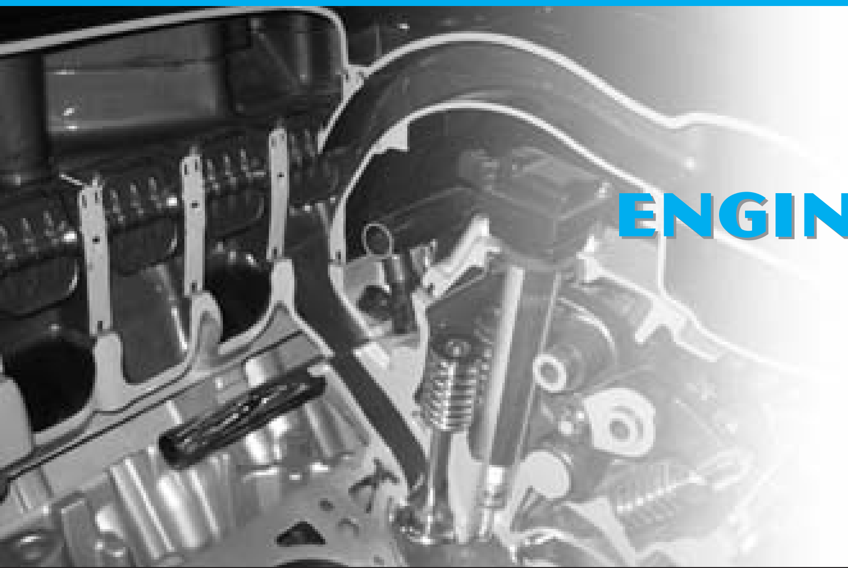
CHAPTER 30



ENGINE BLUEPRINTING AND ASSEMBLY

OBJECTIVES

After studying Chapter 30, the reader will be able to:

1. Prepare for Engine Repair (A1) ASE certification test content area "C" (Engine Block Diagnosis and Repair).
2. List the steps for assembling an engine.
3. Describe how to measure bearing oil clearance using plastic gauging material.
4. Explain how to check for crankshaft end play and connecting rod side clearance.
5. Discuss how to fit pistons to individual cylinder bores.
6. Describe how to test for proper oil pressure before starting the engine.

KEY TERMS

Acetic Acid (p. 586)
Amine-Type Silicone (p. 586)
Armor (p. 581)
Braided Fabric Seals (p. 572)
Cork-Rubber Gasket (p. 587)
Crankshaft End Play (p. 574)
Fire Ring (p. 581)
Lash (p. 603)
Multilayered Steel (MLS) (p. 581)
No-Retorque Gasket (p. 582)
Piston Ring Compressor (p. 576)
Room-Temperature Vulcanization (RTV) (p. 586)
Strip Feeler Gauge (p. 575)
Torque-Angle (p. 582)
Torque-To-Yield (p. 582)
Welsh Plugs (p. 569)
Wet Holes (p. 582)

All parts are attached to the engine block. The block, therefore, must be prepared before assembly can begin. The key to proper assembly of any engine is cleanliness. The work area and the workbench space must be clean to prevent dirt or other engine-damaging particles from being picked up and causing possible serious engine damage.

BLUEPRINTING

The term *blueprinting* means that all of the components of an engine have been carefully measured and checked that they match the specifications listed by the manufacturer. The engine manufacturer builds a new engine to the dimensions and tolerances specified on the blueprint, which is the engineering drawing of the parts and assembly. Therefore, to "blueprint" an engine is to make sure that all component parts and dimensions are within the range specified by the engine manufacturer.

BLOCK PREPARATION

All surfaces of the block should also be checked for damage resulting from the machining processes. Items that should be done before assembly begins include the following:

1. The block, including the oil gallery passages, should be thoroughly cleaned. See Figures 30-1 and 30-2.
2. All threaded bolt holes should be chamfered.
3. All threaded holes should be cleaned with a tap. See Figure 30-3.

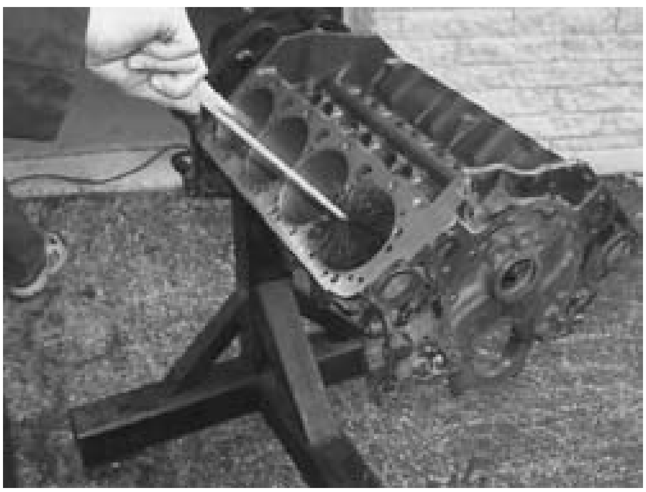


FIGURE 30-1 The best way to clean cylinders is to use soap (detergent) and water and thoroughly clean using a large washing brush. This method floats the machining particles out of the block and washes them away.

INSTALLING CUPS AND PLUGS

Oil gallery plugs should be installed using sealant on the threads. Core holes left in the external block wall are machined

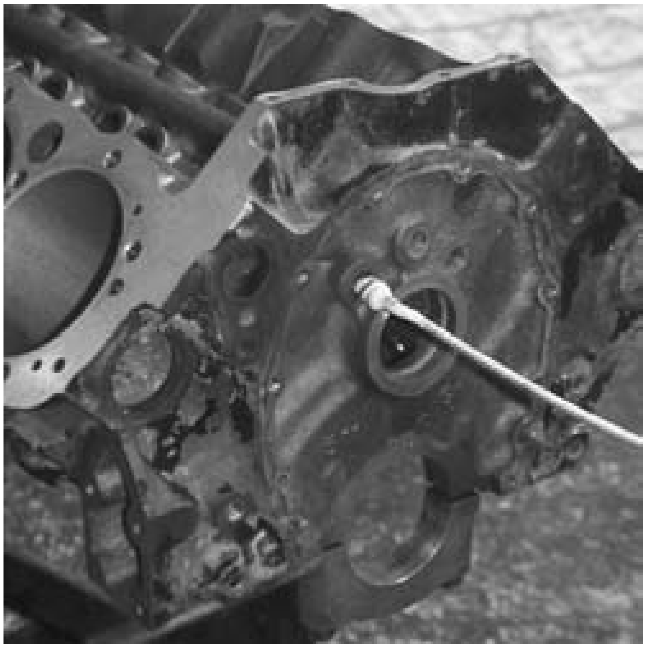


FIGURE 30-2 All oil galleries should be cleaned using soap (detergent) and water using a long oil gallery cleaning brush.

FIGURE 30-3 All threaded holes should be cleaned using a thread chaser or a bottoming tap.

and sealed with soft core plugs or expansion plugs (also called freeze plugs or **welsh plugs).**

CAUTION: Avoid using Teflon tape on the threads of oil gallery plugs. The tape is often cut by the threads, and thin strips of the tape are then free to flow through the oil galleries where the tape can cause a clog, thereby limiting lubricating engine oil to important parts of the engine.

Soft plugs are of two designs:

- **Convex type.** The core hole is counter bored with a shoulder. The convex soft plug is placed in the counter bore, convex side out. It is driven in and upset with a fitted seating tool. This causes the edge of the soft plug to enlarge to hold it in place. Figure 30-4 shows an installed convex soft plug. A convex plug should be driven in until it reaches the counter bore of the core plug hole.
- **Cup type.** This most common type fits into a smooth, straight hole. The outer edge of the cup is slightly bell mouthed. The bell mouth causes it to tighten when it is driven into the hole to the correct depth with a seating tool. An installed cup-type soft plug is shown in Figure 30-5. A cup plug is installed about 0.020 to 0.050 inch (0.5 to 1.3 millimeters) below the surface of the block, using sealant to prevent leaks. See Figure 30-6.

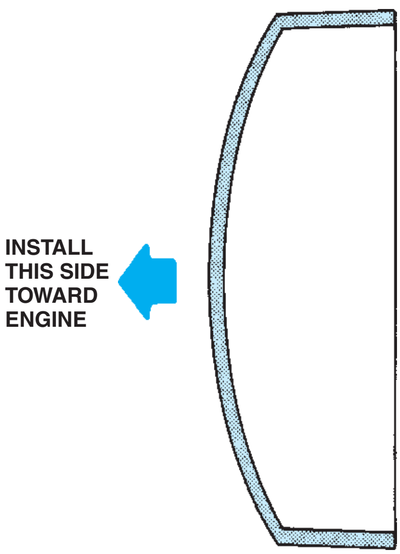


FIGURE 30-4 Convex plugs have a deep tapered flange. The flange should be coated with water-resistant sealer before being driven into the block.

INSTALLING CAM BEARINGS

A cam bearing installing tool is required to insert the new cam bearing without damaging the bearing. A number of tool manufacturers design and sell cam bearing installing tools. Their common feature is a shoulder on a bushing that fits inside the cam bearing, with a means of keeping the bearing aligned as it is installed. Figure 30-7 shows a camshaft bearing on the removing and installing tool. The bearing is placed on the bushing of the tool and rotated to properly align the oil hole. The

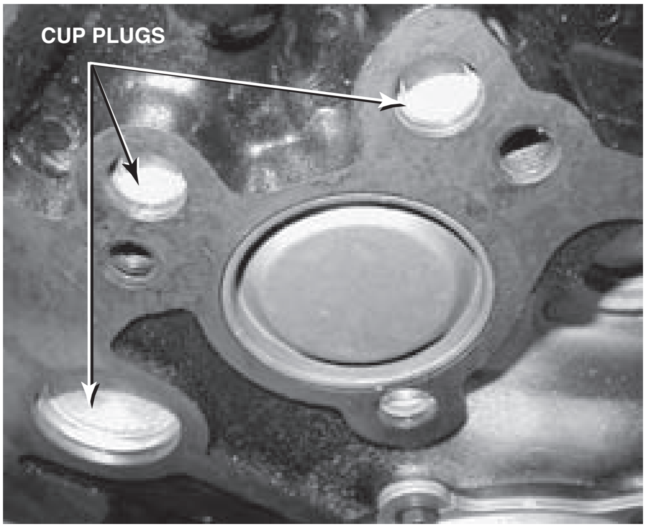


FIGURE 30-5 This engine uses many cup plugs to block off coolant and oil passages as well as a large plug over the end of the camshaft bore.

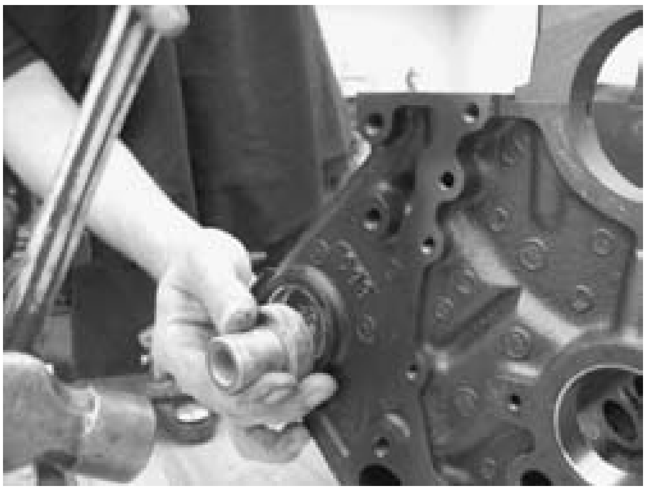


FIGURE 30-6 Sealer should be used on the cup plug before being driven into the block.

bearing is then forced into the bearing bore of the block by either a pulling screw or a slide hammer. A pulling screw type of tool is illustrated in Figure 30-8. The installed bearing must be checked to make sure that it has the correct depth and that the oil hole is indexed with the oil passage in the block. No additional service is required on cam bearings that have been properly installed. The opening at the back of the camshaft is closed with an expansion plug.

CAUSES OF PREMATURE BEARING FAILURE

According to a major manufacturer of engine bearings, the major causes of premature (shortly after installation) bearing failure include the following:

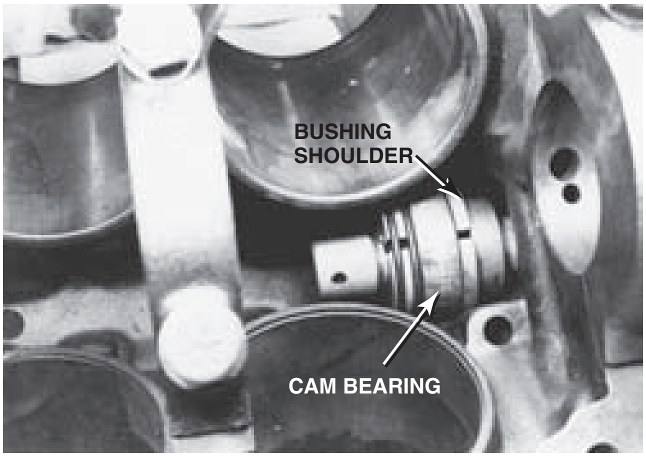


FIGURE 30-7 Cam bearing tool being used to remove a used cam bearing.

Dirt (45%)
Misassembly (13%)
Misalignment (13%)
Lack of lubrication (11%)
Overloading or lugging (10%)
Corrosion (4%)
Other (4%)

Many cases of premature bearing failure may result from a combination of several of these items. Therefore, to help prevent bearing failure, *keep everything as clean as possible.*

MEASURING MAIN BEARING CLEARANCE

The engine is assembled from the inside out. Checks are made during assembly to ensure correct fits and proper assembly of the parts.

The main bearings are properly fit before the crankshaft is lubricated or turned. The oil clearance of both main and connecting rod bearings is set by selectively fitting the bearings. In this way, the oil clearance can be adjusted to within 0.0005 inch of the desired clearance.

