUT
2. INJECTION LINE CLAMP
3. INTAKE MANIFOLD
4. COMMON RAIL
5. HIGH-PRESSURE FUEL INJECTION LINE (COMMON RAIL TO INJECTOR)
6. HIGH-PRESSURE FUEL INJECTION LINE (COMMON RAIL TO SUPPLY PUMP)

Figure 17. Fuel injection lines

14. Remove the high-pressure fuel injection lines. See Figure 17 and Diesel fuel system repair for procedure.

15. Remove the intake manifold mounting bolts from the intake manifold. See Figure 15 or Figure 16.

16. Remove the intake collector mounting bolts and nuts. See Figure 15 or Figure 16.

17. For engine with DPF, remove the intake collector assembly, intake manifold, common rail, intake throttle, and EGR valve as one unit. See Figure 15. Dispose of the intake manifold gasket.

For engine with DOC, remove the intake collector assembly and EGR valve as one unit. See Figure 16. Dispose of the intake manifold gasket.

18. Clean the intake side of the common rail, where the high pressure injection lines were removed. See Figure 18. Cover with a plastic bag.

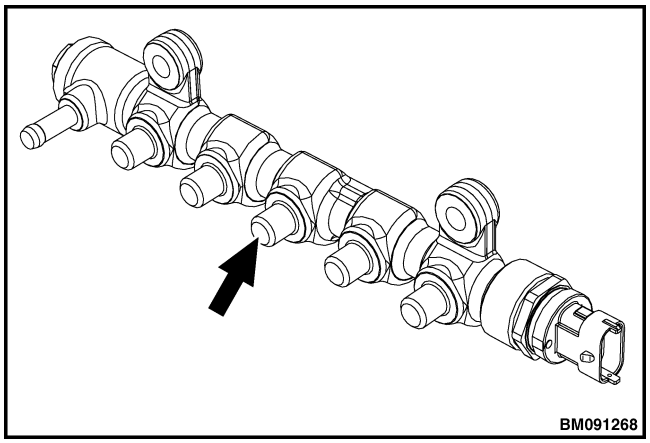


Figure 18. Common rail intake side

19. Disconnect the electrical connector from the turbo inlet temperature sensor (2, Figure 19).

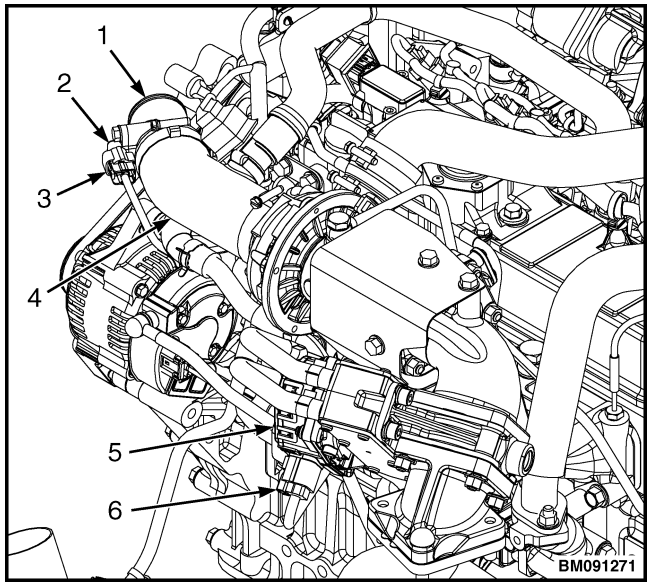


Figure 19. Turbo connectors

Legend for Figure 19.

NOTE: ENGINE WITH DPF SHOWN. OTHER OPTIONS APPEAR SIMILAR.

1. TURBO INLET ADAPTER
2. TURBO INLET TEMPERATURE SENSOR
3. CONNECTOR
4. TURBO INLET
5. EXHAUST THROTTLE
6. CONNECTOR

20. Disconnect the electrical connector from the exhaust throttle (5, Figure 19).

21. Remove the exhaust manifold mounting bolts. See Figure 20 or Figure 21.

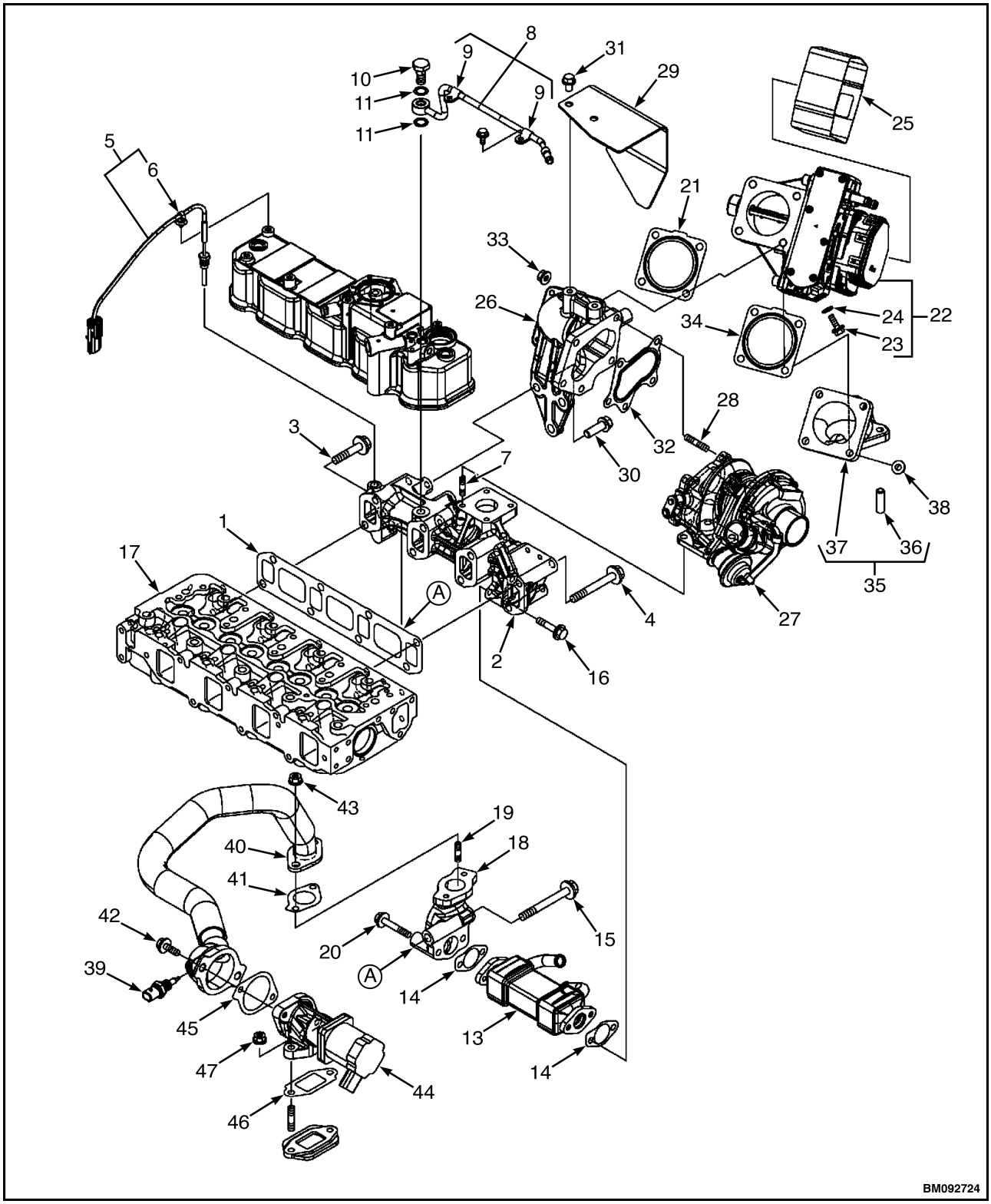


Figure 20. Exhaust manifold (2.1L diesel engine with DPF)

Legend for Figure 20.

1. EXHAUST MANIFOLD GASKET
2. EXHAUST MANIFOLD
3. BOLT
4. BOLT
5. TEMPERATURE SENSOR
6. CLIP
7. STUD
8. PRESSURE PIPE ASSEMBLY
9. CLAMP
10. BOLT
11. GASKET
12. BOLT
13. EGR COOLER
14. EGR COOLER GASKET
15. BOLT
16. BOLT
17. CYLINDER BLOCK
18. EGR OUTLET PIPE
19. STUD
20. BOLT
21. SILENCER GASKET
22. EXHAUST THROTTLE
23. EXHAUST THROTTLE BOLT
24. EXHAUST THROTTLE WASHER
25. HEAT INSULATOR
26. TURBOCHARGER OUTLET ELBOW
27. TURBOCHARGER
28. STUD
29. TURBOCHARGER COVER
30. BOLT
31. BOLT
32. TURBINE OUTLET GASKET
33. NUT
34. SILENCER GASKET
35. EXHAUST ELBOW ASSEMBLY
36. STUD
37. EXHAUST ELBOW
38. NUT
39. EGR GAS TEMP SENSOR
40. EGR PIPE ASSEMBLY
41. EGR PIPE GASKET
42. BOLT
43. NUT
44. EGR VALVE
45. EGR INLET GASKET
46. EGR OUTLET GASKET
47. NUT

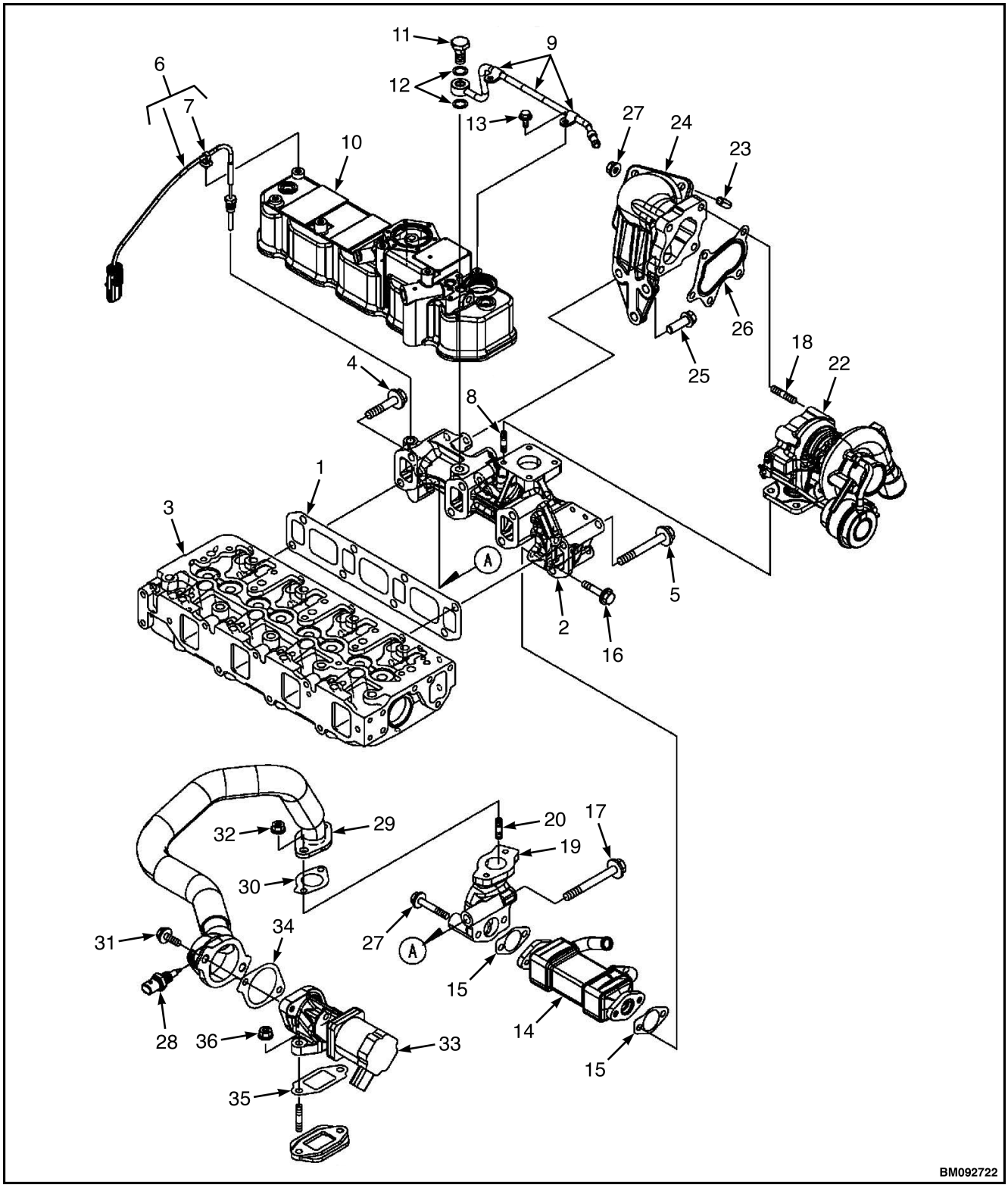


Figure 21. Cylinder head components (2.1L diesel engine with DOC)

Legend for Figure 21.

1. GASKET
2. EXHAUST MANIFOLD
3. CYLINDER HEAD
4. BOLT
5. BOLT
6. TEMPERATURE SENSOR
7. CLIP
8. STUD
9. EXHAUST PIPE ASSEMBLY
10. CYLINDER HEAD COVER
11. BOLT (PIPE JOINT)
12. GASKET
13. BOLT
14. EGR COOLER
15. GASKET, EGR COOLER
16. BOLT
17. BOLT
18. STUD
19. PIPE, EGR OUT
20. STUD
21. BOLT
22. TURBO CHARGER
23. STUD
24. TURBO CHARGER OUTLET ELBOW
25. BOLT
26. TURBO CHARGER GASKET (OUTLET)
27. NUT
28. EGR GAS TEMP SENSOR
29. EGR PIPE ASSEMBLY
30. EGR PIPE GASKET
31. BOLT
32. NUT
33. EGR VALVE
34. EGR INLET GASKET
35. EGR OUTLET GASKET
36. NUT

22. Remove the turbocharger, exhaust throttle, EGR cooler, EGR cooler outlet vent and exhaust manifold as one unit. See Figure 20 or Figure 21. Dispose of the exhaust manifold gasket.

23. Remove the alternator. See Diesel electrical system repair for procedure.

24. Remove the injectors from the cylinder head. See Diesel fuel system repair for procedure.

REMOVE

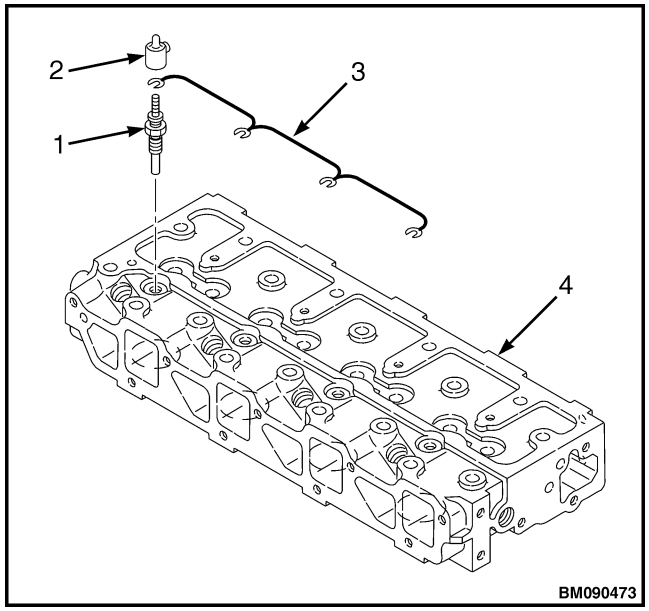
Glow plugs

CAUTION

The length of the glow plugs extend beyond the surface of the cylinder head. It is important to remove each glow plug before removing the cylinder head to avoid damaging the glow plugs.

1. Disconnect the glow plug wire harness from the engine wire harness. See Figure 22.

2. Loosen the nut from each glow plug to remove the glow plug connector. See Figure 22.



1. GLOW PLUG
2. GLOW PLUG CONNECTOR
3. GLOW PLUG WIRE HARNESS
4. CYLINDER HEAD

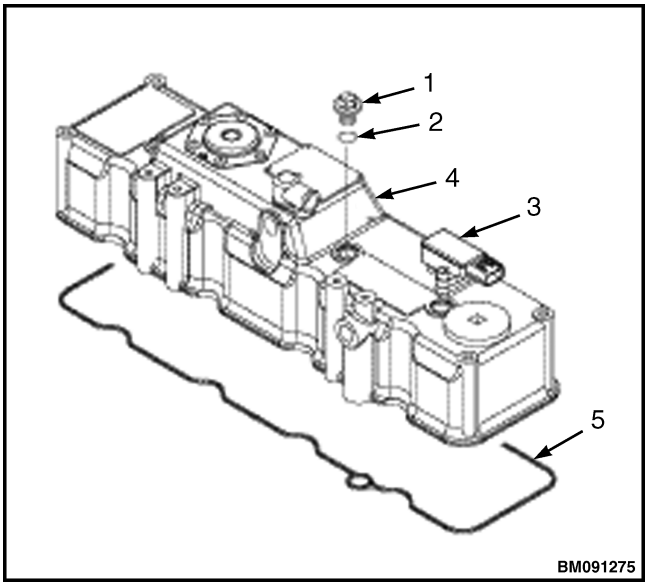
Figure 22. Glow plugs

Valve cover

1. Disconnect the engine wire harness from the sensor on the cylinder head cover (3, Figure 23).

2. Remove the three valve cover bolts. See Figure 23.

3. Remove the valve cover and gasket. See Figure 23.



1. VALVE COVER BOLT
2. WASHER
3. PRESSURE SENSOR
4. VALVE COVER
5. VALVE COVER GASKET

Figure 23. Valve cover

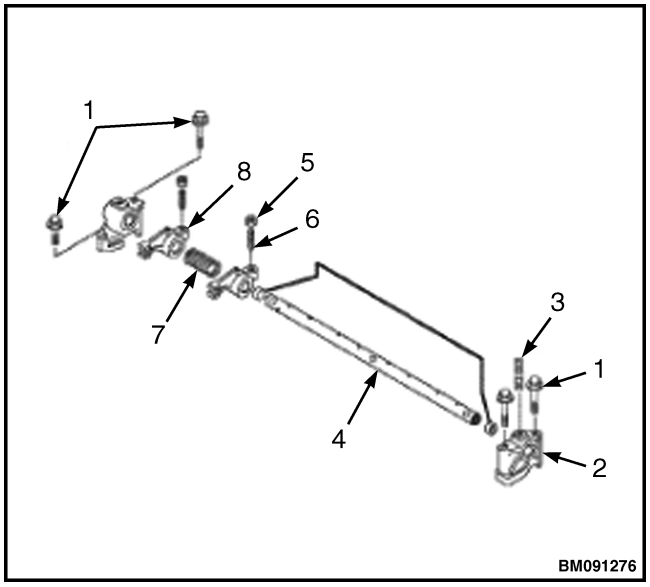
Rocker arm assembly

1. Remove the bolts (1, Figure 24) that retain the rocker arm shaft supports to the cylinder head.

2. Remove the entire rocker arm shaft asssembly from the cylinder head. See Figure 6.

NOTE: Make sure to identify the push rods so they can be installed in their original locations during reassembly.

3. Remove the push rods. See Figure 6.



1. BOLT
2. ROCKER ARM SUPPORT
3. ALIGNMENT STUD
4. ROCKER ARM SHAFT
5. LOCK NUT
6. VALVE ADJUSTING SCREW
7. SPRING
8. ROCKER ARM

Figure 24. Rocker arm assembly

4. Remove the alignment stud that retains the rocker arm shaft to the rocker arm support. See Figure 24.

NOTE: The rocker arm shaft fits tightly in the rocker arm supports. Use a padded vise to aid in removing the rocker arm shaft.

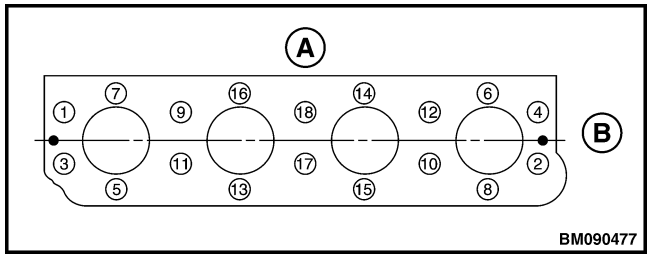
5. Clamp the rocker arm support in a padded vise. Twist and pull on the rocker arm shaft to remove it from the rocker arm supports, springs, and rocker arms. See Figure 24.

NOTE: Mark the rocker arms, to ensure they are installed with the same valve and pushrod during reassembly.

6. Remove the valve adjusting screw and lock nut from the rocker arms. See Figure 24.

Cylinder head

1. Loosen the cylinder head bolts, following the sequence shown in Figure 25.

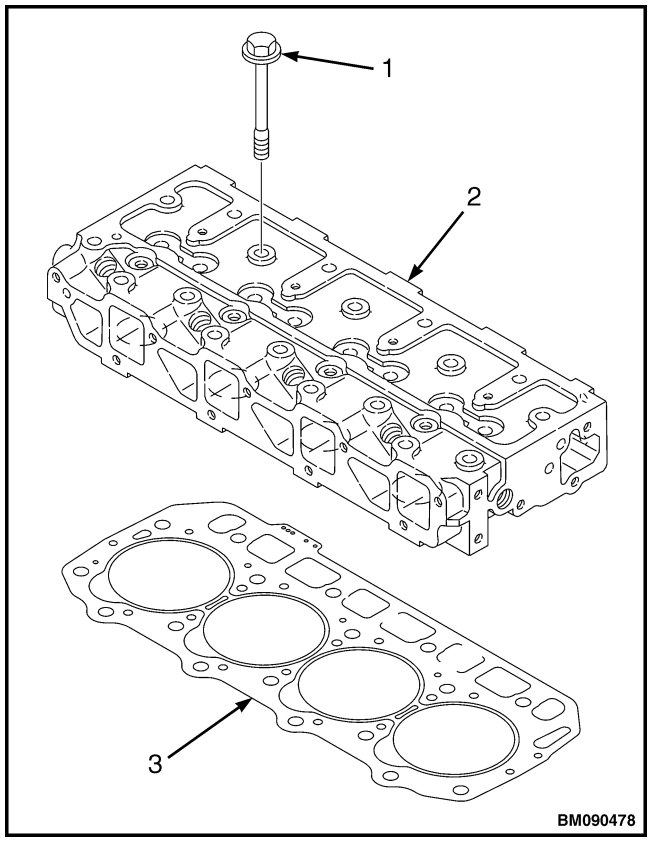


A. CAMSHAFT SIDE
B. FAN SIDE

Figure 25. Cylinder head bolt loosening sequence

2. Remove the cylinder head bolts.

3. Lift the cylinder head up and away from the cylinder block. Discard the cylinder head gasket. See Figure 26.



1. BOLT
2. CYLINDER HEAD
3. CYLINDER HEAD GASKET

Figure 26. Cylinder head and gasket

4. Place the cylinder head on a work bench. To prevent damage to the combustion surface, lay the cylinder on the workbench with the combustion side down.

Intake and exhaust valves

1. Confirm the cylinder head is on the work bench with the combustion side down, as referenced in previous step.

2. Remove the valve cap (9, Figure 28). Keep the valve cap together with the same valve it was installed on.

3. Locate the valve spring compressor tool. See Special tools for diesel engines.

4. Use the valve spring compressor tool to compress one of the valve springs. See Figure 27.

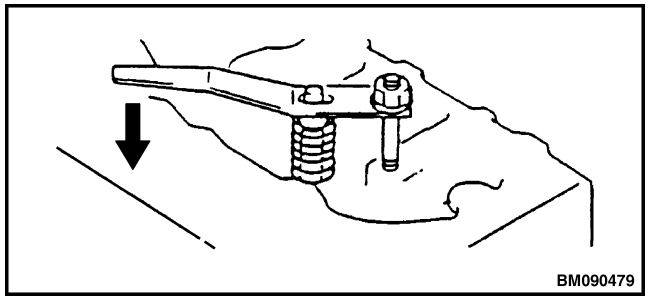
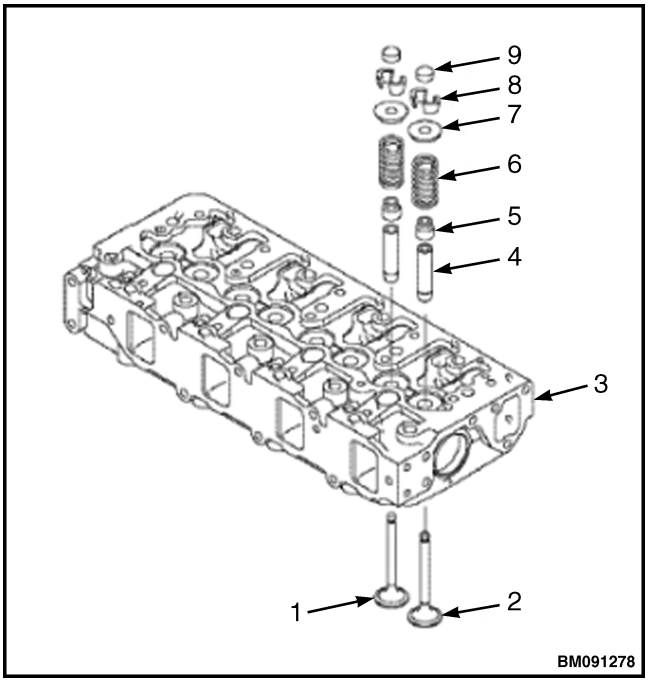


Figure 27. Valve spring compressor

5. Remove the valve keepers from the end of the valve. See Figure 28.



1. EXHAUST VALVE
2. INTAKE VALVE
3. CYLINDER HEAD
4. VALVE GUIDE
5. VALVE STEM SEAL
6. VALVE SPRING
7. VALVE SPRING RETAINER
8. VALVE KEEPERS
9. VALVE CAP

Figure 28. Valve and valve springs

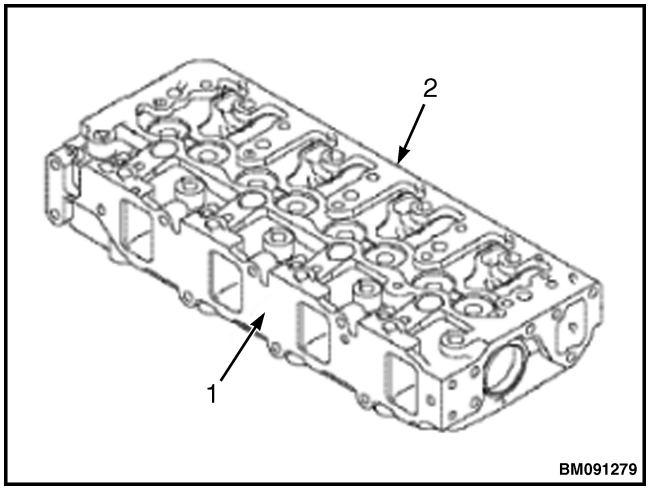
6. Slowly release the tension on the valve spring.

7. Remove the spring retainer and valve spring. See Figure 28.

NOTE: If the valves are being reused, identify them so they can be installed in the original location.

8. Repeat for all remaining valves.

9. Turn the cylinder head over on the work bench so the exhaust port side faces down. See Figure 29.



1. INTAKE SIDE
2. EXHAUST SIDE

Figure 29. Intake and exhaust side

10. Remove the intake and exhaust valves from the cylinder head. See Figure 28.

11. Remove the valve stem seals. See Figure 28.

Valve guides

NOTE: The valve guides should not be removed until inspection and measurement procedures have been performed. See Valve guides.

1. Confirm valve guides have been inspected.

2. If the valve guides were determined to be not within specifications, use a drift pin and hammer to drive the valve guides out of the cylinder head.

CLEAN AND INSPECT

DANGER

Fume/burn hazard!

Always read and follow safety related precautions found on containers of hazardous substances such as cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

WARNING

Cleaning solvents can be flammable and toxic and can cause skin irritation. When using cleaning solvents, always follow the recommendations of the manufacturer.

CAUTION

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

CAUTION

Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.

CAUTION

Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.

CAUTION

Use caution not to scratch the gasket mating surfaces when cleaning the exhaust manifold and cylinder head.

CAUTION

Use caution not to scratch the gasket mating surfaces when cleaning the cylinder head and cylinder block.

1. Carefully remove all gasket residue from the exhaust manifold and cylinder head. See Figure 15. Inspect the exhaust manifold for scratches, cracks, or any other damage. Repair or replace as needed.
2. Carefully remove all gasket residue from the intake manifold and cylinder head. See Figure 15. Inspect the intake manifold for scratches, cracks, or any other damage. Repair or replace as needed.
3. Carefully remove all gasket residue from the cylinder head and cylinder block. See Figure 26. Inspect the cylinder head for scratches, cracks, or any other damage. Repair or replace as needed.

NOTE: Do not use any cleaning solvent that is silicone-based, as this can cause damage to the engine oxygen sensor.

4. Thoroughly clean all components using a non-metallic brush and an appropriate solvent, such as brake cleaner or laquer thinner. Each cylinder head component must be free of carbon, metal shavings and other debris.
5. Visually inspect the parts. Replace any parts that are obviously discolored, heavily pitted, or otherwise damaged. Replace parts that do not meet the specified limit. Refer to Diesel engine specifications for service limit.

Cylinder head components

Push rods

Determine if the bend of the push rods are within the specified limit.

Push rod bend

1. Place the push rods on a flat inspection block or layout bed.
2. Roll the push rods until a gap can be observed bewteen a portion of the push rod and the surface of the inspection block or layout bed.
3. Use a feeler gauge to measure the gap. See Figure 30. See Diesel engine specifications for service limit.

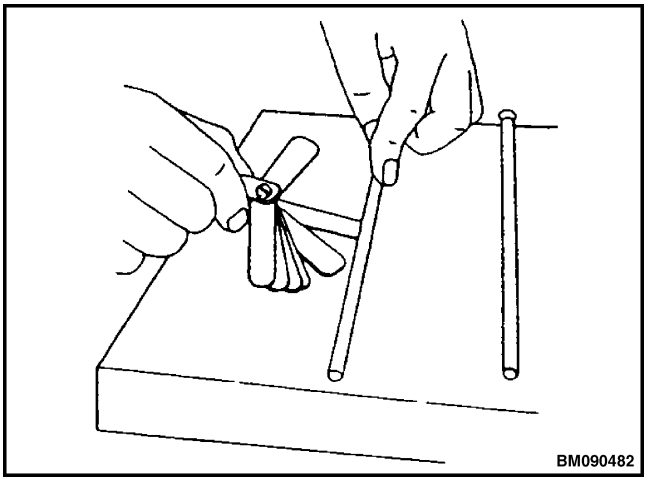


Figure 30. Push rod inspection

Rocker arm assembly

Rocker arm shaft hole diameter

1. Use a test indicator and micrometer to determine if the inside diameter of all the rocker arms and rocker arm support brackets are within the specified limits. See Figure 31.

2. Inspect the contact areas for excessive wear or damage.

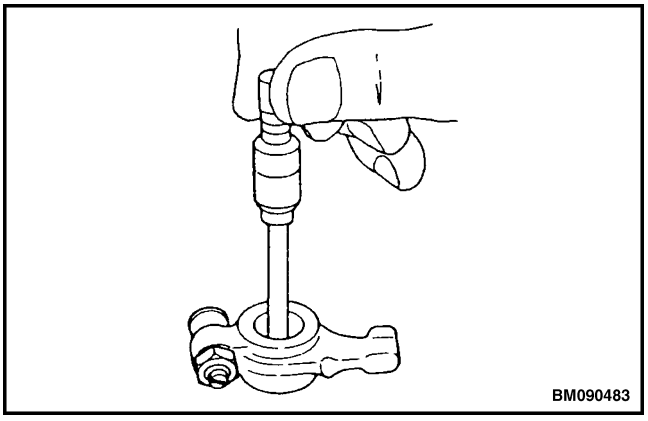


Figure 31. Inside diameter

Rocker arm shaft outside diameter

1. Use a micrometer to measure the rocker arm shaft diameter. Measure at each rocker arm location in two directions 90° apart. See Figure 32.

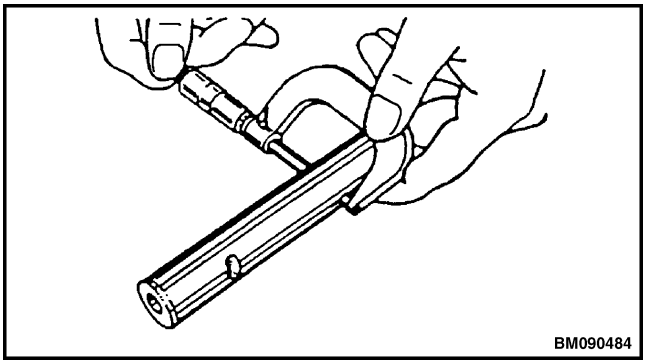


Figure 32. Outside diameter

Valve guides

1. Visually inspect the valve guides for distortions, scoring or other damage.

NOTE: Measure the valve guides while they are installed in the cylinder heads.

2. Use a telescoping gauge and micrometer to measure the inside diameter at each end of the valve guide. Measure the diameter in three places, with two of those three measurements being 90° apart. See Diesel engine specifications for service limit. Replace valve guides if not within specifications.

Cylinder head

Cylinder head distortion

1. Place the cylinder head flat on the work bench, with the combustion side up.

2. Use a straight edge and a feeler gauge to measure cylinder head distortion. Measure diagonally and along each side. See Diesel engine specifications for service limit.

3. If distortion exceeds the service limit, resurface or replace the cylinder head. Remove only enough material to make the cylinder head flat, but do not remove more than 0.20 mm (0.008 in.).

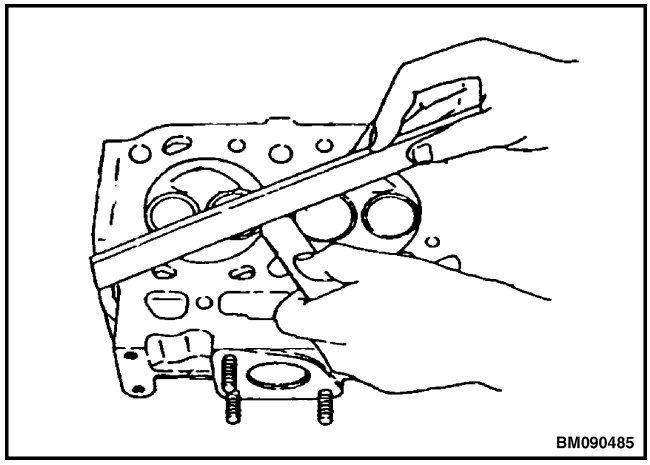


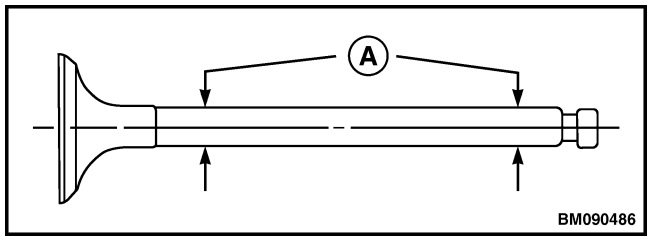
Figure 33. Cylinder head distortion check

Intake and exhaust valves

Visually inspect the intake and exhaust valves. Replace any valves that are discolored, heavily pitted or otherwise damaged.

Valve stem diameter

Use a micrometer to measure the valve stem diameter. Measure the valve stem near the combustion end and near the opposite end. See Figure 34, and Diesel engine specifications for service limit.



A. MEASUREMENT POINTS

Figure 34. Valve stem diameter measurement points

Valve stem straightness

Place the valve stem on a flat inspection block or layout bed. Roll the valve until a gap can be observed between a portion of the valve stem and the surface of the inspection block or layout bed. Use a feeler gauge to measure the gap. See Figure 35 and refer to Diesel engine specifications for service limit.

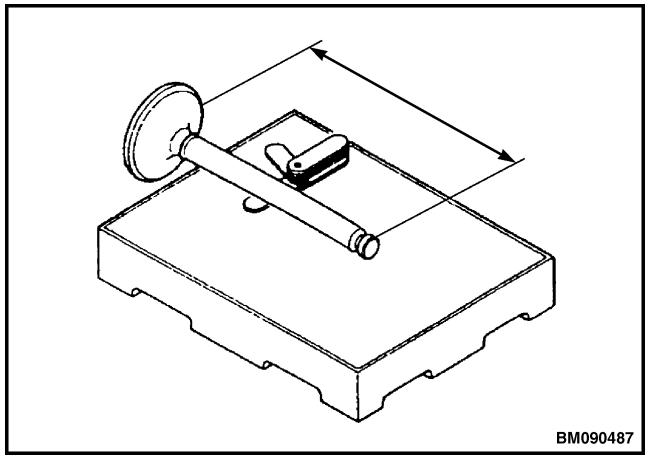


Figure 35. Valve stem straightness check

Valve recession

NOTE: The valve guides must be installed to perform this check.

1. Insert the valves into their original locations in the cylinder head and press them down until they are fully seated.

2. Using a depth micrometer, measure the difference between the cylinder head gasket surface and the combustion surface of each exhaust and intake valve. See Figure 36 and Figure 37. Refer to Diesel engine specifications for service limit.

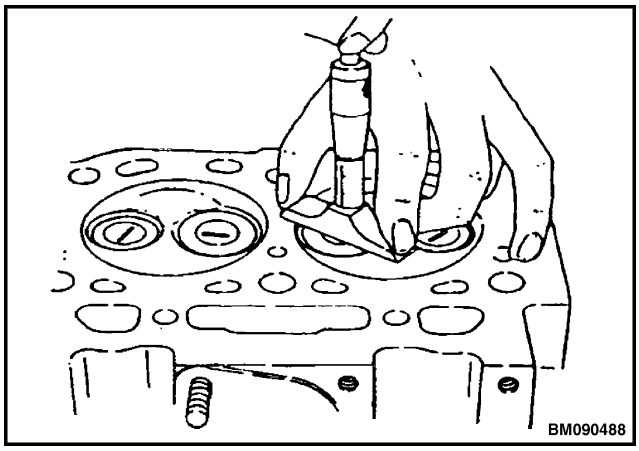


Figure 36. Valve recession measurement

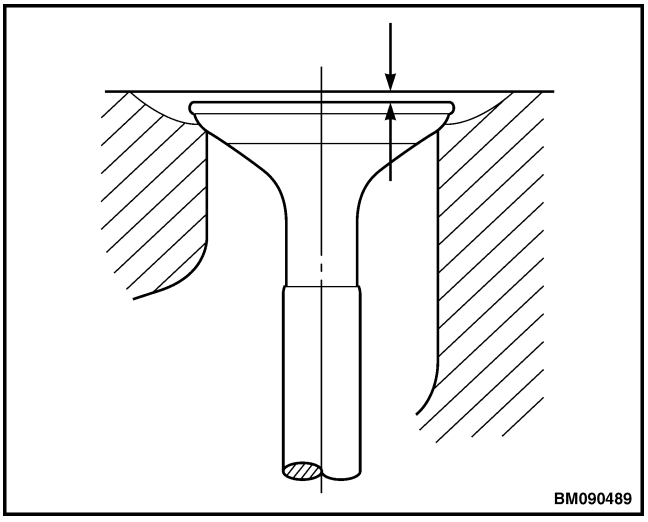


Figure 37. Valve recession

Valve face and valve seat

1. Always check the clearance between the valve and valve guide before correcting the valve seat. See Valve guides, inspection. Refer to Diesel engine specifications for service limit.

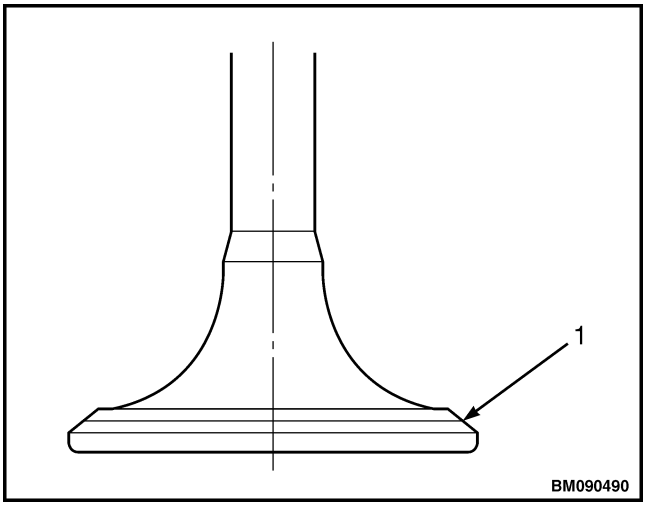
2. If the clearance exceeds the limit, replace the valve or valve guide to bring the clearance within the limit.

3. Roughness or burrs will cause poor seating of a valve. Visually inspect the seating of each valve and determine if lapping or grinding is needed. Lapping or grinding is needed if the cylinder head's seat width exceeds standard limits. Refer to Diesel engine specifications for service limit.

4. Visually inspect all valve faces and valve seats for pitting, distortion, cracking, or evidence of overheating. Usually the valves and valve seats can be lapped or ground ro return them to serviceable condition. Severly worn or damaged components require replacement.

5. Coat the valve seat with a thin coat of bluing compound. Install the valve and rotate it to distribute bluing on to the valve. The contact pattern should be approximately centered on the valve face and uniform in width. See Figure 38.

6. Visually inspect the valve seat for even contact.



1. VALVE SEAT

Figure 38. Valve seat

7. Adjust the valve seat diameter by top-grinding with a 150° stone to make the seat diameter smaller, then by bottom-grinding using a 40° stone to make the seat diameter larger. Once the seat location has been corrected, grind and lap the seat angle to specification.

8. Grind the valve face and/or valve seat only enough to return them to serviceable condition. Grinding is only necessary if the valve and valve seat do not contact correctly. Check recession after grinding.

9. If the valve requires grinding, lap the valve after grinding. Lap the valve seat and the cylinder head with a mixture of valve compound and engine oil. Be sure to thoroughly wash the parts to remove all valve compound.

Valve springs

Inspect the valve springs. If damage or corrosion is seen, or if measurements exceed the specified limits, replace the springs.

Fractures - Check for fractures on the inside and outside portions of the springs. If the valve spring is fractured, replace the spring.

Corrosion - Check for corrosion of spring material caused by oxidation.

Squareness - Use a flat surface and a square to check each spring for squareness. Refer to the Engine Specifications for the service limit.

Free Length - Use a caliper to measure the length of the spring. Refer to Diesel engine specifications for service limit.

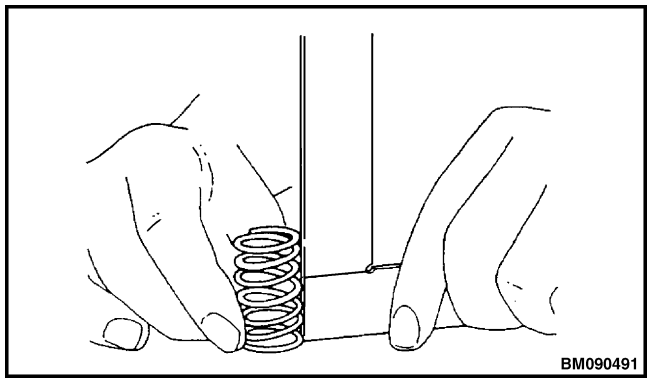


Figure 39. Spring squareness check

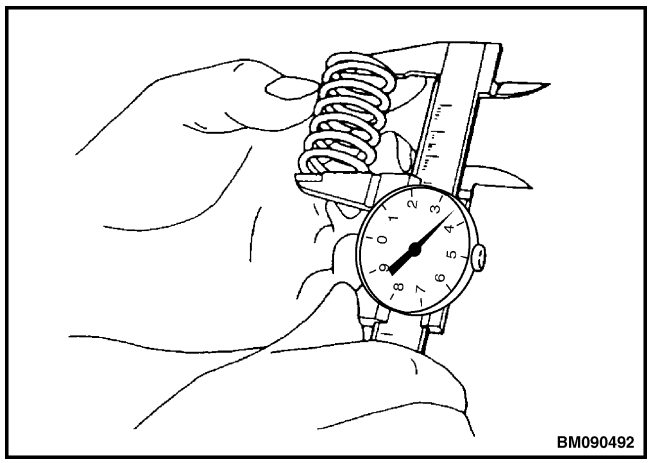


Figure 40. Spring free length check

ASSEMBLE AND INSTALL

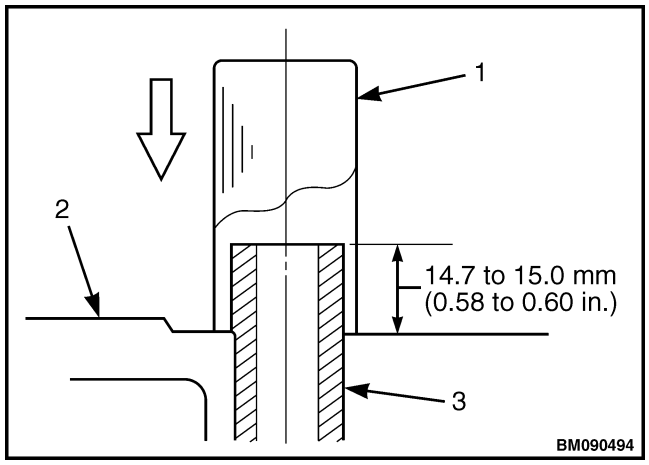
Valve Guides

1. The valve guides are installed into the cylinder head with an extremely tight press fit. Before installing the valve guides, place the valve guides in a freezer for at least twenty minutes. This will cause the valve guides to contract, making it easier to install the valve guides into place.

2. Immediately after removing the valve guides from the freezer, insert the valve guides in their proper positions in the cylinder head.

3. Locate the valve guide installation tool. See Special tools for diesel engines.

4. Use the valve guide installation tool to finish installing the valve guides into the cylinder head to the proper height. See Figure 41.



1. VALVE GUIDE INSTALLATION TOOL
2. CYLINDER HEAD
3. VALVE GUIDE

Figure 41. Valve Guide Installation

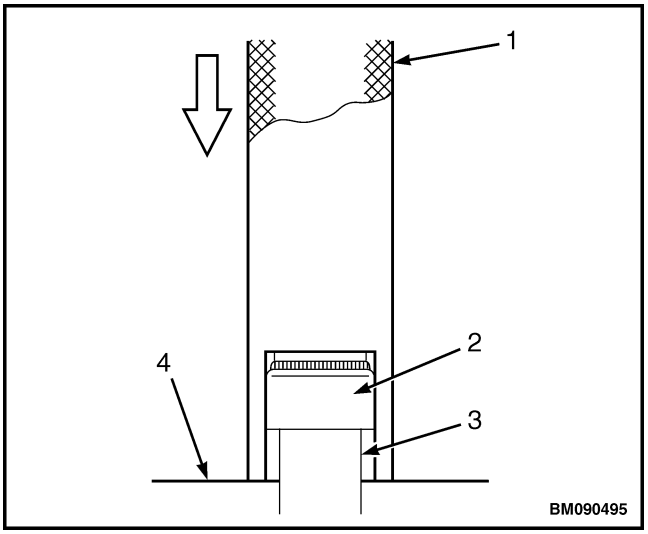
Valves and valve springs

Always install new valve stem seals. The exhaust valve steam seals are different from the intake valve stem seals and can be identified by either by different colored paint marks (intake seals may have red paint, exhaust seals may have blue, for example) in the outside of the seals or by the color of the seal spring. Ensure they are installed in the correct locations.

1. Apply clean engine oil to the lip of the valve stem seal.

2. Locate the valve stem seal installation tool. See Special tools for diesel engines.

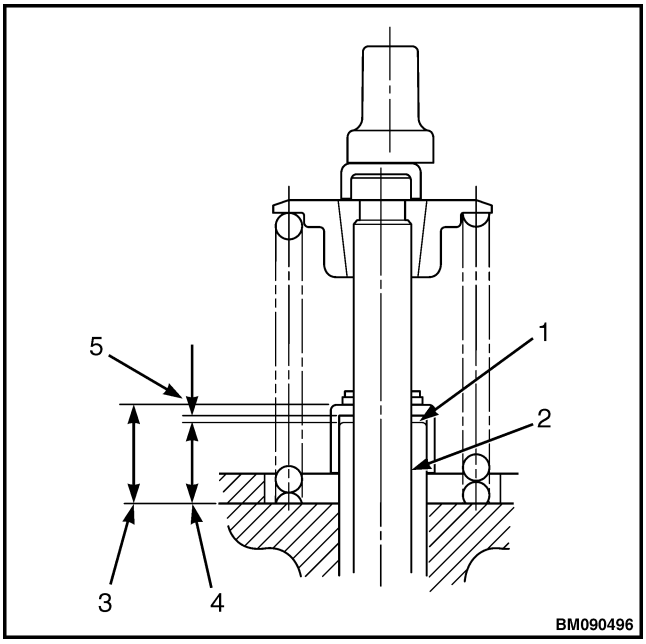
3. Use the valve stem seal installation tool to insert a new valve stem seal on each of the valves. See Figure 42.



1. VALVE STEM SEAL INSTALLATION TOOL
2. VALVE STEM SEAL
3. VALVE GUIDE
4. CYLINDER HEAD

Figure 42. Valve Stem Seal Installation

4. Measure the distance from the cylinder head to the valve stem seal. Refer to Diesel engine specifications for the clearance specifications. See Figure 43.



1. VALVE STEM OIL SEAL
2. VALVE GUIDE
3. VALVE STEM SEAL PROJECTION
4. VALVE GUIDE PROJECTION
5. CLEARANCE

Figure 43. Valve Stem Seal Clearance

5. Place the cylinder head assembly down on its exhaust port side.

6. Place all the valves in their proper positions in the cylinder head, as marked when disassembled.

7. Place the cylinder head on the work bench with the combustion chamber facing down. Install the valve springs and valve spring retainers. See Figure 28.

8. Using the valve compressor tool, compress the valve spring. See Figure 27.

9. Install the valve keepers and slowly release the tension in the valve spring. See Figure 28.

10. Install the valve cap.

11. Repeat these procedures until all the intake and exhaust valves are installed.

Cylinder head

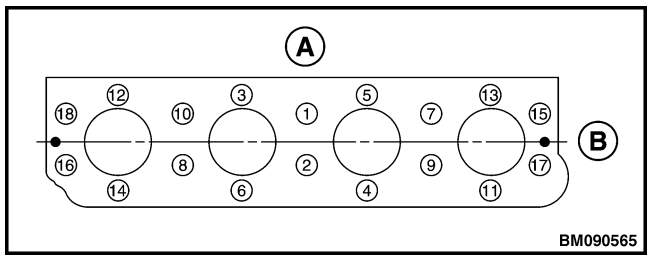
1. Carefully clean the combustion surface of the cylinder head and the top surface of the cylinder block.

2. Place a new cylinder head gasket on the cylinder block. See Figure 26.

3. Position the cylinder head on the cylinder head gasket and cylinder block.

4. Lightly oil the threads of the cylinder head bolts.

5. Install the cylinder head bolts and tighten the cylinder head bolts to 46 to 49 N•m (34 to 36 lbf ft) in the sequence shown in Figure 44. Then tighten the cylinder head bolts to 92 to 98 N•m (68 to 72 lbf ft) in the same sequence.

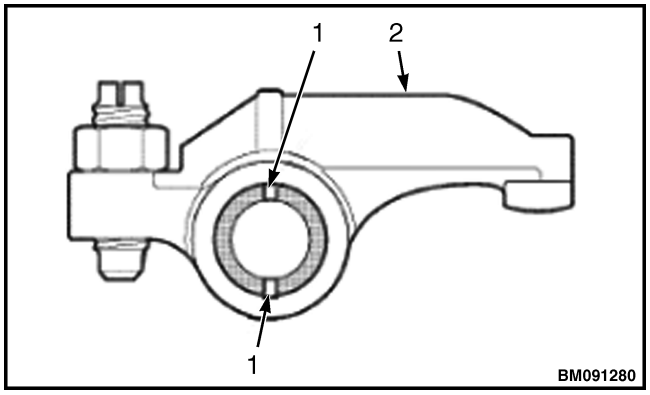


A. CAMSHAFT SIDE
B. FAN SIDE

Figure 44. Cylinder Head Torque Sequence

Rocker arm assembly

1. Confirm the lubrication holes in the rocker arm shaft are oriented correctly with the rocker arms. See Figure 45.



1. LUBRICATION HOLES
2. ROCKER ARM

Figure 45. Rocker arm

2. Lubricate the rocker arm shaft with engine oil.

NOTE: To properly align the rocker arm shaft with the rocker arm supports, first position the rocker arm shaft with the hole for the shaft alignment stud facing up.

3. Align the hole in the rocker arm shaft and the hole in the rocker arm support. Install the alignment stud. See Figure 24.

NOTE: The rocker arm shaft fits tightly in the rocker arm supports. Clamp the rocker arm shaft in a padded vise and twist and push the rocker arm supports onto the rocker arm shaft.

4. Slide the rocker arm supports, springs, and rocker arms onto the shaft. See Figure 24.

NOTE: To properly align the rocker arm shaft with the rocker arm supports, first position the rocker arm shaft with the hole for the shaft alignment stud facing up. Align the hole in the rocker arm shaft and the hole in the rocker arm support. Install the alignment stud. See Figure 24.

5. Place rocker arm assembly in position on the cylinder head.

6. Install and hand tighten the rocker arm shaft retaining bolt and nuts

7. Insert all push rods into the correct push rod holes.

8. Align push rods with their respective rocker arms.

9. Tighten rocker arm shaft retaining bolt and nuts.

10. Tighten rocker arm shaft adjustment screw.

11. Adjust valve lash. See Valve Clearance Adjustments.

12. Install the cylinder head cover. See Valve cover.

Glow plugs

1. Install glow plugs into the cylinder head. See Figure 22. Torque to 15 to 20 N•m (11.1 to 14.8 lbf ft).

2. Connect the glow plug wire harness connectors to each glow plug and secure with the nut. Torque each nut to 1 to 1.5 N•m (0.7 to 1.1 lbf ft).

3. Connect the glow plug wire harness to the engine harness.

Valve cover

1. Lightly grease the new valve cover gasket. Figure 23.

2. Place new valve cover gasket in the groove of the cylinder head cover.

3. Place the valve cover in position on the cylinder head.

4. Verify that the O-rings are installed on the valve cover bolts.

5. Install and tighten the valve cover bolts. See Diesel engine specifications.

Engine assembly

1. Place a new exhaust manifold gasket and the exhaust manifold in position on the cylinder head and install the exhaust manifold mounting bolts. See Figure 15.

2. Connect the exhaust pipe to the exhaust manifold and install retaining nuts. See Figure 15.

3. Place a new gasket and the intake manifold in position on the cylinder head and install the intake manifold mounting bolts. See Figure 15.

4. Connect the fuel hoses to the fuel filter. See Diesel fuel system repair.

5. Install the fuel injectors and high pressure lines. See Figure 15.

6. Connect the air intake hose to the intake manifold. See Figure 15.

7. Install water pump. See Water pump repair.

8. Install alternator. See Diesel electrical system repair.

CAUTION

Additives may damage the cooling system. Before using additives, contact your local Hyster dealer.

9. Fill cooling system with coolant. See Daily periodic maintenance (PM) task schedule in **Periodic Maintenance** 8000SRM2305 for your lift truck for the correct coolant amount and type.

10. Install radiator cap.

11. Change engine oil and oil filter. See **Periodic Maintenance** 8000SRM2305 for procedure.

WARNING

During engine operation, be careful not to touch the fan, pulleys, or drive belts. Contact with these parts can cause serious injury.

WARNING

The radiator or other parts of the cooling system may be hot or under pressure and can cause serious injury.

12. Start engine and check for leaks.

13. Stop engine and resolve any leaks that are discovered.

WARNING

DO NOT remove the radiator cap from the radiator when the engine is hot. When the radiator cap is removed, pressure will release from the coolant system. If the coolant system is hot, the steam and boiling coolant can cause severe burns.

WARNING

The radiator or other parts of the cooling system may be hot or under pressure and can cause serious injury. Wait 30 minutes for the radiator and engine to cool before performing maintenance to the cooling system. After 30 minutes, do a touch test by touching the radiator with your hand. If the radiator is still hot to the touch, wait another 30 minutes before attempting any maintenance to the cooling system.

CAUTION

Additives may damage the cooling system. Before using additives, contact your local Hyster dealer.

14. If coolant is hot, allow engine time to cool. Check coolant level and fill as required between the ADD and FULL marks on the coolant reservoir.

DIESEL TIMING GEAR CASE REPAIR 202001-013

TIMING GEAR CASE COVER

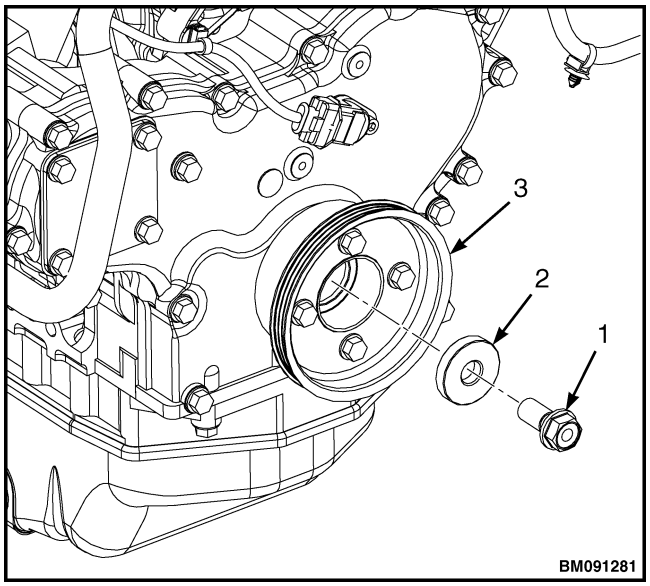
Remove

1. Remove the engine. See Diesel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

2. Place the engine on an engine stand or a clean, flat working surface large enough to accomodate the engine and components.

3. Remove the coolant fan, V-belt and water pump. See **Cooling system** 0700SRM2300 service manual.

4. Use a gear puller to remove the crankshaft pulley and spacer. See Figure 46.

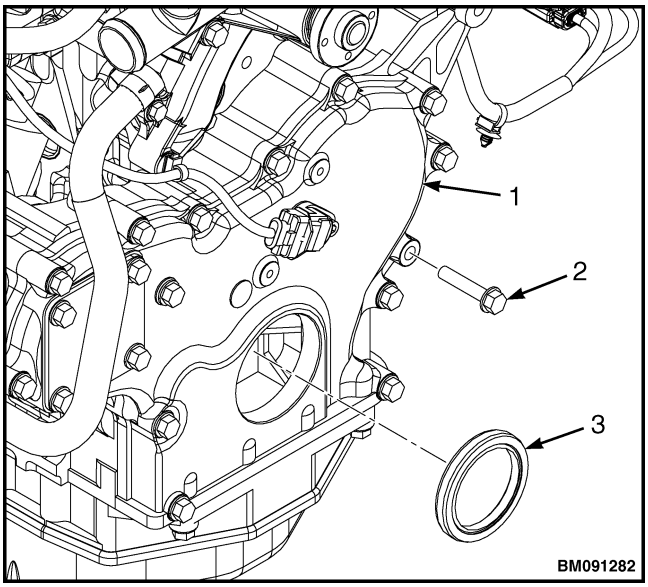


1. BOLT
2. SPACER
3. CRANKSHAFT PULLEY

Figure 46. Crankshaft pulley

5. Remove the 14 bolts retaining the timing gear case cover. See Figure 47.

6. Remove the timing gear case cover. If necessary, remove the front oil seal from the timing gear case cover. See Figure 47.



1. TIMING GEAR CASE COVER
2. BOLT
3. FRONT OIL SEAL

Figure 47. Timing gear case cover

Inspect

WARNING

Cleaning solvents can be flammable and toxic and can cause skin irritation. When using cleaning solvents, always follow the recommendations of the manufacturer.

WARNING

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

Clean all old sealant from the timing gear case cover and the timing gear case. Clean the timing gear case cover in cleaning solvent. Dry the timing gear case cover with compressed air. Inspect for wear, cracks, and any other damage. If necessary, replace timing gear case cover.

Install

1. Apply a continuous bead of Three Bond Liquid Gasket, Hyster Part Number 1599478, to the outside diameter of a new front oil seal.

2. Using a special tool, install the new front oil seal into the timing gear case cover. Apply lithium grease to the lip of the front oil seal. See Special tools for diesel engines for appropriate tool.

3. Apply a continuous bead of Three Bond Liquid Gasket, Hyster Part Number 1599478, to the surface of the timing gear on the side that adjoins the engine block.

4. Place the timing gear case cover in position on the timing gear case and install retaining bolts. See Figure 47. Tighten bolts to standard torque value.

TIMING GEAR CASE

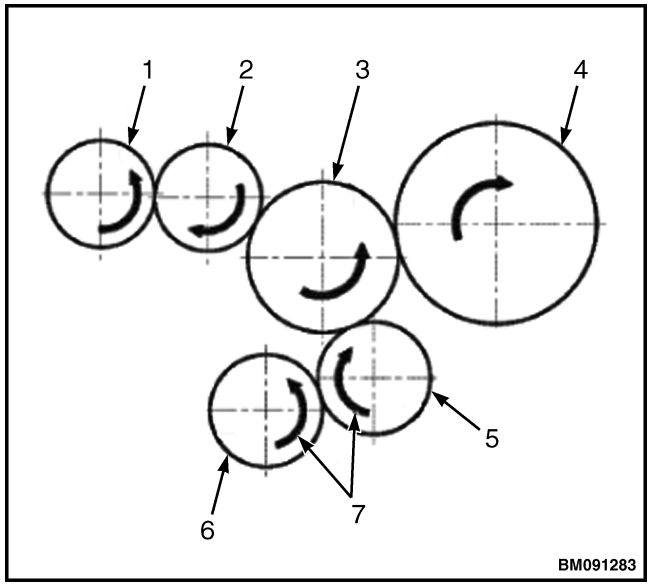
Checks

Check timing gear backlash

Prior to removing the timing gears, measure the gear backlash and determine the gear wear.

Check the backlash between each pair of connecting gears. See Figure 48. If not within specification, replace both connecting gears. See Table 18 in Diesel engine specifications for service limits.

NOTE: Do not allow the gear being checked to move axially as excess end play could cause a false reading.



1. SUPPLY PUMP GEAR
2. IDLER GEAR (B)
3. IDLER GEAR (A)
4. CAMSHAFT GEAR
5. CRANKSHAFT GEAR
6. LUBRICATING OIL PUMP GEAR
7. DIRECTION OF ROTATION

Figure 48. Timing gear backlash

Measuring idler gear-to-crankshaft gear backlash

1. Position a dial indicator as shown in Figure 49, on the SIDE of the gear to measure.

NOTE: Figure below is oriented to show the SIDE of the gear at the TOP of the figure.

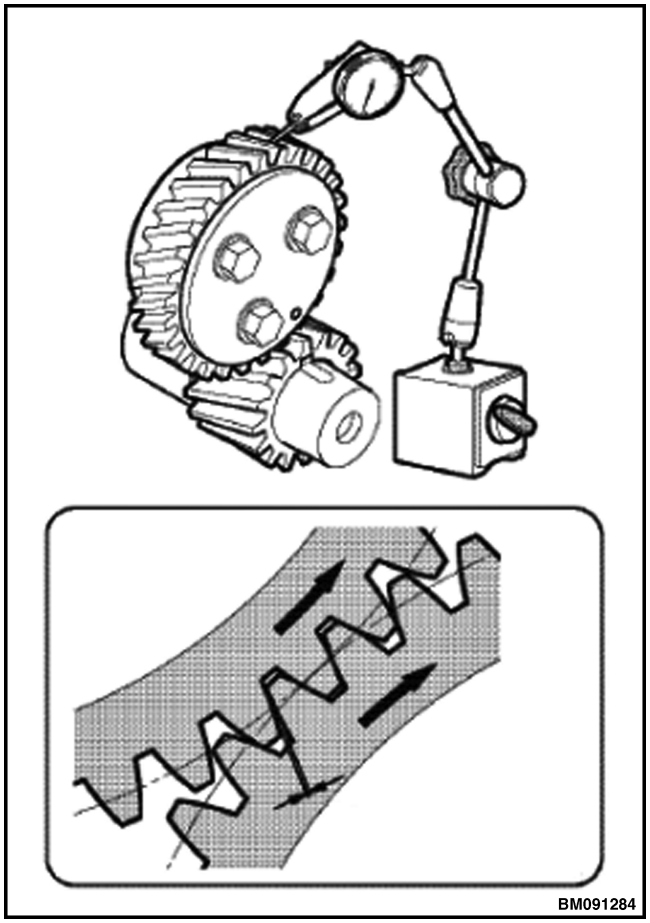


Figure 49. Dial indicator

2. Rotate the idler gear back and forth to check the idler gear backlash, by measuring the movement between gears before they engage. The total indicator reading is the backlash. Record the measurement.

Measuring idler gear-to-camshaft gear backlash

1. Drive a small wooden wedge between the crankshaft gear and idler gear to prevent the idler gear from rotating.

2. Install the dial indicator to read the camshaft gear backlash. Rotate the camshaft drive gear against the idler gear to measure the backlash. Record the measurement.

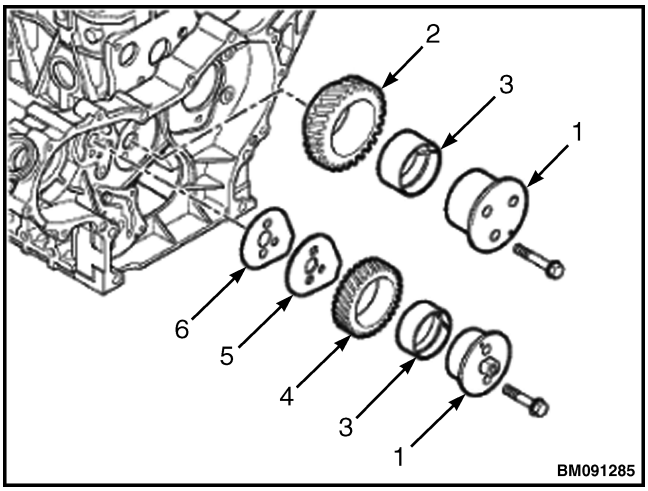
3. Check the idler gear-to-fuel injection pump drive gear backlash in the same manner as the camshaft drive gear. Record the measurement.

Remove

1. Rotate the engine to align the timing gears. Mark the gears with paint markers to aid in reinstallation.

2. Remove the bolts from the idler gear shaft. See Figure 50.

3. Remove the idler gear shafts, idler gear A and B, and bushing. See Figure 50.



1. IDLER GEAR SHAFT
2. IDLER GEAR (B)
3. IDLER GEAR BUSHING
4. IDLER GEAR (A)
5. PLATE, IDLE SHAFT
6. PLATE

Figure 50. Timing gears

NOTE: DO NOT remove the crankshaft gear unless it or the crankshaft is damaged and requires replacement.

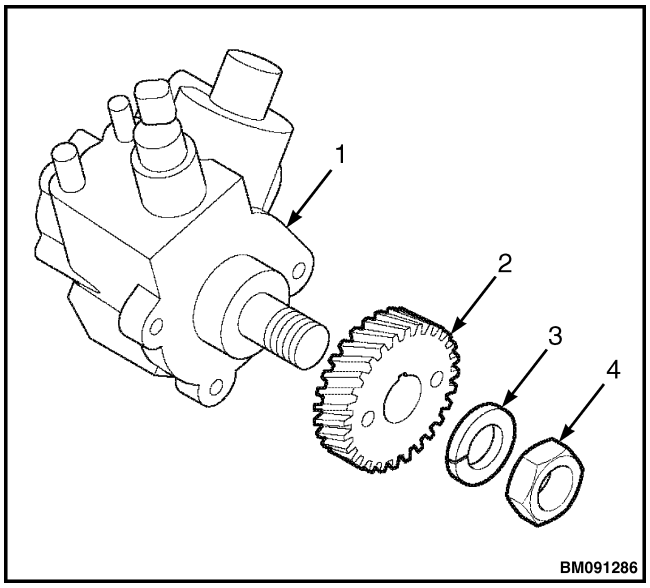
4. If the crankshaft gear or crankshaft are damaged and require replacement, use a gear puller to remove the crankshaft gear. See Figure 48.

NOTE: Removal of the camshaft gear requires the camshaft be removed and placed in a press. DO NOT remove the camshaft gear unless it or the camshaft is damaged and requires replacement.

5. If necessary, remove the camshaft. See Step 8.

6. Confirm gears are aligned properly. Mark the gears with paint markers to aid in reinstallation.

7. Use a gear puller to remove the supply pump drive gear. See Figure 51.

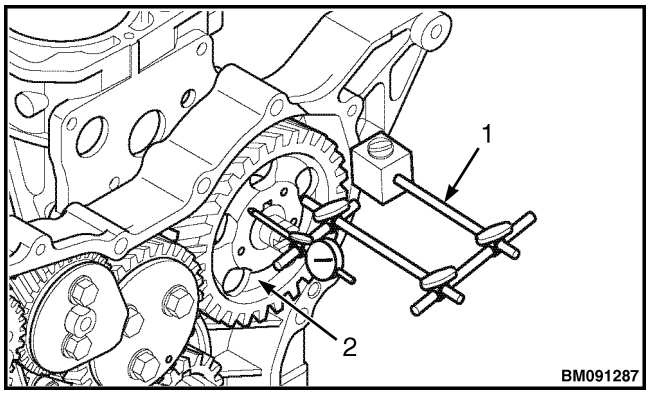


1. SUPPLY PUMP
2. SUPPLY PUMP DRIVE GEAR
3. WASHER
4. NUT

Figure 51. Supply pump drive gear

8. Before removing the camshaft, check the camshaft end play.

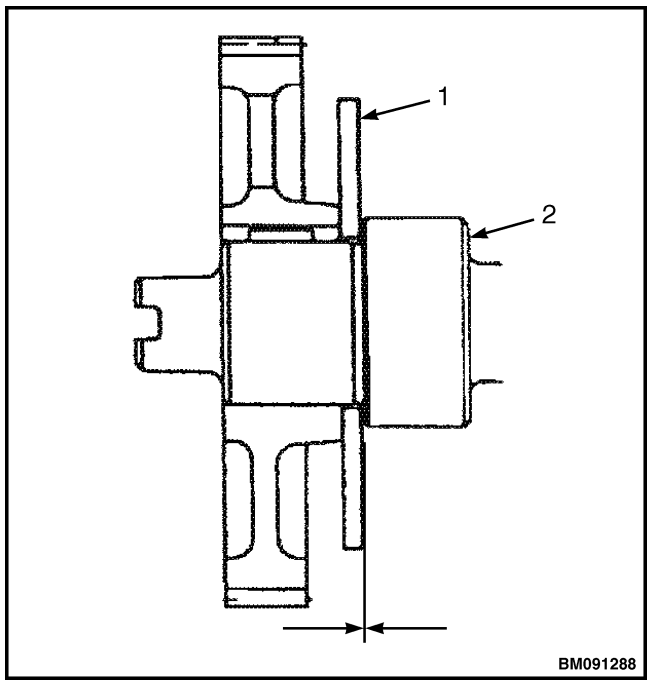
   - Method A: Install a dial indicator on the cylinder block. See Figure 52. Move the camshaft back and forth to measure the end play. Record the measurement. See Camshaft and timing gear train specifications in Diesel engine specifications for service limit.



1. DIAL INDICATOR
2. CAMSHAFT GEAR

Figure 52. Method A

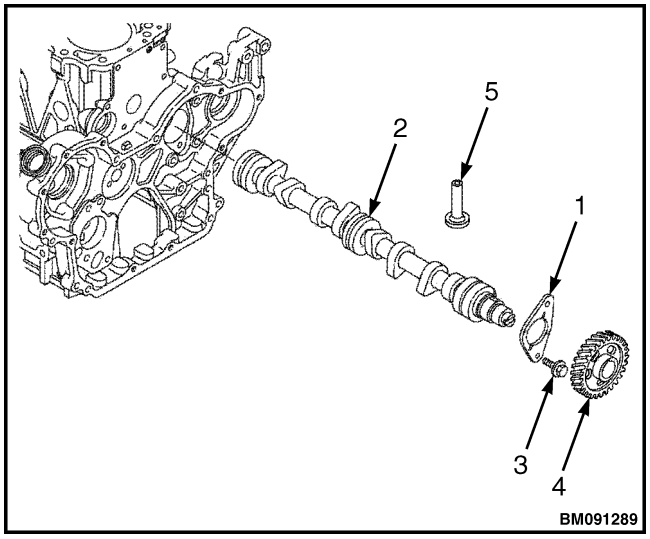
- Method B: Use a feeler gauge to measure the clearance between the thrust plate and front camshaft bearing. See Figure 53. See Table 20 in Diesel engine specifications for service limit.



1. THRUST PLATE
2. FRONT CAMSHAFT BEARING

Figure 53. Method B

9. Remove the two bolts retaining the camshaft thrust plate. See Figure 54.



1. CAMSHAFT THRUST PLATE
2. CAMSHAFT
3. BOLT
4. CAMSHAFT DRIVE GEAR
5. TAPPETS

Figure 54. Camshaft

- If using an engine stand, rotate the engine so that gravity causes the tappets to drop away from the camshaft lobes.
- If using a work surface instead of an engine stand, place the engine upright on the flywheel end mounting flange.

10. Rotate the camshaft at least two turns to bump any sticking tappets away from the camshaft.

11. Slowly pull the camshaft assembly out of the engine. Be careful not to damage the front camshaft bushing. See Figure 55

NOTE: The tappets are "mushroom" shaped and must be removed from inside the engine crankcase.

12. Remove the tappets. Mark the tappets so they can be reinstalled in the same location. See Figure 54.

NOTE: Only remove the camshaft drive gear if the drive gear or camshaft require being replaced.

13. Use a gear puller to press and remove the camshaft drive gear. The drive gear is shrink-fit and must be heated to 180-200°C (356-392°F). See Figure 54.

14. Remove the oil pump. See Diesel lubrication system repair.

15. Remove the bolts. See Figure 55.

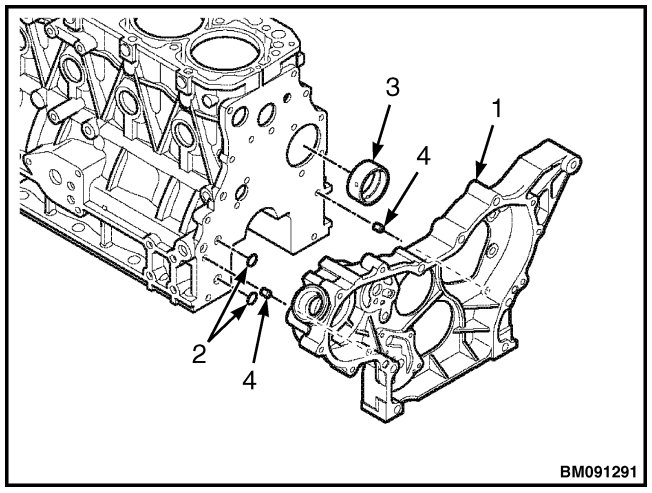
16. Remove the timing gear case from the cylinder block. Thoroughly clean and remove all old sealant from the mating surfaces. See Figure 55.

17. Inspect and measure the camshaft bushing. See Figure 55.

See Table 16 in Diesel engine specifications for service limit.

18. Remove the camshaft bushing if damaged or worn beyond service limit. See Figure 55. See Special tools for diesel engines for appropriate tool.

19. Remove the O-rings and two dowels. See Figure 55.



1. TIMING GEAR CASE
2. O-RINGS
3. CAMSHAFT BUSHING
4. DOWEL

Figure 55. Timing gear case

Install

1. If removed, install a new camshaft bushing using the appropriate service tool. See Figure 55. See Special tools for diesel engines.

2. Apply a continuous bead of Three Bond Liquid Gasket, Hyster Part Number 1599478, to the mounting area of the gear case. Circle each bolt hole with the sealant as well.

3. Install two new O-rings and the two dowels. See Figure 55.

4. Install the timing gear case to the cylinder block. Tighten the bolts to specified torque value. See Figure 55. See Special torque chart.

NOTE: Heat the camshaft drive gear to 180-200°C (356-392°F) before pressing it onto the camshaft.

5. Use a press to install the camshaft thrust plate and camshaft drive gear onto the camshaft. See Figure 54. See Special tools for diesel engines for appropriate tool.

NOTE: The tappets are mushroom shaped and must be installed from inside the engine crankcase.

- If using an engine stand, rotate the cylinder block so that gravity will keep the tappets in place and out of the way of the camshaft lobes when the camshaft is being installed.
- If using a work surface instead of an engine stand, place the engine upright on the flywheel end mounting flange.

6. Lubricate the tappets with clean engine oil or assembly lube. See Diesel engine specifications.

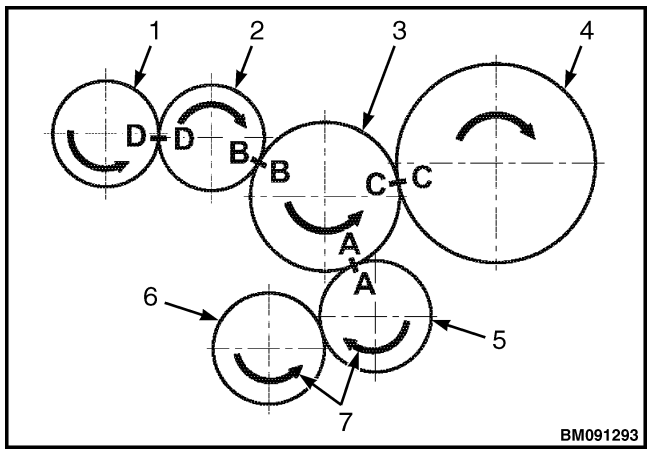
7. Install the tappets back into their position in the cylinder block. Push the tappets fully into the tappet bores so they will not interfere with the installation of the camshaft.

8. Lubricate the camshaft with clean engine oil or assembly lube. Slowly insert the camshaft through the front of the engine into the timing gear case. See Figure 54.

9. Insert the capscrews to retain the camshaft thrust plate to the timing gear case. See Figure 54. Tighten the capscrews to specified torque value. See Special torque chart.

10. Set the piston of the timing gear case side cylinder to center position. See Diesel camshaft and cylinder block repair.

11. Rotate the camshaft until the mark "C" is at approximately the 9 o'clock position and aligns with the mark on the idler gear. See Figure 56.



1. SUPPLY PUMP GEAR
2. IDLER GEAR
3. IDLER GEAR
4. CAMSHAFT GEAR
5. CRANKSHAFT GEAR
6. LUBRICATING OIL PUMP GEAR
7. DIRECTION OF ROTATION

Figure 56. Timing gears

12. Lubricate the idler gear (A), idler gear bushing, and idler gear shaft with clean engine oil. See Figure 50.

13. Align the timing gears according to the marks from the paint marker. See Figure 56.

14. Install the idler gear, idler gear shaft and idler gear bushing while aligning the timing marks AA and CC. At this time, direct the punch mark on the idler gear shaft end surface to the upper part of the engine.

15. While aligning the timing marks BB and DD of the idler gear, install the idler gear, idler gear shaft and idler gear bushing.

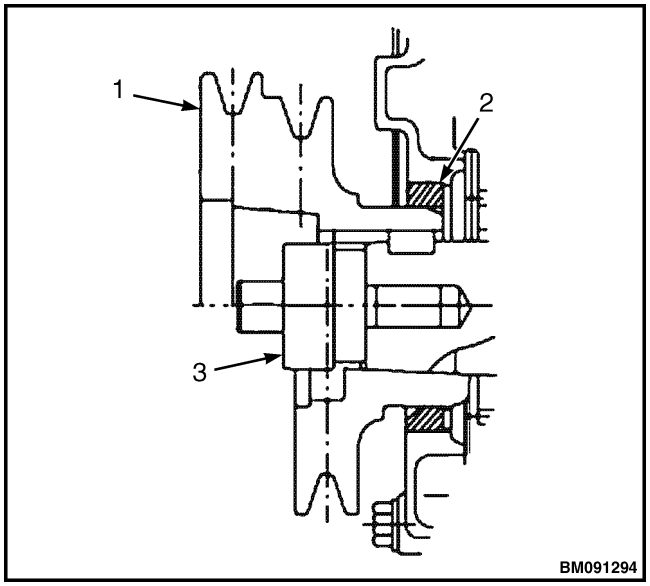
16. When all gears are properly aligned, tighten the idler gear retaining bolts to specified torque value. See Special torque chart.

17. Inspect the marks on all gears to confirm alignment.

NOTE: If you have not used a paint marker to mark gear alignment, do so prior to installing the timing gear case cover.

18. Install the timing gear case cover. See Timing gear case cover, Install.

19. Use the crankshaft pulley installation tool to reinstall the crankshaft pulley. The crankshaft pulley installation tool will guide the pulley hub and protect the front seal from damage. See Figure 57 and Special tools for diesel engines.



1. CRANKSHAFT PULLEY
2. FRONT SEAL
3. CRANKSHAFT PULLEY INSTALLATION TOOL

Figure 57. Crankshaft pulley installation tool

20. Insert the washer and bolt to retain the crankshaft pulley and spacer. See Figure 46. Tighten the bolt to specified torque value. See Diesel engine specifications.

21. Install the water pump, V-belt and coolant fan. See **Cooling system** 0700SRM2300 service manual.

22. Install the engine. See Diesel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

23. Fill the engine oil to the correct level. See Every 2000 hour periodic maintenance (PM) schedule in the **Periodic Maintenance** 8000SRM2305 for correct oil amount and type.

24. Follow the procedure for priming the fuel system. See Every 500 hour periodic maintenance (PM) procedures in the **Periodic Maintenance** 8000SRM2305 manual.

25. Start the engine and check for leaks.

DIESEL CAMSHAFT AND CYLINDER BLOCK REPAIR 202001-014

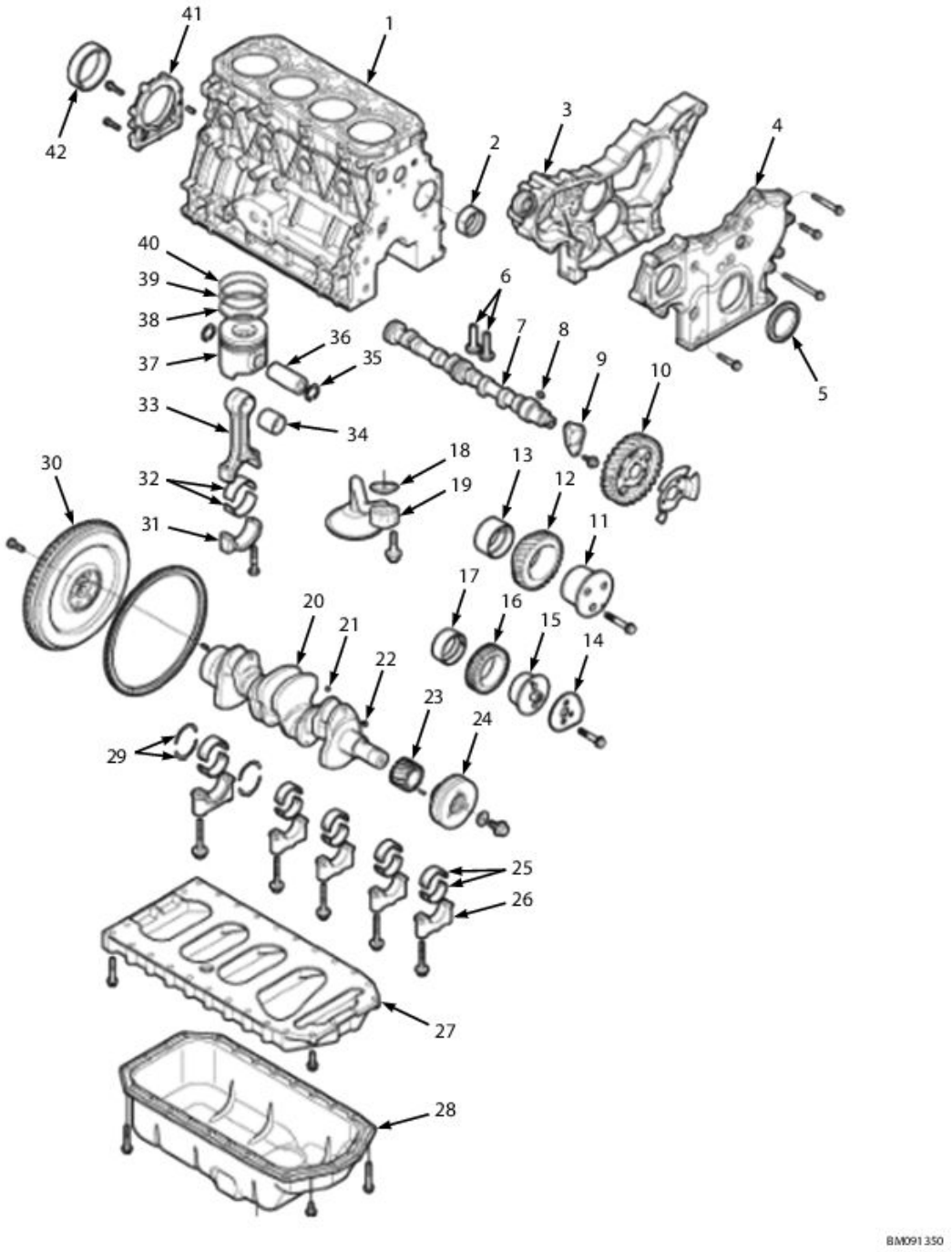


Figure 58. Crankshaft and camshaft components

Legend for Figure 58.

1. CYLINDER BLOCK
2. CAMSHAFT BUSHING
3. GEAR CASE
4. GEAR CASE COVER
5. FRONT CRANKSHAFT SEAL
6. TAPPETS
7. CAMSHAFT
8. CAMSHAFT GEAR KEY
9. CAMSHAFT END PLATE
10. CAMSHAFT GEAR
11. IDLER GEAR SHAFT (A)
12. IDLER GEAR
13. IDLER GEAR BUSHING (A)
14. IDLER GEAR PLATE (A)
15. IDLER GEAR SHAFT (B)
16. IDLER GEAR (B)
17. IDLER GEAR BUSHING (B)
18. OIL PICKUP GASKET
19. OIL PICKUP
20. CRANKSHAFT
21. BALL
22. CRANKSHAFT GEAR KEY
23. CRANKSHAFT GEAR
24. CRANKSHAFT PULLEY
25. MAIN BEARINGS
26. MAIN BEARING CAP
27. OIL PAN SPACER
28. OIL PAN
29. THRUST BEARINGS
30. FLYWHEEL
31. CONNECTING ROD CAP
32. CONNECTING ROD BEARINGS
33. CONNECTING ROD
34. WRIST PIN BUSHING
35. SNAP RING
36. WRIST PIN
37. PISTON
38. OIL RING
39. SECOND COMPRESSION RING
40. TOP COMPRESSION RING
41. CRANKSHAFT REAR SEAL HOUSING
42. CRANKSHAFT REAR SEAL

REMOVE ENGINE COMPONENTS

1. Remove the engine. See Diesel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

2. Remove the starter. See Diesel electrical system repair.

3. Remove the flywheel and flywheel housing. See Diesel flywheel repair.

4. Remove the alternator. See Diesel electrical system repair.

5. Remove the water pump. See Water pump repair in the **Cooling system** 0700SRM2300 service manual.

6. Remove the fuel injection pump. See Diesel fuel system repair.

7. Remove the cylinder head. See Diesel cylinder head repair.

8. Remove the oil pan. Remove the oil suction tube. See Diesel lubrication system repair.

9. Remove the timing gear case cover. See Diesel timing gear case repair.

10. Remove the oil pump. See Diesel lubrication system repair.

NOTE: Do not remove the camshaft gear at this time.

11. Before removing the camshaft, check the camshaft end play. See Diesel timing gear case repair.

DISASSEMBLE

Pistons and connecting rods

NOTE: Keep the piston pin parts, piston assemblies, and connecting rod assemblies together and label all parts, to ensure all parts are returned to the same position during the reassembly process. Note the location of each bearing cap and make sure to not mix up bearing caps during installation.

NOTE: Engines with high operating hours may have a ridge near the top of the cylinders that will catch the piston rings and make it impossible to remove the pistons. Use a suitable ridge reamer to remove ridges and carbon prior to removing the pistons.

NOTE: Pistons can fall from cylinder block if the engine is inverted. Rotate the engine so the connecting rods are horizontal before removing the connecting rod caps.

1. Use a feeler gauge to measure the connecting rod thrust clearance. See Figure 59. Refer to Diesel engine specifications for the standard limit. If the measurement is out of specification, replace the crankshaft, connecting rod, or both.

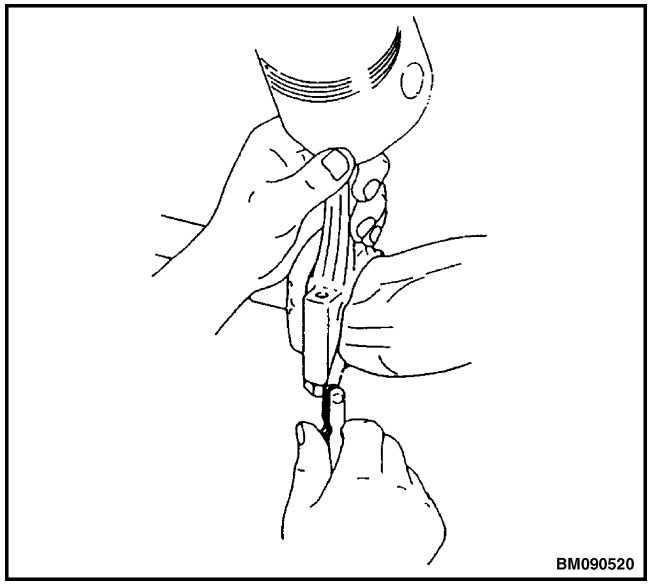


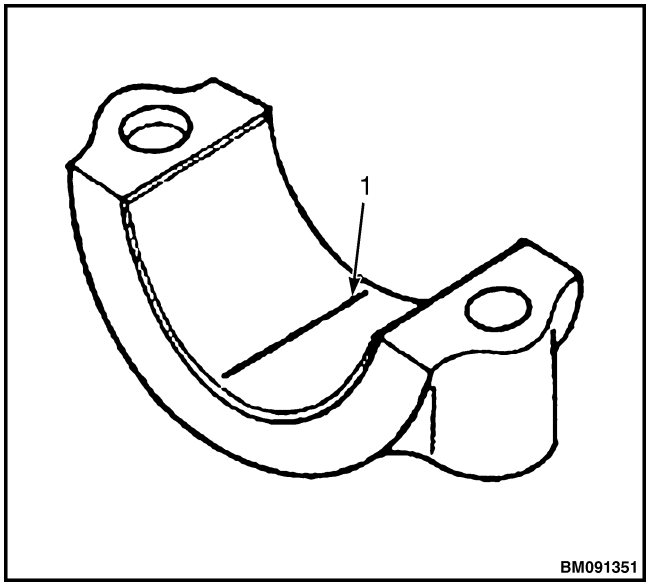
Figure 59. Connecting rod thrust clearance

2. Measure bearing oil clearance prior to removing the pistons and connecting rods to determine extent of wear. Record the measurements.

a. Remove the bearing cap. Do not remove the bearings at this time.

b. Wipe oil from the bearing and crankshaft surfaces.

c. Place a piece of PLASTIGAUGE® along the full width of the bearing (see Figure 60). Do not rotate the crankshaft when using PLASTIGAUGE. A false reading may result.



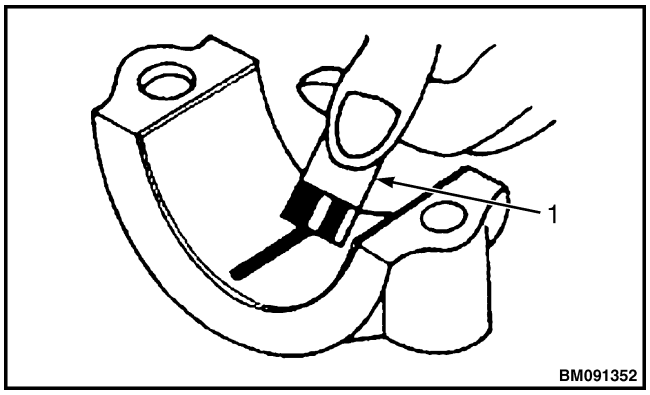
1. PLASTIGAUGE

Figure 60. PLASTIGAUGE placement

d. Reinstall the bearing cap and tighten to 96.0-100 N•m (70.8-73.8 lbf ft).

e. Remove the bearing cap.

f. Compare the width of the flattened PLASTIGAUGE to the graduation marks on the package (see Figure 61). The mark that most closely matches the width of the flattened PLASTIGAUGE will indicate the bearing oil clearance.



1. PLASTIGAUGE

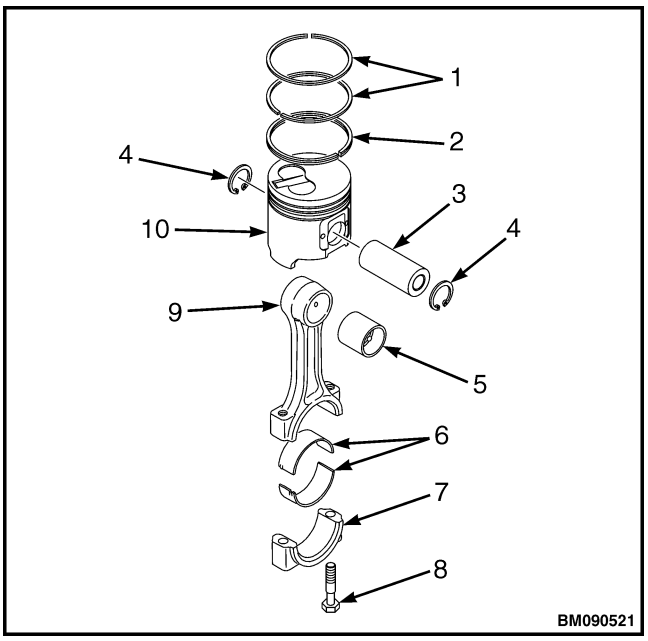
Figure 61. Graduation marks

g. Repeat with each remaining connecting rod.

3. Mark the piston, connecting rod assembly and cylinder, to aid in reinstallation. Use a wooden dowel against the connecting rod and tap the piston and connecting rod assembly out of the cylinder.

4. Mark the cylinder number on the piston and the connecting rod. See Figure 62.

5. Remove the bearing. See Figure 62.



1. COMPRESSION RINGS
2. OIL SEAL RING
3. WRIST PIN
4. SNAP RING
5. WRIST PIN BUSHING
6. BEARING
7. CONNECTING ROD CAP
8. BOLT
9. CONNECTING ROD
10. PISTON

Figure 62. Piston and Connecting Rod

6. Use a piston ring expander to remove the two compression rings from the piston. See Figure 62. Refer to Special tools for diesel engines for appropriate tool.

7. Use the piston ring expander to remove the oil seal ring from the piston. See Figure 62. See Special tools for diesel engines for appropriate tool.

8. Remove the snap ring from the wrist pin. See Figure 62.

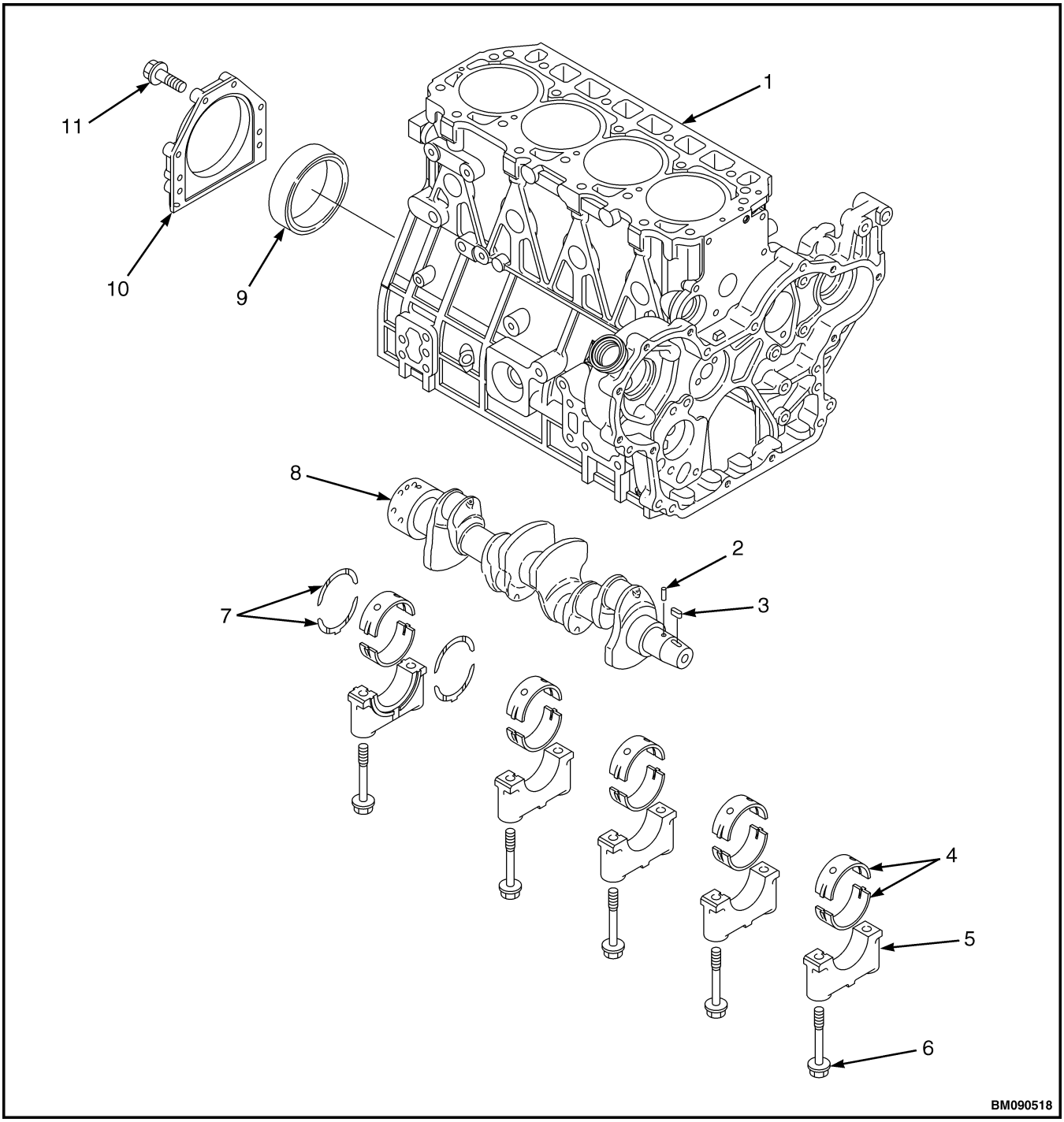
9. Remove the wrist pin and connecting rod from the piston. See Figure 62.

10. Repeat Step 5 through Step 9 for the remaining pistons and piston rods.

REMOVE

Crankshaft

1. Remove the bolts retaining the rear oil seal assembly and remove the rear oil seal assembly. See Figure 63.



1. CYLINDER BLOCK
2. PARALLEL PIN
3. KEY
4. MAIN BEARINGS
5. MAIN BEARING CAP
6. BOLT
7. THRUST BEARINGS
8. CRANKSHAFT
9. REAR OIL SEAL
10. REAR OIL SEAL HOUSING
11. BOLT

Figure 63. Crankshaft

2. If the rear oil seal is worn or damaged, remove the rear oil seal.

3. Measure the crankshaft thrust end play using one of the following two methods:

a. Install a dial gauge on the cylinder block. Move the crankshaft in and out to measure the end play. Record the measurement. See Figure 64.

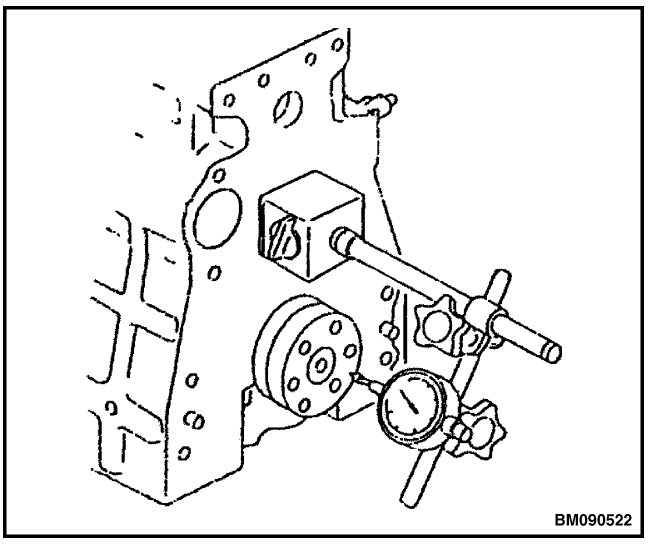
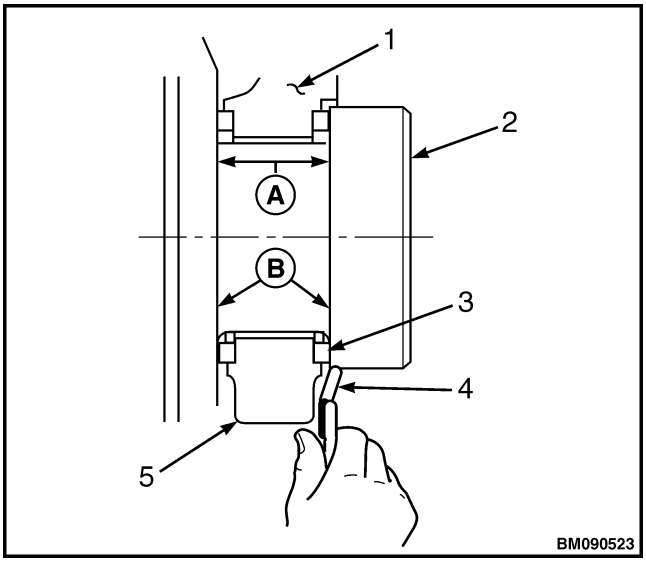


Figure 64. Crankshaft end play measurement with dial gauge

b. Use a feeler gauge to measure the clearance between the thrust bearing and the crankshaft. See Figure 65.



A. STANDARD WIDTH
B. THRUST FACE

1. CYLINDER BLOCK
2. CRANKSHAFT
3. THRUST BEARING
4. SHIM GAUGE
5. CYLINDER BLOCK

Figure 65. Crankshaft side gap measurement with feeler gauge

NOTE: Be sure to note the markings on the main bearing caps, or mark them yourself, so they can be reinstalled in the same location as they were removed.

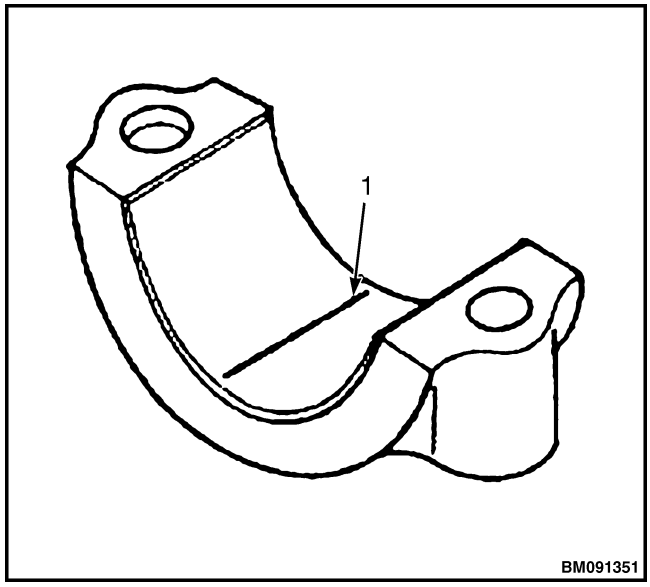
NOTE: The arrows on the main bearing caps point to the flywheel end of the engine.

4. Remove the bolts retaining the main bearing caps and remove the main bearing caps. Do not remove the bearings at this time.

5. Measure bearing oil clearance prior to removing the **crankshaft** to determine the extent of wear. Record the measurement.

a. Wipe oil from the bearing and crankshaft surfaces.

b. Place a piece of PLASTIGAUGE® along the full width of the bearing (see Figure 66). Do not rotate the crankshaft when using PLASTIGAUGE. A false reading may result.



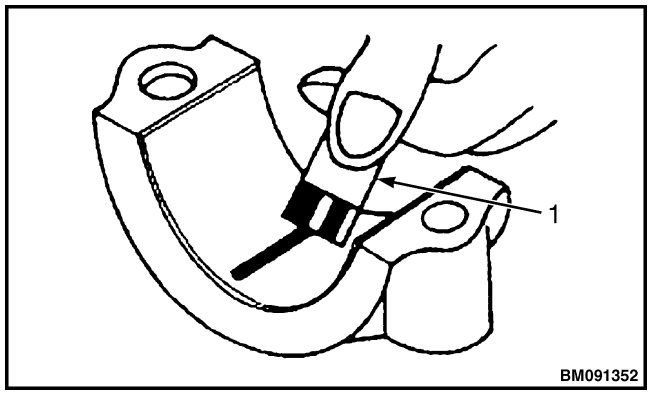
1. PLASTIGAUGE

Figure 66. PLASTIGAUGE placement

c. Reinstall bearing cap and torque to 96.0-100 N•m (70.8-73.8 lbf ft).

d. Remove the bearing cap.

e. Compare the width of the flattened PLASTIGAUGE to the graduation marks on the package (see Figure 67). The mark that most closely matches the width of the flattened PLASTIGAUGE will indicate the bearing oil clearance.



1. PLASTIGAUGE

Figure 67. Graduation marks

6. Remove the crankshaft from the engine.

CAUTION

Do not remove the crankshaft gear unless the gear or crankshaft are damaged and require replacement.

7. Remove the bearings and thrust bearings.

8. If necessary, remove the crankshaft, parallel pin, and key. If using a gear puller, be careful not to damage threads in the end of the crankshaft. See Figure 63.

INSPECT

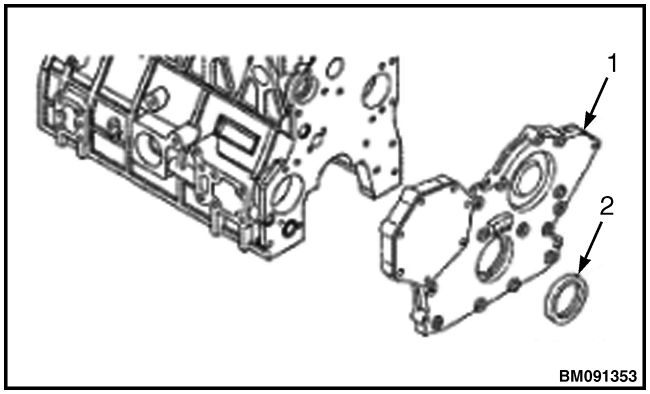
DANGER

Always read and follow safety related precautions found on the containers of hazardous substances like parts cleaners, primers, sealants and sealant removers. Failure to comply could result in death or serious injury.

Thoroughly clean all components using a brush and appropriate solvent such as brake cleaner or laquer thinner. Each part must be free of carbon, gasket material, metal filings and other debris.

Crankshaft oil seals

1. Remove the front oil seal from the timing gear case cover. See Figure 68.

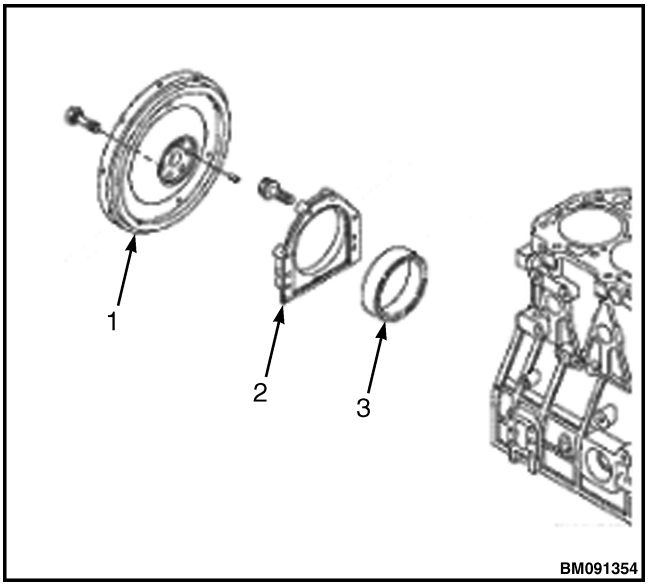


1. TIMING GEAR CASE COVER
2. FRONT OIL SEAL

Figure 68. Front oil seal

2. Apply a continuous bead of ThreeBond Liquid Gasket Hyster part number 2084312 to the outside diameter of a new front oil seal and install in the timing gear case cover. Apply lithium grease to the lip of the seal.

3. Remove the rear oil seal from the seal housing. See Figure 69.



1. FLYWHEEL
2. REAR CRANKCASE COVER
3. REAR OIL SEAL

Figure 69. Rear oil seal

4. Apply a continuous bead of ThreeBond Liquid Gasket Hyster part number 2084312 to the outside diameter of a new oil seal and install in the housing. Apply lithium grease to the lip of the seal.

5. Measure crankshaft bearing oil clearance during disassembly to determine the extent of wear. Measure during assembly to ensure long engine life. Follow this procedure also for connecting rods and main bearings.

Cylinder Block

1. Verify that oil passages are clear and unobstructed. Clear any oil passages as needed.

2. Check for discoloration or evidence of cracks. If evidence of a fracture is found, use the color check method or spray the cylinder block with Magnaflux to determine if the cylinder block is fractured.

3. Inspect the cylinder roundness and cylindricity for evidence of distortions. Collect and record the measurements. See Figure 70 and Table 27.

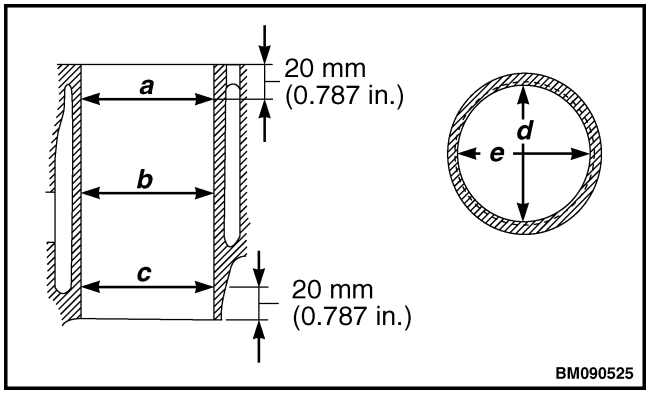


Figure 70. Cylinder measurement points

4. Perform the calculations as follows:

NOTE: The cylinders are numbered in order starting from the fan side of the engine.

a. Measure the inside diameter of cylinder number one near the top of the cylinder (**a**) and in the (**d**) direction. Record that measurement as data **f**.

b. Measure the inside diameter of cylinder number one, near the top of the cylinder (**a**) and in the (**e**) direction. Record that measurement as data **g**.

c. Measure the inside diameter of cylinder number one, near the center of the cylinder (**b**) and in the (**d**) direction. Record that measurement as data **h**.

d. Measure the inside diameter of cylinder number one, near the center of the cylinder (**b**) and in the (**e**) direction. Record that measurement as data **I**.

e. Measure the inside diameter of cylinder number one, near the bottom of the cylinder (**c**) and in the (**d**) direction. Record that measurement as data **j**.

f. Measure the inside diameter of cylinder number one, near the bottom of the cylinder (**c**) and in the (**e**) direction. Record that measurement as data **k**.

g. **Roundness**: Roundness for cylinder number one is calculated as follows:

f - g = X

h - I = Y

j - k = Z

X is the difference between the **f** and **g** measurements at the top of the cylinder.

Y is the difference between the **h** and **I** measurements at the center/middle of the cylinder.

Z is the difference between the **j** and **k** measurements at the bottom of the cylinder.

Select the greatest of values **X**, **Y** and **Z**, then record it as **V**. This value represents the roundness of the cylinder.

h. **Cylindricity** - Cylindricity for cylinder number one is calculated as follows:

Select the least value of values **X**, **Y** and **Z** record that value as **S**. Complete the calculation as follows:

V - S =W

W is the difference between the **V** and **S** measurements. This value represents the cylindricity of the cylinder.

5. Repeat the cylindricity and roundness measurements and calculations for the remaining cylinders.

6. Compare the worksheet findings with the specifications listed in Diesel engine specifications.

7. Consider honing, re-boring, or replacing the cylinder block if the measurements fall outside the specifications.

Table 27. Cylinder Measurement Worksheet

Cylinder Number	Measurements			Calculated Values	
Cylinder #1	Top (***a***)	Dimension (***d***) ***f*** = _____	Dimension (***e***) ***g*** = _____	***f*** - ***g*** = ***X*** ***X*** = _____	Greatest of ***X***, ***Y*** and ***Z*** = ***V*** Roundness ***V*** = _____
	Center (***b***)	Dimension (***d***) ***h*** = _____	Dimension (***e***) ***I*** = _____	***h*** - ***I*** = ***Y*** ***Y*** = _____	Least of ***X***, ***Y*** and ***Z*** = ***S*** ***S*** = _____
	Bottom (***c***)	Dimension (***d***) ***j*** = _____	Dimension (***e***) ***k*** = _____	***j*** - ***k*** = ***Z*** ***Z*** = _____	***V*** - ***S*** = ***W*** Cylindricity ***V*** = _____
Cylinder #2	Top (***a***)	Dimension (***d***) ***f*** = _____	Dimension (***e***) ***g*** = _____	***f*** - ***g*** = ***X*** ***X*** = _____	Greatest of ***X***, ***Y*** and ***Z*** = ***V*** Roundness ***V*** = _____
	Center (***b***)	Dimension (***d***) ***h*** = _____	Dimension (***e***) ***I*** = _____	***h*** - ***I*** = ***Y*** ***Y*** = _____	Least of ***X***, ***Y*** and ***Z*** = ***S*** ***S*** = _____
	Bottom (***c***)	Dimension (***d***) ***j*** = _____	Dimension (***e***) ***k*** = _____	***j*** - ***k*** = ***Z*** ***Z*** = _____	***V*** - ***S*** = ***W*** Cylindricity ***V*** = _____
Cylinder #3	Top (***a***)	Dimension (***d***) ***f*** = _____	Dimension (***e***) ***g*** = _____	***f*** - ***g*** = ***X*** ***X*** = _____	Greatest of ***X***, ***Y*** and ***Z*** = ***V*** Roundness ***V*** = _____
	Center (***b***)	Dimension (***d***) ***h*** = _____	Dimension (***e***) ***I*** = _____	***h*** - ***I*** = ***Y*** ***Y*** = _____	Least of ***X***, ***Y*** and ***Z*** = ***S*** ***S*** = _____
	Bottom (***c***)	Dimension (***d***) ***j*** = _____	Dimension (***e***) ***k*** = _____	***j*** - ***k*** = ***Z*** ***Z*** = _____	***V*** - ***S*** = ***W*** Cylindricity ***V*** = _____
Cylinder #4 (As Needed)	Top (***a***)	Dimension (***d***) ***f*** = _____	Dimension (***e***) ***g*** = _____	***f*** - ***g*** = ***X*** ***X*** = _____	Greatest of ***X***, ***Y*** and ***Z*** = ***V*** Roundness ***V*** = _____
	Center (***b***)	Dimension (***d***) ***h*** = _____	Dimension (***e***) ***I*** = _____	***h*** - ***I*** = ***Y*** ***Y*** = _____	Least of ***X***, ***Y*** and ***Z*** = ***S*** ***S*** = _____
	Bottom (***c***)	Dimension (***d***) ***j*** = _____	Dimension (***e***) ***k*** = _____	***j*** - ***k*** = ***Z*** ***Z*** = _____	***V*** - ***S*** = ***W*** Cylindricity ***V*** = _____

Honing and Boring

Pistons must move freely in the cylinders while maintaining adequate compression and oil sealing. If the cylinder walls are scuffed, scored, out of round, or have poor cylindricity, honing or boring and honing might correct cylinder problems. Re-boring is necessary if the bore dimensions fall outside specified limits. Honing must follow any re-boring operations. Slight imperfections can be corrected by honing alone.

1. **Boring** - Significant cylinder damage might be corrected by re-boring.
   - Boring out a cylinder block can only be done in a properly equipped machine shop.
   - After re-boring, existing pistons must be replaced. See **Parts manual** for correct part information.
   - After re-boring a cylinder block, each cylinder must be honed.
2. **Honing** - Slight cylinder imperfections might be corrected by honing.
   a. Insert the appropriate honing tool into the chuck of an electric drill.
   b. Saturate the cylinder wall with solvent using a 50% diesel fuel and 50% engine oil mixture.
   c. Rotate the honing tool at 300 to 1200 rpm.

CAUTION

DO NOT allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.

NOTE: Tilt the honing tool at a 30 to 40 degree angle during the honing operation, to leave a cross hatch mark on the cylinder wall. See Figure 71.

d. Insert the rotating honing tool into the cylinder and move it down through the entire length of the cylinder in a five-second motion. See Figure 72.

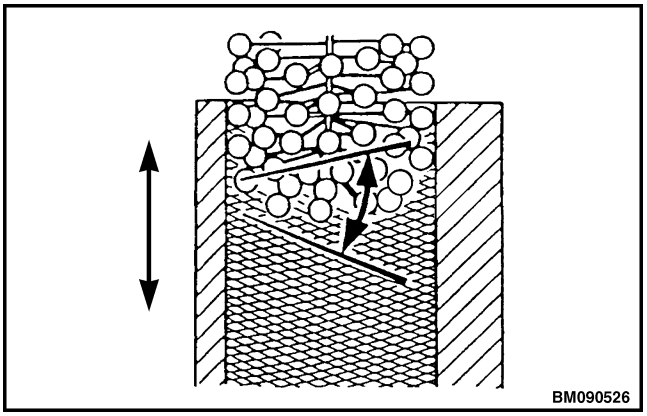


Figure 71. Cylinder honing angle

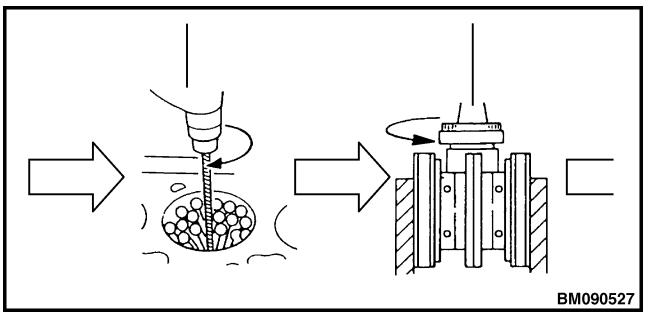


Figure 72. Cylinder honing

e. Without stopping the honing tool, pull it up through the entire length of the cylinder in a five-second motion.

f. Maintain the up-and-down motion for 30 to 40 seconds.

WARNING

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

g. When the honing is completed, wash the cylinder block with hot water and soap. Use brushes to clean all passages and crevices. Rinse with hot water and blow dry with compressed air. Apply clean engine oil to all steel surfaces to prevent rusting.

Pistons

NOTE: On an engine with low hours, the pistons and piston rings may be reused if they are found to be within specifications. The piston and piston rings must be reinstalled in the same cylinders from which they were originally removed.

On an engine with high hours, the piston rings should be replaced and the cylinder honed or replaced (see Honing and Boring). The piston should be replaced as necessary.

1. Use a piston ring groove cleaning tool to clean the piston ring grooves. See Special tools for diesel engines and follow manufacturer's instructions for correct operation.

2. Wash the pistons in an appropriate solvent using a soft brush.

3. Visually inspect each piston for cracks. Pay particular attention to between the piston ring grooves.

4. Use a micrometer to measure the diameter of the piston skirt at 90° to the wrist pin bore as shown in Figure 73. Refer to the Diesel engine specifications for the service limit.

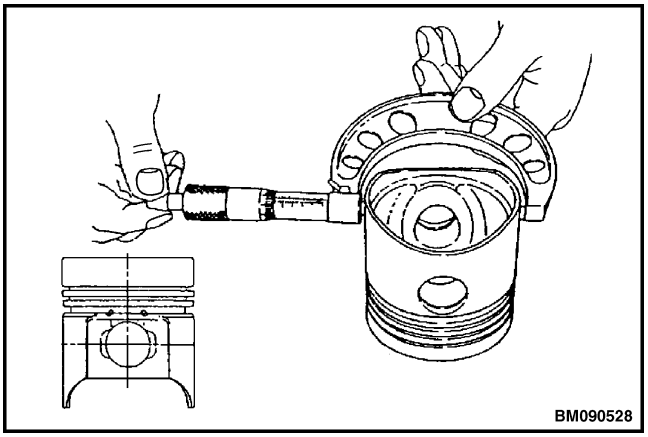


Figure 73. Piston skirt measurement

5. Subtract the piston measurement from the greatest measurement acquired during cylinder inspection to obtain piston-to-cylinder clearance. See Diesel engine specifications. Record the measurements.

6. Measure the diameter of the wrist pin bore on both sides of the piston. See Figure 74. Refer to Diesel engine specifications. Record the measurements.

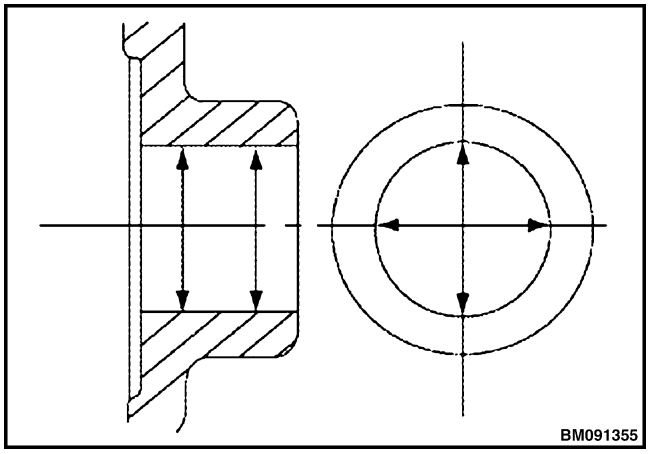


Figure 74. Diameter

7. Measure the outside diameter of the wrist pin in three places and at 90°. See Figure 75. Refer to Diesel engine specifications. Record the measurements.

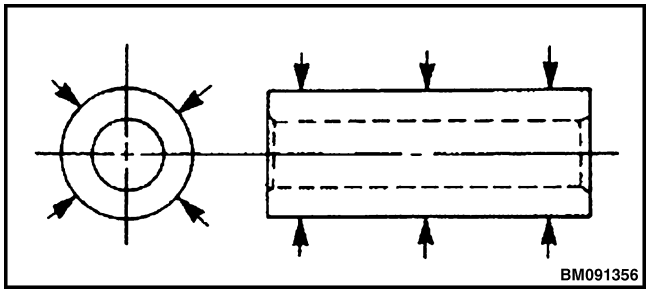
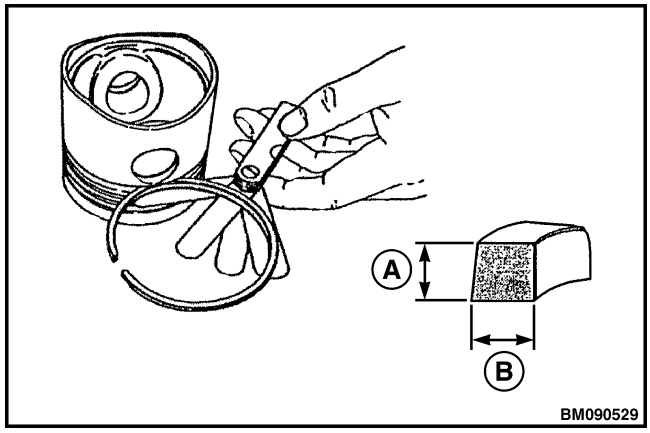


Figure 75. Outside diameter

8. Measure the piston ring and the piston ring groove for cylinder number one.

   a. Use a micrometer to measure the thickness of the top compression ring. Refer to the Diesel engine specifications for the service limit. Record the measurement.

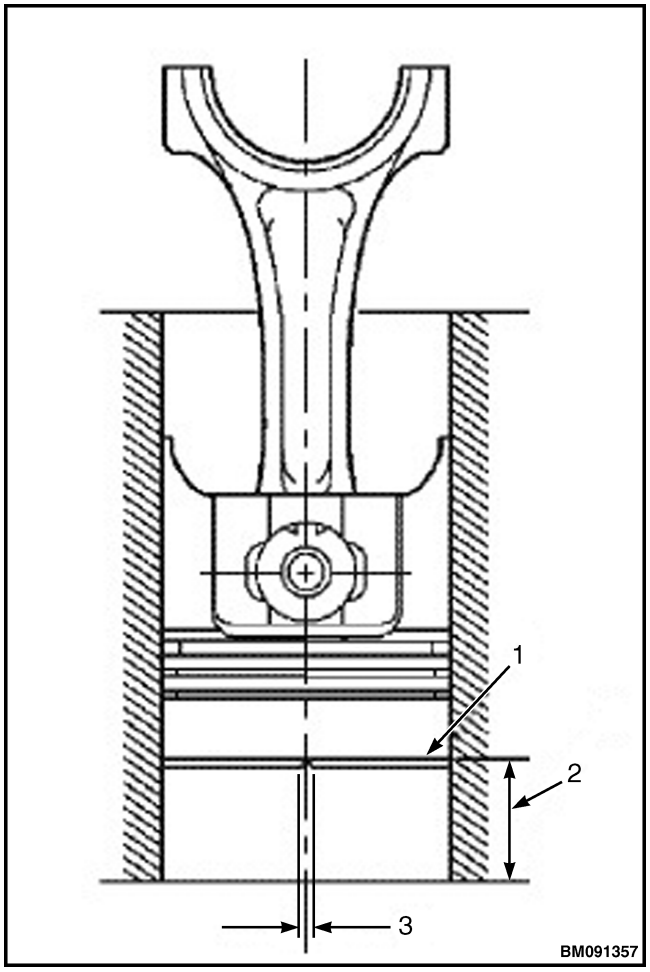
   b. Place each compression ring in the groove as shown in Figure 76. Use a feeler gauge to measure the gap between the ring and the piston. Record the measurement. Refer to the Diesel engine specifications for the service limit. Replace the piston if not within specification.



A. WIDTH
B. THICKNESS

Figure 76. Piston and piston ring groove clearance

9. To measure piston ring end gap, insert each compression ring, one at a time, into the cylinder (see, Figure 77). Use a piston with the piston rings removed to slide the ring into the cylinder bore until it is approximately 30 mm (1.18 in.) from the bottom of the bore. Remove the piston. Measure the end gap of each piston ring. Record the measurements. See Diesel engine specifications.



1. COMPRESSION PISTON RING
2. BORE MEASUREMENT
3. END GAP

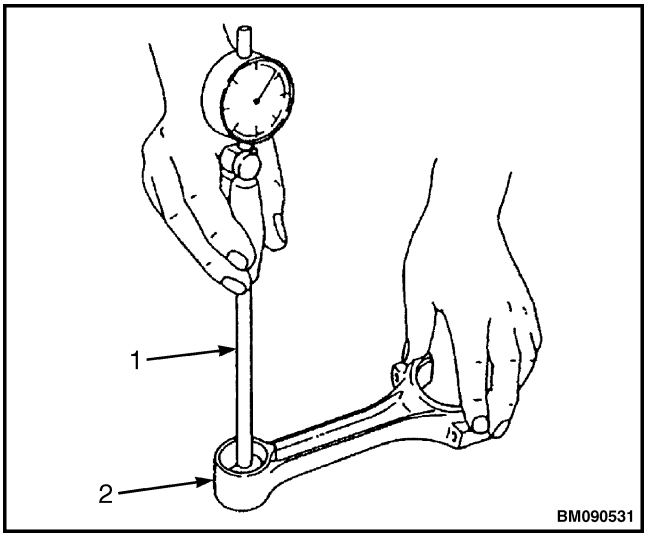
Figure 77. Piston and cylinder bore

NOTE: Always check the piston ring end gap when installing new piston rings. See Diesel engine specifications. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.

10. Repeat Step 8 for each of the pistons.

Connecting Rod

1. Use a bore gauge to measure the wrist pin bushing bore. Replace the bushing if not within specifications. If the bushing has been removed, measure the inside diameter of the connecting rod small end. Refer to the Diesel engine specifications for the service limit. See Figure 78.



1. CYLINDER GAUGE
2. CONNECTING ROD SMALL END

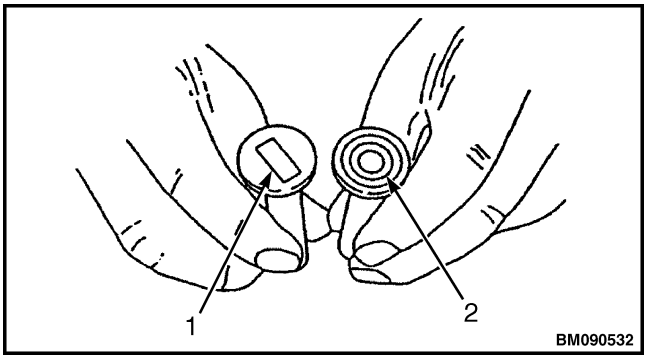
Figure 78. Connecting rod small end

2. Measure the crankpin and connecting rod bearings. Place the connecting rod bearings into the connecting rod and connecting rod cap. Install the end of the connecting rod to the connecting rod cap. Install the bolts and tighten to 54 to 59 N•m (40 to 44 lbf ft).

3. Measure the inside diameter. Refer to Diesel engine specifications for the service limit.

Tappets

1. Check the tappet contact surfaces for abnormal wear. Slight surface defects can be corrected using an oilstone. See Figure 79.



1. ABNORMAL CONTACT SURFACE
2. NORMAL CONTACT SURFACE

Figure 79. Tappet contact surface

2. Measure the outside diameter of the tappet stem. Refer to Diesel engine specifications for the service limit. See Figure 80.

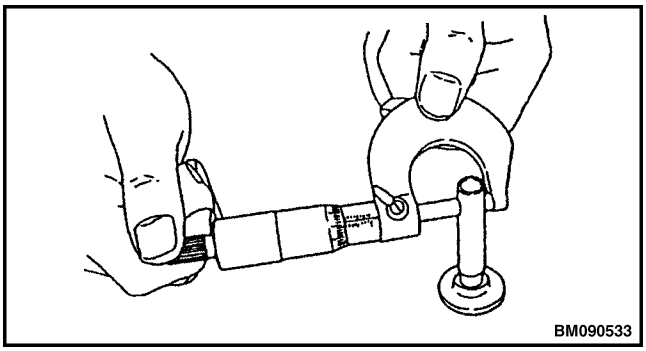
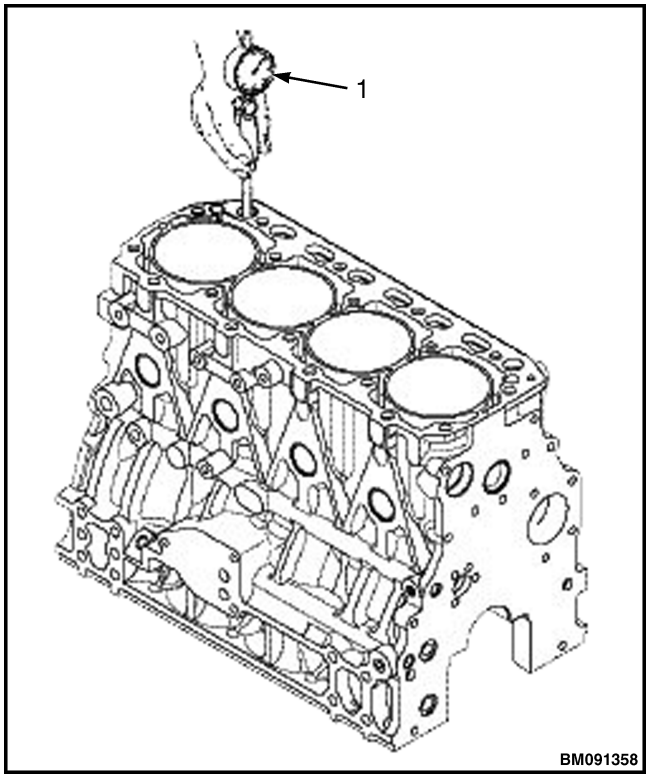


Figure 80. Tappet stem measurement

3. Use a cylinder gauge to measure the tappet bore. See Figure 81.



1. CYLINDER GAUGE

Figure 81. Measure tappet bore

Crankshaft

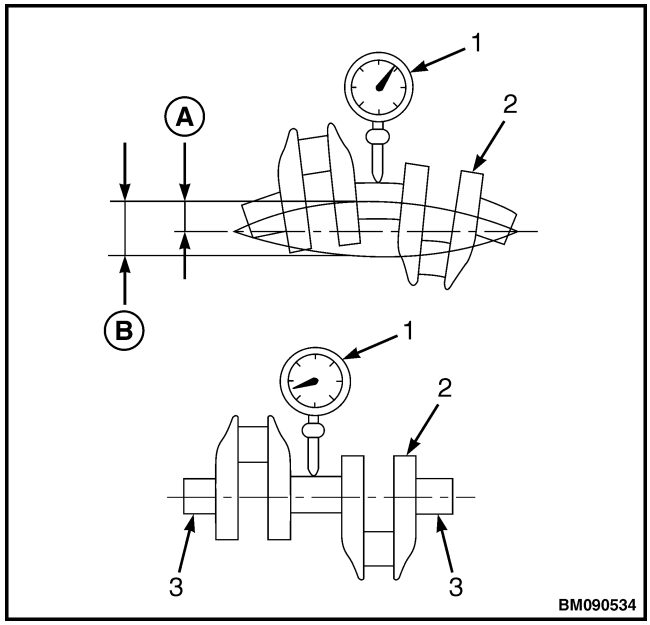
1. Measure the trueness of the crankshaft.

   a. Place the crankshaft on V-blocks at the end journals. See Figure 82.

   b. Place a dial indicator on a main bearing surface and zero the gauge.

   c. Rotate the crankshaft and observe the run out. Refer to the Diesel engine specifications for the service limit.

   d. Repeat this procedure for the remaining bearing surfaces.



A. BEND
B. DEFLECTION

1. DIAL GAUGE
2. CRANKSHAFT
3. V-BLOCK

Figure 82. Crankshaft bend measurement

2. Inspect the crankshaft for fractures.

   a. Use the color check method to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures are found. See Figure 83.

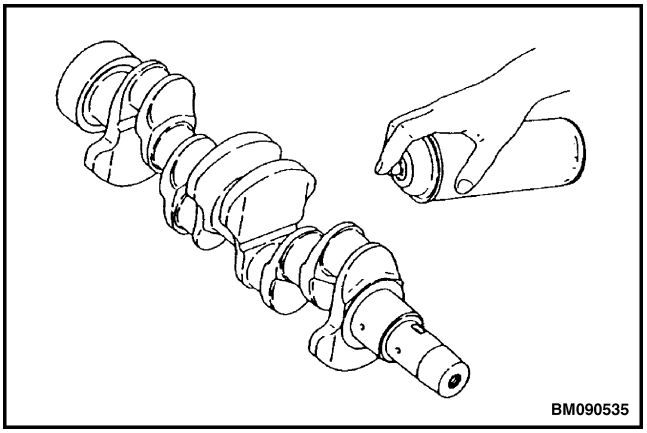


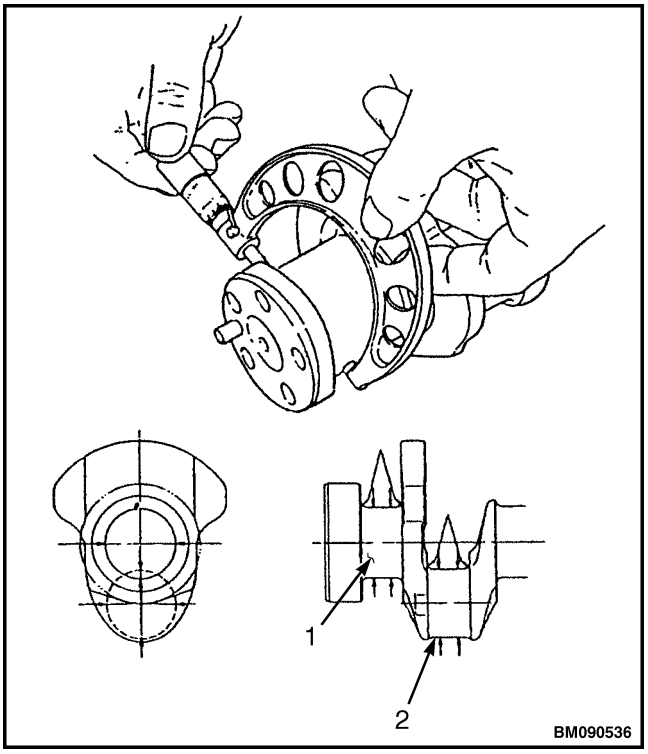
Figure 83. Crankshaft fracture check

   b. If the color check method is not available, spray Magnaflux on the crankshaft to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures are found.

3. Measure the outside diameter of each crankpin and main bearing journal. See Figure 84.

   a. If the crankpin clearance exceeds the service limit, use an undersized bearing. Refer to the Diesel engine specifications for the service limit.

   b. If the journal clearance exceeds the service limit, use an undersized bearing. Refer to the Diesel engine specifications for the service limit.



1. CRANKSHAFT JOURNAL
2. CRANKPIN

Figure 84. Crankpin and crankshaft journal measurement

Camshaft

1. Measure the trueness of the camshaft.

a. Place the camshaft on V-blocks positioned at the end journals. See Figure 85.

b. Place a dial indicator on the gear side bearing surface and set the gauge to zero.

c. Rotate the camshaft and observe the run out. Refer to the Diesel engine specifications for the service limit.

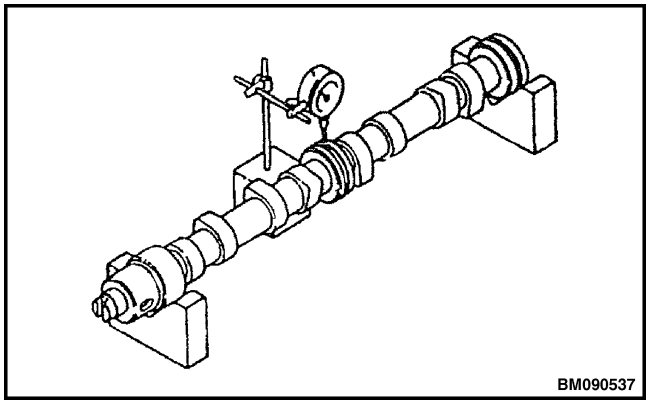
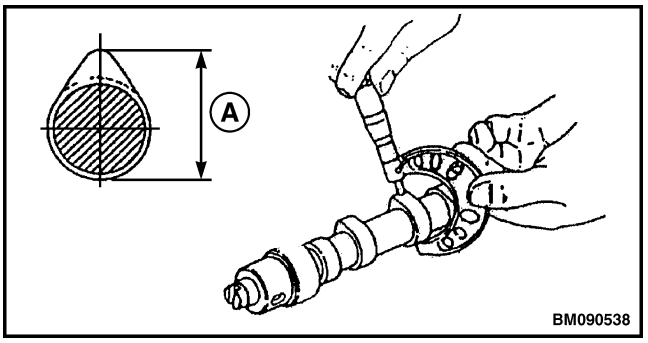


Figure 85. Camshaft Run out Check

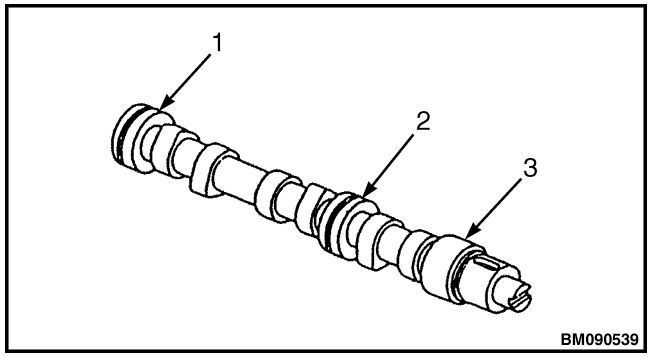
2. Measure the intake/exhaust cam lobe height. Refer to the Diesel engine specifications for the service limit. See Figure 86.



A. CAM HEIGHT

Figure 86. Intake/Exhaust Cam Lobe Height Measurement

3. Measure the gear end bearing surface, intermediate position bearing surface, and flywheel end bearing surface diameters. See Figure 87. Determine the oil clearance. The oil clearance is calculated by subtracting the measured camshaft bearing surface diameter from the camshaft bushing inside diameter. Refer to the Diesel engine specifications for the service limit.



