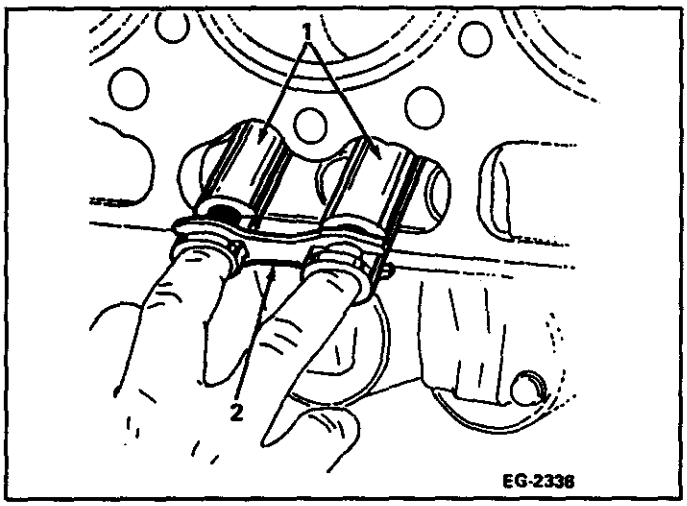
8.4 CAMSHAFT, TAPPETS AND PUSH RODS



1. Roller Tappets
2. Roller Tappet Guide

FIGURE 8–16

NOTE:

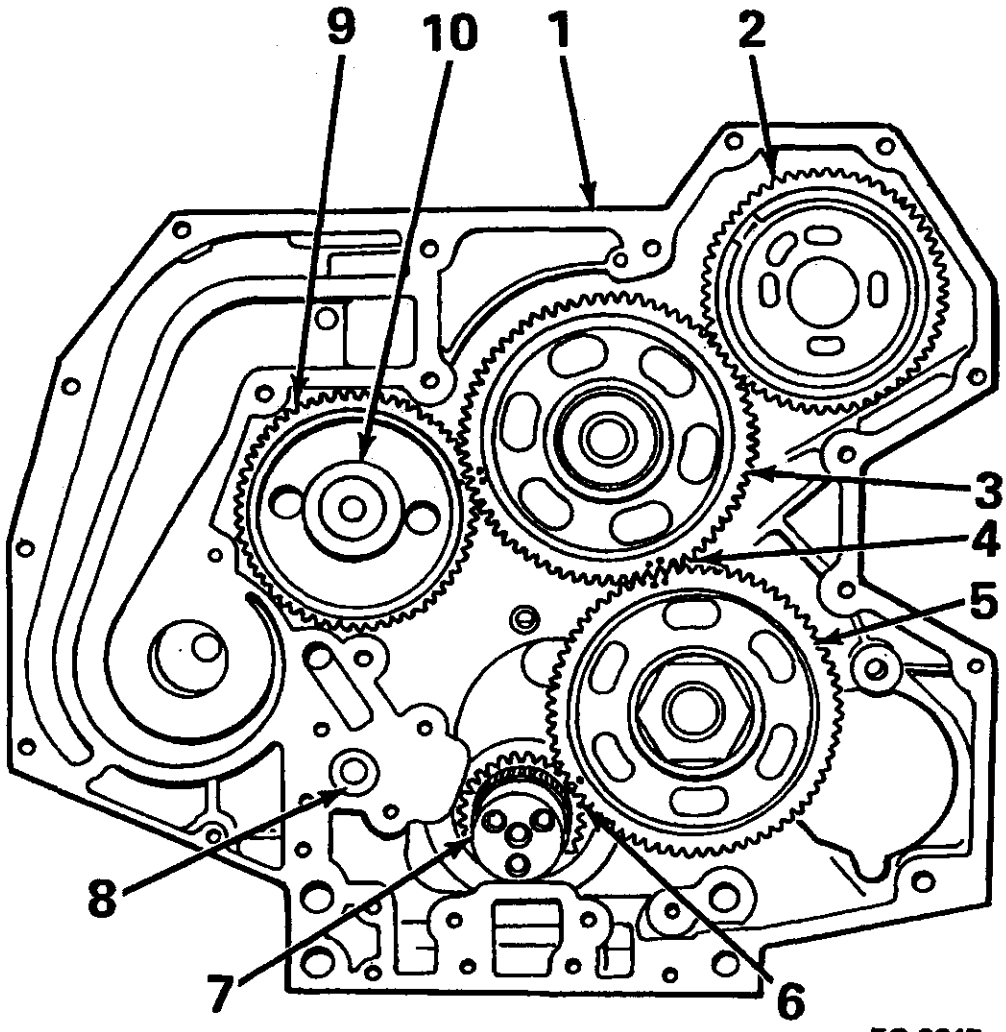
Refer to the appropriate manual sections for removal instructions for fuel, turbocharger, cylinder head and front cover items.

1. Remove roller tappets and roller tappet guides from their bores. Refer to FIGURE 8–16.

NOTE:

Mark the tappets as to location in the engine block, so they can be returned to their original position.

CAMSHAFT, TAPPETS AND PUSH RODS

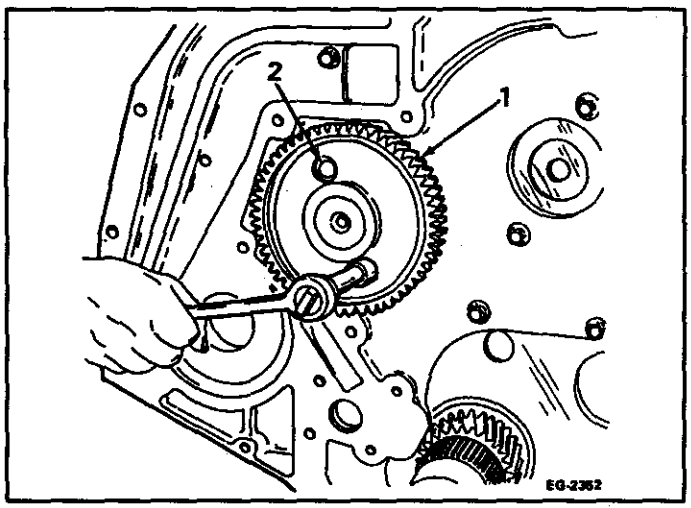


1. Rear Half Front Cover
2. Fuel Injection Pump Timing Gear
3. Upper Idler Gear
4. Upper Idler/Lower Idler Gear Timing Marks
5. Lower Idler Gear
6. Lower Idler Gear/Crankshaft Timing Marks
7. Crankshaft
8. Pressure Regulator Valve (80 lb/in.^{2})
9. Camshaft Gear
10. Camshaft

FIGURE 8–17 Align Gear Train Timing Marks

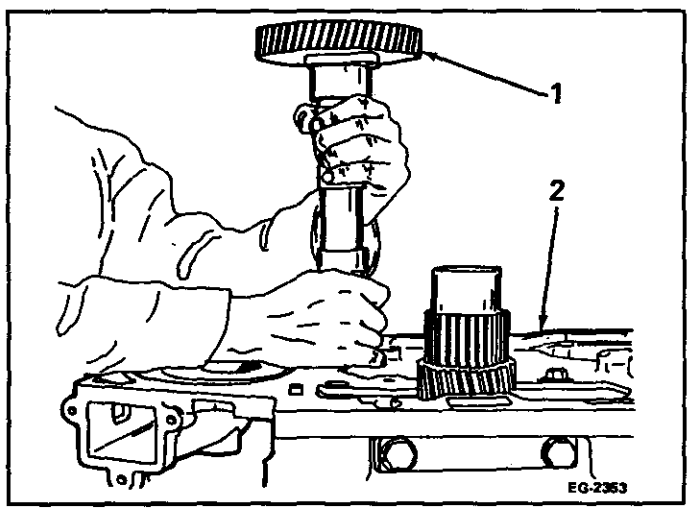
2. Refer to **FIGURE 8–17** for location of gears and timing marks.
3. Remove the fuel injection pump timing gear as outlined in Section 14 "Fuel Injection Pump."

CAMSHAFT, TAPPETS AND PUSH RODS



1. **Camshaft Gear**
2. **Access Hole/bolt**

FIGURE 8–18



1. **Camshaft Assembly**
2. **Crankcase**

FIGURE 8–19

4. Rotate the engine so that timing marks on lower and upper idler gears, crankshaft and camshaft gear are aligned.

NOTICE: **Prior to removing any gear, mount a magnetic base dial indicator onto the engine and check for gear backlash and end play. Refer to Section 11, "Timing Gear Train And Front Cover" for instructions.**

5. Remove idler gears as described in Section 11, "Timing Gear Train and Front Cover."

NOTE:

When the engine is mounted in a turn–over stand, rotate engine so front of engine is facing up (engine in vertical position). This position allows for easy removal of camshaft assembly.

6. Rotate the camshaft gear so the access holes in the gear align with the thrust plate retaining bolts.

7. Remove the two thrust plate bolts and washers. Refer to **FIGURE 8–18.**

8. Remove the camshaft from the crankcase by lifting the assembly straight up. Refer to **FIGURE 8–19.**

NOTE:

This method reduces the risk of damaging the camshaft journals and/or bushings.

CAMSHAFT, TAPPETS AND PUSH RODS

8.4.1 Camshaft Disassembly

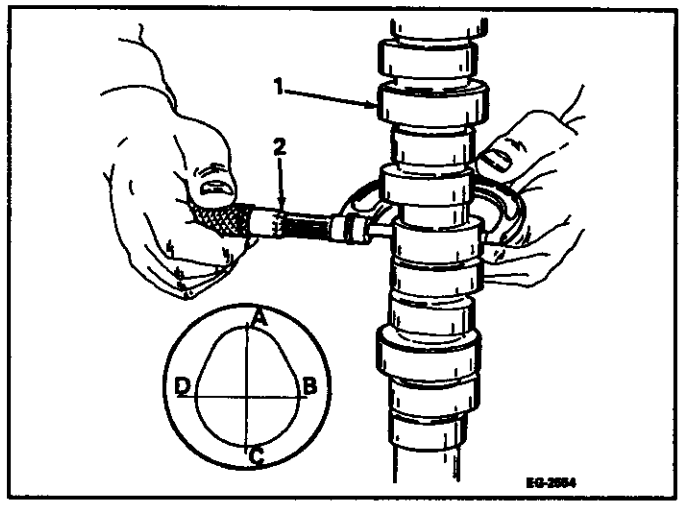
NOTE:
The camshaft gear is a shrink fit and must be pressed off.

1. Using a suitable arbor press, press camshaft from the gear.
2. With gear removed, remove woodruff key and the thrust plate.

8.4.2 Camshaft Cleaning and Inspection

1. Wash the camshaft in a suitable solvent using a soft bristle brush.
2. Visually inspect camshaft. If any lobes are scuffed, scored or cracked, replace camshaft.
3. Evaluate camshaft journal and lobe condition using a micrometer. Refer to **FIGURE 8–20**. To check camshaft lobe wear using a micrometer:
   a. Measure across (A–C) and across (B–D).
   b. Subtract (B–D) from (A–C). This will give cam lobe lift. (See "Specifications".) Replace camshaft when cam lobe wear exceeds specifications.
4. Visually inspect thrust plate for wear, cracks or distortion. Use a micrometer to measure thrust plate thickness (see "Specifications"). Replace thrust plate if worn, damaged or if excessive end play is measured.
5. Visually inspect camshaft gear for worn or damaged teeth and gear bore for damage. Replace gear if any of these conditions exist. Repeat for each cam lobe.

NOTE:
If camshaft gear backlash exceeds specifications, replace the gear.



1. **Camshaft Lobe**
2. **Micrometer**

FIGURE 8–20

CAMSHAFT, TAPPETS AND PUSH RODS

8.4.3 Camshaft Reassembly

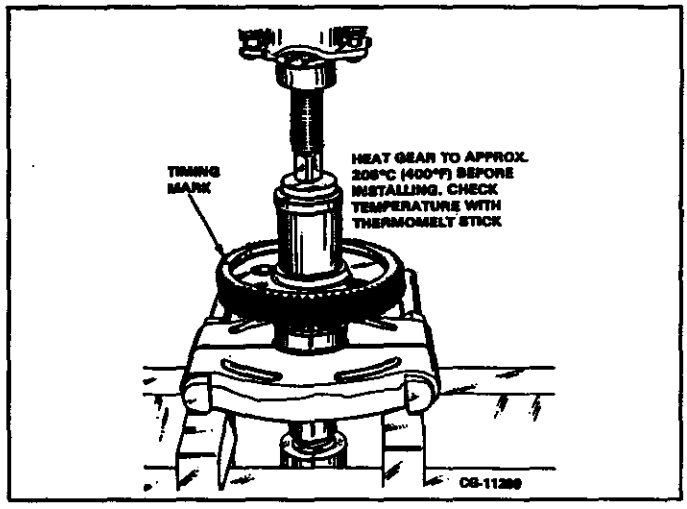


FIGURE 8–21

CAUTION

Use protective gloves when installing gear.

Reassemble the camshaft, thrust plate and camshaft gear as follows:

1. Support the camshaft in an appropriate arbor press.
2. Place the thrust plate on the keyway end of the camshaft against the bearing journal.
3. Insert the woodruff key into the keyway.
4. Heat the camshaft gear in an oven, to approximately 400 F (206°C).

NOTE:

Use a thermomelt stick, available at any welding supply house, to determine temperature.

5. Press gear against shoulder on camshaft with timing mark pointed outward as shown in **FIGURE 8–21.**

CAMSHAFT, TAPPETS AND PUSH RODS

8.4.4 Camshaft Bushing Inspection

Inspect the four camshaft bushings for wear and proper running clearance as follows:

1. Measure camshaft bushing journal diameter using a micrometer. Measure at two locations (at 90°) and record the readings.
2. Using a telescoping gauge and micrometer, measure the camshaft bushing I.D. with bushing installed in the crankcase). Record the readings.
3. Subtract the readings obtained in steps 1 and 2, to determine running clearance.
4. If maximum allowable running clearance is exceeded (see "Specifications"), replace the camshaft bushings using the camshaft bushing remover and installer (J39537).

NOTICE: **When servicing the camshaft bushings, the crankshaft and main bearing must be removed from the crankcase to avoid debris contamination.**

CAMSHAFT, TAPPETS AND PUSH RODS

8.4.5 Camshaft Bushing Removal

1. Use the camshaft bushing service set (J39537) to remove the camshaft bushings. J39537 includes:
   - ❑ Puller screw
   - ❑ Expanding mandrel
   - ❑ Puller screw extension
   - ❑ Expanding collet
   - ❑ Pulling nut
   - ❑ Back–up nut
   - ❑ Thrust bearing

Refer to **FIGURE 8–22.**

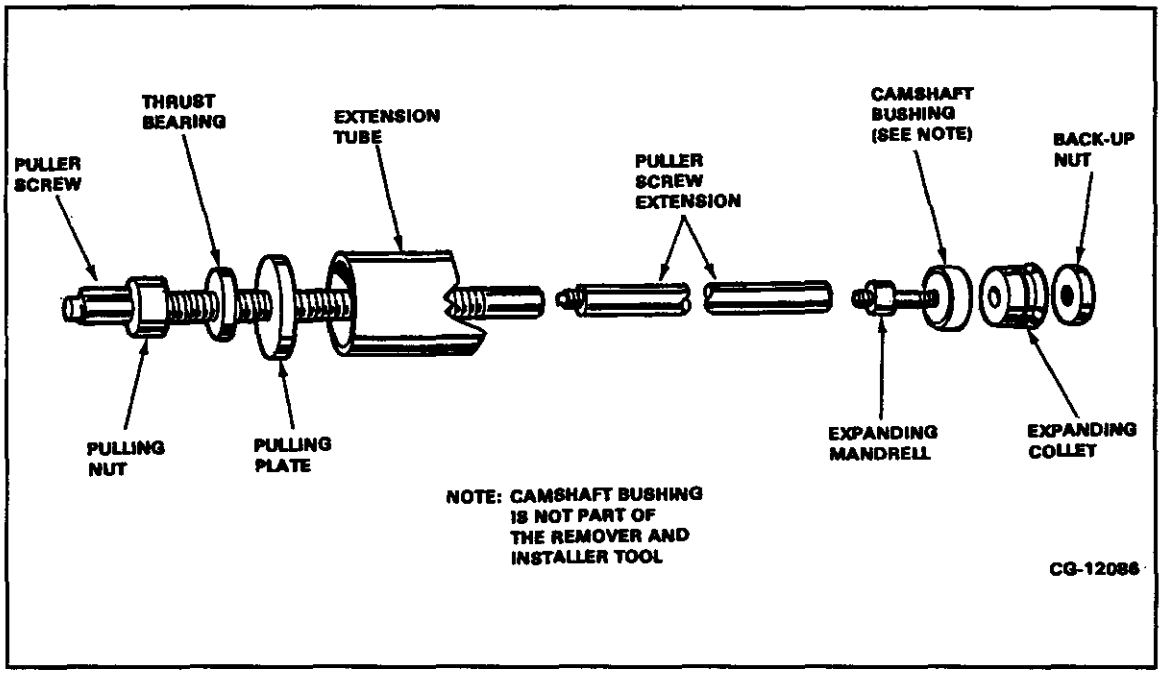


FIGURE 8–22

CAMSHAFT, TAPPETS AND PUSH RODS

NOTE:

The four camshaft bushings have the same inside diameter, but the outside diameter and widths of each bushing are different, as is the crankcase bore into which each bushing fits. Refer to the chart below.

