SECTION 7
CAMSHAFT GEAR TRAIN, AUXILIARY DRIVE, AND CAMSHAFT ASSEMBLIES

ELECTRO-MOTIVE

ENGINE MAINTENANCE MANUAL

SECTION 7

CAMSHAFT GEAR TRAIN, AUXILIARY DRIVE, AND CAMSHAFT ASSEMBLIES

CAMSHAFT GEAR TRAIN

DESCRIPTION

Power necessary to drive the camshafts, and the turbocharger before it becomes free wheeling, is supplied through the gear train at the rear of the engine. Fig. 7-1 shows the gear train before the camshaft drive housing and turbocharger are installed, and Fig. 7-2 shows a cross-section of the gear train.

The gear train, Fig. 7-1, consists of a crankshaft gear mounted on the crankshaft, No. 1 idler gear,

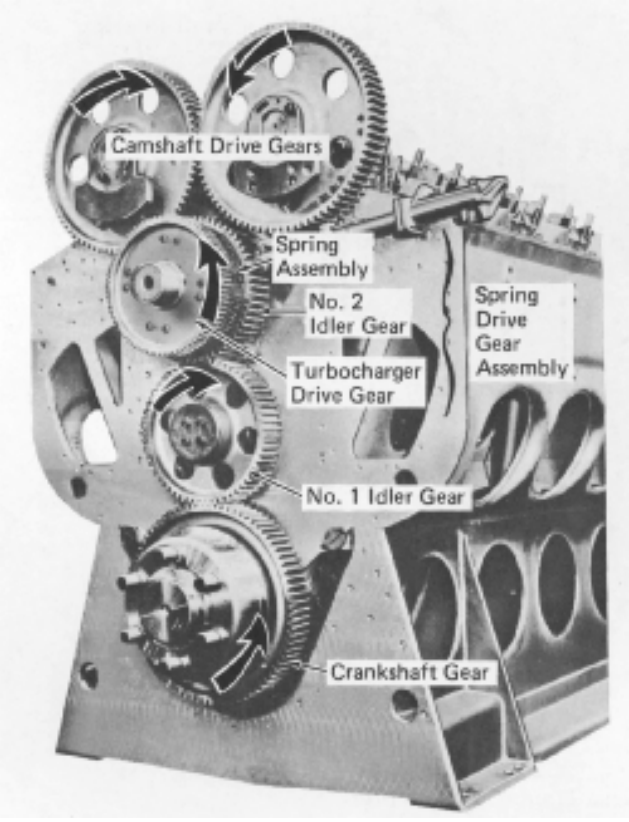

Fig. 7-1 - Camshaft Gear Train

a spring drive gear assembly, and the left and right camshaft drive gears. The spring drive gear assembly is made up of the No. 2 idler gear, a spring assembly, and the turbocharger drive gear.

MAINTENANCE

Unless a complete engine disassembly is being undertaken, it is unlikely that the entire gear train would be removed from the engine at one time. With the exception of the No. 2 idler gear and the turbocharger drive gear, which are part of the spring drive gear assembly, each gear in the train can be removed independently.

When any of the gears are removed from the gear train, they should be inspected for excessive backlash upon reassembly by inserting a feeler gauge the entire width of the gear face. Excessive backlash can cause improper valve operation and injection periods. Backlash clearance limits are given in the Service Data page at the end of this section. Clearances between gear stubshaft and bearings and thrust clearances must also be maintained within specified limits.

NOTE: Refer to "No. 1 Idler Gear" for a bearing clearance check without disassembly.

The turbocharger, aftercooler ducts, auxiliary drive assembly, and coupling disc must be removed from the engine to facilitate access to the camshaft gear train. If removal of the No. 1 idler gear or the crankshaft gear is required, the camshaft gears, oil retainer, and camshaft drive housing must be removed.

NOTE: Engine timing will not be disturbed during idler gear removal as long as the camshafts and crankshaft are not moved when gears are removed.

If original idler gears are to be reapplied and it is desired to retain timing mark orientation for future work, mark the gears as they lie before removal.

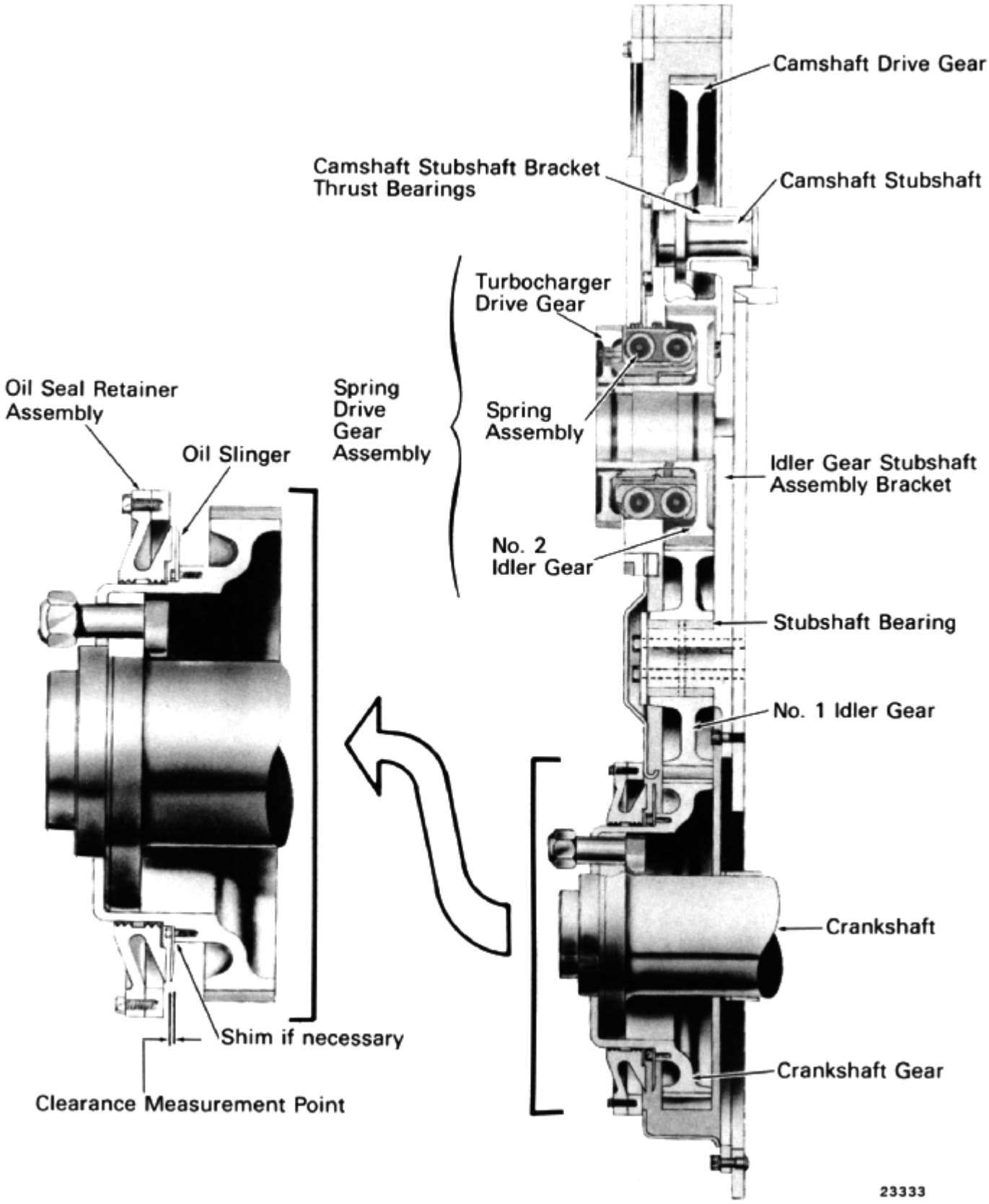

Fig. 7-2 - Camshaft Gear Train, Cross-Section

The following paragraphs contain the removal, inspection, and installation procedures for each gear in the train.

CAMSHAFT DRIVE GEARS

REMOVAL

1. Remove the Lockwire and the four bolts holding the counterweight and camshaft drive gear to the stubshaft.

2. Remove the dowel bolts and the retainer plate.

3. The counterweight and camshaft drive gear can now be removed from the stubshaft.

4. Remove the dowels from the counterweight and camshaft drive gear by driving them out from the back side of the gear.

INSPECTION

Inspect the gear teeth for fatigue indications, cracks or other evidence of failure. If possible, a magnaflux inspection should be performed.

In addition to the above, also check the camshaft gear which mates with the auxiliary drive gear for a wear step. Normal discoloration, due to a narrow gear mating with a wider gear, should not be considered as a wear step.

An accurate measurement can be made using a 0.420"-0.430" diameter roller. Place the roller on the unworn portion of the gear tooth so it is suspended over the worn portion. The distance between the roller and the worn gear tooth should not exceed the limit given in the Service Data. If wear step exceeds the wear limit, the camshaft gear and the auxiliary drive gear should be replaced. Pitting or gouging of the cam gear teeth, where the auxiliary drive gear mates, indicates misalignment. The cause should be determined before applying replacement gears.

INSTALLATION

1. Install the camshaft drive gear on the stubshaft being sure to position it on the stubshaft so the position markings line up with the markings on the mating parts, as shown in Fig. 7-21.

