Overhaul Manual

TK270, TK370, and TK376

TK 53163-1-OM (Rev. 0, 03/08)

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TK270, TK370, and TK376 Diesel Engine Specifications

This manual contains information about the TK270, TK370, and TK376 diesel engines, which comply with EPA Tier 2 regulations.

- The TK270 is a two cylinder engine.
- The TK370 and TK376 are three cylinder engines.

See “Engine Model Identification” on page 18 for information about identifying the engine models.

NOTE: The number 1 cylinder is on the flywheel (rear) end of the engine.

Except where noted, the specifications for these engines are the same.	
General	
Type	Four Stroke Cycle, Water Cooled
Number of Cylinders	
TK270	2
TK370 and TK376	3
Cylinder Arrangement	In-line Vertical, Number 1 on Flywheel End
Bore	
TK270 and TK370	2.76 in. (70.0 mm)
TK376	2.99 in. (76.0 mm)
Stroke	
TK270 and TK370	2.91 in. (74.0 mm)
TK376	3.23 in. (82.0 mm)
Displacement	
TK270	34.72 cu. in. (0.569 liters)
TK370	52.11 cu. in. (0.854 liters)
TK376	68.04 cu. in. (1.115 liters)
Power Rating	
TK270	10.0 hp (7.5 kW) @ 2950 rpm
TK370	15.0 hp (11.2 kW) @ 2425 rpm
TK376	19.6 hp (14.6 kW) @ 2425 rpm
Compression Ratio	23.4 to 1
Direction of Rotation	Counterclockwise (Viewed from Flywheel)
Firing Order	
TK270	1-2 (Number 1 on Flywheel End)
TK370 and TK376	1-3-2 (Number 1 on Flywheel End)
Fuel Injection Timing	16 ± 1 Degrees BTDC
Nozzle Injection Pressure	1,784-1,929 psi (12,300-13,300 kPa)
Oil Pressure	40-60 psi (276-414 kPa) High Speed
Engine Coolant Thermostat	180 F (82 C) for HK units only 160 F (71 C) recommended for all except HK units per T&T 470
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)

General (Continued)		
Fuel Type	No. 2 Diesel (normal conditions) must meet latest release of ASTM D975 No. 1 Diesel (acceptable cold weather fuel) must meet latest release of ASTM D975 B5 Biodiesel (acceptable with no modifications to engine or maintenance intervals) must meet latest release of ASTM 6751	
Oil Type	API Classification CI-4 or better (ACEA Rating E3 or better for Europe)	
Valve Train	**Standard Dimensions**	**Wear Limit**
Valve Spring		
Free Length	1.49 in. (37.8 mm)	1.49 in. (37.8 mm)
Inclination (Top to Bottom from Vertical)	0-0.05 in. (0-1.3 mm)	0.05 in. (1.3 mm)
Valve Guide Inside Diameter		
Intake	0.2362-0.2367 in. (6.000-6.012 mm)	0.2394 in. (6.080 mm)
Exhaust	0.2362-0.2367 in. (6.000-6.012 mm)	0.2394 in. (6.080 mm)
Valve Stem Outside Diameter		
Intake	0.2346-0.2352 in. (5.960-5.975 mm)	0.2323 in. (5.900 mm)
Exhaust	0.2341-0.2346 in. (5.945-5.960 mm)	0.2323 in. (5.900 mm)
Valve Stem to Valve Guide Clearance		
Intake	0.0010-0.0020 in. (0.025-0.052 mm)	0.0063 in. (0.160 mm)
Exhaust	0.0016-0.0026 in. (0.040-0.067 mm)	0.0067 in. (0.170 mm)
Valve Margin		
Intake	0.035-0.043 in. (0.90-1.10 mm)	0.020 in. (0.50 mm)
Exhaust	0.039-0.047 in. (1.00-1.20 mm)	0.020 in. (0.50 mm)
Valve Depth (Cylinder Head Deck to Valve)		
Intake	0.016-0.024 in. (0.40-0.60 mm)	0.035 in. (0.90 mm)
Exhaust	0.016-0.024 in. (0.40-0.60 mm)	0.031 in. (0.80 mm)
Valve Guide Projection (Above Valve Spring Seat in Cylinder Head)		
Intake	0.386-0.394 in. (9.80-10.00 mm)	
Exhaust	0.386-0.394 in. (9.80-10.00 mm)	
Valve Stem Seal Projection (Above Valve Spring Seat in Cylinder Head)		
Intake	0.43-0.44 in. (10.9-11.2 mm)	
Exhaust	0.43-0.44 in. (10.9-11.2 mm)	
Valve Angle		
Intake	30 Degrees	
Exhaust	45 Degrees	
Valve Seat Angle		
Intake	30 Degrees	
Exhaust	45 Degrees	

Valve Train (Continued)	Standard Dimensions	Wear Limit
Rocker Arm Bushing Inside Diameter	0.4724-0.4732 in. (12.000-12.020 mm)	0.4752 in. (12.070 mm)
Rocker Arm Shaft Outside Diameter	0.4711-0.4718 in. (11.966-11.984 mm)	0.4701 in. (11.940 mm)
Rocker Arm Bushing to Rocker Arm Shaft Clearance	0.0006-0.0021 in. (0.016-0.054 mm)	0.0051 in. (0.130 mm)
Tappet Outside Diameter	0.8239-0.8252 in. (20.927-20.960 mm)	0.8231 in. (20.907 mm)
Tappet Bore Inside Diameter	0.8268-0.8276 in. (21.000-21.021 mm)	0.8284 in. (21.041 mm)
Tappet To Tappet Bore Clearance	0.0016-0.0037 in. (0.040-0.094 mm)	0.0053 in. (0.134 mm)
Push Rod Bend	0-0.001 in. (0-0.03 mm)	0.001 in. (0.03 mm)
Camshaft	**Standard Dimensions**	**Wear Limit**
Cam Lobe Height	1.3439-1.3490 in. (34.135-34.265 mm)	1.3343 in. (33.890 mm)
Camshaft Journal Outside Diameter		
Timing Gear End	1.5724-1.5732 in. (39.940-39.960 mm)	1.5711 in. (39.905 mm)
Middle	1.5713-1.5722 in. (39.910-39.935 mm)	1.5699 in. (39.875 mm)
Flywheel End	1.5724-1.5732 in. (39.940-39.960 mm)	1.5711 in. (39.905 mm)
Camshaft Bearing Inside Diameter		
Timing Gear End Bearing Insert	1.5748-1.5778 in. (40.000-40.075 mm)	1.5807 in. (40.150 mm)
Middle Bearing(s) (No Insert)	1.5748-1.5758 in. (40.000-40.025 mm)	1.5787 in. (40.100 mm)
Flywheel End Bearing (No Insert)	1.5748-1.5758 in. (40.000-40.025 mm)	1.5787 in. (40.100 mm)
Camshaft Journal to Camshaft Bearing Clearance		
Timing Gear End	0.0016-0.0053 in. (0.040-0.135 mm)	0.0096 in. (0.245 mm)
Middle	0.0026-0.0045 in. (0.065-0.115 mm)	0.0089 in. (0.225mm)
Flywheel End	0.0016-0.0033 in. (0.040-0.085 mm)	0.0077 in. (0.195 mm)
Camshaft Deflection	0-0.001 in. (0-0.02 mm)	0.002 in. (0.05 mm)
Camshaft End Play	0.002-0.006 in. (0.05-0.15 mm)	0.010 in. (0.25 mm)
Piston, Piston Rings, and Wrist Pin		
Piston Outside Diameter Measuring Point (From Bottom of Piston Perpendicular to Wrist Pin)	0.87-0.98 in. (22.0-25.0 mm)	
Piston Outside Diameter		
TK270 and TK370		
Standard	2.7543-2.7555 in. (69.960-69.990 mm)	2.7526 in. (69.915 mm)
1st Oversize 0.010 in. (0.25 mm)	2.7642-2.7654 in. (70.210-70.240 mm)	2.7624 in. (70.165 mm)
TK376		
Standard	2.9904-2.9915 in. (75.955-75.985 mm)	2.9886 in. (75.910 mm)
1st Oversize 0.010 in. (0.25 mm)	3.0002-3.0014 in. (76.205-76.235 mm)	2.9984 in. (76.160 mm)
Piston to Cylinder Wall Clearance		
TK270 and TK370	0.0012-0.0020 in. (0.030-0.050 mm)	
TK376	0.0014-0.0022 in. (0.035-0.055 mm)	
Piston Ring Groove Width		
Top Ring Groove	0.0610-0.0618 in. (1.550-1.570 mm)	
Middle Ring Groove		
TK270 and TK370	0.0606-0.0614 in. (1.540-1.560 mm)	0.0654 in. (1.660 mm)
TK376	0.0622-0.0628 in. (1.580-1.595 mm)	0.0667 in. (1.695 mm)
Bottom Ring Groove	0.1185-0.1193 in. (3.010-3.030 mm)	0.1232 in. (3.130 mm)

Piston, Piston Rings, and Wrist Pin (Continued)	Standard Dimensions	Wear Limit
Piston Ring Width		
Top Ring	0.0579-0.0587 in. (1.470-1.490 mm)	0.0571 in. (1.450 mm)
Middle Ring		
TK270 and TK370	0.0579-0.0587 in. (1.470-1.490 mm)	0.0571 in. (1.450 mm)
TK376	0.0563-0.0571 in. (1.430-1.450 mm)	0.0555 in. (1.410 mm)
Bottom Ring	0.1169-0.1177 in. (2.970-2.990 mm)	0.1161 in. (2.950 mm)
Piston Ring to Ring Groove Clearance		
Top	0.0024-0.0039 in. (0.060-0.100 mm)	
Middle		
TK270 and TK370	0.0020-0.0035 in. (0.050-0.090 mm)	0.0083 in. (0.210 mm)
TK376	0.0051-0.0065 in. (0.130-0.165 mm)	0.0112 in. (0.285 mm)
Bottom	0.0008-0.0024 in. (0.020-0.060 mm)	0.0071 in. (0.180 mm)
Piston Ring End Gap		
Top Ring	0.006-0.012 in. (0.15-0.30 mm)	0.015 in. (0.39 mm)
Middle Ring	0.007-0.013 in. (0.18-0.33 mm)	0.017 in. (0.42 mm)
Bottom Ring		
TK270 and TK370	0.006-0.014 in. (0.15-0.35 mm)	0.017 in. (0.44 mm)
TK376	0.008-0.018 in. (0.20-0.45 mm)	0.021 in. (0.54 mm)
Piston Wrist Pin Bore Inside Diameter	0.8661-0.8665 in. (22.000-22.009 mm)	0.8677 in. (22.039 mm)
Wrist Pin Outside Diameter	0.8659-0.8661 in. (21.995-22.000 mm)	0.8648 in. (21.965 mm)
Wrist Pin to Piston Wrist Pin Bore Clearance	0-0.0006 in. (0-0.014 mm)	0.0029 in. (0.074 mm)
Connecting Rod	**Standard Dimensions**	**Wear Limit**
Wrist Pin Bushing Inside Diameter	0.8671-0.8676 in. (22.025-22.038 mm)	0.8688 in. (22.068 mm)
Wrist Pin Outside Diameter	0.8659-0.8661 in. (21.995-22.000 mm)	0.8648 in. (21.965 mm)
Wrist Pin to Wrist Pin Bushing Clearance	0.0010-0.0017 in. (0.025-0.043 mm)	0.0041 in. (0.103 mm)
Large End Bore (Without Bearing)	1.7717-1.7720 in. (45.000-45.008 mm)	
Rod Bearing Clearance	0.0008-0.0020 in. (0.020-0.050 mm)	0.0043 in. (0.110 mm)
Side Clearance (Crank to Rod)	0.008-0.016 in. (0.20-0.40 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	1.8485-1.8489 in. (46.952-46.962 mm)	1.8465 in. (46.902 mm)
Undersize	1.8387-1.8391 in. (46.702-46.712 mm)	1.8367 in. (46.652 mm)
Main Bearing Inside Diameter		
Standard	1.8497-1.8505 in. (46.982-47.002 mm)	1.8513 in. (47.022 mm)
Undersize	1.8398-1.8406 in. (46.732-46.752 mm)	1.8414 in. (46.772 mm)
Main Bearing Clearance	0.0008-0.0020 in. (0.020-0.050 mm)	0.0047 in. (0.120 mm)
Main Bearing Bore Inside Diameter (Without Bearing)	2.0083-2.0087 in. (51.010-51.020 mm)	
Rod Journal Outside Diameter		
Standard	1.6517-1.6520 in. (41.952-41.962 mm)	1.6891 in. (42.902 mm)
Undersize	1.6418-1.6422 in. (41.702-41.712 mm)	1.6792 in. (42.652 mm)

Crankshaft and Crankshaft Bearings (Continued)	Standard Dimensions	Wear Limit
Rod Bearing Inside Diameter		
Standard	1.6528-1.6536 in. (41.982-42.002 mm)	1.6934 in. (43.012 mm)
Undersize	1.6430-1.6438 in. (41.732-41.752 mm)	1.6835 in. (42.762 mm)
Rod Bearing Clearance	0.0008-0.0020 in. (0.020-0.050 mm)	0.0043 in. (0.110 mm)
End Play	0.0044-0.0098 in. (0.111-0.250 mm)	0.0110 in. (0.280 mm)
Thrust Bearing Thickness		
Standard	0.0760-0.0780 in. (1.930-1.980 mm)	0.0728 in. (1.850 mm)
Oversize	0.0809-0.0829 in. (2.055-2.105 mm)	0.0778 in. (1.975 mm)
Deflection		0.0008 in. (0.020 mm)
Cylinder Block		
Cylinder Inside Diameter		
TK270 and TK370		
Standard	2.7563-2.7567 in. (70.010-70.020 mm)	2.7638 in. (70.200 mm)
1st Oversize	2.7661-2.7665 in. (70.260-70.270 mm)	2.7736 in. (70.450 mm)
TK376		
Standard	2.9925-2.9929 in. (76.010-76.020 mm)	3.0000 in. (76.200 mm)
1st Oversize	3.0024-3.0028 in. (76.260-76.270 mm)	3.0098 in. (76.450 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	0.002-0.005 in. (0.06-0.12 mm)	0.006 in. (0.14 mm)
Crankshaft Gear to Oil Pump Gear	0.002-0.005 in. (0.06-0.12 mm)	0.006 in. (0.14 mm)
Idler Gear to Camshaft Gear	0.002-0.005 in. (0.06-0.12 mm)	0.006 in. (0.14 mm)
Idler Gear to Fuel Injection Pump Gear	0.002-0.005 in. (0.06-0.12 mm)	0.006 in. (0.14 mm)
Idler Gear Bushing Inside Diameter	1.4567-1.4577 in. (37.000-37.025 mm)	1.4596 in. (37.075 mm)
Idler Gear Shaft Outside Diameter	1.4547-1.4557 in. (36.950-36.975 mm)	1.4528 in. (36.900 mm)
Idler Gear Shaft to Idler Gear Bushing Clearance	0.0010-0.0030 in. (0.025-0.075 mm)	0.0069 in. (0.175 mm)
Oil Pump		
Type	Trochoid	
Outer Rotor to Gear Case Cover Clearance	0.005-0.008 in. (0.12-0.21 mm)	0.012 in. (0.30 mm)
Oil Pump Cover to Outer Rotor Clearance	0.001-0.003 in. (0.02-0.07 mm)	0.005 in. (0.12 mm)
Outer Rotor to Inner Rotor Tip Clearance		0.006 in. (0.16 mm)
Inner Rotor Shoulder Outside Diameter	1.810-1.811 in. (45.98-46.00 mm)	
Gear Case Cover Opening Inside Diameter	1.816-1.818 in. (46.13-46.18 mm)	

Oil Pump (Continued		
Inner Rotor Shoulder to Gear Case Cover Opening Clearance	0.005-0.008 in. (0.13-0.20 mm)	0.010 in. (0.25 mm)
Pressure Control Valve Setting	40-60 psi (276-414 kPa)	
Starter	**Standard Dimensions**	**Wear Limit**
No Load Test		
Voltage	11.5 volts	
Current	Maximum of 90 amps @ 11.5 volts	
Speed	Minimum of 3000 rpm @ 11.5 volts	
Loaded Properties		
Voltage	8.7 volts	
Current	Maximum of 325 amps	
Commutator Outside Diameter	1.10 in. (28.0 mm)	1.06 in. (27.0 mm)

Torque Values

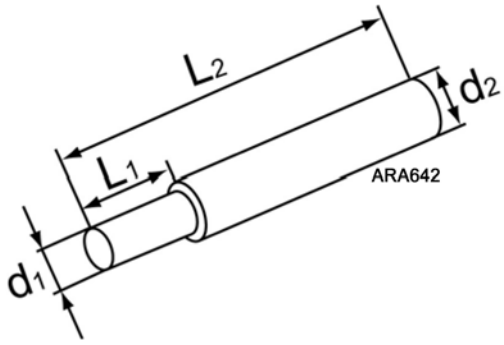
Description	Dia. x Pitch (mm)	N•m	ft-lb	kgm
Connecting Rod Bolt	7x1.0	22.6-27.5	16.7-20.3	2.3-2.8
Crankshaft Pulley Bolt	12x1.25	83.3-93.3	61.4-68.8	8.5-9.5
Cylinder Head Mtg. Bolt	9x1.25	53.9-57.9	39.8-42.7	5.5-5.9
Flywheel Mtg. Bolt	10x1.25	80.4-86.4	59.3-63.7	8.2-8.8
Fuel Injection Line Nut	12x1.25	29.4-34.3	21.7-25.3	3.0-3.5
Fuel Injection Nozzle Assembly	20x1.5	49.0-59.0	36.1-43.5	5.0-6.0
Fuel Injection Nozzle Nut		29.0-49.0	21.4-36.1	3.0-5.0
Fuel Injection Pump Gear Mtg. Nut	12x1.75	59.0-69.0	43.5-50.9	6.0-7.0
Glow Plug	10x1.25	14.7-19.6	10.8-14.5	1.5-2.0
Main Bearing Bolt	10x1.25	75.5-81.5	55.7-60.1	7.7-8.3
Oil Pan Drain Plug for TK270		54.0-63.7	39.8-47.0	5.5-6.5
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	78.4-98.0	57.8-72.3	8.0-10.0
Standard 14 mm Bolt and Nut	14x1.5	127.5-147.1	94.0-108.5	13.0-15.0
Standard 16 mm Bolt and Nut	14x1.5	215.7-235.4	159.0-173.6	22.0-24.0
NOTE: For standard bolts in aluminum parts use 80% of the specified torque.				

Special Tools

The following special tools for all versions of TK270, TK370, and TK376 engines are available from the Thermo King Service Parts Department. Refer to the Tool Catalog (TK 5955).

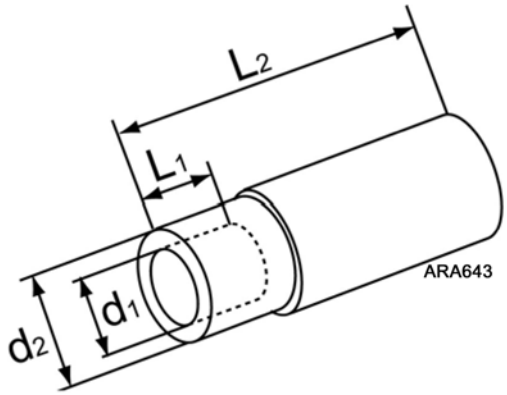
Description	Part Number
Compression Test Adapters (Both are required for use with Compression Tester 204-542.)	204-672 204-675

The following drawings show dimensions for special tools that are to be made a locally. The tools are for all versions of TK270, TK370, and TK376 engines.



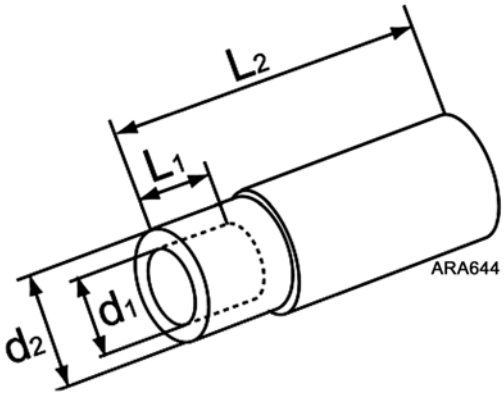
L1.	0.79 in. (20.0 mm)
L2.	2.95 in. (75.0 mm
d1.	0.22 in. (5.5 mm)
d2.	0.37 in. (9.5 mm)

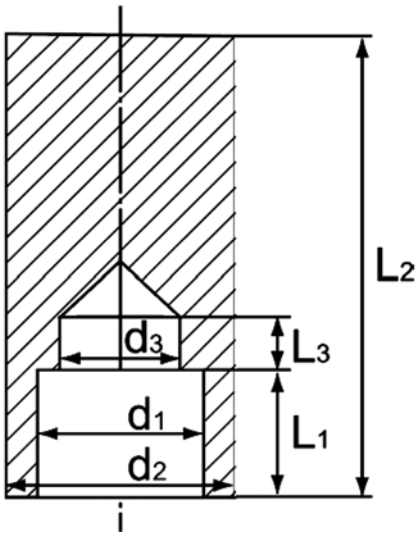
Figure 1: Valve Guide Removal Tool



L1.	0.39 in. (10.0 mm)
L2.	2.36 in. (60.0 mm)
d1.	0.43 in. (11.0 mm)
d2.	0.67 in. (17.0 mm)

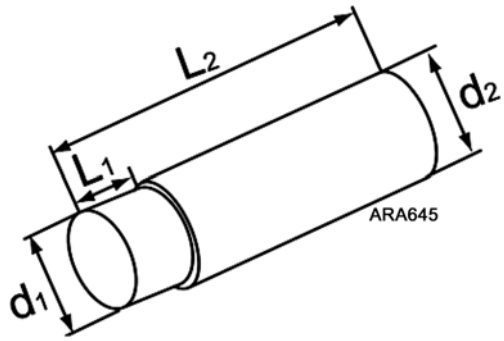
Figure 2: Valve Guide Installation Tool





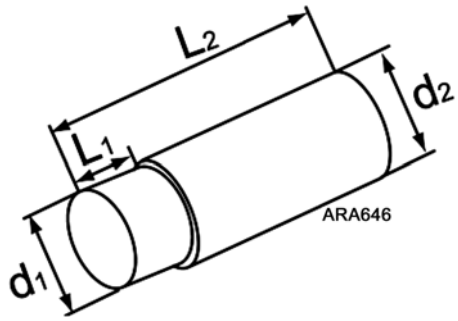
L1.	0.43 in. (11.0 mm)
L2.	2.56 in. (65.0 mm)
L3.	0.16 in. (4.0 mm)
d1.	0.59 in. (15.0 mm)
d2.	0.83 in. (21.0 mm)
d3.	0.47 in. (12.0 mm)

Figure 3: Valve Stem Seal Installation Tool



L1.	0.98 in. (25.0 mm)
L2.	3.35 in. (85.0 mm)
d1.	0.87 in. (22.0 mm)
d2.	0.98 in. (25.0 mm)

Figure 4: Connecting Rod Bushing Removal and Installation Tool

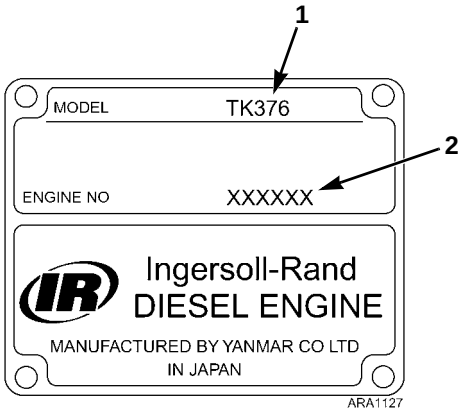


L1.	0.71 in. (18.0 mm)
L2.	2.76 in. (70.0 mm)
d1.	1.77 in. (45.0 mm)
d2.	1.89 in. (48.0 mm)

Figure 5: Camshaft Bearing Removal Tool

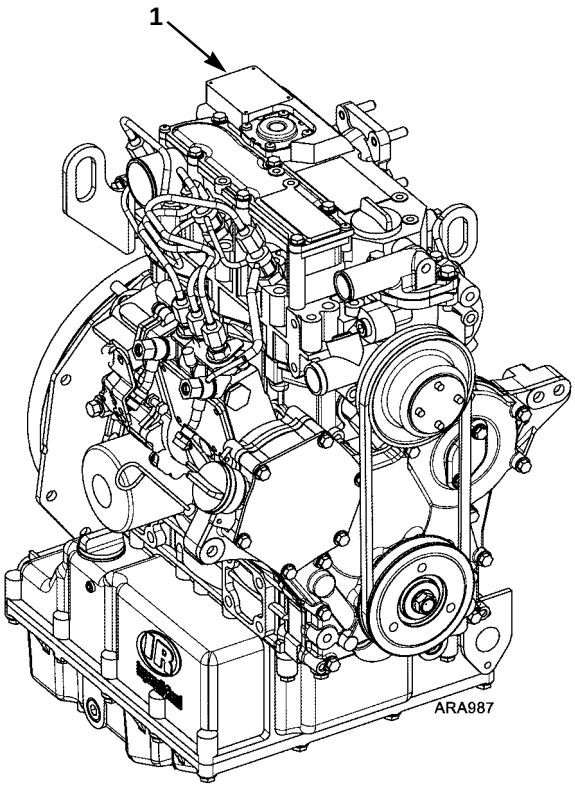
Engine Model Identification

The engine model is listed above the serial number on the serial number nameplate. The serial number nameplate is usually located on the top of the valve cover.



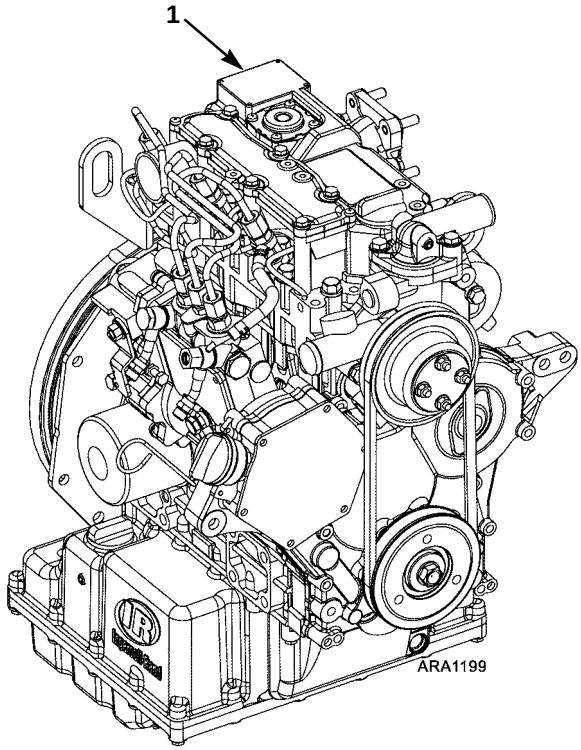
1.	Engine Model
2.	Engine Serial Number

Figure 6: Typical Serial Number Nameplate



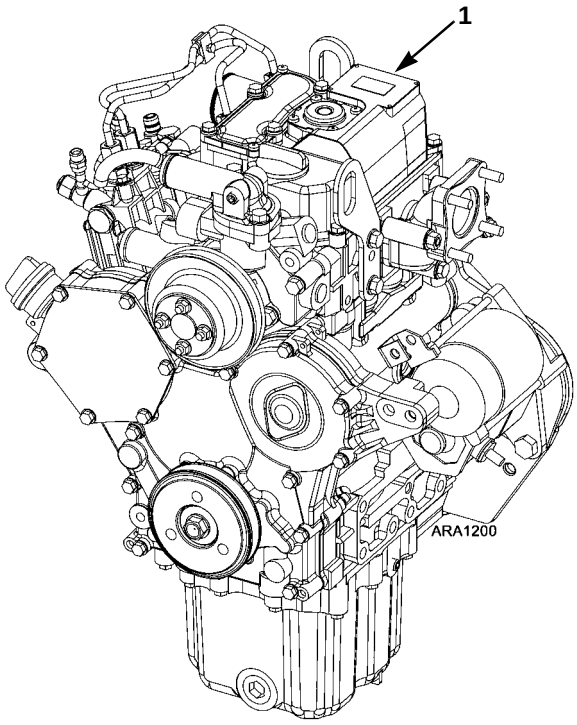
1.	Serial Number Nameplate

Figure 7: Typical Serial Number Nameplate Location on TK376 Engine



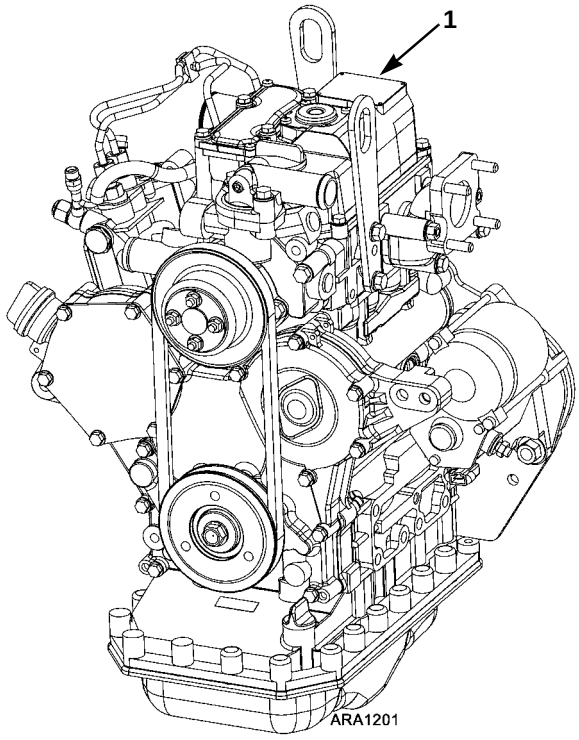
1.	Serial Number Nameplate

Figure 8: Typical Serial Number Nameplate Location on TK370 Engine



1.	Serial Number Nameplate

Figure 9: Typical Serial Number Nameplate Location on TK270 Engine for HK Units



1.	Serial Number Nameplate

Figure 10: Typical Serial Number Nameplate Location on TK270 Engine for TriPac Units

Engine Storage

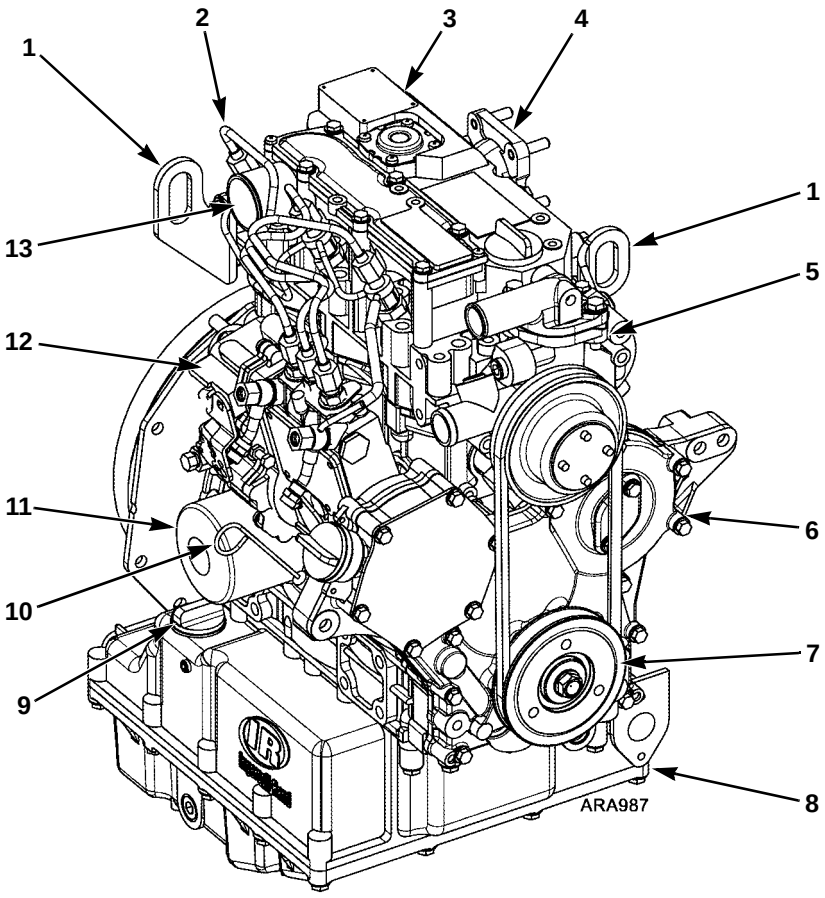
The following periodic checks and maintenance must be performed when engines are stored for prolonged periods (4 months or more). Failure to comply with these recommended maintenance procedures might limit or void any applicable warranty on the engines.

1. Store the engines inside of buildings in places that are well ventilated and free of excessive humidity.
2. Spray a rust preventative (fogging) oil into the cylinders.
3. Circulate a diesel fuel stabilizer (such as Sea-Foam) through the fuel system.
4. Rotate each engine by hand every 4 months.
5. Pre-oil the engine before start-up. Circulate oil throughout the engine lubrication system by cranking the engine for a total of 2 minutes at 20 second intervals (six 20 second intervals) while making sure the engine cannot start.
6. The engine must be warmed up before a full load is applied. Run the engine for at least 3 minutes in low speed before running it in high speed.
7. Keep service records showing that the required maintenance has been performed.

Engine Disassembly

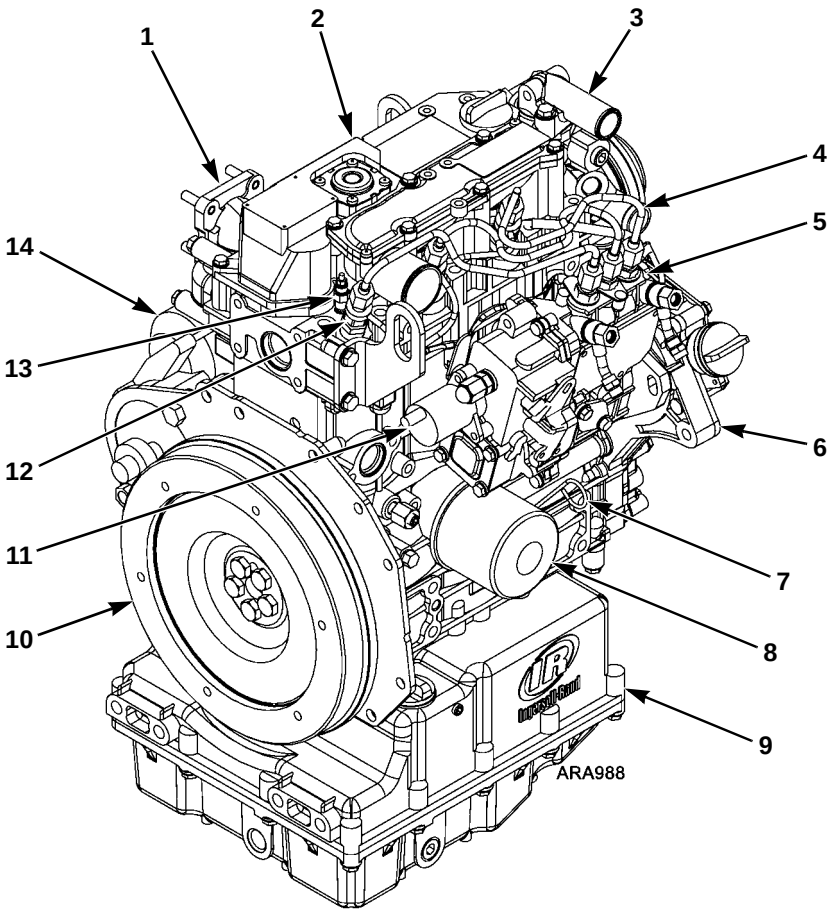
NOTE: Most of the illustrations in this manual show the TK376 engine. The other engines are similar and significant differences are noted.

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



1.	Lift Bracket	8.	Oil Pan
2.	Fuel Injection Line	9.	Oil Level Switch
3.	Cylinder Head Cover	10.	Dipstick
4.	Exhaust Manifold	11.	Oil Filter
5.	Water Pump	12.	Fuel Injection Pump
6.	Gear Case Cover	13.	Air Intake
7.	Crankshaft Pulley		

Figure 11: Front View of TK376 Engine



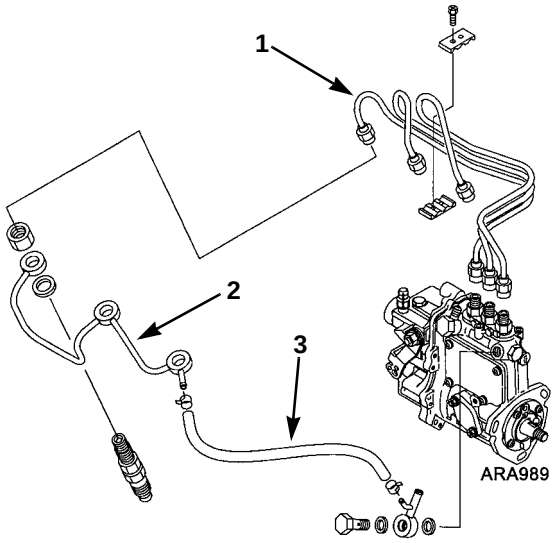
1.	Exhaust Manifold	8.	Oil Filter
2.	Cylinder Head Cover	9.	Oil Pan
3.	Thermostat Housing	10.	Flywheel
4.	Fuel Injection Line	11.	Fuel Solenoid
5.	Fuel Injection Pump	12.	Fuel Injection Nozzle
6.	Gear Case Cover	13.	Glow Plug
7.	Dipstick	14.	Starter

Figure 12: Rear View of TK376 Engine

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 water pump pulley and water pump belt.
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.

   NOTE: Avoid contaminating the fuel system. Make sure to work in a clean area and do not use abrasives.



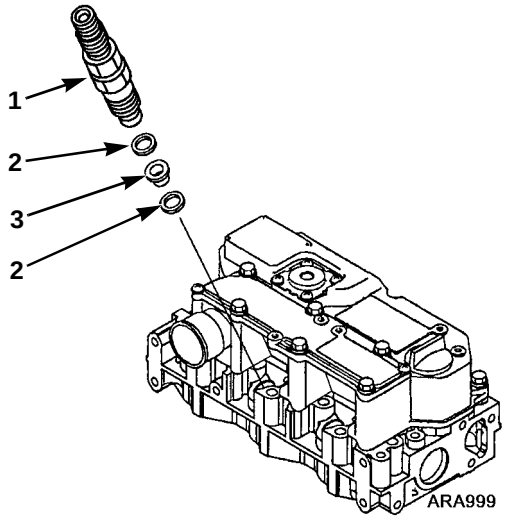
1.	Fuel Injection Lines
2.	Fuel Return Tube
3.	Fuel Return Line

Figure 13: Remove Fuel Injection Lines

4. Remove the fuel return line and the fuel return tubes.

   NOTE: Make sure to use a backup wrench to avoid damaging the fuel lines.

5. Remove the lift brackets from the cylinder head.
6. Remove the fuel injection nozzles.



1.	Fuel Injection Nozzle
2.	Nozzle Gaskets
3.	Nozzle Protector

Figure 14: Remove Fuel Injection Nozzles

7. Remove the cylinder head cover.

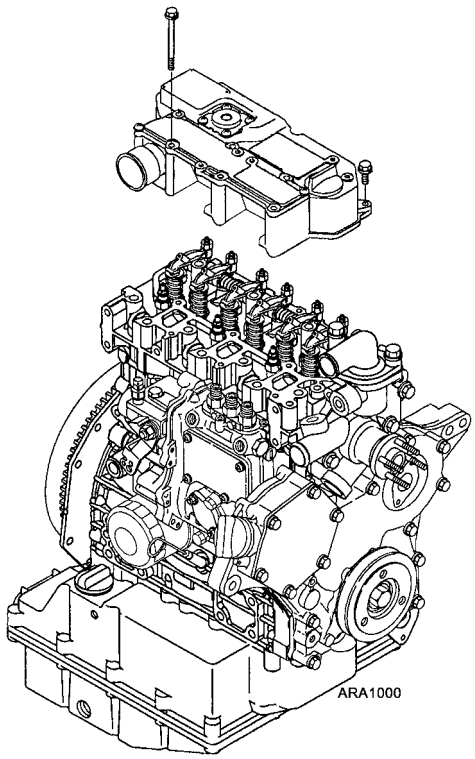


Figure 15: Remove Cylinder Head Cover

8. Remove the glow plugs.

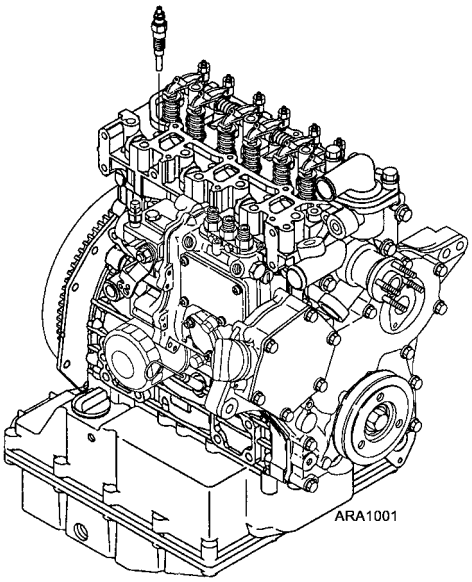


Figure 16: Remove Glow Plugs

9. 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.

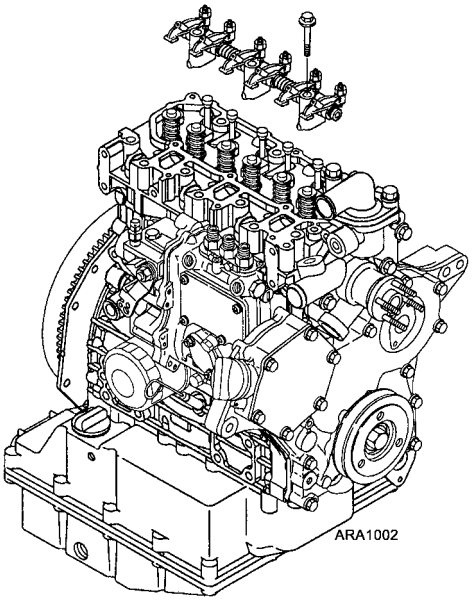


Figure 17: Remove Rocker Arm Assembly

10. Remove the push rods and keep them in order if they will be reused.
11. Remove the valve stem caps and keep them in order.

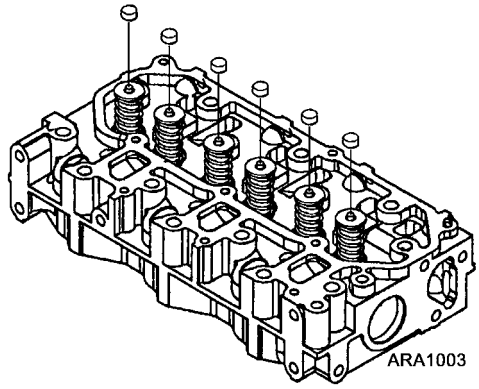


Figure 18: Remove Valve Stem Caps

12. Remove the water pump.

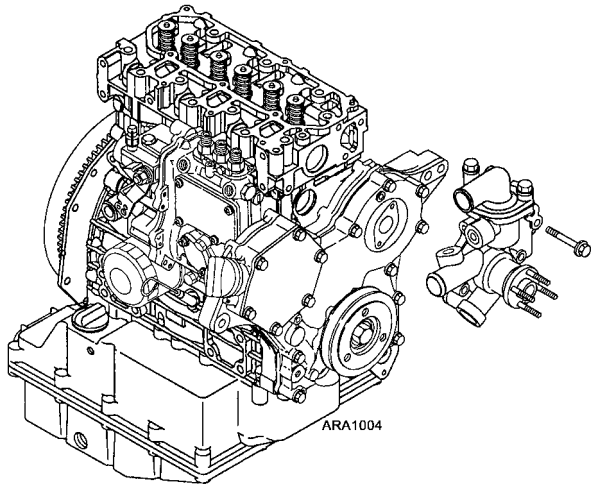


Figure 19: Remove Water Pump

13. 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.
14. Remove the cylinder head from the cylinder block.

