GE
Transportation

7FDL Diesel Engine Maintenance

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SMI-90042

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7FDL16 DIESEL ENGINE
MAINTENANCE

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1. INTRODUCTION

This publication covers component replacement procedures that may be required to service the General Electric (GE) locomotive 7FDL16 diesel engine.

1.1. RELATED PUBLICATIONS

Recommended Fuel, Oil and Lubricants MI–00152 (GEK–76679)

1.2. SAFETY INFORMATION

Safety precautions which must be observed when working on the 7FDL16 Diesel Engine appear throughout this publication. WARNINGS indicate the potential for personal injury, and CAUTIONS indicate the potential for equipment damage.

1.2.1. Personal Protective Equipment (PPE)

- Safety glasses must be worn at ALL times.
- Appropriate personal protective equipment (PPE) must be worn when working on the diesel engine.
- Latex gloves must be worn to protect the hands when working with fuel, oil, and other lubricants or fluids.
- Suitable earplugs must be worn to prevent hearing damage when using air–operated tools.
- Kneepads should be worn when kneeling for extended periods of time.

1.2.2. Engine Barring Over Safety

When using an engine barring–over device, the following precautions must be taken to ensure the safety of all persons:

- Keep hands away from pinch points.
- Keep loose clothing away from moving parts.
- Ensure barring–over device/motor is properly secured.
- Warn fellow workers of engine movements.

1.2.3. Tool Safety And Use

To ensure the safety of all workers, proper care must be taken when using all hand tools:

- Watch finger clearance when using hand tools.
- Pull hand tools (ratchets, wrenches) towards yourself for better control.
- If unable to pull hand tools, push with an open palm.
- Do not use torque wrenches to break bolts loose.

2. ENGINE DATA

Description: . . . . . 7FDL16, 16–Cylinder Turbocharged, 4–Cycle Diesel Engine
Firing Order: . . . . . 1R – 1L – 3R – 3L – 7R – 7L – 4R – 4L – 8R – 8L – 6R – 6L – 2R – 2L – 5R – 5L
Horsepower – Traction: . . . . . 4020 Hp
Number of Cylinders : 16
Bore and Stroke (in.): . . . . . 9 X 10.5
RPM: 1050
Compression Ratio: 15.5:1
Cycle: 4
Turbocharged: . . . . . Yes (7S1716)
Electronic Fuel Injection: . . . . . Yes (EFI)
Engine Cooling Fan: . . . . . 1 (C38 – AChe uses 2)
Engine Cooling Fan Drive: . . . . . AC Motor
Engine Heating Unit: . . . . . 2, Diesel Fired with Integral Circulating Pumps
Overall Engine Dimensions and Weight:

- Height (overall, including stack): 2,984 mm (9.79 ft.)
- Length (overall, including alternator): 6,536 mm (21.44 ft.)
- Width (overall): 1,740 mm (5 ft. 8 in.)
- Weight (dry engine): 19,736 Kg (43,510 lb.)

Fluid Capacities:

- Lubricating Oil: 1675 liters, ±80 liters (442 gallons, ±21 gallons)
- Coolant Water: 925 liters, ±80 liters (244 gallons, ±21 gallons)
- Diesel Fuel: 9000 liters, ±1% (2378 gallons ±1%)

Fluid Specifications:

- Lubricating Oil: Refer to Publication GEK–76679
- Diesel Fuel: Refer to Publication GEK–76679

3. POWER ASSEMBLY

Special Tools Required:

NOTE: GE part numbers shown except as otherwise noted.

Air Operated Wrench . . . . . GE 147X2204
Air Motor Support Bracket . . . . . TESCO
Basic Standard Tool Kit . . . . . Locally Purchased
Cylinder Head Lifting Device . . . . . GE 147–1606–1
Guide Pins . . . . . GE 147X1367
Impact Wrench . . . . . GE 147X1684–2
Lubriplate® Spray Lube A . . . . . GE 147X1614
Lubriplate® 630–AA . . . . . GE 147X2163
Piston Protector . . . . . GE 147X1951
Piston Retainer . . . . . GE 147X1406–2
Piston Ring Compressor . . . . . GE 147X1089–1
Piston Support Bar . . . . . GE 147X1090
Pneutorque Wrench . . . . . GE 147X1568–1
Rocker Arm Depressor . . . . . GE 147X1040–1
Rod Shank Pad . . . . . GE 147X1828
Torque Multiplier . . . . . GE 147X2360

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

ECC

CAUTION: The power assembly (in all configurations) is an Emission Critical Component (ECC). Do not replace it with a non–ECC part. Refer to the NOTICE at the beginning of this publication and consult the latest revision of the manufacturer's Parts Catalog to obtain the correct replacement part.

3.1. REMOVE POWER ASSEMBLY

The power assembly is made up of several components including the cylinder liner and head, the cylinder jacket, the piston and connecting rod. The power assemblies are bolted to the engine mainframe. They are arranged in rows on both sides of the engine commonly called the left and right bank of cylinder assemblies.

Removing a complete power assembly includes cylinder removal steps and piston assembly/connecting rod removal steps. Instruction for removing a complete power assembly follows.

3.1.1. Cylinder Removal

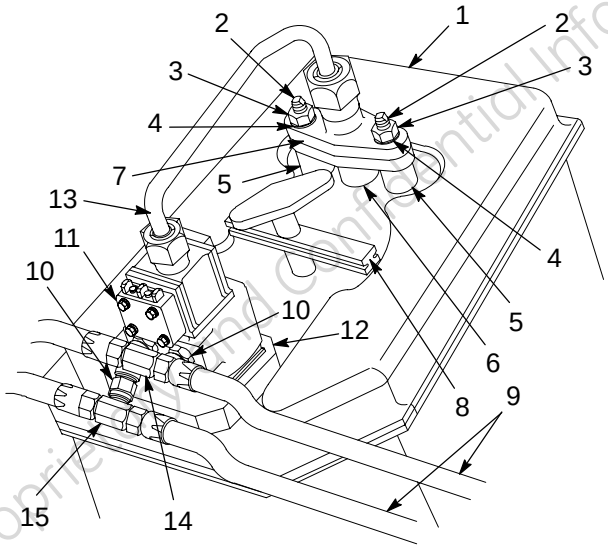
A cylinder may be replaced either with or without its respective piston and connecting rod, depending on the nature of the work to be performed. The cooling water must be drained before cylinder removal.

The lubricating oil should be drained if extensive work is to be performed to guard against contamination of the oil.

To remove a cylinder from a diesel engine with EFI, proceed as follows:

1. Disconnect and remove the following parts from the cylinder:
   a. Cylinder head cover (Figure 1).
   b. Air intake manifold. Unbolt the clamp rings and slip the tubes free of the intake manifold body.
   c. Water inlet and discharge headers. Loosen the compression couplings and remove the bolts from the flanges. Remove the upper water discharge connection and compression elbow.
   d. Exhaust manifold at the cylinder flange.
   e. Fuel–oil injection pump. Refer to *Section 8.2.1., FUEL–OIL INJECTION PUMP REMOVAL,* of this publication.

CAUTION: Ensure that all camshaft sections are in place before barring over the diesel engine. Barring over the engine with camshaft sections removed WILL damage valve train components.



REF.	DESCRIPTION
1	CYLINDER HEAD COVER
2	STUD, NOZZLE
3	HEX JAM NUTS (1/2–13, HEAVY)
4	WASHER, THREAD SEAL
5	COLLAR, RUBBER (THICK WALL)
6	FUEL–OIL INJECTION NOZZLE
7	NOZZLE CLAMP
8	COVER CLAMP
9	FUEL–OIL HEADER LINES
10	ELBOW FITTINGS
11	FUEL–OIL PUMP SOLENOID
12	FUEL–OIL INJECTION PUMP
13	HIGH PRESSURE FUEL–OIL LINE
14	OUTLET TEE FITTING
15	INLET TEE FITTING

E–44223A

Figure 1. Cylinder Upper Components With EFI.

2. Bar the crankshaft so the piston in the cylinder to be removed is near top dead center with all valves closed. Refer to *Section 8.2.1., FUEL–OIL INJECTION PUMP REMOVAL,* of this publication for barring–over instructions.

3. Remove the short crossover pushrod, and then the two (2) vertical pushrods. Use the rocker arm depressor (refer to *Section 20., SPECIAL TOOLS)* to rotate the rocker arms for clearance to free the pushrods. Do NOT bend the pushrods by forcing or prying. The fuel push–rod assembly will be removed with the cylinder.

4. Remove the four (4) cylinder hold–down bolts as follows:

NOTE: Use the Pneutorque wrench (GE Tool 147X1568–1) or torque multiplier (GE Tool 147X2360) with manual wrench and the TESCO Air Motor Support Bracket (Figure 2). An impact wrench (GE Tool 147X1684–2) also can be used to remove the bolts.

CAUTION: If it should be necessary to apply heat to a bolt head to facilitate removal, scrap that bolt. Heat changes the tensile strength of the bolt.

a. Firmly grasp and lift Air Motor Support Bracket. Avoiding pinch points, place tool on top of power assembly (Figure 2).

E–44589

Figure 2. Applying TESCO Air Motor Support Bracket.

b. Ensure all four “L” brackets are positioned inside rocker arm shaft cover bolts (Figure 3).

c. Rotate “T” handles until flat side of clamping plates are squared to bottom of head clamping boss and “T” handles are parallel with the rocker arm shafts (Figure 4).

d. Fully tighten the knurled clamping rods below the “T” handle and then verify clamping plates are fully engaged.

e. Assemble the air motor, extension and socket. Avoiding pinch points, carefully lift and place the air motor on the support rack pins and on bolt head (Figure 5). **Verify clamping plates are still properly aligned and re–tighten both knurled clamping rods.**

WARNING: EVERY TIME you proceed to another bolt, ALWAYS ensure clamping plates are still properly aligned and re–tighten the knurled clamping rods.

f. Remove the four (4) cylinder hold–down bolts as follows:

1) Ensure support bracket is positioned properly and air motor is applied.

2) Apply air hose to air motor ensuring air motor rotation control is in OFF position.

3) Apply air to motor.

4) Start air motor and remove your hand from motor control while the bolt is being turned. **Avoid placing your hand between the air motor and the carbody wall or Engine Room door frames when turning motor ON or OFF.**

WARNING: EVERY TIME you proceed to another bolt, ALWAYS ensure clamping plates are still properly aligned and re–tighten the knurled clamping rods.

5) Repeat Steps 1 through 4 for remaining bolts.

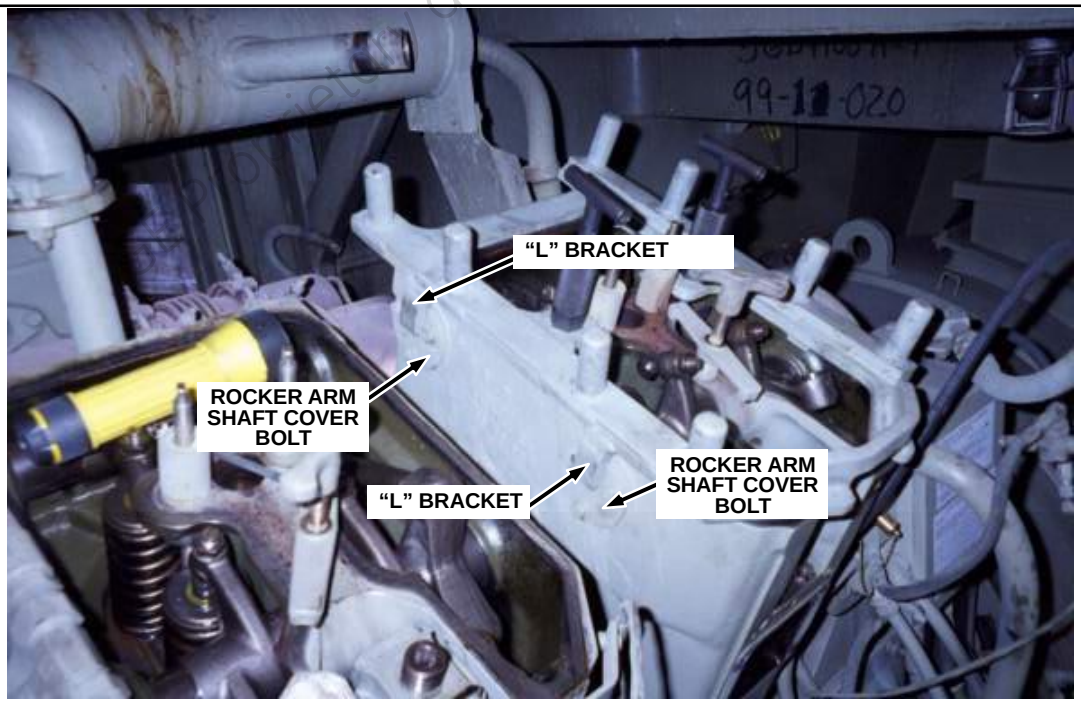


Figure 3. Properly Position TESCO Air Motor Support Bracket.

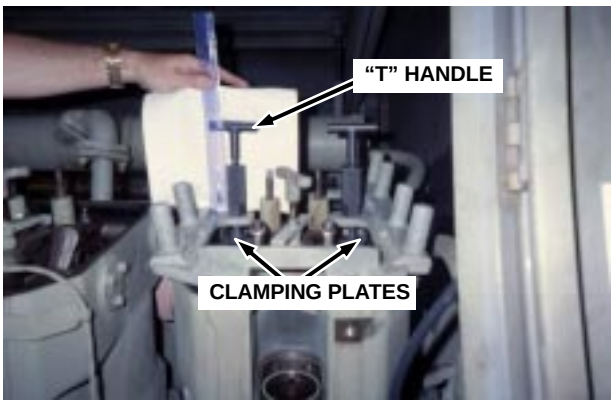


Figure 4. Align TESCO Air Motor Support Bracket Clamping Plates And "T" Handles.

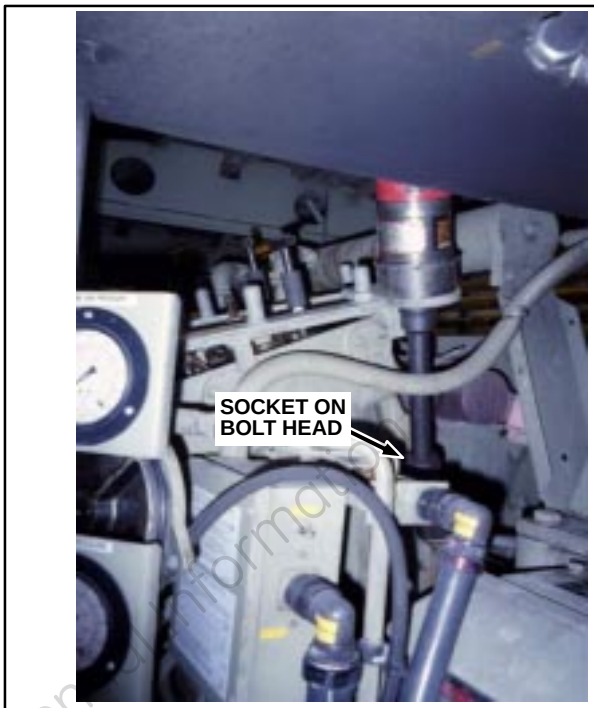


Figure 5. Positioning Air Motor, Extension And Socket On Bolt Head.

3.1.2. Piston and Connecting Rod Removal

If the connecting rod and piston are to be removed with the cylinder assembly, proceed as follows:

1. To hold the piston assembly in the cylinder, apply the piston retainer (Figure 6 and *Section 20., SPECIAL TOOLS)*.
2. If an articulated rod is to be removed, remove the articulated rod pin bolts.
3. If a master rod is to be removed, remove the master rod bearing cap. Use a rod shank pad (refer to *Section 20., SPECIAL TOOLS)* on the master rod to avoid damage to other parts during removal.
4. Attach the cylinder lifter (refer to *Section 20., SPECIAL TOOLS*) over the water discharge opening on the back of the cylinder (Figure 7). Use only the high–strength bolts supplied with the cylinder lifter. Ensure the bolts are tight.

NOTE: If the piston and connecting rod are not removed with the cylinder, open the cylinder compression release plug. Protect the piston from damage that could be caused by the piston falling and scuffing against the engine frame as the cylinder is lifted off. Apply the piston protector (refer to Section 20., SPECIAL TOOLS) to protect and guide the piston when the crankshaft is rotated with cylinders removed.

CAUTION: If pistons and rods are not properly supported when cylinders are removed, in certain positions of the crankshaft, the articulated connecting rods can contact and damage the articulated pin bushings.

5. After ensuring that the cylinder has been completely disconnected, carefully lift the cylinder, using the angular lifting eye and guiding the cylinder.

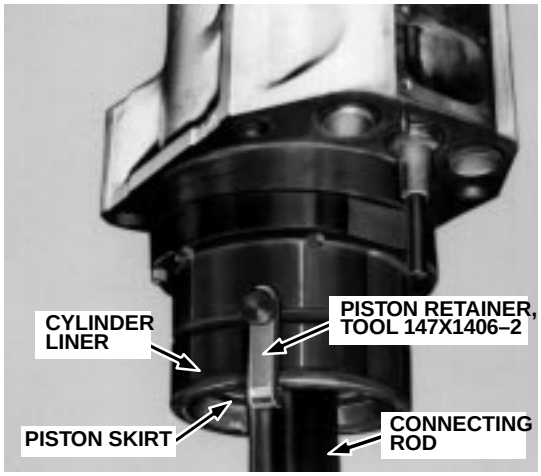


Figure 6. Cylinder Piston Retainer.

Figure 7. Cylinder Lifter Rigged For Angular Lift (Typical).

NOTE: If desired, with the cylinder removed, the piston may be removed while the rod remains in the engine. Refer to Section 3., PISTON AND PISTON RINGS, of this publication.

NOTE: For detailed information regarding the cylinder head, piston, or connecting rod, refer to the following sections of this publication: Section 5., CYLINDER HEAD, Section 3., PISTON AND PISTON RINGS, and Section 7., CONNECTING ROD AND CONNECTING ROD BEARINGS.

3.2. INSTALL POWER ASSEMBLY

Installation of a complete power assembly includes the connecting rod, piston, cylinder liner and head, and the cylinder jacket. When both the left and right bank assemblies have been removed, the left assembly with the master rod is replaced first.

Power assembly installation is basically the reverse of the removal process.

1. Back out all cylinder valve tappet adjusting screws to provide maximum clearance between the tappet buttons and the valve stems on the power assembly to be installed (Figure 8).

2. Adjust the fuel pump tappet rod to its minimum length to prevent over–stroking the fuel pump in case the engine is barred over before the timing adjustment has been made (Figure 9).

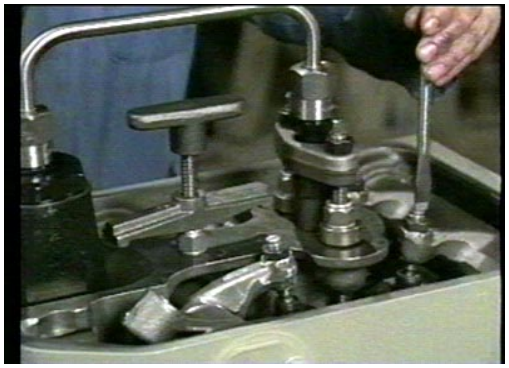


Figure 8. Back–Out Cylinder Valve Tappet Adjusting Screws.

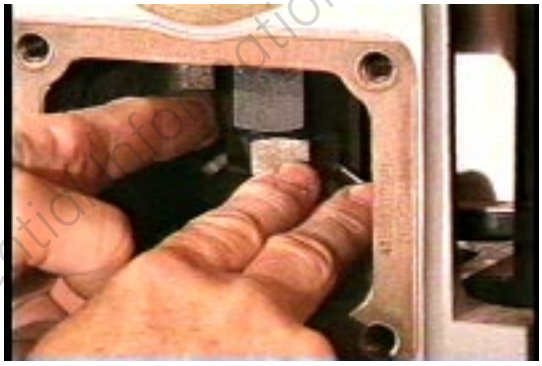


Figure 9. Adjust The Fuel Pump Tappet Rod.

3. Use the screwjack fuel crosshead guide puller to prevent damage to the assembly. Be sure to keep the positioning dowels. After the guide is loose, remove the puller. Working with one hand through the crankcase door, remove all the components. Discard and replace the O–rings around the three (3) cross head guides and apply Lubriplate® Spraylube A.

4. Carefully reassemble the complete crosshead and guide, being sure to check that all parts work freely. Reinstall the assembly in the center position. Using the end of a wooden hammer handle or another soft object, tap the guide down (Figure 10). Use the tool to line up the guide and insert the dowel to keep the guide aligned.

Figure 10. Reinstall Crosshead And Guide.

5. Pull the valve cross head guides using a hammer jack for assistance. Disassemble and reassemble as previously described taking care to keep the positioning dowel.

6. Apply Lubriplate® Spraylube A around the valve pushrod ferrules and the fuel pump pushrod guide. Install new O–rings. Spray a wide band of the lubricant at the radius of the lower cylinder jacket extension and install a new O–ring at this location also. Use a clean, lint–free cloth or towel to wipe out the cylinder liner.

7. Insert guide pins in the cylinder mounting–bolt holes and hand–tighten. Wipe the top surface of the main frame where the cylinder will seat. Use the lifter to hoist the cylinder assembly at a 22–1/2° angle and position it over the guide pins.

8. Remove the protective pad from the crankshaft.

9. Clean the crankshaft journal and the new lower bearing half with a lint–free cloth. Be sure the serial numbers match on the master rod and the master rod cap. Apply lubricating oil to both the bearing and the journal. Install the bearing shell and apply oil.

10. As the assembly is lowered into place, reach through the crankcase door and guide the rod over the crankshaft (Figure 11).

E–46824

Figure 11. Placing the Power Assembly.

11. Install the rod cap being sure to match the serial number to the master rod. Lubricate the bolts with MOLY-KOTE® G–n Paste and torque them to the value found in *Section 21., TORQUE VALUES,* of this publication.

12. Use lubricated bolts to install the power assembly to the mainframe. Initially, the bolts should be installed finger–tight. Working diagonally across the cylinder, tighten the bolts with the air operated wrench (refer to *Section 20., SPECIAL TOOLS*) in two to three passes (Figure 12).

13. Reconnect the water intake manifold taking care to use new gaskets/O–rings at each step in the assembly. Install the exhaust manifold flange and reassemble the water outlet connection and compression elbow. Again, new gaskets should be used.

E–46825

Figure 12. Tighten Bolts With Air Operated Wrench.

14. Before installation, check the existing pushrods for nicks, dents and bends. Replace any component that does not meet the standards of this visual inspection. If necessary, bar over the crankshaft to ensure that the rollers are on the base circle of the cams. Use the rocker arm depressor tool to slide the inlet pushrod into its cavity on the rocker. Depress the exhaust valve rocker arm until the short exhaust pushrod can be inserted into its area.

15. Conduct the proper valve last and fuel pump adjustments. Fill the cooling water system according to the instructions contained in **SMI–02003, ENGINE COOLING SYSTEM**.

3.2.1. Cylinder Installation

A cylinder may be installed either with its piston and connecting rod assembly or separately. The general procedure on a diesel engine with EFI is the same in either case. Proceed as follows:

CAUTION: Do NOT use chrome piston rings with chrome cylinder liners. Do NOT use iron piston rings in hardened cylinder liners. Refer to your Renewal Parts Catalog for the proper ring and liner combinations. If improper combinations are installed, severe cylinder liner scoring will occur very quickly.

ECC

CAUTION: The cylinder is an Emission Critical Component (ECC). Do not replace it with a non–ECC part. Refer to the NOTICE at the beginning of this publication and consult the latest revision of the manufacturer's Parts Catalog to obtain the correct replacement part.

NOTE: When replacing cylinders only, install new piston rings. Refer to Section 6.3., REPLACE PISTON RINGS, of this publication. Also, renew the three (3) crosshead guide O–rings whenever a cylinder assembly is removed from the engine. Refer to* MI–93200, GEK–18033, CROSSHEADS AND GUIDES *publication.

CAUTION: Ensure that all camshaft sections are in place before barring over the diesel engine. Barring over the engine with camshaft sections removed WILL damage valve train components.

1. Ensure the piston is in good condition. If the piston and rod assembly is in the engine, remove the piston protector (refer to *Section 20., SPECIAL TOOLS*), and place the piston support bar (refer to *Section 20., SPECIAL TOOLS*) under the piston across the main frame opening (Figure 13). Bar the crankshaft to lower the piston firmly onto the cradle of the support bar. Stagger the end gaps of adjacent piston rings approximately 180° apart. Coat the piston with a liberal quantity of clean engine lubricating oil. Apply the ring compressor (Figure 14 and refer to *Section 20., SPECIAL TOOLS*).

2. Back out all four (4) cylinder valve tappet adjusting screws to provide maximum clearance between the tappet buttons and the valve stems. Adjust the fuel–oil injection pump tappet rod to its minimum length. Open the cylinder compression release plug.

3. Apply new O–rings, lubricated with Lubriplate® Spray Lube A (refer to *Section 20., SPECIAL TOOLS*), to the cylinder assembly at the bottom frame fit radius, the valve pushrod ferrules, and the fuel–oil injection pump pushrod guide.

4. Install two (2) guide pins (refer to *Section 20., SPECIAL TOOLS*) in diagonally opposite frame hold–down bolt holes. Using the angular lifting eye on the cylinder lifter (Figure 7 and refer to *Section 20., SPECIAL TOOLS*), lift the cylinder and lower it carefully over the piston. The ring compressor can be removed after it is pushed down and drops free of the bottom ring. Then bar the crankshaft to raise the piston sufficiently to remove the support bar from under the piston. Lower the cylinder into place.

NOTE: If the piston and rod assembly is to be installed at the same time as the cylinder, the piston may be held in the cylinder by using the piston retainer (Figure 6). Install left–bank cylinders with master rods first, followed by right–bank cylinders with articulated rods. Use suitable protection with the master rod to avoid damage to other parts. Complete the installation of connecting rods as described in Section 7.2., INSTALL CONNECTING ROD, of this publication.

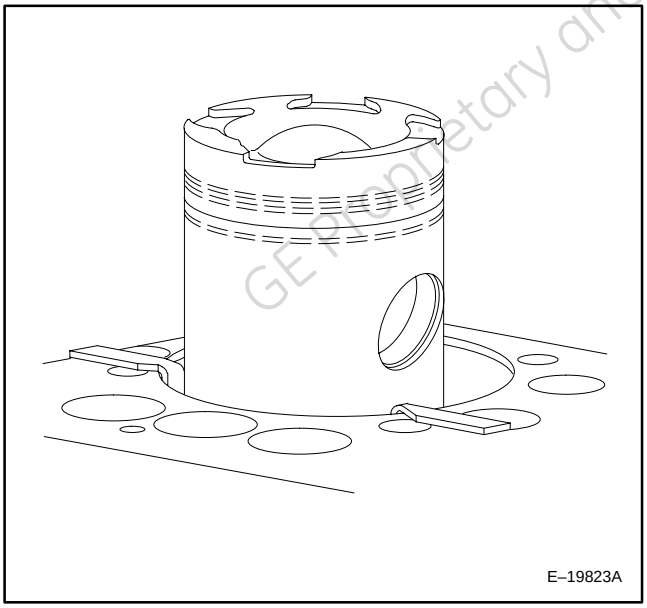


Figure 13. Piston Support Bar, (Typical).

Figure 14. Applying Piston Ring Compressor.