CAUTION: **Avoid touching bearings with bare hands. The oils on your fingers can start corrosion of the bearing materials. Always wear protective cloth or rubber gloves to avoid the possibility of damage to the bearing surface.**

Bearings are usually made in 0.010, 0.020, and 0.030 inch undersize for use on reground journals. See Figure 30-9 for a typical main bearing set.

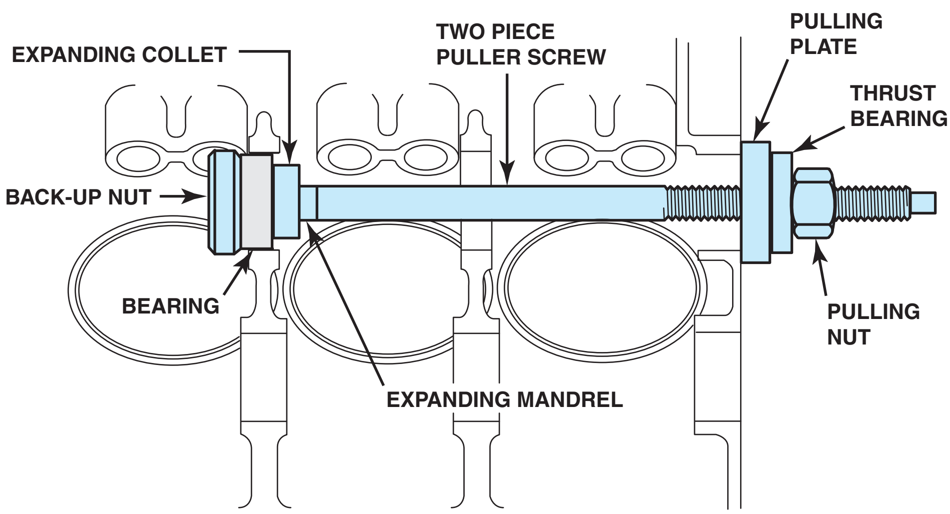


FIGURE 30-8 Screw-type puller being used to install a new cam bearing. Most cam bearings are crush fit. The full, round bearing is forced into the cam bearing bore. Cam bearing are installed "dry" without any lubrication.

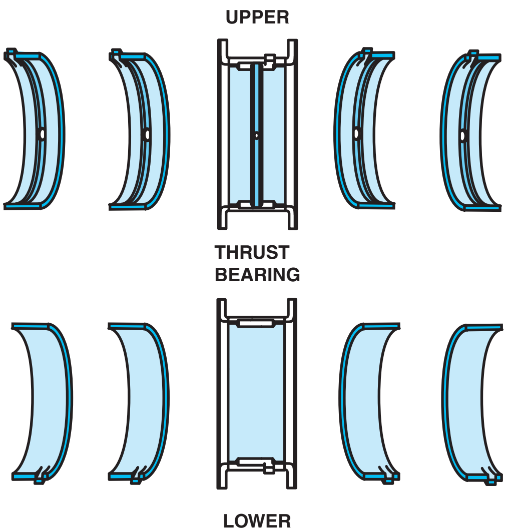


FIGURE 30-9 Typical main bearing set. Note that the upper halves are grooved for better oil flow and the lower halves are plain for better load support. This bearing set uses the center main bearing for thrust control.

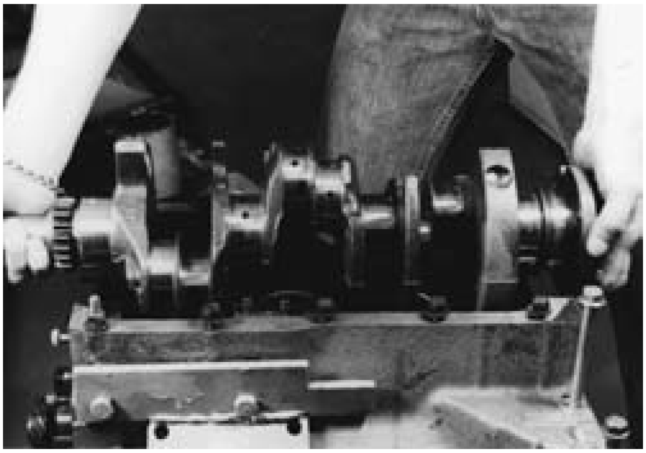


FIGURE 30-10 Crankshaft being carefully lowered into place.

The crankshaft bearing journals should be measured with a micrometer to select the required bearing size. Remember that each of the main bearing caps will only fit one location and the caps must be positioned correctly. The correct-size bearings should be placed in the block and cap, making sure that the bearing tang locks into its slot. The upper main bearing has an oil feed hole. Carefully rest the clean crankshaft in the block on the upper main bearings. Lower it squarely, as shown in Figure 30-10, so that it does not damage the thrust bearing. Place a strip of Plastigage (gauging plastic) on each main bearing journal. Install the main bearing caps and tighten the bolts to specifications. Remove each cap and check the width of the Plastigage with the markings on the gauge envelope, as shown in Figure 30-11. This will indicate the oil clearance. If the shaft is out-of-round, the oil clearance should be checked at the point that has the *least* oil clearance.

CORRECTING BEARING CLEARANCE

The oil clearance can be reduced by 0.001 inch by replacing both bearing shells with bearing shells that are 0.001 inch undersize. The clearance can be reduced by 0.0005 inch by replacing only one of the bearing shells with a bearing shell that is 0.001 inch smaller. This smaller bearing shell should be placed in the engine-block side of the bearing (the upper shell). Oil clearance can be adjusted accurately using this procedure. Never mismatch the bearing shells by more than a 0.001 inch difference in size. Oil clearances normally run from 0.0005 to 0.002 inch.

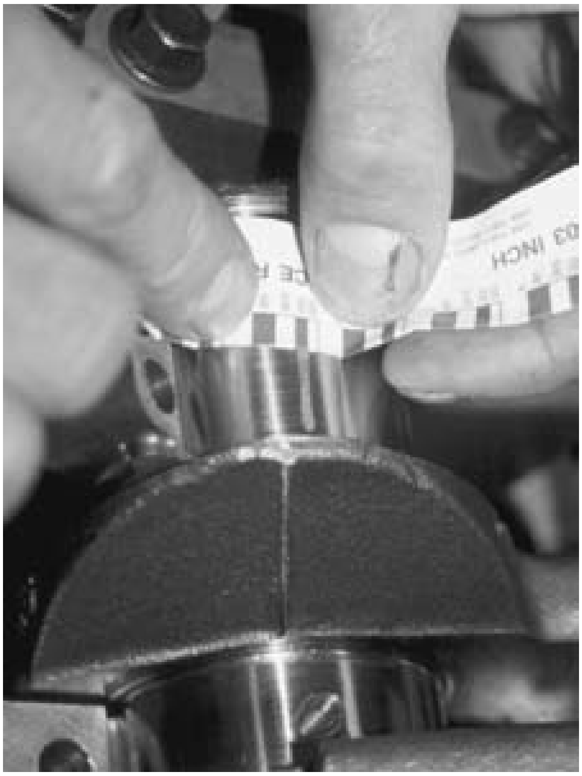


FIGURE 30-11 Checking the width of the plastic gauging strip to determine the oil clearance of the main bearing. An alternate method of determining oil clearance includes careful measurement of the crankshaft journal and bearings after they are installed and the main housing bore caps are torqued to specifications.

The crankshaft is removed once the correct oil clearance has been established. The rear oil seal is installed in the block and cap; then the crankshaft journals are lubricated with assembly lubricant.

TECH TIP

"ONE TO THREE"

When engine technicians are talking about clearances and specifications, the unit of measure most often used is thousandths of an inch (0.001 inch). Therefore, a clearance expressed as "one to three" would actually be a clearance of 0.001 to 0.003 inch. The same applies to parts of a thousandth of an inch. For example, a specification of 0.0005 to 0.0015 inch would be spoken of as simply being "one-half to one and one-half." The unit of a thousandth of an inch is assumed, and this method of speaking reduces errors and misunderstandings.

NOTE: Most engine clearance specifications fall within one- to three-thousandths of an inch. The written specification could be a misprint; therefore, if the specification does not fall within this general range, double-check the clearance value using a different source.

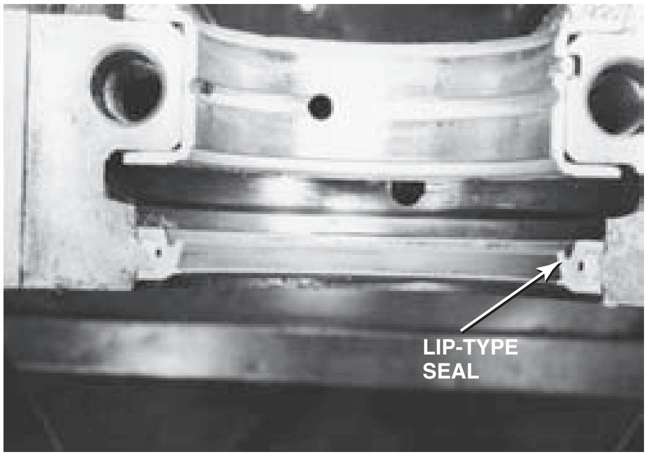


FIGURE 30-12 Lip-type rear main bearing seal in place. The crankshaft is removed.

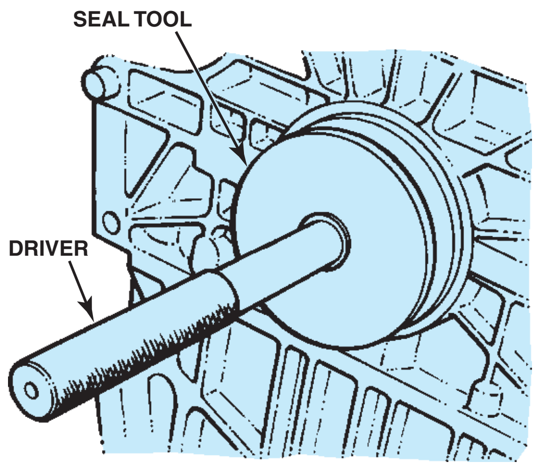


FIGURE 30-13 Always use the proper driver to install a main seal. Never pound directly on the seal.

LIP SEAL INSTALLATION

Seals are always used at the front and rear of the crankshaft. Overhead cam engines may also have a seal at the front end of the camshaft and at the front end of an auxiliary accessory shaft. Either a lip seal or a rope seal is used in these locations. See Figure 30-12. The rear crankshaft oil seal is installed after the main bearings have been properly fit.

The lip seal may be molded in a steel case or it may be molded around a steel stiffener. The counter bore or guide that supports the seal must be thoroughly clean. In most cases, the back of the lip seal is dry when it is installed. Occasionally, a manufacturer will recommend the use of sealants behind the seal. The engine service manual should be consulted for specific sealing instructions. The lip of the seal should be well lubricated before the shaft and cap are installed. See Figures 30-13 and 30-14.

CAUTION: Teflon seals should not be lubricated. This type of seal should be installed dry. When the engine is first started, some of the Teflon transfers to the crankshaft so a Teflon-to-Teflon surface is created. Even touching the seal with your hands could remove some of the outer coating on the seal and could cause a leak. Carefully read, understand, and follow the installation instructions that should come with the seal.

ROPE SEAL INSTALLATION

Rope-type seals, usually called **braided fabric seals,** are sometimes used as rear crankshaft oil seals. Some engines manufactured by Buick use rope-type seals at both the front and rear of the crankshaft. Rope-type oil seals must be compressed tightly into the groove so that no oil can leak behind them. With the crankshaft removed, the upper half of the rope seal is put in a clean groove and compressed by rolling a round object against it to force it tightly into the groove. A piece of pipe, a large socket, or even a hammer handle can be used for this, as shown in Figure 30-15. When the seal is fully seated in the groove, the ends that extend above the parting surface are cut to be flush with the surface using a sharp single-edge razor blade or a sharp tool specially designed to cut the seal.

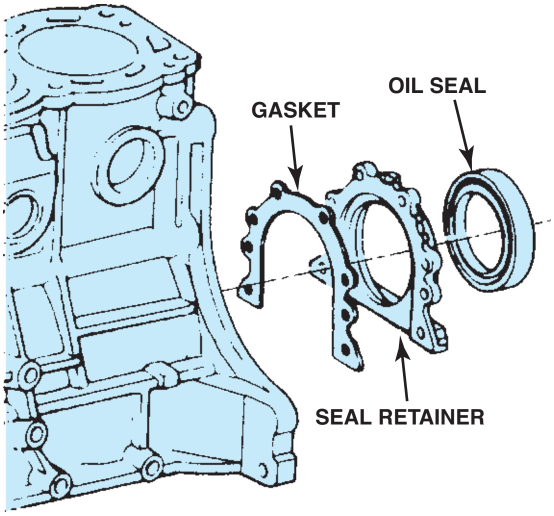


FIGURE 30-14 The rear seal for this engine mounts to a retainer plate. The retainer is then bolted to the engine block.

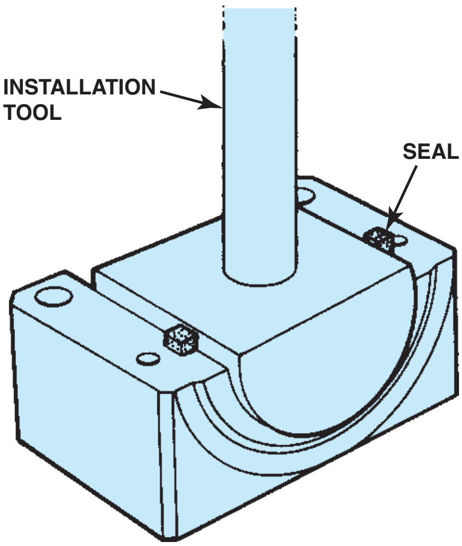


FIGURE 30-15 Use a special tool or other round object like a hammer handle to roll the seal to the bottom of the groove.