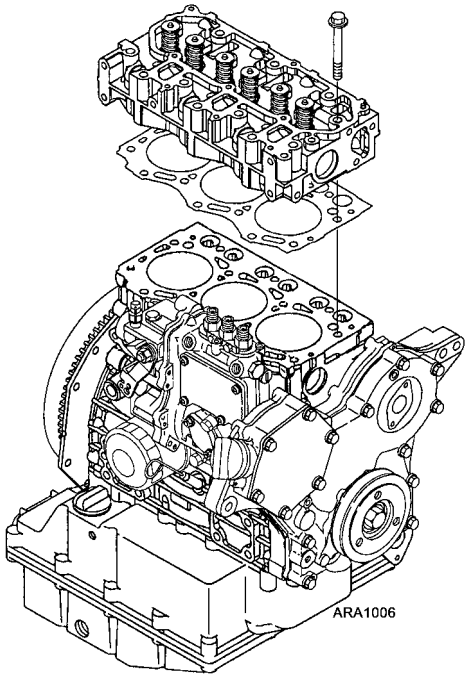


Figure 20: Remove Cylinder Head

15. 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.

    NOTE: The tappets can be removed from either the top or the bottom of the block. If the engine is turned upside down with the cylinder head off, the tappets may fall out.

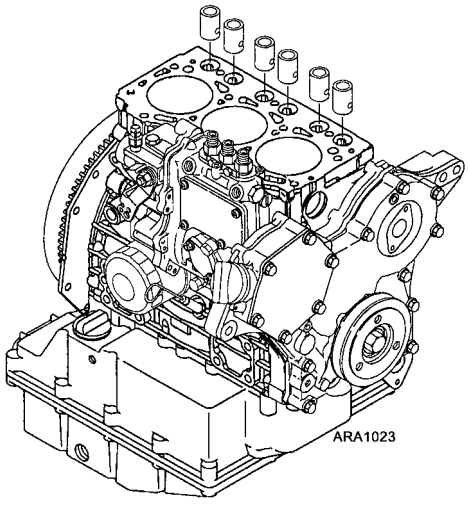


Figure 21: Remove Tappets

16. Remove the dipstick.
17. Remove the oil filter.

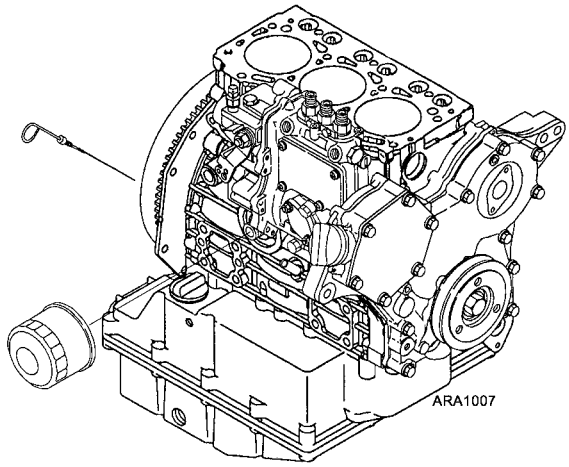


Figure 22: Remove Dipstick and Oil Filter

18. Remove the front crankshaft bolt.
19. The end of the crankshaft is tapered. Remove the crankshaft pulley by using a suitable puller.

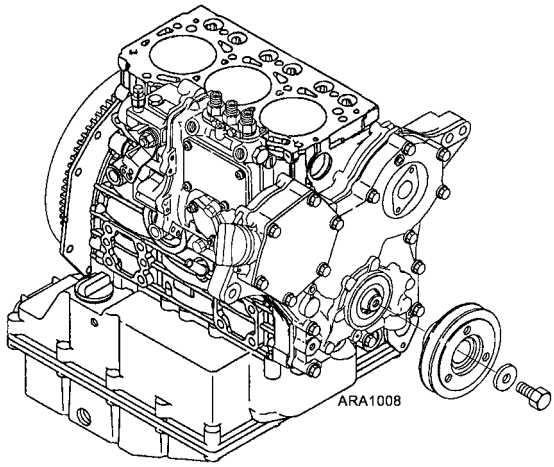


Figure 23: Remove Crankshaft Pulley

20. Remove the injection pump timing cover.
21. Remove the gear case cover.

NOTE: The oil pump is located in the gear case cover. See "Oil Pump" on page 50.

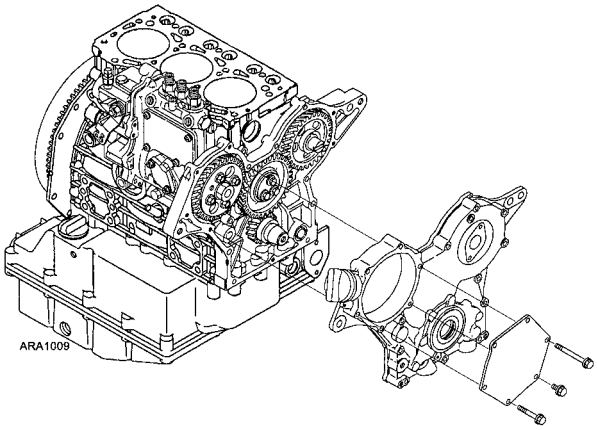


Figure 24: Remove Injection Pump Timing Cover and Gear Case Cover

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.

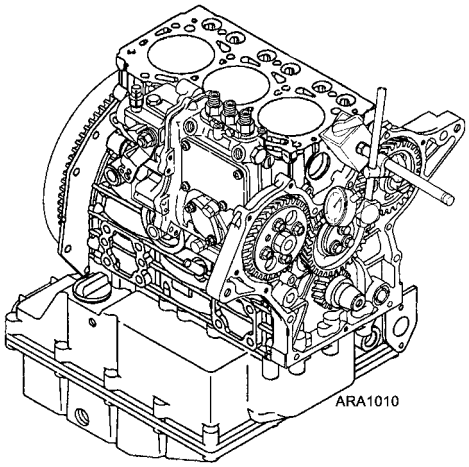


Figure 25: Check Timing Gear Lash

23. Remove the oil line that goes from the cylinder block to the fuel injection pump.

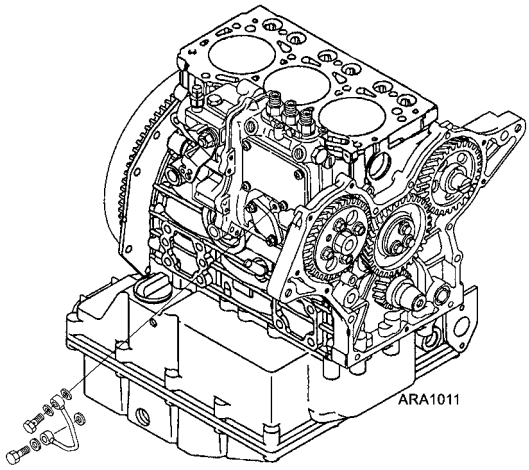


Figure 26: Remove Oil Line

24. Note the timing marks on the timing gears. The timing marks must be aligned when the engine is assembled.
25. Remove the fuel injection pump gear nut and lock washer.

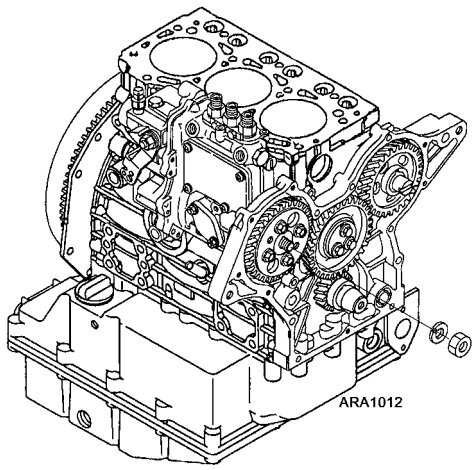


Figure 27: Remove Fuel Injection Pump Gear Nut and Lock Washer

26. 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.

NOTE: See "Injection Pump Removal and Installation" on page 80 for information about removing the injection pump without removing the crankshaft pulley and gear case cover.

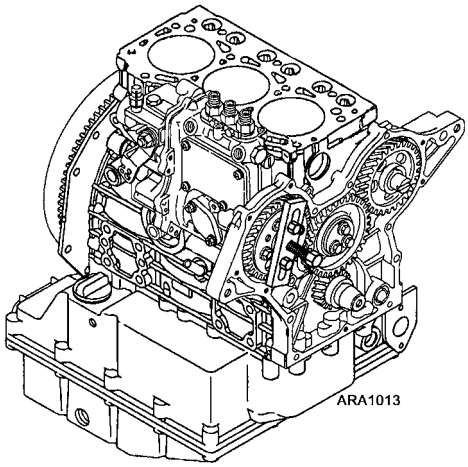
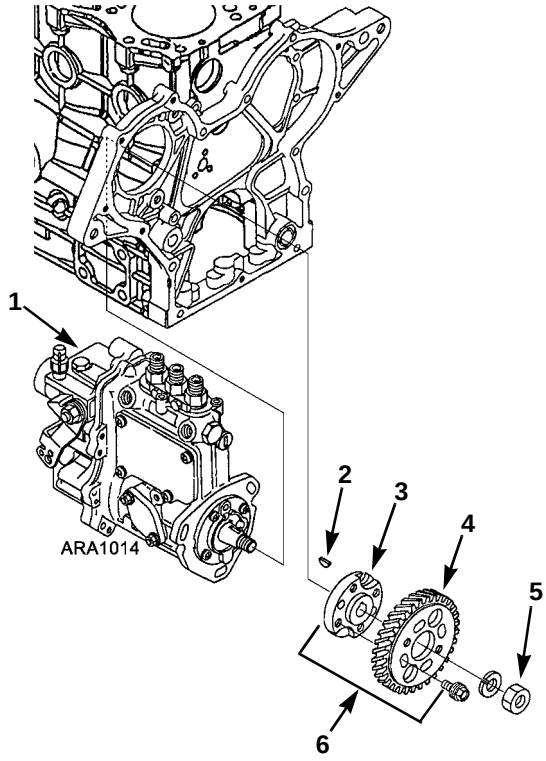


Figure 28: Use Puller to Remove Fuel Injection Pump Gear

NOTE: These engines use a two-piece fuel injection pump gear assembly (see Figure 29). Do not loosen or remove the four bolts that fasten the injection pump gear to the flange because that changes the timing. See "Attaching Injection Pump Gear to Flange" on page 82 if the injection pump gear is detached from the flange.

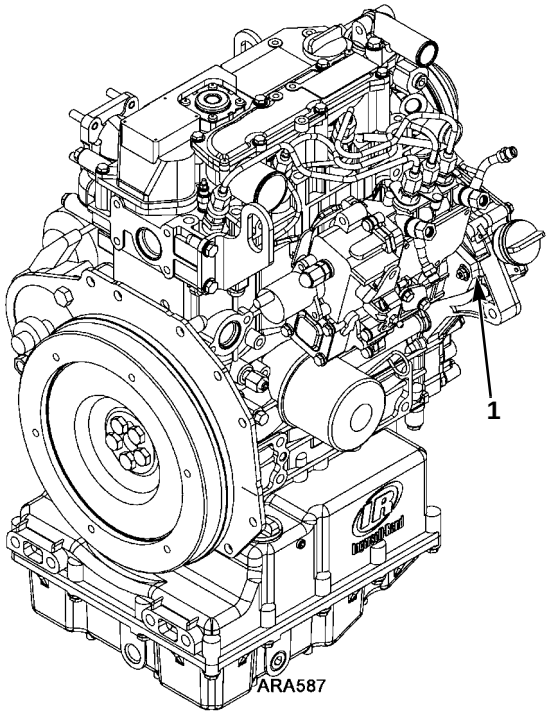
NOTE: It is an EPA compliancy violation to alter the injection pump timing.



1.	Fuel Injection Pump
2.	Key
3.	Flange
4.	Injection Pump Gear
5.	Nut (Injection Pump Gear)
6.	Do Not Remove Gear From Flange

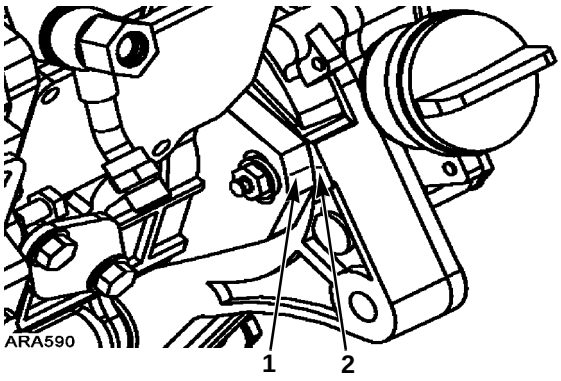
Figure 29: Two-Piece Fuel Injection Pump Gear

27. Note the alignment of the index marks on the injection pump and the gear case. The index mark on the injection pump is usually aligned with the single index mark on the gear case. If not, mark it so the injection pump can be returned to the same position when it is reinstalled.



1.	Index Marks

Figure 30: Index Mark Location



1.	Index Mark on Injection Pump
2.	Center Index Mark on Gear Case

Figure 31: Index Mark Alignment

28. Remove the fuel injection pump from the gear case.

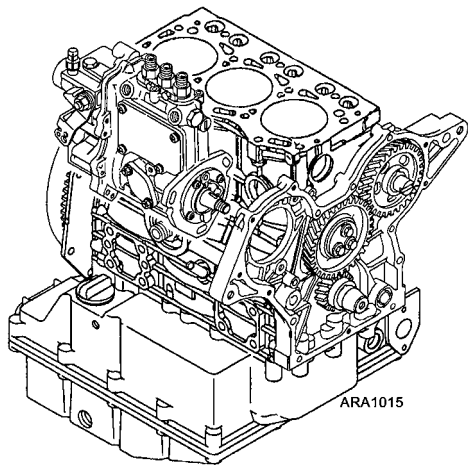


Figure 32: Remove Fuel Injection Pump

29. Remove the three bolts from the idler gear shaft.

30. Remove the idler gear and the idler gear shaft from the cylinder block.

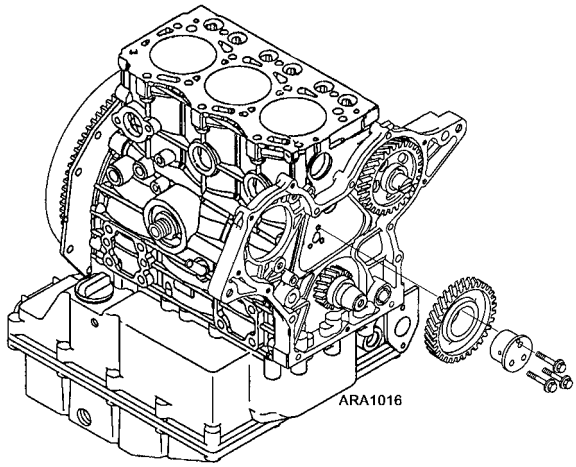


Figure 33: Remove Idler Gear and Idler Gear Shaft

31. Remove the starter.
32. Remove the flywheel.

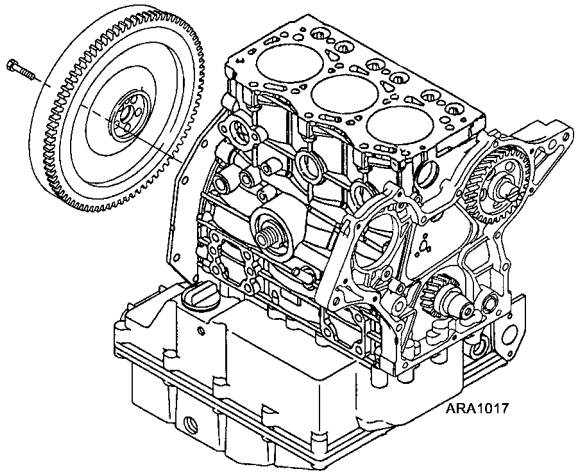


Figure 34: Remove Flywheel

33. Remove the starter mounting flange.

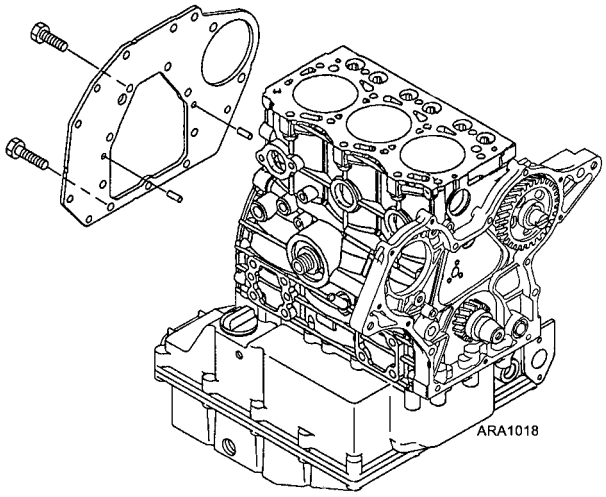


Figure 35: Remove Starter Mounting Flange

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

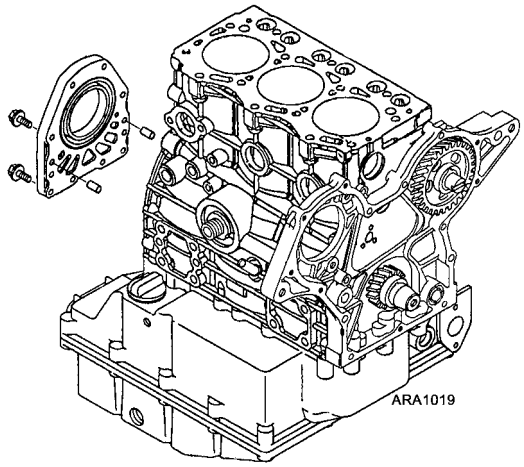


Figure 36: Remove Rear Seal Housing

35. 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.

NOTE: The TK270 engine in HK-400 units has a one-piece oil pan.

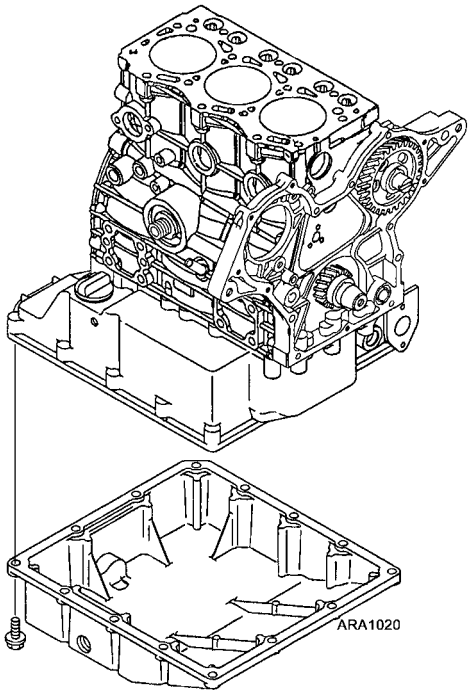


Figure 37: Remove Lower Part of Oil Pan

36. Remove the oil pump intake pipe.

    NOTE: On some two cylinder engines you must remove the upper part of the oil pan before removing the oil pump intake pipe.

37. Remove the upper part of the oil pan.

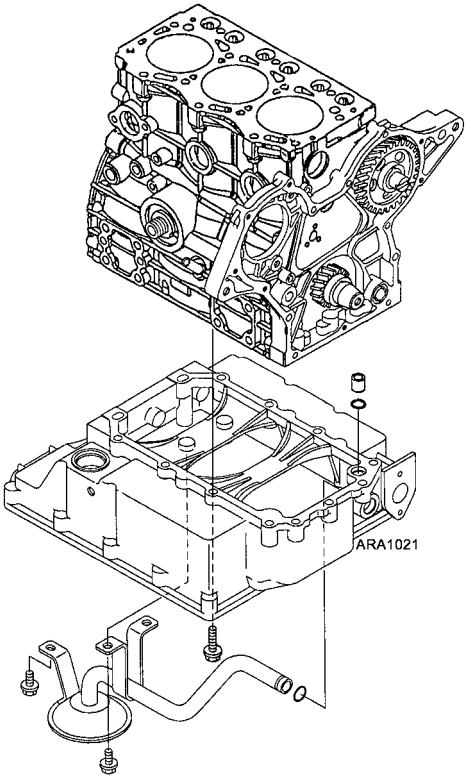


Figure 38: Remove Oil Pump Intake Pipe and Upper Part of Oil Pan

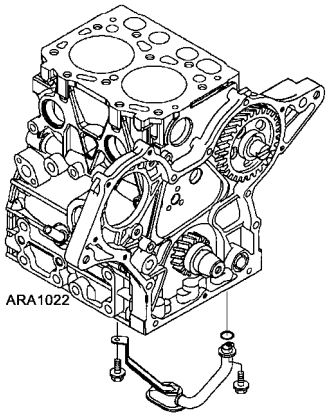


Figure 39: Remove Oil Pump Intake Pipe (Two Cylinder Engine)

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

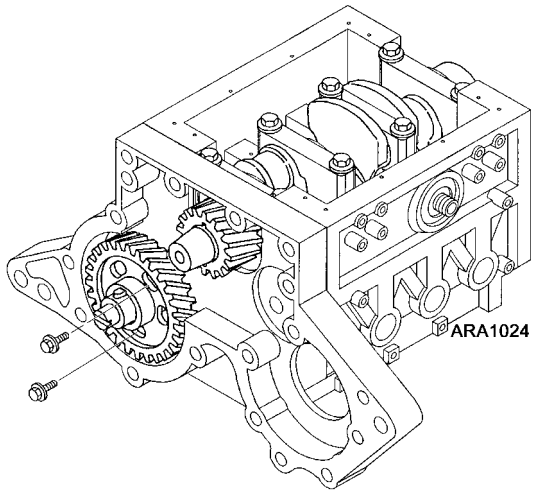


Figure 40: Remove Camshaft Mounting Bolts

39. 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.

    NOTE: Removal of the camshaft gear from the camshaft can damage the gear and camshaft. Therefore, it is not recommended.

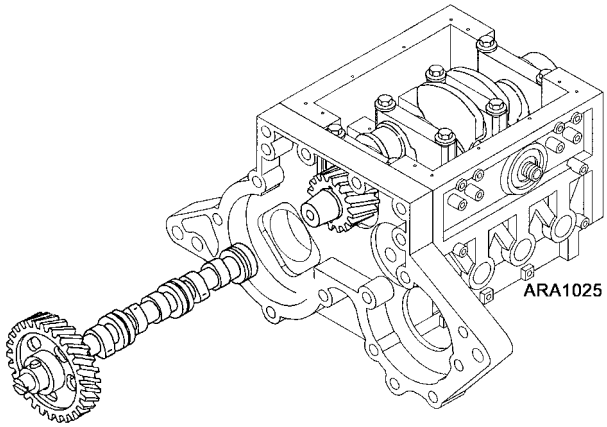


Figure 41: Remove Camshaft

40. Remove the gear case. Also remove the two O-rings from the oil passages between the gear case and the cylinder block.

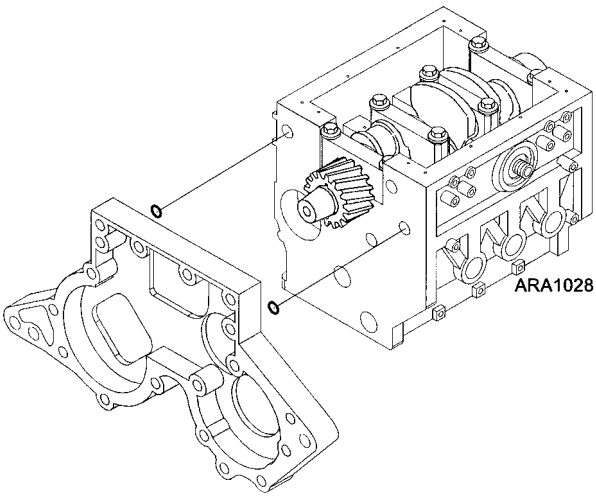


Figure 42: Remove Gear Case

41. Remove the carbon buildup/ring ridge from the top of each cylinder before removing the pistons, if necessary.
42. Mark the connecting rod caps, connecting rods, pistons, and main bearing caps so they can be placed in the same position when assembled.
43. Remove the connecting rod caps.
44. Carefully remove the piston and connecting rod assemblies through the top of the cylinders to avoid scratching or marring the cylinder walls.

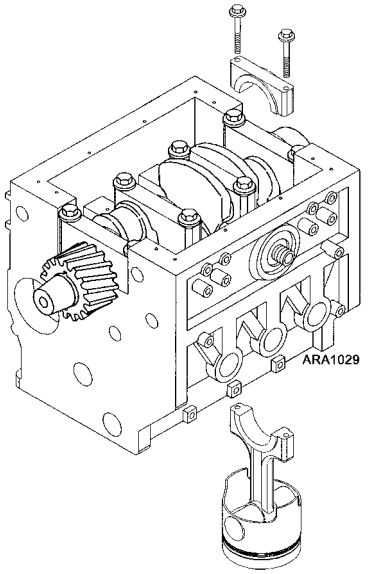


Figure 43: Remove Piston and Rod Assemblies

45. 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.

46. 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.

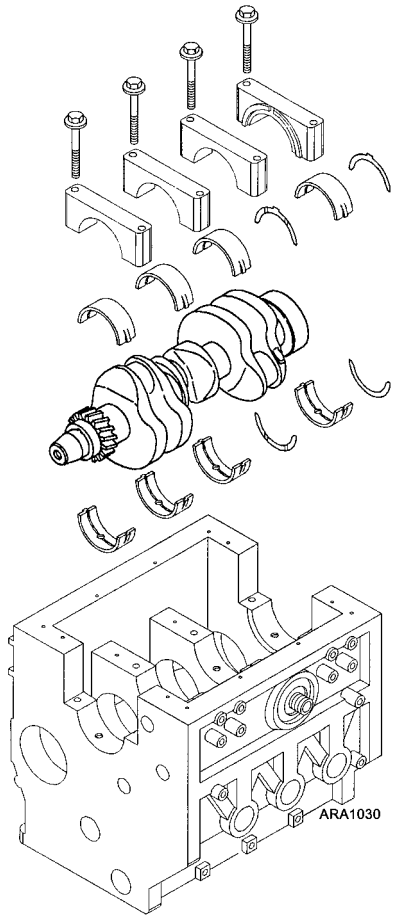


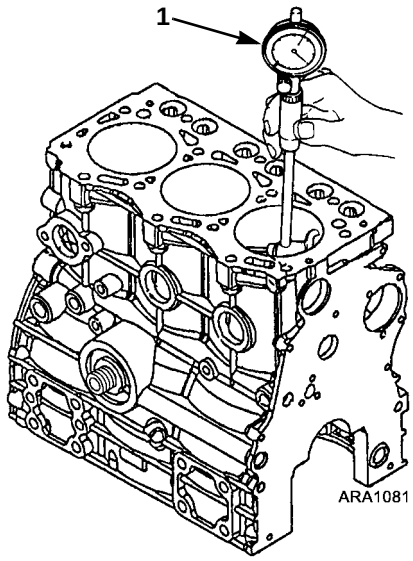
Figure 44: Remove Crankshaft

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.

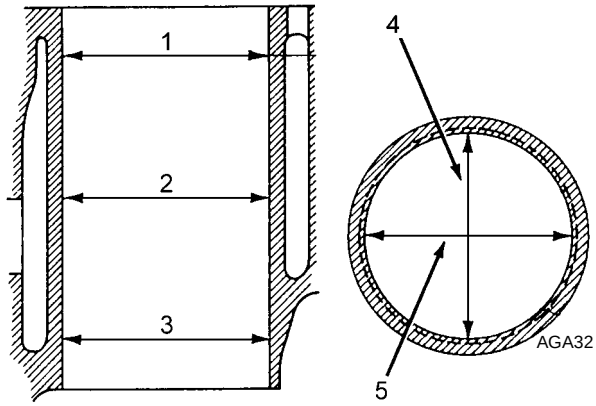
Cylinder Block

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 (0.25 mm) oversize.



1.	Dial Bore Gauge

Figure 45: Measuring Cylinder Diameter



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

Figure 46: Cylinder Measuring Positions

4. Measure each piston. Bore and hone each cylinder to obtain the correct piston to cylinder wall clearance (see Specifications).

   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 1.5807 in. (40.150 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.

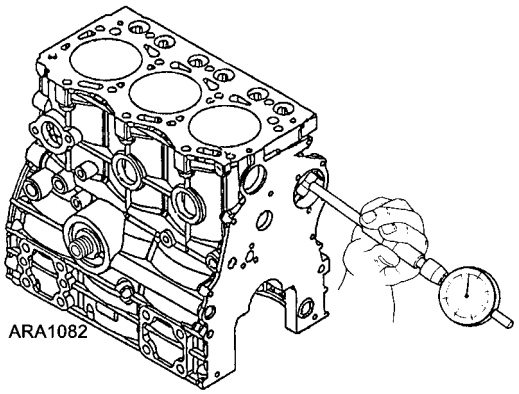
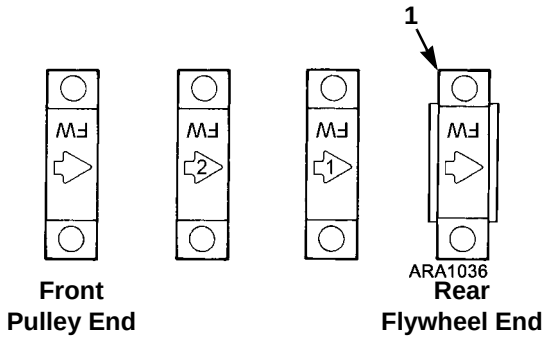


Figure 47: Measuring Front Camshaft Bearing Insert

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 1.5787 in. (40.100 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 55.7 to 60.1 ft-lb (75.5 to 81.5 N•m).



1.	Rear Main Bearing Cap

Figure 48: Main Bearing Cap Marks

8. Measure the main bearing bores both vertically and horizontally. The standard dimension is 2.0083 to 2.0087 in. (51.010 to 51.020 mm). If the main bearing bores are more than 0.001 in. (0.25 mm) out of round, the block must be align bored.

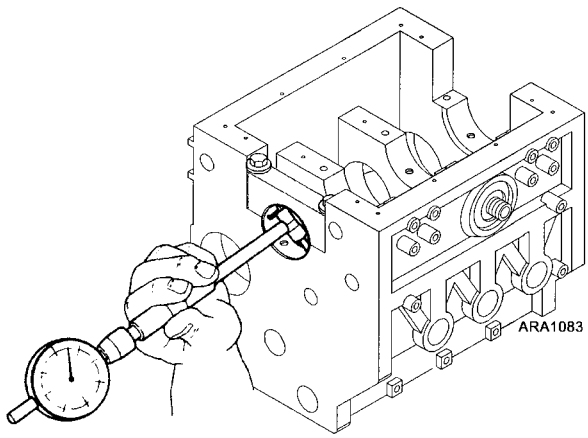


Figure 49: Measuring Main Bearing Bore

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.

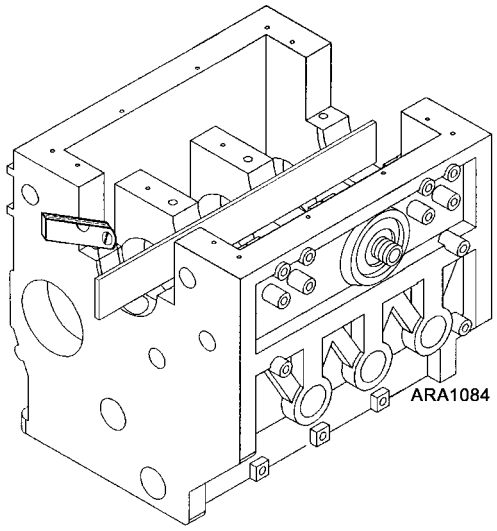


Figure 50: Checking Main Bearing Bore Alignment

10. Measure each tappet bore in the block. If any of the tappet bores are larger than 0.8284 in. (21.041 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 1.8465 in. (46.902 mm), or tapered or out of round more than 0.0080 in. (0.020 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 1.8367 in. (46.652 mm).

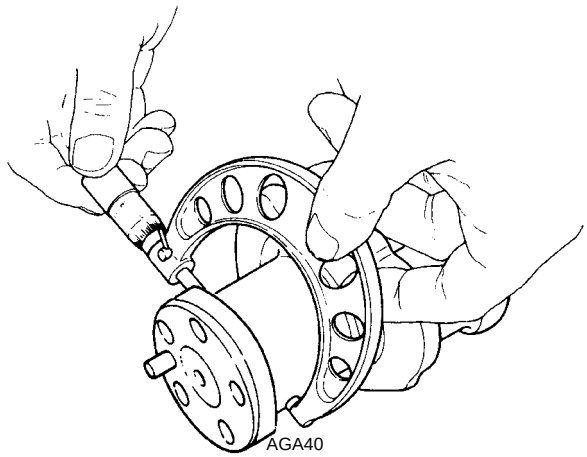


Figure 51: Measuring Main Journal

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 0.0008 to 0.0020 in. (0.020 to 0.050 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 1.6891 in. (42.902 mm), or tapered or out of round more than 0.0080 in. (0.020 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 1.6792 in. (42.652 mm).

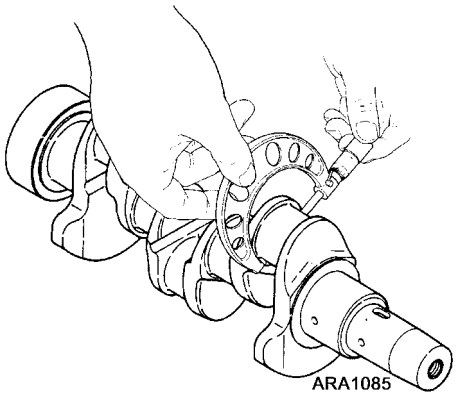
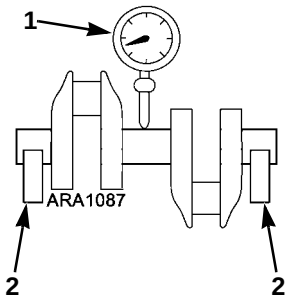


Figure 52: Measuring Rod Journal

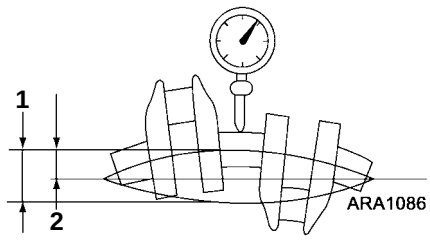
NOTE: The most accurate method of determining the outside diameter of the undersized rod journals is to install the rod caps with the undersized bearing inserts in place. Properly torque the rod caps to the rods and measure the inside diameter of the rod bearings. Subtracting the suggested oil clearance of 0.0008 to 0.0020 in. (0.020 to 0.050 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

Figure 53: Measuring Crankshaft Deflection (Two Cylinder Shown)



1.	Difference in Readings
2.	Deflection

Figure 54: Crankshaft Deflection (Two Cylinder Shown)

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.

   NOTE: Removal of the crankshaft timing gear from the crankshaft can damage the gear. Therefore, it is not recommended except when necessary.

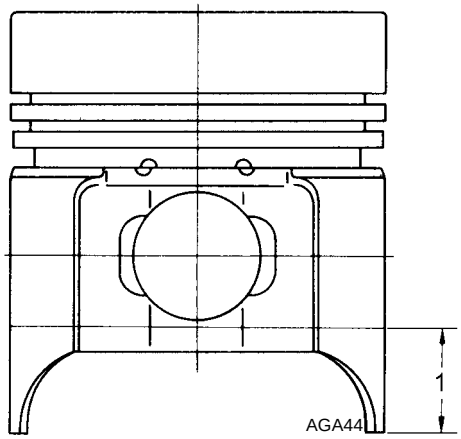
6. Check the area on the end of the crankshaft from which the rear seal was removed. Any scratches, nicks, or damage to this area of the crankshaft must be cleaned up.

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 0.88 to 0.98 in. (22.0 to 25.0 mm) above the bottom of the piston skirt. If the piston is smaller than the wear limit (see Specifications), replace the piston.



1.	0.88 to 0.98 in. (22.0 to 25.0 mm)

Figure 55: Piston Measuring Point

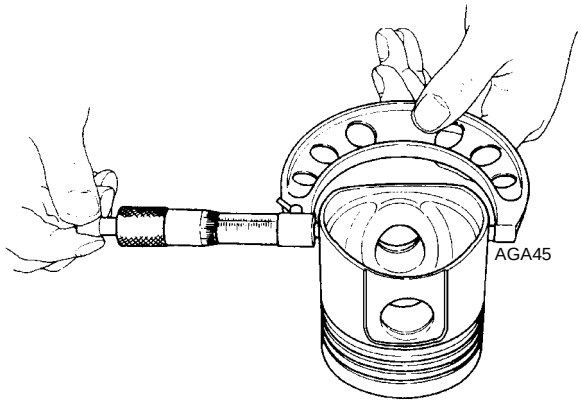


Figure 56: Measuring Piston

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 for the middle and the bottom rings. If the clearance between a new ring and its respective ring groove is greater than the wear limit (see Specifications), the piston must be replaced.

   NOTE: The top ring is a keystone ring so the clearance cannot be measured.

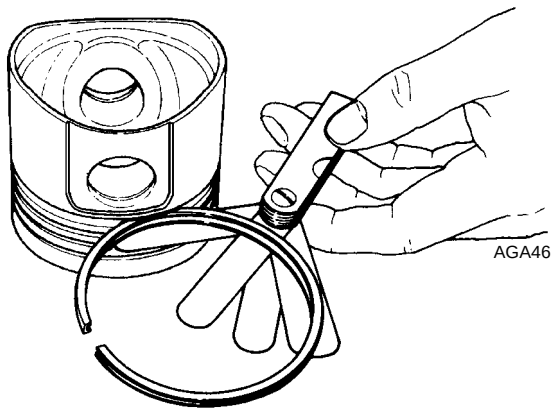


Figure 57: Checking Ring Clearance

7. Measure the inside diameter of the wrist pin bore. If the inside diameter of the wrist pin bore is larger than 0.8677 in. (22.039 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 0.8648 in. (21.965 mm), replace the wrist pin.

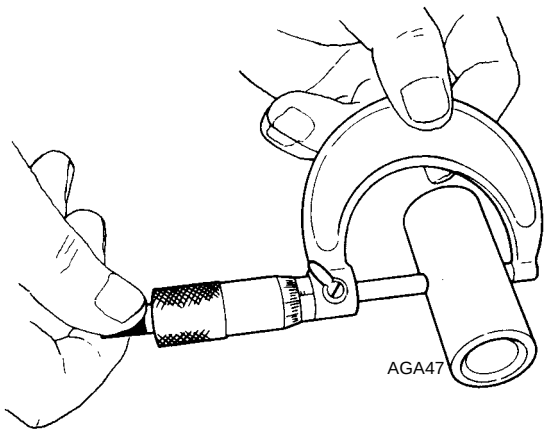


Figure 58: Measuring Wrist Pin

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 16.7 to 20.3 ft-lb (22.6 to 27.5 N•m).

3. Measure the inside diameter of the connecting rod bearings. If any of the connecting rod bearings are larger than the wear limit (see Specifications), 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 16.7 to 20.3 ft-lb (22.6 to 27.5 N•m).

5. Measure each connecting rod bearing bore both parallel and perpendicular to the rod. The standard dimension is 1.7717 to 1.7720 in. (45.000 to 45.008 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.

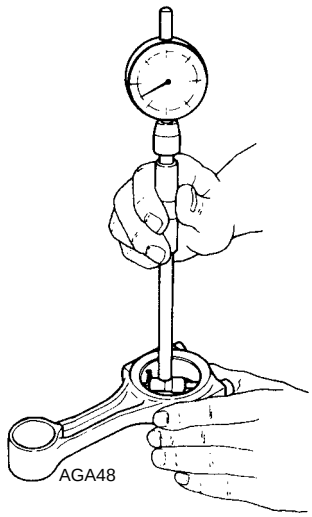
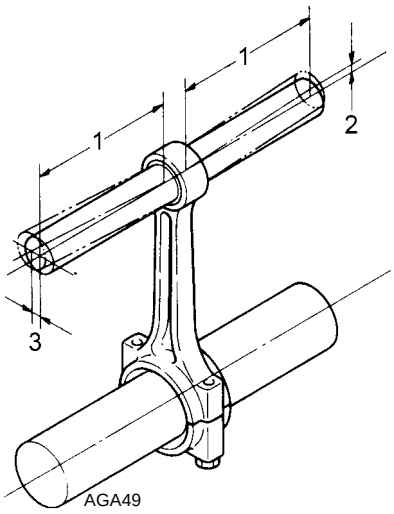


Figure 59: Measuring Rod Bearing or Bearing Bore

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

Figure 60: Measuring Connecting Rod Twist and Parallelism

7. Measure the inside diameter of the wrist pin bushings. If the wrist pin bushings are larger than 0.8688 in. (22.068 mm), or show significant damage, replace the wrist pin bushings.

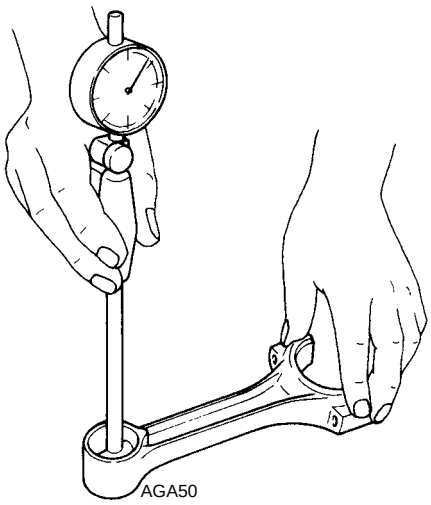


Figure 61: Measuring Wrist Pin Bushing

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 crankshaft gear uses a press fit. Use a hydraulic press to remove and install the crankshaft gear. Removing the crankshaft gear can damage it. Therefore, it is not recommended except when necessary.

   The camshaft gear uses a very secure press fit. It cannot be removed without damaging the camshaft and the camshaft gear. Therefore, the camshaft gear and camshaft must be replaced as an assembly.

2. Measure the inside diameter of the idler gear bushing. If the idler gear bushing is larger than 1.4596 in. (37.075 mm), or is significantly damaged, replace the idler gear.

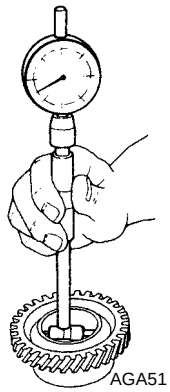


Figure 62: Measuring Idler Gear Bushing

3. Measure the outside diameter of the idler gear shaft. If the idler gear shaft is smaller than 1.4528 in. (36.900 mm), or is significantly damaged, replace the idler gear shaft.

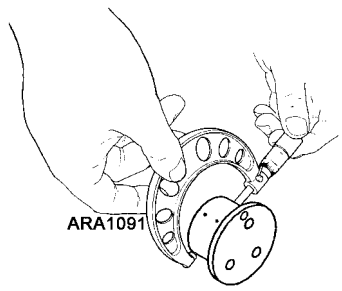


Figure 63: Measuring Idler Gear Shaft

Camshaft

NOTE: The camshaft gear cannot be removed without damaging the camshaft and the camshaft gear. Therefore, the camshaft gear and camshaft must be replaced as an assembly.