5. Coat the threads and washer face of the four (4) cylinder hold–down bolts with Lubriplate® 630–AA* grease (refer to *Section 20., SPECIAL TOOLS*). Install two (2) bolts finger–tight in the empty holes, then remove the two (2) guide pins and install the other two (2) bolts. Torque all four (4) cylinder hold–down bolts EVENLY to the torque specified in *Section 21., TORQUE VALUES,* of this publication. Refer to procedure presented in *Section 3.1.1., CYLINDER REMOVAL,* for proper use of the TESCO Air Motor Support Bracket (Figure 2).

6. Connect the air intake and exhaust manifolds and the water headers using new gaskets. Refer to the *Section 4., EXHAUST MANIFOLD,* of this publication.

7. Install the fuel–oil injection pump. Refer to *Section 8., FUEL–OIL INJECTION PUMP,* of this publication.

8. To obtain sufficient clearance when installing pushrods, each valve crosshead roller must be on the base circle of its cam. Insert the vertical pushrods into their sockets in the crossheads; then install the short crossover pushrod. Rotate the rocker arms using the rocker arm depressor (refer to *Section 20., SPECIAL TOOLS*) until the pushrods can be inserted into their respective rocker arm sockets.

9. Set cylinder valve tappet clearance. Refer to the *Section 5., CYLINDER HEAD,* of this manual.

4. EXHAUST MANIFOLD

Special Tools Required:

Fel–Pro C–5A GE147X1640

Torque Wrench . . . . . Locally Purchased

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

The exhaust manifold returns the diesel engine exhaust gases from the cylinder exhaust ports to the turbocharger. The turbocharger, which is driven by the engine exhaust gases, compresses cleaned and filtered air for the combustion process in the engine cylinders.

NOTE: The transition section and any main section of the dual–pipe exhaust manifold may be replaced without removing the water header.

CAUTION: Always renew all exhaust manifold gaskets where joints are loosened or removed.

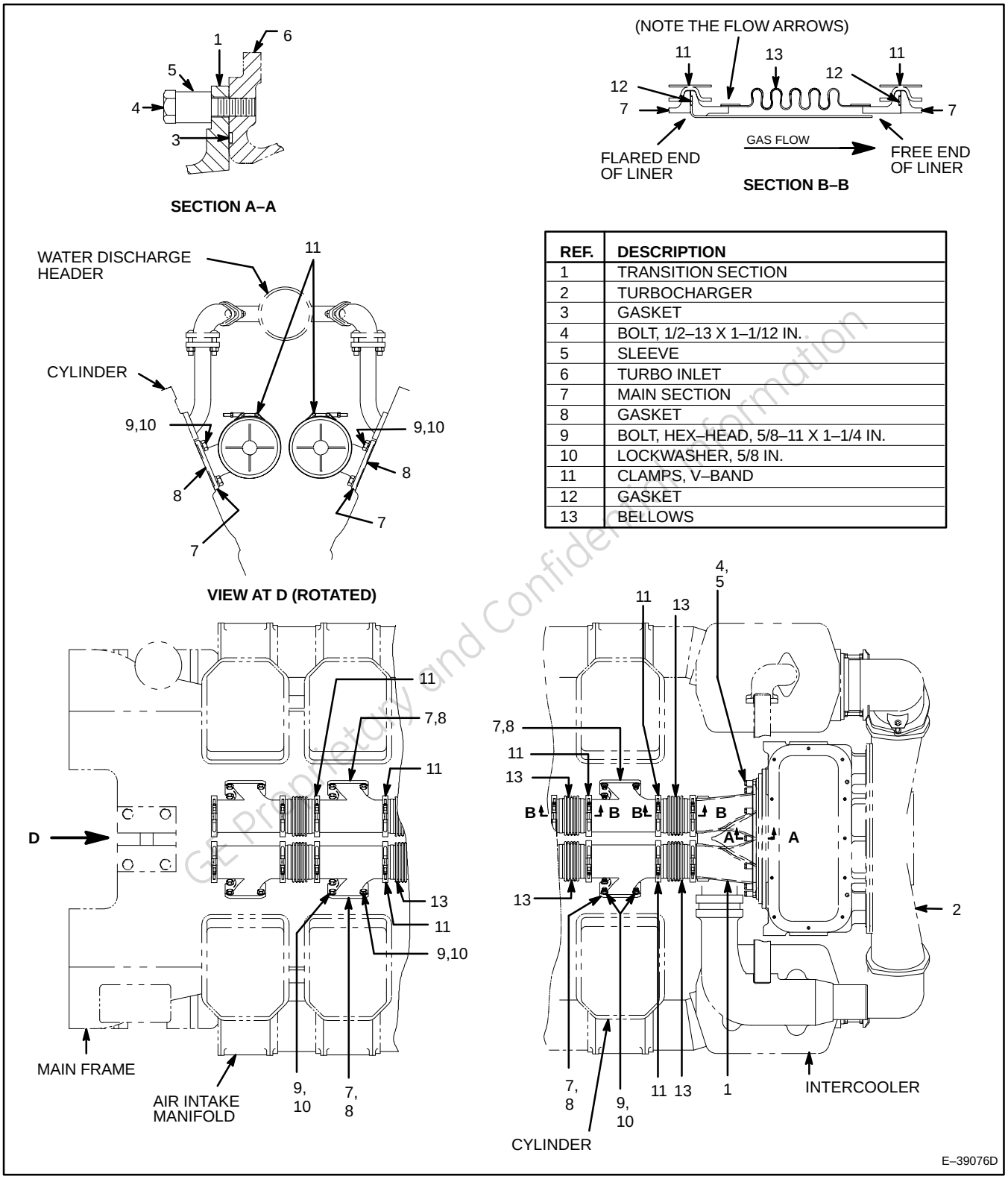
When changing–out a cylinder assembly, remove dual–pipe exhaust manifold bellows on both sides of the cylinder to be changed. Apply the main section to the new cylinder, and then replace the bellows. The V–band clamps are the last items applied and tightened (Figure 15).

CAUTION: Do NOT damage the exhaust manifold bellows attached to the transition section.

When removing the turbocharger, support the dual–pipe exhaust manifold transition section by either blocking or suspending from the water header.

CAUTION: Do NOT pry against the exhaust manifold bellows, only against the main casting.

After operation, it is normal for the dual–pipe exhaust manifold V–band clamps to remain tight on the flanges when the nuts are loosened. To remove the V–band clamps, use a large screwdriver or small prybar, and pry up at the end of each of the three clamp sections.



REF.	DESCRIPTION
1	TRANSITION SECTION
2	TURBOCHARGER
3	GASKET
4	BOLT, 1/2–13 X 1–1/12 IN.
5	SLEEVE
6	TURBO INLET
7	MAIN SECTION
8	GASKET
9	BOLT, HEX–HEAD, 5/8–11 X 1–1/4 IN.
10	LOCKWASHER, 5/8 IN.
11	CLAMPS, V–BAND
12	GASKET
13	BELLOWS

Figure 15. Dual–Pipe Exhaust Manifold Details.

NOTE: Numbers in parentheses () refer to items found on Figure 15 of this publication, unless noted otherwise.

4.1. REMOVE DUAL–PIPE EXHAUST MANIFOLD SECTIONS

Remove dual–pipe exhaust manifold sections as follows:

1. Secure the engine so that it cannot be started.

2. Loosen the band clamps for the exhaust manifold section to be removed (11). Use a large screwdriver or small prybar, and pry up at the end of each of the clamps.

3. Remove the dual–pipe exhaust manifold bellows on both sides of the exhaust manifold section to be changed (13).

4. Unscrew the bolts (4) and remove the exhaust manifold section.

4.2. INSTALL DUAL–PIPE EXHAUST MANIFOLD SECTIONS

Apply dual–pipe exhaust manifold sections as follows:

NOTE: Apply Fel–Pro C–5A (refer to Section 20., SPECIAL TOOLS) high–temperature anti–seize thread compound to all bolt–head washer faces and threads, and to tapped holes.

NOTE: Clamping plates are not used with current production dual–pipe manifold transition sections. Instead, the connection between the transition section and the bellows uses the same V–band clamp used with other bellows.

1. Ensuring that the gasket (3) is properly positioned between the transition section (1) and the turbocharger turbine inlet flange (6), attach the transition section to the turbine inlet flange using long bolts and spacers as shown in section A–A. Torque the bolts to 70 to 75 lb.–ft. (95 to 102 Nm).

2. Attach the main sections (7) and gaskets (8) to the cylinders using bolts (9) and lockwashers (10). Ensure that the main sections are oriented in the proper direction and not excessively out–of–line by pushing them down against the bolts prior to tightening. Torque the bolts to 140 to 150 lb.–ft. (190 to 204 Nm).

CAUTION: Always make the V–band connections last, after tightening the main sections to the cylinders.

3. Place the V–band clamps (11) loosely over the ends of the transition and main sections (7). Position the clamps so that the bolts and nuts are oriented towards the outside of the engine for easy access. Keep the clamps behind the flanges.

4. Place gaskets (12) into the grooves of the bellows (13). To help hold the gaskets in place while handling, the gaskets may be glued.

5. Noting the proper flow direction (refer to section B–B), attach the bellows (13) to the main sections (7). Ensure the bellows are reasonably concentric with the main sections; if there is more than 0.13 in. (3.3 mm) eccentricity, correct the alignment of the main sections.

CAUTION: Use only the silver–plated nuts supplied with the V–band clamps to prevent galling with T–bolts.

6. At each connection, place one V–band clamp (11) in position and torque to the torque specified in *Section 21., TORQUE VALUES,* of this publication. While tightening, observe the alignment of the other bellows end. More than 0.13 in. (3.3 mm) misalignment indicates that improvement in the alignment is needed. Then move the other clamp into position and tighten.

CAUTION: Ensure all bellow convolutions are parallel and not touching each other.

7. Run the engine for a minimum of one hour at full load after replacing any exhaust manifold gasket.

CAUTION: The exhaust manifold metal should be allowed to cool below 200 F (94 C) before retorquing.

8. After the load test, retorque all bolts. Then apply a second nut to each V–band clamp, torquing to 12 to 15 lb.–ft. (16 to 20 Nm) in a jamming fashion.

5. CYLINDER HEAD

Special Tools Required:

Air–Operated Wrench . . . . . GE 147X2204
Barring Over Device . . . . . TESCO T58440
Basic Standard Tool Kit . . . . . Locally Purchased
Cylinder Head Lifting Device . . . . . TESCO T85320
HOTSY Cleaner Kit . . . . . GE 147X2332
1.0 in. Drive Ratchet Wrench . . . . . GE 147X1982

CAUTION: Do NOT use imperial feeler gages or stiff stacked feeler gages when measuring. Use of these may result in inaccurate measurements/settings.

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

The cylinder head is part of the power assembly (cylinder head, cylinder liner, cylinder jacket, piston and connecting rod). The cylinder head contains two (2) inlet valves, two (2) exhaust valves, and one (1) injector.

For instructions on removing the cylinder, refer to *Section 3.1., REMOVE POWER ASSEMBLY,* of this publication.

5.1. CHECK AND ADJUST CYLINDER HEAD VALVES

Check cylinder valve tappet clearance as follows:

1. Back off the compression release plugs one full turn on all cylinders.

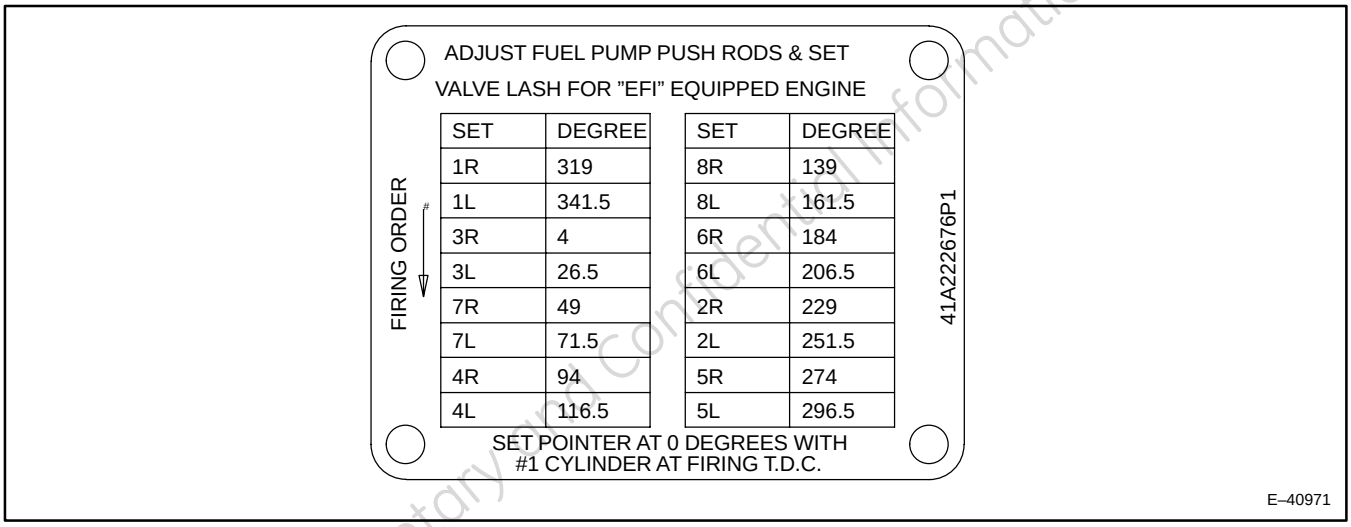
2. Remove the cylinder head cover (Figure 1) from all cylinders.

CAUTION: Ensure that all camshaft sections are in place before barring over the diesel engine. Barring over the engine with camshaft sections removed WILL damage valve train components.

3. Remove the timing window cover and the barring–over access cover from the right side of the camshaft gear cover on the cable side of the locomotive. Install the barring over tool (TESCO T58440), ensuring the over tool is fully inserted with the tool housing tight against the gear cover. Then bolt the over tool to the gear cover using the bolts from the barring–over access cover. After moving the barring–over gear inward into engagement with the camshaft gear, apply either a 1.0 in. drive ratchet wrench (Tool 147X1982) or an air–operated wrench (Tool 147X2204) to the barring–over gear.

CAUTION: The use of an impact wrench for this operation is NOT recommended, as engine internal damage may result.

4. Using the ratchet wrench or air–operated wrench, slowly bar over the crankshaft in its normal direction of rotation until the pointer in the barring–over gearbox timing window aligns with the degree mark for the cylinder being worked as specified on the timing nameplate near the gearbox (Figure 16). Timing nameplates vary by the number of cylinders on the engine.



SET	DEGREE	SET	DEGREE
1R	319	8R	139
1L	341.5	8L	161.5
3R	4	6R	184
3L	26.5	6L	206.5
7R	49	2R	229
7L	71.5	2L	251.5
4R	94	5R	274
4L	116.5	5L	296.5

Figure 16. Typical Timing Nameplate For Engine With EFI.

5. Assure that all valves are closed on the cylinder being worked, which should be on its compression stroke. If the valves are closed, a small amount of free movement will be noted by manually moving the rocker arms.

Another check is to observe the radial position of the fuel and valve cams for the cylinder being worked. If the cylinder is on its compression stroke, the valve crosshead rollers will be off the lobe and on the base circle of the cam. The fuel crosshead roller will be rising on the lobe of its cam.

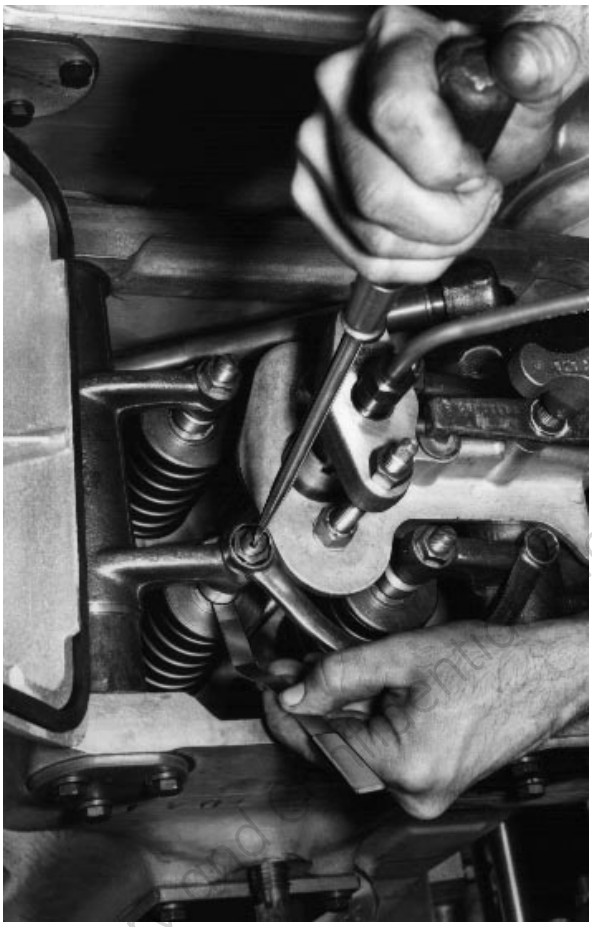
NOTE: While this step is not mandatory, it is recommended since it assures the integrity of the camshaft assemblies and the engine firing order.

6. Loosen each cylinder valve tappet locknut (Figure 17) and adjust the tappet screw to give the following valve tappet clearances:

   a. Inlet – 0.018 to 0.020 in. (0.46 to 0.51 mm).

   b. Exhaust – 0.028 to 0.030 in. (0.71 to 0.76 mm).

   c. Tighten all locknuts with 50 to 55 lb.–ft. (68 to 75 Nm) of torque and recheck the clearance.



E–13113A

Figure 17. Adjusting Cylinder Tappet Valve Clearance With Standard Tools.

7. Bar the crankshaft to the next cylinder in the firing order and adjust the valve tappet clearances. Repeat until all valve tappets have been properly adjusted.

8. After all of the cylinder valve tappets have been adjusted replace the cylinder head covers. Tighten the cylinder compression release plugs. Remove the barring over tool, and replace the timing window cover and the barring–over access cover on the camshaft gear cover.

5.2. CYLINDER INLET PORTS

With the engine shut down, remove the air inlet manifold clamp rings, manifold tubes, manifold bodies and manifold heads (Figure 18) to expose the cylinder inlet ports (Figure 19). Note the degree of carbon deposits on all visible surfaces of the cylinder jacket, cylinder head and cylinder inlet valves. If carbon deposits exceed 0.13 in. (3 mm) on any surface, clean the inlet ports of all cylinders on the engine using the HOTSY cleaner, similar to HOTSY Cleaner Kit (Tool 147X2332).

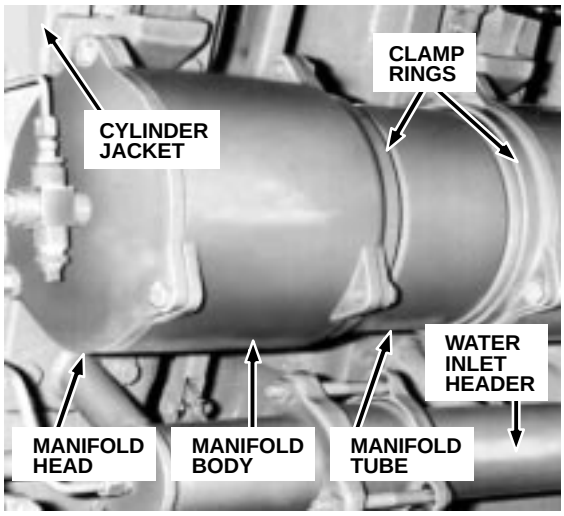


Figure 18. Air Inlet Manifold.

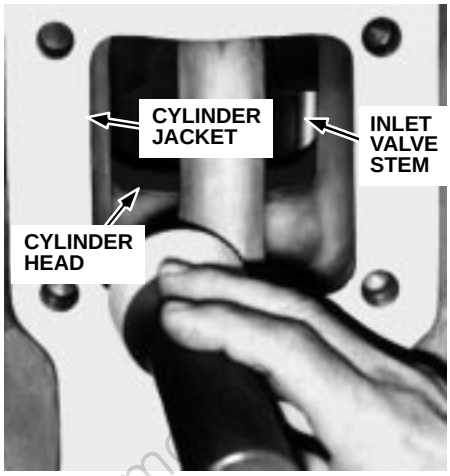


Figure 19. Cylinder Inlet Port.

6. PISTON AND PISTON RINGS

Special Tools Required:

Barring Device	TESCO T58440
Brass or Hardwood Driver	Locally Purchased
Guide Pin	GE 147X1326
MOLYKOTE® G–n	GE 147X1143
Piston Pin Bolt Socket	GE 147X1511
Piston Pin Bolt Wrench	GE 147X1841–1
Piston Lifter	TESCO T85340
Piston Protector	GE 147X1951
Piston Ring Groove Scraper	GE 147X1098
Piston Ring Expander	GE 147X1099–2
Piston Support Bar	GE 147X1090
Torque Wrench	Locally Purchased
0.75 in. Drive Ratchet	GE 147X1866

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

The piston is a two–piece assembly consisting of the crown (top) and the skirt (bottom). The crown is shaped to form the combustion chamber. The skirt has drilled passages for lubrication and cooling.

NOTE: Refer to publication* MI–93404, GEK–76740, STEEL CROWN PISTON *for maintenance information on the Piston Crown.

6.1. REMOVE PISTON

To replace a piston, the cylinder assembly must be removed first (refer to *Section 3., POWER ASSEMBLY,* of this manual). After the cylinder is removed, remove the piston as follows:

1. Remove the piston protector (refer to *Section 20., SPECIAL TOOLS*) and place the piston support bar (refer to *Section 20., SPECIAL TOOLS*) under the piston across the main frame opening (Figure 13) . Bar the crankshaft to lower the piston firmly onto the cradle of the support bar.
2. Using a piston pin bolt wrench (Figure 20 and *SPECIAL TOOLS*) and piston pin bolt socket (refer to *Section 20., SPECIAL TOOLS*) with a 0.75 in. drive ratchet, remove both piston pin bolts and spacers.
3. Carefully remove the piston using the TESCO Piston Lifter (refer to *Section 20., SPECIAL TOOLS*).

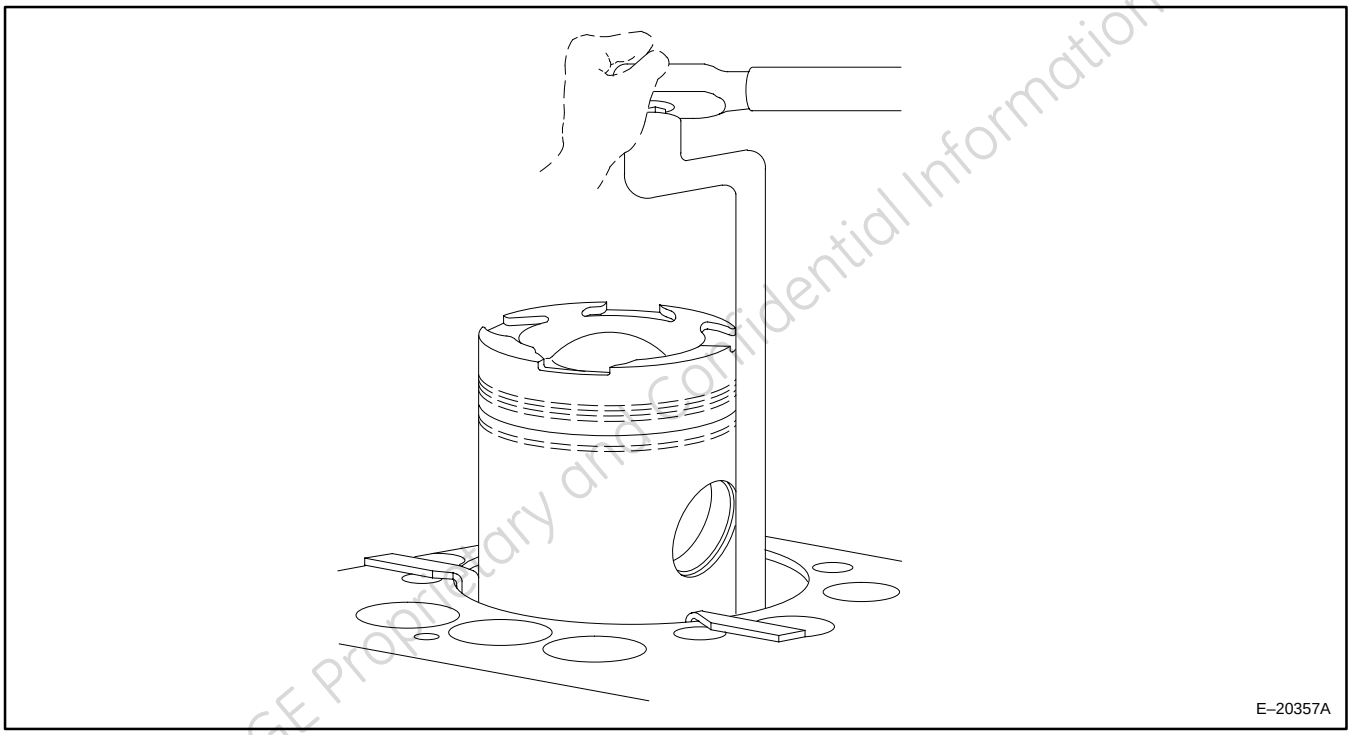


Figure 20. Loosening Piston Pin Bolts (Typical).

6.2. INSTALL PISTON

CAUTION: The piston crown valve pockets must align with the outboard intake valves. This alignment is necessary to provide clearance for intake valves.

Install a piston as follows:

1. Coat the piston pin liberally with clean engine lubricating oil and insert the pin into the piston. Thread a piston pin guide pin into one (1) of the holes in the piston pin. A guide pin may be purchased as GE Tool 147X1326, or may be made from a piston pin bolt with the head cut off and the end tapered (Figure 21).
2. Lower the piston with piston pin onto the connecting rod, allowing the guide pin to enter one (1) of the piston pin bolt holes in the connecting rod.

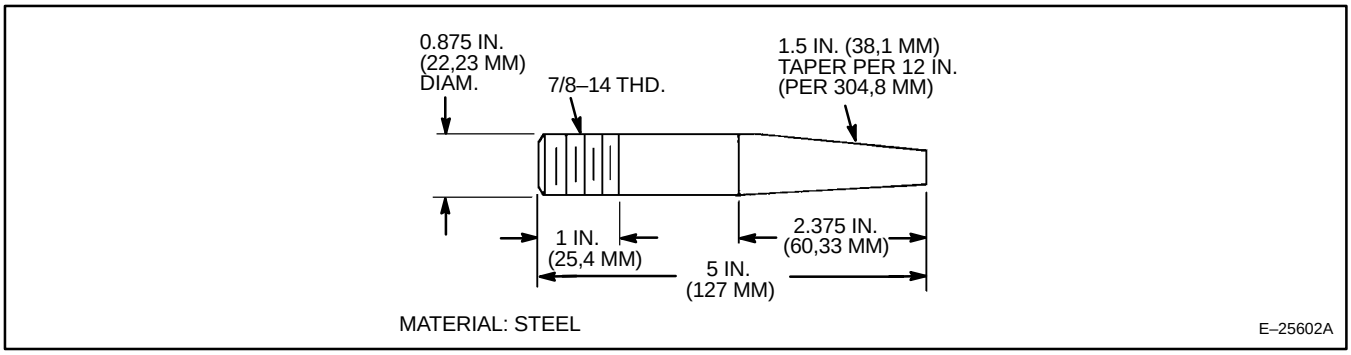


Figure 21. Piston Pin Guide Pin.

