Study Unit

# Ignition System Components and Operation

# Preview

In your previous study units, you learned about the components of an engine and how they affect engine operation. You also learned about automotive lubrication and cooling systems. In this study unit, you'll learn how an engine's ignition system operates. An engine's ignition system generates the high voltage needed to make a spark plug fire. The sparks from the spark plugs ignite the air-and-fuel mixture in the engine's cylinders and start the engine.

When you complete this study unit, you'll be able to

- Explain the difference between voltage, current, and resistance in a circuit
- Describe how a spark plug is constructed and how it operates
- Identify the components used in conventional and electronic ignition systems
- Describe the operation of spark-advance mechanisms
- Explain the operation of direct-fire ignition systems

# Contents

# Ignition System Components and Operation

## INTRODUCTION TO ELECTRICITY

In this study unit, you'll learn the different types of ignition systems used to start and run automotive engines. Let's begin with a review of some basic concepts about electricity and circuits. Don't worry if these concepts aren't familiar. You don't need to be an electrician in order to work on automotive ignition systems. However, a basic knowledge of electricity makes these systems easier to understand and troubleshoot.

In this study unit, we'll limit our discussion to electrical concepts that apply to ignition systems. You'll learn more about electricity in general in a later study unit.

### A Simple Circuit

In order to work effectively on ignition systems, you need to know how electricity is generated, distributed, used, and controlled. Let's begin by examining a simple circuit. A circuit is defined as a complete electrical path. A typical circuit includes a *power source*, *conductors*, a *load*, and a *switch*. A power source is simply a source of electrical power. A wall outlet is a common household power source. Conductors are the wires that carry the electricity. The load is a device, such as a light or an appliance, that we want to run with electricity. The switch is the device that's used to turn the circuit on and off.

Circuits may be closed or open. In a closed circuit, the switch is in the ON position. Electrical power from the battery flows on an unbroken path to the load, flows through the load, and then returns back to the battery. A closed circuit is complete—the power flows through the entire circuit path to reach the load and then returns back to the original power source. In contrast, in an open circuit, the switch is in the OFF position. When the switch is turned off, the circuit path is broken and the power can't reach the load.

A simple flashlight circuit is shown in Figure 1. The power source in this circuit is a battery. The conductors are copper wire. The load is a standard light bulb. In Figure 1A, the switch is open—turned to the OFF position. The electrical circuit is therefore open, and power can't flow through the wires to reach the bulb. In Figure 1B, the switch is closed—turned to the ON position. The circuit is therefore complete,

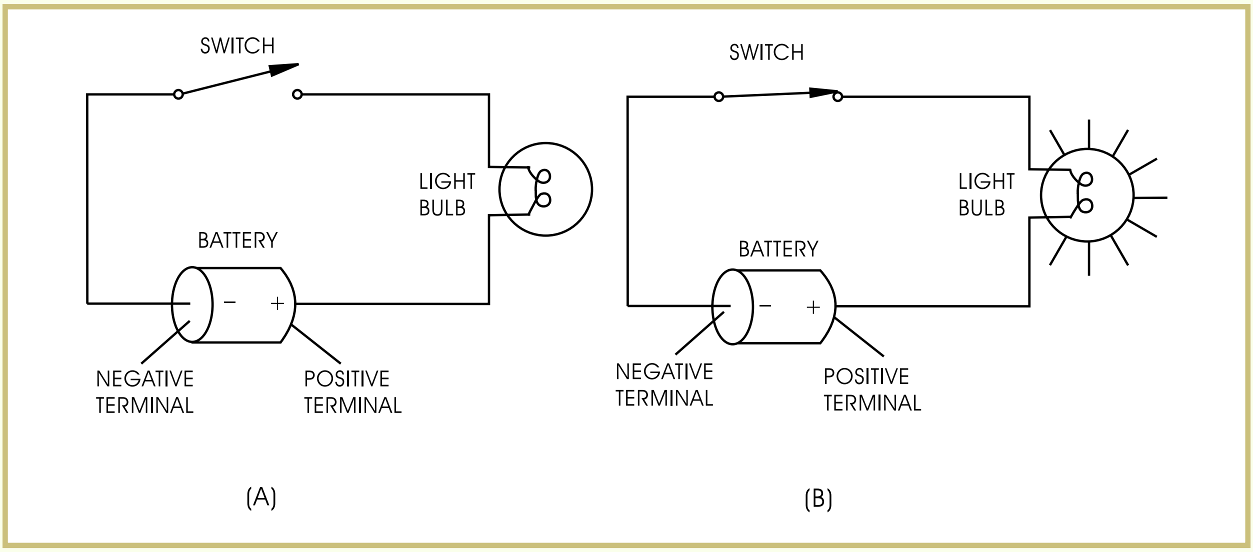



***FIGURE 1—This figure illustrates a simple electrical circuit. In Figure 1A, the switch is open, so electricity can't flow to the light bulb. In Figure 1B, the switch is closed, allowing electricity to reach the light bulb and light it.***

and electricity can flow through the wires to reach the bulb and turn it on.

Now that you understand what a basic circuit is, let's take a closer look at electricity itself. What exactly is electricity? Electricity is a natural force produced by the movement of electrons. Electrons are tiny atomic particles that have a negative electrical charge. In the circuit shown in Figure 1, moving electrons come from the battery. The battery produces a flow of electrons that moves through the wires to light the flashlight bulb.

Note that the battery has two different ends. The end of the battery that's labeled with a negative or minus sign (–) is called the *negative terminal*. The opposite end of the battery that's labeled with a positive or plus sign (+) is called the *positive terminal*. The negative battery terminal has a negative charge—that is, it contains too many electrons. The positive battery terminal has a positive charge—it contains too few electrons.

The negative and positive charges in a battery are produced by a simple chemical reaction. Figure 2 shows a simplified diagram of the parts of a battery. The battery contains a chemical solution called *electrolyte*. The battery terminals or electrodes are two strips of metal. Each electrode is made from a different type of metal. When the strips of metal are placed into the electrolyte solution, a chemical reaction occurs. As a result of this reaction, a negative charge forms on one electrode, and a positive charge forms on the other electrode.

You may have heard the phrase “opposites attract.” Well, this is definitely true in the world of electricity. Opposite electrical charges, positive and negative, attract each other very strongly and try to balance each other out. Because of this attraction, whenever lots of electrons are concentrated in one place, the electrons try to move to a place that contains fewer electrons.

This is the basic operating principle of a battery. The negative terminal of a battery has a high concentration of electrons, while the positive terminal has very few electrons. So, the electrons at the negative battery terminal are strongly drawn toward the positive battery terminal. However, in order to actually move from the negative terminal to the positive terminal, the electrons need a path to follow. We can create a path for the electrons by connecting a wire between the battery terminals.

By attaching the two ends of a piece of wire to the two battery terminals, we create a path for the electrons to follow between the terminals. By attaching the wire in this way, we actually build a circuit. Note, however, that this is not a practical experiment. Completing such a circuit could cause the battery to explode or, at the very least, the wire to become very hot. In either case, someone could be seriously injured. If we would like to use the electrons to perform useful work, we can connect a light bulb to the circuit. We can also connect a switch to the circuit so that it can be turned on and off.

When we turn on the switch, the circuit is closed, and the electrons from the negative battery terminal move to the positive battery terminal. As the electrons flow through the light bulb, they cause the bulb's filament to heat up and glow, producing visible light. The flow of electrons through a circuit is called *electric current*.

A simple circuit is shown in Figure 2. Electrons flow from the negative battery terminal to the positive terminal through the conductors attached to them. Note that the flow of electricity produced by the battery continues as long as there's a chemical reaction in the battery. After some time, the chemical reaction in the battery stops and the battery stops functioning. At that point the battery needs to be recharged or replaced.

# Conductors and Insulators

You've just learned that electrons are atomic particles. All matter in the universe is formed from about one hundred or so substances called *elements*. Each different element, such as hydrogen, gold, or uranium, is made up of its own unique hydrogen, gold, or uranium atoms. An atom is the smallest particle of an element that still keeps the properties of the element.

All atoms are made up of tiny atomic particles called *protons, neutrons,* and *electrons*. The electron is a very lightweight particle that has a negative electrical charge. Protons are much heavier than electrons and have a positive electrical charge. Neutrons have no electrical charge at

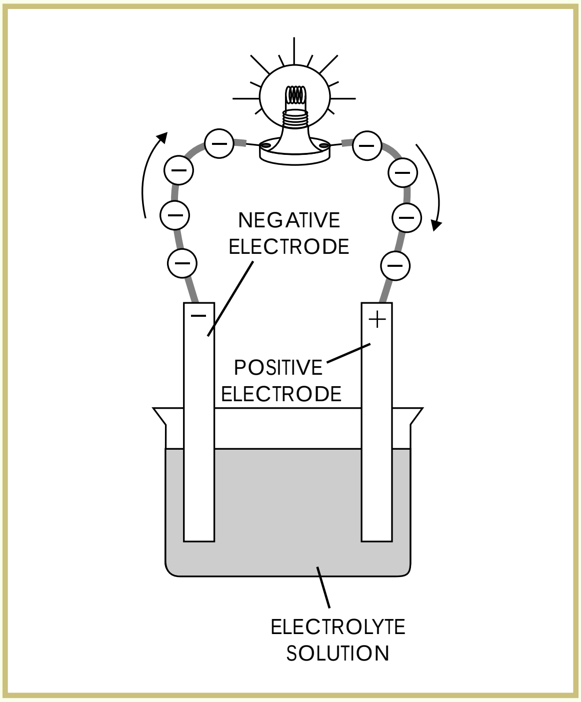



***FIGURE 2—In a simple battery, a chemical reaction takes place between the electrodes and the electrolyte solution. This chemical reaction produces an electrical charge on each of the electrodes.***

all—they're neutral. Electrons are the smallest type of atomic particle; one electron is much smaller than the atom as a whole.

Figure 3A shows a drawing of a hydrogen atom, which is the simplest atom known. (The element hydrogen is a gas that's found in the atmosphere.) A hydrogen atom contains one electron and one proton. The proton is located at the center of the atom in an area called the *nucleus*. The electron orbits around the nucleus in a circle, just like the moon orbits around the earth. All atoms are constructed this way, but the number of electrons, protons, and neutrons varies in each different element.

The hydrogen atom contains one positively charged proton and one negatively charged electron. The proton's positive charge and the electron's negative charge balance each other out. Thus, as a whole, the hydrogen atom is perfectly balanced electrically. Because opposite electrical charges attract each other, the electron in a hydrogen atom is very strongly attracted to the proton. The electron can't be easily removed from the atom.

Now, in comparison, let's look at the copper atom shown in Figure 3B. (The element copper is a metal.) The copper atom contains 29 electrons and 29 protons. The electrons orbit the nucleus of the copper atom in several layers called *shells*. The outermost shell contains only one electron; this electron is called a *free electron*. Since the free electron is alone and very far from the ato'ms nucleus, it's not strongly attached to the nucleus like the hydrogen's electron was. For this reason, the free electron in a copper atom can easily be dislodged from its orbit.

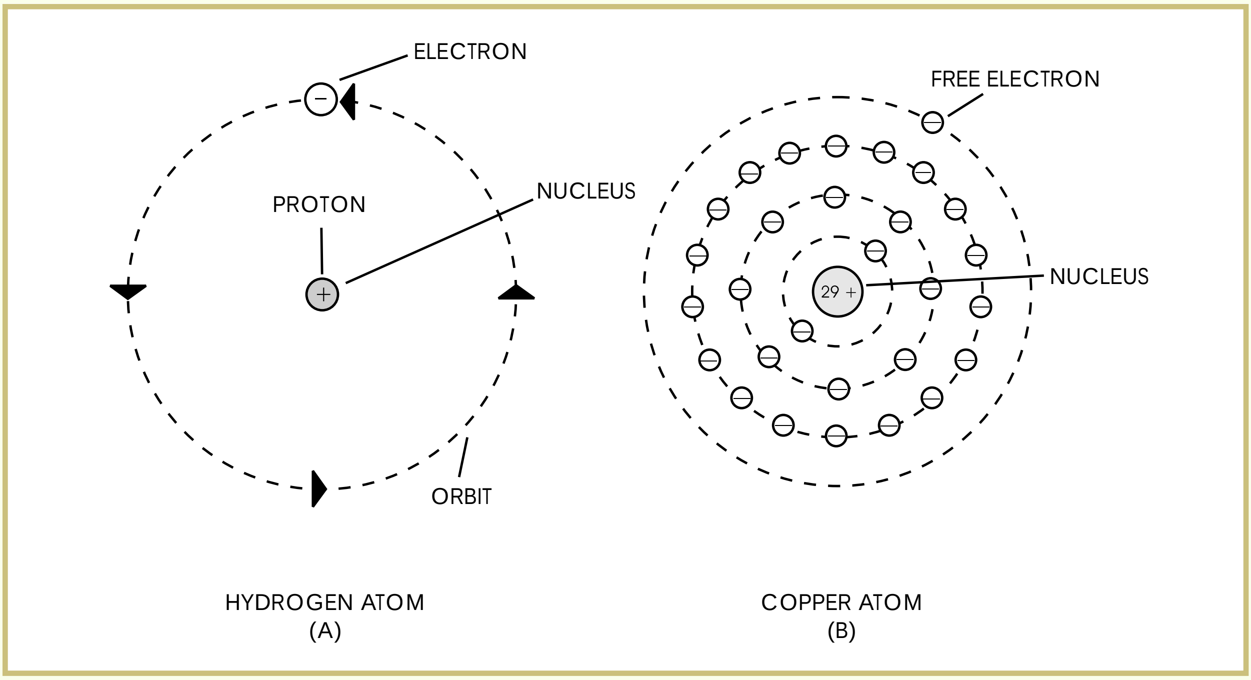



***FIGURE 3—The single atom of hydrogen in Figure 3A contains one proton and one electron. The proton is represented by the circle with the plus sign (+). The electron is represented by the circle with the minus sign (–). The copper atom in Figure 3B contains a single electron in its outermost orbit. This free electron can easily be dislodged from its orbit, which makes copper a good conductor of electricity.***

In general, protons and neutrons can't be easily removed from an atom. However, in some atoms, electrons can be easily removed from their orbits. You already know that electric current is produced by the movement of electrons. Well, in order to get the electrons moving, we have to remove them from atoms.

The idea of removing electrons from atoms may seem strange and impossible. However, we remove electrons from atoms all the time without realizing it. For example, if you shuffle across a carpet and then touch a metal surface, what happens? You probably receive a small shock, and you might even see a spark. This happens because, as you scuffed your shoes along the carpet, you actually rubbed electrons off the carpet. Your body held onto these electrons, and you became negatively charged. When you touched the metal surface, the free electrons from your body jumped to the metal, restoring your body to a neutral charge. The discharge of electrons caused the small spark that you felt.

Thus, you can see that it's not impossible to get electrons moving from one place to another. However, it's easier to get electrons moving in some materials than in others. The structure of an individual atom determines how easily an electron can be removed. For example, you saw that the structure of the hydrogen atom makes it very difficult to remove an electron from its orbit. So, it's difficult to produce a flow of electricity in hydrogen. However, in a copper atom, the outermost electron can easily be dislodged from its orbit. Therefore, it's very easy to get a flow of electricity moving in copper. This is why copper is used to make electrical wires and cables.

Any substance in which electrons can move freely is called an *electrical conductor*. Copper, silver, gold, and other metals are good electrical conductors. (In fact, silver and gold are better electrical conductors than copper, but because silver and gold are so expensive, they aren't used to make electrical wires.) Materials in which the electrons are very tightly bonded to the nucleus are called *insulators*. Plastic, nylon, ceramic, and other such materials are very resistant to the flow of electricity and are classified as insulators.

Now, let's see how electrons flow within an electrical circuit. Figure 4 shows a simple circuit in which a copper wire is attached to a battery. One section of the copper wire is enlarged so you can see how electrons would flow through the wire.

In the figure, the circuit is closed, and the electrons from the negative battery terminal are drawn to the positive terminal. Remember that the outermost electron in each copper atom is easily dislodged from its orbit. The flow of current starts at the negative battery terminal.

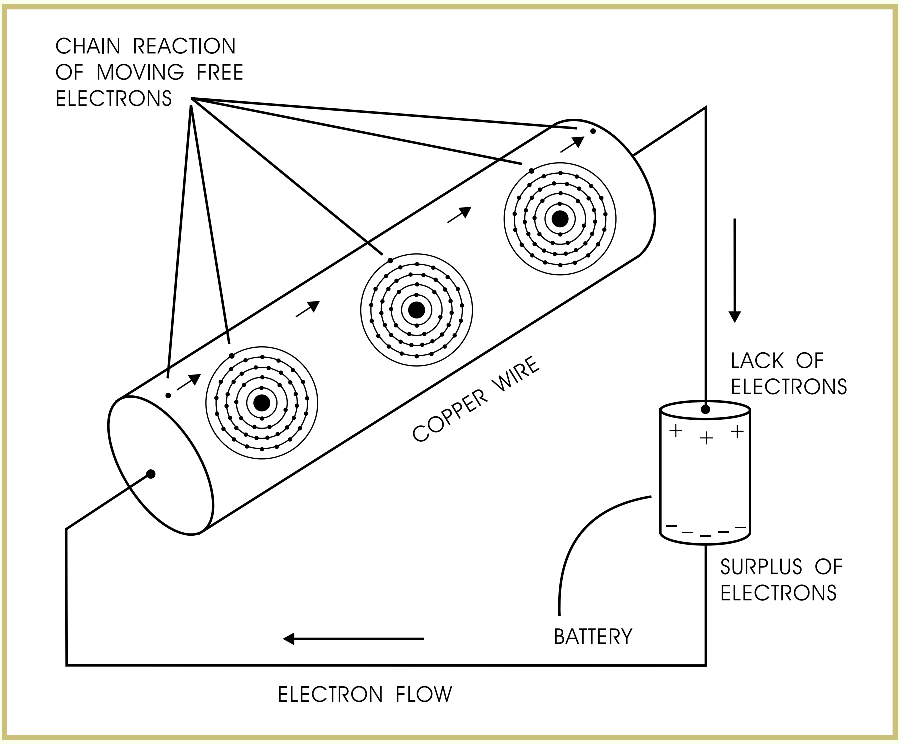



***FIGURE 4—In this simple circuit, a section of the conductor wire has been enlarged so that you can see how electrons would flow through the wire. A free electron from the battery enters the wire. As the battery electron enters the wire, it displaces free electrons from the copper atoms in the wire, creating a "chain reaction" of moving electrons.***

An electron is drawn from the negative battery terminal into the copper conductor wire. This electron then collides with a free electron in a copper atom, bumping the copper electron and taking its place. The displaced copper atom moves to a neighboring copper atom, bumps another free electron out of orbit, and takes its place. As this chain reaction continues, each free electron bumps its neighbor out of orbit and takes its place. (When we refer to the electrons bumping each other, you might think of the balls on a billiards table. One ball strikes another, causing it to move.) This chain reaction of moving electrons is *electric current*.

In reality, of course, atoms are much too small to see, so we can't follow the movement of just one electron through a wire. Many millions of copper atoms make up a wire. When a circuit is closed, millions of electrons move through the wire at the same time at a very high rate of speed. The more electrons that move through a circuit, the higher the current is in the circuit.

## Current, Voltage, and Resistance

Electrical and electronic circuits have three basic quantities associated with them: current, voltage, and resistance. These quantities have a very important relationship in a circuit.

As you've already learned, current is the flow of electrons through a conductor. When a complete conducting path is present between two opposing electrical charges, electrons begin to flow between the two points. Current is measured in units called *amperes* or *amps*. The abbreviation for amperes is the letter *A*. So, the quantity 3 amperes would be abbreviated 3 A. In electrical drawings, diagrams, and mathematical formulas, current is usually represented by the letter I.

Small amounts of current may be noted with the abbreviations mA (milliamperes) or A (microamperes). One milliampere of current is equal to one one-thousandth of an ampere, or 0.001 A of current. One microampere of current is equal to one-millionth of an ampere, or 0.000001 A of current. The following table shows you how to convert between these different values.

**Table**
**ELECTRICAL QUANTITIES**

| UNIT | ABBREVIATION | VALUE |
|---|---|---|
| Ampere | A | 1 ampere |
| Milliampere | mA | 0.001 ampere |
| Microampere | A | 0.000001 ampere |
| Volt | V | 1 volt |
| Megavolt | MV | 1,000,000 volts |
| Kilovolt | kV | 1,000 volts |
| Millivolt | mV | 0.001 volt |
| Microvolt | V | 0.000001 volt |
| Ohm | Ω | 1 ohm |
| Megohm | MΩ | 1,000,000 |
| Kilohm | kΩ | 1,000 |

CONVERSION EXAMPLES

To convert megohms to ohms, multiply the number of megohms by 1,000,000.

To convert kilohms to ohms, multiply the number of kilohms by 1,000.

To convert ohms to megohms, divide the number of ohms by 1,000,000.

To convert ohms to kilohms, divide the number of kilohms by 1,000.

To convert microamperes to amperes, divide the number of microamperes by 1,000,000.

To convert milliamperes to amperes, divide the number of milliamperes by 1,000.

To convert amperes to microamperes, multiply the number of amperes by 1,000,000.

To convert amperes to milliamperes, multiply the number of amperes by 1,000.

Now, let's look at the electrical quantity *voltage*. Remember that in a battery, one terminal has a negative charge and the other terminal has a positive charge. Whenever a positive charge and a negative charge are positioned close to each other in this way, a force is produced between the two charges. This force is called *electrical potential*. Electrical potential is simply the difference in electrical charge between the two opposing terminals. The bigger the difference between the two opposing charges, the greater the electrical potential is.

Voltage is a measure of the amount of electrical potential in a circuit. Voltage is measured in units called *volts*. The abbreviation for volts is the letter *V*. So, the quantity 2 volts would be abbreviated as 2 V. In electrical diagrams and mathematical formulas, voltage is usually represented by the letter *E*.

The last electrical quantity you'll learn about is *resistance*. Resistance is a force of opposition that works against the flow of electric current in a circuit. You've already seen that current flows easily through copper wires. However, frayed wires, corroded connections, and other obstructions slow down the movement of electrons through a circuit. That is, the circuit resists the flow of current through it. When a lot of resistance is present in a circuit, a higher voltage is needed to get the flow of electrons moving through the circuit.

Resistance is measured in units called *ohms*. The abbreviation for ohms is the Greek letter omega, represented by the symbol Ω. Resistance is usually represented by the letter *R* in electrical diagrams and mathematical formulas.

Standard abbreviations are used to describe large values of resistance. The value 10,000 ohms, for example, may be noted as either 10 kΩ or 10 kilohms. The prefixes *k* and *kil* stand for kilo—one thousand. The value 20 million ohms may be noted as 20 MΩ or 20 megohms. The prefixes *M* and *meg* stand for mega—one million.

Engine service manuals often provide electrical specifications in ohms. For example, if you were measuring the amount of resistance in an ignition module's pins, the service manual would list the correct value in ohms. The service manual may state that the resistance between Pin 1 and Pin 3 on an electronic ignition module is 300 Ω . (We'll discuss ignition components, specifications, and how to measure circuit quantities in more detail later.)

To enhance your understanding of the relationship of current, voltage, and resistance in a circuit, let's compare an electrical circuit to a simple water system. Electric circuits and water distribution systems have many of the same properties.

In Figure 5, a simple electrical circuit is compared to a water circuit. The water pipes form a path for the water to follow, so the pipes are like the conductors in the electrical system. The water valve turns the flow of water on and off, so the valve is like the switch in the electrical system. The waterwheel is being operated by the flow of water, so the wheel compares to the light bulb—the load—in the electrical circuit. The water reservoir—the water source—can be compared to the battery—the power source—in the electrical circuit. The flow of water can be compared to the flow of electrons. The water pump pushes the

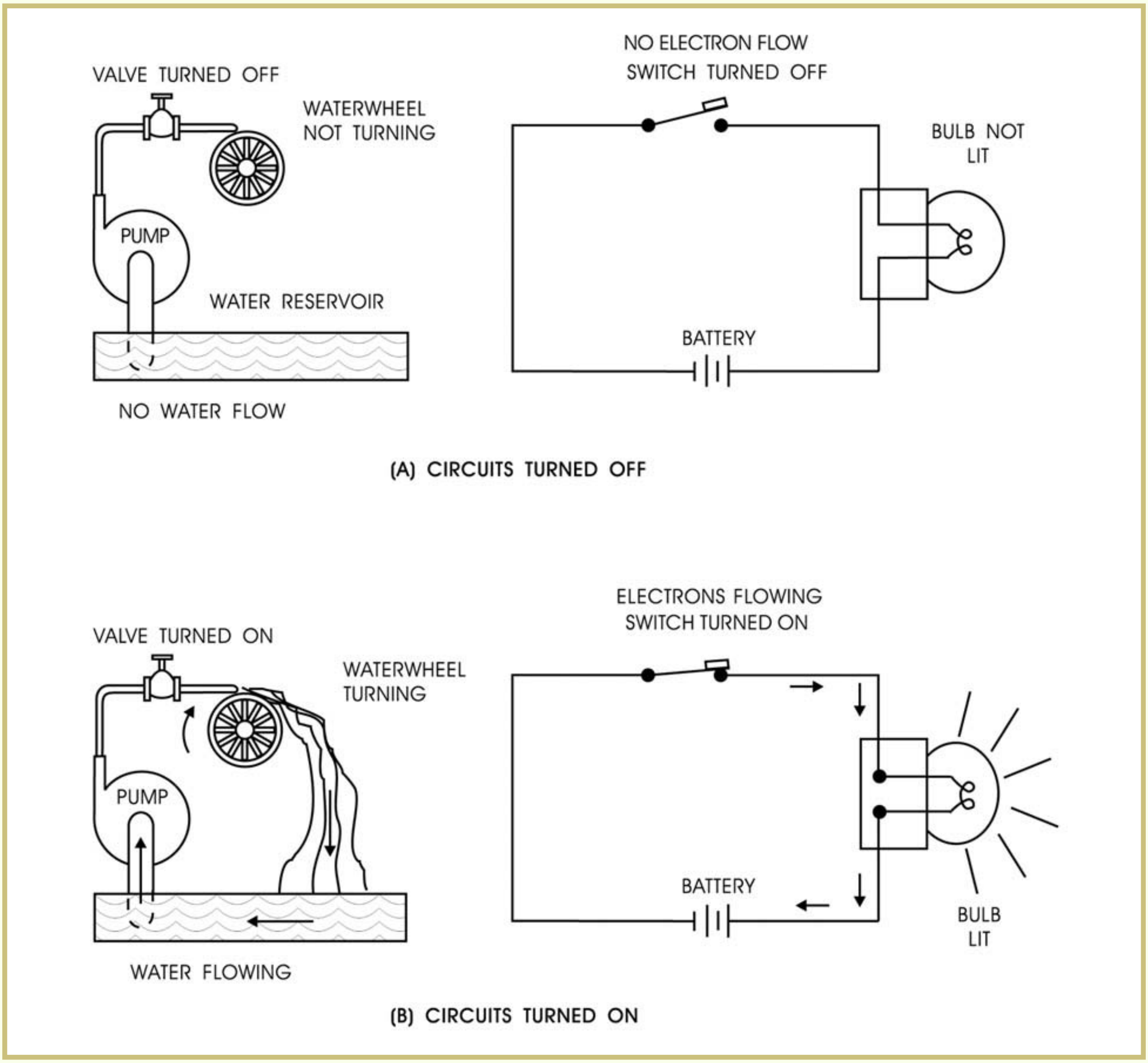



***FIGURE 5—Basic electrical principles can be visualized easily when you compare an electrical circuit to a water system.***

water into the pipes, so the pump can be compared to the voltage or potential in the electrical circuit.

In Figure 5A, both the water circuit and the electrical circuit are turned off. Both the water valve and the electric switch are in the OFF position, so no water or current flows. The waterwheel doesn't turn and the light bulb doesn't light up.

In Figure 5B, the water valve is turned on. Water is pumped out of the reservoir and into the pipes; the water flows through the pipes, turns the waterwheel, and then returns to the reservoir. In the electrical system, the switch is in the ON position. Electric current flows out of the battery through the wires, lights the bulb, and returns to the battery.

When you look at this example, think of resistance as a blockage or clog in the water pipe. If some debris was stuck in the pipe, the flow of water through the pipe would be reduced. In a similar way, a resistor in an electrical circuit reduces the flow of current through the circuit.

## DC and AC Voltage and Current

In this study unit, you'll learn about two different types of current. *Direct current (DC)* is the flow of electrons in one direction only. A DC voltage is nonvarying and is usually produced by a battery or a DC power supply. If you were to graph a DC voltage of 9 volts over a period of time, your graph would look like the one shown in Figure 6A. Whatever the voltage value, a DC voltage remains constant over time.

In an *alternating current (AC)*, electrons flow in one direction first, and then in the opposite direction. An alternating current reverses direction continually and is produced by an AC voltage source. An alternating current is the type of current found in household electrical systems and wall outlets.

A graph of an alternating current is shown in Figure 6B. The current starts at zero, then rises to a maximum positive value. At the maximum positive point, the current reverses direction and falls back to zero. The current continues to drop until it reaches the maximum negative value. The current then reverses direction again and rises back to zero. One complete transition of the current from zero to the positive peak, down to the negative peak, and back up to zero is called a *cycle*. These alternating current cycles repeat continuously for as long as the current flows.

In a modern automobile, a DC current from a battery powers the various automotive systems. However, in addition to a DC current, an automotive charging system often uses an alternating current. Therefore, to understand the operation of automotive electrical systems, technicians must be familiar with both DC and AC current.

## The Relationship Between Current, Voltage, and Resistance

The values of resistance, current, and voltage have a very important relationship in a circuit. Note that as the resistance in a circuit increases, the current decreases. If the resistance in a circuit decreases, the current increases. All circuits are designed to carry a particular amount of current. In fact, a circuit is usually protected by a fuse that's rated at a value just slightly higher than the current value of the circuit.

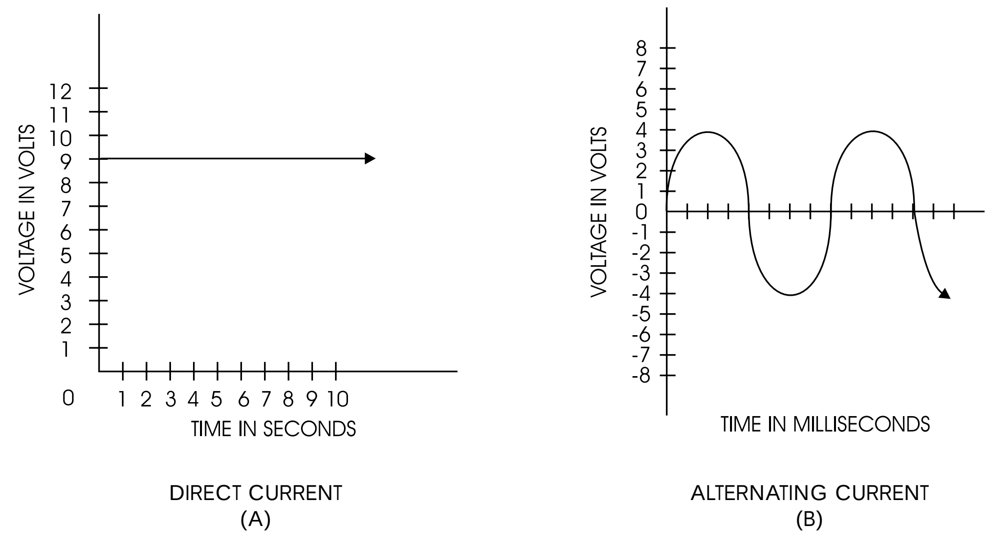



***FIGURE 6—In the graph shown in Figure 6A, you can see that the voltage level of a direct current (DC) remains exactly the same over time. In the graph shown in Figure 6B, the voltage level of an alternating current (AC) changes constantly.***

If a problem develops in the circuit, the circuit draws too much current from the battery. As a result, the excess current causes the fuse's elements to melt, and the circuit is broken or opened. When a fuse's elements melt in this way, we say that the fuse has "blown."

