Figure 70-1 A spark tester looks like a regular spark plug with an alligator clip attached to the shell. This tester has a specified gap that requires at least 25,000 volts (25 kV) to fire.

Figure 70-2 A close-up showing the recessed center electrode on a spark tester. It is recessed 3/8 in. into the shell and the spark must then jump another 3/8 in. to the shell for a total gap of 3/4 in.
Figure 70-3 Checking an ignition coil using a multimeter set to read ohms.

Figure 70-4 If the coil is working, the end of the magnetic pickup tool will move with the changes in the magnetic field around the coil with the engine running.

**TECH TIP:** Always Use a Spark Tester

A spark tester looks like a spark plug except it has a recessed center electrode and no side electrode. It can be clamped on a grounded part of the engine. The tester commonly has an alligator clip attached to the shell so that it can be easily connected to a grounded part of the engine. A good spark plug system should be able to cause a spark to jump the wide gap at atmospheric pressure. Without a spark tester, a technician might assume that the ignition system is okay, because it can spark across a normal plug gap. The voltage required to fire a standard spark plug is very low. Therefore, without a spark tester, it is very easy to assume that the ignition system is okay. A spark tester requires a minimum of 25,000 volts to jump the 3/4 inch plug gap. Therefore, never assume that the ignition system is okay because it fires a spark plug—always use a spark tester.

Remember that an intermittent spark across a spark tester should be interpreted as a no-spark condition.
TECH TIP: The Magnetic Pickup Tool Test

All ignition coils are pulsed on and off by the ignition control module or PCM. When the coil charges and discharges, the magnetic field around the coil changes. This pulsing of the coil can be observed by holding the magnetic end of a pickup tool near an operating ignition coil. The magnet at the end of the pickup tool will move as the magnetic field around the coil changes. See Figure 70-4.

Figure 70-5: A waveform showing the primary current flow through the primary windings of an ignition coil.

Figure 70-6: Schematic of a typical waste-spark ignition system showing the location for the power feed and grounds. (Courtesy of Fluke Corporation)
CHART 70–1  The ignition coil ramp times vary according to the type of ignition system.

<table>
<thead>
<tr>
<th>Observed Current Ramp Times</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GM electronic (G) systems</td>
<td>3.6 ms</td>
</tr>
<tr>
<td>GM late 1996 and up (G)</td>
<td>2.5 ms</td>
</tr>
<tr>
<td>GM electronic (E) systems</td>
<td>2.5 ms</td>
</tr>
<tr>
<td>Ford electronic (E) systems</td>
<td>3.6 ms</td>
</tr>
<tr>
<td>Ford electronic (F) systems</td>
<td>2.6 ms</td>
</tr>
<tr>
<td>Chrysler electronic (GB)</td>
<td>3.8 ms</td>
</tr>
<tr>
<td>Chrysler electronic (E)</td>
<td>2.6 ms</td>
</tr>
</tbody>
</table>

Figure 70-7  An example of a good coil current flow waveform pattern. Note the regular shape of the waveform and peak. Duration of the waveform increases as the engine speed increases. The dwell is usually increased as the engine speed is increased. (Courtesy of Fluke Corporation)

Figure 70-8 (a)  A waveform pattern showing an open in the coil primary. (Courtesy of Fluke Corporation)
Figure 70-8 (b) A shorted coil pattern waveform. (Courtesy of Fluke Corporation)

Figure 70-9 Measuring the resistance of an HEI pickup coil using a digital multimeter set to the ohms position. The reading on the face of the meter is 0.796 kΩ or 796 ohms in the middle of the 500 to 1,500 ohm specifications.

Figure 70-10 A typical pickup coil showing how the waveform is created as the timer core rotates inside the pole piece.
REAL WORLD FIX: The Weird Running Chevrolet Truck

An older Chevrolet pickup truck equipped with a V-8 engine was towed into a shop because it would not start. A quick check of the ignition system showed that the pickup coil had a broken wire below it and the ignition control module. The distributor was removed from the engine and the distributor shaft was removed, cleaned, and a replacement pickup coil was installed. The engine started but ran rough and hesitated when the accelerator pedal was depressed.

After an hour of troubleshooting, a careful inspection of the new pickup coil showed that the time core had six instead of eight points, meaning that the new pickup coil was meant for a V-6 instead of a V-8 engine. Replacing the pickup coil again solved the problem.

REAL WORLD FIX: The Hard-to-Start Chevrolet HHR

The owner of a 2008 Chevrolet HHR complained that the engine was hard to start and required a long period of cranking. Once the engine started, it ran great all day. A P0336 crankshaft position (CKP) sensor fault code was stored. The CKP sensor had been replaced several times before and the sensor output was scope tested and everything appeared to be normal. Then one time when the engine started, the tech noticed that while it was running, the engine speed (RPM) displayed on the Tech 2 scan tool was zero. After replacing the crankshaft position sensor again and checking the wiring, the technician looked at the reluctor wheel using a boroscope. Some blades of the reluctor were bent. The cause was likely when the first sensor failed and possibly damaged the reluctor. As a result of the testing, the local Chevrolet dealer replaced the crankshaft under warranty. 
Figure 70-12 A diagnostic trouble code P0336 was displayed on a Tech 2 scan tool as the only code.