NOTICE: **Because of the different size outside diameters of the bushings, the order of removal is limited as follows: remove the front and rear bushings first. Then remove the two inter– mediate bushings through the front of the crankcase.**

Camshaft Bushing Chart

BUSHING POSITION	BUSHING O.D.	DIA. IN CRANKCASE	BUSHING BORE BUSHING WIDTH
	2.5065 in.	2.5020 in.	
Front	2.5050 in.	2.5005 in.	1.00 in.
Intermediate/	2.4865 in.	2.4820 in.	0.709 in.
Front	2.4850 in.	2.4805 in.	0.689 in.
Intermediate/	2.4665 in.	2.4620 in.	0.709 in.
Rear	2.4650 in.	2.4605 in.	0.689 in.
	2.4465 in.	2.4420 in.	0.740 in.
Rear	2.4450 in.	2.4405 in.	0.660 in.

CAMSHAFT, TAPPETS AND PUSH RODS

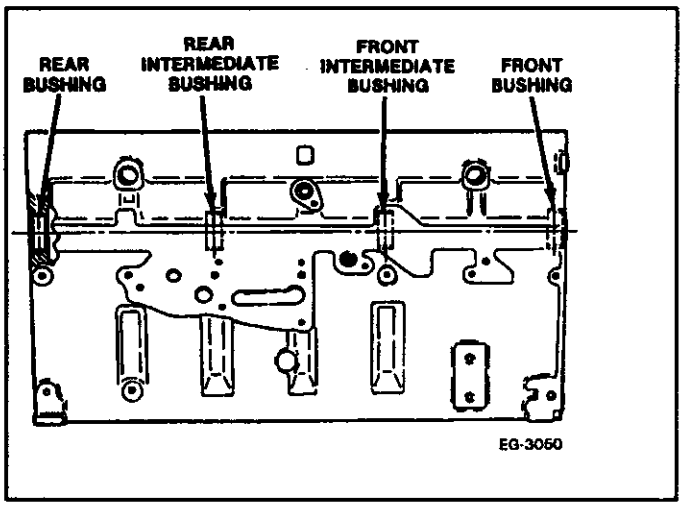


FIGURE 8–23

2. Using the camshaft bushing remover and installer tool (**J39537**), select the proper size expanding collet and back–up nut and assemble onto the expanding mandrel. With the expanding collet collapsed, install the collet assembly into the camshaft bushing to be removed and tighten the back–up nut onto the expanding mandrel until the collet fits the camshaft housing. Refer to **FIGURE 8–22 and FIGURE 8–23.**
3. Assemble the puller screw and extension, if necessary, and install onto the expanding mandrel. Tighten the pulling nut against the thrust bearing and pulling plate to remove the camshaft bushing.

NOTE:

Be sure to hold the end of the puller screw with a wrench to prevent it from turning, when tightening the pulling nut.

4. Repeat the procedure for each bushing.

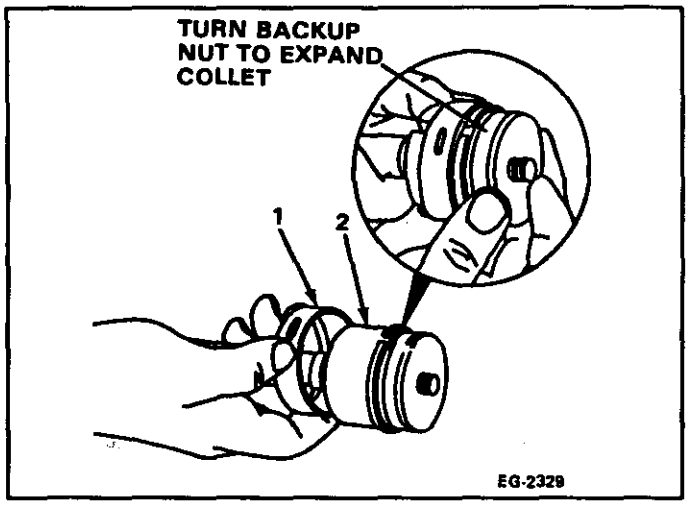
NOTE:

To remove the front bushing, install the puller screw from the rear of the crankcase. All other bushings are removed by going through the front of the crankcase.

8.4.6 Crankcase Bushing Bore Inspection

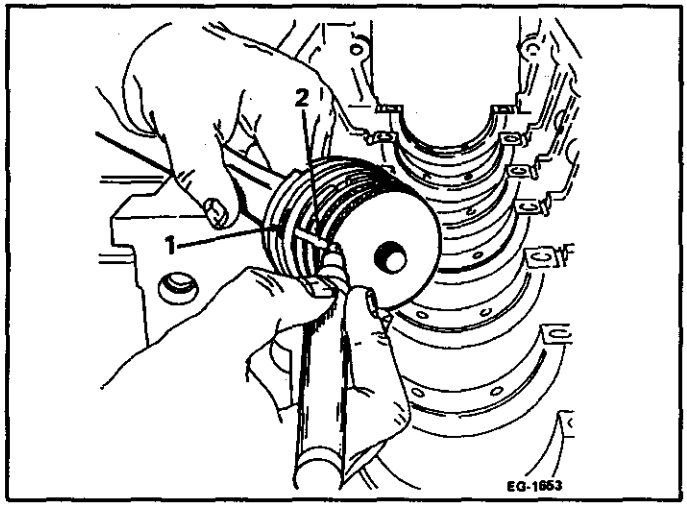
1. Visually inspect each bushing bore in the crankcase for burrs or debris that could damage new bushings when they are installed.
2. Remove any burrs and clean bores thoroughly before installing new camshaft bushings.

CAMSHAFT, TAPPETS AND PUSH RODS



1. **Bushing**
2. **Expanding Collet**

FIGURE 8–24



1. **Bushing Oil Hole**
2. **Alignment Mark**

FIGURE 8–25

8.4.7 Camshaft Bushing Installation

1. Identify each bushing by its outside diameter. Refer to the "Camshaft Bushing Chart."
2. Lubricate new camshaft bushings as well as crankcase bushing bore with clean engine oil.
3. Install new bushing onto expanding collet and tighten collet by turning backup nut until bushing is held securely. Refer to **FIGURE 8–24.**
4. Mark oil hole location on back–up nut of installation tool to aid in alignment of bushing and crankcase oil holes. Refer to **FIGURE 8–25.**

NOTE:
This step must be repeated for each bushing installed.

5. Install rear intermediate bushing through front of crankcase, then pull it into place at rear of crankcase by turning pulling nut on puller screw. Remove tool and inspect oil hole alignment.

NOTE:
The bushings must be installed in the proper order because of the different size outside diameters of the bushings.

CAMSHAFT, TAPPETS AND PUSH RODS

6. Install front intermediate bushing next. Install through front of crankcase and pull into place from rear. Refer to **FIGURE 8–26.**
7. Next install front camshaft bushing by pulling it into place from rear.
8. The rear camshaft bushing must be pulled into place from front of crankcase.

NOTICE: **All bushing oil holes must be in alignment with oil holes in crankcase.**

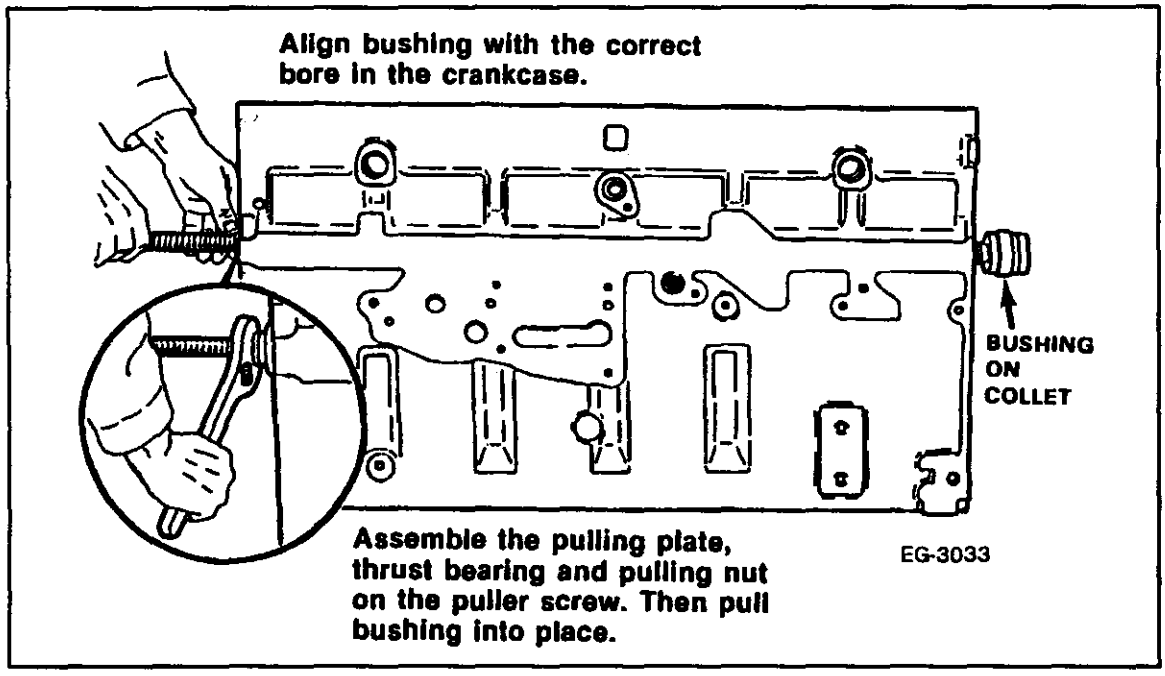


FIGURE 8–26

CAMSHAFT, TAPPETS AND PUSH RODS

8.4.8 Tappet Inspection

Visually inspect all roller tappets and rollers for pitting, roughness and free rotation of roller. Check dimensionally, if "Specifications" are exceeded replace the tappet.

8.4.9 Push Rod Cleaning And Inspection

1. Thoroughly clean each push rod using a suitable solvent and dry using filtered compressed air.
2. Visually inspect each rod for wear at ends. Replace as required.
3. Check all push rods for straightness by rolling on a flat surface, **FIGURE 8–27**. Replace any rod which is bent.
4. Check push rod run–out. If "Specifications" are exceeded, replace the rod.

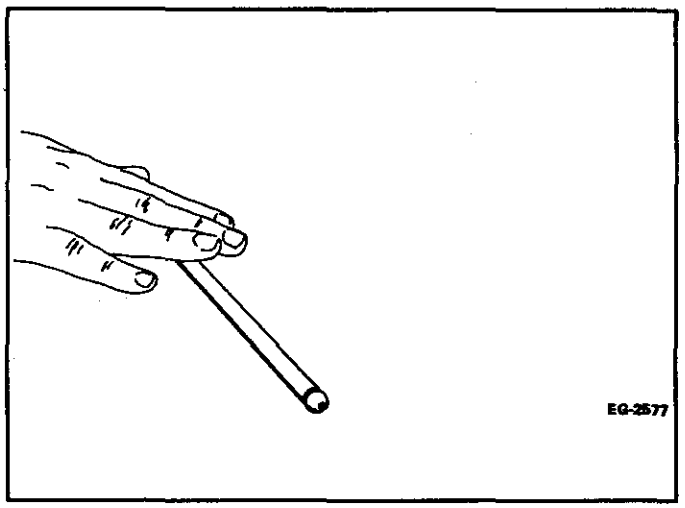


FIGURE 8–27

8.5 CAMSHAFT, TAPPET AND PUSH ROD ASSEMBLY AND INSTALLATION

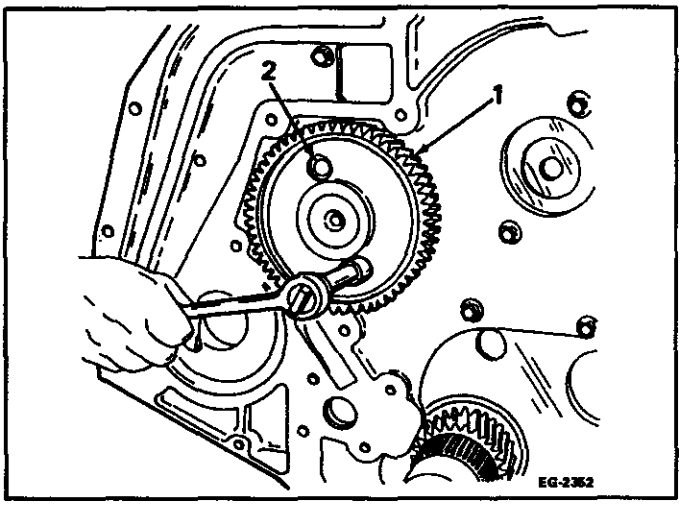


FIGURE 8–28

1. With the engine in the vertical position, lubricate the camshaft and the camshaft bushings using clean engine oil.
2. Gently slide camshaft assembly into crankcase. Be careful not to damage camshaft bushings.
3. Align camshaft gear so bolts can be inserted through gear access holes into thrust plate. Tighten each bolt to special torque value. Refer to **FIGURE 8–28.**
4. Install idler gears as described in Section 11 "Timing Gear Train and Front Cover."
5. Align gear train timing marks. Refer to **FIGURE 8–28.**
6. Check camshaft gear backlash and camshaft end play as described in Section 11 "Timing Gear Train and Front Cover". Specifications must be met.

8.5.1 Tappets

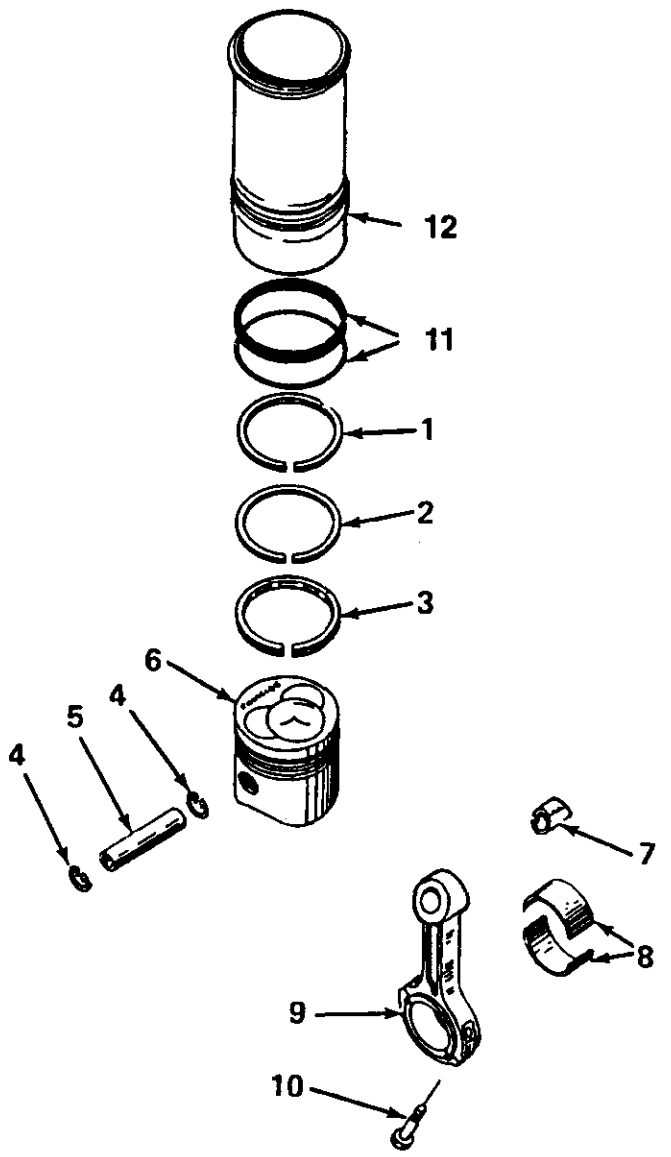
Install the roller tappets and guides into their original bores, unless new tappets are used.

8.5.2 Push Rods

Install push rods with the cup end up. Refer to Section 8.

9 CONNECTING RODS, PISTONS, RINGS AND SLEEVES

9.1 CONNECTING RODS, PISTONS, RINGS AND LINERS EXPLODED VIEW



1. Piston Ring (Top Compression) (6)
2. Piston Ring (Intermediate Compression) (6)
3. Piston ring (Oil Regulating) (6)
4. Piston Pin Retainer (12)
5. Piston Pin (6)
6. Piston (6)
7. Piston Pin Bushing (6)
8. Connecting Rod Bearing (6)
9. Connecting Rod And Cap (6)
10. Bolt (12)
11. Sleeve Seals
12. Sleeve (6)

FIGURE 9–1 Connecting Rods, Pistons, Rings and Sleeves.