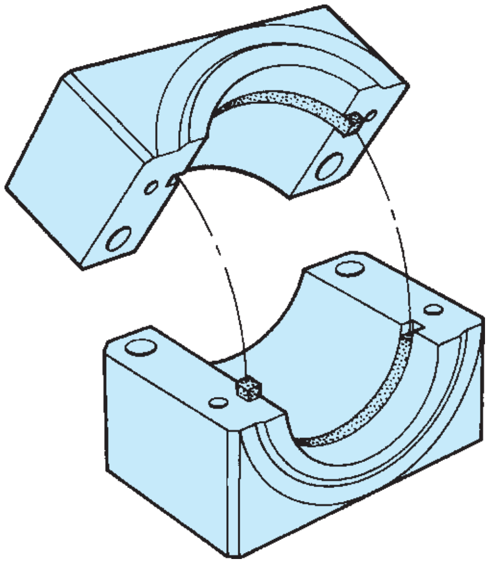


FIGURE 30-16 Many engine builders prefer to stagger the parting lines of a split seal.

FIGURE 30-17 Engine assembly lubricant is best to use because it contains additives that provide protection to engine parts during the critical original start-up phase.

The same procedures are used to install the lower half of the rope seal in the rear main bearing cap or seal retainer. See Figure 30-16.

INSTALLING THE CRANKSHAFT

The main bearing saddles, the caps, and the back of all the main bearing shells should be wiped clean; the bearing shells can then be put in place. It is important that each bearing tang line up with the slot in the bearing support. The bearing shells must have some spread to hold them in the bearing saddles and caps during assembly. The surface of the bearings is then given a thin coating of assembly lubricant to provide initial lubrication for engine start-up. See Figure 30-17.

The crankshaft with lubricant on the journals is carefully placed in the bearings to avoid damage to the thrust bearing surfaces. The bearing caps are installed with their identification numbers correctly positioned. The caps were originally machined in place, so they can only fit correctly in their original position. The main bearing cap bolts are tightened finger-tight, and the crankshaft is rotated. It should rotate freely.

MEASURING THRUST BEARING CLEARANCE

Pry the crankshaft forward and rearward to align the cap half of the thrust bearing with the block saddle half. Most engine specifications for thrust bearing clearance (also called **crankshaft end play**) can range from 0.002 to 0.012 inch (0.02 to 0.3 millimeter). This clearance or play can be measured with a feeler gauge (Figure 30-18) or a dial indicator (Figure 30-19).

If the clearance is too great, oversize main thrust bearings may be available for the engine. Semifinished bearings may have to be purchased and machined to size to restore proper tolerance.

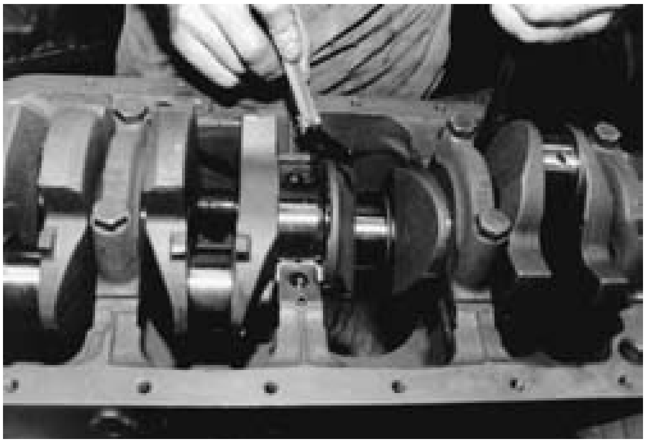


FIGURE 30-18 Checking crankshaft thrust bearing clearance with a feeler gauge. The technician in this photo has not yet installed the thrust bearing cap; this allows a better view of the actual movement and clearance as the crankshaft is pried back and forth.

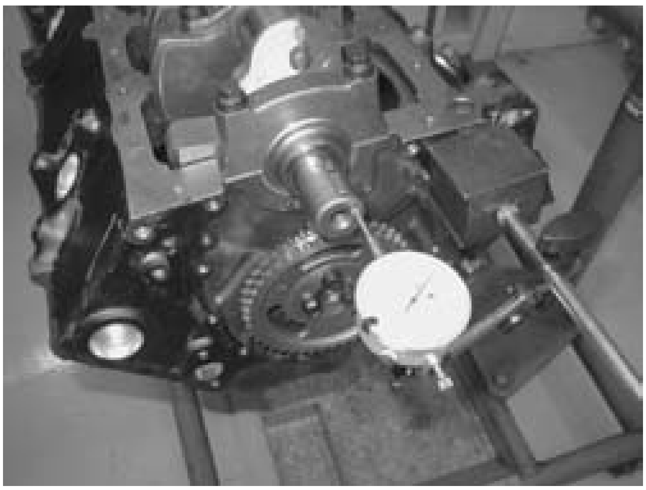


FIGURE 30-19 A dial indicator is being used to check the crankshaft end play (also known as thrust bearing clearance). Always follow the manufacturer's recommended testing procedures.

TIGHTENING PROCEDURE FOR THE MAIN BEARING

Tighten the main bearing caps to the specified assembly torque, and in the specified sequence. Many manufacturers require that the crankshaft be pried forward or rearward during the main bearing tightening process. The crankshaft should turn freely after all main bearing cap bolts are fully torqued. See Figure 30-20. It should never require over 5 pound-feet (6.75 Newton-meters [N-m]) of torque to rotate the crankshaft. An increase in the torque needed to rotate the crankshaft is often caused by a foreign particle that was not removed during cleanup. It may be on the bearing surface, on the crankshaft journal, or between the bearing and saddle.

INSTALLING TIMING CHAINS AND GEARS

On pushrod engines, the timing gears or chain and sprocket can be installed after the crankshaft. The timing marks should be aligned according to the factory-specified marks. See Figure 30-21. When used, the replaceable fuel-pump eccentric is installed as the cam sprocket is fastened to the cam. The crankshaft should be rotated several times to see that the camshaft and timing gears or chain rotate freely. The timing mark alignment should be rechecked at this time. If the engine is equipped with a slinger ring, it should also be installed on the crankshaft, in front of the crankshaft gear.

It is assumed that the front oil seal is installed in the cover. The timing cover and gasket are placed over the timing gears and/or chain and sprockets. The attaching bolts are loosely installed to allow the damper hub to align with the cover as it

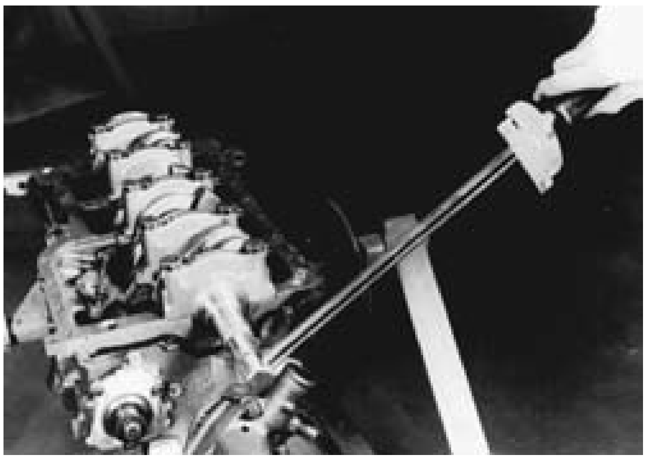


FIGURE 30-20 Measuring the crankshaft turning torque after each main bearing cap is properly tightened. An abnormal increase in torque indicates a problem that should be corrected before additional assembly.

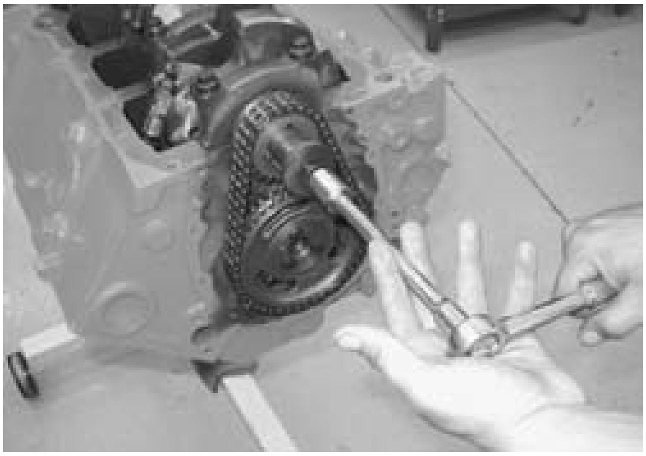


FIGURE 30-21 Timing chain and gears can be installed after the crankshaft and camshaft have been installed. The technician is rotating the crankshaft using the harmonic balancer bolt to check for proper rotating torque and to confirm that the timing marks are aligned.

fits in the seal. The damper is installed on the crankshaft. On some engines, it is a press-fit and on others it is held with a large center bolt. After the damper is secured, the attaching bolts on the timing cover can be tightened to the specified torque.

PISTON FITTING

After thorough block cleaning, the piston-to-cylinder clearance should be checked to ensure that the piston properly fits the cylinder in which it is to operate. The fit can be checked by determining the difference in the measured size of the piston and cylinder. A **strip feeler gauge** placed between the piston and the cylinder can be used to measure the piston-to-cylinder clearance. The gauge thickness is the desired clearance measurement. Typical piston clearances range from about 0.0005 in. (1/2 thousandth of an inch) to 0.0025 in. (2 1/2 thousandths of an inch) (0.02 to 0.06 millimeter).

The cylinders and pistons, without rings, should be wiped thoroughly clean to remove any excess protective lubricant and dust that may have accumulated on the surface. The strip thickness (feeler) gauge is placed in the cylinder along the thrust side. The piston is inserted in the cylinder upside down, with the piston thrust surface against the thickness (feeler) gauge. The piston is held in the cylinder with the connecting rod as the strip gauge is withdrawn. A moderate pull (from 5 to 10 pounds) on the gauge indicates that the clearance is the same as the gauge thickness. A light pull indicates that the clearance is greater than the gauge thickness, whereas a heavy pull indicates that the clearance is smaller than the gauge thickness.

All pistons should be tested in all cylinder bores. Even though all cylinders were honed to the exact same dimension

FIGURE 30-22 A feeler gauge is used to check piston ring gap.

and all pistons were machined to the same diameter, some variation in dimensions will occur. *Each piston should be selectively fitted to each cylinder.* This procedure helps to prevent mismatched assembled components and results in a better-performing and longer-lasting engine. By checking all cylinders, the technician is also assured that the machining of the block was done correctly.

Ring End Gap

The bottom of the combustion chamber is sealed by the piston rings. They have to fit correctly in order to seal properly. Piston rings are checked both for side clearance and for gap. See Figure 30-22. Typical ring gap clearances are about 0.004 inch per inch of cylinder bore, or as follows:

Piston Diameter	Ring Gap
2 to 3 inches	0.007 to 0.018 inch
3 to 4 inches	0.010 to 0.020 inch
4 to 5 inches	0.013 to 0.023 inch

NOTE: If the gap is greater than recommended, some engine performance is lost. However, too small a gap will result in scuffing because of ring butting during operation, which forces the rings to scrape the cylinders.

If the ring gap is too large, the ring should be replaced with one having the next oversize diameter. If the ring gap is too small, the ring should be removed and filed to make the gap larger.

INSTALLING PISTON AND ROD ASSEMBLIES

Be sure to note which piston/rod assembly goes into which cylinder. Double-check the following:

1. Be sure the piston notch "front" or arrow points toward the front of the engine.
2. Be sure that the valve reliefs end up closest to the lifter valley on a V-type OHV engine.
3. Be sure that the larger valve reliefs always match the intake valve.
4. Make sure the connecting rod has been installed on the piston correctly—the chamfer on the side of the big end should face outward (toward the crank throw). See Figure 30-23.
5. Be sure the piston ring gaps are set according to the manufacturer's recommendations. See Figure 30-24.

The cylinder is wiped with a lintless cleaning cloth. It is then given a liberal coating of clean engine oil. This oil is spread over the entire cylinder wall surface by hand.

The connecting rod bearings are prepared for assembly in the same way, as are the main bearings. The piston can be dipped in a bath of clean engine oil to lubricate the piston pin as well as the piston rings. See Figure 30-25.

NOTE: Some overlapping (gapless) piston rings are installed dry, without oil. See Figure 30-26. Some manufacturers recommend oiling only the oil control ring. Always check the piston ring instruction sheet for the exact procedure.

When the piston is lifted from the oil, it is held and let drip for a few seconds. This allows the largest part of the oil to run out of the piston and ring grooves. The **piston ring compressor** is then put on the piston to hold the rings in their grooves. See Figures 30-27 and 30-28.

The bearing cap is removed from the rod, and protectors are placed over the rod bolts. See Figure 30-29. The crankshaft is rotated so that the crankpin is at the bottom center. The upper rod bearing should be in the rod, and the piston should

FIGURE 30-23 On V-type engines that use paired rod journals, the side of the rod with the large chamfer should face toward the crank throw (outward).

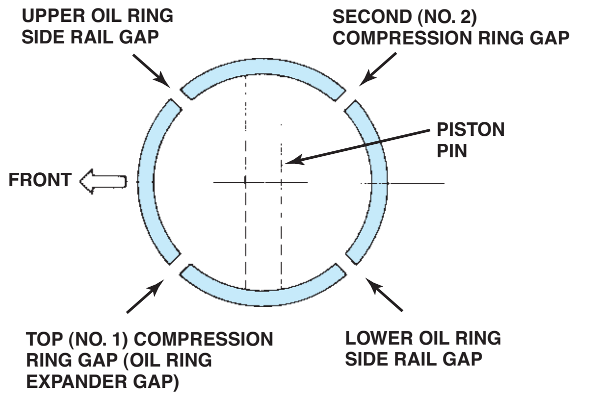


FIGURE 30-24 One method of piston ring installation showing the location of ring gaps. Always follow the manufacturer's recommended method for the location of ring gaps and for ring gap spacing.

FIGURE 30-25 Dipping the piston, with rings installed, into a container of engine oil is one method that can be used to ensure proper lubrication of pistons during installation in the engine cylinder. This method also ensures that the piston pin will be well lubricated.