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 the wear limit (see Specifications) or significantly damaged, replace the camshaft assembly.

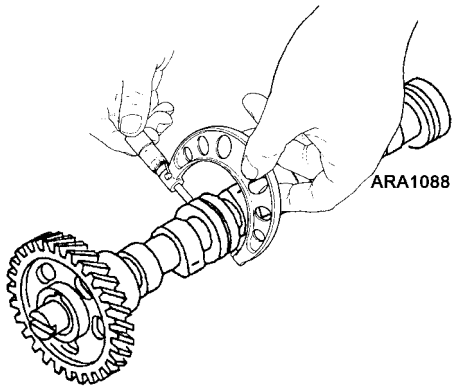


Figure 64: Measuring Camshaft Journals

3. Measure the cam lobes. If any of the cam lobes are smaller than 1.3343 in. (33.890 mm), or significantly damaged, replace the camshaft assembly.

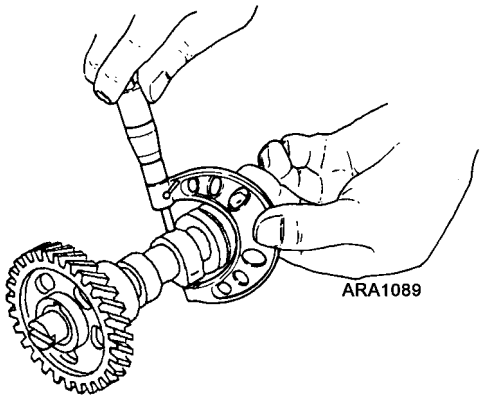


Figure 65: Measuring Cam Lobes

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 assembly must be replaced.

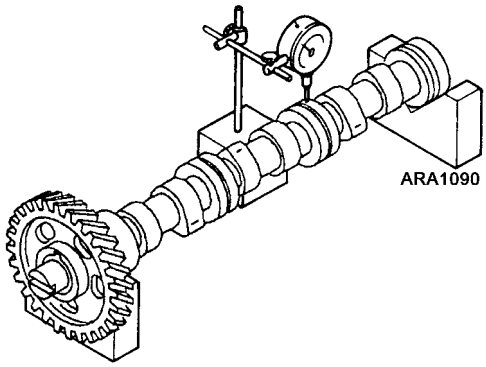


Figure 66: Measuring Camshaft Deflection

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 0.010 in. (0.25 mm), replace the camshaft assembly.

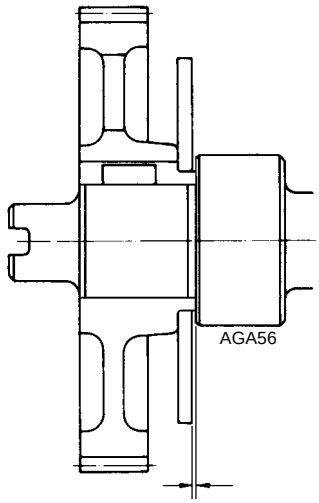


Figure 67: Checking Thrust Plate Clearance

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).

   NOTE: When resurfacing the cylinder head, remove only enough material to make it flat. Do not remove more than 0.008 in. (0.20 mm).

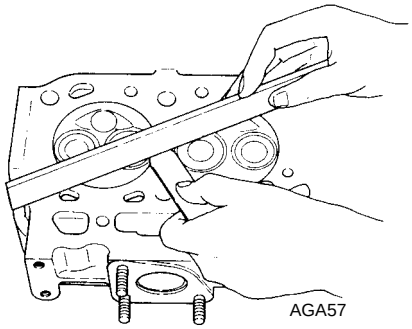
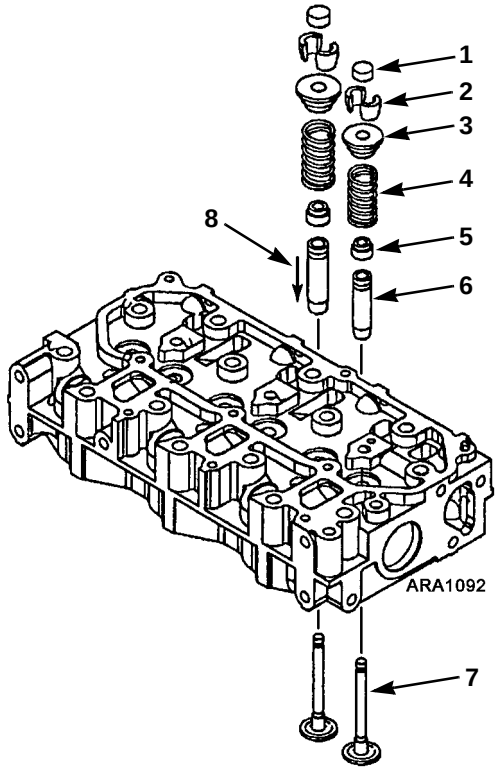


Figure 68: Checking Cylinder Head Distortion

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.



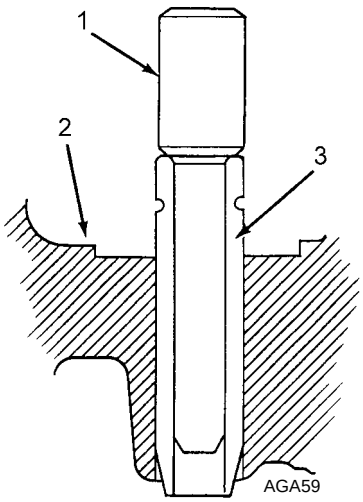
1.	Valve Stem Cap
2.	Valve Keeper
3.	Valve Spring Retainer
4.	Valve Spring
5.	Valve Stem Seal
6.	Valve Guide
7.	Valve
8.	Drive Valve Guides in this Direction

Figure 69: 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 0.2394 in. (6.080 mm), replace the valve guides.

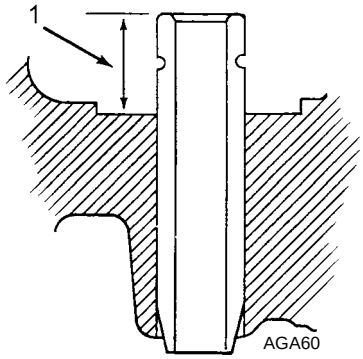
   NOTE: If the engine has been in use for some time and has accumulated many hours of running time, it is advisable to replace the valve guides because they usually show significant wear after numerous hours of service. Because the valve seat grinding procedure is centered by a pilot placed in the valve guide, new straight valve guides allow the valve seats to be ground accurately.
3. Remove the valve guides by using a valve guide removal tool (see Figure 1 on page 16) and a press or a hammer to drive the valve guides out through the combustion chamber.



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

Figure 70: Removing or Installing Valve Guides

4. Install the new valve guides using a valve guide installation tool (see Figure 2 on page 16) 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 0.386 to 0.394 in. (9.80 to 10.00 mm).



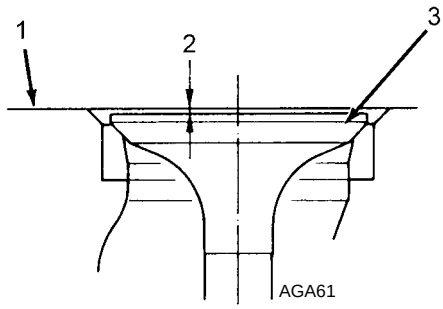
1.	Valve Guide Projection

Figure 71: Valve Guide Projection

5. After installation, ream the new valve guides. Use a 0.2362 in. (6.000 mm) ream for both the intake and 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

Figure 72: 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 the intake valves is 0.035 in. (0.90 mm). The wear limit for the exhaust valves is 0.031 in. (0.80 mm).

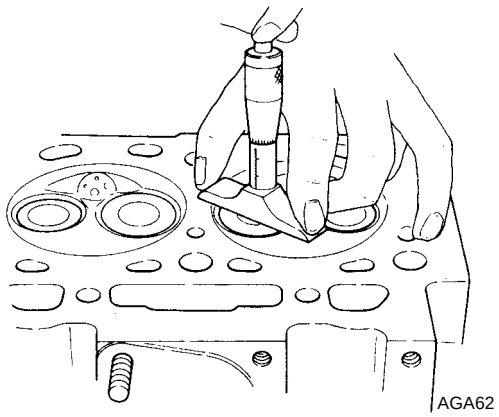


Figure 73: Measuring Valve Depth

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 0.2323 in. (5.900 mm), replace the valve.

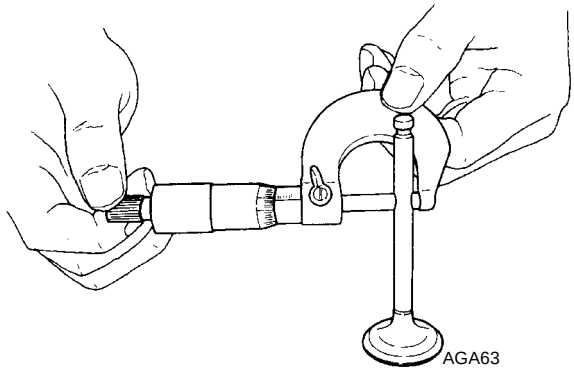


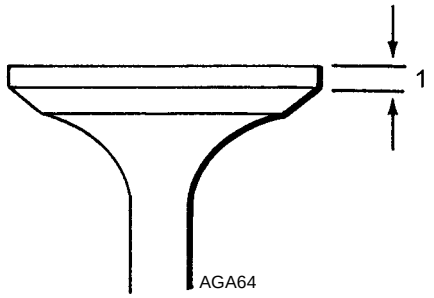
Figure 74: Measuring Valve Stem

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

Figure 75: 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.

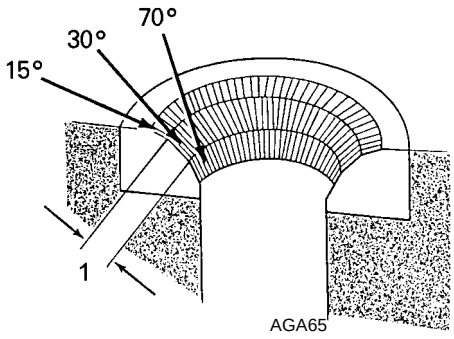
5. After grinding the valves, install the valves in their respective valve seats and check the valve depth of each. Replace any valve that has a valve depth over the wear limit.

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:

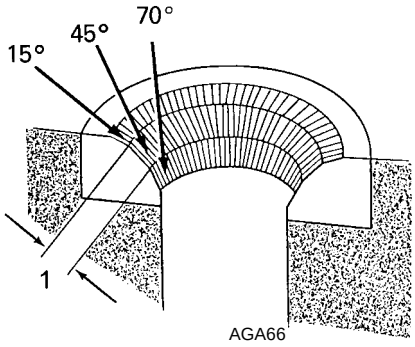
   Intake 30 degrees

   Exhaust 45 degrees



1.	Valve Seat Width

Figure 76: Intake Valve Seat Angles



1.	Valve Seat Width

Figure 77: 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.

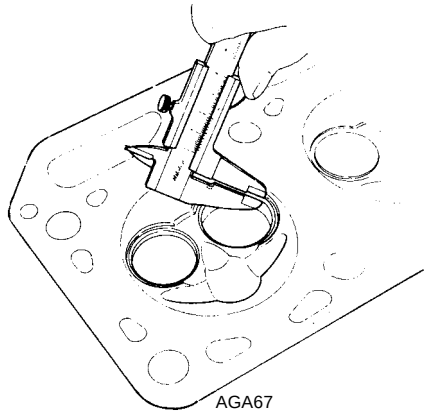


Figure 78: Measuring Valve Seat Width

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 alignment recommendation above.

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 1.49 in. (37.8 mm).

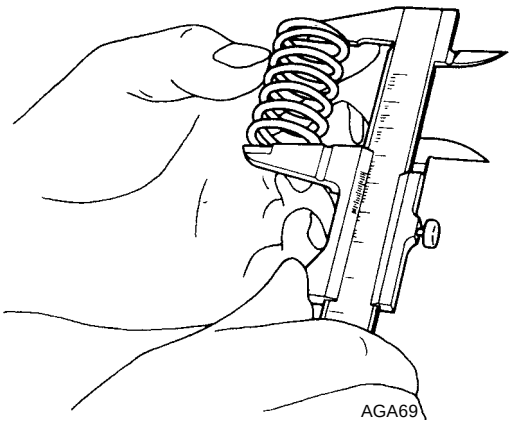


Figure 79: Measuring Valve Spring Free Length

3. Check the inclination of the valve springs with a square. Replace any valve springs with inclinations larger than 0.05 in. (1.3 mm).

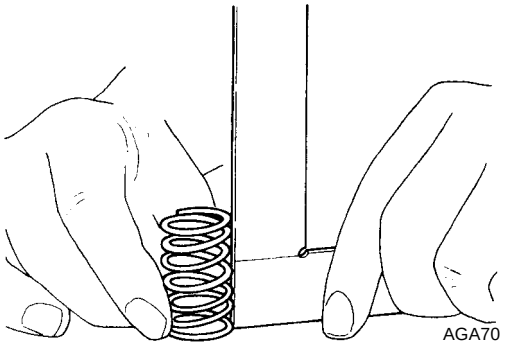
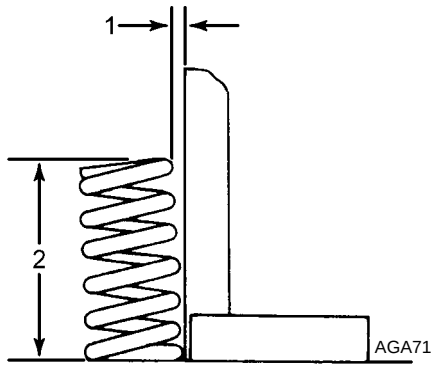


Figure 80: Checking Valve Spring Inclination



1.	Inclination
2.	Free Length

Figure 81: 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.

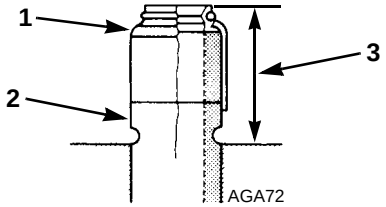
Cylinder Head Assembly

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 install them on the valve guides by using a valve stem seal installation tool (see Figure 3 on page 17). The intake and exhaust valve stem seals are different from each other. The intake valve stem seals are marked with white paint.The exhaust valve stem seals are marked with black paint. Make sure to put the intake and exhaust valve stem seals on the matching valve guides.

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

2. Check the valve stem seal projection (the distance between the top of the valve stem seal and the top of the valve spring seat) It should be 0.43 to 0.44 in. (10.9 to 11.2 mm). Adjust it if necessary to ensure the proper clearance between the valve guide and the valve stem seal.

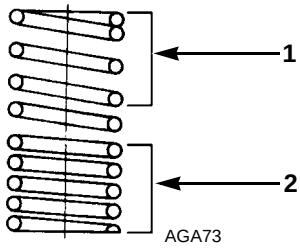


1.	Valve Stem Seal
2.	Valve Guide
3.	Valve Stem Seal Projection

Figure 82: Installing Valve Stem Seals

3. 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.

4. 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

Figure 83: Valve Spring

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

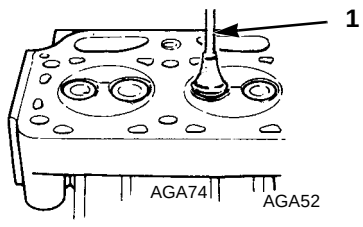
6. Install the valve keepers and remove the valve spring compressor.

7. 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

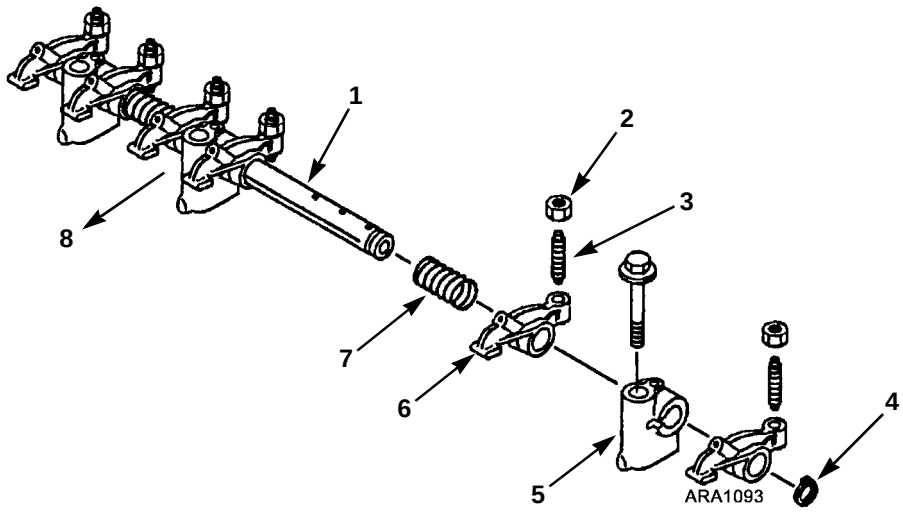
Figure 84: Lapping Valves

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.

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

Rocker Arm Assembly

1. 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.
2. Clean and inspect all the components of the rocker arm assembly. Replace any parts that show significant wear or damage.



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

Figure 85: Rocker Arm Assembly

3. 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 0.4701 in. (11.940 mm), at any of the rocker arm pivot points.

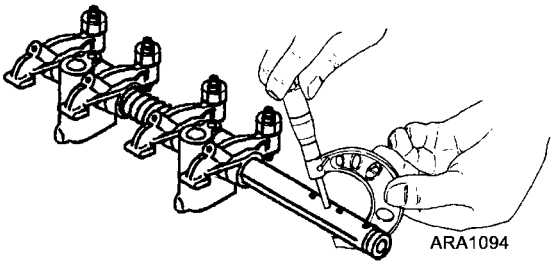


Figure 86: Measuring Rocker Arm Shaft

4. Measure the inside diameter of each rocker arm bushing. If a rocker arm bushing is larger than 0.4752 in. (12.070 mm), or shows significant damage, replace the rocker arm.

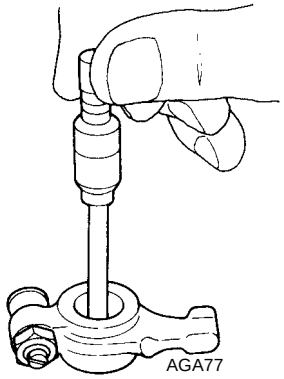


Figure 87: Measuring Rocker Arm Bushing

5. 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.

6. Reassemble the rocker arm assembly and make sure the parts are in the correct order. See Figure 85 on page 47 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 rocker arm supports are identical. They go on the rocker arm shaft with the mounting bolts to the intake (front) side.

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).

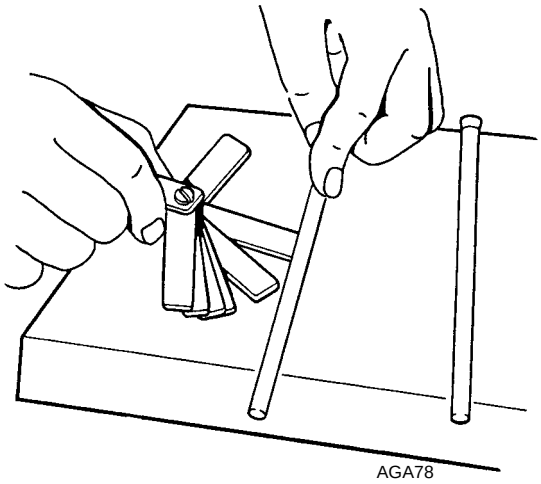
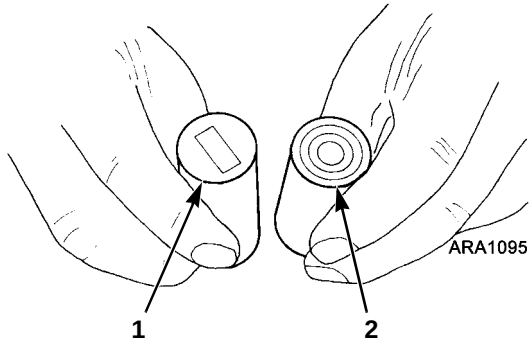


Figure 88: Checking Bend in Push Rods

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

Figure 89: Tappet Wear

2. Measure the outside diameter of each tappet. Replace any tappets that are smaller than 0.8231 in. (20.907 mm).

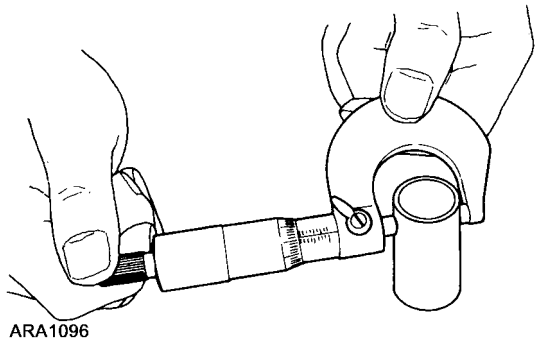
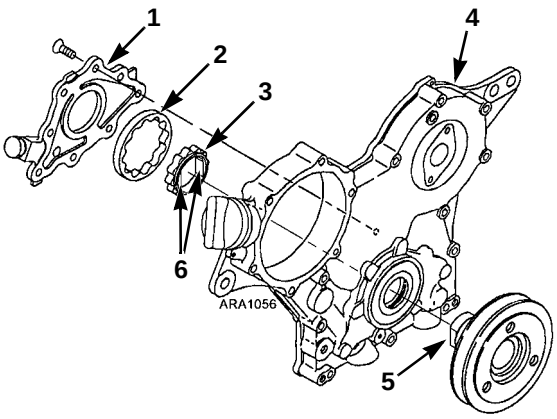


Figure 90: Measuring Tappet

Oil Pump

The oil pump is located in the gear case cover. The end of the crankshaft pulley fits inside the inner rotor of the oil pump. The flat sides on the outside of the crankshaft pulley drive the flat sides inside the inner rotor of the oil pump. The inner rotor of the oil pump fits around the boss on the crankshaft gear.

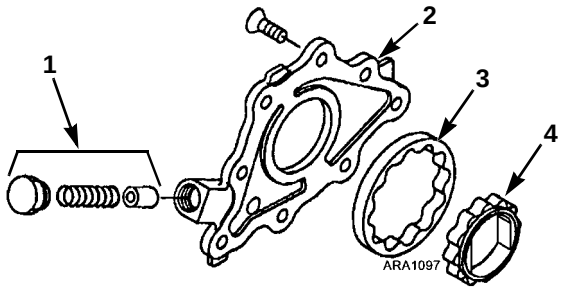
NOTE: Replace the oil pump as an assembly when replacing the oil pump.



1.	Oil Pump Cover
2.	Outer Rotor
3.	Inner Rotor
4.	Gear Case Cover
5.	Flat Side on Crankshaft Pulley
6.	Flat Sides on Inner Rotor

Figure 91: Gear Case Cover and Oil Pump Components

1. Remove the oil pump cover and inspect the oil pump components. Mark the side of the outer rotor that If the oil pump cover, the inner rotor, or the outer rotor show significant wear, scratches, or damage, replace the oil pump.

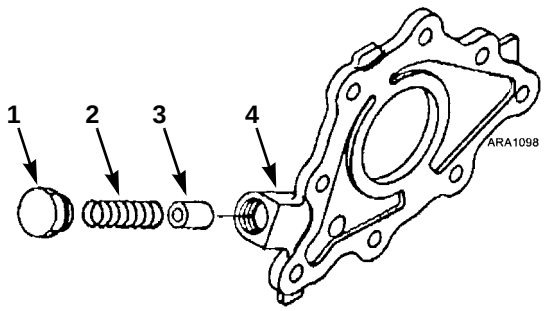


1.	Oil Pressure Control Valve
2.	Oil Pump Cover
3.	Outer Rotor
4.	Inner Rotor

Figure 92: Oil Pump Components

2. Place the outer rotor in the gear case cover. Use a feeler gauge to check the clearance between the outer rotor and the gear case cover. If the clearance between the outer rotor and the gear case cover exceeds 0.012 in. (0.30 mm), replace the oil pump.
3. Place the inner rotor inside the outer rotor while it is in the gear case cover. 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 0.006 in. (0.16 mm), replace the oil pump.
4. Check the clearance between the oil pump cover and the outer rotor. Place a straight edge across the gear case cover where the oil pump cover mounts. Insert a feeler gauge between the straight edge and the outer rotor. If the clearance between the oil pump cover and the outer rotor exceeds 0.005 in. (0.12 mm), replace the oil pump.

5. Check the oil pressure control valve to make sure that the piston moves smoothly and is returned by the spring. If not, replace the oil pump.



1.	Cap
2.	Spring
3.	Piston
4.	Oil Pump Cover

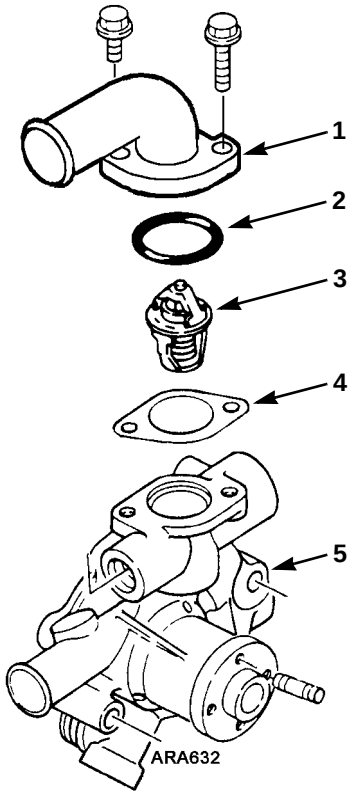
Figure 93: Oil Pressure Control Valve

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.

   NOTE: Check the cooling system to make sure it is clean. A dirty cooling system can cause water pump leaks.

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.



1.	Thermostat Housing
2.	Gasket
3.	Thermostat 180 F (82 C)
4.	Gasket
5.	Water Pump

Figure 94: Water Pump Assembly and Thermostat

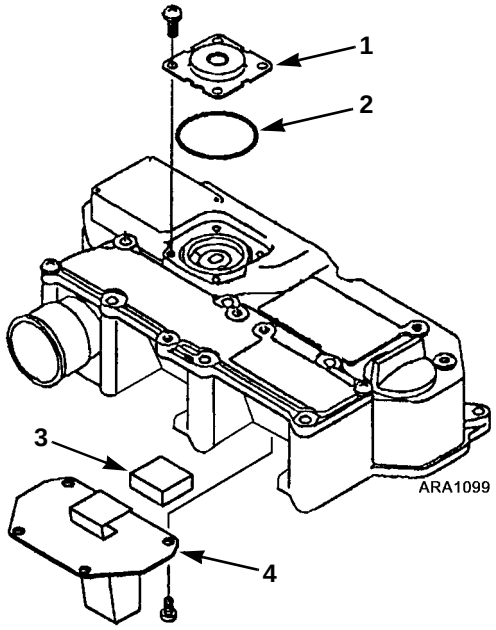
Manifolds

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).

Crankcase Breather System

The crankcase breather system ducts crankcase gases formed in the crankcase directly to the air intake. Harmful vapors that would otherwise collect in the crankcase and contaminate the oil, or escape to the outside, are drawn back into the engine and burned.

The crankcase breather is located in the cylinder head cover, which is a combination of valve cover and intake manifold. A restrictor in the cylinder head cover limits the flow of gases from the crankcase to the intake and keeps the crankcase pressure from getting too low.



1.	Breather Cover
2.	O-ring
3.	Baffle
4.	Baffle Plate

Figure 95: Crankcase Breather Components

Normal crankcase pressures with a new air cleaner are shown below:

Unit/Speed	in. (mm) H_2O of vacuum
Truck/Low	0 to 8 in. (0 to 203 mm)
Truck/High	2 to 11 in. (51 to 279 mm)
TriPac	0 to 8 in. (0 to 203 mm)

The vacuum will increase as the air cleaner gets dirty and becomes more restrictive. Remove the breather cover and the baffle plate and check to make sure nothing is plugged or damaged.

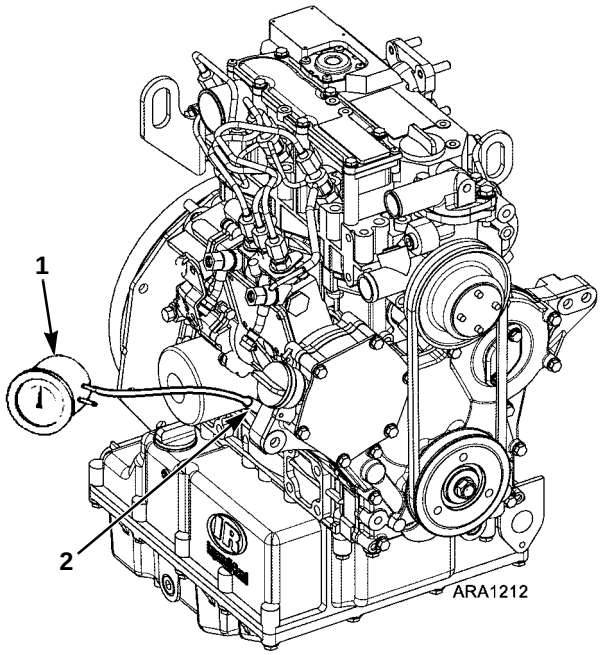
See “Checking Crankcase Pressure” below to check the crankcase pressure. If your readings are significantly more positive than 0 to 11 in. (0 to 279 mm) H_2O of vacuum, you may have excess blowby past the rings. A compression check should be performed to confirm this.

The following items can effect the crankcase pressure readings.

Crankcase Pressure Effect	Typical Cause
Increase	Piston Rings Stuck or Worn
Increase	Restrictor Plugged
Decrease	Air Cleaner Dirty or Plugged

Checking Crankcase Pressure

1. Remove the dipstick.
2. Connect the low pressure side of the Magnehelic gauge (10 in. [254 mm] minimum) to the dipstick tube.
3. Run the engine and note the readings during both low speed and high speed.



1.	Magnehelic Gauge
2.	Dipstick Tube

Figure 96: Measuring Crankcase Pressure

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.

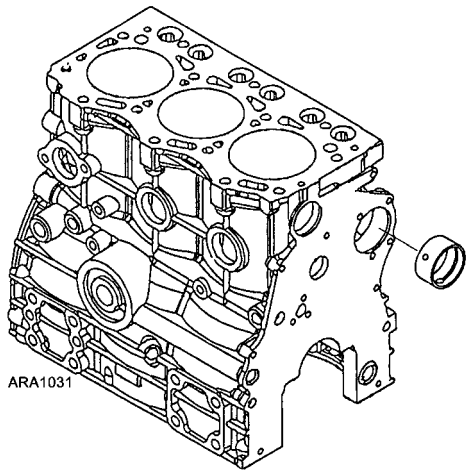


Figure 97: Install Camshaft Bearing

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.

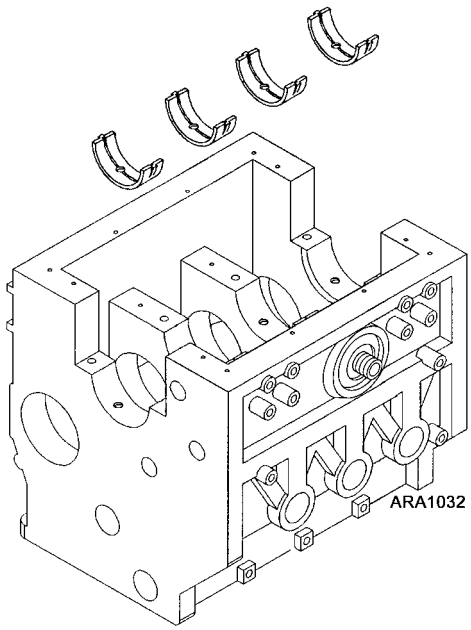
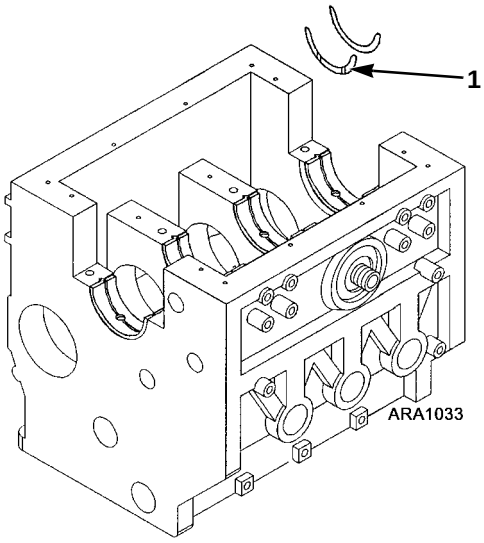


Figure 98: Install Upper Main Bearings

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

Figure 99: Install Upper Thrust Bearings

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

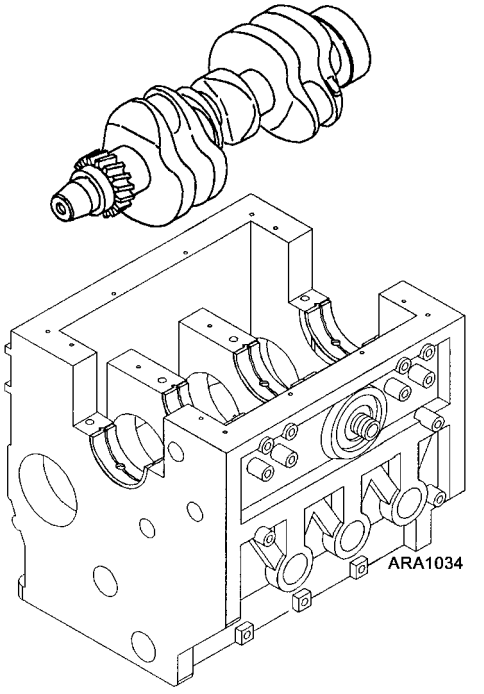


Figure 100: Install Crankshaft

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

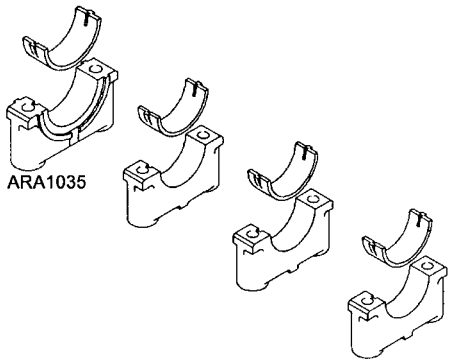
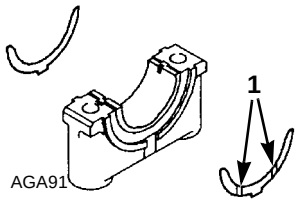


Figure 101: Install Lower Main Bearings

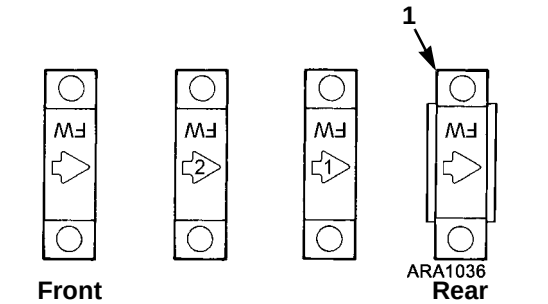
7. Place the lower thrust bearings in position on each side of the rear main bearing cap. The lower thrust bearings each have a tab on the bottom. The grooves on the thrust bearings should face away from the rear main bearing cap.



1.	Grooves Face Away From Main Bearing

Figure 102: 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.



1.	Rear Main Bearing Cap

Figure 103: Main Bearing Cap Placement

9. Install and torque the main bearing bolts to 55.7 to 60.1 ft-lb (75.5 to 81.5 N•m) in two or three equal increments.

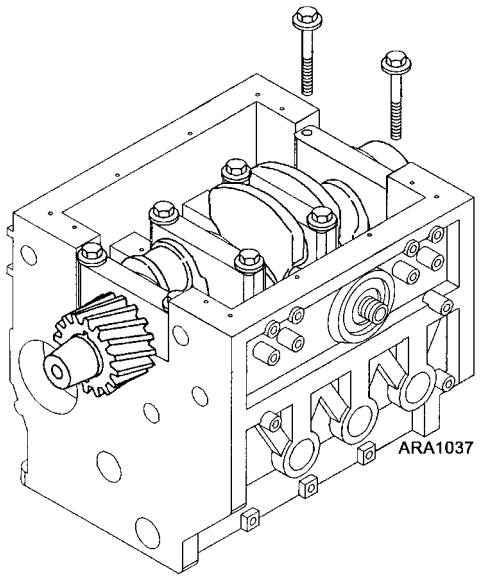


Figure 104: Install Main Bearing Bolts

10. Remove the main bearing caps and check the plastigauge to determine the clearance of each main bearing. The recommended main bearing clearance is 0.0008 to 0.0020 in. (0.020 to 0.050 mm).

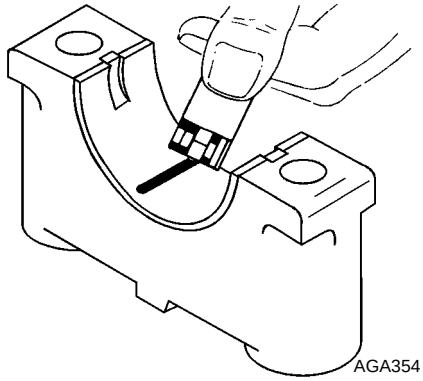


Figure 105: Check Plastigauge

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 0.0110 in. (0.280 mm). If the end play is larger than the wear limit, the thrust bearings must be replaced.

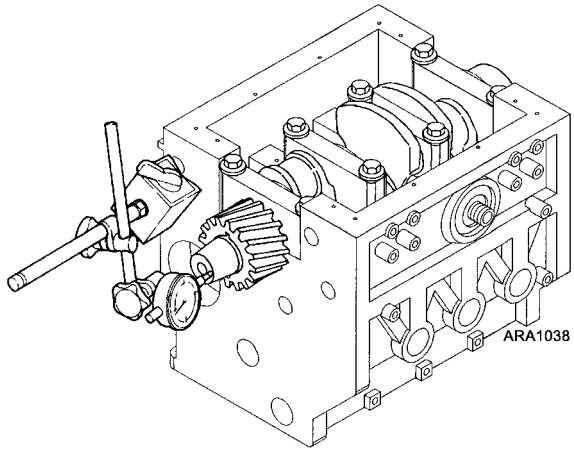
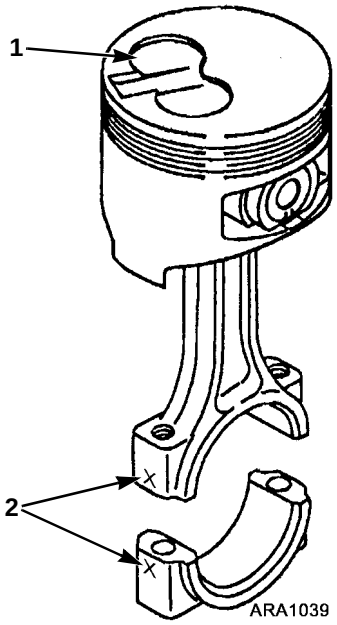


Figure 106: Check End Play

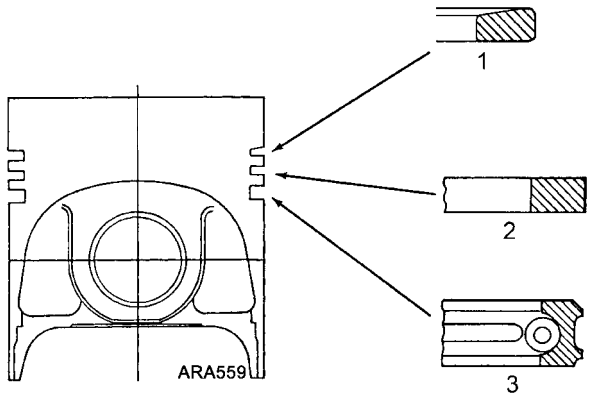
13. Install each piston on its respective connecting rod by heating the piston in hot water and then pressing the wrist pin into the piston and through the rod bushing. Install the circlips. The swirl chamber on the top of the piston must be positioned so it is on the identification mark side of the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



1.	Swirl Chamber
2.	Identification Marks

Figure 107: Assemble Piston and Rod

14. Each piston has three piston rings.
    a. The top ring is a keystone 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.	Keystone Ring
2.	Tapered Face Ring
3.	Oil Ring with Expander

Figure 108: 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 for the top ring is 0.006 to 0.012 in. (0.15 to 0.30 mm). The recommended end gap for the middle ring is 0.007 to 0.013 in. (0.18 to 0.33 mm). The recommended end gap for the bottom ring in the TK270 and TK370 is 0.006 to 0.014 in. (0.15 to 0.35 mm). The recommended end gap for the bottom ring in the TK376 is 0.008 to 0.018 in. (0.20 to 0.45 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.

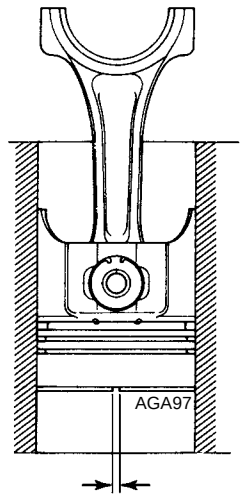


Figure 109: Check Ring End Gap

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.

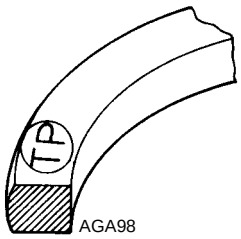
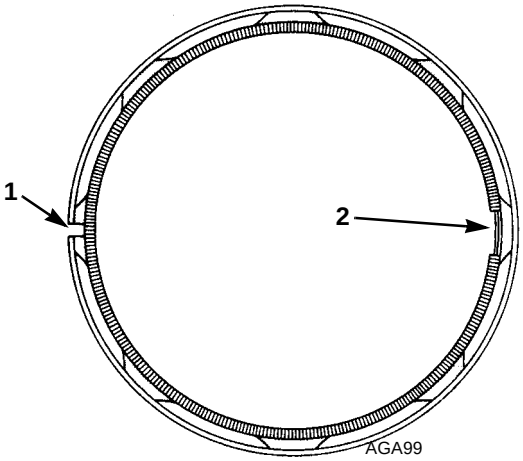


Figure 110: Mark on Ring Faces Up

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

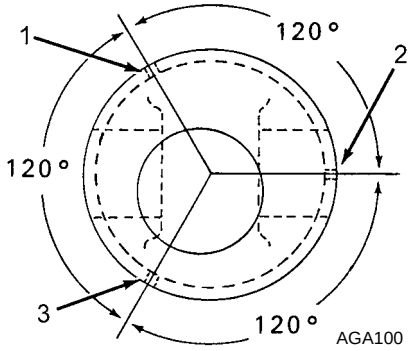
Figure 111: Oil Ring Installation

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

d. Place the keystone 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. Make sure that the end gap for the top ring is not above either end of the wrist pin.

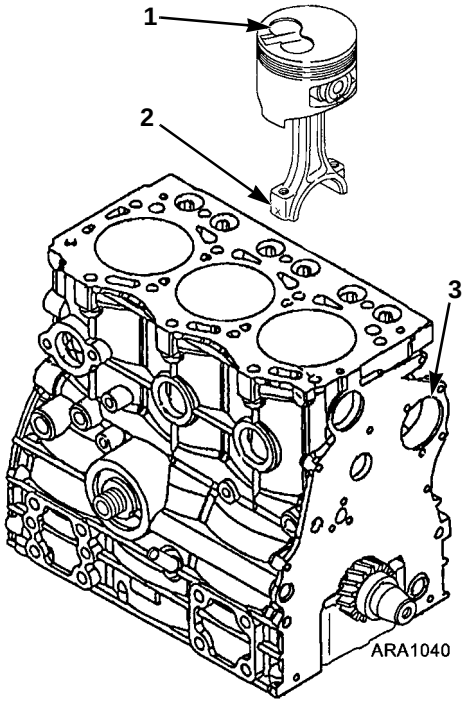


1.	Top Ring End Gap
2.	Oil Ring End Gap
3.	Middle Ring End Gap

Figure 112: 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

Figure 113: 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 16.7 to 20.3 ft-lb (22.6 to 27.5 N•m) in two or three equal increments.