9.2 SPECIFICATIONS

DIMENSION	VALUES
CONNECTING RODS:	
Center–to–Center Distance between Connecting Rod Bearing Bore and Piston Pin Bushing	8.638 in. (219.4 mm)/ 8.642 in. (219.5 mm)
Bushing Bore Diameter (Pin End)	1.9235 in. (48.8 mm)/ 1.9255 in. (48.9 mm)
Piston Pin Bushing I.D. (Installed)	1.8257 in. (46.3 mm)/ 1.8260 in. (46.3 mm)
Bearing Bore Diameter (Crankshaft End)	3.3516 in. (85 mm)
Maximum Out–of–Round	0.002 in. (0.05 mm)
Maximum Taper/Inch	0.005 in. (0.013mm)
Connecting Rod Bearing I.D. (Installed)	3.1533 in. (80.094 mm)/ 3.1535 in. (80.099 mm)
Bearing Running Clearance	0.0018 in. (0.046 mm)/ 0.0050 in. (0.127 mm)
Maximum Permissible Bearing Running Clearance (Before Reconditioning)	0.007 in. (0.18 mm)
Connecting Rod Side Clearance on Crankshaft	0.012 in. (0.30 mm)
Maximum Permissible Side Clearance on Crankshaft	0.0165 in. (0.425 mm)
Connecting Rod Alignment	
Twist	0.002 in. (.051 mm)
Bend	0.0015 in. (0.42 mm)
PISTONS:	
Running Clearance between Piston and Cylinder Liner(6.7L & 7.6L)	0.0025 in. (0.064 mm)/ 0.0045 in. (0.081 mm)
(Measured 90° from pin bore and Skirt Diameter 3.174 in. (80.6mm) below bottom ring land) (6.7L)	4.297 in. (109.14 mm)/ 4.298 in. (109.17 mm)
(Measured 90° from pin bore and Skirt Diameter 3.271 in. (83mm) below bottom ring land) (7.6L)	4.297 in. (109.14 mm)/ 4.298 in. (109.17 mm)
Number of Rings per Piston	3

SPECIFICATIONS

DIMENSION	VALUES
Piston Ring Groove Widths:	
Top Compression Ring – Measure over 0.1150 in. gauge pins (6.7L & 7.6L)	4.3118 in. (110 mm)
Top Compression Ring – Measure over 0.1150 in. gauge pins (8.7L)	4.5015 in. (114 mm)
(Full Keystone) (6.7L & 7.6L)	4.2794 in. (109 mm)
(Full Keystone) (8.7L)	4.4676 in. (113 mm)
Intermediate Compression Ring –	
Measured over 0.1150 in. gauge pins (6.7L & 7.6L)	4.3168 in. (110 mm)
Measured over 0.1150 in. gauge pins (8.7L)	4.6050 in. (118 mm)
(Full Keystone) (6.7L & 7.6L)	4.2844 in. (109 mm)
(Full Keystone) (8.7L)	4.5712 in. (116 mm)
Side Clearance:	
Oil Control Ring	0.002 in. (0.0508 mm)/ 0.0040 in. (0.1016 mm)
PISTON RINGS – COMPRESSION:	
Number of rings per piston	2
Type (face and finish):	
Top Ring	Full Keystone (barrel faced) – Plasma Coated
Intermediate Ring	Full Keystone (taper crown) – Chromeless
Ring Gap with New Liner:	
Top Ring	0.014 in. (0.040 mm)/ 0.026 in. (0.066 mm)
Intermediate Ring	0.065 in. (1.65 mm)/ 0.075 in. (1.91 mm)
PISTON RINGS – OIL CONTROL:	
Number of Rings Per Piston	1
Type	One Piece Slotted – Chrome
Ring Gap (6.7L & 7.6L)	0.012 in. (0.305 mm)/ 0.022 in. (0.559 mm)
Ring Gap (8.7L)	0.014 in. (0.356 mm)/ 0.026 in. (0.660 mm)

SPECIFICATIONS

DIMENSION	VALUES
PISTON PINS:	
Diameter	1.8249 in. (46.3 mm)/ 1.8251 in. (46.3 mm)
Length	3.480 in. (88.4 mm)/ 3.490 in. (88.6 mm)
Clearance in Rod	0.0006 in. (0.015 mm)/ 0.0011 in. (0.028 mm)
Maximum Permissible Clearance in Rod, before replacing	0.003 in. (0.08 mm)
CYLINDER LINERS:	
Clearance in Piston	0.0006 in. (0.015 mm/ 0.0011 in. (0.028 mm)
Maximum Permissible Clearance in Piston, before replacing	0.003 in. (0.08 mm)
Inside Diameter (New)	4.3005 in. (109.233 mm)/ 4.3015 in. (109.258 mm)
Maximum Permissible Diameter Liner Wear, at Top of Ring Travel before Replacement (liner Taper)	0.004 in. (0.10 mm)/0.350 in. (8.89 mm)
Inside Diameter (New)	4.5895 in. (116.6 mm)/ 4.5905 in. (114.5 mm)
Counterbore Dimension in Crankcase	0.348 in. (8.84 mm)
Maximum Allowable Variation of Counterbore Depth (Between Four Points)	0.001 in. (0.025 mm)
Maximum Cylinder Liner Counterbore Allowable Depth (used with shim kit)	0.353 in. (8.97 mm)/0.413 in. (10.49 mm)
Flange Thickness	0.005 in. (0.13 mm)/ 0.0352 in. (0.894 mm)
Protrusion above Crankcase	0.002 in. (0.05 mm)

9.2.1 Special Torque Values

Connecting Rod Bolts	115 lb·ft (156 N·m)

SPECIFICATIONS

9.2.2 Special Tools

Tool No.	Description
PT2200–55	Counter Bore Tool
PT2250A	Counter Bore Cutter Head
PT6410	Cylinder liner Puller
J29511	Piston Groove Wear Measuring Tool
J41166	Piston Ring Compressor (8.7L)

9.3 CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

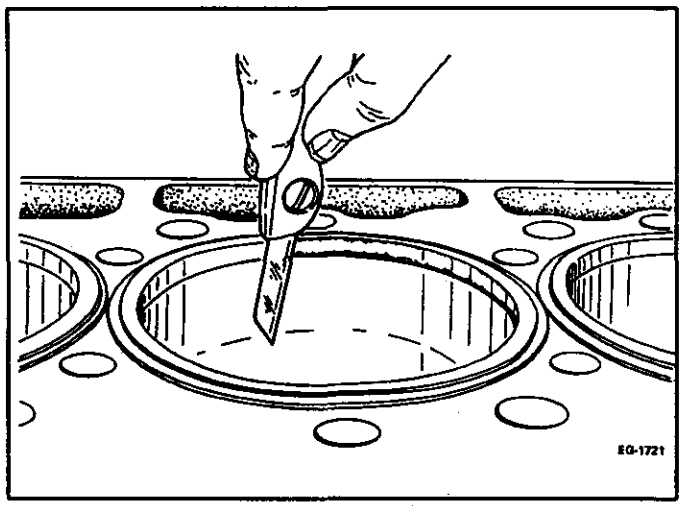


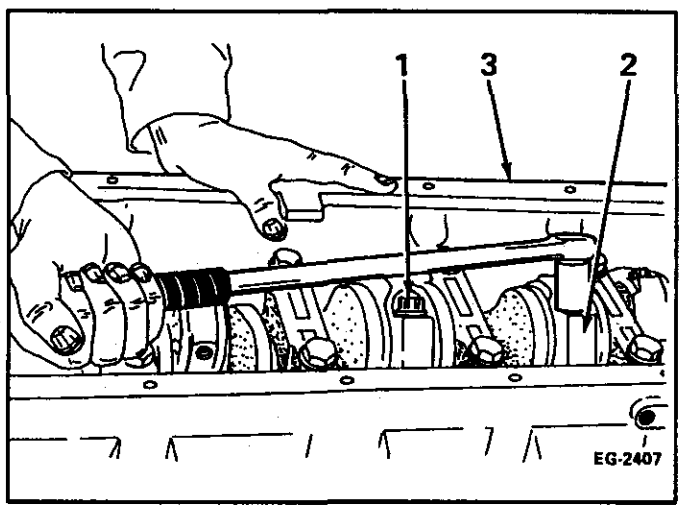
FIGURE 9–2

Remove the following:

Fuel injection lines (high pressure)
Fuel leak–off lines (low pressure)
Aneroid tube
Valve cover/Intake manifold
Turbocharger oil inlet and oil drain tubes
Valve lever assembly
Cylinder head assembly
Vibration damper
Oil pan
Oil pick–up tube

Refer to the appropriate manual section for detailed removal procedures.

9.3.1 Piston and Rod Assembly Removal



1. Connecting Rod Bolt (12)
2. Connecting Rod Cap (6)
3. Crankcase

FIGURE 9–3

1. Using a razor knife, scrape the carbon ridge from the top of the cylinder liner. Refer to **FIGURE 9–2.**

NOTICE: **The carbon ridge must be removed before removing the piston and rod assembly. This reduces the chance of piston ring land damage during removal.**

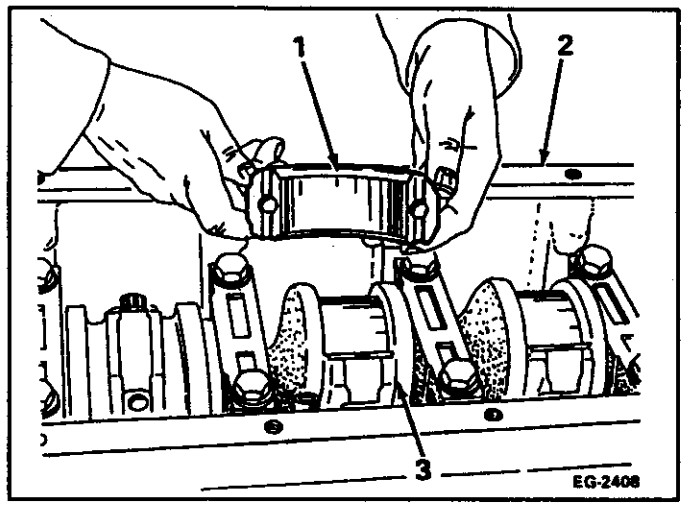
2. Loosen the connecting rod bolts using a socket and breaker–bar, **FIGURE 9–3.**
3. Remove the bolts by hand.

NOTE:

The bolts should turn out of the connecting rod freely. If binding exists, check thread condition carefully.

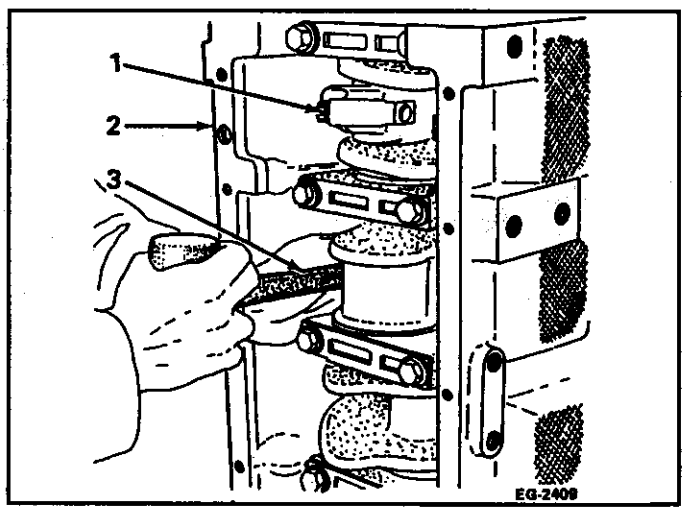
CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

4. Remove the connecting rod cap and bearing insert. Refer to **FIGURE 9–4.**
5. Remove the piston and connecting rod assemblies as follows:
   a. Push the piston and rod assembly from the cylinder bore using a wood or plastic handle. Refer to **FIGURE 9–5.**



1. **Connecting Rod Cap (6)**
2. **Crankcase**
3. **Crankshaft**

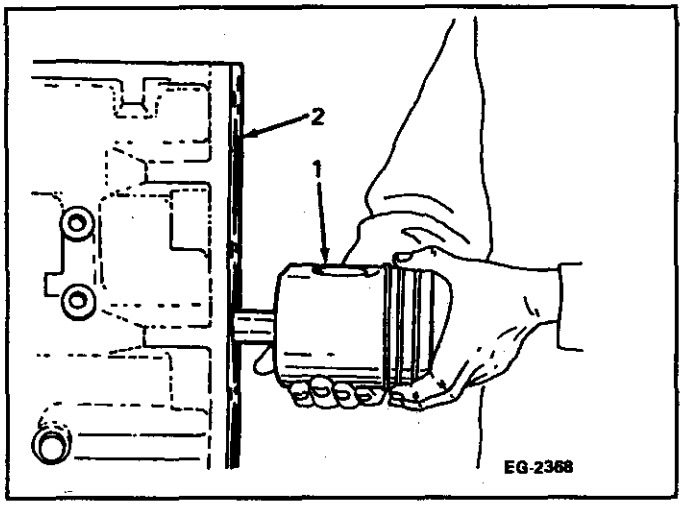
FIGURE 9–4



1. **Connecting Rod**
2. **Crankcase**
3. **Hammer**

FIGURE 9–5

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY



1. Connecting Rod/ Piston Assembly
2. Crankcase

FIGURE 9–6

b. Once the piston rings are free of cylinder bore, the assembly can be removed from the top of the crankcase. Refer to **FIGURE 9–6**.

c. Rotate engine and remove all of the remaining pistons as outlined. Be sure to replace each bearing cap on its respective connecting rod after removal of the piston from the engine.

d. Identify the connecting rod and piston assemblies upon removal so they can be reinstalled in their respective cylinder bores.

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

9.3.2 Cylinder Liner Removal

Use the liner puller PT6410 to remove the cylinder liners as follows: (Refer to **FIGURE 9–7**).

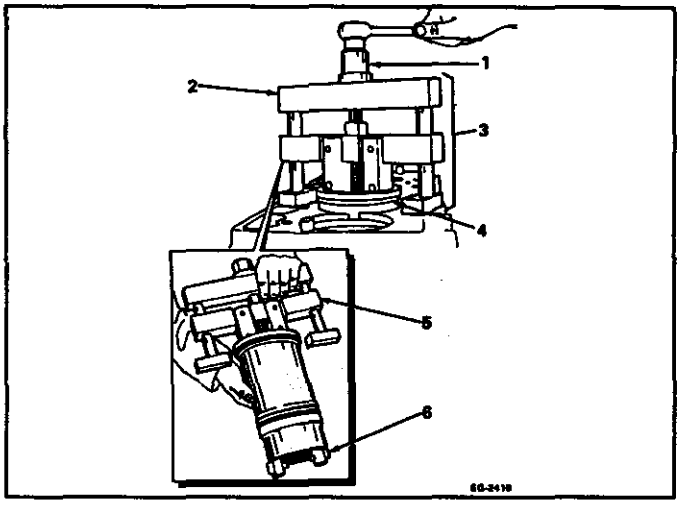
NOTICE: **Prior to installing the puller, bar the engine over so the crankshaft journal is located at the bottom (low point) of its travel. This prevents possible damage to the journal by the puller lifting jaws during puller installation.**

1. Position the puller in the liner and spread the lifting jaws so the tangs grip the bottom of the liner.

2. With the lifting bridge firmly on the crankcase top deck, turn the forcing nut to break the cylinder liner loose from the crankcase.

3. Lift the liner and puller from the crankcase.

4. Remove liner from puller and mark liner with its cylinder bore number, also mark liner position in block for purposes of inspection and reassembly.



1. **Forcing Nut**
2. **Liner Puller**
3. **Lifting Bridge and liner**
4. **Cylinder Liner**
5. **Lifting Bridge**
6. **Lifting Jaws**

FIGURE 9–7

9.3.3 CONNECTING ROD, PISTON & RING DISASSEMBLY

1. Using pliers, remove the two piston retaining rings. Refer to **FIGURE 9–8**.

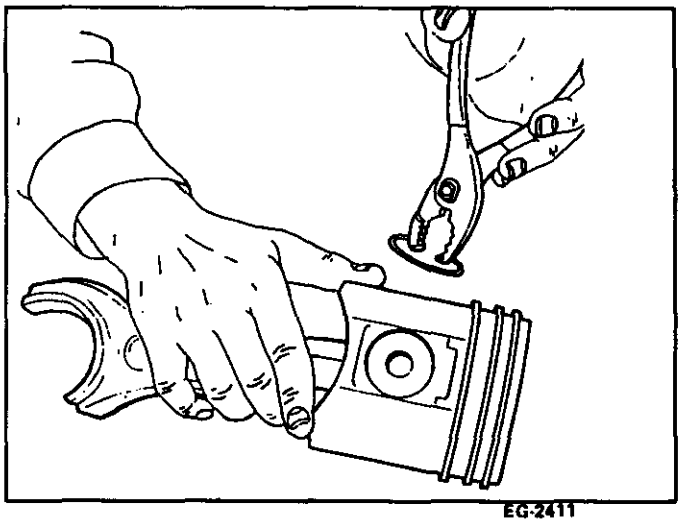
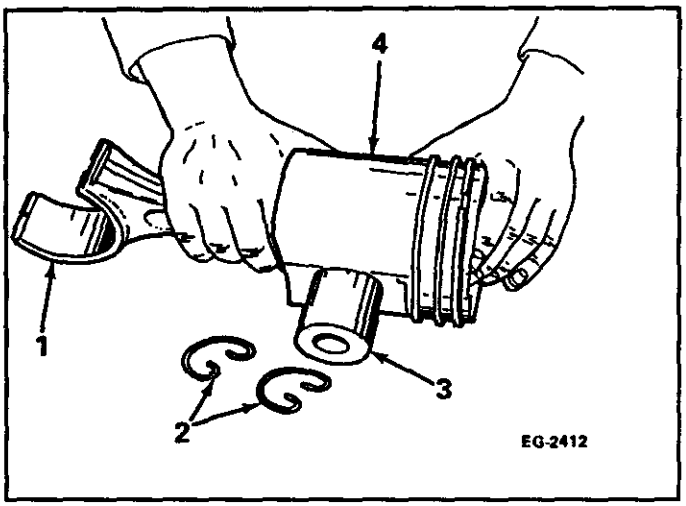


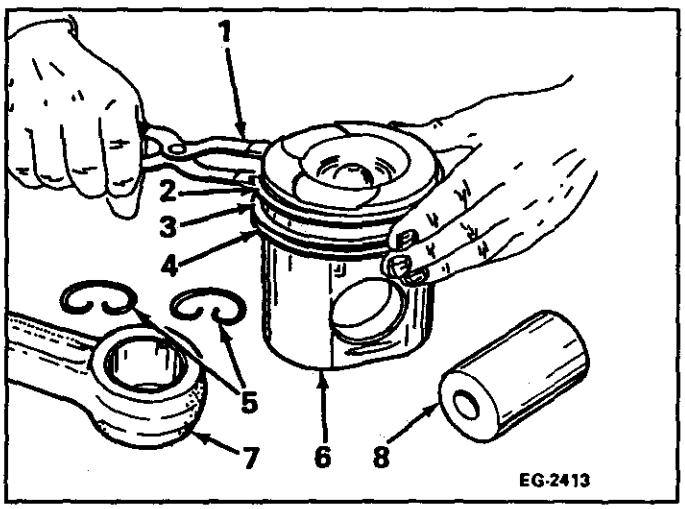
FIGURE 9–8

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY



1. Connecting Rod
2. Retaining Ring (2)
3. Piston Pin
4. Piston

FIGURE 9–9



1. Ring Expander
2. Top Ring
3. Intermediate Ring
4. Oil Control Ring
5. Retaining Ring (2)
6. Piston
7. Connecting Rod
8. Piston Pin

FIGURE 9–10

2. Remove the piston pin from its bore, by hand. Refer to **FIGURE 9–9**. Then separate the connecting rod from the piston.
3. Use a piston ring expander tool to remove the piston rings. Remove the top ring first, then the intermediate ring and the oil control ring. Refer to **FIGURE 9–10.**
4. Tag or mark the components with the cylinder number from which they were removed, so they may be reinstalled in their respective cylinders once inspected.