CAUTION: The piston pin bolt spacer must be installed with the flat surface next to the bolt head and the convex surface next to the concave seat in the rod. A bolt with an incorrectly installed spacer may back out, with resultant failure of the second bolt, causing severe damage to the engine.

3. Coat the threads and washer faces of two (2) piston pin bolts with MOLYKOTE® G–n* (refer to *Section 20., SPECIAL TOOLS*). Install a piston pin bolt and spacer in the empty piston pin bolt hole and finger–tighten. Remove the guide pin from the other bolt hole and install the remaining pin bolt and spacer. Using a torque wrench and the piston pin bolt wrench, tighten the piston pin bolts evenly in increments of 100 to 125 lb.–ft. (136–169 Nm) to the torque specified in *Section 21., TORQUE VALUES,* of this publication. Then loosen both bolts and retighten them evenly in increments to a final torque as specified in *Section 21., TORQUE VALUES,* of this publication.

CAUTION: Do NOT use chrome piston rings with chrome cylinder liners. Do NOT use iron piston rings in hardened cylinder liners. Refer to your Renewal Parts Catalog for the proper ring and liner combinations. If improper combinations are installed, severe cylinder liner scoring will occur very quickly.

4. Install new piston rings as described in *Section 3., PISTON AND PISTON RINGS,* of this publication. Stagger the end gaps of adjacent piston rings approximately 180° apart.
5. Install the cylinder assembly as described within *Section 3., POWER ASSEMBLY,* of this publication.

6.3. REPLACE PISTON RINGS

Any time that a cylinder is replaced, the piston rings also should be renewed regardless of condition for most efficient operation and best economy. It is recommended that piston rings removed from an engine for ANY reason be discarded and new rings applied. Any rings which indicate sticking, scuffing, burning or other abnormal conditions MUST be renewed regardless of wear.

Piston rings may be renewed after a cylinder is taken off without removing the piston from the engine. When on or near top dead center, the piston extends above the engine main frame. To renew rings, proceed as follows:

1. Ensure the piston is in good condition. If the piston is in the engine, remove the piston protector (refer to *Section 20., SPECIAL TOOLS*) and place the piston support bar (refer to *Section 20., SPECIAL TOOLS*) under the piston across the main frame opening. Bar the crankshaft to lower the piston firmly onto the cradle of the support bar.
2. Remove the old rings and discard. Clean the carbon from the ring grooves using the piston ring groove scraper (Figure 22 and refer to *Section 20., SPECIAL TOOLS*) to assure full ring side clearance.

NOTE: When installing rings, always use the piston ring expander (refer to Section 20., SPECIAL TOOLS) to prevent permanent distortion of the rings (Figure 23).

* Product of Dow Corning Corporation.

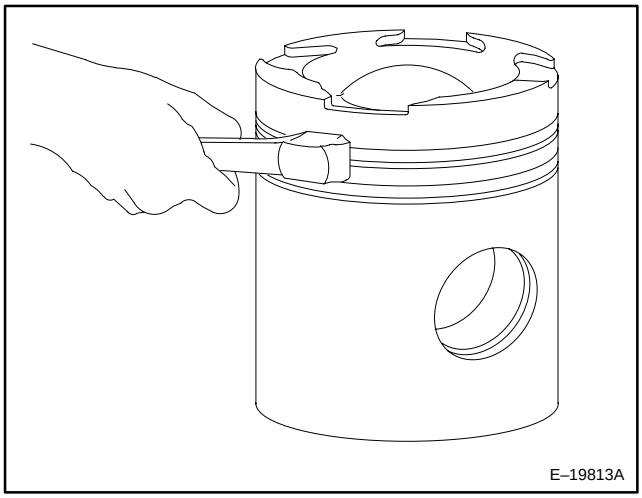


Figure 22. Cleaning Piston Ring Grooves With Scraper (Typical).

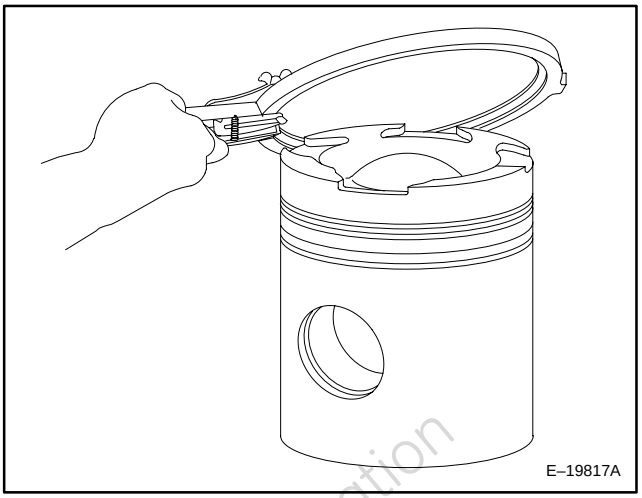


Figure 23. Applying Piston Rings (Typical).

CAUTION: Do NOT use chrome piston rings with chrome cylinder liners. Do NOT use iron piston rings in hardened cylinder liners. Refer to your Renewal Parts Catalog for the proper ring and liner combinations. If improper combinations are installed, severe cylinder liner scoring will occur very quickly.

3. Install the oil control ring expander spring in the bottom ring groove first. Then place the oil control ring, SCRAPING EDGES DOWN, over the expander spring in the groove. Position the oil control ring end gap 180° from its expander spring joint.
4. Install the two (2) compression rings in their proper grooves and as indicated by their markings. The printing on the ring MUST be installed so it is towards the top of the piston (Figure 24).
5. Assure that all rings fit freely in their grooves all around the piston. Then stagger the end gaps of adjacent rings approximately 180° apart.

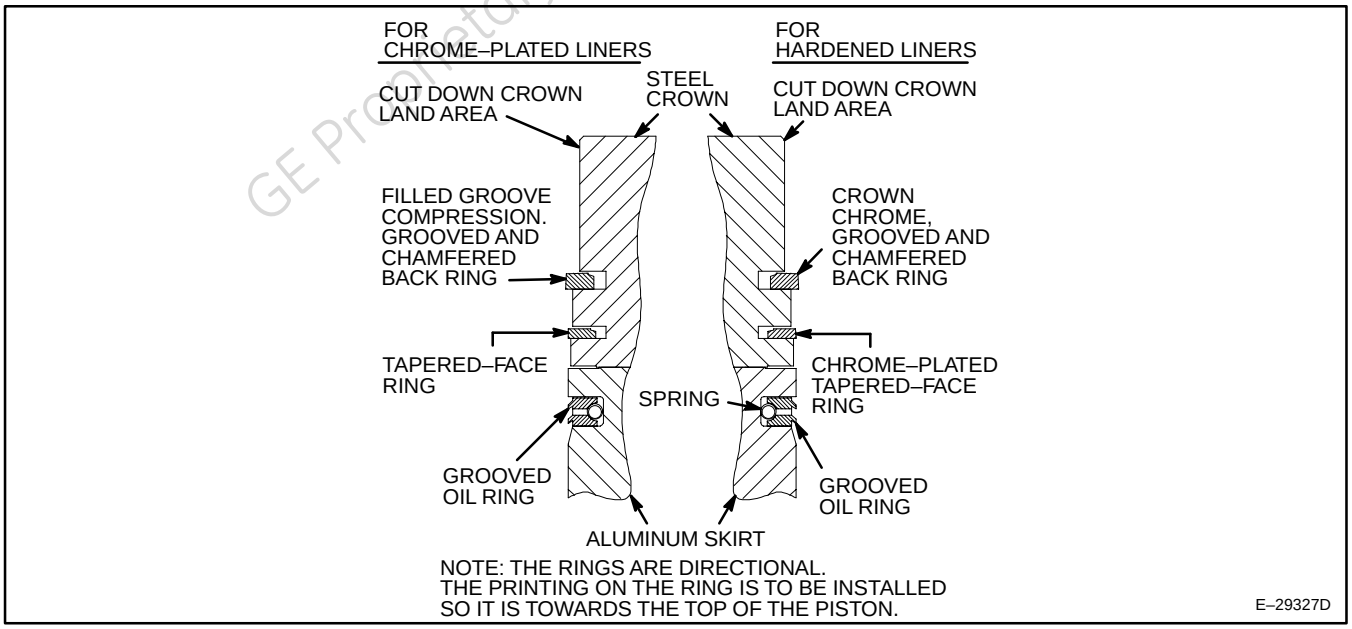


Figure 24. Piston Ring Details.

7. CONNECTING ROD AND CONNECTING ROD BEARINGS

Special Tools Required:

Articulated Rod Guide Pin Bolt 147X1122
Articulated Rod Pin Bolt Wrench 147X1458–2
Articulated Rod Pin Retainer 147X1474
Barring Over Device . . . . . TESCO T58440
Bearing Retainers 147–1492–1
Connecting Rod Holding Fixture 147X1651
Crankshaft Journal Protective Pad 147X1827
MOLYKOTE® G–n 147X1143–1
Piston Pin Bolt Wrench 147X1841–1
Piston Retainer 147X1406–2
0.75 in. Drive Ratchet Wrench 147X1866
1.13 in. Socket 147X1866

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

Each pair of cylinders has a master rod and an articulating rod. The master rod is installed in the left bank of the engine. The articulated rod, linked to the master rod by a pin connection, operates in the right bank. Oil for lubricating the bearings and cooling the piston is received from the crankshaft under pressure. It flows upward to each piston through drilled passages in the pins and rods, and then is returned to the crankcase through drain holes in each piston.

7.1. REMOVE CONNECTING ROD

Since the cylinder assembly must be removed before a master or articulated rod can be replaced, it is recommended that the cylinder, piston and rod be removed as a complete power assembly. Refer to the instructions listed in *Section 3., POWER ASSEMBLY,* of this publication.

Remove a connecting rod as follows:

1. Removing either rod requires the articulated rod to be disconnected. Remove the articulated rod pin bolts using an articulated rod pin bolt wrench (refer to *Section 20., SPECIAL TOOLS*). If the articulated rod is not being removed from the engine, block or otherwise secure the rod in its topmost position.
2. Install an articulated rod pin retainer (refer to *Section 20., SPECIAL TOOLS*) to hold the articulated rod pin in place until the rod is reassembled (Figure 25).
3. If the master rod is to be removed, loosen the rod cap bolts and back the bolts off, leaving several threads engaged, using a 1.13 in. socket for 0.75 in. drive (refer to *Section 20., SPECIAL TOOLS*).
4. Tap the master rod cap sideways with a heavy brass bar to drop the cap onto the bolt heads. Remove the bolts and the cap.
5. Remove the power assembly as described in *Section 3., POWER ASSEMBLY,* of this publication.

CAUTION: Protect the crankshaft rod journal with a protective pad (refer to Section 20., SPECIAL TOOLS) while the journal is exposed (Figure 26).

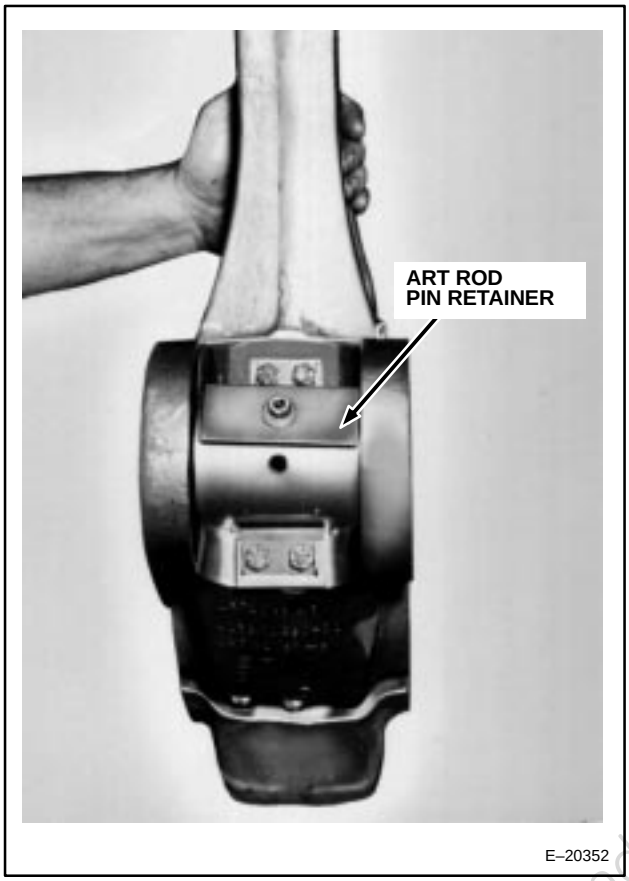


Figure 25. Articulated Rod Pin Retainer.

Figure 26. Protective Pad On Crankshaft Journal.

6. Secure the connecting rod in a rod holding fixture (refer to *Section 20., SPECIAL TOOLS*) and separate the cylinder assembly from the piston and rod assembly.

7. Remove the piston pin bolts with the piston pin bolt wrench (GE Tool 147X1499–3). Remove the piston with piston pin from the connecting rod.

7.2. INSTALL CONNECTING ROD

Install a connecting rod as follows:

CAUTION: The piston pin bolt spacer must be installed with the flat surface next to the bolt head and the convex surface next to the concave seat in the rod. A bolt with an incorrectly installed spacer may back out, with resultant failure of the second bolt, causing severe damage to the engine.

1. With the connecting rod secured in a rod holding fixture (refer to *Section 20., SPECIAL TOOLS*), assemble the piston with piston pin to the rod as described in *Section 3., PISTON AND PISTON RINGS,* of this publication.

CAUTION: Do NOT use chrome piston rings with chrome cylinder liners. Do NOT use iron piston rings in hardened cylinder liners. Refer to your Renewal Parts Catalog for the proper ring and liner combinations. If improper combinations are installed, severe cylinder liner scoring will occur very quickly.

2. Install new piston rings as described in *Section 3., PISTON AND PISTON RINGS,* of this publication. Stagger the end gaps of adjacent piston rings approximately 180° apart.

CAUTION: A grooveless rod bearing should NEVER be installed in the lower connecting rod bearing position. With all oil to that journal blocked off by the grooveless bearing, the engine will fail in only a few revolutions of the crankshaft.

3. If installing a master rod, clean the bore of the rod and rod cap. Verify use of a master rod machined to accept a grooveless top bearing shell. Also match the serial numbers of the rod and cap, and locate the cap with the numbers on the same side as the rod. Caps are not interchangeable or reversible. Assemble new connecting rod bearings in the rod and cap. Coat the threads and washer faces of the rod cap bolts with MOLYKOTE® G–n (refer to *Section 20., SPECIAL TOOLS*). Assemble the cap to the rod and torque the cap bolts alternately in increments of 100 to 125 lb.–ft. (136–169 Nm) to the torque specified in *Section 21., TORQUE VALUES,* of this publication. Then disassemble the rod cap. Secure the upper bearing with two (2) bearing retainers (refer to *Section 20., SPECIAL TOOLS*).

4. Install a cylinder assembly over the piston and rod as described in *Section 3., POWER ASSEMBLY,* of this publication. Secure the piston and rod assembly in the cylinder with a piston retainer (refer to *Section 20., SPECIAL TOOLS*).

5. If installing a power assembly with a master rod, lift the assembly and carefully lower it into position on the crankshaft rod journal after removing the protective pad. Remove the articulated rod pin retainer and thread an articulated rod guide pin (refer to *Section 20., SPECIAL TOOLS*) into one of the articulated rod pin bolt holes (Figure 27). Carefully lower the articulated rod onto the articulated rod pin.

CAUTION: The piston pin bolt spacer must be installed with the flat surface next to the bolt head and the convex surface next to the concave seat in the rod. A bolt with an incorrectly installed spacer may back out, with resultant failure of the second bolt, causing severe damage to the engine.

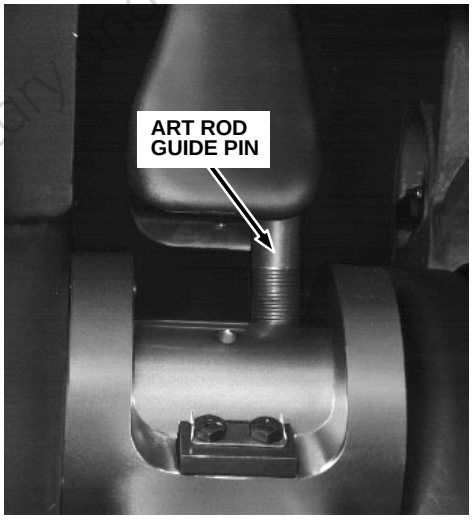


Figure 27. Installing Articulated Rod Using Guide Pin.

6. Coat the master rod cap bolts and the articulated rod pin bolts with MOLYKOTE® G–n on the threads and washer faces. After removing the two (2) bearing retainers, assemble the rod cap if installing a master rod. Torque the master rod cap bolts (Figure 28) alternately in increments of 100 to 125 lb.–ft. (136–169 Nm) to the torque specified in *Section 21., TORQUE VALUES,* of this publication. Torque the articulated rod pin bolts alternately in the same increments to the torque specified in *Section 21., TORQUE VALUES,* of this publication. Loosen the articulated rod pin bolts and retorque to a final value as specified in *Section 21., TORQUE VALUES,* of this publication.

7. Complete the installation of the cylinder assembly as described in *Section 3., POWER ASSEMBLY,* of this publication.

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Figure 28. Torquing Master Rod Cap Bolts.

7.3. CONNECTING ROD BEARINGS

The connecting rod bearings are secured by connecting rod caps which are bolted in place. The precision bearings are replaceable without machining or scraping. Each bearing has a steel back plated on the running surface with carefully formulated bearing material.

Engines with EFI have grooveless connecting rod bearings in the UPPER (rod) positions and grooved connecting rod bearings in the LOWER (cap) positions (Figures 29 and 30). Each grooved bearing has ONE (1) locating tab to locate it in its correct position; each grooveless bearing has TWO (2) locating tabs to prevent inadvertent installation in the lower position (Figure 30).

CAUTION: A grooveless rod bearing should NEVER be installed in the lower connecting rod bearing position. With all oil to that journal blocked off by the grooveless bearing, the engine will fail in only a few revolutions of the crankshaft.

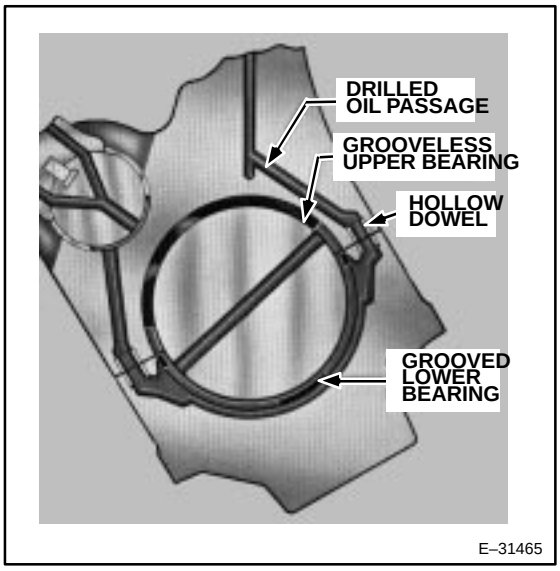

Figure 29. Master Rod Lubricating–Oil Passages.

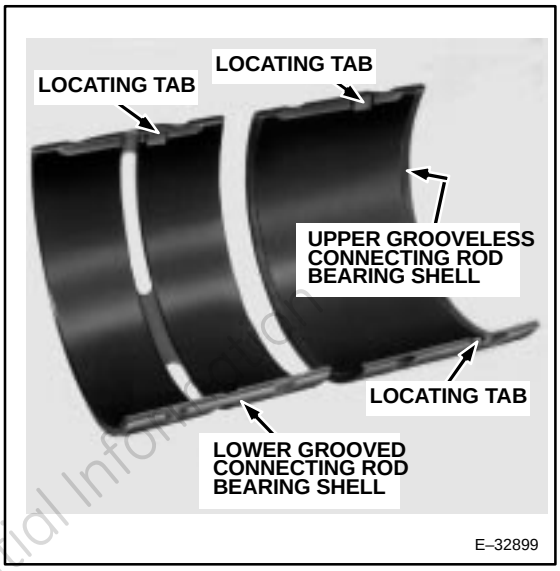

Figure 30. Connecting Rod Bearing Shells.

7.3.1. Remove Connecting Rod Bearings

Connecting rod bearings may be replaced without removing the master rod from the engine, as follows:

1. Bar the crankshaft to position the rod journal with the bearings to be replaced near the topmost position.
2. Loosen the master rod cap bolts several turns, using the 1.13 in. socket (refer to *Section 20., SPECIAL TOOLS*). Tap the rod cap sideways with a heavy brass bar and the cap will separate from the rod. Remove the bolts and the cap.
3. Block or otherwise secure the pistons and rods in their upper position and bar the crankshaft to get the journal out of the way.

CAUTION: Do NOT use any metal object as a drift.

4. Using a wood or fiber block as a drift, tap the old rod bearings out of the master rod and cap. Clean the bore of the master rod and cap to make sure there are no high spots. Carefully stone off any high spots on the split line of the rod and cap. Stone off any high spots on the back of the new bearings.

7.3.1.1. Install Connecting Rod Bearings

NOTE: Do NOT lubricate between the rod bore and the bearing.

CAUTION: The locating tabs on the bearings must be positioned in the locating tab slots in the rod and rod cap; or they will be crushed in, causing a bearing failure and possibly further severe engine damage.

1. Apply the new rod bearings. Verify that the locating tabs on the bearings are properly positioned, and tap the bearings into place with a wood or fiber drift.

2. Lubricate the crankshaft rod journal with clean engine lubricating oil. Bar the crankshaft to position the rod journal up close to the rod, and lower the pistons and rods assembly onto the journal.

3. Ensure the rod and cap serial numbers match and are located on the same side of the rod. Coat the threads and washer faces of the rod cap bolts with MOLYKOTE® G–n (refer to *Section 20., SPECIAL TOOLS*). Torque in increments of 100 to 125 lb.–ft. (136–169 Nm) to a final value as specified in *Section 21., TORQUE VALUES,* of this publication. Check that the rod has freedom of lateral movement on the crankshaft rod journal (Figure 31).

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Figure 31. Checking Master Rod Free Movement.

8. FUEL–OIL INJECTION PUMP

Special Tools Required:

Air–Operated Wrench GE147X2204
Barring Over Device . . . . . TESCO T58440
Flexible Hose Banjo Fitting and High–Pressure Fuel–Oil Pump/Injector Line Wrench . . . . . GE 147X1595–1
Fuel–Oil Injection Pump Wrench . . . . . GE 147X2460
Lubriplate® Spray Lube A . . . . . GE 147X1614
Pump Gage Block . . . . . GE 41A222587 or TESCO T55970
Tappet Nut Torque Wrench . . . . . TESCO T56050
Torque Wrench . . . . . Locally Purchased
1.0–in. Drive Ratchet . . . . . GE 147X1982
12–Point Socket Head, 1/2–13 x 1.875 in. Bolts . . . . . GE 115x2530–1

ECC

CAUTION: The fuel–oil injection (high pressure) pump is an Emission Critical Component (ECC). Do not replace it with a non–ECC part. Refer to the NOTICE at the beginning of this publication and consult the latest revision of the manufacturer's Parts Catalog to obtain the correct replacement part.

The EFI System (Figure 32) sequentially delivers an appropriate amount of fuel, at the appropriate time, to each of the cylinders of the diesel engine. The EFI system monitors engine pressures, engine temperatures, and crankshaft speed/position to evaluate the quantity and timing of the fuel delivery.

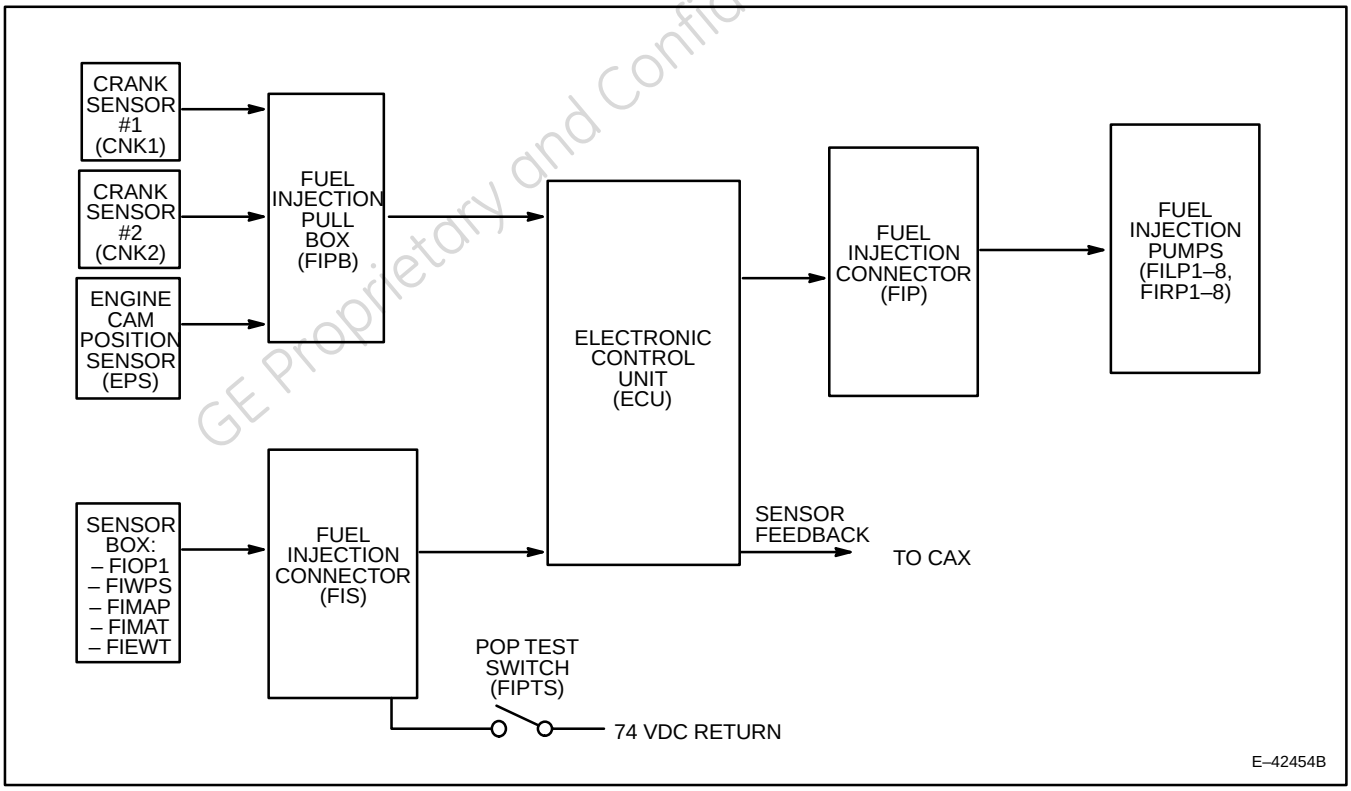


Figure 32. EFI System Block Diagram.

8.1. CYLINDER FIRING

Cylinder firing can be checked by using either the Dead Cylinder Detection (DCD) test or the POP test. DCD is the recommended test; the POP test should be used only when the DCD test is not available.

Details on the DCD and POP Tests can be found in **SMI–86006, DIESEL ENGINE CONDITION–BASED MAINTENANCE**.

8.1.1. Dead Cylinder Detection (DCD) Test

Dead Cylinder Detection (DCD) is a standalone test that is installed on a portable computer. Use these steps to run DCD:

1. Connect the computer to the ECU via the FIRS connector in the Control Area 1 of the cab.
2. Set the locomotive to N3 Self–Load and let the engine stabilize.
3. Click the Start Test button. Once initiated, the software takes a baseline and subsequent data sets for each cylinder. After completing all cylinders, the results are displayed graphically. The complete test takes about 5 minutes (comparable to the POP test).