Figure 70-13 The engine started and was running, but the Tech 2 displayed zero RPM.

Figure 70-14 The old crankshaft showing the reluctor notches. The damage was not visible, but the engine started each time after the crankshaft was replaced.
Figure 70-15  
The connection required to test a Hall-effect sensor. A typical waveform from a Hall-effect sensor is a digital square wave. Check service information for the signal wire location.

Figure 70-16 (a)  
The low-resolution signal has the same number of pulses as the engine has cylinders.

Figure 70-16 (b)  
A dual trace pattern showing both the low-resolution and the high-resolution signals that usually represent 1 degree of rotation.
A track inside an ignition coil is not a short, but a low-resistance path or hole that has been burned through from the secondary wiring to the steel core.

**TECH TIP: Bad Wire? Replace the Coil!**

When performing engine testing (such as a compression test), always ground the coil wire or disable the primary ignition circuit by removing the ignition fuse. If the spark cannot spark to ground, the coil energy can (and usually does) arc inside the coil itself, creating a low-resistance path to the primary windings or the steel laminations of the coil. - SEE FIGURE 70–17.

This low-resistance path is called a track and could cause an engine miss under load even though all of the remaining component parts of the ignition system are functioning correctly. Often these tracks do not show on a high-output scope, but will show on a low-output scope. Because the track is a lower resistance path to ground than normal, it requires that the ignition system be put under a load for it to be detected, and even then, the problem such as an engine missfire may be intermittent.

**Figure 70-18** Corroded terminals on a waste-spark coil can cause misfire diagnostic trouble codes to be set.
TECH TIP: Spark Plug Wire Pliers Are a Good Investment

Spark plug wires are often difficult to remove. Using good-quality spark plug wire pliers, as shown in Figure 70–18, saves time and reduces the chance of harming the wire during removal.

Figure 70–19 This spark plug boot on an overhead camshaft engine has been arcing to the valve cover causing a misfire to occur.

Figure 70–20 Measuring the resistance of a spark plug wire with a multimeter set to the ohms position. The reading of 16.03 kΩ (16.03 ohms) is okay because the wire is about 2 ft long. Maximum allowable resistance for a spark plug wire this long would be 20 kΩ (20,000 ohms).
Figure 70-21 Spark plug wire boot pliers are a handy addition to any tool box.

Figure 70-22 A water spray bottle is an excellent diagnostic tool to help find an intermittent engine misfire caused by a break in a secondary ignition circuit component.

**TECH TIP:** Use a Water Spray Bottle to Check for Bad Spark Plug Wires

For intermittent problems, use a spray bottle to apply a water mist to the spark plugs, distributor cap, and spark plug wires. **SEE FIGURE 70–22.** With the engine running, the water may cause an arc through any weak insulating materials and cause the engine to miss or stall.

**NOTE:** Adding a little salt or liquid soap to the water makes the water more conductive and also makes it easier to find those hard-to-diagnose intermittent ignition faults.
Figure 70-23  Parts of a spark plug.

Figure 70-24  The heat range of a spark plug is determined by the distance the heat flows from the tip to the cylinder head.

Figure 70-25  When removing spark plugs, it is wise to arrange them so that they can be compared and any problem can be identified with a particular cylinder.
A spark plug thread chaser is a low-cost tool that hopefully will not be used often, but is necessary in order to clean the threads before installing new spark plugs.

A normally worn spark plug that uses a tapered platinum-tipped center electrode.

Spark plug removed from an engine after a 500-mile race. Note the clipped side (ground) electrode. The electrode design and narrow (0.025 in.) gap are used to ensure that a spark occurs during extremely high engine speed operation.
Figure 70-29  Typical worn spark plug. Notice the rounded center electrode. The deposits indicate a possible coolant usage problem.

Figure 70-30  New spark plug that was fouled by an overly rich air-fuel mixture. The engine from which this spark plug came had a defective (stuck partially open) injector on this one cylinder only.

CHART 70-2  Typical spark plug installation torque.
TECH TIP: Two-Finger Trick

To help prevent overtightening a spark plug when a torque wrench is not available, simply use two fingers on the ratchet handle. Even the strongest service technician cannot overtighten a spark plug by using two fingers.

Figure 70-31: Ignition timing marks are found on the harmonic balancers on engines equipped with distributors that can be adjusted for timing.