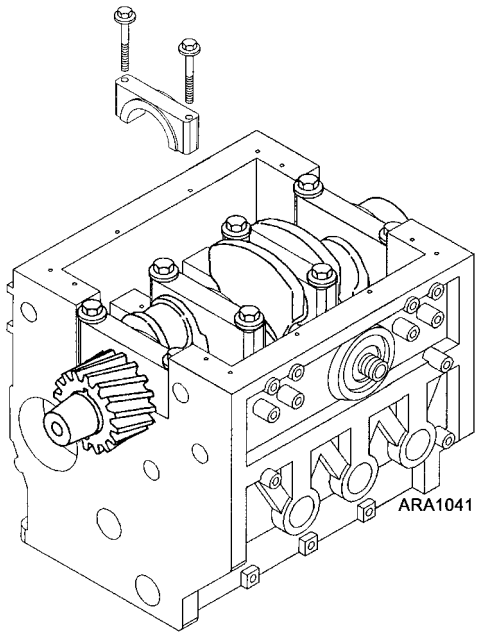


Figure 114: Install Rod Cap and Bolts

23. Remove the rod cap and check the plastigauge to determine the clearance of each connecting rod bearing. The recommended rod bearing clearance is 0.0008 to 0.0020 in. (0.020 to 0.050 mm).

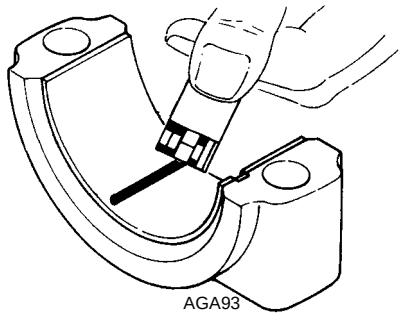
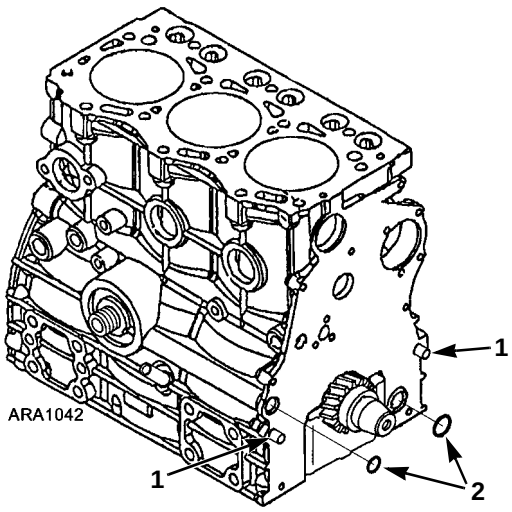


Figure 115: Check Plastigauge

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 (Tier 1 and Earlier Engines Only)

Figure 116: Front of Engine Block

28. Place a thin layer of silicone sealant on the back sealing surface of the gear case.
29. Install the gear case. Make sure to align the dowel pins and tighten the mounting bolts.

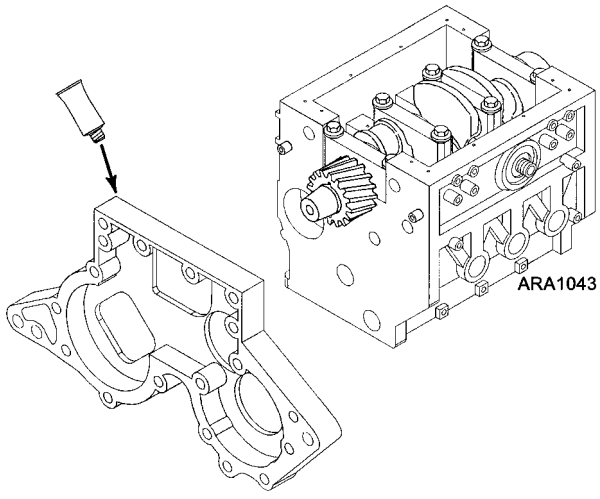


Figure 117: Install Gear Case

30. Lubricate the camshaft bearing, journals, and lobes with engine assembly compound or engine oil.
31. Carefully install the camshaft to avoid damaging the camshaft bearing.

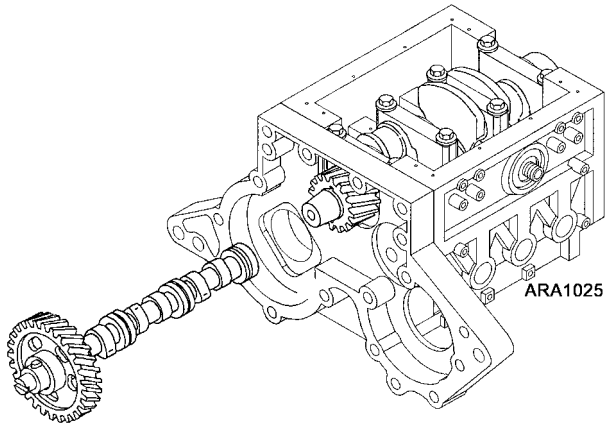


Figure 118: Install Camshaft

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

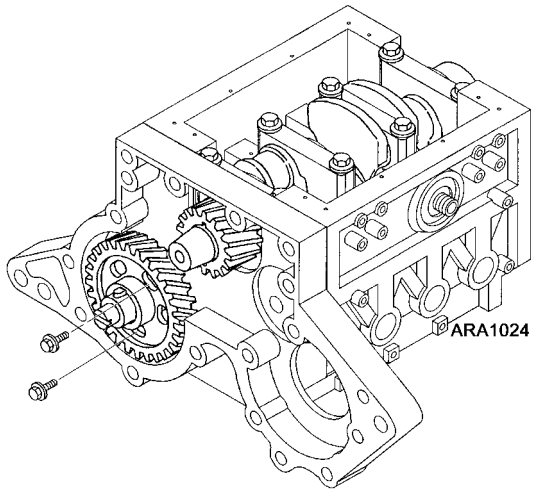


Figure 119: Install Camshaft Mounting Bolts

33. Install the fuel injection pump, align the index marks (as they were when the fuel injection pump was removed, see step 27 on page 28), and tighten the mounting nuts.

    NOTE: The injection timing will be correct if the original injection pump is being reinstalled and the index marks are aligned as they were when the fuel injection pump was removed. If not, see "Injection Pump Timing" on page 77.

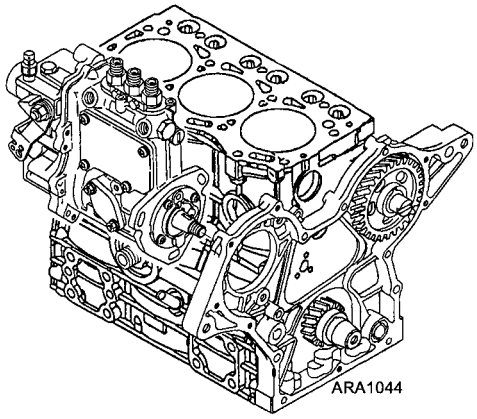
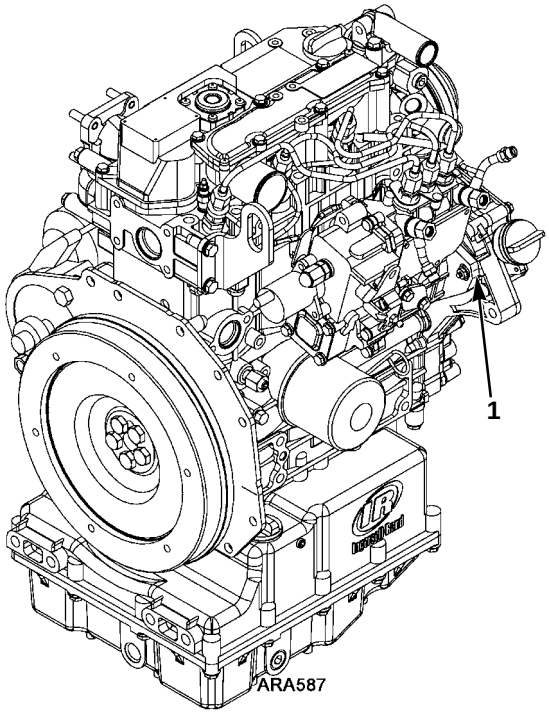
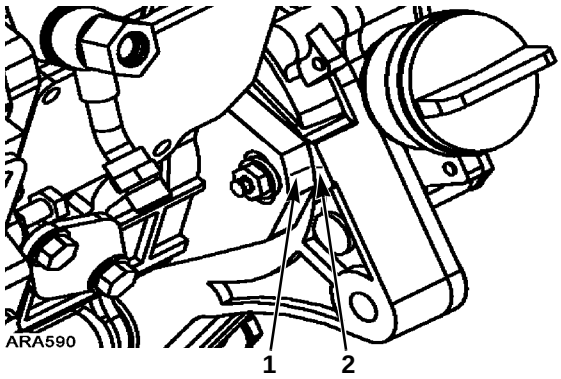


Figure 120: Install Fuel Injection Pump



1.	Index Marks

Figure 121: Index Mark Location



1.	Index Mark on Injection Pump
2.	Center Index Mark on Gear Case

Figure 122: Index Mark Alignment

34. Install the fuel injection pump gear, lock washer, and mounting nut. Make sure the key is aligned properly. Torque the mounting nut to 43.5 to 50.9 ft-lb (59.0 to 69.0 N•m).

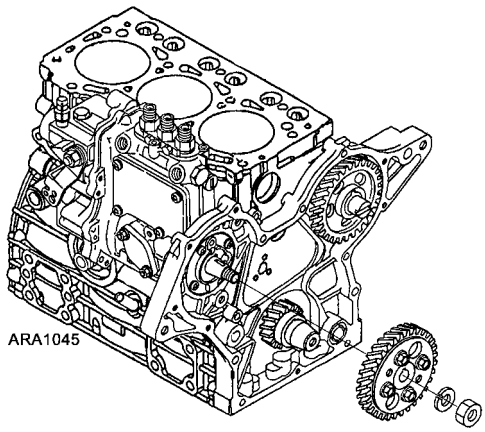


Figure 123: Install Fuel Injection Pump Gear

35. Install the idler gear and the idler shaft. Align the timing marks on the idler gear with the corresponding timing marks on the crankshaft gear, the camshaft gear, and the injection pump gear.

NOTE: Typically, 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 camshaft gear, and the C mark on the idler gear should line up with the C mark on the injection pump gear.

However, you might see engines with the B mark on the injection pump gear and the C mark on the camshaft gear. You might also see engines that use one, two, and three dots instead of letters for timing marks. In any case, Align the timing marks on the idler gear with the corresponding timing marks on the crankshaft gear, the camshaft gear, and the injection pump gear.

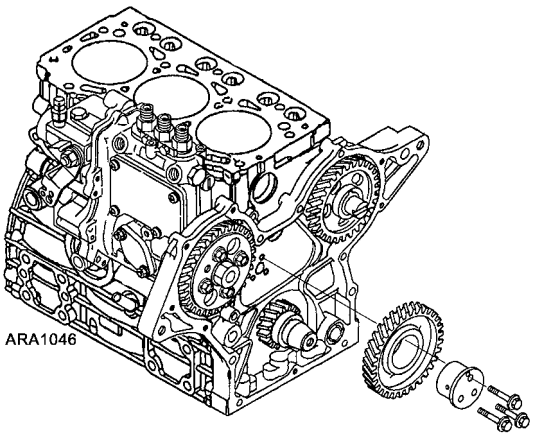
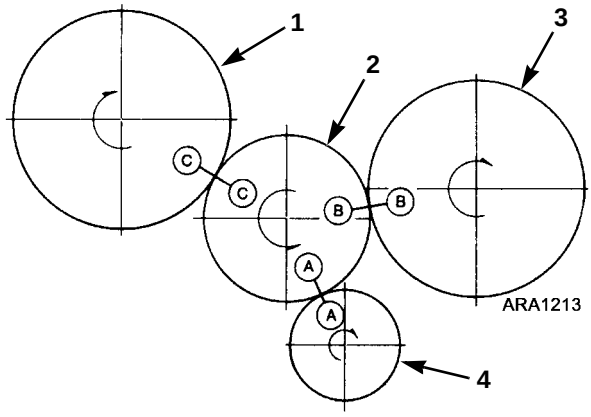
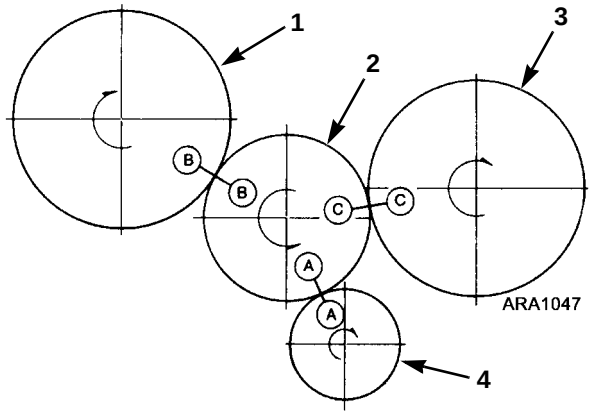


Figure 124: Install Idler Gear and Idler Shaft



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

Figure 125: Typical Timing Mark Alignment



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

Figure 126: Alternate Timing Mark Alignment

36. Install and tighten the idler shaft mounting bolts.
37. Use a dial indicator to check the gear lash between the timing gears, if it has not been checked already.
38. Install the oil line that goes from the cylinder block to the fuel injection pump.

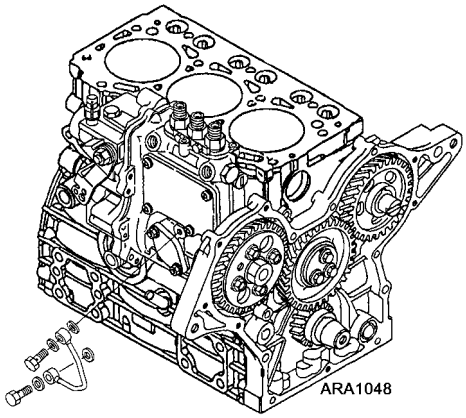


Figure 127: Install Oil Line

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

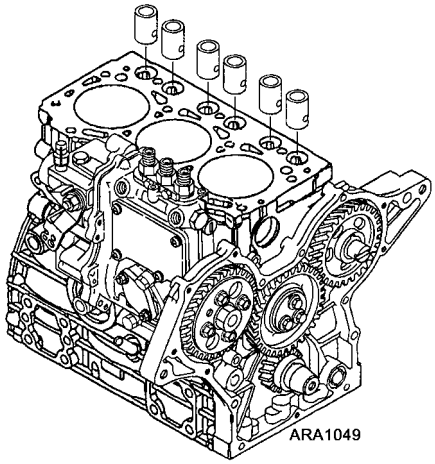


Figure 128: Install Tappets

40. Make sure the dowel pins are in place in the top of the block.
41. Place a new head gasket on the block and align the head gasket with the dowel pins to ensure it is positioned correctly.
42. Place the cylinder head on top of the block and the head gasket. Make sure to align the head with the dowel pins.

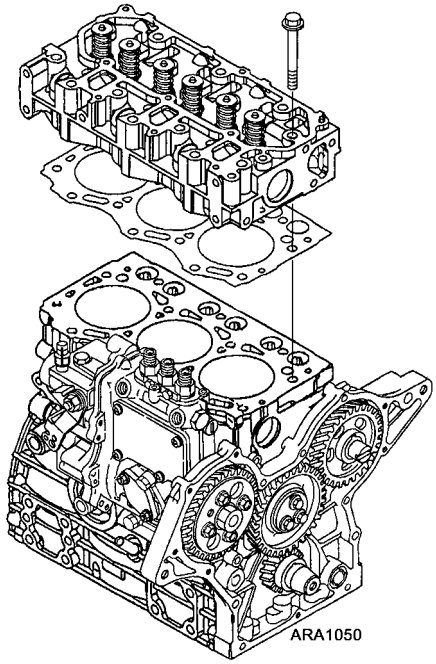


Figure 129: Install Cylinder Head and Gasket

43. Install the cylinder head bolts. Torque the cylinder head bolts to 39.8 to 42.7 ft-lb (53.9 to 57.9 N•m) in two equal increments using the sequence shown in the following illustrations.

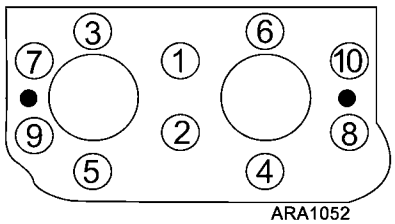


Figure 130: Cylinder Head Bolt Torque Sequence for Two Cylinder Engines

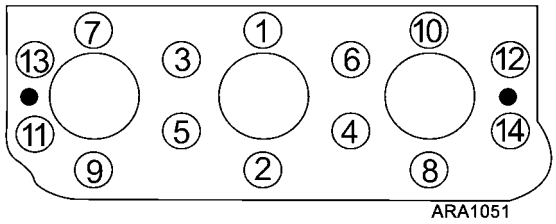


Figure 131: Cylinder Head Bolt Torque Sequence for Three Cylinder Engines

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

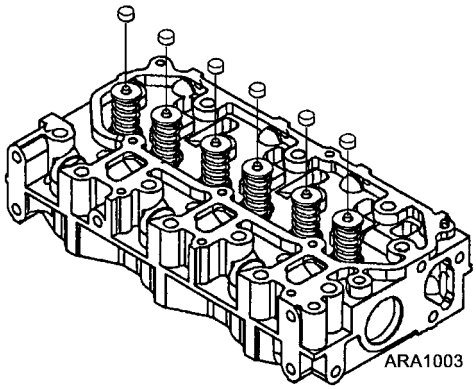


Figure 132: Install Valve Stem Caps

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.

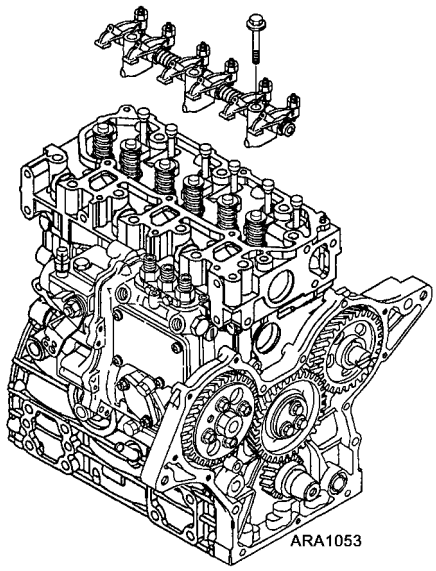


Figure 133: Install Rocker Arm Assembly

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. See “Valve Clearance Adjustment” on page 108.

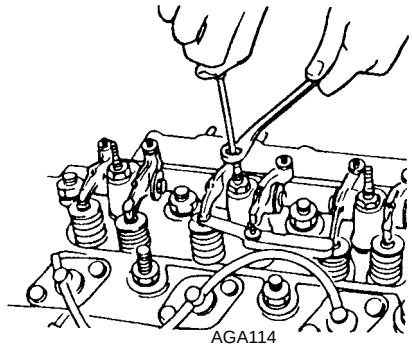


Figure 134: Adjust Valves

50. Install the oil filter and the dipstick.

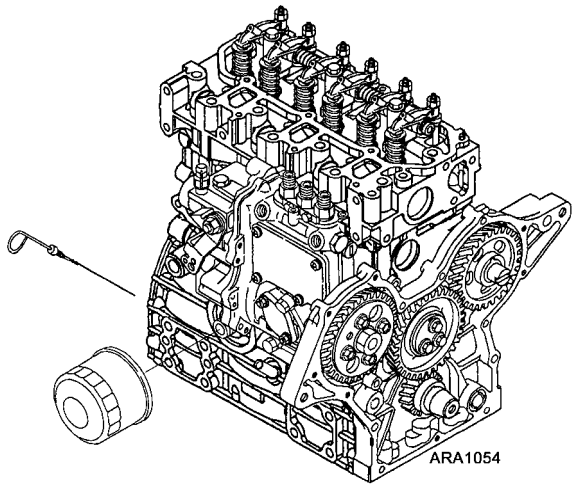


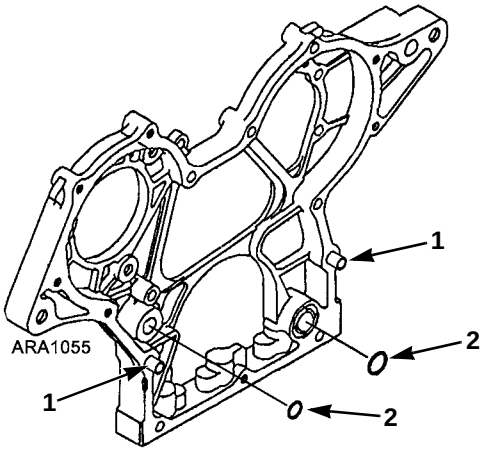
Figure 135: Install Oil Filter and Dipstick

51. Check to make sure the dowel pins are in position in the gear case (see Figure 136).

52. Replace the front seal by pressing the old seal out and pressing a new seal into the gear case cover.

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

54. Place new O-rings in the gear case.

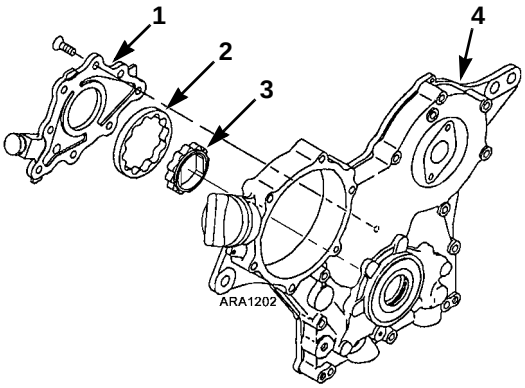


1.	Dowel Pins
2.	O-Rings

Figure 136: Gear Case

55. Place a thin layer of sealant on the sealing surface of the gear case cover.

NOTE: The oil pump is located in the gear case cover. It is driven by flats on the end of crankshaft pulley. See step 62 and Figure 142 on page 66 for information about installing crankshaft pulley and aligning the flats.



1.	Oil Pump Cover
2.	Outer Rotor
3.	Inner Rotor
4.	Gear Case Cover

Figure 137: Oil Pump Located in Gear Case Cover

56. Place the gear case cover in position and make sure to align the dowel pins.

57. Install and tighten the gear case cover mounting bolts.

58. Install the injection pump timing cover.

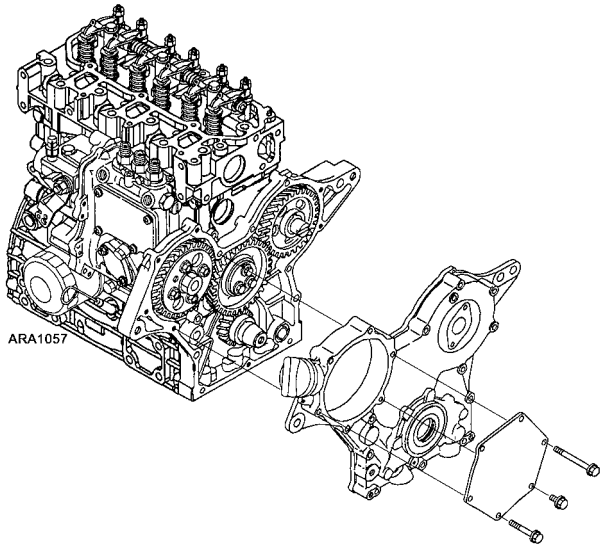


Figure 138: Install Gear Case Cover and Injection Pump Timing Cover

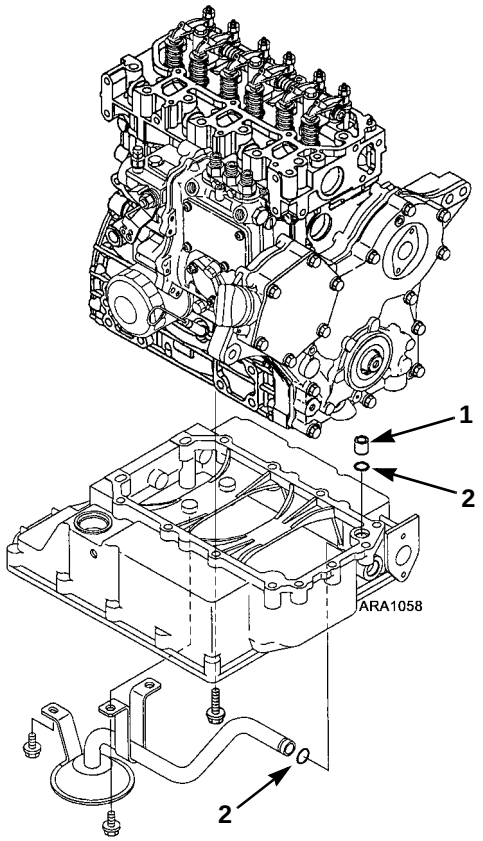
59. Install the upper part of oil pan (if necessary). Three cylinder engines and some two cylinder require that the upper part of the oil pan be installed before the oil pump intake pipe is installed. Make sure that the dowel pin and O-ring are in place if used.

    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.

60. Install the oil pump intake pipe. Make sure O-ring is installed properly because a missing or damaged O-ring will cause low oil pressure.



1.	Dowel Pin
2.	O-Rings

Figure 139: Install Upper Part of Oil Pan and Oil Pump Intake Pipe

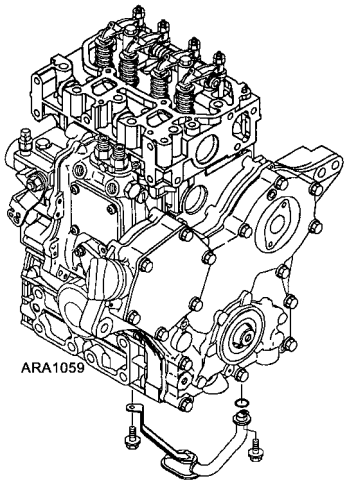


Figure 140: Install Oil Pump Intake Pipe (Two Cylinder Engine)

61. Install the lower part of the oil pan (or the one-piece oil pan on some two cylinder engines.)

    d. Place a thin layer of sealant on the sealing surface of the lower part of the oil pan (or the sealing surface of the one-piece oil pan).

    e. Place the lower part of the oil pan in position on the upper part of the oil pan (or place the one-piece oil pan in position on the bottom of the block.

    f. Install and tighten the mounting bolts for the lower part of oil pan (or the one-piece oil pan, and make sure the rear end of the block and the one-piece oil pan are flush before tightening the mounting bolts).

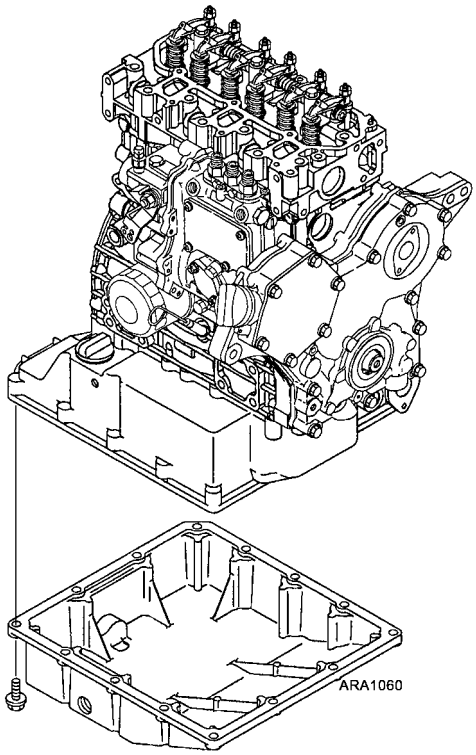
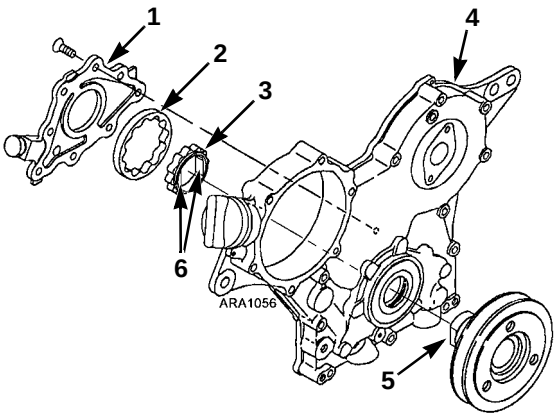


Figure 141: Install Lower Part of Oil Pan

62. Install the crankshaft pulley. Make sure that the end of crankshaft pulley fits inside the inner rotor of the oil pump by aligning the flat sides on the outside of the crankshaft pulley with the flat sides inside the inner rotor of the oil pump. Torque the crankshaft pulley mounting bolt to 61.4 to 68.8 ft-lb (83.3 to 93.3 N•m).

    NOTE: The oil pump is located in the gear case cover. The end of the crankshaft pulley fits inside the inner rotor of the oil pump. The flat sides on the outside of the crankshaft pulley drive the flat sides inside the inner rotor of the oil pump.



1.	Oil Pump Cover
2.	Outer Rotor
3.	Inner Rotor
4.	Gear Case Cover
5.	Flat Side on Crankshaft Pulley
6.	Flat Sides on Inner Rotor

Figure 142: Align Flat Sides of Crankshaft Pulley with Flat Sides of Inner Rotor in Gear Case Cover

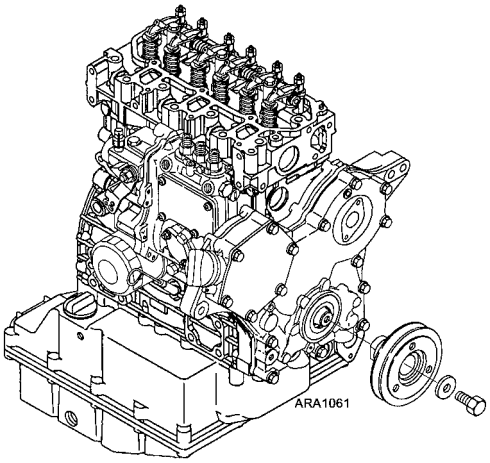


Figure 143: Install Crankshaft Pulley

63. Replace the rear seal by pressing the oil seal out of the rear seal housing and pressing a new seal in.

64. 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 starter mounting flange.

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

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

67. 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.

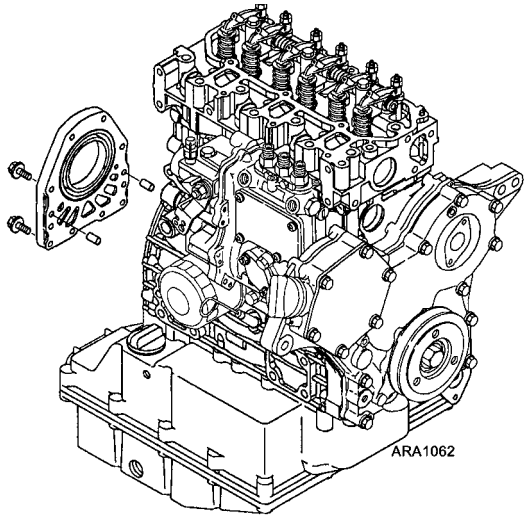


Figure 144: Install Rear Seal Housing

68. Place the starter mounting flange in position on the rear of the block and make sure to align the dowel pins.

69. Install and tighten the mounting bolts for the starter mounting flange.

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

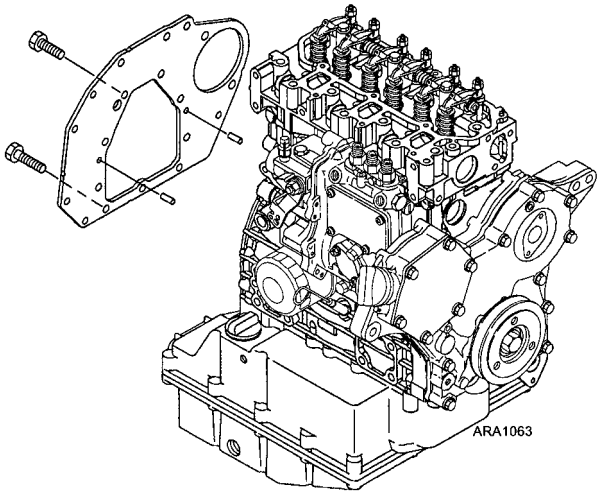


Figure 145: Install Starter Mounting Flange

70. Install the flywheel and align it with the dowel pin in the end of the crankshaft. Torque the flywheel mounting bolts to 59.3 to 63.7 ft-lb (80.4 to 86.4 N•m).

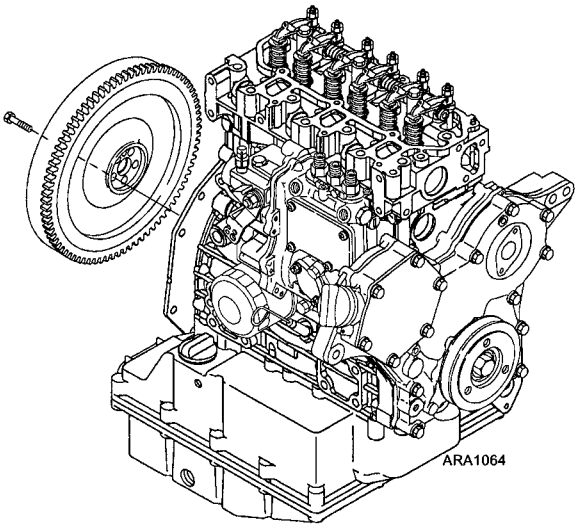


Figure 146: Install Flywheel

71. Install the starter.

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

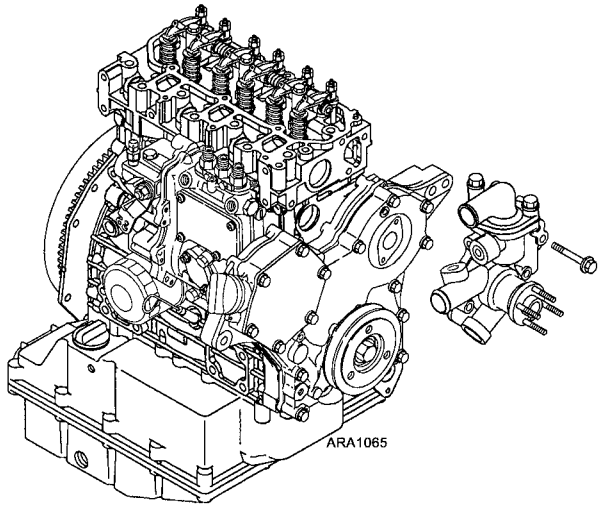


Figure 147: Install Water Pump

73. Install the glow plugs and the connector wire between the glow plugs.

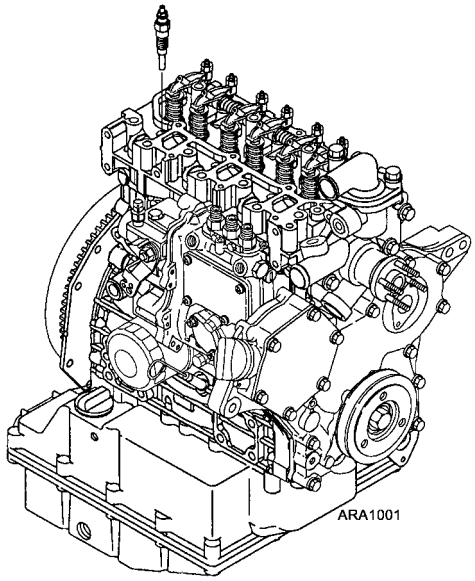


Figure 148: Install Glow Plugs

74. Install the cylinder head cover with a new gasket.

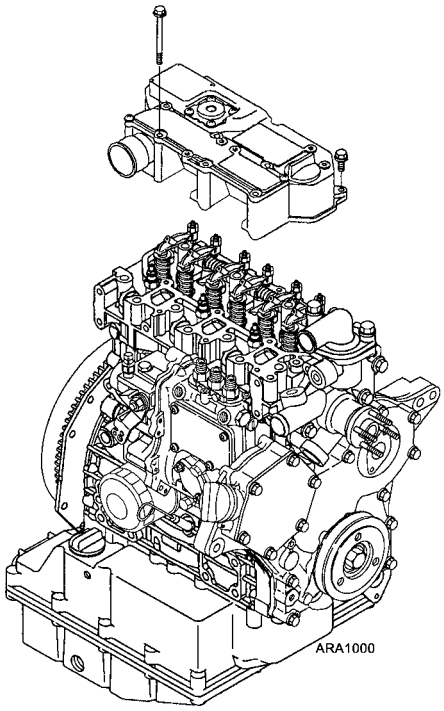
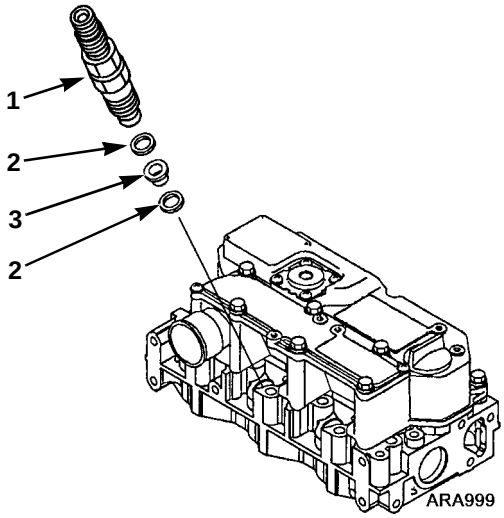


Figure 149: Install Cylinder Head Cover

75. Place a nozzle gasket, a nozzle protector, and another nozzle gasket in each opening for the fuel injection nozzles. The nozzle protector is shaped like a cup and the bottom of the cup should face down.

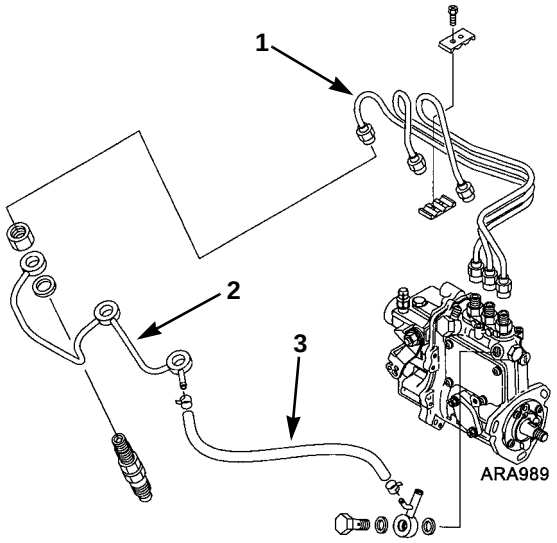
76. Install the fuel injection nozzles and torque them to 36.1 to 43.5 ft-lb (49.0 to 59.0 N•m).



1.	Fuel Injection Nozzle
2.	Nozzle Gaskets
3.	Nozzle Protector

Figure 150: Install Fuel Injection Nozzles

77. Install the lift brackets.
78. Install the fuel return tube.
79. Install a new fuel return line.
80. Install the fuel injection lines.



1.	Fuel Injection Lines
2.	Fuel Return Tube
3.	Fuel Return Line

Figure 151: Install Fuel Injection Lines

81. Install the exhaust manifold with a new gasket.

Lubrication System

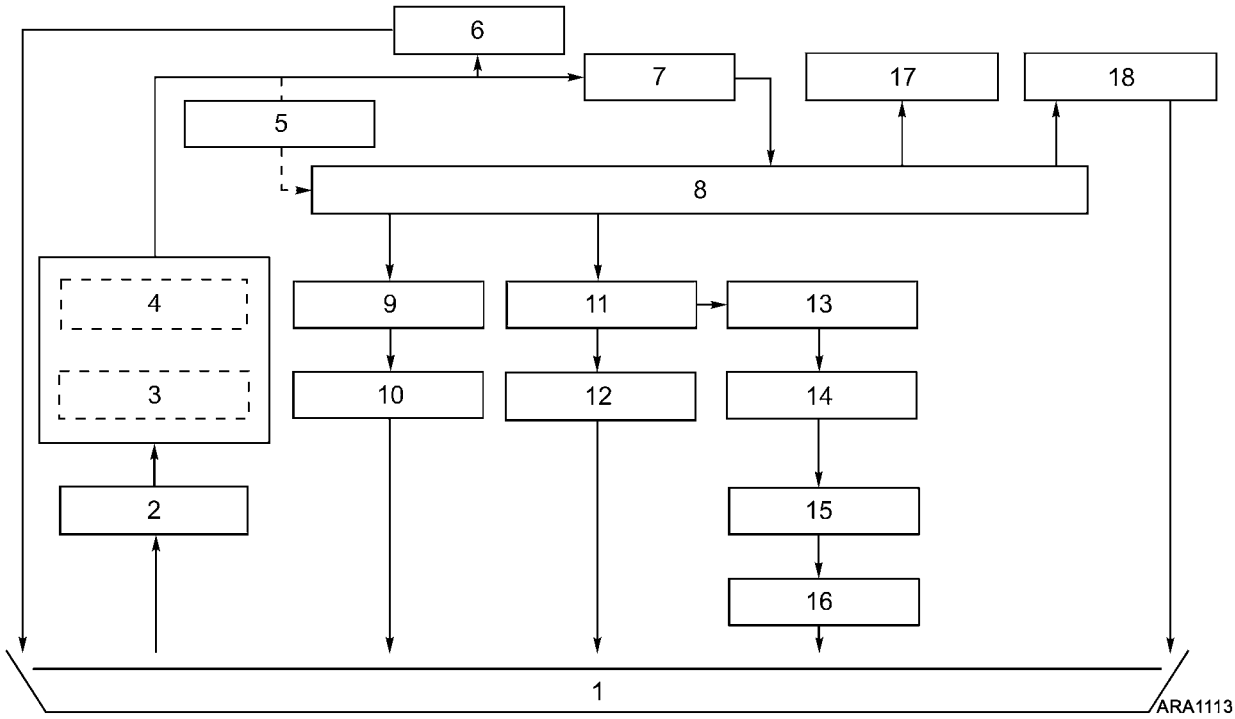
These engines use a pressure lubrication system. A trochoid type oil pump circulates the oil through the system to lubricate the engine components. The oil pump contains a pressure control valve that limits the oil pressure to 40 to 60 psi (276 to 414 kPa).

The oil pump is driven by the flats on the crankshaft pulley, and is located in the gear case cover.

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.

The oil pump forces a large volume of high pressure oil through an oil gallery to the full flow 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 into the full flow oil filter 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 full flow oil filter, the oil enters the main oil gallery. Oil passages connected to the main oil gallery supply oil to the idler gear shaft and the main bearings. An external oil line is connected to the main oil gallery and the fuel injection pump.



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

Figure 152: Lubrication System

Oil from the idler gear shaft lubricates the idler gear bushing, the idler gear, and the other timing gears before returning to the oil pan.

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 main bearings flows through passages in the cylinder block to the camshaft bearings. From here some of the oil 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 through the oil line 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. See flow chart “EDP05 Low Oil Pressure” on page 120 to help diagnose low oil pressure.

Fuel System

Description

The major components of the typical fuel system are:

- Fuel Tank (may be the truck fuel tank)
- Electric Fuel Pump
- Fuel Filter
- Injection Pump
- Injection Nozzles.

