

INTRODUCTION

Cylinder heads support the valves and valve train, and contain passages for the flow of intake, exhaust gases, coolant, and sometimes engine oil. In an overhead camshaft design engine, the cylinder head also supports all of the valve train components, including the camshaft, rocker arms, or followers, as well as the intake and exhaust valves and valve guides. Fig 1.

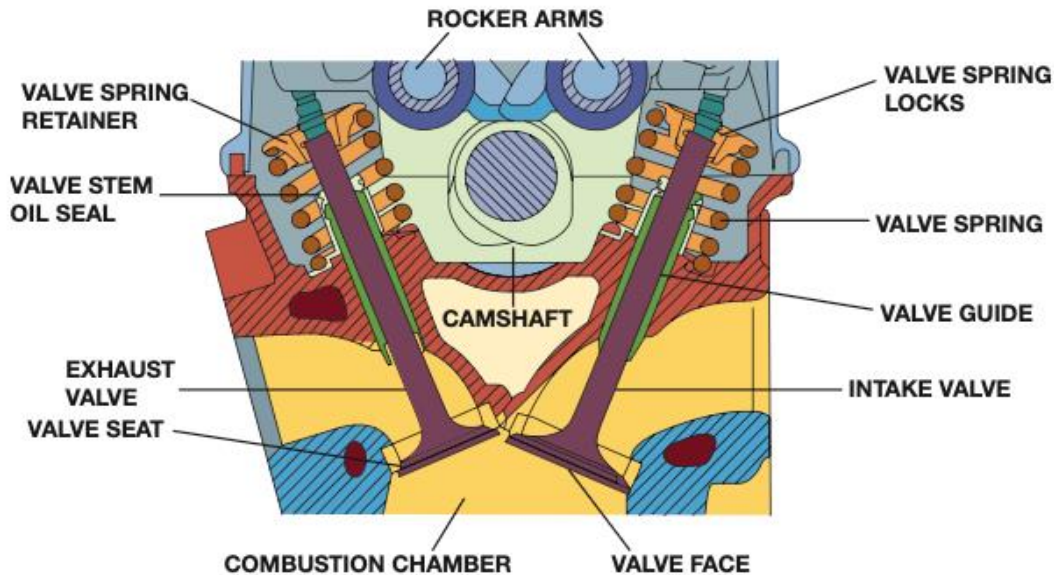


Figure 1. Parts of a cylinder head.

Adding more than two valves per cylinder permits more air to flow into and out of the engine with greater velocity without excessive valve duration. Valve duration is the number of degrees by which the crankshaft rotates when the valve is off the valve seat. Fig 2.

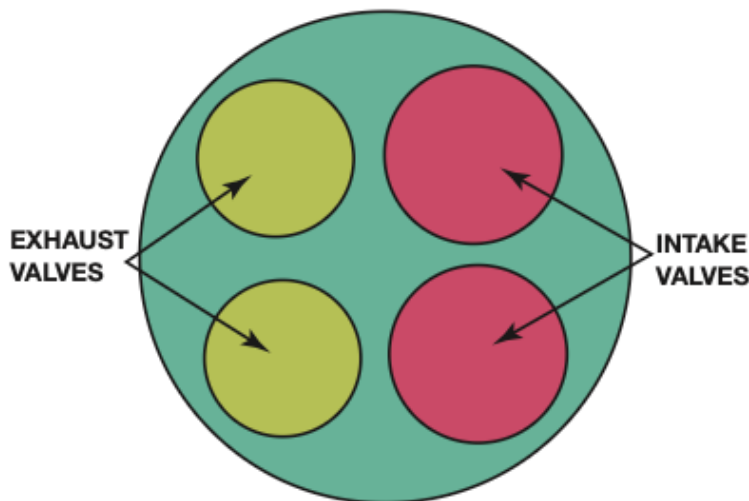


Figure 2. Four valve cylinder head.

Increased valve duration increases valve overlap. The valve overlap occurs when both valves are open at the same time at the end of the exhaust stroke and at the beginning of the intake stroke. At lower engine

speeds, the gases can move back and forth between the open valves. Therefore, the greater valve duration hurts low engine speed performance and drivability, but it allows for more air-fuel mixture to enter the engine for better high-speed power.

More total area under the valve is possible when two smaller valves are used, rather than one larger valve at the same valve lift. When four valves are used, either the combustion chamber has a pentroof design, with each pair of valves in line, or it is hemispherical, with each valve on its own axis. Fig 3.

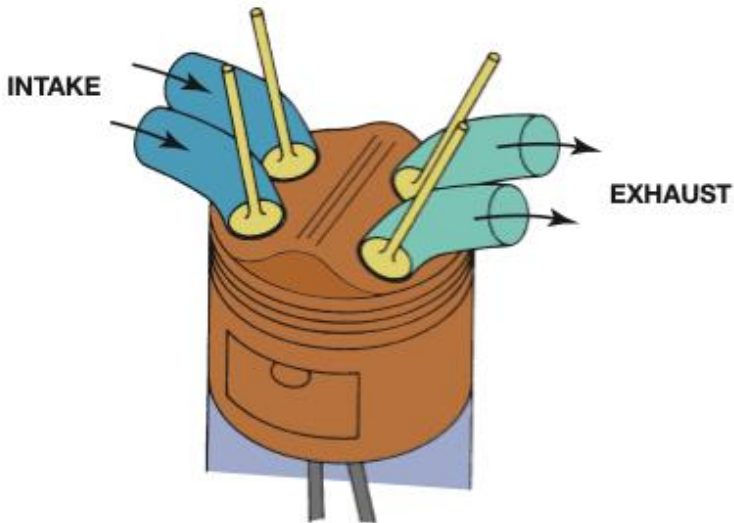


Figure 3. Four valves in a pentroof combustion chamber.

The part of the intake or exhaust system passage that is cast in the cylinder head is called a port. Ports lead from the manifolds to the valves. Fig 4.

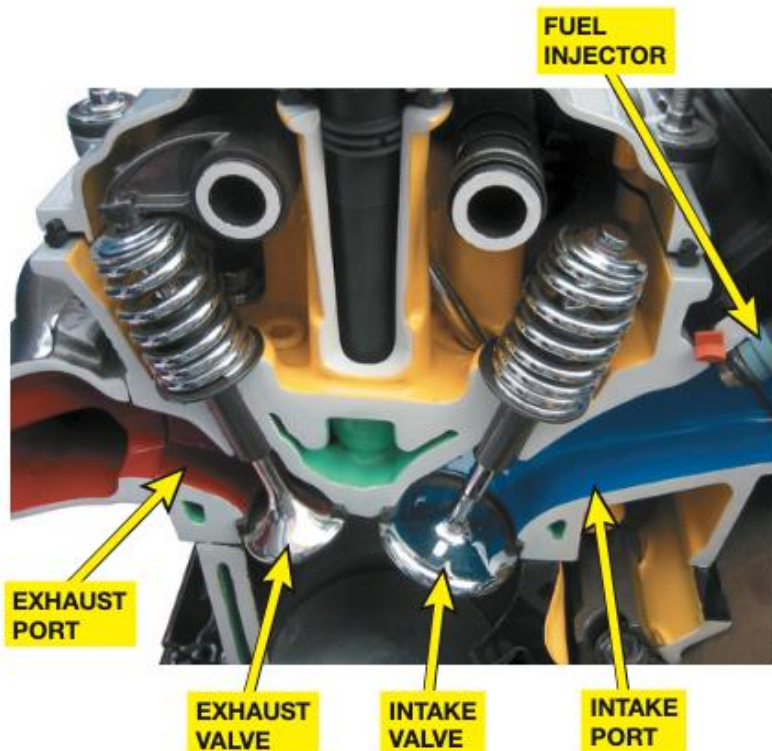


Figure 4. Intake and exhaust ports.

