1.21 GEAR TRAIN AND ENGINE TIMING

The gear train is completely enclosed between the gear case and gear case cover and is located at the front of the engine. The gear train consists of a camshaft drive gear, camshaft idler gear, fuel pump drive gear, air compressor and power steering pump drive gear, bull gear, oil pump drive gear, crankshaft timing gear, water pump drive gear, accessory pulley drive gear, and adjustable idler gear. The gear ratio of each gear in relationship to the crankshaft timing gear is shown directly below the gear title. See Figure 1–245.

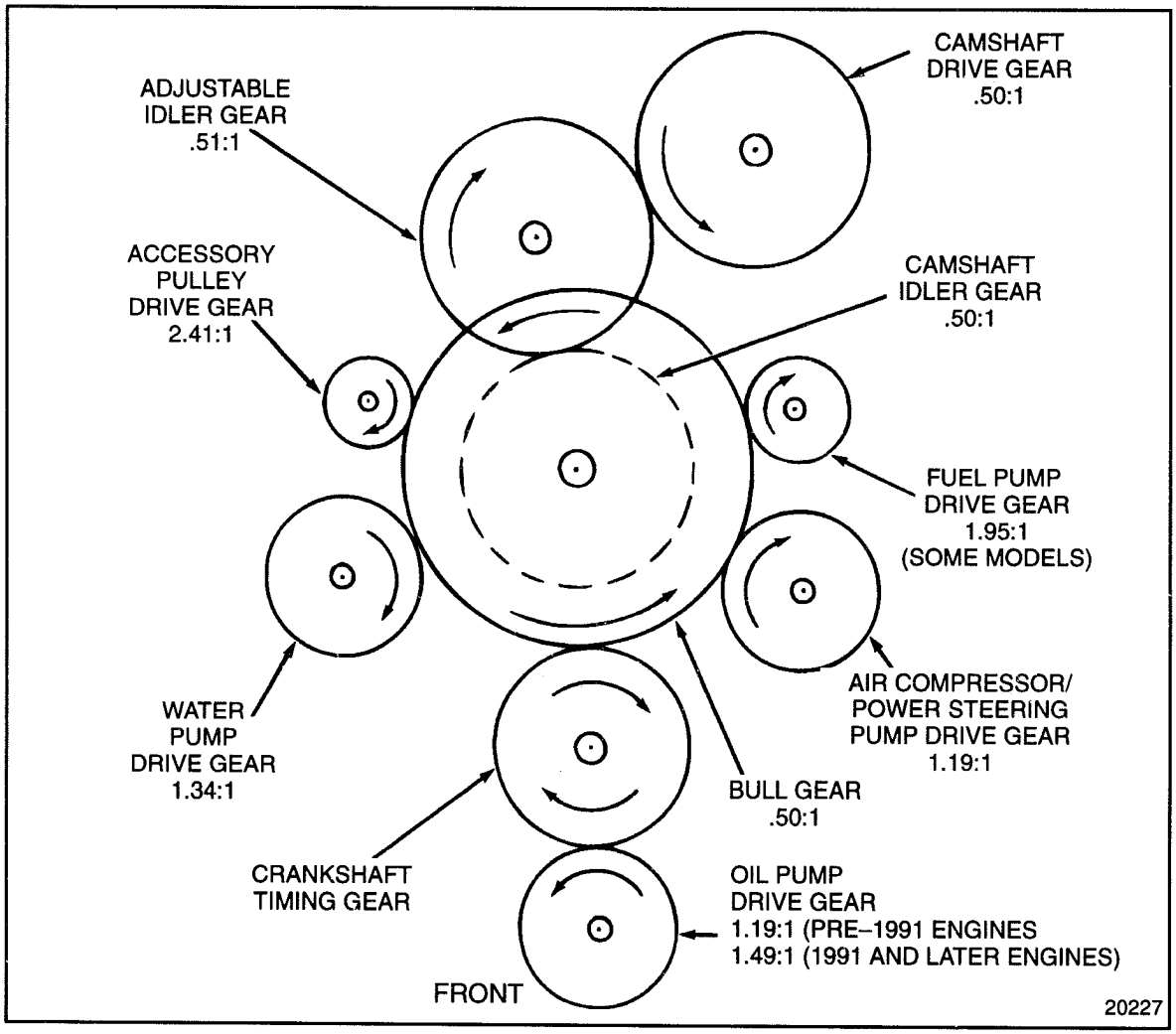
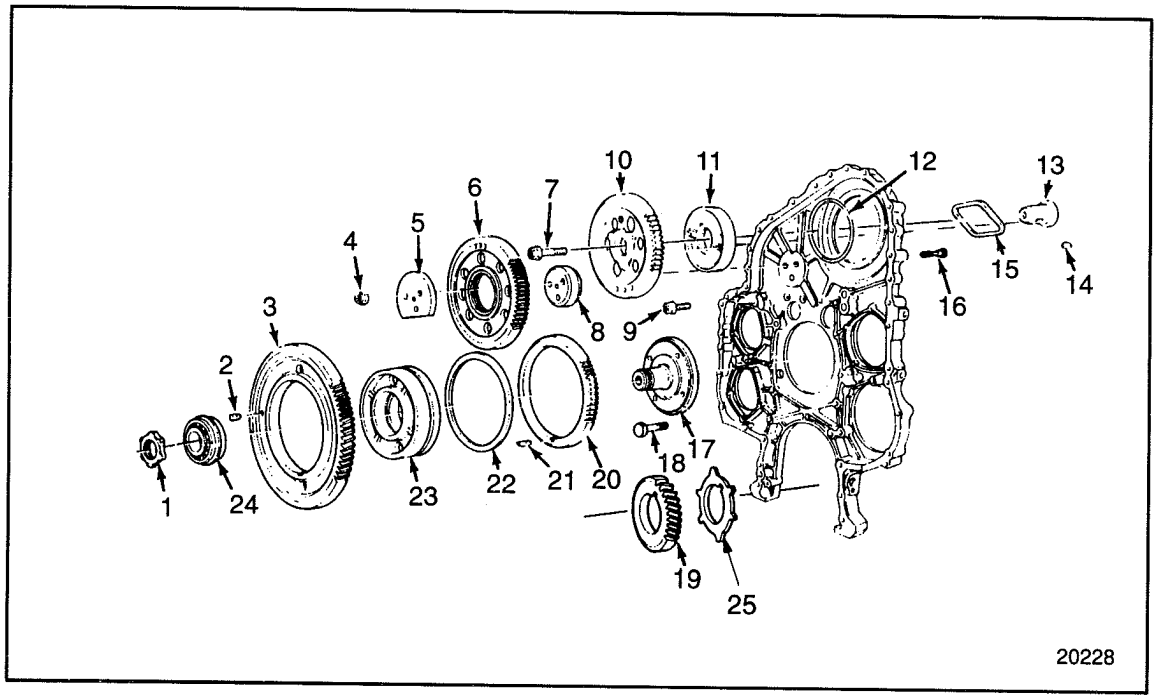


FIGURE 1–245 Engine Gear Train

The crankshaft timing gear, pressed onto the front end of the crankshaft, directly drives the bull gear and oil pump drive gear, and indirectly (through the bull gear), drives the fuel pump drive gear, air compressor and power steering pump drive gear, accessory pulley drive gear and water pump drive gear.

The camshaft idler gear is mounted to the rear of the bull gear on the same carrier, and rotates along with the bull gear at the same speed. This camshaft idler gear drives the adjustable idler gear, which in turn, drives the camshaft drive gear. See Figure 1–246.



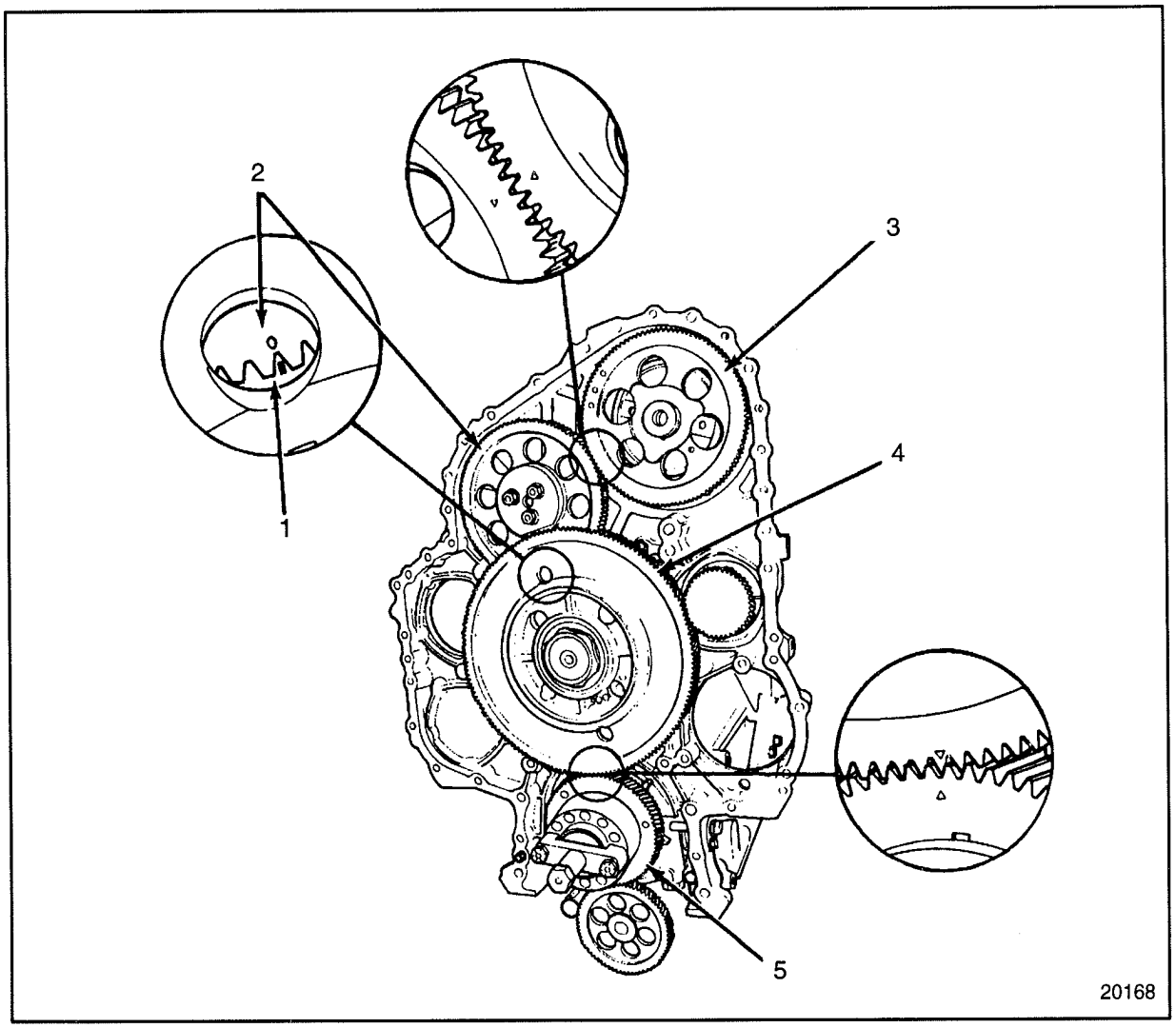
1. Bull Gear Retaining Nut
2. Timing Pin
3. Bull Gear
4. Adjustable Idler Gear Retaining (3) Locknut
5. Adjustable Idler Gear Plate
6. Adjustable Idler Gear
7. Camshaft Retaining Bolt
8. Adjustable Idler Gear Hub
9. Thrust Plate Retaining (2) Bolt
10. Camshaft Drive Gear
11. Camshaft Thrust Plate
12. Camshaft Thrust Plate Seal O–Ring
13. Camshaft Drive Gear Hub
14. Camshaft Drive Gear Hub Key
15. Camshaft Thrust Plate Seal
16. Adjustable Idler Gear Hub Retaining Stud
17. Bull Gear/Idler Gear Hub
18. Bull Gear Hub Retaining (4) Bolt
19. Crankshaft Timing Gear
20. Camshaft Idler Gear
21. Bull Gear/Idler Gear Key
22. Spacer
23. Bull Gear/Idler Gear Carrier
24. Bull Gear/Idler Gear Bearings
25. Crankshaft Timing Rings

FIGURE 1–246 Gear Train and Related Parts

The bull gear and camshaft idler gear are a press–fit to the bull gear and camshaft idler gear carrier. Both gears are keyed to the carrier by the same key. The carrier is supported by two tapered roller bearings, which ride on a hub bolted to the engine block by four bolts. The bull gear and camshaft idler gear assembly is retained to the hub by a **left–hand threaded nut**.

The camshaft idler gear drives the camshaft drive gear through an adjustable idler gear. The adjustable idler gear is supported by a bushing and is mounted on an adjustable hub secured by three studs pressed into the gear case from the rear.

The camshaft must be in time with the crankshaft timing gear. Since there are three gears between them, timing marks have been stamped or etched on the face of the gears to facilitate correct gear train timing. See Figure 1–247.



1. Camshaft Idler Gear
2. Adjustable Idler Gear
3. Camshaft Drive Gear
4. Bull Gear
5. Crankshaft Timing Gear

FIGURE 1–247 Engine Gear Train and Timing Marks

The symbol system of marking the gears makes gear train timing a comparatively easy operation. When assembling the engine, work from the crankshaft timing gear to the camshaft drive gear and line up the appropriate symbols on the gears as each gear assembly is installed on the engine.

There are no timing marks on the drive gears for the fuel pump, air compressor and power steering pump, water pump or accessory drive pulley. Therefore, it is not necessary to align these gears in any particular position during their installation.

The gear train is lubricated by oil splash. The bull gear and camshaft idler gear are pressure–fed lubricating oil through two holes in the bull gear recess area of the engine block. See Figure 1–248.

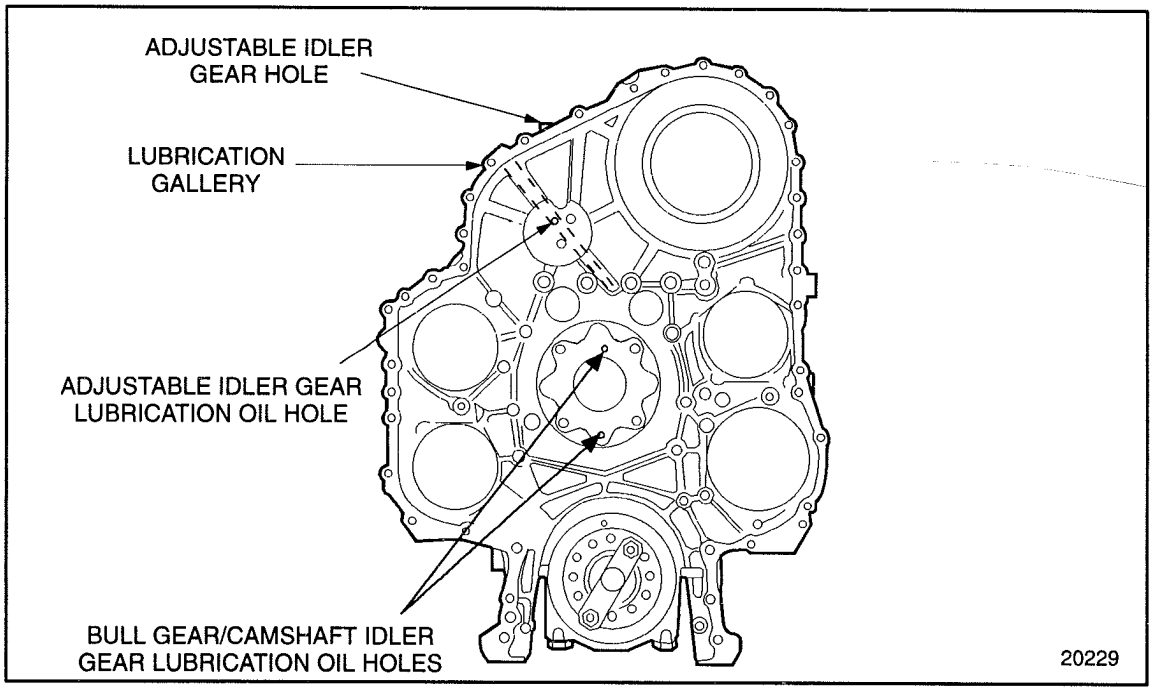


FIGURE 1–248 Gear Train Lubricating Oil Hole Locations

These two holes are connected to the main oil gallery. The adjustable idler gear assembly is pressure-fed by an oil gallery in the gear case that indexes with a hole in the engine block. The hole in the engine block is connected to the main oil gallery.

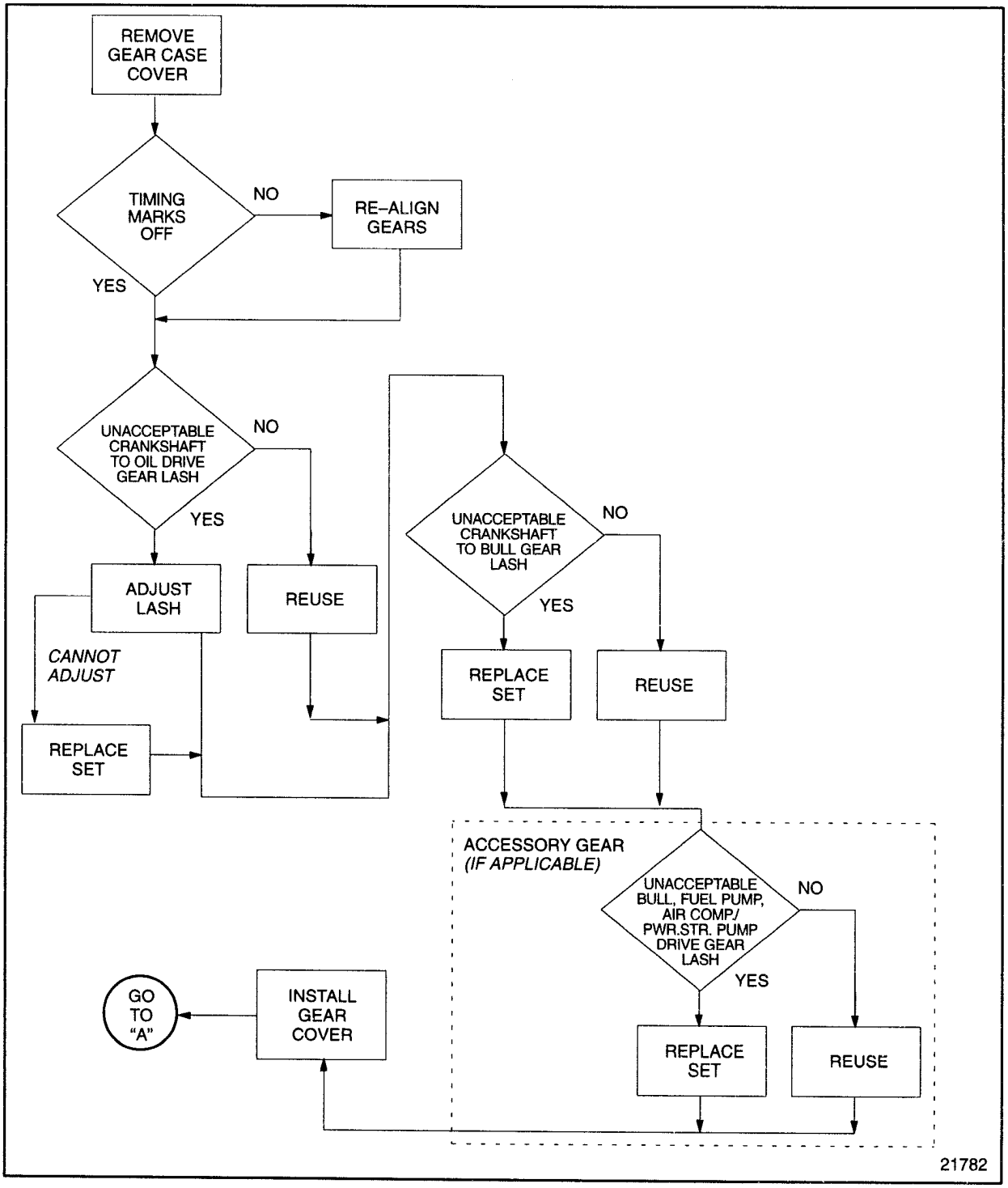
The correct relationship between the crankshaft and the camshaft must be maintained to properly control the opening and closing of the intake and exhaust valves, and the operation of the fuel injectors and to help maintain engine balance.

The crankshaft and camshaft gears can only be mounted in one position as they are both keyed to their mating parts. Therefore, when the engine is properly timed, the timing marks on the various gears will match. See Figure 1–247.

An "out of time" engine may result in valve-to-piston dome contact, a no-start condition or loss of power.

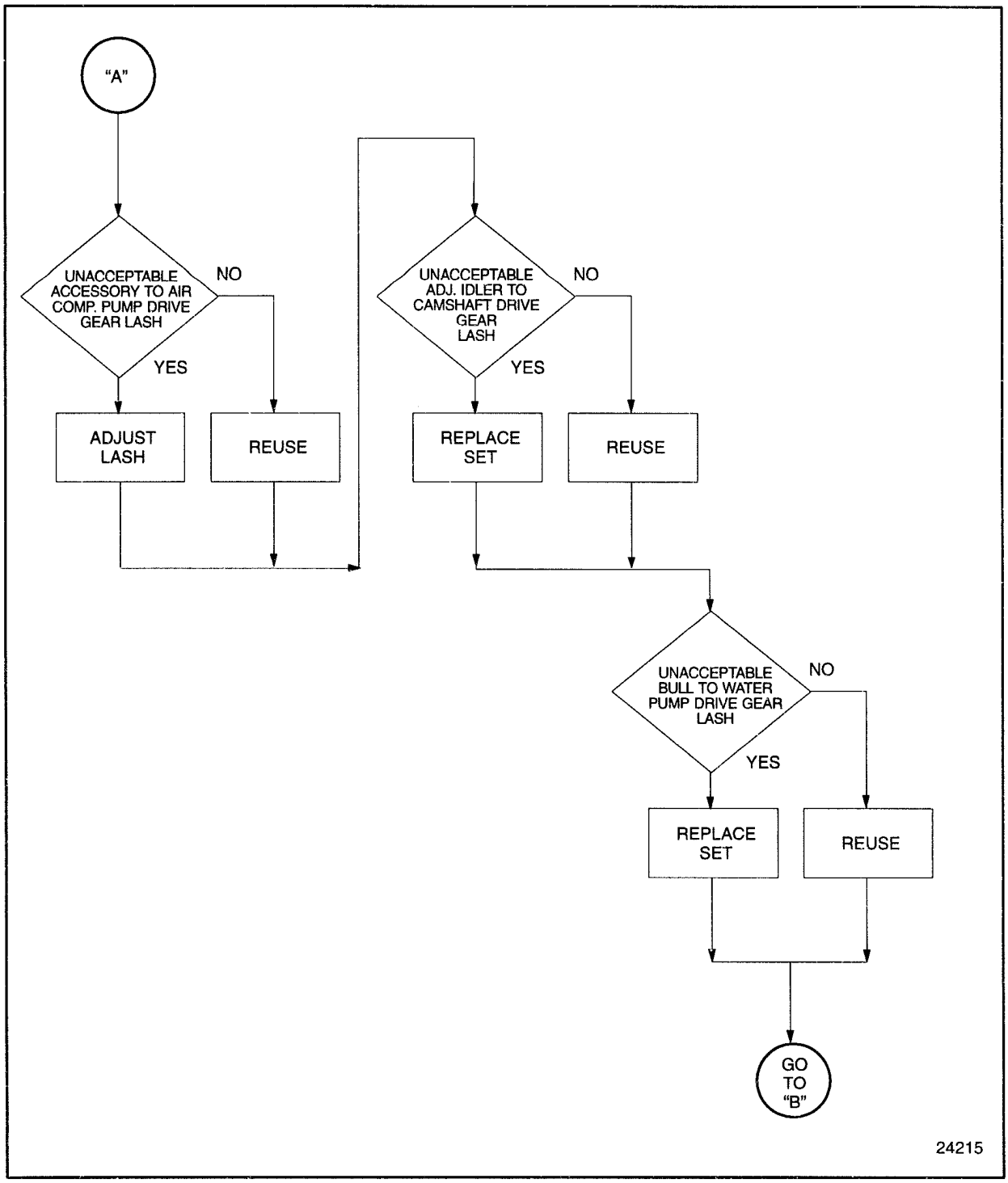
1.21.1 Repair or Replacement of Gear Train and Engine Timing

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-249.



To go to "A", see Figure 1-250.

FIGURE 1-249 Flowchart for Repair or Replacement of Gear Train and Engine Timing – Part 1 of 3



To go to "B", see Figure 1-251.

FIGURE 1–250 Flowchart for Repair or Replacement of Gear Train and Engine Timing – Part 2 of 3

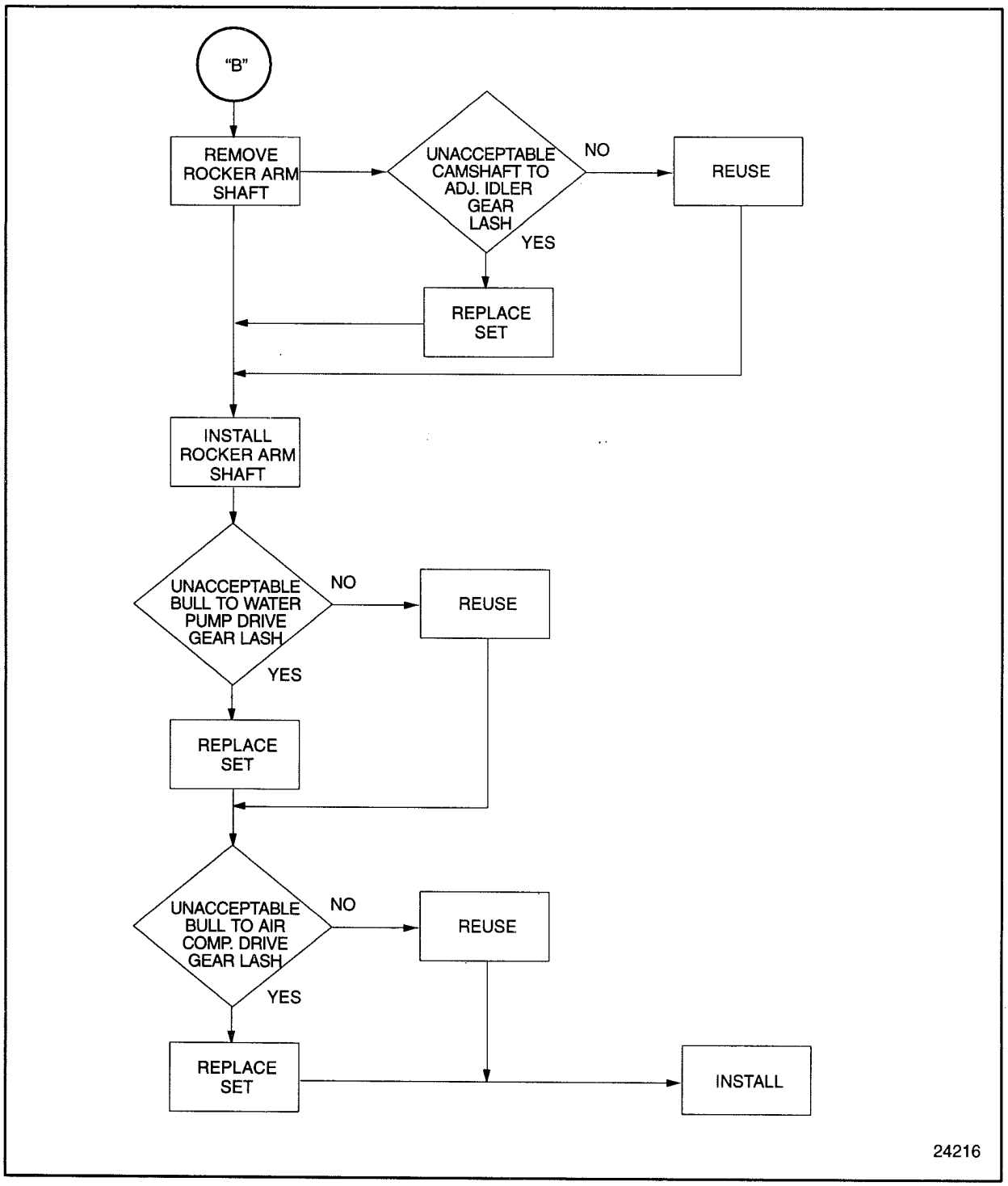


FIGURE 1–251 Flowchart for Repair or Replacement of Gear Train and Engine Timing – Part 3 of 3

1.21.2 Cleaning and Removal of Gear Train and Engine Timing

When an engine is out of time, the camshaft timing can be checked by following the camshaft timing check procedure. Refer to section 1.22.6.1. If the engine is out of time, a visual inspection of the gear train is required.