1. FLYWHEEL END BEARING SURFACE
2. INTERMEDIATE POSITION BEARING SURFACE
3. GEAR END BEARING SURFACE

Figure 87. Camshaft Bearing Surface Measurements

Camshaft bushing and bores

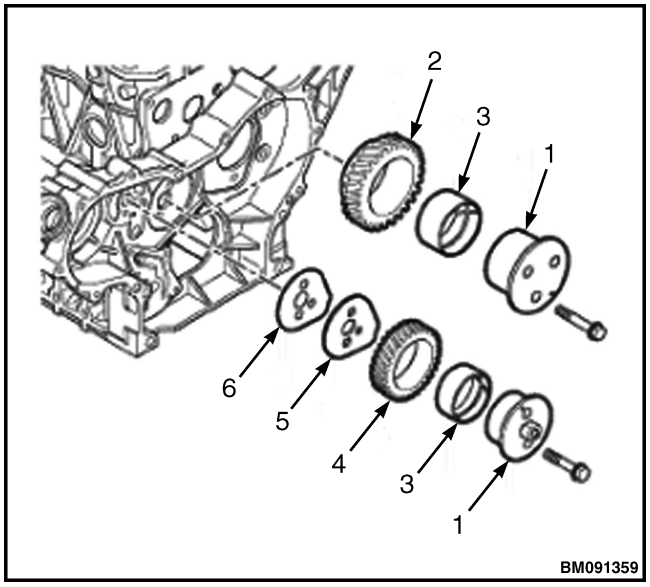
1. Measure the inside diameter of the front bushing and the remaining bores in the cylinders block. See Figure 58. Refer to Table 16 in Diesel engine specifications.

2. If the camshaft bushing is not within specification, replace it using the appropriate service tool. If the remaining bores are not within specification, the cylinder block will require replacement as there are no alternative bearings available to correct the bearing to camshaft journal oil clearance specification.

Idler gear and shaft

1. Measure the outside diameter of each idler gear shaft. See Figure 88. Refer to Diesel engine specifications.

2. Measure the inside diameter of each idler gear bushing. See Figure 88. Refer to Diesel engine specifications.



1. IDLER GEAR SHAFT
2. IDLER GEAR (B)
3. IDLER GEAR BUSHING
4. IDLER GEAR (A)
5. PLATE, IDLE SHAFT
6. GASKET

Figure 88. Idler gear

ASSEMBLE

Camshaft

1. Verify that all parts are clean. Lightly lubricate all parts with clean engine oil.

2. If removed, install new camshaft bushing. See Figure 58.

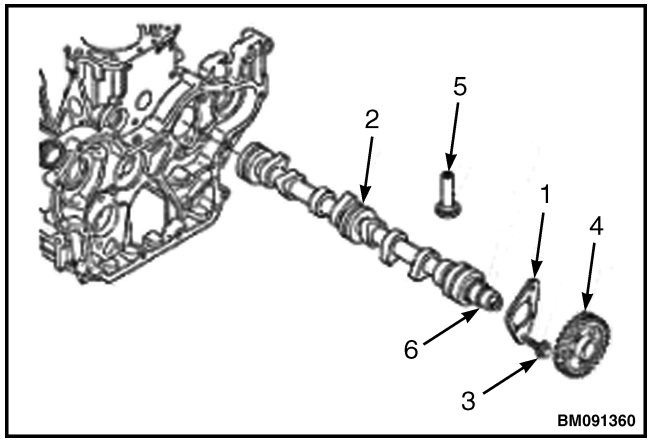
3. Install the timing gear case. See Diesel timing gear case repair.

NOTE: Rotate the cylinder block into a position in which it allows gravity to keep the tappets in place and out of the way of the camshaft lobes for when the camshaft is installed.

4. Install the tappets into the cylinder block in the same locations as they were removed.

5. Slowly insert the camshaft through the front of the engine. See Figure 89.

6. Place the camshaft thrust plate in position and install the retaining bolts. See Figure 89.



1. CAMSHAFT THRUST PLATE
2. CAMSHAFT
3. BOLT
4. CAMSHAFT DRIVE GEAR
5. TAPPETS
6. KEY

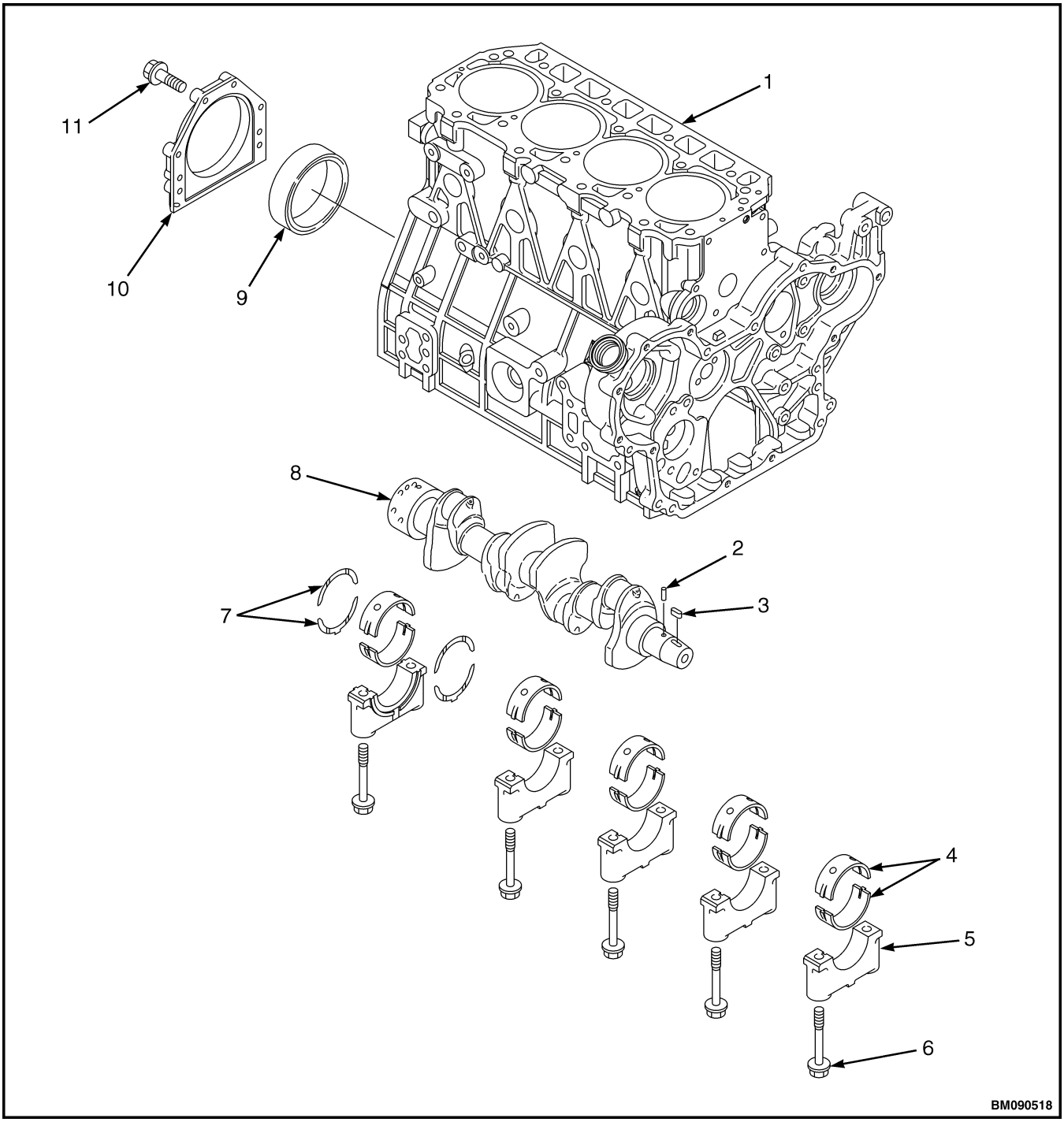
Figure 89. Camshaft

7. Install the key on the camshaft. See Figure 89.
8. Install the camshaft drive gear. See Figure 89.

Crankshaft

NOTE: The numbers and arrows on the main bearing caps are used for positioning during installation. The caps are numbered 1, 2, 3, and 4 with the number 1 cap at the flywheel end of the cylinder block. The arrows on the bearing caps should point towards the flywheel end of the cylinder block.

1. Reinstall new bearings, thrust bearings in the cylinder block and main bearing caps. Apply a liberal coat of clean engine oil to the bearings and crankshaft.
2. Place the crankshaft into the engine. See Figure 90.



1. CYLINDER BLOCK
2. PARALLEL PIN
3. KEY
4. BEARINGS
5. MAIN BEARING CAP
6. BEARING CAP BOLT
7. THRUST BEARINGS
8. CRANKSHAFT
9. REAR OIL SEAL
10. REAR OIL SEAL HOUSING
11. BOLT

Figure 90. Crankshaft

3. Reinstall the main bearing caps. See Figure 90.

4. Apply a light coat of clean engine oil to the bearing cap bolts and tighten the bolts to 96.0-100 N•m (70.8-73.8 lbf ft) in two stages (½ at first, then full torque).

5. Rotate the crankshaft to confirm it turns freely.

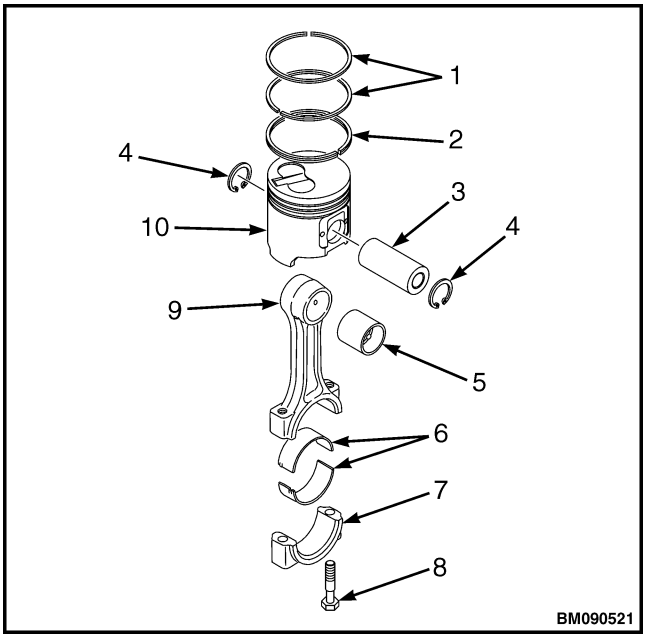
6. Apply a continuous bead of ThreeBond Liquid Gasket, Hyster Part Number 1599478, to the mounting flange of the rear oil seal housing.

7. Align the rear oil seal housing with the two dowel pins on the cylinder block and install the rear oil seal housing. Install the retaining bolts and tighten to standard torque.

Pistons and Connecting Rods

1. Select the components mentioned in the previous steps to assemble the piston and connecting rod for the Number 1 cylinder. See Figure 91.

2. Lubricate and insert the wrist pin bushing into the small end of the connecting rod. See Figure 91.



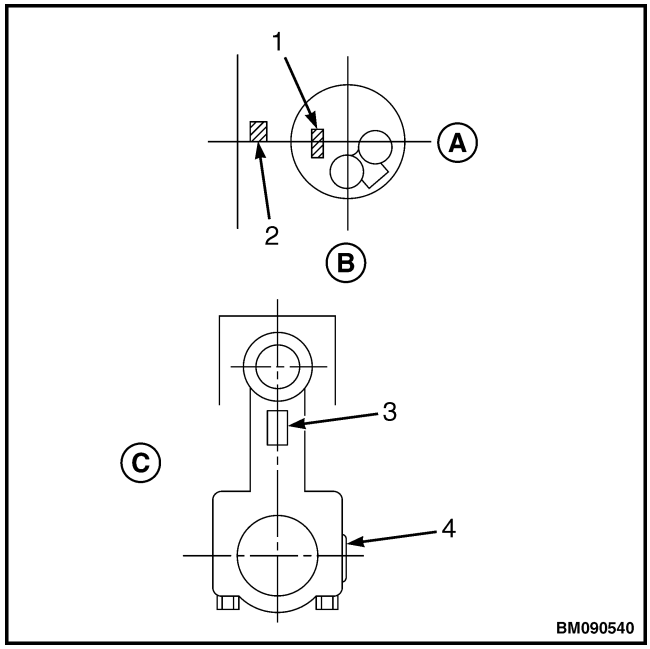
1. COMPRESSION RINGS
2. OIL SEAL RING
3. WRIST PIN
4. SNAP RING
5. WRIST PIN BUSHING
6. BEARINGS
7. CONNECTING ROD CAP
8. BOLT
9. CONNECTING ROD
10. PISTON

Figure 91. Piston and Connecting Rod

3. Install one snap ring into the piston. See Figure 91.

NOTE: The piston and connecting rod must be assembled together in the correct orientation. The orientation of the piston and connecting rod are different depending on engine model.

4. Position the connecting rod into the piston under the skirt. The match marks on the connecting rod must be opposite of the piston identification mark on the top of the piston. See Figure 92.



A. FUEL INJECTION PUMP SIDE
B. FLYWHEEL SIDE
C. CAMSHAFT SIDE

1. PISTON IDENTIFICATION MARK
2. CYLINDER SIZE MARK
3. EMBOSSED MARK (ON CONNECTING ROD)
4. PUNCHED MARK

Figure 92. Piston and connecting rod identification marks

5. Confirm when the piston is installed in the cylinder, that the piston identification mark that is stamped on the top of the piston is facing the fuel injection pump side of the engine and the embossed mark on the connecting rod is facing the flywheel side. See Figure 92.

6. Lubricate and install the piston wrist pin through the piston and wrist pin bushing.

7. Install the second snap ring and confirm it is fully seated in the groove.

8. Use piston ring pliers to install the piston rings.

a. Install each piston ring on the piston with the punched manufacture's mark facing upward. See Figure 93.

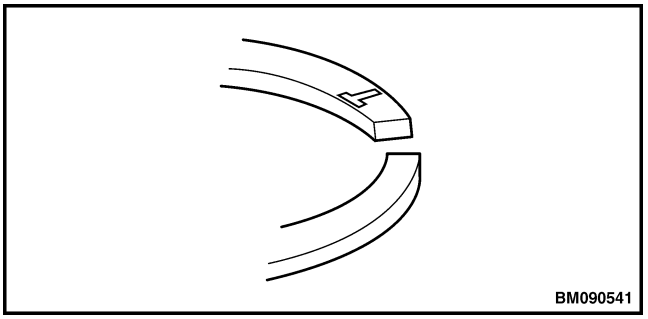
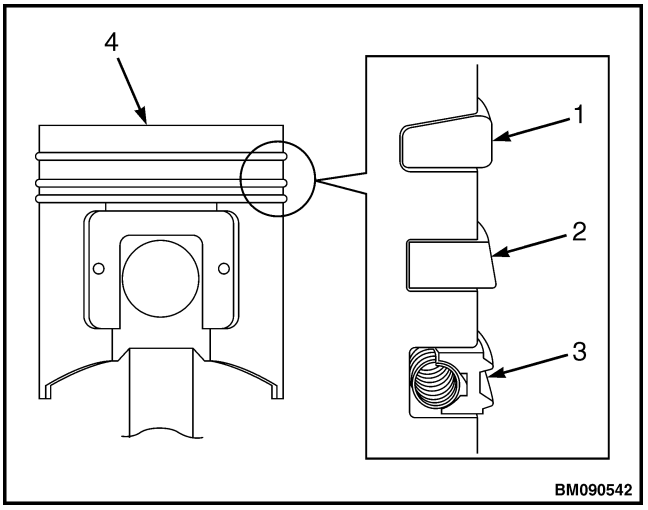


Figure 93. Piston ring mark

b. Install the top compression ring, second compression ring, and oil ring. See Figure 94.

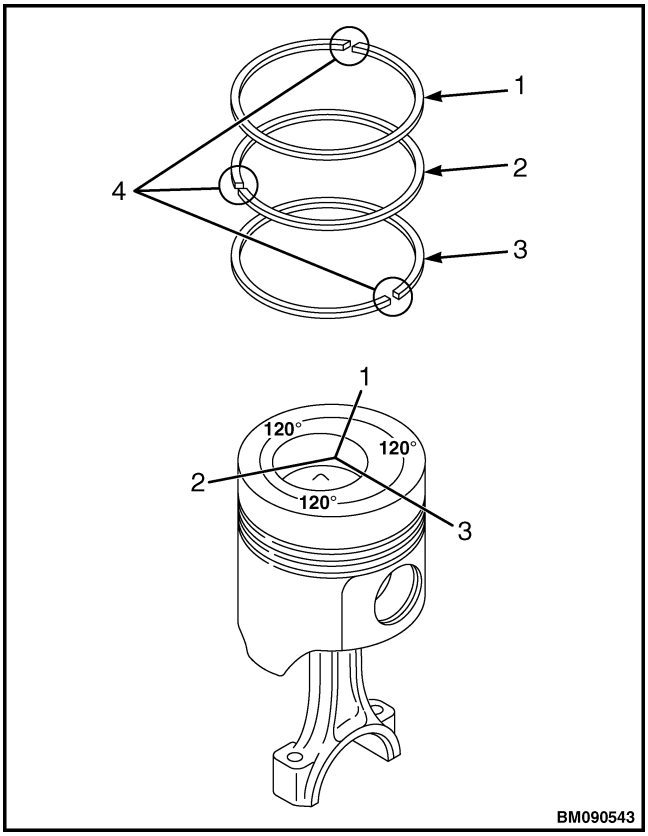
c. Confirm the oil ring coil expander end gap is located 180° from the oil ring end gap. See Figure 94.



1. TOP COMPRESSION RING
2. SECOND COMPRESSION RING
3. OIL RING
4. PISTON
5. OIL RING COIL EXPANDER

Figure 94. Piston rings

d. Stagger the piston ring joints at 120° intervals. DO NOT position the top compression ring joint in line with the piston wrist pin. The coil expander joint must be opposite the oil ring joint. See Figure 95.



1. TOP COMPRESSION RING
2. SECOND COMPRESSION RING
3. OIL RING
4. JOINTS

Figure 95. Piston rings staggering

9. Perform Step 1 through Step 8 for the assembly of each remaining piston.

INSTALL

NOTE: Do not allow the connecting rod to contact the crankshaft journal during piston installation. Damage to the crankshaft journal may result.

1. Lubricate the Number 1 piston, piston rings, and cylinder with clean engine oil.

2. Rotate the crankshaft so the crankpin for the piston being installed is near the bottom and center.

3. Confirm the piston ring gaps are located correctly. See Figure 95.

4. Use a piston ring compressor to compress the piston rings on the Number 1 piston. See Diesel engine specifications.

5. Carefully install the piston into the Number 1 cylinder. Be sure the punched mark on the connecting rod is facing the fuel injector side and the embossed mark is facing the flywheel. See Figure 92.

6. Install the connecting rod bearings and connecting rod cap. Install the connecting rod bolts and tighten to
44 to 49 N•m (32.5 to 36 lbf ft) to seat bearing to rod and cap.

7. Remove Hardware loosen and remove hardware from bearing cap. Pull the bearing cap and apply a liberal coat of clean engine oil to the bearings and crankshaft journal.

8. Install a light coat of clean engine oil to the rod cap bolts. Reinstall the connecting rod cap. Tighten the connecting rod bolts to
44.1-49 N•m (33-36 lbf ft) N•m in two stages (½ torque first, then full torque).

9. Perform Step 1 through Step 6 to install the remaining pistons in their respective cylinders.

10. Install the crankshaft drive gear and idler gear. See Diesel timing gear case repair.

11. Install the oil pump. See Diesel lubrication system repair.

12. Install the timing gear case cover. See Diesel timing gear case repair.

13. Install the oil pan. Install the oil suction tube. See Diesel lubrication system repair.

14. Install the cylinder head. See Diesel cylinder head repair.

15. Install the fuel injection pump. See Diesel fuel system repair.

16. Install the water pump. See Water pump repair in the **Cooling system** 0700SRM2300 service manual.

17. Install the alternator. See Diesel electrical system repair.

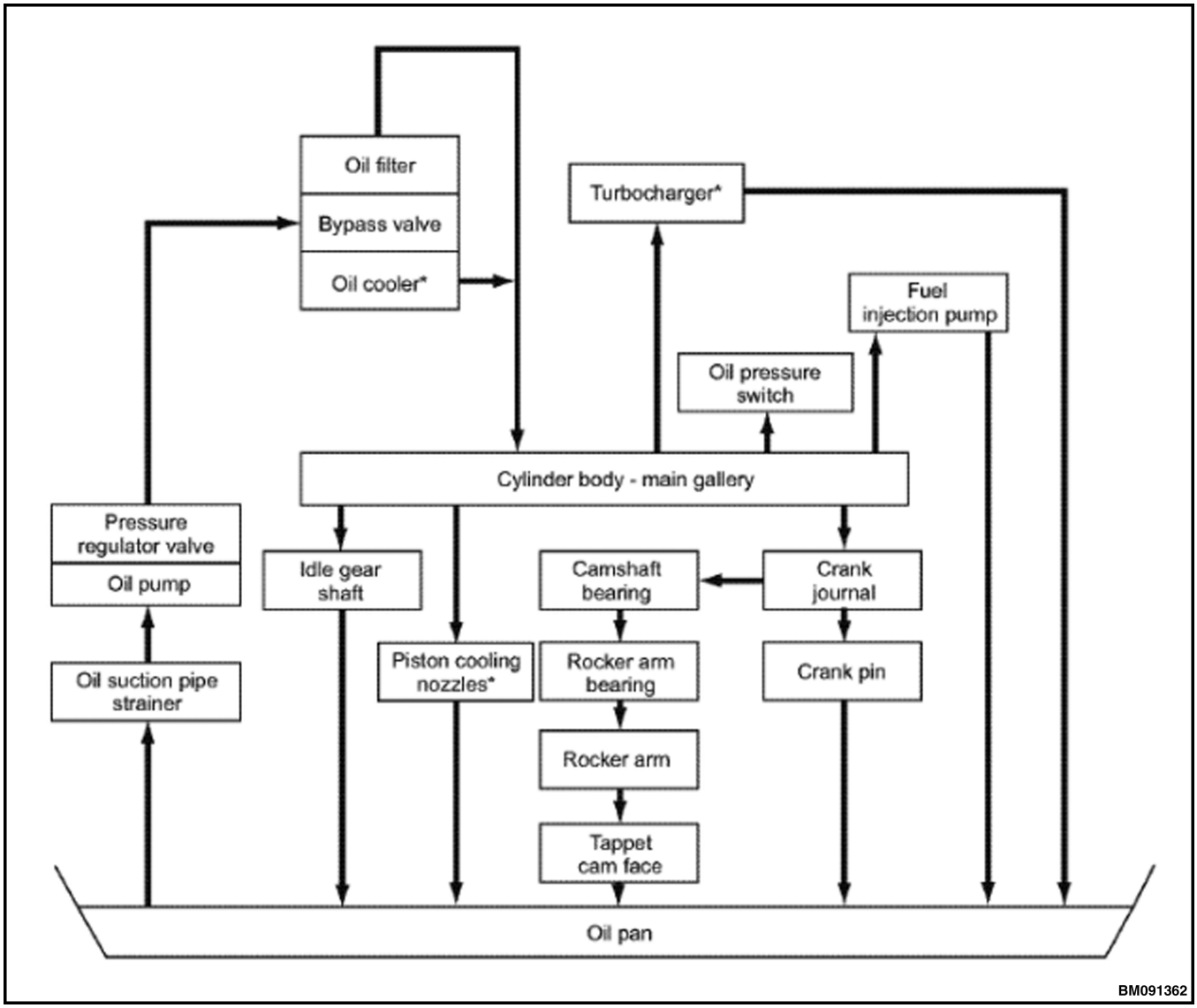
18. Install the flywheel and flywheel housing. See Diesel flywheel repair.

19. Install the starter. See Diesel electrical system repair.

20. Install the engine. See Diesel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

21. Install the engine. See Diesel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

DIESEL LUBRICATION SYSTEM REPAIR 202001-015



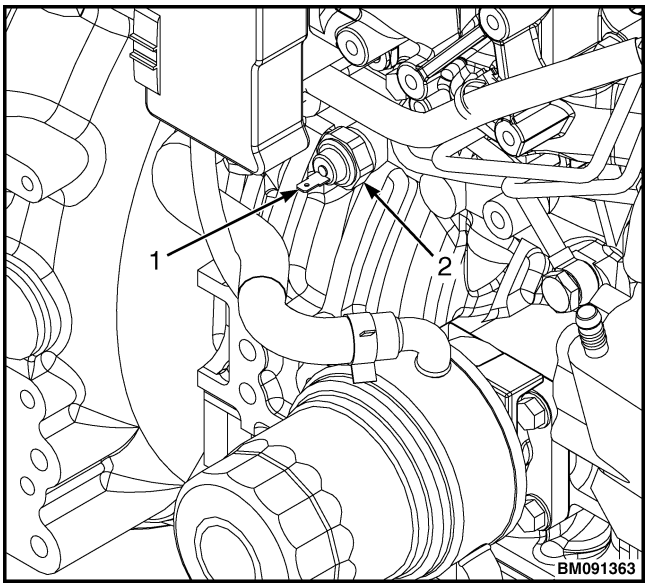
NOTE: ITEMS MARKED* ARE NOT STANDARD EQUIPMENT ON ALL MODELS.

Figure 96. Lubrication system diagram

CHECK ENGINE LUBRICATING OIL PRESSURE

An engine oil pressure check must be performed if the oil pressure indicator is on, or the Engine oil pressure gauge on the instrument panel indicates low engine oil pressure. See Table 28 for specifications.

1. Disconnect the electrical connector from the oil pressure switch. See Figure 97.



1. ELECTRICAL CONNECTOR
2. OIL PRESSURE SWITCH

Figure 97. Oil pressure switch

2. Remove the oil pressure switch.

3. Insert a mechanical oil pressure gauge into the port where the oil pressure switch was removed.

4. Start the engine.
   - If the mechanical oil pressure test gauge indicates satisfactory oil pressure (see Table 28 for specifications), one of the following items may be faulty and must be replaced:
     - Oil pressure switch
     - Sending unit
   - If the mechanical oil pressure test gauge indicates low oil pressure (see Table 28 for specifications), follow steps to troubleshoot the lubrication system to determine the cause of low engine oil pressure. See **Diagnostic and Troubleshooting manual**.

5. Rev the engine to the RPM indicated in the table below (see Table 28). Compare the reading on the oil pressure gauge to the specifications listed in the table.

REMOVE

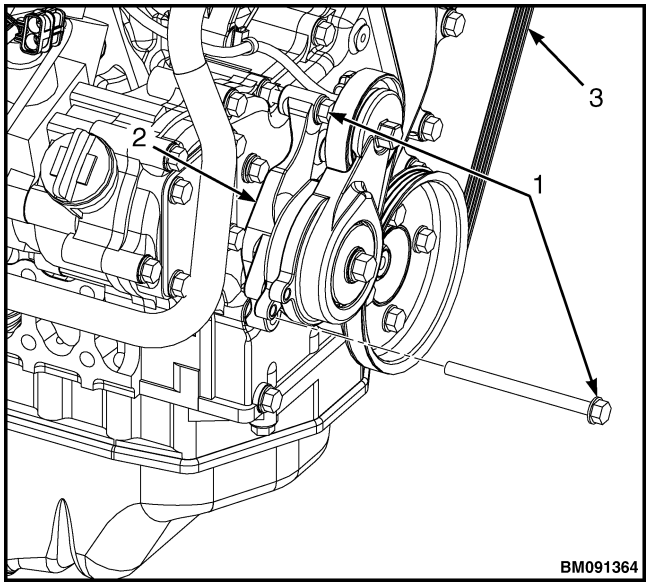
Oil pump components

The oil pump assembly is located in the front gear case and is driven by the same gear train as the camshaft and fuel injection pump.

1. Remove the cooling fan. See **Cooling system** 0700SRM2300 manual for procedure.

2. Remove the V-belt. See Figure 98.

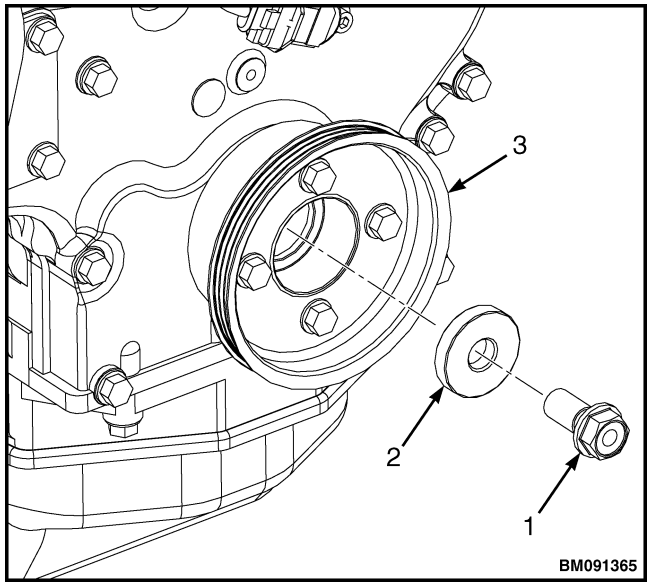
3. Loosen the two mounting bolts retaining the V-belt tensioner. See Figure 98.



1. V-BELT TENSIONER MOUNTING BOLT
2. V-BELT TENSIONER
3. V-BELT

Figure 98. Tensioner and V-belt

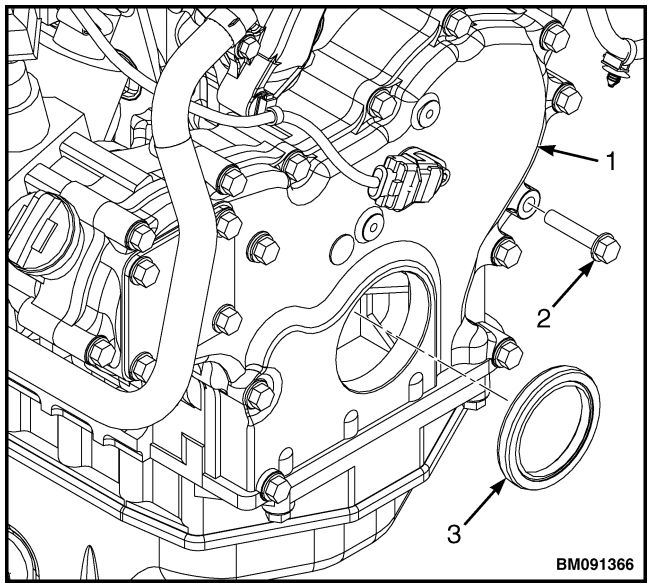
4. Loosen the crankshaft pulley mounting bolt and spacer retaining the crankshaft pully. Remove the crankshaft pulley. See Figure 99.



1. CRANKSHAFT PULLEY MOUNTING BOLT
2. SPACER
3. CRANKSHAFT PULLEY

Figure 99. Crankshaft pulley

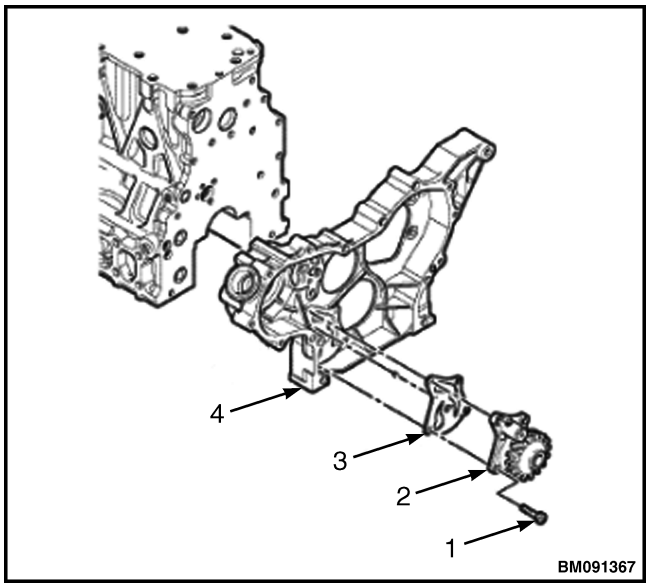
5. Remove the front gear case cover to gain access to the oil pump. See Figure 100, and Diesel timing gear case repair for removal procedure.



1. FRONT GEAR CASE
2. BOLT
3. SEAL

Figure 100. Front gear case cover

6. Remove the oil pump assembly mounting bolts. See Figure 101.

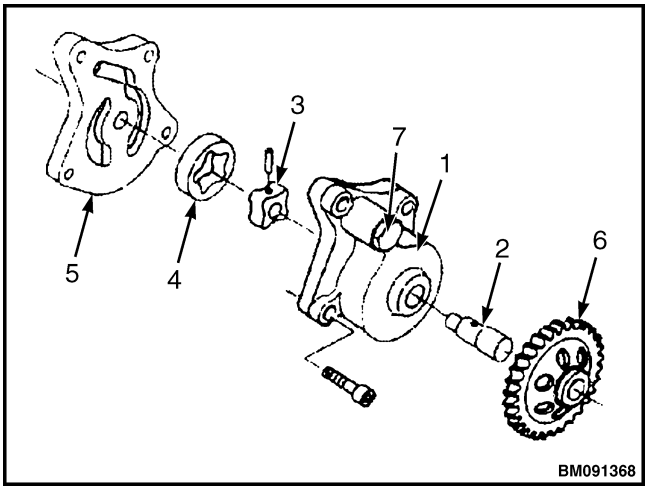


1. OIL PUMP ASSEMBLY MOUNTING BOLT
2. OIL PUMP ASSEMBLY
3. OIL PUMP ASSEMBLY COVER
4. GEAR CASE FLANGE

Figure 101. Oil pump assembly

7. Remove the oil pump assembly from the gear case flange. See Figure 101.

8. Remove the oil pump cover and outer rotor. See Figure 102.



1. OIL PUMP BODY
2. SHAFT
3. INNER ROTOR
4. OUTER ROTOR
5. OIL PUMP COVER
6. DRIVE GEAR
7. PRESSURE REGULATOR VALVE

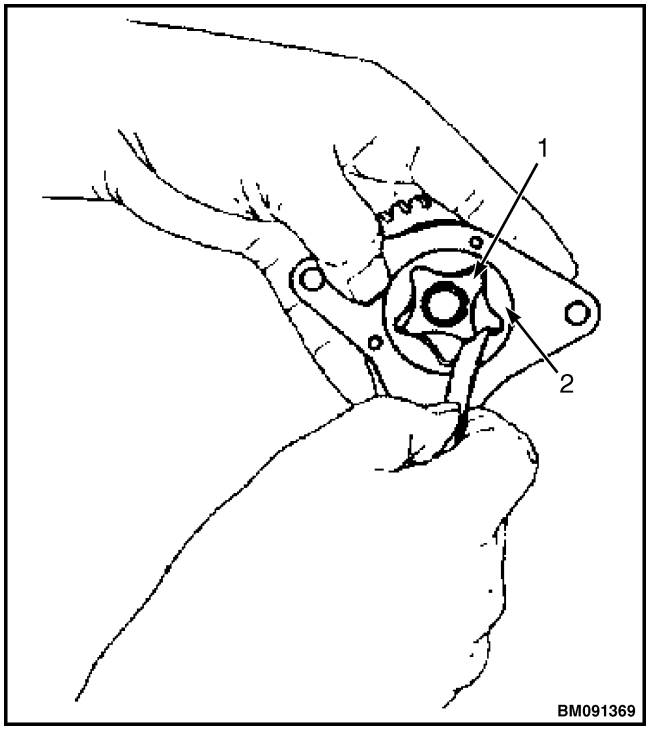
Figure 102. Oil pump assembly

CLEAN AND INSPECT

Clean all of the parts with cleaning solvent. Dry the parts with compressed air. Inspect for wear and damage. If necessary, replace oil pump assembly.

Outer rotor outside clearance

Inspect the outside diameter clearance of the outer rotor, by inserting a feeler gauge between the outer rotor and the oil pump body. See Figure 103. Record the measurements, and see Table 29 for service limits.

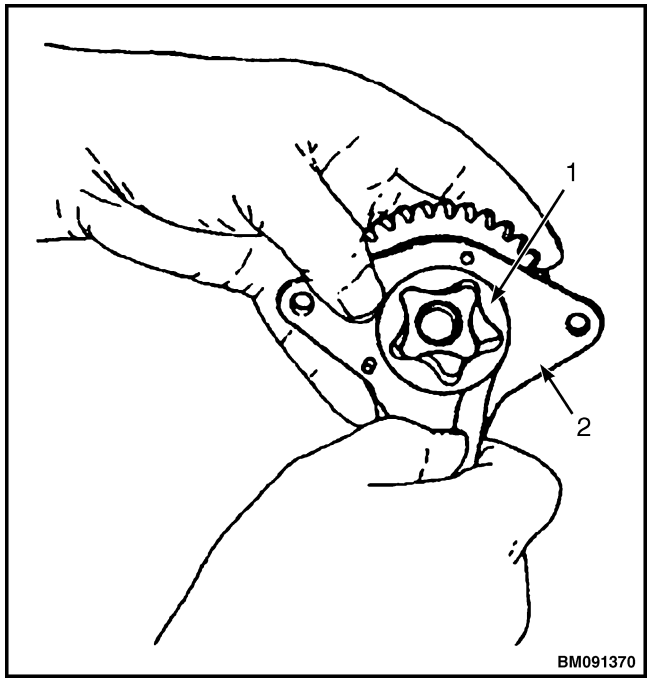


1. OUTER ROTOR
2. PUMP BODY

Figure 103. Outer rotor outside clearance check

Outer rotor to inner rotor tip clearance

Inspect the tip clearance between the outer and inner rotors, by inserting a feeler gauge between the inner rotor tooth tip and the outer rotor tooth tip. See Figure 104. Measure the clearance. Record the measurements, and see Table 31 for service limits.



1. INNER ROTOR TOOTH TIP
2. OUTER ROTOR TOOTH TIP

Figure 104. Inner rotor tip clearance check

Outer rotor side clearance

Inspect the side clearance between the oil pump body and the outer rotor, by using a straight edge and feeler gauge or a depth micrometer. See Figure 105. Record the measurements, and see Table 30 for service limits.

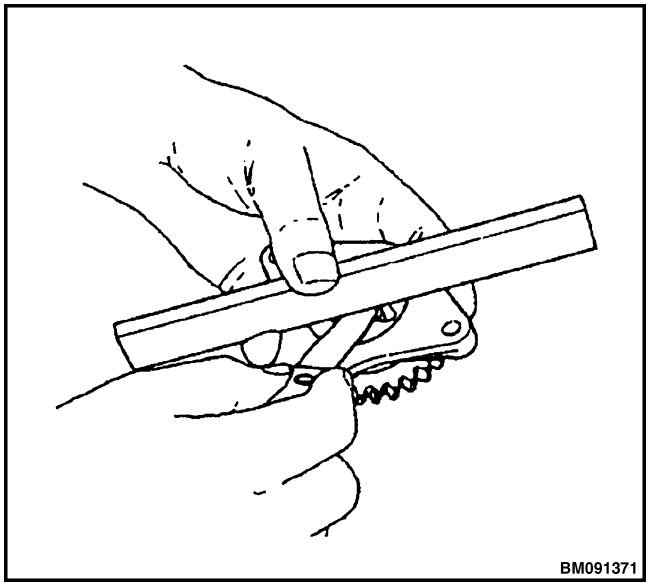
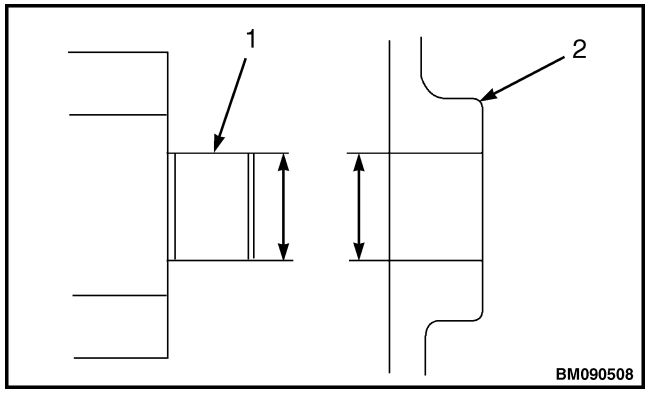


Figure 105. Outer rotor side clearance check

Rotor shaft clearance

Inspect the rotor shaft clearance, by measuring the outside diameter of the rotor shaft and the inside diameter of the cover. Determine clearance by subtracting the outside diameter of the rotor from the inside diameter of the cover. See Figure 106. Record the measurements, and see Table 32 for service limits.



1. ROTOR SHAFT
2. GEAR CASE HOUSING

Figure 106. Rotor shaft clearance check

INSTALL

1. Apply clean lubricating oil to the oil pump body, inner rotor and outer rotor. See Figure 102.

2. Assemble the oil pump assembly by inserting the inner and outer rotor into the oil pump body and aligning the oil pump cover with the oil pump body. See Figure 102.

3. Position the oil pump assembly in the gear case housing. Insert the mounting bolts to retain the oil pump assembly. See Special torque chart for torque specifications.

4. Install the timing gear case cover. See Figure 100 and refer to Diesel timing gear case repair for procedure.

5. Position the crankshaft pulley, aligned with the timing gear case cover. Insert crankshaft pulley mounting bolt and and spacer to retain the crankshaft pulley. See Figure 99. Torque to 112.7-122.7 N•m (83-91 lbf ft).

6. Position the the V-belt tensioner, aligned with the timing gear case cover. Insert the V-belt tensioner mounting bolts to retain the V-belt tensioner. Install the V-belt. See Figure 98, and refer to Special torque chart for torque specifications.

7. Install the V-belt. See Figure 98. See Diesel engine specifications.

8. Install the cooling fan. See **Cooling system** 0700SRM2300 manual for procedure.

OIL PUMP SERVICE INFORMATION

Table 28. Engine lubricating oil pressure

Model	At rated engine RPM (min)						At low idle speed
	1500-1800	2000-2500	2600	2700	2800	2900-3000	
4TNV86CT, 4TNV86CHT	0.29-0.44 MPa (42.1-63.8 psi)	0.34-0.49 MPa (49-71.07 psi)					0.06 MPa (8.7 psi)

Table 29. Outer rotor outside clearance

Model	Standard	Limit	Reference page
4TNV86CT, 4TNV86CHT	0.09-0.15 mm (0.0035-0.0059 in.)	0.25 mm (0.0098 in.)	Check outer rotor outside clearance. See Outer rotor outside clearance.

Table 30. Outer rotor side clearance

Model	Standard	Limit	Reference page
4TNV86CT, 4TNV86CHT	0.05-0.09 mm (0.0020-0.0035 in.)	0.15 mm (0.0059 in.)	Check outer rotor side clearance. See Outer rotor side clearance.

Table 31. Outer rotor to inner rotor tip clearance

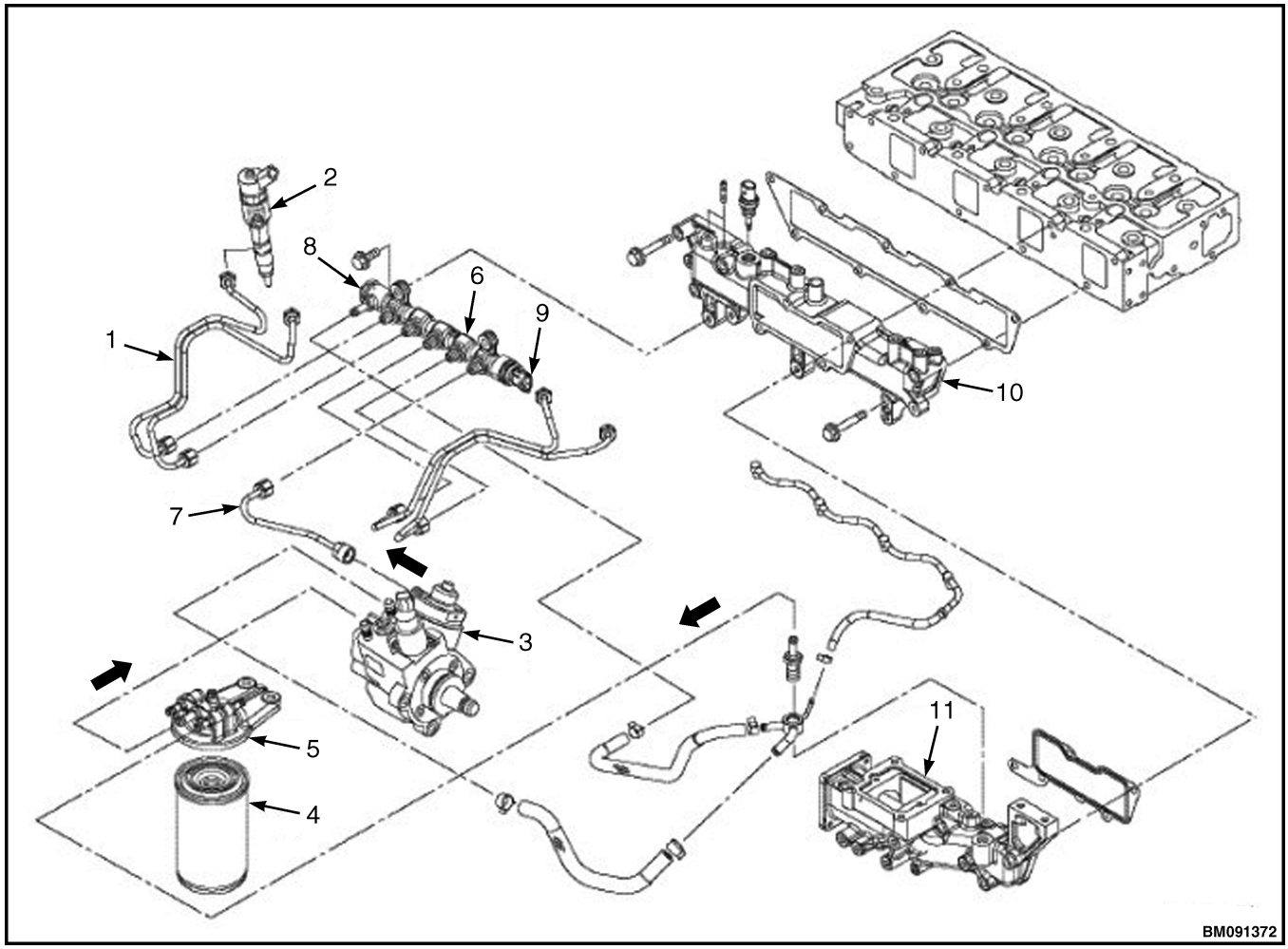
Model	Standard	Limit	Reference page
4TNV86CT, 4TNV86CHT	---	0.16 mm (0.0063 in.)	Check outer rotor to inner rotor tip clearance. See Outer rotor to inner rotor tip clearance.

Table 32. Rotor shaft clearance

Model		Standard	Limit	Reference page
4TNV86CT, 4TNV86CHT	Plate bearing I.D.	10.020-10.038 mm (0.3945-0.3952 in.)	10.063 mm (0.3962 in.)	Check rotor shaft clearance. See Rotor shaft clearance.
	Rotor shaft O.D.	9.978-9.987 mm (0.3928-0.3932 in.)	9.963 mm (0.3922 in.)	
	Rotor clearance	0.033-0.060 mm (0.0013-0.0024 in.)	0.100 mm (0.0039 in.)	

DIESEL FUEL SYSTEM REPAIR
202001-016

FUEL SYSTEM COMPONENTS



1. HIGH-PRESSURE FUEL INJECTION LINES (COMMON RAIL TO INJECTOR)
2. FUEL INJECTOR
3. SUPPLY PUMP
4. FUEL FILTER
5. FUEL FILTER HOUSING
6. COMMON RAIL
7. HIGH-PRESSURE FUEL INJECTION LINES (SUPPLY PUMP TO COMMON RAIL)
8. PRESSURE LIMITING VALVE
9. PRESSURE SENSOR
10. INTAKE MANIFOLD
11. MANIFOLD COLLECTOR

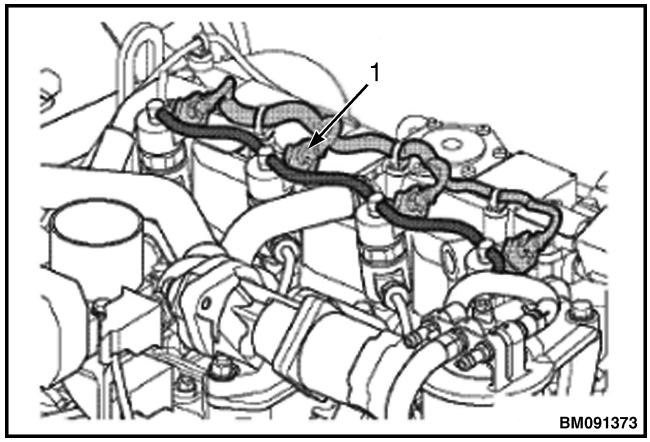
Figure 107. Fuel system components

REMOVE

Injector

1. Remove the intake hose, if attached. See Diesel cylinder head repair.

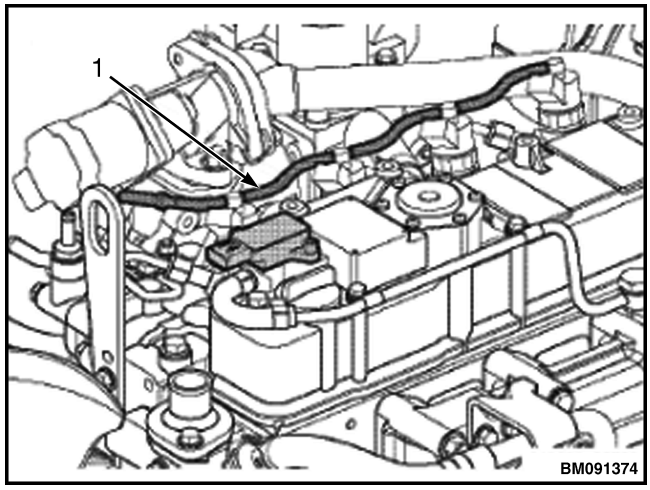
2. Disconnect the engine harness electrical connector from the upper portion of each injector and move the engine harness out of the way. See Figure 108.



1. ENGINE HARNESS ELECTRICAL CONNECTOR

Figure 108. Injector electrical connectors

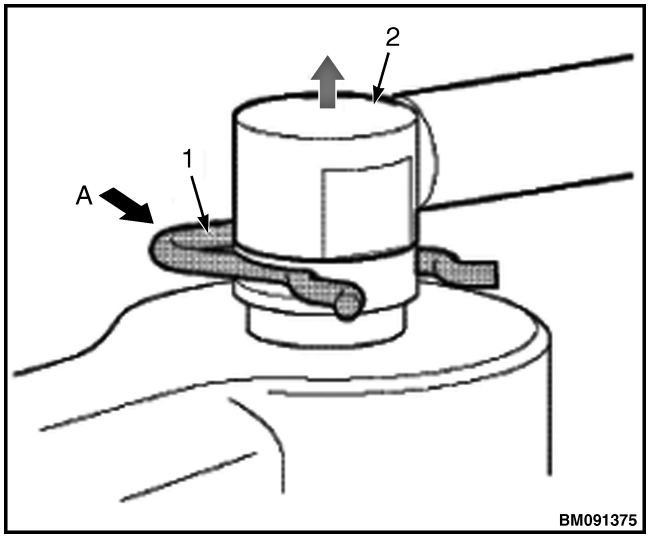
3. Locate the fuel return hose connected to the injectors. See Figure 109.



1. FUEL RETURN HOSE

Figure 109. Fuel return hose

4. To remove the fuel return hose, disconnect each fuel return hose connector from the injector, by pulling vertically on the connector, while fully pressing the retaining clip that is attached on the top of the injector in the direction of the arrow (A, Figure 110). DO NOT hold on to the fuel return hose when removing. Doing so may cause damage to the hose. Discard the retaining clips, as they may not be reused. See Figure 110.



1. RETAINING CLIP
2. CONNECTOR

Figure 110. Fuel return hose connectors

5. Remove the high-pressure fuel injection lines between the injector and the common rail:

a. Use a brush or aspirator to clean around the cap nuts on both the injector and common rail sides. See Figure 111.

b. For each injector, use a spanner or similar tool to hold the injector intake connector in place while turning and loosening the cap nut. See Figure 112. This will prevent the cap nut and intake connector from rotating together.

c. Use the same method to loosen the four cap nuts of the high-pressure line on the common rail side. See Figure 112.

d. Remove each cap nut by hand while pushing the high-pressure line on both the injector side and rail side.

e. Remove the high-pressure line.

f. Use a vacuum to clean the part of the high-pressure line on the injector side that was removed from the injector. Cover with a plastic bag.

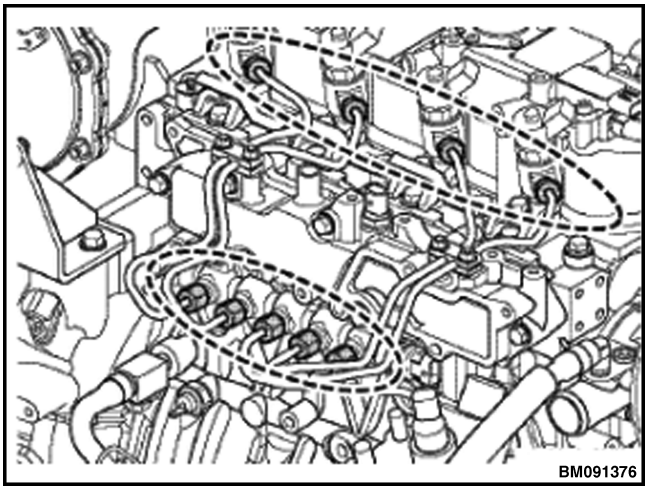
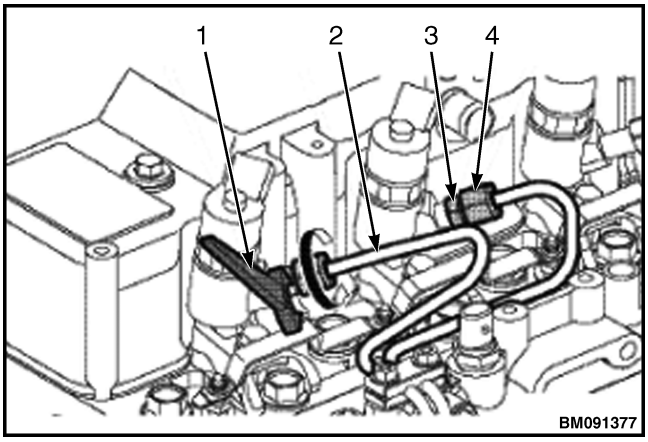


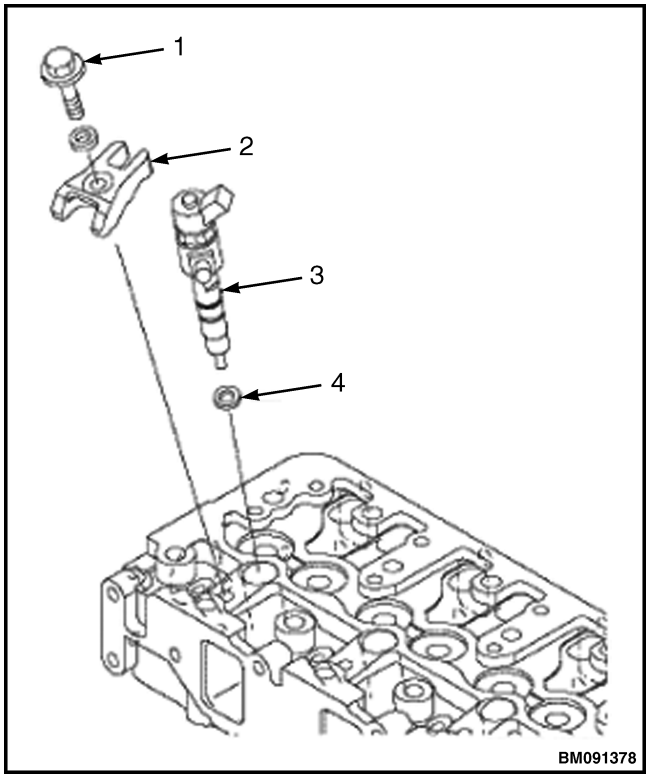
Figure 111. High-pressure lines



1. SPANNER OR WRENCH
2. HIGH-PRESSURE LINE
3. INJECTOR INTAKE CONNECTOR
4. HIGH-PRESSURE LINE CAP NUT

Figure 112. Remove and install high-pressure lines

6. Loosen the injector retainer mounting bolt and remove the retainer. See Figure 113.



1. RETAINER MOUNTING BOLT
2. RETAINER
3. INJECTOR
4. GASKET

Figure 113. Injector and retainer

NOTE: Identify each injector by the cylinder it was removed from. Mark the injectors.

7. Remove the injector and injector gaskets. See Figure 113.

NOTE: Do not reuse the injector gaskets.

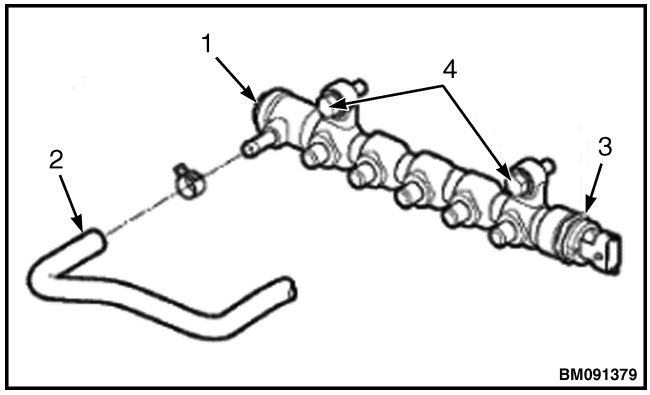
NOTE: Clean the removed injectors and cover them with a plastic bag.

NOTE: Never dissassemble the injector. The entire injector must replaced as one assembly.

Common rail

1. Follow the same procedure to remove the high-pressure fuel line as removed in Step 5 above.

2. Remove the overflow line from the pressure limiting valve. See Figure 114.



1. PRESSURE LIMITING VALVE
2. OVERFLOW LINE
3. FUEL PRESSURE SENSOR
4. COMMON RAIL MOUNTING BOLTS

Figure 114. Common rail

3. Disconnect the electrical connector from the common rail fuel pressure sensor. See Figure 114.

4. Hold the common rail securely with one hand while loosening the two mounting bolts retaining the common rail. Make sure to hold the body of the common rail and NOT the sensors.

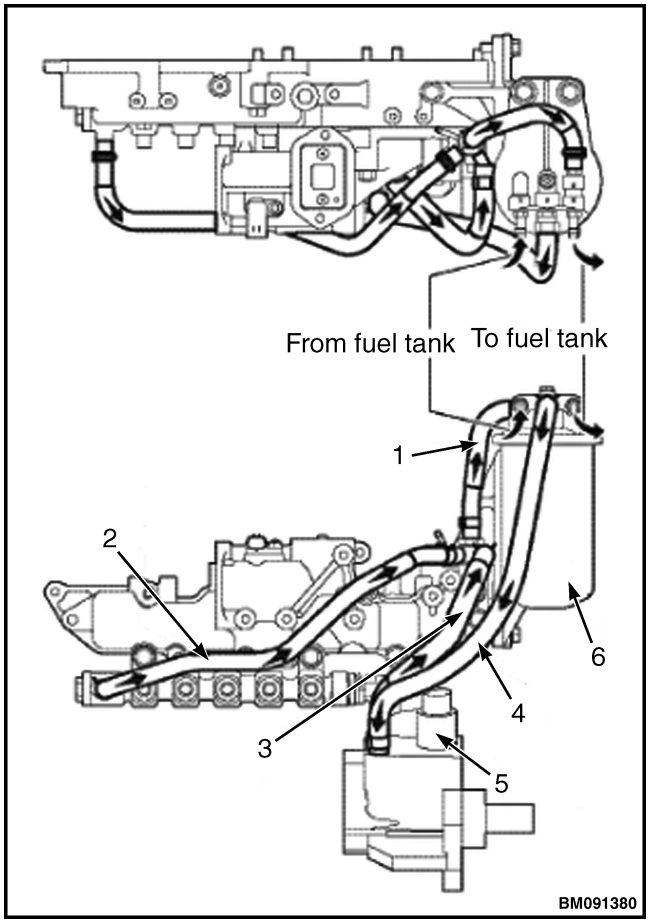
5. If replacing the rail pressure sensor, remove the sensor from the common rail and discard. Replace with new rail pressure sensor and O-ring. See Parts Manual.

6. If removing the pressure limiting valve, unthread the valve and O-ring from the common rail and discard. Replace with new pressure limiting valve and O-ring. See Parts Manual.

Supply pump

1. Disconnect the electrical connector from the fuel pressure sensor. See Figure 114.

2. Disconnect the electrical connector from the Suction Control Valve (SCV). See Figure 115.



1. INJECTOR OVERFLOW LINE
2. COMMON RAIL OVERFLOW LINE
3. SUPPLY PUMP OUTLET LINE
4. SUPPLY PUMP INLET LINE
5. SUCTION CONTROL VALVE (SCV)
6. FUEL FILTER

Figure 115. Supply pump and lines

NOTE: Place a container under the fuel lines to collect any spills.

3. Disconnect the fuel supply pump inlet line from the fuel filter. See Figure 115.

4. Disconnect the fuel supply pump outlet line from the fuel filter. See Figure 115.

5. Disconnect the common rail overflow and injector overflow lines from the common rail and injector. See Figure 115.

6. Remove the high pressure line from the supply pump to the common rail. See Figure 107.
   a. Use a brush or aspirator to clean around the cap nuts on both the supply pump and common rail sides.
   b. Use one hand to press and hold the high-pressure line connecting the supply pump and common rail while loosening the cap nut.
   c. Remove the high-pressure line.
   d. Use an aspirator to clean the high-pressure line on the side that was removed from the common rail. Cover with a plastic bag.

NOTE: For Step 7 through Step 10, see procedure in Diesel timing gear case repair.

7. Remove the supply pump drive gear from the gear case.

NOTE: Make an alignment mark between the supply pump drive gear and the idle gear. DO NOT rotate the crankshaft of the engine after drawing the mark.

8. Remove the supply pump drive gear nut.

9. Use the gear extraction tool to remove the supply pump drive gear. See Special tools for diesel engines for gear extraction tool part number.

NOTE: The supply pump may not be disassembled and must be replaced as an entire assembly.

10. Remove the three nuts that retain the supply pump and remove the supply pump.

INSTALL

Supply pump

NOTE: For Step 1 through Step 4, see procedure in Diesel timing gear case repair.

1. Align the position of the supply pump shaft to the drive gear and reinstall the supply pump to the gear case.

2. Insert the three nuts to retain the supply pump to the gear case. Torque to 22.6-28.4 N•m (16.7-20.9 lbf ft).

3. Attach the nuts to retain the supply pump drive gear to the supply pump drive shaft. Torque to 75-85 N•m (55.3-62.7 lbf ft).

4. Insert the bolts to retain the supply pump cover. Torque to 22.6-28.4 N•m (16.7-20.9 lbf ft).

5. Install the high pressure line from the supply pump to the common rail. See Figure 107 for Item a. through Item c.
   a. Before installing the high-pressure line, apply fuel to the threads of the cap nut.
   b. Seat the high-pressure line on to the supply pump and the common rail and tighten the cap nuts by hand.
   c. Torque to 29.4-34.3 N•m (21.7-25.3 lbf ft).

6. Install the common rail overflow and injector overflow lines to the common rail and injector. See Figure 115.

7. Install the fuel supply pump outlet line to the fuel filter. See Figure 115.

8. Install the fuel supply pump inlet line to the fuel filter. See Figure 115.

9. Connect the electrical connector to the fuel pressure sensor. See Figure 114.

10. Connect the electrical connector to the (SCV). See Figure 115.

NOTE: When replacing the fuel supply pump, it is necessary to write the pump correction values to the engine ECU. Use SMARTASSIST-Direct to download the current software. See the **SMARTASSIST-Direct Operation Manual** for more information.

11. After closing up the fuel system and installing the pump, key on the truck for a minimum of 5 seconds before attempting to start the engine. **This is the priming procedure.** The fuel system must be primed to ensure all air is removed from the fuel. Air that is mixed with fuel can cause the supply pump and injectors to seize.

Common rail

1. Hold the common rail securely with one hand, aligned with the intake manifold. See Figure 107.

2. Insert the two bolts to retain the common rail to the intake manifold, and tighten by hand at first to secure. See Figure 114. Tighten the nuts. Torque to 22.6-28.4 N•m (16.7-20.9 lbf ft).

3. If replacing the rail pressure sensor, install the new rail pressure sensor into the common rail. Torque to 90-100 N•m (66.4-73.8 lbf ft).

4. If replacing the pressure limiting valve, thread the new pressure limiting valve and O-ring into the common rail. Torque to 95-105 N•m (70.1-77.4 lbf ft).

5. Install the high-pressure lines from the injectors to the common rail. See Step 4, below.

When replacing the common rail, it is necessary to write the correction values of the injector nozzle to the engine ECU. Use SMARTASSIST-Direct to download the current software. See the **SMARTASSIST-Direct Operation Manual** for more information.

Injector

NOTE: If you reuse the injector be sure to reinstall it into the same cylinder it was removed from.

NOTE: When replacing the injector, replace it as an entire assembly.

NOTE: If you replace the injector, it is required to write the correction value of each injector to the ECU, to ensure proper engine performance. Rewrite the correction value using SMARTASSIST-DIRECT (SA-D). The proper correction value is written on each injector. See the **SMARTASSIST-Direct Operation Manual** for more information.

1. Insert the injector and a NEW injector gasket into the cylinder head. See Figure 113.

2. Reinstall the injector retainer. See Figure 113. Tighten the bolt by hand. The bolt will be torqued after all high-pressure lines are installed.

3. Repeat Step 1 through Step 2

4. Install the high-pressure fuel injection lines:

CAUTION

DO NOT bend any of the high-pressure fuel lines when installing. Bending the fuel lines may cause them to break.

NOTE: Replace the high-pressure fuel lines as an assembly.

a. Before reintstalling the high-pressure lines, apply fuel to the threads of the cap nuts.
b. Tighten the clamp of the high-pressure line to half-tight.

CAUTION

When tightening the high-pressure lines at the fuel injectors, hold the the fuel injector with a second wrench or spanner tool to prevent the injector from turning with the nut and damaging the return line fitting.

c. Start all high-pressure fuel line cap nuts by hand, leaving the nuts on both the fuel injection side and the rail side finger-tight. See Figure 112.

5. Tighten the injector retainer bolt. Torque to 24.4-28.4 N•m (18.0-20.9 lbf ft).

6. Tighten the high-pressure line cap nuts on the fuel injector side. See Figure 111. Torque to 26.5-31.4 N•m (19.5-23.2 lbf ft).

7. Tighten the high-pressure line cap nuts on the rail side. See Figure 111. Torque to 29.4-34.3 N•m (21.7-25.3 lbf ft).

8. Install the fuel return line by pushing the connector downward in a vertical motion while pushing the retaining ring of the injector in the direction of the arrow (A). See Figure 110.

9. Apply diesel oil to the O-ring at the mounting area of the connector to prevent it from being worn. **Do not use lubricating oil**.

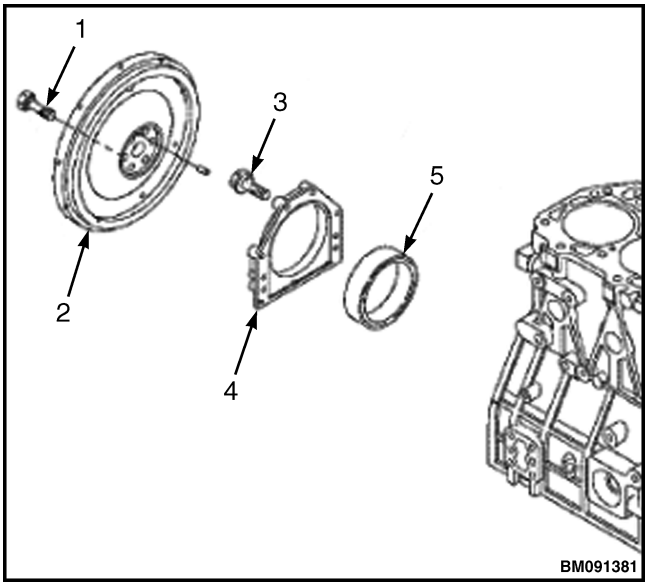
10. Connect the electrical connectors on the engine harness to the top of each of the injectors. See Figure 108.

DIESEL FLYWHEEL REPAIR 202001-017

REMOVE

1. Remove the engine. See Diesel engine removal and replacement section in the **Drive Train** 0900SRM2301 service manual.

2. Remove the six flywheel mounting bolts retaining the flywheel to the crankshaft flange and remove the flywheel assembly. See Figure 116.



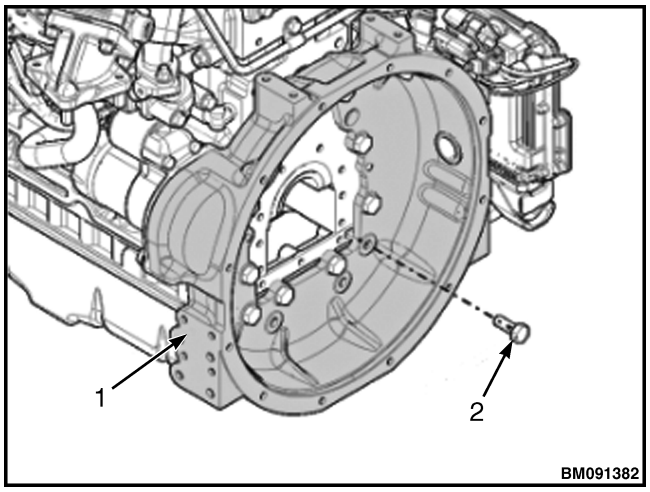
1. FLYWHEEL MOUNTING BOLT
2. FLYWHEEL ASSEMBLY
3. BOLT
4. REAR CRANKCASE COVER
5. REAR OIL SEAL

Figure 116. Flywheel

3. Remove the nine bolts retaining the rear crankcase cover and remove the rear crankcase cover. See Figure 116.

4. Remove the rear oil seal from the rear crankcase cover. See Figure 116.

5. Remove the flywheel housing mounting bolts and remove the flywheel housing. See Figure 117.



1. FLYWHEEL HOUSING
2. FLYWHEEL HOUSING MOUNTING

Figure 117. Flywheel housing

INSTALL

1. Insert the flywheel housing mounting bolts and install the flywheel housing. See Figure 117. Tighten the flywheel housing mounting bolts to standard torque value.

2. Install the rear oil seal in the rear crankcase cover. See Figure 116.

3. Install the rear crankcase cover and insert the nine bolts to retain the rear crankcase cover to the crankshaft flange. See Figure 116. Tighten the bolts to standard torque value.

4. Align the flywheel assembly with the crankshaft flange. Install the six flywheel mounting bolts to retain the flywheel to the crankshaft flange. See Figure 116.

5. Tighten the flywheel mouning bolts to 83.3 to 88.2 N•m (61 to 65 lbf ft) following the sequence shown in Figure 118.

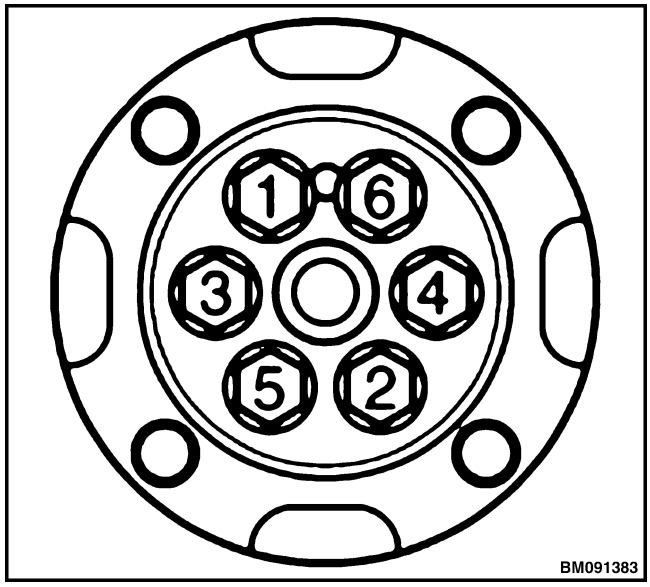


Figure 118. Torque sequence

6. Install the engine. See Diesel engine removal and replacement section in the **Drive Train** 0900SRM2301 service manual.

DIESEL ELECTRICAL SYSTEM REPAIR 202001-018

STARTER

Remove

WARNING

SHOCK HAZARD. Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

DANGER

Check the electrical harnesses for cracks, abrasions and damaged or corroded connectors. Always keep the connectors and terminals clean. Failure to comply could result in death or serious injury.

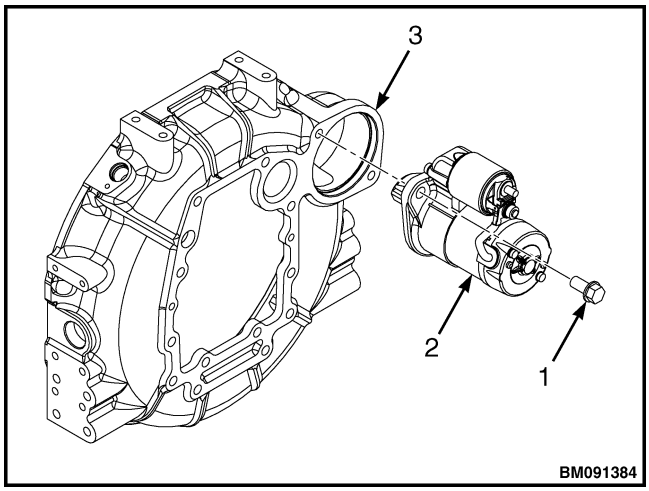
NOTE: While starter design varies between models, the basic repair procedures are the same. The following procedures are typical and may differ from the starter being serviced.

1. Disconnect the negative battery cable at the negative terminal post on the battery.

2. Disconnect the positive battery cable at the positive terminal post on the battery.

3. Put labels on wires and cables prior to disconnecting to aid in correct installation. Disconnect all cables and wires from the starter.

4. Remove the two starter mounting bolts. Remove the starter from the flywheel housing. See Figure 119.



1. STARTER MOUNTING BOLT
2. STARTER
3. FLYWHEEL HOUSING

Figure 119. Starter mounting

Disassemble

1. Loosen the nut from the magnetic switch (solenoid) assembly. Disconnect the wire from the magnetic switch. See Figure 120.

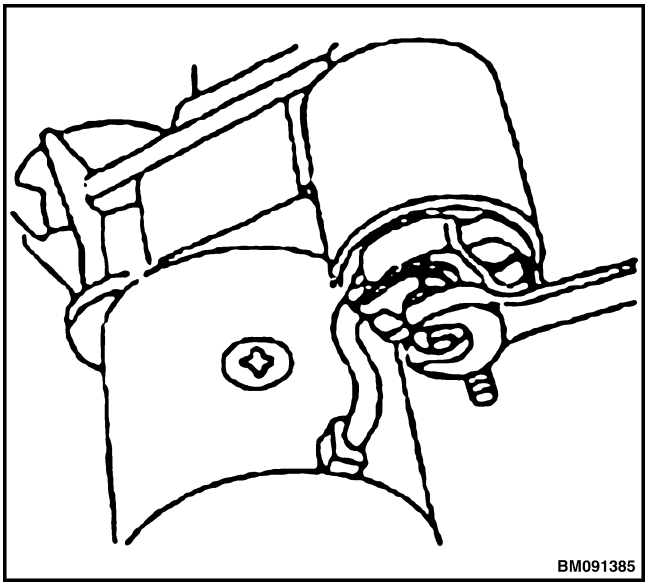
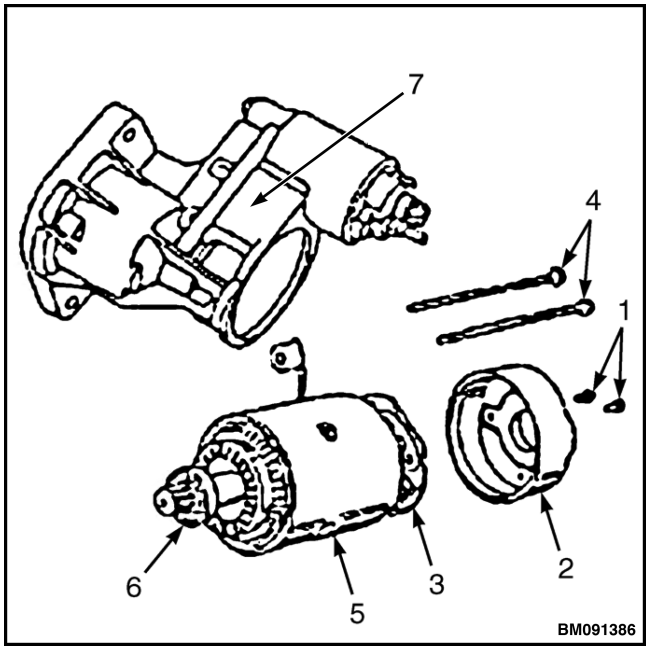


Figure 120. Magnetic switch nut

2. Remove the two bolts securing (1, Figure 121) the rear cover of the starter to the brush holder assembly.

3. Remove the two bolts (4, Figure 121) securing the rear cover from the field coil assembly.

4. Remove the field coil assembly and armature assembly from the gear housing. See Figure 121.



1. BOLTS
2. REAR COVER
3. BRUSH HOLDER ASSEMBLY
4. THROUGH BOLTS
5. FIELD COIL ASSEMBLY
6. ARMATURE ASSEMBLY
7. GEAR HOUSING

Figure 121. Starter components

Install

1. Insert the two starter mounting bolts and attach the starter to the flywheel housing. See Figure 119.

2. Connect all cables and wires to the starter.

3. Connect the positive battery cable to the positive terminal.

4. Connect the negative battery cable to the negative terminal.

Table 33. Starter Specifications

Nominal output			1.7 kW (2.3 hp)
Weight			3.4 kg (7.5 lb)
Revolution direction (As viewed from pinion)			Clockwise
Engagement system			Magnetic shift
No-load	Terminal voltage / urrent		11 V / 90 A max
	Revolution		2300 rpm min
Loaded	Terminal voltage / current		8 V / 370 A max
	Torque		15.1 N•m, 1.1 kgf•m (11.2 lbf ft) min
Clutch system			Overrunning
Pinion projection Voltage at 100°C (212°F)			8.6 V max
Pinion DP or module / number of teeth			M3 / 9
Difference (O-ring, oil seal)			Dry (none)
Application			Standard
Brush	Spring force		35 N, 3.6 kgf (7.868 lbf)
	Height	Standard	15 mm (0.591 in.)
		Limit	9 mm (0.354 in.)
Magnetic switch	Series coil resistance		0.27 Ω at 20°C (68°F)
	Shunt coil resistance		0.60 Ω at 20°C (68°F)
Commutator	Outside diameter	Standard	36.5 mm (1.437 in.)
		Limit	35 mm (1.398 in.)
	Run-out	Standard	0.03 mm (0.001 in.)
		Limit	0.2 mm (0.008 in.)
	Insulation depth	Standard	0.5 to 0.8 mm (0.020 to 0.031 in.)
		Limit	0.2 mm (0.008 in.)
Armature	Run-out	Standard	0.03 mm (0.001 in.)
		Limit	0.2 mm (0.008 in.)
Bearing type	Armature front	Nominal number	6903DDU
	Armature rear		608DDU
	Pinion front		60004DDU
	Pinion rear		6904DDU
Pinion projection length (length L)			0.3 to 1.5 mm (0.012 to 0.059 in.)

ALTERNATOR

Remove

WARNING

SHOCK HAZARD. Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

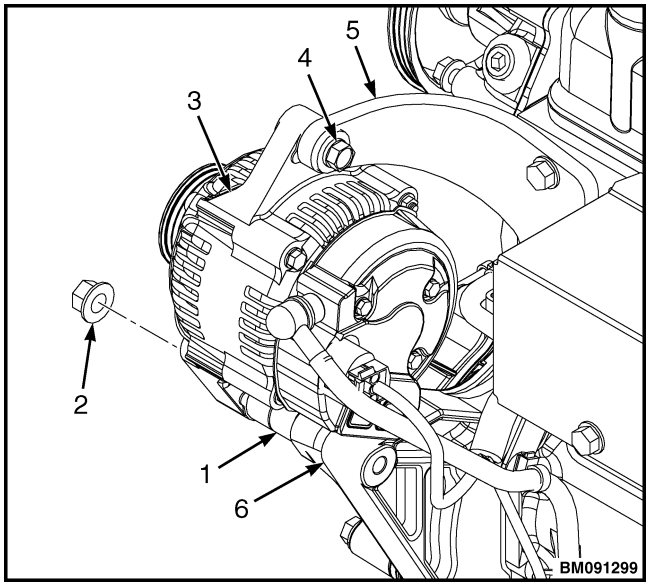
DANGER

Check the electrical harnesses for cracks, abrasions and damaged or corroded connectors. Always keep the connectors and terminals clean. Failure to comply could result in death or serious injury.

CAUTION

PINCH HAZARD. Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

1. Remove the V-belt. See **Cooling system** 0700SRM2300 service manual.
2. Put labels on wires and cables prior to disconnecting to aid in correct installation. Disconnect all cables and wires from the alternator.
3. Perform the following steps to remove the alternator.
   a. Loosen the alternator mounting nut (item 2, Figure 122) and remove.
   b. Loosen the mounting bolt (item 4, Figure 122) attaching the alternator to the alternator mounting bracket.
   c. Remove the alternator.



1. SPACER AND STUD
2. ALTERNATOR MOUNTING NUT
3. ALTERNATOR
4. MOUNTING BOLT
5. ALTERNATOR MOUNTING BRACKET
6. TIMING GEAR CASE

Figure 122. Alternator mounting

Install

1. Perform the following steps to install the alternator.
   a. Install the alternator onto the stud attached to the timing gear case. Temporarily tighten the alternator mounting nut. See Figure 122.
   b. Temporarily tighten the mounting bolt (item 4, Figure 122) to retain the alternator to the alternator mounting bracket.
2. Reconnect the electrical wires to the alternator. Tighten the nuts to secure the wires to the alternator. Torque to 1.7-2.3 N•m (15-20 lbf in).
3. Fully tighten the alternator mounting nut. Torque to 1.7-2.3 N•m (15-20 lbf in).
4. Fully tighten the mounting bolt. Torque to 1.7-2.3 N•m (15-20 lbf in).
5. Reinstall the V-belt. Tighten the V-belt to the correct tension. See First 150 hours periodic maintenance (PM) procedures in the **Periodic Maintenance** 8000SRM2305 service manual.

NOTE: DO NOT operate the engine if the alternator is producing unusual sounds. Damage to the alternator will result.

6. Start the engine. Listen for any unusual sounds from the alternator.

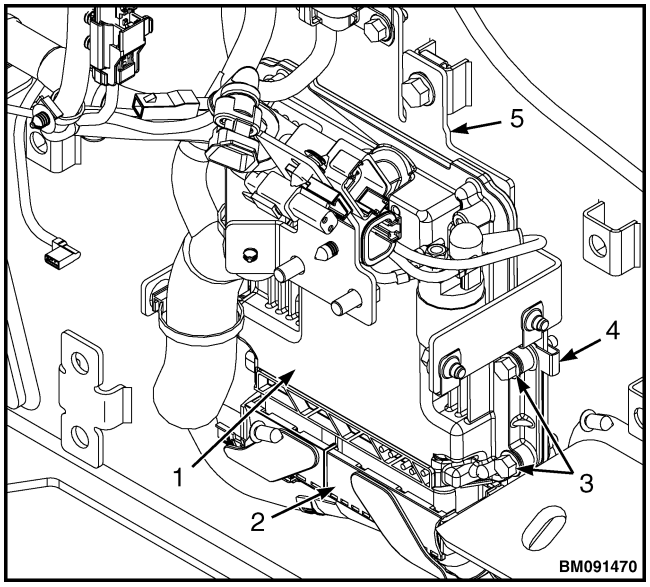
7. Verify that the alternator icon does not display while the engine is operating. If the alternator displays, repair the problem before operating the engine. See the Guided Troubleshooting for this lift truck.

Figure 123. Alternator icon

ENGINE CONTROL UNIT

Remove

1. Disconnect the engine harness from the ECU. See Figure 124.
2. Locate the top capscrews on each side that attach the ECU to the mounting bracket. See Figure 124.
3. Remove the two top capscrews and foldover nuts.
4. Locate the bottom capscrews on each side that attach the ECU to the mounting bracket. See Figure 124.
5. Remove the two bottom capscrews.
6. Remove the ECU. See Figure 124.



1. ECU
2. ENGINE WIRE HARNESS
3. CAPSCREW
4. FOLDOVER NUT
5. MOUNTING BRACKET

Figure 124. ECU

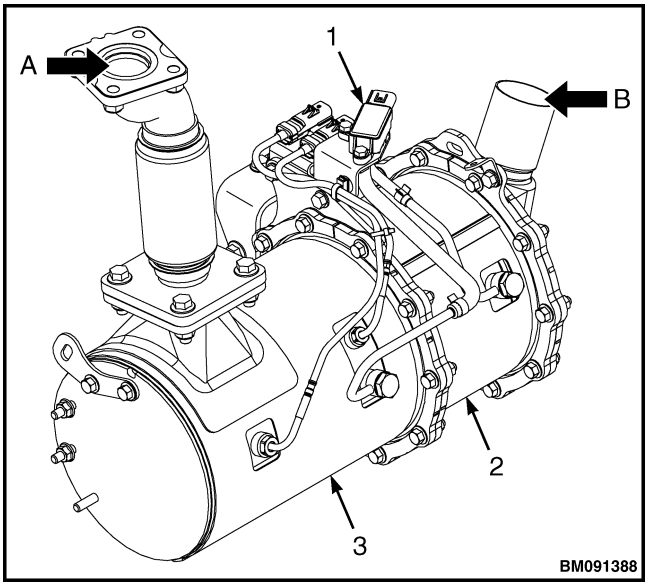
Install

1. Locate the new ECU and align it with the holes on the mounting bracket. See Figure 124.
2. Insert the two bottom capscrews to retain the ECU to the mounting bracket. See Figure 124. Torque the capscrews to
3. Insert the two top capscrews into the ECU and foldover nuts to attach the ECU to the mounting bracket. See Figure 124. Torque the capscrews to
4. Connect the engine harness to the ECU. See Figure 124.

When replacing the ECU or if an update to the ECU software is required, it is necessary to write the software to the new ECU (Service ECU) or ECU equipped machine. Use SMARTASSIST-Direct to download the current software. See the **SMARTASSIST-Direct Operation Manual** for more information.

DIESEL EXHAUST AND AFTER TREATMENT REPAIR 202001-019

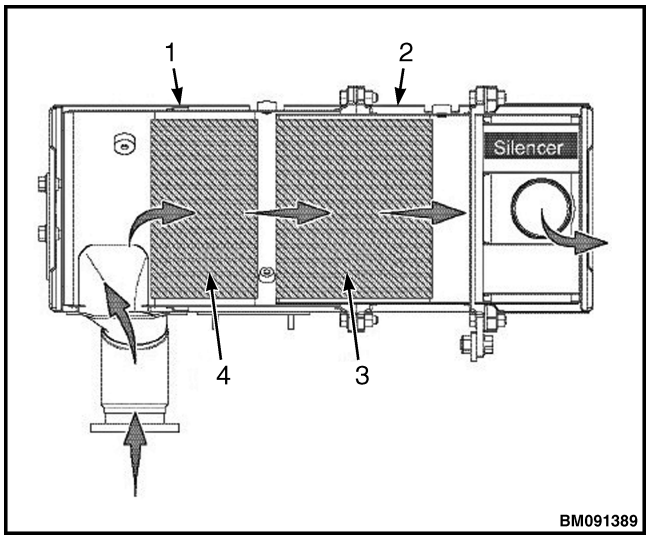
DIESEL PARTICULATE FILTER (DPF) SYSTEM



A. EXHAUST GAS IN
B. EXHAUST GAS OUT

1. PRESSURE DIFFERENTIAL SENSOR
2. SOOT FILTER (SF) CASE
3. DIESEL OXIDATION CATALYST (DOC) CASE

Figure 125. DPF assembly



1. DOC CASE
2. SOOT FILTER CASE
3. DOC
4. SOOT FILTER

Figure 126. DPF flow

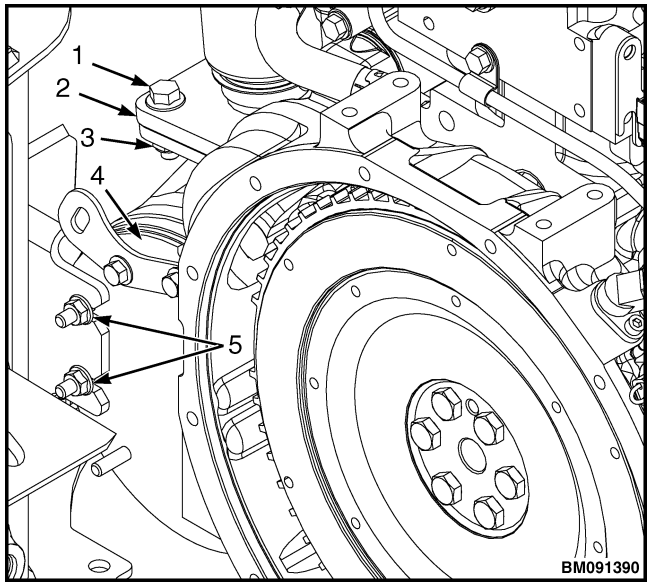
Remove

DPF assembly

1. Place the lift truck on blocks, to allow for enough clearance to remove the DPF from below the frame. See How to put a lift truck on blocks.

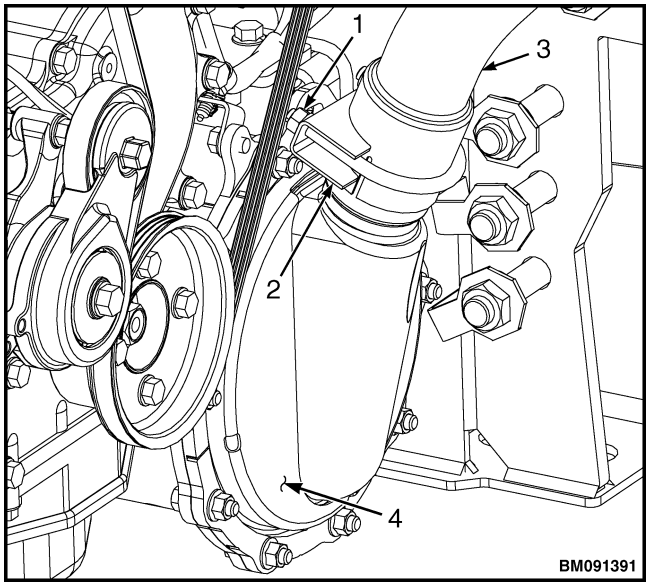
2. Remove the battery and battery box to gain access to the Diesel Particulate Filter (DPF) assembly.

3. Locate the DPF assembly (item, 4) attached to the frame. See Figure 127.



1. MOUNTING BOLT
2. INTAKE EXHAUST PIPE FLANGE
3. NUT
4. DPF ASSEMBLY
5. NUT

Figure 127. DPF mounting



1. BOLT
2. HOSE CLAMP
3. OUTLET EXHAUST PIPE
4. DPF ASSEMBLY

Figure 128. Outlet exhaust pipe

WARNING

The DPF assembly weighs approximately 12.9 kg (28.4 lb). Make sure to use a lifting device with enough capacity to lift the DPF assembly. Make sure not to damage the DPF assembly by falling or impact as it contains a ceramic filter. Even if there is no apparent damage, a dropped or shocked DPF will need to be replaced with a new one.

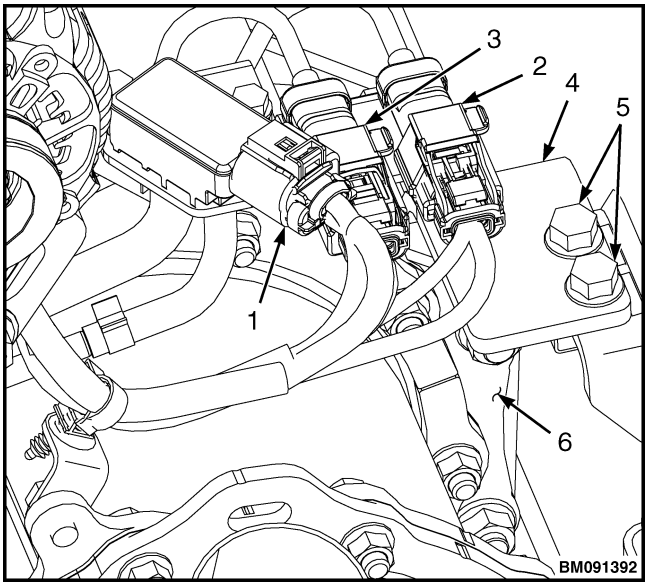
4. Attach a lifting device to the two lifting eyes on the DPF assembly (see Figure 130.

5. Use a 10 mm socket wrench to loosen and remove the four mounting bolts and nuts attaching the intake exhaust pipe flange to the DPF assembly. See Figure 127. Remove the intake exhaust pipe.

6. Loosen and remove the hose clamp attaching the outlet exhaust pipe to the DPF assembly. See Figure 128.

7. Detach the outlet exhaust pipe from the DPF assembly. See Figure 128.

8. Disconnect the differential pressure sensor connector (item 1) and the two temperature sensor connectors (item 2, 3) on the engine wire harness from the connectors on the DPF assembly. See Figure 129.



1. EXHAUST DIFFERENTIAL PRESSURE SENSOR CONNECTOR
2. EXHAUST TEMPERATURE SENSOR CONNECTOR 1
3. EXHAUST TEMPERATURE SENSOR CONNECTOR 2
4. MOUNTING BRACKET
5. MOUNTING BOLTS
6. DPF ASSEMBLY

Figure 129. DPF mounting bracket

9. Use the 8 mm socket wrench to loosen and remove the two mounting bolts (item 5) from the mounting bracket. See Figure 129.

10. Use a 8 mm socket wrench to loosen and remove the two nuts attaching the DPF assembly to the frame. See Figure 127.

CAUTION

When using the lifting device to move the DPF assembly, make sure not to damage the assembly by dropping or causing impact, as it contains a ceramic filter. Even if there is no apparent damage, a dropped or shocked DPF will need to be replaced with a new one.

11. Use the lifting device to lower the DPF assembly out of the lift truck from the bottom of the frame. Move the DPF assembly free of the frame, and relocate to a flat work surface.

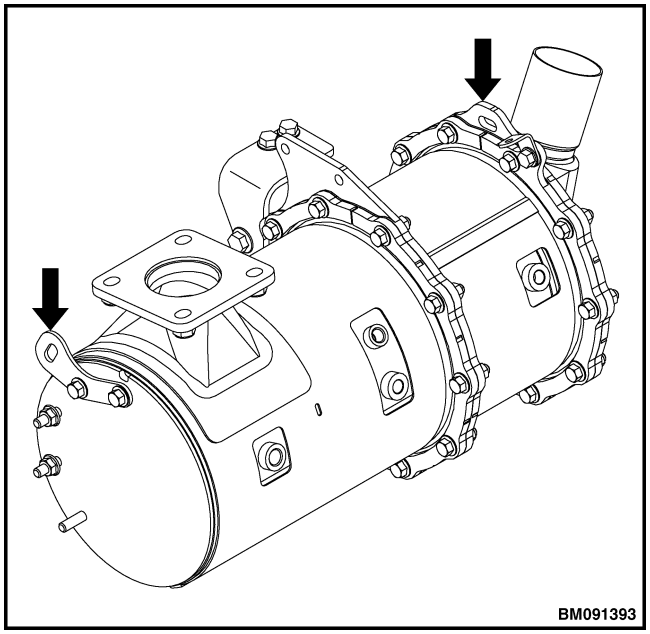
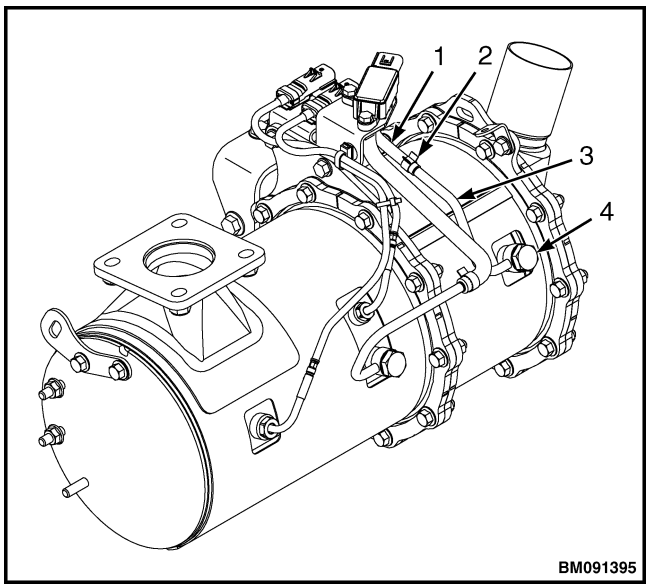


Figure 130. DPF lifting eyes

Soot filter

1. Locate the soot filter side exhaust pressure hose. See Figure 131.



1. SOOT FILTER SIDE EXHAUST PRESSURE HOSE
2. HOSE CLIP
3. SOOT FILTER SIDE EXHAUST PRESSURE PIPE
4. BOLT

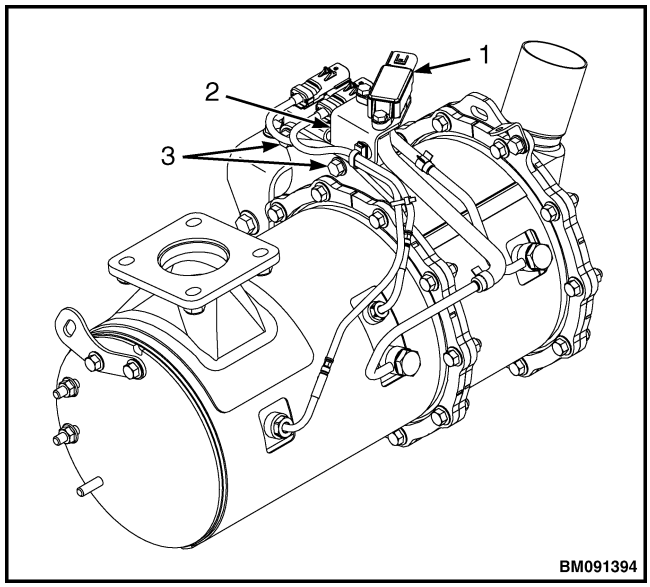
Figure 131. Soot filter side exhaust pressure hose

2. Loosen the hose clip that secures the soot filter side exhaust pressure hose to the soot filter side exhaust pressure pipe. See Figure 131.

3. Remove the soot filter side exhaust pressure hose. See Figure 131.

4. If removing the entire soot filter case, disconnect the bolt (item 4, Figure 131) that attaches the soot filter side exhaust pressure pipe and remove the pipe. If only replacing the soot filter, it is not necessary to remove the bolt and pipe.

5. Locate the sensor bracket that retains the exhaust differential pressure sensor and the exhaust temperature sensor connectors. See Figure 132.



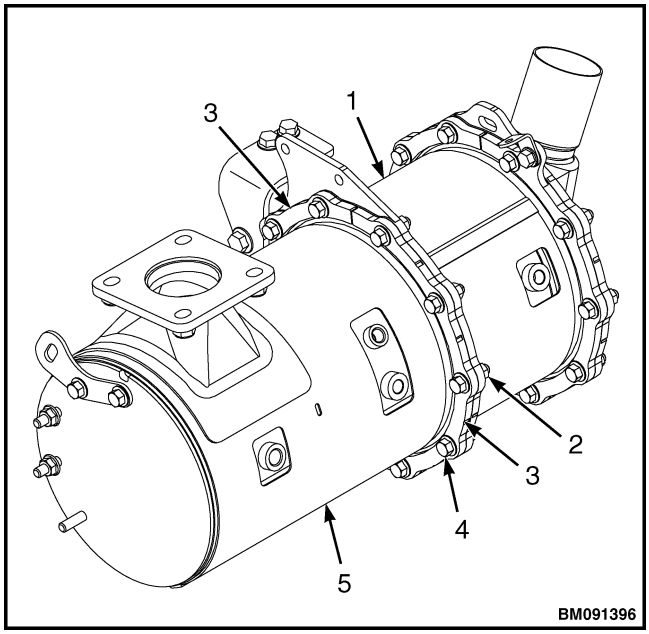
1. EXHAUST DIFFERENTIAL PRESSURE SENSOR
2. SENSOR BRACKET
3. FLANGE BOLT

Figure 132. Exhaust differential pressure sensor

6. Use an 8 mm socket wrench to loosen and remove the two flange bolts that attach the sensor bracket. See Figure 132.

7. Move the sensor bracket with the sensor, connectors, and wire harness still attached, so it does not interfere with removal of other parts.

8. Remove and discard the ten flange bolts and flange nuts that connect the soot filter case to the DOC case. See Figure 133.



1. SOOT FILTER CASE
2. FLANGE NUT
3. STIFFENERS
4. FLANGE BOLT
5. DOC CASE

Figure 133. Flange bolts and nuts

9. Remove the soot filter and soot filter case as a unit. Mark the stiffeners so that they can be reassembled in the original position. Remove the stiffeners that hold the mating surface of the soot filter case and DOC case flange.

10. Remove the soot filter from the soot filter case.

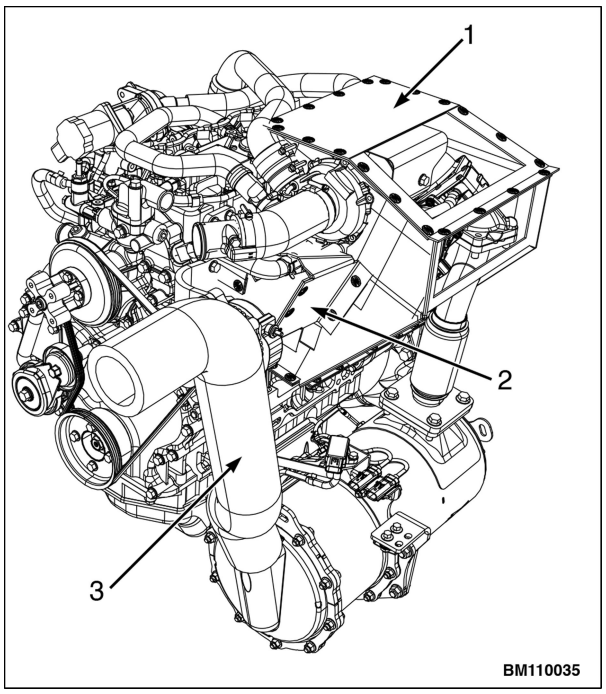
11. Replace the DOC if necessary.

When replacing the DOC, it is required to write the correction value of the DOC to the ECU. Rewrite the correction value using SMARTASSIST-DIRECT (SA-D). See the **SMARTASSIST-Direct Operation Manual** for more information.

Inspect

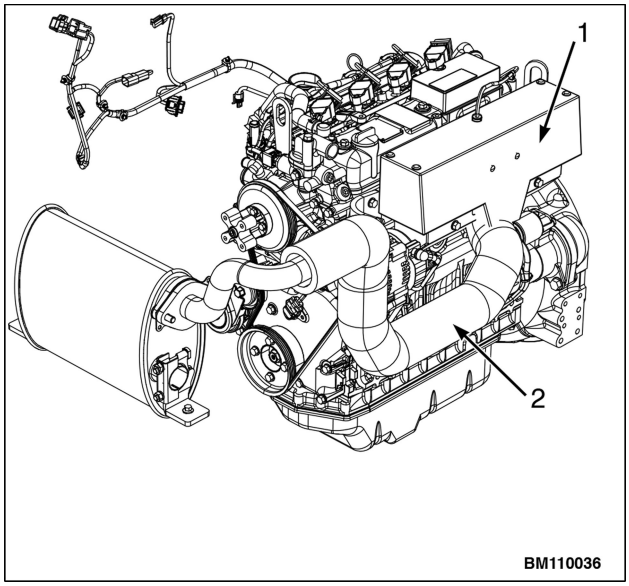
- Inspect all exhaust pipes for damage, corrosion, and rust. Replace as needed.

- If equipped, inspect all exhaust wraps for wear, proper fit, contamination with oil or antifreeze, gaps in coverage, and failed fasteners. See Figure 134 or Figure 135. Replace as needed. If replacing an exhaust pipe section that has a wrap, also replace the wrap. DO NOT reuse wraps if they have been removed for a service operation.
- Inspect the catalytic converter (if equipped) and muffler for damage, corrosion, and rust. Replace as needed.



1. EXHAUST WRAP-MANIFOLD
2. EXHAUST WRAP-TURBO
3. EXHAUST WRAP-TUBES

Figure 134. Inspect exhaust wraps (with DPF)



1. EXHAUST WRAP-MANIFOLD
2. EXHAUST WRAP-TUBES

Figure 135. Inspect exhaust wraps (Diesel, non-cert)

Install

Soot filter

1. Install the new soot filter into the soot filter case.

2. Position the stiffeners between the soot filter case and DOC case, as marked in Step 9.

3. Align the soot filter case with the DOC case. Insert ten new flange bolts and flange nuts to attach the soot filter case to the DOC case, and tighten. See Figure 133.

4. Torque the flange bolts to 23-29 N•m (17-21 lbf ft).

5. Align the sensor bracket in position on the soot filter. See Figure 132.

6. Insert two flange bolts and nuts to attach the Figure 132 sensor bracket to the soot filter case and tighten.

7. Torque the flange bolts to 23-29 N•m (17-21 lbf ft).

8. If the soot filter side exhaust pressure pipe was removed, insert the bolt to attach the pipe to the soot filter case. (item 4, Figure 131). Torque the bolt to 24.4-34.4 MPa (18-25 lbf ft).

9. Attach the soot filter side exhaust pressure hose to the soot filter side exhaust pressure pipe. See Figure 131.

10. Tighten the hose clip that secures the soot filter side exhaust pressure hose to the soot filter side exhaust pressure pipe. See Figure 131.

When replacing the soot filter, it is required to write the correction value of the soot filter to the ECU. Rewrite the correction value using SMARTASSIST-DIRECT (SA-D). See the **SMARTASSIST-Direct Operation Manual** for more information.

DPF assembly

1. Move the DPF assembly into position beneath the frame of the lift truck.

WARNING

The DPF assembly weighs approximately 12.9 kg (28.4 lb). Make sure to use a lifting device with enough capacity to lift the DPF assembly. Make sure not to damage the DPF assembly by falling or impact as it contains a ceramic filter. Even if there is no apparent damage, a dropped or shocked DPF will need to be replaced with a new one.

2. Attach a lifting device to the DPF assembly.

3. Use the lifting device to lift the DPF assembly into position in the lift truck.

4. Insert the two 8 mm mounting bolts (item 5) to attach the DPF assembly to the mounting bracket and tighten by hand. See Figure 129.

5. Insert the two nuts to attach the DPF assembly to the frame. See Figure 127. Tighten to 23-29 N•m (17-21 lbf ft).

6. Align the intake exhaust flange with the DPF assembly. See Figure 127.

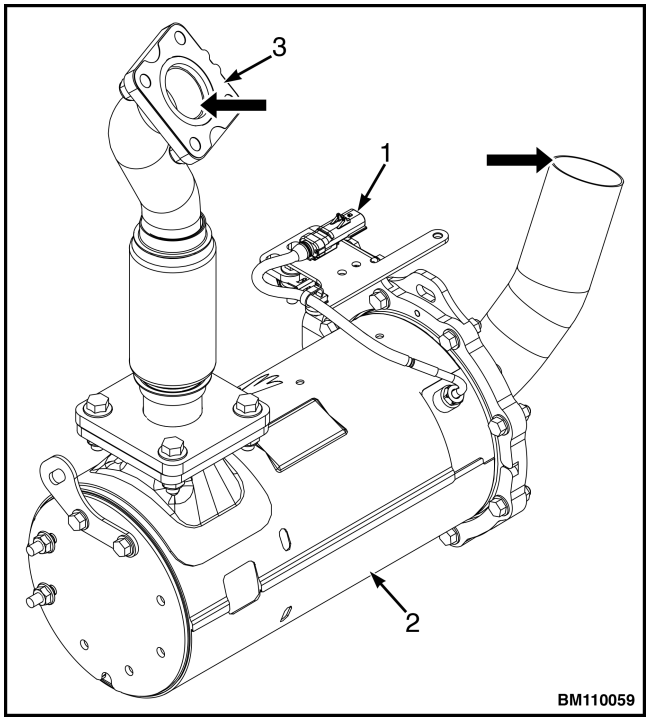
7. Insert a new gasket and the four mounting bolts and nuts retaining the intake exhaust flange to the DPF assembly. See Figure 127. Tighten the bolts to 44-54 N•m (32-40 lbf ft).

8. Connect the outlet exhaust pipe to the DPF assembly and tighten the hose clamp. See Figure 128.

9. Connect the differential pressure sensor connector (item 1) and the two temperature sensor connectors (item 2, 3) on the engine wire harness to the connectors on the DPF assembly. SeeFigure 129.

When replacing the DPF, it is required to write the correction value of the DPF to the ECU. Rewrite the correction value using SMARTASSIST-DIRECT (SA-D). See the **SMARTASSIST-Direct Operation Manual** for more information.

DIESEL OXIDATION CATALYST (DOC) SYSTEM



A. EXHAUST GAS IN
B. EXHAUST GAS OUT

1. DIFFERENTIAL PRESSURE SENSOR
2. DIESEL OXIDATION CATALYST (DOC)
3. GASKET

Figure 136. DOC assembly

Remove

DOC assembly

1. Place the lift truck on blocks, to allow for enough clearance to remove the DOC from below the frame. See How to put a lift truck on blocks.

2. Remove the battery and battery box to gain access to the DOC assembly.

WARNING

The DOC assembly weighs approximately 10 kg (22 lb). Make sure to use a lifting device with enough capacity to lift the DOC assembly. Make sure not to damage the DOC assembly by dropping or impacting. Even if there is no apparent damage, a dropped or impacted DOC will need to be replaced with a new one.

3. Attach a lifting device to the two lifting eyes. See Figure 137.

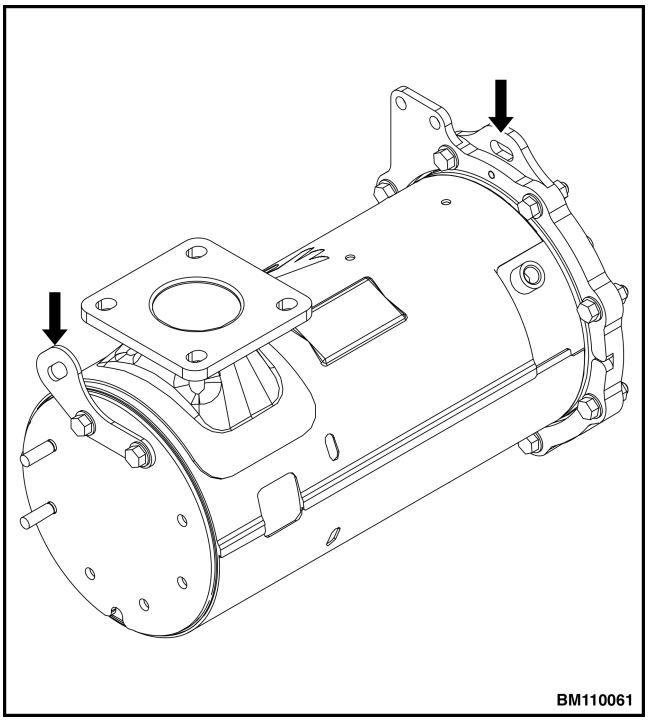
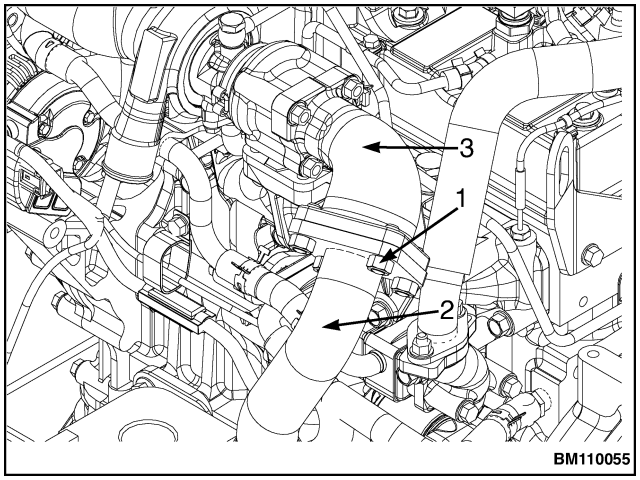


Figure 137. DOC lifting eyes

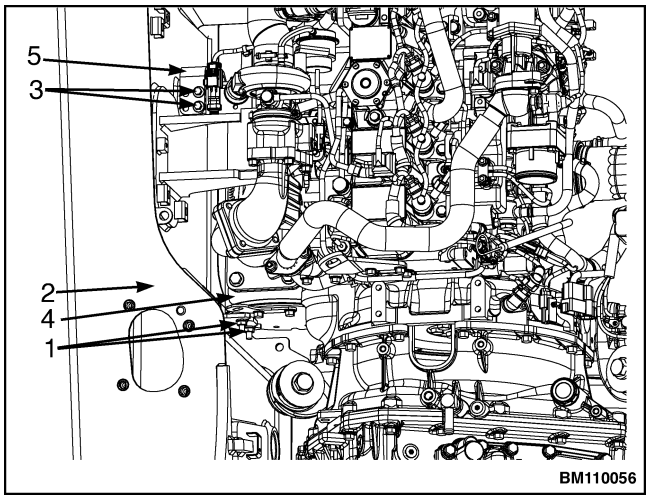
4. Loosen the four nuts (item 1, Figure 138) to remove the exhaust pipe from the turbo outlet.



1. NUTS
2. EXHAUST PIPE
3. TURBO OUTLET

Figure 138. Disconnect DOC exhaust pipe

5. Loosen the two nuts (item 1, Figure 139) attaching the inlet side of the DOC to the frame.

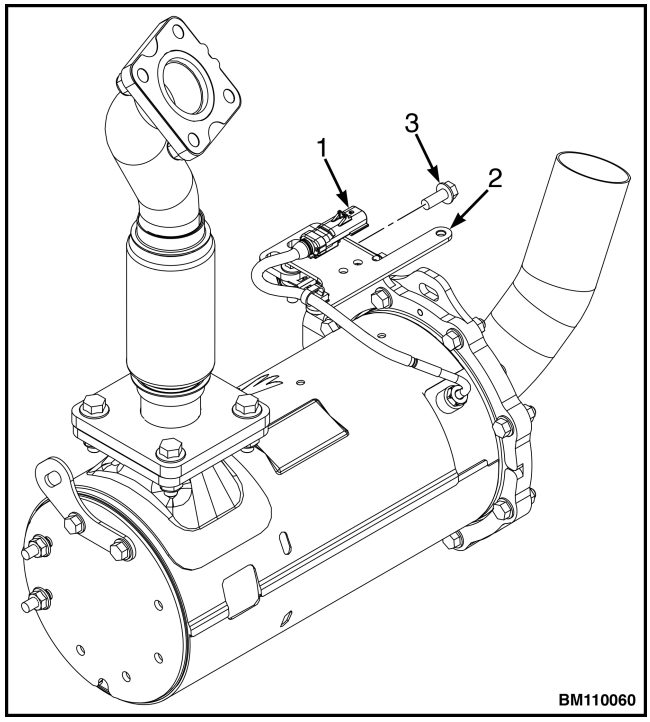


1. NUTS
2. FRAME
3. CAPSCREWS
4. DOC ASSEMBLY
5. MOUNTING BRACKET

Figure 139. DOC mounting

6. Loosen the two capscrews (item 3, Figure 139) attaching the DOC mounting bracket to the frame.

7. Disconnect the differential pressure sensor connector (item 1, Figure 140).



1. DIFFERENTIAL PRESSURE SENSOR CONNECTOR
2. MOUNTING BRACKET
3. MOUNTING BOLT

Figure 140. DOC differential pressure sensor connector

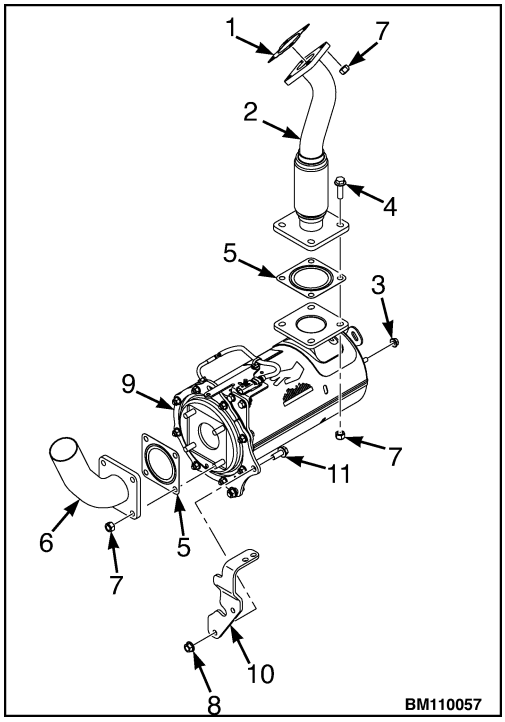
CAUTION

When using the lifting device to move the DOC assembly, make sure not to damage the assembly by dropping or causing impact, as it contains a ceramic filter. Even if there is no apparent damage, a dropped or shocked DOC will need to be replaced with a new one.

8. Use the lifting device to lower the DOC assembly out of the lift truck from the bottom of the frame. Move the DOC assembly free of the frame, and relocate to a flat work surface.

9. Remove the hardware attaching the inlet and outlet exhaust pipes to the DOC and remove the exhaust pipes. See Figure 141.

10. Remove the hardware attaching the mounting bracket to the DOC and remove the mounting bracket. See Figure 141.



1. GASKET
2. INLET EXHAUST PIPE
3. NUT
4. CAPSCREW
5. GASKET
6. OUTLET EXHAUST PIPE
7. NUT
8. NUT
9. DIESEL OXIDATION CATALYST
10. DOC MOUNTING BRACKET
11. CAPSCREW

Figure 141. Exhaust pipe and DOC

Inspect

- Inspect all exhaust pipes for damage, corrosion, and rust. Replace as needed.
- Inspect the catalytic converter (if equipped) and muffler for damage, corrosion, and rust. Replace as needed.

Install

DOC assembly

1. Install the hardware to attach the mounting bracket to the DOC. See Figure 141.

2. Install the hardware to attach the inlet and outlet exhaust pipes to the DOC. See Figure 141.

3. Move the DOC assembly into position beneath the frame of the lift truck.

WARNING

The DOC assembly weighs approximately 10 kg (22 lb). Make sure to use a lifting device with enough capacity to lift the DOC assembly. Make sure not to damage the DOC assembly by falling or impact. Even if there is no apparent damage, a dropped or impacted DOC must be replaced with a new one.

4. Attach a lifting device to the DOC assembly.

5. Use the lifting device to lift the DOC assembly into position in the lift truck.

6. Install the two capscrews (item 3, Figure 139) to attach the DOC mounting bracket to the frame. Tighten to standard torque.

7. Install the two nuts (item 1, Figure 139) to attach the inlet side of the DOC to the frame. Tighten to standard torque.

8. Align the exhaust pipe with the turbo outlet. See Figure 138.

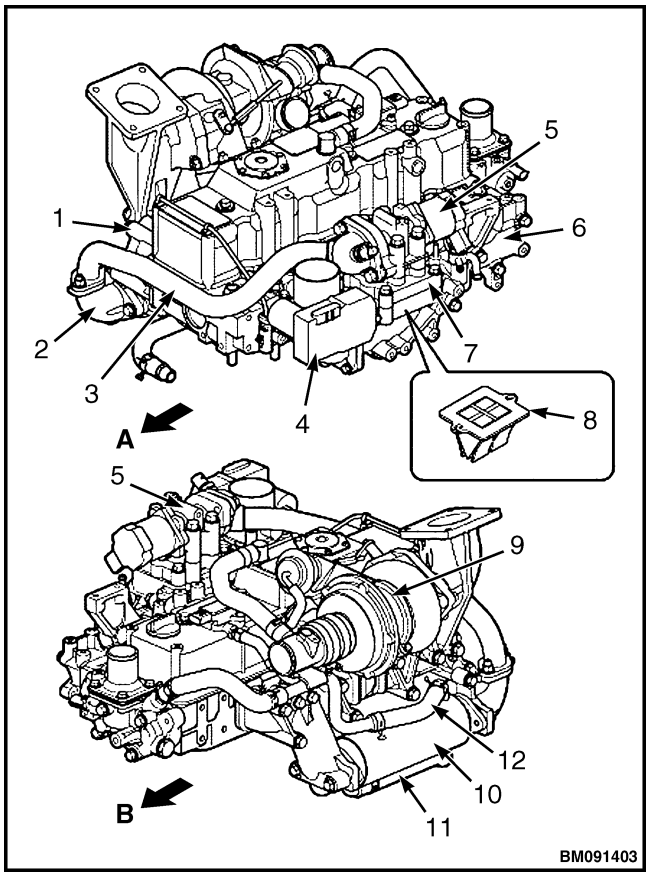
9. Insert a new gasket (item 3, Figure 136) and install the four nuts (item 1, Figure 138) to attach the exhaust pipe to the turbo outlet. Tighten the nuts to 39 N•m (28.8 lbf ft).

10. Connect the differential pressure sensor connector. See Figure 140.

When replacing the DOC, it is required to write the correction value of the DOC to the ECU. Rewrite the correction value using SMARTASSIST-DIRECT (SA-D). See the **SMARTASSIST-Direct Operation Manual** for more information.

EXHAUST GAS RECIRCULATION (EGR) SYSTEM

EGR system configuration



A. FLYWHEEL SIDE
B. GEAR CASE SIDE

1. EXHAUST MANIFOLD
2. EGR COOLER OUTLET VALVE
3. EGR PIPE
4. INTAKE THROTTLE VALVE
5. EGR VALVE
6. INTAKE MANIFOLD
7. EGR VALVE SPACER
8. EGR LEAD VALVE
9. TURBO CHARGER
10. EGR COOLER
11. EGR COOLER INLET SIDE COOLANT HOSE
12. EGR COOLER OUTLET SIDE COOLANT HOSE

Figure 142. Engine with turbo charger

Disassemble

DANGER

BURN HAZARD! Keep hands and other body parts away from engine components such as the muffler, exhaust pipe, turbo charger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and can cause serious burns. Failure to comply can result in death or serious injury.

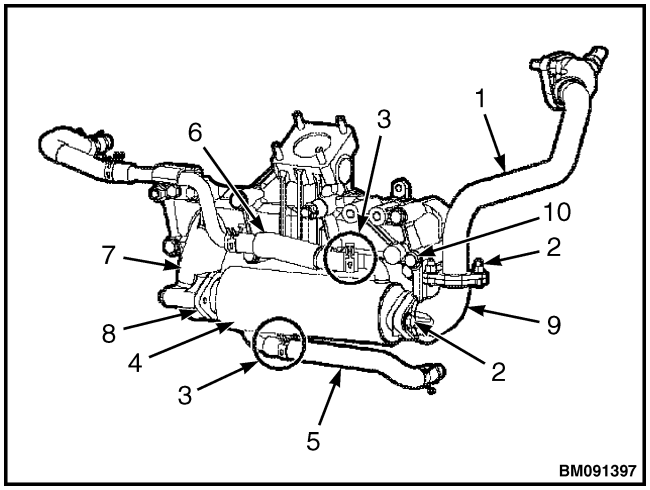
WARNING

COOLANT HAZARD! Wear eye protection and rubber gloves when handling long-life or extended-life engine coolant. If contact with the eyes or skin should occur, flush eyes immediately with clean water. Failure to comply can result in moderate injury.

EGR cooler

1. Drain all coolant from the engine into a suitable container.

2. Loosen the mounting nuts (item 2, Figure 143) that attach the EGR pipe to the EGR cooler outlet vent.



1. EGR PIPE
2. MOUNTING NUT
3. HOSE CLAMP
4. EGR COOLER
5. INLET SIDE COOLANT HOSE
6. OUTLET SIDE COOLANT HOSE
7. EXHAUST MANIFOLD
8. BOLT
9. EGR COOLER OUTLET VENT
10. BOLT

Figure 143. EGR and attaching parts

3. Loosen the mounting nuts (item 4, Figure 144) that attach the EGR pipe to the EGR valve. Remove the EGR pipe.

NOTE: Place a rag underneath the hose connections when removing the hose clamps, to catch any water that flows out.

4. Loosen the hose clamps (item 3) on the inlet side coolant hose (item 5) of the EGR cooler. See Figure 143.

5. Loosen the hose clamps (item 3) on the outlet side coolant hose (item 6) of the EGR cooler. See Figure 143.

6. Remove the inlet and outlet side coolant hoses. See Figure 143.

7. Loosen the bolt that attaches the EGR cooler to the exhaust manifold. See Figure 143.

8. Loosen the bolt that attaches the EGR cooler outlet vent to the exhaust manifold. See Figure 143.

9. Remove the EGR cooler and the EGR cooler outlet vent as one assembly.

EGR valve and lead valve

1. Remove any engine components, such as the air cleaner, that may be still attached and are blocking the EGR valve. See Diesel engine removal and replacement in **Drive Train** 0900SRM2301 service manual.

2. Disconnect the EGR valve connector from the wire harness.

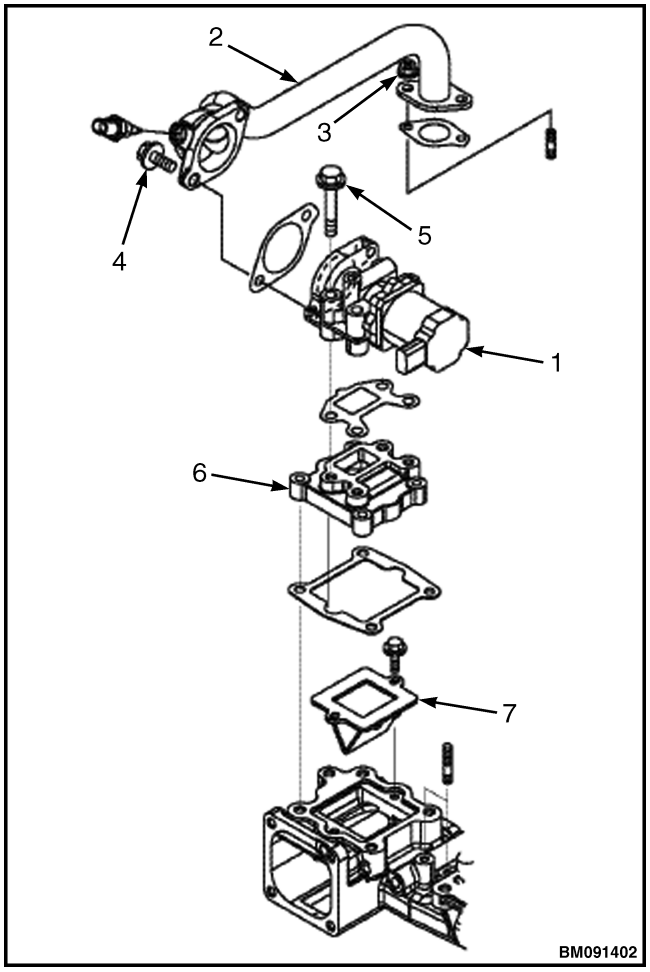
3. Loosen the mounting nuts (item 2, Figure 143) that attach the EGR pipe to the EGR cooler outlet vent.

4. Loosen the mounting nuts (item 4, Figure 144) that attach the EGR pipe to the EGR valve.

5. Loosen the two mounting bolts (item 5) that retain the EGR valve. See Figure 144. Remove the EGR valve.

6. Remove the EGR valve spacer. See Figure 144.

7. Remove the lead valve. See Figure 144.



1. EGR VALVE
2. EGR PIPE
3. MOUNTING NUTS
4. MOUNTING BOLT
5. EGR MOUNTING BOLT
6. EGR VALVE SPACER
7. LEAD VALVE

Figure 144. EGR valve and lead valve

NOTE: The EGR valve must be replaced as an assembly. Do not attempt to disassemble and repair the EGR valve or replace any of the EGR valve components.

NOTE: The gaskets between the different components of the EGR system are specific to each component and must be replaced along with that component.

Clean

EGR cooler

The EGR cooler must be cleaned periodically. See Every 2000 hour periodic maintenance (PM) procedures in the **Periodic Maintenance** 8000SRM2305 manual. The exhaust gas passage and cooling water transit portion are subject to carbon deposits. These carbon deposits gradually deteriorate the cooling of recirculated gas, resulting in higher gas temperatures and a lowering of effective circulation amount (EGR ratio).

To remove deposited carbon from the gas passage, use compressed air (0.19 MPa (2 kg/cm^2) or lower). Plug both ends of the engine coolant transit portion and dip the gas passage in carbon cleaner, kerosene or other liquid used for removing carbon. Let dry, then clean again with compressed air.

To clean the engine coolant transit portion, soak it in a solution of descaling detergent.

EGR pipe and other connecting elbows

The exhaust gas passage is subject to carbon deposits when used over time. To remove deposited carbon from the gas passage, use compressed air (0.19 MPa (2 kg/cm^2) or lower). If the exhaust gas passage is heavily fouled, dip it in carbon cleaner, kerosene or other liquid used for removing carbon. Let dry, then clean again with compressed air.

NOTE: Follow all guidelines from the EPA or other government agencies regarding the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult local authorities or chemical recycling facility.

EGR lead valve

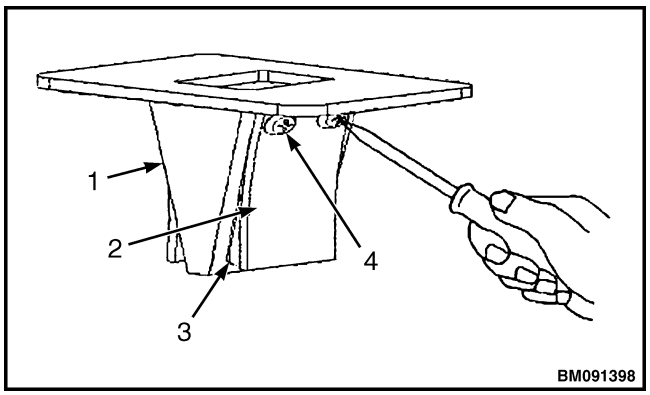
Cleaning the EGR lead valve is not included in the Periodic Maintenance schedule. However, after extended use, an accumulation of carbon can build up in the exhaust gas circulation passage, and cause the EGR rate to drop. At this point, the EGR lead valve must be cleaned.

1. Use a cross-head screwdriver to remove the two machine screws retaining the stopper. See Figure 145.
2. Remove the valve. See Figure 145.

To remove carbon deposited inside the EGR lead valve, disassemble and clean the valve. Use carbon cleaner, kerosene or other liquid used for removing carbon as well as a soft brush to clean the valve. Take care to not damage the parts.

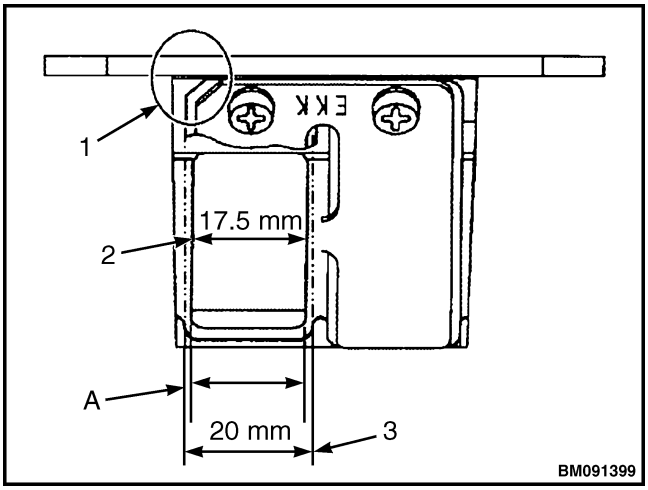
Upon completion of the carbon removal, wipe off water and liquid. Ensure that the case, valve and stopper are free of foreign matter. Reinstall the valve and related parts.

3. Install the valve and stopper in the same orientation as removed, located on the left-hand side of the lead valve. See Figure 146.
4. Install the valve by tightening the machine screw while ensuring it is evenly positioned inside the case window. Torque to 1.35-1.39 N•m (1-1.03 lbf ft).
5. Mark each screw after torquing, to indicate it has already been tightened.



1. CASE
2. STOPPER
3. VALVE
4. MACHINE SCREW

Figure 145. EGR lead valve



A. ALIGN WHEN INSTALLING

1. STOPPER CHAMFER
2. EXHAUST GAS PASSAGE HOLE
3. VALVE PLATE

Figure 146. Install EGR lead valves

Install

EGR valve and lead valve

1. Install the lead valve. See Figure 144.

2. Install the EGR valve spacer. See Figure 144.

3. Install the EGR valve. See Figure 144.

4. Insert the two mounting bolts (item 5) that retain the EGR valve. See Figure 144. Tighten to standard torque.

5. Insert the mounting nuts (item 4, Figure 144) that attach the EGR pipe to the EGR valve. Tighten to standard torque.

6. Insert the mounting nuts (item 2, Figure 143) that attach the EGR pipe to the EGR cooler outlet vent. Tighten to standard torque.

7. Connect the EGR valve connector to the wire harness.

EGR Cooler

1. Install the EGR cooler and EGR cooler outlet vent as one assembly.

2. Insert the bolt that attaches the EGR cooler outlet vent to the exhaust manifold. See Figure 143. Tighten to standard torque.

3. Insert the bolt that attaches the EGR cooler to the exhaust manifold. See Figure 143. Tighten to standard torque.

4. Install the hose clamps (item 3) on the outlet side coolant hose (item 6) of the EGR cooler. See Figure 143.

5. Install the hose clamps (item 3) on the inlet side coolant hose (item 5) of the EGR cooler. See Figure 143.

6. Install the inlet and outlet side coolant hoses. See Figure 143. Tighten the hose clamps.

7. Install the EGR pipe.

8. Insert the mounting nuts (item 4, Figure 144) that attach the EGR pipe to the EGR valve. Tighten to standard torque.

9. Insert the mounting nuts (item 2, Figure 143) that attach the EGR pipe to the EGR cooler outlet vent. Tighten to standard torque.

INTAKE THROTTLE

Precautions for handling the intake throttle

WARNING

Follow the precautions below when handling the intake throttle to prevent injury.

- Do not use the intake throttle if it has been dropped. Even if no exterior damage is visible, there may be internal damage.
- Do not apply excessive impact or load to the throttle.
- Do not touch the stop screw part, as it has already been adjusted.
- Prevent any matter such as oil, dust, and water droplets from entering the air passage.
- Do not remove the sensor cover installation rivet.
- Be aware of static electricity and prevent static electric charge when handling the throttle.
- Do not touch the sensor cover terminal.

- Do not touch the throttle valve when the throttle is energized.
- Do not check operation with the installation surface of the throttle pointing down, as the valve protrudes from the installation surface.
- Prevent matter and water from entering the connector.

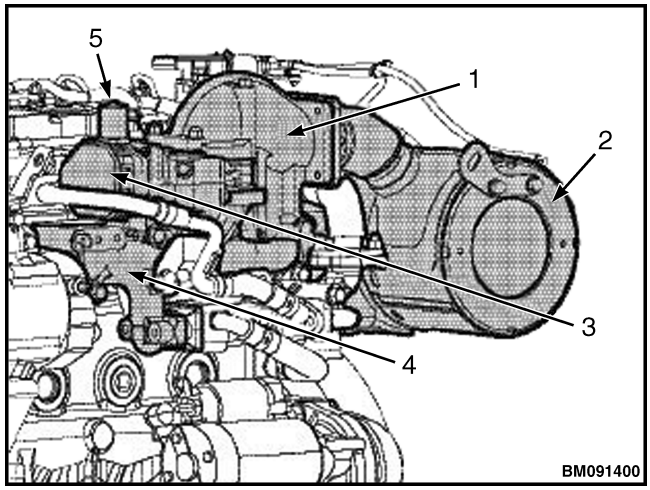
EXHAUST THROTTLE

Check the operation of the exhaust throttle every 3000 hours. If an exhaust pipe is attached above the exhaust throttle, remove before inspecting so exhaust throttle valve is exposed during inspection.

Connect and check the operation of the engine diagnostic tool, SMARTASSIST-DIRECT in the same manner as EGR valve active control. For operation procedures, refer to the SMARTASSIST-DIRECT (SA-D) Operation Manual.

If valve operation is affected by exhaust passage contamination, clean the passage according to the following procedures.

1. Remove the wire harness connector from the electric signal input terminal. See Figure 147.



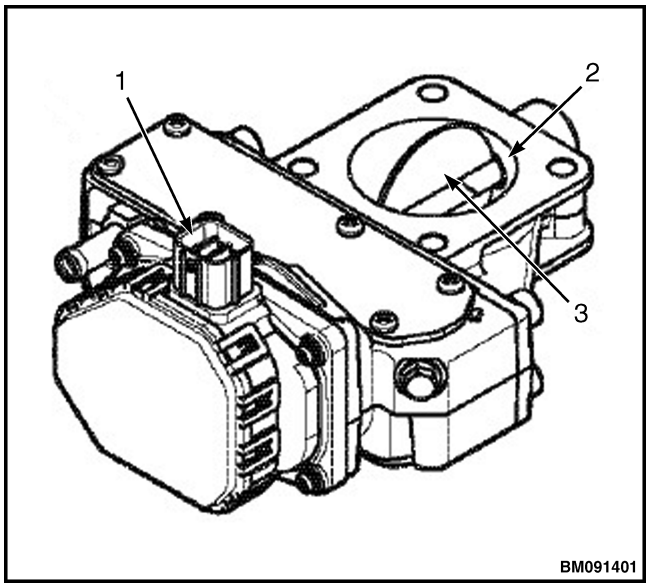
1. EXHAUST PIPE
2. DPF
3. EXHAUST THROTTLE
4. EXHAUST MANIFOLD
5. ELECTRIC SIGNAL INPUT CONNECTOR

Figure 147. Exhaust throttle and attaching parts

2. Remove the exhaust throttle from the exhaust manifold. Take care to not damage the connector, flange surface, and valve when removing. See Figure 147.

3. A cooling hose is attached to the exhaust throttle. If it is necessary to remove the hose for cleaning, place a rag beneath the hose connection to catch any coolant spills.

4. Remove any deposits from the exhaust throttle and valve using a rag or plastic scraper. Do not use compressed air at a short distance or immerse valves in cleaning fluid.



1. ELECTRIC SIGNAL INPUT TERMINAL
2. EXHAUST PASSAGE
3. EXHAUST THROTTLE VALVE

Figure 148. Exhaust throttle

5. Do not disassemble the exhaust throttle body.

6. When installing the exhaust throttle, replace inlet and outlet side gaskets with new. See Parts Manual for correct part number.

DIESEL ENGINE CHECKS, ADJUSTMENTS, AND CALIBRATIONS 202001-020

VALVE CLEARANCE ADJUSTMENTS

NOTE: Make measurements and adjustments while the engine is cold.

NOTE: The cylinder to be adjusted first does not have to be the number one cylinder. Select and adjust the cylinder where the piston is the nearest to top dead center (TDC) after rotating and make the adjustment for the other cylinders in the order of the ignition by turning the crankshaft 180 degrees each time.

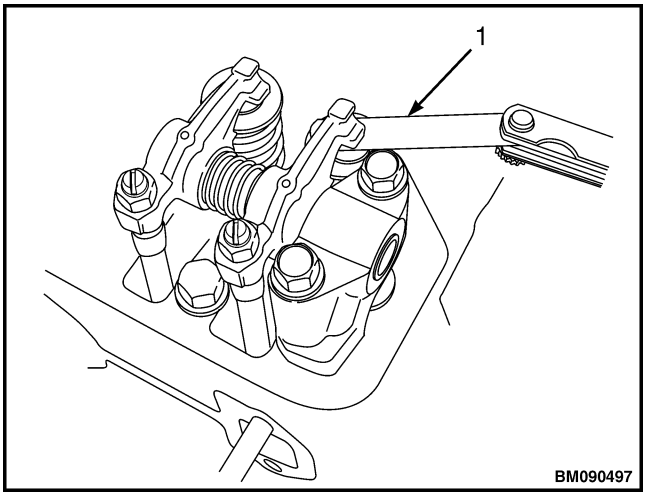
1. Remove cylinder head cover. See Diesel cylinder head repair.

NOTE: The number one piston position is on the flywheel end of the engine, opposite side of the radiator, and the ignition order is 1 - 3 - 4 - 2 at 180 degree intervals.

NOTE: Since intake and exhaust valve rocker arms are operated the same and there is a clearance between rocker arm and valve generally at top dead center, the position can be checked by means of the play when the arm head is held with a hand. Also, see that the crankshaft pulley top mark is positioned at zero on the timing scale. If there is no valve clearance, inspection in the disassembled state is necessary since the valve seat may be worn abnormally.

2. Rotate crankshaft clockwise, as seen from the coolant pump end, to bring the number one piston to top dead center (TDC) on the compression stroke while watching the rocker arm motion, timing grid on the flywheel. (Position where both the intake and exhaust valves are closed.)

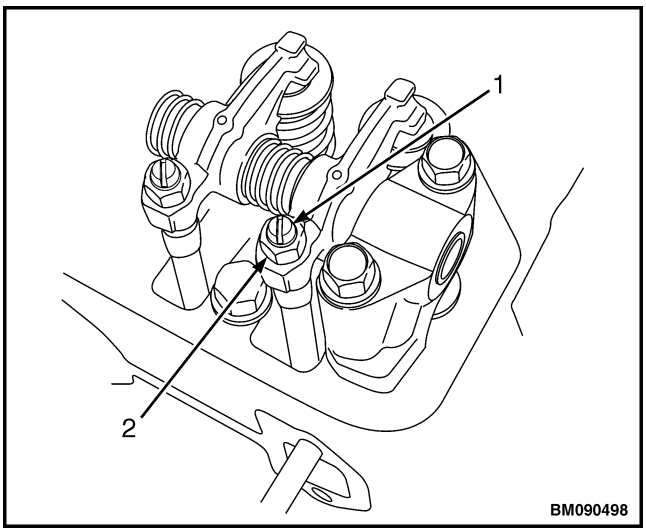
3. Insert a feeler gauge between the rocker arm and valve cap. See Figure 149. Record the measured valve clearance. The valve clearance should be between
0.15 to 0.25 mm (0.006 to 0.010 in.) when cold.