It's important to remember how resistance and current act in a circuit. The relationship between electrical quantities is summarized by Ohm's law and is expressed with the following mathematical formula:

$$E = I \quad R$$

In this formula, the variable $E$ stands for the circuit voltage in volts, the variable $I$ stands for the circuit current in amperes, and the variable $R$ stands for the circuit resistance in ohms.

Ohm's law is a very useful formula that's used to analyze circuits and troubleshoot circuit problems. Any time you know two of the three circuit values—voltage, current, or resistance—you can calculate the third, unknown circuit value using Ohm's law.

## Measuring Electrical Quantities

Technicians use several testing tools to measure circuit quantities. The most common testing instrument is the *multimeter* or *volt-ohm-milliammeter (VOM)*. A multimeter enables you to measure voltage, current, and resistance. The multimeter is a box-like device with two wires called *test leads* connected to it. The ends of the wire leads hold probes that are used to make the actual circuit tests. A dial on the front of the multimeter is used to select the quantity you want to measure. The multimeter also has a display face where it displays the circuit information it reads. Depending on the type of multimeter, the display may be a moving metal needle or a digital display.

To operate a multimeter, follow these steps.

*Step 1:* Select the quantity you want to measure by turning the dial.

*Step 2:* Take the two test leads in your hands and touch the probes to two points in a circuit.

*Step 3:* Read the resulting information on the meter's display.

Note that this is a very basic description of the operation of a multimeter. The actual operation is somewhat more involved, and electrical safety precautions must be observed. If you use a multimeter incorrectly, you could receive a serious electrical shock and destroy the multimeter. (You'll learn how to operate a multimeter in a later study unit.)

Note that when a multimeter is set to read resistance, it's sometimes called an *ohmmeter*. When it's set to measure voltage, it's called a *voltmeter*. When it's set to measure current, it's called an *ammeter*.

# Electromagnetism

*Electromagnetism* is very important to the operation of ignition systems. Electromagnetism is the magnetic effect produced when electric current flows through a conductor. When a conductor is carrying an electric current, the wire is surrounded by a magnetic field. A magnetic field is the space around a magnet or magnetic object that contains a force of attraction. This force of attraction is sometimes called *magnetic lines of force* or *magnetic flux*. The magnetic field is strongest in the space immediately surrounding the conductor. The force of electromagnetism has many interesting and highly useful applications.

If an insulated piece of conductor wire is looped around to form a coil, the resulting device is called a *magnetic coil* (Figure 7). When current flows through a magnetic coil, each separate loop of wire develops its own small magnetic field. The small magnetic fields around each separate loop of wire then combine to form a larger and stronger magnetic field around the entire coil. The coil develops a north pole and a south pole. The magnetic field at the center of a magnetic coil is stronger than the fields above or below the coil.

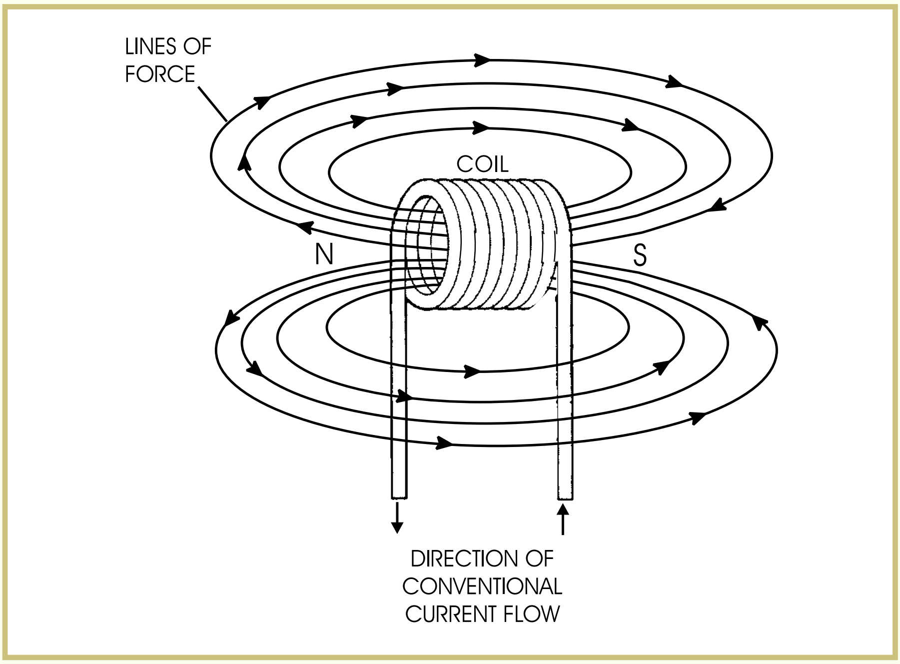



***FIGURE 7—This figure shows a basic magnetic coil and the magnetic lines of force that surround it.***

An electromagnet is a device that's made by inserting a piece of magnetic material, usually iron or soft steel, into a magnetic coil (Figure 8). The piece of metal that the conductor is coiled around is called the *core*. When current is applied to the coil, the core becomes magnetized and develops a north and south pole. The addition of the metal core to the coil increases the magnetic force of the coil. So, an electromagnet is generally much stronger than a magnetic coil of a similar size.

Another useful electromagnetic property is *mutual inductance*. If two conductors are placed close together, and current is applied to one of the conductors, a voltage is induced in the other conductor. Therefore, because the two conductors are physically close to each other, the energy in the "live" conductor energizes the other conductor. This effect is called mutual inductance, and it can be used to operate transformers. Note that if the conductors are moved apart from each other, the effect of mutual inductance weakens. If the conductors are moved very

***FIGURE 8—This figure shows the construction of a basic electromagnet. A piece of magnetic material is inserted into a magnetic coil.***

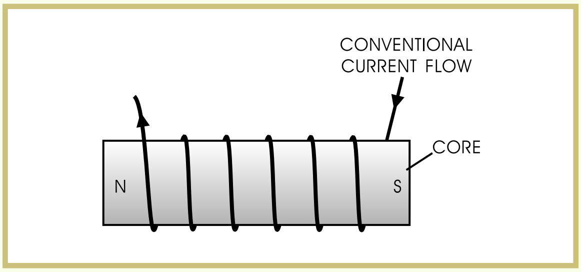
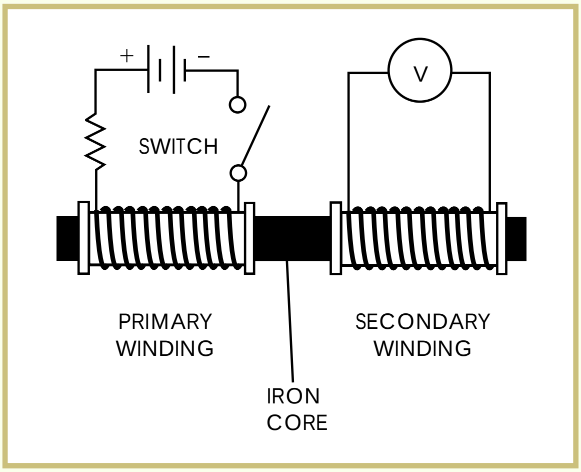


**FIGURE 9—A basic transformer is shown here. A change in voltage in the primary winding induces a voltage in the secondary winding.**




far apart, the energy of the "live" conductor won't be strong enough to influence the second conductor, and the mutual inductance will stop.

A basic transformer is shown in Figure 9. The transformer is a device that consists of two windings of wire wound around an iron core. The first winding is called the *primary winding* and the second winding is called the *secondary winding*. In this figure, the primary winding is connected to a battery through a switch and a resistor; the secondary winding is connected to a voltmeter.

When the switch is open as shown in Figure 9, no current flows through the primary winding; thus, no magnetic field is produced, and no voltage is induced in the secondary winding. However, when the switch is closed, current flows through the primary winding, and produces a magnetic field around the primary winding. The magnetic field spreads outward and cuts across the secondary winding, inducing a voltage. The voltage registers on the voltmeter attached to the secondary winding. Later in this study unit, you'll learn how the principle of mutual inductance is used in automotive ignition systems.

Now, take a few moments to review what you've learned by completing *Power Check 1*.

# Power Check 1

**At the end of each section of *Ignition System Components and Operation,* you'll be asked to pause and check your understanding of what you've just read by completing a "Power Check" exercise. Writing the answers to these questions will help you to review what you've studied so far. Please complete *Power Check 1* now.**

1. The measure of the amount of electrical potential in a circuit is called the _______.

2. Electrical current is measured in units called _______.

3. The symbol Ω is used as an abbreviation for _______.

4. The flow of electrons through a circuit is called _______.

5. When electricity flows through a conductor, a _______ field is created around the conductor.

6. Electrical resistance is measured in units called _______.

7. Opposition to the flow of electricity in a circuit is called _______.

**Questions 8–12: Indicate whether the following statements are True or False.**

_____ 8. Electrons are the smallest type of atomic particle.

_____ 9. The letter that's used as an abbreviation for electric current is *V*.

_____10. One milliampere is equal to 0.001 ampere.

_____11. One kilovolt is equal to 10 volts.

_____12. An electron has a negative electrical charge.

**Check your answers with those on page 99.**

# INTRODUCTION TO IGNITION SYSTEM OPERATION

## An Overview of Operation

Now that you have a general understanding of what electricity is and how it flows through a circuit, let's examine how automotive ignition systems operate. We'll begin with the basics, and then move on to a more detailed discussion of automotive ignition systems.

What exactly does an ignition system do? Well, once the air-and-fuel mixture has been compressed in an engine's combustion chamber, the engine needs something to ignite the mixture. The engine's ignition system performs this task. The ignition system takes electricity from the vehicle's battery, increases the battery voltage to a much higher voltage, and then sends this high voltage to the spark plugs. The high voltage causes the spark plugs to produce a powerful, hot spark.

Each spark plug is threaded into a hole that leads directly into a cylinder's combustion chamber. In simple terms, a spark plug is a device that electricity flows through. At the very end of the spark plug are a pair of metal contacts called *electrodes*. These contacts are separated from one another by a small air space. When electricity flows through a spark plug, it jumps across this air space from one electrode to the other. As the electricity jumps across the space, a powerful spark is produced. This spark ignites the air-and-fuel mixture that surrounds it inside the cylinder. The resulting "explosion" in the combustion chamber forces the piston down and gets the crankshaft turning.

Remember the four stages of operation in a four-stroke engine. During the intake stage, the piston moves down in the cylinder to take the air-and-fuel mixture into the cylinder. Then, the piston rises during the compression stage to compress the air-and-fuel mixture in the combustion chamber. When the piston reaches top dead center (TDC), the spark plug fires and ignites the compressed air-and-fuel mixture. The ignition of the air-and-fuel mixture forces the piston down in the cylinder, producing the power stage. The power produced by the ignition of the air-and-fuel mixture gets the crankshaft turning, which keeps the piston moving and the engine running. The ignition process keeps the engine running for as long as the fuel lasts and for as long as the spark plug continues firing.

An ignition system must produce a very high voltage in order to force electric current—moving electrons—across the spark plug gap. As many as 90,000 volts are needed to make this spark in some engines. The spark that's produced must be very powerful so that it can quickly ignite the air-and-fuel mixture in the cylinder. The more completely the fuel is burned, the more power that's produced. The spark must also occur near the end of each cylinder's compression stage in order to properly ignite and burn the air-and-fuel mixture. Also, an engine requires many sparks per minute in order to keep running at the proper speed. Remember that by the time the crankshaft completes two rotations, every engine cylinder must have fired. Therefore, if a typical six-cylinder engine is operating at a speed of 3,000 rpms, a spark occurs 1,500 times per minute in each cylinder. Since the engine has six cylinders, this is a total of 9,000 spark occurrences for all of the cylinders! You can see that the ignition system has a very difficult job to do.

How does the ignition system produce a powerful spark, time it perfectly, and keep making sparks over and over again? Let's find out.

Figure 10 shows a simplified view of a typical automotive ignition system. This basic ignition system contains a battery, an ignition switch, an ignition coil, a distributor, a triggering device, a spark plug wire, and a spark plug. These components perform the following functions.

- The battery supplies electricity to the system.
- The ignition switch turns the system on and off.
- The ignition coil strengthens the electricity from the battery.
- The distributor directs the electricity to the spark plug.
- The triggering device controls when the spark occurs.
- The spark plug wire carries the electricity to the spark plug.

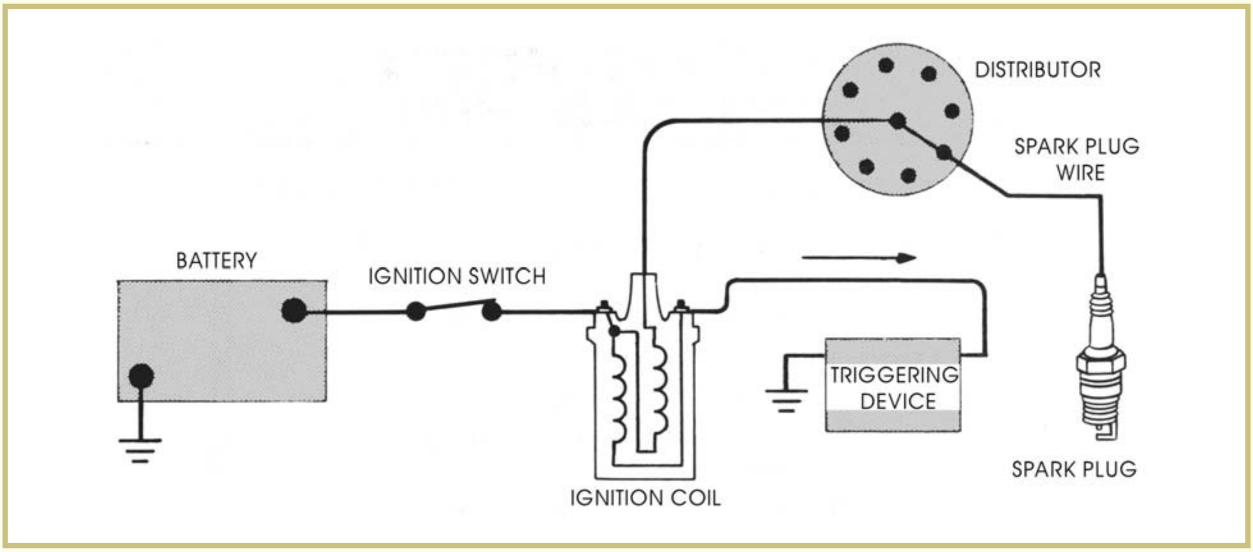



***FIGURE 10—A simplified view of a typical automotive ignition system is shown here.***

- The spark plug produces the spark in the cylinder that ignites the air-and-fuel mixture.

To better understand a basic ignition system, let's explore each of its components in a little more detail. We'll begin with the battery.

## The Battery

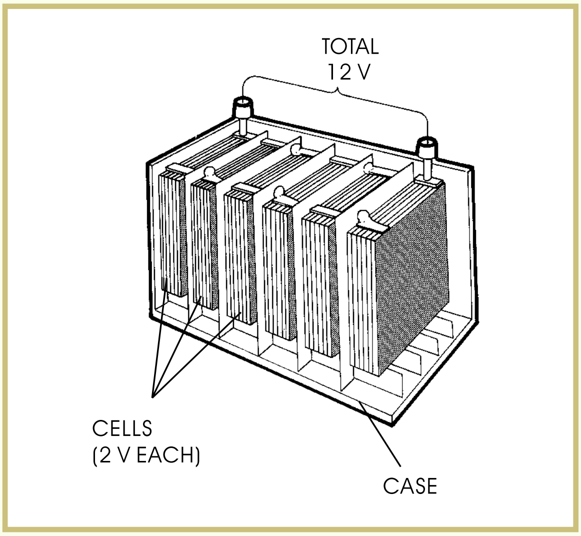
In most automobiles, the power source for the ignition is a battery and an alternator. In a battery ignition system, the battery provides power to the ignition coil. The battery used in this type of system is a lead-acid storage battery. In addition to providing electricity to the ignition coil, the battery may also be used to power lights, horns, and other accessory circuits.

A typical lead-acid storage battery is made up of several individual compartments called *cells*. Each cell is made up of a series of lead plates. Small spaces between the plates are filled with an electrolyte solution. This solution is usually made from sulfuric acid diluted with water. Each cell produces approximately 2 V when the battery is fully charged, so a 12 V battery contains six cells. A diagram of a typical storage battery is shown in Figure 11.

*Note:* The acid used in storage batteries can cause burns and destroy clothing. Always use extreme caution when working near a lead-acid battery.

Normally, a battery has a total output voltage of 12 volts of direct current, or 12 DC. The current produced by the battery is often measured in units called *ampere/hours (Ah)*. In a battery ignition system, the alternator is used to recharge the battery as the engine operates.

***FIGURE 11—This figure shows a storage battery that contains six 2 V cells. The total voltage of the battery is 12 V.***



## The Ignition Switch

The type of ignition switch used on vehicles many years ago was much simpler than the type used today. This is because old switches had only one function—to open and close the primary ignition circuit. Modern ignition switches must accomplish this function and many others. For example, the ignition switch must operate the cranking-motor circuit, a buzzer if the ignition key is left in the switch when the vehicle's door is opened, a locking mechanism for the steering wheel to prevent theft, and a means for the radio and other accessory circuits to operate when the engine is off.

Because of these many functions, the ignition switch assembly is somewhat larger than it was many years ago. The switch assembly is usually mounted a short distance down the steering column from the key lock cylinder assembly. The two assemblies are then connected by an ignition switch actuator rod (Figure 12). Note that turning the key moves a gear-and-rack assembly. The gear-and-rack assembly, in turn, moves the ignition switch actuator rod and plunger to the various positions required for performing ignition switch functions.

Several different types of ignition switches are commonly used. The most common is the *five-position switch* (Figure 13). In the accessory or ACT position, the engine is shut off and a connection is made from the battery terminal to the accessory terminal of the switch. This allows accessories such as the radio, heater, blower, and windshield wiper to be operated when the ignition, fuel gage, and indicator light circuits are off.

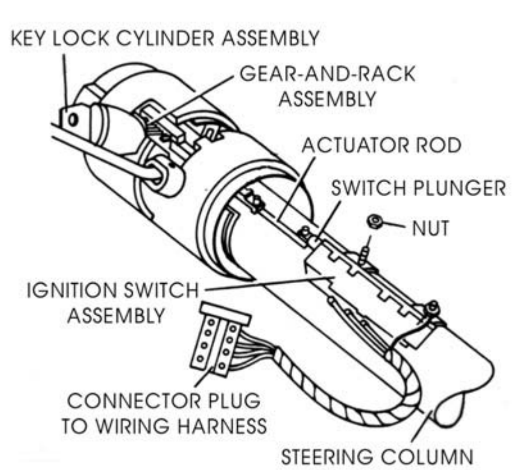



***FIGURE 12—In modern automobiles, the ignition switch assembly is mounted to the steering column and is operated by a key lock cylinder assembly at the top of the steering column.***

In the OFF and LOCK positions, accessories that are supplied with power through the ignition switch can't be operated. Also, it's general practice to ground the resistance wire circuit to the ignition coil when the switch is in the LOCK position. This prevents the engine from being operated with a jumper to the coil.

Generally, in the START position, all accessories that are supplied with power through the switch are temporarily disconnected. (However, you may see some exceptions to this rule.) One connection is made to the starter solenoid, and a second connection is made directly to the ignition coil. Because the battery voltage lowers when an engine is started, the ballast resistor, which supplies the switch with power, is bypassed to provide a higher secondary winding voltage to start the engine.

When the ignition switch is released from the START position, a spring returns the switch to the ON position.

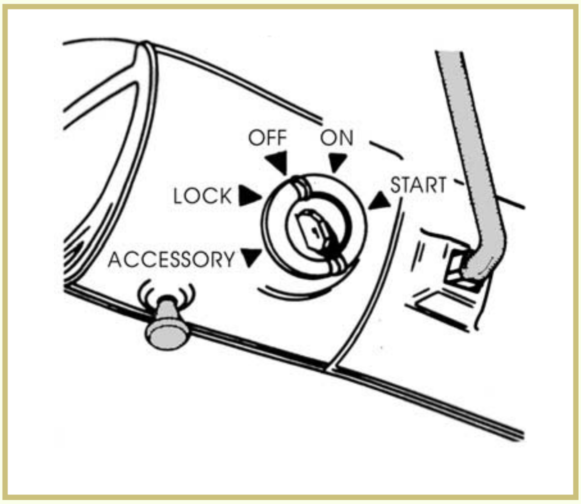



***FIGURE 13—Most automobiles use a five-position ignition switch like the one shown here.***

## The Ignition Coil

All ignition systems contain an ignition coil. The ignition coil is actually a type of electric transformer that changes low-voltage electricity to high-voltage electricity.

Ignition coils work on the principles of magnetic induction. An ignition coil contains two coils of wire called the *primary winding* and the *secondary winding* (Figure 14). The primary winding is made of turns of heavy-gage wire; in contrast, the secondary winding is made of many turns of very fine-gage wire wrapped around a soft iron core. The secondary winding has many more turns of wire than the primary winding. The difference in the number of turns of wire between the two is what allows the ignition coil to increase voltage.

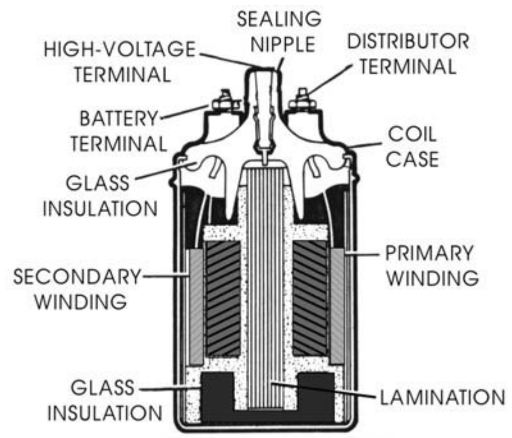



***FIGURE 14—An ignition coil contains two wire windings called the primary winding and the secondary winding. The primary winding is made of turns of heavy wire, while the secondary winding is made of many turns of fine wire.***

In all vehicles, the ignition coil performs the same function—it uses the forces of electromagnetism to convert a low voltage from the battery into the high voltage that's needed to fire the spark plug.

All ignition coils contain the following basic components:

1. A small number of turns of heavy wire
2. A large number of turns of fine wire
3. A central core of soft iron
4. Insulation between each turn of wire, and between the turns and the iron core
5. External electrical connections

In the ignition coil, one end of the transformer's primary winding is connected to the vehicle's battery. The battery applies low-voltage electricity to the coil's primary winding. The flow of electricity from the battery is controlled by the ignition switch. When the ignition switch is in the OFF position, no electricity is available to the ignition coil. When the ignition switch is in the ON position, current is allowed to flow through the primary winding of the coil. A resistor is often placed between the ignition switch and the other ignition system components. The resistor prevents damage to the components due to excessive current flow.

As you know, when a current flows through a conductor wire, a magnetic field builds up around the wire. The magnetic field that accumulates in the primary winding of the ignition coil is very strong. If the current flow to the primary winding is suddenly stopped or turned off, the magnetic field in the primary winding collapses. This collapsing magnetic field then induces a very high voltage in the secondary winding of the ignition coil.

In an ignition system, a triggering device is attached to the primary winding of the ignition coil. The triggering device is used to turn the current flow in the primary winding on and off at the proper time.

Because the coil's secondary winding has many more turns of wire than the primary winding, the voltage that's induced in the secondary winding is much higher than the original voltage applied to the primary winding. In a typical automotive ignition system, the battery supplies about 12 volts to the coil's primary winding, and the ignition coil increases that voltage to between 20,000 and 90,000 volts.

The secondary coil winding is connected to the spark plug wire. The spark plug wire is a heavily insulated wire that leads directly to the spark plug. When the strong voltage is induced in the secondary winding, current flows through the secondary winding and then out through the spark plug wire. The current flows through the spark plug wire directly to the spark plugs in the engine cylinders. The current then flows through the spark plug and produces a strong electrical spark at the end of the plug. The spark ignites the air-and-fuel mixture in the cylinder, and the engine starts running.

Remember that the high voltage in the secondary winding is produced only when the current stops. This is a very important concept to understand. Current from the battery passes through the transformer's primary winding, and when the current flow is stopped, the magnetic field collapses and produces a high voltage in the secondary winding. This means that an ignition system needs the triggering device to keep turning the current from the power source on and off.

Two types of ignition coils are commonly used in automotive ignition systems: *round coils* and *flat coils,* which are also called *E-type coils*. Round coils have two sets of windings that are held inside a round cylindrical housing (Figure 15A). The primary winding is placed on the outer edge of the coil. The winding has two terminals that stick up out of the top of the coil. One of these terminals connects the coil to the battery, while the other terminal connects the coil to the triggering device. The secondary winding, which consists of many turns of very fine wire, is located toward the center of the coil. The high voltage is produced in these windings. The output from these windings leads to a large terminal at the very top of the coil. From this terminal, the high voltage is directed through the coil wire and spark plug wire to the spark plug.

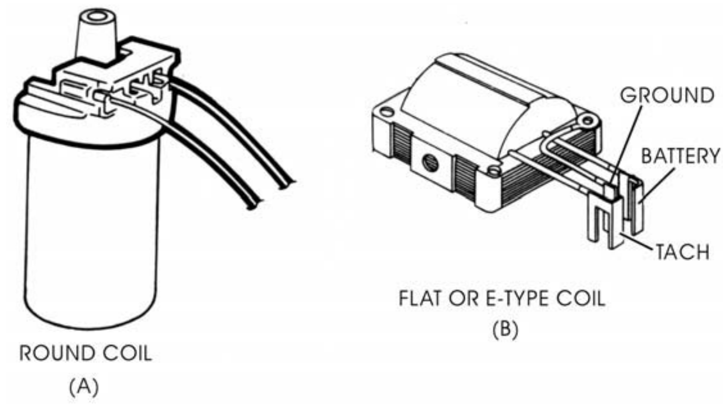



***FIGURE 15—Most ignition systems use either a round ignition coil like the one shown in Figure 15A, or a flat coil like the one shown in Figure 15B. The flat coil is sometimes called an E-type coil.***

The flat coil or E-type coil (Figure 15B) consists of an iron frame that surrounds the primary and secondary windings. The entire assembly is covered with epoxy insulation and doesn't contain oil. The positive and negative primary terminals project from the side of the coil assembly, along with a third wire that serves as a ground. The secondary voltage discharge is at the center of the coil.

## Triggering Devices

All ignition systems use some type of triggering device to turn the primary coil winding on and off. A triggering device works much like a switch. Earlier you learned about open and closed circuits. The ignition system's circuit is closed when the switch closes. When the switch closes, current flows from the power source to the transformer. When the switch opens, the circuit is opened and the flow of current immediately stops. When the current stops, the magnetic field in the transformer collapses, producing the voltage needed to fire the spark plug.

Imagine that you're standing near a light switch in your home, flipping the switch on and off. Each time you flip the switch on, the light comes on. When you flip the switch off, the light goes out. If you keep doing this, you'll get an ON, OFF, ON, OFF pattern. This is very similar to the action of the triggering device in an ignition system. The triggering device is connected to one end of the ignition coil's primary winding. Each time the triggering device stops the current flow in the primary winding, the spark plug fires. The spark plug keeps firing continually—about 1,800 times per minute—so the engine keeps running.

In modern automobiles, the triggering devices used vary greatly from one engine to another. Years ago, the triggering was handled by a set of contact points. A system that uses contact points is called a *point-type ignition system* or a *conventional ignition system*. Contact points are simple electrical contacts that open and close as needed to turn the primary winding on and off.

However, because contact points tend to wear out and can handle only a limited amount of current, all modern automobiles use electronic triggering devices. A system that uses an electronic triggering device is called an *electronic ignition system*. Since there isn't any physical contact between the various components in an electronic ignition system, parts don't wear out or need adjustment. Also, electronic ignition systems can handle more current than conventional ignition systems. This allows electronic systems to perform reliably for a long period of time.

Most modern vehicles also use a computer control system to control engine operation. In these vehicles, the ignition system is usually connected to the computer control system. In a computer-controlled ignition system, the electronic triggering device sends information to the onboard computer. The computer then uses the information to turn the coil on and off at the proper time. A computer control system can precisely vary the ignition timing to match current engine conditions, which results in better efficiency and more power.

You'll learn more about different types of triggering devices later in this study unit. For now, just remember that the triggering device turns the power in the coils on and off, and this produces a spark in the cylinder at the proper time. Once the current in the primary winding is shut off, the magnetic field collapses and produces a high voltage in the secondary winding.

## Spark Plug Wires

Ignition system wires can be classified into two general types: *primary wires* and *secondary wires*. Primary wires carry high-current loads at low voltages from the battery to the ignition components. These wires are made of large-diameter conductors that are covered with light insulation. In contrast, secondary wires are used to carry small amounts of current, but at very high voltages. Therefore, secondary wires are made of small-diameter conductors that are covered with thick coatings of rubber, plastic, or neoprene insulation. Figure 16 shows a comparison of primary and secondary wires.

As you've learned, the electricity that's sent to the spark plug must be very strong to produce a proper spark. In modern ignition systems, it isn't uncommon for ignition coils to produce voltages as high as 90,000 volts. When you consider that the voltage supplied to a typical house-

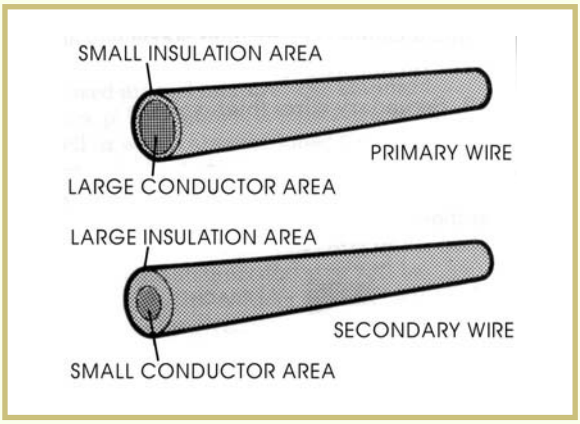



***FIGURE 16—This illustration shows the differences between primary and secondary wires. Primary wires are made of large-diameter conductors that are covered with light insulation. Secondary wires are made of small-diameter conductors that are covered with thick insulation.***

hold circuit is only 110 volts, you can see that a coil produces a very high voltage! Because of these high voltages, special, heavily insulated wires called spark plug wires or *high-tension wires* must be used to connect the coil to the spark plug.

Spark plug wires are made from heavily insulated secondary wires because they must carry very high voltages. If the spark plug wire wasn't heavily insulated, the high voltage might jump to any metal object, such as the engine block, instead of flowing to the spark plug.

Note that the conductor inside the spark plug wire isn't a metal wire. Instead, the conductor is made from a special type of carbon-impregnated fiberglass. The fiberglass conductor prevents radio and television interference, increases firing voltages, and reduces spark plug wear by reducing current.

Both ends of a spark plug wire have metal connectors called *terminals* attached to them. The internal end of each terminal is connected to the conductor, and the exposed end of the terminal is used to make a solid physical connection to the spark plugs or the distributor. For example, a spark plug wire's terminal is placed over the spark plug's terminal nut to create a connection between the two. By using this type of connection, spark plug wires can be easily removed and installed when you're testing the system or replacing the spark plugs.

In addition to the insulation around the wire itself, spark plug wire terminals are also surrounded by *insulating boots* made of rubber, silicon, or neoprene. The boots help to prevent current from leaking or arcing out of the spark plug wire to nearby metal parts. In addition, insulating boots help keep dirt and moisture from collecting on the terminals.

