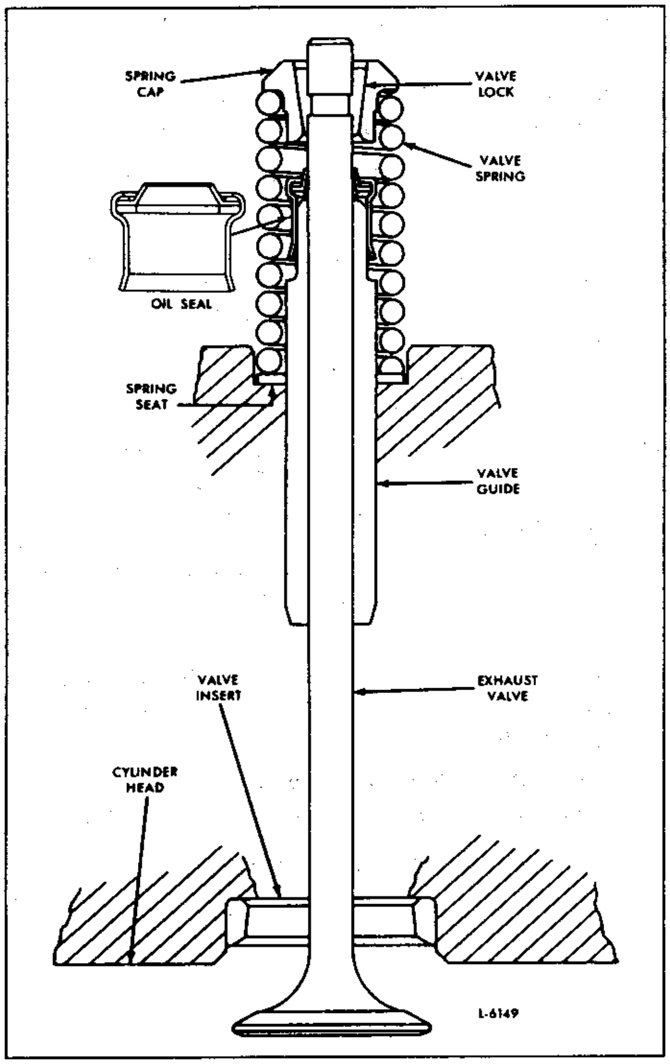


Fig. 18 – Current Valve Guide Oil Seal

Install Exhaust Valves and Springs

When installing exhaust valves, check to see that the valves are within the specifications (Figs. 13 and 14). Also, do not use "N" pistons with former four–valve cylinder head assemblies unless the valves are flush with the cylinder head. If the valves are not flush, it may be necessary to regrind the valve seats so that the valves will be flush with the bottom surface of the cylinder head.

The distance from the top of the four–valve cylinder head to the bottom of the valve spring seat counterbore is 1.175" ± .015" in current design cylinder heads or 1.078" ± .015" in former design heads. The former head was discontinued in May, 1971.

Be sure and install the correct parts in the four–valve cylinder head. Current design cylinder heads are equipped with the thin valve spring seats (.060") and current design exhaust valves (Fig. 17). To facilitate replacement of a four–valve head on an engine using the former exhaust valves, the proper quantity of the thick spring seats (.150") must be used.

Service cylinder heads are of the current design. The current thin valve springs seats (.060") are included with each cylinder head as a shipped loose item.

Install exhaust valves as follows:

1. Lubricate the valve stems with sulphurized oil (E.P. type) and slide the valves all the way into the guides. *If reconditioned valves are used, install them in the same relative location from which they were removed.*
2. Hold the valves in place temporarily with a strip of masking tape. Then, turn the cylinder head right side up on the work bench. Place a board under the head to support the valves and to provide clearance between the cam followers and the bench.
3. Install the valve spring seats.
4. Install the valve guide oil seals, if used, on the valve guides as follows:
   a. Lubricate the oil seal and the valve stem with engine oil and start the oil seal carefully over the valve stem.

Fig. 19 – Checking Valve Opening Pressure with Gage J 25076–B

b. Using installer J 29579 drive the seal down slowly until the tool bottoms on the cylinder head (spring seat washer removed). Then, tap the tool with a mallet for final location and seating of the seal.

NOTICE: The tool positions the seal so that it does not bottom out on the shoulder of the valve guide. If the oil seal is installed too far, it will be distorted and will not function as an effective seal.

c. Install the spring seat washer over the valve guide and let it drop into the valve counterbore (Fig. 18).

5. Install the valve springs and valve spring caps.

6. Thread the valve spring compressor J 7455 into one of the rocker shaft bolt holes in the cylinder head (Fig. 2).

7. Apply pressure to the free end of the tool to compress the valve spring and install the two–piece tapered valve lock. Exercise care to avoid scoring the valve stem with the valve cap when compressing the spring.

NOTICE: If valve guide oil seals are used, compress the valve spring only enough to permit installation of the valve locks. Compressing the spring too far may result in damage to the oil seal.

8. Release the tool and install the valve locks on the remaining exhaust valves in the same manner.

9. Check the position of the exhaust valve (Figs. 13 and 14).

10. Support the cylinder head at each end with wood blocks and remove the masking tape so that the exhaust valves are free. Then, give the ends of the valve stem a sharp tap with a plastic hammer to seat the valve locks. This will aid in the proper seating of the valve locks and reduce the chances of failure.

11. With the exhaust valves installed in the cylinder head, use spring checking gage J 25076–B and note the gage reading the moment the exhaust valve starts to open (Fig. 19). The minimum pressure required to start to open the exhaust valve must not be less than 33 pounds for a two–valve cylinder head or 25 pounds for a four–valve cylinder head.

12. Install the injectors, rocker arms, shafts, brackets and any other parts that were previously removed from the cylinder head.

13. Install the cylinder head. Refer to *Pre–Installation Inspection* and *Install Cylinder Head* in Section 1.2.

14. Perform a complete engine tune–up.

VALVE ROCKER COVER

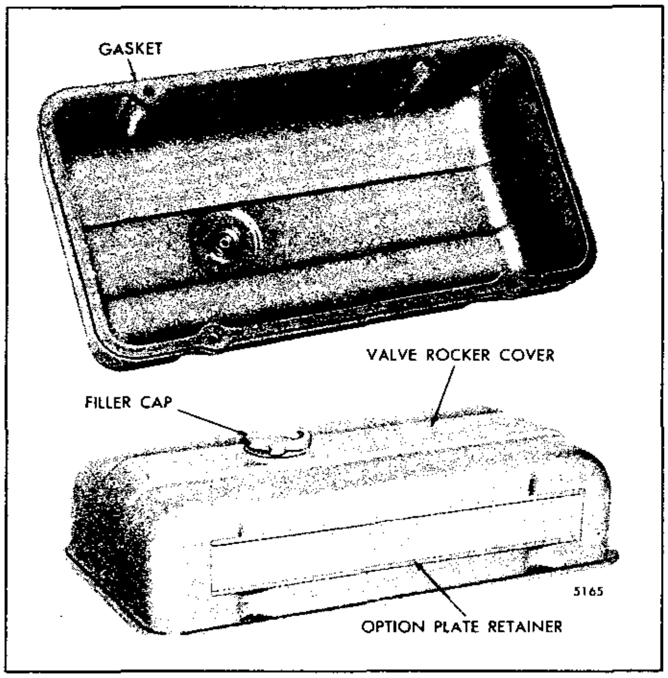


Fig. 1 – Typical Stamped Steel Valve Rocker Cover Assembly

The valve rocker cover assembly completely encloses the valve and injector rocker arm compartment at the top of the cylinder head (Figs. 1 and 2). The top of the cylinder head is sealed against oil leakage by a gasket located in the flanged edge of the cover.

- An option label is attached to the cover on each In–line engine and to one of the covers on a V–type engine. An option plate inserted into a retainer (Fig. 2) was formerly used.

The valve rocker cover assembly on certain engines may include a breather assembly or an oil filler, depending upon the engine application.

Remove and Install Valve Rocker Cover

Clean the valve rocker cover before removing it from the engine to keep dust or dirt from entering the valve mechanism. Then, loosen the bolts (cast aluminum rocker cover) or the screws (stamped steel rocker cover) and lift the cover straight up from the cylinder head. Use a new gasket when reinstalling the cover.

- Before a die cast rocker cover is installed on a cylinder head, it is important that the silicone gasket be properly installed in its groove in the rocker cover.

1. Clean and blow out the groove in the rocker cover with compressed air. Oil in the rocker cover groove or on the silicone gasket will make it difficult to install.

   CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

2. Press the stem side of the new T–shaped gasket down into the groove at the four corners of the cover first. Then press the remainder of the gasket into place in the groove. Be sure the stem of the entire gasket bottoms in the groove. When the gasket is completely installed in the groove it should not fall out.
3. Before installing the rocker cover, lubricate the cylinder head rail and the flat surface of the gasket with a thin film of engine oil. This will keep the gasket from sticking to the cylinder head rail.
4. Tighten the 3/8″–16 cast aluminum rocker cover hold–down bolts to 8–13 lb–ft (11–18 N·m) torque. Do not overtighten.

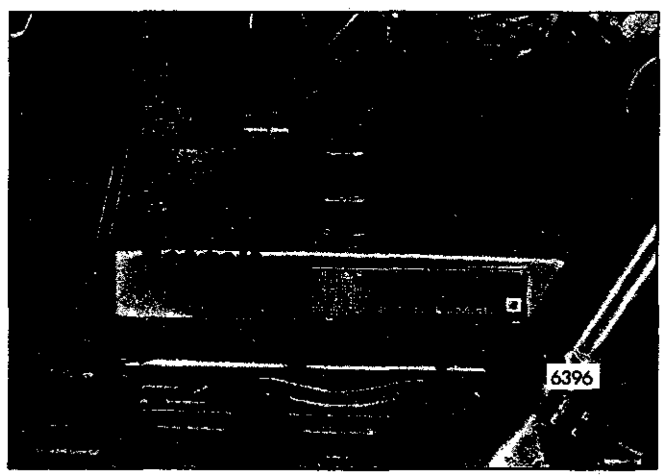


Fig. 2 – Die–Cast Aluminum Rocker Cover on 6V–53T Engine (Former Option Plate Shown)

CRANKSHAFT

The crankshaft is a one–piece steel forging, heat–treated to ensure strength and durability (Figs. 1 and 2). All main and connecting rod bearing journal surfaces, oil seal surfaces and fillets on the 4–53 vehicle engine (since 4D–146948) and 6V crankshafts are induction hardened. All Series 53 engine crankshaft fillets are now induction hardened effective with 3D–187345 and 4D–201209 (non–vehicle engines).

Complete static and dynamic balance of the crankshaft has been achieved by counterweights incorporated in the crankshaft.

The crankshaft end play is controlled by thrust washers located at the rear main bearing cap of the engine. Full pressure lubrication to all connecting rod and main bearings is provided by drilled passages within the crankshaft and cylinder block.

On certain 4–53 and 6V engines, a crankshaft with splines at the front end is used. These engines use a splined crankshaft pulley and pulley mounting components.

On In–line and 6V engines, six tapped holes are provided in the rear end of the crankshaft for attaching the flywheel.

On the 8V engine, two dowels are provided in the rear end of the crankshaft for locating the flywheel and six tapped holes are provided for attaching the flywheel. One hole is unequally spaced so that the flywheel can be attached in only one position.

The 8V engine crankshaft no longer incorporates the two dowels in the flywheel end of the crankshaft. However, the former and current crankshafts are interchangeable.

In–line engine main bearing journals are 3.000" in diameter and the connecting rod journals are 2.500" in diameter. On the V–type engine, the main bearing journals are 3.500" in diameter and the connecting rod journals are 2.750" in diameter.

Effective with 8V engine serial number 8D–149, the 2.878" diameter position at the front of the crankshaft serves as a journal for the outboard bearing (bushing type). A spacer (sleeve) is used on the 2.500" diameter position to provide a replaceable contact surface for the front oil seal which is located in the outboard bearing support assembly. Prior to engine 8D–149, the 2.878" diameter position served as a contact surface for the front oil seal assembled in the front cover.

Remove Crankshaft

When removal of the crankshaft becomes necessary, first remove the transmission, then proceed as follows:

1. Clean the exterior of the engine.
2. Drain the cooling system.
3. Drain the engine crankcase.
4. Remove all engine–to–base attaching bolts. Then, with a chain hoist and sling attached to the lifter brackets at each end of the engine, remove the engine from its base.

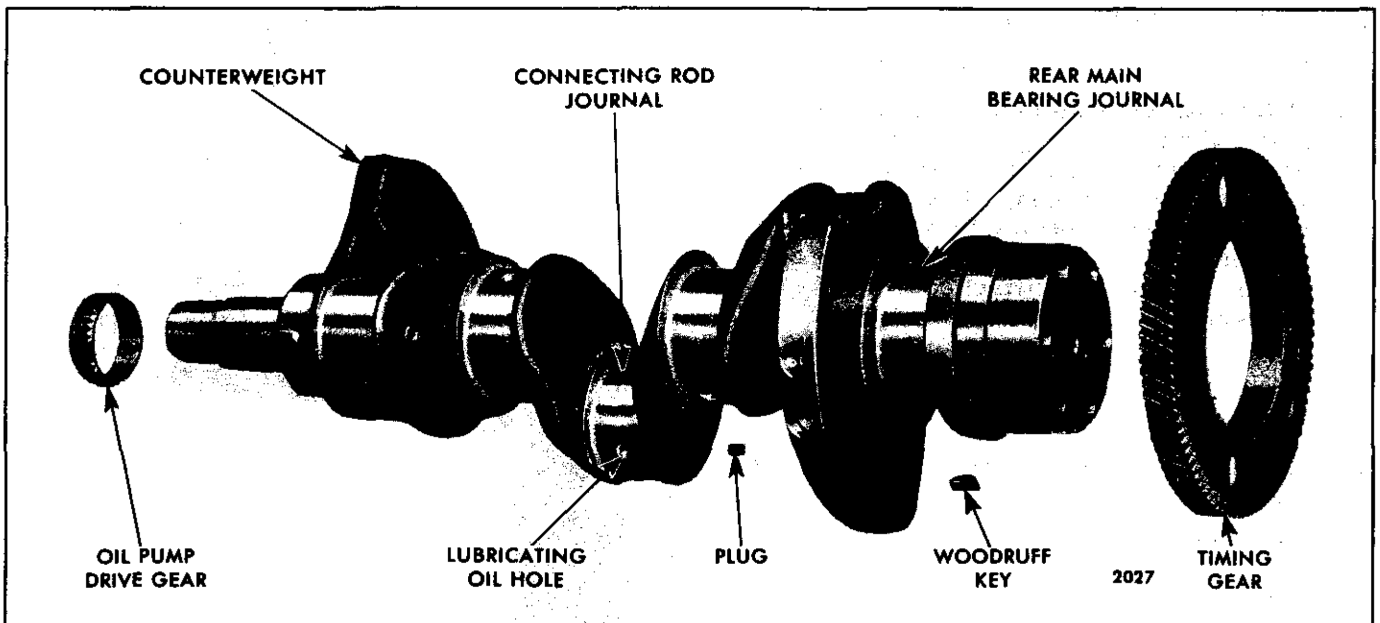


Fig. 1 – Crankshaft Details and Relative Location of Parts (3–53 Crankshaft Shown)

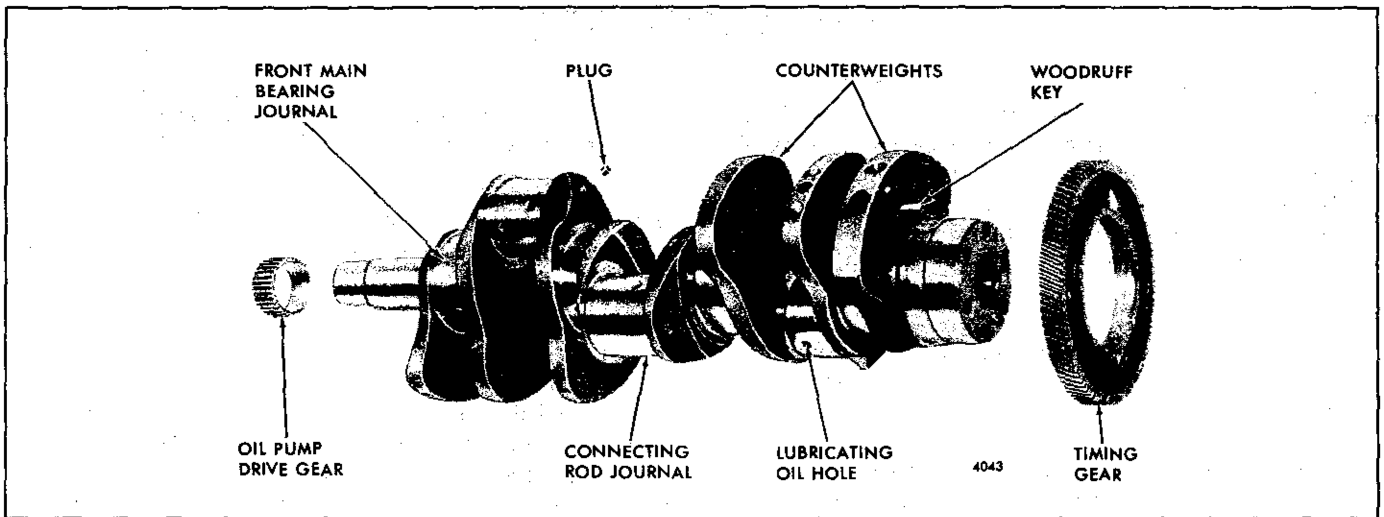


Fig. 2 – Crankshaft Details and Relative Location of Parts (6V Crankshaft Shown)

5. Remove all of the accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an overhaul stand.

6. Mount the engine on an overhaul stand and fasten it securely to the mounting plate.

CAUTION: Be absolutely sure the engine is securely attached to the stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the stand.

7. Remove the oil pan.

8. Remove the oil pump inlet pipe and screen.

9. Remove the flywheel and flywheel housing.

- **CAUTION: Extreme caution should be used when removing a flywheel by either leaving one or two bolts in the flywheel, or installing two suitable guide pins to support the flywheel until a lifting tool or some other suitable safe lifting device is attached to the flywheel.**

10. Remove the crankshaft pulley.

11. Remove the front engine support.

12. Remove the engine lower front cover and oil pump assembly.

13. Remove the cylinder head(s).

14. On the V–type engines, remove the main bearing cap stabilizers.

15. Remove the connecting rod bearing caps.

16. Remove the main bearing caps.

17. Remove the thrust washers from each side of the rear main bearing.

18. Remove the pistons, connecting rods and liners.

19. Remove the crankshaft, including the timing gear (Fig. 3).

20. Refer to Section 1.7.5 for removal of the crankshaft timing gear and Section 4.1 for the procedure covering removal of the oil pump drive gear.

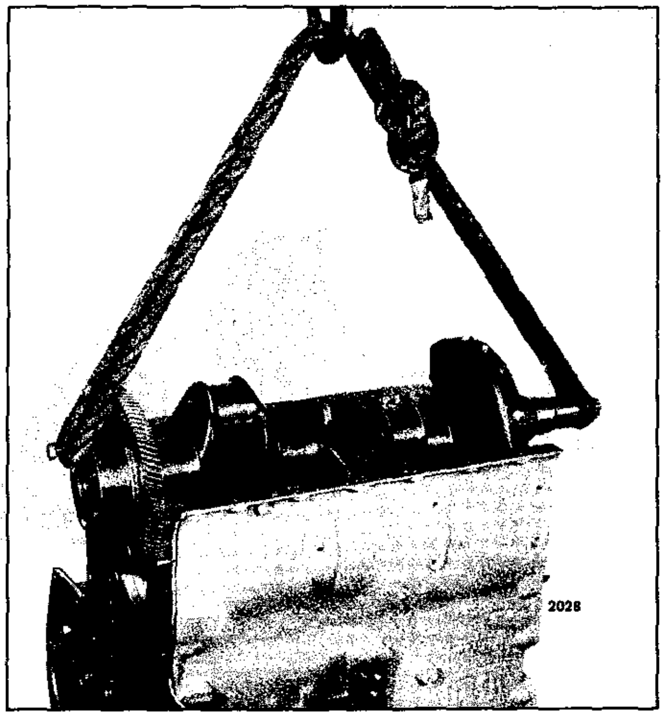


Fig. 3 – Removing or Installing Crankshaft

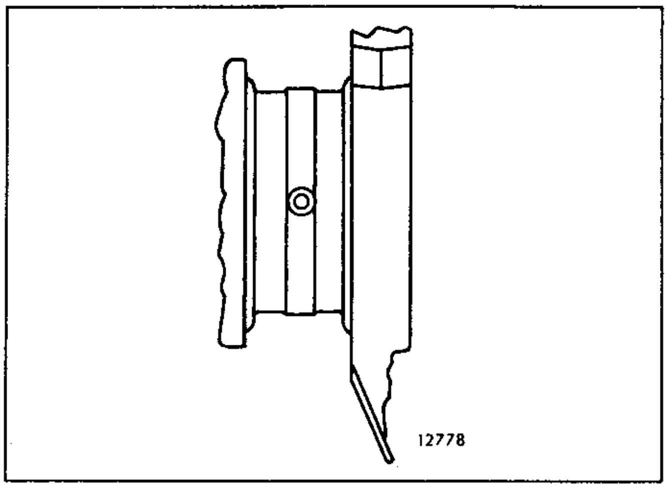


Fig. 4 – Typical Ridging of Crankshaft

Inspection

After the crankshaft has been removed, clean and inspect it thoroughly before reinstalling it in the engine.

Remove the plugs and clean out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air. Then, reinstall the plugs and torque to 10–12 lb-ft (14–16 N·m). Use tool J 34650 to install the new sealant-coated 1/8″-27 pipe plugs.

Inspect the keyways for evidence of cracks or wear. Replace the crankshaft, if necessary.

If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heat treatment has probably been destroyed.

Used crankshafts will sometimes show a certain amount of ridging caused by the groove in the upper main bearing shell or lower connecting rod bearing shell (Fig. 4). Ridges exceeding .0002″ must be removed. If the ridges are not removed, localized high unit pressures on new bearing shells will result during engine operation.

The ridges may be removed by working crocus cloth, wet with fuel oil, around the circumference of the crankshaft journal. If the ridges are greater than .0005″, first use 120 grit emery cloth to clean up the ridge, 240 grit emery cloth for finishing and wet crocus cloth for polishing. Use of a piece of rawhide or other suitable rope wrapped around the emery cloth or crocus cloth and drawn back and forth will minimize the possibility of an out-of-round condition developing (keep the strands of rawhide apart to avoid bind). If rawhide or rope is not used, the crankshaft should be rotated at intervals. If the ridges are greater than .001″, the crankshaft may have to be reground.

Carefully, inspect the front and rear end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surface will result in oil leakage at this point.

Slight ridges on the crankshaft oil seal contact surface may be cleaned up with emery cloth and crocus cloth in the same manner as detailed for the crankshaft journals. If the crankshaft cannot be cleaned up satisfactorily, the oil seal may be repositioned in the flywheel housing and front cover as outlined in Section 1.3.2.

Check the crankshaft thrust surfaces for excessive wear or grooving. If only slightly worn, the surfaces may be dressed with a stone. Otherwise, it will be necessary to regrind the thrust surfaces.

Check the oil pump drive gear and the crankshaft timing gear for worn or chipped teeth. Replace the gears, if necessary.

On an 8V engine, check the crankshaft dowel extension. The dowels should not extend more than .500″ from the crankshaft.

Inspect the crankshaft for cracks as outlined under *Inspection for Cracks.*

Crankshaft Measurements

Support the crankshaft on its front and rear journals on V-blocks, in a lathe or the inverted engine block with only the front and rear upper bearing shells in place and check the alignment at the adjacent intermediate main journals with a dial indicator.

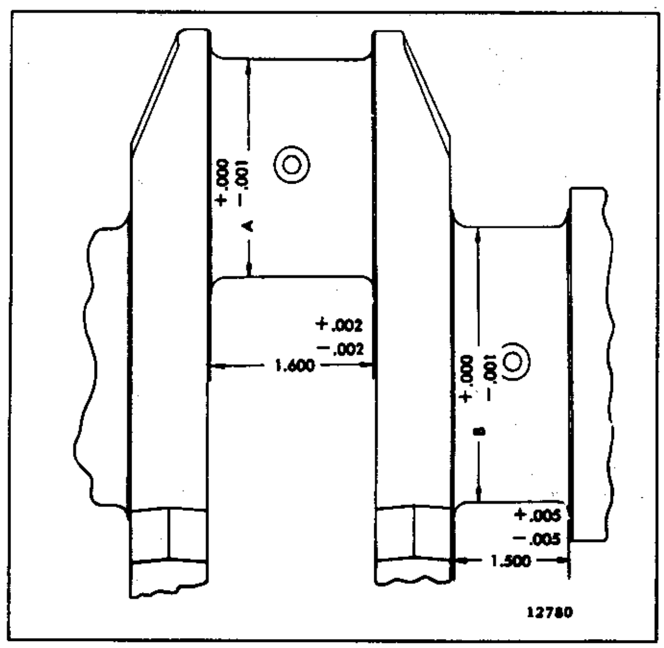


Fig. 5 – Dimensions of Crankshaft Journals – In-Line Engine

On 2-53, 3-53, 4-53 and 6V crankshafts, the maximum runout on the intermediate journals must not exceed .002" total indicator reading.

On an 8V crankshaft, the maximum runout at the No. 2 and 4 journals must not exceed .002", the maximum runout at No. 3 journal must not exceed .004" and the maximum runout on the outboard journal must not exceed .001".

On the 6V and 8V crankshaft, when the high spots of runout on the adjacent journals is in opposite directions, the sum must not exceed .003" total indicator reading. When the high spots of runout on the adjacent journals is in the same direction, the difference must not exceed .003" total indicator reading. When the high spots of runout on the adjacent journals are at right angles to each other, the sum must not exceed .004" total indicator reading, or .002" on each journal. If the runout limit is greater than given above, the crankshaft must be replaced.

Measure all of the main and connecting rod bearing journals (Figs. 5 and 6). Measure the journals at several places on the circumference so that taper, out-of-round and bearing clearances can be determined. If the crankshaft is worn so that the maximum connecting rod journal-to-bearing shell clearance (with new shells) exceeds .0045" (In-line engine) or .0041" (V-type engine) or the main bearing journal-to-bearing shell clearance (with new shells) exceeds .0040" (In-line and V-type engines), the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest .0002". Also, if the journal taper or the out-of-round is greater than .003", the crankshaft must be reground.

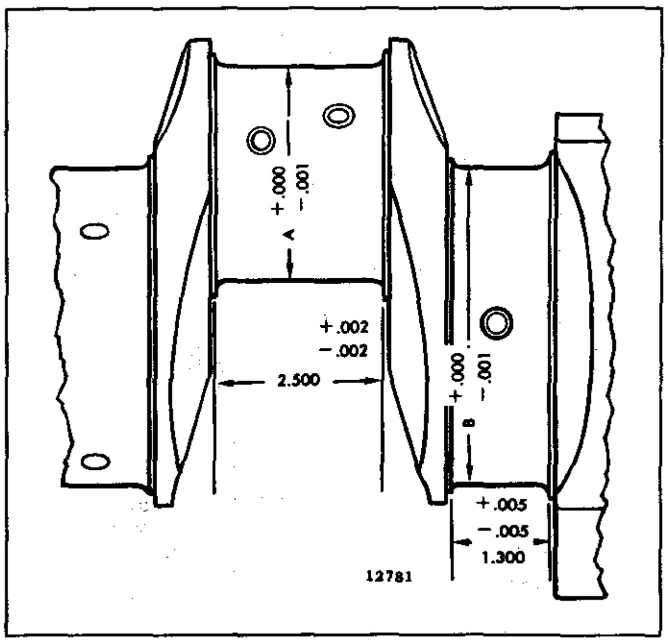


Fig. 6 - Dimensions of Crankshaft Journals - V-Type Engine

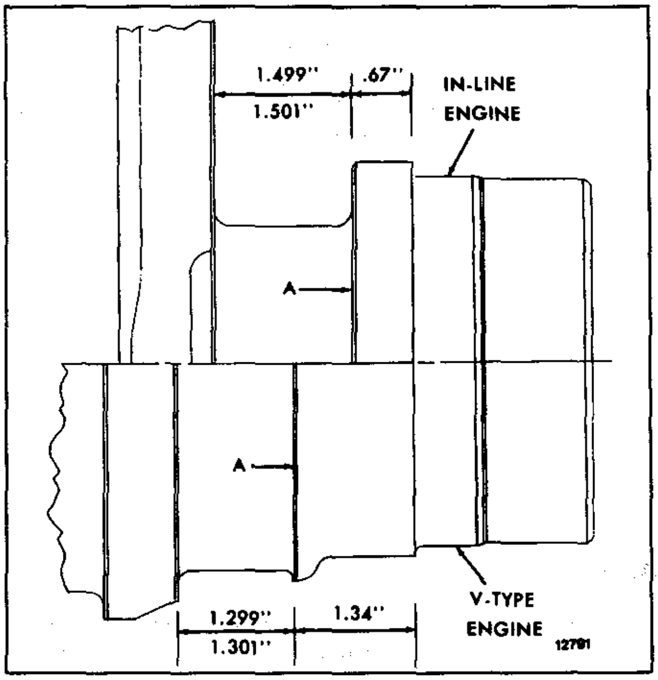


Fig. 7 - Standard Dimensions at Crankshaft Thrust Surfaces — In-Line and V-Type Engines

Also, measure the crankshaft thrust surfaces (Fig. 7).

Inspection for Cracks

Carefully, check the crankshaft for cracks which start at an oil hole and follow the journal surface at an angle of 45° to the axis. Any crankshaft with such cracks must be rejected. Several methods of determining the presence of minute cracks not visible to the eye are outlined below.

Magnetic Particle Method: The part is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which causes the magnetic particles in the powder or solution to gather there, effectively marking the crack. The crankshaft must be demagnetized after the test.

Fluorescent Magnetic Particle Method: This method is similar to the magnetic particle method, but is more sensitive since it employs magnetic particles which are fluorescent and glow under "black light". Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the "black light".

Fluorescent Penetrant Method: This is a method which may be used on both *non-magnetic and magnetic* materials. A highly fluorescent liquid penetrant is applied to the part. Then, the excess penetrant is removed from the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection is carried out under "black-light".

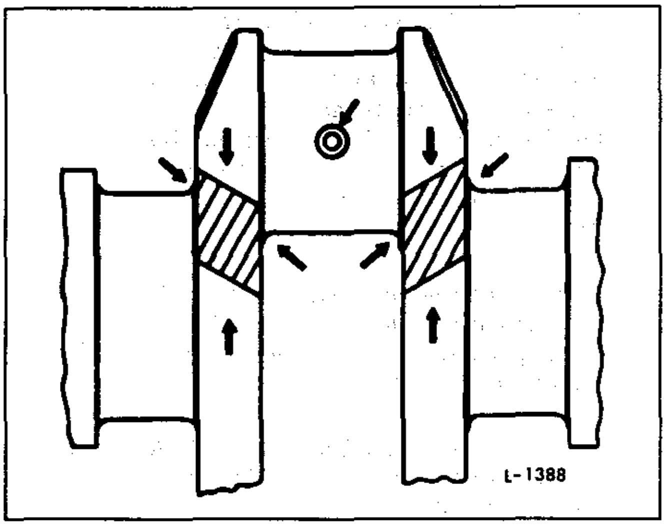


Fig. 8 – Critical Crankshaft Loading Zones

Non–Fluorescent Penetrant Method: The test area being inspected is sprayed with "Spotcheck" or Dye Check. Allow one to thirty minutes to dry. Remove the excess surface penetrant with clean cloths premoistened with cleaner/remover. DO NOT flush surface with cleaner/remover because this will impair sensitivity. Repeat this procedure with additional wipings until residual surface penetrant has been removed. Shake developer thoroughly until agitator rattles. Invert spray can and spray short bursts to clear valve. Then, spray this even developer film evenly over the test area being inspected. Allow developer film to dry completely before inspecting. Recommended developing time is 5 to 15 minutes.

The above methods provide basic instructions. Specific details should be obtained from the supplier of the equipment or material.

A majority of indications revealed by the above inspection methods are normal and harmless and only in a small percentage of cases is reliability of the part impaired when indications are found. Since inspection reveals the harmless indications with the same intensity as the harmful ones, detection of the indications is but a first step in the procedure. **Interpretation** of the indications is the most important step.

All Detroit Diesel crankshafts are magnetic particle inspected after manufacture to ensure against any shafts with harmful indications getting into the original equipment or factory parts stock.

Crankshaft failures are rare and when one cracks or breaks completely, it is very important to make a thorough inspection for contributory factors. Unless abnormal conditions are discovered and corrected, there will be a repetition of the failure.

There are two types of loads imposed on a crankshaft in service — a *bending* force and a *twisting* force. The design of the shaft is such that these forces produce practically no stress over most of the surface. Certain small areas, designated as critical areas, sustain most of the load (Fig. 8).

Bending fatigue failures result from bending of the crankshaft which takes place once per revolution.

The crankshaft is supported between each of the cylinders by a main bearing and the load imposed by the gas pressure on top of the piston is divided between the adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, bearing failures, a loose or broken bearing cap, or unbalanced pulleys. Also, drive belts which are too tight may impose a bending load upon the crankshaft.

Failures resulting from bending start at the pin fillet and progress throughout the crank cheek, sometimes extending into the journal fillet. If main bearings are replaced due to one or more badly damaged bearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

Torsional fatigue failures result from torsional vibration which takes place at high frequency.

A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, referred to as torsional vibration, which imposes high stresses at the locations shown in Fig. 8.

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek. Connecting rod journal failures are usually at the fillet at 45° to the axis of the shaft.

A loose, damaged or defective vibration damper, a loose flywheel or the introduction of improper or additional pulleys or couplings are usual causes of this type of failure. Also, overspeeding of the engine or resetting the governor at a different speed than intended for the engine application may be contributory factors.

As previously mentioned, most of the indications found during inspection of the crankshaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas and 45° cracks (45° with the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal oil holes (Fig. 9). Replace the crankshaft when cracks of this nature are found.

Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, .002", .010", .020" and .030" undersize bearings are available. The .002" undersize bearings are used only to compensate for slight wear on crankshafts on which regrinding is unnecessary.

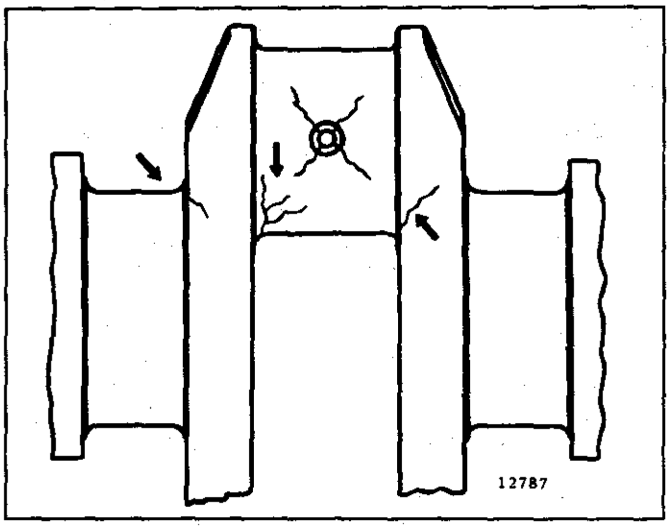


Fig. 9 – Crankshaft Fatique Cracks

Crankshaft main bearing journals and/or connecting rod journals which exhibit discoloration due to excessive overheating from bearing failure are not acceptable for rework.

If the crankshaft is to be reground, proceed as follows:

1. Compare the crankshaft journal measurements taken during inspection with the dimensions in Table 1 and Figs. 5 or 6 and determine the size to which the journals are to be reground.

Bearing Size	Conn. Rod Journal Dia.	Main Bearing Journal Dia.
In-Line Engines		
Standard	2.499"/2.500"	2.999"/3.000"
.002" Undersize	2.497"/2.498"	2.997"/2.998"
.010" Undersize	*2.489"/2.490"	*2.989"/2.990"
.020" Undersize	*2.479"/2.480"	*2.979"/2.980"
.030" Undersize	*2.469"/2.470"	*2.969"/2.970"
V-Engines		
Standard	2.749"/2.750"	3.499"/3.500"
.002" Undersize	2.747"/2.748"	3.497"/3.498"
.010" Undersize	*2.739"/2.740"	*3.489"/3.490"
.020" Undersize	*2.729"/2.730"	*3.479"/3.480"
.030" Undersize	*2.719"/2.720"	*3.469"/3.470"

*Dimension of reground crankshaft

TABLE 1

2. If one or more main or connecting rod journals require grinding, then grind all of the *main* journals or all of the connecting rod journals to the same required size.

3. All journal fillets on the In–line crankshafts must have a .130" to .160" radius and on the 6V and 8V crankshafts, a .100" to .130" radius between the crank cheek and the journal and must not have any sharp grind marks (Fig. 10). The fillet must blend smoothly into the journal and the crank cheek and must be free of scratches. The radius may be checked with a fillet gage.

4. Care must be taken to avoid localized heating which often produces grinding cracks. Cool the crankshaft while grinding, using coolant generously. Do not crowd the grinding wheel into the work.

5. Polish the ground surfaces to an 8–12 R.M.S. finish. The reground journals will be subject to excessive wear unless polished smooth.

6. If the thrust surfaces of the crankshaft (Fig. 7) are worn or grooved excessively, they must be reground and polished. Care must be taken to leave a .130" to .160" radius on the In–line crankshaft and .100" to .130" radius on the 6V and 8V engines between each thrust surface and the bearing journal.

7. Stone the edge of all oil holes in the journal surfaces smooth to provide a radius of approximately 3/32".

8. After grinding has been completed, inspect the crankshaft by the magnetic particle method to determine whether cracks have originated due to the grinding operation.

9. Demagnetize the crankshaft.

10. Remove the plugs and clean the crankshaft and oil passages thoroughly with fuel oil. Dry the shaft with compressed air and reinstall the plugs.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

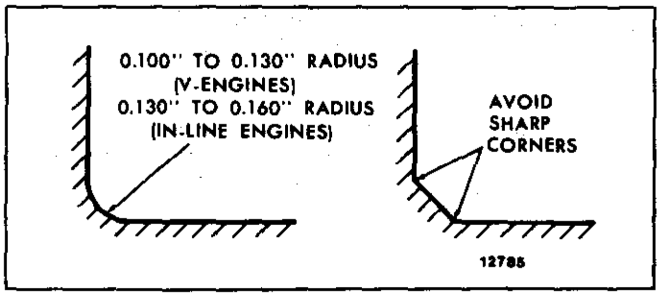


Fig. 10 – Crankshaft Journal Fillets

Install Crankshaft

If a new crankshaft is to be installed, steam clean it to remove the rust preventive, blow out the oil passages with compressed air and install the plugs. Then, install the crankshaft as follows:

1. Assemble the crankshaft timing gear (Section 1.7.5) and the oil pump drive gear (Section 4.1) on the crankshaft.

2. Refer to Section 1.3.4 for main bearing details and install the upper *grooved* main bearing shells in the block. If the old bearing shells are to be used again, install them in the same locations from which they were removed. When a new or reground crankshaft is installed, *ALL* new main and connecting rod (upper and lower) bearing shells and new thrust washers must also be installed.

3. Apply clean engine oil 360° around all crankshaft bearing journals and install the crankshaft in place so that the timing marks on the crankshaft timing gear and the idler gear match. Refer to Section 1.7.1 for the correct method of timing the gear train.

4. Install the upper halves of the crankshaft thrust washers on each side of the rear main bearing support and the doweled lower halves on each side of the rear main bearing cap. *The grooved side of the thrust washers must face toward the crankshaft thrust surfaces.* If the crankshaft thrust surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the rear main journal. Refer to Fig. 7 and Table 2.

Nominal Size	Thrust Washer Thickness	
	Min.	Max.
Standard	.1190"	.1220"
.005" Oversize	.1240"	.1270"
.010" Oversize	.1290"	.1320"

TABLE 2

5. Install the lower bearing shells (no oil grooves) in the bearing caps. If the old bearing shells are to be used again, install them in the same bearing caps from which they were removed.

6. Install the bearing caps and lower bearing shells as outlined under *Install Main Bearing Shells* in Section 1.3.4. If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

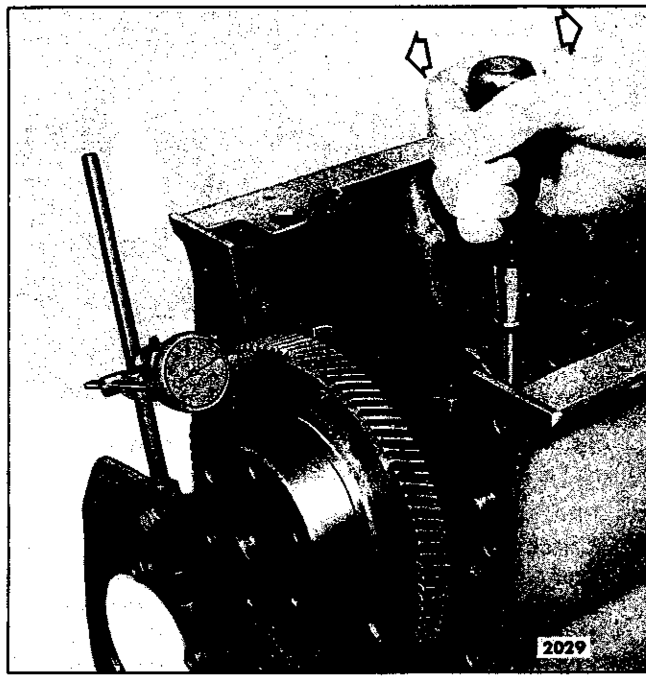


Fig. 11 – Checking Crankshaft End Play

7. Check the crankshaft end play by moving the crankshaft toward the gage (Fig. 11) with a small (less than 12") pry bar. Keep a constant pressure on the pry bar and set the dial indicator to zero. Then, remove and insert the pry bar on the other side of the bearing cap. Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play should be .004" to .016" with new parts or a maximum of .018" with used parts. Insufficient end play can be the result of a misaligned rear main bearing or a burr or dirt on the inner face of one or more of the thrust washers.

8. Install the cylinder liner, piston and connecting rod assemblies (Section 1.6.3).

9. Install the cylinder head(s) (Section 1.2).

10. Install the flywheel housing (Section 1.5), then install the flywheel (Section 1.4).

11. Install the crankshaft lower engine front cover and oil pump assembly on In-line and 6V engines or the engine front cover and outboard bearing support on 8V engines (Section 1.3.5).

12. Install the engine front support, if used.

13. Install the crankshaft pulley (Section 1.3.7).

14. Install the oil pump inlet pipe and screen on In-line and 6V engines; on the 8V engines, install the oil pump, inlet pipe and screen assembly (Section 4.1).

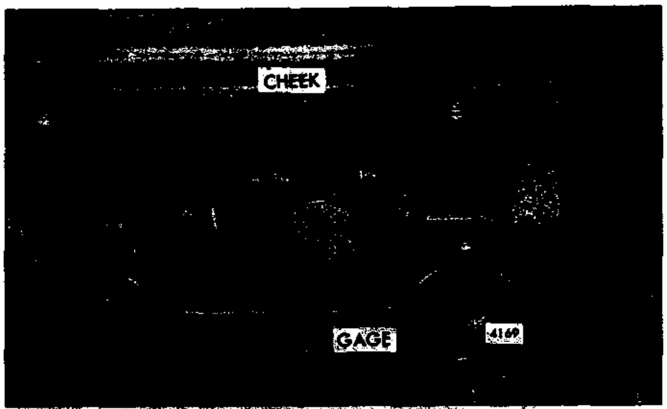


Fig. 12 – Crankshaft Distortion Measuring Gage Mounted on Crankshaft

15. Check the crankshaft for **distortion** (bending) at the rear connecting rod journal counterweights *before* and *after* installing a power takeoff assembly, marine gear, transmission or power generator. If improperly installed these components can distort the crankshaft and cause a crankshaft malfunction. Overtightened drive belts can also cause crankshaft distortion. See Section 15.1 for recommended belt tension.

    NOTICE: While in each case one must be guided by the individual circumstances and facts that evolve, generally speaking Detroit Diesel Corporation cannot be responsible for system damage caused by engine–to–driven component interference and/or distortion. Consequently, the engine crankshaft end play check and crankshaft distortion check are **musts**.

    Check the crankshaft distortion as follows:

    a. Rotate the crankshaft clockwise until the crankshaft counterweights at the rear connecting rod journal are in the *six o'clock* position.

    b. Center punch a hole in the inside face of each counterweight cheek, one quarter of an inch from the lower end of each counterweight, to support the gage.

    c. Install a gage (Starrett Co. No. 696 dial gage, or equivalent) in the center punch holes in the cheek of each counterweight (Fig. 12).

    d. Set the dial indicator at zero, then rotate the crankshaft approximately 90° in both directions. Do not allow the gage to contact the connecting rod caps or bolts. Note and record the dial indicator readings at the *3, 6 and 9 o'clock crankshaft counterweight* positions. The maximum allowable variationis .0045" total indicator reading. Remove the tool that was used to rotate the crankshaft when taking the dial indicator readings.

    e. If the reading on the gage exceeds .0045", check the power takeoff assembly, transmission, marine gear or power generator for improper installation and realign, as necessary.

16. Affix a new gasket to the oil pan flange and install the oil pan.

17. Use a chain hoist and sling attached to the lifting bracket at each end of the engine and remove the engine from the overhaul stand.

18. Install all of the accessories that were removed.

19. After the engine has been completely reassembled, refer to the *Lubrication Specifications* in Section 13.3 and refill the crankcase to the proper level on the dipstick.

20. Close all of the drains and fill the cooling system.

21. After replacing the main or connecting rod bearings or installing a new or reground crankshaft, operate the engine as outlined in the *run–in* schedule (Section 13.2.1).

CRANKSHAFT OIL SEALS

An oil seal is used at each end of the crankshaft to retain the lubricating oil in the crankcase. The sealing lips of the oil seals are held firmly, but not tight, against the crankshaft sealing surfaces by a coil spring.

The front oil seal is pressed into the lower front cover on In–line and 6V–53 engines (Fig. 1). The seal is pressed into the front cover on early 8V–53 engines; effective with engine 8D–149, the seal is pressed into the outboard bearing support.

A single–lip oil seal is used at the rear end of the crankshaft of most industrial engines. A double–lip oil seal is used in engines where there is oil on both sides of the oil seal; the lips of the seal face in opposite directions. The rear oil seal is pressed into the flywheel housing (Fig. 2).

Oil leaks indicate worn or damaged oil seals. Oil seals may become worn or damaged due to improper installation, excessive main bearing clearances, excessive flywheel housing bore runout or grooved sealing surfaces on the crankshaft. To prevent a repetition of any oil seal leaks, these conditions must be checked and corrected.

Remove Crankshaft Oil Seals

Remove the engine front cover (Section 1.3.5), outboard bearing support or the flywheel housing (Section 1.5) and remove the oil seals as follows:

1. Support the forward face of the front cover, or the outboard bearing support, on two wood blocks next to the oil seal bore. Then, press or drive the oil seal out of the front cover or the outboard bearing support. Discard the oil seal.

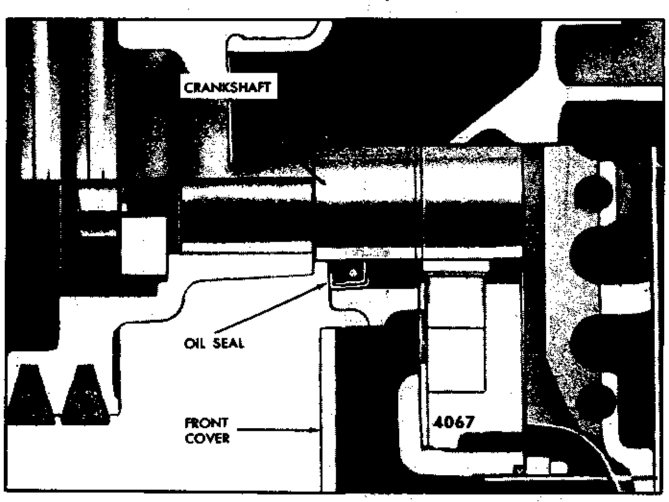


Fig. 1 – Crankshaft Front Oil Seal

2. Support the forward face of the flywheel housing on In–line or 6V–53 engines and the rear face of the flywheel housing on 8V–53 engines on two wood blocks next to the oil seal bore. Then, press or drive the oil seal out of the housing. Discard the oil seal.

3. Clean the oil seal bore in the front cover, outboard bearing support or flywheel housing thoroughly before installing a new oil seal.y

When necessary, an oil seal may be removed without removing the front cover, outboard bearing support or flywheel housing. This may be done by drilling diametrically opposite holes in the seal casing and threading metal screws, backed by flat washers, into the casing. Remove the seal by prying against the washers with pry bars.

Inspection

Inspect the front and rear end of the crankshaft and the crankshaft front end oil seal sleeve (8V–53 engines) for wear due to the rubbing action of the oil seal, dirt build–up or fretting caused by action of the flywheel.

The crankshaft surface must be clean and smooth to prevent damaging the seal lip when a new oil seal is installed. Slight ridges may be removed from the crankshaft as outlined under *Inspection* in Section 1.3.

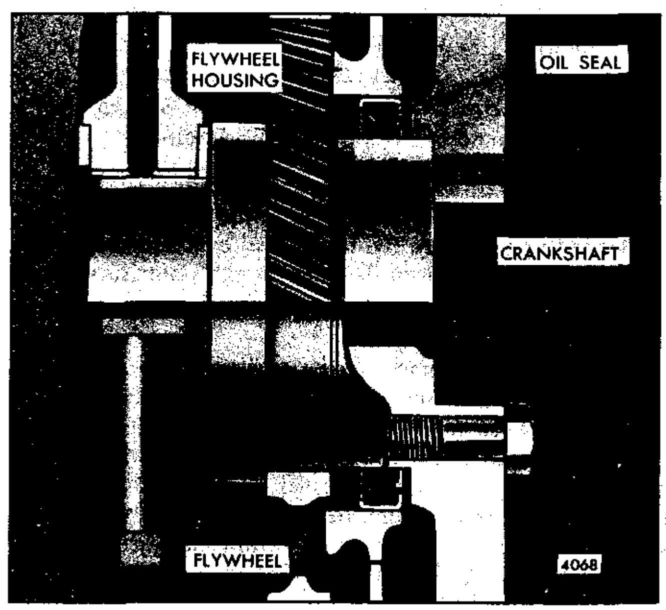


Fig. 2 – Crankshaft Rear Oil Seal (In–line and 6V–53 Engines)

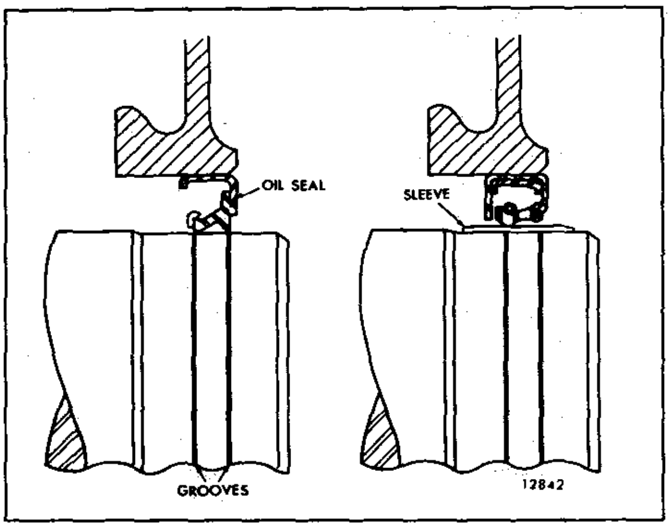


Fig. 3 – Use of Rear Oil Seal Sleeve on Grooved Crankshaft (In–line and 6V–53 Engines)

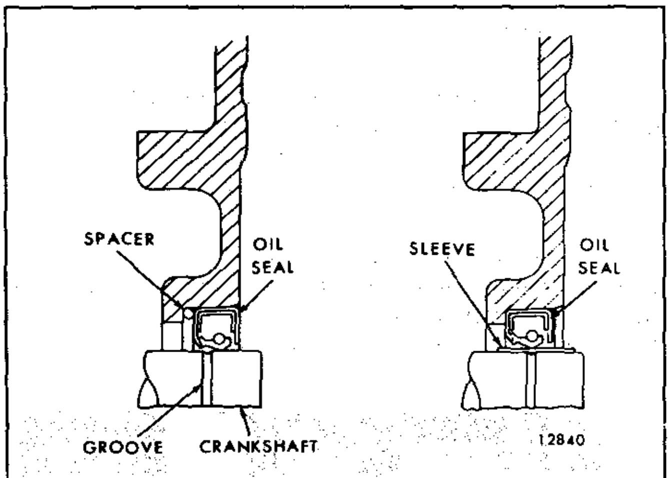


Fig. 4 – Use of Rear Oil Seal Spacer or Sleeve on Grooved Crankshaft (8V–53 Engines)

On In–line or 6V–53 engines, if the crankshaft cannot be cleaned up satisfactorily, the oil seal may be pressed into the flywheel housing or the front cover 1/8" from its original position.

On 8V–53 engines, if the crankshaft rear oil seal surface is grooved excessively, an oil seal spacer may be installed between the counterbore in the flywheel housing and the oil seal (Fig. 4). The spacer changes the relative position of the seal and establishes a new contact surface. However, the spacer cannot be used with a double–lip type seal since the grooves worn in the crankshaft are too close together to permit repositioning of the seal.

If excessive wear or grooving is present, install an oil seal sleeve which provides a replaceable wear surface for the lip–type oil seal (Figs. 3, 4 and 5). The oil seal sleeve may be used with either the single–lip or double–lip type oil seal, and can also be used in conjunction with the seal spacer. However, an oversize oil seal must be used with the sleeve.

Install the rear oil seal sleeve (Figs. 3 and 4) as follows:

1. Stone the high spots from the oil seal contact surface of the crankshaft.
2. Coat the area of the shaft where the sleeve will be positioned with shellac or an equivalent sealant.
3. Drive the sleeve squarely on the shaft with crankshaft rear oil seal sleeve installer J 21277 (In–line or 6V–53 engines) or installer J 4194–01 (8V–53 engines).
4. Wipe off any excess sealant.
5. Coat the outside diameter of the sleeve with engine oil.

Install the front oil seal sleeve (Fig. 5) as follows:

1. Stone the high spots from the oil seal contact surface of the crankshaft.
2. Coat the area of the shaft where the sleeve will be positioned with shellac or an equivalent sealant.
3. Position the sleeve on the crankshaft with the radius on the sleeve facing away from the engine.
4. Drive the sleeve squarely on the shaft with front oil seal sleeve installer J 22524 and the crankshaft pulley retaining bolt.
5. Wipe off any excess sealant.
6. Coat the outside diameter of the sleeve with engine oil.

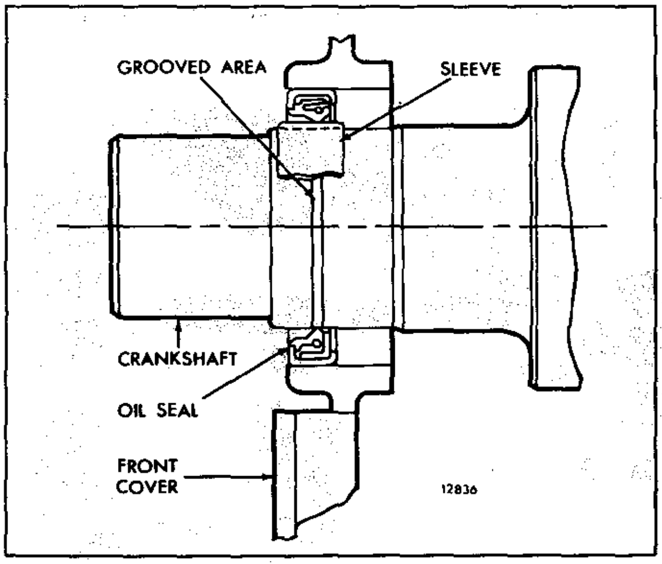


Fig. 5 – Use of Front Oil Seal Sleeve on Grooved Crankshaft

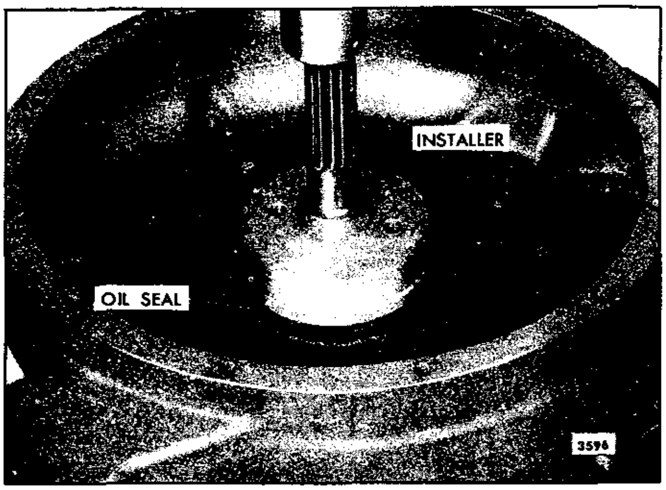


Fig. 6 – Installing Oil Seal in Flywheel Housing

To remove a worn sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the end of the crankshaft.

Current oil seals are made of an oil resistant synthetic rubber which is pre–lubricated with a special lubricant. *Do not remove this lubricant.* Keep the sealing lip clean and free from scratches. In addition, a plastic coating which acts as a sealant has been applied to the outer surface of the casing. Do not remove this coating.

The rear oil seal may have either an open or closed back. Both types are serviced.

Install Crankshaft Front Oil Seal

1. If the oil seal is not pre–coated, apply a non–hardening sealant to the periphery of the metal casing.
2. Coat the lip of the new oil seal lightly with grease or vegetable shortening. Then, position the seal in the cover or outboard bearing support with the lip of the seal pointed toward the inner face of the cover or bearing support.
3. On In–line and 6V–53 engines, use installer J 9783 to press the oil seal into the cover until the seal is flush with the outside face of the cover. On 8V–53 engines, press the oil seal into the outboard bearing support with installer J 22153.
4. Remove any excess sealant.
5. Install the engine front cover (Section 1.3.5) or the outboard bearing support.

Install Crankshaft Rear Oil Seal

A new, unidirectional Teflon rear crankshaft oil seal is being used in all right–hand rotating engines,. To help insure proper installation, the seal part number and the direction of shaft rotation are stamped on the seal case. The new seal is packaged around a special plastic sleeve which protects the Teflon lip of the seal during shipment and storage and functions as an installation tool. It is designed to be placed over the crankshaft end so that the seal can be easily slipped in place without damaging the lip.

NOTICE: Do not lubricate a Teflon seal lip or the O.D. of the crankshaft wear sleeve before seal installation. Teflon lip oil seals must be installed dry. This is to allow transfer of the Teflon to the wear sleeve surface for proper sealing.

1. Support the inner face of the flywheel housing in an arbor press or on a flat surface.
2. If the new seal is not pre–coated, apply a non–hardening sealant to the periphery of the metal casing. Then, position the seal with the lip pointed toward the inner face of the housing.
3. Coat the lip of a silcon oil seal lightly with engine oil (single–lip seal) or vegetable shortening (double–lip seal). Do not scratch or nick the sealing edge of the oil seal.
4. On In–line and 6V–53 engines, use installer J 9479 to press the oil seal into the flywheel housing until the seal is flush with the outside face of the housing (Fig. 6).

   If the flywheel housing was not removed from the engine, place oil seal expander J 9769 (standard size seal) or J 21278–01 (oversize seal) against the end of the crankshaft. Then, with the lip of the seal pointed toward the engine, slide the seal over the expander and on the crankshaft. Next, thread the guide studs J 9479–2 into the crankshaft. Now drive the seal into the flywheel housing with installer J 9479–1 until it is flush with the face of the housing.
5. On 8V–53 engines, use installer J 9727 and handle J 3154–1 to press the oil seal in the flywheel housing bore until it seats in the bottom of the counterbore. If the flywheel housing was not removed from the engine, place oil seal expander J 22425 against the end of the crankshaft. Then, with the lip of the seal pointed toward the engine, slide the seal over the tool and on the crankshaft. Remove the seal expander and drive the seal in place with installer J 9727 and handle J 3154–1.
6. Remove any excess sealant from the flywheel housing and the seal.

   NOTICE: If the oil seal is of the type which incorporates a brass retainer in the inner diameter of the seal, be sure the retainer is in place in the seal before installing the flywheel housing on the engine. If the retainer is left out, oil leakage will result.
7. Install the flywheel housing as outlined in Section 1.5.

CRANKSHAFT MAIN BEARINGS

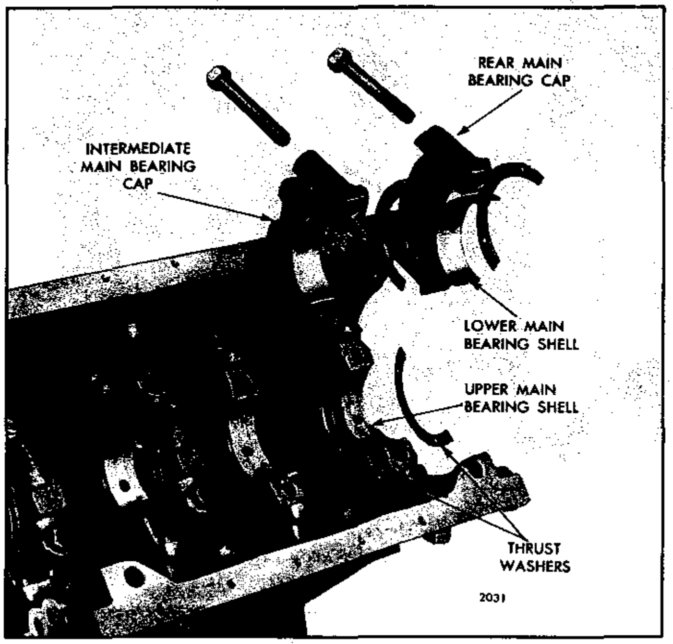


Fig. 1 – Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers — In-line Engines

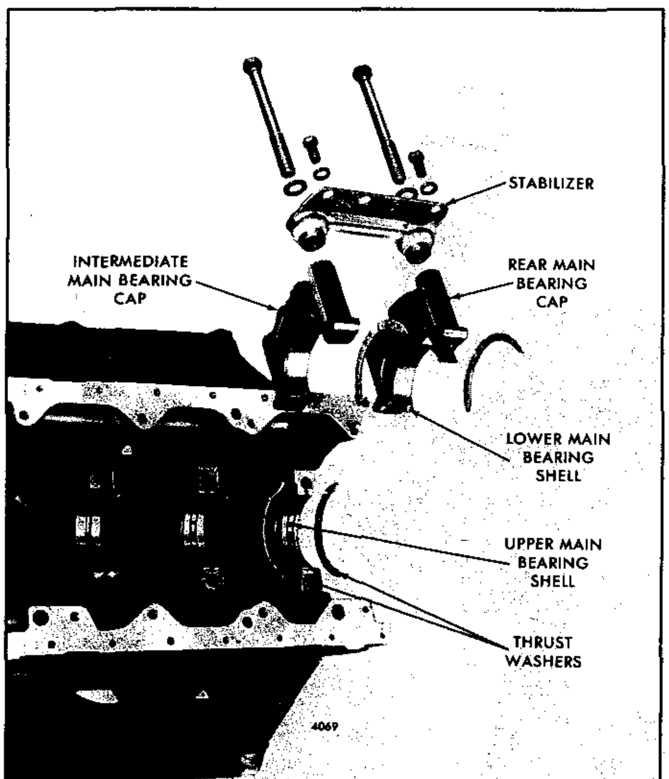


Fig. 2 – Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers — V-Type Engines

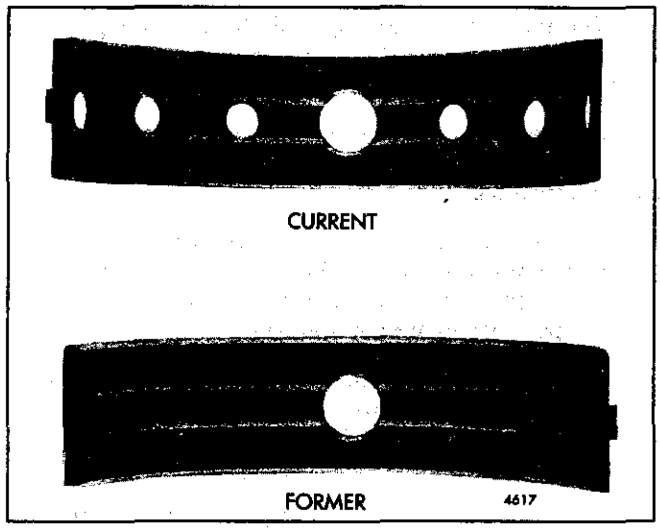


Fig. 3 – Old and New Upper Main Bearing Shells (V-Type Engines)

The crankshaft main bearings shells are precision made and are replaceable without machining (Figs. 1 and 2). They consist of an upper bearing shell seated in each cylinder block main bearing support and a lower bearing shell seated in each main bearing cap. The upper and lower bearing shells are located in the respective block and bearing cap by a tang at the parting line at one end of each bearing shell. The tangs on the lower bearing shells are off-center and the tangs on the upper bearing shells are centered to aid correct installation.

On In-line and early V-type engines, a 7/16" oil hole in the groove of each upper bearing shell, midway between the parting lines, registers with a vertical oil passage in the cylinder block. Lubricating oil, under pressure, passes from the cylinder block oil gallery by way of the bearing shells to the drilled passages in the crankshaft, then to the connecting rods and connecting rod bearings.

On 6V marine engines effective with engine serial number 6D-11074 and all other 6V and 8V engines effective with serial numbers 6D-17960 and 8D-4611, an upper main bearing shell which has six 1/4" holes and one 7/16" hole (Fig. 3) is used. The additional holes in the upper main bearing shells improve piston cooling by allowing more oil, under pressure, to flow to the drilled passages in the crankshaft. On the 8V engines, a new high capacity oil pump is used in combination with the seven hole bearing shells.

The single hole and the seven hole upper main bearings are not interchangeable. If the seven hole upper main bearing shells are used on an early engine, the current lower engine front cover (Section 1.3.5), lubricating oil distribution system (Section 4.1) and revised cast iron oil pan (Section 4.7) must be used together. *The single hole and* *seven hole upper main bearing shells must never be mixed in an engine.*

The lower main bearing shells have no oil grooves; therefore, the upper and lower bearing shells must not be interchanged.

On Brazil built engines the upper main bearing shell is slotted and the lower shell has grooved sides for continuous piston lubrication.

Thrust washers on each side of the rear main bearing, absorb the crankshaft thrust (Figs. 1 and 2). The lower halves of the two–piece washers are doweled to the bearing cap; the upper halves are not doweled.

All of the main bearing load is carried on the lower bearings; therefore, wear will occur on the lower bearing shells first. The condition of the lower bearing shells may be observed by removing the main bearing caps.

If main bearing trouble is suspected, remove the oil pan, then remove the main bearing caps, one at a time, as outlined below and examine the bearing shells.

Remove Main Bearing Shells (Crankshaft in Place)

The bearing caps are numbered 1, 2, 3, etc., indicating their respective positions and, when removed, must always be reinstalled in their original position.

All crankshaft main bearing journals, except the rear journal, are drilled for an oil passage. Therefore, the procedure for removing the upper bearing shells with the crankshaft in place is somewhat different on the drilled journals than on the rear journal.