1. FEELER GAUGE

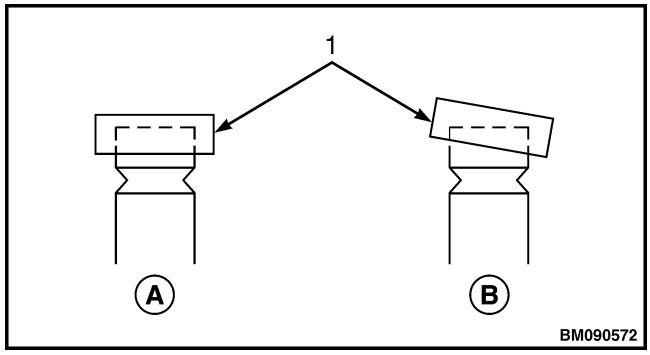
Figure 149. Valve Clearance Measurement

4. If adjustment is needed, loosen the valve adjusting screw lock nut and valve adjusting screw on the rocker arm (see Figure 150) and check the valve for any slope of valve cap, entrance of dirt, or wear. See Figure 151.



1. VALVE ADJUSTING SCREW
2. VALVE ADJUSTING SCREW LOCK NUT

Figure 150. Valve Clearance Adjustment



A. NORMAL
B. ABNORMAL

1. VALVE CAP

Figure 151. Valve Cap Check

NOTE: Clearance will decrease slightly when the lock nut is tightened. Make the clearance adjustment slightly on the loose side before tightening the lock nut.

5. Insert a 0.2 mm (0.008 in.) feeler gauge between the rocker arm and valve cap and adjust the clearance so there is a slight drag on the feeler gauge when sliding it between the rocker arm and valve cap. Tighten the valve adjusting screw lock nut and recheck the clearance. The valve clearance should be between 0.15 to 0.25 mm (0.006 to 0.010 in.).

6. Apply clean engine oil to the contact surface between the adjusting screw and push rod.

7. Turn the crankshaft 180 degrees and make the measurement and adjustment for the number three cylinder. Then turn the crankshaft 180 degrees and make the measurement and adjustment for the number four cylinder. Then turn the crankshaft 180 degrees and make the measurement and adjustment for the number 2 cylinder.

8. Install the valve cover. See Diesel cylinder head repair.

ALTERNATOR CHECKS

Test stater coil continuity

1. Disconnect the alternator output wire connector.

2. Connect one meter lead to each of the stator wire terminals and read the meter.

Results: The meter reading should indicate continuity. If continuity is not indicated, the stator must be replaced.

Test stater coil short to ground

1. Disconnect the alternator output wire connector.

2. Test continuity between each stator wire terminal and engine ground.

Results: The meter reading should be infinity. If continuity is indicated, the stator must be replaced.

Test alternator regulated output

1. Test and record the battery voltage with the engine not running.

2. Start the engine and operate it at normal operating rpm.

3. Again, check the battery voltage with the engine running.

Results: The meter reading with the engine running must be higher than with the engine not running. If this is not the outcome:

- Test the stator for continuity and shorts to the ground.
- Check the charging system wiring.
- If no problems are found in previous checks, replace the IC regulator.

EXHAUST AND AFTERTREATMENT

EGR valve (check, clean, and test)

DANGER

FUME/BURN HAZARD! Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers. Failure to comply may result in death or serious injury.

WARNING

FLYING OBJECT HAZARD! Always wear eye protection when servicing the engine and when using compressed air or pressurized water. Dust, flying debris, compressed air, pressurized water, or steam may cause injury to the eyes. Failure to comply may result in moderate or minor injury.

Checking and cleaning the EGR valve is not included in the Periodic Maintenance schedule. However, after extended use, an accumulation of carbon can build up in the exhaust gas circulation passage, and cause the EGR rate to drop. At this point, the EGR valve must be cleaned.

Because the EGR valve is in a closed state when the engine key switch is off, in order to check, clean, and test the valve, connect the interface box to forcibly send signal from the ECU to fully open the EGR valve by SMARTASSIST-DIRECT (SA-D) (see Figure 152). When removing the EGR valve from the engine, leave the harness in a connected state. If it is difficult to remove with the harness connected, disconnect the harness once, then reconnect it after removing the EGR valve.

EGR active control

First connect the interface box to the engine harness via the connector cable. Turn on SMARTASSIST-DIRECT (SA-D) (see Figure 152). Force open the EGR valve and clean the valve. Before activating the EGR, check for errors that affect the closing process of the EGR. Select **Defect Display**, then **Current Defect**.

If an error is displayed

a. Select **Diagnostic Codes**.
b. Select **Defect History**.
c. Select **All Clear** button. Error information is now cleared from the Defect History.

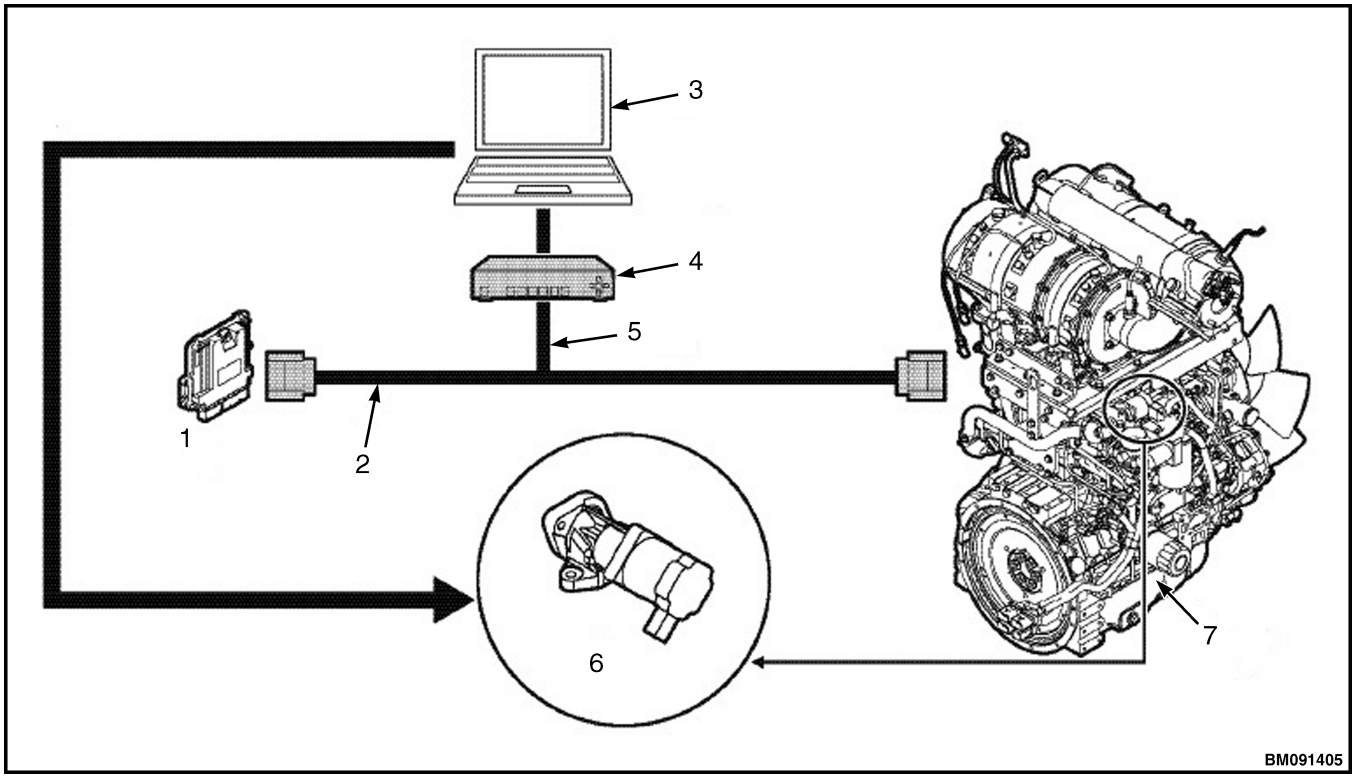
If no error is displayed

a. Select Diagnosis Tests.
b. Select Active Control.
c. From **EGR Valve Opening Control**, press the **Execute** button.
d. Enter user ID and password. Wait for *EGR Valve Opening Control* to display.
e. In the *Desired* field, enter "106". Press **Set**.
f. Active control starts if no error is found.

Check that the desired value on the screen indicates the set target value. EGR valve opening control lamp comes on.

NOTE: Do not end the SA-D while cleaning the EGR.

For details on how to operate the EGR Active Control, refer to the SMARTASSIST-DIRECT (SA-D) Operation Manual.



1. ECU
2. ENGINE HARNESS
3. LAPTOP WITH SMARTASSIST-DIRECT (SA-D)
4. INTERFACE BOX
5. CONNECTOR CABLE
6. EGR VALVE
7. ENGINE

Figure 152. Connecting software

Precautions for cleaning

- Do not disassemble the EGR valve.
- Do not use a hard brush made of metal.
- Clean the entire circumference of the valve and the valve seat, and blow with compressed air.
- Do not put your fingers into the valve portion.

Cleaning the EGR valve

- Use compressed air (0.19 MPa (2 kg/cm^2) or lower) to remove deposited carbon.
- If the valve is heavily fouled, use carbon cleaner, kerosene or other liquid used for removing carbon as well as a soft brush to clean the valve. Take care to not damage the parts.
- When cleaning the valve, take extreme care to prevent water, solvent, cleaner and other liquid from entering into the motor and coupler terminals, otherwise, failure may result.
- Remove remaining carbon deposits by blowing with compressed air.
- If the carbon deposits can not be removed by a brush, replace the EGR valve assembly.

Exit the EGR active control

You can exit the EGR Active Control from the SMARTASSIST-DIRECT screen.

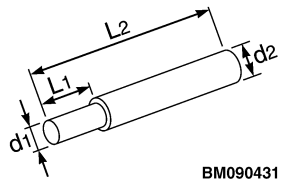
a. From *EGR Valve Opening Control*, select **Stop**.
b. The EGR valve opening control lamp goes off and *EGR Active Control* is exited.

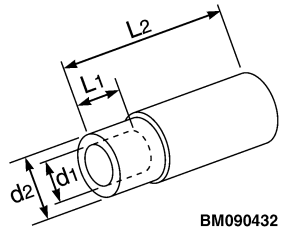
Intake throttle

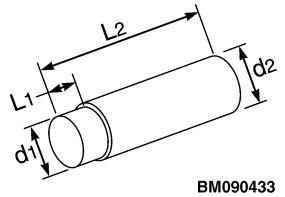
Check the performance of the intake throttle every 3000 hours of operation. Connect SMARTASSIST-DIRECT for EGR valve cleaning. For details, refer to the SMARTASSIST-DIRECT (SA-D) Operation Manual.

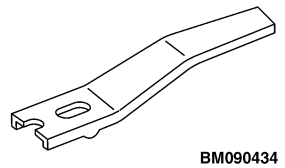
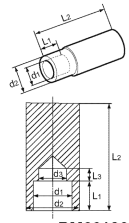
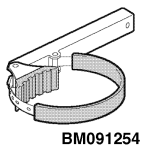
SPECIAL TOOLS FOR DIESEL ENGINES
202001-021

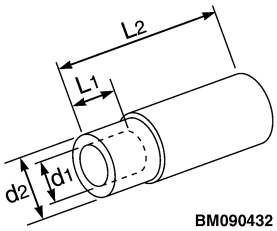
Table 34. Special service tools

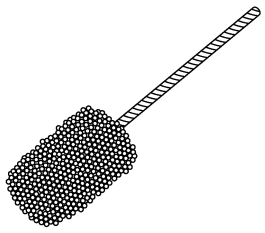
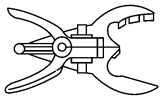
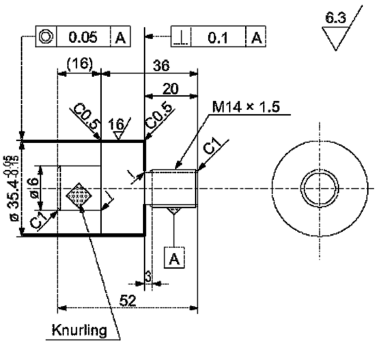
<table>
<tr><th>No.</th><th>Tool Name</th><th>Applicable model and tool size</th><th>Illustration</th></tr>
<tr><td>1</td><td>Valve guide tool (for extracting valve guide)</td><td><table><tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>20 mm (0.787 in.)</td><td>75 mm (2.953 in.)</td><td>7.5 mm (0.295 in.)</td><td>11 mm (0.433 in.)</td></tr></table>Locally manufactured</td><td> 

BM090431</td></tr>
<tr><td>2</td><td>Valve guide tool (for inserting valve guide)</td><td><table><tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>15 mm (0.591 in.)</td><td>65 mm (2.559 in.)</td><td>14 mm (0.551 in.)</td><td>20 mm (0.787 in.)</td></tr></table>Locally manufactured</td><td> 

BM090432</td></tr>
<tr><td>3</td><td>Connecting rod bushing replacer (for removal/ installation of connecting rod bushing)</td><td><table><tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>20 mm (0.787 in.)</td><td>100 mm (3.937 in.)</td><td>26 mm (1.024 in.)</td><td>29 mm (1.142 in.)</td></tr></table>Locally manufactured</td><td> 

BM090433</td></tr>
<tr><td>4</td><td>Valve spring compressor (for removal or installation of valve spring)</td><td>Hyster Part No. 1607211</td><td> 
BM090434</td></tr>
<tr><td>5</td><td>Stem seal inserter (for inserting stem seal)</td><td><table><tr><th>d1</th><th>d2</th><th>d3</th><th>L1</th><th>L2</th><th>L3</th></tr><tr><td>16.2 mm (0.638 in.)</td><td>22 mm (0.866 in.)</td><td>13.5 mm (0.531 in.)</td><td>18.8 mm (0.740 in.)</td><td>65 mm (2.560 in.)</td><td>4 mm (0.157 in.)</td></tr></table>Locally manufactured</td><td> 
BM091261</td></tr>
<tr><td>6</td><td>Filter wrench (for removal or installation of engine oil filter)</td><td>Available locally Hyster part number</td><td> 
BM091254</td></tr>
</table>

<table>
<tr><th>No.</th><th>Tool Name</th><th>Applicable model and tool size</th><th>Illustration</th></tr>
<tr><td>7</td><td>Camshaft bushing tool (for extracting camshaft bushing)</td><td>
<table>
<tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr>
<tr><td>18 mm (0.709 in.)</td><td>70 mm (2.756 in.)</td><td>50 mm (1.969 in.)</td><td>53 mm (2.087 in.)</td></tr>
</table>
Locally manufactured</td><td> 

BM090432</td></tr>
<tr><td>7</td><td>Flex-hone (for preparation of cylinder walls)</td><td>
<table>
<tr><th>Model</th><th>Part number</th><th>Cylinder bore</th></tr>
<tr><td>4TNE92</td><td>Hyster Part No. 1607212</td><td>83 to 95 mm (3.268-3.740 in.)</td></tr>
</table>
</td><td>  </td></tr>
<tr><td>9</td><td>Piston ring compressor (for inserting piston)</td><td>Hyster Part No. 1607213
The piston insertion tool is applicable for
60 to 125 mm (2.362 to 4.921 in.)
Diameter pistons</td><td> 
BM091255</td></tr>
<tr><td>10</td><td>Piston ring replacer (for removal/ installation of piston ring)</td><td>Available locally</td><td> 
BM090440</td></tr>
<tr><td>11</td><td>Pulley installing tool</td><td> 

BM091256</td></tr>
<tr><td></td><td>Compression gauge adapter (129A00-92950)</td><td>
<table>
<tr><th>L1</th><th>L2</th><th>L3</th><th>L4</th></tr>
<tr><td>141 mm (5.551 in.)</td><td>17 mm (0.669 in.)</td><td>68 mm (2.677 in.)</td><td>18 mm (0.709 in.)</td></tr>
<tr><th>L5</th><th>L6</th><th>L7</th><th>d1</th></tr>
<tr><td>25 mm (0.984 in.)</td><td>13 mm (0.511 in.)</td><td>82 mm (3.228 in.)</td><td>13 mm (0.5118 in.)</td></tr>
</table>
</td><td>See Figure 153</td></tr>
</table>

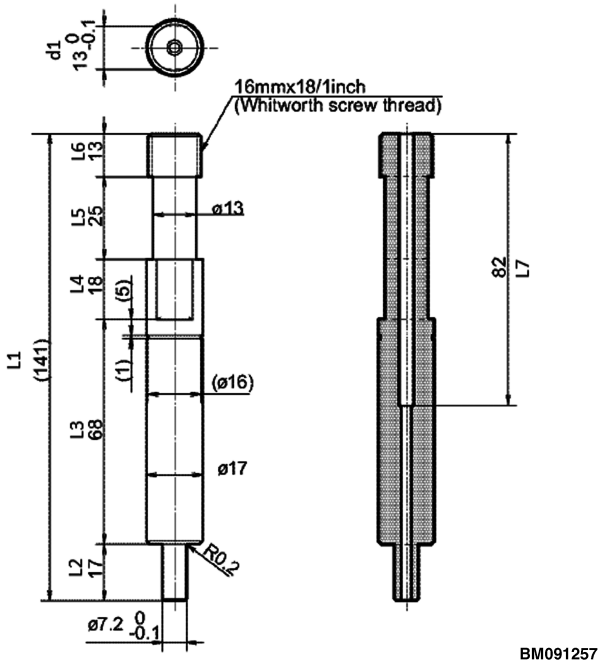


Figure 153. Compression gauge adapter

Table 35. Measuring instruments

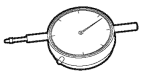
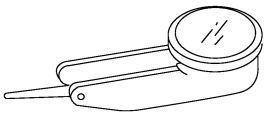
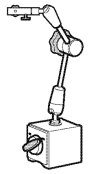
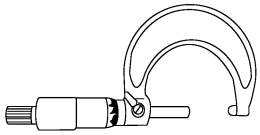
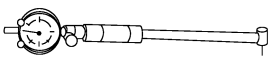
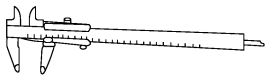
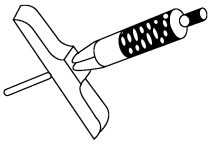
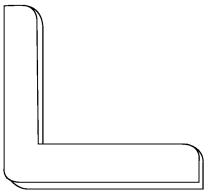
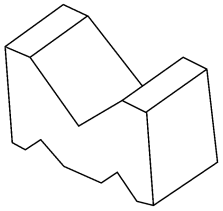
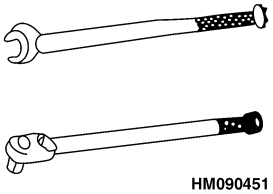
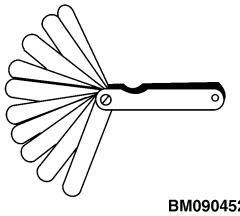
No.	Instrument name	Application	Illustration
1	Dial indicator	Measures shaft bend and end play	 BM091258
2	Test indicator	Measures narrow or deep portions that cannot be measured by dial gauge	 BM090443
3	Magnetic stand	Holds dial gauge when measuring	 BM091259
4	Micrometer	Measures the outside diameters of crankshaft, pistons, piston pins, etc.	 BM090445

Table 35. Measuring instruments (Continued)

No.	Instrument name	Application	Illustration
5	Cylinder bore gauge	Measures the inside diameters of cylinder liners, rod metal, etc.	 BM090446
6	Calipers	Measures outside diameters, depth, thickness, and width	 BM090447
7	Depth micrometer	Measures valve recession	 BM090448
8	Square	Measures valve spring inclination and straightness of parts	 BM090449
9	V-block	Measures shaft bend	 BM090450
10	Torque wrench	Tightens nuts and bolts to the specified torque	 HM090451
11	Thickness gauge ("feeler" gauge)	Measures gaps between ring and ring groove and shaft joints during assembly	 BM090452

Diesel engine repair (Yanmar 3.0 and 3.3L)

DIESEL ENGINE SPECIFICATIONS 202001-355

GENERAL ENGINE DATA

Table 36. Yanmar 3.0L diesel engines

Specification type	4TNE94
Number of cylinders	4
Aspiration/combustion type	NA/IDI
Minimum idle speed	825-875 rpm
Maximum idle speed	2425-2475 rpm
Bore x stroke	94 x 110 mm (3.7 x 4.3 in.)
Displacement	3053 cm^3
Compression ratio	22.4:1
Starting aid	Glow plug
EGR	None
Aftertreatment	None
Peak torque	161.5 N•m (119.12 lbf ft)
Peak torque speed	1500 rpm
Rated output	35.3 kW (47.3 hp)
Rated speed	2200 rpm

Table 37. Yanmar 3.3L diesel engines

Specification type	4TNE98
Number of cylinders	4
Aspiration/combustion type	NA/IDI
Minimum idle speed	825-875 rpm
Maximum idle speed	2600-2650 rpm
Bore x stroke	98 x 110 mm (3.9 x 4.3 in.)
Displacement	3319 cm^3
Compression ratio	21.4:1
Starting aid	Glow plug
EGR	None
Aftertreatment	None
Peak torque	190.4 N•m (140.4 lbf ft)
Peak torque speed	1600 rpm
Rated output	43.7 kW (58.6 hp)
Rated speed	2300 rpm

COOLING SYSTEM

Table 38. Yanmar 3.0 and 3.3L diesel engines

Specification type	4TNE94/4TNE98
Coolant type	LLC
Coolant temp (max)	105°C (221°F)
Coolant volume (engine only)	4.2 liter (4.4 qt)
Thermostat start to full open temp	71-85°C (160-185°F)
Radiator cap pressure	88.3 kPa (12.8 psi)

ENGINE PERFORMANCE

Table 39. Yanmar 3.0L diesel engine: 4TNE94

Speed (RPM)	Torque	Power
850	151.6 N•m (111.8 lbf ft)	13.5 kW (18.1 hp)
1000	153.5 N•m (113.2 lbf ft)	16.1 kW (21.6 hp)
1200	156.2 N•m (115.2 lbf ft)	19.6 kW (26.3 hp)
1300	157.2 N•m (115.9 lbf ft)	21.4 kW (28.7 hp)
1400	160.7 N•m (118.5 lbf ft)	23.6 kW (31.6 hp)
1500	165.1 N•m (121.8 lbf ft)	25.9 kW (34.7 hp)
1600	165.3 N•m (121.9 lbf ft)	27.7 kW (37.1 hp)
1700	163.0 N•m (120.2 lbf ft)	29.0 kW (38.9 hp)
1800	161.4 N•m (119.0 lbf ft)	30.4 kW (40.8 hp)
1900	158.4 N•m (116.8 lbf ft)	31.5 kW (42.2 hp)
2000	158.0 N•m (116.5 lbf ft)	33.1 kW (44.4 hp)
2100	155.9 N•m (115.0 lbf ft)	34.3 kW (46.0 hp)
2150	153.3 N•m (113.7 lbf ft)	34.5 kW (46.3 hp)
2175	152.7 N•m (112.6 lbf ft)	34.8 kW (76.7 hp)
2200	153.2 N•m (113.0 lbf ft)	35.3 kW (47.3 hp)
2225	152.4 N•m (112.4 lbf ft)	35.5 kW (47.6 hp)
2250	151.5 N•m (111.7 lbf ft)	35.7 kW (47.9 hp)
2300	149.0 N•m (109.9 lbf ft)	35.9 kW (48.1 hp)
2450	0 N•m (0 lbf ft)	0 kW (0 hp)

Table 40. Yanmar 3.3L diesel engine: 4TNE98

Speed (RPM)	Torque	Power
850	172.4 N•m (127.2 lbf ft)	15.3 kW (20.5 hp)
1000	174.1 N•m (128.4 lbf ft)	18.2 kW (24.4 hp)
1200	176.5 N•m (130.2 lbf ft)	22.2 kW (29.8 hp)

Table 40. Yanmar 3.3L diesel engine: 4TNE98 (Continued)

Speed (RPM)	Torque	Power
1400	186.0 N•m (137.2 lbf ft)	27.3 kW (36.6 hp)
1500	188.7 N•m (139.2 lbf ft)	29.6 kW (39.7 hp)
1600	190.4 N•m (140.4 lbf ft)	31.9 kW (42.8 hp)
1700	190.3 N•m (140.4 lbf ft)	33.9 kW (45.5 hp)
1800	189.7 N•m (139.9 lbf ft)	35.7 kW (47.9 hp)
2000	185.9 N•m (137.1 lbf ft)	38.9 kW (52.2 hp)
2100	183.4 N•m (135.3 lbf ft)	40.3 kW (54.0 hp)
2200	181.9 N•m (134.2 lbf ft)	41.9 kW (56.2 hp)
2250	181.6 N•m (133.9 lbf ft)	42.8 kW (57.4 hp)
2275	181.5 N•m (133.9 lbf ft)	43.3 kW (58.1 hp)
2300	181.6 N•m (133.9 lbf ft)	43.7 kW (58.6 hp)
2325	180.8 N•m (133.4 lbf ft)	44.0 kW (59.0 hp)
2350	179.4 N•m (132.2 lbf ft)	44.1 kW (59.1 hp)
2400	175.0 N•m (129.1 lbf ft)	44.0 kW (59.0 hp)
2500	149.9 N•m (110.6 lbf ft)	39.2 kW (52.6 hp)
2600	50.1 N•m (37.0 lbf ft)	13.6 kW (18.2 hp)
2625	0 N•m (0 lbf ft)	0 kW (0 hp)

Cylinder head specifications

Table 41. Adjustment specifications

Model	Valve clearance
4TNE94, 4TNE98	0.15-0.25 mm (0.006-0.010 in.)

Table 42. Cylinder head

Inspection item		Standard	Limit	Reference page
Combustion surface distortion (flatness)		0.05 mm (0.0020 in.)	0.15 mm (0.0059 in.)	See Valve recession section, in Diesel cylinder head repair
Valve recession	Intake	0.5-0.7 mm (0.020-0.028 in.)	1.0 mm (0.039 in.)	
	Exhaust	0.6-0.8 mm (0.024-0.032 in.)	1.1 mm (0.043 in.)	
Valve seat angle	Intake	120°	-	See Valve face and valve seat section, in Diesel cylinder head repair
	Exhaust	90°	-	

Table 43. Intake/Exhaust valve guard

Inspection item		Standard	Limit	Reference page
Intake valve	Guide inside diameter	8.015-8.030 mm (0.3156-0.3161 in.)	8.10 mm (0.3189 in.)	See Inspection of valve guides section, in Diesel cylinder head repair
	Valve stem outside diameter	7.965-7.980 mm (0.3136-0.3142 in.)	7.90 mm (0.3110 in.)	
	Oil clearance	0.035-0.065 mm (0.0014-0.0026 in.)	0.18 mm (0.0071 in.)	
Exhaust	Guide inside diameter	8.015-8.030 mm (0.3156-0.3161 in.)	8.10 mm (0.3189 in.)	
	Valve stem outside diameter	7.965-7.970 mm (0.3136-0.3138 in.)	7.90 mm (0.3110 in.)	
	Oil clearance	0.045-0.075 mm (0.0018-0.0030 in.)	0.18 mm (0.0071 in.)	
Valve guide projection from cylinder head		14.7-15.00 mm (0.58-0.60 in.)		See Reassembly of intake and exhaust valves, in Diesel cylinder head repair
Valve guide projection from cylinder head		16.7-17.0 mm (0.66-0.70 in.)		

Table 44. Push rod

Model	Inspection item	Standard	Limit	Reference page
4TNE94, 4TNE98	Push rod bend straightness	-	0.03 mm (0.0012 in.)	See Push rod bend section, in Diesel cylinder head repair

Table 45. Rocker arm and shaft

Model	Inspection item	Standard	Limit	Reference page
4TNE94, 4TNE98	Arm shaft inside diameter	18.50-18.52 mm (0.7283-0.7291 in.)	18.57 mm (0.7311 in.)	See Inspection of Rocker Arm Assembly section, in Diesel cylinder head repair
	Shaft outside diameter	18.47-18.49 mm (0.7272-0.7280 in.)	18.42 mm (0.7252 in.)	
	Oil clearance	0.01-0.05 mm (0.0004-0.0020 in.)	0.15 mm (0.0059 in.)	

Table 46. Valve spring

Model	Inspection item	Standard	Limit	Reference page
4TNE94, 4TNE98	Free length	47.5 mm (1.87 in.)	-	See Inspection of Valve Springs section, in Diesel cylinder head repair
	Squareness	-	1.2 mm (0.05 in.)	

Camshaft and timing gear train specifications

Table 47. Camshaft

Inspection item	Standard	Limit	Reference page
Side gap	0.05-0.20 mm (0.0020-0.0079 in.)	0.030 mm (0.0118 in.)	See Removal of camshaft section, in Diesel cylinder head repair
Bend (1/2 the dial gauge reading)	0-0.2 mm (0-0.0008 in.)	0.05 mm (0.0020 in.)	See Inspection of camshaft section, in Diesel cylinder head repair

Table 47. Camshaft (Continued)

Inspection item			Standard	Limit	Reference page
Cam height		4TNE94, 4TNE98	42.435-42.565 mm (1.6707-1.6758 in.)	42.185 mm (1.6608 in.)	
Camshaft oil clearance	Gear end	Bushing inside diameter	49.990-50.055 mm (1.9681-1.9707 in.)	50.130 mm (1.9736 in.)	See Inspection of camshaft section, in Diesel cylinder head repair
		Camshaft outside diameter	44.925-45.950 mm (1.7687-1.7697 in.)	49.890 mm (1.9642 in.)	
		Oil clearance	0.040-0.130 mm (0.0016-0.0051 in.)	0.240 mm (0.0094 in.)	
	Intermediate	Bushing inside diameter	50.000-50.025 mm (1.9685-1.9695 in.)	50.100 mm (1.9724 in.)	
		Camshaft outside diameter	44.910-44.935 mm (1.9650-1.9659 in.)	49.875 mm (1.9636 in.)	
		Oil clearance	0.065-0.115 mm (0.0026-0.0045 in.)	0.225 mm (0.0089 in.)	
	Flywheel end	Bushing inside diameter	50.000-50.025 mm (1.9685-1.9695 in.)	50.100 mm (1.9724 in.)	
		Camshaft outside diameter	49.925-49.950 mm (1.9656-1.9665 in.)	49.890 mm (1.9642 in.)	
		Oil clearance	0.050-0.100 mm (0.0020-0.0039 in.)	0.210 mm (0.0083 in.)	

Table 48. Idler gear shaft and bushing

Model	Inspection item	Standard	Limit	Reference page
4TNE94, 4TNE98	Shaft outside diameter	45.950-49.975 mm (1.8091-1.9675 in.)	45.900 mm (1.8071 in.)	-
	Bushing inside diameter	46.000-46.025 mm (1.8110-1.8120 in.)	46.075 mm (1.8140 in.)	
	Oil clearance	0.025-0.075 mm (0.0010-0.0030 in.)	0.175 mm (0.0068 in.)	

Table 49. Timing gear backlash

Model	Inspection item	Standard	Limit	Reference page
4TNE94, 4TNE98	Crank gear, cam gear, idler gear fuel injection pump gear and PTO gear	0.08-0.14 mm (0.0031-0.0055 in.)	0.16 mm (0.0063 in.)	See Checking timing gear backlash section, in Diesel cylinder head repair
	Lubricating oil pump gear	0.09-0.15 mm (0.0035-0.0059 in.)	0.17 mm (0.0067 in.)	

Crankshaft and piston specifications

NOTE: Check appropriate parts catalog for various sizes of replacement main bearing inserts.

Table 50. Crankshaft

Inspection item			Standard	Limit	Reference page
Bend (1/2 the dial gauge reading)			-	0.02 mm (0.0008 in.)	See Inspection of crankshaft section, in Diesel cylinder head repair
Model: 4TNE94, 4TNE98	Connecting rod journals	Pin outside diameter	47.952-47.962 mm (1.8879-1.8883 in.)	57.902 mm (2.2796 in.)	
		Bearing halves inside diameter	58.000-58.026 mm (2.2835-2.2845 in.)	-	
		Bearing halves thickness	1.492-1.500 mm (0.0587-0.0591 in.)	-	
		Oil clearance	0.038-0.074 mm (0.0015-0.0029 in.)	0.150 mm (0.0059 in.)	
	Crank journal selective pairing	Journal outside diameter	64.952-64.962 mm (2.5572-2.5576 in.)	64.902 mm (2.5552 in.)	See Inspection of crankshaft section, in Diesel cylinder head repair
		Bearing halves inside diameter	65.000-65.020 mm (2.5591-2.5598 in.)	-	
		Bearing halves insert thickness	1.995-2.010 mm (0.0785-0.0791 in.)	-	
		Oil clearance	0.038-0.068 mm (0.0015-0.0027 in.)	0.150 mm (0.0059 in.)	

Table 51. Thrust bearing

Inspection item	Standard	Limit	Reference page
Crankshaft side gap	0.11-0.21 mm (0.0043-0.0083 in.)	0.28 mm (0.0110 in.)	See Removal of crankshaft section, in Diesel cylinder head repair

Table 52. Piston

Inspection item		Standard	Limit	Reference page
Piston outside diameter (Measure at 90° to the piston pin)	4TNE94	93.945-93.955 mm (3.6986-3.6990 in.)	93.900 mm (3.6969 in.)	See Inspection of pistons, piston rings and wrist pin section, in Diesel cylinder head repair
	4TNE98	97.940-97.950 mm (3.8559-3.8563 in.)	97.900 mm (3.8543 in.)	
Piston diameter measure location (Upward from the bottom of the piston)		22 mm (0.8661 in.)	-	
Piston pin	Hole inside diameter	30.000-30.009 mm (1.1811-1.1815 in.)	30.039 mm (1.1826 in.)	See Inspection of pistons, piston rings and wrist pin section, in Diesel cylinder head repair
	Pin outside diameter	29.985-30.000 mm (1.1807-1.1811 in.)	29.959 mm (1.1795 in.)	
	Oil clearance	0.000-0.020 mm (0.000-0.0008 in.)	0.080 mm (0.0032 in.)	

Table 53. Piston ring

Model	Inspection item		Standard	Limit	Reference page
4TNE94, 4TNE98	Top ring	Ring groove width	2.040-2.060 mm (0.0803-0.0811 in.)	-	See Inspection of pistons, piston rings and wrist pin section, in Diesel cylinder head repair
		Ring width	1.940-1.960 mm (0.0764-0.0772 in.)	1.920 mm (0.0756 in.)	
		Side clearance	0.080-0.120 mm (0.0032-0.0047 in.)	-	
		End clearance	0.250-0.450 mm (0.0098-0.0177 in.)	0.540 mm (0.0213 in.)	
	Second ring	Ring groove width	2.080-2.095 mm (0.0819-0.0825 in.)	2.195 mm (0.0864 in.)	
		Ring width	1.970-1.990 mm (0.0776-0.0783 in.)	1.950 mm (0.0768 in.)	
		Side clearance	0.090-0.125 mm (0.0035-0.0049 in.)	0.245 mm (0.0096 in.)	
		End clearance	0.450-0.650 mm (0.0177-0.0256 in.)	0.730 mm (0.0287 in.)	
4TNE94, 4TNE98	Oil ring	Ring groove width	3.015-3.030 mm (0.1187-0.1193 in.)	3.130 mm (0.1232 in.)	See Inspection of pistons, piston rings and wrist pin section, in Diesel cylinder head repair
		Ring width	2.970-2.990 mm (0.1169-0.1177 in.)	2.950 mm (0.1161 in.)	
		Side clearance	0.025-0.060 mm (0.0010-0.0024 in.)	0.180 mm (0.0071 in.)	

Table 53. Piston ring (Continued)

Model	Inspection item		Standard	Limit	Reference page
		End gap	0.250-0.450 mm (0.0100-0.0177 in.)	0.550 mm (0.0217 in.)	

Table 54. Connecting rod

Model	Inspection item	Standard	Limit	Reference page
4TNE94, 4TNE98	**Connecting rod small end**			
	Wrist pin bushing inside diameter	30.025-30.038 mm (1.1821-1.1826 in.)	30.068 mm (1.1838 in.)	See Inspection of connecting rod section, in Diesel cylinder head repair
	Wrist pin outside diameter	29.987-30.000 mm (1.1806-1.1811 in.)	29.959 mm (1.1795 in.)	
	Oil clearance	0.025-0.051 mm (0.0010-0.0020 in.)	0.025-0.051 mm (0.0010-0.0020 in.)	
	Connecting rod big end			
	Thrust clearance	0.13-0.23 mm (0.0051-0.0091 in.)	-	

Table 55. Tappet

Model	Inspection item	Standard	Limit	Reference page
4TNE94, 4TNE98	Tappet bore (block) inside diameter	12.000-12.018 mm (0.4724-0.4732 in.)	12.038 mm (0.4739 in.)	See Inspection of tappets section, in Diesel cylinder head repair
	Tappet stem outside diameter	11.975-11.990 mm (0.4715-0.4720 in.)	11.955 mm (0.4707 in.)	
	Oil clearance	0.010-0.043 mm (0.0004-0.0017 in.)	0.083 mm (0.0033 in.)	

Special torque chart

Model	Component	Thread diameter and pitch	Torque	Lubricating oil application (Thread portion and seat surface)
4TNE94, 4TNE98	Cylinder head bolt	M11 x 1.25 mm	103.1-112.9 N·m (76.0-83.3 lbf ft)	Applied
	Connecting rod bolt	M10 x 1.0 mm	53.9-58.8 N·m (39.8-43.4 lbf ft)	Applied
	Flywheel bolt	M14 x 1.5 mm	186.2-205.8 N·m (137.3-151.8 lbf ft)	Applied
	Main bearing cap bolt	M11 x 1.25 mm	108.1-117.9 N·m (79.7-87.0 lbf ft)	Applied
	Crankshaft pulley bolt	M14 x 1.5 mm	107.9-127.5 N·m (79.6-87.0 lbf ft)	Applied

DIESEL CYLINDER HEAD REPAIR 202001-356

DISASSEMBLE CYLINDER HEAD

NOTE: Locate and identify all components prior to disassembly, to ensure all components are returned to the same position during reassembly.

Prior to disassembly, prepare a clean, flat surface on a workbench large enough to accommodate the cylinder head assembly. Discard all gaskets, O-rings and seals. New gaskets, O-rings and seals are required when reassembling the cylinder head.

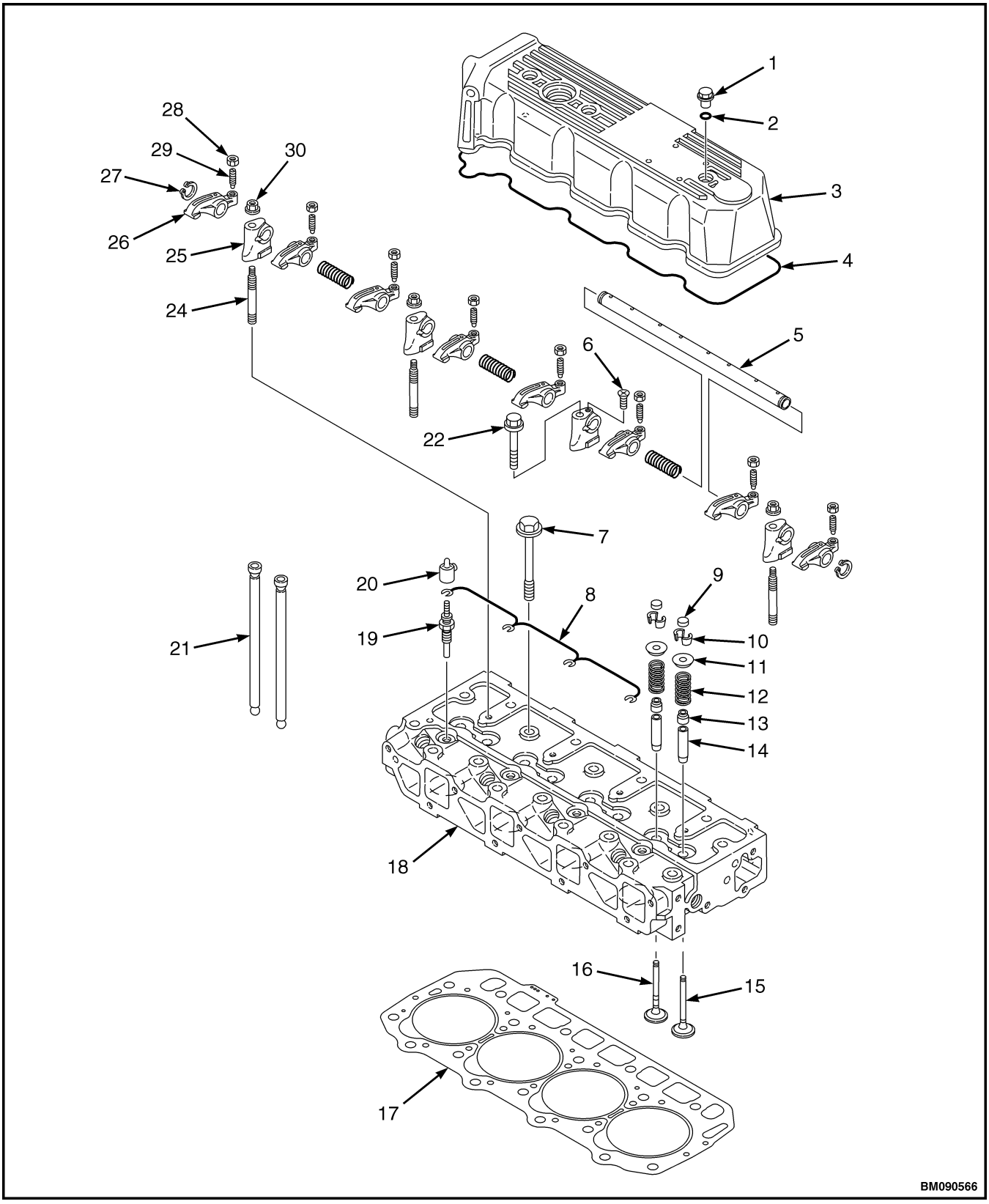


Figure 154. Cylinder Head

Legend for Figure 154.

1. VALVE COVER NUT
2. VALVE COVER NUT O-RING
3. VALVE COVER
4. VALVE COVER GASKET
5. ROCKER ARM SHAFT
6. ROCKER ARM SHAFT RETAINING SCREW
7. CYLINDER HEAD BOLT
8. GLOW PLUG HARNESS
9. VALVE CAP
10. VALVE KEEPERS
11. SPRING RETAINER
12. VALVE SPRING
13. VALVE STEM SEAL
14. VALVE GUIDE
15. INTAKE VALVE
16. EXHAUST VALVE
17. CYLINDER HEAD GASKET
18. CYLINDER HEAD
19. GLOW PLUG
20. GLOW PLUG COVER
21. PUSH ROD
22. SUPPORT BRACKET BOLT
23. ROCKER ARM SHAFT SPRING
24. SUPPORT BRACKET STUD
25. SUPPORT BRACKET
26. ROCKER ARM SHAFT
27. ROCKER ARM SHAFT RETAINING RING
28. VALVE ADJUSTING SCREW LOCK NUT
29. VALVE ADJUSTING SCREW
30. SUPPORT BRACKET NUT

Glow Plugs

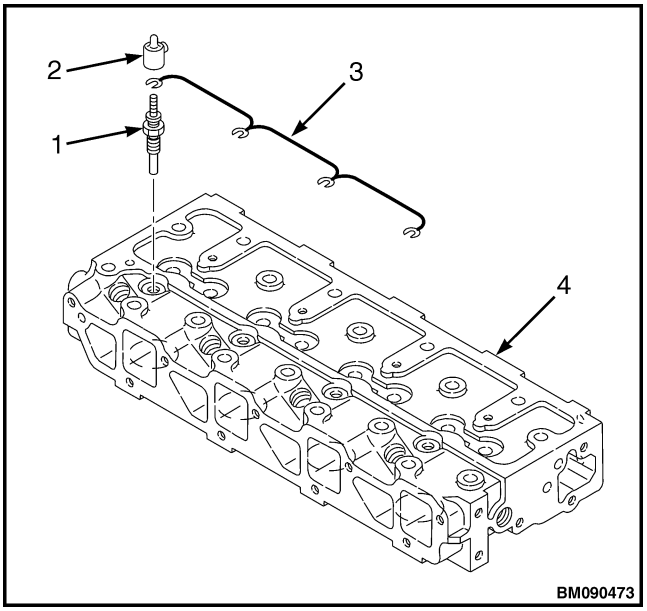
Remove

1. Disconnect the negative battery cable at the battery.

2. Remove the glow plug cover (item 2, Figure 155) from each of the glow plugs.

3. Disconnect the glow plug harness (item 3, Figure 155) from the glow plugs.

4. Remove the glow plugs from the cylinder head. See Figure 155.



1. GLOW PLUG
2. GLOW PLUG CONNECTOR
3. GLOW PLUG WIRE HARNESS
4. CYLINDER HEAD

Figure 155. Glow Plugs

Install

1. Install the glow plugs into the cylinder head.

2. Connect the glow plug harness to the glow plugs.

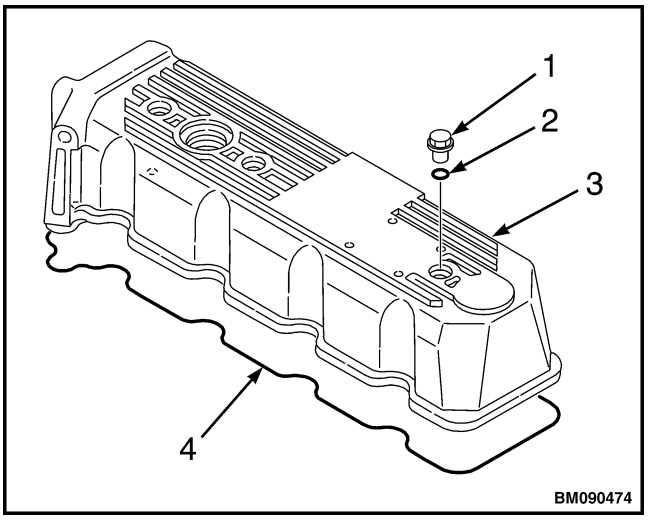
3. Install the glow plug covers on each glow plug.

4. Connect the negative battery cable.

Valve Cover

Remove and Disassemble

1. Remove the valve cover bolts. See Figure 156.
2. Inspect the condition of the O-rings for each valve cover nut. Replace the O-rings if necessary. See Parts Manual for correct part number.
3. Remove the valve cover from cylinder head. See Figure 156.
4. Remove and discard valve cover gasket (item 4, Figure 156).



1. VALVE COVER BOLT
2. WASHER
3. PRESSURE SENSOR
4. VALVE COVER
5. VALVE COVER GASKET

Figure 156. Valve Cover Assembly

Clean and Inspect

WARNING

Cleaning solvents can be flammable and toxic and can cause skin irritation. When using cleaning solvents, always follow the recommendations of the manufacturer.

WARNING

Compressed air can move particles so that they cause injury to the user or the other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

CAUTION

Use caution not to scratch the gasket mating surfaces when cleaning the valve cover and cylinder head.

Carefully remove all gasket residue from the valve cover and cylinder head.

Clean valve cover in cleaning solvent. Dry valve cover with compressed air. Inspect for wear, cracks, and any other damage. If necessary, replace valve cover.

Inspect O-rings for valve cover bolts and filler cap. Replace as needed.

Install

1. Lightly grease the new valve cover gasket.
2. Place the new valve cover gasket in the groove of the valve cover. See Figure 156.
3. Place valve cover in position on the cylinder head. See Figure 156.
4. Verify that the O-rings are installed on the valve cover bolts.
5. Install and tighten the valve cover bolts to standard torque. See Figure 156.

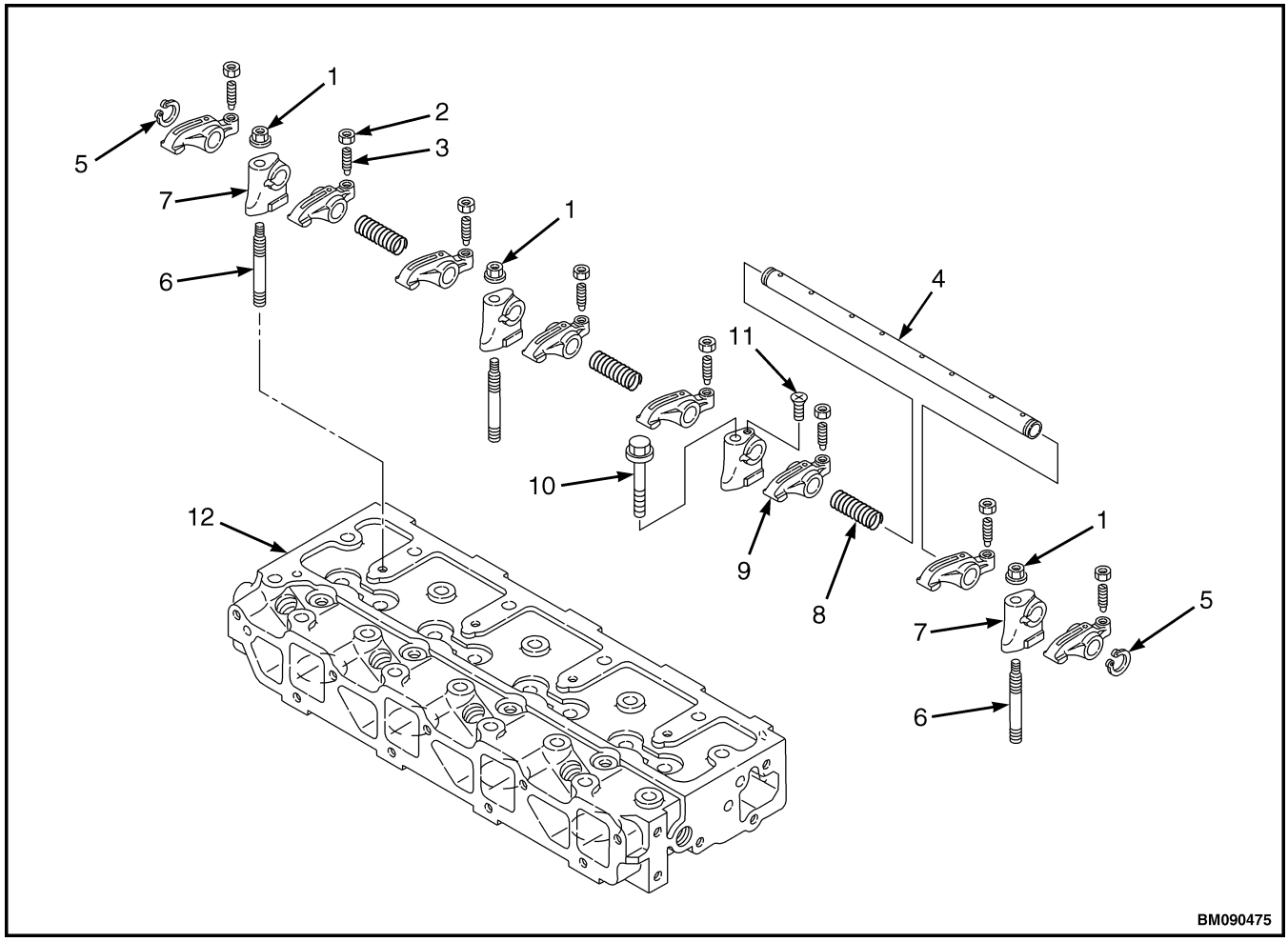
Rocker Arm Assembly

Remove

1. Remove valve cover. See Valve Cover, Remove and Disassemble.
2. Remove the bolt and locking nuts that retain the rocker arm assembly support brackets to the cylinder head. See Figure 157.
3. Lift the rocker arm assembly from the cylinder head.

NOTE: Mark the push rods so they can be reinstalled in original location during reassembly.

4. Remove the push rods from the cylinder head.



1. SUPPORT BRACKET NUT
2. VALVE ADJUSTING SCREW LOCK NUT
3. VALVE ADJUSTING SCREW
4. ROCKER ARM SHAFT
5. ROCKER ARM SHAFT RETAINING RING
6. SUPPORT BRACKET STUD
7. SUPPORT BRACKET
8. ROCKER ARM SHAFT SPRING
9. ROCKER ARM
10. SUPPORT BRACKET BOLT
11. ROCKER ARM SHAFT RETAINING BOLT
12. CYLINDER HEAD

Figure 157. Rocker Arm Assembly

Disassemble

1. Remove the rocker arm shaft alignment screw from the support bracket that secures the rocker arm shaft. See Figure 157.

2. Remove the retaining rings from the ends of the rocker arm shaft.

NOTE: Mark the rocker arms so they can be reinstalled in original location during reassembly.

NOTE: The rocker arm shaft fits tightly in the rocker arm support brackets. Clamp the support bracket in a padded vise and twist and pull the rocker arm shaft to remove the shaft.

3. Slide the rocker arm shaft out of the rocker arm support brackets, springs, and rocker arms. See Figure 157.

4. If necessary, remove the valve adjusting screw and locknut from the rocker arms.

Clean and Inspect

WARNING

Cleaning solvents can be flammable and toxic and can cause skin irritation. When using cleaning solvents, always follow the recommendations of the manufacturer.

WARNING

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

Clean all parts in cleaning solvent. Dry parts with compressed air. Inspect for wear, cracks, and any other damage. Replace all parts as needed.

Push Rods

1. Place push rods on a flat inspection block.
2. Roll push rods until a gap can be observed between a portion of the push rod and the surface of the inspection block.
3. Use a feeler gauge to measure the gap. Refer to the for the service limit. See Figure 158.

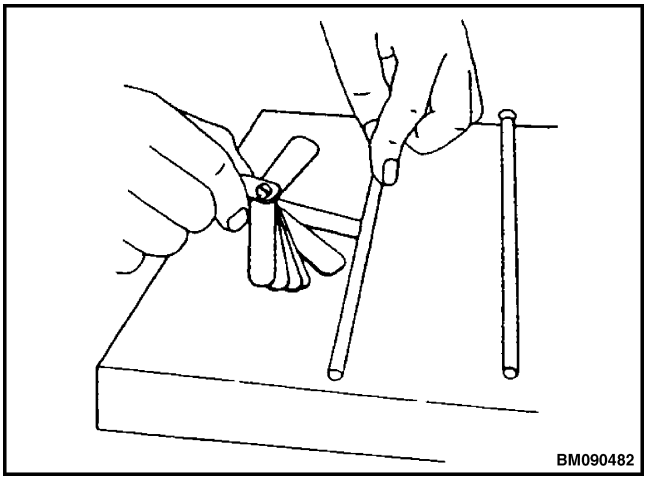


Figure 158. Push Rod Inspection

Rocker Arm Assembly

Rocker Arm and Support Bracket Inside Diameter - Use a test indicator and micrometer to determine if the inside diameter of all the rocker arm support brackets and rocker arms are within limits. Refer the to the Diesel engine specifications for the service limit. See Figure 159.

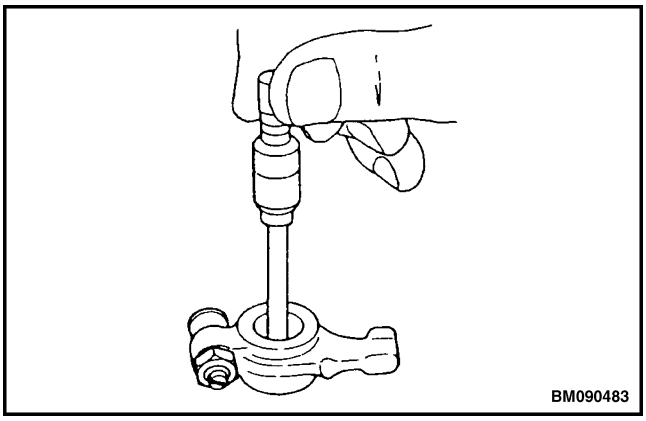


Figure 159. Rocker Arm Inside Diameter

Shaft Outside Diameter - Use a micrometer to measure the rocker arm shaft outside diameter. Refer to the Diesel engine specifications for the service limit. See Figure 160.

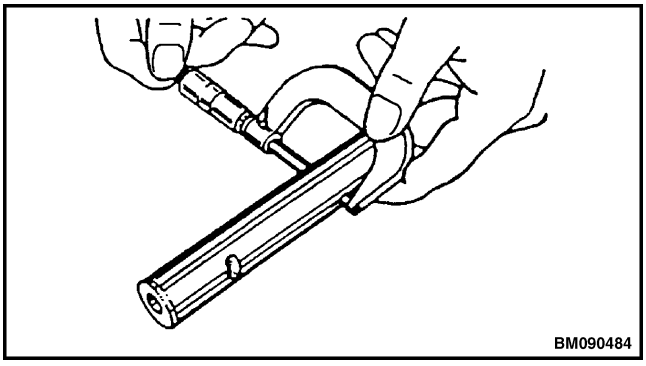


Figure 160. Rocker Arm Shaft Outside Diameter

Assemble

NOTE: The rocker arm shaft fits tightly in the rocker arm support brackets. Clamp the rocker arm shaft in a padded vice and twist and push the support brackets onto the rocker arm shaft.

NOTE: To properly align the rocker arm shaft with the support brackets, first install the rocker arm shaft support bracket with the hole for the shaft alignment screw. Align the hole in the rocker arm shaft and the hole in the support bracket. Install the alignment screw. See Figure 157.

1. Lubricate the rocker arm shaft. Slide the rocker arm A supports, rocker B support, springs, and rocker arms onto the shaft. See Figure 157.

Install

1. Position the rocker arm assembly on a flat surface.
2. Install the retaining rings (item 5, Figure 157) onto the end of the rocker arm shaft (item 4).
3. Install and hand tighten the rocker arm shaft retaining bolts and nuts. See Figure 157.
4. Install the valve adjusting screws (item 3,Figure 157) and lock nuts (item 2).
5. Place the rocker arm assembly in place on the cylinder head.
6. Tighten the rocker arm support bracket nuts (item 1, Figure 157) and bolts (item 10, Figure 157) to standard torque.
7. Tighten the rocker arm shaft alignment screw.
8. Align the push rods with their respective rocker arms and adjust the valve lash. See Valve Clearance Adjustments.
9. Install valve cover. See Valve Cover, Install.

VALVE CLEARANCE ADJUSTMENTS

NOTE: Make measurements and adjustments while the engine is cold.

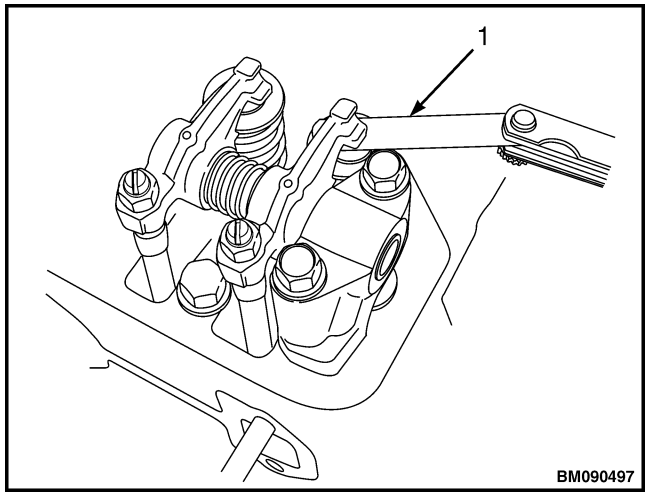
NOTE: The cylinder to be adjusted first does not have to be the number one cylinder. Select and adjust the cylinder where the piston is the nearest to top dead center (TDC) after rotating and make the adjustment for the other cylinders in the order of the ignition by turning the crankshaft 180 degrees each time.

1. Remove valve cover. See Valve Cover, Remove and Disassemble.

NOTE: The number one piston position is on the flywheel end of the engine, opposite of the radiator, and the ignition order is 1 - 3 - 4 - 2 at 180 degree intervals.

NOTE: Since intake and exhaust valve rocker arms are operated the same and there is a clearance between rocker arm and valve generally at top dead center, the position can be checked by means of the play when the rocker arm head is held with a hand. Also, see that the crankshaft pulley top mark is positioned at zero on the timing scale. If there is no valve clearance, inspection in the disassembled state is necessary since the valve seat may be worn abnormally.

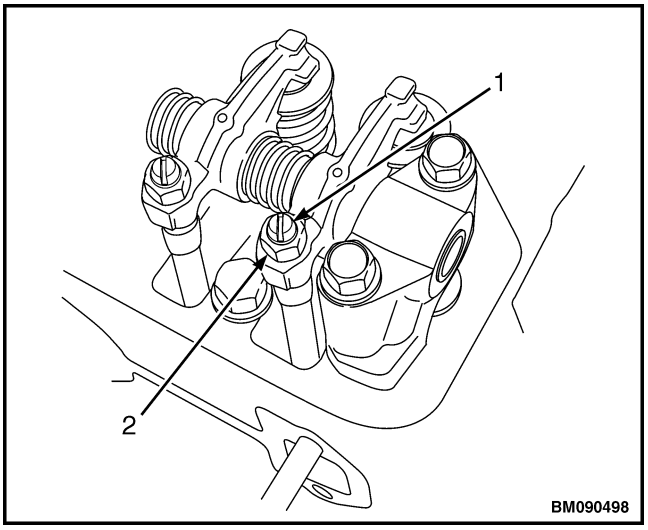
2. Rotate crankshaft clockwise, as seem from the radiator side, to bring the number one piston to top dead center (TDC) while watching the rocker arm motion, timing scale, and top mark position of the crankshaft pulley. (Position where both the intake and exhaust valves are closed.)
3. Insert a feeler gauge between the rocker arm and valve cap. See Figure 161. Record the measured valve clearance. The valve clearance should be between
0.15 to 0.25 mm (0.006 to 0.010 in.).



1. FEELER GAUGE

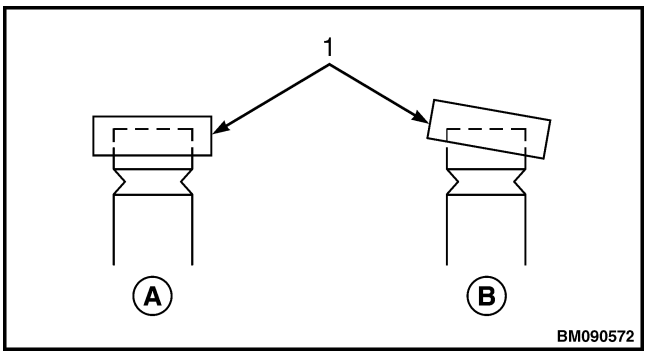
Figure 161. Valve Clearance Measurement

4. If adjustment is needed, loosen the valve adjusting screw locknut and valve adjusting screw on the rocker arm (see Figure 162) and check the valve for any inclination of valve cap, entrance of dirt, or wear. See Figure 163.



1. VALVE ADJUSTING SCREW
2. VALVE ADJUSTING SCREW LOCKNUT

Figure 162. Valve Clearance Adjustment



A. NORMAL
B. ABNORMAL

1. VALVE CAP

Figure 163. Valve Cap Check

NOTE: There is a tendency for the clearance to decrease slightly when the locknut is tightened. It is suggested that you make the clearance adjustment slightly on the loose side before tightening the locknut.

5. Insert a 0.2 mm (0.008 in.) feeler gauge between the rocker arm and valve cap and adjust the clearance so there is a slight drag on the feeler gauge when sliding it between the rocker arm and valve cap. Tighten the valve adjusting screw locknut and recheck the clearance. The valve clearance should be between 0.15 to 0.25 mm (0.006 to 0.010 in.).

6. Apply clean engine oil to the contact surface between the adjusting screw and push rod.

7. Turn the crankshaft 180 degrees and make the measurement and adjustment for the number three cylinder. Then turn the crankshaft 180 degrees and make the measurement and adjustment for the number four cylinder. Then turn the crankshaft 180 degrees and make the measurement and adjustment for the number 2 cylinder.

8. Install the valve cover. See Valve Cover, Install.

CYLINDER HEAD ASSEMBLY

Remove

1. Disconnect negative battery cable at the battery.

2. Remove alternator. See Alternator.

3. Remove water pump. See Water Pump, Remove section in **Cooling system** 0700SRM2300.

4. Disconnect air intake hose from the intake manifold.

5. Remove glow plugs. See Glow Plugs, Remove.

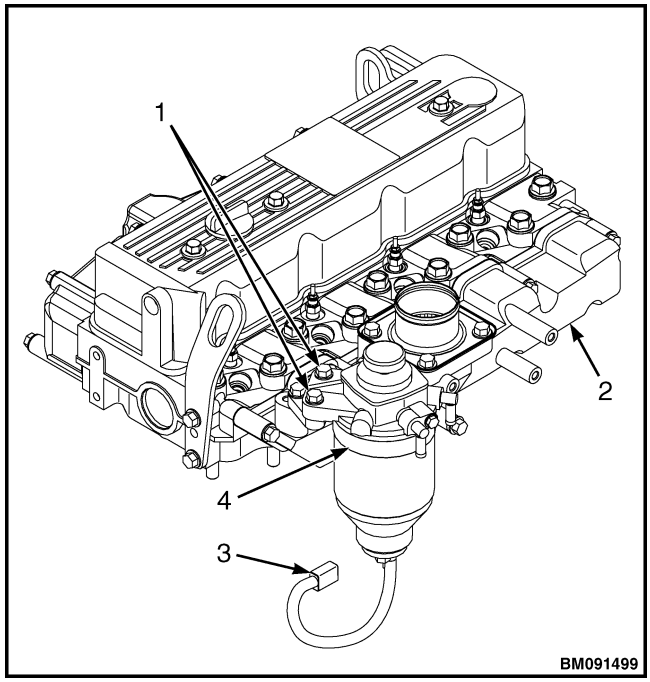
6. Remove fuel injectors and high pressure lines. See Diesel fuel system repair.

7. If equipped, remove the pull actuator and mounting bracket. See Diesel fuel system repair.

8. Disconnect the electrical connector for the fuel filter sensor.

9. Tag and disconnect the fuel hoses from the fuel filter.

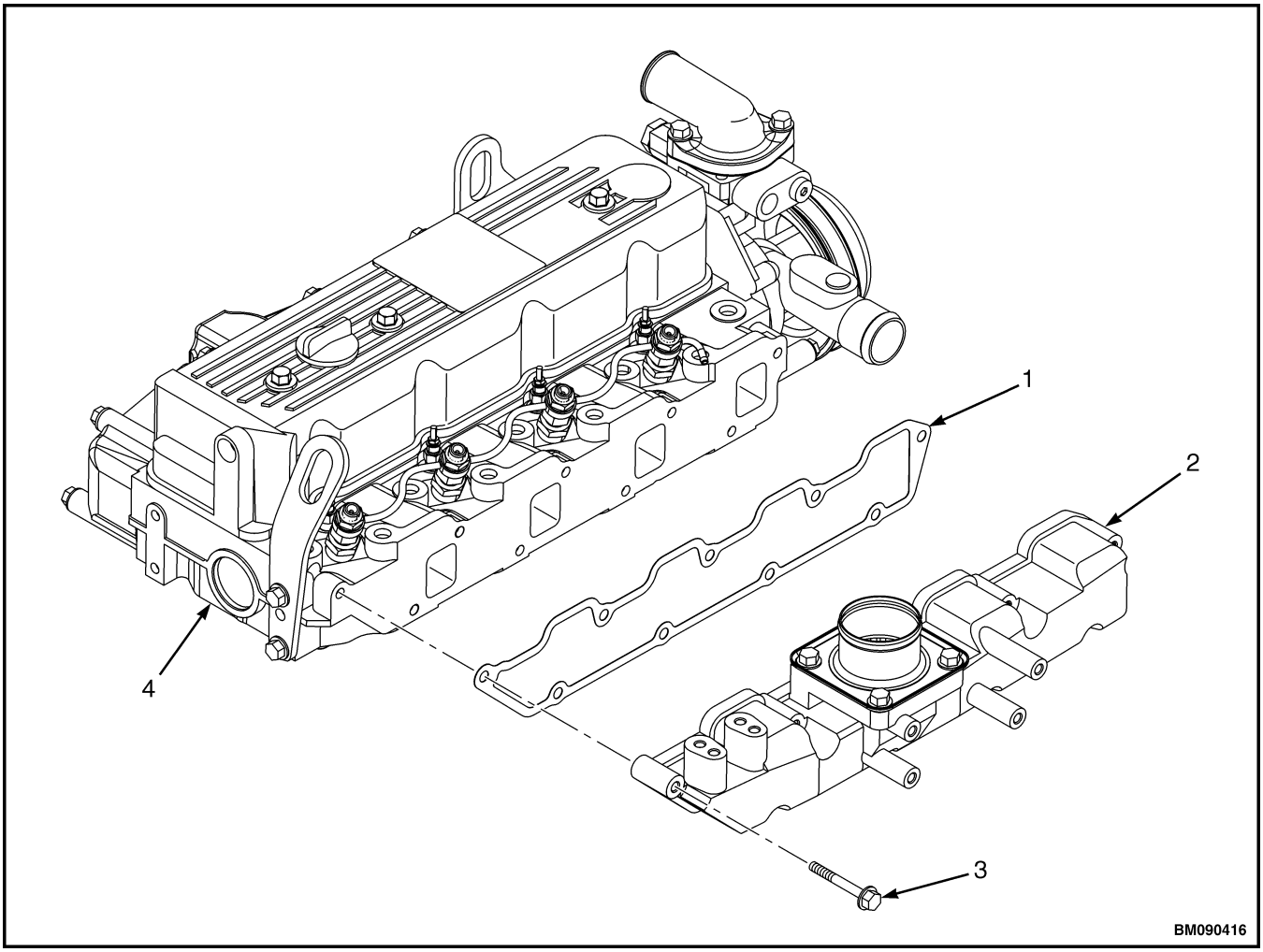
10. Remove the bolts retaining the fuel filter housing assembly to the intake manifold and remove the fuel filter housing assembly. See Figure 164.



1. BOLTS
2. INTAKE MANIFOLD
3. FUEL SENSOR ELECTRICAL CONNECTOR
4. FUEL FILTER HOUSING ASSEMBLY

Figure 164. Fuel Filter Housing Assembly

11. Remove the bolts retaining the intake manifold to the cylinder head and remove the intake manifold and gasket. Discard gasket. See Figure 165.

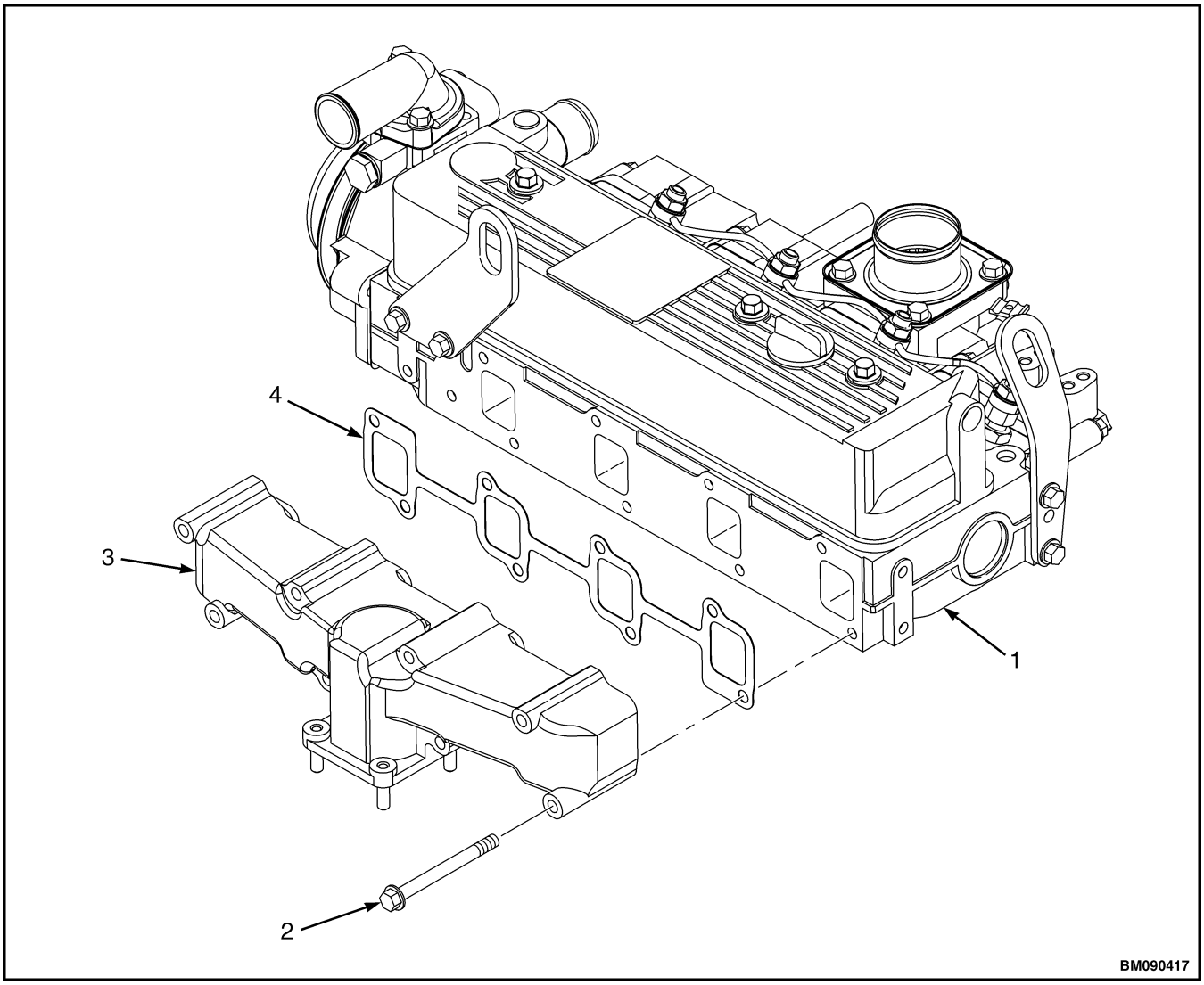


1. GASKET
2. INTAKE MANIFOLD
3. BOLT
4. CYLINDER HEAD

Figure 165. Intake Manifold

12. Remove the nuts retaining the exhaust pipe to the exhaust manifold and disconnect the exhaust pipe from the exhaust manifold.

13. Remove the bolts retaining the exhaust manifold to the cylinder head and remove the exhaust manifold and gasket. Discard gasket. See Figure 166.



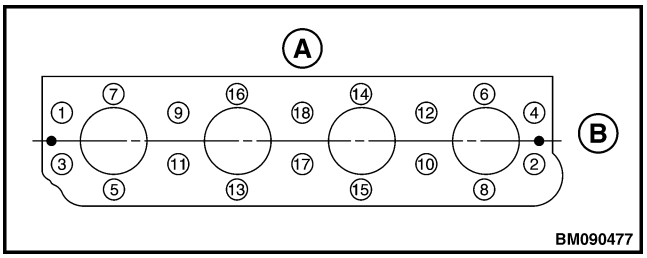
1. CYLINDER HEAD
2. BOLT
3. EXHAUST MANIFOLD
4. GASKET

Figure 166. Exhaust Manifold

14. Remove the valve cover. See Valve Cover, Remove and Disassemble.

15. Remove the rocker arm assembly. See Rocker Arm Assembly, Remove.

16. Loosen the cylinder head bolts following the sequence shown in Figure 167.



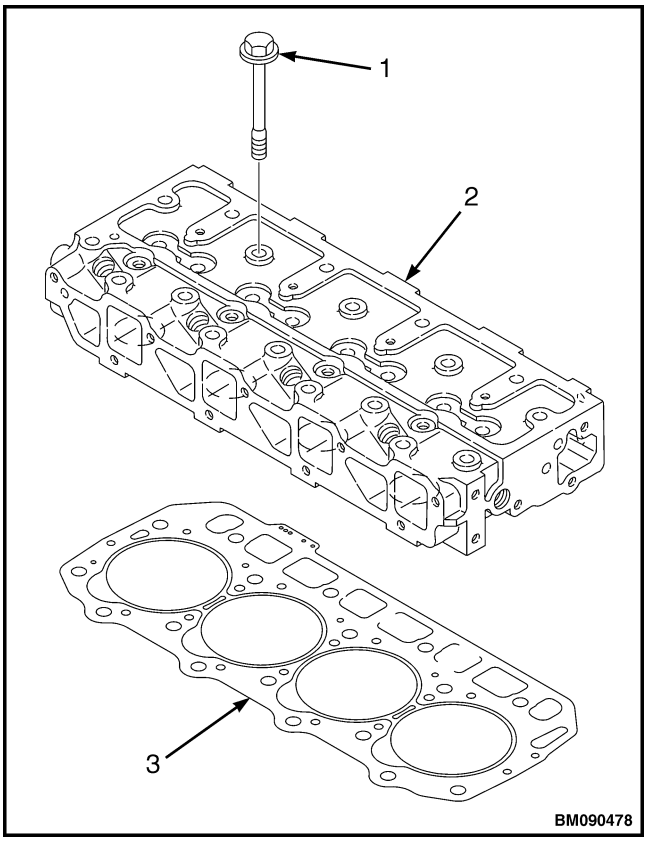
A. CAMSHAFT SIDE
B. FAN SIDE

Figure 167. Cylinder Head Bolt Loosening Sequence

17. Remove the cylinder head bolts. See Figure 168.

18. Lift the cylinder head away from the cylinder block. Place the cylinder head on a work bench to prevent damage to the combustion chamber.

19. Remove the cylinder head gasket and discard. See Figure 168.



1. BOLT
2. CYLINDER HEAD
3. GASKET

Figure 168. Cylinder Head and Gasket

Disassemble

Valves and Valve Springs, Remove

1. Place the cylinder head on a work bench with the combustion side down.

2. Using a valve spring compressor tool, compress one of the valve springs. See Figure 169.

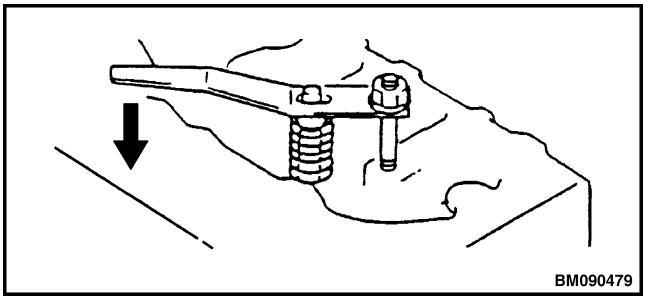
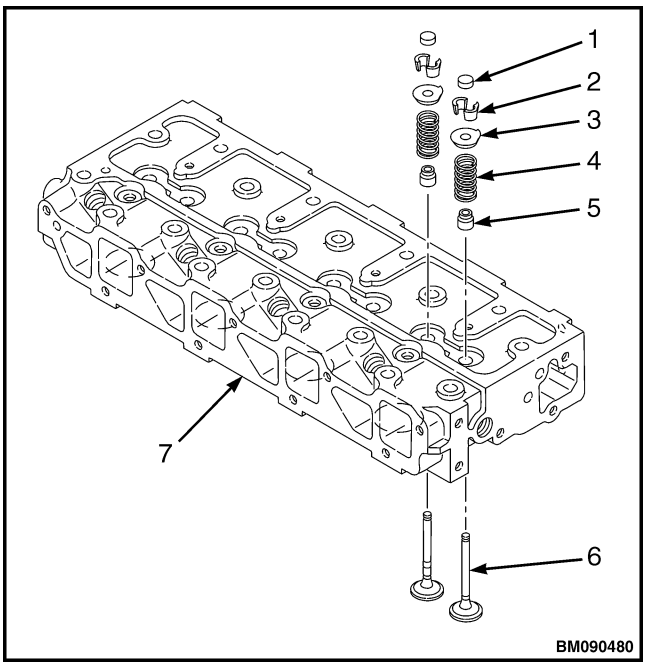


Figure 169. Valve Spring Compressor

3. Remove the valve keepers and the valve cap from the end of the valve. See Figure 170.



1. VALVE CAP
2. VALVE KEEPERS
3. SPRING RETAINER
4. SPRING
5. EXHAUST VALVE STEM SEAL
6. INTAKE VALVE STEM SEAL
7. VALVE GUIDE
8. EXHAUST VALVE
9. INTAKE VALVE
10. CYLINDER HEAD

Figure 170. Valves, Valve Springs, and Valve Guides

4. Slowly release the tension on the valve spring.

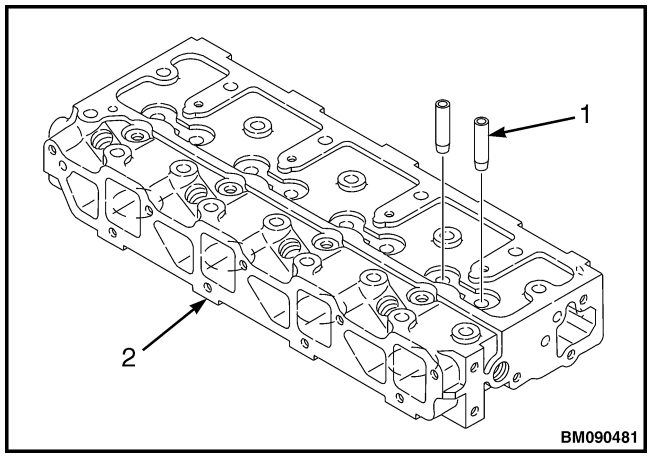
5. Remove the spring retainer, valve spring, and valve stem seal. See Figure 170.

6. Repeat this procedure until all intake and exhaust valve springs and valve seals are removed.

7. Turn the cylinder head so the exhaust port side faces down. Remove the intake and exhaust valves from the cylinder head.

Valve Guides, Remove

1. Using a drift pin and hammer, drive the valve guides out of the cylinder head. See Figure 171.



1. VALVE GUIDE
2. CYLINDER HEAD

Figure 171. Valve guides

Clean and Inspect

WARNING

Cleaning solvents can be flammable and toxic and can cause skin irritation. When using cleaning solvents, always follow the recommendations of the manufacturer.

WARNING

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

CAUTION

Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.

CAUTION

Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.

CAUTION

Use caution not to scratch the gasket mating surfaces when cleaning the exhaust manifold and cylinder head.

1. Carefully remove all gasket residue from the exhaust manifold and cylinder head. Inspect the exhaust manifold for scratches, cracks, or any other damage. Repair or replace as needed.

CAUTION

Use caution not to scratch the gasket mating surfaces when cleaning the intake manifold and cylinder head.

2. Carefully remove all gasket residue from the intake manifold and cylinder head. Inspect the intake manifold for scratches, cracks, or any other damage. Repair or replace as needed.

CAUTION

Use caution not to scratch the gasket mating surfaces when cleaning the cylinder had and cylinder block.

3. Carefully remove all gasket residue from the cylinder head and cylinder block. Inspect the cylinder head for scratches, cracks, or any other damage. Repair or replace as needed.

4. Thoroughly clean all components using a nonmetallic brush and cleaning solvent. Dry the parts with compressed air. Each part must be free of carbon, metal filings, and other debris.

5. Visually inspect the parts. Replace any parts that are obviously discolored, heavily pitted, or otherwise damaged. Replace parts that do not meet the specified limit.

Cylinder Head

1. Place the cylinder head flat and inverted (combustion side up) on the work bench.

2. Use a straight edge and feeler gauge to measure the amount of cylinder head distortion. Refer to the Diesel engine specifications for the service limit. See Figure 172.

3. Use a Magnaflux method and inspect the cylinder head for cracks. Replace the cylinder head if evidence of fractures are found.

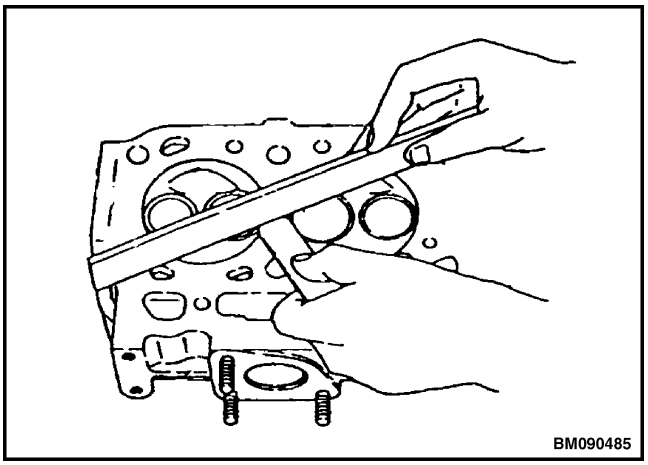


Figure 172. Cylinder Head Distortion Check

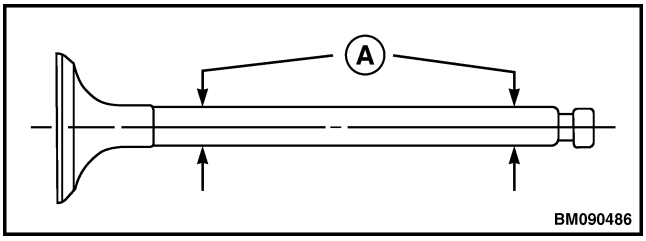
Valve Guides

1. Visually inspect the valve guides for distortions, scoring, or other damage.

2. Use a test indicator and micrometer to measure the inside diameter at each end of the valve guide. Refer to the Diesel engine specifications for the service limit.

Valves

1. **Valve Stem Diameter** - Use a micrometer to measure the valve stem diameter. Measure the valve stem diameter near the combustion end and near the opposite end. Refer to the Diesel engine specifications for the service limit. See Figure 173.



A. MEASUREMENT POINTS

Figure 173. Valve Stem Diameter Measurement Points

2. **Valve Stem Straightness** - Place the valve stem on a flat surface. Roll the valve until a gap can be observed between a portion of the valve stem and the flat surface. Use a feeler gauge to measure the gap. Refer to the Diesel engine specifications for the service limit. See Figure 174.

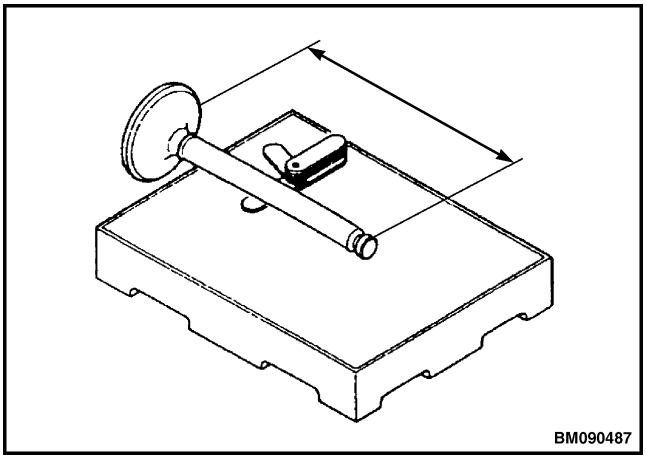


Figure 174. Valve Stem Straightness Check

Valve Sink

1. Insert the valves into their proper places in the cylinder head and press them down until they are fully seated. Using a depth micrometer, measure the difference between the cylinder head surface and the combustion surface of each exhaust and intake valve. Refer to the Diesel engine specifications for the service limit. See Figure 175 and Figure 176.

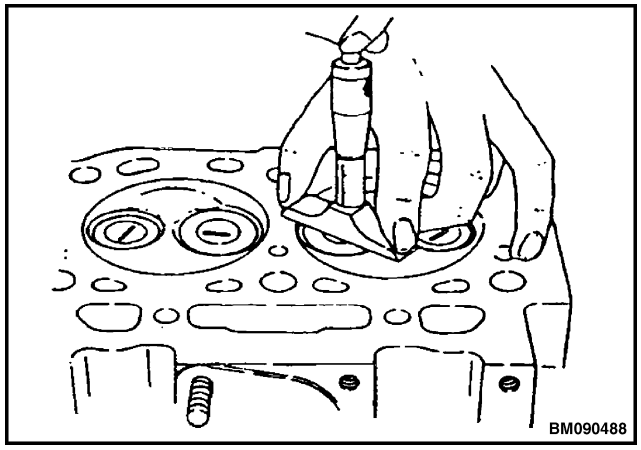


Figure 175. Valve Sink Measurement

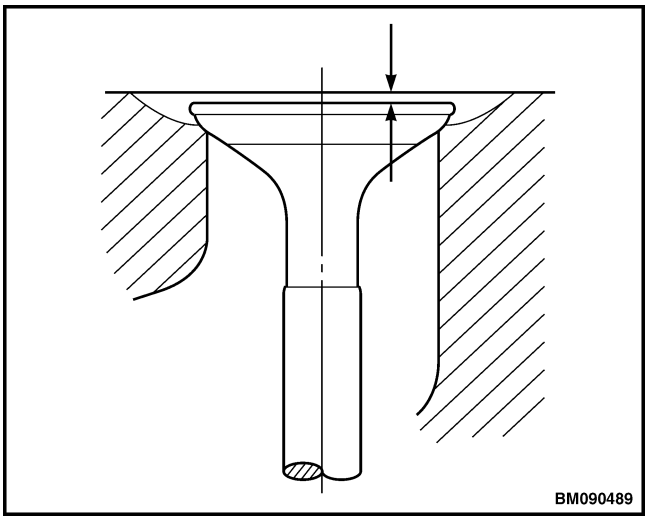


Figure 176. Valve Sink

Valve Seat

1. Always check the clearance between the valve and valve guide before correcting the valve seat. See Figure 177. If the clearance exceeds the limit, replace the valve or valve guide to bring the clearance within the limit.

2. Roughness or burrs will cause poor seating of a valve. Visually inspect the seating of each valve and determine if lapping or grinding is needed. Grinding is needed if the cylinder head's seat width exceeds standard limits. Refer to Diesel engine specifications for the service limit.

3. Lap the valve seat and the cylinder head with a mixture of valve compound and engine oil.

4. If the valve requires grinding, lap the valve after grinding. Be sure to thoroughly wash the parts to remove all grinding powder or compound.

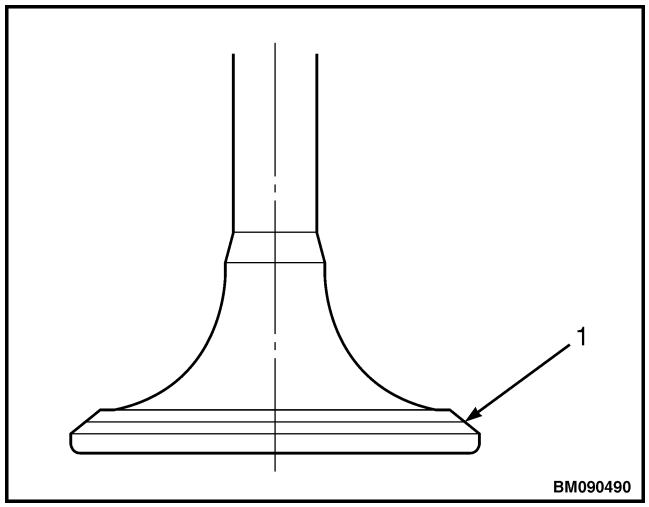


Figure 177. Valve Seat

Valve Springs

Inspect the valve springs. If damage or corrosion is seen, or if measurements exceed the specified limits, replace the springs.

1. **Fractures** - Check for fractures on the inside and outside portions of the springs. If the valve spring is fractured, replace the spring.

2. **Corrosion**- Check for corrosion of spring material caused by oxidation.

3. **Squareness** - Use a flat surface and a square to check each spring for squareness. Refer to the Diesel engine specifications for the service limit. See Figure 178.

4. **Free Length** - Use a caliper to measure the length of the spring. Refer to the Diesel engine specifications for the service limit. See Figure 179.

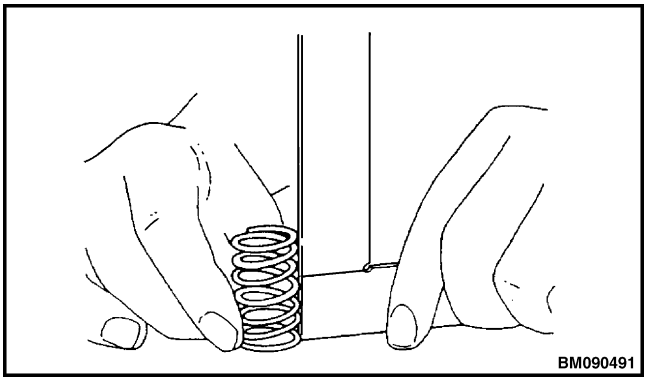


Figure 178. Spring Squareness Check

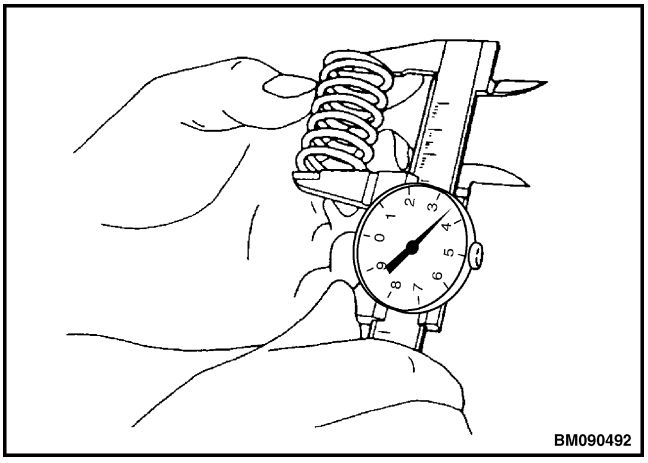


Figure 179. Spring Free Length Check

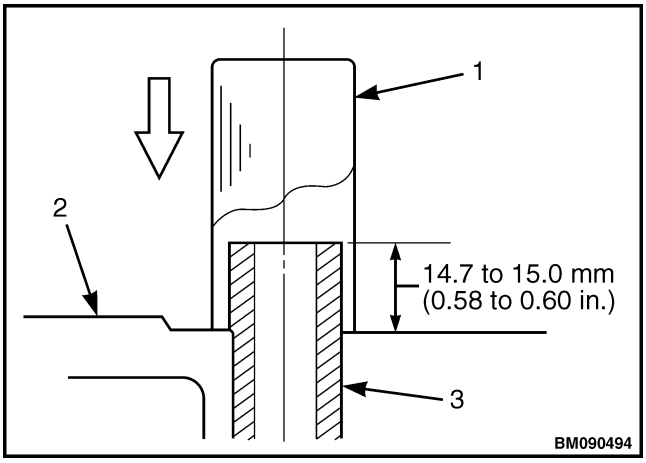
Assemble

Valve Guides, Install

1. The valve guides are installed into the cylinder head with an extremely tight press fit. Before installing the valve guides, place the valve guides in the freezer for at least twenty minutes. This will cause the valve guides to contract, making it easier to install the valve guides into place.

2. Immediately after removing the valve guides from the freezer, insert the valve guides in their proper positions in the cylinder head.

3. Finish installing the valve guides into the cylinder head to the proper height using a special tool, valve guide installation tool. See Figure 180.



1. VALVE GUIDE INSTALLATION TOOL
2. CYLINDER HEAD
3. VALVE GUIDE

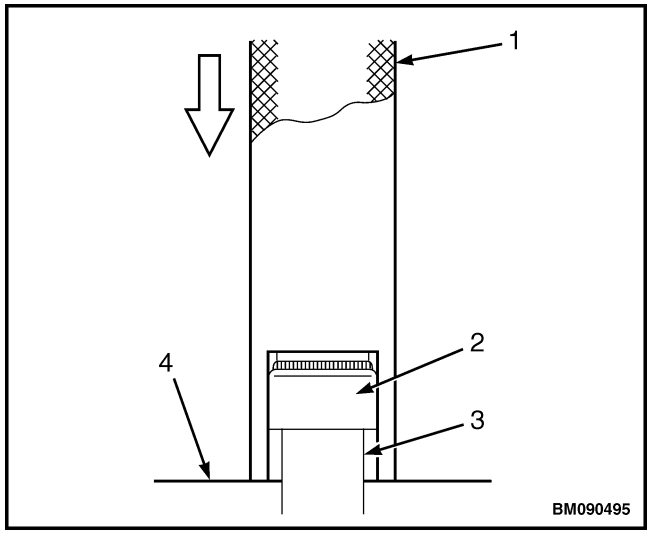
Figure 180. Valve Guide Installation

Valves and Valve Springs, Install

1. Place the cylinder head assembly on the exhaust port side.

2. Place all the valves in their proper positions, as marked when disassembled, in the cylinder head.

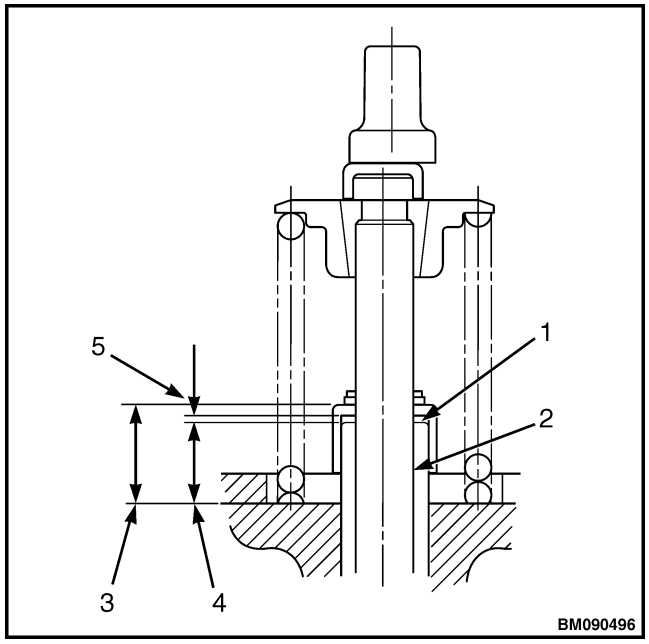
3. Apply clean engine oil to the lip of the valve stem seal. Using a special tool, valve stem seal installation tool, insert a new valve stem seal on each of the valves. See Figure 181.



1. VALVE STEM SEAL INSTALLATION TOOL
2. VALVE STEM SEAL
3. VALVE GUIDE
4. CYLINDER HEAD

Figure 181. Valve Stem Seal Installation

4. Measure the distance from the cylinder head to the valve stem seal. Refer to the Diesel engine specifications for the clearance specifications. See Figure 182.



1. VALVE STEM SEAL
2. VALVE GUIDE
3. VALVE STEM SEAL PROJECTION
4. VALVE GUIDE PROJECTION
5. CLEARANCE

Figure 182. Valve Stem Seal Clearance

5. Place the cylinder head on the work bench with the combustion chamber facing down. Install the valve springs and valve spring retainers. See Figure 170.

6. Using the valve compressor tool, compress the valve spring.

7. Install the valve keepers and slowly release the tension in the valve spring.

8. Install the valve cap.

9. Repeat these procedures until all the intake and exhaust valves are installed.

Install

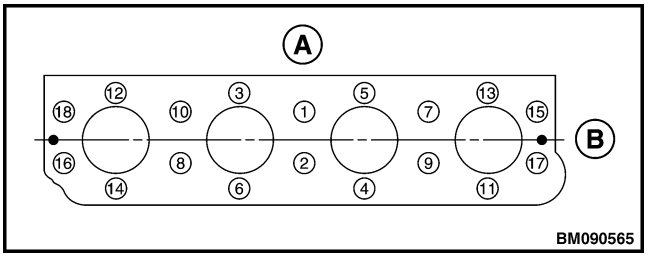
1. Carefully clean the combustion surface of the cylinder head and the top surface of the cylinder block.

2. PLACE a new cylinder head gasket on the cylinder block. See Figure 168.

3. Position the cylinder head on the cylinder head gasket and cylinder block.

4. Lightly oil the threads of the cylinder head bolts.

5. Install the cylinder head bolts and tighten the cylinder head bolts to
49 to 59 N•m (36 to 43 lbf ft) in the sequence shown in Figure 183. Then tighten the cylinder heads bolts to 103 to 113 N•m (76 to 83 lbf ft) in the same sequence.



A. CAMSHAFT SIDE
B. FAN SIDE

Figure 183. Cylinder Head Torque Sequence

6. Install the push rods and rocker arm assembly. See Rocker Arm Assembly, Install.

7. Install the valve cover. See Valve Cover, Install.

8. Place a new gasket and the exhaust manifold in position on the cylinder head and install the exhaust manifold retaining bolts.

9. Connect the exhaust pipe to the exhaust manifold and install

10. Place a new gasket and the intake manifold in position on the cylinder head and install the intake manifold retaining bolts.

11. Place the fuel filter housing assembly in position on the intake manifold and install retaining bolts.

12. Connect the fuel hoses to the fuel filter.

13. Connect the electrical connector for the fuel filter sensor.

14. If equipped, install the pull actuator and mounting bracket. See Diesel fuel system repair.

15. Install the fuel injectors and high pressure lines. See Diesel fuel system repair.

16. Install the glow plugs. See Glow Plugs, Install.

17. Connect the air intake hose to the intake manifold.

18. Install water pump. See **Cooling system** 0700SRM2300 .

19. Install alternator. See Diesel electrical system repair.

20. Fill cooling system with coolant. See **Periodic Maintenance** 8000SRM2305 **Periodic Maintenance** 8000SRM2305 for the correct coolant amount and type.

21. Install radiator cap.

22. Connect negative battery cable.

WARNING

During engine operation, be careful not to touch the fan, pulleys, or drive belts. Contact with these parts can cause serious injury.

WARNING

The radiator or other parts of the cooling system may be hot or under pressure and can cause serious injury.

23. Start engine and check for leaks.

24. Change engine oil and oil filter. See **Periodic Maintenance** 8000SRM2305 **Periodic Maintenance** 8000SRM2305 for the procedures.

WARNING

DO NOT remove the radiator cap from the radiator when the engine is hot. When the radiator cap is removed, pressure will release from the coolant system. If the coolant system is hot, the steam and boiling coolant can cause severe burns.

WARNING

The radiator or other parts of the cooling system may be hot or under pressure and can cause serious injury. Wait 30 minutes for the radiator and engine to cool before performing maintenance to the cooling system. After 30 minutes, do a touch test by touching the radiator with your hand. If the radiator is still hot to the touch, wait another 30 minutes before attempting any maintenance to the cooling system.

DIESEL TIMING GEAR CASE REPAIR 202001-357

TIMING GEAR CASE COVER

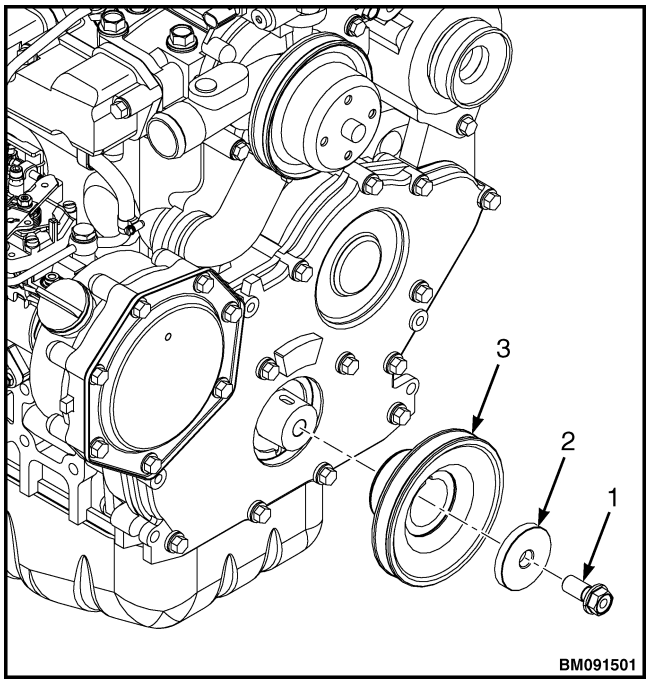
Remove

1. Remove the engine. See Diesel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.
2. Place the engine on an engine stand or a clean, flat working surface large enough to accommodate the engine and components.
3. Remove the coolant fan, V-belt and water pump. See **Cooling system** 0700SRM2300 service manual.
4. Remove the bolt retaining the crankshaft pulley. See Figure 184.
5. Use a gear puller to remove the crankshaft pulley and spacer. See Figure 184.

CAUTION

Additives may damage the cooling system. Before using additives, contact your local Hyster dealer

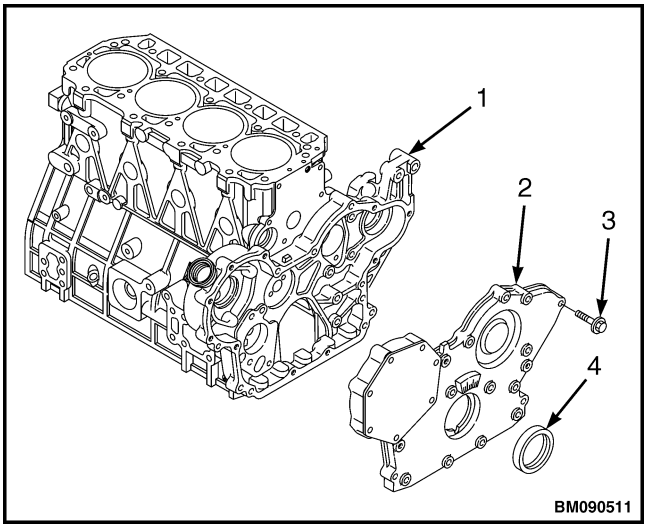
25. Stop engine. If coolant is hot, allow engine time to cool. Check coolant level and fill as required between the ADD and FULL marks on the coolant reservoir.



1. BOLT
2. SPACER
3. CRANKSHAFT PULLEY

Figure 184. Crankshaft Pulley

6. Remove the bolts and washer retaining the timing gear case cover. See Figure 185.
7. Remove the timing gear case cover. If necessary, remove the front oil seal from the timing gear case cover. See Figure 185.



1. TIMING GEAR CASE
2. TIMING GEAR CASE COVER
3. BOLT
4. FRONT OIL SEAL

Figure 185. Timing Gear Case Cover

Inspect

WARNING

Cleaning solvents can be flammable and toxic and can cause skin irritation. When using cleaning solvents, always follow the recommendations of the manufacturer.

WARNING

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

Clean all old sealant from the timing gear case cover and the timing gear case. Clean the timing gear case cover in cleaning solvent. Dry the timing gear case cover with compressed air. Inspect for wear, cracks, and any other damage. If necessary, replace timing gear case cover.

Install

1. Apply a continuous bead of liquid gasket to the outside diameter of a new front oil seal.
2. Using a special tool, install the new front oil seal into the timing gear case cover. Apply lithium grease to the lip of the front oil seal. See Special tools for diesel engines for appropriate tool.
3. Apply a continuous bead of liquid gasket to the surface of the timing gear on the side that adjoins the engine block.
4. Place the timing gear case cover in position on the timing gear case and install retaining bolts and washer. See Figure 185. Tighten bolts to standard torque value.

TIMING GEAR CASE

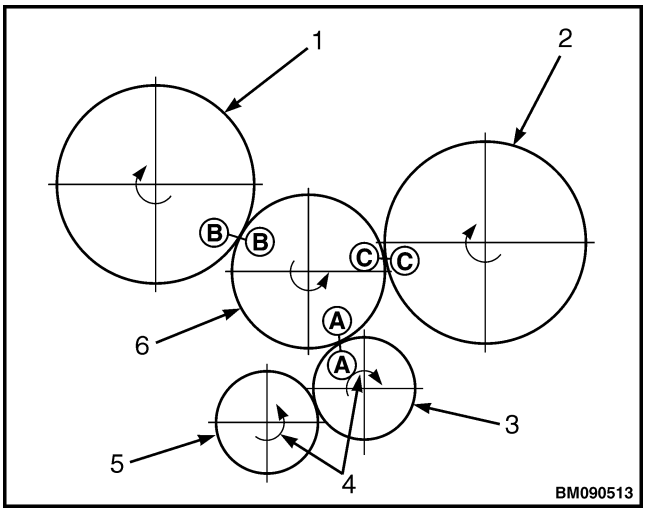
Checks

Check timing gear backlash

Prior to removing the timing gears, measure the gear backlash and determine the gear wear.

Check the backlash between each pair of connecting gears. See Figure 186. If not within specification, replace both connecting gears. See Table 49 in Diesel engine specifications for service limits.

NOTE: Do not allow the gear being checked to move axially as excess end play could cause a false reading.



1. FUEL INJECTION PUMP DRIVE GEAR
2. CAMSHAFT GEAR
3. CRANKSHAFT GEAR
4. DIRECTION OF ROTATION
5. LUBRICATING OIL PUMP GEAR
6. IDLER GEAR

Figure 186. Timing gear backlash

Measuring idler gear-to-crankshaft gear backlash

1. Position a dial indicator as shown in Figure 187, on the SIDE of the gear to measure.

NOTE: Figure below is oriented to show the SIDE of the gear at the TOP of the figure.

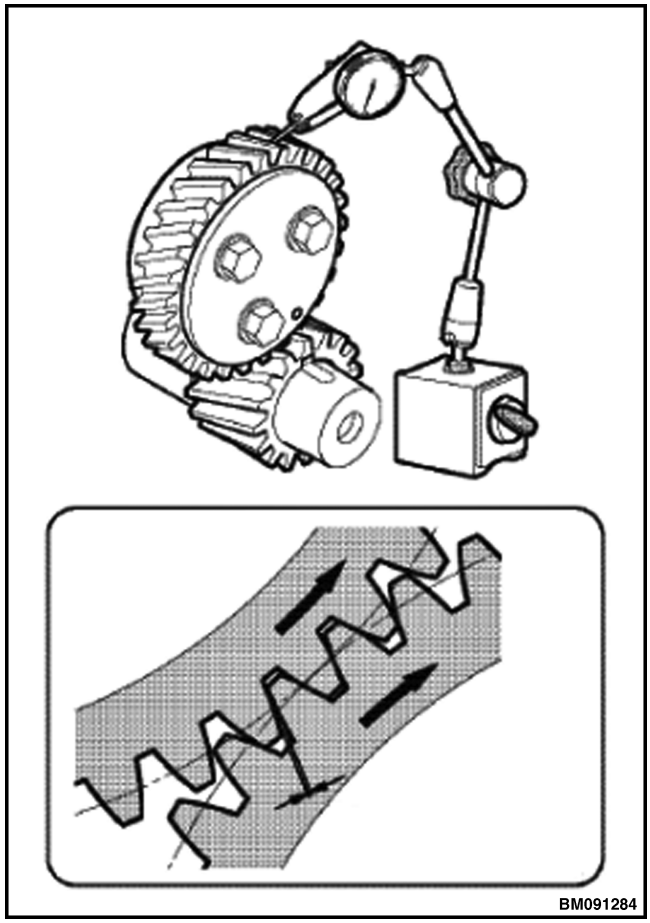


Figure 187. Dial indicator

2. Rotate the idler gear back and forth to check the idler gear backlash, by measuring the movement between gears before they engage. The total indicator reading is the backlash. Record the measurement.

Measuring idler gear-to-camshaft gear backlash

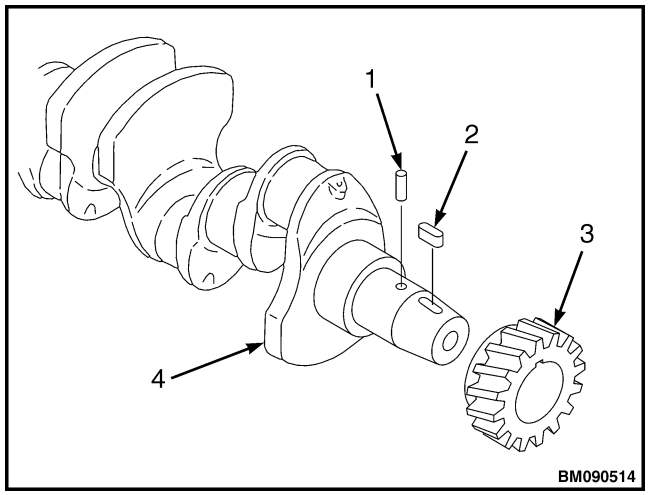
1. Drive a small wooden wedge between the crankshaft gear and idler gear to prevent the idler gear from rotating.
2. Install the dial indicator to read the camshaft gear backlash. Rotate the camshaft drive gear against the idler gear to measure the backlash. Record the measurement.
3. Check the idler gear-to-fuel injection pump drive gear backlash in the same manner as the camshaft drive gear. Record the measurement.

Remove

1. Rotate the engine to align the timing gears. Mark the gears with paint markers to aid in reinstallation.

NOTE: If using a gear puller to remove the crankshaft gear, be careful not to damage the threads in the end of the crankshaft.

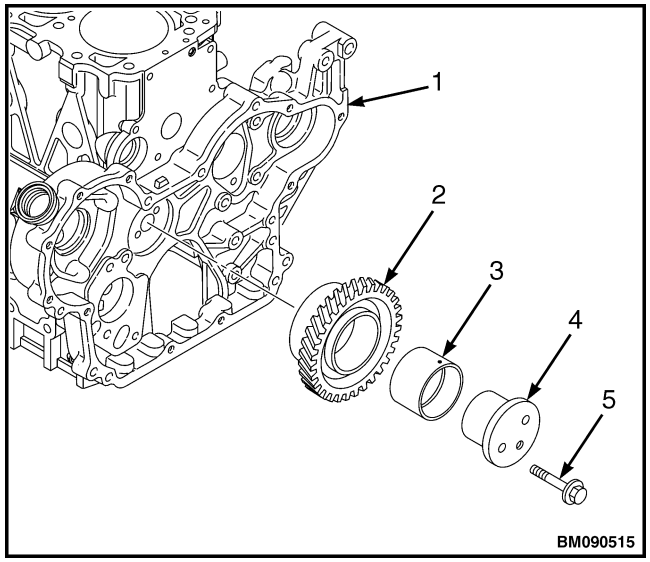
2. Remove the crankshaft gear. See Figure 188.
3. Remove the parallel pin and key from the crankshaft. See Figure 188.



1. PARALLEL PIN
2. KEY
3. CRANKSHAFT GEAR
4. CRANKSHAFT

Figure 188. Crankshaft gear

4. Remove the bolts from the idler gear shaft. See Figure 189.
5. Remove the idler gear shaft and bushing. See Figure 189.



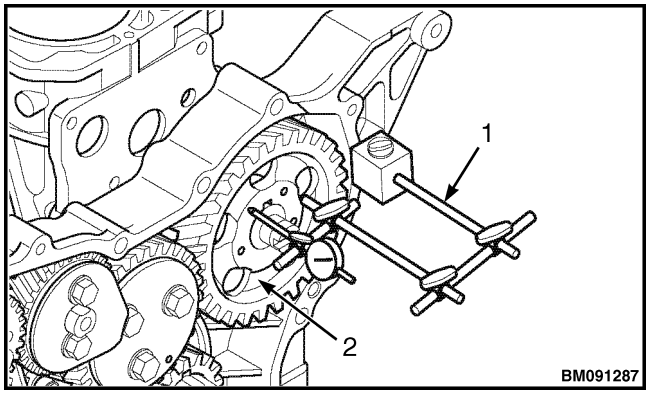
1. IDLER GEAR CASE
2. IDLER GEAR
3. BUSHING
4. IDLER GEAR SHAFT
5. BOLT

Figure 189. Timing gears

6. Confirm gears are aligned properly. Mark the gears with paint markers to aid in reinstallation.

7. Before removing the camshaft, check the camshaft end play.

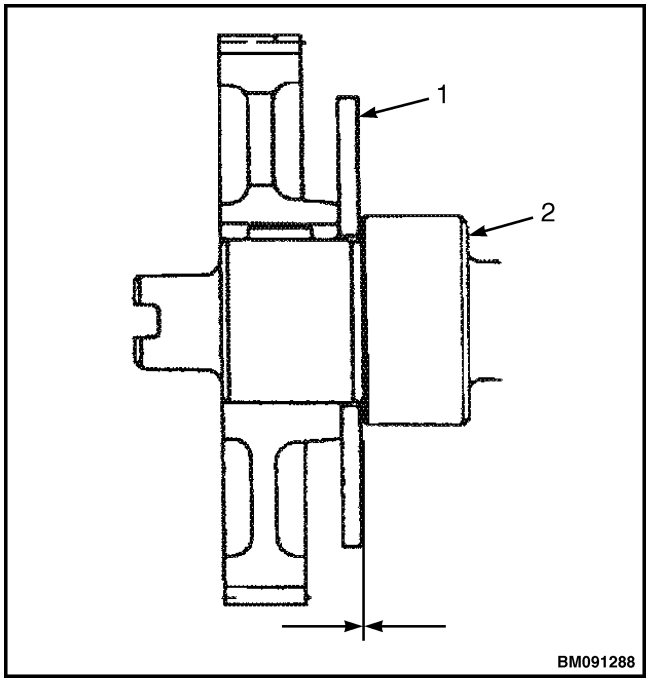
- Method A: Install a dial indicator on the cylinder block. See Figure 190. Move the camshaft back and forth to measure the end play. Record the measurement. See Camshaft and timing gear train specifications in Diesel engine specifications for service limit.



1. DIAL INDICATOR
2. CAMSHAFT GEAR

Figure 190. Method A

- Method B: Use a feeler gauge to measure the clearance between the thrust plate and front camshaft bearing. See Figure 191. See Table 51 in Diesel engine specifications for service limit.

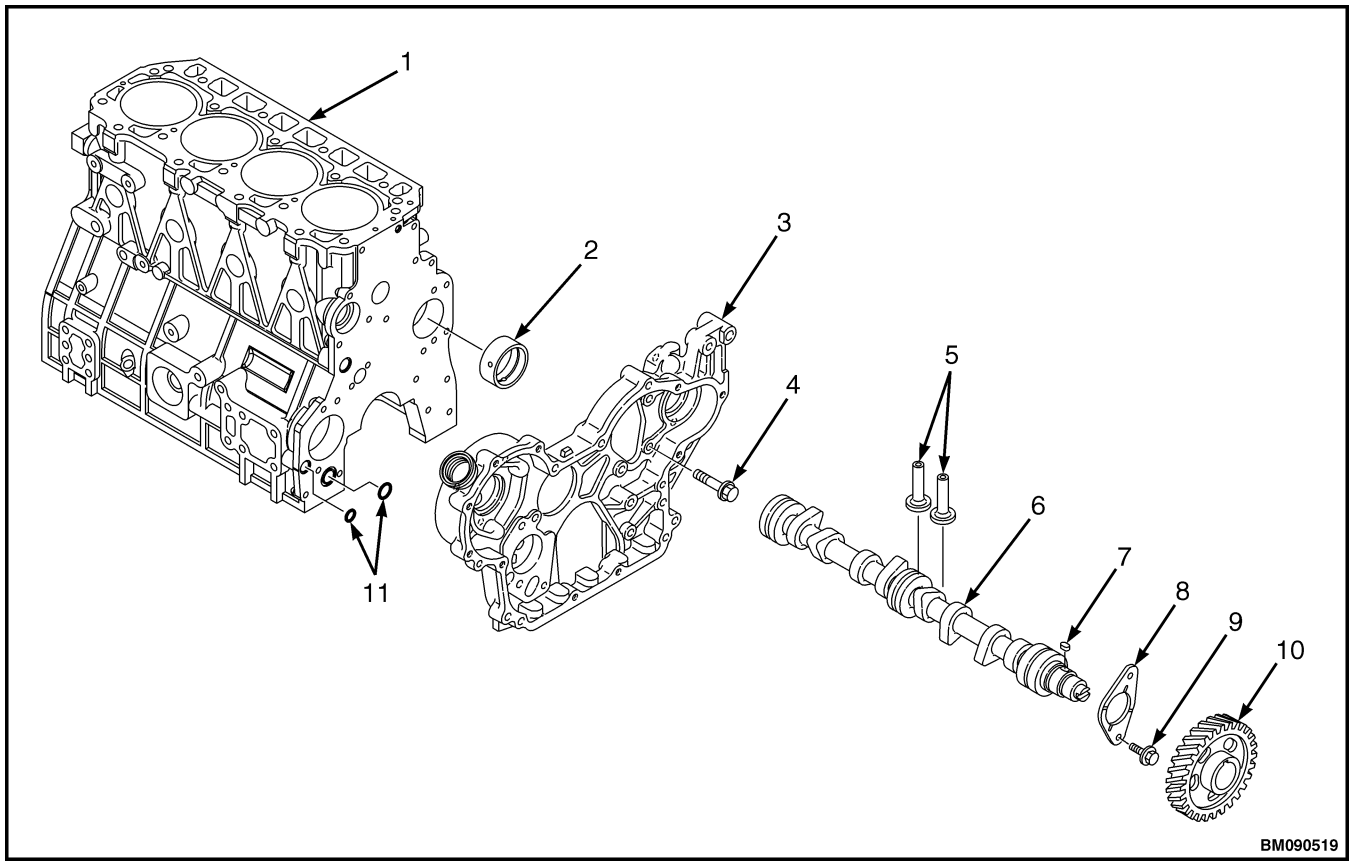


1. THRUST PLATE
2. FRONT CAMSHAFT BEARING

Figure 191. Method B

8. Use a gear puller to remove the camshaft gear. See Figure 192. Remove the key from the camshaft. See Figure 192.

9. Remove the two bolts retaining the camshaft thrust plate. See Figure 192.



1. CYLINDER BLOCK
2. CAMSHAFT BUSHING
3. TIMING GEAR CASE
4. BOLT
5. TAPPETS
6. CAMSHAFT
7. KEY
8. THRUST PLATE
9. BOLT
10. CAMSHAFT GEAR
11. O-RINGS

Figure 192. Camshaft and Idle Gear

- If using an engine stand, rotate the engine so that gravity causes the tappets to drop away from the camshaft lobes.
- If using a work surface instead of an engine stand, place the engine upright on the flywheel end mounting flange.

10. Rotate the camshaft at least two turns to bump any sticking tappets away from the camshaft.

11. Slowly pull the camshaft assembly out of the engine. Be careful not to damage the front camshaft bushing. See Figure 185.

NOTE: The tappets are "mushroom" shaped and must be removed from inside the engine crankcase.

12. Remove the tappets. Mark the tappets so they can be reinstalled in the same location. See Figure 192.

13. Remove the oil pump. See Diesel lubrication system repair.

14. Remove the bolts securing the timing gear case to the engine block. See Figure 192.

15. Remove the timing gear case from the cylinder block. Thoroughly clean and remove all old sealant from the mating surfaces. See Figure 185.

16. Inspect and measure the camshaft bushing.

See Table 47 in Diesel engine specifications for service limit.

17. Remove the camshaft bushing if damaged or worn beyond service limit. See Special tools for diesel engines for appropriate tool. See Figure 192.

18. Remove O-rings. See Figure 192.

Install

1. If removed, install a new camshaft bushing using the appropriate service tool. See Special tools for diesel engines.

2. Apply a continuous bead liquid gasket to the mounting area of the gear case. Circle each bolt hole with the sealant as well.

3. Install the timing gear case to the cylinder block. Tighten the bolts to specified torque value. See Special torque chart.

NOTE: The tappets are mushroom shaped and must be installed from inside the engine crankcase.

- If using an engine stand, rotate the cylinder block so that gravity will keep the tappets in place and out of the way of the camshaft lobes when the camshaft is being installed.
- If using a work surface instead of an engine stand, place the engine upright on the flywheel end mounting flange.

4. Lubricate the tappets with clean engine oil or assembly lube. See Diesel engine specifications.

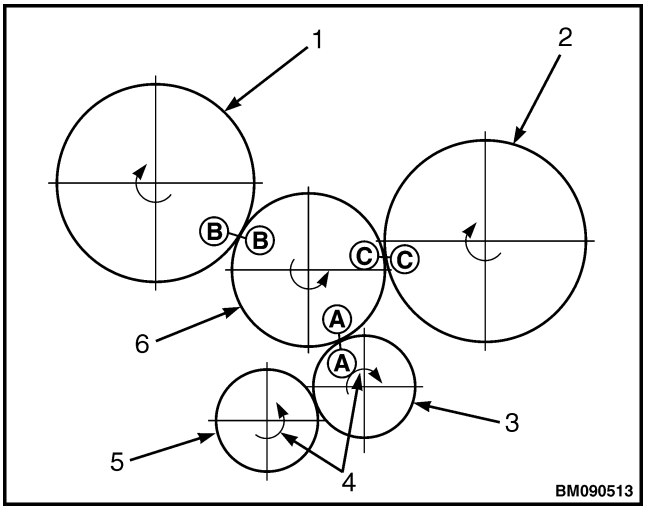
5. Install the tappets back into their position in the cylinder block. Push the tappets fully into the tappet bores so they will not interfere with the installation of the camshaft.

6. Lubricate the camshaft with clean engine oil or assembly lube. Slowly insert the camshaft through the front of the engine into the timing gear case. See Figure 192.

7. Insert the capscrews to retain the camshaft thrust plate to the timing gear case. See Figure 192. Tighten the capscrews to specified torque value. See Special torque chart.

8. Set the piston of the timing gear case side cylinder to center position. See Diesel camshaft and cylinder block repair.

9. Rotate the camshaft until the mark "C" is at approximately the 9 o'clock position and aligns with the mark on the idler gear. See Figure 193.



1. FUEL INJECTION PUMP DRIVE GEAR
2. CAMSHAFT GEAR
3. CRANKSHAFT GEAR
4. DIRECTION OF ROTATION
5. LUBRICATING OIL PUMP GEAR
6. IDLER GEAR

Figure 193. Timing gears

10. Lubricate the idler gear, idler gear bushing and idler gear shaft. See Figure 189.

11. Install the idler gear and idler gear shaft, making sure the oil hole in the bushing is facing toward the top of the engine. See Figure 189.

12. Tighten the idler gear bolts to specified torque value.

13. Align the timing gears as follows:

- Align mark "A" on the crankshaft gear with mark "A" on the idler gear.

- Align mark "B" on the fuel injection pump gear with mark "B" on the idler gear.
- Align mark "C" on the camshaft gear with mark "C" on the idler gear.

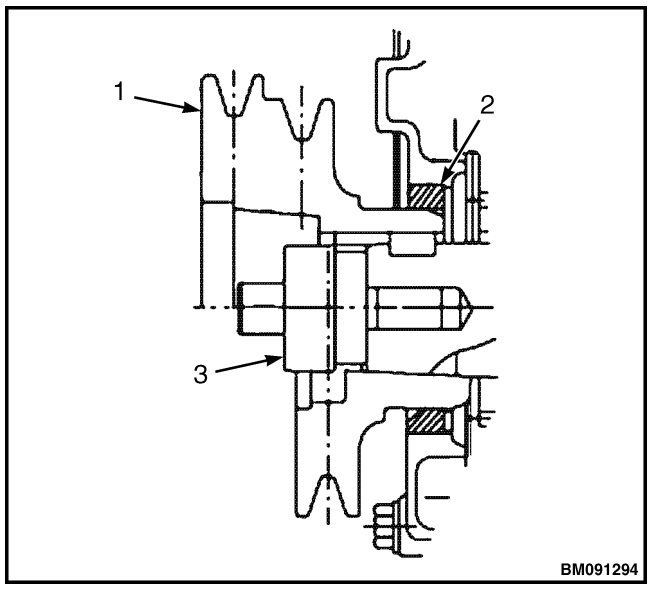
14. When all gears are properly aligned, tighten the idler gear retaining bolts to specified torque value. See Special torque chart.

15. Inspect the marks on all gears to confirm alignment.

NOTE: If you have not used a paint marker to mark gear alignment, do so prior to installing the timing gear case cover.

16. Install the timing gear case cover. See Timing gear case cover, Install.

17. Use the crankshaft pulley installation tool to reinstall the crankshaft pulley. The crankshaft pulley installation tool will guide the pulley hub and protect the front seal from damage. See Figure 194 and Special tools for diesel engines.



1. CRANKSHAFT PULLEY
2. FRONT SEAL
3. CRANKSHAFT PULLEY INSTALLATION TOOL

Figure 194. Crankshaft pulley installation tool

18. Insert the washer and bolt to retain the crankshaft pulley and spacer. See Figure 184. Tighten the bolt to specified torque value. See Diesel engine specifications.

19. Install the water pump, V-belt and coolant fan. See **Cooling system** 0700SRM2300 service manual.

20. Install the engine. See Diesel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

21. Fill the engine oil to the correct level. See **Periodic Maintenance** 8000SRM2305 **Periodic Maintenance** 8000SRM2305 for correct oil amount and type.

22. Follow the procedure for priming the fuel system. See **Periodic Maintenance** 8000SRM2305 **Periodic Maintenance** 8000SRM2305 for the procedures.

23. Start the engine and check for leaks.

DIESEL CAMSHAFT AND CYLINDER BLOCK REPAIR 202001-358

REMOVE ENGINE COMPONENTS

1. Remove the engine. See Diesel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.
2. Remove the starter. See Diesel electrical system repair.
3. Remove the flywheel and flywheel housing. See Diesel flywheel repair.
4. Remove the alternator. See Diesel electrical system repair.
5. Remove the water pump. See **Water Pump Repair** in the **Cooling system** 0700SRM2300 service manual.
6. Remove the fuel injection pump. See Diesel fuel system repair.
7. Remove the cylinder head. See Diesel cylinder head repair.
8. Remove the oil pan. Remove the oil suction tube. See Diesel lubrication system repair.
9. Remove the timing gear case cover. See Diesel timing gear case repair.
10. Remove the oil pump. See Diesel lubrication system repair.

NOTE: Do not remove the camshaft gear at this time.

11. Before removing the camshaft, check the camshaft end play. See Diesel timing gear case repair.

DISASSEMBLE

Pistons and connecting rods

NOTE: Keep the piston pin parts, piston assemblies, and connecting rod assemblies together and label all parts, to ensure all parts are returned to the same position during the reassembly process. Note the location of each bearing cap and make sure to not mix up bearing caps during installation.

NOTE: Engines with high operating hours may have a ridge near the top of the cylinders that will catch the piston rings and make it impossible to remove the pistons. Use a suitable ridge reamer to remove ridges and carbon prior to removing the pistons.

NOTE: Pistons can fall from cylinder block if the engine is inverted. Rotate the engine so the connecting rods are horizontal before removing the connecting rod caps.

1. Use a feeler gauge to measure the connecting rod thrust clearance. See Figure 195. Refer to Diesel engine specifications for the standard limit. If the measurement is out of specification, replace the crankshaft, connecting rod, or both.

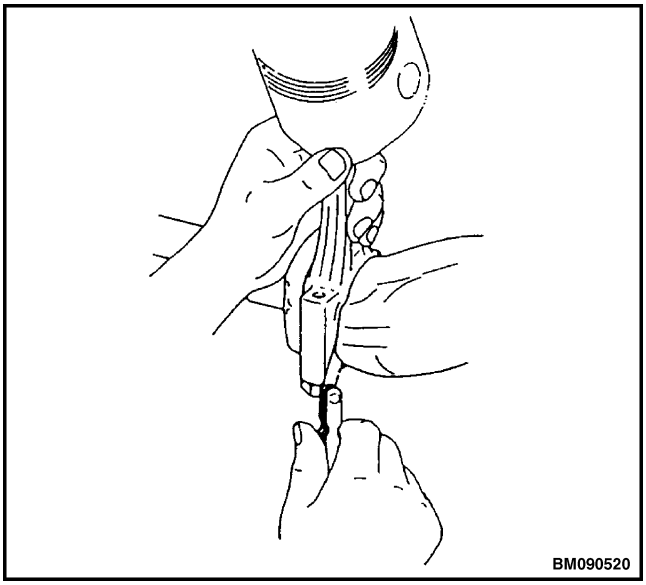
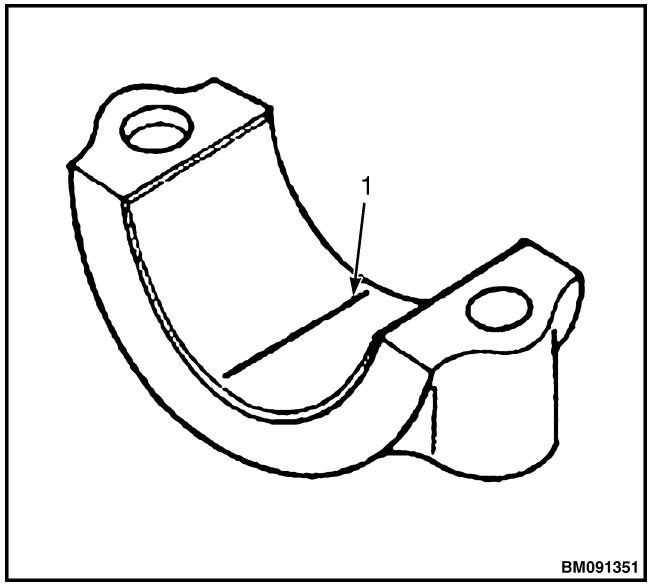


Figure 195. Connecting rod thrust clearance

2. Measure bearing oil clearance prior to removing the pistons and connecting rods to determine extent of wear. Record the measurements.
   a. Remove the bearing cap. Do not remove the bearings at this time.
   b. Wipe oil from the bearing and crankshaft surfaces.

c. Place a piece of PLASTIGAUGE® along the full width of the bearing (see Figure 196). Do not rotate the crankshaft when using PLASTIGAUGE. A false reading may result.



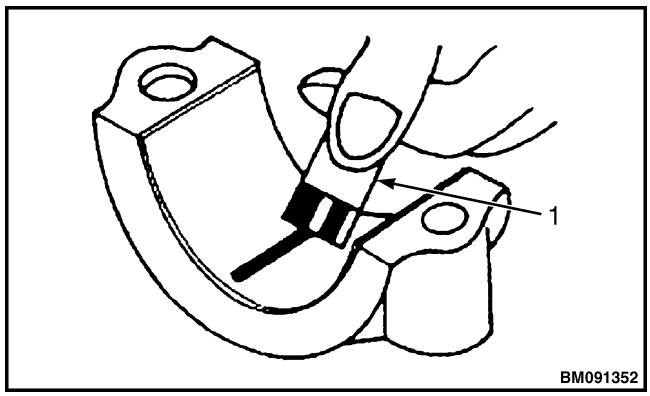
1. PLASTIGAUGE

Figure 196. PLASTIGAUGE placement

d. Reinstall the bearing cap and tighten to 96.0-100 N•m (70.8-73.8 lbf ft).

e. Remove the bearing cap.

f. Compare the width of the flattened PLASTIGAUGE to the graduation marks on the package (see Figure 197). The mark that most closely matches the width of the flattened PLASTIGAUGE will indicate the bearing oil clearance.



1. PLASTIGAUGE

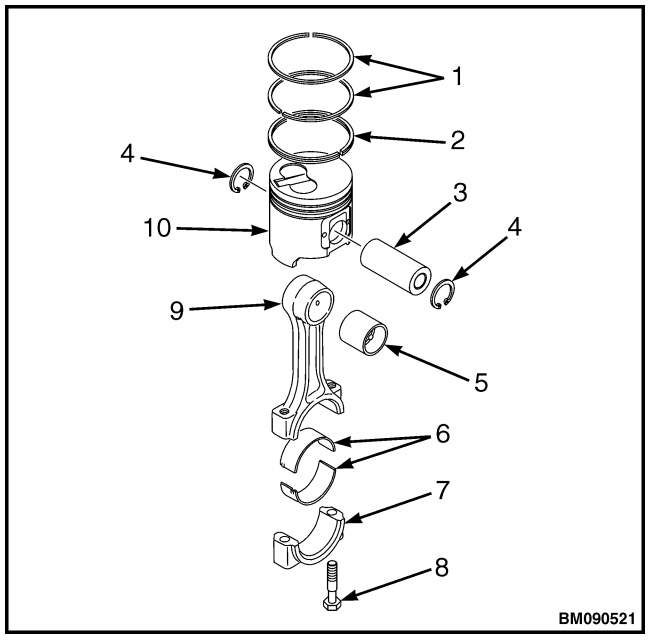
Figure 197. Graduation marks

g. Repeat with each remaining connecting rod.

3. Mark the piston, connecting rod assembly and cylinder, to aid in reinstallation. Use a wooden dowel against the connecting rod and tap the piston and connecting rod assembly out of the cylinder.

4. Mark the cylinder number on the piston and the connecting rod. See Figure 198.

5. Remove the bearings. See Figure 198.



1. COMPRESSION RINGS
2. OIL SEAL RING
3. WRIST PIN
4. SNAP RING
5. WRIST PIN BUSHING
6. BEARINGS
7. CONNECTING ROD CAP
8. BOLT
9. CONNECTING ROD
10. PISTON

Figure 198. Piston and Connecting Rod

6. Use a piston ring expander to remove the two compression rings from the piston. See Figure 198. Refer to Special tools for diesel engines for appropriate tool.

7. Use the piston ring expander to remove the oil seal ring from the piston. See Figure 198. See Diesel engine specifications for appropriate tool.

8. Remove the snap ring from the wrist pin. See Figure 198.

9. Remove the wrist pin and connecting rod from the piston. See Figure 198.

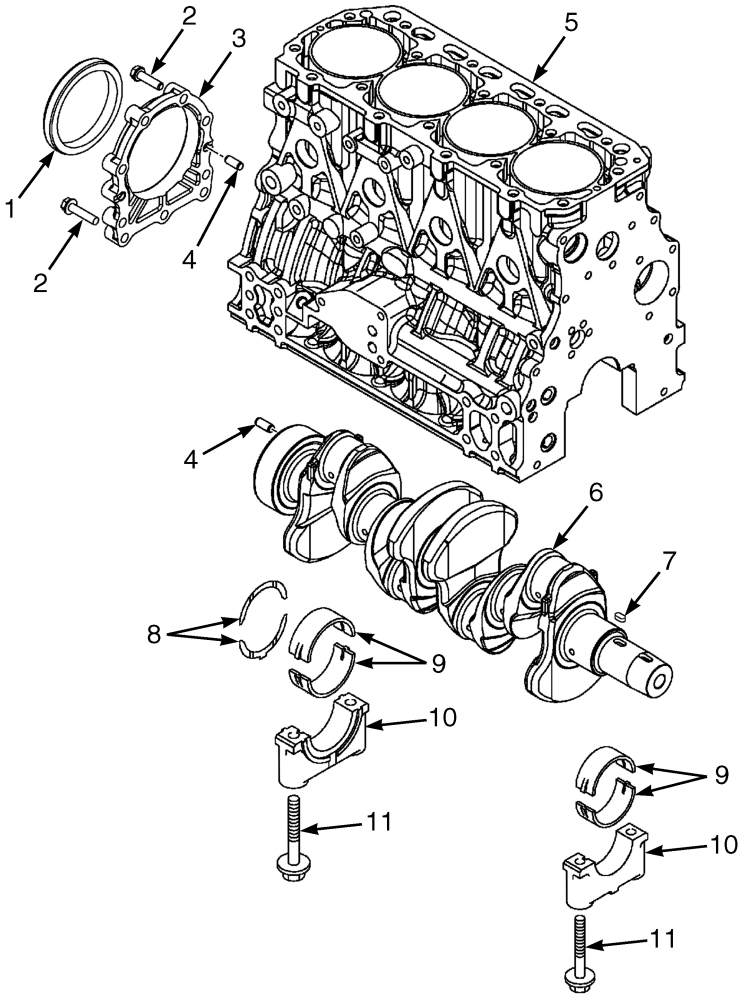
10. Repeat Step 5 through Step 9 for the remaining pistons and piston rods.

REMOVE

Crankshaft

1. Remove the flywheel. See Diesel flywheel repair.

2. Remove the bolts retaining the rear oil seal assembly and remove the rear oil seal assembly. See Figure 199.



1. REAR OIL SEAL
2. BOLT
3. REAR OIL SEAL HOUSING
4. PARALLEL PIN
5. CYLINDER BLOCK
6. CRANKSHAFT
7. KEY
8. THRUST BEARING
9. MAIN BEARINGS
10. MAIN BEARING CAP
11. BOLT

Figure 199. Crankshaft

3. If the rear oil seal is worn or damaged, remove the rear oil seal.

4. Measure the crankshaft thrust end play using one of the following two methods:

   a. Install a dial gauge on the cylinder block. Move the crankshaft in and out to measure the end play. Record the measurement. See Figure 200.

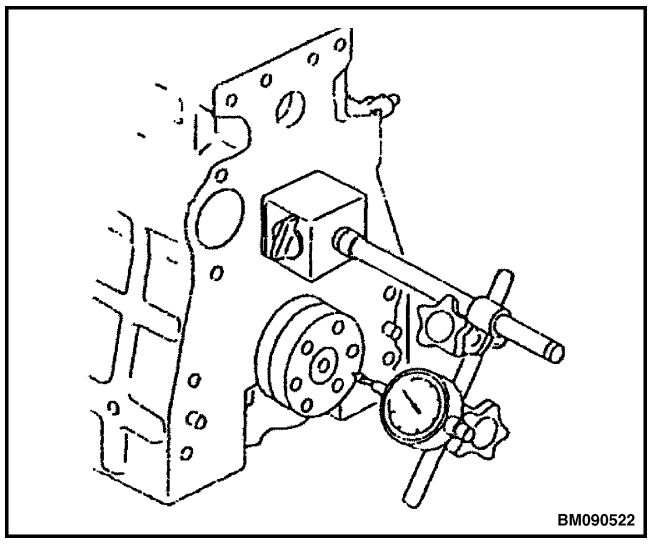
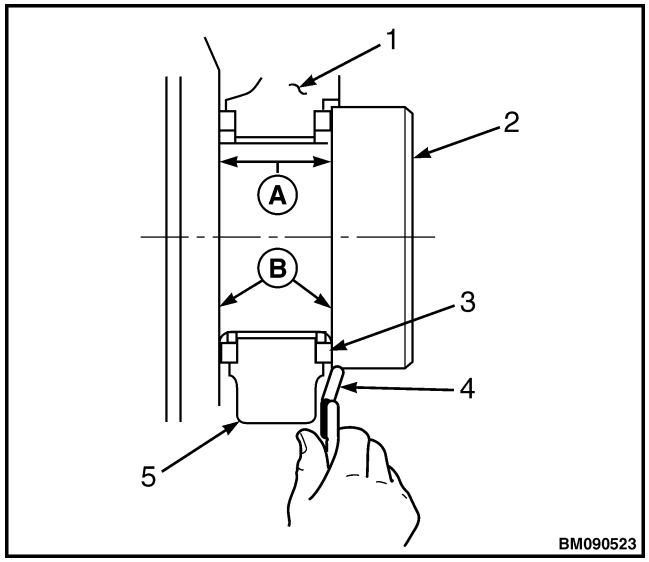


Figure 200. Crankshaft end play measurement with dial gauge

   b. Use a feeler gauge to measure the clearance between the thrust bearing and the crankshaft. See Figure 201.