ASE TEST TOPICS

1. Remove cylinder heads; clean and prepare for inspection.

Cam-in-block engine

- Remove the rocker arm covers. Examine the rocker arms, valve springs, and valve tips for obvious defects. Remove the rocker arms and pushrods and, if they are to be reused, place them in a location so that the rockers and the pushrods can be installed back to their original location.
- Remove or disconnect the intake and exhaust manifolds.
- Remove the cylinder head bolts (also called cap screws) following the reverse of the installation procedure. Loosening the fasteners at the ends of the cylinder head first, then working toward the center, helps reduce the chance of warpage to the cylinder head. Be sure to notice and mark the head bolt locations, as they are often different lengths, depending on their location in the head. Carefully lift the head from the block deck.

Overhead cam engine

Disassembling an overhead camshaft engine differs from a cam-in-block (OHV) engine. This is necessary due to the timing chain/belt that drives the camshaft(s). Some steps that are different are:

- Remove the crankshaft harmonic balancer pulley that will allow access to the timing chain or belt cover.
 - Remove the timing belt/chain cover(s) and then the timing belt(s) or chain(s).
 - With most overhead camshaft engines, the camshaft(s) must be removed before removing the cylinder head due to location of the head bolts.
 - Remove the cylinder head by removing the cylinder head bolts in the opposite order of assembly.
- Fig 5.

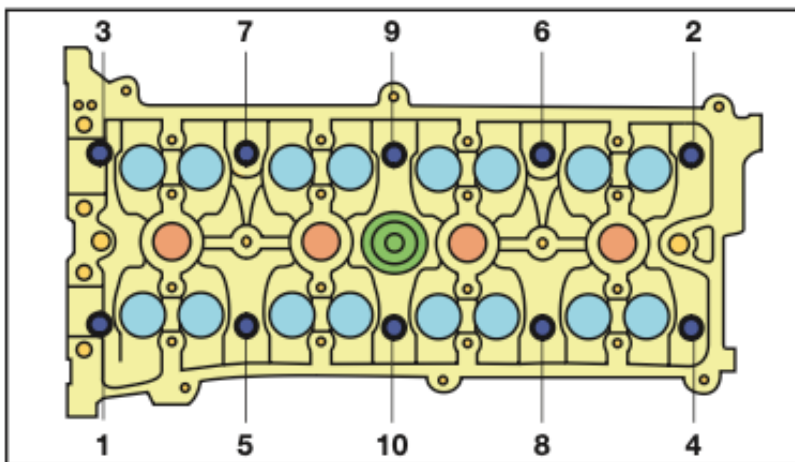


Figure 5. Head bolt loosening sequence.

2. Visually inspect cylinder heads for cracks, warpage, corrosion, leakage, and the condition of passages.

Although not all cylinder heads require all service operations, cylinder heads should be repaired using the following sequence.

1. Disassemble and thoroughly clean the heads.
2. Check for cracks and repair as necessary.
3. Check the surface that contacts the engine block and machine, if necessary.
4. Check valve guides and replace or service, as necessary.
5. Grind valves and reinstall them in the cylinder head with new valve stem seals.

The overhead camshaft cylinder head will have either one-piece bearings in a solid bearing support or split bearings and a bearing cap. When bearing caps are used, they should be loosened alternately so that bending loads are not placed on either the cam or bearing caps. Fig 6.

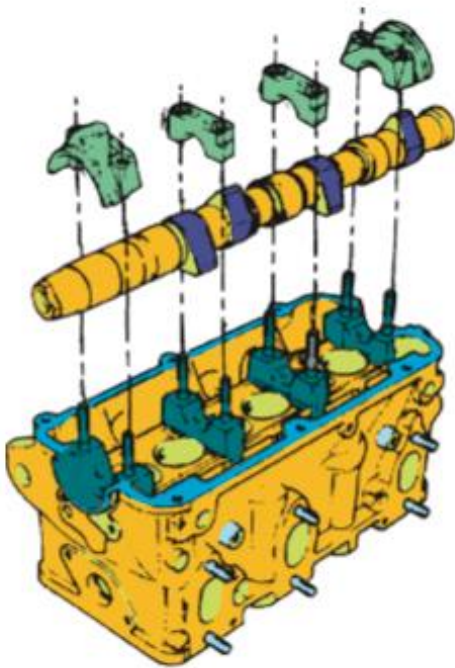


Figure 6. Overhead camshaft and bearing caps.

The surface must be thoroughly cleaned and inspected as follows:

- After removing the old gasket material, use a file and draw it across the surface of the head to remove any small burrs.
- The head surface should be checked in five planes. Checking the cylinder head gasket surface with a precision straightedge in five planes checks the head for warpage, distortion, bend, and twist. These defects are determined by trying to slide a 0.004 inch (0.1 mm) feeler gauge under a precision straightedge held against the head surface. The clearance between the cylinder head

and the straightedge should not vary by over 0.002 inch (0.05 mm) in any 6 inch (15 cm) length, or by more than 0.004 inch overall. Fig 7.

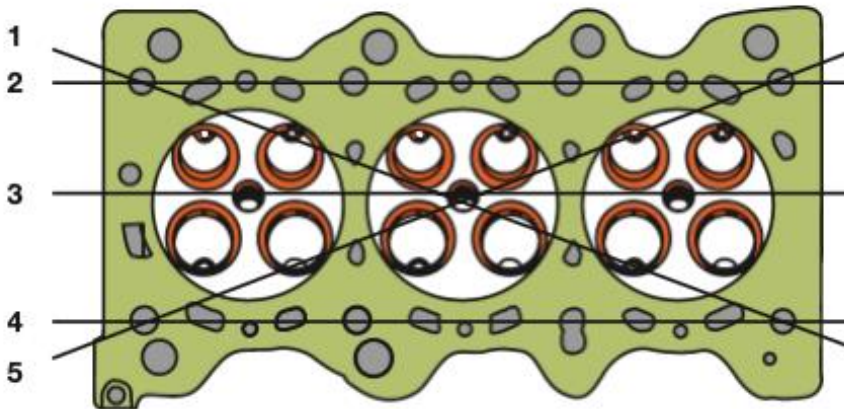


Figure 7. Straightedge positions for measuring head warpage.

3. Inspect valves and valve seats.

Automotive engine valves are of a poppet valve design. The term poppet refers to the shape of the valve and their operation in automotive engines. The valve is opened by means of a valve train that is operated by a cam. The cam is timed to the piston position and crankshaft cycle. The valve is closed by one or more springs. Fig 8.