A 10 psi (69 kPa) electric fuel pump pulls fuel from the fuel tank through a fuel pump filter, then pushes it to the fuel filter, and to the injection pump. The fuel pump filter is designed for diesel fuel and is the only type that should be used.

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.

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

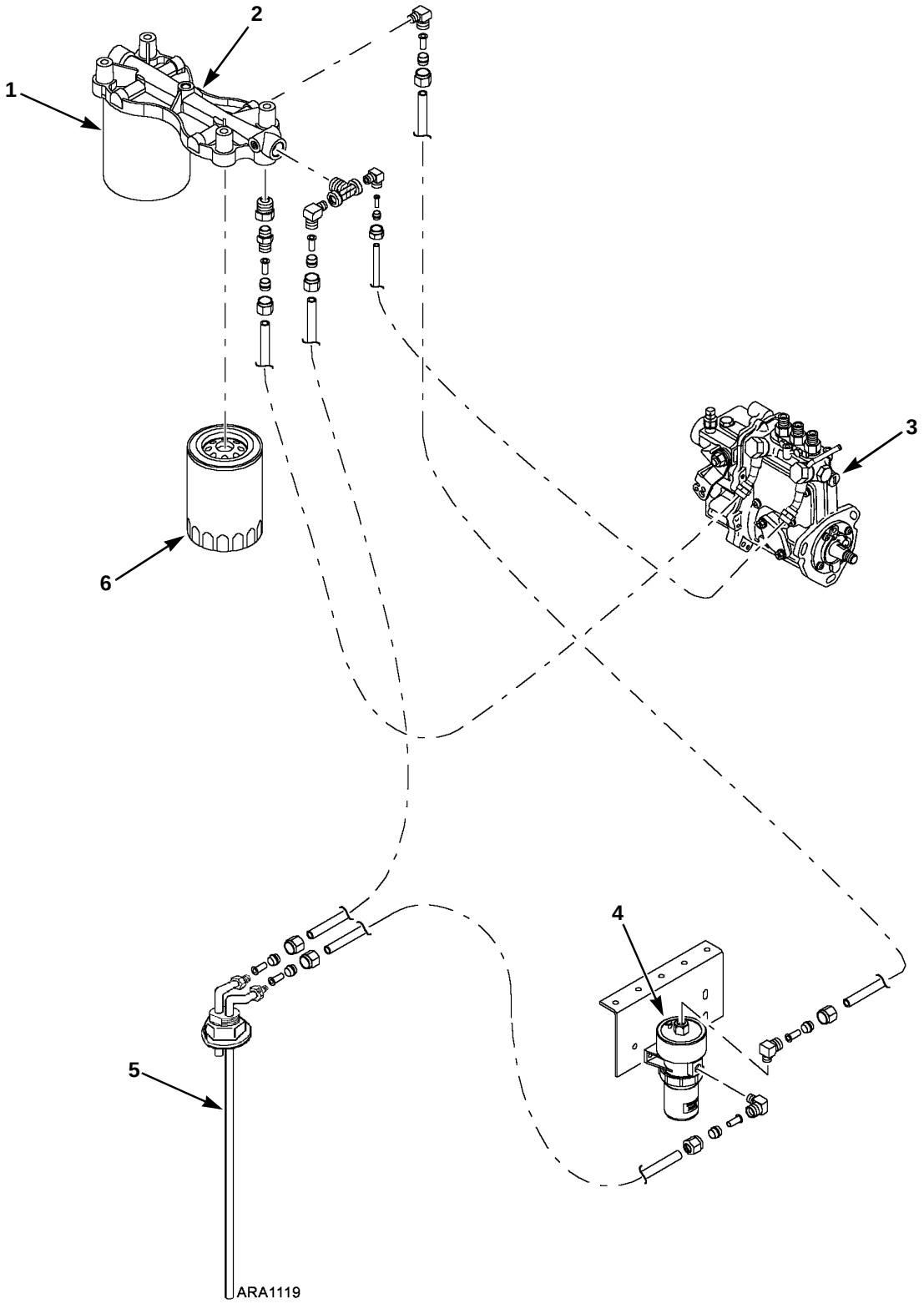
The fuel system is relatively trouble free, and if properly maintained will usually not require major service repairs between engine overhauls.

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 must be changed regularly. The fuel pump filter should be cleaned when the fuel filter is changed. Any time that the fuel system is opened up, 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 quality diesel injection service specialty shop. The investment in equipment and facilities to service these components is quite high. Therefore, this equipment is not found in most repair shops.

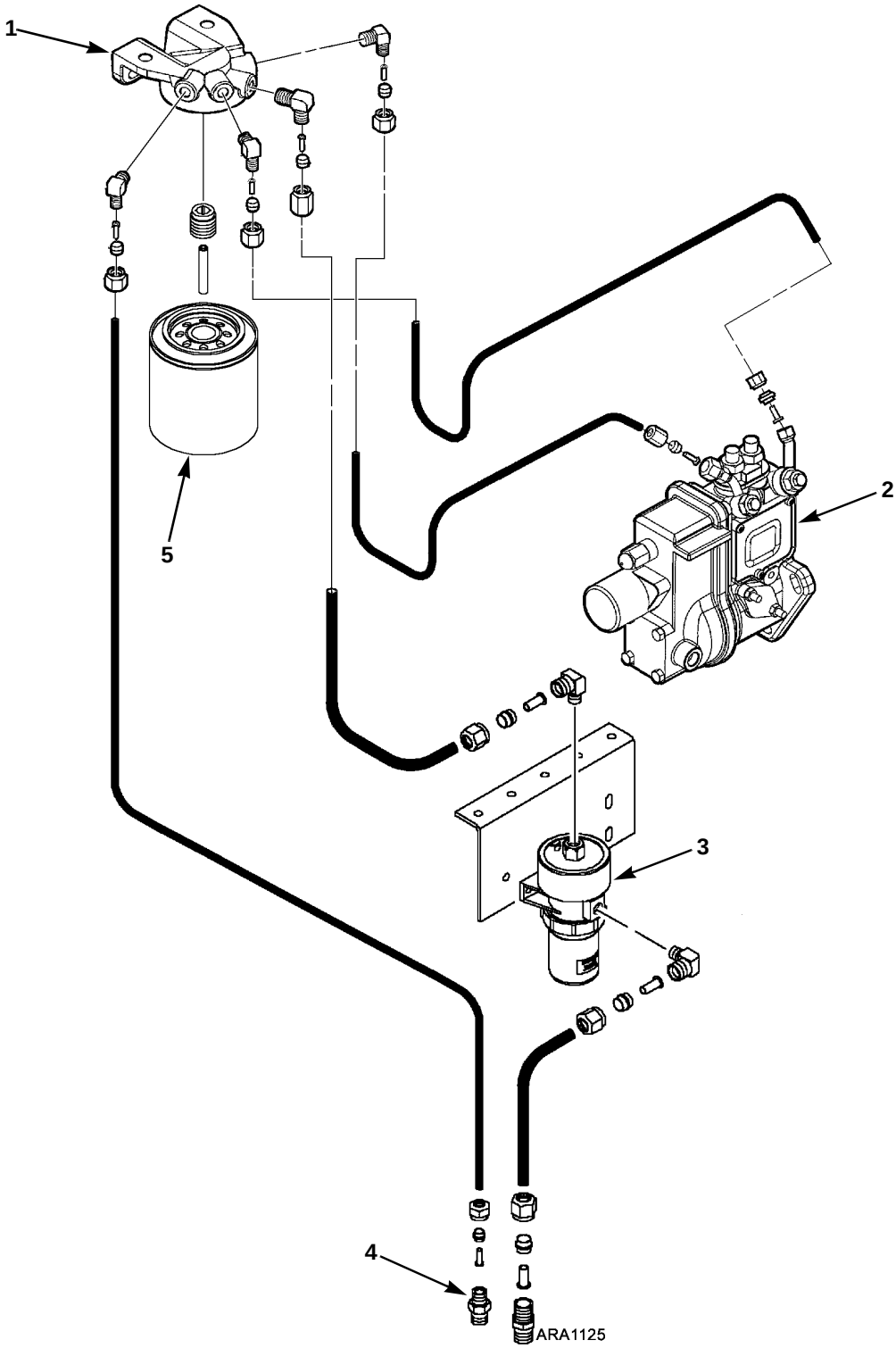
The following procedures can be performed under field conditions:

- Bleeding air from the fuel system
- Maintenance of the fuel tank and fuel filter system
- Electric transfer pump replacement or repair (10 psi [69 kPa] pump with diesel filter).
- Injection line replacement.
- Engine speed adjustments
- Injection pump timing
- Injection nozzle testing, adjustment, and minor repair



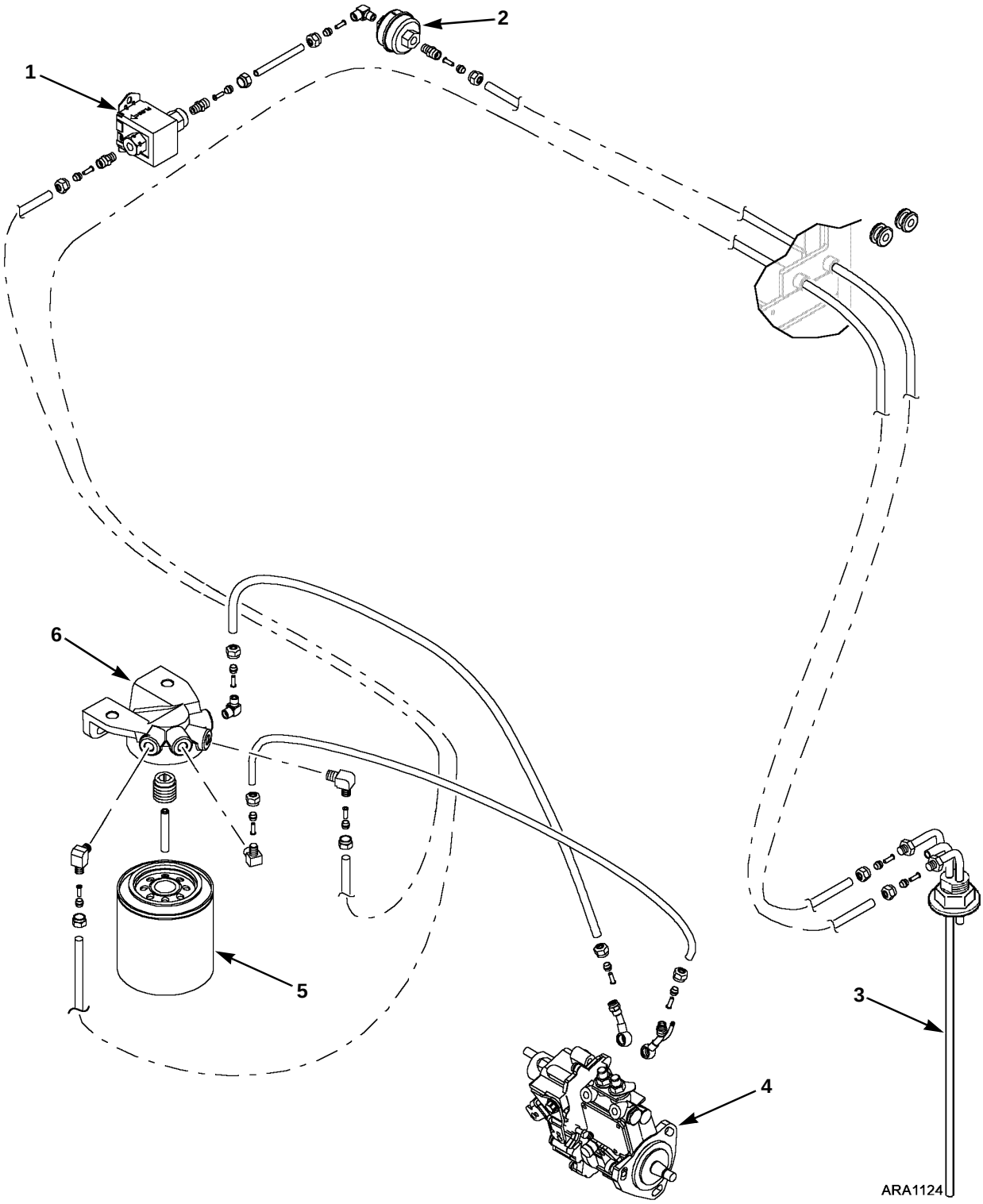
1.	Bypass Oil Filter (If Used)	4.	Electric Fuel Pump
2.	Filter Head	5.	Fuel Pickup Tube
3.	Injection Pump	6.	Fuel Filter

Figure 153: Typical Fuel System for Truck Units



1.	Filter Head	4.	Fuel Tank Fittings
2.	Injection Pump	5.	Fuel Filter
3.	Electric Fuel Pump		

Figure 154: Typical Fuel System for HK Units



1.	Electric Fuel Pump	4.	Injection Pump
2.	In-Line Fuel Filter	5.	Fuel Filter
3.	Fuel Pickup Tube	6.	Filter Head

Figure 155: Typical Fuel System for TriPac Units

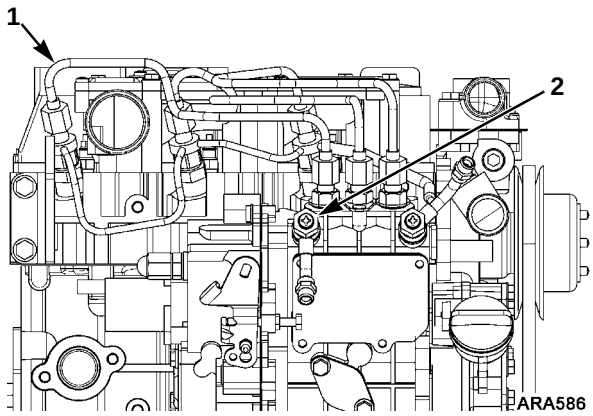
Bleeding Air from the Fuel System

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 on the inlet fuel fitting of the injection pump about two turns.



1.	Fuel Injection Line
2.	Bleed Screw

Figure 156: TK376 Injection Pump

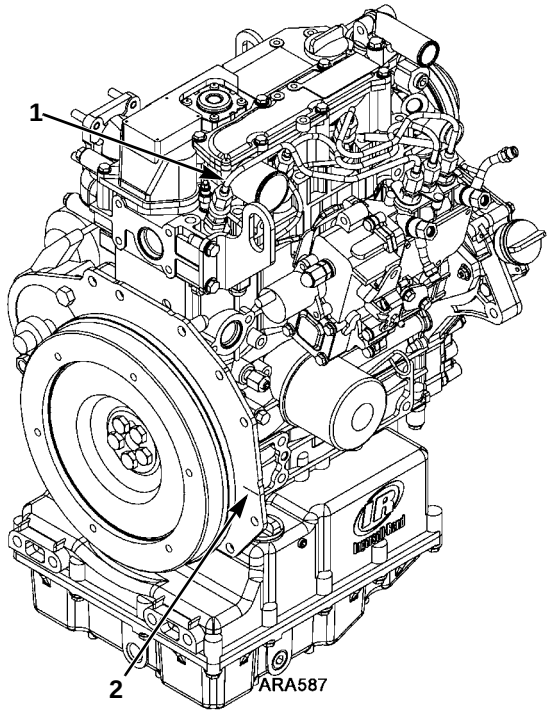
2. Energize the electric fuel pump using the Service Test Mode or by turning the unit On.
3. Tighten the bleed screw on the injection pump when clear flow of fuel appears.
4. Loosen the fuel injection lines on the injection nozzles.
5. Crank the engine until fuel appears at the nozzles. Tighten the fuel injection lines, and start the engine.

   NOTE: Fuel will not appear at the nozzles by merely running the electric pump. The engine must be cranked.

Injection Pump Timing

This timing procedure requires fuel pressure at the injection pump inlet. This is be accomplished by using the electric fuel pump to supply fuel to the fuel pump inlet.

CAUTION: The cylinders on the engine are numbered from the flywheel end to the water pump end. On two cylinder engines The number 1 cylinder is next to the flywheel and the number 2 cylinder is next to the water pump. On three cylinder engines The number 1 cylinder is next to the flywheel, the number 2 cylinder is the center cylinder, and the number 3 cylinder is next to the water pump. The timing marks on the flywheel are matched to this system.



1.	Number 1 Cylinder Fuel Injection Line
2.	Index Mark on Starter Mounting Plate

Figure 157: Component Location

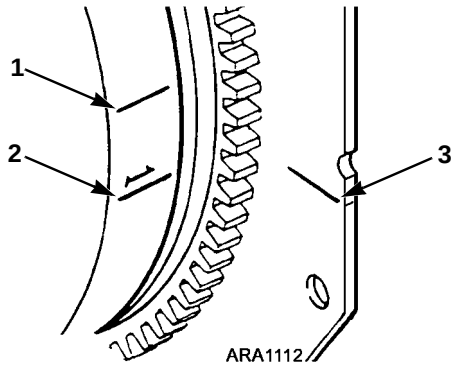
CAUTION: Loosen all of the injection lines at the injection nozzles to prevent the possibility of the engine firing while it is being rotated.

1. If the engine is in the unit, make sure the unit is turned off.
2. Remove the injection line for the number 1 cylinder from the delivery valve holder on the injection pump and from the injection nozzle.

   NOTE: The number 1 cylinder is the cylinder at the flywheel end of the engine.

3. Remove the delivery valve spring for the number 1 cylinder by removing the delivery valve holder and the delivery valve spring, and then reinstalling the delivery valve holder without the delivery valve spring in place.
4. Remove the cylinder head cover.
5. Place the engine at top dead center of the compression stroke for the number 1 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 until the top dead center mark for the number 1 cylinder on the flywheel lines up with the index timing mark on the starter mounting plate.



1.	Injection Timing Mark
2.	Top Dead Center Mark for Number 1 Cylinder
3.	Index Timing Mark on Starter Mounting Plate

Figure 158: Timing Marks

   b. Check the rocker arms on the number 1 cylinder to see if they are loose.

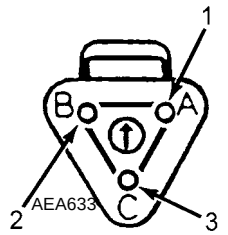
   c. If the rocker arms are loose, the engine is at top dead center of the compression stroke for the number 1 cylinder.

   d. If the rocker arms are tight, the engine is at top dead center of the exhaust stroke for the number 1 cylinder. Rotate the engine 360 degrees to place the engine at top dead center of the compression stroke for the number 1 cylinder.

6. Disconnect the 8S wire from the starter solenoid to prevent the engine from cranking when the unit is turned On.
7. Energize the fuel solenoid and the fuel pump using the Service Test Mode or by turning the unit On. Make sure the Diesel/Electric switch is in the Diesel position on units so equipped.

   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.

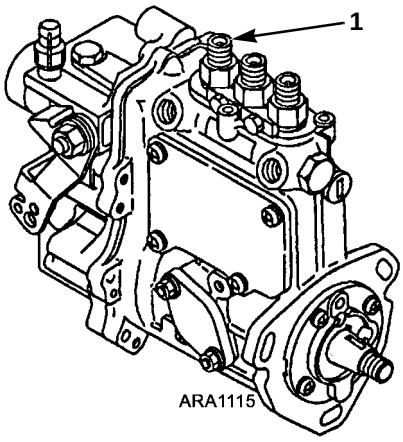


1.	Red (8D)
2.	White (8DP)
3.	Black (CH)

Figure 159: Fuel Solenoid Connector Pin Identification

8. Rotate the engine backwards (counterclockwise viewed from the water pump end) until the injection timing mark (or the 16 degree BTDC mark see Figure 162) is positioned about 1.0 in. (25 mm) below the index timing mark on the starter mounting plate.

9. Use a clean towel to remove the fuel from the top end of the delivery valve holder.

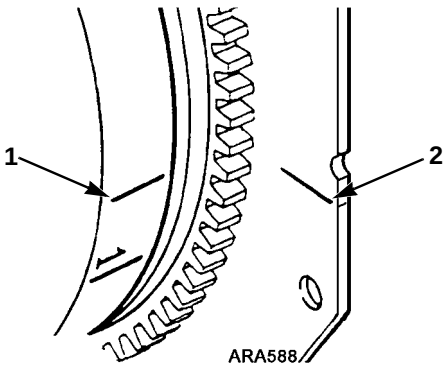


1.	Delivery Valve Holder

Figure 160: Injection Pump

10. 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.

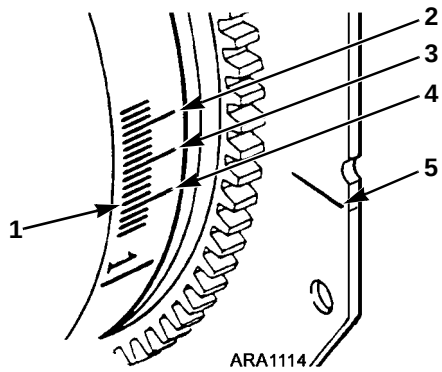
11. Check position of the timing marks. The injection timing mark on the flywheel should be aligned with the index timing mark on the starter mounting plate. Repeat steps 8 through 11 to recheck the timing.



1.	Injection Timing Mark
2.	Index Timing Mark on Starter Mounting Plate

Figure 161: Correct Injection Timing Mark Alignment

NOTE: Some engines have a series of injection timing marks as shown below. The 16 degrees BTDC (before top dead center) mark is the mark that should be aligned with the index timing mark on the starter mounting plate.



1.	16 Degrees BTDC Mark (Correct Timing Mark)
2.	25 Degrees BTDC Mark
3.	20 Degrees BTDC Mark
4.	15 Degrees BTDC Mark
2.	Index Timing Mark on Starter Mounting Plate

Figure 162: Correct Injection Timing Mark Alignment With Series Of Injection Timing Marks

12. 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.

13. Tighten the injection pump mounting nuts and recheck the timing. Repeat steps 8 through 13 until the timing is correct.

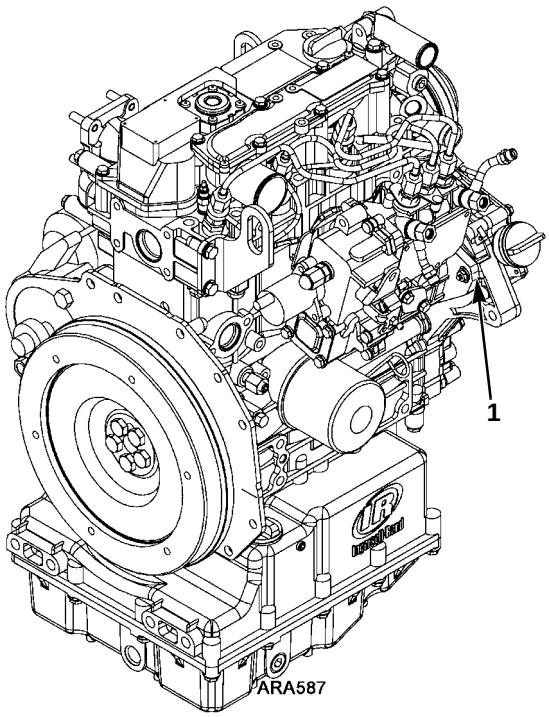
14. Install the delivery valve spring for the number one cylinder by removing the delivery valve holder, installing the delivery valve spring, and then reinstalling the delivery valve holder.

15. Install the injection line for the number one cylinder, the cylinder head cover, tighten the other injection lines, and reconnect the 8S wire to the starter solenoid when finished with the procedure.

Injection Pump Removal and Installation

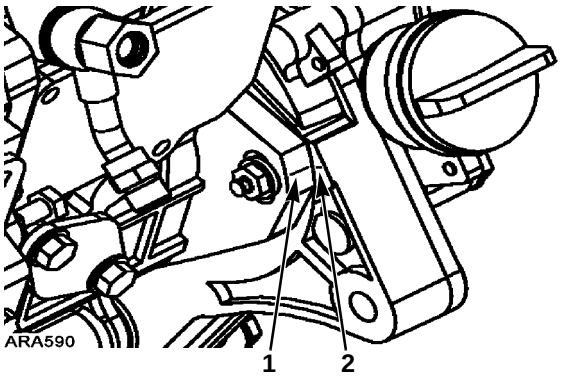
Injection Pump Removal

1. Note the alignment of the index marks on the injection pump and the gear case. If they are not marked, mark them so the injection pump can be returned to the same position when it is reinstalled.



1.	Index Marks

Figure 163: Index Mark Location



1.	Index Mark on Injection Pump
2.	Index Mark on Gear Case

Figure 164: Index Mark Alignment

2. Remove the throttle linkage, fuel lines, wire harness, and mounting hardware from the injection pump.
3. Remove the injection pump timing cover from the gear case.
4. Loosen the injection pump gear mounting nut, but do not remove it yet.

   NOTE: The injection pump gear assembly is made of two pieces, the flange and the gear. Do not loosen or remove the four bolts that fasten the gear to the flange because that changes the timing.

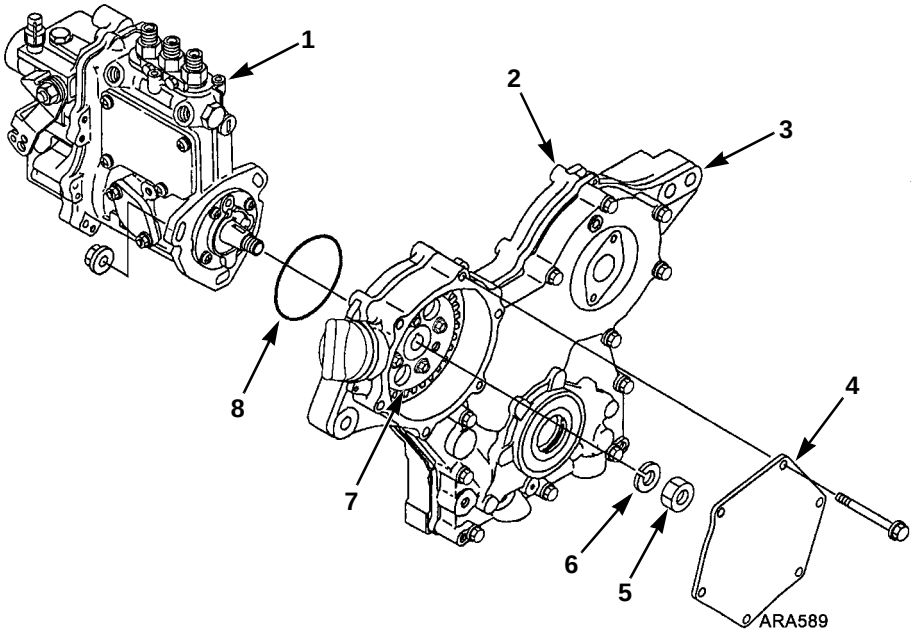
5. Use a suitable puller to loosen the injection pump gear from the injection pump shaft.
6. Remove the injection pump gear mounting nut and lock washer. Use a shop rag to prevent the lock washer or nut from falling into the gear case.
7. Remove the injection pump from the gear case, but leave the injection pump gear in the gear case. This keeps the teeth on the injection pump gear aligned properly with the teeth on the idler gear. If you remove the injection pump gear from the gear case you will have to remove the gear case cover to realign the timing marks on the injection pump gear and the idler gear.

Injection Pump Installation

1. Place a new O-ring on the injection pump and lubricate it with engine oil.
2. Place the injection pump in the gear case. Rotate the injection pump shaft to mate the key in the shaft with the keyway in the injection pump gear. Take care to make sure the key mates with the keyway.
3. Secure the injection pump to gear case with previously removed hardware. Make sure to align the index marks on the injection pump and the gear case like they were in step 1 of “Injection Pump Removal”.

   NOTE: If a different injection pump is being installed, see “Injection Pump Timing” on page 77 to set the timing.

4. Secure the injection pump gear to the injection pump shaft with the lock washer and mounting nut. Use a shop rag, as before, to prevent the lock washer or nut from falling into the gear case. Torque the nut to 43.5 to 50.9 ft-lb (59.0 to 69.0 N•m).
5. Install the injection pump timing cover on the gear case cover, and reinstall all components removed previously to facilitate the injection pump removal.

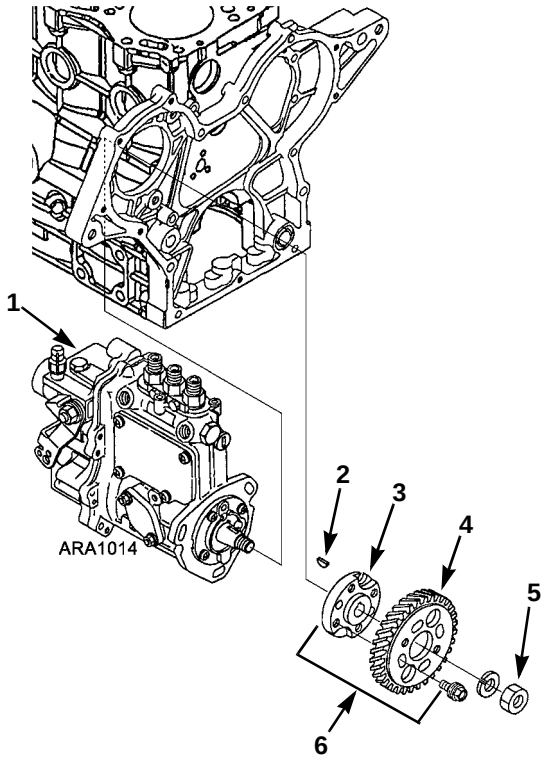


1.	Injection Pump	5.	Injection Pump Gear Mounting Nut
2.	Gear Case	6.	Lock Washer
3.	Gear Case Cover	7.	Injection Pump Gear
4.	Injection Pump Timing Cover	8.	O-Ring

Figure 165: Injection Pump Removal and Installation

Attaching Injection Pump Gear to Flange

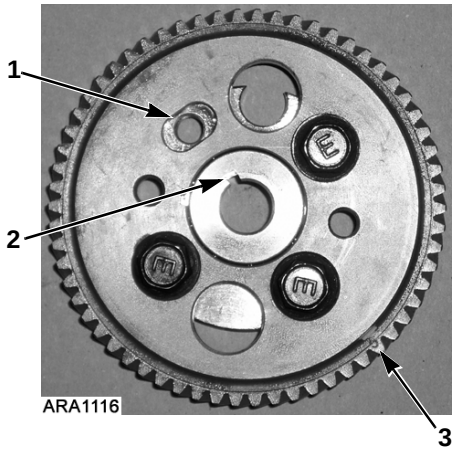
These engines have a two-piece injection pump gear. The injection pump gear should not be removed from the flange because that changes the timing. However, if the injection pump gear was removed from the flange, use the following procedure to assemble them correctly.



1.	Fuel Injection Pump
2.	Key
3.	Flange
4.	Injection Pump Gear
5.	Nut (Injection Pump Gear)
6.	Do Not Remove Gear From Flange

Figure 166: Two-Piece Fuel Injection Pump Gear

1. Find the timing mark on the injection pump gear. The timing mark is typically the letter “B”, stamped on a tooth near the edge of the gear. However, it can be the letter “C” or one or more dots. It is also marked with a dab of white paint.
2. Place the injection pump gear on the flange so the timing mark on the injection pump gear is approximately 180 degrees from the keyway in the flange.
3. Install three of the injection pump gear mounting bolts and tighten them finger tight.
4. Center the remaining mounting bolt hole the flange in the remaining mounting bolt slot in the injection pump gear. The slotted adjustment is used to enable the factory to adjust the timing more rapidly during assembly. If the flange and gear are disassembled, the hole is centered in the slot and the injection pump must be flow timed.



1.	Hole in Flange Centered in Slot in Gear
2.	Keyway in Flange
3.	Letter “B”

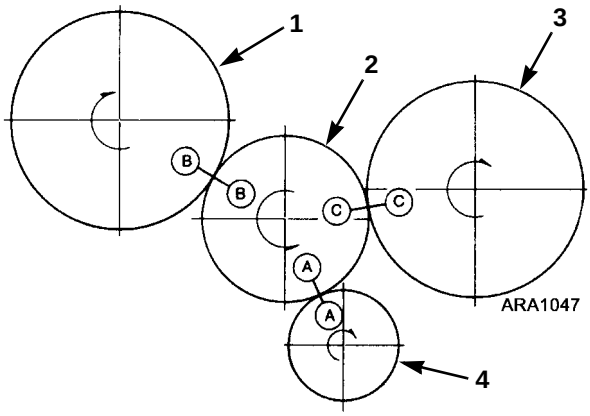
Figure 167: Flange and Injection Pump Gear Alignment

5. Install the remaining injection pump gear mounting bolt and torque all of them to 25 ft-lb (34 N•m).

6. Install the injection pump gear assembly on the fuel injection pump. Torque the mounting nut to 43.5 to 50.9 ft-lb (59.0 to 69.0 N•m). The timing marks on the timing gears must be aligned as shown below with the Number 1 Cylinder at TDC (Top Dead Center) of the compression stroke. It helps to install the idler gear last when aligning the timing marks.

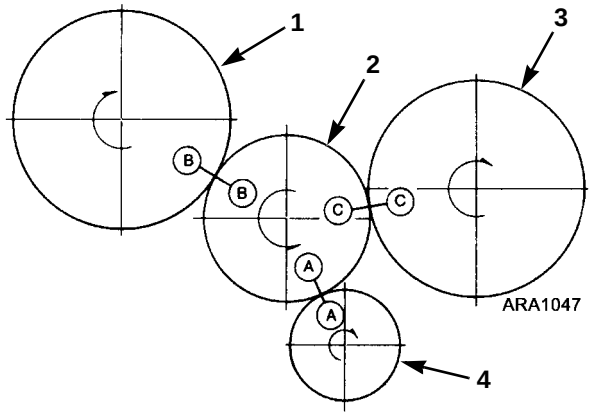
   NOTE: Typically, the A mark on the idler gear should line up with the A mark on the crankshaft gear, the B mark on the idler gear should line up with the B mark on the camshaft gear, and the C mark on the idler gear should line up with the C mark on the injection pump gear.

   However, you might see engines with the B mark on the injection pump gear and the C mark on the camshaft gear. You might also see engines that use one, two, and three dots instead of letters for timing marks. In any case, Align the timing marks on the idler gear with the corresponding timing marks on the crankshaft gear, the camshaft gear, and the injection pump gear.



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

Figure 168: Typical Timing Mark Alignment



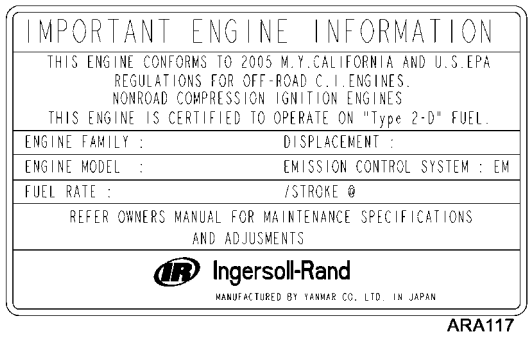
1.	Fuel Injection Pump Gear
2.	Idler Gear
3.	Camshaft Gear
4.	Crankshaft Gear

Figure 169: Alternate Timing Mark Alignment

7. Flow time the fuel injection pump. See “Injection Pump Timing” on page 77.

Fuel Limit Screw

The fuel limit screw is not adjustable. It is equipped with an anti-tamper cap to fulfill requirements for CARB (California Air Resources Board) emission regulations. Service technicians must be CARB certified to perform service on the fuel limit screw for equipment operating in California.


IMPORTANT ENGINE INFORMATION

THIS ENGINE CONFORMS TO 2005 M.Y. CALIFORNIA AND U.S.EPA REGULATIONS FOR OFF-ROAD C.I. ENGINES.
NONROAD COMPRESSION IGNITION ENGINES
THIS ENGINE IS CERTIFIED TO OPERATE ON "Type 2-D" FUEL.

ENGINE FAMILY :	DISPLACEMENT :
ENGINE MODEL :	EMISSION CONTROL SYSTEM : EM
FUEL RATE :	/STROKE @

REFER OWNERS MANUAL FOR MAINTENANCE SPECIFICATIONS AND ADJUSMENTS

Ingersoll-Rand

MANUFACTURED BY YANMAR CO. LTD. IN JAPAN

ARA117

Figure 170: Emission Control Label

Fuel Injection Nozzles

The fuel injection nozzles for the TK270 and TK370 engines are not interchangeable with the fuel injection nozzles for the TK376 engine, but the testing and repair procedures are the same.

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.

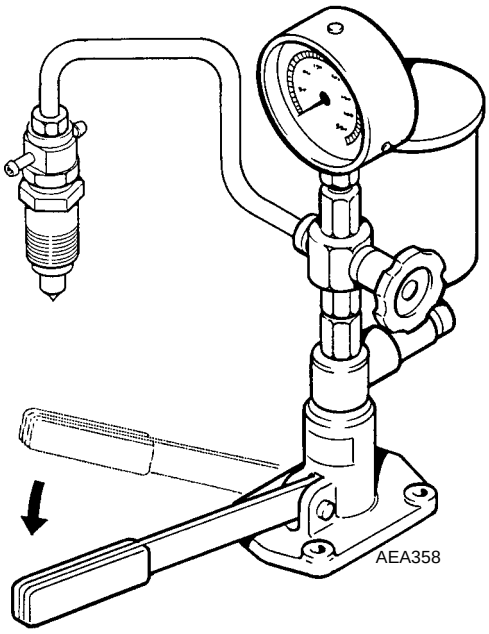


Figure 171: Testing Injection Nozzles

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. A straight conical spray pattern should form along the center line of the injection nozzle, with a cone angle of 5 to 10 degrees.

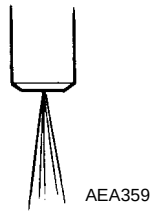


Figure 172: Acceptable Spray Pattern

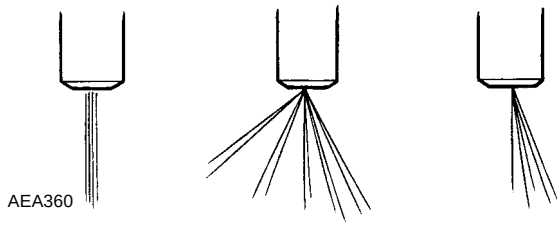


Figure 173: Unacceptable Spray Patterns

   c. The spray pattern should make a perfect circle on a piece of paper placed 12 in. (300 mm) below the injection nozzle.

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 1,784 to 1,929 psi (12,300 to 13,300 kPa).

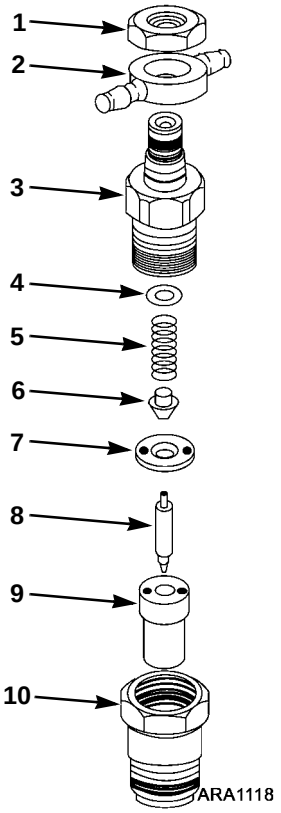
   c. Adjust the opening pressure by changing the size or number of adjustment shims above the spring. See the repair procedure on page 85.

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 collar ports 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, spring seat, spring, and adjustment shim(s) from the nozzle holder.



1.	Return Collar Nut
2.	Return Collar (Part of Fuel Return Tube)
3.	Nozzle Body
4.	Adjustment Shim
5.	Spring
6.	Spring Seat
7.	Spacer
8.	Nozzle Valve
9.	Nozzle Seat
10	Nozzle Nut

Figure 174: Injection Nozzle Assembly

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.
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.

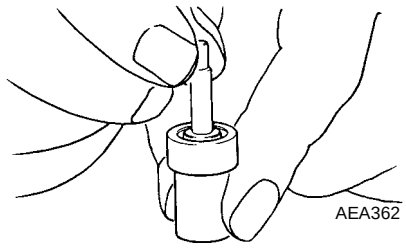


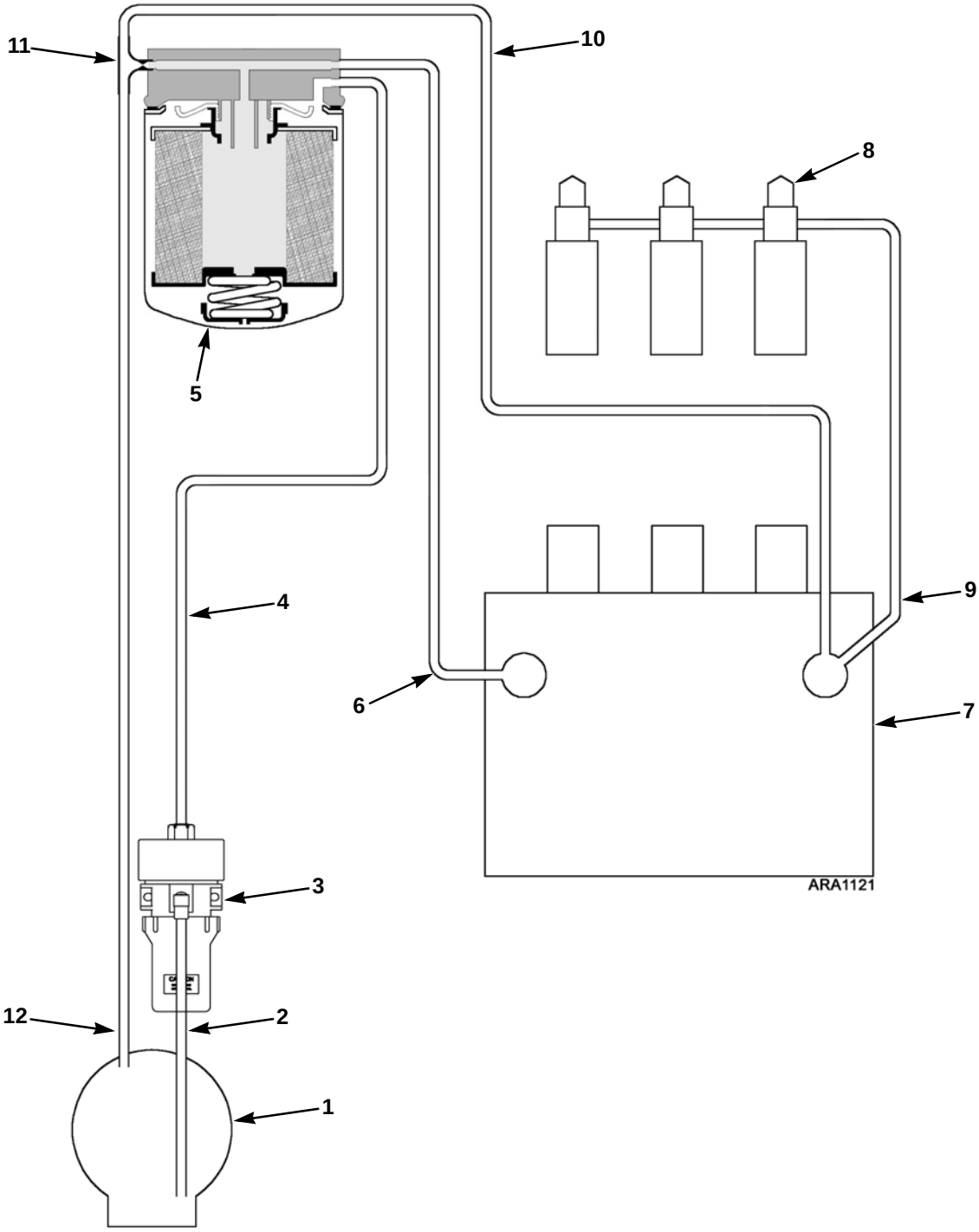
Figure 175: Testing Nozzle Valve and Seat Set

   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.