Figure 70-32: The initial (base) timing is where the spark plug fires at idle speed. The PCM then advances the timing based primarily on engine speed.
TECH TIP

Two Marks Are the Key to Success

When a distributor is removed from an engine, always mark where the rotor is pointing to ensure that the distributor is reinstalled in the correct position. Because of the helical cut on the distributor drive gear, the rotor rotates as the distributor is being removed from the engine. To help reinstall a distributor without problems, simply make another mark where the rotor is pointing just as the distributor is lifted out of the engine. Then to reinstall, line up the rotor to the second mark and lower the distributor into the engine. The rotor should then line up with the original mark as a double check.

Figure 70-33 The firing order is cast or stamped on the intake manifold of most engines that have a distributor ignition.

Figure 70-34 Always take the time to install spark plug wires back into the original holding brackets (wiring combs).
The relationship between the crankshaft position (CKP) sensor and the camshaft position (CMP) sensor is affected by wear in the timing gear and/or chain.

Figure 70-36 A scan tool displays excessive cam retard on a Chevrolet pickup truck V-6. The cam retard value should be ± 2 degrees.

A worn distributor drive gear can be the cause of an out-of-specification camshaft position (CMP) signal.
Figure 70-38  Typical engine analyzer hookup that includes a scope display. (1) Coil wire or tap of the distributor if integral type of coil; (2) number 1 spark plug connection; (3) negative side of the ignition coil; (4) ground (negative) connection of the battery.

Figure 70-39  Clip-on adapters are used with an ignition system that uses an integral ignition coil.

Figure 70-40  Typical secondary ignition oscilloscope pattern.
Figure 70-41 A single cylinder is shown at the top and a 4-cylinder engine at the bottom.

Figure 70-42 Drawing shows what is occurring electrically at each part of the scope pattern.

Figure 70-43 Typical secondary ignition pattern. Note the lack of firing lines on the superimposed pattern.
Figure 70-44  Raster is the best scope position to view the spark lines of all the cylinders to check for differences. Most scopes display cylinder 1 at the bottom. The other cylinders are positioned by firing order above cylinder 1.

Figure 70-45  Display is the only position to view the firing lines of all cylinders. Cylinder 1 is displayed on the left (usually by its firing line, which is drawn on the right). The cylinders are displayed from left to right by firing order.

REAL WORLD FIX: A Technician’s Toughie

A vehicle ran poorly, yet its scope patterns were “perfect.” Remembering that the scope indicates only that a spark has occurred (not necessarily inside the engine), the technician grounded one spark plug wire at a time using a vacuum hose and a test light. Every time a plug wire was grounded, the engine ran worse, until the last cylinder was checked. When the last spark plug wire was grounded, the engine ran the same. The technician checked the spark plug wire with an ohmmeter; it tested within specifications (less than 10,000 ohms per foot of length). The technician also removed and inspected the spark plug. The spark plug looked normal. The spark plug was reinstalled and the engine tested again. The test had the same results as before—the engine seemed to be running on seven cylinders, yet the scope pattern was perfect.
The technician then replaced the spark plug for the affected cylinder. The engine ran correctly. Very close examination of the spark plug showed a thin crack between the wire terminal and the shell of the plug. Why didn’t the cracked plug show on the scope? The scope simply indicated that a spark had occurred. The scope cannot distinguish between a spark inside and outside the engine. In this case, the voltage required to travel through the spark plug crack to ground was about the same voltage required to jump the spark plug electrodes inside the engine. The spark that occurred across the cracked spark plug, however, may have been visible at night with the engine running.

CHART 70–3

Converting between units is sometimes needed depending on the type of scope used.

<table>
<thead>
<tr>
<th>NUMBER OF CYLINDERS</th>
<th>MILLISECONDS</th>
<th>PERCENTAGE (%) OF DWELL SCALE</th>
<th>DEGREES</th>
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<tbody>
<tr>
<td>4</td>
<td>1–2</td>
<td>3–6</td>
<td>3–5</td>
</tr>
<tr>
<td>6</td>
<td>1–2</td>
<td>4–9</td>
<td>2–5</td>
</tr>
<tr>
<td>8</td>
<td>1–2</td>
<td>6–13</td>
<td>3–6</td>
</tr>
</tbody>
</table>

Figure 70–46

A downward-sloping spark line usually indicates high secondary ignition system resistance or an excessively rich air-fuel mixture.
Figure 70-47 An upward-sloping spark line usually indicates a mechanical engine problem or a lean air-fuel mixture.

Figure 70-48 The relationship between the height of the firing line and length of the spark line can be illustrated using a rope. Because energy cannot be destroyed, the stored energy in an ignition coil must dissipate totally, regardless of engine operating conditions.

Figure 70-49 A dual trace scope pattern showing both the power and the waste spark from the same coil (cylinders 1 and 6). Note how the firing line is higher in the cylinder that is under compression (cylinder 1). However, that pattern is almost identical.
Figure 70-30  A secondary waveform of a Ford 4.6 liter V-8, showing three sparks occurring at idle speed.