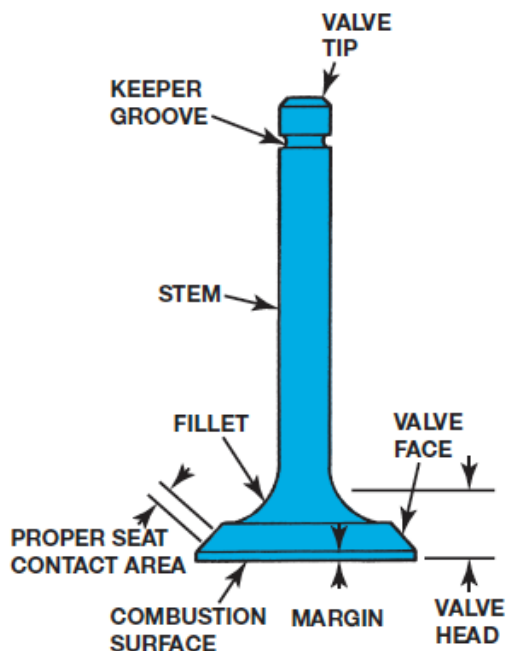


Figure 8. A poppet valve.

The valve is held in place and is positioned in the head by the valve guide. The portion of the valve that seals against the valve seat in the cylinder head is called the valve face. The face and seat will have an

angle of either 30 or 45 degrees, which are the nominal angles; actual service angles may vary. Most engines use a nominal 45-degree valve and seat angle.

Valves should be inspected for wear, cracks, high temperature damage. Fig 9.



Figure 9. A valve damaged by excessive temperature in the combustion chamber.

4. Inspect, test, and verify valve springs for squareness; perform free height comparison.

Valve springs close the valves after they have been opened by the cam. They must close squarely to form a tight seal and to prevent valve stem and guide wear. They should be within 1/16 inch (1.6 mm) of being square. Out-of-square springs will have to be replaced. Free height (or length) without being compressed, should be within 1/16 (0.06) inch of specifications and all springs should be the same height. Fig 10.

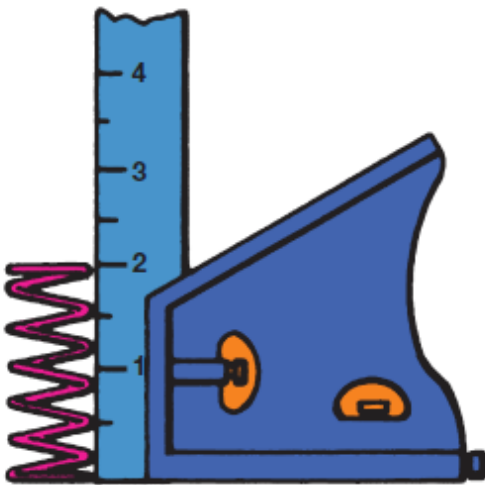


Figure 10. Measuring free height and squareness.

5. Inspect valve spring retainers, rotators, valve locks, and valve lock grooves.

A valve spring holds the valve against the seat. The valve keepers (also called locks) secure the spring retainer to the stem of the valve. For valve removal, it is necessary to compress the spring and remove the valve keepers. Then the spring, valve seals, and valve can be removed from the head. Fig 11.

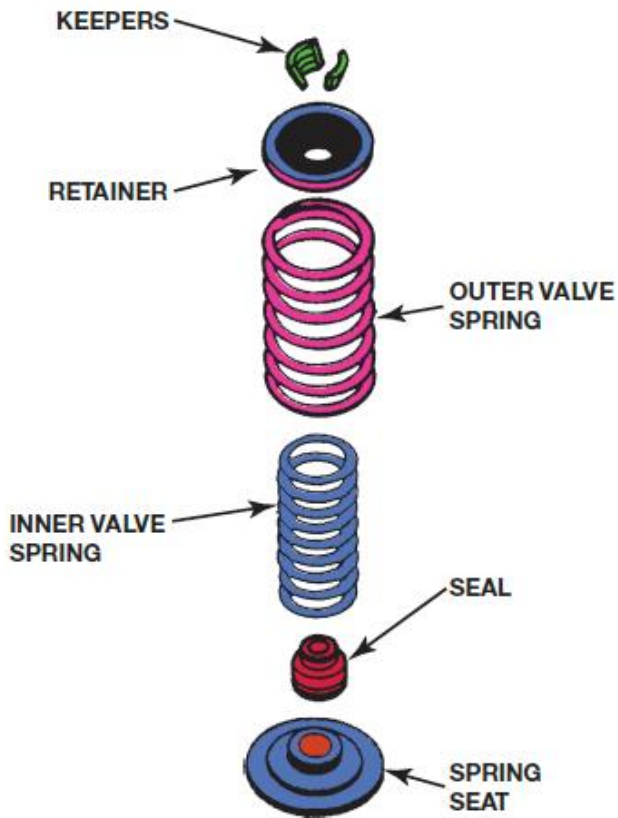


Figure 11. Valve springs, retainer, and keepers.

6. Replace valve stem seals.

Valve stem seals are used on overhead valve engines to control the amount of oil used to lubricate the valve stem as it moves in the guide. The stem and guide will scuff if they do not have enough oil. Too much oil will cause excessive oil consumption and will cause heavy carbon deposits to build up on the spark plug nose and on the valves. Different types of seals are used. The most common is the positive valve stem seal that holds tightly around the valve guide, and the valve stem moves through the seal.

Use a plastic sleeve over the tip of the valve when installing positive seals to prevent damage to the seal lip. Make sure that the positive seal is fully seated on the valve guide and that it is square. Fig 12.

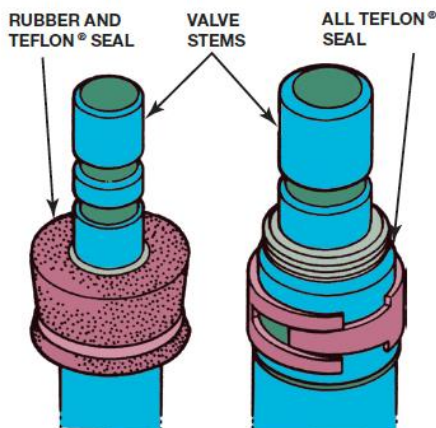


Figure 12. Valve stem seals.

7. Inspect valve guides for wear; check valve stem-to-guide clearance.

In operation, the valve opening mechanism pushes the valve tip sideways. This is the major cause of valve stem and guide wear. The movement of the valve causes both the top and bottom ends of the guide to wear until the guide has bell-mouth shapes at both ends. Engine manufacturers usually recommend the following valve stem-to-guide clearances:

- Intake valve: 0.001 to 0.003 inch (0.025 to 0.076 mm)
- Exhaust valve: 0.002 to 0.004 inch (0.05 to 0.1 mm)

The valve guide is measured in the middle with a small-hole gauge. The gauge size is checked with a micrometer. The guide is then checked at each end.

The dimension of the valve stem diameter is subtracted from the dimension of the valve guide diameter. If the clearance exceeds the specified clearance, the valve guide will have to be replaced. Fig 13.