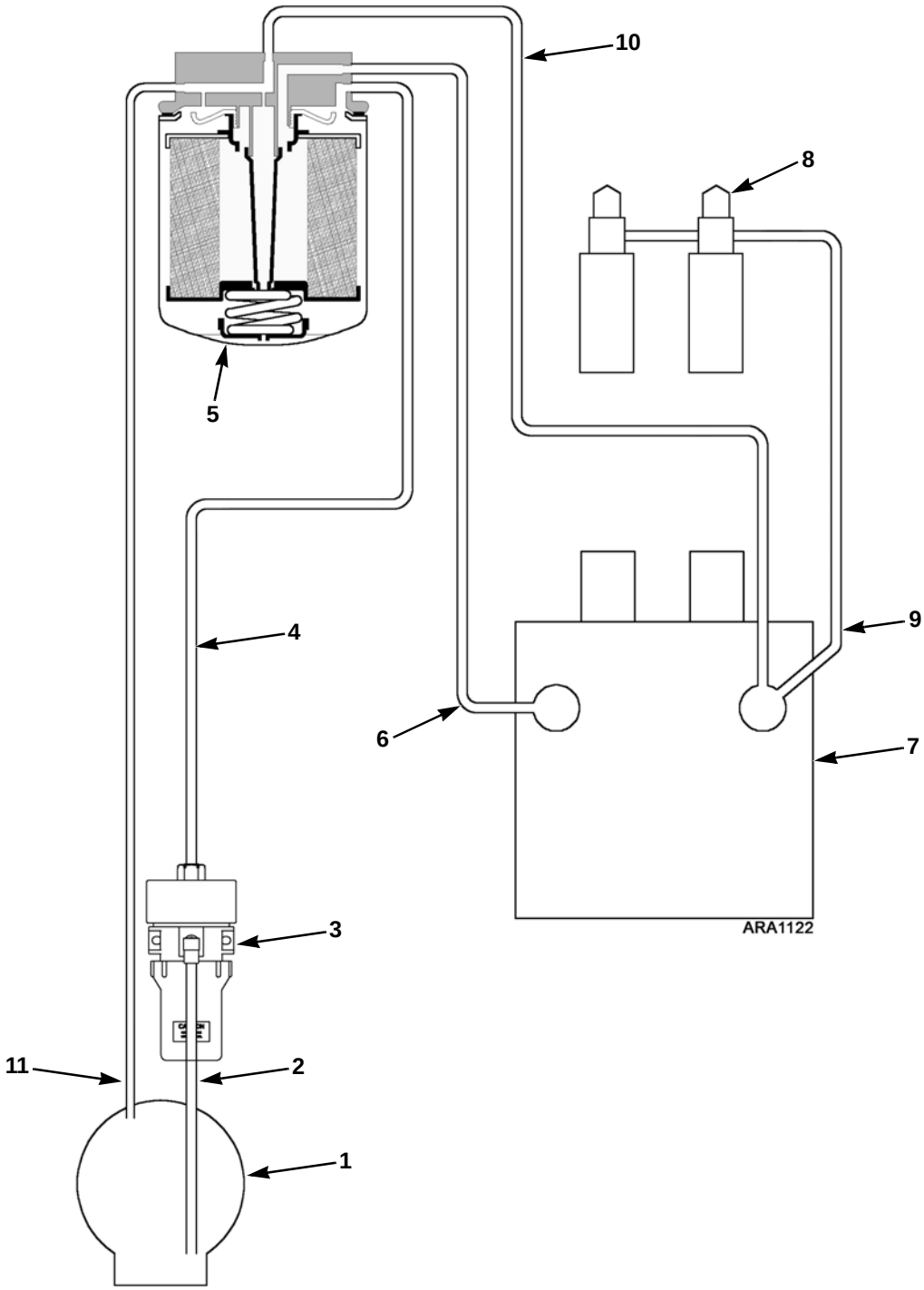
10. Clamp the nozzle body in a vise with the nozzle nut end up.

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 and spring seat in the nozzle body.
13. Place the spacer on the spring seat and nozzle body.
14. Place the nozzle valve and seat set on the spacer.
15. Install the nozzle nut and torque it to 21.4 to 36.1 ft-lb (29.0 to 49.0 N•m).
16. Test the injection nozzle and adjust the opening pressure as necessary.



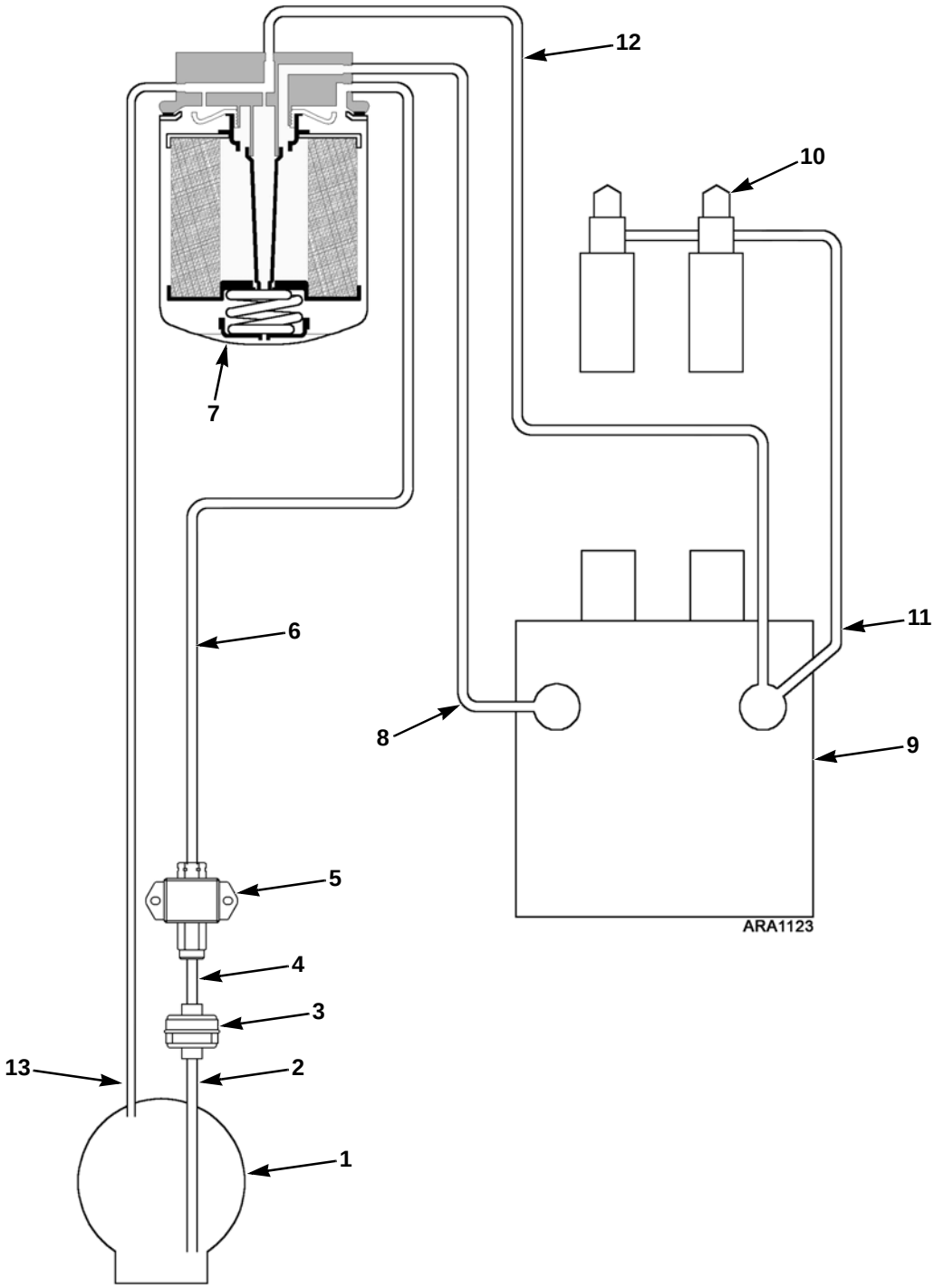
1.	Fuel Tank	7.	Fuel Injection Pump
2.	Supply from Fuel Tank to Electric Fuel Pump	8.	Fuel Injection Nozzle
3.	Electric Fuel Pump	9.	Return from Injection Nozzles to Injection Pump
4.	Supply from Electric Fuel Pump to Fuel Filter	10.	Return from Injection Pump to Fuel Filter
5.	Fuel Filter Assembly	11.	Return Tee with 0.020 in. (0.51 mm) Orifice
6.	Supply from Fuel Filter to Fuel Injection Pump	12.	Return from Fuel Filter to Fuel Tank

Figure 176: Fuel System Diagram for Typical Truck Unit



1.	Fuel Tank	7.	Fuel Injection Pump
2.	Supply from Fuel Tank to Electric Fuel Pump	8.	Fuel Injection Nozzle
3.	Electric Fuel Pump	9.	Return from Injection Nozzles to Injection Pump
4.	Supply from Electric Fuel Pump to Fuel Filter	10.	Return from Injection Pump to Fuel Filter
5.	Fuel Filter Assembly	11.	Return from Fuel Filter to Fuel Tank
6.	Supply from Fuel Filter to Fuel Injection Pump		

Figure 177: Fuel System Diagram for Typical HK Unit



1.	Fuel Tank	8.	Supply from Fuel Filter to Fuel Injection Pump
2.	Supply from Fuel Tank to In-Line Fuel Filter	9.	Fuel Injection Pump
3.	In-Line Fuel Filter	10.	Fuel Injection Nozzle
4.	Supply from In-Line Fuel Filter to Electric Fuel Pump	11.	Return from Injection Nozzles to Injection Pump
5.	Electric Fuel Pump	12.	Return from Injection Pump to Fuel Filter
6.	Supply from Electric Fuel Pump to Fuel Filter	13.	Return from Fuel Filter to Fuel Tank
7.	Fuel Filter Assembly		

Figure 178: Fuel System Diagram for Typical TriPac Unit

Fuel System Operation and Diagnosis

The following section discusses some characteristics of the fuel system and some things to consider when troubleshooting the fuel system. The Fuel System Diagrams (Figures 176, 177, and 178) on the previous pages show the main components of various fuel systems.

Normal Fuel System Operation

The electric fuel pump creates a vacuum in the supply line at the fuel tank, and the atmospheric pressure in the tank pushes the fuel up the pickup tube, into the fuel supply line, and on to the electric fuel pump. Some units such as the TriPac have an inline fuel filter in the supply line between the fuel tank and the electric fuel pump. The pressure in the pickup line should always be negative when the electric fuel pump is energized. It will be negative or at atmospheric pressure when the electric fuel pump is de-energized.

Electric Fuel Pump

The electric fuel pump pushes the fuel through the supply line to the fuel filter assembly. Fuel pressure near the outlet of the electric fuel pump should be 9.0 to 10.5 psi (62 to 72 kPa).

As fuel is pushed up to the filter head, the pressure drops. This is caused partially by the flow resistance from the fuel lines, and partially by the weight of the fuel pushing against gravity. System pressure at the filter head will depend on how high the unit is mounted above the fuel tank, and the restrictions created by the fuel line and fuel line routing.

You can also check the electric fuel pump by energizing it with the outlet line placed in a bucket or can. There should be a good flow of solid fuel coming out of the pump when the fuel pump is energized.

If the pump does not operate, check for the following:

- A good ground to the pump body.
- Clean and tighten the electrical connections.
- The pump requires a minimum of 9 Vdc at the positive terminal.

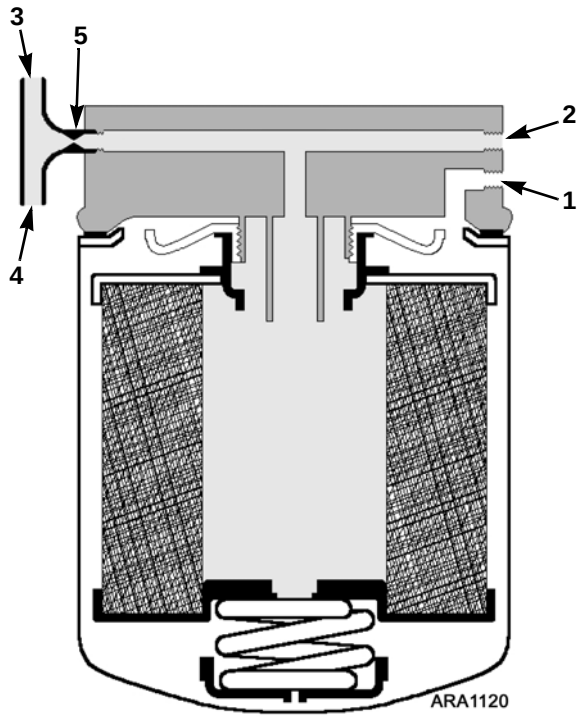
If the pump operates but does not deliver fuel, check for the following:

- Air leaks in the fuel lines or connections.
- Kinks or other restrictions in the fuel lines.
- A leaking or distorted cover gasket.
- A clogged or dirty fuel pump filter (or inline filter if used).

Refer to the unit Maintenance Manual for more information about the electric fuel pump.

Fuel Filter Assembly Used In Truck Units

The fuel filter assembly removes air and filters the fuel. There are five openings on the filter housing. One is the inlet for fuel from the electric fuel pump. The other openings are all connected to the same internal passage. The outlet for clean fuel to the injection pump is connected to one. The return tee is connected to another. The other openings are plugged.



1.	Inlet from Electric Fuel Pump
2.	Outlet to Injection Pump
3.	Inlet for Return from Injection Pump and Nozzles
4.	Outlet for Return to Fuel Tank
5.	0.020 in. (0.51 mm) Orifice in Return Tee

Figure 179: Fuel Filter Assembly Used In Truck Units

The inlet for fuel returning from the injection pump and nozzles, and the outlet that returns air, and excess fuel to the fuel tank are connected to the return tee.

The fuel is forced through the filter media to remove the dirt. Any air in the fuel rises to the top. There is a small orifice in the return tee that allows air out into the return fuel line where it returns to the fuel tank with the return fuel. There is a limit to the amount of air that can flow through the orifice, and eventually the engine will stop if enough air passes through the filter assembly to the injection pump. The orifice also causes a small drop in fuel pressure as it bleeds off air and fuel. Under normal conditions there is plenty of extra flow and the small reduction of flow (and pressure) is not significant.

The fuel then travels to the injection pump. However, there are still some things to consider.

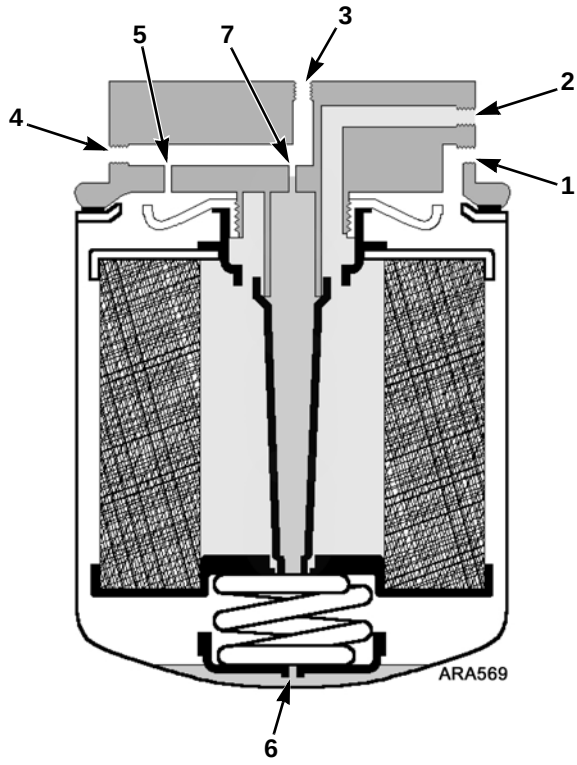
The first is that the system pressure drops as the fuel is pushed up to the filter.

The second is that there will be a pressure drop through the filter media and the outlet pressure to the injection pump is a few psi (or kPa) less than the outlet pressure from the electric fuel pump.

The third thing to be aware of is that the pressure drop is proportional to the amount of dirt the filter has trapped in the media. If there is a lot of dirt, there is a lot of restriction, and more of a pressure drop. As the dirt builds up, the outlet pressure keeps dropping, and eventually the engine dies. The outlet pressure from the fuel filter is a good measurement of how clogged the filter is.

Fuel Filter Assembly Used In HK and TriPac Units

The fuel filter assembly used in HK and TriPac units is the same one used in trailer units. The fuel filter assembly removes air, removes water, and filters the fuel. There are four openings on the filter housing; the inlet for fuel from the transfer pump, the outlet for clean fuel to the injection pump, the inlet for fuel returning from the injection pump and nozzles, and the outlet that returns air, water, and excess fuel to the fuel tank.



1.	Inlet from Electric Fuel Pump
2.	Outlet to Injection Pump
3.	Inlet for Return from Injection Pump and Nozzles
4.	Outlet for Return to Fuel Tank
5.	Air Outlet Hole
6.	Water Pickup Tube Inlet
7.	Water Outlet (Bleed) Hole

Figure 180: Fuel Filter Assembly Used In HK and TriPac Units

First, the air is removed. As the fuel is pushed in to the filter assembly, any air in the fuel rises to the top. There is a small outlet hole drilled in the top of the assembly that allows air out into the return fuel passage where it returns to the fuel tank with the return fuel. There is a limit to the amount of air that can flow through the outlet hole, and eventually the engine will stop if enough air passes through the filter assembly to the injection pump. The small bleed hole also causes a small drop in fuel pressure as it bleeds off air and fuel. Under normal conditions there is plenty of extra flow and the small reduction of flow (and pressure) is not significant.

Next, the water is removed. The filter media contains a coating that attracts water. It is called coalescing media. The water builds up on the coalescing media and forms drops that fall to the bottom of the filter can. The Thermo King filter has a patented system to remove the water that collects at the bottom of the filter. The filter has a long rubber tube that extends almost to the bottom. The tube is sealed to the small metal pipe that protrudes down through the filter spud. The pipe is screwed into the filter housing. There is a small (0.030 in.) bleed hole drilled from the passage the pipe is screwed into up into the return fuel passage in the filter head. The water is pushed up the rubber tube, through the pipe and bleed hole into the return fuel passage because the pressure in the return fuel passage is lower than the pressure in the filter. This also causes a small drop in fuel pressure as it bleeds off water and fuel.

As the air and water are being removed, fuel is also being forced through the filter media. The fuel is now free of air, water, and dirt. It then travels to the injection pump. However, there are still some things to consider.

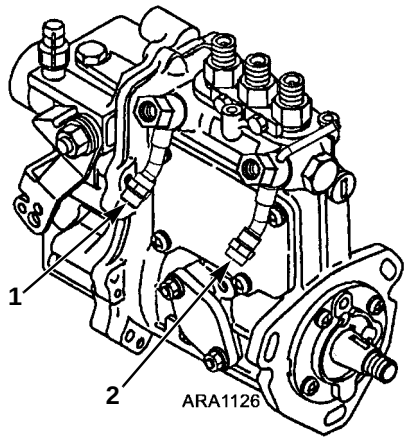
The first is that the system pressure drops as the fuel is pushed up to the filter.

The second is that there will be a pressure drop through the filter media and the outlet pressure to the injection pump is a few psi (or kPa) less than the outlet pressure from the electric fuel pump.

The third thing to be aware of is that the pressure drop is proportional to the amount of dirt the filter has trapped in the media. If there is a lot of dirt, there is a lot of restriction, and more of a pressure drop. As the dirt builds up, the outlet pressure keeps dropping, and eventually the engine dies. The outlet pressure from the fuel filter is a good measurement of how clogged the filter is.

Injection Pump

The clean fuel enters the injection pump at the fitting farthest from the gear end of the pump. It then travels in the pump gallery and provides fuel to each plunger. The electric fuel pump provides more fuel than the engine needs so a return outlet port is provided at the gear end of the pump. To help maintain consistent system pressure, a relief valve is installed in the return outlet of the injection pump. The relief valve protects the injection pump. Unfortunately, it can also cause some problems that are discussed later in this section.



1.	Inlet from Fuel Filter Assembly
2.	Return Outlet to Fuel Filter Assembly

Figure 181: Injection Pump

Return System

There are three sources of return fuel that goes back to the fuel tank:

- Excess fuel from the injection pump.
- Fuel that leaks from the injection nozzles.
- Fuel that is bled through the orifice in return tee on truck units, or fuel that is bled through the air and water bleed ports in the filter housing on HK and TriPac units.

The excess fuel from the injection pump and the leakage fuel from the injection nozzles are combined at a fitting on the outlet of the injection pump. This is located after the relief valve. The combined return fuel from the injection pump and injection nozzles travels through a return line to the return tee on truck units, or to the return passage in fuel filter head on HK and TriPac units. The return tee, or the return passage in the filter head, takes the return fuel from the injection pump and injection nozzles and transfers it to the return fuel outlet to the fuel tank. The air and water bleed ports also empty into this passage so this combines all the fuel, air, and water returning to the fuel tank.

Static Pressures

When the engine is shut off the return fuel that is in the return line wants to drain back down into the tank. To do that the drain-back fuel would need to be replaced with air pulled into the system or fuel pulled from the system. When the engine stops there is positive pressure in the fuel system. This pressure closes the check valve in the electric fuel pump. As long as the pressure in the system stays positive, the check valve stays closed. The fuel in the supply line also tries to drain back and it helps keep the check valve closed. If there is no air and there is no fuel to replace the drain-back fuel, a vacuum starts to form in the system. The air and water bleed holes in the filter head connect the pressure (supply side) of the system to the return side of the system so when the vacuum occurs, it occurs throughout the whole system, right to the check valve in the electric pump. If there are no air leaks in the system, it will stay like this until the engine is started again. There is no air so the engine starts easily.

Static Air Leaks

There are two places where air can leak into the static fuel system:

- One is through the plungers in the injection pump. It leaks from the pump camshaft and lifter area around the plungers and into the fuel galley in the pump. Over the years the plunger clearances have been reduced to try to prevent air leaks.
- The other is anywhere else.

If air is leaking through the plungers, the injection pump could fill with air and the air may not be forced out by the electric fuel pump in time to start because of the restriction created at the relief valve. The engine will not start, and might not even try to fire because of the air in the injection pump.

Use the following procedure to diagnose air leaking through the plungers: Install clear fuel lines for the injection pump supply and return lines. Run the engine enough to purge all air from the clear fuel lines. Turn the unit off and allow it to sit for awhile. While watching the clear fuel lines, energize the fuel pump. If air comes out the return line but not the supply line, the plungers in the injection pump are leaking. Make sure to verify it is not the banjo sealing washers leaking before condemning the injection pump.

If the air is getting in anywhere else, it will end up in the fuel filter and the engine will start, run for a few seconds, and then die. In this case you may see an Alarm Code 63 on a unit with a microprocessor.

FAQ (Frequently Asked Questions)

If the unit is leaking air when it’s off, why doesn't it leak fuel when it runs?

It is probably a matter of time and size. Most of the hard starting problems caused by air take a long engine off period, usually days or weeks, indicating they are extremely small. It could be that the fuel boils off a warm engine before it is even seen.

Why can't I find the leaks when I pressurize the fuel system?

Again, it is time and size. If you pressurize the fuel tank, do not go over 5 to 10 psi (34 to 69 kPa). Never pressurize a fuel system without a relief valve in the supply regulator set at 10 psi [69 kPa] maximum. A leak that pulls in 50 cc of air in a week (enough to affect starting) is going to take hours or days to show under pressure.

How do I know if air is leaking through the injection pump plungers?

Use the following procedure to diagnose air leaking through the plungers: Install clear fuel lines for the injection pump supply and return lines. Run the engine enough to purge all air from the clear fuel lines. Turn the unit off and allow it to sit for awhile. While watching the clear fuel lines, energize the fuel pump. If air comes out the return line but not the supply line, the plungers in the injection pump are leaking. Make sure to verify it is not the banjo sealing washers leaking before condemning the injection pump.

What if there is air coming from somewhere else and I just cannot find it?

Pressurizing the system for 24 hours, if possible, may show a small leak. Use clear fuel lines and pressure gauges to diagnose problems that are difficult to find.

Why doesn't other diesel-powered equipment have air leakage problems when they are off?

Refrigeration units on trucks are one of the few pieces of equipment that mount the fuel tank so far below the engine.

Using Clear Fuel Lines To Diagnose Problems

To use clear fuel lines most effectively use the following lines and gauges.

1. Remove the supply line from the fuel tank at the electric fuel pump. Add on about two or three feet of clear line and attach it to the inlet of the electric fuel pump. This allows you to see if the fuel drops down after the engine stops. If it does, either the electric fuel pump check valve is not working, or air is being pulled in at the supply fitting. You do not normally need a gauge at this point. This line is usually in a vacuum when the engine is off or running.
2. Verify the fuel pump output pressure by installing a gauge on the fuel pump outlet and energizing the pump. With the outlet plugged off, the pressure should build to 9 to 12 psi (62 to 83 kPa).
3. Install a clear line from the fuel filter outlet to the injection pump. This line allows you to see fuel come from the fuel filter to the injection pump when the engine starts. If a gauge is used it should show a pressure a couple psi (or kPa) lower than the fuel filter inlet pressure because of drop from the filter.
4. Install a clear line from the return outlet of the injection pump to the fuel filter head. This line allows you to see air that comes from the injection pump when the engine starts. The gauge should show the 3 to 5 psi (21 to 34 kPa) of return line back pressure.

By observing the formation and travel of air, knowing fuel pump output pressure, along with some basic knowledge of the fuel system, you should be able to diagnose and repair most problems.

Glow Plugs

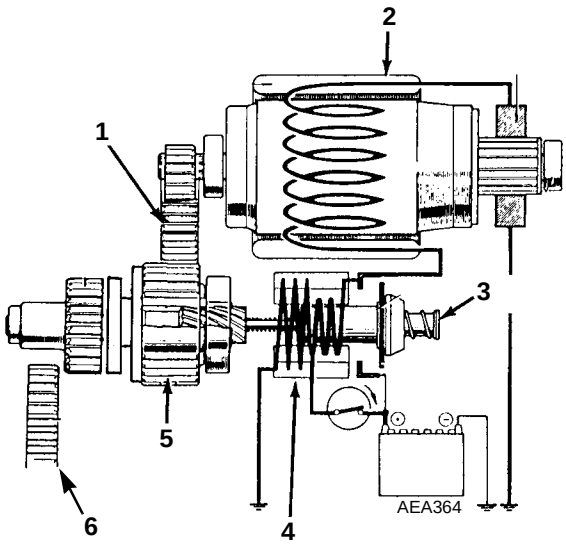
The glow plugs heat the prechambers in the cylinder head. This helps the engine start easier in cold weather. The glow plugs can be tested with an ohmmeter. Each glow plug should have a resistance of 2.1 to 2.5 ohms. Replace glow plugs with a resistance that is out of this range.

Figure 182: Glow Plug

Starter

Description

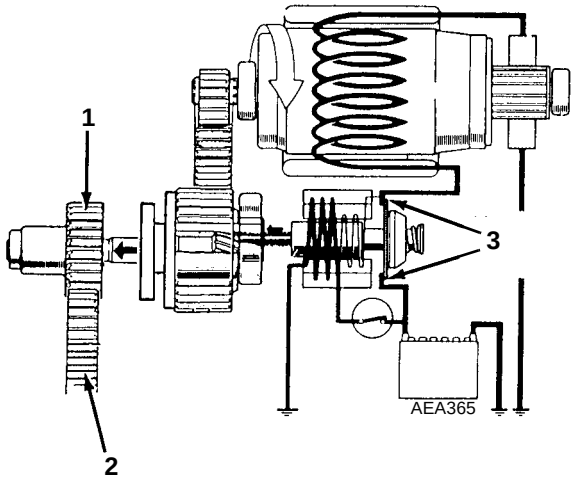
The major components of the starter are the starter motor, the starter solenoid, and the pinion assembly. The starter motor turns the pinion assembly through an idler gear.



1.	Idler Gear
2.	Starter Motor
3.	Plunger
4.	Starter Solenoid
5.	Pinion Assembly
6.	Ring Gear

Figure 183: De-energized Starter

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

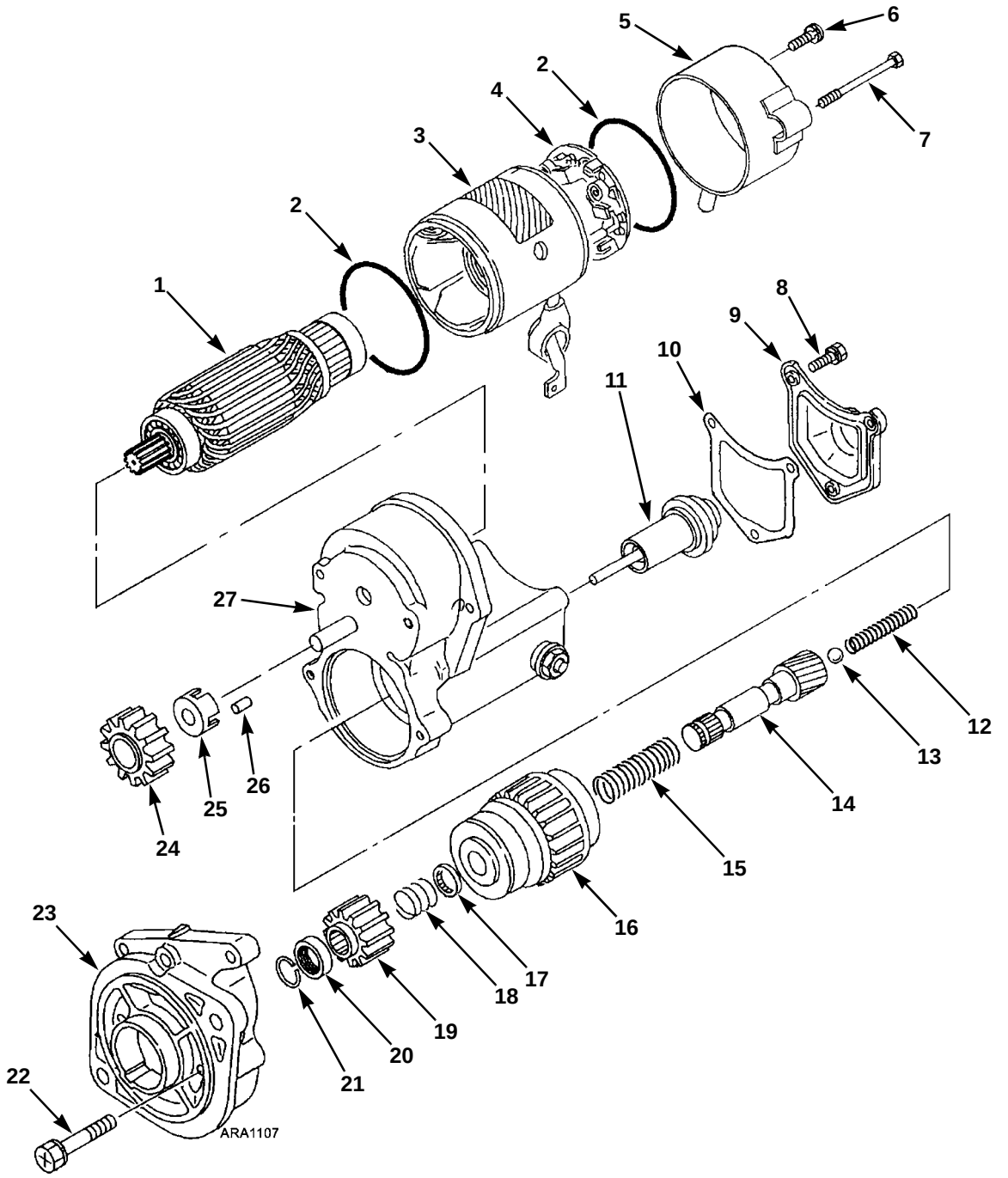


1.	Pinion Gear
2.	Ring Gear
3.	Heavy Duty Contacts

Figure 184: Energized Starter

Disassembly

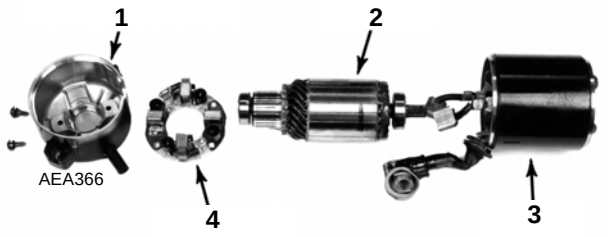
1. Disconnect the stator lead from the C terminal on the side of the starter solenoid.
2. Remove the two through bolts from the commutator cover and remove the starter motor from the starter solenoid and pinion housing.



1.	Armature	10.	Gasket	19.	Pinion Gear
2.	O-Ring	11.	Starter Solenoid Plunger	20.	Stop Ring
3.	Stator	12.	Solenoid Spring	21.	Snap Ring
4.	Brush Ring	13.	Ball	22.	Screw
5.	Commutator Cover	14.	Pinion Shaft	23.	Pinion Housing
6.	Screw	15.	Pinion Shaft Spring	24.	Idler Gear
7.	Through Bolt	16.	Pinion Clutch	25.	Bearing Retainer
8.	Bolt	17.	Pinion Shaft Retainer	26.	Bearing (Roller)
9.	Starter Solenoid Cover	18.	Pinion Gear Spring	27.	Starter Solenoid Housing

Figure 185: Starter Assembly

3. Disassemble the starter motor.



1.	Commutator Cover
2.	Armature
3.	Stator
4.	Brush Ring

Figure 186: Starter Motor

a. Remove the two screws, which fasten the brush ring to the commutator, from the back of the commutator cover and remove the commutator cover from the starter motor.

b. Place the brush springs on the sides or the brush holders.

c. Remove the positive brushes (the brushes connected to the stator) from the brush holders.

d. 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.

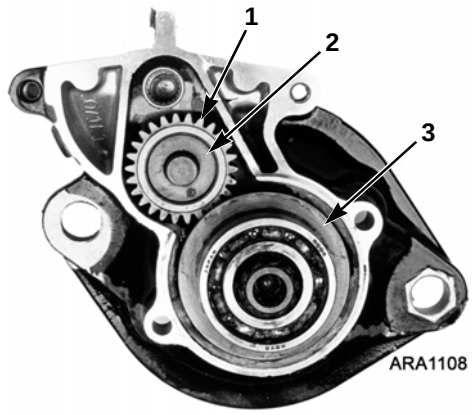
e. Remove the brush holder assembly from the commutator.

f. Remove the armature from the stator.

4. Remove the two screws from the pinion housing and separate the pinion housing from the starter solenoid housing. Make sure to keep track of the solenoid spring and the steel ball that are located between the solenoid plunger and the pinion shaft.

5. Remove the components from the pinion housing.

a. Remove the idler gear, bearing retainer, and bearings.



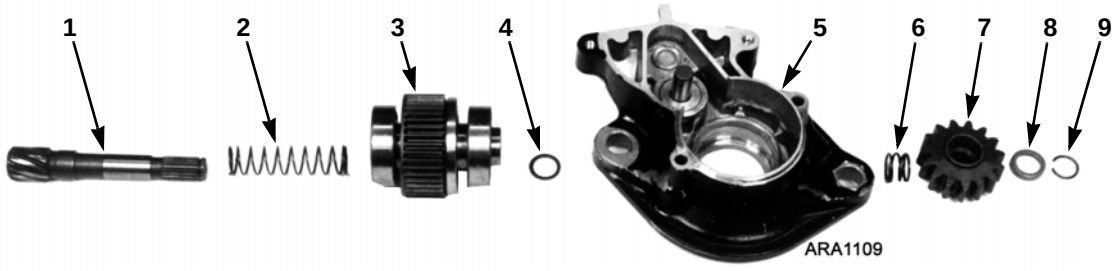
1.	Idler Gear
2.	Bearing Retainer
3.	Pinion Assembly

Figure 187: Pinion Housing

b. Support the end of the pinion shaft that faces the starter solenoid.

c. Push the pinion gear away from the stop ring and hold the pinion gear in that position.

d. Push the stop ring off the snap ring and remove the snap ring from the end of the pinion shaft.



1.	Pinion Shaft	4.	Pinion Shaft Retainer	7.	Pinion Gear
2.	Pinion Shaft Spring	5.	Pinion Housing	8.	Stop Ring
3.	Pinion Clutch	6.	Pinion Gear Spring	9.	Snap Ring

Figure 188: Pinion Assembly

e. Remove the stop ring, pinion gear, and pinion gear spring from the pinion gear shaft.

f. Remove what remains of the pinion assembly from the pinion housing.

g. Remove the pinion shaft retainer, pinion clutch, and pinion shaft spring from the pinion shaft.

6. Disassemble the starter solenoid.

   a. Remove the three screws from the cover and remove the cover from the starter solenoid housing.

   b. Remove the plunger from the starter solenoid housing.

Figure 189: Starter Solenoid Assembly

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 0.45 in. (11.1 mm) on the short side. Replace the brushes as a set, or replace the brush ring assembly.

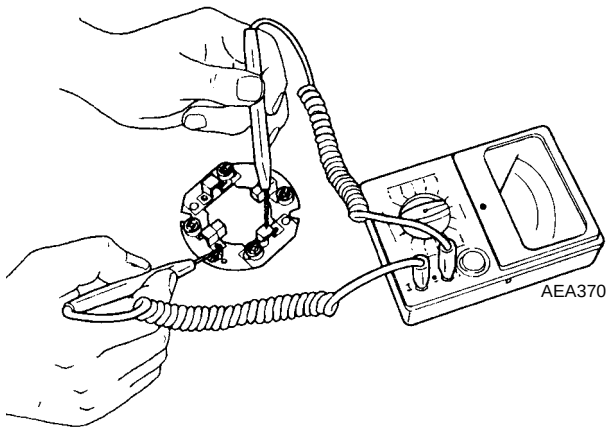


Figure 190: Check Brush Holders

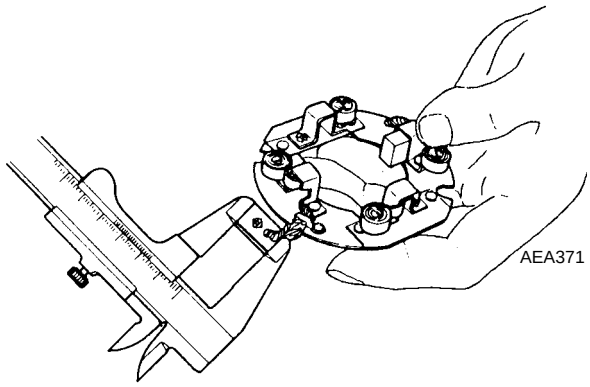


Figure 191: Measure Brushes

   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.

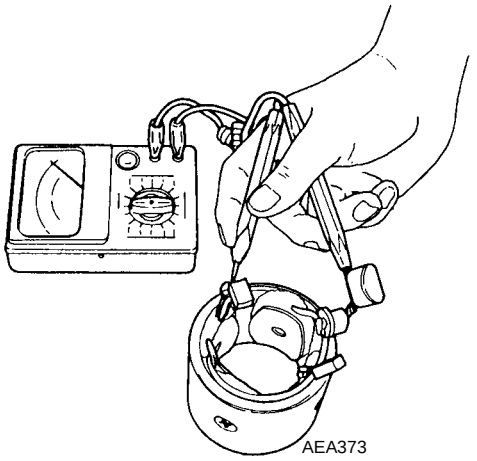


Figure 192: Check Field Coil

   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.

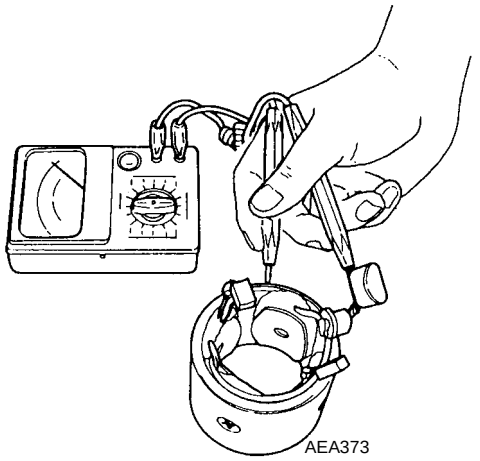


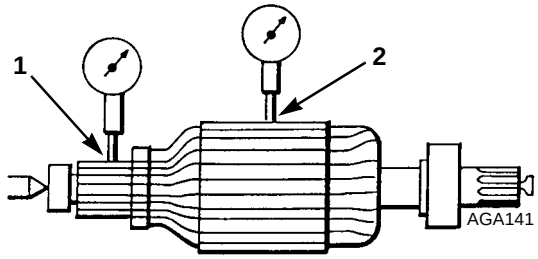
Figure 193: Check Stator Insulation

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 0.002 in. (0.05 mm).



1.	Commutator
2.	Core

Figure 194: 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 1.06 in. (27.0 mm) after being turned down.

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

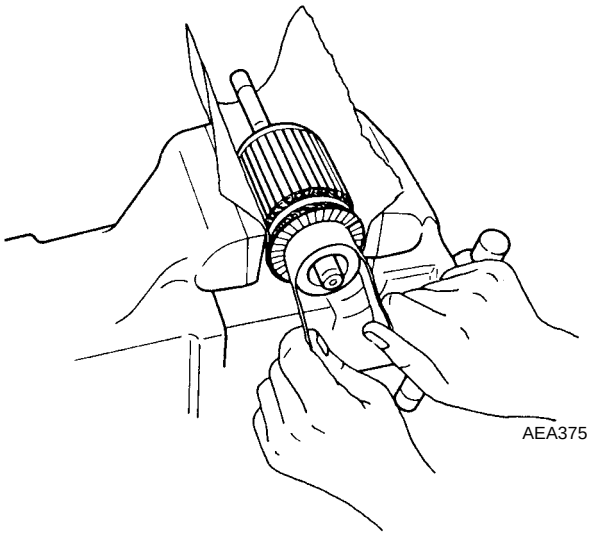
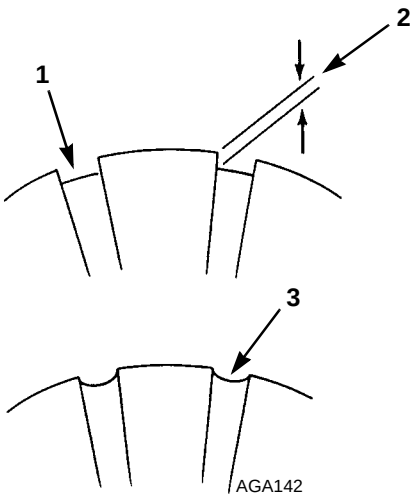


Figure 195: Clean Up Commutator

g. After turning down the commutator, check the undercut of the mica. The standard undercut is 0.02 in. (0.6 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 in. (0.6 mm)
3.	Incorrect

Figure 196: 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.

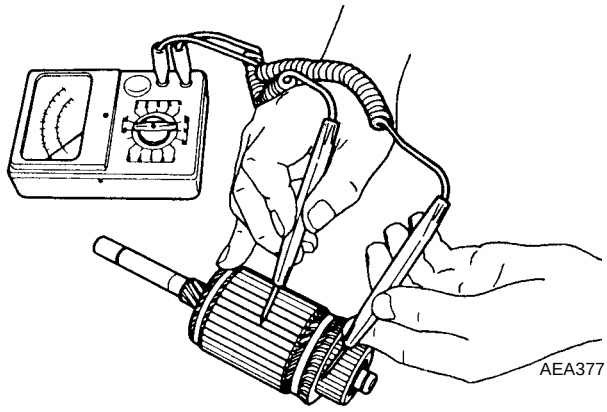
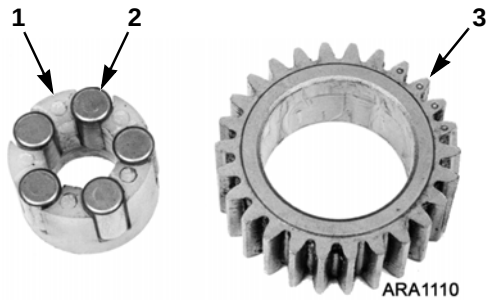


Figure 197: Check Armature Insulation

Gear and Bearings

Inspect the idler gear, idler gear bearings, and bearing retainer. Replace any of these parts that show significant wear or damage.