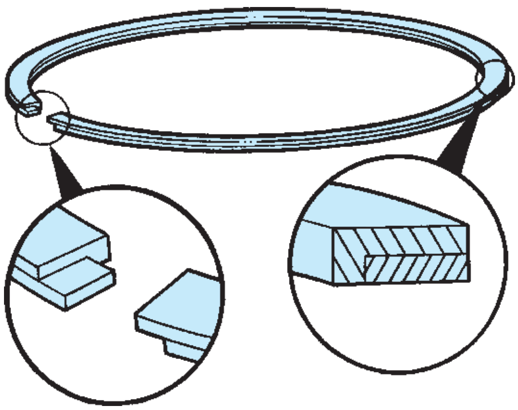


FIGURE 30-26 A gapless ring is made in two pieces that overlap.

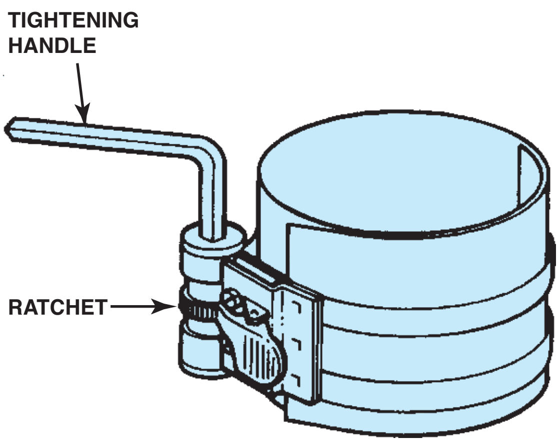


FIGURE 30-27 This style of ring compressor uses a ratchet to contract the spring band and compress the rings into their grooves.

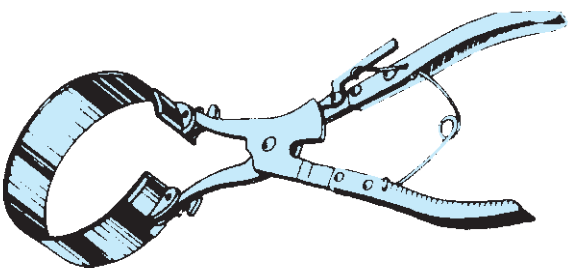


FIGURE 30-28 This plierslike tool is used to close the metal band around the piston to compress the rings. An assortment of bands are available to service different size pistons.

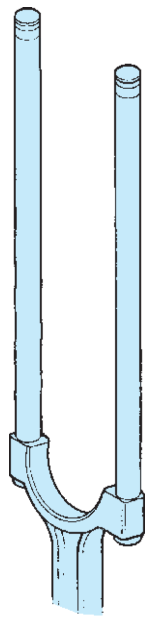


FIGURE 30-29 When threaded onto the rod bolts, these guides not only help align the rod but they also protect the threads and hold the bearing shell in place. The soft ends also will not damage the crankshaft journals.

FIGURE 30-30 Installing a piston using a ring compressor to hold the rings in the ring grooves of the piston and then using a hammer handle to drive the piston into the bore. Connecting rod bolt protectors have been installed to help prevent possible damage to the crankshafts during piston installation.

be turned so that the notch on the piston head is facing the front of the engine.

The piston and rod assembly is placed in the cylinder through the block deck. The ring compressor must be kept tightly against the block deck as the piston is pushed into the cylinder. The ring compressor holds the rings in their grooves so that they will enter the cylinder. See Figure 30-30. The piston is pushed into the cylinder until the rod bearing is fully seated on the journal.

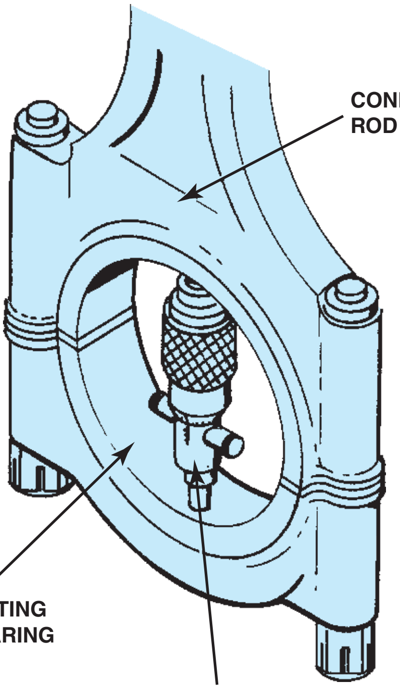


FIGURE 30-31 An inside micrometer can be used to measure the inside diameter of the big end of the connecting rod with the bearings installed. This dimension subtracted from the rod journal diameter is equal to the bearing clearance.

TECH TIP

TIGHTENING TIP FOR ROD BEARINGS

Even though the bearing clearances are checked, it is still a good idea to check and record the torque required to rotate the crankshaft with all piston rings dragging on the cylinder walls. Next, the retaining nuts on one bearing should be torqued; then the torque required to rotate the crankshaft should be rechecked and recorded. Follow the same procedure on all rod bearings. If tightening any one of the rod bearing caps causes a large increase in the torque required to rotate the crankshaft, immediately stop the tightening process. Determine the cause of the increased rotating torque using the same method, as used on the main bearings. Rotate the crankshaft for several revolutions to make sure that the assembly is turning freely and that there are no tight spots.

The rotating torque of the crankshaft with all connecting rod cap bolts fully torqued should be as follows:

- **four-cylinder engine**—20 pound-feet maximum (88 Newton-meters)
- **six-cylinder engine**—25 pound-feet maximum (110 Newton-meters)
- **eight-cylinder engine**—30 pound-feet maximum (132 Newton-meters)

Connecting Rod Bearing Clearance

The rod cap, with the bearing in place, is put on the rod. There are two methods that can be used to check for proper connecting rod clearance:

- Use Plastigage following the same procedure discussed for main bearing clearance.
- Measure the assembled connecting rod big-end devices with the bearing installed and the caps torqued to specification. Subtract the diameter of the rod journal to determine the bearing clearance. See Figure 30-31.

NOTE: **Be certain to check for piston-to-crankshaft counterweight clearance. Most manufacturers specify a minimum 0.060 inch (1.5 millimeters).**

Connecting Rod Side Clearance

The connecting rods should be checked to make sure that they still have the correct side clearance. This is measured by fitting the correct thickness of feeler gauge between the connecting rod and the crankshaft cheek of the bearing journal. See Figure 30-32.

A dial gauge can also be set up to measure the connecting rod side clearance.

- *If the side clearance is too great*, excessive amounts of oil may escape that can cause lower-than-normal oil pressure. To correct excessive clearance:
  1. Weld and regrind or replace the crankshaft
  2. Carefully measure all connecting rods and replace those that are too thin or mismatched.
- *If the side clearance is too small*, there may not be enough room for heat expansion. To correct a side clearance that is too small:
  1. Regrind the crankshaft
  2. Replace the rods

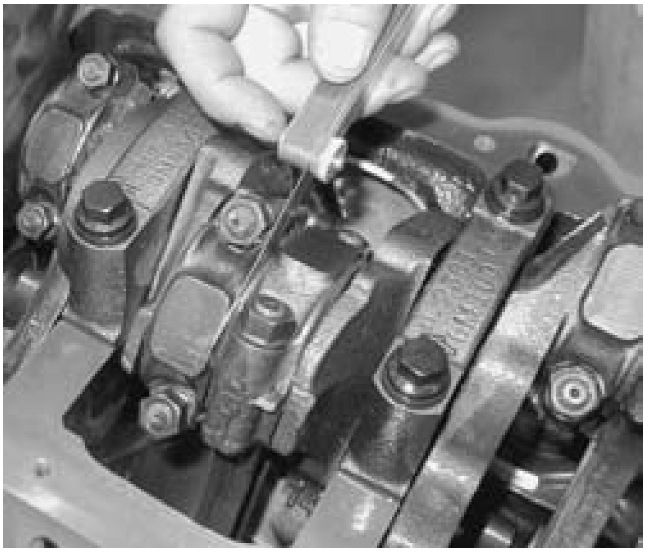


FIGURE 30-32 The connecting rod side clearance is measured with a feeler gauge.

INSTALLING THE CAMSHAFT FOR OVERHEAD CAM ENGINES

The camshaft is usually installed on overhead cam engines before the head is fastened to the block deck. Some engines have the camshaft located directly over the valves. The cam bearings on these engines can be either one piece or split. The cam bearings and journals are lubricated before assembly. In other engine types, the camshaft bearings are split to allow the camshaft to be installed without the valves being depressed. The caps are tightened evenly to avoid bending the camshaft. The valve clearance or lash is checked with the overhead camshaft in place. Some engines use shims under a follower disk as shown in Figure 30-33. On these, the camshaft is turned so that the follower is on the base circle of the cam. The clearance of each bucket follower can then be checked with a feeler gauge. The amount of clearance is recorded and compared with the specified clearance, and then a shim of the required thickness is put in the top of the bucket followers, as shown in Figure 30-34.

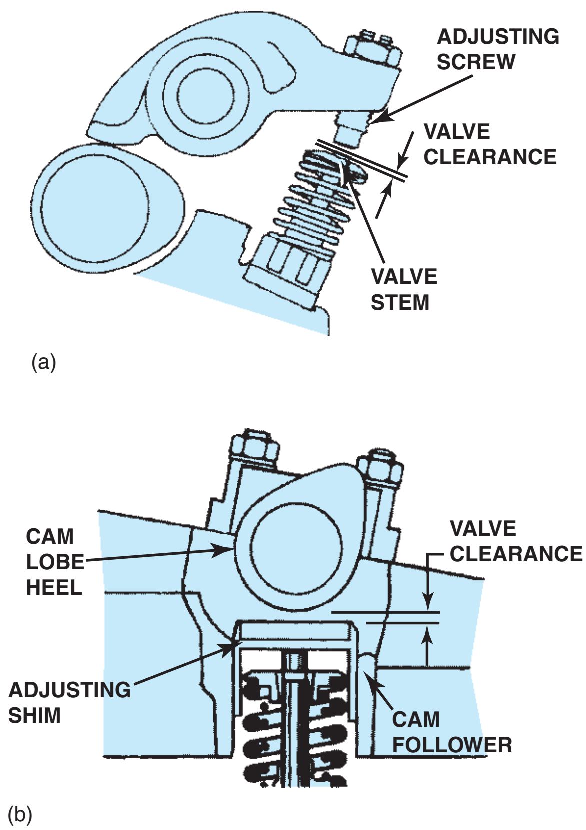


FIGURE 30-33 Valve clearance allows the metal parts to expand and maintain proper operation, both when the engine is cold or at normal operating temperature. (a) Adjustment is achieved by turning the adjusting screw. (b) Adjustment is achieved by changing the thickness of the adjusting shim.

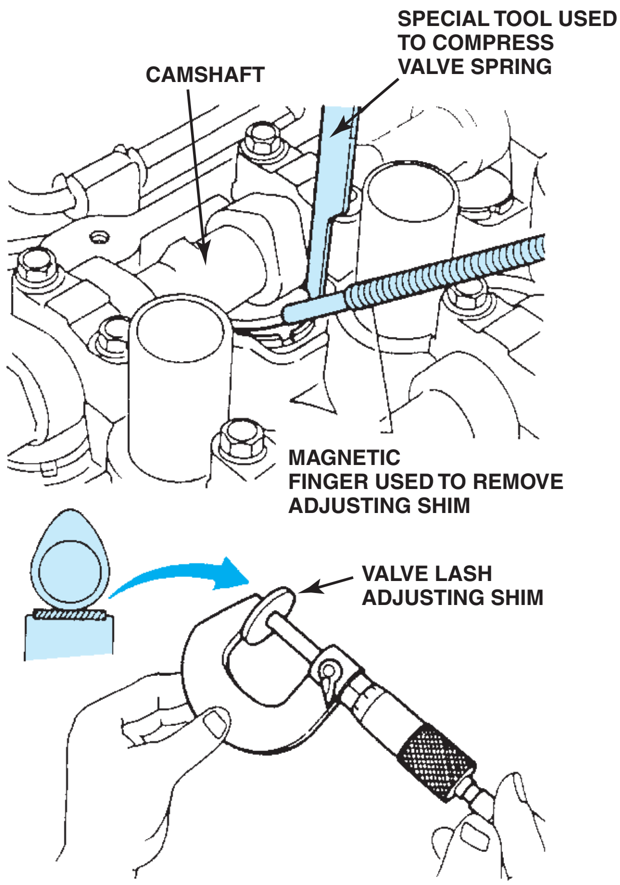


FIGURE 30-34 Some overhead camshaft engines use valve lash adjusting shims to adjust the valve lash. A special tool is usually required to compress the valve spring so that a magnet can remove the shim.

HEAD GASKETS

The head gasket is under the highest clamping loads. It must seal passages that carry coolant with antifreeze and often is required to seal a passage that carries hot engine oil. The most demanding job of the head gasket is to seal the combustion chamber. As a rule of thumb, about 75% of the head bolt clamping force is used to seal the combustion chamber. The remaining 25% seals the coolant and oil passages. See Figure 30-35.

The gasket must seal when the temperature is as low as 40° below zero and as high as 400°F (204°C). The combustion pressures can get up to 1,000 PSI (6,900 kPa) on gasoline engines.

Cylinder head bolts are tightened to a specified torque, which stretches the bolt. The combustion pressure tries to push the head upward and the piston downward on the power stroke. This puts additional stress on the head bolts and it reduces the clamping load on the head gasket just when the greatest seal is needed. On a normally aspirated engine (without turbocharging), a partial vacuum on the intake stroke tries to pull the head more tightly against the gasket. As the crankshaft rotates, the force on the head changes from pressure on the combustion stroke to vacuum on the intake stroke, then back to pressure. Newer engines have lightweight thin-wall castings. The castings are quite flexible, so that they move as the pressure in the combustion chamber changes from high pressure to vacuum. The gasket must be able to compress and recover fast enough to maintain a seal as the pressure in the combustion chamber changes back and forth between pressure and vacuum. As a result, head gaskets are made of several different materials assembled in numerous ways, depending on the engine.