Remove the main bearing shells as follows:

1. Drain and remove the oil pan to expose the main bearing caps.
2. Remove the oil pump and the oil inlet pipe and screen assembly. If shims are used between the oil pump (8V engine) and the main bearing caps, save the shims so that they may be reinstalled in exactly the same location.
3. Remove one main bearing cap at a time and inspect the bearing shells as outlined under *Inspection*. Reinstall each bearing shell and bearing cap before removing another bearing cap:
   a. To remove all except the rear main bearing shell, insert a 1/4" x 3/4" bolt with a 1/2" diameter and 1/16" thick head (made from a standard bolt) into the crankshaft journal oil hole. Then, revolve the shaft to the right (clockwise) and roll the bearing shell out of position (Fig. 4). The head of the bolt must not extend beyond the outside diameter of the bearing shell.

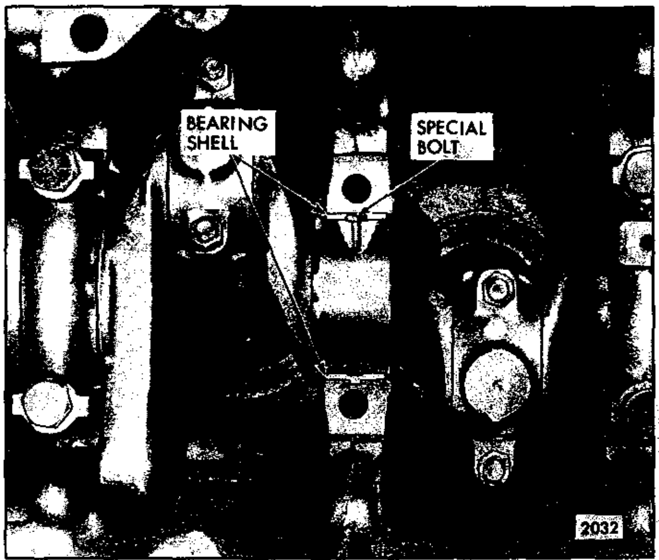


Fig. 4 – Removing Upper Main Bearing Shell (Except Rear Main)

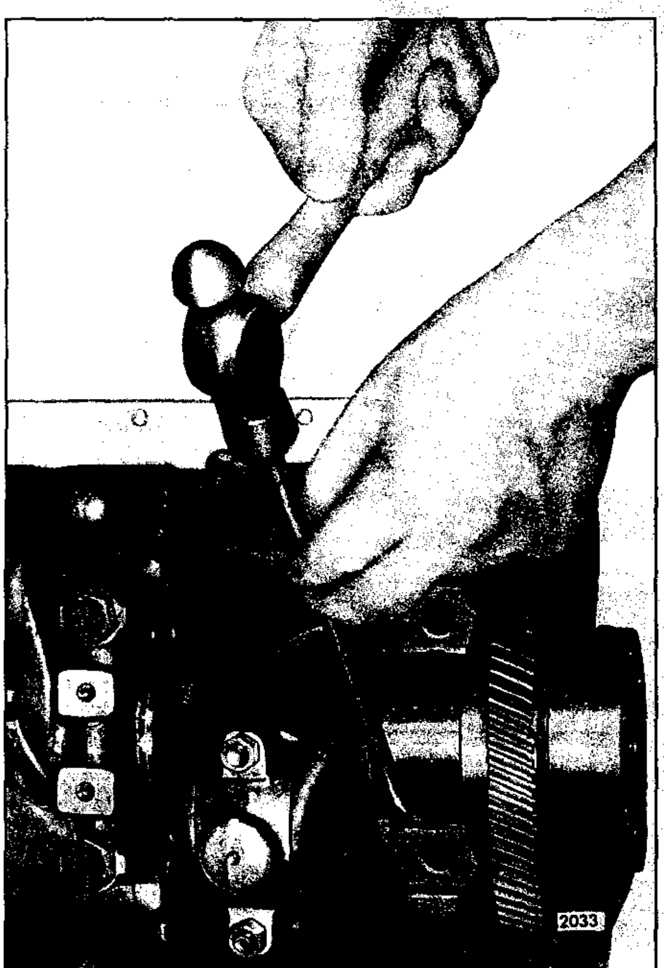


Fig. 5 – Removing Upper Rear Main Bearing Shell

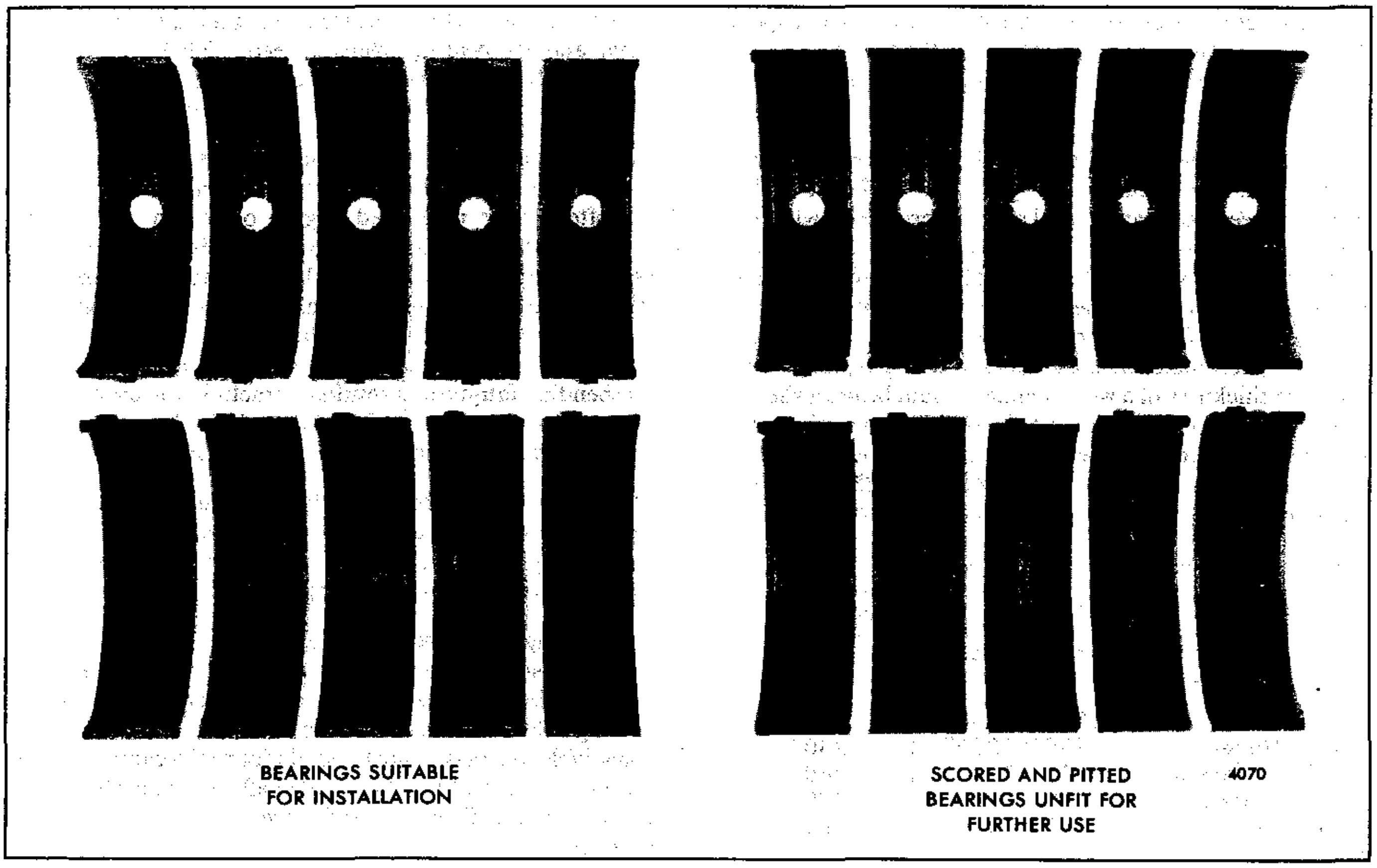


Fig. 6 – Comparison of Main Bearing Shells

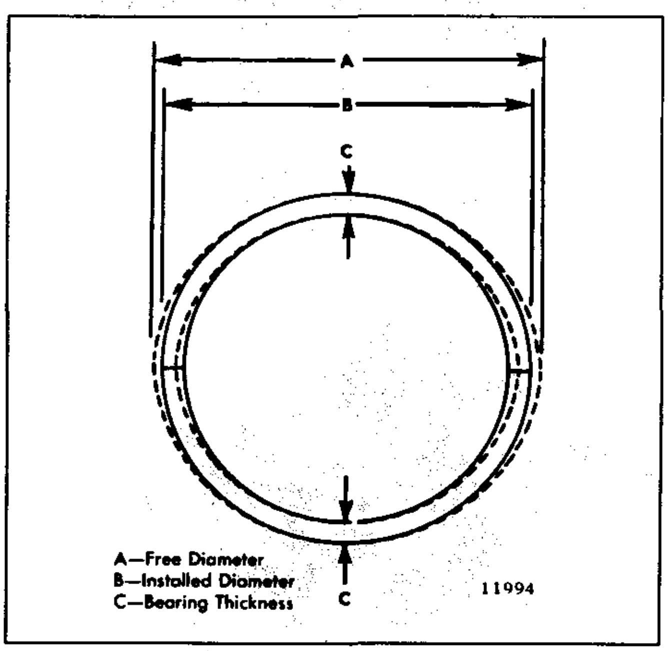


Fig. 7 – Main Bearing Measurements

b. Remove the rear main bearing upper shell by tapping on the edge of the bearing with a small curved rod, revolving the crankshaft at the same time to roll the bearing shell out (Fig. 5).

c. The lower halves of the crankshaft thrust washers will be removed along with the rear main bearing cap. The upper halves of the washers can be removed for inspection by pushing on the ends of the washers with a small rod, forcing them around and out of the main bearing support.

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

Check the oil filter elements and replace them, if necessary. Also, check the oil bypass valve to make sure it is operating freely.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching, loss of babbitt or signs of overheating (Fig. 6). The lower bearing shells, which carry the load, will normally show signs of distress before the upper bearing shells.

Inspect the backs of the bearing shells for bright spots which indicate they have been moving in the bearing caps or bearing supports. If such spots are present, discard the bearing shells.

Measure the thickness of the bearing shells at point "C", 90° from the parting line (Figs. 7 and 8). Tool J 4757, placed between the bearing shell and a micrometer, will give an accurate measurement. The bearing shell thickness will be the total thickness of the steel ball in the tool and the bearing shell, less the diameter of the ball. This is the only practical method for measuring the bearing thickness, unless a special micrometer is available for this purpose. The minimum thickness of a worn standard main bearing shell is .1230" and, if any of the bearing shells are thinner than this dimension, replace all of the bearing shells. A new standard bearing shell has a thickness of .1245" to .1250" (In-line engine) or .1240" to .1245" (V engine). Refer to Table 1.

Bearing Size	Bearing Thickness	Minimum Thickness
In-Line Engines		
Standard	.1245"/.1250"	.1230"
.002" Undersize	.1255"/.1260"	.1240"
.010" Undersize	.1295"/.1300"	.1280"
.020" Undersize	.1345"/.1350"	.1330"
.030" Undersize	.1395"/.1400"	.1380"
V-Type Engine		
Standard	.1240"/.1245"	.1230"
.002" Undersize	.1250"/.1255"	.1240"
.010" Undersize	.1290"/.1295"	.1280"
.020" Undersize	.1340"/.1345"	.1330"
.030" Undersize	.1390"/.1395"	.1380"

TABLE 1

In addition to the thickness measurement, check the clearance between the main bearings and the crankshaft journals. This clearance may be determined with the crankshaft in place by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to *Shop Notes* in Section 1.0). With the crankshaft removed, measure the outside diameter of the crankshaft main bearing journals and the inside diameter of the main bearing shells when installed in place with the proper torque on the bearing cap bolts. When installed, the bearing shells are .001" larger in diameter at the parting line than 90° from the parting line.

The bearing shells do not form a true circle when not installed. When installed, the bearing shells have a squeeze fit in the main bearing bore and must be tight when the bearing cap is drawn down. This *crush* assures a tight, uniform contact between the bearing shell and bearing seat. Bearing shells that do not have sufficient crush will not have uniform contact, as shown by shiny spots on the back, and must be replaced. If the clearance between any crankshaft journal and its bearing shells exceeds .0060", all of the bearing shells must be discarded and replaced. This clearance is .0010" to .0040" with new parts.

Before installing new replacement bearings, it is very important to thoroughly inspect the crankshaft journals. Very often, after prolonged engine operation, a ridge is formed on the crankshaft journals in line with the journal oil holes. If this ridge is not removed before the new bearings are installed, then, during engine operation, localized high unit pressures in the center area of the bearing shell will cause pitting of the bearing surface. Also, damaged bearings may cause bending fatigue and resultant cracks in the crankshaft. Refer to Section 1.3 under *Crankshaft Inspection* for removal of ridges and inspection of the crankshaft.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .002", .010", .020" and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to *Crankshaft Grinding* in Section 1.3. Bearings which are .002" undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft. Bearing shells are NOT reworkable from one undersize to another under any circumstances.

Oversize O.D. main bearing shells are also available in .010" and .020" oversize to salvage engine blocks which have experienced block bore wear or damage. The oversize bearing sets may be installed after the block bores have been line-bored to the oversized diameter (Section 1.0 Shop Notes).

Do not mix main bearing shell kits on an engine. Use all oversize or all undersize bearing shells of the same size or use all standard main bearing shell kits.

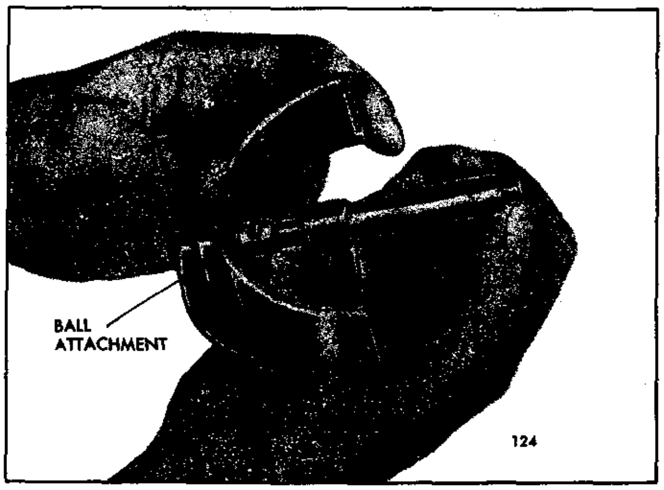


Fig. 8 – Measuring Thickness of Bearing Shell

Inspect the crankshaft thrust washers (Fig. 9). If the washers are scored or worn excessively or the crankshaft end play is excessive, they must be replaced. Improper clutch adjustment can contribute to excessive wear on the thrust washers. Inspect the crankshaft thrust surfaces. Refer to *Install Crankshaft* in Section 1.3. If, after dressing or regrinding the thrust surfaces, new standard size thrust washers do not hold the crankshaft end play within the specified limits, it may be necessary to install oversize thrust washers on one or both sides of the rear main bearing. A new standard size thrust washer is .1190" to .1220" thick. Thrust washers are available in .005" and .010" oversize.

The discovery of a crack in the rear main bearing cap of a 6V naturally aspirated or turbocharged engine does not automatically mean that the cap should be scrapped. The cap may be reused if the crack occurs on the bearing shell side of the dowel pin hole (Item 1 – Fig. 10). Fig. 10 shows the types of cracks which may be encountered on the 6V–53 rear main bearing cap. The reusability of the cap is defined as follows:

1. Cap *can* be reused. Crack occurs on the bearing shell side of the dowel pin hole.
2. Cap *cannot* be reused. Crack occurs on both sides of the dowel pin hole, extending toward the bearing shell area and the cap bolt hole.
3. Cap *cannot* be reused. Crack occurs at a location other than the dowel pin hole.

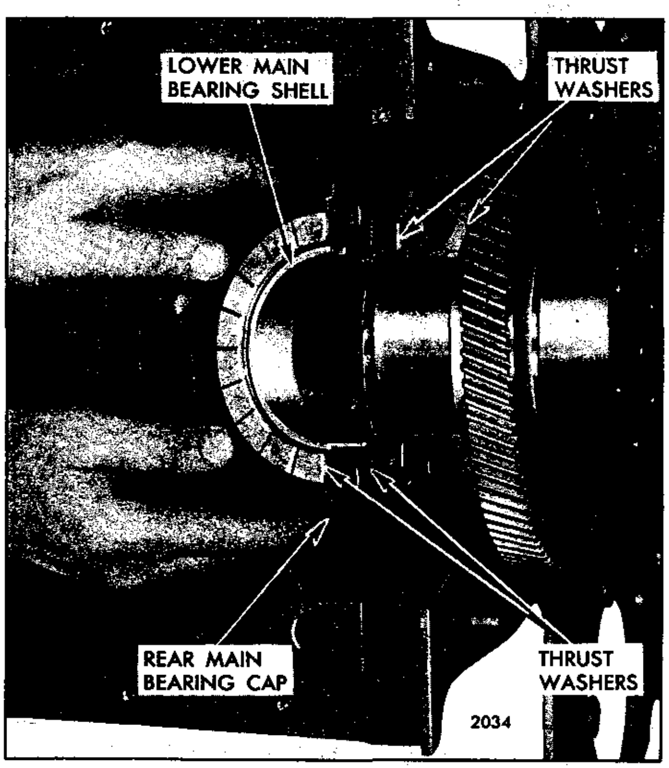


Fig. 9 – Crankshaft Thrust Washers in Place

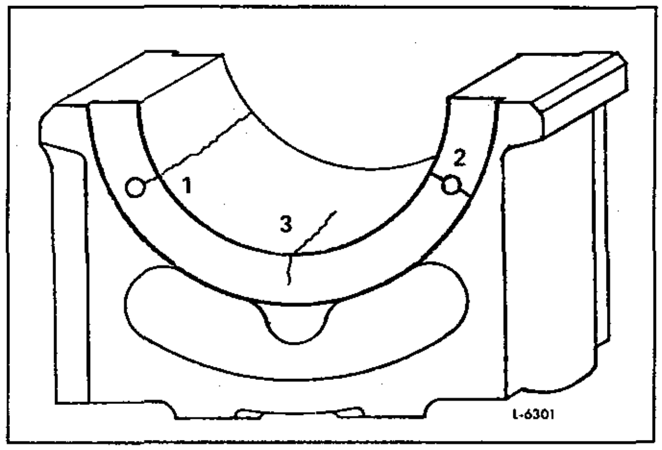


Fig. 10 – 6V Rear Main Bearing Cap Cracks

A pre–finished rear main bearing cap with machined thrust washer surface is available as a service part. After the bearing cap is replaced, the block must be line–bored to insure proper alignment (see Section 1.0 Shop Notes).

Install Main Bearing Shells (Crankshaft in Place)

Make sure all of the parts are clean. Then, apply clean engine oil 360° around each crankshaft bearing journal and install the upper main bearing shells by reversing the sequence of operations given for removal.

- *Upper and lower bearing shells are serviced only in sets. Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.*

Do not mix one hole and seven hole upper main bearing shells in a V–type engine. If the current seven hole bearing shells are installed in an early engine, the current oil pump must be included, otherwise low oil pressure will result.

The upper and lower main bearing shells are not alike; the upper bearing shell is grooved and drilled for lubrication — the lower bearing shell is not. Be sure to install the grooved and drilled bearing shells in the cylinder block and the plain bearing shells in the bearing caps, otherwise the oil flow to the bearings and to the upper end of the connecting rods will be blocked off. Used bearing shells must be reinstalled on the same journal from which they were removed.

1. When installing an upper main bearing shell with the crankshaft in place, start the plain end of the bearing shell around the crankshaft journal so that, when the bearing is in place, the tang will fit into the groove in the bearing support.
2. Install the lower main bearing shell so that the tang on the bearing fits into the groove in the bearing cap.

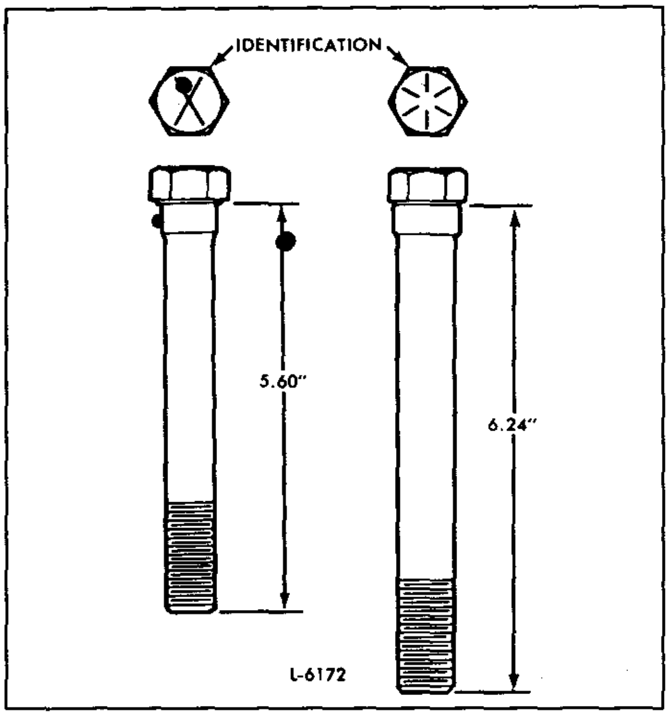


Fig. 11 – Identification of Stabilizer Bolts

3. Assemble the crankshaft thrust washers before installing the rear main bearing cap (Fig. 9). Clean both halves of each thrust washer carefully and remove any burrs from the washer seats — the slightest burr or particle of dirt may decrease the clearance between the washers and the crankshaft beyond the specified limit. Slide the upper halves of the thrust washers into place. Then, assemble the lower halves over the dowel pins in the bearing cap. The main bearing caps are bored in position and stamped 1, 2, 3, etc. They must be installed in their *original* positions with the marked side of each cap facing the same side of the cylinder block that carried the engine serial number.

Bearing cap stabilizers are used at all 6V–53 engine main bearing cap positions. However, effective with engine serial number 6D–183126 the stabilizers were removed from the two front main bearing cap positions for the 6V naturally aspirated engines only.

Shorter bolts (9/16"–12 x 5.60") are now used at these two front main bearing cap positions that do not have the stabilizers. The longer 9/16"–12 x 6.24" bolt continues to be used with the stabilizers for the No. 3 and No. 4 main bearing caps. Refer to Fig. 11 for identification of bolts and Fig. 12 for modifications to the 6.24" bolt and washer.

NOTICE: Do not use the shorter bolt with a stabilizer, as this may result in insufficient bolt thread contact and possible engine damage.

4. Apply a small quantity of International Compound No. 2, or equivalent, to the bolt threads and the bolt head contact area. Install the bearing caps and stabilizers (if used) and draw the bolts up snug. Then, rap the caps sharply with a soft hammer to seat them properly. Tighten all bolts (except the rear main bearing bolts) to 120–130 lb–ft (163–177 N·m) torque starting with the center bearing cap bolts and working alternately towards both ends of the block. Tighten the rear main bearing bolts to 40–50 lb–ft (54–68 N·m) torque. Strike both ends of the crankshaft two or three sharp blows with a soft hammer to insure proper positioning of the rear main bearing cap in the block saddle. Retorque all bearing bolts to 120–130 lb–ft (163–177 N·m). On a V–type engine, tighten the 7/16"–14 stabilizer bolts to 46–50 lb–ft (62–68 N·m) torque. If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

5. Check the crankshaft end play as outlined under *Install Crankshaft* in Section 1.3.

6. Install the lubricating oil pump and the oil inlet pipe assembly. If shims were used between the pump (8V engine) and the bearing caps, install them in their *original* positions.

7. Install the oil pan, using a new gasket.

8. Fill the crankcase to the proper level on the dipstick with *heavy–duty* lubricating oil of the recommended grade and viscosity (refer to *Lubrication Specifications* in Section 13.3).

9. After installing new bearing shells, operate the engine on a *run–in* schedule as outlined in Section 13.2.1.

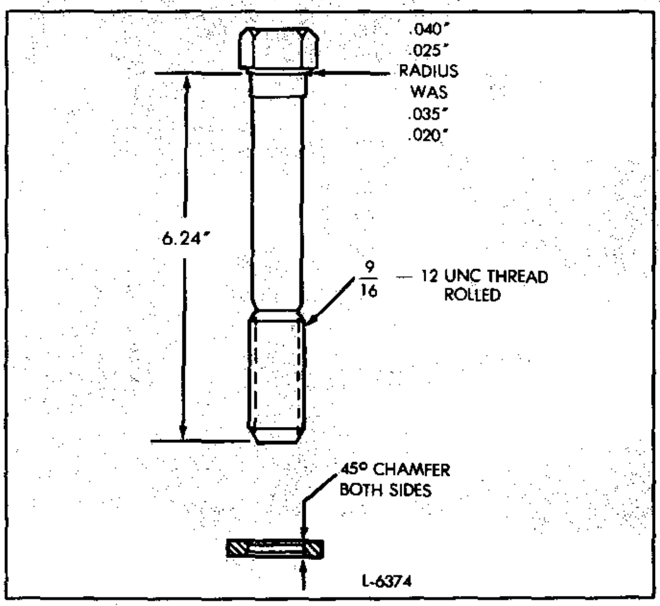


Fig. 12 – Modified 6V Main Bearing Cap Bolt and Washer

ENGINE FRONT COVER (Lower)

In–line and 6V Engines

The engine lower front cover is mounted against the cylinder block at the lower front end of the engine (Figs. 1 and 2). It serves as a housing for the crankshaft front oil seal, the lubricating oil pump, the oil pressure regulator valve and the oil cooler by–pass valve. The clean–out openings in the periphery of the current cover incorporate tapped holes and 1/2"–14 threaded plugs.

On all In–line and 6V engines effective with engine serial numbers 2D–13569 (except 2D–13592, 13597, 13622 and 13626), 3D–4295 (except 3D–4373), 4D–6027 and 6D–3858 (6D–3246, model 5063–5200), the oil pressure regulator valve is located on the right–hand side of the engine front cover, as viewed from the front of the engine. Prior to the above engine serial numbers, the oil pressure regulator valve was located on the left–hand side of the front cover just below the oil cooler by pass valve.

Current 6V engines include a regulator valve with a non–replaceable stop swaged in the valve. When it becomes necessary to replace the regulator valve or plug in an early engine, both must be replaced together. Also, when the valve and plug in either side of the engine lower front cover needs to be replaced, the valve and plug in both sides of the cover must be replaced.

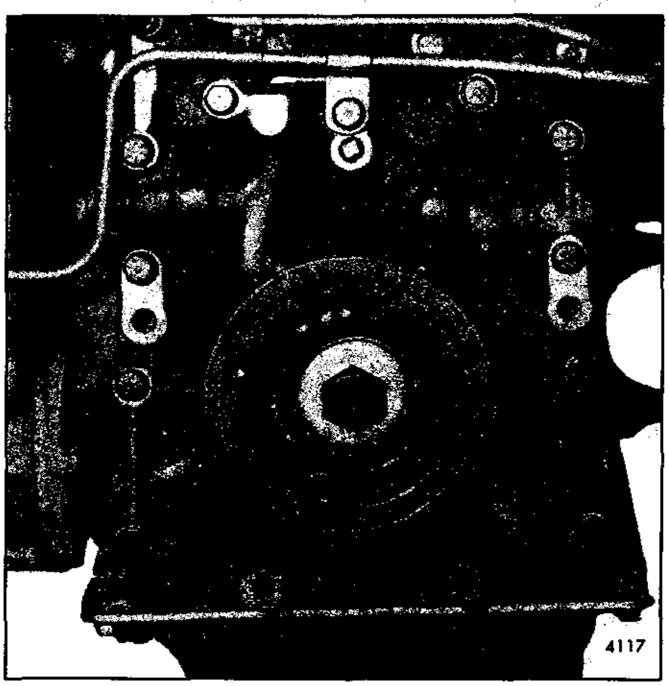


Fig. 1 – Engine Front Cover Mounting (Lower) — In–Line Engine

Remove Engine Front Cover

1. Allow the engine to cool, then drain the oil and remove the oil pan.

2. Remove the crankshaft pulley as outlined in Section 1.3.7.

3. Remove the two bolts and lock washers that secure the lubricating oil pump inlet tube flange or elbow to the engine front cover.

4. Remove the bolts and lock washers that secure the engine front cover to the cylinder block.

5. Strike the cover with a soft hammer to free it from the dowels. Pull the cover straight off the end of the crankshaft.

6. Remove the cover gasket.

7. Inspect the oil seal and lubricating oil pump as outlined in Sections 1.3.2 and 4.1. Also check the oil pressure regulator valve and oil cooler bypass valve as outlined in Sections 4.1.1 and 4.4.

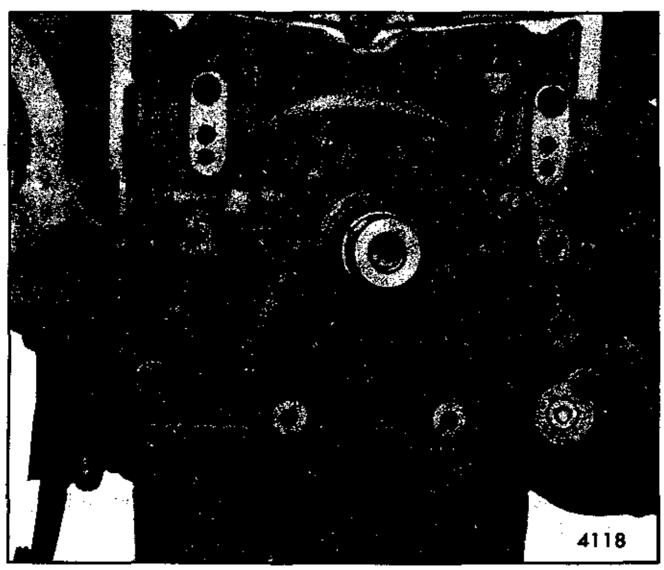


Fig. 2 – Engine Front Cover Mounting (Lower) — 6V–Engine

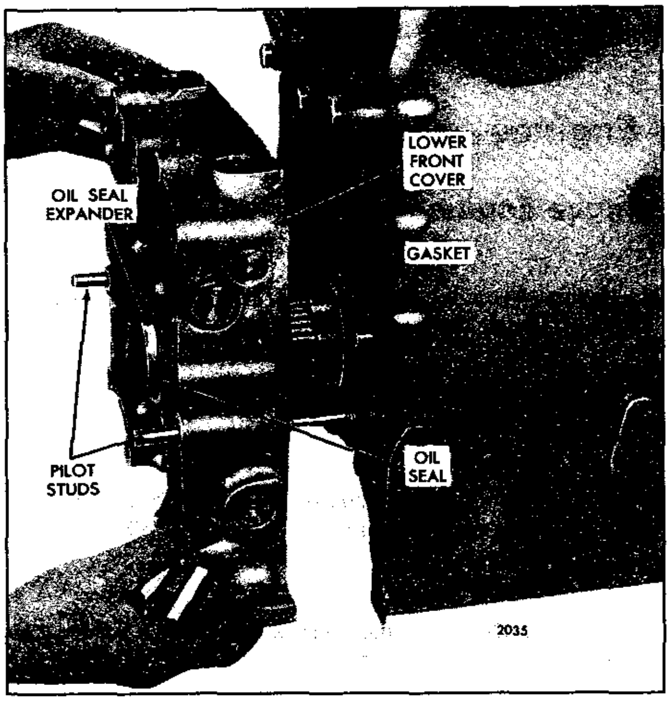


Fig. 3 – Installing Lower Engine Front Cover — In–Line Engine

Install Engine Front Cover

1. Affix a new cover gasket to the cylinder block.
2. Install oil seal expander J 7454 over the front end of the crankshaft.
3. Thread two 3/8"–16 pilot studs approximately 8" long into two diametrically opposite bolt holes in the cylinder block to guide the cover in place (Fig. 3).
4. Apply a light coat of cup grease to the lip of the oil seal. Slide the engine front cover over the oil seal expander and pilot studs as shown in Fig. 3. Push the cover forward until the inner rotor of the oil pump contacts the pump drive gear on the crankshaft. Rotate the crankshaft slightly to align the teeth, then push the cover up against the gasket and block. Do not force the cover.
5. Remove the oil seal expander and pilot studs.
6. Refer to Figs. 1 and 2 and install the 3/8"–16 bolts and lock washers. Tighten the bolts to 30–35 lb–ft (41–47 N·m) torque.
7. Affix a new seal ring on the end of the lubricating oil pump inlet tube next to the flange on an In–line engine, or a new gasket to the elbow on a 6V–engine. Attach the flange or elbow to the front cover with bolts and lock washers. Tighten the bolts to 13–17 lb–ft (18–23 N·m) torque.
8. Affix a new oil pan gasket to the bottom of the cylinder block, then install and secure the oil pan to the block with bolts and lock washers. Tighten the bolts to 13–17 lb–ft (18–23 N·m) torque.
9. Install the crankshaft pulley as outlined in Section 1.3.7.
10. Refer to *Lubricating Oil Specifications* in Section 13.3 and refill the crankcase to the proper level on the dipstick.

ENGINE FRONT COVER

8V Engine

The engine front cover serves as a housing for the camshaft front oil seals, the oil pressure regulator valve and the oil cooler by–pass valve. Prior to engine 8D–149, it served as a housing for the crankshaft front oil seal. Effective with engine 8D–149, the crankshaft front oil seal is mounted in the outboard bearing support assembly (Section 1.3.5.1).

Remove Engine Front Cover

1. Remove the crankshaft pulley as outlined in Section 1.3.7.
2. Remove the pulleys from the front ends of the camshafts as outlined in Section 1.7.
3. Remove the engine front cover, including the engine front trunnion and/or outboard bearing support assembly, if used, (Section 1.3.5.1).
4. Remove and discard the cover gaskets.
5. Remove and discard the oil seals.
6. Check the oil pressure regulator and oil cooler by–pass valves as outlined in Section 4.1.1.