9.3.4 Cylinder Liner Disassembly

1. Use a pick to remove two (2) O–rings at the lower counterbore area of each cylinder liner.
2. Discard the O–rings.

9.3.5 Cleaning Connecting Rod, Piston & Rings

1. Clean the aluminum pistons using a soap and water solution; soak and then clean piston, using a non–metallic brush.

NOTE:

Never use a caustic solution or a wire brush for cleaning the aluminum pistons.

2. All piston ring grooves must be cleaned thoroughly. Be sure the two drilled or cast oil holes in the oil ring groove are open.
3. The following disassembled components may be cleaned using a suitable solvent:
   a. Piston rings
   b. Piston pins
   c. Piston pin retainers
   d. Connecting rods
   e. Connecting rod caps
   f. Connecting rod bolts

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

4. Clean all rod bolt holes and threads.
5. Clean the oil hole at the top of the rod. Make sure it is not blocked.

9.3.6 Inspect Cylinder Liners & Pistons

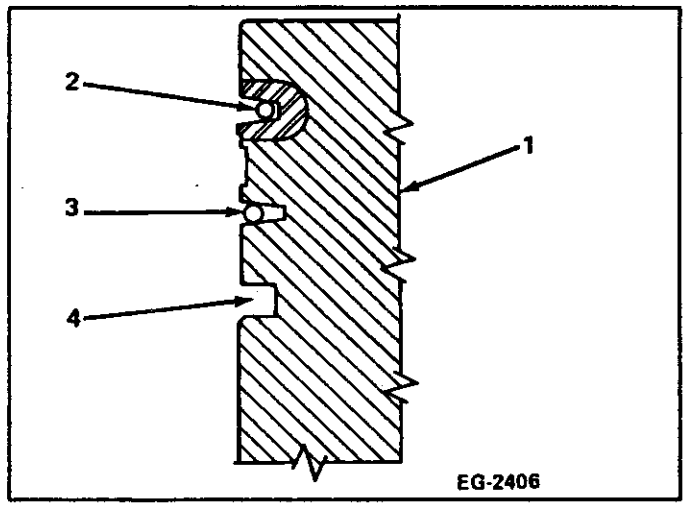
1. Soak the cylinder liners in a soap and water solution and clean thoroughly using a non–metallic brush.
2. Dry with filtered compressed air.
3. Visually inspect the pistons for scuffed or scored skirts and cracked or worn lands. Replace the pistons as required.

NOTICE: **These engines use full keystone compression rings (first and second groove) and a rectangular oil control ring. The piston ring groove configuration corresponds to the shape of the piston ring (FIGURE 9–11). The keystone compression ring grooves are measured over gauge pins to determine wear. The rectangular oil control ring groove does not use gauge pins, but side clearance to determine piston ring groove wear.**

4. To check top and intermediate compression ring groove widths for wear install the 0.1150 in. (2.921 mm) gauge pins from the piston groove wear gauge pin set (Tool No. J29511), into the groove to be measured. Refer to **FIGURE 9–11.**

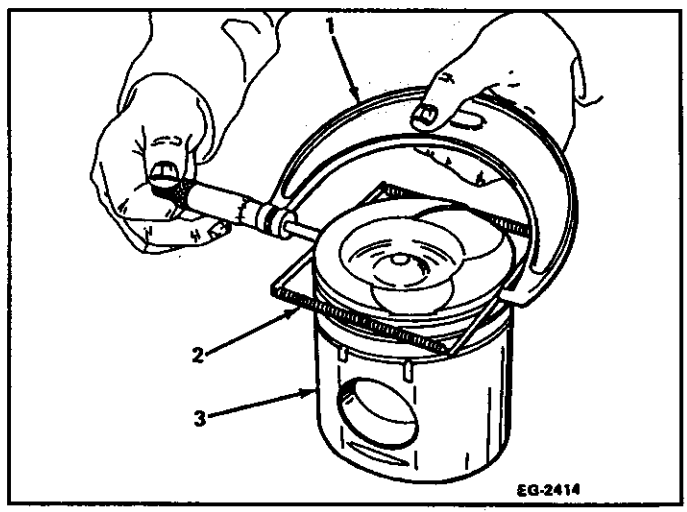
NOTE:
Gauge pins must be parallel

5. Measure the piston diameter over gauge pins using an outside micrometer, **FIGURE 9–12.**



1. **Piston**
2. **Top Ring**
3. **Intermediate Ring**
4. **Oil Control Ring**

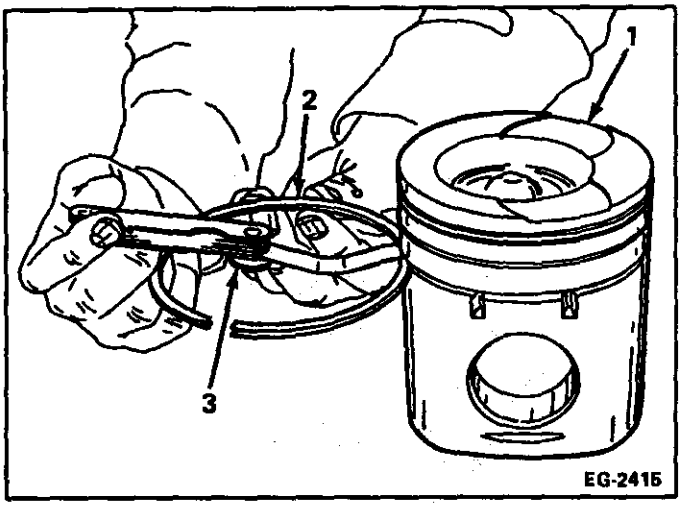
FIGURE 9–11 Figure



1. **Micrometer**
2. **Piston Ring Gauge**
3. **Piston**

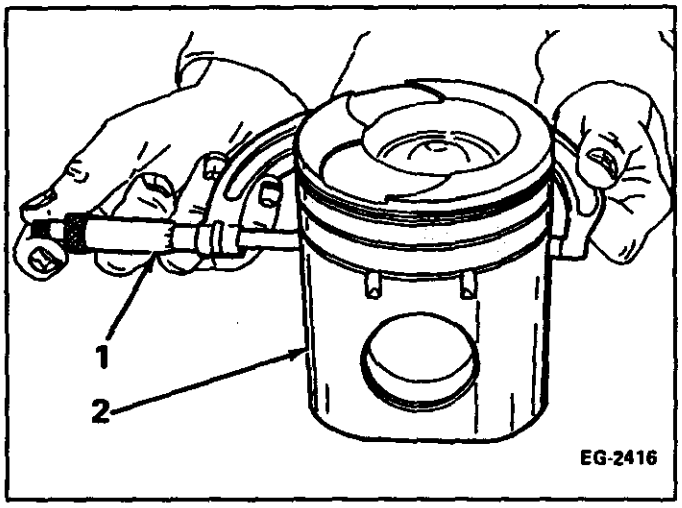
FIGURE 9–12

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY



1. Piston
2. Oil Control Ring
3. Feeler Gauge

FIGURE 9–13



1. Micrometer
2. Piston

FIGURE 9–14

6. If the measurement over the gauge pins is **NOT** within specifications, excessive piston groove wear exists and the piston must be replaced with new. Refer to "Specifications".

7. Check the rectangular oil control ring groove for side clearance as follows:

   a. Using a new ring, place the outer edge of the ring in the oil control ring groove.

   b. Roll the ring, in its respective groove, entirely around the piston. Make sure the ring is free in the groove.

   c. With a feeler gauge check the side clearance of each oil control ring in its respective groove, **FIGURE 9–13.**

   d. Excessive side clearance indicates ring groove wear and requires piston replacement.

8. Check piston to cylinder liner running clearance, as follows:

   a. Measure and record the piston skirt diameter. With the piston at room temperature, place an outside micrometer 1.080 in. (27.43 mm) below the bottom land of the oil control ring, 90 degrees from the pin bore. Refer to **FIGURE 9–14.**

   b. Measure cylinder liner inside diameter, refer to "Cylinder Liner Inspection" later in this section for the procedure. Record the reading.

   c. Subtract the piston skirt diameter from the cylinder liner I.D. The resulting dimension is the piston to cylinder liner running clearance.

   d. If running clearance is not within "Specifications", replace the piston.

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

NOTE:

Faulty rings cannot always be detected by visual inspection. When a piston is removed from a cylinder, replace the piston rings.

1. Visually inspect NEW rings for cleanliness.
2. Prior to installing the rings on the piston, check each ring for proper gap as follows:
   a. Push the ring down into the cylinder bore making sure the ring is square with the cylinder wall.
   b. Measure the gap between the ends of each ring with a feeler gauge as shown in **FIGURE 9–15**. Refer to "Specifications" for ring gap. Discard any used ring which does not meet the specifications.

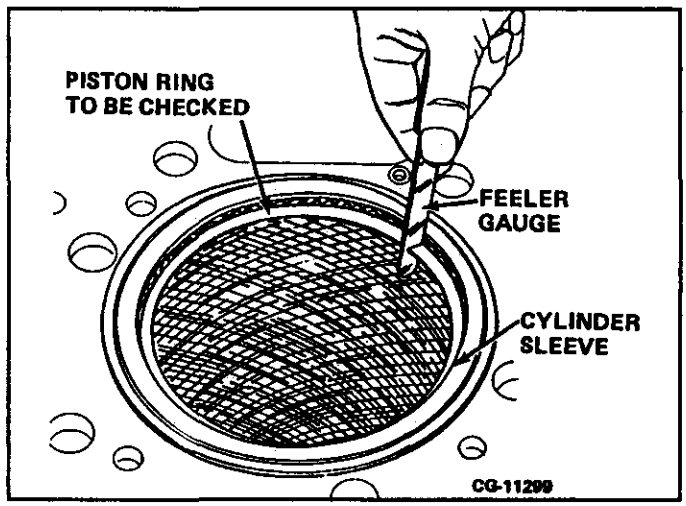
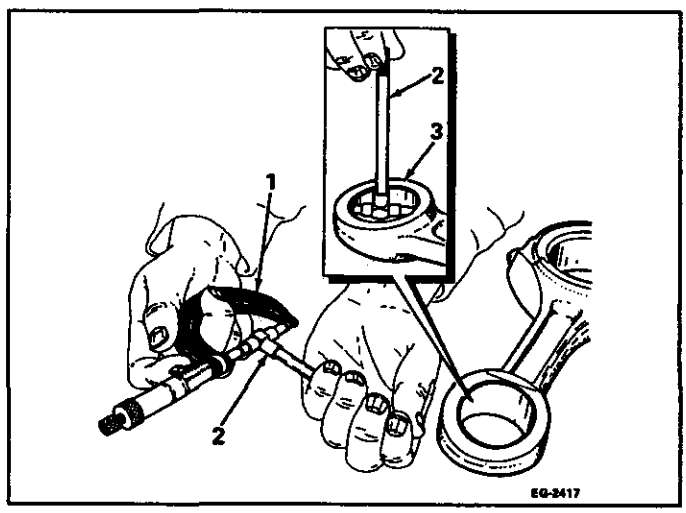


FIGURE 9–15

9.3.7 Inspect Connecting Rods

1. Visually inspect the connecting rod bolts for nicks or damage.
2. Visually inspect the rod and cap mating surfaces for fretting. Replace as required.
3. Inspect the connecting rod piston pin bushing for wear using a telescoping gauge and an outside micrometer. Measure the pin bore at two locations 90 degrees from one another and record the readings. Refer to **FIGURE 9–16**.

NOTICE: **When lubricated with clean engine oil, the bolts must screw into the rod by hand. If resistance is met, clean the rod threads again and try a new bolt. If a new bolt does not screw in freely, the rod must be discarded. Rod threads cannot be retapped.**



1. **Micrometer**
2. **Telescoping Gauge**
3. **Connecting Rod**

FIGURE 9–16

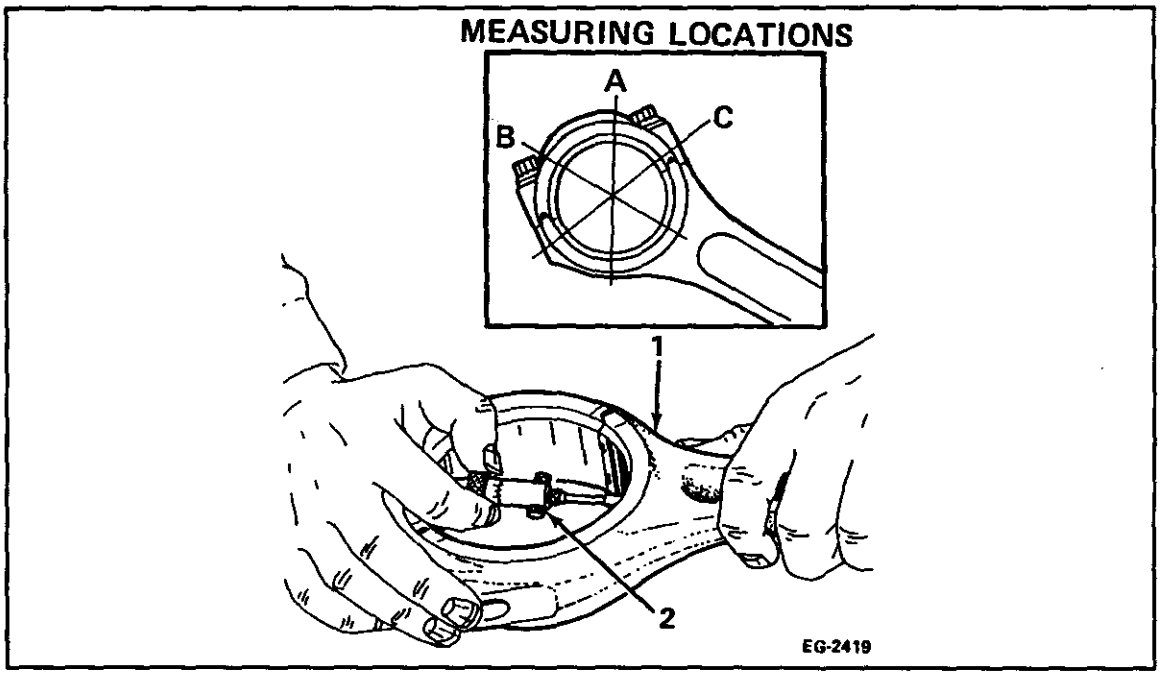
CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

4. Refer to "Specifications". If piston pin bushing I.D. exceeds minimum specification, it is worn and must be replaced.

9.3.7.1 Out–of–round Check

Check connecting rod bearing bore for "out–of–round" as follows:

1. Lubricate connecting rod bolts with clean engine oil and assemble the cap to rod without bearing insert. Tighten bolts to specified torque value.
2. Use an inside micrometer or a dial bore gauge and measure connecting rod in three locations as shown in **FIGURE 9–17.**
3. If the difference between point "B" and average of points "A" and "C" ([A + C] ÷ 2), exceeds "Specifications", rod must be replaced.

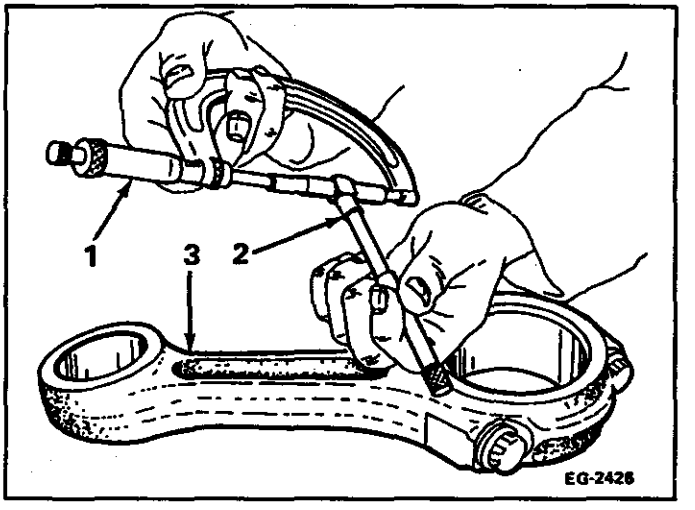


1. Connecting Rod
2. Inside Micrometer

FIGURE 9–17

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

4. Measure connecting rod bearing bore taper (**FIGURE 9–18**), by measuring bore I.D. on each side of bearing bore. Record the readings. The difference between two readings is bore taper. (See "Specifications.") Replace rod as required.
5. With connecting rod cap removed, visually inspect surface finish of connecting rod bearing bore. The bore must be smooth and free of scoring, nicks or burrs. Replace as required.