A. STANDARD WIDTH
B. THRUST FACE

1. CYLINDER BLOCK
2. CRANKSHAFT
3. THRUST BEARING
4. SHIM GAUGE
5. CYLINDER BLOCK

Figure 201. Crankshaft side gap measurement with feeler gauge

NOTE: Be sure to note the markings on the main bearing caps, or mark them yourself, so they can be reinstalled in the same location as they were removed.

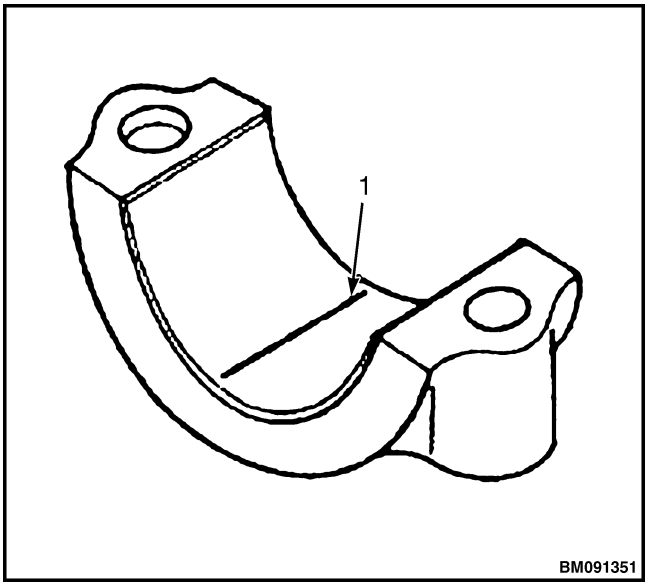
NOTE: The arrows on the main bearing caps point to the flywheel end of the engine.

5. Remove the bolts retaining the main bearing caps and remove the main bearing caps. Do not remove the bearings at this time.

6. Measure bearing oil clearance prior to removing the **crankshaft** to determine the extent of wear. Record the measurement.

   a. Wipe oil from the bearing and crankshaft surfaces.

   b. Place a piece of PLASTIGAUGE® along the full width of the bearing (see Figure 202). Do not rotate the crankshaft when using PLASTIGAUGE. A false reading may result.



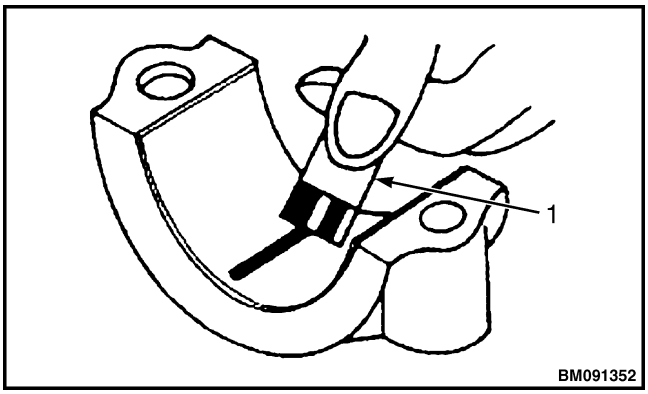
1. PLASTIGAUGE

Figure 202. PLASTIGAUGE placement

c. Reinstall bearing cap and torque to 96.0-100 N•m (70.8-73.8 lbf ft).

d. Remove the bearing cap.

e. Compare the width of the flattened PLASTIGAUGE to the graduation marks on the package (see Figure 203). The mark that most closely matches the width of the flattened PLASTIGAUGE will indicate the bearing oil clearance.



1. PLASTIGAUGE

Figure 203. Graduation marks

7. Remove the crankshaft from the engine.

CAUTION

Do not remove the crankshaft gear unless the gear or crankshaft are damaged and require replacement.

8. Remove the bearings and thrust bearings.

9. If necessary, remove the crankshaft, parallel pin, and key. If using a gear puller, be careful not to damage threads in the end of the crankshaft. See Figure 199.

INSPECT

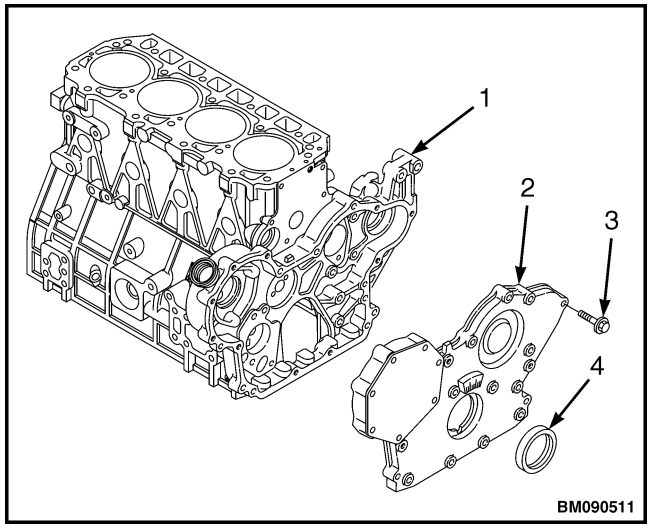
DANGER

Always read and follow safety related precautions found on the containers of hazardous substances like parts cleaners, primers, sealants and sealant removers. Failure to comply could result in death or serious injury.

Thoroughly clean all components using a brush and appropriate solvent such as brake cleaner or laquer thinner. Each part must be free of carbon, gasket material, metal filings and other debris.

Crankshaft oil seals

1. Remove the front oil seal from the timing gear case cover. See Figure 204.

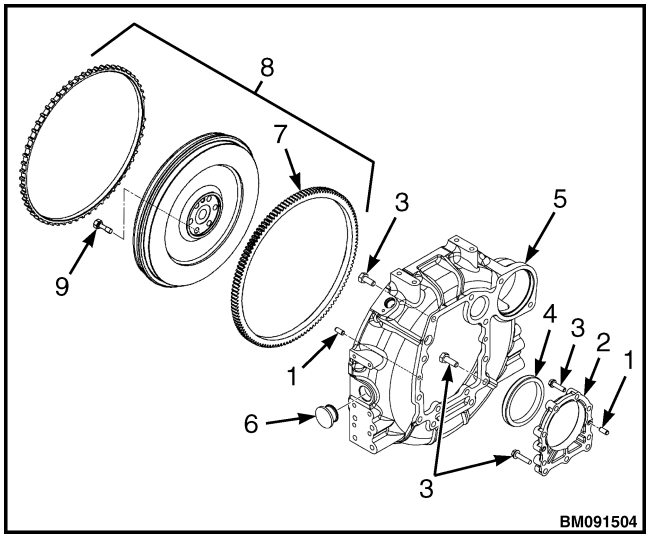


1. TIMING GEAR CASE
2. TIMING GEAR CASE COVER
3. BOLT
4. FRONT OIL SEAL

Figure 204. Gear Housing

2. Apply a continuous bead of liquid gasket to the outside diameter of a new front oil seal and install in the timing gear case cover. Apply lithium grease to the lip of the seal.

3. Remove the rear oil seal from the seal housing. See Figure 205.



1. PIN
2. OIL SEAL CASE
3. BOLT
4. OIL SEAL
5. FLYWHEEL HOUSING
6. WHEEL COVER CAP
7. FLYWHEEL GEAR
8. FLYWHEEL ASSEMBLY
9. FLYWHEEL BOLT

Figure 205. Flywheel and Housing

4. Apply a continuous bead of liquid gasket to the outside diameter of a new oil seal and install in the housing. Apply lithium grease to the lip of the seal.

5. Measure crankshaft bearing oil clearance during disassembly to determine the extent of wear. Measure during assembly to ensure long engine life. Follow this procedure also for connecting rods and main bearings.

Cylinder Block

1. Verify that oil passages are clear and unobstructed. Clear any oil passages as needed.

2. Check for discoloration or evidence of cracks. If evidence of a fracture is found, use the color check method or spray the cylinder block with Magnaflux to determine if the cylinder block is fractured.

3. Inspect the cylinder roundness and cylindricity for evidence of distortions. Collect and record the measurements. See Figure 206 and Table 56.

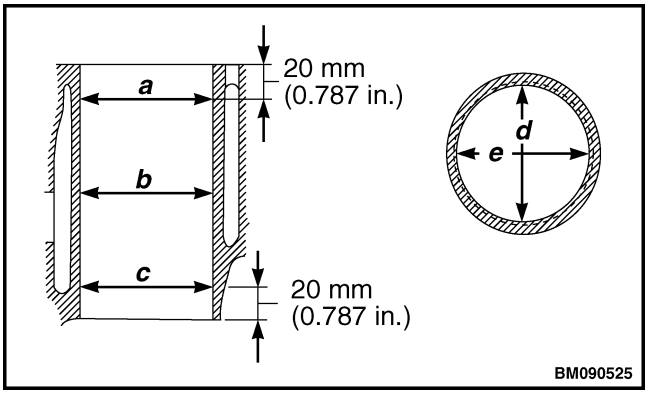


Figure 206. Cylinder measurement points

4. Perform the calculations as follows:

NOTE: The cylinders are numbered in order starting from the fan side of the engine.

a. Measure the inside diameter of cylinder number one near the top of the cylinder (**a**) and in the (**d**) direction. Record that measurement as data **f**.

b. Measure the inside diameter of cylinder number one, near the top of the cylinder (**a**) and in the (**e**) direction. Record that measurement as data **g**.

c. Measure the inside diameter of cylinder number one, near the center of the cylinder (**b**) and in the (**d**) direction. Record that measurement as data **h**.

d. Measure the inside diameter of cylinder number one, near the center of the cylinder (**b**) and in the (**e**) direction. Record that measurement as data **I**.

e. Measure the inside diameter of cylinder number one, near the bottom of the cylinder (**c**) and in the (**d**) direction. Record that measurement as data **j**.

f. Measure the inside diameter of cylinder number one, near the bottom of the cylinder (**c**) and in the (**e**) direction. Record that measurement as data **k**.

g. **Roundness**: Roundness for cylinder number one is calculated as follows:

f - g = X

h - I = Y

j - k = Z

X is the difference between the **f** and **g** measurements at the top of the cylinder.

Y is the difference between the **h** and **I** measurements at the center/middle of the cylinder.

Z is the difference between the **j** and **k** measurements at the bottom of the cylinder.

Select the greatest of values **X**, **Y** and **Z**, then record it as **V**. This value represents the roundness of the cylinder.

h. **Cylindricity** - Cylindricity for cylinder number one is calculated as follows:

Select the least value of values **X**, **Y** and **Z** record that value as **S**. Complete the calculation as follows:

V - S =W

W is the difference between the **V** and **S** measurements. This value represents the cylindricity of the cylinder.

5. Repeat the cylindricity and roundness measurements and calculations for the remaining cylinders.

6. Compare the worksheet findings with the specifications listed in Diesel engine specifications.

7. Consider honing, re-boring, or replacing the cylinder block if the measurements fall outside the specifications.

Table 56. Cylinder Measurement Worksheet

Cylinder Number	Measurements			Calculated Values	
Cylinder #1	Top (***a***)	Dimension (***d***) ***f*** = _____	Dimension (***e***) ***g*** = _____	***f*** - ***g*** = ***X*** ***X*** = _____	Greatest of ***X***, ***Y*** and ***Z*** = ***V*** Roundness ***V*** = _____
	Center (***b***)	Dimension (***d***) ***h*** = _____	Dimension (***e***) ***I*** = _____	***h*** - ***I*** = ***Y*** ***Y*** = _____	Least of ***X***, ***Y*** and ***Z*** = ***S*** ***S*** = _____
	Bottom (***c***)	Dimension (***d***) ***j*** = _____	Dimension (***e***) ***k*** = _____	***j*** - ***k*** = ***Z*** ***Z*** = _____	***V*** - ***S*** = ***W*** Cylindricity ***V*** = _____
Cylinder #2	Top (***a***)	Dimension (***d***) ***f*** = _____	Dimension (***e***) ***g*** = _____	***f*** - ***g*** = ***X*** ***X*** = _____	Greatest of ***X***, ***Y*** and ***Z*** = ***V*** Roundness ***V*** = _____
	Center (***b***)	Dimension (***d***) ***h*** = _____	Dimension (***e***) ***I*** = _____	***h*** - ***I*** = ***Y*** ***Y*** = _____	Least of ***X***, ***Y*** and ***Z*** = ***S*** ***S*** = _____
	Bottom (***c***)	Dimension (***d***) ***j*** = _____	Dimension (***e***) ***k*** = _____	***j*** - ***k*** = ***Z*** ***Z*** = _____	***V*** - ***S*** = ***W*** Cylindricity ***V*** = _____
Cylinder #3	Top (***a***)	Dimension (***d***) ***f*** = _____	Dimension (***e***) ***g*** = _____	***f*** - ***g*** = ***X*** ***X*** = _____	Greatest of ***X***, ***Y*** and ***Z*** = ***V*** Roundness ***V*** = _____
	Center (***b***)	Dimension (***d***) ***h*** = _____	Dimension (***e***) ***I*** = _____	***h*** - ***I*** = ***Y*** ***Y*** = _____	Least of ***X***, ***Y*** and ***Z*** = ***S*** ***S*** = _____
	Bottom (***c***)	Dimension (***d***) ***j*** = _____	Dimension (***e***) ***k*** = _____	***j*** - ***k*** = ***Z*** ***Z*** = _____	***V*** - ***S*** = ***W*** Cylindricity ***V*** = _____
Cylinder #4 (As Needed)	Top (***a***)	Dimension (***d***) ***f*** = _____	Dimension (***e***) ***g*** = _____	***f*** - ***g*** = ***X*** ***X*** = _____	Greatest of ***X***, ***Y*** and ***Z*** = ***V*** Roundness ***V*** = _____
	Center (***b***)	Dimension (***d***) ***h*** = _____	Dimension (***e***) ***I*** = _____	***h*** - ***I*** = ***Y*** ***Y*** = _____	Least of ***X***, ***Y*** and ***Z*** = ***S*** ***S*** = _____
	Bottom (***c***)	Dimension (***d***) ***j*** = _____	Dimension (***e***) ***k*** = _____	***j*** - ***k*** = ***Z*** ***Z*** = _____	***V*** - ***S*** = ***W*** Cylindricity ***V*** = _____

Honing and Boring

Pistons must move freely in the cylinders while maintaining adequate compression and oil sealing. If the cylinder walls are scuffed, scored, out of round, or have poor cylindricity, honing or boring and honing might correct cylinder problems. Re-boring is necessary if the bore dimensions fall outside specified limits. Honing must follow any re-boring operations. Slight imperfections can be corrected by honing alone.

1. **Boring** - Significant cylinder damage might be corrected by re-boring.
   - Boring out a cylinder block can only be done in a properly equipped machine shop.
   - After re-boring, existing pistons must be replaced. See **Parts manual** for correct part information.
   - After re-boring a cylinder block, each cylinder must be honed.

2. **Honing** - Slight cylinder imperfections might be corrected by honing.

   a. Insert the appropriate honing tool into the chuck of an electric drill.

   b. Saturate the cylinder wall with solvent using a 50% diesel fuel and 50% engine oil mixture.

   c. Rotate the honing tool at 300 to 1200 rpm.

CAUTION

DO NOT allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.

NOTE: Tilt the honing tool at a 30 to 40 degree angle during the honing operation, to leave a cross hatch mark on the cylinder wall. See Figure 207.

   d. Insert the rotating honing tool into the cylinder and move it down through the entire length of the cylinder in a five-second motion. See Figure 208.

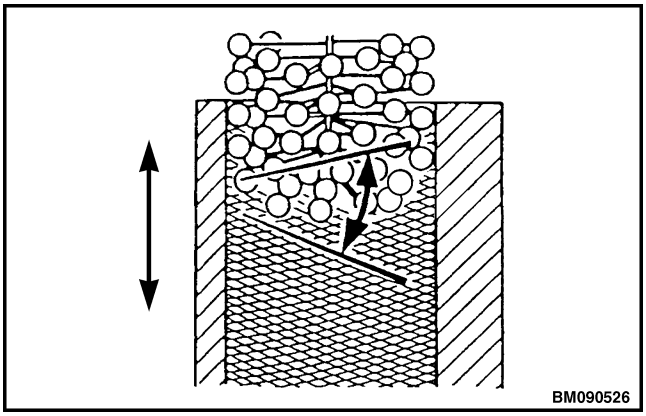


Figure 207. Cylinder honing angle

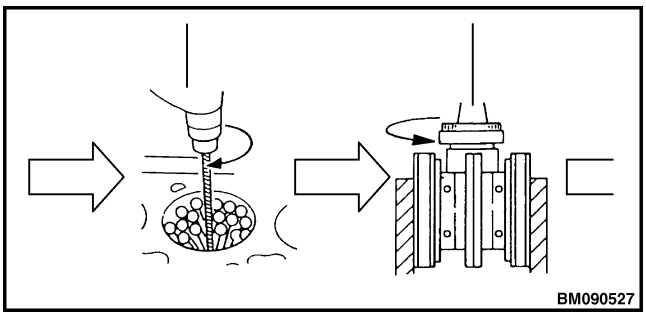


Figure 208. Cylinder honing

   e. Without stopping the honing tool, pull it up through the entire length of the cylinder in a five-second motion.

   f. Maintain the up-and-down motion for 30 to 40 seconds.

WARNING

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

   g. When the honing is completed, wash the cylinder block with hot water and soap. Use brushes to clean all passages and crevices. Rinse with hot water and blow dry with compressed air. Apply clean engine oil to all steel surfaces to prevent rusting.

Pistons

NOTE: On an engine with low hours, the pistons and piston rings may be reused if they are found to be within specifications. The piston and piston rings must be reinstalled in the same cylinders from which they were originally removed.

On an engine with high hours, the piston rings should be replaced and the cylinder honed or replaced (see Honing and Boring). The piston should be replaced as necessary.

1. Use a piston ring groove cleaning tool to clean the piston ring grooves. See Special tools for diesel engines and follow manufacturer's instructions for correct operation.

2. Wash the pistons in an appropriate solvent using a soft brush.

3. Visually inspect each piston for cracks. Pay particular attention to between the piston ring grooves.

4. Use a micrometer to measure the diameter of the piston skirt at 90° to the wrist pin bore as shown in Figure 209. Refer to the Diesel engine specifications for the service limit.

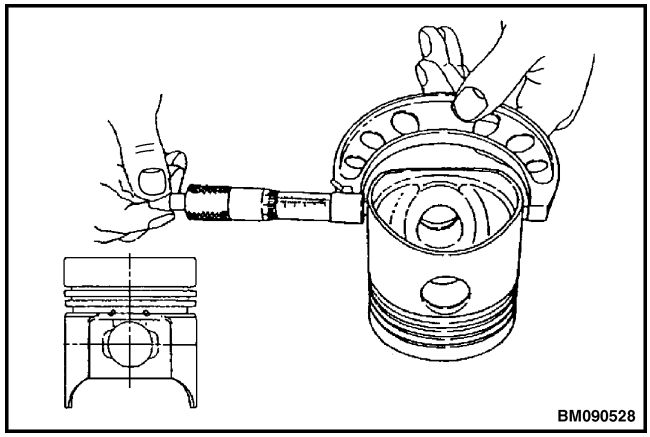


Figure 209. Piston skirt measurement

5. Subtract the piston measurement from the greatest measurement acquired during cylinder inspection to obtain piston-to-cylinder clearance. See Diesel engine specifications. Record the measurements.

6. Measure the diameter of the wrist pin bore on both sides of the piston. See Figure 210. Refer to Diesel engine specifications. Record the measurements.

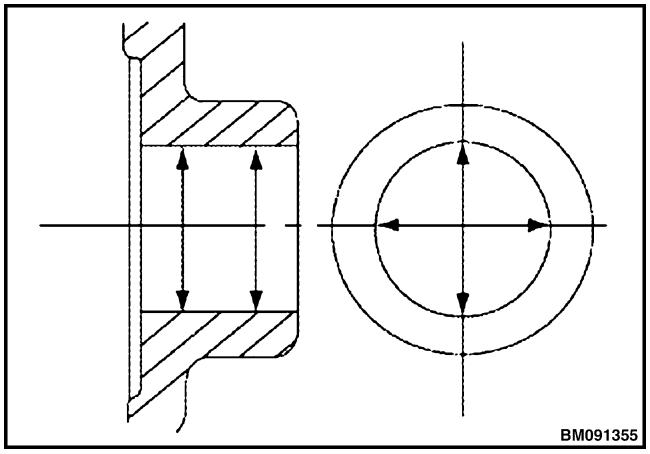


Figure 210. Diameter

7. Measure the outside diameter of the wrist pin in three places and at 90°. See Figure 211. Refer to Diesel engine specifications. Record the measurements.

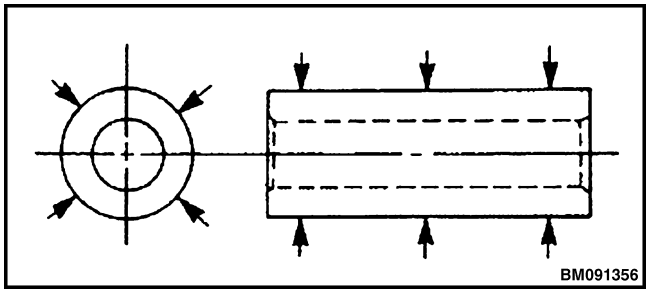
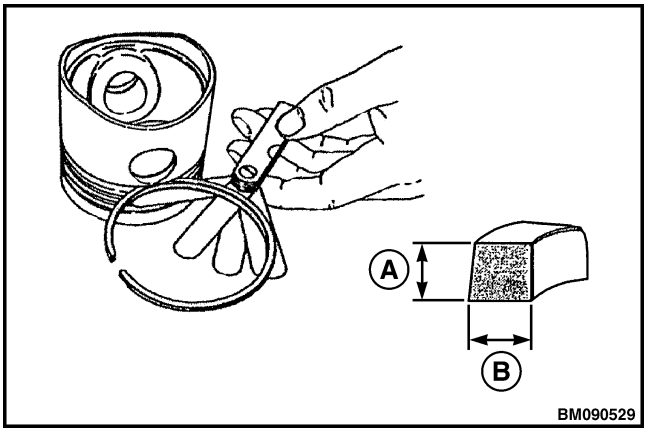


Figure 211. Outside diameter

8. Measure the piston ring and the piston ring groove for cylinder number one.

   a. Use a micrometer to measure the thickness of the top compression ring. Refer to the Diesel engine specifications for the service limit. Record the measurement.

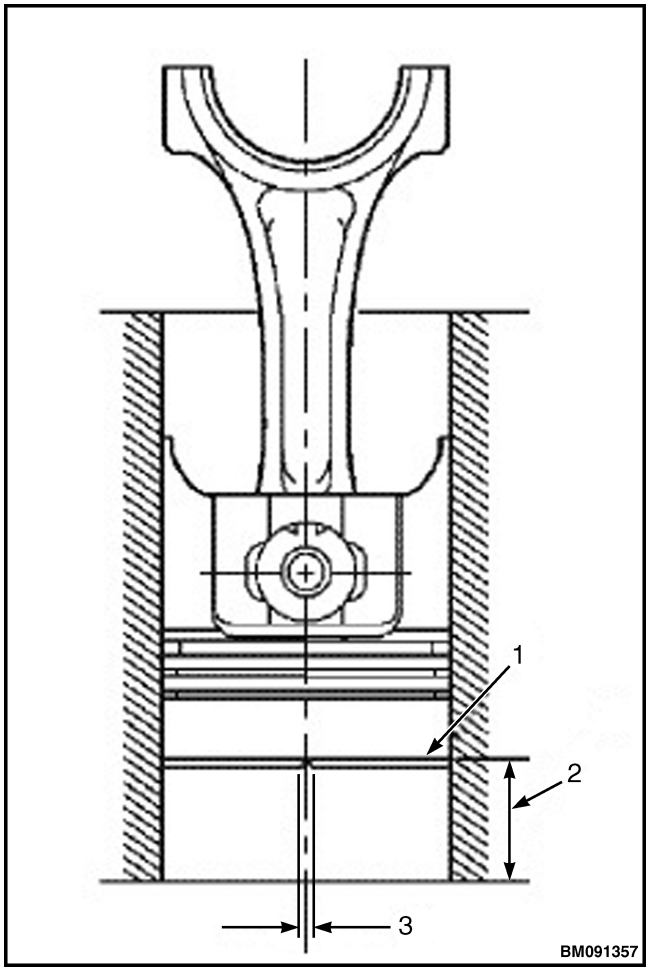
   b. Place each compression ring in the groove as shown in Figure 212. Use a feeler gauge to measure the gap between the ring and the piston. Record the measurement. Refer to the Diesel engine specifications for the service limit. Replace the piston if not within specification.



A. WIDTH
B. THICKNESS

Figure 212. Piston and piston ring groove clearance

9. To measure piston ring end gap, insert each compression ring, one at a time, into the cylinder (see, Figure 213). Use a piston with the piston rings removed to slide the ring into the cylinder bore until it is approximately 30 mm (1.18 in.) from the bottom of the bore. Remove the piston. Measure the end gap of each piston ring. Record the measurements. See Diesel engine specifications.



1. COMPRESSION PISTON RING
2. APPROX 30 MM
3. END GAP

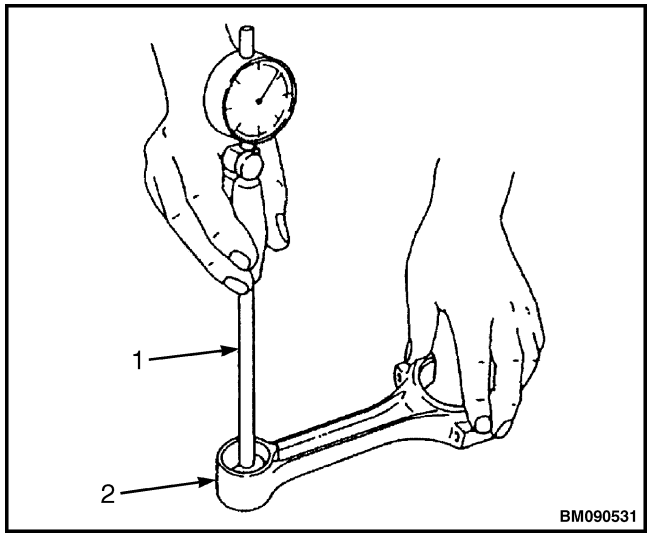
Figure 213. Piston and cylinder bore

NOTE: Always check the piston ring end gap when installing new piston rings. See Diesel engine specifications. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.

10. Repeat Step 8 for each of the pistons.

Connecting Rod

1. Use a bore gauge to measure the wrist pin bushing bore. Replace the bushing if not within specifications. If the bushing has been removed, measure the inside diameter of the connecting rod small end. Refer to the Diesel engine specifications for the service limit. See Figure 214.



1. CYLINDER GAUGE
2. CONNECTING ROD SMALL END

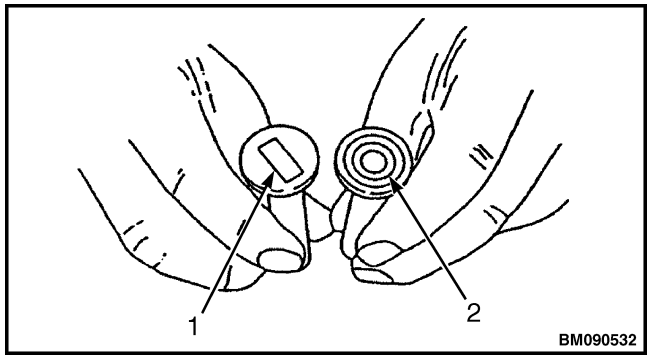
Figure 214. Connecting rod small end

2. Measure the crankpin and connecting rod bearings. Place the connecting rod bearings into the connecting rod and connecting rod cap. Install the end of the connecting rod to the connecting rod cap. Install the bolts and tighten to 54 to 59 N•m (40 to 44 lbf ft).

3. Measure the inside diameter. Refer to Diesel engine specifications for the service limit.

Tappets

1. Check the tappet contact surfaces for abnormal wear. Slight surface defects can be corrected using an oilstone. See Figure 215.



1. ABNORMAL CONTACT SURFACE
2. NORMAL CONTACT SURFACE

Figure 215. Tappet contact surface

2. Measure the outside diameter of the tappet stem. Refer to Diesel engine specifications for the service limit. See Figure 216.

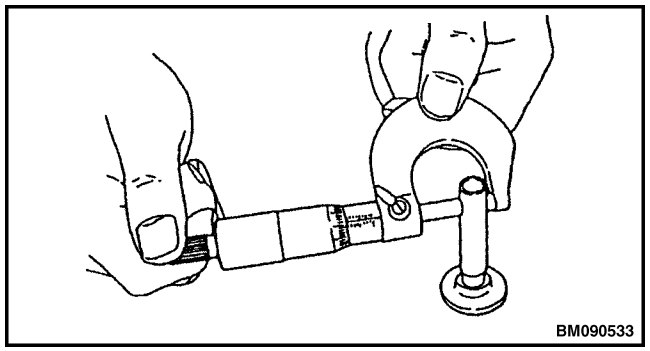
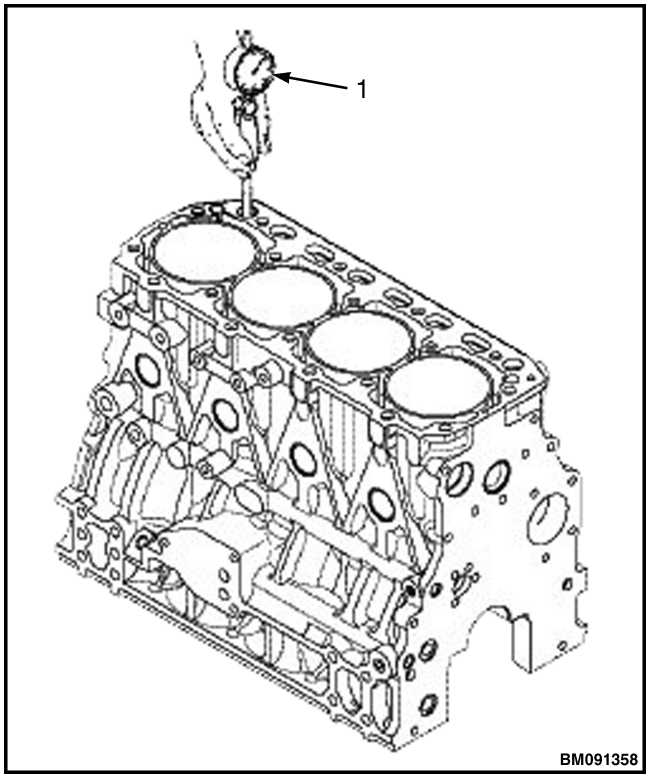


Figure 216. Tappet stem measurement

3. Use a cylinder gauge to measure the tappet bore. See Figure 217.



1. CYLINDER GAUGE

Figure 217. Measure tappet bore

Crankshaft

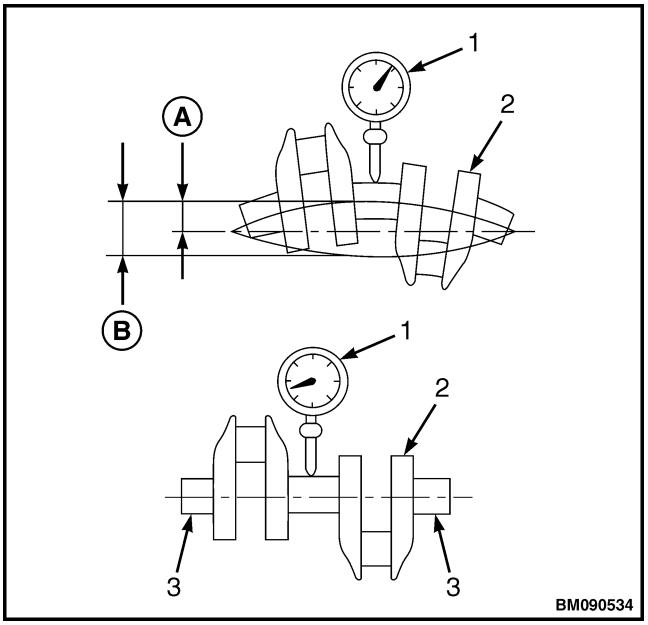
1. Measure the trueness of the crankshaft.

   a. Place the crankshaft on V-blocks at the end journals. See Figure 218.

   b. Place a dial indicator on a main bearing surface and zero the gauge.

   c. Rotate the crankshaft and observe the run out. Refer to the Diesel engine specifications for the service limit.

   d. Repeat this procedure for the remaining bearing surfaces.



A. BEND
B. DEFLECTION

1. DIAL GAUGE
2. CRANKSHAFT
3. V-BLOCK

Figure 218. Crankshaft bend measurement

2. Inspect the crankshaft for fractures.

   a. Use the color check method to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures are found. See Figure 219.

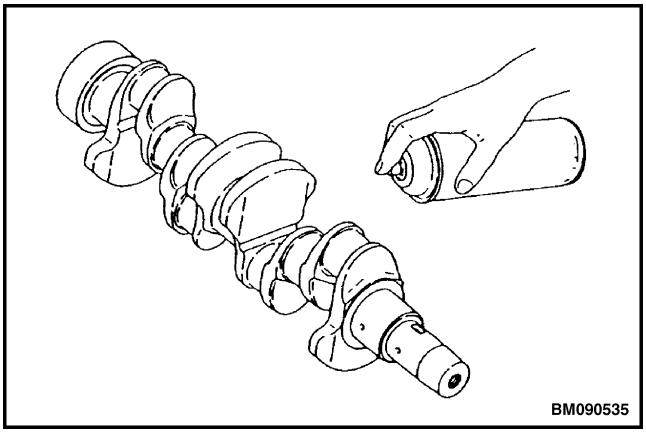


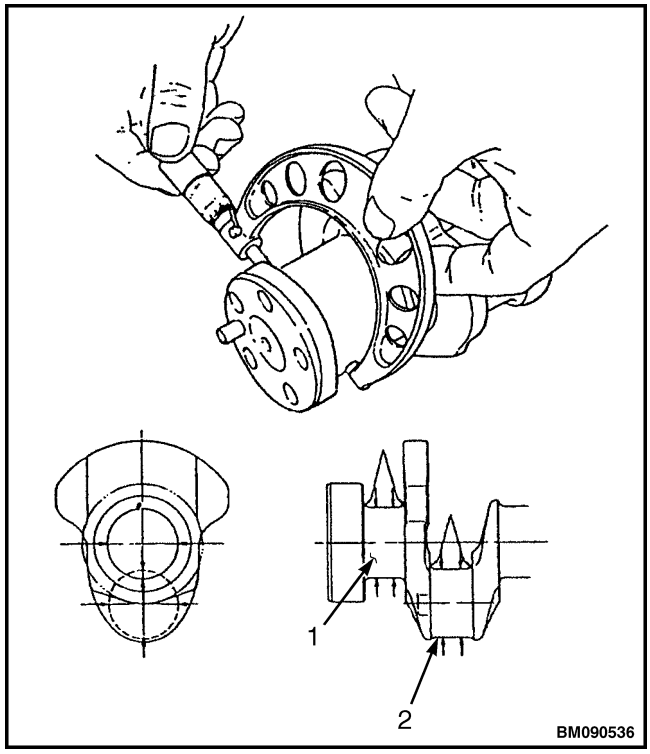
Figure 219. Crankshaft fracture check

   b. If the color check method is not available, spray Magnaflux on the crankshaft to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures are found.

3. Measure the outside diameter of each crankpin and main bearing journal. See Figure 220.

   a. If the crankpin clearance exceeds the service limit, use an undersized bearing. Refer to the Diesel engine specifications for the service limit.

   b. If the journal clearance exceeds the service limit, use an undersized bearing. Refer to the Diesel engine specifications for the service limit.



1. CRANKSHAFT JOURNAL
2. CRANKPIN

Figure 220. Crankpin and crankshaft journal measurement

Camshaft

1. Measure the trueness of the camshaft.

a. Place the camshaft on V-blocks positioned at the end journals. See Figure 221.

b. Place a dial indicator on the gear side bearing surface and set the gauge to zero.

c. Rotate the camshaft and observe the run out. Refer to the Diesel engine specifications for the service limit.

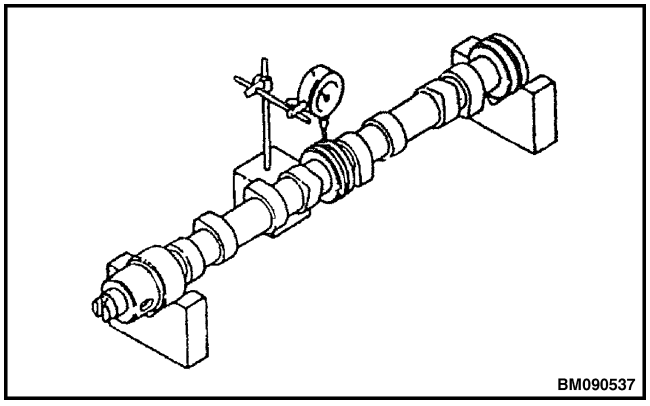
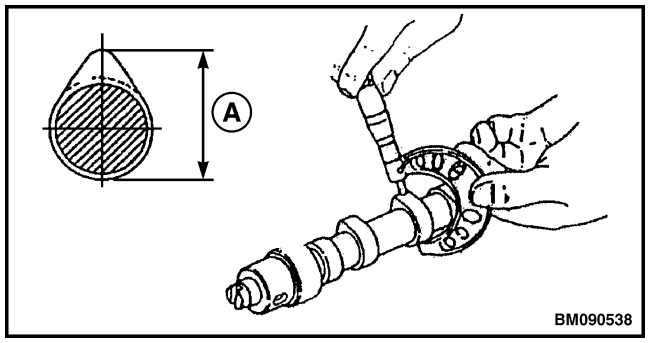


Figure 221. Camshaft Run out Check

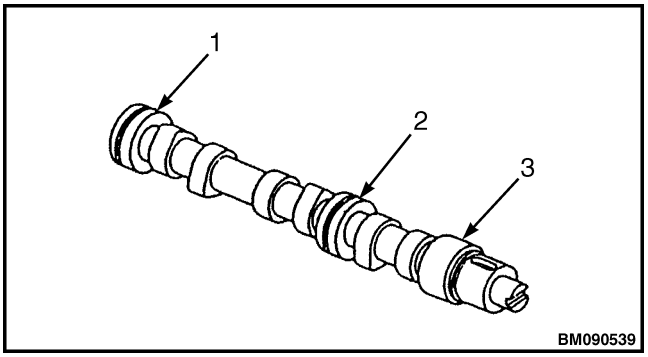
2. Measure the intake/exhaust cam lobe height. Refer to the Diesel engine specifications for the service limit. See Figure 222.



A. CAM HEIGHT

Figure 222. Intake/Exhaust Cam Lobe Height Measurement

3. Measure the gear end bearing surface, intermediate position bearing surface, and flywheel end bearing surface diameters. See Figure 223. Determine the oil clearance. The oil clearance is calculated by subtracting the measured camshaft bearing surface diameter from the camshaft bushing inside diameter. Refer to the Diesel engine specifications for the service limit.



1. FLYWHEEL END BEARING SURFACE
2. INTERMEDIATE POSITION BEARING SURFACE
3. GEAR END BEARING SURFACE

Figure 223. Camshaft Bearing Surface Measurements

Camshaft bushing and bores

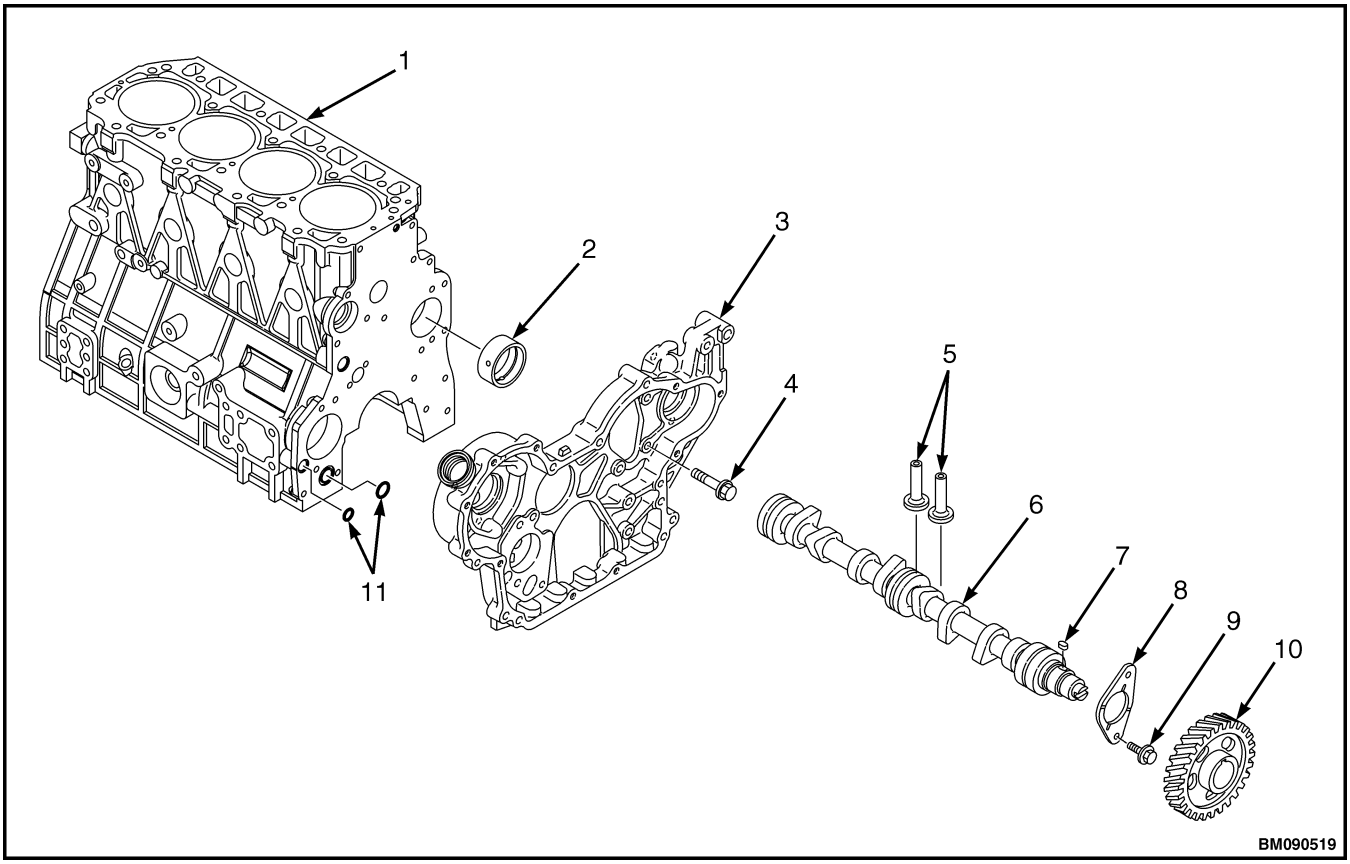
1. Measure the inside diameter of the front bushing and the remaining bores in the cylinders block. Refer to Table 47 in Diesel engine specifications.

2. If the camshaft bushing is not within specification, replace it using the appropriate service tool. If the remaining bores are not within specification, the cylinder block will require replacement as there are no alternative bearings available to correct the bearing to camshaft journal oil clearance specification.

Idler gear and shaft

1. Measure the outside diameter of each idler gear shaft. See Figure 224. Refer to Diesel engine specifications.

2. Measure the inside diameter of each idler gear bushing. See Figure 224. Refer to Diesel engine specifications.



1. CYLINDER BLOCK
2. CAMSHAFT BUSHING
3. TIMING GEAR CASE
4. BOLT
5. TAPPETS
6. CAMSHAFT
7. KEY
8. THRUST PLATE
9. BOLT
10. CAMSHAFT GEAR
11. O-RINGS

Figure 224. Idler Gear and Camshaft

ASSEMBLE

Camshaft

1. Verify that all parts are clean. Lightly lubricate all parts with clean engine oil.

2. If removed, install new camshaft bushing.

3. Install the timing gear case. See Diesel timing gear case repair.

NOTE: Rotate the cylinder block into a position in which it allows gravity to keep the tappets in place and out of the way of the camshaft lobes for when the camshaft is installed.

4. Install the tappets into the cylinder block in the same locations as they were removed.

5. Slowly insert the camshaft through the front of the engine. See Figure 224.

6. Place the camshaft thrust plate in position and install the retaining bolts. See Figure 224.

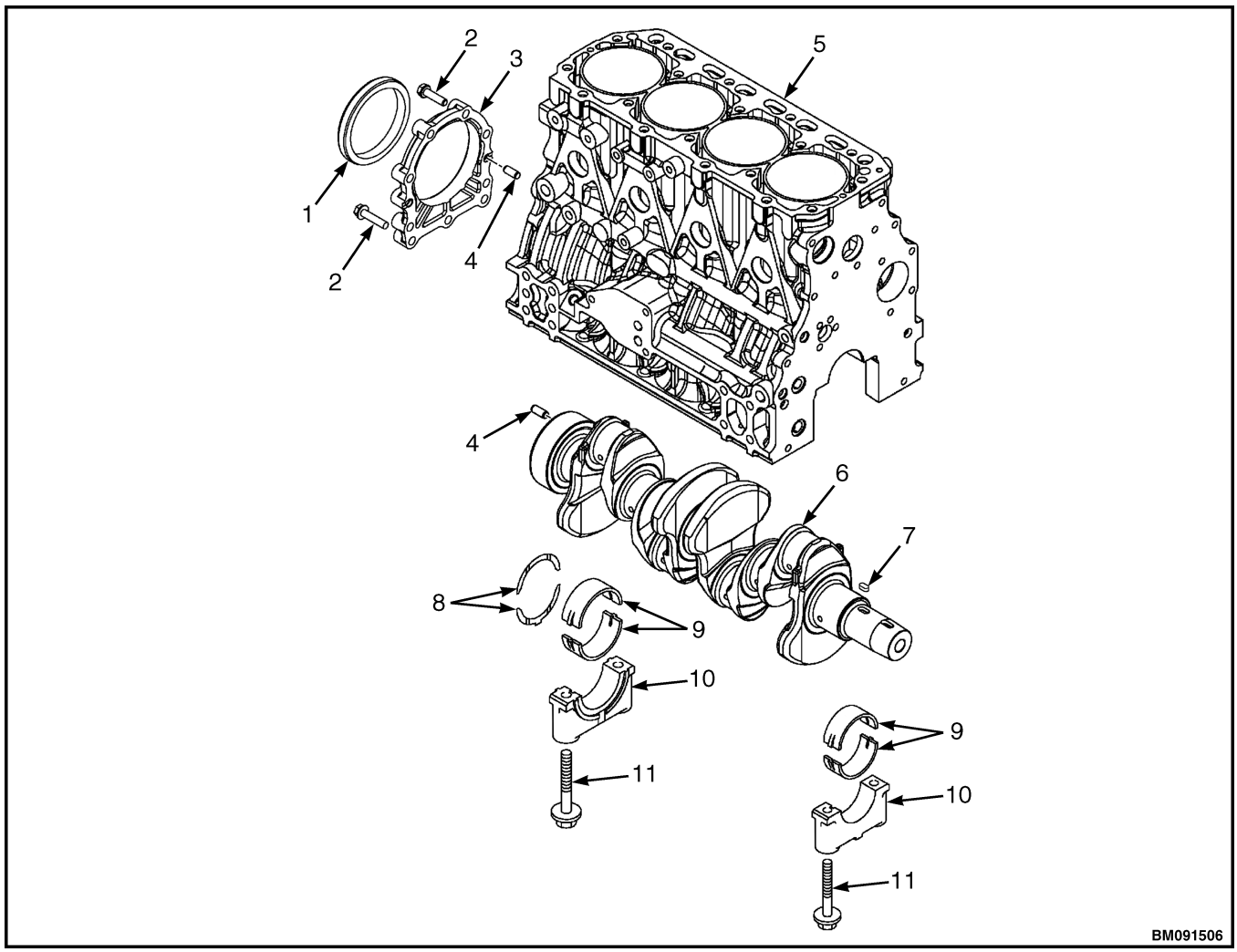
7. Install the key on the camshaft. See Figure 224.

8. Install the camshaft drive gear. See Figure 224.

Crankshaft

NOTE: The numbers and arrows on the main bearing caps are used for positioning during installation. The caps are numbered 1, 2, 3, and 4 with the number 1 cap at the flywheel end of the cylinder block. The arrows on the bearing caps should point towards the flywheel end of the cylinder block.

1. Reinstall new bearings, thrust bearings in the cylinder block and main bearing caps. Apply a liberal coat of clean engine oil to the bearings and crankshaft.
2. Place the crankshaft into the engine. See Figure 225.



1. REAR OIL SEAL
2. BOLT
3. REAR OIL SEAL HOUSING
4. PARALLEL PIN
5. CYLINDER BLOCK
6. CRANKSHAFT
7. KEY
8. THRUST BEARING
9. MAIN BEARINGS
10. MAIN BEARING CAP
11. BOLT

Figure 225. Crankshaft

3. Reinstall the main bearing caps. See Figure 225.

4. Apply a light coat of clean engine oil to the bearing cap bolts and tighten the bolts to 108-118 N•m (79.7-87.0 lbf ft) in two stages (½ at first, then full torque).

5. Rotate the crankshaft to confirm it turns freely.

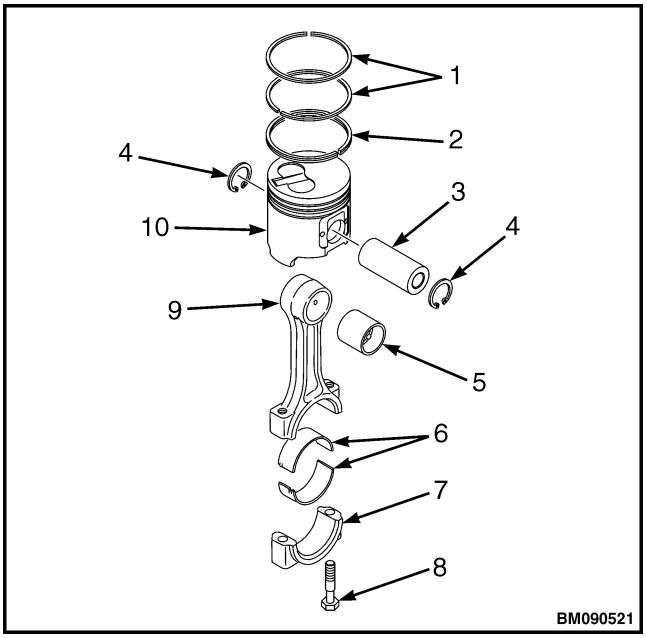
6. Apply a continuous bead of liquid gasket to the mounting flange of the rear oil seal housing.

7. Align the rear oil seal housing with the two dowel pins on the cylinder block and install the rear oil seal housing. Install the retaining bolts and tighten to standard torque.

Pistons and Connecting Rods

1. Select the components mentioned in the previous steps to assemble the piston and connecting rod for the Number 1 cylinder. See Figure 226.

2. Lubricate and insert the wrist pin bushing into the small end of the connecting rod. See Figure 226.



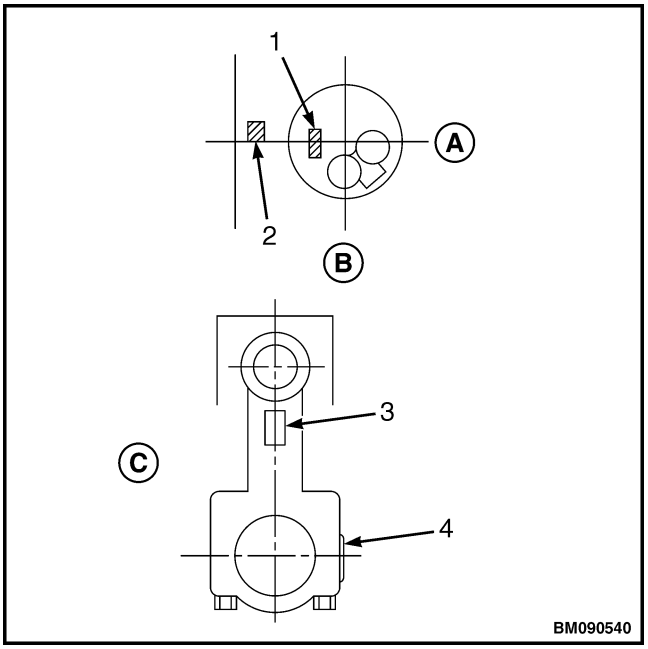
1. COMPRESSION RINGS
2. OIL SEAL RING
3. WRIST PIN
4. SNAP RING
5. WRIST PIN BUSHING
6. BEARINGS
7. CONNECTING ROD CAP
8. BOLT
9. CONNECTING ROD
10. PISTON

Figure 226. Piston and Connecting Rod

3. Install one snap ring into the piston. See Figure 226.

NOTE: The piston and connecting rod must be assembled together in the correct orientation. The orientation of the piston and connecting rod are different depending on engine model.

4. Position the connecting rod into the piston under the skirt. The match marks on the connecting rod must be opposite of the piston identification mark on the top of the piston. See Figure 227.



A. FUEL INJECTION PUMP SIDE
B. FLYWHEEL SIDE
C. CAMSHAFT SIDE

1. PISTON IDENTIFICATION MARK
2. CYLINDER SIZE MARK
3. EMBOSSED MARK (ON CONNECTING ROD)
4. PUNCHED MARK

Figure 227. Piston and connecting rod identification marks

5. Confirm when the piston is installed in the cylinder, that the piston identification mark that is stamped on the top of the piston is facing the fuel injection pump side of the engine and the embossed mark on the connecting rod is facing the flywheel side. See Figure 227.

6. Lubricate and install the piston wrist pin through the piston and wrist pin bushing.

7. Install the second snap ring and confirm it is fully seated in the groove.

8. Use piston ring pliers to install the piston rings.

a. Install each piston ring on the piston with the punched manufacture's mark facing upward. See Figure 228.

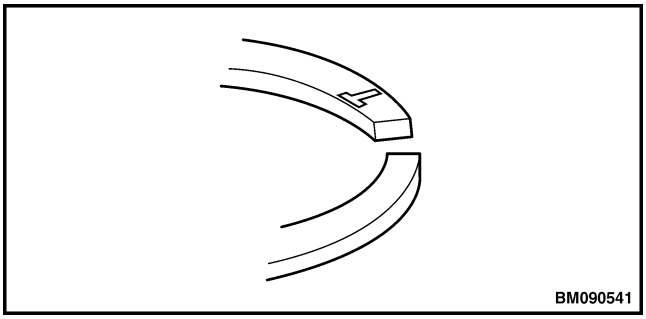
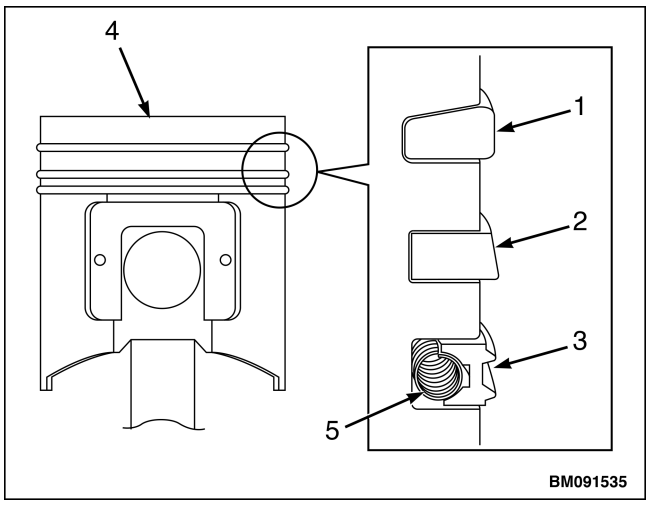


Figure 228. Piston ring mark

b. Install the top compression ring, second compression ring, and oil ring. See Figure 229.

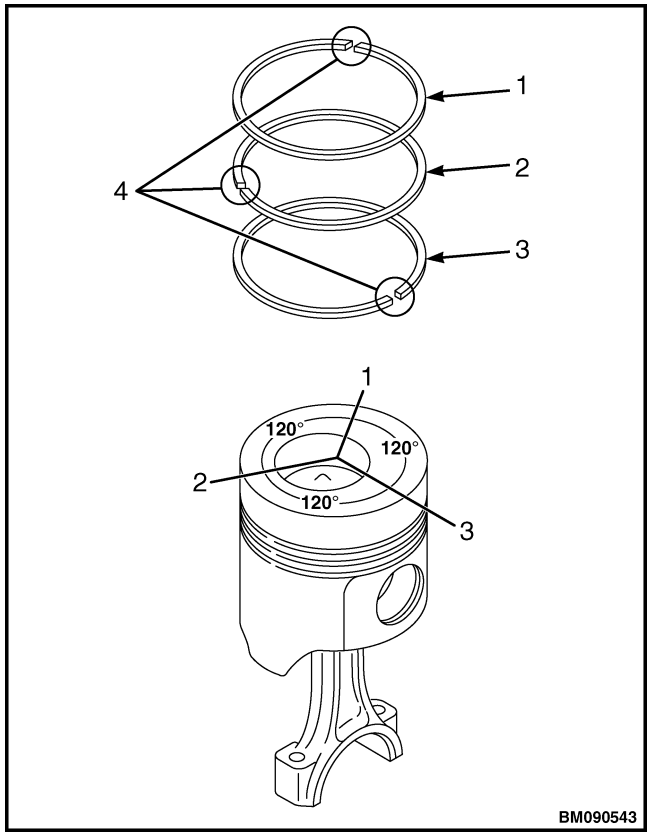
c. Confirm the oil ring coil expander end gap is located 180° from the oil ring end gap. See Figure 229.



1. TOP COMPRESSION RING
2. SECOND COMPRESSION RING
3. OIL RING
4. PISTON
5. OIL RING COIL EXPANDER

Figure 229. Piston rings

d. Stagger the piston ring joints at 120° intervals. DO NOT position the top compression ring joint in line with the piston wrist pin. The coil expander joint must be opposite the oil ring joint. See Figure 230.



1. TOP COMPRESSION RING
2. SECOND COMPRESSION RING
3. OIL RING
4. JOINTS

Figure 230. Piston rings staggering

9. Perform Step 1 through Step 8 for the assembly of each remaining piston.

INSTALL

NOTE: Do not allow the connecting rod to contact the crankshaft journal during piston installation. Damage to the crankshaft journal may result.

1. Lubricate the Number 1 piston, piston rings, and cylinder with clean engine oil.

2. Rotate the crankshaft so the crankpin for the piston being installed is near the bottom and center.

3. Confirm the piston ring gaps are located correctly. See Figure 230.

4. Use a piston ring compressor to compress the piston rings on the Number 1 piston. See Diesel engine specifications.

5. Carefully install the piston into the Number 1 cylinder. Be sure the punched mark on the connecting rod is facing the fuel injector side and the embossed mark is facing the flywheel. See Figure 227.

6. Install the connecting rod bearings and connecting rod cap. Install the connecting rod bolts and tighten to
54 to 59 N•m (40 to 44 lbf ft) to seat bearing to rod and cap.

7. Remove Hardware loosen and remove hardware from bearing cap. Pull the bearing cap and apply a liberal coat of clean engine oil to the bearings and crankshaft journal.

8. Install a light coat of clean engine oil to the rod cap bolts. Reinstall the connecting rod cap. Tighten the connecting rod bolts to
54 to 59 N•m (40 to 44 lbf ft) in two stages (½ torque first, then full torque).

9. Perform Step 1 through Step 6 to install the remaining pistons in their respective cylinders.

10. Install the crankshaft drive gear and idler gear. See Diesel timing gear case repair.

11. Install the oil pump. See Diesel lubrication system repair.

12. Install the timing gear case cover. See Diesel timing gear case repair.

13. Install the oil pan. Install the oil suction tube. See Diesel lubrication system repair.

14. Install the cylinder head. See Diesel cylinder head repair.

15. Install the fuel injection pump. See Diesel fuel system repair.

16. Install the water pump. See **Water Pump Repair** in the **Cooling system** 0700SRM2300 service manual.

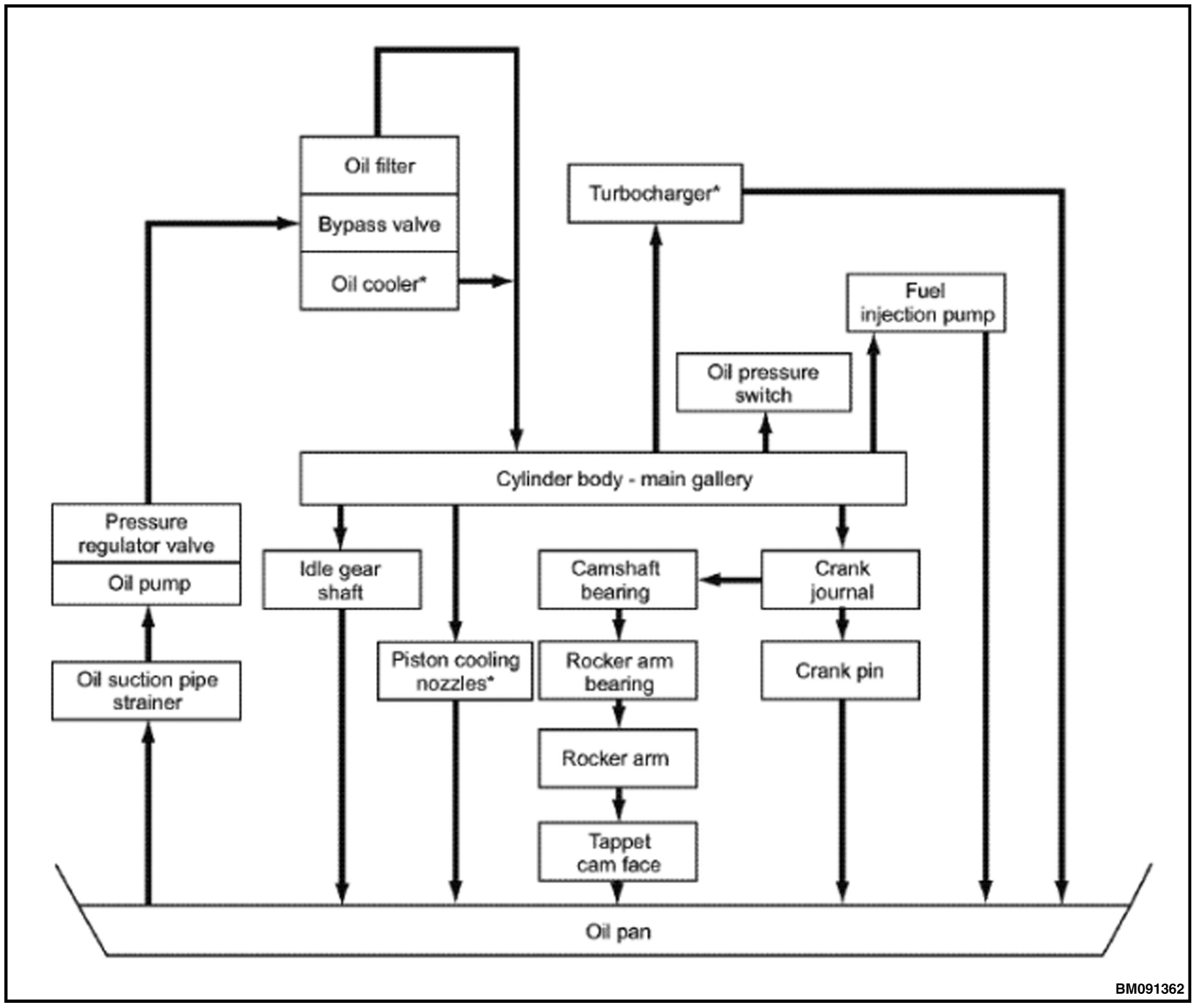
17. Install the alternator. See Diesel electrical system repair.

18. Install the flywheel and flywheel housing. See Diesel flywheel repair.

19. Install the starter. See Diesel electrical system repair.

20. Install the engine. See Diesel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

DIESEL LUBRICATION SYSTEM REPAIR 202001-359



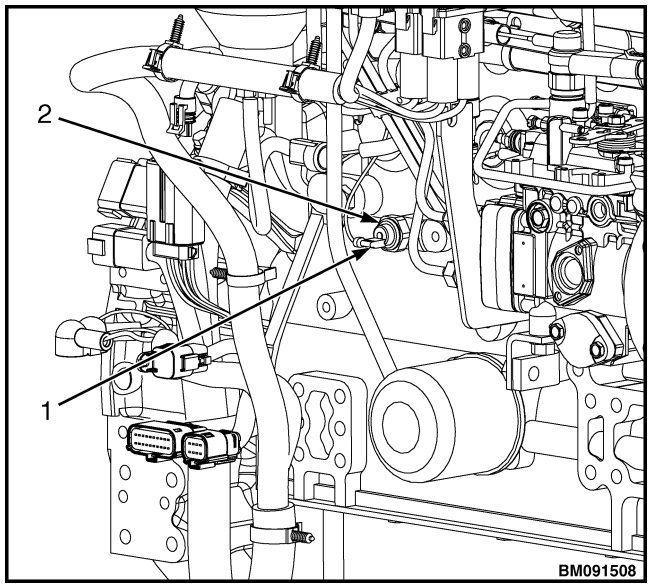
NOTE: ITEMS MARKED* ARE NOT STANDARD EQUIPMENT ON ALL MODELS.

Figure 231. Lubrication system diagram

CHECK ENGINE LUBRICATING OIL PRESSURE

An engine oil pressure check must be performed if the oil pressure indicator is on, or the Engine oil pressure gauge on the instrument panel indicates low engine oil pressure. See Table 57 for specifications.

1. Disconnect the electrical connector from the oil pressure switch. See Figure 232.



1. ELECTRICAL CONNECTOR
2. OIL PRESSURE SWITCH

Figure 232. Oil pressure switch

2. Remove the oil pressure switch.

3. Insert a mechanical oil pressure gauge into the port where the oil pressure switch was removed.

4. Start the engine.
   - If the mechanical oil pressure test gauge indicates satisfactory oil pressure (see Table 57 for specifications), one of the following items may be faulty and must be replaced:
     - Oil pressure switch or sending unit
     - Oil pressure gauge
   - If the mechanical oil pressure test gauge indicates low oil pressure (see Table 57 for specifications), follow steps to troubleshoot the lubrication system to determine the cause of low engine oil pressure. See **Diagnostic and Troubleshooting manual**.

5. Rev the engine to the RPM indicated in the table below (see Table 57). Compare the reading on the oil pressure gauge to the specifications listed in the table.

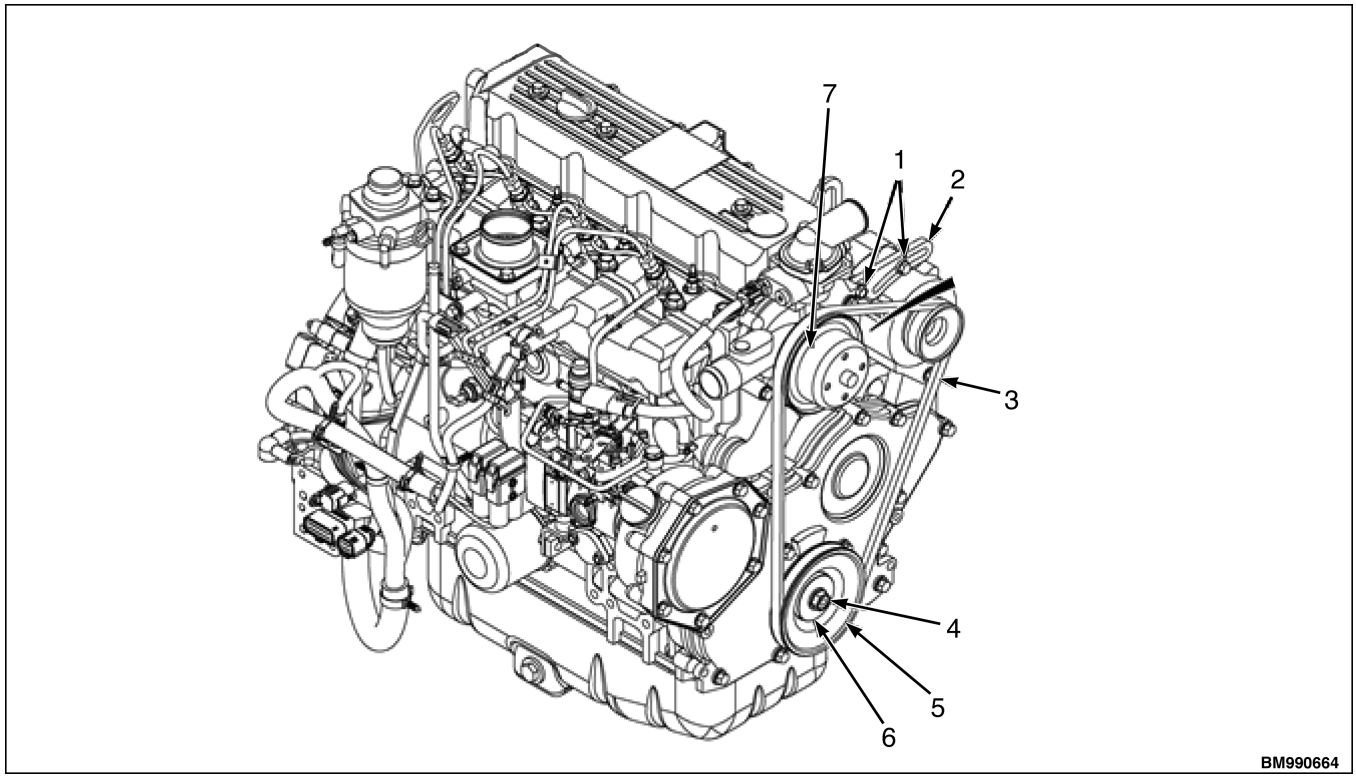
REMOVE

Oil pump components

The oil pump assembly is located in the front gear case and is driven by the same gear train as the camshaft and fuel injection pump.

1. Remove the cooling fan guard and cooling fan. See **Cooling system** 0700SRM2300 manual for procedure.

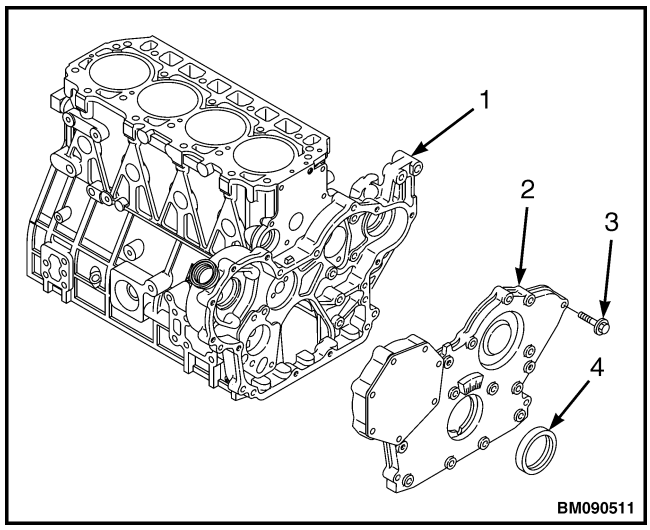
2. Loosen the crankshaft pulley mounting bolt and spacer retaining the crankshaft pulley. Remove the crankshaft pulley. See Figure 233.



1. V-BELT TENSIONER MOUNTING BOLT
2. V-BELT TENSIONER
3. V-BELT
4. CRANKSHAFT PULLEY MOUNTING BOLT
5. CRANKSHAFT PULLEY
6. SPACER
7. PULLEY

Figure 233. V-belt and Crankshaft Pulley

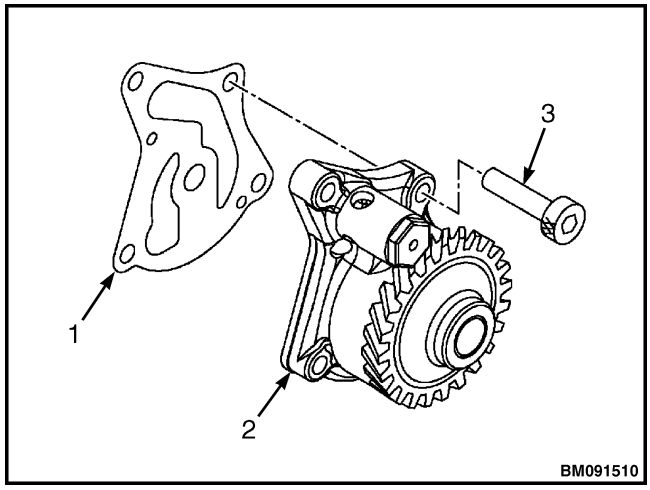
3. Remove the front gear case cover to gain access to the oil pump. See Figure 234, and Diesel timing gear case repair for removal procedure.



1. FRONT GEAR CASE
2. FRONT GEAR CASE COVER
3. BOLT
4. FRONT OIL SEAL

Figure 234. Front gear case cover

4. Remove the oil pump assembly mounting bolts. See Figure 235.

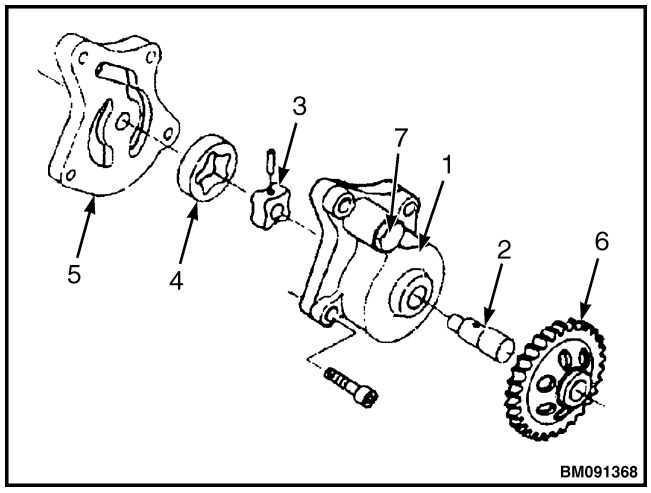


1. PUMP GASKET
2. OIL PUMP ASSEMBLY
3. OIL PUMP ASSEMBLY BOLT

Figure 235. Oil Pump

5. Remove the oil pump assembly from the gear case flange.

6. Remove the oil pump cover and outer rotor. See Figure 236.



1. OIL PUMP BODY
2. SHAFT
3. INNER ROTOR
4. OUTER ROTOR
5. OIL PUMP COVER
6. DRIVE GEAR
7. PRESSURE REGULATOR VALVE

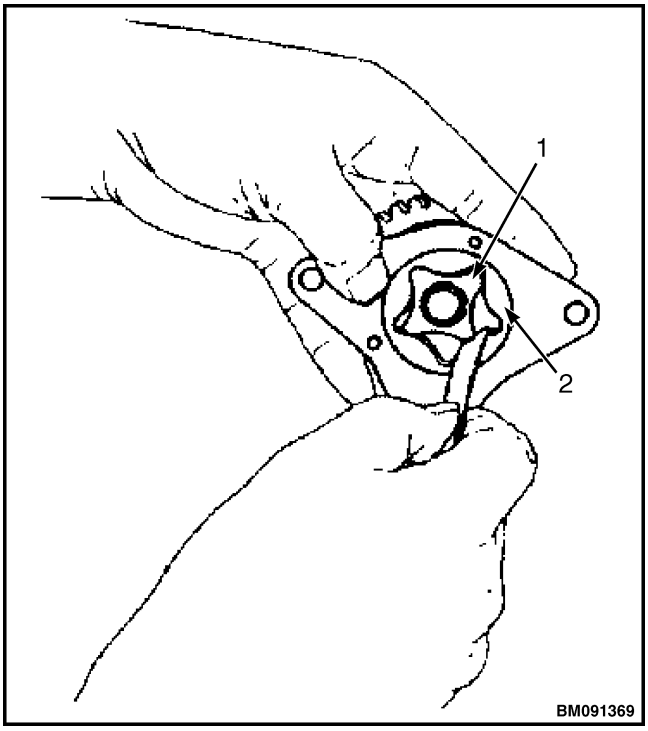
Figure 236. Oil pump assembly

CLEAN AND INSPECT

Clean all of the parts with cleaning solvent. Dry the parts with compressed air. Inspect for wear and damage. If necessary, replace oil pump assembly.

Outer rotor outside clearance

Inspect the outside diameter clearance of the outer rotor, by inserting a feeler gauge between the outer rotor and the oil pump body. See Figure 237. Record the measurements, and see Table 58 for service limits.

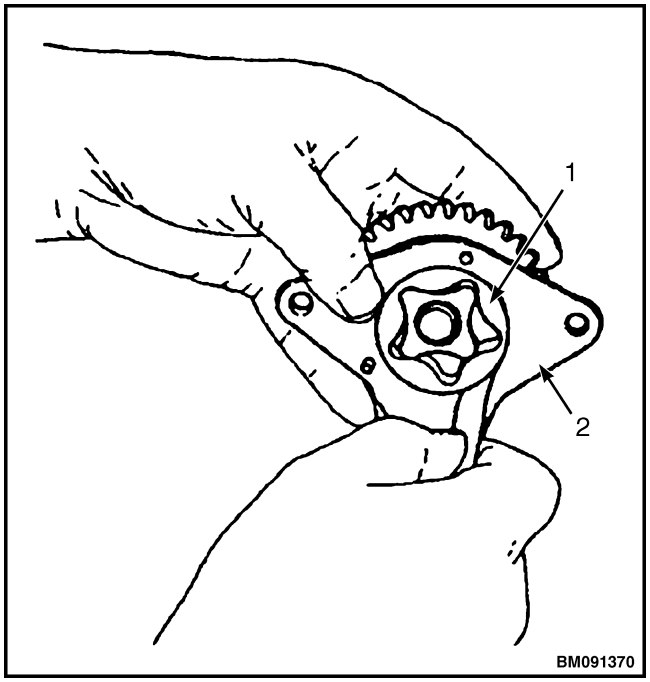


1. OUTER ROTOR
2. PUMP BODY

Figure 237. Outer rotor outside clearance check

Outer rotor to inner rotor tip clearance

Inspect the tip clearance between the outer and inner rotors, by inserting a feeler gauge between the inner rotor tooth tip and the outer rotor tooth tip. See Figure 238. Measure the clearance. Record the measurements, and see Table 60 for service limits.



1. INNER ROTOR TOOTH TIP
2. OUTER ROTOR TOOTH TIP

Figure 238. Inner rotor tip clearance check

Outer rotor side clearance

Inspect the side clearance between the oil pump body and the outer rotor, by using a straight edge and feeler gauge or a depth micrometer. See Figure 239. Record the measurements, and see Table 59 for service limits.

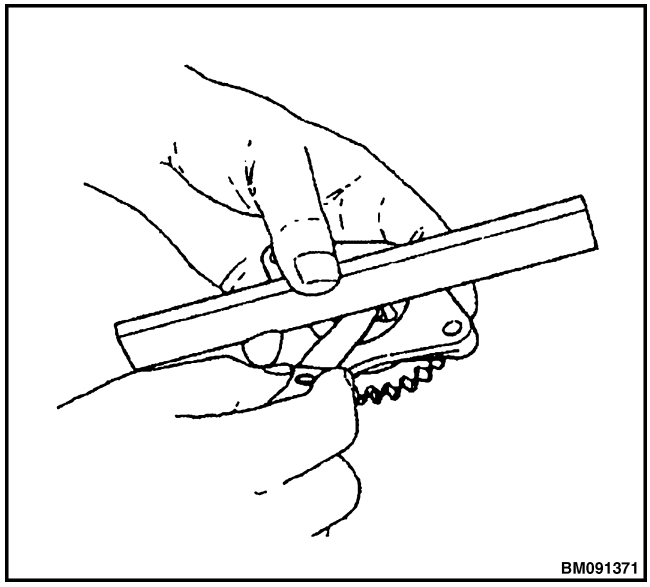
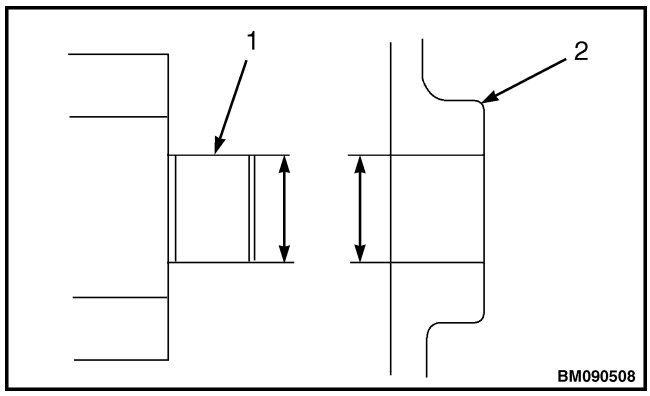


Figure 239. Outer rotor side clearance check

Rotor shaft clearance

Inspect the rotor shaft clearance, by measuring the outside diameter of the rotor shaft and the inside diameter of the cover. Determine clearance by subtracting the outside diameter of the rotor from the inside diameter of the cover. See Figure 240. Record the measurements, and see Table 61 for service limits.



1. ROTOR SHAFT
2. GEAR CASE HOUSING

Figure 240. Rotor shaft clearance check

INSTALL

1. Apply clean lubricating oil to the oil pump body, inner rotor and outer rotor. See Figure 236.
2. Assemble the oil pump assembly by inserting the inner and outer rotor into the oil pump body and aligning the oil pump cover with the oil pump body. See Figure 236.
3. Position the oil pump assembly in the gear case housing. Insert the mounting bolts to retain the oil pump assembly. See Special torque chart for torque specifications.
4. Install the timing gear case cover. See and refer to Diesel timing gear case repair for procedure.
5. Position the crankshaft pulley, aligned with the timing gear case cover. Insert crankshaft pulley mounting bolt and and spacer to retain the crankshaft pulley. See Figure 233. Torque to 108-128 N•m (80-87 lbf ft).
6. Install the V-belt. See Figure 233. Adjust the V-belt to standard tensile strength. See Diesel engine specifications.
7. Install the cooling fan guard and cooling fan. See **Cooling system** 0700SRM2300 manual for procedure.

OIL PUMP SERVICE INFORMATION

Table 57. Engine lubricating oil pressure

Model	At rated engine RPM (min)	At low idle speed
4TNE92, 4TNE94, 4TNE98	0.29-0.39 MPa (42.06-56.57 psi)	0.06 MPa (8.5 psi)

Table 58. Outer rotor outside clearance

Model	Standard	Limit	Reference page
4TNE92, 4TNE94, 4TNE98	0.100-0.155 mm (0.0039-0.0061 in.)	0.25 mm (0.0098 in.)	Check outer rotor outside clearance. See Outer rotor outside clearance.

Table 59. Outer rotor side clearance

Model	Standard	Limit	Reference page
4TNE92, 4TNE94, 4TNE98	0.05-0.1 mm (0.0020-0.0039 in.)	0.15 mm (0.0059 in.)	Check outer rotor side clearance. See Outer rotor side clearance.

Table 60. Outer rotor to inner rotor tip clearance

Model	Standard	Limit	Reference page
4TNE92, 4TNE94, 4TNE98	—	0.16 mm (0.0063 in.)	Check outer rotor to inner rotor tip clearance. See Outer rotor to inner rotor tip clearance.

Table 61. Rotor shaft clearance

Model		Standard	Limit	Reference page
4TNE92, 4TNE94, 4TNE98	Plate bearing I.D.	10.020-10.038 mm (0.5110-0.5126 in.)	10.063 mm (0.3962 in.)	Check rotor shaft clearance. See Rotor shaft clearance.
	Rotor shaft O.D.	9.978-9.987 mm (0.5089-0.5106 in.)	9.963 mm (0.3922 in.)	
	Rotor clearance	0.010-0.065 mm (0.0004-0.0026 in.)	0.105 mm (0.0041 in.)	

DIESEL FUEL SYSTEM REPAIR 202001-360

CAUTION

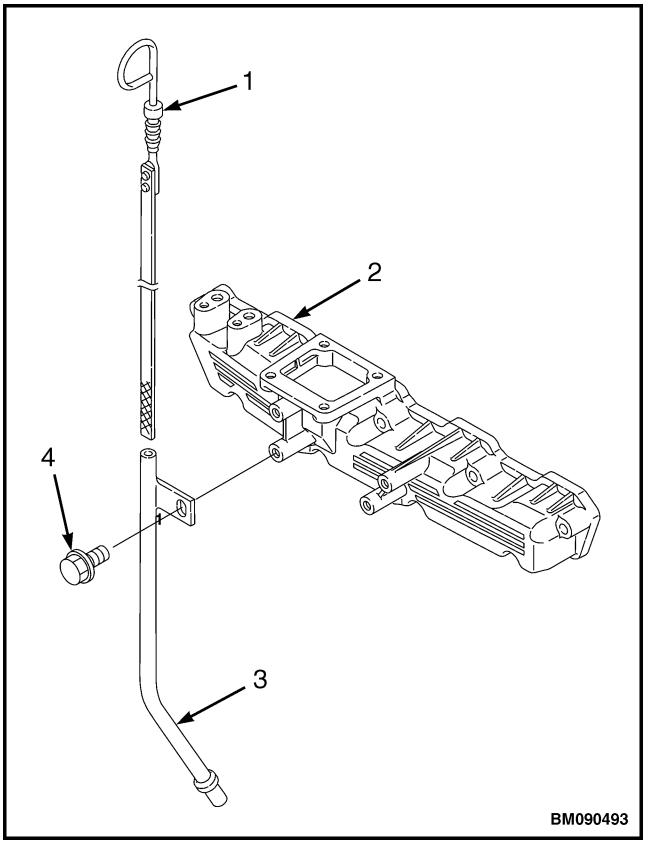
DO NOT attempt to remove or adjust the tamper-proof devices from the full-load fuel adjusting screw or the high-speed throttle limit screw on the fuel injection pump and governor assembly. These adjustments have been made at the factory to meet all applicable emissions regulations and then sealed.

DO NOT attempt to make any adjustments to these sealed adjustment screws. If adjustments are required, they can be made only by a qualified fuel injection shop that will ensure the injection pump continues to meet all applicable emissions regulations and then replace the tamper-proof seals.

FUEL INJECTORS

Remove

1. Remove the bolt holding the oil dipstick tube clamp. Rotate the dipstick tube to one side. This is to allow removal of the high pressure fuel lines. See Figure 241.



1. OIL DIPSTICK
2. INTAKE MANIFOLD
3. DIPSTICK TUBE
4. BOLT

Figure 241. Oil Dipstick Tube

CAUTION

Remove the high pressure fuel lines as an assembly whenever possible. Disassembling the high pressure fuel lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

2. Remove the high pressure fuel lines. See Figure 242.

CAUTION

When loosening or tightening the lines at the fuel injectors, you must hold the fuel injector with a second wrench to prevent the injector from turning and damaging the fuel return line fitting.

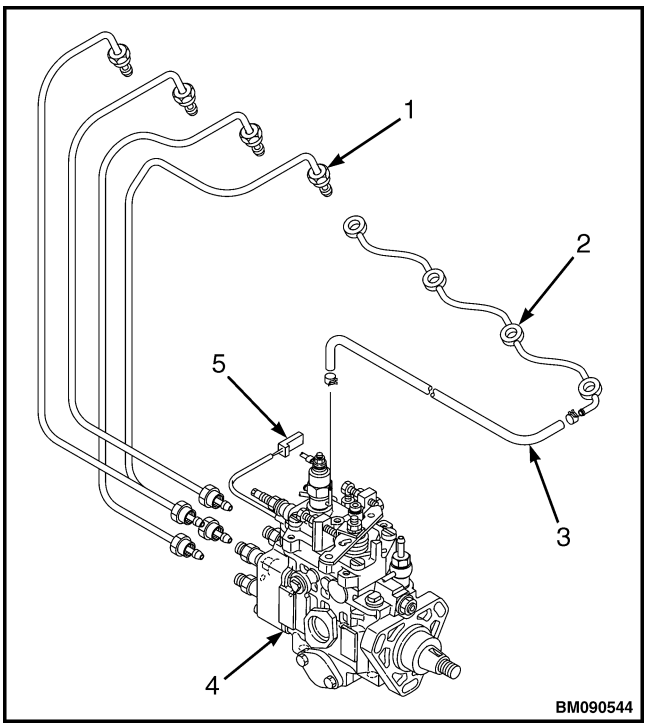
a. First loosen the high pressure fuel line nuts at the fuel injectors.

b. Loosen the high pressure fuel line nuts on the fuel injection pump.

CAUTION

DO NOT bend any of the fuel lines when removing them.

c. Finish loosening all of the high pressure fuel line nuts and remove the fuel lines as an assembly.



1. HIGH PRESSURE LINE
2. RETURN LINE FITTING
3. RETURN LINE
4. FUEL INJECTION PUMP
5. MAGNETIC VALVE (STOP SOLENOID) ELECTRICAL CONNECTOR

Figure 242. Fuel Injection Pump High Pressure Lines

3. Remove the nuts retaining the fuel injector return line fittings and return lines.

4. Remove the fuel injector return lines and fittings as an assembly.

5. Unscrew the fuel injectors from the cylinder head. Also remove the two copper washers and the nozzle protectors from the injector port in the cylinder head.

Inspect

Visually inspect the fuel injectors and nozzle protectors for deposits or damage. Clean and repair as necessary.

Clean

1. Clean the exterior of the nozzle, taking care not to damage the needle.

2. Pull out the needle and clean carefully so as not to damage it. Avoid use of hard, metallic tools.

3. Check for dents, damage, rusting, and wear. Pay special attention to the stem and seat of the needle.

4. When setting the needle on the nozzle body after thorough cleaning, check that it falls by its own weight.

Test

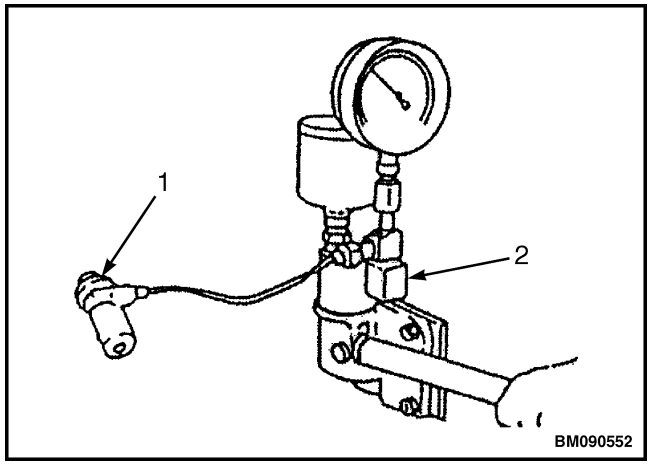
1. Test the fuel injector using a special tool, fuel injection nozzle tester. Use clean, filtered fuel for the test.

WARNING

Never inject fuel toward you. Since the fuel is injected at high pressure from the nozzle, it may penetrate the skin, resulting in injury.

Never inject fuel toward a fire source. Atomized fuel is highly flammable and may cause fire or skin burning.

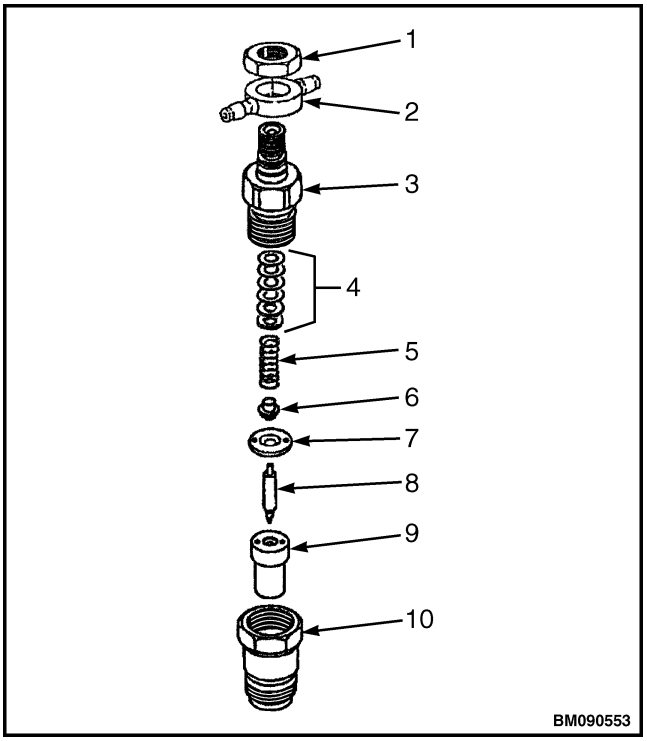
2. Using the correct adapter, connect the fuel injector to the high pressure pipe of the nozzle tester. Aim the fuel injector nozzle into a suitable container to catch the fuel spray. See Figure 243.



1. INJECTION NOZZLE
2. NOZZLE TESTER

Figure 243. Fuel Injector Tester

3. Pump the operating lever of the tester slowly, observing the pressure reading at the point where the fuel injector begins spraying fuel. The fuel injectors should begin spraying fuel at 11.8 to 13.2 MPa (1711 to 1914 psi). The operating pressure may be adjusted by adding or subtracting internal fuel injector shims. See Figure 244.



1. NUT
2. RETURN LINE FITTING
3. NOZZLE HOLDER
4. PRESSURE ADJUSTING SHIM
5. NOZZLE SPRING
6. NOZZLE SPRING SEAT
7. VALVE STOP SPACER
8. NOZZLE VALVE
9. NOZZLE BODY
10. NOZZLE CASE

Figure 244. Fuel Injector

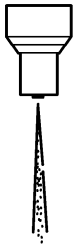
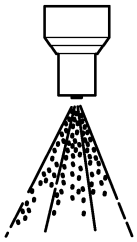
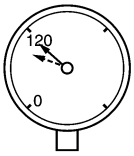
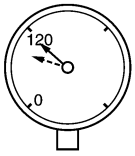
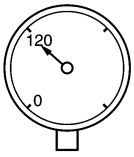
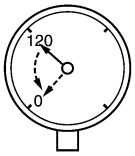
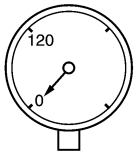
4. Adding or removing a 0.1 mm (0.0039 in.) shim (shims are available in 0.4 mm (0.016 in.) increments) changes the pressure by 1.2 to 2.2 MPa (174 to 319 psi).

5. Pump the operating lever more rapidly to repeatedly "pop" the injector and observe the spray pattern. See Table 62 for examples of "good" and "bad" spray patterns.

6. Pump the operating lever slowly to hold the pressure steady at a point just below the "pop off" pressure point. Observe the injector to see that it is sealing properly and is not "dripping."

7. If the fuel injector fails any of these tests, it should be repaired or replaced as necessary.

Table 62. Fuel Injector Spray Patterns

	A	B	C	D	E
Injection Pattern					
Pressure Gauge Reading	 Pointer fluctuate around the valve opening pressure.	 Same as A.	 Pointer stays at a position near the valve opening pressure.	 Although the pointer reaches the valve opening pressure, the pressure drop is large.	 Pressure does not increase even when the tester lever is operated.
Atomization Pattern	Roughly uniform.	Atomization is excessively one sided.	Although atomized, the needle does not pulsate (burner like shape).	Bar shape with excessive after drops.	Drops (bar shape).
Possible Cause	(Normal)	1 Normally caused by carbon contamination of the nozzle tip. 2 Sometimes caused by flaws in or damage to the needle tip.	1 Caused by excessive carbon contamination of the nozzle tip. 2 Sometimes caused by contamination.	1 Damage to the seat. 2 Contamination of seat by fine foreign particles. 3 Excessively worn seat.	1 Sticking of needle. 2 Excessively damaged or worn seat. 3 Contamination of seat by foreign matter. 4 Damaged or broken internal parts of nozzle holder.

Install

1. Install a new copper washer at the bottom of the injector well.
2. Install nozzle protector in injector well.
3. Install second new copper washer on top of nozzle protector.
4. Install fuel injectors. Tighten fuel injectors to 39 N•m (29 lbf ft).
5. Install fuel return lines and fittings as an assembly using new copper washers.
6. Install fuel return line fitting retaining nuts and tighten to 44 N•m (33 lbf ft).
7. Connect fuel injector return line to fuel pump.
8. Install high pressure fuel lines.

CAUTION

DO NOT bend any of the fuel lines when installing them.

NOTE: Replace high pressure fuel lines as an assembly.

   a. Start all high pressure fuel line nuts by hand, leaving the nuts on the fuel injection pump and the fuel injectors loose.
   b. Tighten high pressure fuel line nuts on the fuel injection pump. Tighten to standard torque.

CAUTION

When loosening or tightening the lines at the fuel injectors, you must hold the fuel injector with a second wrench to prevent the injector from turning and damaging the fuel return line fitting.

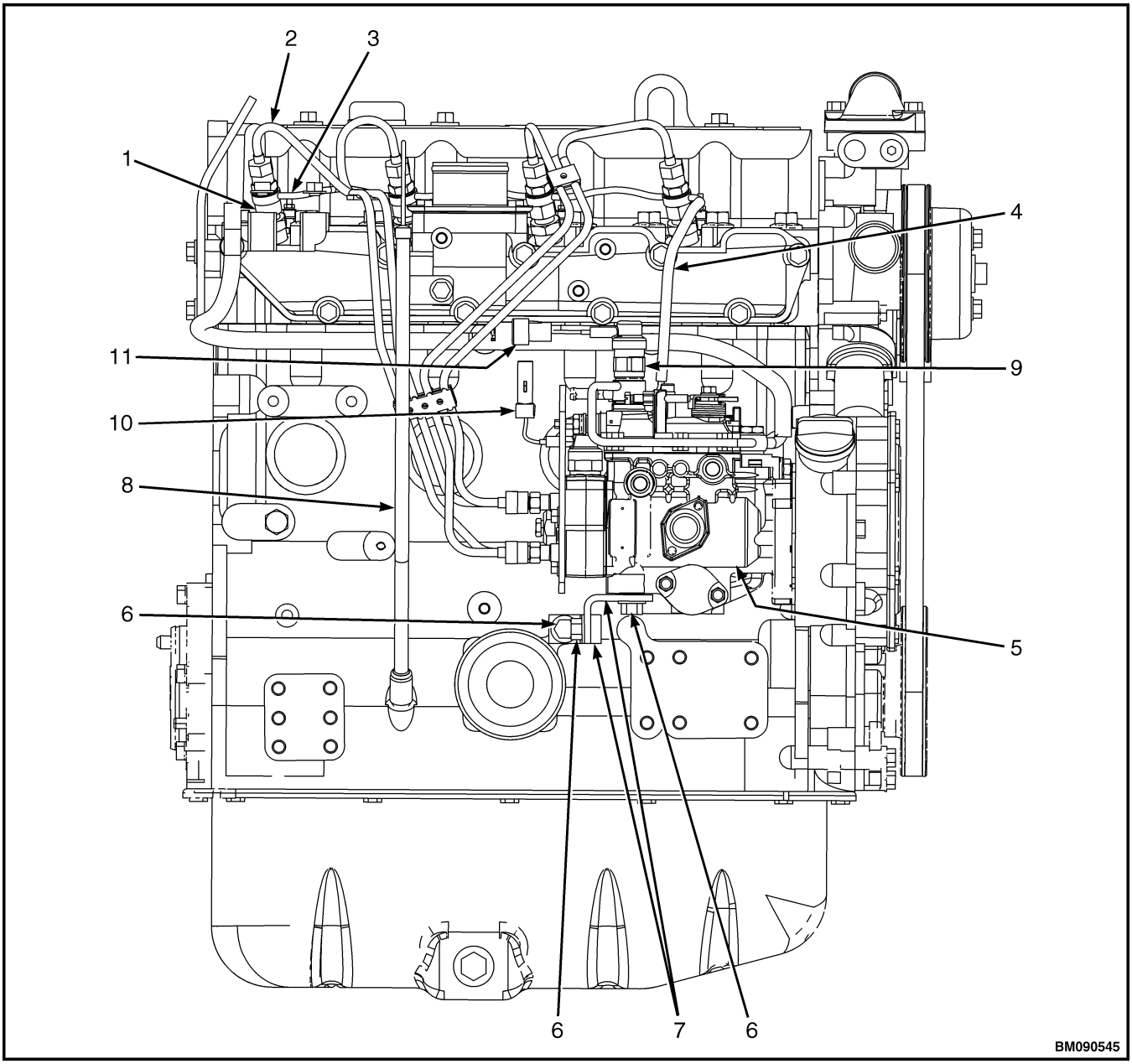
   c. Tighten high pressure fuel line nuts on fuel injectors. Tighten to standard torque.

9. Rotate dipstick tube back to original position. Install retaining bolt to hold oil dipstick tube clamp to intake manifold. See Figure 241.
10. Prime fuel system and check for leaks.

FUEL INJECTION PUMP

Remove

1. Disconnect fuel supply line from the fuel injection pump. See Figure 245.
2. Disconnect fuel tank return line. See Figure 245.
3. Disconnect fuel injector return line from the fuel pump. See Figure 245.



1. FUEL INJECTOR
2. HIGH PRESSURE FUEL LINE
3. RETURN LINE FITTINGS
4. RETURN LINE
5. FUEL INJECTION PUMP
6. BOLT
7. L-SHAPED BRACKET
8. DIPSTICK TUBE
9. COLD START AID
10. MAGNETIC VALVE (STOP SOLENOID) ELECTRICAL CONNECTOR
11. COLD START AID ELECTRICAL CONNECTOR

Figure 245. Fuel Injection Pump

4. Disconnect electrical connection to the magnetic valve (stop solenoid).

5. If equipped, disconnect throttle cable.

6. Remove the bolt holding the oil dipstick tube clamp. Rotate the dipstick tube to one side. This is to allow removal of the high pressure fuel lines. See Figure 241.

CAUTION

Remove the high pressure fuel lines as an assembly whenever possible. Disassembling the high pressure fuel lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

7. Remove the high pressure fuel lines. See Figure 242.

CAUTION

When loosening or tightening the lines at the fuel injectors, you must hold the fuel injector with a second wrench to prevent the injector from turning and damaging the fuel return line fitting.

a. First loosen the high pressure fuel line nuts at the fuel injectors.

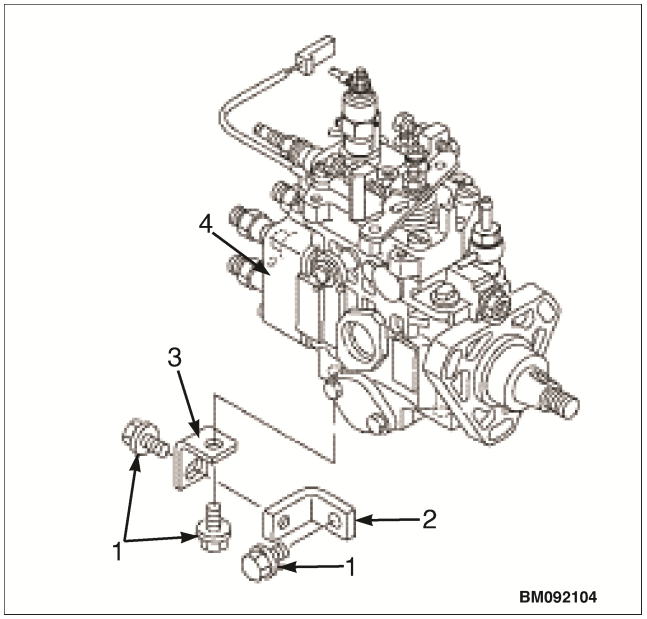
b. Loosen the high pressure fuel line nuts on the fuel injection pump.

CAUTION

DO NOT bend any of the fuel lines when removing them.

c. Finish loosening all of the high pressure fuel line nuts and remove the fuel lines as an assembly.

8. Remove the bolts retaining the L-shaped brackets and remove brackets. See Figure 246.

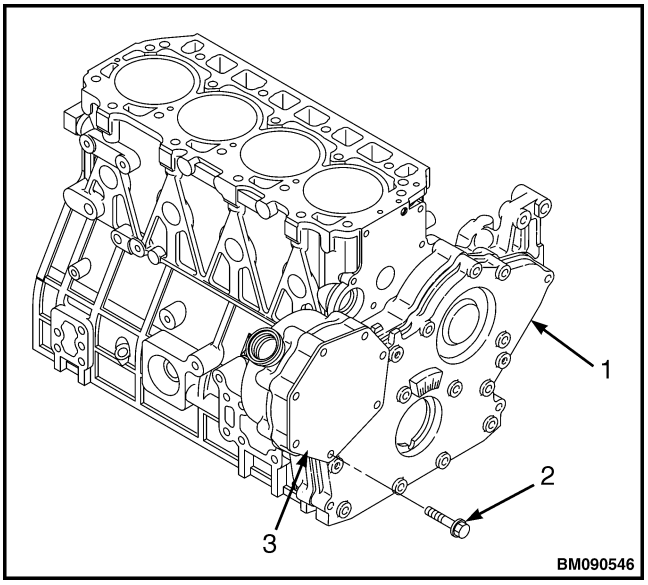


1. BOLTS
2. BRACKET
3. BRACKET
4. FUEL INJECTION PUMP

Figure 246. Fuel injection pump

9. Remove the V-belt and fan assembly. See **Cooling system** 0700SRM2300 manual for procedure.

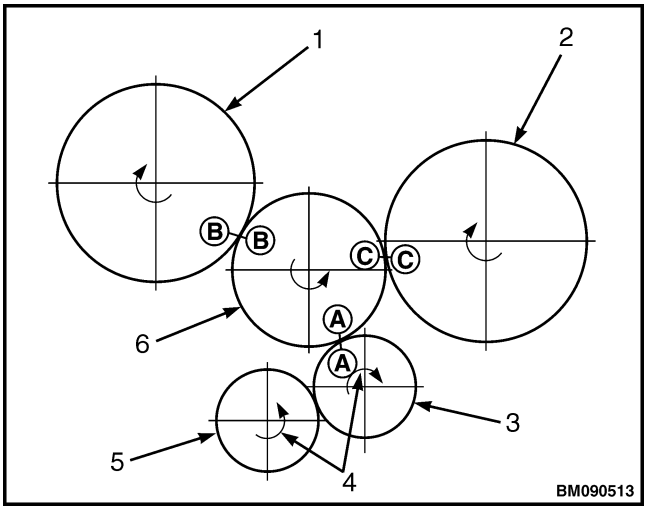
10. Remove the bolts from the fuel injection pump cover on the front of the timing gear case cover. Remove the fuel injection pump cover. See Figure 247.



1. TIMING GEAR CASE COVER
2. BOLT
3. FUEL INJECTION PUMP COVER

Figure 247. Fuel Injection Pump Cover

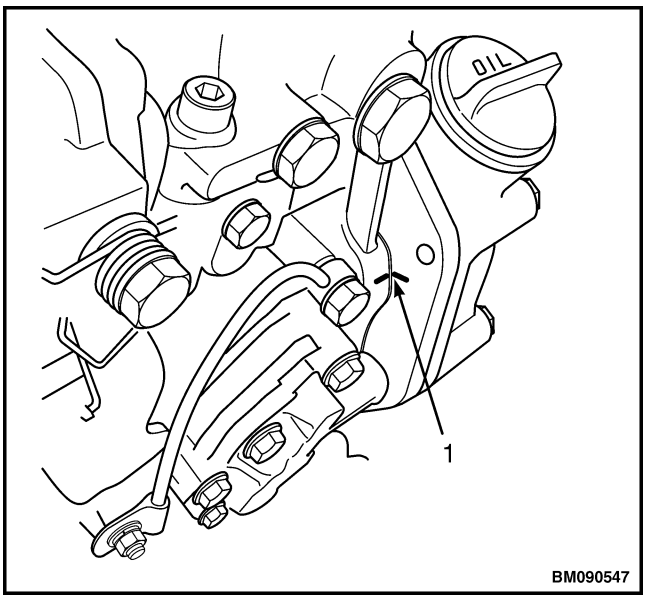
11. To aid in reassembly, mark one tooth on the idler gear and two teeth on the fuel injection pump drive gear with a dot of white paint. See Figure 248.



1. FUEL INJECTION PUMP DRIVE GEAR
2. CAMSHAFT GEAR
3. CRANKSHAFT GEAR
4. DIRECTION OF ROTATION
5. OIL PUMP GEAR
6. IDLER GEAR

Figure 248. Timing Gear Alignment

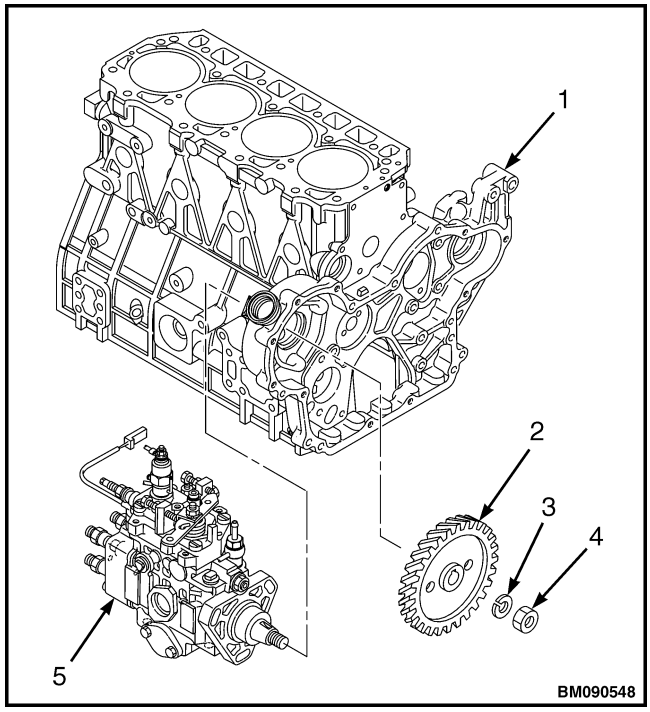
12. Make matching marks on the rear of the timing gear case housing and on the fuel injection pump mounting flange before loosening the fuel injection pump mounting bolts. See Figure 249.



1. ALIGNMENT MARKS

Figure 249. Fuel Injection Pump Alignment Marks

13. While holding the engine from turning with a wrench on the crankshaft pulley bolt, remove the fuel injection pump drive gear retaining nut and lockwasher. See Figure 250.



1. TIMING GEAR CASE
2. FUEL INJECTION PUMP DRIVE GEAR
3. LOCKWASHER
4. NUT
5. FUEL INJECTION PUMP

Figure 250. Fuel Injection Pump Drive Gear

NOTE: The fuel injection pump shaft is tapered with a woodruff key. Once you have applied some pressure with a puller, a slight tap with a hammer on the center puller bolt will help pop the gear from the shaft.

14. Using a two-bolt gear puller, remove the fuel injection pump drive gear from the fuel injection pump shaft. See Figure 250.

15. Remove the three nuts securing the fuel injection pump to the rear of the timing gear case.

16. Remove the fuel injection pump.

17. If the fuel injection pump requires servicing, it must be taken to an authorized **ZEXEL** fuel injection shop or the fuel injection pump assembly must be replaced.

Clean and Inspect

Clean all old sealant from the timing gear case cover and the fuel injection pump drive gear cover. Inspect all parts for damage. Replace as needed.

Install

1. Place the fuel injection pump in position and align the matching marks on the timing gear case housing and the fuel injection pump flange. Install the retaining nuts. Tighten to standard torque. See Figure 249.

2. Install the fuel injection pump drive gear onto the fuel injection pump shaft while lining up the two marks made on the pump drive gear with the mark made on the idler gear.

3. Install the drive gear retaining nut and washer. While holding the engine from turning with a wrench on the crankshaft pulley bolt, tighten the retaining nut to 59 to 69 N•m (44 to 51 lbf ft).

4. Apply a continuous bead of ThreeBond Liquid Gasket, Hyster Part Number 1599478 , to the mating surface of the fuel injection pump cover.

5. Place the fuel injection pump cover in position on the timing gear case cover and install retaining bolts. Tighten to standard torque.

6. Install the fan assembly and V-belt. See **Cooling system** 0700SRM2300 manual for procedure.

7. Install the L-shaped brackets and bolts to retain brackets. See Figure 246. Tighten to standard torque.

8. Install the high pressure fuel lines.

CAUTION

DO NOT bend any of the fuel lines when installing them.

NOTE: Replace the high pressure fuel lines as an assembly.

a. Start all high pressure fuel line nuts by hand, leaving the nuts on the fuel injection pump and the fuel injectors loose. See Figure 242.

b. Tighten the high pressure fuel line nuts on the fuel injection pump. Tighten to standard torque.

CAUTION

When loosening or tightening the lines at the fuel injectors, you must hold the fuel injector with a second wrench to prevent the injector from turning and damaging the fuel return line fitting.

c. Tighten the high pressure fuel line nuts on the fuel injectors. Tighten to standard torque.

9. Connect the throttle linkage.

10. Connect the electrical connection to the magnetic valve (stop solenoid). See Figure 242.

11. Connect the fuel injector return line to the fuel pump. See Figure 245.

12. Connect the fuel tank return line. See Figure 242.

13. Connect the fuel injector return line. See Figure 242.

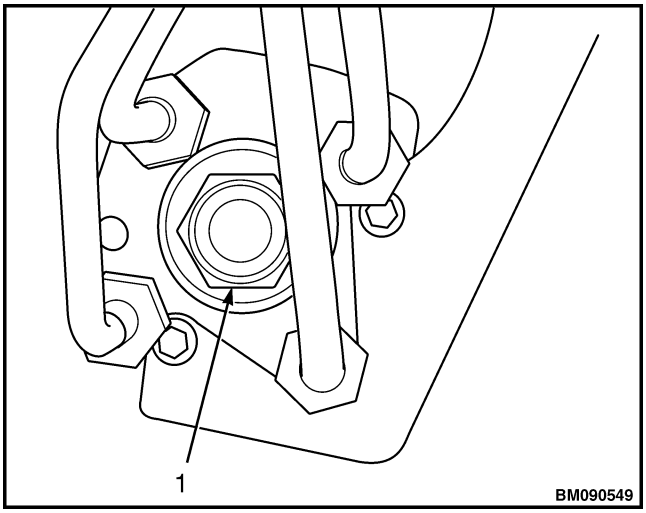
14. Connect the fuel supply line to the fuel injection pump. Tighten to standard torque.

15. Prime the fuel system and check for leaks.

Check/Adjust Fuel Injection Timing

1. Using a wrench on the front crankshaft pulley bolt, rotate the engine clockwise until the timing mark on the crankshaft pulley is aligned with the "O" or TDC (Top Dead Center) mark on the timing grid of the gear case cover.

2. Remove the center bolt and sealing washer from the rear of the fuel injection pump. See Figure 251.

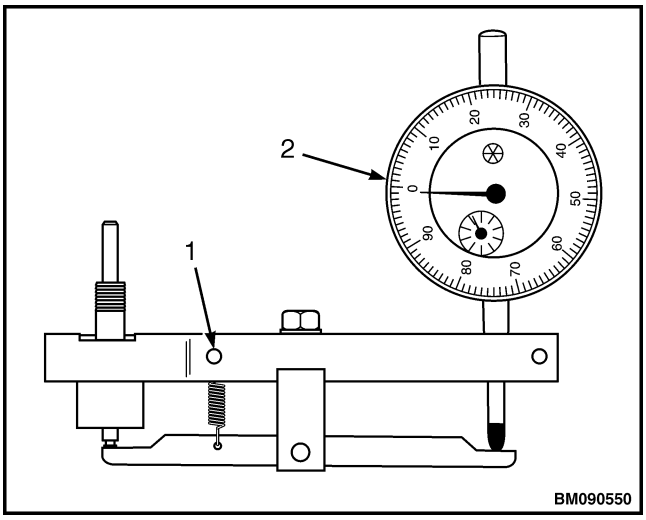


1. CENTER BOLT

Figure 251. Fuel Injection Pump Center Bolt

NOTE: The dial indicator is not included with timing tool. Collet size 8 mm (0.31 in.) and equivalent.

3. Locate special timing tool. Install a dial indicator into the timing tool. See Figure 252.

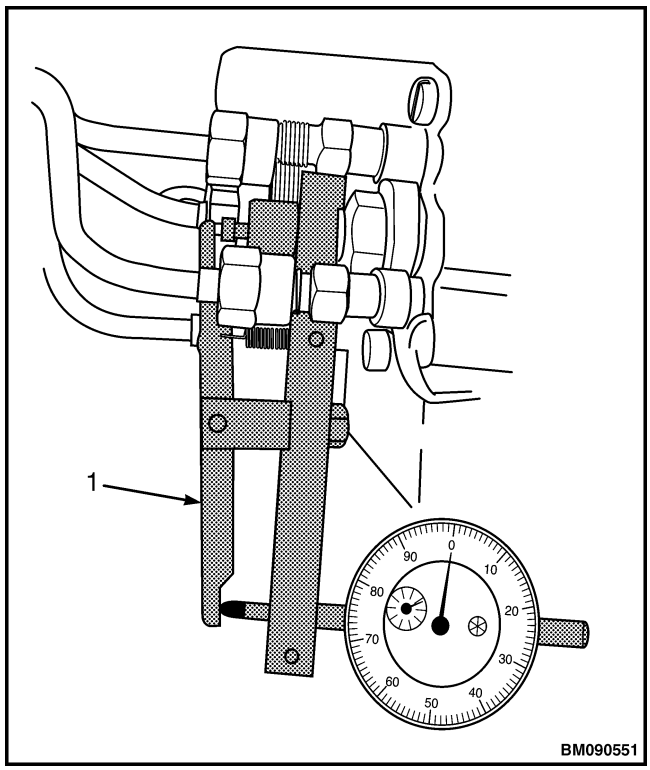


1. TIMING TOOL
2. DIAL INDICATOR

Figure 252. Fuel Injection Pump Timing Tool

NOTE: The dial indicator is not included with timing tool. Collet size 8 mm (0.31 in.) and equivalent.

4. Install the timing tool into the port where the center bolt was removed. This will provide a reading of the fuel injection pump plunger lift. See Figure 253.



1. TIMING TOOL

Figure 253. Fuel Injection Pump Timing Tool Installation

5. Rotate the engine about 25 degrees in the counterclockwise direction. The dial indicator should move for approximately the first 10 degrees of engine rotation and then stop. When you reach approximately the 25 degrees position, rotate the engine slightly back and forth to make sure the needle of the dial indicator does not move.

6. Set the dial indicator to "0."

NOTE: Timing is 4 degrees ATDC (After Top Dead Center).

7. Rotate the engine in the clockwise rotation until the timing mark on the crankshaft pulley is aligned with the mark at 4 degrees, 6 degrees, or 8.5 degrees ATDC (After Top Dead Center) on the timing grid on the gear case cover.

8. If the injection timing is correct, the dial indicator should read 0.97 to 1.03 mm (0.038 to 0.041 in.).

NOTE: Rotating the injection pump away from the engine advances the injection timing. Rotating the injection pump toward the engine retards the injection timing.

9. If the injection timing is not correct, loosen the three fuel Injection pump mounting nuts and the bolts retaining the bottom / rear L-shaped injection pump mounting brackets. Rotate the injection pump to bring the dial indicator reading into the correct range.

10. Retighten the pump mounting nuts and the mounting bracket bolts.

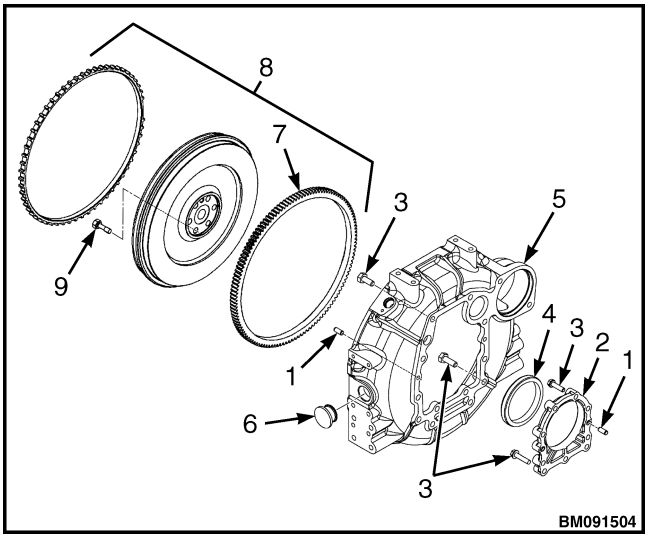
11. Remove the timing tool and dial indicator. Replace and tighten the center bolt and sealing washer into the injection pump port.

DIESEL FLYWHEEL REPAIR 202001-361

REMOVE

1. Remove the engine. See Diesel engine removal and replacement section in the **Drive Train** 0900SRM2301 service manual.

2. Remove the six flywheel bolts retaining the flywheel to the crankshaft flange and remove the flywheel assembly. See Figure 254.



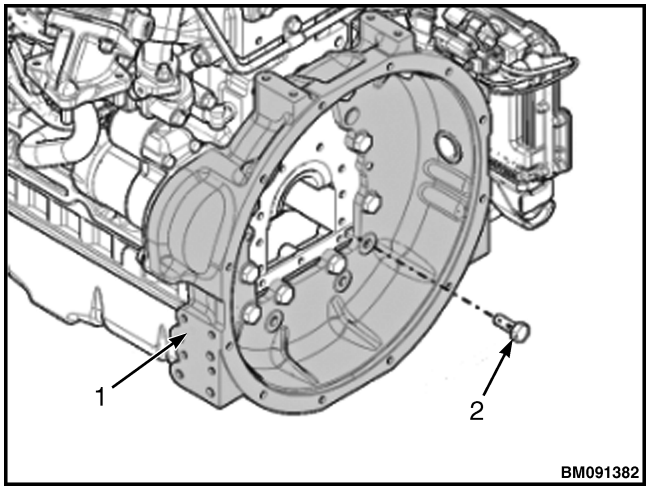
1. PIN
2. OIL SEAL CASE
3. BOLT
4. OIL SEAL
5. FLYWHEEL HOUSING
6. WHEEL COVER CAP
7. FLYWHEEL GEAR
8. FLYWHEEL ASSEMBLY
9. FLYWHEEL BOLT

Figure 254. Flywheel

3. Remove the nine bolts retaining the oil seal case and remove the oil seal case. See Figure 254.

4. Remove the oil seal from the oil seal case. See Figure 254.

5. Remove bolts and flywheel housing. See Figure 255.



1. FLYWHEEL HOUSING
2. FLYWHEEL HOUSING MOUNTING

Figure 255. Flywheel housing

INSTALL

1. Insert bolts and install the flywheel housing. See Figure 255. Tighten the flywheel housing mounting bolts to standard torque value.

2. Install the oil seal in the oil seal case. See Figure 254.

3. Install the oil seal case and insert the bolts to retain the oil seal case to the crankshaft flange. See Figure 254. Tighten the bolts to standard torque value.

4. Align the flywheel assembly with the crankshaft flange. Install the six flywheel bolts to retain the flywheel to the crankshaft flange. See Figure 254.

5. Tighten the flywheel bolts to 186-206 N•m (137-152 lbf ft) following the sequence shown in Figure 256.

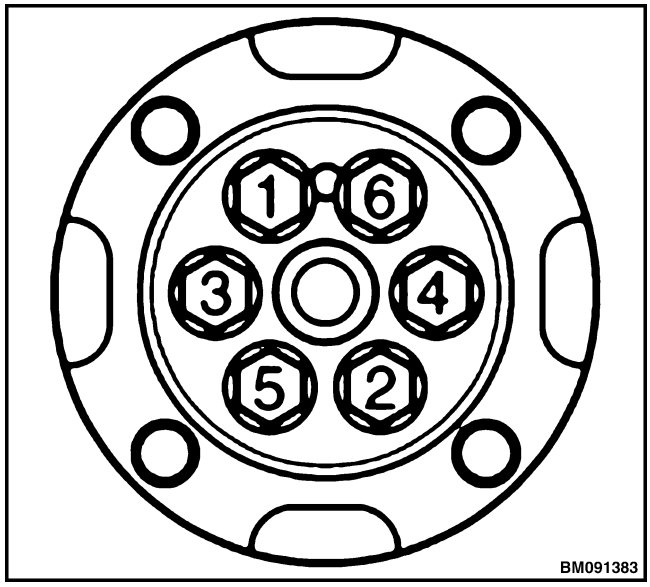


Figure 256. Torque sequence

DIESEL ELECTRICAL SYSTEM REPAIR 202001-362

STARTER

Remove

WARNING

SHOCK HAZARD. Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

DANGER

Check the electrical harnesses for cracks, abrasions and damaged or corroded connectors. Always keep the connectors and terminals clean. Failure to comply could result in death or serious injury.

NOTE: While starter design varies between models, the basic repair procedures are the same. The following procedures are typical and may differ from the starter being serviced.

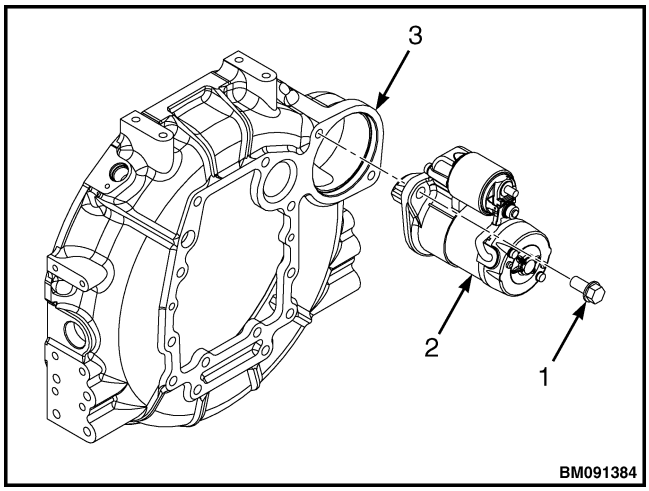
1. Disconnect the negative battery cable at the negative terminal post on the battery.

2. Disconnect the positive battery cable at the positive terminal post on the battery.

6. Install the engine. See Diesel engine removal and replacement section in the **Drive Train** 0900SRM2301 service manual.

3. Put labels on wires and cables prior to disconnecting to aid in correct installation. Disconnect all cables and wires from the starter.

4. Remove the two starter mounting bolts. Remove the starter from the flywheel housing. See Figure 257.



1. STARTER MOUNTING BOLT
2. STARTER
3. FLYWHEEL HOUSING

Figure 257. Starter mounting

Disassemble

1. Loosen the solenoid nut on the solenoid assembly. Disconnect the wire from the solenoid. See Figure 258.
2. Remove solenoid nut, e-clip, solenoid assembly, all items in the dust cover kit, and shift lever set. See Figure 258.
3. Remove the two bolts and gear case assembly. Remove gear case cover and starter metal from gear case assembly. See Figure 258.
4. Remove the through bolts securing the starter cover assembly to the yoke assembly. See Figure 258.
5. Remove the two bolts and starter cover assembly. Remove metal rear cover from starter cover assembly. See Figure 258.
6. Remove the keyhole spacer, brush holder assembly, yoke assembly, and armature assembly from the gear case. See Figure 258.
7. Remove center A bracket, internal gear, planetary gear, pinion shaft, washer, center P bracket, center bracket, washer, e-clip, pinion assembly, washer, and snap ring from the gear case. See Figure 258.

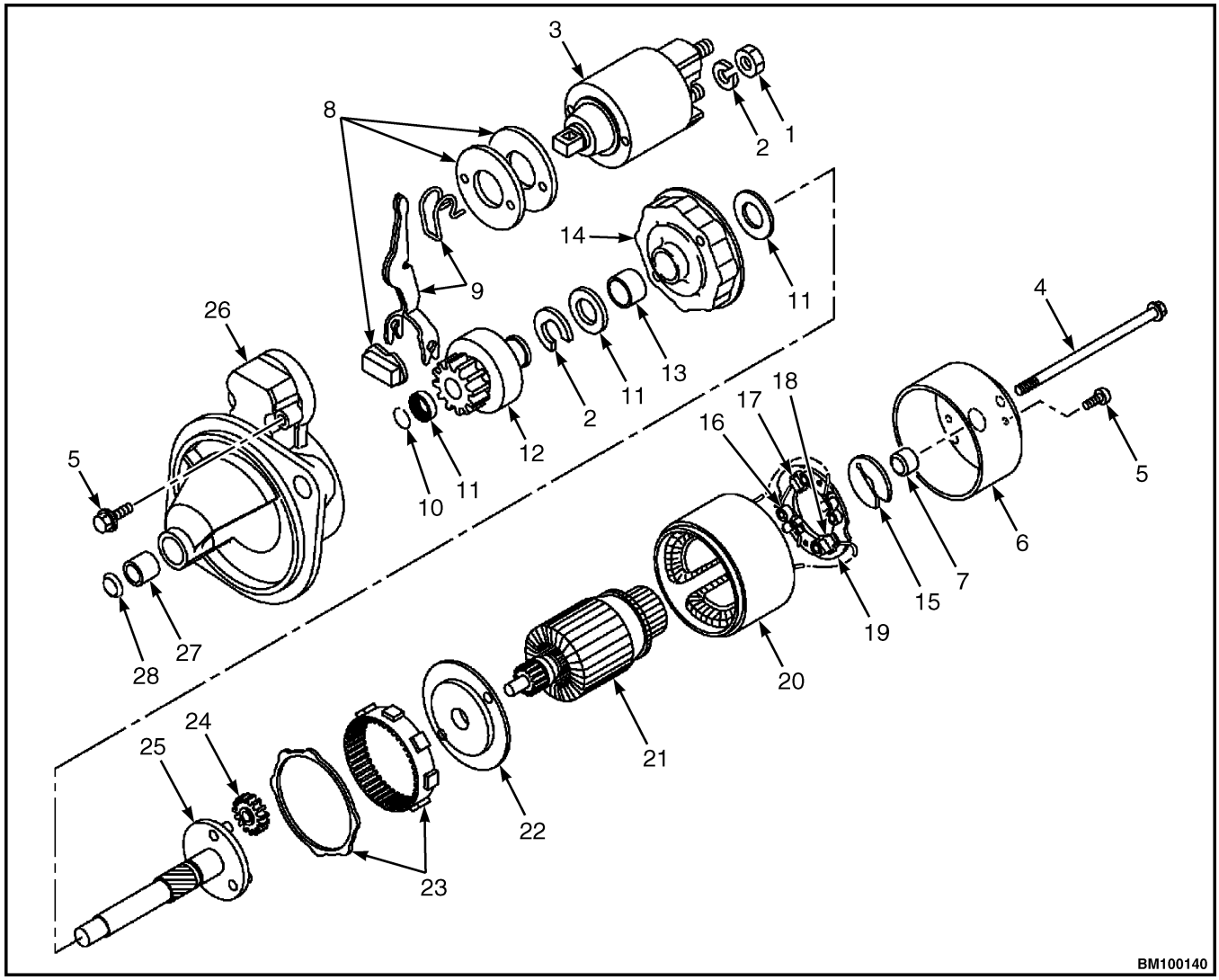


Figure 258. Starter Disassembly/Assembly

Legend for Figure 258.

1. SOLENOID NUT
2. E-CLIP
3. SOLENOID ASSEMBLY
4. THROUGH BOLT
5. BOLT
6. STARTER COVER ASSEMBLY
7. METAL REAR COVER
8. DUST COVER KIT
9. SHIFT LEVER SET
10. SNAP RING
11. WASHER
12. PINION ASSEMBLY
13. CENTER BRACKET
14. CENTER P BRACKET
15. KEYHOLE SPACER
16. BRUSH SPRING
17. BRUSH
18. BRUSH SET
19. BRUSH HOLDER ASSEMBLY
20. YOKE ASSEMBLY
21. ARMATURE ASSEMBLY
22. CENTER A BRACKET
23. INTERNAL GEAR
24. PLANETARY GEAR
25. PINION SHAFT
26. GEAR CASE ASSEMBLY
27. STARTER METAL
28. GEAR CASE COVER

Install

1. Install center A bracket, internal gear, planetary gear, pinion shaft, washer, center P bracket, center bracket washer, center P bracket, center bracket, washer, e-clp, pinion assembly, washer, and snap ring to the gear case. See Figure 258.

2. Install armature, yoke assembly, brush holder assembly, and keyhole spacer to the gear case. See Figure 258.

3. Install metal rear cover to starter cover assembly. Intall starter cover assembly and two bolts to starter cover assembly. See Figure 258.

4. Install starter cover assembly to the yoke assembly and install the through bolts. See Figure 258.

5. Install starter metal and gear case cover to gear case assembly. Install gear case assembly and two bolts. See Figure 258.

6. Install shift lever set, all items in the dust cover kit, solenoid assembly and solenoid nut. See Figure 258.

7. Connect the wire to the solenoid. Tighten solenoid nut to
7.4 to 9.8 N•m (65.5 to 86.7 lbf in).

Table 63. Starter Specifications

Nominal output			2.3 kW (3.0 hp)
Weight			5.5 kg (12.1 lb)
Revolution direction (As viewed from pinion)			Clockwise
Engagement system			Magnetic shift
No-load	Terminal voltage / urrent		11 V / 140 A max
	Revolution		4100 rpm min
Loaded	Terminal voltage / current		2.5 V / 1050 A max
	Torque		24.5 N•m, 2.5 kgf•m (18.1 lbf ft) min
Clutch system			Overrunning
Pinion projection Voltage at 100°C (212°F)			8.6 V max
Pinion DP or module / number of teeth			M3 / 9
Difference (O-ring, oil seal)			Dry (none)
Application			Standard
Brush	Spring force		35 N, 3.6 kgf (7.868 lbf)
	Height	Standard	15 mm (0.591 in.)
		Limit	9 mm (0.354 in.)
Magnetic switch	Series coil resistance		0.27 Ω at 20°C (68°F)
	Shunt coil resistance		0.60 Ω at 20°C (68°F)
Commutator	Outside diameter	Standard	36.5 mm (1.437 in.)
		Limit	35 mm (1.398 in.)
	Run-out	Standard	0.03 mm (0.001 in.)
		Limit	0.2 mm (0.008 in.)
	Insulation depth	Standard	0.5 to 0.8 mm (0.020 to 0.031 in.)
		Limit	0.2 mm (0.008 in.)
Armature	Run-out	Standard	0.03 mm (0.001 in.)
		Limit	0.2 mm (0.008 in.)
Bearing type	Armature front	Nominal number	6903DDU
	Armature rear		608DDU
	Pinion front		60004DDU
	Pinion rear		6904DDU
Pinion projection length (length L)			0.3 to 1.5 mm (0.012 to 0.059 in.)

ALTERNATOR

Remove

WARNING

SHOCK HAZARD. Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

DANGER

Check the electrical harnesses for cracks, abrasions and damaged or corroded connectors. Always keep the connectors and terminals clean. Failure to comply could result in death or serious injury.

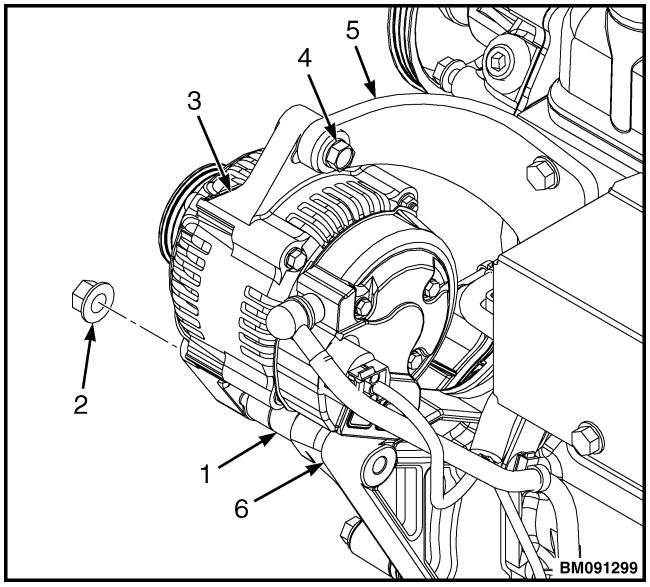
CAUTION

PINCH HAZARD. Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

1. Remove the V-belt. See **Periodic Maintenance** 8000SRM2305 **Periodic Maintenance** 8000SRM2305 service manual.

2. Put labels on wires and cables prior to disconnecting to aid in correct installation. Disconnect all cables and wires from the alternator.

3. Perform the following steps to remove the alternator.
   a. Loosen the alternator mounting nut (item 2, Figure 259) and remove.
   b. Loosen the mounting bolt (item 4, Figure 259) attaching the alternator to the alternator mounting bracket.
   c. Remove the alternator.



1. SPACER AND STUD
2. ALTERNATOR MOUNTING NUT
3. ALTERNATOR
4. MOUNTING BOLT
5. ALTERNATOR MOUNTING BRACKET
6. TIMING GEAR CASE

Figure 259. Alternator mounting

Disassembly

1. Remove pulley nut, pulley, and collar from end cover (item 5, Figure 260).

2. Remove end cover bolt and end cover (item 26, Figure 260).

3. Remove screw, brush holder assembly, screw and washer, small screw, regulator assembly, and holder assembly. See Figure 260.

4. Remove holder assembly nut and insulation bushing from holder assembly. See Figure 260.

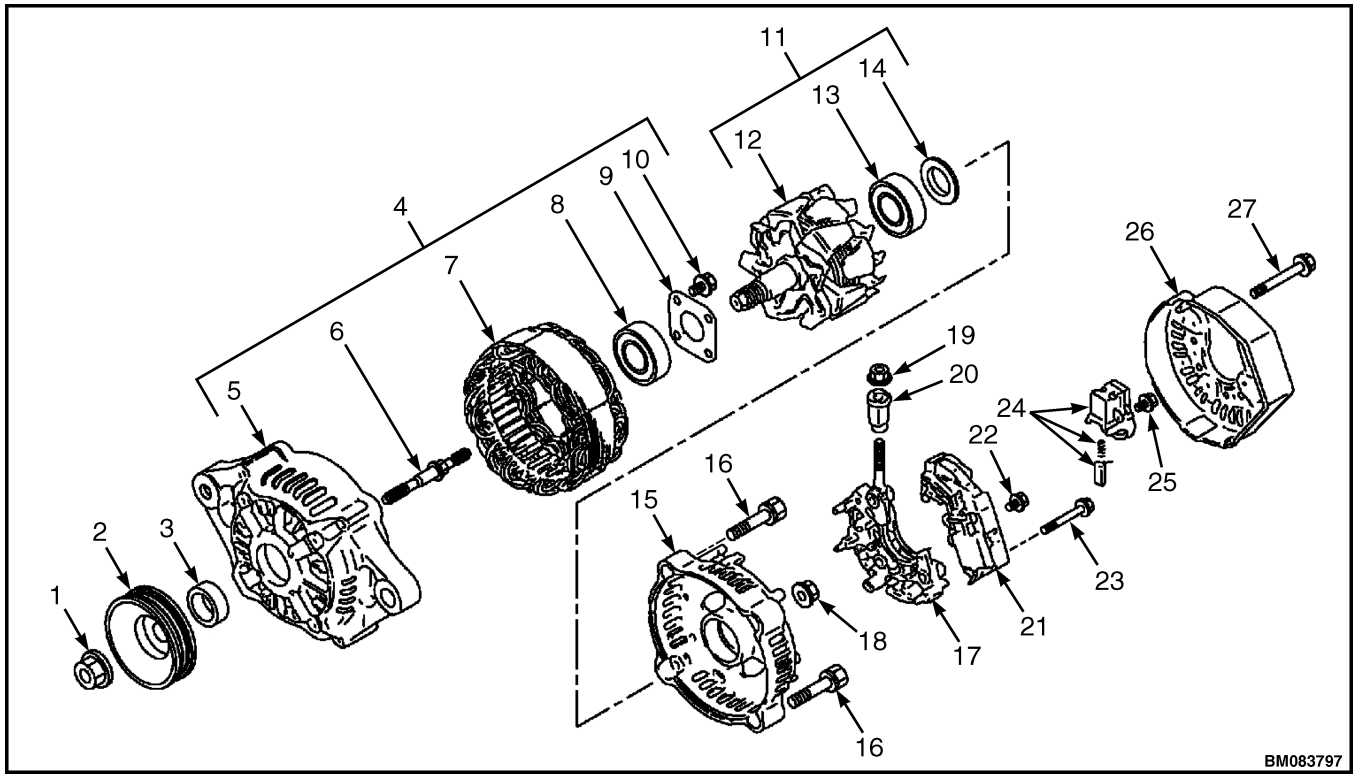
5. Remove end cover bolts, end frame and end cover. See Figure 260.