Refer to section 1.10.2 and perform all of the steps under "Engine Gear Case Cover Removal".

NOTE:
The oil pan cannot be used to support the engine. It can not support the weight. Lifter bracket, J 35641, can be installed between cylinders one and two to provide support. Do NOT use the bracket to lift or remove the engine from the vehicle.

Clean the gear train and engine timing components prior to inspection as follows:

1. Clean the old gasket material from the mating surfaces of the gear case and gear case cover. The proper gasket eliminator removal procedure is printed in section 0 of this manual.
2. Remove the front crankshaft oil seal, if necessary.

1.21.2.1 Check Engine Timing

Gear train noise is usually an indication of excessive gear lash, chipped, pitted or burred gear teeth, or excessive bearing wear. Therefore, when noise develops in a gear train, the gear case cover should be removed and the gear train and its bearings inspected. A rattling noise usually indicates excessive gear lash. A whining noise indicates too little gear lash.

1. Check engine timing as follows:
   [a] Examine all timing marks to ensure they are aligned. See Figure 1-247.

NOTE:
The gear ratio between the adjustable idler gear and the camshaft drive gear causes a "hunting-tooth" situation. Therefore, the bull gear and rocker arm assemblies should be removed to align the timing marks. See Figure 1-247.

   [b] It may be necessary to remove the gears to align the timing marks. Refer to section 1.25.2.
   [c] If any gears are removed or installed, or if lash between any two gears is out of specification, check the lash between the mating gears.
2. Check the crankshaft timing gear-to-oil pump idler gear lash measurement as follows:
   [a] Fasten a dial indicator and magnetic base to the cylinder block so that the stem of the dial indicator rests on a tooth of the oil pump drive gear. See Figure 1-252.

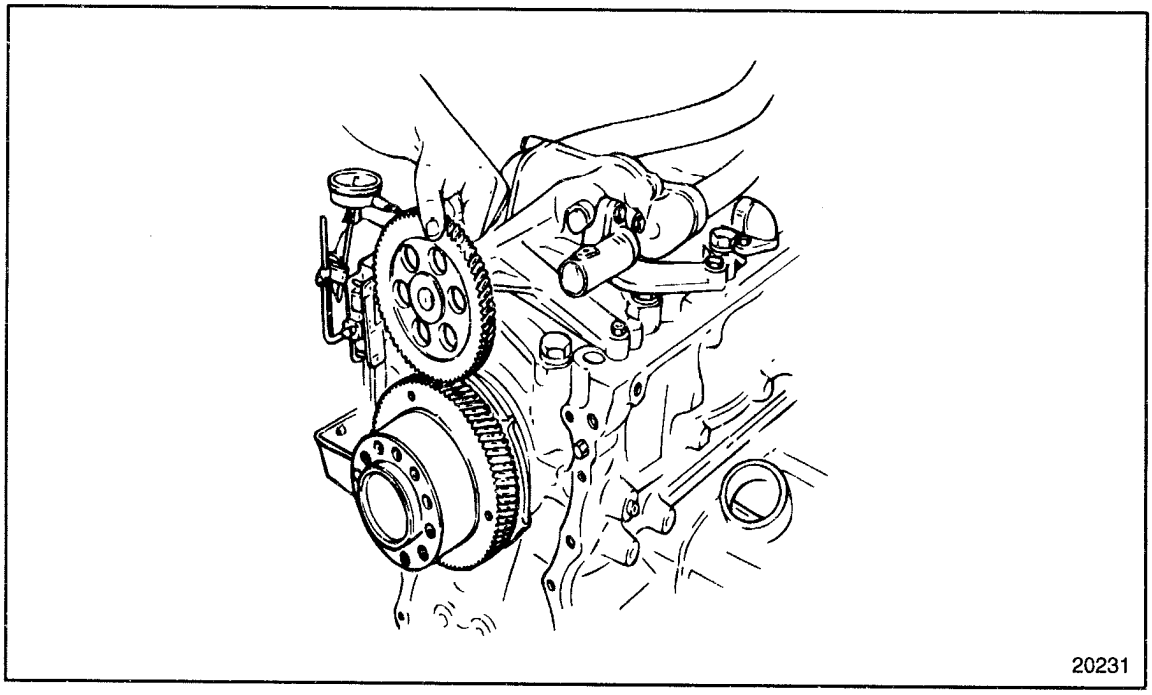


FIGURE 1–252 Crankshaft Timing Gear–to–Oil Drive Gear Lash Measurement

NOTE:
The oil pump design changed effective with 1991 model year engines. However, the oil pump gear lash measurement procedure is the same for both style pumps.

[b] Hold the crankshaft timing gear stationary, and rotate the oil pump drive gear in one direction, as far as it will go, without moving the crankshaft timing gear.

[c] Zero the dial indicator.

[d] Move the oil pump drive gear in the opposite direction, as far as it will go, without moving the crankshaft timing gear.

[e] Read and record the total gear lash.

NOTE:
The gear lash must be checked in four positions 90° apart.

NOTE:
The lash between the crankshaft timing gear and oil pump drive gear must be measured with the engine in a running position. See Figure 1–252.

Proper lash between the crankshaft timing gear and oil pump drive gear is 0.051–0.229 mm (.002–.009 in.).

The gear lash between the crankshaft timing gear and the oil pump drive gear can be adjusted utilizing shims inserted between the oil pump body and the cylinder block. See Figure 1–253.

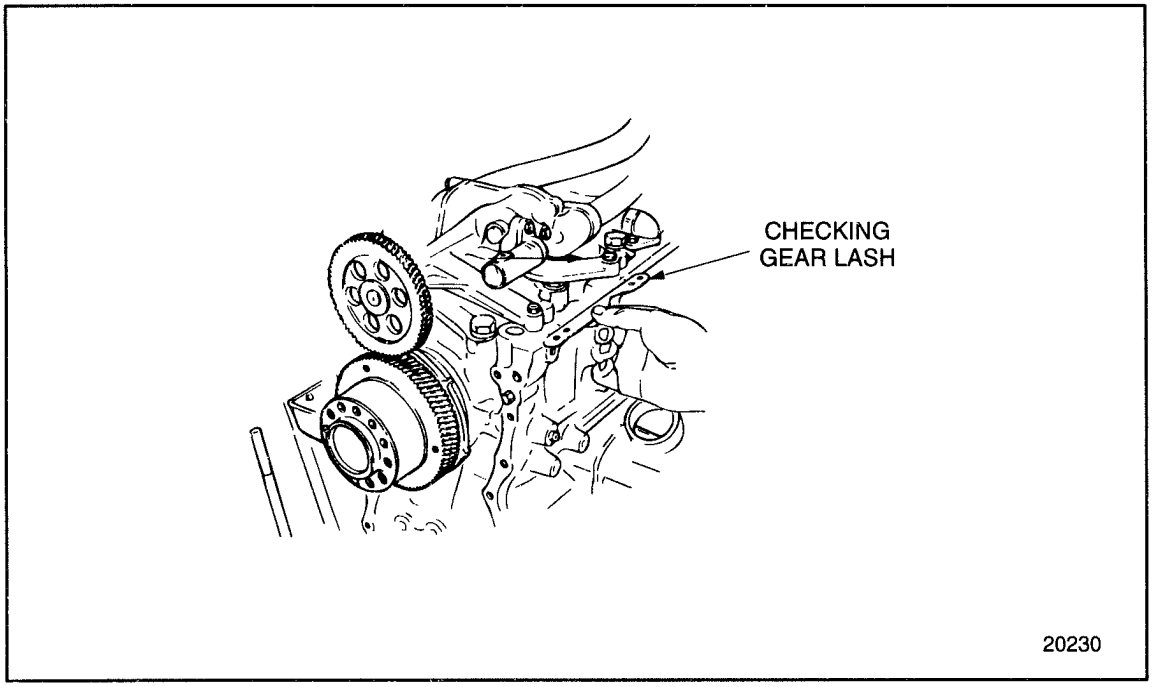


FIGURE 1–253 Lubricating Oil Pump Shim Installation

[a] Remove or install shims as necessary to obtain the proper gear lash clearance.

NOTE:
When adjusting for gear tooth lash by installing or removing shims, the same number of shims must be changed under each foot so that the pump will always be level on the engine block. The insertion or removal of one 0.127 mm (.005 in.) shim will change the gear tooth lash by approximately 0.098 mm (.004 in.).

NOTE:
If it is necessary to remove the oil pump, refer to section 3.2.2.

[b] If the use of shims cannot bring gear lash within acceptable limits, the gear or gears for that gear set must be replaced.

3. Check the crankshaft timing gear–to–bull gear lash measurement as follows:

[a] Install a dial indicator and magnetic base. See Figure 1–254.

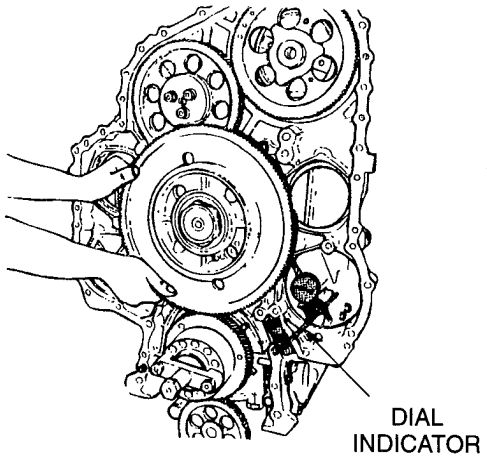


FIGURE 1–254 Crankshaft Timing Gear–to–Bull Gear Lash Measurement

[b] Adjust the stem of the dial indicator to rest on the center of a tooth on the bull gear.

[c] Preload the bull gear.

[d] Zero the dial indicator pointer.

[e] Hold the crankshaft timing gear stationary with one hand. Rotate the bull gear and check the total gear lash in four positions of crank gear, approximately 90° apart.

[f] Although gear lash for the remaining gear sets is not adjustable, the lash must still be measured. Lash specifications is 0.051–1.229 mm (.002–.009 in.) for new parts and a maximum of 0.305 mm (.012 in.) for used parts.

[g] If lash measurement is exceeded, replace gear with a new part.

4. The procedure for measuring the lash between the bull gear and the fuel pump drive gear (if applicable) and the air compressor and power steering pump drive gear is similar to the steps just mentioned. Refer to step 3., as the first step and refer to step 8., as the final step.

Gear case cover must be installed to continue on checking the engine timing. Refer to section 1.10.3 and perform all of the steps under gear case cover installation.

NOTE:
Due to the possibility of damaging the crankshaft front oil seal, whenever the gear case cover is removed, the front crankshaft oil seal must be replaced. Replace the crankshaft front oil seal after the gear case cover is installed. Refer to section 1.8.2.

5. The procedure for measuring the lash between the accessory drive gear and air compressor pump drive gear (on vehicle without power steering) is similar to the steps just mentioned. Refer to step 3., as the first step and refer to step 8., as the final step.

NOTE:
Lash can be measured with the gear case cover installed. Access covers are provided for checking the lash between these gears and the bull gear. For engines with no access cover for accessory drive gear lash is to be measured off the accessory drive pulley.

6. The procedure for measuring the lash between the adjustable idler gear and camshaft drive gear is similar to the steps just mentioned. Refer to step 3., as the first step and refer to step 8., as the final step.

NOTE:
These gears are measured and adjusted with the gear case cover installed.

7. The procedure for measuring the lash between the bull gear and the water pump drive gear is similar to the steps just mentioned. Refer to step 3., as the first step and refer to step 8., as the final step.

NOTE:
These gears can be measured with the pump installed.

Refer to section 1.3.2 and perform all of the steps under "Rocker Arm Shaft Removal," in order to continue checking the engine timing.

8. When measuring or adjusting the gear lash between the adjustable idler gear and the camshaft drive gear, the valve and injector spring pressures must be removed from the camshaft lobes. Use the following procedure for this adjustment:

NOTE:
The front and rear rocker shafts look identical, but must not be interchanged due to different oil passage patterns. The outboard ends of the rocker arm shafts are marked for identification with the DDC logo. See Figure 1–255. Use care to ensure that the rocker arm shaft assemblies are replaced exactly as removed.

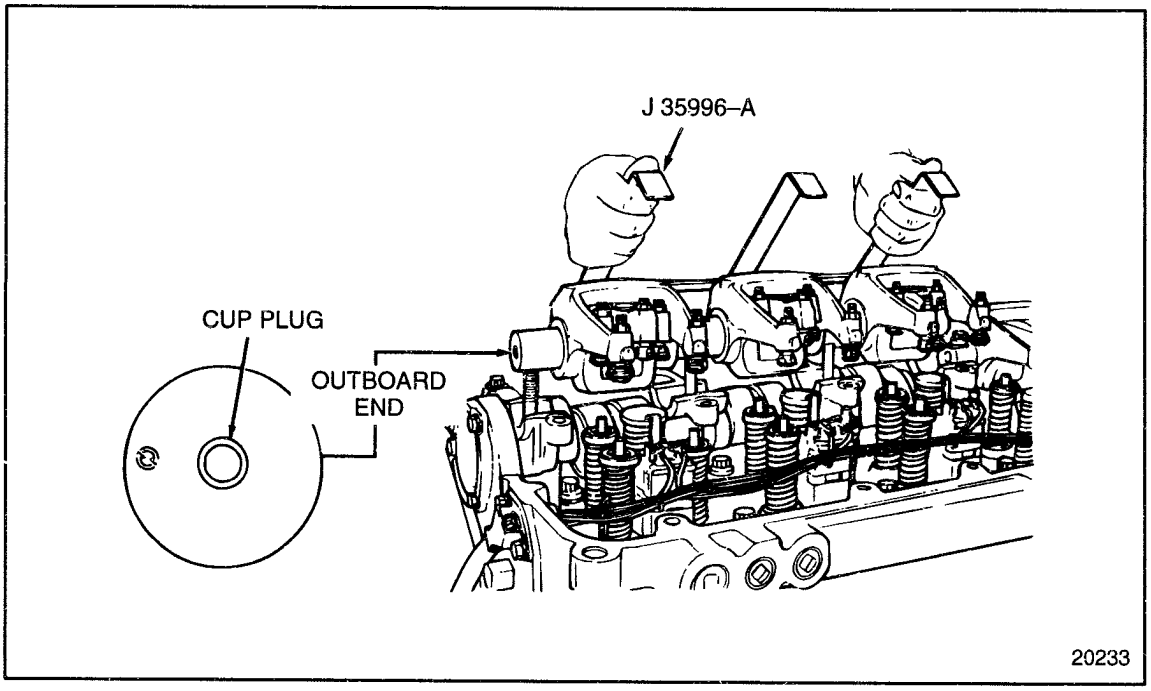
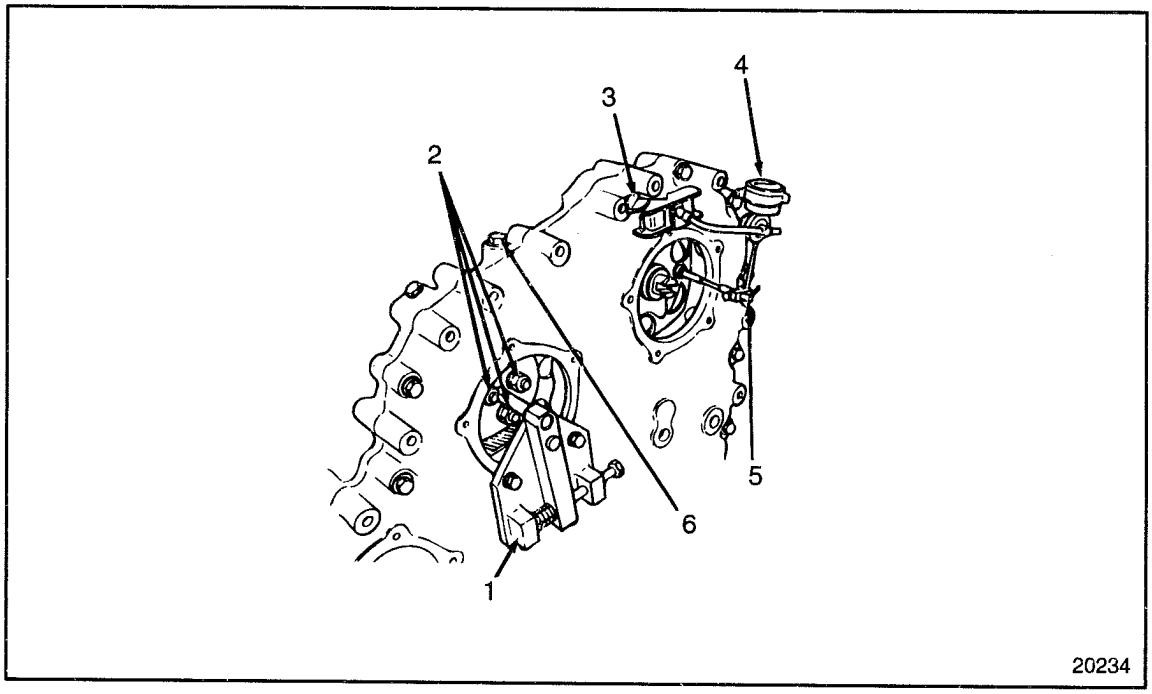


FIGURE 1–255 Rocker Arm Shaft Identification Mark

[a] Install the gear lash pedestal, J 35596–15, into the threaded hole of the camshaft drive gear. Bar the engine over until the tool is at the three o'clock position. See Figure 1–256.



1. Gear Lash Adjustment Tool
2. Adjustable Idler Gear Retaining Nut
3. Magnetic Base
4. Dial Indicator
5. Pedestal Idler Gear Hole
6. Adjustable Idler Gear Retaining Nut

FIGURE 1–256 Camshaft Drive Gear–to–Adjustable Idler Gear Lash Measurement

NOTE:
Since the teeth of the camshaft drive gear are not accessible with the gear case cover installed, the lash is measured on the pedestal installed in the threaded hole, which is located exactly half–way between the center and edge of the camshaft drive gear. For this reason, the reading obtained will be exactly 1/2 of the actual gear lash.

[b] Mount a dial indicator adaptor and dial indicator. See Figure 1–256.

[c] Adjust the stem of the dial indicator to rest on the flat of the pedestal.

[d] If the adjustable idler gear has been removed, torque the three flanged nuts that retain the adjustable idler gear hub to the gear case to 57–67 N·m (42–49 lb·ft) to seat the assembly before proceeding.

[e] Loosen the three locknuts that retain the adjustable idler gear hub to the gear case until they are hand tight.

[f] Insert the dowel portion of the gear lash adjusting tool, J 35596, through the hole in the adjustable idler gear retaining plate and into the adjustable idler gear hub, using the bottom two adjustable idler gear cover bolt holes. See Figure 1–256.

[g] Turn the adjusting screw of the tool in a clockwise direction to force the adjustable idler gear against the camshaft drive gear, until there is zero lash between the two gears. See Figure 1–257.

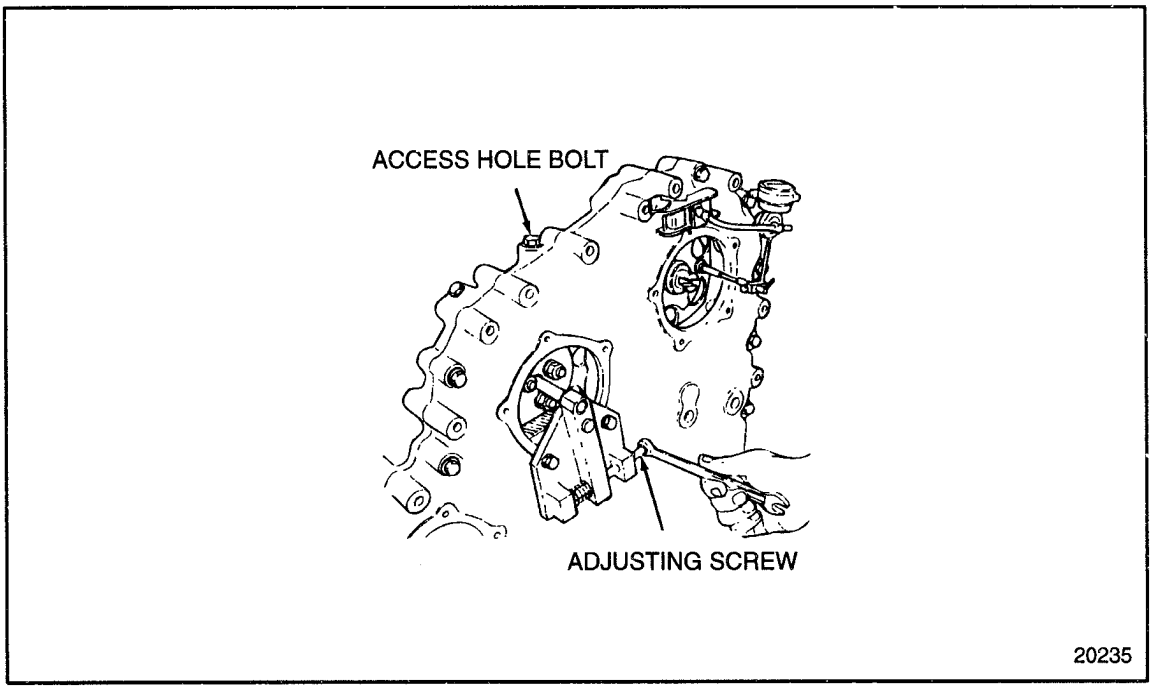


FIGURE 1–257 Adjustable Idler Gear–to–Camshaft Drive Gear Lash Adjustment

[h] Zero the dial indicator.

[i] Hold the adjustable idler gear by inserting a screwdriver through the hole provided in the gear case. Engage one of the adjustable idler gear teeth and apply pressure on the screwdriver to move the gear in a counterclockwise direction. This will prevent the gear from moving.

[j] Attempt to turn the camshaft drive gear, and watch the dial indicator pointer.

NOTE:
If there is zero lash between the two gears, the dial indicator pointer will not move from zero.

[k] Turn the adjusting screw of the tool approximately 1-1/2 turns or until the proper gear lash is obtained.

[l] When checking gear lash, hold the adjustable idler gear stationary. Refer to step [h] as the first step and refer to step [i] as the final step, and rotate the camshaft drive gear with your right hand. See Figure 1-258.

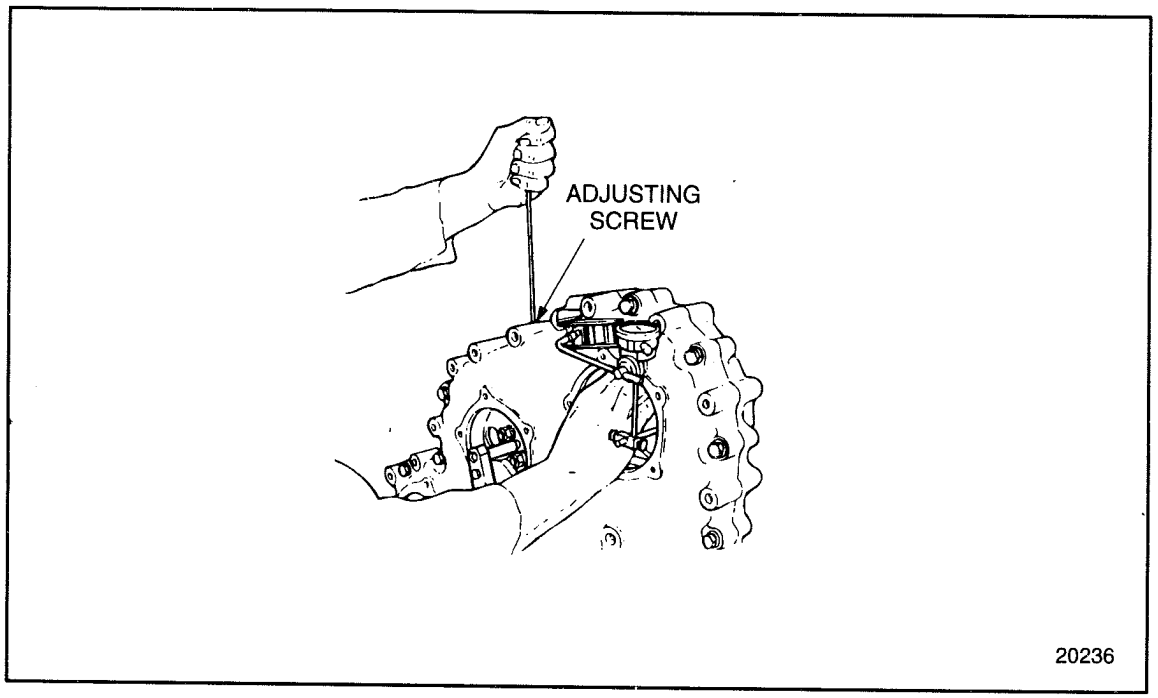


FIGURE 1-258 Checking Adjustable Idler Gear-to-Camshaft Drive Gear Lash

NOTE:
Remember to multiply the reading obtained by two to get the actual lash measurement. The specification of gear lash is 0.051–0.229 mm (.002–.009 in.) with a maximum of 0.305 mm (.012 in.) for used parts.

[m] Check the gear lash with the pedestal at the 3,6,9 and 12 o'clock positions, exactly as previously performed.

[n] When the proper readings of 0.025–0.114 mm (.001–.0045 in.) are obtained at all four (4) positions, hold the idler gear.. Refer to step [i] as the first step and refer to step [j] as the final step, and tighten the top two adjustable idler gear flanged nuts to 57–67 N·m (42–49 lb·ft) torque.

[o] Check the gear lash again as outlined above, with the flanged nuts torqued, to ensure that gear lash is still within limits.