## Spark Plugs

As you learned, a spark plug is designed to allow a voltage to jump across a gap, producing a spark that ignites the engine's fuel. Four-stroke engines contain one spark plug for each cylinder. An external

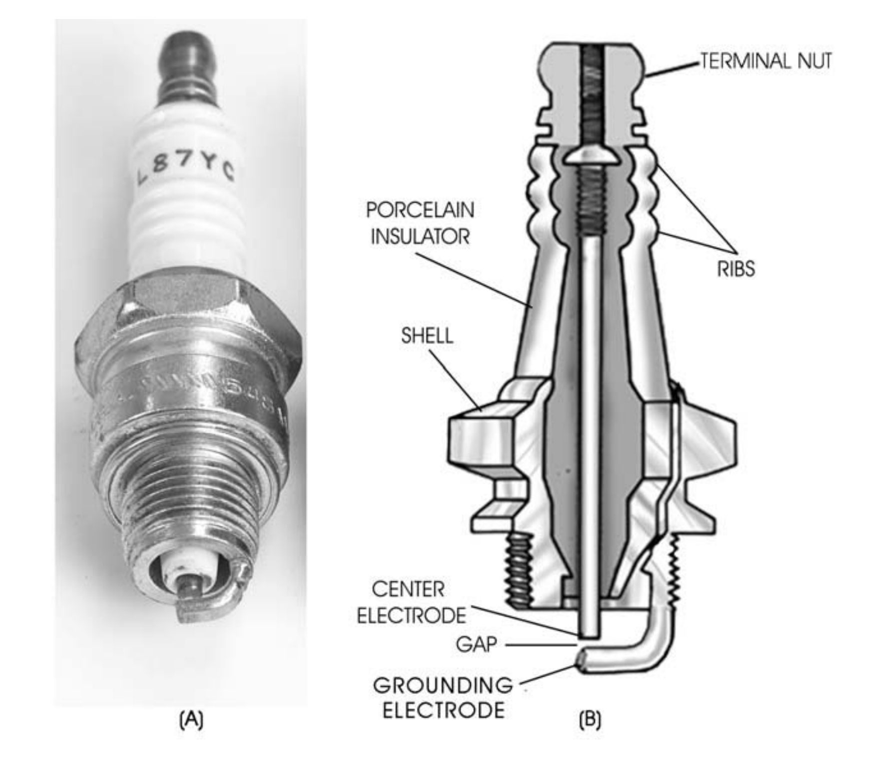



***FIGURE 17—Figure 17A shows an external view of a typical spark plug. Figure 17B shows the parts of a spark plug.***

view of a spark plug is shown in Figure 17A. The basic parts of a spark plug are shown in Figure 17B.

The metal section at the bottom of the spark plug is called the *shell*. The top section of the shell is molded into a hexagon shape that fits into a wrench or socket. Thus, a wrench or socket can be used to install or remove a spark plug. The lower section of the shell is threaded. Remember that a spark plug screws into a hole of the cylinder head. The threads on the bottom of the spark plug mate with threads inside the hole in the cylinder head.

A spark plug has two metal electrodes or terminals. The metal electrodes are conductors through which current flows. One electrode runs through the entire length of the spark plug. This is called the *center electrode*. The second electrode is connected to the threaded part of the spark plug. This electrode is sometimes called the *side electrode* or the *grounding electrode*. The grounding electrode bends around so that it's very close to the end of the center electrode. The small air space between the two electrodes is called the *gap*.

The top end of the center electrode connects to the terminal nut of the spark plug. When the spark plug is screwed into the cylinder head, the terminal nut is connected to the spark plug wire.

The high voltage produced by the ignition coil travels through the spark plug wire and enters the spark plug through the terminal nut. The electricity then flows down the spark plug through the center electrode and jumps across the gap from one electrode to the other to produce the spark.

Different plugs have different types of electrodes. In some plugs, the center electrode is made of an alloy of copper and steel. Other plugs have electrodes that are made of a platinum alloy. Platinum-alloy electrodes operate better under high temperatures and burn off combustion deposits at lower temperatures. The various spark plug manufacturers usually indicate what type of electrode the spark plug is equipped with. The best advice as far as choosing a particular type of spark plug is to use the plug that's recommended by the vehicle manufacturer. This information is usually listed in the vehicle's service manual.

In some spark plugs, a small ceramic element is placed in the center electrode. This element acts as a resistor, preventing the spark plug from interfering with radio frequencies. When a spark plug fires, it sometimes interferes with the radio. This interference causes a popping noise in radios, televisions, and in some types of communication systems. The resistance element in the plug helps to prevent this interference.

The shape of the grounding electrodes in spark plugs varies. Most grounding electrodes bend and extend over the entire width of the center electrode. This is sometimes called an *automotive gap spark plug*. However, in some plugs, the grounding electrode is split to form two separate grounding electrodes. This type of spark plug is sometimes called a *split-fire or split-electrode spark plug*. The manufacturers of these plugs claim that the split-type electrode offers better engine performance and fuel economy. However, this is a matter of opinion; some technicians believe the split electrode does provide benefits, while others feel it offers no performance advantages. Again, use the spark plugs recommended by the manufacturer. An automotive gap and a split-electrode spark plug are shown in Figure 18.

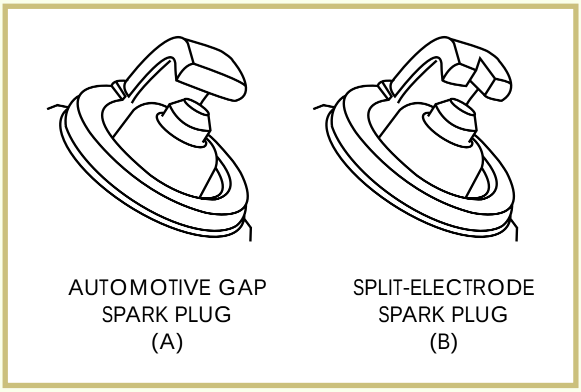



***FIGURE 18—Figure 18A shows the end of an automotive gap spark plug. Figure 18B shows a split-electrode spark plug.***

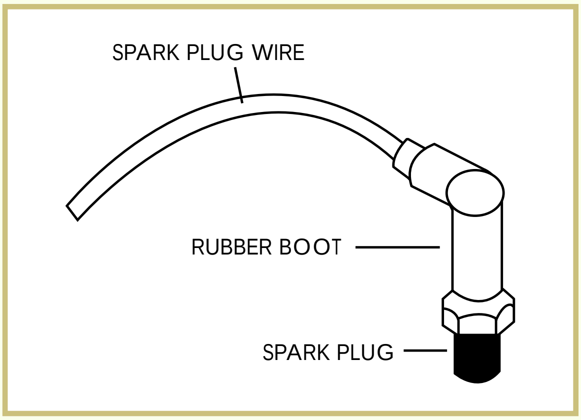
The gap between the two plug electrodes is very small and is usually measured in thousandths of an inch. The correct gap measurement is very important to the correct operation of the spark plug. If a gap is too narrow, the spark produced is weak and the ignition is poor. In contrast, if the gap is too wide, it's difficult for the electricity to jump the gap. This condition also results in a weak spark. Therefore, you can see that the width of the gap is a very important factor in ignition system performance.

The body of a spark plug is encased in a porcelain shell. Porcelain, a china-like substance, is used for the shell because it's an electrical insulator—it doesn't conduct electricity. This porcelain insulator electrically isolates the voltage inside the spark plug. The spark plug's manufacturer and identification number are usually printed on the porcelain insulation.

Note that the porcelain covering is ribbed. The ribs extend from the terminal nut to the shell of the plug to prevent a condition called *flashover*. In flashover, current jumps or arcs from the terminal nut to the metal shell on the outside of the plug instead of traveling down through the center electrode.

You learned earlier that the spark plug wire is connected to the spark plug by a metal connector that fits down over the plug's terminal nut. A typical spark plug wire connection is shown in Figure 19. Note that this connector has a rubber boot that seals out dirt and moisture. The boot also prevents the high voltage from jumping out to the cylinder head instead of flowing down to the spark plug electrode.

***FIGURE 19—The insulated connector on the end of a spark plug wire fits down around the spark plug's terminal nut as shown here.***




If you look quickly at a group of spark plugs, they may all look alike. However, spark plugs are manufactured with minute differences that affect their performance. Each type of spark plug is identified by a specific manufacturer identification number. When you replace a spark plug, always use the same type of plug.

Now, let's discuss some of these different spark plug specifications. The first specification is called *reach*. The reach of a spark plug is the length of the metal threads at the end of the plug. The reach of a spark plug is shown in Figure 20.

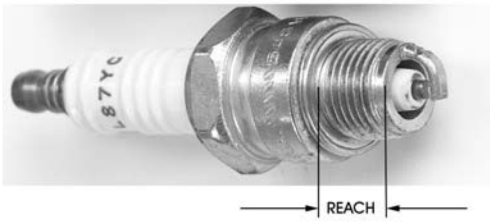



***FIGURE 20—The length of the threaded area of a spark plug is called the reach.***

The correct spark plug reach is essential to proper engine operation. If the spark plug reach is too long, the threaded part extends down into the combustion chamber and hits the piston each time it rises, which seriously damages the engine. If the reach is too short, the spark occurs too high in the cylinder head. This causes the air-and-fuel mixture to burn too slowly in the combustion chamber and delays the start of the power stroke. The delayed power stroke causes a loss of power and makes the engine difficult to start.

Spark plugs also differ in terms of how much heat they can withstand. Heat from the fuel combustion process is absorbed by the spark plug during engine operation and is conducted upward through the plug. Combustion temperatures normally range from 1,000 to 1,500 degrees Fahrenheit. Thus, a spark plug must be able to withstand these temperatures.

Each spark plug has a heat range. A spark plug's heat range determines, to a large extent, engine performance under different conditions and speeds. A heat range classifies a spark plug according to its ability to transfer heat from the gap end of the plug to the engine's cooling system. The rate of heat transfer is controlled by the length of the insulator tip, as shown in Figure 21.

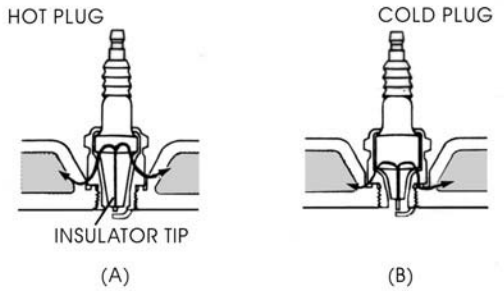



***FIGURE 21—A spark plug's heat range is a measure of the plug's ability to transfer heat. The rate of heat transfer is controlled by the length of the insulator tip. The hot plug in Figure 21A transfers less heat than the cold plug shown in Figure 21B.***

A spark plug is called a *cold plug* if it can easily transfer combustion heat from the firing end of the plug out to the cylinder head. In a *hot plug,* the center electrode is more isolated from the shell and the cylinder head. Therefore, a hot plug tends to retain its heat. Cold plugs have shorter insulator tips than hot plugs.

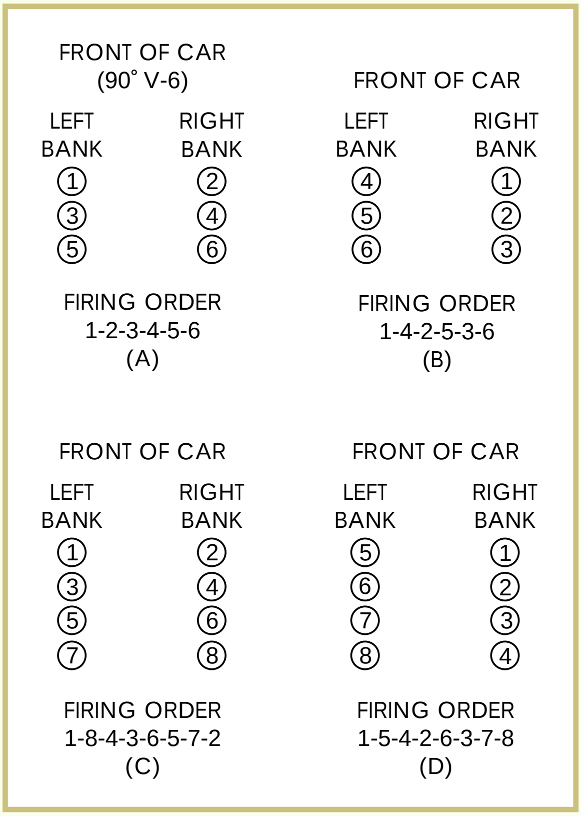
Spark plugs are made in several heat ranges to suit different engines and different operating conditions. A spark plug with the correct heat range must be installed in an engine. For instance, a cold plug should be installed in an engine that has high combustion temperatures. A hot plug should be installed in an engine with low combustion temperatures. If a hot plug is installed in a hot-running engine, the spark plug may overheat. If a cold plug is installed in a cool-running engine, heavy carbon deposits form on the electrodes, making it difficult for the spark plug to fire. When the plug is in the correct temperature range, the heat from combustion burns the byproducts of combustion off the electrodes and keep them clean without causing them to overheat.

## Firing Order

Earlier in this program, you learned that all automobiles contain multicylinder engines; that is, engines with more than one cylinder. Usually, an automotive engine contains four, six, or eight cylinders. Each of the cylinders fires at a different time at equally spaced intervals. By firing the engine cylinders at different times, the forces in the engine are balanced and vibration is kept to a minimum. In order to achieve the most efficient engine operation, each engine cylinder must be fired as it approaches TDC on its compression stroke. As you may remember, the order in which an engine's cylinders fire is called the firing order. The firing order of the cylinders varies from engine to engine, depending on the manufacturer's design.

In an earlier study unit, you learned how an engine's cylinders are numbered—in most cases, from the front of the engine to the back. In an in-line, four-cylinder engine, the cylinders are usually numbered 1-2-3-4 from the front of the engine to the back. However, in most cases, the engine's firing order doesn't follow a simple numerical order. For example, a typical firing order for an in-line, four-cylinder engine is 1-3-4-2. The firing order for a particular engine is listed in the vehicle's service manual. Figure 22 shows some typical automotive firing orders for six-cylinder and eight-cylinder engines.

***FIGURE 22—Figure 22A shows the cylinder arrangement and firing order for a General Motors V-6 engine; Figure 22B shows the cylinder arrangement and firing order for a Ford V-6 engine; Figure 22C shows the cylinder arrangement and firing order for a General Motors V-8 engine; and Figure 22D shows the cylinder arrangement and firing order for a Ford V-8 engine.***




## The Distributor

Two different types of ignition systems are used to control the spark that's delivered to an engine's cylinders: *distributor-type systems* and *direct-fire systems*. In a distributor-type ignition system, a single ignition coil powers all the spark plugs in the engine. A device called a *distributor* is used to direct the high voltage from the ignition coil to the spark plugs. Remember that in most engines, each cylinder ignites at a different time so that the engine runs more smoothly. Therefore, the distributor directs the high voltage to the cylinder that's currently on its compression stroke and ready to have the air-and-fuel mixture ignited to produce power.

In contrast, a direct-fire system uses a single battery and triggering device, and separate coils to control the spark at each engine cylinder. A computer control system takes the information from the triggering device and uses it to fire each cylinder at the proper time.

You'll learn about direct-fire ignition systems in detail later in the study unit. For now, let's concentrate on the ignition systems that use distributors. A simplified view of a distributor-type ignition system is shown in Figure 23.

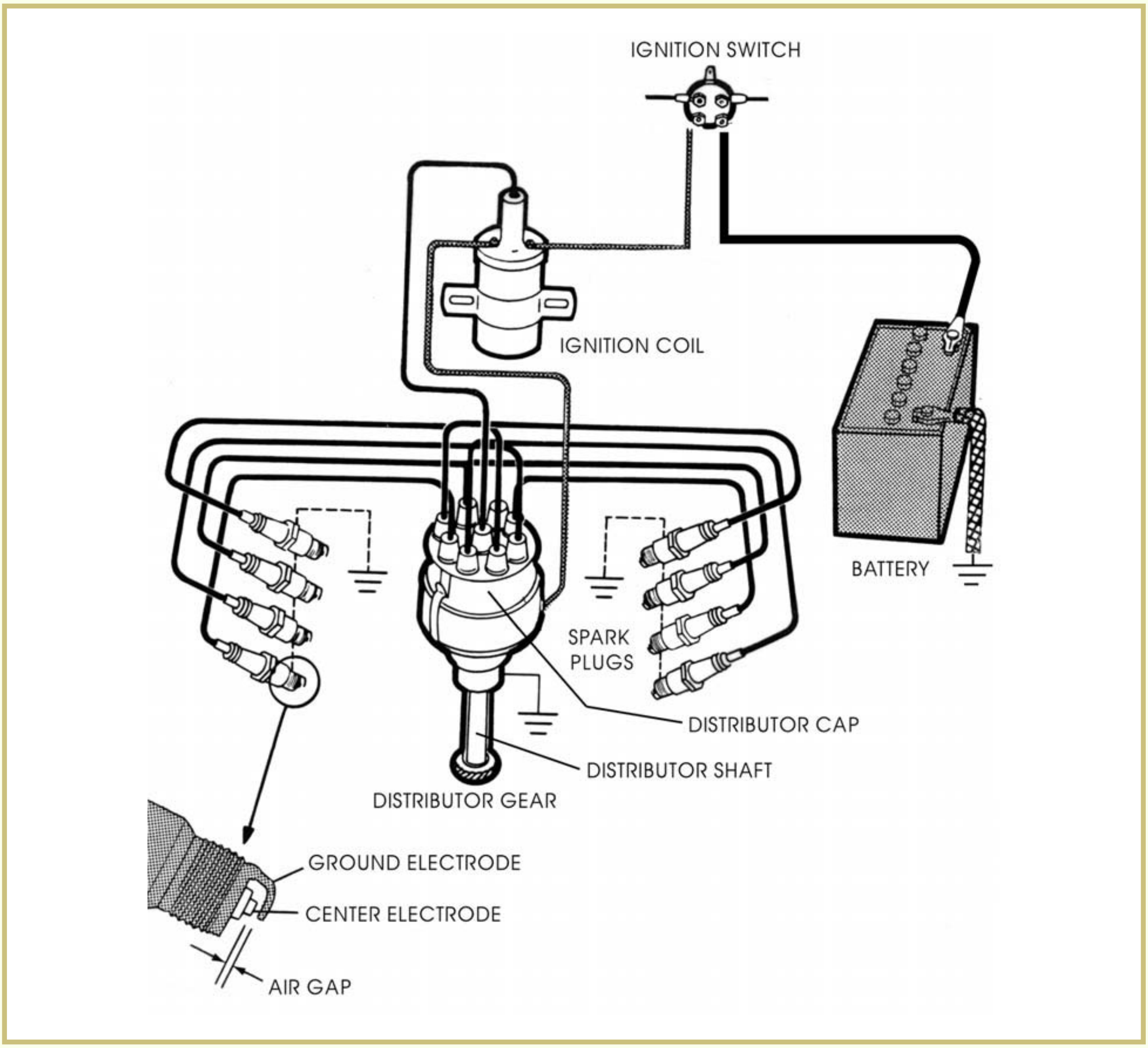



***FIGURE 23—A typical distributor-type ignition system for an eight-cylinder engine is shown here.***

The main parts of the distributor are the housing, gear, shaft, cap, and rotor. In some systems, the ignition coil and the triggering device are both housed inside the distributor.

The distributor itself consists of several different components, as shown in Figure 24. The distributor's outer shell is called the housing. The distributor's top covering is called the distributor cap. The distributor shaft runs through the middle of the distributor. The distributor gear is attached to the end of the distributor shaft. The distributor is usually mounted to an engine with its housing placed in a hole in the engine block or cylinder head.

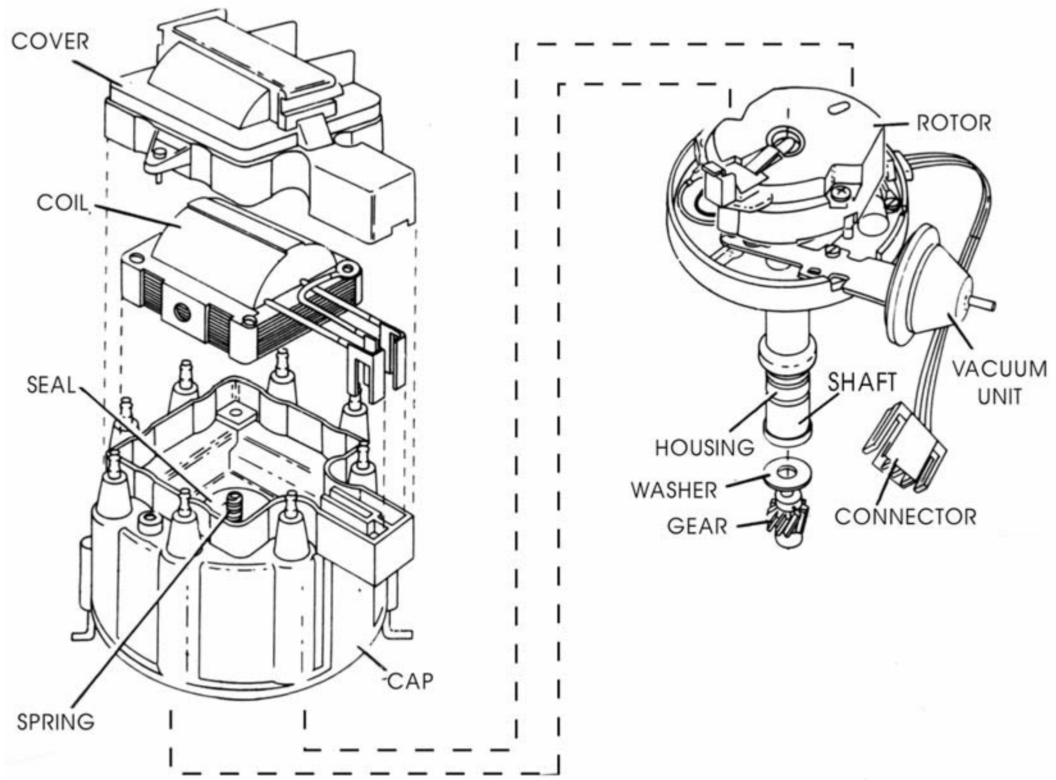



***FIGURE 24—The components of a typical distributor are shown here. Note that the ignition coil is mounted inside this particular distributor.***

When a distributor is installed in an engine, the gear on the end of the distributor shaft is driven by a similar gear that's attached to the engine's camshaft. Therefore, whenever the engine is running, the distributor shaft turns with the camshaft at the same speed. Therefore, one camshaft rotation results in one distributor rotation.

Distributor caps are made from heat-resistant plastic and are heavily insulated (Figure 25A). The distributor cap fits snugly over the top of the distributor housing. In this figure, note that the distributor cap contains several points called *towers*. The towers that are arranged evenly around the outer edge of the distributor cap are called the *spark towers*. The tower in the center of the distributor cap is called the *coil tower*.

Note that a distributor cap contains one spark tower for each of the engine's cylinders. Therefore, the distributor cap in an eight-cylinder engine has eight spark towers, and the cap in a six-cylinder engine has six spark towers. Remember that a complete circle contains 360 degrees. So, if a distributor cap contains four towers, each tower is positioned 90 degrees apart from its neighboring towers on the distributor ($360 \div 4 = 90$). If a distributor contains six towers, the towers are positioned 60 degrees apart ($360 \div 60 = 6$). In a distributor with eight towers, the towers are 45 degrees apart ($360 \div 8 = 45$). The distributor

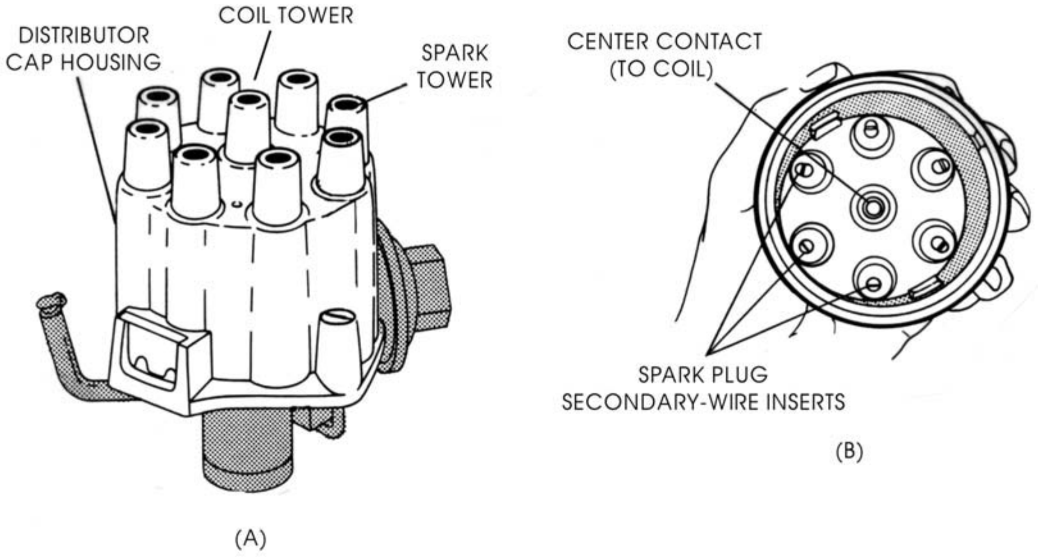



***FIGURE 25—Figure 25A shows an external view of a typical automotive distributor cap. Figure 25B shows the metal contacts on the underside of the cap.***

cap shown in Figure 25A has eight spark towers that are positioned 45 degrees apart.

Figure 25B shows the underside of the distributor cap. Metal inserts are cast into each tower in the cap. These metal inserts extend downward into the cap as shown in the figure. The metal contact in the center of the cap is inserted into the coil tower. This center contact is called the *rotor button*.

Each of the engine's spark plug wires is fastened to the spark towers. The opposite ends of the spark plug wires are then fastened to the spark plugs. Each spark plug wire is attached to a spark tower and a spark plug. Spark plug wires are made in different lengths, depending on how far the wire must travel between the spark tower and the spark plug.

Note that the spark plug wires are attached to the spark towers in the same order as the firing order. For example, Figure 26 shows a typical automotive spark plug wire arrangement for a six-cylinder engine. Remember this is only an example—the actual spark plug wire arrangement and firing order depend on the vehicle design. In this example, the distributor rotor turns clockwise and the firing order of the engine is 1-4-2-5-3-6. The spark plug wires are installed around the edge of the distributor cap in that order.

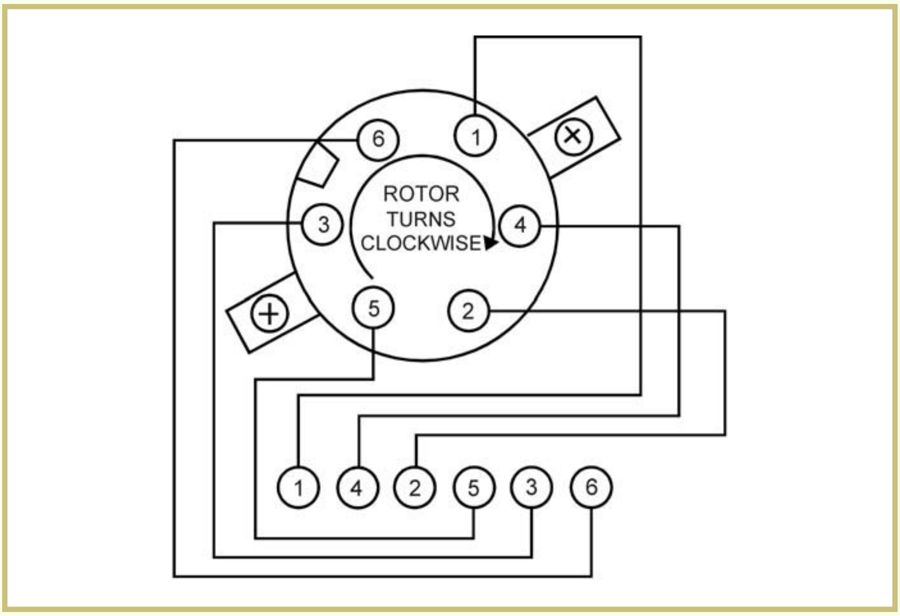



***FIGURE 26—This illustration shows a spark plug wire arrangement for a six-cylinder engine. The spark plug wires are installed around the distributor cap in the direction of rotor rotation. The rotor rotates clockwise, and the firing order of the engine is 1-4-2-5-3-6.***

A separate wire called a *coil wire* leads from the engine's ignition coil to the coil tower on the distributor cap. The coil wire is similar in construction to a spark plug wire, but the coil wire is a different length and the terminals in its ends are shaped differently.

A component called a rotor is attached to the top of the distributor shaft. As the distributor shaft rotates, the rotor also rotates. The rotor's function is to direct the high voltage from the ignition coil to the spark plugs.

Two typical distributor rotors are shown in Figure 27. Rotors are usually constructed of materials that have a very high insulating quality. Note that a conducting metal strip runs from the center of a rotor to its outer tip. This metal strip on the rotor touches the rotor button on the inside of the distributor cap. The metal strip on the rotor doesn't touch the spark tower contacts, however. Instead, a small air gap is between the end of the rotortip and the spark tower contacts inside the distributor cap.

Now, let's discuss the basic operation of the distributor and rotor in more detail. In Figure 28 on page 38 you can see the operation of a distributor-type ignition system for a four-cylinder engine. In the figure, note how the spark plug wires are attached to the four towers on the distributor cap. The firing order of the cylinders in this engine is 1-3-4-2, so the spark plug wires are installed around the edge of the distributor cap in that order. Also note how the coil wire is connected between the ignition coil and the coil tower on the distributor cap.

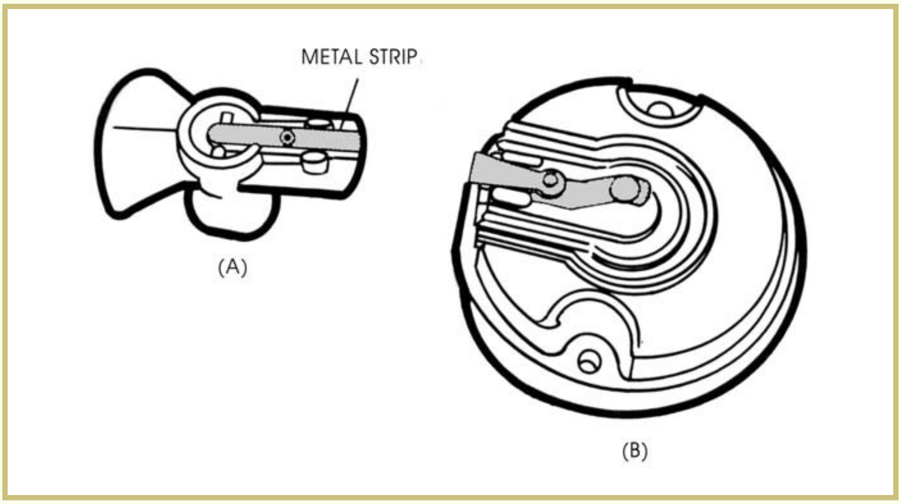



***FIGURE 27—Shown here are two common types of rotors. Rotors are attached to the distributor shaft and transfer the high voltage from the coil to the proper spark plug wire.***

As the engine operates, the engine's camshaft rotates and causes the distributor shaft to rotate inside the distributor cap. When the distributor shaft rotates, the rotor also rotates. At this time, the engine's ignition coil is also operating. Current from the secondary winding of the ignition coil passes through the coil wire to the coil tower in the center of the distributor cap. Current passes down through the coil tower, through the rotor button, and into the contact strip on the rotor. (Note that in some ignition systems, the ignition coil is located inside the distributor. If an ignition coil is located inside a distributor, no separate coil wire is needed. Instead, the ignition coil output travels directly to the rotor.)