6. Remove stud nut and stud.

7. Remove rotor assembly from frame assembly.

8. Remove bearing cover and ball bearing from rotor. See Figure 260.

9. Remove rotor screw, retainer plate, and ball bearing from stator. See Figure 260.



1. PULLEY NUT
2. PULLEY
3. COLLAR
4. FRAME ASSEMBLY
5. END COVER
6. STUD
7. STATOR
8. BALL BEARING
9. RETAINER PLATE
10. SCREW
11. ROTOR ASSEMBLY
12. ROTOR
13. BALL BEARING
14. BEARING COVER
15. END FRAME
16. BOLT
17. HOLDER ASSEMBLY
18. NUT
19. NUT
20. INSULATION BUSHING
21. REGULATOR ASSEMBLY
22. SCREW
23. SCREW AND WASHER
24. BRUSH HOLDER ASSEMBLY
25. SCREW
26. END COVER
27. BOLT

Figure 260. Alternator

Assembly

1. Assemble stator, ball bearing, retainer plate, and rotor screw. See Figure 260.
2. Assemble rotor, ball bearing, and bearing cover. See Figure 260.
3. Assemble rotor assembly and frame assembly. See Figure 260.
4. Install stud to frame assembly, then install stud nut. See Figure 260.
5. Install end cover, end frame, and bolts. See Figure 260.
6. Install insulation bushing and holder assembly nut on holder assembly. See Figure 260.
7. Assemble holder assembly, regulator assembly, small screw, screw and washer, brush holder assembly, and screw. See Figure 260.
8. Install end cover (item 26, Figure 260) and end cover bolt.
9. Assemble collar, pulley, and pulley nut onto end cover (item 5, See Figure 260).

Install

1. Perform the following steps to install the alternator.
   a. Install the alternator onto the stud attached to the timing gear case. Temporarily tighten the alternator mounting nut. See Figure 259.
   b. Temporarily tighten the mounting bolt (item 4, Figure 259) to retain the alternator to the alternator mounting bracket.
2. Reconnect the electrical wires to the alternator. Tighten the nuts to secure the wires to the alternator. Torque to 1.7-2.3 N•m (15-20 lbf in).
3. Fully tighten the alternator mounting nut. Torque to 1.7-2.3 N•m (15-20 lbf in).
4. Fully tighten the mounting bolt. Torque to 1.7-2.3 N•m (15-20 lbf in).
5. Reinstall the V-belt. Tighten the V-belt to the correct tension. See **Periodic Maintenance** 8000SRM2305 **Periodic Maintenance** 8000SRM2305 service manual.

NOTE: DO NOT operate the engine if the alternator is producing unusual sounds. Damage to the alternator will result.

6. Start the engine. Listen for any unusual sounds from the alternator.
7. Verify that the alternator icon does not display while the engine is operating. If the alternator displays, repair the problem before operating the engine. See the Guided Troubleshooting for this lift truck.

Figure 261. Alternator icon

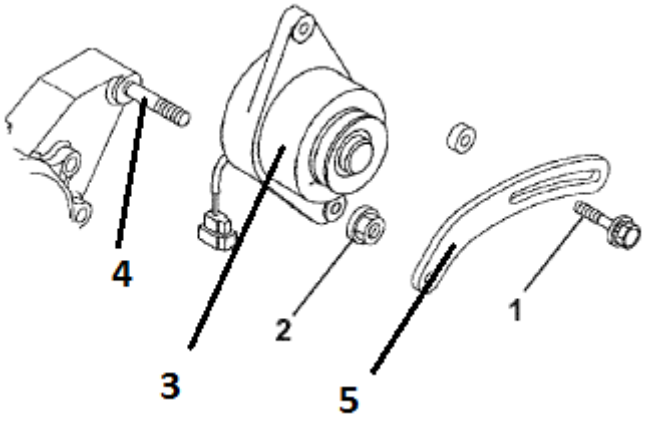
DYNAMO

Remove

CAUTION

PINCH HAZARD. Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

1. Disconnect the output wire connector from the dynamo.
2. Loosen the V-belt.
3. Remove the V-belt adjuster from the dynamo bolt. See Figure 262.



1. V-BELT ADJUSTER BOLT
2. NUT
3. DYNAMO
4. GEAR CASE STUD
5. V-BELT ADJUSTER

Figure 262. Dynamo mounting

4. Remove the nut from the gear case stud. See Figure 262.

5. Remove the dynamo.

Install

1. Position the dynamo on the gear case. See Figure 262.

2. Loosely install the nut on the gear case stud and the V-belt adjuster bolt. See Figure 262.

3. Reconnect the dynamo output wire connector.

4. Reinstall the V-belt. Tighten the V-belt to the correct tension. See **Periodic Maintenance** 8000SRM2305 **Periodic Maintenance** 8000SRM2305 service manual.

NOTE: DO NOT operate the engine if the alternator is producing unusual sounds. Damage to the alternator will result.

5. Start the engine. Listen for any unusual sounds from the alternator.

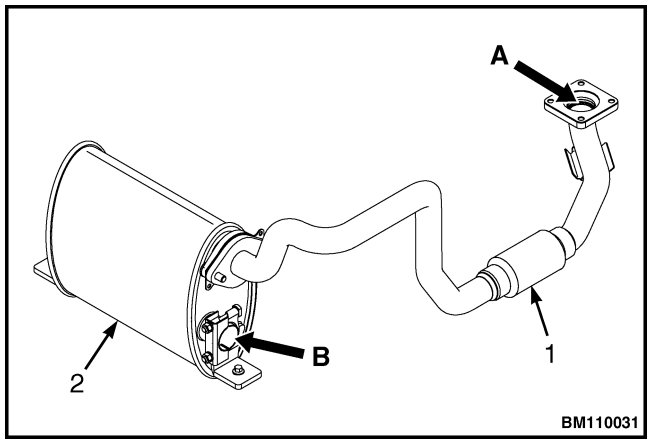
6. Verify that the charge indicator is ON while the engine is operating. If the charge indicator is not ON, repair the problem before operating the engine.

Table 64. Dynamo specifications

Nominal output	20 A
Weight	1.8 kg (3.97 lb)
Revolution direction (as viewed from pulley)	Clockwise
Rating	Continuous
Battery voltage	12 V
Rated revolution	3500 min rpm
Operating range	1400-6600 min rpm
Grounding characteristics	Negative (-) side of circuit
Integrated regulator	Current limiter
Outside diameter of pulley	A-belt: 65 mm (2.56 in.)
	Special M-belt: 58 mm (2.28 in.)
Belt shape	Type A or type special M

DIESEL EXHAUST REPAIR
202001-363

DIESEL EXHAUST SYSTEM



A. EXHAUST GAS IN
B. EXHAUST GAS OUT

1. EXHAUST PIPE
2. MUFFLER

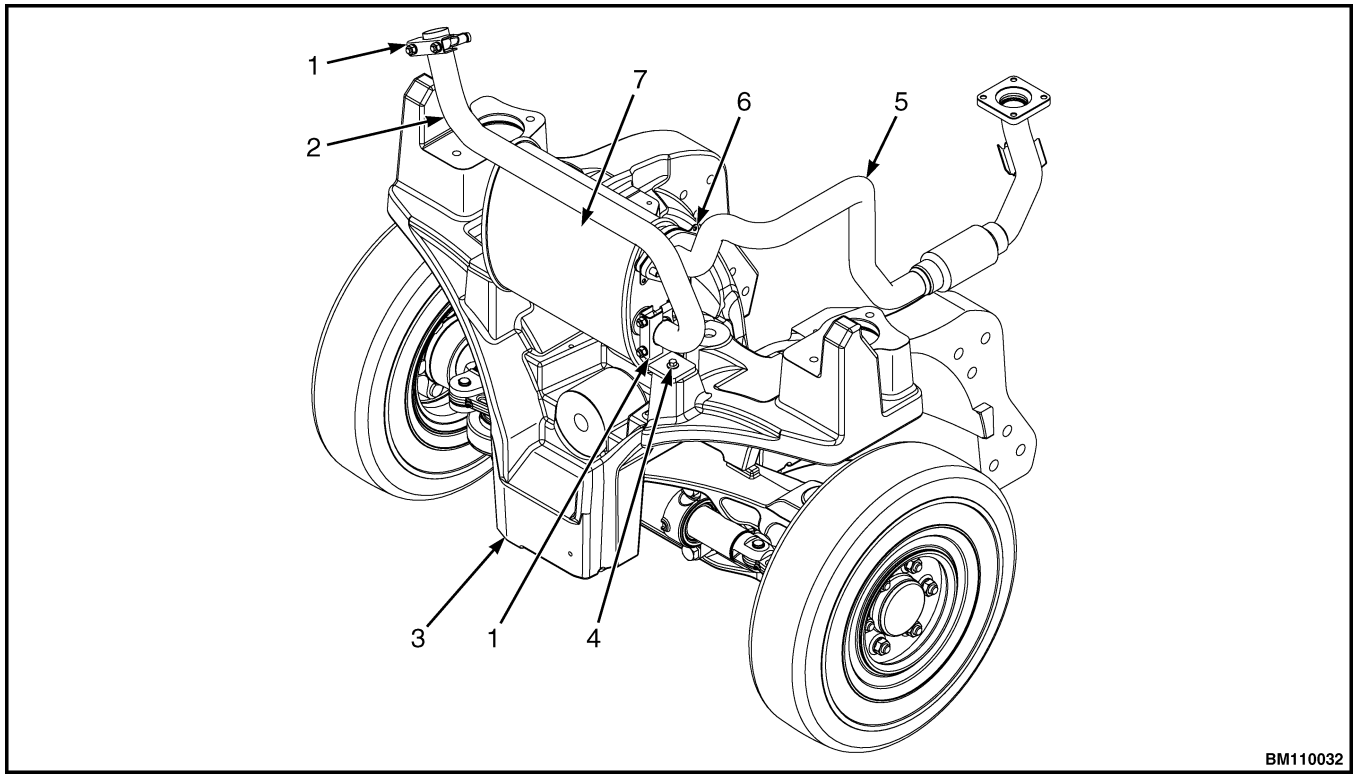
Figure 263. Muffler and Exhaust Pipes

Remove

WARNING

Exhaust system components are hot to touch. Be sure exhaust system components are cool before starting disassembly, or personal injury may occur.

1. Remove the counterweight, exhaust pipes and muffler. See **Counterweight Repair** in **Front End** 4000SRM2303 service manual.



1. CLAMP
2. OVERHEAD EXHAUST PIPE SECTION
3. COUNTERWEIGHT
4. CAPSCREW
5. EXHAUST PIPE
6. GASKET
7. MUFFLER

Figure 264. Exhaust System Components

Install

1. Install muffler, exhaust pipes, and the counterweight. See **Counterweight Repair** in **Front End** 4000SRM2303 service manual.

DIESEL ENGINE CHECKS, ADJUSTMENTS, AND CALIBRATIONS 202001-364

VALVE CLEARANCE ADJUSTMENTS

NOTE: Make measurements and adjustments while the engine is cold.

NOTE: The cylinder to be adjusted first does not have to be the number one cylinder. Select and adjust the cylinder where the piston is the nearest to top dead center (TDC) after rotating and make the adjustment for the other cylinders in the order of the ignition by turning the crankshaft 180 degrees each time.

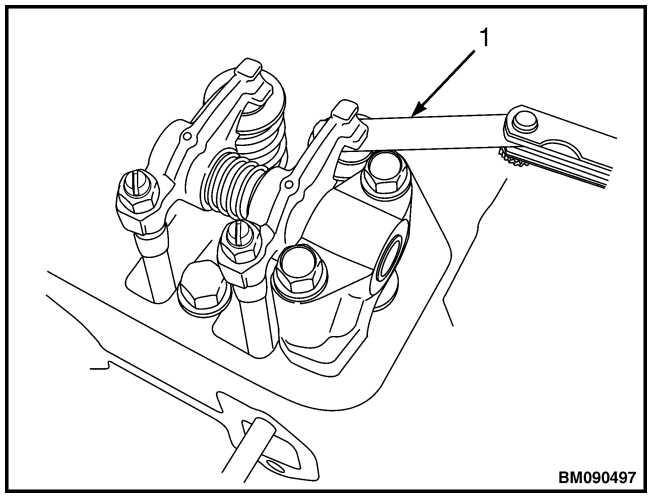
1. Remove cylinder head cover. See Diesel cylinder head repair.

NOTE: The number one piston position is on the flywheel end of the engine, opposite side of the radiator, and the ignition order is 1 - 3 - 4 - 2 at 180 degree intervals.

NOTE: Since intake and exhaust valve rocker arms are operated the same and there is a clearance between rocker arm and valve generally at top dead center, the position can be checked by means of the play when the arm head is held with a hand. Also, see that the crankshaft pulley top mark is positioned at zero on the timing scale. If there is no valve clearance, inspection in the disassembled state is necessary since the valve seat may be worn abnormally.

2. Rotate crankshaft clockwise, as seen from the coolant pump end, to bring the number one piston to top dead center (TDC) on the compression stroke while watching the rocker arm motion, timing grid on the flywheel. (Position where both the intake and exhaust valves are closed.)

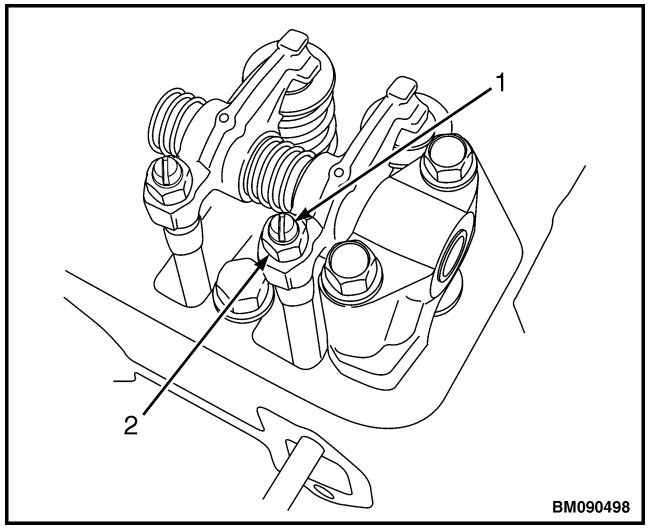
3. Insert a feeler gauge between the rocker arm and valve cap. See Figure 265. Record the measured valve clearance. The valve clearance should be between
0.15 to 0.25 mm (0.006 to 0.010 in.) when cold.



1. FEELER GAUGE

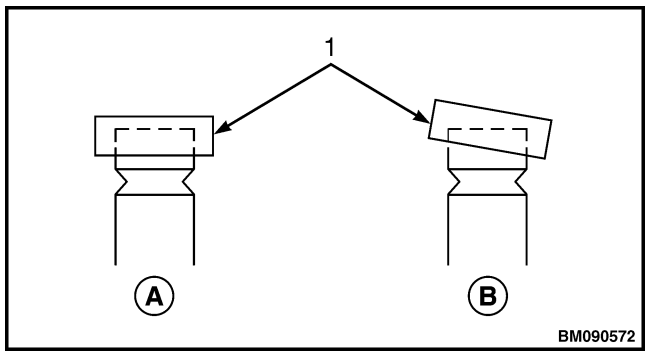
Figure 265. Valve Clearance Measurement

4. If adjustment is needed, loosen the valve adjusting screw lock nut and valve adjusting screw on the rocker arm (see Figure 266) and check the valve for any slope of valve cap, entrance of dirt, or wear. See Figure 267.



1. VALVE ADJUSTING SCREW
2. VALVE ADJUSTING SCREW LOCK NUT

Figure 266. Valve Clearance Adjustment



A. NORMAL
B. ABNORMAL

1. VALVE CAP

Figure 267. Valve Cap Check

NOTE: Clearance will decrease slightly when the lock nut is tightened. Make the clearance adjustment slightly on the loose side before tightening the lock nut.

5. Insert a 0.2 mm (0.008 in.) feeler gauge between the rocker arm and valve cap and adjust the clearance so there is a slight drag on the feeler gauge when sliding it between the rocker arm and valve cap. Tighten the valve adjusting screw lock nut and recheck the clearance. The valve clearance should be between 0.15 to 0.25 mm (0.006 to 0.010 in.).

6. Apply clean engine oil to the contact surface between the adjusting screw and push rod.

7. Turn the crankshaft 180 degrees and make the measurement and adjustment for the number three cylinder. Then turn the crankshaft 180 degrees and make the measurement and adjustment for the number four cylinder. Then turn the crankshaft 180 degrees and make the measurement and adjustment for the number 2 cylinder.

8. Install the valve cover. See Diesel cylinder head repair.

ALTERNATOR CHECKS

Test stater coil continuity

1. Disconnect the alternator output wire connector.

2. Connect one meter lead to each of the stator wire terminals and read the meter.

   Results: The meter reading should indicate continuity. If continuity is not indicated, the stator must be replaced.

Test stater coil short to ground

1. Disconnect the alternator output wire connector.

2. Test continuity between each stator wire terminal and engine ground.

   Results: The meter reading should be infinity. If continuity is indicated, the stator must be replaced.

Test alternator regulated output

1. Test and record the battery voltage with the engine not running.

2. Start the engine and operate it at normal operating rpm.

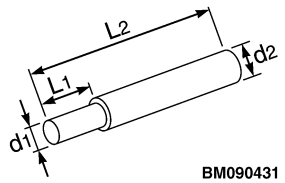
3. Again, check the battery voltage with the engine running.

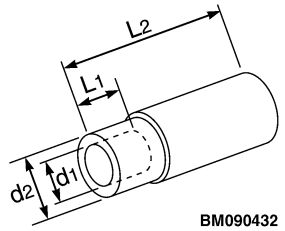
   Results: The meter reading with the engine running must be higher than with the engine not running. If this is not the outcome:

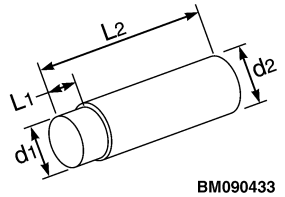
   - Test the stator for continuity and shorts to the ground.
   - Check the charging system wiring.
   - If no problems are found in previous checks, replace the IC regulator.

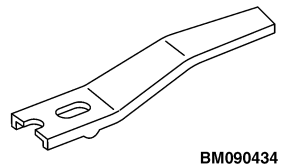
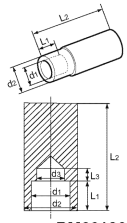
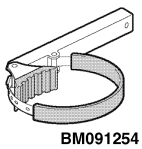
SPECIAL TOOLS FOR DIESEL ENGINES
202001-365

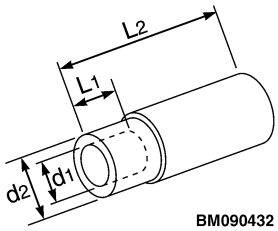
Table 65. Special service tools

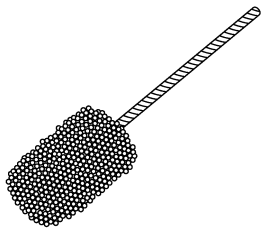
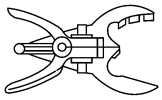
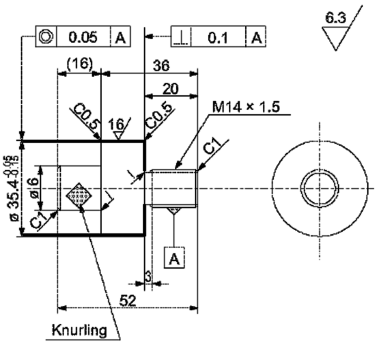
<table>
<tr><th>No.</th><th>Tool Name</th><th>Applicable model and tool size</th><th>Illustration</th></tr>
<tr><td>1</td><td>Valve guide tool (for extracting valve guide)</td><td><table><tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>20 mm (0.787 in.)</td><td>75 mm (2.953 in.)</td><td>7.5 mm (0.295 in.)</td><td>11 mm (0.433 in.)</td></tr></table>Locally manufactured</td><td> 

BM090431</td></tr>
<tr><td>2</td><td>Valve guide tool (for inserting valve guide)</td><td><table><tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>15 mm (0.591 in.)</td><td>65 mm (2.559 in.)</td><td>14 mm (0.551 in.)</td><td>20 mm (0.787 in.)</td></tr></table>Locally manufactured</td><td> 

BM090432</td></tr>
<tr><td>3</td><td>Connecting rod bushing replacer (for removal/ installation of connecting rod bushing)</td><td><table><tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>20 mm (0.787 in.)</td><td>100 mm (3.937 in.)</td><td>30 mm (1.18 in.)</td><td>33 mm (1.3 in.)</td></tr></table>Locally manufactured</td><td> 

BM090433</td></tr>
<tr><td>4</td><td>Valve spring compressor (for removal or installation of valve spring)</td><td>Hyster Part No. 1607211</td><td> 
BM090434</td></tr>
<tr><td>5</td><td>Stem seal inserter (for inserting stem seal)</td><td><table><tr><th>d1</th><th>d2</th><th>d3</th><th>L1</th><th>L2</th><th>L3</th></tr><tr><td>16.2 mm (0.638 in.)</td><td>22 mm (0.866 in.)</td><td>13.5 mm (0.531 in.)</td><td>17 mm (0.67 in.)</td><td>65 mm (2.560 in.)</td><td>4 mm (0.157 in.)</td></tr></table>Locally manufactured</td><td> 
BM091261</td></tr>
<tr><td>6</td><td>Filter wrench (for removal or installation of engine oil filter)</td><td>Available locally Hyster part number</td><td> 
BM091254</td></tr>
</table>

<table>
<tr><th>No.</th><th>Tool Name</th><th>Applicable model and tool size</th><th>Illustration</th></tr>
<tr><td>7</td><td>Camshaft bushing tool (for extracting camshaft bushing)</td><td>
<table>
<tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr>
<tr><td>18 mm
(0.709 in.)</td><td>70 mm
(2.756 in.)</td><td>50 mm
(1.969 in.)</td><td>53 mm
(2.087 in.)</td></tr>
</table>
Locally manufactured</td><td> 

BM090432</td></tr>
<tr><td>7</td><td>Flex-hone (for preparation of cylinder walls)</td><td>
<table>
<tr><th>Model</th><th>Part number</th><th>Cylinder bore</th></tr>
<tr><td>4TNE92</td><td>Hyster Part No. 1607212</td><td>83 to 95 mm (3.268-3.740 in.)</td></tr>
</table>
</td><td>  </td></tr>
<tr><td>9</td><td>Piston ring compressor (for inserting piston)</td><td colspan="2">Hyster Part No. 1607213
The piston insertion tool is applicable for
60 to 125 mm (2.362 to 4.921 in.)
Diameter pistons</td><td> 
BM091255</td></tr>
<tr><td>10</td><td>Piston ring replacer (for removal/ installation of piston ring)</td><td colspan="2">Available locally</td><td> 
BM090440</td></tr>
<tr><td>11</td><td>Pulley installing tool</td><td colspan="2"> 

BM091256</td><td></td></tr>
</table>

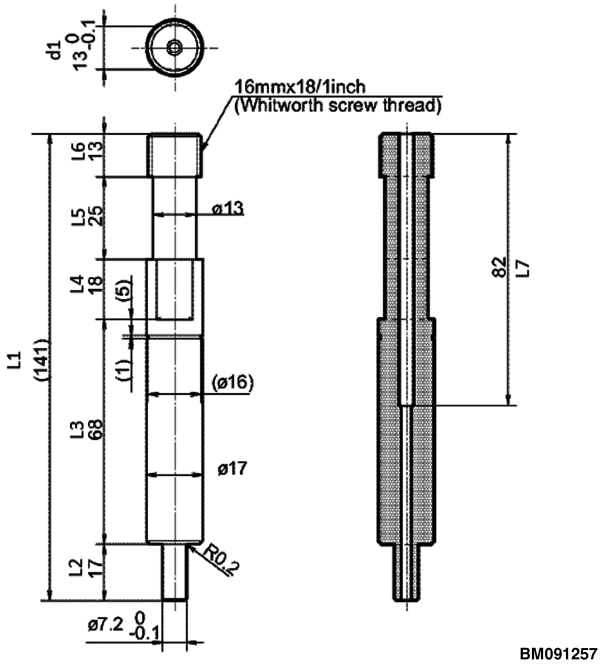


Figure 268. Compression gauge adapter

Table 66. Measuring instruments

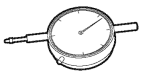
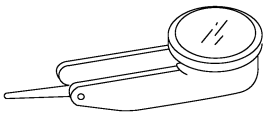
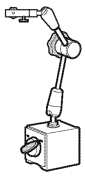
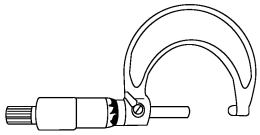
No.	Instrument name	Application	Illustration
1	Dial indicator	Measures shaft bend and end play	 BM091258
2	Test indicator	Measures narrow or deep portions that cannot be measured by dial gauge	 BM090443
3	Magnetic stand	Holds dial gauge when measuring	 BM091259
4	Micrometer	Measures the outside diameters of crankshaft, pistons, piston pins, etc.	 BM090445

Table 66. Measuring instruments (Continued)

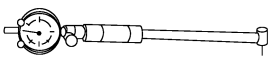
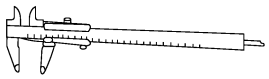
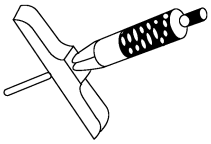
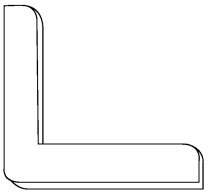
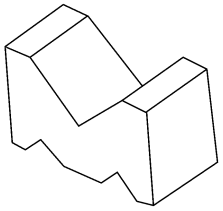
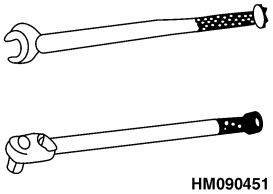
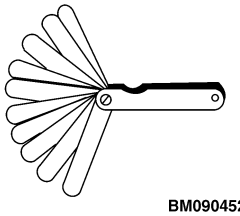
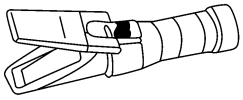
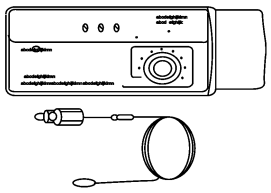
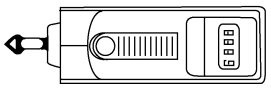
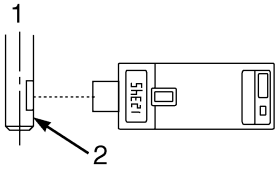
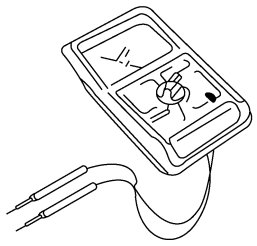
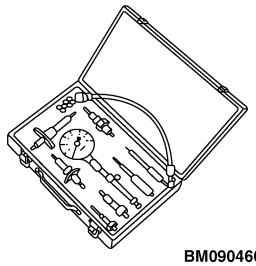
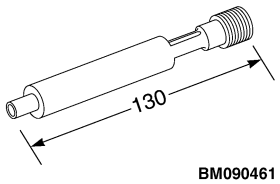
No.	Instrument name	Application	Illustration
5	Cylinder bore gauge	Measures the inside diameters of cylinder liners, rod metal, etc.	 BM090446
6	Calipers	Measures outside diameters, depth, thickness, and width	 BM090447
7	Depth micrometer	Measures valve recession	 BM090448
8	Square	Measures valve spring inclination and straightness of parts	 BM090449
9	V-block	Measures shaft bend	 BM090450
10	Torque wrench	Tightens nuts and bolts to the specified torque	 HM090451
11	Thickness gauge ("feeler" gauge)	Measures gaps between ring and ring groove and shaft joints during assembly	 BM090452
12	Battery coolant tester	For checking concentration of antifreeze and the battery electrolyte charge status	 BM090454

Table 66. Measuring instruments (Continued)

No.	Instrument name		Application	Illustration
13	Digital thermometer		For measuring temperatures	 BM090456
14	Tachometer	Contact type	For measuring revolution by contacting the revolving shaft	 BM090457
		Photoelectric type	For measuring revolution by sensing the reflecting mark on the outer periphery of the revolving shaft	 BM090458
		Fuel high pressure pipe clamp type	This measures the revolution regardless of the center or periphery of the revolving object	
15	Circuit tester		For measuring resistance, voltage and continuity of electrical circuits	 BM090459
16	Compression guage kit		For measuring compression pressure Gauge Set Part No. TOL-97190080	 BM090460
	New compression test adaptor		Adapter for direct injection 2-valve cylinder head Adapter Part No. 119802-92950	 BM090461

LPG engine repair

LPG ENGINE SPECIFICATIONS
202001-022

CYLINDER HEAD SPECIFICATIONS

Table 67. Adjustment specifications

Model	Valve clearance
4TN88G, 4TN88GN-NHYG	Intake: 0.15-0.25 mm (0.006-0.010 in.) Exhaust: 0.15-0.25 mm (0.006-0.010 in.)

Table 68. Cylinder head

Inspection item			Standard	Limit	Reference page
Combustion surface distortion			0.05 mm (0.0020 in.) or less	0.15 mm (0.0059 in.)	See Valve recession section, in LPG cylinder head repair
Valve recession		Intake	0.30-0.50 mm (0.0118-0.0197 in.)	0.8 mm (0.0315 in.)	
		Exhaust	0.20-0.40 mm (0.0079-0.0157 in.)	0.7 mm (0.0276 in.)	
Valve seat	Seat angle	Intake	120°	-	See Valve face and valve seat section, in LPG cylinder head repair
		Exhaust	120°	-	
	Seat correction angle		40°, 150°	-	

Table 69. Intake/Exhaust valve guard

Inspection item		Standard	Limit	Reference page
Intake	Guide inside diameter	8.010-8.025 mm (0.3154-0.3159 in.)	8.10 mm (0.3189 in.)	See Inspection of valve guides section, in LPG cylinder head repair
	Valve stem outside diameter	7.960-7.975 mm (0.3134-0.3140 in.)	7.90 mm (0.3110 in.)	
	Valve stem bend	0.035-0.070 mm (0.0014-0.0028 in.)	0.18 mm (0.0071 in.)	
Exhaust	Guide inside diameter	8.015-8.030 mm (0.3156-0.3161 in.)	8.10 mm (0.3189 in.)	
	Valve stem outside diameter	7.955-7.970 mm (0.3132-0.3138 in.)	7.90 mm (0.3110 in.)	
	Valve stem bend	0.045-0.075 mm (0.0018-0.0030 in.)	0.18 mm (0.0071 in.)	

Table 69. Intake/Exhaust valve guard (Continued)

Inspection item	Standard	Limit	Reference page
Valve guide projection from cylinder head	14.8-15.2 mm (0.5827-0.5984 in.)	-	See Reassembly of intake and exhaust valves, in LPG cylinder head repair
Valve guide installation method	Press-fitted	-	
Valve stem seal projection from the cylinder head	16-16.2 mm (0.6299-0.6378 in.)	-	

Table 70. Push rod

Inspection item	Standard	Limit	Reference page
Push rod bend	Less than 0.03 mm (0.0118 in.)	0.03 mm (0.0118 in.)	See Push rod bend section, in LPG cylinder head repair

Table 71. Rocker arm and shaft

Inspection item	Standard	Limit	Reference page
Arm shaft hole diameter	16.000-16.020 mm (0.6299-0.6307 in.)	16.07 mm (0.6327 in.)	See Inspection of Rocker Arm Assembly section, in LPG cylinder head repair
Shaft outside diameter	15.966-15.988 mm (0.6286-0.6294 in.)	15.94 mm (0.6276 in.)	
Oil clearance	0.012-0.054 mm (0.0005-0.0021 in.)	0.13 mm (0.0051 in.)	

Table 72. Valve spring

Inspection item	Standard	Limit	Reference page
Free length	44.4 mm (1.7480 in.)	44 mm (1.7323 in.)	See Inspection of Valve Springs section, in LPG cylinder head repair
Squareness	-	1.4 mm (0.0551 in.)	

CAMSHAFT AND TIMING GEAR TRAIN SPECIFICATIONS

Table 73. Camshaft

Inspection item		Standard	Limit	Reference page
End play		0.05-0.20 mm (0.0020-0.0079 in.)	0.030 mm (0.0118 in.)	See Removal of camshaft section, in LPG cylinder head repair
Bend (1/2 the dial gauge reading)		0-0.2 mm (0-0.0008 in.)	0.05 mm (0.0020 in.)	See Inspection of camshaft section, in LPG cylinder head repair
Cam lobe height		38.675-38.725 mm (1.5226-1.5246 in.)	38.425 mm (1.5128 in.)	
Shaft outside diameter/bearing inside diameter				
Gear end	Bushing inside diameter	44.990-45.055 mm (1.7713-1.7738 in.)	45.130 mm (1.7768 in.)	See Inspection of camshaft section, in LPG cylinder head repair
	Camshaft outside diameter	44.925-45.950 mm (1.7687-1.7697 in.)	44.890 mm (1.7673 in.)	
	Oil clearance	0.040-0.130 mm (0.0016-0.0051 in.)	0.240 mm (0.0094 in.)	
Intermediate	Bore inside diameter	45.000-45.025 mm (1.7716-1.7726 in.)	45.100 mm (1.7756 in.)	
	Camshaft outside diameter	44.910-44.935 mm (1.7681-1.7691 in.)	44.875 mm (1.7667 in.)	
	Oil clearance	0.065-0.115 mm (0.0026-0.0045 in.)	0.225 mm (0.0089 in.)	
Flywheel end	Bore inside diameter	45.000-45.025 mm (1.7716-1.7726 in.)	45.100 mm (1.7756 in.)	
	Camshaft outside diameter	44.925-45.950 mm (1.7687-1.7697 in.)	44.890 mm (1.7673 in.)	
	Oil clearance	0.050-0.100 mm (0.0020-0.0039 in.)	0.210 mm (0.0083 in.)	

Table 74. Idler gear shaft and bushing

Inspection item	Standard	Limit	Reference page
Shaft outside diameter	45.950-45.975 mm (1.8091-1.8100 in.)	45.900 mm (1.8071 in.)	See LPG cylinder head repair
Bushing inside diameter	46.000-46.025 mm (1.8110-1.8120 in.)	46.075 mm (1.8140 in.)	
Oil clearance	0.025-0.075 mm (0.0010-0.0030 in.)	0.175 mm (0.0068 in.)	

Table 75. Timing gear backlash

Inspection item	Standard	Limit	Reference page
Crank gear, cam gear, idler gear and PTO gear	0.07-0.15 mm (0.0028-0.0059 in.)	0.16 mm (0.0063 in.)	See Checking timing gear backlash section, in LPG cylinder head repair

CRANKSHAFT AND PISTON SPECIFICATIONS

NOTE: Check appropriate parts catalog for various sizes of replacement main bearings.

Table 76. Crankshaft

Inspection item		Standard	Limit	Reference page
Bend (1/2 the dial gauge reading)		-	0.02 mm (0.0008 in.)	See Inspection of crankshaft section, in LPG cylinder head repair
Connecting rod journals	Journal outside diameter	47.952-47.962 mm (1.8879-1.8883 in.)	47.902 mm (1.8859 in.)	
	Bearing inside diameter	48.000-48.026 mm (1.8898-1.8909 in.)	-	
	Bearing insert thickness	1.492-1.500 mm (0.0587-0.0591 in.)	-	
	Oil clearance	0.038-0.074 mm (0.0015-0.0029 in.)	0.150 mm (0.0059 in.)	
Main bearing journal	Journal outside diameter	49.952-49.962 mm (1.9666-1.9670 in.)	49.902 mm (1.9646 in.)	See Inspection of crankshaft section, in LPG cylinder head repair
	Bearing inside diameter	50.000-50.020 mm (1.9685-1.9693 in.)	-	
	Bearing insert thickness	1.995-2.010 mm (0.0785-0.0791 in.)	-	
	Oil clearance	0.038-0.068 mm (0.0015-0.0027 in.)	0.150 mm (0.0059 in.)	

Table 77. Thrust bearing

Inspection item	Standard	Limit	Reference page
Crankshaft end play	0.13-0.23 mm (0.0051-0.0091 in.)	0.28 mm (0.0110 in.)	See Removal of crankshaft section, in LPG cylinder head repair

Table 78. Piston

Inspection item		Standard	Limit	Reference page
Piston outside diameter (Measure at 90° to the piston pin)		87.908-87.938 mm (3.4609-3.4621 in.)	87.863 mm (3.4592 in.)	See Inspection of pistons, piston rings and wrist pin section, in LPG cylinder head repair
Piston diameter measure location (Upward from the bottom of the piston)		24 mm (0.9449 in.)	-	
Piston pin	Hole inside diameter	26.000-26.009 mm (1.0236-1.0240 in.)	26.039 mm (1.0252 in.)	See Inspection of pistons, piston rings and wrist pin section, in LPG cylinder head repair
	Pin outside diameter	25.995-26.000 mm (1.0234-1.0236 in.)	25.965 mm (1.0222 in.)	
	Oil clearance	0.000-0.014 mm (0.000-0.0006 in.)	0.074 mm (0.0029 in.)	

Table 79. Piston ring

Inspection item		Standard	Limit	Reference page
Top ring	Ring groove width	1.560-1.575 mm (0.0614-0.0620 in.)	-	See Inspection of pistons, piston rings and wrist pin section, in LPG cylinder head repair
	Ring width	1.470-1.490 mm (0.0579-0.0587 in.)	1.450 mm (0.0571 in.)	
	Side clearance	0.070-0.105 mm (0.0028-0.0041 in.)	-	
	End gap	0.200-0.350 mm (0.0079-0.0138 in.)	0.440 mm (0.173 in.)	
Second ring	Ring groove width	2.025-2.040 mm (0.0797-0.0803 in.)	2.140 mm (0.0843 in.)	
	Ring width	1.970-1.990 mm (0.0776-0.0783 in.)	1.950 mm (0.0768 in.)	
	Side gap	0.035-0.070 mm (0.0014-0.0028 in.)	0.190 mm (0.0075 in.)	
	End gap	0.20-0.40 mm (0.0079-0.0157 in.)	0.490 mm (0.0193 in.)	
Oil ring	Ring groove width	4.015-4.030 mm (0.1581-0.1587 in.)	4.130 mm (0.1626 in.)	See Inspection of pistons, piston rings and wrist pin section, in LPG cylinder head repair
	Ring width	3.970-3.990 mm (0.1563-0.1571 in.)	3.950 mm (0.01555 in.)	
	Side clearance	0.025-0.060 mm (0.0010-0.0024 in.)	0.180 mm (0.0071 in.)	
	End gap	0.200-0.400 mm (0.0079-0.0157 in.)	0.490 mm (0.0193 in.)	

Table 80. Connecting rod

Inspection item	Standard	Limit	Reference page
Connecting rod small end			
Wrist pin bushing inside diameter	26.025-26.038 mm (1.0234-1.0251 in.)	26.068 mm (1.0263 in.)	See Inspection of connecting rod section, in LPG cylinder head repair
Wrist pin outside diameter	25.995-26.000 mm (1.0234-1.0236 in.)	25.967 mm (1.0223 in.)	
Oil clearance	0.025-0.043 mm (0.0010-0.0017 in.)	0.101 mm (0.0040 in.)	
Connecting rod big end			
Side clearance	0.20-0.40 mm (0.0079-0.0157 in.)	-	

Table 81. Tappet

Inspection item	Standard	Limit	Reference page
Tappet bore (block) inside diameter	12.000-12.018 mm (0.4724-0.4731 in.)	12.038 mm (0.4739 in.)	See Inspection of tappets section, in LPG cylinder head repair
Tappet stem outside diameter	11.975-11.990 mm (0.4715-0.4720 in.)	11.955 mm (0.4707 in.)	
Oil clearance	0.010-0.043 mm (0.0004-0.0017 in.)	0.083 mm (0.0033 in.)	

CYLINDER BLOCK SPECIFICATIONS

Table 82. Cylinder block

Inspection item	Standard	Limit	Reference page
Cylinder inside diameter	88.000-88.030 mm (3.4646-3.4657 in.)	88.200 mm (3.4724 in.)	See Inspection of cylinder block section, in LPG cylinder head repair
Cylinder bore	0.01 mm (0.0004 in.) or less	0.03 mm (0.0012 in.)	

FUEL SPECIFICATIONS

Item		Unit	Value limit	Test method/ Fuel specifications
Fuel composition	Propane	Vol % (liquid phase)	> 90	GPA2140, HD-5
	Propylene		≤ 5	GPA2140, HD-5
	Ethane + Ethylene	mol %	≤ 5	JIS K2240
	Diene		≤ 0.5	EN589
Vapor pressure		kPa @37.8°C (psi @100° F)	≤ 1434 (208)	GPA2140, HD-5
Temperature when 95% of fuel is vaporized		°C (°F)	≤ -38.3 (-36.9)	GPA2140, HD-5

Item		Unit	Value limit	Test method/ Fuel specifications
Density		g/cm³ @15°C(lb/in3 @59°F)	0.5-0.62 (0.018-.022)	JIS K2240
Impurities in fuel	N_2	%	<60	YIS
	CO_2	%	<40	YIS
	H_2	%	<50	YIS
	H_2S	%	0	EN589
	Dust	g/Nm³(ppm)	> 0.05 (28)	YIS
	Ammonia	mg (oz)/10 kWh	O	GPA2140
	Material with carbon number C4 or higher	Vol % (liquid phase)	≤ 2.5	GPA2140, HD-5
	Material with carbon number C5 or higher		≤ 2.0	GPA2140, HD-5
	Residue	mg/kg (ppm)	< 60	EN589
Fuel contamination		_	No contamination shall be observed	GPA2140
Copper corrosion		-	No change shall be observed on copper plate before/after the test	EN ISO 6251 ASTM D1838 JIS K2240 6.11
Total volatile sulfur		ppmw	≤ 50	EN589
Moisture content		-	ASTM D2713, EN 15469, GPA note C shall be complied	ASTM D2713 EN 15469 GPA Note C

OIL PUMP SERVICE INFORMATION

Table 83. Engine lubricating oil pressure

Model	At rated engine RPM (min)	At low idle speed
	2600 min^{-1}	
4TN88G, 4TN88GN-NHYG	0.31-0.41 MPa (44.96-59.47 psi)	0.1 MPa (8.7 psi)

Table 84. Outer rotor outside clearance

Model	Standard	Limit	Reference page
4TN88G, 4TN88GN-NHYG	0.09-0.15 mm (0.0035-0.0059 in.)	0.25 mm (0.0098 in.)	Check outer rotor outside clearance. See Outer rotor outside clearance in LPG lubrication system repair.

Table 85. Outer rotor side clearance

Model	Standard	Limit	Reference page
4TN88G, 4TN88GN-NHYG	0.05-0.09 mm (0.0020-0.0035 in.)	0.15 mm (0.0059 in.)	Check outer rotor side clearance. See Figure 367 in LPG lubrication system repair.

Table 86. Outer rotor to inner rotor tip clearance

Model	Standard	Limit	Reference page
4TN88G, 4TN88GN-NHYG	---	0.16 mm (0.0063 in.)	Check outer rotor to inner rotor tip clearance. See Figure 366 in LPG lubrication system repair.

Table 87. Starter Specifications

Nominal output		1.7 kW (2.3 hp)
Weight		3.4 kg (7.5 lb)
Revolution direction (As viewed from pinion)		Clockwise
Engagement system		Magnetic shift
No-load	Terminal voltage / current	11V / 90A or less
	Revolution	2300 rpm min $^{-1}$(rpm)
Loaded	Terminal voltage / current	8V / 370A or less
	Torque	15.1 N•m (11.1 lbf ft)
Restraint	Terminal voltage / current	2.7V / 650A or less
	Torque	18.6 N•m (13.7 lbf ft)
Clutch system		Overrunning
Pinion projection Voltage at 100°C (212°F)		8V or lower
Pinion DP or module / number of teeth		ø27.94/11

Table 88. Alternator specifications

Nominal output (13.5 volts heat)	55 A
Weight	3.2 kg (7.1 lb)
Revolution direction (as viewed from pulley)	Clockwise
Rating	Continuous
Battery voltage	12 V
Rated revolution	5000 min^{-1}rpm
Operating range	1070-18000 min^{-1} rpm
Grounding characteristics	Negative (-) side of circuit
Integrated regulator	IC regulator
Outside diameter of pulley	69.2 mm (2.724 in.)
Belt shape	Type A

SPECIAL TORQUE CHART

Table 89. Torque for bolts and nuts

Component	Thread diameter and pitch	Torque	Lubricating oil application (Thread portion and seat surface)
Cylinder head bolt	M10 x 1.25 mm	92-98 N•m (68-72 lbf ft)	Applied
Connecting rod bolt	M9 x 1.0 mm	44.1-49 N•m (33-36 lbf ft)	Applied
Flywheel bolt	M10 x 1.25 mm	83.3-88.2 N•m (61-65 lbf ft)	Applied
Main bearing cap bolt	M10 x 1.25 mm	96.0-100 N•m (70.8-73.8 lbf ft)	Applied
Crankshaft pulley bolt	M14 x 1.5 mm	Cast metal (FC250) 83.3-93.1 N•m (62-69 lbf ft)	Applied
		Steel metal (S45C) 112.7-122.7 N•m (83-91 lbf ft)	
Crank speed sensor bolt	M6 x 1.0 mm	4.4-7.4 N•m (6-10 lbf ft)	Not applied
Cam speed sensor bolt	M6 x 1.0 mm	7.5-8.5 N•m (5.6-6.3 lbf ft)	Not applied
Engine coolant temperature sensor	M12 x 1.5 mm	16-20 N•m (11.8-14.8 lbf ft)	Not applied
O^2 sensor	M18 x 1.5 mm	39.1-48.9 N•m (28.9-36.1 lbf ft)	Burning prevention medicine
Gas fuel pressure sensor bolt	M5 coarse thread	4.0-6.0 N•m (3.0-4.4 lbf ft)	Not applied
Ignition coil bolt	M6 x 1.0 mm	6-9.5 N•m (4.4-7.0 lbf ft)	Not applied
Spark plugs	M14 x 1.25 mm	24.0-34.0 N•m (17.7-25.1 lbf ft)	Not applied
Vaporizer bolt	M6 x 1.0 mm	17 N•m (12.5 lbf ft)	Not applied
Knock sensor bolt	M8 x 1.25 mm	18.0-26.0 N•m (13.3-19.2 lbf ft)	Not applied
Accelerator sensor bolt	M6 x 1.0 mm	6.0-9.5 N•m (4.4-7.0 lbf ft)	Not applied
Intake temperature and pressure sensor bolt	M6 x 1.0 mm	4.0-6.0 N•m (3.0-4.4 lbf ft)	Not applied
Exhaust temperature sensor bolt	M12 x 1.25 mm	34.3-44.1 N•m (25.3-32.5 lbf ft)	Not applied
Intake throttle bolt	M6 x 1.0 mm	7.84-9.44 N•m (5.3-6.9 lbf ft)	Not applied

Table 89. Torque for bolts and nuts (Continued)

Component	Thread diameter and pitch	Torque	Lubricating oil application (Thread portion and seat surface)
Oil pressure switch	R1/8 (PT1/8)	18-22 N • m (13.3-16.2 lbf ft)	Not applied
Engine lubricating oil filter	M20 x 1.5 mm	15-18 N • m (11.1-13.3 lbf ft)	Applied
Drain plug (oil fan)	M22 x 1.5 mm	54-64 N • m (39.9-47.2 lbf ft)	Not applied
PCV valve	M14 x 1.5 mm	40-50 N • m (29.5-36.9 lbf ft)	Not applied
Adapter (injector)	M14 x 1.5 mm	4.0-6.0 N • m (3.0-4.4 lbf ft)	Not applied
Piston cooling nozzle banjo bolt	M8 x 1.25 mm	12.7-16.7 N • m (9.4-12.3 lbf ft)	Not applied

LPG CYLINDER HEAD REPAIR
202001-023

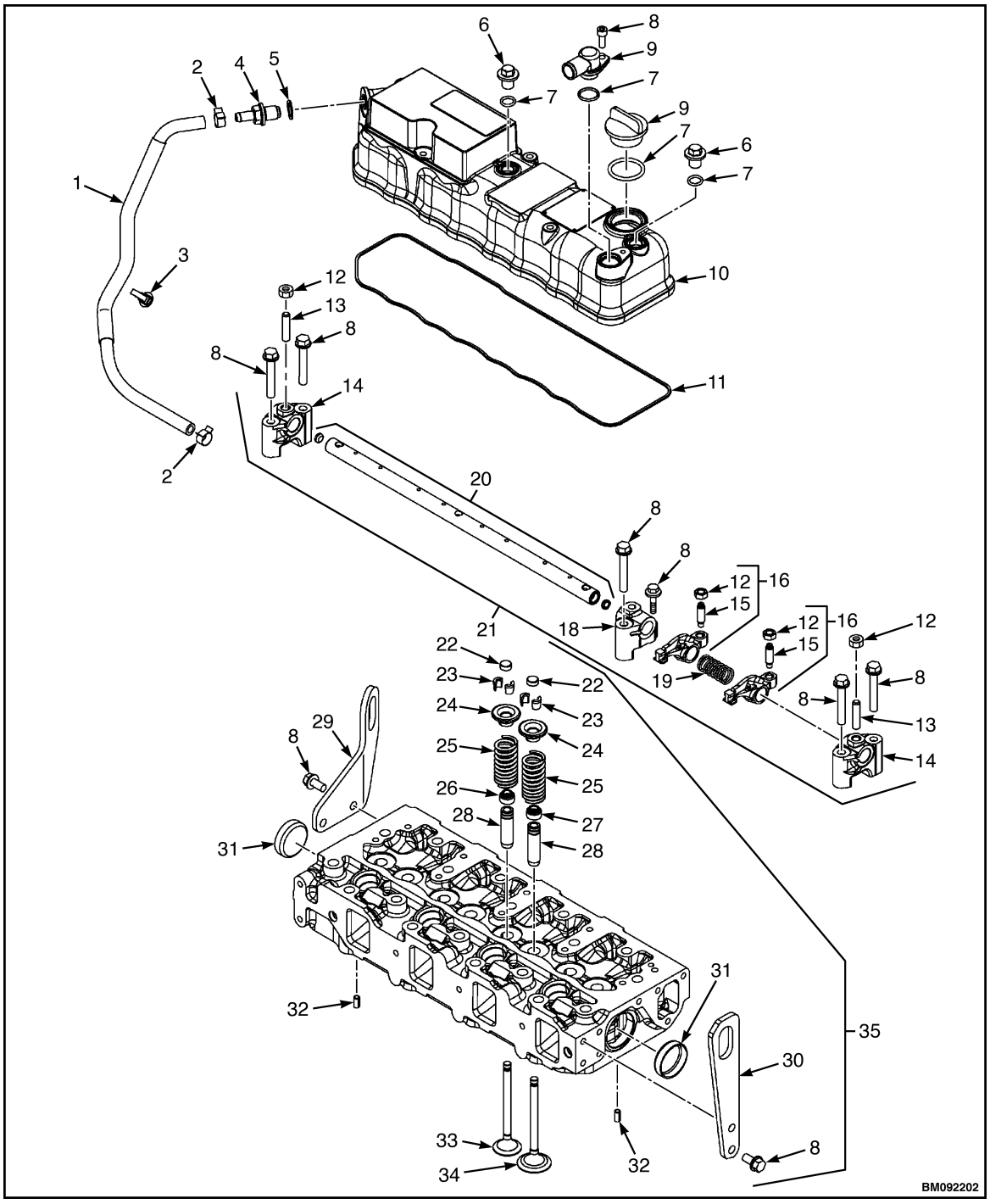


Figure 269. Cylinder head components

Legend for Figure 269.

1. BREATHER HOSE ASSEMBLY
2. CLAMP
3. CLIP
4. PCV VALVE
5. GASKET
6. PLUG
7. O-RING
8. BOLT
9. BREATHER JOINT
10. VALVE COVER
11. VALVE COVER GASKET
12. NUT
13. STUD
14. ROCKER A SUPPORT
15. SCREW
16. ROCKER ARM
17. ROCKER SHAFT ASSEMBLY
18. ROCKER B SUPPORT
19. SHAFT SPRING
20. SHAFT
21. ROCKER SHAFT ASSEMBLY
22. CAP
23. VALVE SPRING COTTERS
24. VALVE SPRING RETAINER
25. SPRING
26. VALVE STEM SEAL
27. VALVE STEM SEAL
28. VALVE GUIDES
29. ENGINE LIFTING EYE
30. ENGINE LIFTING EYE
31. PLUG
32. PIN 6X12
33. EXHAUST VALVE
34. INTAKE VALVE
35. CYLINDER HEAD ASSEMBLY

DISASSEMBLE CYLINDER HEAD

NOTE: Locate and identify all components prior to disassembly, to ensure all components are returned to the same position during reassembly.

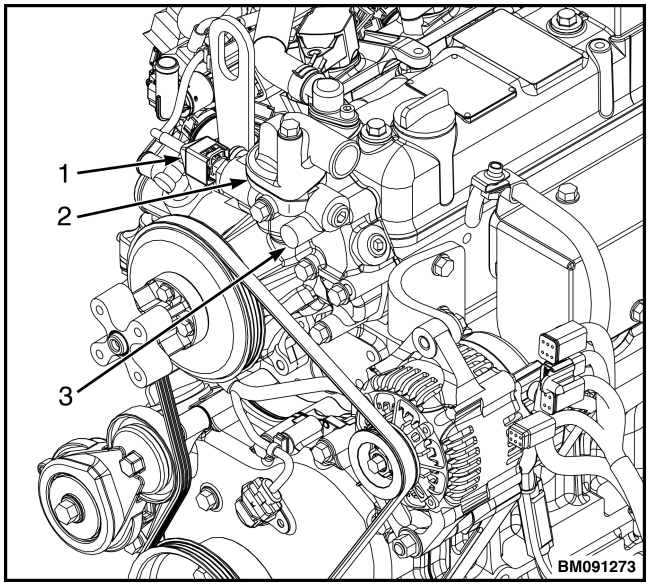
Prior to disassembly, prepare a clean, flat surface on a workbench large enough to accomodate the cylinder head assembly. Discard all gaskets, O-rings and seals. New gaskets, O-rings and seals are required when reassembling the cylinder head.

1. Drain all coolant from the engine into a suitable container.

2. Remove the alternator. See Removing the alternator, in LPG electrical system repair.

Disconnect the water pump electrical connector from the water pump. See Figure 270.

3. Disconnect the electrical connector from the coolant temperature sensor. See Figure 270.

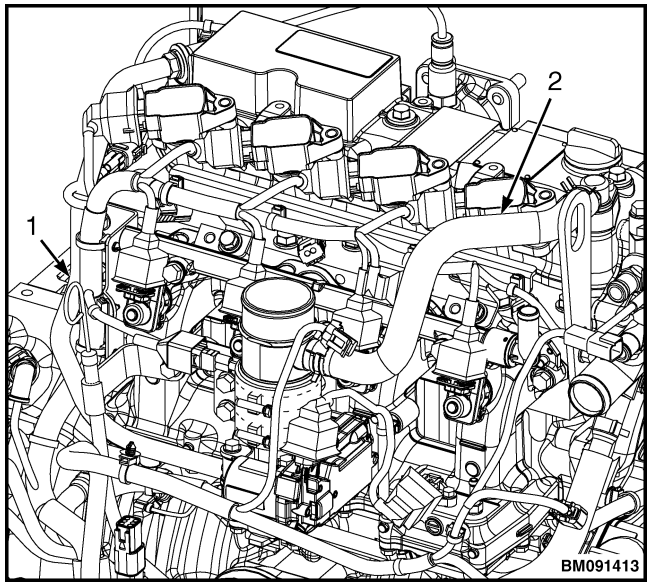


1. COOLANT TEMPERATURE SENSOR
2. CAM POSITION SENSOR
3. WATER PUMP

Figure 270. Coolant temperature sensor

4. Remove the cooling fan and the water pump. See Water pump repair in the **Cooling system** 0700SRM2300 manual.

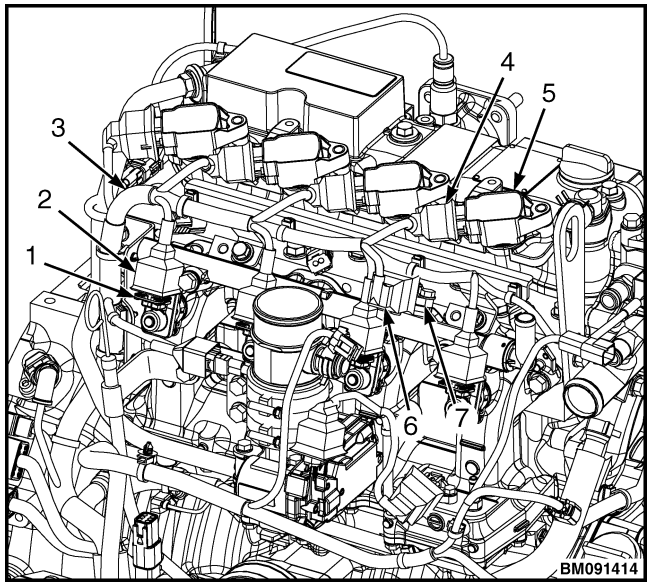
5. Loosen the hose clip on each end, and remove the breather hose and ambient air hose. See Figure 271.



1. BREATHER HOSE
2. AMBIENT AIR HOSE

Figure 271. Breather hose and ambient air hose

6. Disconnect the wire harness connectors from the four ignition coils and four injectors. See Figure 272.



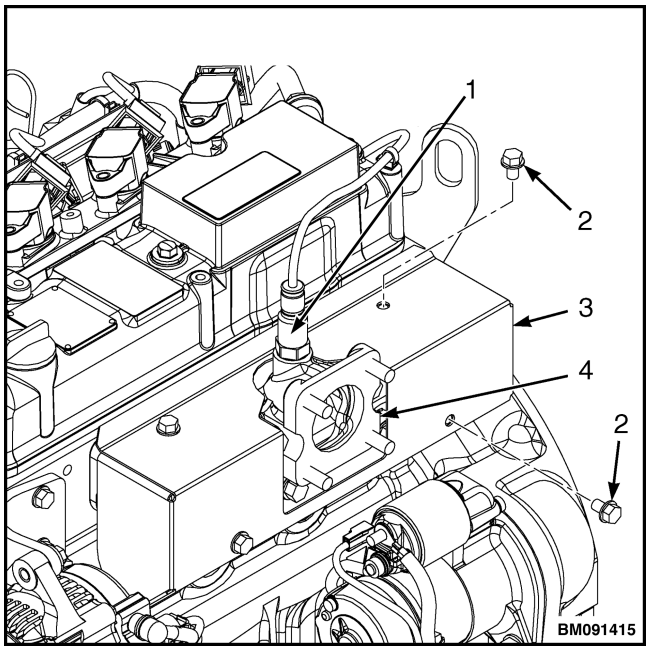
1. INJECTOR
2. INJECTOR CONNECTOR
3. WIRE HARNESS
4. IGNITION COIL CONNECTOR
5. IGNITION COIL

Figure 272. Wire harness and ignotion coils

7. Remove the wire harness clamp, then remove the wire harness and bracket.

8. Disconnect the O_2 sensor from the exhaust manifold. See Figure 273.

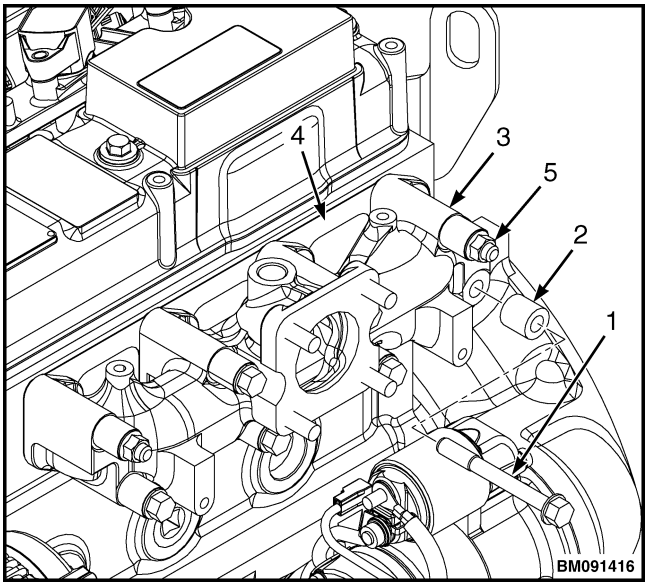
9. Remove the four bolts attaching the heat shield to the exhaust manifold. Remove the heat shield. See Figure 273.



1. O_2 SENSOR
2. BOLT
3. HEAT SHIELD
4. EXHAUST MANIFOLD

Figure 273. O_2 sensor

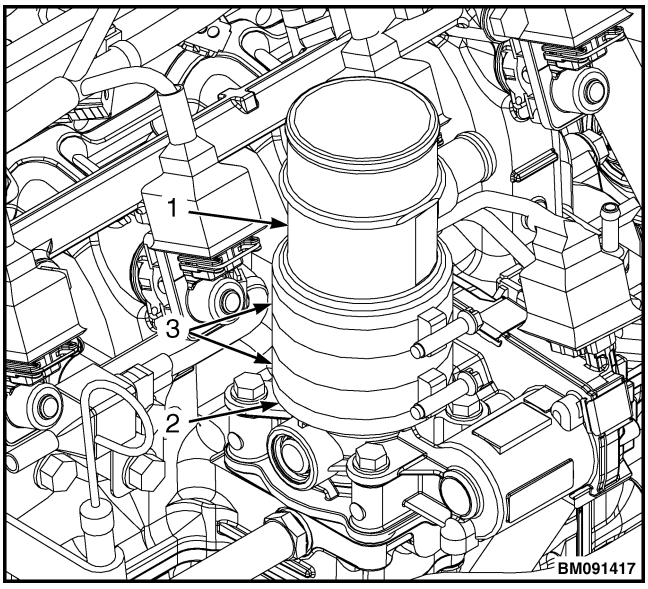
10. Loosen the bolts and nuts attaching the exhaust manifold to the engine block. Remove the exhaust manifold and discard the gasket. See Figure 274.



1. BOLT
2. SPACER
3. EXHAUST MANIFOLD
4. GASKET
5. NUT

Figure 274. Exhaust manifold

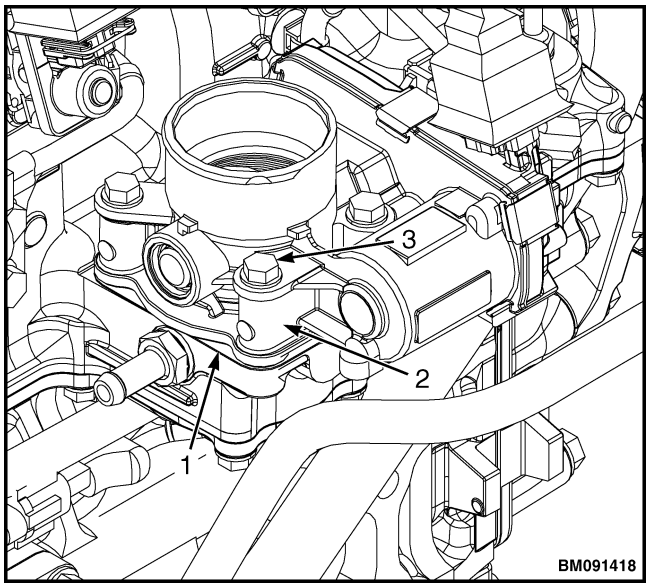
11. Loosen the hose clamp retaining the intake joint and hose. See Figure 275.



1. INTAKE JOINT
2. HOSE
3. HOSE CLAMP

Figure 275. Intake joint

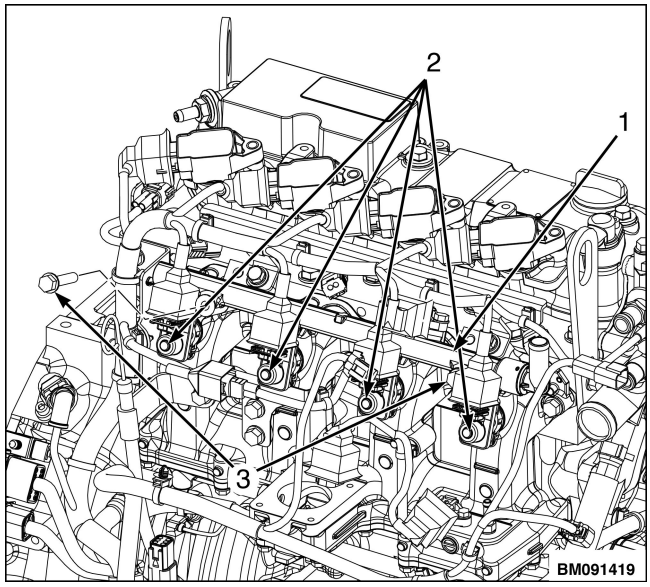
12. Loosen the four bolts attaching the intake throttle. Remove the intake throttle and discard the gasket. See Figure 276.



1. GASKET
2. INTAKE THROTTLE
3. BOLT

Figure 276. Intake throttle

13. Loosen the two bolts and remove the fuel rail. See Figure 277.



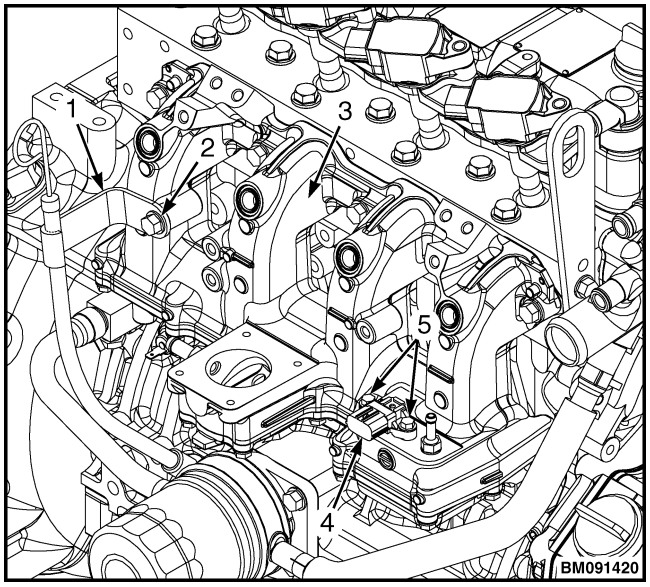
1. FUEL RAIL
2. INJECTOR COILS
3. BOLTS

Figure 277. Fuel rail

14. Release the retaining clip and remove the four injectors.

15. Remove the bolt retaining the dipstick mounting bracket to the intake manifold. See Figure 278.

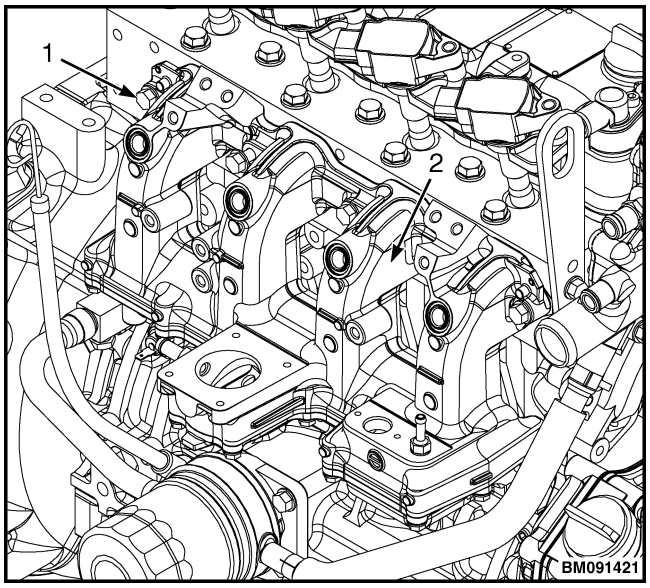
16. Remove the connector from the intake temperature and pressure sensor. Remove the intake temperature and pressure sensor. See Figure 278.



1. DIPSTICK MOUNTING BRACKET
2. BOLT
3. INTAKE MANIFOLD
4. INTAKE TEMPERATURE AND PRESSURE SENSOR
5. BOLT

Figure 278. Intake temperature and pressure sensor

17. Remove the five bolts retaining the intake manifold. See Figure 279.

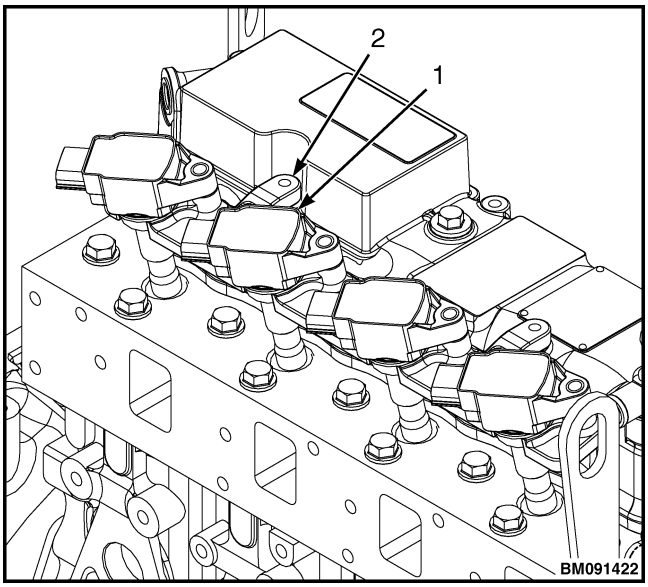


1. BOLT
2. INTAKE MANIFOLD

Figure 279. Intake manifold

18. Remove the intake manifold. Discard the gasket.

19. Remove the bolts retaining the ignition coils. Remove the four ignition coils and ignition coil bracket. See Figure 280.



1. IGNITION COILS
2. IGNITION COIL BRACKET

Figure 280. Ignition coils and bracket

20. Use a 16 mm long socket wrench to remove the four spark plugs from the engine block. See Figure 281.

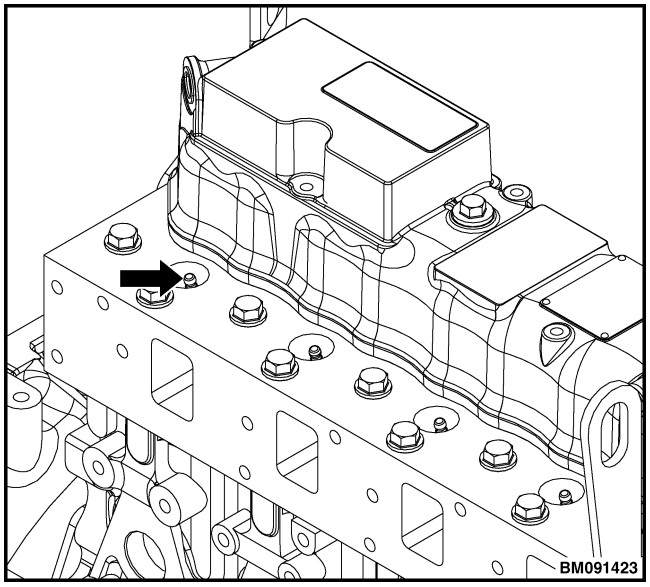
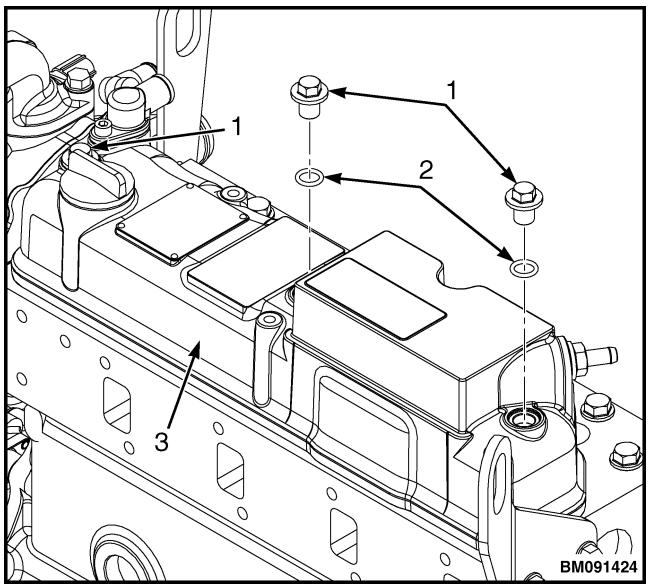


Figure 281. spark plugs

REMOVE

Valve cover

1. Remove the three bolts and O-rings attaching the valve cover to the engine block. Discard the O-rings. See Figure 282.



1. BOLT
2. O-RING
3. VALVE COVER

Figure 282. Valve cover

2. Remove the valve cover and discard the gasket.

Rocker arm

1. Remove the ten bolts that retain the rocker arm shaft supports. See Figure 269.

2. Remove the rocker arm shaft assembly from the cylinder head. See Figure 269.

3. Remove the push rods, taking note of thier location to aid in installation. See Figure 269.

Dissassemble rocker arm

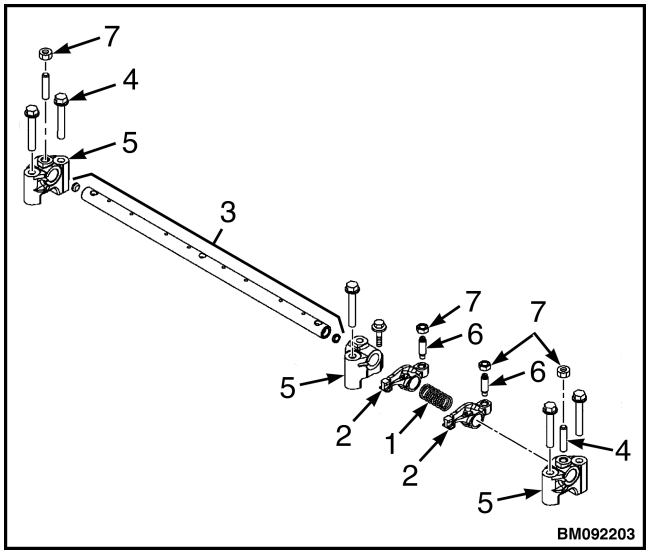
NOTE: Mark the rocker arms to aid in installation. Rocker arms must be installed with original matching valve and pushrod.

The rocker arm shaft fits tightly in the rocker arm supports. Clamp the support in a padded vise. Twist and pull out on the rocker arm shaft to remove. Reverse this process when you reinstall the rocker arm shaft into the supports.

1. Remove the rocker arm shaft alignment stud from the support. See Figure 283.

2. Slide the rocker arm shaft out of the rocker arm supports, springs and rocker arms. See Figure 283.

3. Remove the valve adjusting screw and the locknut from the rocker arms. See Figure 283.

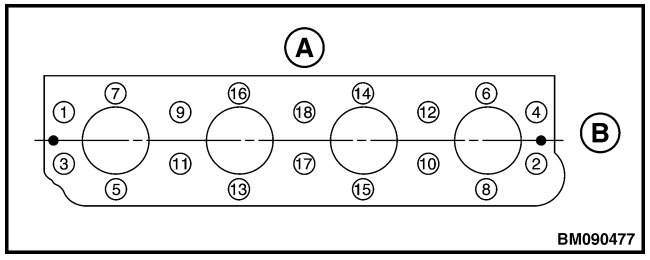


1. SPRING
2. ROCKER ARM
3. ROCKER ARM SHAFT
4. ALIGNMENT STUD
5. SUPPORT
6. VALVE ADJUSTING SCREW
7. LOCKNUT

Figure 283. Rocker arm assembly

Cylinder head

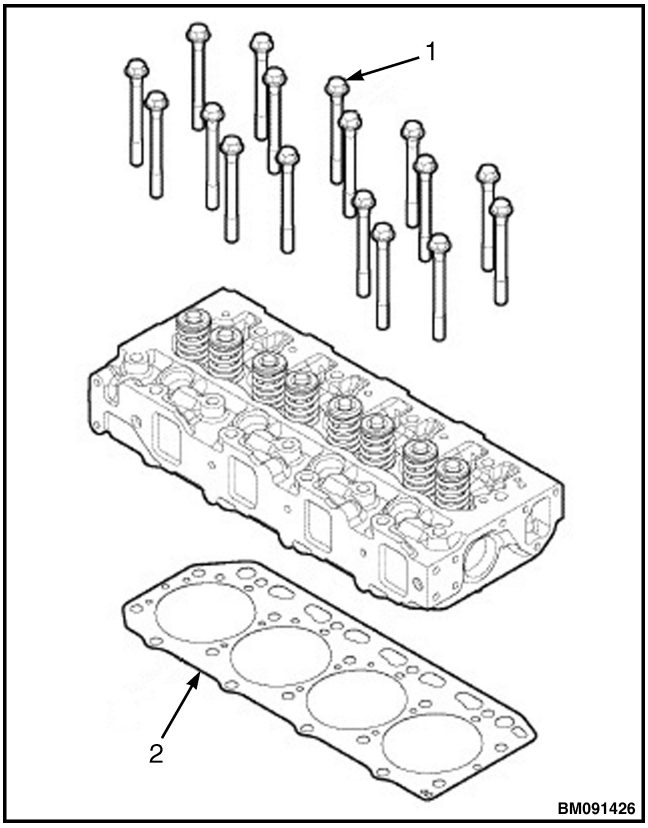
1. Loosen the cylinder head bolts in the sequence shown in Figure 284.



A. CAMSHAFT SIDE
B. FAN SIDE

Figure 284. Cylinder Head Torque Sequence

2. Remove the cylinder head bolts. See Figure 285.



1. CYLINDER HEAD BOLTS
2. CYLINDER HEAD GASKET

Figure 285. Cylinder head bolts

3. Lift the cylinder head away from the cylinder block. Discard the cylinder head gasket. Position the cylinder head on the work bench to prevent damage to the combustion surface.

Intake and exhaust valves

1. Place the cylinder head on the work bench with the combustion side down.

2. Remove the valve cap and keep with the valve it was installed on. See Figure 287.

3. Using the valve spring compressor tool, compress one of the valve springs. See Figure 286 and Special tools for LPG engines.

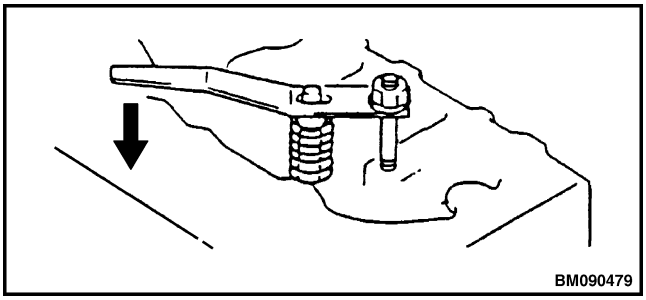
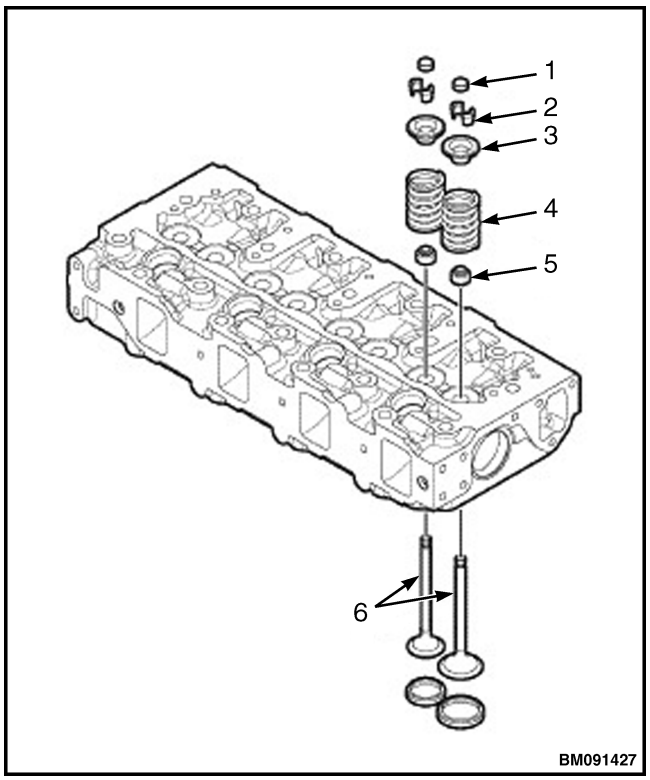


Figure 286. Valve spring compressor tool

4. Remove the valve stem cotters. See Figure 287.

5. Slowly release the tension on the valve spring. See Figure 287.

6. Remove the spring retainer and valve spring. See Figure 287.



1. VALVE CAP
2. VALVE STEM COTTERS
3. SPRING RETAINER
4. VALVE SPRING
5. VALVE STEM SEALS
6. VALVE

Figure 287. Install valves

7. Repeat the steps above for all remaining valves.

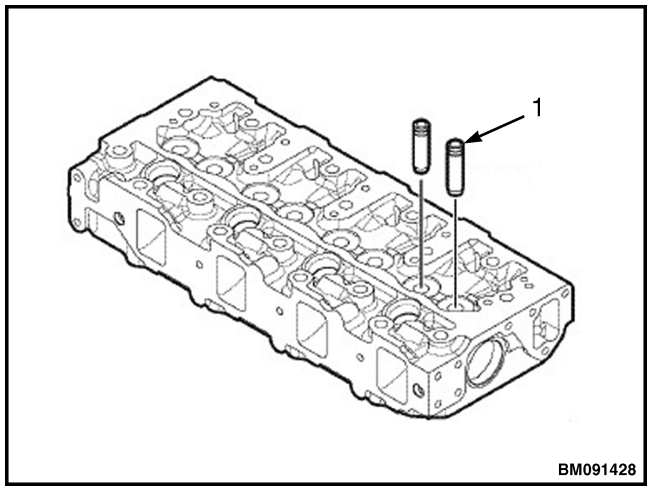
8. Turn the cylinder head so the exhaust port side faces down. Remove the intake and exhaust valves from the cylinder head. See Figure 287.

9. Remove the valve stem seals. See Figure 287.

Valve guides

1. Measure the valve guides. See LPG engine checks, adjustments, and calibrations for procedure.

2. If the valve guides are not within specification after measuring, use a drift pin and hammer to drive the valve guides out of the cylinder head.



1. VALVE GUIDES

Figure 288. Valve guides

CLEAN AND INSPECT

DANGER

Fume/burn hazard!

Always read and follow safety related precautions found on containers of hazardous substances such as cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

WARNING

Cleaning solvents can be flammable and toxic and can cause skin irritation. When using cleaning solvents, always follow the recommendations of the manufacturer.

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

CAUTION

Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.

Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.

Use caution not to scratch the gasket mating surfaces when cleaning the exhaust manifold and cylinder head.

Use caution not to scratch the gasket mating surfaces when cleaning the cylinder head and cylinder block.

1. Carefully remove all gasket residue from the exhaust manifold and cylinder head. See Figure 269. Inspect the exhaust manifold for scratches, cracks, or any other damage. Repair or replace as needed.

2. Carefully remove all gasket residue from the intake manifold and cylinder head. See Figure 269. Inspect the intake manifold for scratches, cracks, or any other damage. Repair or replace as needed.

3. Carefully remove all gasket residue from the cylinder head and cylinder block. See Figure 269. Inspect the cylinder head for scratches, cracks, or any other damage. Repair or replace as needed.

NOTE: Do not use any cleaning solvent that is silicone-based, as this can cause damage to the engine oxygen sensor.

4. Thoroughly clean all components using a non-metallic brush and an appropriate solvent, such as brake cleaner or laquer thinner. Each cylinder head component must be free of carbon, metal shavings and other debris.

5. Visually inspect the parts. Replace any parts that are obviously discolored, heavily pitted, or otherwise damaged. Replace parts that do not meet the specified limit. Refer to LPG engine specifications for service limit.

Cylinder head components

Push rods

Determine if the bend of the push rods are within the specified limit.

Push rod bend

1. Place the push rods on a flat inspection block or layout bed.

2. Roll the push rods until a gap can be observed bewteen a portion of the push rod and the surface of the inspection block or layout bed.

3. Use a feeler gauge to measure the gap. See Figure 289. See LPG engine specifications for service limit.

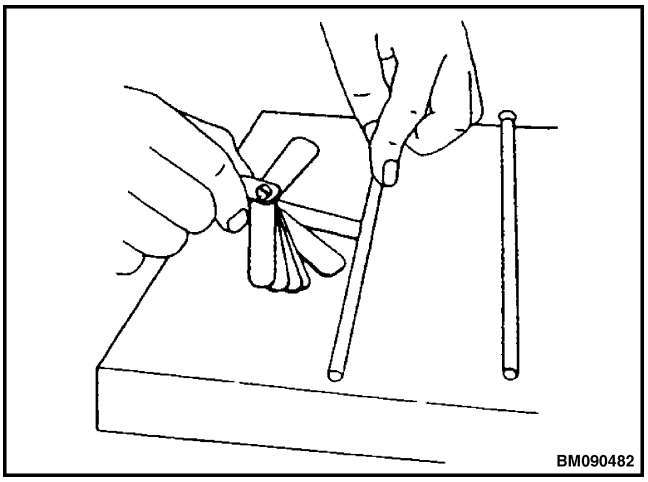


Figure 289. Push rod inspection

4. If the measured gap is not within specified limits, replace the piston rod.

Rocker arm assembly

Rocker arm shaft hole diameter

1. Use a test indicator and micrometer to determine if the inside diameter of all the rocker arms and rocker arm support brackets are within the specified limits. See Figure 290. See LPG engine specifications.

2. Inspect the contact areas for excessive wear or damage.

3. If excessive wear or damage is found, or if components are not within specified limits, replace the rocker arm assembly.

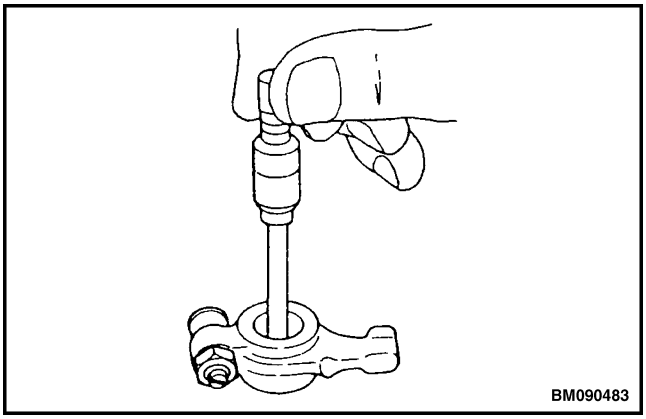


Figure 290. Inside diameter

Rocker arm shaft outside diameter

1. Use a micrometer to measure the rocker arm shaft diameter. Measure at each rocker arm location in two directions 90° apart. See Figure 291.

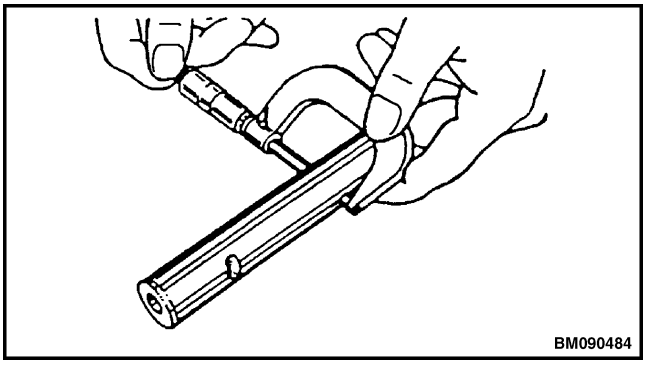


Figure 291. Outside diameter

Valve guides

1. Visually inspect the valve guides for distortions, scoring or other damage.

NOTE: Measure the valve guides while they are installed in the cylinder heads.

2. Use a telescoping gauge and micrometer to measure the inside diameter at each end of the valve guide. Measure the diameter in three places, with two of those three measurements being 90° apart. See LPG engine specifications for service limit. Replace valve guides if not within specifications.

Cylinder head

Cylinder head distortion

1. Place the cylinder head flat on the work bench, with the combustion side up.

2. Use a straight edge and a feeler gauge to measure cylinder head distortion. Measure diagonally and along each side. See LPG engine specifications for service limit.

3. If distortion exceeds the service limit, resurface or replace the cylinder head. Remove only enough material to make the cylinder head flat, but do not remove more than 0.20 mm (0.008 in.). If the cylinder head is still not flat after removing 0.20 mm, replace the cylinder head.

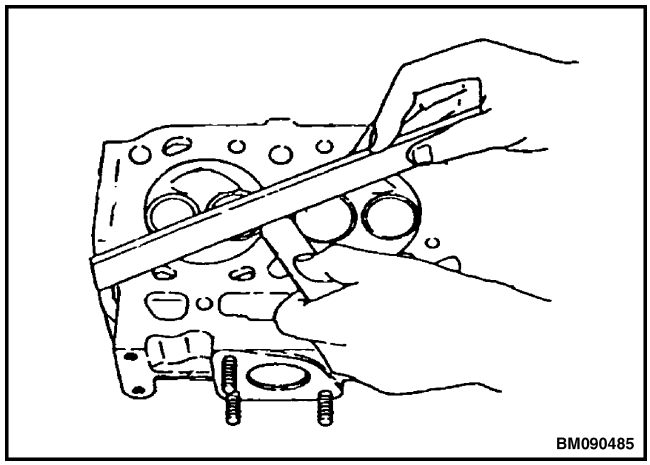


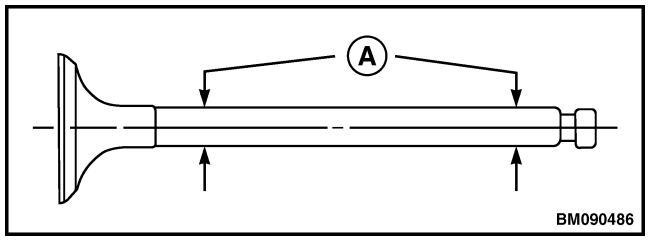
Figure 292. Cylinder head distortion check

Intake and exhaust valves

Visually inspect the intake and exhaust valves. Replace any valves that are discolored, heavily pitted or otherwise damaged.

Valve stem diameter

Use a micrometer to measure the valve stem diameter. Measure the valve stem near the combustion end and near the opposite end. See Figure 293, and LPG engine specifications for service limit.



A. MEASUREMENT POINTS

Figure 293. Valve stem diameter measurement points

Valve stem straightness

Place the valve stem on a flat inspection block or layout bed. Roll the valve until a gap can be observed between a portion of the valve stem and the surface of the inspection block or layout bed. Use a feeler gauge to measure the gap. See Figure 294 and refer to LPG engine specifications for service limit.

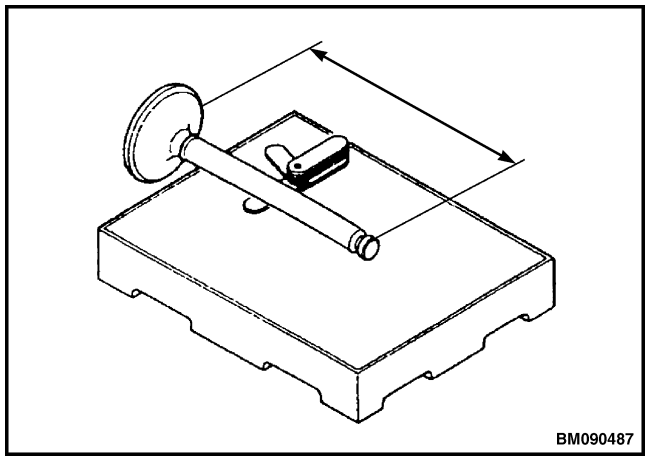


Figure 294. Valve stem straightness check

Valve recession

NOTE: The valve guides must be installed to perform this check.

1. Insert the valves into their original locations in the cylinder head and press them down until they are fully seated.

2. Using a depth micrometer, measure the difference between the cylinder head gasket surface and the combustion surface of each exhaust and intake valve. See Figure 295 and Figure 296. Refer to Special tools for LPG engines for service limit.

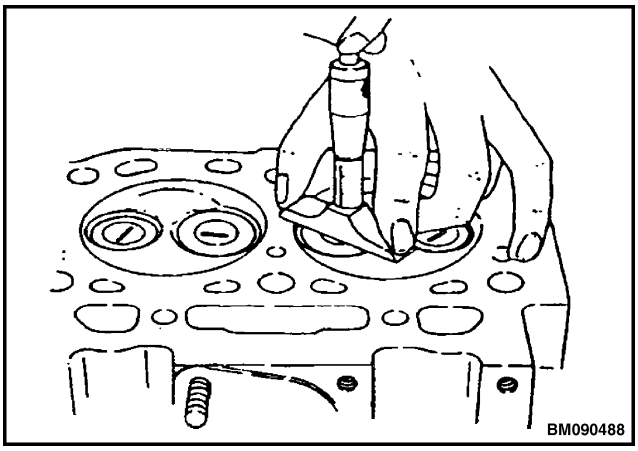


Figure 295. Valve recession measurement

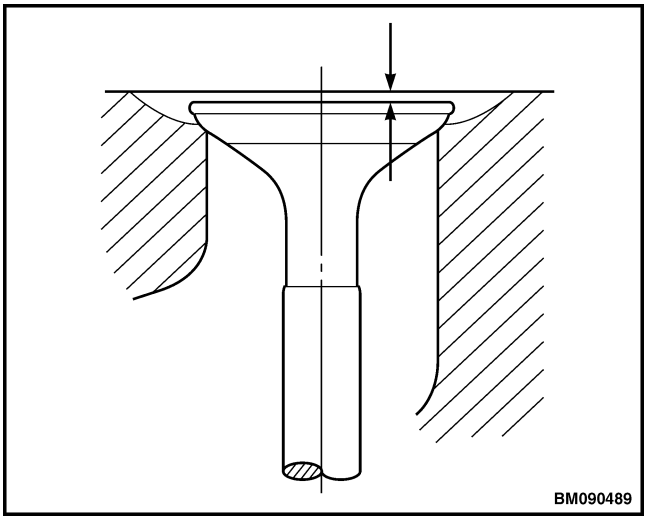


Figure 296. Valve recession

Valve face and valve seat

1. Always check the clearance between the valve and valve guide before correcting the valve seat. See Valve guides, inspection. Refer to LPG engine specifications for service limit.

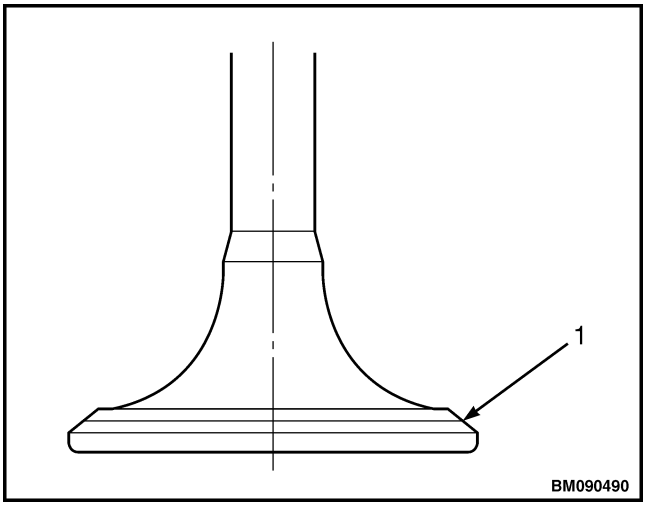
2. If the clearance exceeds the limit, replace the valve or valve guide to bring the clearance within the limit.

3. Roughness or burrs will cause poor seating of a valve. Visually inspect the seating of each valve and determine if lapping or grinding is needed. Lapping or grinding is needed if the cylinder head's seat width exceeds standard limits. Refer to LPG engine specifications for service limit.

4. Visually inspect all valve faces and valve seats for pitting, distortion, cracking, or evidence of overheating. Usually the valves and valve seats can be lapped or ground ro return them to serviceable condition. Severly worn or damaged components require replacement.

5. Coat the valve seat with a thin coat of bluing compound. Install the valve and rotate it to distribute bluing on to the valve. The contact pattern should be approximately centered on the valve face and uniform in width. See Figure 297.

6. Visually inspect the valve seat for even contact.



1. VALVE SEAT

Figure 297. Valve seat

7. Adjust the valve seat diameter by top-grinding with a 150° stone to make the seat diameter smaller, then by bottom-grinding using a 40° stone to make the seat diameter larger. Once the seat location has been corrected, grind and lap the seat angle to specification.

8. Grind the valve face and/or valve seat only enough to return them to serviceable condition. Grinding is only necessary if the valve and valve seat do not contact correctly. Check recession after grinding.

9. If the valve requires grinding, lap the valve after grinding. Lap the valve seat and the cylinder head with a mixture of valve compound and engine oil.

10. Thoroughly wash the parts to remove all grinding residue and valve compound.

Valve springs

Inspect the valve springs. If damage or corrosion is seen, or if measurements exceed the specified limits, replace the springs.

Fractures - Check for fractures on the inside and outside portions of the springs. If the valve spring is fractured, replace the spring.

Corrosion - Check for corrosion of spring material caused by oxidation.

Squareness - Use a flat surface and a square to check each spring for squareness. Refer to the LPG engine specifications for the service limit.

Free Length - Use a caliper to measure the length of the spring. Refer to LPG engine specifications for service limit.

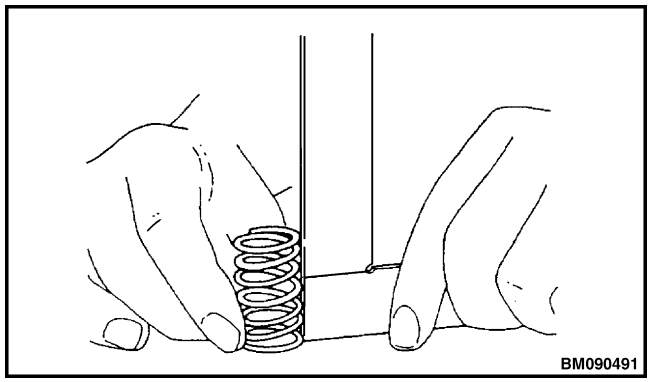


Figure 298. Spring squareness check

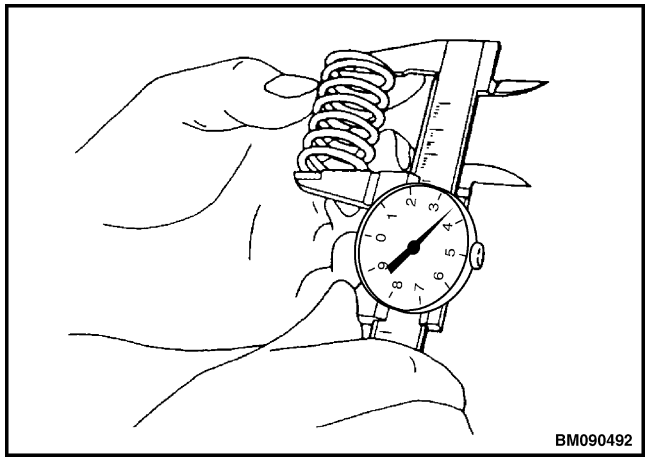


Figure 299. Spring free length check

ASSEMBLE

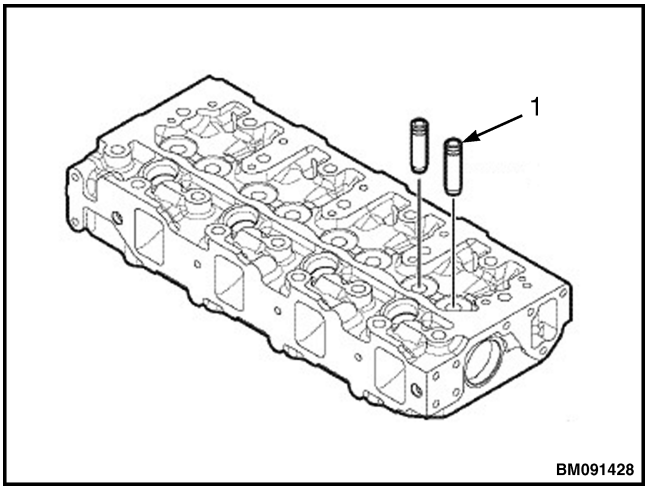
NOTE: Always use new gaskets, O-rings, and seals for reassembly of the cylinder head. See **Parts Manual** for part numbers.

NOTE: Generously oil all components during reassembly of the cylinder head. For more information regarding oil specifications, see LPG engine specifications.

Valve guides

1. The valve guides are installed into the cylinder head with an extremely tight press fit. Before installing the valve guides, place the valve guides in a freezer for at least twenty minutes. This will cause the valve guides to contract, making it easier to install the valve guides into place.

2. Immediately after removing the valve guides from the freezer, insert the valve guides in their correct positions in the cylinder head. See Figure 300.

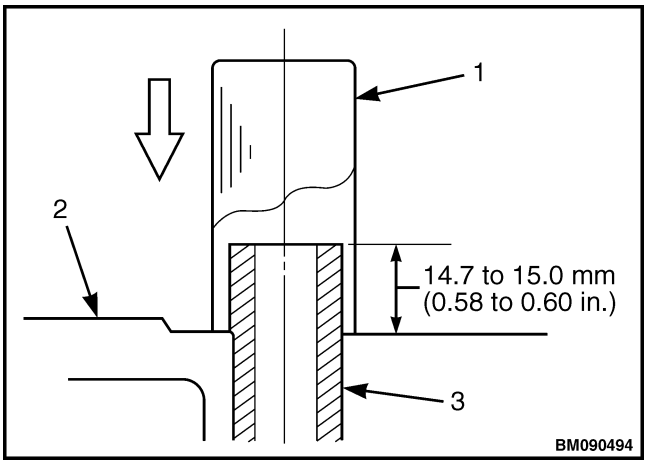


1. VALVE GUIDE

Figure 300. Valve guides

3. Locate the valve guide installation tool. See Special tools for LPG engines.

4. Use the valve guide installation tool to finish installing the valve guides into the cylinder head to the correct height. See Figure 301.



1. VALVE GUIDE INSTALLATION TOOL
2. CYLINDER HEAD
3. VALVE GUIDE

Figure 301. Valve Guide Installation

Valves and valve springs

Always install new valve stem seals. The exhaust valve steam seals are different from the intake valve stem seals and can be identified by different colored paint marks in the outside of the seals.

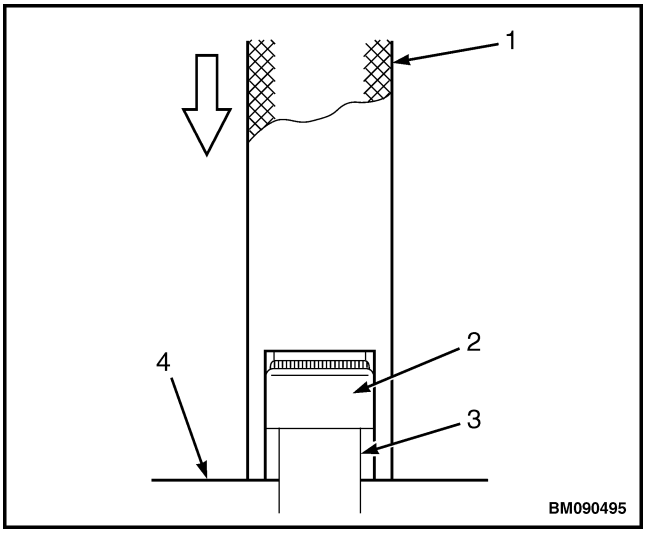
Ensure valve stems are installed in the correct locations.

Engine model	Marking	
	Intake	Exhaust
4TN88G	None	White paint on outside of seal

1. Apply clean engine oil to the lip of the valve stem seal.

2. Locate the valve stem seal installation tool. See Special tools for LPG engines.

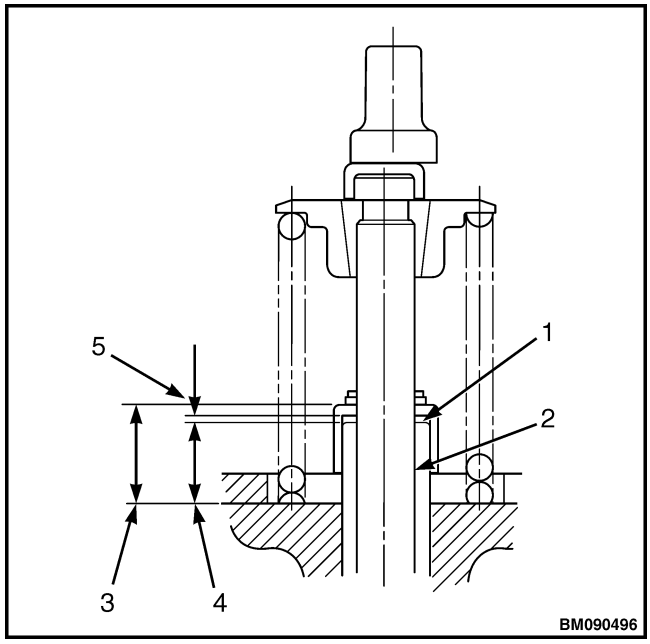
3. Use the valve stem seal installation tool to insert a new valve stem seal on each of the valves. See Figure 302.



1. VALVE STEM SEAL INSTALLATION TOOL
2. VALVE STEM SEAL
3. VALVE GUIDE
4. CYLINDER HEAD

Figure 302. Valve Stem Seal Installation

4. Measure the distance from the cylinder head to the valve stem seal to ensure correct clearance between the guide and the seal. Refer to LPG engine specifications for the clearance specifications. See Figure 303.

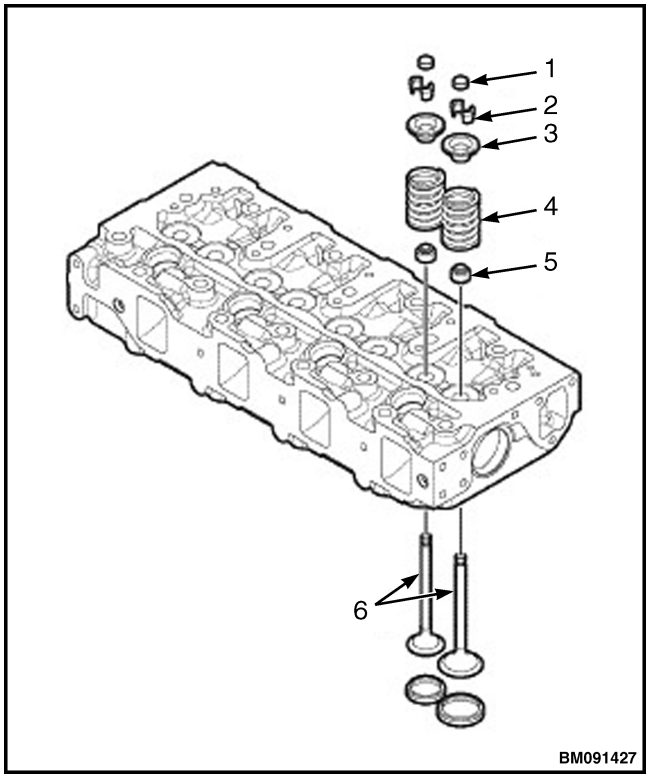


1. VALVE GUIDE
2. VALVE STEM SEAL
3. VALVE GUIDE PROJECTION
4. VALVE STEM SEAL PROJECTION
5. CLEARANCE

Figure 303. Valve stem seal clearance

5. Place the cylinder head assembly down on its exhaust port side.

6. Place all the valves in their correct positions in the cylinder head as marked when disassembled. See Figure 304.



1. VALVE CAP
2. VALVE STEM COTTERS
3. SPRING RETAINER
4. VALVE SPRING
5. VALVE STEM SEALS
6. VALVE

Figure 304. Install valves

7. Place the cylinder head on the work bench with the combustion chamber facing down. Install the valve springs and valve spring retainers. See Figure 286.

8. Using the valve compressor tool, compress the valve spring. See Figure 286.

9. Install the valve keepers and slowly release the tension in the valve spring. See Figure 286.

10. Install the valve cap.

11. Repeat these procedures until all the intake and exhaust valves are installed.

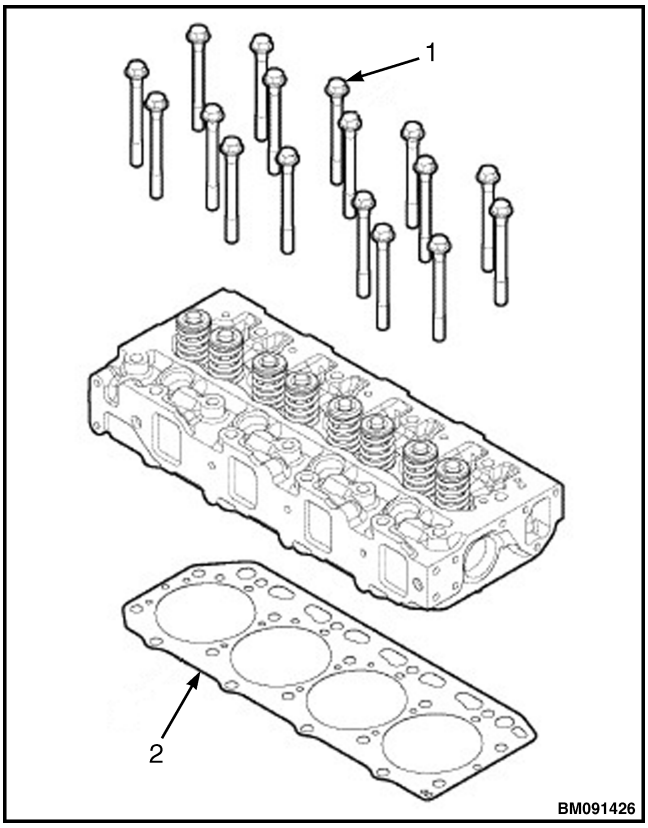
Cylinder head

1. Carefully clean the combustion surface of the cylinder head and the top surface of the cylinder block.

2. Place a new cylinder head gasket on the cylinder block. See Figure 305.

3. Position the cylinder head on the cylinder head gasket and cylinder block.

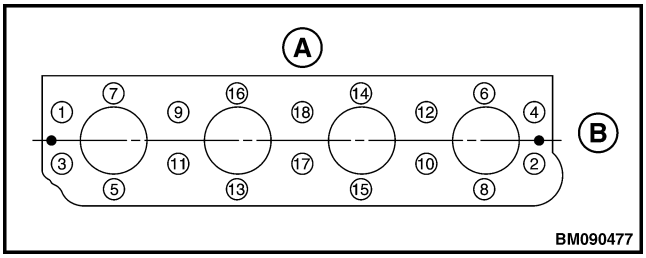
4. Lightly oil the threads of the cylinder head bolts. See Figure 305.



1. CYLINDER HEAD BOLTS
2. CYLINDER HEAD GASKET

Figure 305. Cylinder head bolts

5. Install the cylinder head bolts and tighten the cylinder head bolts to
46 to 49 N•m (34 to 36 lbf ft) in the sequence shown in Figure 306. Then tighten the cylinder head bolts to 92 to 98 N•m (68 to 72 lbf ft) in the same sequence.



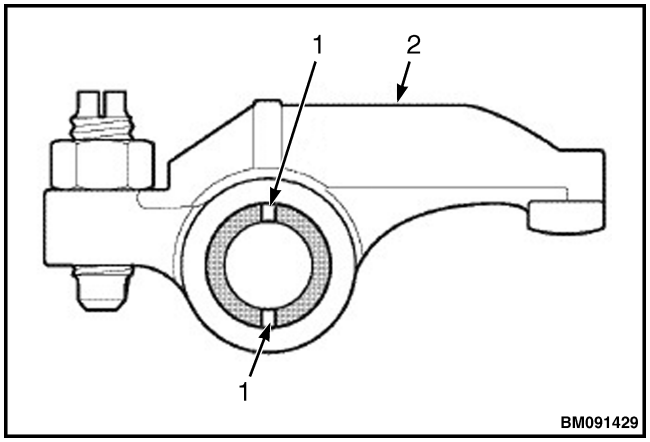
A. CAMSHAFT SIDE
B. FAN SIDE

Figure 306. Cylinder Head Torque Sequence

6. Insert all push rods into the correct push rod holes. See Figure 269.

Rocker arm assembly

1. Confirm the lubrication holes in the rocker arm shaft are oriented as shown in Figure 307.



1. LUBRICATION HOLES
2. ROCKER ARM

Figure 307. Rocker arm

2. Lubricate the rocker arm shaft with engine oil.

NOTE: To correctly align the rocker arm shaft with the rocker arm supports, first position the rocker arm shaft with the hole for the shaft alignment stud facing up.

3. Align the hole in the rocker arm shaft and the hole in the rocker arm support. Install the alignment stud. See Figure 308.

NOTE: The rocker arm shaft fits tightly in the rocker arm supports. Clamp the support in a padded vise and twist and push the rocker arm supports onto the rocker arm shaft.

4. Slide the rocker arm supports, springs, and rocker arms onto the shaft. See Figure 308.

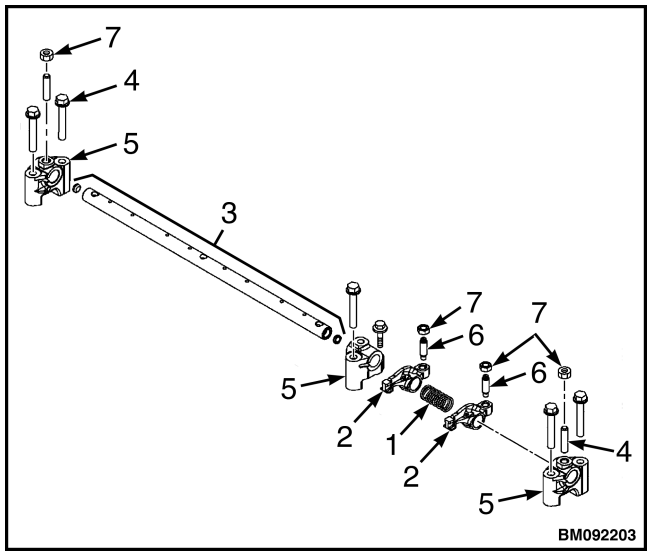
5. Place rocker arm shaft assembly in position on the cylinder head.

6. Install the valve adjusting screws and the lock nuts. See Figure 308.

7. Align the push rods with their respective rocker arms. See Figure 269.

8. Install and tighten the rocker arm shaft retaining bolt and nuts. See Figure 308.

9. Tighten the rocker arm shaft alignment studs. See Figure 308.



1. SPRING
2. ROCKER ARM
3. ROCKER ARM SHAFT
4. ALIGNMENT STUD
5. SUPPORT
6. VALVE ADJUSTING SCREW
7. LOCKNUT

Figure 308. Rocker arm assembly

10. Adjust valve clearance. See LPG engine checks, adjustments, and calibrations.

INSTALL

1. Lightly grease the new valve cover gasket. Figure 282.

2. Place new valve cover gasket in the groove of the valve cover.

3. Place the valve cover in position on the cylinder head. See Figure 282.

4. Verify that the O-rings are installed on the valve cover bolts.

5. Install and tighten the valve cover bolts. See Figure 282.

6. Install the four spark plugs into the cylinder head. See Figure 281.

7. Use a 16 mm socket wrench to tighten the spark plugs. See Figure 281. Torque to 24 to 34 N•m (17.7 to 25.1 lbf ft).

8. Install the ignition coil bracket and insert the two bolts to retain the ignition coil bracket to the cylinder head. See Figure 280. Torque to 24 to 34 N•m (17.7 to 25.1 lbf ft).

9. Install the ignition coils and insert the four bolts to retain each of the four ignition coils to the ignition coil bracket. See Figure 280. Torque to 6 to 9.5 N•m (4.4 to 7.0 lbf ft).

10. Install the exhaust manifold with new gasket onto the cylinder head.

11. Insert the bolts to attach the exhaust manifold to the cylinder head. See Figure 274. Torque to 44.1 to 53.9 N•m (32.5 to 39.8 lbf ft).

12. Install the heat shield in place on the exhaust manifold.

13. Insert the bolts to attach the heat shield to the exhaust manifold. See Figure 273. Torque to 22.6 to 28.4 N•m (16.7 to 21.0 lbf ft).

14. Insert the O_2 sensor. See Figure 273.

15. Insert the four bolts to attach the intake throttle with new gasket to the intake manifold. See Figure 276. Torque to 22.6 to 28.4 N•m (16.7 to 21.0 lbf ft).

16. Install the intake throttle and intake manifold with new gasket onto the cylinder head. See Figure 279.

17. Insert the bolts to attach the intake manifold to the cylinder head. See Figure 279.

18. Torque to 22.6 to 28.4 N•m (16.7 to 21.0 lbf ft).

19. Insert the bolt to retain the dipstick mounting bracket to the intake manifold. See Figure 278.

20. Tighten to standard torque.

21. Insert the two bolts to retain the intake pressure and temperature sensor to the intake manifold. See Figure 278.

22. Tighten to standard torque.

23. Install the injectors. See LPG fuel system repair.

24. Install the fuel rail. See Figure 277.

25. Insert the two bolts to attach the fuel rail to the engine block. See Figure 277. Torque to 7.8 to 9.4 N•m (5.8 to 6.9 lbf ft).

26. Install the intake joint and hose. See Figure 275.

27. Install the the hose band retaining the intake joint and hose. See Figure 275.

28. Install the wire harness. Connect the wire harness connectors to the ignition coils and injectors. See Figure 272.

29. Connect the wire harness to the Intake temperature sensor, exhaust temperature sensor, O_2 sensor and intake throttle.

30. Install the water pump and fan. See Water pump repair in the **Cooling system** 0700SRM2300.

31. Connect the wire harness to the coolant temperature sensor. See Figure 270.

32. Attach the breather hose and ambient air hose. See Figure 271.

33. Install the alternator. See LPG electrical system repair.

CAUTION

Additives may damage the cooling system. Before using additives, contact your local Hyster dealer.

34. Fill cooling system with coolant. See **Periodic Maintenance** 8000SRM2305 for the correct coolant amount and type.

35. Install radiator cap.

36. Change engine oil and oil filter. See **Periodic Maintenance** 8000SRM2305 for procedure.

WARNING

During engine operation, be careful not to touch the fan, pulleys, or drive belts. Contact with these parts can cause serious injury.

WARNING

The radiator or other parts of the cooling system may be hot or under pressure and can cause serious injury.

37. Start engine and check for leaks.

38. Stop engine and resolve any leaks that are discovered.

WARNING

DO NOT remove the radiator cap from the radiator when the engine is hot. When the radiator cap is removed, pressure will release from the coolant system. If the coolant system is hot, the steam and boiling coolant can cause severe burns.

WARNING

The radiator or other parts of the cooling system may be hot or under pressure and can cause serious injury. Wait 30 minutes for the radiator and engine to cool before performing maintenance to the cooling system. After 30 minutes, do a touch test by touching the radiator with your hand. If the radiator is still hot to the touch, wait another 30 minutes before attempting any maintenance to the cooling system.

CAUTION

Additives may damage the cooling system. Before using additives, contact your local Hyster dealer.

39. If coolant is hot, allow engine time to cool. Check coolant level and fill as required between the ADD and FULL marks on the coolant reservoir.

LPG TIMING GEAR CASE REPAIR 202001-024

REMOVE

Timing gear case cover

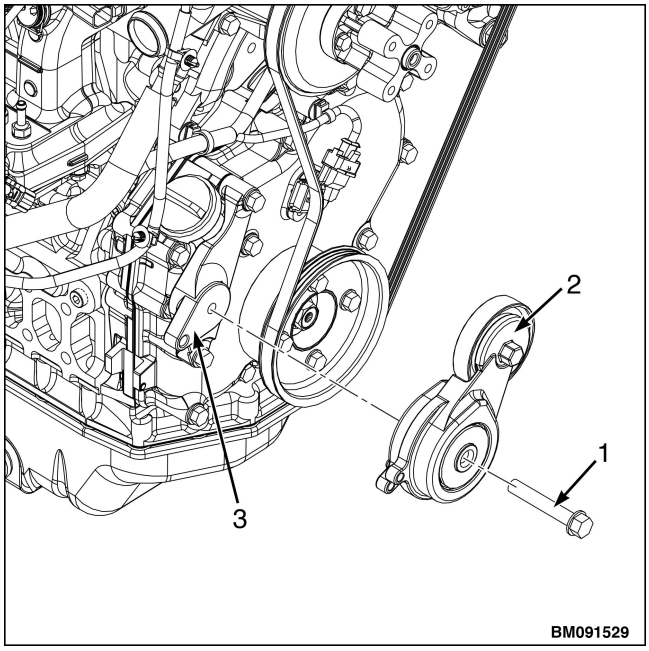
1. Remove the engine. See LPG engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

2. Place the engine on an engine stand or a clean, flat working surface large enough to accomodate the engine and components.

3. Remove the alternator. See LPG electrical system repair.

4. Remove the cooling fan, V-belt and water pump. See **Cooling system** 0700SRM2300 service manual.

5. Loosen the bolt retaining the auto tensioner to the tensioner bracket. Remove the bolt and auto tensioner. See Figure 309.



1. BOLT
2. AUTO TENSIONER
3. TENSIONER BRACKET

Figure 309. Auto tensioner

6. Disconnect the camshaft speed sensor connector on the engine wire harness from the camshaft speed sensor. See Figure 310.

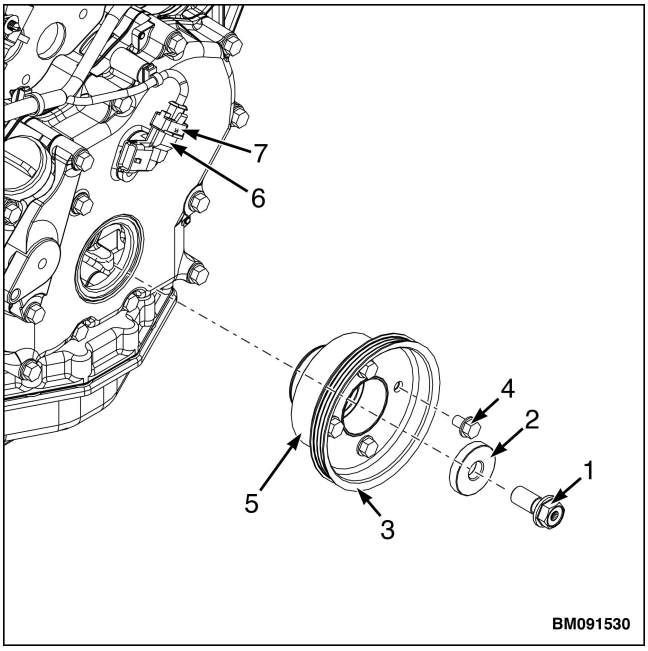
7. Remove the bolt retaining the crankshaft pulley (item 1, Figure 310).

CAUTION

Take care to not damage the threads in the end of the crankshaft when removing the crankshaft pulley.

8. Use a gear puller to remove the crankshaft pulley and spacer, with the crankshaft pulley adapter still attached. See Figure 310.

If replacing the crankshaft pulley adapter, remove the four bolts and the adapter from the crankshaft pulley.



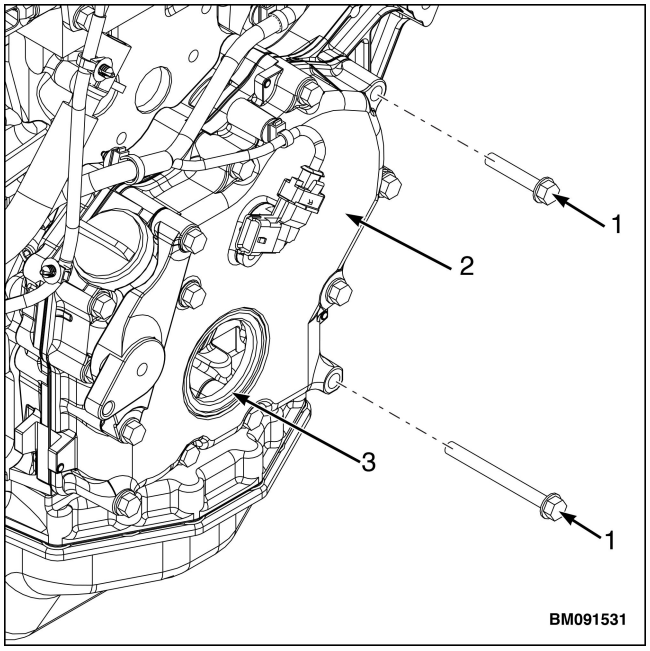
1. BOLT
2. SPACER
3. CRANKSHAFT PULLEY
4. BOLT
5. CRANKSHAFT PULLEY ADAPTER
6. CAMSHAFT SPEED SENSOR
7. CAMSHAFT SPEED SENSOR CONNECTOR

Figure 310. Crankshaft Pulley

9. Remove the auto tensioner.

10. Remove the 13 bolts retaining the timing gear case cover. See Figure 311.

11. Remove the timing gear case cover. See Figure 311.



1. TIMING GEAR CASE COVER
2. BOLT
3. FRONT OIL SEAL

Figure 311. Timing Gear Case Cover

12. If the front oil seal is worn or damaged, remove the front oil seal from the timing gear case cover. See Figure 311.

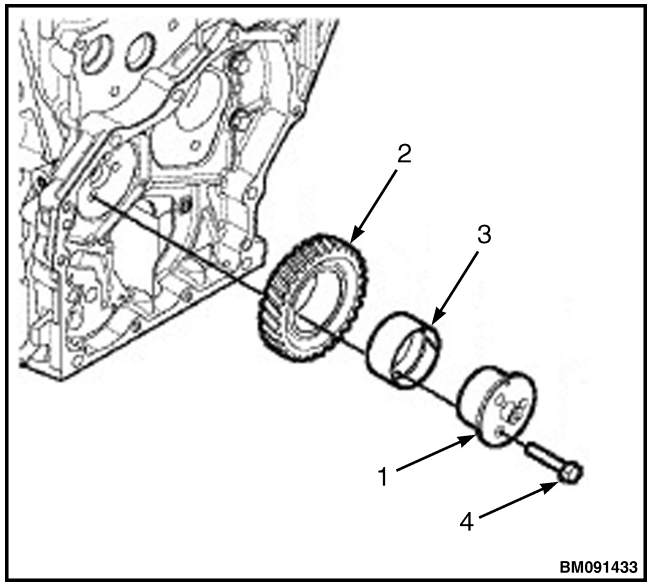
Timing gear case

Idler shaft gear

1. Rotate the engine to align the timing gears. Mark the gears with paint markers to aid in reinstallation.

2. Remove the bolts from the idler gear shaft. See Figure 312.

3. Remove the idler gear shaft, idler gear, and bushing. See Figure 312.



1. IDLER GEAR SHAFT
2. IDLER GEAR
3. IDLER GEAR BUSHING
4. BOLT

Figure 312. Timing Gears

4. If the crankshaft gear or crankshaft are damaged and require replacement, use a gear puller to remove the crankshaft gear. See Special tools for LPG engines.

5. Measure the backlash of the timing gear and idler gears. See LPG engine checks, adjustments, and calibrations.

Camshaft and camshaft gear

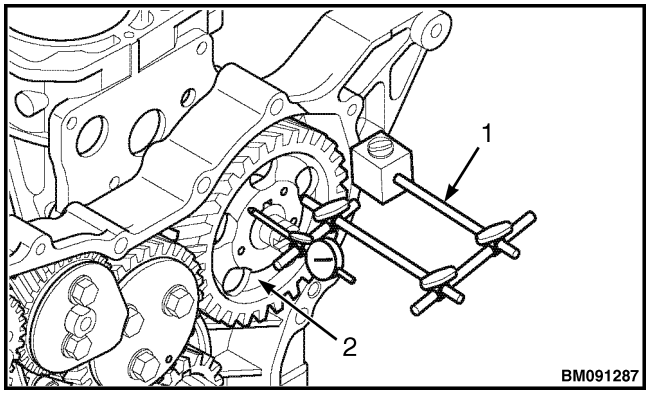
NOTE: Removal of the camshaft gear requires the camshaft be removed and placed in a press. DO NOT remove the camshaft gear unless it or the camshaft is damaged and requires replacement.

1. If necessary, remove the camshaft. See Step 3.

2. Confirm gears are aligned properly. Mark the gears with paint markers to aid in reinstallation.

3. Before removing the camshaft, check the camshaft end play.

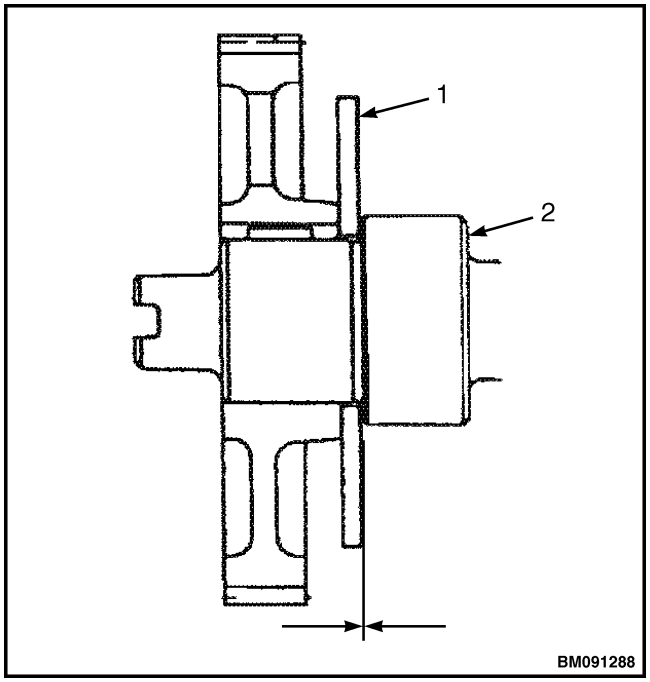
- Method A: Install a dial indicator on the cylinder block. See Figure 313. Move the camshaft back and forth to measure the end play. Record the measurement. See Camshaft and timing gear train specificationsin LPG engine specifications for service limit.



1. DIAL INDICATOR
2. CAMSHAFT

Figure 313. Method A

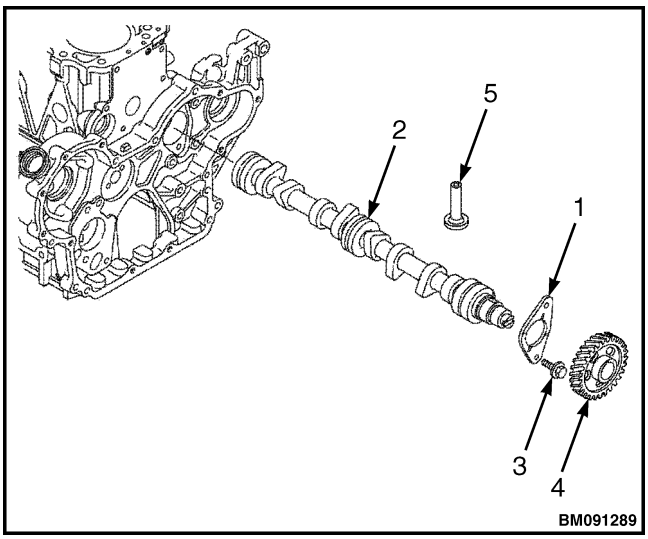
- Method B: Use a feeler gauge to measure the clearance between the thrust plate and front camshaft bearing. See Table 77 in LPG engine specifications for service limit.



1. THRUST PLATE
2. FRONT CAMSHAFT BEARING

Figure 314. Method B

4. Remove the two bolts retaining the camshaft thrust plate. See Figure 315.



1. CAMSHAFT THRUST PLATE
2. CAMSHAFT
3. BOLT
4. CAMSHAFT DRIVE GEAR
5. TAPPETS

Figure 315. Camshaft

- If using an engine stand, rotate the engine so that gravity causes the tappets to drop away from the camshaft lobes.
- If using a work surface instead of an engine stand, place the engine upright on the flywheel end mounting flange.

5. Rotate the camshaft at least two turns to bump any sticking tappets away from the camshaft.

6. Slowly pull the camshaft assembly out of the engine. Be careful not to damage the front camshaft bushing. See Figure 315.

NOTE: The tappets are "mushroom" shaped and must be removed from inside the engine crankcase.

7. Remove the tappets. Mark the tappets so they can be reinstalled in the same location. See Figure 315.

NOTE: Only remove the camshaft drive gear if the drive gear or camshaft require being replaced.

8. Use a gear puller to press and remove the camshaft drive gear. The drive gear is shrink-fit and must be heated to 180-200°C (356-392°F) to be removed. See Figure 315.

Timing gear case

1. Remove the oil pump. See LPG lubrication system repair.

2. Remove the bolts. See Figure 316.

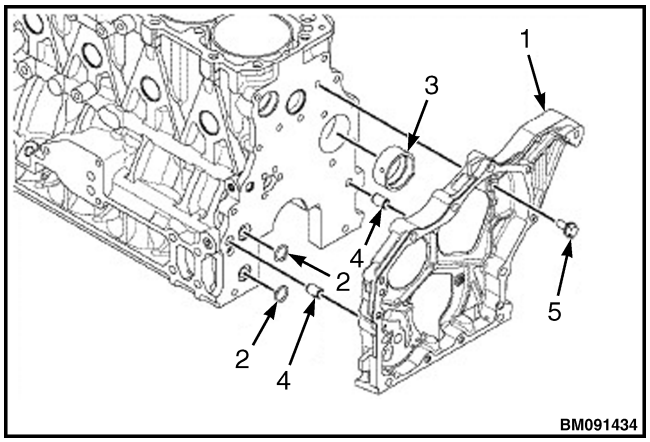
3. Remove the timing gear case from the cylinder block. Thoroughly clean and remove all old sealant from the connecting surfaces. See Figure 316.

4. Inspect and measure the camshaft bushing. See Figure 316.

   See Table 73 in LPG engine specifications for service limit.

5. Remove the camshaft bushing if damaged or worn beyond service limit. See Figure 316. See Special tools for LPG engines for appropriate tool.

6. Remove the O-rings and two dowels. See Figure 316.



1. TIMING GEAR CASE
2. O-RINGS
3. CAMSHAFT BUSHING
4. DOWELS
5. BOLTS

Figure 316. Timing Gear Case

INSPECT

WARNING

Cleaning solvents can be flammable and toxic and can cause skin irritation. When using cleaning solvents, always follow the recommendations of the manufacturer.

WARNING

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

Clean all old sealant from the timing gear case cover and the timing gear case. Clean the timing gear case cover in cleaning solvent. Dry the timing gear case cover with compressed air. Inspect for wear, cracks, and any other damage. If necessary, replace timing gear case cover.

INSTALL

1. If removed, reinstall the camshaft end plate, key, and timing gear onto the camshaft. See Figure 315.

2. Apply a continuous bead of Three Bond Liquid Gasket, Hyster Part Number 1599478, to the mounting area of the gear case. Circle each bolt hole with the sealant as well.

3. Install new O-rings and dowells into the cylinder block. See Figure 316.

NOTE: Heat the camshaft drive gear to 180-200°C (356-392°F) before pressing it onto the camshaft.

4. Use a press to install the camshaft end plate. See Figure 315. See Special tools for LPG engines for appropriate tool.

NOTE: The tappets are mushroom shaped and must be installed from inside the engine crankcase.

- If using an engine stand, rotate the cylinder block so that gravity will keep the tappets in place and out of the way of the camshaft lobes when the camshaft is being installed.
- If using a work surface instead of an engine stand, place the engine upright on the flywheel end mounting flange.

5. Lubricate the tappets with clean engine oil or assembly lube. See LPG engine specifications.

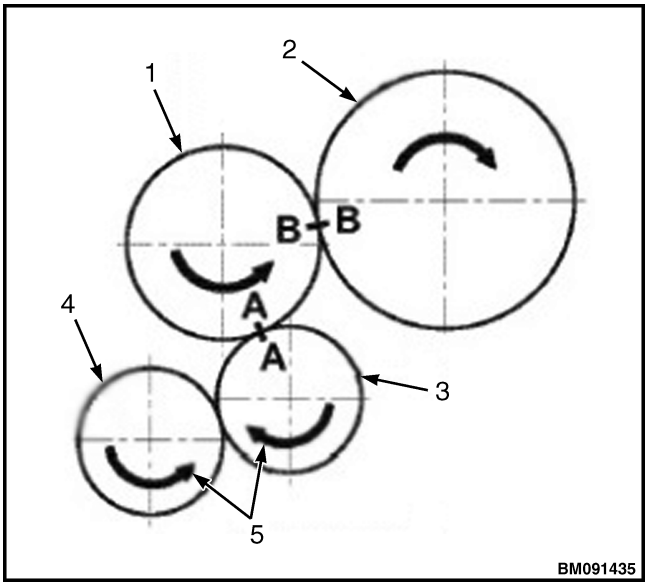
6. Install the tappets back into their position in the cylinder block. Push the tappets fully into the tappet bores so they will not interfere with the installation of the camshaft.

7. Lubricate the camshaft with clean engine oil or assembly lube. Slowly insert the camshaft through the front of the engine into the timing gear case. See Figure 315.

8. Insert the capscrews to retain the camshaft thrust plate to the timing gear case. See Figure 315. Tighten the capscrews to specified torque value. See Special torque chart.

9. Set the piston of the timing gear case side cylinder (No. 4) to top dead center position. See Figure 317.

10. Rotate the camshaft until the mark (B, Figure 317) is approximately at the 9 o'clock position.



1. IDLER GEAR
2. CAMSHAFT DRIVE GEAR
3. CRANKSHAFT GEAR
4. OIL PUMP DRIVE GEAR
5. DIRECTION OF ROTATION

Figure 317. Timing Gears

11. Lubricate the idler gear (1), idler gear bushing, and idler gear shaft with clean engine oil. See Figure 317. See LPG engine specifications.

12. Align the timing gears according to the marks from the paint marker. See or Figure 317.

13. Install the idler gear, idler gear shaft and idler gear bushing while aligning the timing mark A on the idler gear with mark A on the crankshaft gear. At this time, direct the punch mark on the idler gear shaft end surface to the upper part of the engine.

14. While aligning the timing mark B on the idler gear with mark B on the camshaft drive gear, install the idler gear, idler gear shaft and idler gear bushing.

15. When all gears are properly aligned, tighten the idler gear retaining bolts to specified torque value. See Special torque chart.

16. Inspect the marks on all gears to confirm alignment.

NOTE: If the front oil seal was removed, follow Step 17 through Step 18 to install.

17. Apply a continuous bead of Three Bond Liquid Gasket, Hyster Part Number 1599478, to the outside diameter of a new front oil seal.

18. Install the new front oil seal into the timing gear case cover. Apply lithium grease to the lip of the front oil seal. See Figure 311.

19. Apply a continuous bead of Three Bond Liquid Gasket, Hyster Part Number 1599478, to the surface of the timing gear case on the side that adjoins the engine block.

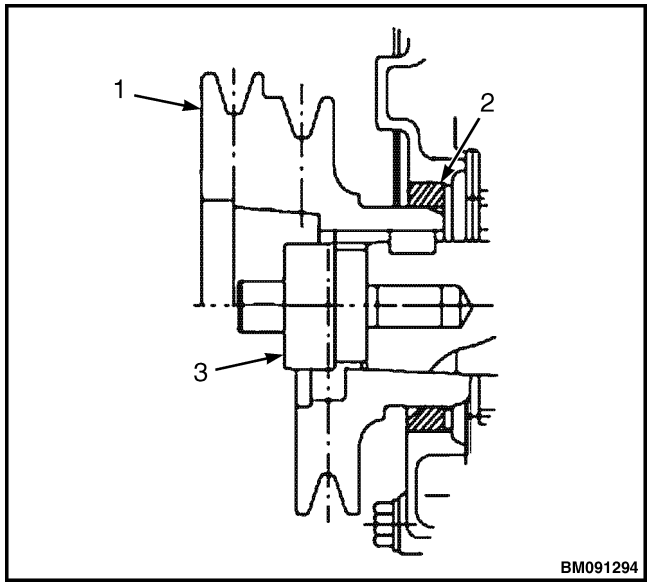
20. Place the timing gear case cover in position on the timing gear case and install retaining bolts. See Figure 311. Tighten bolts to standard torque value.

NOTE: If you have not used a paint marker to mark gear alignment, do so prior to installing the timing gear case cover.

21. Install the timing gear case cover. See Figure 311.

22. Insert the bolts to to retain the timing gear case cover to the timing gase cover. Tighten to standard torque. See Figure 311.

23. Use the crankshaft pulley installation tool to reinstall the crankshaft pulley. The crankshaft pulley installation tool will guide the pulley hub and protect the front seal from damage. See Figure 318 and Special tools for LPG engines.



1. CRANKSHAFT PULLEY
2. FRONT SEAL
3. CRANKSHAFT PULLEY INSTALLATION TOOL

Figure 318. Crankshaft Pulley Installation Tool

24. Insert the washer and bolt to retain the crankshaft pulley and spacer. See Figure 310. Tighten the bolt to specified torque value. See LPG engine specifications.

25. Align the auto tensioner with the hole on the tensioner bracket. See Figure 309.

26. Insert the bolt to retain the auto tensioner to the tensioner bracket. See Figure 309. TIghten to standard torque.

27. Install the water pump, V-belt and coolant fan. See **Cooling system** 0700SRM2300.

28. Install the alternator. See LPG electrical system repair.

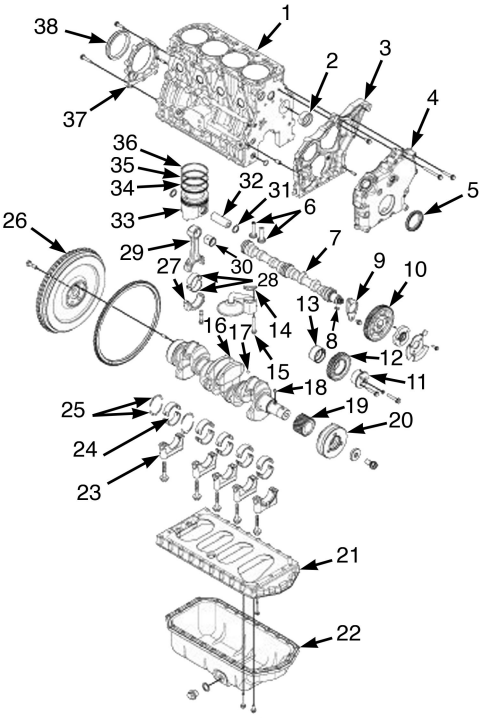
29. Install the engine. See **LPG engine removal and replacement** in the **Drive Train** 0900SRM2301 service manual.