Install Engine Front Cover

<u>ON ENGINES</u> Effective with 8D–149:

1. Install the camshaft oil seals, if removed, with installer J 21899.

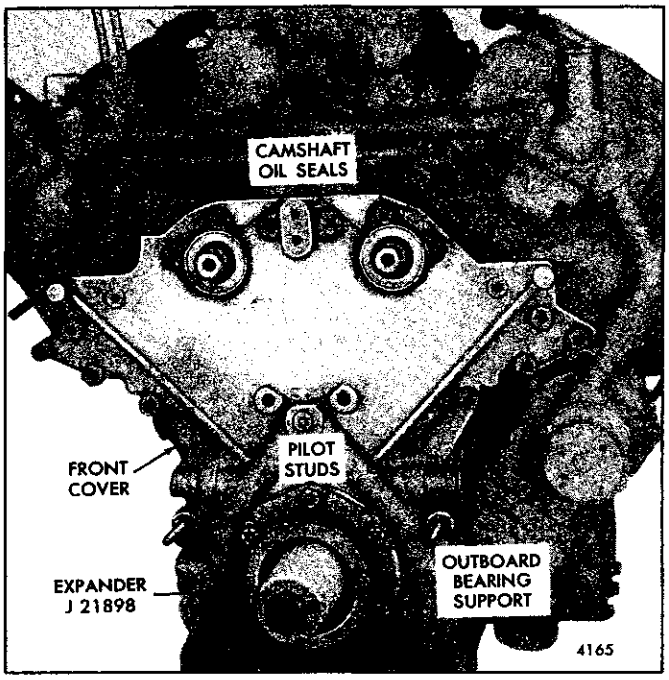


Fig. 4 – Installing Engine Front Cover – 8V–Engine

2. Affix new front cover gaskets to the cylinder block.
3. Install two pilot studs (Fig. 4) into diametrically opposite bolt holes in the cylinder block to guide the engine front cover in place.
4. Slide the front cover over the pilot studs.
5. Remove the pilot studs and install the front cover attaching bolts and lock washers. Tighten the bolts to 30–35 lb–ft (41–47 N·m) torque.
6. Install the outboard bearing support on the engine front cover as follows:
   a. Install oil seal expander J 21898 (Fig. 4) over the end of the crankshaft. Then apply a light coat of cup grease to the lip of the oil seal and install the outboard bearing support over the oil seal expander and against the engine front cover. Remove the seal expander.
   b. Install the six attaching bolts. Hold the outboard bearing support in a downward position with light hand pressure when tightening the bolts. First snug all the bolts, then tighten them to 75–85 lb–ft (102–115 N·m) torque.
   c. Check the outboard bearing-to-crankshaft clearance with a feeler gage. The clearance must not be less than .0035" or more than .008" with the bearing support in the downward position.
   d. Install the front trunnion, if used.
7. Install the crankshaft front sleeve, if used.
8. Install the crankshaft pulley as outlined in Section 1.3.7.
9. Install the camshaft pulleys as outlined in Section 1.7.

ON ENGINES Prior to 8D–149:

1. Install the camshaft oil seals, if removed, with installer J 21899.
2. Install the crankshaft front oil seal as outlined in Section 1.3.2.
3. Affix new front cover gaskets to the cylinder block.
4. Install the oil seal expander J 21898 over the end of the crankshaft.
5. Install two pilot studs into diametrically opposite bolt holes in the cylinder block.
6. Apply a light coat of cup grease to the lip of the oil seal and guide the front cover over the pilot studs and against the cylinder block.
7. Install the front cover attaching bolts and lock washers and tighten the bolts to 30–35 lb–ft (41–47 N·m) torque.
8. Remove the oil seal expander and the pilot studs.
9. Install the crankshaft front sleeve, if used.
10. Install the crankshaft pulley as outlined in Section 1.3.7.
11. Install the camshaft pulleys as outlined in Section 1.7.

CRANKSHAFT OUTBOARD BEARING SUPPORT

8V Engines

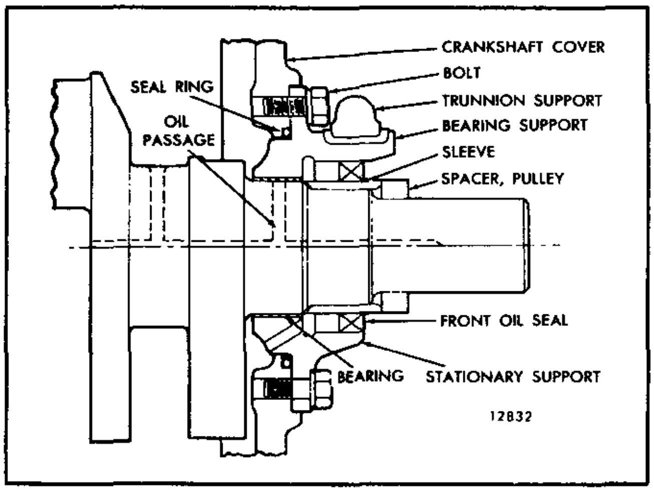


Fig. 1 – Outboard Bearing Support Assembly

The crankshaft outboard bearing support (Fig. 1) houses the crankshaft front outboard bearing (bushing) and the crankshaft front oil seal. The support is a one–piece casting which bolts directly to the engine front cover, providing easy access for removing and installing the oil seal and bearing. A seal ring is used between the bearing support and the engine front cover.

The bearing is pressure lubricated by oil from an internal oil passage in the crankshaft.

The bearing support must be removed when replacement of the bearing or crankshaft oil seal is required.

Remove Outboard Bearing Support

1. Remove the crankshaft pulley (Section 1.3.7).
2. Remove the front trunnion (Fig. 1), if used.
3. Remove the six attaching bolts and detach the bearing support from the engine front cover.
4. Remove and discard the seal ring.

Inspection

Oil leaks are indications of worn or damaged seals.

Inspect the oil seal sleeve for wear due to the rubbing action of the oil seal or dirt build–up. The sleeve must be smooth and clean, otherwise the oil seal lip will be damaged when a new seal is installed.

The oil seal sleeve may be smoothed up with emery cloth and polished with crocus cloth wet with fuel oil. Clean up the circumference of the sleeve without disturbing the concentricity.

Excessive wear or grooving in the crankshaft oil seal sleeve may require the use of a new sleeve (refer to Section 1.3.2).

Inspect the bearing for scoring or excessive wear. The crankshaft to bearing clearance with new parts is .0035" to .0071" and a maximum of .0080" with used parts. The crankshaft journal diameter (new) is 2.8770" to 2.8780".

Install Outboard Bearing Support

1. If the bearing was removed, position a new bearing in the support, with the split line in the bearing toward the bottom of the support (Fig. 2), and press it in until it is flush with the rear face of the support.

   NOTICE: The top of the bearing support is identified by the word "TOP" cast in the front face of the support.

2. Install a new oil seal as outlined in Section 1.3.2.
3. Install a new seal ring on the bearing support.
4. Install the bearing support assembly on the engine front cover as outlined in Section 1.3.5.
5. Install the trunnion support.
6. Install the crankshaft pulley (Section 1.3.7).

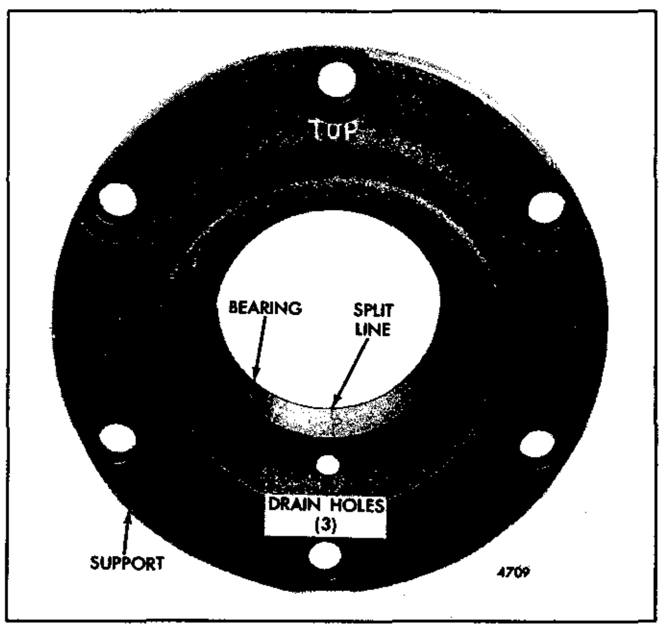


Fig. 2 – Location of Bearing in Support

CRANKSHAFT VIBRATION DAMPER

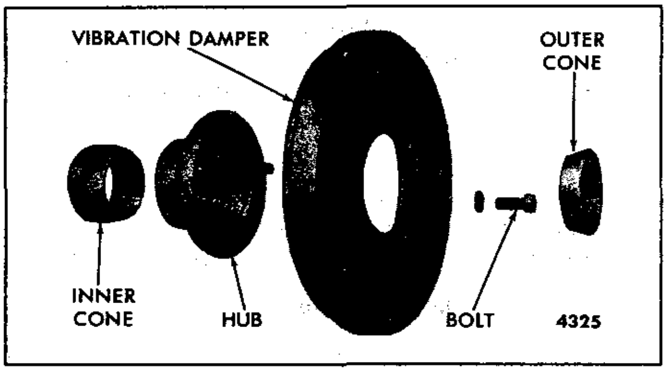


Fig. 1 – Vibration Damper Details and Relative Location of Parts

On certain 8V engines, a viscous type vibration damper is mounted on the front end of the crankshaft to reduce crankshaft stresses to a safe value (Fig. 1). The vibration damper is bolted to a hub which is retained on the front end of the crankshaft.

A viscous type vibration damper consists of an inertia mass (flywheel) enclosed in a fluid–tight outer case but separated therefrom by a thin wall of viscous liquid not responsive to temperature changes. Any movement of the inertia mass, therefore, is resisted by the friction of the fluid, which tends to dampen excessive torsional vibrations in the crankshaft.

The vibration damper must be removed whenever the crankshaft, crankshaft front oil seal or crankshaft front cover is removed.

• Vibration Damper Safety Shields

The need for a vibration damper safety shield is mandatory in certain industrial and marine applications in which the engine operates without a hood or in an open or unprotected area. A properly designed and installed safety shield prevents direct physical contact with the damper during engine operation. It also keeps the damper from "walking off" the crankshaft and causing property damage or injury to personnel working near the engine if the crankshaft pulley bolt should loosen and become detached during engine operation.

Detroit Diesel Corporation does not manufacture, sell, or install vibration damper safety shields as it has no control over the great variety of installations in which DDC engines are applied. Space restrictions in these numerous applications make the supply of a properly designed and shaped vibration damper safety shield the responsibility of the OEM (original equipment manufacturer) or distributor designing and/or manufacturing products in which they apply Detroit Diesel engines. However, DDC believes that the following guidelines should be followed when fabricating or installing shields:

1. Shields should be made form 1/8" to 3/16" perforated steel or heavy steel screen.
2. The perforated or open screen area of the shield should be equal to, or greater than, the total area of both sides of the damper and its circumference.
3. Shields should be no closer than 1/2" from the damper when installed.
4. In all cases, safety shields *must* permit the vibration damper to be well ventilated during engine operation to prevent vibration damper overheating.

   NOTICE: Shielded vibration dampers are frequently difficult to inspect visually because of the design of the shield and/or end items in which the engine is installed. As a result, it is important for OEM's and distributors to supply written instructions to users of their products, cautioning them to periodically inspect the viscous vibration damper for evidence of a split seam, bulged cover, leaks, dents, etc. Any such evidence is sufficient cause for replacement because these conditions can prevent vibration dampers from functioning properly and, as a result, cause serious engine damage. *At time of normal major engine overhaul, the damper must be replaced, regardless of condition.*

Remove Vibration Damper

1. Remove the crankshaft pulley retaining bolt and washer.
2. Remove the crankshaft pulley. If required, use a suitable puller to remove the pulley.
3. Reinstall the pulley retaining bolt in the end of the crankshaft.
4. Attach puller J 24420 to the vibration damper hub, as shown in Fig. 2, with two long bolts threaded into the two 3/8"–24 tapped holes provided in the hub. Pull the damper and hub assembly, together with the outer cone, until the outer cone is loose on the crankshaft.
5. Remove the puller from the damper hub and pull the outer cone off of the crankshaft.

   NOTICE: Pounding with a hammer or prying with other tools must not be resorted to when removing a viscous type damper from the crankshaft. Dents in the damper outer case may render the damper ineffective. *The damper cannot be repaired.*

6. Slide the vibration damper and damper hub as an assembly off of the end of the crankshaft by hand.
7. If necessary, remove the vibration damper inner cone from the crankshaft.

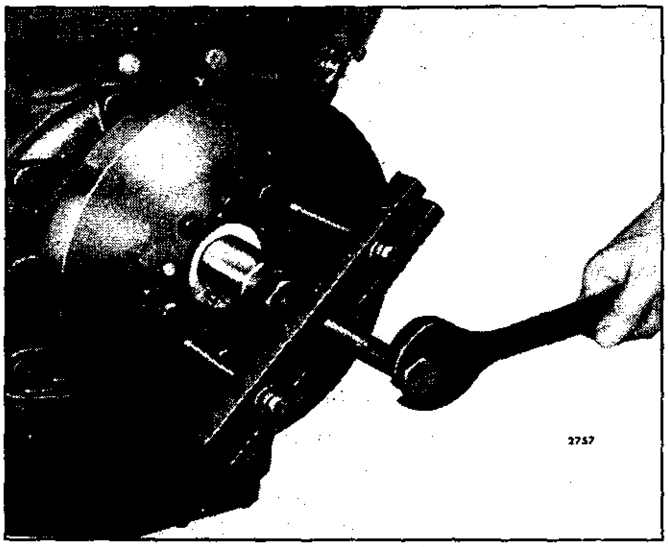


Fig. 2 – Removing Vibration Damper Outer Cone

Inspection

Inspect the damper for dents, nicks, fluid leaks or bulges in the outer casing. Any indications of the above are sufficient cause for replacement of the damper. Due to the close clearances between the damper internal flywheel and the outer casing, dents may render the damper ineffective. Bulges or splits indicate the fluid in the damper has deteriorated and has bulged or forced the casing open at its crimped edges.

Regardless of condition, a viscous type damper must be replaced at the time of normal periodic major engine overhaul.

If damage to the vibration damper is extensive, inspect the crankshaft as outlined in Section 1.3. A loose or defective vibration damper, after extended operation, may result in a cracked crankshaft.

Inspect the damper inner and outer cones, damper hub and the end of the crankshaft for galling or burrs. Slight scratches or burrs may be removed with emery cloth. If seriously damaged, replace the parts and refinish the end of the crankshaft. Check the outside diameter of the inner cone for wear at the crankshaft front oil seal contact surface. If worn, replace the oil seal and cone (refer to Section 1.3.2).

A loose engine mount could also damage the vibration damper by allowing the engine to move slightly during operation. Therefore, it is good practice to periodically inspect the engine mounts to be sure they are not loose, cracked or deteriorated.

Install Vibration Damper

All parts on the front of the crankshaft must be positioned without any noticeable interference.

1. If removed, pilot the damper inner cone over the end of the crankshaft, through the oil seal and up against the oil slinger, with the tapered end of the cone pointing toward the front end of the crankshaft.
2. Slide the damper and hub as an assembly over the end of the crankshaft (with the long end of the hub facing the inner cone) and up against the damper inner cone. *Do not* hit the damper with a hammer to position it on the crankshaft.
3. Slide the damper outer cone over the end of the crankshaft and up against the damper hub, with the tapered end of the cone pointing toward the hub.
4. Install the pulley on the crankshaft.
5. Place the washer on the crankshaft end bolt and thread the bolt into the end of the crankshaft.
6. Tighten the crankshaft end bolt as follows:
   a. Tighten the bolt to 180 lb–ft (244 N·m) torque.
   b. Strike the end of the bolt a sharp blow with a 2 to 3 pound lead hammer.
   c. Tighten the bolt to 300 lb–ft (407 N·m) torque and strike the bolt again.
   d. Retighten the bolt to 300 lb–ft (407 N·m) torque. *Do not hit the crankshaft end bolt after the last tightening of the bolt or the clamping effect will be reduced.*

The damper must be securely fastened to the crankshaft. When the bolt is drawn up to the specified torque, the cone will hold the damper rigidly in place.

- **NOTICE:** The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. However, the barring operation should always be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened during the barring operation. Otherwise, serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.
- **NOTICE:** Barring a left–hand rotating marine engine equipped with a Jabsco raw water pump may result in damage to the rubber impeller if the impeller vanes are forced to rotate against their normal direction of deflection. To avoid damage, detach the cover and remove the impeller before barring the engine. Mark the front of the impeller for easy reinstallation.
- **CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.**

CRANKSHAFT PULLEY

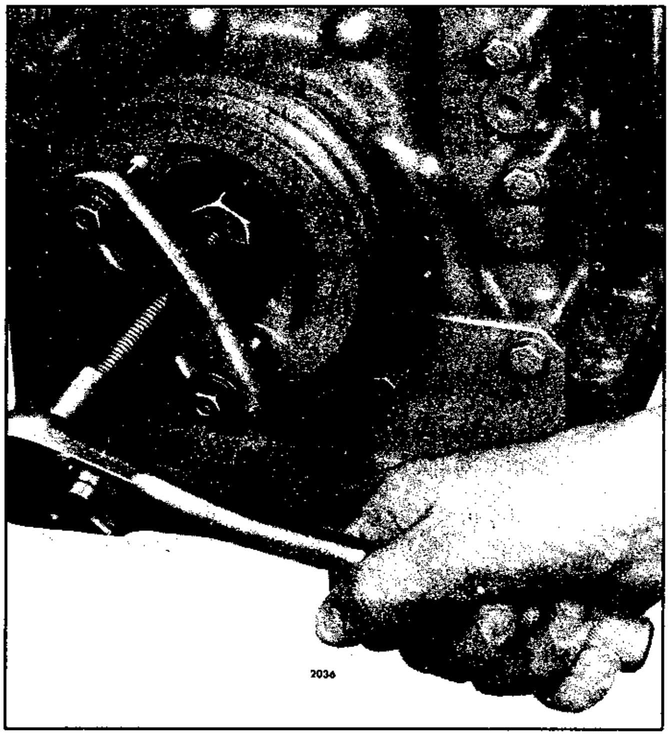


Fig. 1 – Removing Crankshaft Pulley Using Puller J 24420–A

The crankshaft pulley is secured to the front end of the crankshaft by a special washer and a bolt. The engine application determines the type of crankshaft pulley to be used.

The appearance of the rubber bushing (if used) does not determine the condition of a rubber mounted crankshaft pulley. Check for failure of the rubber bushing by locking the crankshaft and applying pressure to the crankshaft pulley. If the pulley cannot be rotated, the bushing is in satisfactory condition. If necessary, replace the rubber bushing.

Remove Crankshaft Pulley

1. Remove the belts from the crankshaft pulley.
2. Remove the crankshaft pulley retaining bolt and special washer.
3. If a rigid type pulley is being removed from an In–line or 6V engine, install the pulley retaining bolt and puller J 24420–A (Fig. 1). Then, force the pulley off the crankshaft by turning the puller center screw in.

On pulleys that do not incorporate two tapped holes in the front face of the pulley, use a two arm universal type puller.

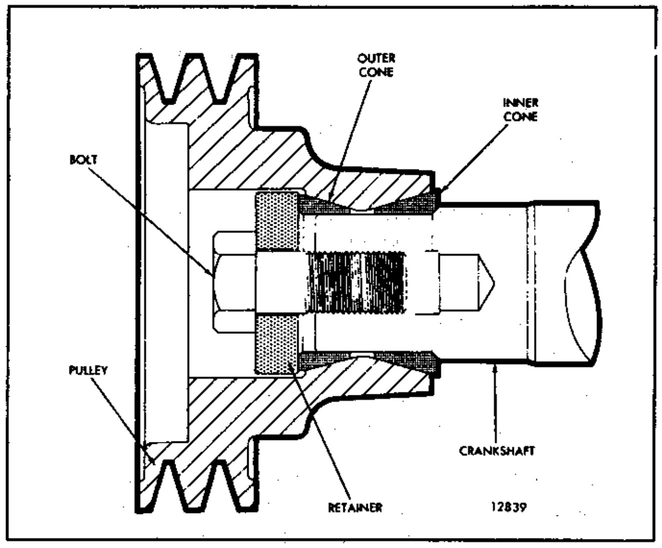


Fig. 2 – Cone Mounted Pulley

If a puller is required to remove a rigid type pulley from an 8V engine, use a universal type puller. Three tapped holes are provided in the pulley to facilitate removal.

4. Remove the outer and inner cones, if used.
5. If a rubber mounted pulley with an internal thread is being removed from an 8V engine, use puller J 5356. To use the tool, screw the 2–1/2"–16 thread into the pulley hub as far as possible with the center screw backed off. Then, force the pulley off the crankshaft by turning the center screw in.

Install Crankshaft Pulley

1. Lubricate the end of the crankshaft with engine oil to facilitate pulley installation.
2. Slide the inner cone (Fig. 2), if used, on the crankshaft.

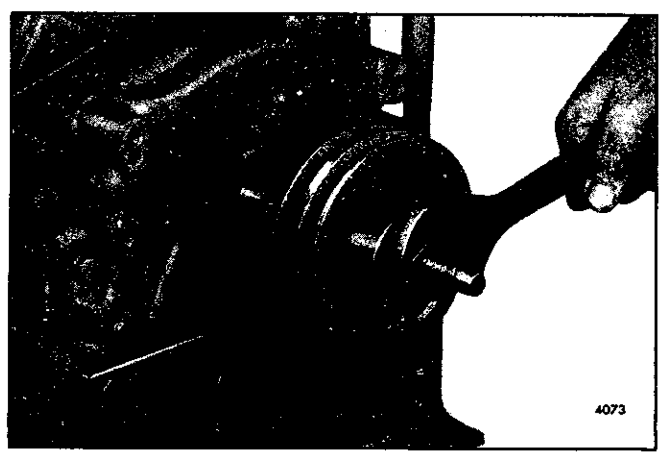


Fig. 3 – Installing Crankshaft Pulley Using Installer J 7773

3. On an 8V engine, install two Woodruff keys (if removed) in the keyways in the front end of the crankshaft.

4. Start the pulley straight on the end of the crankshaft.

5. Install a rigid type pulley on an In-line or 6V engine with installer J 7773 (Fig. 3). Then, remove the installer.

6. Slide a rigid type pulley on an 8V engine. If necessary, hold a block of wood against the hub of the pulley and tap the pulley on the crankshaft with a hammer.

7. Slide the outer cone (Fig. 2), if used, on the crankshaft.

8. Place the washer on the crankshaft bolt and thread the bolt into the front end of the crankshaft.

9. On certain 4-53 and 6V engines, a splined crankshaft pulley is used. Place a drive flange washer over the splined end of the crankshaft. Align the splines and tap the pulley on the crankshaft with a plastic hammer. Place another drive flange washer on the bolt and thread it into the end of the crankshaft. Tighten the 3/4"-16 bolt to 290-300 lb-ft (393-407 N·m) torque.

10. On In-line engines with cone mounted pulleys NOT stamped with the letter "A", tighten the 3/4"-16 bolt to 290-300 lb-ft (393-407 N·m) torque.

11. On all In-line and 6V engines with the rigid type pulleys and cone mounted pulleys stamped with the letter "A", tighten the 3/4"-16 bolt to 200-220 lb-ft (271-298 N·m) torque.

12. When pulleys stamped with the letter "U" (in a square box) are used, tighten the 3/4"-16 bolt to 290-310 lb-ft (393-421 N·m) torque.

13. On 8V engines, tighten the 1"-14 crankshaft end bolt as follows:

    a. Tighten the bolt to 180 lb-ft (244 N·m) torque.

    b. Strike the end of the bolt a sharp blow with a 2 to 3 pound lead hammer.

    c. Retighten the bolt to 300 lb-ft (407 N·m) torque. *Do not hit the crankshaft end bolt after the last tightening of the bolt or the clamping effect will be reduced.*

14. Install and adjust the belts.

FLYWHEEL

The flywheel is attached to the rear end of the crankshaft with six self–locking bolts. On an 8V engine, two dowels are provided in the rear end of the crankshaft for locating the flywheel. A scuff plate is used between the flywheel and the bolt heads to prevent the bolt heads from scoring the flywheel surface.

A steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the flywheel.

The flywheel is machined to provide true alignment with the clutch or a power take–off driving ring, and the center bore provides for installation of a clutch pilot bearing. The clutch or power take–off driving ring is bolted to the flywheel.

An oil seal ring, which provides an oil tight connection between the crankshaft and the flywheel, is fitted into a groove on flywheels used with hydraulic couplings, clutches or Torqmatic converters.

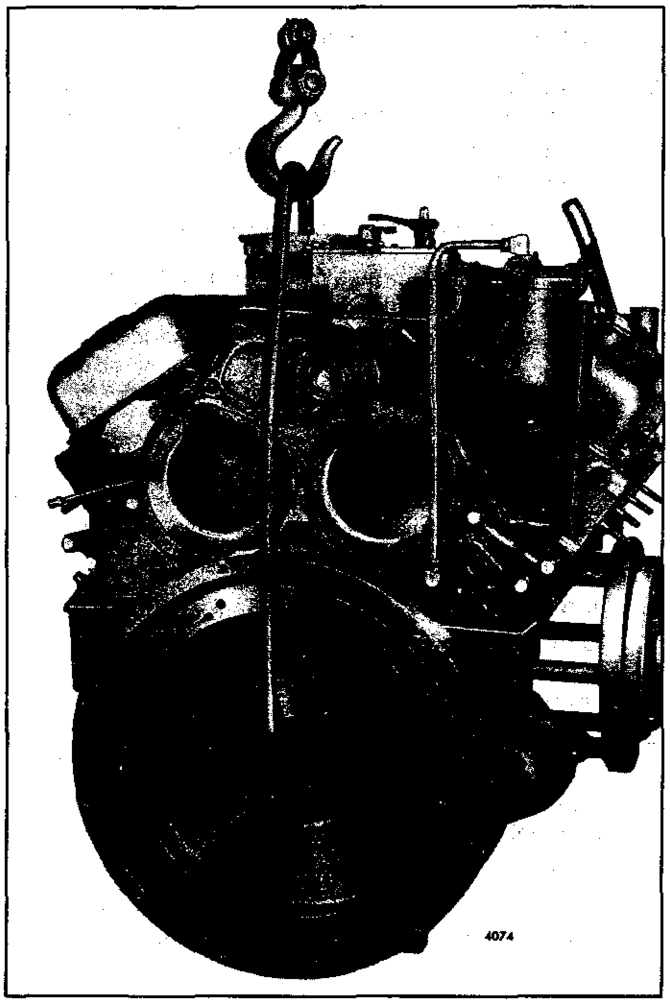


Fig. 1 – Removing Flywheel

The flywheel must be removed for service operations such as replacing the starter ring gear, crankshaft or flywheel housing. On torque converter units, the flywheel is part of the torque converter assembly and is covered in the applicable converter service manual.

Remove Flywheel (Transmission Removed)

1. If a clutch housing is attached to the flywheel housing, remove the flywheel as follows:
   a. Remove the flywheel attaching bolts and the scuff plate.
   b. Lift the flywheel off the end of the crankshaft and out of the clutch housing.
2. If a clutch housing is not used, remove the flywheel as follows:
   a. Remove the flywheel attaching bolts and the scuff plate while holding the flywheel in position by hand, then reinstall one bolt.

   CAUTION: When removing or installing the attaching bolts, hold the flywheel firmly against the crankshaft by hand to prevent it from slipping off the end of the crankshaft. The flywheel is NOT doweled to the crankshaft, except on 8V engines.

   b. Attach flywheel lifting tool J 6361–01 to the flywheel with two 3/8"–16 bolts of suitable length as shown in Fig. 1 or use tool J 25026.
   c. Attach a chain hoist to the lifting tool.
   d. Remove the remaining flywheel attaching bolt.
   e. Move the upper end of the lifting tool in and out to loosen the flywheel, then withdraw the flywheel from the crankshaft and the flywheel housing.
   f. Remove the clutch pilot bearing, if used, as outlined in Section 1.4.1.
   g. Remove the oil seal ring, if used.

Inspection

Check the clutch contact face of the flywheel for scoring, overheating or cracks. If scored, the flywheel may be refaced. However, *do not* remove more than .020" of metal from the flywheel. Maintain all of the radii when refacing the flywheel.

Replace the ring gear if the gear teeth are excessively worn or damaged.

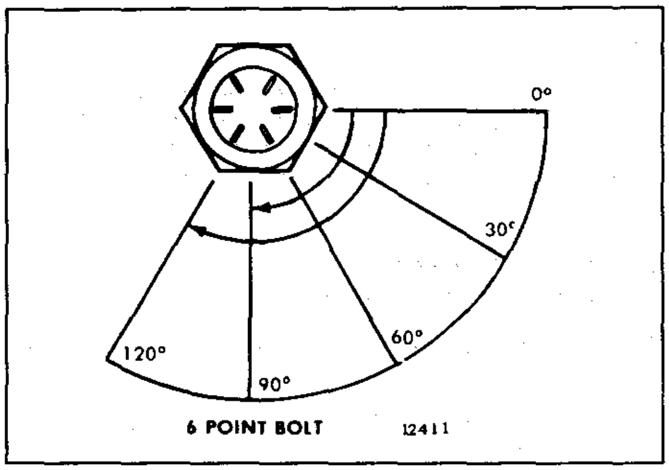


Fig. 2 – Torque–Turn Limits

Check the butt end of the crankshaft and flywheel contact surface. If necessary, lightly stone the crankshaft end and the flywheel contact surface to remove any fretting or brinnelling.

On crankshafts with dowels, be sure and check the dowel extension. Dowels must not extend more than 1/2" from the crankshaft.

Make sure that the crankshaft and flywheel contact surfaces and the bolt threads in the crankshaft end are clean and dry, to ensure proper metal–to–metal contact and maximum friction, before attaching the flywheel.

New bolts should be used to mount or remount the flywheel. However, if the original bolts are determined to be serviceable and are to be reused, clean them thoroughly before starting the assembly procedure.

Remove Ring Gear

Note whether the ring gear teeth are chamfered. The replacement gear must be installed so that the chamfer on the teeth faces the same direction with relationship to the flywheel as on the gear that is to be removed. Then remove the ring gear as follows:

1. Support the flywheel, crankshaft side down, on a solid flat surface or a hardwood block which is slightly smaller than the inside diameter of the ring gear.
2. Drive the ring gear off the flywheel with a suitable drift and hammer. Work around the circumference of the gear to avoid binding the gear on the flywheel.
3. If a clutch pilot bearing is used, inspect the bearing and replace it, if necessary.

Install Ring Gear

1. Support the flywheel, ring gear side up, on a solid flat surface.
2. Rest the ring gear on a flat **metal surface** and heat the gear uniformly with an acetylene torch, keeping the torch moving around the gear to avoid hot spots.

   NOTICE: Do not, under any circumstances, heat the gear over 400°F (204°C); excessive heat may destroy the original heat treatment. Heat indicating "crayons", which are placed on the ring gear and melt at a pre–determined temperature, may be obtained from most tool vendors. Use of these "crayons" will ensure against overheating the gear.

3. Use a pair of tongs to place the gear on the flywheel with the chamfer, if any, facing the same direction as on the gear just removed.
4. Tap the gear in place against the shoulder on the flywheel. If the gear cannot be tapped into place readily so that it is seated all the way around, remove it and apply additional heat. Refer to the notice above.

Install Flywheel

1. Install a new oil seal ring, if used.
2. Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing (use guide studs) or clutch housing. Align the flywheel bolt holes with the crankshaft bolt holes.
3. Install the clutch pilot bearing (if used).
4. Install two bolts through the scuff plate 180° from each other. Snug the bolts to hold the flywheel and scuff plate to the crankshaft. Remove the guide studs.
5. Remove the flywheel lifting tool.
6. Apply International Compound No. 2, or equivalent, to the threads and to the bolt head contact area (underside) of the remaining bolts. The bolt threads must be completely filled with International Compound No. 2 and any excess wiped off.

   NOTICE: International Compound No. 2 must never be used between two surfaces where maximum friction is desired, as between the crankshaft and the flywheel.

7. Install the remaining bolts and run them in snug.
8. Remove the two bolts used temporarily to retain the flywheel, apply International Compound No. 2 as described above, then reinstall them.
9. Use an accurately calibrated torque wrench and tighten the bolts to 50 lb–ft (68 N·m) torque.
10. Turn the bolts an additional 90°–120° (Fig. 2) to obtain the required clamping.

NOTICE: Since the *torque–turn method* provides more consistent clamping than the former method of flywheel installation, bolt torque values should be ignored.

When a clutch pilot bearing is installed, index the flywheel bolts so that the corners of the bolt heads do not overlap the pilot bearing bore in the flywheel. Thus, one of the flats of each bolt head will be in line with the bearing bore. Always rotate bolts in the increased *clamp direction* to prevent underclamping.

11. Mount a dial indicator on the flywheel housing and check the runout of the flywheel at the clutch contact face. The maximum allowable runout is .001" total indicator reading per inch of radius (or .001 mm per millimeter of radius). The radius is measured from the center of the flywheel to the outer edge of the clutch contact face of the flywheel.

CLUTCH PILOT BEARING

The clutch pilot bearing is pressed into the bore of the flywheel assembly and serves as a support for the inner end of the clutch drive shaft.

On most applications, the clutch pilot bearing is held in place on one side by a shoulder in the flywheel and on the other side by a bearing retainer.

On certain applications, the clutch pilot bearing is held in place on one side by a bearing retainer, placed between the flywheel and the end of the crankshaft, and on the other side by the flywheel bolt scuff plate.

Lubrication

A single–shielded ball type clutch pilot bearing should be packed with an all purpose grease such as Shell Alvania No. 2, or equivalent, if not previously packed by the manufacturer. A double–sealed clutch ball type pilot bearing is prepacked with grease and requires no further lubrication.

Remove Clutch Pilot Bearing (Transmission Removed)

With the flywheel attached to the crankshaft, the clutch pilot bearing may be removed as follows:

1. Remove the flywheel attaching bolts and scuff plate while holding the flywheel in position by hand, then reinstall two bolts to hold the flywheel in place.

   When removing or installing the attaching bolts, hold the flywheel firmly against the crankshaft by hand to prevent it from slipping off the end of the crankshaft. The flywheel is NOT doweled to the crankshaft, except on an 8V engine.

2. With the clutch pilot bearing remover adaptor J 23907–2 attached to slide hammer J 23907–1, insert the fingers of the adaptor through the pilot bearing and tighten the thumb screw to expand the fingers against the inner race of the bearing.