1. **Micrometer**
2. **Telescoping Gauge**
3. **Connecting Rod**

FIGURE 9–18

9.3.7.2 Connecting Rod Bend and Twist

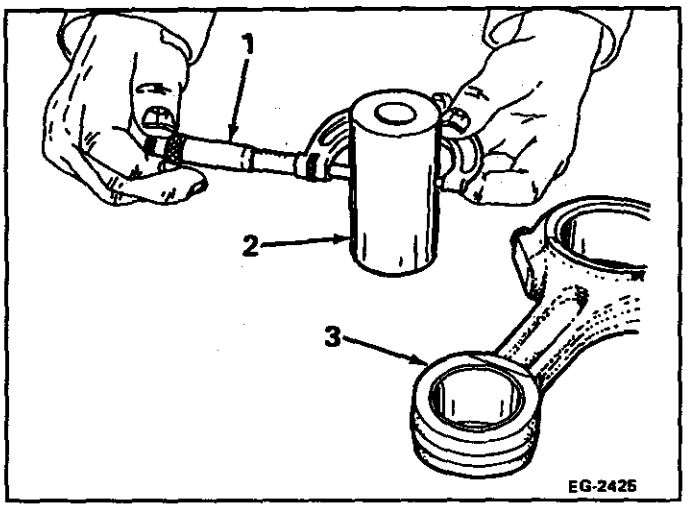
Often engine component wear patterns can be identified and used to diagnose a problem. Some common examples of connecting rod wear patterns include:

1. A shiny surface on edge of piston pin bushing usually indicates that a connecting rod is bent or piston pin hole is not in proper relation to piston skirt and ring grooves.
2. Abnormal connecting rod bearing wear can be caused by either a bent connecting rod or a tapered connecting rod bore.
3. Twisted connecting rods will not create an easily identifiable wear pattern, but badly twisted rods will disturb action of entire piston, rings, and connecting rod assembly and may be the cause of excessive oil consumption.

If any of these conditions exist, check the connecting rods for bends or twists using a suitable alignment fixture. Follow the instructions of the fixture manufacturer. If bend or twist exceeds "Specifications", replace the rod.

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

9.3.8 Inspect Pistons Pins



1. **Micrometer**
2. **Piston Pin**
3. **Connecting Rod**

FIGURE 9–19

NOTICE: **If the connecting rods do not meet the requirements set forth in pages 9–16 through 9–18, replace the entire connecting rod assembly.**

1. Visually inspect piston pins for corrosion or wear. Replace as required.
2. Use a micrometer to measure piston pin O.D. at two locations. Record the readings. Refer to **FIGURE 9–19**. If piston pin wear exceeds "Specifications", replace the pin.
3. Check piston pin clearance in rod as follows:
   a. Subtract piston pin O.D. from piston pin bushing I.D. measurement. Refer to **FIGURE 9–16.**
   b. If clearance exceeds "Specifications", replace the bushing.

9.3.9 Inspect Cylinder Liners

1. Visually inspect inside surface of liner for scuffing or scoring and polishing. Replace liner (and piston) as required. Examine outer surface of liner for cavitation erosion, replace as required.
2. Check cylinder liners for wear (taper) using any one of the three methods described.

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

9.3.10 Method One – Telescoping Gauge Method

(Refer to **FIGURE 9–20** and **FIGURE 9–21**).

Using a telescoping gauge, and an outside micrometer:

1. Measure liner I.D. at top of piston ring travel (just below carbon ridge area) (**FIGURE 9–20**) and record reading.
2. Measure liner. I.D. below ring travel area (**FIGURE 9–21**) and record reading.
3. The difference between two readings is cylinder liner taper. If specifications are exceeded, replace liner.

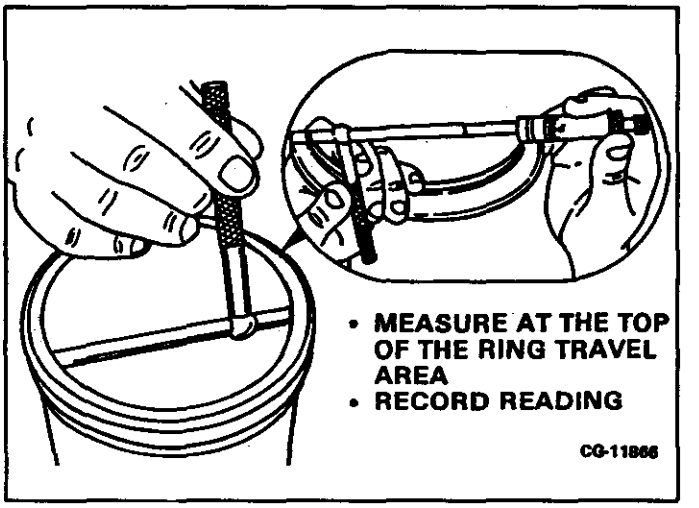
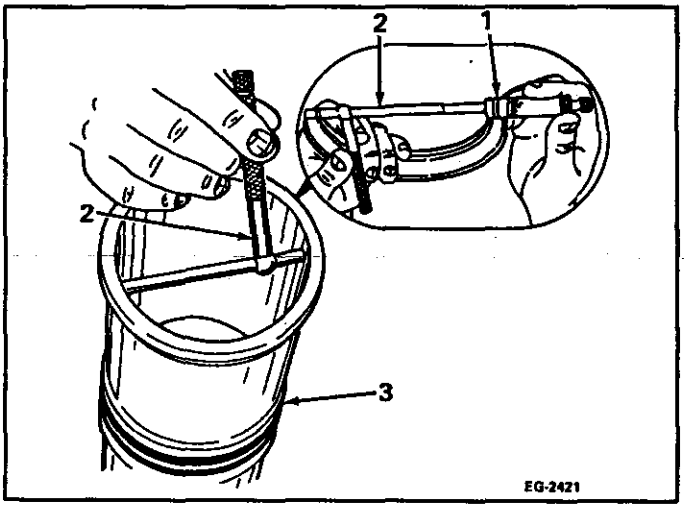


FIGURE 9–20



1. **Micrometer**
2. **Telescoping Gauge**
3. **Cylinder Liner**

FIGURE 9–21

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

9.3.11 Method Two – Dial Bore Gauge Method

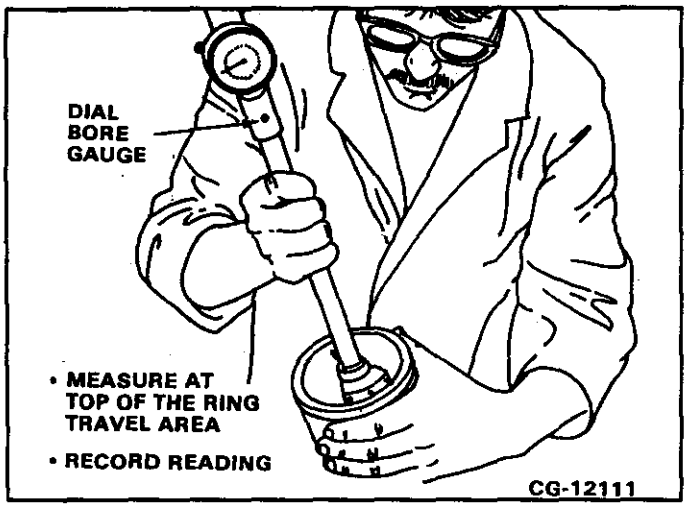
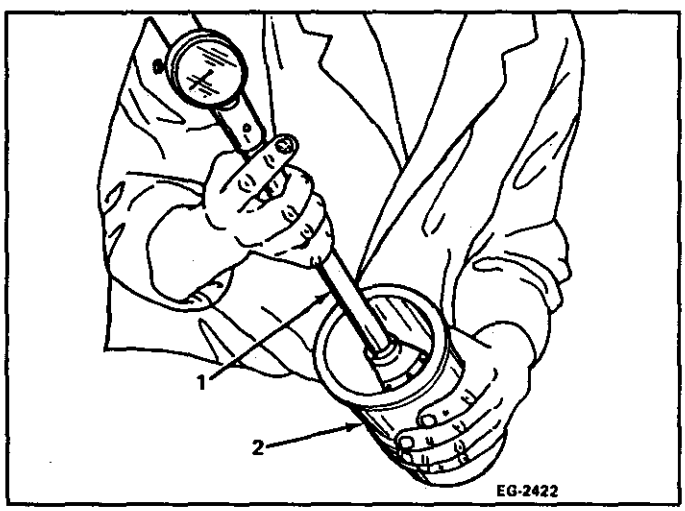


FIGURE 9–22



1. Dial Bore Gauge
2. Liner

FIGURE 9–23

(Refer to **FIGURE 9–22** and **FIGURE 9–23**).

Using a dial bore gauge:

1. Measure at the top of the piston ring travel just below the carbon ridge area) **(FIGURE 9–22)** and record the reading.
2. Measure below ring travel area **(FIGURE 9–23)** and record the reading.

The difference between the two readings is the cylinder liner taper. If specifications are exceeded, replace liner.

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

9.3.12 Method Three – Feeler Gauge Method

(Refer to **FIGURE 9–24** and **FIGURE 9–25).**

1. Install a top compression ring squarely at top of ring travel (**FIGURE 9–24**) and measure ring end gap with a feeler gauge. Record reading.
2. Install same piston ring squarely below ring travel area (**FIGURE 9–25**) and measure ring end gap. Record readings.

NOTE:
Use a piston to be sure ring is seated squarely into bore.

Every 0.003 in. (0.07 mm) increase in ring gap equals a 0.001 in. (0.025 mm) increase in bore size.

3. If liner is worn beyond specifications, replace liner.

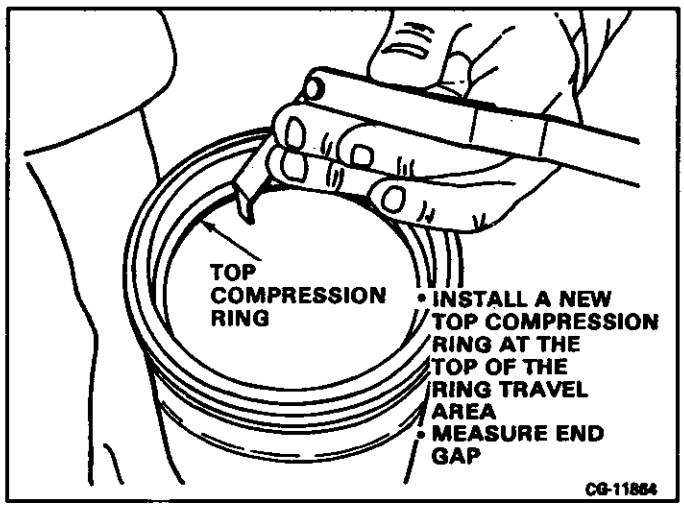


FIGURE 9–24

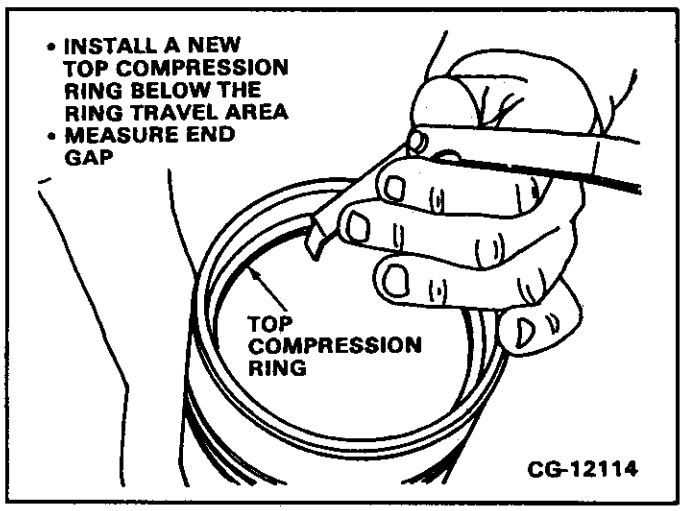


FIGURE 9–25

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

9.3.13 Bearing Fitting Procedure

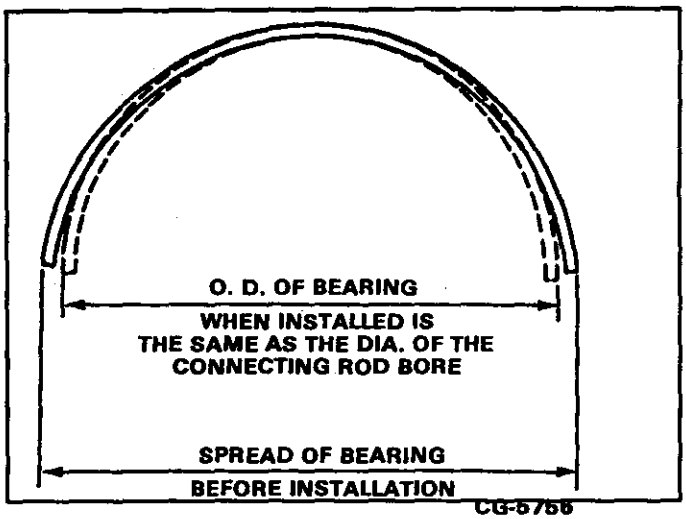


FIGURE 9–26

1. If bearing–to–crankshaft running clearances exceed specifications because of wear on the crankshaft, replace or regrind the crankshaft and install undersize precision type bearing shells.

NOTE:

Do not attempt to reduce journal–to–bearing running clearances by re-working bearing cap, bearings or both. Regrind or replace the crank-shaft only. Refer to Section 10.

NOTICE: **Reworking the bearing cap will destroy the engineered fit of the bearing shells in their bores.**

2. Tighten the connecting rod bolts alternately and evenly to the specified torque.

NOTE:

About Bearing Crush and Spread! Bearing shells must fit tightly in the bore. When bearing shells are inserted into the connecting rod and cap, they protrude above the parting line. This protrusion is required to achieve "Bearing Crush". Bearing shells are designed with "Spread". That is, the width across the open ends are slightly larger than the diameter of the connecting rod bore into which they are assembled, as shown in FIGURE 9–26. This condition is designed into the bearing shell causing it to spread outward at the parting line when "Crush" load is applied by tightening the bolts. Some snap may be lost in normal use, but bearing replacement is not required because of a nominal loss of snap.

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

When the assembly is drawn up tight, the bearing is compressed, assuring a positive contact between the bearing back and the bore as shown in **FIGURE 9–27.**

3. Fit connecting rod bearings and measure bearing running clearance as follows:

   a. With bearing cap removed, wipe oil from the face of the bearing insert and exposed portion of the crankshaft journal.

   b. Place a piece of "Plastigage®" across the full width of the bearing about ¼ in. (6 mm) off center.

   c. Install the cap and tighten bolts evenly and alternately to specified torque.