NOTE: Older gasket designs often contained asbestos and required that the head bolts be retorqued after the engine had been run to operating temperature. Head gaskets today are dense and do not compress like those older-style gaskets. Therefore, most gaskets are called **no-retorque**-type gaskets, meaning the cylinder head bolts do not have to be retorqued after the engine has run. New gaskets do not contain asbestos.

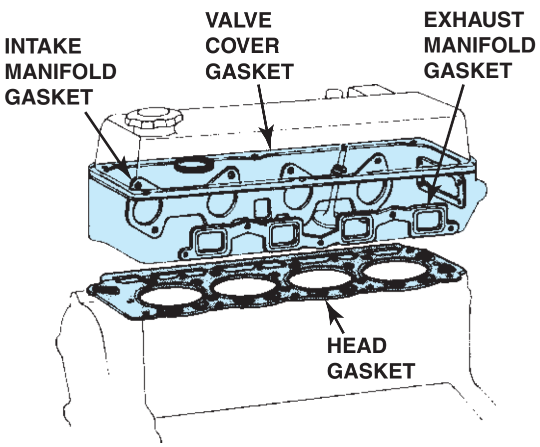


FIGURE 30-35 Gaskets help prevent leaks between two surfaces.

Perforated Steel-Core Gaskets

A perforated steel-core gasket uses a wire-mesh core with fiber facings. Another design has rubber-fiber facings cemented to a solid steel core with an adhesive. See Figures 30-36 and 30-37. The thickness of the gasket is controlled by the thickness of the metal core. The facing is thick enough to compensate for minor warpage and surface defects.

TECH TIP

WOW—I CAN'T BELIEVE A CYLINDER CAN DEFORM THAT MUCH!

An automotive instructor used a dial bore gauge in a four-cylinder, cast-iron engine block cylinder to show students how much a block can deform. Using just one hand, the instructor was able to grasp both sides of the block and squeeze. The dial bore gauge showed that the cylinder deflected about 0.0003 in. (3/10,000 of an inch) just by squeezing the block with one hand—and that was with a cast-iron block!

After this demonstration, the students were more careful during engine assembly and always used a torque wrench on each and every fastener that was installed in or on the engine block.

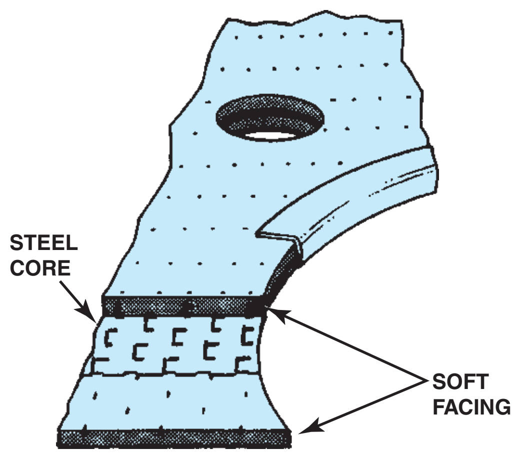


FIGURE 30-36 A typical perforated steel core head gasket with a graphite or composite facing material.

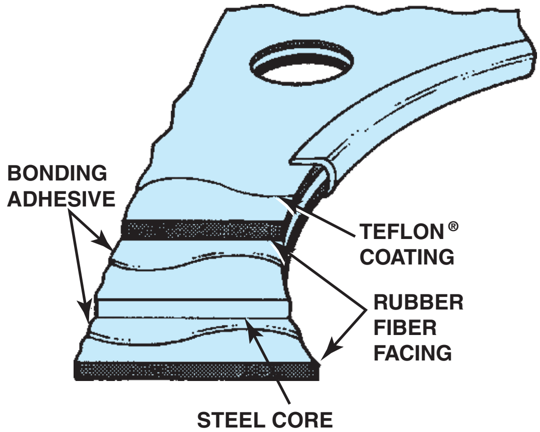


FIGURE 30-37 A solid steel core head gasket with a non-stick coating, which allows some movement between the block and the head, which is especially important on engines that use cast-iron blocks with aluminum cylinder heads.

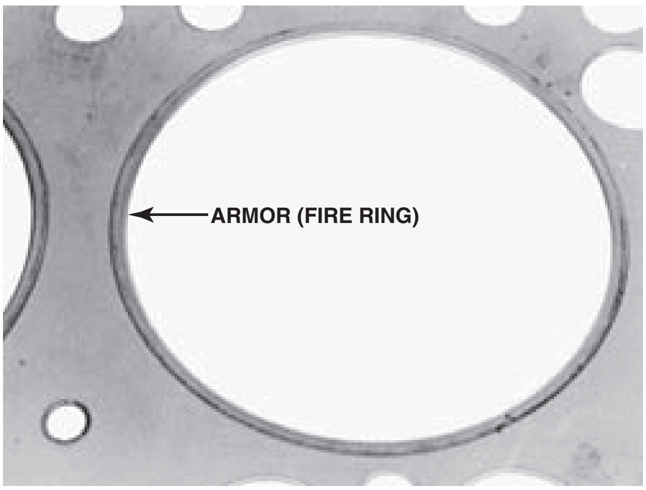


FIGURE 30-38 Head gasket with armor.

The fiber facing is protected around the combustion chamber with a metal **armor** (also called **fire ring**). See Figure 30-38. The metal also increases the gasket thickness around the cylinder so that it uses up to 75% of the clamping force and forms a tight combustion seal.

MULTILAYERED STEEL GASKETS

Multilayered steel (MLS) is being used from the factory on many newer engine designs such as the overhead camshaft Ford V-8s. The many layers of thin steel reduce bore and overhead camshaft distortion with less clamping force loss than previous designs. See Figure 30-39. The use of multilayered

FIGURE 30-39 Multilayer steel (MLS) gaskets are used on many newer all-aluminum engines as well as engines that use a cast block with aluminum cylinder heads. This type of gasket allows the aluminum to expand without losing the sealing ability of the gasket.

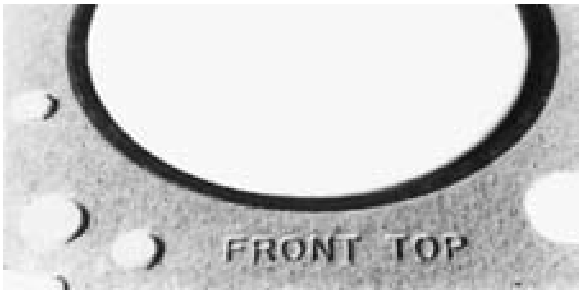


FIGURE 30-40 Typical head gasket markings.

steel gaskets also reduces the torque requirement and, therefore, reduces the stresses on the fastener and engine block.

INSTALLING THE HEAD GASKET

The block deck and head surfaces should be rechecked for any handling nicks that could cause a gasket leak. All tapped holes should be cleaned with the correct-size thread chaser. Also check the block and cylinder head surfaces for any dirt or burrs. There are usually alignment pins or dowels at the front and rear of the block deck to position the gasket and head. Care should be taken to properly position any head gasket with markings (up, top, front, and so forth). See Figure 30-40. The gasket and head are placed on the block deck. All the head bolts are loosely installed. Very often, the head bolts have different lengths. Make sure that a bolt of the correct length is put into each location.

NOTE: The word "front" means toward the timing belt or chain end of the engine. This can be confusing for a technician working on an engine in a front-wheel-drive vehicle.

Put sealer on the threads of the assembly bolts that go into the cooling system. Put antiseize compound on bolts that hold the exhaust manifold. Lightly oil the threads of bolts that go into blind holes. See the Tech Tip, "Watch Out for Wet and Dry Holes."

NOTE: Most manufacturers recommend putting oil on the threads of bolts (not in the block holes!) during reassembly. Lubricated threads will give as much as 50% more clamping force at the same bolt torque than threads that are tightened dry.

Often, the assembly bolts have different lengths. Make sure that the correct length of bolt is put into each hole.

TECH TIP

WATCH OUT FOR WET AND DRY HOLES

Many engines, such as the small-block Chevrolet V-8, use head bolts that extend through the top deck of the block and end in a coolant passage. These bolt holes are called **wet holes.** When installing head bolts that end up in the coolant passage, use sealer on the threads of the head bolt. Some engines have head bolts that are "wet," whereas others are "dry" because they end in solid cast-iron material. Dry hole bolts do not require sealant, but they still require some oil on the threads of the bolts for lubrication. Do not put oil into a dry hole because the bolt may bottom out in the oil. The liquid oil cannot compress, so the force of the bolt being tightened is transferred to the block by hydraulic force, which can crack the block.

NOTE: Apply oil to a shop cloth and rotate the bolt in the cloth to lubricate the threads. This procedure lubricates the threads without applying too much oil.

HEAD BOLT TORQUE SEQUENCE

The torque put on the bolts is used to control the clamping force. The clamping force is correct only when the threads are clean and properly lubricated. In general, the head bolts are tightened in a specified torque sequence in three steps. By tightening the head bolts in three steps, the head gasket has time to compress and conform to the block deck and cylinder head gasket surfaces. Follow that sequence and tighten the bolts to *one-third* the specified torque. Tighten them a second time following the torque sequence to *two-thirds* the specified torque. Follow the sequence with a final tightening to the specified torque. See Figures 30-41 and 30-42.

TORQUE-TO-YIELD BOLTS

Many engines use a tightening procedure called the **torque-to-yield,** or **torque-angle,** method. The purpose of the torque-to-yield procedure is to have a more constant clamping load from bolt to bolt. This aids in head gasket sealing performance and eliminates the need for retorquing. The torque-to-yield head bolts are made with a narrow section between the head and threads. As the bolts are tightened

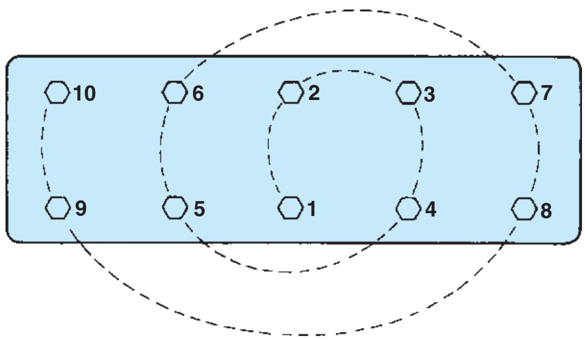


FIGURE 30-41 Typical cylinder head tightening sequence.

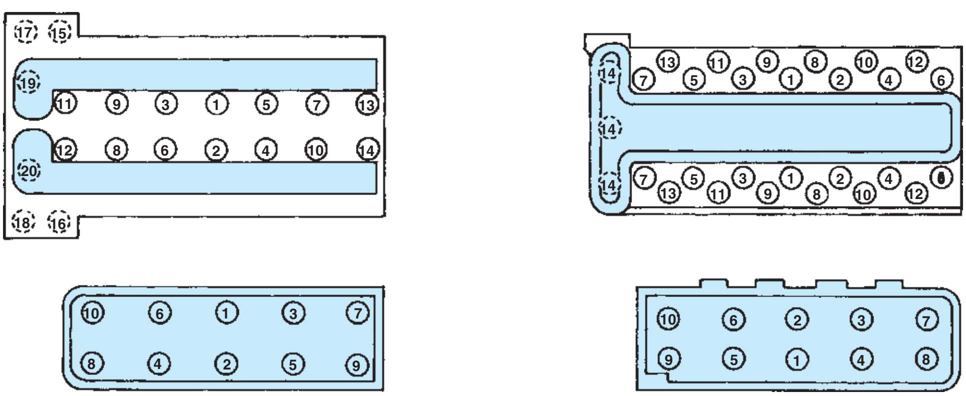


FIGURE 30-42 Examples of cylinder head bolt torquing sequences.

past their elastic limit, they yield and begin to stretch in this narrow section.

Torque-to-yield head bolts will not become any tighter once they reach this elastic limit, as you can see on the graph in Figure 30-43. The torque-angle method also decreases the differences in clamping force that can occur depending on the condition or lubrication of the threads. See Figure 30-44.

As a result, many engine manufacturers specify *new* head bolts each time the head is installed. If these bolts are reused, they are likely to break during assembly or fail prematurely as the engine runs. If there is any doubt about the head bolts, replace them.

Torque-to-yield bolts are tightened to a specific initial torque, from 18 to 50 pound-feet (25 to 68 Newton-meters).

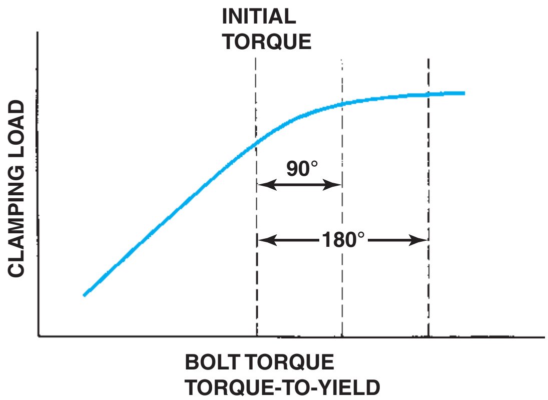


FIGURE 30-43 Due to variations in clamping force with turning force (torque) of head bolts, some engines are specifying the torque-to-yield procedure. The first step is to torque the bolts by an even amount called the initial torque. Final clamping load is achieved by turning the bolt a specified number of degrees. Bolt stretch provides the proper clamping force.

The bolts are then tightened a specified number of degrees, following the tightening sequence. In some cases they are turned a specified number of degrees two or three times. Some specifications limit the maximum torque that can be applied to the bolt while the degree turn is being made. Torque tables in a service manual will show how much initial torque should be applied to the bolt and how many degrees the bolt should be rotated after torquing.

NOTE: The torque-turn method does not necessarily mean torque-to-yield. Some engine specifications call for a beginning torque and then a specified angle, but the fastener is not designed to yield. These head bolts can often be reused. Always follow the manufacturer's recommended procedures.

Head bolts are tightened following a sequence specified in the service manual or torque tables. In general, the tightening sequence starts at the center of the head and moves outward, alternating front to rear and side to side. The bolts are usually tightened to approximately one-half the specified torque, following the tightening sequence. They are then retorqued to the specified torque following the same tightening sequence. See Figures 30-45 and 30-46.