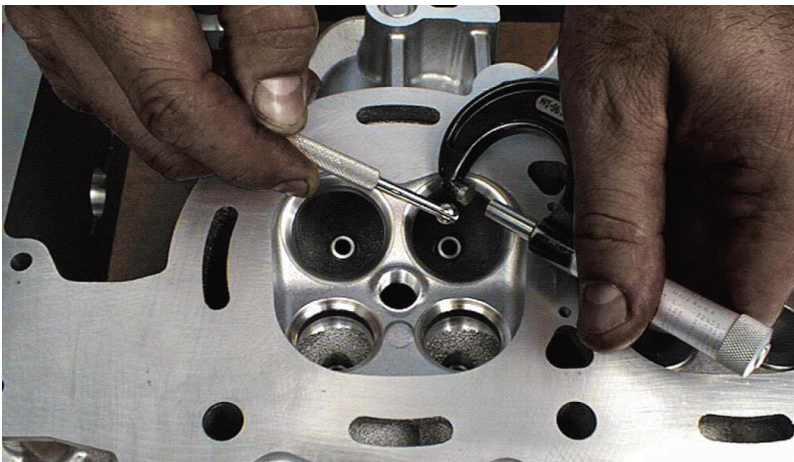




Figure 13. Measuring valve guide and valve stem using a micrometer.

8. Check valve spring installed (assembled) height uniformity; check valve stem height uniformity.

Installed height is the distance between the valve spring seat and the underside of the valve spring retainer. When the valves and/or valve seats have been machined, the valve projects farther than before on the rocker arm side of the head. The valve face is slightly recessed into the combustion chamber side of the head. The valve spring tension is reduced because the spring is not as compressed as it was originally. To restore original valve spring tension, special valve spring spacers, inserts, or shims are installed under the valve springs.

Valve stem height is the distance the valve stem is above the spring seat. Valve stem height is a different measurement from installed height. Valve stem height is important to maintain for all engines, but especially for overhead camshaft engines. Incorrect stem height makes it difficult or impossible to set the correct valve clearances. Fig 14.

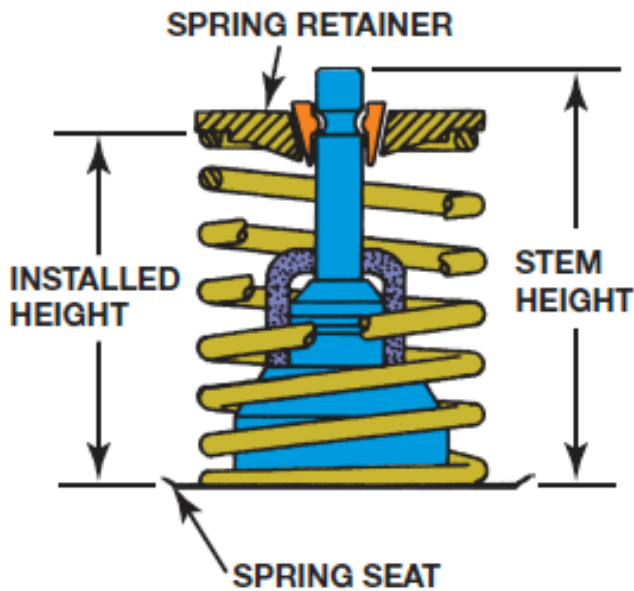


Figure 14. Installed height and stem height

9. Inspect pushrods, rocker arms, rocker arm pivots, and rocker arm shafts for wear, bending, cracks, looseness, and blocked oil passages.

A rocker arm reverses the upward movement of the pushrod to produce a downward movement on the tip of the valve. Stud-mounted rockers are only found on OHV engines, and each rocker arm is attached to a stud that is pressed or threaded into the cylinder head. Fig 15.

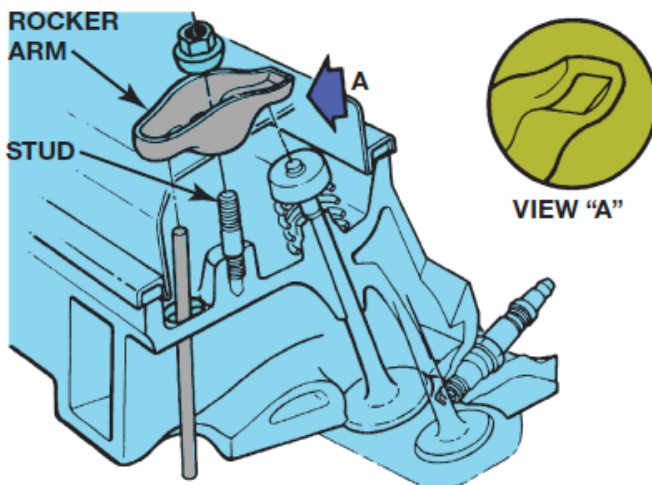


Figure 15. Rocker arm and pushrod.

Pushrods are used on OHV (cam-in-block) engines and transfer the lifting motion of the valve train from the cam lobe and lifters to the rocker arms. Pushrods are designed to be as light as possible and still maintain their strength. They may be either solid or hollow. If they are to be used as passages for oil to lubricate rocker arms, they must be hollow. All pushrods should be rolled on a flat surface to check for straightness. Fig 16.

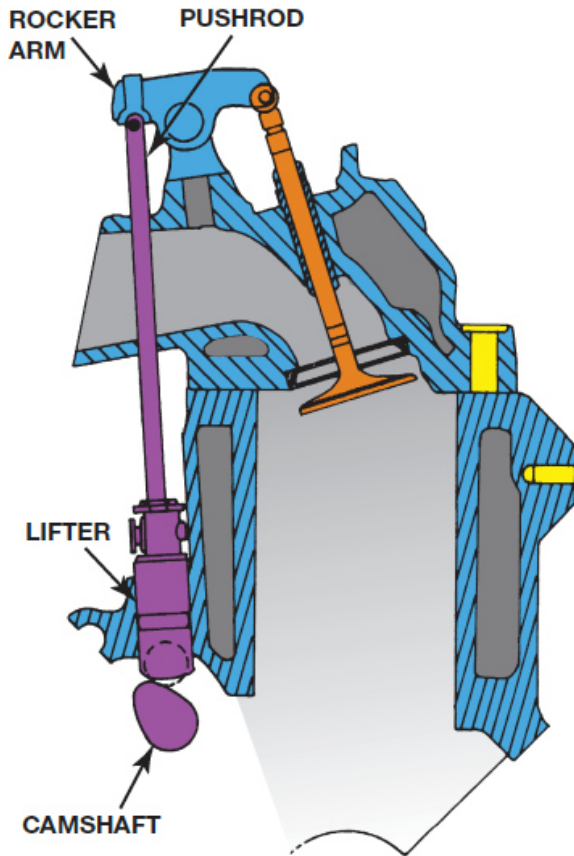


Figure 16. Overhead valve train, showing cam, lifter, pushrod, and rocker arm.

10. Inspect hydraulic or mechanical lifters/lash adjusters.

Valve lifters or tappets follow the contour or shape of the camshaft lobe. This arrangement changes the rotary cam motion to a reciprocating motion in the valve train. Older-style lifters have a relatively flat surface that slides on the cam.

Most lifters, however, are designed with a roller to follow the cam contour. Roller lifters are used primarily in production engines to reduce valve train friction (by up to 8%). This friction reduction can increase fuel economy.

Valve train clearance is also called valve lash, which is needed to help compensate for thermal expansion and wear. Two methods are commonly used to make the necessary valve clearance adjustments.

- One involves a solid valve lifter, which can be adjusted mechanically at the rocker arm or by changing shims on certain overhead camshaft engines. Fig 17.
- The other involves a lifter with an automatic hydraulic adjustment built into the lifter body, called a hydraulic valve lifter. Fig 18.