8.1.2. POP Test

The ECU controller initiates the POP test. To test the engine cylinders, place the engine in IDLE. Toggle the POP test switch located on the engine near the Start Station (hold switch up for 5 seconds and then release).

The test will run sequentially from cylinders L8 to L1, followed by a 30–second pause (allows the operator to walk around the engine), and then from R1 to R8. The test delivers an increased quantity of fuel to each cylinder for a predetermined number of firings (typically around 20). The resulting POP sound indicates a functioning cylinder. A non– functioning high pressure fuel pump typically causes a NO POP condition. However, other items should also be considered such as wiring, injectors or valve adjustment. A weak or intermittent POP does not indicate a defective component. This can occur from changes in the engine load.

Toggling the POP test switch when the test is between cylinders will end the test. Toggling the POP test switch while a cylinder is being tested will cause the test to remain on that cylinder. The cylinder will pause 5 seconds, POP, pause 5 seconds, POP, and repeat the pattern for 1 minute or until the POP test switch is toggled again, whichever comes first. The sequence then resumes.

NOTE: EFI will POP test only at IDLE (engine speeds of 440 rpm or lower).

8.2. REMOVE/INSTALL FUEL–OIL INJECTION PUMP

ECC

CAUTION: The fuel–oil injection (high pressure) pump is an Emission Critical Component (ECC). Do not replace it with a non–ECC part. Refer to the NOTICE at the beginning of this publication and consult the latest revision of the manufacturer's Parts Catalog to obtain the correct replacement part.

Use this section to replace EFI (41C642286P1 or P2) pumps because of **No Pop** during **the POP Test, or indication from the Dead Cylinder Detection Test.**

8.2.1. Fuel–Oil Injection Pump Removal

NOTE: Record the engine position of the pump being replaced, the serial number of the pump being removed, and the serial number of the pump being installed.

1. Back off the compression release plugs one (1) full turn on all cylinders.
2. Remove the cylinder head cover at the position where the fuel–oil injection pump is to be changed (Figure 1).
3. Remove the timing window cover and the barring–over access cover from the right side of the camshaft gear cover on the cable side of the locomotive. Install the barring over tool (refer to *Section 20., SPECIAL TOOLS*), ensuring that the over tool is fully inserted with the tool housing tight against the gear cover. Then bolt the over tool to the gear cover using the bolts from the barring–over access cover. After moving the barring–over gear inward into engagement with the camshaft gear, apply either a 1.0–in. drive ratchet or an air–operated wrench (refer to *Section 20., SPECIAL TOOLS*) to the barring–over gear.

CAUTION: The use of an impact wrench for this operation is NOT recommended, as engine internal damage may result.

CAUTION: Ensure that all camshaft sections are in place before barring over the diesel engine. Barring over the engine with camshaft sections removed WILL damage valve train components.

4. Using the ratchet wrench or air–operated wrench, slowly bar over the crankshaft in its normal direction of rotation until the pointer in the barring–over gearbox timing window aligns with the degree mark on the camshaft gear specified for the position of the pump to be replaced on the pump timing nameplate near the gearbox (Figure 16).
5. Assure all valves are closed at the cylinder where the pump is to be replaced. That cylinder should be on its compression stroke. If the valves are closed, a small amount of free movement will be noted by manually moving the rocker arms. Another check is to observe the radial position of the fuel and valve cams for the cylinder. If the cylinder is on its compression stroke, the valve crosshead rollers will be off the lobe and on the base circle of the cam. The fuel crosshead roller will be rising on the lobe of its cam.

NOTE: While this step is not mandatory, it is recommended since it assures the integrity of the camshaft assemblies and the engine firing order.

6. Assure the Local Control Circuit Breaker (LCCB) and Fuel Pump Breaker (FPB) in the operating cab are turned OFF. Disconnect the solenoid wires from the EFI pump.
7. Clean the high–pressure fuel–oil line between the injection pump and nozzle with a stiff–bristle brush and fuel oil before disconnecting. Then remove the high–pressure fuel–oil line. Cover all openings with threaded or plastic caps.
8. Carefully remove the solenoid rubber boot by gripping the tab at the back of the boot, lifting and pulling forward.
9. Remove the wire harness terminals from the pump solenoid as follows:
   a. Loosen the terminal screws, **they DO NOT come out.**
   b. Once screw is loose, push the terminal toward the cylinder until the wide section of the slot is under the terminal screw.
   c. Carefully lift and remove the wire terminal.

10. Disconnect both (Inlet and Outlet) low–pressure fuel–oil line tee fittings from the pump elbow fittings. Then remove both elbow fittings from the pump. Cover the low–pressure fittings after the fuel oil has drained from the header. Apply a plastic plug to the pump inlet and outlet.

CAUTION: Be careful not to damage the fuel–oil injection pump solenoid while loosening the mounting bolts.

11. Remove the mounting bolts at the base of the pump, using the Fuel Oil Injection Pump Wrench (refer to *Section 20., SPECIAL TOOLS*). Lift the pump from the engine. Remove and discard the square cut O–ring from the groove in the jacket. Ensure groove is clean and free of all foreign matter (dirt, debris, old seal).

12. Inspect the removed square cut mounting O–ring for indications of installation error (e.g., pinched between pump mounting base and cylinder jacket or double gaskets). If any error is apparent, discard the mounting bolts.

13. Cover the area where the pump was removed to prevent foreign matter from entering the engine unless the replacement pump is installed immediately.

8.2.2. Preparation For Pump Installation

CAUTION: Do NOT bar the engine over during any step of this procedure.

Before installing the EFI pump on a diesel engine, adjust the length of the pump tappet rod as follows:

CAUTION: Excessive tappet rod travel can severely damage the pump and tappet rod assembly.

1. Remove the pump tappet rod adjustment cover from the lower front face of the cylinder.

CAUTION: To loosen the tappet rod locknut, use two (2) wrenches: a 1.38 in. wrench on the tappet nut and a 1.13 in. wrench on the locknut.

2. Shorten the tappet rod length by loosening the locknut and tappet adjusting nut, and turn the tappet nut four (4) or five (5) full turns clockwise.

3. Zero the pump gage block (refer to *Section 20., SPECIAL TOOLS*) indicator on the master. Then bolt the pump gage block to the cylinder in place of the pump.

4. Raise the tappet rod until the indicator on the gage block is zeroed. Lock the tappet rod by tightening the umbrella nut against the adjusting nut to the torque specified in *Section 21., TORQUE VALUES,* of this publication, using the tappet nut torque wrench (refer to *Section 20., SPECIAL TOOLS*).

5. Remove the pump gage block, and replace the pump tappet rod adjustment cover with a new gasket on the cylinder.

8.2.3. Pump Installation

CAUTION: When installing a fuel–oil injection pump, ensure no dirt or foreign matter enters the fuel–oil lines, connections and the engine. Keep the plugs and caps in place until the connections are to be made.

CAUTION: An improperly seated O–ring may cause fuel–oil leakage and/or mounting bolt failure, resulting in a fuel–oil integrity issue.

1. Apply a new sealing square cut O–ring to the pump mounting cavity groove and ensure it seats squarely and fully into the groove.

CAUTION: When replacing a fuel–oil injection pump, be sure to use the newest configuration. Consult the latest revision of the manufacturer's Parts Catalog to verify the correct replacement part number.

2. Install the pump on the cylinder taking care not to displace the O–ring from the groove.

CAUTION: Use only 12–point socket–head, 1/2–13 x 1.875 bolts (refer to Section 20., SPECIAL TOOLS). Equipment failure will occur if wrong bolts are used.

3. Install the mounting bolts and torque in a criss–cross pattern in 30 lb.–ft. (41 Nm) increments until the final torque specified in *Section 21., TORQUE VALUES,* of this publication is reached, using the Fuel Oil Injection Pump Wrench (refer to *Section 20., SPECIAL TOOLS*).
4. Elbow and Tee Fitting or Fuel Header Block Installation
   a. Depending on which EFI high pressure fuel pump is being installed on the engine, either the elbow and tee fittings (Figure 33) or fuel header block (Figure 34) can be installed.
   b. The fuel header block was developed to replace the elbows and orificed tee fittings (tee fittings identified by either an "I" or "O"). However, the block must be used with the latest style high–pressure fuel pump (132X1825–2; 84C623439P1). This pump has a unique housing with a flat machined face (Figure 35). This new mounting face will accept either the fuel header block or elbow and tees.

NOTE: The fuel header block must not be installed on pumps that do not have this new, flat machined face.

5. Elbow Fitting Installation
   a. Rotate the jam nut away from the back up washer so that the jam nut is against the body of the fitting.
   b. Remove the original used O–ring, if present.
   c. Verify that the back up washer slides freely over the entire machined surface between the two (2) threaded portions of the fitting.
   d. Spray the new O–ring with Lubriplate® Spray Lube A (refer to *Section 20., SPECIAL TOOLS*).

Figure 33. Elbow and Tee Configuration.

Figure 34. Fuel Header Configuration.

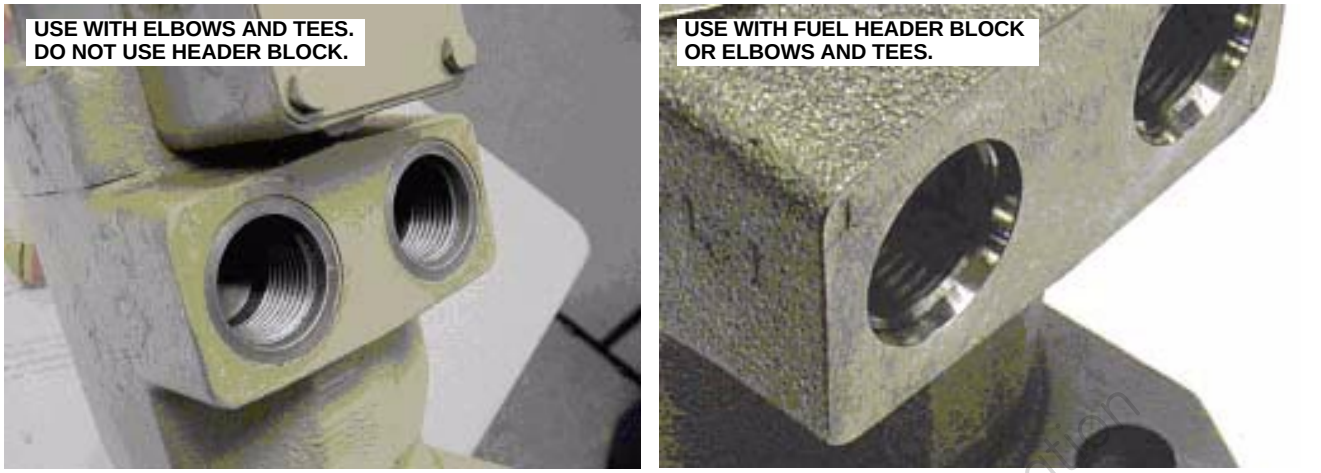


Figure 35. Fuel Pump Housings.

e. Install the new O–ring on the machined surface between the two (2) threaded portions, next to the back up washer.

f. Slide the O–ring and back up washer all the way towards the jam nut on the machined surface.

g. Return the low pressure elbow fittings to the pump as follows:

   1) Tighten the fitting by hand until the back up washer contacts the face of the pump housing.

   2) Position the fitting to the proper vertical position by rotating the fitting either 1/4 turn clockwise or 3/4 turn counterclockwise.

   3) Once oriented in the vertical position, tighten the locknut until the back up washer contacts the pump housing forcing the O–ring into the chamfer.

   4) Tighten the jam nut to 46–50 lb.–ft. (62–68 Nm) while holding the elbow in a vertical position.

h. After torquing the elbow fittings, inspect each fitting to determine the number of threads exposed behind the jam nut. There should be less than three (3) threads exposed. If three (3) or more threads are exposed, remove the fitting and correct (Figure 36).

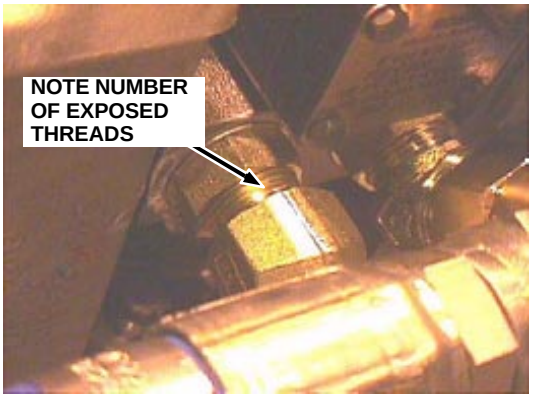


Figure 36. Proper Fitting Installation.

6. Tee Fitting Installation

Assemble the low pressure tee fittings to the elbow fittings. Verify that the Inlet “I” tee fitting gets installed into the left inlet port and that the Outlet “O” tee fitting gets installed into the right outlet port (Figure 37). Tighten the fittings to the torque given in *Section 21., TORQUE VALUES,* of this publication.

NOTE: The inlet and outlet tees fittings are not interchangeable. Improper installation can affect performance and emissions.

Figure 37. Tee Fittings Aligned With Pump Ports.

7. Fuel Header Block Installation
   a. Obtain a fuel header block and verify its cleanliness. Clean if required.
   b. Apply a small quantity of lubricating grease to the four (4) O–ring grooves of the header block.
   c. Install the O–rings into the grooves using the grease to hold them in place.
   d. Assemble the banjo bolts into the header block. Be careful to not disrupt the O–rings.
   e. Assemble the header block onto the pump with the Poke–Yoke tab facing down (Figure 38). Ensure sure the O–rings seat properly.
   f. Tighten each Banjo bolt snugly (a few lbs.–ft. of torque) so that the O–rings become compressed. Torque the banjo bolts to 60 lbs.–ft. (81 Nm) as shown in Figure 39.
8. Low Pressure Hose Assembly

Assemble the low pressure flexible hoses to the header blocks or Tee Fittings (if equipped with elbows). Torque hoses to the torque given in *Section 21., TORQUE VALUES,* of this publication.

NOTE: The header block and tee fittings use the same hoses.

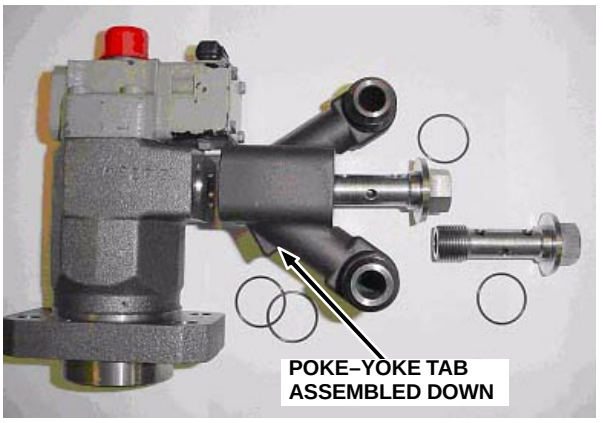


Figure 38. Pump with Poke–Yoke Tab.

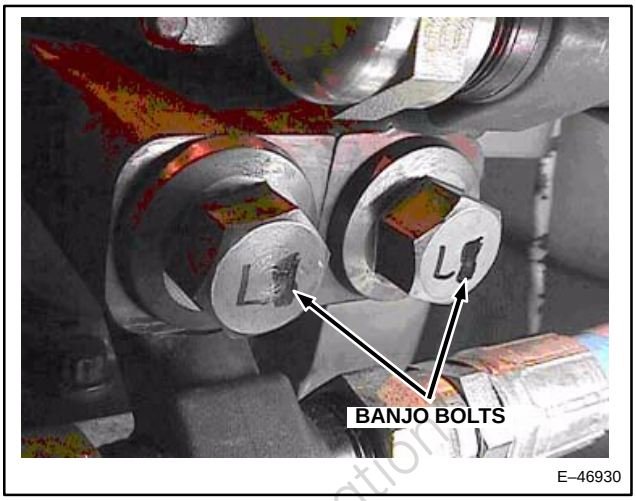


Figure 39. Banjo Bolts.

9. Return the wire harness terminals to the pump solenoid as follows:

   a. Carefully place the wire terminal on the mounting screw.

   b. Pull back on the terminal until the narrow part of the slot is totally under the screw head.

   c. Tighten the terminal screws to value given in *Section 21., TORQUE VALUES,* of this publication.

10. Using the solenoid boot tab, position the front of the boot into the groove at the base of the terminal block. Push boot back and down toward the cylinder until the boot snaps into the groove on the back of the terminal block.

NOTE: Ensure the two (2) colored seals are showing at the end of the boot where the wires exit.

11. Before applying the high–pressure line, check the line for any damage (fretting, rub marks, nicks, etc.) any–where on the conical seat or on the outside of the line. If **any** damage is present, scrap and replace the line.

NOTE: Ensure the high–pressure line is the current version (GE Part No. 140X2950).

12. Remove the protective caps from the ends of the high–pressure line and from the pump and nozzle connection-s. Apply the high–pressure line and ensure the line nuts may be run down using fingers only. Tighten the nuts finger tight first, then tighten the nuts to torque given in *Section 21., TORQUE VALUES,* of this publication, using the Fuel Oil Injection Pump Wrench (refer to *Section 20., SPECIAL TOOLS*). Ensure no dirt gets into the connection.

13. Ensure the Local Control Circuit Breaker (LCCB) and Fuel Pump Breaker (FPB) in the operating cab are turned OFF. Connect the wires to the fuel–oil injection pump solenoid studs.

14. Replace the cylinder head covers, and tighten all cylinder compression release plugs. Remove the barring over tool, and replace the timing window cover and the barring–over access cover on the camshaft gear cover.

15. Check for leaks at the fuel–oil line joints and proper cylinder firing when the engine is started. Run the engine in Self Load for 30 minutes and check for leaks.

16. Shut engine down and re–torque pump mounting bolts to the final torque given in *Section 21., TORQUE VAL-UES,* of this publication, using the special wrench (refer to *Section 20., SPECIAL TOOLS*).

9. FUEL–OIL INJECTION NOZZLE

Special Tools Required:

Flexible Hose Banjo Fitting and High–Pressure Fuel–Oil Pump/Injector Line Wrench . . . . . GE 147X1595–1
Fuel–Oil Injection Pump Wrench . . . . . GE 147X2460
Lubriplate® Spray Lube A . . . . . GE 147X1614
Nozzle Knocker . . . . . GE 147X1856
Portable Power Drill . . . . . Locally Purchased
Stud Installation Tool . . . . . SnapOn K2352
1.0 in. (25.4 mm)Diameter Cup Wire Brush . . . . . [0.020 in. (0.51 mm) diameter wire] on a 15.0 in. (380 mm) Extension

The injection nozzle receives the high–pressure fuel from the high–pressure fuel pump. After the fuel in the injection nozzle reaches a predetermined pressure, the fuel will be injected directly into the combustion chamber.

9.1. REMOVE NOZZLE

ECC

CAUTION: The fuel–oil injection nozzle is an Emission Critical Component (ECC). Do not replace it with a non–ECC part. Refer to the NOTICE at the beginning of this publication and consult the latest revision of the manufacturer's Parts Catalog to obtain the correct replacement part.

NOTE: Refer to Figure 1 of this publication unless noted otherwise.

1. Clean the high–pressure fuel–oil line between the fuel–oil injection pump and nozzle with a stiff–bristle brush and fuel oil before disconnecting. Remove the high–pressure fuel–oil line. Cover all openings with threaded or plastic caps.

NOTE: Do NOT reuse high–pressure fuel–oil line if injector stud has failed.

2. Remove the cylinder head cover (1).
3. Remove the two heavy jam nuts (3) and thread seal washers (4) securing the nozzle hold–down clamp plate (7). Remove and save the clamp plate and hardware.
4. Remove and save the green rubber collars (5).

CAUTION: Handle the fuel–oil injection nozzle with care, and take measures to prevent dirt from entering the nozzle. DO NOT BUMP THE TIP. Place protective caps or plugs over connections, and put a protective cover over the tip end. RETURN INJECTION NOZZLES FOR REPAIR PROTECTED IN THE SAME MANNER AS NEW NOZZLES ARE RECEIVED.

5. Remove the fuel–oil injection nozzle from the cylinder. Use the nozzle knocker (refer to *Section 20., SPECIAL TOOLS*) to facilitate removal (Figure 40). Ensure the copper gasket on the spray tip end (between the nozzle body seat and cavity in the head) is removed and discarded.

E–19803A

Figure 40. Removing Cylinder Fuel–Oil Injection Nozzle With Nozzle Knocker (Typical).

9.2. PREPARE FOR NOZZLE INSTALLATION

If difficulty is encountered in removing a fuel–oil injection nozzle from the cylinder, the nozzle recess in the cylinder head probably is packed with carbon, scale, etc. This must be cleaned before installing a new nozzle, as follows:

1. If necessary to clean the nozzle recess with the cylinder on the engine, ensure the valves are closed and the cylinder–head cover is in place.
2. Use a 1.0 in. (25.4 mm) diameter cup wire brush [0.020 in. (0.51 mm) diameter wire] on a 15.0 in. (380 mm) extension, driven by a portable power drill.

NOTE: The entire length of the recess should be cleaned, but the seat is of particular importance.

WARNING: When blowing with compressed air, personal injury may result if proper eye protection is not worn. To prevent personal injury when using compressed air, observe all normal shop practices.

3. Apply air pressure through the compression–release hole to blow dirt up through the recess, instead of allowing it to fall down on the seat and into the cylinder.
4. Clean the cylinder jacket surface where the studs are applied and the nozzle seating surface.

9.3. INSTALL NOZZLE

ECC

CAUTION: The fuel–oil injection nozzle is an Emission Critical Component (ECC). Do not replace it with a non–ECC part. Refer to the NOTICE at the beginning of this publication and consult the latest revision of the manufacturer's Parts Catalog to obtain the correct replacement part.

NOTE: Refer to Figure 1 of this publication unless noted otherwise.

1. Apply a new O–ring to the groove around the outside of the nozzle (6). Apply a light coating of grease or Lubriplate® Spray Lube A (refer to *Section 20., SPECIAL TOOLS*) to protect the O–ring during installation. Place a new copper gasket on the small end of the nozzle. A small amount of grease can be used to hold the gasket in place.

CAUTION: Ensure correct gasket is installed. The Injector Installation Kit contains two (2) gaskets: 0.100 in. (2.54 mm) and 0.150 in. (3.81 mm) thick. Refer to instruction sheet packed with the kit. Use the 0.150 (3.81 mm) gasket ONLY with the EFI pump.

2. Insert the small end of the nozzle into the recess.
3. If studs (2) were removed, return and torque to the value given in *Section 21., TORQUE VALUES,* using the Stud Installation Tool (refer to *Section 20., SPECIAL TOOLS*).
4. Before applying the nozzle hold–down clamp plate, examine the plate for any damage (warping, galling, gouging, etc.). If any damage is found, scrap and replace the plate.

NOTE: Ensure hold–down clamp plate is the current version (GE Part No. 121X127–3). To verify, carefully examine the top and bottom flats on the forging. If there is no indication of machining or grinding at these surfaces, replace the plate.

CAUTION: Proper tightening of the nozzle clamp nuts is important. If the nuts are not tight enough, the exhaust gases will allow a carbon build–up between the fuel–oil injection nozzle and the recess, causing the nozzle to be bound in place. If the clamp nuts are tightened excessively, parts of the nozzle assembly will become distorted, causing the nozzle valve to leak. Excessive tightening of these nuts can also cause cracks to develop between the nozzle recess and valve–seat bores of the cylinder head and, in extreme cases, can result in unseating of the exhaust and inlet valves.

5. Place the green rubber collars (5) over the nozzle studs.
6. Place the nozzle clamp (7) over the nozzle (6), studs (2) and rubber collars (5).
7. Return the thread seal washers (4) and hex jam nuts (3) and finger tighten. **Ensure clamp is level.**
8. Gradually torque the nuts to 15 lb.–ft. (19 Nm), then to the torque (alternating sides) specified in *Section 21., TORQUE VALUES,* of this publication.
9. Before applying the high–pressure line, check the line for any damage (fretting, rub marks, nicks, etc.) anywhere on the conical seat or on the outside of the line. If **any** damage is present, scrap and replace the line.

NOTE: Ensure the high–pressure line is the current version (GE Part No. 140X2950).

10. Remove the protective caps from the ends of the high–pressure line and from the pump and nozzle connections. Hand tighten the high pressure line nut on top of the nozzle, then tighten the line nut on top of the pump. Tighten the nuts initially with 80 lb.–ft. (108 Nm) then to the torque specified in *Section 21., TORQUE VALUES,* of this publication, using the special wrench (refer to *Section 20., SPECIAL TOOLS*). Ensure no dirt gets into the connection.

11. Carefully wipe/clean the head cover gasket surface and cylinder mating area to assure no debris is present. Reinstall the head cover and hand–tighten the hold–down handle.

12. Run engine at idle and POP test the cylinders to ensure all cylinders are firing. Check for any fuel leaks.

13. Run the engine at normal speed for 30 minutes and check for any leaks.

10. CRANKSHAFT MAIN BEARINGS

Special Tools Required:

Barring Over Device . . . . . TESCO T58440
Brass Drift . . . . . Locally Purchased
Hydraulic Frame Spreader . . . . . GE 147X1742
Lead Hammer . . . . . Locally Purchased
Lubriplate® Spray Lube A . . . . . GE 147X1614
Main Bearing Insert Tool . . . . . GE 147X1342
MOLYKOTE® G–n . . . . . GE 147X1143–1
Stretch Gage . . . . . GE 147X2309–1
Torque Wrench . . . . . Locally Purchased

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

Semi–circular main bearings support the crankshaft in the engine. The bearings are secured by bearing caps that are bolted in place. The precision bearings are replaceable without machining or scraping. Each bearing has a steel back supporting two (2) or more layers of carefully formulated bearing material.

Diesel engines with EFI have grooveless main bearings in the LOWER positions and grooved main bearings in the UPPER positions. Each grooved bearing has ONE (1) locating tab to locate it in its correct position; each grooveless bearing has TWO (2) locating tabs to prevent inadvertent installation in the upper position (Figure 41).

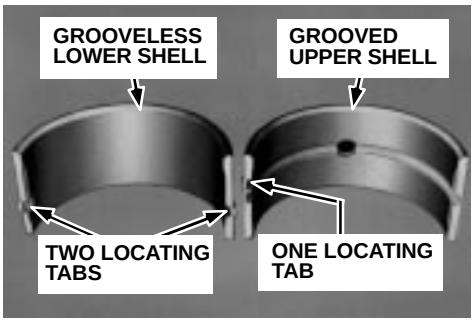


Figure 41. Main Bearing Shells.

CAUTION: A grooveless main bearing should NEVER be installed in the upper main bearing position. With all oil to that journal blocked off by the grooveless bearing, the engine will fail in only a few revolutions of the crankshaft.

A lower main bearing can be inspected by removing the main bearing cap nuts and dropping the cap just far enough to view the bearing surface. Completely removing the cap is not necessary. An upper bearing, however, can only be inspected by removing the bearing cap and then rolling the upper bearing out of its position. The locating tab end must be rolled out first. Once removed from its fit in the frame, the upper bearing should be replaced with a new bearing regardless of condition.

A bearing should be replaced if one–third of the bearing area is worn down to the bronze–colored, copper–lead matrix.

NOTE: It is good practice to inspect main bearings adjacent to the worn main bearing also.