3. Tap the slide hammer against the shoulder on the shaft and pull the pilot bearing out of the flywheel.

Inspection

Wipe the prepacked double–sealed bearing clean on the outside and inspect it. *Shielded bearings must not be washed;* dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Clean the other types of bearing thoroughly with clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Check the bearing for free rolling by holding the inner race and revolving the outer race *slowly* by hand. Rough spots in the bearing are sufficient cause for rejecting it.

Install Clutch Pilot Bearing

1. Lubricate the outside diameter of the bearing with clean engine oil.

2. Start the pilot bearing straight into the bore of the flywheel, with the numbered side of the bearing facing away from the crankshaft.

3. Place bearing installer J 3154–04, with suitable adaptor plates, against the pilot bearing. Then drive the bearing straight into and against the shoulder in the flywheel.

4. Install the flywheel as outlined in Section 1.4.

ENGINE DRIVE SHAFT FLEXIBLE COUPLING

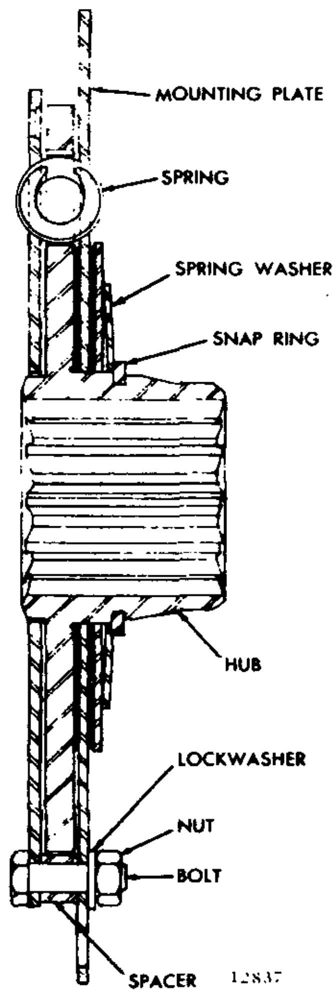


Fig. 1 - Engine Drive Shaft Flexible Coupling

The engine drive shaft flexible coupling (Fig. 1) is of the spring-loaded type having a splined hub to match with the splines on the transmission drive line shaft used on certain applications. The coupling, bolted to the engine flywheel, serves as a drive and also dampens out torque fluctuations between the engine and the transmission.

Remove Coupling (Transmission Removed)

Remove the eight 3/8"-16 x 7/8" bolts which attach the coupling to the flywheel and remove the coupling.

Inspection

Wash the coupling in clean fuel oil and dry it with compressed air. Check for broken or worn springs.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Springs may be replaced by removing the six bolts, lock washers, nuts and spacers holding the two plates together and removing the smaller plate. After replacing the springs, bolt the plates together and tighten the nuts to 25–30 lb-ft (34–41 N·m) torque.

Examine the hub splines for wear and check the flatness of the mounting plate (the plate which bolts to the flywheel). Since the plates, spacers and hubs are manufactured in matched sets, worn hubs or plates cannot be replaced individually, but must be replaced by a complete flexible coupling assembly.

Install Coupling

Align the bolt holes in the coupling with the tapped holes in the flywheel. Since one bolt hole is offset, the coupling can be attached in only one position. Install the eight 3/8"-16 x 7/8" bolts and tighten them securely.

FLYWHEEL HOUSING

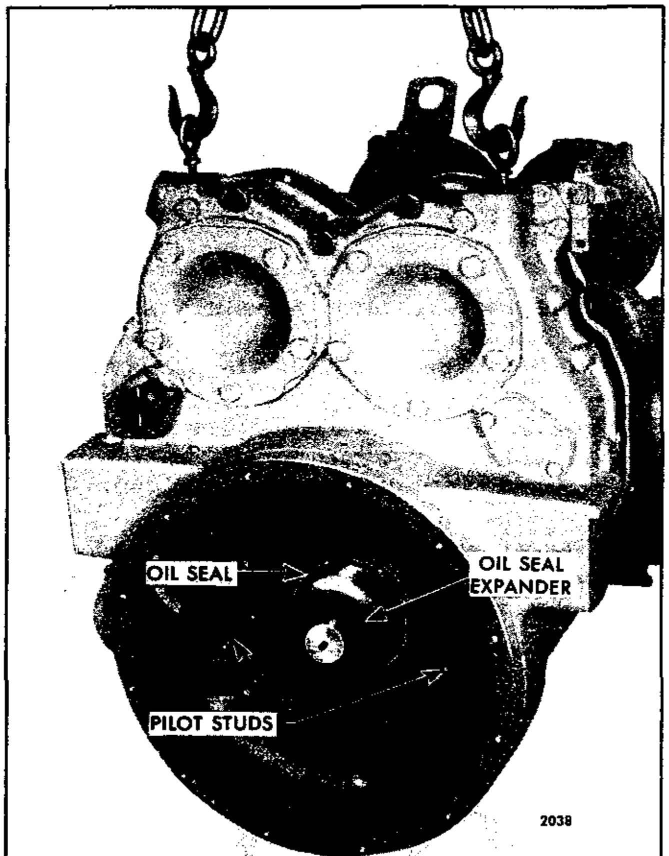


Fig. 1 – Removing or Installing Flywheel Housing

The flywheel housing is a one-piece casting, mounted against the rear cylinder block end plate, which provides a cover for the gear train and the flywheel. It also serves as a support for the starting motor and the transmission.

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing (Section 1.3.2).

Remove Flywheel Housing

1. Mount the engine on an overhaul stand as outlined in Section 1.1.
2. Remove the starting motor from the flywheel housing or the clutch housing.
3. Remove the flywheel.
4. Remove the oil pan.
5. Remove the clutch housing, if used.

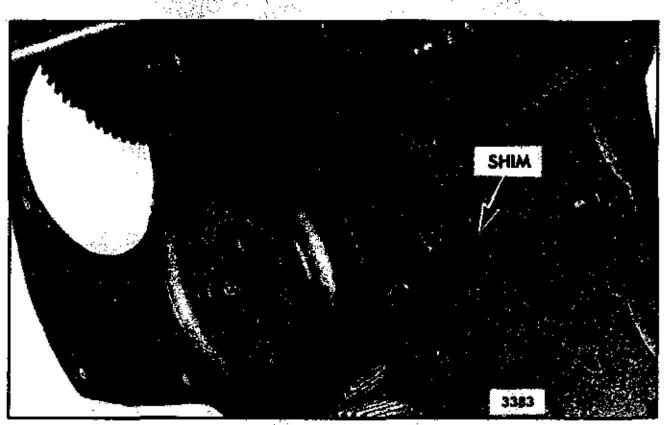


Fig. 2 – Location of Shim

6. Remove the fuel pump, if it is mounted on the flywheel housing.
7. Remove the blower drive cover on 6V and 8V engines, the blower drive shaft retainer ring and the blower drive shaft on the 6V engine.
8. Remove the governor and blower drive support (6V engine).
9. Remove all of the bolts from the flywheel housing. Also remove the blower-to-flywheel housing bolts on the 2-53 or 3-53 engines.

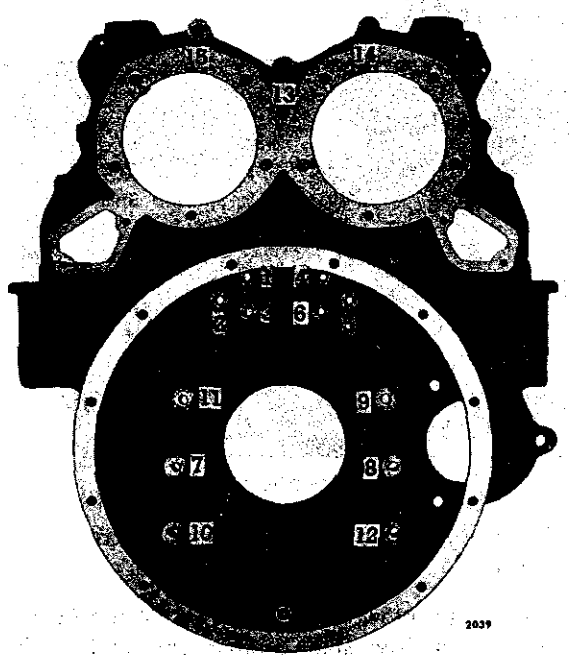
   When removing the flywheel housing bolts, note the location of the various size bolts, lock washers, flat washers and copper washers so they may be reinstalled in their proper location.
10. To guide the flywheel housing until it clears the end of the crankshaft, thread two pilot studs J 7540 into the cylinder block (Fig. 1).
11. Thread eyebolts into the tapped holes in the pads (if provided) on the top or sides of the flywheel housing and attach a chain hoist with a suitable sling to the eyebolts. Then strike the front face of the housing alternately on each side with a soft hammer to loosen and work it off the dowel pins.

Inspection

Clean the flywheel housing and inspect it for cracks or any other damage.

It is very important that all old gasket material be thoroughly removed from the flywheel housing and the end plate, otherwise, runout of the pilot and face of the housing may be affected when the housing is installed on the engine.

Remove and discard the crankshaft rear oil seal. Install a new oil seal as outlined in Section 1.3.2.



Bolt Size	Location
5/16"-18x2 1/2"	3-6
3/8"-16x7/8"	1-2-4-5
3/8"-16x2 1/2"	7-8-9-10-11-12
3/8"-24x3 9/16"	13-14-15

Fig. 3 – Flywheel Housing Bolt Sizes and Tightening Sequence (Operation 1)—In-Line Engine

Install Flywheel Housing

1. Lubricate the gear train teeth with clean engine oil.

2. Affix a new flywheel housing gasket to the rear face of the cylinder block rear end plate. The V-type engines employ two gaskets (one large and one small). Affix the small (7/8" dia.) gasket near the top of the end plate.

3. If the flywheel housing has an integral cast hub, install a flywheel housing-to-end plate shim (.015" thick). Use grease to hold the shim to the cylinder block rear end plate (Fig. 2).

4. Coat the lip of the crankshaft oil seal lightly with engine oil (single-lip seal) or vegetable shortening (double-lip seal). Do not scratch or nick the sealing edge of the oil seal.

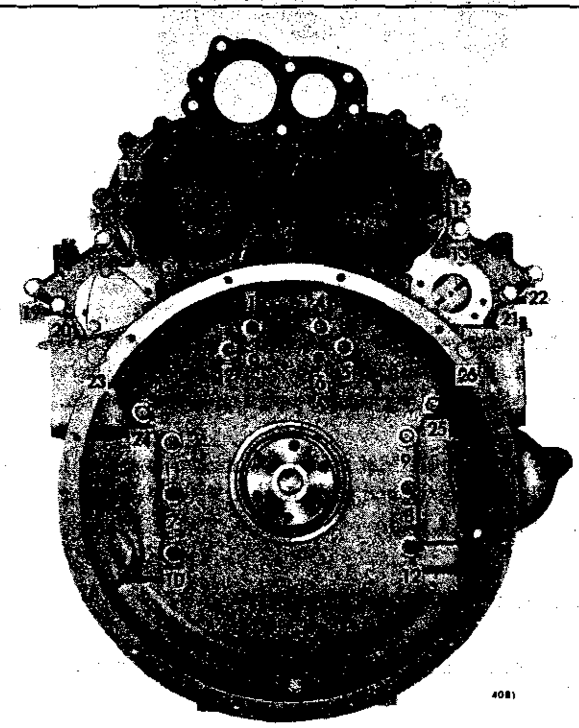
- **NOTICE:** Do not lubricate a Teflon seal lip or the O.D. of the crankshaft wear sleeve before seal installation. Teflon lip seals must be installed dry. This is to allow the transfer of the Teflon to the crankshaft or wear sleeve for proper sealing.

5. Thread two pilot studs J 7540 into the cylinder block to guide the housing in place (Fig. 1). On In-line and 6V engines, to pilot the oil seal on the crankshaft successfully, use oil seal expander J 9769 (standard size seal) or J 21278-01 (oversize seal) on the end of the crankshaft. On 8V engines, use oil seal expander J 22425.

6. With the housing suitably supported, position it over the crankshaft and up against the cylinder block rear end plate and gasket(s). Remove the oil seal expander.

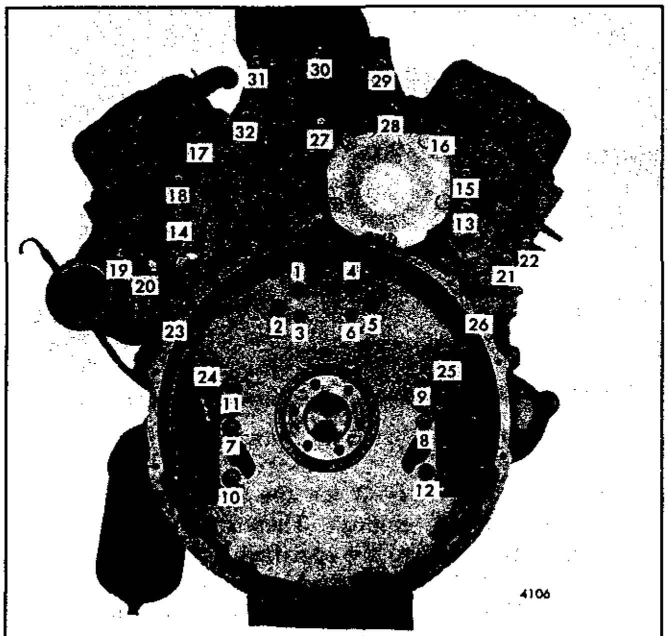
7. Install all of the flywheel housing bolts, lock washers, flat washers and copper washers in their proper location, finger tight. Remove the pilot studs.

   If the engine is equipped with a clutch housing, do not install the six bolts numbered 7 through 12 (Fig. 3) until the clutch housing is installed.



Bolt Size	Location
5/16"-18x2 1/2"	3-6
3/8"-16x2 1/2"	1-2-4-5-7-8-9-10-11-12-24-25
3/8"-16x2 3/4"	23-26
3/8"-16x3 3/4"	13-14-19-20-21-22
3/8"-24x3 1/4"	15-16
3/8"-24x3 1/2"	17-18

Fig. 4 – Flywheel Housing Bolt Sizes and Tightening Sequence (Operation 1)—6V Engine



Bolt Size	Location
5/16"-18x2 1/2"	3-6
3/8"-16x2 1/2"	1-2-4-5
3/8"-16x2 3/4"	7-8-9-10-11-12-24-25
3/8"-16x3 1/2"	13-14
3/8"-16x3 3/4"	27-28-29-32
3/8"-16x4" Cad	19-20-21-22
3/8"-24x3 1/4"	15-16
3/8"-24x3 1/2"	17-18
3/8"-16x6 3/4"	23-26

Fig. 5 – Flywheel Housing Bolt Sizes and Tightening Sequence (Operation 1)—8V Engine

8. On an In–line right–hand rotation engine, start at No. 1 (No. 4 on left–hand rotation engine) and draw the bolts up snug in the sequence shown in Fig. 3. On V engines, start at No. 4 on a right–hand rotation engine (No. 1 on a left–hand rotation engine) and draw the bolts up snug in the sequence shown in Figs. 4 and 5.

NOTICE: On an 8V engine, when tightening the idler gear hub bolts, turn the engine crankshaft to prevent any bind or brinelling of the idler gear bearing. The crankshaft must be rotated for the flywheel housing bell bolt tightening also.

9. Refer to Fig. 6 for the final bolt tightening sequence on an In–line engine. Then start at No. 1 and tighten the bolts to the specified torque.

   a. Tighten the 5/16"–18 bolts (numbers 11 and 12) to 19–23 lb–ft (26–31 N·m) torque and the 3/8"–16 bolts (numbers 7 through 10) to 40–45 lb–ft (54–61 N·m) torque. Tighten the remaining 3/8"–16 and 3/8"–24 bolts to 25–30 lb–ft (34–41 N·m) torque.

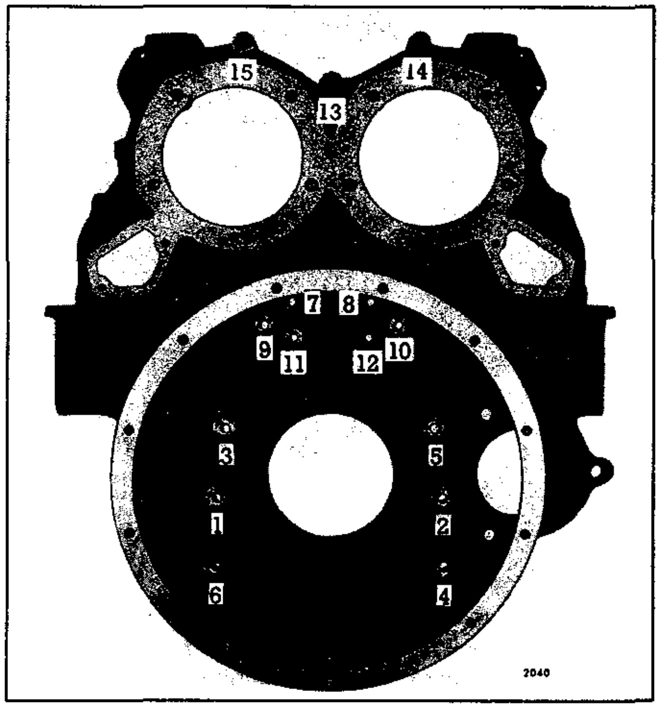


Fig. 6 – Flywheel Housing Bolt Tightening Sequence (Operation 2)—In–Line Engine

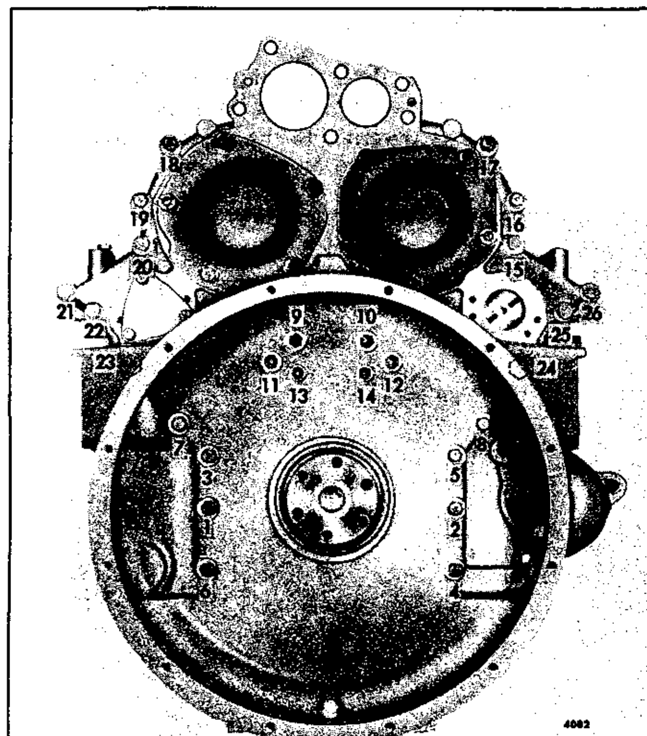


Fig. 7 – Flywheel Housing Bolt Tightening Sequence (Operation 2)—6V Engine

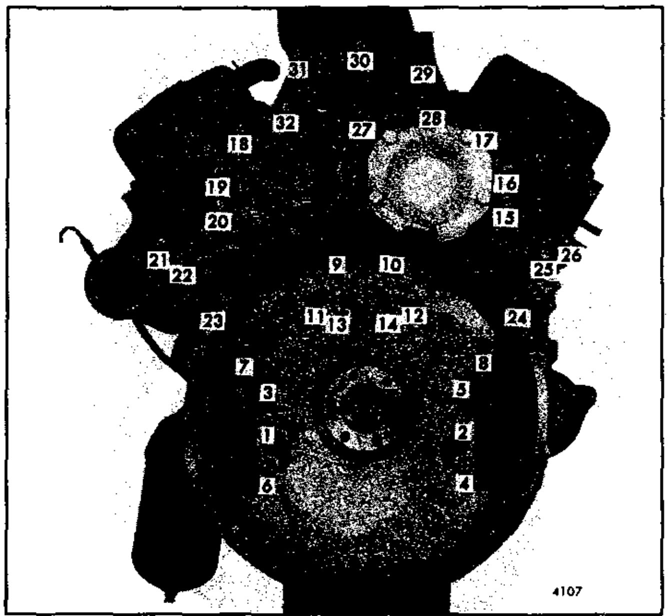


Fig. 8 – Flywheel Housing Bolt Tightening Sequence (Operation 2)—8V Engine

NOTICE: Prior to Engine Serial Numbers 2D–903, 3D–011 and 4D–103, the bolts numbered 7 through 12 in Fig. 3 were all 5/16"–18 bolts and must be tightened to 19–23 lb–ft (26–31 N·m) torque.

b. On the two, three and four cylinder engines, tighten the two 5/16"–18 bolts that secure the top of the governor to the flywheel housing to 10–12 lb–ft (14–16 N·m) torque.

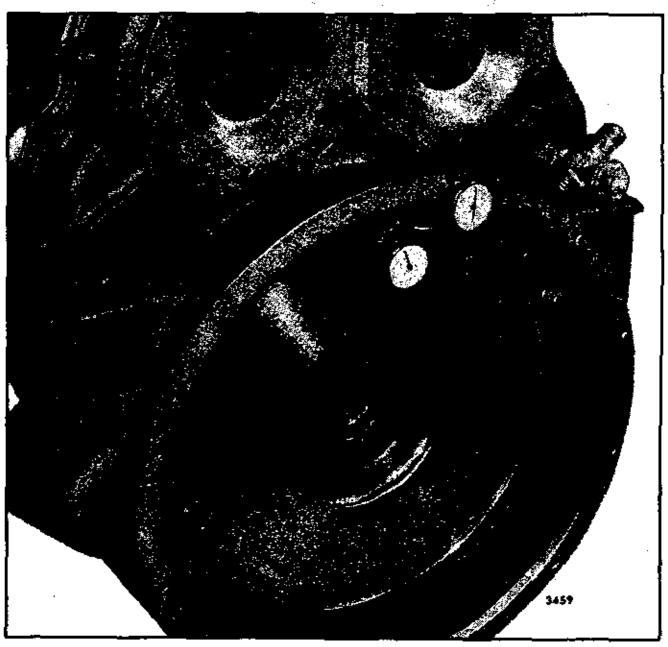


Fig. 9 – Checking Flywheel Housing Concentricity

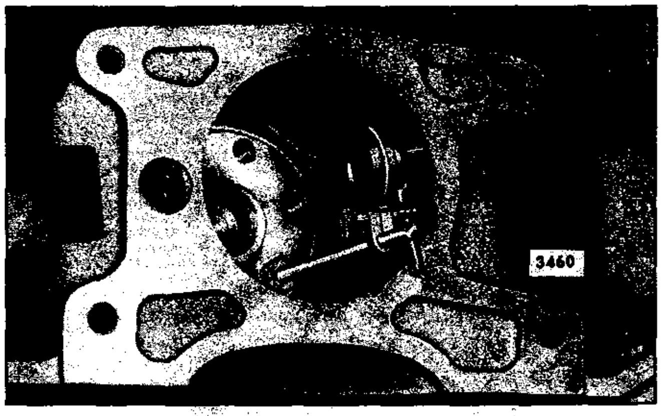


Fig. 10 – Checking Bore Runout

10. Refer to Fig. 7 or 8 for the final bolt tightening sequence for V engines. Then start at No. 1 and tighten the bolts to the specified torque. Tighten the 5/16"–18 bolts (numbers 13 and 14) to 19–23 lb–ft (26–31 N·m) torque and the 3/8"–16 bolts (numbers 9 through 12) to 40–45 lb–ft (54–61 N·m) torque. Tighten the remaining 3/8"–16 and 3/8"–24 bolts to 25–30 lb–ft (34–41 N·m) torque. Be sure to rotate the crankshaft when tightening the idler gear hub bolts and flywheel housing bell bolt on an 8V engine.

11. On a 6V engine, install the blower and governor drive support assembly as outlined in Section 2.7.1.1 or 2.7.2.1.

12. Install the flywheel (Section 1.4).

13. Check the flywheel housing concentricity and bolting flange face runout with tool J 9737–C, as follows:

   a. Refer to Fig. 9 and thread the base post J 9737–3 tightly into one of the tapped holes in the flywheel. Then assemble the dial indicators on the base post.

   b. Position the dial indicators straight and square with the flywheel housing bell face and inside bore of the bell. Make sure each indicator has adequate travel in each direction.

   If the flywheel extends beyond the housing bell, the bore and face must be checked separately. Use the special adaptor in the tool set to check the housing bore.

   c. Pry the crankshaft toward one end of the block to ensure that end play is in one direction only.

   d. *Adjust each dial indicator to read zero at the twelve o'clock position.* Rotate the crankshaft one full revolution, recording readings at 90° intervals (4 readings each for the bore and the bolting flange face). On "bossed" flywheel housings position the dial indicators at a location where clearance or obstruction is not a problem.

NOTICE: The hex head of the front crankshaft bolt may be used to turn the crankshaft. However, the barring operation should ALWAYS be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened. Serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

- **CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.**

e. Stop and remove the wrench or cranking bar before recording each reading to ensure accuracy. Record the readings and interpret as follows:

BORE AND FACE RUNOUT

Check value at six o'clock (6:00) position. This value cannot exceed ± .013".

Check values at three o'clock (3:00) and nine o'clock (9:00) positions.

3:00	9:00	EXAMPLES			
		Good		Bad	
+	+	+ .002"	+ .014"	+ .002"	+ .016"
		Difference =	.012"	Difference =	.014"
–	–	– .002"	– .014"	– .002"	– .016"
		Difference =	– .012"	Difference =	– .014"

1

1. Both readings "+" or "–". The difference must not exceed .013".

3:00	9:00	EXAMPLES			
		Good		Bad	
+	–	+ .002"	– .010"	+ .002"	– .012"
		Total =	.012"	Total =	.014"
–	+	– .002"	+ .010"	– .002"	+ .012"
		Total =	.012"	Total =	.014"

2

2. Both readings different, "+/–" or "–/+". The total of dimensions must not .013".

BORE DIAMETER

Verification of bore diameter is required when 3:00 and 9:00 o'clock readings are both "+" or both "–". The total of dimensions must not exceeed .013".

3:00	9:00	EXAMPLES			
		Good		Bad	
+	+	+ .014"	+ .015"	+ .014"	+ .017"
		Total =	.029"	Total =	.031"
–	–	– .014"	– .015"	– .014"	– .017"
		Total =	.029"	Total =	.031"

3

f. If the bore or face runout exceeds the maximum limits, remove the flywheel housing and check for dirt or foreignmaterial (such as old gasket material) between the flywheel housing and the end plate and between the end plate and the cylinder block.

g. Reinstall the flywheel housing and the flywheel and tighten the attaching bolts in the proper sequence and to the specified torque. Then recheck the bore and face runout and the bore diameter. If necessary, replace the flywheel housing.

14. Install the clutch housing, if used. Tighten the 3/8"–16 attaching bolts to 30–35 lb–ft (41–47 N·m) torque and the 3/8"–24 nuts to 35–39 lb–ft (47–53 N·m) torque.

a. Install tool J 9748 in one of the crankshaft bolt holes.

b. Install the dial indicator J 8001–3 and position it to read the bore runout of the housing (Fig. 10). Now check the runout by rotating the crankshaft. The runout should not exceed .008".

c. Reposition the dial indicator to read the face runout and rotate the crankshaft. The maximum allowable runout is .008".

d. If the bore or face runout is excessive, loosen the housing attaching bolts and nuts slightly and tap the housing with a soft hammer in the required direction until the runout is within limits. Tighten the attaching bolts and nuts evenly to 30–35 and 35–39 lb–ft (41–47 and 47–53 N·m) torque respectively. Then recheck the runout.

15. Install the fuel pump (V–type engine), if removed.

16. Use a new gasket and install the oil pan. On 8V engines, if the flywheel housing and oil pan include outriggers for the installation of reinforcement bolts, be sure the oil pan butts up against the flywheel housing before tightening the oil pan bolts. Install and tighten the 1/2"–13 reinforcement bolts.

17. Remove the engine from the overhaul stand and complete assembly of the engine.

PISTON AND PISTON RINGS

TRUNK TYPE PISTON

The trunk type malleable iron piston (Fig. 1) is plated with a protective coating of tin which permits close fitting, reduces scuffing and prolongs piston life. The top of the piston forms the combustion chamber bowl and is designed to compress the air into close proximity to the fuel spray.

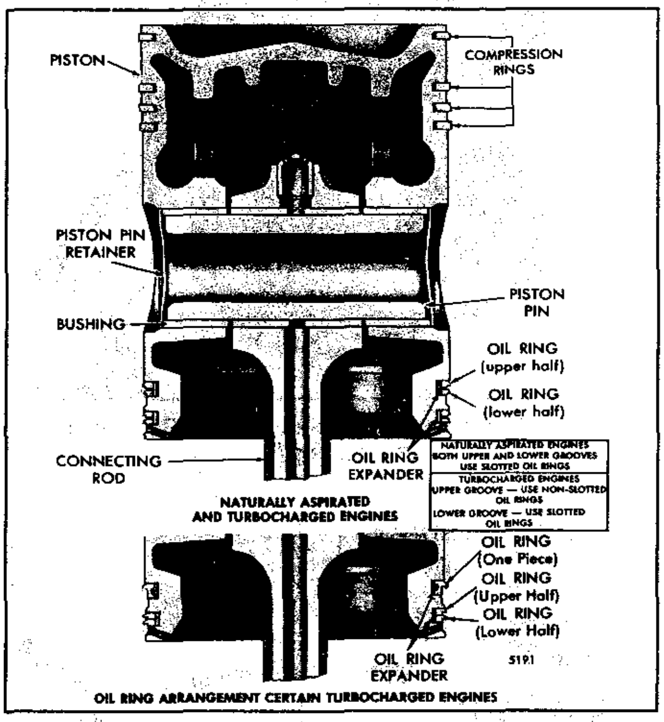


Fig. 1 – Typical Trunk Type Piston Assembly

Each piston is internally braced with fin–shaped ribs and circular struts, scientifically designed to draw heat rapidly from the piston crown and transfer it to the lubricating oil spray to ensure better control of piston ring temperature.

The piston is cooled by a spray of lubricating oil directed at the underside of the piston head from a nozzle in the top of the connecting rod, by fresh air from the blower to the top of the piston and indirectly by the water jacket around the cylinder.

Each piston is balanced to close limits by machining a balancing rib, provided on the inside at the bottom of the piston skirt.

Two bushings, with helical grooved oil passages, are pressed into the piston to provide a bearing for the hardened, floating piston pin (1.375" diameter). After the piston pin has been installed, the hole in the piston at each end of the pin is sealed with a steel retainer. Thus, lubricating oil returning from the sprayed underside of the piston head and working through the grooves in the piston pin bushings is prevented from reaching the cylinder walls.

The current piston pin retainer (formerly colored black) for the 1.375" diameter piston pin has a greater outside diameter (1.6110") and is now brass colored for identification. The former and new retainers are interchangeable in an engine. When rebuilding a turbocharged engine with the 1.375" diameter piston pin, use only the current retainer.

Effective with engine serial numbers 3D–170958, 4D–181763 and 6D–187523, turbocharged engines use a 1.500" diameter piston pin. With the use of the 1.500" diameter piston pin, new piston assemblies, piston pin retainers and connecting rod assemblies are required. The former piston pin diameter is 1.375". The former and new piston and connecting rod assemblies differ only in that they have larger bushing bores to facilitate the installation of new, larger diameter bushings. The larger bushing inner diameter is necessary to accommodate the new, larger piston pin. Because of the larger pin diameter, former and new parts are not separately interchangeable. When it becomes necessary to replace any one of the three major cylinder components, it will be necessary to include the other two to assure interchangeability. Current piston assemblies and connecting rods can be mixed in an engine with the former piston assemblies and connecting rods.

Turbocharged engines incorporate pistons and connecting rod assemblies which utilize "vapor blasted" piston pin bushings. Vapor blasting is a surface finishing process which is applied to the bushing after it is installed and finished bored in the piston or rod. This process cannot be performed in the field. Piston pin bushings may not be replaced in turbocharged engines and when excessive wear exists it will be necessary to replace the piston and/or connecting rod assembly.

Each piston is fitted with compression rings and oil control rings (Fig. 1). Equally spaced drilled holes just below each oil control ring groove permits excess oil, scraped from the cylinder walls, to return to the crankcase.

A new fire ring (top compression ring), prestressed for increased durability, has been released for Series 53 naturally aspirated (NA) engines effective with 3D–189578, 4D–203354 and 6D–223676. The fire ring is identified with the word "TOP" stamped adjacent to the gap and a permanent oval mark on top to indicate prestressing. Current turbocharged engine fire ring (identified by a black oxide coating and a permanent oval mark on top to indicate prestressing) will continue to be available to service turbocharged engines. The chrome facing on both the new NA engine fire ring and the current turbocharged engine fire ring has been increased for improved wear characteristics.

- Two service–only piston ring sets are available for engines operating at light loads or with extended idle periods where high oil consumption or wet stacking may be a concern. These have a tapered face, grooved fire ring, barrel–face compression rings, two–piece oil control rings in each groove, and 5–10 lb tension expanders.

The upper drain holes in the oil ring groove and the "J" relief are omitted on built engines. The piston pins are polished and drilled for positive piston pin bushing lubrication.

Inspect Piston Rings

When an engine is hard to start, runs rough or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed. If the rings are free and are not worn to the extent that the plating or grooves are gone, compression should be within operating specifications. Refer to Section 15.2 for the procedure for checking compression pressure.

Remove Piston and Connecting Rod

1. Drain the cooling system.
2. Drain the oil and remove the oil pan.
3. Remove the oil pump and inlet and outlet pipes, if necessary (Section 4.1).
4. Remove the cylinder head (Section 1.2).
5. Remove the carbon deposits from the upper inner surface of the cylinder liner.
6. Remove the bearing cap and the lower bearing shell from the connecting rod. Then, push the piston and rod assembly out through the top of the cylinder block. The piston cannot be removed from the bottom of the cylinder block.
7. Reassemble the bearing cap and lower bearing shell to the connecting rod.

