Overhaul Manual

TK 482 and TK 486

TK 50136-2-OM (Rev. 1, 08/02)

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Specifications 1

TK 482 & TK 486 Diesel Engine Specifications

Except where noted, the specifications for both engines are the same.

General	
Type	Four Stroke Cycle Water Cooled
Number of Cylinders	4
Cylinder Arrangement	In-line Vertical, Number 1 on Flywheel End
Bore	
TK 482	3.23 in. (82.0 mm)
TK 486	3.39 in. (86.0 mm)
Stroke	3.54 in. (90.0 mm)
Displacement	
TK 482	116 cu. in. (1.90 liters)
TK 486	128 cu. in. (2.09 liters)
Power Rating	
TK 482	30.3 hp (22.6 kW) @ 2200 rpm
TK 486	33.9 hp (25.3 kW) @ 2200 rpm
Compression Ratio	18.0 to 1
Direction of Rotation	Counterclockwise (Viewed from Flywheel)
Firing Order	1-3-4-2 (Number 1 on Flywheel End)
Fuel Injection Timing	12 ± 1 Degrees BTDC
Nozzle Injection Pressure	2,800-3,000 psi (19,600-20,600 kPa)
Oil Pressure	18.5 psi (127 kPa) Minimum @ 230 F (110 C) & 1600 rpm
	45-57 psi (310-390 kPa) @ 230 F (110 C) & 2200 rpm
Valve Clearance (Static @ 70 F [21 C])	
Intake	0.006-0.010 in. (0.15-0.25 mm)
Exhaust	0.006-0.010 in. (0.15-0.25 mm)

Valve Train	**Standard Dimensions**	**Wear Limit**
Valve Spring		
Free Length	1.75 in. (44.5 mm)	1.67 in. (42.5 mm)
Inclination (Top to Bottom from Vertical)	0-0.04 in. (0-1.1 mm)	0.04 in. (1.1 mm)
Valve Guide Inside Diameter		
Intake	0.3154-0.3159 in. (8.010-8.025 mm)	0.3189 in. (8.100 mm)
Exhaust	0.3156-0.3161 in. (8.015-8.030 mm)	0.3189 in. (8.100 mm)
Valve Stem Outside Diameter		
Intake	0.3132-0.3140 in. (7.955-7.975 mm)	0.3110 in. (7.900 mm)
Exhaust	0.3132-0.3138 in. (7.955-7.970 mm)	0.3110 in. (7.900 mm)

Valve Train (continued)	Standard Dimensions	Wear Limit
Valve Stem to Valve Guide Clearance		
Intake	0.0014.0028 in. (0.035-0.070 mm)	0.0079 in. (0.200 mm)
Exhaust	0.0018-0.0030 in. (0.045-0.075 mm)	0.0079 in. (0.200 mm)
Valve Margin		
Intake	0.0490-0.0569 in. (1.244-1.444 mm)	0.020 in. (0.50 mm)
Exhaust	0.0531-0.0610 in. (1.350-1.550 mm)	0.020 in. (0.50 mm)
Valve Depth (Cylinder Head Deck to Valve)		
Intake	0.0120-0.0199 in. (0.306-0.506 mm)	0.039 in. (1.00 mm)
Exhaust	0.0118-0.0197 in. (0.300-0.500 mm)	0.039 in. (1.00 mm)
Valve Guide Projection (Above Valve Spring Seat in Cylinder Head)		
Intake	0.591 in. (15.00 mm)	
Exhaust	0.591 in. (15.00 mm)	
Valve Angle		
Intake	30 Degrees	
Exhaust	45 Degrees	
Valve Seat Angle		
Intake	30 Degrees	
Exhaust	45 Degrees	
Valve Seat Width		
Intake	0.042-0.049 in. (1.07-1.24 mm)	0.069 in. (1.74 mm)
Exhaust	0.049-0.057 in. (1.24-1.45 mm)	0.076 in. (1.94 mm)
Rocker Arm Bushing Inside Diameter	0.6299-0.6307 in. (16.000-16.020 mm)	0.6335 in. (16.090 mm)
Rocker Arm Shaft Outside Diameter	0.6286-0.6293 in. (15.966-15.984 mm)	0.6280 in. (15.950 mm)
Rocker Arm Bushing to Rocker Arm Shaft Clearance	0.0006-0.0021 in. (0.016-0.054 mm)	0.0055 in. (0.140 mm)
Tappet Outside Diameter	0.4715-0.4720 in. (11.975-11.990 mm)	0.4697 in. (11.930 mm)
Tappet Bore Inside Diameter	0.4724-0.4731 in. (12.000-12.018 mm)	0.4744 in. (12.050 mm)
Tappet To Tappet Bore Clearance	0.0004-0.0017 in. (0.010-0.043 mm)	0.0047 in. (0.120 mm)
Camshaft		
Cam Lobe Height	1.5211-1.5262 in. (38.635-38.765 mm)	1.5118 in. (38.400 mm)
Camshaft Journal Outside Diameter		
Timing Gear End	1.7687-1.7697 in. (44.925-44.950 mm)	1.7657 in. (44.850 mm)
Middle	1.7681-1.7691 in. (44.910-44.935 mm)	1.7657 in. (44.850 mm)
Flywheel End	1.7687-1.7697 in. (44.925-44.950 mm)	1.7657 in. (44.850 mm)
Camshaft Bearing Inside Diameter		
Timing Gear End Bearing Insert	1.7713-1.7738 in. (44.990-45.055 mm)	1.7756 in. (45.100 mm)
Middle Bearing (No Insert)	1.7717-1.7726 in. (45.000-45.025 mm)	1.7756 in. (45.100 mm)
Flywheel End Bearing (No Insert)	1.7717-1.7726 in. (45.000-45.025 mm)	1.7756 in. (45.100 mm)

Camshaft (continued)	**Standard Dimensions**	**Wear Limit**
Camshaft Journal to Camshaft Bearing Clearance		
Timing Gear End	0.0016-0.0051 in. (0.040-0.130 mm)	0.0079 in. (0.200 mm)
Middle	0.0026-0.0045 in. (0.065-0.115 mm)	0.0079 in. (0.200 mm)
Flywheel End	0.0020-0.0039 in. (0.050-0.100 mm)	0.0079 in. (0.200 mm)
Camshaft Deflection	0.001 in. (0.02 mm)	0.002 in. (0.05 mm)
Camshaft End Play	0.002-0.010 in. (0.05-0.25 mm)	0.016 in. (0.40 mm)
Piston, Piston Rings, and Wrist Pin		
Piston Outside Diameter Measuring Point (From Bottom of Piston Perpendicular to Wrist Pin)	0.95 in. (24.0 mm)	
Piston Outside Diameter		
TK 482		
Standard	3.2260-3.2272 in. (81.940-81.970 mm)	3.2244 in. (81.900 mm)
1st Oversize 0.010 in. (0.25 mm)	3.2358-3.2370 in. (82.190-82.220 mm)	3.2343 in. (82.150 mm)
2nd Oversize 0.020 in. (0.50 mm)	3.2457-3.2469 in. (82.440-82.470 mm)	3.2441 in. (82.400 mm)
TK 486		
Standard	3.3835-3.3846 in. (85.940-85.970 mm)	3. 3819 in. (85.900 mm)
1st Oversize 0.010 in. (0.25 mm)	3.3933-3.3945 in. (86.190-86.220 mm)	3.3917 in. (86.150 mm)
2nd Oversize 0.020 in. (0.50 mm)	3.4031-3.4043 in. (86.440-86.470 mm)	3.4016 in. (86.400 mm)
Piston to Cylinder Wall Clearance	0.0012-0.0035 in. (0.030-0.090 mm)	
Piston Top Clearance (Between Top of Piston at TDC and Combustion Chamber with Cylinder Head Installed)	0.026-0.033 in. (0.65-0.83 mm)	
Piston Ring Groove Width		
Top Ring Groove	0.0813-0.0819 in. (2.065-2.080 mm)	
Middle Ring Groove	0.0801-0.0807 in. (2.035-2.050 mm)	
Bottom Ring Groove	0.1581-0.1587 in. (4.015-4.030 mm)	
Piston Ring Width		
Top Ring	0.0776-0.0783 in. (1.970-1.990 mm)	
Middle Ring		
TK 482	0.0776-0.0783 in. (1.970-1.990 mm)	
TK 486	0.0768-0.0776 in. (1.950-1.970 mm)	
Bottom Ring	0.1563-0.1571 in. (3.970-3.990 mm)	
Piston Ring to Ring Groove Clearance		
Top	0.0030-0.0043 in. (0.075-0.110 mm)	0.0098 in. (0.250 mm)
Middle		
TK 482	0.0018-0.0031 in. (0.045-0.080 mm)	0.0098 in. (0.250 mm)
TK 486	0.0026-0.0039 in. (0.065-0.100 mm)	0.0098 in. (0.250 mm)
Bottom	0.0010-0.0024 in. (0.025-0.060 mm)	0.0079 in. (0.200 mm)

Piston, Piston Rings, and Wrist Pin (continued)	Standard Dimensions	Wear Limit
Piston Ring End Gap		
Top Ring	0.008-0.016 in. (0.20-0.40 mm)	0.059 in. (1.50 mm)
Middle Ring	0.008-0.016 in. (0.20-0.40 mm)	0.059 in. (1.50 mm)
Bottom Ring	0.008-0.016 in. (0.20-0.40 mm)	0.059 in. (1.50 mm)
Piston Wrist Pin Bore Inside Diameter	1.0236 -1.0240 in. (26.000-26.009 mm)	1.0244 in. (26.020 mm)
Wrist Pin Outside Diameter	1.0231-1.0236 in. (25.987-26.000 mm)	1.0197 in. (25.900 mm)
Wrist Pin to Piston Wrist Pin Bore Clearance	0-0.0009 in. (0-0.022 mm)	0.0047 in. (0.120 mm)
Connecting Rod		
Wrist Pin Bushing Inside Diameter	1.0246-1.0251 in. (26.025-26.038 mm)	1.0276 in. (26.100 mm)
Wrist Pin to Wrist Pin Bushing Clearance	0.0010-0.0020 in. (0.025-0.051 mm)	0.0079 in. (0.200 mm)
Large End Bore (Without Bearing)	2.0079-2.0083 in. (51.000-51.010 mm)	
Rod Bearing Clearance	0.0015-0.0029 in. (0.038-0.074 mm)	0.0063 in. (0.160 mm)
Side Clearance (Crank to Rod)	0.008-0.016 in. (0.20-0.40 mm)	0.022 in. (0.55 mm)
Twist per 4 in. (100 mm)	0.001 in. (0.03 mm)	0.003 in. (0.08 mm)
Parallelism per 4 in. (100 mm)	0.001 in. (0.03 mm)	0.003 in. (0.08 mm)
Crankshaft and Crankshaft Bearings		
Main Journal Outside Diameter		
Standard	1.9666-1.9670 in. (49.952-49.962 mm)	1.9650 in. (49.910 mm)
Undersize	1.9568-1.9572 in. (49.702-49.712 mm)	1.9551 in. (49.660 mm)
Main Bearing Inside Diameter		
Standard	1.9685-1.9693 in. (50.000-50.020 mm)	1.9709 in. (50.060 mm)
Undersize	1.9587-1.9594 in. (49.750-49.770 mm)	1.9610 in. (49.810 mm)
Main Bearing Clearance	0.0015-0.0027 in. (0.038-0.068 mm)	0.0059 in. (0.150 mm)
Main Bearing Bore Inside Diameter (Without Bearing)	2.1260-2.1267 in. (54.000-54.019 mm)	
Rod Journal Outside Diameter		
Standard	1.8879-1.8883 in. (47.952-47.962 mm)	1.8862 in. (47.910 mm)
Undersize	1.8780-1.8784 in. (47.702-47.712 mm)	1.8764 in. (47.660 mm)
Rod Bearing Inside Diameter		
Standard	1.8898-1.8908 in. (48.000-48.026 mm)	1.8925 in. (48.070 mm)
Undersize	1.8799-1.8809 in. (47.750-47.776 mm)	1.8827 in. (47.820 mm)
Rod Bearing Clearance	0.0015-0.0029 in. (0.038-0.074 mm)	0.0063 in. (0.160 mm)
End Play	0.0035-0.0107 in. (0.090-0.271 mm)	0.0130 in. (0.330 mm)
Deflection		0.0008 in. (0.020 mm)

Cylinder Block	Standard Dimensions	Wear Limit
Cylinder Inside Diameter		
TK 482		
Standard	3.2283-3.2295 in. (82.000-82.030 mm)	3.2362 in. (82.200 mm)
1st Oversize	3.2382-3.2394 in. (82.250 -82.280 mm)	3.2461 in. (82.450 mm)
2nd Oversize	3.2480-3.2492 in. (82.500-82.530 mm)	3.2559 in. (82.700 mm)
TK 486		
Standard	3.3858-3.3870 in. (86.000-86.030 mm)	3.3937 in. (86.200 mm)
1st Oversize	3.3957-3.3969 in. (86.250-86.280 mm)	3.4035 in. (86.450 mm)
2nd Oversize	3.4055-3.4067 in. (86.500-86.530 mm)	3.4134 in. (86.700 mm)
Cylinder Roundness	0-0.0004 in. (0-0.010 mm)	0.0012 in. (0.030 mm)
Cylinder Taper (Cylindricity)	0-0.0004 in. (0-0.010 mm)	0.0012 in. (0.030 mm)
Deck Distortion		0.002 in. (0.05 mm)
Cylinder Head		
Distortion	0-0.002 in. (0-0.05 mm)	0.006 in. (0.15 mm)
Timing Gears		
Timing Gear Lash		
Crankshaft Gear to Idler Gear	0.0028-0.0059 in. (0.070-0.150 mm)	0.0079 in. (0.200 mm)
Crankshaft Gear to Oil Pump Gear	0.0028-0.0059 in. (0.070-0.150 mm)	0.0079 in. (0.200 mm)
Idler Gear to Camshaft Gear	0.0028-0.0059 in. (0.070-0.150 mm)	0.0079 in. (0.200 mm)
Idler Gear to Fuel Injection Pump Gear	0.0028-0.0059 in. (0.070-0.150 mm)	0.0079 in. (0.200 mm)
Idler Gear Bushing Inside Diameter	1.8110-1.8120 in. (46.000-46.025 mm)	1.8142 in. (46.080 mm)
Idler Gear Shaft Outside Diameter	1.8091-1.8100 in. (45.950-45.975 mm)	1.8083 in. (45.930 mm)
Idler Gear Shaft to Idler Gear Bushing Clearance	0.0010-0.0030 in. (0.025-0.075 mm)	0.0059 in. (0.150 mm)
Oil Pump		
Type	Trochoid	
Outer Rotor to Pump Body Clearance	0.0039-0.0063 in. (0.100-0.160 mm)	0.0098 in. (0.250 mm)
Inner Rotor Tip to Outer Rotor Lobe Clearance		0.0059 in. (0.150 mm)
Rotor Plate to Rotor Clearance	0.0012-0.0035 in. (0.030-0.090 mm)	0.0059 in. (0.150 mm)
Rotor Shaft to Rotor Shaft Bore Clearance	0.0005-0.0017 in. (0.013-0.043 mm)	0.0079 in. (0.200 mm)
Pressure Control Valve Setting	36-50 psi (245-343 kPa)	

Starter	Standard Dimensions	Wear Limit
No Load Test		
Voltage	11 volts	
Current	Maximum of 140 amps @ 11 volts	
Speed	Minimum of 3900 rpm @ 11 volts	
Loaded Properties		
Voltage	8.76 volts	
Current	300 amps	
Commutator Outside Diameter	1.44 in. (36.5 mm)	1.40 in. (35.5 mm)

Torque Values for TK 482 & TK 486 Engines

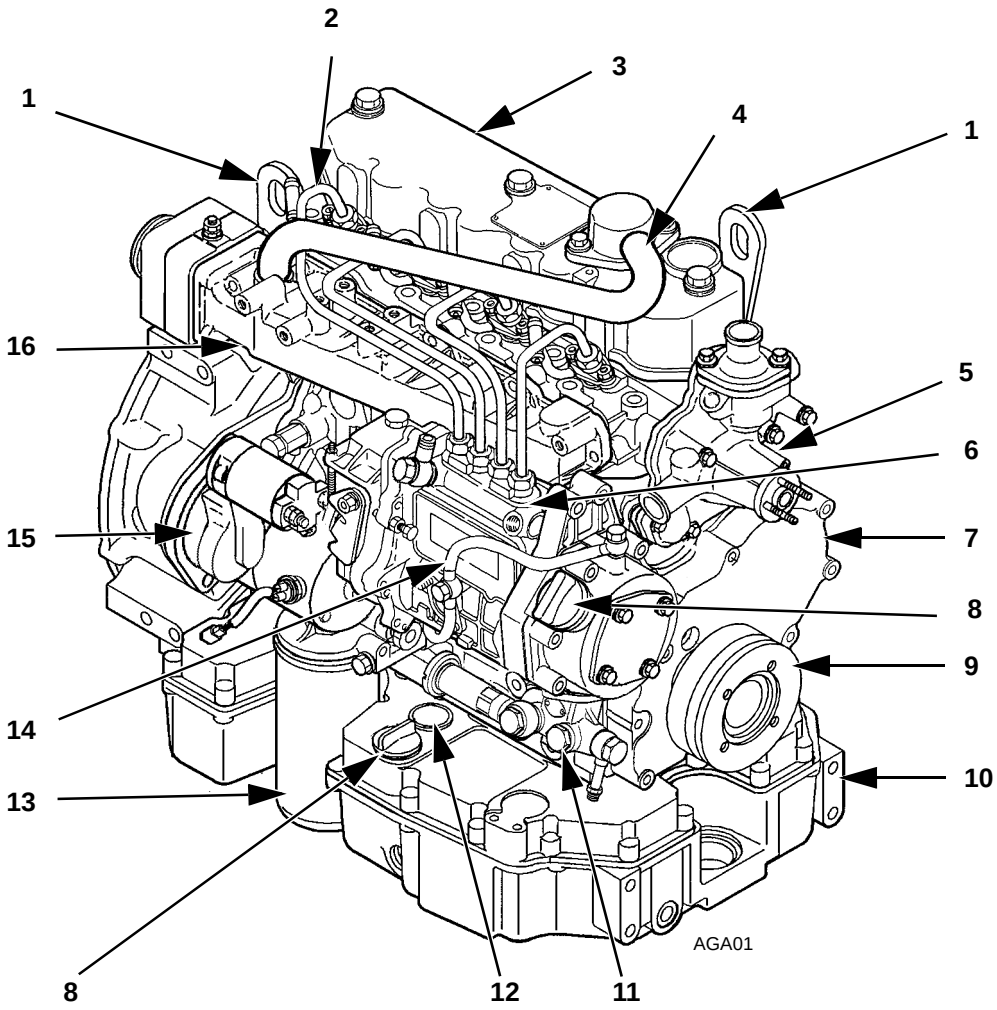
Description	Dia. x Pitch (mm)	N•m	ft-lb	kgm
Connecting Rod Bolt	9X1.0	44.1-53.9	32.5-39.8	4.5-5.5
Crankshaft Pulley Bolt	14X1.25	112.8-122.6	83.2-90.4	11.5-12.5
Cylinder Head Mtg. Bolt	10X1.25	85.3-91.2	62.9-67.3	8.7-9.3
Flywheel Mtg. Bolt	10X1.25	83.4-88.3	61.5-65.1	8.5-9.0
Fuel Injection Line Nut.	12X1.5	29.4-34.3	21.7-25.3	3.0-3.5
Fuel Injection Nozzle Mtg. Nut	6X1.0	6.9-8.8	5.1-6.5	0.7-0.9
Fuel Injection Nozzle Nut		39.2-44.1	28.9-32.5	4.0-4.5
Fuel Injection Pump Gear Mtg. Nut	12X1.75	58.8-68.6	43.4-50.6	6.0-7.0
Main Bearing Bolt	12X1.5	96.1-100.0	70.9-73.8	9.8-10.2
Rocker Arm Support Mtg. Bolt	8X1.25	22.6-28.4	16.6-21.0	2.3-2.9
Standard 6 mm Bolt and Nut	6X1.0	9.8-11.8	7.2-8.7	1.0-1.2
Standard 8 mm Bolt and Nut	8X1.25	22.6-28.4	16.6-21.0	2.3-2.9
Standard 10 mm Bolt and Nut	10X1.5	44.1-53.9	32.5-39.8	4.5-5.5
Standard 12 mm Bolt and Nut	12X1.75	78.5-98.1	57.9-72.3	8.0-10.0

NOTE: For standard bolts in aluminum parts use 80% of the specified torque.

Engine Disassembly 2

Engine Disassembly

Before disassembling the engine, drain the engine oil and coolant, disconnect the battery cables, and remove the engine from the unit.

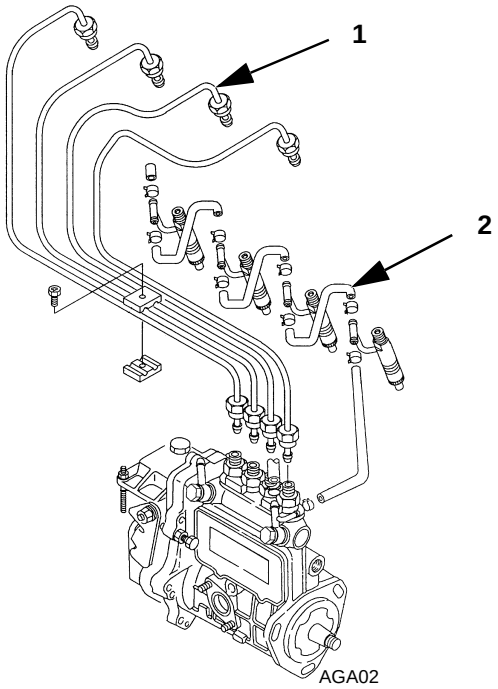


1.	Lift Bracket	9.	Crankshaft Pulley
2.	Fuel Injection Line	10.	Oil Pan
3.	Valve Cover	11.	Fuel Transfer Pump
4.	Crankcase Breather Hose	12.	Oil Level Switch
5.	Water Pump	13.	Oil Filter
6.	Fuel Injection Pump	14.	Oil Line
7.	Timing Gear Cover	15.	Starter
8.	Oil Filler	16.	Intake Manifold

Front View

While disassembling the engine, note things such as the position of dowel pins and O-rings, and the existing timing marks and bearing cap marks. Identical components in the valve train and the crankshaft assembly should be kept in order or marked. This prevents mixing up these components and allows the components to be placed in their original positions when the engine is assembled.

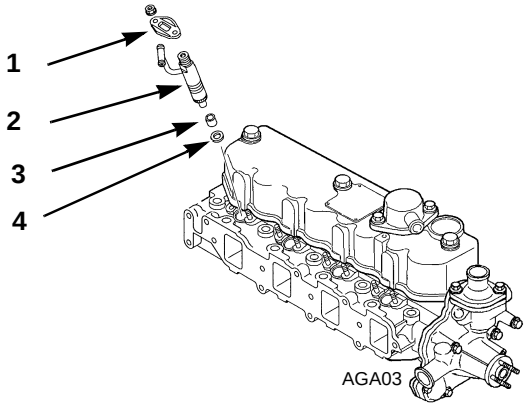
1. Remove the exhaust manifold.
2. Remove the crankcase breather hose.
3. Remove the fuel injection lines. Cover all the injection lines, fuel lines, and fittings with plastic covers or tape. The smallest amount of dirt can damage the fuel system.
4. Remove the fuel injection return lines.



1.	Fuel Injection Lines
2.	Fuel Injection Return Lines

Remove Fuel Injection Lines

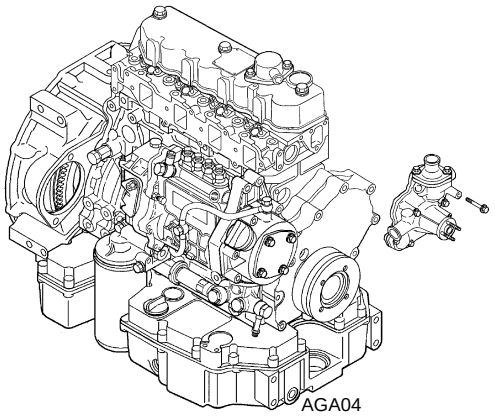
5. Remove the intake manifold.
6. Remove the lift brackets from the cylinder head.
7. Remove the fuel injection nozzle mounting nuts and retainers.
8. Remove the fuel injection nozzles. Use injection nozzle puller P/N 204-902 if necessary.



1.	Retainer
2.	Fuel Injection Nozzle
3.	Nozzle Protector
4.	Nozzle Gasket

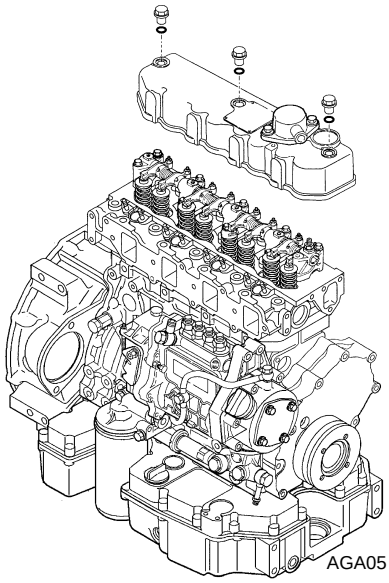
Remove Fuel Injection Nozzles

9. Remove the water pump.



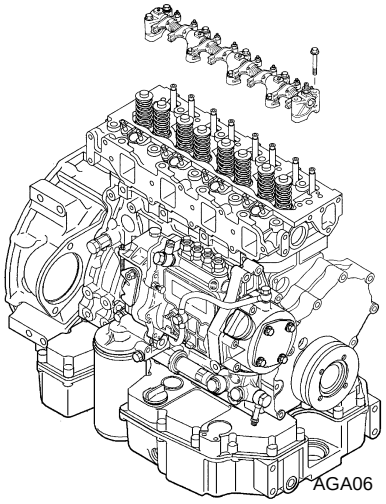
Remove Water Pump

10. Remove the valve cover by removing the three special cap nuts. Inspect the O-rings under these cap nuts and replace the O-rings, if necessary, during assembly.



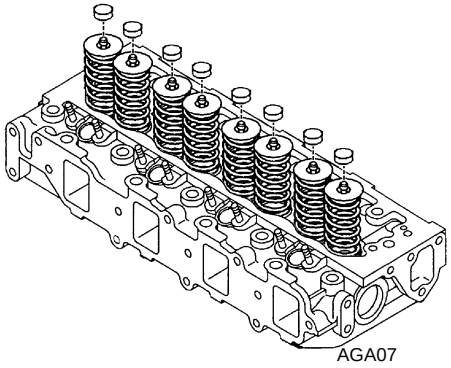
Remove Valve Cover

11. Remove the rocker arm assembly by removing the bolts that mount the rocker arm supports. Alternately loosen each bolt one turn at a time to evenly release the spring pressure on the rocker arm assembly.



Remove Rocker Arm Assembly

12. Remove the valve stem caps and keep them in order.

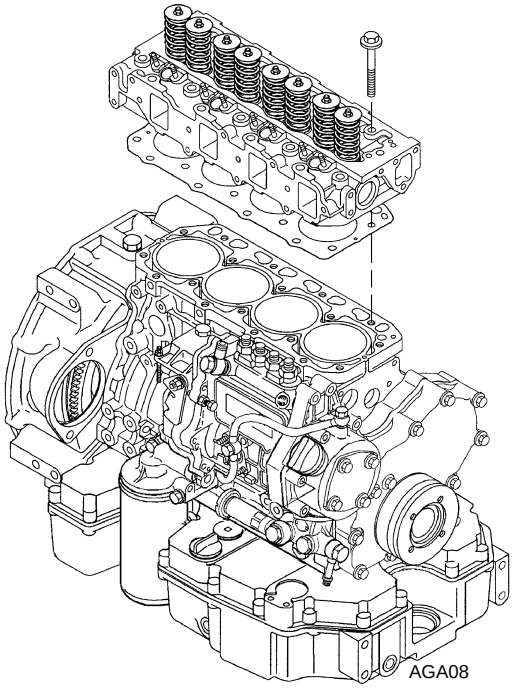


Remove Valve Stem Caps

13. Remove the push rods and keep them in order if they will be reused.

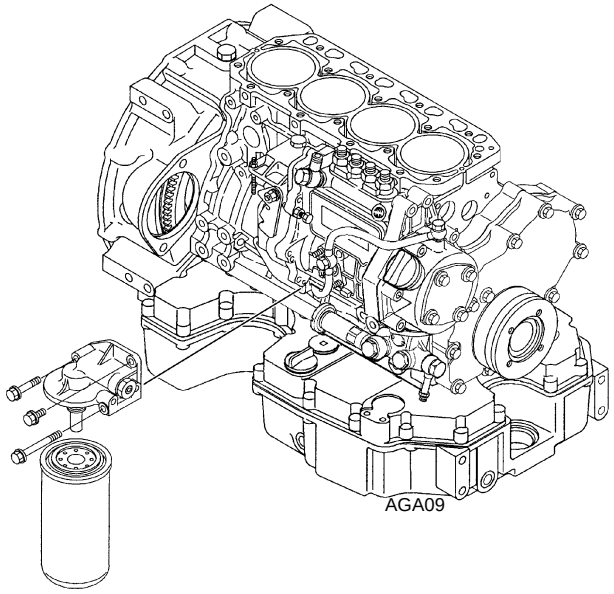
14. Break each cylinder head bolt loose 1/4 to 1/2 turn in a crisscross pattern starting at the ends. Then remove the cylinder head bolts.

15. Remove the cylinder head from the cylinder block.



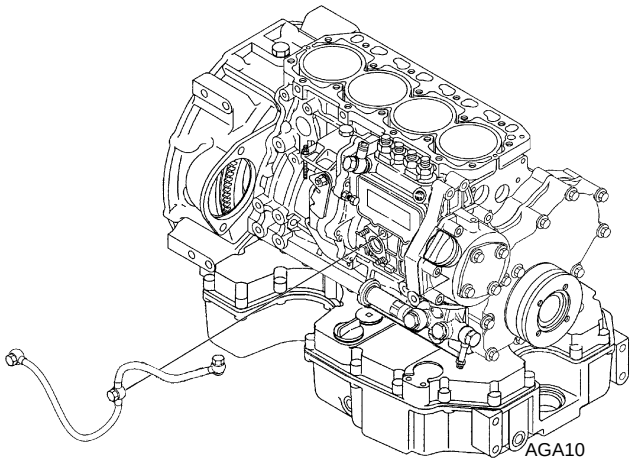
Remove Cylinder Head

16. Remove the oil filter and the oil filter adapter.



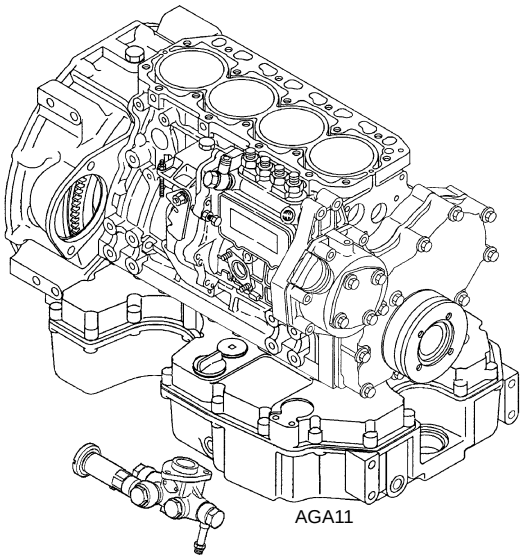
Remove Oil Filter and Adapter

17. Remove the oil line that goes from the cylinder block to the fuel injection pump and the timing gear cover.



Remove Oil Line

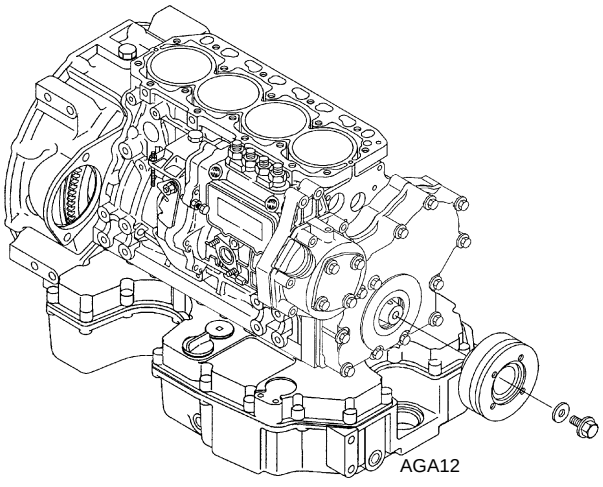
18. Remove the fuel transfer pump from the timing gear cover.