2. Install counterweight on stubshaft with counterweight to stubshaft marks aligned.

3. Install dowels, dowel retainer plate, and counterweight to stubshaft bolts. Torque bolts to 122 N-m (90 ft-lbs).

4. Install dowel bolts and torque to 22 N-m (17 ft-lbs).

5. Lockwire mounting bolts and dowel bolts in groups of three (two mounting bolts and one dowel bolt).

6. If any gears in the camshaft gear train are replaced or the relationship of the crankshaft to the camshaft has been disturbed, refer to "Exhaust Valve Timing" at the end of this section for information on positioning and marking of gears.

SPRING DRIVE GEAR ASSEMBLY

The spring drive gear assembly, Fig. 7-3, consists of the No. 2 idler gear, the turbocharger drive gear, and a spring assembly mounted between the two gears to absorb any torsional vibration which might be transmitted through the gear assembly to the turbocharger. The spring drive gear assembly should be removed as an assembly and then disassembled for inspection.

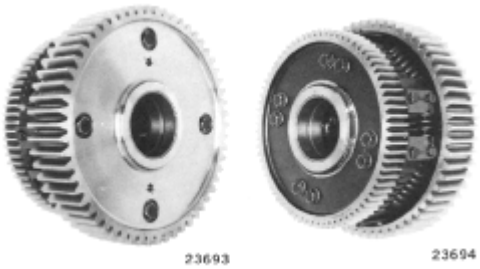

Fig. 7-3 - Spring Drive Gear Assembly

DISASSEMBLY

1. Remove the spring drive gear assembly from the stubshaft and check for any loose gearto-spider bolts. Discard any loose bolts. This is necessary because loose bolts caused by movement of the spiders due to high loads will have damaged threads. Damaged bolts will result in unsatisfactory clamp load.

2. Remove Lockwire and the eight 1/2"-1 3 bolts that hold the turbocharger drive gear to the outer spider.

3. Remove the snap ring near the inner circumference of the gear. The turbocharger drive gear can now be separated from the assembly.

4. Next remove the spring assembly from the idler gear by removing the 5/8"-11 bolts and the 1/2" dowels from the idler gear.

5. It should not be necessary to further disassemble the spring drive gear assembly. The spiders, springs, and spring seats making up the spring assembly do not require any routine type of maintenance. If the spring drive gear assembly is found to be defective, it should be replaced with a qualified assembly.

WARNING: Any attempt to disassemble the spring assembly with the use of vises, clamps, rams, or pinch bars can be extremely hazardous and is not recommended.

INSPECTION

Inspect the gear teeth for fatigue indications, cracks, pits, or other evidence of failure. If possible, a magnaflux inspection should be performed on the gears. Inspect the idler gear bearings to see that they are not gouged or damaged in any way. Also check oil holes to see that they are not plugged.

ASSEMBLY

1. Thoroughly clean four 5/8"-11 idler to spider mounting bolts to remove all traces of thread lubricant. Use cleaner activator listed in Service Data. Also clean spider bolt holes of lubricant and contaminants, using the same cleaner.

2. Slide spring assembly over the idler gear hub. Apply sealing compound to the 5/8"-11 bolts and install bolts through the idler gear into the inner spider. Torque to 224 N-m (165 ft-lbs). If the same idler gear and spring assembly are used, install the gear to spider dowels to 6.35 mm (1/4") below the surface and stake the dowel holes in three places, 120° apart.

   If a new idler gear and spring assembly are being used, drill two holes through the gear web and into the spider. Drill 37.34 mm (1-5/16") deep and line ream the holes to 34.52 mm (1-9/32") deep x 12.662 mm plus 0.013 mm minus 0.000 mm (.4985" plus .005" minus .000"). Locate the holes 100.00 mm ± 0.08 mm (3.937" ± .003") above and below the idler gear centerline and in line with two gear mounting bolt holes. Drive two dowels to 6.35 mm (1/4") below the surface and stake the holes at three places, 120° apart.

3. Install the turbocharger drive gear on the idler gear hub and install the snap ring in the idler gear hub groove.

4. Apply thread lubricant to the bolt threads and washer surfaces and install the eight 1/2"-13 x 1-1/4" bolts with hardened washers (replace 1-1/8" bolts used on early models and add washers) through the turbocharger drive gear into the outer spider. Torque bolts to 111 N-m (82 ft-lbs) and lockwire the bolt heads.

INSTALLATION

1. Place the spring drive gear assembly on the idler gear stubshaft being sure the tooth position marks are aligned as shown in Fig. 7-21.

2. If a new gear is used, refer to "Exhaust Valve Timing" at the end of this section for information on positioning and marking of gears. Timing procedures are not required if camshaft and crankshaft positions have not been disturbed.

NO. 1 IDLER GEAR

BEARING CLEARANCE CHECK WITHOUT DISASSEMBLY

The No. 1 idler gear bearing clearance can be checked without any disassembly of the engine.

1. Remove the rear left bank oil pan handhole cover and insert the rod assembly into the camshaft drive housing so that the end with the flattened side is at the bottom.

2. Position the rod so that the bracket mount straddles the crankcase endplate, and the top of the rod contacts the side of the No. 1 idler gear, Fig. 7-4. Hand tighten the bracket bolt.

3. Apply the light tension spring between the lower part of the rod and the edge of the handhole opening, Fig. 7-4, to maintain idler gear to rod contact.

NOTE: Photo at right was taken without the camshaft drive housing to illustrate the rod assembly-to-idler gear application.

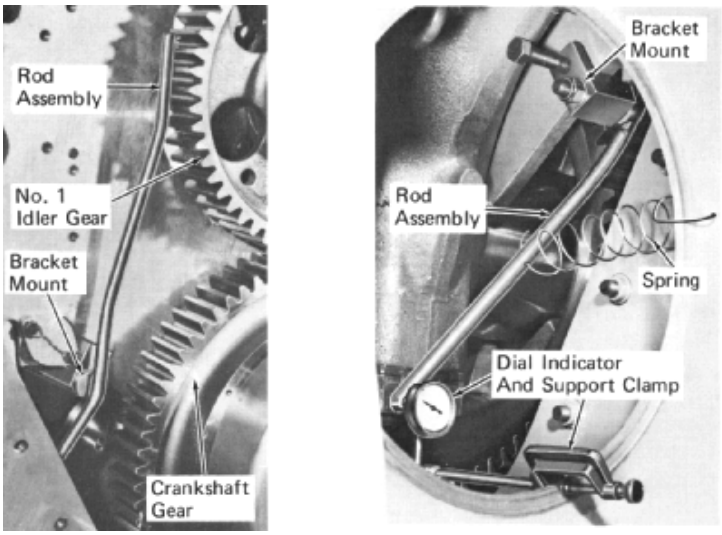

Fig. 7-4 - Application Of Parts For Checking Bearing Clearance

4. Secure the support clamp of' a dial indicator to the edge of the handhole opening. Position the indicator plunger so that it contacts the flattened side of the rod, Fig. 7-4.
5. With the cylinder test valves closed, use the engine turning bar, and manually rock the crankshaft as many times as necessary to remove the oil from the idler gear bearing. This will be evidenced on the dial indicator by no increase over previous reading taken for each direction of crankshaft travel.
6. Bar the crankshaft slightly in one direction until there is no further dial indicator movement, and set the indicator to zero. Bar the crankshaft in the opposite direction until there is no further dial indicator movement, and note reading. Multiply the reading by 1.3 to obtain No. 1 idler gear bearing clearance. Refer to limits in Service Data.

NOTE: It may be necessary to lock the left bank camshaft in order to provide sufficient load on the No. 1 idler gear to obtain full movement. This should be done if clearance does not fall within the limits given in Service Data.

If idler gear is to be removed, refer to the following procedures.

REMOVAL

1. Remove the four bolts and washers holding the thrust plate and idler gear.
2. Remove the thrust plate and idler gear from the stubshaft.

INSPECTION

Inspect the gear teeth for fatigue indications, cracks, pits, or other evidence of failure. If possible a magnaflux inspection should be performed.

INSTALLATION

See "Camshaft Gear Train Assembly" information for complete installation procedure.

IDLER GEAR STUBSHAFT ASSEMBLY

REMOVAL

1. After the spring drive gear assembly, the No. 1 idler gear and the attached oil lines have been removed, the stubshaft assembly can be taken off.
2. Remove the lockwire, dowel bolts, and the locating dowels.
3. Remove the mounting bolts and stubshaft assembly.

INSPECTION

1. Check that oil passages are not plugged.
2. Check alignment of oil holes in upper stubshaft sleeve with holes in stubshaft. Inspect sleeve for nicks or gouges.
3. Inspect upper stubshaft seal and replace, if necessary.
4. Check bearing on lower stubshaft and sleeve on upper stubshaft to see that they are not gouged or damaged in any way.

NO. 1 STUBSHAFT BEARING REPLACEMENT

1. Remove pressfit bearing from stubshaft by heating bearing until it can be removed.
2. Install new bearing by heating bearing in oil to 149°-163° C (300°-325° F) and pressing on stubshaft. Make certain that oil hole through bearing is at the 12 o'clock position.