Disassemble Piston and Connecting Rod

Note the condition of the piston and rings. Then, remove the rings and connecting rod from the piston as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 (Fig. 2).
2. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and pry the retainer from the piston, being careful not to damage the piston or bushings.

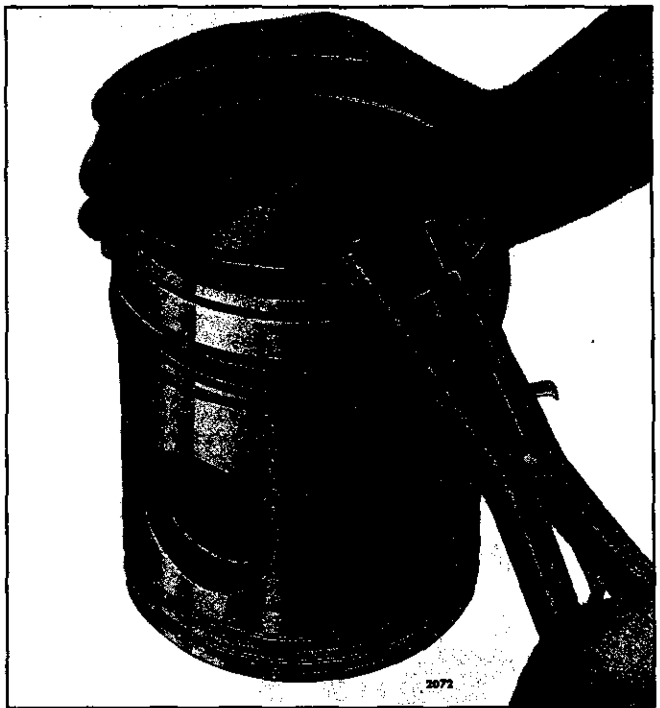


Fig. 2 – Removing or Installing Piston Ring Using Tool J 8128

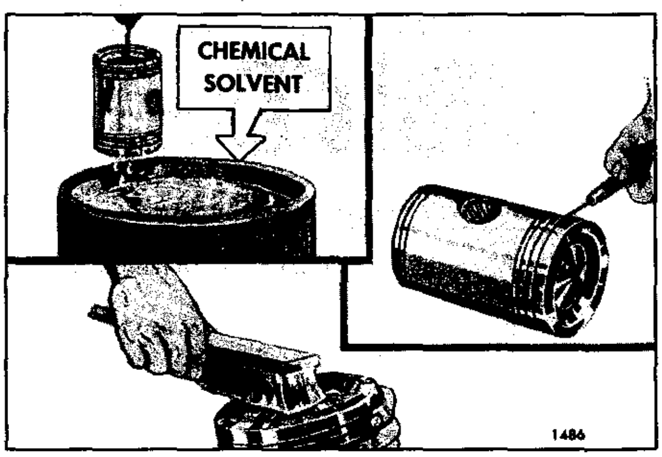


Fig. 3 – Cleaning Piston

3. Withdraw the piston pin from the piston, then remove the connecting rod.
4. Drive the remaining piston pin retainer out from the inside with a brass rod or other suitable tool.

Clean Piston

Clean the piston components with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Fig. 4 – Comparison of Pistons

If fuel oil does not remove the carbon deposits, use a chemical solvent (Fig. 3) that will not harm the piston pin bushings or the tin–plate on the piston.

The upper part of the piston, including the compression ring lands and grooves, is not tin–plated and may be wire–brushed to remove any hard carbon. However, use care to avoid damage to the tin–plating on the piston skirt. Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.

Clean the inside surfaces of the piston and the oil drain holes in the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

Inspection

If the tin–plate on the piston and the original grooves in the piston rings are intact, it is an indication of very little wear.

Excessively worn or scored pistons, rings or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct types and proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise a heavy formation of carbon may result and cause the rings to stick.

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

Examine the piston for score marks, cracks, damaged ring groove lands or indications of overheating. A piston with light score marks which may be cleaned up and reused (Fig. 4). Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots on the piston may be the result of an obstruction in the connecting rod oil passage.

Replace the piston if cracks are found across the internal struts.

Check the cylinder liner and block bore for excessive out–of–round, taper or high spots which could cause failure of the piston (refer to Section 1.0 for Specifications).

Inspection of the connecting rod and piston pin are covered in Section 1.6.1.

Other factors that may contribute to piston failure include oil leakage into the air box, oil pull–over from the air cleaner, dribbling injectors, combustion blow–by and low oil pressure (dilution of the lubricating oil).

Inspect and measure the piston pin bushings. The piston pin–to–bushing clearance with new parts is .0025" to .0034". A maximum clearance of .010" is allowable with worn parts. The piston pin bushings in the connecting rod are covered in Section 1.6.1.

Remove Bushings from Piston

1. Place the piston in the holding fixture J 1513–1 so that the bushing bores are in alignment with the hole in the fixture base.

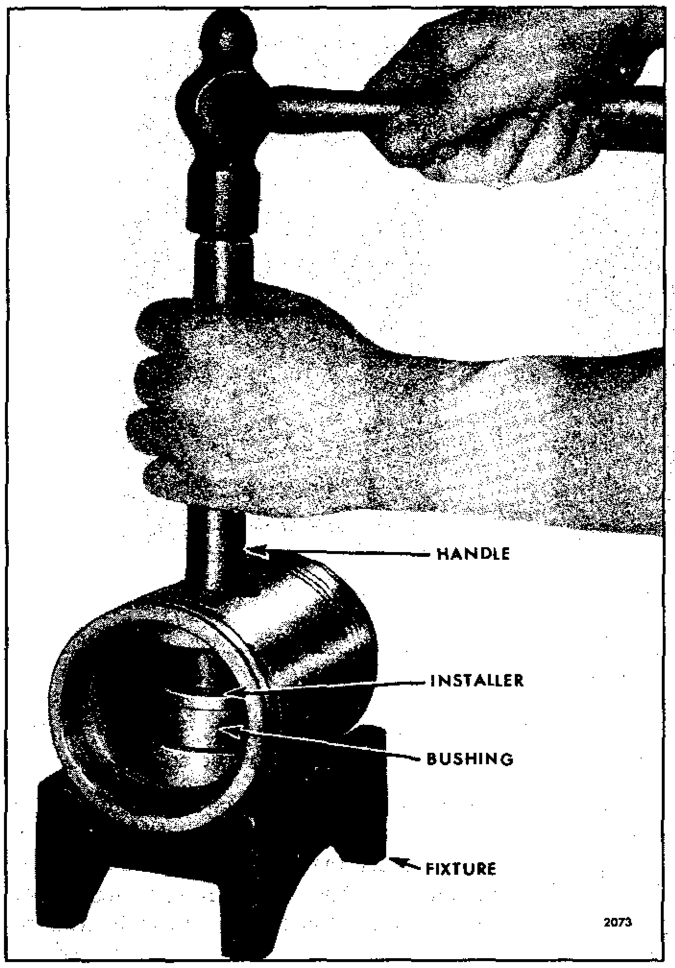


Fig. 5 – Removing or Installing Piston Pin Bushings

Do not remove the bushings from the pistons used in turbocharged engines because they are not serviced separately.

2. Drive each bushing from the piston (non–turbocharged engines) with the bushing remover J 4972–4 and handle J 1513–2 (Fig. 5).

Install Bushings in Piston

1. Place the spacer J 7587–1 in the counterbore in the fixture J 1513–1 (small end up).
2. Place the piston on the fixture so that the spacer protrudes into the bushing bore.
3. Insert the installer J 4972–2 in a bushing, then position the bushing and installer over the lower bushing bore. Locate the joint in the bushing toward the bottom of the piston (Fig. 6).
4. Insert the handle J 1513–2 in the bushing installer and drive the bushing in until it bottoms on the spacer.
5. Install the second bushing in the same manner.
6. The bushings must withstand an end load of 1,800 pounds without moving after installation.

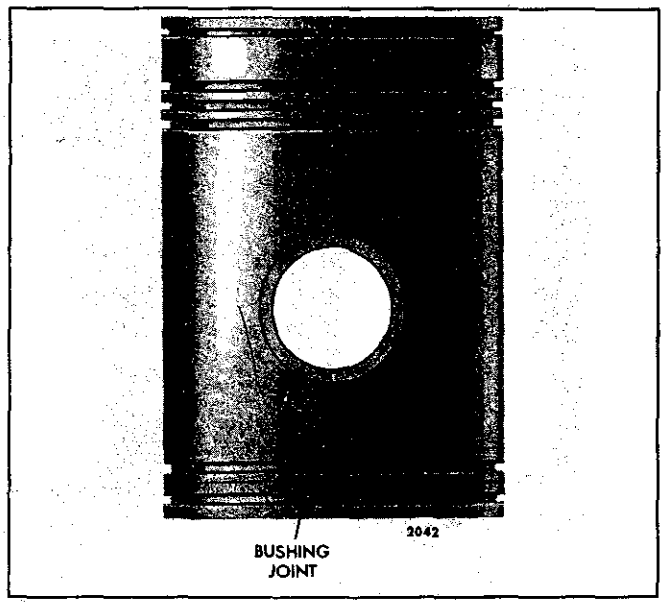


Fig. 6 – Location of Joint in Piston Pin Bushings

7. Ream the bushings to size as follows:
   a. Clamp the reaming fixture J 5273 in a vise (Fig. 7). Then, insert the guide bushing J 4970–5 in the fixture and secure it with the set screw.
   b. Place the piston in the fixture and insert the pilot end of the reamer J 4970–4 through the clamping bar, bushings and into the guide bushing.
   c. With the piston, fixture and reamer in alignment, tighten the wing nuts securely.

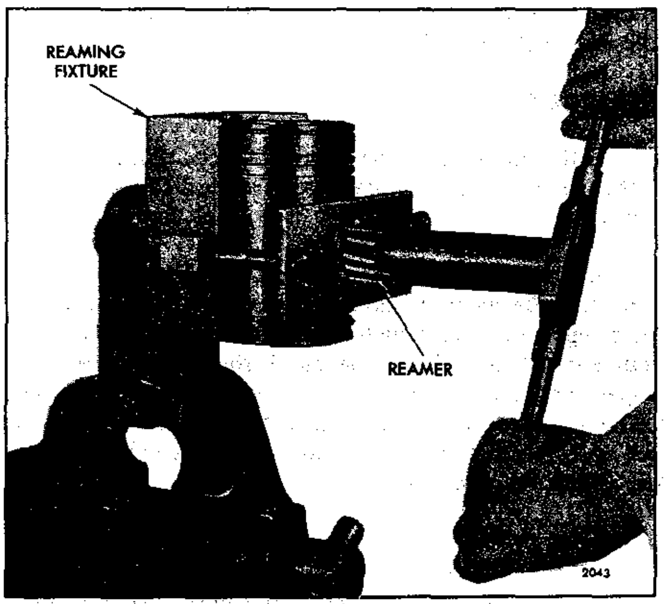


Fig. 7 – Reaming Piston Pin Bushings

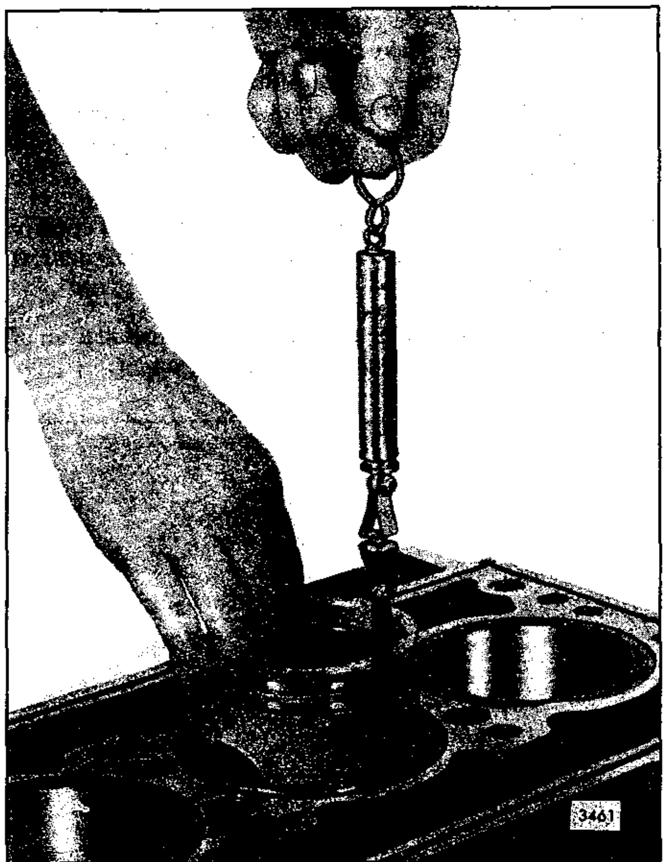


Fig. 8 – Measuring Piston-to-liner Clearance

d. Ream the bushings (Fig. 7). Turn the reamer in a clockwise direction only, when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.

e. Withdraw the reamer and remove the piston from the fixture. Blow out the chips and measure the inside diameter of the bushings. The diameter must be 1.3775" to 1.3780".

Fitting Piston

Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore. Measurements should be taken at room temperature (70°F or 21°C). The taper and out-of-round must not exceed .0005". Refer to Section 1.0 for piston diameter Specifications.

A new cylinder liner has an inside diameter of 3.8752" to 3.8767". The piston-to-liner clearance, with new parts, is .0027" to .0068" (non-turbocharged engines) or .0047" to .0088" (turbocharged engines). A maximum clearance of .010" (non-turbocharged engines) or .012" (turbocharged engines) is allowable with used parts.

With the cylinder liner installed in the cylinder block, hold the piston upside down in the liner and check the clearance in four places 90° apart (Fig. 8).

Use feeler gage set J 5438-01 to check the clearance. The spring scale, attached to the proper feeler gage, is used to measure the force in pounds required to withdraw the feeler gage.

Select a feeler gage with a thickness that will require a pull of six pounds to remove. The clearance will be .001" greater than the thickness of the feeler gage used, i.e., a .004" feeler gage will indicate a clearance of .005" when it is withdrawn with a pull of six pounds. The feeler gage must be perfectly flat and free of nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs. Remove burrs with a fine hone (a flat one is preferable) and recheck the clearance.

Fitting Piston Rings

Each piston is fitted with a fire ring, three compression rings and two oil control rings (Fig. 1).

The current top compression (fire) ring can be identified by the bright chrome on the bottom side and oxide (rust color) on the top. The former ring had a plain metal color on both sides.

A two-piece oil control ring is used in both oil ring grooves in the pistons for non-turbocharged (naturally aspirated) engines. A one-piece oil control ring is used in the upper ring groove and a two-piece ring in the lower ring groove in the pistons for turbocharged engines. Brazil built engines use non-slotted upper oil control rings and low tension expanders.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston or cylinder liner is installed.

Insert one ring at a time inside of the cylinder liner and far enough down to be within the normal area of ring travel. Use a piston to push the ring down to be sure it is parallel with the top of the liner. Then, measure the ring gap with a feeler gage (Fig. 9). Refer to Section 1.0 for ring gap specifications.

If the gap on a compression ring is insufficient, it may be increased by filing or stoning the ends of the ring. File or stone both ends of the ring so the cutting action is from the outer surface to the inner surface. This will prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must be approximately .015".

Check the ring side clearance (Fig. 10). Ring side clearances are specified in Section 1.0.

• Lubrication

Use a mixture of clean engine oil and *STP* (or equivalent) on all moving parts of the cylinder kit during assembly. This mixture adheres to the parts for a longer period of time than plain engine oil, thus helping prevent scuffing of parts at engine start–up. The suggested mix ratio is 8:1 (8 parts engine oil to 1 part *STP*, or equivalent).

Install Piston Rings

Before installing the piston rings, assemble the piston and rod as outlined under *Assemble Connecting Rod to Piston* in Section 1.6.1. Then, refer to Fig. 1 and install the piston rings. Lubricate the piston rings and piston with the clean engine oil *STP* mix before installing the rings.

COMPRESSION RINGS

1. Starting with the bottom ring, install the compression rings with tool J 8128 (Fig. 2). To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston. When installing the top compression (fire) ring with the tapered face, be sure the side marked "TOP" is toward the top of the piston.
2. Stagger the ring gaps around the piston.

OIL CONTROL RINGS

The upper and lower oil control rings used on pistons for *naturally aspirated and turbocharged* engines consist of two halves (upper and lower). The upper oil control ring used on pistons for certain *turbocharged* engines is a one–piece ring while the lower ring is a two–piece ring (upper and lower halves). Install the oil control rings as follows:

1. Install the ring expanders in the oil control ring grooves in the piston.

   NOTICE: When installing the oil control rings, use care to prevent overlapping the ends of the ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption.

2. To install the one–piece ring on certain turbocharged engines, position it over the upper ring groove, using tool J 8128, with the gap 180° from the gap in the expander and the scraper edge facing down. Press the ring against the gap side of the expander to prevent the ends of the expander from overlapping, then align the ring with the groove and release the tension on the tool, permitting the ring to slip in position.

   Install the upper and lower halves of the lower oil control ring by hand. Install the upper half with the gap 180° from the gap in the expander. Then, install the lower half with the gap 45° from the gap in the upper half of the ring. Make sure the scraper edges are facing down (toward the bottom of the piston). The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.

3. Install the upper and lower halves of both oil control rings (naturally aspirated and turbocharged engines) as outlined above.

If there is a noticeable resistance during installation of the piston, check for an overlapped ring expander.

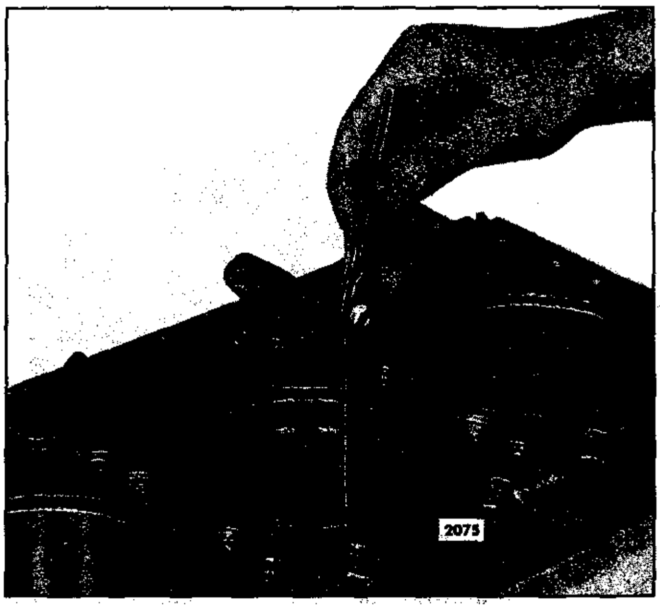


Fig. 9 – Measuring Piston Ring Gap

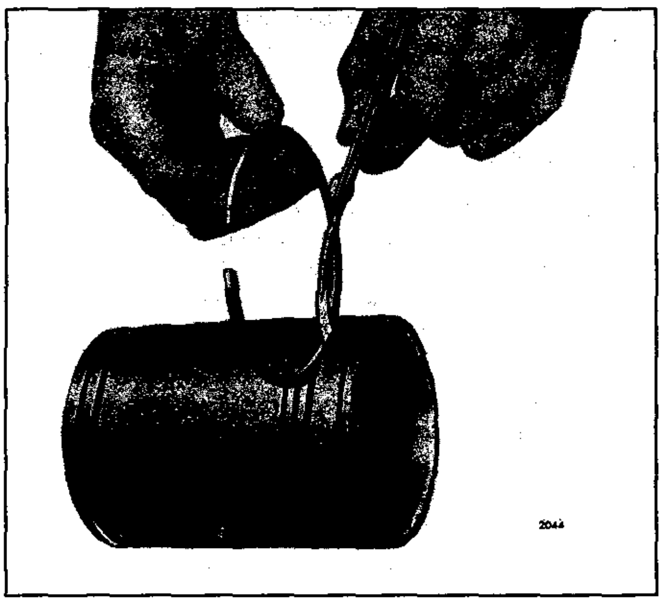


Fig. 10 – Measuring Piston Ring Side Clearance

CROSS–HEAD TYPE PISTON

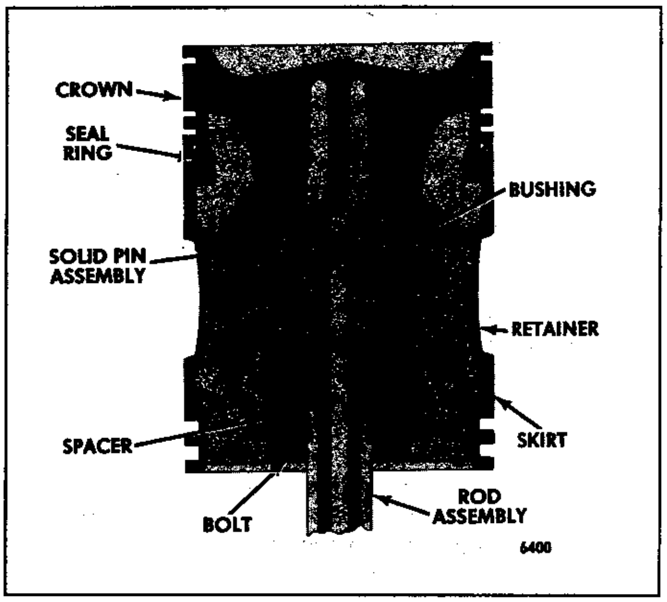


Fig. 11 – Cross–Head Piston and Connecting Rod Assembly

The cross–head piston (Figs. 11 and 12) is a two–piece piston consisting of a crown and skirt. A fluoroelastomer oil seal ring is used between the crown and skirt which are held together by the piston pin. Ring grooves are machined in the piston crown for a fire ring and two compression rings. The crown is also machined to accept a 150° slipper type bushing (bearing). The piston skirt incorporates two oil control ring grooves, piston pin holes and piston pin retainer counterbores. Equally spaced drain holes are located in the oil ring groove area to permit excess oil, scraped from the cylinder walls, to return to the crankcase. A lubricating oil hole is drilled through the solid piston pin. Two bolts and spacers are used to attach the connecting rod to the piston pin.

Internal parts of the piston are lubricated and cooled by the engine lubricating oil. Oil is pressure–fed up the drilled passage in the connecting rod, through the oil tube in the piston pin, then through the center hole in the bushing to the underside of the piston crown. A portion of the oil flows along the grooves in the bushing to lubricate the piston pin.

During engine operation, gas loads pushing down on the piston crown are taken directly by the piston pin and bushing. The piston skirt, being separate, is free from vertical load distortion; thermal distortion is also reduced as the piston crown expands. As the connecting rod swings to one side during downward travel of the piston, the major portion of the side load is taken by the piston skirt.

In cross–head piston equipped engines, a complete new balance weight system is used. When replacing trunk–type pistons with cross–head pistons, new camshaft front pulleys (integral weight) plus new bolt–on weights on the rear camshaft gears (Sections 1.7.2 and 1.7.3) must be used.

- New cross–head pistons and rings, connecting rods, and cylinder liners became standard in all turbocharged industrial engines equipped with bypass blowers, effective with unit serial numbers 3D193526, 4D209292, 6D0229545.

- A new high–durability piston dome with 14% thicker standpipe struts for improved dome support became standard on all cross–head pistons approximately May 24, 1988.

- **NOTICE:** Cross–head pistons and trunk–type pistons must not be used together in an engine. The difference in weight of the pistons will affect engine balance. Failure to observe this precaution can result in serious engine damage.

Inspect Piston Rings

When an engine is hard to start, runs rough or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed. If the rings are free and are not worn to the extent that the plating or grooves are gone, compression should be within operating specifications. Refer to Section 15.2 for the procedure for checking compression pressure.

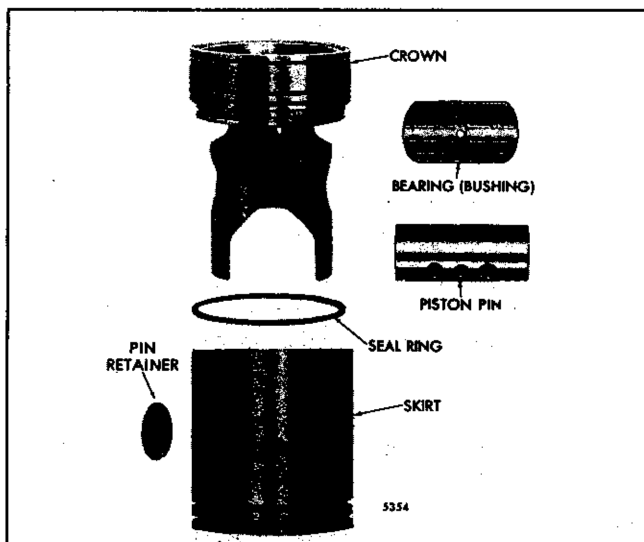


Fig. 12 – Cross–Head Piston and Connecting Rod Components

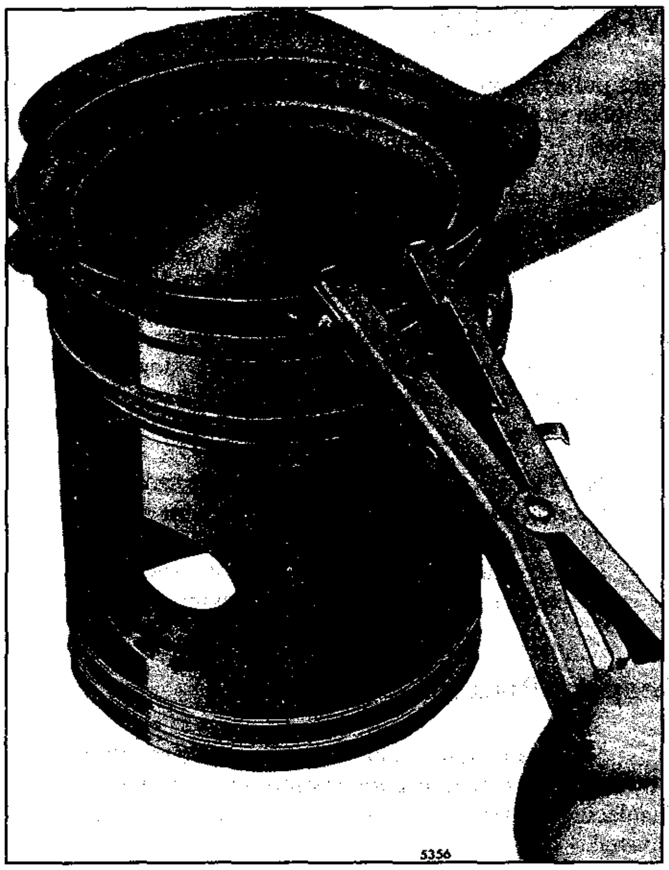


Fig. 13 – Removing or Installing Piston Rings with Tool J 8128

Remove Piston and Connecting Rod

1. Drain the cooling system.
2. Drain the oil and remove the oil pan.
3. Remove the oil pump inlet pipe, if necessary (Section 4.1).
4. Remove the cylinder head (Section 1.2).
5. Remove the carbon deposits from the upper inner surface of the cylinder liner.
6. Remove the bearing cap and the lower bearing shell from the connecting rod. Then, push the piston and rod assembly out through the top of the cylinder block. The piston cannot be removed from the bottom of the cylinder block.
7. Reassemble the bearing cap and lower bearing shell to the connecting rod.

• Fluoroelastomer (Viton) Caution

Under normal design conditions, fluoroelastomer (Viton) parts, such as crown–to–skirt seal rings, are perfectly safe to handle. However, a potential hazard may occur if these components are raised to a temperature above 600°F (316°C), such as during a cylinder failure or engine fire. At temperatures above 600°F (316°C) fluoroelastomer will decompose (indicated by charring or the appearance of a black, sticky mass) and produce hydrofluoric acid. This is extremely corrosive and, if touched by bare skin, may cause severe burns, sometimes with symptoms delayed for several hours.

CAUTION: To avoid personal injury, wear goggles or a faceplate and neoprene or PVC gloves when handling fluoroelastomer seals which have been degraded by excess heat. Make sure engine parts have cooled before handling them. If hydrogen fluoride condensate is expected, wash equipment and parts well with lime water (calcium hydroxide solution) before reusing. Discard gloves after handling degraded fluoroelastomer.

Disassemble Piston and Connecting Rod

Piston assembly components should be match–marked during disassembly to ensure that they are reassembled in the same position. Note the condition of the piston and rings. Then, remove the rings and disassemble the piston, as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 (Fig. 13).
2. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and pry the retainer from the piston, being careful not to damage the piston or bushing. Remove the opposite retainer in the same manner.
3. Loosen the two bolts which secure the connecting rod to the piston pin. Then, remove the rod and piston assembly from the vise and place the assembly on the bench. Remove the two bolts and spacers and remove the connecting rod.
4. Withdraw the piston pin.
5. Separate the piston skirt from the piston crown. Tool J 33048 may be used to aid in disassembling the dome from the skirt, of piston assemblies using fluoroelastomer seal rings. The piston assembly should be grasped by the skirt, and the pin area of the dome brought down onto the neoprene head of the tool with sufficient force to separate the dome from the skirt. The neoprene–padded base of the tool will absorb the impact of any dropped piston skirt.

CAUTION:To reduce the risk of personal injury when disassembling the piston dome from the skirt, keep fingers out of the piston pin hole and wear steel-toed shoes.

6. Remove the seal ring from the piston crown.
7. Remove the piston pin bushing (bearing).

Cleaning

Clean the piston components with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

If fuel oil does not remove the carbon deposits, use an approved chemical solvent that will not harm the tin–plate on the piston skirt. Do not use chemical solvent on the bushing.

The piston crown, including the compression ring grooves, is not tin–plated and may be wire–brushed to remove any hard carbon. *Do not wire–brush the piston skirt.* Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.

Clean the inside surfaces of the piston crown and skirt and the oil drain holes in the lower half of the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

Glass beading can be used to clean a piston crown. Mico Bead Glass Shot MS–M (.0029" – .0058") is recommended. Allowable air pressure is 80–100 psi (552–689 kPa). After cleaning, do not leave glass beads in the piston crown.

NOTICE: Do not attempt to clean the piston skirt by glass beading, as it will remove the tin–plating.

Use crocus cloth wet with fuel oil to remove any trace of fretting and/or corrosion on the connecting rod saddle–to– piston pin contact surface. Do not use crocus cloth on the bushing side of the pin. Polishing or refinishing the piston pin on the bushing side is not recommended.

Inspection

If the tin–plate on the piston skirt and the original grooves in the piston rings are intact, it is an indication of very little wear.

Excessively worn or scored piston skirts, rings or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct types and proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise, a heavy formation of carbon may result and cause the rings to stick.

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

Examine the piston skirt and crown for score marks, cracks, damaged ring groove lands or indications of overheating. Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots may be the result of an obstruction in the connecting rod oil passage.

Check the cylinder liner and block bore for excessive out–of–round, taper or high spots which could cause failure of the piston (refer to Section 1.0 for Specifications).

Inspection of the connecting rod, piston pin and piston pin bushing are covered in Section 1.6.1.

Other factors that may contribute to piston failure include oil leakage into the air box, oil pull–over from the air cleaner, dribbling injectors, combustion blow–by and low oil pressure (dilution of the lubricating oil).

• Crosshead Piston Dome Inspection

Before reusing a crosshead piston dome, inspect the dome for serviceability, using the magnetic particle or fluorescent magnetic particle inspection method. In both cases, the direction of magnetism must be proper to assure finding the cracks of concern.

Magnetic Particle Method – Magnetize the dome, then cover with a fine magnetic powder (dry) or solution (wet). Flaws such as cracks will form small local magnets which will attract the metallic particles, effectively marking the crack. Demagnetize the dome and clean throughly after completing the test.

Fluorescent Magnetic Particle Method – This method is similar to the magnetic particle method, but is more sensitive since it employs magnetic particles which are fluorescent and glow under "Black Light". Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the "Black Light".

If magnetic particle inspection reveals a crack in any strut of a crosshead piston dome, the dome must be discarded and replaced.

NOTICE: Reusing a crosshead piston dome with a cracked strut can result in dome separation and serious engine damage.

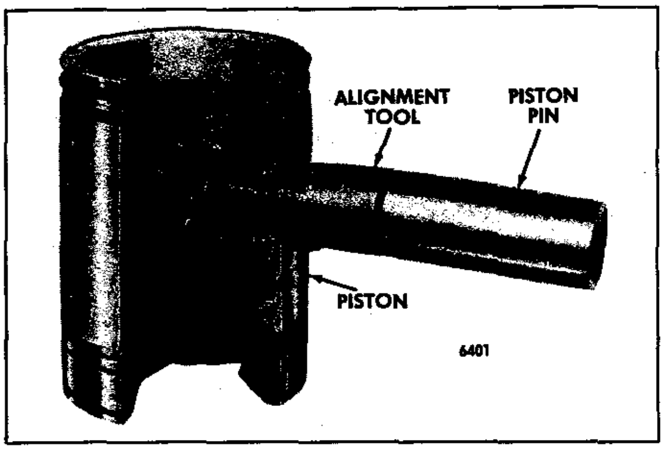


Fig. 14 – Installing Piston Pin Using Alignment Tool J 35619

When conducting a magnetic particle inspection, make sure that a casting joint is not mistaken for a crack.

• Lubrication

Use a mixture of clean engine oil and *STP* (or equivalent) on all moving parts of the cylinder kit during assembly. This mixture adheres to the parts for a longer period of time than plain engine oil, thus helping prevent scuffing of parts at engine start–up. The suggested mix ratio is 8:1 (8 parts engine oil to 1 part *STP*, or equivalent).