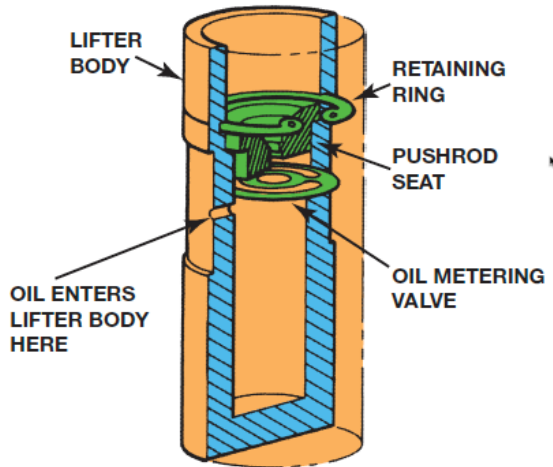


Figure 17. A solid lifter. The oil metering valve supplies oil to the hollow pushrod to lubricate the rocker arms. This type requires mechanical adjustment.

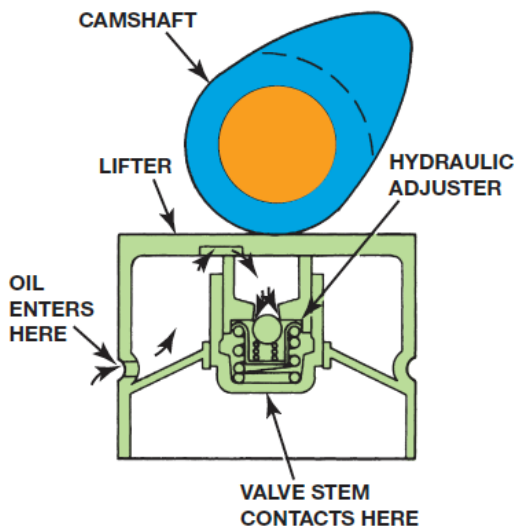


Figure 18. Hydraulic lifter on an overhead cam engine.

11. Adjust valves on engines with mechanical or hydraulic lifters.

On solid lifters, the valve clearance or lash is checked with the overhead camshaft in place. Some engines use shims under a follower disk. On these engine types, the camshaft is turned so that the follower is on the base circle of the cam. The clearance of each bucket follower can 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. Fig. 19.

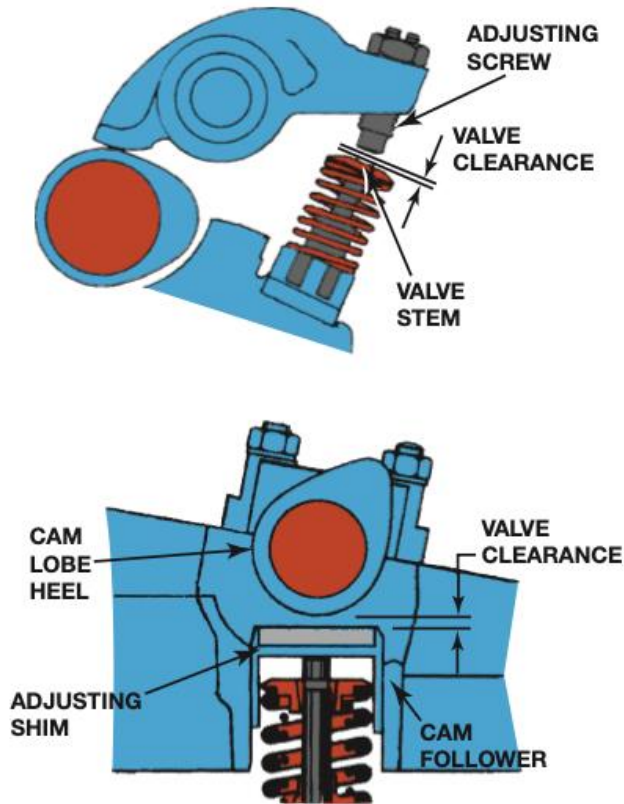


Figure 19. Mechanical or solid lifters adjust with an adjusting screw or shim.

For engines with hydraulic lifters, rocker arms are tightened to a position that will center the hydraulic lifter. The general steps are:

- Rotate the engine until cylinder 1 is at TDC on the compression stroke to be assured that both the intake and exhaust valves are on the base circle of the cam lobes.
- Tighten the retaining nut to the point that all free lash is gone and the pushrod cannot be easily rotated. Fig 20.
- 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.
- Rotate the engine until the next cylinder in the firing order is at top dead center on the compression stroke. The valves on this next cylinder are adjusted in the same manner as those on cylinder 1. This procedure is repeated on each cylinder following the engine firing order until all the valves have been adjusted.



Figure 20. Adjusting to zero lash.

12. Inspect camshaft drive gear train components (includes gear(s), chain(s), tensioner(s), guide(s) and belt systems).

The crankshaft drives the camshaft with one of the following:

- Timing gears
- Sprockets and chains
- Sprockets and timing belts

Timing chains often have tensioners (dampers) pressing on the unloaded side of the chain. The tensioner is held against the chain by either a spring or hydraulic oil pressure. Fig 21.

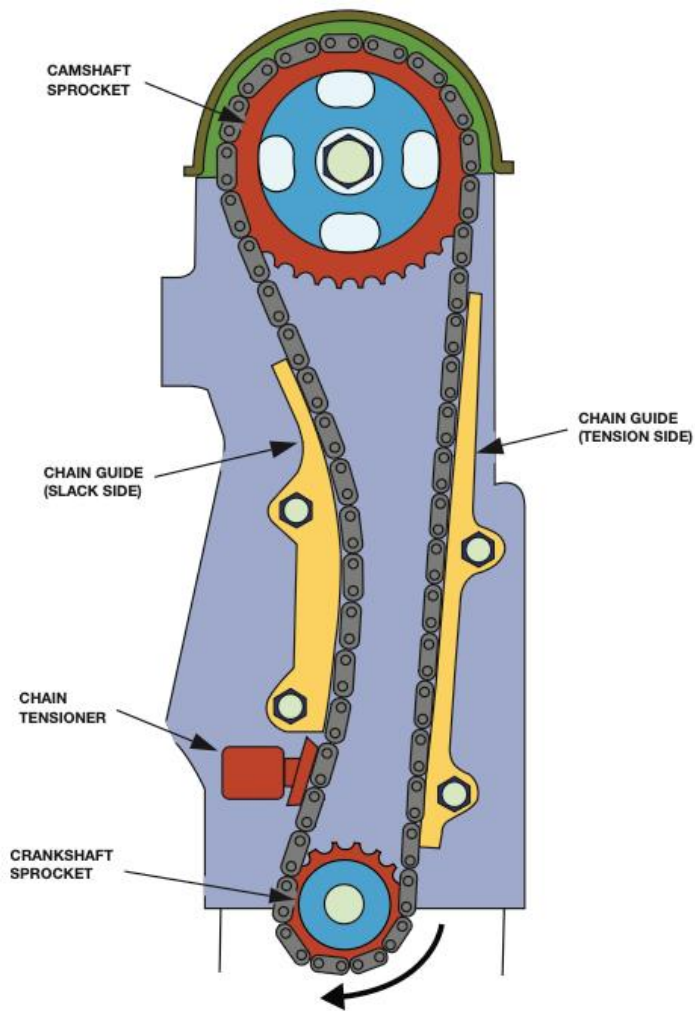


Figure 21. Timing chain, guides, and tensioner.

