Figure 32-1. This high-performance camshaft has a lobe that opens the valve quickly and keeps it open for a long time.

Figure 32-2. In many engines, the camshaft drives the distributor and the oil pump through a shaft from the end of the distributor.
Figure 32-3 The camshaft rides on bearings inside the engine block above the crankshaft on a typical cam-in-block engine.

Figure 32-4 Parts of a cam and camshaft terms (nomenclature).

Figure 32-5 A composite camshaft is lightweight and yet flexible, because the hollow tube can absorb twisting forces and the lobes are hard enough to withstand the forces involved in opening and closing valves.
Figure 32-6  Worn camshaft with two lobes worn to the point of being almost round.

Figure 32-7  The fuel pump rocker arm rides on the camshaft eccentric.

Figure 32-8  A timing chain hydraulic tensioner.
Figure 32-9  The larger camshaft gear is usually made from fiber and given a helical cut to help reduce noise. By making the camshaft gear twice as large as the crankshaft gear, the camshaft rotates one revolution for every two of the crankshaft.

Figure 32-10  A replacement silent chain and sprockets. The original camshaft sprocket was aluminum with nylon teeth to help control noise. This replacement set will not be noticeably louder than the original and should give the owner many thousands of miles of useful service.

Figure 32-11  The industry standard for when to replace a timing chain and gear is when 0.2 in. (5 mm) or more of slack is present in the chain. However, it is best to replace the timing chain and gear anytime at which it is present in the chain, regardless of its form. Replace the timing chain and gear anytime at which it is present in the chain, regardless of its form.
Figure 32-12 A replacement high-performance double roller chain. Even though it is noisier than a single chain, it stretches so much and less that it is able to maintain accurate valve timing for a long time.

Figure 32-13 This dual overhead camshaft (DOHC) engine uses one chain from the crankshaft to the intake cam and a secondary chain to rotate the exhaust camshaft.

Figure 32-14 A timing belt failed when the teeth were sheared off. This belt failed at 88,000 miles because the owner failed to replace it at the recommended interval of 60,000 miles.
Figure 32-15 - This timing belt broke because an oil leak from one of the camshaft seals caused oil to get into and weaken the belt. Most experts recommend replacing all engine seals in the front of the engine whenever a timing belt is replaced. If the timing belt travels over the water pump, the water pump should also be replaced as a precaution.

Figure 32-16 - Many engines are of the interference design. If the timing belt (or chain) breaks, the piston(s) continue to move up and down in the cylinder while the valves remain stationary. This is a freewheeling design, nothing is damaged, but in an interference engine, the valves are often bent.

Figure 32-17 - A head from a Mercedes showing bent valves when the timing chain stretched and skipped over the crankshaft sprocket. When this happened, the piston kept moving and bent the valves.
Figure 32-18 The slight angle and the curve on the bottom of a flat bottom lifter cause the lifter and the pushrod to rotate during normal operation.

Figure 32-19 The lobe lift is the amount the cam lobe lifts the lifter. The blue circle is called the base circle. Because the valve train adds to the lift, the entire valve train has to be considered when selecting a camshaft that has the desired lift and duration.

Figure 32-20 The ramps on the cam lobe allow the valves to be opened and closed quickly yet under control to avoid damaging valve train components, especially at high engine speeds.
Tech Tip: Best to Warn the Customer
A technician replaced a timing chain and gears on a high-mileage Chevrolet V-8. The repair was accomplished correctly, yet after starting, the engine burned an excessive amount of oil. Before the timing chain replacement, oil consumption was minimal. The replacement timing chain restored proper operation of the valves. The technician also replaced the timing chain tensioner and sprockets to ensure proper valve timing. Increased engine vacuum increased vacuum and drew oil from the crankcase past worn piston rings and through worn valve guides during the intake stroke. Similar increased oil consumption problems occur if a valve job is performed on a high-mileage engine with worn piston rings and/or valve guides. To satisfy the owner of the vehicle, the technician had to disassemble and recondition the cylinders and replace the piston rings. Therefore, all technicians should warn customers that increased oil usage might result from almost any engine repair to a high-mileage engine.