[p] If proper lash measurement cannot be obtained, replace gear(s) with new part(s). Refer to section 1.25.2.

[q] Remove the gear lash adjusting tool from the gear case.

[r] Torque the bottom adjustable idler gear flanged nut to 57–67 N·m (42–49 lb·ft) torque.

[s] Remove the dial indicator and pedestal from the gear case.

[t] Before installing the rocker arm shaft assemblies, check the torque on the end studs to ensure they were not loosened at time of removal. The torque specification is 101–116 N·m (75–86 lb·ft).

[u] Install the front and rear rocker arm shaft assemblies to the cylinder head. Install the six rocker arm shaft thru-bolts and two nuts, finger tight.

[v] Install the rocker arms and tighten the rocker arm shaft's thru-bolts and nuts to 101–116 N·m (75–86 lb·ft) using the sequence. See Figure 1–259.

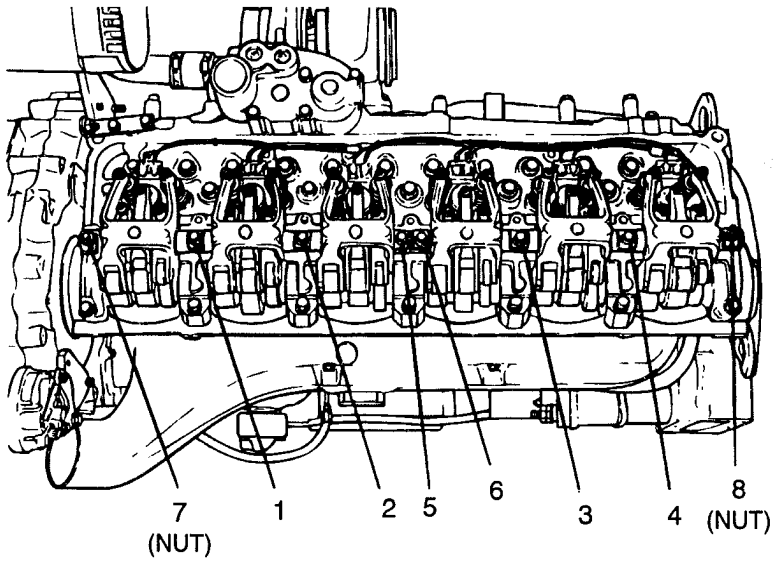


FIGURE 1–259 Rocker Arm Shaft Bolt and Nut Torque Sequence

[w] Refer to section 12.2 and adjust the intake and exhaust valve clearances, and fuel injector heights.

[x] Install the valve rocker cover. Refer to section 1.6.6.

[y] Insert a new gasket between the camshaft drive gear access cover and the gear case cover. Install the camshaft drive gear access cover to the gear case cover. Tighten the bolts to 30–38 N·m (22–28 lb·ft) torque using the tightening sequence. See Figure 1–260.

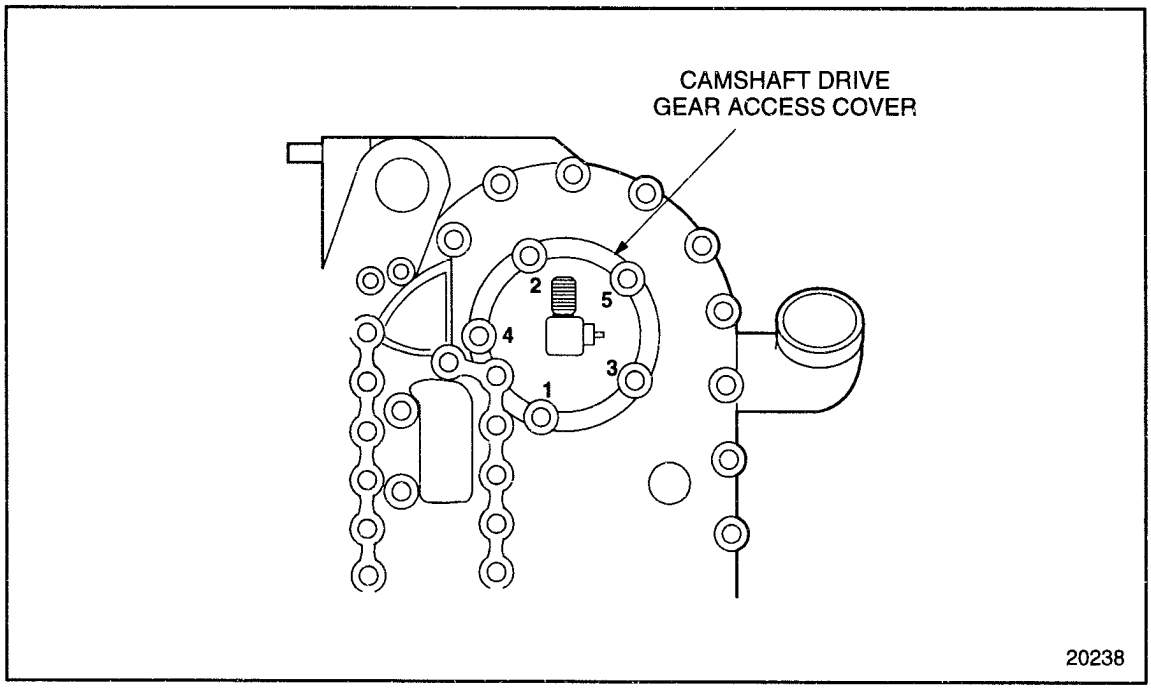


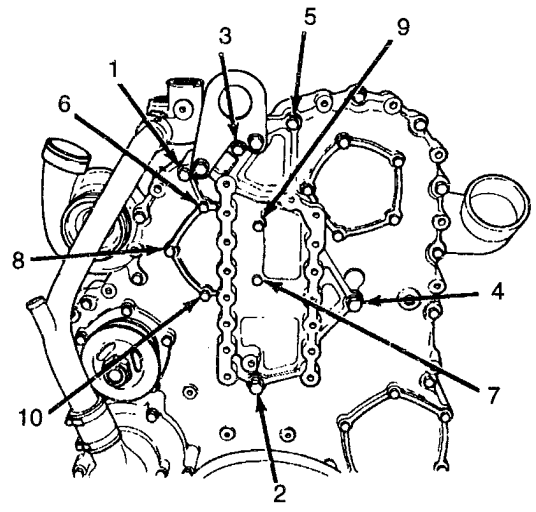
FIGURE 1–260 Camshaft Drive Gear Access Cover Bolt Torque Sequence

[z] Install the fan support bracket if required as follows:

Clean the mating surfaces of the fan support bracket and gear case of all old gasket eliminator. Gasket eliminator removal information may be found in the section 0 of this manual.

Apply a 1/16 in. bead of Gasket Eliminator PT–7276 (Loctite 51580), or equivalent, to the machined surface of the gear case cover surrounding the adjustable idler gear access.

Install the fan support bracket to the gear case cover using the torque values and tightening sequence. See Figure 1–261.



BOLT	TORQUE
1–3–5	58–73 N·m(43–45 lb·ft)
2–4	160–200 N·m(118–148 lb·ft)
6 through 10	33–38 N·m(22–28 lb·ft)

FIGURE 1–261 Fan Support Bracket Bolt Torque Sequence

9. Check the bull gear–to–accessory drive gear lash measurement as follows:

[a] Mount a magnetic dial indicator base and dial indicator to the gear case cover. See Figure 1–262.

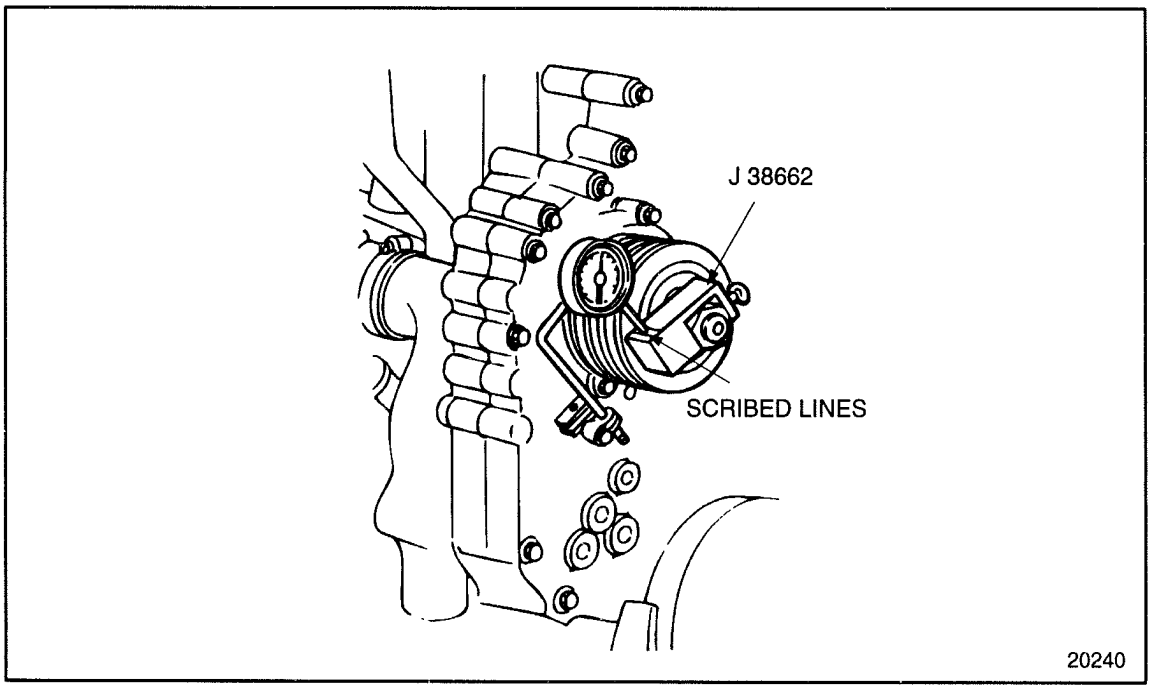


FIGURE 1–262 Accessory Drive Gear–to–Bull Gear Lash Measurement

[b] Install the gear lash tool J 38662. See Figure 1–262.

[c] Position the dial indicator to read between the scribed lines on the tool. See Figure 1–262.

[d] Rotate the accessory drive pulley, read and record the total gear lash.

[e] Lash should be 0.051–0.229 mm (.002–.009 in.) for new parts, with a maximum of 0.305 mm (.012 in.) for used parts.

[f] If proper lash measurement cannot be obtained, replace gear with a new part.

[g] Remove the dial indicator and gear lash tool.

10. Check the bull gear–to–water pump drive gear lash measurement for 1991 and later engines (with water pump impeller slip tester, J 35687) as follows:

NOTE:
The bull gear–to–water pump drive gear lash can be measured using the water pump impeller slip tester, J 35687, refer to step [j], or by using the water pump gear lash tool, J 38977, refer to step [k]. Early built 1991 engines will need the water pump gear lash checked with the slip tester. These engines do not have a threaded hole in the water pump drive gear retaining bolt to accept the gear lash tool. For pre–1991 engines, refer to step [l].

CAUTION:

Due to the size and tension of the ring, use snap ring pliers of a type to ensure maximum safety whenever removing or installing the water pump cover snap ring. Wear adequate eye protection, and press a hammer against the pump cover to help prevent personal injury, should the snap ring slip off the pliers.

[a] Remove the water pump cover snap ring with snap ring pliers. Remove water pump cover and seal ring.

[b] Install the water pump impeller slip tester, J 35687, to the water pump impeller with two 5/16–18 bolts, using the instructions supplied with the tool. See Figure 1–263.

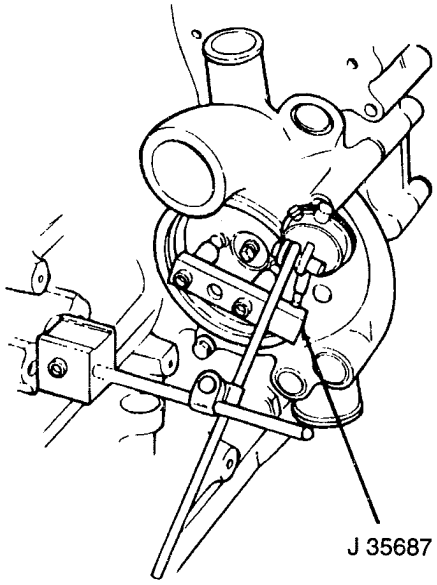


FIGURE 1–263 Water Pump Impeller Slip Tester Method

[c] One leg (the long one) of the tool has an inscribed line. Measuring with a dial indicator at this line of the tool, the gear lash measurement will be an exact 1:1 reading. Lash should be 0.051–0.229 mm (.002–.009 in.).

[d] If proper lash cannot be obtained, replace gear with a new part.

[e] Remove the dial indicator.

[f] Remove the tool from the water pump.

[g] Inspect the water pump cover seal for cracks or splitting. If any damage is detected, refer to section 4.2.3.1 or refer to section 4.3.3.1 for front mounted water pump.

[h] Install a new seal, if necessary, between the water pump cover and the water pump housing.

[i] Using snap ring pliers, install the water pump snap ring in groove of water pump body.

[j] Tap around the inside rim of snap ring with a brass drift, and hammer to seat snap ring in groove fully.

11. Check the bull gear-to-water pump drive gear lash measurement for 1991 and later engines (with water pump gear lash tool, J 38977) as follows:

[a] Remove the pipe plug in the gear case cover.

[b] Install the water pump gear lash tool, J 38977, through the hole in the gear case and thread it into the special water pump drive gear retaining bolt. See Figure 1-264.

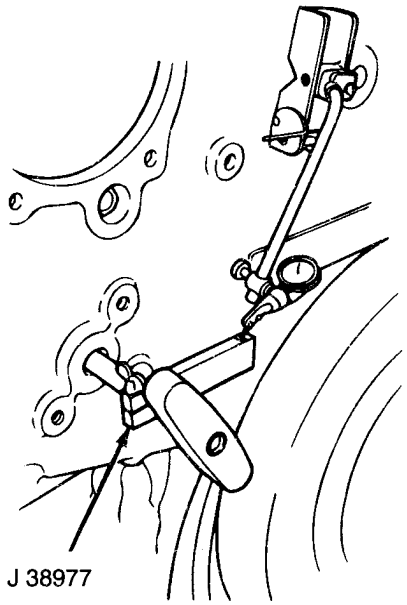


FIGURE 1-264 Water Pump Gear Lash Tool Method

[c] The arm of this tool has an inscribed line. Measuring with a dial indicator at this line of the tool, the gear lash measurement will be an exact 1:1 reading. Lash should be 0.051-0.229 mm (.002-.009 in.).

[d] If proper lash cannot be obtained, replace the gear with a new part.

[e] Remove the dial indicator and the gear lash tool.

[f] Install the pipe plug in the gear case cover. Torque to 24-31 N·m (18-23 lb·ft).

12. Check the bull gear-to-water pump drive gear lash measurement of pre-1991 engines (with the water pump impeller slip tester method) as follows. (Skip this step and the following step, if engine was built after 1990.):

NOTE:
The bull gear-to-water pump drive gear lash can be measured using the water pump impeller slip tester, J 35687, or by inserting a bolt into one of the tapped holes in the water pump impeller. The lash can then be measured using a dial indicator.

[a] Install the water pump impeller slip tester, J 35687, to the water pump impeller with two 5/16-18 bolts, using the instructions supplied with the tool. See Figure 1-265.

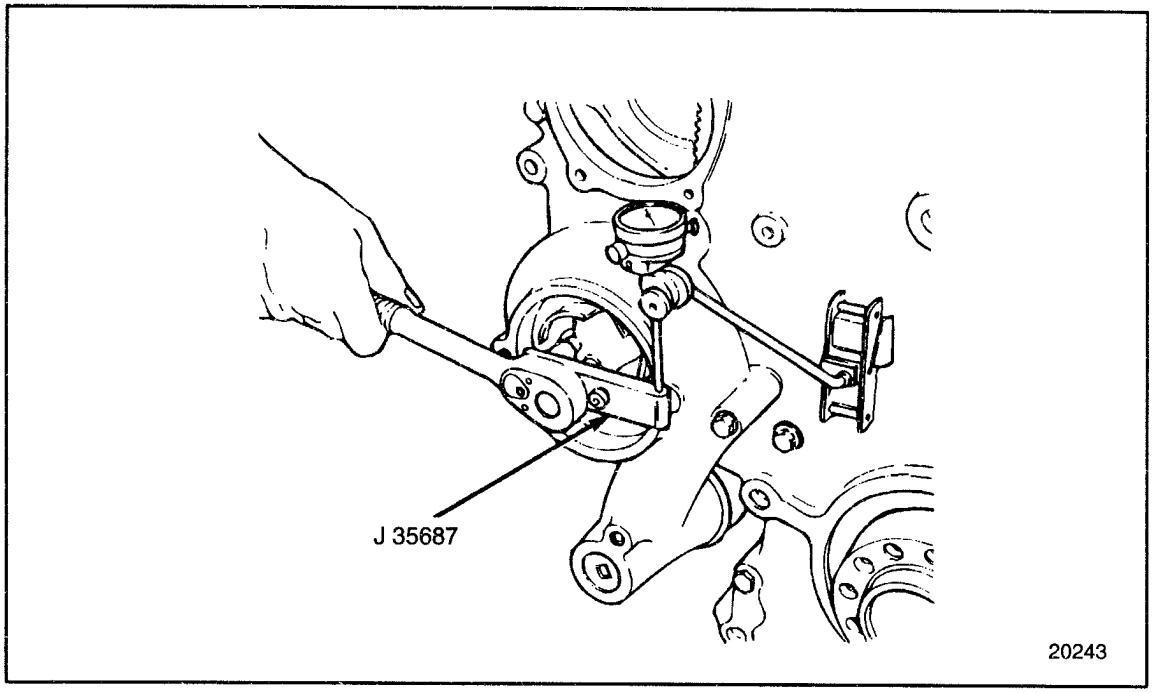


FIGURE 1-265 Water Pump Drive Gear Lash Measurement

[b] One leg (the long one) of the tool has an inscribed line. Measuring with a dial indicator at this line of the tool, the gear lash measurement will be an exact 1:1 reading. Lash should be 0.051-0.229 mm (.002-.009 in.).

[c] If proper lash measurement cannot be obtained, replace the gear with a new part.

13. Check the bull gear-to-water pump drive gear lash measurement for pre-1991 engines (with the bolt method) as follows:

[a] Install a 5/16-18 bolt and nut into one of the tapped holes in the water pump impeller. See Figure 1-266.

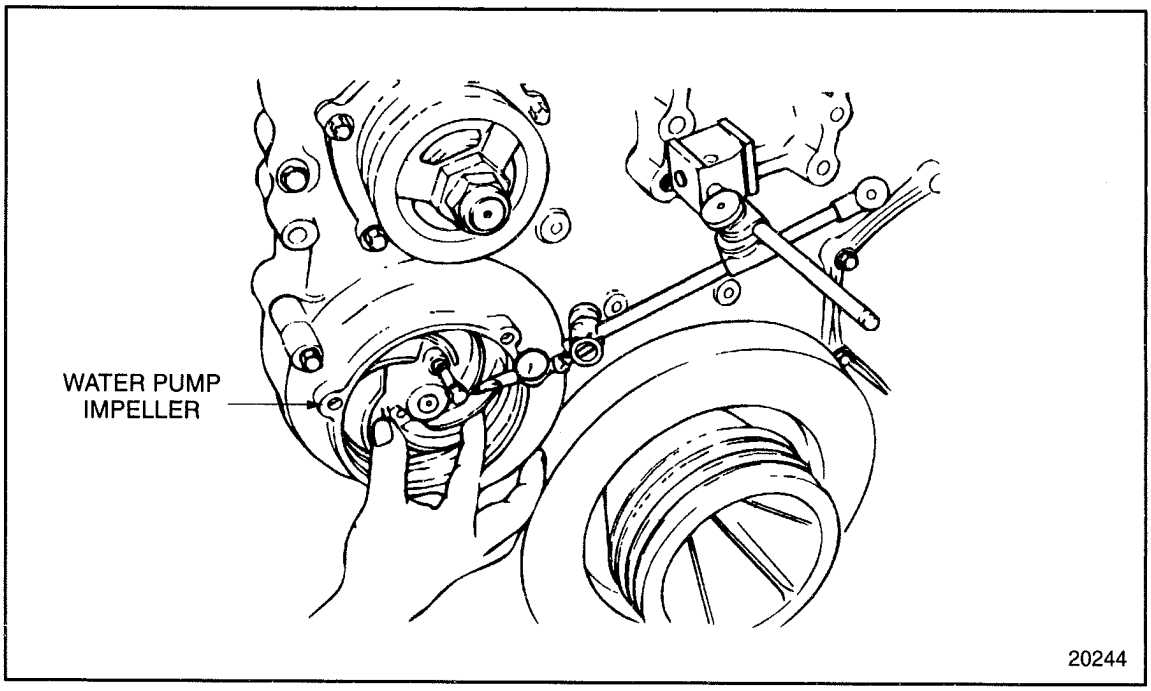


FIGURE 1–266 Water Pump Drive Gear–to–Bull Gear Lash Measurement

[b] Install a magnetic dial indicator base and dial indicator. See Figure 1–266.

[c] Position the stem of the dial indicator on a flat of the bolt.

[d] Preload the water pump impeller.

[e] Zero the dial indicator.

[f] Rotate the water pump impeller, read and record the total gear lash. Multiply this reading by 2.45 to obtain actual lash. Lash should be 0.051 to 0.229 mm (.002–.009 in.).

[g] If proper lash cannot be obtained, replace the gear with a new part.

[h] Remove the dial indicator base and dial indicator.

[i] Remove the bolt and nut from the water pump impeller (if used).

[j] Inspect the rubber seal ring on the water pump cover for splitting or cracks. Install a new seal, if necessary, between the water pump cover and the water pump housing.

[k] Install the two bolts that secure the water pump cover to the water pump housing. Tighten the bolts to 30–38 N·m (22–28 lb·ft).

14. Check the bull gear–to–air compressor drive gear lash measurement as follows:

[a] Mount a magnetic dial indicator base and dial indicator to the gear case cover so that the stem of the dial indicator may be positioned on a tooth of the air compressor drive gear.

[b] Preload the drive gear in one direction.

[c] Zero the dial indicator.

[d] Rotate the air compressor drive gear, read and record the total gear lash. Lash should be 0.051–0.229 mm (.002–.009 in.) for new parts, with a maximum of 0.305 mm (.012 in.) for used gears.

[e] If proper lash cannot be obtained, replace the gear with a new part.

[f] Remove the dial indicator and magnetic base.

[g] Install the power steering drive coupling to the air compressor drive gear (if equipped with power steering).

[h] Insert a new O–ring on the power steering pump (if so equipped).

[i] Install the power steering pump to the gear case cover, meshing the drive coupling properly

[j] Install and tighten the power steering pump mounting bolts to 30–38 N·m (22–28 lb·ft) torque. Tighten the five bolts alternately and evenly, in a star–shaped pattern, to progressively draw the power steering pump into the gear case cover

NOTE:
Do not force the bolts. If resistance is encountered, remove the power steering pump and re–engage the drive hub with the coupling.

[k] If the engine is not equipped with power steering, install the air compressor drive gear access cover using a new gasket.

[l] Install and tighten the retaining bolts to 30–38 N·m (22–28 lb·ft) torque, using a star–shaped pattern.

1.21.3 Installation of Gear Train and Engine Timing

After all of the gear lash measurements have been taken, assemble the engine components as follows:

1. Install the air conditioner compressor and brackets (if so equipped). Install the air conditioner drive belt.
2. Install the alternator and brackets. Refer to section 8.2.3. Install the alternator drive belts. Refer to section 8.2.3.1.
3. Install the fan and fan hub assembly. Refer to section 4.6.5.
4. Adjust the alternator, fan and air conditioner compressor drive belts to the specifications. Refer to section 13.5.8. Torque the accessory mounting bolts to specifications.
5. Install any other equipment such as hoses, brackets, lines or electrical looms that were removed to gain access to the engine gear case cover.
6. Install the engine oil pan and fill the engine crankcase. Refer to section 13.5.1.
7. Continue engine assembly.

1.22 CAMSHAFT AND CAMSHAFT BEARINGS

The Series 60 camshaft is located on top of the cylinder head, just below the valve cover. The camshaft actuates the intake and exhaust valves and injector operating mechanism. See Figure 1–267.