TIMING DRIVES FOR OVERHEAD CAM ENGINES

After the head bolts have been torqued, the cam drive can be installed on overhead cam engines. This is done by aligning the timing marks of the crankshaft and camshaft drive sprockets with their respective timing marks. The location of these marks differs between engines, but the marks can

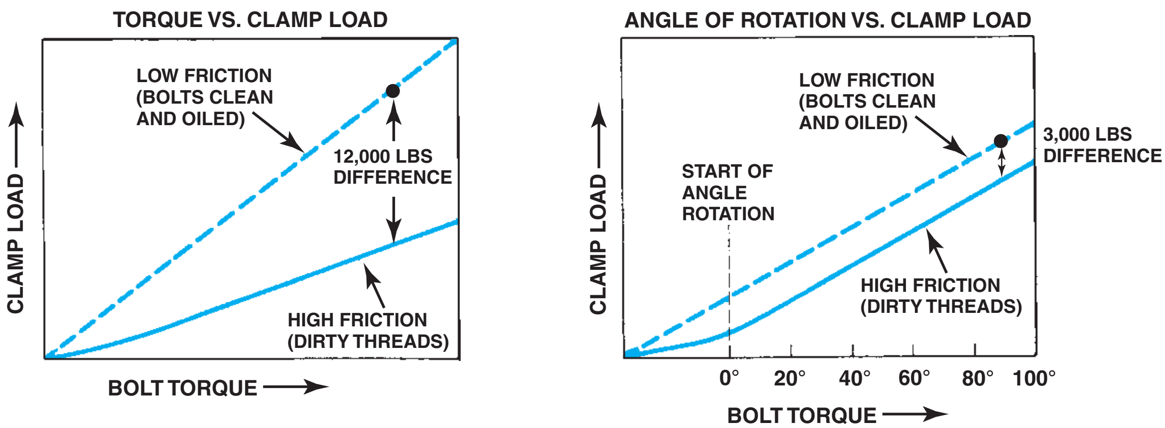


FIGURE 30-44 To ensure consistent clamp force (load), many manufacturers are recommending the torque-angle or torque-to-yield method of tightening head bolts. The torque-angle method specifies tightening fasteners to a low torque setting and then giving an additional angle of rotation. Notice that the difference in clamping force is much smaller than it would be if just a torque wrench with dirty threads were used.

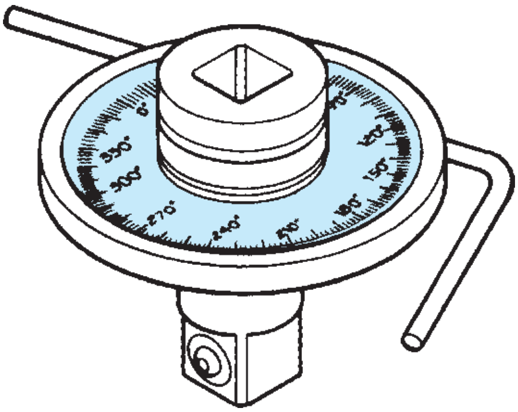


FIGURE 30-45 Torque angle can be measured using a special adaptor.

FIGURE 30-46 An electronic torque wrench showing the number of degrees of rotation. These very accurate and expensive torque wrenches can be programmed to display torque or number of degrees of rotation.

be identified by looking carefully at the sprockets. See Figures 30-47 and 30-48. The tightening idler may be on either or both sides of the timing belt or chain. After the camshaft drive is engaged, rotate the crankshaft through two full revolutions. On the first full revolution, you should see the exhaust valve almost close and the intake valve just starting to open when the *crankshaft* timing mark aligns. At the end of the second revolution, both valves should be closed, and all the timing marks should align on most engines. This is the position the crankshaft should have when cylinder #1 is to fire.

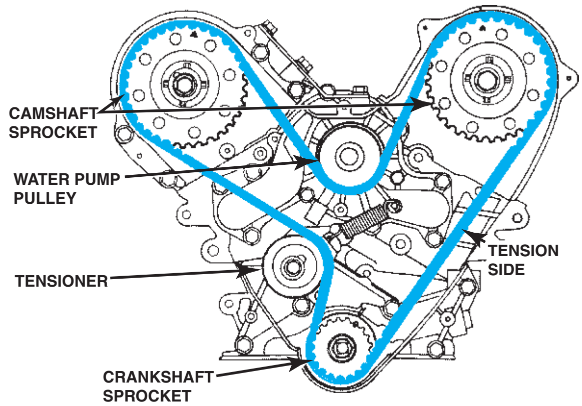


FIGURE 30-47 Both crankshafts have to be timed on this engine, and the timing belt also drives the water pump.

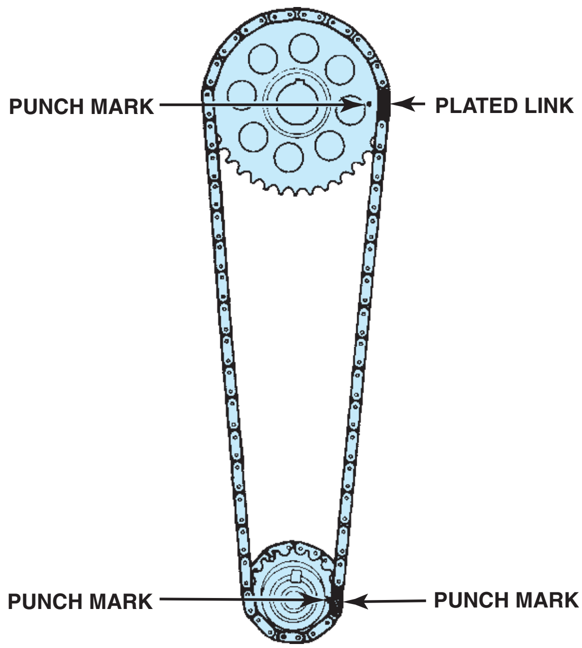


FIGURE 30-48 Some timing chains have plated links that are used to correctly position the chain on the sprockets.

NOTE: Always check the manufacturer's recommended timing chain installation procedure. Engines that use primary and secondary timing chains often require an exact detailed procedure for proper installation.

LIFTER AND PUSHROD INSTALLATION

The outside of the lifters and the lifter bores in the block should be cleaned and coated with assembly lubricant. The lifters are installed in the lifter bores and the pushrods put in

TECH TIP

SOAK THE TIMING CHAIN

Many experts recommend that a new timing chain be soaked in engine oil prior to engine assembly to help ensure full lubrication at engine start-up. The timing chain is one of the last places in the engine to get lubrication when the engine first starts. This procedure may even extend the life of the chain.

place. There are different-length pushrods on some engines. Make sure that the pushrods are installed in the proper location. The rocker arms are then put in place, aligning with the valves and pushrods. Rocker arm shafts should have their retaining bolts tightened a little at a time, alternating between the retaining bolts. This keeps the shaft from bending as the rocker arm pushes some of the valves open.

HYDRAULIC LIFTERS

The retaining nut on some rocker arms mounted on studs can be tightened to a specified torque. The rocker arm will be adjusted correctly at this torque when the valve tip has the correct height. Other types of rocker arms require tightening the nut to a position that will center the hydraulic lifter. The general procedure for adjusting the hydraulic lifter types is to tighten the retaining nut to the point that all the free lash is gone. See Figure 30-49. The lifter plunger starts to move down after the lash is gone. From this point, the retaining nut is tightened by a specified amount, such as three-fourths of a turn or one and one-half turns.

NOTE: This method usually results in about three threads showing above the adjusting nut on a *stock* small-block Chevrolet V-8 equipped with flat-bottom hydraulic lifters.

SOLID LIFTERS

The valve clearance or **lash** must be set on a solid lifter engine, so that the valves can positively seat. Some service manuals give an adjustment sequence to follow to set the lash. If this is not available, then the following procedure can be used on all engines requiring valve lash adjustment. The valve lash is adjusted with the valves completely closed. See Figure 30-50.

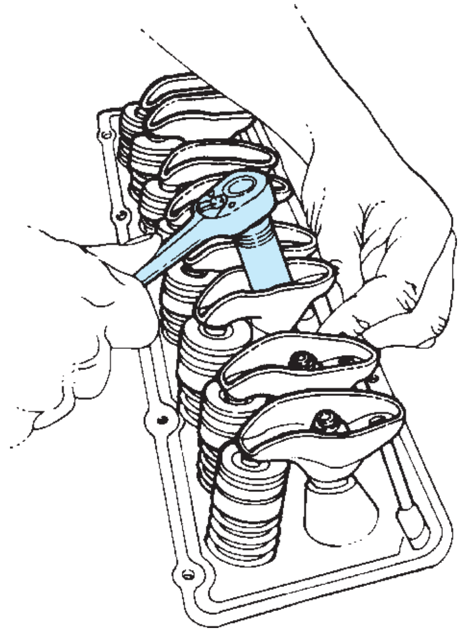


FIGURE 30-49 With the lifter resting on the base circle of the cam, zero lash is achieved by tightening the rocker arm lock nut until the pushrod no longer rotates freely.

FIGURE 30-50 Most adjustable valves use a nut to keep the adjustment from changing, so to adjust the valves the nut has to be loosened and the screw rotated until the proper valve clearance is achieved. Then the screw should be held while tightening the lock nut to keep the adjustment from changing. Double-check the valve clearance after tightening the nut.

After the valve lash on cylinder #1 is set, the crankshaft is rotated in its normal direction of rotation to the next cylinder in the firing order. This is done by turning the crankshaft 90 degrees on eight-cylinder engines, 120 degrees on even-firing six-cylinder engines, and 180 degrees on four-cylinder engines. The valves on this next cylinder are adjusted in the same manner, as were those on cylinder #1. This procedure is repeated on each cylinder *following the engine firing order* until all the valves have been adjusted.

The same valve lash adjustment sequence is used on overhead cam engines. Those engines with rocker arms or with adjustable finger follower pivots are adjusted in the same way, as are pushrod engines with rocker arms.

ASSEMBLY SEALANTS

RTV Silicone

RTV Silicone is used by most technicians in sealing engines. **RTV,** or **room-temperature vulcanization,** means that the silicone rubber material will cure at room temperature. It is not really the temperature that causes RTV silicone to cure, but the moisture in the air. RTV silicone cures to a tack-free state in about 45 minutes. It takes 24 hours to fully cure.

CAUTION: Some RTV silicone sealers use **acetic acid,** and the fumes from this type can be drawn through the engine through the PCV system and cause damage to oxygen sensors. Always use an **amine-type** RTV **silicone** or one that states on the package that it is safe for oxygen sensors.

RTV silicone is available in several different colors. The color identifies the special blend within a manufacturer's product line. Equal grades of silicone made by different manufacturers may have different colors. RTV silicone can be used in two ways in engine sealing:

1. It can be used as a gasket substitute between a stamped cover and a cast surface.
2. It is used to fill gaps or potential gaps. A joint between gaskets or between a gasket and a seal is a potential gap.

NOTE: RTV silicone should *never* be used around fuel because the fuel will cut through it. Silicone should not be used as a sealer on gaskets. It will squeeze out to leave a bead inside and a bead outside the flange. The inside bead might fall into the engine, plugging passages and causing engine damage. The thin film still remaining on the gasket stays uncured, just as it would be in the original tube. The uncured silicone is likely to let the gasket or seal slip out of place. See Figure 30-51.

Anaerobic Sealers

Anaerobic sealers are sealers that cure in the absence of air. They are used as thread lockers (such as Loctite), and they are used to seal rigid machined joints between cast parts. Anaerobic sealers lose their sealing ability at temperatures above 300°F (149°C). On production lines, the curing process is speeded up by using ultraviolet light.

FIGURE 30-51 Improperly sealed valve cover gasket. Note the use of RTV silicone sealant on a cork-rubber gasket. The cover bolts were also overtightened, which deformed the metal cover around the bolt holes.

When the anaerobic sealer is used on threads, air does not get to it so it hardens to form a seal to prevent the fastener from loosening. Teflon is added to some anaerobic sealers to seal fluids better. Anaerobic sealers can be used to seal machined surfaces without a gasket. The surfaces *must* be thoroughly clean to get a good seal. Special primers are recommended for use on the sealing surface to get a better bond with anaerobic sealers.

INSTALLING MANIFOLDS

The intake manifold gasket for a V-type engine may be a one-piece gasket or it may have several pieces. V-type engines with open-type manifolds have a cover over the lifter valley. The cover may be a separate part or it may be part of a one-piece intake manifold gasket. Closed-type intake manifolds on V-type engines require gasket pieces (end seals) at the front and rear of the intake manifold. See Figure 30-52. Inline engines usually have a one-piece intake manifold gasket.

The intake manifold is put in place over the gaskets. Use a contact adhesive to hold the gasket and end seal if there is a chance they might slip out of place. Just before the manifold is installed, put a spot of RTV silicone on each of the four joints between the intake manifold gasket and end seals. Install the bolts and tighten to the specified torque following the correct tightening sequence.

Only some exhaust manifolds use gaskets. The exhaust manifold operates at very high temperatures, so there is usually some expansion and contraction movement in the manifold-to-head joint. It is very important to use attachment bolts, cap screws, and clamps of the correct type and length. See Figure 30-53. They must be properly torqued to avoid both leakage and cracks.

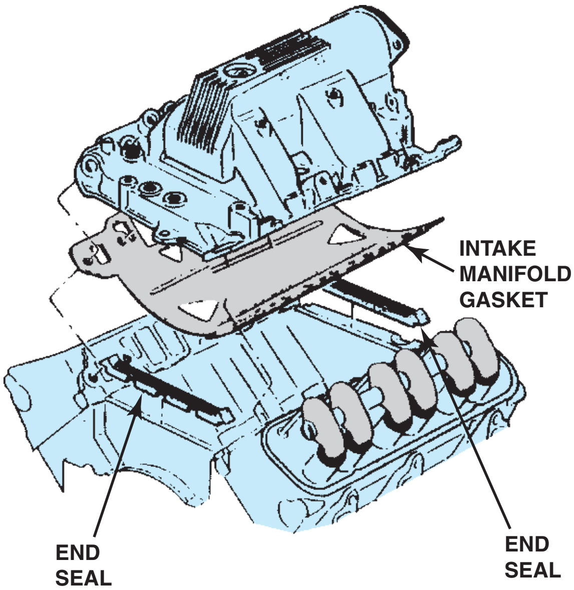


FIGURE 30-52 This intake manifold gasket includes end seals and a full shield cover for the valley to keep hot engine oil from heating the intake manifold.