NOTE:
Do not turn the crankshaft during running clearance check.

   d. Remove bearing cap. The "Plastigage®" material will be found adhering to either the bearing shell or the crankshaft. **DO NOT REMOVE "PLASTIGAGE®".**

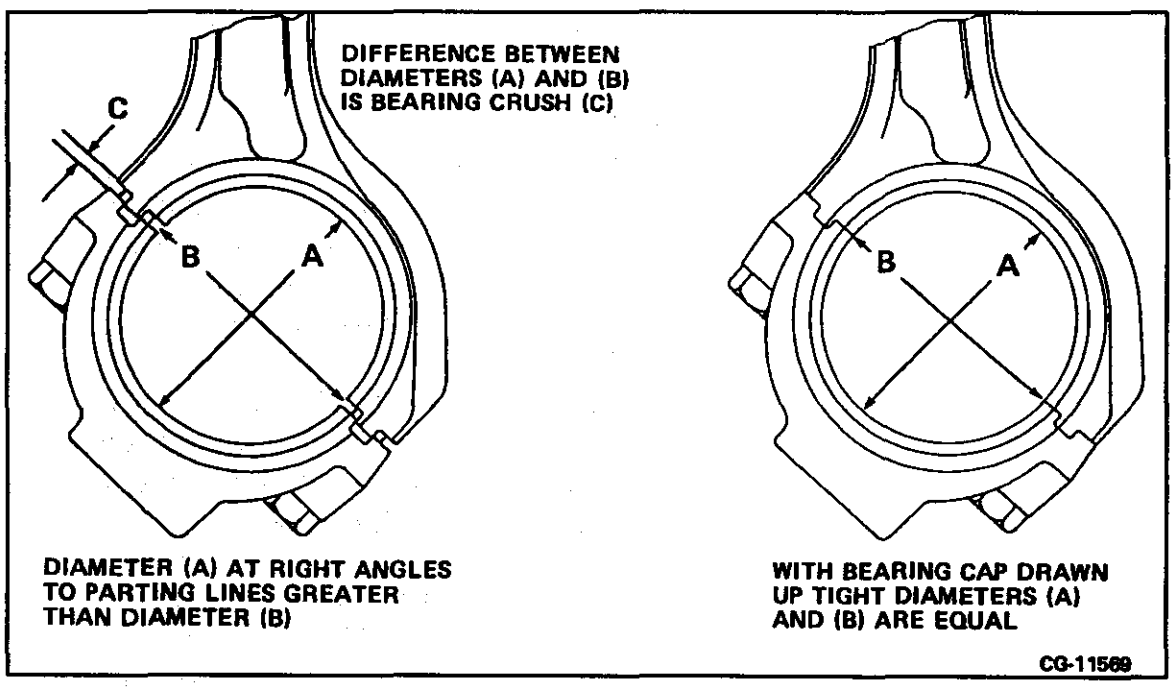
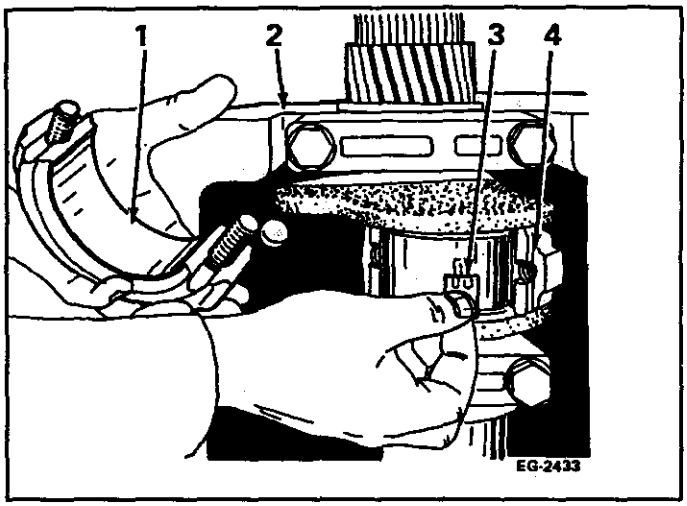


FIGURE 9–27

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY



1. Bearing
2. Crankcase
3. Scale
4. Connecting Rod

FIGURE 9–28

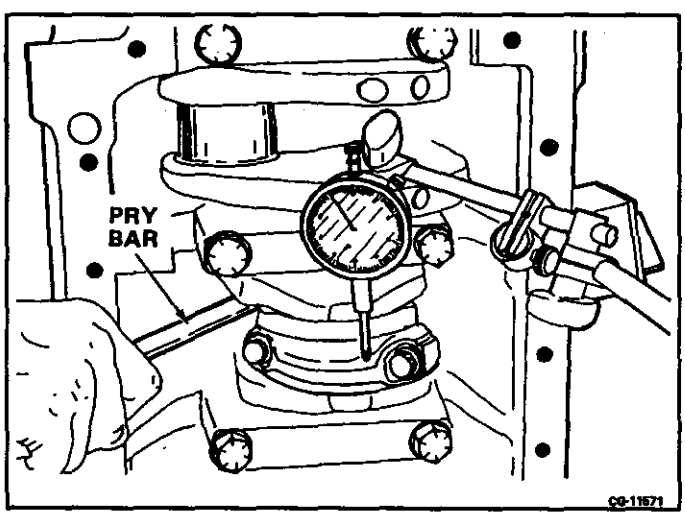


FIGURE 9–29

e. Use "Plastigage®" scale to measure widest point of flattened plastic material, **FIGURE 9–28**. The number within the graduated marks on the scale indicates the clearance in thousandths of an inch or millimeters (See "Specifications").

f. Remove the test material and the repeat test for each connecting rod bearing.

NOTE:

With the precision bearings used, no problem should be encountered. If proper clearance is NOT achieved, a problem with the crankshaft may exist which requires regrinding and the use of undersize bearings. (Refer to Section 10 for crankshaft rework information.) Bearing cap torque is very important. Repeat running clearance check procedure before condemning the crankshaft.

4. Check connecting rod side clearance using a dial indicator as follows:
   a. Place the tip of the dial indicator on the connecting rod cap as shown in **FIGURE 9–29**.
   b. Pry the connecting rod towards the rear of the engine and zero the dial indicator.
   c. Pry the connecting rod toward the front of the engine and read the indicator. Refer to "Specifications" and repeat for all connecting rods.

NOTE:

The connecting rod side clearance must be checked to be certain that the specified clearance exists.

Lack of clearance could indicate a damaged rod or a rod bearing out of position. Excessive clearance may require replacement of the rods or crankshaft. Correct as required.

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

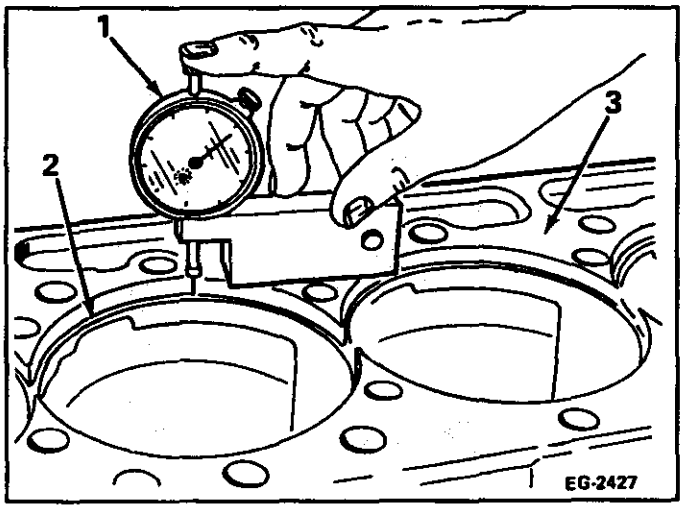
9.3.14 Cylinder Liner Fitting Procedure

Check the crankcase counterbore depth using the surface gauge or a depth micrometer.

9.3.14.1 Surface Gauge Method

(Refer to **FIGURE 9–30**).

1. "Zero" the dial indicator on the crankcase deck.
2. Move the indicator onto the counterbore ledge and check the depth at four points.
3. Refer to "Specifications" for counterbore depth and maximum variation between the four measurement points.
4. If maximum variation between the four points exceeds specifications, resurface the counterbore.



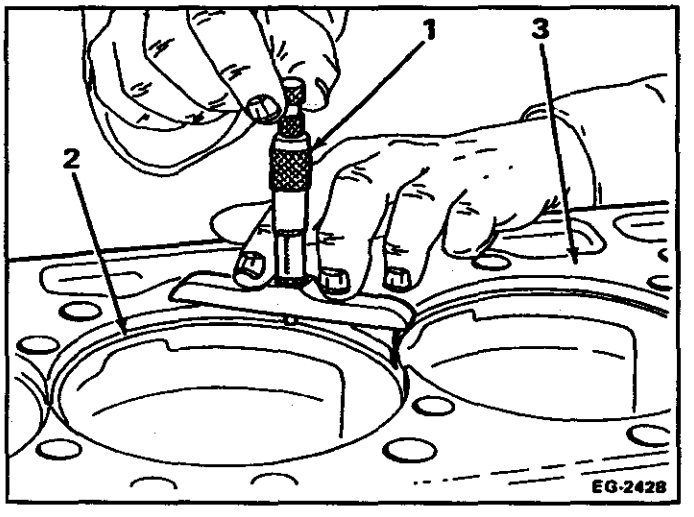
1. **Dial Indicator**
2. **Counter Bore Ledge**
3. **Crankcase**

FIGURE 9–30

9.3.14.2 Depth Micrometer Method

(Refer to **FIGURE 9–31**).

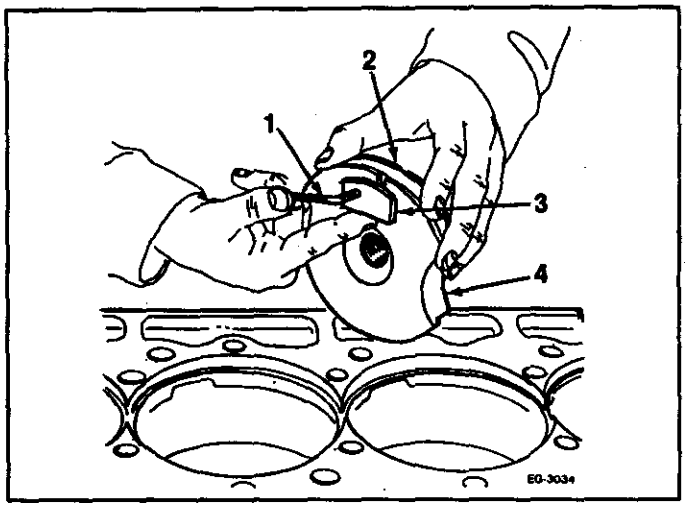
1. Check the counterbore depth at four points around the crankcase counterbore.
2. Record the measurements.
3. Refer to "Specifications", and resurface the counterbore if the maximum variation between measurement points is exceeded.



1. **Depth Micrometer**
2. **Counter Bore Ledge**
3. **Crankcase**

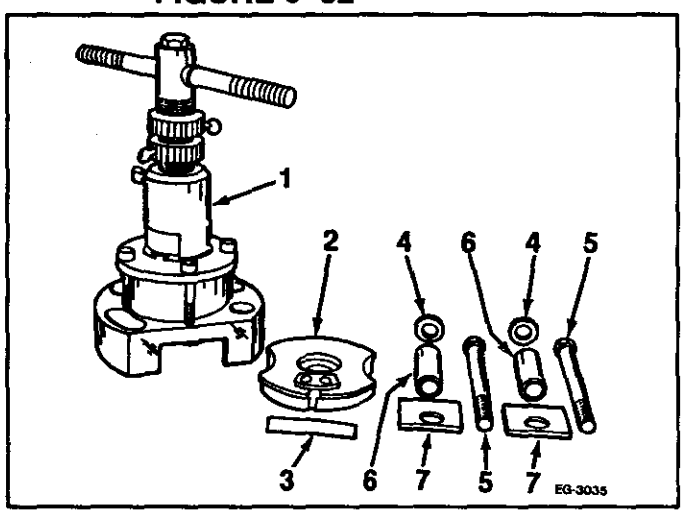
FIGURE 9–31

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY



1. Allen Wrench
2. Feeler Gauge
3. Locking Plate
4. Tool Bit Molder

FIGURE 9–32



1. Cutting Tool
2. Tool Bit
3. Feeler Gauge
4. Washers (2)
5. Mounting Bolts (2)
6. Spacer (2)
7. Locking Plate (7)

FIGURE 9–33

4. Resurface the counterbore using the counterboring tool, PT2200–55 along with the appropriate cutter head as follows:

NOTE:

The counterboring tool is a low profile tool which can be used in chassis.

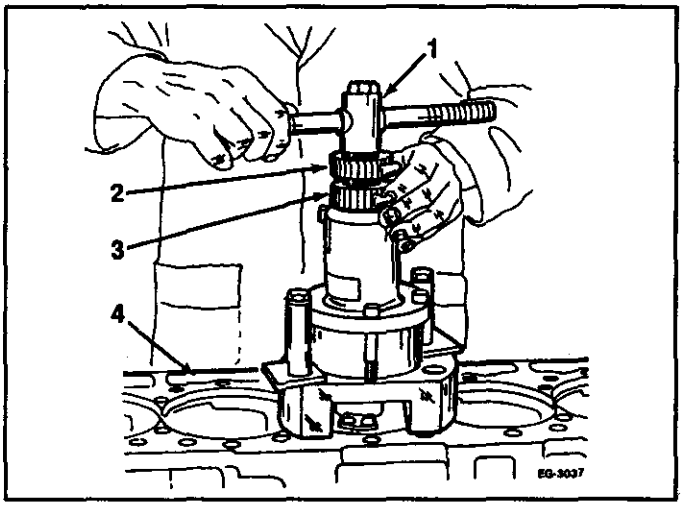
a. **PRE–SET TOOL BIT** by placing a 0.008 in. to 0.010 in.(0.20 to 0.25 mm) feeler gauge on the O.D. of the cutter head PT2250A. Push the tool bit out until it touches the feeler gauge. Lock the tool bit in place using an Allen wrench as shown in **FIGURE 9–32.**

b. **INSTALL THE CUTTER HEAD** PT2250A onto the driver unit and adapter plate of the counterboring tool. Refer to **FIGURE 9–33.**

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

c. **RAISE THE CUTTER HEAD** by pulling the plunger and lifting up on the handle. Mount the counterboring tool assembly to the crankcase as shown in **FIGURE 9–34.** Tighten the cap screw with washers finger–tight than apply 33 lb·ft (45 N·m) torque.

d. **LOWER THE CUTTING HEAD** by loosening locking screws on turn knuckles. Pull plunger up, to desired height. tighten turn knuckle in position and lock in place with locking screws.



1. Handle
2. Upper Turn Knuckle
3. Lower Turn Knuckle
4. Cylinder Head

FIGURE 9–34

9.3.15 Setting the Depth of the Cut

Set the depth of the cut using one of two methods.

9.3.15.1 Method One – Use Graduated Marks On Tool

Use the following steps:

1. Loosen locking screw.
2. Rotate the adjusting nut in a counterclockwise direction until the nut contacts the driver unit housing.
3. Back off the adjusting nut by the amount of cut desired.

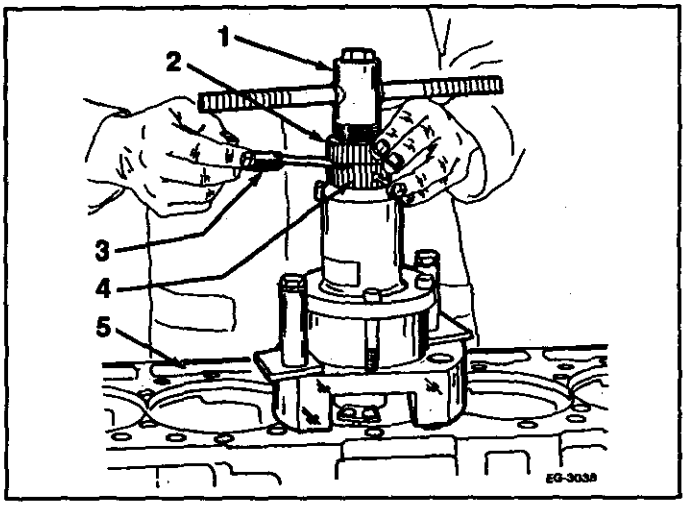
NOTE:

Each graduated marking equals 0.001 in. If 0.002 in. material is to be removed, you must back off the adjusting nut two marks.

4. Tighten the adjusting nut lock screw.

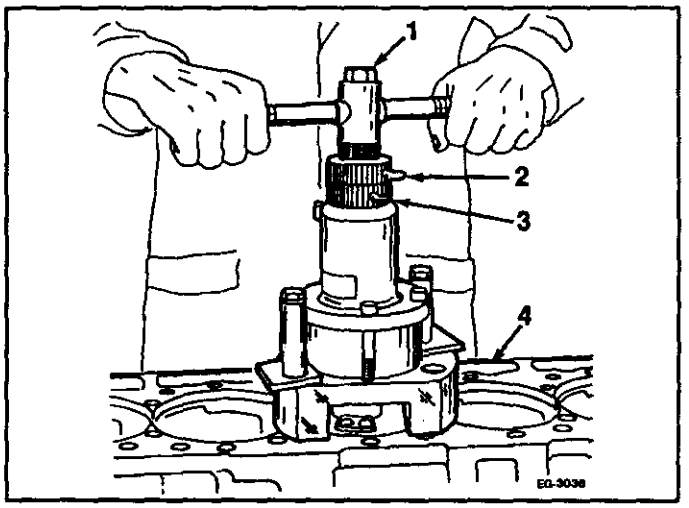
NOTICE: **Never attempt to remove more than 0.002 in. material at a time as damage to block may occur.**

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY



1. Handle
2. Upper Turn Knuckle
3. Feeler Gauge
4. Cylinder Block
5. Lower Turn Knuckle

FIGURE 9–35



1. Handle
2. Upper Turn Knuckle
3. Lower Turn Knuckle
4. Crankcase

FIGURE 9–36

9.3.15.2 Method Two – Use Feeler Gauge

(See **FIGURE 9–35**)

Use the following steps:

1. Loosen locking screw.

2. Insert an appropriate size feeler gauge (0.002 in.{0.05 mm} max.) between upper and lower turn knuckle. Rotate upper turn knuckle until feeler gauge is just held in place.

3. Tighten the locking screw and remove the feeler gauge.

4. **Cut the counterbore** by rotating handle smoothly in a clockwise direction until unit turns freely and is bottomed out between adjusting nut and top of driver unit housing. Refer to **FIGURE 9–36**.

5. Remeasure counterbore depth once counterbore has been resurfaced and cleaned up. Refer to "Cylinder Liner Fitting Procedure", step one in this section.

6. Check cylinder liner protrusion as follows:

   a. Clean cylinder bore and crankcase counter bore area.

NOTE:

To avoid damage to the tool bit, never rotate counterclockwise when tool bit is in contact with counterbore ledge.