30. Fill the engine oil to the correct level. See **Periodic Maintenance** 8000SRM2305 for procedure.

31. Follow the procedure for priming the fuel system. See **Periodic Maintenance** 8000SRM2305 for procedure.

32. Start the engine and check for leaks.

LPG CAMSHAFT AND CYLINDER BLOCK REPAIR 202001-025



1. CYLINDER BLOCK
2. CAMSHAFT BUSHING
3. GEAR CASE
4. GEAR CASE COVER
5. FRONT CRANKSHAFT SEAL
6. TAPPETS
7. CAMSHAFT
8. CAMSHAFT GEAR KEY
9. CAMSHAFT END PLATE
10. CAMSHAFT GEAR
11. IDLER GEAR SHAFT
12. IDLER GEAR
13. IDLER GEAR BUSHING
14. OIL PICKUP GASKET
15. OIL PICKUP
16. CRANKSHAFT
17. BALL
18. CRANKSHAFT GEAR KEY
19. CRANKSHAFT GEAR
20. CRANKSHAFT PULLEY
21. OIL PAN SPACER
22. OIL PAN
23. MAIN BEARING CAP
24. MAIN BEARINGS
25. THRUST BEARINGS
26. FLYWHEEL
27. CONNECTING ROD CAP
28. CONNECTING ROD BEARINGS
29. CONNECTING ROD
30. WRIST PIN BUSHING
31. SNAP RING
32. WRIST PIN
33. PISTON
34. OIL RING
35. SECOND COMPRESSION RING
36. TOP COMPRESSION RING
37. CRANKSHAFT REAR SEAL HOUSING
38. CRANKSHAFT REAR SEAL

Figure 319. Crankshaft and camshaft components

REMOVE THE ENGINE COMPONENTS

1. Remove the engine. See LPG engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

2. Remove the starter and alternator. See LPG electrical system repair.

1. Remove the flywheel and flywheel housing. See LPG flywheel repair.

2. Remove the water pump. See Water pump repair in the **Cooling system** 0700SRM2300 service manual.

3. Remove the cylinder head. See LPG cylinder head repair.

4. Remove the oil pan, oil pump and oil suction tube. See LPG lubrication system repair.

5. Remove the timing gear case cover. See LPG timing gear case repair.

6. Remove the crankshaft drive gear and idler gear. See LPG timing gear case repair.

DISASSEMBLE

Pistons and connecting rods

NOTE: Keep the piston pin parts, piston assemblies, and connecting rod assemblies together and label all parts, to ensure all parts are returned to the same position during the reassembly process. Note the location of each bearing cap and make sure to not mix up bearing caps during installation.

NOTE: Engines with high operating hours may have a ridge near the top of the cylinders that will catch the piston rings and make it impossible to remove the pistons. Use a suitable ridge reamer to remove ridges and carbon prior to removing the pistons.

NOTE: Pistons can fall from cylinder block if the engine is inverted. Rotate the engine so the connecting rods are horizontal before removing the connecting rod caps.

1. Use a feeler gauge to measure the connecting rod side clearance. See Figure 320. Refer to LPG engine specifications for the standard limit. If the measurement is out of specification, replace the crankshaft, connecting rod, or both.

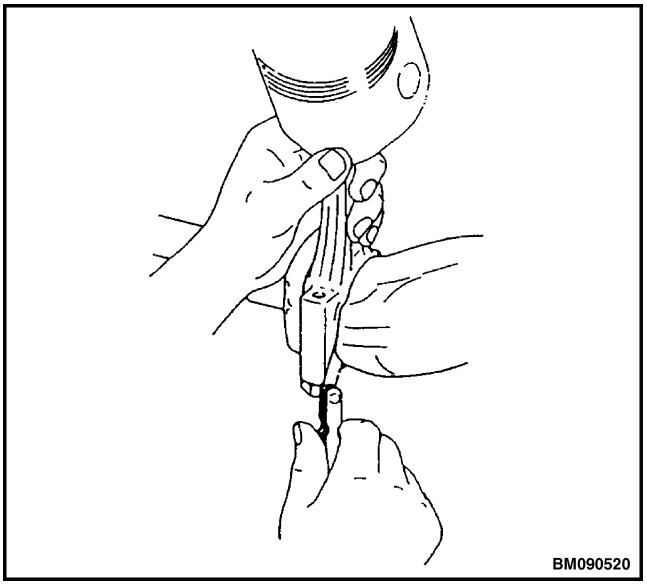
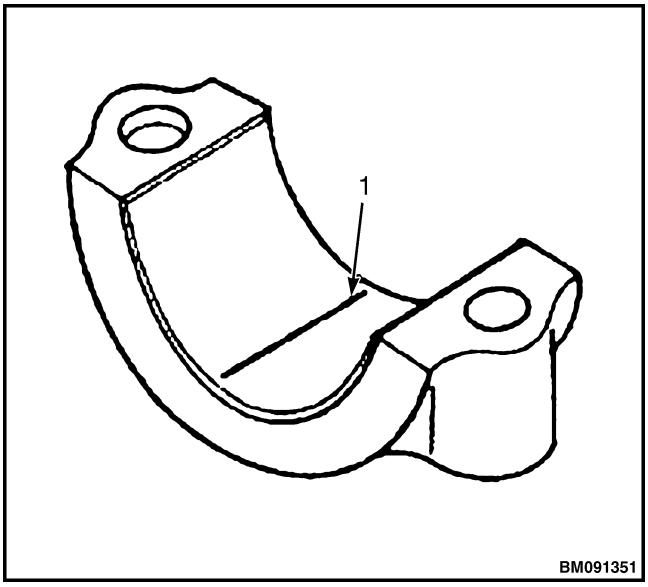


Figure 320. Connecting rod side clearance

2. Measure bearing oil clearance prior to removing the pistons and connecting rods to determine extent of wear. Record the measurements.
   a. Remove the bearing cap. Do not remove the bearings at this time.
   b. Wipe oil from the bearing and crankshaft surfaces.
   c. Place a piece of plastigauge® along the full width of the bearing (see Figure 321). Do not rotate the crankshaft when using plastigauge. A false reading may result.



1. PLASTIGAUGE

Figure 321. plastigauge placement

d. Reinstall the bearing cap and tighten to 96.0-100 N•m (70.8-73.8 lbf ft).

e. Remove the bearing cap.

f. Compare the width of the flattened plastigauge to the graduation marks on the package (see Figure 322). The mark that most closely matches the width of the flattened plastigauge will indicate the bearing oil clearance.

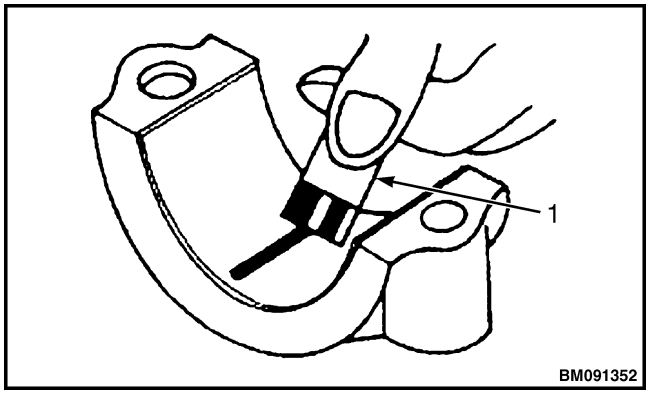


Figure 322. Graduation marks

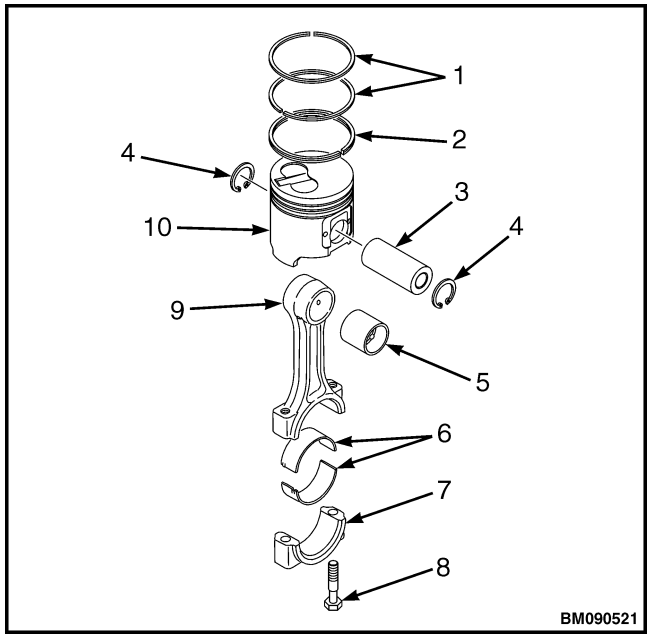
g. Repeat with each remaining connecting rod.

NOTE: Do not allow the connecting rod to contact the crankshaft journal during piston removal. Damage to the bearing journal may result.

3. Use a wooden dowel against the connecting rod and tap the piston and connecting rod assembly out of the cylinder.

4. Mark the piston, connecting rod assembly and cylinder, to aid in reinstallation. See Figure 323.

5. Remove the bearings. See Figure 323.



1. COMPRESSION RINGS
2. OIL SEAL RING
3. WRIST PIN
4. SNAP RING
5. WRIST PIN BUSHING
6. BEARINGS
7. CONNECTING ROD CAP
8. BOLT
9. CONNECTING ROD
10. PISTON

Figure 323. Piston and Connecting Rod

6. Use a piston ring expander to remove the two compression rings from the piston. See Figure 323. Refer to Special tools for LPG engines for appropriate tool.

7. Use the piston ring expander to remove the oil seal ring from the piston. See Figure 323. See Special tools for LPG engines for appropriate tool.

8. Remove the snap rings from the wrist pin. See Figure 323.

9. Remove the wrist pin and connecting rod from the piston. See Figure 323.

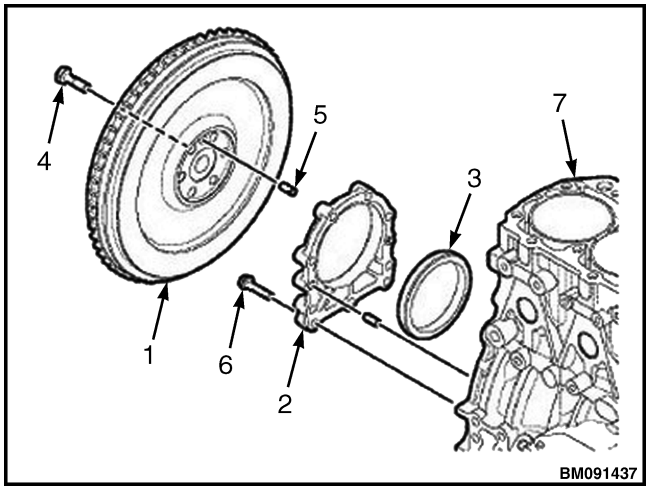
10. Repeat Step 5 through Step 9 for the remaining pistons and piston rods.

REMOVE

Crankshaft

1. Remove the flywheel from the crankshaft. See Figure 324.

2. Remove the bolts retaining the rear oil seal housing and remove the rear oil seal. See Figure 324.



1. FLYWHEEL
2. REAR OIL SEAL HOUSING
3. REAR OIL SEAL
4. FLYWHEEL HOUSING BOLT
5. DOWEL
6. OIL SEAL HOUSING MOUNTING BOLT
7. CYLINDER BLOCK

Figure 324. Rear oil seal

3. Measure the crankshaft thrust end play using one of the following two methods:

a. Install a dial gauge on the cylinder block. Move the crankshaft in and out to measure the end play. See Figure 325. Record the measurement.

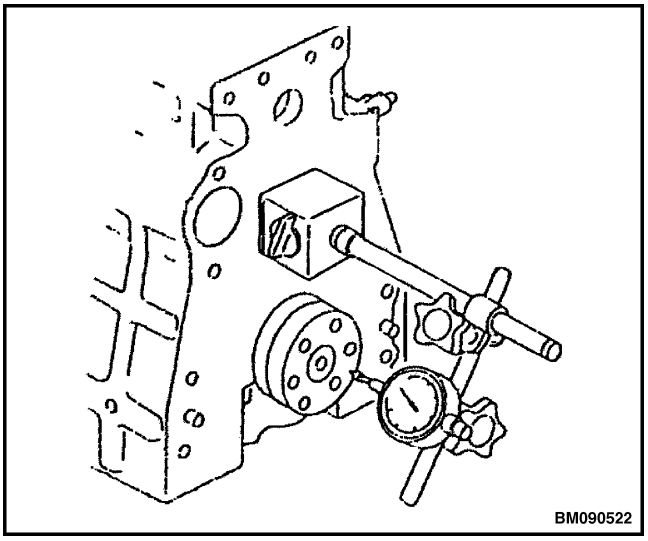
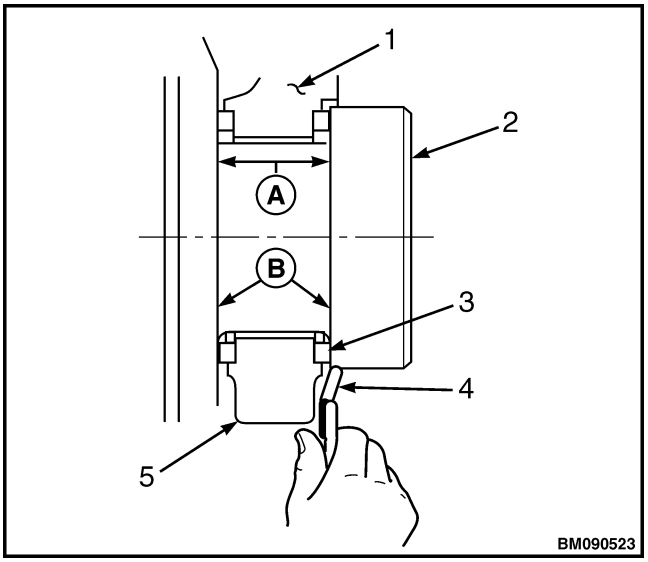


Figure 325. Crankshaft end play measurement with dial gauge

b. Use a feeler gauge to measure the clearance between the thrust bearing and the crankshaft. See Figure 326. Record the measurement.



A. STANDARD WIDTH
B. THRUST FACE

1. CYLINDER BLOCK
2. CRANKSHAFT
3. THRUST BEARING
4. SHIM GAUGE
5. CYLINDER BLOCK

Figure 326. Crankshaft side gap measurement with feeler gauge

NOTE: Be sure to note the markings on the main bearing caps, or mark them yourself, so they can be reinstalled in the same location as they were removed.

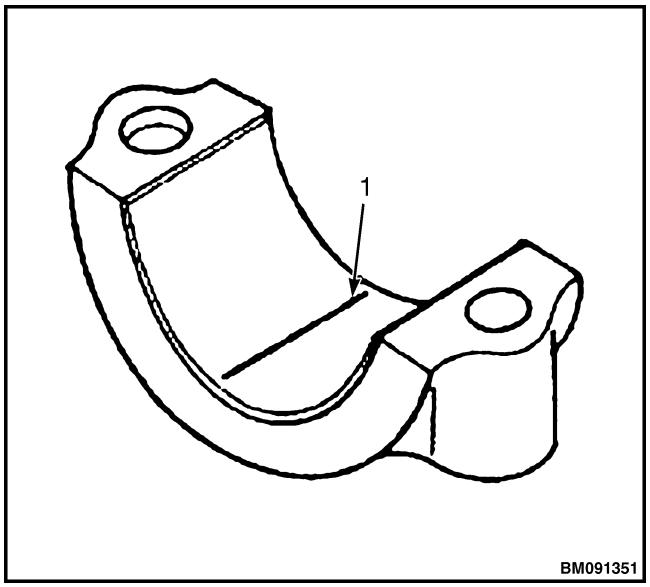
NOTE: The arrows on the main bearing caps point to the flywheel end of the engine.

4. Remove the bolts retaining the main bearing caps and remove the main bearing caps. Do not remove the bearings at this time.

5. Measure bearing oil clearance prior to removing the **crankshaft** to determine the extent of wear. Record the measurement.

a. Wipe oil from the bearing and crankshaft surfaces.

b. Place a piece of plastigauge® along the full width of the bearing (see Figure 327). Do not rotate the crankshaft when using plastigauge. A false reading may result.



1. PLASTIGAUGE

Figure 327. plastigauge placement

c. Reinstall bearing cap. Tighten the bearing cap bolt on the first pass to 48 to 50 N•m (35.4 to 36.9 lbf ft). Then torque to 96.0-100 N•m (70.8-73.8 lbf ft).

d. Remove the bearing cap.

e. Compare the width of the flattened plastigauge to the graduation marks on the package (see Figure 328). The mark that most closely matches the width of the flattened plastigauge will indicate the bearing oil clearance.

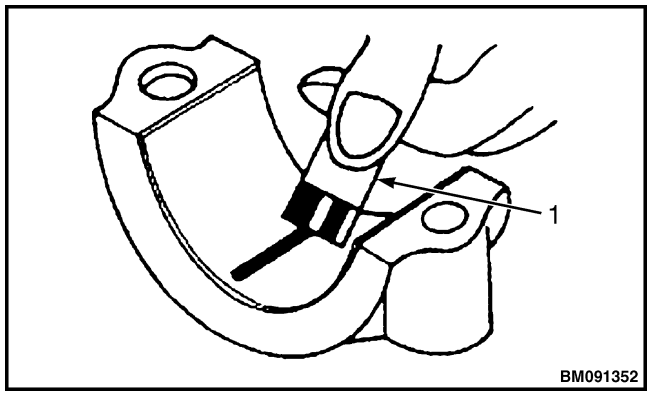


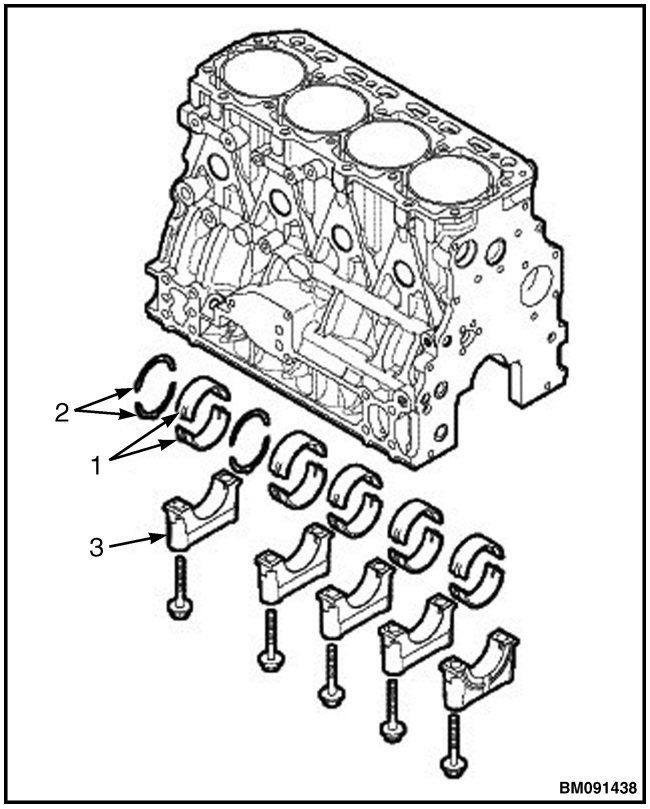
Figure 328. Graduation marks

6. Remove the crankshaft from the engine. See Figure 319.

CAUTION

Do not remove the crankshaft gear unless the gear or crankshaft are damaged and require replacement.

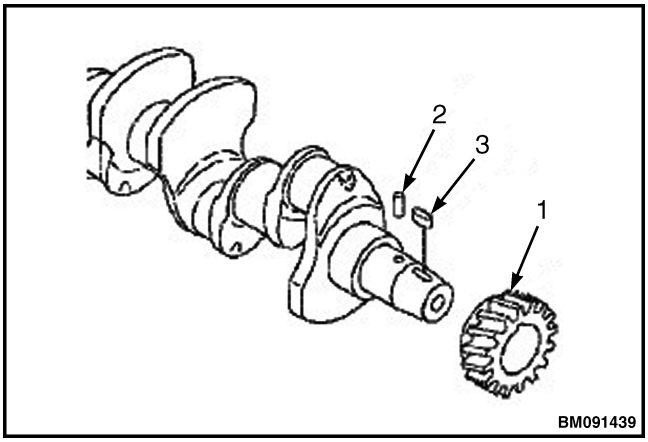
7. Remove the bearings and thrust bearings. See Figure 329.



1. BEARINGS
2. THRUST BEARINGS
3. MAIN BEARING CAPS

Figure 329. Crankshaft thrust bearings

8. If necessary, remove the crankshaft, gear, parallel pin, and key. If using a gear puller, be careful not to damage threads in the end of the crankshaft. See Figure 330.



1. CRANKSHAFT GEAR
2. PARALLEL PIN
3. KEY

Figure 330. Crankshaft

INSPECT

Crankshaft oil seals

DANGER

Always read and follow safety related precautions found on the containers of hazardous substances like parts cleaners, primers, sealants and sealant removers. Failure to comply could result in death or serious injury.

NOTE: Thoroughly clean all components using a brush and appropriate solvent such as brake cleaner or laquer thinner. Each part must be free of carbon, gasket material, metal filings and other debris.

1. Remove the front oil seal from the timing gear case cover. See Figure 331.

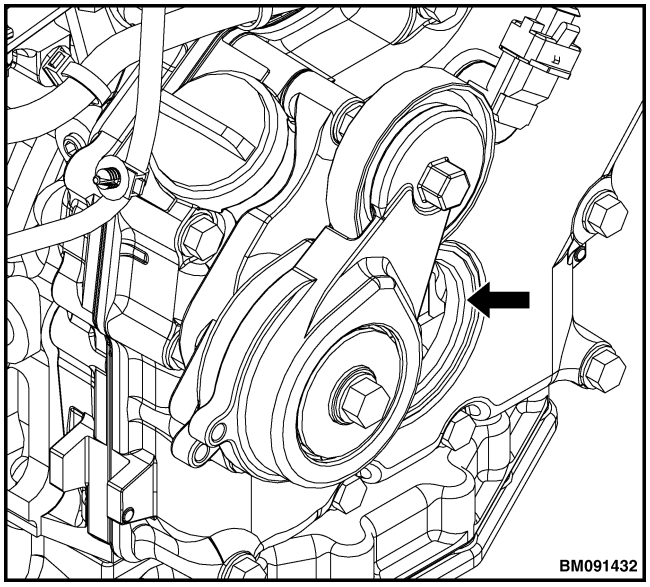
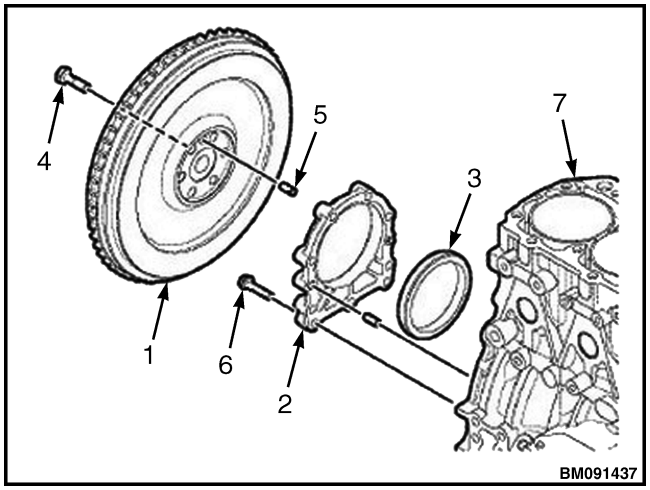


Figure 331. Front oil seal

2. Apply a continuous bead of ThreeBond Liquid Gasket Hyster part number 2084312 to the outside diameter of a new front oil seal and install in the timing gear case cover. Apply lithium grease to the lip of the seal.

3. Remove the rear oil seal from the seal housing. See Figure 332.



1. FLYWHEEL
2. REAR OIL SEAL HOUSING
3. REAR OIL SEAL
4. FLYWHEEL HOUSING BOLT
5. DOWEL
6. OILS SEAL HOUSING MOUNTING BOLT
7. CYLINDER BLOCK

Figure 332. Rear oil seal

Cylinder block

1. Verify that oil passages are clear and unobstructed. Clear any oil passages as needed.

2. Check for discoloration or evidence of cracks. If evidence of a fracture is found, use the color check method or the Magnaflux method to determine if the cylinder block is fractured.

3. Inspect the cylinder roundness and cylindricity for evidence of distortions. Collect and record the measurements. See Figure 333.

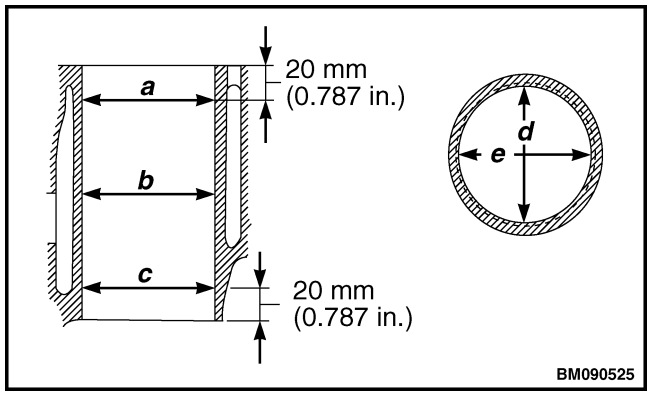


Figure 333. Cylinder measurement points

Honing and Boring

Pistons must move freely in the cylinders while maintaining adequate compression and oil sealing. If the cylinder walls are scuffed, scored, out of round, or have poor cylindricity, honing or boring and honing might correct cylinder problems. Re-boring is necessary if the bore dimensions fall outside specified limits. Honing must follow any re-boring operations. Slight imperfections can be corrected by honing alone.

1. **Boring** - Significant cylinder damage might be corrected by re-boring.
   - Boring out a cylinder block can only be done in a properly equipped machine shop.
   - After re-boring, existing pistons must be replaced. See **Parts manual** for correct part information.
   - After re-boring a cylinder block, each cylinder must be honed.

2. **Honing** - Slight cylinder imperfections might be corrected by honing.

   a. Insert the appropriate honing tool into the chuck of an electric drill.

   b. Saturate the cylinder wall with solvent using a 50% fuel and 50% engine oil mixture.

   c. Rotate the honing tool at 300 to 1200 rpm.

CAUTION

DO NOT allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.

NOTE: Tilt the honing tool at a 30 to 40 degree angle during the honing operation, to leave a cross hatch mark on the cylinder wall. See Figure 334.

   d. Insert the rotating honing tool into the cylinder and move it down through the entire length of the cylinder in a five-second motion. See Figure 335.

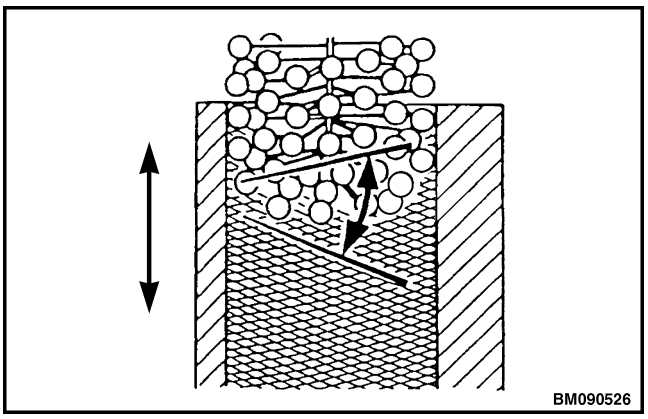


Figure 334. Cylinder honing angle

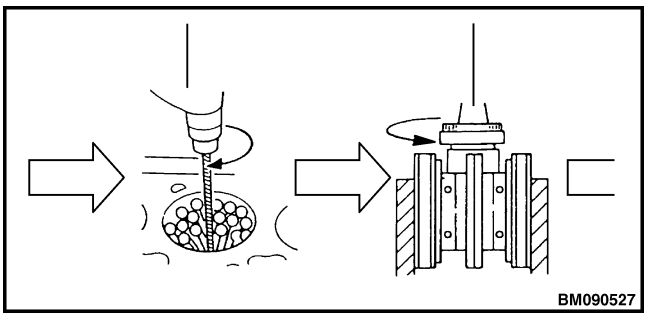


Figure 335. Cylinder honing

   e. Without stopping the honing tool, pull it up through the entire length of the cylinder in a five-second motion.

   f. Maintain the up-and-down motion for 30 to 40 seconds.

WARNING

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

   g. When the honing is completed, wash the cylinder block with hot water and soap. Use brushes to clean all passages and crevices. Rinse with hot water and blow dry with compressed air. Apply clean engine lubricating oil to all steel surfaces to prevent rusting.

Pistons

NOTE: On an engine with low hours, the pistons and piston rings may be reused if they are found to be within specifications. The piston and piston rings must be reinstalled in the same cylinders from which they were originally removed.

On an engine with high hours, the piston rings should be replaced and the cylinder honed or replaced (see Honing and Boring). The piston should be replaced as necessary.

1. Use a piston ring groove cleaning tool to clean the piston ring grooves. See Special tools for LPG engines and follow manufacturer's instructions for correct operation.

2. Wash the pistons in an appropriate solvent using a soft brush.

3. Visually inspect each piston for cracks. Pay particular attention to between the piston ring grooves.

4. Use a micrometer to measure the diameter of the piston skirt at 90° to the wrist pin bore as shown in Figure 336. Refer to the LPG engine specifications for the service limit.

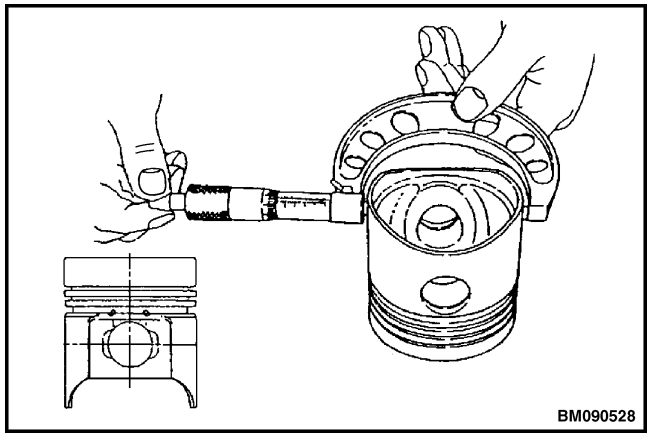


Figure 336. Piston skirt measurement

5. Subtract the piston measurement from the greatest measurement acquired during cylinder inspection to obtain piston-to-cylinder clearance. See LPG engine specifications. Record the measurements.

6. Measure the diameter of the wrist pin bore on both sides of the piston. See Figure 337. Refer to LPG engine specifications. Record the measurements.

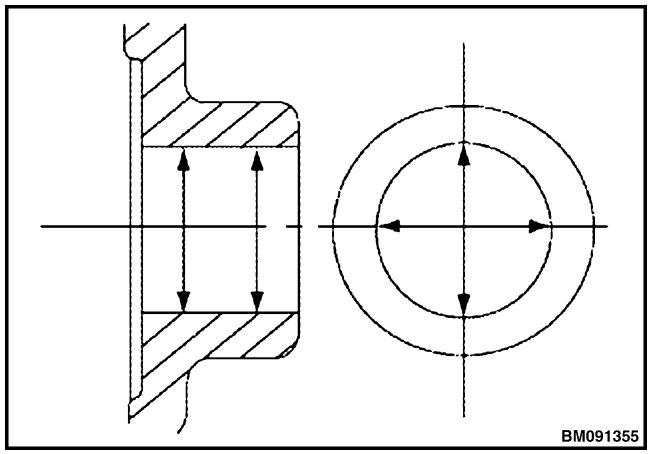


Figure 337. Diameter

7. Measure the outside diameter of the wrist pin in three places and at 90°. See Figure 338. Refer to LPG engine specifications. Record the measurements.

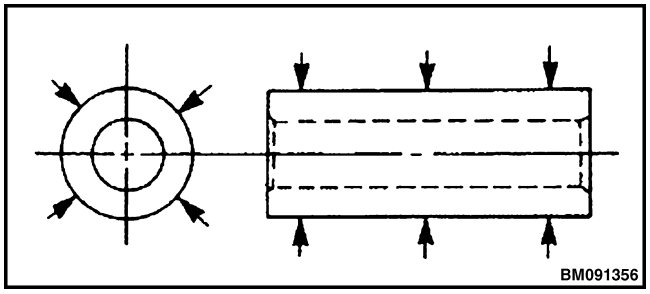


Figure 338. Outside diameter

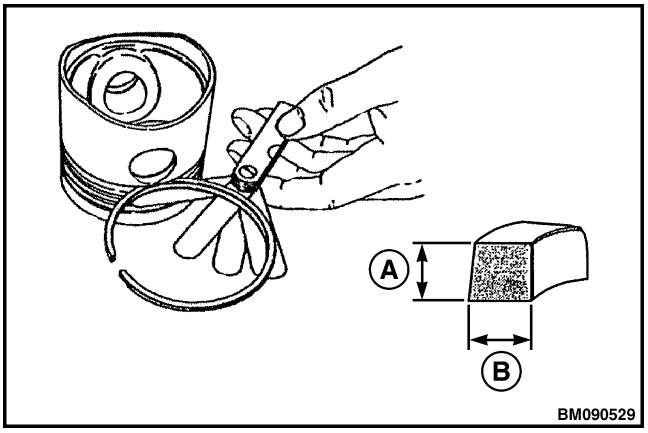
NOTE: On an engine with low hours, the pistons and piston rings may be reused if they are found to be within specifications. The piston and piston rings must be reinstalled in the same cylinders from which they were originally removed.

On an engine with high hours, the piston rings should be replaced and the cylinder honed or replaced (see Honing and Boring). The piston should be replaced as necessary.

8. Measure the piston ring and the piston ring groove for cylinder number one.

   a. Use a micrometer to measure the thickness of the top compression ring. Refer to the LPG engine specifications for the service limit. Record the measurement.

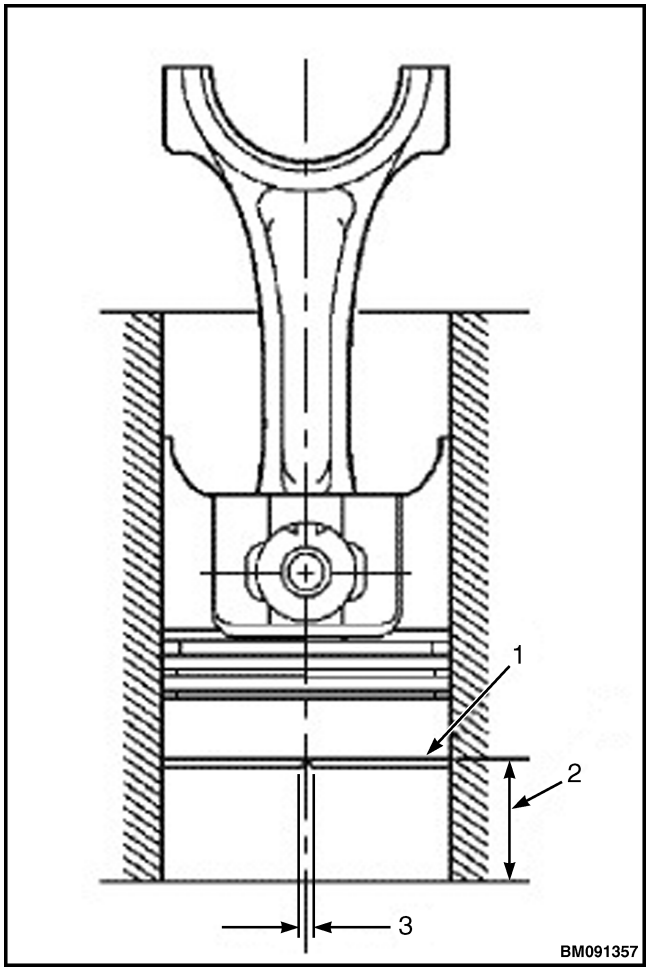
   b. Place each compression ring in the groove as shown in Figure 339. Use a feeler gauge to measure the gap between the ring and the piston. Record the measurement. Refer to the LPG engine specifications for the service limit. Replace the piston if not within specification.



A. WIDTH
B. THICKNESS

Figure 339. Piston and piston ring groove clearance

9. To measure piston ring end gap, insert each compression ring, one at a time, into the cylinder (see, Figure 340). Use a piston with the piston rings removed to slide the ring into the cylinder bore until it is approximately 30 mm (1.18 in.) from the bottom of the bore. Remove the piston. Measure the end gap of each piston ring. Record the measurements. See LPG engine specifications.



1. COMPRESSION PISTON RING
2. BORE MEASUREMENT
3. END GAP

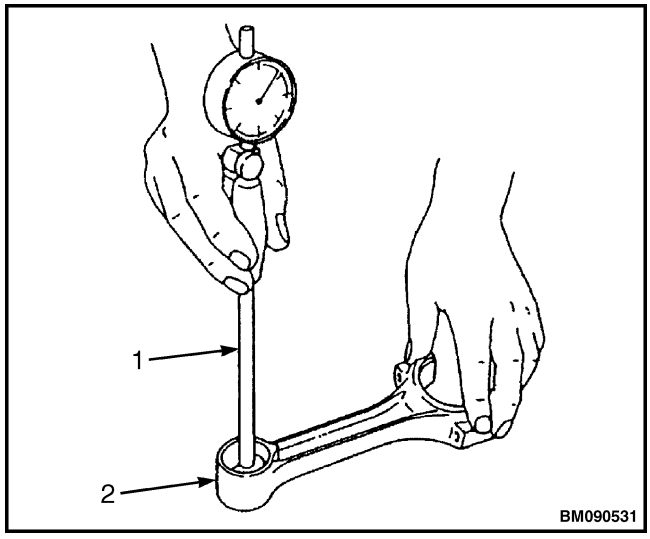
Figure 340. Piston and cylinder bore

NOTE: Always check the piston ring end gap when installing new piston rings. See LPG engine specifications. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.

10. Repeat Step 8 for each of the pistons.

Connecting Rod

1. Use a bore gauge to measure the wrist pin bushing bore. Replace the bushing if not within specifications. If the bushing has been removed, measure the inside diameter of the connecting rod small end. Refer to the LPG engine specifications for the service limit. See Figure 341.



1. CYLINDER GAUGE
2. CONNECTING ROD SMALL END

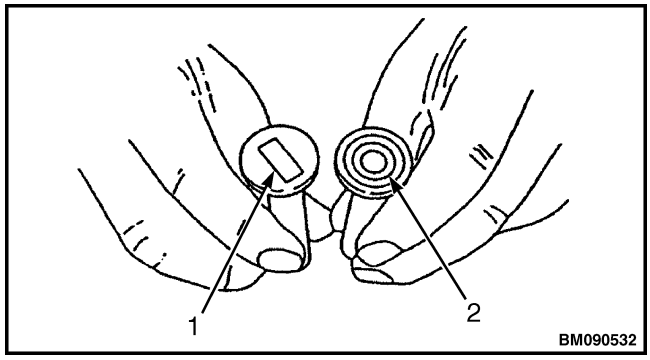
Figure 341. Connecting rod small end

2. Measure the crankpin and connecting rod bearings. Place the connecting rod bearings into the connecting rod and connecting rod cap. Install the end of the connecting rod to the connecting rod cap. Install the bolts and tighten to 54 to 59 N•m (40 to 44 lbf ft).

3. Measure the inside diameter. Refer to LPG engine specifications for the service limit.

Tappets

1. Check the tappet contact surfaces for abnormal wear. Slight surface defects can be corrected using an oilstone. See Figure 342.



1. ABNORMAL CONTACT SURFACE
2. NORMAL CONTACT SURFACE

Figure 342. Tappet contact surface

2. Measure the outside diameter of the tappet stem. Refer to LPG engine specifications for the service limit. See Figure 343.

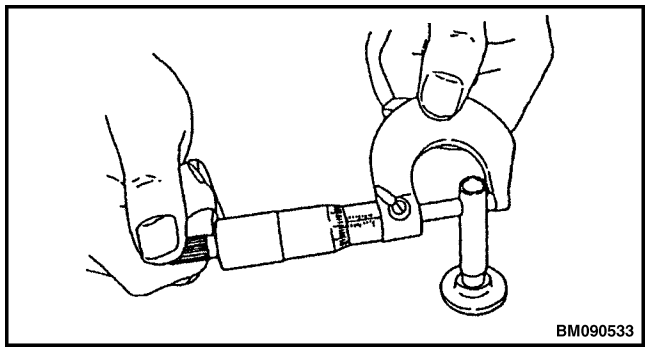
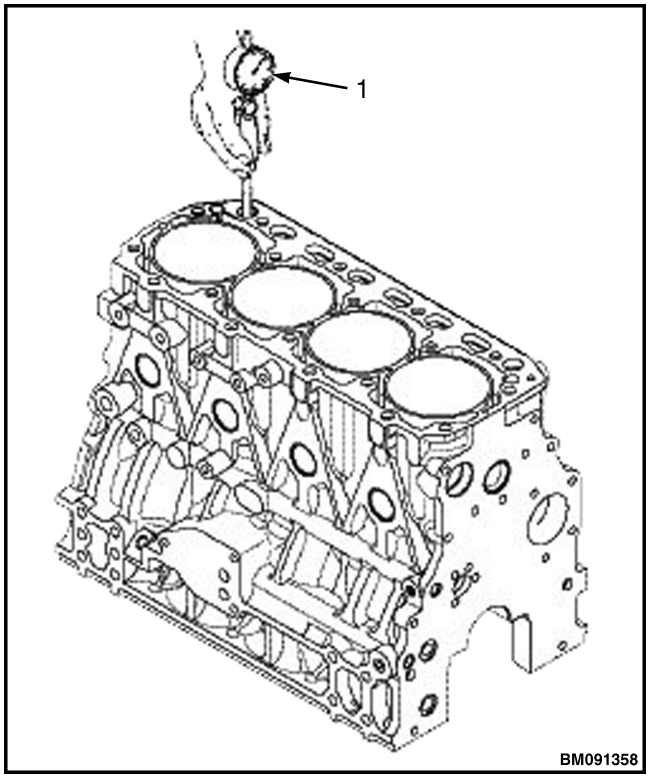


Figure 343. Tappet stem measurement

3. Use a cylinder gauge to measure the inside diameter of the tappet bore. See Figure 344.



1. CYLINDER GAUGE

Figure 344. Measure tappet bore

Crankshaft

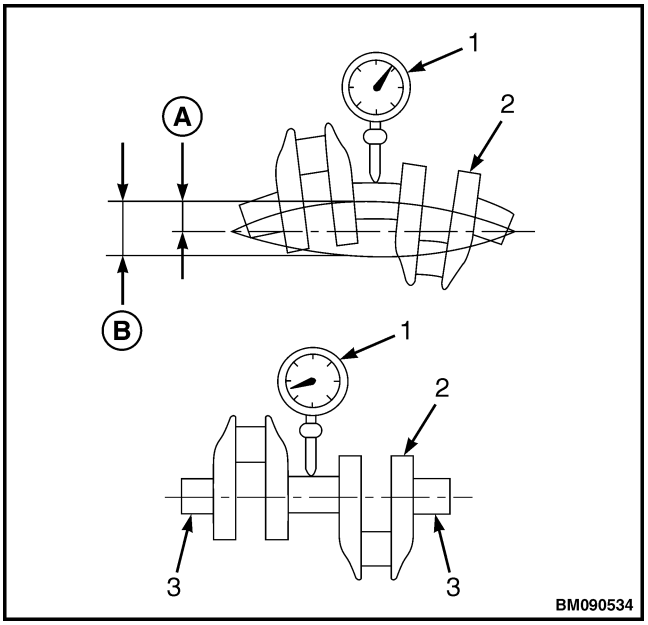
1. Measure the trueness of the crankshaft.

a. Place the crankshaft on V-blocks at the end journals. See Figure 345.

b. Place a dial indicator on a main bearing journal and zero the gauge.

c. Rotate the crankshaft and observe the run out. Refer to the LPG engine specifications for the service limit.

d. Repeat this procedure for the remaining bearing journals.



A. BEND
B. DEFLECTION

1. DIAL GAUGE
2. CRANKSHAFT
3. V-BLOCK

Figure 345. Crankshaft bend measurement

2. Inspect the crankshaft for fractures.

a. Use the color check or Magnaflux method to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures are found. See Figure 346.

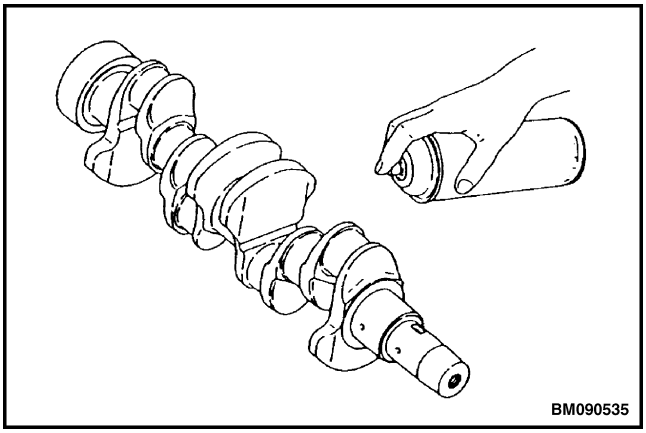


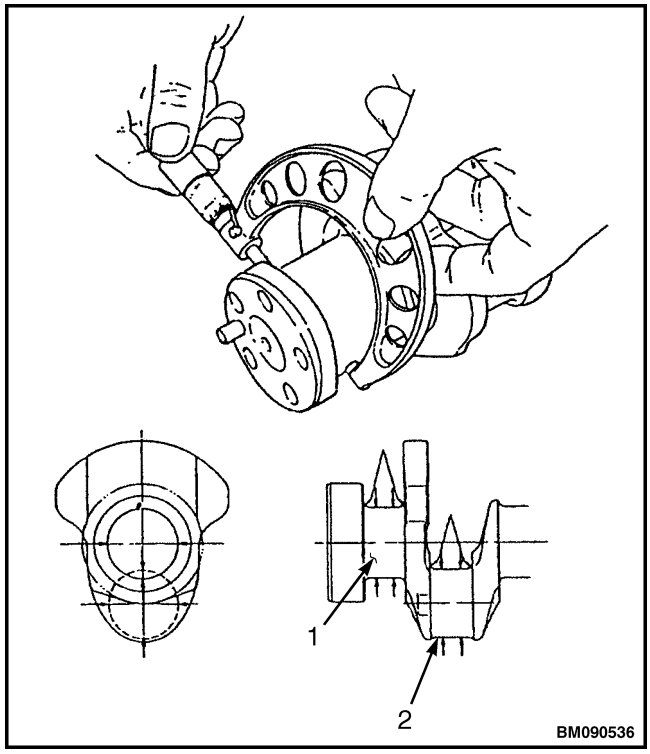
Figure 346. Crankshaft fracture check

b. If the color check method is not available, spray Magnaflux on the crankshaft to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures are found.

3. Measure the outside diameter of each crankpin and main bearing journal. See Figure 347.

a. Take measurements at several places around each bearing journal. Refer to LPG engine specifications for the service limit.

b. If the bearing journal clearance exceeds the service limit, use an undersized bearing. Refer to the LPG engine specifications for the service limit.



1. CRANKSHAFT JOURNAL
2. CRANKPIN

Figure 347. Crankpin and crankshaft journal measurement

Camshaft

1. Measure the trueness of the camshaft.

a. Place the camshaft on V-blocks positioned at the end journals. See Figure 348.

b. Place a dial indicator on the on the center bearing journal and set the gauge to zero.

c. Rotate the camshaft and observe the run out. Refer to the LPG engine specifications for the service limit.

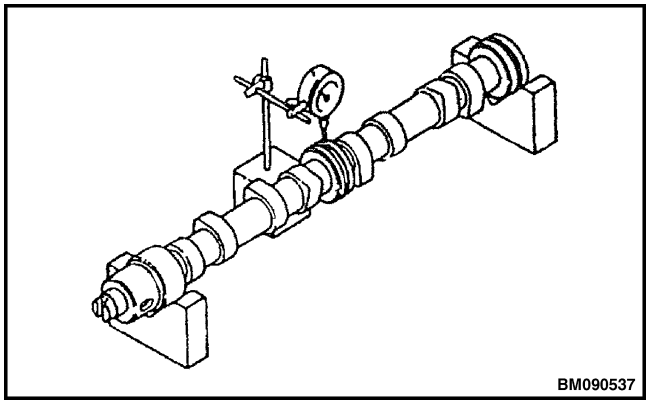
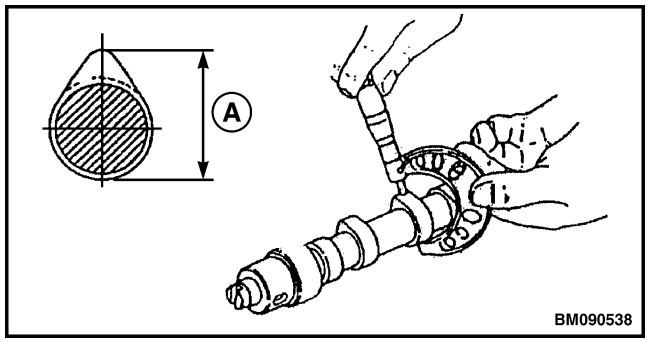


Figure 348. Camshaft Run out Check

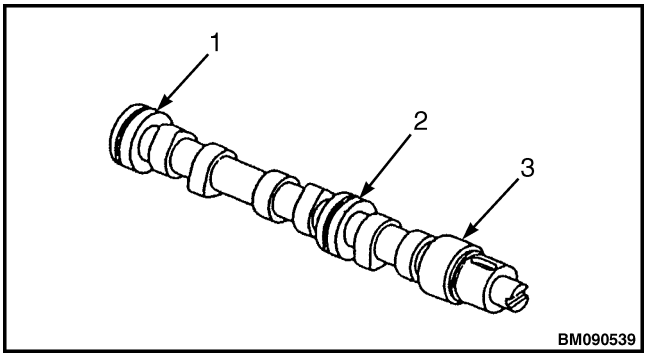
2. Measure the intake/exhaust cam lobe height. Refer to the LPG engine specifications for the service limit. See Figure 349.



A. CAM HEIGHT

Figure 349. Intake/Exhaust Cam Lobe Height Measurement

3. Measure the gear end bearing surface, intermediate position bearing surface, and flywheel end bearing surface diameters. See Figure 350. Determine the oil clearance. The oil clearance is calculated by subtracting the measured camshaft bearing surface diameter from the camshaft bushing inside diameter. Refer to the LPG engine specifications for the service limit.



1. FLYWHEEL END BEARING SURFACE
2. INTERMEDIATE POSITION BEARING SURFACE
3. GEAR END BEARING SURFACE

Figure 350. Camshaft Bearing Surface Measurements

Camshaft bushing and bores

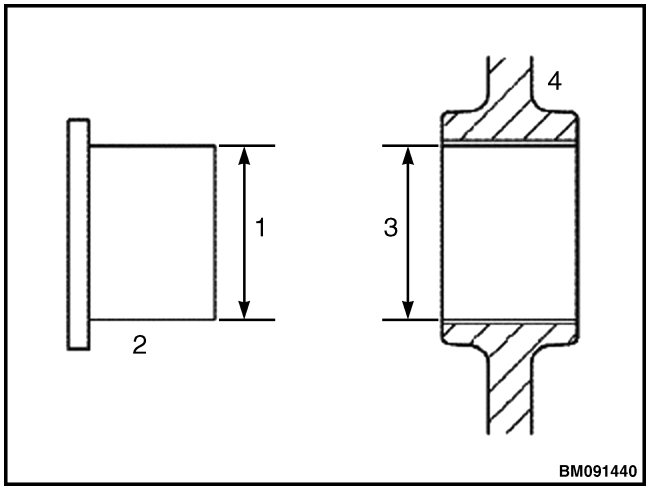
1. Measure the inside diameter of the front bushing and the remaining bores in the cylinders block. See Figure 319. Refer to Table 73 in LPG engine specifications.

2. If the camshaft bushing is not within specification, replace it using the appropriate service tool. If the remaining bores are not within specification, the cylinder block will require replacement as there are no alternative bearings available to correct the bearing to camshaft journal oil clearance specification.

Idler gear and shaft

1. Measure the outside diameter of the idler gear shaft. See Figure 351. Refer to LPG engine specifications.

2. Measure the inside diameter of the idler gear bushing. See Figure 351. Refer to LPG engine specifications.



1. OUTSIDE DIAMETER
2. IDLER GEAR SHAFT
3. INSIDE DIAMETER
4. IDLER GEAR BUSHING

Figure 351. Idler gear

ASSEMBLE

NOTE: Proceed slowly. Make no forced assemblies unless a pressing operation is called for. All parts must be perfectly clean and lightly lubricated when assembled.

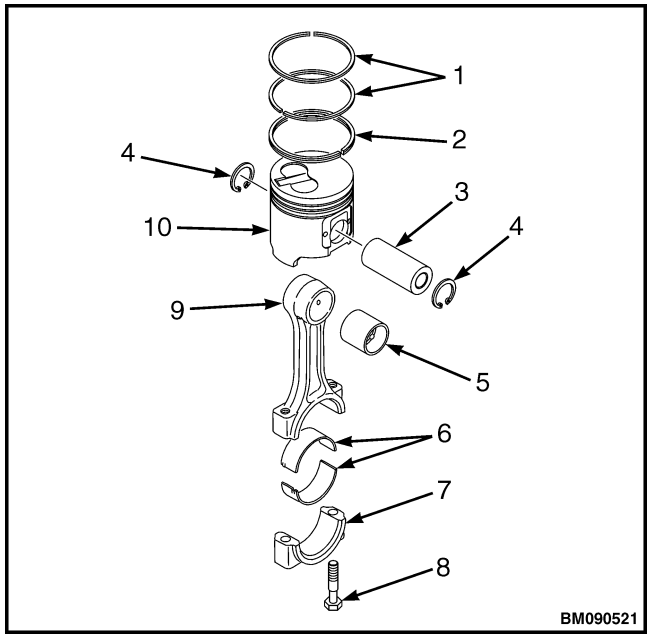
NOTE: Always use new gaskets, seals and O-rings during assembly.

NOTE: Apply clean engine lubricating oil to all internal parts during assembly.

Pistons and Connecting Rods

1. Select the components needed to assemble the piston and connecting rod for the Number 1 cylinder. See Figure 352.

2. Lubricate and use a press to insert the wrist pin bushing. Be sure to align the oil holes. See Figure 352.



1. COMPRESSION RINGS
2. OIL SEAL RING
3. WRIST PIN
4. SNAP RING
5. WRIST PIN BUSHING
6. BEARINGS
7. CONNECTING ROD CAP
8. BOLT
9. CONNECTING ROD
10. PISTON

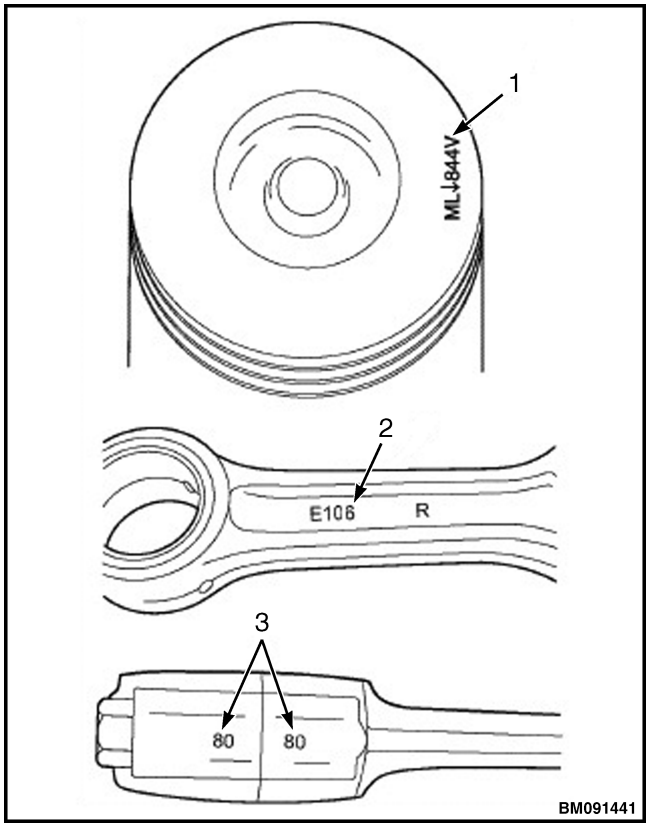
Figure 352. Piston and Connecting Rod

3. Install one snap ring into the piston. See Figure 352.

NOTE: The piston and connecting rod must be assembled together in the correct orientation. The orientation of the piston and connecting rod are different depending on engine model.

The actual appearance of the match marks on the piston and connecting rod may vary, but they will always be in the same locations.

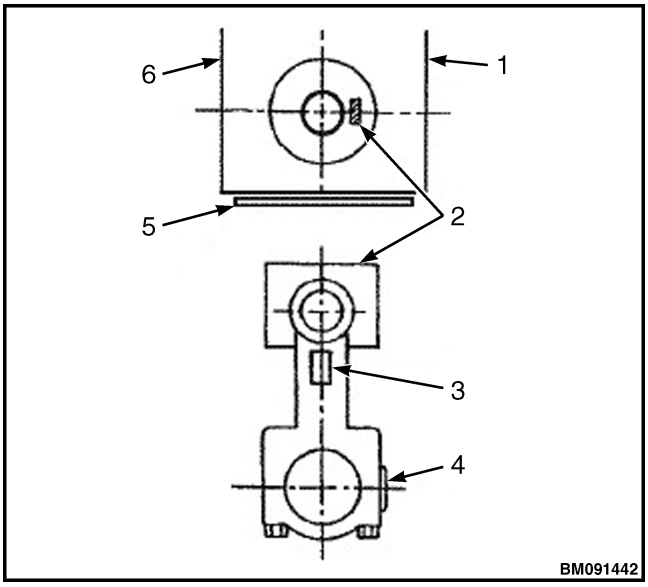
4. Orient the piston identification mark stamped on top of the piston on the same side as the rod and cap match marks stamped on the connecting rod. See Figure 353.



1. PISTON IDENTIFICATION MARK
2. EMBOSSED MARK (ON CONNECTING ROD)
3. MATCHING ROD AND CAP MARKS

Figure 353. Piston and connecting rod identification marks

5. Confirm when the piston is installed in the cylinder, the piston identification mark stamped on the top of the piston is facing the oil filter side of the engine and the embossed mark on the connecting rod is facing the flywheel side. See Figure 354.



1. OIL FILTER SIDE OF ENGINE
2. PISTON IDENTIFICATION MARK
3. EMBOSSED MARK ON CONNECTING ROD
4. ROD AND CAP MATCH MARKS
5. FLYWHEEL END OF ENGINE
6. CAMSHAFT SIDE OF ENGINE

Figure 354. Piston installed

6. Lubricate and install the piston wrist pin through the piston and connecting rod. See Figure 352.

7. Install the second snap ring and confirm it is fully seated in the groove. See Figure 352.

NOTE: Always check the piston ring end gap when installing new piston rings. See LPG engine specifications. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.

8. Use piston ring pliers to install the piston rings.

a. Install each piston ring on the piston with the punched manufacture's mark facing upward. See Figure 355.

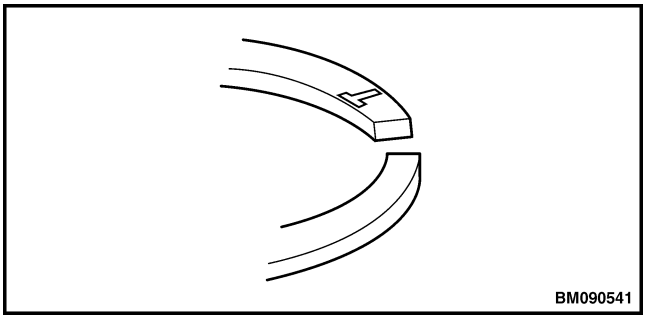
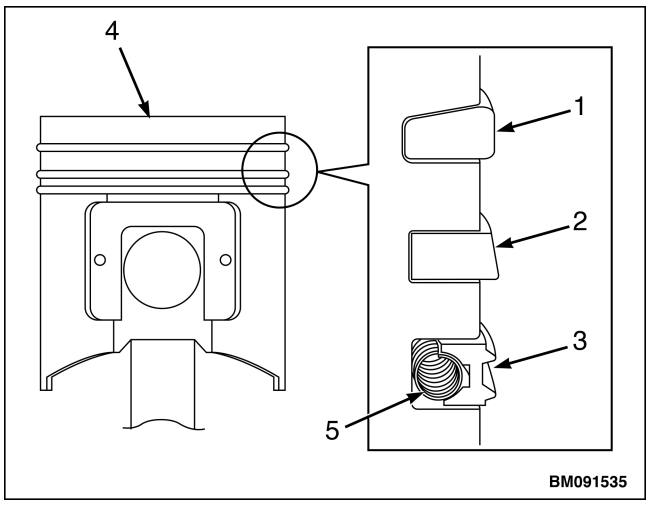


Figure 355. Piston ring mark

b. Install the top compression ring, second compression ring, and oil ring. See Figure 356.

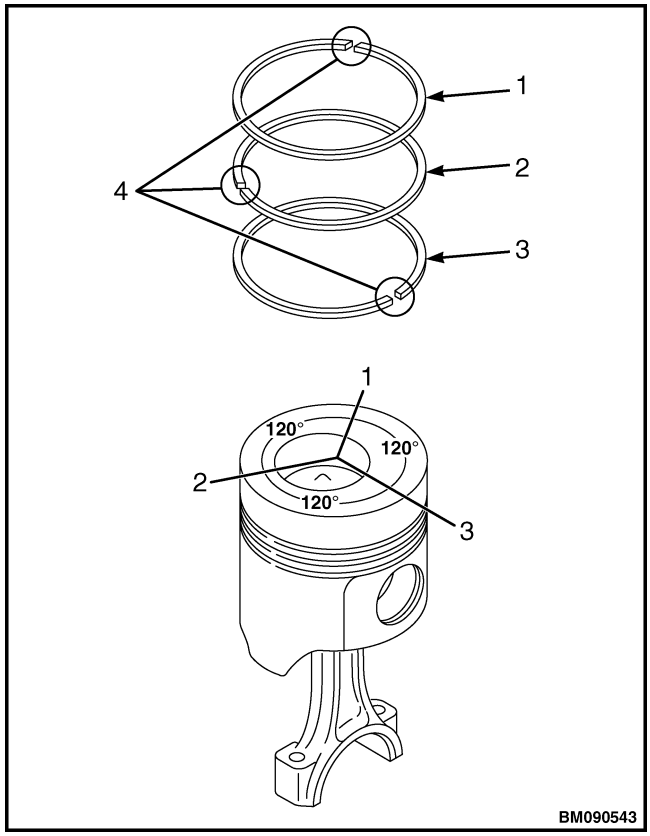
c. Confirm the oil ring coil expander end gap is located 180° from the oil ring end gap. See Figure 356.



1. TOP COMPRESSION RING
2. SECOND COMPRESSION RING
3. OIL RING
4. PISTON
5. OIL RING COIL EXPANDER

Figure 356. Piston rings

d. Stagger the piston ring joints at 120° intervals. DO NOT position the top compression ring joint in line with the piston wrist pin. The coil expander joint must be opposite the oil ring joint. See Figure 357.



1. TOP COMPRESSION RING
2. SECOND COMPRESSION RING
3. OIL RING
4. JOINTS

Figure 357. Piston rings staggering

9. Perform Step 1 through Step 8 for the assembly of each remaining piston.

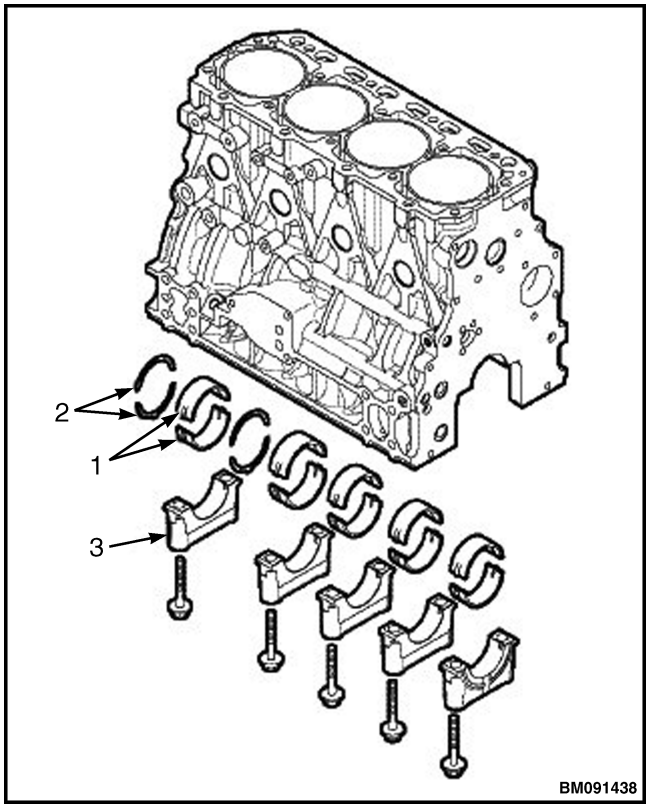
INSTALL

Crankshaft

1. If removed, reinstall the key, parallel pin and crankshaft gear on the crankshaft. See Figure 330.

2. Reinstall new bearings and thrust bearing in the cylinder block and main bearing caps. See Figure 358.

3. Apply a liberal coat of engine lubricating oil to the bearings and crankshaft journal. See Figure 358.



1. BEARINGS
2. THRUST BEARINGS
3. MAIN BEARING CAPS

Figure 358. Crankshaft thrust bearings

4. Place the crankshaft into the engine. See Figure 319.

NOTE: The main bearing caps are numbered and have arrows for proper positioning. The No. 1 cap is located at the flywheel end. The arrows point towared the flywheel end of the engine.

5. Reinstall the main bearing caps. See Figure 358.

6. Apply a liberal coat of engine lubricating oil to the bearings cap bolts and tighten the bolts to the specified torque in two stages. Torque to 48 to 50 N•m (35.4 to 36.9 lbf ft) on first pass then torque to 96 to 100 N•m (70.8 to 73.8 lbf ft).

7. Rotate the crankshaft to confirm it turns freely.

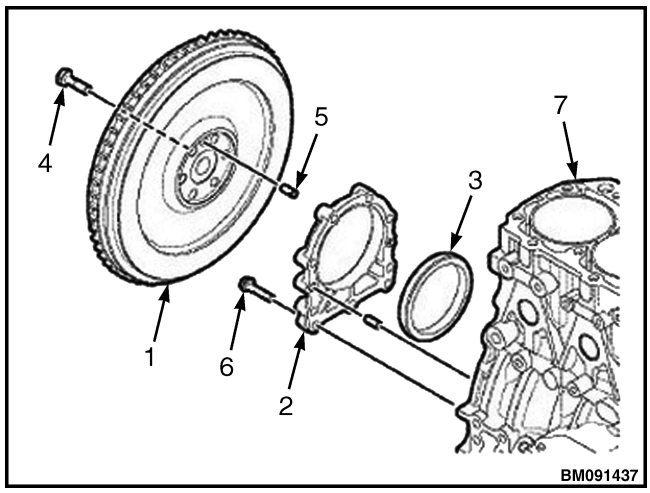
8. Apply a continuous bead of ThreeBond Liquid Gasket Hyster part number 2084312 to the mounting flange of the seal housing.

9. Align the rear oil seal housing with the two dowel pins. See Figure 359.

10. Insert the bolts to retain the rear oil seal housing and rear oil seal. See Figure 359. Tighten to standard torque.

11. Install the flywheel on to the crankshaft. See Figure 359.

12. Insert the bolts to retain the flywheel. See Figure 359. Torque to 83.3 to 88.2 N•m (61 to 65 lbf ft).



1. FLYWHEEL
2. REAR OIL SEAL HOUSING
3. REAR OIL SEAL
4. FLYWHEEL HOUSING BOLT
5. DOWEL PIN
6. OILS SEAL HOUSING MOUNTING BOLT
7. CYLINDER BLOCK

Figure 359. Rear oil seal

Pistons

NOTE: Do not allow the connecting rod to contact the crankshaft journal during piston installation. Damage to the crankshaft journal may result.

1. Lubricate the Number 1 piston, piston rings, and cylinder with clean engine lubricating oil.

2. Rotate the crankshaft so the crankpin for the piston being installed is near the bottom dead center.

3. Confirm the piston ring gaps are located correctly. See Figure 357.

4. Use a piston ring compressor to compress the piston rings on the Number 1 piston. See Special tools for LPG engines.

5. Carefully install the piston into the Number 1 cylinder. Be sure the punched mark on the connecting rod is facing the oil filter side and the embossed mark is facing the flywheel. See Figure 323.

6. Install the connecting rod bearings into the connecting rod and connecting rod cap.

7. Apply a liberal coat of clean engine oil to the bearings and crankshaft journal.

8. Install a light coat of clean engine oil to the rod cap bolts. Reinstall the connecting rod cap. Tighten the connecting rod bolts to 44.1-49 N•m (33-36 lbf ft) N•m in two stages (½ torque first, then full torque).

9. Perform Step 1 through Step 6 to install the remaining pistons in their respective cylinders.

INSTALL THE ENGINE COMPONENTS

1. Install the crankshaft drive gear and idler gear. See LPG timing gear case repair.

2. Install the oil pump. See LPG lubrication system repair.

3. Install the timing gear case cover. See LPG timing gear case repair.

4. Install the oil pan. Install the oil suction tube. See LPG lubrication system repair.

5. Install the cylinder head. See LPG cylinder head repair.

6. Install the water pump. See Water pump repair in the **Cooling system** 0700SRM2300 service manual.

7. Install the alternator. See LPG electrical system repair.

8. Install the flywheel and flywheel housing. See LPG flywheel repair.

9. Install the starter. See LPG electrical system repair.

10. Install the engine. See LPG engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

LPG LUBRICATION SYSTEM REPAIR 202001-026

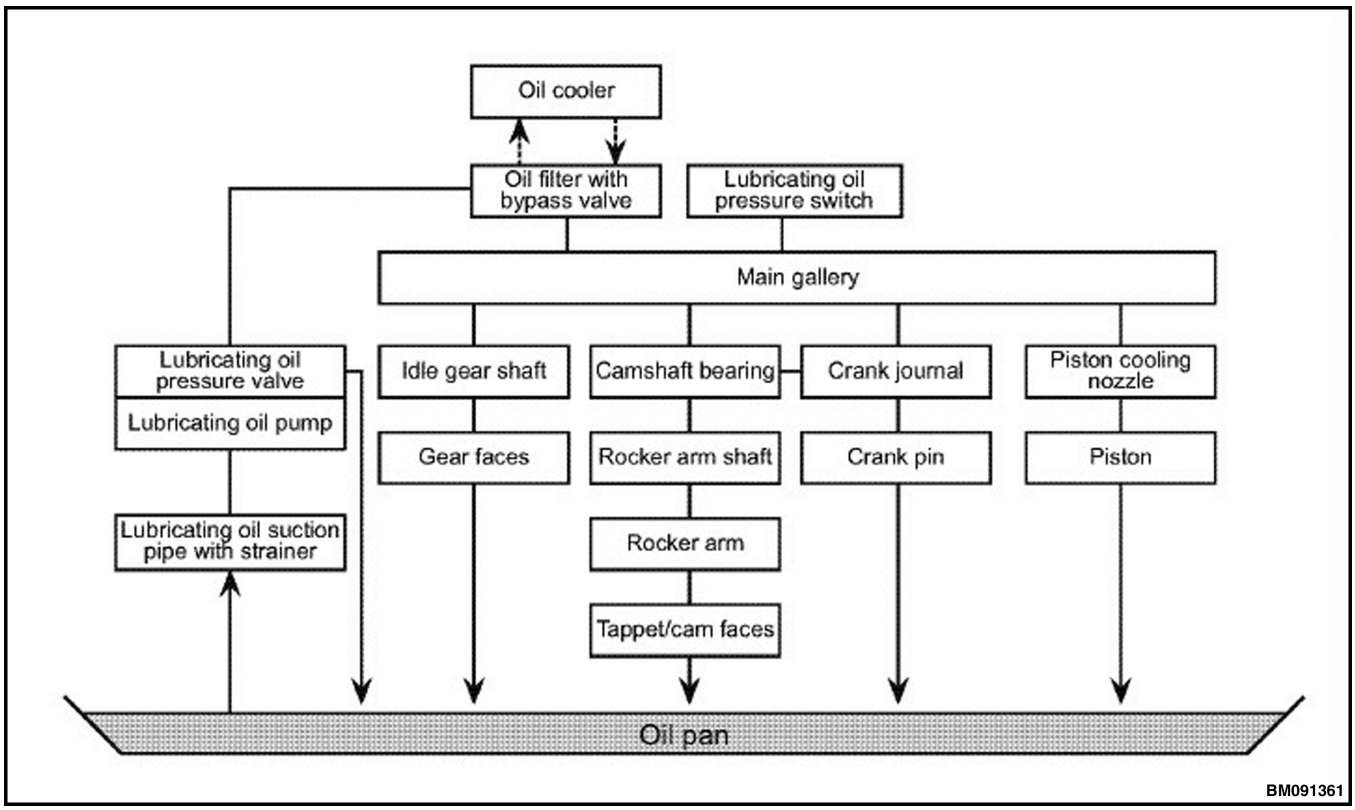
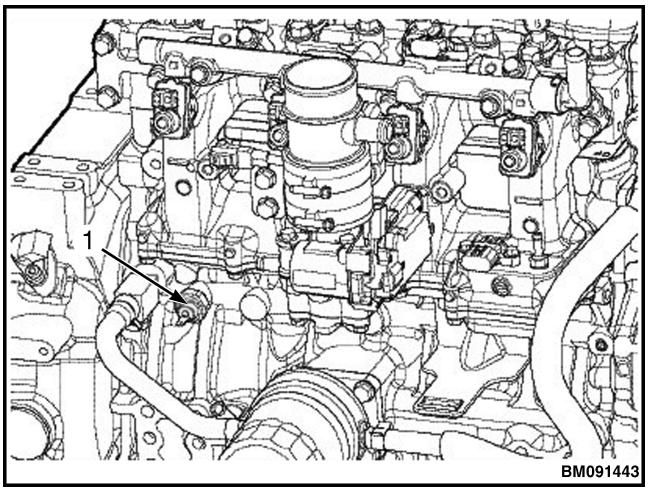


Figure 360. Lubrication system diagram

CHECK ENGINE LUBRICATING OIL PRESSURE

An engine oil pressure check must be performed if the oil pressure indicator is on, or the engine oil pressure gauge on the instrument panel indicates low engine oil pressure. See Table 90 for specifications.

1. Locate the oil pressure switch. See Figure 361. Disconnect the electrical connector (not shown) from the oil pressure switch.



1. OIL PRESSURE SWITCH

Figure 361. Oil pressure switch

2. Remove the oil pressure switch.

3. Insert a mechanical oil pressure gauge into the port where the oil pressure switch was removed.

4. Start the engine. Rev the engine to the RPM indicated in the table below (see Table 90). Compare the reading on the oil pressure gauge to the specifications listed in the table.
   - If the mechanical oil pressure test gauge indicates satisfactory oil pressure (see Table 90 for specifications), the oil pressure switch or sending unit must be replaced.
   - If the mechanical oil pressure test gauge indicates low oil pressure (see Table 90 for specifications), follow steps to troubleshoot the lubrication system to determine the cause of low engine oil pressure. See **Guided troubleshooting** for this lift truck.

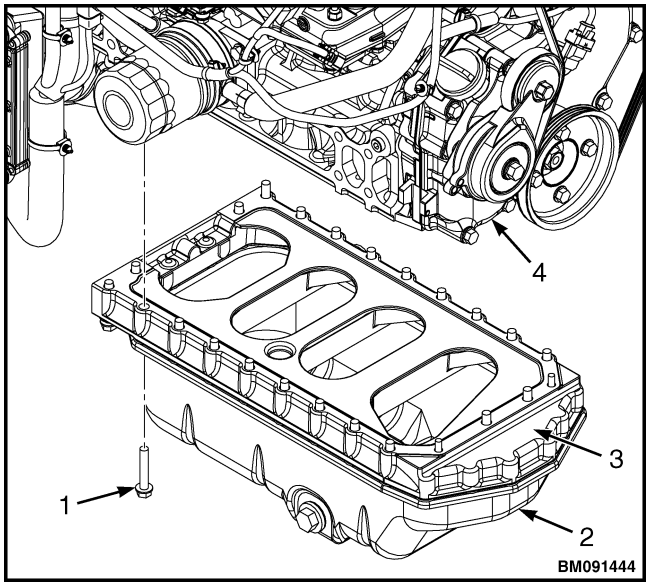
REMOVE

Oil pan

1. Remove the engine assembly from the lift truck and place on an engine stand. See LPG engine removal and replacement.

2. Invert the engine (oil pan side up) on the engine stand.

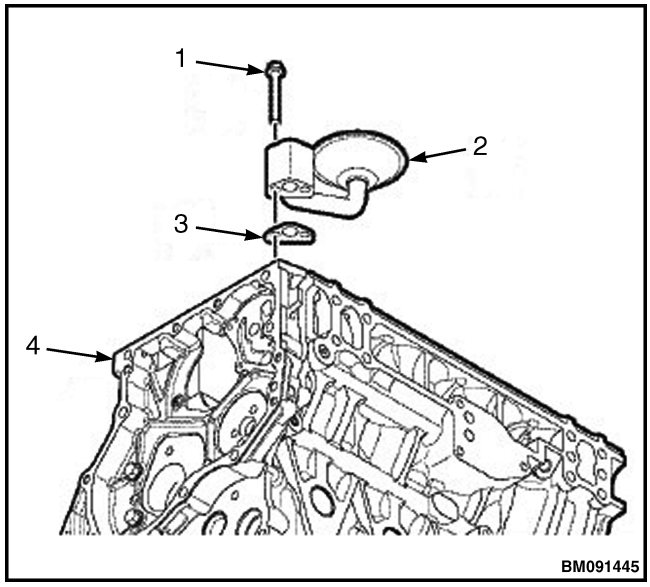
3. Remove 26 bolts retaining the oil pan and oil pan spacer to the engine block. See Figure 362.



1. BOLT
2. OIL PAN
3. OIL PAN SPACER
4. ENGINE BLOCK

Figure 362. Oil pan

4. Remove the oil pickup tube and gasket. See Figure 363.



1. BOLT
2. OIL PICKUP TUBE
3. GASKET
4. ENGINE BLOCK

Figure 363. Oil pickup tube

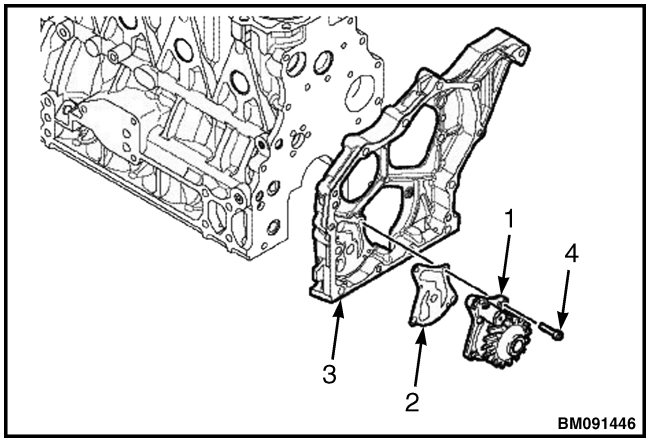
Oil pump

1. Remove the fan guard, cooling fan, spacer, water pump V-pulley and V-belt. See **Cooling system** 0700SRM2300 service manual.

2. Remove the crankshaft pulley and timing gear case cover. See LPG timing gear case repair.

3. Remove the oil pump mounting bolts. See Figure 364.

4. Remove the oil pump assembly from the timing gear case flange. See Figure 364.



1. OIL PUMP ASSEMBLY
2. GASKET
3. TIMING GEAR CASE FLANGE
4. OIL PUMP MOUNTING BOLTS

Figure 364. Oil pump

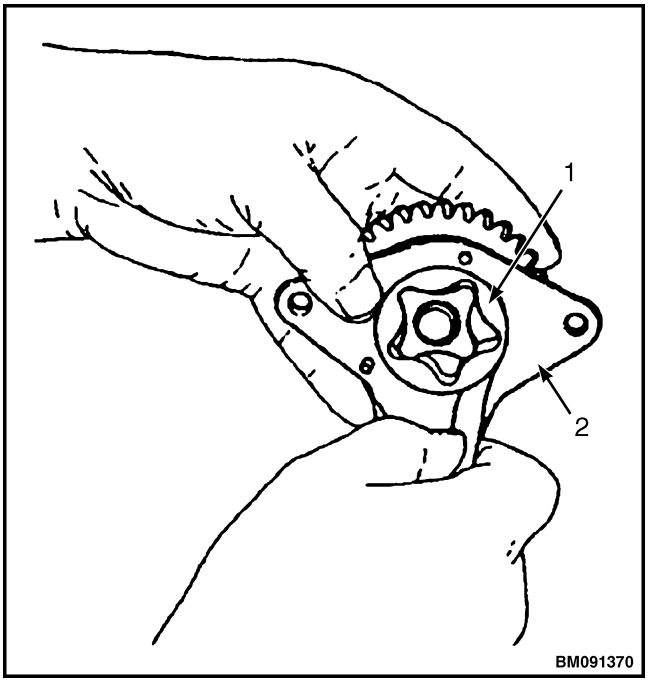
Clean and inspect

NOTE: Internal components of the oil pump cannot be purchased separately. If any component is worn or damaged, replace the oil pump assembly.

Clean all of the parts with cleaning solvent. Dry the parts with compressed air. Inspect for wear and damage. If necessary, replace oil pump assembly.

Outer rotor outside clearance

Inspect the outside diameter clearance of the outer rotor, by inserting a feeler gauge between the outer rotor and the oil pump body. See Figure 365. Record the measurements, and see Table 91 for service limits.

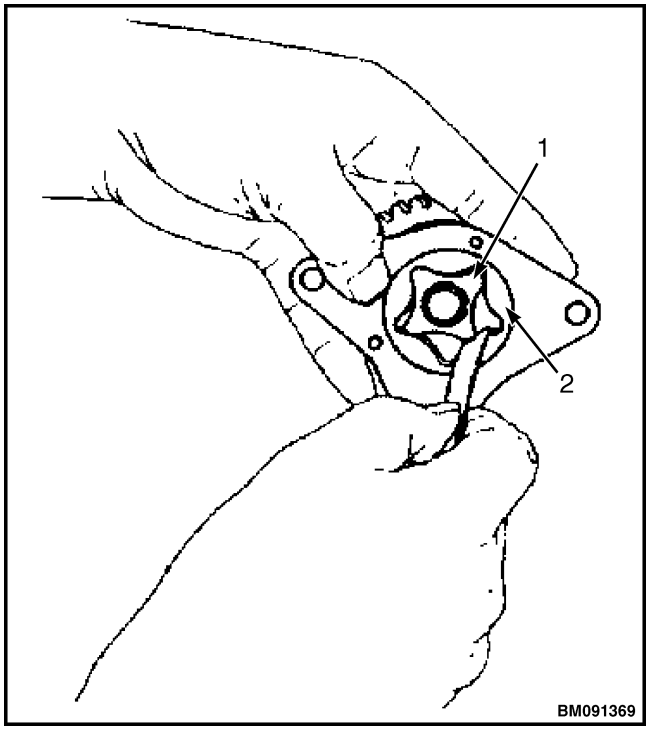


1. OUTER ROTOR
2. PUMP BODY

Figure 365. Outer rotor outside clearance check

Outer rotor to inner rotor tip clearance

Inspect the tip clearance between the outer and inner rotors, by inserting a feeler gauge between the inner rotor tooth tip and the outer rotor tooth tip. See Figure 366. Measure the clearance. Record the measurements, and see Table 93 for service limits.



1. INNER ROTOR TOOTH TIP
2. OUTER ROTOR TOOTH TIP

Figure 366. Inner rotor tip clearance check

Outer rotor side clearance

Inspect the side clearance between the oil pump body and the outer rotor, by using a straight edge and feeler gauge or a depth micrometer. See Figure 367. Record the measurements, and see Table 92 for service limits. for service limits.

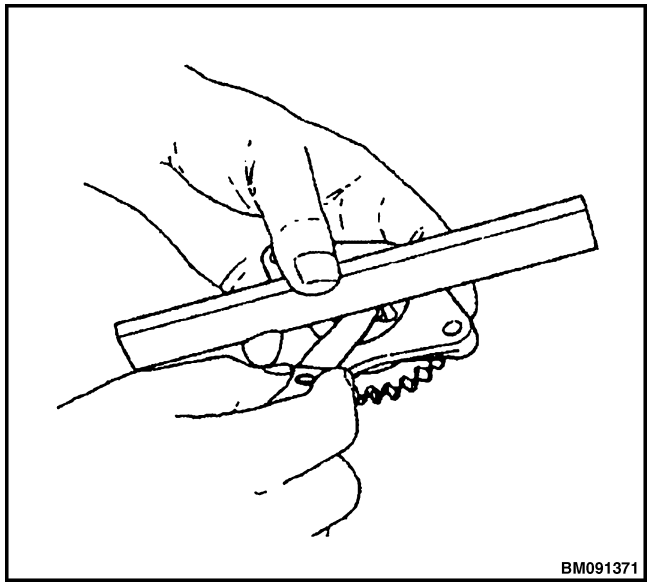
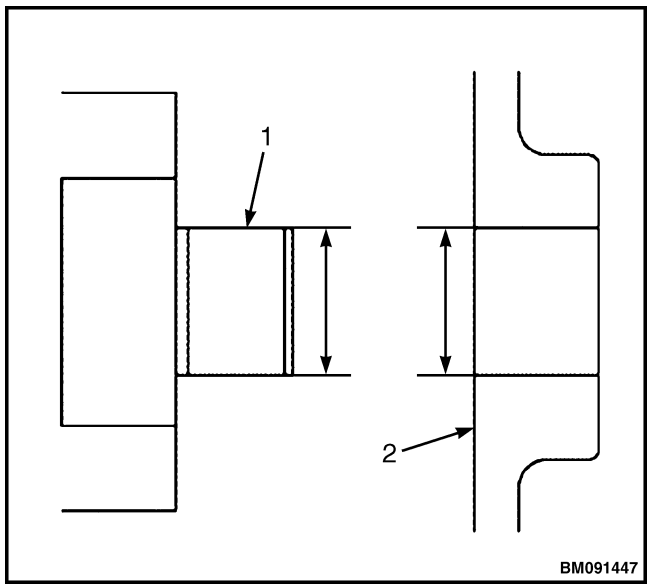


Figure 367. Outer rotor side clearance check

Rotor shaft clearance

Inspect the rotor shaft clearance, by measuring the outside diameter of the rotor shaft and the inside diameter of the cover. Determine clearance by subtracting the outside diameter of the rotor from the inside diameter of the cover. See Figure 368. Record the measurements, and see Table 94 for service limits. for service limits.



1. ROTOR SHAFT
2. OIL PUMP COVER

Figure 368. Rotor shaft clearance check

ASSEMBLE

1. Apply clean lubricating oil to the oil pump body, the inner rotor assembly and the outer rotor.
2. Insert the outer rotor into the oil pump body and inner rotor assembly and install the cover.
3. Replace the gasket with new.

INSTALL

Oil pump

1. Insert the two bolts to attach the oil pump assembly to the timing gear case flange. Tighten to standard torque.
2. Install the timing gear case cover. See LPG timing gear case repair.
3. Install the crankshaft pulley. See LPG timing gear case repair.
4. Install the V-belt, water pump V-pulley, spacer, and cooling fan. See **Cooling system** 0700SRM2300 service manual.

Oil pan

1. Install the oil pickup tube with a new gasket. See Figure 363.
2. Apply a continuous bead of ThreeBond Liquid Gasket (2084312) to the mounting face of the oil pan and oil pan spacer. Apply a thin circle around each bolt hole of the oil pan.
3. Install the oil pan spacer and oil pan to the engine block. Insert the bolts and tighten to standard torque. See Figure 362.

OIL PUMP SERVICE INFORMATION

Table 90. Engine lubricating oil pressure

Model	At rated engine RPM (min)	At low idle speed
	2600 min^{-1}	
4TN88G, 4TN88GN-NHYG	0.31-0.41 MPa (45-59.5 psi)	0.1 MPa (8.7 psi)

Table 91. Outer rotor outside clearance

Model	Standard	Limit	Reference page
4TN88G, 4TN88GN-NHYG	0.09-0.15 mm (0.0035-0.0059 in.)	0.25 mm (0.0098 in.)	Check outer rotor outside clearance. See Outer rotor outside clearance.

Table 92. Outer rotor side clearance

Model	Standard	Limit	Reference page
4TN88G, 4TN88GN-NHYG	0.05-0.09 mm (0.0020-0.0035 in.)	0.15 mm (0.0059 in.)	Check outer rotor side clearance. See Figure 367.

Table 93. Outer rotor to inner rotor tip clearance

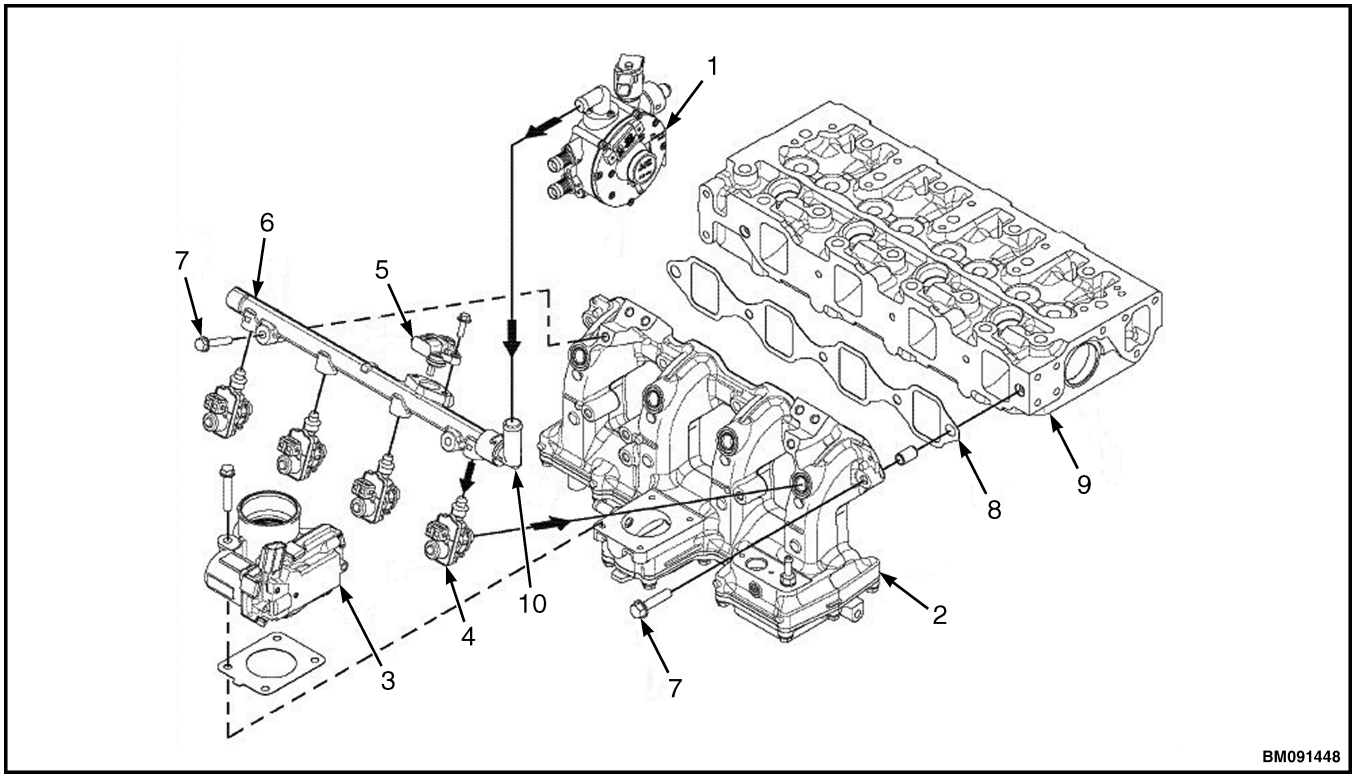
Model	Standard	Limit	Reference page
4TN88G, 4TN88GN-NHYG	---	0.16 mm (0.0063 in.)	Check outer rotor to inner rotor tip clearance. See Figure 366.

Table 94. Rotor shaft clearance

Model		Standard	Limit	Reference page
4TN88G, 4TN88GN-NHYG	Plate bearing I.D.	10.020-10.038 mm (0.3945-0.3952 in.)	10.063 mm (0.3962 in.)	Check rotor shaft clearance. See Rotor shaft clearance.
	Rotor shaft O.D.	9.978-9.987 mm (0.3928-0.3932 in.)	9.963 mm (0.3922 in.)	
	Rotor clearance	0.033-0.060 mm (0.0013-0.0024 in.)	0.100 mm (0.0039 in.)	

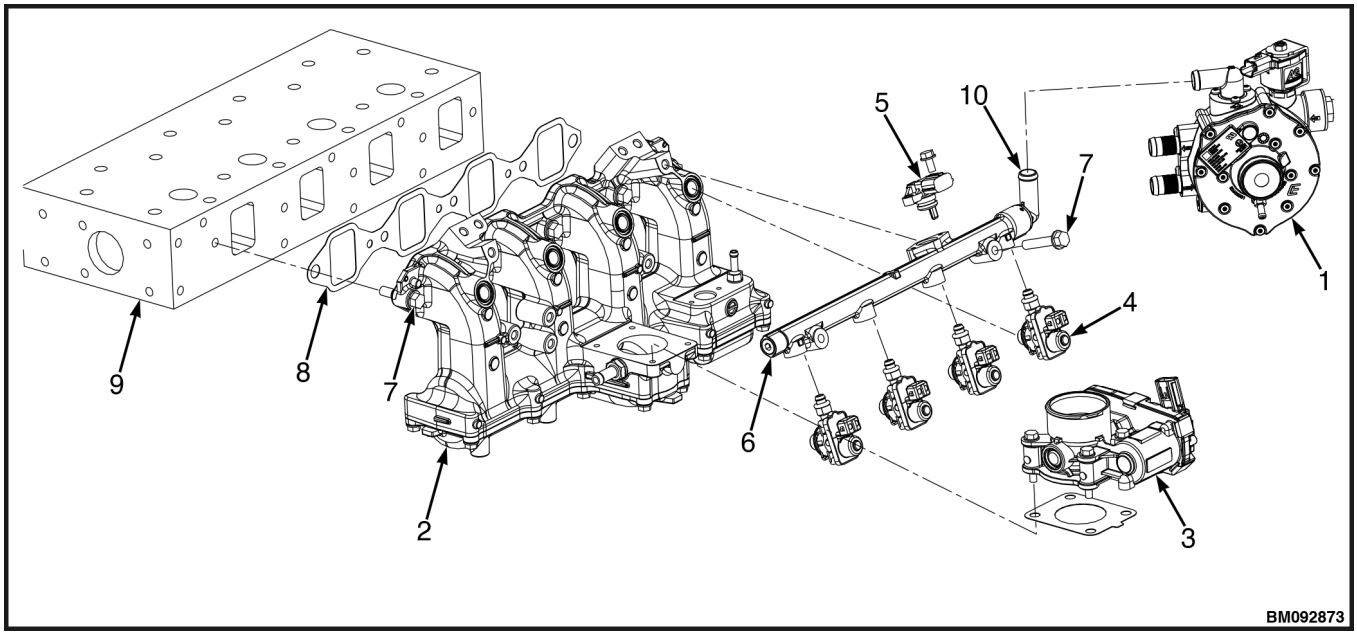
LPG FUEL SYSTEM REPAIR
202001-027

FUEL SYSTEM COMPONENTS



1. VAPORIZER
2. INTAKE MANIFOLD
3. INTAKE THROTTLE
4. FUEL INJECTOR
5. FUEL TEMPERATURE AND PRESSURE SENSOR
6. FUEL RAIL
7. MOUNTING BOLT
8. GASKET
9. CYLINDER HEAD
10. FUEL RAIL JOINT

Figure 369. Fuel system components prior to October 27, 2025



1. VAPORIZER
2. INTAKE MANIFOLD
3. INTAKE THROTTLE
4. FUEL INJECTOR
5. FUEL TEMPERATURE AND PRESSURE SENSOR
6. FUEL RAIL
7. MOUNTING BOLT
8. GASKET
9. CYLINDER HEAD
10. FUEL RAIL JOINT

Figure 370. Fuel system components after October 27, 2025

REMOVE

1. Prior to removing the injectors, remove all engine parts interfering with access to the injectors. See LPG cylinder head repair.

2. Remove the wire harness connectors from each ignition coil and the fuel temperature and pressure sensor. See Figure 371.

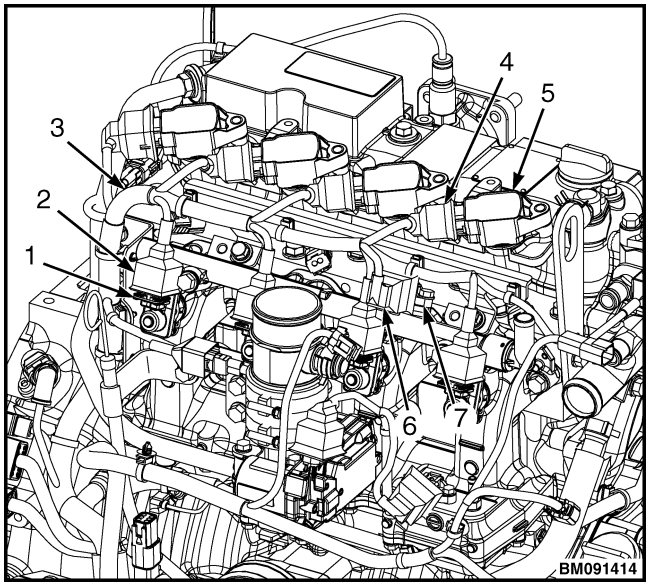


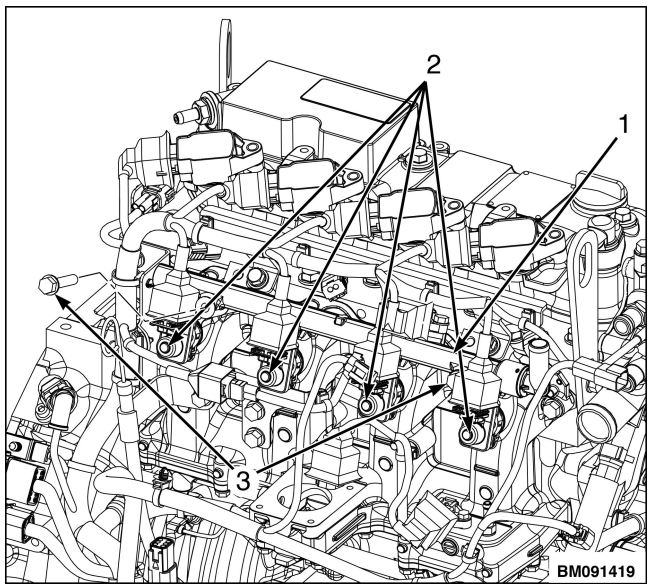
Figure 371. Ignition coils and wire harness

Legend for Figure 371.

1. INJECTOR
2. INJECTOR CONNECTOR
3. WIRE HARNESS
4. IGNITION CONNECTOR
5. IGNITION COIL
6. FUEL TEMPERATURE AND PRESSURE SENSOR CONNECTOR
7. FUEL TEMPERATURE AND PRESSURE SENSOR

3. Disconnect the hose from the fuel rail joint to the vaporizer. See Figure 369 or Figure 370.

4. Loosen the two bolts retaining the fuel rail to the intake manifold and remove the fuel rail. See Figure 372.



1. FUEL RAIL
2. INJECTOR
3. BOLTS

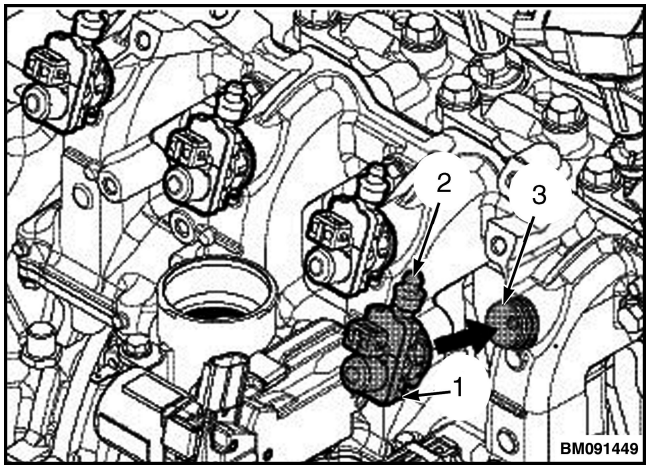
Figure 372. Fuel rail

NOTE: Mark each injector prior to removal. Do not disassemble the injectors. Replace the injector as an entire assembly.

5. Remove the four injectors by pulling out the retaing clip for each injector and pulling injector free. See Figure 372.

6. Clean the injectors and cover with a vinyl bag.

7. If replacing the injector adapters, use a 6 mm hex wrench to loosen and remove the adapter from the intake manifold. Discard the O-ring. See Figure 373.



1. INJECTOR
2. FUEL INLET
3. INJECTOR ADAPTER

Figure 373. Injector adapters

INSTALL

1. If the injector adapter was removed, install a new O-ring to the adapter. Apply lubricating oil, and use the 6 mm hex wrench to tighten the adapter. See Figure 373.

2. Torque to 4 to 6 N•m (3.0 to 4.4 lbf ft).

3. With the fuel inlet of the injector facing upward, push the injector into the adapter until the retaining clip makes a locking sound. See Figure 373.

4. Align the ports of the fuel rail with the fuel inlet of each injector. Install the fuel rail onto the injectors. See Figure 372.

5. Insert the two bolts to attach the fuel rail to the intake manifold. See Figure 372.

6. Torque to 7.8 to 9.4 N•m (5.8 to 6.9 lbf ft).

7. Reconnect the hose from the vaporizer to the fuel rail joint. See Figure 369 or Figure 370.

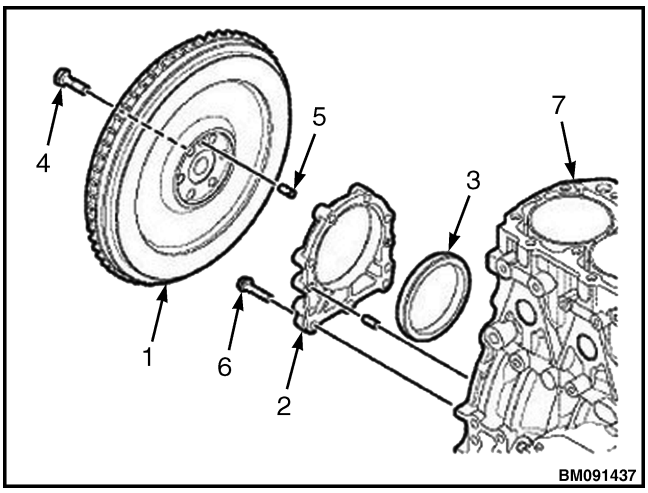
8. Connect the wire harness connectors to each injector coil and the fuel temperature and pressure sensor. See Figure 371.

LPG FLYWHEEL REPAIR 202001-028

REMOVE

1. Remove the engine. See LPG engine removal and replacement section in the **Drive Train** 0900SRM2301 service manual.

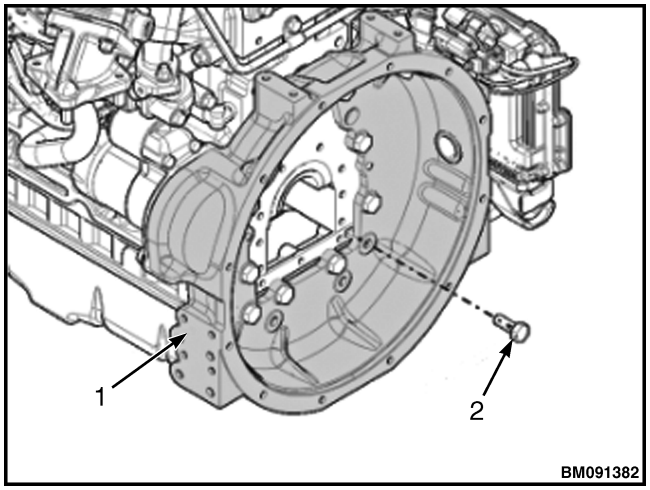
2. Remove the six flywheel mounting bolts retaining the flywheel to the crankshaft and remove the flywheel. See Figure 374.



1. FLYWHEEL
2. REAR OIL SEAL HOUSING
3. REAR OIL SEAL
4. FLYWHEEL MOUNTING BOLT
5. DOWEL
6. REAR OIL SEAL HOUSING MOUNTING BOLT
7. CYLINDER BLOCK

Figure 374. Flywheel

3. Remove the flywheel housing mounting bolts and remove the flywheel housing. See Figure 375.



1. FLYWHEEL HOUSING
2. FLYWHEEL HOUSING MOUNTING BOLT

Figure 375. Flywheel housing

INSPECT

1. Check for crack and wear on the flywheel friction surface, and replace it if there is damage.

2. Check the ring gear tooth surface and replace the ring gear if there is damage or excessive wear.

3. Place a rod on the ring gear, along the outer rim of the flywheel. Strike the rod with a hammer alomg the circumference of the ring gear to remove the ring gear.

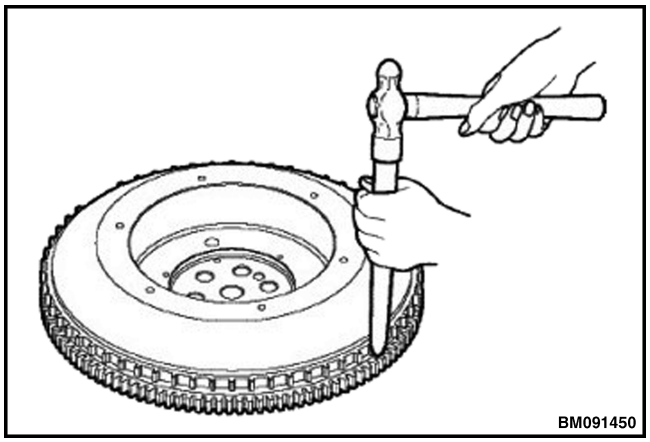


Figure 376. Remove ring gear

4. Evenly heat a new ring gear with a gas burner (approximately 200°C (392°F)).

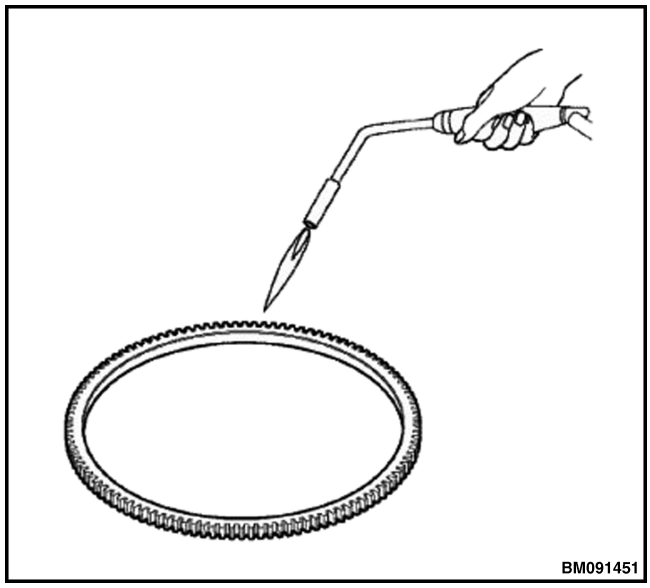


Figure 377. Heating new ring gear

5. Quickly install the ring gear with the chamfered side of the tooth surface facing the block side. Confirm the ring gear is securely attached to the flywheel before installing the flywheel.

INSTALL

1. Insert the flywheel housing mounting bolts and install the flywheel housing. See Figure 375. Tighten the flywheel housing mounting bolts to standard torque value.

2. Align the flywheel with the rear oil seal housing. Install the six flywheel mounting bolts to retain the flywheel to the crankshaft. See Figure 374.

3. Tighten the flywheel mouning bolts to 83.3 to 88.2 N•m (61-65 lbf ft) following the sequence shown in Figure 378.

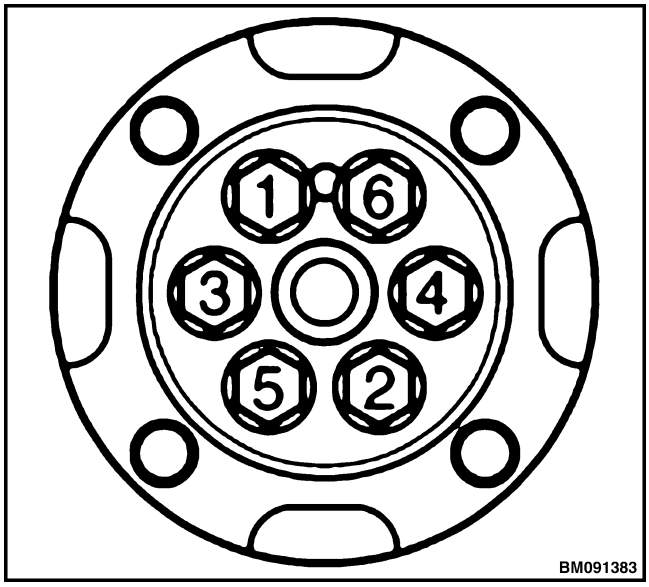


Figure 378. Torque sequence

4. Install the engine. See LPG engine removal and replacement section in the **Drive Train** 0900SRM2301 service manual.

LPG ELECTRICAL SYSTEM REPAIR 202001-029

STARTER

Remove

WARNING

SHOCK HAZARD. Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

DANGER

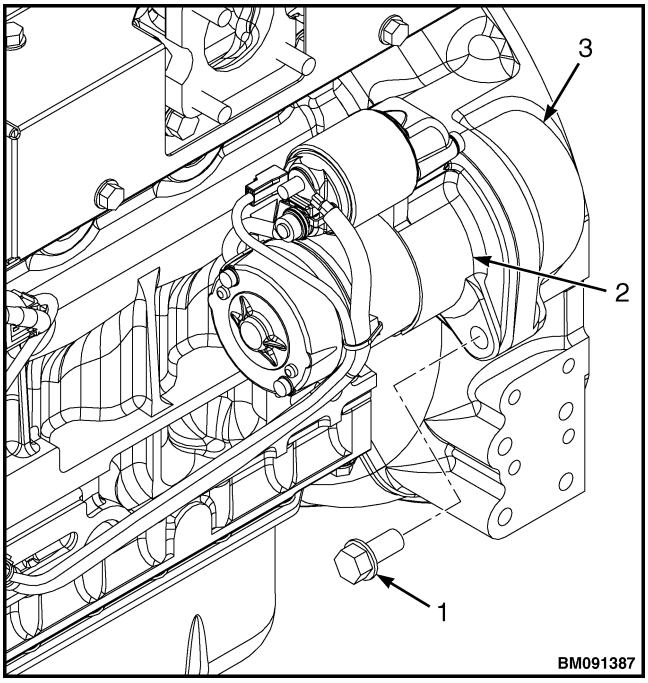
Check the electrical harnesses for cracks, abrasions and damaged or corroded connectors. Always keep the connectors and terminals clean. Failure to comply could result in death or serious injury.

1. Disconnect the negative battery cable at the negative terminal post on the battery.

2. Disconnect the positive battery cable at the positive terminal post on the battery.

3. Put labels on wires and cables prior to disconnecting to aid in correct installation. Disconnect all cables and wires from the starter.

4. Remove the two starter mounting bolts. Remove the starter from the flywheel housing. See Figure 379.



1. STARTER MOUNTING BOLT
2. STARTER
3. FLYWHEEL HOUSING

Figure 379. Starter mounting

Disassemble

1. Loosen the nut from the magnetic switch (solenoid) assembly. Disconnect the wire from the magnetic switch. See Figure 380.

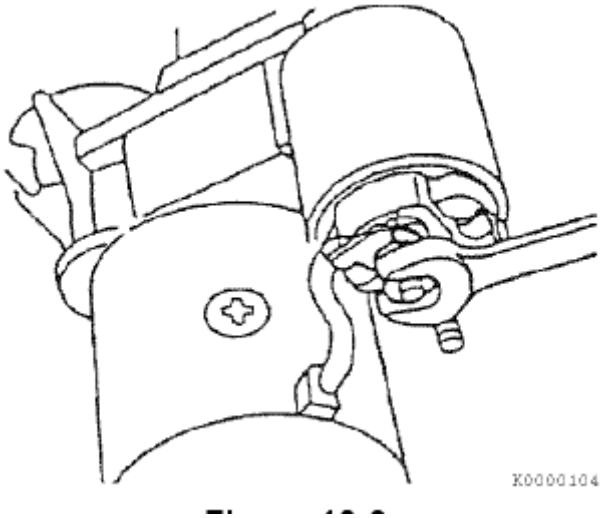
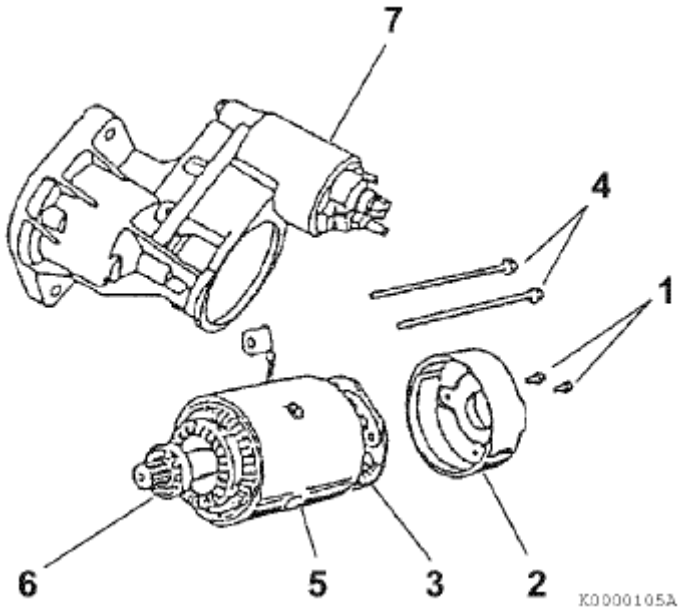


Figure 380. Magnetic switch nut

2. Remove the two bolts securing (1, Figure 381) the rear cover of the starter to the brush holder assembly.

3. Remove the two bolts (4, Figure 381) securing the rear cover from the field coil assembly.

4. Remove the field coil assembly and armature assembly from the gear housing. See Figure 381.



1. BOLTS
2. REAR COVER
3. BRUSH HOLDER ASSEMBLY
4. THROUGH BOLTS
5. FIELD COIL ASSEMBLY
6. ARMATURE ASSEMBLY
7. GEAR HOUSING

Figure 381. Starter components

Install

1. Insert the two starter mounting bolts and attach the starter to the flywheel housing. See Figure 379.

2. Connect all cables and wires to the starter.

3. Connect the positive battery cable to the positive terminal on the battery.

4. Connect the negative battery cable to the negative terminal on the battery.

ALTERNATOR

Remove

WARNING

SHOCK HAZARD. Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

DANGER

Check the electrical harnesses for cracks, abrasions and damaged or corroded connectors. Always keep the connectors and terminals clean. Failure to comply could result in death or serious injury.

1. Remove the V-belt. See **Cooling system** 0700SRM2300 service manual.

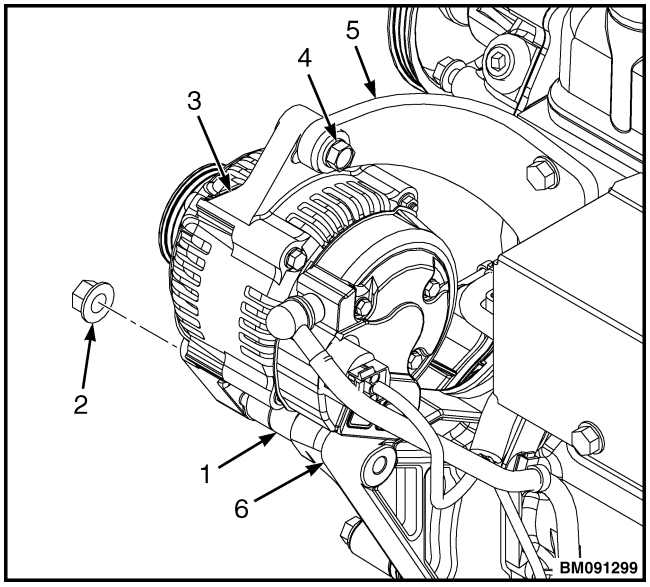
2. Put labels on wires and cables prior to disconnecting to aid in correct installation. Disconnect all cables and wires from the alternator.

3. Perform the following steps to remove the alternator.

a. Loosen the alternator mounting nut (item 2, Figure 382) and remove.

b. Loosen the mounting bolt (item 4, Figure 382) attaching the alternator to the alternator mounting bracket.

c. Remove the alternator.



1. SPACER AND STUD
2. ALTERNATOR MOUNTING NUT
3. ALTERNATOR
4. MOUNTING BOLT
5. ALTERNATOR MOUNTING BRACKET
6. TIMING GEAR CASE

Figure 382. Alternator mounting

Install

1. Perform the following steps to install the alternator.
   a. Install the alternator onto the stud attached to the timing gear case. Temporarily tighten the alternator mounting nut. See Figure 382.
   b. Temporarily tighten the mounting bolt (item 4, Figure 382) to retain the alternator to the alternator mounting bracket.
2. Reconnect the electrical wires to the alternator. Tighten the nuts to secure the wires to the alternator. Torque to 1.7-2.3 N•m (15-20 lbf in).
3. Fully tighten the alternator mounting nut. Torque to 1.7-2.3 N•m (15-20 lbf in).
4. Fully tighten the mounting bolt. Torque to 1.7-2.3 N•m (15-20 lbf in).
5. Reinstall the V-belt.

NOTE: DO NOT operate the engine if the alternator is producing unusual sounds. Damage to the alternator will result.

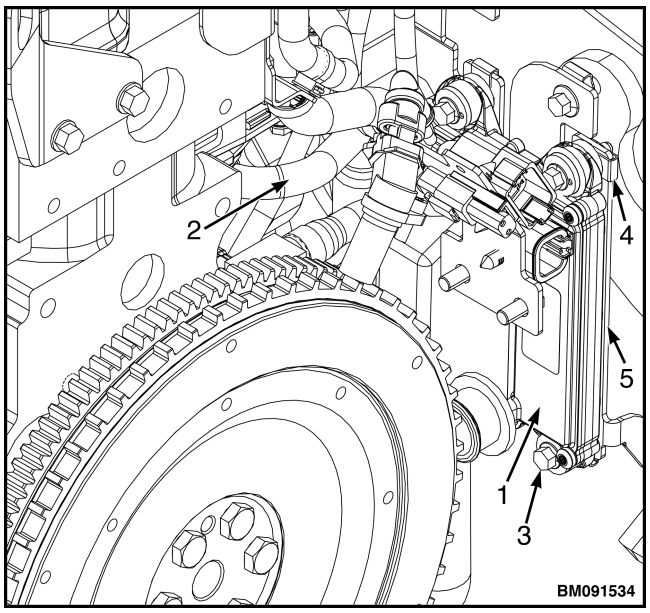
6. Start the engine. Listen for any unusual sounds from the alternator.
7. Verify that the alternator icon does not display while the engine is operating. If the alternator displays, repair the problem before operating the engine. See the Guided Troubleshooting for this lift truck.

Figure 383. Alternator icon

Engine Control Unit

Remove

1. Disconnect the engine harness from the ECU. See Figure 384.
2. Locate the top capscrews on each side that attach the ECU to the mounting bracket. See Figure 384.
3. Remove the two top capscrews and foldover nuts.
4. Locate the bottom capscrews on each side that attach the ECU to the mounting bracket. See Figure 384.
5. Remove the two bottom capscrews.
6. Remove the ECU. See Figure 384.



1. ECU
2. ENGINE WIRE HARNESS
3. CAPSCREW
4. FOLDOVER NUT
5. MOUNTING BRACKET

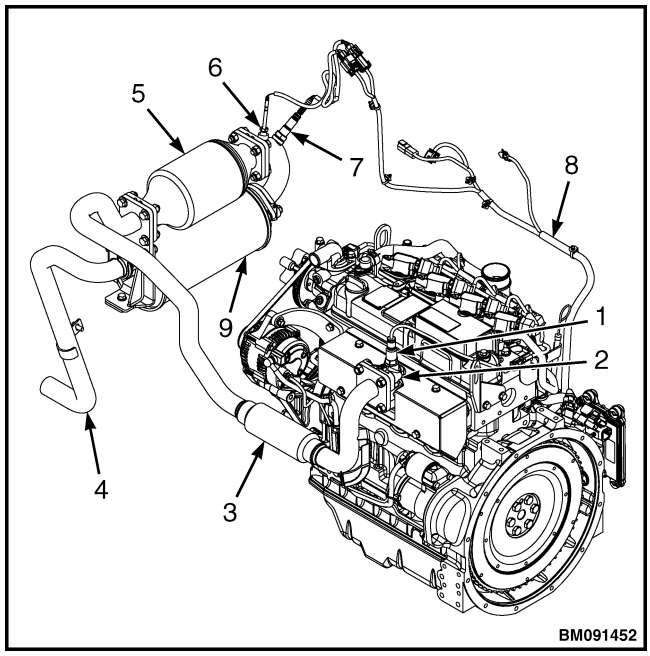
Figure 384. ECU

Install

1. Locate the new ECU and align it with the holes on the mounting bracket. See Figure 384.
2. Insert the two bottom capscrews to retain the ECU to the mounting bracket. See Figure 384. Torque the capscrews to
3. Insert the two top capscrews into the ECU and foldover nuts to attach the ECU to the mounting bracket. See Figure 384. Torque the capscrews to
4. Connect the engine harness to the ECU. See Figure 384.

When replacing the ECU or if an update to the ECU software is required, it is necessary to write the software to the new ECU (Service ECU) or ECU equipped machine. Use SMARTASSIST-Direct to download the current software. See the **SMARTASSIST-Direct Operation Manual** for more information.

LPG EXHAUST AND AFTERTREATMENT REPAIR, CERTIFIED ENGINE 202001-030



1. PRE-O^2 SENSOR
2. EXHAUST MANIFOLD
3. EXHAUST PIPE
4. TAIL PIPE
5. CATALYTIC CONVERTER
6. EXHAUST TEMPERATURE SENSOR
7. POST O^2 SENSOR
8. ENGINE HARNESS
9. MUFFLER

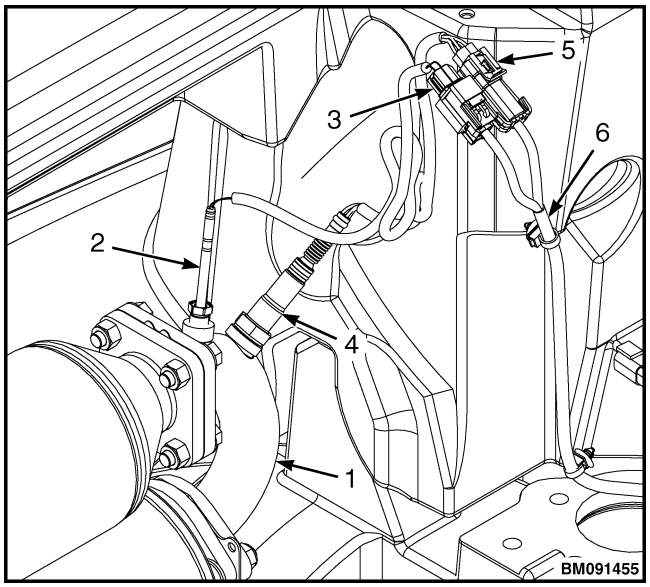
Figure 385. Exhaust system

REMOVE

WARNING

Exhaust system components are hot to touch. Make sure exhaust system components are cool before starting disassembly, or personal injury may occur.

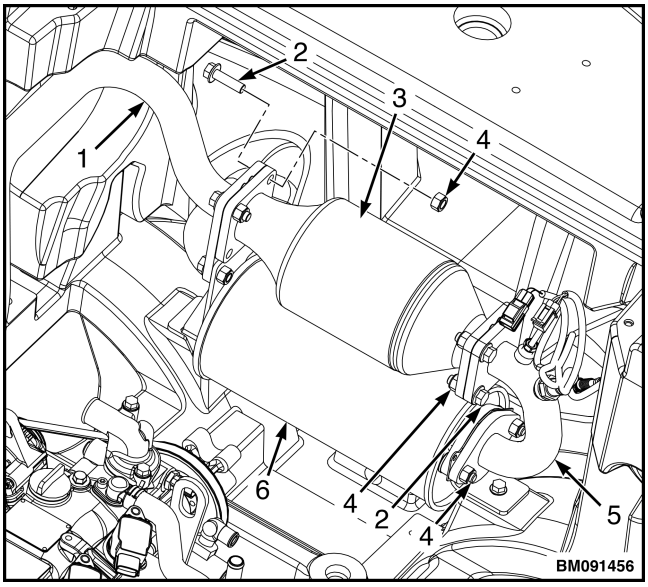
1. Remove the counterweight. See **Counterweight repair** in **Frame and Main Components** 8000SRM2306 service manual.
2. Open the hood to access the engine.
3. Disconnect the two sensor connectors from the engine harness. See Figure 386.
4. If replacing the sensors, remove the sensor from the elbow exhaust pipe. See Figure 386.



1. EXHAUST PIPE (ELBOW)
2. EXHAUST TEMPERATURE SENSOR
3. EXHAUST SENSOR CONNECTOR
4. POST O^2 SENSOR
5. OXYGEN SENSOR CONNECTOR
6. WIRE HARNESS

Figure 386. Exhaust and oxygen sensor

5. Remove the four bolts and nuts retaining the elbow exhaust pipe to the catalytic converter. See Figure 387.

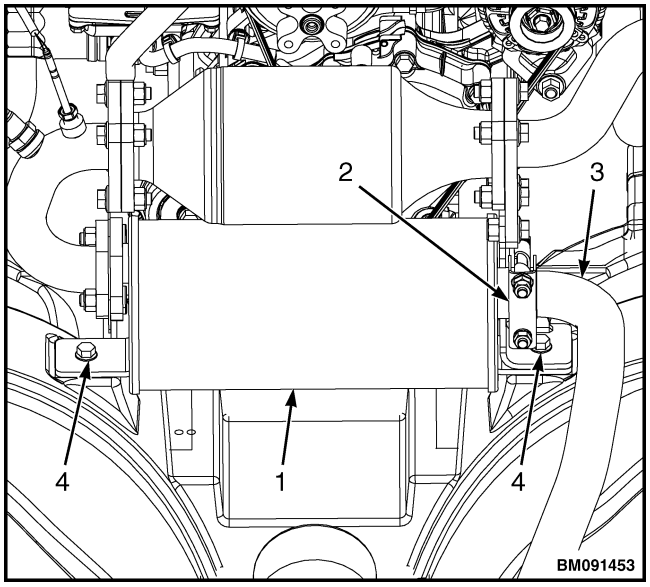


1. EXHAUST PIPE
2. BOLT
3. CATALYTIC CONVERTER
4. NUT
5. EXHAUST PIPE (ELBOW)
6. MUFFLER

Figure 387. Exhaust pipe and catalytic converter

6. Remove the four nuts and bolts retaining the other end of the catalytic converter to the exhaust pipe. See Figure 387. Remove the catalytic converter.

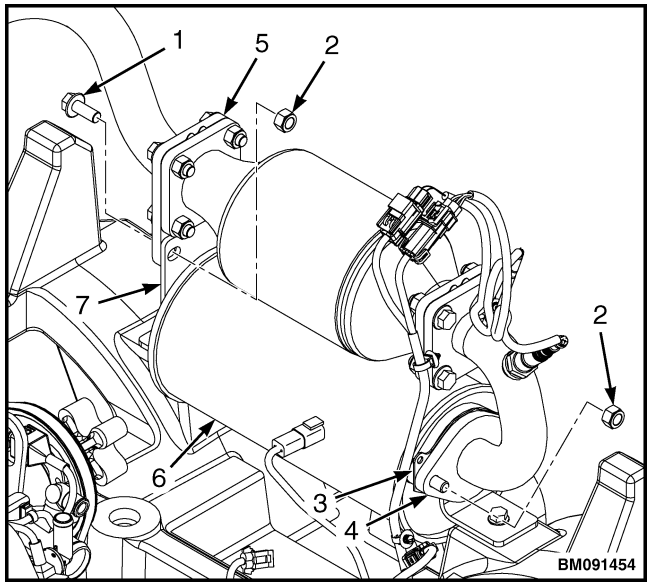
7. Remove the clamp retaining the tail pipe to the muffler and disconnect the tail pipe. See Figure 388.



1. MUFFLER
2. CLAMP
3. TAIL PIPE
4. BOLT

Figure 388. Muffler

8. Remove the two nuts attaching the muffler and mounting bracket to the exhaust pipe (item 5, Figure 389).



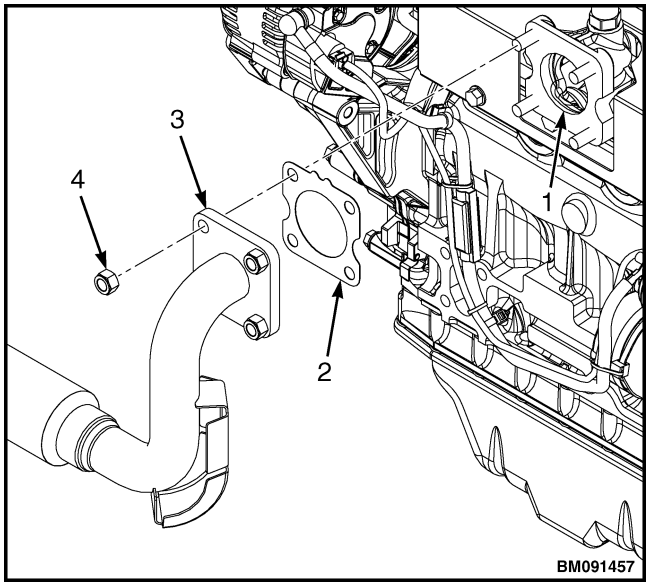
1. BOLT
2. NUT
3. GASKET
4. EXHAUST PIPE (ELBOW)
5. EXHAUST PIPE
6. MUFFLER
7. MOUNTING BRACKET

Figure 389. Muffler and exhaust pipes

9. Remove the two bolts (item 4, Figure 388) retaining the muffler to the frame. Remove the muffler.

10. Remove the mounting bracket (item 7, Figure 389).

11. Remove the four nuts retaining the other end of the exhaust pipe to the exhaust manifold. See Figure 390.

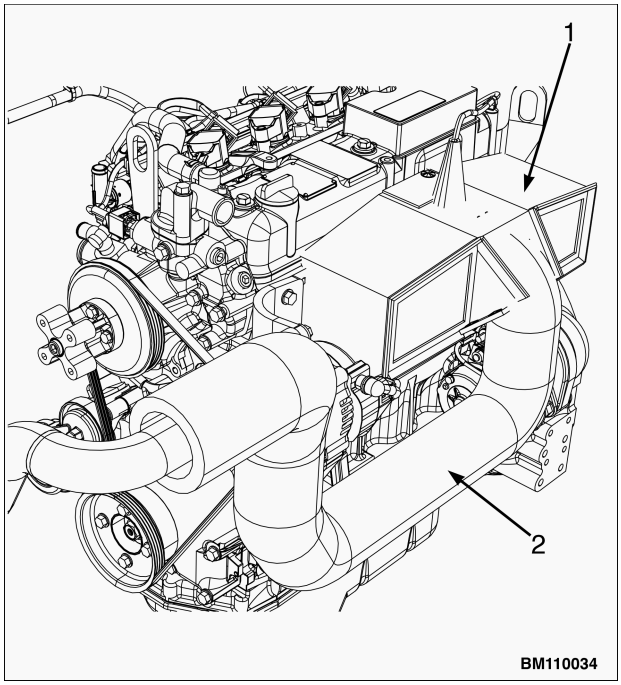


1. EXHAUST MANIFOLD
2. GASKET
3. EXHAUST PIPE
4. NUT

Figure 390. Exhaust pipe and exhaust manifold

INSPECT

- Inspect all exhaust pipes for damage, corrosion, and rust. Replace as needed.
- If equipped, inspect all exhaust wraps for wear, proper fit, contamination with oil or antifreeze, gaps in coverage, and failed fasteners. See Figure 391. Replace as needed. If replacing an exhaust pipe section that has a wrap, also replace the wrap. DO NOT reuse wraps if they have been removed for a service operation.
- Inspect the catalytic converter (if equipped) and muffler for damage, corrosion, and rust. Replace as needed.



1. EXHAUST WRAP-MANIFOLD
2. EXHAUST WRAP-TUBES

Figure 391. Inspect exhaust wraps

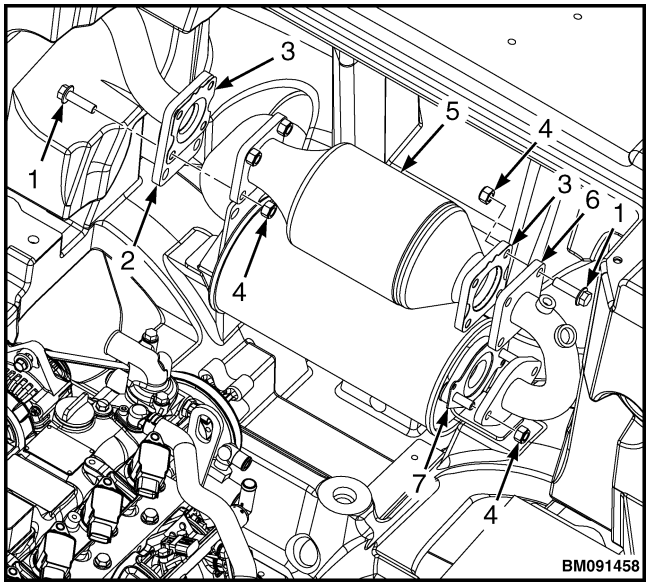
INSTALL

1. Install the muffler, aligned with the holes on the frame. Insert the nuts to mount the muffler to the frame. See Figure 388. Torque the nuts to 22.6-28.4 N•m (17-21 lbf ft).

2. Install the two bolts and nuts to attach the muffler and mounting bracket to the exhaust pipe. See Figure 389. Torque the nuts to 39 N•m (28.8 lbf ft).

3. Connect the tail pipe to the muffler. Install the clamp to retain the tail pipe to the muffler. See Figure 392. Tighten the nuts on the clamp to 19 N•m (14.0 lbf ft). If using the optional clamp (Hyster No. 4264370) tighten to 10-15 N•m (7.4-11.1 lbf ft).

4. Install the elbow exhaust pipe and new gasket. Insert the nuts onto the studs of the muffler to retain the bottom of the elbow exhaust pipe. See Figure 392. Torque to 39 N•m (28.8 lbf ft).



1. BOLT
2. EXHAUST PIPE
3. GASKET
4. NUT
5. CATALYTIC CONVERTER
6. EXHAUST PIPE (ELBOW)
7. GASKET

Figure 392. Install exhaust pipes

5. Install the catalytic converter and new gasket. Install the four bolts and nuts to retain the elbow exhaust pipe to the catalytic converter. See Figure 392. Torque to 39 N•m (28.8 lbf ft).

6. Install the four nuts and bolts to retain the other side of the catalytic converter to the exhaust pipe. Make sure to use a new gasket when installing the exhaust pipe. See Figure 392. Torque to 39 N•m (28.8 lbf ft).

7. Install the four nuts to retain the other side of the exhaust pipe and new gasket to the exhaust manifold. See Figure 390. Torque to 39 N•m (28.8 lbf ft).

8. Close the hood.

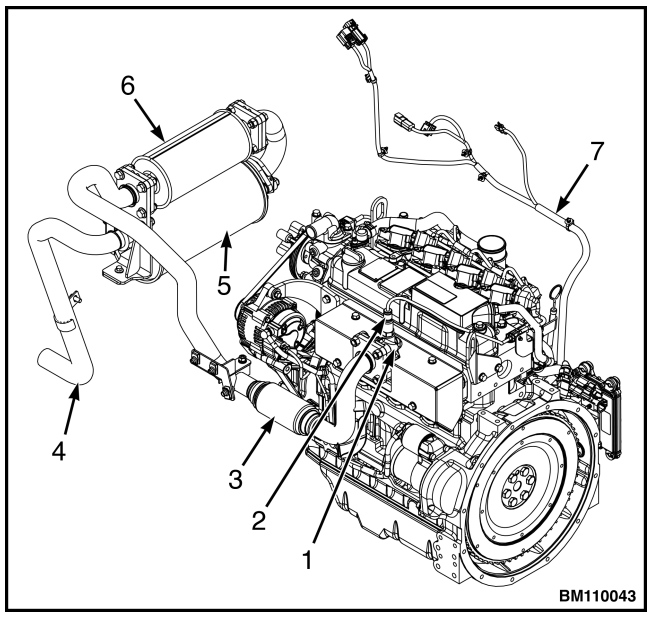
9. If the sensors were removed, insert the sensors. See Figure 386.

- Insert the exhaust sensor into the elbow exhaust pipe. Torque to 34-44 N•m (25.0-32.5 lbf ft).
- Insert the oxygen sensor into the elbow exhaust pipe. Torque to 49 N•m (36.1 lbf ft).

10. Connect the two sensor connectors to the engine harness. See Figure 386.

11. Install the counterweight. See **Counterweight repair** in **Frame and Main Components** 8000SRM2306 service manual.

LPG EXHAUST AND AFTERTREATMENT REPAIR, NON-CERTIFIED ENGINE 202001-348



1. EXHAUST MANIFOLD
2. PRE-O^2 SENSOR
3. EXHAUST PIPE
4. TAIL PIPE
5. MUFFLER
6. CATALYTIC CONVERTER
7. ENGINE HARNESS

Figure 393. Exhaust system

REMOVE

WARNING

Exhaust system components are hot to touch. Make sure exhaust system components are cool before starting disassembly, or personal injury may occur.

1. Remove the counterweight. See Counterweight repair in **Frame and Main Components** 8000SRM2306 service manual.

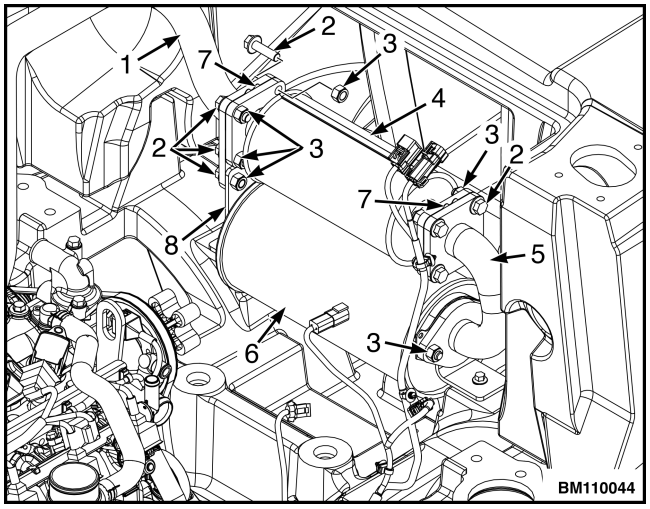
2. Open the hood to access the engine.

3. Remove the four bolts and nuts retaining the elbow exhaust pipe (item 5, Figure 394) to the catalytic converter.

4. Remove the four nuts and bolts retaining the other end of the catalytic converter to the exhaust pipe. See Figure 394.

5. Remove the catalytic converter and two gaskets. See Figure 394.

6. Remove the two nuts and bolts retaining the exhaust pipe (item 1, Figure 394) to exhaust support bracket (item 8, Figure 394).