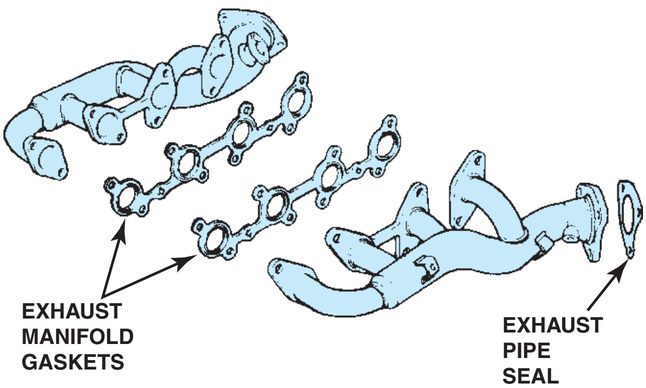


FIGURE 30-53 An exhaust manifold gasket is used on some engines and seals the exhaust manifold to the cylinder head.

NOTE: When the exhaust manifold gasket has facing on one side, put the facing toward the head and let the manifold rest against the metal side of the gasket.

COVER GASKET MATERIALS

The gasket must be *impermeable* to the fluids it is designed to seal in or out. The gasket must *conform* to the shape of the surface, and it must be *resilient*, or elastic, to maintain the sealing force as it is compressed. Gaskets work best when they are compressed about 30%.

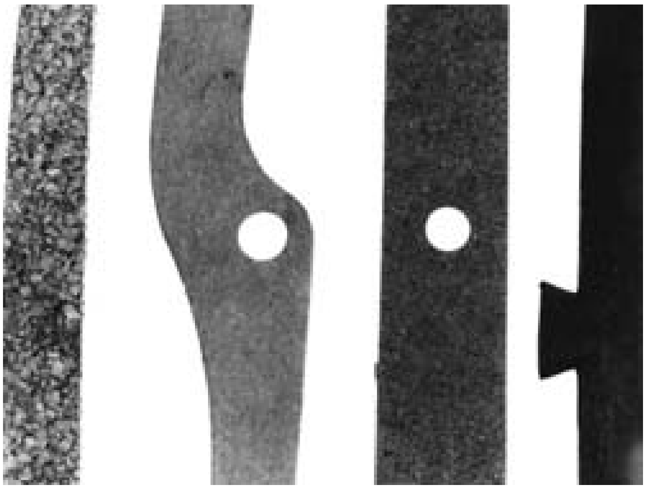


FIGURE 30-54 *Left to right:* Cork-rubber, paper, composite, and synthetic rubber (elastomer) gaskets.

Cork Gaskets

Cork is the bark from a Mediterranean cork oak tree. It is made of very small, flexible, 14-sided, air-filled fiber cells, about 0.001 inch (0.025 millimeter) in size. The air-filled cells act like a pneumatic system. This gives resiliency to the cork gasket until the air leaks out. Because cork is mostly wood, it expands when it gets wet and shrinks when it dries. This causes cork gaskets to change in size when they are in storage and while installed in the engine. Oil gradually wicks through the organic binder of the cork, so a cork gasket often looks like it is leaking. Problems with cork gaskets led the gasket industry to develop cork cover gaskets using synthetic rubber as a binder for the cork. This type of gasket is called a **cork-rubber gasket.** These cork-rubber gaskets are easy to use, and they outlast the old cork gaskets. See Figure 30-54.

Fiber Gaskets

Some oil pans use fiber gaskets. Covers with higher clamping forces use gaskets with fibers that have greater density. For example, timing covers may have either fiber or paper gaskets.

Synthetic Rubber Gaskets

Molded, oil-resistant synthetic rubber is being used in more applications to seal covers. When it is compounded correctly, it forms a superior cover gasket. It operates at high temperatures for a longer period of time than does a cork-rubber cover gasket. See Figure 30-55.

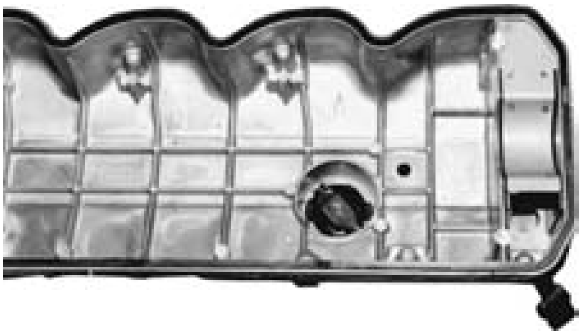


FIGURE 30-55 Typical cast-aluminum cam (valve) cover. Note the rubber gasket in the cast groove of the cover.

Sealers

Sealers are nonhardening materials. Examples of sealer trade names include Form-A-Gasket 2, Pli-A-Seal, Tight Seal 2, Aviation Form-A-Gasket, Brush Tack, Copper Coat, Spray Tack, and High Tack. Sealers are always used to seal the threads of bolts that break into coolant passages. Sealers for sealing threads may include Teflon. Sealer is often recommended for use on shim-type head gaskets and intake manifold gaskets. These gaskets have a metal surface that does not conform to any small amounts of surface roughness on the sealing surface. The sealer fills the surface variations between the gasket and the sealing surface.

Sealer may be used as a sealing aid on paper and fiber gaskets if the gasket needs help with sealing on a scratched, corroded, or rough surface finish. The sealer may be used on one side or on both sides of the gasket.

CAUTION: Sealer should *never* be used on rubber or cork-rubber gaskets. Instead of holding the rubber gasket or seal, it will help the rubber to slip out of place because the sealer will never harden.

Antiseize Compounds

Antiseize compounds are used on fasteners in the engine that are subjected to high temperatures to prevent seizing caused by galvanic action between dissimilar metals. These compounds minimize corrosion from moisture. Exhaust manifold bolts and nuts, oxygen sensors, and spark plugs, especially those that go into aluminum heads, are kept from seizing. The antiseize compound minimizes the chance of threads being pulled or breaking as the oxygen sensor or spark plug is removed.

INSTALLING TIMING COVERS

Most timing covers are installed with a gasket, but some use RTV sealer in place of the gasket. Cast covers use anaerobic compound as a gasket substitute. A bead of RTV silicone 1/8 to 3/16 inch in diameter is put on the clean sealing surface. See Figure 30-56. Encircle the bolt holes with the sealant. Install the cover before the silicone begins to cure so that the uncured silicone bonds to both surfaces. While installing the cover, do not touch the silicone bead; otherwise, the bead might be displaced, causing a leak. Carefully press the cover into place. Do not slide the cover after it is in place. Install the assembly bolts finger-tight, and let the silicone cure for about 30 minutes; then torque the cover bolts.

TECH TIP

HINTS FOR GASKET USAGE

Never reuse an old gasket. A used gasket or seal has already been compressed, has lost some of its resilience, and has taken a set. If a used gasket does reseal, it will not seal as well as a new gasket or seal.

A gasket should be checked to make sure it is the correct gasket. Also check the list on the outside of the gasket set to make sure that the set has all the gaskets that may be needed *before* the package is opened.

An instruction sheet is included with most gaskets. It includes a review of the things the technician should do to prepare and install the gaskets to give the best chance of a good seal. The instruction sheet also includes special tips on how to seal spots that are difficult to seal or that require special care to seal on a particular engine.

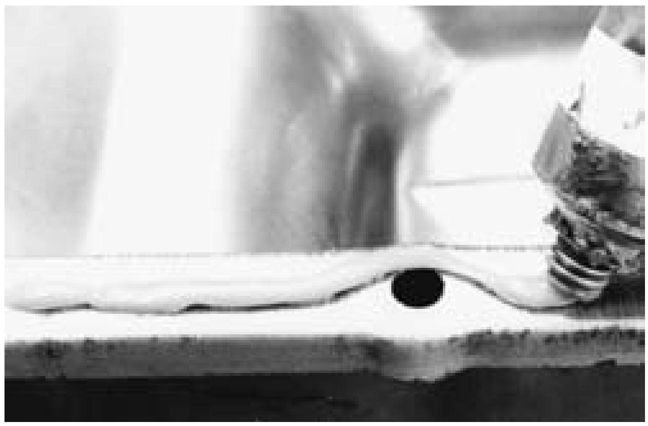


FIGURE 30-56 1/8- to 3/16-inch (3- to 5-millimeter) bead of RTV silicone on a parting surface with silicone going around the bolt hole.

FIGURE 30-57 Installing the harmonic balancer. Always follow the manufacturer's recommended procedure and torque specifications.

INSTALLING THE VIBRATION DAMPER

Vibration dampers are seated in place by one of three methods.

- The damper hub of some engines is pulled into place using the hub-attaching bolt. See Figure 30-57.
- The second method uses a special installing tool that screws into the attaching bolt hole to pull the hub into place. The tool is removed and the attaching bolt is installed and torqued.
- The last method is used on engines that have no attaching bolt. These hubs depend on a press-fit to hold the hub on the crankshaft. The hub is seated using a hammer and a special tube-type driver.

INSTALLING THE OIL PUMP

When an engine is rebuilt, the oil pump should be replaced with a new pump. This ensures positive lubrication and long pump life. Oil pump gears should be coated with assembly lubricant before the cover is put on the pump. This provides initial lubrication, and it primes the pump so that it will draw the oil from the pan when the lubrication system is first operated.

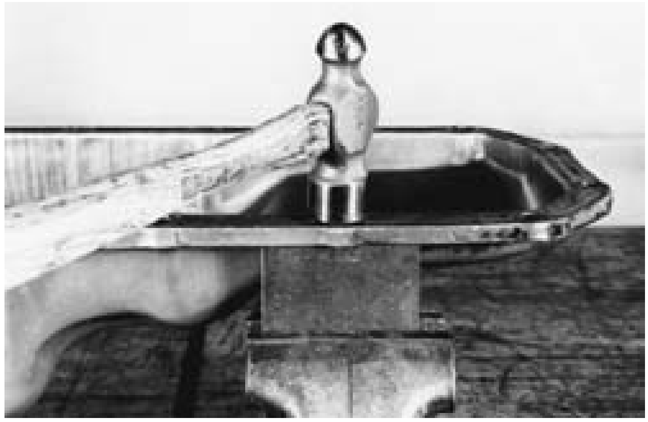


FIGURE 30-58 Using a hammer to straighten the gasket rail surface before installing a new gasket. When the retaining bolts are tightened, some distortion of sheet-metal covers occurs. If the area around the bolt holes is not straightened, leaks can occur with the new gasket.

THE OIL PAN

The oil pan should be checked and straightened as necessary. See Figure 30-58. With the oil pump in place, the oil pan gaskets are properly positioned. A spot of RTV silicone is placed at each gasket joint just before the pan is installed. The oil pan is carefully placed over the gaskets. All oil pan bolts should be started into their holes before any are tightened. The bolts should be alternately snugged up; then they should be properly torqued.

REAL WORLD FIX

THE NEW OIL PUMP THAT FAILED

A technician replaced the oil pump and screen on a V-8 with low oil pressure. After the repair, the oil pressure returned to normal for two weeks, but then the oil pressure light came on and the valve train started making noise. The vehicle owner returned to the service garage where the oil pump had been replaced. The technician removed the oil pan and pump. The screen was almost completely clogged with the RTV sealant that the technician had used to "seal" the oil pan gasket. The technician had failed to read the instructions that came with the oil pan gasket. Failure to follow directions and using too much of the wrong sealer cost the repair shop an expensive comeback repair.

TECH TIP

OIL PUMP PRECAUTIONS

The oil pump is the heart of any engine, and any failure of the oil circulation system often results in severe and major engine damage. To help prevent possible serious oil pump-related failures, many engine builders recommend the following precautions:

1. Always be sure that the oil pump pickup tube (screen) is securely attached to the oil pump to prevent the pickup tube from vibrating out of the pump.
2. Use modeling clay to check pickup screen-to-oil pan clearance. For proper operation, there should be about 1/4 inch (6 millimeters) between the oil pump pickup screen and the bottom of the oil pan.

REAL WORLD FIX

"OOPS"

After overhauling a big-block Ford V-8 engine, the technician used an electric drill to rotate the oil pump with a pressure gauge connected to the oil pressure sending unit hole. When the electric drill was turned on, oil pressure would start to increase (to about 10 PSI), then drop to zero. In addition, the oil was very aerated (full of air). Replacing the oil pump did not solve the problem. After hours of troubleshooting and disassembly, it was discovered that an oil gallery plug had been left out underneath the intake manifold. The oil pump was working correctly and pumped oil throughout the engine and out of the end of the unplugged oil gallery. It did not take long for the oil pan to empty; therefore, the oil pump began drawing in air that aerated the oil and the oil pressure dropped. Installing the gallery plug solved the problem. It was smart of the technician to check the oil pressure before starting the engine. This oversight of leaving out one gallery plug could have resulted in a ruined engine shortly after the engine was started.

NOTE: Many overhead camshaft engines use an oil passage check valve in the block near the deck. The purpose of this valve is to hold oil in the cylinder head around the camshaft and lifters when the engine is stopped. Failure to reinstall this check valve can cause the valve train to be noisy after engine start-up.

INSTALLING THE WATER PUMP

A reconditioned, rebuilt, or new water pump should be used. Once gaskets are fitted in place, the pump is secured with assembly bolts tightened to the correct torque.

A new thermostat is usually installed at this time. It is put in place, with care being taken to place the correct side of the thermostat toward the engine. The thermostat gasket is put in place. Sealers are used on the gasket where they are required. The thermostat housing is installed, and the retaining bolts are tightened to the proper torque.