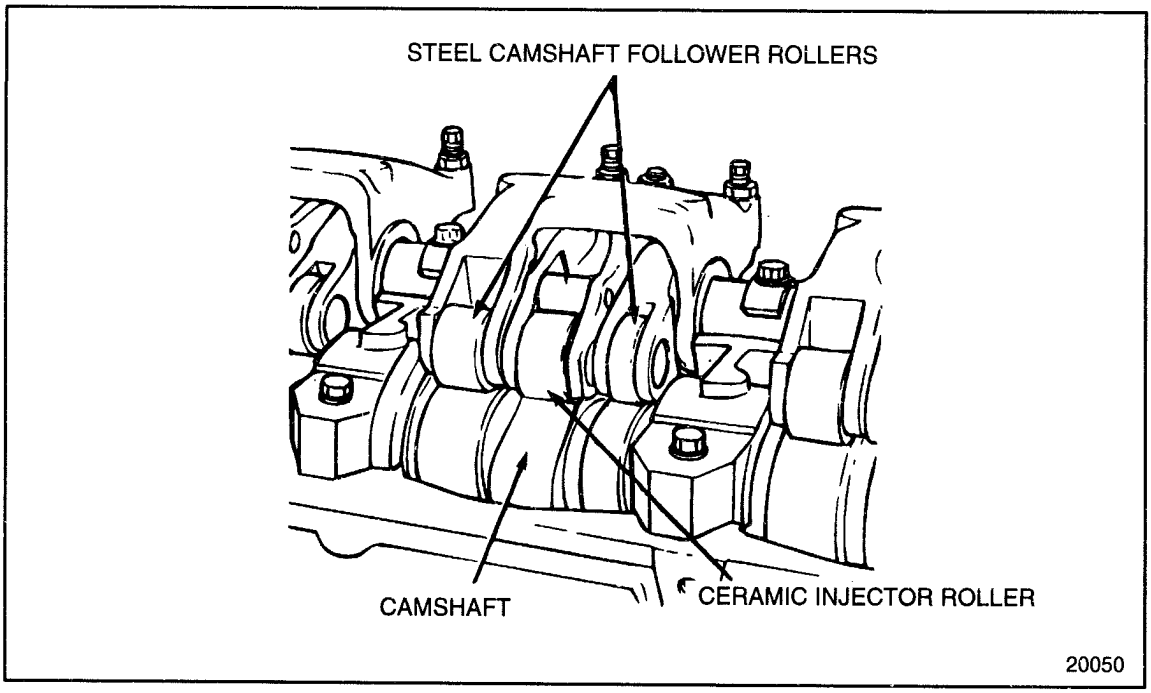
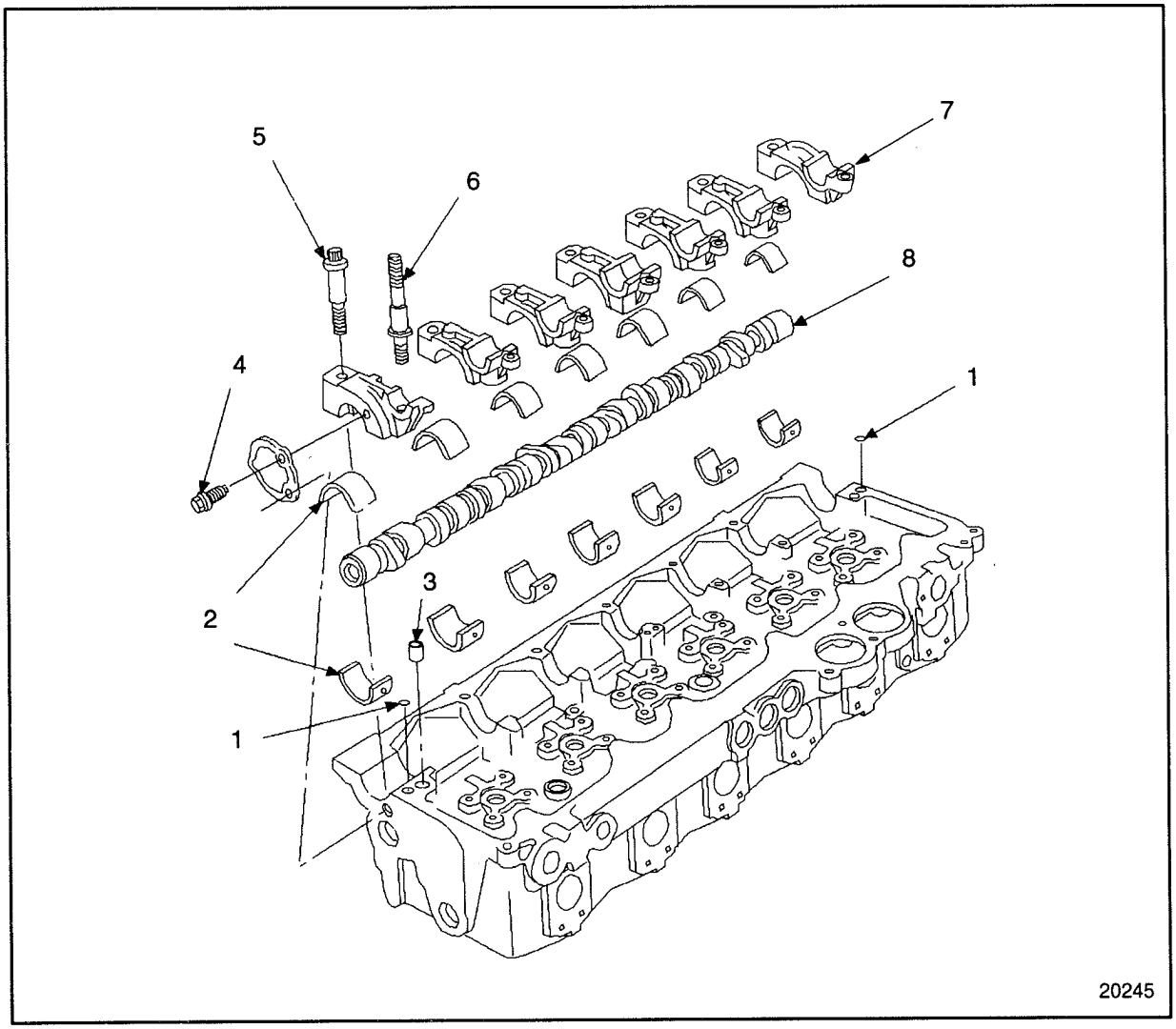


FIGURE 1–267 Series 60 Camshaft and Related Parts

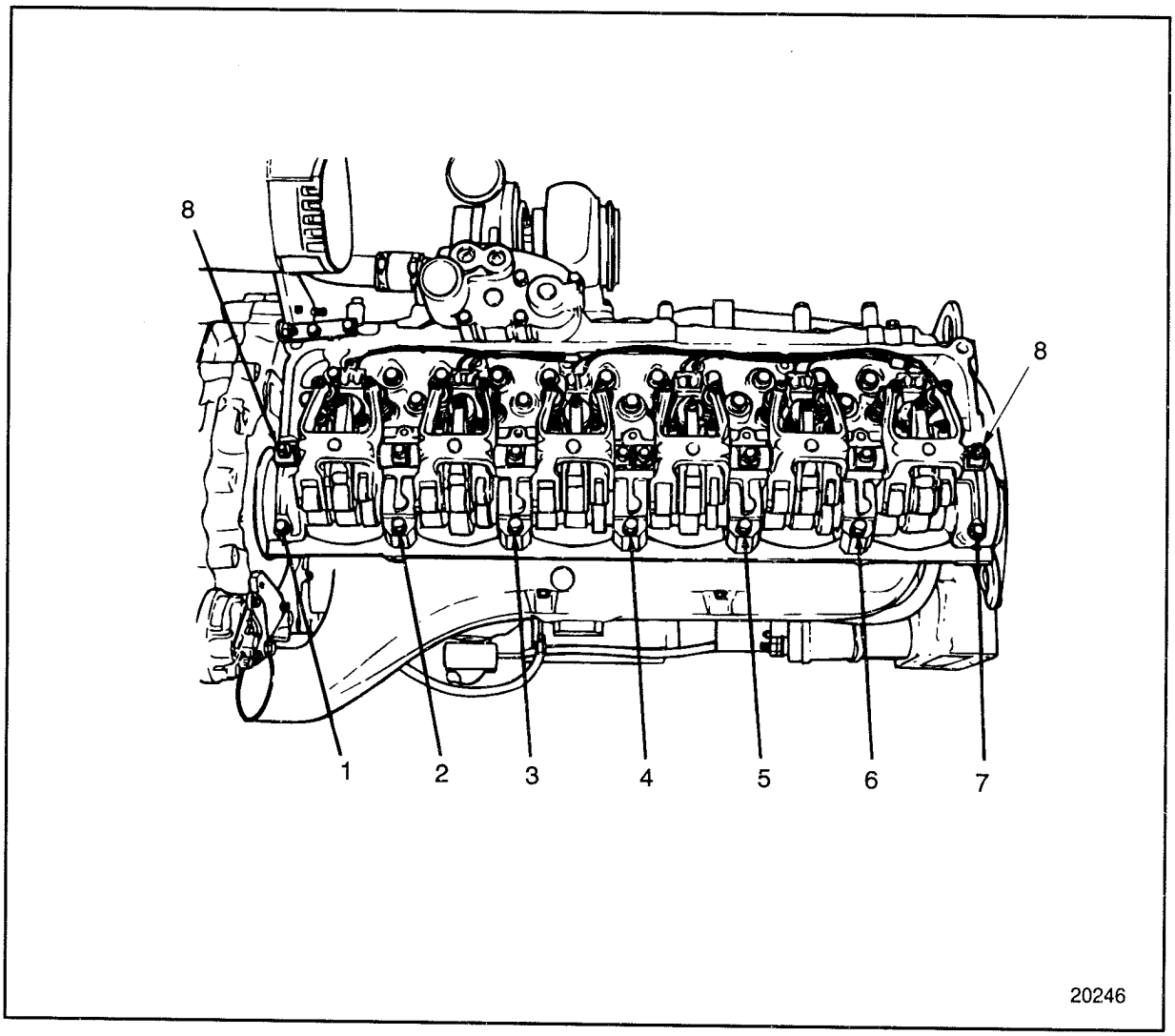
The camshaft is supported by seven bearing assemblies, consisting of precision–type, replaceable bearing shell inserts that are split at their center lines. The lower bearing shell is positioned in a saddle that is integral with the cylinder head. The upper bearing shell is held in place by a machined camshaft cap. Upper and lower bearing shells are identical and have locating tangs and oil holes. Only the upper bearing shell oil holes index with oil supply holes in the camshaft caps. See Figure 1–268. These camshaft caps are precision line–bored after assembly to the cylinder head. Caps are NOT interchangeable once the head is finished. Caps are numbered and must NOT be interchanged with other caps of the same part number from stock or from a different cylinder head.



1. O–ring (2)
2. Bearing Shells
3. Dowel
4. Bolt, Camshaft Cover
5. Bolt, Camshaft Cap (13)
6. Stud, Camshaft Cap (2)
7. Camshaft Cap
8. Camshaft

FIGURE 1–268 Camshaft Bearings and Caps

The Number 4 camshaft cap is secured to the cylinder head with three bolts, with Number 2, 3, 5, and 6 caps utilize two bolts each. Caps one and seven have a stud and one bolt each. The stud and nut arrangement on the end caps (1 and 7) allows rocker arm shaft removal without disturbing the gasket eliminator seal from the end camshaft caps to the cylinder head. There are four different camshaft cap configurations. Only the intermediate caps number 2, 3, 5, and 6 are identical but must not be interchanged during re–assembly. See Figure 1–269.



1. Camshaft Cap Bolt Number 1
2. Camshaft Cap Bolt Number 2
3. Camshaft Cap Bolt Number 3
4. Camshaft Cap Bolt Number 4
5. Camshaft Cap Bolt Number 5
6. Camshaft Cap Bolt Number 6
7. Camshaft Cap Bolt Number 7
8. Camshaft Cap Stud and Nut (2)

FIGURE 1–269 Camshaft Caps Location

The camshaft is driven by a camshaft drive gear, located in the gear case at the front of the engine and is driven, through a series of intermediate gears, by the crankshaft timing gear. Refer to section 1.21.2.1 for gear train information and camshaft drive gear lash measurement and adjustment procedures. See Figure 1–270.

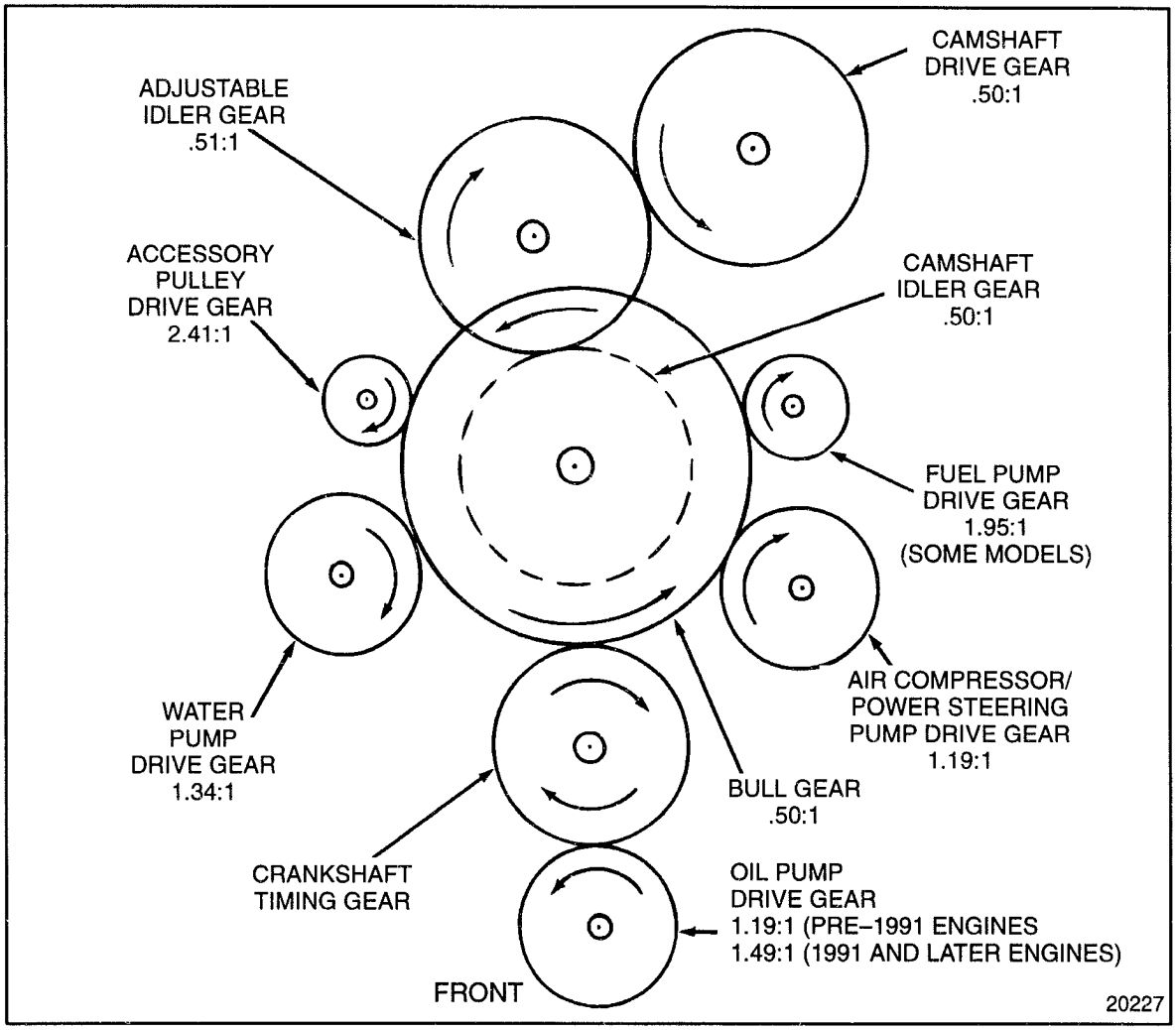
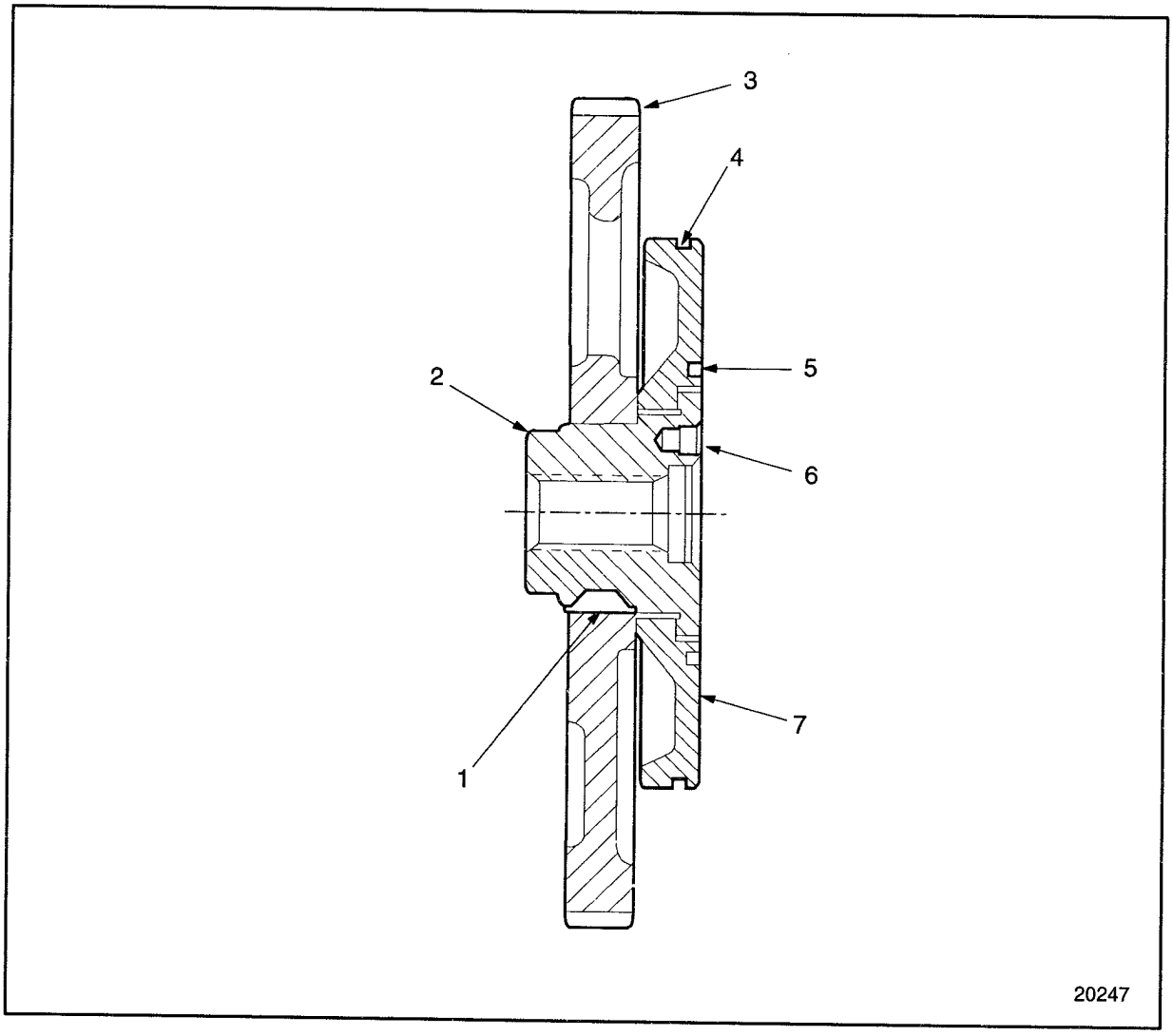


FIGURE 1–270 Engine Gear Train

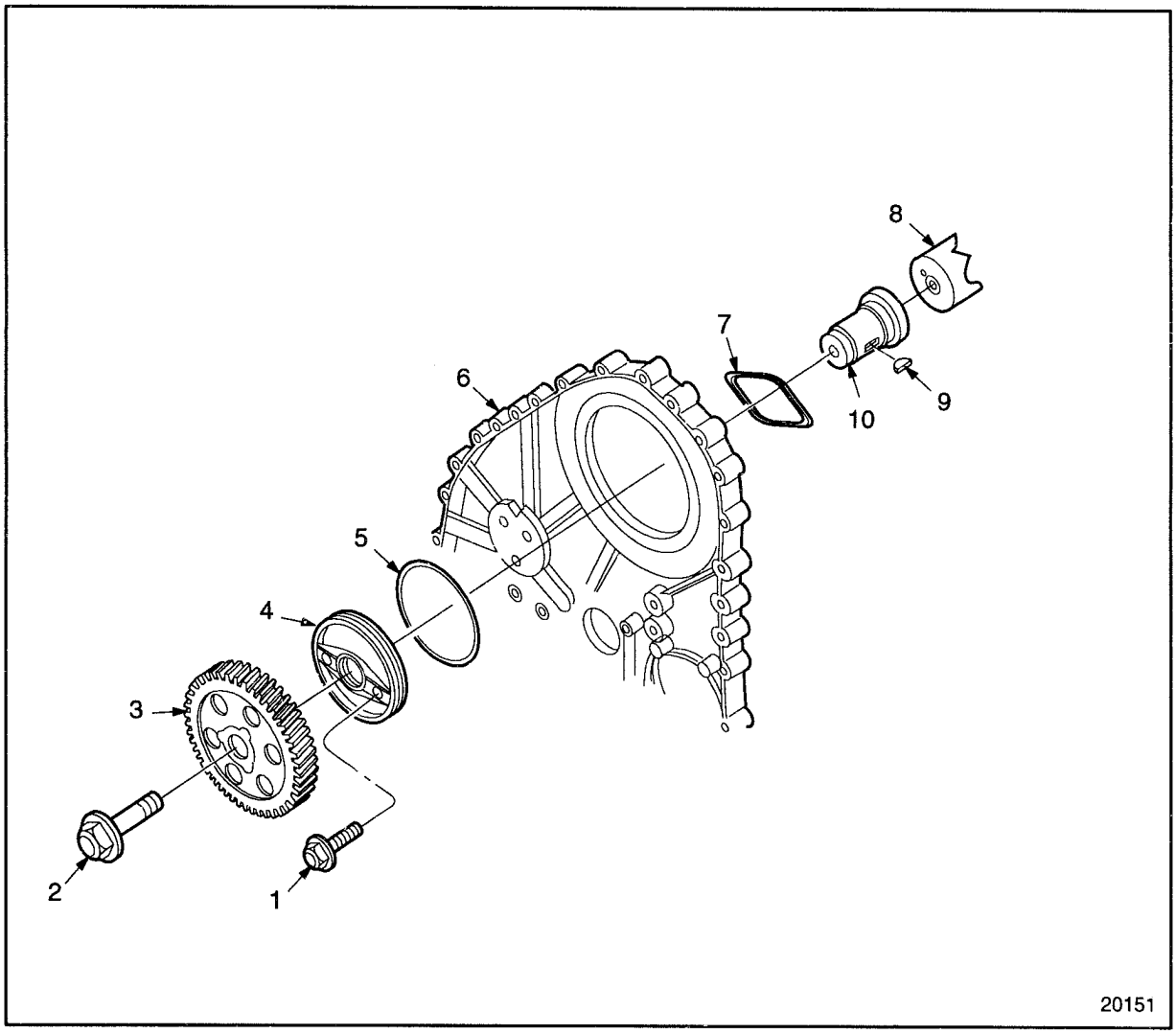
The camshaft drive gear is indexed to the camshaft drive gear hub by a Woodruff key and retained by a bolt which goes through the camshaft drive gear and hub and threads into the end of the camshaft. The camshaft has a dowel which indexes and fits into the mating hole in the camshaft hub. See Figure 1–271.



1. Woodruff Key
2. Camshaft Drive Gear Hub
3. Camshaft Drive Gear
4. O–ring Groove
5. Seal Groove
6. Camshaft Dowel Hole
7. Camshaft Thrust Plate

FIGURE 1–271 Cross Section of Camshaft Drive Gear and Related Parts

The camshaft hub is located in the camshaft thrust plate, which is positioned in an opening in the gear case housing. Refer to section 1.11.1. See Figure 1–272.



1. Bolt, Thrust Plate Retaining (2)
2. Bolt, Camshaft Hub Retaining
3. Drive Gear, Camshaft
4. Thrust Plate, Camshaft
5. O–ring
6. Gear Case
7. Seal, Thrust Plate
8. Camshaft
9. Key
10. Hub

FIGURE 1–272 Camshaft Thrust Plate and Related Parts

Access openings are provided in the gear case cover for camshaft drive gear lash adjustment and camshaft retaining bolt removal. See Figure 1–273.

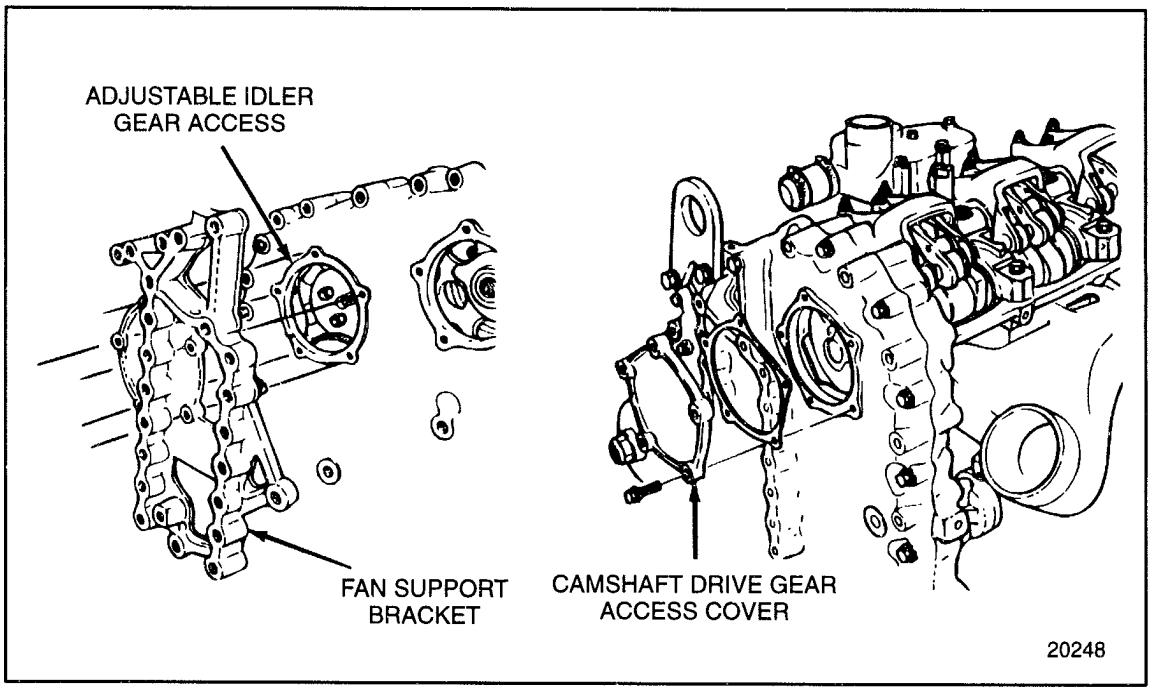


FIGURE 1–273 Camshaft Drive Gear and Adjustable Idler Gear Access Cover

A cover is provided at the rear end of the camshaft and is secured to the Number 7 camshaft bearing cap and the cylinder head by three bolts. See Figure 1–274.