For more details regarding the crankshaft and main bearings, refer to **MI–91100F, GEK–18086F, 7FDL CRANKSHAFT AND MAIN BEARINGS** publication.

10.1. REMOVE MAIN BEARINGS

Remove a main bearing as follows:

1. Loosen the main bearing cap nuts two (2) or three (3) turns.
2. Remove the main bearing cap side bolts and loosen the side bolts of the adjacent main bearings.

NOTE: To facilitate removal of the main bearing cap from the frame, spread the frame slightly using a hydraulic frame spreader (refer to Section 20., SPECIAL TOOLS).

3. Loosen the main bearing cap by tapping downward with a lead hammer or brass drift.
4. Remove the nuts and main bearing cap containing the lower bearing shell. Keep a firm grip on the bearing cap, as the cap is heavy.

CAUTION: Handle the bearings carefully so they do not become damaged in any way.

5. The upper bearing may roll out by hand. If necessary, apply a main bearing insert tool (refer to *Section 20., SPECIAL TOOLS*) in a crankshaft oil hole. Then bar the crankshaft to roll the bearing out, locating tab end first.

10.2. INSTALL MAIN BEARINGS

Install a main bearing as follows:

1. Inspect the crankshaft main journal to assure it is in good condition. Clean the surfaces of the journal, main frame, bearings and bearing cap. Coat the journal and inner bearing surfaces with clean engine lubricating oil.
2. Roll the upper grooved main bearing into place. To avoid damage to the bearing, assure that the locating tab is properly seated.
3. Seat the lower grooveless main bearing in the main bearing cap.

4. Use new O–rings on the bearing cap side bolts, and apply Lubriplate® Spray Lube A (refer to *Section 20., SPECIAL TOOLS*) to the O–rings. Also apply MOLYKOTE® G–n (refer to *Section 20., SPECIAL TOOLS*) to the threads and washer face of the bearing cap side bolts and the threads and contact face of the cap stud nuts. Position the main bearing cap on its dowel and apply the cap nuts and side bolts finger–tight.

5. Torque the main bearing cap side bolts to approximately the torque specified in *Section 21., TORQUE VALUES,* of this publication. Tighten the bearing cap nuts to achieve 0.037 to 0.043 in. (0.94 to 1.09 mm) stud stretch for 12 and 16–cylinder engines, using a stretch gage (refer to *Section 20., SPECIAL TOOLS*). Then torque the main bearing cap side bolts to the torque specified in *Section 21., TORQUE VALUES,* of this publication.

11. CRANKSHAFT THRUST BEARING COLLARS

Special Tools Required:

Magnetic Base Dial Indicator (or equivalent) . . . . . GE 147X1229
Pry Bar . . . . . Locally Purchased
Standard Tools . . . . . Locally Purchased

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

Two (2) half–ring thrust bearing collars, located in the engine frame at the second main bearing from the generator end, control the axial thrust of the crankshaft. These collars are loosely fitted and are held in place by the main bearing cap and the crankshaft.

The thrust bearing collars are of solid bronze, with a heavy lead–tin plate on the thrust bearing surface and a thin lead–tin flash plate all over. The bearing face of the collar can be identified by its radial oil grooves. When in place, the side of the collar with the oil grooves must face the crankshaft.

11.1. CHECK CRANKSHAFT THRUST BEARING COLLAR CLEARANCE

To determine if renewal of the thrust bearing collars is necessary, the crankshaft thrust clearance should be measured.

NOTE: The crankshaft thrust clearance check is most easily done immediately after shutting down the engine. If excessive crankshaft thrust clearance is evident, refer to the alternate corrective method in publication* GEK–61350, CRANKSHAFT THRUST BEARING ASSEMBLY *for maintaining proper thrust clearance.

With the engine shut down and crankcase inspection cover(s) removed, set up a magnetic base dial indicator similar to Tool 147X1229. Attach the magnetic base to the main frame and position the indicator needle against the face of one of the counterweights (Figure 42). With a pry bar, move the crankshaft to its extreme forward and rear positions. Note the total movement of the dial indicator which is the crankshaft thrust clearance. If total clearance exceeds 0.040 in. (1.02 mm), renew the crankshaft thrust bearings.

NOTE: New GE engines have a maximum crankshaft clearance of 0.018 in. (0.46 mm).

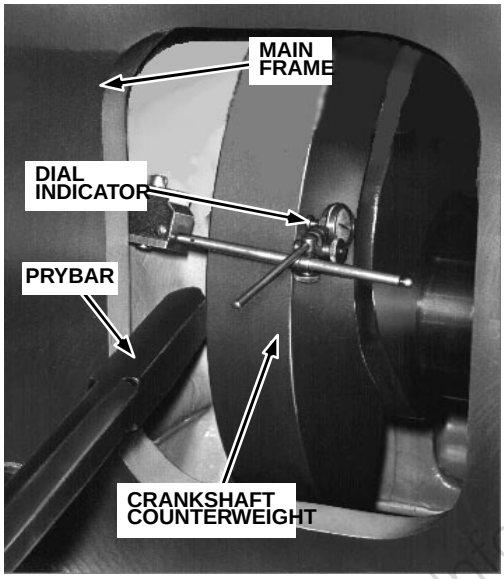


Figure 42. Checking Crankshaft Thrust Clearance.

11.2. REMOVE/INSTALL CRANKSHAFT THRUST BEARING COLLARS

Replace the thrust bearing collars as follows:

1. Remove the main bearing cap, which retains the thrust bearing collars. Refer to *Section 10., CRANKSHAFT MAIN BEARINGS,* of this publication.
2. Roll the thrust bearing collars out of their fits in the main frame. They are a loose fit.

CAUTION: Consult your Renewal Parts Catalog for the correct thrust bearing collar part number.

3. Coat the new thrust bearing collars with clean engine lubricating oil and install, ensuring that the collar side with the oil grooves is against the crankshaft.
4. Check the crankshaft thrust clearance (Figure 42).
5. Reinstall the main bearing cap. Refer to *Section 10., CRANKSHAFT MAIN BEARINGS,* of this publication.

12. PUMP DRIVE GEAR COUPLING AND GEAR TRAIN

Special Tools Required:

Barring Over Device . . . . . TESCO T58440
Flashlight . . . . . Locally Purchased
Mirror . . . . . Locally Purchased
Pry Bar . . . . . Locally Purchased

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

The pump drive gear assembly is mounted on the crankshaft and is used to transmit the torque needed to drive the water and lubricating–oil pumps from the crankshaft to the pump idler gear. The assembly consists of three (3) basic parts: the gear hub, gear ring and gear coupling (Figure 43).

The gear coupling is made of two (2) basic parts, the clamp ring and the coupling, which are put together with a press fit. The coupling has an inner flange and an outer sleeve held together with a bonded resilient material.

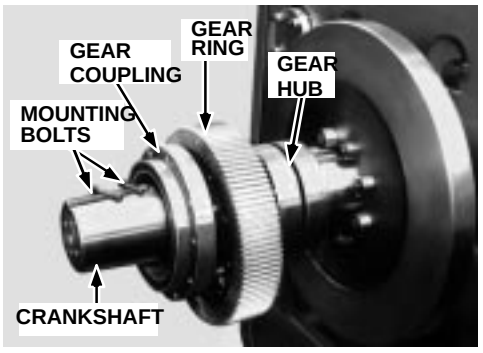


Figure 43. Pump Drive Gear Components.

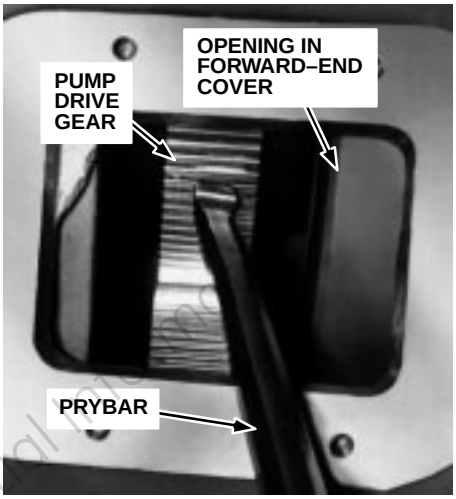


Figure 44. Checking Integrity of Pump Drive Gear Rubber–Bonded Coupling.

12.1. CHECK PUMP DRIVE GEAR COUPLING AND GEAR TRAIN

With the engine shut down, remove the lubricating–oil fill pipe plate from the water pump side of the free–end cover. Through the opening in the free–end cover (Figure 44), apply a pry bar and GENTLY rotate the crankshaft gear on its hub 0.03 to 0.06 in. (0.8 to 1.6 mm). If the rubber–bonded coupling is intact (not sheared), the gear will return quickly to its original position when the force on the pry bar is removed.

A second, and better, check requires a flashlight and a mirror. Work through the opening in the free–end cover (Figure 45) and view the rear surfaces of the crankshaft gear and hub (Figure 46). At least one set of match–mark numbers should be visible (Figure 47). The match–mark number sets will be aligned if the rubber–bonded coupling is intact. Misaligned numbers indicate a sheared coupling, which must be replaced.

CAUTION: Ensure that all camshaft sections are in place before barring over the diesel engine. Barring over the engine with camshaft sections removed WILL damage valve train components.

With the lubricating–oil fill pipe plate removed, check the pump drive gear train. Through the opening in the free–end cover and while barring–over the engine, visually inspect all gear teeth for broken teeth, excessive wear and over–heating discoloration (Figure 48).

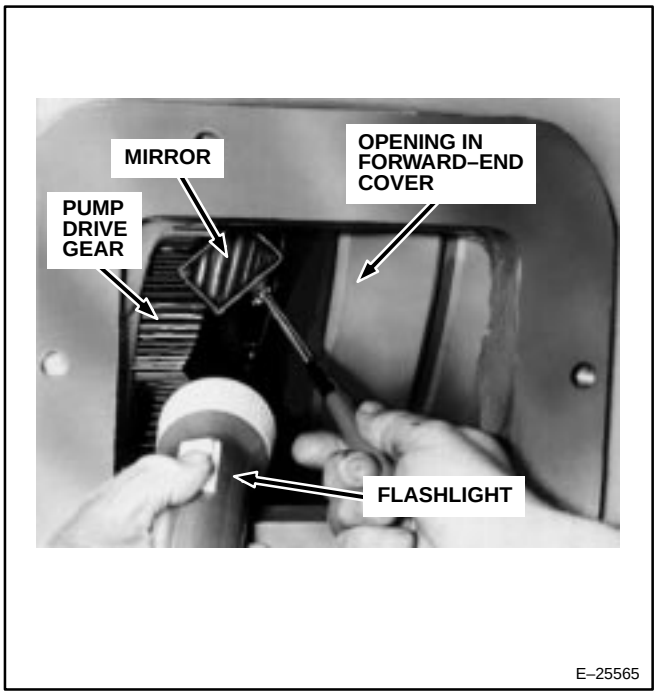


Figure 45. Checking Pump Drive Gear Match–Mark Numbers.

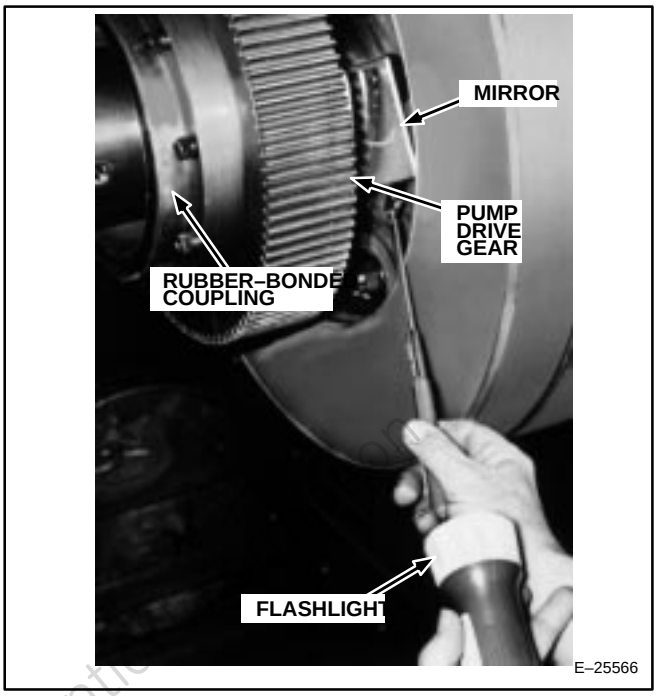


Figure 46. Checking Pump Drive Gear Match–Mark Numbers.

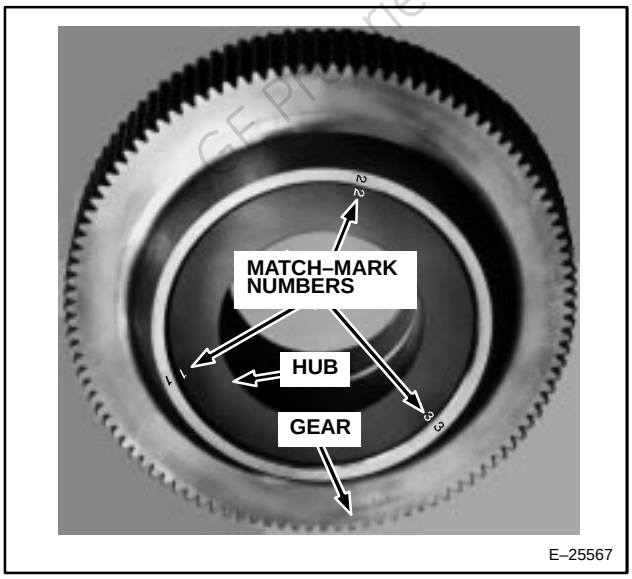


Figure 47. Match–Mark Numbers on Pump Drive Gear.

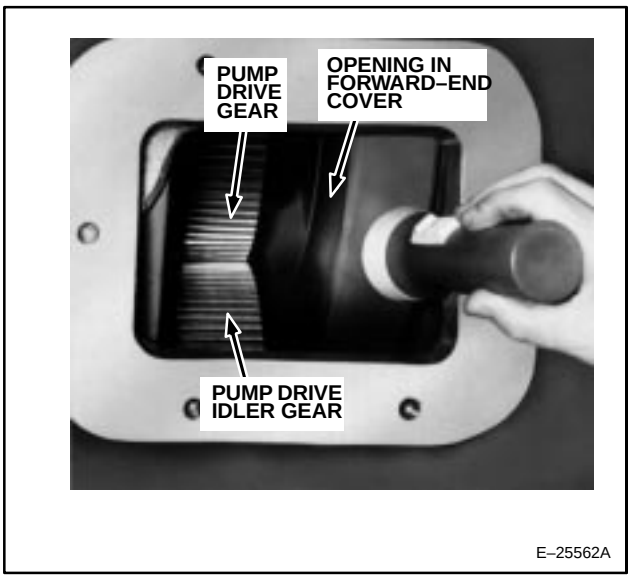


Figure 48. Checking Pump Drive Gear Train.

12.2. REMOVE/INSTALL PUMP DRIVE GEAR COUPLING

NOTE: To gain access to the coupling, it is first necessary that the drive hub, guard and bearing be removed from the free–end cover. It is also necessary to unbolt the lubricating–oil fill pipe assembly from the water pump side of the free–end cover.

Through the opening around the crankshaft created by removing the bearing:

1. Remove the bolts and washers holding the coupling to the gear.
2. Remove the bolts and washers holding the coupling to the hub.
3. Remove the defective coupling. Install a new coupling and secure to the hub and gear with bolts and washers. Torque bolts to value found in *Section 21., TORQUE VALUES,* of this publication.

NOTE: It may be necessary to bar the crankshaft or rotate the gear to achieve bolt hole alignment and alignment of match–mark numbers on the back face of the hub and gear (Figures 49 and 50).

4. Replace the free–end bearing, drive hub and guard, and the lubricating–oil fill pipe assembly.

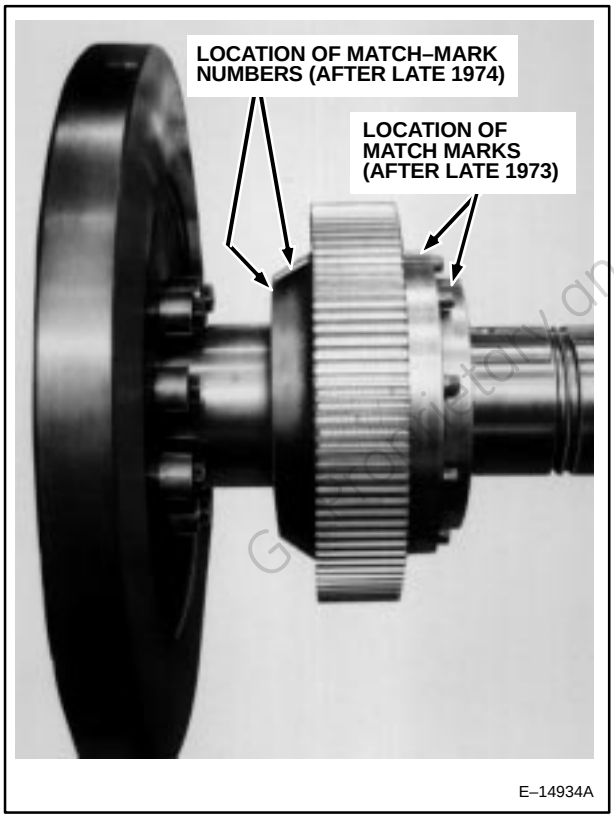


Figure 49. Pump Drive Gear Assembly Match–Mark Number Locations.

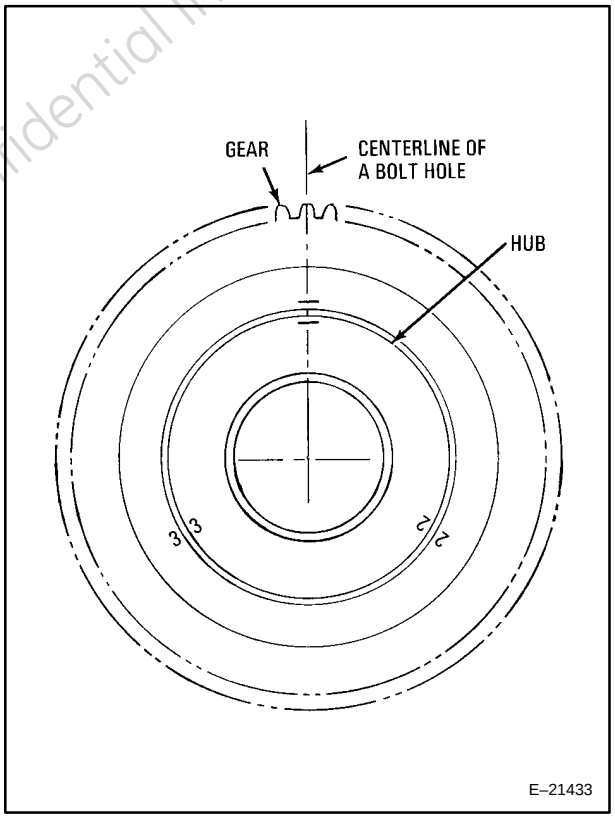


Figure 50. Pump Drive Gear Assembly Match–Mark Numbers.

13. ENGINE ALTERNATOR ALIGNMENT

Special Tools Required:

Air Wrench: 90° . . . . . GE 147X2204
Alignment Dowels (qty 3) . . . . . GE 41A286801P1
Coupling Bolt Breaker Bar . . . . . Locally Purchased
Deflection Gage (must have 0.0001 in. graduations) . . . . . GE 41D797425P2
Heavy Socket: 2.5 in. . . . . Locally Purchased
Hex Sockets: 3/4 in., 1 3/8 in., 2 in., M12 . . . . . Locally Purchased
Hydraulic Jack . . . . . TESCO T80860
Impact Wrench: 1 in. drive . . . . . Locally Purchased
Shim Packs . . . . . GE 41B513208
Torque Wrench:
60 Nm (44 lb.–ft.), 498 Nm (367 lb.–ft.), 916 Nm (675 lb.–ft.), 2169 Nm (1600 lb.–ft.) . Locally Purchased
Level Bubble Protractor . . . . . Locally Purchased
Barring Over Device T58440

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

WARNING: Do not remove the crankcase inspection cover until at least 10 minutes after the engine has come to a standstill, and after oil recirculation has been interrupted. Do not start work until sufficient ventilation time has elapsed.

WARNING: When rotating the crankshaft during alignment and checking procedures, always check for the following before rotating:

- ***There are no other persons working in or at the diesel engine or alternator.***
- ***There are no tools impeding the rotation of the crankshaft and causing possible damage to it.***
- ***The drive mechanism will not be brought out of equilibrium when parts of it are removed.***
- ***The rotating device is properly engaged.***

NOTE: Make sure that no dust or sand can penetrate into the drive compartment.

13.1. REMOVING ENGINE AND ALTERNATOR

To remove the engine and alternator from the locomotive, proceed as follows:

1. Remove the complete engine hood.
2. Remove the Blower Cab.
3. Drain the cooling water and lubricating oil from the systems. Disconnect all piping connections to the engine, carefully sealing all pipe ends to prevent dirt from entering.
4. Disconnect the air duct to the turbocharger.
5. Disconnect all wiring, and tie the wiring clear of the engine and alternator.
6. Remove the engine and alternator hold–down bolts. Back off the horizontal jacking bolts several turns. Break the tack–welds, and remove the wedges located in each of the pads at the alternator (Figure 51).

7. Attach the lifting rig. Remove the engine and alternator from the locomotive.

NOTE: If desired, the alternator may be disconnected from the engine and lifted out first. Refer to Section 13.3., REMOVING ALTERNATOR FROM ENGINE, of this publication.

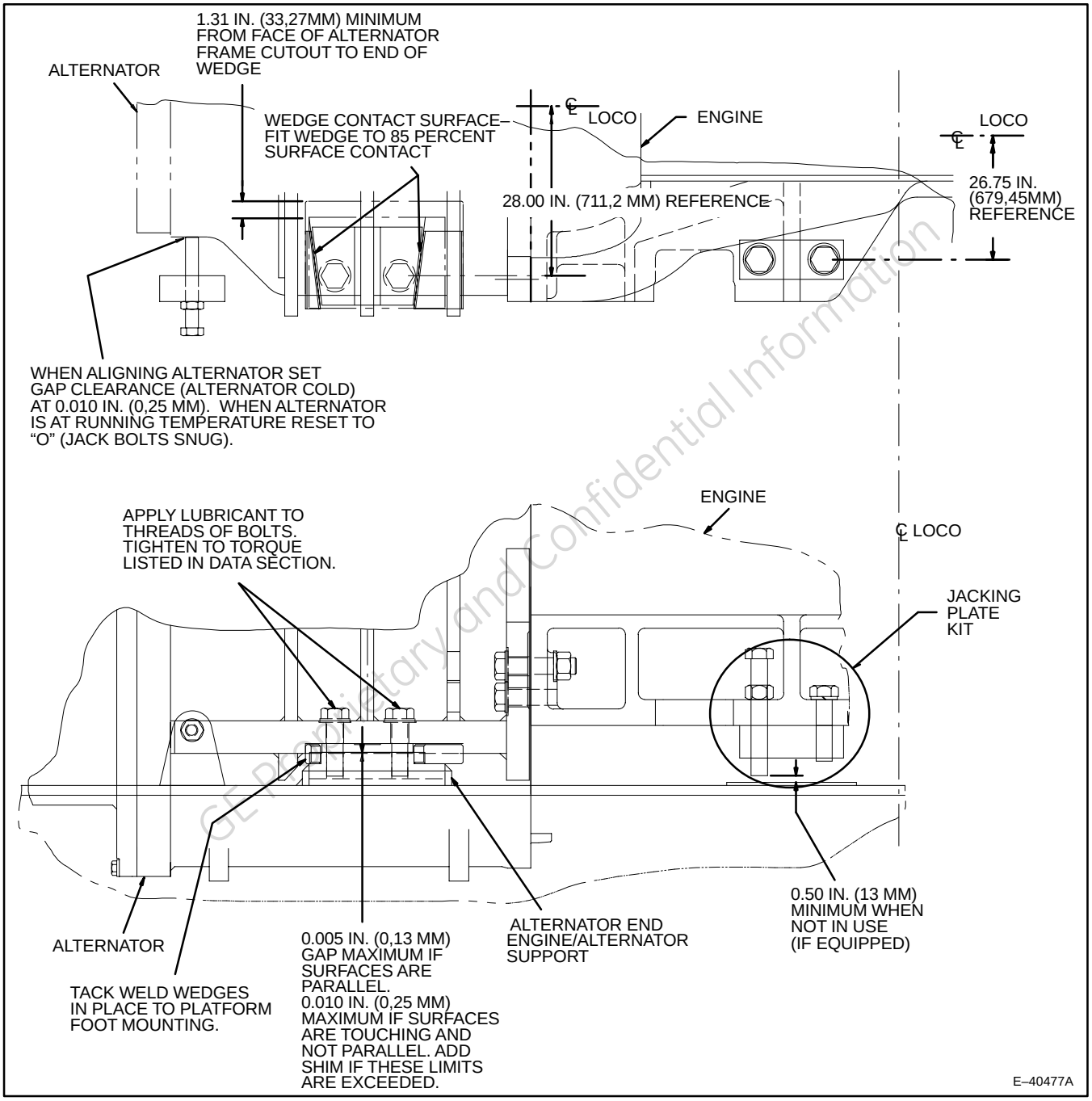


Figure 51. Engine And Alternator Mounting Arrangement, Alternator End.

13.2. PREPARE FOR REMOVAL OF ALTERNATOR FROM ENGINE

If the alternator is to be removed while the engine is left in place in the locomotive, the following preliminary steps must be taken:

1. If only the alternator is to be removed, remove the blower cab.
2. Remove the alternator hold–down bolts. Back off the horizontal jack bolts at the alternator several turns. Break the tack–welds, and remove the wedges located in each of the pads at the alternator.
3. Remove the electrical connections.
4. **If Jacking Plate Kit (GE Part No. 84D709334) is present** on both sides of the engine (Figure 51), lower the vertical jack bolts at the alternator end of the engine until they contact the pads on the platform.
5. **If Jacking Plate Kit (GE Part No. 84D709334) is NOT present** on both sides of the engine (Figure 51), install the kit (plates, bolts, lockwashers and hex nuts) as shown in Figure 51. After installing the kit, lower the vertical jack bolts at the alternator end of the engine until they contact the pads on the platform.

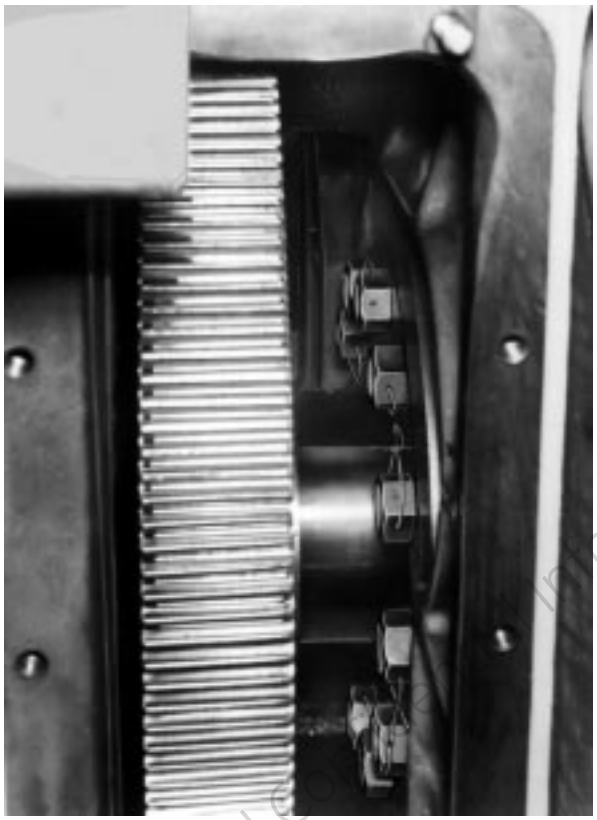
13.3. REMOVING ALTERNATOR FROM ENGINE

1. Remove the cover over the engine left–bank camshaft gear. Through this opening, remove the twelve bolts connecting the crankshaft to the alternator rotor.
2. Attach lifting cables to the alternator lifting eyes and tighten up the slack.
3. Remove the alternator mounting bolts. Then work the alternator evenly off the dowels in the upper two mounting pads, using 1–3/8 in.–12 jacking bolts in these pads or a pry bar as necessary to prevent binding.
4. When the alternator shims have been freed, collect and tag them for return to their original locations at assembly.