Assemble Piston and Connecting Rod

1. Refer to Section 1.0 (Shop Notes and Specifications) on reusing piston assembly components.
2. Install the bearing (bushing) in the piston crown. It should slide into the piston crown without force. With new parts, there is .0005" to .0105" clearance between the edge of the bushing and the groove in the piston crown. The bearing must be installed before assembling the piston skirt and crown.
3. Lubricate the seal ring with engine oil and install in the groove on the piston crown. Allow time for the seal to return to its original shape before installing the skirt. *Excessive stretching should be avoided.*.
4. The fluoroelastomer seal ring can be compressed by hand when the skirt is pushed into position on the piston crown. Lubricate the seal with engine oil. Before completely assembling the piston, check to make sure the seal ring does not roll out of the groove during assembly. This condition can cause the skirt to cock with respect to the dome. This may result in premature piston wear or the inability to install the piston in the liner. This condition is evidenced by the non–uniform clearance between the dome and the skirt after assembly. This condition may be corrected by cleaning the skirt counterbore with crocus cloth the remove any tin or sharp edge that may be pulling the seal out of the groove.
5. Lubricate the piston pin with clean engine oil and install it (Fig. 14).

   NOTICE: Line up the piston pin opening in the piston skirt with the bearing (bushing) opening in the piston crown to prevent damage to the pin or bushing.

6. Install the spacers on the two 3/8"–24 x 1.88" connecting rod to piston pin attaching bolts.
7. Apply a small amount of International Compound No. 2, or equivalent, to the bolt threads and bolt head contact contact surfaces.
8. Install and tighten the bolts finger tight. Then, clamp the connecting rod in a vise and tighten the bolts to 30–35 lb–ft (41–47 N·m) torque (Fig. 15). Do not exceed this torque.
9. • Place a new piston pin retainer in position. Then, place the crowned end of installer J 35572 against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston (Fig. 16).
10. Install the second piston pin retainer in the same manner. Due to the size of the counterbore in the piston skirt, be careful when installing the piston pin retainers and inspect them to be sure they are not buckled and that they are fully seated in the counterbores. The width of the land should be even around the retainer.
11. One important function of the piston pin retainer is to prevent the oil, which cools the underside of the piston and lubricates the piston pin bushing, from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23987–01 (Fig. 17). Place the suction cup over the retainer and hand operate the lever to pull a vacuum of ten inches on the gage. A drop in the gage reading indicates air leakage at the retainer.

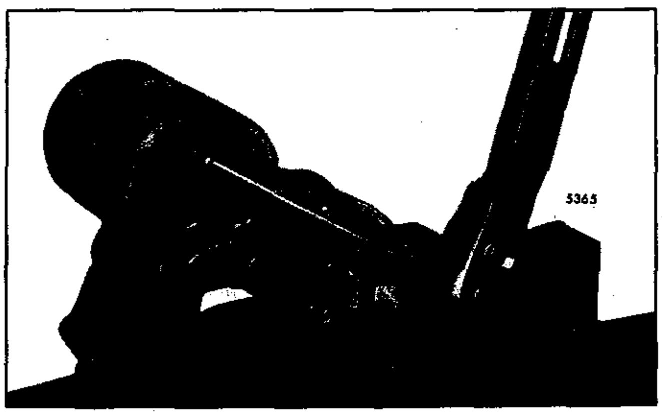


Fig. 15 – Tightening Connecting Rod to Piston Pin Bolts

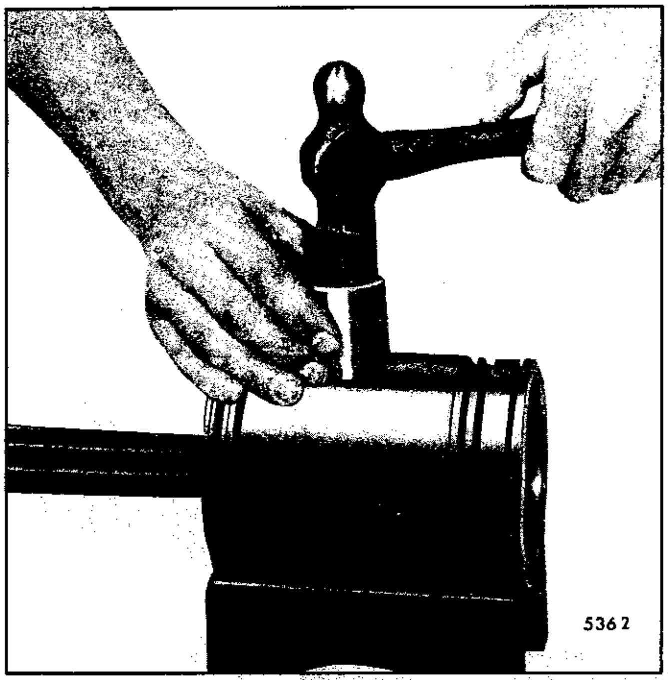


Fig. 16 – Installing Piston Pin Retainer Using Tool J 35572

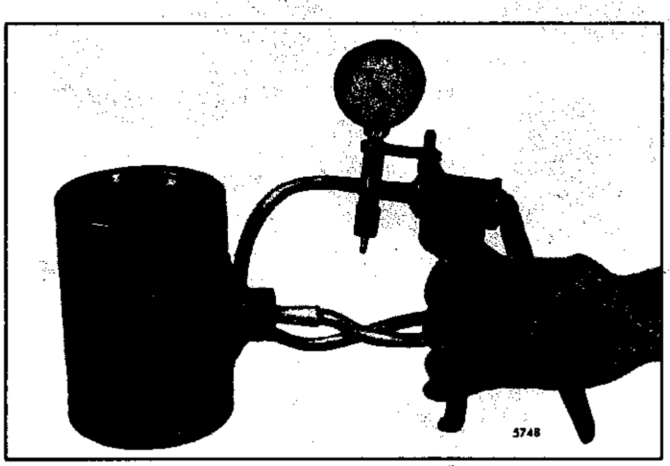


Fig. 17 – Checking Piston Pin Retainer for Proper Sealing with Tool J 23987–01

Fitting Piston

Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore. Measurements should be taken at room temperature (70°F or 21°C). Refer to Section 1.0 for Specifications.

The piston–to–liner clearance, with new parts, will vary with the particular piston and cylinder liner (refer to Section 1.0). A maximum clearance of .012" is allowable with used parts.

With the cylinder liner installed in the cylinder block, hold the piston skirt upside down in the liner and check the clearance in four places 90° apart (Fig. 18).

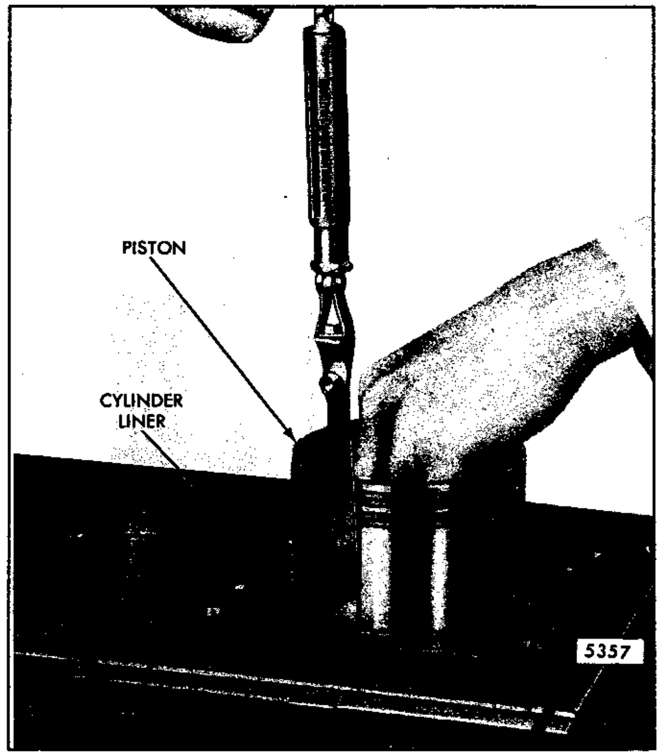


Fig. 18 – Measuring Piston–to–Liner Clearance with Tool J 5438–01

Use feeler gage set J 5438–01 to check the clearance. The spring scale, attached to the proper feeler gage, is used to measure the force in pounds required to withdraw the feeler gage.

Select a feeler gage with a thickness that will require a pull of six pounds to remove. The clearance will be .001" greater than the thickness of the feeler gage used, i.e., a .004" feeler gage will indicate a clearance of .005" when it is withdrawn with a pull of six pounds. The feeler gage must be perfectly flat and free of nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs. Remove burrs with a fine hone (a flat one is preferable) and recheck the clearance.

Fitting Piston Rings

Each piston is fitted with a fire ring, two compression rings and two oil control rings (Fig. 19).

The top (fire) ring is pre–stressed. It is identified by a small indentation mark on the top side.

A new "wide gap" prestressed fire ring and a new one piece new upper oil control ring and expander are being used on cross–head pistons. The fire rings differ only in their width dimensions. The trunk type piston ring has a .0804"–.0820" width. The cross–head piston ring has a .1034"–.1050" width.

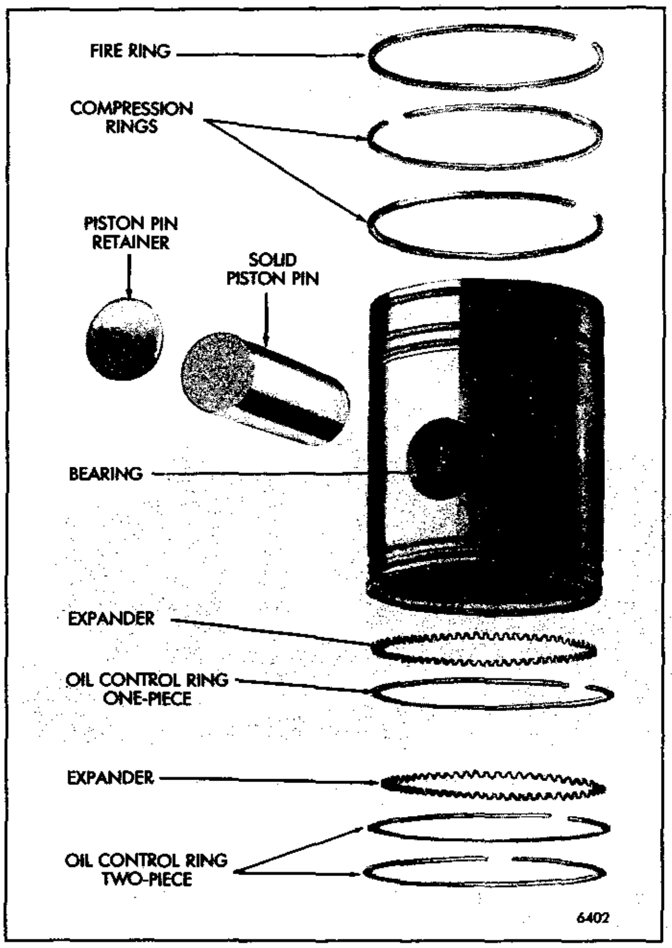


Fig. 19 – Piston Ring Location

A one–piece oil control ring in the upper ring groove and a two–piece ring in the lower ring groove are used in the cross–head pistons for *turbocharged* engines (Fig. 22).

The former and new fire rings, upper groove oil control rings and expanders are not functionally interchangeable. The new components must be used together on cross–head piston equipped turbocharged engines. The former fire ring will continue to be used in production and service for engines with trunk type pistons. The former oil control ring and expander will continue to be used in the upper oil control ring groove of trunk type pistons.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston or cylinder liner is installed. Refer to the parts catalog or microfiche to select the current piston rings for a particular engine.

Insert one ring at a time inside of the cylinder liner and far enough down to be within the normal area of ring travel. Use a piston skirt to push the ring down to be sure it is parallel with the top of the liner. Then, measure the ring gap with a feeler gage (Fig. 20). Refer to Section 1.0 for ring gap specifications.

If the gap on a compression ring is insufficient, it may be increased by filing or stoning the ends of the ring. File or stone both ends of the ring so the cutting action is from the outer surface to the inner surface. This will prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must be approximately .015".

Check the ring side clearance (Fig. 21). Ring side clearances are specified in Section 1.0.

Fig. 20 – Measuring Piston Ring Gap

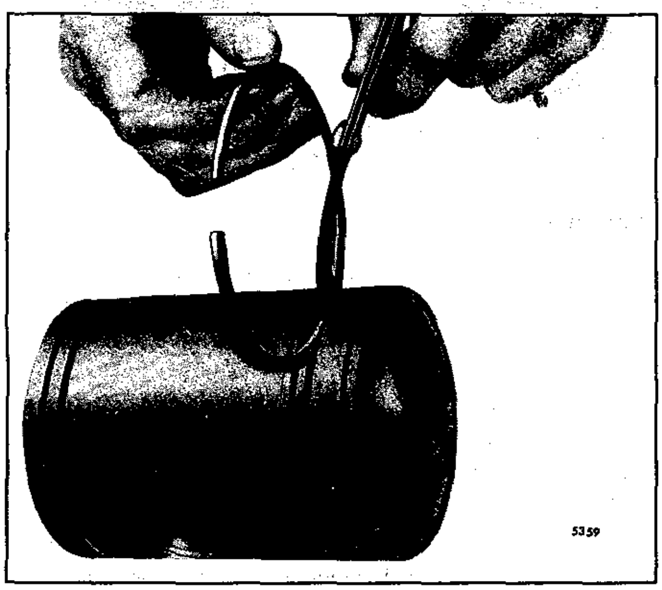


Fig. 21 – Measuring Piston Ring Side Clearance

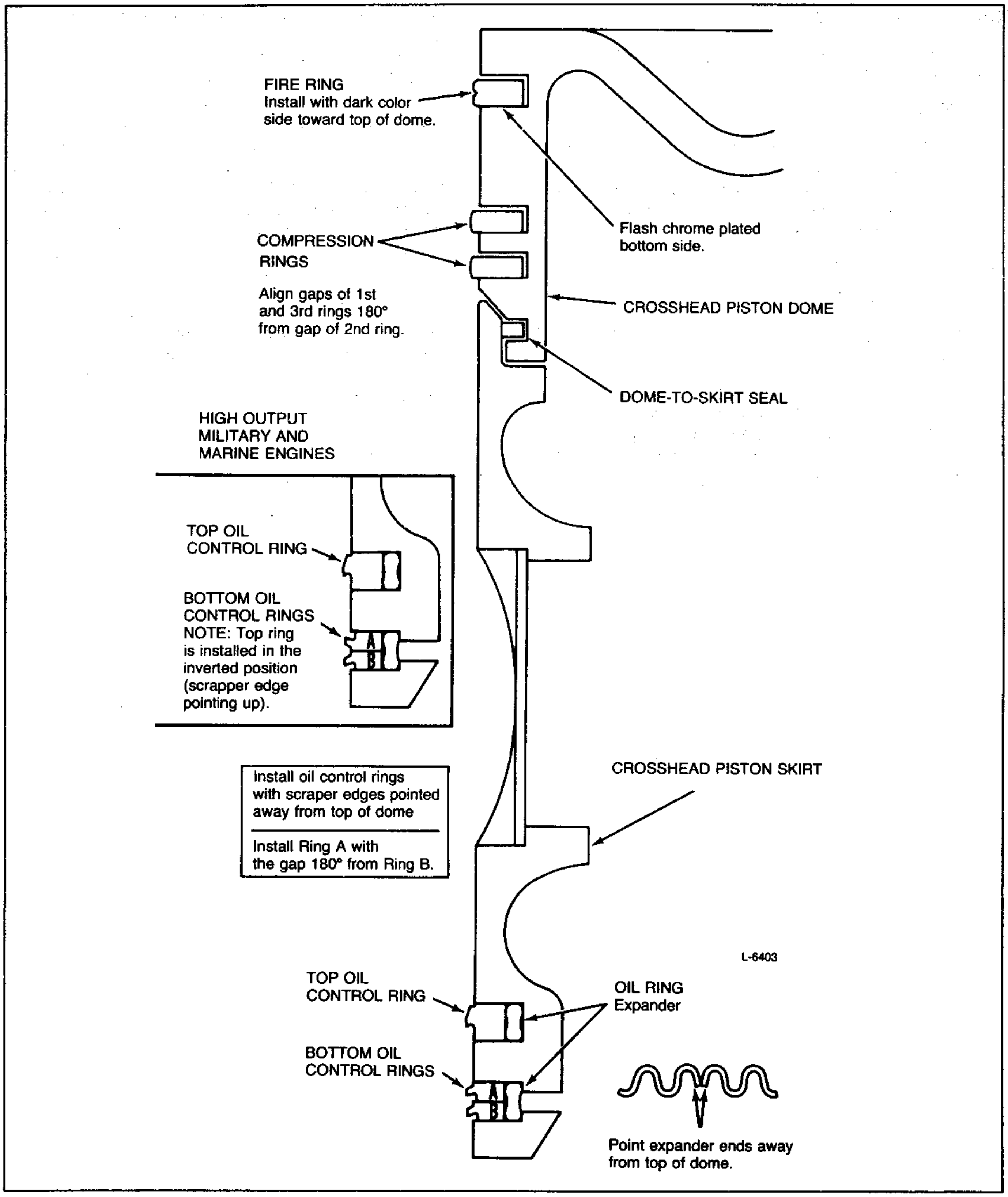


Fig. 22 – Piston Ring Installation Instructions

Install Piston Rings

Lubricate the piston rings and piston with engine oil before installing the rings.

COMPRESSION RINGS

1. Starting with the bottom ring, install the compression rings with tool J 8128 (Fig. 13). To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston. Refer to Fig. 22 for ring identification and location.
2. Stagger the ring gaps around the piston.

OIL CONTROL RINGS

Refer to Fig. 22 for the type and location and install the oil rings as follows:

1. Install the ring expanders in the oil control ring grooves in the piston skirt. When installing the oil control rings, use care to prevent overlapping the ends of the ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption. When peripheral abutment type ring expanders are used, install them with the legs of the free ends toward the bottom of the piston. Noticeable resistance will be encountered during installation of the piston if the ends of the expander are overlapped. Corrective action should be taken to prevent ring breakage before this occurs.
2. Install the oil control rings by hand. Start with the top oil ring and align the gaps as indicated in Fig. 22. The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control, except on high output military and marine engines (Fig. 22).

Install the piston and connecting rod assembly in the engine as outlined in Section 1.6.3.

CONNECTING ROD

TRUNK TYPE PISTON

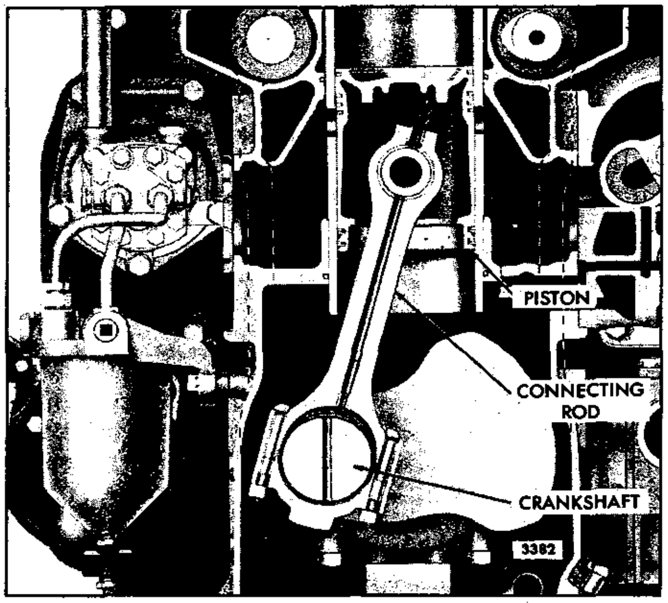


Fig. 1 – Connecting Rod Mounting

Each connecting rod is forged to an "I" section with a closed hub at the upper end and a bearing cap at the lower end (Figs. 1 and 2). The connecting rod is drilled to provide lubrication to the piston pin at the upper end and is equipped with a nozzle to spray cooling oil to the underside of the piston head on engines equipped with an oil cooler. Engines that are not equipped with an oil cooler do not use nozzle type connecting rods. An orifice is pressed into a counterbore at the lower end of the oil passage (in rods equipped with a spray nozzle) to meter the flow of oil.

Never intermix nozzle type connecting rods in an engine with non–nozzle type connecting rods.

A helically–grooved bushing is pressed into each side of the connecting rod at the upper end. The cavity between the inner ends of these bushings registers with the drilled oil passage in the connecting rod and forms a duct around the piston pin. Oil entering this cavity lubricates the piston pin bushings and is then forced out the spray nozzle to cool the piston. The piston pin floats in the bushings of both the piston and the connecting rod.

The turbocharged engine connecting rods include vapor blasted bushings and increased width oil grooves.

A service connecting rod includes the bearing cap, bolts, nuts, spray nozzle (if used), orifice and the piston pin bushings pressed in place and bored to size.

The replaceable connecting rod bearing shells are covered in Section 1.6.2.

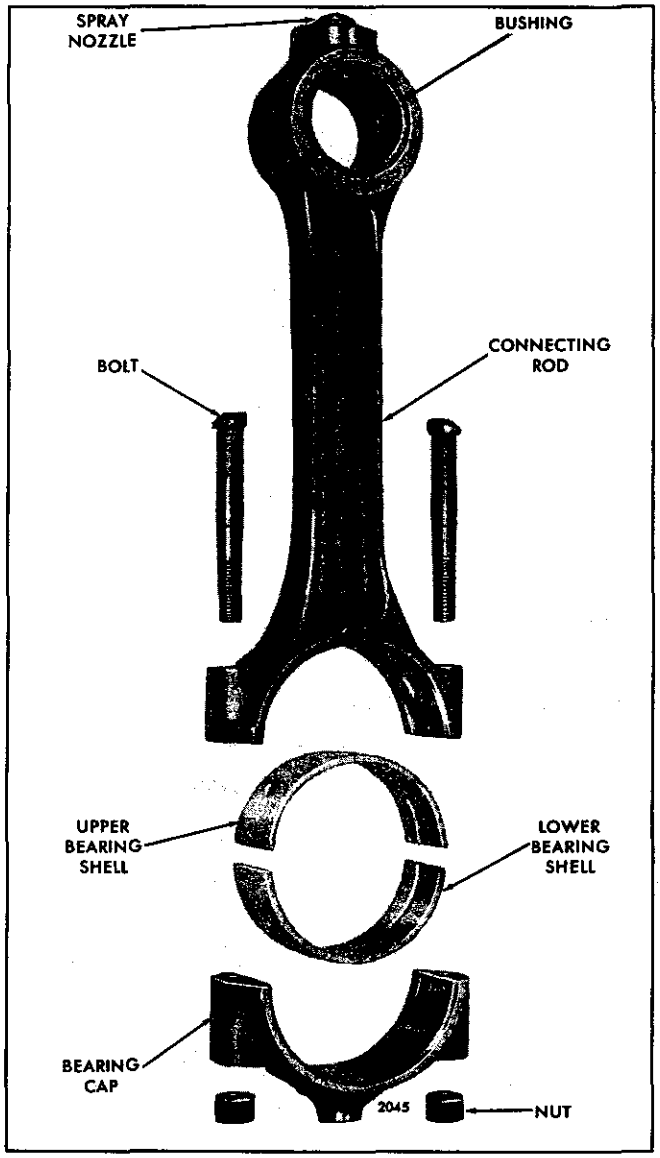


Fig. 2 – Connecting Rod Details and Relative Location of Parts

Effective with engine serial numbers 3D–170958, 4D–181763 and 6D–187523, turbocharged engines use a 1.500" diameter piston pin. With the use of the 1.500" diameter piston pin, new piston assemblies, piston pin retainers and connecting rod assemblies are required. The former piston pin diameter is 1.375". The former and new piston and connecting rod assemblies differ only in that they have larger bushing bores to facilitate the installation of new, larger diameter bushings. The larger bushing inner diameter is necessary to accommodate the new, larger piston pin.

Because of the larger pin diameter, former and new parts are not separately interchangeable. When it becomes necessary to replace any one of the three major cylinder components, it will be necessary to include the other two to assure interchangeability. Current piston assemblies and connecting rods can be mixed in an engine with the former piston assemblies and connecting rods.

- New cross–head pistons and rings, connecting rods, and cylinder liners became standard in all turbocharged industrial engines equipped with bypass blowers, effective with unit serial numbers 3D193526, 4D209292, 6D0229545.

> **NOTICE:** Do not mix trunk style pistons and cross–head pistons in the same engine. The difference in weight will affect engine balance. Failure to observe this precaution can result in serious engine damage.

Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod, as outlined in Section 1.6.

Inspection

Clean the connecting rod and piston pin with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Blow compressed air through the drilled oil passage in the connecting rod to be sure the orifice, oil passage and spray holes are not clogged.

Visually check the connecting rod for twist or bending. Check for cracks (Fig. 3) by the magnetic particle method outlined in Section 1.3 under *Crankshaft Inspection.*

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap (refer to Section 1.6.3).

Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure the orifice, oil passage and spray holes are not clogged. Also, make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell "crush".

Check the connecting rod bushings for indications of scoring, overheating or other damage. Bushings that have overheated may become loose and creep together, thus blocking off the supply of lubricating oil to the piston pin, bushings and spray nozzle.

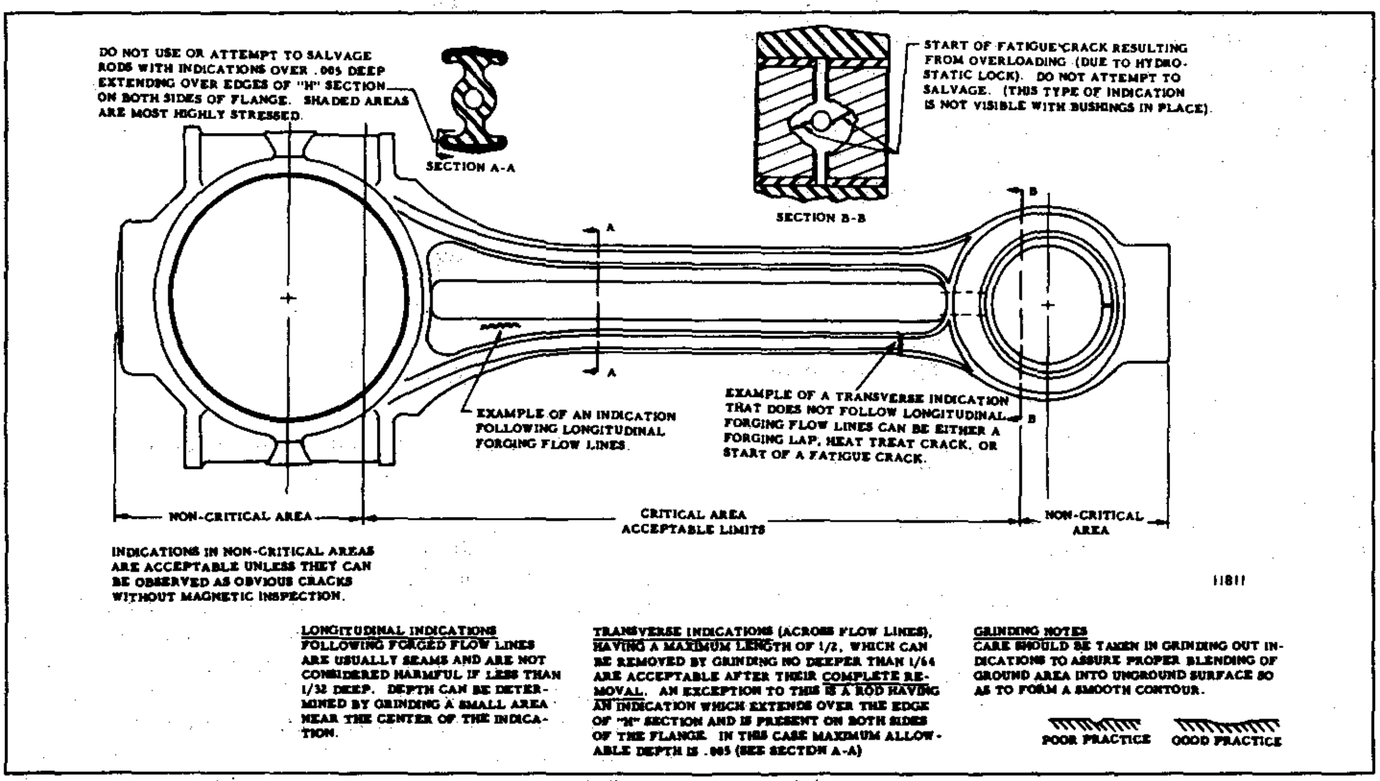


Fig. 3 – Magnetic Particle Inspection Limits for Connecting Rod

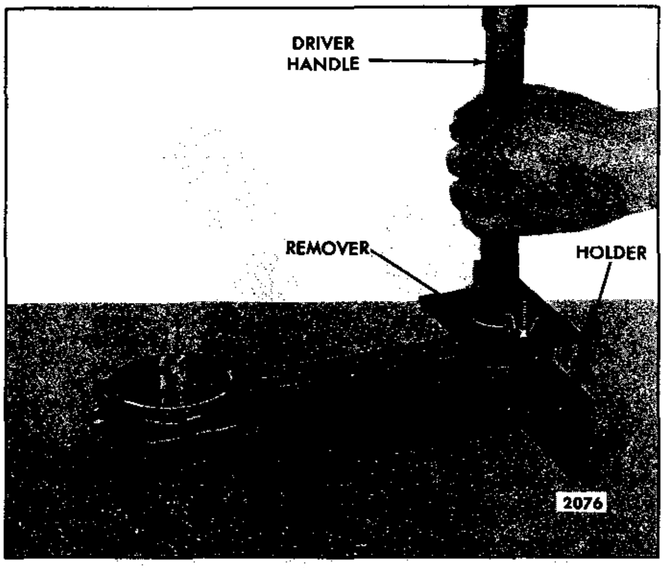


Fig. 4 – Removing or Installing Bushings

Turbocharged engines with trunk type pistons use two different diameter piston pins with a special surface finish. Engines built prior to 3D–170958, 4D–181763 and 6D–187523 have a 1.375" diameter piston pin. Those built after have a 1.500" diameter piston pin, except marine applications which continue to use the 1.375" diameter piston pin.

Inspect the piston pin for signs of fretting. When reusing a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear.

Since it is subjected to downward loading only, free movement of the piston pin is desired to secure perfect alignment and uniform wear. Therefore, the piston pin is assembled with a full floating fit in the connecting rod and piston bushings, with relatively large clearances. Worn piston pin clearances up to .010" are satisfactory.

Remove Bushings

If it is necessary to replace the connecting rod bushings, remove them as follows:

Do not remove the bushings from the connecting rods used in turbocharged engines because they are not serviced separately.

1. Clamp the upper end of the connecting rod in holder J 7632 (Fig. 4) so that the bore in the bushings is aligned with the hole in the base of the holder.
2. Place the bushing remover J 4972–4 in the connecting rod bushing, insert handle J 1513–2 in the remover and drive the bushings from the rod.

Replace Spray Nozzle

The connecting rod bushings must be removed before the spray nozzle can be replaced. The orifice in the lower end of the drilled passage in the connecting rod is not serviced and it is not necessary to remove it when replacing the spray nozzle.

Replace the spray nozzle, as follows:

1. Remove the connecting rod bushings (non–turbocharged engines only).
2. Insert spray nozzle remover J 8995 through the upper end of the connecting rod and insert the pin, in the curved side of the tool, in the opening in the bottom of the spray nozzle.
3. Support the connecting rod and tool in an arbor press (Fig. 5).
4. Place a short sleeve directly over the spray nozzle. Then, press the nozzle out of the connecting rod.
5. Remove the tool.
6. Start the new spray nozzle straight into the counterbore in the connecting rod.
7. Support the connecting rod in the arbor press, place a short 3/8" I.D. sleeve on top of the nozzle and press the nozzle into the connecting rod until it bottoms in the counterbore.
8. Install new bushings in the connecting rod.

Install Bushings

1. Clamp the upper end of the connecting rod assembly in holder J 7632 so that the bore for the bushings aligns with the hole in the base of the tool (Fig. 4).

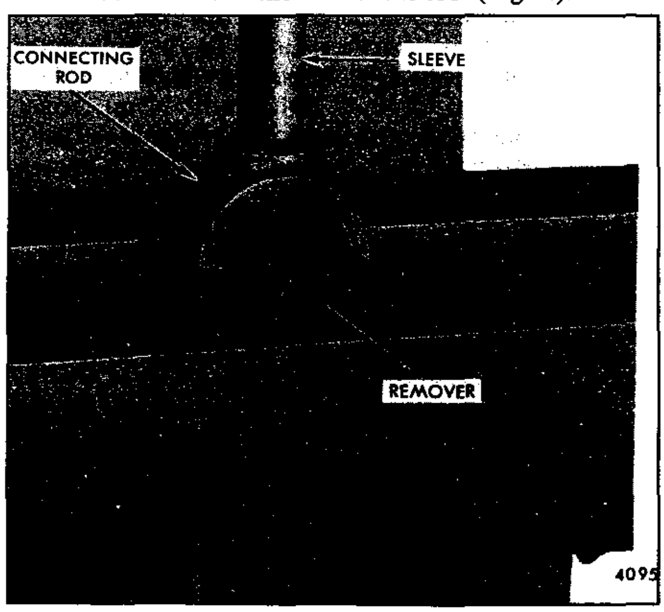


Fig. 5 – Removing Spray Nozzle

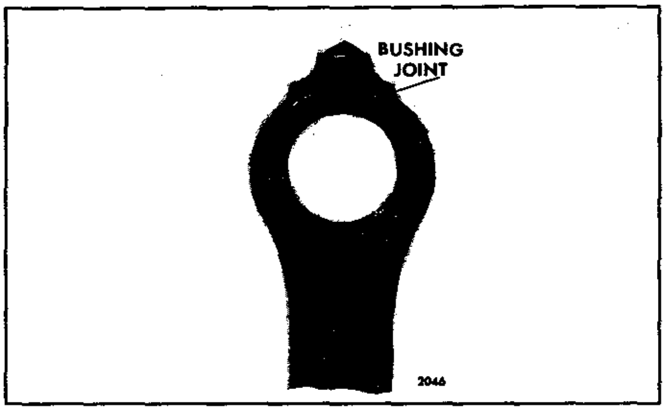


Fig. 6 – Location of Bushing Joint

2. Start a new bushing straight into the bore of the connecting rod, with the bushing joint at the top of the rod (Fig. 6).

3. Insert installer J 4972–2 in the bushing, then insert handle J 1513–2 in the installer and drive the bushing in until the flange of the installer bottoms on the connecting rod.