As the rotor rotates, it passes under each of the spark towers. Each time the rotor passes under a spark tower, the high voltage jumps across the air gap to the spark plug tower contact. The spark travels through the distributor tower, through the spark plug wire attached to that tower, and then to the engine cylinder on the other end of the spark plug wire. No more than 2,000 or 3,000 volts is required to carry the current across the air gap, so almost all of the voltage produced by the ignition coil reaches the spark plug.

Remember that the firing order of this engine is 1-3-4-2. Therefore, as the rotor rotates, it passes under the spark tower for Cylinder 1 first, and Cylinder 1 receives a spark. The rotor then passes under the spark tower for Cylinder 3, and Cylinder 3 receives a spark. Next, the rotor passes under the spark tower for Cylinder 4, and Cylinder 4 receives a spark. Finally, the rotor passes under the spark tower for Cylinder 2, and Cylinder 2 receives a spark.

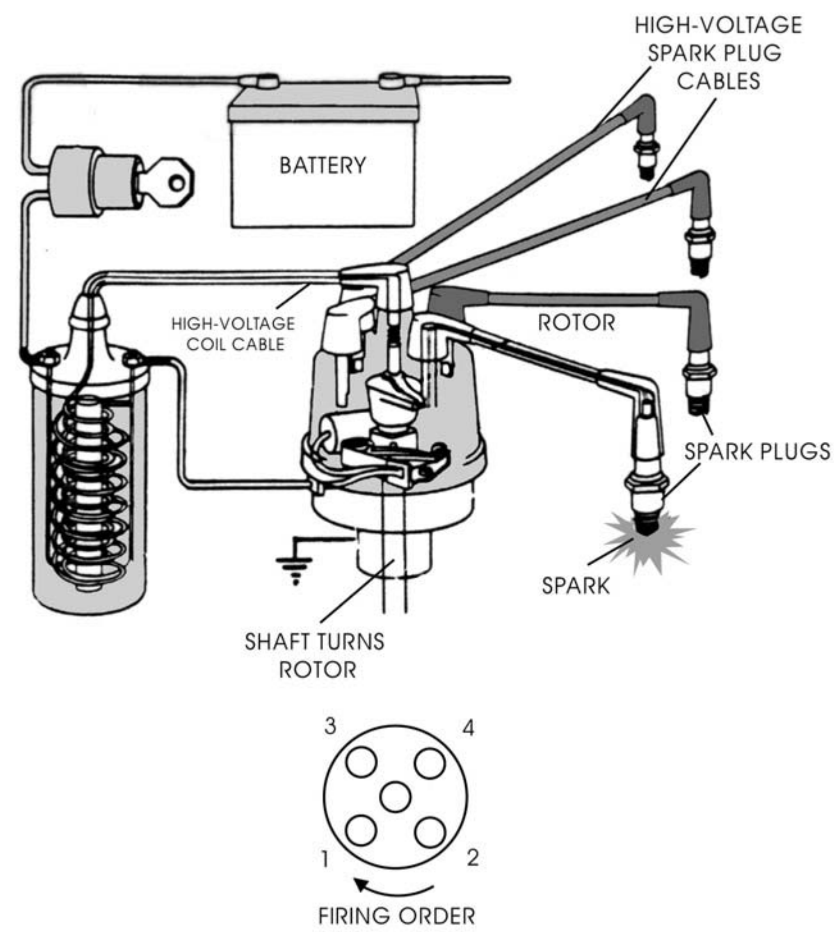



***FIGURE 28—The spark plug wires are installed around the distributor cap in their proper firing order, the direction of rotor rotation.***

The relationship between the movement of the rotor and the position of the spark tower contacts is critical. At the exact time a spark is produced by the ignition coil, the rotor tip must pass under one of the spark tower contacts inside the distributor cap. If the rotor tip isn't properly aligned with the spark tower contact inside the cap, the air space between the rotor tip and the spark tower contact will be too large. If the air gap is too large, more voltage is needed to complete the circuit to the spark plugs. For this reason, it's very important to select the proper replacement rotor recommended by the manufacturer.

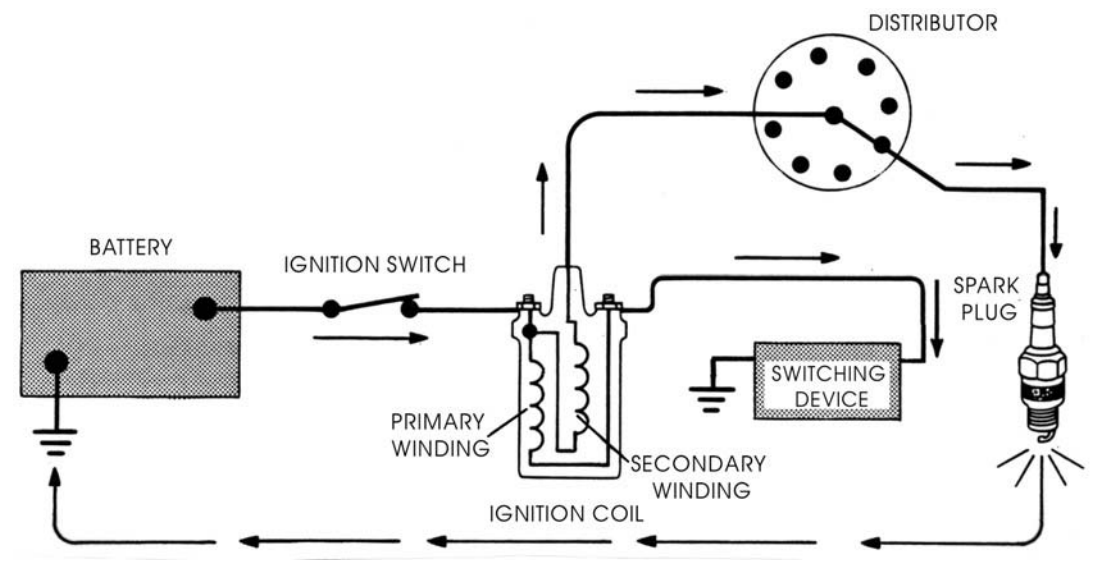



***FIGURE 29—Shown here is a simplified drawing of an automotive ignition system. The arrows indicate the flow of electricity through the system.***

## Review of Ignition System Operation

Now, let's quickly review how all the components in a distributor-type ignition system work together. A simplified view of a distributor-type ignition system is shown in Figure 29.

In this system, the battery provides the voltage needed to energize the primary winding of the ignition coil. The battery voltage is turned on by the ignition switch, which is operated with a key. When the ignition key is turned on, the ignition circuit closes. When the circuit closes, electric current flows from the battery through the triggering device and into the ignition coil's primary winding. The current flow produces a magnetic field around the primary winding.

Next, as the first piston in the firing order approaches TDC in its cylinder, the triggering device opens and cuts off the current flow to the primary winding. When the current in the primary windings stops flowing, the magnetic field around the coil windings collapses. The collapsing magnetic field induces a high-voltage current in the coil's secondary winding.

The high-voltage current from the coil's secondary winding flows to the rotor and the distributor. The rotor and distributor then send the current to the proper spark plug through the spark plug wire. The current that's sent to the spark plug then arcs across the spark plug gap, igniting the air-and-fuel mixture in the cylinder.

After each ignition occurs, the triggering device again turns on the current in the primary winding, and the cycle continues for the next cylinder in the firing order. Once all the cylinders have been fired, the cycle repeats, starting with the first cylinder in the firing order.

When the driver wishes to stop the vehicle, the ignition key is turned off, and the flow of power from the battery to the primary winding is stopped. As a result, the engine stops running.

Now, take a few moments to review what you've learned by completing *Power Check 2.*

# *Power Check 2*

1. The order in which an engine's cylinders fire is called the _______.

2. In most automobiles, the power source for the ignition and accessory circuits is a _______.

3. In a distributor-type ignition system, the _______ directs the high voltage from the ignition coil to the cylinder that's currently on its compression stroke.

4. The high voltage required for electricity to jump the gap of a spark plug is produced in the _______ of the ignition coil.

5. The small air space between the two electrodes in a spark plug is called the _______.

6. In an ignition system, the _______wire leads from the ignition coil to the distributor cap.

7. In a distributor cap, the spark plug wire towers are arranged evenly around the outer edge, and the tower in the center of the cap receives the high voltage from the _______.

8. The most common type of ignition switch has _______ positions.

9. A typical automotive battery has a total output voltage of _______ volts of direct current.

10. A type of transformer that changes low-voltage electricity to high-voltage electricity in an ignition system is called a(n) _______.

11. An ignition coil contains two coils of wire called the _______ winding and the _______ winding.

12. In a distributor-type ignition system, the distributor gear is attached to the end of the _______.

*(Continued)*

# *Power Check 2*

13. A _______ is often placed between the ignition switch and the other ignition system components to prevent them from being damaged by excessive current flow.

14. If the current flow to an ignition coil's primary winding is suddenly turned off, the magnetic field in the _______ winding collapses and induces a very high voltage in the _______ winding of the ignition coil.

15. Spark plug wire terminals are surrounded by insulating _______ made of rubber, silicon, or neoprene.

16. The _______ fits snugly over the top of the distributor housing.

**Questions 17–28: Indicate whether the following statements are True or False.**

_____17. In an ignition system, a triggering device is used to turn the current flow in the secondary winding on and off at the proper time.

_____18. An ignition system that uses contact points is called an electronic ignition system.

_____19. If the spark plug reach is too short, the threaded part of the plug extends down into the combustion chamber and hits the piston each time it rises.

_____20. All modern automobiles use electronic triggering devices in their ignition systems because they can tolerate more current than contact points.

_____21. The secondary winding of an ignition coil is connected to the spark plug wire.

_____22. A spark plug's heat range is a classification that's based on the spark plug's ability to transfer heat.

_____23. The spark plug wires are attached to the distributor cap's terminals in the same order as the firing order.

_____24. The conductor inside the spark plug wire is made of copper or steel.

_____25. In a typical automotive ignition system, each engine cylinder has its own spark plug wire and spark plug.

_____26. The spark plug gap is usually measured in inches.

_____27. If a spark plug gap is too narrow or too wide, the spark produced will be weak.

_____28. In an ignition system, the coil wire is a heavily insulated wire that leads directly to the spark plug.

**Check your answers with those on page 99.**

# TRIGGERING IN CONVENTIONAL IGNITION SYSTEMS

All ignition systems use some type of triggering device to turn the primary-coil winding on and off. In distributor-type ignition systems, the triggering device is usually located in the distributor housing. In the distributor, the triggering device is controlled by the rotating distributor shaft, which is, in turn, driven by the engine's camshaft. This allows the triggering device to be timed in reference to the position of the pistons. Several different types of triggering devices can be used.

## Point-type Triggering Devices

As you learned earlier, the point-type triggering device is no longer used on modern automobiles; however, you may see point-type triggering devices in some vehicles, particularly classic cars that are being restored. Point-type triggering devices were used in the ignition systems of virtually every automobile that was manufactured between the 1920s and the mid-1970s. We'll discuss point-type triggering devices in detail in this section because they're an excellent, easy-to-understand example of how automotive ignition systems work. As you learned earlier, an ignition system that contains a point-type triggering device is often called a conventional ignition system.

The components of a conventional ignition system with a point-type triggering device are shown in Figure 30. In this system, the primary-winding triggering device is a set of contact points mounted inside the distributor. The contact points are opened and closed by a rotating cam that's mounted on the distributor shaft. The distributor shaft is driven by the camshaft. When the contact points rest on the low point of the rotating cam lobe, the points are closed. When the points are closed, current flows through the ignition coil, creating a magnetic field (Figure 30A).

As the cam continues to rotate, the high point of the cam lobe causes the points to move apart, stopping the flow of current in the primary winding (Figure 30B). This causes the coil's magnetic field to collapse, which produces current in the secondary windings and causes a spark in the spark plug.

The distributor cam is driven by the engine, usually by a gear on the camshaft. The number of lobes on the distributor cam is the same as the number of cylinders in the engine. The distributor is mounted in the engine so that when the points open and the spark plug is fired, one of the pistons is near the top of its compression stroke. The rotor in the distributor then directs the high voltage to the proper cylinder.

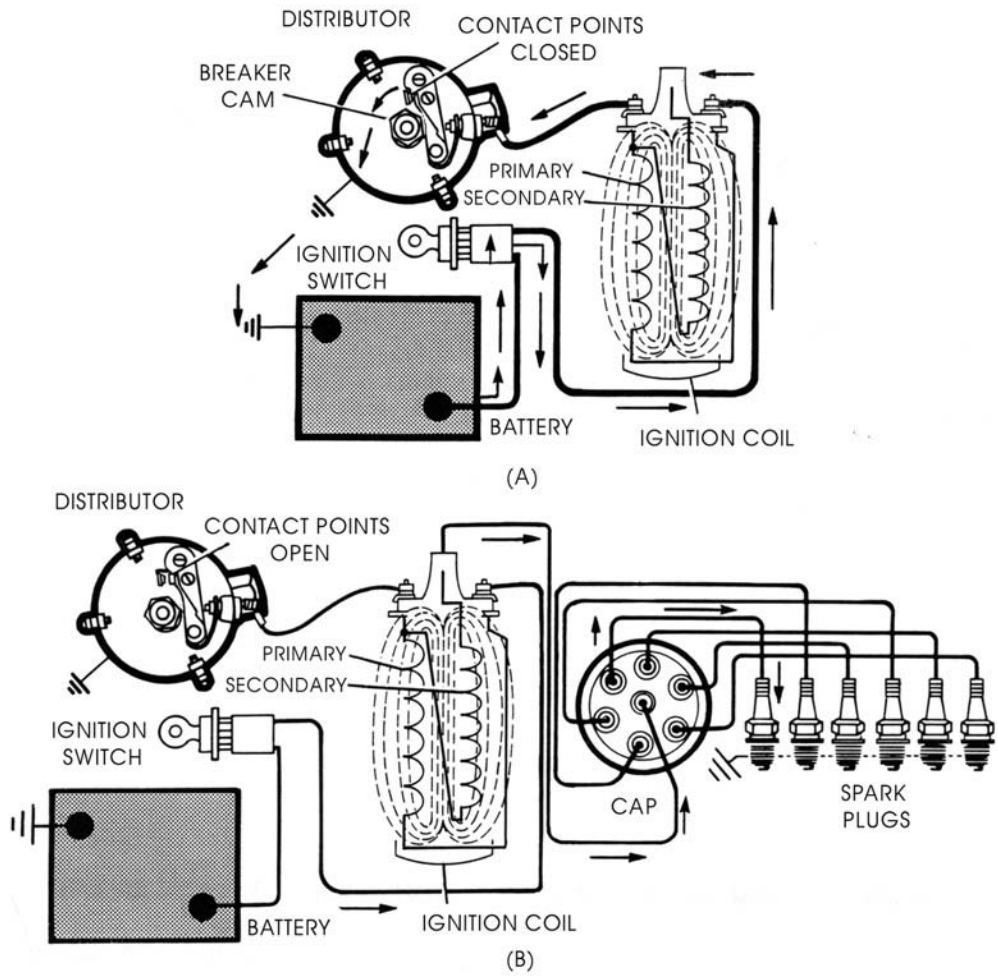



***FIGURE 30—The flow of current through a point-type ignition system is shown here. In Figure 30A, the points are closed and current flows through the primary winding of the ignition coil. In Figure 30B, the points open and stop the flow of current in the primary winding. When the current flow in the primary stops, the coil's magnetic field collapses. This produces current in the secondary windings and causes a spark at the spark plug.***

## The Contact Points

Figure 31 shows a close-up of a typical point-type triggering device. Note the position of the contact points in the figure. Contact points usually carry between 3 and 4 amperes of current, and must open and close as many as 10,000 times per minute at average speeds. To handle such a difficult job, the contact points must be manufactured from high-quality materials. Most contact points are made from high-grade steel coated with tungsten, a heat-resistant metal used to make light bulb filaments.

A *rubbing block* made of a dense, fibrous material rides on the distributor cam. This rubbing block must be lubricated to prevent excessive

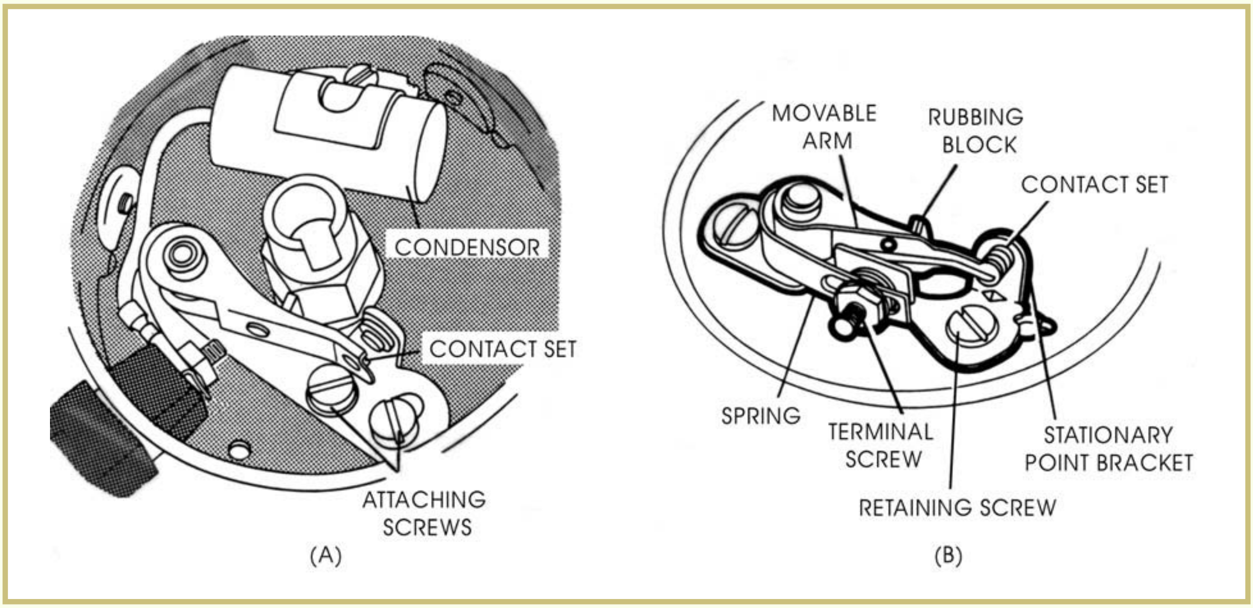



***FIGURE 31—Figure 31A shows a typical contact point set for a conventional ignition system. Figure 31B shows a close-up of the points.***

wear. The rubbing block is attached to the contact point and is used to open the points.

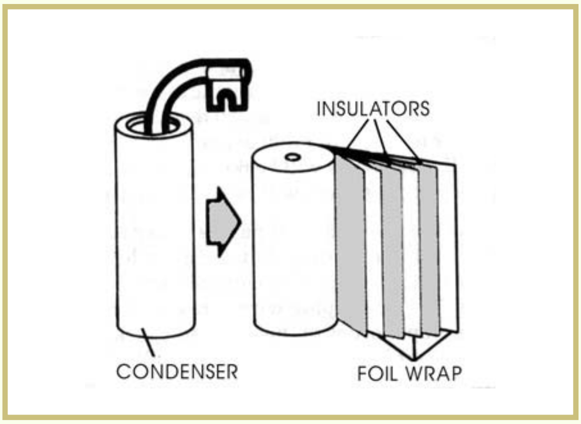
The points are held closed by spring tension that's built into the point assembly. The spring tension must be strong enough to prevent the points from bouncing or *floating*. Floating is a tendency to remain open when an engine is running at high speeds. However, if the spring tension is too strong, it causes excessive wear at the rubbing block and distributor cam.

In any point-type triggering device, the amount of current that the contact points can carry is limited. Therefore, the coil output is limited to about 25,000 volts in conventional ignition systems. This voltage was adequate in older vehicles, but a newer car with an emission control device needs a stronger spark to fire the leaner air-and-fuel mixture in its cylinders. This is the reason why contact point ignition systems were replaced by electronic ignition systems. You'll learn about electronic ignition systems later in this study unit.

## The Condenser

When the coil's magnetic field collapses, current is produced in the primary winding as well as in the secondary winding. Since all of the primary current must pass through the contact points, a device is needed to prevent the current from arcing across the points when they're opened. This device is called a *condenser*. A condenser can absorb and store current, helping the ignition system work more efficiently.

*FIGURE 32—A condenser consists of many layers of metal foil separated by insulation.*




An external view of a condenser can be seen in the point-type triggering device shown in Figure 32. A condenser consists of many layers of metal foil that are separated by insulation. One set of foil wraps is grounded, and the other set is attached to the points. The condenser is usually connected in parallel with the points. The closeness of the foil wrappings attracts electrons that would usually jump across the point gap. When the points open, the condenser absorbs any current that's induced into the coil's primary windings (Figure 33). When the points close, the current is discharged from the condenser.

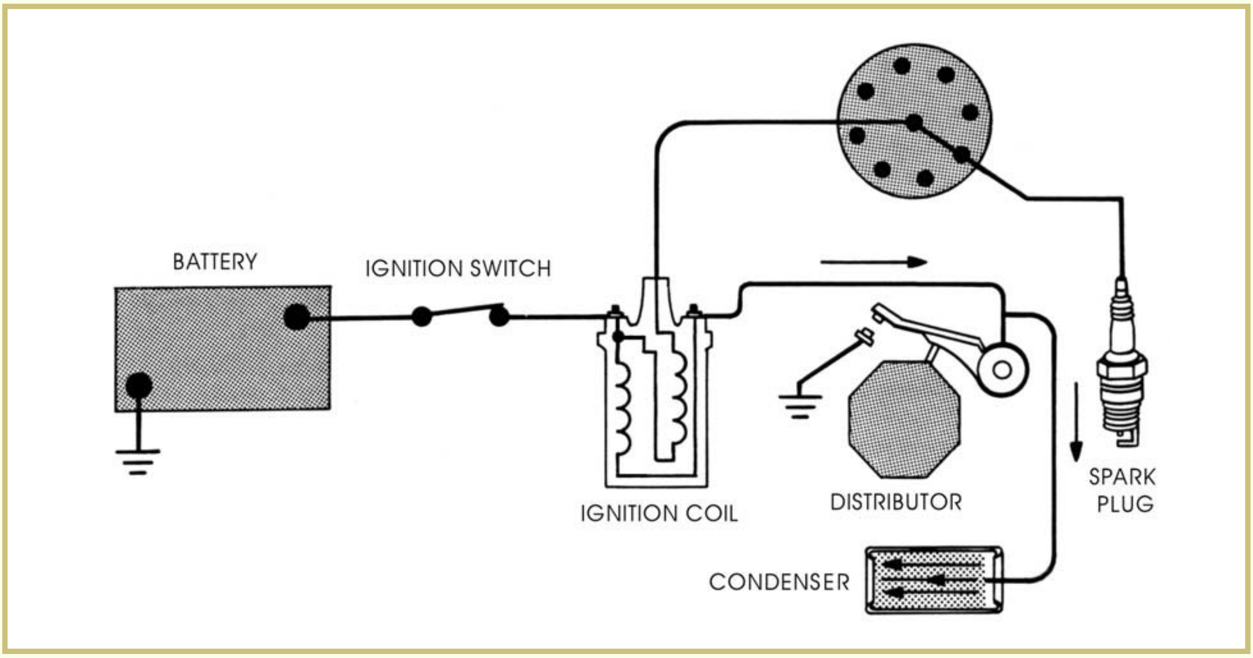



*FIGURE 33—When the points open, the condenser absorbs any current that's induced into the coil's primary windings.*

The number of electrons that the condenser can attract is a measure of its capacity. Condenser capacity must be closely matched to the needs of the primary ignition system. A condenser with too much capacity wears out the contact points as quickly as a condenser with too little capacity.

## Primary-current Resistor

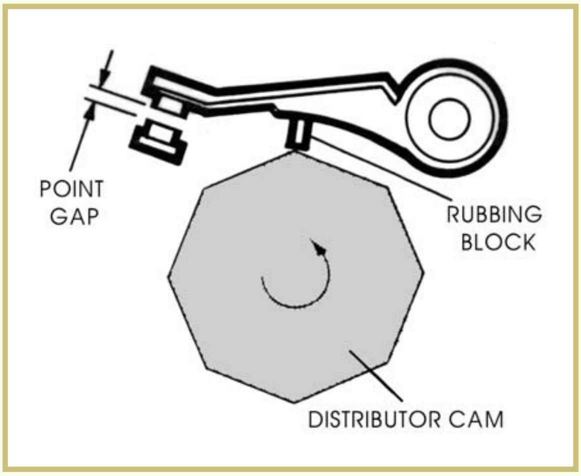
In a point-type ignition system, the primary current travels from the battery to the coil and distributor by way of the ignition switch and a *resistor*. The resistor reduces the current flow to protect the coil and the contact points from overheating. The resistor may be a separate component, commonly called a *ballast resistor*, or it may be a resistance wire that's built into the wiring harness.

When an engine is cranked, the battery voltage is lower than normal, and current flow through the resistor to the coil is considerably reduced. At this time, there may not be enough current to produce a spark strong enough to start the vehicle. Therefore, the resistor is bypassed to provide full battery current to the coil. The bypass circuit is usually built into the starter, although some bypass circuits are incorporated into the ignition switch.

## The Point Gap

The distance between the contact points when they're open is called the *point gap* (Figure 34). You now know that the distance between the points must be correct in order for the engine to operate properly. When an engine is started, the point gap must be wide enough to prevent current from arcing across the points, or the automobile won't start easily. However, if the point gap is too small, the points will deteriorate rapidly when the engine is operating at low speed. If the points open slowly and don't open wide enough, an arc may continue across the contact points, using energy that would usually produce a spark at one of the spark plugs. When an arc does occur at the contact points due to a small point gap, the spark plug usually won't fire at that time.

**FIGURE 34—The distance between the contact points when they're open is called the point gap.**



The proper gap can be set by using a feeler gage. With the rubbing block on the high point of the distributor cam, the feeler gage can be used to measure the point gap. The proper adjustment allows the points to open and close at the proper time.

## The Dwell

An ignition system's *dwell* is the number of degrees that the distributor cam rotates during the time that the contact points are closed. When the rubbing block reaches the lobe or corner of the distributor cam, the points open and the dwell period ends. After the rubbing block passes a cam lobe, the block returns to the flat side of the cam, and the next dwell period begins. The dwell setting is very important to the proper operation of an ignition system.

There are 360 degrees in a circle, so the maximum dwell for any engine is 360 degrees divided by the number of engine cylinders. One complete rotation of the distributor cam equals 360 degrees. An 8-cylinder engine has 8 cam lobes, so 45 degrees of rotation is between each cam lobe ($360 \div 8 = 45$). A 6-cylinder engine has 60 degrees between each cam lobe ($360 \div 6 = 60$). A 4-cylinder engine has 90 degrees between each cam lobe ($360 \div 4 = 90$).

Therefore, the maximum possible dwell setting in an 8-cylinder engine would be 45 degrees. If the dwell was set higher than 45 degrees, the contact points would remain closed for the entire time as the distributor rotates from cam lobe to cam lobe. In this situation, the primary current flowing through the coil would never be interrupted, so no spark would ever be produced.

In contrast, if the dwell was set at 0 degrees, the points would remain open constantly and would never close. In this situation, no magnetic field would build up in the coil, so no spark would occur.

In a contact point system, the dwell and the point gap are related—if you increase one, you decrease the other. For example, if the point gap is too wide, the dwell will be too short. If the point gap is too small, the dwell will be too long.

The preferred way to adjust contact points is by setting the dwell. Setting the dwell is easier and more accurate than setting the point gap. However, setting the dwell requires a specialized instrument called a *dwell tester.* A dwell tester measures the amount of time that a set of contact points is closed, and displays the time in degrees of distributor cam rotation. The use of a dwell tester will be discussed later in this study unit.

Now, take a few moments to review what you've learned by completing *Power Check 3*.

# Power Check 3

1. The tendency of contact points to remain open when an engine is running at high speeds is called _______.

2. The measured distance between the contact points when they're open is called the _______.

3. A special instrument called a _______ is needed to set the dwell in a conventional ignition system.

4. The _______ prevents current from arcing across the contact points when they're opened.

5. An ignition system that contains a point-type triggering device is often called a _______ ignition system.

**Questions 6–10: Indicate whether the following statements are True or False.**

_____ 6. In a conventional ignition system, when the contact points close, current is discharged from the condenser.

_____ 7. In a conventional ignition system, if the point gap is too large, the points will deteriorate rapidly.

_____ 8. In a contact point system, the points are held closed by spring tension.

_____ 9. The preferred way to adjust contact points is to set the point gap rather than the dwell.

_____10. In a contact point system, if the point gap is too small, the dwell will be too long.

**Check your answers with those on page 100.**

# TRIGGERING IN ELECTRONIC IGNITION SYSTEMS

As you just learned, a conventional ignition system uses a set of contact points to turn the ignition coil's primary winding on and off. All of the voltage that flows through the coil must pass through the contact points when they're closed. Because a set of contact points can accept only a certain amount of voltage without burning up, the amount of voltage that can flow through the ignition coil is limited—only about 25,000 volts.

However, because an electronic ignition system's components can tolerate higher voltages than contact points, electronic ignition systems can produce much more secondary voltage than conventional ignition systems. In addition, an electronic ignition system can handle much more current because a transistor is used to turn the primary circuit on and off. As you learned, transistors are electronic devices that can tolerate very high voltages.

In most electronic ignition systems, the electronic triggering device doesn't control the coil voltage directly. Instead, the triggering device uses a separate component called an *ignition module* to turn the coil on and off. The triggering device sends signals to the ignition module, telling it when to turn the primary-winding voltage on and off. An ignition module can tolerate much higher voltages than contact points, so a higher voltage can be used in the coil's primary winding. This high voltage produces a very strong spark. Typically, electronic ignition systems can produce spark plug voltages of between 60,000 and 90,000 volts. These strong sparks ignite the fuel in the cylinders quickly and efficiently.

An ignition module may be mounted inside the distributor next to the triggering device (Figure 35B), or it may be mounted somewhere outside the distributor (Figure 35A). In either location, the ignition module performs the same functions.

Now that you have a general idea of how electronic ignition systems operate, let's examine some common electronic triggering devices. The operation of electronic triggering devices is very similar to the operation of the point-type devices you learned about earlier, except that electronic triggering devices use electronic components instead of contact points. The distributor looks much the same in both types of systems, but the triggering device inside the distributor is different.

The type of triggering device used in a particular engine depends on the vehicle's make and model. The vehicle's service manual should indicate the type of triggering device that the vehicle uses. Most engines use one of the following electronic triggering devices:

- Magnetic pickup triggering device

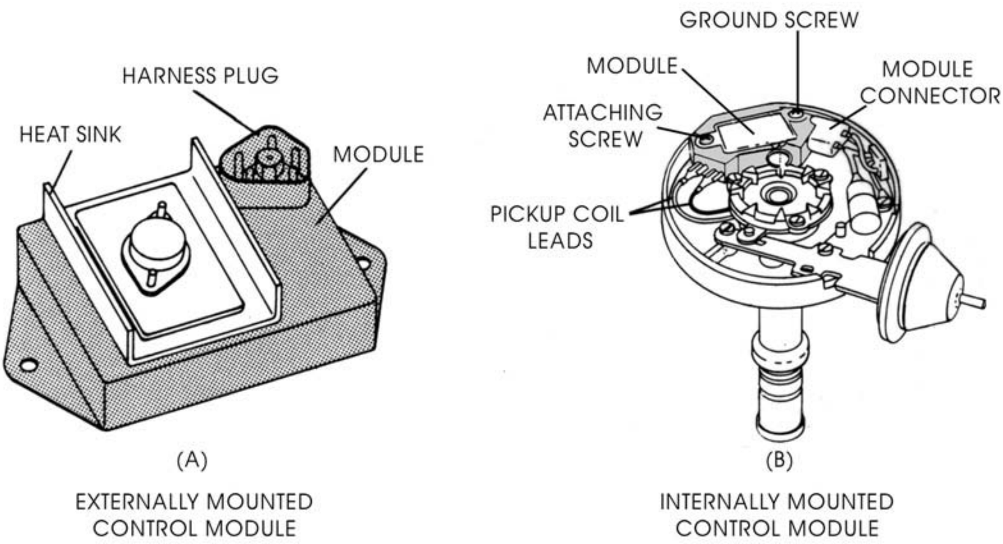



***FIGURE 35—The ignition module can be mounted somewhere outside the distributor, as shown in Figure 35A, or it may be mounted inside the distributor next to the triggering device, as shown in Figure 35B.***

- Hall-effect triggering device
- Optical triggering device

## Magnetic-pickup Triggering Devices

In a magnetic-pickup triggering device, a small coil called a *magnetic pickup coil* is mounted in the distributor (Figure 36A). This coil is mounted in the same place that the contact points were mounted in the conventional distributor. In the electronic ignition distributor, a *trigger wheel* is mounted on the distributor shaft instead of a cam (Figure 36B).