13.4. ASSEMBLING ALTERNATOR TO ENGINE

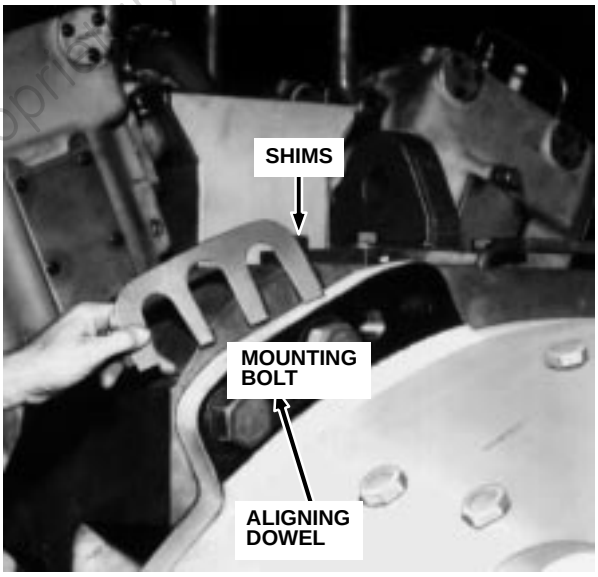
To mount the alternator on the engine, proceed as follows:

1. Thoroughly clean the coupling flange on both the alternator rotor and the engine crankshaft, as well as the finished mounting surfaces on the alternator and engine frame. Run a file lightly over the mounting surfaces to remove any nicks or burrs. Finish wipe all mating surfaces clean and apply lubricant to all contact surfaces.
2. Install three (3) dowel pins in rotor yoke at 120° apart to allow for yoke–to–crankshaft flange alignment.
3. Pre–align the alternator rotor and crankshaft coupling boltholes with each other. Match the angular position of two (2) adjacent boltholes in each flange, using a protractor containing a level bubble. Bar the crankshaft as required to give the correct alignment.
4. Lift the alternator, and move the alternator carefully up to the engine, aligning the alternator with the dowels in the two (2) upper mounting pads. Insert all the bolts in the mounting pads and screw in several turns. Install all rotor flange coupling bolts (Figure 52) with hardened washers, and screw in several turns.
5. Install the 1.52 mm (0.060 in.) alternator aligning shims, which were removed at disassembly, in their original positions (Figure 53).



E–10031

Figure 52. Alternator Rotor Coupling Bolts.



E–9939

Figure 53. Installing Alternator Alignment Shims.

NOTE: If this particular engine and alternator have not been assembled together previously, start with an equal thickness of shims on the top two (2) mounting pads. Notice that 3/32–in. (1.4 mm) shims have been bolted to the lower alternator pads.

6. Replace the alignment dowels with the connecting bolts. Tighten the alternator mounting bolts evenly to the torque listed in *Section 21., TORQUE VALUES,* of this publication. Tighten the bolts three (3) at a time in the 10–point pattern shown in Figure 54.

7. Tighten the rotor flange coupling bolts EVENLY to the torque specified in *Section 21., TORQUE VALUES,* of this publication. Bar–over the crankshaft as necessary.

8. Reinstall the camshaft gear cover.

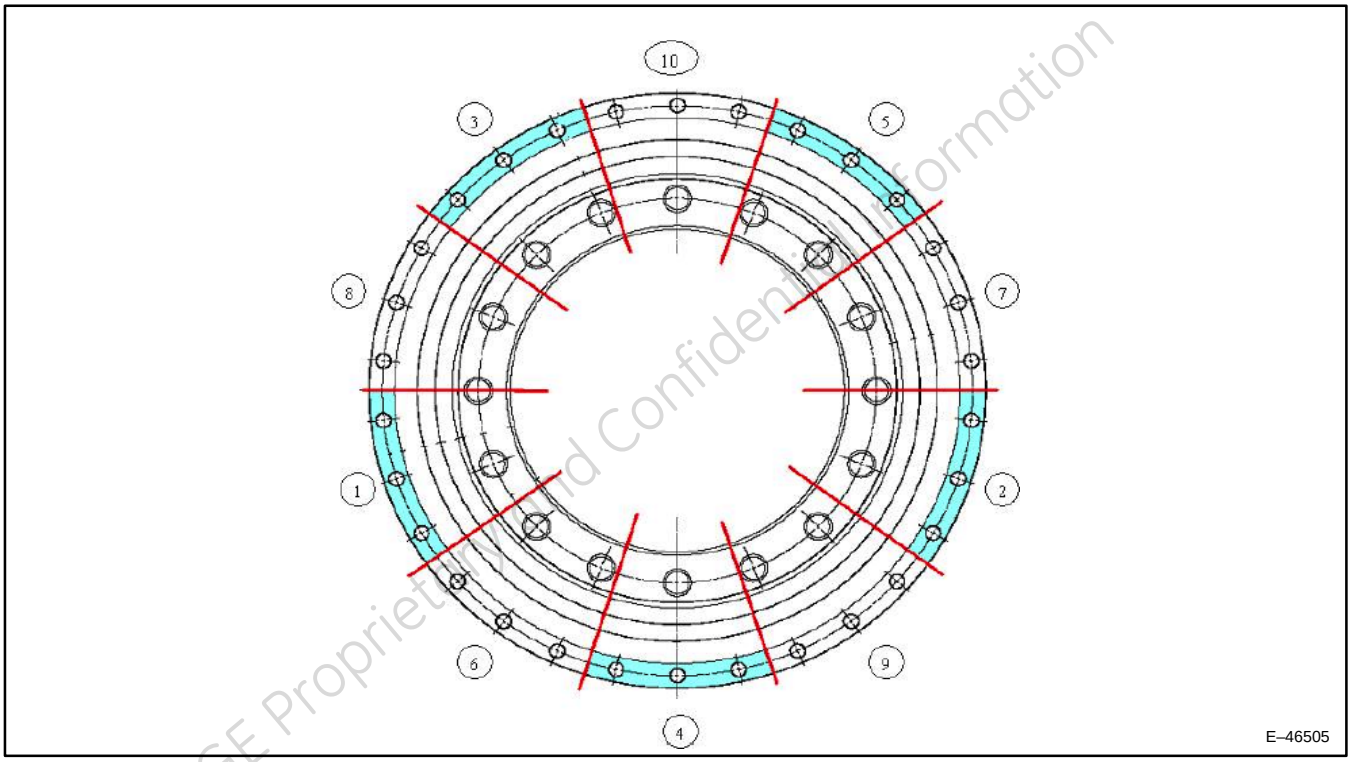


Figure 54. Flex Plate/Flange Bolt Installation Pattern.

13.5. ENGINE – ALTERNATOR ALIGNMENT

Engine – alternator alignment must be checked carefully and maintained accurately. Improper alignment of the alternator with the engine may cause engine main bearing failure, crankshaft failure, or even alternator shaft failure. Proper alignment must be determined after assembling an alternator to an engine. A check of the alternator alignment also must be made whenever the engine and alternator assembly has been installed in the locomotive, when engine main bearings have been renewed, or whenever any signs of distress that could be associated with this alignment are observed.

NOTE: If the engine and alternator are being aligned on the shop floor, the free end of the engine should be supported on two equally high stands and the alternator should be supported on two hydraulic jacks connected to the same hydraulic pump.

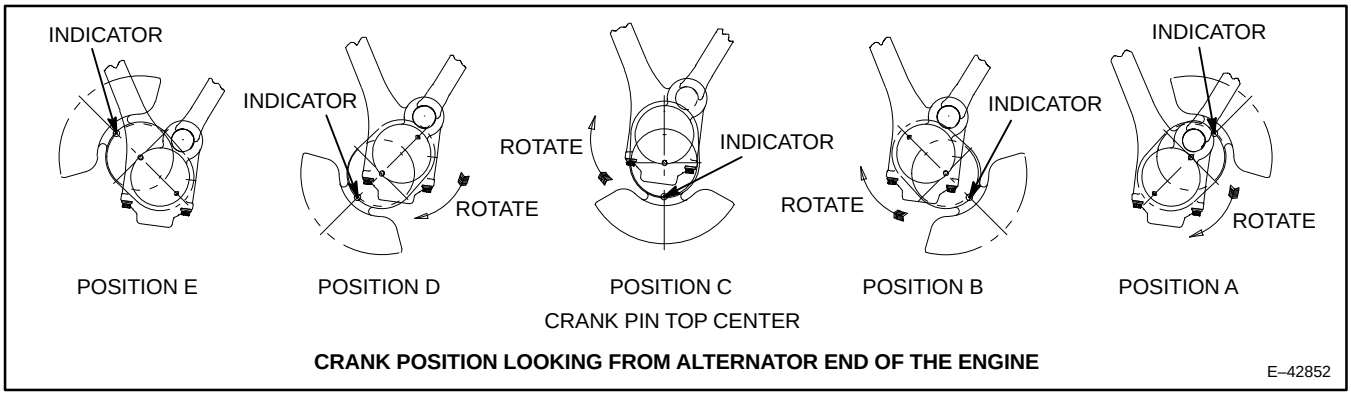


Figure 55. Engine Crankshaft Positions When Measuring Web Deflections.

Engine–alternator alignment is determined by measuring the web deflection of the engine crankshaft at the 7 connecting–rod throw nearest the alternator (No. 8 throw for 16–cylinder engines, the No. 6 throw for 12–cylinder engines, or the No. 4 throw for 8–cylinder engines). The procedure for measuring the deflection and making the necessary corrections is as follows:

1. With all compression release plugs loose, rotate the crankshaft until the rear crank pin is approximately 45° from top center (Position A, Figure 55). Place the crankshaft deflection gage (GE Tool 41D797425P1 or equivalent – MUST have 0.0001 in. graduations) between these webs, using the punch marks which will be found about 0.1875 in. (4.8 mm) in from the edge of the web (Figure 56).

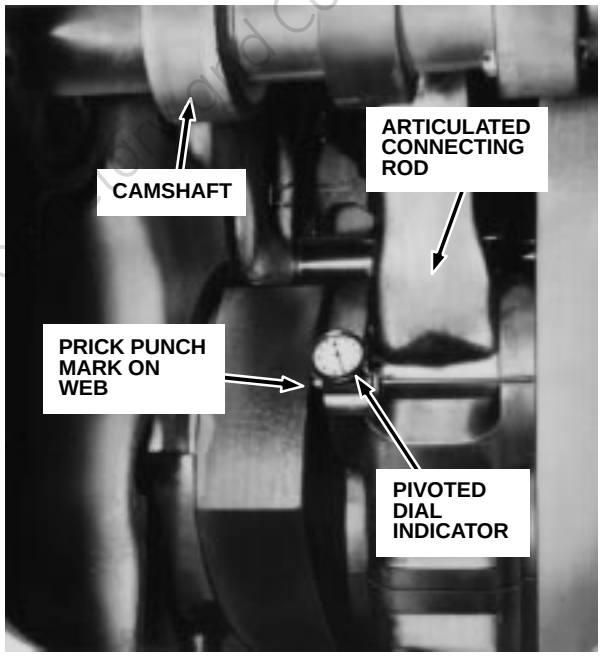


Figure 56. Measuring Crankshaft Web Deflection On Rear Crank Throw.

2. ZERO the gage and rotate or spin the crankshaft to ensure the gage is seated. Rezero gage if necessary.

3. Rotate the crankshaft and take readings as indicated in Figure 55 (at Positions **C** and **E**). Do **NOT** allow the connecting rod to hit the deflection gage by rotating the crankshaft too far.

4. Finally, return the crankshaft to its original position and again check the dial indicator. It should have returned to ZERO. If not, repeat **Steps 2, 3 and 4** and – if necessary – check the accuracy of the indicator.

5. The indicator must not show more than the total deflection given in *Section 22., DATA,* among the three measuring points. If the deflection exceeds this value, correction must be made by changing the shims under the bolting pads of the alternator. Refer to *Section 13.7., SHIMMING,* for shimming rules and shim pack size determination.

6. Ensure the final web deflection readings are taken with all alternator rotor coupling and mounting bolts torqued evenly to the values specified in *Section 21., TORQUE VALUES,* of this publication. Final torque should be applied with a torque wrench. Do not use an impact wrench as it may cause over–torque leading to premature bolt failure.

13.6. INSTALLING ENGINE AND ALTERNATOR

NOTE: The procedures in this section are only required if the alternator was mounted to the diesel engine while the engine was sitting on the shop floor.

CAUTION: Ensure that the heavy lifter does not damage the cylinder heads, valve covers, water headers, etc. during lifting and installing the alternator/engine assembly.

Installation of the engine and alternator assembly in the locomotive is essentially the reverse of the removal procedure. Before the assembly is lowered into place, ensure the mounting surfaces on the engine and alternator feet as well as on the pedestals are clean and free of chips, weld splatter, or other foreign material. The procedure for properly locating and bolting down the engine–alternator set is as follows:

1. Using the lifting rig, lower the assembly to within about 0.5 in. (13 mm) of being in place. Insert the mounting bolts through each of the four pads and into the pedestals to act as guides for final lowering.

2. Lower the assembly into place.

3. Assemble and align the alternator to the engine now if the alternator is not already in place. Refer to *Section 13.4., ASSEMBLING ALTERNATOR TO ENGINE,* and *Section 13.5., ENGINE–ALTERNATOR ALIGNMENT,* of this publication.

NOTE: If the alternator was assembled to the engine before the engine was placed in the locomotive, alignment of the alternator must be rechecked after the assembly is in place and before the mounting bolts are tightened. This is necessary to assure against misalignment during handling.

4. If there is a gap between the four (4) support pads on the engine and alternator assembly and the pedestals on the platform, such a gap should be a maximum of 0.005 in. (0.13 mm) if the surfaces are parallel or 0.010 in. (0.25 mm) if the surfaces are touching and not parallel. If the gap exceeds these limits, then shims must be used to fill the gap.

5. When alignment of the engine and alternator assembly is correct, tighten the alternator–end mounting bolts to torques listed in *Section 21., TORQUE VALUES,* of this publication.

6. Secure the engine and alternator assembly in position at the alternator end as follows:

   a. Install the wedges toward the engine side of the pedestal on each side of the engine and alternator assembly. Lightly tap these wedges into place, and tack–weld the wedges to the pedestal.

b. Install the second wedge on the pedestals on each side of the alternator. Lightly tap these wedges into place, and weld the wedges to the pedestal.

c. Adjust the horizontal jack bolts for proper end clearance, and tighten the locknuts. Refer to *Section 22., DATA,* of this publication.

NOTE: These bolts will require readjustment after the engine has been run a sufficient time to attain maximum operating temperature.

7. Secure the mounting bolts at the free end of the engine as follows (Figure 57):

a. Apply a thin layer of grease to the concave (under) side of the Belleville washers.

b. Place the Belleville washers over the mounting hole with the convex (crown) side up.

NOTE: If the washer is installed upside down, considerable difficulty will be encountered in installing the bolt–locking device.

c. Install the mounting bolts, and tighten to the torque listed in *Section 21., TORQUE VALUES,* this publication.

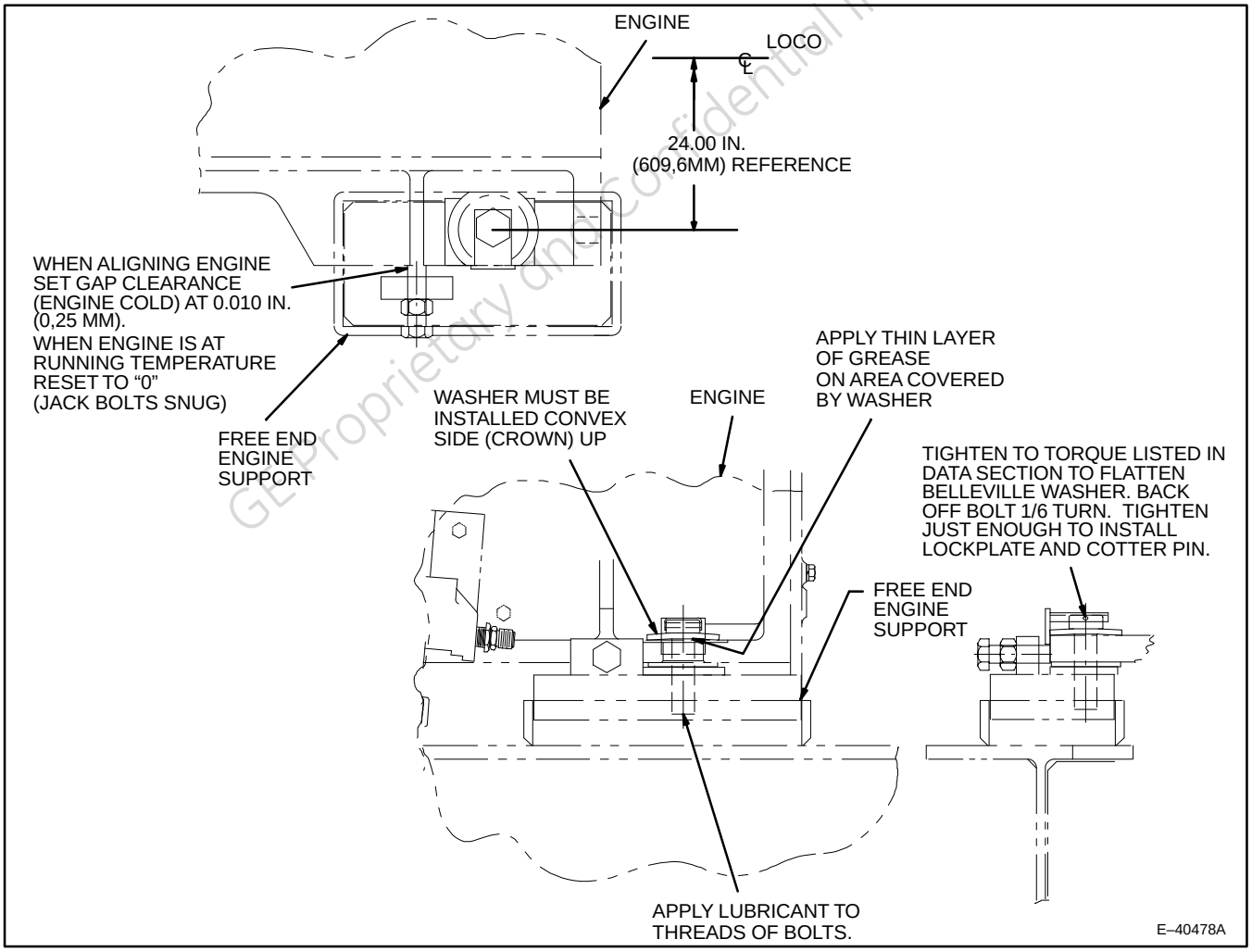


Figure 57. Engine Mounting Arrangement, Free End.

d. Back the bolts off 1/6 turn, then tighten if necessary, to align the holes in the bolt locking device with the holes in the bolt. Position the locking devices over the bolts, and insert the cotter pins to secure the locking device in place.

NOTE: If the mounting bolt is loose after the locking device has been installed, the Belleville washer is not properly installed.

CAUTION: Follow the inspection schedule for checking the tightness of the mounting bolts. If the proper torque is not maintained, serious engine damage may result.

8. Make a final check of the alternator alignment to be sure misalignment has not occurred during installation.

13.7. SHIMMING

The following formulas will approximate the amount of shims to be added or removed from the TL (Top Left) or TR (Top Right) shim packs based on deflections at Positions **C and E**, Figure 55 (view engine from alternator end; Sign convention is "+" reading indicates web spread while "–" reading indicates web compression. Check gage and adjust sign accordingly):

- TL (add) = (–14 x E) + (7.8 x C).
- TR (add) = (8.6 x E) + (8.5 x C).

The following rules govern shim pack size:

- Shim packs at the top ears cannot exceed 0.120 in. (3.05 mm).
- Difference between the top two shim packs should not exceed 0.060 in. (1.52 mm).
- If the shim pack difference is at 0.060 in. (1.52 mm) and deflection is not in specification, it is permissible to replace the bottom left shim with a 0.070 in. (1.78 mm) [GE Part 41A330541P1] or a 0.110 in. (2.79 mm) [GE Part 41A330541P3] shim.
- If the above shim pack rules cannot be satisfied, an error exists somewhere and must be investigated.

14. CAMSHAFT

Special Tools Required:

Bearing Press and Removal Tool . . . . . TESCO T55960
Camshaft Bolt Torque Wrench . . . . . TESCO T54440
Camshaft Section Lifter . . . . . TESCO T55991
Crosshead Lifter . . . . . GE 147X2397
Fuel Roller Retaining Plate . . . . . TESCO T57150
MOLYKOTE® G–n . . . . . GE 147X1143–1
Pry Bar . . . . . Locally Purchased
Rocker Arm Depressor . . . . . GE 147X1040–1

ECC

CAUTION: The right and left camshaft mid–section and end section are Emission Critical Components (ECC). Do not replace it with a non–ECC part. Refer to the NOTICE at the beginning of this publication and consult the latest revision of the manufacturer's Parts Catalog to obtain the correct replacement part.

Two (2) sectional camshafts, one (1) on each bank (or side) of the engine, are driven by gearing directly from the crankshaft.

The camshaft sections are stamped with the letters L (left) or R (right) on the edge of one flange to indicate for which bank of the engine the sections are intended. The edge of the other flange is stamped with numbers (**TABLE 1**) that index the angular rotation of the section with respect to the cylinder position. These camshaft sections are inter–changeable between positions within their respective banks, but they are NOT interchangeable between the left and right banks because of the reversal of the valve cam locations.

The camshaft journal bearing sections are universal – except for the drive–end journal bearing section on each bank – and may be assembled with appropriate indexing in either the left or right–bank camshaft of any engine, regard-less of the number of cylinders.

Whether assembling a complete camshaft or replacing a camshaft section, the sections must be properly indexed with respect to their location in the shaft. Beginning at the drive end of the shaft, the notch on the journal bearing section bolted to the camshaft drive gear is aligned with the numeral of the drive–end cylinder in the bank (6 or 8) on the drive–end camshaft section. The proper bank letter (L or R) on the other end of the camshaft section is aligned to the notch on the next journal bearing section. The numeral for the next cylinder (5 marked as 4/5, or 7 marked as 3/7) on the next camshaft section is aligned to the notch on the other end of the previous journal bearing section. Proceed to the following journal bearing and camshaft sections in a like manner, until the free end of the engine is reached. Refer to **TABLE 1** for proper numerical markings.

14.1. CAMSHAFT SECTIONS

Two (2) sectional camshafts, one (1) on each bank (or side) of the engine, are driven by gearing directly from the crankshaft.

TABLE 1. CAMSHAFT MARKINGS.

Cylinder Location (Right or Left Bank)	Engine Model	
	16 Cyl.	12 Cyl.
8	8	
7	3/7	
6	6	6
5	1/5	4/5
4	4	4/5
3	3/7	3
2	2	1/2
1	1/5	1/2

CAUTION: Specified camshafts are not interchangeable with other configurations.

On diesel engines equipped with EFI, the camshaft sections nearest the camshaft gears are larger than the other camshaft sections, and cannot be interchanged with the other sections along that bank. The camshaft gear is bolted through the end journal bearing section to this larger end camshaft section from the gear side with twelve (12) long bolts.

The camshaft journal bearing sections are universal – except for the drive–end journal bearing section on each bank – and may be assembled with appropriate indexing in either the left or right–bank camshaft of any engine, regardless of the number of cylinders. However, the end journal bearing sections – between the camshaft gear and the drive–end camshaft section – are machined to accept the through bolts from the gear to the drive–end section, and are not inter–changeable between left and right banks, or with any other journal bearing section along the banks.

Whether assembling a complete camshaft or replacing a camshaft section, the sections must be properly indexed with respect to their location in the shaft. Beginning at the drive end of the shaft, the notch on the journal bearing section bolted to the camshaft drive gear is aligned with the numeral of the drive–end cylinder in the bank (6 or 8) on the drive–end camshaft section. The proper bank letter (L or R) on the other end of the camshaft section is aligned to the notch on the next journal bearing section. The numeral for the next cylinder (5 marked as 4/5, or 7 marked as 3/7) on the next camshaft section is aligned to the notch on the other end of the previous journal bearing section. Proceed to the following journal bearing and camshaft sections in a like manner, until the free end of the engine is reached. Refer to **TABLE 1** for proper numerical markings.

CAUTION: Camshaft sections are NOT interchangeable between the right and left bank of the same EFI engine, NOR are sections interchangeable between engines having different numbers of cylinders. For example, a camshaft section from a 12–cylinder engine cannot be used in a 16–cylinder engine. Also, camshaft sections are NOT interchangeable between EFI engines and mechanical injection engines, even those with the same number of cylinders.

A cover bolted over the end of both free–end camshaft sections seals the lubricating–oil passage in each shaft.

14.2. REMOVE/INSTALL CAMSHAFT SECTIONS

To replace a camshaft section, proceed as follows:

1. Remove the cylinder covers from ALL cylinders on the bank of the engine where the camshaft section is to be removed.
2. Compress the valve springs and remove the valve pushrods from their sockets on ALL cylinders on the bank of the engine where the camshaft section is to be removed. Use the rocker arm depressor (refer to *Section 20., SPECIAL TOOLS*).
3. Remove the fuel–oil injection pumps (refer to *Section 8., FUEL–OIL INJECTION PUMP*) from ALL cylinders on the bank of the engine where the camshaft section is to be removed.
4. Remove ALL crankcase inspection covers on the bank of the engine where the camshaft section is to be removed. Lift the valve and fuel crossheads on ALL cylinders on that bank. Hold the valve crossheads up with 0.25–20 bolts threaded into the tapped holes in the crosshead guides. To raise the fuel crossheads, use a crosshead lifter (refer to *Section 20., SPECIAL TOOLS,* of this publication) or force a hardwood or fiber wedge between the roller and cam. Hold the fuel crossheads up with the fuel roller retaining plate (refer to *Section 20., SPECIAL TOOLS*) attached to the valve crossheads with 0.25–20 bolts.

CAUTION: Ensure that all camshaft sections are in place before barring over the diesel engine. Barring over the engine with camshaft sections removed WILL damage valve train components.

5. Bar the crankshaft until the index marks on the flanges of the camshaft section to be removed are visible in the crankcase inspection opening.

CAUTION: The camshaft section flange bolt heads will not pass through the camshaft bearing when sliding the camshaft. Do NOT move the camshaft far enough for the bolt heads to contact and damage the camshaft bearing. Move the camshaft just far enough to disengage the bolts.

6. Remove the eight (8) bolts from the camshaft section flange toward the drive end of the camshaft. Using a pry bar placed carefully between the side of a cam and the main frame, separate the camshaft sections. Pry the free end of the camshaft towards the free end of the engine just enough to disengage the bolts [approximately 0.75 in. (18 mm)].