Figure 32-21 A 1.5:1 ratio rocker arm means that dimension A is 1.5 times the length of dimension B. Therefore, if the pushrod is moved up 0.4 in. by the camshaft lobe, the valve will be pushed down (opened) 0.6 in., or 1.5, or 2.5 in.

Figure 32-22 A high-performance aluminum roller rocker arm. Both the pivot and the tip that contacts the stem of the valve are equipped with rollers to help reduce friction for more power and better fuel economy.
Figure 32-23 Some engines today use rocker shafts to support rocker arms such as the V-6 engine with a single overhead camshaft located in the center of the cylinder head.

Figure 32-24 A typical stud-mounted rocker arm.

Figure 32-25 Pushrod guide plates are bolted to the head and help stabilize the valve train, especially at high engine speeds.
Figure 32-26 A pedestal-type rocker arm design that used one bolt for each rocker arm and is nonadjustable. If valve lash needs to be adjusted, different length pushrods must be used.

FREQUENTLY ASKED QUESTION

Are the Valves Adjustable?
If the stud has the same diameter for its whole length, the rockers are adjustable and the nut will be the “interference” type (lock-type nut). If the stud has a shoulder of a different diameter, the rockers are nonadjustable and the nut will not have interference threads.

Figure 32-27 Overhead valve engines are also known as pushrod engines because of the long pushrod that extends from the lifter to the rocker arm.
TECH TIP: Rocker Arm Shafts Can Cause Sticking Valves

As oil oxidizes, it forms a varnish. Varnish buildup is particularly common on hot upper portions of the engine, such as rocker arm shafts. The varnish restricts clean oil from getting into and lubricating the rocker arms. The cam lobe can easily force the valves open, but the valve springs often do not exert enough force to fully close the valves. The result is an engine miss, which may be intermittent. Worn valve guides and/or weak valve springs can also cause occasional rough idle, uneven running, or an engine misfire.

Figure 32–28  When the timing chain broke, the valves stopped moving up and down but the pistons kept moving and hit the valves causing the pushrods to bend.

TECH TIP: The Scratch Test

All pushrods used with guide plates must be hardened on the sides and on the tips. To easily determine if a pushrod is hardened, simply use a sharp pocketknife to scrape the wall of the pushrod. A heat-treated pushrod will not scratch. ● SEE FIGURE 32–29.
Figure 32-29 Hardened pushrods should be used in any engine that uses pushrod guides (plates). To determine if the pushrod is hardened, simply try to scratch the side of the pushrod with a pocketknife.

TECH TIP: Hollow Pushrod Dirt

Many engine rebuilders and remanufacturers do not reuse old hollow pushrods. Dirt, carbon, and other debris are difficult to thoroughly clean from inside a hollow pushrod. When an engine is run with used pushrods, the trapped particles can be dislodged and run new bearings and other new engine parts. Therefore, for best results, consider purchasing new hollow pushrods instead of trying to clean and reuse the originals.

Figure 32-30 Hydraulic lifters may be built into bucket-type lifters on some overhead camshaft engines.
Figure 32–31 The use of cam followers allows the use of hydraulic lifters with an overhead camshaft design.

Figure 32–32 Hydraulic lash adjusters (HLA) are built into the rocker arms on some OHC engines. Sometimes hydraulic lash adjusters may not bleed down properly if the wrong viscosity (SAE rating) oil is used.

Figure 32–33 Graphic representation of a typical camshaft showing the relationship between the intake and exhaust valves. The shaded area represents the overlap period of 200 degrees.
Figure 32-34  As the lobe center angle decreases, the overlap increases, with no other changes in the lobe profile lift and duration.