NO. 2 STUBSHAFT SLEEVE REPLACEMENT

1. Remove 3/8" dowel which pins sleeve to stubshaft. Heat sleeve until it can be removed from stubshaft.
2. Install new sleeve by heating sleeve in oil to 260° C (500° F) and pressing on stubshaft. Oil holes in sleeve should be aligned to within 1/32" of oil passages in stubshaft. Install new dowel.

INSTALLATION

If a new stubshaft assembly is to be applied, see "Camshaft Gear Train Assembly" for installation procedure. If the stubshaft assembly that was removed from the engine is to be re-used, see the following installation procedure.

1. Attach the stubshaft assembly to the crankcase with the three vertically centered mounting bolts, and finger tighten.
2. Apply the lower idler gear to the stubshaft assembly to mesh with the crankshaft gear.
3. Place a feeler gauge between the lower idler and crankshaft gear teeth, and check the backlash. Backlash limits are in the Service Data.
4. If necessary, reposition the stubshaft assembly until the allowable backlash is obtained.
5. Apply the remaining stubshaft assembly mounting bolts, and torque all bolts.
6. Install dowels and dowel bolts, and lockwire all bolts.
7. Apply the oil lines to the stubshaft bracket.

CRANKSHAFT GEAR

REMOVAL

1. Remove the crankshaft gear from crankshaft.
2. The oil slinger can be removed from the crankshaft gear by removing the oil slinger to crankshaft gear bolts.

INSPECTION

Inspect the gear teeth for fatigue indications, cracks, pits, or other evidence of failure. If possible a magnaflux inspection should be performed. Inspect the oil slinger and oil seal retainer to see that they are not bent or damaged in any way.

INSTALLATION

See the "Camshaft Gear Train Assembly" information for complete installation procedure.

CAMSHAFT GEAR TRAIN ASSEMBLY

If the complete gear train has been disassembled (not including the camshaft stubshaft brackets), the following procedure should be used to install and align the various components.

STUBSHAFT BRACKET APPLICATION

1. Inspect the crankcase end plate for any burrs or damaged areas.
2. Clean any dirt or debris from the holes in the end plate or the end plate surface.
3. Wipe the crankshaft gear teeth clean, insert the coupling bolts in the gear from the back side and install it in its proper position on the crankshaft, as shown in Fig. 7-21. Secure the crankshaft gear with two nuts, moderately tightened.

   If a new gear is used, refer to "Exhaust Valve Timing" at the end of this section for information on positioning and marking of gears. Timing procedures are not required if camshaft positions have not been disturbed.
4. Inspect the stubshaft bracket rear surface for burrs and wipe clean, making sure all oil passages are clean and free of dirt.
5. Install two temporary locating pins, Fig. 7-5, into the idler gear stubshaft bracket mounting holes in the crankcase end plate.
6. Install the stubshaft bracket in position and apply the three vertically centered 1/2"-20 mounting bolts with hardened washers. Finger tighten the mounting bolts.
7. Apply the idler gear gauge (File 768) to the No. 1 idler gear stubshaft, Fig. 7-6, and place a feeler gauge between the idler gear gauge teeth and the crankshaft gear teeth to check the gear backlash which is specified in the Service Data at the end of this section.

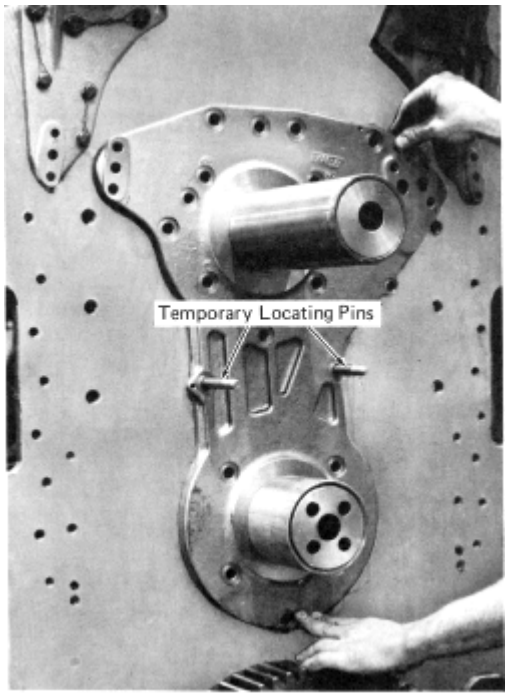

Fig. 7-5 - Idler Stubshaft Bracket Application

NOTE: The No. 1 idler gear may be used if a gauge is not available.

8. If the backlash is not within limits specified, gently tap the stubshaft bracket with a brass hammer until it is in position to obtain the proper backlash.

CAUTION: Do not tap on machined surfaces of the stubshaft bracket.

9. When the stubshaft bracket is properly aligned, tighten the bottom bolt to the proper torque and re-check the backlash.

10. Apply an idler gear stubshaft to camshaft stubshaft gauge (File 769), Fig. 7-7, and check the dimension between the No. 2 idler gear stubshaft and the left bank camshaft stubshaft making sure both stubshafts are wiped clean. Gauge must indicate less than 0.005 ".

NOTE: The No. 2 idler gear and left bank camshaft drive gear may be applied and backlash reading taken between No. 2 idler gear and camshaft drive gear if gauge is not available. See Service Data for limits.

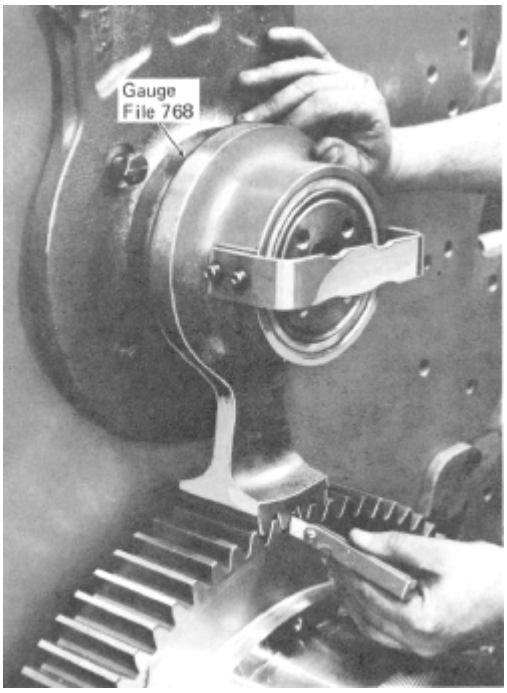

Fig. 7-6 - Checking No. 1 Idler Gear To Crankshaft Gear Backlash

11. If the dimension is not within limits, gently tap the stubshaft bracket until it is properly positioned.

CAUTION: Do not tap on machined surfaces of the stubshaft bracket.

12. When the stubshaft bracket is properly positioned, tighten the top and center mounting bolts to the proper torque and recheck the backlash between the idler gear gauge and the crankshaft gear.

13. If the backlash is not within the proper limits, the three vertical mounting bolts must be loosened and Steps 7 thru 12 repeated.

14. Remove the idler gear gauge and apply the remaining stubshaft mounting bolts and washers.

NOTE: One 3/8"-24 bolt is used at the edge of the stubshaft bracket directly below the lube oil manifold connection to the stubshaft bracket.

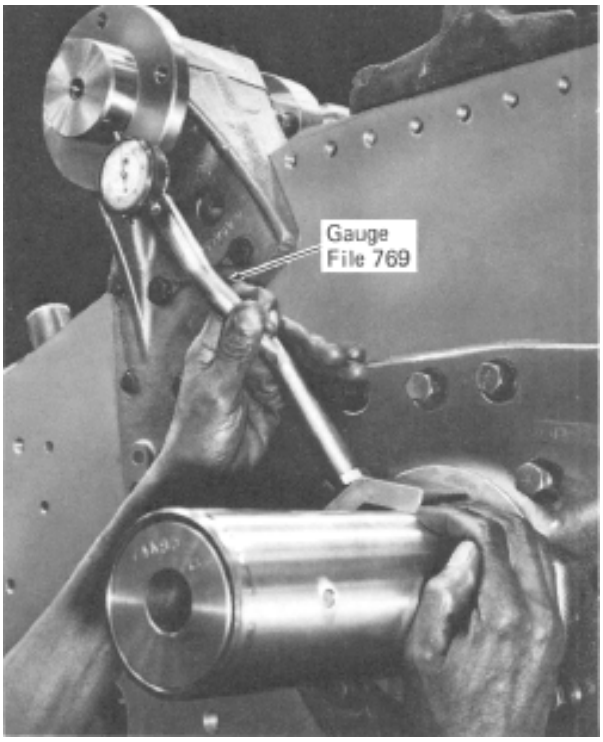

Fig. 7-7 - Idler Gear Stubshaft Bracket Alignment

15. Remove the two temporary locating pins and apply the two mounting bolts and washers. Then tighten all mounting bolts to the proper torque.

16. Ream the two dowel holes with a 0.494" tapered reamer and a 0.4998" ± 0.0002" bottoming reamer while using cutting oil.

NOTE: If dowel holes in idler gear stubshaft bracket do not align with holes in crankcase, drill and ream for oversize dowels as required to produce full circumference fit. See parts catalog for listing of oversize dowels.