7. Remove the eight (8) bolts from the camshaft section flange away from the drive end of the camshaft. Remove the camshaft section through the crankcase inspection opening.

8. Install the new camshaft section in the reverse of the above sequence. Observe the index markings as previously described. Use the camshaft section lifter (refer to *Section 20., SPECIAL TOOLS*).

Use special care to keep flanges and cams clean and free of burrs. Lubricate the bolt threads and faces with MOLYKOTE® G–n (refer to *Section 20., SPECIAL TOOLS*). Torque the camshaft bolts in a criss–cross pattern to the torque specified in *Section 21., TORQUE VALUES,* of this publication using the camshaft bolt torque wrench (refer to *Section 20., SPECIAL TOOLS*), then repeat the pattern tightening the nuts to a final torque as specified in *Section 21., TORQUE VALUES,* of this publication.

9. Remove the fuel roller retaining plates and crosshead guide retaining bolts from all crosshead guides on that engine bank, replace all fuel–oil injection pumps and valve pushrods, and reset all valve tappets. (Refer to *Section 5., CYLINDER HEAD,* in this publication.)

14.3. CAMSHAFT BEARING

A diesel engine with EFI has steel sleeve bearings for the camshaft. Replace a camshaft bearing as follows:

1. Remove the camshaft on the free–end side of the camshaft bearing to be replaced. Refer to *Section 14.2., REMOVE/INSTALL CAMSHAFT SECTIONS,* of this publication.
2. Remove the camshaft on the camshaft drive side of the camshaft bearing to be replaced. Refer to *Section 14.2., REMOVE/INSTALL CAMSHAFT SECTIONS,* of this publication.
3. Remove the camshaft bearing journal from the bearing to be replaced.
4. Press the camshaft sleeve bearing out of the main frame bore using the bearing press and removal tool (refer to *Section 20., SPECIAL TOOLS*).

Before installing a new bearing, inspect the bearing bore in the main frame for damage. To install a camshaft bearing, reverse the above sequence. Ensure the lubricating–oil hole in the sleeve bearing is in line with the lubricating–oil passage in the frame when pressing in the new bearing; the notch in the bearing should be at the bottom.

15. CROSSHEADS AND GUIDES

Special Tools Required:

Crosshead Lifter . . . . . GE 147X2397

Fuel Roller Retaining Plate . . . . . TESCO T57150

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

Three (3) crosshead assemblies are mounted in the main frame under each cylinder (Figure 58). The crossheads transmit the reciprocating force from the cams to the pushrods to operate the valves and the fuel–oil injection pump on each cylinder.

The crosshead assemblies for the air and exhaust valves are identical and interchangeable. The assemblies consist of two (2) major parts: the crosshead with its roller and a guide in which the crosshead operates (Figure 59). Parts of the fuel crosshead assembly are similar in appearance, but are not interchangeable with those for the valves. The fuel crosshead assembly major parts include the crosshead, spring, spring retainer and guide (Figure 60).

For more details regarding the crossheads and guides, refer to **MI–93200, GEK–18033, CROSSHEADS AND GUIDES** publication.

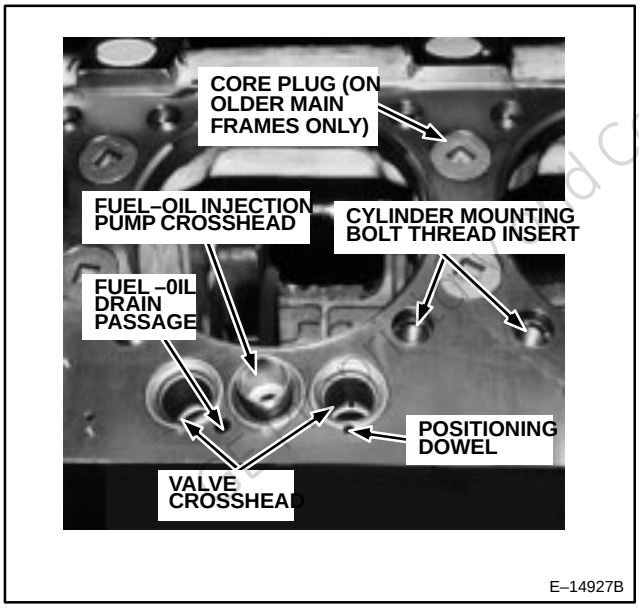


Figure 58. Crosshead Assembly Locations.

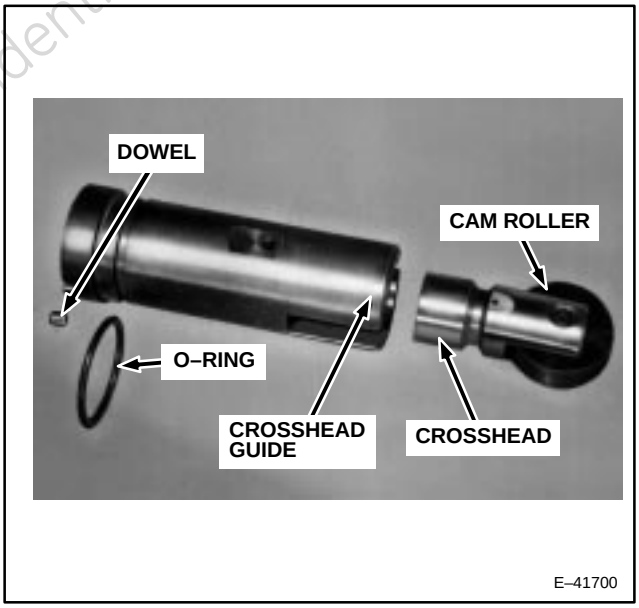


Figure 59. Valve Crosshead and Guide Assembly (Typical).

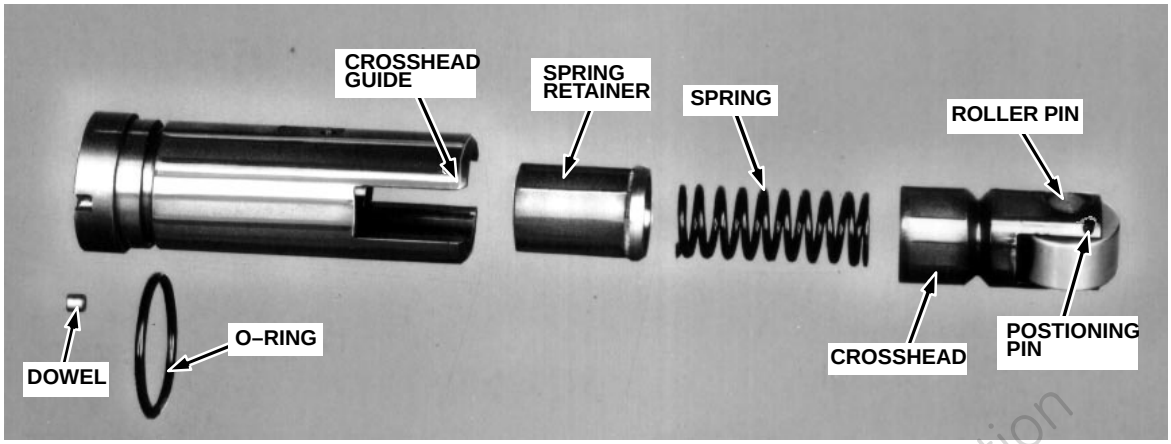


Figure 60. Fuel Crosshead and Guide Assembly (Typical).

15.1. REMOVE CROSSHEADS AND GUIDES

Remove crossheads and guides as follows:

CAUTION: The fuel crosshead and guide have no lubricating–oil passages, and will cause failures of upper cylinder parts from lack of lubrication if installed in either of the valve crosshead positions by error.

1. Crossheads and guides may be replaced without completely removing the cylinder.
2. With the piston at top dead center, disconnect the cylinder and lift it just high enough to permit removal of the crosshead assembly, but not high enough to remove the piston rings from the cylinder bore. Refer to *Section 3., POWER ASSEMBLY,* of this publication.

NOTE: Use care when handling crossheads and guides. Burrs may be formed on the edge of the guide bore if the crosshead is dropped into the guide with the guide inverted. Burrs must be removed to prevent binding of the crosshead during operation. Also, in case of a pushrod failure, the crosshead will probably be stuck in the guide and should be carefully inspected for damage.

3. The crosshead assemblies and positioning dowel pins can be pushed upward and removed.
4. Hold the valve crossheads up with 0.25–20 bolts inserted through the tapped holes in the crosshead guides.
5. To raise the fuel crosshead, use a crosshead lifter (refer to *Section 20., SPECIAL TOOLS*) or force a hardwood or fiber wedge between the roller and cam.
6. Hold the fuel crosshead up with the fuel roller retaining plate (refer to *Section 20., SPECIAL TOOLS*) attached to the valve crossheads with a 0.25–20 bolt.

15.2. INSTALL CROSSHEADS AND GUIDES

Install crossheads and guides as follows:

1. Immerse the replacement crosshead in SAE–10 lubricating oil for 5 minutes, then install the new crosshead assembly in the main frame with lubricant applied to the sealing O–ring.
2. Position the guide and insert the dowel.
3. Apply new O–rings to the pushrod ferrules.
4. Restore the cylinder to position and reconnect.

16. WATER PUMP

Special Tools Required:

Lifting Hoist . . . . . Locally Purchased

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

The purpose of the engine cooling water system is to maintain a nearly constant engine operating temperature throughout the load range of the diesel engine, despite wide variations in outside temperatures. The water pump, mounted to the Free End Cover is the critical component in moving the cooling water through the engine and the entire cooling system.

16.1. REMOVE WATER PUMP

1. Drain the crankcase lubricating oil by removing the crankcase drain pipe plug and opening the drain valve (refer to **SMI–02001, ENGINE LUBRICATING OIL SYSTEM** publication).
2. Drain the cooling–water system by opening the water drain valve (refer to **SMI–02003, ENGINE COOLING SYSTEM** publication).
3. Remove the Victaulic® coupling from the water pump inlet pipe.
4. Remove the flange bolts at both ends of the water pump discharge elbow and remove the elbow.
5. Position a suitable lifting hoist over the water pump and attach the hoist to the eyebolt to support the pump weight.
6. Remove the water pump mounting bolts. Install two (2) jack bolts in the threaded holes in the pump housing (Figure 61), and evenly jack the pump from its rabbet fit. Lift and remove the pump from the engine.

E–20897

Figure 61. Water Pump.

16.2. INSTALL WATER PUMP

NOTE: If the water pump drive gear is being replaced, thoroughly clean the tapered fits. Ensure the large flat washer between the drive gear nut and the drive gear is assembled with the chamfer toward the gear. Torque the nut to the torque specified in Section 21., TORQUE VALUES, of this publication and install a new cotter pin.

1. Install the water pump using a new gasket. Align the drive gear teeth and the pump register fit. Install the pump mounting bolts finger–tight.

CAUTION: Care must be taken to ensure that the water pump pipe flange alignment is correct; otherwise, the pump casing may be distorted and broken.

2. Assemble the pump discharge elbow using new gaskets. Install the elbow mounting bolts finger–tight first, then snug these and the pump mounting bolts lightly and finally tighten all securely.
3. Assemble the Victaulic® coupling connecting the water pump inlet pipe to the pipe from the lubricating–oil cooler.
4. Fill the cooling–water system to the proper level and add water treatment as needed.
5. Add lubricating oil to bring the crankcase to the proper level.

NOTE: A small amount of water seal leakage may be noted on a newly installed water pump. However, after a short period of operation, the water seal should become seated, stopping all leakage.

17. LUBRICATING–OIL PUMP

Special Tools Required:

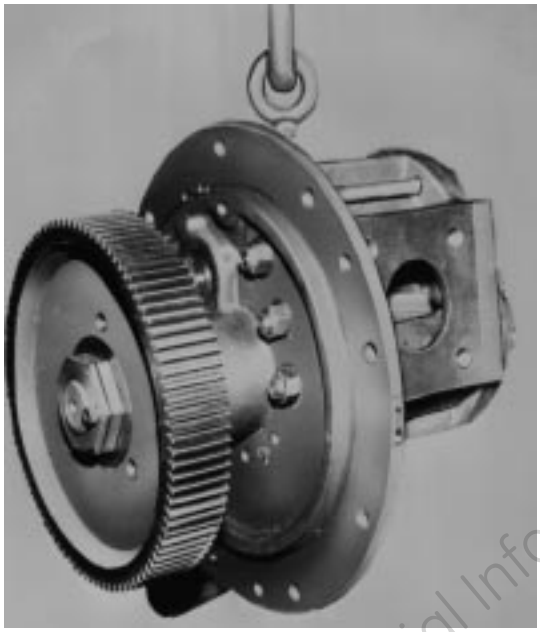
Lifting Hoist . . . . . Locally Purchased

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

The Lubricating Oil System on provides pressure lubrication to engine bearings and power assemblies and carries away heat produced by friction and combustion. The lubricating oil pump is a gear–type positive displacement pump located on the left side of the free end cover on the diesel engine.

17.1. REMOVE LUBRICATING–OIL PUMP

1. Drain the crankcase lubricating oil by removing the crankcase drain pipe plug and opening that drain valve. Drain the lubricating oil from the lubricating–oil cooler and filter tank by removing the cooler drain pipe plug and opening that drain valve (refer to **SMI–02001, ENGINE LUBRICATING OIL SYSTEM** publication).
2. Remove the four (4) bolts from the discharge pipe flange at the pump (Figure 62).
3. Install a 0.75 in.–10 lifting eyebolt in the lubricating–oil pump casing. Position a suitable lifting hoist over the pump, and attach the hoist to the eyebolt to support the pump weight.
4. Remove the lubricating–oil pump mounting bolts. Install three (3) jack bolts in the threaded holes in the pump mounting flange and evenly jack the pump from its rabbet fit. Lift and remove the pump from the engine.



E–9927

Figure 62. Lubricating–Oil Pump.

17.2. INSTALL LUBRICATING–OIL PUMP

NOTE: If the lubricating–oil pump drive gear is being replaced, thoroughly clean the tapered fits and install the key. Torque the large drive gear nut to the torque specified in Section 21., TORQUE VALUES, of this publication, and the lockscrew on the nut to 30 to 36 lb.–ft. (41 to 49 Nm).

1. Place a 0.75 in.–10 lifting eyebolt in the lubricating–oil pump casing. Install the pump with a new gasket. Align the drive gear teeth and the pump register fit. Install the pump mounting bolts finger–tight.
2. Apply the pump discharge pipe flange bolts finger–tight to allow the discharge pipe to be aligned.
3. When the pipe is aligned, torque the pump mounting bolts to the torque specified in *Section 21., TORQUE VALUES,* of this publication. Tighten the discharge pipe flange bolts.
4. Fill the lubricating–oil system to the proper level. After starting the engine, check the lubricating–oil pump for overheating or unusual noises.

18. TURBOCHARGER

Special Tools Required:

Crane . . . . . Locally Purchased
High–Temperature Anti–Seize Thread Compound . . . . . GE 147X1640
High–Temperature FS1292 Grease . . . . . GE 147X2428
Lifting Sling (Alternate to Turbocharger Lifter) . . . . . Locally Purchased
Lubriplate® Spray Lube “A” GE147X1614
Turbocharger Lifter . . . . . GE 147X1916–2
Turbocharger Mounting Bolt Adapter . . . . . GE 147X2350
Viton O–rings . . . . . GE 115X1902–2
19 in. Torque Wrench . . . . . GE 147X2252

WARNING: To prevent personal injury and potential equipment damage, make sure the engine cannot be started before beginning to remove, install, or adjust any engine components. Open the Battery Switch (BS) to prevent starting attempts. Also place the Fuel Pump Circuit Breaker (FCB), the Battery and Computer Circuit Breaker (BCCB) and the Local Control Circuit Breaker (LCCB) in the OFF position and apply a warning tag to the Engine Control (EC) switch.

ECC

CAUTION: The turbocharger (including turbine disk assembly, buckets, and rotor) is an Emission Critical Component (ECC). Do not replace it with a non–ECC part. Refer to the NOTICE at the beginning of this publication and consult the latest revision of the manufacturer’s Parts Catalog to obtain the correct replacement part.

The General Electric 7S1716 Turbocharger is a centrifugal air compressor (blower) powered by an axial–flow turbine. The turbine is driven by the energy in the engine exhaust gases prior to discharge to the atmosphere.

Refer to publication **MI–???? GEK–????, TURBOCHARGER** for additional information on the turbocharger and its components.

18.1. REMOVE TURBOCHARGER

Remove the turbocharger as follows:

1. Drain the cooling–water system (refer to **SMI–02003, ENGINE COOLING SYSTEM** for details).
2. Open the Engine Cab hatch over the turbocharger.
3. Disconnect the crankcase breather from the muffler or exhaust stack. Remove the aspirator hoses, if used. Remove the muffler or exhaust stack from the turbocharger turbine casing (Figure 63).
4. Remove the intercooler support bar. Remove the two (2) compression couplings from the water discharge pipe (Figure 64).
5. To disconnect the exhaust manifold from the turbine inlet assembly, support the transition casting by blocking underneath or suspending the casting from the water header. Remove the bolts holding the transition casting to the turbocharger turbine inlet flange.
6. Remove both air discharge pipes between the turbocharger and the intercoolers by unbolting the clamp rings at the turbocharger and intercooler ends of both pipes. Slide the discharge pipes into the respective intercoolers, and remove the clamp rings.
7. Remove the two (2) clamps, flexible air duct and metal air duct from the compressor inlet.

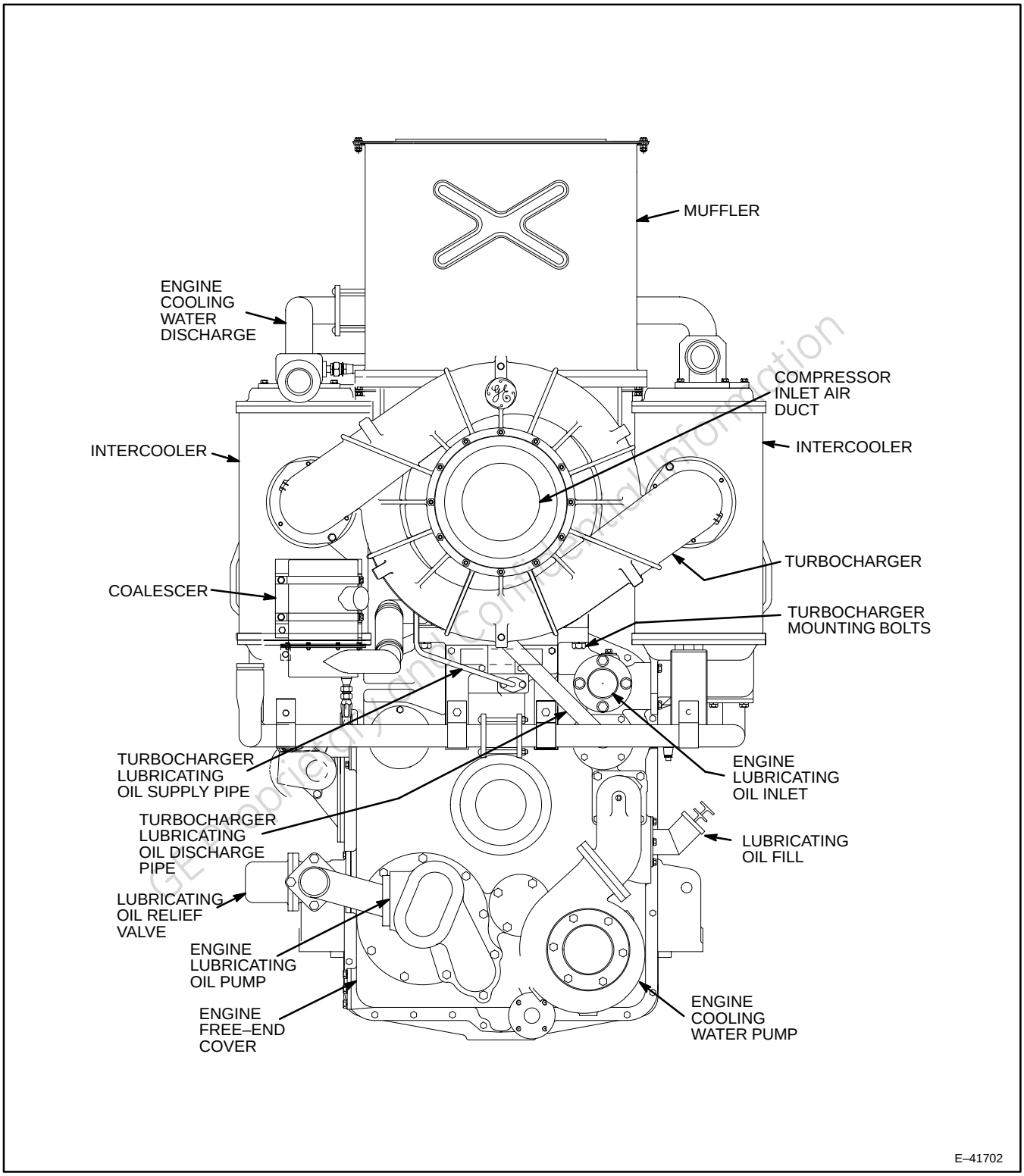


Figure 63. Turbocharger Compressor–End Details (Typical).

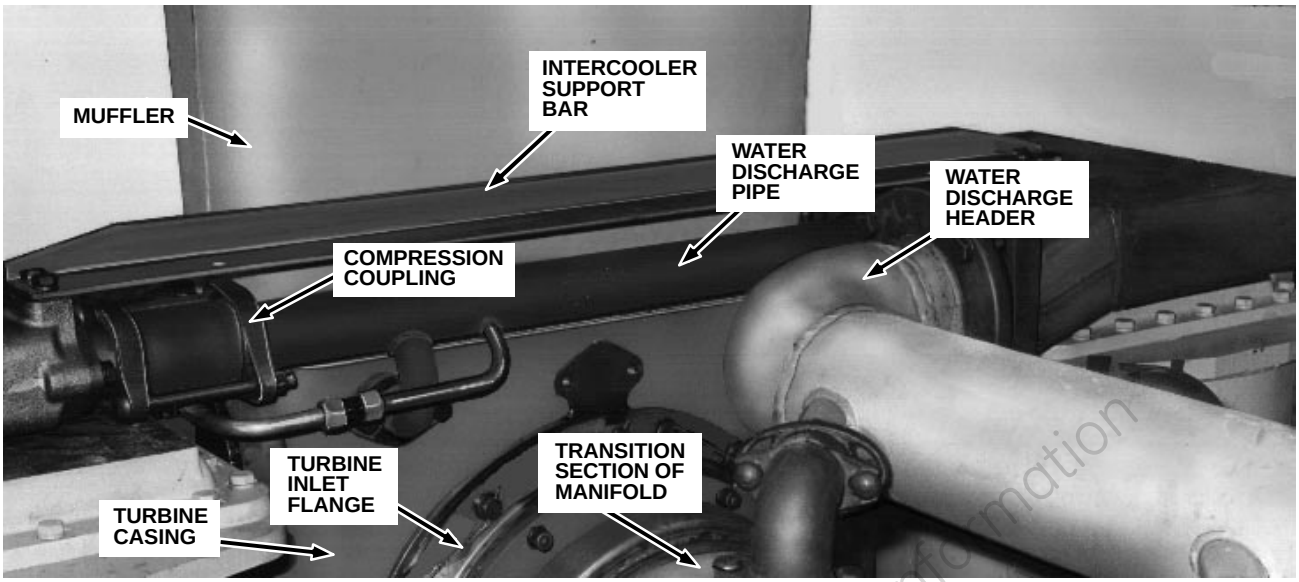


Figure 64. Turbocharger Turbine–End Details (Typical).

CAUTION: Be extremely careful to not get ANY foreign debris or objects in the lubricating–oil supply pipe or the turbocharger. Openings in the lubricating–oil system should be immediately plugged or covered.

8. Remove the turbocharger lubricating–oil supply pipe, with orifice, between the free–end cover and the turbocharger casing. Remove the turbocharger lubricating–oil discharge pipe between the turbocharger casing and the free–end cover (Figure 63).

CAUTION: Before removing the turbocharger mounting bolts, ensure the turbocharger is securely held by the crane.

9. Remove the four (4) mounting bolts and lockwashers which secure the turbocharger to the free–end cover. Use a turbocharger lifter (refer to *Section 20., SPECIAL TOOLS*) and/or a lifting sling to remove the turbocharger from the engine. Slightly rock the turbocharger as it is lifted to free the two (2) rear mounting feet from their locating dowels.

CAUTION: Exercise care while removing the turbocharger to avoid damaging the exhaust manifold.

10. After positioning the removed turbocharger securely on the floor:

    a. Remove the water discharge header and retain for application to the replacement turbocharger.

    b. If the turbocharger was removed because of failure (and not for a periodic replacement), thoroughly examine the turbocharger and DETERMINE THE INITIAL CAUSE OF THE FAILURE. Not doing so probably will result in a repeat turbocharger failure. If the failure was caused by foreign material, it is MANDATORY that all traces of this material be removed from the engine. It may be necessary to remove and clean the exhaust manifold, or to remove the engine air filters and clean and inspect the filter air plenum. Also inspect the inlet side of both intercoolers for foreign material.

    c. Apply protective covers and pipe plugs to all openings in the removed turbocharger. Use either new covers and plugs or remove them from the replacement turbocharger.

CAUTION: If the turbocharger is being replaced because of a bearing failure, check the cavity in the top of the free–end cover with the crankcase breather plate removed, and ensure that the pipe–tapped hole is fitted with a pipe plug. Failure to plug this hole will cause the loss of the lubricating–oil supply to the turbocharger bearings.

CAUTION: Exercise care while removing the turbocharger to avoid damaging the exhaust manifold.

18.2. INSTALL TURBOCHARGER

CAUTION: If the turbocharger is being replaced as a result of a failure, correct the initial cause of the failure before installing the new turbocharger. Consult the latest revision of the manufacturer's Parts Catalog to obtain the correct replacement part.

Install the turbocharger as follows:

1. Remove all protective covers and pipe plugs from openings in the replacement turbocharger. Ensure that no foreign material is in the turbocharger.

CAUTION: Ensure the turbocharger speed sensor opening is plugged or covered. Otherwise, dirt will be pulled into the turbocharger and delivered to the engine. For detailed information regarding the turbocharger speed sensor, refer to* MI–????, GEK–?????, TURBOCHARGER *publication.

2. Pour some clean engine lubricating oil into the oil inlet near the top of the turbocharger casing and rotate the rotor assembly several revolutions.

3. Assemble the water discharge header to the turbine casing using new gaskets (Figure 64).

CAUTION: Exercise care while installing the turbocharger to avoid damaging the exhaust manifold.

4. Clean the turbocharger mounting surface on the free–end cover and deburr the two (2) locating dowels if required. Apply a film of Lubriplate® Spray Lube "A" (refer to *Section 20., SPECIAL TOOLS*) to the dowels, and install two (2) new O–rings around the water inlet openings. Use a turbocharger lifter (refer to *Section 20., SPECIAL TOOLS*) and/or a lifting sling to raise the turbocharger. Clean and deburr (if required) the four (4) turbocharger mounting feet. Align the two (2) dowel holes in the rear feet with the locating dowels. Slightly rock the turbocharger while lowering it onto the dowels.

CAUTION: Ensure the turbocharger mounting bolts are securely tightened before removing the crane hooks.

5. Using new lock washers, assemble the four (4) mounting bolts. Torque the bolts to the torque specified in *Section 21., TORQUE VALUES,* of this publication using the turbocharger mounting bolt adapter (refer to *Section 20., SPECIAL TOOLS*).