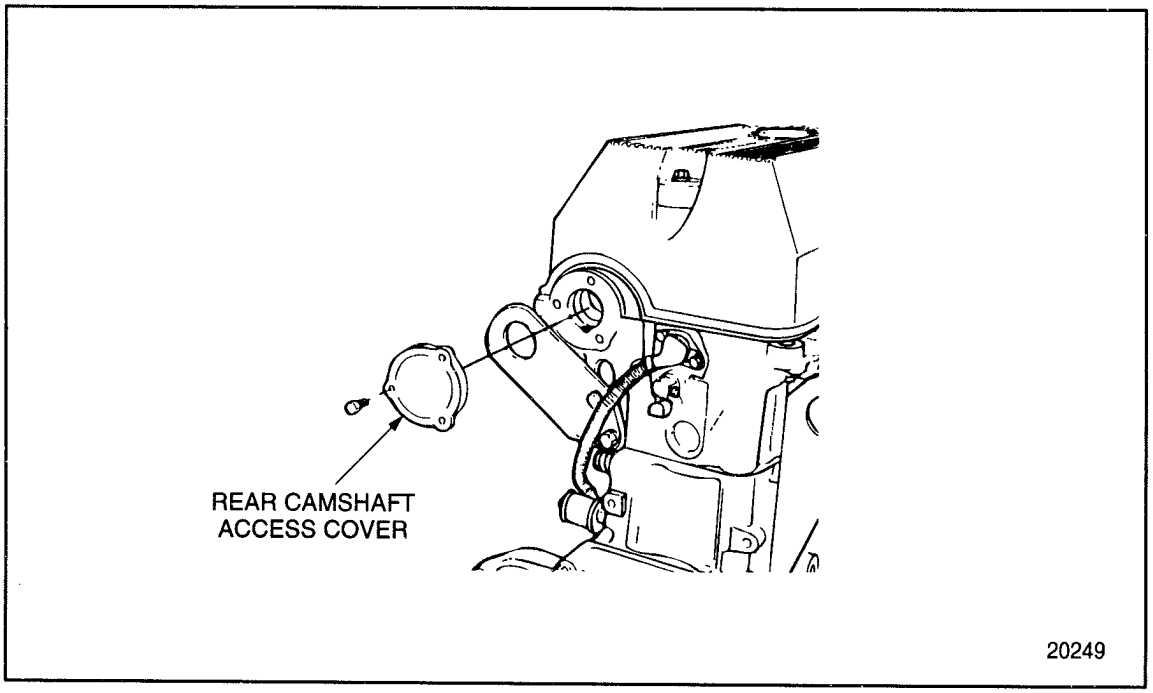
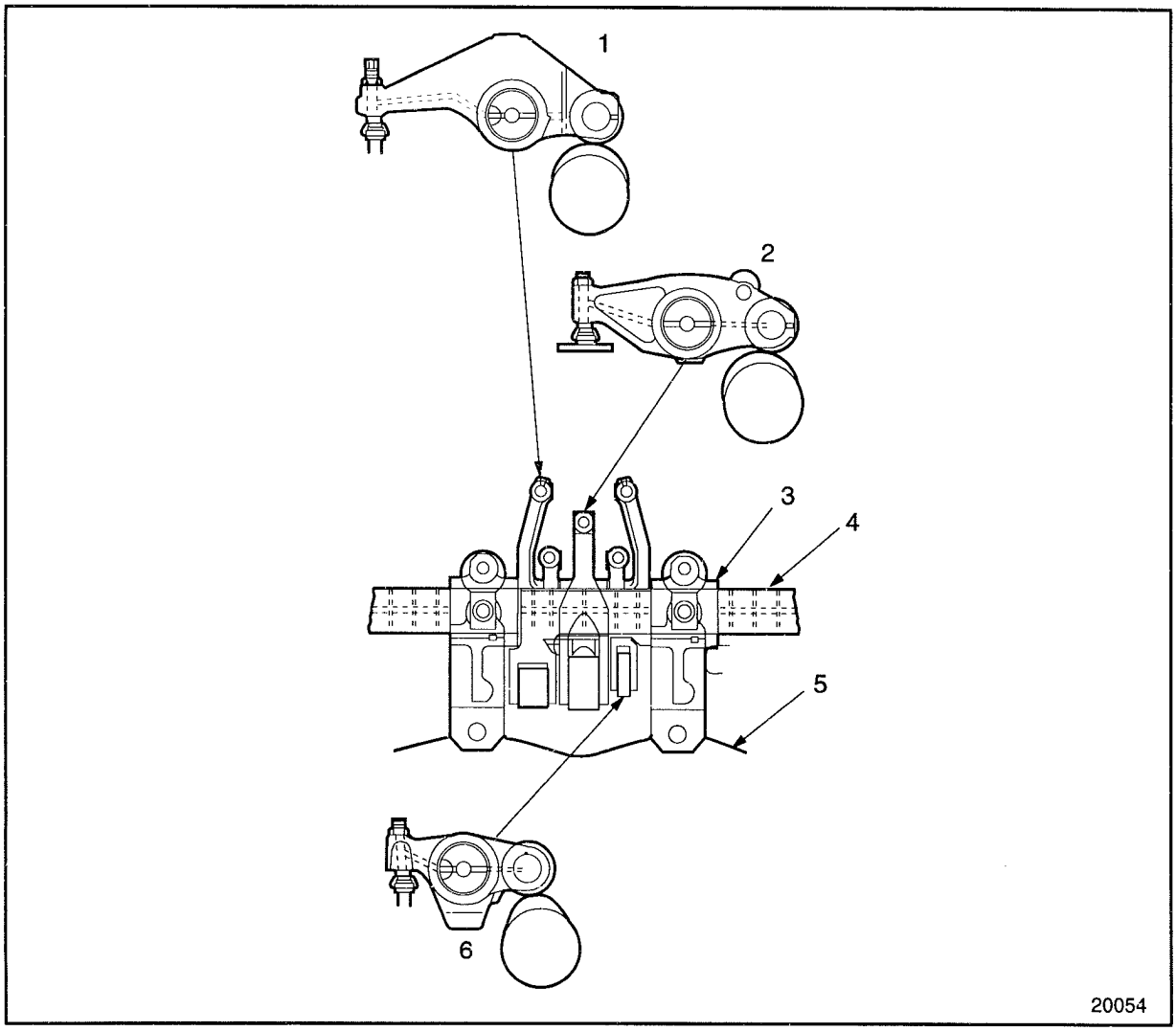


FIGURE 1–274 Rear Camshaft Access Cover

Vertical oil passages at the front and rear of the cylinder head deliver oil from the cylinder block front and rear oil galleries to the Number 1 and lower camshaft bearing saddles. From there, the oil is directed upward (through the enlarged stud hole) to the Number 1 and 7 upper bearing caps. A drilled passage in each of these caps exits at the rocker arm shaft seat area, where it indexes with a hole in each

rocker arm shaft. The rocker arm shafts have internal oil passages that deliver oil to the rocker arm bushings and intermediate upper camshaft bearings. Some of the oil supplied to the rocker arm bushing passes through the oil hole in the bushing to the rocker arm. The rocker is drilled to supply oil to the camshaft follower, roller pin, and bushing. The rocker is also drilled to supply oil to the valve adjusting screw, valve button, retainer clip, intake, and exhaust valve stems and the fuel injector follower. The Number 4 camshaft cap is "Y" drilled, forming an oil path connection between the front and rear rocker arm shafts, to ensure complete lubrication. See Figure 1–275.



1. Rocker Arm, Exhaust Valve
2. Rocker Arm, Fuel Injector
3. Camshaft Cap
4. Rocker Arm Shaft
5. Cylinder Head
6. Rocker Arm, Intake Valve

FIGURE 1–275 Cylinder Head Lubrication Schematic

1.22.1 Repair or Replacement of Camshaft and Camshaft Bearings

To determine if repair or replacement of the camshaft and camshaft bearings is necessary, perform the following procedure. See Figure 1–276.

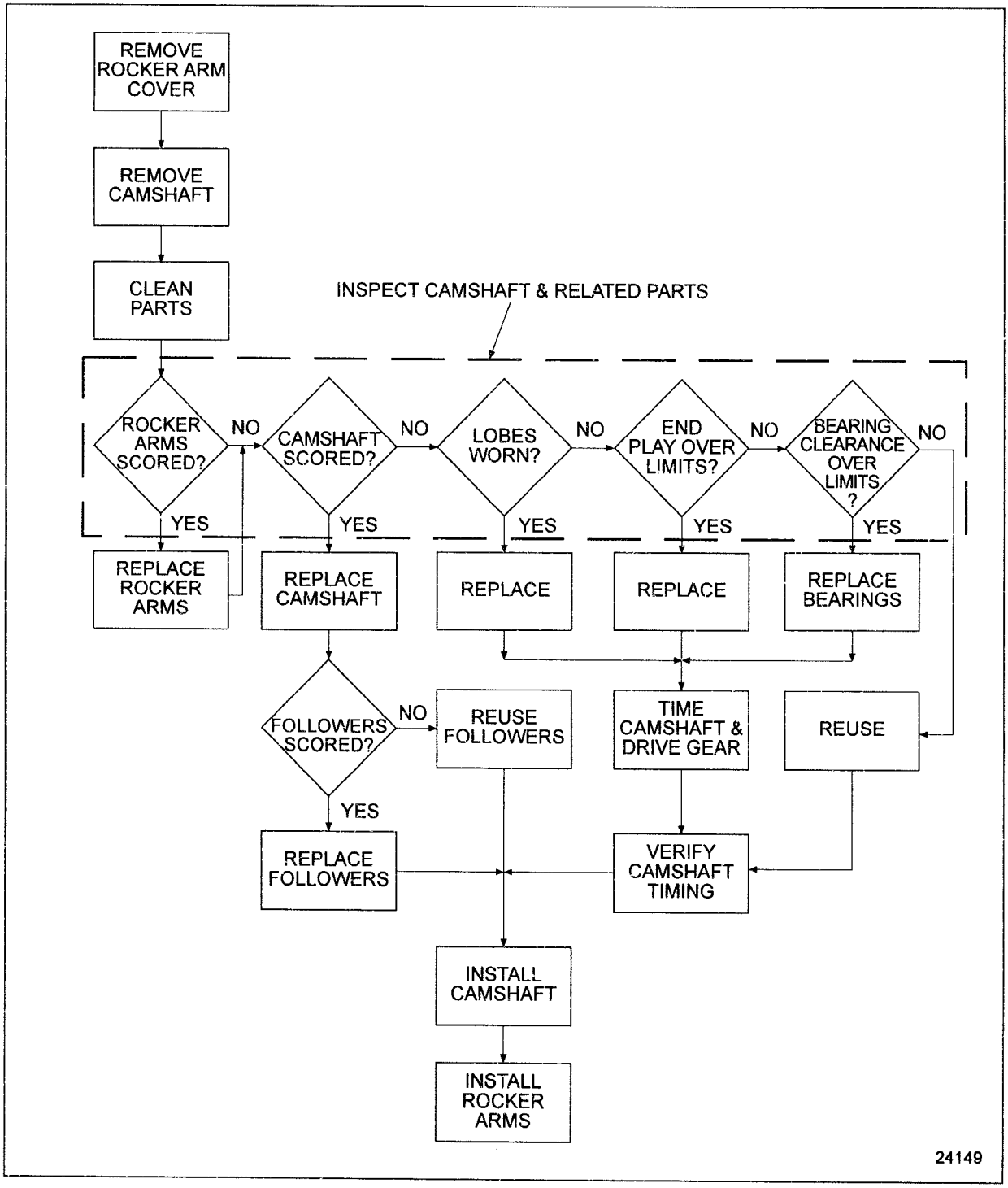


FIGURE 1–276 Flowchart for Repair or Replacement of Camshaft

1.22.2 Removal of Camshaft and Camshaft Bearings

Removal of camshaft and camshaft bearings as follows:

1. Remove the valve rocker cover. Refer to section 1.6.1.
2. Remove the five bolts that secure the camshaft drive gear access cover to the gear case. See Figure 1-273.
3. Remove both rocker arm shaft assemblies. Refer to section 1.3.2.

NOTICE:
Only special tool, J 35652, should be used to hold the camshaft drive gear stationary while loosening or tightening the camshaft drive gear–to–camshaft bolt. Other tools or devices can cause engine damage.

4. Insert the shoe of the camshaft drive gear torque holding tool, J 35652, through a lightening hole of the camshaft drive gear.
5. Bar the engine over slightly to position the camshaft drive gear holding tool so that the bolt holes in the holding tool align with the access cover bolt holes in the gear case cover. Using the 3/4 in. square hole in the center of the crankshaft pulley.
6. Install the Camshaft Drive Gear Torque Holding Tool, J 35652 to the gear case, engaging one of the lightening holes in the camshaft drive gear. Use two of the access cover bolts to secure the tool to the gear case. See Figure 1-277.
7. Use a long 3/4 in. drive breaker bar and a 27 mm impact socket to remove the camshaft drive gear–to–camshaft bolt.
8. Remove the camshaft drive gear torque holding tool from the gear case.

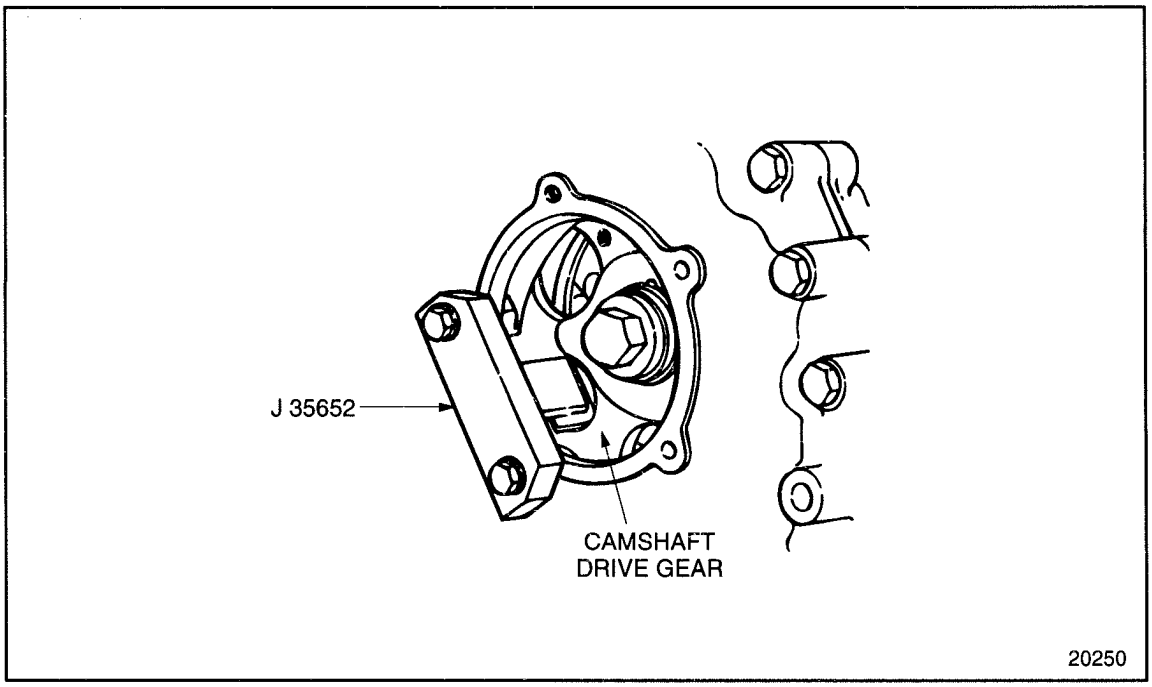


FIGURE 1–277 Camshaft Drive Gear Torque Holding Tool Installation

9. Rotate the crankshaft, using the square hole in the middle of the crankshaft pulley, to align the lightening holes in the camshaft drive gear to the camshaft thrust plate mounting bolts.
10. Remove the two camshaft thrust plate mounting bolts carefully, to avoid dropping them into the gear case. See Figure 1–278.

NOTE:
A clean shop towel may be inserted into the gear case opening to trap the bolts in case they are dropped. Do not allow the shop towel to drop into the gear case.

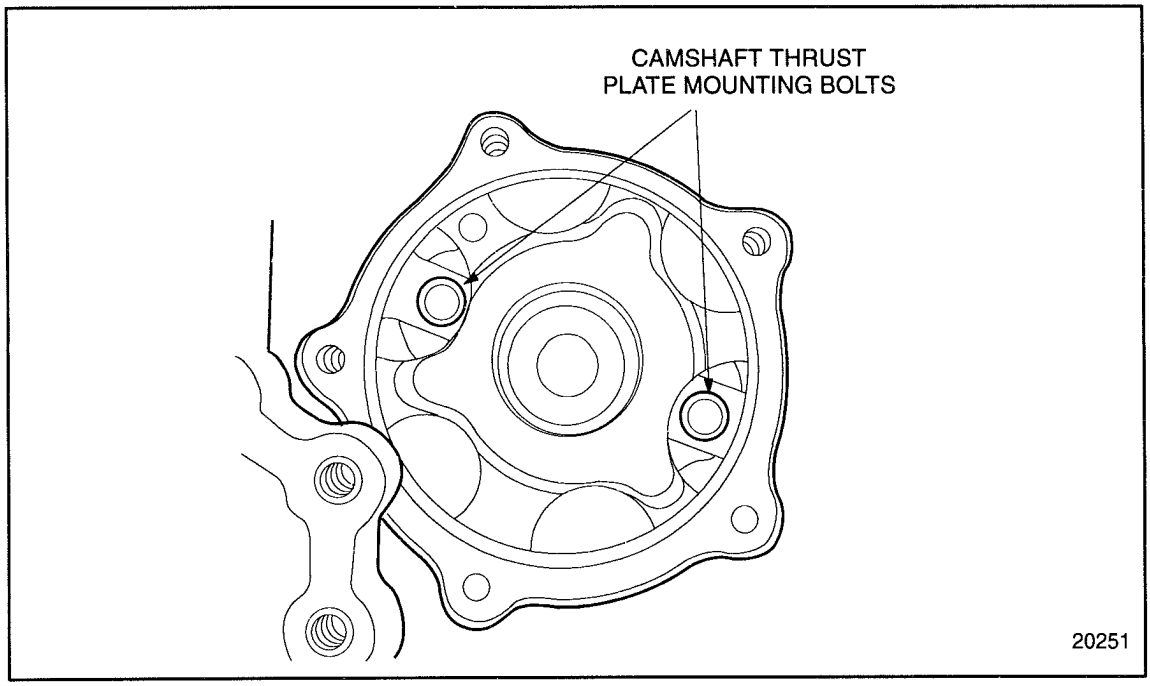


FIGURE 1–278 Camshaft Thrust Plate Bolts

11. Install the Camshaft Gear Pilot, J 35906, to the camshaft drive gear access opening, using three of the access cover bolt holes. Engage the puller screw in the threads of the camshaft drive gear hub, until the screw is tight. See Figure 1–279.

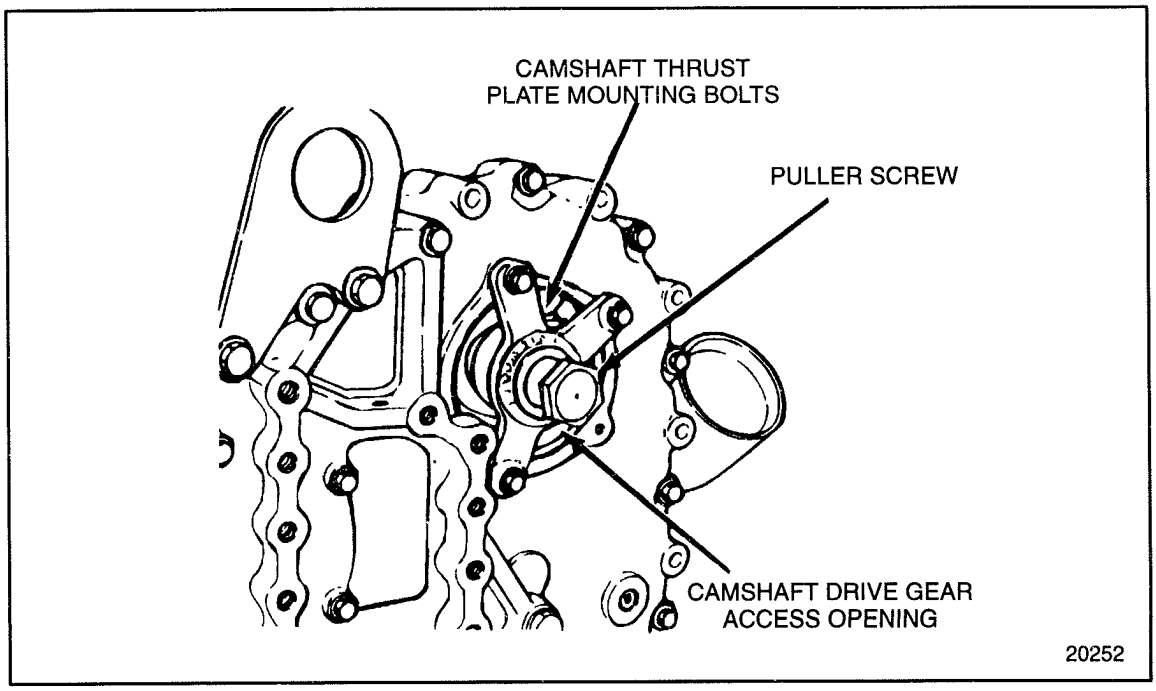


FIGURE 1–279 Camshaft Gear Pilot

12. Continue turning the puller screw to pull the camshaft drive gear hub and thrust plate forward approximately 6–7 mm (1/4 in.) until the

thrust plate seal is clear of the camshaft front bearing cap and cylinder head. See Figure 1-280.

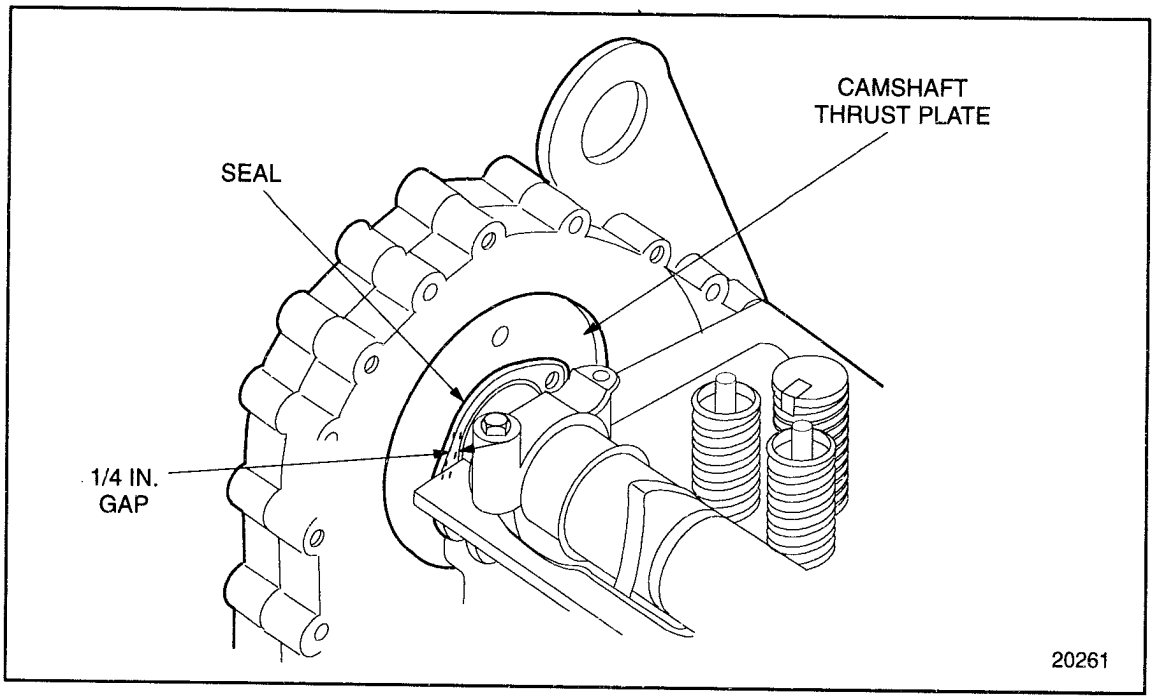


FIGURE 1–280 Camshaft Thrust Plate Clearance

13. Remove the three bolts that secure the rear camshaft cover to the engine and remove the cover.
14. Remove the remaining seven camshaft cap bolts. Remove the Number 1 and 7 studs using socket tool J 36003. See Figure 1-281.

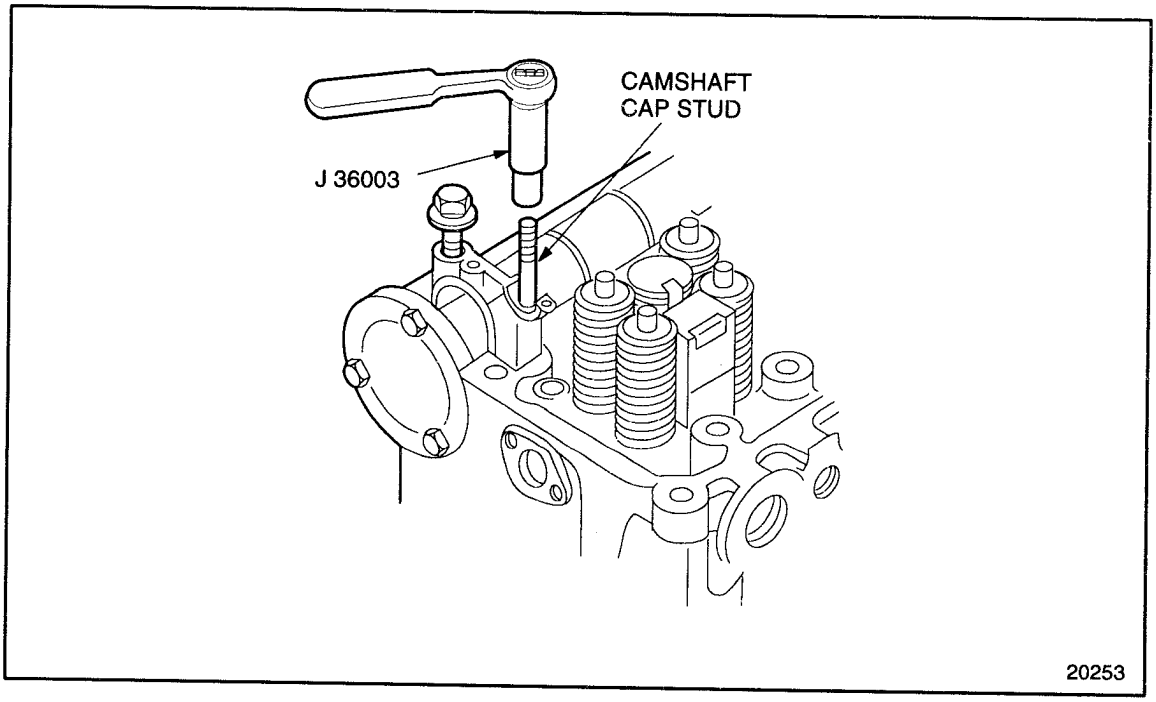


FIGURE 1–281 Camshaft Cap Stud Removal

15. Remove the seven camshaft bearing caps and the upper bearing shells. Keep the caps and shells together for possible later installation. Tag the bearing cap location, as they must always be installed in the same location.
16. Remove the center screw from the camshaft gear pilot tool. The camshaft gear pilot tool will remain in place, holding the camshaft drive gear in contact with the adjustable idler gear, to prevent accidental disengagement. This arrangement makes it unnecessary to retime the gear train.

NOTE:
The camshaft gear can go out of time if the pilot tool is removed.

17. Slide the camshaft rearward to completely disengage the dowel from the hub. Lift out the camshaft.
18. Remove the lower camshaft bearing shells, and group them with the upper shells and caps for possible reuse.

1.22.3 Disassembly of Camshaft and Camshaft Bearings

Refer to section 1.23.2 for disassembly of camshaft drive gear, camshaft hub and thrust plate assembly.

NOTE:
Disassembly of camshaft and drive gear assembly is not required for inspection. Disassembly will require timing of the camshaft gear again.

1.22.3.1 Inspection of Camshaft and Camshaft Bearings

Inspect camshaft and camshaft bearings as follows:

1. Clean all of the removed parts in clean fuel oil.
2. Ensure all oil passages are clear.

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

3. Dry with compressed air.
4. Inspect the rocker arm components for scoring. Refer to section 1.3.2.1.
5. Replace damaged rocker arm components.
6. Inspect the camshaft lobes and journals for scoring, pitting, or flat spots.

NOTE:
Camshafts may exhibit surface pits on the exhaust lobes. See Figure 1–282. Extensive durability and field testing has shown that surface pits on the exhaust lobes can occur early in the operation of the engine. These blemishes do not adversely affect engine performance or the durability of the camshaft and followers. Camshafts with this condition may be reused.