17. Use an air hose to blow chips and oil out of the dowel holes.

18. Insert 5/16"-24 bolts approximately 12.70 mm (1/2") into the dowel pins.

19. Place dowels in dowel holes of stubshaft bracket and drive into crankcase end plate.

20. Torque the dowel bolts to 23 N-m (17 ft-lbs) and lockwire all mounting and dowel bolts in groups of three or less.

21. Using a No. 1 stubshaft to No. 2 stubshaft gauge (File 770) check parallelism between the No. 1 and No. 2 stubshafts, Fig. 7-8. Take one indicator reading with gauge as close to the stubshaft bracket as possible and the other reading with gauge near the end of the No. 1 stubshaft. Dial indicator readings must be within 0.004".

NOTE: Parallelism may also be checked by applying both idler gears, then checking gear teeth mesh and taking backlash measurements. See Service Data for backlash limits.

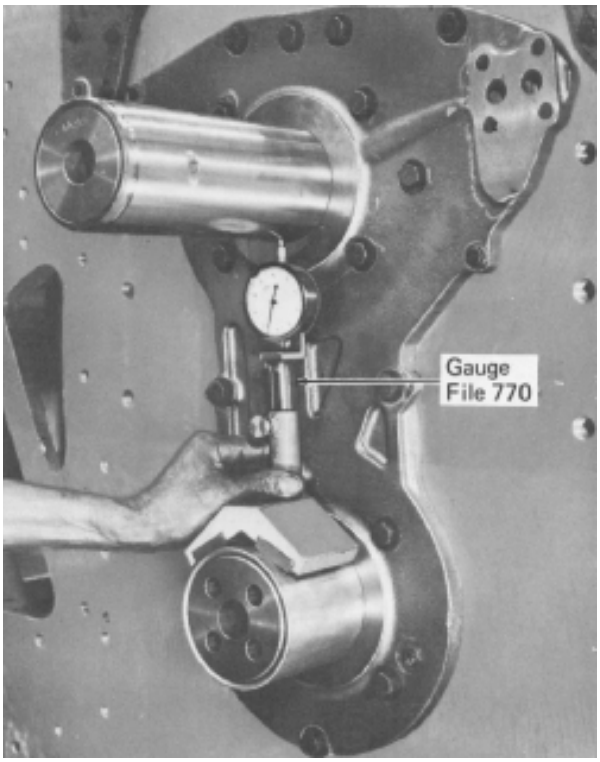

Fig. 7-5 - Checking Parallelism Of No. 1 And No. 2 Stubshafts

22. After a double idler stubshaft bracket has been applied to the crankcase rear end sheet, with all bolts torqued, the assembly should be checked for gaps in excess of .004" which could cause a critical loss of oil pressure. To perform this check, run a .004" feeler gage around the periphery of the bracket. If the feeler gage can be inserted into an oil passage, the bracket must be removed and the cause eliminated.

23. Re-check the dimension between the No. 2 idler stubshaft and the left bank camshaft stubshaft.

NO. 1 IDLER GEAR APPLICATION

1. Apply a light coat of lubricating oil to the No. 1 idler gear stubshaft and place the idler gear on the stubshaft so the tooth position marks are aligned as shown in Fig. 7-21.

If a new gear is used, refer to "Exhaust Valve Timing" at the end of this section for information on positioning and marking of gears. Timing procedures are not required if camshaft and crankshaft positions have not been distrubed.

2. Install the No. 1 idler gear thrust plate, hardened washers, and bolts. Tighten bolts to the proper torque and lockwire in pairs using a crisscross pattern.

3. Use a feeler gauge to check that the No. I idler gear thrust clearance is within the limit specified in the Service Data.

4. Re-check the backlash between the crankshaft gear and the No. 1 idler gear as in Step 7 of "Stubshaft Bracket Application."

PISTON COOLING FLANGES AND LUBE OIL MANIFOLD APPLICATION

l. If the flanges Governing the piston cooling manifold openings on the crankcase end plate have been removed, install the flange gaskets, flanges, and 3/8"-24 bolts, Fig. 7-9. Torque the bolts to 37 N-m (27 ft-lbs) and lockwire.

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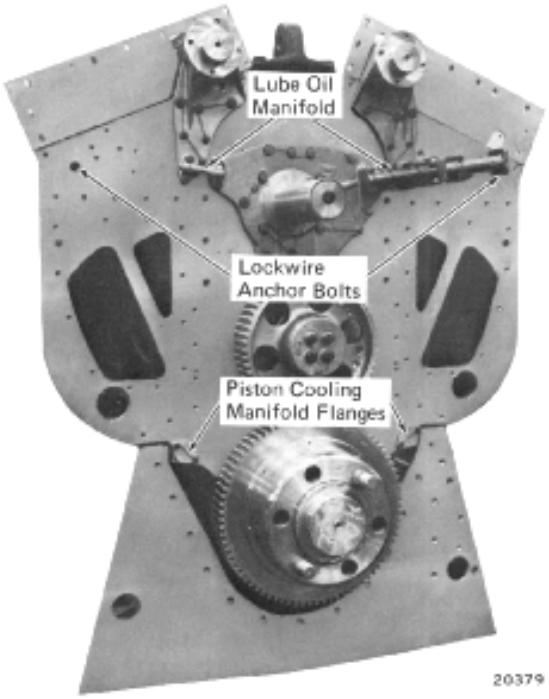


Fig. 7-9 -- Lube Oil Manifold Application

2. Assemble the end and center oil manifold sections being sure to install a gasket between them. Use 3/8"-24 bolts with locknuts and tighten to 37 N-m (27 ft-lbs).

3. Install the previously assembled manifold section and the stubshaft to left bank camshaft oil line, Fig. 7-9, being sure to place gaskets under the manifold sections. Tighten the 3/8"-24 bolts to 37 N-m (27 ft-lbs) and lockwire.

NOTE: If the stubshaft to left bank camshaft manifold does not have the pipe plug installed, coat the threads with high temperature thread compound and install in the manifold.

4. Install two 1/2"-20 bolts, Fig. 7-9, and tighten to 88 N-m (65 ft-lbs) torque. These bolts will be used for an anchor for lockwiring camshaft drive housing to crankcase bolts.

CAMSHAFT DRIVE HOUSING APPLICATION

1. Check the camshaft drive housing seal surfaces for burrs and wipe free of dust and dirt.

2. Apply a coat of gasket sealer to the camshaft drive housing. Apply the gasket in sections to the camshaft drive housing being sure the gasket interlocks are joined properly.

3. Apply the camshaft drive housing to crankcase bolts to the housing and wipe the crankcase end plate clean.

4. Trim the rubber crankcase to oil pan gasket extending from the joint at the crankcase end plate and apply Permatex to the joint area.

5. Locate the camshaft drive housing in its proper position and snug down several of the bolts to hold it in place.

6. 7-10, to act as positioning points for a dial indicator.

7. Install the camshaft drive housing alignment gauge (File 771) on the left bank camshaft stubshaft, and sweep the left bank locating pin, Fig. 7-10. The camshaft drive housing is properly aligned when an 0.008"-0.010" reading is obtained on the dial indicator.

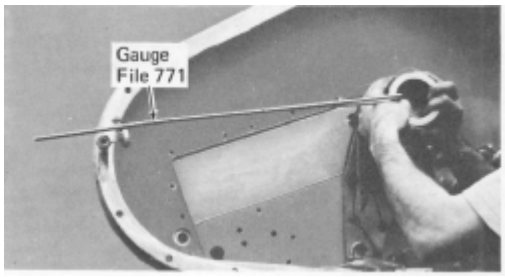


Fig. 7-10 - Camshaft Drive Housing Alignment

8. Repeat Step 7 on the right bank camshaft stubshaft.

9. If the housing is not aligned properly, place a wedge (File 772) between the camshaft stubshaft bracket and the housing, and drive the wedge in with a brass hammer.

10. If the dial indicator shows the camshaft drive housing to be properly aligned, torque the mounting bolts to the proper torque, then remove the wedge and recheck the alignment.

11. Ream the two dowel holes in the camshaft drive housing with a 0.494" tapered reamer and a 0.4998" ± 0.0002" bottoming reamer, being sure to use cutting oil.

NOTE: If dowel holes in camshaft drive housing do not align with holes in crankcase, drill and ream for oversize dowels as required to produce full circumference fit. See parts catalog for listing of oversize dowels.

12. Use an air hose to blow chips and oil out of the dowel holes, and insert 5/16'-24 bolts approximately 12.70 mm (1/2") into the dowel pins.

13. Place dowels in dowel holes in the housing, and drive into the crankcase end plate. Remove the dowel bolts.

14. Install the two remaining camshaft drive mounting bolts in the holes next to the dowel pins, and torque to the specified torque.

15. Lockwire the camshaft drive housing upper bolts in three groups of three each, and the two remaining mounting bolts to the bolts previously installed in the end plate for anchoring the lockwire.

16. Install the remaining oil manifold section, being sure to apply the proper gasket between the manifold and crankcase and between the manifold section previously installed and the one being applied. Use locknuts on the bolts connecting the two sections, and lockwire the manifold to crankcase bolts. If the turbocharger filter is not installed at this time, temporary bolts and spacers should be applied to the filter mounting bolts.

17. Install the oil slinger and the oil slinger-to-crankshaft gear bolts.

18. Prior to installation of the oil seal retainer, measure the distance from the inner face of the retainer mounting flange to the inner face of the retainer tapered flange, Fig. 7-2. Then measure the distance from the outer face of the camshaft drive housing to the face of the oil slinger with the crankshaft positioned toward the rear of the engine. The difference between the two measurements should equal the clearance specified in Service Data. If required, add or remove oil slinger shims to obtain proper clearance.