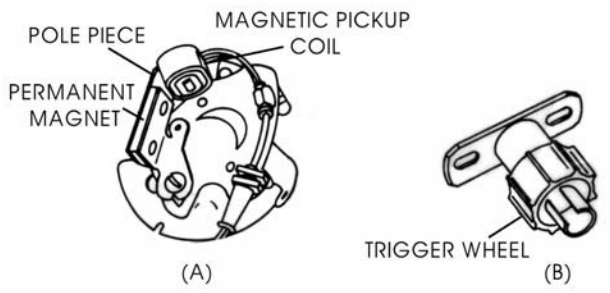



***FIGURE 36—Most electronic ignition systems use a pickup coil as shown in Figure 36A. A trigger wheel like the one shown in Figure 36B signals the ignition module when the primary current should be interrupted.***

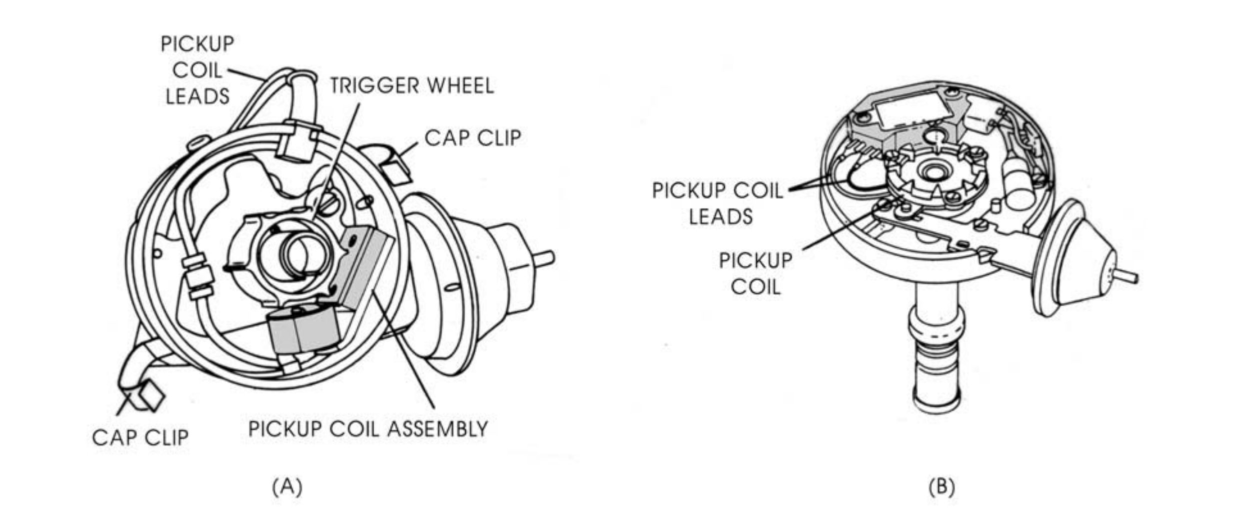



***FIGURE 37—In the electronic ignition distributor shown in Figure 37A, the trigger wheel is driven by the engine, while the pickup coil remains stationary. In the ignition distributor shown in Figure 37B, the pickup coil completely surrounds the trigger wheel.***

(A trigger wheel may also be called a *reluctor* or an *armature*, depending on the engine manufacturer.) The trigger wheel has metal teeth around its outer edge—one tooth for each cylinder. The pickup coil remains stationary, and the trigger wheel rotates on the distributor shaft. Two typical pickup coil distributors are shown in Figure 37.

When the ignition switch is on, current from the battery reaches the magnetic pickup coil, and as the distributor shaft turns the trigger wheel, a magnetic field is induced at the pickup coil. In addition, a magnetic field develops between the pickup coil and the trigger wheel (Figure 38A). The strength of the magnetic field is influenced by the trigger wheel as it revolves. In Figure 38A, note that none of the teeth on the trigger wheel are aligned with the pickup coil. Because of the wide air gap between the pickup coil and the trigger wheel at this moment, the magnetic field is quite weak.

In Figure 38B, a trigger wheel tooth approaches the pickup coil. (Note that the trigger wheel tooth doesn't come into direct contact with the pickup coil—it merely passes close by.) The air gap between the trigger wheel tooth and the pickup coil is now quite small, and the strength of the magnetic field in the pickup unit increases. The increased magnetic field induces a voltage in the pickup coil. This voltage signal is sent to the ignition module.

In Figure 38C, the trigger wheel tooth passes by the pickup coil, and the air gap widens again. This causes a decrease in the strength of the magnetic field, which reduces the voltage in the pickup coil. The change in the voltage signal that's produced by the pickup coil is detected by the ignition module.

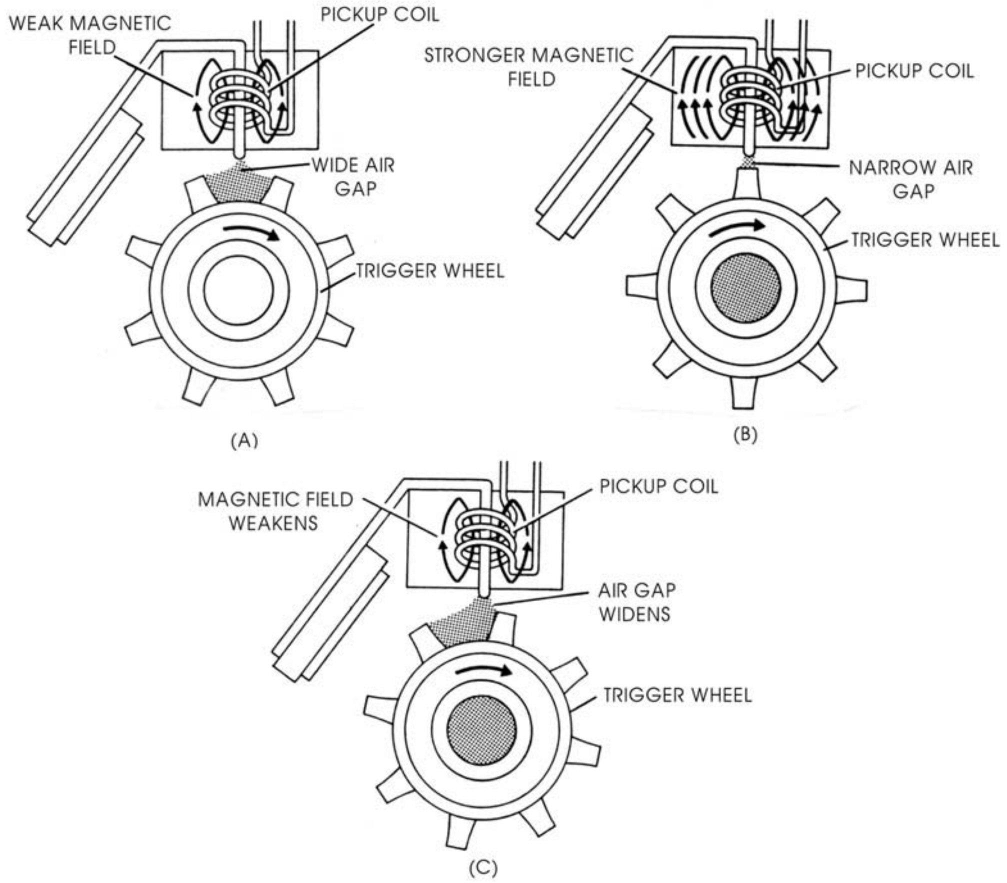



***FIGURE 38—When the trigger wheel teeth aren't in alignment with the pickup coil, the magnetic field between the trigger wheel and the pickup coil is weak (Figure 38A). As a trigger wheel tooth approaches the pickup coil, the magnetic field becomes stronger. The stronger field induces a voltage in the pickup unit (Figure 38B). As the trigger wheel tooth moves away from the pickup coil, the magnetic field weakens (Figure 38C).***

As long as the ignition module receives a voltage signal from the pickup coil, the module directs current to the primary winding of the ignition coil. However, when the voltage signal from the pickup coil decreases, the ignition module interrupts the flow of current in the primary winding. The magnetic field in the ignition coil collapses, and a spark is produced. Therefore, in this electronic ignition system, the pickup coil times the occurrence of the spark, and the ignition module controls the actual spark.

Remember that the dwell is the period of time when current flows through the coil's primary winding. In an electronic ignition system, the dwell is regulated within the ignition module by electronic devices and isn't adjustable, so periodic maintenance isn't needed.

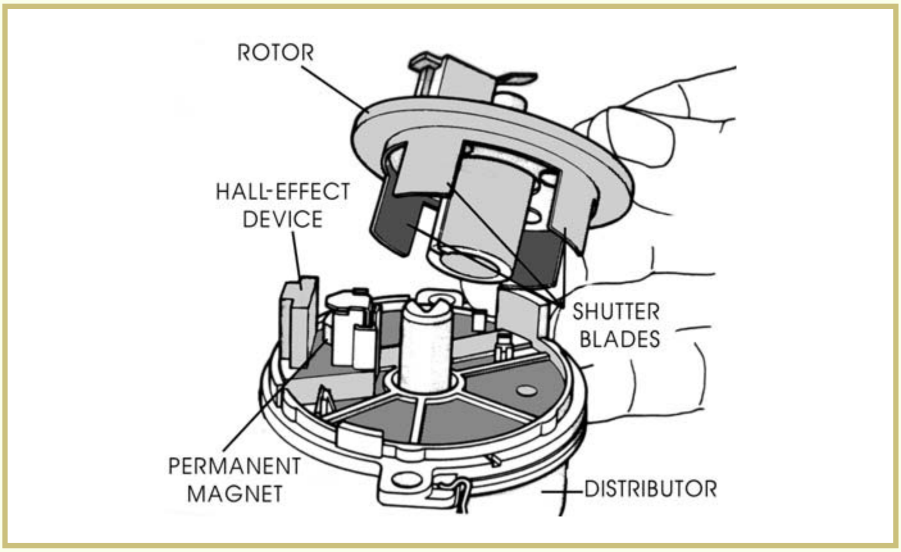



***FIGURE 39—A typical Hall-effect triggering device is shown here.***

## Hall-effect Triggering Devices

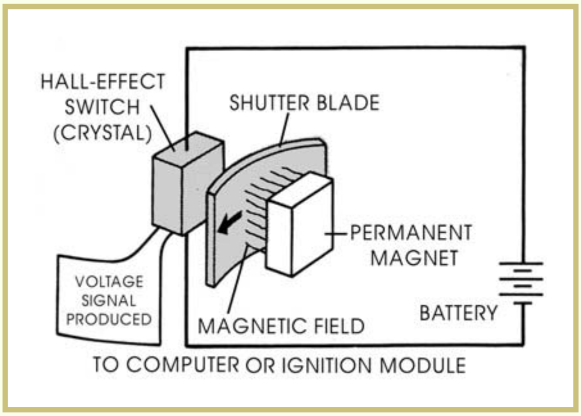
Another type of triggering device that's often used in modern automobiles is the *Hall-effect triggering device,* sometimes referred to as a *Hall-effect switch.* A Hall-effect triggering device is usually mounted inside the distributor. The device consists of a permanent magnet, a Hall-effect switch, and several thin metal plates called *shutter blades*. A typical Hall-effect triggering device is shown in Figure 39.

In a distributor, the Hall-effect device is usually placed directly next to the permanent magnet, with only a small air space in between. The permanent magnet is simply a small piece of metal that holds a magnetic charge. Permanent magnets are very similar to common household magnets used to hold notes on a refrigerator.

Since the Hall-effect switch is placed next to a permanent magnet, the Hall-effect switch has a magnetic field around it. As long as a magnetic field is present around the device, no electrical signal is produced. However, when there isn't a magnetic field around the switch, the Hall-effect switch sends a signal to the ignition module.

In a Hall-effect triggering device, shutter blades are attached to a round disk that rotates with the distributor shaft. This disk may be a separate item, or the blades may be attached to the distributor rotor. In either case, the operation of the device is the same. The shutter blades rotate with the distributor shaft as the engine operates. Each time a shutter blade passes between the permanent magnet and the Hall-effect switch, the shutter blade prevents the magnetic field from reaching the Hall-effect switch (Figure 40). As a result, the Hall-effect triggering device sends a signal to the ignition module.

**FIGURE 40—As the shutter blade passes between the permanent magnet and the Hall-effect switch, it prevents the magnetic field from reaching the Hall-effect switch. This causes the Hall-effect switch to produce a voltage signal that's sent to the ignition module.**




The signal tells the ignition module that a cylinder is ready to receive a spark. A typical Hall-effect triggering device has one shutter blade for each cylinder.

## Optical Triggering Devices

So far, you've learned about two electronic triggering devices that use the forces of electromagnetism to signal the ignition module as to the position of the cylinders. Each time a cylinder is ready to fire, the triggering device signals the ignition module to turn off the voltage in the primary winding of the ignition coil. The distributor rotor and cap then direct the high voltage to the proper spark plug.

An *optical* or *LED triggering device* performs the same function as a magnetic pickup coil or a Hall-effect switch. However, an optical triggering device uses a light source and a thin, flat metal plate for triggering. Holes in the metal plate represent the TDC point of each cylinder. A typical optical triggering device is shown in Figure 41.

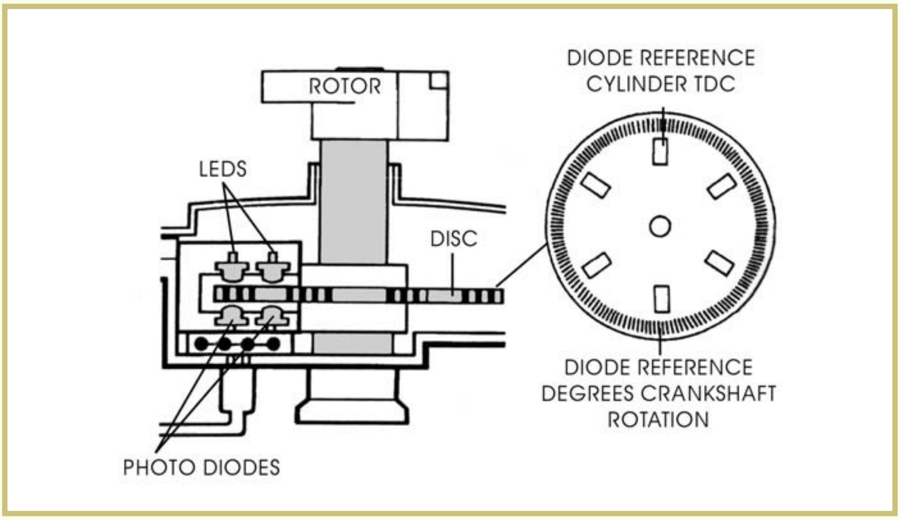



**FIGURE 41—A typical optical triggering device is shown here.**

In an optical triggering device, light shines on the metal plate. The light is produced by special electronic components called *light-emitting diodes (LEDs)*. On the other side of the plate, electronic light sensors called *photoelectric cells* or *photo diodes* are used to detect the light from the LEDs.

In operation, the metal plate is attached to the distributor shaft, so the plate rotates when the engine is running. When the light from the LED shines against the surface of the plate, no light reaches the photo diode on the other side of the plate. However, whenever one of the holes in the plate passes over the LED, the light passes through the hole and reaches the photo diode on the other side of the plate. When the light reaches the photo diode, the photo diode sends a signal to the ignition module to fire a particular spark plug.

Thus, each time one of the holes in the plate passes over the LED, the photo diode sends a signal to the ignition module. In this way, the ignition module and/or computer can determine the exact crankshaft position and then fire the spark plug for the proper cylinder.

In many optical triggering devices, a second LED and photo diode and a second series of holes on the plate are used to indicate the position of the crankshaft. For example, in the optical triggering device shown in Figure 42, each hole in the outer edge of the metal plate represents one degree of crankshaft rotation. The larger, inner slits in the plate represent the TDC points of each cylinder. The second LED and photoelectric cell monitor the positions of the holes in the outer edge of the plate. The additional information provided by the second LED and photoelectric cell helps the computer system determine the ignition timing. Therefore, if a computer determines that a cylinder should be fired a few degrees of crankshaft rotation before it reaches TDC, the computer can simply monitor the information from the second LED and photoelectric cell so it knows exactly when to fire the spark plug.

Some LED systems are also used to operate a vehicle's fuel system. To operate the fuel system properly, the computer must be able to tell which holes on the plate represent which cylinders. Therefore, in some systems, the plate used to indicate the crankshaft position contains a small space without holes. This space indicates the TDC point for Cylinder 1. When the area without holes passes over the LED, the computer recognizes that this area indicates the current position of Cylinder 1. The computer can then use the engine's firing order to identify the rest of the holes in the plate.

Now, take a few moments to review what you've learned by completing *Power Check 4*.

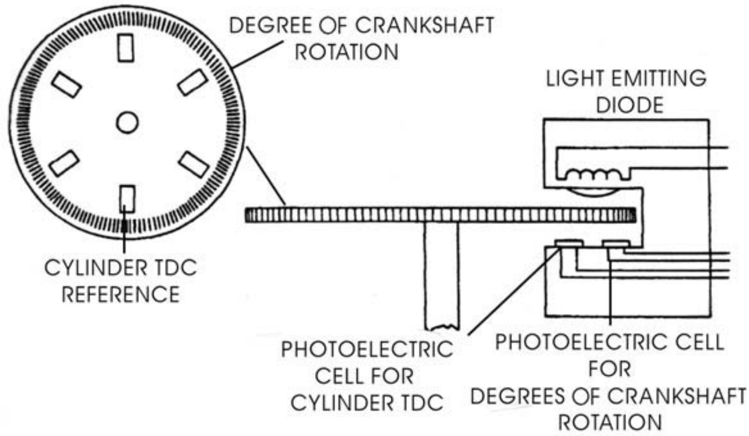



***FIGURE 42—In this optical system, each hole in the outer edge of the plate represents one degree of crankshaft rotation. The larger, inner holes represent the TDC points of the cylinders. One LED and photoelectric cell monitor the inner holes, and a second LED and photoelectric cell monitor the outer holes.***

# *Power Check 4*

1. When a magnetic-pickup triggering device is used in an ignition system, the magnetic pickup coil is mounted in the _______.

2. In a typical electronic ignition system, the _______ turns the primary circuit on and off.

3. In a Hall-effect triggering device, _______ are attached to a round disk that rotates within the distributor shaft.

4. *True or False?* Contact points can handle higher voltages than electronic components, so conventional ignition systems can produce much more secondary voltage than electronic ignition systems.

5. *True or False?* In newer electronic ignition systems, ignition modules control the spark timing as well as the ignition coil triggering.

**Check your answers with those on page 100.**

# IGNITION TIMING IN DISTRIBUTOR-TYPE IGNITION SYSTEMS

The ignition system must be closely timed to match the operation of the engine, or the engine won't run properly. In fact, if the ignition system timing is very far off, the engine won't operate at all.

The ignition is timed in reference to the position of the engine's crankshaft. In order for the air-and-fuel mixture to burn properly, the spark must occur when the greatest amount of power is produced by combustion. For this reason, an engine's ignition system is usually timed to produce a spark when each piston is near TDC at the end of its compression stroke.

Ignition timing is expressed in degrees of crankshaft rotation. Therefore, if an engine has an ignition timing of eight degrees before TDC, the spark occurs when the crankshaft is positioned at eight degrees of rotation before a cylinder's TDC point. Changing the ignition timing so that the spark plug fires earlier is called *advancing* the ignition timing. Changing the ignition timing so that the spark occurs later is called *retarding* the ignition timing.

In distributor-type ignition systems, settings for ignition timing are usually made at the distributor. Distributor timing is divided into two main processes:

- Initial timing
- Precision timing

## Initial Timing

The initial or "rough" timing is completed whenever the distributor has been removed from the vehicle and is being reinstalled. The main purpose of setting the initial timing is to get the ignition timing close enough to specifications so the engine can start. Once the engine can be started, precision timing can be set.

Initial timing is completed by setting the distributor cap, rotor, and spark plug wires to transfer the spark at the proper time. This involves installing these components so that the spark plug in a cylinder fires when the piston is at the top of its compression stroke.

For example, if the firing order of an eight-cylinder engine is 1-8-4-3-6-5-7-2, the rotor should be lined up with Tower 1 when Piston 1 is at the top of its compression stroke. Then, each wire, starting with the Cylinder 1, should be installed in the correct firing order around the distributor cap in the direction of rotor rotation.

## Precision Timing

The spark must occur at exactly the right time for proper combustion, which is usually at or near TDC. Before you can make precision adjustments to ignition timing, the distributor clamp must be loosened. Then, the position of the distributor housing is shifted relative to the rotating shaft until the proper timing is set (Figure 43). Finally, the distributor clamp is retightened. The distributor shaft may rotate either clockwise or counterclockwise, depending on the engine design. If the distributor housing is rotated in the same direction in which the shaft rotates, the spark timing will be retarded. If the distributor housing is rotated in the opposite direction from which the shaft rotates, the spark timing will be advanced. This timing adjustment is usually set at the factory, or by a technician when performing a tune-up.

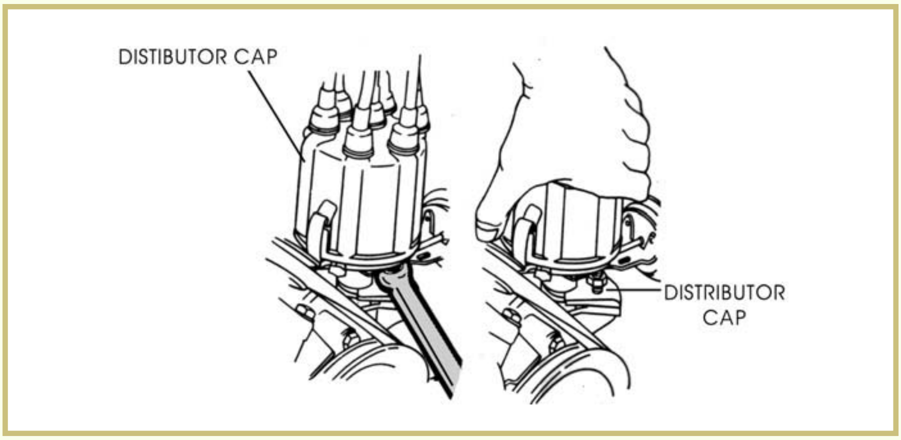



***FIGURE 43—Ignition timing is adjusted by loosening the distributor clamp, rotating the distributor until the proper timing is set, and then retightening the distributor clamp.***

*Note:* Once the precision timing is set, the distributor clamp is tightened to hold the housing in place.

If the distributor is removed from the engine, both the shaft and housing must be reinstalled in exactly the same position to maintain the original ignition timing. Spark plug wires must also be reconnected in the same order in which they were removed.

## Spark-advance Mechanisms

Theoretically, the ignition of the air-and-fuel mixture should occur when the piston reaches the top of the cylinder—TDC—at the end of its compression stroke. However, several factors can cause variations in the time at which a spark plug fires and the time at which a piston reaches TDC. These factors include the following:

- The engine’s compression ratio

- The load
- The number of revolutions per minute (rpms)
- The engine temperature
- The valve timing
- The composition—ratio—of the air-and-fuel mixture
- The fuel's ability to vaporize quickly
- The octane rating of the fuel

Engine design characteristics such as the cylinder bore, the combustion chamber contour, and the spark plug location also affect spark timing. Many of these factors can be controlled through proper servicing procedures and correct driving techniques. However, engine speed and load change every time the position of the accelerator pedal changes. The distributor compensates for these changes by varying the ignition timing. This produces the greatest expansion force from combustion, which provides the best engine performance and fuel economy.

In order to achieve the best engine performance, the spark timing must vary according to the current position of the piston in the cylinder. When an engine is idling, the spark is timed to occur a few degrees before TDC, just before the piston completes the compression stroke. At higher engine speeds, the period in which the air-and-fuel mixture can ignite, burn, and apply force to the piston is much shorter. Thus, at high engine speeds, the spark must jump the spark plug gap *earlier* in the compression stroke. An earlier spark gives the air-and-fuel mixture more time to burn and release power to the piston as the piston starts moving down in the power stroke.

For example, suppose that a particular air-and-fuel mixture takes 0.003 of a second to burn. To give the mixture time to burn, and thus obtain full power from combustion, the maximum cylinder pressure on the power stroke must be reached between 10 and 20 degrees of crankshaft rotation past TDC. When this engine is operating at a speed of 1,000 rpms, the crankshaft travels through 18 degrees of rotation in 0.003 of a second. At 2,000 rpms, however, the crankshaft would travel twice as fast, or 36 degrees of rotation in 0.003 second (Figure 44).

Of course, these times vary with different engines. However, this example illustrates the need to advance ignition timing in order to maintain power as the engine speed increases. As you can see, the piston moves faster as the engine gains speed. Unless the ignition timing is advanced along with the increase in piston speed, the forces of combustion are applied to the piston too late in the engine cycle.

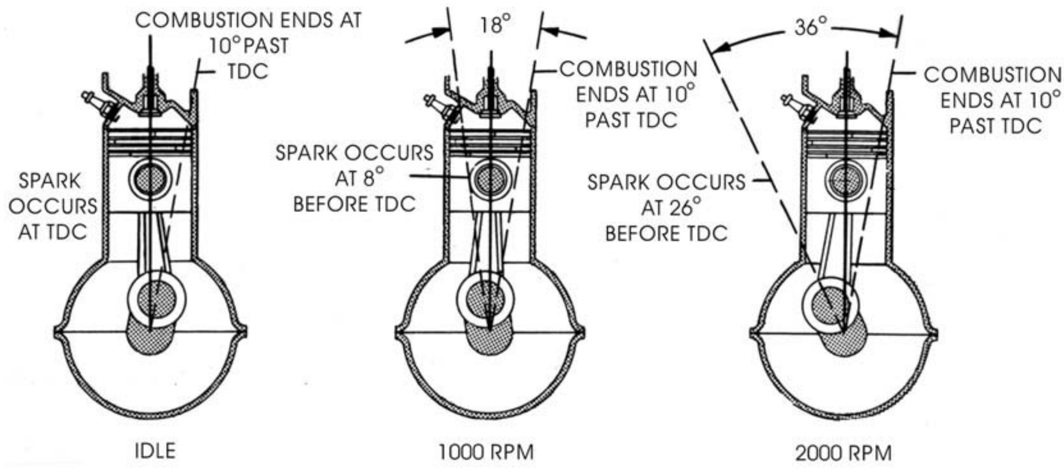



***FIGURE 44—At higher engine speeds, the time period available to burn the air-and-fuel mixture properly is shorter. Therefore, the spark must occur earlier in the engine cycle.***

Now, let's look at two devices that are used to advance ignition timing.

## Centrifugal-Advance Mechanisms

An advance in ignition timing can be produced by a mechanical *centrifugal-advance mechanism* built into the distributor. A centrifugal-advance mechanism varies ignition timing in relation to changes in engine speed. It consists of two weights, a base plate, weight springs, and an advance cam (Figure 45). The base plate is permanently attached to the distributor shaft. The two centrifugal weights are pivoted on pins riveted to the base plate. Another pin extends upward on each side of the advance cam. Springs are attached between the two pins. The distributor cam is located in the center of the advance cam and is free to rotate with it.

The weights are thrown out against the spring tension as the engine speed increases. The motion of the weights turns the advance cam, so that the distributor cam is rotated to an advanced position; cam rotation is in the same direction as distributor shaft rotation. The higher the engine speed, the more the weights are thrown out, and the farther the distributor cam is advanced.

## Vacuum-Advance Mechanisms

When an engine is operating under a light load, usually when the throttle is opened only partway, combustion is slower than when an engine is operating under a full load, such as when it's pulling a vehicle up a hill, and the throttle is wide open. Combustion is slower when an engine is operating under a light load because a small amount of the air-and-fuel mixture enters the cylinders at a part-throttle setting.

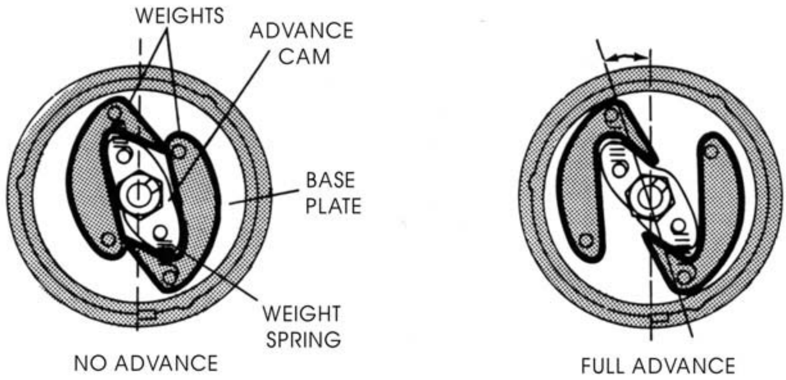



***FIGURE 45—In most point-type ignition systems, a centrifugal-advance mechanism is used to advance the timing as engine speed increases.***

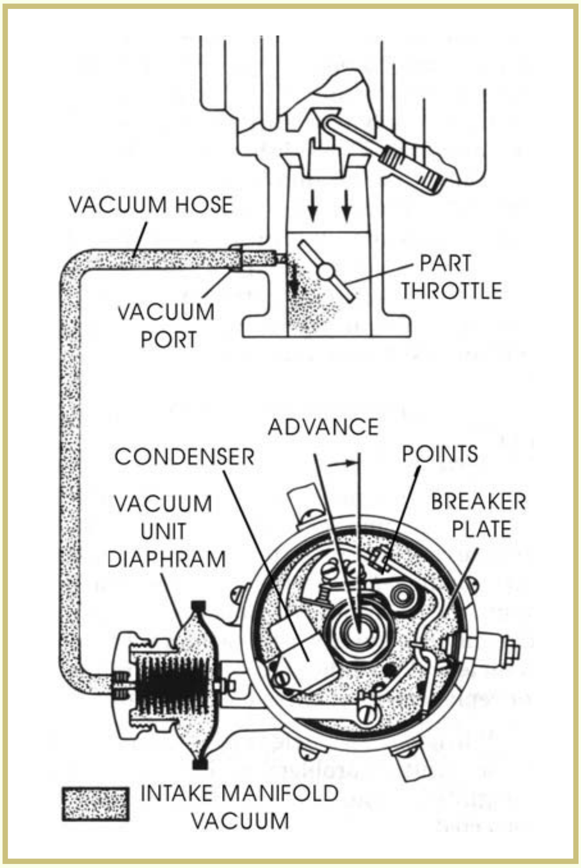
This smaller amount isn't compressed as much as a full-throttle mixture, so the combustion process requires more to burn completely. This means that when an engine is operating under a light load, additional spark advance is required to produce maximum power and economy.

However, more advance is needed than the centrifugal-advance mechanism can provide. Because the intake manifold vacuum varies with changes in the engine load, the vacuum can be used to increase the spark advance. Thus, a *vacuum-advance mechanism* is used to adjust the timing in relation to the load on the engine.