1.	Bearing Retainer
2.	Bearing
3.	Idler Gear

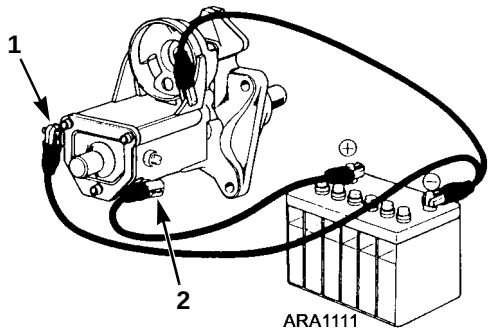
Figure 198: Inspect Idler Gear and Bearings

Pinion Assembly

1. Inspect each part of the pinion assembly and replace any part that shows significant wear or damage.
2. Check the overrunning clutch.
   a. Hold the pinion clutch.
   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 heavy duty contacts on the plunger and inside the starter solenoid. Clean these contacts if they are dirty or burnt.
2. Use the following assembly procedure to assemble the starter solenoid, place the pinion assembly in the pinion housing, and attach the starter solenoid to the pinion housing. Test this assembly as follows:
   a. Use jumper wires to connect the negative (-) terminal of a 12 volt battery to the starter solenoid chassis and to the C terminal on the starter solenoid.
   b. Use a jumper wire to connect the positive terminal of the battery to the 8S terminal on the starter solenoid. The starter solenoid should energize and the pinion gear should extend. If the starter solenoid does not energize, replace it.
   c. Disconnect the jumper wire from the C terminal on the starter solenoid. The starter solenoid should remain energized. If the start solenoid does not remain energized, replace it.
   d. Disconnect the jumper wire from the 8S terminal on the starter solenoid. The starter solenoid should de-energize and the pinion gear should retract. If the start solenoid does not de-energize, replace it.



1.	C Terminal
2.	8S Terminal

Figure 199: Energize Starter Solenoid

Assembly

1. Place the plunger back inside the starter solenoid and install the cover.
2. Install the components of the pinion housing. Use a light grease to lubricate the components in the pinion housing.
   a. Place the pinion shaft spring, pinion clutch, and pinion shaft retainer on the pinion shaft.
   b. Place this part of the pinion assembly in the pinion housing.
   c. Support the end of the pinion shaft that faces the starter solenoid.
   d. Place the pinion gear spring and the pinion gear on the pinion shaft.
   e. Push the pinion gear onto the pinion shaft as far as possible and hold it in that position.
   f. Place the stop ring on the pinion shaft and push the stop ring to the pinion gear. Make sure the groove in the stop ring faces away from the pinion gear.
   g. Place the snap ring in the groove on the end of the pinion shaft.

h. Release the pinion gear and let it push the stop ring over the snap ring. Make sure the snap ring is seated in the groove in the stop ring.

3. Place the steel ball in the end of the pinion shaft that faces the starter solenoid.
4. Place the spring on the starter solenoid plunger.
5. Attach the starter solenoid housing to the pinion housing.

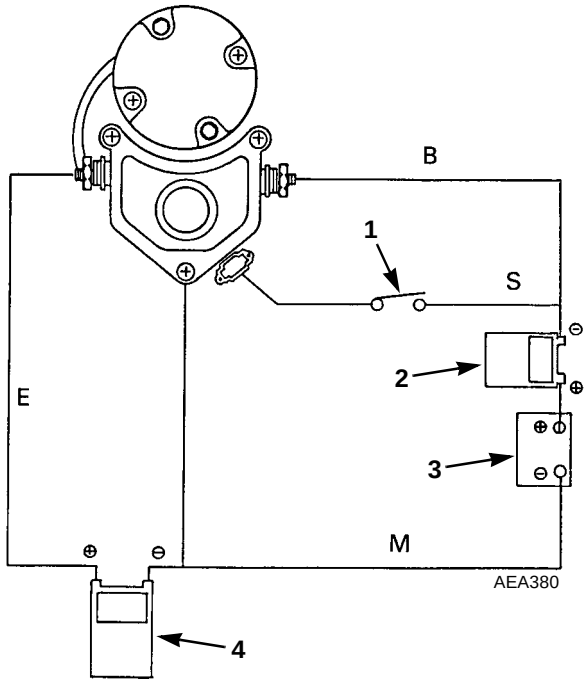
   NOTE: Check the operation of this assembly see "Starter Solenoid" on page 101).

6. Place the idler gear around the shaft in the pinion housing.
7. Place the bearings in the bearing retainer and use some light grease to lubricate the bearings and to hold them in place.
8. Place the bearings and bearing retainer inside the idler gear with the closed end of the bearing retainer covering the bearings.
9. Assemble the starter motor.
   a. Place the armature in the stator.
   b. Make sure the negative brushes are in the locked position and place the brush ring on the commutator.
   c. Place the positive brushes in the brush holders.
   d. 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.
   e. Place the commutator cover in position on the starter motor. Make sure the armature bearing is seated in the commutator.
   f. Install the two screws that fasten the brush ring assembly to the commutator cover.
10. Place the starter motor in position on the starter solenoid and pinion housing. Make sure that the armature shaft engages the idler gear and that the armature bearing is seated in the starter solenoid and pinion housing.
11. Install the two through bolts.
12. Connect the stator lead to the C 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: 90 amps, 11.5 volts, and 3000 rpm.



1.	Start Switch	3.	Battery
2.	Ammeter	4.	Voltmeter

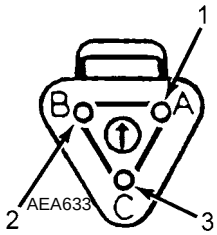
Figure 200: No Load Test

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.

NOTE: Some units use a fuel solenoid timer to momentarily energize the pull-in coil in the fuel solenoid. This function is built into the relay or interface boards on microprocessor controllers such as the µP-T and Spectrum TS. Refer to the unit maintenance manual for information about the fuel solenoid timer.

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)

Figure 201: 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 positive battery terminal. 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 positive battery terminal.

   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 positive battery terminal. 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 positive battery terminal. The fuel solenoid should make a definite click when the hold-in coil is de-energized.

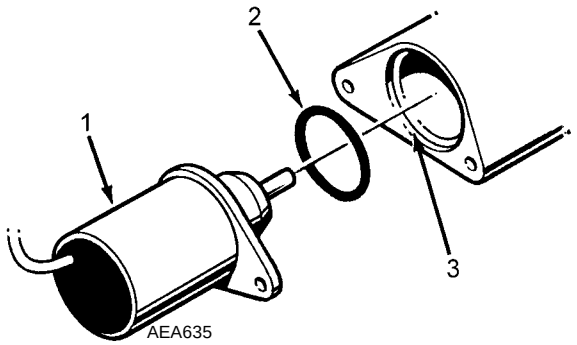
   d. If the hold-in coil does not function properly, check the resistance of the hold-in coil by placing an ohmmeter between the red wire (8D - pin A) and the black wire (CH - pin C) in the fuel solenoid connector. The resistance of the hold-in coil should be 24 to 29 ohms. If the resistance of the hold-in 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. Use the Service Test Mode to energize the fuel solenoid if the unit has a microprocessor.

   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

Figure 202: Fuel Solenoid Components

Bleeding Air from the Cooling System

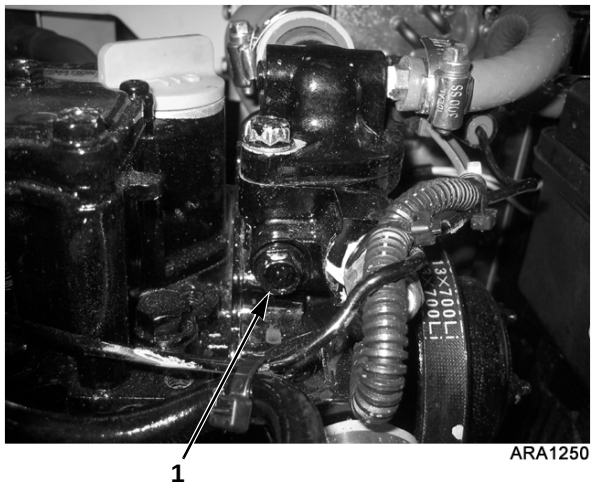
Bleeding Air from Truck and HK Unit Cooling Systems

Often when a self powered truck or HK unit cooling system is refilled, air is trapped in the engine block and/or under the thermostat. Use the following procedure to bleed air out of the block and the cooling system:

NOTE: If an engine runs with air trapped in the block, the engine may be damaged. The high water temperature switch may not protect an engine that has air trapped in the block, because the high water temperature switch is designed to protect an engine from overheating due to failures in the cooling system and the loss of coolant.

CAUTION: Do not start the engine without bleeding the air out of the block.

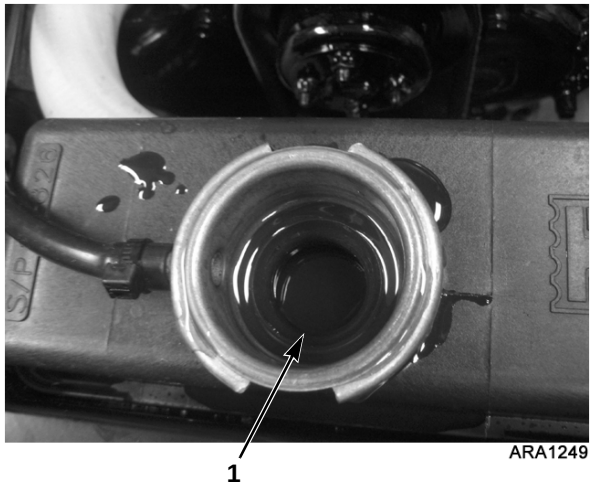
1. Verify that a 160 F (71 C) thermostat (P/N 13-954) is installed in all except HK units (see T&T 470 for details).
2. Remove the bleeder bolt from the side of the engine thermostat housing below the thermostat. In some applications it may be easier to remove the thermostat and housing.



1.	Bleeder Bolt

Figure 203: Remove Bleeder Bolt

3. Slowly pour the coolant into the system until you see coolant coming out of the bleeder bolt fitting or coming up to the top of the opening for the thermostat in the water pump.
4. Reinstall the bleeder bolt or reinstall the thermostat and housing.
5. Fill the reservoir tank (or expansion tank or filler neck on HK units) with coolant to the bottom of the filler neck.



1.	Fill to bottom of filler neck.

Figure 204: Fill Reservoir Tank

6. Make sure that the amount of coolant that goes back into the system is approximately equal to the amount of coolant that came out of the system.
7. Install the radiator cap and leave it partially loose.
8. Run the unit in low speed while watching the unit engine temperature gauge or use a non-contact thermometer pointed at the water pump bleeder bolt located on the curbside of the water pump (see Figure 203).
9. When the temperature reaches 150 F (66 C) for units with 160 F (71 C) thermostats, or 170 F (76 C) for units with 180 F (82 C) thermostats, shut off the engine for 2 minutes to allow the thermostat to heat soak and open completely to purge air out of block, head, and water pump.

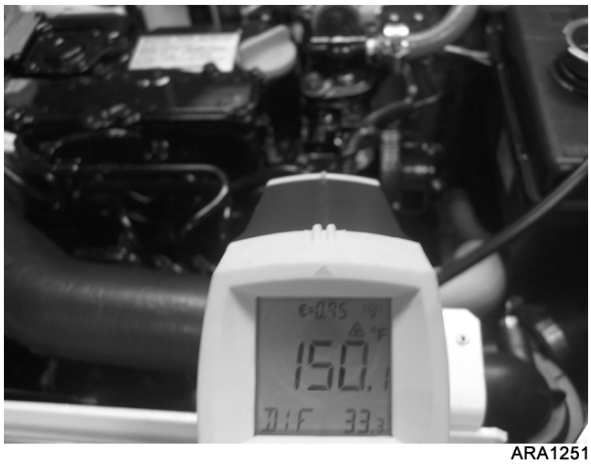


Figure 205: Checking Temperature

10. After 2 minutes, re-start the engine and run it in low speed while filling the reservoir tank completely full. Install the radiator cap fully seated and run the unit for approximately 15 minutes. Shut off the engine and re-check the coolant level after the unit cools down for 15 minutes. If the unit has a coolant recovery bottle, fill the bottle half full with coolant.

WARNING: Failure to follow this procedure can result in engine damage. Air trapped in the engine block and head can create localized hot spots that can cause permanent damage. Air can also cause the thermostat and engine safety shutdown feature to malfunction, causing further engine damage.

Bleeding Air from TriPac Unit Cooling Systems

Often when a TriPac unit cooling system is refilled, air is trapped in the engine block and/or under the thermostat. Use the following procedure to bleed air out of the block and the cooling system:

NOTE: If an engine runs with air trapped in the block, the engine may be damaged. The high water temperature switch may not protect an engine that has air trapped in the block, because the high water temperature switch is designed to protect an engine from overheating due to failures in the cooling system and the loss of coolant.

CAUTION: Do not start the engine without bleeding the air out of the block.

1. Verify the APU OUTLET hand valve is CLOSED (tractor inlet, next to water pump). If this valve is left open, coolant will be sitting on top of the TriPac thermostat and not allow the TriPac engine to bleed air.
2. Open the APU INLET hand valve.
3. Place a clean container under the bleed line to catch coolant that is drained.

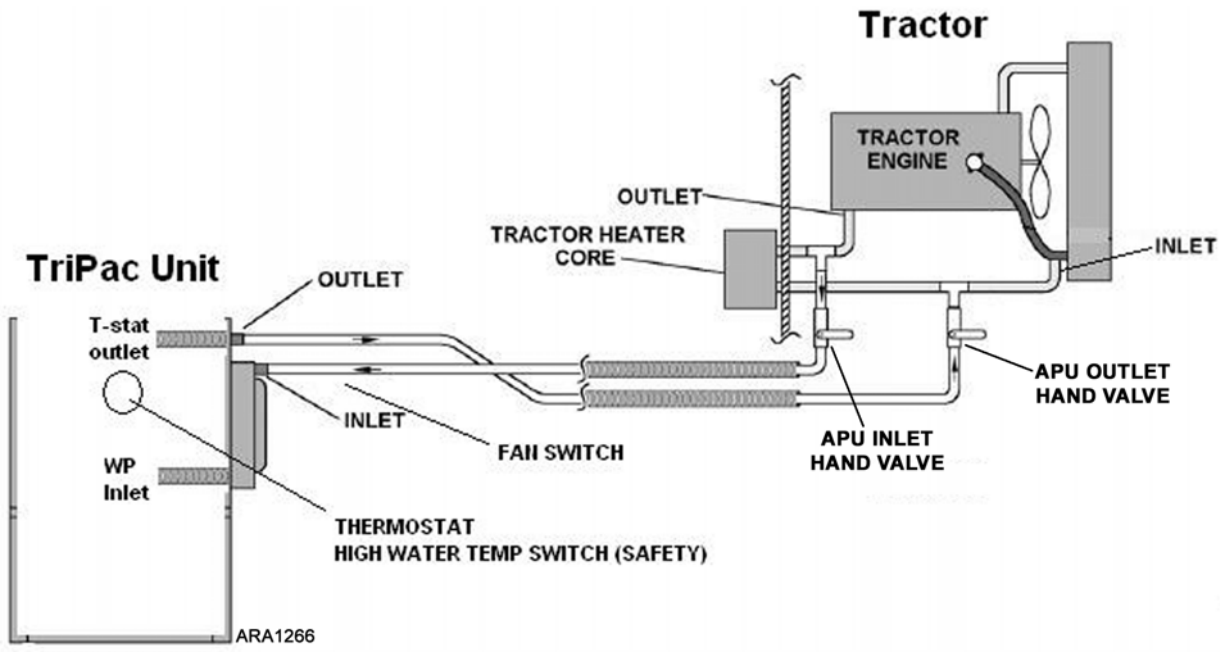
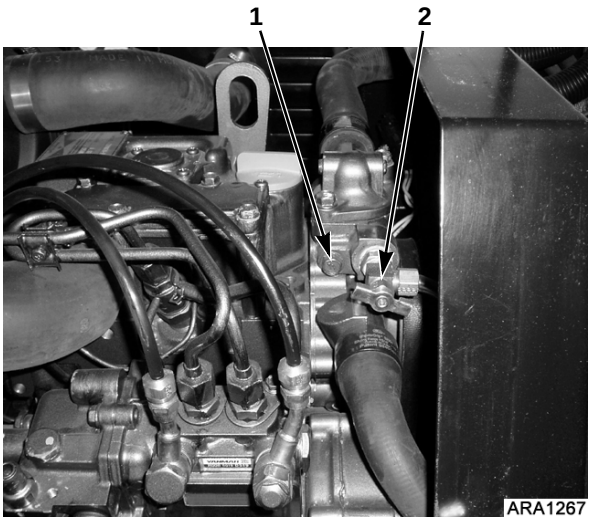


Figure 206: TriPac Cooling System

4. Open the bleed petcock on the APU engine to allow air to bleed out.

   NOTE: Units built prior to September 2006 have the bleed petcock on the top of the thermostat housing. On these units, remove the water pump bleeder bolt and bleed the air until there is a steady stream of coolant. Then reinstall the water pump bleeder bolt.



1.	Water Pump Bleeder Bolt
2.	Bleed Petcock

Figure 207: Water Pump Bleeder Bolt and Bleed Petcock Locations

5. When a steady stream of coolant flows from the bleed line, close the bleed petcock.
6. Open the APU OUTLET hand valve.
7. Replace drained coolant from the TriPac back into the tractor's radiator.
8. Start the TriPac engine and use a non-contact thermometer pointed at the water pump bleeder bolt to monitor the coolant temperature. The water pump bleeder bolt located next to the bleed petcock on the water pump (see Figure 207 above).
9. When the temperature reaches 150 F (66 C), shut off the engine for 2 minutes to allow the thermostat to heat soak and open completely to purge air out of block, head, and water pump.
10. After 2 minutes, re-start the engine. The remaining air in the system will be forced to the tractor radiator and the TriPac APU should now be bled of all air.

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 1400 rpm with a load that is 6 to 8% of the engine's rated output for a short time.
3. Run the engine at 1400 rpm with a load that is 15% of the engine's rated output for 15 minutes.
4. Run the engine at 2400 rpm with a load that is 22 to 25% of the engine's rated output for 30 minutes.
5. Run the engine at 1400 rpm with a load that is 15% of the engine's rated output for 30 minutes.
6. Run the engine at 2400 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 2400 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 (1400 rpm) and high speed (2400 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

The valve clearance should be checked after every 2000 operating hours, maximum. It is important that valves be adjusted to the correct specifications for satisfactory engine operation. Insufficient valve clearance will result in compression loss and misfiring of cylinders resulting in burned valves and seats. Excessive valve clearance will result in noisy valve operation and abnormal wear of the valves and rocker arms. The intake and exhaust valves are adjusted with the valve in the closed position.

Two Cylinder Procedure

NOTE: The cylinders these engines are numbered from the flywheel end to the water pump end. The number 1 cylinder is next to the flywheel. The number 2 cylinder is next to the water pump. The timing marks on the flywheel are also numbered this way.

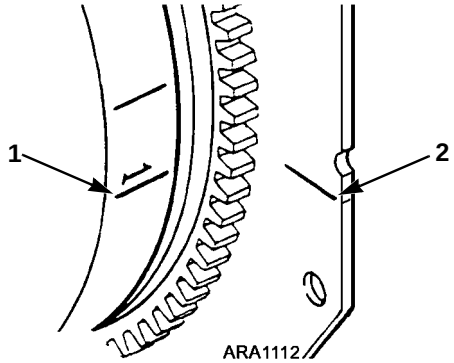
The timing marks on the flywheel of the two cylinder engines are stamped 180 degrees apart. The top dead center marks have the cylinder number stamped next to them. The injection timing marks have no identification marks (see Figure 208).

The index timing mark is stamped on the side of the starter mounting plate that faces the flywheel. This index timing mark is on the intake side of the engine.

1. Remove the cylinder head cover.

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

2. Place the engine at top dead center of the compression stroke for the number 1 cylinder.
   a. Rotate the engine in the normal direction of rotation (counterclockwise viewed from the flywheel end) until the top dead center timing mark for the number 1 cylinder on the flywheel lines up with the index timing mark on the starter mounting plate.



1.	Top Dead Center Mark for Number 1 Cylinder
2.	Index Timing Mark on Starter Mounting Plate

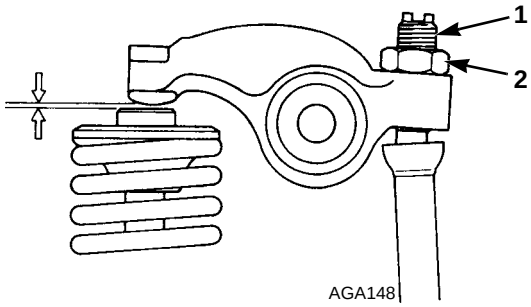
Figure 208: Timing Marks

   b. Check the rocker arms on the number 1 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 1 cylinder.
   d. If the rocker arms are tight, the engine is at top dead center of the exhaust stroke for the number 1 cylinder. Rotate the engine 360 degrees to place the engine at top dead center of the compression stroke for the number 1 cylinder.

3. Use a feeler gauge to check the valve clearance on both valves for the number 1 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.

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



1.	Adjustment Screw
2.	Lock Nut

Figure 209: Valve Clearance

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

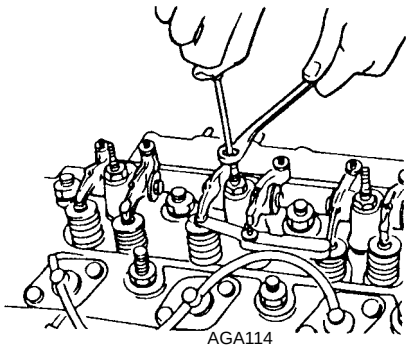


Figure 210: Adjusting Valves

6. Recheck the valve clearance.

7. Place the engine at top dead center of the compression stroke for the number 2 cylinder.

   a. Rotate the engine in the normal direction of rotation (counterclockwise viewed from the flywheel end) until the top dead center timing mark for the number 2 cylinder on the flywheel lines up with the index timing mark on the starter mounting plate.

   b. Check the rocker arms on the number 2 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 2 cylinder.

   d. If the rocker arms are tight, the engine is at top dead center of the exhaust stroke for the number 2 cylinder. Rotate the engine 360 degrees to place the engine at top dead center of the compression stroke for the number 2 cylinder.

8. Check and adjust both valves for the number 2 cylinder.

9. Replace the cylinder head cover.

Three Cylinder Procedure

NOTE: The cylinders on these engines are numbered from the flywheel end to the water pump end. The number 1 cylinder is next to the flywheel. The number 2 cylinder is in the middle and the number 3 cylinder is next to the water pump. The timing marks on the flywheel are also numbered this way.

The timing marks on the flywheel of the three cylinder engines are stamped 120 degrees apart. The top dead center marks have the cylinder number stamped next to them. The injection timing marks have no identification marks (see Figure 212).

The index timing mark is stamped on the side of the starter mounting plate that faces the flywheel. This index timing mark is on the intake side of the engine.

On the three cylinder engines the order for the flywheel timing marks is 1, 2, 3, but the firing order is 1, 3, 2. The reason for this is that the engine fires every 240 degrees of crankshaft rotation. Therefore, when adjusting the valves, check the number 1 cylinder first. Then rotate the engine past the number 2 cylinder timing marks to the number 3 cylinder timing marks and check the number 3 cylinder. Finally, rotate the engine past the number 1 cylinder timing marks to the number 2 cylinder timing marks and check the number 2 cylinder.

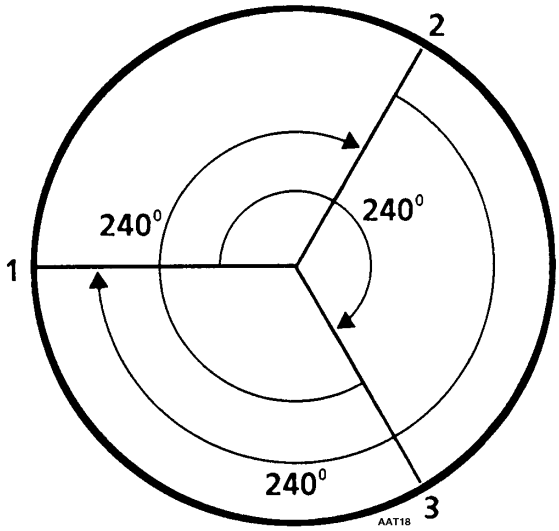
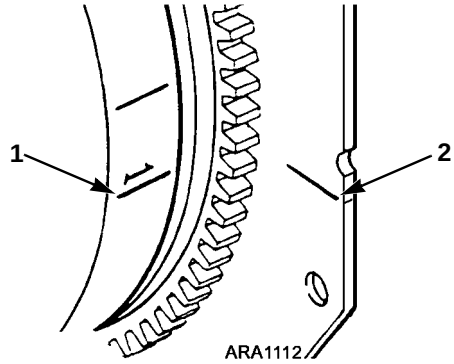


Figure 211: Valve Adjustment and Firing Order

1. Remove the cylinder head cover.

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

2. Place the engine at top dead center of the compression stroke for the number 1 cylinder.
   a. Rotate the engine in the normal direction of rotation (counterclockwise viewed from the flywheel end) until the top dead center timing mark for the number 1 cylinder on the flywheel lines up with the index timing mark on the starter mounting plate.



1.	Top Dead Center Timing Mark for Number 1 Cylinder
2.	Index Timing Mark on Starter Mounting Plate

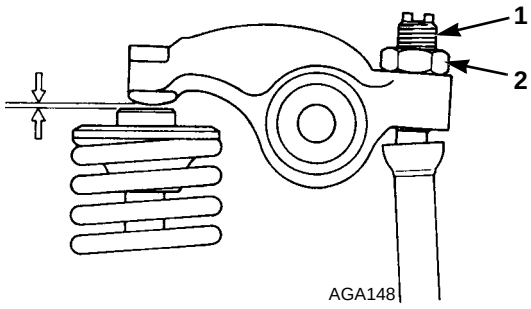
Figure 212: Timing Marks

   b. Check the rocker arms on the number 1 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 1 cylinder.
   d. If the rocker arms are tight, the engine is at top dead center of the exhaust stroke for the number 1 cylinder. Rotate the engine 360 degrees to place the engine at top dead center of the compression stroke for the number 1 cylinder.

3. Use a feeler gauge to check the valve clearance on both valves for the number 1 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.

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



1.	Adjustment Screw
2.	Lock Nut

Figure 213: Valve Clearance

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

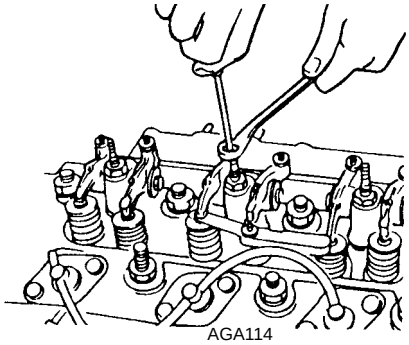


Figure 214: Adjusting Valves

6. Recheck the valve clearance.
7. Place the engine at top dead center of the compression stroke for the number 3 cylinder.
   a. Rotate the engine in the normal direction of rotation (counterclockwise viewed from the flywheel end) until the top dead center timing mark for the number 3 cylinder on the flywheel lines up with the index timing mark on the starter mounting plate.
   b. Check the rocker arms on the number 3 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 3 cylinder.
   d. If the rocker arms are tight, the engine is at top dead center of the exhaust stroke for the number 3 cylinder. Rotate the engine 360 degrees to place the engine at top dead center of the compression stroke for the number 3 cylinder.
8. Check and adjust both valves for the number 3 cylinder.
9. Place the engine at top dead center of the compression stroke for the number 2 cylinder.
   a. Rotate the engine in the normal direction of rotation (counterclockwise viewed from the flywheel end) until the top dead center timing mark for the number 2 cylinder on the flywheel lines up with the index timing mark on the starter mounting plate.
   b. Check the rocker arms on the number 2 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 2 cylinder.
   d. If the rocker arms are tight, the engine is at top dead center of the exhaust stroke for the number 2 cylinder. Rotate the engine 360 degrees to place the engine at top dead center of the compression stroke for the number 2 cylinder.
10. Check and adjust both valves for the number 2 cylinder.
11. Replace the cylinder head cover.

Compression Test

Compression Test Equipment

Adapters (P/N 204-672 and P/N 204-675 are both required) are now available for compression tester (P/N 204-542).

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

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.

Compression Test Procedure

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 percent lower than those on a warm engine.

2. Disconnect the wires from the fuel solenoid and loosen the injection lines at the injection nozzles.

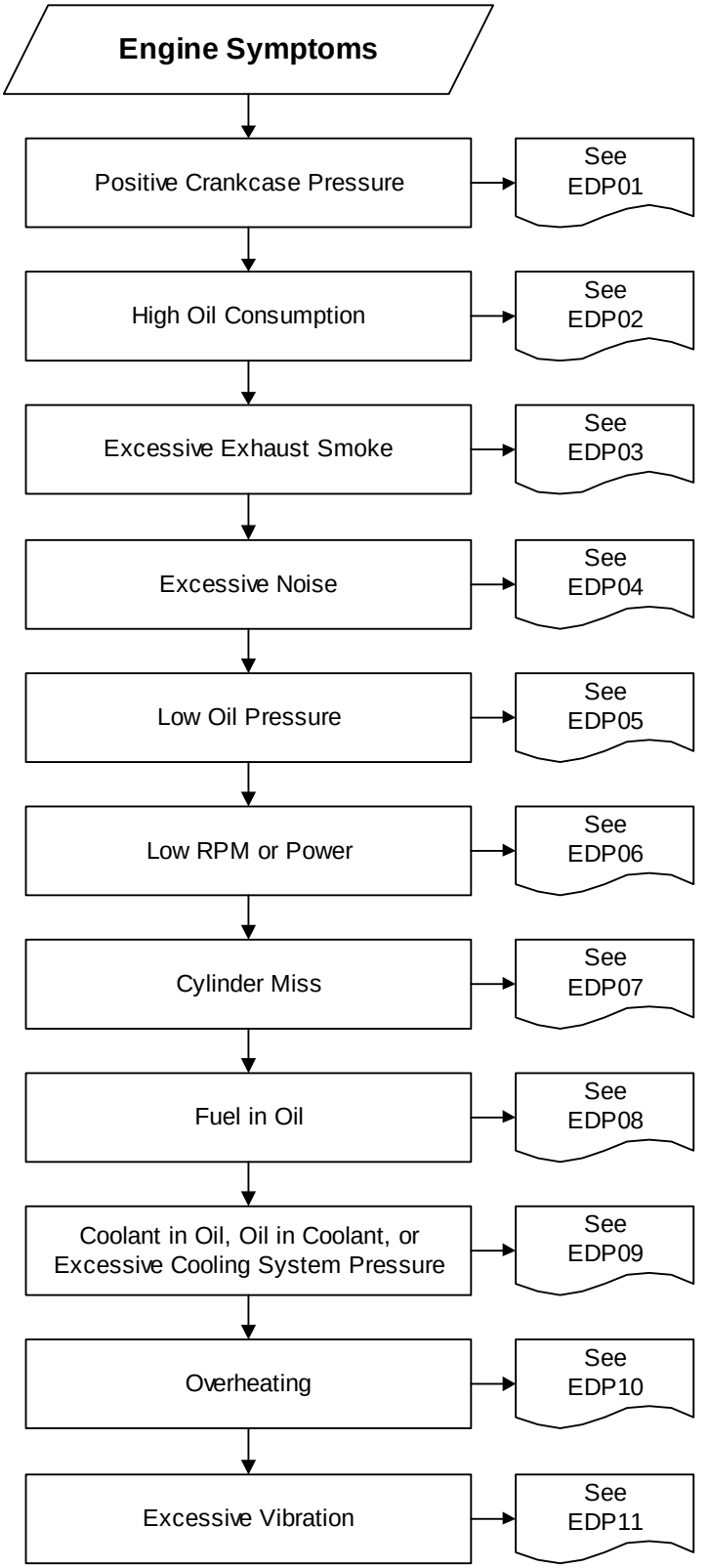
   CAUTION: The fuel solenoid must be disconnected and the injection lines must be loosened to prevent the injection of fuel into the cylinders during the test. If a cylinder fires during the test, the resulting pressure will destroy the test equipment. The manufacturer of the test equipment disclaims all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

3. Remove all of the glow plugs.
4. Disconnect the air cleaner.
5. Connect the compression tester (P/N 204-542) to a cylinder with the adapters (P/N 204-672 and P/N 204-675).
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 375 to 400 psi (2586 to 2758 kPa) at cranking speed (250 rpm minimum) using the Thermo King compression tester (P/N 204-542) and the adapters (P/N 204-672 and P/N 204-675).
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 percent.

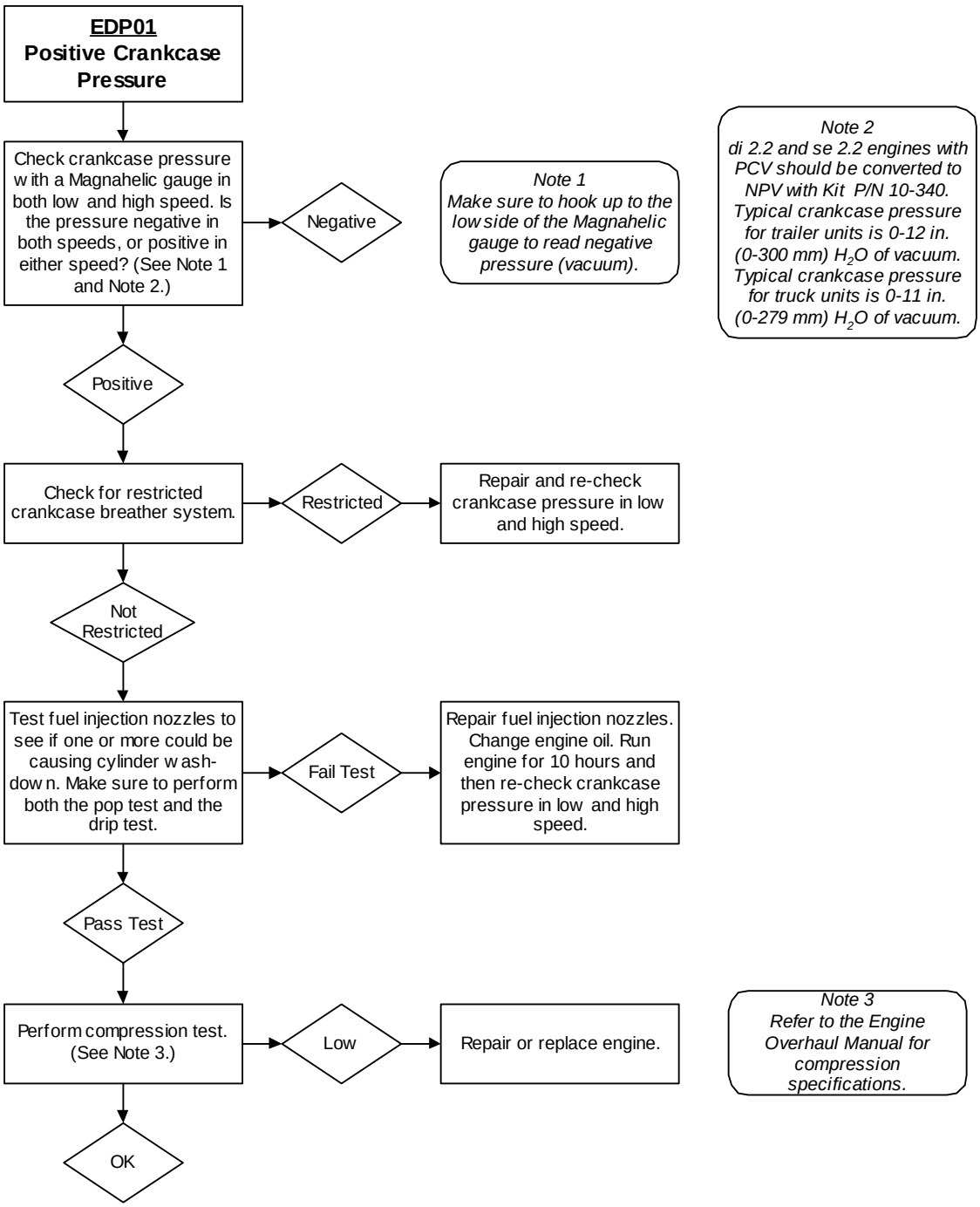
Diagnostic Guide

Use the following flow charts to help diagnose engine problems.

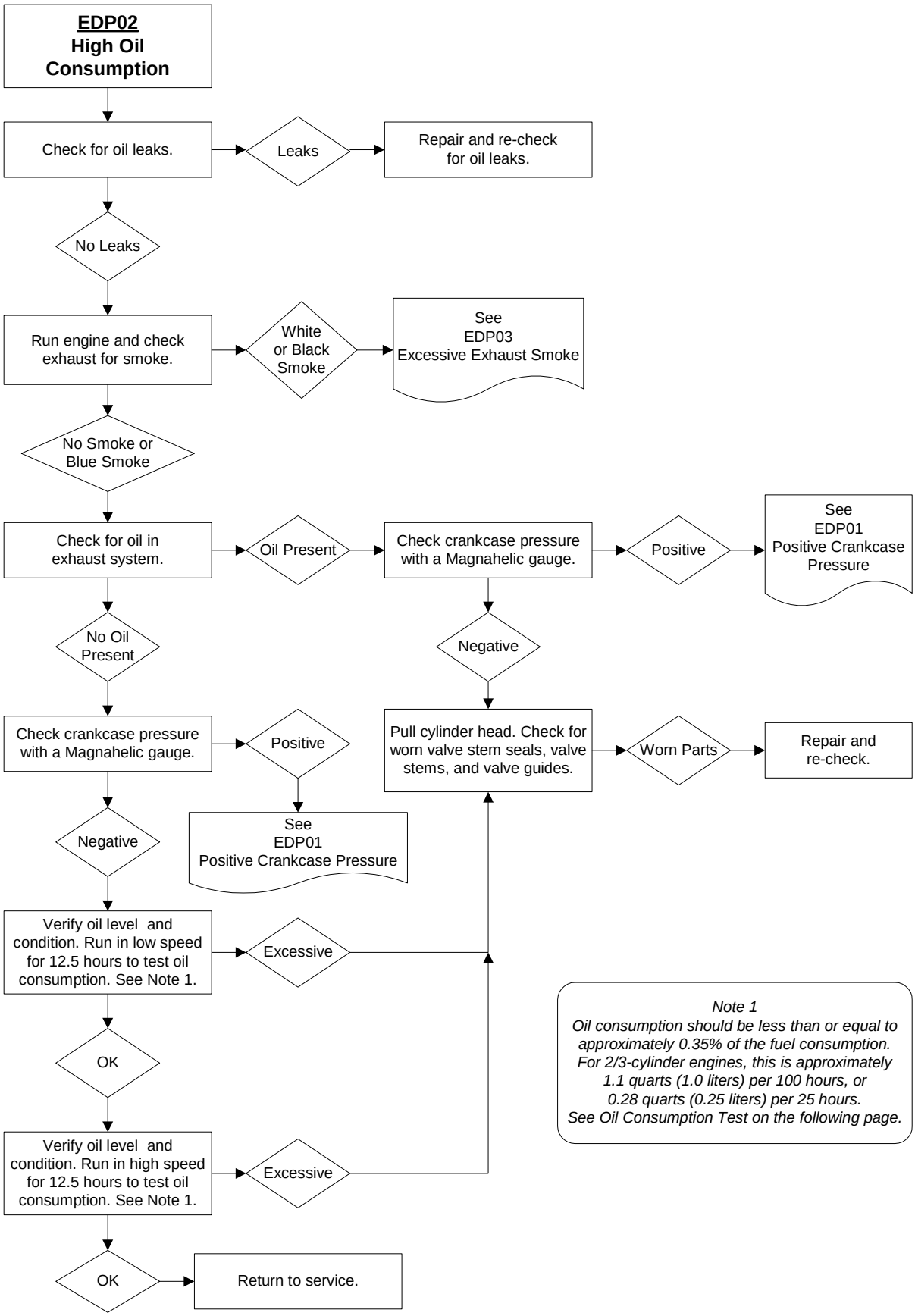
Engine Symptoms



EDP01 Positive Crankcase Pressure



EDP02 High Oil Consumption



Oil Consumption Test

1. Run the engine for a minimum of 15 minutes (to get the engine to full operating temperature) and then turn it off.
2. Wait for a minimum of 10 minutes to allow for oil drain back, then remove the dipstick, measure the drop using an accurate metric steel rule, and record the oil level in millimeters.
3. Run the engine in low speed for exactly 12.5 hours.
4. Run the engine in high speed for exactly 12.5 hours and then turn it off.
5. Wait for a minimum of 10 minutes to allow for oil drain back, then remove the dipstick, measure the drop using an accurate metric steel rule, and record the oil level in millimeters.
6. Compare the oil level from step 2 to the oil level from step 5 to determine how much oil was used in 25 hours. Record and compare with chart below to determine if the consumption is within acceptable limits.

   NOTE: Further run time may be required to validate any reading that is close to the acceptable limits. This is only intended to be used as a quick checkout process to reduce the amount of run time needed for warranty inspections.