Remove Fuel Transfer Pump

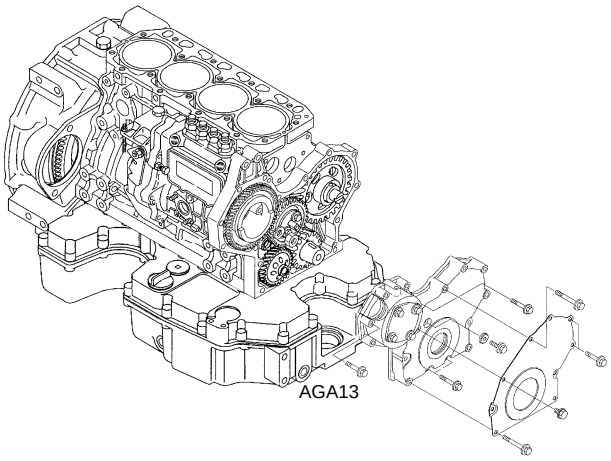
19. Remove the front crankshaft bolt.

20. The end of the crankshaft is tapered. Remove the crankshaft pulley by using a suitable puller.



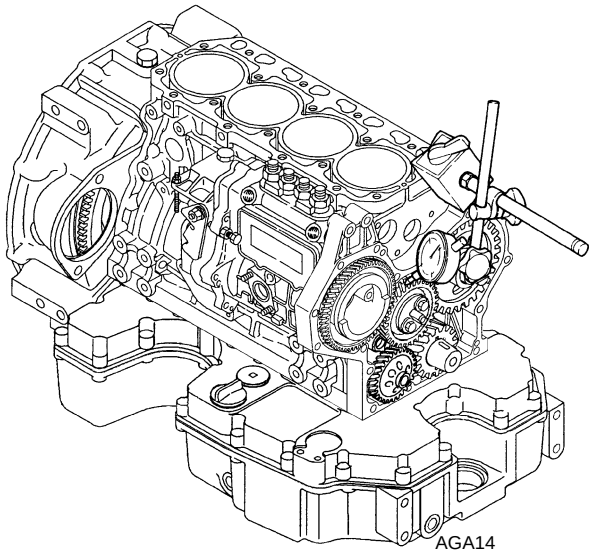
Remove Crankshaft Pulley

21. Remove the timing gear cover and sound shield.



Remove Timing Gear Cover and Sound Shield

22. Check the timing gear lash. If the gear lash is within specifications (refer to Specifications), the gears can probably be reused. If the gear lash is excessive, some or all of the gears must be replaced to meet the specifications.

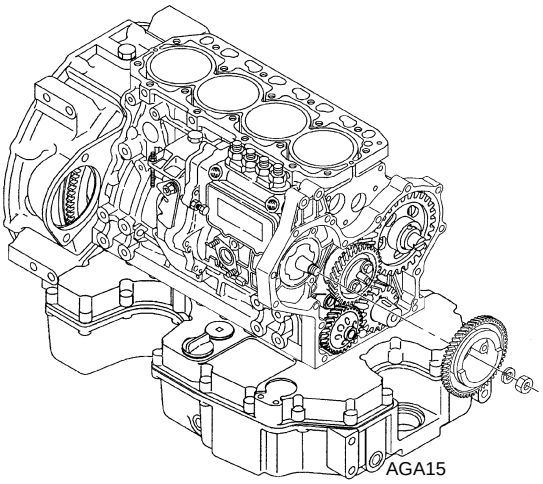


Check Timing Gear Lash

23. Note the timing marks on the timing gears. The timing marks must be aligned when the engine is assembled.

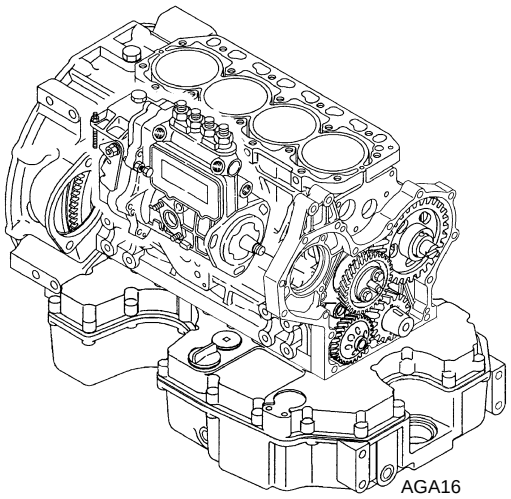
24. Remove the fuel injection pump gear nut and lock washer.

25. The fuel injection pump shaft is tapered. The fuel injection pump gear must be removed to remove the fuel injection pump. Remove the fuel injection pump gear by using a suitable puller.



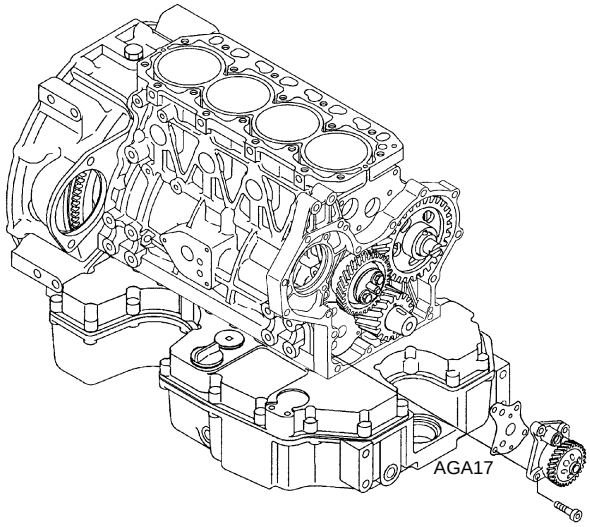
Remove Fuel Injection Pump Gear

26. Note the position of the index marks and remove the fuel injection pump from the timing gear housing.



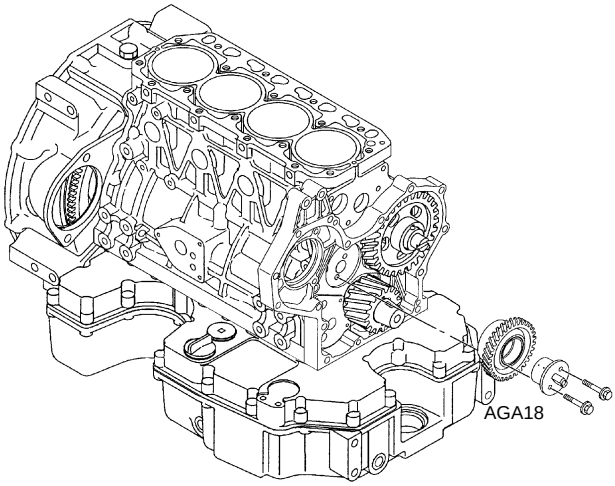
Remove Fuel Injection Pump

27. Remove the oil pump.



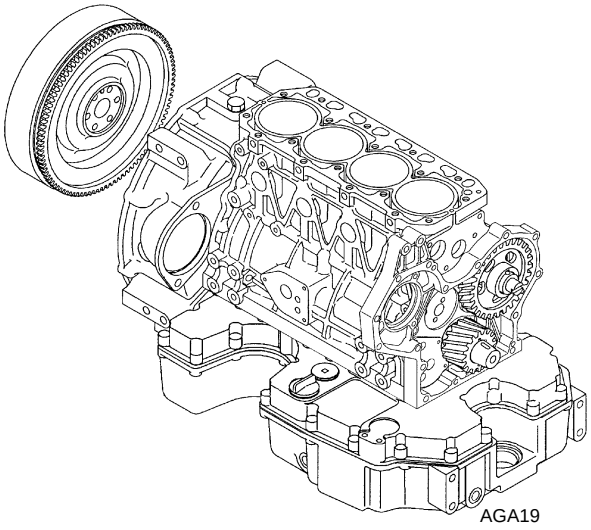
Remove Oil Pump

28. Remove the two bolts from the idler gear shaft.
29. Remove the idler gear and the idler gear shaft from the cylinder block.



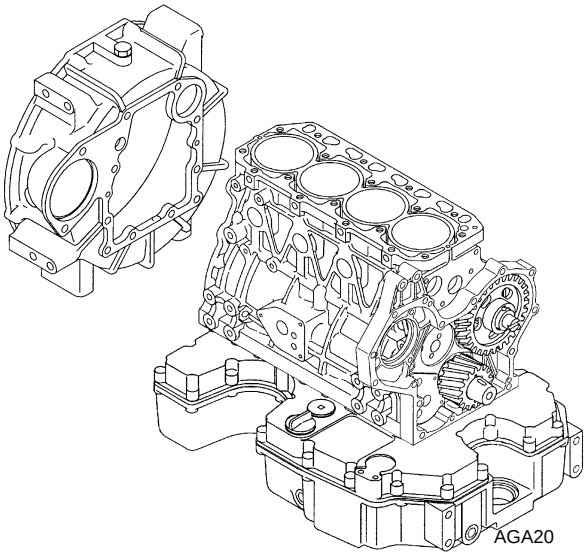
Remove Idler Gear and Idler Gear Shaft

30. Remove the flywheel.



Remove Flywheel

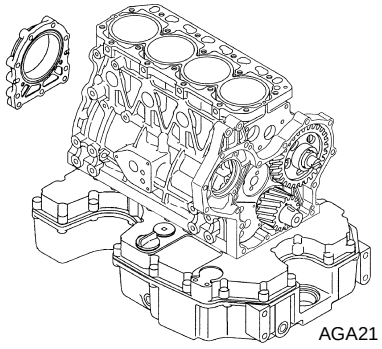
31. Remove the bellhousing.



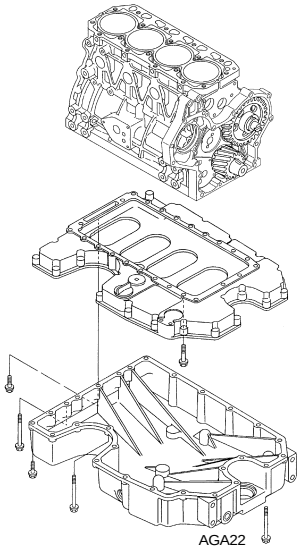
Remove Bellhousing

32. Remove the rear seal housing. Use the slots on the sides to pry it off if necessary.

    NOTE: The engine is equipped with an axial rear seal. The metal seal ring may stay on the crankshaft when the rear seal housing is removed. The metal seal ring must be removed before a new rear seal is installed. To remove the metal seal ring first remove the old seal from the rear seal housing. Then place the rear seal housing back on the engine and use two pry bars (one on each side) to pry the metal seal ring off the crankshaft. Be careful not to damage the crankshaft or the rear seal housing.



Remove Rear Seal Housing

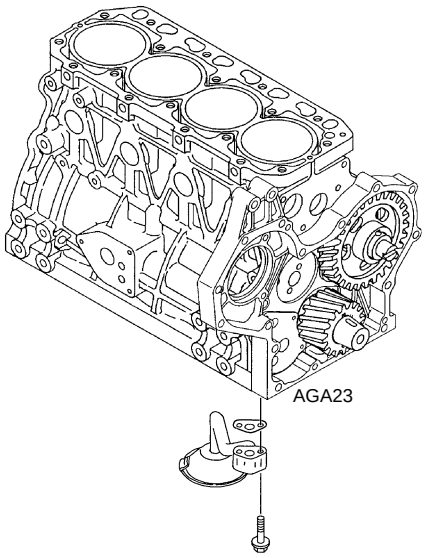


Remove Oil Pan

33. Make sure the oil has been drained and remove the lower part of the oil pan. The lower part of the oil pan must be removed to access some of the mounting bolts for the upper part of the oil pan.

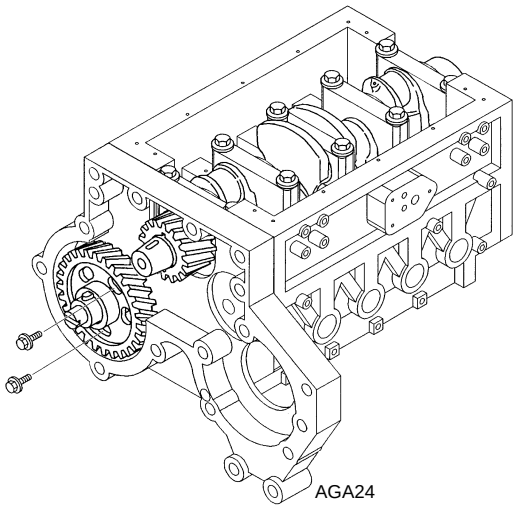
34. Remove the upper part of the oil pan.

35. Remove the oil intake pipe.



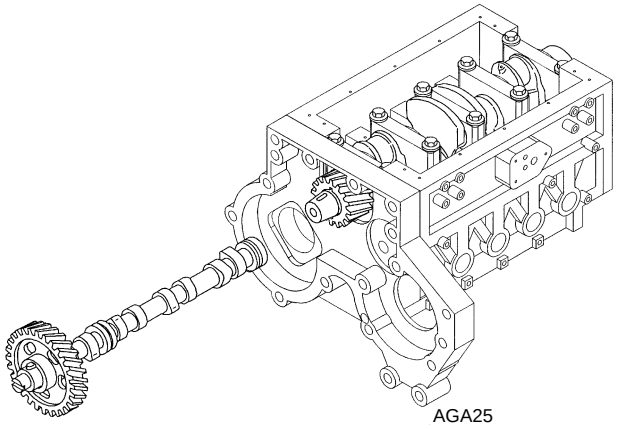
Remove Oil Intake Pipe

36. Remove the mounting bolts from the camshaft thrust plate by turning the camshaft gear to access the bolts through the holes in the gear.



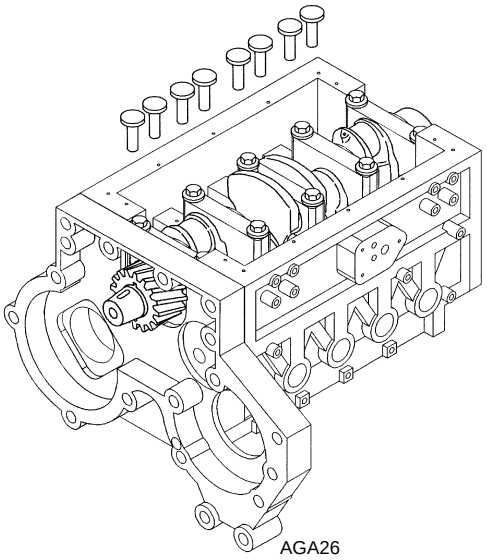
Remove Camshaft Mounting Bolts

37. Carefully remove the camshaft to avoid scratching or marring the camshaft bearings. The engine must be upside down to prevent the tappets from interfering with the removal of the camshaft.


AGA25

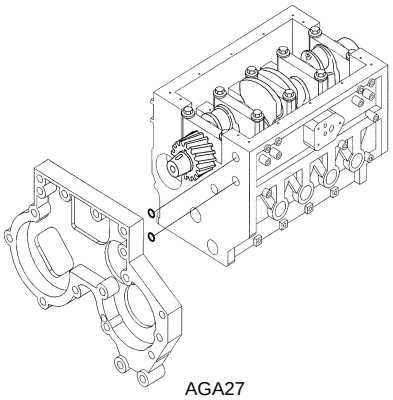
Remove Camshaft

38. Remove the tappets (valve lifters) with a valve lapping tool or a magnet. Keep the tappets in order so they will be placed in the same position when assembled.


AGA26

Remove Tappets

39. Remove the timing gear housing, and the two O-rings from the oil passages between the timing gear housing and the cylinder block.


AGA27

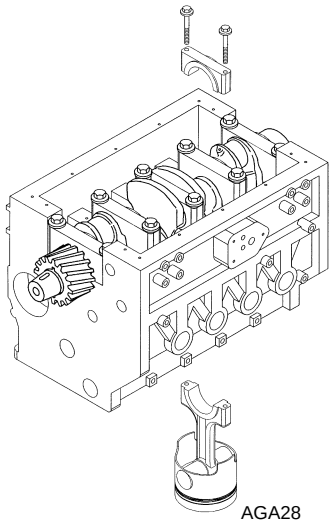
Remove Timing Gear Housing

40. Remove the ring ridge from the top of each cylinder, if necessary.

41. Mark the connecting rod caps, connecting rods, pistons, and main bearing caps so they can be placed in the same position when assembled. The main bearing caps are marked as shown on page 28.

42. Remove the connecting rod caps.

43. Carefully remove the piston and connecting rod assemblies through the top of the cylinders to avoid scratching or marring the cylinder walls.


AGA28

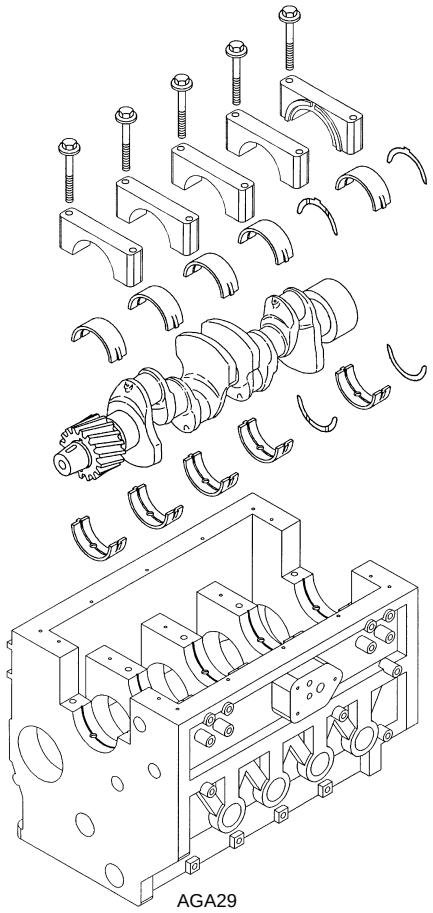
Remove Piston and Rod Assemblies

44. Remove the main bearing caps.

    NOTE: The rear main bearing cap (flywheel end) has a thrust bearing on each side. Make sure to remove these two thrust bearings.

45. Carefully remove the crankshaft from the block.

    NOTE: The upper rear main bearing (flywheel end) has a thrust bearing on each side. Make sure to remove these two thrust bearings.



Remove Crankshaft

Inspection and Reconditioning 3

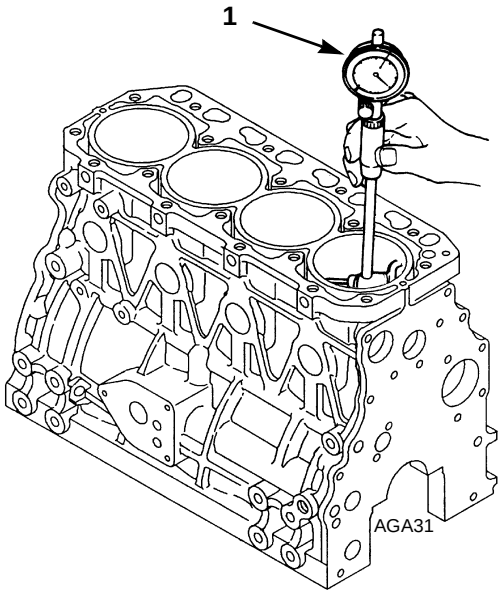
Inspection and Reconditioning

NOTE: Refer to the Specifications Chapter for specific dimensions that are not given in this chapter.

This chapter covers the cleaning, inspection, overhaul, and assembly of individual engine components. After disassembling the engine, check the components and discard unusable parts such as gaskets, O-rings, burned valves, and broken rings. Check the items that may need machine shop work first so this work can be completed by the time the rest of the engine is ready to assemble.

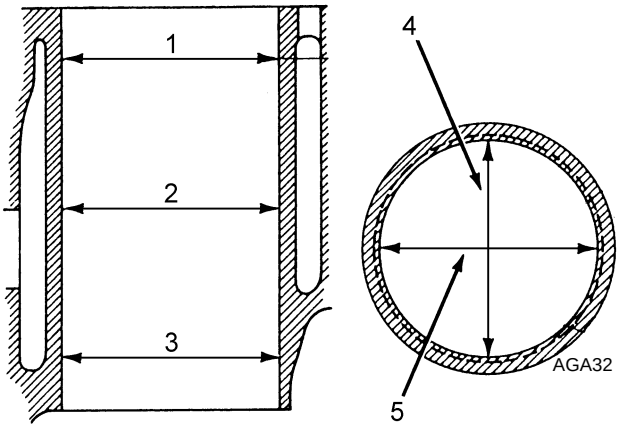
Cylinder Block

1. Inspect the cylinder block for cracks, damage, and distortion. Use a straight edge and a feeler gauge to check the cylinder block deck for distortion. Check all four sides, both diagonals, and the center lines of the cylinder block deck. If there is more than 0.002 in. (0.05 mm) distortion, resurface the cylinder block. Do not remove more than 0.002 in. (0.05 mm) from the surface of the cylinder block.
2. Check each cylinder for out of round, taper, pocketing, or any other damage that would require boring the cylinders. Use a dial bore gauge or a snap gauge to measure the cylinders. Measure each cylinder both parallel and perpendicular to the crankshaft, at the top, the middle, and the bottom of the cylinder bore. The cylinder out of roundness and taper should not exceed 0.0012 in. (0.030 mm). If the cylinders are in good condition, deglaze the cylinders with a glaze breaker.
3. If the cylinders must be bored, determine which oversize pistons should be used. Pistons are available in 0.010 and 0.020 in. (0.25 and 0.50 mm) oversizes.



1.	Dial Bore Gauge

Measuring Cylinder Diameter



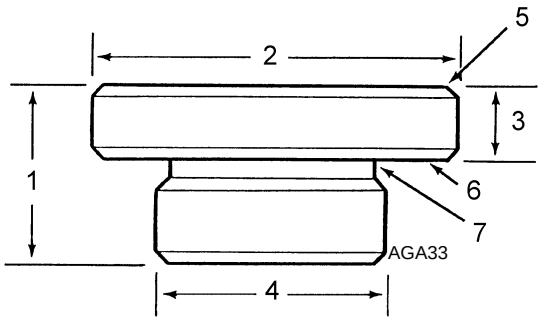
1.	Top
2.	Middle
3.	Bottom
4.	Perpendicular to Crankshaft
5.	Parallel to Crankshaft

Cylinder Measuring Positions

NOTE: If the 0.020 in. (0.50 mm) oversize is not large enough to clean up the cylinders, cylinder sleeves and standard pistons must be installed. Cylinder sleeves are available from the Service Parts Department. Use P/N 11-9036 for the TK 482. Use P/N 11-8919 for the TK 486. Use the following procedure to install cylinder sleeves:

a. Bore and hone the cylinder block to accept the cylinder sleeves. The recommended interference fit for the cylinder sleeves is 0.0024 to 0.0047 in. (0.060 to 0.120 mm).

   Measure each cylinder sleeve and subtract 0.0035 in. (0.090 mm). Bore and hone each cylinder to match this dimension. The final surface finish should have an RA (Roughness Average) less than 248 micro inches (6.3 microns).



1.	1.575 in. (40.00 mm)
2.	TK 482 — 3.819 in. (97.00 mm) TK 486 — 3.976 in. (101.00 mm)
3.	0.591 in. (15.00 mm)
4.	TK 482 — 3.177-3.181 in. (80.70-80.80 mm) TK 486 — 3.335-3.33.9 in. (84.70-84.80 mm)
5.	Plane B
6.	Plane A
7.	Area C - Relieve this area as shown.

Pressing Tool Dimensions

b. Press the cylinder sleeves into the cylinder block using a hydraulic press and a pressing tool.

   The pressing tool can be fabricated using the dimensions in the preceding illustration.

   Planes A and B must be parallel.

   Planes A and B must be perpendicular to the center line of the tool.

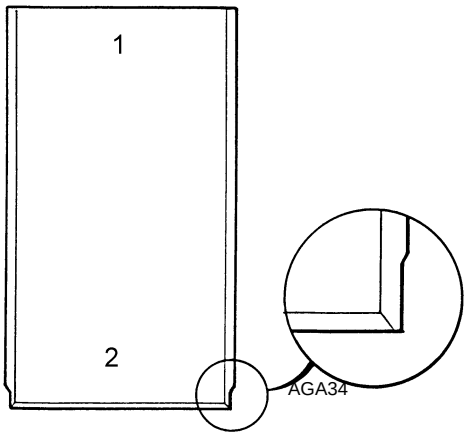
   Relieve area C slightly as shown to prevent interference with the sleeve.

   Bevel all the edges slightly.

c. Use a hydraulic press to press the cylinder sleeves into the block.

   Place the pressing tool in the top end of the cylinder sleeve.

   The bottom end of a cylinder sleeve has a slightly smaller outside diameter than the rest of the sleeve.



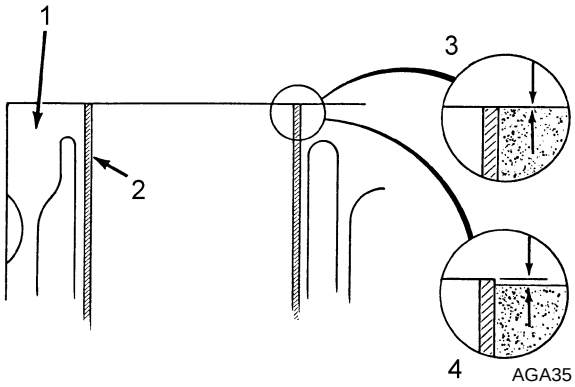
1.	Top
2.	Bottom

Cylinder Sleeve

Spray oil on the outside of the cylinder sleeve or on the inside of the cylinder bore in the block.

Place the cylinder sleeve in the block and press the sleeve into place. The pressing load should be 2200 to 4400 lb. (1000 to 2000 kg).

The top of the cylinder sleeve must be flush with the top of the block. The cylinder sleeve cannot protrude above the top of the block at all.



1.	Cylinder Block
2.	Cylinder Sleeve
3.	The cylinder sleeve must be flush.
4.	The cylinder sleeve cannot protrude above the block.

Cylinder Sleeve Installation

d. Bore and hone each cylinder sleeve to obtain the correct piston clearance.

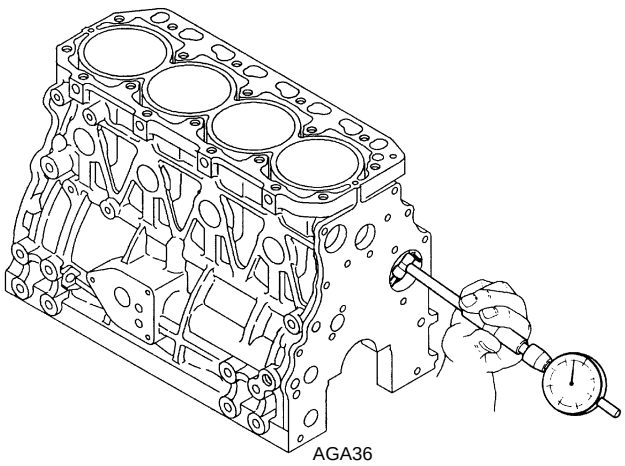
4. Measure each piston. Bore and hone each cylinder to obtain a piston to cylinder clearance of 0.0012 to 0.0035 in. (0.030 to 0.090 mm).

CAUTION: The pistons will vary slightly in diameter. Therefore, each piston must be measured and each cylinder must be bored and honed to match each piston.

The final surface finish in the cylinders should have an RA (Roughness Average) of 10 to 35 micro inches (0.25 to 0.90 microns).

5. Measure the front camshaft bearing insert. If the front camshaft bearing insert is larger than 1.7756 in. (45.100 mm) or has a damaged surface, remove the bearing insert with a bearing driver. If the block will be boiled out, remove the bearing insert and all the core plugs.

NOTE: The middle and rear camshaft bearings do not have bearing inserts.

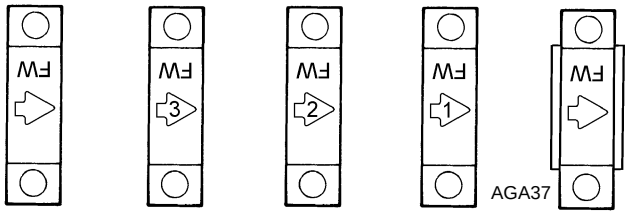


Measuring Front Camshaft Bearing Insert

6. This engine does not have middle and rear camshaft bearing inserts. The bearing surfaces for middle and rear camshaft bearings are machined into the block. Measure the middle and rear camshaft bearings. If the middle or rear camshaft bearings are larger than 1.7756 in. (45.100 mm), or if the surfaces have been damaged significantly, replace the block.

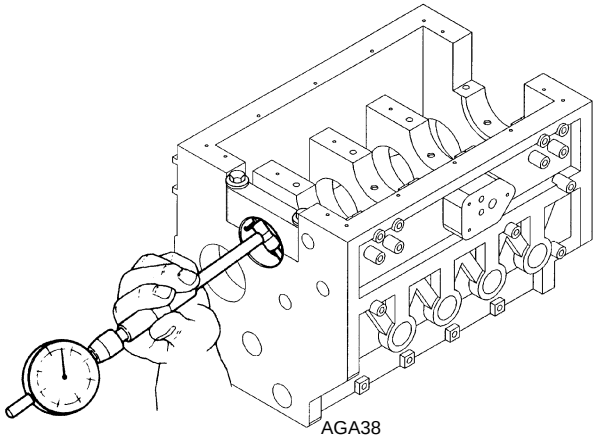
Minor damage to the middle and rear camshaft bearings can be cleaned up with a brake cylinder hone. The middle and rear camshaft bearings should also be lightly honed after the block has been boiled out.

7. Install the main bearing caps in their proper positions. The cast arrows are labeled FW and should point to the rear (flywheel end) of the engine. The main bearing cap that is machined for the thrust bearing goes to the rear end of the engine. The main bearing caps with numbers stamped on them go to the middle of the engine with the main bearing cap marked number one closest to the rear of the engine. The main bearing cap with no number goes to the front end of the engine. Torque the main bearing cap bolts to 70.9 to 73.8 ft-lb (96.1 to 100.0 N•m).



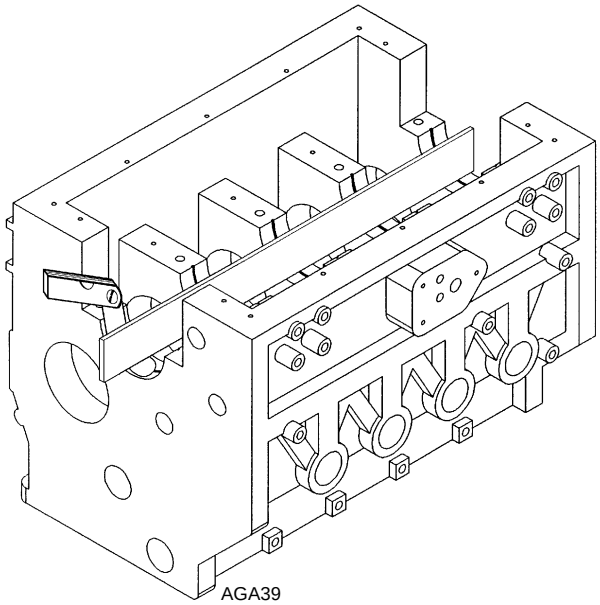
Main Bearing Cap Marks

8. Measure the main bearing bores both vertically and horizontally. The standard dimension is 2.1260 to 2.1267 in. (54.000 to 54.019 mm). If the main bearing bores are more than 0.001 in. (0.25 mm) out of round, the block must be align bored.



Measuring Main Bearing Bore

9. Check the main bearing bore alignment with a straight edge and a 0.0015 in. (0.038 mm) feeler gauge. Lay the straight edge in main bearing bores of the block and place the feeler gauge between the straight edge and each main bearing bore. There should be some drag on the feeler gauge at each main bearing bore. If there is no drag on the feeler gauge at any main bearing bore, the block must be align bored.



Checking Main Bearing Bore Alignment

10. Measure each tappet bore in the block. If any of the tappet bores are larger than 0.4744 in. (12.050 mm), the block must be replaced. Small scratches or nicks should be cleaned up with a brake cylinder hone. The tappet bores should also be lightly honed after the block has been boiled out.

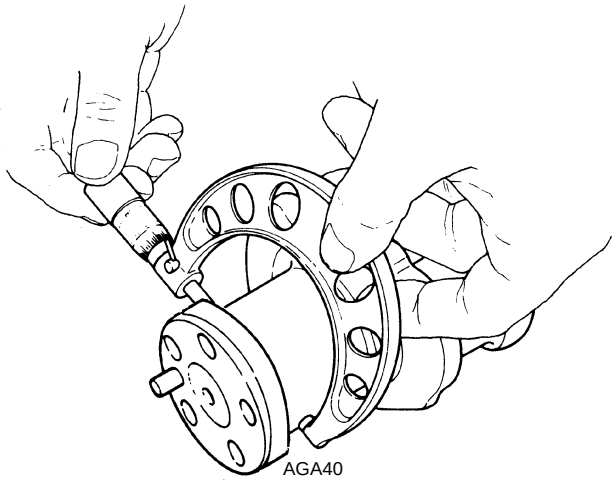
11. Check or replace all of the core plugs.