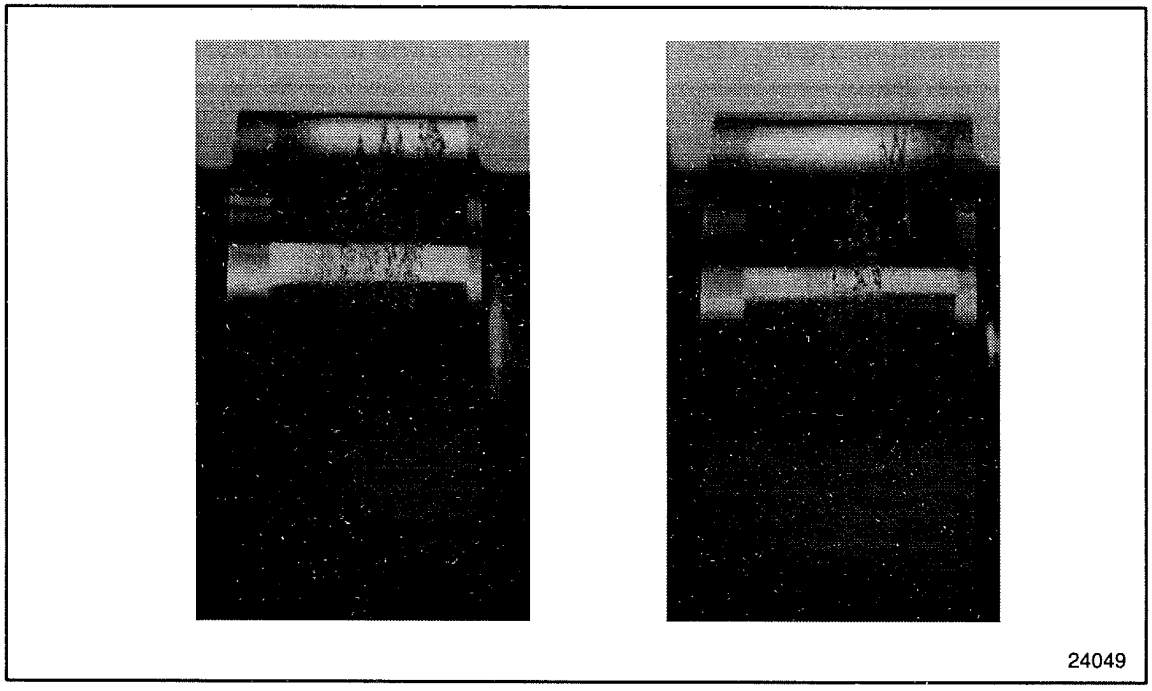


FIGURE 1–282 Camshafts Acceptable for Reuse

NOTE:
Camshafts exhibiting extensive wear and pitting must be replaced. See Figure 1–283.

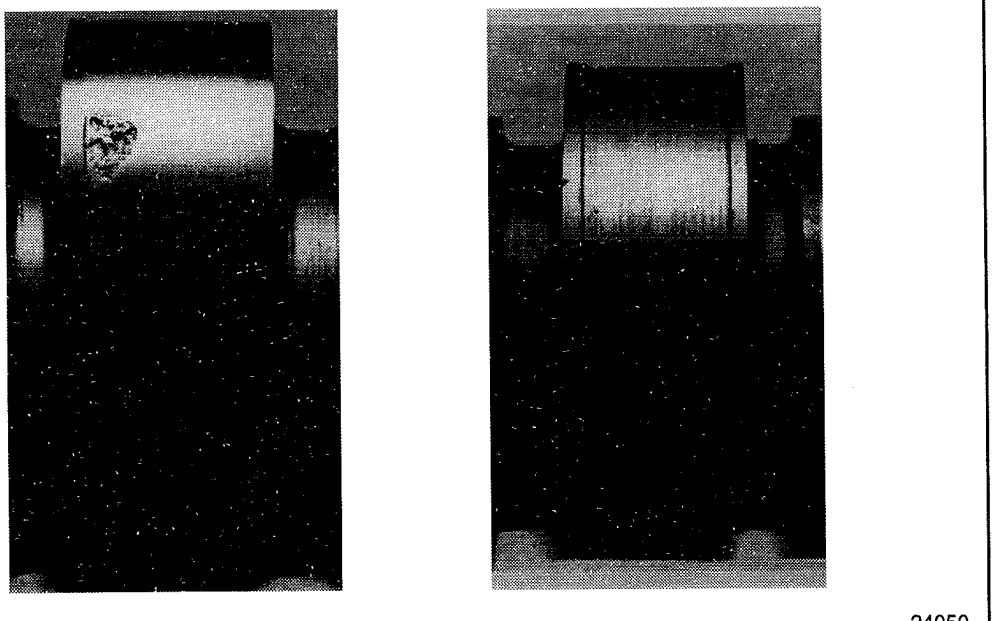


FIGURE 1–283 Camshafts Not Acceptable for Reuse

7. If the camshaft is scored, inspect the camshaft follower rollers.
8. Replace damaged camshaft followers.
9. If there is a doubt as to the acceptability of the camshaft for further service, determine the extent of camshaft lobe wear as follows:

NOTE:
The camshaft can be in or out of the engine during this procedure.

[a] With a set of feeler gages, 0.038–0.254 mm (.0015 – .010 in.) and a piece of square, hard material 3 x 10 x 25mm (1/8 in. x 3/8 in. x 1 in.), measure the flat on the injector rise side of the camshaft lobes and nose of valve lobes. See Figure 1–284.

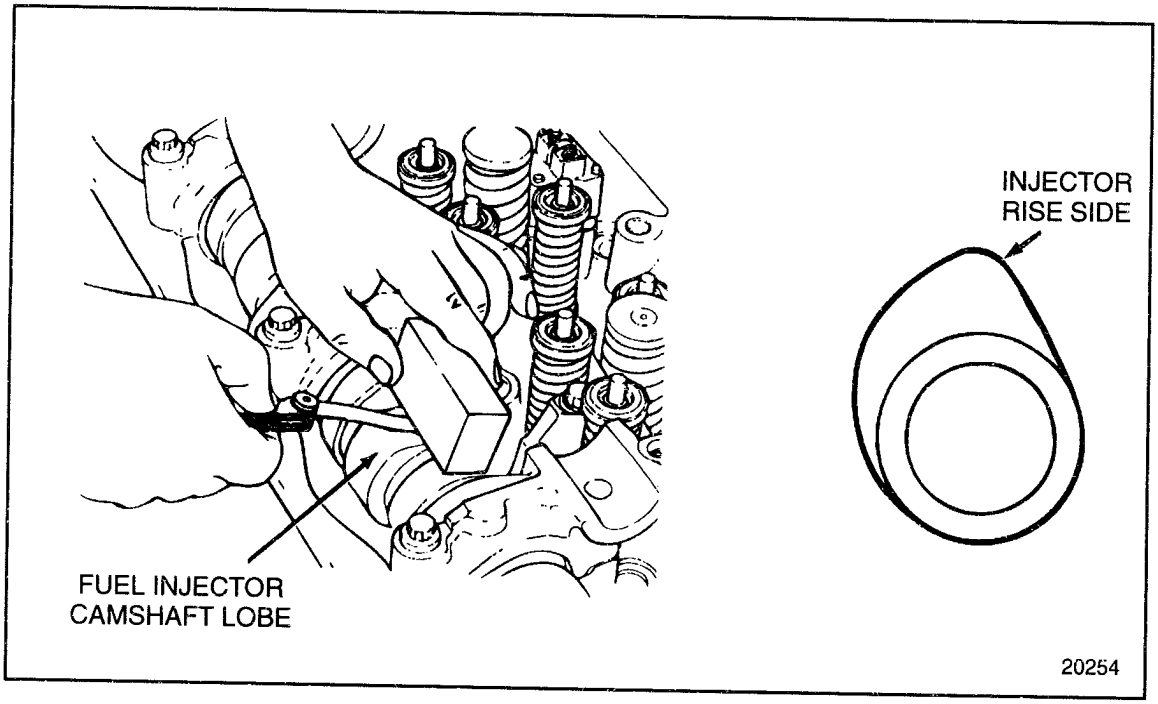


FIGURE 1–284 Checking Camshaft Lobe Wear

[b] If the flats measure greater than 0.076 mm (.003 in.) in depth and there are no other camshaft defects, replace the camshaft.

[c] Inspect the camshaft bearings for signs of excessive wear, scoring or pitting.

[d] Replace camshaft bearings as necessary.

NOTE:
If one camshaft bearing needs to be replaced, replace all of the camshaft bearing shells.

[e] Check the camshaft bearing clearance using plastic gaging material under each upper shell. See Figure 1–285.

NOTE:
Check camshaft bearing clearance with bearing shells, camshaft, bearing caps and rocker arm shafts (without rocker assemblies in place) installed, and cap bolts, studs and nuts tightened to specification.

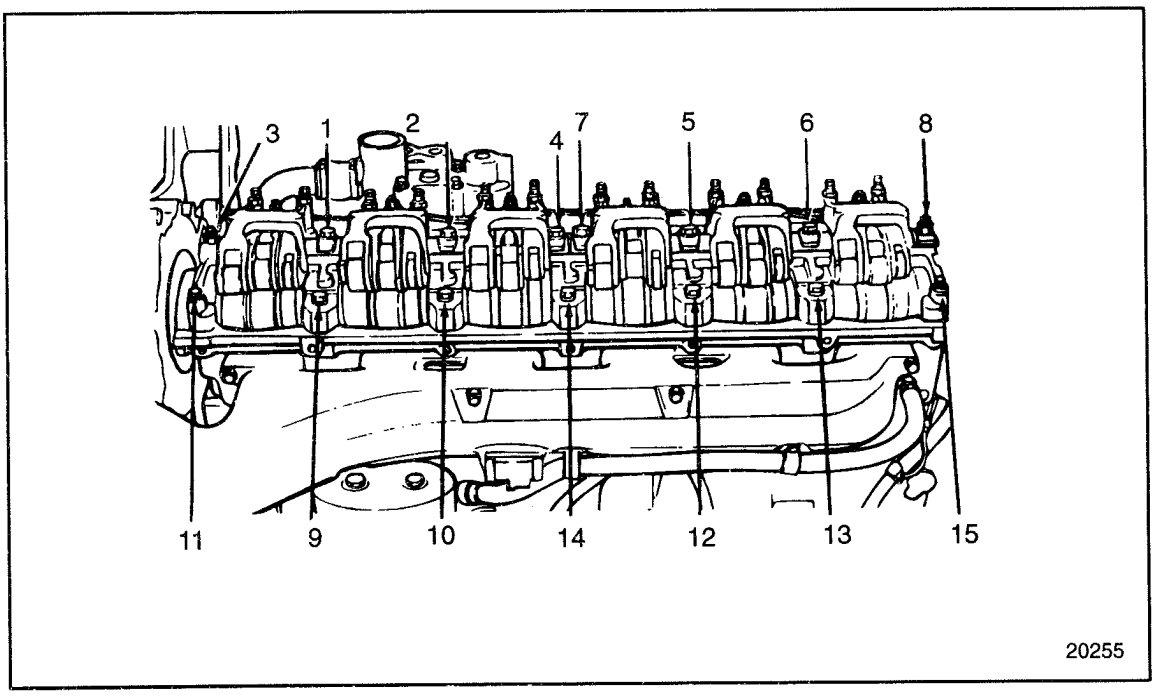


FIGURE 1–285 Camshaft Bearing Clearance Setup

[f] Allowable clearance is 0.09 - 0.166 mm (.0035 - .0065 in.) or a maximum of 0.191 mm (.0075 in.) with used parts.

[g] Replace excessively worn or scored parts.

[h] After completing the camshaft bearing clearance measurements, remove the rocker arm shafts, bearing caps, camshaft, and camshaft bearings. Keep the caps and shells together for possible reuse.

[i] Clean all of the plastic gaging material from the bearing shells and camshaft journals if used parts are to be reused.

[j] Remove all of the Gasket Eliminator from both the cylinder head and camshaft caps.

[k] Coat the Nos. 1 and 7 bearing shell inserts with clean engine oil and install them to their respective locations in the cylinder head and camshaft caps.

[l] Install the camshaft to its normal position in the bearing saddles. Install the Number 1 and 7 camshaft caps to the cylinder head.

[m] Install the Nos. 1 and 7 camshaft cap outboard bolts and inboard studs and tighten both to 101–116 N·m (75–86 lb·ft) torque. Use tool J 36003 to tighten the studs.

[n] Using a dial indicator with magnetic base, check the runout of the camshaft at the Number 4 bearing journal. See Figure 1–286.

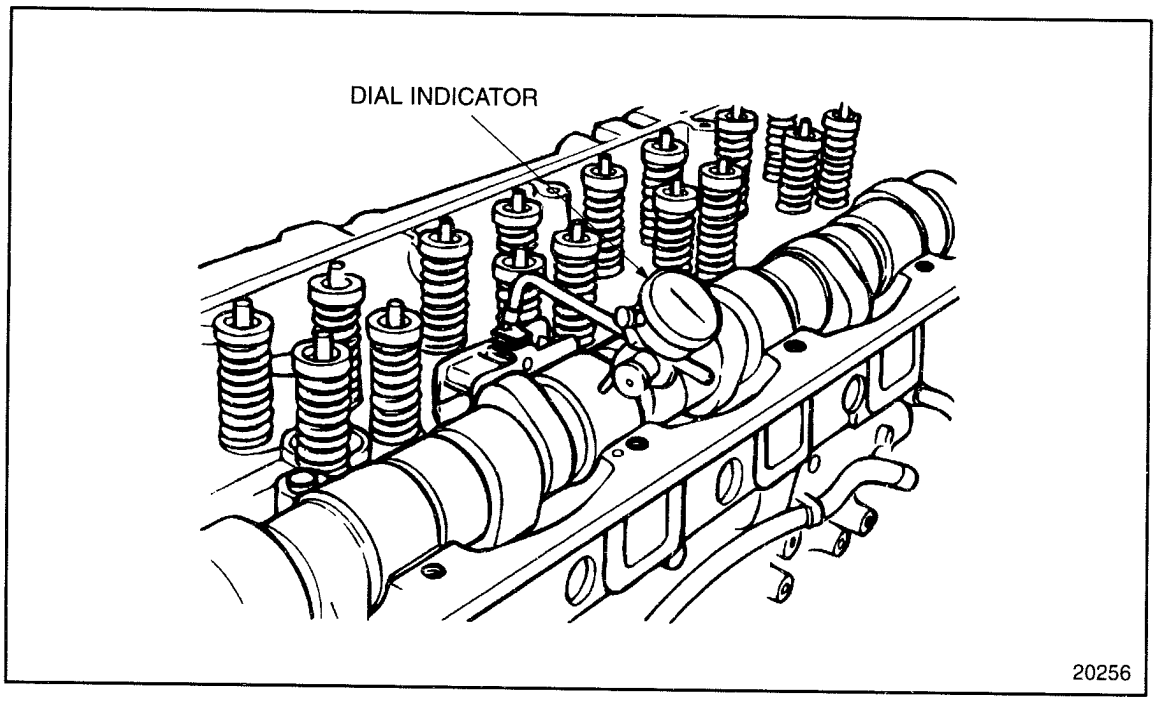


FIGURE 1–286 Camshaft Runout

[o] If camshaft runout exceeds 0.050 mm (.002 in.), replace the camshaft.

1.22.4 Assembly of Camshaft and Camshaft Bearings

Refer to section 1.23.3 for assembly of camshaft drive gear, camshaft hub and thrust plate assembly.

1.22.5 Installation of Camshaft and Camshaft Bearings

Install the camshaft and camshaft bearings as follows:

1. Coat the lower camshaft bearing shells with clean engine lubricating oil, and install them to their original positions. Note the position of oil holes and locating tangs.

NOTE:
If new bearings are to be installed, the upper and lower shells MUST be replaced as a set.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. When installing a new camshaft, steam clean it to remove the rust preventive and blow dry with compressed air.

3. Before installing the camshaft dowel into the camshaft hub, ensure that the dimple in the thrust plate is located at the 12 o'clock position to properly position bolt holes to cam cap and cylinder head. See Figure 1–287.

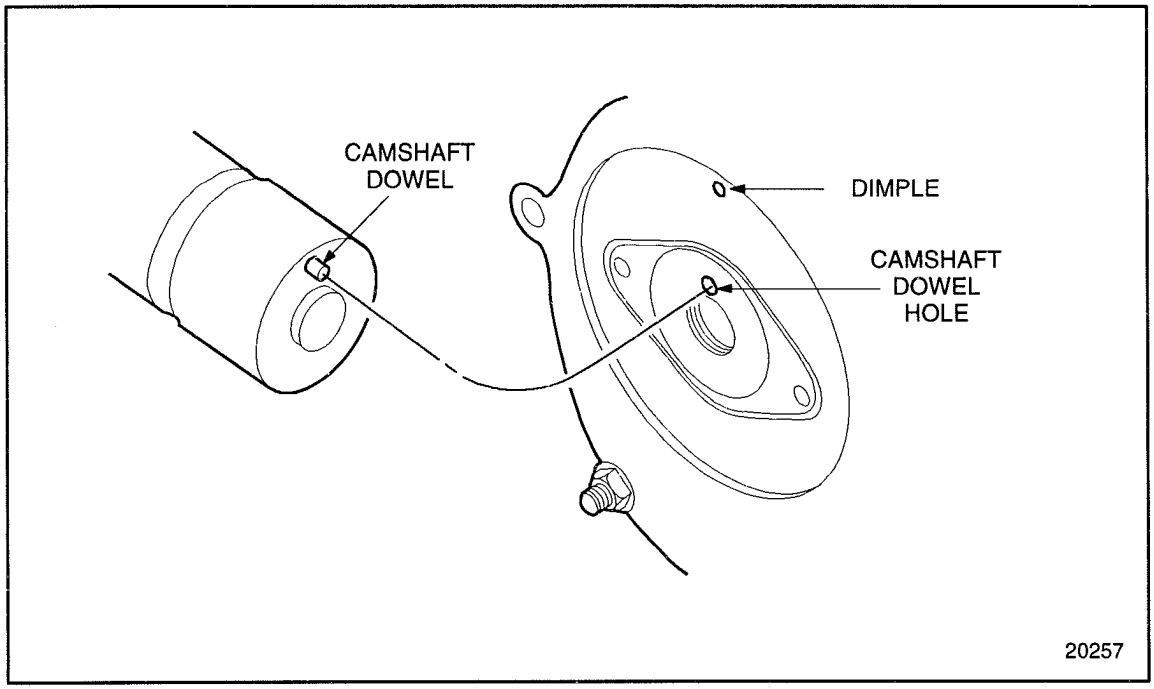


FIGURE 1–287 Indexing Camshaft Dowel

4. Coat the lobes and journals of the camshaft with clean engine lubricating oil. Index the dowel pin in the camshaft with the dowel hole in the camshaft hub.
5. Lower the camshaft into position and slide the camshaft forward, making certain that the camshaft dowel indexes with its mating hole in the camshaft thrust plate hub.
6. Install the upper bearing shells to the Number 1, 4 and 7 camshaft caps, noting the position of the oil holes and locating tangs.
7. Coat the bearing shells with clean engine lubricating oil.
8. Install the two rubber O–rings to the counterbores in the cylinder head at the Number 1 and 7 camshaft cap locations.

NOTICE:
Gasket Eliminator must be kept from the bearing shell sets and bearing surfaces. Gasket Eliminator cures with the absence of air. The length of time between installation of the Number 1 and 7 camshaft caps, and torquing the camshaft cap bolts and nuts should be kept to a minimum or improper lubrication will result causing engine damage.

9. Before assembling the camshaft caps to the cylinder head, ensure the two O-rings are in place on the cylinder head.
10. Apply a thin bead of Gasket Eliminator PT-7276, Loctite 51580 or equivalent to the joint face surfaces of the Number 1 and 7 camshaft caps. See Figure 1-288.

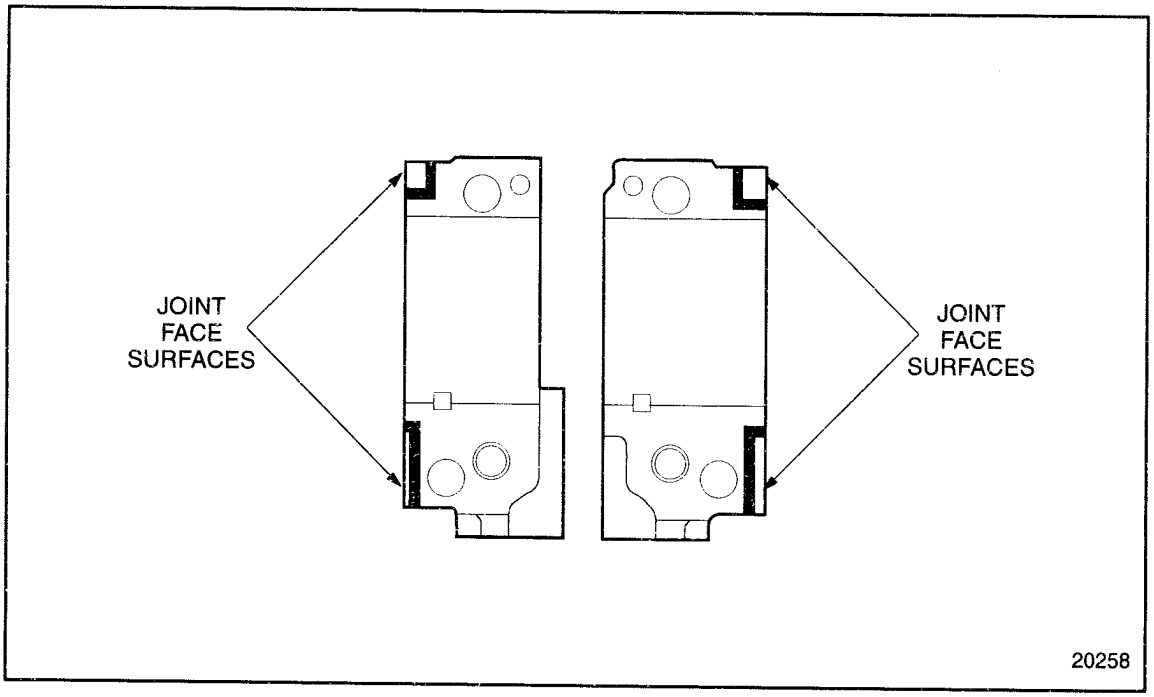


FIGURE 1-288 Gasket Eliminator Application

11. Install the Number 1, 4 and 7 camshaft caps, with bearing shells in place, to their respective locations.
12. Install and tighten the two inboard studs and outboard bolts on bearing caps Number 1 and 5 to 101-116 N·m (75-86 lb·ft) torque. Use tool J 36003 to tighten the bearing cap studs.
13. Install the number four bearing cap outboard bolt and tighten it to 101-116 N·m (75-86 lb·ft) torque.
14. Remove the three bolts holding the camshaft gear pilot, J 35906 to the gear case. Remove the camshaft gear pilot.
15. Working through the camshaft drive gear access hole in the front of the gear case, tap the center of the camshaft drive gear with a fiber mallet or plastic hammer to move the camshaft thrust plate, hub and camshaft drive gear rearward in the gear case until the camshaft thrust plate bolts can be started in the cylinder head and Number 1 camshaft cap.

NOTICE:

Use care to ensure that the camshaft dowel is not disengaged during this step or damage to engine may result.

NOTICE:

Using care to prevent dropping thrust plate mounting bolts into the gear case.

16. Install the thrust plate mounting bolts through the thrust plate and into the cylinder head and Number 1 camshaft cap. Using a 13 mm socket and ratchet, tighten the bolts alternately and progressively to draw the thrust plate straight into the gear case. Tighten the bolts to 30–38 N·m (22–28 lb·ft) torque.
17. Coat the threads and underside of the head of the camshaft drive gear–to–camshaft bolt with International Compound Number 2 (or equivalent). Install the bolt to the camshaft, finger tight.

NOTE:
The camshaft should be held in place while starting the camshaft drive gear–to–camshaft bolt, to prevent disengaging the camshaft dowel from the thrust plate hub and requiring disassembly and timing of camshaft.

18. Insert the shoe of the camshaft drive gear torque holding tool through a lightening hole of the camshaft drive gear

NOTICE:

Only Camshaft Drive Gear Torque Holding Tool, J 35652 should be used to hold the camshaft drive gear stationary while loosening or tightening the camshaft drive gear–to–camshaft bolt to prevent component damage.

19. Bar the engine over slightly to position the camshaft drive gear holding tool so that the bolt holes in the holding tool align with the access cover bolt holes in the gear case cover using the 3/4 in. square hole in the center of the crankshaft pulley to bar the engine over.
20. Install the two of the access cover bolts to secure the tool to the gear case.
21. Using a 27 mm impact socket and suitable torque wrench, tighten the camshaft drive gear–to–camshaft bolt to 334–370 N·m (246–272 lb·ft) torque. See Figure 1–289.

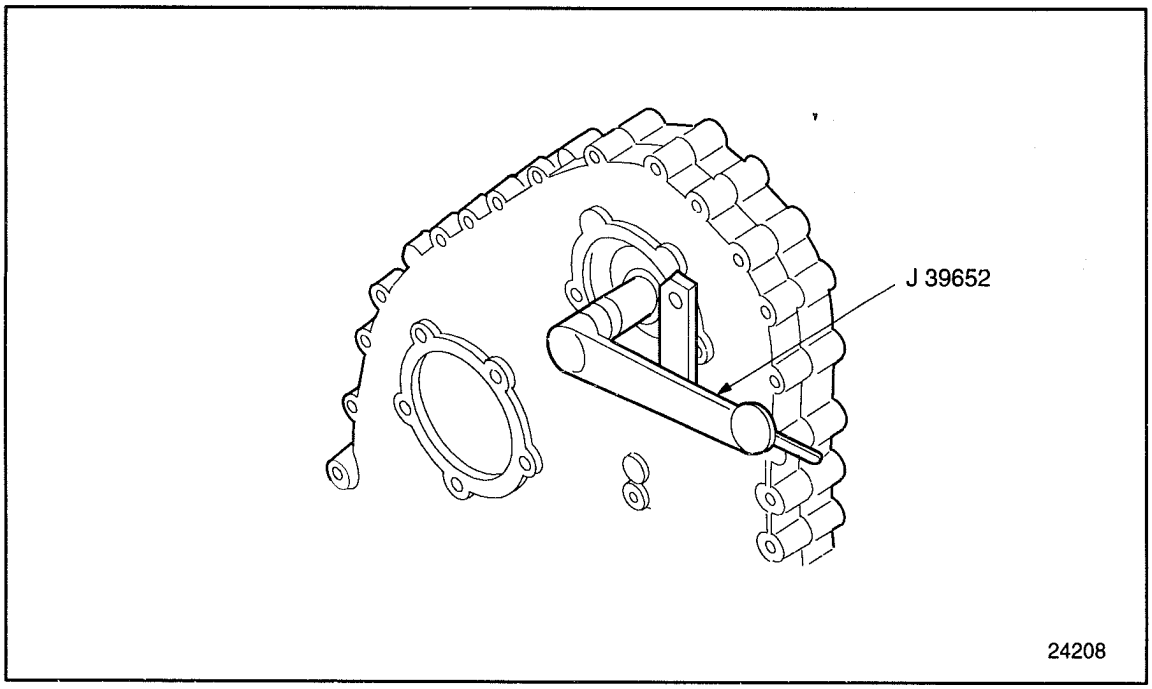


FIGURE 1–289 Camshaft Drive Gear–to–Camshaft Bolt Tightening

22. Remove the camshaft drive gear torque holding tool, J 35652.
23. Adjust the camshaft drive gear–to–adjustable idler gear lash. Refer to section 1.21.2.1.

NOTE:
Correct camshaft drive gear lash adjustment depends on the bolt and stud for Number 1 and 7 camshaft caps, the outboard bolt on Number 4 camshaft cap, and the camshaft drive gear–to–camshaft retaining bolt being tightened to the specified torque. However the valve and injector spring pressures will not allow correct camshaft rotation. Therefore, do NOT install the rocker arm shaft assemblies before the camshaft gear lash has been measured and adjusted.