Engine Family	Test Purpose	Maximum Drop in 25 Hours	Consumption per 100 Hours Run Time
2 Cylinder	Warranty	18 mm	1.1 quart (1 liter)
3 Cylinder	Warranty	5 mm	1.1 quart (1 liter)

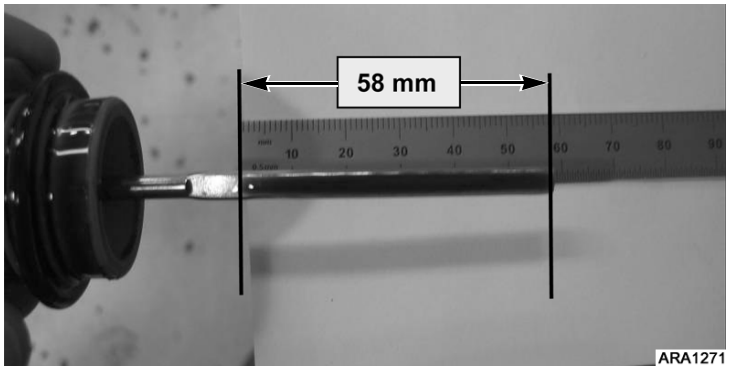
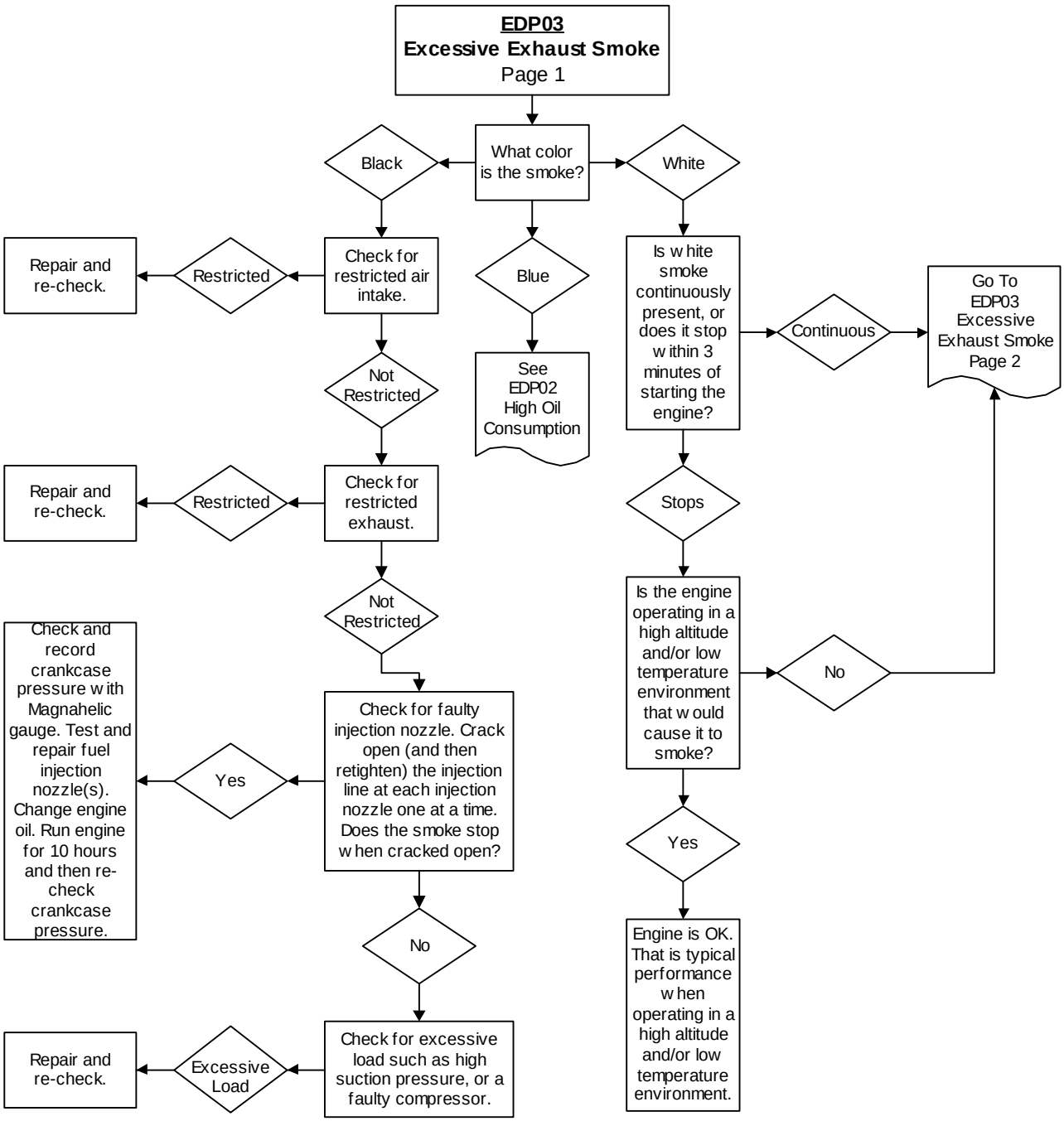
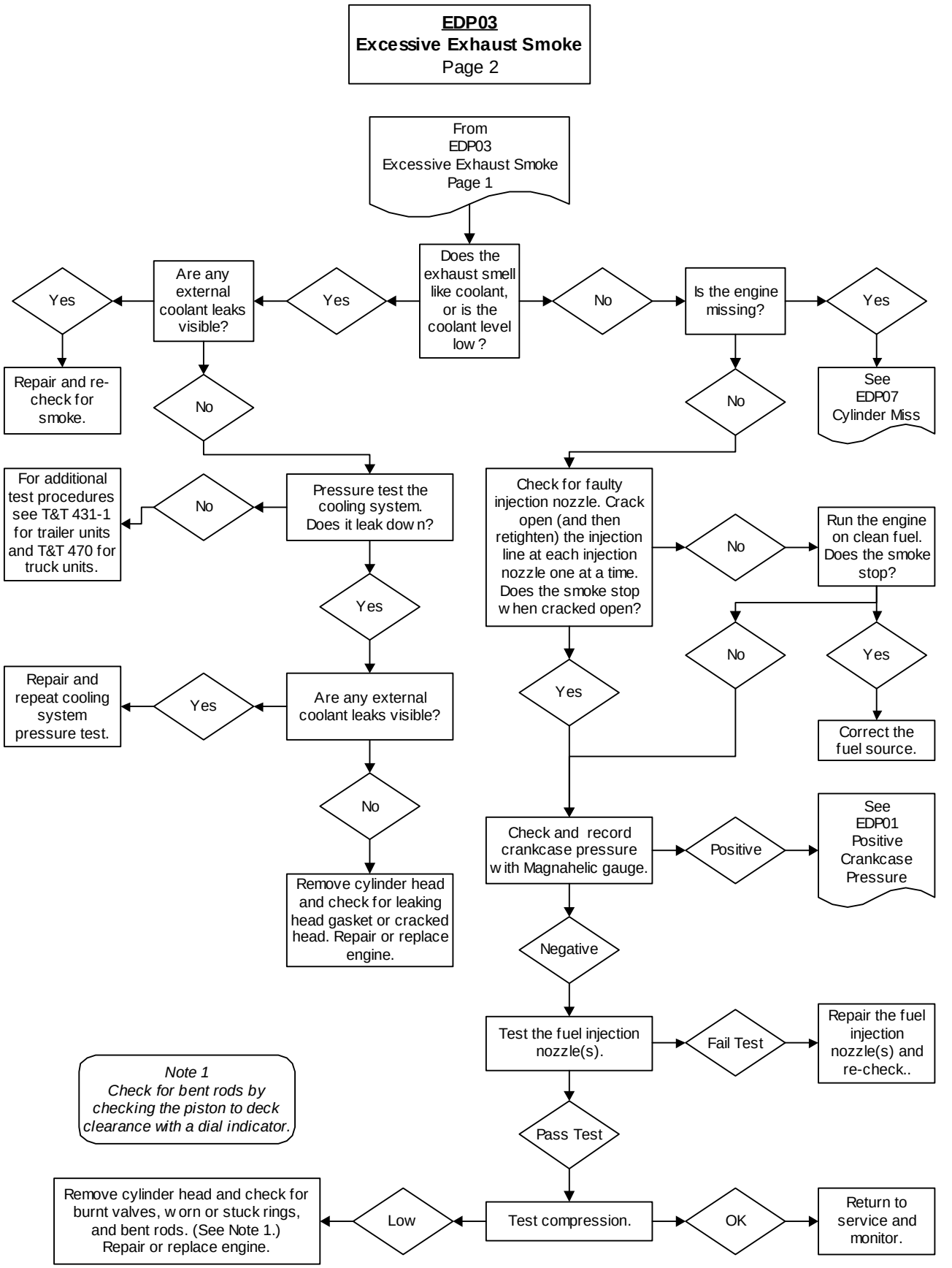


Figure 215: Example of Measuring and Recording Oil Level

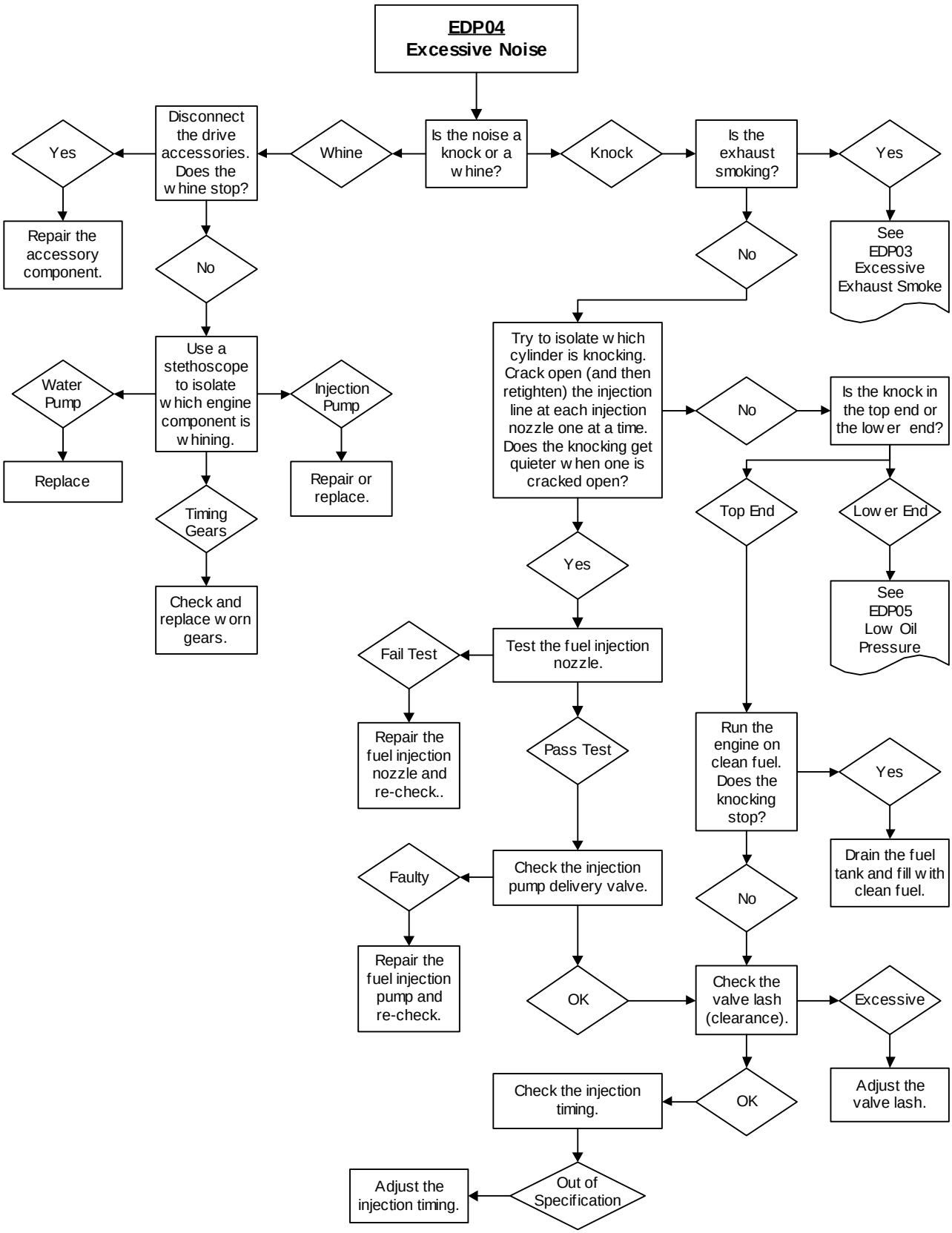
EDP03 Excessive Exhaust Smoke



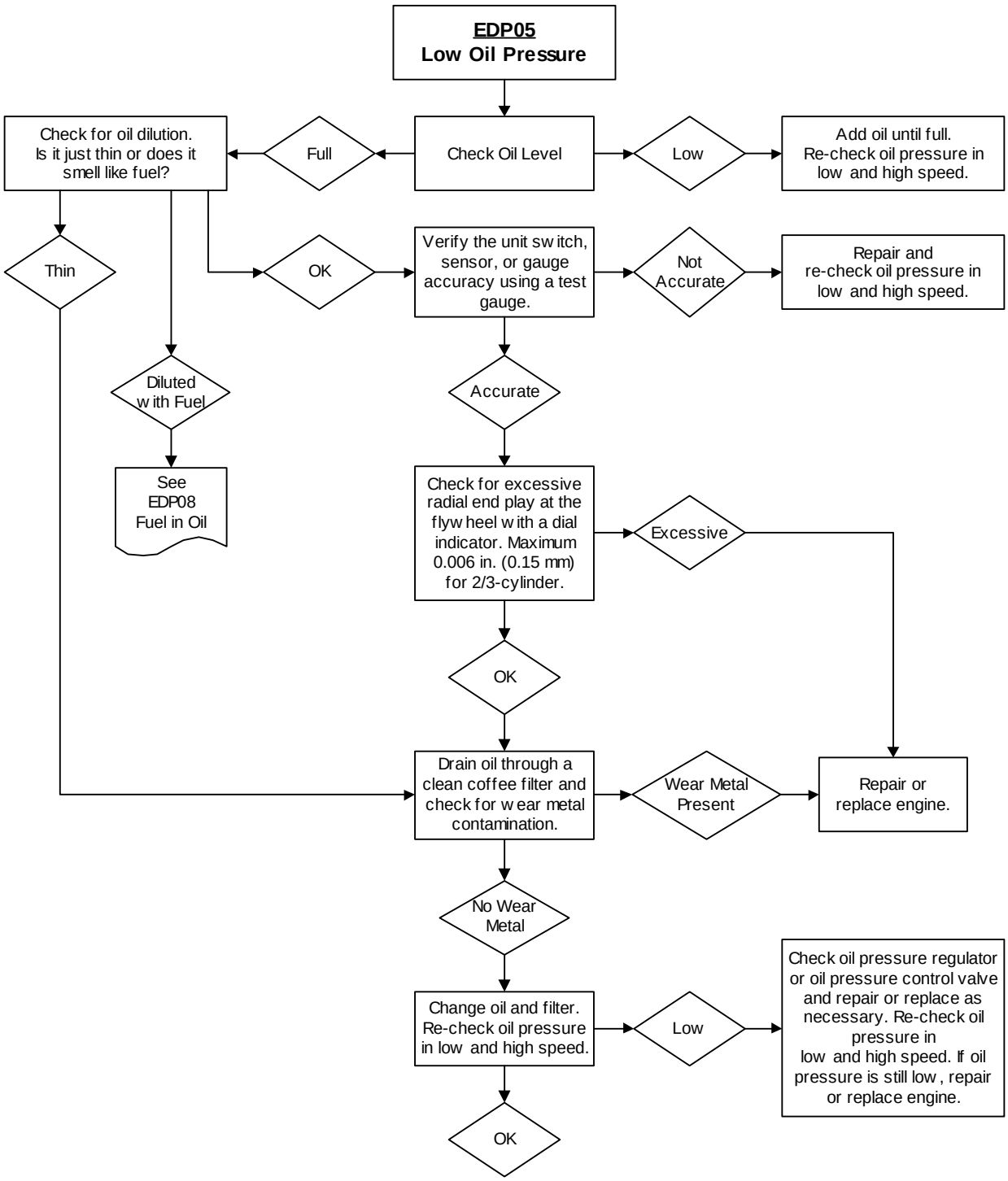
EDP03 Excessive Exhaust Smoke (Continued)



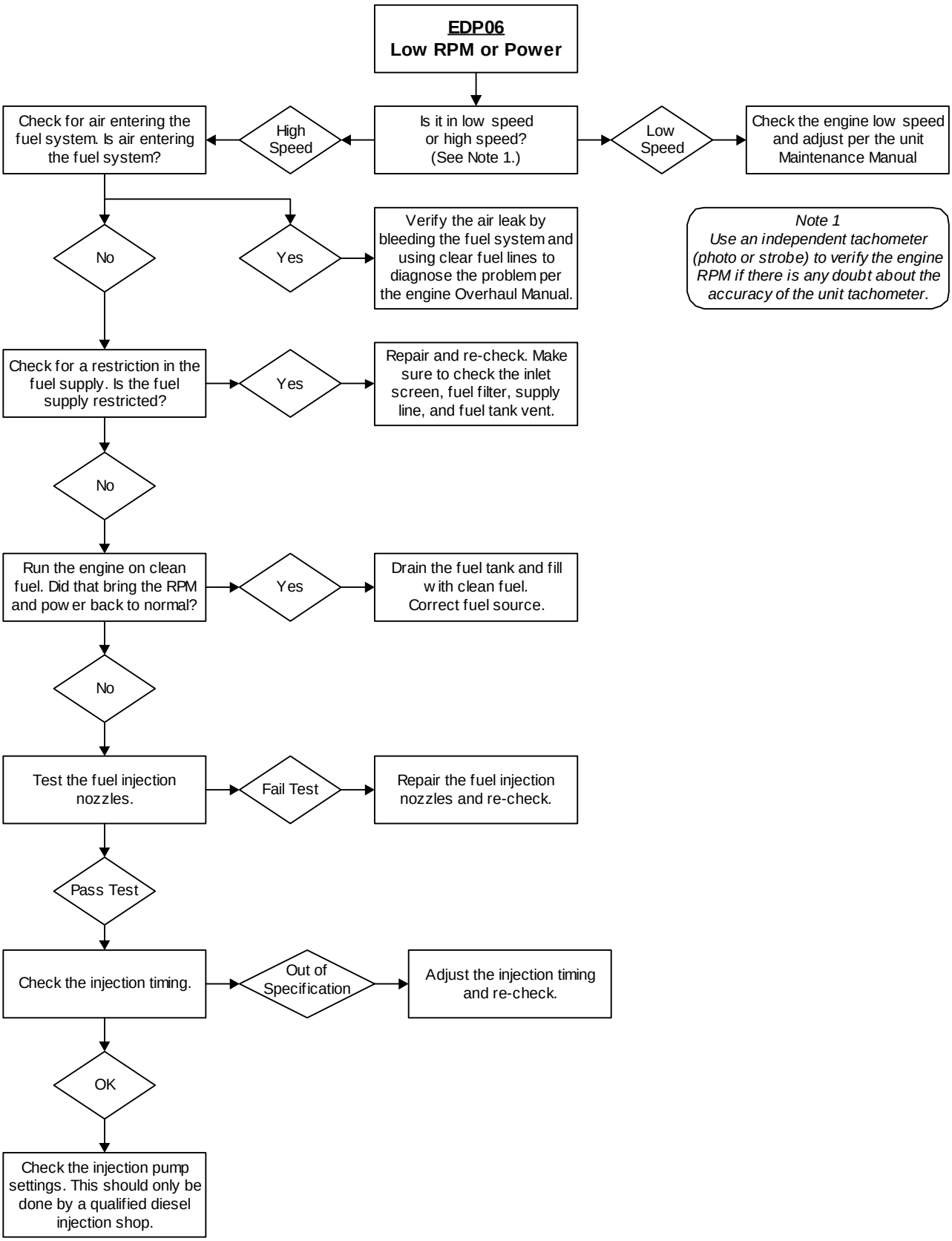
EDP04 Excessive Noise



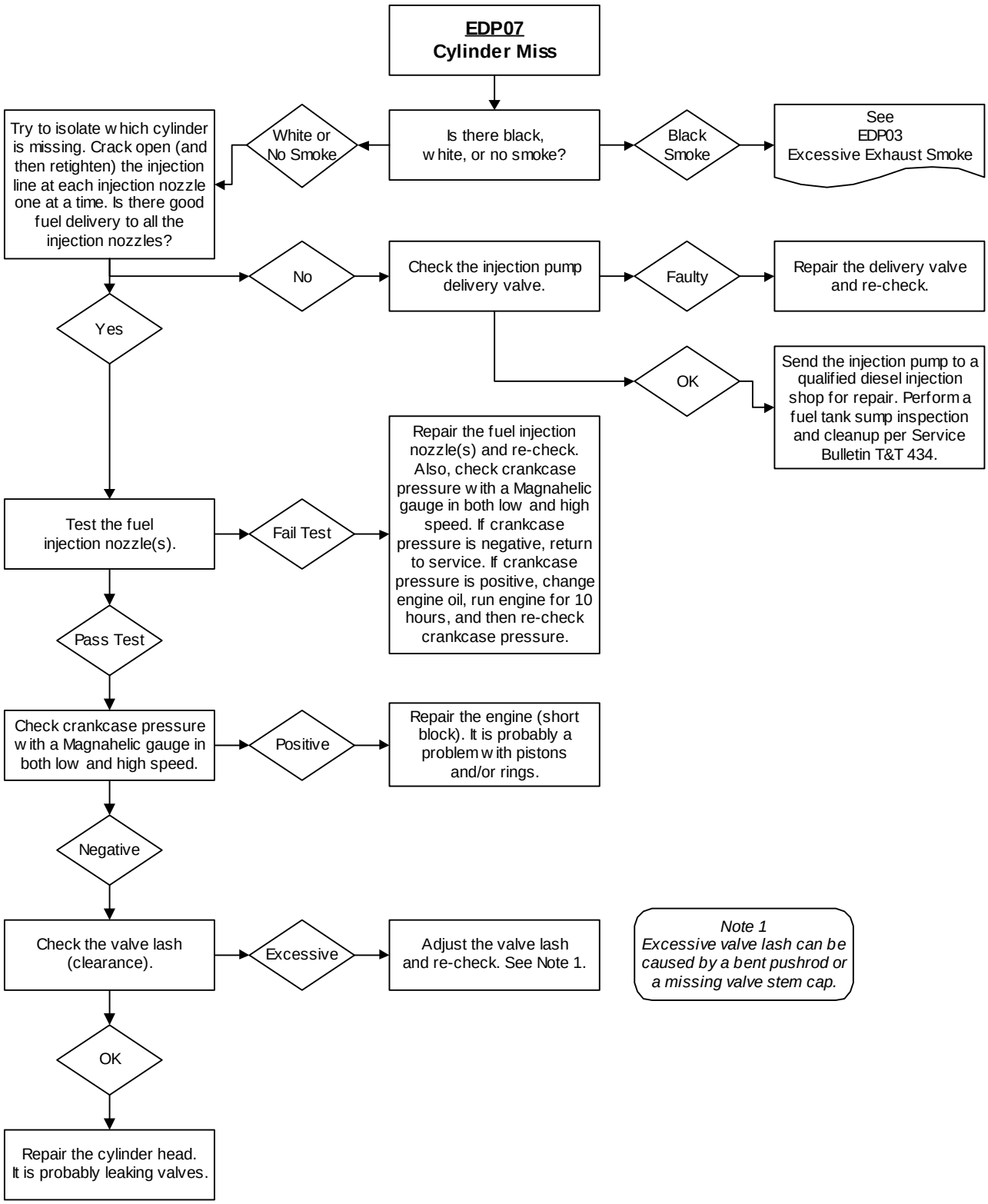
EDP05 Low Oil Pressure



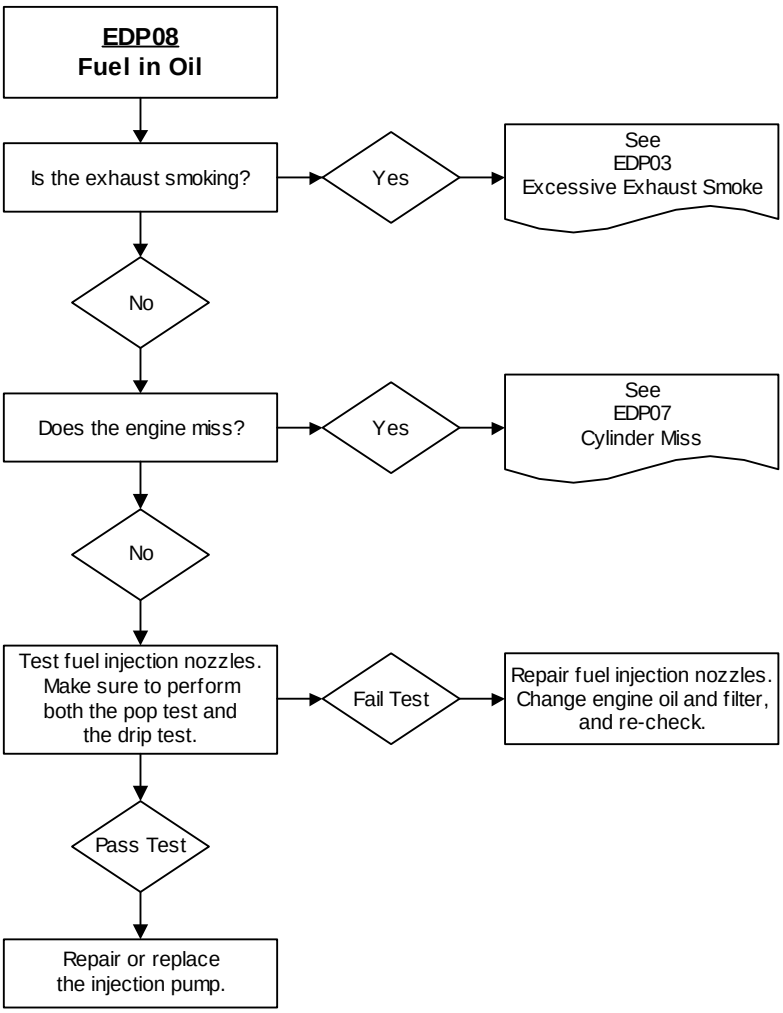
EDP06 Low RPM or Power



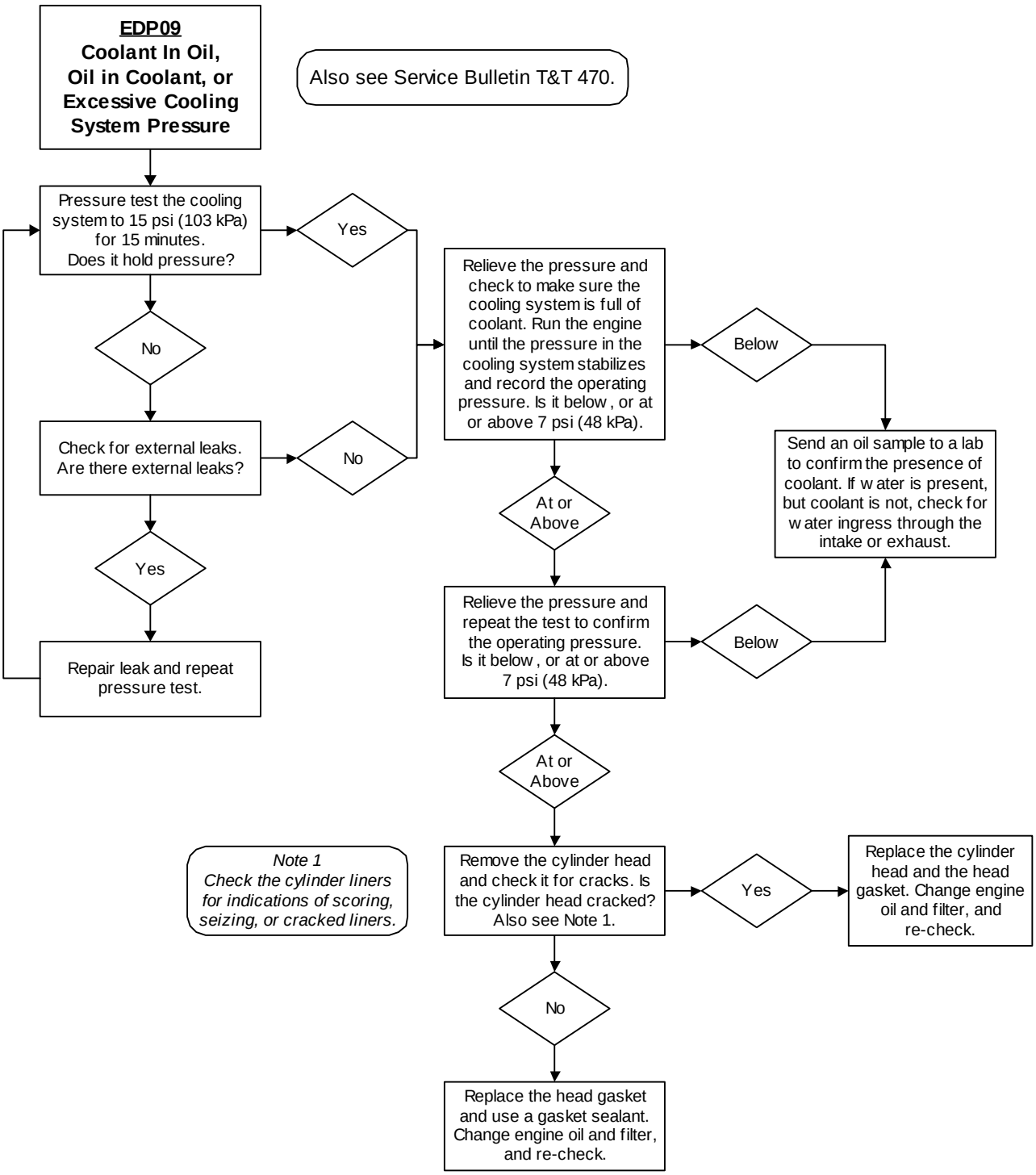
EDP07 Cylinder Miss



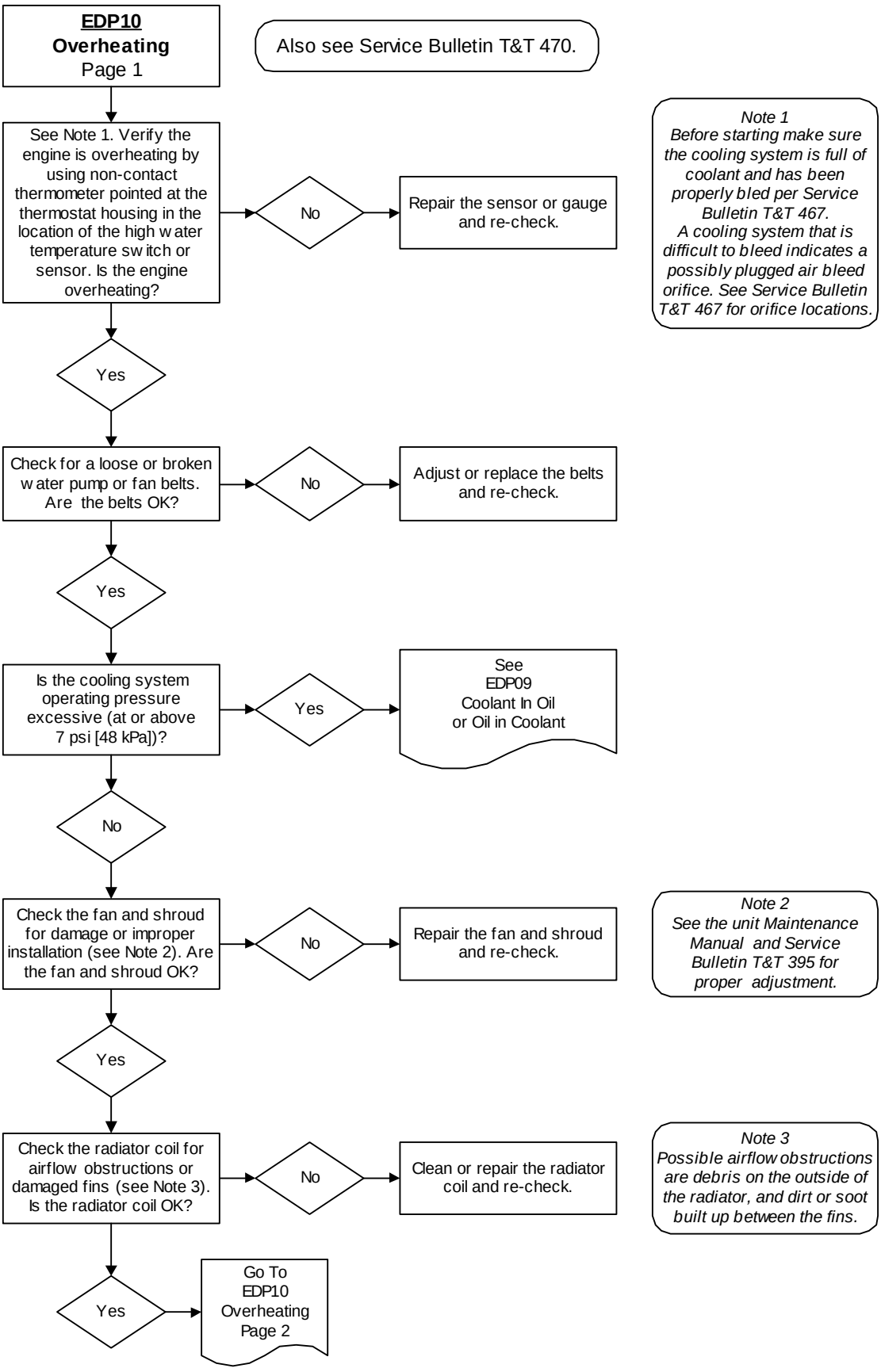
EDP08 Fuel in Oil



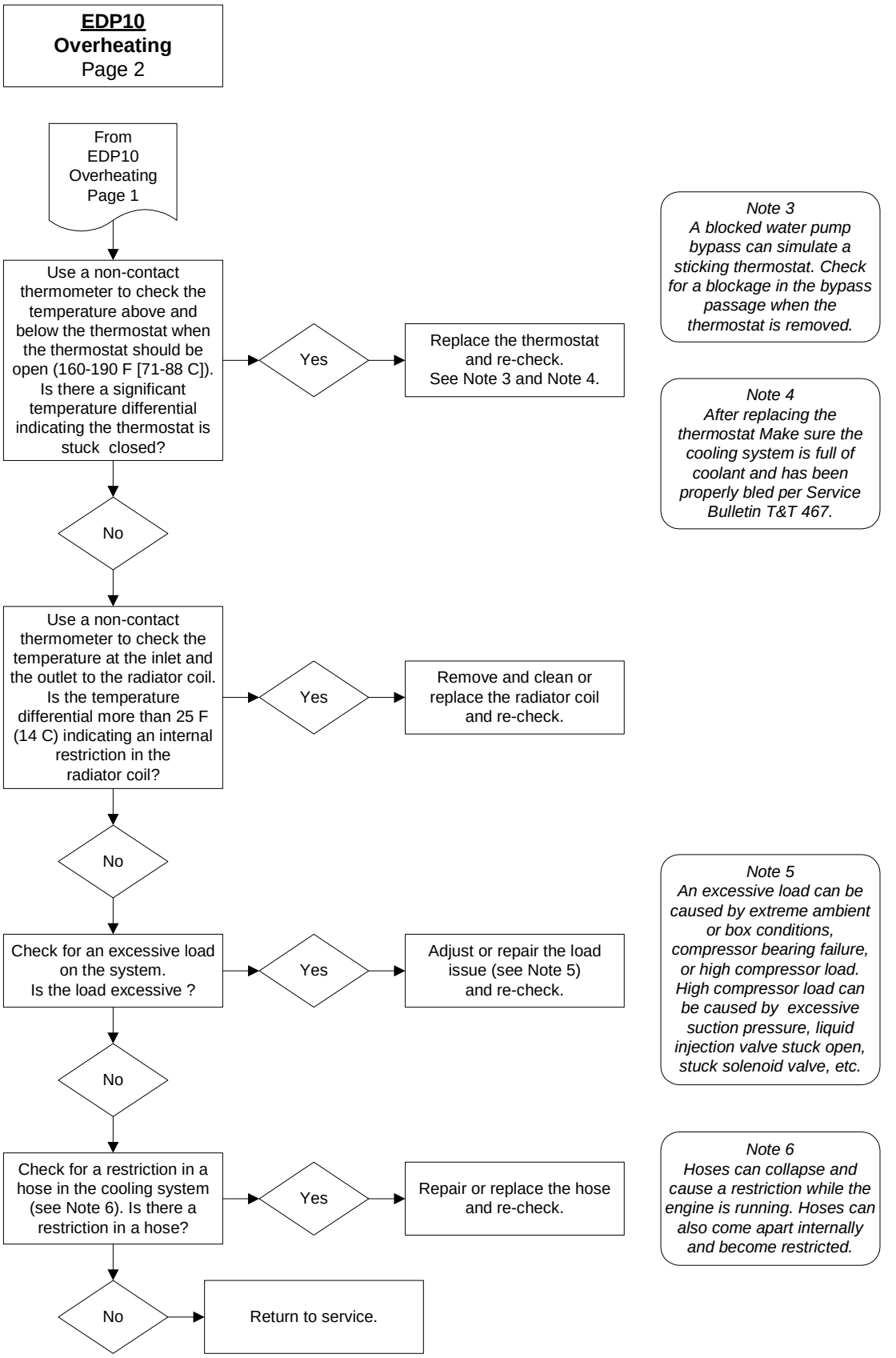
EDP09 Coolant in Oil or Oil in Coolant



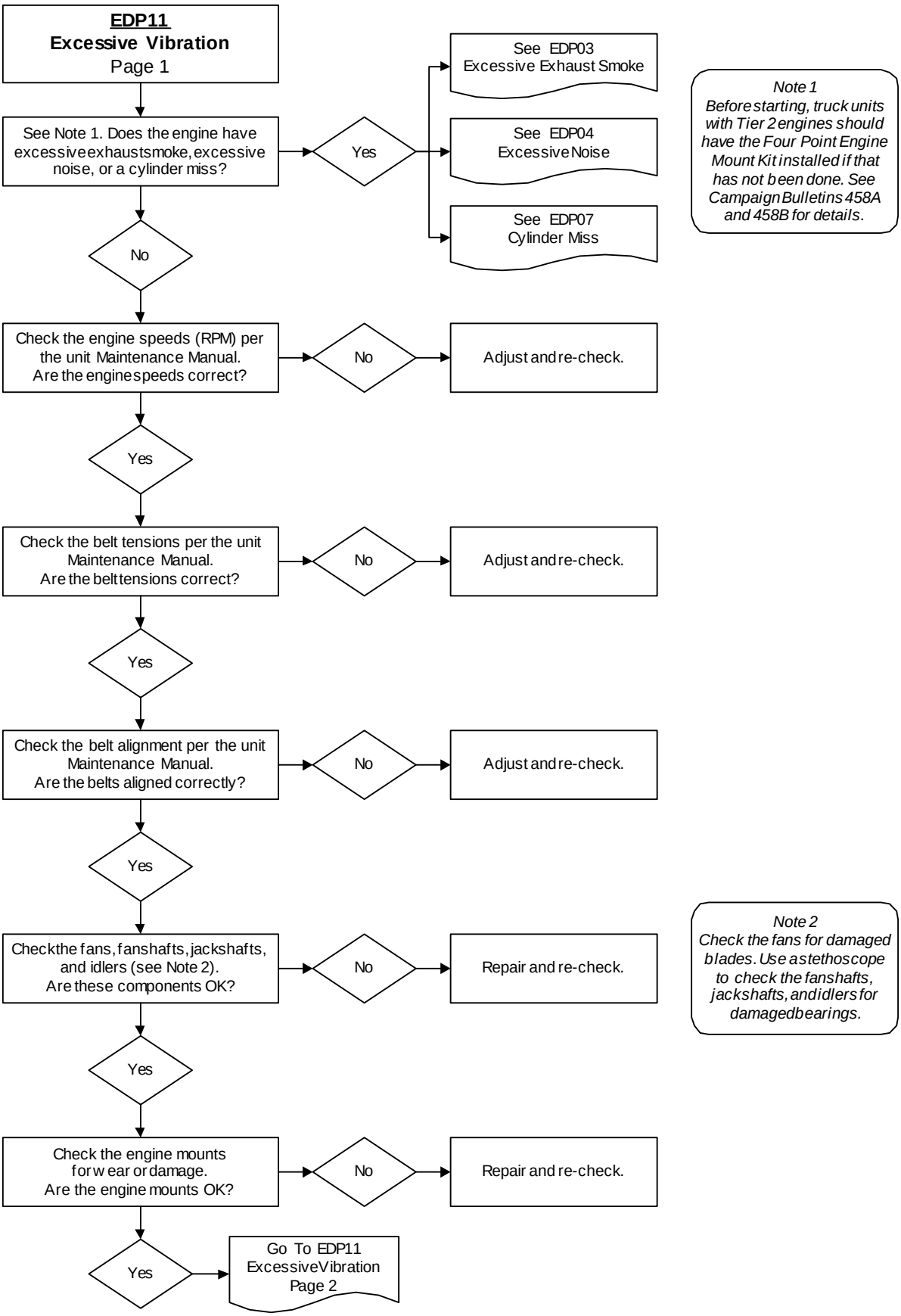
EDP10 Overheating



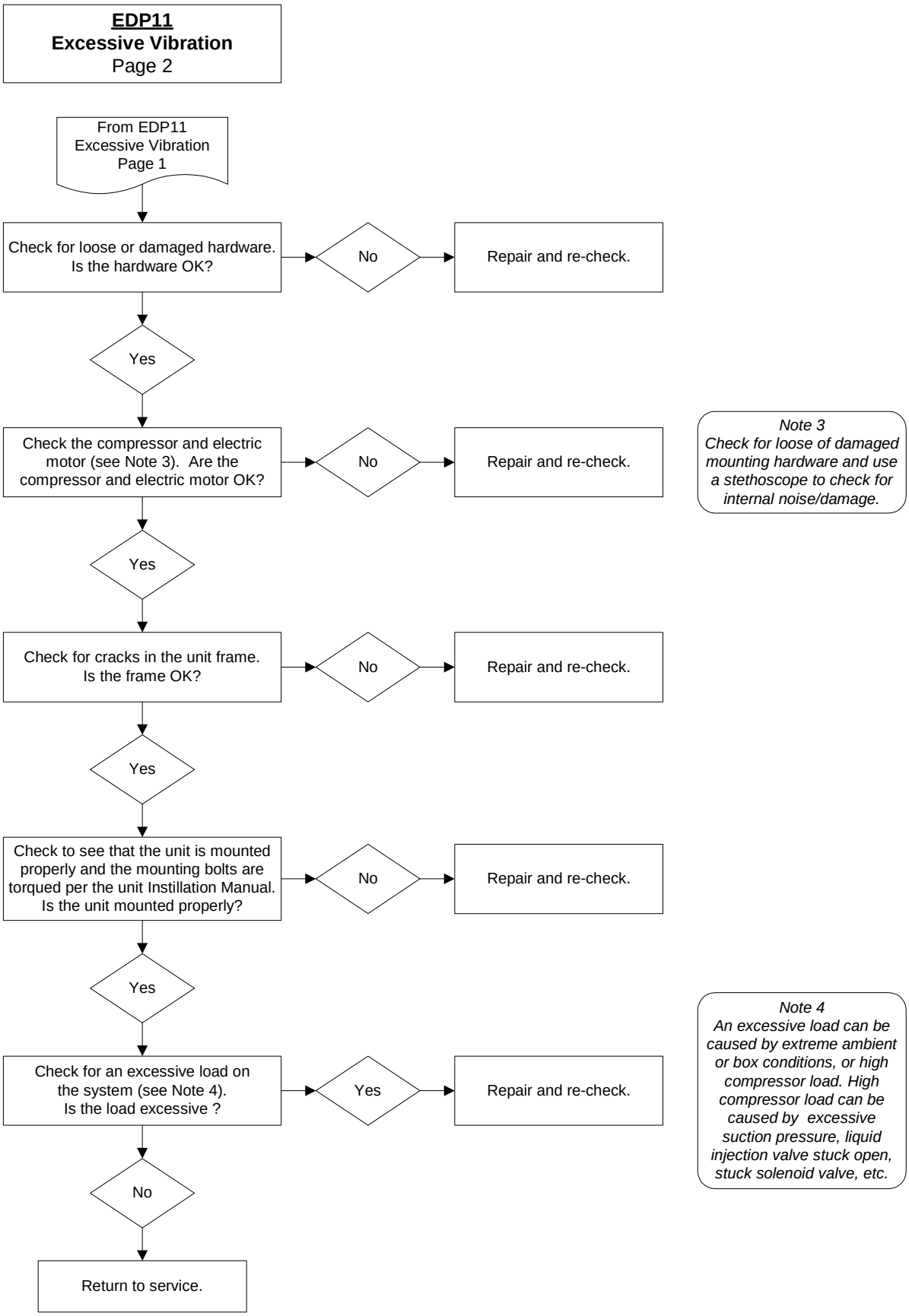
EDP10 Overheating (Continued)



EDP11 Excessive Vibration



EDP11 Excessive Vibration (Continued)



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