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY

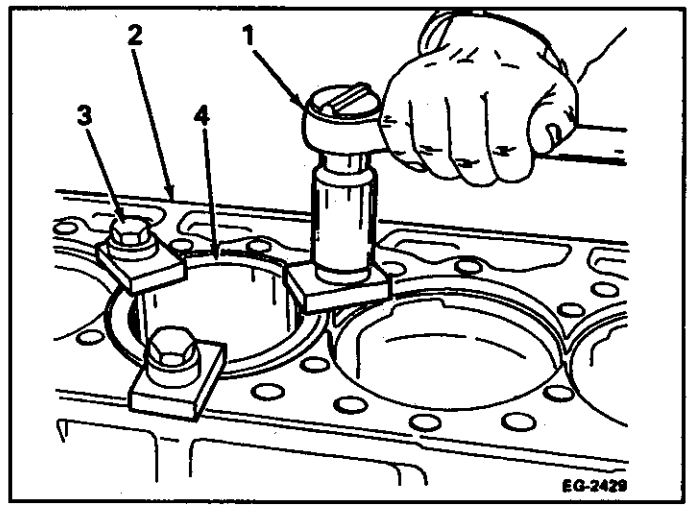
b. Place each liner in crankcase without O–rings. Clamp liner down using three holding adapters.

c. Install the liner into its bore and install the holding adapters as shown in **FIGURE 9–37.** Fasten the holding adapters using grade 8 bolts and hardened washers. Tighten the bolts in two stages as follows:

a. 40 lb·ft (55 N·m)

b. 80 lb·ft (110 N·m)

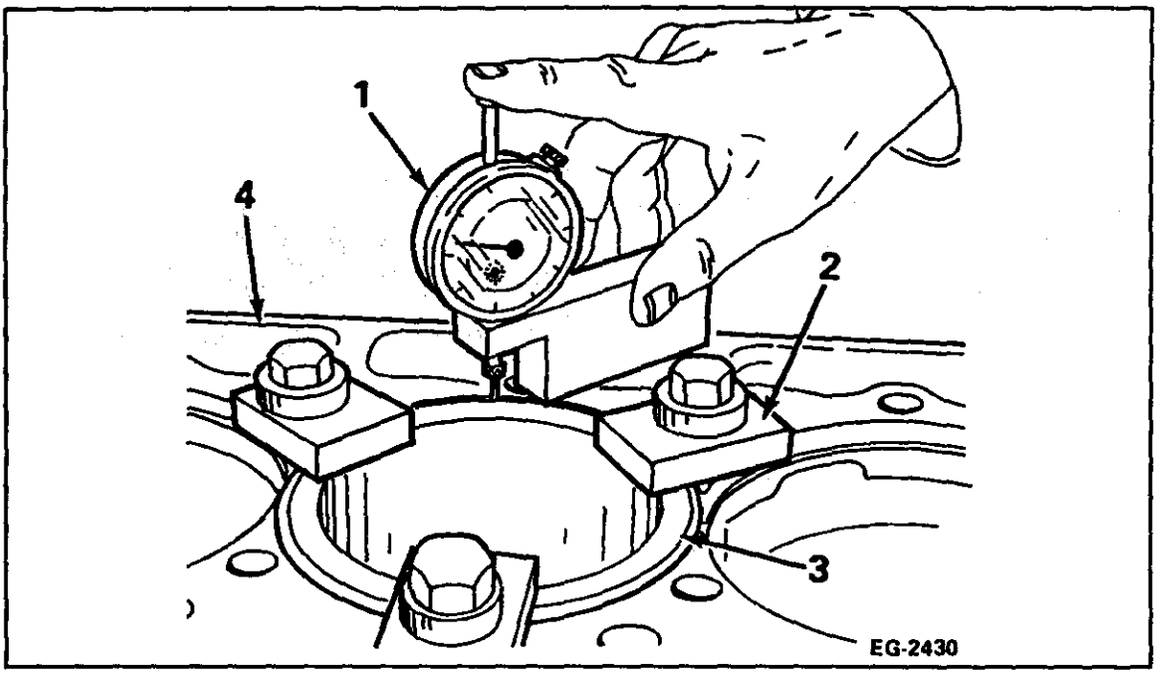
c. Using a surface gauge, place the dial indicator tip on the cylinder liner flange.



1. **Wrench**
2. **Crankcase**
3. **Holding Adapters**
4. **Sleeve**

FIGURE 9–37

CONNECTING RODS, PISTONS, RINGS AND LINERS DISASSEMBLY



1. Dial Indicator
2. Holding Adapters
3. Liner
4. Crankcase

FIGURE 9–38

d. Zero the indicator and move the block until the indicator tip slides off the flange to the crankcase deck. Record the reading. Refer to **FIGURE 9–38.**

NOTE:

Take readings at three points around the liner and use the average reading to determine which shim(s), if any, is needed to bring the cylinder liner protrusion within the specification.

7. Adjust the liner protrusion, as follows:

   a. Remove the holding adapters and cylinder liner.

   b. Clean the top deck of the crankcase and the cylinder liner counterbore.

REASSEMBLY OF CONNECTING RODS, PISTONS, RINGS AND LINERS

c. Install the shim(s){two maximum}, as required to bring the protrusion above the crankcase deck within specifications. Refer to **FIGURE 9–39.**

NOTE:
Shims are available as a package consisting of the following:

Shim Quantity	Shim Size	Shim Size
2	.002 in.	.05 mm
2	.004 in.	.10 mm
1	.010 in.	.25 mm
1	.020 in.	.50 mm
2	.032 in.	.81 mm

d. Follow cylinder liner installation instructions.

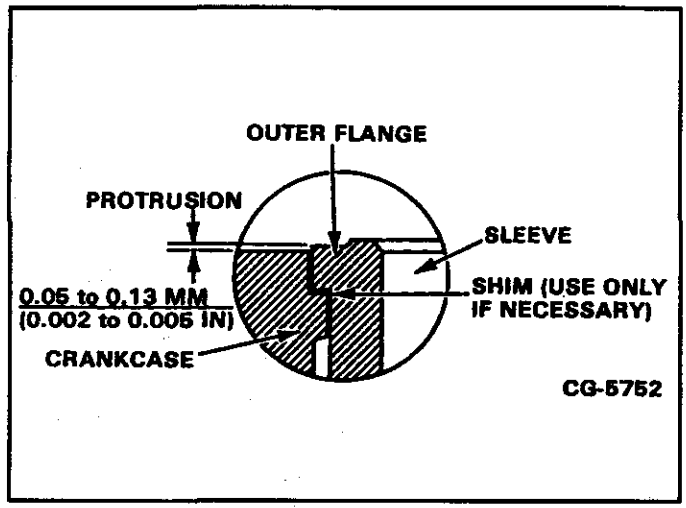


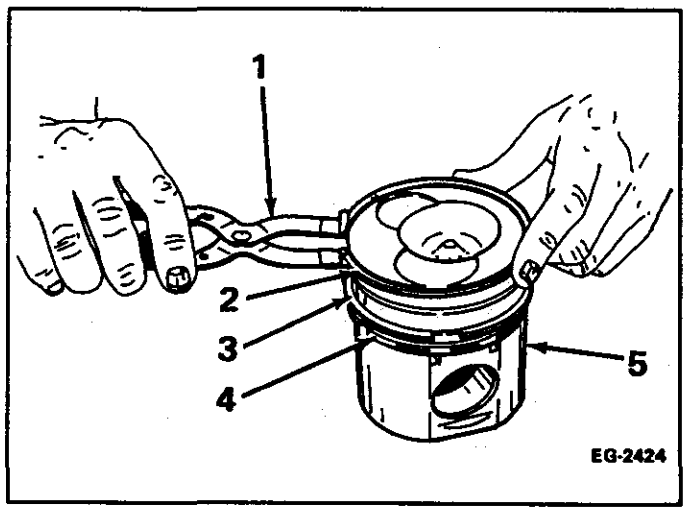
FIGURE 9–39

9.4 REASSEMBLY OF CONNECTING RODS, PISTONS & RINGS

1. Install the rings onto the pistons using a piston ring expander tool as follows: Refer to **FIGURE 9–40.**
2. Install rings in the following order:
   a. Oil control ring
   b. 2nd compression ring
   c. Top compression ring
   d. **Identification marks must face up. (Top ring has UP–TOP. 2nd ring has UP–2ND).**

NOTE:
The oil ring does NOT have identification marks. There is no top or bottom, it may be installed in either direction.

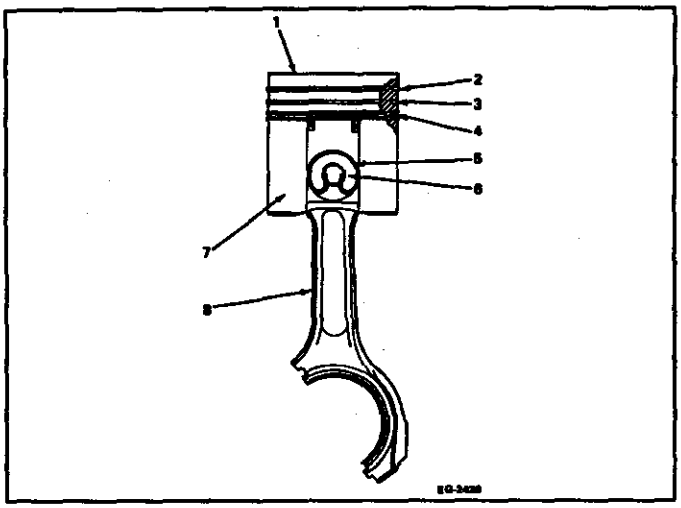
e. Stagger the ring gaps 120° apart.



1. **Piston Ring Expander Tool**
2. **Top Ring**
3. **Intermediate Ring**
4. **Oil Control Ring**
5. **Piston**

FIGURE 9–40

REASSEMBLY OF CONNECTING RODS, PISTONS, RINGS AND LINERS



1. **Piston Crown**
2. **Top Ring**
3. **Intermediate Ring**
4. **Oil Control Ring**
5. **Retaining Ring**
6. **Piston Pin**
7. **Piston Skirt**
8. **Connecting Rod**

FIGURE 9–41

3. Assemble the piston and connecting rod as follows: Refer to **FIGURE 9–41.**

   a. Lubricate the connecting rod piston pin bushing with clean engine oil.

   b. Install the retaining ring at one end of the piston pin bore.

   c. Insert the connecting rod into the piston aligning bored holes of the rod and piston (the short side of the split on the crank end of the rod is to be toward the side of the piston marked "Camside").

   d. Align the pin bores and insert the piston pin.

   e. Install the second retaining ring.

NOTE:

Connecting rod and cap matching numbers must be opposite the camside of piston.

REASSEMBLY OF CONNECTING RODS, PISTONS, RINGS AND LINERS

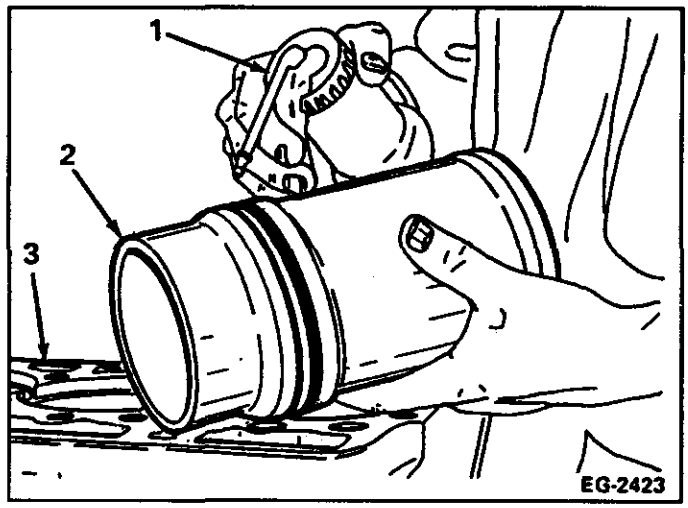
9.4.1 Cylinder Liners

1. Lubricate the O–rings with Lubriplate and install one into each cylinder liner groove, (without twist). Refer to **FIGURE 9–42**.

NOTE:
Lightly lubricate O–ring area of liner and lower counterbore of crankcase to ease installation and avoid O–ring twist or pinch.

NOTE:
Each cylinder liner uses two O–rings.

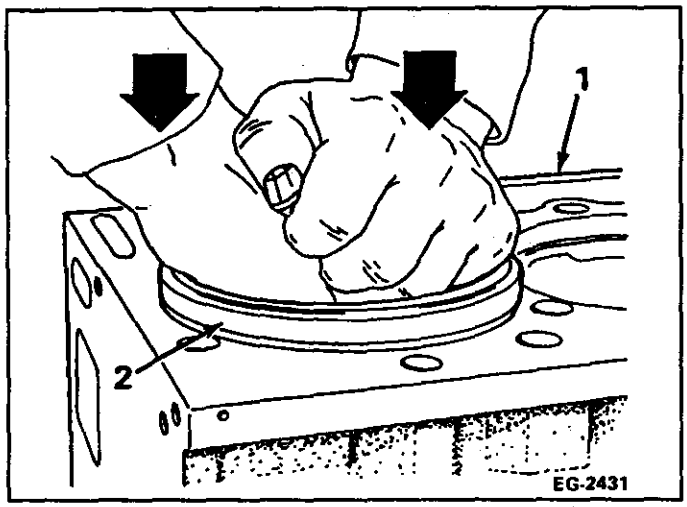
2. If required, assure the proper shim(s) is installed, in the crankcase counterbore, so cylinder liner protrusion is within specifications. Refer to "Cylinder Liner Fitting Procedure", **FIGURE 9–7**.



1. Oil Can
2. Liner
3. Crankcase

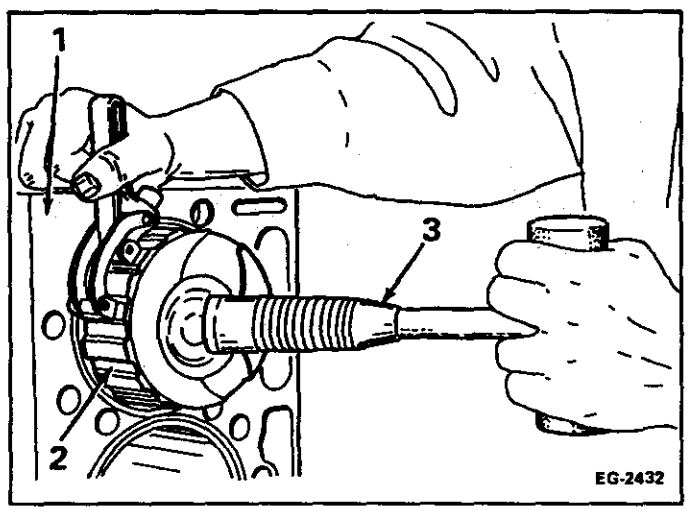
FIGURE 9–42

REASSEMBLY OF CONNECTING RODS, PISTONS, RINGS AND LINERS



1. Crankcase
2. Cylinder liner

FIGURE 9–43



1. Crankcase
2. Ring Compressor
3. Hammer

FIGURE 9–44

3. Be sure the O–rings are properly aligned in the groove.
4. Apply Lubriplate to the lower crankcase counterbore, then install the liner carefully. If reusing liner, rotate 90° from original position and install in the same bore from which it was removed. Refer to **FIGURE 9–43.**

9.4.2 Piston & Rod Assembly

1. Lubricate the piston rings with clean engine oil and stagger the ring gaps 120° apart.
2. Install the piston ring compressor J41166 over the piston rings.
3. Lubricate the cylinder liner with clean engine oil.

NOTE:

The piston and rod assemblies can be installed by turning the crankshaft three times. Position the No. 1 and 6 crankpins at BDC. Install the No. 1 and 6 piston assemblies. Repeat this procedure for the Nos. 2 and 5 and Nos. 3 and 4 piston and rod assemblies.

4. Insert piston and connecting rod assembly into liner. The numbers on connecting rod must face away from camshaft while markings on top of piston faces toward the camshaft side of the engine.
5. Push piston into the liner with a wooden or plastic handle. Refer to **FIGURE 9–44.**

REASSEMBLY OF CONNECTING RODS, PISTONS, RINGS AND LINERS

6. Guide the connecting rod into place on the crankpin. Refer to **FIGURE 9–45**.

9.4.3 Connecting Rod Bearing Inserts & Caps

NOTE:
Refer to "Bearing Fitting Procedure" earlier in this section for running and side clearance procedures.

1. With the bearing inserts lubricated, install the connecting rod cap so the numbers on the cap and rod match. Refer to **FIGURE 9–46**.

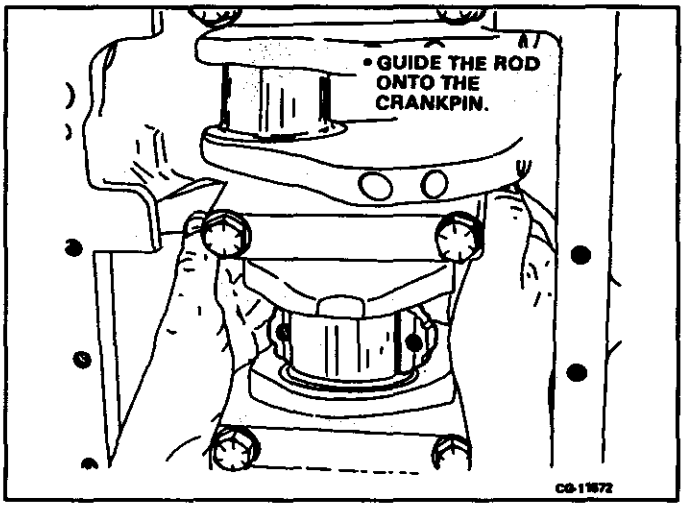


FIGURE 9–45

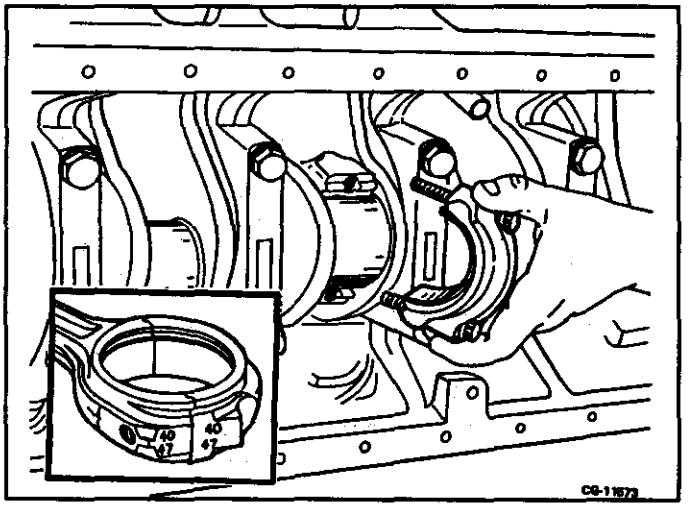


FIGURE 9–46

REASSEMBLY OF CONNECTING RODS, PISTONS, RINGS AND LINERS

2. Install mounting bolts, by hand into connecting rods until finger–tight. Tighten mounting bolts to special torque. Refer to **FIGURE 9–47**.
3. Check connecting rod side clearance (See "Specifications".) Refer to **FIGURE 9–29.**

9.4.4 Priming The Lubricating System

When the engine has been assembled, it is recommended to lubricate the engine with oil before starting. This is done to prevent any damage to internal parts. The following procedure is the preferred method to use when priming the lubricating system.