NOTE: With the turbocharger mounting bolt torque adapter (refer to Section 20., SPECIAL TOOLS), use the 19 in. torque wrench (refer to Section 20., SPECIAL TOOLS). Set the torque wrench at 225 lb.–ft. (305 Nm) and keep the adapter in line with the wrench for final torquing. Torque on the bolt will be 425 lb.–ft. (576 Nm).

6. Clean and blow out the lubricating–oil piping. Assemble the turbocharger lubricating–oil discharge pipe between the turbocharger casing and the free–end cover. Assemble the turbocharger lubricating–oil supply pipe, with orifice, between the free–end cover and the turbocharger casing (Figure 63).

CAUTION: The turbocharger lubricating–oil supply pipe must have an open orifice in the free–end cover flange of the correct size to assure the correct oil pressure and flow to the turbocharger bearings. Orifice diameter must be per TABLE 2.

TABLE 2. ORIFICE SIZES.

Turbocharger Model	Orifice Diameter, in. (mm.)
7S1612, 7S1616, 7S1716	0.352–0.348 (8.94–8.84)

7. Assemble the metal air duct to the compressor inlet, if used. Assemble the flexible air duct and secure with the two (2) clamps.
8. Assemble the two (2) air discharge pipes between the turbocharger and the intercoolers as follows:

CAUTION: Do NOT use GE Part 115X1268 black O–rings on the air discharge elbow; they will not withstand the higher air temperatures.

   a. Lubricate four (4) new green Viton O–rings (GE Part 115X1902–2) with high–temperature FS1292 grease (GE Part 147X2428). This reduces the probability of O–ring damage during installation, and provides high–temperature lubrication during operation. Apply the O–rings to four (4) clamp rings.
   b. Apply two (2) clamp rings – one facing the intercooler and the other facing the turbocharger – over the portion of each air discharge pipe extending out of the intercooler.
   c. Slide both air discharge pipes into the turbocharger discharge elbows, centering each between the turbocharger and respective intercooler as evidenced by the beads being visible at each side.
   d. Apply high–temperature anti–seize thread compound (GE Part 147X1640) to the three (3) bolts for each clamp ring. Using flat washers, install all clamp ring bolts finger–tight. Then torque all twelve (12) bolts to 30 to 35 lb.–ft. (41 to 47 Nm).
   e. Apply high–temperature anti–seize thread compound to the end of two (2) studs. Ensure the use of the latest stud design; look for “8” marked on the end of the stud. Assemble two (2) nuts onto each stud, with flat washers on the outboard side of each nut. Install one (1) stud in each intercooler in line with the turbocharger flange cutout, and run one (1) nut and washer each up against the intercooler and the turbocharger flange until they are snug. Torque the nuts at the intercooler to 55 to 60 lb.–ft. (75 to 81 Nm).
   f. Install a flat washer and nut on the outer end of each stud, and run these washers and nuts up against the turbocharger flange. Using two (2) wrenches, simultaneously tighten the two (2) nuts on each stud uniformly against the sides of the turbocharger flange in a locking fashion. Then advance the torque on the nut on the outside of each flange to 55 to 60 lb.–ft. (75 to 81 Nm), holding the nut on the inside of the flange with the wrench to keep the stud from turning.
9. Connect the exhaust manifold to the turbine inlet assembly.
   a. Ensure all manifold to turbocharger bolt threads are clean. If necessary, wire brush all bolt threads and re–tap all threaded holes. Apply high–temperature anti–seize thread compound to all threads of bolts and tapped holes and to the washer face of bolt heads.
   b. Install a new gasket in the turbine inlet flange groove.
   c. Ensure the dual–pipe exhaust manifold gasket is properly positioned between the transition section and the turbocharger turbine inlet flange. Attach the transition section to the turbine inlet flange using long bolts and spacers, torquing the bolts to 70 to 75 lb.–ft. (95 to 102 Nm).
10. Using new gaskets, assemble the two (2) compression couplings to the water discharge header (Figure 64).
11. Assemble the intercooler support bar (Figure 64).

12. Install the muffler or exhaust stack and secure with bolts and new lockwashers. Torque bolts to the torque specified in *Section 21., TORQUE VALUES,* of this publication.
13. Connect the crankcase breather pipe to the crankcase breather and to the muffler or stack, if used. Assemble and connect the aspirator hoses, if used.
14. Close the Engine Cab hatch over the turbocharger.
15. Fill the cooling water system with properly treated water (refer to **SMI–02003, ENGINE COOLING SYSTEM**).

18.3. CHECK TURBOCHARGER OPERATION

After the turbocharger replacement has been completed and the engine is running, listen near the turbocharger and the exhaust stack for unusual noises, such as parts rubbing.

If possible, load the engine. Enter the MONITOR mode of Level 2 on the DID or IFD in the Operating Cab. Specify Parameter 3001 (intake air manifold pressure) and observe that the turbocharger is functioning properly.

Check the turbocharger for water, lubricating oil, air and exhaust leaks, and correct any found.

19. INTERCOOLER

Special Tools Required:

Standard Tool Kit . . . . . Locally Purchased
Lifting Hoist . . . . . Locally Purchased
Flashlight . . . . . Locally Purchased
Air Compressor . . . . . Locally Purchased
Wax Crayon . . . . . Locally Purchased
Scale or Ruler . . . . . Locally Purchased

ECC

CAUTION: The left and right intercooler assemblies are Emission Critical Components (ECC). Do not replace it with a non–ECC part. Refer to the NOTICE at the beginning of this publication and consult the latest revision of the manufacturer's Parts Catalog to obtain the correct replacement part.

The diesel engine is equipped with two (2) intercoolers that alter the temperature of the air supplied to the cylinders. This air, heated by compression in the turbocharger, passes horizontally through the intercooler core. Heat is removed from the air and carried away by engine cooling water which flows through the tubes in the core in three (3) passes: up, down and up again. (At idle or at light loads in cold weather, the air may be warmed by heat transferred from the water.)

Intercooler assemblies are located between the Turbocharger Discharge and the first Air Manifold Body (Figure 65).

Figure 65. Intercooler Location.

19.1. INTERCOOLER INSPECTION

Each intercooler should be inspected periodically for dirt build–up in the air passages of the core. If allowed to accumulate in the intercoolers because of poor filter maintenance, the dirt will restrict air flow to the cylinders, resulting in high cylinder temperatures, a smoky exhaust and loss of horsepower.

To inspect the intercoolers, remove the air discharge fittings between the turbocharger and intercoolers, and observe the condition of the core fins through the inlet opening. A very light coating of oily dust is normal. Intercoolers also should be inspected for damage and degradation of the core. The core face at the air inlet is prone to separation and breakage of the aluminum fins. Intercoolers manufactured since late 1990 have built–in air baffles to protect this area of the core. Older intercoolers should be run to overhaul or until the damaged area of the core reaches 40 sq. in. (258 sq. mm) [approximately the area of the air inlet port]. Intercoolers exhibiting this much damage should be retrofitted with the baffled turbocharger air discharge elbow or replaced, as advanced fin separation can lead to an internal water leak and possible hydraulic lock, broken connecting rods and further damage.

For locomotives experiencing tube erosion, intercoolers may be retrofitted with the inlet water baffle now standard in production. These baffles – which may have to be ground to fit – can be ordered through GE Renewal Parts.

19.2. INTERCOOLER CLEANING

The preferred method of cleaning intercoolers is to remove the top and bottom headers. Upon removing the lower header, inspect the tube inlets to the first water pass for erosion. Erosion indications are pits on the inside of the tube and tube recession from the gasket surface. If any tube end has receded more than 0.13 in. (3.3 mm) from the gasket surface, or has individual pits deeper than 0.025 in. (0.64 mm) [half of the wall thickness], the intercooler should be replaced.

CAUTION: The intercooler core fins are aluminum; therefore, do NOT subject the cores to cleaning agents which are harmful to aluminum.

Completely immerse the case and core in a tank containing an appropriate agitated cleaning solution, followed by a thorough rinse of the case and core with clean water. Tubes should be cleaned by running a wire brush through each tube to remove water treatment build–up. Refer to *Section 23., SPECIAL COMPOUNDS REQUIRED,* of this publication for recommended cleaning compounds. Intercooler lower headers should be inspected for cracks around the bolt flange and between the water inlet and outlet ports. Cracked headers should not be reused.

Intercooler cases with cracked welds should be unit–exchanged for repair, as field re–welds rarely last long, and can lead to tubes loosening in the case and subsequent internal water leaks.

Intercooler upper headers with the 2.0 in. (51 mm) water outlet hole should be bushed with the 1.5 in. (38 mm) inside–diameter orifice washer to reduce the opening to the current standard.

Before the top and bottom headers are re–applied, the intercooler core should be tested for leaks in the core tubes. Construct and apply gasketed blanking plates over the air openings with one (1) plate adapted for an air hose connection. With the intercooler case completely immersed in clean water, apply regulated air pressure of 30 psi (207 kPa) maxi–mum to the core. Inspect the case and tubes for leaks as indicated by air bubbles. For later repair, mark the location of leaks using a wax crayon.

Leaks in the intercooler core tubes may be repaired by plugging both ends of the leaking tubes with solder or by drilling out the tube and applying a pipe plug. If leaks develop in more than ten (10) percent of the tubes in any one of the three (3) sections determined by the water flow path, renew the intercooler.

19.3. REMOVE/INSTALL INTERCOOLER

ECC

CAUTION: The left and right intercooler assemblies are Emission Critical Components (ECC). Do not replace it with a non–ECC part. Refer to the NOTICE at the beginning of this publication and consult the latest revision of the manufacturer's Parts Catalog to obtain the correct replacement part.

Several steps are necessary in the removal of the intercoolers. Refer to Figures 66 and 67 for reference regarding part locations.

To remove intercoolers from the locomotive, follow the steps described below.

1. Remove water pipes and coalescer bracket from intercoolers.
2. Detach fuel lines from cast outlets.
3. Remove Inlet Manifold Air Bodies from 1L and1R cylinders.
4. Remove Right and Left intercoolers from engine.
5. Check interior of new intercoolers for freedom from foreign material and damage.

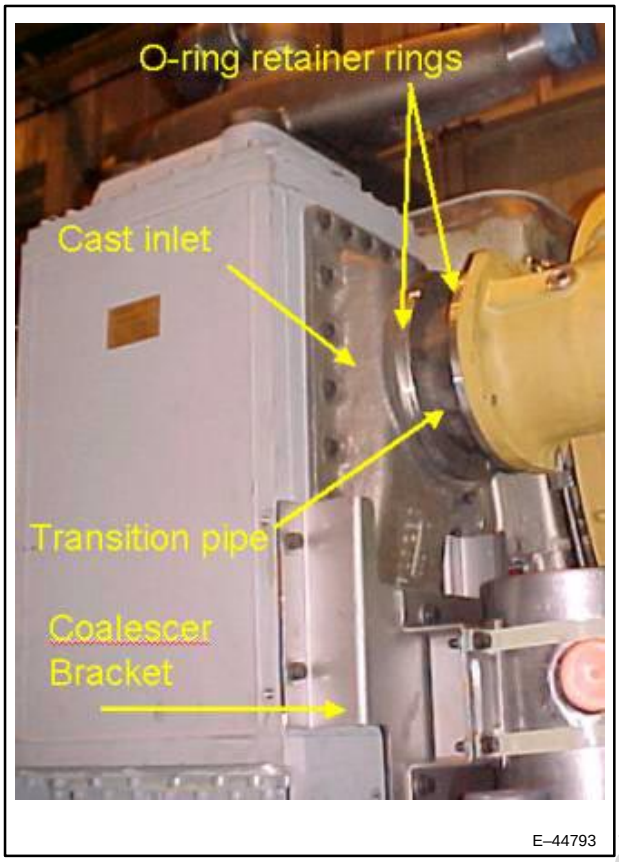


Figure 66. Parts Location. Right Intercooler, Front End.

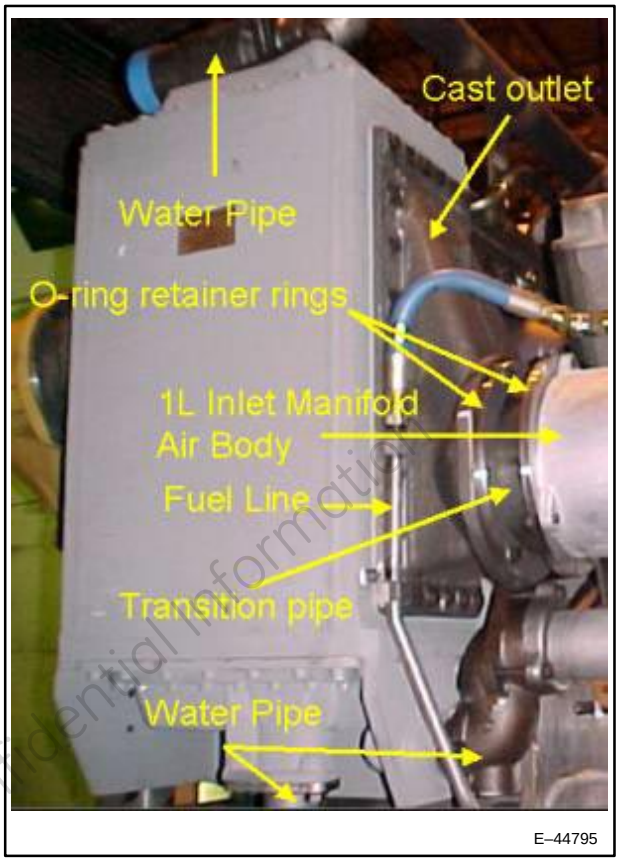


Figure 67. Parts Location. Left Intercooler, Rear End.

6. Apply cast inlet and outlet sections to left and right intercoolers with new gaskets (Figure 66). Torque to 55 to 60 lb.–ft.
7. Re–apply Inlet Manifold Air Bodies to 1L and 1R cylinders.
8. Using a scale, measure and mark a line on the center of the length of the air can (Figure 68).
9. Insert transition pipes into intercooler inlets and into inlet manifold air bodies on 1R and 1L cylinders before setting intercoolers in place.
10. Check area where intercooler mounts to free end cover for cleanliness. Be sure O–rings are in place.
11. Re–apply intercoolers to engine with O–ring retainers. The P3 retainers are applied on the aft flange of the intercooler outlet with the flats aligned. Torque mounting bolts to 105–115 lb.–ft.
12. Center the transition pipes and torque the retainer ring bolts to 55 to 60 lb.–ft.
13. Reattach fuel lines to cast outlets.
14. Re–apply water pipes and coalescer (Figure 69).

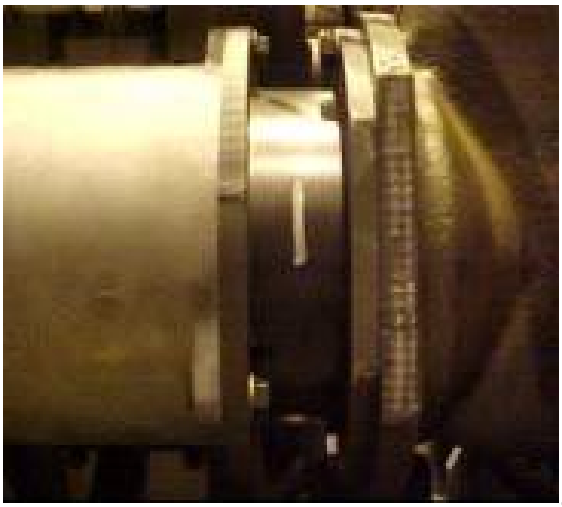


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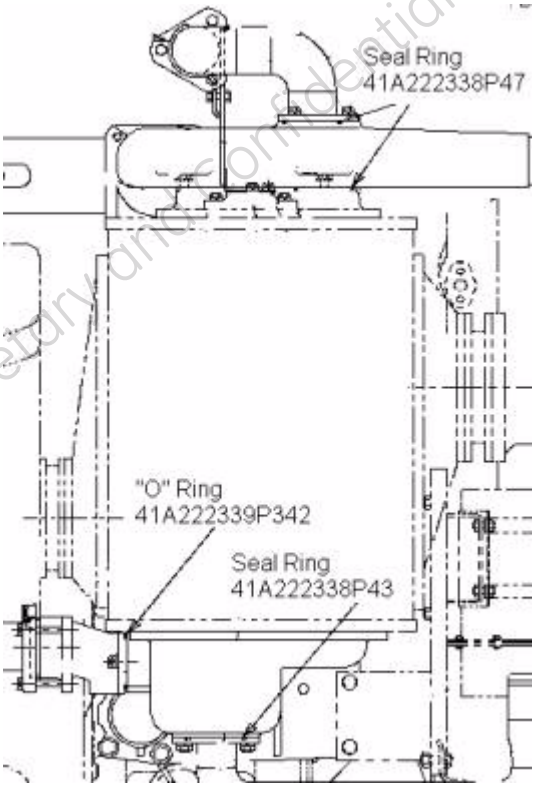
Figure 68. Installation of Air Can.



E–44799

Figure 69. Intercooler Water Connections.

20. SPECIAL TOOLS

Description:	Part Number (if applicable)
POWER ASSEMBLY	
Air Motor Support Bracket	TESCO
Basic Standard Tool Kit	Locally Purchased
Cylinder Head Lifting Device	GE 147–1606–1
Guide Pins	GE 147X1367
Impact Wrench	GE 147X1684–2
Lubriplate® Spray Lube A	GE 147X1614
Lubriplate® 630–AA	GE 147X2163
Piston Protector	GE 147X1951
Piston Retainer	GE 147X1406–2
Piston Ring Compressor	GE 147X1089–1
Piston Support Bar	GE 147X1090
Pneutorque Wrench	GE 147X1568–1
Rocker Arm Depressor	GE 147X1040–1
Rod Shank Pad	GE 147X1828
Torque Multiplier	GE 147X2360
EXHAUST MANIFOLD	
Fel–Pro C–5A	GE147X1640
Torque Wrench	Locally Purchased
CYLINDER HEAD	
Air–Operated Wrench	GE 147X2204
Barring Over Device	TESCO T58440
Basic Standard Tool Kit	Locally Purchased
Cylinder Head Lifting Device	TESCO T85320
HOTSY Cleaner Kit	GE 147X2332
1.0 in. Drive Ratchet Wrench	GE 147X1982
PISTON AND PISTON RINGS	
Barring Device	TESCO T58440
Brass or Hardwood Driver	Locally Purchased
Guide Pin	GE 147X1326
MOLYKOTE® G–n	GE 147X1143
Piston Pin Bolt Socket	GE 147X1511
Piston Pin Bolt Wrench	GE 147X1841–1
Piston Lifter	TESCO
Piston Protector	GE 147X1951
Piston Ring Groove Scraper	GE 147X1098
Piston Ring Expander	GE 147X1099–2
Piston Support Bar	GE 147X1090
Torque Wrench	Locally Purchased
0.75 in. Drive Ratchet	GE 147X1866

Description:	Part Number (if applicable)
CONNECTING ROD AND CONNECTING ROD BEARINGS	
Articulated Rod Guide Pin Bolt	GE 147X1122
Articulated Rod Pin Bolt Wrench	GE 147X1458–2
Articulated Rod Pin Retainer	GE 147X1474
Barring Over Device	TESCO T58440
Bearing Retainers	GE 147–1492–1
Connecting Rod Holding Fixture	GE 147X1651
Crankshaft Journal Protective Pad	GE 147X1827
MOLYKOTE® G–n	GE 147X1143–1
Piston Pin Bolt Wrench	GE 147X1841–1
Piston Retainer	GE 147X1406–2
0.75 in. Drive Ratchet Wrench	GE 147X1866
1.13 in. Socket	GE 147X1866
FUEL–OIL INJECTION PUMP	
Air–Operated Wrench	GE147X2204
Barring Over Device	TESCO T58440
Flexible Hose Banjo Fitting and High–Pressure Fuel–Oil Pump/Injector Line Wrench	GE 147X1595–1
Fuel–Oil Injection Pump Wrench	GE 147X2460
Lubriplate® Spray Lube A	GE 147X1614
Pump Gage Block	GE 41A222587 or TESCO T55970
Tappet Nut Torque Wrench	TESCO T56050
Torque Wrench	Locally Purchased
1.0–in. Drive Ratchet	GE 147X1982
12–Point Socket Head, 1/2–13 x 1.875 in. Bolts	GE 115x2530–1
FUEL–OIL INJECTION NOZZLE	
Flexible Hose Banjo Fitting and High–Pressure Fuel–Oil Pump/Injector Line Wrench	GE 147X1595–1
Fuel–Oil Injection Pump Wrench	GE 147X2460
Lubriplate® Spray Lube A	GE 147X1614
Nozzle Knocker	GE 147X1856
Portable Power Drill	Locally Purchased
Stud Installation Tool	SnapOn K2352
1.0 in. (25.4 mm) Diameter Cup Wire Brush	[0.020 in. (0.51 mm) diameter wire] on a 15.0 in. (380 mm) Extension
CRANKSHAFT MAIN BEARINGS	
Barring Over Device	TESCO T58440
Brass Drift	Locally Purchased
Hydraulic Frame Spreader	GE 147X1742
Lead Hammer	Locally Purchased
Lubriplate® Spray Lube A	GE 147X1614
Main Bearing Insert Tool	GE 147X1342
MOLYKOTE® G–n	GE 147X1143–1
Stretch Gage	GE 147X2309–1
Torque Wrench	Locally Purchased

Description:	Part Number (if applicable)
CRANKSHAFT THRUST BEARING COLLARS	
Magnetic Base Dial Indicator (or equivalent)	GE 147X1229
Pry Bar	Locally Purchased
Standard Tools	Locally Purchased
PUMP DRIVE GEAR COUPLING AND GEAR TRAIN	
Barring Over Device	TESCO T58440
Flashlight	Locally Purchased
Mirror	Locally Purchased
Pry Bar	Locally Purchased
ENGINE ALTERNATOR ALIGNMENT	
Air Wrench: 90°	GE 147X2204
Alignment Dowels (qty 3)	GE 41A286801P1
Coupling Bolt Breaker Bar	
Deflection Gage (must have 0.0001 in. graduations)	GE 41D797425P2
Heavy Socket: 2.5 in	
Hex Sockets: 3/4 in, 1 3/8 in, 2 in, M12	
Hydraulic Jack	TESCO T80860
Impact Wrench: 1 in. drive	
Shim Packs	GE 41B513208
Torque Wrench: 60 Nm (44 lb.–ft.), 498 Nm (367 lb.–ft.), 916 Nm (675 lb.–ft.), 2169 Nm (1600 lb.–ft.)	
Level Bubble Protractor	Locally Purchased
Barring Over Device	T58440
CAMSHAFT	
Bearing Press and Removal Tool	TESCO T55960
Camshaft Bolt Torque Wrench	TESCO T54440
Camshaft Section Lifter	TESCO T55991
Crosshead Lifter	GE 147X2397
Fuel Roller Retaining Plate	TESCO T57150
MOLYKOTE® G–n	GE 147X1143–1
Pry Bar	Locally Purchased
Rocker Arm Depressor	GE 147X1040–1
CROSSHEADS AND GUIDES	
Crosshead Lifter	GE 147X2397
Fuel Roller Retaining Plate	TESCO T57150
WATER PUMP	
Lifting Hoist	Locally Purchased
LUBRICATING–OIL PUMP	
Lifting Hoist	Locally Purchased

Description:	Part Number (if applicable)
TURBOCHARGER	
Crane	Locally Purchased
High–Temperature Anti–Seize Thread Compound	GE 147X1640
High–Temperature FS1292 Grease	GE 147X2428
Lifting Sling (Alternate to Turbocharger Lifter)	Locally Purchased
Lubriplate® Spray Lube “A”	GE147X1614
Turbocharger Lifter	GE 147X1916–2
Turbocharger Mounting Bolt Adapter	GE 147X2350
Viton O–rings	GE 115X1902–2
19 in. Torque Wrench	GE 147X2252
INTERCOOLER	
Standard Tool Kit	Locally Purchased
Lifting Hoist	Locally Purchased
Flashlight	Locally Purchased
Air Compressor	Locally Purchased
Wax Crayon	Locally Purchased
Scale or Ruler	Locally Purchased

21. TORQUE VALUES

	lb.–ft.	Nm
Alternator Mounting Bolts:		
Alternator Frame To Engine Frame	625–675	847–915
Crankshaft To Alternator Rotor (With Hardened Washers)	1040–1160	1410–1573
Camshaft Bolts:		
Initial	50	68
Final	95	129
Cylinder Hold–Down Bolts	1300–1400	1763–1898
Engine and Alternator Assembly Mounting Bolts:		
Alternator End	600–650	813–881
Engine (Free) End	600	813
Exhaust Manifold V–Band Clamp	12–15	16–20
Fuel–Oil Injection Pump Mounting Bolts (EFI)	85–93	115–126
Fuel–Oil Injection Nozzle Studs (EFI)	55–65	75–88
Fuel–Oil Injection Nozzle Clamp Nuts (EFI)	40–45	54–61
Fuel–Oil Injection Pump Hoses	79–87	107–118
High–Pressure Fuel–Oil Line Nuts	145–150	197–203
Low–Pressure Fuel–Oil Line Hose To Header Block	70–75	95–102
Head Block To Fuel Pump (Banjo Bolts)	60–62	81–84
Lubricating Oil Pump Drive Gear Nut	375–400	508–542
Lubricating Oil Pump Mounting Bolts:		
Lubricated	70	94
Dry	90	122
Lubricating Oil Pump Tee Fittings	79–87	107–118
Main Bearing Cap Side Bolts:		
Initial	75	102
Final	365–375	495–508
Muffler Or Exhaust Stack Mounting Bolts	55–60	75–81
Piston Pin Bolts:		
Initial	400	542
Final	250	339
Pump Drive Gear Coupling Bolts	44–49	60–66
Pump Tappet Rod Umbrella Nut Against Adjusting Nut	195–205	264–278
Rod Cap Bolts	400–420	542–569
Rod Pin Bolts:		
Initial	450	610
Final	375	508
Solenoid Terminal Screws	9–11 lb.–in.	1.00–1.25
Turbocharger Mounting Bolts	400–450	542–610
Water Pump Drive Gear Nut	200–220	271–298

22. DATA

Crankshaft Web Deflection at No. 8 Crank Pin (16–cylinder engine) or In. mm
Crankshaft Web Deflection at No. 6 Crank Pin (12–cylinder engine) or
Crankshaft Web Deflection at No. 4 Crank Pin (8–cylinder engine):
Maximum Total Deflection Permissible at Realignment
(New or Used Equipment) . . . . . 0.0000 to 0.0005 in. (0.000 to 0.013 mm)
Condemning Limit for In Service Equipment
(If Greater, Equipment MUST BE Realigned) . . . . . 0.002 in. (0.05 mm)
Jack Bolt to Frame Clearance:
Each Side of Engine – Engine Cold . . . . . 0.010 in. (0.25 mm)
Readjust after Engine is at Maximum Operating Temperature . . . . . 0.000in. (0.00 mm)

23. SPECIAL COMPOUNDS REQUIRED

(Non–caustic cleaning compounds recommended for aluminum and galvanized steel – use according to directions supplied by the manufacturer of the cleaning compound.)

Manufacturer . . . . . Product
Oakite Products, Inc. . . . . Oakite Composition No 111
Pennsalt Chemicals Corp. . . . . Pennsalt Delchem Super CR, Pennsalt Cleaner 44
Magnus Chemical Co., Inc. . . . . Magnusol
Turco Products, Inc. . . . . Turco Mulsirex

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