Crankshaft

1. Check the crankshaft for cracks and check the main journals, rod journals, and the oil seal surface for excessive wear or damage. Check to see that the oil passages are not clogged or dirty.

2. Measure the main journals. If any of the main journals are smaller than 1.9650 in. (49.910 mm), or tapered or out of round more than 0.0010 in. (0.025 mm), the main journals must be ground undersize.

   Only the 0.010 in. (0.25 mm) undersize main bearings are available. The wear limit for the outside diameter of undersized main journals is 1.9551 in. (49.660 mm).

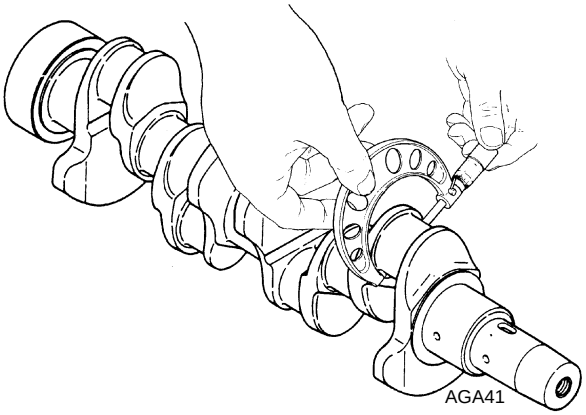


Measuring Main Journal

NOTE: The most accurate method of determining the outside diameter of the undersized main journals is to install the main bearing caps with the undersized bearing inserts in place. Properly torque the main bearing caps to the block and measure the inside diameter of the main bearings. Subtracting the suggested oil clearance of 0.0015 to 0.0027 in. (0.038 to 0.068 mm) from the inside diameter of the main bearings results in the correct outside diameter for the undersized main journals.

3. Measure the rod journals. If any of the rod journals are smaller than 1.8862 in. (47.910 mm), or tapered or out of round more than 0.0010 in. (0.025 mm), the rod journals must be ground undersize.

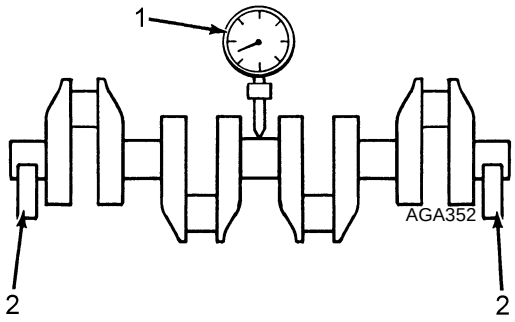
   Only the 0.010 in. (0.25 mm) undersize rod bearings are available. The wear limit for the outside diameter of undersized rod journals is 1.8764 in. (47.660 mm).



Measuring Rod Journal

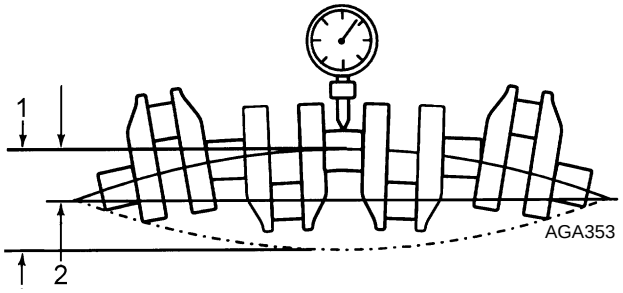
NOTE: The most accurate method of determining the outside diameter of the undersized rod journals is to install the rod caps with the undersized bearing inserts in place. Properly torque the rod caps to the rods and measure the inside diameter of the rod bearings. Subtracting the suggested oil clearance of 0.0015 to 0.0029 in. (0.038 to 0.074 mm) from the inside diameter of the rod bearings results in the correct outside diameter for the undersized rod journals.

4. Measure the crankshaft deflection by placing the front and rear main journals in a set of "V" blocks, or place the crankshaft in the block resting on only the old front and rear upper main bearing inserts. Set a dial indicator on the middle main journal and rotate the crankshaft one full turn. The crankshaft deflection equals one half of the largest difference in readings on the dial indicator. If the crankshaft deflection is greater than 0.0008 in. (0.020 mm) the crankshaft must be replaced.



1.	Dial Indicator
2.	“V” block

Measuring Crankshaft Deflection



1.	Difference in Readings
2.	Deflection

Crankshaft Deflection

5. Inspect the crankshaft timing gear for chipped or worn teeth and for any cracks on or between the teeth. To remove the gear use a standard gear puller. Install the gear by pressing it onto the crankshaft. Apply a sealant to the inside of the gear to prevent oil leaks.

6. Check the area on the end of the crankshaft from which metal seal ring for the rear seal was removed. Any scratches, nicks, or damage to this area of the crankshaft must be cleaned up, or the new metal seal ring may not seal to the crankshaft. Remove the metal seal ring for the rear seal if it has not yet been removed. The metal seal ring can then be removed by carefully cutting it with a sharp chisel.

Pistons

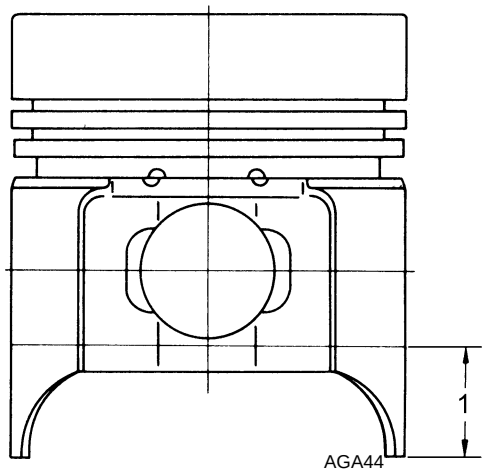
1. Remove and discard the old piston rings.

2. Remove the wrist pin circlips and push the wrist pin out of the piston. If it is difficult to push the wrist pin out of the piston, heat the piston in hot water that is at 120 to 140 F (49 to 60 C).

   NOTE: Do not clamp a connecting rod in a vise with steel jaws. Instead, use a vise that has soft jaws, or use soft jaw covers. Clamping a connecting rod in the steel jaws of a vise will put small nicks in the connecting rod. These nicks raise the stress on the connecting rod and can cause the connecting rod to break while the engine is running.

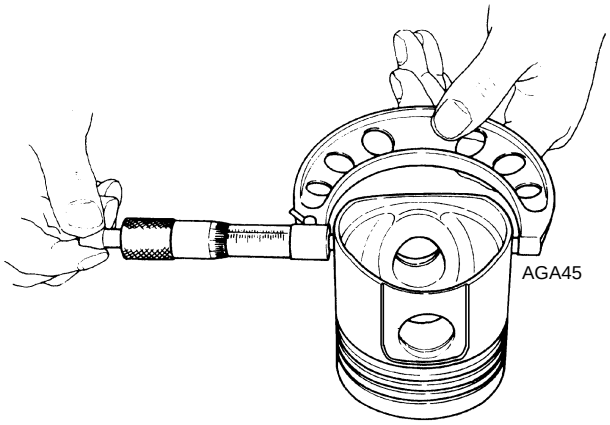
3. Remove the carbon from the top of the piston but do not scratch the piston. Clean the piston and inspect it for damage. Replace the piston if it has any cracks, or if the top of the piston is significantly burned or damaged.

4. Measure the outside diameter of each piston. This measurement should be taken perpendicular to the wrist pin 0.95 in. (24.0 mm) above the bottom of the piston skirt. If the piston is smaller than the wear limit (refer to Specifications), replace the piston.



1.	0.95 in. (24.0 mm)

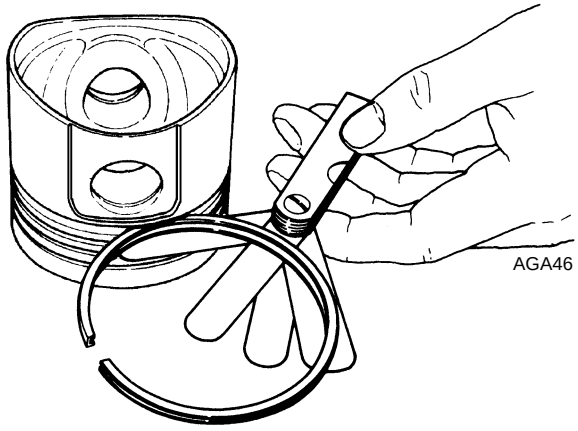
Piston Measuring Point



Measuring Piston

5. Clean the ring groves with a ring groove cleaner. Be careful to avoid scraping any metal off the piston. If a ring groove cleaner is not available, break a used ring and sharpen the end. This can be used to clean the ring grooves.

6. Use a new set of piston rings and a feeler gauge to check the clearance between the rings and the ring grooves. If the clearance between a new ring and its respective ring groove is greater than 0.0098 in. (0.250 mm) for the top and middle rings or 0.0079 in. (0.200 mm) for the bottom ring, the piston must be replaced.



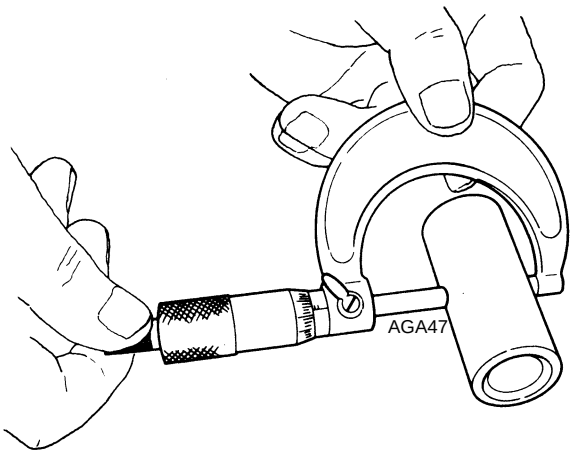
Checking Ring Clearance

7. Measure the inside diameter of the wrist pin bore. If the inside diameter of the wrist pin bore is larger than 1.0244 in. (26.020 mm), replace the piston.

Wrist Pins

The wrist pin and the connecting rod bushing carry a large load concentrated in a small area. Therefore a precise fit is critical. If possible, a qualified machine shop should fit new wrist pins to new connecting rod bushings when an engine is overhauled.

1. Measure the outside diameter of the wrist pins with a micrometer. If a wrist pin is smaller than 1.0197 in. (25.900 mm), replace the wrist pin.



Measuring Wrist Pin

2. If a micrometer with this degree of accuracy is not available, the fit between the wrist pin and the connecting rod bushing can be checked by oiling the wrist pin and inserting it into the connecting rod bushing. The fit should be snug and it should take a slight push to move the wrist pin through the connecting rod bushing, but the wrist pin should rotate freely.

Connecting Rods

The procedures used to recondition a connecting rod, which include honing the connecting rod bearing bore, straightening the connecting rod, and replacing the connecting rod bushing, require various pieces of expensive equipment. If this equipment is not available, most machine shops can recondition serviceable connecting rods to meet standard specifications.

1. If possible, bead blast the connecting rods with glass beads. Bead blasting does an exceptional job of cleaning the rods, and it also relieves stress by removing minor surface damage that tends to increase stress.

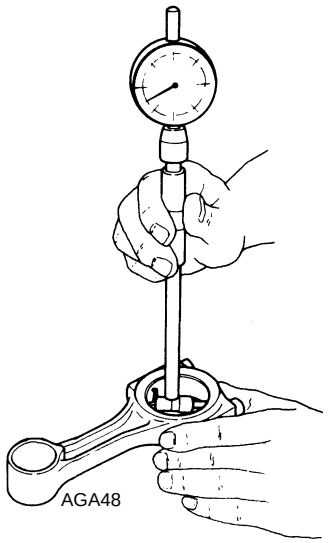
   NOTE: Bead blasting the connecting rods is highly recommended. Most machine shops offer this service and the price is usually quite reasonable.

2. Check each connecting rod bearing by installing the connecting rod cap with the original bearing inserts in place and torquing the rod cap bolts to 32.5 to 39.8 ft-lb (44.1 to 53.9 N•m).

3. Measure the inside diameter of the connecting rod bearings. If any of the connecting rod bearings are larger than 1.8925 in. (48.070 mm) for standard bearings or 1.8827 in. (47.820 mm) for undersized bearings, or show significant damage, replace the entire set of connecting rod bearing inserts.

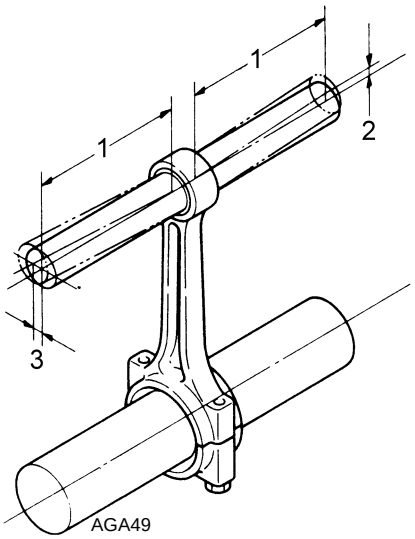
4. Check each connecting rod bearing bore by installing the rod caps with the rod bearing inserts removed and properly torquing the rod cap bolts to 32.5 to 39.8 ft-lb (44.1 to 53.9 N•m).

5. Measure each connecting rod bearing bore both parallel and perpendicular to the rod. The standard dimension is 2.0079 to 2.0083 in. (51.000 to 51.010 mm). If the rod bearing bore is more than 0.001 in. (0.25 mm) out of round the rod must be reconditioned or replaced.



Measuring Rod Bearing or Bearing Bore

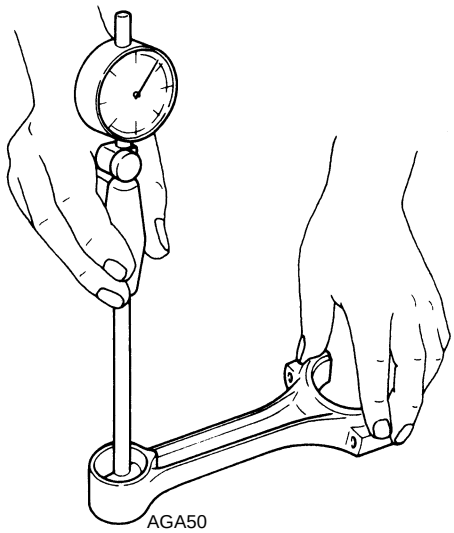
6. Use a connecting rod alignment fixture to check each rod for twist and parallelism. The wear limit for both twist and parallelism is 0.003 in. per 4 in. (0.08 mm per 100 mm). If the twist or parallelism exceeds the wear limit, straighten or replace the rod.



1.	4 in. (100 mm)
2.	Parallelism
3.	Twist

Measuring Connecting Rod Twist and Parallelism

7. Measure the inside diameter of the wrist pin bushings. If the wrist pin bushings are larger than 1.0276 in. (26.100 mm) or show significant damage, replace the wrist pin bushings.



Measuring Wrist Pin Bushing

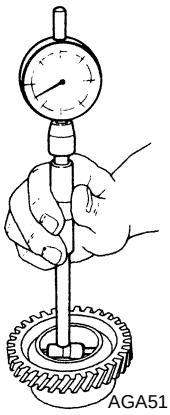
8. To replace a wrist pin bushing, press the old bushing out of the connecting rod. Press the new bushing into the rod and make sure to align the oil hole in the bushing with the oil hole in the top of the rod. The bushing is pre-finished.

Timing Gears

1. Inspect the timing gears for chipped or excessively worn teeth, and for any cracks on or between the teeth. The gear lash should have been checked during the disassembly of the engine. If not, check the gear lash during the assembly of the engine.

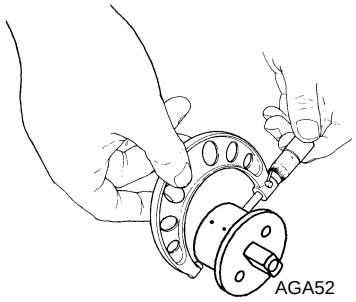
NOTE: The camshaft and crankshaft gears use a press fit. To remove these gears use a standard gear puller or a hydraulic press. Install these gears with a hydraulic press.

2. Measure the inside diameter of the idler gear bushing. If the idler gear bushing is larger than 1.8142 in. (46.080 mm) or is significantly damaged, replace the idler gear bushing. To replace the bushing, press the old bushing out of the idler gear and press the new bushing into the idler gear.



Measuring Idler Gear Bushing

3. Measure the outside diameter of the idler gear shaft. If the idler gear shaft is smaller than 1.8083 in. (45.930 mm) or is significantly damaged, replace the idler gear shaft.

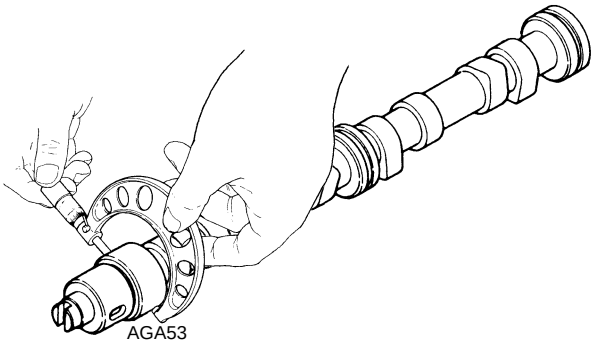


Measuring Idler Gear Shaft

Camshaft

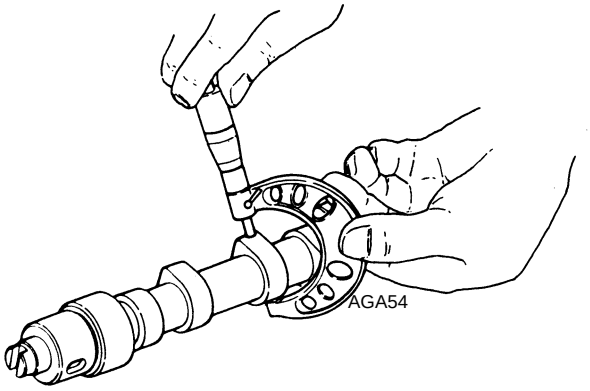
1. Check the camshaft journals, the cam lobes, the thrust plate, and the camshaft gear for wear or damage.

2. Measure the camshaft journals. If any of the camshaft journals are smaller than 1.7657 in. (44.850 mm) or significantly damaged, replace the camshaft.



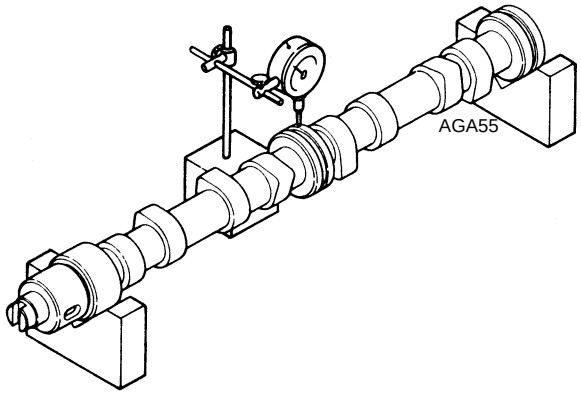
Measuring Camshaft Journals

3. Measure the cam lobes. If any of the cam lobes are smaller than 1.5118 in. (38.400 mm) or significantly damaged, replace the camshaft.

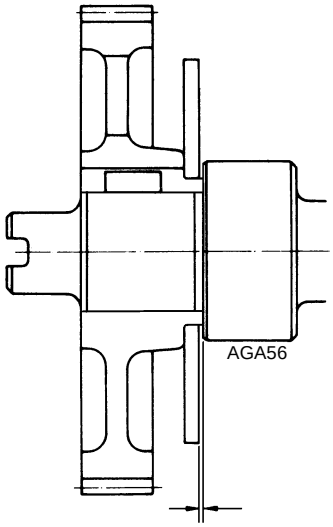


Measuring Cam Lobes

4. Measure the camshaft deflection by placing the front and rear camshaft journals in a set of "V" blocks. Set a dial indicator on the middle camshaft journal and rotate the camshaft one full turn. The camshaft deflection equals one half of the largest difference in readings on the dial indicator. If the camshaft deflection exceeds 0.002 in. (0.05 mm), the camshaft must be replaced.



Measuring Camshaft Deflection



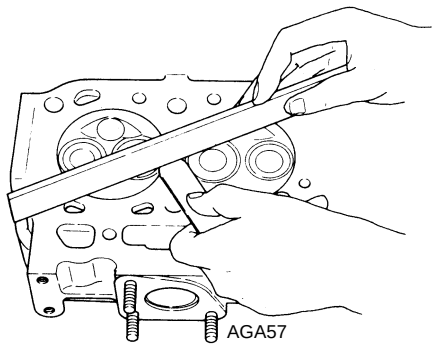
Checking Thrust Plate Clearance

5. Check the thrust plate clearance (end play) by placing a feeler gauge between the thrust plate and the camshaft journal (or camshaft gear). If the clearance exceeds the 0.016 in. (0.40 mm), replace the thrust plate and check the clearance again. If the clearance still exceeds the wear limit after replacing the thrust plate, replace the camshaft gear also. To remove the camshaft gear use a standard gear puller or a hydraulic press. Install the

camshaft gear with a hydraulic press. The thrust plate fits around a shoulder on the camshaft gear. Press the camshaft gear onto the camshaft until the shoulder contacts the camshaft journal. Be careful not to pinch the thrust plate between the shoulder and the journal.

Cylinder Head

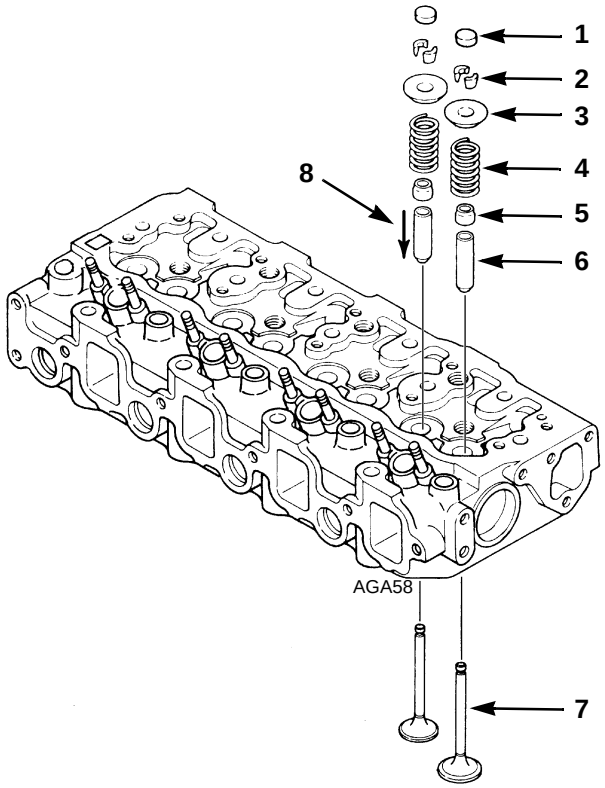
1. Clean all the carbon and any other deposits from the cylinder head with a gasket scraper or a wire brush. Visually inspect the cylinder head for cracks and check the sealing surfaces for damage.
2. Use a straight edge and a feeler gauge to check the cylinder head deck for distortion. Check all four sides, both diagonals, and the center lines of the cylinder head deck. Resurface or replace the head if the distortion exceeds 0.006 in. (0.15 mm).



Checking Cylinder Head Distortion

Disassembly

1. Use a valve spring compressor to remove the valve keepers.
2. Remove the keepers, the valve spring retainers, the valve springs, and the valves. Mark each valve or keep them in order so they can be returned to their original positions when assembled.
3. Remove the valve stem seals and boil out the head if possible.



1.	Valve Stem Cap
2.	Valve Keeper
3.	Valve Spring Retainer
4.	Valve Spring
5.	Valve Stem Seal
6.	Valve Guide
7.	Valve
8.	Drive Valve Guides in this Direction

Cylinder Head Components

Valve Guides

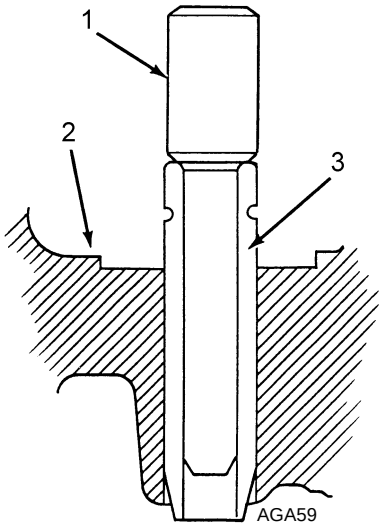
1. Remove the carbon from the valve guides with a valve guide carbon beater.

2. Measure the inside diameter of the valve guides with a small hole gauge or a graduated set of tapered pilots. If the valve guides are larger than 0.3189 in. (8.100 mm), replace the valve guides.

   NOTE: If the engine has been in use for some time and has accumulated many hours of running time, it is advisable to replace the valve guides because they usually show significant wear after numerous hours of service. Because the valve seat grinding procedure is centered by a pilot placed in the valve guide, new straight valve guides allow the valve seats to be ground accurately.

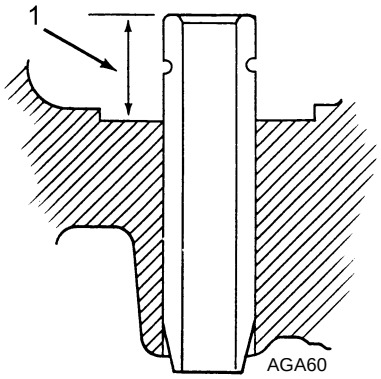
3. Remove the valve guides by using a valve guide tool and a press or a hammer to drive the valve guides out through the combustion chamber.

4. Install the new valve guides using the valve guide tool and a press or a hammer. Drive the valve guide into the top of the cylinder head until the valve guide projection (the distance between the top of the valve guide and the top of the valve spring seat) is 0.591 in. (15.00 mm).



1.	Valve Guide Tool
2.	Cylinder Head
3.	Valve Guide

Removing or Installing Valve Guides



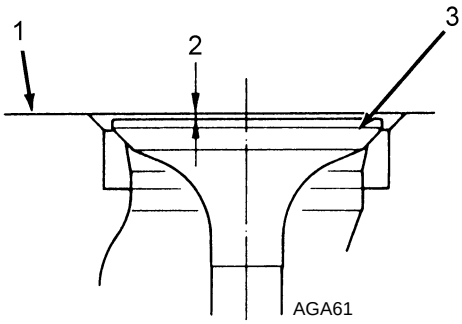
1.	Valve Guide Projection 0.591 in. (15.00 mm)

Valve Guide Projection

5. After installation, ream the new valve guides. Use a 0.3155 in. (8.010 mm) ream for the intake valve guides. Use a 0.3155 in. (8.015 mm) ream for the exhaust valve guides.

Valve Depth

The valve depth is the distance between the cylinder head deck and the valve.

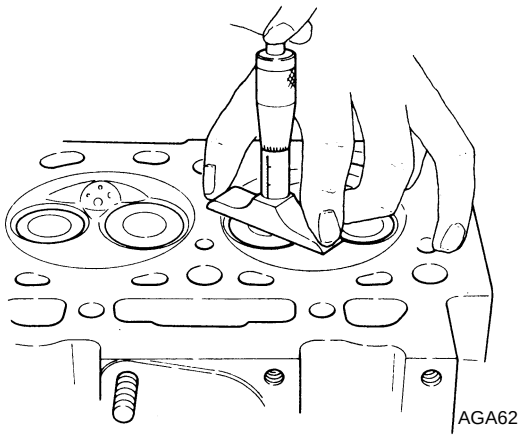


1.	Cylinder Head Deck
2.	Valve Depth
3.	Valve

Valve Depth

The valve depth is a critical dimension for most diesel engines. Grinding the valve or the valve seat increases the valve depth. As the valve depth increases, the volume of the combustion chamber also increases and the compression ratio decreases. Decreasing the compression ratio can cause hard starting or poor performance. Therefore it is very important to check the valve depth of each valve before and after grinding the valve, and before and after grinding the valve seat. If the valve depth is near the wear limit before grinding the valve or valve seat, the valve, the valve seat or both may need replacement. If the valve depth exceeds the wear limit after grinding the valve or the valve seat, the valve, the valve seat or both must be replaced.

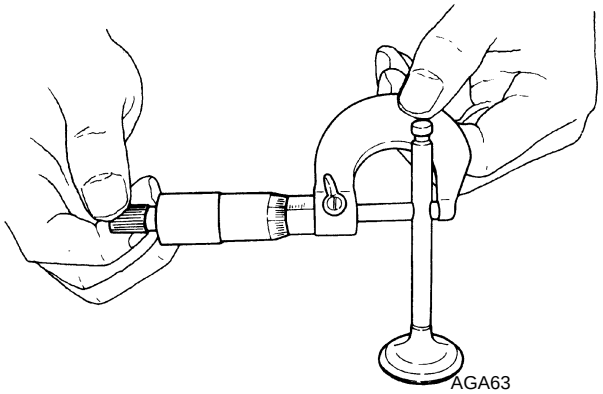
To check the valve depth, install the valves in their respective valve seats and measure the valve depth of each with a depth gauge or a caliper. The wear limit for both the intake and exhaust valve depth is 0.039 in. (1.00 mm).



Measuring Valve Depth

Valves

1. Clean and inspect the valves. Replace valves that are cracked, bent, or have valve faces that are significantly damaged.
2. Measure the outside diameter of the valve stems. If the valve stem is smaller than 0.3110 in. (7.900 mm), replace the valve.

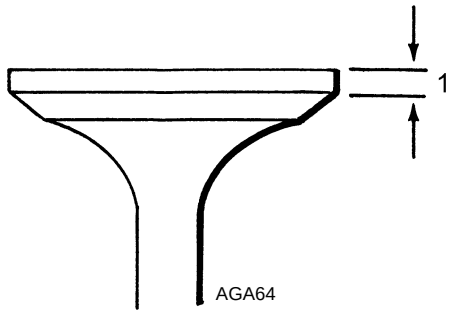


Measuring Valve Stem

3. The valves can be ground to clean up any wear or minor damage on the valve faces. Grind the valves until all signs of wear or damage are removed. Grind the valve faces to the following angles:

   Intake 30 degrees
   Exhaust 45 degrees

4. After grinding the valves, check the valve margin. Replace any valve with a valve margin that is less than 0.020 in. (0.50 mm).



1.	0.020 in. (0.50 mm) Minimum

Valve Margin

NOTE: Valves with a valve margin that is not even after being ground are slightly bent. These valves should be replaced if the valve margin is less than 0.020 in. (0.50 mm) at the narrowest point.

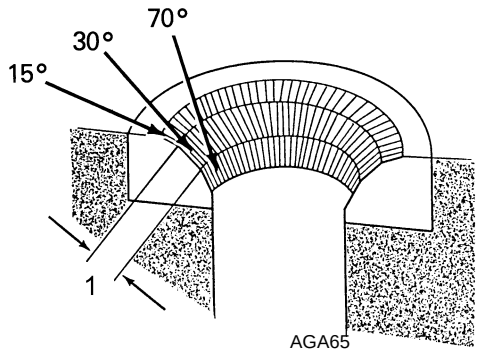
5. After grinding the valves, install the valves in their respective valve seats and check the valve depth of each. Replace any valve that has a valve depth over the wear limit.

Valve Seats

1. Inspect the valve seats for any major damage that would require valve seat replacement.

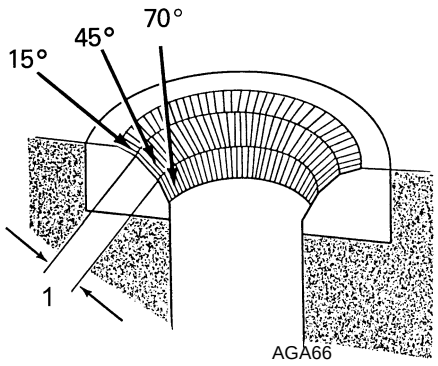
2. Grind each valve seat to remove any sign of wear or minor damage. Valve seats that show no wear or damage should also be ground lightly to clean up any slight imperfections. Grind the valve seats to the following angles:

   Intake 30 degrees
   Exhaust 45 degrees



1.	Valve Seat Width

Intake Valve Seat Angles

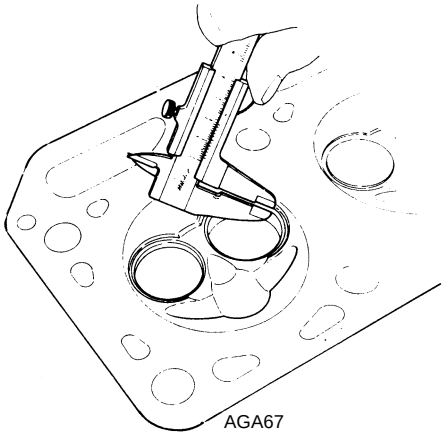


1.	Valve Seat Width

Exhaust Valve Seat Angles

3. After grinding the valve seats, install the valves in their respective valve seats and check the valve depth of each. Replace any valve that has been ground and now has a valve depth over the wear limit. Replace any valve seat that has a new valve installed and still has a valve depth over the wear limit.