In a vacuum-advance mechanism, a movable plate called a *breaker plate* holds the points and the condenser. The breaker plate can be revolved about the cam by connecting it to the vacuum-advance mechanism (Figure 46).

In a typical vacuum-advance system, vacuum is taken from a port in the intake manifold. A hose connects the vacuum to a diaphragm assembly mounted on the side of the distributor housing. The spring-loaded diaphragm is connected by a lever to the movable distributor breaker plate. Movement of the diaphragm causes the breaker plate to rotate, changing the position of the points in relation to distributor cam rotation. This, of course, changes the timing of the point opening, and it changes the ignition timing. The arrangement is usually such that an increase in vacuum causes the diaphragm to move the points in the direction opposite of the cam rotation. This advances the timing, since the points open earlier. When the vacuum decreases—for example, when the throttle is opened wider for higher-speed operation—the spring pushes against the diaphragm and the points are moved back. This reduces the amount of spark advance provided by the vacuum unit.

***FIGURE 46—A vacuum-advance mechanism is used in point-type ignition systems to adjust the timing in relation to the load on the engine.***




At high engine speeds, when the vacuum in the intake manifold is low, most—if not all—of the spark advance is provided by the centrifugal-advance unit. When an engine is idle, the centrifugal-advance unit doesn't provide any advance. The weights are unable to overcome their springs at low speed, so the centrifugal advance doesn't work. The vacuum-advance unit may or may not provide a spark advance when an engine is idle. This depends on the location of the vacuum port in the intake manifold and on what type of emission control system the vehicle has.

## Timing in Electronic Ignition Systems

In older electronic ignition systems, the spark-advance function was performed by centrifugal-advance and vacuum-advance mechanisms similar to those used in conventional ignition systems (Figure 47).

However, in newer electronic ignition systems, ignition modules are designed to control the spark timing as well as the ignition coil triggering. This eliminates the need for traditional vacuum-advance or centrifugal-advance units. Ignition modules often have a vacuum hose attached to sense the amount of suction vacuum in the intake manifold. The heavier the load that's placed on the engine, the lower the vacuum. The ignition module can use this information to adjust the ignition timing to current engine conditions.

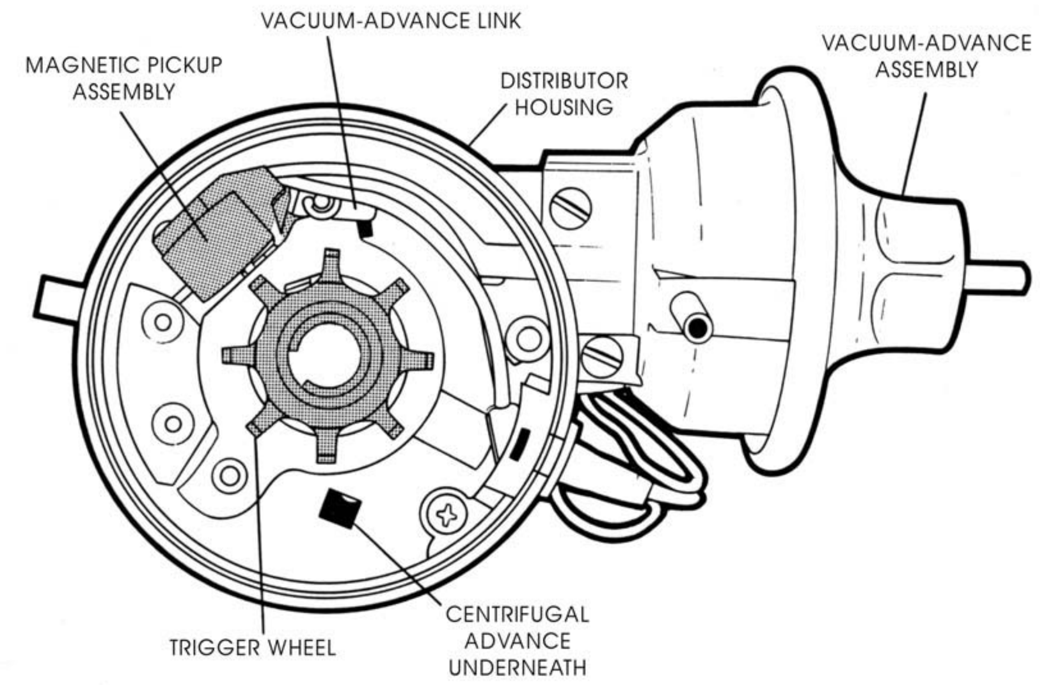



***FIGURE 47—In older electronic ignition systems, the spark-advance function was performed by centrifugal-advance and vacuum-advance mechanisms.***

Note that in most newer cars, the ignition module is either a part of the computer system or is controlled by the computer system. Various sensors in the engine gather information about current engine conditions, including engine temperature, the amount of oxygen in the exhaust gases, the current throttle position, and the vehicle speed. The sensors then deliver this information to the computer. Using the information from its sensors, the computer can determine the best timing advance for current engine conditions. The computer then directs the ignition module to set the timing at that value.

The computer operates at a very high speed, performing thousands of functions every second. This allows it to continuously adjust the ignition timing so that it's always at the proper setting for current engine conditions. Since the timing is continuously adjusted, a computer-controlled engine performs better and is more fuel-efficient than an engine in which the timing is controlled by vacuum-advance and centrifugal-advance systems.

Now, take a few moments to review what you've learned by completing *Power Check 5*.

# Power Check 5

1. Changing an engine's ignition timing so that the spark plug fires earlier is called _______ the ignition timing.

2. Changing an engine's ignition timing so that the spark plug fires later is called _______ the ignition timing.

3. A _______ is a device that adjusts ignition timing in relation to the load on the engine.

4. *True or False?* A distributor shaft may rotate either clockwise or counterclockwise, depending on the engine design.

**Check your answers with those on page 100.**

# DIRECT-FIRE IGNITION SYSTEMS

## Introduction

Earlier in this study unit, you learned that two different systems may be used to control the spark that's delivered to an engine's cylinders: *distributor-type systems* and *direct-fire systems*. In a distributor-type ignition system, a single ignition coil delivers the spark to all of the cylinders, and a distributor delivers the spark to the appropriate cylinder at the proper time.

In contrast, a direct-fire system doesn't use a distributor. For this reason, a direct-fire ignition system is sometimes called a *distributorless ignition system (DIS).*

An external view of a typical direct-fire ignition system is shown in Figure 48. This system consists of a computer, an ignition module, ignition coils, a crankshaft position sensor, a trigger wheel, spark plug wires, and spark plugs. Note that the ignition module and the ignition coils are contained within one housing called a *coil pack*.

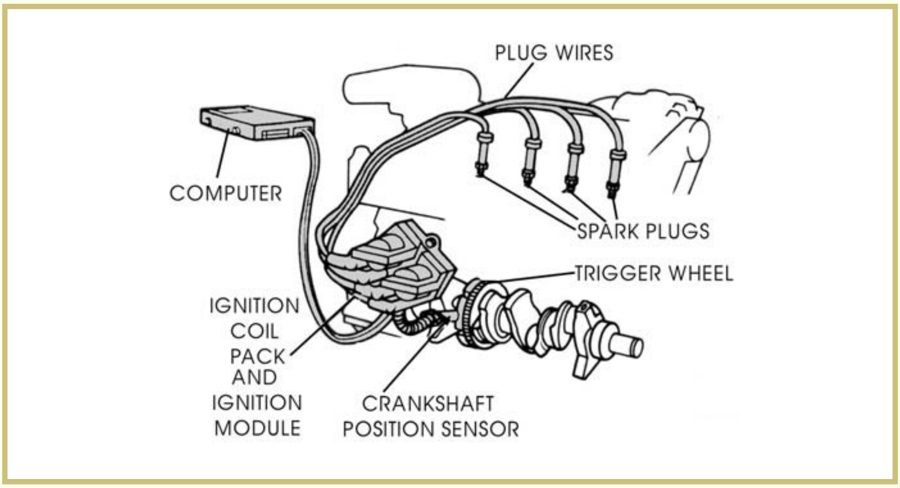



***FIGURE 48—A typical direct-fire ignition system is shown here.***

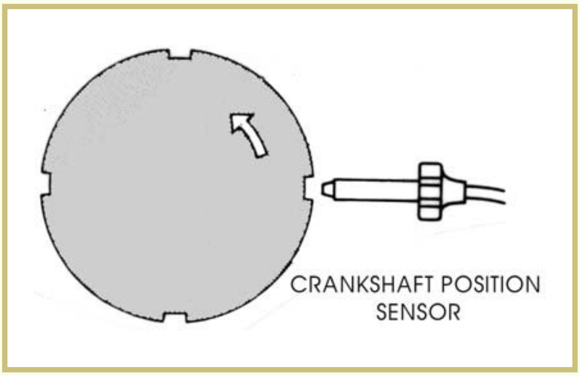
In a direct-fire system, the computer, ignition module, and ignition coils work together to control the spark at the cylinders. Various sensors positioned in the engine send information about different engine conditions to the computer. The computer then processes the information and determines the ideal spark timing for the current engine conditions. The computer tells the ignition module when to trigger the primary windings in the ignition coils. In this type of system, the ignition module takes the place of the distributor.

In order for a direct-fire ignition system to work properly, the computer must know the exact crankshaft position at all times so that it can determine when the cylinders should be fired. For this reason, a special *crankshaft position sensor* is used to monitor the crankshaft position. As the crankshaft rotates, the crankshaft position sensor monitors its position and sends signals about the crankshaft position to the computer. The computer uses these signals to determine when to fire the various cylinders.

As you can see in Figure 48, the crankshaft position sensor is usually mounted in the engine block close to the crankshaft. A special rotating wheel on the crankshaft is then used to trigger the sensor. Depending on the manufacturer, this wheel may be called a *trigger wheel, a trigger ring,* a *reluctor*, an *interrupter ring*, or a *pulse ring*. The trigger wheel may be an integral part of the crankshaft, or it may be attached to the crankshaft.

The exact design of the trigger wheel varies depending on the engine make and model. In all cases, though, the outer edge of the trigger wheel contains some type of notches or holes that represent crankshaft positions. One common type of trigger wheel is shown in Figure 49. This trigger wheel has four notches cut out of its edge. Each notch in the trigger wheel represents a one-quarter turn—90 degrees—of crankshaft rotation.

FIGURE 49—This trigger wheel has four notches cut into its edge. Each notch represents one-quarter turn—90 degrees—of crankshaft rotation. As the trigger wheel rotates, each time one of the notches passes the crankshaft position sensor, the sensor sends a signal to the computer.




How exactly does a crankshaft position sensor work? One common type of crankshaft position sensor contains a permanent magnet and a wire winding. When the sensor's winding is energized, a magnetic field develops between the crankshaft position sensor and the surface of the metal trigger wheel. As the trigger wheel rotates, the notches in the trigger wheel cause the strength of this magnetic field to change. Each time a notch passes by the crankshaft position sensor, the magnetic field changes and an electrical signal is sent to the computer. The computer then uses the signals from the crankshaft position sensor to determine the current crankshaft position.

Remember that this trigger wheel has four notches, one for every 90 degrees of crankshaft rotation. Each time a notch passes the crankshaft position sensor, the sensor sends a voltage pulse to the computer. The computer simply counts the voltage pulses to figure out the correct crankshaft position. The first pulse tells the computer that the crankshaft is at 90 degrees of rotation. The second pulse tells the computer that the crankshaft is at 180 degrees of rotation. The third pulse tells the computer that the crankshaft is at 270 degrees of rotation. The fourth pulse tells the computer that the crankshaft has rotated a complete 360 degrees and is back where it started. The computer continually counts the voltage pulses from the crankshaft position sensor as the engine operates.

Once the computer knows the current position of the crankshaft, it can determine when to fire the engine's cylinders. For example, suppose an engine contains four cylinders that fire in a 1-2-3-4 firing order. When the computer receives the first signal from the crankshaft position sensor, at 90 degrees of crankshaft rotation, the computer knows that Cylinder 1 is at TDC on its compression stroke and is ready to be fired. The computer signals the ignition module to fire the spark plug attached to Cylinder 1. When the computer receives the second signal from the crankshaft position sensor—at 180 degrees of crankshaft rotation—it knows that Cylinder 2 is ready to be fired. The computer signals the ignition module to fire the spark plug at Cylinder 2. At the third signal from the crankshaft position sensor, at 270 degrees of crankshaft rotation, the computer fires Cylinder 3. Finally, at the fourth signal from the crankshaft position sensor, at 360 degrees of crankshaft rotation, the computer fires Cylinder 4. This process continues over and over as the engine operates.

In addition to firing the engine cylinders, the computer in a direct-fire ignition system also controls the ignition timing and timing advance. A variety of different sensors in the engine monitor conditions, such as engine speed and temperature, and send information about current conditions to the computer. The computer then determines how many degrees of crankshaft rotation before TDC the spark should occur. Once this is determined, the computer waits until the crankshaft is at that exact degree of rotation. At that moment, the computer signals the ignition module to trigger the ignition coil for that cylinder. The ignition module shuts off the voltage in the primary winding of that ignition coil, the magnetic field in the coil collapses, and a spark is sent to the spark plug for that cylinder.

This ignition system process repeats thousands of times every minute. This isn't always easy, considering how fast an engine operates. However, the computers used in direct-fire ignition systems can make decisions very quickly and can control engine operation efficiently even at high speeds.

Note that this is a very basic description of the operation of a direct-fire system. Many individual system variations are possible, depending on the engine design, number of engine cylinders, and type of ignition system components used. For example, there are many different styles of trigger wheels. Also, some direct-fire systems may use more than one crankshaft position sensor to signal the computer. However, the basic principles of operation are the same in all systems—a rotating trigger wheel and sensor work together to tell the computer when to fire the engine cylinders. Remember that all of the ignition timing and firing functions in a direct-fire system are performed electronically, without a distributor. Because electronic components are long-lasting and require no adjustments, direct-fire ignition systems are very reliable.

Now, let's discuss some of the different components that may be used in direct-fire ignition systems.

## The Crankshaft Position Sensor

In many engines, the crankshaft position sensor fits into a machined hole in the engine block next to the trigger wheel (Figure 50A). In some ignition systems, however, the crankshaft position sensor may be mounted to the engine's front cover, with the trigger wheel mounted at the front of the crankshaft (Figure 50B). Or, the trigger wheel may be a part of the flywheel at the very back of the engine. In all cases, though, the crankshaft position sensor and the trigger wheel are very close to each other.

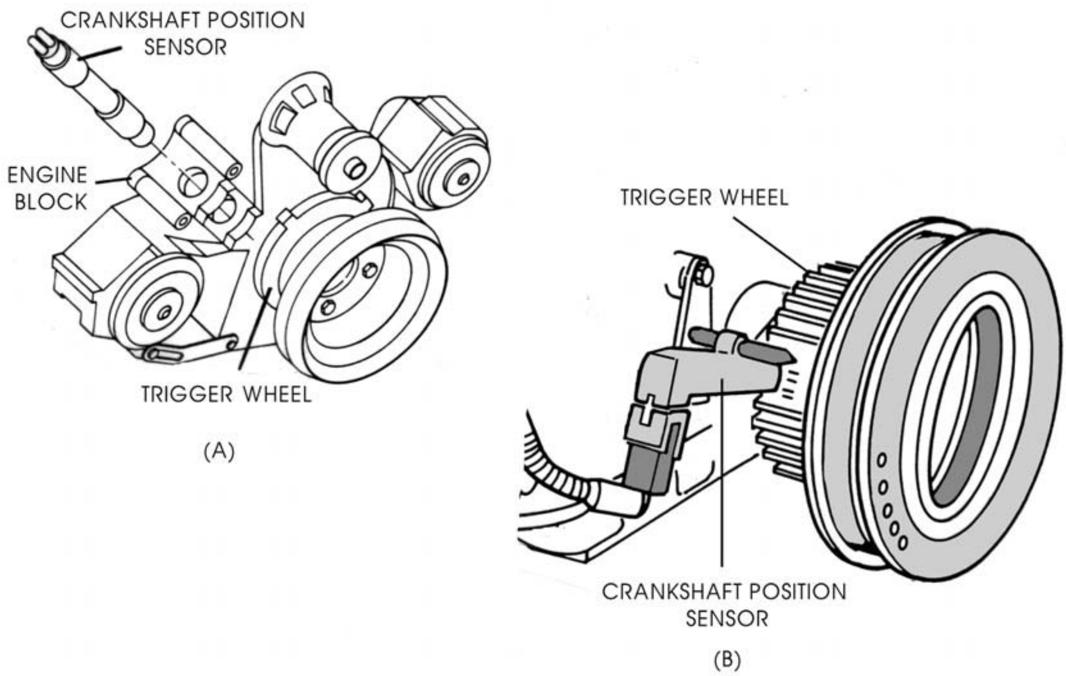



***FIGURE 50—In most cases, the crankshaft position sensor fits into a machined hole in the engine block next to the trigger wheel, as shown in Figure 50A. In Figure 50B, the crankshaft position sensor is mounted to the engine's front cover, and the trigger wheel is mounted at the front of the crankshaft.***

As you learned earlier, two common types of crankshaft position sensors are the magnetic sensor and the Hall-effect sensor. While magnetic sensors are used in some vehicles, Hall-effect sensors are used more often in modern cars. Let's discuss each of these sensors now.

A magnetic crankshaft position sensor uses a magnetic field to sense the crankshaft position. The magnetic crankshaft position sensor is placed about 0.05 of an inch away from the trigger wheel on the crankshaft. The trigger wheel, often called a reluctor wheel in a magnetic crankshaft position sensor, contains several notches. As the reluctor wheel begins to rotate, a magnetic field flows easily through it. At this time, there's no change in the magnetic field and the crankshaft position sensor doesn't produce a voltage signal. However, when a notch passes by the magnetic sensor, the strength of the magnetic field changes, and the sensor sends a low-voltage AC signal to the computer. This signal tells the computer that a notch is passing by the sensor (Figure 51).

Hall-effect crankshaft position sensors work in much the same way as magnetic sensors; however, instead of sending a low-voltage AC signal to the computer, the Hall-effect sensor sends a pulse signal. An interrupter ring is placed on the crankshaft pulley as shown in Figure 52A. The ring contains three equally spaced blades. As the crankshaft rotates, the blades on the interrupter ring pass through the Hall-effect switch to trigger the crankshaft position sensor. Therefore, each time a blade passes through the Hall-effect sensor, the sensor sends a voltage pulse to the computer system. These pulses are usually called *square waves,* because they look like a series of small squares as shown in Figure 52B.

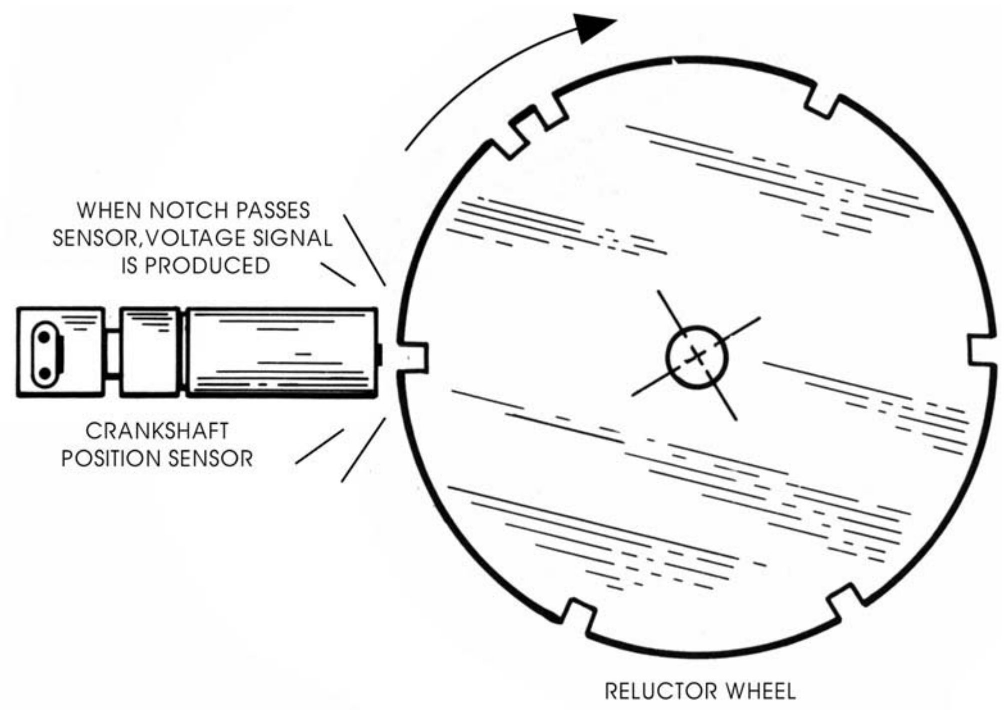



***FIGURE 51—When a reluctor wheel notch passes by the magnetic crankshaft position sensor, the strength of the magnetic field changes, and the sensor sends a low-voltage AC signal to the computer.*** (Courtesy of General Motors Corp.)

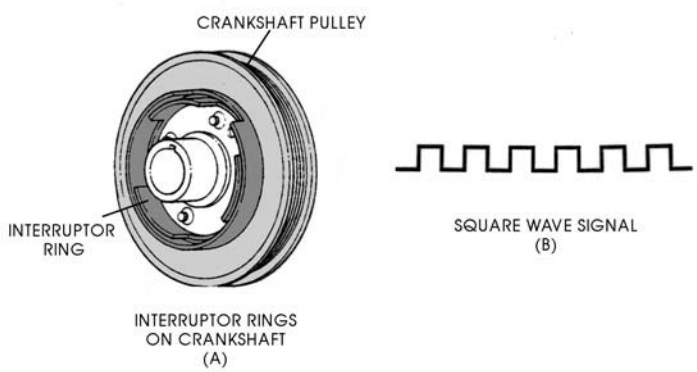



***FIGURE 52—In a Hall-effect crankshaft position sensor, one or more interrupter rings is placed on the crankshaft as shown in Figure 52A. When a Hall-effect crankshaft position sensor sends a voltage pulse to the computer, these voltage pulses produce a signal pattern called a square wave, as shown in Figure 52B.***

## The Trigger Wheel

A wide variety of different trigger wheels are used in direct-fire ignition systems. Some wheels have notches cut into their edges, while others may use holes or slits to trigger the crankshaft position sensor. Figure 53 shows a typical trigger wheel for a six-cylinder engine. The wheel contains six equally spaced notches around its edge—one notch for each 60 degrees of crankshaft rotation. Each time one of the notches rotates by the crankshaft position sensor, the sensor sends a signal to the vehicle's computer. In this way, the computer always knows the current crankshaft position.

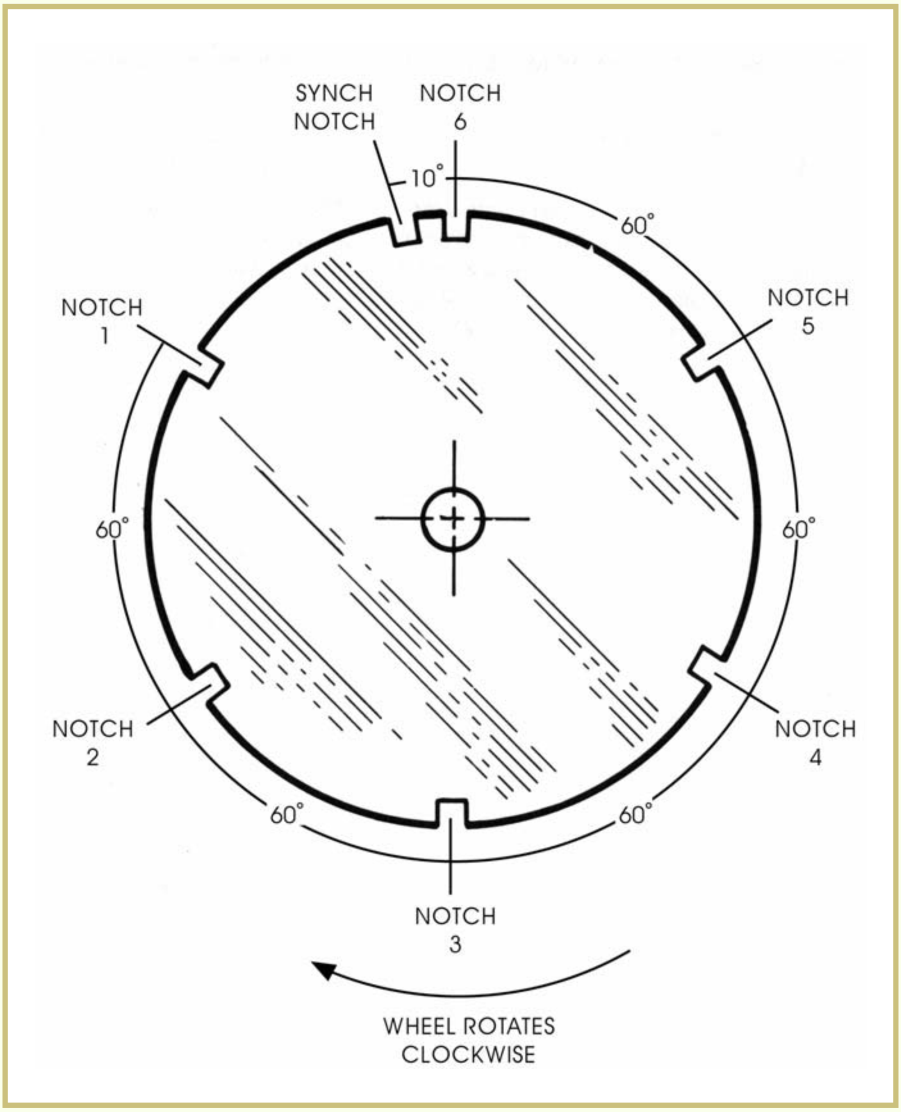



***FIGURE 53—The trigger wheel for a six-cylinder engine contains six crankshaft position notches in its edge, one for each 60 degrees of crankshaft rotation. The wheel also contains a seventh notch called a synch notch. The synch notch is used to determine the starting point for the cylinder firing order.***

Note that the trigger wheel in Figure 53 also contains a seventh notch that's very close to one of the crankshaft position notches. This extra notch is called a *synch notch*. The synch notch is used to help the computer identify the starting point in the firing order. In other words, when the synch notch passes by the crankshaft position sensor, it gives the computer a point of reference to help identify the engine cylinders. Once the computer determines the location of one cylinder in relation to the notches on the trigger wheel, the computer can determine the positions of the other cylinders.

Each time a notch passes by the crankshaft position, a signal is sent to the computer. The spaces between the six regular notches are equal. However, when the synch notch passes by the crankshaft position sensor, another notch passes almost immediately after it. So, when the computer receives two signals very close together, it knows that the synch notch has just passed by the crankshaft position sensor. The computer then begins counting the crankshaft position signals from that point. In this way, the computer can tell which cylinder is ready to be fired.

In addition to counting the signals sent by the crankshaft position sensor, the computer measures the amount of time between each signal. The computer can use this information to determine the engine speed. For instance, the computer knows that when the time between pulses is long, the engine is running slow, and when the time between pulses is very short, the engine is running fast. In systems that use a synch notch, the computer can also use the time between pulses to identify the synch notch. Remember that the synch notch is located very close to another crankshaft position notch. When the computer measures a very short time between two signals, it knows that the second signal is for the synch notch.

Many different types of trigger wheels are used by different manufacturers. The trigger wheel shown in Figure 54 has notches all the way around its edge. In this trigger wheel, each notch represents a certain amount of crankshaft rotation. The crankshaft position trigger points are indicated by areas of missing teeth in the wheel. In a similar type of trigger wheel, the crankshaft position trigger points are indicated by areas where the notches are placed closer together.

Still another type of trigger wheel is a plate that contains a series of slots in its outer edge. The plate is then bolted to the rear of the crankshaft near the transmission (Figure 55). Since this wheel is bolted directly to the rear of the crankshaft, the wheel rotates with the crankshaft as the engine operates. In this design, the crankshaft position sensor detects whenever one of the slots passes by, and indicates the current crankshaft position.

**FIGURE 54—In this trigger wheel design, notches are placed all the way around the edge of the wheel. The crankshaft position trigger points are indicated by areas of missing teeth on the wheel.**

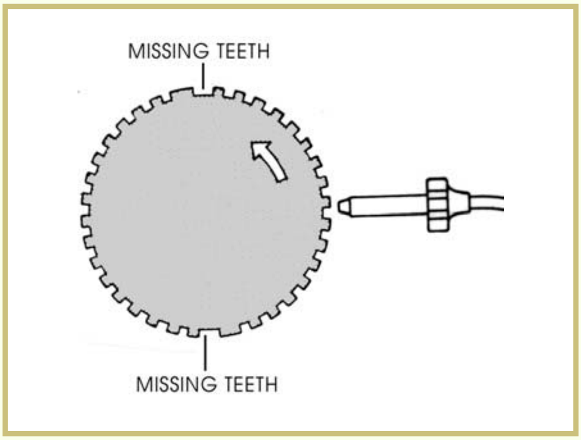
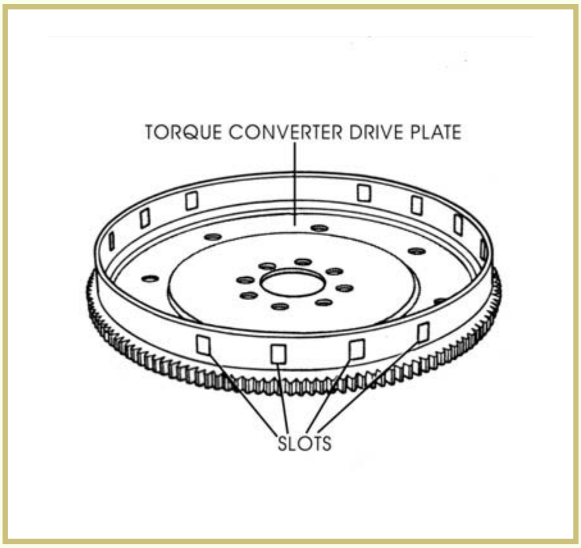



**FIGURE 55—Another type of trigger wheel uses a series of slots placed in the outer edge of a plate that's bolted to the rear of the crankshaft, as shown here.** (Courtesy of Chrysler Corporation)




As you can see, the exact design of the trigger wheel varies, depending on the engine make and model. However, all trigger wheels operate in the same basic way. All trigger wheels are designed to rotate with the crankshaft, and the notches or holes in the trigger wheel indicate the crankshaft position to the crankshaft position sensor.

## The Camshaft Position Sensor

As you've seen, some direct-fire ignition systems use a synch notch on the trigger wheel to help the computer identify which cylinder is ready to fire. However, some systems use an additional sensor called a *camshaft position sensor* instead of a synch notch to perform this function. In this type of system, the camshaft position sensor sends a signal to the computer to indicate that a particular cylinder is ready to be fired.

A typical camshaft position sensor is shown in Figure 56A. In most cases, the camshaft position sensor is mounted in the engine's front cover, next to the camshaft gear as shown in Figure 56B. A notched wheel is mounted on the camshaft gear. As the camshaft rotates, the notches on the wheel cause the camshaft position sensor to signal the computer. This signal is used to identify the notches so that the computer can keep track of them. Once the computer knows the location of one notch, it can count the number of signals from that point to determine the current camshaft position.