Many overhead camshaft engines use a timing belt rather than a chain. Cam drive belts are made from rubber and reinforced with fabric. Fig 22.

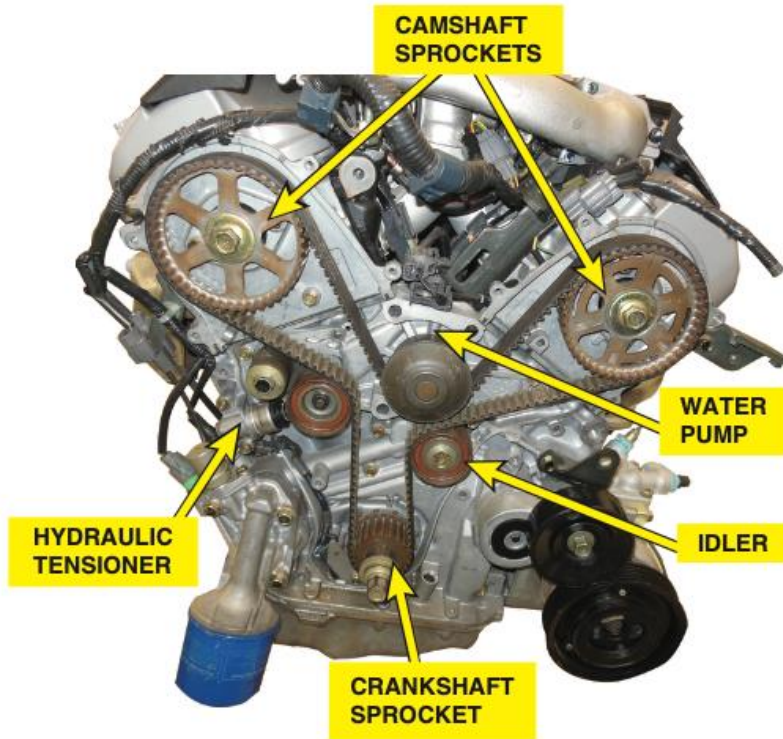


Figure 22. Timing Belt and related components.

Unless the engine is freewheeling, the piston can hit the valves if the belt breaks. A freewheeling engine is one that causes no internal damage if the camshaft drive belt breaks when the engine is running. An interference engine, however, causes some of the valves that are open to hit the pistons, causing major engine damage.

13. Inspect camshaft journals and lobes; measure camshaft lift.

The bearing journals of the camshaft(s) can be measured using a micrometer and compared with factory specifications for taper. Camshaft journals should be measured in three locations, 120 degrees apart, to check for out-of-round. The cam lift can also be measured with a micrometer and compared with factory specifications. Fig 23 and 24.

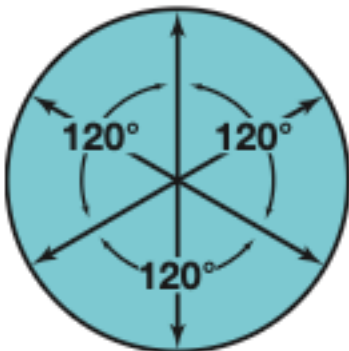


Figure 23. Measuring cam journals.

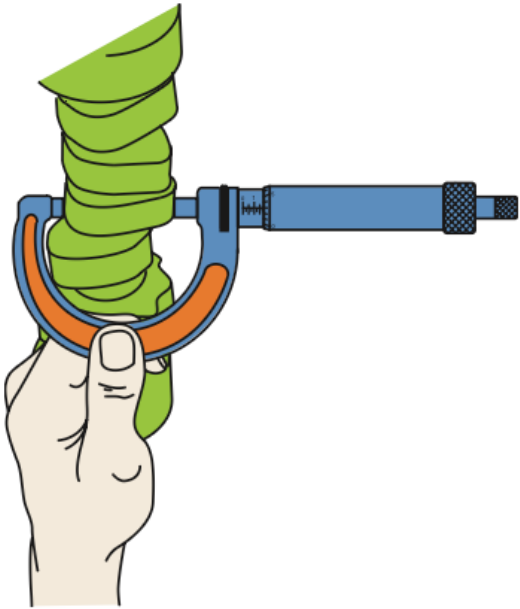


Figure 24. Measuring lobe wear.

14. Inspect camshaft bore (caps and pedestal) for wear, damage, out-of-round, and alignment.

A telescopic gauge is used with a micrometer to measure the inside diameter cam bearings. The bearings is measured by inserting a telescopic gauge into the bore and rotating the handle lock to allow the arms of the gauge to contact the inside of the bearing. Tighten the handle lock and remove the gauge. Use a micrometer to measure the telescopic gauge. Fig 25.

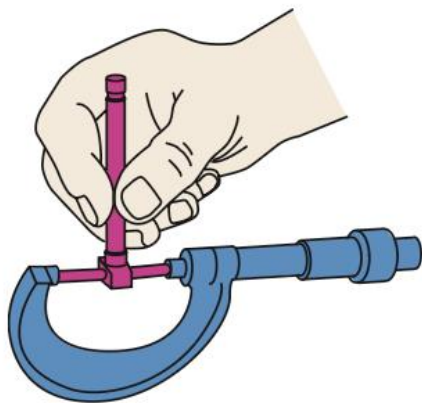
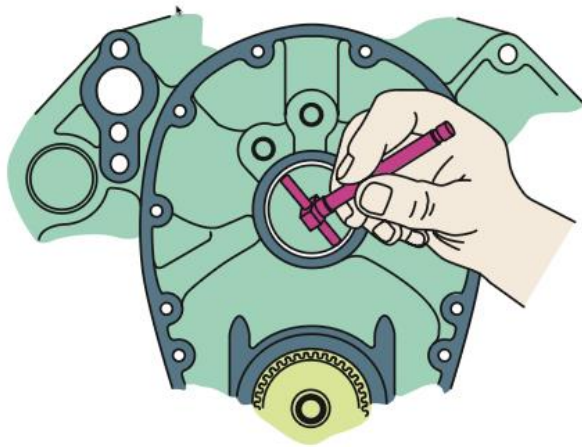


Figure 25. Measuring camshaft bearings.

15. Inspect valve timing; time camshaft(s) to crankshaft.

Checking the cam-to-crank timing 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 be identified by looking carefully at the sprockets. Fig 26.