1.22.5.1 Test of Camshaft End–play

Measure the camshaft end–play, using a dial indicator and magnetic base, as follows:

1. Install the dial indicator so that the pointer is in contact with either the camshaft drive gear–to–camshaft retaining bolt, or at the rear end of the engine, in contact with the end of the camshaft. See Figure 1–290.

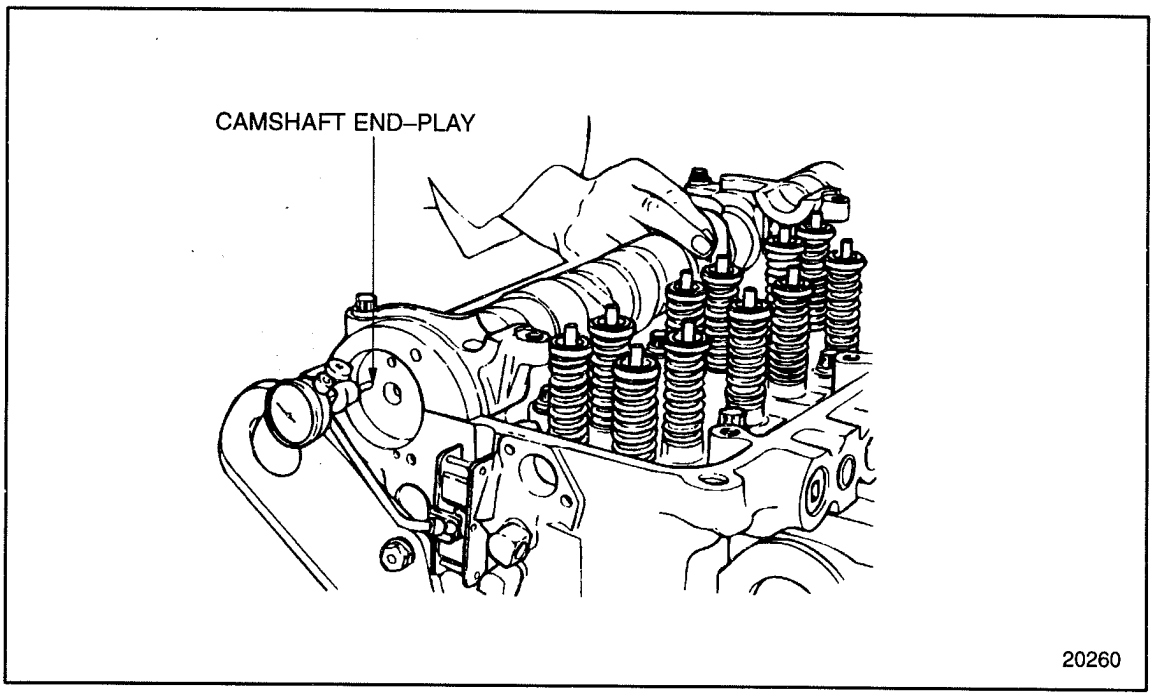


FIGURE 1–290 Camshaft End Play

2. Grasp the camshaft between the numbers one and four camshaft caps, and move the cam as far forward as possible. Zero the dial indicator.
3. Move the camshaft as far as possible, to the rear. Read and record the total amount of end–play as indicated.
4. Allowable camshaft end–play is 0.076 – 0.381 mm (.003 – .015 in.).
5. If the end–play is beyond the maximum limit, loosen and retorque the camshaft drive gear–to–camshaft retaining bolt, and the camshaft thrust plate retaining bolts, to ensure that the camshaft thrust plate is seated properly in the gear case.
6. If the end–play is still beyond the maximum limit, replace the camshaft thrust plate. Refer to section 1.22.2.

1.22.6 Installation of Camshaft and Camshaft Bearings – cont'd

Continue installing camshaft and camshaft bearings as follows:

1. Install the bearing shells to the remaining Number 2, 3, 5, and 6 camshaft caps, noting the oil holes and locating tangs.
2. Coat the bearing shells with clean engine lubricating oil.
3. Install the remaining camshaft caps to their saddles on the cylinder head. Install the four outboard camshaft cap bolts for caps Number 2, 3, 5, and 6 finger tight.
4. If they were removed, install the adjusting screws, valve buttons and clips to the rocker arms.
5. Install the rocker arms to the rocker arm shafts in their original positions. Use the rocker arm identification marks to ensure correct component installation. See Figure 1–291.

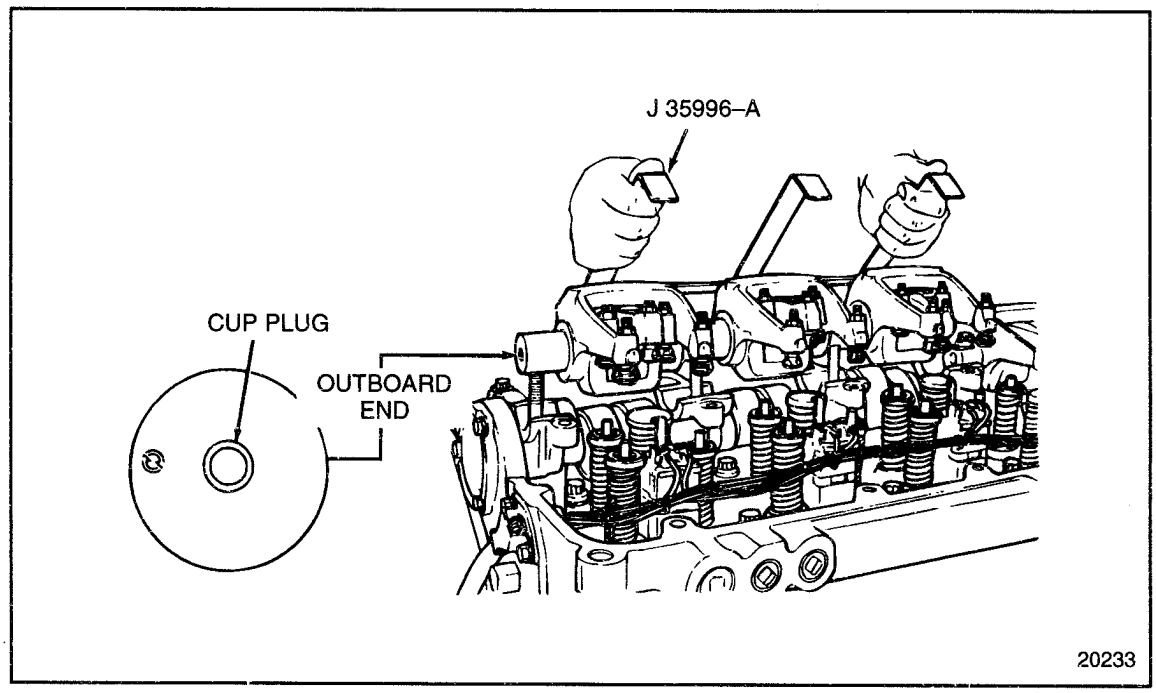


FIGURE 1–291 Rocker Arm Installation

6. Coat the rocker arm assemblies and camshaft liberally with clean engine lubricating oil.
7. Install the rocker arm shaft assemblies to the cylinder head. See Figure 1–291. Use care to locate the valve buttons to their respective valve stem and injector followers.
8. Install the remaining inboard camshaft cap bolts and spacers through the rocker arm shafts and into Number 2, 3, 4, 5, and 6 camshaft caps. Install the two nuts and spacers to the studs at Nos. 1 and 7 camshaft caps.
9. Tighten the 13 camshaft cap bolts and two nuts to 101–116 N·m (75–85 lb·ft) using the sequence. See Figure 1–292.

NOTE:
It is not necessary to tighten bolts 9, 13, and 14 if a Jake Brake is to be installed.

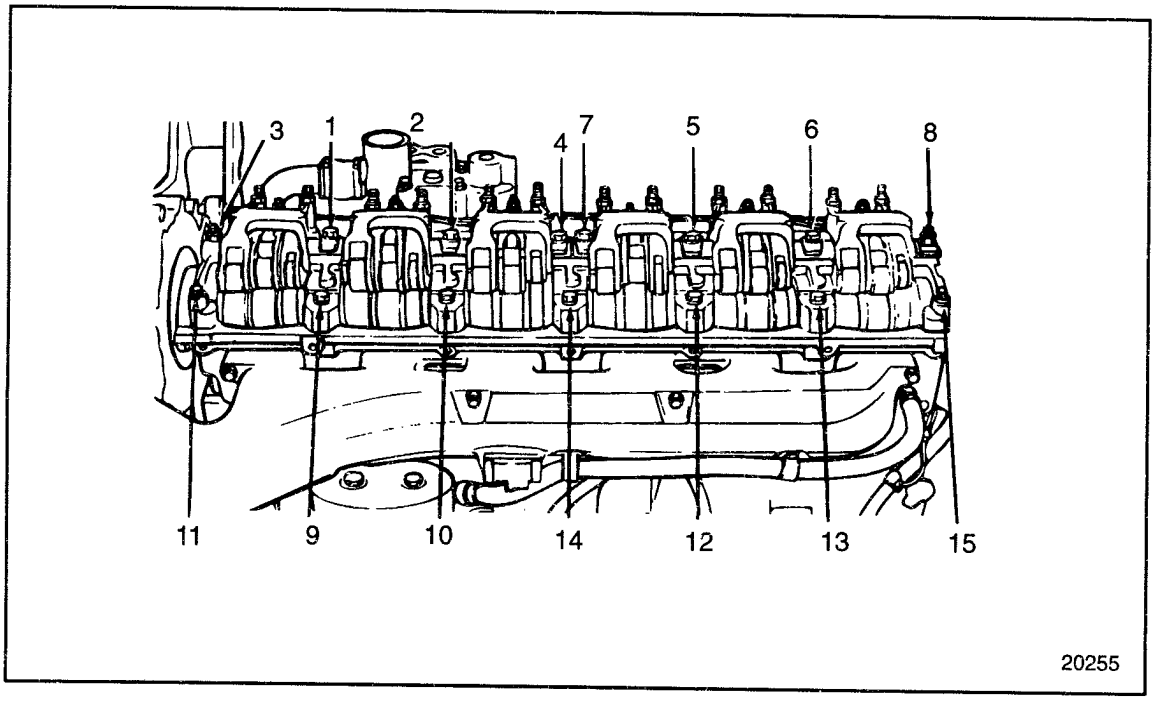


FIGURE 1–292 Camshaft Cap and Rocker Arm Shaft Bolt and Nut Torque Sequence

10. Clean all old gasket material from the mating surfaces of the rear camshaft cover and the cylinder head.
11. Apply a thin 1.5 mm (1/16 in.) bead of Gasket Eliminator, PT 7276 (Loctite 51580) or equivalent to the mating surface of the cover.
12. Install the cover and tighten the three bolts to 30–38 N·m (22–28 lb·ft) torque.
13. Clean all old gasket material from the mating faces of the camshaft drive gear access cover and the gear case cover.
14. Insert a new gasket between the camshaft drive gear access cover and the gear case.
15. Tighten the bolts to the torque values using the tightening sequence. See Figure 1–293.

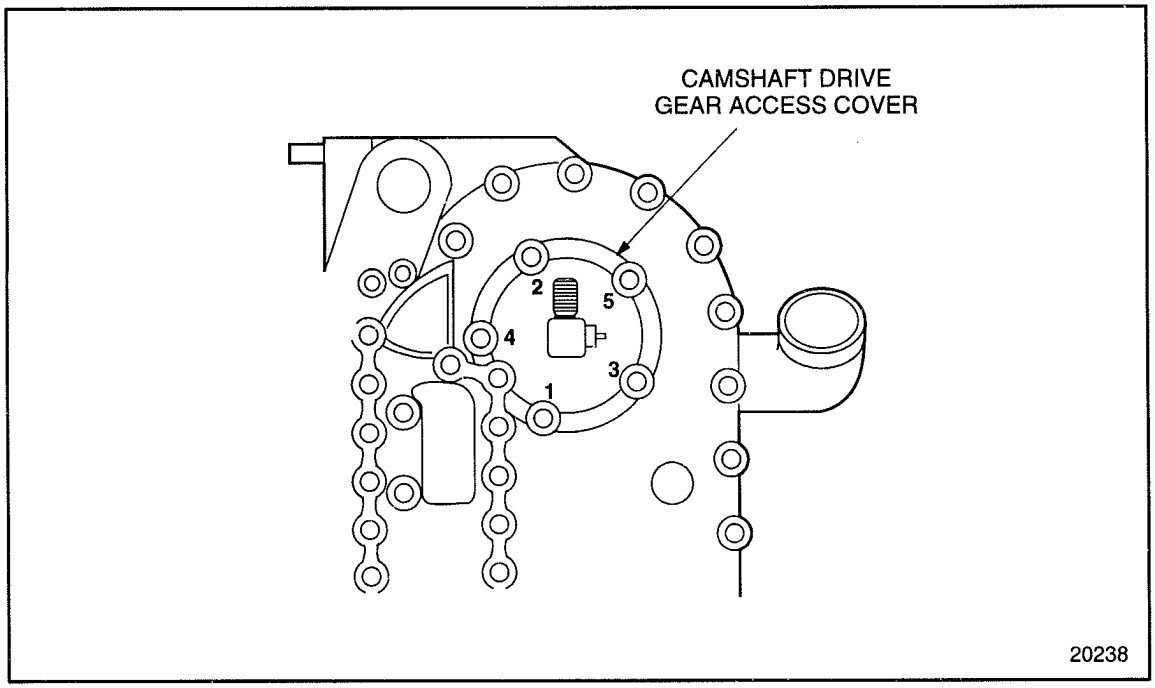


FIGURE 1–293 Camshaft Drive Gear Access Cover

16. Adjust the intake and exhaust valve clearances and set the injector heights. Refer to section 12.2.
17. Install the fan hub, fan, (refer to section 4.6.5), and drive belts; refer to section 13.5.8.
18. Install any other components that were removed for this procedure.

NOTICE:
The camshaft must be in time with the crankshaft. An engine which is "out of time" may result in pre–ignition, uneven running or a loss of power.

1.22.6.1 Test of Camshaft Timing

Check the camshaft timing as follows:

1. Remove the valve cover. Refer to section 1.6.2 for one–piece rocker cover. Refer to section 1.6.3 for two–piece rocker cover. Refer to section 1.6.4 for three–piece rocker cover.
2. Select any cylinder for the timing check.
3. Remove the rocker arm assembly for the cylinder selected. Refer to section 1.3.2.
4. Remove the injector for that cylinder. Refer to section 2.2.2.
5. Carefully slide a rod, approximately 30 mm (12 in.) long, through the injector tube hole until the end of the rod rests on top of the piston.

6. Turn the crankshaft slowly in the direction of engine rotation. Stop when the rod reaches the end of its upward travel.

NOTE:
The cylinder selected must be on the compression stroke when performing this check.

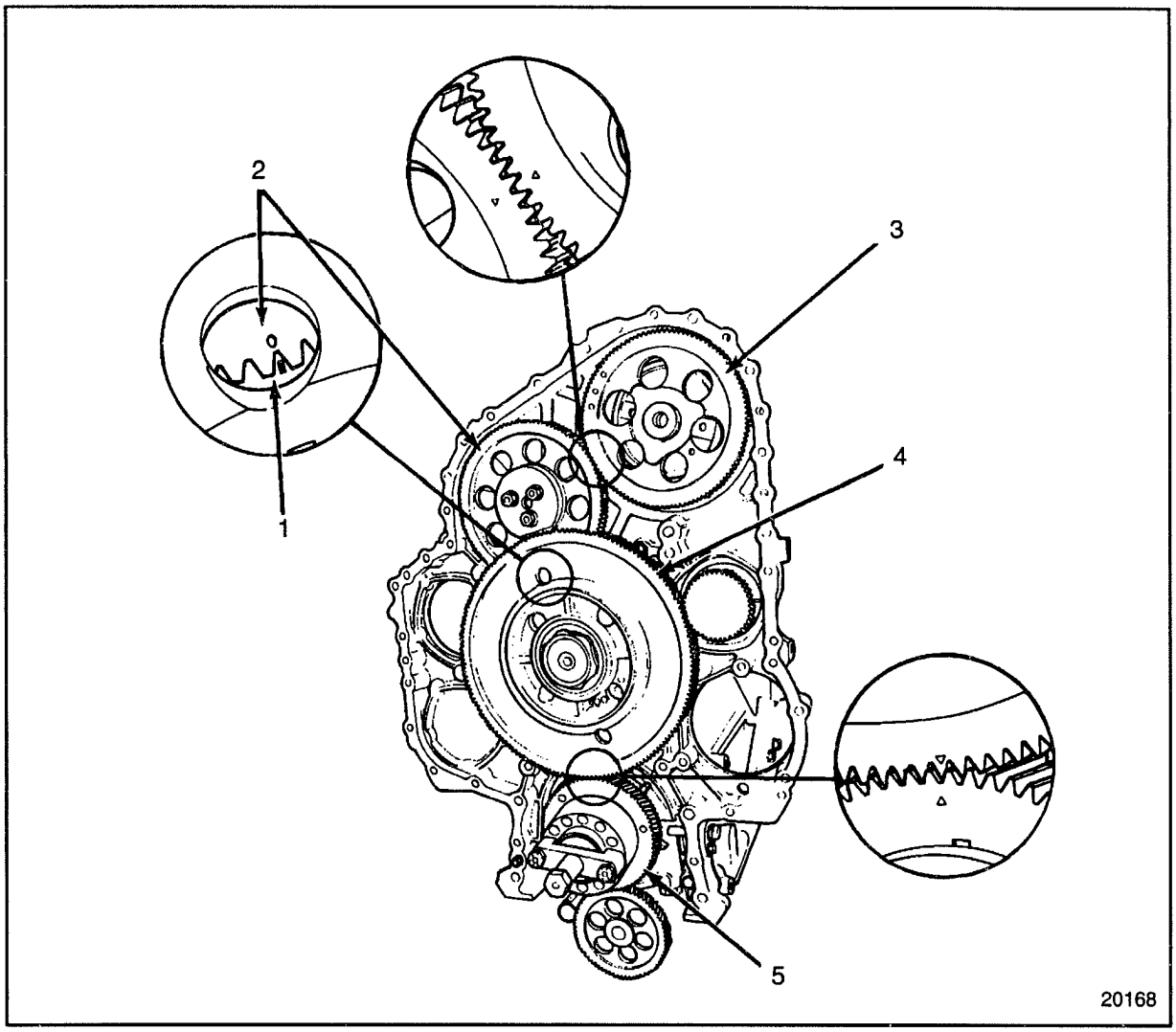
7. Remove the rod and turn the crankshaft, opposite the direction of rotation, between 1/16 and 1/8 of a turn.
8. Select a dial indicator with 0.01 mm (.001 in.) graduations and a spindle movement of at least 25 mm (1 in.). Provide an extension for the indicator spindle. The extension must be long enough to contact the piston just before it reaches the end of its upward stroke.
9. Install a magnetic dial indicator base in a suitable place on the cylinder head and position the dial indicator over the injector hole tube.
10. Attach a suitable pointer to the gear case cover. The outer end of the pointer should extend over the vibration damper.
11. Turn the crankshaft slowly in the direction of engine rotation until the indicator hand just stops moving. Continue turning the crankshaft until the indicator hand starts to move again.
12. Reset the dial to zero. Turn the crankshaft until the indicator reading is 0.25 mm (.010 in.).
13. Turn the crankshaft until the indicator reading is 0.25 mm (.010 in.).
14. Scribe a line on the vibration damper in line with the end of the pointer.
15. Slowly turn the crankshaft opposite the direction of engine rotation until the indicator hand just stops moving. Continue turning the crankshaft until the indicator hand starts to move again.
16. Reset the dial to zero. Then turn the crankshaft in the same direction until the indicator reading is 0.25 mm (.010 in.).
17. Scribe a second line on the vibration damper in line with the end of the pointer.
18. Scribe a third line half way between the first two lines. This is top dead center for the cylinder selected when the pointer is lined up with it.
19. Remove the dial indicator and base from the engine.
20. Install the injector that was removed. Refer to section 2.2.5.
21. Install the overhead assembly. Refer to section 1.3.3.
22. Turn the crankshaft opposite the direction of engine rotation while watching the injector rocker arm cam follower for the cylinder selected. Turn the crankshaft until the cam follower is on the base circle of the injector lobe of the cam.
23. Install a magnetic dial indicator base on the cylinder head. Install a dial indicator so that the spindle rests directly on the injector cam follower roller for the cylinder selected.

NOTE:
The spindle should be on the center line of the injector cam follower roller pin in order to get an accurate measurement of cam lift.

24. Turn the crankshaft slowly, in the direction of engine rotation, until the center mark on the vibration damper lines up with the pointer.
25. The correct indicator reading for all engines is 4.39 mm (.173 in.) to 5.46 mm (.215 in.).
26. If the cam lift is incorrect, retime the engine. Refer to section 1.21.2.1.

1.23 CAMSHAFT DRIVE GEAR

The camshaft drive gear, located at the front of the engine, under the gear case cover, is driven by the crankshaft through a series of intermediate gears. See Figure 1–294.



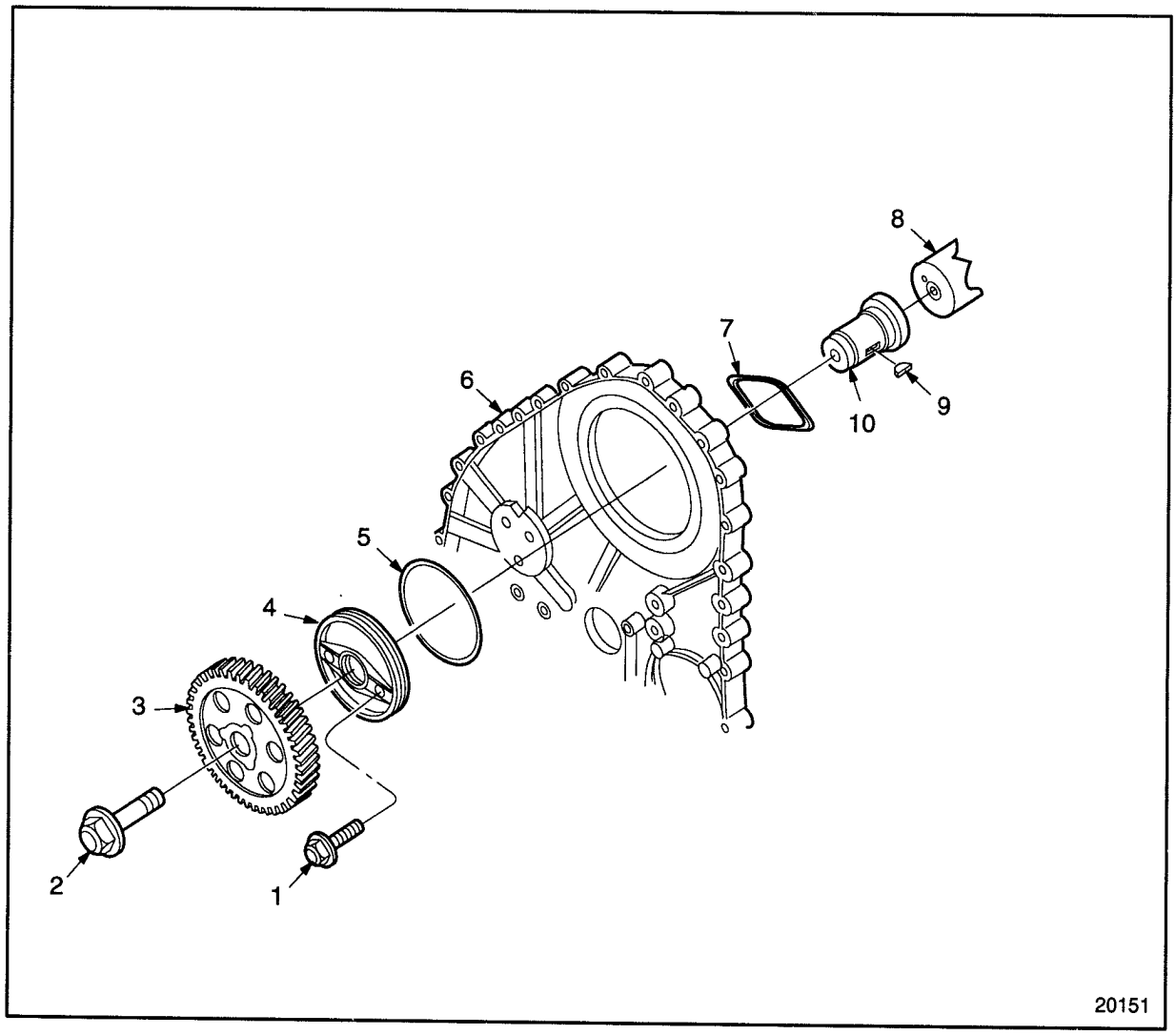
1. Idler Gear, Camshaft
2. Idler Gear, Adjustable
3. Drive Gear, Camshaft
4. Bull Gear
5. Timing Gear, Crankshaft

FIGURE 1–294 Engine Gear Train and Timing Marks

The gear train for the crankshaft drive consists of a crankshaft timing gear, mounted to the end of the crankshaft, meshing with a bull gear. To the rear of the bull gear is the camshaft idler gear, which is mounted on the same hub and rotates at the same speed as the bull gear. The camshaft idler gear meshes with an adjustable idler gear, which is mounted on a separate hub. The adjustable idler gear in turn meshes with the camshaft drive gear, which is mounted on the camshaft drive gear hub. The gears are designed so that the camshaft is driven at half crankshaft speed.

Since the camshaft must be timed exactly to the crankshaft, a series of timing marks are stamped or etched on the gear faces of these gears so that they may be installed in correct relationship to each other. Refer to section 1.21.3.

The camshaft drive gear is keyed and pressed onto a hub located in the thrust plate assembly at the end of the camshaft. The camshaft drive gear and hub are retained to the end of the camshaft by the camshaft drive gear retaining bolt which goes through the camshaft drive gear and the hub, and is threaded into the end of the camshaft. See Figure 1–295.



1. Bolt, Thrust Plate Retaining (2)
2. Bolt, Camshaft Hub Retaining
3. Drive Gear, Camshaft
4. Thrust Plate, Camshaft
5. O–ring
6. Gear Case
7. Seal, Thrust Plate
8. Camshaft
9. Key
10. Hub

FIGURE 1–295 Camshaft Drive Gear and Related Parts

The camshaft is indexed to the hub by a dowel. The camshaft drive gear hub rides in a camshaft thrust plate, which is retained by two bolts. One of these bolts screws into the cylinder head, while the other bolt screws into the number one camshaft bearing cap.

The camshaft thrust plate is sealed to the gear case by an O–ring which fits into a groove machined in the outer diameter of the thrust plate. A diamond shaped rubber seal that fits into a groove machined in the rear camshaft thrust plate face, seals the camshaft thrust plate to the cylinder head and number one camshaft cap. The dimple in the thrust plate must be installed at the 12 o'clock position to allow alignment of the thrust plate bolt holes with those in the cylinder head and Number 1 camshaft cap. See Figure 1–296.

