Figure 69-1 A point-type distributor from a hot rod being tested on a distributor machine.

**WARNING:**
The spark from an ignition coil is strong enough to cause physical injury. Always follow the exact service procedure and avoid placing hands near the secondary ignition components when the engine is running.
Figure 69-2 The primary ignition system is used to trigger and therefore create the secondary (high-voltage) spark from the ignition coil. Some ignition coils are electrically connected, called married (top figure) whereas others use separated primary and secondary windings, called divorced (lower figure).

Figure 69-3 The steel laminations used in an E coil help increase the magnetic field strength, which helps the coil produce higher energy output for a more complete combustion in the cylinders.

Figure 69-4 The primary windings are inside the secondary windings on this General Motors coil.
Figure 69-5 - The primary ignition system is used to trigger and therefore create the secondary (high-voltage) spark from the ignition coil.

Figure 69-6 - Operation of a typical pulse generator (pickup coil). At the bottom is a line drawing and a typical scope pattern of the output voltage of a pickup coil. The ICM receives this voltage from the pickup coil and opens the ground circuit to the ignition coil when the voltage starts down from its peak (just as the reluctor teeth start moving away from the pickup coil).

Figure 69-7 - A magnetic sensor uses a permanent magnet surrounded by a coil of wire. The notches of the crankshaft (or camshaft) create a variable magnetic field strength around the coil. When a metallic section is close to the sensor, the magnetic field is stronger because metal is a better conductor of magnetic lines of force than air.
Figure 69-8 A hall-effect sensor produces an on-off voltage signal whether it is used with a blade or a notched wheel.

Figure 69-9 Some hall-effect sensors look like magnetic sensors. This hall-effect camshaft reference sensor and crankshaft position sensor have an electronic circuit built in that creates a 0 to 5 volt signal as shown at the bottom. These hall-effect sensors have three wires: a power supply (5 volts) from the computer (controller), a signal (0 to 5 volts), and a signal ground.
Figure 69-10 (a) Typical optical distributor.

Figure 69-10 (b) Cylinder 1 slit signals the computer the piston position for cylinder 1. The 1-degree slits provide accurate engine speed information to the PCM.

Figure 69-11 A light shield being installed before the rotor is attached.
TECH TIP: Optical Distributors Do Not Like Light
Optical distributors use the light emitted from LEDs to trigger phototransistors. Most optical distributors use a shield between the distributor rotor and the optical interrupter ring. Sparks jump the gap from the rotor tip to the distributor cap inserts. This shield blocks the light from the electrical arcs from interfering with the detection of the light from the LEDs. If this shield is not replaced during service, the light signals are reduced and the engine may not operate correctly. See Figure 69–11. This can be difficult to detect because nothing looks wrong during a visual inspection. Remember that all optical distributors must be shielded between the rotor and the interrupter ring.

Figure 69–12. The firing order is cast or stamped on the intake manifold on most engines that have a distributor ignition.

Figure 69–13. A waste-spark system fires one cylinder while its piston is on the compression stroke and then fires in companion cylinders while it is on the exhaust stroke. In a typical engine, it requires only about 2 to 3 kV to fire the spark on the exhaust stroke. The remaining coil energy is available to fire the spark plug under compression (typically about 8 to 12 kV).
FREQUENTLY ASKED QUESTION

How Can You Determine the Companion Cylinder?

Companion cylinders are two cylinders in the same engine that both reach top dead center at the same time.

- One cylinder is on the compression stroke.
- The other cylinder is on the exhaust stroke.

To determine which two cylinders are companion cylinders in the engine, follow these steps:

**STEP 1** Determine the firing order (such as 1-6-5-4 for a typical V-6 engine).

**STEP 2** Write the firing order and then place the second half under the first half:

```
1 6
4 3
2
```

**STEP 3** The cylinder numbers above and below each other are companion or paired cylinders. In this case, 1 and 4, 6 and 3, and 5 and 2 are companion cylinders.

TECH TIP: Odds Fire Straight

Waste-spark ignition systems fire two spark plugs at the same time. Most vehicle manufacturers use a waste-spark system that fires the odd-number cylinders (1, 3, and 5) by straight polarity (current flows from the top of the spark plug through the gap and to the ground electrode). The even-number cylinders (2, 4, and 6) are fired reverse polarity, meaning that the spark jumps from the side electrode to the center electrode. Some vehicle manufacturers equip their vehicles with platinum plugs, with the expensive platinum alloy only on one electrode as follows:

- On odd-number cylinders (1, 3, 5), the platinum is on the center electrode.
- On even-number cylinders (2, 4, 6), the platinum is on the ground electrode.

Replacement spark plugs use platinum on both electrodes, allowing platinum to be placed in any cylinder location.
The slight (5 microsecond) difference in the firing of the companion cylinders is needed time to allow the PCM to determine which cylinder is firing on the compression stroke. The compression sensing ignition (CSI) signal is then processed by the PCM which then determines which cylinder is on the compression stroke.

A typical coil-on-plug ignition system showing the triggering and the switching being performed by the PCM via input from the crankshaft position sensor.

**SAFETY TIP:** Never Disconnect a Spark Plug Wire When the Engine Is Running!

Ignition systems produce a high-voltage pulse necessary to ignite a lean air-fuel mixture. If you disconnect a spark plug wire when the engine is running, this high-voltage spark could cause personal injury or damage to the ignition coil and/or ignition module.
Figure 69-17  An overhead camshaft engine equipped with variable valve timing on both the intake and exhaust camshafts and the coil-on-plug ignition.

Figure 69-18  A Chrysler Hemi V-8 that has two spark plugs per cylinder. The coil on top of one spark plug fires the plug and, through a spark plug wire, fires a plug in the companion cylinder.

Figure 69-19  A DC voltage is applied across the spark plug gap after the plug fires and the circuit measures the current through the gap to determine if the correct air-fuel ratio was present in the cylinder and if knock occurred. The applied voltage for ion sensing does not jump the spark plug gap but rather determines the conductivity of the ionized gases left over from the combustion process.
**Figure 69-20** A typical knock sensor on the side of the block. Some are located in the “V” of a V-type engine and are not noticeable until the intake manifold has been removed.

**Figure 69-21** A typical waveform from a knock sensor during a spark knock event. This signal is sent to the computer which in turn retards the ignition timing. This timing retard is accomplished by an output command from the computer to either a spark advance control unit or directly to the ignition module.

**REAL WORLD FIX: The Low Power Toyota**
A technician talked to the driver of a Toyota who complained about poor performance and low fuel economy. The technician checked everything and even replaced all secondary ignition components. Then the technician connected a scan tool and noticed that the knock sensor was commanding the timing to be retarded. Careful visual inspection revealed a “chunk” missing from the serpentine belt, causing a noise similar to a spark knock. Apparently the knock sensor was “hearing” the accessory drive belt noise and kept retarding the ignition timing. 

After replacing the accessory drive belt, a test drive confirmed that normal engine power was restored.

Other items that can fool the knock sensor to retard the ignition timing include:
- Loose valve lifter adjustment
- Engine knocks
- Loose accessory brackets such as the air-conditioning compressor, power steering pumps, or alternator.
Figure 69-22: A SPOUT connector on a Ford that is equipped with a distributor ignition. This connector has to be disconnected to separate the PCM in order to set base ignition timing.