Figure 32-35  Typical cam timing diagram.

Chart 32-1  Changing the lobe separation angle has a major effect on engine operation.

<table>
<thead>
<tr>
<th>LOBE SEPARATION ANGLE (LSA)</th>
<th>NARROWER</th>
<th>WIDER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve overlap</td>
<td>Greater</td>
<td>Less</td>
</tr>
<tr>
<td>Intake valve opening</td>
<td>Sooner</td>
<td>Later</td>
</tr>
<tr>
<td>Intake valve closing</td>
<td>Sooner</td>
<td>Later</td>
</tr>
<tr>
<td>Exhaust valve opening</td>
<td>Later</td>
<td>Sooner</td>
</tr>
<tr>
<td>Exhaust valve closing</td>
<td>Later</td>
<td>Sooner</td>
</tr>
<tr>
<td>Idle quality</td>
<td>Later</td>
<td>Sooner</td>
</tr>
</tbody>
</table>

CHART 32-1
Typical high-performance camshaft specifications on a straight-line graph. Intake valve duration = 30° + 180° + 71° = 290 degrees. Exhaust valve duration = 7° + 180° + 47° = 234 degrees. Because intake and exhaust valve specifications are different, the camshaft grind is called asymmetrical.

Figure 32-37 Typical camshaft valve timing diagram with the same specifications as those shown in Figure 32–36.

Older engines used flat-bottom lifters, whereas all engines since the 1990s use roller lifters.
All roller lifters must use some method to keep the lifter straight and not rotating.

A cutaway of a flat-bottom solid lifter. Because this type of lifter contains a retaining ring and oil holes, it is sometimes confused with a hydraulic lifter that also contains additional parts. The holes in the lifter are designed to supply oil to the rocker arms through a hollow pushrod.

An exploded view of a hydraulic roller lifter.
The cause of a misfire diagnostic trouble code was discovered to be a pushrod that had worn through the rocker arms on a General Motors 3.1 liter V-6 engine.

Shaft-mounted rocker arms are held in position by an assortment of springs, spacers, and washers, which should be removed so that the entire shaft can be inspected for wear.

TECH TIP: The Rotating Pushrod Test
To quickly and easily test whether the camshaft is okay, observe if the pushrods are rotating when the engine is running. This test will work on any overhead valve pushrod engine that uses flat-bottom lifters. Due to the slight angle on the cam lobe and lifter offset, the lifter (and pushrod) should rotate whenever the engine is running. To check, simply remove the rocker arm cover and observe the pushrods when the engine is running. If one or more pushrods are not rotating, this camshaft and/or the lifter for that particular valve is worn and needs to be replaced.
REAL WORLD FIX: The Noisy Camshaft

The owner of an overhead cam 4-cylinder engine complained of a noisy engine. After taking the vehicle to several technicians and getting high estimates to replace the camshaft and followers, the owner tried to find a less expensive solution. Finally, another technician replaced the serpentine drive belt on the front of the engine and "cured" the "camshaft" noise for a fraction of the previous estimates.

Remember, accessory drive belts can often make noises similar to valve or bad bearing types of noises. Many engines have been disassembled and/or overhauled because of a noise that was later determined to be one of the following:

- Loose or defective accessorie drive belt(s)
- Loose torque converter-to-flex plate bolts (nuts)
- Defective mechanical fuel pump (if equipped)

TECH TIP: Hot Lifter in 10 Minutes?

A technician at a shop discovered a noisy (defective) valve lifter on an older Chevrolet small block V-8. Another technician questioned how long it would take to replace the lifter and was told, "Less than an hour!" (The factory flat rate was much longer than one hour.) Ten minutes later the repair technician handed the questioning technician a hot lifter that had been removed from the engine. The lifter was removed using the following steps.