4. Check the width of the valve seats with a caliper.



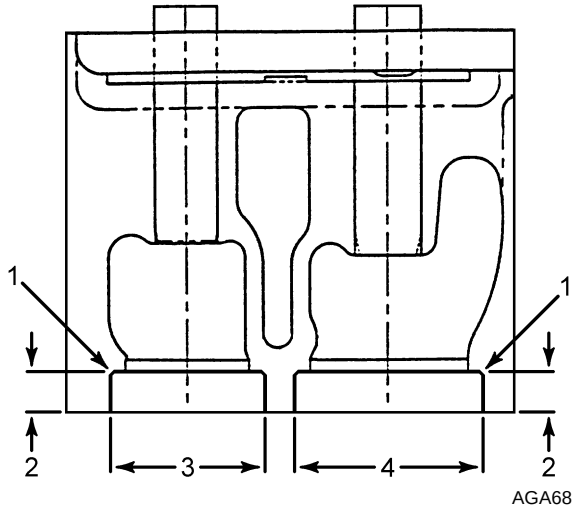
Measuring Valve Seat Width

5. Use Prussian Blue or a similar dye to check the alignment of the each valve seat and valve face. The valve seat should contact the middle of the valve face.

6. Use 15 and 70 degree grinding stones to size and align the valve seats to meet the width specifications (refer to Specifications), and alignment recommendation above.

Valve Seat Replacement

The original cylinder head is not equipped with removable valve seats. The cylinder head must be machined to accept replacement valve seats. Replacement valve seats are available from the Service Parts Department. The following illustration shows the dimensions for replacement valve seat bores.



1.	Bevel 0.016 to 0.031 in. (0.4 to 0.8 mm)
2.	Depth 0.321 to 0.329 in. (8.15 to 8.35 mm)
3.	Exhaust Diameter 1.2402 to 1.2408 in. (31.500 to 31.516 mm)
4.	Intake Diameter 1.4567 to 1.4573 in. (37.000 to 37.016 mm)

Dimensions for Replacement Valve Seat Bores

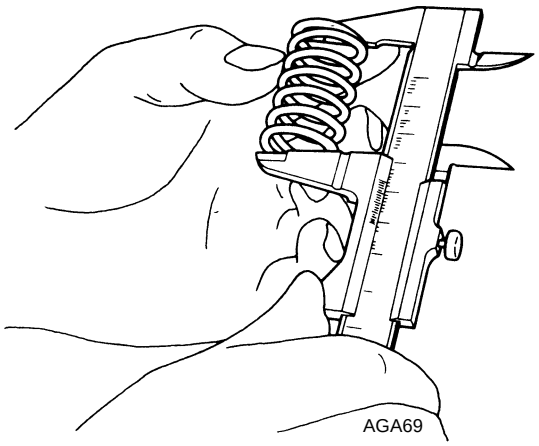
1. After machining the head, chill each replacement valve seat and install it with a valve seat installation tool.

2. Grind the new valve seats after installation.

Valve Springs

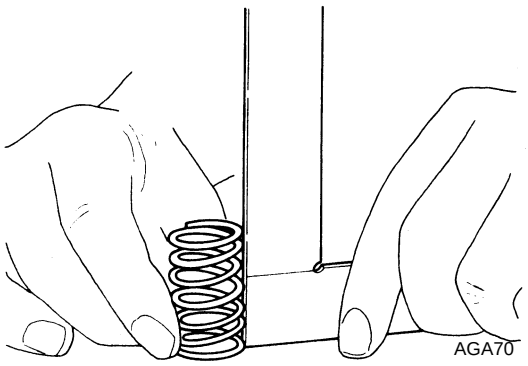
1. Clean and inspect the valve springs. Replace valve springs that are cracked, or significantly scratched or damaged.

2. Measure the free length of the valve springs with a caliper. Replace any valve springs that are shorter than 1.67 in. (42.5mm).

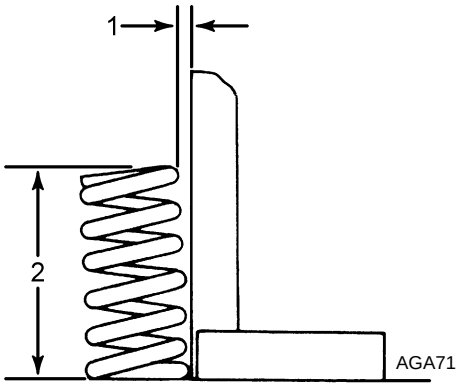


Measuring Valve Spring Free Length

3. Check the inclination of the valve springs with a square. Replace any valve springs with inclinations larger than 0.04 in. (1.1 mm).



Checking Valve Spring Inclination



1.	Inclination
2.	Free Length

Valve Spring Measurements

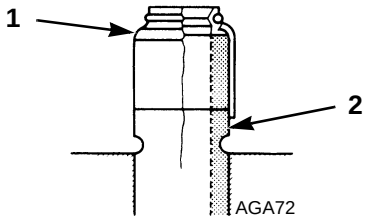
4. Inspect the valve stem caps, the valve spring retainers, and the valve keepers. Replace any of these components that show significant wear or damage.

Cylinder Head Assembly

Assemble the cylinder head after all the components have been reconditioned or replaced. Thoroughly clean the cylinder head and all the components before assembly.

1. Lightly oil the valve stem seals and place them on the valve guides.

   NOTE: New valve stem seals should always be used when assembling the cylinder head.

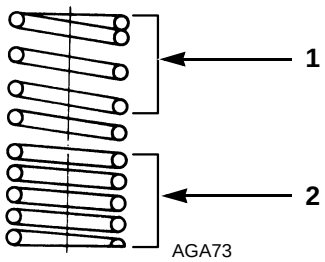


1.	Valve Stem Seal
2.	Valve Guide

Installing Valve Stem Seals

2. Oil the valve stem and place the valves in their respective valve seats. Oiling the valve stems prevents them from seizing to the new valve stem seals.

3. Install the valve springs. The end of a valve spring that has less pitch (this end is wound tighter and may have some paint on it) should be placed on the cylinder head.



1.	Top—More Pitch
2.	Bottom—Less Pitch—Place On Cylinder Head

Valve Spring

4. Place the valve spring retainers in the valve springs and compress the valve springs with a valve spring compressor.

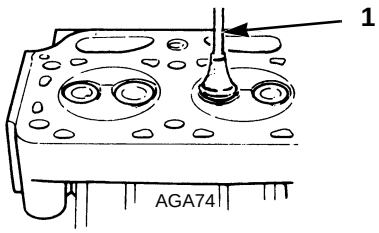
5. Install the valve keepers and remove the valve spring compressor.

6. After installing the valves, place the cylinder head on the intake side and fill the exhaust ports with diesel fuel. Check to see if any diesel fuel is leaking past the exhaust valves. Turn the cylinder head over and check the intake valves in the same way. Minor seeping is acceptable, but any valves that leak significantly must be removed and lapped.

   a. To lap a valve place a small amount of medium grit valve lapping compound on the valve face.

   b. Place the valve in the valve seat and use a valve lapping tool to spin the valve against the valve seat for a short time.

c. Lift the valve off the valve seat, rotate the valve about a quarter of a turn, and drop the valve back onto the valve seat. Spin the valve against the valve seat again for a short time. Repeat this several times.



1.	Valve Lapping Tool

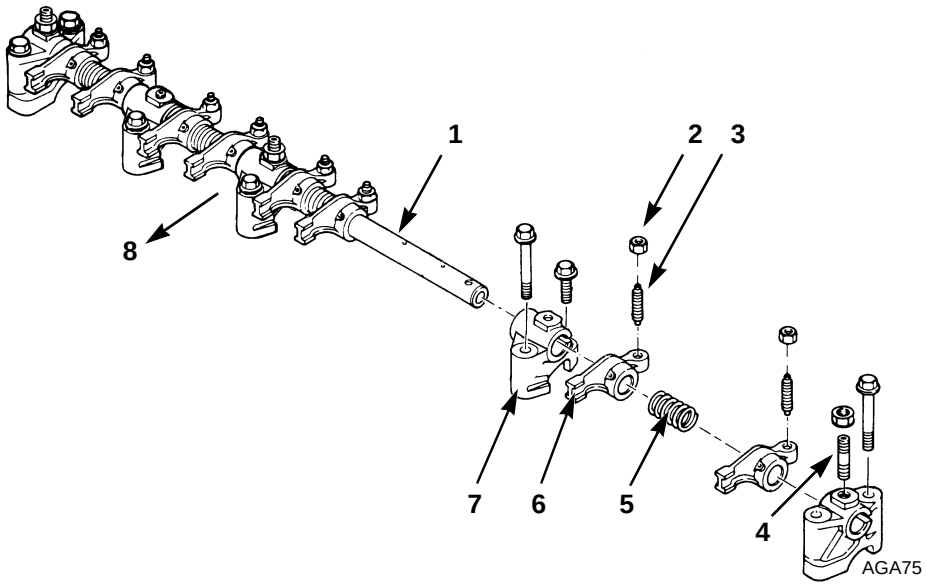
Lapping Valves

d. Remove the valve and wipe the lapping compound off the valve seat and the valve face. The valve seat should appear smooth and be an even gray color. The valve face should show a smooth, even gray ring where it contacts the valve seat. Repeat the lapping procedure if either the valve seat or the valve face does not appear smooth and even.

7. Recheck the valves for leaks after they have been lapped.

Rocker Arm Assembly

1. Remove the studs from the rocker arm supports on both ends of the rocker arm shaft and from the rocker arm support in the center of the rocker arm shaft.



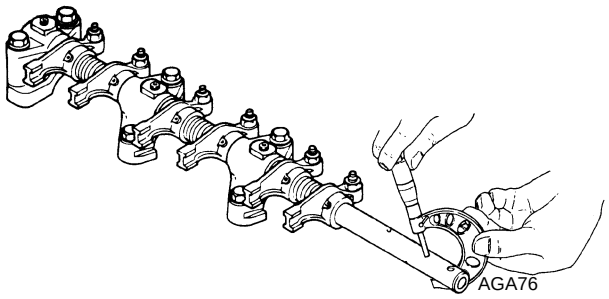
1.	Rocker Arm Shaft	5.	Spring
2.	Locknut	6.	Rocker Arm
3.	Valve Adjustment Screw	7.	Rocker Arm Support
4.	Stud	8.	Intake (Front) Side

Rocker Arm Assembly

2. Remove the rocker arm supports, the rocker arms, and the springs from the rocker arm shaft. Keep these parts in order, to make sure they will be assembled correctly.

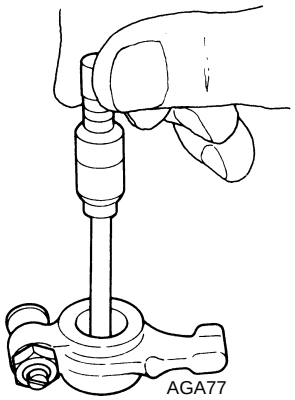
3. Clean and inspect all the components of the rocker arm assembly. Replace any parts that show significant wear or damage.

4. Measure the outside diameter of the rocker arm shaft at the pivot point of each rocker arm. Replace the rocker arm shaft if it is smaller than 0.6280 in. (15.950 mm) at any of the rocker arm pivot points.



Measuring Rocker Arm Shaft

5. Measure the inside diameter of each rocker arm bushing. If a rocker arm bushing is larger than 0.6335 in. (16.090 mm) or shows significant damage, replace the rocker arm.



Measuring Rocker Arm Bushing

6. Loosen the locknut and remove the valve adjustment screw from each rocker arm. Inspect each valve adjustment screw and replace any that show significant wear or damage. Place the valve adjustment screws back in the rocker arms but do not tighten the locknuts.

7. Reassemble the rocker arm assembly and make sure the parts are in the correct order. Refer to the illustration on page 41 and note the following items:

   a. The rocker arm shaft is symmetrical.

   b. The intake and exhaust rocker arms are identical. The valve adjustment screws go to the push rod (back) side.

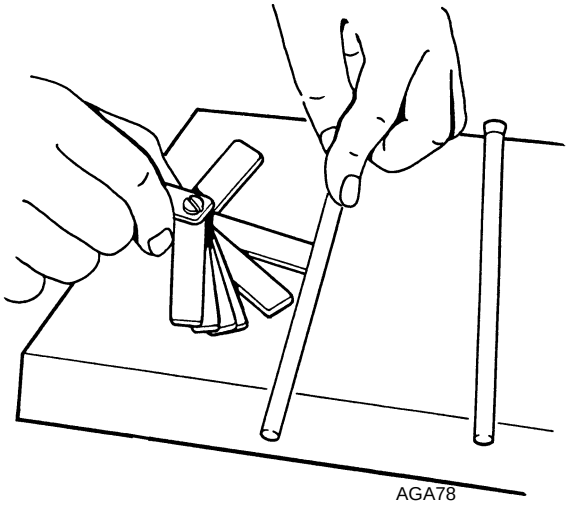
   c. The three middle rocker arm supports are identical. They go on the rocker arm shaft with the long mounting bolts to the intake (front) side.

   d. The center rocker arm support and both end rocker arm supports are fastened to the rocker arm shaft with studs. The studs go through the tops of the rocker arm supports into holes in the rocker arm shaft.

   e. The two rocker arm supports on the ends of the rocker arm shaft are identical. Each has an oil passage in its bottom. This oil passage carries oil from the cylinder head to the rocker arm shaft. The oil passage must go to the push rod (back) side and align with the oil passage in the cylinder head.

Push Rods

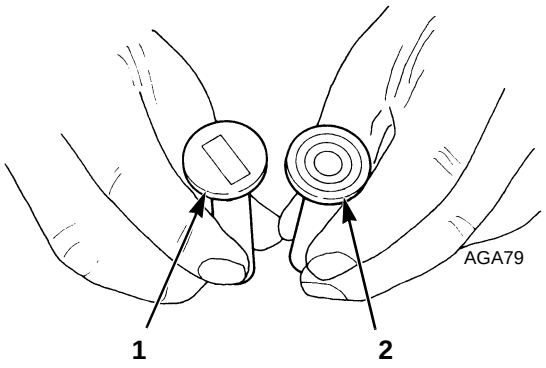
1. Clean and inspect the push rods. Replace any push rods that show significant wear or damage.
2. Place each push rod on a completely flat surface and use a feeler gauge to check how much the push rod is bent. Replace any push rod that is bent more than 0.001 in. (0.03 mm).



Checking Bend in Push Rods

Tappets

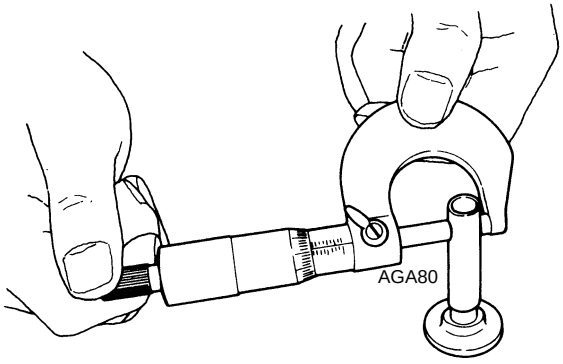
1. Clean and inspect the tappets. Normally the tappets rotate while the engine is running. This causes normal wear to appear as concentric rings on the surface of the tappet that contacts the cam lobe. A tappet that does not rotate shows an abnormal wear pattern straight across its contact surface. Replace any tappet that shows an abnormal wear pattern, significant wear, or significant damage.



1.	Abnormal Wear
2.	Normal Wear

Tappet Wear

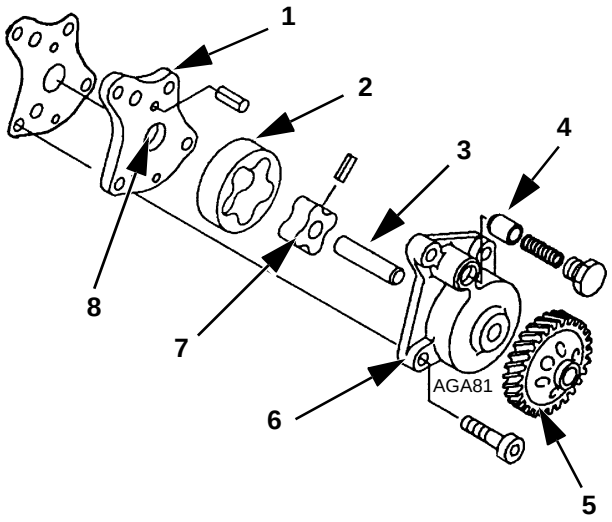
2. Measure the outside diameter of each tappet. Replace any tappets that are smaller than 0.4697 in. (11.930 mm).



Measuring Tappet

Oil Pump

1. Remove the rotor plate and inspect the oil pump. If the rotor plate, the inner rotor, the outer rotor, or the oil pump body show significant wear, scratches, or damage, replace the oil pump.

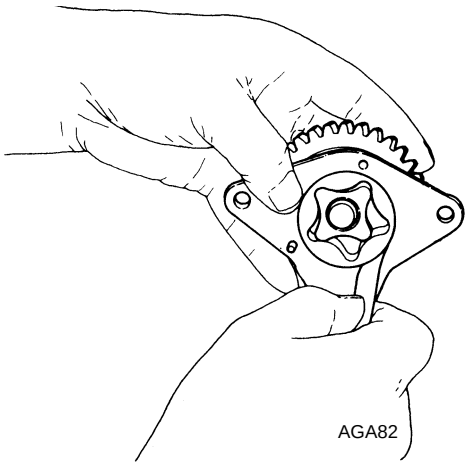


1.	Rotor Plate
2.	Outer Rotor
3.	Rotor Shaft
4.	Oil Pressure Control Valve
5.	Gear
6.	Pump Body
7.	Inner Rotor
8.	Rotor Shaft Bore

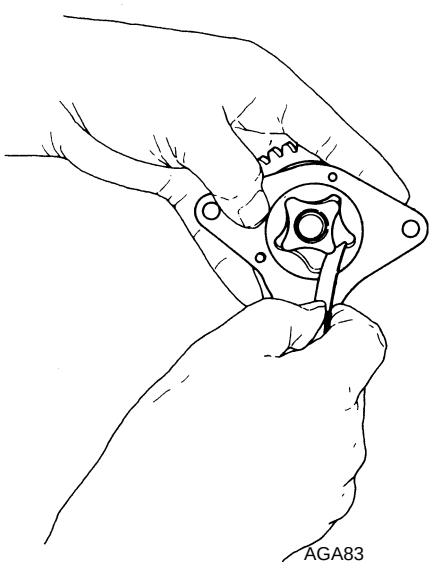
Oil Pump Assembly

2. Use a feeler gauge to check the clearance between the oil pump body and the outer rotor. If the clearance between the oil pump body and the outer rotor exceeds 0.0098 in. (0.250 mm), replace the oil pump.

3. Use a feeler gauge to check the clearance between the inner rotor and the outer rotor. Place the feeler gauge between the tip of a vane on the inner rotor and the high point of a lobe on the outer rotor. If the clearance between the inner rotor and the outer rotor exceeds 0.0059 in. (0.150 mm), replace the oil pump.

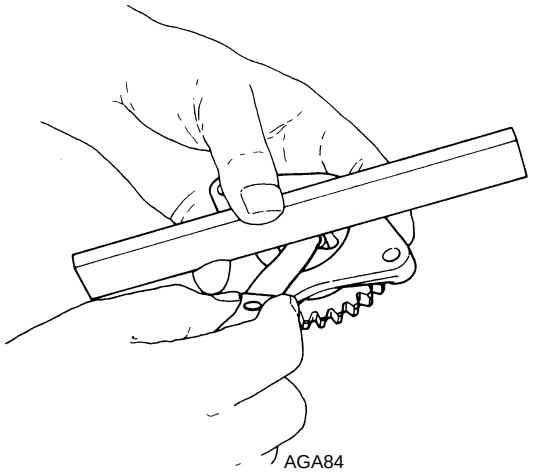


Checking Clearance Between Oil Pump Body and Outer Rotor



Checking Clearance Between Inner Rotor and Outer Rotor

4. Check the clearance between the rotor plate and both rotors. Place a straight edge across the oil pump body and insert a feeler gauge between the straight edge and the rotors. If the clearance between the rotor plate and either rotor exceeds 0.0059 in. (0.150 mm), replace the oil pump.



Checking Clearance Between Rotor Plate and Rotors

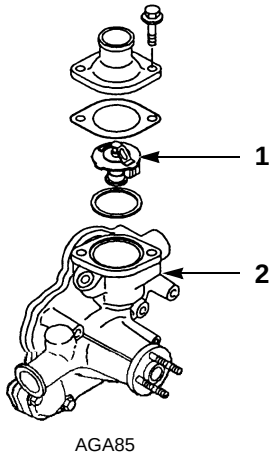
5. Measure the outside diameter of the rotor shaft and the inside diameter of the rotor shaft bore in the rotor plate. Subtract the diameter of rotor shaft from the diameter of the rotor shaft bore to obtain the rotor shaft clearance. If the rotor shaft clearance exceeds 0.0079 in. (0.200 mm), replace the oil pump.

6. Hold the oil pump body in one hand and the oil pump gear in the other hand. Wiggle the gear to check the clearance between the rotor shaft and the oil pump body. The wear limit is 0.0079 in. (0.200 mm). If the clearance exceeds this, replace the oil pump.

7. Press on the oil pressure control valve piston from the cylinder block side of the oil pump. Check to make sure that the piston moves smoothly and is returned by the spring. If not, replace the oil pump.

Water Pump

1. Check the weep hole on the bottom of the water pump for any signs of leaking coolant. If coolant is leaking out of the weep hole, the mechanical seal is leaking and the water pump must be replaced.



1.	Thermostat
2.	Water Pump

Water Pump and Thermostat Assembly

2. Check the water pump bearing. If the water pump shaft does not rotate smoothly, or if it is loose or wobbly, replace the water pump.

Manifolds

1. Inspect the manifolds for cracks, damage, or a build up of carbon.

2. Use a straight edge and a feeler gauge to check the manifolds for distortion. Resurface or replace the manifold if it is distorted more than 0.006 in. (0.15 mm).

Engine Assembly 4

Assembly Precautions

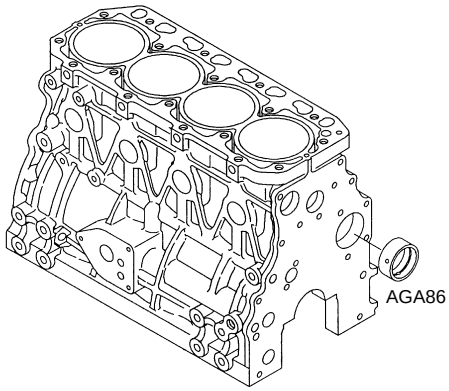
NOTE: Refer to the Specifications chapter for specifications not given in this chapter.

After the components of the engine have been repaired, reconditioned, or replaced, the engine can be assembled. It is very important to keep the engine as clean as possible while it is being assembled, because dirt is one of the major factors that contributes to the failure of rebuilt engines. To avoid problems, take these precautions:

1. Do not assemble the engine in an area where any type of grinding is done.
2. Keep your workbench, tools, and hands clean.
3. Keep sub-assemblies covered until they are needed.
4. If the engine must be left, even for a short period of time, cover the engine until you return.
5. Make sure to follow the sequence of assembly exactly. If certain parts are not installed in the correct order, the engine may require some disassembly to install these parts properly.
6. Check all the assembly tolerances such as bearing clearance, end play, and gear lash carefully. Neglecting these tolerances can cause serious reliability problems in a rebuilt engine.

Assembly Procedure

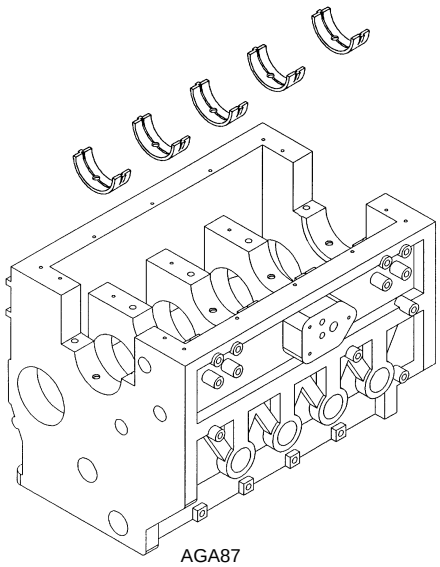
1. Install the front camshaft bearing insert using a bearing driver. Make sure the oil holes in the bearing insert line up with the oil holes in the front camshaft bearing bore. The camshaft bearing insert is pre-finished.
2. Install new oil gallery and core plugs.



Install Camshaft Bearing

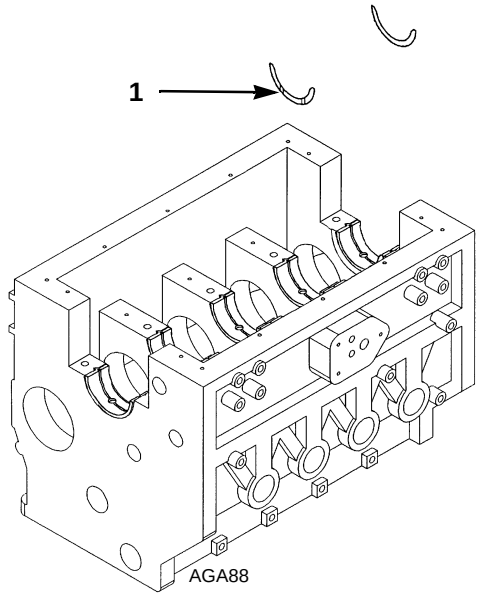
3. Place the new upper main bearing inserts in the cylinder block. The upper main bearing inserts are identical and have oil holes and oil groves in them. Make sure the holes in the bearing inserts line up with the holes in the main bearing bores.

CAUTION: The lower main bearing inserts are plain and do not have oil holes and grooves. If they are placed in the cylinder block, oil will not flow to the crankshaft bearings. The crankshaft will be damaged and the engine may seize.



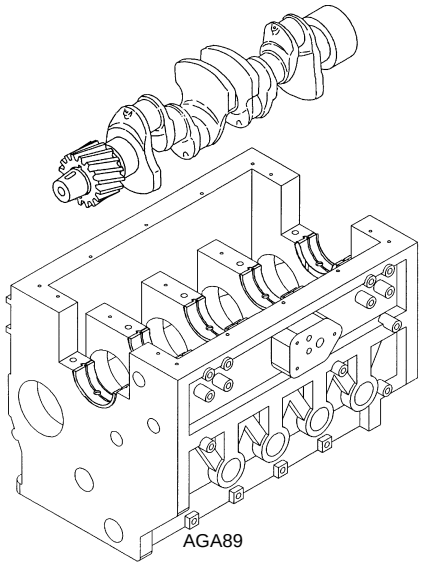
Install Upper Main Bearings

4. Place the upper thrust bearings in position in the cylinder block on each side of the upper rear main bearing. The grooves on the thrust bearings should face away from the upper rear main bearing. Use a little grease to help hold them in place.



1.	Grooves Face Away From Main Bearing

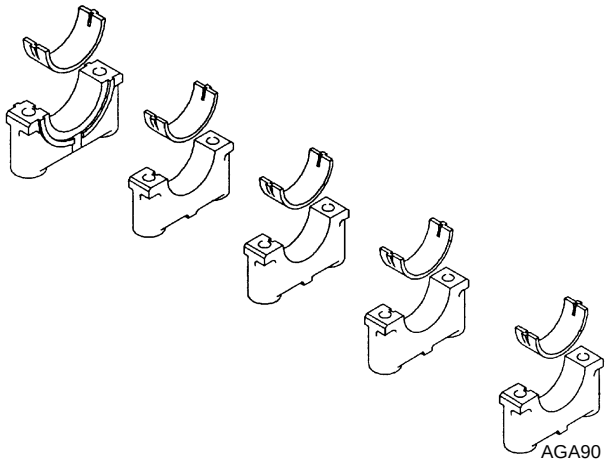
Install Upper Thrust Bearings



Install Crankshaft

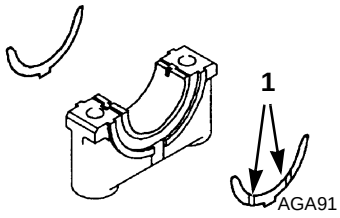
5. Carefully lay the crankshaft in the upper main bearing inserts.

6. Place the new lower main bearing inserts in the main bearing caps. The lower main bearing inserts are plain and identical.



Install Lower Main Bearings

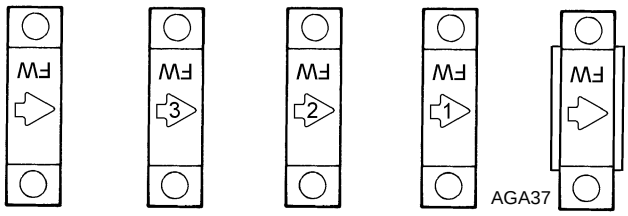
7. Place the lower thrust bearings in position on each side of the rear main bearing cap. The lower thrust bearings each have a tab on the bottom. The grooves on the thrust bearings should face away from the rear main bearing cap.



1.	Grooves Face Away From Main Bearing

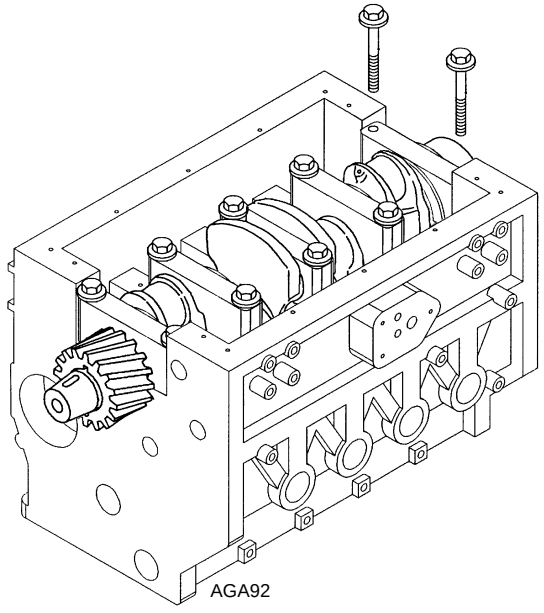
Install Lower Thrust Bearings

8. Place a piece of plastigauge on each main bearing journal and install the main bearing caps in their proper positions. The cast arrows on the main bearing caps are labeled FW and should point to the rear (flywheel end) of the engine. The main bearing cap with the thrust bearings goes to the rear end of the engine. The main bearing caps with numbers stamped on them go to the middle of the engine with the main bearing cap marked number one closest to the rear main bearing. The main bearing cap with no number goes to the front end of the engine.



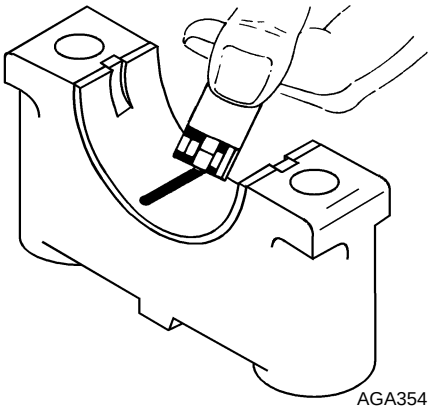
Main Bearing Cap Placement

9. Install and torque the main bearing bolts to 70.9 to 73.8 ft-lb (96.1 to 100.0 N•m) in two or three equal increments.



Install Main Bearing Bolts

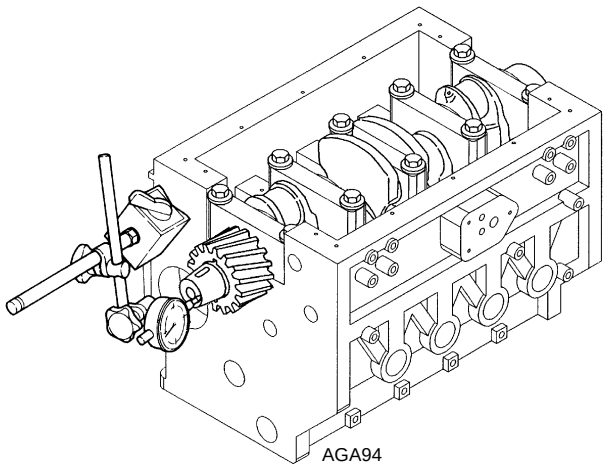
10. Remove the main bearing caps and check the plastigauge to determine the clearance of each main bearing. The recommended main bearing clearance is 0.0015 to 0.0027 in. (0.038 to 0.068 mm).