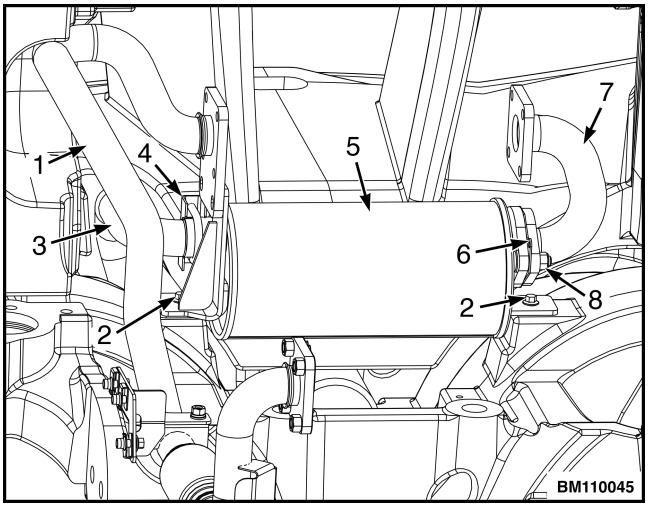
1. EXHAUST PIPE
2. BOLT
3. NUT
4. CATALYTIC CONVERTER
5. EXHAUST PIPE (ELBOW)
6. MUFFLER
7. GASKET
8. EXHAUST SUPPORT BRACKET

Figure 394. Exhaust pipes and catalytic converter

7. Remove the clamp retaining the tail pipe to the muffler and disconnect and remove the tail pipe. See Figure 395.

8. Remove the two nuts, exhaust pipe (elbow), and gasket from muffler. See Figure 395.

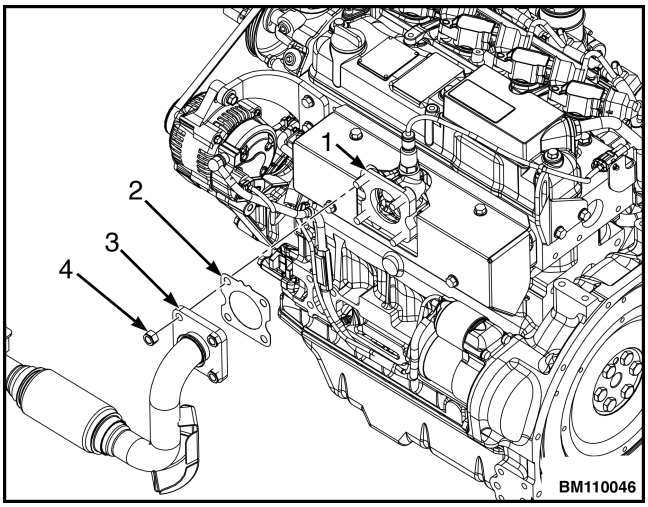
9. Remove the two bolts, exhaust support bracket, and muffler from frame. See Figure 395.



1. EXHAUST PIPE
2. BOLT
3. TAIL PIPE
4. CLAMP
5. MUFFLER
6. GASKET
7. EXHAUST PIPE
8. LOCKNUT

Figure 395. Tailpipe, Exhaust Pipe and Muffler

10. Remove the four nuts, exhaust pipe, and gasket from exhaust manifold. See Figure 396.

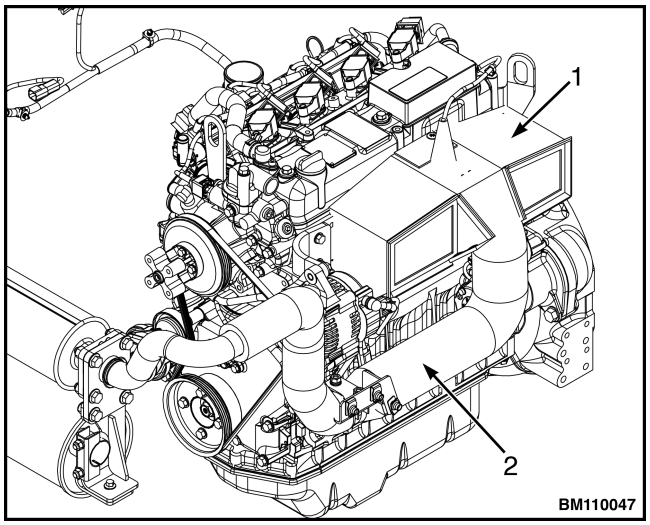


1. EXHAUST MANIFOLD
2. GASKET
3. EXHAUST PIPE
4. NUT

Figure 396. Exhaust pipe and exhaust manifold

INSPECT

- Inspect all exhaust pipes for damage, corrosion, and rust. Replace as needed.
- If equipped, inspect all exhaust wraps for wear, proper fit, contamination with oil or antifreeze, gaps in coverage, and failed fasteners. See Figure 397. Replace as needed. If replacing an exhaust pipe section that has a wrap, also replace the wrap. DO NOT reuse wraps if they have been removed for a service operation.
- Inspect the catalytic converter (if equipped) and muffler for damage, corrosion, and rust. Replace as needed.



1. EXHAUST WRAP-MANIFOLD
2. EXHAUST WRAP-TUBES

Figure 397. Inspect exhaust wraps

INSTALL

1. Install the exhaust support bracket and muffler, aligned with the holes on the frame. Install and tighten the bolts to mount the muffler to the frame. See Figure 395.

2. Install gasket, exhaust pipe, and four nuts on exhaust manifold. See Figure 396.

3. Install the two bolts and nuts to attach the muffler and mounting bracket to the exhaust pipe. See Figure 395. Tighten the nuts to 39 N•m (28.8 lbf ft).

4. Connect the tail pipe to the muffler. Install the clamp to retain the tail pipe to the muffler. See Figure 395. Tighten the nuts on the clamp to 19 N•m (168 lbf in).

5. Install the new gasket, exhaust pipe (elbow) and two nuts onto the studs of the muffler to retain the bottom of the exhaust pipe (elbow). See Figure 395. Tighten nuts to 39 N•m (28.8 lbf ft).

6. Install the catalytic converter and new gaskets. See Figure 394.

7. Install the four bolts and nuts to retain the exhaust pipe (elbow) to the catalytic converter. See Figure 394. Tighten nuts to 39 N•m (28.8 lbf ft).

8. Install the four nuts and bolts to retain the other side of the catalytic converter to the exhaust pipe. Make sure to use a new gasket when installing the exhaust pipe. See Figure 394. Tighten nuts to 39 N•m (28.8 lbf ft).

9. Close the hood.

10. Install the counterweight. See **Counterweight repair** in **Frame and Main Components** 8000SRM2306 service manual.

LPG ENGINE CHECKS, ADJUSTMENTS, AND CALIBRATIONS 202001-031

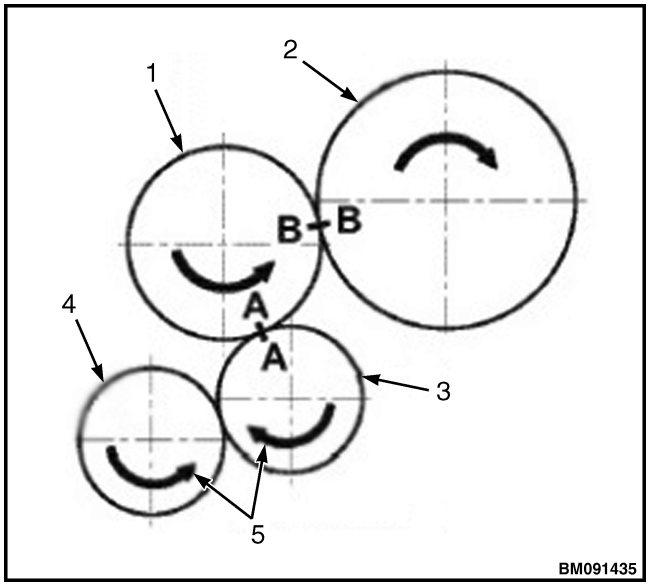
TIMING GEAR CHECKS

Check timing gear backlash

Prior to removing the timing gears, measure the gear backlash and determine the gear wear.

Check the backlash between each pair of connecting gears. See Figure 398. If not within specification, replace both connecting gears. See Table 75 in LPG engine specifications for service limits.

NOTE: Do not allow the gear being checked to move axially as excess end play could cause a false reading.



1. IDLER GEAR
2. CAMSHAFT DRIVE GEAR
3. CRANKSHAFT GEAR
4. OIL PUMP DRIVE GEAR
5. DIRECTION OF ROTATION

Figure 398. Timing gear backlash

Measuring idler gear-to-crankshaft gear backlash

1. Position a dial indicator as shown in Figure 399, on the SIDE of the gear to measure.

NOTE: The following figure (Figure 399) is oriented to show the SIDE of the gear at the TOP of the figure.

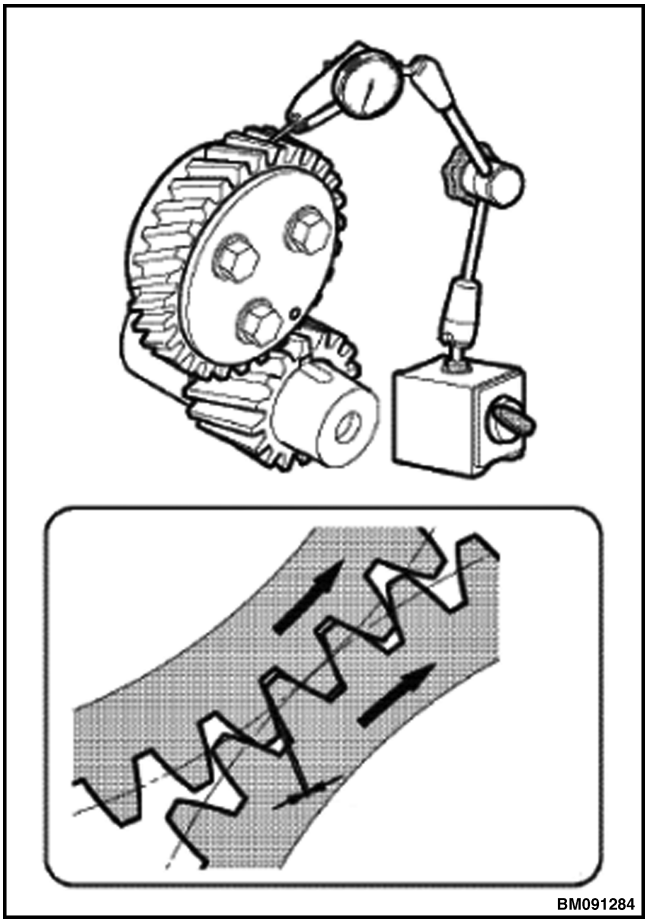


Figure 399. Dial indicator

2. Rotate the idler gear back and forth to check the idler gear backlash, by measuring the movement between gears before they engage. The total indicator reading is the backlash. Record the measurement.

Measuring idler gear-to-camshaft gear backlash

1. Drive a small wooden wedge between the crankshaft gear and idler gear to prevent the idler gear from rotating.

2. Install the dial indicator to read the camshaft gear backlash. Rotate the camshaft drive gear against the idler gear to measure the backlash. Record the measurement.

3. Check the idler gear-to-oil pump drive gear backlash in the same manner as the camshaft drive gear. Record the measurement.

VALVE CLEARANCE ADJUSTMENTS

NOTE: Make measurements and adjustments while the engine is cold.

NOTE: Valve clearance of both the intake and exhaust valves can be checked with the piston for that cylinder at top dead center (TDC) of the compression stroke. When a piston is at TDC of the compression stroke, both rocker arms will be loose and the cylinder TDC mark on the flywheel will be visible in the timing port of the flywheel housing.

If there is no valve clearance, and the cylinder is at TDC of the compression stroke, extreme wear, or damage to the cylinder head or valves may be possible.

If adjusting each cylinder individually, the cylinder to be adjusted first does not have to be the No. 1 cylinder. Select and adjust the cylinder where the piston is nearest to the TDC after turning. Make adjustment for the remaining cylinders in the order of the firing by turning the crankshaft each time.

To decrease the number of rotations required to check all cylinders, other cylinders can also be checked as indicated in the chart below:

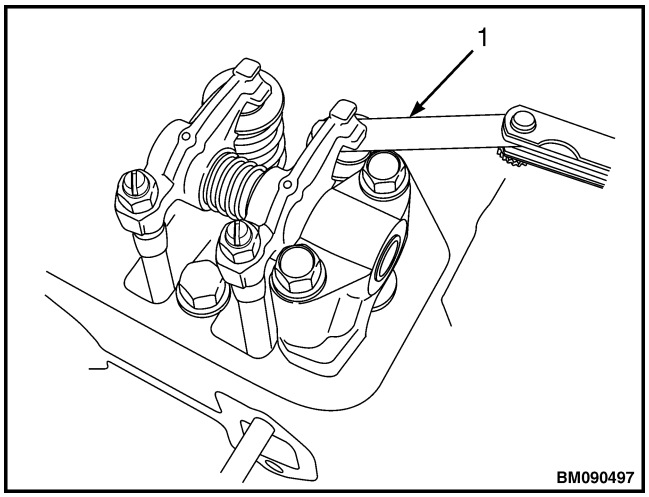
Cylinder No.	1		2		3		4	
Valve	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust
No. 1 cylinder at TDC compression	•	•	•			•		
No. 4 cylinder at TDC compression				•	•		•	•

1. Remove cylinder head cover. See LPG cylinder head repair.

NOTE: The number one piston position is on the flywheel end of the engine, opposite side of the radiator, and the ignition order is 1 - 3 - 4 - 2 at 180 degree intervals.

2. Rotate crankshaft clockwise, as seen from the radiator side, to bring the number one piston to top dead center (TDC) while watching the rocker arm motion, timing scale, and top mark position of the crankshaft pulley. (Position where both the intake and exhaust valves are closed.)

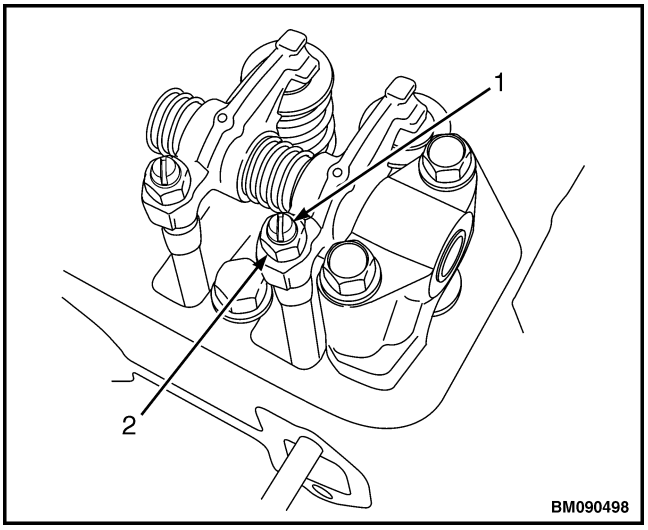
3. Insert a feeler gauge between the rocker arm and valve cap. See Figure 400. Record the measured valve clearance. The valve clearance (when cold) should be:
   - Intake: 0.25 to 0.35 mm (0.01 to 0.013 in.)
   - Exhaust: 0.35 to 0.45 mm (0.013 to 0.018 in.)



1. FEELER GAUGE

Figure 400. Valve Clearance Measurement

4. If adjustment is needed, loosen the valve adjusting screw lock nut and valve adjusting screw on the rocker arm (see Figure 401) and check the valve for any slope of valve cap, entrance of dirt, or wear.



1. VALVE ADJUSTING SCREW
2. VALVE ADJUSTING SCREW LOCK NUT

Figure 401. Valve Clearance Adjustment

NOTE: Clearance will decrease slightly when the lock nut is tightened. Make the clearance adjustment slightly on the loose side before tightening the lock nut.

5. Insert a feeler gauge between the rocker arm and valve cap and adjust the clearance so there is a slight drag on the feeler gauge when sliding it between the rocker arm and valve cap.

6. Hold the adjusting screw and tighten the valve adjusting screw lock nut and recheck the clearance. See Figure 401. The valve clearance (when cold) should be:

- Intake: 0.25 to 0.35 mm (0.01 to 0.013 in.)
- Exhaust: 0.35 to 0.45 mm (0.013 to 0.018 in.)

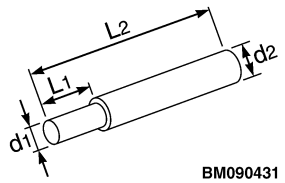
7. Apply clean engine oil to the contact surface between the adjusting screw and push rod.

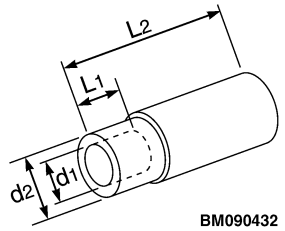
8. Turn the crankshaft 180 degrees and make the measurement and adjustment for the number three cylinder. Then turn the crankshaft 180 degrees and make the measurement and adjustment for the number four cylinder. Then turn the crankshaft 180 degrees and make the measurement and adjustment for the number 2 cylinder.

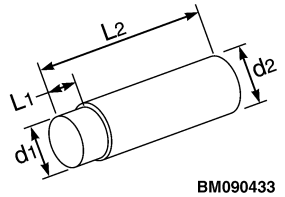
9. Install the valve cover. See LPG cylinder head repair.

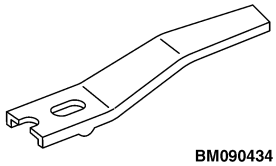
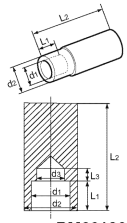
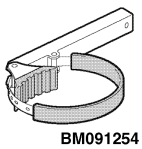
SPECIAL TOOLS FOR LPG ENGINES
202001-032

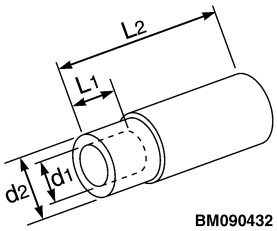
Table 95. Special service tools

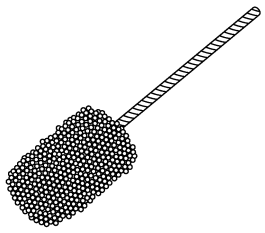
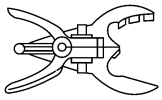
<table>
<tr><th>No.</th><th>Tool Name</th><th>Applicable model and tool size</th><th>Illustration</th></tr>
<tr><td>1</td><td>Valve guide tool (for extracting valve guide)</td><td><table><tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>20 mm (0.787 in.)</td><td>75 mm (2.953 in.)</td><td>7.5 mm (0.295 in.)</td><td>11 mm (0.433 in.)</td></tr></table>Locally manufactured</td><td> 

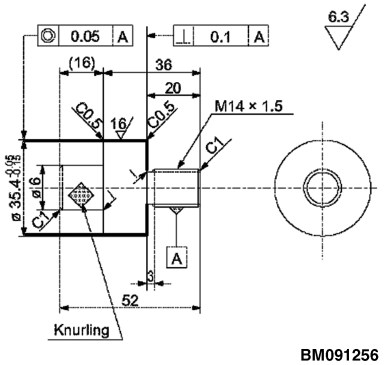
BM090431</td></tr>
<tr><td>2</td><td>Valve guide tool (for inserting valve guide)</td><td><table><tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>15 mm (0.591 in.)</td><td>65 mm (2.559 in.)</td><td>14 mm (0.551 in.)</td><td>20 mm (0.787 in.)</td></tr></table>Locally manufactured</td><td> 

BM090432</td></tr>
<tr><td>3</td><td>Connecting rod bushing replacer (for removal/ installation of connecting rod bushing)</td><td><table><tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>20 mm (0.787 in.)</td><td>100 mm (3.937 in.)</td><td>26 mm (1.024 in.)</td><td>29 mm (1.142 in.)</td></tr></table>Locally manufactured</td><td> 

BM090433</td></tr>
<tr><td>4</td><td>Valve spring compressor (for removal or installation of valve spring)</td><td>Hyster Part No. 1607211</td><td> 
BM090434</td></tr>
<tr><td>5</td><td>Stem seal inserter (for inserting stem seal)</td><td><table><tr><th>d1</th><th>d2</th><th>d3</th><th>L1</th><th>L2</th><th>L3</th></tr><tr><td>16.2 mm (0.638 in.)</td><td>22 mm (0.866 in.)</td><td>13.5 mm (0.531 in.)</td><td>18.8 mm (0.740 in.)</td><td>65 mm (2.560 in.)</td><td>4 mm (0.157 in.)</td></tr></table>Locally manufactured</td><td> 
BM091261</td></tr>
<tr><td>6</td><td>Filter wrench (for removal or installation of engine oil filter)</td><td>Available locally</td><td> 
BM091254</td></tr>
</table>

<table>
<tr><th>No.</th><th>Tool Name</th><th>Applicable model and tool size</th><th>Illustration</th></tr>
<tr><td>7</td><td>Camshaft bushing tool (for extracting camshaft bushing)</td><td>
<table>
<tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr>
<tr><td>18 mm (0.709 in.)</td><td>70 mm (2.756 in.)</td><td>45 mm (1.772 in.)</td><td>48 mm (1.890 in.)</td></tr>
</table>
Locally manufactured</td><td> 

BM090432</td></tr>
<tr><td>8</td><td>Flex-hone (for preparation of cylinder walls)</td><td>
<table>
<tr><th>Model</th><th>Part number</th><th>Cylinder bore</th></tr>
<tr><td>4TNE92</td><td>Hyster Part No. 1607212</td><td>83 to 95 mm (3.268-3.740 in.)</td></tr>
</table>
</td><td>  </td></tr>
<tr><td>9</td><td>Piston ring compressor (for inserting piston)</td><td colspan="2">Hyster Part No. 1607213
The piston insertion tool is applicable for 60 to 125 mm (2.362 to 4.921 in.) Diameter pistons</td><td> 
BM091255</td></tr>
<tr><td>10</td><td>Piston ring replacer (for removal/ installation of piston ring)</td><td colspan="2">Available locally</td><td> 
BM090440</td></tr>
<tr><td>11</td><td>Pulley installing tool (Available locally)</td><td colspan="2">
<table>
<tr><th>L1</th><th>L2</th><th>L3</th><th>L4</th></tr>
<tr><td>52 mm (2.05 in.)</td><td>3 mm (0.12 in.)</td><td>16 mm (0.63 in.)</td><td>36 mm (1.42 in.)</td></tr>
<tr><th>L5</th><th>W1</th><th></th><th></th></tr>
<tr><td>20 mm (0.79 in.)</td><td>35.4 mm (1.4 in.)</td><td></td><td></td></tr>
</table>
</td><td>See Figure 402</td></tr>
</table>



BM091256

Figure 402. Pulley installing tool

Table 96. Measuring instruments

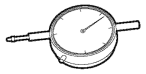
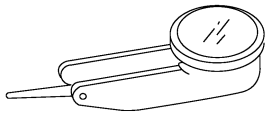
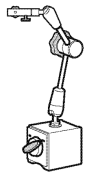
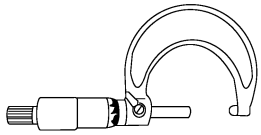
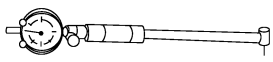
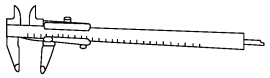
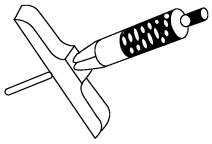
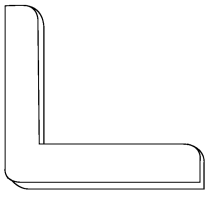
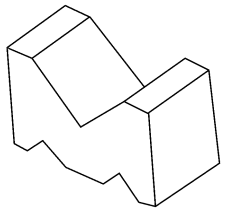
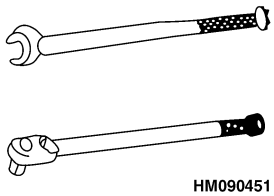
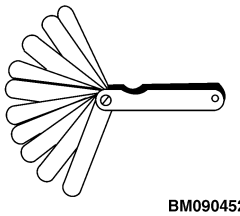
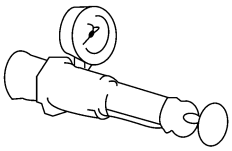
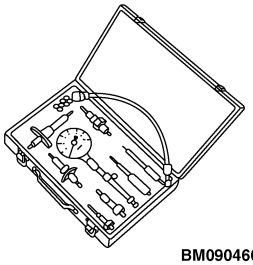
No.	Instrument name	Application	Illustration
1	Dial indicator	Measures shaft bend and end play	 BM091258
2	Test indicator	Measures narrow or deep portions that cannot be measured by dial gauge	 BM090443
3	Magnetic stand	Holds dial gauge when measuring	 BM091259
4	Micrometer	Measures the outside diameters of crankshaft, pistons, piston pins, etc.	 BM090445
5	Cylinder bore gauge	Measures the inside diameters of cylinder liners, rod metal, etc.	 BM090446
6	Calipers	Measures outside diameters, depth, thickness, and width	 BM090447
7	Depth micrometer	Measures valve recession	 BM090448
8	Square	Measures valve spring inclination and straightness of parts	 BM090449

Table 96. Measuring instruments (Continued)

No.	Instrument name	Application	Illustration
9	V-block	Measures shaft bend	 BM090450
10	Torque wrench	Tightens nuts and bolts to the specified torque	 HM090451
11	Thickness gauge ("feeler" gauge)	Measures gaps between ring and ring groove and shaft joints during assembly	 BM090452
12	Cap tester	Check for leakage from engine coolant system	 BM090453
13	Compression gauge adapter set	Cylinder internal compression pressure measurement	 BM090460

Bi-fuel engine repair

BI-FUEL ENGINE SPECIFICATIONS 202001-033

CYLINDER HEAD SPECIFICATIONS

Table 97. Adjustment specifications

Model	Valve clearance
4TN88B, 4TN88BN-NHYG	Intake: 0.15-0.25 mm (0.006-0.010 in.) Exhaust: 0.15-0.25 mm (0.006-0.010 in.)

Table 98. Cylinder head

Inspection item			Standard	Limit	Reference page
Combustion surface distortion			0.05 mm (0.0020 in.) or less	0.15 mm (0.0059 in.)	See Valve recession section, in Bi-fuel cylinder head repair
Valve recession		Intake	0.30-0.50 mm (0.0118-0.0197 in.)	0.8 mm (0.0315 in.)	
		Exhaust	0.20-0.40 mm (0.0079-0.0157 in.)	0.7 mm (0.0276 in.)	
Valve seat	Seat angle	Intake	120°	-	See Valve face and valve seat section, in Bi-fuel cylinder head repair
		Exhaust	120°	-	
	Seat correction angle		40°, 150°	-	

Table 99. Intake/Exhaust valve guard

Inspection item		Standard	Limit	Reference page
Intake	Guide inside diameter	8.010-8.025 mm (0.3154-0.3159 in.)	8.10 mm (0.3189 in.)	See Inspection of valve guides section, in Bi-fuel cylinder head repair
	Valve stem outside diameter	7.960-7.975 mm (0.3134-0.3140 in.)	7.90 mm (0.3110 in.)	
	Valve stem bend	0.035-0.070 mm (0.0014-0.0028 in.)	0.18 mm (0.0071 in.)	
Exhaust	Guide inside diameter	8.015-8.030 mm (0.3156-0.3161 in.)	8.10 mm (0.3189 in.)	
	Valve stem outside diameter	7.955-7.970 mm (0.3132-0.3138 in.)	7.90 mm (0.3110 in.)	
	Valve stem bend	0.045-0.075 mm (0.0018-0.0030 in.)	0.18 mm (0.0071 in.)	

Table 99. Intake/Exhaust valve guard (Continued)

Inspection item	Standard	Limit	Reference page
Valve guide projection from cylinder head	14.8-15.2 mm (0.5827-0.5984 in.)	-	See Reassembly of intake and exhaust valves, in Bi-fuel cylinder head repair
Valve guide installation method	Press-fitted	-	
Valve stem seal projection from the cylinder head	16-16.2 mm (0.6299-0.6378 in.)	-	

Table 100. Push rod

Inspection item	Standard	Limit	Reference page
Push rod bend	Less than 0.03 mm (0.0118 in.)	0.03 mm (0.0118 in.)	See Push rod bend section, in Bi-fuel cylinder head repair

Table 101. Rocker arm and shaft

Inspection item	Standard	Limit	Reference page
Arm shaft hole diameter	16.000-16.020 mm (0.6299-0.6307 in.)	16.07 mm (0.6327 in.)	See Inspection of Rocker Arm Assembly section, in Bi-fuel cylinder head repair
Shaft outside diameter	15.966-15.988 mm (0.6286-0.6294 in.)	15.94 mm (0.6276 in.)	
Oil clearance	0.012-0.054 mm (0.0005-0.0021 in.)	0.13 mm (0.0051 in.)	

Table 102. Valve spring

Inspection item	Standard	Limit	Reference page
Free length	44.4 mm (1.7480 in.)	44 mm (1.7323 in.)	See Inspection of Valve Springs section, in Bi-fuel cylinder head repair
Squareness	-	1.4 mm (0.0551 in.)	

CAMSHAFT AND TIMING GEAR TRAIN SPECIFICATIONS

Table 103. Camshaft

Inspection item		Standard	Limit	Reference page
End play		0.05-0.20 mm (0.0020-0.0079 in.)	0.030 mm (0.0118 in.)	See Removal of camshaft section, in Bi-fuel cylinder head repair
Bend (1/2 the dial gauge reading)		0-0.2 mm (0-0.0008 in.)	0.05 mm (0.0020 in.)	See Inspection of camshaft section, in Bi-fuel cylinder head repair
Cam lobe height		38.675-38.725 mm (1.5226-1.5246 in.)	38.425 mm (1.5128 in.)	
Shaft outside diameter/bearing inside diameter				
Gear end	Bushing inside diameter	44.990-45.055 mm (1.7713-1.7738 in.)	45.130 mm (1.7768 in.)	See Inspection of camshaft section, in Bi-fuel cylinder head repair
	Camshaft outside diameter	44.925-45.950 mm (1.7687-1.7697 in.)	44.890 mm (1.7673 in.)	
	Oil clearance	0.040-0.130 mm (0.0016-0.0051 in.)	0.240 mm (0.0094 in.)	
Intermediate	Bore inside diameter	45.000-45.025 mm (1.7716-1.7726 in.)	45.100 mm (1.7756 in.)	
	Camshaft outside diameter	44.910-44.935 mm (1.7681-1.7691 in.)	44.875 mm (1.7667 in.)	
	Oil clearance	0.065-0.115 mm (0.0026-0.0045 in.)	0.225 mm (0.0089 in.)	
Flywheel end	Bore inside diameter	45.000-45.025 mm (1.7716-1.7726 in.)	45.100 mm (1.7756 in.)	
	Camshaft outside diameter	44.925-45.950 mm (1.7687-1.7697 in.)	44.890 mm (1.7673 in.)	
	Oil clearance	0.050-0.100 mm (0.0020-0.0039 in.)	0.210 mm (0.0083 in.)	

Table 104. Idler gear shaft and bushing

Inspection item	Standard	Limit	Reference page
Shaft outside diameter	45.950-45.975 mm (1.8091-1.8100 in.)	45.900 mm (1.8071 in.)	See Bi-fuel cylinder head repair
Bushing inside diameter	46.000-46.025 mm (1.8110-1.8120 in.)	46.075 mm (1.8140 in.)	

Table 104. Idler gear shaft and bushing (Continued)

Inspection item	Standard	Limit	Reference page
Oil clearance	0.025-0.075 mm (0.0010-0.0030 in.)	0.175 mm (0.0068 in.)	

Table 105. Timing gear backlash

Inspection item	Standard	Limit	Reference page
Crank gear, cam gear, idler gear and PTO gear	0.07-0.15 mm (0.0028-0.0059 in.)	0.16 mm (0.0063 in.)	See Checking timing gear backlash section, in Bi-fuel cylinder head repair

CRANKSHAFT AND PISTON SPECIFICATIONS

NOTE: Check appropriate parts catalog for various sizes of replacement main bearings.

Table 106. Crankshaft

Inspection item		Standard	Limit	Reference page
Bend (1/2 the dial gauge reading)		-	0.02 mm (0.0008 in.)	See Inspection of crankshaft section, in Bi-fuel cylinder head repair
Connecting rod journals	Journal outside diameter	47.952-47.962 mm (1.8879-1.8883 in.)	47.902 mm (1.8859 in.)	
	Bearing inside diameter	48.000-48.026 mm (1.8898-1.8909 in.)	-	
	bearing thickness	1.492-1.500 mm (0.0587-0.0591 in.)	-	
	Oil clearance	0.038-0.074 mm (0.0015-0.0029 in.)	0.150 mm (0.0059 in.)	
Main bearing journal	Journal outside diameter	49.952-49.962 mm (1.9666-1.9670 in.)	49.902 mm (1.9646 in.)	See Inspection of crankshaft section, in Bi-fuel cylinder head repair
	Bearing inside diameter	50.000-50.020 mm (1.9685-1.9693 in.)	-	
	bearing thickness	1.995-2.010 mm (0.0785-0.0791 in.)	-	
	Oil clearance	0.038-0.068 mm (0.0015-0.0027 in.)	0.150 mm (0.0059 in.)	

Table 107. Thrust bearing

Inspection item	Standard	Limit	Reference page
Crankshaft end play	0.13-0.23 mm (0.0051-0.0091 in.)	0.28 mm (0.0110 in.)	See Removal of crankshaft section, in Bi-fuel cylinder head repair

Table 108. Piston

Inspection item		Standard	Limit	Reference page
Piston outside diameter (Measure at 90° to the piston pin)		87.908-87.938 mm (3.4609-3.4621 in.)	87.863 mm (3.4592 in.)	See Inspection of pistons, piston rings and wrist pin section, in Bi-fuel cylinder head repair
Piston diameter measure location (Upward from the bottom of the piston)		24 mm (0.9449 in.)	-	
Piston pin	Hole inside diameter	26.000-26.009 mm (1.0236-1.0240 in.)	26.039 mm (1.0252 in.)	See Inspection of pistons, piston rings and wrist pin section, in Bi-fuel cylinder head repair
	Pin outside diameter	25.995-26.000 mm (1.0234-1.0236 in.)	25.965 mm (1.0222 in.)	
	Oil clearance	0.000-0.014 mm (0.000-0.0006 in.)	0.074 mm (0.0029 in.)	

Table 109. Piston ring

Inspection item		Standard	Limit	Reference page
Top ring	Ring groove width	1.560-1.575 mm (0.0614-0.0620 in.)	-	See Inspection of pistons, piston rings and wrist pin section, in Bi-fuel cylinder head repair
	Ring width	1.470-1.490 mm (0.0579-0.0587 in.)	1.450 mm (0.0571 in.)	
	Side clearance	0.070-0.105 mm (0.0028-0.0041 in.)	-	
	End gap	0.200-0.350 mm (0.0079-0.0138 in.)	0.440 mm (0.173 in.)	
Second ring	Ring groove width	2.025-2.040 mm (0.0797-0.0803 in.)	2.140 mm (0.0843 in.)	
	Ring width	1.970-1.990 mm (0.0776-0.0783 in.)	1.950 mm (0.0768 in.)	
	Side gap	0.035-0.070 mm (0.0014-0.0028 in.)	0.190 mm (0.0075 in.)	
	End gap	0.20-0.40 mm (0.0079-0.0157 in.)	0.490 mm (0.0193 in.)	

Table 109. Piston ring (Continued)

Inspection item		Standard	Limit	Reference page
Oil ring	Ring groove width	4.015-4.030 mm (0.1581-0.1587 in.)	4.130 mm (0.1626 in.)	See Inspection of pistons, piston rings and wrist pin section, in Bi-fuel cylinder head repair
	Ring width	3.970-3.990 mm (0.1563-0.1571 in.)	3.950 mm (0.01555 in.)	
	Side clearance	0.025-0.060 mm (0.0010-0.0024 in.)	0.180 mm (0.0071 in.)	
	End gap	0.200-0.400 mm (0.0079-0.0157 in.)	0.490 mm (0.0193 in.)	

Table 110. Connecting rod

Inspection item	Standard	Limit	Reference page
Connecting rod small end			
Wrist pin bushing inside diameter	26.025-26.038 mm (1.0234-1.0251 in.)	26.068 mm (1.0263 in.)	See Inspection of connecting rod section, in Bi-fuel cylinder head repair
Wrist pin outside diameter	25.995-26.000 mm (1.0234-1.0236 in.)	25.967 mm (1.0223 in.)	
Oil clearance	0.025-0.043 mm (0.0010-0.0017 in.)	0.101 mm (0.0040 in.)	
Connecting rod big end			
Side clearance	0.20-0.40 mm (0.0079-0.0157 in.)	-	

Table 111. Tappet

Inspection item	Standard	Limit	Reference page
Tappet bore (block) inside diameter	12.000-12.018 mm (0.4724-0.4731 in.)	12.038 mm (0.4739 in.)	See Inspection of tappets section, in Bi-fuel cylinder head repair
Tappet stem outside diameter	11.975-11.990 mm (0.4715-0.4720 in.)	11.955 mm (0.4707 in.)	
Oil clearance	0.010-0.043 mm (0.0004-0.0017 in.)	0.083 mm (0.0033 in.)	

CYLINDER BLOCK SPECIFICATIONS

Table 112. Cylinder block

Inspection item	Standard	Limit	Reference page
Cylinder inside diameter	88.000-88.030 mm (3.4646-3.4657 in.)	88.200 mm (3.4724 in.)	See Inspection of cylinder block section, in Bi-fuel cylinder head repair
Cylinder bore	0.01 mm (0.0004 in.) or less	0.03 mm (0.0012 in.)	

FUEL SPECIFICATIONS

Item		Unit	Value limit	Test method/ Fuel specifications
Fuel composition	Propane	Vol % (liquid phase)	> 90	GPA2140, HD-5
	Propylene		≤ 5	GPA2140, HD-5
	Ethane + Ethylene	mol %	≤ 5	JIS K2240
	Diene		≤ 0.5	EN589
Vapor pressure		kPa @37.8°C (psi @100° F)	≤ 1434 (208)	GPA2140, HD-5
Temperature when 95% of fuel is vaporized		°C (°F)	≤ -38.3 (-36.9)	GPA2140, HD-5
Density		g/cm^3 @15°C(lb/in3 @59°F)	0.5-0.62 (0.018-.022)	JIS K2240
Impurities in fuel	N_2	%	<60	YIS
	CO_2	%	<40	YIS
	H_2	%	<50	YIS
	H_2S	%	0	EN589
	Dust	g/Nm^3(ppm)	> 0.05 (28)	YIS
	Ammonia	mg (oz)/10 kWh	O	GPA2140
	Material with carbon number C4 or higher	Vol % (liquid phase)	≤ 2.5	GPA2140, HD-5
	Material with carbon number C5 or higher		≤ 2.0	GPA2140, HD-5
	Residue	mg/kg (ppm)	< 60	EN589
Fuel contamination		_	No contamination shall be observed	GPA2140
Copper corrosion		-	No change shall be observed on copper plate before/after the test	EN ISO 6251 ASTM D1838 JIS K2240 6.11
Total volatile sulfur		ppmw	≤ 50	EN589
Moisture content		-	ASTM D2713, EN 15469, GPA note C shall be complied	ASTM D2713 EN 15469 GPA Note C

OIL PUMP SERVICE INFORMATION

Table 113. Engine lubricating oil pressure

Model	At rated engine RPM (min)	At low idle speed
	2600 min^{-1}	
4TN88B, 4TN88BN-NHYG	0.31-0.41 MPa (44.96-59.47 psi)	0.1 MPa (8.7 psi)

Table 114. Outer rotor outside clearance

Model	Standard	Limit	Reference page
4TN88B, 4TN88BN-NHYG	0.09-0.15 mm (0.0035-0.0059 in.)	0.25 mm (0.0098 in.)	Check outer rotor outside clearance. See Outer rotor outside clearance in Bi-fuel lubrication system repair.

Table 115. Outer rotor side clearance

Model	Standard	Limit	Reference page
4TN88B, 4TN88BN-NHYG	0.05-0.09 mm (0.0020-0.0035 in.)	0.15 mm (0.0059 in.)	Check outer rotor side clearance. See Outer rotor outside clearance in Bi-fuel lubrication system repair.

Table 116. Outer rotor to inner rotor tip clearance

Model	Standard	Limit	Reference page
4TN88B, 4TN88BN-NHYG	---	0.16 mm (0.0063 in.)	Check outer rotor to inner rotor tip clearance. See Figure 500 in Bi-fuel lubrication system repair.

Table 117. Starter Specifications

Nominal output		1.7 kW (2.3 hp)
Weight		3.4 kg (7.5 lb)
Revolution direction (As viewed from pinion)		Clockwise
Engagement system		Magnetic shift
No-load	Terminal voltage / current	11V / 90A or less
	Revolution	2300 rpm min^{-1}(rpm)
Loaded	Terminal voltage / current	8V / 370A or less
	Torque	15.1 N•m (11.1 lbf ft)

Table 117. Starter Specifications (Continued)

Restraint	Terminal voltage / current	2.7V / 650A or less
	Torque	18.6 N•m (13.7 lbf ft)
Clutch system		Overrunning
Pinion projection Voltage at 100°C (212°F)		8V or lower
Pinion DP or module / number of teeth		ø27.94/11

Table 118. Alternator specifications

Nominal output (13.5 volts heat)	55 A
Weight	3.2 kg (7.1 lb)
Revolution direction (as viewed from pulley)	Clockwise
Rating	Continuous
Battery voltage	12 V
Rated revolution	5000 min^{-1}rpm
Operating range	1070-18000 min^{-1} rpm
Grounding characteristics	Negative (-) side of circuit
Integrated regulator	IC regulator
Outside diameter of pulley	69.2 mm (2.724 in.)
Belt shape	Type A

SPECIAL TORQUE CHART

Table 119. Torque for bolts and nuts

Component	Thread diameter and pitch	Torque	Lubricating oil application (Thread portion and seat surface)
Cylinder head bolt	M10 x 1.25 mm	92-98 N•m (68-72 lbf ft)	Applied
Connecting rod bolt	M9 x 1.0 mm	44.1-49 N•m (33-36 lbf ft)	Applied
Flywheel bolt	M10 x 1.25 mm	83.3-88.2 N•m (61-65 lbf ft)	Applied
Main bearing cap bolt	M10 x 1.25 mm	96.0-100 N•m (70.8-73.8 lbf ft)	Applied
Crankshaft pulley bolt	M14 x 1.5 mm	Cast metal (FC250) 83.3-93.1 N•m (62-69 lbf ft)	Applied
		Steel metal (S45C) 112.7-122.7 N•m (83-91 lbf ft)	

Table 119. Torque for bolts and nuts (Continued)

Component	Thread diameter and pitch	Torque	Lubricating oil application (Thread portion and seat surface)
Crank speed sensor bolt	M6 x 1.0 mm	4.4-7.4 N•m (6-10 lbf ft)	Not applied
Cam speed sensor bolt	M6 x 1.0 mm	7.5-8.5 N•m (5.6-6.3 lbf ft)	Not applied
Engine coolant temperature sensor	M12 x 1.5 mm	16-20 N•m (11.8-14.8 lbf ft)	Not applied
O^2 sensor	M18 x 1.5 mm	39.1-48.9 N•m (28.9-36.1 lbf ft)	Burning prevention medicine
Gas fuel pressure sensor bolt	M5 coarse thread	4.0-6.0 N•m (3.0-4.4 lbf ft)	Not applied
Ignition coil bolt	M6 x 1.0 mm	6-9.5 N•m (4.4-7.0 lbf ft)	Not applied
Spark plugs	M14 x 1.25 mm	24.0-34.0 N•m (17.7-25.1 lbf ft)	Not applied
Vaporizer bolt	M6 x 1.0 mm	17 N•m (12.5 lbf ft)	Not applied
Knock sensor bolt	M8 x 1.25 mm	18.0-26.0 N•m (13.3-19.2 lbf ft)	Not applied
Accelerator sensor bolt	M6 x 1.0 mm	6.0-9.5 N•m (4.4-7.0 lbf ft)	Not applied
Intake temperature and pressure sensor bolt	M6 x 1.0 mm	4.0-6.0 N•m (3.0-4.4 lbf ft)	Not applied
Exhaust temperature sensor bolt	M12 x 1.25 mm	34.3-44.1 N•m (25.3-32.5 lbf ft)	Not applied
Intake throttle bolt	M6 x 1.0 mm	7.84-9.44 N•m (5.3-6.9 lbf ft)	Not applied
Oil pressure switch	R1/8 (PT1/8)	18-22 N•m (13.3-16.2 lbf ft)	Not applied
Engine lubricating oil filter	M20 x 1.5 mm	15-18 N•m (11.1-13.3 lbf ft)	Applied
Drain plug (oil fan)	M22 x 1.5 mm	54-64 N•m (39.9-47.2 lbf ft)	Not applied
PCV valve	M14 x 1.5 mm	40-50 N•m (29.5-36.9 lbf ft)	Not applied
Adapter (injector)	M14 x 1.5 mm	4.0-6.0 N•m (3.0-4.4 lbf ft)	Not applied
Piston cooling nozzle banjo bolt	M8 x 1.25 mm	12.7-16.7 N•m (9.4-12.3 lbf ft)	Not applied

BI-FUEL CYLINDER HEAD REPAIR 202001-034

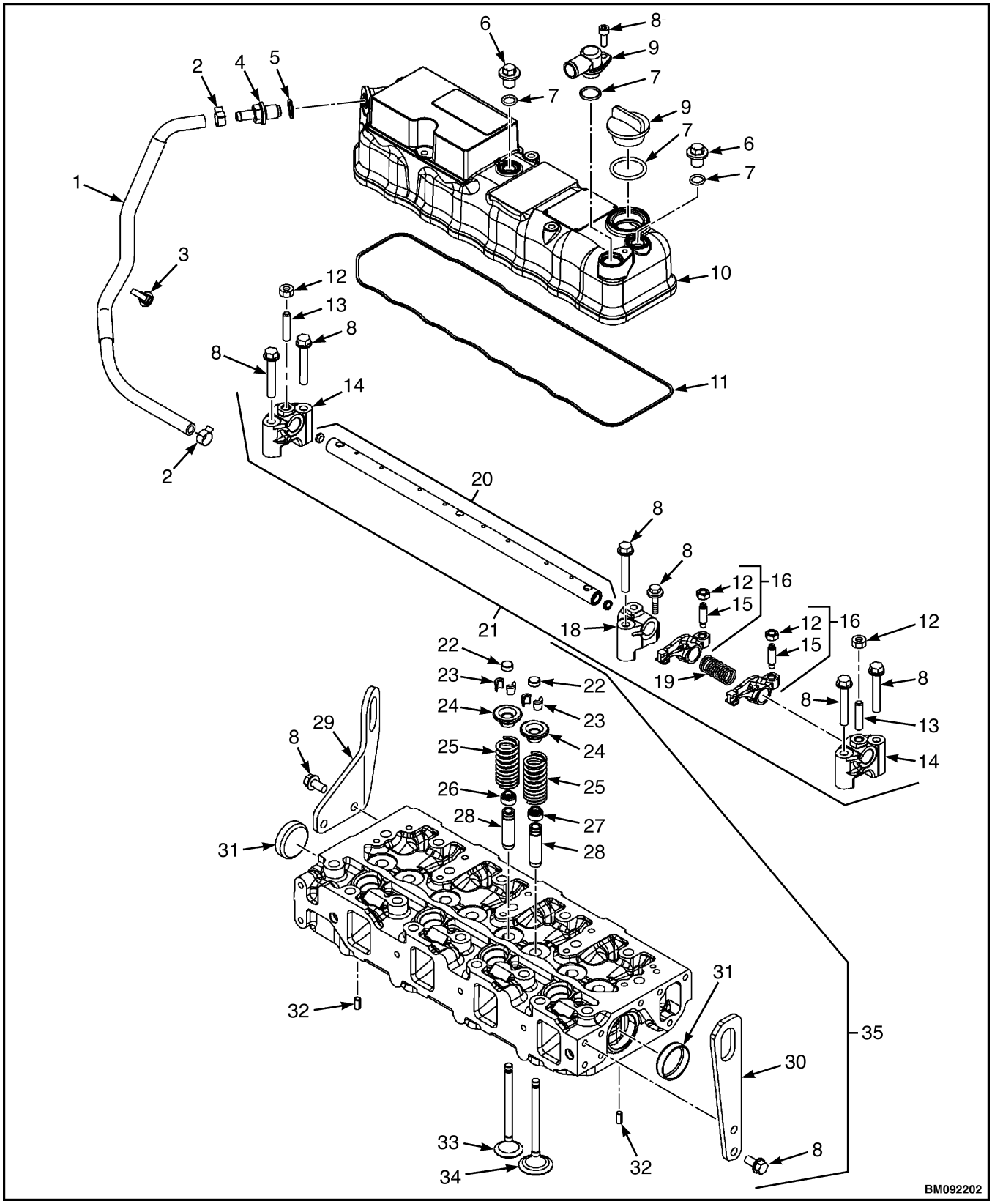


Figure 403. Cylinder head components

Legend for Figure 403.

1. BREATHER HOSE ASSEMBLY
2. CLAMP
3. CLIP
4. PCV VALVE
5. GASKET
6. PLUG
7. O-RING
8. BOLT
9. BREATHER JOINT
10. VALVE COVER
11. VALVE COVER GASKET
12. NUT
13. STUD
14. ROCKER A SUPPORT
15. SCREW
16. ROCKER ARM
17. ROCKER SHAFT ASSEMBLY
18. ROCKER B SUPPORT
19. SHAFT SPRING
20. SHAFT
21. ROCKER SHAFT ASSEMBLY
22. CAP
23. VALVE SPRING COTTERS
24. VALVE SPRING RETAINER
25. SPRING
26. VALVE STEM SEAL
27. VALVE STEM SEAL
28. VALVE GUIDES
29. ENGINE LIFTING EYE
30. ENGINE LIFTING EYE
31. PLUG
32. PIN 6X12
33. EXHAUST VALVE
34. INTAKE VALVE
35. CYLINDER HEAD ASSEMBLY

DISASSEMBLE CYLINDER HEAD

NOTE: Locate and identify all components prior to disassembly, to ensure all components are returned to the same position during reassembly.

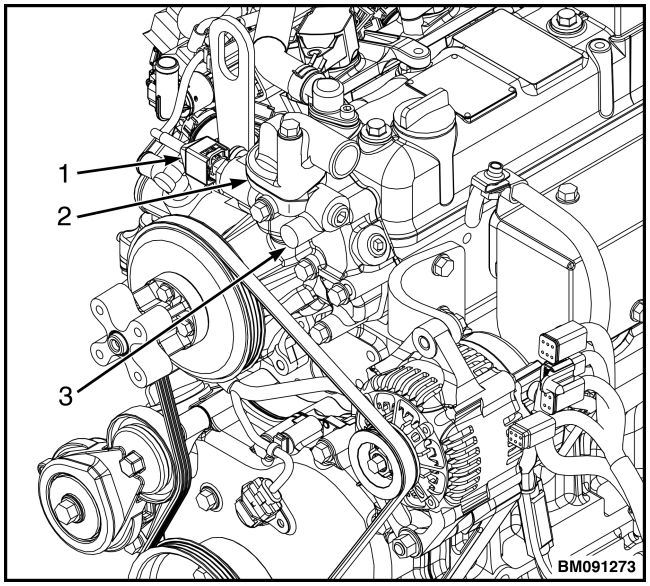
Prior to disassembly, prepare a clean, flat surface on a workbench large enough to accomodate the cylinder head assembly. Discard all gaskets, O-rings and seals. New gaskets, O-rings and seals are required when reassembling the cylinder head.

1. Drain all coolant from the engine into a suitable container.

2. Remove the alternator. See Removing the alternator, in Bi-fuel electrical system repair.

Disconnect the water pump electrical connector from the water pump. See Figure 404.

3. Disconnect the electrical connector from the coolant temperature sensor. See Figure 404.

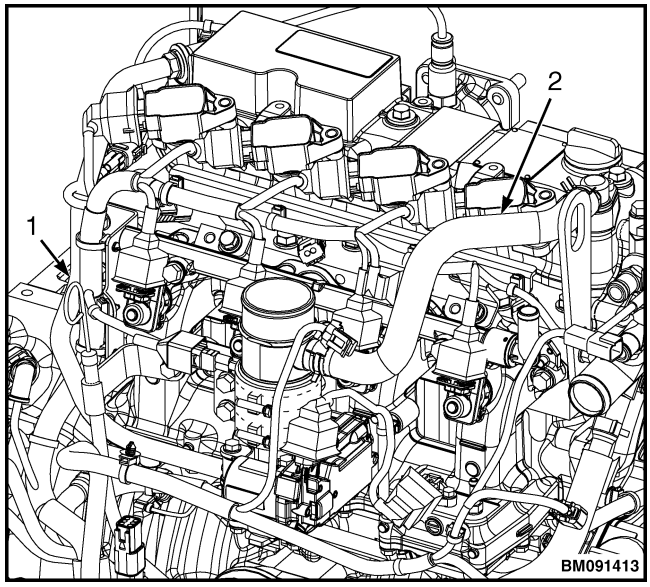


1. COOLANT TEMPERATURE SENSOR
2. CAM POSITION SENSOR
3. WATER PUMP

Figure 404. Coolant temperature sensor

4. Remove the cooling fan and the water pump. See Water pump repair in the **Cooling system** 0700SRM2300 manual.

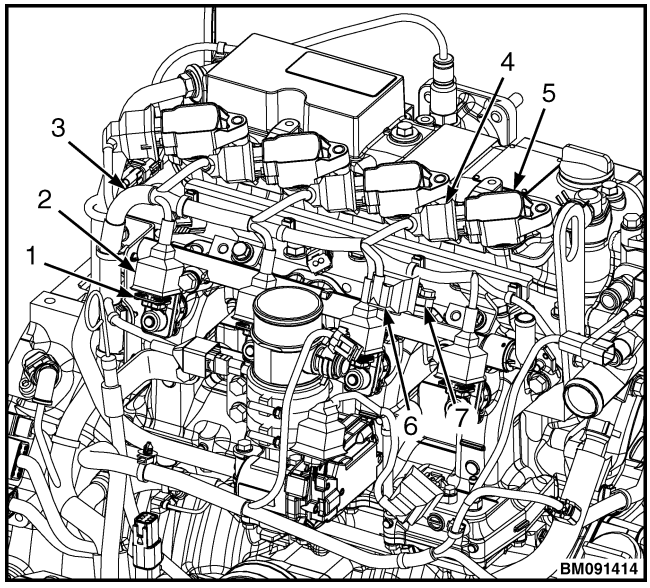
5. Loosen the hose clip on each end, and remove the breather hose and ambient air hose. See Figure 405.



1. BREATHER HOSE
2. AMBIENT AIR HOSE

Figure 405. Breather hose and ambient air hose

6. Disconnect the wire harness connectors from the four ignition coils and four injectors. See Figure 406.



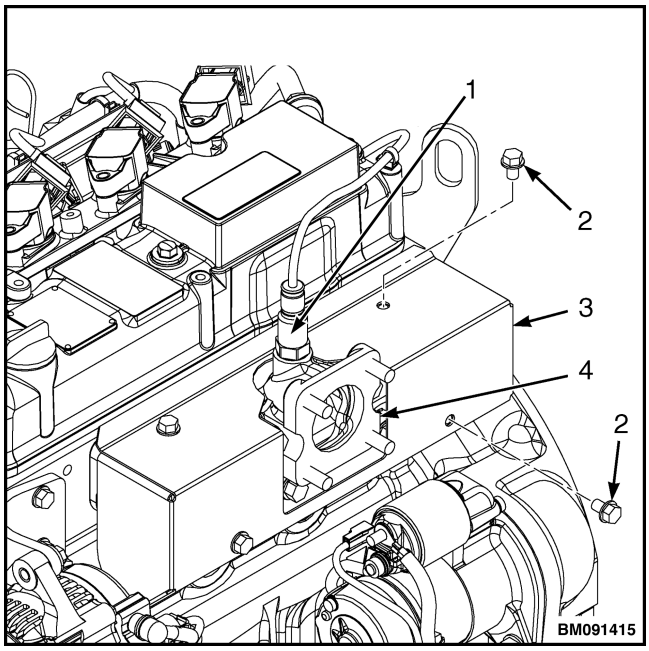
1. INJECTOR
2. INJECTOR CONNECTOR
3. WIRE HARNESS
4. IGNITION COIL CONNECTOR
5. IGNITION COIL

Figure 406. Wire harness and ignotion coils

7. Remove the wire harness clamp, then remove the wire harness and bracket.

8. Disconnect the O_2 sensor from the exhaust manifold. See Figure 407.

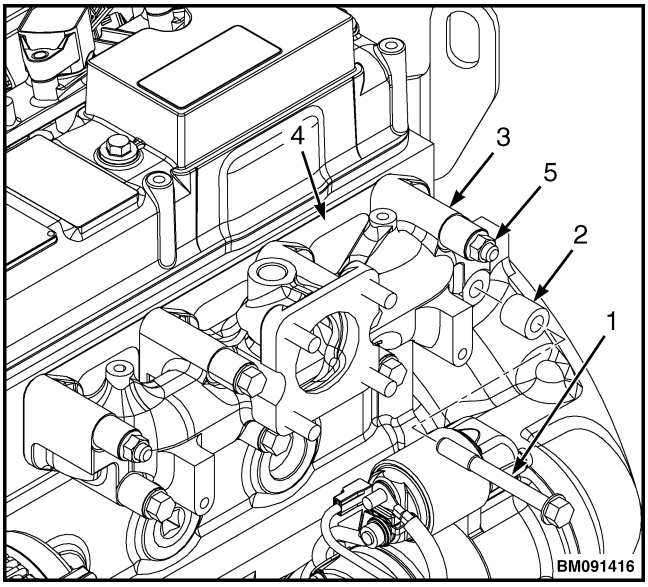
9. Remove the four bolts attaching the heat shield to the exhaust manifold. Remove the heat shield. See Figure 407.



1. O_2 SENSOR
2. BOLT
3. HEAT SHIELD
4. EXHAUST MANIFOLD

Figure 407. O_2 sensor

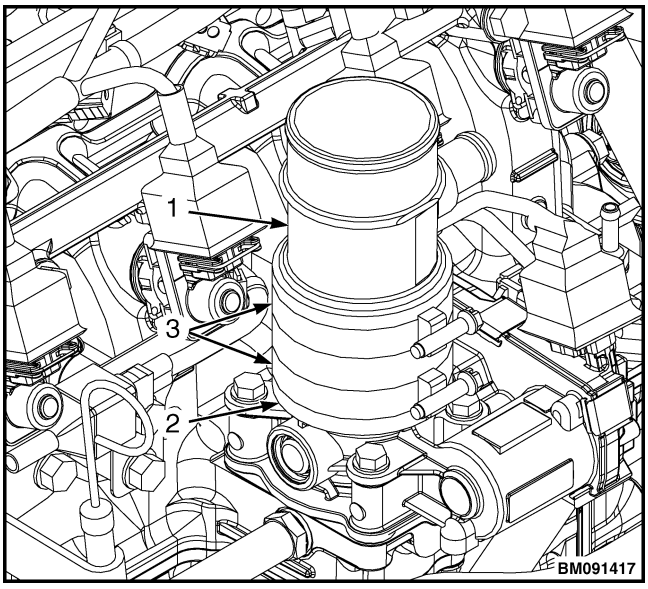
10. Loosen the bolts and nuts attaching the exhaust manifold to the engine block. Remove the exhaust manifold and discard the gasket. See Figure 408.



1. BOLT
2. SPACER
3. EXHAUST MANIFOLD
4. GASKET
5. NUT

Figure 408. Exhaust manifold

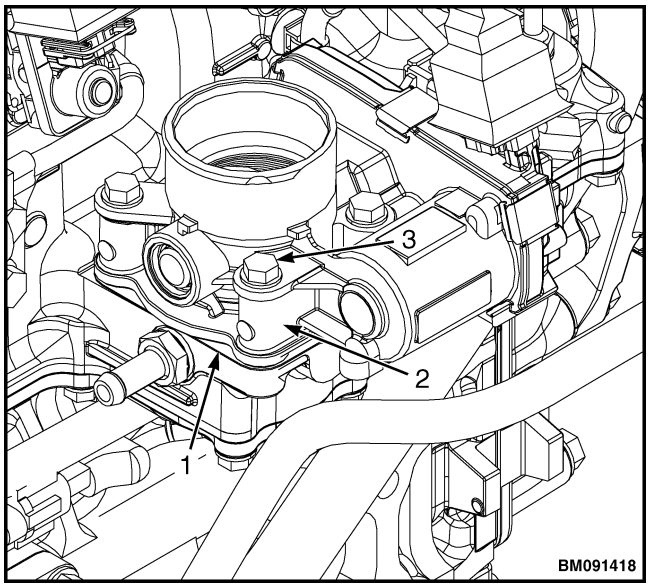
11. Loosen the hose clamp retaining the intake adapter and hose. See Figure 409.



1. INTAKE ADAPTER
2. HOSE
3. HOSE CLAMP

Figure 409. Intake adapter

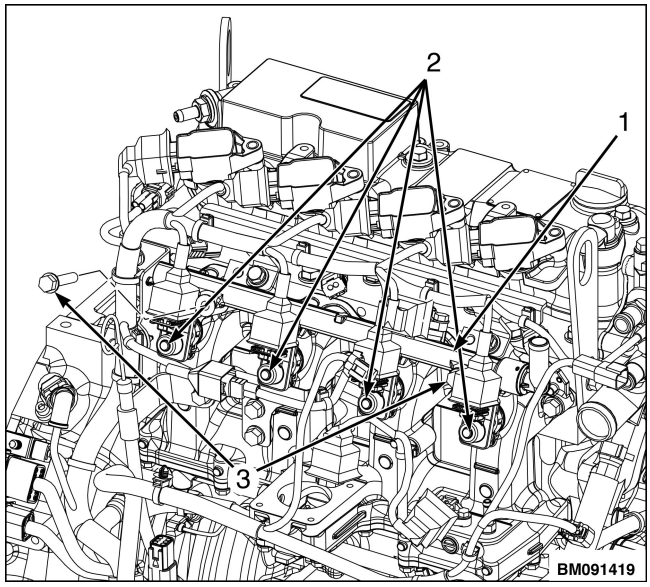
12. Loosen the four bolts attaching the intake throttle. Remove the intake throttle and discard the gasket. See Figure 410.



1. GASKET
2. INTAKE THROTTLE
3. BOLT

Figure 410. Intake throttle

13. Loosen the two bolts and remove the fuel rail. See Figure 411.



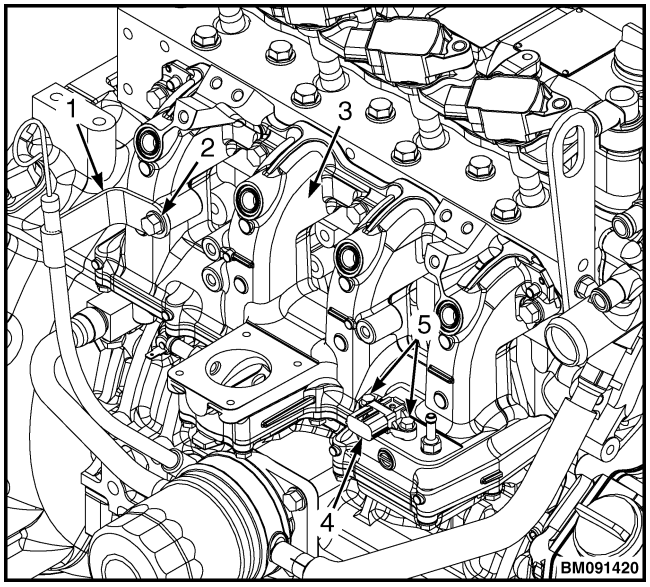
1. FUEL RAIL
2. INJECTOR COILS
3. BOLTS

Figure 411. Fuel rail

14. Release the retaining clip and remove the four injectors.

15. Remove the bolt retaining the dipstick mounting bracket to the intake manifold. See Figure 412.

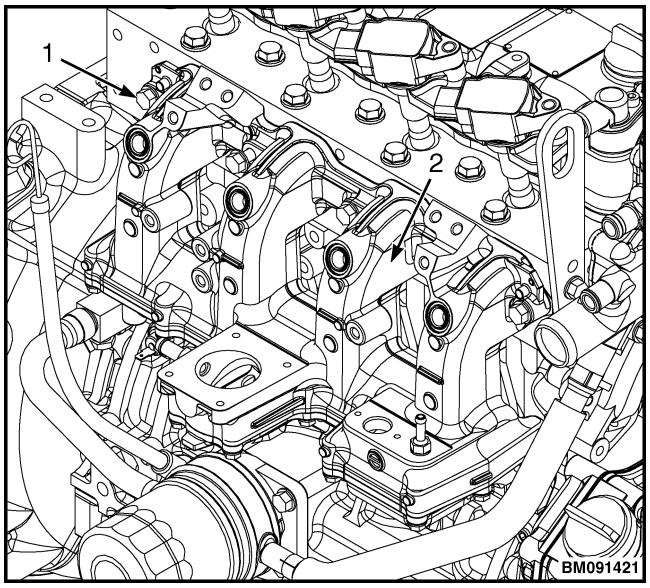
16. Remove the connector from the intake temperature and pressure sensor. Remove the intake temperature and pressure sensor. See Figure 412.



1. DIPSTICK MOUNTING BRACKET
2. BOLT
3. INTAKE MANIFOLD
4. INTAKE TEMPERATURE AND PRESSURE SENSOR
5. BOLT

Figure 412. Intake temperature and pressure sensor

17. Remove the five bolts retaining the intake manifold. See Figure 413.

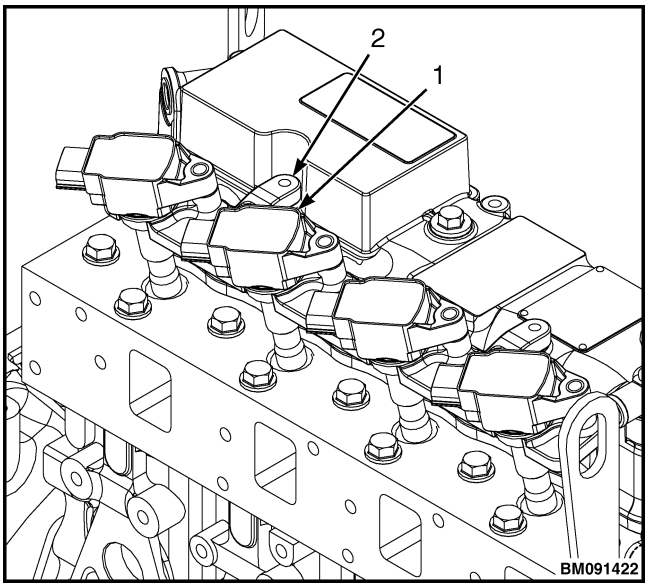


1. BOLT
2. INTAKE MANIFOLD

Figure 413. Intake manifold

18. Remove the intake manifold. Discard the gasket.

19. Remove the bolts retaining the ignition coils. Remove the four ignition coils and ignition coil bracket. See Figure 414.



1. IGNITION COILS
2. IGNITION COIL BRACKET

Figure 414. Ignition coils and bracket

20. Use a 16 mm long socket wrench to remove the four spark plugs from the engine block. See Figure 415.

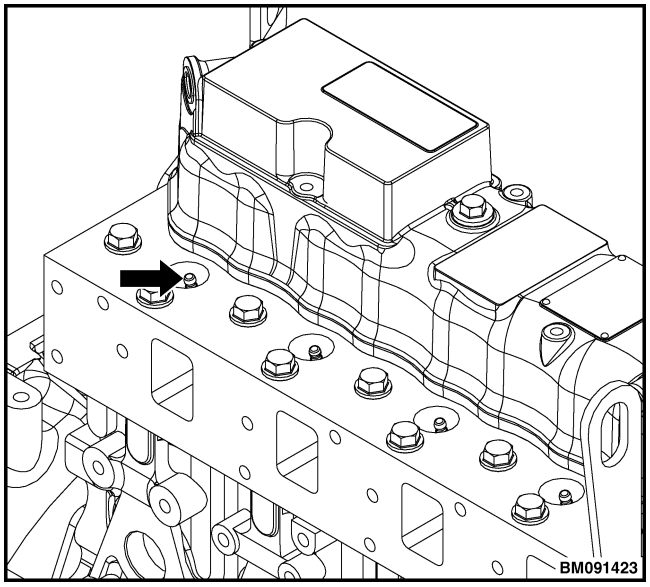
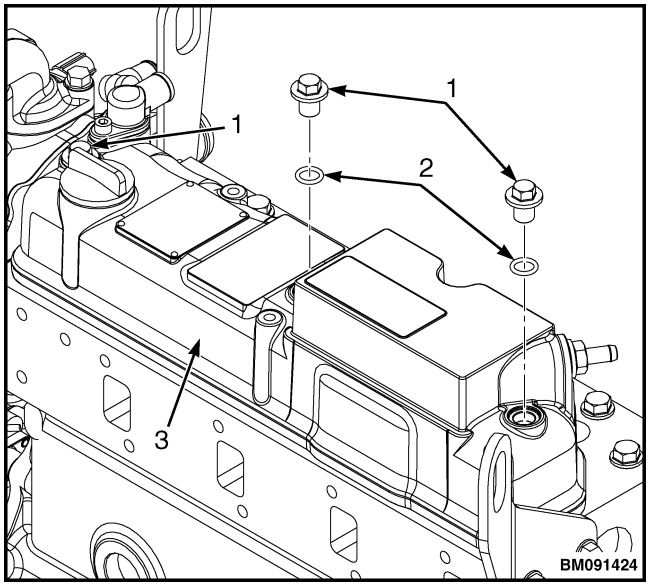


Figure 415. spark plugs

REMOVE

Valve cover

1. Remove the three bolts and O-rings attaching the valve cover to the engine block. Discard the O-rings. See Figure 416.



1. BOLT
2. O-RING
3. VALVE COVER

Figure 416. Valve cover

2. Remove the valve cover and discard the gasket.

Rocker arm

1. Remove the ten bolts that retain the rocker arm shaft supports. See Figure 403.

2. Remove the rocker arm shaft assembly from the cylinder head. See Figure 403.

3. Remove the push rods, taking note of thier location to aid in installation. See Figure 403.

Dissassemble rocker arm

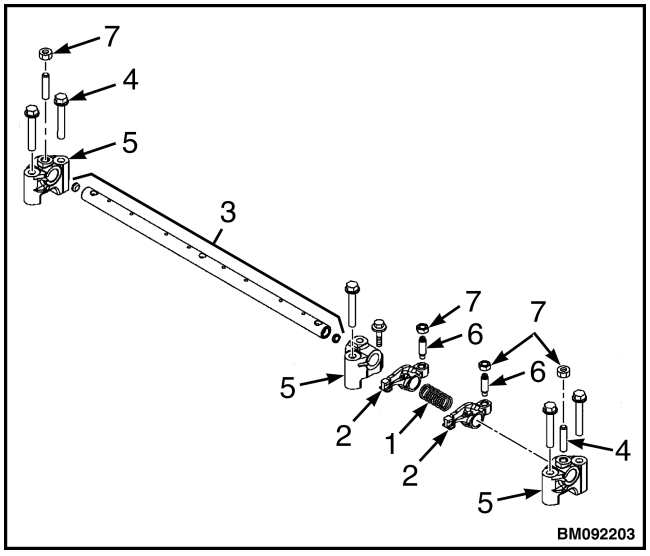
NOTE: Mark the rocker arms to aid in installation. Rocker arms must be installed with original matching valve and pushrod.

The rocker arm shaft fits tightly in the rocker arm supports. Clamp the support in a padded vise. Twist and pull out on the rocker arm shaft to remove. Reverse this process when you reinstall the rocker arm shaft into the supports.

1. Remove the rocker arm shaft alignment stud from the support. See Figure 417.

2. Slide the rocker arm shaft out of the rocker arm supports, springs and rocker arms. See Figure 417.

3. Remove the valve adjusting screw and the locknut from the rocker arms. See Figure 417.

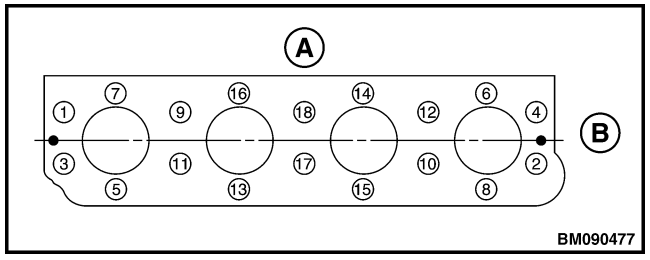


1. SPRING
2. ROCKER ARM
3. ROCKER ARM SHAFT
4. ALIGNMENT STUD
5. SUPPORT
6. VALVE ADJUSTING SCREW
7. LOCKNUT

Figure 417. Rocker arm assembly

Cylinder head

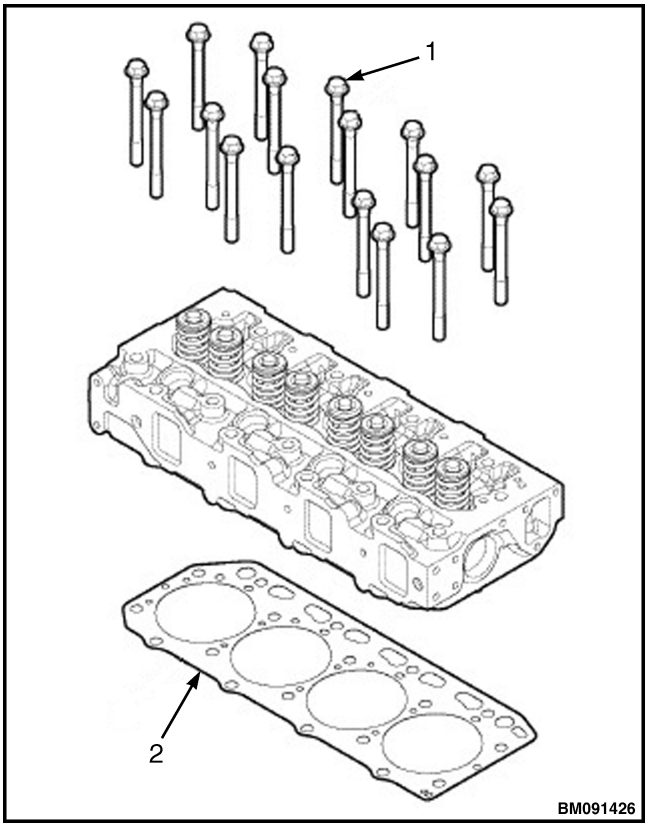
1. Loosen the cylinder head bolts in the sequence shown in Figure 418.



A. CAMSHAFT SIDE
B. FAN SIDE

Figure 418. Cylinder Head Torque Sequence

2. Remove the cylinder head bolts. See Figure 419.



1. CYLINDER HEAD BOLTS
2. CYLINDER HEAD GASKET

Figure 419. Cylinder head bolts

3. Lift the cylinder head away from the cylinder block. Discard the cylinder head gasket. Position the cylinder head on the work bench to prevent damage to the combustion surface.

Intake and exhaust valves

1. Place the cylinder head on the work bench with the combustion side down.

2. Remove the valve cap and keep with the valve it was installed on. See Figure 421.

3. Using the valve spring compressor tool, compress one of the valve springs. See Figure 420 and Special tools for bi-fuel engines.

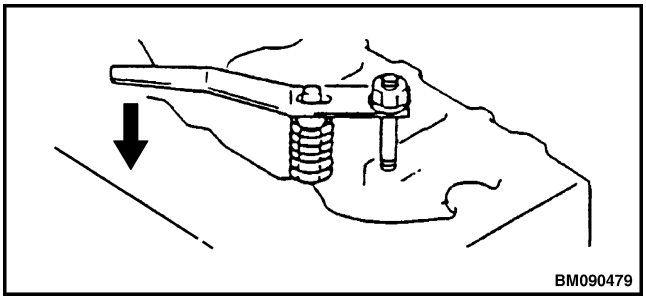
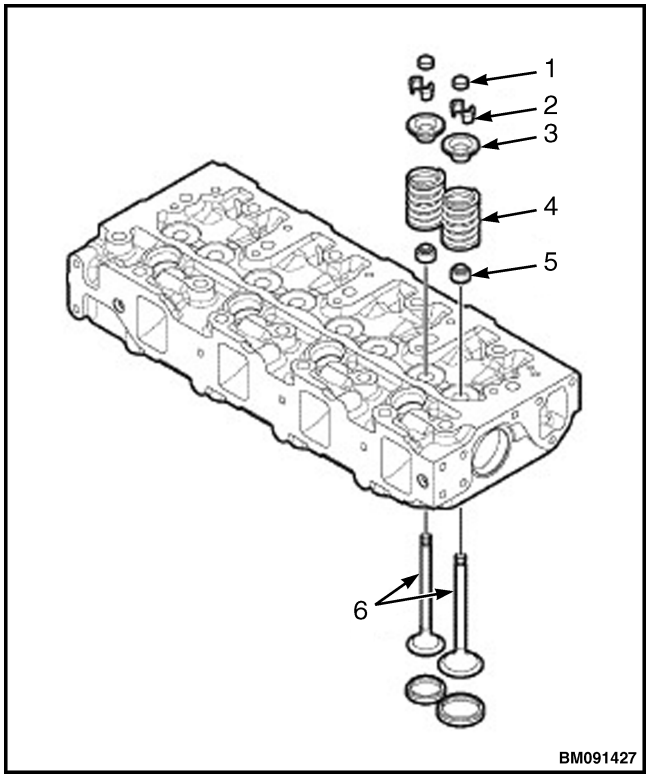


Figure 420. Valve spring compressor tool

4. Remove the valve stem cotters. See Figure 421.

5. Slowly release the tension on the valve spring. See Figure 421.

6. Remove the spring retainer and valve spring. See Figure 421.



1. VALVE CAP
2. VALVE STEM COTTERS
3. SPRING RETAINER
4. VALVE SPRING
5. VALVE STEM SEALS
6. VALVE

Figure 421. Install valves

7. Repeat the steps above for all remaining valves.

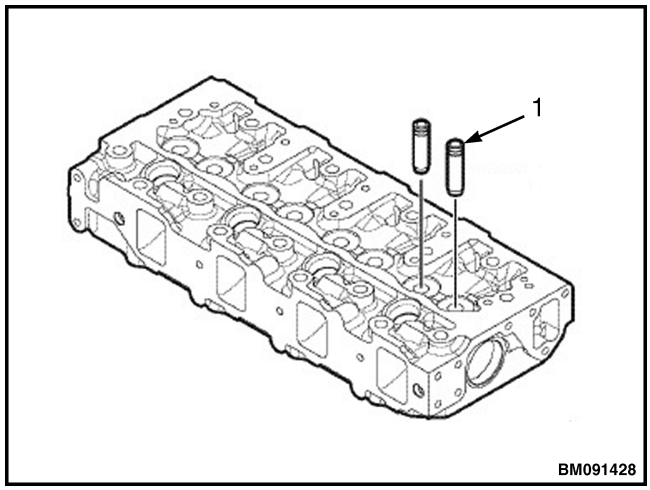
8. Turn the cylinder head so the exhaust port side faces down. Remove the intake and exhaust valves from the cylinder head. See Figure 421.

9. Remove the valve stem seals. See Figure 421.

Valve guides

1. Measure the valve guides. See Bi-fuel engine checks, adjustments, and calibrations for procedure.

2. If the valve guides are not within specification after measuring, use a drift pin and hammer to drive the valve guides out of the cylinder head.



1. VALVE GUIDES

Figure 422. Valve guides

CLEAN AND INSPECT

DANGER

Fume/burn hazard!

Always read and follow safety related precautions found on containers of hazardous substances such as cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

WARNING

Cleaning solvents can be flammable and toxic and can cause skin irritation. When using cleaning solvents, always follow the recommendations of the manufacturer.

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

CAUTION

Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.

Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.

Use caution not to scratch the gasket mating surfaces when cleaning the exhaust manifold and cylinder head.

Use caution not to scratch the gasket mating surfaces when cleaning the cylinder head and cylinder block.

1. Carefully remove all gasket residue from the exhaust manifold and cylinder head. See Figure 403. Inspect the exhaust manifold for scratches, cracks, or any other damage. Repair or replace as needed.

2. Carefully remove all gasket residue from the intake manifold and cylinder head. See Figure 403. Inspect the intake manifold for scratches, cracks, or any other damage. Repair or replace as needed.

3. Carefully remove all gasket residue from the cylinder head and cylinder block. See Figure 403. Inspect the cylinder head for scratches, cracks, or any other damage. Repair or replace as needed.

NOTE: Do not use any cleaning solvent that is silicone-based, as this can cause damage to the engine oxygen sensor.

4. Thoroughly clean all components using a non-metallic brush and an appropriate solvent, such as brake cleaner or laquer thinner. Each cylinder head component must be free of carbon, metal shavings and other debris.

5. Visually inspect the parts. Replace any parts that are obviously discolored, heavily pitted, or otherwise damaged. Replace parts that do not meet the specified limit. Refer to Bi-fuel engine specifications for service limit.

Cylinder head components

Push rods

Determine if the bend of the push rods are within the specified limit.

Push rod bend

1. Place the push rods on a flat inspection block or layout bed.

2. Roll the push rods until a gap can be observed bewteen a portion of the push rod and the surface of the inspection block or layout bed.

3. Use a feeler gauge to measure the gap. See Figure 423. See Bi-fuel engine specifications for service limit.

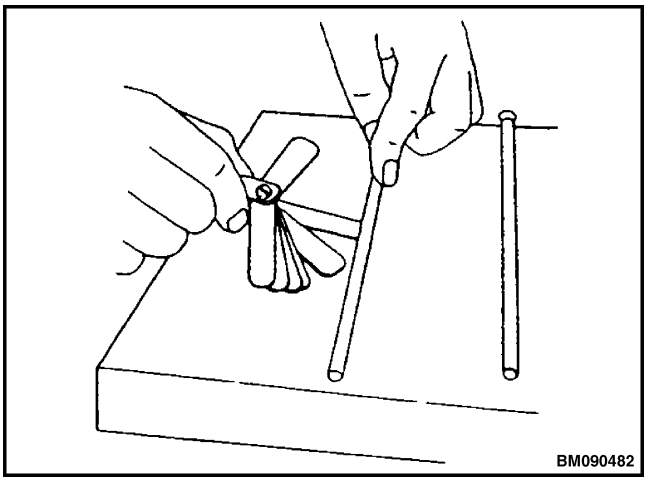


Figure 423. Push rod inspection

4. If the measured gap is not within specified limits, replace the piston rod.

Rocker arm assembly

Rocker arm shaft hole diameter

1. Use a test indicator and micrometer to determine if the inside diameter of all the rocker arms and rocker arm support brackets are within the specified limits. See Figure 424. See Bi-fuel engine specifications.

2. Inspect the contact areas for excessive wear or damage.

3. If excessive wear or damage is found, or if components are not within specified limits, replace the rocker arm assembly.

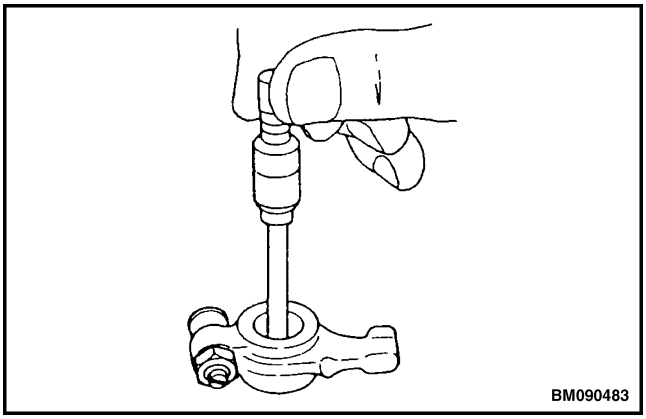


Figure 424. Inside diameter

Rocker arm shaft outside diameter

1. Use a micrometer to measure the rocker arm shaft diameter. Measure at each rocker arm location in two directions 90° apart. See Figure 425.

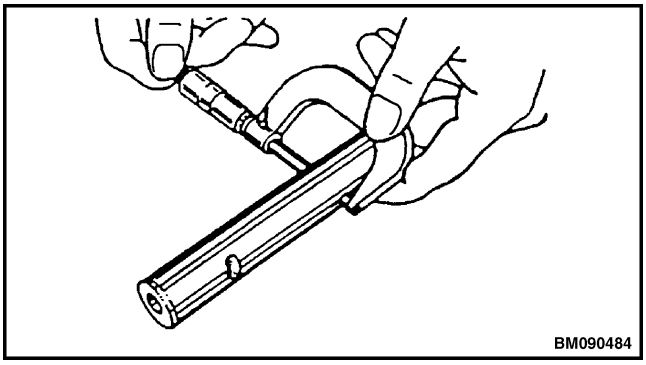


Figure 425. Outside diameter

Valve guides

1. Visually inspect the valve guides for distortions, scoring or other damage.

NOTE: Measure the valve guides while they are installed in the cylinder heads.

2. Use a telescoping gauge and micrometer to measure the inside diameter at each end of the valve guide. Measure the diameter in three places, with two of those three measurements being 90° apart. See Bi-fuel engine specifications for service limit. Replace valve guides if not within specifications.

Cylinder head

Cylinder head distortion

1. Place the cylinder head flat on the work bench, with the combustion side up.

2. Use a straight edge and a feeler gauge to measure cylinder head distortion. Measure diagonally and along each side. See Bi-fuel engine specifications for service limit.

3. If distortion exceeds the service limit, resurface or replace the cylinder head. Remove only enough material to make the cylinder head flat, but do not remove more than 0.20 mm (0.008 in.). If the cylinder head is still not flat after removing 0.20 mm, replace the cylinder head.

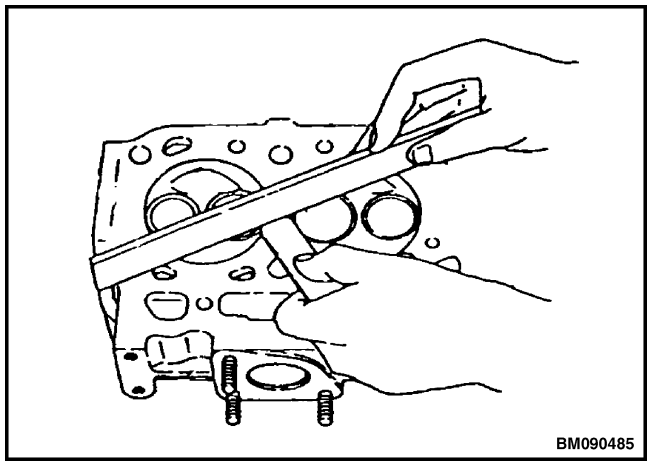


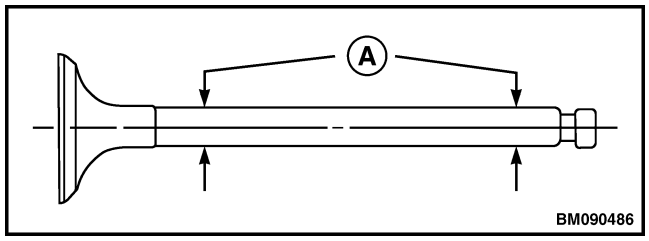
Figure 426. Cylinder head distortion check

Intake and exhaust valves

Visually inspect the intake and exhaust valves. Replace any valves that are discolored, heavily pitted or otherwise damaged.

Valve stem diameter

Use a micrometer to measure the valve stem diameter. Measure the valve stem near the combustion end and near the opposite end. See Figure 427, and Bi-fuel engine specifications for service limit.



A. MEASUREMENT POINTS

Figure 427. Valve stem diameter measurement points

Valve stem straightness

Place the valve stem on a flat inspection block or layout bed. Roll the valve until a gap can be observed between a portion of the valve stem and the surface of the inspection block or layout bed. Use a feeler gauge to measure the gap. See Figure 428 and refer to Bi-fuel engine specifications for service limit.

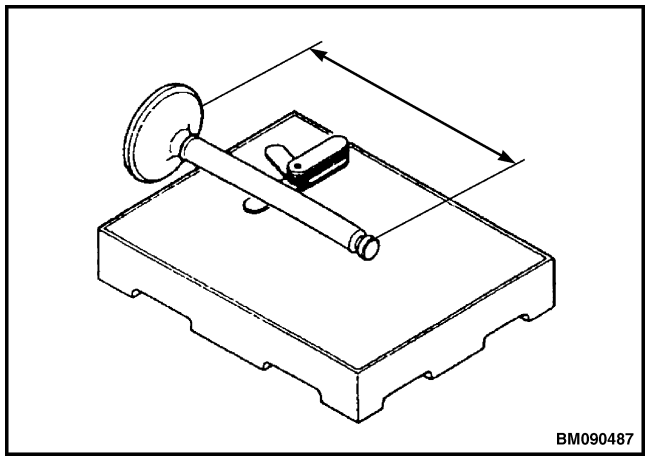


Figure 428. Valve stem straightness check

Valve recession

NOTE: The valve guides must be installed to perform this check.

1. Insert the valves into their original locations in the cylinder head and press them down until they are fully seated.

2. Using a depth micrometer, measure the difference between the cylinder head gasket surface and the combustion surface of each exhaust and intake valve. See Figure 429 and Figure 430. Refer to Special tools for bi-fuel engines for service limit.

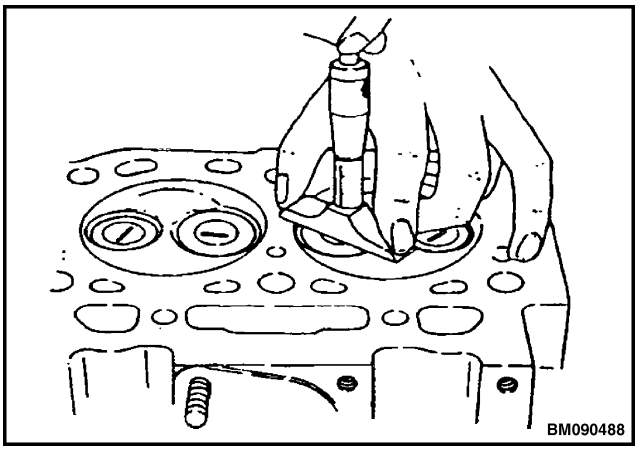


Figure 429. Valve recession measurement

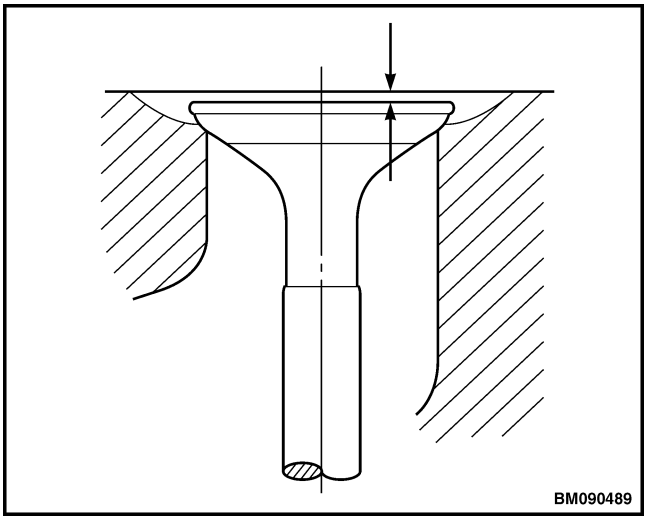


Figure 430. Valve recession

Valve face and valve seat

1. Always check the clearance between the valve and valve guide before correcting the valve seat. See Valve guides, inspection. Refer to Bi-fuel engine specifications for service limit.

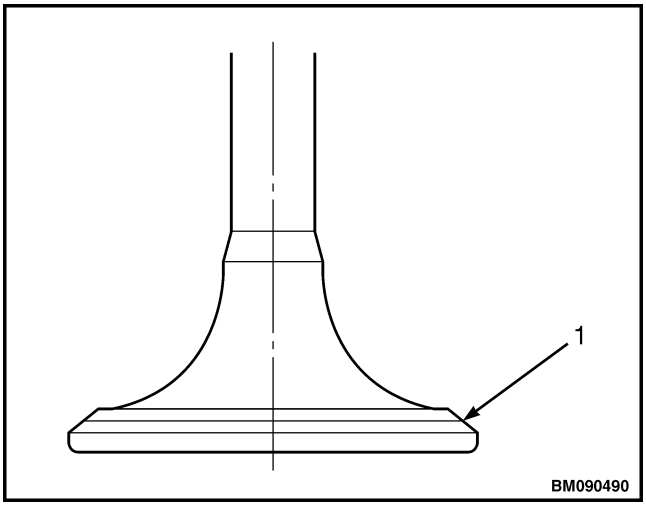
2. If the clearance exceeds the limit, replace the valve or valve guide to bring the clearance within the limit.

3. Roughness or burrs will cause poor seating of a valve. Visually inspect the seating of each valve and determine if lapping or grinding is needed. Lapping or grinding is needed if the cylinder head's seat width exceeds standard limits. Refer to Bi-fuel engine specifications for service limit.

4. Visually inspect all valve faces and valve seats for pitting, distortion, cracking, or evidence of overheating. Usually the valves and valve seats can be lapped or ground ro return them to serviceable condition. Severly worn or damaged components require replacement.

5. Coat the valve seat with a thin coat of bluing compound. Install the valve and rotate it to distribute bluing on to the valve. The contact pattern should be approximately centered on the valve face and uniform in width. See Figure 431.

6. Visually inspect the valve seat for even contact.



1. VALVE SEAT

Figure 431. Valve seat

7. Adjust the valve seat diameter by top-grinding with a 150° stone to make the seat diameter smaller, then by bottom-grinding using a 40° stone to make the seat diameter larger. Once the seat location has been corrected, grind and lap the seat angle to specification.

8. Grind the valve face and/or valve seat only enough to return them to serviceable condition. Grinding is only necessary if the valve and valve seat do not contact correctly. Check recession after grinding.

9. If the valve requires grinding, lap the valve after grinding. Lap the valve seat and the cylinder head with a mixture of valve compound and engine oil.

10. Thoroughly wash the parts to remove all grinding residue and valve compound.

Valve springs

Inspect the valve springs. If damage or corrosion is seen, or if measurements exceed the specified limits, replace the springs.

Fractures - Check for fractures on the inside and outside portions of the springs. If the valve spring is fractured, replace the spring.

Corrosion - Check for corrosion of spring material caused by oxidation.

Squareness - Use a flat surface and a square to check each spring for squareness. Refer to the Bi-fuel engine specifications for the service limit.

Free Length - Use a caliper to measure the length of the spring. Refer to Bi-fuel engine specifications for service limit.

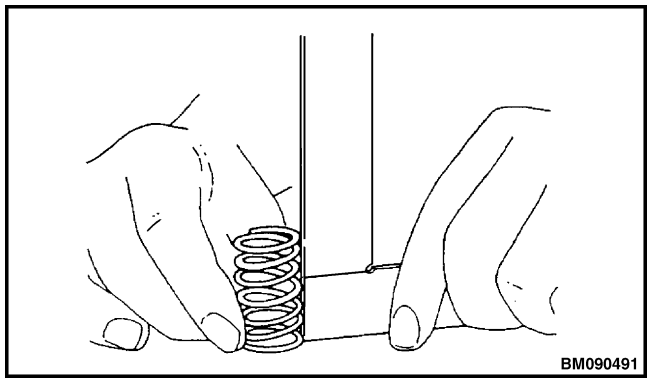


Figure 432. Spring squareness check

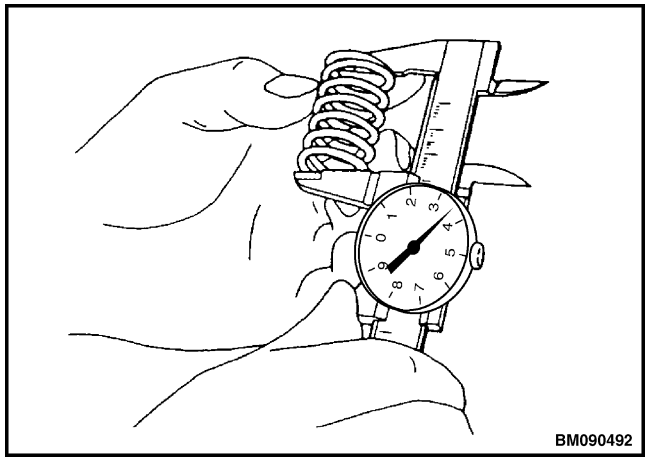


Figure 433. Spring free length check

ASSEMBLE

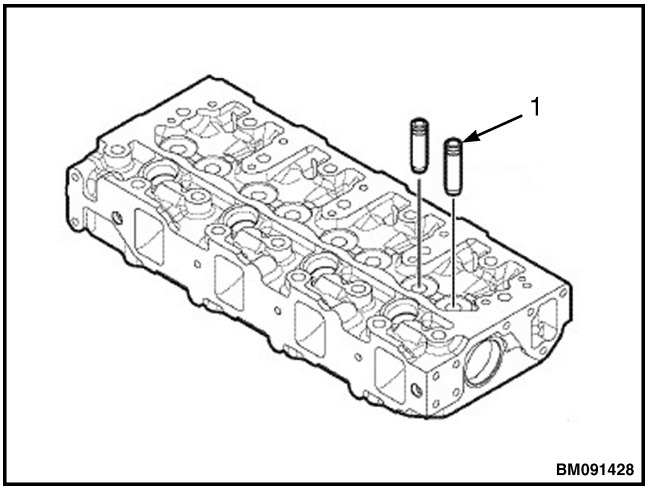
NOTE: Always use new gaskets, O-rings, and seals for reassembly of the cylinder head. See **Parts Manual** for part numbers.

NOTE: Generously oil all components during reassembly of the cylinder head. For more information regarding oil specifications, see Bi-fuel engine specifications.

Valve guides

1. The valve guides are installed into the cylinder head with an extremely tight press fit. Before installing the valve guides, place the valve guides in a freezer for at least twenty minutes. This will cause the valve guides to contract, making it easier to install the valve guides into place.

2. Immediately after removing the valve guides from the freezer, insert the valve guides in their correct positions in the cylinder head. See Figure 434.

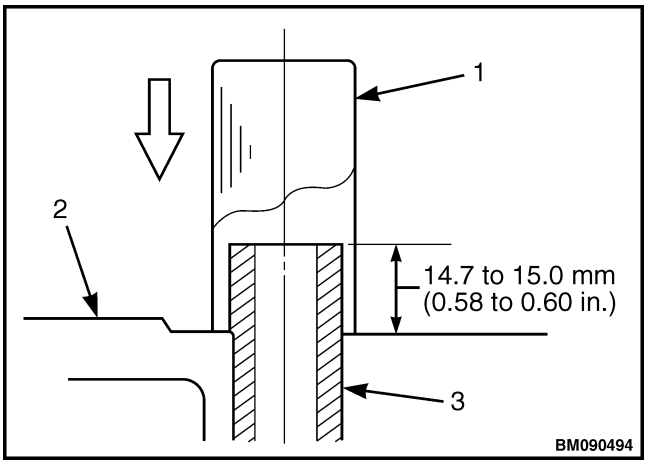


1. VALVE GUIDE

Figure 434. Valve guides

3. Locate the valve guide installation tool. See Special tools for bi-fuel engines.

4. Use the valve guide installation tool to finish installing the valve guides into the cylinder head to the correct height. See Figure 435.



1. VALVE GUIDE INSTALLATION TOOL
2. CYLINDER HEAD
3. VALVE GUIDE

Figure 435. Valve Guide Installation

Valves and valve springs

Always install new valve stem seals. The exhaust valve steam seals are different from the intake valve stem seals and can be identified by different colored paint marks in the outside of the seals.

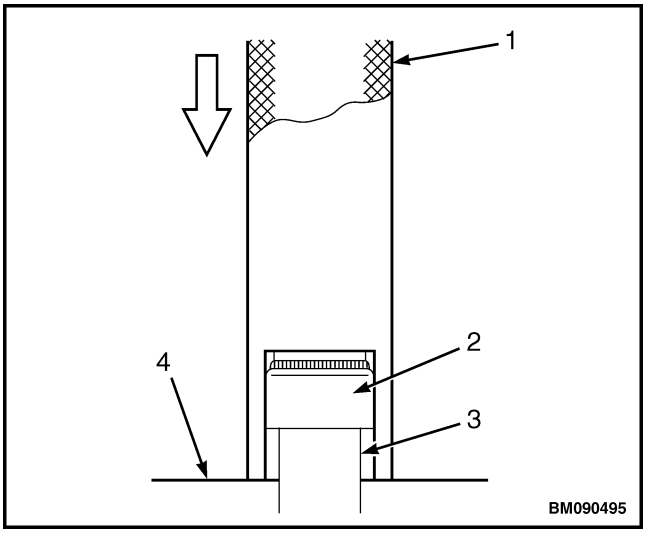
Ensure valve stems are installed in the correct locations.

Engine model	Marking	
	Intake	Exhaust
4TN88B	None	White paint on outside of seal

1. Apply clean engine oil to the lip of the valve stem seal.

2. Locate the valve stem seal installation tool. See Special tools for bi-fuel engines.

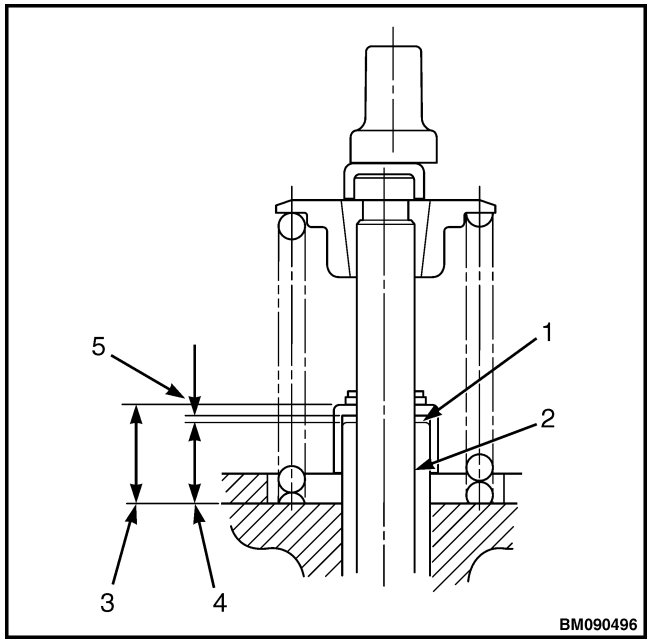
3. Use the valve stem seal installation tool to insert a new valve stem seal on each of the valves. See Figure 436.



1. VALVE STEM SEAL INSTALLATION TOOL
2. VALVE STEM SEAL
3. VALVE GUIDE
4. CYLINDER HEAD

Figure 436. Valve Stem Seal Installation

4. Measure the distance from the cylinder head to the valve stem seal to ensure correct clearance between the guide and the seal. Refer to Bi-fuel engine specifications for the clearance specifications. See Figure 437.

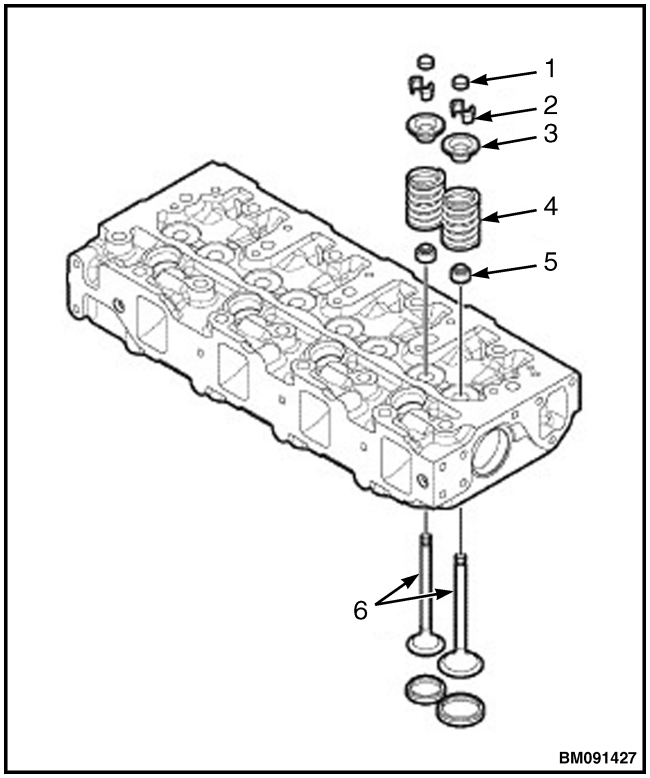


1. VALVE GUIDE
2. VALVE STEM SEAL
3. VALVE GUIDE PROJECTION
4. VALVE STEM SEAL PROJECTION
5. CLEARANCE

Figure 437. Valve stem seal clearance

5. Place the cylinder head assembly down on its exhaust port side.

6. Place all the valves in their correct positions in the cylinder head as marked when disassembled. See Figure 438.



1. VALVE CAP
2. VALVE STEM COTTERS
3. SPRING RETAINER
4. VALVE SPRING
5. VALVE STEM SEALS
6. VALVE

Figure 438. Install valves

7. Place the cylinder head on the work bench with the combustion chamber facing down. Install the valve springs and valve spring retainers. See Figure 420.

8. Using the valve compressor tool, compress the valve spring. See Figure 420.

9. Install the valve keepers and slowly release the tension in the valve spring. See Figure 420.

10. Install the valve cap.

11. Repeat these procedures until all the intake and exhaust valves are installed.

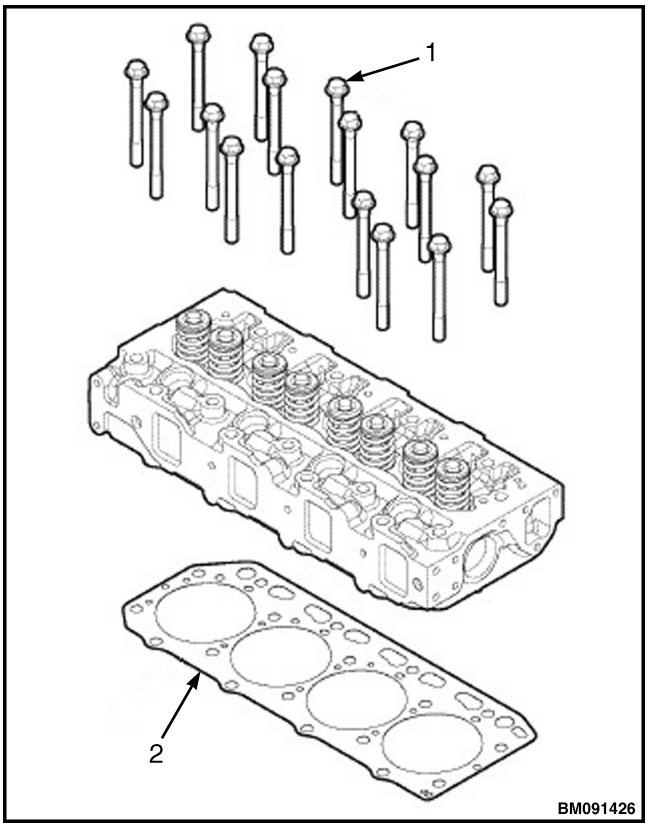
Cylinder head

1. Carefully clean the combustion surface of the cylinder head and the top surface of the cylinder block.

2. Place a new cylinder head gasket on the cylinder block. See Figure 439.

3. Position the cylinder head on the cylinder head gasket and cylinder block.

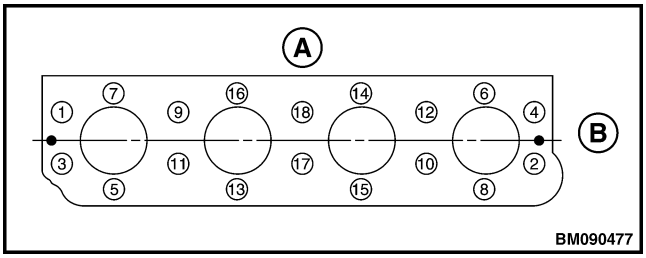
4. Lightly oil the threads of the cylinder head bolts. See Figure 439.



1. CYLINDER HEAD BOLTS
2. CYLINDER HEAD GASKET

Figure 439. Cylinder head bolts

5. Install the cylinder head bolts and tighten the cylinder head bolts to
46 to 49 N•m (34 to 36 lbf ft) in the sequence shown in Figure 440. Then tighten the cylinder head bolts to 92 to 98 N•m (68 to 72 lbf ft) in the same sequence.



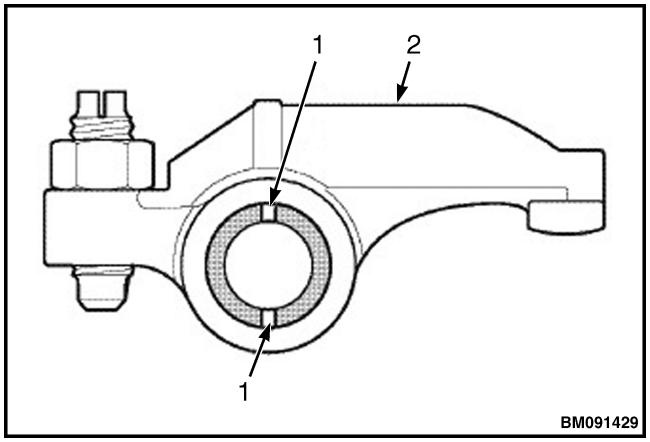
A. CAMSHAFT SIDE
B. FAN SIDE

Figure 440. Cylinder Head Torque Sequence

6. Insert all push rods into the correct push rod holes. See Figure 403.

Rocker arm assembly

1. Confirm the lubrication holes in the rocker arm shaft are oriented as shown in Figure 441.



1. LUBRICATION HOLES
2. ROCKER ARM

Figure 441. Rocker arm

2. Lubricate the rocker arm shaft with engine oil.

NOTE: To correctly align the rocker arm shaft with the rocker arm supports, first position the rocker arm shaft with the hole for the shaft alignment stud facing up.

3. Align the hole in the rocker arm shaft and the hole in the rocker arm support. Install the alignment stud. See Figure 442.

NOTE: The rocker arm shaft fits tightly in the rocker arm supports. Clamp the support in a padded vise and twist and push the rocker arm supports onto the rocker arm shaft.

4. Slide the rocker arm supports, springs, and rocker arms onto the shaft. See Figure 442.

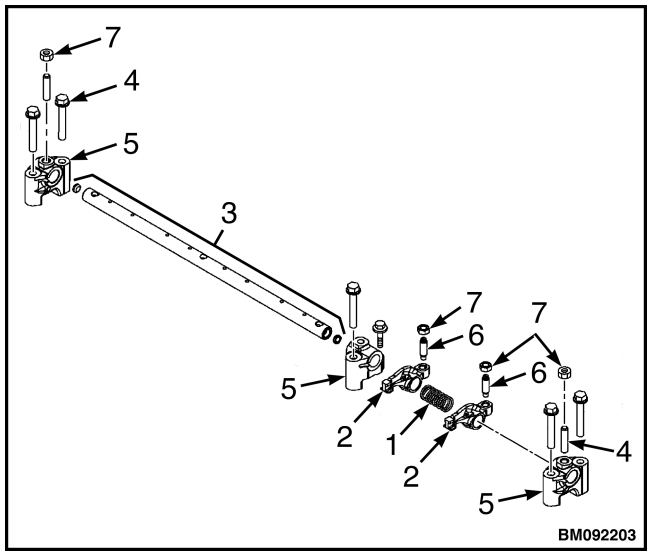
5. Place rocker arm shaft assembly in position on the cylinder head.

6. Install the valve adjusting screws and the lock nuts. See Figure 442.

7. Align the push rods with their respective rocker arms. See Figure 403.

8. Install and tighten the rocker arm shaft retaining bolt and nuts. See Figure 442.

9. Tighten the rocker arm shaft alignment studs. See Figure 442.



1. SPRING
2. ROCKER ARM
3. ROCKER ARM SHAFT
4. ALIGNMENT STUD
5. SUPPORT
6. VALVE ADJUSTING SCREW
7. LOCKNUT

Figure 442. Rocker arm assembly

10. Adjust valve clearance. See Bi-fuel engine checks, adjustments, and calibrations.

INSTALL

1. Lightly grease the new valve cover gasket. Figure 416.

2. Place new valve cover gasket in the groove of the valve cover.

3. Place the valve cover in position on the cylinder head. See Figure 416.

4. Verify that the O-rings are installed on the valve cover bolts.

5. Install and tighten the valve cover bolts. See Figure 416.

6. Install the four spark plugs into the cylinder head. See Figure 415.

7. Use a 16 mm socket wrench to tighten the spark plugs. See Figure 415. Torque to 24 to 34 N•m (17.7 to 25.1 lbf ft).

8. Install the ignition coil bracket and insert the two bolts to retain the ignition coil bracket to the cylinder head. See Figure 414. Torque to 24 to 34 N•m (17.7 to 25.1 lbf ft).

9. Install the ignition coils and insert the four bolts to retain each of the four ignition coils to the ignition coil bracket. See Figure 414. Torque to 6 to 9.5 N•m (4.4 to 7.0 lbf ft).

10. Install the exhaust manifold with new gasket onto the cylinder head.

11. Insert the bolts to attach the exhaust manifold to the cylinder head. See Figure 408. Torque to 44.1 to 53.9 N•m (32.5 to 39.8 lbf ft).

12. Install the heat shield in place on the exhaust manifold.

13. Insert the bolts to attach the heat shield to the exhaust manifold. See Figure 407. Torque to 22.6 to 28.4 N•m (16.7 to 21.0 lbf ft).

14. Insert the O_2 sensor. See Figure 407.

15. Insert the four bolts to attach the intake throttle with new gasket to the intake manifold. See Figure 410. Torque to 22.6 to 28.4 N•m (16.7 to 21.0 lbf ft).

16. Install the intake throttle and intake manifold with new gasket onto the cylinder head. See Figure 413.

17. Insert the bolts to attach the intake manifold to the cylinder head. See Figure 413.

18. Torque to 22.6 to 28.4 N•m (16.7 to 21.0 lbf ft).

19. Insert the bolt to retain the dipstick mounting bracket to the intake manifold. See Figure 412.

20. Tighten to standard torque.

21. Insert the two bolts to retain the intake pressure and temperature sensor to the intake manifold. See Figure 412.

22. Tighten to standard torque.

23. Install the injectors. See Bi-fuel fuel system repair.

24. Install the fuel rail. See Figure 411.

25. Insert the two bolts to attach the fuel rail to the engine block. See Figure 411. Torque to 7.8 to 9.4 N•m (5.8 to 6.9 lbf ft).

26. Install the intake adapt and hose. See Figure 409.

27. Install the the hose band retaining the intake adapter and hose. See Figure 409.

28. Install the wire harness. Connect the wire harness connectors to the ignition coils and injectors. See Figure 406.

29. Connect the wire harness to the Intake temperature sensor, exhaust temperature sensor, O_2 sensor and intake throttle.

30. Install the water pump and fan. See Water pump repair in the **Cooling system** 0700SRM2300.

31. Connect the wire harness to the coolant temperature sensor. See Figure 404.

32. Attach the breather hose and ambient air hose. See Figure 405.

33. Install the alternator. See Bi-fuel electrical system repair.

CAUTION

Additives may damage the cooling system. Before using additives, contact your local Hyster dealer.

34. Fill cooling system with coolant. See **Periodic Maintenance** 8000SRM2305 for the correct coolant amount and type.

35. Install radiator cap.

36. Change engine oil and oil filter. See **Periodic Maintenance** 8000SRM2305 for procedure.

WARNING

During engine operation, be careful not to touch the fan, pulleys, or drive belts. Contact with these parts can cause serious injury.

WARNING

The radiator or other parts of the cooling system may be hot or under pressure and can cause serious injury.

37. Start engine and check for leaks.

38. Stop engine and resolve any leaks that are discovered.

WARNING

DO NOT remove the radiator cap from the radiator when the engine is hot. When the radiator cap is removed, pressure will release from the coolant system. If the coolant system is hot, the steam and boiling coolant can cause severe burns.

WARNING

The radiator or other parts of the cooling system may be hot or under pressure and can cause serious injury. Wait 30 minutes for the radiator and engine to cool before performing maintenance to the cooling system. After 30 minutes, do a touch test by touching the radiator with your hand. If the radiator is still hot to the touch, wait another 30 minutes before attempting any maintenance to the cooling system.

CAUTION

Additives may damage the cooling system. Before using additives, contact your local Hyster dealer.

39. If coolant is hot, allow engine time to cool. Check coolant level and fill as required between the ADD and FULL marks on the coolant reservoir.

BI-FUEL TIMING GEAR CASE REPAIR 202001-035

REMOVE

Timing gear case cover

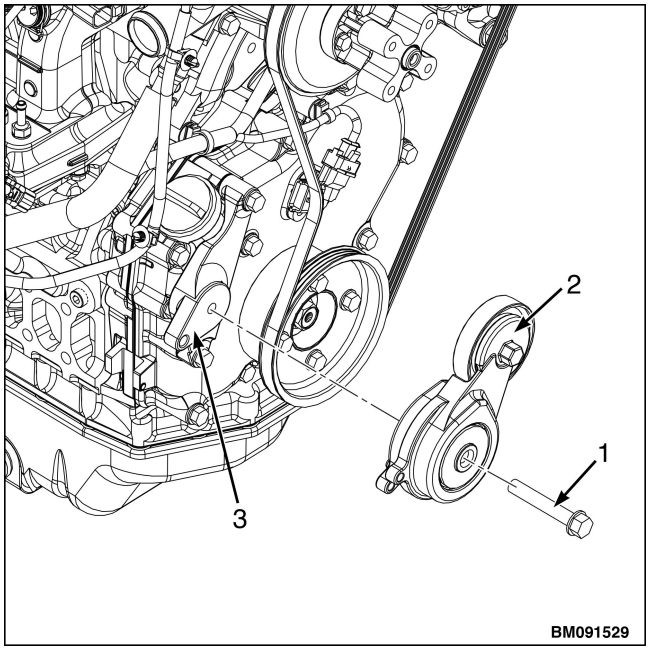
1. Remove the engine. See Bi-fuel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

2. Place the engine on an engine stand or a clean, flat working surface large enough to accomodate the engine and components.

3. Remove the alternator. See Bi-fuel electrical system repair.

4. Remove the cooling fan, V-belt and water pump. See **Cooling system** 0700SRM2300 service manual.

5. Loosen the bolt retaining the auto tensioner to the tensioner bracket. Remove the bolt and auto tensioner. See Figure 443.



1. BOLT
2. AUTO TENSIONER
3. TENSIONER BRACKET

Figure 443. Auto tensioner

6. Disconnect the camshaft speed sensor connector on the engine wire harness from the camshaft speed sensor. See Figure 444.

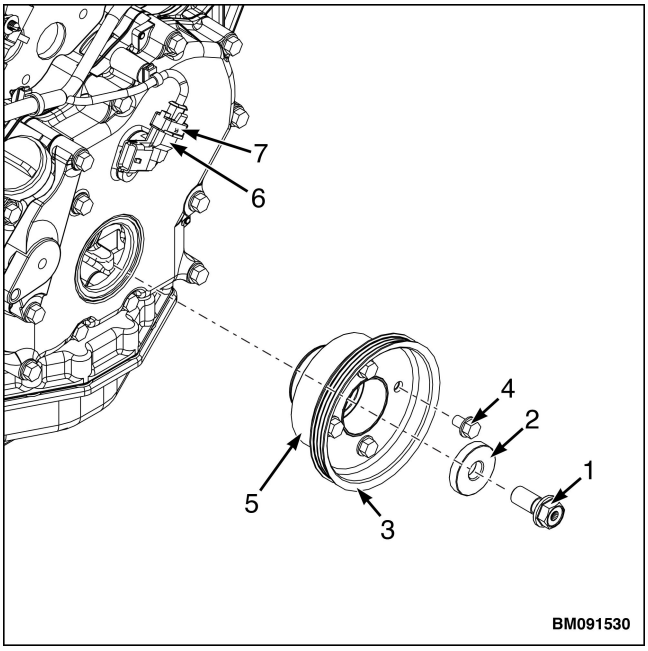
7. Remove the bolt retaining the crankshaft pulley (item 1, Figure 444).

CAUTION

Take care to not damage the threads in the end of the crankshaft when removing the crankshaft pulley.

8. Use a gear puller to remove the crankshaft pulley and spacer, with the crankshaft pulley adapter still attached. See Figure 444.

If replacing the crankshaft pulley adapter, remove the four bolts and the adapter from the crankshaft pulley.



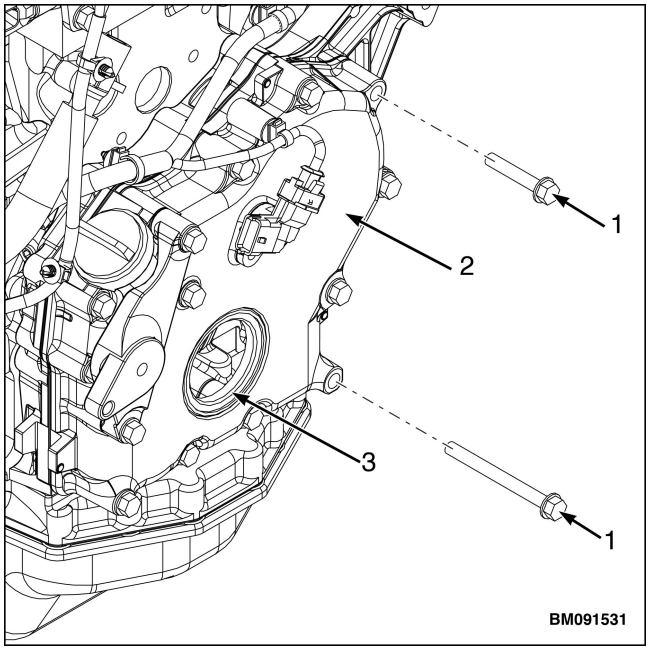
1. BOLT
2. SPACER
3. CRANKSHAFT PULLEY
4. BOLT
5. CRANKSHAFT PULLEY ADAPTER
6. CAMSHAFT SPEED SENSOR
7. CAMSHAFT SPEED SENSOR CONNECTOR

Figure 444. Crankshaft Pulley

9. Remove the auto tensioner.

10. Remove the 13 bolts retaining the timing gear case cover. See Figure 445.

11. Remove the timing gear case cover. See Figure 445.



1. TIMING GEAR CASE COVER
2. BOLT
3. FRONT OIL SEAL

Figure 445. Timing Gear Case Cover

12. If the front oil seal is worn or damaged, remove the front oil seal from the timing gear case cover. See Figure 445.

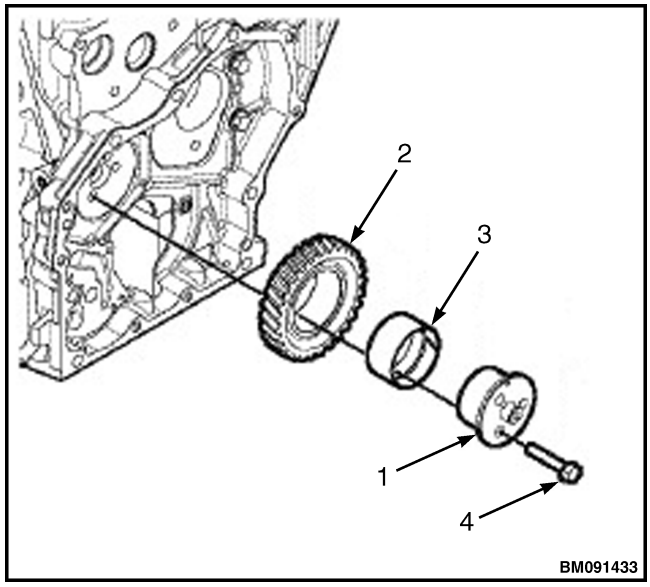
Timing gear case

Idler shaft gear

1. Rotate the engine to align the timing gears. Mark the gears with paint markers to aid in reinstallation.

2. Remove the bolts from the idler gear shaft. See Figure 446.

3. Remove the idler gear shaft, idler gear, and bushing. See Figure 446.



1. IDLER GEAR SHAFT
2. IDLER GEAR
3. IDLER GEAR BUSHING
4. BOLT

Figure 446. Timing Gears

4. If the crankshaft gear or crankshaft are damaged and require replacement, use a gear puller to remove the crankshaft gear. See Special tools for bi-fuel engines.

5. Measure the backlash of the timing gear and idler gears. See Bi-fuel engine checks, adjustments, and calibrations.

Camshaft and camshaft gear

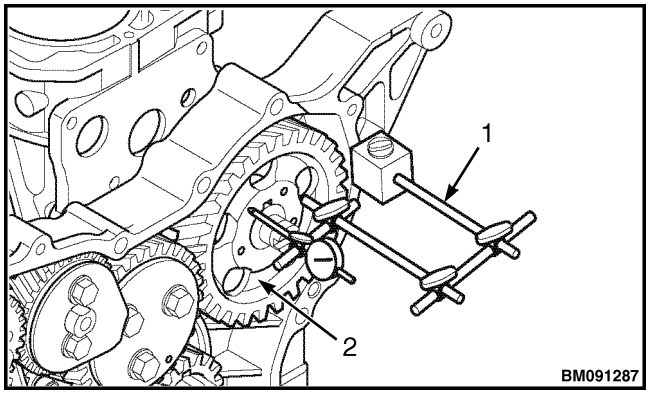
NOTE: Removal of the camshaft gear requires the camshaft be removed and placed in a press. DO NOT remove the camshaft gear unless it or the camshaft is damaged and requires replacement.

1. If necessary, remove the camshaft. See Step 3.

2. Confirm gears are aligned properly. Mark the gears with paint markers to aid in reinstallation.

3. Before removing the camshaft, check the camshaft end play.

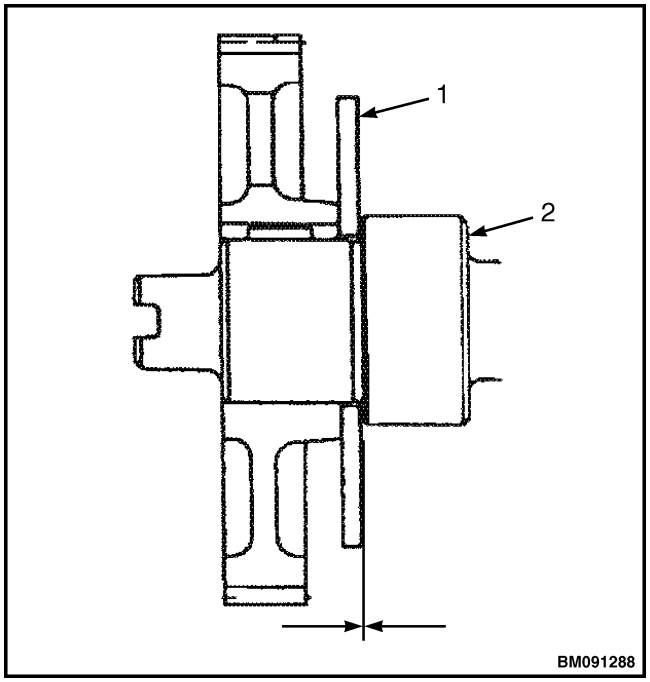
- Method A: Install a dial indicator on the cylinder block. See Figure 447. Move the camshaft back and forth to measure the end play. Record the measurement. See Camshaft and timing gear train specifications in Bi-fuel engine specifications for service limit.



1. DIAL INDICATOR
2. CAMSHAFT

Figure 447. Method A

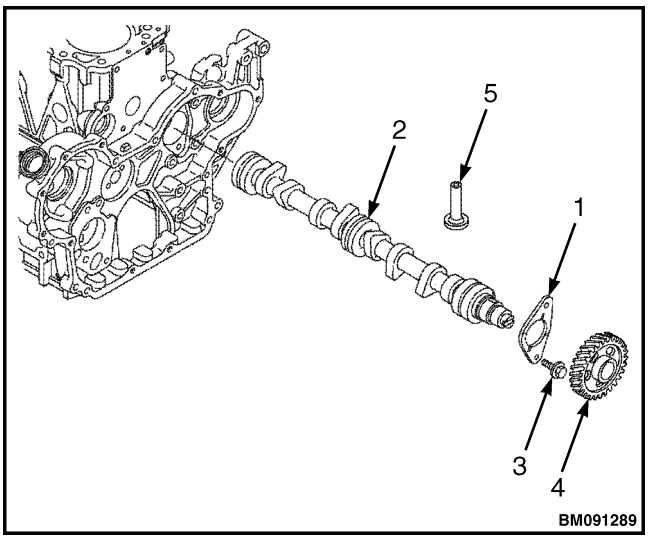
- Method B: Use a feeler gauge to measure the clearance between the thrust plate and front camshaft bearing. See Table 77 in Bi-fuel engine specifications for service limit.



1. THRUST PLATE
2. FRONT CAMSHAFT BEARING

Figure 448. Method B

4. Remove the two bolts retaining the camshaft thrust plate. See Figure 449.



1. CAMSHAFT THRUST PLATE
2. CAMSHAFT
3. BOLT
4. CAMSHAFT DRIVE GEAR
5. TAPPETS

Figure 449. Camshaft

- If using an engine stand, rotate the engine so that gravity causes the tappets to drop away from the camshaft lobes.
- If using a work surface instead of an engine stand, place the engine upright on the flywheel end mounting flange.

5. Rotate the camshaft at least two turns to bump any sticking tappets away from the camshaft.

6. Slowly pull the camshaft assembly out of the engine. Be careful not to damage the front camshaft bushing. See Figure 449.

NOTE: The tappets are "mushroom" shaped and must be removed from inside the engine crankcase.

7. Remove the tappets. Mark the tappets so they can be reinstalled in the same location. See Figure 449.

NOTE: Only remove the camshaft drive gear if the drive gear or camshaft require being replaced.

8. Use a gear puller to press and remove the camshaft drive gear. The drive gear is shrink-fit and must be heated to 180-200°C (356-392°F) to be removed. See Figure 449.

Timing gear case

1. Remove the oil pump. See Bi-fuel lubrication system repair.

2. Remove the bolts. See Figure 450.

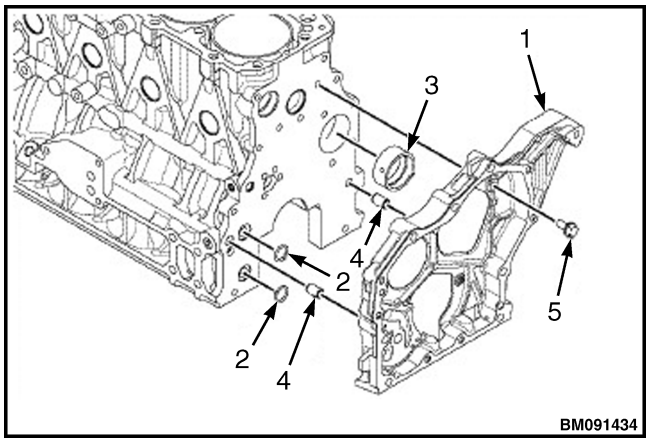
3. Remove the timing gear case from the cylinder block. Thoroughly clean and remove all old sealant from the connecting surfaces. See Figure 450.

4. Inspect and measure the camshaft bushing. See Figure 450.

   See Table 73 in Bi-fuel engine specifications for service limit.

5. Remove the camshaft bushing if damaged or worn beyond service limit. See Figure 450. See Special tools for bi-fuel engines for appropriate tool.

6. Remove the O-rings and two dowels. See Figure 450.



1. TIMING GEAR CASE
2. O-RINGS
3. CAMSHAFT BUSHING
4. DOWELS
5. BOLTS

Figure 450. Timing Gear Case

INSPECT

WARNING

Cleaning solvents can be flammable and toxic and can cause skin irritation. When using cleaning solvents, always follow the recommendations of the manufacturer.

WARNING

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

Clean all old sealant from the timing gear case cover and the timing gear case. Clean the timing gear case cover in cleaning solvent. Dry the timing gear case cover with compressed air. Inspect for wear, cracks, and any other damage. If necessary, replace timing gear case cover.

INSTALL

1. If removed, reinstall the camshaft end plate, key, and timing gear onto the camshaft. See Figure 449.

2. Apply a continuous bead of Three Bond Liquid Gasket, Hyster Part Number 1599478, to the mounting area of the gear case. Circle each bolt hole with the sealant as well.

3. Install new O-rings and dowells into the cylinder block. See Figure 450.

NOTE: Heat the camshaft drive gear to 180-200°C (356-392°F) before pressing it onto the camshaft.

4. Use a press to install the camshaft end plate. See Figure 449. See Special tools for bi-fuel engines for appropriate tool.

NOTE: The tappets are mushroom shaped and must be installed from inside the engine crankcase.

- If using an engine stand, rotate the cylinder block so that gravity will keep the tappets in place and out of the way of the camshaft lobes when the camshaft is being installed.
- If using a work surface instead of an engine stand, place the engine upright on the flywheel end mounting flange.

5. Lubricate the tappets with clean engine oil or assembly lube. See Bi-fuel engine specifications.

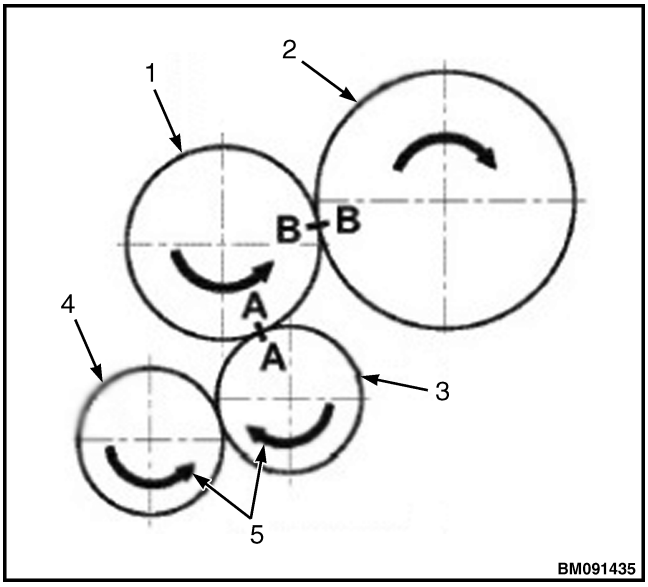
6. Install the tappets back into their position in the cylinder block. Push the tappets fully into the tappet bores so they will not interfere with the installation of the camshaft.

7. Lubricate the camshaft with clean engine oil or assembly lube. Slowly insert the camshaft through the front of the engine into the timing gear case. See Figure 449.

8. Insert the capscrews to retain the camshaft thrust plate to the timing gear case. See Figure 449. Tighten the capscrews to specified torque value. See Special torque chart.

9. Set the piston of the timing gear case side cylinder (No. 4) to top dead center position. See Figure 451.

10. Rotate the camshaft until the mark (B, Figure 451) is approximately at the 9 o'clock position.



1. IDLER GEAR
2. CAMSHAFT DRIVE GEAR
3. CRANKSHAFT GEAR
4. OIL PUMP DRIVE GEAR
5. DIRECTION OF ROTATION

Figure 451. Timing Gears

11. Lubricate the idler gear (1), idler gear bushing, and idler gear shaft with clean engine oil. See Figure 451. See Bi-fuel engine specifications.

12. Align the timing gears according to the marks from the paint marker. See or Figure 451.

13. Install the idler gear, idler gear shaft and idler gear bushing while aligning the timing mark A on the idler gear with mark A on the crankshaft gear. At this time, direct the punch mark on the idler gear shaft end surface to the upper part of the engine.

14. While aligning the timing mark B on the idler gear with mark B on the camshaft drive gear, install the idler gear, idler gear shaft and idler gear bushing.

15. When all gears are properly aligned, tighten the idler gear retaining bolts to specified torque value. See Special torque chart.

16. Inspect the marks on all gears to confirm alignment.

NOTE: If the front oil seal was removed, follow Step 17 through Step 18 to install.

17. Apply a continuous bead of Three Bond Liquid Gasket, Hyster Part Number 1599478, to the outside diameter of a new front oil seal.

18. Install the new front oil seal into the timing gear case cover. Apply lithium grease to the lip of the front oil seal. See Figure 445.

19. Apply a continuous bead of Three Bond Liquid Gasket, Hyster Part Number 1599478, to the surface of the timing gear case on the side that adjoins the engine block.

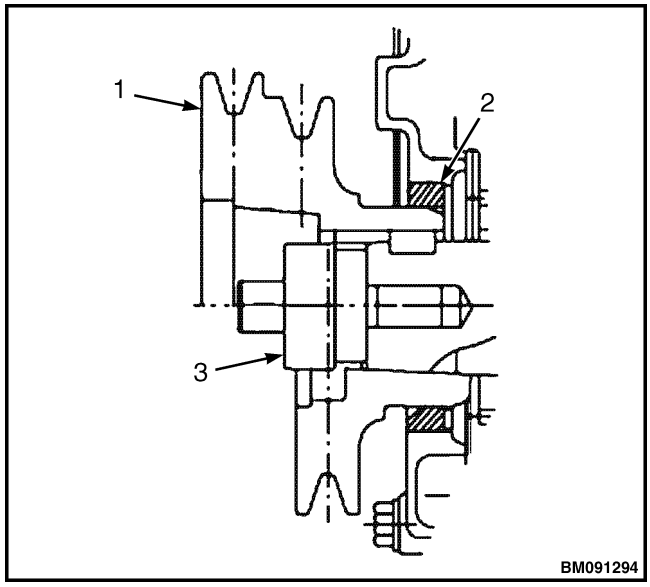
20. Place the timing gear case cover in position on the timing gear case and install retaining bolts. See Figure 445. Tighten bolts to standard torque value.

NOTE: If you have not used a paint marker to mark gear alignment, do so prior to installing the timing gear case cover.

21. Install the timing gear case cover. See Figure 445.

22. Insert the bolts to to retain the timing gear case cover to the timing gase cover. Tighten to standard torque. See Figure 445.

23. Use the crankshaft pulley installation tool to reinstall the crankshaft pulley. The crankshaft pulley installation tool will guide the pulley hub and protect the front seal from damage. See Figure 452 and Special tools for bi-fuel engines.



1. CRANKSHAFT PULLEY
2. FRONT SEAL
3. CRANKSHAFT PULLEY INSTALLATION TOOL

Figure 452. Crankshaft Pulley Installation Tool

24. Insert the washer and bolt to retain the crankshaft pulley and spacer. See Figure 444. Tighten the bolt to specified torque value. See Bi-fuel engine specifications.

25. Align the auto tensioner with the hole on the tensioner bracket. See Figure 443.

26. Insert the bolt to retain the auto tensioner to the tensioner bracket. See Figure 443. TIghten to standard torque.

27. Install the water pump, V-belt and coolant fan. See **Cooling system** 0700SRM2300 service manual.

28. Install the alternator. See Bi-fuel electrical system repair.

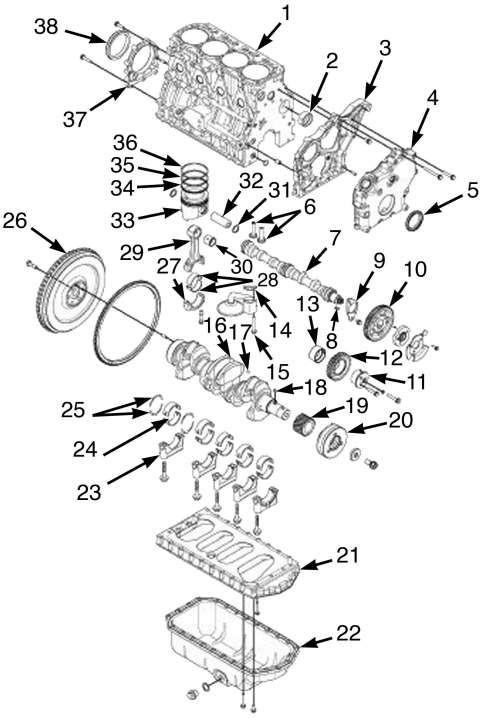
29. Install the engine. See Bi-fuel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

30. Fill the engine oil to the correct level. See Every 2000 hour periodic maintenance (PM) schedule. See **Periodic Maintenance** 8000SRM2305 for procedure.

31. Follow the procedure for priming the fuel system. See Every 500 hour periodic maintenance (PM) procedures. See **Periodic Maintenance** 8000SRM2305 for procedure.

32. Start the engine and check for leaks.

BI-FUEL CAMSHAFT AND CYLINDER BLOCK REPAIR 202001-036



1. CYLINDER BLOCK
2. CAMSHAFT BUSHING
3. GEAR CASE
4. GEAR CASE COVER
5. FRONT CRANKSHAFT SEAL
6. TAPPETS
7. CAMSHAFT
8. CAMSHAFT GEAR KEY
9. CAMSHAFT END PLATE
10. CAMSHAFT GEAR
11. IDLER GEAR SHAFT
12. IDLER GEAR
13. IDLER GEAR BUSHING
14. OIL PICKUP GASKET
15. OIL PICKUP
16. CRANKSHAFT
17. BALL
18. CRANKSHAFT GEAR KEY
19. CRANKSHAFT GEAR
20. CRANKSHAFT PULLEY
21. OIL PAN SPACER
22. OIL PAN
23. MAIN BEARING CAP
24. MAIN BEARING
25. THRUST BEARINGS
26. FLYWHEEL
27. CONNECTING ROD CAP
28. CONNECTING ROD BEARINGS
29. CONNECTING ROD
30. WRIST PIN BUSHING
31. SNAP RING
32. WRIST PIN
33. PISTON
34. OIL RING
35. SECOND COMPRESSION RING
36. TOP COMPRESSION RING
37. CRANKSHAFT REAR SEAL HOUSING
38. CRANKSHAFT REAR SEAL

Figure 453. Crankshaft and camshaft components

REMOVE THE ENGINE COMPONENTS

1. Remove the engine. See Bi-fuel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

2. Remove the starter and alternator. See Bi-fuel electrical system repair.

1. Remove the flywheel and flywheel housing. See Bi-fuel flywheel repair.

2. Remove the water pump. See Water pump repair in the **Cooling system** 0700SRM2300 service manual.

3. Remove the cylinder head. See Bi-fuel cylinder head repair.

4. Remove the oil pan, oil pump and oil suction tube. See Bi-fuel lubrication system repair.

5. Remove the timing gear case cover. See Bi-fuel timing gear case repair.

6. Remove the crankshaft drive gear and idler gear. See Bi-fuel timing gear case repair.

DISASSEMBLE

Pistons and connecting rods

NOTE: Keep the piston pin parts, piston assemblies, and connecting rod assemblies together and label all parts, to ensure all parts are returned to the same position during the reassembly process. Note the location of each bearing cap and make sure to not mix up bearing caps during installation.

NOTE: Engines with high operating hours may have a ridge near the top of the cylinders that will catch the piston rings and make it impossible to remove the pistons. Use a suitable ridge reamer to remove ridges and carbon prior to removing the pistons.