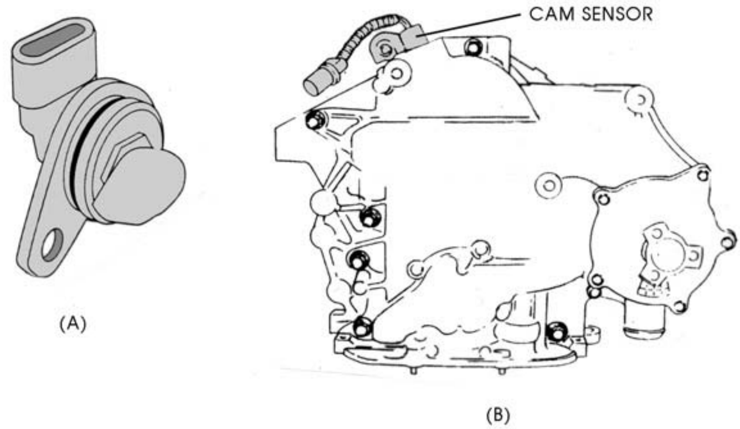


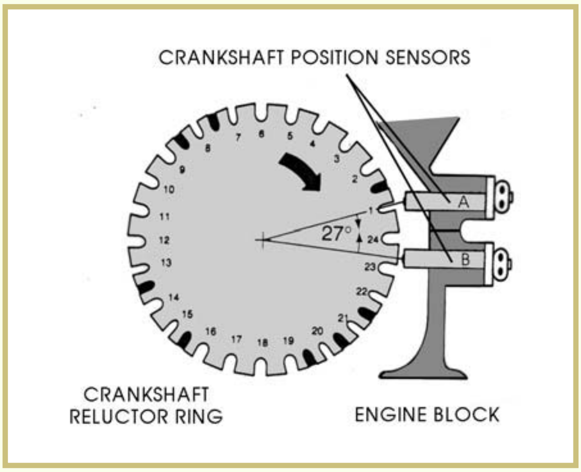

***FIGURE 56—A typical camshaft position sensor is shown in Figure 56A. Most camshaft position sensors are mounted in the engine's front cover, as shown in Figure 56B.***

In most systems, the camshaft position sensor is needed only when an engine is started. Once the camshaft position sensor has indicated the positions of the different cylinders to the computer, the sensor won't be needed again until the engine is shut off and restarted. However, in some systems, the camshaft position sensor may be used to directly control the operation of the ignition system or the fuel-injection system. In these engines, the camshaft position sensor provides information to the computer the entire time the engine is operating. Once the computer receives the information from its sensors, it can then decide when to fire the spark plug for each cylinder.

You may also see some engines in which two crankshaft position sensors are used instead of a camshaft position sensor (Figure 57). In this type of system, the second crankshaft position sensor monitors a second set of marks on the crankshaft trigger wheel. The signals from the two sensors tell the computer how the crankshaft is positioned, as well as which cylinder is in position to receive a spark. Thus, the system doesn't require the use of a camshaft position sensor.

Another type of ignition system uses a *dual crankshaft position sensor*. In this type of system, the trigger wheel contains an inner ring and an outer ring (Figure 58). The inner ring has three blades, and the outer ring is notched. The dual crankshaft position sensor monitors both sets of notches on the trigger wheel. This system doesn't require a camshaft sensor.

***FIGURE 57—This direct-fire ignition system uses two crankshaft position sensors to monitor the crankshaft position.***



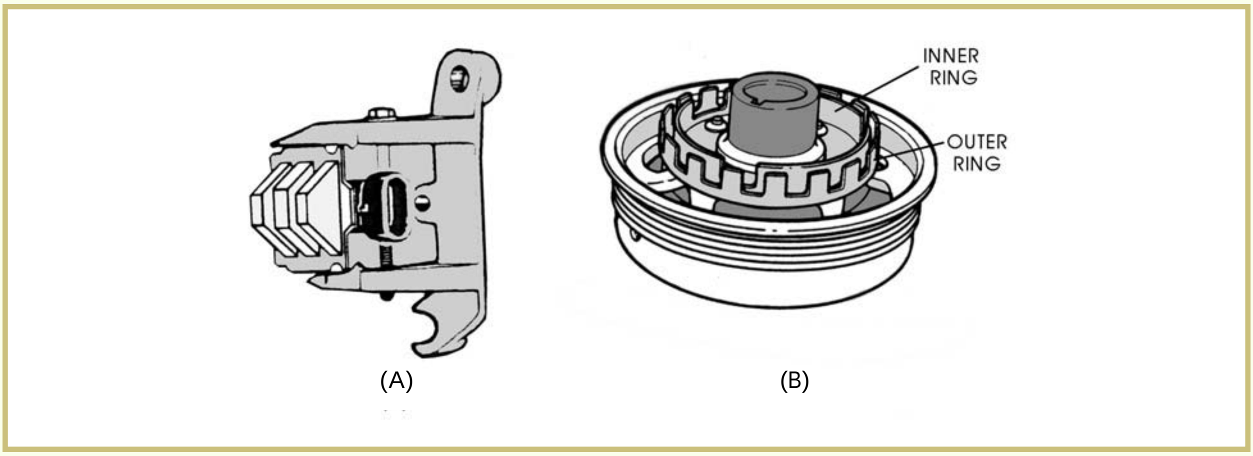




***FIGURE 58—A dual crankshaft position sensor is shown in Figure 58A, and its trigger wheel is shown in Figure 58B.***

## Ignition Coils in Direct-fire Systems

The ignition coils used in most direct-fire ignition systems are very similar in construction to those used in other types of ignition systems. These coils have primary and secondary windings, and the spark is produced in the same way. However, direct-fire systems use more than one ignition coil. In some direct-fire systems, a separate ignition coil is used to fire each cylinder. However, most systems use a separate coil to fire each pair of cylinders. That is, one coil fires two cylinders at the same time.

The coils used in a direct-fire system are usually mounted all in one housing, as shown in Figure 59. Ignition coils that are contained in a single housing are often called a *coil pack*. The coil pack shown in Figure 59A contains one ignition coil for each of the cylinders in a four-cylinder engine. Note how the spark plug wires connect to the towers on the coil pack. In contrast, the coil pack shown in Figure 59B contains one ignition coil for each pair of cylinders in a six-cylinder engine. That is, each of the three ignition coils fires two of the engine's six cylinders. Note the location of the spark towers on this coil pack. The coil pack shown in Figure 59C contains one ignition coil for each pair of cylinders in a four-cylinder engine. Each of the two ignition coils fires two of the engine's four cylinders.

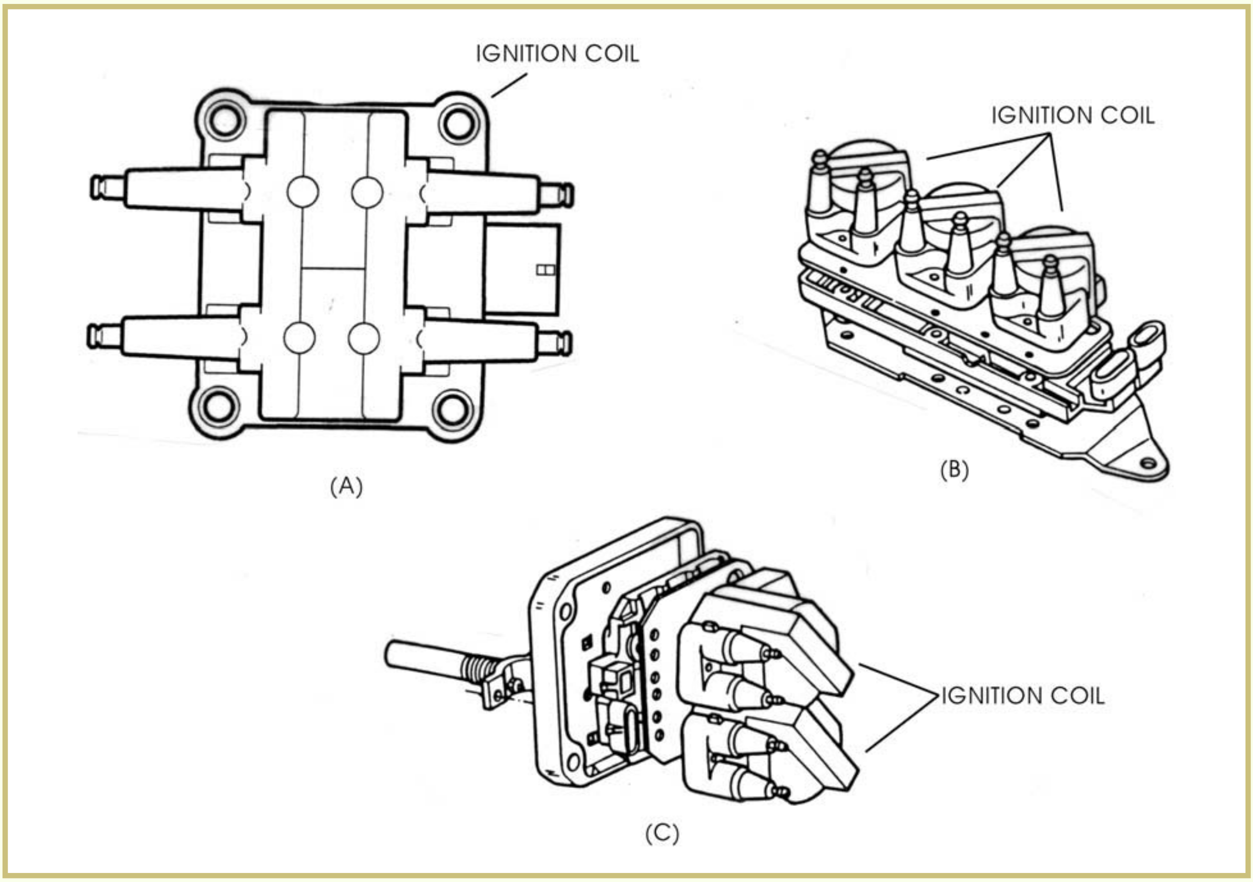



***FIGURE 59—The ignition coil in Figure 59A contains one ignition coil for each of the four cylinders in the engine. The ignition coil pack shown in Figure 59B contains one ignition coil for each pair of cylinders in a six-cylinder engine. The coil pack in Figure 59C contains one ignition coil for each pair of cylinders in a four-cylinder engine.*** (59A Courtesy of Chrysler Corporation; 59B and C Courtesy of General Motors Corp.)

Ignition coil packs can produce very high voltages. In a typical direct-fire ignition system, the voltage supplied to the spark plug could be as high as 90,000 volts. Because the voltage is so high, care must be taken when working on these systems to prevent injury from electrical shocks.

An ignition coil pack is usually mounted to the outside of the engine. The most common mounting locations are the very top of the engine or the side of the engine block. The spark plug wires attach the separate coils to each engine cylinder.

In a variation to the typical ignition coil arrangement, some manufacturers use small ignition coils to fire each separate engine cylinder, as shown in Figure 60. These ignition coils are mounted directly to the spark plugs, so no spark plug wires are needed. This system's operation is similar to the other direct-fire systems we've discussed, except that the ignition coils are separate and not contained in a single housing.

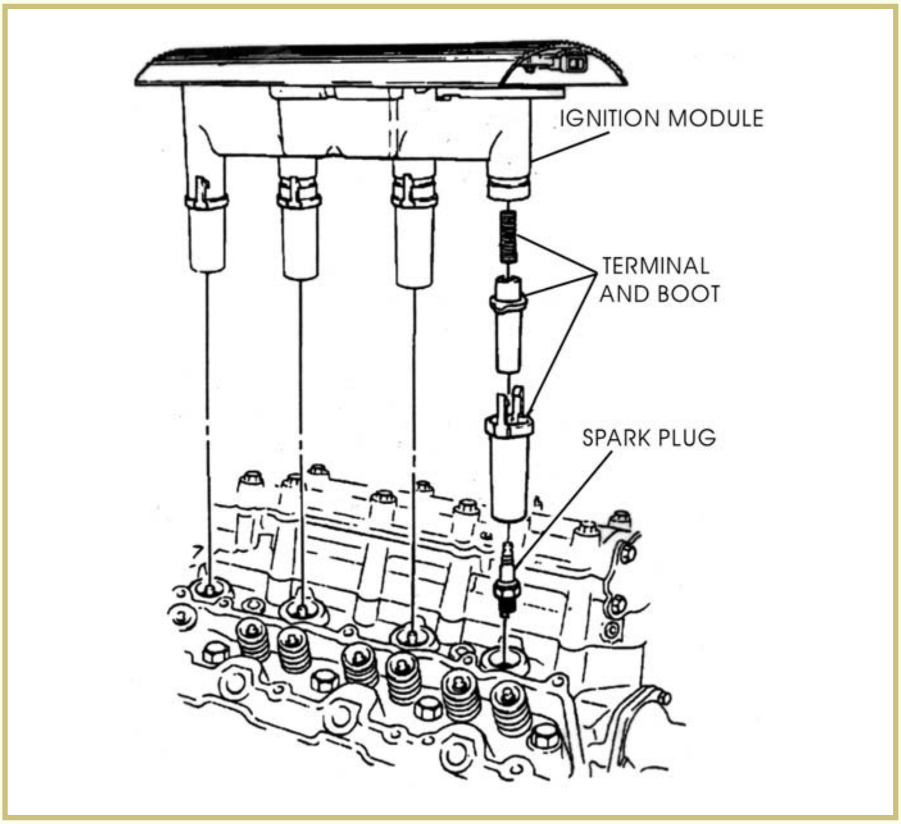



***FIGURE 60—In this ignition system, separate ignition coils are used to fire each engine cylinder. These coils are mounted directly to the spark plugs, so no spark plug wires are needed.*** (Courtesy of General Motors Corp.)

## Waste Sparks

You've just learned that a direct-fire ignition system may use a separate coil to fire each cylinder, or one coil may fire two cylinders. In most direct-fire systems, the cylinders are paired together so that one coil fires two cylinders. In these systems, the ignition system fires two spark plugs at once. However, only one of the sparks produces power in a cylinder. The second spark occurs in a cylinder that isn't on its compression stroke, so the spark produces no ignition and has no effect on the engine. This spark is called a *waste spark*. This type of system requires fewer coils, so the triggering system can be made much simpler.

To better understand what occurs, let's take a closer look at the operation of a four-cylinder engine with a direct-fire ignition system.

Figure 61 illustrates the operation of an in-line, four-cylinder engine. In a four-cylinder engine, all four cylinders in the engine will have fired after two complete crankshaft rotations. After one complete crankshaft rotation, Cylinders 2 and 3 are both moving toward TDC (Figure 61A). Cylinder 2 is on its compression stroke and ready to fire, and Cylinder 3 is on its exhaust stroke. After the second complete crankshaft rotation, Cylinders 2 and 3 are again moving toward TDC (Figure 61B). However, this time, Cylinder 2 is on its exhaust stroke, and Cylinder 3 is on its compression stroke and ready to fire.

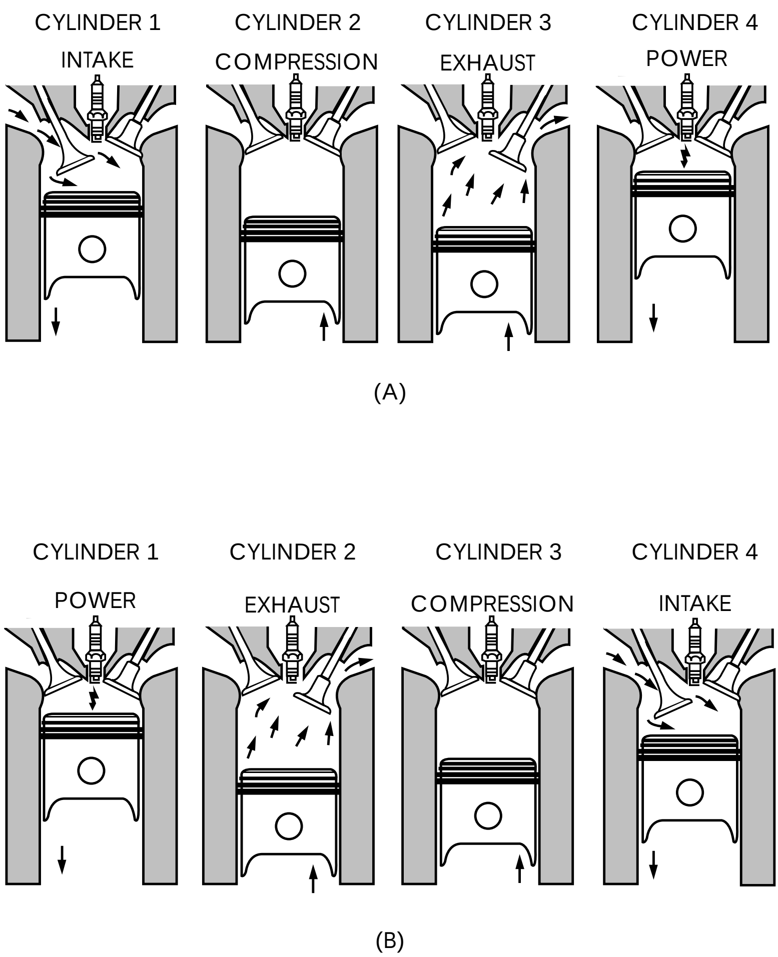



***FIGURE 61—This figure illustrates the operation of an in-line, four-cylinder engine. In Figure 61A, after one complete crankshaft rotation, Cylinder 2 is at TDC on its compression stroke, and Cylinder 3 is at TDC on its exhaust stroke and ready to fire. In Figure 61B, after the second crankshaft rotation, Cylinder 2 is at TDC on its exhaust stroke and ready to fire, and Cylinder 3 is at TDC on its compression stroke.***

Cylinders 1 and 4 operate together in the same way as Cylinders 2 and 3. After one complete crankshaft rotation, Cylinders 1 and 4 are both moving toward TDC (Figure 62A). Cylinder 1 is on its compression stroke and ready to fire, and Cylinder 4 is on its exhaust stroke. After the second complete crankshaft rotation, Cylinders 1 and 4 are again moving toward TDC (Figure 62B). However, this time, Cylinder 1 is on its exhaust stroke, and Cylinder 4 is on its compression stroke and ready to fire.

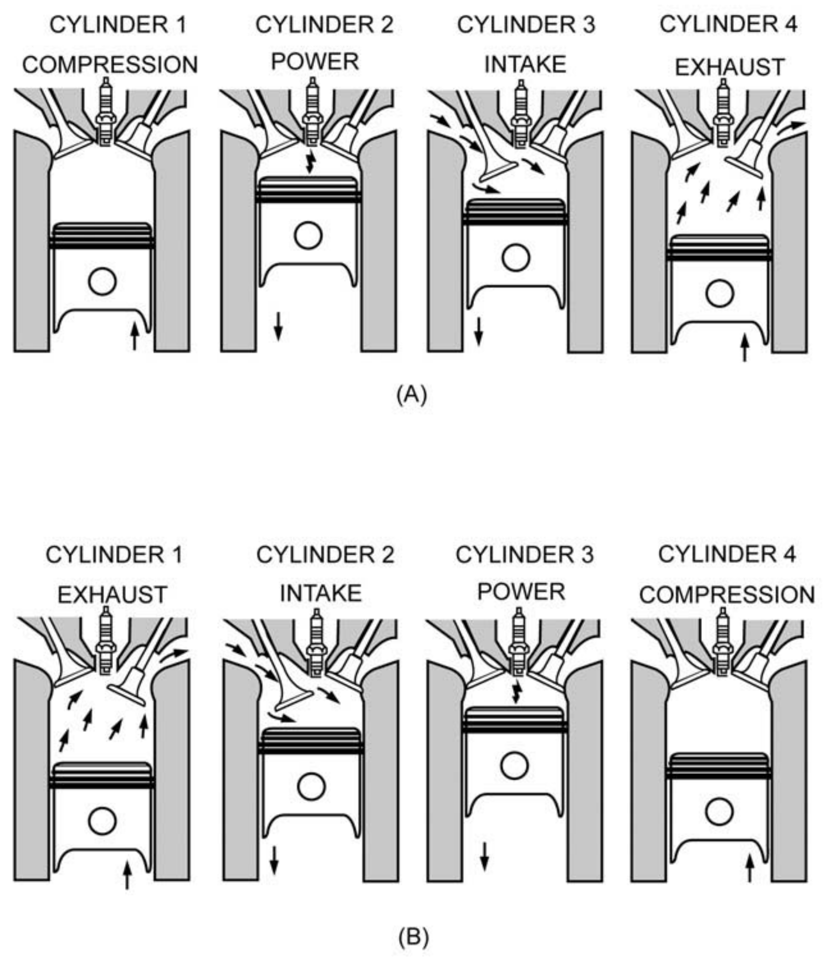



***FIGURE 62—In Figure 62A, after one complete crankshaft rotation, Cylinder 4 is at TDC on its exhaust stroke, and Cylinder 1 is at TDC on its compression stroke and ready to fire. In Figure 62B, after the second crankshaft rotation, Cylinder 4 is at TDC on its compression stroke and ready to fire, and Cylinder 1 is at TDC on its exhaust stroke.***

You can see that because Cylinder 2 and 3 both reach TDC at the same time, one ignition coil can be used to fire both of them. The same is true for Cylinders 1 and 4—one coil can be used to fire both cylinders. The crankshaft position for each cylinder pair is the same, regardless of which cylinder is ready to fire. Therefore, the notch on the trigger wheel is also in the same spot.

Now, let's imagine that one ignition coil is attached to Cylinders 2 and 3, and another coil is attached to Cylinders 1 and 4. The crankshaft rotates, and Cylinders 2 and 3 both rise to TDC. Cylinder 2 is on its compression stroke, and Cylinder 3 is on its exhaust stroke. When the ignition coil fires that pair of cylinders, the coil sends sparks to both Cylinder 2 and Cylinder 3 at the same time. The spark fires Cylinder 2, igniting the air-and-fuel mixture in the cylinder and producing power. The spark that goes to Cylinder 3 is a waste spark. Because Cylinder 3 is on its exhaust stroke, it doesn't contain any air-and-fuel mixture. Therefore, when the spark reaches Cylinder 3, the spark simply jumps across the spark plug gap. A waste spark has no effect on engine performance—since that cylinder isn't ready to fire, the spark doesn't cause any ignition.

On the next crankshaft rotation, Cylinders 2 and 3 both rise to TDC again. However, this time, Cylinder 2 is on its exhaust stroke, and Cylinder 3 is on its compression stroke. The ignition coil fires that pair of cylinders, and sparks are sent to Cylinder 2 and Cylinder 3. The spark fires Cylinder 3, and the spark in Cylinder 2 is a waste spark.

What about Cylinders 1 and 4? Well, the other ignition coil would fire Cylinders 1 and 4 in exactly the same way that we just described. The cylinder pairs would be fired alternately in the engine—Cylinders 2 and 3 would fire together, then Cylinders 1 and 4, then Cylinders 2 and 3 again, and finally Cylinders 1 and 4.

A lot of voltage is needed to fire a spark plug. However, much less voltage is needed to produce a waste spark. Since there's no compression and very little combustible material in the cylinder during the exhaust stroke, only a very small spark is needed to fire the cylinder. Since so little voltage is needed to produce a waste spark, no voltage is taken away from the other spark plug that's fired simultaneously. The other plug needs the higher voltage, since it's fired during the compression stroke.

## Ignition Timing in Direct-fire Systems

As you learned earlier, in most systems the crankshaft position sensor and/or the camshaft position sensor are used to tell the computer-control system when a cylinder is in position and ready to be ignited. The computer then uses the information from its sensors to decide precisely when to ignite the cylinder. In most cases, the cylinder is ignited a few degrees before it reaches TDC. The ignition timing is measured in degrees of crankshaft rotation. For example, if the ignition timing for a particular engine is 10 degrees before TDC, the spark occurs when the crankshaft is 10 degrees of rotation before the TDC point of that cylinder.

The reason that the spark occurs before TDC is because the air-and-fuel mixture takes a short amount of time to actually ignite and start burning. Remember that an engine is operating at a very high speed, and the crankshaft is turning thousands of rotations per minute. Therefore, if the computer waited until the exact TDC point to ignite the mixture, the piston would already be partly down in the cylinder. Thus, the power stroke has already begun before the mixture can start to burn. This greatly reduces the amount of power the piston can produce. Therefore, the most power in an engine is produced when the air-and-fuel mixture is ignited before the cylinder reaches TDC and then begins to burn fully when the piston reaches TDC.

So, the faster an engine runs, the faster the pistons travel, and the farther the pistons are past TDC before the fuel begins to burn. To compensate for this and to ensure that the fuel begins to burn fully when the cylinder reaches TDC, the ignition timing must occur earlier when the engine runs faster. This is called *timing advance*. In the distributor-type ignition systems you learned about earlier, timing advance was controlled by a separate mechanical system, such as a vacuum-advance or centrifugal-advance. However, in a direct-fire ignition system, all timing advance is controlled by the computer control system.

The computer control system receives information about engine conditions from the engine sensors. This information includes the air temperature, engine temperature, engine speed, throttle position, and so on. From this information, the computer control system can determine the proper timing advance needed for the current engine conditions. Once the timing advance is determined, the computer sends a signal to the ignition module to activate the coil for the cylinder that's ready to fire. The ignition module is usually built into the set of ignition coils. Remember that a computer system operates very quickly, and makes thousands of decisions in a single second. This speed ensures that the ignition timing is always adjusted precisely for the current engine conditions.

## Timing Control in Direct-fire Systems

The computer system used on a particular car may be given a special name by the manufacturer, such as the *electronic control module (ECM)* or *ignition control module (ICM)*. However, in general, the computer system is simply a small computer that controls many vehicle functions.

As you learned earlier in this study unit, the spark must occur sooner in the compression stroke as an engine's speed increases. However, the engine speed isn't the only factor that influences spark timing. The load placed on the engine, external air temperature, engine temperature, and air pressure also affect the spark timing. In order to accurately track current engine conditions, therefore, the computer system gathers information from a number of different sensors mounted in the engine. These sensors measure the engine temperature, speed of the car, outside air temperature, amount of vacuum in the intake manifold, amount of air entering the engine, and many other factors. The computer system analyzes the information from all the sensors and then determines the best time for the spark to occur under the current engine conditions. The computer system continually monitors all of these factors as the car is running, and continuously changes the ignition timing to best match the current conditions.

In addition, many vehicles use sensors to help the computer system control the spark under certain conditions. For example, a condition called *spark knock* or *detonation* can occur in an engine when the air-and-fuel mixture in a cylinder explodes rather than burns. These explosions may occur when the engine temperature rises, or when an incorrect air-and-fuel mixture is used in an engine. The explosions are usually loud enough for the driver to hear, and sound like a tapping or knocking noise coming from inside the engine.

Spark knock usually happens when an engine is placed under a heavy load, such as when it's pulling a trailer or going up a steep hill. Under these conditions, the mixture in the cylinder can explode and can actually start to burn in several areas of the combustion chamber at the same time. As the exploding fuel smashes into the top of the piston, it causes a shock wave to flow through the cylinder. In most cases, the fuel explodes so quickly that the piston may not even reach TDC before the pressure from the explosion forces it back down. The forces of detonation can be strong enough to cause damage to the pistons and piston rings.

One way to control detonation is to reduce the amount of ignition timing advance under those conditions. Therefore, to help determine when these conditions occur, some ignition systems use special sensors called *antiknock sensors*. An antiknock sensor is usually mounted in the engine block. When detonation occurs, the knocking noise causes the antiknock sensor to send a signal to the computer system. The computer system can then retard the ignition timing until the knocking stops. By using an antiknock sensor, the computer control system can help to prevent detonation damage.

As you can see, an automotive computer control system has many capabilities. The computer must continually make decisions about ignition timing as the engine is running—many times per second. By continually adjusting the ignition timing to match current engine conditions, the computer helps the engine perform better, consume less fuel, and produce fewer harmful exhaust emissions. You'll examine automotive computer systems in much more detail in a later study unit.

## Actual Direct-fire Examples

As you learned earlier, most direct-fire ignition systems operate on the same basic principles. However, the design of the systems varies in different vehicle makes and models. In fact, it isn't uncommon for a manufacturer to use several different systems in different car models. For these reasons, a skilled technician almost always needs to refer to a service manual for the exact servicing procedures for a particular direct-fire system. However, to get a better idea of how these systems operate, let's look at a few examples.

Figure 63A shows a direct-fire ignition system that's used in many General Motors V-6 engines. The components in this system are a computer, the ignition module and coil pack (located in one housing), a crankshaft position sensor, and a trigger wheel. In addition, the system contains six spark plug wires and six spark plugs—one for each cylinder.

In this system, the crankshaft position sensor is triggered by a trigger wheel on the crankshaft. A close-up view of the trigger wheel and crankshaft position sensor is shown in Figure 63B. This trigger wheel has seven separate notches. Six of the notches are spaced evenly at 60-degree intervals around the wheel, and the seventh notch is a synch notch that's placed very close to one of the other notches. The synch notch tells the computer where Notch 1 is located. Once the computer system knows where Notch 1 is located, it can count from that point to determine the location of the other notches.

In this direct-fire system, the coil pack has three separate ignition coils. Each ignition coil fires two cylinders at the same time. The firing order for the engine is 1-2-3-4-5-6. In this engine, Cylinders 5 and 2 are fired at Notch 2; Cylinders 3 and 6 are fired at Notch 4; and Cylinders 4 and 1 are fired at Notch 6.

Now, let's observe the operation of the ignition system. Remember that the crankshaft must rotate twice to fire all of the cylinders once. After the first crankshaft rotation, half of the cylinders will be in position to be fired. After the second crankshaft rotation, the remaining cylinders will be in position to be fired.

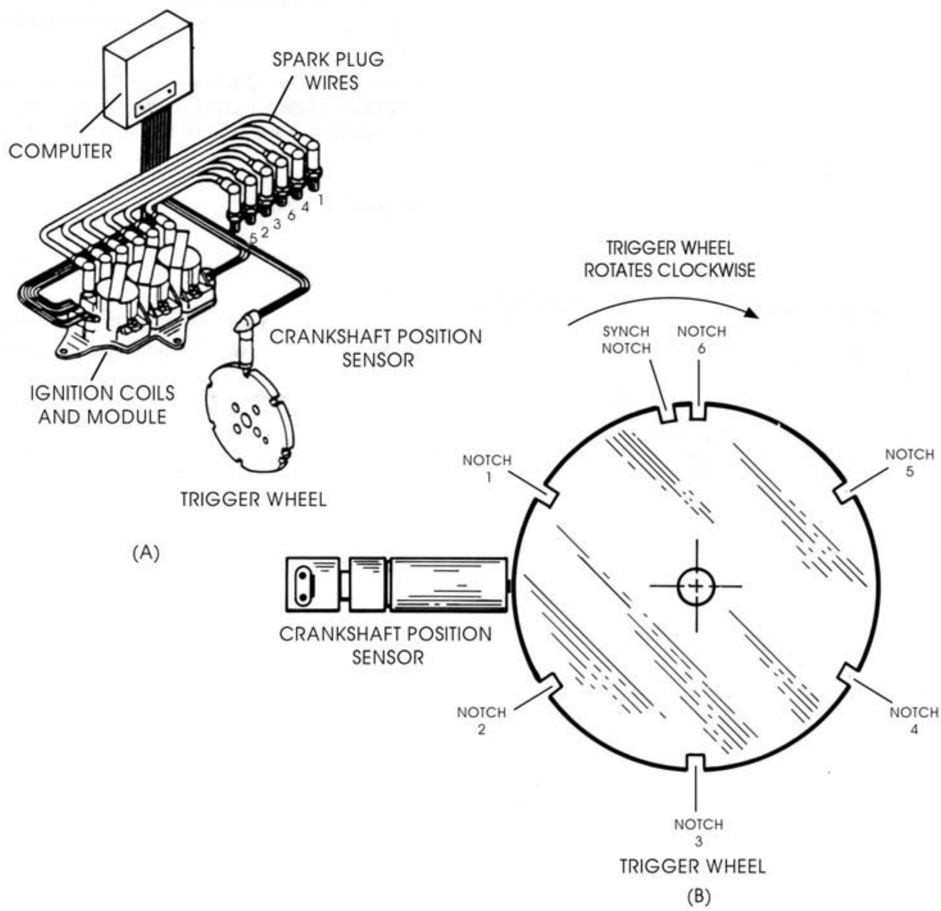



***FIGURE 63—A typical direct-fire ignition system used in many General Motors V-6 engines is shown in Figure 63A. Figure 63B shows a close-up view of the crankshaft position sensor and trigger wheel used in this system.*** (Courtesy of General Motors Corp.)