Check Plastigauge

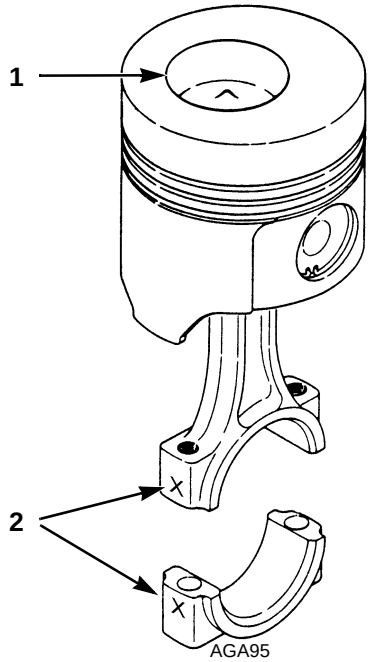
11. Lubricate the main bearings, the main journals, and the thrust bearings with engine assembly compound or engine oil. Install the main bearing caps and torque the bolts. Check to make sure the crankshaft rotates freely.

12. Use a dial indicator to check the crankshaft end play. The wear limit is 0.0130 in. (0.330 mm). If the end play is larger than the wear limit, the thrust bearings must be replaced.



Check End Play

13. Install each piston on its respective connecting rod by heating the piston in hot water and then pressing the wrist pin into the piston and through the rod bushing. Install the circlips. The swirl chamber on the top of the piston must be positioned so it is on the identification mark side of the connecting rod.



1.	Swirl Chamber
2.	Identification Marks

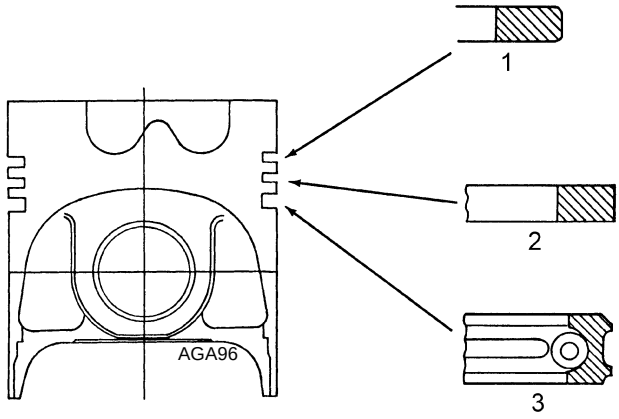
Assemble Piston and Rod

14. Each piston has three piston rings.

    a. The top ring is a barrel faced compression ring.

    b. The middle ring is compression ring with a tapered face.

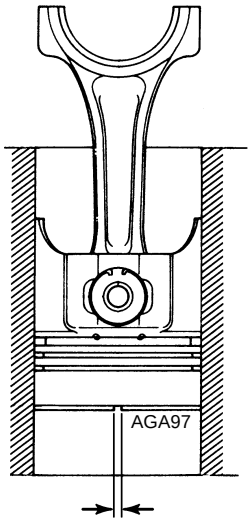
    c. The bottom ring is an oil ring with a separate internal expander.



1.	Barrel Face Ring
2.	Tapered Face Ring
3.	Oil Ring with Expander

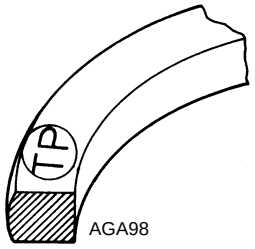
Ring Placement

15. Before installing the piston rings, check the end gap of each ring. Place a ring in its respective cylinder. Level the ring in the cylinder with a piston and check the end gap with a feeler gauge. The recommended end gap is 0.008 to 0.016 in. (0.20 to 0.40 mm). If the end gap is not correct, check to make sure that the cylinder bore is the correct size and that the ring is the correct size.



Check Ring End Gap

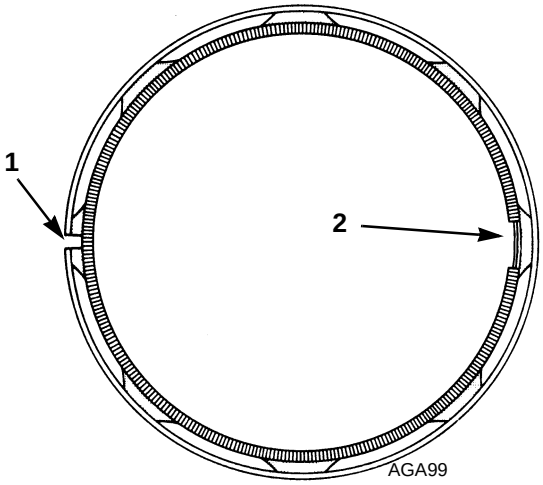
16. Place the piston rings on their respective pistons in the proper order. Use a ring spreader to install the rings, but do not spread the rings more than necessary. The manufacturer's mark near the end gap of each ring should always face the top of the piston.



Mark On Ring Faces Up

a. Place the oil ring expander in the bottom ring groove.

b. Place the oil ring in the bottom ring groove over the expander. Position the end gap of the oil ring 180 degrees from the joint in the expander.



1.	Oil Ring End Gap
2.	Expander Joint

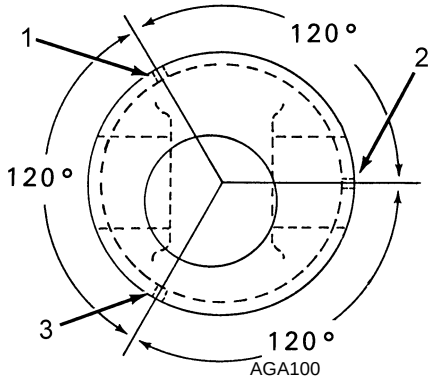
Oil Ring Installation

c. Place the compression ring with the tapered face in the middle ring groove.

d. Place the barrel faced compression ring in the top ring groove.

17. Place the connecting rod bearing inserts in the connecting rods and the rod caps.

18. Stagger the end gaps of the piston rings on each piston so the end gaps are at 120 degree intervals.

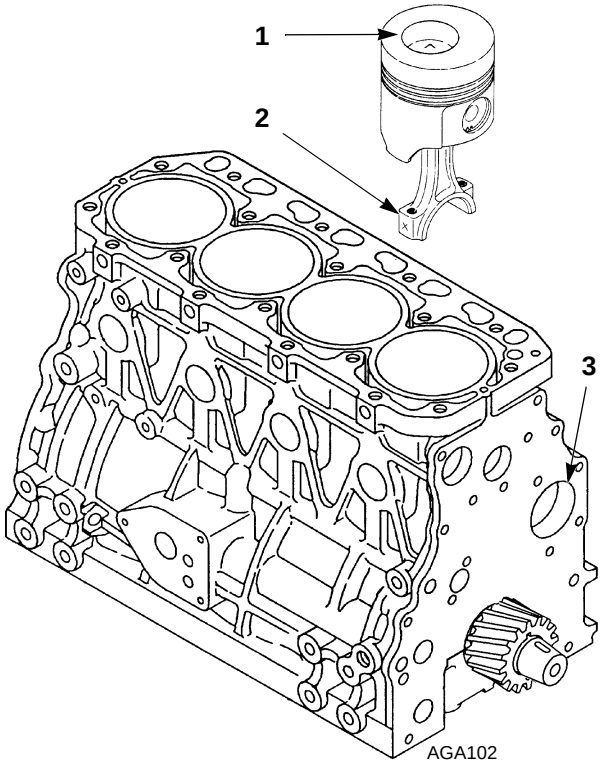


1.	Top Ring End Gap
2.	Oil Ring End Gap
3.	Middle Ring End Gap

Ring Alignment

19. Oil each cylinder, piston, piston ring, wrist pin, and rod bushing, with engine oil.

20. Use a ring compressor to install each piston assembly. The swirl chamber on top of the piston and the identification marks on the connecting rod should face toward the intake side of the engine, away from the camshaft bearings.

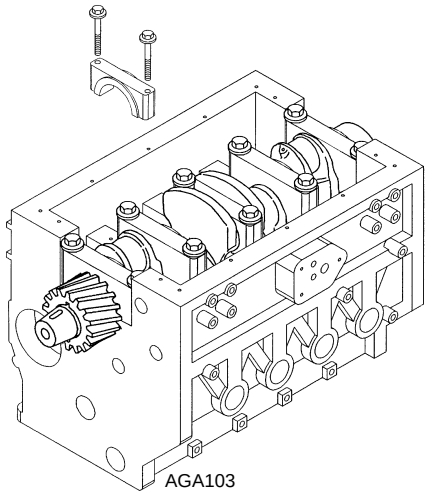


1.	Swirl Chamber
2.	Identification Mark
3.	Camshaft Bearing

Install Piston

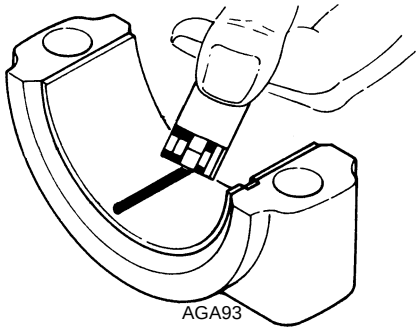
21. Place a piece of plastigauge on each rod journal. Install each rod cap correctly by matching the identification marks with those on the connecting rod.

22. Install and torque the connecting rod bolts to 32.5 to 39.8 ft-lb (44.1 to 53.9 N•m) in two or three equal increments.



Install Rod Cap and Bolts

23. Remove the rod cap and check the plastigauge to determine the clearance of each connecting rod bearing. The recommended rod bearing clearance is 0.0015 to 0.0029 in. (0.038 to 0.074 mm).



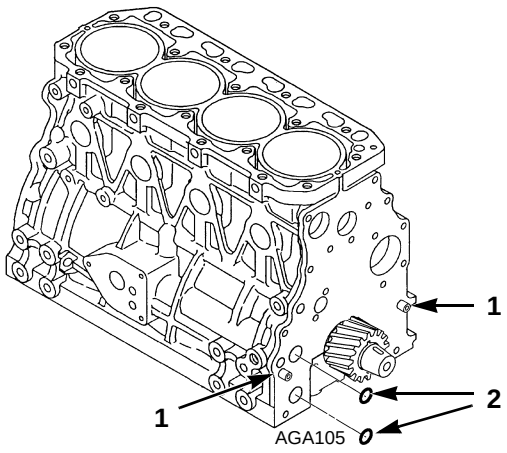
Check Plastigauge

24. Lubricate the rod journal and the rod bearings of each connecting rod with engine assembly compound or engine oil. Install the rod caps and torque the bolts.

25. After installing each piston assembly, turn the crankshaft over several times. Check to see that the bearings move freely and that the pistons and rings slide through the cylinders easily.

26. Use a feeler gauge to check the side clearance between the crankshaft and each connecting rod. The standard dimension is 0.008 to 0.016 in. (0.20 to 0.40 mm).

27. Place new O-rings on the front of the engine block and make sure the dowel pins are in place.

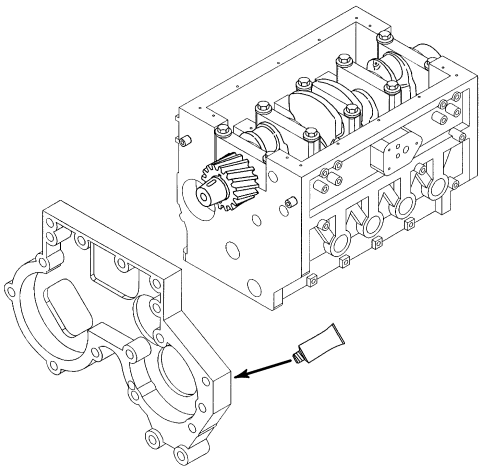


1.	Dowel Pins
2.	O-rings

Front of Engine Block

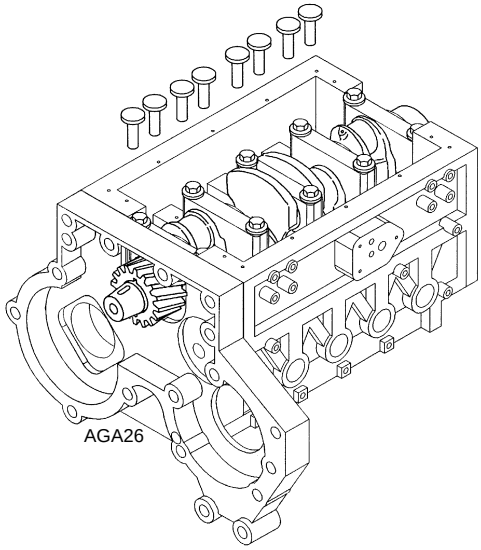
28. Place a thin layer of silicone sealant on the back sealing surface of the timing gear housing.

29. Install the timing gear housing. Make sure to align the dowel pins and tighten the mounting bolts.



Install Timing Gear Housing

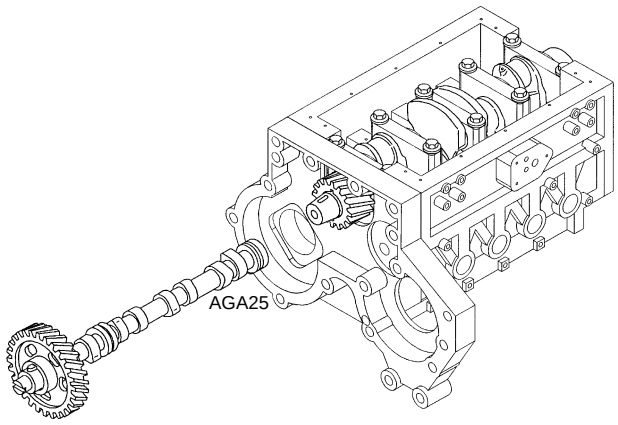
30. Lubricate the tappets with engine assembly compound or engine oil. Insert each tappet into its respective tappet bore.



Install Tappets

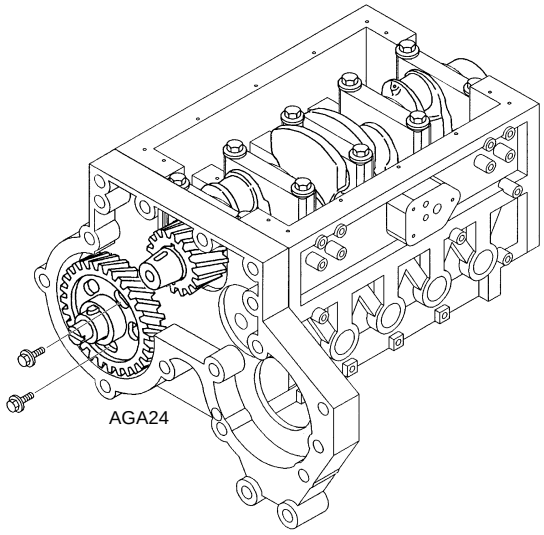
31. Lubricate the camshaft bearing, journals, and lobes with engine assembly compound or engine oil.

32. Carefully install the camshaft to avoid damaging the camshaft bearings.



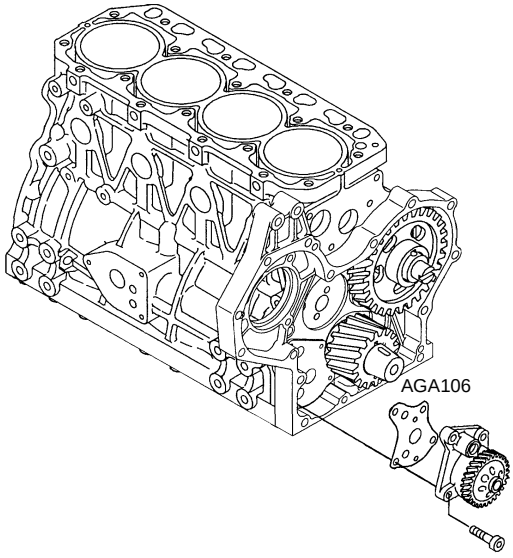
Install Camshaft

33. Install and tighten the camshaft thrust plate mounting bolts.



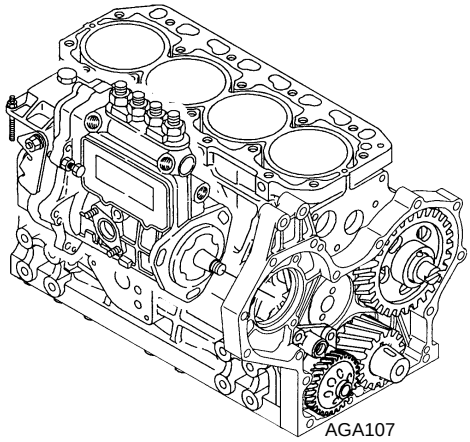
Install Camshaft Mounting Bolts

34. Install the oil pump with a new gasket and tighten the mounting bolts.



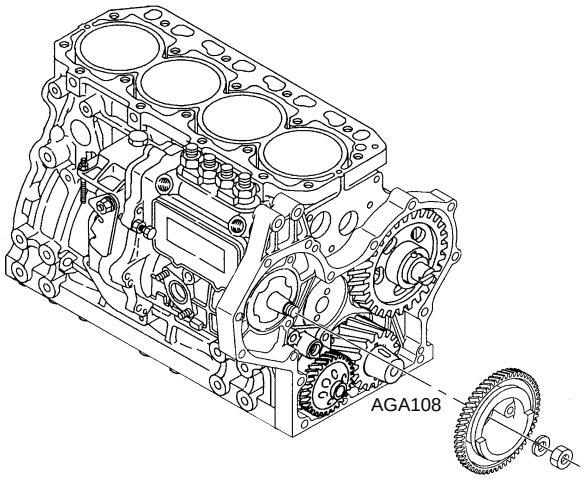
Install Oil Pump

35. Install the fuel injection pump, align the index marks, and tighten the mounting nuts.



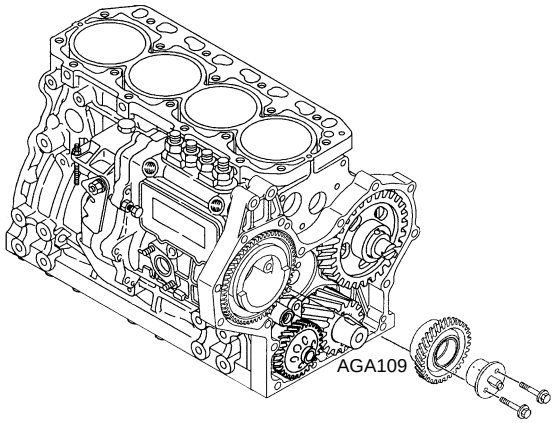
Install Fuel Injection Pump

36. Install the fuel injection pump gear, lock washer, and mounting nut. Make sure the key is aligned properly. Torque the mounting nut to 43.4 to 50.6 ft-lb (58.8 to 68.6 N•m).

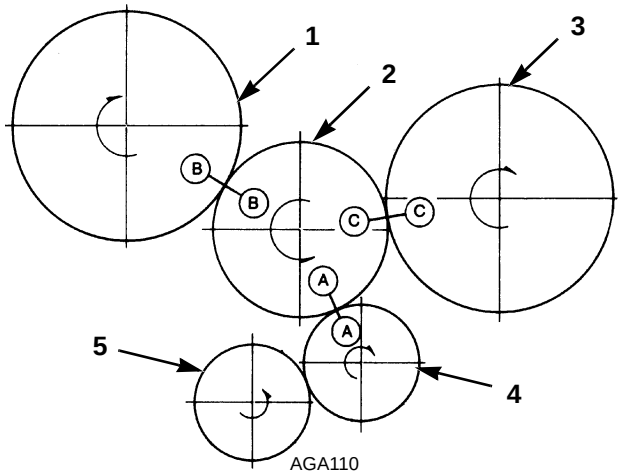


Install Fuel Injection Pump Gear

37. Install the idler gear and the idler shaft and align the timing marks. The A mark on the idler gear should line up with the A mark on the crankshaft gear. The B mark on the idler gear should line up with the B mark on the injection pump gear. The C mark on the idler gear should line up with the C mark on the camshaft gear.



Install Idler Gear and Idler Shaft



1.	Fuel Injection Pump Gear
2.	Idler Gear
3.	Camshaft Gear
4.	Crankshaft Gear
5.	Oil Pump Gear

Align Timing Marks

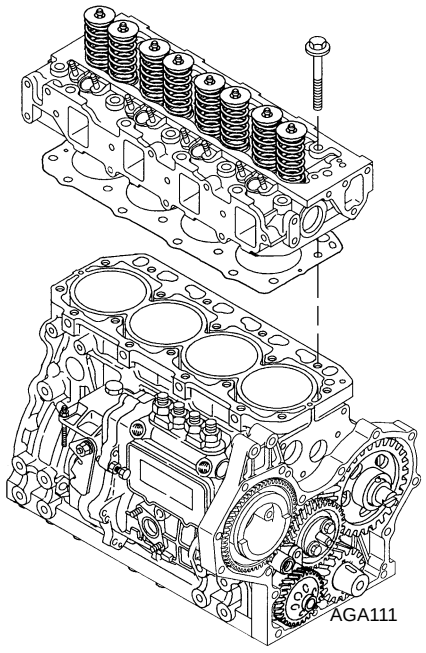
38. Install and tighten the idler shaft mounting bolts.

39. Use a dial indicator to check the gear lash between the timing gears, if it has not been checked already.

40. Make sure the dowel pins are in place in the top of the block.

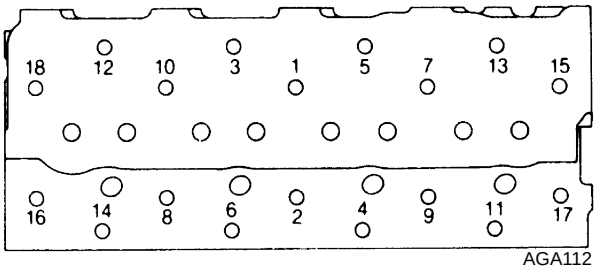
41. Place a new head gasket on the block. Align the head gasket with the dowel pins and make sure the engine model inscription is facing up.

42. Place the cylinder head on top of the block and the head gasket. Make sure to align the head with the dowel pins.



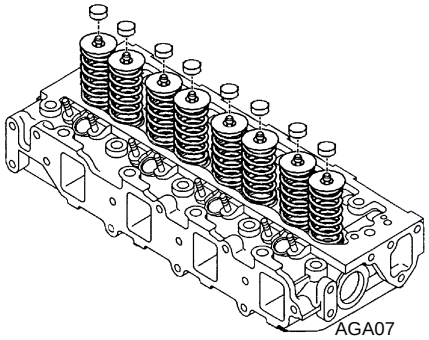
Install Cylinder Head and Gasket

43. Install the cylinder head bolts. Torque the cylinder head bolts to 62.9 to 67.3 ft-lb (85.3 to 91.2 N•m) in two or three equal increments using the sequence shown in the illustration.



Cylinder Head Bolt Torque Sequence

44. Place the valve stem caps on the valve stems.

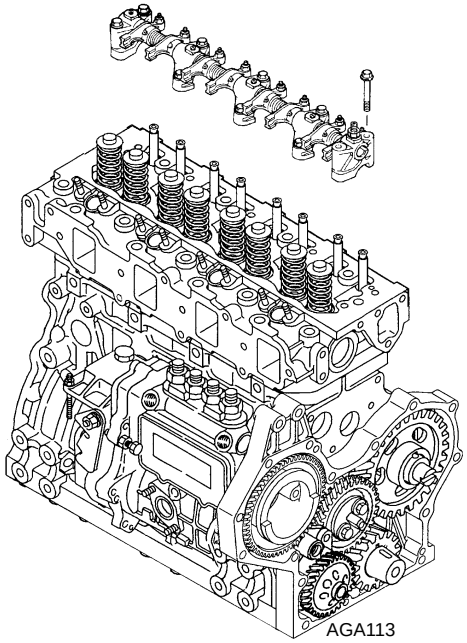


Install Valve Stem Caps

45. Install the push rods in their respective openings. Make sure the push rods are seated properly in the tappets. Lubricate the socket in the top end of each push rod with engine oil.

46. Place the rocker arm assembly in position. Make sure all the valve adjustment screws are loose and have been backed out a few turns.

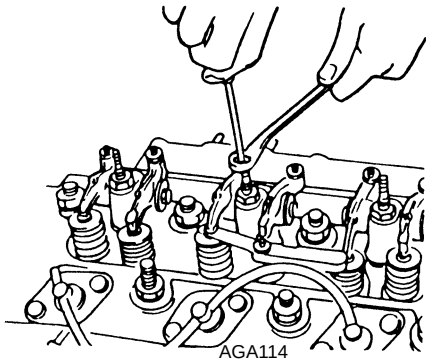
47. Install the rocker arm mounting bolts. Alternately turn each bolt one turn at a time to evenly apply the valve spring pressure to the rocker arm assembly. Make sure the valve adjustment screws all seat properly in the sockets on the ends of the push rods while the rocker arm assembly is being tightened.



Install Rocker Arm Assembly

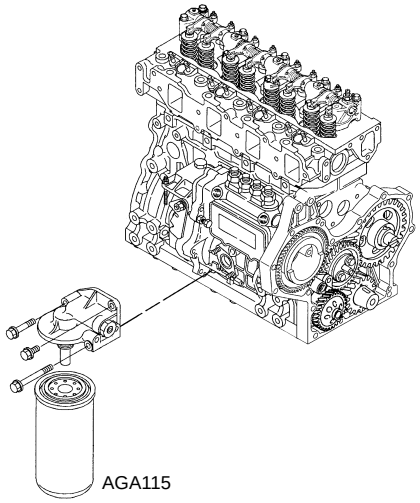
48. Torque the rocker arm mounting bolts to 16.6 to 21.0 ft-lb (22.6 to 28.4 N•m).

49. Adjust both the intake and the exhaust valves. Refer to the valve adjustment procedure at the end of the Run In Procedure Chapter.



Adjust Valves

50. Install the oil filter adapter and the oil filter.



Install Oil Filter Adapter and Filter

51. Pressure check the engine's lubrication system, if possible. A pressure check can point out problem areas in the lubrication system, and it eliminates the possibility that any of the engine components are dry when the engine is first started.

    a. Fill the pressure tank with engine oil and attach the outlet line to the engine at the fitting for an oil pressure gauge or oil pressure switch.

    b. Cap off any other open oil system fittings such as the fitting for the oil line to the fuel injection pump and timing gear cover.

    c. Pressurize the tank to 60 psi (413 kPa) and open the outlet line to the engine.

    d. The tank will fill the oil filter first and will then pressurize the whole lubrication system. The oil pressure control valve may release some oil into the bottom end.

    e. Check each main bearing and rod bearing. Oil should drip from each bearing at a fairly good rate, but there should be no large streams of oil from any of the bearings.

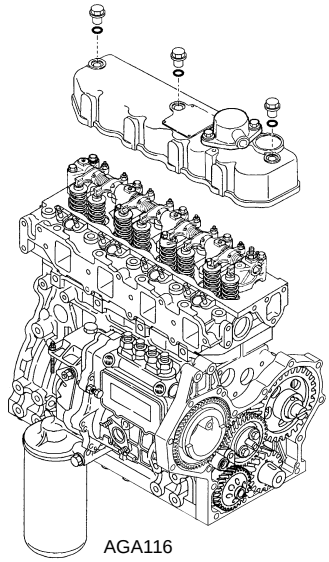
    f. Check the idler gear shaft and the front camshaft bearing. Oil should drip from each at a fairly good rate, but there should be no large streams of oil from either.

    g. Check the rocker arm assembly. Oil flows to the rocker arm assembly through internal oil passages in the cylinder block, the cylinder head, the two end rocker arm supports, and the rocker arm shaft. Oil should drip from each rocker arm bushing and from the hole in each rocker arm at a fairly good rate, but there should be no large streams of oil from any of the rocker arms or bushings.

    h. Turn the engine over several times and check the components again.

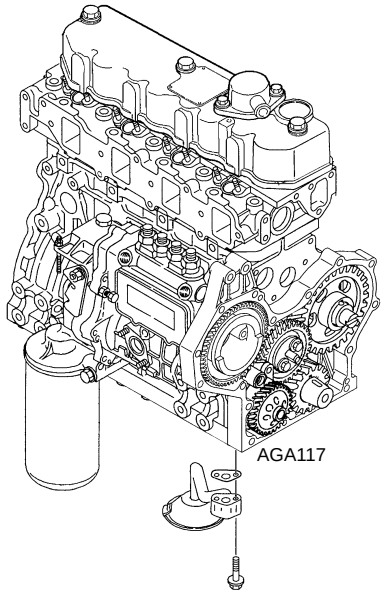
    i. Lack of oil or a low flow rate at any of these components indicates there is a restriction in an oil gallery or passage leading to the component. Excessive oil flow at any of the components indicates that the oil clearance is too large, the wrong part has been used, or a component is damaged or missing.

52. Install the valve cover with a new gasket and put new O-rings on the special cap nuts.



Install Valve Cover

53. Install the oil intake pipe.



Install Oil Intake Pipe

54. Install the oil pan.

    a. Place a thin layer of sealant on the top sealing surface of the upper part of the oil pan.

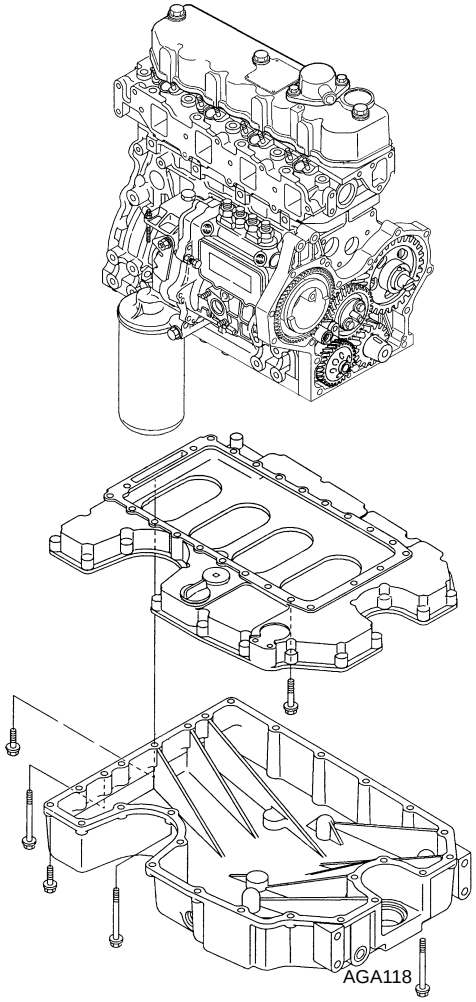
    b. Place the upper part of the oil pan in position on the bottom of the block.

    c. Install the mounting bolts for the upper part of the oil pan. Make sure the rear end of the block and the upper part of the oil pan are flush before tightening the mounting bolts.

    d. Place a thin layer of sealant on the sealing surface of the lower part of the oil pan.

    e. Place the lower part of the oil pan in position on the upper part of the oil pan.

    f. Install and tighten the mounting bolts for the lower part of oil pan.



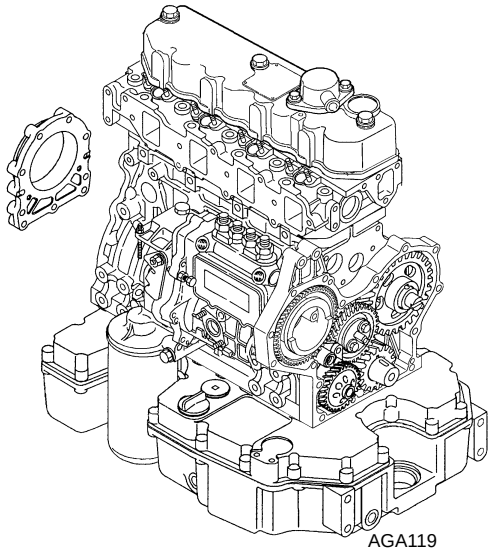
Install Oil Pan

55. Check to make sure the dowel pins are in position in the rear of the block. There are two for the rear seal housing and two for the bellhousing.