9.4.4.1 Preferred Method

NOTE:
Install new lube oil filters.

1. Pressure prime the lubrication system with oil, prior to starting as follows:
   a. Inject sufficient oil into the engine to fill the oil filters and charge the entire system.

CAUTION

DO NOT rotate the engine when priming with oil to prevent accidental starting.

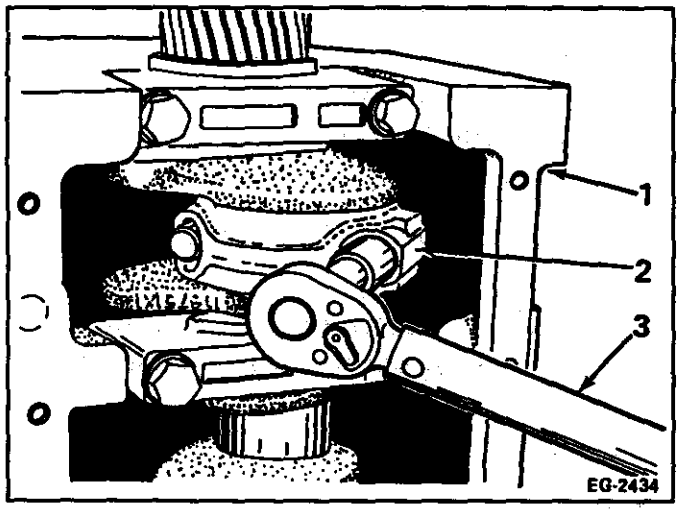


FIGURE 9–47

1. **Crankcase**
2. **Connecting Rod Mounting Bolt (12)**
3. **Torque Wrench**

REASSEMBLY OF CONNECTING RODS, PISTONS, RINGS AND LINERS

b. After priming, check the oil level before the engine is put back into service. Refer to chart for proper oil capacity.

Crankcase Refill Capacities:

- ☐ 28 qts. with filter change
- ☐ 22 qts. without filter change

NOTE:

Engines equipped with a bypass filtering system require additional oil.

9.4.4.2 Alternate Method

NOTE:

Be sure the engine was well oiled during reassembly in order to use this procedure. If the engine was not well oiled do not use this procedure, refer to Section 9.4.4 Priming The Lubricating System and 9.4.4.1 Preferred Method, in this section for further information.

Use the following instructions prior to starting the engine. This is done to prevent any damage to internal parts.

1. Spin but **DO NOT** start, the engine using the cranking motor until oil pressure is read on the oil pressure gauge.
2. When oil pressure is read, the engine may be started.

9.4.5 Engine Run–In Procedure

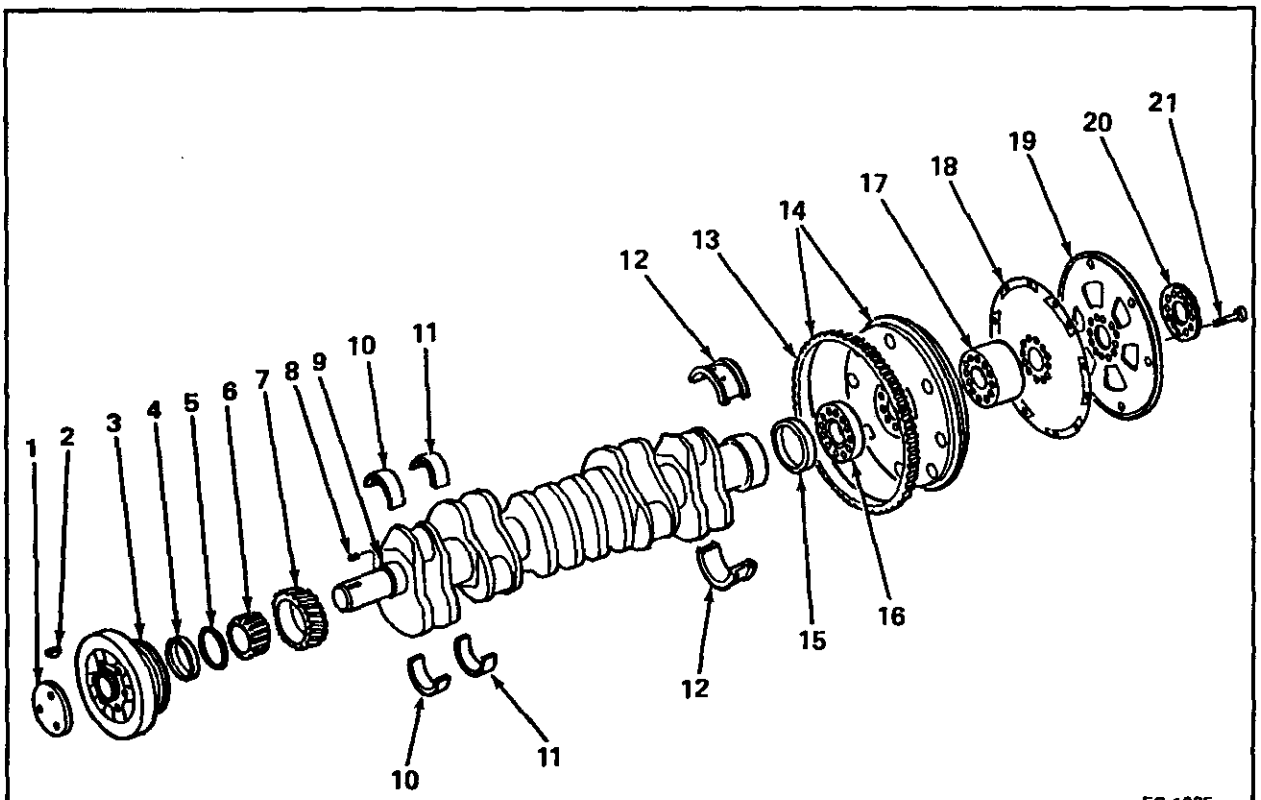
NOTE:

After installing new pistons and/or new rings, the engine must be "run–in" as follows:

1. Operate engine at low idle (no load) for 5 minutes.
   a. Check for leaks in the water, lube oil, fuel and air induction systems.
2. Operate engine at 3/4 rated speed (r/min) and 1/2 to 3/4 throttle for 10 minutes.
3. Operate engine at rated speed and full throttle for 30 minutes. Recheck for lube oil, fuel, water and air leaks.

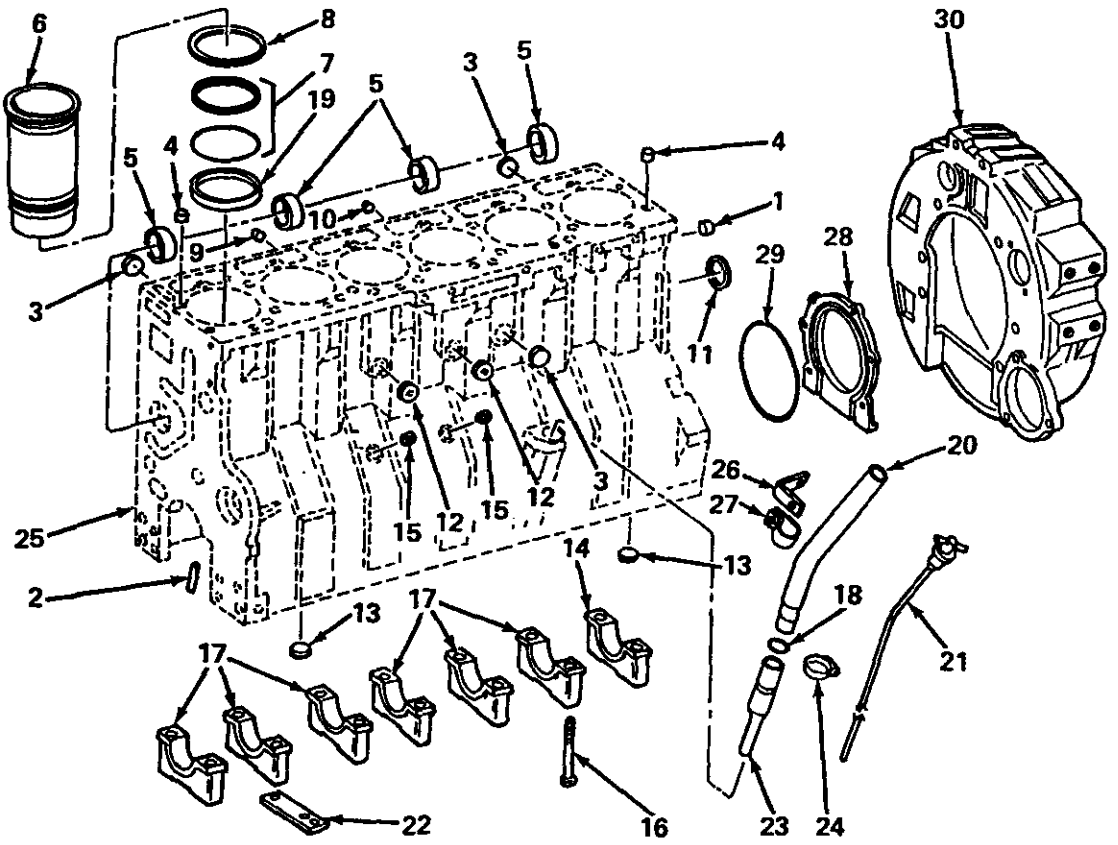
10 VIBRATION DAMPER, CRANKSHAFT, MAIN BEARINGS, FLYWHEEL & CRANKCASE

10.1 CRANKSHAFT, BEARINGS, FLYWHEEL AND RELATED COMPONENTS EXPLODED VIEW



1. Damper Retaining Plate
2. Woodruff Key
3. Vibration Damper
4. Front Wear Liner
5. Seal Washer
6. Oil Pump Drive Spline
7. Crankshaft Gear
8. Roll Pin
9. Crankshaft
10. Crankshaft Bearings
11. Connecting Rod Bearings
12. Thrust Bearing
13. Flywheel Ring Gear
14. Flywheel
15. Rear Oil Seal
16. Crankshaft To Flexplate Adapter
17. Flywheel Adapter
18. Flexplate (Automatic Transmission)
19. Flexplate (Automatic Transmission)
20. Reinforcing Ring
21. Flywheel Mounting Bolt

FIGURE 10–1 Crankshaft, Bearings, Flywheel and Related Components.



1. Cup Plug
2. Oil Jet Cooling Tube
3. Cup Plug
4. Cylinder Head Alignment Dowel
5. Camshaft Bearing Set
6. Cylinder Liner
7. Cylinder Liner O–rings (2)
8. Cylinder Liner Shim
9. Plug
10. Plug
11. Camshaft Seal Ring
12. Plug
13. Plug
14. Number 7 Main Bearing Cap (Thrust)
15. Plug
16. Main Bearing Cap Mounting Bolt
17. Main Bearing Caps
18. Oil Level Gauge Tube Seal
19. Lower Counterbore Insert
20. Oil Filler Tube
21. Oil Level Gauge
22. Oil Inlet Tube Support Bracket (If Applied)
23. Oil Level Gauge Lower Tube
24. Oil Filler Tube Clamp
25. Crankcase
26. Oil Filler Tube Brace
27. Oil Filler Tube Brace Clamp
28. Rear Oil Seal Carrier
29. Rear Oil Seal Carrier Gasket
30. Flywheel Housing

FIGURE 10–2 Crankcase and Related Parts.

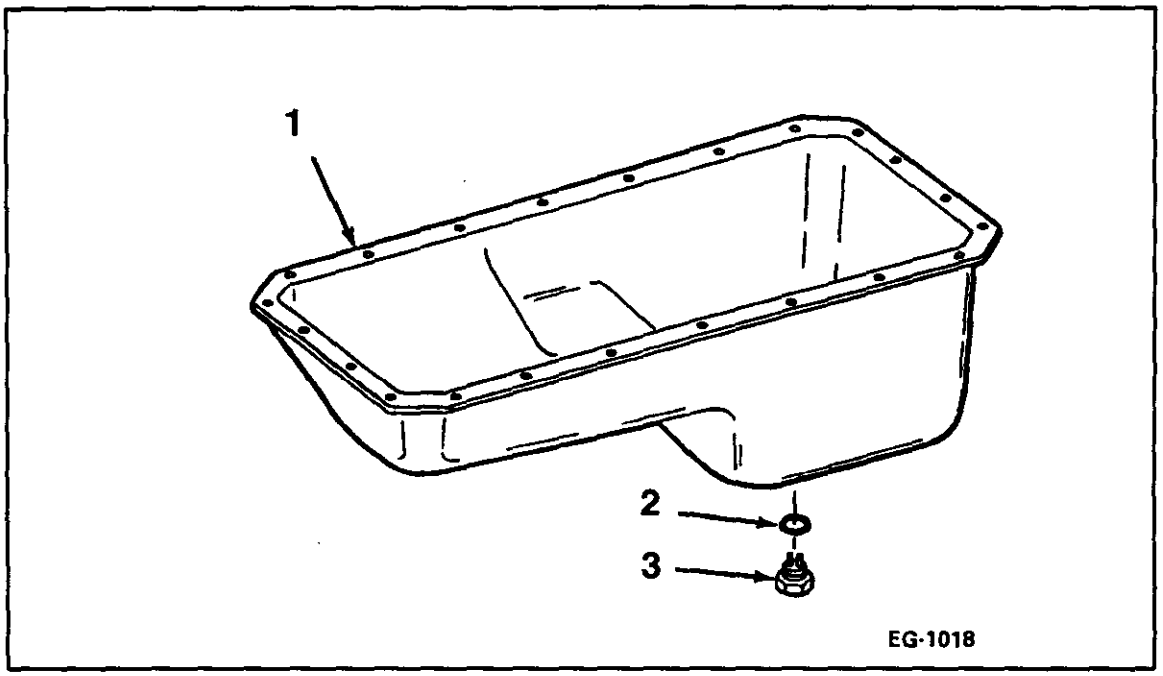


FIGURE 10–3

1. **Oil Pan**
2. **Oil Drain Plug Gasket**
3. **Oil Drain Plug**

10.2 SPECIFICATIONS

DIMENSION	VALUES
CRANKSHAFT:	
Type	Steel Forging, Induction Hardened, Grindable
Main Bearing Journal Diameter	
Standard Size	3.535 ± 0.0006 in. (89.7 ± 0.00152mm)
.010" Undersize	3.525 ± 0.0006 in. (89.5 ± 0.00152 mm)
.020" Undersize	3.515 ± 0.0006 in. (89.2 ± 0.00152 mm)
.030" Undersize	3.505 ± 0.0006 in. (89.0 ± 0.00152 mm)
Main Bearing Width (Except Rear Thrust)	1.286 ± 0.010 in. (32.7 ± 0.254 mm)
Main Bearing Journal Max. Out–of–Round	0.002 in. (0.05 mm)
Main Bearing Thrust Face Runout (TIR Max.)	0.001 in. (0.025 mm)
Main Bearing Journal Taper (Max./In.)	0.0028 in. (0.0076 mm)
Main Bearing Journal Fillet Radius	0.225/0.050 in. (5.72/1.27 mm)
Rod Journal Fillet Radius	0.225/0.050 in. (5.72/1.27 mm)
Rear Oil Seal Journal Runout (Max.)	0.003 in. (0.08 mm)
Damper Mounting Area Runout (Max.)	0.0005 in. (0.013 mm)
Flywheel Mounting Surface Runout (Max.)	0.002 in. (0.05 mm)
Number of Main Bearings	7
Thrust Taken By	Rear Main
Thrust Bearing Journal Length	
Standard Size to .020" Undersize	1.3545 ± .010 in. (34.4 ± 0.254 mm)
.030" Undersize	1.3545 ± .010 in. (34.4 ± 0.254 mm)
Main Bearing to Crankshaft Clearance	0.0047/0.0018 in. (0.120/0.046 mm)
Connecting Rod Journal Diameter	
Standard Size	3.1500 ± 0.0006 in. (80.0 ± 0.0152 mm)
.010" Undersize	3.1400 ± 0.0006 in. (79.7 ± 0.0152 mm)
.020" Undersize	3.1300 ± 0.0006 in. (79.5 ± 0.0152 mm)
.030" Undersize	3.1200 ± 0.0006 in. (79.2 ± 0.0152 mm)
Connecting Rod Bearing Width	1.385 in. (35.2 mm)
Connecting Rod Journal Max. Out–of–Round	.00025 in. (0.0064 mm)