1. The valve cover was removed.
2. The rocker arm and pushrod for the affected valve were removed.
3. The distributor was removed.
4. A strong magnet was fed through the distributor opening and into the valley area of the engine. If the valve lifter is not mushroomed or does not have varnish deposits, the defective lifter can be lifted up and out of the engine; remember, the technician was working on a new vehicle.
5. A replacement lifter was attached to the magnet and fed down the distributor hole and over the lifter bore.
6. A pushrod was used to guide the lifter into the lifter bore.

After the lifter preload was adjusted and the valve cover was replaced, the vehicle was returned to the customer in less than one hour.
Chart 32-2 A comparison showing the effects of valve timing and lift on engine performance.

<table>
<thead>
<tr>
<th>Valve Timing</th>
<th>Lift in Inches</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>0.38</td>
<td>Valve lift power - 5500 RPM</td>
</tr>
<tr>
<td>Late</td>
<td>0.40</td>
<td>Valve lift power - 6000 RPM</td>
</tr>
<tr>
<td>Early</td>
<td>0.35</td>
<td>Valve lift power - 5000 RPM</td>
</tr>
</tbody>
</table>

Chart 32-3 The purpose for varying the cam timing includes providing for more engine torque and power over a wide engine speed and load range.

<table>
<thead>
<tr>
<th>Operating Condition</th>
<th>Engine Performance Improvement</th>
<th>Objective</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late</td>
<td>No change</td>
<td>None</td>
<td>Valve lift power - 5500 RPM</td>
</tr>
<tr>
<td>Early</td>
<td>Increased valve lift</td>
<td>Valve lift power - 6000 RPM</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Reduced valve lift</td>
<td>Valve lift power - 5000 RPM</td>
<td></td>
</tr>
<tr>
<td>Jarred</td>
<td>Valve lift loss</td>
<td>Valve lift power - 5000 RPM</td>
<td></td>
</tr>
<tr>
<td>High RPM with heavy load</td>
<td>Valve lift loss</td>
<td>Valve lift power - 5000 RPM</td>
<td></td>
</tr>
</tbody>
</table>

Figure 32-45 Camshaft rotation during advance and retard.
Figure 32-46  The camshaft is rotated in relation to the crankshaft by the PCM to provide changes in valve timing.

Figure 32-47  Spline cam phaser assembly

Chart 32-4  Changing the exhaust cam timing mainly helps reduce exhaust emissions, whereas changing the intake cam timing mostly helps the engine produce increased power and torque.

<table>
<thead>
<tr>
<th>CAMSHAFT PHASING CHANGED</th>
<th>IMPROVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust cam phasing</td>
<td>Reduces exhaust emissions</td>
</tr>
<tr>
<td>Exhaust cam phasing</td>
<td>Increases fuel economy</td>
</tr>
<tr>
<td></td>
<td>(reduced pumping losses)</td>
</tr>
<tr>
<td>Intake cam phasing</td>
<td>Increases low-speed torque</td>
</tr>
<tr>
<td>Intake cam phasing</td>
<td>Increases high-speed power</td>
</tr>
</tbody>
</table>

**CHART 32-4**
Figure 32-48 A spline phaser.

Figure 32-49 The screen(s) protect the solenoid valve from dirt and debris that can cause the valve to stick. This can set a P0017 diagnostic trouble code (crankshaft position/camshaft position correlation error).
A vane phaser is used to move the camshaft, using changes in oil pressure from the oil control valve.

A magnetically controlled vane phaser.

A camshaft position actuator used in a cam-in-block engine.
Figure 32-53 A plastic mockup of a Honda VTEC system that uses two different camshaft profiles—one for low-speed engine operation and the other for high speed.

Figure 32-54 Engine oil pressure is used to switch cam lobes on a VTEC system.

Figure 32-55 Oil pressure applied to the locking pin causes the inside of the lifter to freely move inside the outer shell of the lifter, thereby keeping the valve closed.
Active fuel management includes many different components and changes to the engine system, which make routine oil changes even more important on engines equipped with this system.