56. Make sure the old rear seal has been removed from the rear seal housing. If not, remove it.

57. Place a thin layer of sealant on the sealing surface of the rear seal housing.

58. Place the rear seal housing in position and make sure to align the dowel pins.



Install Rear Seal Housing

59. Install and tighten the mounting bolts for the rear seal housing.

    NOTE: The bolts at the bottom of the rear seal housing screw into the oil pan and are longer than the other bolts that fasten the rear seal housing to the block.

60. Install the rear seal using installation tool P/N 204-952 and the following procedure.

    CAUTION: Do not attempt to install this seal without using the installation tool. Driving the seal in by hand will crush the rubber lip into the metal ring and cause the seal to burn up when the engine is run.

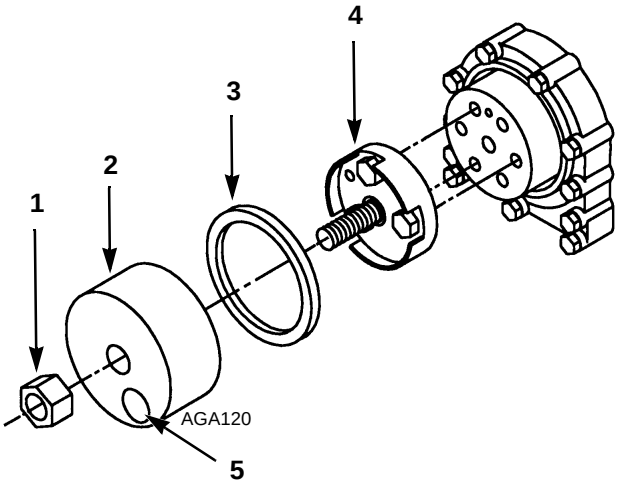
    NOTE: If necessary, the inside diameter of the metal seal ring can be lightly coated with Loc-Tite 620 or silicone gasket sealant. The original seal ring was installed without sealant, but the use of sealant offers some insurance against leaks if the crankshaft has some surface damage. However, sealant will make future removal of the metal ring more difficult. If necessary, a light coat of silicone sealer may also be applied to the outside diameter of the seal.

a. If necessary, remove the old metal ring and any imperfections from the surface of the crankshaft that contacts the metal ring of the seal. Check your work by placing the installation tool cup over the end of the crankshaft to check the fit. The cup must fit smoothly over the crankshaft or it will bind when installing the seal.

b. Attach the installation tool mandrel to the crankshaft using three flywheel bolts as shown in the illustration. If a point of the hex on a bolt is facing directly out it may extend past the mandrel. Grind down the points as required.

c. Place the seal over the installation tool mandrel with the metal face of the seal toward the engine.

d. Place the tool cup over the mandrel and against the seal. Align the cutout on the cup away from the bolts on the mandrel as shown. This allows you to see when the cup has completely bottomed on the mandrel.



1.	Nut
2.	Cup
3.	Seal
4.	Mandrel
5.	Check Cutout To Be Sure Mandrel Contacts Cup

Install Rear Seal with Tool P/N 204-952

e. Carefully tighten the installation tool nut. This pulls the cup over the mandrel and presses the seal into place. When the nut stops turning, check the cutout on the cup to be sure it is completely bottomed on the mandrel. The seal is now installed to the proper depth.

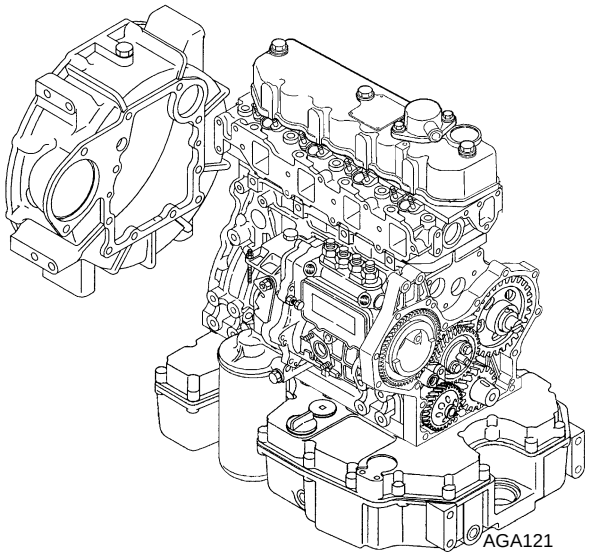
f. Remove the installation tool.

NOTE: If there are any imperfections on the crankshaft the cup may jam and be difficult to remove. Tapping alternately on each side will assist in removing a jammed cup. This problem can be eliminated by testing the fit of the cup on the crankshaft before installing the seal.

61. Place the bellhousing in position on the rear of the block and make sure to align the dowel pins.

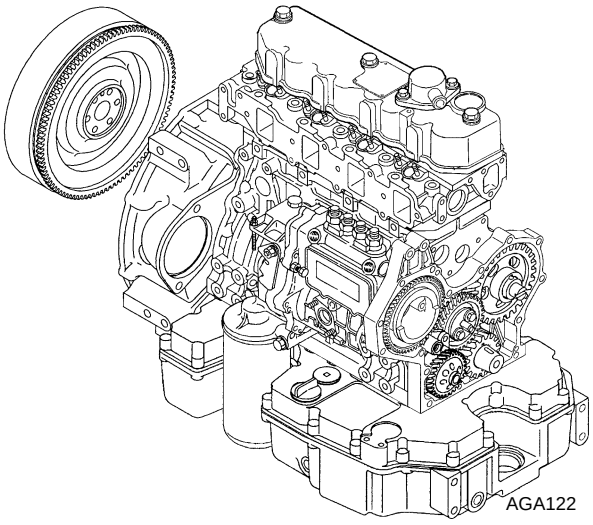
62. Install and tighten the mounting bolts for the bellhousing.

NOTE: The bolts at the bottom of the bellhousing screw into the oil pan and are longer than the other bolts that fasten the bellhousing to the block.



Install Bellhousing

63. Install the flywheel and align it with the dowel pin in the end of the crankshaft. Torque the flywheel mounting bolts to 61.5 to 65.1 ft-lb (83.4 to 88.3 N•m).



Install Flywheel

64. Check to make sure the dowel pins are in position in the timing gear housing.

65. Replace the front seal by pressing the old seal out and pressing a new seal into the timing gear cover.

66. Coat the lip of the front seal with engine oil.

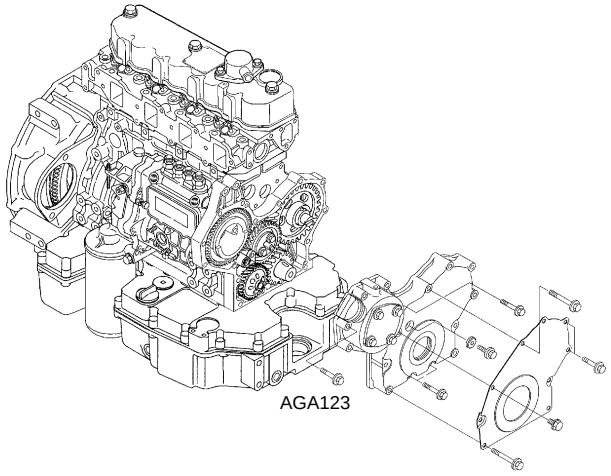
67. Place a thin layer of sealant on the sealing surface of the timing gear cover.

68. Place the timing gear cover in position and make sure to align the dowel pins.

69. Install and tighten the timing gear cover mounting bolts that are covered by the sound shield.

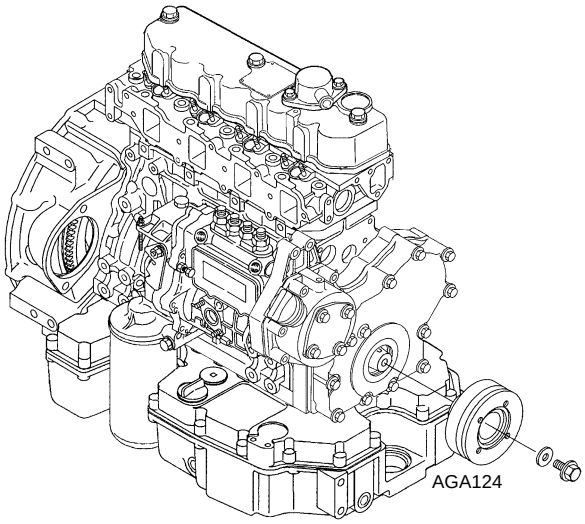
70. If the sponge on the back of the sound shield is damaged, replace it before installing the sound shield.

71. Place the sound shield in position and install and tighten the mounting bolts.



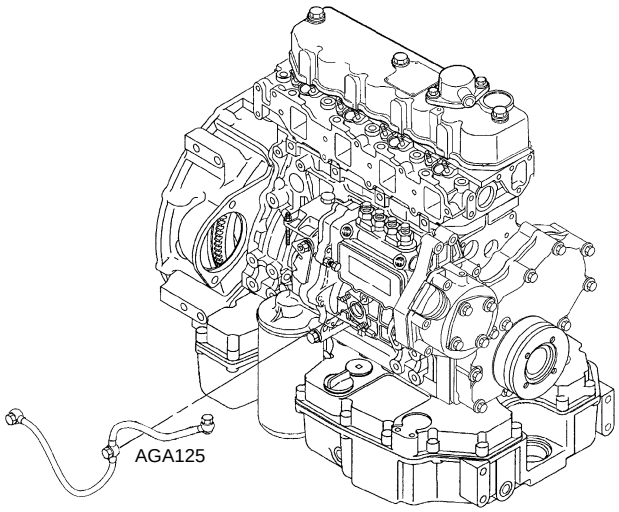
Install Timing Gear Cover and Sound Shield

72. Install the crankshaft pulley and align it with the dowel pin in the crankshaft gear. Torque the mounting bolt to 83.2 to 90.4 ft-lb (112.8 to 122.6 N•m).



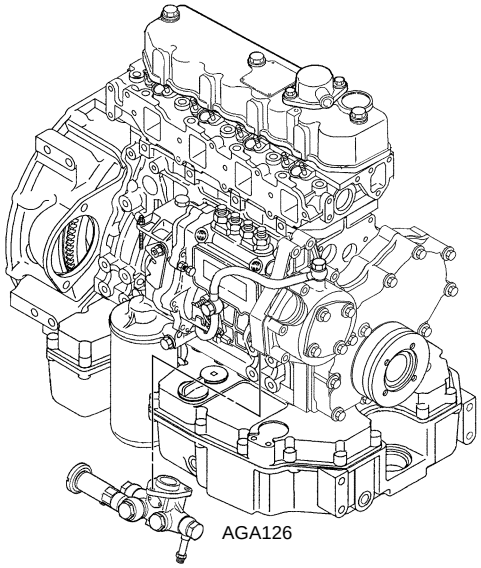
Install Crankshaft Pulley

73. Install the oil line that goes from the cylinder block to the fuel injection pump to the timing gear cover.



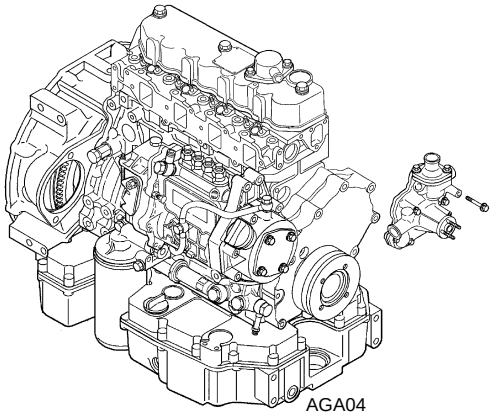
Install Oil Line

74. Install the fuel transfer pump in the timing gear cover.



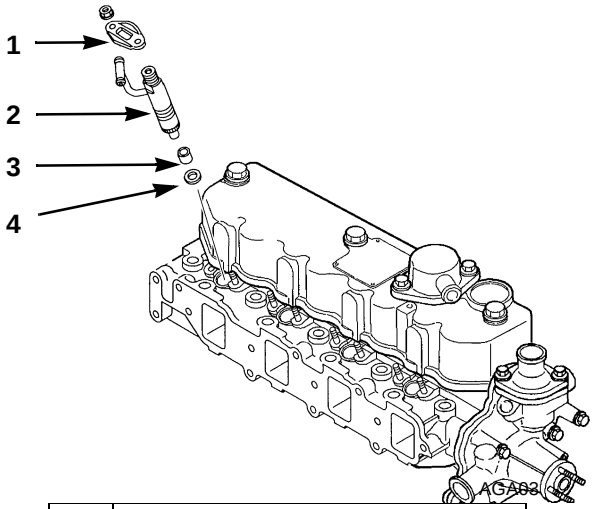
Install Fuel Transfer Pump

75. Install the water pump with a new O-ring, a new thermostat, and new gaskets.



Install Water Pump

76. Place a nozzle gasket and a nozzle protector in each opening for the fuel injection nozzles. Install the nozzle gasket first, then install the nozzle protector. The nozzle protector is shaped like a cup, and the bottom of the cup should face down.



1.	Retainer
2.	Fuel Injection Nozzle
3.	Nozzle Protector
4.	Nozzle Gasket

Install Fuel Injection Nozzles

77. Install the fuel injection nozzles.

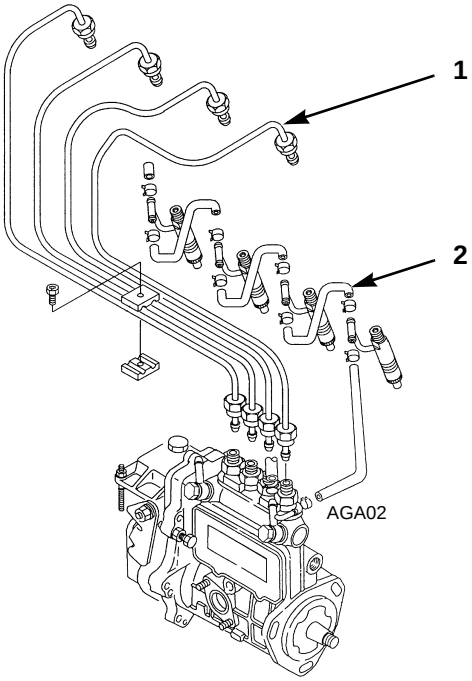
78. Install the fuel injection nozzle retainers and mounting nuts. Torque the mounting nuts to 5.1 to 6.5 ft-lb (6.9 to 8.8 N•m).

79. Install the lift brackets.

80. Install the intake manifold with a new gasket.

81. Install the fuel return lines.

82. Install the fuel injection lines.



1.	Fuel Injection Lines
2	Fuel Injection Return Lines

Install Fuel Injection Lines

83. Install the crankcase breather hose. Clean the restrictor in the crankcase breather hose to make sure it is not blocked.

84. Install the exhaust manifold with a new gasket.

85. Install the starter.

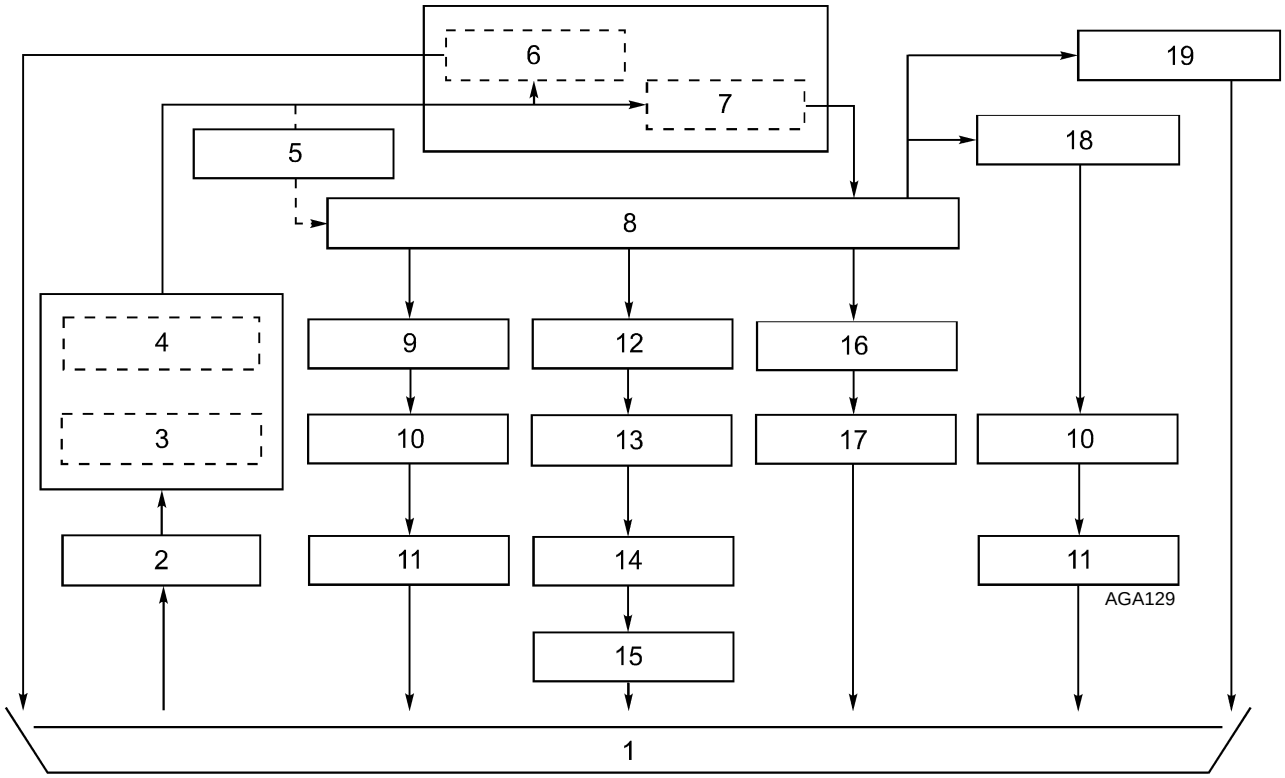
86. Check the fuel injection pump timing using the procedure in the Fuel System Chapter.

Lubrication System 5

Lubrication System

The TK 482 and TK 486 engines use a pressure lubrication system. A trochoid type oil pump circulates the oil through the system to lubricate the engine components. The oil pump contains a pressure control valve that limits the oil pressure to 36 to 50 psi (245 to 343 kPa). The oil pump is driven by the crankshaft gear, and is attached to the lower part of the timing gear housing.

The oil is picked up by a screened inlet near the bottom of the oil pan. The inlet is positioned far enough from the bottom of the pan to avoid picking up any of the residue that tends to settle on the bottom of the pan. The oil then passes through the intake pipe to the oil pump.



1.	Oil Pan	11.	Fuel Transfer Pump
2.	Oil Inlet Pipe (Strainer)	12.	Camshaft Bearing
3.	Oil Pump	13.	Valve Rocker Arm Shaft
4.	Pressure Control Valve	14.	Valve Rocker Arm
5.	Bypass Valve	15.	Tappet and Cam Faces
6.	Bypass Oil Filter	16.	Crankshaft Journals—Main Bearings
7.	Full Flow Oil Filter	17.	Crank Pins—Rod Bearings
8.	Cylinder Body and Main Oil Gallery	18.	Fuel Injection Pump Gear
9.	Idler Gear Shaft	19.	Fuel Injection Pump
10.	Timing Gear Faces		

Lubrication System

The oil pump forces a large volume of high pressure oil through an oil gallery to the dual element (full flow/bypass) oil filter. Dirt and other particles are trapped in the filter element as the oil passes through the oil filter. If the filter element becomes clogged, a bypass valve built in the oil filter adapter allows the oil to bypass the filter element. This keeps the engine components from being starved for oil if the filter element is clogged.

After passing through the oil filter, the oil enters the main oil gallery. Oil passages connected to the main oil gallery supply oil to the idler gear shaft, the camshaft bearings, and the main bearings. An external oil line is connected to the main oil gallery, the fuel injection pump, and the timing gear cover. The external oil line supplies oil to the fuel injection pump and the fuel injection pump gear.

Oil from the idler gear shaft lubricates the idler gear bushing, the idler gear, the other timing gears, and the fuel transfer pump before returning to the oil pan. Oil is also delivered to the fuel injection pump gear, the timing gears, and the fuel transfer pump through the external oil line connected to the top of the timing gear cover.

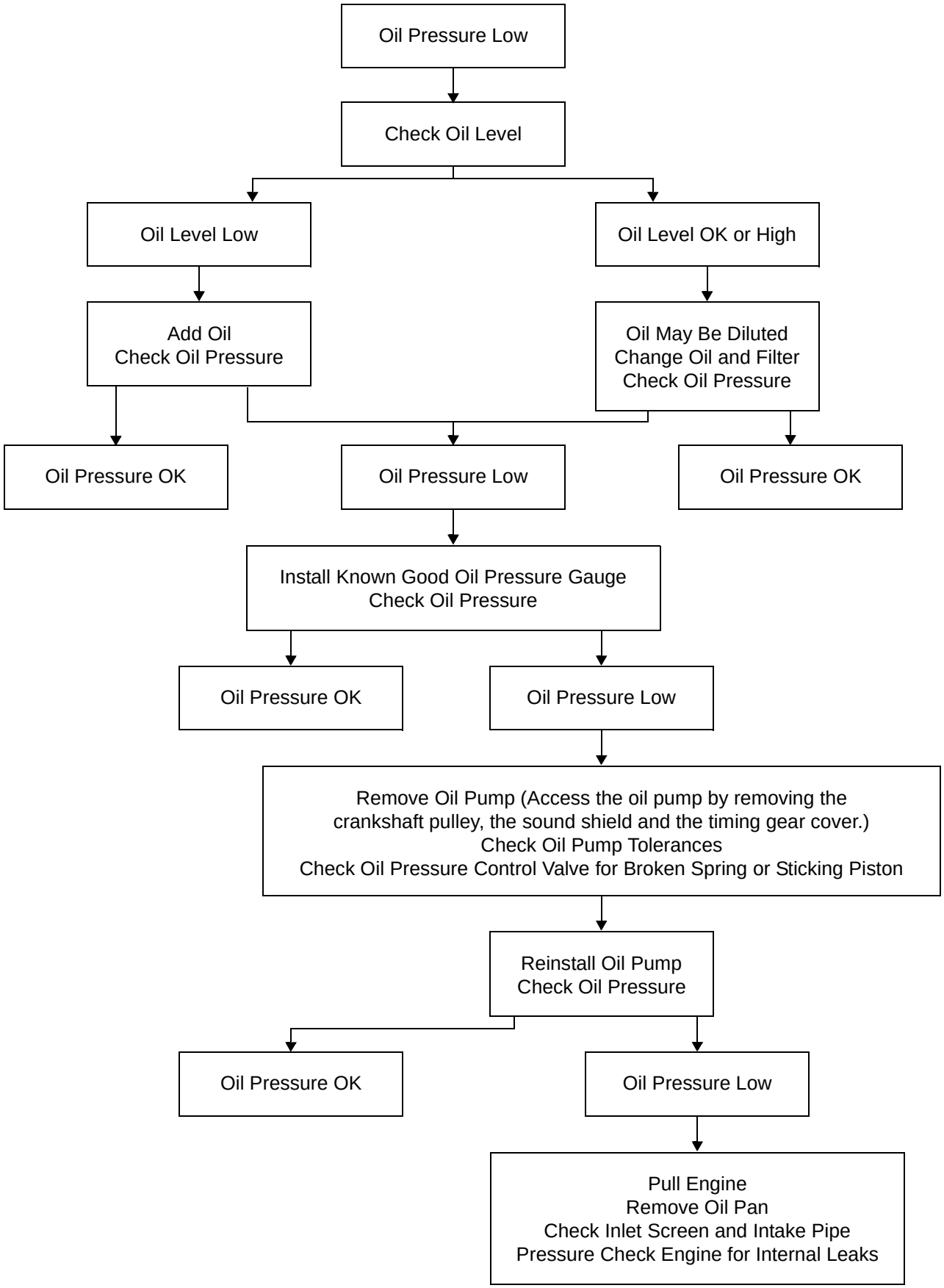
Some of the oil supplied to the main bearings flows through passages in the crankshaft to the connecting rod bearings. This oil is thrown around the bottom end of the engine as it flows out of the bearings while the crankshaft rotates. Some of this oil lubricates the cylinder walls. Some of this oil lands in the holes on the top of the connecting rods and lubricates the wrist pins and the connecting rod bushings. The oil eventually returns to the oil pan.

Some of the oil supplied to the camshaft bearings flows through passages in the cylinder block, the cylinder head, and the rocker arm supports to the rocker arm shaft. The rocker arm shaft supplies oil to the rocker arm bushings and the rocker arms. Some oil squirts out of holes in the rocker arms to lubricate the valve stem caps and the valve stems. The oil that is pumped up to the rocker arm assembly flows back down through the push rod openings and lubricates the tappets and the cam lobes as it returns to the oil pan.

The oil that flows to the fuel injection pump returns to the oil pan after lubricating the injection pump components.

Oil pressure is affected by oil temperature, oil viscosity, and engine speed. Low oil pressure can usually be traced to the lack of oil, diluted oil, a faulty oil pressure control valve, loose connections in the lubrication system, or worn bearings. Low oil pressure is not normally caused by a faulty oil pump. Use the flow chart on the following page to help diagnose low oil pressure.

Low Oil Pressure Flow Chart



Fuel System 6

Fuel System

The major components of the fuel system are:

1. Fuel Tank
2. Prefilter
3. Priming Pump
4. Fuel Transfer Pump
5. Fuel Filter
6. Water Separator
7. Fuel Injection Pump
8. Injection Nozzles

The priming pump is used to manually draw fuel from the tank up to the fuel transfer pump if the unit should run out of fuel.

The fuel is drawn from the fuel tank through the prefilter by the fuel transfer pump. The fuel transfer pump forces the fuel through the water separator and fuel filter to the injection pump. The injection pump forces the fuel, at a very high pressure, through the injection nozzles. The injection nozzles atomize the fuel as it is injected directly into the combustion chambers.

The system uses an in-line injection pump. The injection pump camshaft is driven at one end by the engine timing gears. The cam lobes actuate the plungers, which force fuel through the injection nozzles. A governor assembly is connected to the other end of the injection pump camshaft. The governor meters the amount of fuel delivered to the injection nozzles by controlling the position of the plungers.

Injection pump leakage, injection nozzle overflow, and excess fuel from the fuel filter assembly return to the fuel tank through the return lines.

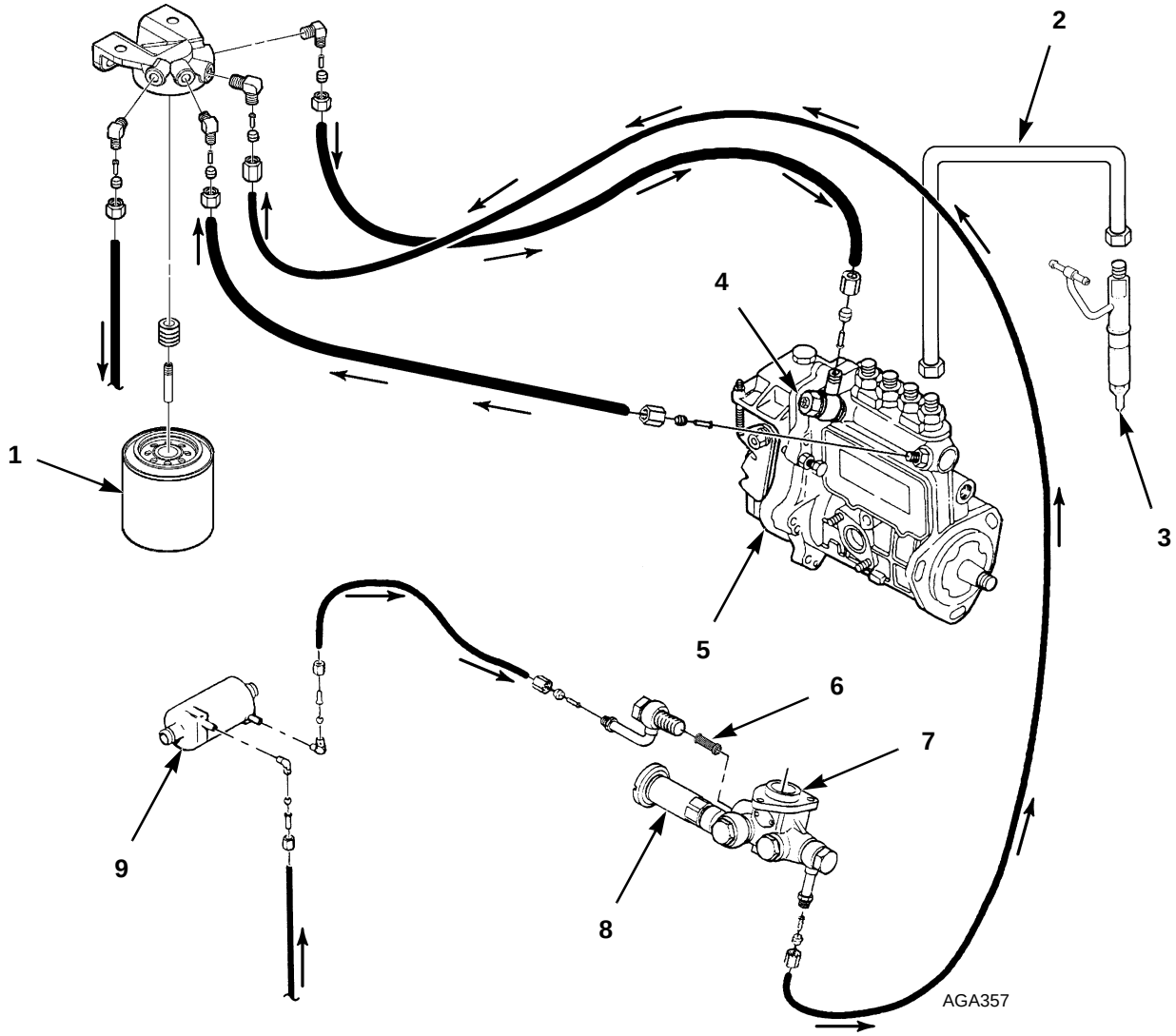
The injection pump and the fuel transfer pump are relatively trouble free and if properly maintained will usually not require major service or repair between engine overhauls.

The most common cause of problems in the fuel system is contamination. The fuel must be clean and the fuel tank must be kept free of contaminants. The fuel filter and water separator must be changed regularly. The prefilter should be cleaned when the fuel filter is changed. Any time the fuel system is opened, all possible precautions must be taken to keep dirt from entering the system. All fuel lines must be capped when disconnected. The work should be done in a relatively clean area and the work should be completed in the shortest time possible.

Thermo King recommends that any major injection pump or nozzle repairs be done by a qualified diesel injection service shop. The investment in equipment and facilities to service these components is quite high. Therefore, this equipment is not found in most repair shops.

The following procedures can be performed under field conditions:

1. Bleeding air from the fuel system.
2. Maintenance of the fuel tank and fuel filter system.
3. Priming pump repair or replacement.
4. Fuel transfer pump repair or replacement.
5. Injection line replacement.
6. Engine speed adjustments.
7. Injection pump timing.
8. Injection nozzle testing, adjustment, and minor repair.



1.	Fuel Filter/Water Separator	6.	Prefilter
2.	Injection Line	7.	Fuel Transfer Pump
3.	Injection Nozzle	8.	Priming Pump
4.	Bleed Screw	9.	Fuel Heater (Optional)
5.	Injection Pump		

Fuel System

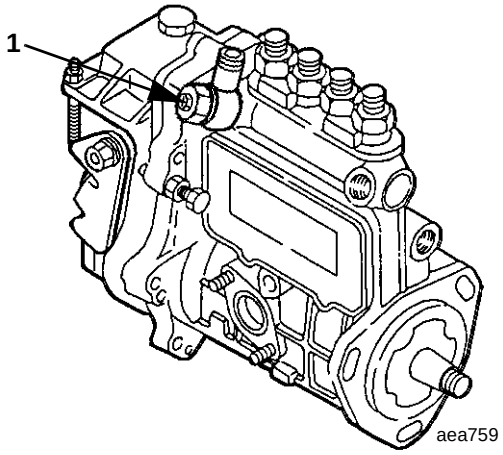
Bleeding Air From The Fuel System

Air usually gets into the fuel system when the engine runs out of fuel or if repairs are made to the fuel system.

NOTE: Be sure to keep the vent in the fuel tank open. If the vent becomes clogged, a partial vacuum develops in the fuel tank. This increases the chance that air will enter the fuel system.

Use the following procedure to bleed air out of the fuel system.