4. Turn the connecting rod over in the holder and install the second bushing in the same manner.

5. The bushings must withstand an end load of 2,000 pounds without moving after installation.

6. Ream the bushings to size as follows:

   a. Clamp reaming fixture J 7608–4 in a bench vise.

   b. Slide sleeve J 7608–5 on the arbor of the fixture (for V–type engine connecting rod).

   c. Place the crankshaft end of the connecting rod on the arbor of the fixture (Fig. 7). Tighten the nuts on the 3/8"–24 bolts (In–line and V–type engines) to 40–45 lb–ft (54–61 N·m) torque. Tighten the nuts on the 5/16"–24 bolts (early 6V engines) to 24–28 lb–ft (33–38 N·m) torque.

   d. Slide the front guide bushing J 4971–6 (with the pin end facing out) in the fixture.

   e. Install spacer J 7608–3 in the fixture.

   f. Align the upper end of the connecting rod with the hole in the reaming fixture.

   g. Install the rear guide bushing J 1686–5 on the reamer J 7608–21, then slide the reamer and bushing into the fixture.

   h. Turn the reamer in a clockwise direction only, when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.

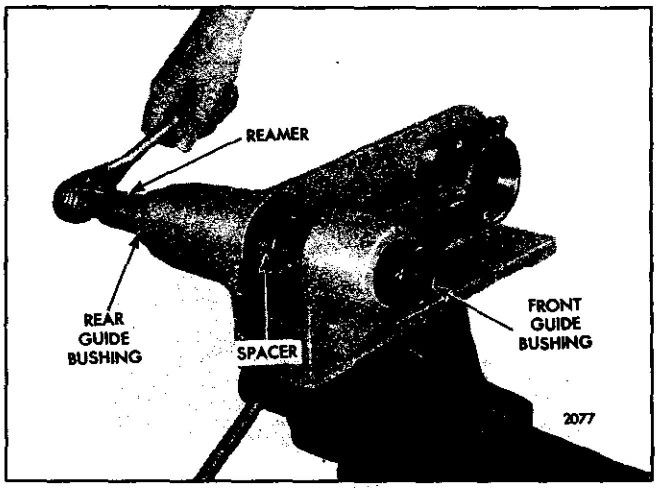


Fig. 7 – Reaming Bushings

NOTICE: Do not at any time turn the reamer counterclockwise as this will dull the cutting edges of the reamer.

   i. Remove the reamer and the connecting rod from the fixture, blow out the chips and measure the inside diameter of the bushings. The inside diameter of the bushings must be 1.3760" to 1.3765". This will provide a piston pin–to–bushing clearance of .0010" to .0019" with a new piston pin. A new piston pin has a diameter of 1.3746" to 1.3750". On the 6V–53T the inside diameter of the bushings must be 1.5025" to 1.5030". This will provide a piston pin–to–bushing clearance of .0025" to .0034" with a new piston pin. A new piston pin has a diameter of 1.4996" to 1.5000".

Assemble Connecting Rod to Piston

Apply clean engine oil to the piston pin and bushings. Refer to Fig. 2 and assemble the connecting rod to the piston as follows:

1. Place the "N/A" piston in the holding fixture (Fig. 8).

2. Place a new piston pin retainer in position. Then, place the crowned end of installer J 23762–A against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the "N/A" piston.

   If you have a turbo–trunk type piston, use tool J 24107–01 to seat the piston pin retainer. Do not drive the retainer in too far or the piston bushing may be moved inward and result in reduced piston pin end clearance.

3. Place the upper end of the connecting rod between the piston pin bosses and in line with the piston pin holes. Then, slide the piston pin in place. If the piston pin–to–bushing clearances are within the specified limits, the pin will slip into place without use of force.

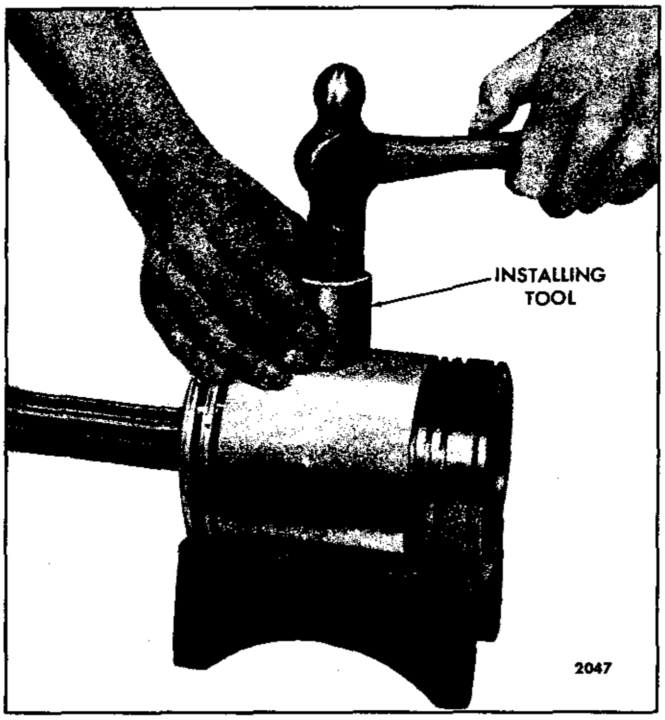


Fig. 8 – Installing Piston Pin Retainer Using Holder J 1513–02

4. Install the second piston pin retainer as outlined in Steps 1 and 2.

5. After the piston pin retainers have been installed, check for piston pin end clearance by *cocking* the connecting rod and shifting the pin in its bushings.

6. One important function of the piston pin retainer is to prevent the oil, which cools the underside of the piston and lubricates the piston pin bushings, from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23987–01 (Fig. 9). Place the suction cup over the retainer and hand operate the lever to pull a vacuum of ten inches on the gage. A drop in the gage reading indicates air leakage at the retainer.

7. Install the piston rings on the piston, as outlined in Section 1.6.

8. Install the piston and connecting rod assembly in the engine, as outlined in Section 1.6.3.

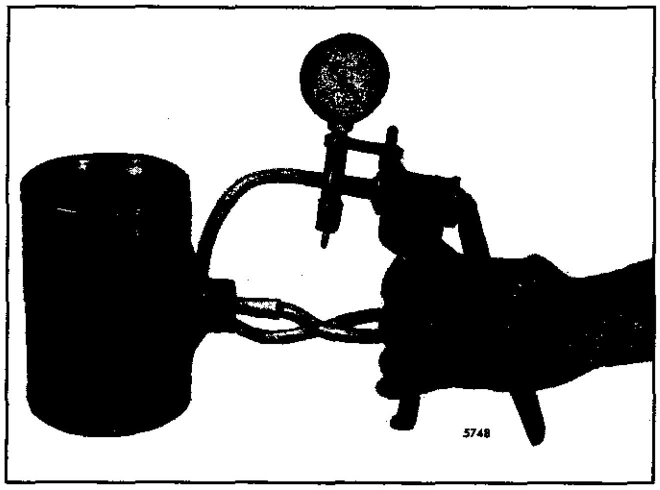


Fig. 9 – Checking Piston Pin Retainer for Proper Sealing Using Tool J 23987–01

CROSS-HEAD TYPE PISTON

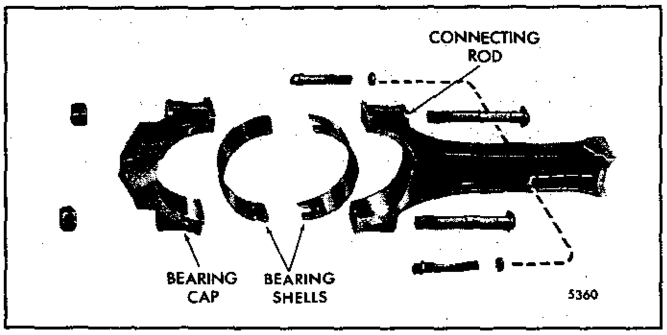


Fig. 10 – Connecting Rod Details

The connecting rod is forged to an "I" section with an open or saddle type contour at the upper end and a bearing cap at the lower end (Fig. 10). The bearing cap and connecting rod are forged in one piece and bored prior to separation.

The upper end of the connecting rod is machined to match the contour of the piston pin. The piston pin is secured to the connecting rod with two bolts and spacers. The bearing cap is secured to the connecting rod by two specially machined bolts and nuts.

Lubricating oil is forced through a drilled oil passage in the connecting rod to the piston pin and bushing.

A service connecting rod includes the bearing cap and the attaching bolts and nuts. The replaceable connecting rod bearing shells are covered in Section 1.6.2.

Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod, as outlined in Section 1.6.

Inspection

Clean the connecting rod and piston pin with a suitable solvent and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Blow compressed air through the oil passage in the connecting rod to be sure it is clear of obstructions. Use crocus cloth, wet with fuel oil, to remove any trace of fretting and/or corrosion on the connecting rod saddle and piston pin contact surface with the rod before reassembly. Never use crocus cloth on the bearing side of the pin.

Connecting rods being removed from an original build engine can be reused as is, after considering the following:

1. Check for visual damage (bent).
2. A previous bearing(s) or related failure.
3. The connecting rod is blue at the top or bottom end.
4. Fretting at split line between the connecting rod and cap.
5. Excessive pound–in of the bolt head or nut.

If the connecting rod has been subjected to any of the above, it should be scrapped.

In qualifying a used connecting rod from a source other than an original build engine, the following checks should be made in addition to the above.

1. Check for cracks (Fig. 11) by the magnetic particle method outlined in Section 1.3 under *Crankshaft Inspection*.
2. Determine average bore diameter of the rod, using a dial bore gage and master ring as follows (Fig. 15):
   - • a. Install the connecting rod cap on the connecting rod and tighten the bolt nuts to 40–45 lb ft (54–61 N·m) torque.

   NOTICE: Do not overtorque the connecting rod bolt nuts. Overtorque may permanently distort the connecting rod cap and result in bolt and/or nut damage.

   - b. Measure diameter A and B (Fig. 12).
   - c. Obtain the average of A and B to obtain size at split line.

   $$\frac{A + B}{2} = X \text{ — which is the average of } A + B.$$

   - d. Measure C. The difference in the results of the measurements X and C gives average bore out–of–round and can be .005" maximum.
   - e. Add C with X and average to obtain average bore size.

   $$\frac{C + X}{2} = \text{Average diameter of bore.}$$

   Must be within 2.7515" to 2.7525" (In–line) or 3.0015" to 3.0025" (V–type) engines.

If the crosshead connecting rod bore is not to specifications, the rod must be scrapped and cannot be machined.

3. Determine taper as follows (Fig. 12):

   a. Substract D1 from D2 to find the difference.

   b. The difference can be .0005" maximum.

4. Determine length by finding the distance between E1 and E2 (Fig. 12).

   Specifications: 8.799" to 8.801".

   The length of the rod can be measured on connecting rod measurement fixtures marketed by B. K. Sweeney, Tobin Arp or equivalent.

Remove any nicks or burrs from the connecting rod bolt holes to ensure proper seating of the underside of the bolt head.

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap (refer to Section 1.6.3).

NOTICE: Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure it is clear of obstructions. Also, make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell "crush".

Inspect the bearing (bushing) for indications of scoring, overheating or other damage. Measure the thickness of the bushing along the center. Replace the bushing if it is damaged or worn to a thickness of .085" or less. A new bushing is .086" to .087" thick.

Inspect the piston pin for signs of fretting. When reusing a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear. A new piston pin has a diameter of 1.3746" to 1.3750". Replace the piston pin if it is worn to a diameter of 1.3730" or less.

Assemble Connecting Rod to Piston

Refer to *Assemble Piston* in Section 1.6 for assembly of the connecting rod to the piston.

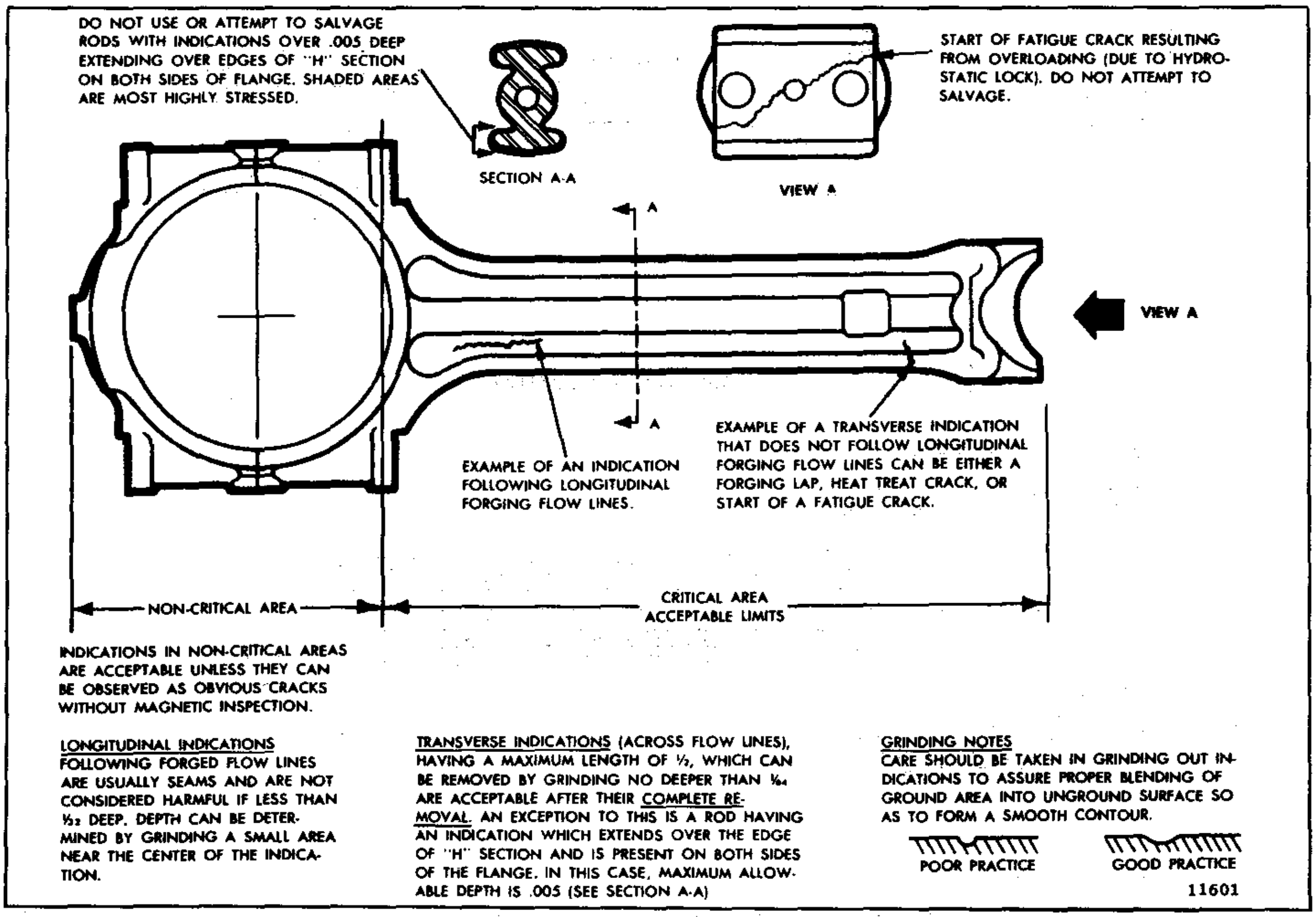


Fig. 11 – Magnetic Particle Inspection Limits for Connecting Rod

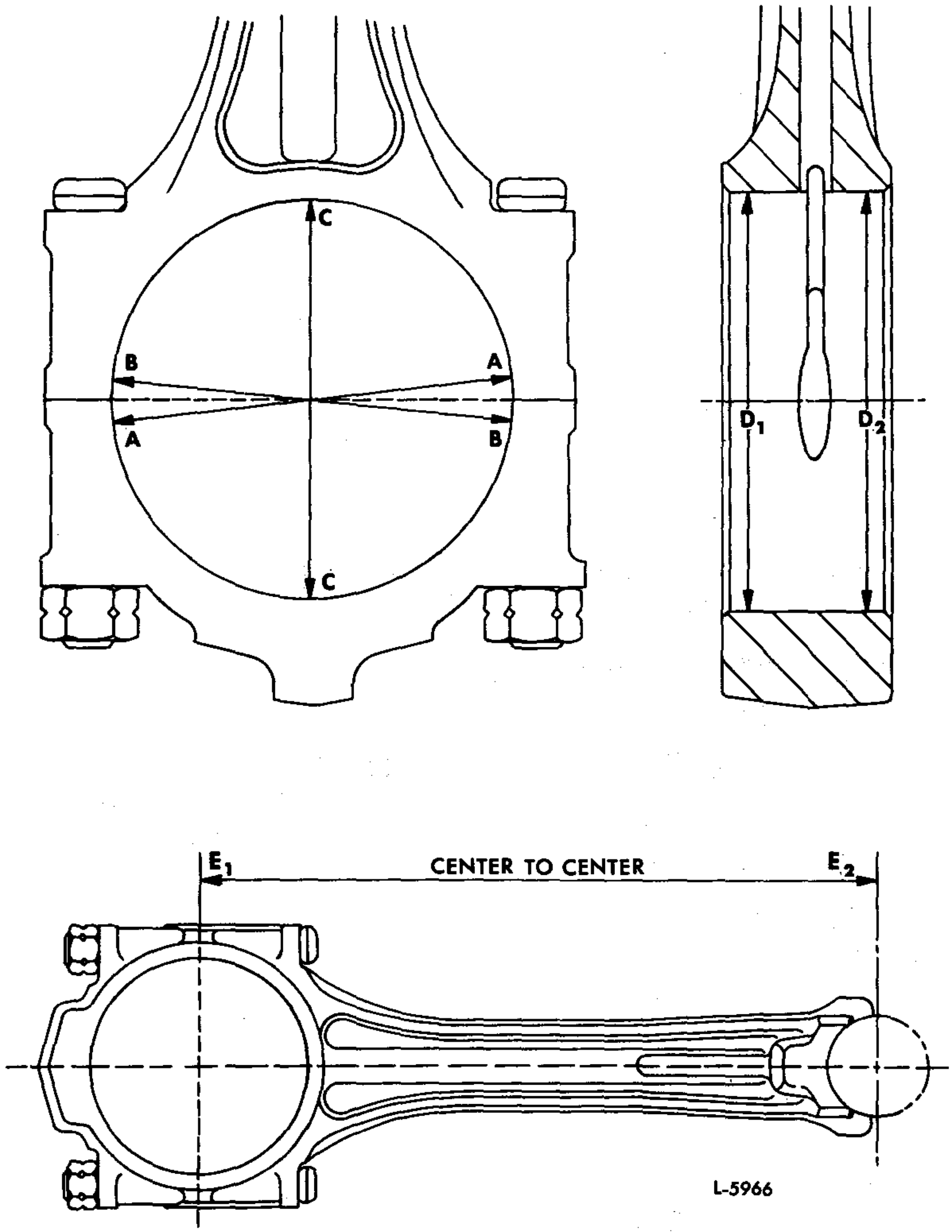


Fig. 12 – Dimensional Inspection of Cross-Head Piston Connecting Rods

CONNECTING ROD BEARINGS

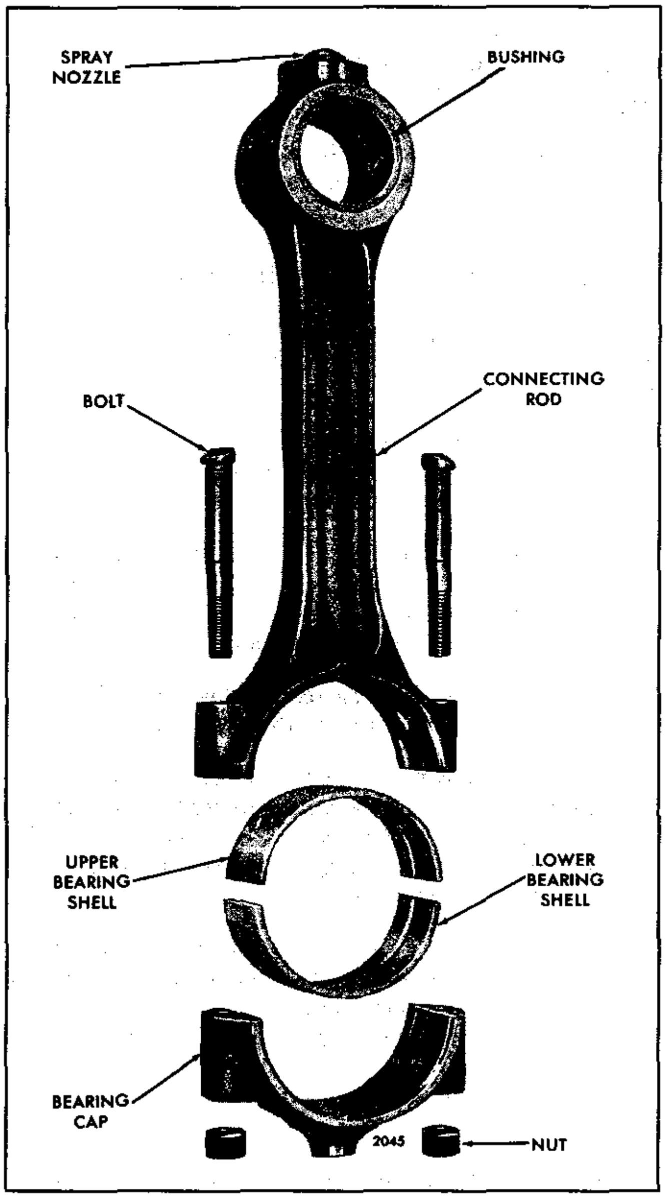


Fig. 1 – Connecting Rod and Bearing Shells

The connecting rod bearing shells (Fig. 1) are precision made and are replaceable without shim adjustments. They consist of an upper bearing shell seated in the connecting rod and a lower bearing shell seated in the connecting rod cap. The upper and lower bearing shells are located in the connecting rod by a tang at the parting line at one end of each bearing shell. The current connecting rod bearing shells used in the V–type engines incorporate a relief groove at each end of each bearing shell to provide clearance for the 3/8" connecting rod bolts.

The upper and lower connecting rod bearing shells are different and are not interchangeable. The upper bearing shell has two short oil grooves and two oil holes; each groove begins at the end of the bearing shell and terminates at an oil hole. The lower bearing shell has a continuous oil groove from one end of the shell to the other. These grooves maintain a continuous registry with the oil hole in the crankshaft connecting rod journal, thereby providing a constant supply of lubricating oil to the connecting rod bearings, piston pin bushings and spray nozzle through the oil passage in the connecting rod.

The Brazilian built engine connecting rod bearings include a slotted upper shell.

Remove Bearing Shells

The connecting rod bearing caps are numbered 1, 2, 3, etc. on an In–line engine and 1R, 1L, 2R, 2L, etc. on the V–type engine, with matching numbers stamped on the connecting rods. When removed, each bearing cap and the bearing shells must always be reinstalled on the original connecting rod.

Remove the connecting rod bearings, as follows:

1. Drain the oil and remove the oil pan.
2. Remove the oil inlet pipe and screen assembly.

   NOTICE: Remove the oil pump on 8V engines and save the shims, if used, so that they may be reinstalled in exactly the same location.

3. Remove one connecting rod bearing cap. Push the connecting rod and piston assembly up into the cylinder liner far enough to permit removal of the upper bearing shell. Do not pound on the edge of the bearing shell with a sharp tool.
4. Inspect the upper and lower bearing shells as outlined under *Inspection*.
5. Install the bearing shells and bearing cap before another connecting rod bearing cap is removed.

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching or signs of overheating.

If any of these defects are present, the bearings must be discarded. The upper bearing shells, which carry the load, will normally show signs of distress before the lower bearing shells do.

Inspect the backs of the bearing shells for bright spots which indicate they have been shifting in their supports. If such spots are present, discard the bearing shells. Also, inspect the connecting rod bearing bore for burrs, foreign particles, etc.

Measure the thickness of the bearing shells, using a micrometer and ball attachment J 4757, as described under *Inspection* in Section 1.3.4. The minimum thickness of a worn standard connecting rod bearing shell should not be less than .1230" and, if either bearing shell is thinner than this dimension, replace both bearing shells. A new standard bearing shell has a thickness of .1245" to .1250" (In-line engine) or .1247" to .1252" (V-engine). Refer to Table 1.

In addition to the thickness measurement, check the clearance between the connecting rod bearing shells and the crankshaft journal. This clearance may be checked by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to *Shop Notes* in Section 1.0). The maximum connecting rod bearing-to-journal clearance with used parts is .006".

Before installing the bearings, inspect the crankshaft journals (refer to *Inspection* in Section 1.3).

Bearing Size	*New Bearing Thickness	Minimum Worn Thickness
	In-Line Engines	
Standard	.1245"/.1250"	.1230"
.002" Undersize	.1255"/.1260"	.1240"
.010" Undersize	.1295"/.1300"	.1280"
.020" Undersize	.1345"/.1350"	.1330"
.030" Undersize	.1395"/.1400"	.1380"
	V-Type Engines	
Standard	.1247"/.1252"	.1230"
.002" Undersize	.1257"/.1262"	.1240"
.010" Undersize	.1297"/.1302"	.1280"
.020" Undersize	.1347"/.1352"	.1330"
.030" Undersize	.1397"/.1402"	.1380"

*Thickness 90° from parting line of bearing.

TABLE 1

Do not replace one connecting rod bearing shell alone. If one bearing shell requires replacement, install both new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .002", .010", .020" and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to *Crankshaft Grinding* in Section 1.3.

Bearings which are .002" undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

NOTICE: Bearing shells are NOT reworkable from one undersize to another under any circumstances.

Install Connecting Rod Bearing Shells

With the crankshaft and the piston and connecting rod assembly in place, install the connecting rod bearings as follows:

1. Rotate the crankshaft until the connecting rod journal is at the bottom of its travel, then wipe the journal clean and lubricate it with clean engine oil.
2. Install the upper bearing shell — the one with the short groove and oil hole at each parting line — in the connecting rod. Be sure the tang on the bearing shell fits in the groove in the connecting rod.
3. Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal.
4. Note the numbers stamped on the connecting rod and the bearing cap and install the lower bearing shell — the one with the continuous oil groove — in the bearing cap, with the tang on the bearing shell in the groove in the bearing cap.
5. Install the bearing and cap and tighten the nuts on the 3/8"-24 bolts (In-line and "V" engines) to 40-45 lb-ft (54-61 N·m) torque. Tighten the nuts on the former 5/16"-24 bolts (6V engine) to 24-28 lb-ft (33-38 N·m) torque. *Be sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut.*
6. Install the lubricating oil pump inlet tube assembly. Replace the inlet tube seal ring or elbow gasket if hardened or broken.

   NOTICE: On the 8V engine, if shims were used between the oil pump body and the main bearing caps, install the shims in exactly the same location from which they were removed.

7. Install the oil pan, using a new gasket.
8. Refer to the *Lubrication Specifications* in Section 13.3 and fill the crankcase to the proper level on the dipstick.
9. If new bearings were installed, operate the engine on the *run-in* schedule, as outlined in Section 13.2.1.

2. Place the piston ring compressor on a wood block, with the tapered end of the ring compressor facing up.

3. Position (stagger) the piston ring gaps properly on the piston. Make sure the ends of the oil control ring expanders are not overlapped.

4. Start the top of the piston straight into the ring compressor. Then, push the piston down until it contacts the wood block ("Operation 1" of Fig. 8).

5. Note the position of the matchmark and place the liner, with the flange end down, on the wood block.

6. Place the ring compressor and the piston and connecting rod assembly on the liner so the numbers on the rod and cap are aligned with the matchmark on the liner ("Operation 2" of Fig. 8). The numbers, or number and letter, on the side of the connecting rod and cap identify the rod with the cap and indicate the particular cylinder in which they are used. If a new service connecting rod is to be installed, the same identification numbers, or number and letter, must be stamped in the same location as on the connecting rod that was replaced.

7. Push the piston and connecting rod assembly down into the liner until the piston is free of the ring compressor (operation 2 of Fig. 8).

- **CAUTION: To avoid scraping knuckles or pinching fingers between the rod end and ring compressor walls, interlock fingers and place hands as shown (operation 2) when pushing down. This keeps fingers out of the installer when the piston slides into the liner.**

NOTICE: Do not force the piston into the liner. The peripheral abutment type expanders apply considerably more force on the oil ring than the standard expander. Therefore, extra care must be taken during the loading operation to prevent ring breakage.

8. Remove the connecting rod cap and the ring compressor. Then, push the piston down until the compression rings pass the cylinder liner ports.

Install Cylinder Liner, Piston and Connecting Rod Assembly

After the piston and connecting rod assembly have been installed in the cylinder liner, install the entire assembly in the engine as follows:

1. Make sure the seal ring grooves in the cylinder block bore are clean. Then, install two new seal rings (Fig. 9).

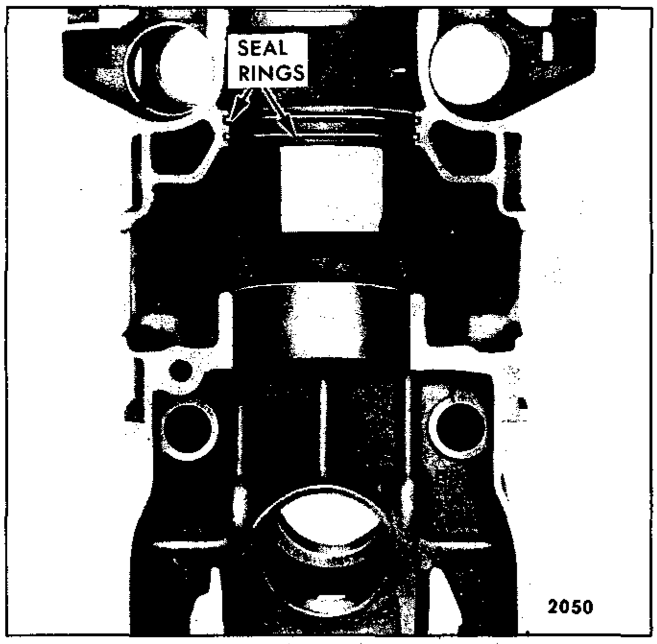


Fig. 9 – Cylinder Liner Seal Ring Location in Cylinder Block Bore

2. Apply hydrogenated vegetable type shortening or ethylene glycol base antifreeze to the inner surface of the seal rings.

3. If any of the pistons and liners are already in the engine, use hold–down clamps to retain the liners in place when the crankshaft is rotated.

4. Rotate the crankshaft until the connecting rod journal of the particular cylinder being worked on is at the bottom of its travel. Wipe the journal clean and lubricate it with clean engine oil.

5. Install the upper bearing shell — the one with a short oil groove at each parting line — in the connecting rod. Lubricate the bearing shell with clean engine oil.

6. Position the piston, rod and liner assembly in line with the block bore (Fig. 10) so that the identification number on the rod is facing the outer edge of the block (V–type engine) or the engine serial number side (In–line engine). Also, align the matchmarks on the liner and the block. Then, slide the entire assembly into the block bore being careful not to damage the seal rings.

7. Push or pull the piston and connecting rod into the liner until the upper bearing shell is firmly seated on the crankshaft journal.

NOTICE: On a V–type engine, the distance from the center of the connecting rod bolts to the sides of the rod are not equal. Therefore, to avoid cocking the rods, the narrow sides of the rods must be together when attached to the crankshaft.

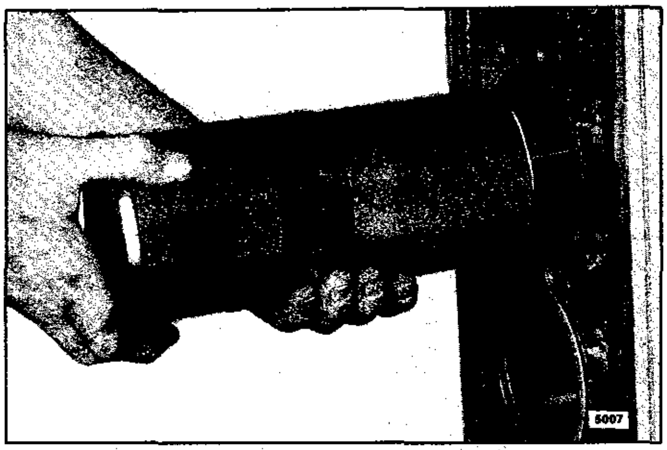


Fig. 10 – Installing Piston, Rod and Liner Assembly in Cylinder Block

8. Place the lower bearing shell — the one with the continuous oil groove from one parting line to the other — in the connecting rod cap, with the tang on the bearing shell in the notch in the connecting rod bearing cap. Lubricate the bearing shell with clean engine oil.

9. Install the bearing cap and the bearing shell on the connecting rod with the identification numbers on the cap and the rod adjacent to each other. On the 3/8"-24 bolts (In-line and "V" engines), tighten the nuts to 40–45 lb-ft (54–61 N·m) torque. Tighten the nuts on the 5/16"-24 bolts (early 6V engines) to 24–28 lb-ft (33–38 N·m) torque. Be sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut. The new 6V rod assembly with 3/8" bolts should be used for replacement at the time of normal overhaul. Rework of an old 6V rod assembly to utilize 3/8" bolts is not recommended.

10. Check the connecting rod side clearance. The clearance between the side of the rod and the crankshaft should be .006" to .012" with new parts on an In-line engine or .008" to .016" clearance between the connecting rods on a V-type engine.

11. Install the remaining liner, piston and rod assemblies in the same manner. Use hold-down clamps to hold each liner in place.

12. After all of the liners and pistons have been installed, remove the hold-down clamps.

13. Install new compression gaskets and water and oil seals as outlined in Section 1.2. Then, install the cylinder head and any other parts which were removed from the engine.

14. After the engine has been completely reassembled, refer to the *Lubrication Specifications* in Section 13.3 and refill the crankcase to the proper level on the dipstick.

15. Close all of the drains and fill the cooling system.

16. If new parts such as pistons, rings, cylinder liners or bearings were installed, operate the engine on the *run-in* schedule given in Section 13.2.1.