19. If oil retainer has dowels, remove the dowels.

20. Apply oil retainer gasket and oil retainer. Install four equally spaced bolts and washers finger tight.

21. Center the retainer by tapping the OD with a soft-faced hammer until the radial clearance between the retainer ID and the gear sealing surface OD is uniform around the circumference, as measured with a feeler gauge. Refer to Service Data for proper radial clearance.

22. Apply the remainder of the 24 bolts and washers and torque to 41 N-m (30 ft-lbs).

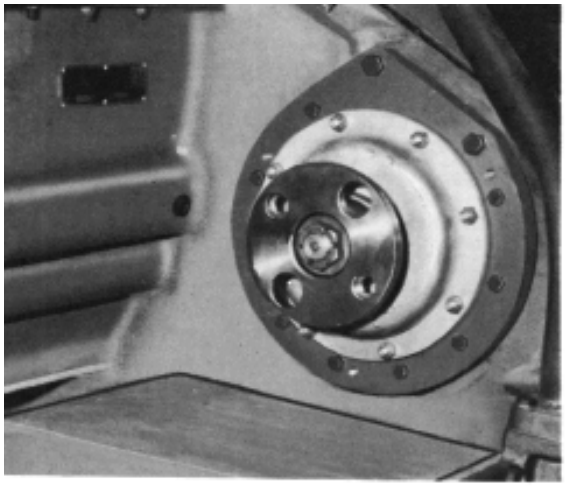
23. Recheck for uniform clearance to ensure that the retainer has not shifted.

24. Apply camshaft drive gears and spring drive gear assembly as previously described.

AUXILIARY DRIVE ASSEMBLY

DESCRIPTION

The auxiliary drive assembly, Fig. 7-11, is mounted on the turbocharger housing and is driven from the right bank camshaft drive gear.



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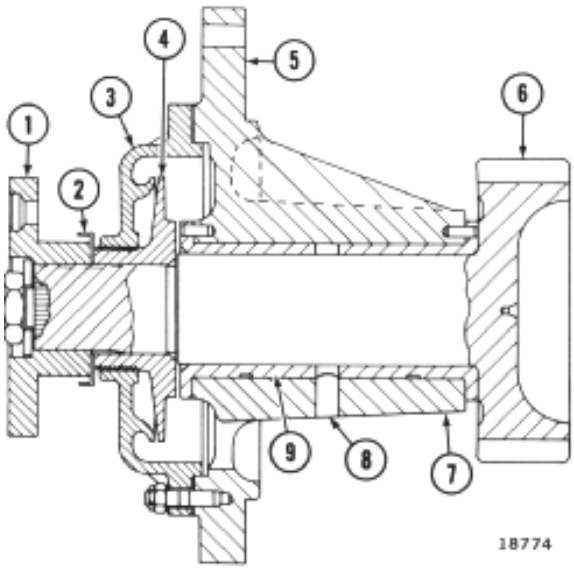

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1. Coupling Flange
2. Dust Shield
3. Cover
4. Oil Slinger
5. Mounting Pilot
6. Drive Shaft And Gear
7. Support Housing
8. Drain
9. Bushing

Fig. 7-11 - Auxiliary Drive Assembly

MAINTENANCE

When new bearings are installed, they are pressed into the support housing and line reamed or bored to the dimension specified in Service Data. After mounting the assembly on the turbocharger housing, the backlash between the gears must be checked and adjusted, if necessary.

Check the backlash with a dial indicator, Fig. 7-12. Attach a small "C" clamp to the coupling flange so that clamp contacts the outer edge of the flange. Position the dial indicator with the contact point touching the "C" clamp. Remove play from gear teeth by turning the coupling flange. Set the dial indicator to zero and move flange in the opposite direction of the previous movement and note reading on dial indicator.

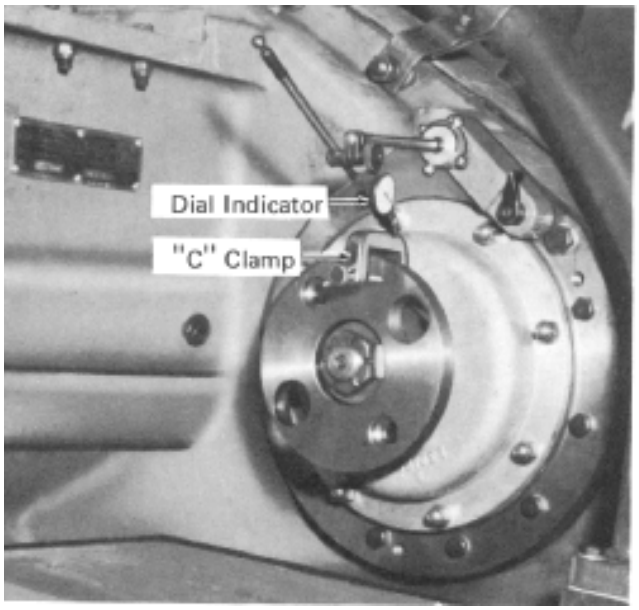


Fig. 7-12 - Checking Auxiliary Drive Gear Backlash

Refer to Service Data for backlash limits. Backlash is adjusted by loosening the turbocharger mounting bolts and repositioning the turbocharger on the camshaft drive housing.

After correct backlash is obtained, the turbocharger mounting bolts are tightened, and the backlash checked to see that it has not changed.

CAMSHAFT ASSEMBLIES

DESCRIPTION

The camshaft assembly, Fig. 7-13, consists of flanged segments, front and rear stubshafts, and a spacer is used on 12, 16, and 20-cylinder engines between the center segments. Each segment spans three (12-cyl.), four (8 & 16-cyl.), and five (20-cyl.) cylinders. Segment flanges are marked as shown in Fig. 7-13 to aid in correct assembly. At each cylinder there are two exhaust cams, one injector cam, and two bearing journals. Two bearing blocks at each cylinder, equipped with steel-backed lead base babbit lined inserts, support the camshaft.

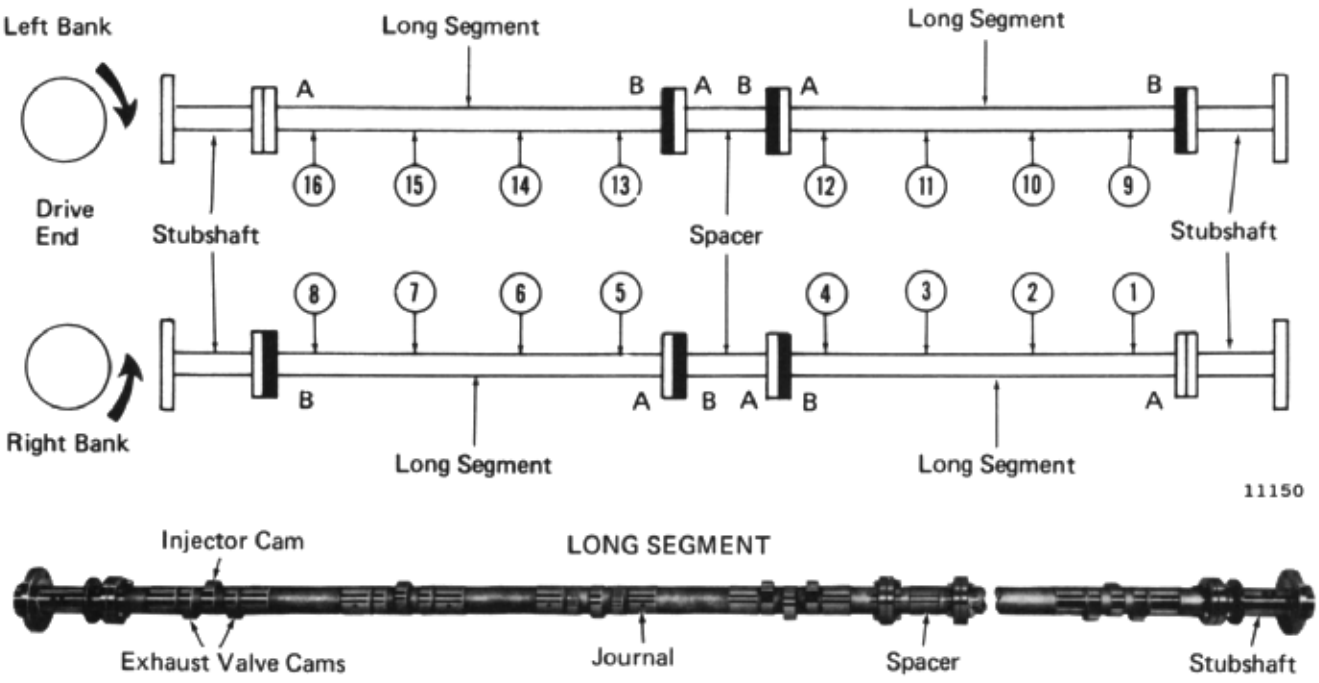


Fig. 7-13 - Camshaft Assembly (16-Cyl.)