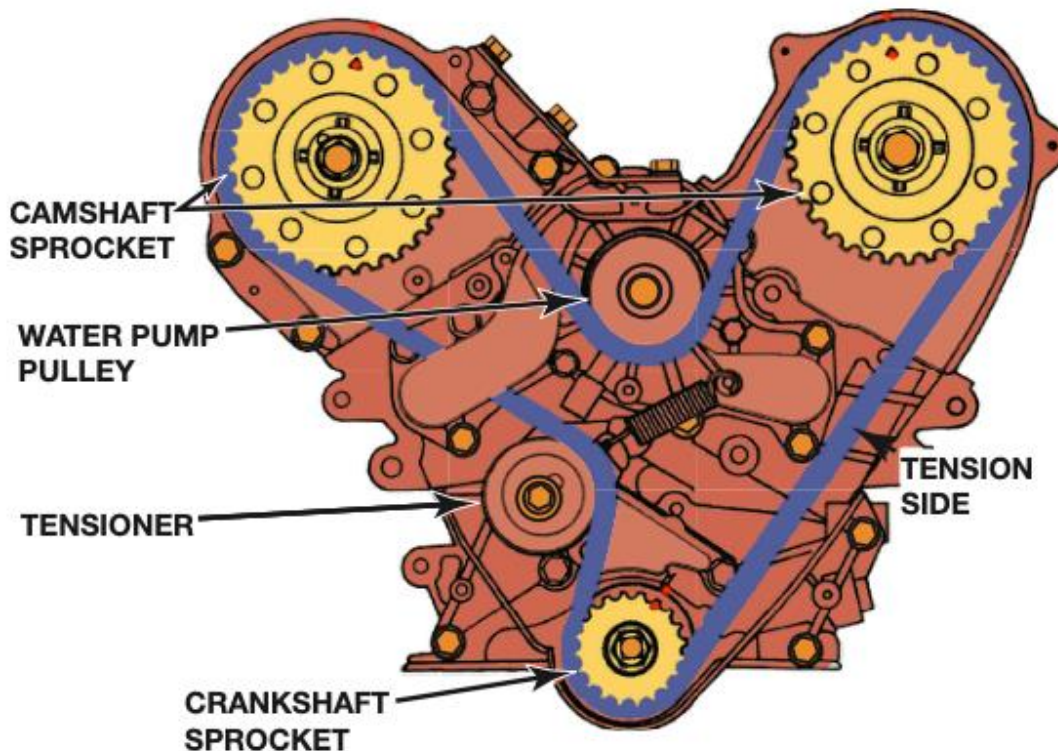


Figure 26. Cam drive timing marks on the sprockets and front engine cover (red marks). Normal rotation for this engine is clockwise.

To double check the cam timing, rotate the crankshaft through two full revolutions in the normal direction. On the first full revolution, the exhaust valve will be almost closed, and the intake valve will just be 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. This is the position the crankshaft should have when cylinder 1 is ready to be fired.

16. Inspect cylinder head mating surface condition and finish, reassemble and install gasket(s) and cylinder head(s); replace/torque bolts according to manufacturer's procedures.

The surface finish is important for the proper sealing of any gasket. If the surface finish is too rough, the gasket will not be able to seal the deep grooves in the surface. If the surface finish is too smooth, the gasket can move out of proper location, causing leakage. Surface finish is measured in microinches, usually abbreviated by using the Greek letter mu (μ) and the abbreviation for inches together (μ inch). For the acceptable roughness for the head gasket surface refer to this chart.

ENGINE PART MATERIAL	GASKET MATERIAL	ACCEPTABLE SURFACE FINISH (RA)
Cast iron/cast iron	Composite	60 to 80 μ inch
Aluminum/cast iron	Composite	20 to 30 μ inch
Aluminum/cast iron	Rubber-coated multilayered steel (MLS)	15 to 30 μ inch

The torque put on the bolts is used to control the clamping force that is applied to the gasket. 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. The procedure starts with the head bolts in the center and then moves to those farther and farther from the center. This procedure helps spread the forces toward the ends of the cylinder. Fig 27.

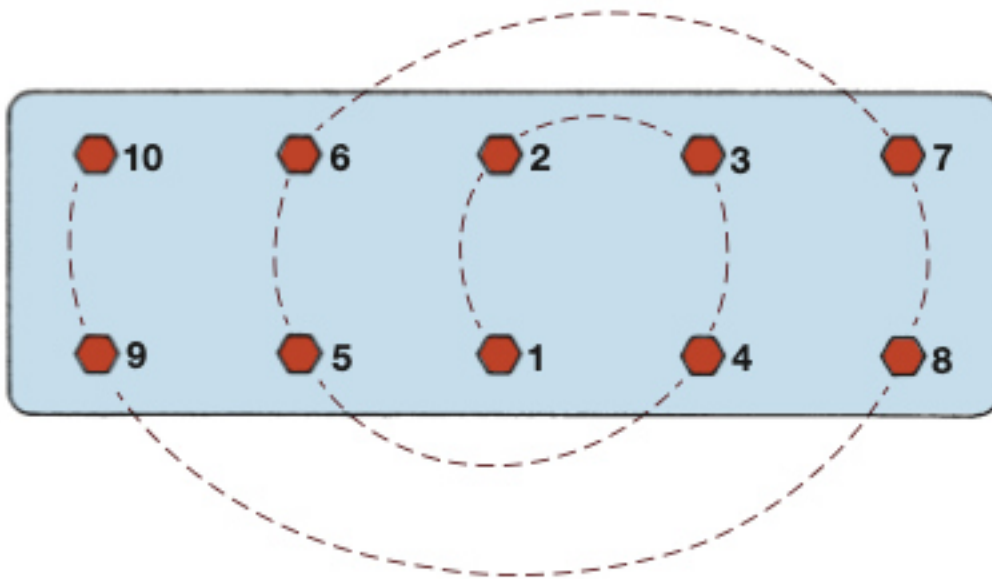


Figure 27. Typical torque sequence.

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 in the following manner.

1. Tighten to one-third the specified torque.
2. - Tighten them a second time following the torque sequence to two-thirds the specified torque.
3. Follow the sequence with a final tightening to the specified torque.

Torque-to-yield bolts are tightened to a specific initial torque, from 18 to 50 pound-feet (25 to 68 N-m). The bolts are then tightened an additional specified number of degrees, following the tightening

sequence. In some cases, they are turned a specified number of degrees two or three times. Torque angle can be measured using a special adaptor. Fig 28.

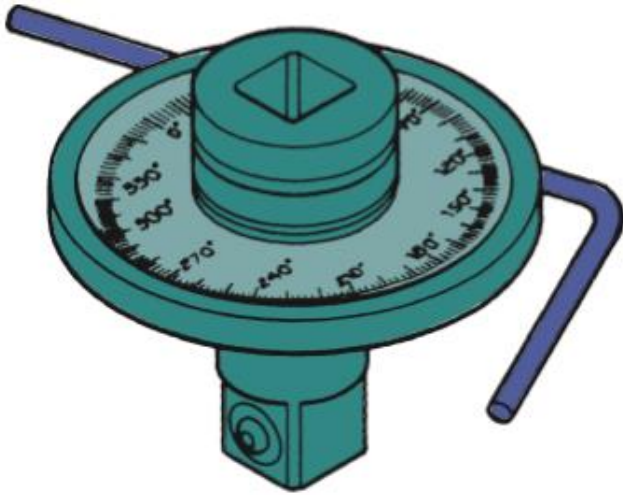


Figure 28. Torque angle gauge.

17. Inspect overhead camshaft variable valve timing (VVT) components.

Variable valve timing (VVT) involves the use of electric and hydraulic actuators that are used to change the timing of the camshaft(s) in relation to the crankshaft. Variable valve timing, also called variable cam timing (VCT), allows the valves to be operated at different points in the combustion cycle to improve performance.