1. Loosen the bleed screw in the inlet fitting on the injection pump.



1.	Bleed Screw

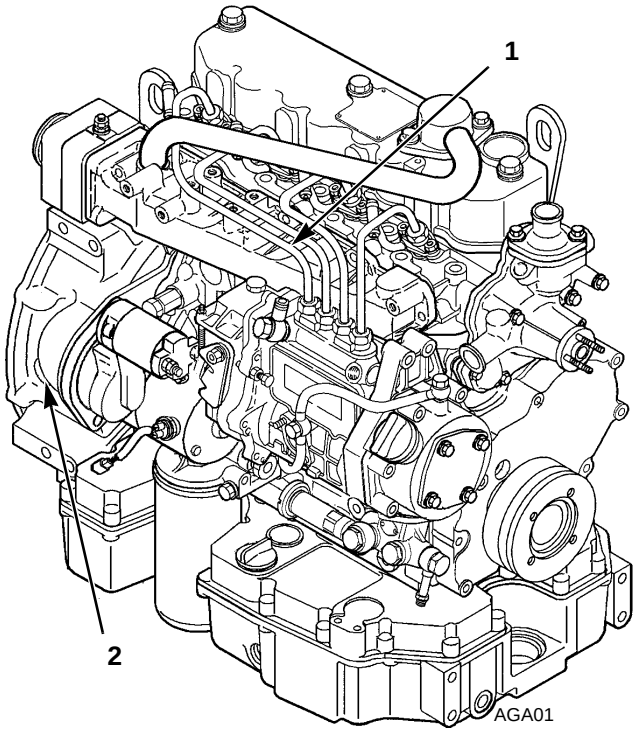
Injection Pump

2. Unscrew the priming pump handle and manually prime the fuel system until air bubbles are no longer visible in the fuel coming out of the bleed screw.
3. Tighten the air bleed screw and screw the priming pump handle back in.
4. Loosen the injection lines at the injection nozzles.
5. Crank the engine over with the starter until fuel appears at all of the injection nozzles.
6. Tighten the injection lines and start the engine.

Injection Pump Timing

This timing procedure requires fuel pressure at the injection pump inlet. This can be accomplished by pumping the priming pump by hand, or by using an electric fuel pump to supply fuel to the fuel pump inlet.

1. If the engine is in the unit, make sure the unit is turned off.
2. Remove the round cover (plug) from the timing mark access hole on the front of the bell housing. The index marks on either side of this hole and the timing marks on the flywheel are used to check the injection pump timing.



1.	Number One Cylinder Injection Line
2.	Timing Mark Access Hole

Component Location

3. ***CAUTION: Loosen all of the injection lines at the injection nozzles to prevent the possibility of the engine firing while it is being rotated.***

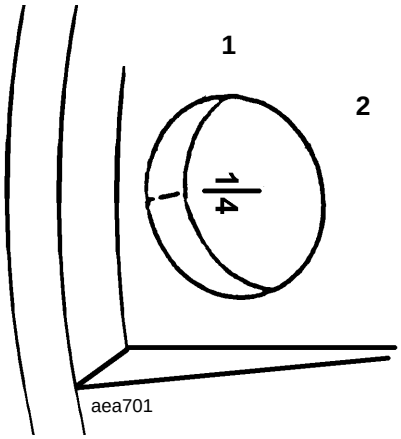
4. Remove the injection line for the number one cylinder from the delivery valve on the injection pump and from the injection nozzle.

   NOTE: The number one cylinder is the cylinder at the flywheel end of the engine.

5. Remove the rocker arm cover.

6. Place the engine at top dead center of the compression stroke for the number one cylinder. Refer to steps a. through d.

   a. Rotate the engine in the normal direction of rotation (clockwise viewed from the water pump end) until the 1-4 timing mark on the flywheel lines up with the index mark in the timing mark access hole.



1.	Index Mark
2.	Top Dead Center Mark for 1 and 4

Top Dead Center one and Four

   b. Check the rocker arms on the number one cylinder to see if they are loose.

   c. If the rocker arms are loose the engine is at top dead center of the compression stroke for the number one cylinder.

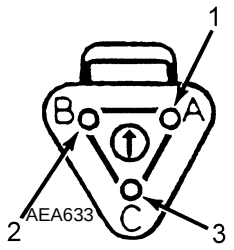
   d. If the rocker arms are tight the engine is at top dead center of the exhaust stroke for the number one cylinder. Rotate the engine 360° to place the engine at top dead center of the compression stroke for the number one cylinder.

7. Energize the fuel solenoid. If the engine is in the unit, place the On-Off switch in the ON position.

   CAUTION: If the unit is equipped with CYCLE-SENTRY, disconnect the 8S wire from the starter solenoid to prevent the CYCLE-SENTRY system from cranking the engine when the unit is turned ON.

   If the engine is not in the unit, use jumper wires to energize the fuel solenoid at the three pin connector. Place a jumper between the black wire (CH - pin C) and ground (-). Place a jumper between the red wire (8D - pin A) and 12 Vdc (+). Momentarily place a jumper between the white wire (8DP - pin B) and 12 Vdc (+).

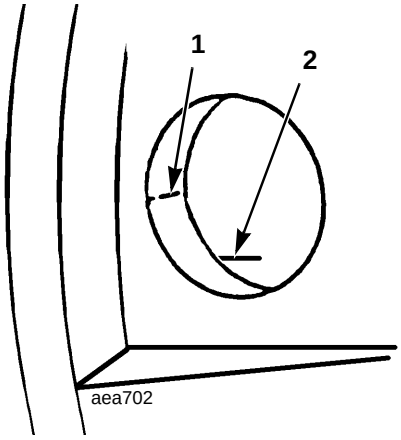
   CAUTION: Do not leave the jumper on the white wire (8PD - pin B) for more than a few seconds or the fuel solenoid will be damaged.



1.	Red (8D)
2.	White (8DP)
3.	Black (CH)

Fuel Solenoid
Connector Pin Identification

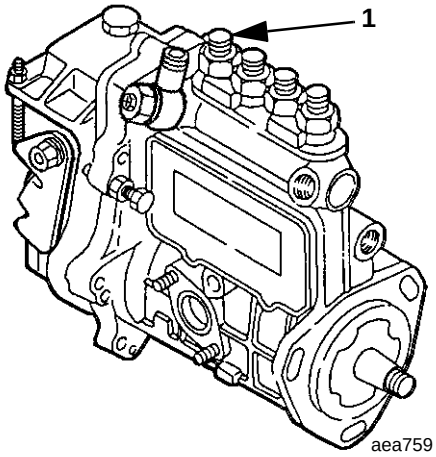
8. Rotate the engine backwards (counterclockwise viewed from the water pump end) until the injection timing mark is positioned in the bottom of the timing mark access hole. The injection timing mark is a horizontal line stamped on the flywheel approximately 1.2 in. (30 mm) before the top dead center mark.



1.	Index Mark
2.	Injection Mark

Timing Mark Alignment

9. Pump the priming pump by hand a few times, or energize the electric fuel pump if an electric fuel pump is being used.



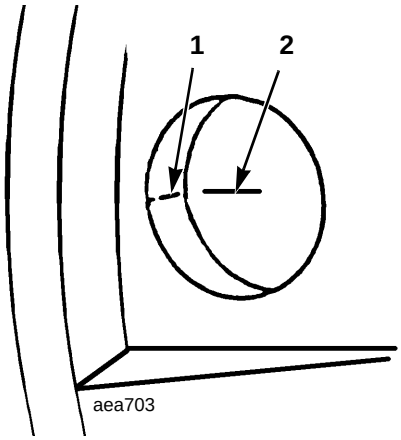
1.	Delivery Valve Holder

Injection Pump

10. Use a clean towel to wipe the fuel from the top end of the delivery valve holder.

11. Slowly turn the engine in the normal direction of rotation until you see the fuel rise in the end of the delivery valve holder. Stop as soon as you see the fuel rise slowly.

12. Check position of the timing marks. The injection timing mark on the flywheel should be aligned with the index mark on the side of the timing mark access hole. Repeat steps 8 through 12 to recheck the timing.



1.	Index Mark
2.	Injection Mark

Correct Timing Mark Alignment

13. If the timing is off by more than 1 degree (0.1 in. [2.5 mm]), loosen the mounting nuts on the studs that fasten the injection pump to the engine and rotate the injection pump to change the timing.

    a. Pull the top of the injection pump away from the engine to advance the timing.

    b. Push the top of the injection pump toward the engine to retard the timing.

14. Tighten the injection pump mounting nuts and recheck the timing. Repeat steps 8 through 14 until the timing is correct.
15. Install the cover in the timing mark access hole, install the injection line for the number one cylinder, and tighten the other injection lines when finished with the procedure.

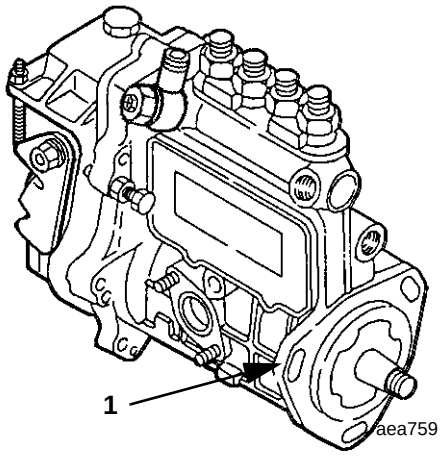
Injection Pump Removal and Installation

Removal

1. Disconnect the fuel lines and injection lines from the injection pump. Cover all the lines and fittings with plastic covers or tape. The smallest amount of dirt can damage the fuel system.
2. Remove the oil line that goes from the cylinder block to the injection pump and the timing gear cover.
3. Remove the fuel transfer pump from the timing gear cover.
4. Remove the front crankshaft bolt.
5. Remove the crankshaft pulley by using a suitable puller.
6. Remove the timing gear cover and sound shield.
7. Remove the injection pump gear nut and lock washer.
8. Remove the injection pump gear by using a suitable puller.
9. Note the position index marks on the edge of injection pump.
10. Remove the injection pump from the timing gear housing.

Installation

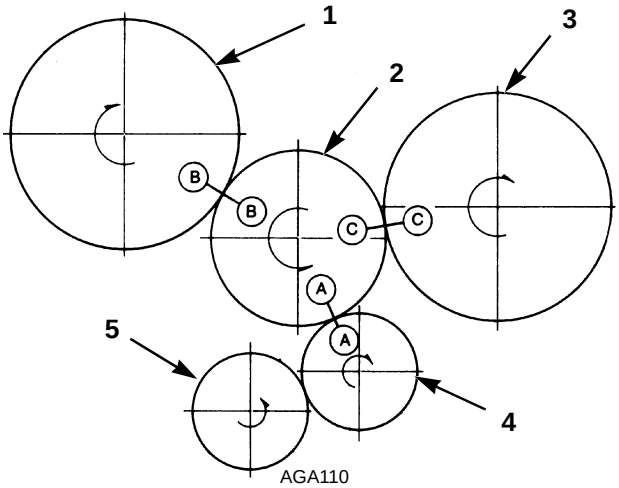
1. Install the injection pump, align the index marks, and tighten the mounting nuts.



1.	Index Mark Location

Index Marks

2. Place the engine at top dead center of the compression stroke for the number one cylinder. This positions the camshaft gear and the crankshaft gear as shown in the following illustration.



1.	Injection Pump Gear
2.	Idler Gear
3.	Camshaft Gear
4.	Crankshaft Gear
5.	Oil Pump Gear

Align Timing Marks

3. Remove the idler shaft and idler gear.
4. Install the injection pump gear, lockwasher and mounting nut. Make sure the key is aligned properly. Torque the mounting nut to 43.4 to 50.6 ft-lb (58.8 to 68.6 N•m).
5. Turn the injection pump gear to the position shown in the illustration on the previous page.
6. Install the idler gear and the idler shaft and align the timing marks as shown in the illustration on the previous page. The A mark on the idler gear should line up with the A mark on the crankshaft gear. The B mark on the idler gear should line up with the B mark on the injection pump gear. The C mark on the idler gear should line up with the C mark on the camshaft gear.
7. Install the timing gear cover and sound shield and tighten the mounting bolts.
8. Install the crankshaft pulley and align it with the dowel pin in the crankshaft gear. Torque the mounting bolt to 83.2 to 90.4 ft-lb (112.8 to 122.6 N•m).
9. Install the oil line that goes from the cylinder block to the fuel injection pump and the timing gear cover.
10. Install the fuel transfer pump in the timing gear cover.
11. Connect the fuel lines and injection lines to the injection pump.
12. Bleed the air from the fuel system.
13. Check the injection pump timing.

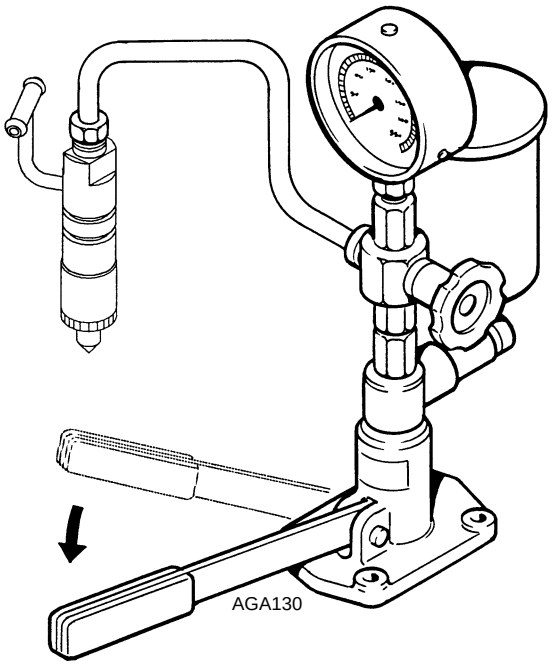
Injection Nozzles

Testing

1. Attach the injection nozzle to a nozzle tester (P/N 204-290).

   NOTE: Use only testing fluid or clean filtered diesel fuel to test injection nozzles.

   CAUTION: Keep your hands away from the nozzle spray. The nozzle spray is at such high pressure that it can break the skin and penetrate into the underlying tissue. Such an injury is very painful and can lead to serious complications such as blood poisoning.

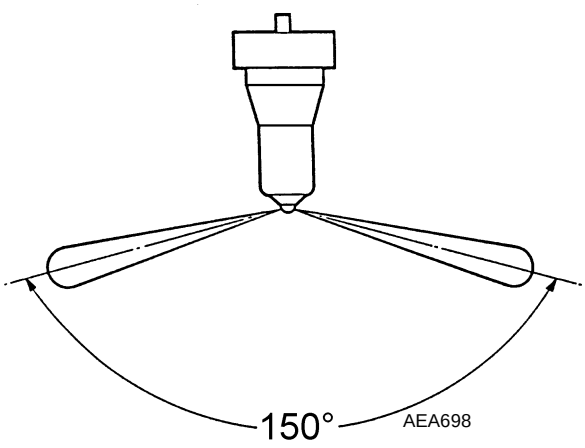


Testing Injection Nozzles

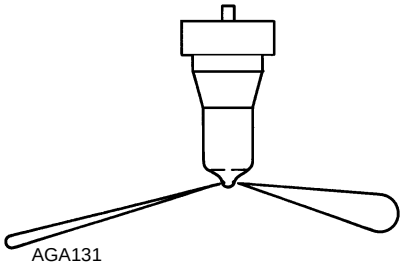
2. Close the pressure gauge valve and push the hand lever completely down several times.

   a. The injection nozzle should make a shrill whistling or buzzing noise.

b. Each hole in the nozzle should form a straight conical spray pattern. The spray patterns should be uniform and separated by an angle of approximately 150 degrees.



Acceptable Spray Pattern



Unacceptable Spray Pattern

3. Open the pressure gauge valve and check the opening pressure by pushing the hand lever completely down several times.

   a. The injection nozzle should make a buzzing sound.

   b. The opening pressure should be 2800 to 3000 psi (19600 to 20600 kPa).

   c. Adjust the opening pressure by changing the size or number of adjustment shims above the spring. Refer to the repair procedure.

4. Leave the pressure gauge valve open and check to see if the injection nozzle drips. Slowly press on the hand lever to bring the pressure up to 300 psi (2068 kPa) below the opening pressure of the injection nozzle. Maintain this pressure for at least 5 seconds. Fuel should not drip from injection nozzle in less than 5 seconds.

5. Repair the injection nozzle if it fails any of these tests or if fuel leaks out of the return tube during the tests.

Repair

1. Clamp the nozzle body in a vise with the nozzle nut up. Use a vise that has aluminum jaws or jaw covers.

2. Loosen and remove the nozzle nut.

3. Remove the nozzle valve and seat set from the nozzle nut and submerge them in diesel fuel. Make sure to keep them together as a set.

4. Remove the nozzle body from the vise.

5. Remove the spacer, pins, spring seat, spring, and adjustment shim(s) from the nozzle holder.

6. Inspect the spacer. Replace the spacer if any wear or damage is evident.

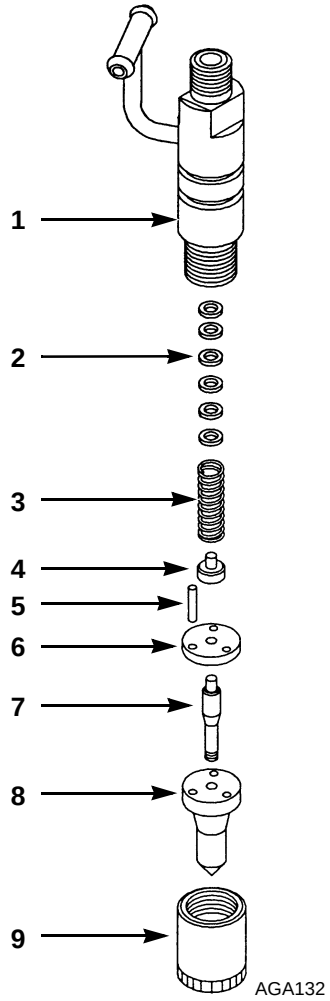
7. Inspect the spring. Replace the spring if it is bent, scratched, or rusted.

8. Use a nozzle cleaning tool kit to clean the nozzle valve and seat set.

   a. Clean the carbon off the outside of the nozzle seat with a cloth and solvent.

   b. Clean the inside of the nozzle with the cleaning tools and solvent.

   c. Thoroughly rinse the nozzle seat and valve with cleaning spray and submerge them separately in diesel fuel.



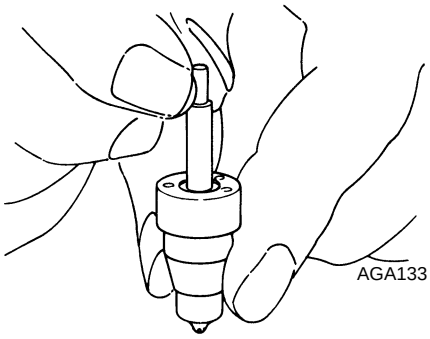
1.	Nozzle Body
2.	Adjustment Shims
3.	Spring
4.	Spring Seat
5.	Pin
6.	Spacer
7.	Nozzle Valve
8.	Nozzle Seat
9.	Nozzle Nut

Injection Nozzle Assembly

9. Test the nozzle valve and seat set.

   a. Place the nozzle valve in the nozzle seat while holding the nozzle seat in a vertical position.

   b. Pull the nozzle valve about one third of the way out of the nozzle seat.



Testing Nozzle Valve and Seat Set

   c. Release the nozzle valve. The nozzle valve should slide into the nozzle seat by itself.

   d. Rotate the nozzle valve in the nozzle seat about 90 degrees at a time, and repeat this test four or five times.

   e. Replace the nozzle valve and seat set if the nozzle valve does not slide smoothly into the nozzle seat.

   NOTE: A new nozzle valve and seat set should be thoroughly cleaned and tested before being installed.

10. Clamp the nozzle body in a vise with the nozzle nut end up.

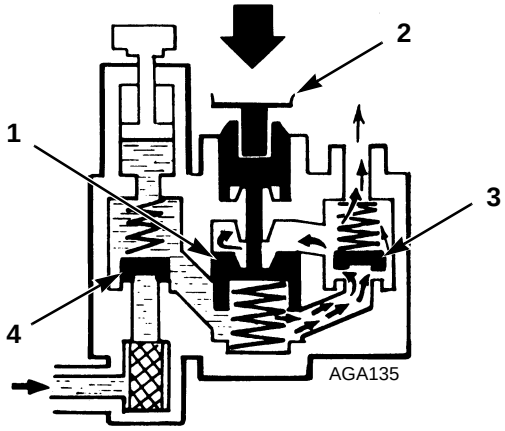
11. Place the adjustment shim(s) in the nozzle body. If the opening pressure needs to be adjusted, change the shims as required. Add shims or replace the present shim with a larger one to increase the opening pressure. Remove shims or replace the present shim with a smaller one to decrease the opening pressure.

12. Place the spring, spring seat, and pins in the nozzle body.

13. Place the spacer over the pins and check the alignment.
14. Place the nozzle valve and seat set on the pins and check the alignment.
15. Install the nozzle nut and torque it to 29 to 33 ft-lb (39 to 44 N•m).
16. Test the injection nozzle and adjust the opening pressure as necessary.

Fuel Transfer Pump

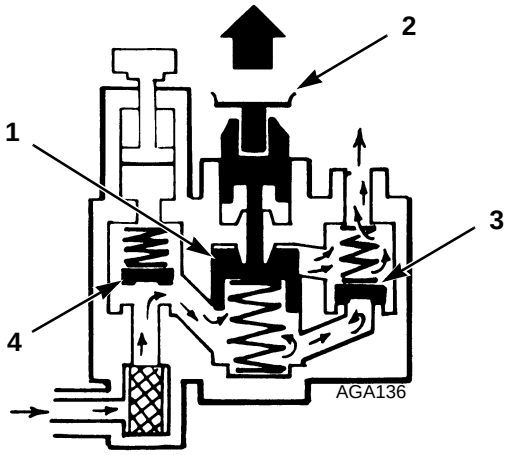
The fuel transfer pump is driven by a cam on the fuel injection pump gear. The cam actuates the piston through the tappet assembly and push rod. Fuel is forced through the outlet check valve when the cam moves towards the piston and compresses the spring. The inlet check valve closes to prevent fuel from flowing back through the inlet.



1.	Piston
2.	Cam
3.	Outlet Check Valve
4.	Inlet Check Valve

Outlet Stroke

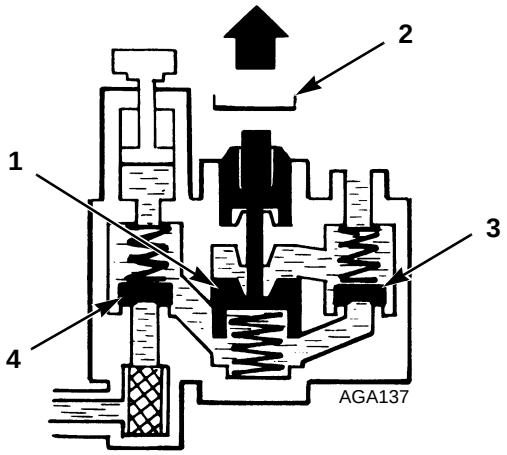
The spring pushes the piston towards the cam when the cam moves away from the piston. This draws fuel through the inlet check valve and forces fuel out of the outlet. The outlet check valve closes to prevent fuel from flowing back behind the piston.



1.	Piston
2.	Cam
3.	Outlet Check Valve
4.	Inlet Check Valve

Inlet and Delivery Stroke

When the fuel pressure at the outlet is more than approximately 7 psi (48 kPa), it stops the spring from pushing the piston back toward the cam. This prevents fuel from being forced out of the outlet. When the pressure drops, operation resumes. This limits the outlet fuel pressure to approximately 7 psi (48 kPa).



1.	Piston
2.	Cam
3.	Outlet Check Valve
4.	Inlet Check Valve

Pressure Controlled Delivery Stroke

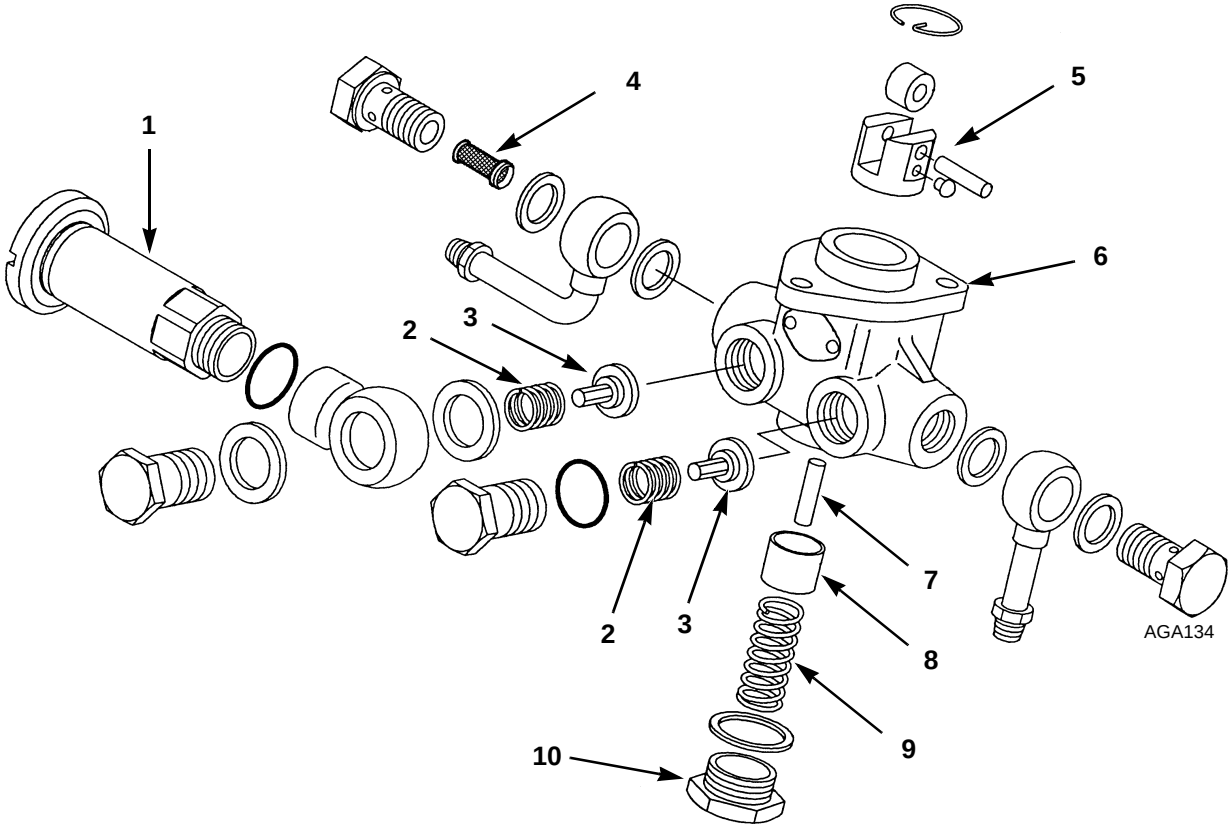
Inspection

Refer to the illustration on the following page.

1. Remove and inspect the check valves and check valve springs. Replace any that are worn or damaged and reassemble the check valves.
2. Remove the transfer pump from the timing gear cover.
3. Carefully remove the retainer. It is under spring pressure.
4. Remove and inspect the spring and piston. Replace the spring if it is worn or damaged. Replace the transfer pump if the piston or pump body is damaged or worn.
5. Reassemble the piston, spring, and retainer.
6. Press on the tappet and release it. Repeat this a few times. Check to see that the tappet moves in and out of the pump body smoothly without sticking or binding. Replace the transfer pump if the tappet sticks or binds.

Testing

1. Install the fuel transfer pump if it was removed for inspection.
2. Disconnect the fuel solenoid wire connector.
3. Disconnect the inlet and outlet fuel lines from the fuel transfer pump.
4. Attach a fuel hose about 6 feet (2 meters) long to the inlet fitting on the fuel transfer pump.
5. Position a container of diesel fuel about 3 feet (1 meter) below the level of the fuel transfer pump, and place the end of the hose in the diesel fuel.
6. Turn the engine over with the starter. The fuel transfer pump should pump fuel out of the outlet within 60 revolutions of the engine. Repair or replace the fuel transfer pump if more than 120 revolutions of the engine are required to pump fuel through the pump.



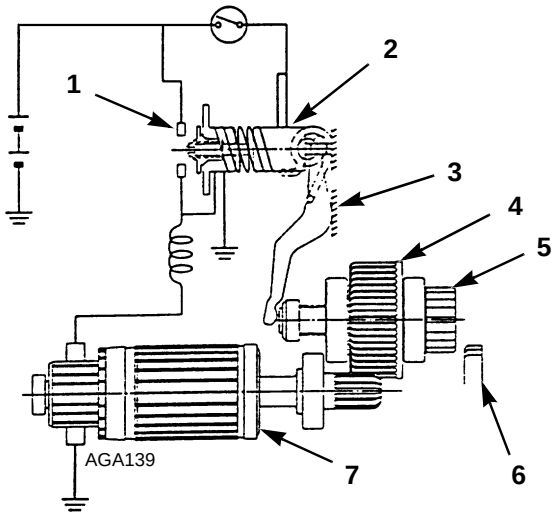
1.	Priming Pump	6.	Pump Body
2.	Check Valve Spring	7.	Push Rod
3.	Check Valve	8.	Piston
4.	Prefilter	9.	Spring
5.	Tappet Assembly	10.	Retainer

Fuel Transfer Pump

Electrical 7

Starter

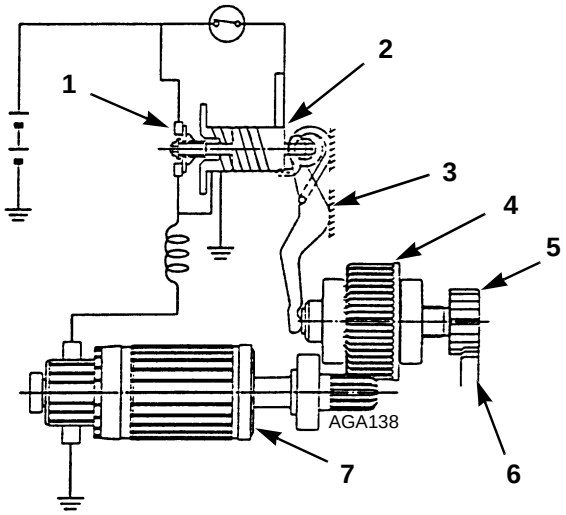
The major components of the starter are the starter motor, the starter solenoid, and the pinion assembly. The starter motor turns the pinion assembly with a small gear on the end of the armature.



1.	Heavy Duty Contacts
2.	Starter Solenoid
3.	Shift Lever
4.	Pinion Assembly
5.	Pinion Gear
6.	Ring Gear
7.	Starter Motor

De-energized Starter

When the starter solenoid is energized, it energizes the starter motor through a set of heavy duty contacts. When the starter solenoid is energized, it also pulls the shift lever. This extends the pinion gear to engage the ring gear on the engine's flywheel. The pinion assembly includes an over-running clutch that allows the pinion gear to turn freely if the engine is turning faster than the starter while the starter is energized.