NOTE: Pistons can fall from cylinder block if the engine is inverted. Rotate the engine so the connecting rods are horizontal before removing the connecting rod caps.

1. Use a feeler gauge to measure the connecting rod side clearance. See Figure 454. Refer to Bi-fuel engine specifications for the standard limit. If the measurement is out of specification, replace the crankshaft, connecting rod, or both.

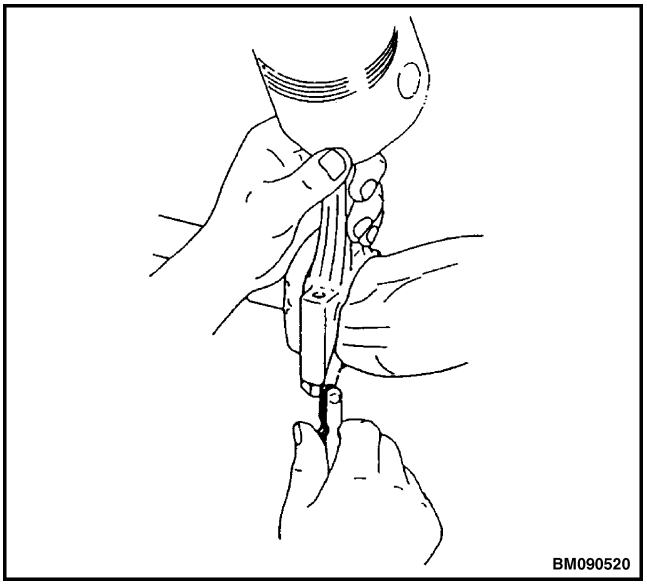
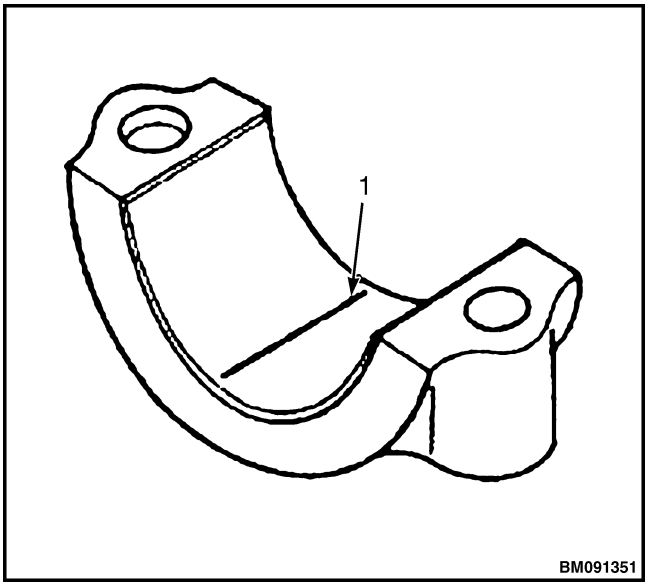


Figure 454. Connecting rod side clearance

2. Measure bearing oil clearance prior to removing the pistons and connecting rods to determine extent of wear. Record the measurements.
   a. Remove the bearing cap. Do not remove the bearings at this time.
   b. Wipe oil from the bearing and crankshaft surfaces.
   c. Place a piece of plastigauge® along the full width of the bearing (see Figure 455). Do not rotate the crankshaft when using plastigauge. A false reading may result.



1. PLASTIGAUGE

Figure 455. plastigauge placement

d. Reinstall the bearing cap and tighten to 96.0-100 N•m (70.8-73.8 lbf ft).

e. Remove the bearing cap.

f. Compare the width of the flattened plastigauge to the graduation marks on the package (see Figure 456). The mark that most closely matches the width of the flattened plastigauge will indicate the bearing oil clearance.

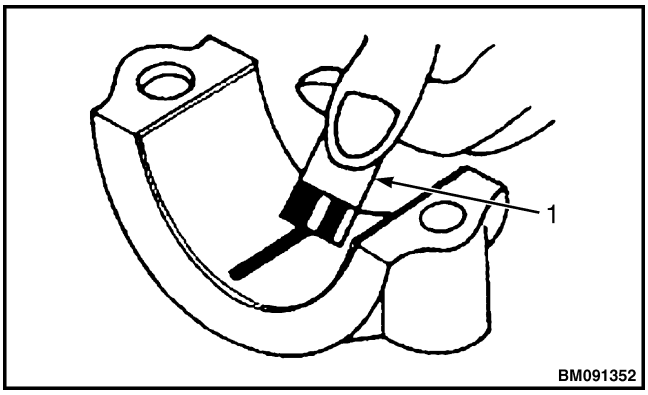


Figure 456. Graduation marks

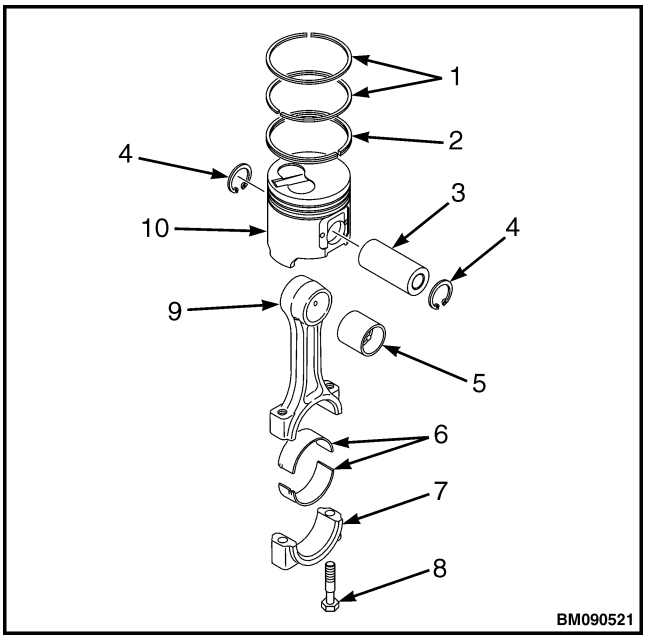
g. Repeat with each remaining connecting rod.

NOTE: Do not allow the connecting rod to contact the crankshaft journal during piston removal. Damage to the bearing journal may result.

3. Use a wooden dowel against the connecting rod and tap the piston and connecting rod assembly out of the cylinder.

4. Mark the piston, connecting rod assembly and cylinder, to aid in reinstallation. See Figure 457.

5. Remove the bearings. See Figure 457.



1. COMPRESSION RINGS
2. OIL SEAL RING
3. WRIST PIN
4. SNAP RING
5. WRIST PIN BUSHING
6. BEARINGS
7. CONNECTING ROD CAP
8. BOLT
9. CONNECTING ROD
10. PISTON

Figure 457. Piston and Connecting Rod

6. Use a piston ring expander to remove the two compression rings from the piston. See Figure 457. Refer to Special tools for bi-fuel engines for appropriate tool.

7. Use the piston ring expander to remove the oil seal ring from the piston. See Figure 457. See Special tools for bi-fuel engines for appropriate tool.

8. Remove the snap rings from the wrist pin. See Figure 457.

9. Remove the wrist pin and connecting rod from the piston. See Figure 457.

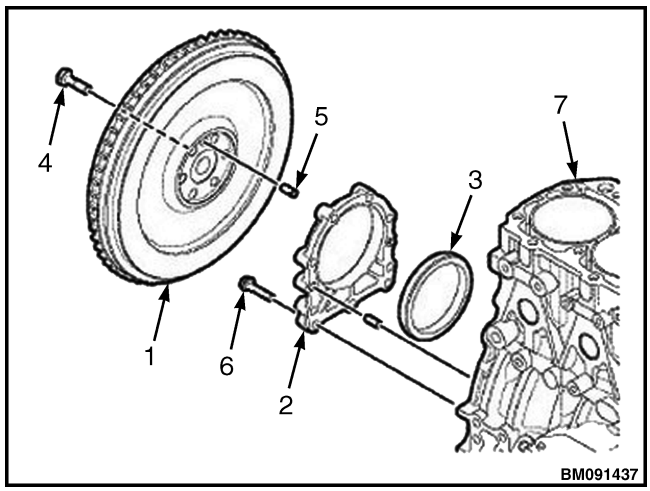
10. Repeat Step 5 through Step 9 for the remaining pistons and piston rods.

REMOVE

Crankshaft

1. Remove the flywheel from the crankshaft. See Figure 458.

2. Remove the bolts retaining the rear oil seal housing and remove the rear oil seal. See Figure 458.



1. FLYWHEEL
2. REAR OIL SEAL HOUSING
3. REAR OIL SEAL
4. FLYWHEEL HOUSING BOLT
5. DOWEL
6. OIL SEAL HOUSING MOUNTING BOLT
7. CYLINDER BLOCK

Figure 458. Rear oil seal

3. Measure the crankshaft thrust end play using one of the following two methods:

a. Install a dial gauge on the cylinder block. Move the crankshaft in and out to measure the end play. See Figure 459. Record the measurement.

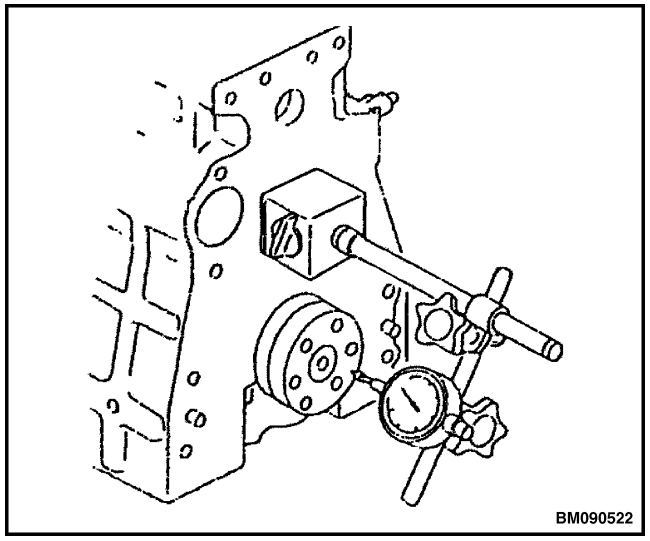
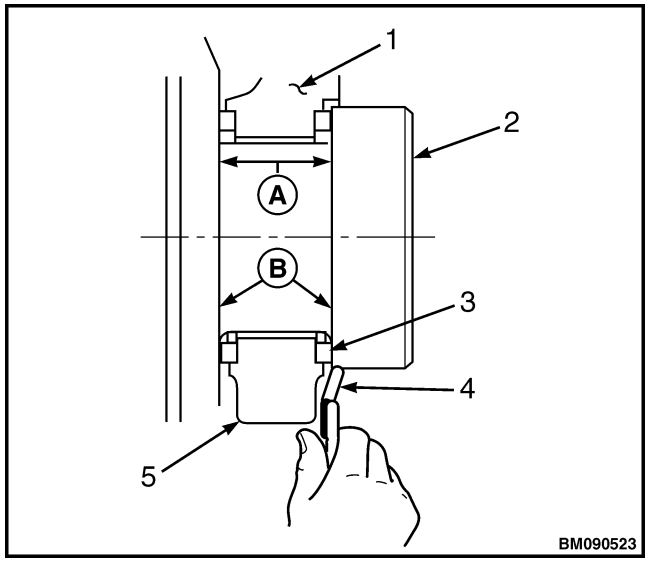


Figure 459. Crankshaft end play measurement with dial gauge

b. Use a feeler gauge to measure the clearance between the thrust bearing and the crankshaft. See Figure 460. Record the measurement.



A. STANDARD WIDTH
B. THRUST FACE

1. CYLINDER BLOCK
2. CRANKSHAFT
3. THRUST BEARING
4. SHIM GAUGE
5. CYLINDER BLOCK

Figure 460. Crankshaft side gap measurement with feeler gauge

NOTE: Be sure to note the markings on the main bearing caps, or mark them yourself, so they can be reinstalled in the same location as they were removed.

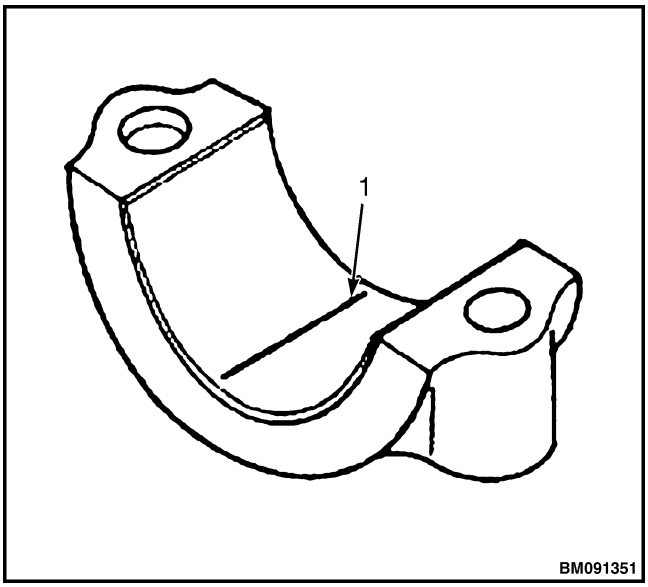
NOTE: The arrows on the main bearing caps point to the flywheel end of the engine.

4. Remove the bolts retaining the main bearing caps and remove the main bearing caps. Do not remove the bearings at this time.

5. Measure bearing oil clearance prior to removing the **crankshaft** to determine the extent of wear. Record the measurement.

a. Wipe oil from the bearing and crankshaft surfaces.

b. Place a piece of plastigauge® along the full width of the bearing (see Figure 461). Do not rotate the crankshaft when using plastigauge. A false reading may result.



1. PLASTIGAUGE

Figure 461. plastigauge placement

c. Reinstall bearing cap. Tighten the bearing cap bolt on the first pass to 48 to 50 N•m (35.4 to 36.9 lbf ft). Then torque to 96.0-100 N•m (70.8-73.8 lbf ft).

d. Remove the bearing cap.

e. Compare the width of the flattened plastigauge to the graduation marks on the package (see Figure 462). The mark that most closely matches the width of the flattened plastigauge will indicate the bearing oil clearance.

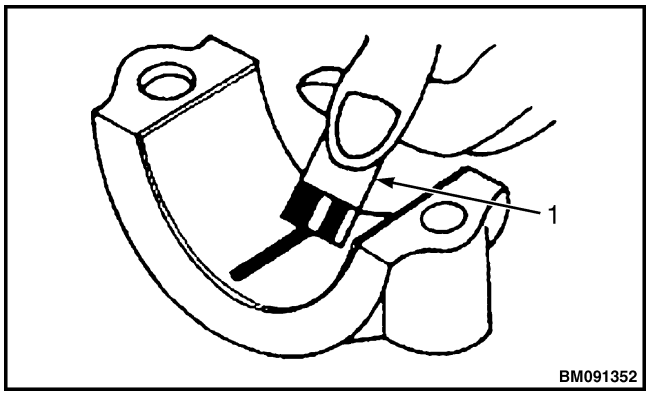


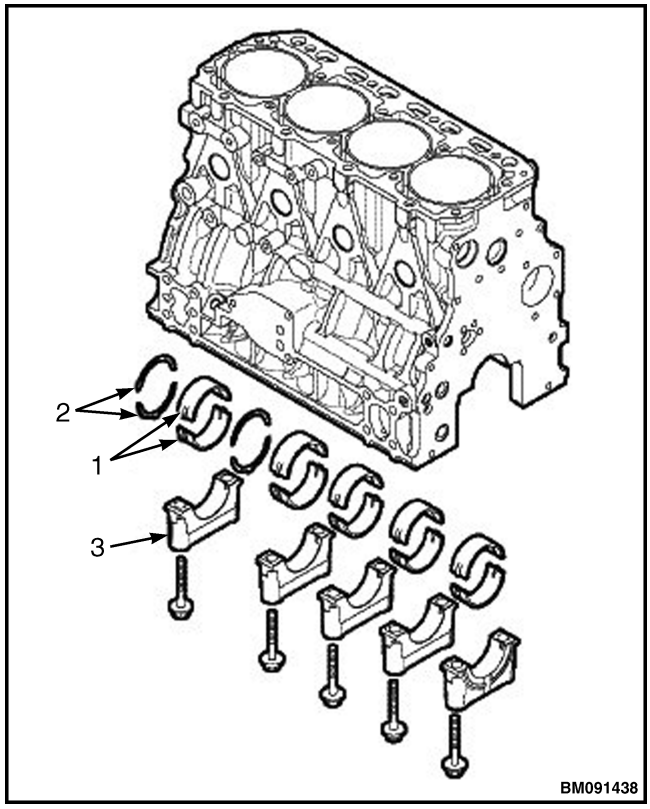
Figure 462. Graduation marks

6. Remove the crankshaft from the engine. See Figure 453.

CAUTION

Do not remove the crankshaft gear unless the gear or crankshaft are damaged and require replacement.

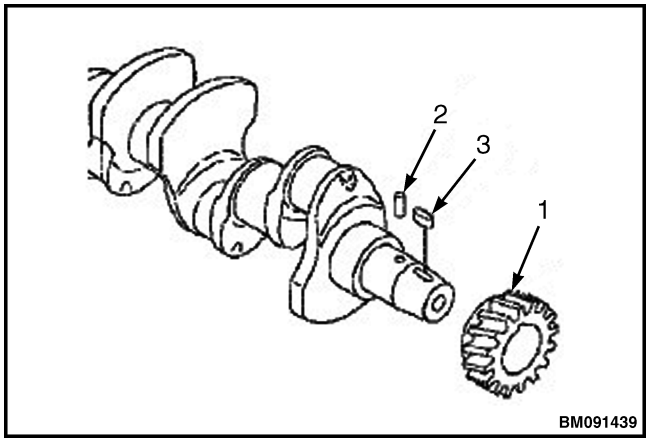
7. Remove the bearings and thrust bearings. See Figure 463.



1. BEARINGS
2. THRUST BEARINGS
3. MAIN BEARING CAPS

Figure 463. Crankshaft thrust bearings

8. If necessary, remove the crankshaft, gear, parallel pin, and key. If using a gear puller, be careful not to damage threads in the end of the crankshaft. See Figure 464.



1. CRANKSHAFT GEAR
2. PARALLEL PIN
3. KEY

Figure 464. Crankshaft

INSPECT

Crankshaft oil seals

DANGER

Always read and follow safety related precautions found on the containers of hazardous substances like parts cleaners, primers, sealants and sealant removers. Failure to comply could result in death or serious injury.

NOTE: Thoroughly clean all components using a brush and appropriate solvent such as brake cleaner or laquer thinner. Each part must be free of carbon, gasket material, metal filings and other debris.

1. Remove the front oil seal from the timing gear case cover. See Figure 465.

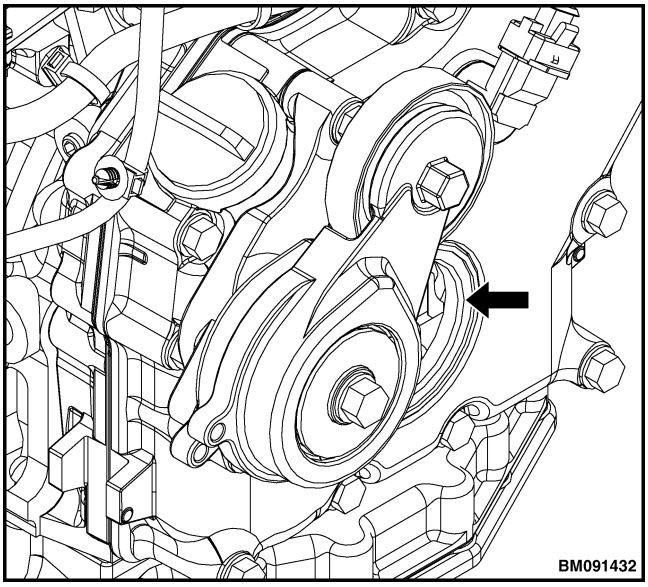
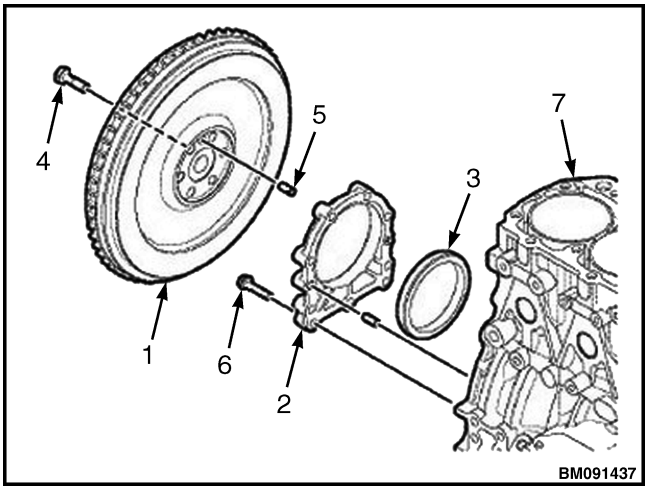


Figure 465. Front oil seal

2. Apply a continuous bead of ThreeBond Liquid Gasket Hyster part number 2084312 to the outside diameter of a new front oil seal and install in the timing gear case cover. Apply lithium grease to the lip of the seal.

3. Remove the rear oil seal from the seal housing. See Figure 466.



1. FLYWHEEL
2. REAR OIL SEAL HOUSING
3. REAR OIL SEAL
4. FLYWHEEL HOUSING BOLT
5. DOWEL
6. OILS SEAL HOUSING MOUNTING BOLT
7. CYLINDER BLOCK

Figure 466. Rear oil seal

Cylinder block

1. Verify that oil passages are clear and unobstructed. Clear any oil passages as needed.

2. Check for discoloration or evidence of cracks. If evidence of a fracture is found, use the color check method or the Magnaflux method to determine if the cylinder block is fractured.

3. Inspect the cylinder roundness and cylindricity for evidence of distortions. Collect and record the measurements. See Figure 467.

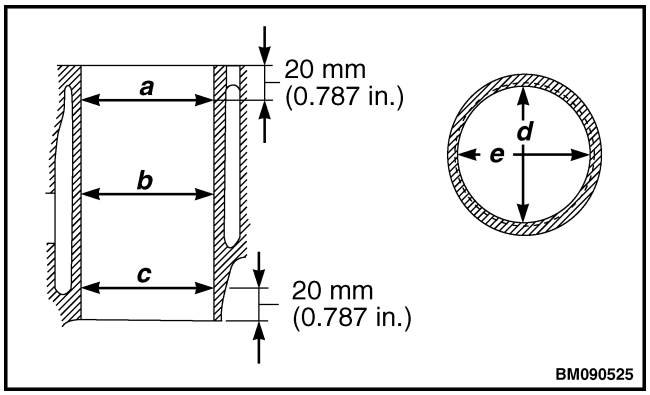


Figure 467. Cylinder measurement points

Honing and Boring

Pistons must move freely in the cylinders while maintaining adequate compression and oil sealing. If the cylinder walls are scuffed, scored, out of round, or have poor cylindricity, honing or boring and honing might correct cylinder problems. Re-boring is necessary if the bore dimensions fall outside specified limits. Honing must follow any re-boring operations. Slight imperfections can be corrected by honing alone.

1. **Boring** - Significant cylinder damage might be corrected by re-boring.
   - Boring out a cylinder block can only be done in a properly equipped machine shop.
   - After re-boring, existing pistons must be replaced. See **Parts manual** for correct part information.
   - After re-boring a cylinder block, each cylinder must be honed.

2. **Honing** - Slight cylinder imperfections might be corrected by honing.

   a. Insert the appropriate honing tool into the chuck of an electric drill.

   b. Saturate the cylinder wall with solvent using a 50% fuel and 50% engine oil mixture.

   c. Rotate the honing tool at 300 to 1200 rpm.

CAUTION

DO NOT allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.

NOTE: Tilt the honing tool at a 30 to 40 degree angle during the honing operation, to leave a cross hatch mark on the cylinder wall. See Figure 468.

   d. Insert the rotating honing tool into the cylinder and move it down through the entire length of the cylinder in a five-second motion. See Figure 469.

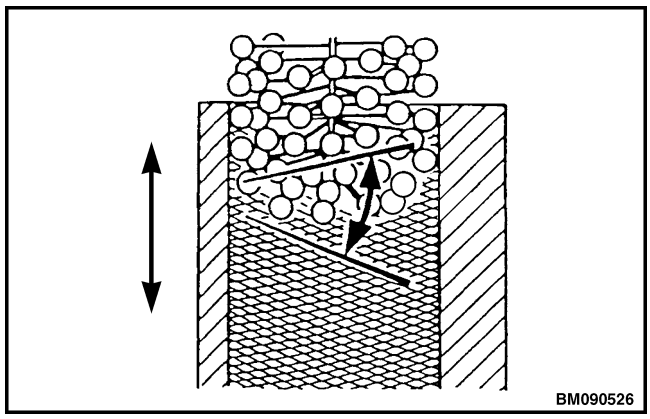


Figure 468. Cylinder honing angle

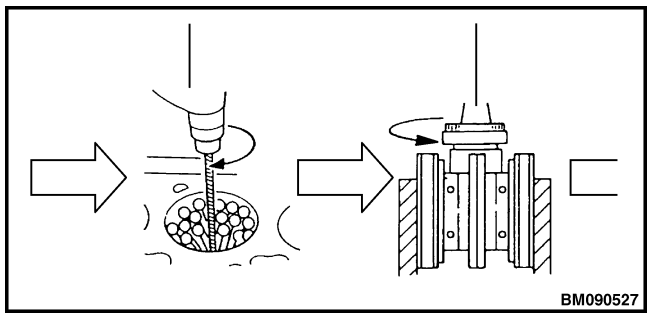


Figure 469. Cylinder honing

   e. Without stopping the honing tool, pull it up through the entire length of the cylinder in a five-second motion.

   f. Maintain the up-and-down motion for 30 to 40 seconds.

WARNING

Compressed air can move particles so that they cause injury to the user or to other personnel. Make sure that the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

   g. When the honing is completed, wash the cylinder block with hot water and soap. Use brushes to clean all passages and crevices. Rinse with hot water and blow dry with compressed air. Apply clean engine lubricating oil to all steel surfaces to prevent rusting.

Pistons

NOTE: On an engine with low hours, the pistons and piston rings may be reused if they are found to be within specifications. The piston and piston rings must be reinstalled in the same cylinders from which they were originally removed.

On an engine with high hours, the piston rings should be replaced and the cylinder honed or replaced (see Honing and Boring). The piston should be replaced as necessary.

1. Use a piston ring groove cleaning tool to clean the piston ring grooves. See Special tools for bi-fuel engines and follow manufacturer's instructions for correct operation.

2. Wash the pistons in an appropriate solvent using a soft brush.

3. Visually inspect each piston for cracks. Pay particular attention to between the piston ring grooves.

4. Use a micrometer to measure the diameter of the piston skirt at 90° to the wrist pin bore as shown in Figure 470. Refer to the Bi-fuel engine specifications for the service limit.

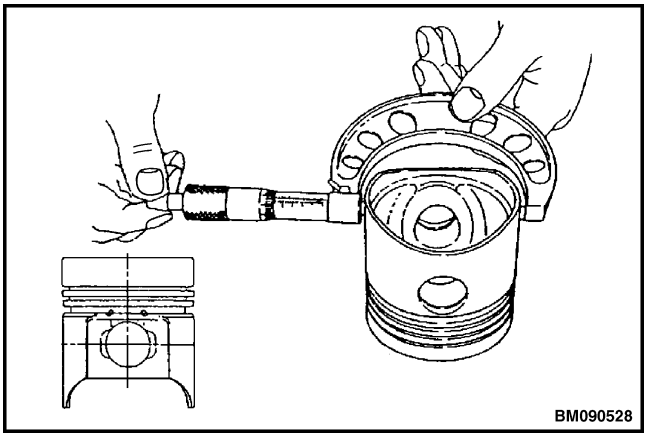


Figure 470. Piston skirt measurement

5. Subtract the piston measurement from the greatest measurement acquired during cylinder inspection to obtain piston-to-cylinder clearance. See Bi-fuel engine specifications. Record the measurements.

6. Measure the diameter of the wrist pin bore on both sides of the piston. See Figure 471. Refer to Bi-fuel engine specifications. Record the measurements.

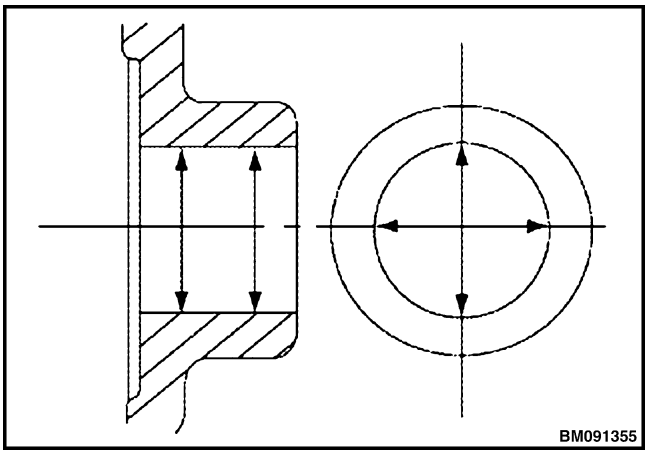


Figure 471. Diameter

7. Measure the outside diameter of the wrist pin in three places and at 90°. See Figure 472. Refer to Bi-fuel engine specifications. Record the measurements.

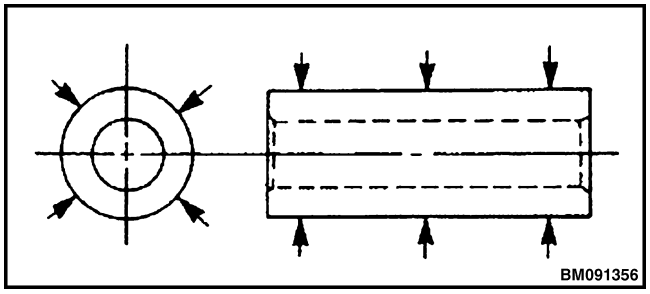


Figure 472. Outside diameter

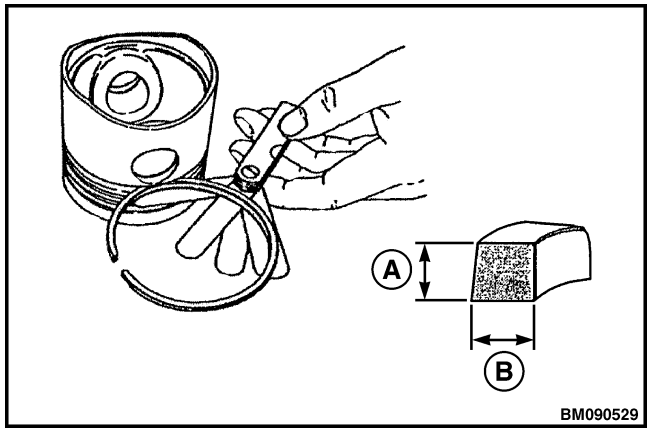
NOTE: On an engine with low hours, the pistons and piston rings may be reused if they are found to be within specifications. The piston and piston rings must be reinstalled in the same cylinders from which they were originally removed.

On an engine with high hours, the piston rings should be replaced and the cylinder honed or replaced (see Honing and Boring). The piston should be replaced as necessary.

8. Measure the piston ring and the piston ring groove for cylinder number one.

   a. Use a micrometer to measure the thickness of the top compression ring. Refer to the Bi-fuel engine specifications for the service limit. Record the measurement.

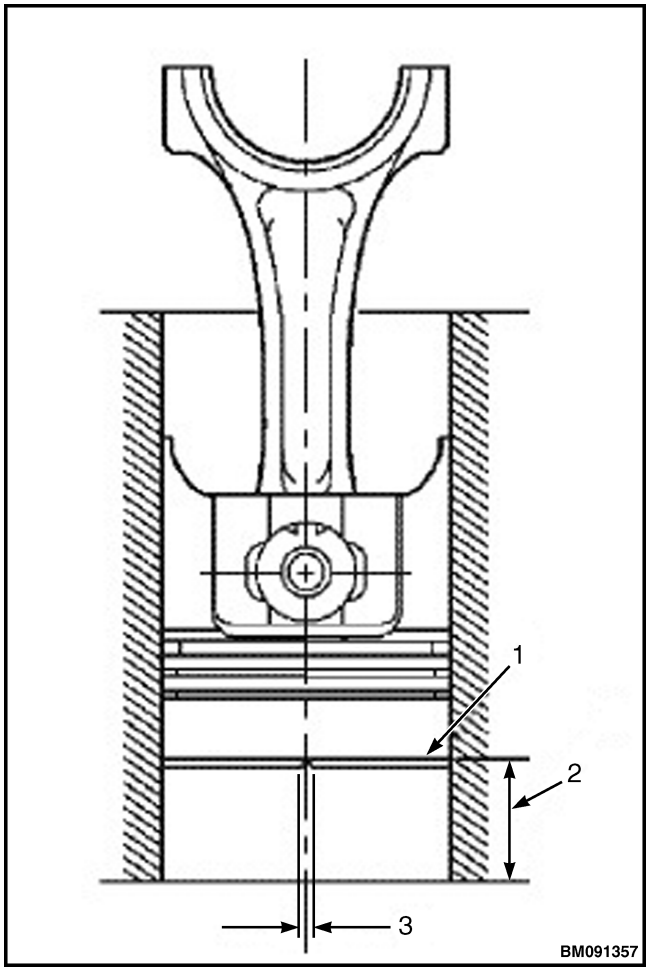
   b. Place each compression ring in the groove as shown in Figure 473. Use a feeler gauge to measure the gap between the ring and the piston. Record the measurement. Refer to the Bi-fuel engine specifications for the service limit. Replace the piston if not within specification.



A. WIDTH
B. THICKNESS

Figure 473. Piston and piston ring groove clearance

9. To measure piston ring end gap, insert each compression ring, one at a time, into the cylinder (see, Figure 474). Use a piston with the piston rings removed to slide the ring into the cylinder bore until it is approximately 30 mm (1.18 in.) from the bottom of the bore. Remove the piston. Measure the end gap of each piston ring. Record the measurements. See Bi-fuel engine specifications.



1. COMPRESSION PISTON RING
2. BORE MEASUREMENT
3. END GAP

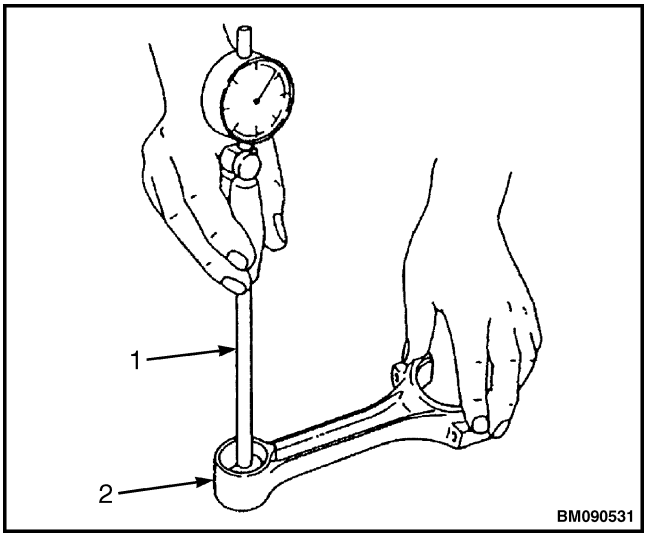
Figure 474. Piston and cylinder bore

NOTE: Always check the piston ring end gap when installing new piston rings. See Bi-fuel engine specifications. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.

10. Repeat Step 8 for each of the pistons.

Connecting Rod

1. Use a bore gauge to measure the wrist pin bushing bore. Replace the bushing if not within specifications. If the bushing has been removed, measure the inside diameter of the connecting rod small end. Refer to the Bi-fuel engine specifications for the service limit. See Figure 475.



1. CYLINDER GAUGE
2. CONNECTING ROD SMALL END

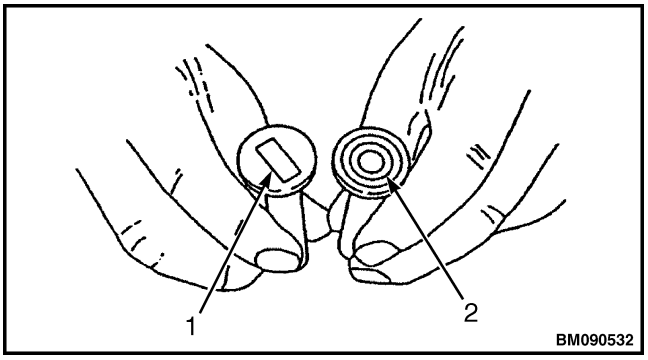
Figure 475. Connecting rod small end

2. Measure the crankpin and connecting rod bearings. Place the connecting rod bearings into the connecting rod and connecting rod cap. Install the end of the connecting rod to the connecting rod cap. Install the bolts and tighten to 54 to 59 N•m (40 to 44 lbf ft).

3. Measure the inside diameter. Refer to Bi-fuel engine specifications for the service limit.

Tappets

1. Check the tappet contact surfaces for abnormal wear. Slight surface defects can be corrected using an oilstone. See Figure 476.



1. ABNORMAL CONTACT SURFACE
2. NORMAL CONTACT SURFACE

Figure 476. Tappet contact surface

2. Measure the outside diameter of the tappet stem. Refer to Bi-fuel engine specifications for the service limit. See Figure 477.

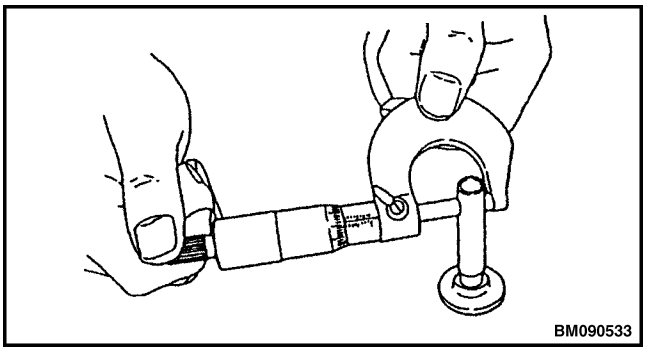
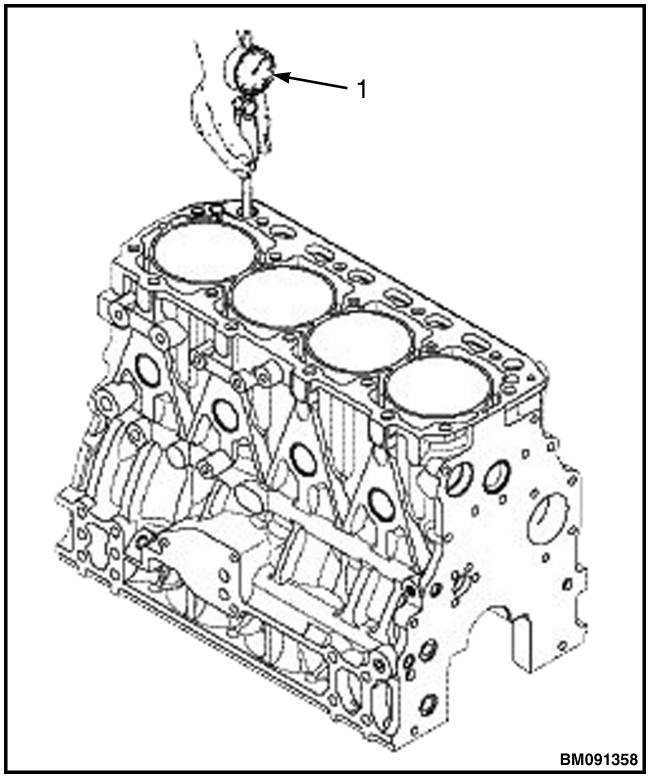


Figure 477. Tappet stem measurement

3. Use a cylinder gauge to measure the inside diameter of the tappet bore. See Figure 478.



1. CYLINDER GAUGE

Figure 478. Measure tappet bore

Crankshaft

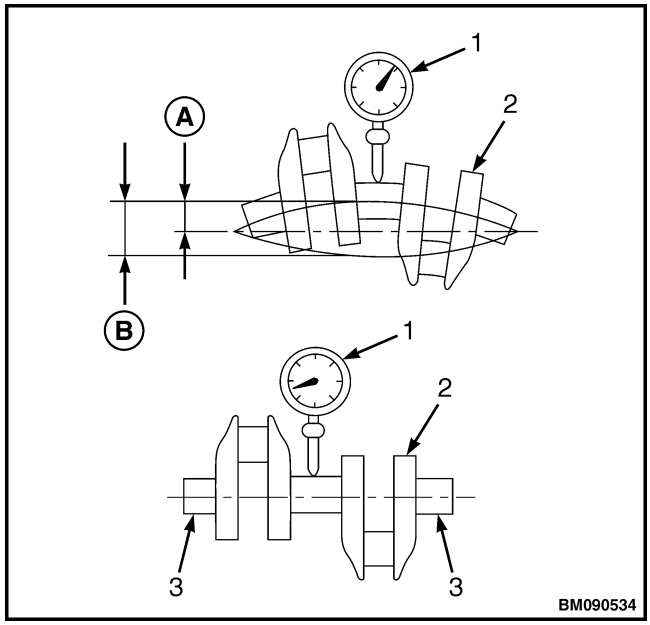
1. Measure the trueness of the crankshaft.

   a. Place the crankshaft on V-blocks at the end journals. See Figure 479.

   b. Place a dial indicator on a main bearing journal and zero the gauge.

   c. Rotate the crankshaft and observe the run out. Refer to the Bi-fuel engine specifications for the service limit.

   d. Repeat this procedure for the remaining bearing journals.



A. BEND
B. DEFLECTION

1. DIAL GAUGE
2. CRANKSHAFT
3. V-BLOCK

Figure 479. Crankshaft bend measurement

2. Inspect the crankshaft for fractures.

   a. Use the color check or Magnaflux method to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures are found. See Figure 480.

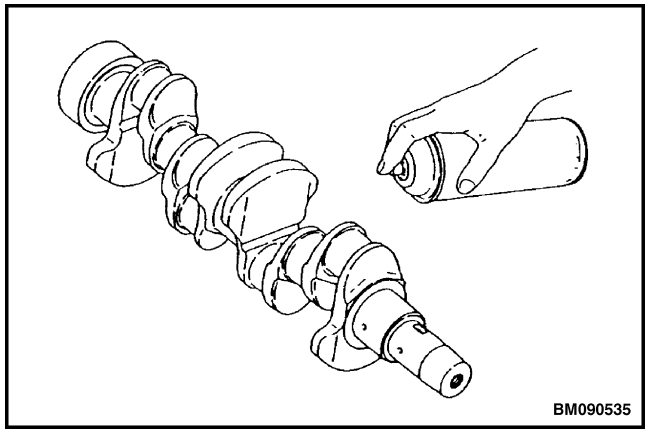


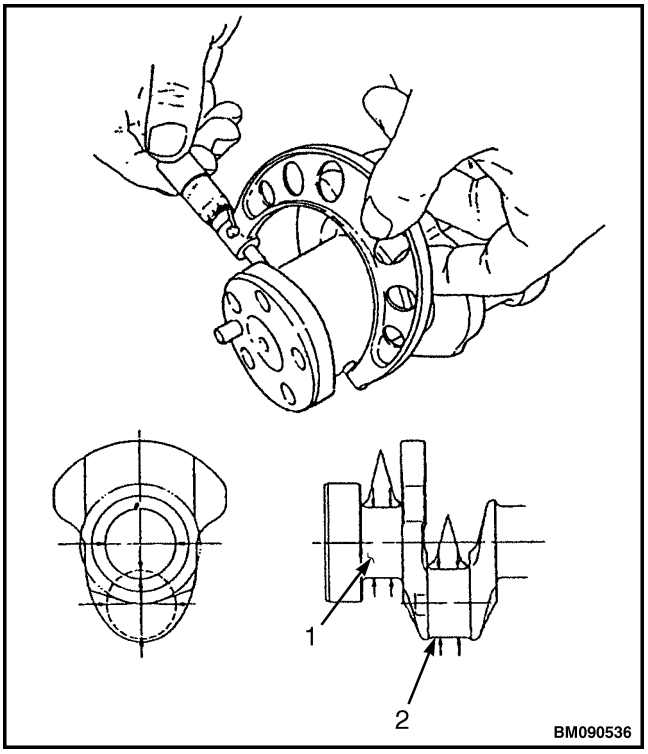
Figure 480. Crankshaft fracture check

   b. If the color check method is not available, spray Magnaflux on the crankshaft to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures are found.

3. Measure the outside diameter of each crankpin and main bearing journal. See Figure 481.

   a. Take measurements at several places around each bearing journal. Refer to Bi-fuel engine specifications for the service limit.

   b. If the bearing journal clearance exceeds the service limit, use an undersized bearing. Refer to the Bi-fuel engine specifications for the service limit.



1. CRANKSHAFT JOURNAL
2. CRANKPIN

Figure 481. Crankpin and crankshaft journal measurement

Camshaft

1. Measure the trueness of the camshaft.

a. Place the camshaft on V-blocks positioned at the end journals. See Figure 482.

b. Place a dial indicator on the on the center bearing journal and set the gauge to zero.

c. Rotate the camshaft and observe the run out. Refer to the Bi-fuel engine specifications for the service limit.

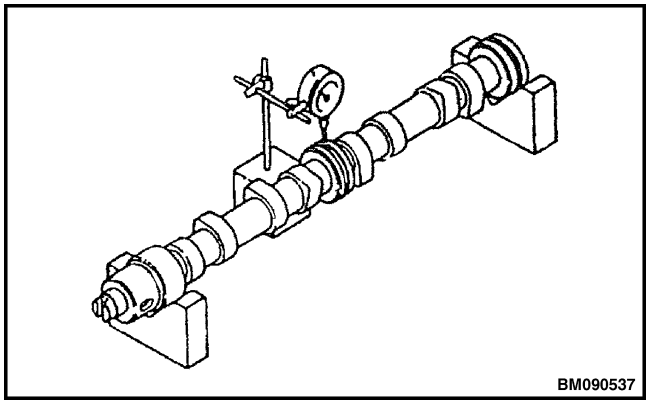
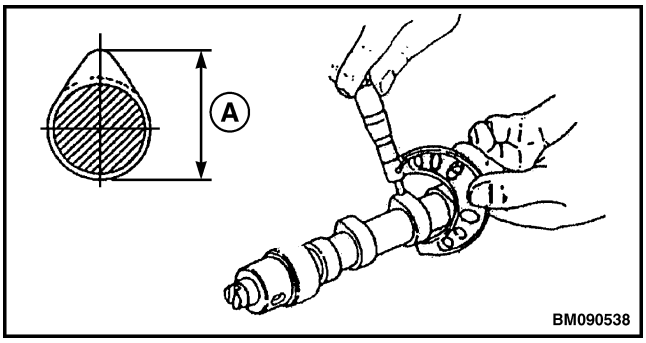


Figure 482. Camshaft Run out Check

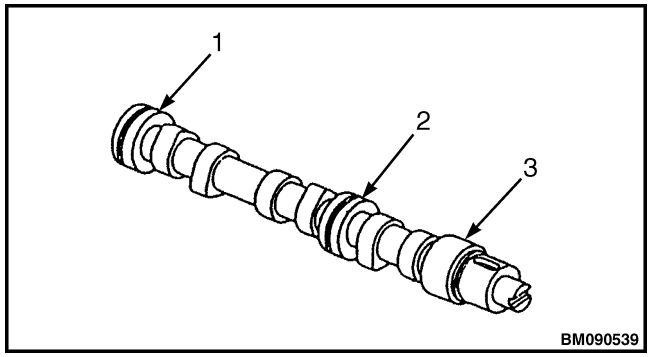
2. Measure the intake/exhaust cam lobe height. Refer to the Bi-fuel engine specifications for the service limit. See Figure 483.



A. CAM HEIGHT

Figure 483. Intake/Exhaust Cam Lobe Height Measurement

3. Measure the gear end bearing surface, intermediate position bearing surface, and flywheel end bearing surface diameters. See Figure 484. Determine the oil clearance. The oil clearance is calculated by subtracting the measured camshaft bearing surface diameter from the camshaft bushing inside diameter. Refer to the Bi-fuel engine specifications for the service limit.



1. FLYWHEEL END BEARING SURFACE
2. INTERMEDIATE POSITION BEARING SURFACE
3. GEAR END BEARING SURFACE

Figure 484. Camshaft Bearing Surface Measurements

Camshaft bushing and bores

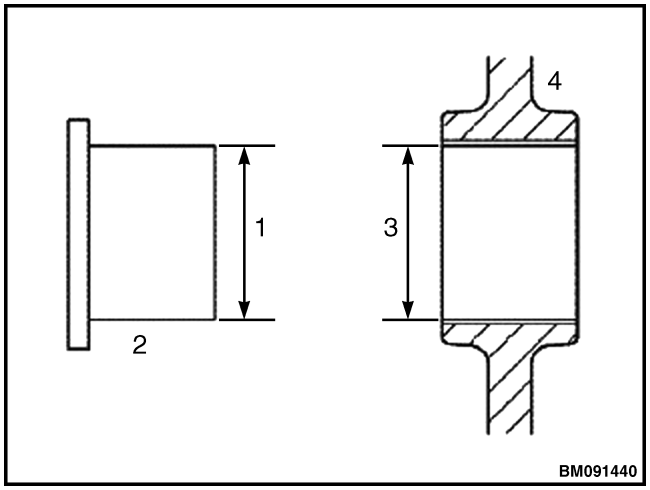
1. Measure the inside diameter of the front bushing and the remaining bores in the cylinders block. See Figure 453. Refer to Table 73 in Bi-fuel engine specifications.

2. If the camshaft bushing is not within specification, replace it using the appropriate service tool. If the remaining bores are not within specification, the cylinder block will require replacement as there are no alternative bearings available to correct the bearing to camshaft journal oil clearance specification.

Idler gear and shaft

1. Measure the outside diameter of the idler gear shaft. See Figure 485. Refer to Bi-fuel engine specifications.

2. Measure the inside diameter of the idler gear bushing. See Figure 485. Refer to Bi-fuel engine specifications.



1. OUTSIDE DIAMETER
2. IDLER GEAR SHAFT
3. INSIDE DIAMETER
4. IDLER GEAR BUSHING

Figure 485. Idler gear

ASSEMBLE

NOTE: Proceed slowly. Make no forced assemblies unless a pressing operation is called for. All parts must be perfectly clean and lightly lubricated when assembled.

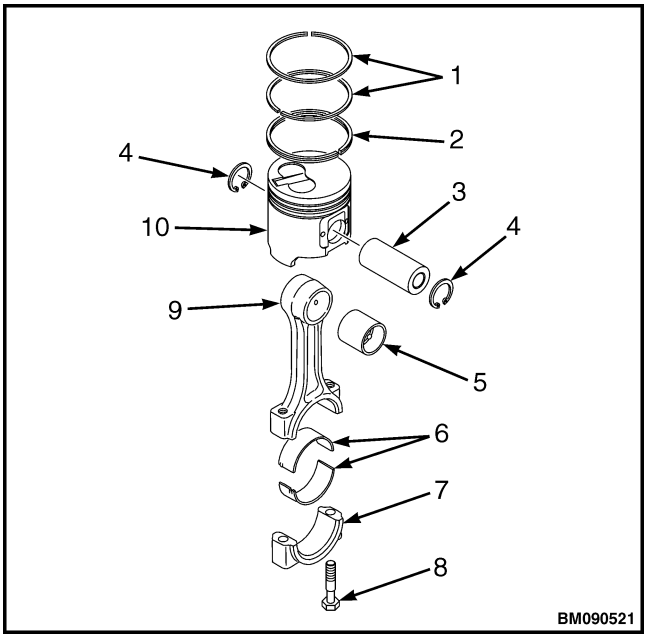
NOTE: Always use new gaskets, seals and O-rings during assembly.

NOTE: Apply clean engine lubricating oil to all internal parts during assembly.

Pistons and Connecting Rods

1. Select the components needed to assemble the piston and connecting rod for the Number 1 cylinder. See Figure 486.

2. Lubricate and use a press to insert the wrist pin bushing. Be sure to align the oil holes. See Figure 486.



1. COMPRESSION RINGS
2. OIL SEAL RING
3. WRIST PIN
4. SNAP RING
5. WRIST PIN BUSHING
6. BEARINGS
7. CONNECTING ROD CAP
8. BOLT
9. CONNECTING ROD
10. PISTON

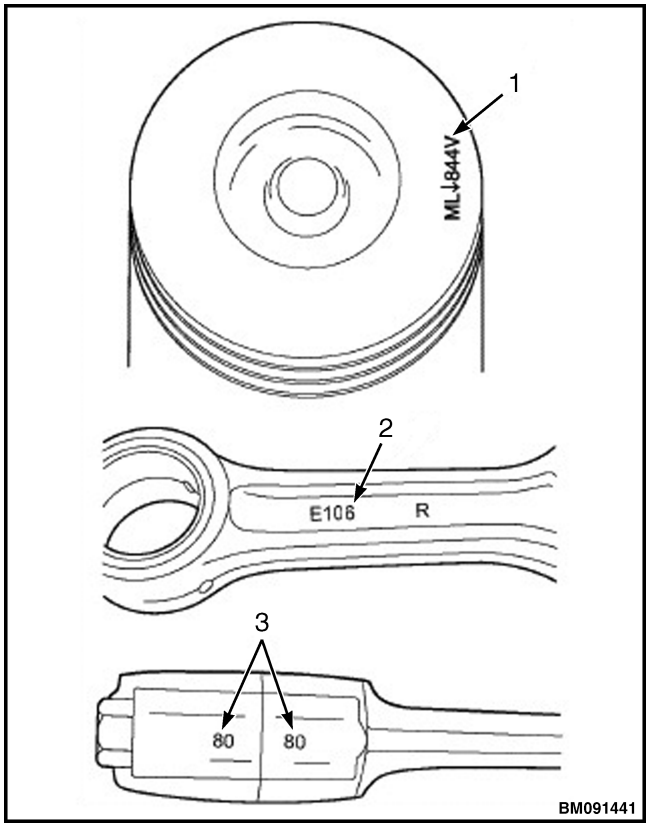
Figure 486. Piston and Connecting Rod

3. Install one snap ring into the piston. See Figure 486.

NOTE: The piston and connecting rod must be assembled together in the correct orientation. The orientation of the piston and connecting rod are different depending on engine model.

The actual appearance of the match marks on the piston and connecting rod may vary, but they will always be in the same locations.

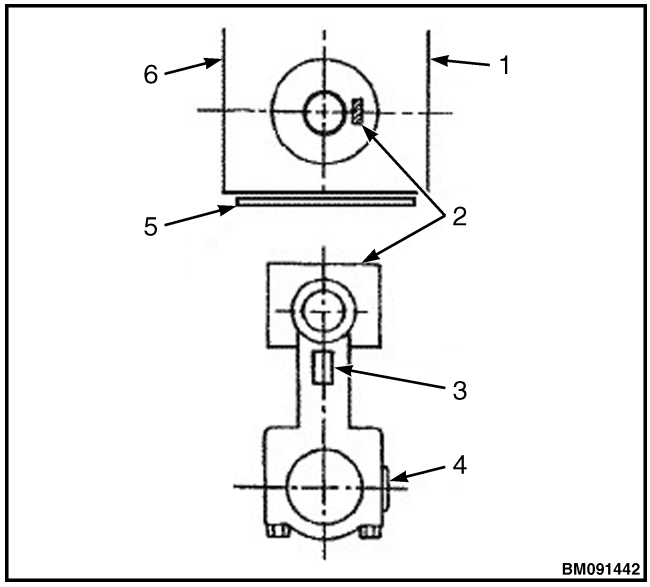
4. Orient the piston identification mark stamped on top of the piston on the same side as the rod and cap match marks stamped on the connecting rod. See Figure 487.



1. PISTON IDENTIFICATION MARK
2. EMBOSSED MARK (ON CONNECTING ROD)
3. MATCHING ROD AND CAP MARKS

Figure 487. Piston and connecting rod identification marks

5. Confirm when the piston is installed in the cylinder, the piston identification mark stamped on the top of the piston is facing the oil filter side of the engine and the embossed mark on the connecting rod is facing the flywheel side. See Figure 488.



1. OIL FILTER SIDE OF ENGINE
2. PISTON IDENTIFICATION MARK
3. EMBOSSED MARK ON CONNECTING ROD
4. ROD AND CAP MATCH MARKS
5. FLYWHEEL END OF ENGINE
6. CAMSHAFT SIDE OF ENGINE

Figure 488. Piston installed

6. Lubricate and install the piston wrist pin through the piston and connecting rod. See Figure 486.

7. Install the second snap ring and confirm it is fully seated in the groove. See Figure 486.

NOTE: Always check the piston ring end gap when installing new piston rings. See Bi-fuel engine specifications. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.

8. Use piston ring pliers to install the piston rings.

a. Install each piston ring on the piston with the punched manufacture's mark facing upward. See Figure 489.

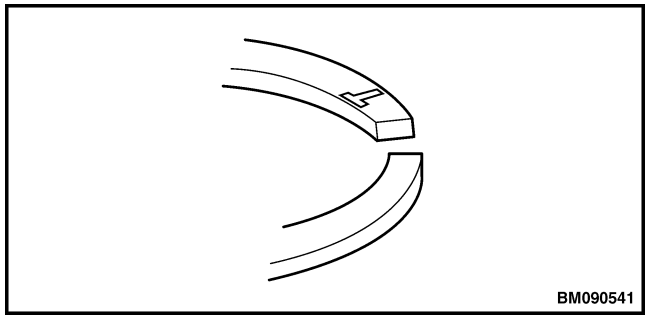
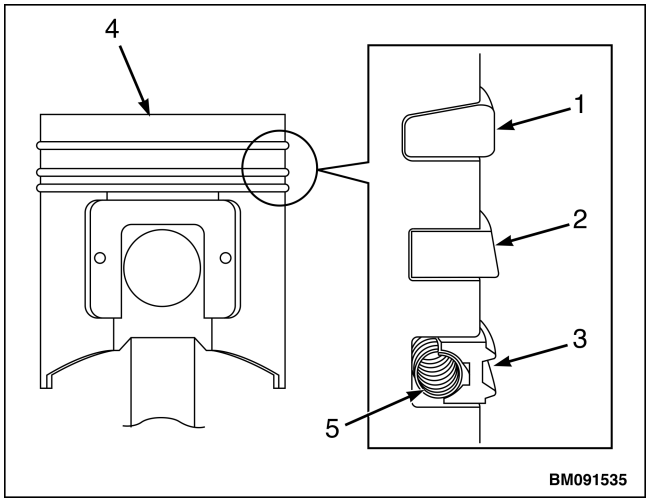


Figure 489. Piston ring mark

b. Install the top compression ring, second compression ring, and oil ring. See Figure 490.

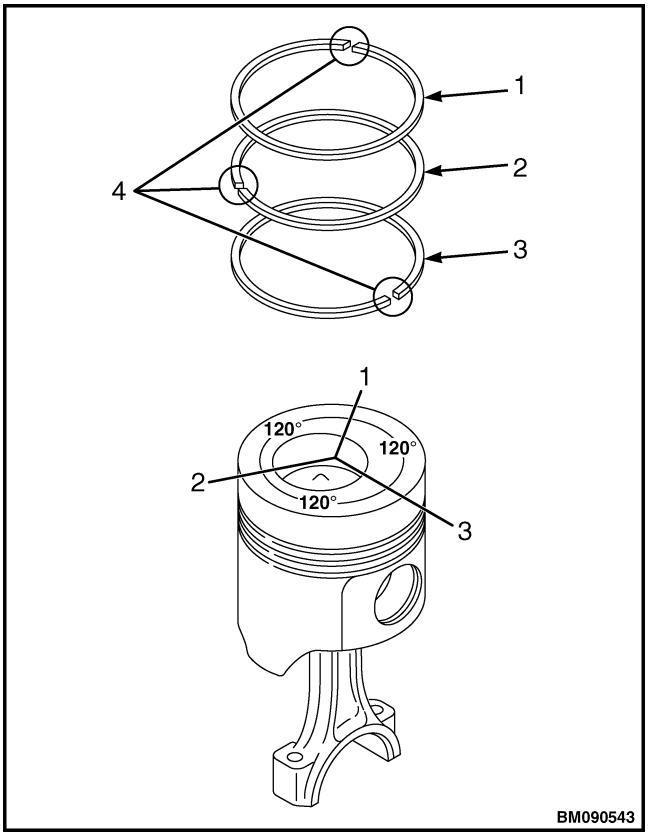
c. Confirm the oil ring coil expander end gap is located 180° from the oil ring end gap. See Figure 490.



1. TOP COMPRESSION RING
2. SECOND COMPRESSION RING
3. OIL RING
4. PISTON
5. OIL RING COIL EXPANDER

Figure 490. Piston rings

d. Stagger the piston ring joints at 120° intervals. DO NOT position the top compression ring joint in line with the piston wrist pin. The coil expander joint must be opposite the oil ring joint. See Figure 491.



1. TOP COMPRESSION RING
2. SECOND COMPRESSION RING
3. OIL RING
4. JOINTS

Figure 491. Piston rings staggering

9. Perform Step 1 through Step 8 for the assembly of each remaining piston.

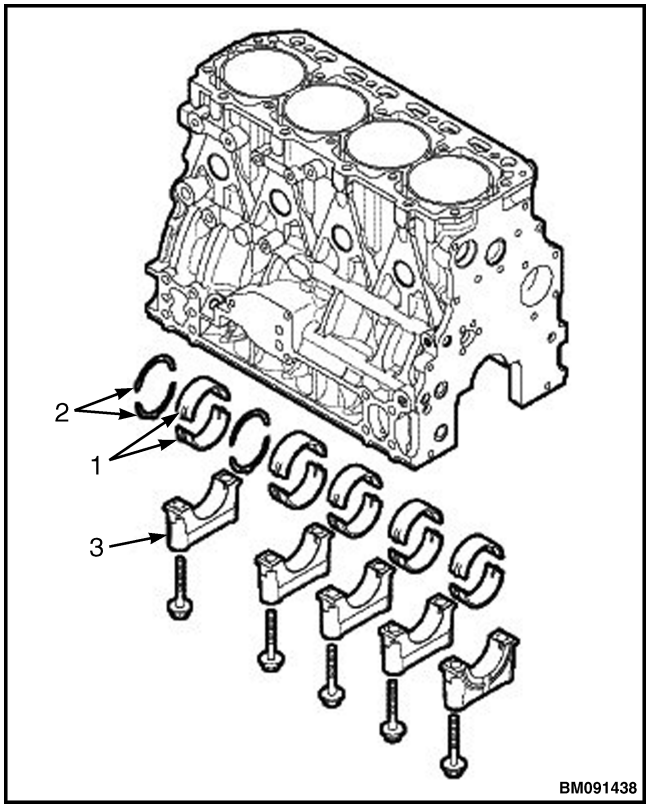
INSTALL

Crankshaft

1. If removed, reinstall the key, parallel pin and crankshaft gear on the crankshaft. See Figure 464.

2. Reinstall new bearings and thrust bearing in the cylinder block and main bearing caps. See Figure 492.

3. Apply a liberal coat of engine lubricating oil to the bearings and crankshaft journal. See Figure 492.



1. BEARINGS
2. THRUST BEARINGS
3. MAIN BEARING CAPS

Figure 492. Crankshaft thrust bearings

4. Place the crankshaft into the engine. See Figure 453.

NOTE: The main bearing caps are numbered and have arrows for proper positioning. The No. 1 cap is located at the flywheel end. The arrows point towared the flywheel end of the engine.

5. Reinstall the main bearing caps. See Figure 492.

6. Apply a liberal coat of engine lubricating oil to the bearings cap bolts and tighten the bolts to the specified torque in two stages. Torque to 48 to 50 N•m (35.4 to 36.9 lbf ft) on first pass then torque to 96 to 100 N•m (70.8 to 73.8 lbf ft).

7. Rotate the crankshaft to confirm it turns freely.

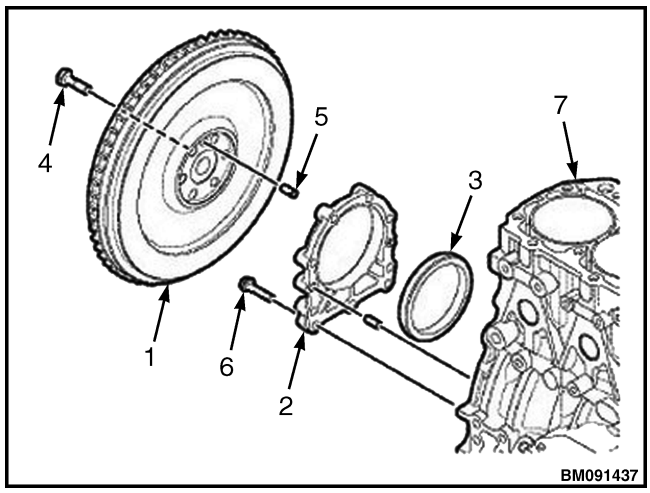
8. Apply a continuous bead of ThreeBond Liquid Gasket Hyster part number 2084312 to the mounting flange of the seal housing.

9. Align the rear oil seal housing with the two dowel pins. See Figure 493.

10. Insert the bolts to retain the rear oil seal housing and rear oil seal. See Figure 493. Tighten to standard torque.

11. Install the flywheel on to the crankshaft. See Figure 493.

12. Insert the bolts to retain the flywheel. See Figure 493. Torque to 83.3 to 88.2 N•m (61 to 65 lbf ft).



1. FLYWHEEL
2. REAR OIL SEAL HOUSING
3. REAR OIL SEAL
4. FLYWHEEL HOUSING BOLT
5. DOWEL PIN
6. OILS SEAL HOUSING MOUNTING BOLT
7. CYLINDER BLOCK

Figure 493. Rear oil seal

Pistons

NOTE: Do not allow the connecting rod to contact the crankshaft journal during piston installation. Damage to the crankshaft journal may result.

1. Lubricate the Number 1 piston, piston rings, and cylinder with clean engine lubricating oil.

2. Rotate the crankshaft so the crankpin for the piston being installed is near the bottom dead center.

3. Confirm the piston ring gaps are located correctly. See Figure 491.

4. Use a piston ring compressor to compress the piston rings on the Number 1 piston. See Bi-fuel engine specifications.

5. Carefully install the piston into the Number 1 cylinder. Be sure the punched mark on the connecting rod is facing the oil filter side and the embossed mark is facing the flywheel. See Figure 457.

6. Install the connecting rod bearings into the connecting rod and connecting rod cap.

7. Apply a liberal coat of clean engine oil to the bearings and crankshaft journal.

8. Install a light coat of clean engine oil to the rod cap bolts. Reinstall the connecting rod cap. Tighten the connecting rod bolts to 44.1-49 N•m (33-36 lbf ft) N•m in two stages (½ torque first, then full torque).

9. Perform Step 1 through Step 6 to install the remaining pistons in their respective cylinders.

INSTALL THE ENGINE COMPONENTS

1. Install the crankshaft drive gear and idler gear. See Bi-fuel timing gear case repair.

2. Install the oil pump. See Bi-fuel lubrication system repair.

3. Install the timing gear case cover. See Bi-fuel timing gear case repair.

4. Install the oil pan. Install the oil suction tube. See Bi-fuel lubrication system repair.

5. Install the cylinder head. See Bi-fuel cylinder head repair.

6. Install the water pump. See Water pump repair in the **Cooling system** 0700SRM2300 service manual.

7. Install the alternator. See Bi-fuel electrical system repair.

8. Install the flywheel and flywheel housing. See Bi-fuel flywheel repair.

9. Install the starter. See Bi-fuel electrical system repair.

10. Install the engine. See Bi-fuel engine removal and replacement in the **Drive Train** 0900SRM2301 service manual.

BI-FUEL LUBRICATION SYSTEM REPAIR 202001-037

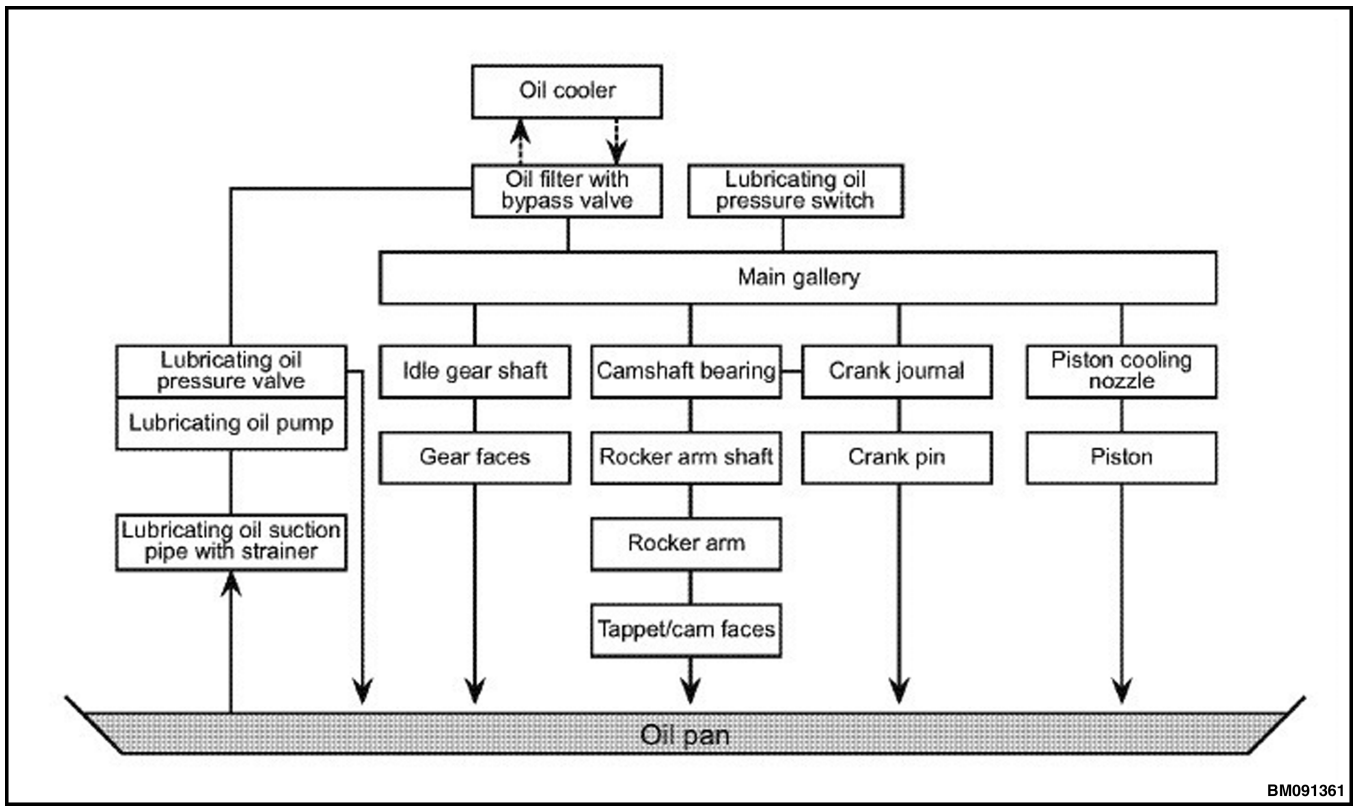
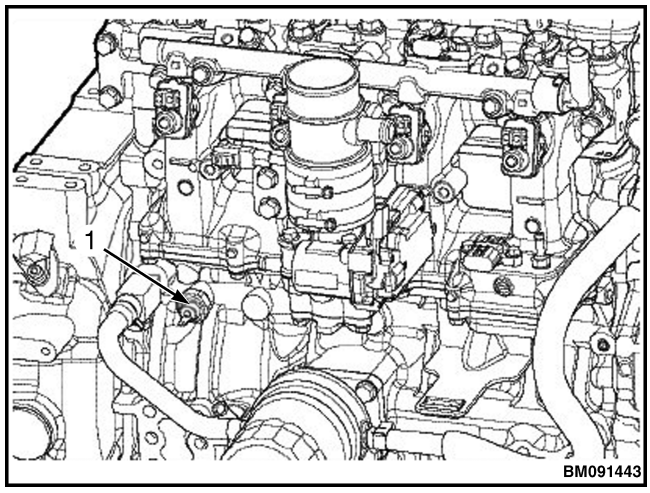


Figure 494. Lubrication system diagram

CHECK ENGINE LUBRICATING OIL PRESSURE

An engine oil pressure check must be performed if the oil pressure indicator is on, or the engine oil pressure gauge on the instrument panel indicates low engine oil pressure. See Table 120 for specifications.

1. Locate the oil pressure switch. See Figure 495. Disconnect the electrical connector (not shown) from the oil pressure switch.



1. OIL PRESSURE SWITCH

Figure 495. Oil pressure switch

2. Remove the oil pressure switch.

3. Insert a mechanical oil pressure gauge into the port where the oil pressure switch was removed.

4. Start the engine. Rev the engine to the RPM indicated in the table below (see Table 120). Compare the reading on the oil pressure gauge to the specifications listed in the table.
   - If the mechanical oil pressure test gauge indicates satisfactory oil pressure (see Table 120 for specifications), the oil pressure switch or sending unit must be replaced.
   - If the mechanical oil pressure test gauge indicates low oil pressure (see Table 120 for specifications), follow steps to troubleshoot the lubrication system to determine the cause of low engine oil pressure. See **Guided troubleshooting** for this lift truck.

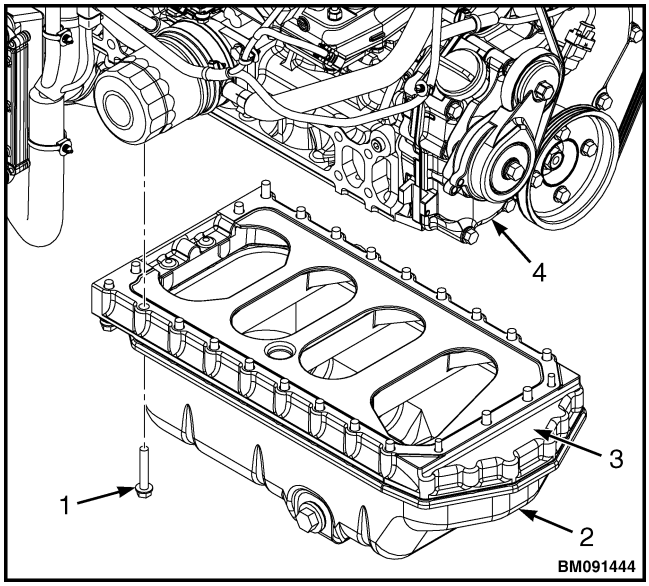
REMOVE

Oil pan

1. Remove the engine assembly from the lift truck and place on an engine stand. See LPG engine removal and replacement.

2. Invert the engine (oil pan side up) on the engine stand.

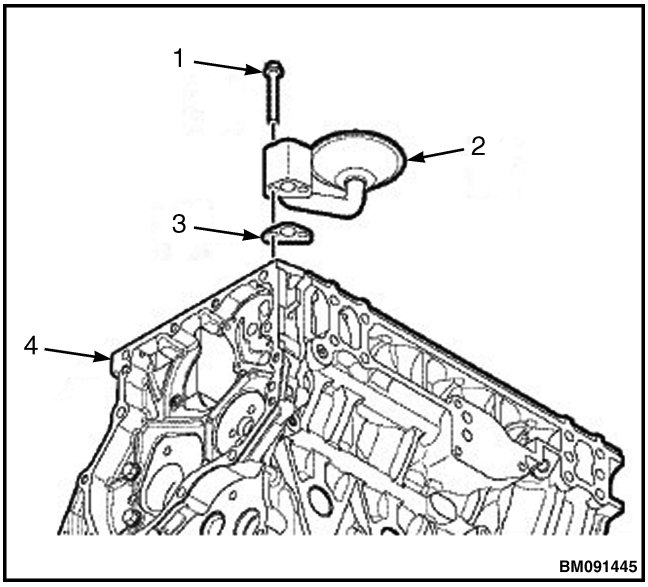
3. Remove 26 bolts retaining the oil pan and oil pan spacer to the engine block. See Figure 496.



1. BOLT
2. OIL PAN
3. OIL PAN SPACER
4. ENGINE BLOCK

Figure 496. Oil pan

4. Remove the oil pickup tube and gasket. See Figure 497.



1. BOLT
2. OIL PICKUP TUBE
3. GASKET
4. ENGINE BLOCK

Figure 497. Oil pickup tube

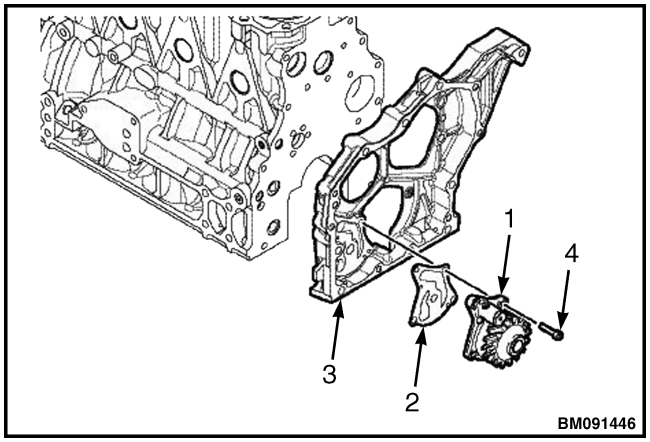
Oil pump

1. Remove the fan guard, cooling fan, spacer, water pump V-pulley and V-belt. See **Cooling system** 0700SRM2300 service manual.

2. Remove the crankshaft pulley and timing gear case cover. See Bi-fuel timing gear case repair.

3. Remove the oil pump mounting bolts. See Figure 498.

4. Remove the oil pump assembly from the timing gear case flange. See Figure 498.



1. OIL PUMP ASSEMBLY
2. GASKET
3. TIMING GEAR CASE FLANGE
4. OIL PUMP MOUNTING BOLTS

Figure 498. Oil pump

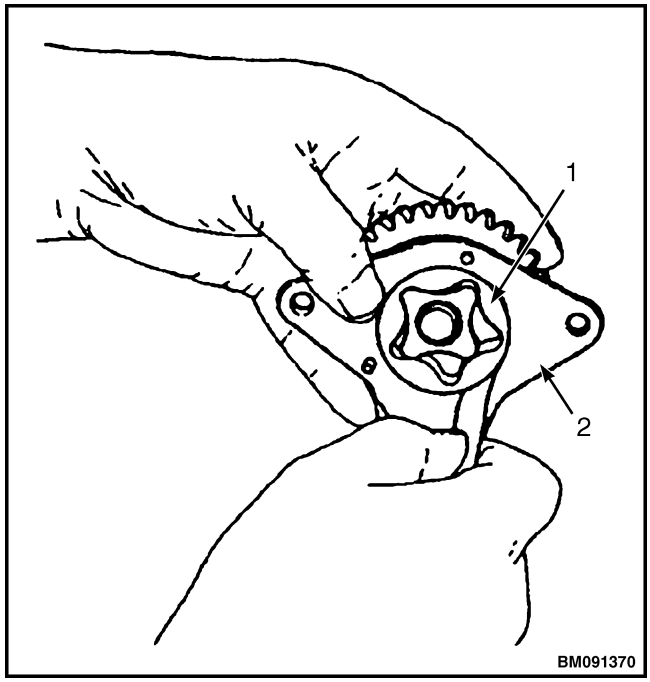
Clean and inspect

NOTE: Internal components of the oil pump cannot be purchased separately. If any component is worn or damaged, replace the oil pump assembly.

Clean all of the parts with cleaning solvent. Dry the parts with compressed air. Inspect for wear and damage. If necessary, replace oil pump assembly.

Outer rotor outside clearance

Inspect the outside diameter clearance of the outer rotor, by inserting a feeler gauge between the outer rotor and the oil pump body. See Figure 499. Record the measurements, and see Table 121 for service limits.

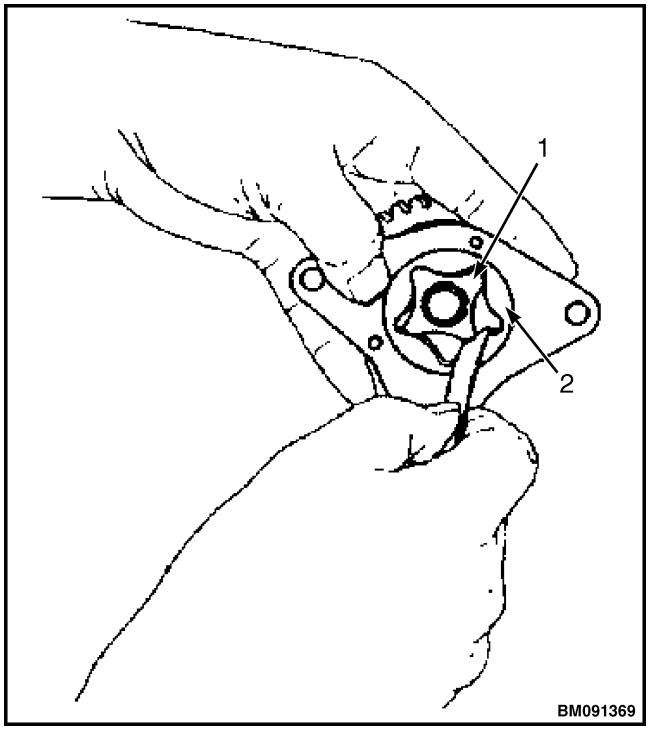


1. OUTER ROTOR
2. PUMP BODY

Figure 499. Outer rotor outside clearance check

Outer rotor to inner rotor tip clearance

Inspect the tip clearance between the outer and inner rotors, by inserting a feeler gauge between the inner rotor tooth tip and the outer rotor tooth tip. See Figure 500. Measure the clearance. Record the measurements, and see Table 123 for service limits.



1. INNER ROTOR TOOTH TIP
2. OUTER ROTOR TOOTH TIP

Figure 500. Inner rotor tip clearance check

Outer rotor side clearance

Inspect the side clearance between the oil pump body and the outer rotor, by using a straight edge and feeler gauge or a depth micrometer. See Figure 501. Record the measurements, and see Table 122 for service limits. for service limits.

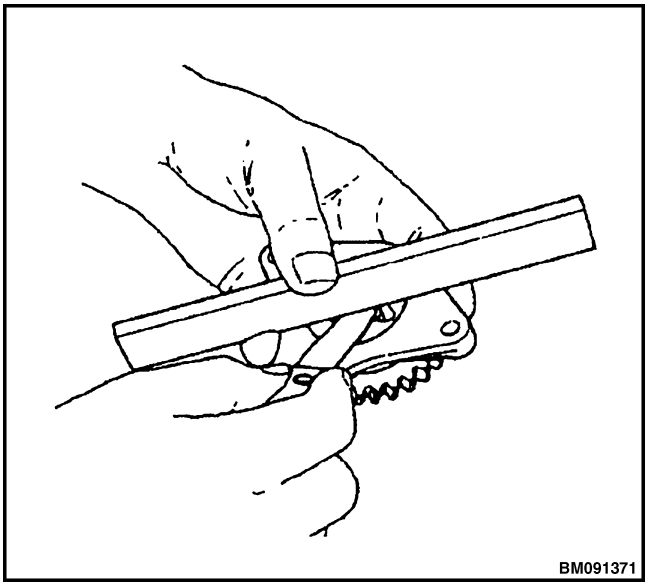
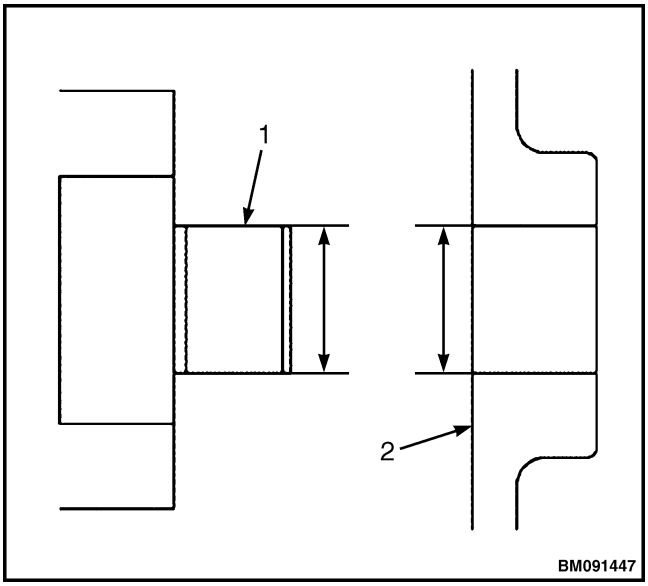


Figure 501. Outer rotor side clearance check

Rotor shaft clearance

Inspect the rotor shaft clearance, by measuring the outside diameter of the rotor shaft and the inside diameter of the cover. Determine clearance by subtracting the outside diameter of the rotor from the inside diameter of the cover. See Figure 502. Record the measurements, and see Table 124 for service limits. for service limits.



1. ROTOR SHAFT
2. OIL PUMP COVER

Figure 502. Rotor shaft clearance check

ASSEMBLE

1. Apply clean lubricating oil to the oil pump body, the inner rotor assembly and the outer rotor.
2. Insert the outer rotor into the oil pump body and inner rotor assembly and install the cover.
3. Replace the gasket with new.

INSTALL

Oil pump

1. Insert the two bolts to attach the oil pump assembly to the timing gear case flange. Tighten to standard torque.
2. Install the timing gear case cover. See Bi-fuel timing gear case repair.
3. Install the crankshaft pulley. See Bi-fuel timing gear case repair.
4. Install the V-belt, water pump V-pulley, spacer, and cooling fan. See **Cooling system** 0700SRM2300 service manual.

Oil pan

1. Install the oil pickup tube with a new gasket. See Figure 497.
2. Apply a continuous bead of ThreeBond Liquid Gasket (2084312) to the mounting face of the oil pan and oil pan spacer. Apply a thin circle around each bolt hole of the oil pan.
3. Install the oil pan spacer and oil pan to the engine block. Insert the bolts and tighten to standard torque. See Figure 496.

OIL PUMP SERVICE INFORMATION

Table 120. Engine lubricating oil pressure

Model	At rated engine RPM (min)	At low idle speed
	2600 min^{-1}	
4TN88B, 4TN88BN-NHYG	0.31-0.41 MPa (45-59.5 psi)	0.1 MPa (8.7 psi)

Table 121. Outer rotor outside clearance

Model	Standard	Limit	Reference page
4TN88B, 4TN88BN-NHYG	0.09-0.15 mm (0.0035-0.0059 in.)	0.25 mm (0.0098 in.)	Check outer rotor outside clearance. See Outer rotor outside clearance.

Table 122. Outer rotor side clearance

Model	Standard	Limit	Reference page
4TN88B, 4TN88BN-NHYG	0.05-0.09 mm (0.0020-0.0035 in.)	0.15 mm (0.0059 in.)	Check outer rotor side clearance. See Figure 501.

Table 123. Outer rotor to inner rotor tip clearance

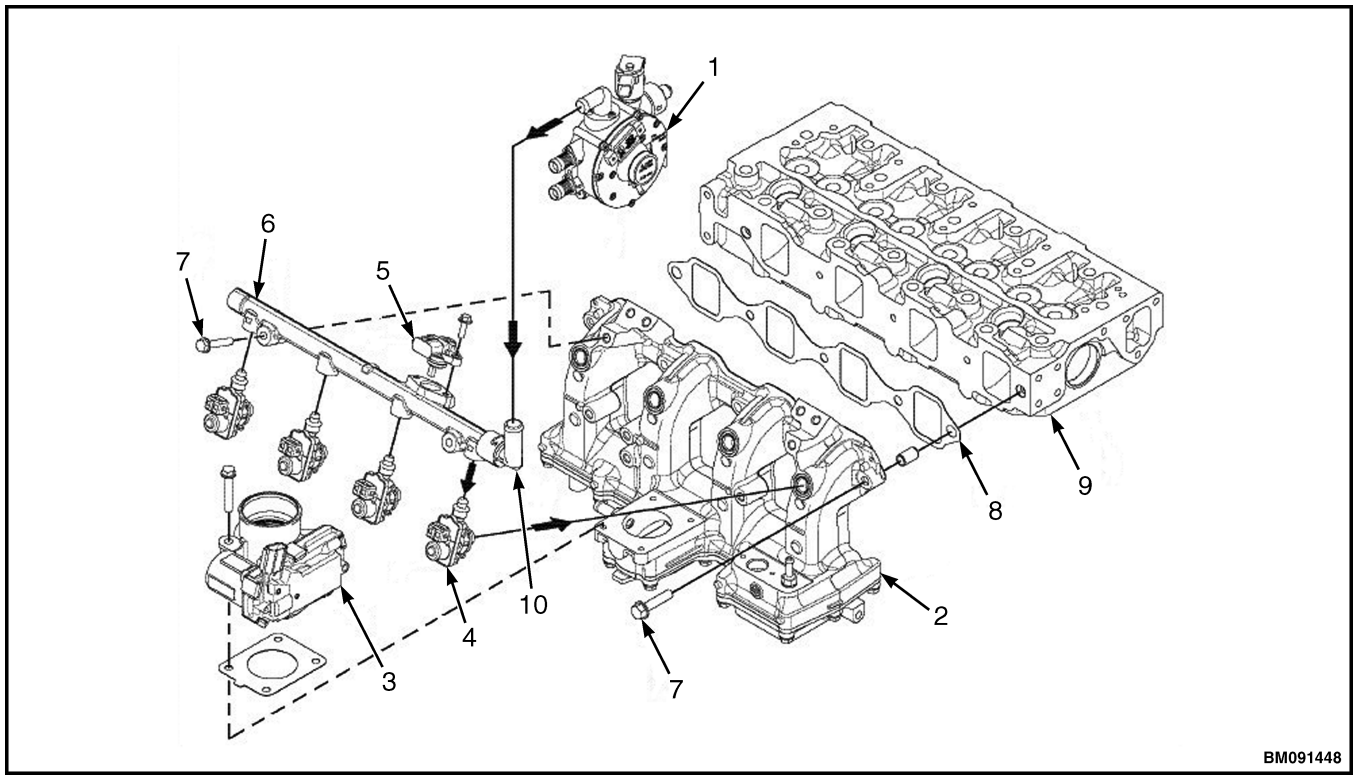
Model	Standard	Limit	Reference page
4TN88B, 4TN88BN-NHYG	---	0.16 mm (0.0063 in.)	Check outer rotor to inner rotor tip clearance. See Figure 500.

Table 124. Rotor shaft clearance

Model		Standard	Limit	Reference page
4TN88B, 4TN88BN-NHYG	Plate bearing I.D.	10.020-10.038 mm (0.3945-0.3952 in.)	10.063 mm (0.3962 in.)	Check rotor shaft clearance. See Rotor shaft clearance.
	Rotor shaft O.D.	9.978-9.987 mm (0.3928-0.3932 in.)	9.963 mm (0.3922 in.)	
	Rotor clearance	0.033-0.060 mm (0.0013-0.0024 in.)	0.100 mm (0.0039 in.)	

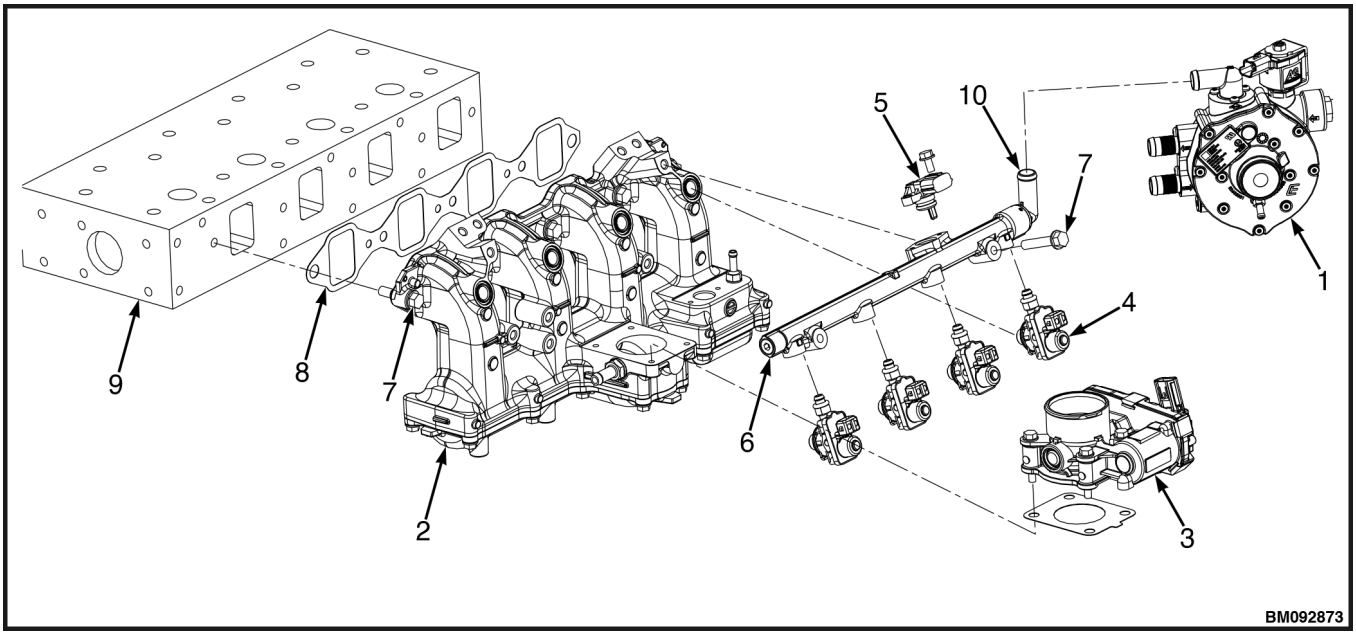
BI-FUEL FUEL SYSTEM REPAIR 202001-038

FUEL SYSTEM COMPONENTS



1. VAPORIZER
2. INTAKE MANIFOLD
3. INTAKE THROTTLE
4. FUEL INJECTOR
5. FUEL TEMPERATURE AND PRESSURE SENSOR
6. FUEL RAIL
7. MOUNTING BOLT
8. GASKET
9. CYLINDER HEAD
10. FUEL RAIL JOINT

Figure 503. Fuel system components prior to October 27, 2025



1. VAPORIZER
2. INTAKE MANIFOLD
3. INTAKE THROTTLE
4. FUEL INJECTOR
5. FUEL TEMPERATURE AND PRESSURE SENSOR
6. FUEL RAIL
7. MOUNTING BOLT
8. GASKET
9. CYLINDER HEAD
10. FUEL RAIL JOINT

Figure 504. Fuel system components after October 27, 2025

REMOVE

1. Prior to removing the injectors, remove all engine parts interfering with access to the injectors. See Bi-fuel cylinder head repair.

2. Remove the wire harness connectors from each ignition coil and the fuel temperature and pressure sensor. See Figure 505.

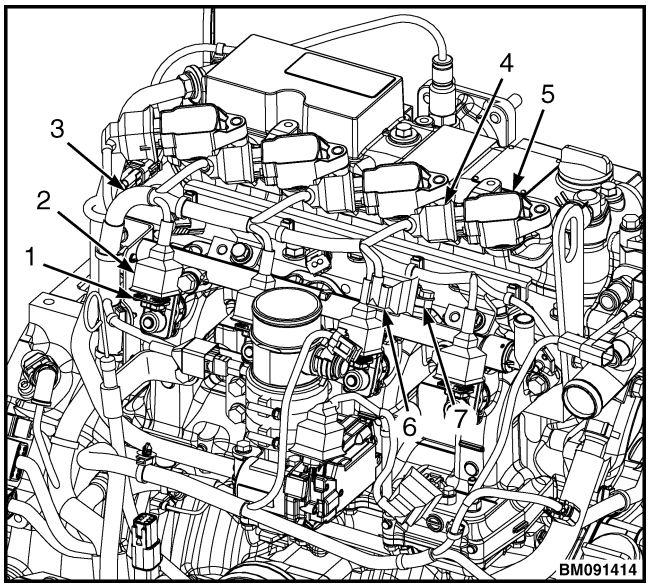


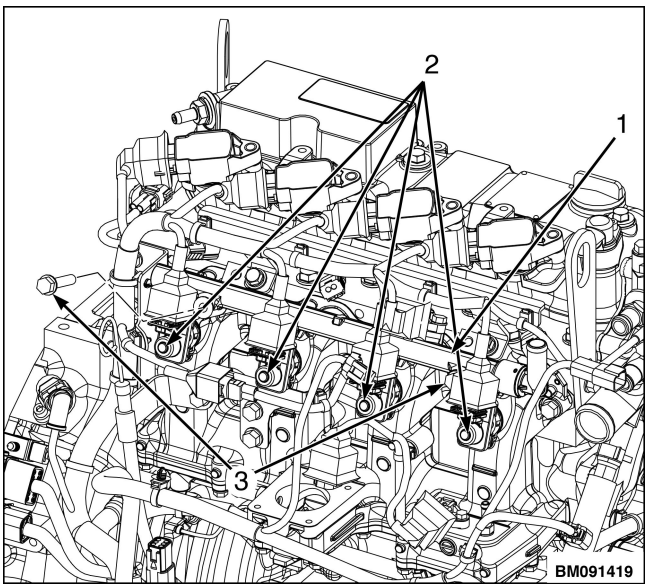
Figure 505. Ignition coils and wire harness

Legend for Figure 505.

1. INJECTOR
2. INJECTOR CONNECTOR
3. WIRE HARNESS
4. IGNITION CONNECTOR
5. IGNITION COIL
6. FUEL TEMPERATURE AND PRESSURE SENSOR CONNECTOR
7. FUEL TEMPERATURE AND PRESSURE SENSOR

3. Disconnect the hose from the fuel rail joint to the vaporizer. See Figure 503.

4. Loosen the two bolts retaining the fuel rail to the intake manifold and remove the fuel rail. See Figure 506.



1. FUEL RAIL
2. INJECTOR
3. BOLTS

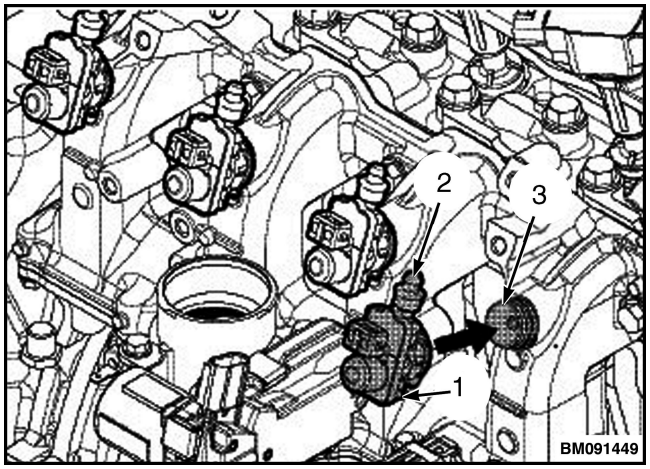
Figure 506. Fuel rail

NOTE: Mark each injector prior to removal. Do not disassemble the injectors. Replace the injector as an entire assembly.

5. Remove the four injectors by pulling out the retaing clip for each injector and pulling injector free. See Figure 506.

6. Clean the injectors and cover with a vinyl bag.

7. If replacing the injector adapters, use a 6 mm hex wrench to loosen and remove the adapter from the intake manifold. Discard the O-ring. See Figure 507.



1. INJECTOR
2. FUEL INLET
3. INJECTOR ADAPTER

Figure 507. Injector adapters

INSTALL

1. If the injector adapter was removed, install a new O-ring to the adapter. Apply lubricating oil, and use the 6 mm hex wrench to tighten the adapter. See Figure 507.

2. Torque to 4 to 6 N•m (3.0 to 4.4 lbf ft).

3. With the fuel inlet of the injector facing upward, push the injector into the adapter until the retaining clip makes a locking sound. See Figure 507.

4. Align the ports of the fuel rail with the fuel inlet of each injector. Install the fuel rail onto the injectors. See Figure 506.

5. Insert the two bolts to attach the fuel rail to the intake manifold. See Figure 506.

6. Torque to 7.8 to 9.4 N•m (5.8 to 6.9 lbf ft).

7. Reconnect the hose from the vaporizer to the fuel rail joint. See Figure 503.

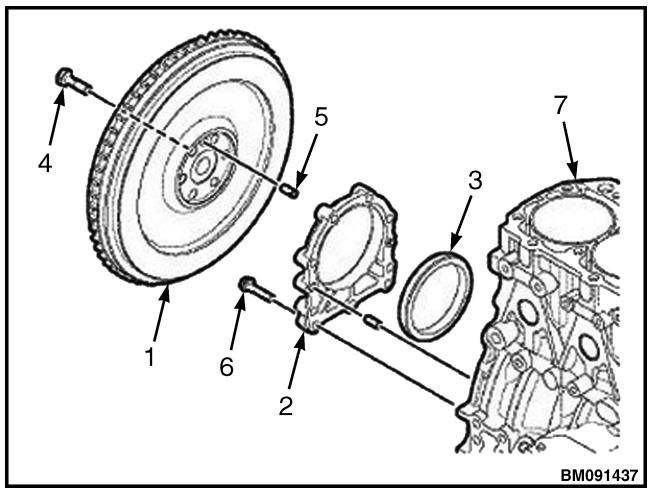
8. Connect the wire harness connectors to each injector coil and the fuel temperature and pressure sensor. See Figure 505.

BI-FUEL FLYWHEEL REPAIR 202001-039

REMOVE

1. Remove the engine. See Bi-fuel engine removal and replacement section in the **Drive Train** 0900SRM2301 service manual.

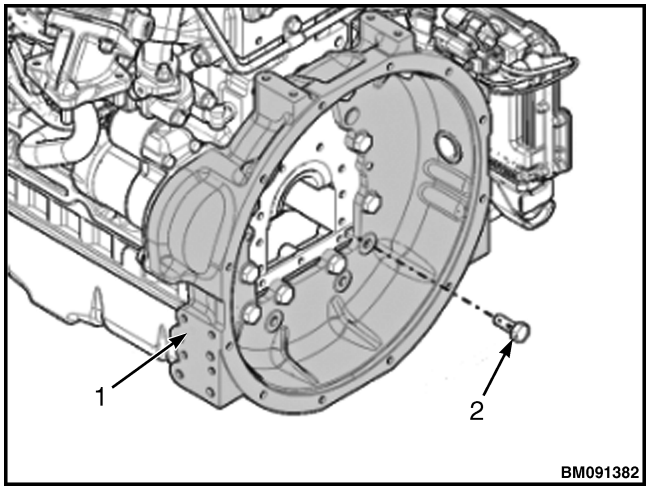
2. Remove the six flywheel mounting bolts retaining the flywheel to the crankshaft and remove the flywheel. See Figure 508.



1. FLYWHEEL
2. REAR OIL SEAL HOUSING
3. REAR OIL SEAL
4. FLYWHEEL MOUNTING BOLT
5. DOWEL
6. REAR OIL SEAL HOUSING MOUNTING BOLT
7. CYLINDER BLOCK

Figure 508. Flywheel

3. Remove the flywheel housing mounting bolts and remove the flywheel housing. See Figure 509.



1. FLYWHEEL HOUSING
2. FLYWHEEL HOUSING MOUNTING BOLT

Figure 509. Flywheel housing

INSPECT

1. Check for crack and wear on the flywheel friction surface, and replace it if there is damage.

2. Check the ring gear tooth surface and replace the ring gear if there is damage or excessive wear.

3. Place a rod on the ring gear, along the outer rim of the flywheel. Strike the rod with a hammer alomg the circumference of the ring gear to remove the ring gear.

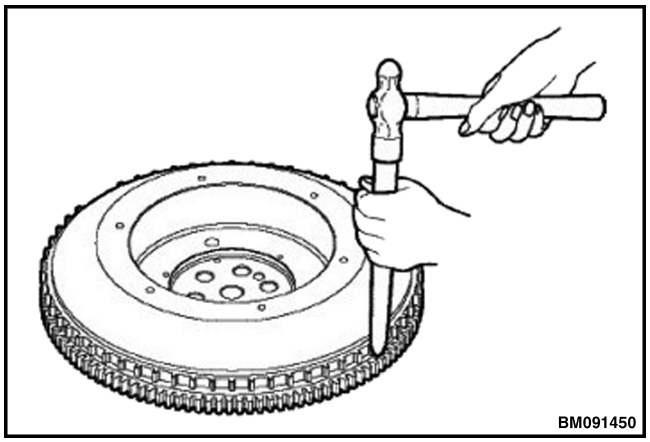


Figure 510. Remove ring gear

4. Evenly heat a new ring gear with a gas burner (approximately 200°C (392°F)).

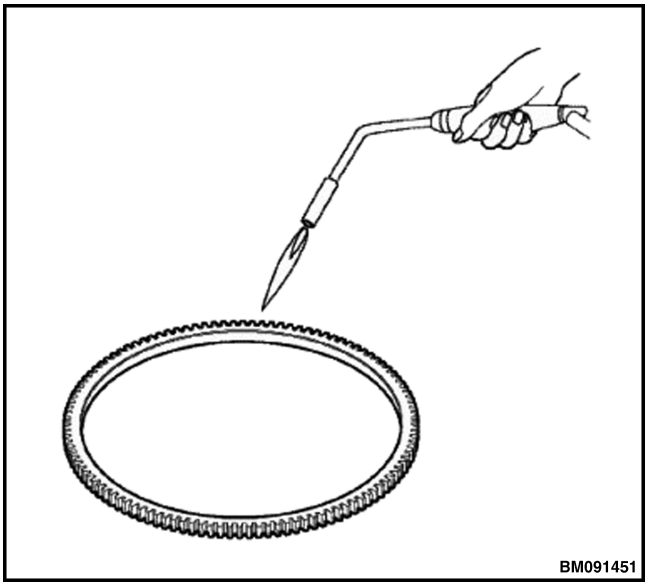


Figure 511. Heating new ring gear

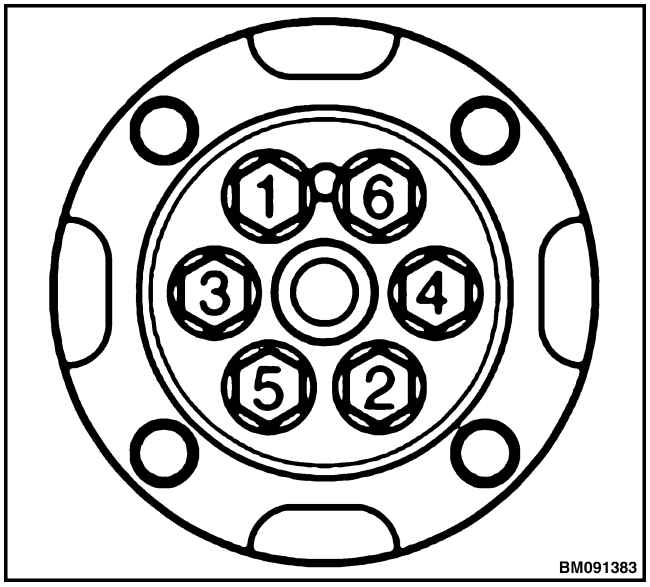


Figure 512. Torque sequence

5. Quickly install the ring gear with the chamfered side of the tooth surface facing the block side. Confirm the ring gear is securely attached to the flywheel before installing the flywheel.

INSTALL

1. Insert the flywheel housing mounting bolts and install the flywheel housing. See Figure 509. Tighten the flywheel housing mounting bolts to standard torque value.

2. Align the flywheel with the rear oil seal housing. Install the six flywheel mounting bolts to retain the flywheel to the crankshaft. See Figure 508.

3. Tighten the flywheel mouning bolts to 83.3 to 88.2 N•m (61-65 lbf ft) following the sequence shown in Figure 512.

4. Install the engine. See Bi-fuel engine removal and replacement section in the **Drive Train** 0900SRM2301 service manual.

BI-FUEL ELECTRICAL SYSTEM REPAIR 202001-040

STARTER

Remove

WARNING

SHOCK HAZARD. Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

DANGER

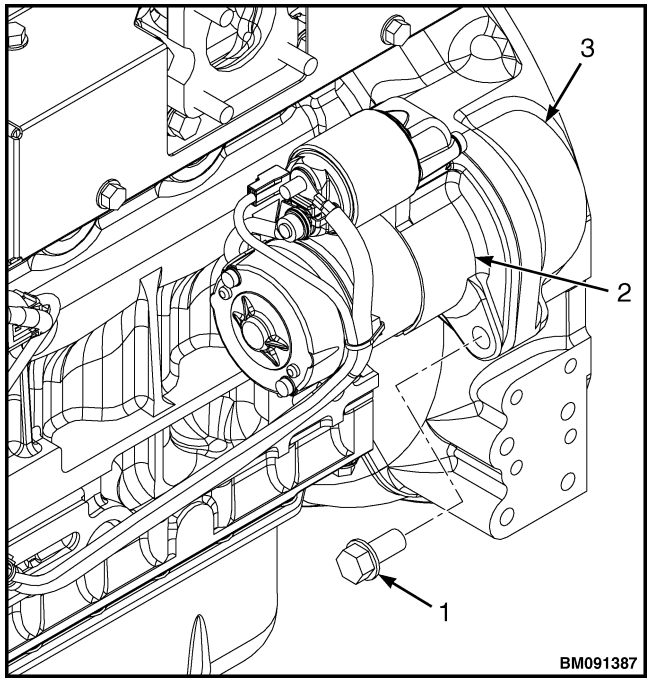
Check the electrical harnesses for cracks, abrasions and damaged or corroded connectors. Always keep the connectors and terminals clean. Failure to comply could result in death or serious injury.

1. Disconnect the negative battery cable at the negative terminal post on the battery.

2. Disconnect the positive battery cable at the positive terminal post on the battery.

3. Put labels on wires and cables prior to disconnecting to aid in correct installation. Disconnect all cables and wires from the starter.

4. Remove the two starter mounting bolts. Remove the starter from the flywheel housing. See Figure 513.



1. STARTER MOUNTING BOLT
2. STARTER
3. FLYWHEEL HOUSING

Figure 513. Starter mounting

Install

1. Insert the two starter mounting bolts and attach the starter to the flywheel housing. See Figure 513.

2. Connect all cables and wires to the starter.

3. Connect the positive battery cable to the positive terminal on the battery.

4. Connect the negative battery cable to the negative terminal on the battery.

ALTERNATOR

Remove

WARNING

SHOCK HAZARD. Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

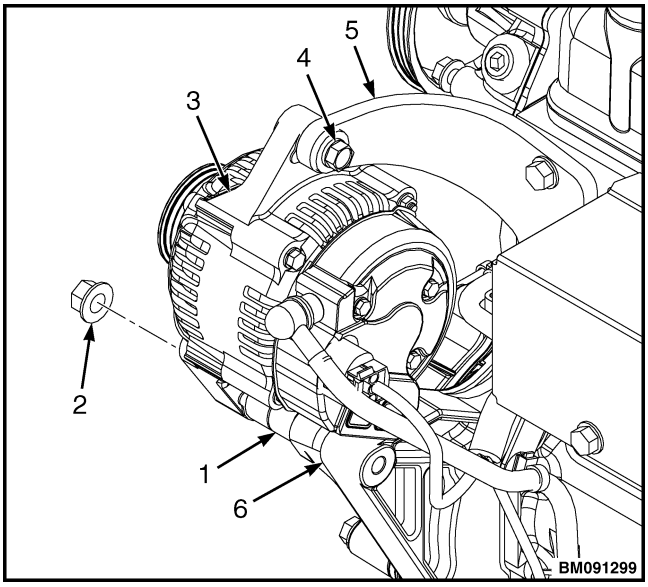
DANGER

Check the electrical harnesses for cracks, abrasions and damaged or corroded connectors. Always keep the connectors and terminals clean. Failure to comply could result in death or serious injury.

1. Remove the V-belt. See **Cooling system** 0700SRM2300 service manual.

2. Put labels on wires and cables prior to disconnecting to aid in correct installation. Disconnect all cables and wires from the alternator.

3. Perform the following steps to remove the alternator.
   a. Loosen the alternator mounting nut (item 2, Figure 514) and remove.
   b. Loosen the mounting bolt (item 4, Figure 514) attaching the alternator to the alternator mounting bracket.
   c. Remove the alternator.



1. SPACER AND STUD
2. ALTERNATOR MOUNTING NUT
3. ALTERNATOR
4. MOUNTING BOLT
5. ALTERNATOR MOUNTING BRACKET
6. TIMING GEAR CASE

Figure 514. Alternator mounting

Install

1. Perform the following steps to install the alternator.

a. Install the alternator onto the stud attached to the timing gear case. Temporarily tighten the alternator mounting nut. See Figure 514.

b. Temporarily tighten the mounting bolt (item 4, Figure 514) to retain the alternator to the alternator mounting bracket.

2. Reconnect the electrical wires to the alternator. Tighten the nuts to secure the wires to the alternator. Torque to 1.7-2.3 N•m (15-20 lbf in).

3. Fully tighten the alternator mounting nut. Torque to 1.7-2.3 N•m (15-20 lbf in).

4. Fully tighten the mounting bolt. Torque to 1.7-2.3 N•m (15-20 lbf in).

5. Reinstall the V-belt.

NOTE: DO NOT operate the engine if the alternator is producing unusual sounds. Damage to the alternator will result.

6. Start the engine. Listen for any unusual sounds from the alternator.

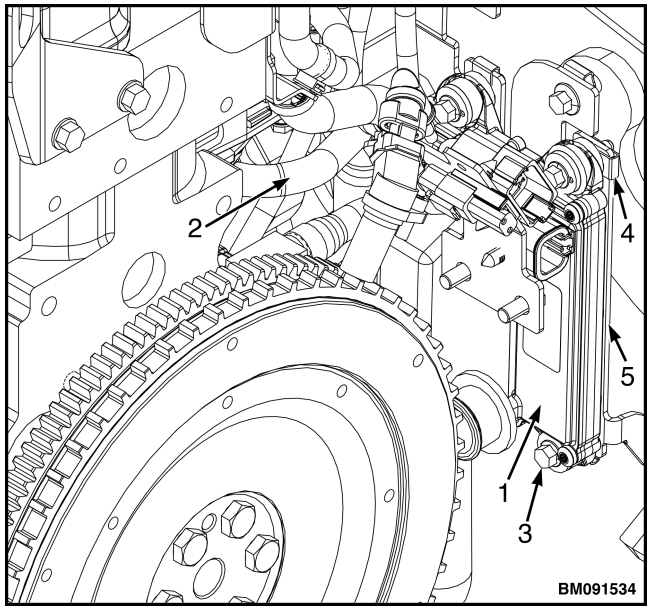
7. Verify that the alternator icon does not display while the engine is operating. If the alternator displays, repair the problem before operating the engine. See the Guided Troubleshooting for this lift truck.

Figure 515. Alternator icon

Engine Control Unit

Remove

1. Disconnect the engine harness from the ECU. See Figure 516.
2. Locate the top capscrews on each side that attach the ECU to the mounting bracket. See Figure 516.
3. Remove the two top capscrews and foldover nuts.
4. Locate the bottom capscrews on each side that attach the ECU to the mounting bracket. See Figure 516.
5. Remove the two bottom capscrews.
6. Remove the ECU. See Figure 516.



1. ECU
2. ENGINE WIRE HARNESS
3. CAPSCREW
4. FOLDOVER NUT
5. MOUNTING BRACKET

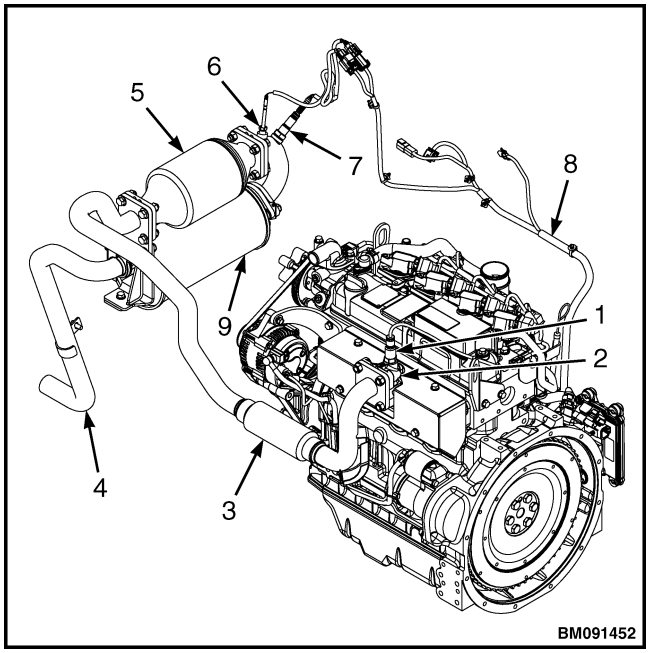
Figure 516. ECU

Install

1. Locate the new ECU and align it with the holes on the mounting bracket. See Figure 516.
2. Insert the two bottom capscrews to retain the ECU to the mounting bracket. See Figure 516. Torque the capscrews to
3. Insert the two top capscrews into the ECU and foldover nuts to attach the ECU to the mounting bracket. See Figure 516. Torque the capscrews to
4. Connect the engine harness to the ECU. See Figure 516.

When replacing the ECU or if an update to the ECU software is required, it is necessary to write the software to the new ECU (Service ECU) or ECU equipped machine. Use SMARTASSIST-Direct to download the current software. See the **SMARTASSIST-Direct Operation Manual** for more information.

BI-FUEL EXHAUST AND AFTERTREATMENT REPAIR, CERTIFIED ENGINE 202001-041



1. PRE-O^2 SENSOR
2. EXHAUST MANIFOLD
3. EXHAUST PIPE
4. TAIL PIPE
5. CATALYTIC CONVERTER
6. EXHAUST TEMPERATURE SENSOR
7. POST-O^2 SENSOR
8. ENGINE HARNESS
9. MUFFLER

Figure 517. Exhaust system

REMOVE

WARNING

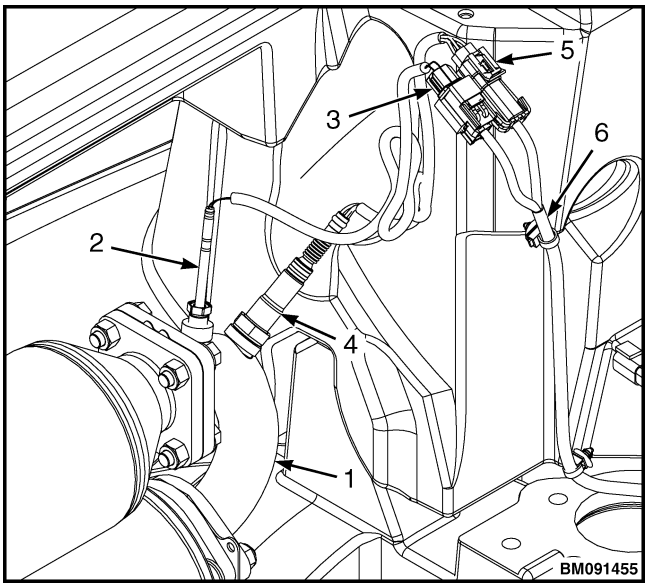
Exhaust system components are hot to touch. Make sure exhaust system components are cool before starting disassembly, or personal injury may occur.

1. Remove the counterweight. See Counterweight repair in **Frame and Main Components** 8000SRM2306 service manual.

2. Open the hood to access the engine.

3. Disconnect the two sensor connectors from the engine harness. See Figure 518.

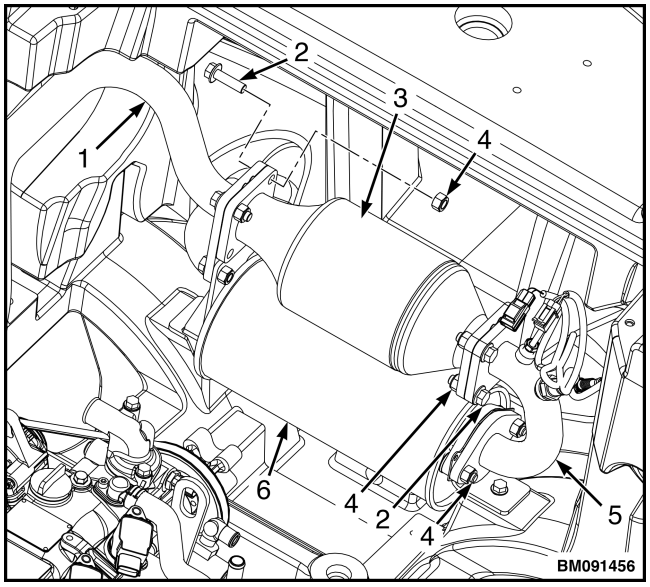
4. If replacing the sensors, remove the sensor from the elbow exhaust pipe. See Figure 518.



1. EXHAUST PIPE (ELBOW)
2. EXHAUST SENSOR (HEATED)
3. EXHAUST SENSOR CONNECTOR
4. OXYGEN SENSOR
5. OXYGEN SENSOR CONNECTOR
6. WIRE HARNESS

Figure 518. Exhaust and oxygen sensor

5. Remove the four bolts and nuts retaining the elbow exhaust pipe to the catalytic converter. See Figure 519.

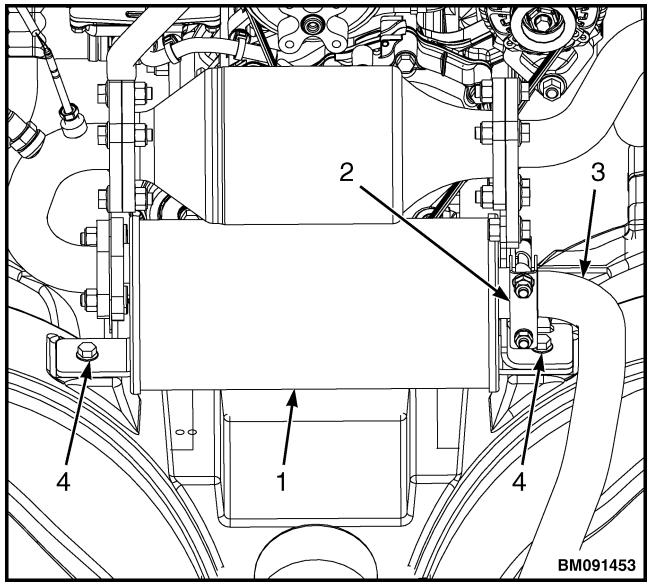


1. EXHAUST PIPE
2. BOLT
3. CATALYTIC CONVERTER
4. NUT
5. EXHAUST PIPE (ELBOW)
6. MUFFLER

Figure 519. Exhaust pipe and catalytic converter

6. Remove the four nuts and bolts retaining the other end of the catalytic converter to the exhaust pipe. See Figure 519. Remove the catalytic converter.

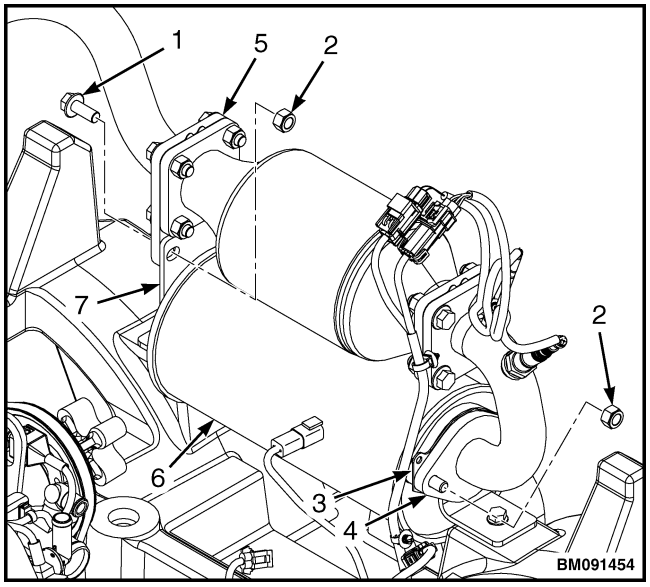
7. Remove the clamp retaining the tail pipe to the muffler and disconnect the tail pipe. See Figure 520.



1. MUFFLER
2. CLAMP
3. TAIL PIPE
4. BOLT

Figure 520. Muffler

8. Remove the two nuts attaching the muffler and mounting bracket to the exhaust pipe (item 5, Figure 521).



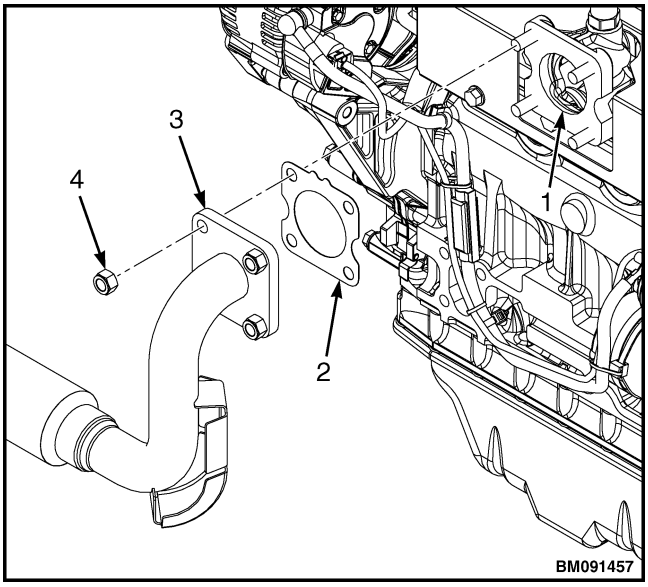
1. BOLT
2. NUT
3. GASKET
4. EXHAUST PIPE (ELBOW)
5. EXHAUST PIPE
6. MUFFLER
7. MOUNTING BRACKET

Figure 521. Muffler and exhaust pipes

9. Remove the two bolts (item 4, Figure 520) retaining the muffler to the frame. Remove the muffler.

10. Remove the mounting bracket (item 7, Figure 521).

11. Remove the four nuts retaining the other end of the exhaust pipe to the exhaust manifold. See Figure 522.

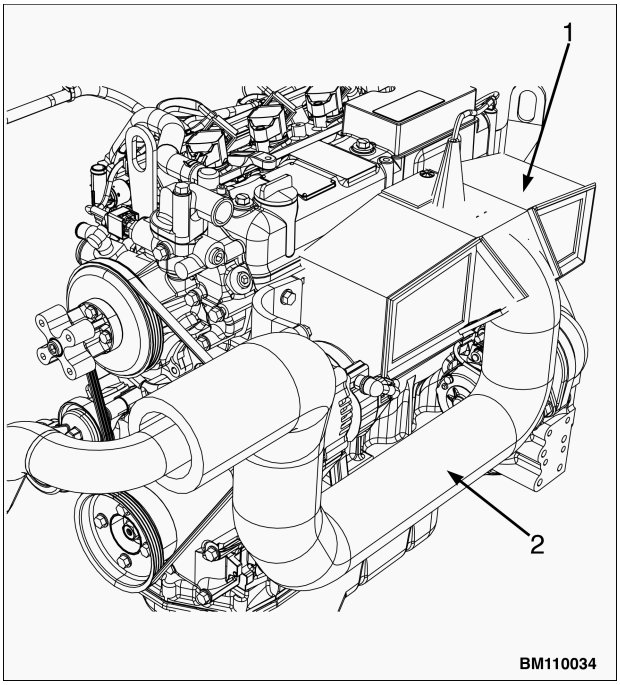


1. EXHAUST MANIFOLD
2. GASKET
3. EXHAUST PIPE
4. NUT

Figure 522. Exhaust pipe and exhaust manifold

INSPECT

- Inspect all exhaust pipes for damage, corrosion, and rust. Replace as needed.
- If equipped, inspect all exhaust wraps for wear, proper fit, contamination with oil or antifreeze, gaps in coverage, and failed fasteners. See Figure 523. Replace as needed. If replacing an exhaust pipe section that has a wrap, also replace the wrap. DO NOT reuse wraps if they have been removed for a service operation.
- Inspect the catalytic converter (if equipped) and muffler for damage, corrosion, and rust. Replace as needed.



1. EXHAUST WRAP-MANIFOLD
2. EXHAUST WRAP-TUBES

Figure 523. Inspect exhaust wraps

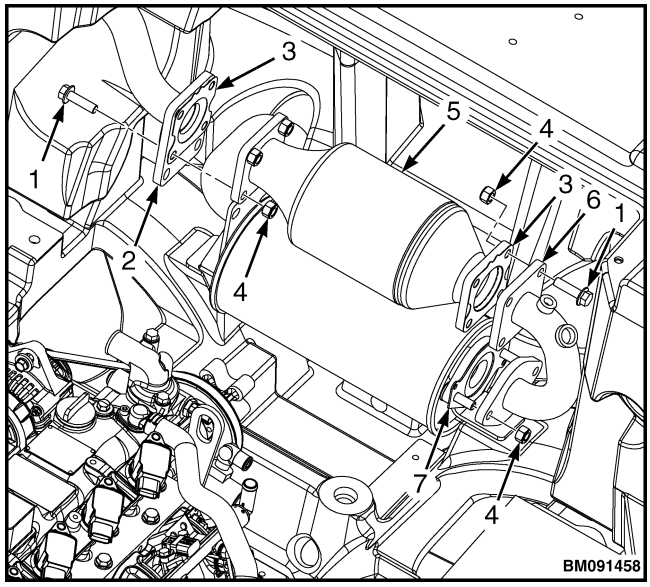
INSTALL

1. Install the muffler, aligned with the holes on the frame. Insert the nuts to mount the muffler to the frame. See Figure 521. Torque the nuts to 22.6-28.4 N•m (17-21 lbf ft).

2. Install the two bolts and nuts to attach the muffler and mounting bracket to the exhaust pipe. See Figure 521. Torque the nuts to 39 N•m (28.8 lbf ft).

3. Connect the tail pipe to the muffler. Install the clamp to retain the tail pipe to the muffler. See Figure 524. Tighten the nuts on the clamp to 19 N•m (14.0 lbf ft). If using the optional clamp (Hyster No. 4264370) tighten to 10-15 N•m (7.4-11.1 lbf ft).

4. Install the elbow exhaust pipe and new gasket. Insert the nuts onto the studs of the muffler to retain the bottom of the elbow exhaust pipe. See Figure 524. Torque to 39 N•m (28.8 lbf ft).



1. BOLT
2. EXHAUST PIPE
3. GASKET
4. NUT
5. CATALYTIC CONVERTER
6. EXHAUST PIPE (ELBOW)
7. GASKET

Figure 524. Install exhaust pipes

5. Install the catalytic converter and new gasket. Install the four bolts and nuts to retain the elbow exhaust pipe to the catalytic converter. See Figure 524. Torque to 39 N•m (28.8 lbf ft).

6. Install the four nuts and bolts to retain the other side of the catalytic converter to the exhaust pipe. Make sure to use a new gasket when installing the exhaust pipe. See Figure 524. Torque to 39 N•m (28.8 lbf ft).

7. Install the four nuts to retain the other side of the exhaust pipe and new gasket to the exhaust manifold. See Figure 522. Torque to 39 N•m (28.8 lbf ft).

8. Close the hood.

9. If the sensors were removed, insert the sensors. See Figure 518.

- Insert the exhaust sensor into the elbow exhaust pipe. Torque to 34-44 N•m (25.0-32.5 lbf ft).
- Insert the oxygen sensor into the elbow exhaust pipe. Torque to 49 N•m (36.1 lbf ft).

10. Connect the two sensor connectors to the engine harness. See Figure 518.

11. Install the counterweight. See Counterweight repair in **Frame and Main Components** 8000SRM2306.

12. Install the counterweight. See Counterweight repair in **Frame and Main Components** 8000SRM2306 service manual.

BI-FUEL ENGINE CHECKS, ADJUSTMENTS, AND CALIBRATIONS 202001-042

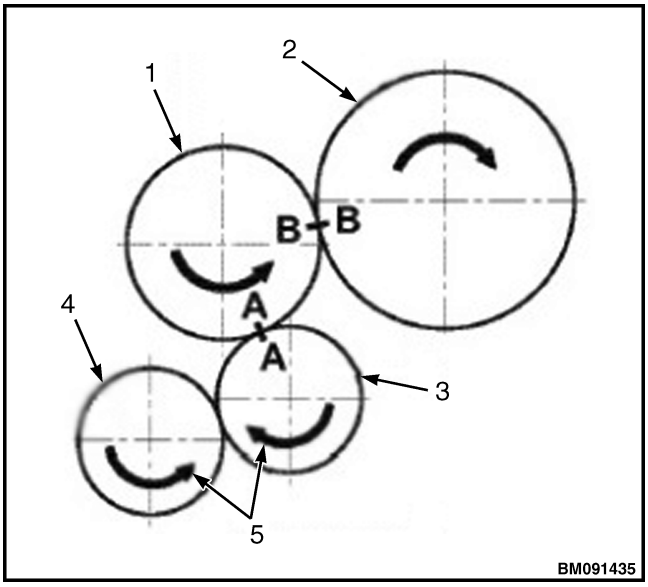
TIMING GEAR CHECKS

Check timing gear backlash

Prior to removing the timing gears, measure the gear backlash and determine the gear wear.

Check the backlash between each pair of connecting gears. See Figure 525. If not within specification, replace both connecting gears. See Table 75 in Bi-fuel engine specifications for service limits.

NOTE: Do not allow the gear being checked to move axially as excess end play could cause a false reading.



1. IDLER GEAR
2. CAMSHAFT DRIVE GEAR
3. CRANKSHAFT GEAR
4. OIL PUMP DRIVE GEAR
5. DIRECTION OF ROTATION

Figure 525. Timing gear backlash

Measuring idler gear-to-crankshaft gear backlash

1. Position a dial indicator as shown in Figure 526, on the SIDE of the gear to measure.

NOTE: The following figure (Figure 526) is oriented to show the SIDE of the gear at the TOP of the figure.

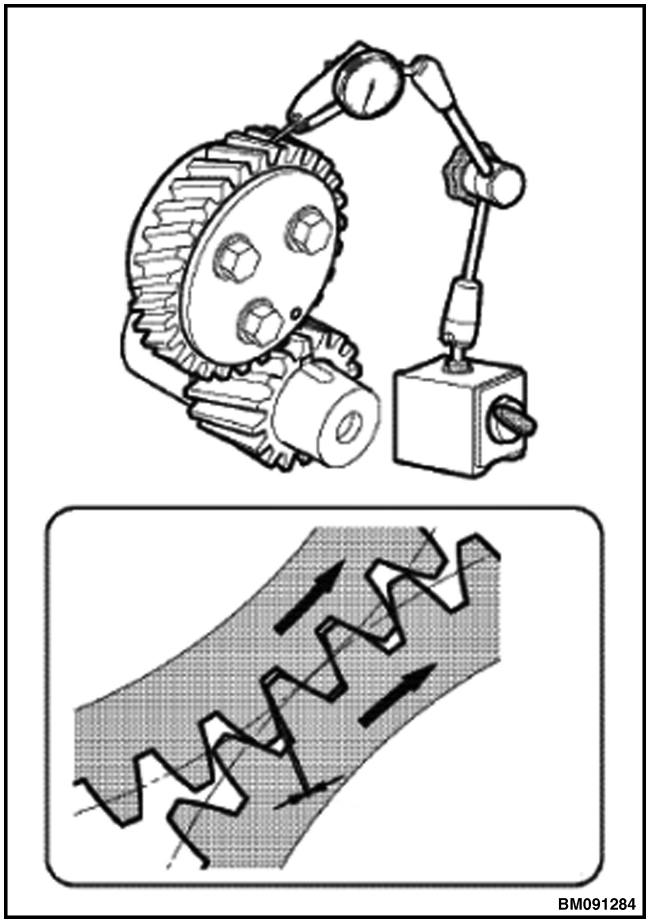


Figure 526. Dial indicator

2. Rotate the idler gear back and forth to check the idler gear backlash, by measuring the movement between gears before they engage. The total indicator reading is the backlash. Record the measurement.

Measuring idler gear-to-camshaft gear backlash

1. Drive a small wooden wedge between the crankshaft gear and idler gear to prevent the idler gear from rotating.
2. Install the dial indicator to read the camshaft gear backlash. Rotate the camshaft drive gear against the idler gear to measure the backlash. Record the measurement.
3. Check the idler gear-to-oil pump drive gear backlash in the same manner as the camshaft drive gear. Record the measurement.

VALVE CLEARANCE ADJUSTMENTS

NOTE: Make measurements and adjustments while the engine is cold.

NOTE: Valve clearance of both the intake and exhaust valves can be checked with the piston for that cylinder at top dead center (TDC) of the compression stroke. When a piston is at TDC of the compression stroke, both rocker arms will be loose and the cylinder TDC mark on the flywheel will be visible in the timing port of the flywheel housing.

If there is no valve clearance, and the cylinder is at TDC of the compression stroke, extreme wear, or damage to the cylinder head or valves may be possible.

If adjusting each cylinder individually, the cylinder to be adjusted first does not have to be the No. 1 cylinder. Select and adjust the cylinder where the piston is nearest to the TDC after turning. Make adjustment for the remaining cylinders in the order of the firing by turning the crankshaft each time.

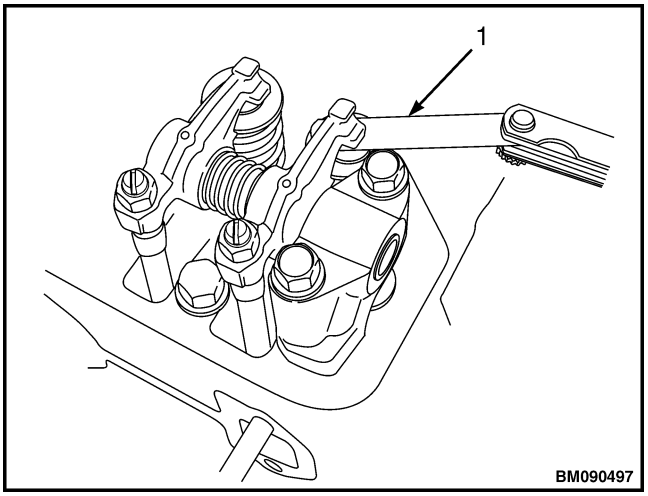
To decrease the number of rotations required to check all cylinders, other cylinders can also be checked as indicated in the chart below:

Cylinder No.	**1**		**2**		**3**		**4**	
Valve	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust
No. 1 cylinder at TDC compression	•	•	•			•		
No. 4 cylinder at TDC compression				•	•		•	•

1. Remove cylinder head cover. See Bi-fuel cylinder head repair.

NOTE: The number one piston position is on the flywheel end of the engine, opposite side of the radiator, and the ignition order is 1 - 3 - 4 - 2 at 180 degree intervals.

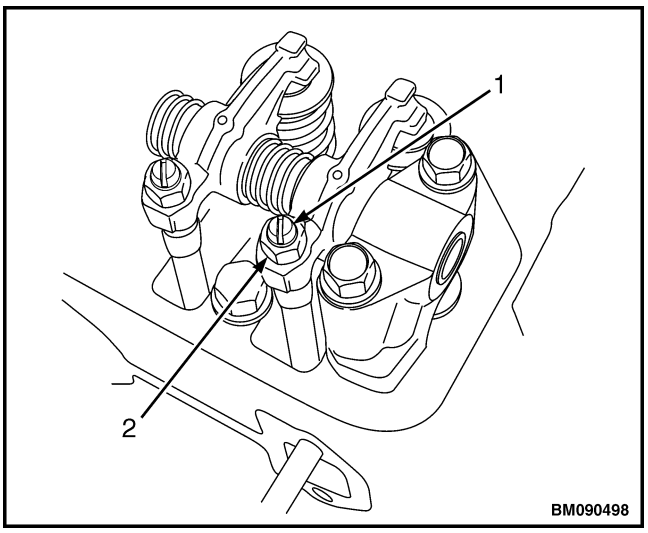
2. Rotate crankshaft clockwise, as seen from the radiator side, to bring the number one piston to top dead center (TDC) while watching the rocker arm motion, timing scale, and top mark position of the crankshaft pulley. (Position where both the intake and exhaust valves are closed.)
3. Insert a feeler gauge between the rocker arm and valve cap. See Figure 527. Record the measured valve clearance. The valve clearance (when cold) should be:
   - Intake: 0.25 to 0.35 mm (0.01 to 0.013 in.)
   - Exhaust: 0.35 to 0.45 mm (0.013 to 0.018 in.)



1. FEELER GAUGE

Figure 527. Valve Clearance Measurement

4. If adjustment is needed, loosen the valve adjusting screw lock nut and valve adjusting screw on the rocker arm (see Figure 528) and check the valve for any slope of valve cap, entrance of dirt, or wear.



1. VALVE ADJUSTING SCREW
2. VALVE ADJUSTING SCREW LOCK NUT

Figure 528. Valve Clearance Adjustment

NOTE: Clearance will decrease slightly when the lock nut is tightened. Make the clearance adjustment slightly on the loose side before tightening the lock nut.

5. Insert a feeler gauge between the rocker arm and valve cap and adjust the clearance so there is a slight drag on the feeler gauge when sliding it between the rocker arm and valve cap.

6. Hold the adjusting screw and tighten the valve adjusting screw lock nut and recheck the clearance. See Figure 528. The valve clearance (when cold) should be:

- Intake: 0.25 to 0.35 mm (0.01 to 0.013 in.)
- Exhaust: 0.35 to 0.45 mm (0.013 to 0.018 in.)

7. Apply clean engine oil to the contact surface between the adjusting screw and push rod.

8. Turn the crankshaft 180 degrees and make the measurement and adjustment for the number three cylinder. Then turn the crankshaft 180 degrees and make the measurement and adjustment for the number four cylinder. Then turn the crankshaft 180 degrees and make the measurement and adjustment for the number 2 cylinder.

9. Install the valve cover. See Bi-fuel cylinder head repair.

SPECIAL TOOLS FOR BI-FUEL ENGINES 202001-043

This content is under development and will be released when available.