The vane phaser system used on OHC engines uses a camshaft position (CMP) sensor on each camshaft. Each camshaft has its own actuator and its own oil control valve (OCV). The vane phaser uses a rotor with four vanes, which is connected to the end of the camshaft. Oil pressure is controlled on both sides of the vanes of the rotor. The OCV varies the balance of pressure on either side of the vanes and thereby controls the position of the camshaft. A return spring is used under the reluctor of the phaser to help return it to the home position. Fig 29.

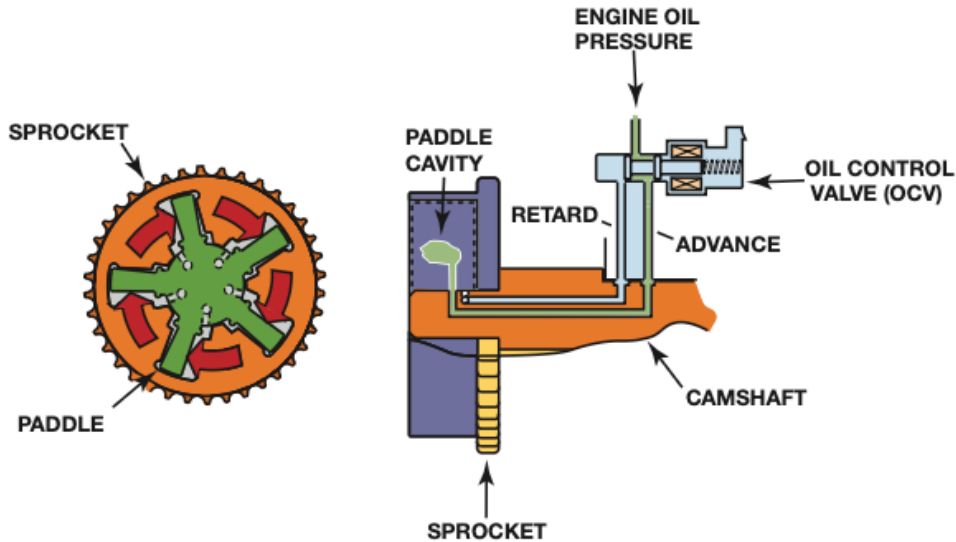


Figure 29. Variable valve timing vane-type phaser.

18. Inspect variable valve lift (VVL) components.

Variable camshafts such as the system used by Honda/Acura are called variable valve timing and lift electronic control (VTEC). This system uses two different camshafts profiles for low and high RPM. When the engine is operating at idle and speeds below about 4000 RPM, the valves are opened by cam lobes that are optimized by maximum torque and fuel economy. When engine speed reaches a predetermined speed, depending on the exact make and model, the computer turns on a solenoid, which opens a spool valve. When the spool valve opens, the engine oil pressure pushes against pins that lock the three intake rocker arms together. With the rocker arms lashed, the valves must follow the profile of the high RPM cam lobe in the center.

19. Inspect, clean, replace, and/or reinstall fasteners; torque fasteners; inspect and repair damaged threads.

All threads in the block should be thoroughly cleaned. Many experts recommend using a thread chaser, because a tap could cut and remove metal. A chaser will restore the threads without removing metal. Check that all liquid has been removed from the bolt holes in the block. If liquid is in the bottom of a blind hole, the block can be cracked when the bolt is installed. Fig 30.

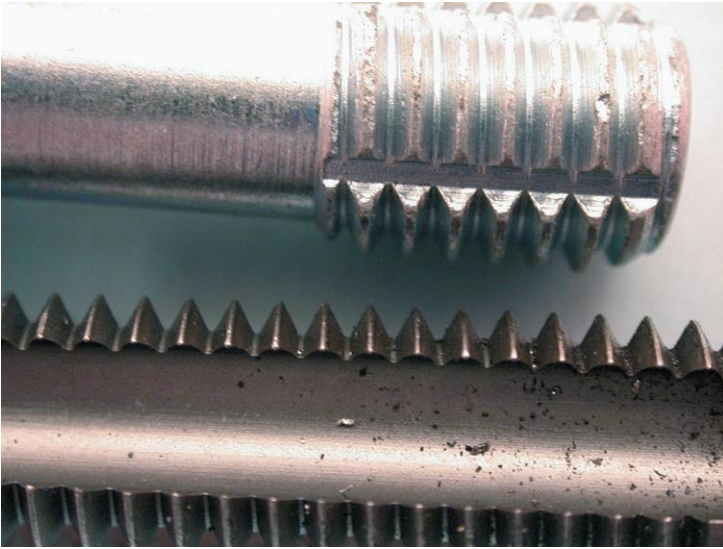


Figure 30. Use a thread chaser (top) to clean threaded holes.

Thread repair inserts are used to replace the original threaded hole when it has become damaged beyond use. The original threaded hole is enlarged and tapped for threads, and a threaded insert is installed to restore the threads to the original size. Fig 31.

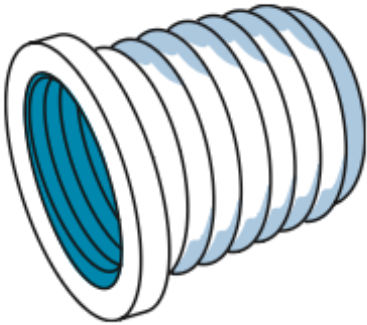


Figure 31. A thread repair insert.

20. Inspect core and gallery plugs; determine needed action.

Core holes left in the external block wall are machined and sealed with soft core plugs or expansion plugs (also called freeze plugs or Welsh plugs). A cup plug is installed about 0.02 to 0.05 inch (0.5 to 1.3 mm) below the surface of the block, using sealant to prevent leaks. Fig 32.

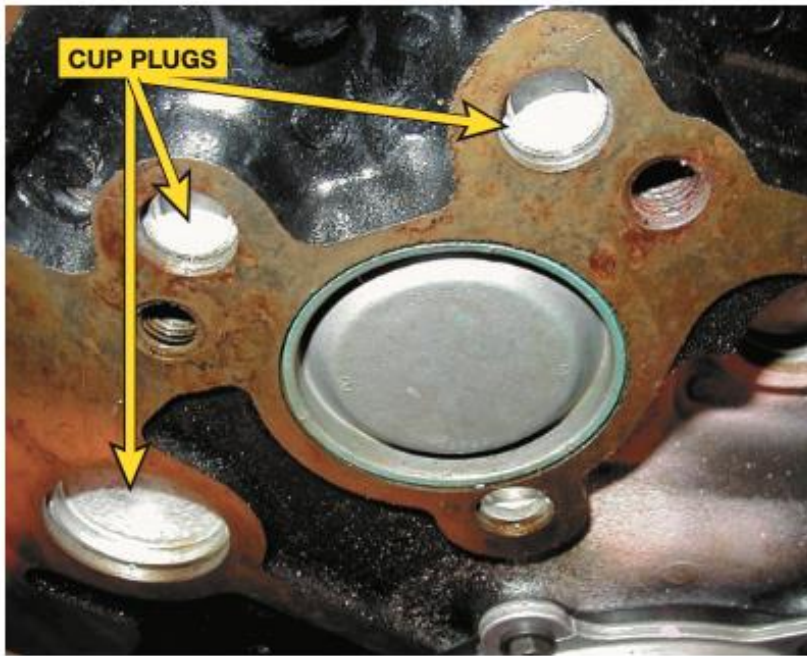


Figure 32. Cup plugs in an engine block.