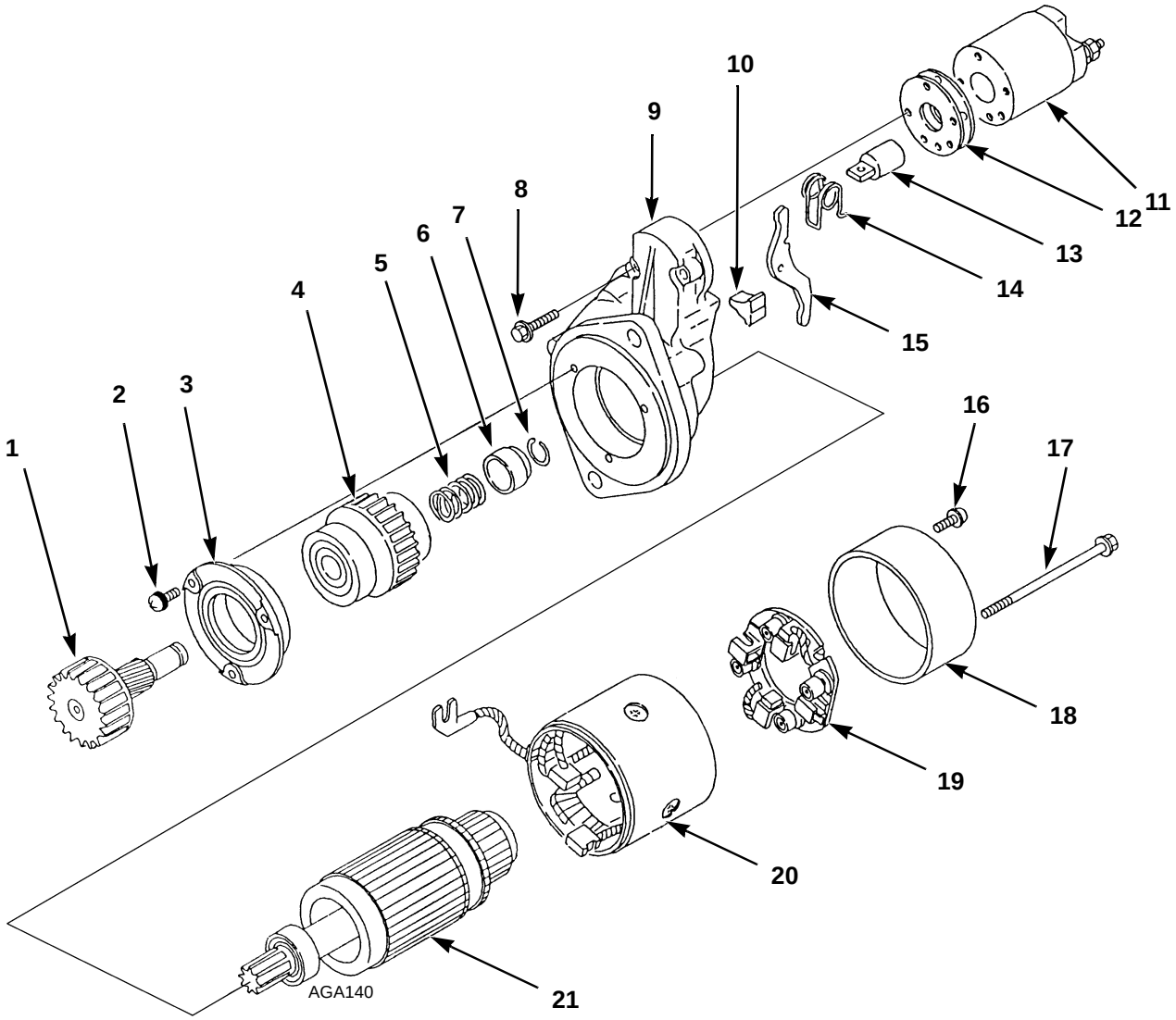


1.	Heavy Duty Contacts
2.	Starter Solenoid
3.	Shift Lever
4.	Pinion Assembly
5.	Pinion Gear
6.	Ring Gear
7.	Starter Motor

Energized Starter

Disassembly

1. Disconnect the stator lead from the M terminal on the starter solenoid.
2. Remove the two 4X10 mm screws from the rear cover. These screws fasten the brush holder assembly to the rear cover.
3. Remove the two through bolts from the rear cover and remove the rear cover from the starter motor.
4. Place the brush springs on the sides or the brush holders.
5. Remove the positive brushes (the brushes connected to the stator) from the brush holders.



1.	Pinion Shaft	12.	Shims
2.	5X16 mm Screw	13.	Plunger
3.	Pinion Assembly Retainer	14.	Shift Lever Spring
4.	Clutch	15.	Shift Lever
5.	Pinion Return Spring	16.	4X10 mm Screw
6.	Stop Ring	17.	Through Bolt
7.	Snap Ring	18.	Rear Cover
8.	6X35 mm Bolt	19.	Brush Ring
9.	Gear Housing	20.	Stator
10.	Dust Cover	21.	Armature
11.	Starter Solenoid		

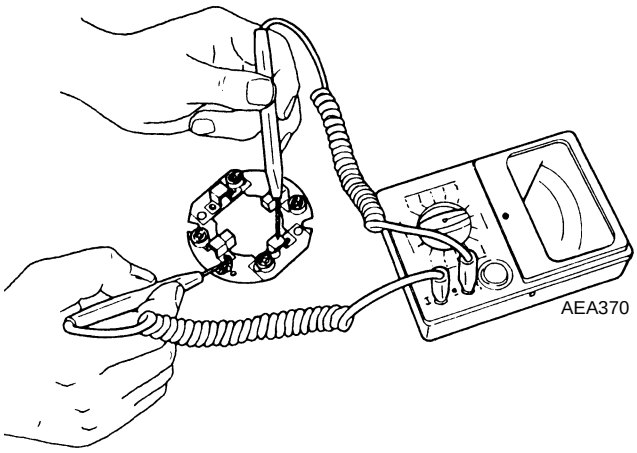
Starter Assembly

6. Pull the negative brushes (the brushes connected to the brush holder assembly) part way out of the brush holders and place the brush springs on top of the brush holders against the sides of brushes. This is called the locked position and it holds the brushes in place off the commutator.
7. Remove the brush holder assembly from the commutator.
8. Remove the armature and stator from the gear housing.
9. Remove the armature from the stator.
10. Remove the two 6X35 mm bolts that fasten the starter solenoid to the gear housing.
11. Remove the starter solenoid, shims, shift lever spring, shift lever, and dust cover from the gear housing.
12. Remove the three 5X16 mm screws from the pinion assembly retainer and remove the pinion assembly from the gear housing.

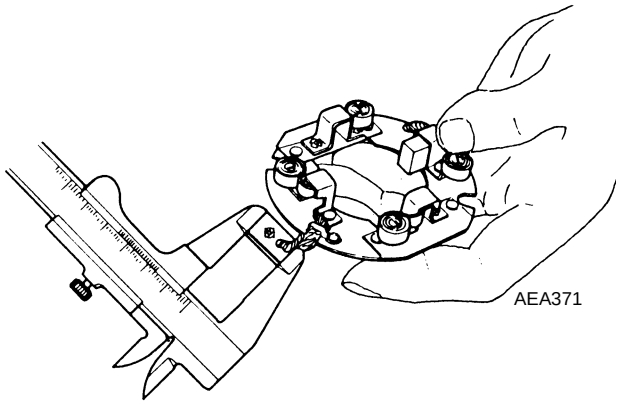
Major Component Inspection

Starter Motor

1. Check the brush ring assembly.
    a. Check the brush holders with an ohmmeter. The positive brush holders should have infinite resistance to the brush ring plate. The negative brush holders should have continuity to the brush ring plate.
    b. Check the brushes. Replace the brushes if they are chipped or cracked, or measure less than 0.4 in. (9 mm) on the short side. Replace the brushes as a set, or replace the brush ring assembly.



Check Brush Holders

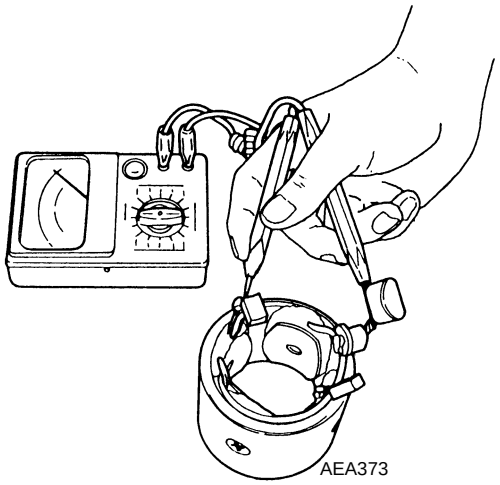


Measure Brushes

    c. Check the brush springs. Replace the brush springs if they are discolored, deformed, or if the spring tension is less than 7.1 lb (3.2 kg). The spring tension should be checked with the brush ring assembly installed on the commutator.

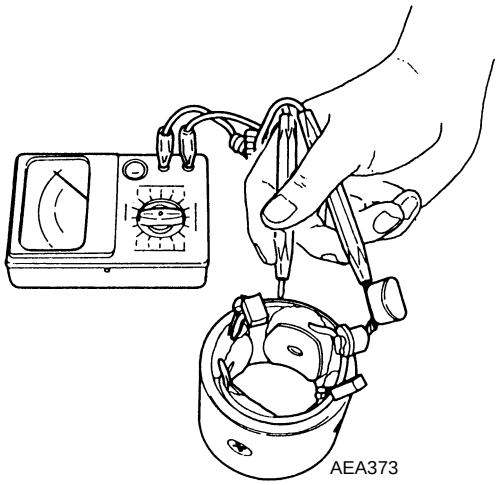
2. Check the stator.

   a. Check the field coil with an ohmmeter. There should be continuity between the stator lead and both positive brushes. Replace the stator if there is no continuity or high resistance in the field coil.



Check Field Coil

   b. Check the stator insulation with an ohmmeter set on the RX1000 scale. There should be infinite resistance between the stator lead and the stator frame. Replace the stator if there is any continuity between the stator lead and the stator frame.



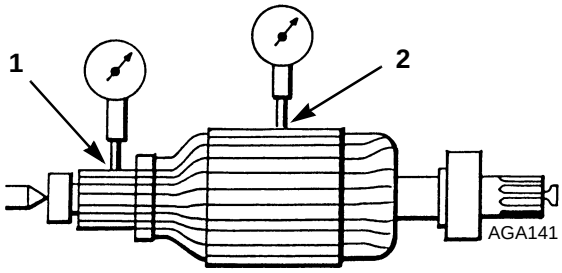
Check Stator Insulation

3. Check the armature.

   a. To check the bearings, turn them by hand. Replace the bearings if they are rough or seem loose.

   b. Visually check the armature. Replace the armature if there is any sign of thrown solder, discolored windings, bubbled insulation, burned or damaged commutator bars, damaged shafts or a damaged gear.

   c. Place the armature in a lath and check the commutator and the core with a dial indicator. The distortion, run out, or out of round should not exceed 0.008 in. (0.20 mm).



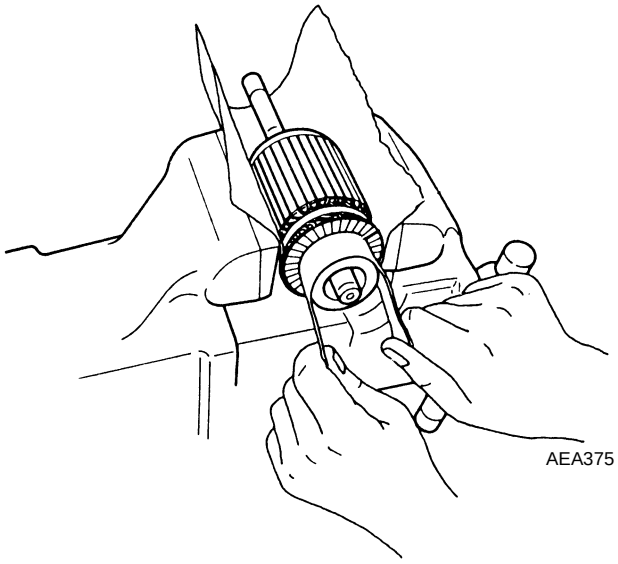
1.	Commutator
2.	Core

Check Armature Distortion

   d. Turn the commutator or the core down if they exceed this limit. Also turn the commutator down to remove any wear grooves made by the brushes.

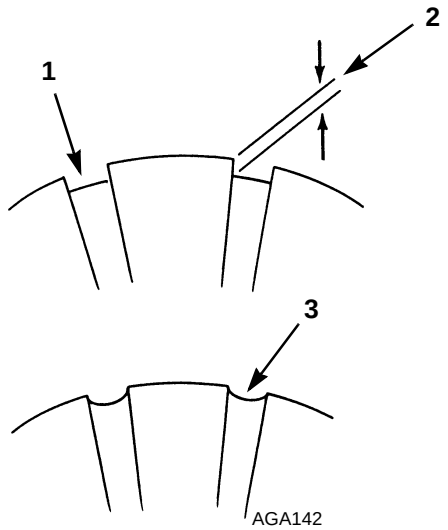
   e. Replace the armature if the commutator has an outside diameter that is less than 1.40 in. (35.5 mm) after being turned down.

   f. If the commutator is only dirty, clean it up with 500-600 grit sandpaper.



Clean Up Commutator

g. After turning down the commutator, check the undercut of the mica. The standard undercut is 0.02 to 0.03 in. (0.5 to 0.8 mm). Cut the undercut down to the proper depth if it is less than 0.01 in. (0.2 mm).

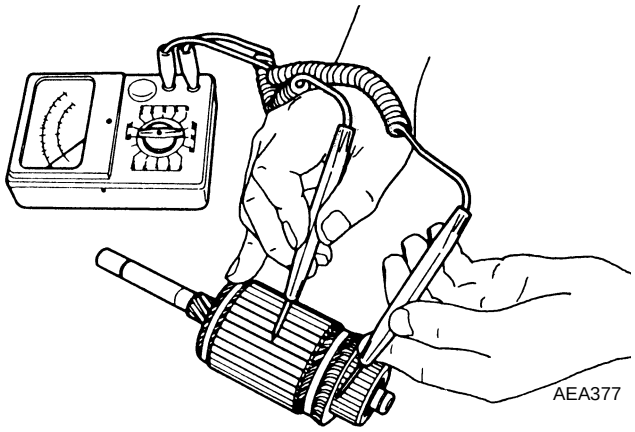


1.	Correct
2.	0.02 to 0.03 in. (0.5 to 0.8 mm)
3.	Incorrect

Check Commutator Undercut

h. Check the armature coils with a growler and an ammeter. Place the ammeter leads on each pair of commutator bars that are directly opposite each other. The ammeter will show no current in an open coil and lower than normal current in a shorted coil. Replace the armature if any of the coils are defective.

i. Check the armature insulation with an ohmmeter set on the RX1000 scale. There should be infinite resistance between each commutator bar and the armature core or shafts. Replace the armature if there is any continuity between the armature coils and the core.



Check Armature Insulation

Pinion Assembly

1. Inspect each part of the pinion assembly and replace any part that shows significant wear or damage. Push the stop ring off the snap ring and remove the snap ring from the end of the pinion shaft to disassemble the pinion assembly.

2. Check the overrunning clutch.

   a. Hold the pinion clutch assembly.

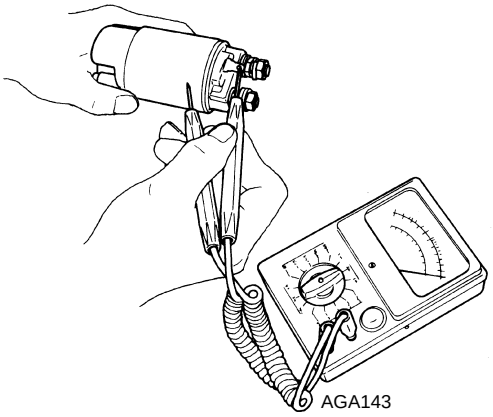
   b. Place the pinion shaft in the pinion clutch and try to rotate the pinion shaft in both directions.

c. The pinion shaft should rotate freely in one direction and should not rotate in the other direction.

d. Replace the pinion clutch if the pinion shaft does not rotate smoothly in the proper direction, or if it rotates in both directions.

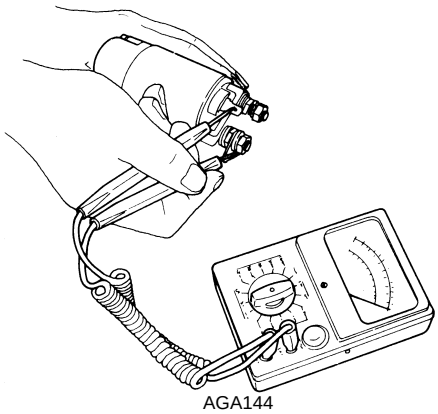
Starter Solenoid

1. Check the continuity between the S terminal and the chassis on the starter solenoid. Replace the starter solenoid if there is no continuity or high resistance.



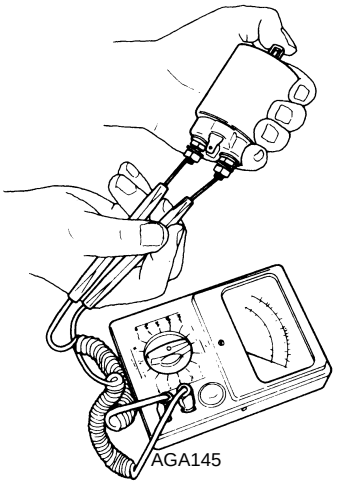
Check Shunt Coil

2. Check the continuity between the S terminal and the M terminal on the starter solenoid. Replace the starter solenoid if there is no continuity or high resistance.



Check Series Coil

3. Push the plunger in and check the continuity between the B terminal and the M terminal on the starter solenoid. Replace the starter solenoid if there is no continuity or high resistance.



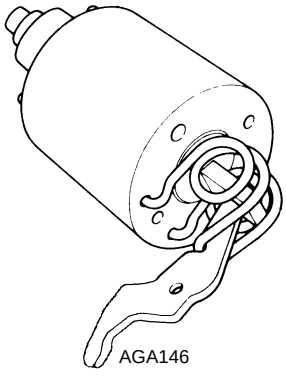
Check Contacts

Assembly

1. Place the pinion assembly in the gear housing and install the three 5X16 mm screws.

2. Place the shims and the shift lever spring over the plunger in the starter solenoid.

3. Place the shift lever in the hole in the end of the plunger, and place the shift lever spring in the notch in the shift lever.



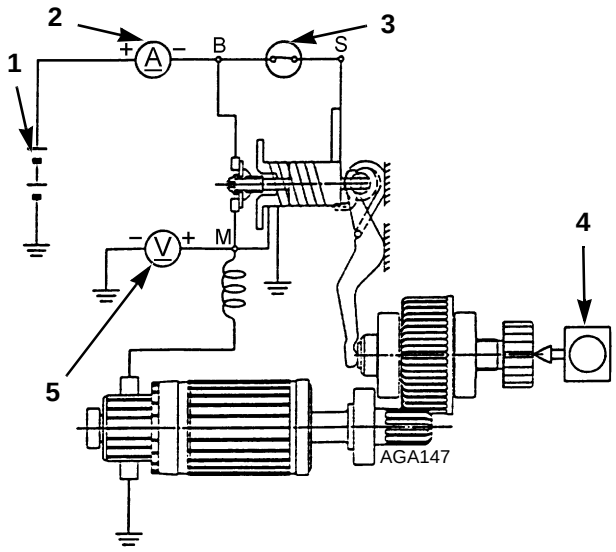
Install Shift Lever and Spring

4. Place the assembled starter solenoid (with shift lever) and the dust cover in the gear housing.
5. Fasten the starter solenoid to the gear housing with the two 6X35 mm bolts.
6. Place the armature in the stator.
7. Place the armature and the stator in the gear housing. Make sure the armature bearing is seated in the gear housing.
8. Make sure the negative brushes are in the locked position and place the brush ring on the commutator.
9. Place the positive brushes in the brush holders.
10. Move the brushes and the brush holders to their normal positions. Make sure that the brushes move freely in the brush holders and that the brush springs hold the brushes against the commutator.
11. Place the rear cover in position on the armature and stator. Make sure the armature bearing is seated in the rear cover.
12. Install the two through bolts.
13. Install the two 4X10 mm screws that fasten the brush holder assembly to the rear cover.
14. Connect the stator lead to the M terminal on the starter solenoid.

No Load Test

CAUTION: Do not run the starter without a load for more than 30 seconds.

1. Clamp the starter in a vise.
2. Connect the starter to a 12 volt battery as shown in the illustration.
3. When the switch is turned on, check the current, voltage, and starter speed. The standard values are: 140 amps, 11 volts, 3900 rpm.

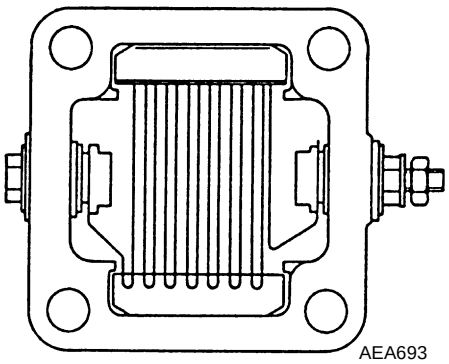


1.	Battery	4.	Tachometer
2.	Ammeter	5.	Voltmeter
3.	Switch		

No Load Test

Air Heater

The air heater is mounted on the open end of the intake manifold. It heats the intake air to help the engine start in cold weather.



1.	M6 Terminal

Air Heater

Check the resistance of the air heater with an ohmmeter between the M6 terminal on the front of the air heater and the screw on the back of the air heater (or the air heater case). The resistance should be 0.1 to 0.2 ohms.

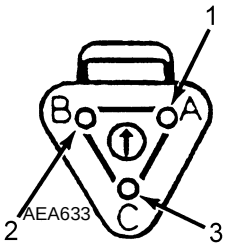
Check the current draw of the air heater with a clamp-on ammeter at the H1 wire near the M6 terminal on the front of the air heater. The current draw should be approximately 89 amps at 12.5 volts and approximately 77 amps at 11 volts when the air heater is energized.

The air heater is defective if the resistance is more than 0.2 ohms and the current draw is less than 60 amps, or if the current draw is more than 100 amps.

Fuel Solenoid

When the fuel solenoid is energized, it places the fuel rack in the on position. This allows fuel to flow in the fuel injection pump. The fuel solenoid has two coils, the pull-in coil and the hold-in coil. The pull-in coil must be momentarily energized to place the fuel rack in the on position. The energized hold-in coil can then hold the fuel rack in the on position. Use the following procedure to test the fuel solenoid.

1. Place a jumper wire between the black wire (CH - pin C) in the fuel solenoid connector and a good chassis ground.



1.	Red (8D)
2.	White (8DP)
3.	Black (CH)

Fuel Solenoid
Connector Pin Identification

2. Test the pull-in coil by momentarily placing a jumper between the white wire (8DP - pin B) in the fuel solenoid connector and the 2 terminal at the fuse link. The fuel solenoid should make a definite click when the pull-in coil is energized and should click again when the pull-in coil is de-energized.

   NOTE: The pull-in coil will draw 35 to 45 amps so do not leave the jumper connected to the white wire (8DP - pin B) for more than a few seconds.

   a. If the pull-in coil does energize, go to step 3.

   b. If the pull-in coil does not energize, check the resistance of the pull-in coil by placing an ohmmeter between the white wire (8DP - pin B) and the black wire (CH - pin C) in the fuel solenoid connector. The resistance of the pull-in coil should be 0.2 to 0.3 ohms. If the resistance of the pull-in coil is not in this range, replace the fuel solenoid.

3. Test the hold-in coil.

   a. Energize the hold-in coil by placing a jumper between the red wire (8D - pin A) in the fuel solenoid connector and the 2 terminal at the fuse link.

   b. Momentarily energize the pull-in coil by placing a jumper between the white wire (8DP - pin B) in the fuel solenoid connector and the 2 terminal at the fuse link. The fuel solenoid should make a definite click when the pull-in coil is energized, but should not click when the pull-in coil is de-energized.

   c. De-energize the hold-in coil by removing the jumper from the white wire (8DP - pin B) and the 2 terminal. The fuel solenoid should make a definite click when the hold-in coil is de-energized.

d. If the hold-in coil does not function properly, check the resistance of the hold-in coil by placing an ohmmeter between the red wire (8D - pin A) and the black wire (CH - pin C) in the fuel solenoid connector. The resistance of the hold-in coil should be 24 to 29 ohms. If the resistance of the hold-in coil is not in this range, replace the fuel solenoid.

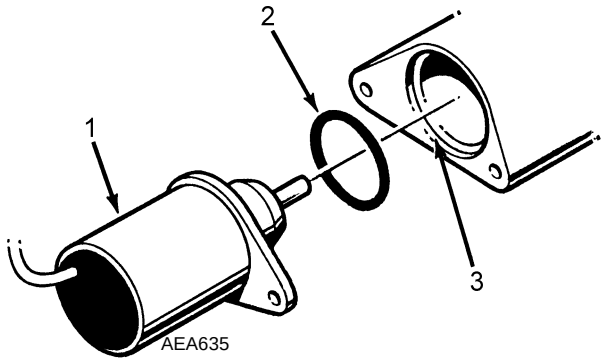
Fuel Solenoid Replacement

This procedure assumes the engine is mounted in the unit. If the engine is not in the unit, use jumper wires to energize the fuel solenoid at the three pin connector. Place a jumper between the black wire (CH - pin C) and ground (-). Place a jumper between the red wire (8D - pin A) and 12 Vdc (+). Momentarily place a jumper between the white wire (8DP - pin B) and 12 Vdc (+).

1. Disconnect the fuel solenoid wire connector and remove the old fuel solenoid.
2. Connect the fuel solenoid wire connector to the new fuel solenoid.
3. If necessary, disable the engine reset switch or the CYCLE-SENTRY system on units so equipped.
4. Turn the unit on to energize the fuel solenoid.

   NOTE: The fuel solenoid must be energized when it is being installed. If not, the plunger and the linkage may not line up correctly and the fuel solenoid will not function properly.

5. Place the O-ring in the groove in the end of the fuel injection pump. Make sure the O-ring is positioned correctly during installation to avoid damage and leaks.
6. Install the new fuel solenoid.
7. Turn the unit off and make sure to enable any disabled systems.



1.	Fuel Solenoid
2.	O-ring
3.	Groove in Fuel Injection Pump

Fuel Solenoid Components

Run In Procedure 8

Run In

The run in of a rebuilt engine will often determine the oil consumption, power output, and other variables during the service life of the engine. It is important to run in a rebuilt engine properly. How an engine will be run in is determined by the type of equipment and the time that is available. Thermo King recommends an engine be run in on a dynamometer if possible.

Dynamometer Run In Procedure

1. Pressurize the lubrication system of the engine with an oil pressure tank if the engine has been stored for any length of time. This prevents a dry start.
2. Start the engine and run it at 1450 rpm with a load that is 6 to 8% of the engine's rated output for a short time.
3. Run the engine at 1450 rpm with a load that is 15% of the engine's rated output for 15 minutes.
4. Run the engine at 2200 rpm with a load that is 22 to 25% of the engine's rated output for 30 minutes.
5. Run the engine at 1450 rpm with a load that is 15% of the engine's rated output for 30 minutes.
6. Run the engine at 2200 rpm with a load that is 30 to 35% of the engine's rated output for 10 minutes.
7. If time permits, additional run in time is desirable. Vary the speed and load in ranges between 1450 to 2200 rpm and 10 to 25% of the engine's rated output.

Run In Procedure Without Dynamometer

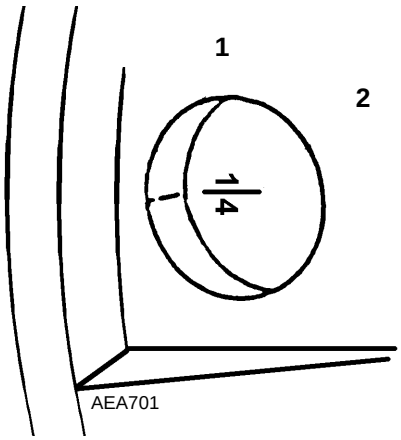
1. Run the engine on a test stand with no load for approximately 15 minutes in both low speed (1450 rpm) and high speed (2200 rpm). Check the engine for abnormal noises, coolant, fuel, or oil leaks.

   CAUTION: DO NOT run a newly rebuilt engine without a load for a long period of time. This can cause the engine's oil consumption to be higher than normal.

2. Mount the engine in a unit and run the unit on high speed heat for 2 hours. Occasionally place the unit in low speed heat to vary the compression pressures and engine temperatures.
3. Mount the unit on a truck and run the unit in high speed heat with truck doors open for 2 to 10 hours.

Valve Clearance Adjustment

1. Remove the rocker arm cover.
2. Remove the round cover (plug) from the timing mark access hole on the front of the bell housing.
3. ***CAUTION: Loosen all of the injection lines at the injection nozzles to prevent the possibility of the engine firing while it is being rotated.***
4. Place the engine at top dead center of the compression stroke for the number one cylinder.
   a. Rotate the engine in the normal direction of rotation (clockwise viewed from the water pump end) until the 1-4 timing mark on the flywheel lines up with the index mark in the timing mark access hole.



1.	Index Mark
2.	Top Dead Center Mark for 1 and 4

Top Dead Center One and Four

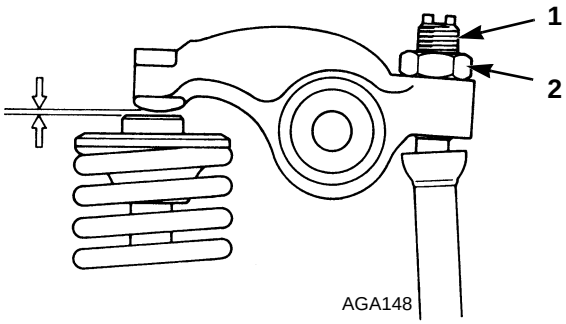
b. Check the rocker arms on the number one cylinder to see if they are loose.

c. If the rocker arms are loose, the engine is at top dead center of the compression stroke for the number one cylinder.

d. If the rocker arms are tight, the engine is at top dead center of the exhaust stroke for the number one cylinder. Rotate the engine 360° to place the engine at top dead center of the compression stroke for the number one cylinder.

5. Use a feeler gauge to check the valve clearance on both valves for the number one cylinder, the intake valve for the number two cylinder, and the exhaust valve for the number three cylinder. The valve clearance for both the intake valves and the exhaust valves should be 0.006 to 0.010 in. (0.15 to 0.25 mm).

   NOTE: Check to make sure that the valve stem cap is in good condition and is positioned squarely on the top of the valve stem. Replace the valve stem cap if it shows significant wear.

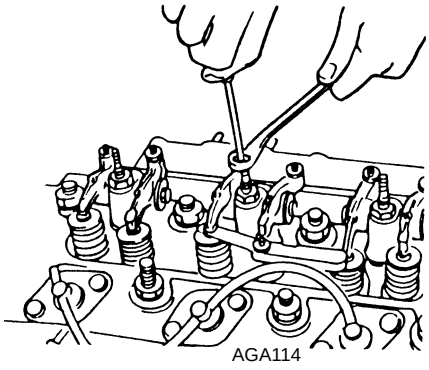


1.	Adjustment Screw
2.	Lock Nut

Valve Clearance

6. Adjust the valves if necessary by loosening the lock nut and turning the adjustment screw until the valve clearance is correct.

7. Hold the adjustment screw in place and tighten the lock nut.



Adjusting the Valve Clearance

8. Recheck the valve clearance.

9. Rotate the engine one full turn (360°) in the normal direction of rotation (clockwise viewed from the water pump end), and align the 1-4 timing mark on the flywheel with the index mark in the timing mark access hole. This is top dead center of the compression stroke for the number four cylinder.

10. Check and adjust the exhaust valve for the number two cylinder, the intake valve for the number three cylinder, and both valves for the number four cylinder.

11. Replace the rocker arm cover, the cover for the timing mark access hole, and tighten the fuel injection lines when finished.

	Front						Rear	
Cylinder No.	**1**		**2**		**3**		**4**	
Valve arrangement	E	I	E	I	E	I	E	I
Piston in No. 1 cylinder is at TDC on compression stroke	◯	◯		◯	◯			
Piston in No. 4 cylinder is at TDC on compression stroke			◎			◎	◎	◎

Valve Adjustments and Cylinder Configurations

Compression Test

Compression tester adapters are not yet available for these engines. Combustion chambers in diesel engines are relatively small, and the compression ratios are relatively high. Therefore, to obtain accurate and consistent compression readings:

- The adapter used to connect a compression tester to an engine must closely approximate the size and shape of the part being replaced.
- A Schrader valve must be installed in the end of the adapter that is facing the combustion chamber.
- The compression tester and connecting hose must have a small internal volume.

An adapter can be fabricated, but it must meet those guidelines. If not, the compression readings will not be accurate.

1. Run the engine until it reaches the normal operating temperature and then stop the engine.

   NOTE: The compression should be tested when the engine is near the normal operating temperature. If it is not possible to run the engine, follow the rest of this procedure. The compression pressures will be approximately 10% lower than those on a warm engine.

2. Remove the wire from the fuel solenoid and loosen the injection lines at the injection nozzles.

   CAUTION: The fuel solenoid must be disconnected and the injection lines must be loosened to prevent the injection of fuel into the cylinders during the test. If a cylinder fires during the test, the resulting pressure will destroy the test equipment. The manufacturer of the test equipment disclaims all responsibility for damage or injury resulting from a cylinder firing during the test.

3. Remove all of the fuel injection nozzles.
4. Disconnect the air cleaner.
5. Connect the compression tester (P/N 204-542) to a cylinder with an acceptable adapter.
6. Turn the engine over with the starter and observe the pressure gauge. Stop cranking the engine when the pressure stabilizes.
7. Note the final reading, release the pressure, and disconnect the tester.
8. Repeat this procedure on each cylinder.
9. Compare the final readings of all the cylinders.

10. An engine in good condition will have a minimum compression pressure of approximately 400 psi (2758 kPa) at cranking speed (250 rpm) using the Thermo King compression tester (Part No. 204-542) and an acceptable adapter.

11. Because the compression pressures will vary depending on what kind of equipment is used, the most important factor is the variation between cylinders. The variation between cylinders should not exceed 10%.