ENGINE PAINTING

Painting an engine helps prevent rust and corrosion and makes the engine look new. Standard engine paints with original colors are usually available at automotive parts stores. Engine paints should be used rather than other types of paints. Engine paints are compounded to stay on the metal as the engine temperatures change. Normal engine fluids will not remove them. These paints are usually purchased in pressure cans so that they can be sprayed from the can directly onto the engine.

All parts that should not be painted must be covered before spray painting. This can be done with old parts, such as old spark plugs and old gaskets. This can also be done by taping paper over the areas to be covered. If the intake manifold of an inline engine is to be painted, it can be painted separately. Engine assembly can continue after the paint has dried.

CHECKING FOR PROPER OIL PRESSURE

With oil in the engine and the distributor out of the engine, oil pressure should be established before the engine is started. This can be done on most engines by rotating the oil pump by hand. This ensures that oil is delivered to all parts of the engine before the engine is started. A socket speed handle makes an ideal crank for turning the oil pump. A flat-blade adapter that fits the speed handle will operate on General Motors engines. The V-type Chrysler engine requires the use of the same flat-blade adapter, but it also requires an oil pump drive. One can be made by removing the gear from an

FIGURE 30-59 Drivers used to rotate oil pumps to prelubricate all parts of the engine before installing the distributor and starting the engine.

FIGURE 30-60 The engine can be pressurized with engine oil from an aerosol can as shown or from a pressurized oil container designed for preoiling the engine.

old oil pump hex driveshaft. A 1/4-inch drive socket can be used on Ford engines. Examples of these are pictured in Figure 30-59. Engines that do not drive the oil pump with the distributor will have to be cranked with the spark plugs removed to establish oil pressure. The load on the starter and battery is reduced with the spark plugs out so that the engine will have a higher cranking speed. A pressurized oil container or an engine oil aerosol could also be used, as shown in Figure 30-60.

SETTING INITIAL IGNITION TIMING

After oil pressure is established, the distributor, if equipped, can be installed. Rotate the crankshaft in its normal direction of rotation until there is compression on cylinder #1. This can be done with the starter or by using a wrench on the damper bolt. The compression stroke can be determined by covering the opening of spark plug #1 with a finger as the crankshaft is rotated. Continue to rotate the crankshaft slowly as compression is felt, until the timing marks on the damper align with the timing indicator on the timing cover.

The angle of the distributor gear drive will cause the distributor rotor to turn a few degrees when installed. Before the distributor is installed, the shaft must be positioned to compensate for the gear angle. After installation, the rotor should be pointing to the #1 tower of the distributor cap.

The distributor position should be close enough to the basic timing position to start the engine. If the distributor hold-down clamp is slightly loose, the distributor housing can be adjusted to make the engine run smoothly after the engine has been started.

PREOILING AN ENGINE Step-by-Step

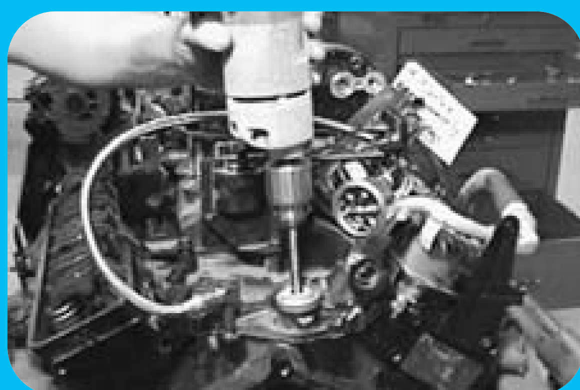
STEP 1 Whenever an engine has been disassembled and then reassembled, it is important to make sure that all internal parts are preoiled before starting the engine. Start by filling the crankcase with the specified amount of oil.

STEP 2 Attach an oil pressure gauge to the engine. On this small-block Chevrolet V-8, the oil pressure tap is located near the distributor at the top of the block.

STEP 3 To rotate the oil pump an old distributor was cut down and the shaft installed in the chuck of an electric drill.

STEP 4 Rotating the oil pump using an electric drill results in the oil pressure increasing to over 50 PSI.

STEP 5 The drill should continue being used to prime the engine with oil until oil is observed coming from the rocker arms, indicating that oil has reached the highest part of the engine.



STEP 6 An overall view of the oil pump drive adapter made from an odd distributor and the oil pressure gauge. After the engine has been primed, the distributor can be installed and the engine can be installed into the vehicle.

VALVE ADJUSTMENT Step-by-Step

STEP 1 Before starting the process of adjusting the valves, look up the specifications and exact procedures. The technician is checking this information from a computer CD-ROM-based information system.

STEP 2 The tools necessary to adjust the valves on an engine with adjustable rocker arms include basic hand tools, feeler gauge, and a torque wrench.

STEP 3 An overall view of the four-cylinder engine that is due for a scheduled valve adjustment according to the vehicle manufacturer's recommendations.

STEP 4 Start the valve adjustment procedure by first disconnecting and labeling, if necessary, all vacuum lines that need to be removed to gain access to the valve cover.

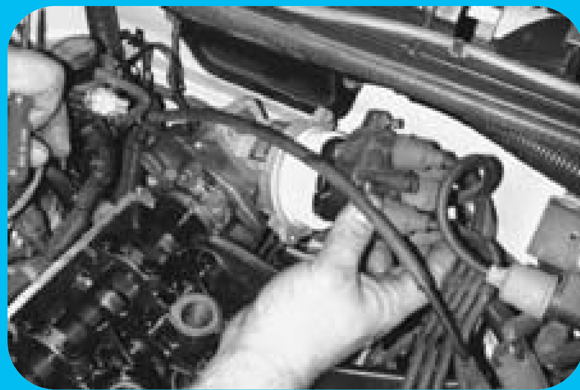
STEP 5 The air intake tube is being removed from the throttle body.

STEP 6 With all vacuum lines and the intake tube removed, the valve cover can be removed after removing all retaining bolts.

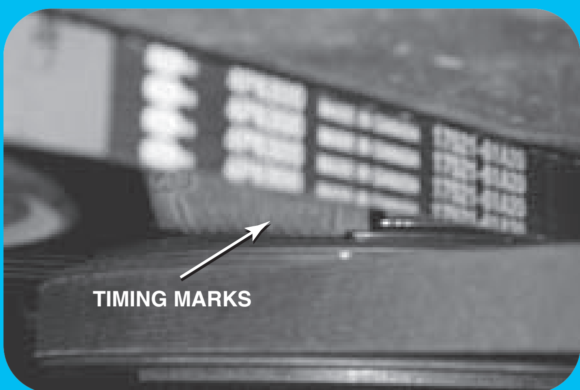
(continued)

VALVE ADJUSTMENT continued

STEP 7 Notice how clean the engine appears. This is a testament to proper maintenance and regular oil changes by the owner.



STEP 8 To help locate how far the engine is being rotated, the technician is removing the distributor cap to be able to observe the position of the rotor.



STEP 9 The engine is rotated until the timing marks on the front of the crankshaft line up with zero degrees—top dead center (TDC)—with both valves closed on #1 cylinder.

STEP 10 With the rocker arms contacting the base circle of the cam, insert a feeler gauge of the specified thickness between the camshaft and the rocker arm. There should be a slight drag on the feeler gauge.

STEP 11 If the valve clearance (lash) is not correct, loosen the retaining nut and turn the valve adjusting screw with a screwdriver to achieve the proper clearance.

STEP 12 After adjusting the valves that are closed, rotate the engine one full rotation until the engine timing marks again align.

VALVE ADJUSTMENT continued

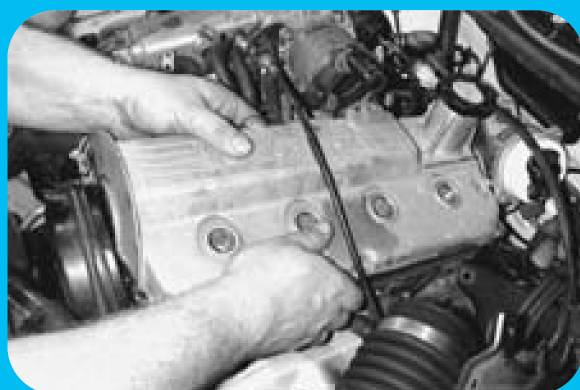
STEP 13 The engine is rotated until the timing marks again align indicating that the companion cylinder will now be in position for valve clearance measurement.

STEP 14 On some engines, it is necessary to watch the direction the rotor is pointing to help determine how far to rotate the engine. Always follow the vehicle manufacturer's recommended procedure.

STEP 15 The technician is using a feeler gauge that is one-thousandth of an inch thinner and another one-thousandth of an inch thicker than the specified clearance as a double-check that the clearance is correct.

STEP 16 Adjusting a valve takes both hands—one to hold the wrench to loosen and tighten the lock nut and one to turn the adjusting screw. Always double-check the clearance after an adjustment is made.

STEP 17 After all valves have been properly measured and adjusted as necessary, start the reassembly process by replacing all gaskets and seals as specified by the vehicle manufacturer.

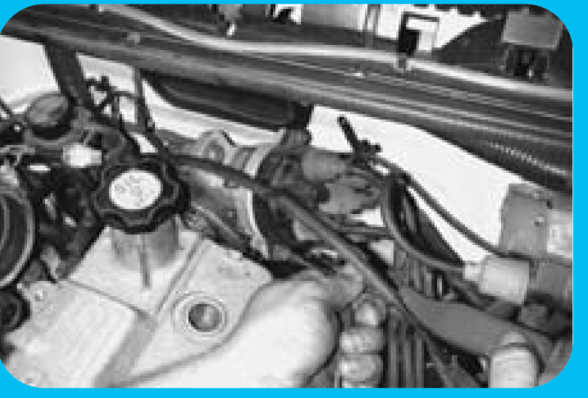


STEP 18 Reinstall the valve cover being careful to not pinch a wire or vacuum hose between the cover and the cylinder head.

(continued)

VALVE ADJUSTMENT continued

STEP 19 Use a torque wrench and torque the valve cover retaining bolts to factory specifications.



STEP 20 Reinstall the distributor cap.

STEP 21 Reinstall the spark plug wires and all brackets that were removed to gain access to the valve cover.

STEP 22 Reconnect all vacuum and air hoses and tubes. Replace with new any vacuum hoses that are brittle or swollen.

STEP 23 Be sure that the clips are properly installed. Start the engine and check for proper operation.

STEP 24 Double-check for any oil or vacuum leaks after starting the engine.

SUMMARY

1. All oil galleries must be thoroughly cleaned before engine assembly can begin.
2. All expansion cups and plugs should be installed with a sealer to prevent leaks. Avoid the use of Teflon tape on threaded plugs.
3. The cam bearings should be installed using a cam bearing installation tool.
4. Main bearings and rod bearings should be checked for proper oil clearance by precision measuring the crankshaft journals and inside diameter of bearings or by using plastic gauging material.
5. The piston and rod assembly should be installed in the cylinder after being carefully fitted for each bore.
6. Connecting rod side clearance should be checked with a feeler (thickness) gauge.
7. Double-check the flatness of the block deck and cylinder head before installing the cylinder head.
8. Torque the cylinder head bolts according to the proper sequence and procedures.
9. Many cylinder heads use the torque-to-yield method, wherein the head bolts are tightened to a specified torque and then rotated a specified number of degrees.
10. The oil pressure should be tested before installation of the engine in the vehicle.

REVIEW QUESTIONS

1. Describe the procedure for fitting pistons to a cylinder.
2. Explain how main bearings should be checked and fitted to the crankshaft.
3. How is plastic gauging material used to determine oil clearance?
4. What is the procedure for checking thrust bearing clearance?
5. How should the connecting rod side clearance be measured and corrected?
6. How is the piston and connecting rod assembly installed in the engine?
7. What procedures should be followed for installing and torquing the cylinder head?
8. Describe the torque-to-yield head bolt tightening procedure.

CHAPTER QUIZ

1. Typical piston-to-cylinder clearance is ______.
   - **a.** 0.001 to 0.003 inch
   - **b.** 0.010 to 0.023 inch
   - **c.** 0.100 to 0.150 inch
   - **d.** 0.180 to 0.230 inch
2. If the gauging plastic strip is wide after the bearings are tightened, this indicates ______.
   - **a.** A large oil clearance
   - **b.** An old, dried strip of plastic gauging material
   - **c.** A small oil clearance
   - **d.** A small side (thrust) clearance
3. The most common cause of premature bearing failure is ______.
   - **a.** Misassembly
   - **b.** Dirt
   - **c.** Lack of lubrication
   - **d.** Overloading
4. Typical thrust bearing clearance is ______.
   - **a.** 0.001 to 0.003 inch
   - **b.** 0.002 to 0.012 inch
   - **c.** 0.025 to 0.035 inch
   - **d.** 0.050 to 0.100 inch

5. Piston ring end gap can be *increased* by ______.
   a. Filing the ring to make the gap larger
   b. Installing oversize rings
   c. Sleeving the cylinder
   d. Knurling the piston
6. The cylinder head bolts should be tightened (torqued) in what general sequence?
   a. The four outside bolts first, then from the center out
   b. From the outside bolts to the inside bolts
   c. From the inside bolts to the outside bolts
   d. Starting at the front of the engine and torquing bolts from front to rear
7. The torque-angle method involves ______.
   a. Turning all bolts the same number of turns
   b. Torquing to specifications and loosening by a specified number of degrees
   c. Torquing to one-half specifications, then to three-quarter torque, then to full torque
   d. Turning bolts a specified number of degrees after initial torque
8. Turning the oil pump before starting the engine should be done ______.
   a. To lubricate engine bearings
   b. To lubricate valve train components
   c. To supply oil to the camshaft
   d. All of the above
9. Most bolt torque specifications are for ______.
   a. Clean threads only
   b. Clean and lubricated threads
   c. Dirty threads
   d. Dirty threads, but 50% can be added for clean threads
10. Cam bearings should be installed ______.
   a. Dry
   b. Oiled
   c. With at least 0.010 inch of crush
   d. Both b and c