MAINTENANCE

REMOVAL

The camshaft may be removed without disturbing the stubshafts by removing the dowel bolts connecting the segment and stubshaft flanges, removing oil lines from segment bearing blocks to rocker arms, and removing rocker arms. Remove segment bearing block caps to allow camshaft removal. If the camshaft is removed for reasons other than bearing replacement, an attempt should be made to retain relative position of the bearing shells on reinstallation of the camshaft. This may be accomplished by immediately replacing caps after camshaft removal, or if the entire block is removed, by inserting block bolts and wiring the free ends of the bolts. It is possible to remove a segment of the 16 and 20-cylinder camshaft without removing the entire camshaft. However, the entire camshaft must be removed on a 12-cylinder engine to change a segment.

INSPECTION

After removal of camshaft, wash and remove all dirt from oil passages. Visually inspect stubshafts and segments paying particular attention to cam lobes and journals for pitting, chipping, excessive scoring and heat discoloration. Journals and cams with light pit marks, minute flat spots, and light score marks may be reused after blending and removal of sharp edges by hand polishing. Check inside of dowel bolt holes for burrs, and remove.

Camshaft segments and stubshafts that show heat discoloration should be magnaflux inspected and hardness tested. Discoloration on the unfinished portion of the camshaft should be disregarded as it results from a production process and may be seen even on a new camshaft.

ASSEMBLY

The camshaft must be assembled as shown in Fig. 7-13. One dowel bolt hole in each segment flange is smaller than the others to ensure correct angular position. After assembly of camshaft and stubshaft, check for concentricity between the stubshaft and camshaft journals and maximum runout over total length of the shaft. Support the camshaft on precision rollers at the number 2 and 7 (8-cyl.); 1, 6, 7, and 12 (12-cyl.); l, 7, 10, and 16 (16-cyl.); and 1, 9, 12 and 20 (20-cyl.) camshaft bearing journals. See Service Data for limits.

INSTALLATION

Camshaft assemblies installed on an engine must conform to segment sequence and position as indicated in Fig. 7-13. On right bank camshafts, the "A" marking on each flange is toward the front of the engine. On left bank camshafts, the "B" marking on the flange must be toward the front of the engine.

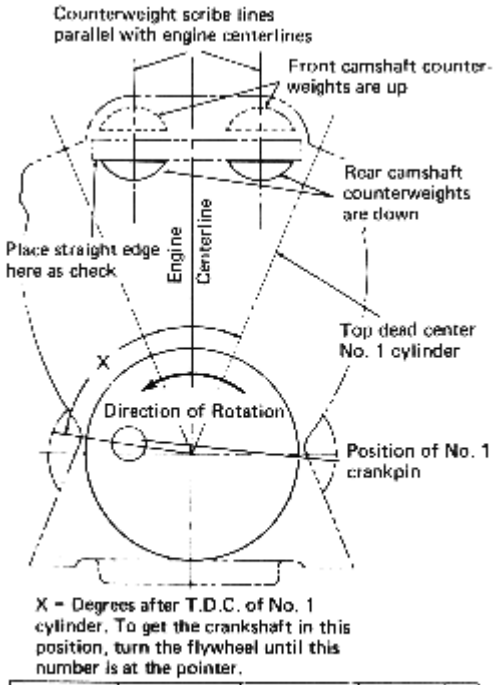
Stubshafts connected to segment flanges with "A" markings are a different configuration than those connected to segment flanges with "B" markings.

Check segment journal to bearing clearance and thrust clearance at rear stubshafts. Limits are listed in the Service Data. Clearance measurement can be obtained with feeler gauges.

Upon installation or replacement of the camshaft, lubricate freely all moving parts, place the assembly in properly aligned position after replacing blocks and bearings as removed. Rotate camshaft to check for binding. Apply flange dowel bolts and reassemble rocker arms and associated parts. Check valve timing of at least one cylinder to check segment positioning, and then make other adjustments such as exhaust valve setting and injector timing.

CAMSHAFT COUNTERWEIGHT APPLICATION

Counterweight replacement usually is not necessary. However, when counterweights are installed, they should be applied in the position as shown in Fig. 7-14.



8-Cyl. Eng.	12-Cyl. Eng.	16-Cyl. Eng.	20-Cyl. Eng.
X = 184°	X = 249-1/2°	X = 105°	X = 149-1/2°

Fig. 7-14 - Camshaft Counterweight Timing section

EXHAUST VALVE TIMING

DESCRIPTION

Exhaust valve timing is very important as it ensures correct relationship of valve operation with the other events in the cylinder power cycle. To check or adjust exhaust valve timing, it is necessary to know the top dead center of each cylinder as shown in Table 1.

	8-Cylinder		12-Cylinder
Firing Order	Top Dead Center	Firing Order	Top Dead Center
1	0°	1	0°
5	45°	12	19°
3	90°	7	45°
7	135°	4	94°
4	180°	3	120°
8	225°	10	139°
2	270°	9	165°
6	315°	5	214°
		2	240°
		11	259°
		8	285°
	16-Cylinder		20-Cylinder
Firing Order	Top Dead Center	Firing Order	Top Dead Center
1	0°	1	0°
8	22-1/2°	19	9°
9	45°	8	36°
16	67-1/2°	11	45°
3	90°	5	72°
6	112-1/2°	18	81°
11	135°	7	108°
14	157-1/20	15	1170
4	180°	2	144°
5	202-1/2°	17	153°
12	2250	10	1800
13	247-1/2°	12	189°
2	270°	3	216°
7	292-1/2°	20	225°
10	315°	6	252°
15	337-1/2°	13	261°

Table 1 - Firing Order And Top Dead Center

Items which govern correct valve timing are given in the following procedures.

MAINTENANCE

LOCATING TOP DEAD CENTER

If it should become necessary to check the position of the flywheel or the flywheel pointer for top dead center, proceed as follows:

1. Remove an air box handhole cover at the No. 1 cylinder.

2. If necessary, bar the engine to position the No. 1 piston below the cylinder liner ports.

3. Insert a brass "stop-bare (minimum 1/2" hex-agonal or square preferred) of suitable length through the ports of the No. 1 cylinder so that the end of the bar passes through a port on the opposite side of the cylinder, Fig. 7-15.

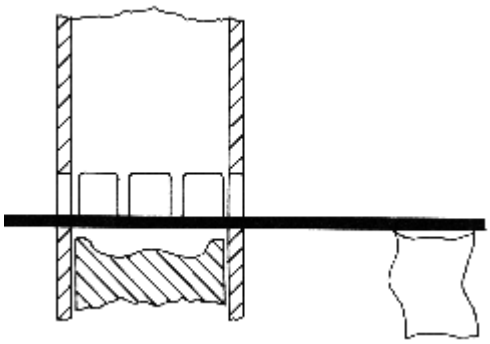


Fig. 7-15 - "Stop-Bar" Inserted Through Cylinder Ports

NOTE: A bar of sufficient length to prevent reapplication of the handhole cover while the bar is in place is recommended. A flag on the end of the bar will caution against inadvertent rotation of the engine with the bar in place.

4. Manually bar the engine slowly in the normal direction of rotation until piston travel is stopped by the bar against the upper surfaces of the cylinder ports, Fig. 7-16.

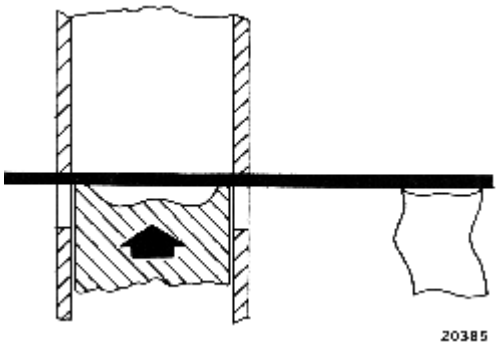


Fig. 7-16 - Piston Travel Limited By "Stop-Bar"

CAUTION: Use extreme care to avoid excessive force.

5. Mark the position of the flywheel pointer on the flywheel, Fig. 7-17.

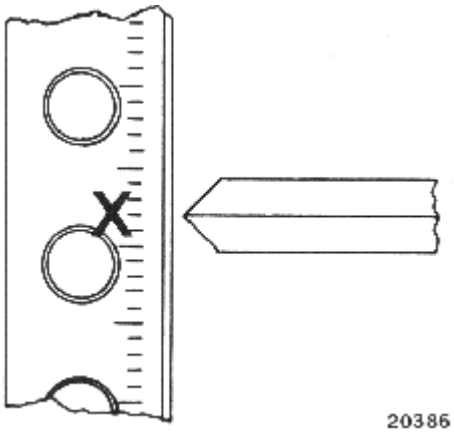


Fig. 7-17 - Limit Of Piston Travel Marked On Flywheel

6. Manually bar the engine slowly in the opposite direction from normal rotation until piston travel is again stopped by the bar against the upper surfaces of the cylinder ports.