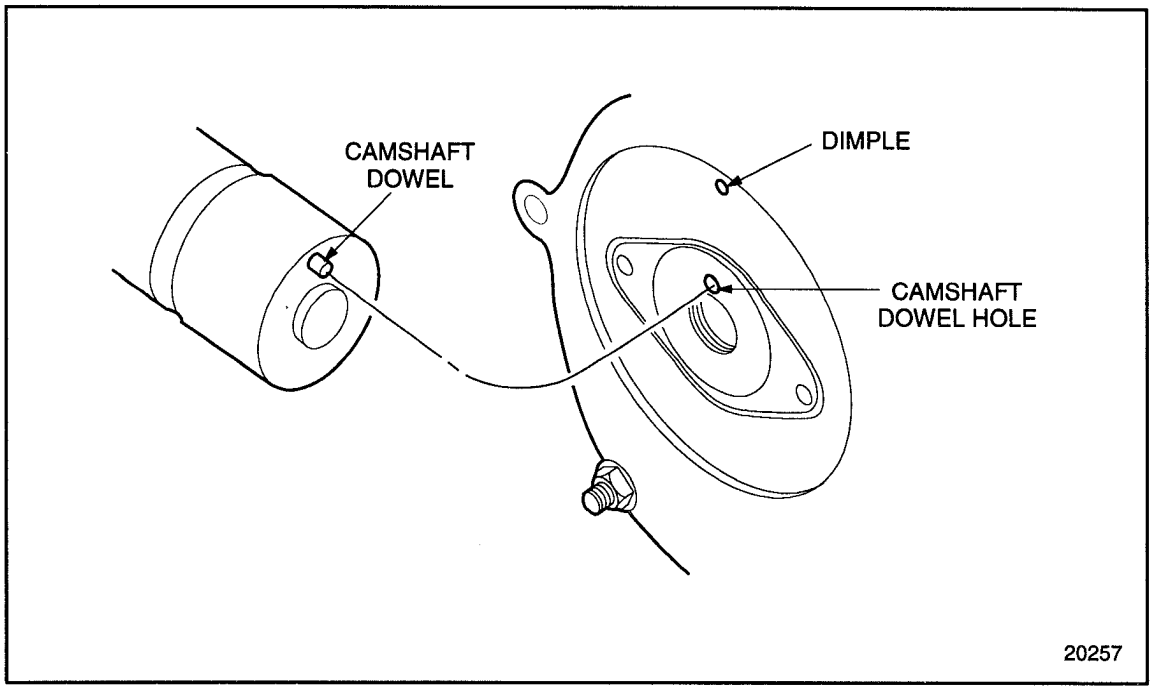


FIGURE 1–296 Camshaft Thrust Plate and Related Parts

The camshaft thrust plate can be moved horizontally in the gear case, to allow camshaft and cylinder head removal without damaging the thrust plate seal or removing the gear case cover. The camshaft drive gear will stay in mesh with its mating gear, and may be returned to its original position without retiming the gears.

1.23.1 Repair or Replacement of Camshaft Drive Gear

To determine if repair or replacement of the camshaft drive gear is necessary, preform the following procedure. See Figure 1–297.

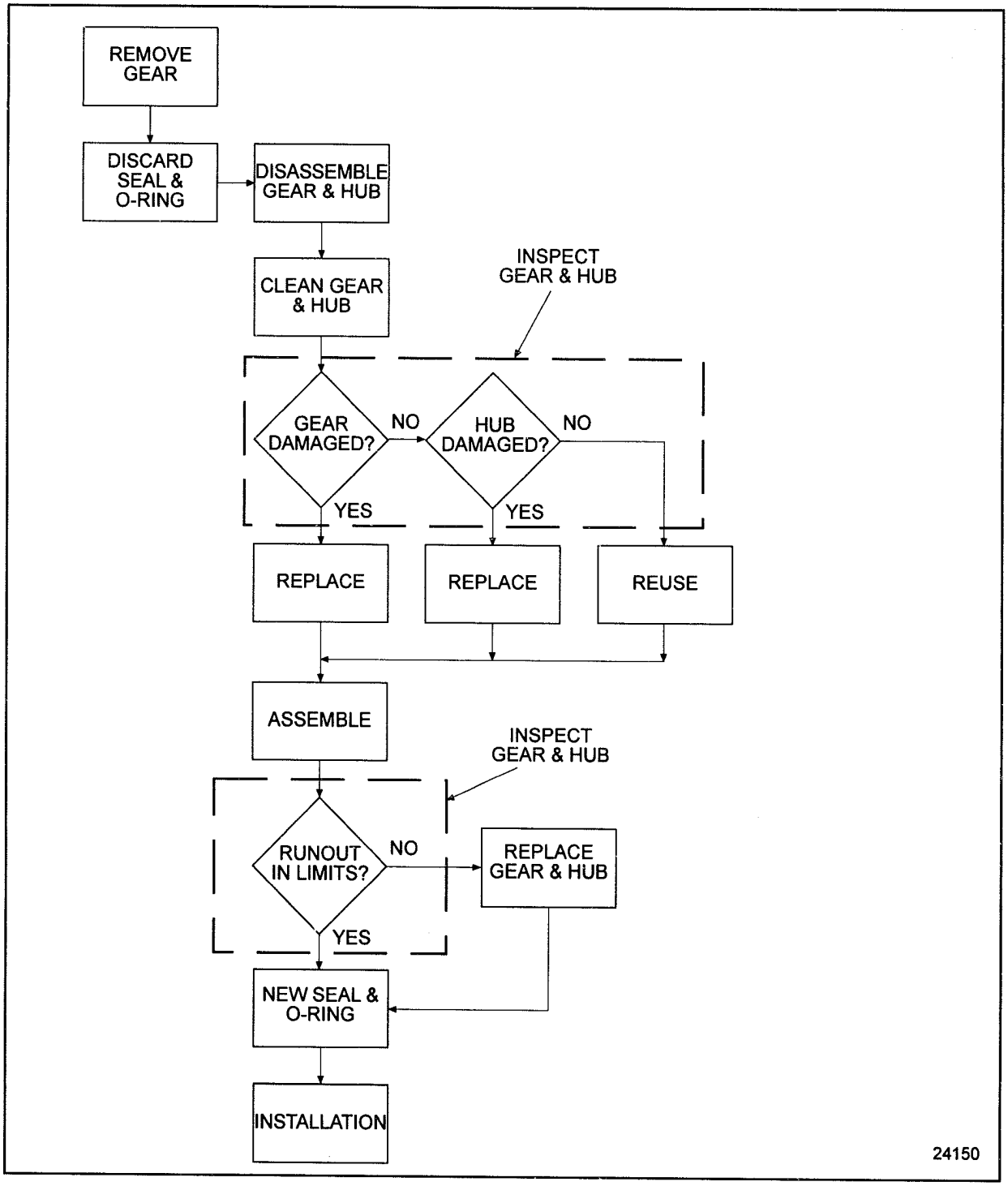


FIGURE 1–297 Flowchart for Repair or Replacement of Camshaft Drive Gear

1.23.2 Removal of Camshaft Drive Gear

Remove the camshaft drive gear as follows:

1. Remove the engine valve rocker cover. Refer to section 1.6.2 for one-piece rocker cover. Refer to section 1.6.3 for two-piece rocker cover. Refer to section 1.6.4 for three-piece rocker cover.
2. Remove the camshaft drive gear access cover, (refer to section 1.10.2) fan bracket, (refer to section 4.6.3) and camshaft retaining bolt, refer to section 1.22.2.

NOTICE:
Use care when removing the camshaft thrust plate retaining bolts to prevent their accidental dropping into the gear case and causing engine damage.

3. Working through the access holes in the camshaft drive gear, remove the two bolts that retain the camshaft thrust plate to the cylinder head and Number 1 camshaft bearing cap. See Figure 1-298.

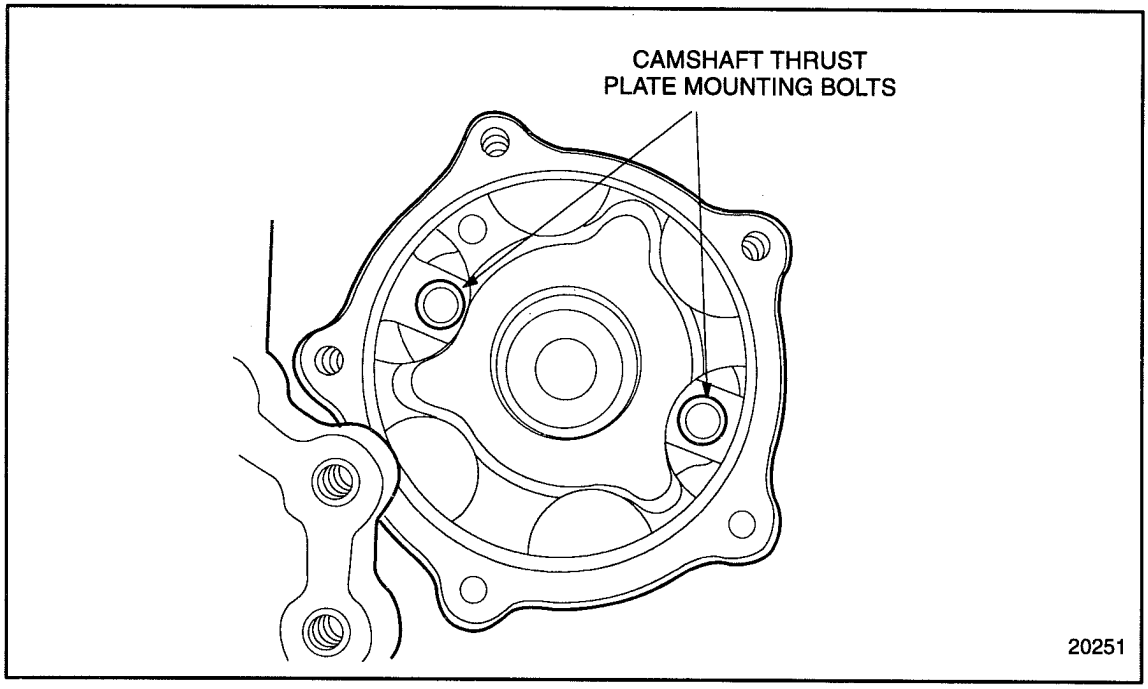


FIGURE 1-298 Camshaft Thrust Plate Retaining Bolts

4. Using the Camshaft Gear Pilot Tool, J 35906, pull the cam gear thrust plate assembly forward as far as possible to separate the assembly from the camshaft.
5. Remove the gear case cover. Refer to section 1.10.2.
6. Using a fiber mallet or plastic hammer, tap the rear face of the camshaft thrust plate forward until it is free of the gear case. See Figure 1-299.

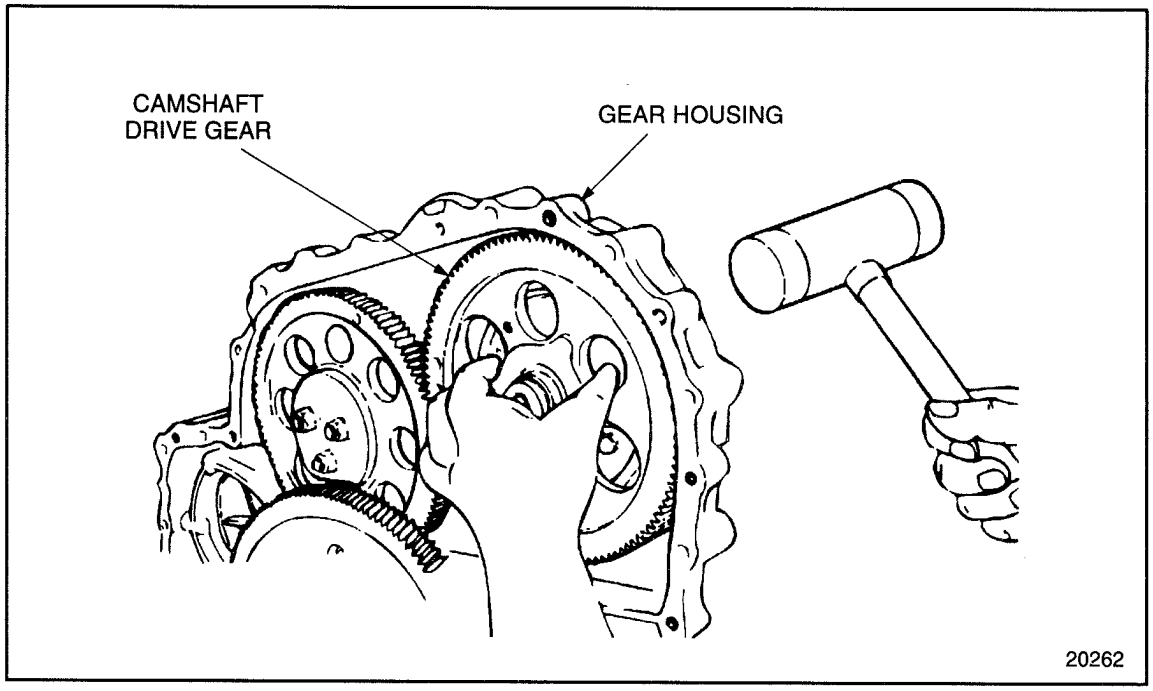


FIGURE 1–299 Removing Camshaft Thrust Plate Assembly

7. Remove the camshaft thrust plate, hub, and camshaft drive gear as an assembly. See Figure 1–300.

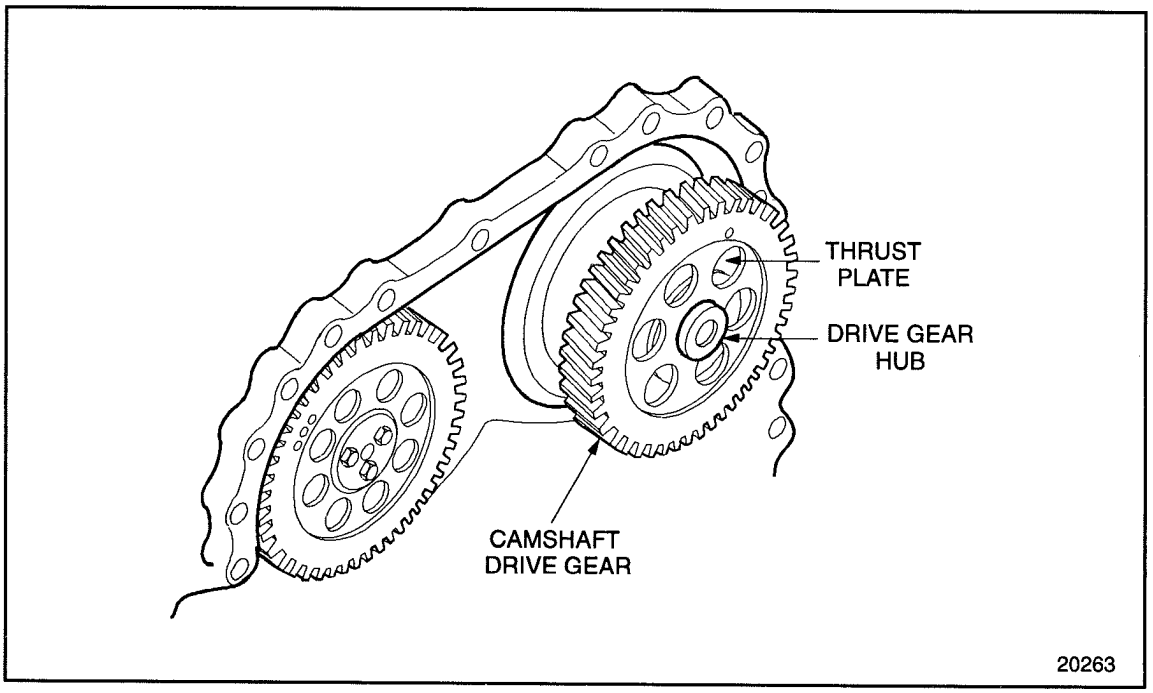


FIGURE 1–300 Camshaft Thrust Plate Assembly

8. Support the camshaft drive gear, with thrust plate facing down, on blocks.

9. Press the hub out of the camshaft drive gear until the hub separates from the camshaft thrust plate. See Figure 1-301.

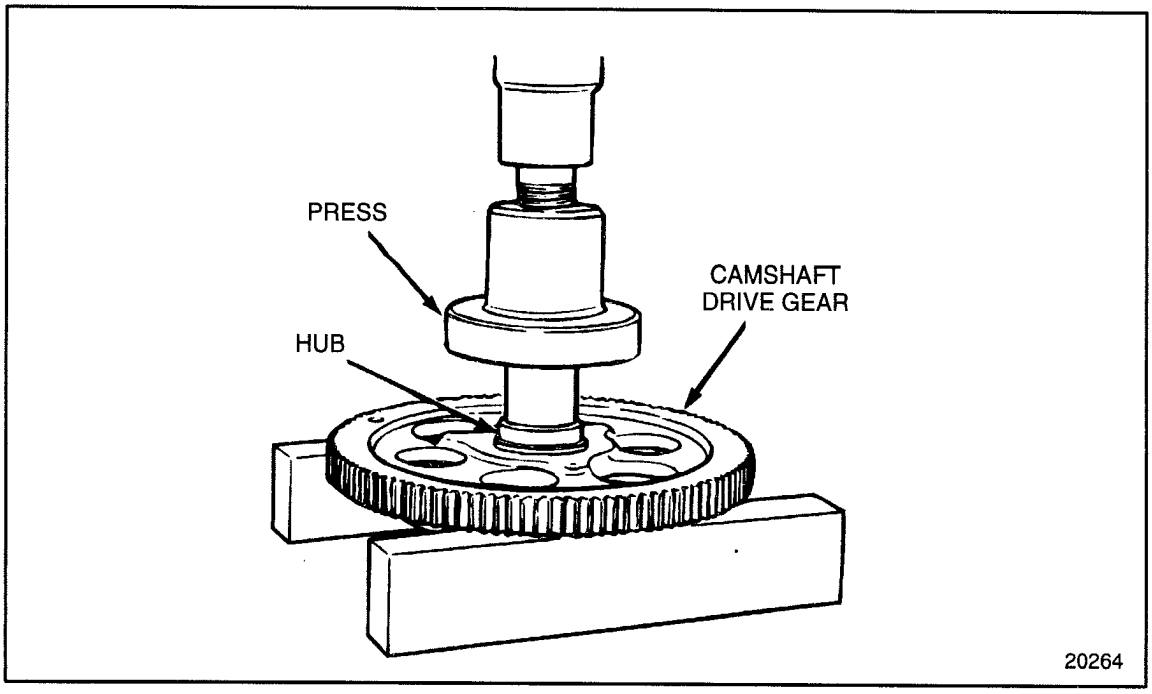


FIGURE 1-301 Camshaft Hub Removal

10. Remove the O-ring and seal from grooves int the camshaft thrust plate. Discard O-ring and seal.

1.23.2.1 Inspection of Camshaft Drive Gear

Inspect camshaft drive gear as follows:

1. Clean all parts with fuel oil.

CAUTION:

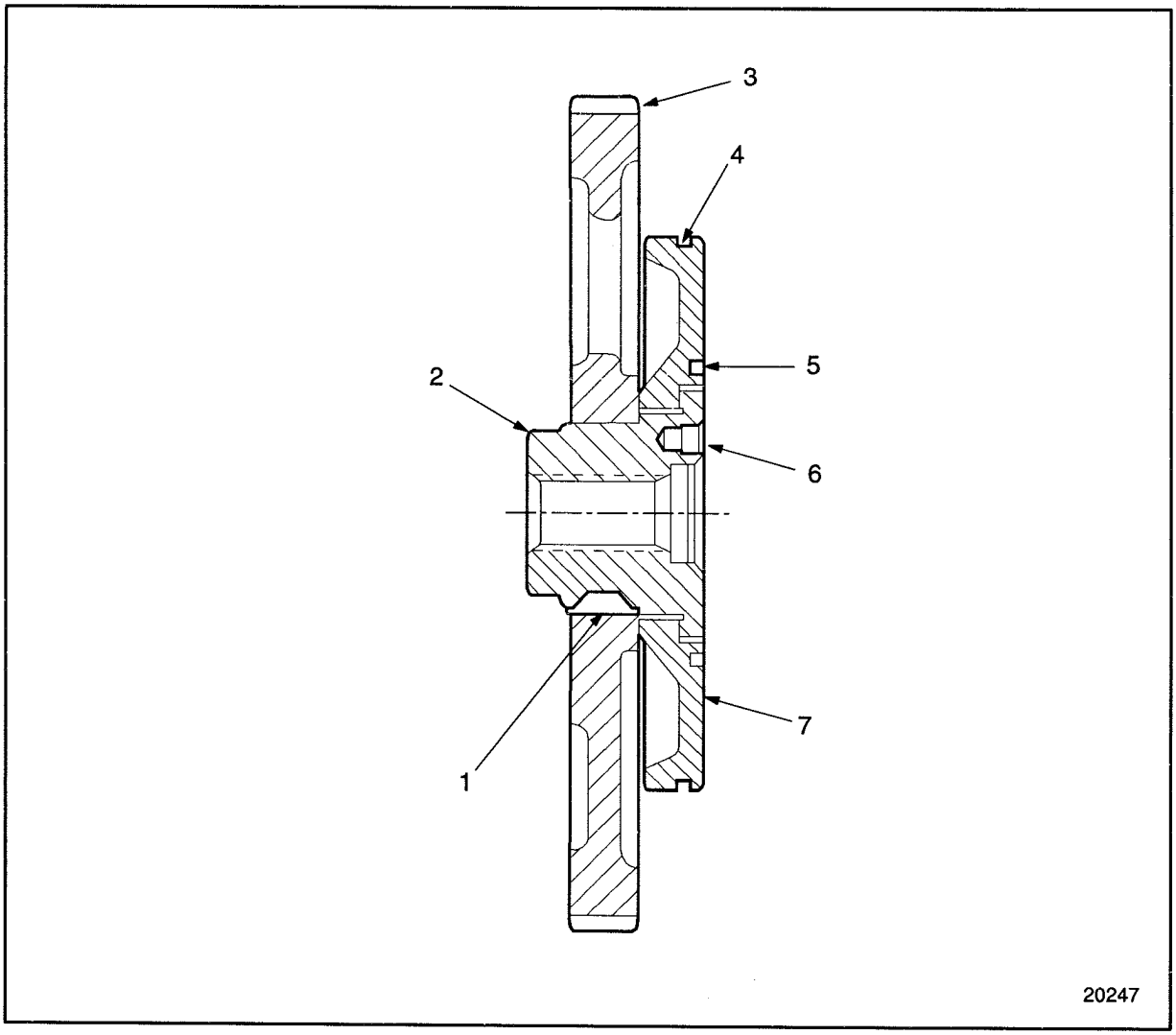
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry them with compressed air.
3. Examine the camshaft drive gear teeth for scoring, pitting, excessive wear and cracking, peening of the Woodruff Key Slot.
4. If camshaft drive gear is damaged, replace drive gear.
5. Inspect the camshaft drive gear hub for scoring, pitting, galling or cracking, peening of the Woodruff Key Slot.
6. If damaged, replace drive gear hub.

1.23.3 Installation of Camshaft Drive Gear

Install the camshaft drive gear, hub and thrust plate as follows:

1. Coat the contact surfaces of the hub and camshaft thrust plate with clean engine oil. See Figure 1–302.



1. Woodruff Key
2. Hub, Camshaft Drive Gear
3. Drive Gear, Camshaft
4. Groove, O–ring
5. Groove, Seal
6. Dowel Hole, Camshaft
7. Thrust Plate, Camshaft

FIGURE 1–302 Cross Section of Camshaft Drive and Related Parts

2. Install the hub to the camshaft thrust plate.
3. Install the key into the keyway on the hub.
4. Apply a thin film of Lubriplate to the bore of the camshaft gear.

NOTICE:
A minimum force of 20 kN (4500 lb) must be obtained when pressing the gear on the hub which can distort camshaft gear if applied off center. Only apply force to the inner hub of the gear when pressing.

5. Support the hub from the engine side.
6. Align the keyway in the camshaft drive gear with the key in the hub and press the gear, timing markup, onto the hub until it is firmly seated against the shoulder.

1.23.3.1 Test of Camshaft Drive Gear Assembly Runout

Measure the camshaft drive gear assembly runout as follows:

1. While supporting the camshaft thrust plate on blocks, position the camshaft drive gear assembly with the engine side facing down.
2. Assemble a dial indicator and magnetic base with the indicator stem rests on the face of the camshaft drive gear, just inboard of the drive gear teeth. Zero the dial indicator.
3. Rotate the drive gear two full rotations while reading the total indicated runout.

NOTE:
The total amount the dial indicator needle moves to the left and right of zero, added together, gives the total indicated runout Total Indicator Reading (TIR).

[a] Maximum allowable TIR is 0.114 mm (.0045 in.).
[b] If TIR exceeds limit, replace parts.

1.23.4 Installation of Camshaft Drive Gear – cont'd

Continue installing camshaft drive gear assembly as follows:

1. Coat the camshaft thrust plate O-ring with clean engine oil.
2. Install it into its groove in the camshaft thrust plate.
3. Install diamond seal into its groove on the engine side of the thrust plate.
4. Be sure the O-ring sealing surface of the gear case is clean and free of burrs.

5. Install the hub and camshaft thrust plate to the opening in the gear case. The depression in the rear face of the camshaft thrust plate must be positioned at 12 o'clock, see Figure 1–296, to align the retaining bolts in the thrust plate with those in the head and Number 1 cam cap.
6. Using a fiber mallet or plastic hammer, tap the camshaft drive gear at 90° intervals toward the engine, until the thrust plate bolts can be started in the cylinder head and Number 1 camshaft cap.

NOTICE:
Make sure camshaft dowel hole in camshaft drive hub is aligned with camshaft dowel prior to tightening thrust plate bolts. A misaligned hub can cause damage to the camshaft and thrust plate components

NOTICE:
Use care when installing the camshaft thrust plate retain bolts to prevent accidentally dropping them into the gear case and causing damage to gear train.

7. Using a 13 mm socket and ratchet, tighten the thrust plate bolts alternately and evenly to draw the thrust plate straight into the gear case. Tighten the bolts to 30 - 38 N·m (22–28 lb·ft) torque.
8. Install Gear Case Cover. Refer to section 1.10.3.

NOTICE:
Always hold the camshaft drive gear stationary using camshaft drive gear retaining tool J 35652 to prevent component damage, while loosening or tightening the camshaft drive gear–to–camshaft bolt.

9. Once the gear case cover has been installed and secured, install the Camshaft Drive Gear Retaining Tool, J 35652.

NOTE:
Before installing the fan support bracket and camshaft drive gear access cover, it will be necessary to install and tighten the camshaft drive gear retaining bolt, and to measure and adjust the adjustable gear–to–camshaft drive gear lash.

10. Install and tighten the camshaft drive gear retaining bolt using the following torques:
    [a] Solid head bolt - 244–280 N·m (179–205 lb·ft).
    [b] Slotted head bolt - 305–348 N·m (225–255 lb·ft).
11. Check the gear train timing and adjustable idler gear–to–camshaft drive gear lash. Refer to section 1.21.2.1.
12. Install the camshaft drive gear access cover, refer to section 1.22.5, and fan bracket. refer to section 4.6.5.
13. Install any components that were removed for access to the gear case cover.
14. Check the lubricating oil. Refer to section 13.5.1.
15. Check the coolant level. Refer to section 13.5.4.