7. Mark the second position of the flywheel pointer on the flywheel, Fig. 7-18.

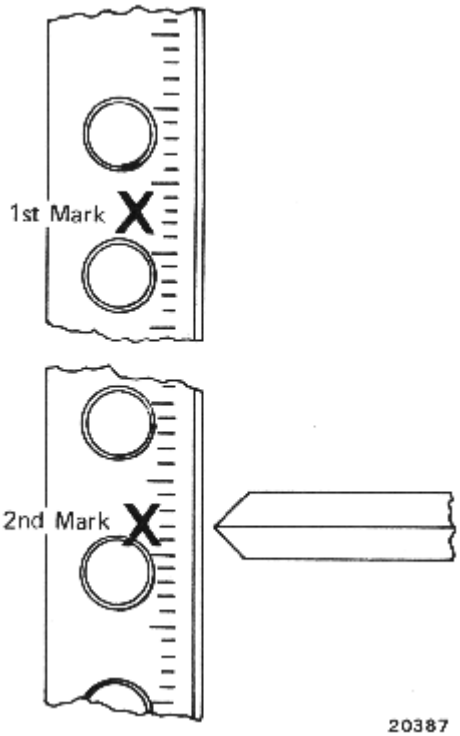
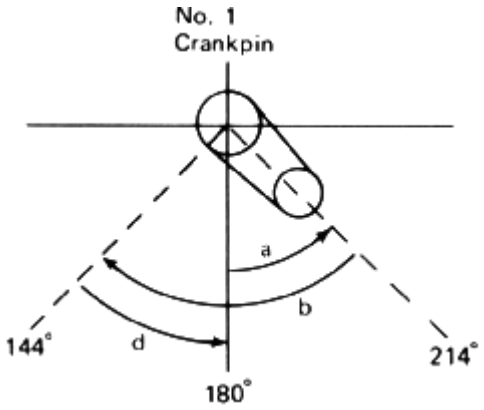


Fig. 7-18 - Second Limit Of Piston Travel Marked On Flywheel

8. Determine the number of degrees between the two marks on the flywheel. Divide that number by 2. See Fig. 7-19 for a sample calculation.



a. Mark flywheel as indicated in Step 5.
b. Mark flywheel as indicated in Step 7.
c. Determine number of degrees as indicated in Step 8. Divide by 2.

$$\begin{array}{lll} 214^\circ & \underline{70^\circ} & \\ \underline{144^\circ} & 2 \quad = & 35^\circ \\ 70^\circ & & \end{array}$$

d. Rotate 35'. Pointer should indicate 180'. If it does not, adjust pointer to indicate 180`. 21158

Fig. 7-19 - Sample Calculation

9. Rotate the crankshaft in the normal direction of rotation the exact number of degrees determined in Step 8 above. Remove the brass "stop-bar" from the engine.

10. The pointer should indicate 180° (bottom dead center). If it does not, position the pointer so that it does indicate 180°. The pointer will now indicate top dead center for the No. 1 crankpin when the engine is rotated so that the pointer is at zero degrees (0°).

CHECKING EXHAUST VALVE TIMING

To check timing, place a dial indicator on the rocker arm adjusting screw as shown in Fig. 7-20. Valve end of rocker arm must be in its highest position, so that the exhaust valves are closed. Press indicator down approximately 2.54 mm (.100") and set dial to zero.

Turn crankshaft in normal direction of rotation until flywheel is at 106° A.T.D.C. of cylinder being checked.

If timing is correct, the valve bridge will have moved down 0.36 mm (.014"). Timing must not be later than 110° or earlier than 104° A.T.D.C. of cylinder being checked.

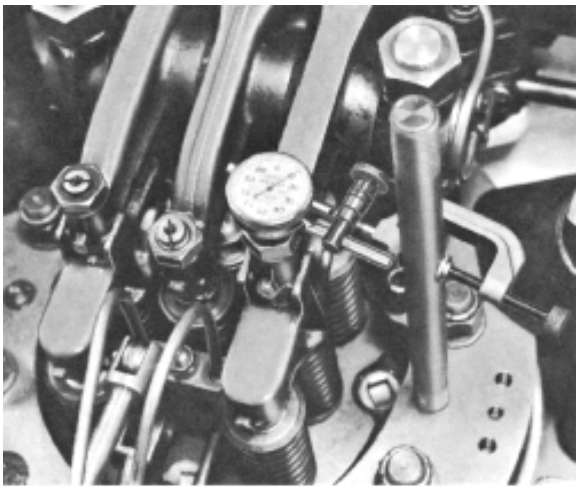


Fig. 7-20 - Timing Exhaust Valves

It timing is incorrect, check for:

1. Proper installation of camshaft.
2. Camshaft gear train correctly timed.
3. Excessively worn gears.

TIMING EXHAUST VALVES

The exhaust valves should be timed when any gear or stubshaft of the camshaft gear train is replaced, with the exception of the No. I or No. 2 idler gears. To do this, the camshaft on each bank must be timed to the crankshaft, but only one cylinder of each bank needs to be timed.

CAUTION: To prevent possible valve damage, remove or loosen all rocker arm assemblies, except the one on the cylinder being timed. If rocker arm assemblies are removed, hydraulic lash adjusters should be checked for proper clearance to valve stems. See Section 5 for instructions.

1. Apply dial indicator to the rocker arm adjusting screw, Fig. 7-20, as done in "Checking Exhaust Valve Timing."
2. Remove the dowels and bolts from the camshaft counterweight and remove counterweight and gear. The camshaft can be rotated by placing a socket and wrench on flange bolt nuts.
3. Rotate the camshaft in its normal direction of rotation until the valve bridge on which the dial indicator is resting moves down 0.36 mm (.014").

4. Turn the crankshaft in the normal direction of rotation until the flywheel pointer is at 105° after top dead center for the cylinder being checked. Install camshaft gear and counterweight on stubshaft, but do not tighten bolts at this time.

5. With flywheel at 105° A.T.D.C. of the cylinder being checked, the dowel holes in the camshaft drive gear, counterweight, and the camshaft stubshaft should be in line or approximately in line with each other. If by turning the crankshaft from 104° to 106° A.T.D.C., the dowel holes can be made to line up, then the bolts should be tightened.

6. If the dowel holes do not line up within this tolerance, remove the camshaft counterweight and gear from the stubshaft. Rotate the gear 180° and replace on stubshaft or move the gear one tooth and replace gear and counterweight on the stubshaft.

7. If dowel holes still do not line up but misalignment is less than 0.190 mm (.0075"), the holes may be reamed for installation of 0.005", 0.010", or 0.015" oversize dowels.

   If misalignment of dowel holes is greater than 0.190 mm (.0075 ")proceed to Step 17.

8. Insert 5/16"-24 bolts approximately 12.7 mm (1/2") into dowel pins.

9. Place dowels in dowel holes and drive into stubshaft. Remove dowel bolts from pins.

10. Remove counterweight to stubshaft bolts.

11. Install dowel retainer plate, and counterweight to stubshaft bolts. Torque bolts to 122 N-m (90 ft-lbs).

12. Install dowel pin bolts and torque to 23 N-m (17 ft-lbs).

13. Lockwire mounting bolts and dowel bolts in groups of three. (Two mounting bolts and one dowel bolt.)

14. The crankshaft should now be rotated in its normal direction and the timing checked so that the valve bridge of the valve being checked has moved down 0.36 mm (.014") when the flywheel timing pointer is at 104°-106° A.T.D.C.

15. Repeat the operation on one cylinder on the opposite bank.

16. After timing has been completed, the relative position of the mating parts should be identified similar to the method used on new engines, shown in Fig. 7-21. The mating parts are marked with No. 1 piston at top dead center. This completes valve timing procedures.

17. Remove counterweight and gear from stubshaft.

18. Plug dowel holes in stubshaft as follows:

    a. Drill and tap the two dowel holes for 3/4"-16 NF thread with a minor diameter of 0.7031" + 0.005" - 0..000" and pitch diameter of 0.7094" + 0.0016" - 0.0000".

    b. Countersink 1.6 mm (1/16") on gear mounting side.

    c. Drive threaded, hex head plugs into holes. See Service Data for plug part number.

    d. Cut plug head off and flare by peening into countersink.

    e. Grind plugs flush with flange face.

    f. Check 146.037 mm + 0.00 mm - 0.03 mm (5.7495" + 0.000" - 0.001") flange O.D. for high spots and grind to proper dimension.

CAUTION: If camshaft to crankshaft relationship has been disturbed, repeat Step 3. 19. Apply camshaft gear to stubshaft and secure with mounting bolts.

20. Rotate engine crankshaft to position indicated in Fig. 7-14.

21. Remove gear mounting bolts and position gear and counterweights on stubshaft with counterweight in down position and counterweight scribe line parallel with engine centerline. Ensure that gear and counterweight dowel holes are aligned.

22. Install mounting bolts to secure gear and counterweight to stubshaft.

23. Drill and ream stubshaft dowel holes to 12.662 mm + 0.13 mm - 0.00 mm (.4985" + .005" - .000").

24. Perform Steps 8 thru 16.

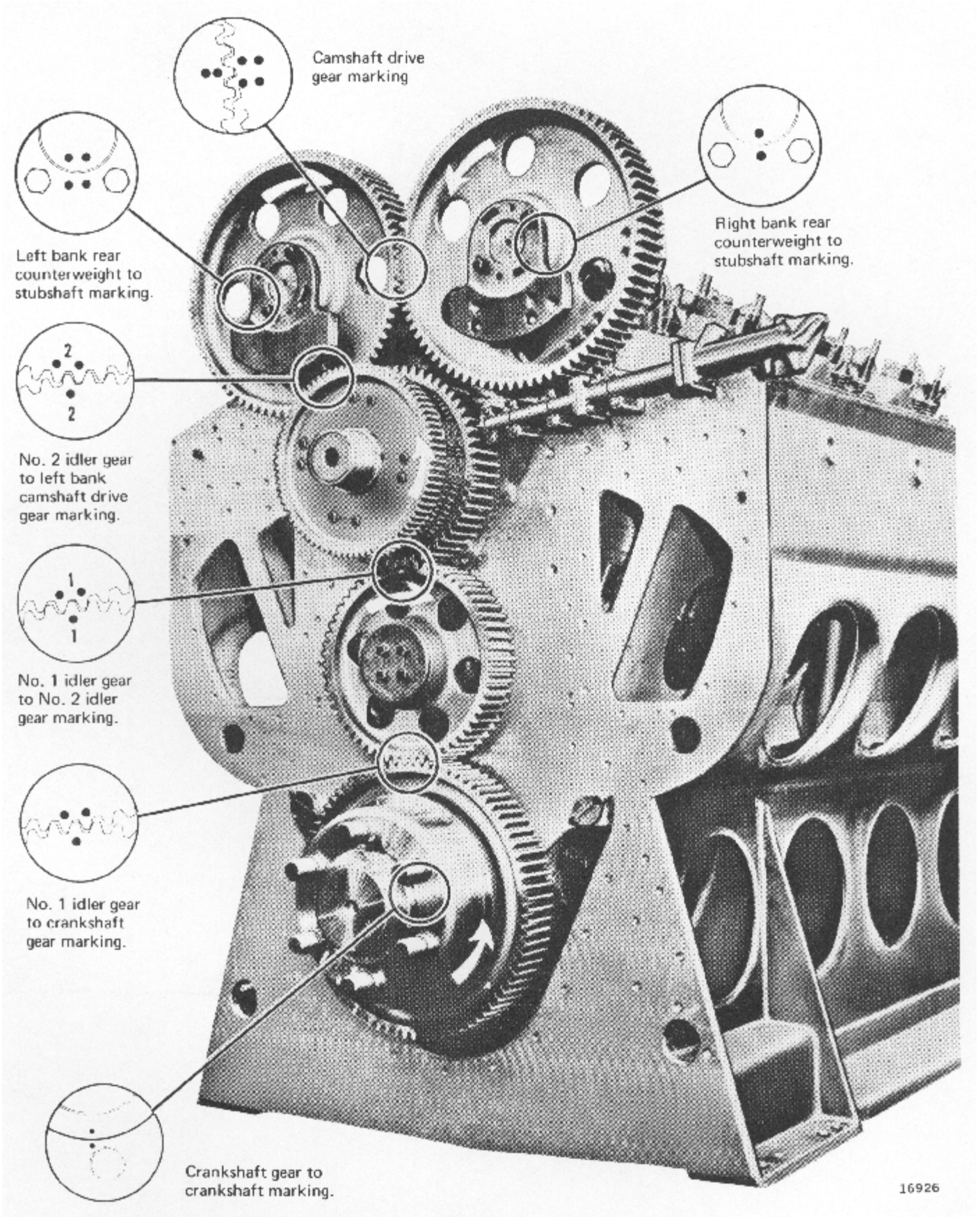


Fig. 7-21 - Camshaft Gear Train Marking

SERVICE DATA
CAMSHAFT GEAR TRAIN, AUXILIARY DRIVE, AND CAMSHAFT ASSEMBLIES

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)

2. Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.

Crankshaft Gear	
Oil slinger to oil retainer clearance	2.29-2.79 mm (.090"-.110")
Shims to obtain required clearance	
8035526	0.25 mm (.010")
8035527	0.51 mm (.020")
8035528	0.76 mm (.030")
Oil retainer ID to crankshaft gear sealing surface OD radial clearance	0.38-0.51 mm (.015"-.020")
Camshaft Drive Gear	
Wear step where mated with auxiliary drive gear -- Max.	0.05 mm (.002")
Gear Backlash	
Crankshaft gear to No. 1 idler - New	0.18-0.36 mm (.007"-.014")
No. 1 idler to No. 2 idler on spring drive gear assembly -- New	0.18-0.36 mm (.007"-.014")
No. 2 idler on spring drive gear assembly to camshaft drive - New	0.18-0.41 mm (.007"-.016")
Camshaft drive to camshaft drive -- New	0.18-0.56 mm (.007"-.022°')
Auxiliary drive to camshaft gear - New	0.25-0.56 mm (.010"-.022")
Max. (all gears above)	0.64 mm (.025")
Turbocharger drive to turbocharger -	
New	0.13-0.25 mm (.005"-.010")
Max.	0.51 mm (.020")
Gear Train	
(Idler gears and stubshafts include sleeve and bearings where applicable.)	
No. 1 idler gear assembly (through bolted, fixed bearing stubshaft assembly)	
Idler gear bore diameter -	
New	117.48-117.50 mm (4.625"-4.626")
Max.	117.58 mm (4.629")
Stubshaft diameter -	
New	117.27-117.35 mm (4.617"-4.620")
Min.	117.14 mm (4.612")
Idler gear to stubshaft clearance -	
New	0.13-0.23 mm (.005"-.009")
Max.	0.43 mm (.017")
Thrust clearance -	
New	0.20-0.51 mm (.008"-.020")
Max.	0.71 mm (.028")

No. 2 idler gear assembly (part of spring drive gear assembly)

Idler gear bore diameter -	
New	101.73-101.75 mm (4.005"-4.006")
Max.	101.83 mm (4.009")
Stubshaft diameter -	
New	101.57-101.62 mm (3.999"-4.001")
Min.	101.52 mm (3.997")
Idler gear to stubshaft clearance -	
New	0.10-0.18 inm (.004"-.007")
Max.	0.30 mm (.012")
Thrust clearance -	
New	1.14-2.11 mm (.045"-.083")
Max.	2.31 mm (0.91")

Auxiliary Drive

Housing

Pilot diameter -	
New	215.85-215.87 mm (8.498"-8.499")
Min.	215.80 mm (8.496")
Bearing diameter (in support housing after line reaming) -	
New	63.564-63.589 mm (2.5025"-2.5035")
Max.	63.65 mm (2.506")
Thrust dimension	
New	164.77-164.97 mm (6.487"-6.495")
Min.	164.54 mm (6.478")

Drive Shaft

Bearing diameter -	
New	63.47-63.50 mm (2.499"-2.500")
Min.	63.462 mm (2.4985")
Thrust dimension -	
New	165.23-165.30 mm (6.505"-6.508")
Max.	165.40 mm (6.512")

Clearance

Shaft to bushing -	
New	0.064-0.114 mm (.0025"-.0045")
Max.	0.190 mm (.0075")
Thrust -	
New	3.43-3.81 mm (.135"-.150")
Max.	4.04 mm (.159")

Camshaft And Stubshaft

Camshaft journal diameter -	
New	63.40-63.45 mm (2.496"-2.498")
Min.	63.37 mm (2.495")
Diametric clearance, segment journal to bearing -	
New	0.05-0.15 mm (.002"-.006")
Max.	0.25 mm (.010")

SERVICE DATA
CAMSHAFT GEAR TRAIN, AUXILIARY
DRIVE, AND CAMSHAFT ASSEMBLIES

Taper length of journal -- Max.	0.02 mm (.001 ")
Runout (journal) T.I.R. when supported on adjacent journals - Max.	0.05 mm (.002")
Runout (base circle relative to journal) - Max.	0.08 mm (.003")
Mounting flange (not convex) flat within* - Max.	0.013 mm (.0005")
Mounting flange square with longitudinal centerline within T.I.R.* -- Max.	0.02 mm (.001")

*(Correct by grinding faces)

Concentricity between stubshaft and camshaft journals and maximum runout over total length of shaft (T.I.R.) Max.	0.10 mm (.004")
Dowel bolt holes in flanges	
One hole	11.15 mm (.439")
Three holes	12.738 mm (.5015")
Stubshaft journal diameter	
New	63.42-63.45 mm (2.497"-2.498")
Min.	63.37 mm (2.495")
Diametric clearance, journal to bearing -	
New	0.089-0.190 mm (.0035"-.0075")
Max.	0.25 mm (.010")
Stubshaft thrust clearance -	
New	0.18-0.38 mm (.007"-.015")
Max.	0.64 mm (.025")
Dimension between thrust faces -- Max.	106.55 mm (4.195")

Camshaft Timing

Ideal timing setting, valve open 0.36 mm (0.014") - A.T.D.C.	106°
Timing of new gear train not earlier than -- Max.	2°
or	
at 0.36 mm (0.014") valve opening A.T.D.C.	104°
Limit of lag - camshaft behind crankshaft due to worn gears -- Max.	4°
or	
at 0.36 mm (0.014") valve opening -- A.T.D.C.	110°

Flywheel pointer setting - T.D.C. of No. 1 cylinder	0°

EQUIPMENT LIST

	Part No.
Feeler gauge set.	8067337
Camshaft stubshaft plug.	8166882
No. 1 idler gear clearance checking spring	8235573
Dial indicator	8255423
Loctite cleaner activator 170 grams (6 oz.)	8352873
No. 1 idler gear clearance checking bar	8466308
Loctite sealing compound 250 cc bottle	9085183
No. 1 idler gear to crankshaft gauge	File 768
Idler gear stubshaft to camshaft stubshaft gauge	File 769
No. 1 stubshaft to No. 2 stubshaft gauge	File 770
Camshaft drive housing alignment gauge	File 771
Camshaft drive housing alignment wedge	File 772