As we start, the trigger wheel is in the position shown in Figure 64. The crankshaft in this engine is rotating clockwise, so the trigger wheel also rotates clockwise. At this point, the synch notch is just passing the crankshaft position sensor. As the synch notch passes the sensor, the sensor sends a signal to the computer. Since this signal occurs only a very short time after the last signal, the computer recognizes that this notch is the synch notch.

The trigger wheel continues to rotate to the position shown in Figure 65. At this point, Notch 1 is passing the crankshaft position sensor. The sensor sends a signal to the computer that indicates the current crankshaft position to the computer. The computer counts this notch as Notch 1.

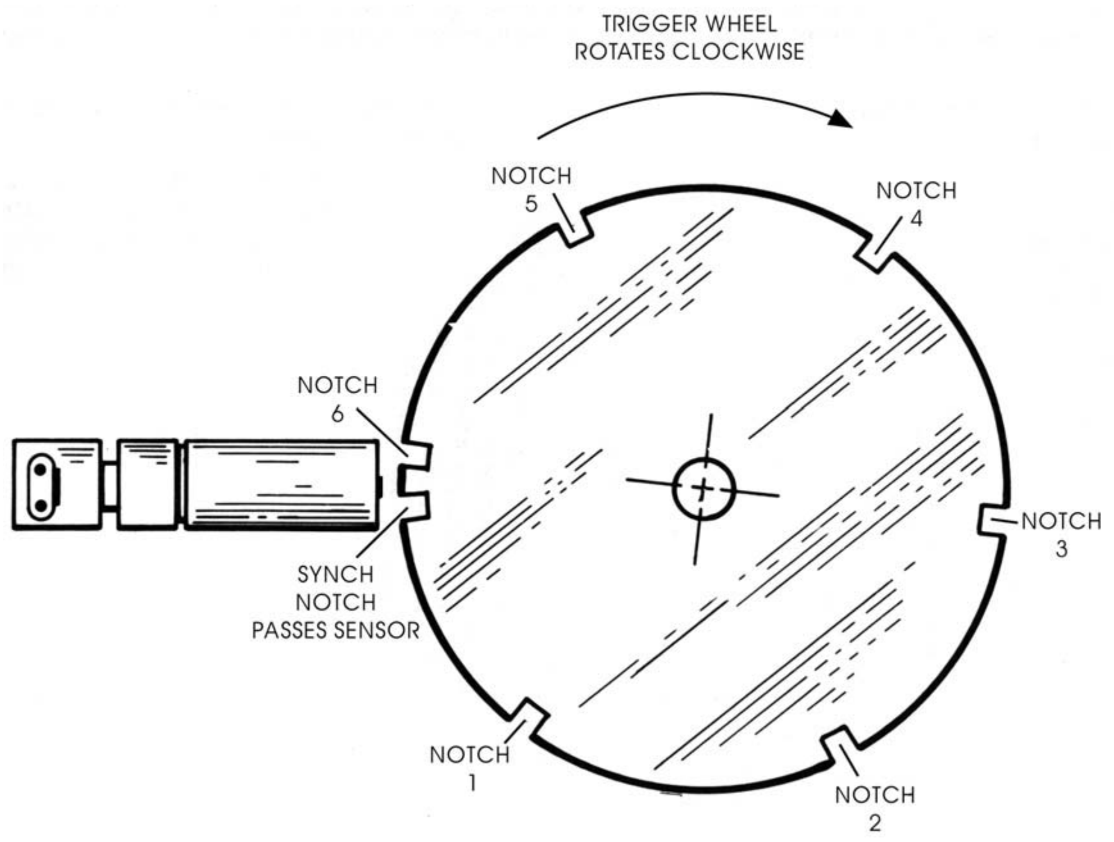



***FIGURE 64—Note the position of the trigger wheel in this illustration. The crankshaft is rotating clockwise. At this point, the synch notch is just passing the crankshaft position sensor. As the notch passes by the sensor, the sensor sends a voltage signal to the computer control system.*** (Courtesy of General Motors Corp.)

The trigger wheel continues to rotate to the position shown in Figure 66A. At this point, Notch 2 is passing the crankshaft position sensor. The sensor sends a signal to the computer indicating the current crankshaft position—60 degrees from the last signal. Since this is the second signal after the synch notch, the computer recognizes that this is Notch 2. Since Notch 2 represents Cylinders 5 and 2, the computer knows that Cylinders 5 and 2 are ready to be fired.

The computer now uses the information from its various sensors to determine the proper ignition timing for the current engine conditions. Then, the computer signals the ignition module to turn off the primary voltage in the coil that's attached to Cylinders 5 and 2. The magnetic field in the coil collapses, and a high voltage is produced in the secondary winding of that coil. This high voltage flows through the spark plug wires to the spark plugs in Cylinder 5 and Cylinder 2 (Figure 66B ). Cylinder 5 is currently on its compression stroke, so the spark at Cylinder 5 ignites the air-and-fuel mixture and forces the piston down in the cylinder. Cylinder 2 is currently on its exhaust stroke, so the spark in that cylinder is a waste spark and has no effect on engine operation.

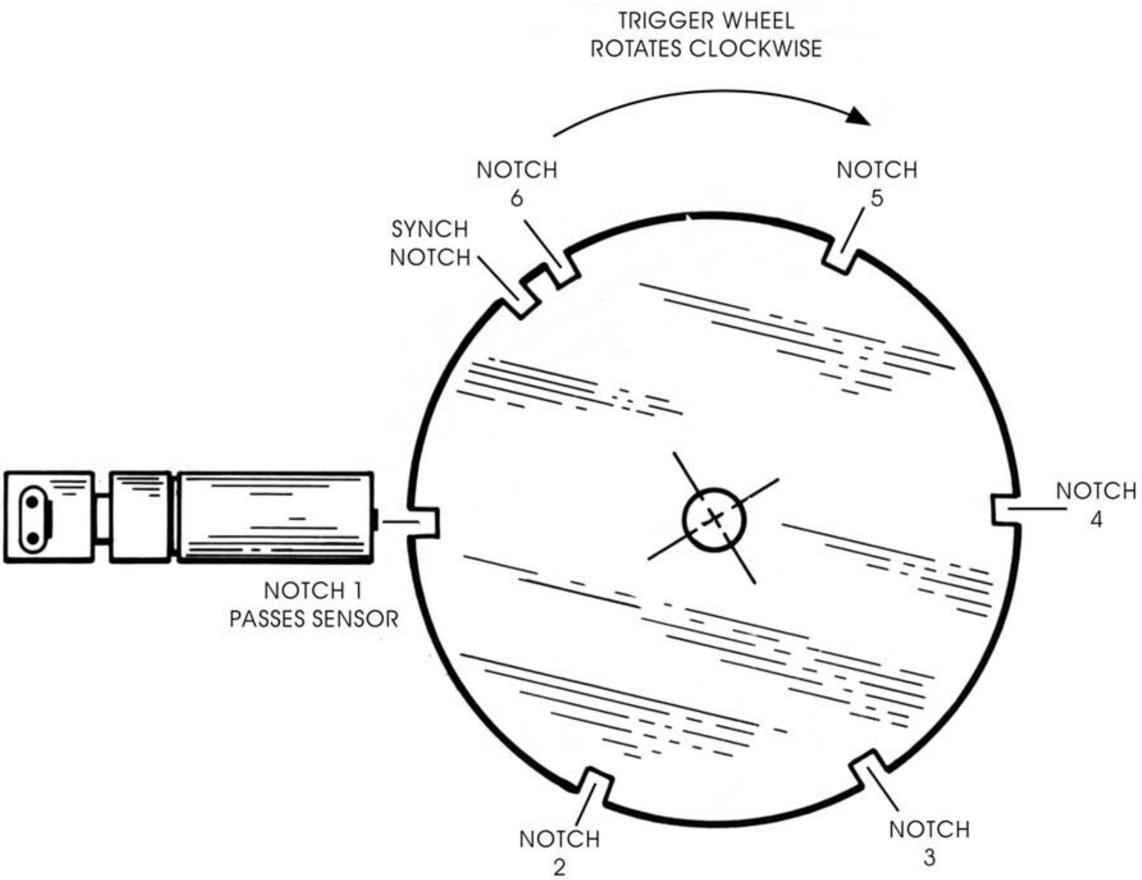



***FIGURE 65—The trigger wheel continues to rotate to the position shown here. At this point, Notch 1 is passing by the crankshaft position sensor. The sensor sends a voltage signal to the computer system indicating that Notch 1 has passed by the sensor.*** (Courtesy of General Motors Corp.)

Next, the trigger wheel continues to rotate to the position shown in Figure 67. At this time, Notch 3 is passing the crankshaft position sensor, and the sensor sends a signal to the computer indicating the current crankshaft position. Remember that in this engine, the notches are spaced 60 degrees apart around the trigger wheel. Therefore, the computer knows that each time it receives a signal from the crankshaft position sensor, the crankshaft has rotated an additional 60 degrees. The computer recognizes that this is the signal for Notch 3.

The trigger wheel continues to rotate to the position shown in Figure 68A. At this time, Notch 4 is passing the crankshaft position sensor, and the sensor sends a signal to the computer indicating the current crankshaft position. The computer recognizes that this is the signal for Notch 4. Because Notch 4 represents Cylinders 3 and 6, the computer knows that Cylinders 3 and 6 are ready to be fired.

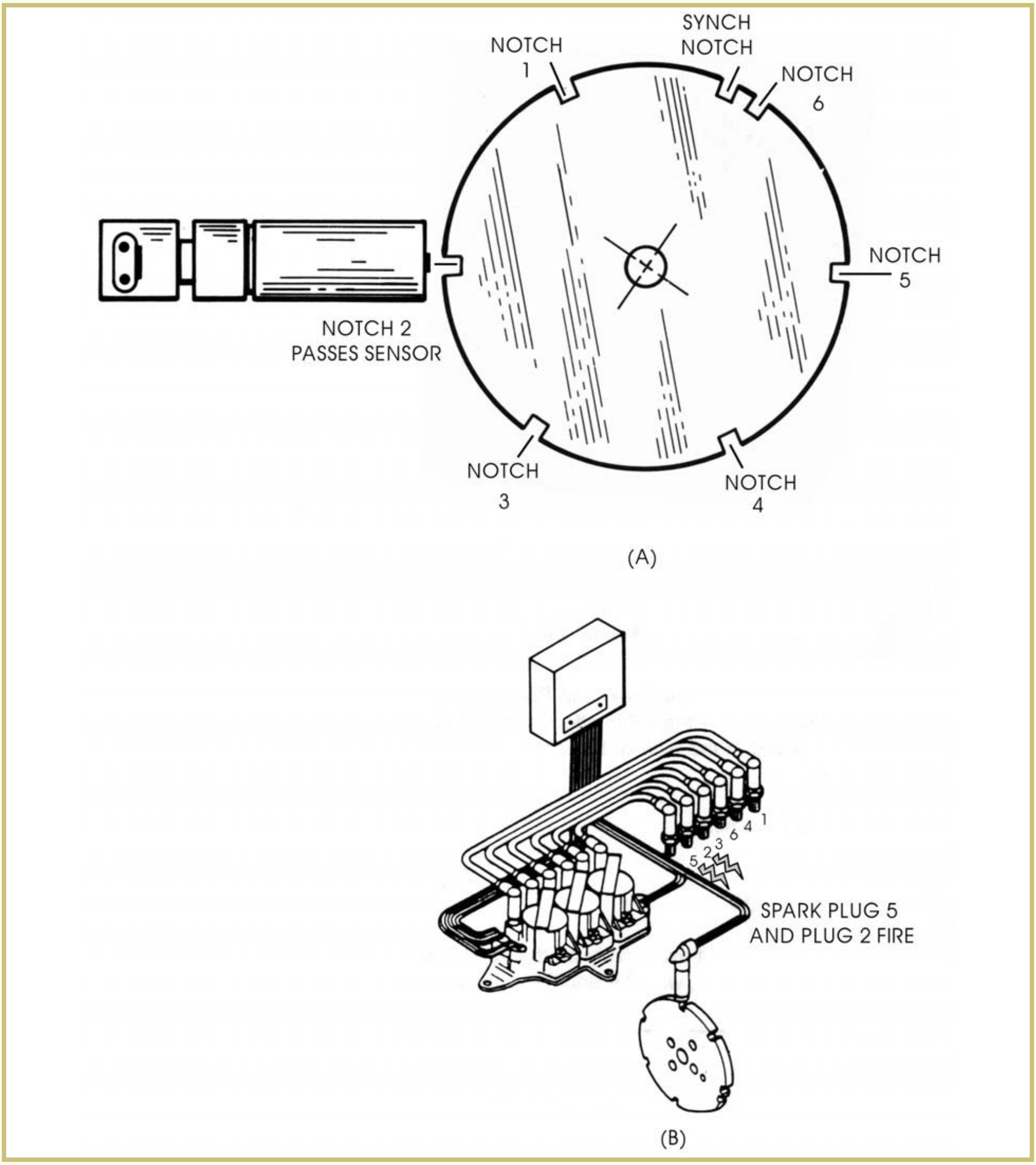



***FIGURE 66—The trigger wheel now rotates to the position shown in Figure 66A. At this point, Notch 2 is passing by the crankshaft position sensor. The sensor sends a voltage signal to the computer system indicating that Notch 2 has passed by the sensor. In Figure 66B, as Notch 2 passes the crankshaft position sensor, the computer signals the ignition module to fire Cylinders 5 and 2.*** (Courtesy of General Motors Corp.)

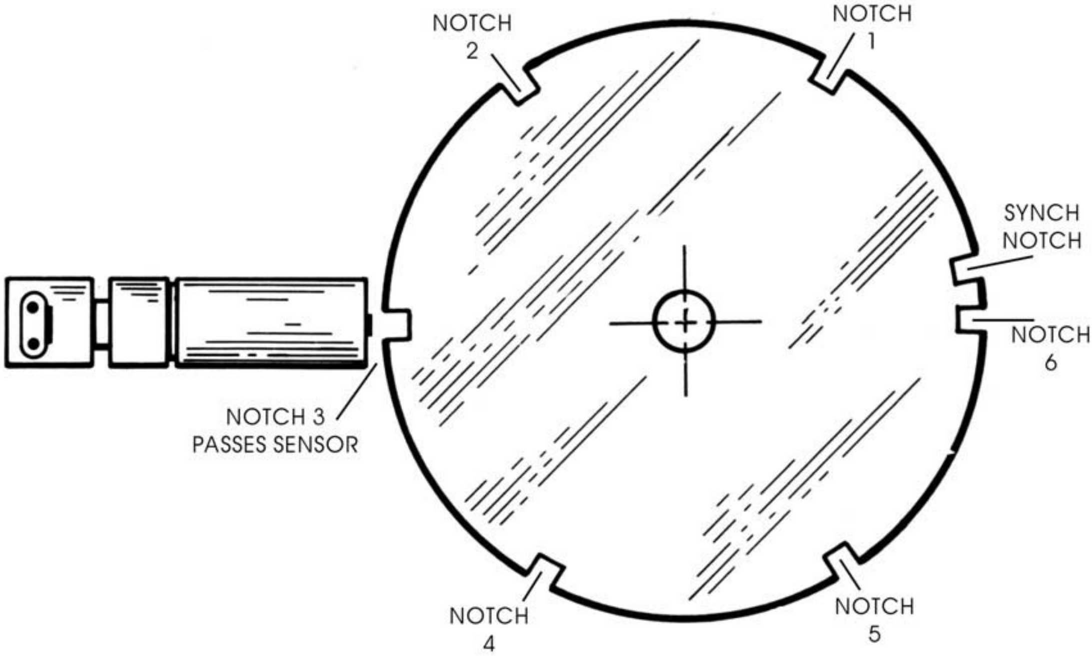



***FIGURE 67—In this illustration, the trigger wheel has rotated so that Notch 3 is passing by the crankshaft position sensor.*** (Courtesy of General Motors Corp.)

The computer again uses the information from its various sensors to determine the proper ignition timing for the current engine conditions. Then, the computer signals the ignition module to fire the coil that's attached to Cylinders 3 and 6 (Figure 68B). Cylinder 3 is on its compression stroke, so the spark at Cylinder 3 ignites the air-and-fuel mixture and forces the piston down in the cylinder. Cylinder 6 is on its exhaust stroke, so the spark in that cylinder is a waste spark that has no effect on engine operation.

The trigger wheel continues to rotate to the position shown in Figure 69. At this time, Notch 5 is passing the crankshaft position sensor, and the sensor sends a signal to the computer indicating the current crankshaft position. The computer recognizes that this is the signal for Notch 5.

The crankshaft continues to rotate until Notch 6 passes the crankshaft position sensor, as shown in Figure 70A. The computer recognizes that this is the signal for Notch 6, so the computer knows that Cylinders 4 and 1 are ready to be fired. The computer determines the proper ignition timing and signals the ignition module to fire Cylinders 4 and 1 (Figure 70B). Cylinder 4 is on its compression stroke, so the spark fires Cylinder 4. Cylinder 1 is on its exhaust stroke, so the spark in that cylinder is a waste spark.

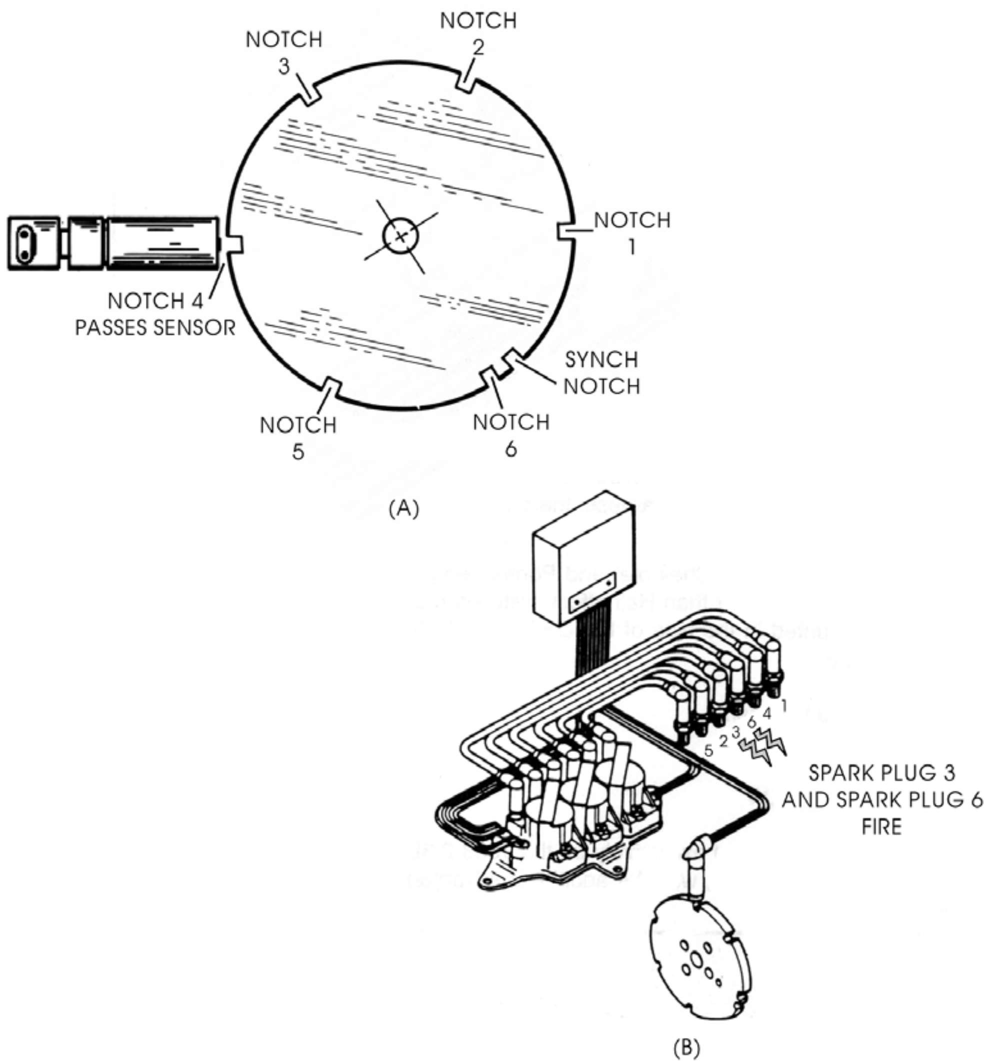



***FIGURE 68—In Figure 68A, the trigger wheel has rotated so that Notch 4 is passing by the crankshaft position sensor. In Figure 68B, as Notch 4 passes the crankshaft position sensor, the computer signals the ignition module to fire Cylinders 3 and 6.*** (Courtesy of General Motors Corp.)

Finally, the trigger wheel rotates until the synch notch passes by the crankshaft position sensor again. Because of the very short space between the Notch 6 signal and the synch notch signal, the computer recognizes the synch notch and begins counting the signals again from this point.

As you learned earlier, it takes two complete crankshaft rotations for all of the engine's cylinders to fire. In our example, the crankshaft has completed one rotation, and power was produced in Cylinders 5, 3, and 4. During the second complete crankshaft rotation, power will be produced in Cylinders 2, 6, and 1, and the sparks that occur in Cylinders 5, 3, and 4 will be waste sparks. This cycle continues as long as the engine is running.

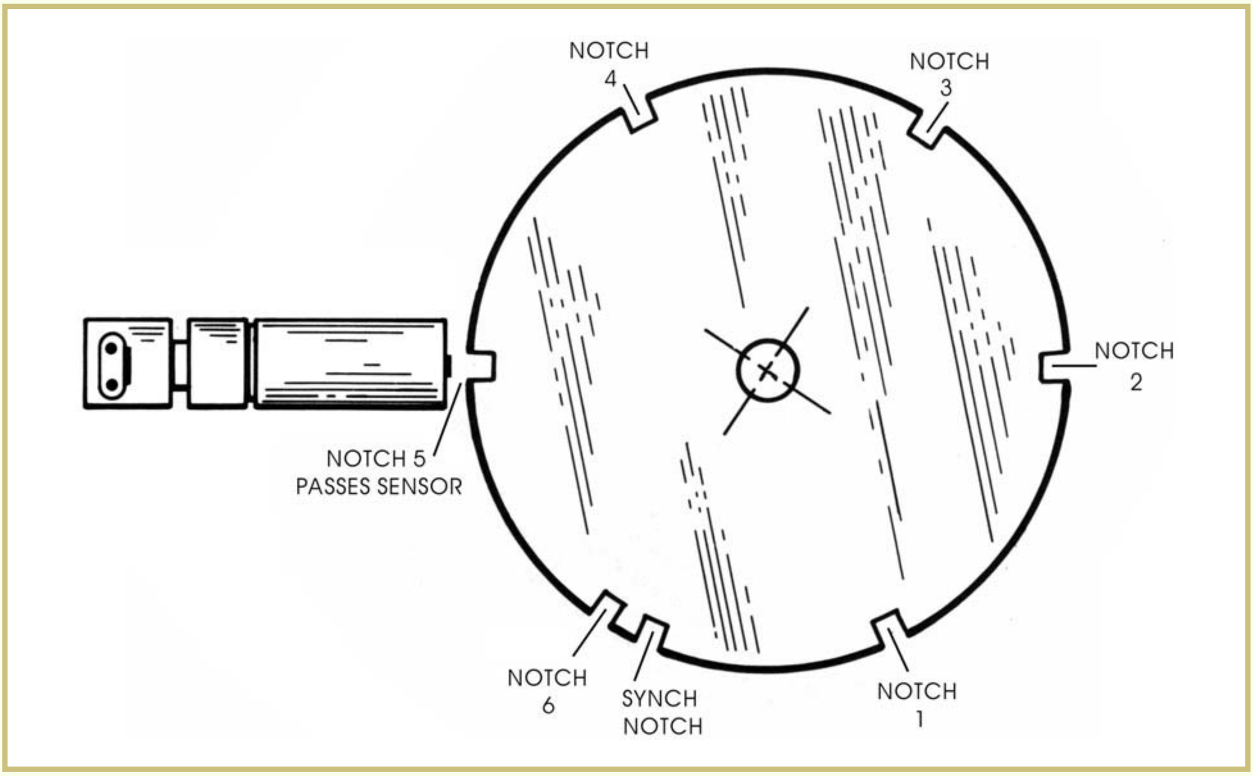



***FIGURE 69—In this figure, the trigger wheel has rotated so that Notch 5 is passing by the crankshaft position sensor.*** (Courtesy of General Motors Corp.)

Because the computer control system determines the proper spark timing, this system, like most direct-fire systems, is relatively simple in construction. First of all, the system is made up of electronic parts that don't wear out or need periodic adjustment. In addition, since the computer is controlling the spark timing, there's no need for a separate vacuum-advance or centrifugal-advance system. In fact, since the system uses a crankshaft position sensor to determine the crankshaft position, the system doesn't require any timing adjustment at all. It's all handled by the computer control system.

Now let's look at a direct-fire system that's used in many Chrysler vehicles. This system uses a crankshaft position sensor to send signals to the computer, just like the system you learned about previously. However, instead of using a notched wheel on the crankshaft, this system uses a drive plate that's attached to the end of the crankshaft at the rear of the engine. This system also uses a camshaft position sensor to help the computer determine which cylinders are ready to be fired. Each ignition coil in the coil pack fires two cylinders at the same time.

The drive plate for this system is shown in Figure 71. Note that the plate contains groups of slots that represent the crankshaft positions, rather than notches. Each set of four holes represents one pair of cylinders. There are three groups of slots, so you can see that this engine has six cylinders.

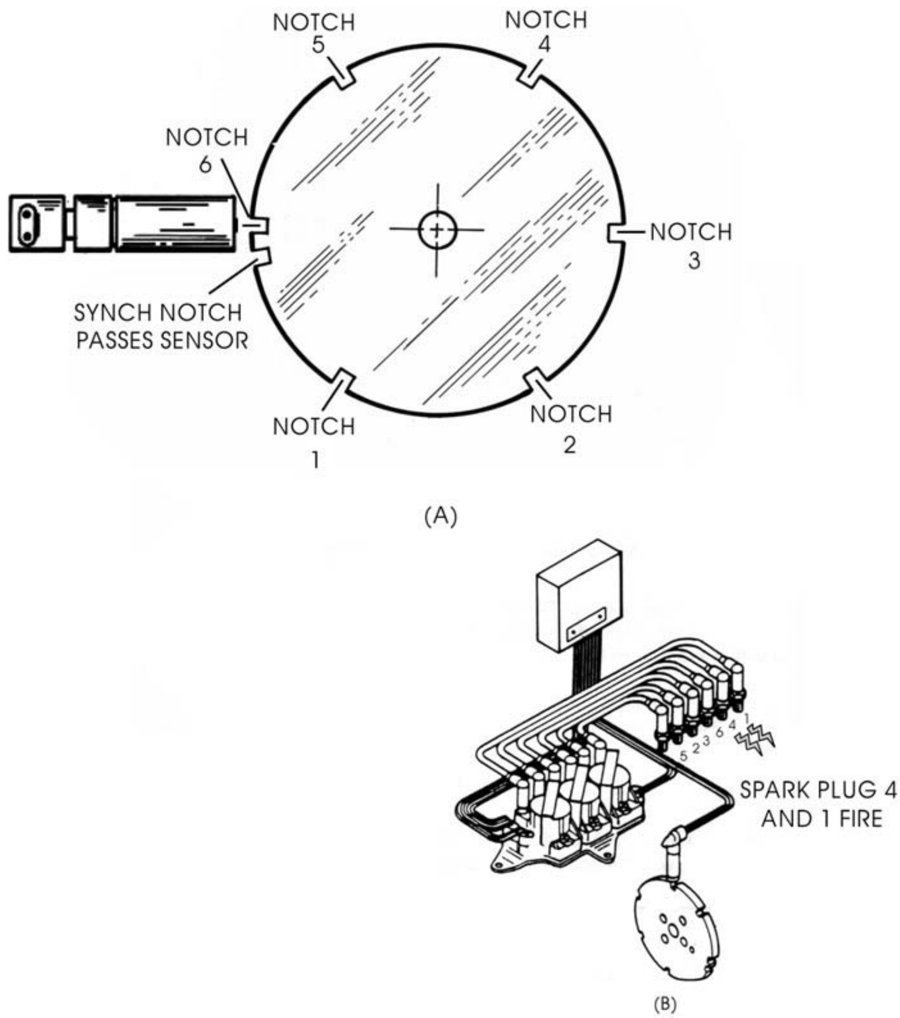
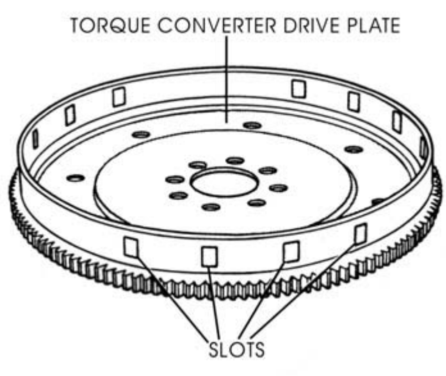



**FIGURE 70—In Figure 70A, the trigger wheel has rotated so that Notch 6 is passing by the crankshaft position sensor. In Figure 70B, as Notch 6 passes the crankshaft position sensor, the computer signals the ignition module to fire Cylinders 4 and 1.** (Courtesy of General Motors Corp.)

**FIGURE 71—A drive plate for a Chrysler direct-fire ignition system is shown here.** (Courtesy of Chrysler Corporation)



In this system, the crankshaft position sensor is mounted in the back of the engine so the end of the sensor is placed right next to the drive plate. The drive plate is attached to the crankshaft, so as the engine runs, the drive plate rotates with the crankshaft. As the drive plate rotates, the holes in the drive plate move past the crankshaft position sensor. Each time one of the holes passes by the sensor, the sensor produces a signal that's sent to the computer control system.

In this system, the leading edge of the first hole in a group is located 9 degrees before the cylinder reaches TDC. This is considered the base or beginning timing point for the engine. The second hole in each group is placed 29 degrees before TDC; the third hole in each group is placed 49 degrees before TDC; and the fourth hole in each group is placed 69 degrees before TDC.

Each hole helps the computer identify the current crankshaft position and fire the spark plug at the correct time. The crankshaft position sensor sends a signal each time a hole passes the sensor. The first hole signals the computer that the cylinder is now 69 degrees before TDC. The second hole signals the computer that the cylinder is now 49 degrees before TDC. The third hole signals the computer that the cylinder is 29 degrees before TDC. The fourth hole signals the computer that the cylinder is 9 degrees before TDC. The computer then fires the spark plugs at the 9-degree hole.

As you can see, each pair of cylinders in the engine has its own set of holes on the drive plate. However, each hole set is the same. There's no way for the computer to know which set of holes goes with which pair of cylinders. For this reason, this system also uses a camshaft position sensor. The camshaft position sensor sends a signal to the computer that identifies the cylinder pair that's ready to be fired.

The camshaft position sensor operates much like a crankshaft position sensor, using a notched wheel to identify the cylinder positions. This camshaft position sensor is mounted in the engine's front cover so that the end of the sensor is next to the timing gear on the end of the camshaft. The notched trigger wheel that's used in this system is shown in Figure 72. Each notch helps the camshaft position sensor determine which cylinders are ready to be fired. The signals from the camshaft position sensor tell the computer which cylinder pair matches the set of holes that's coming up on the crankshaft drive plate. In addition, the computer also uses the signals from the camshaft position sensor to operate the fuel-injection system. (You'll learn about fuel systems in detail in a later study unit.)

Let's discuss the cylinder notches labeled on the camshaft trigger wheel in more detail. Note that the single notches in the wheel correspond to Cylinder 2 and Cylinder 5. The double notches in the wheel correspond to Cylinder 3 and Cylinder 6. The triple notch corresponds to Cylinder 4. The long area on the wheel that has no notches corresponds to Cylinder 1.

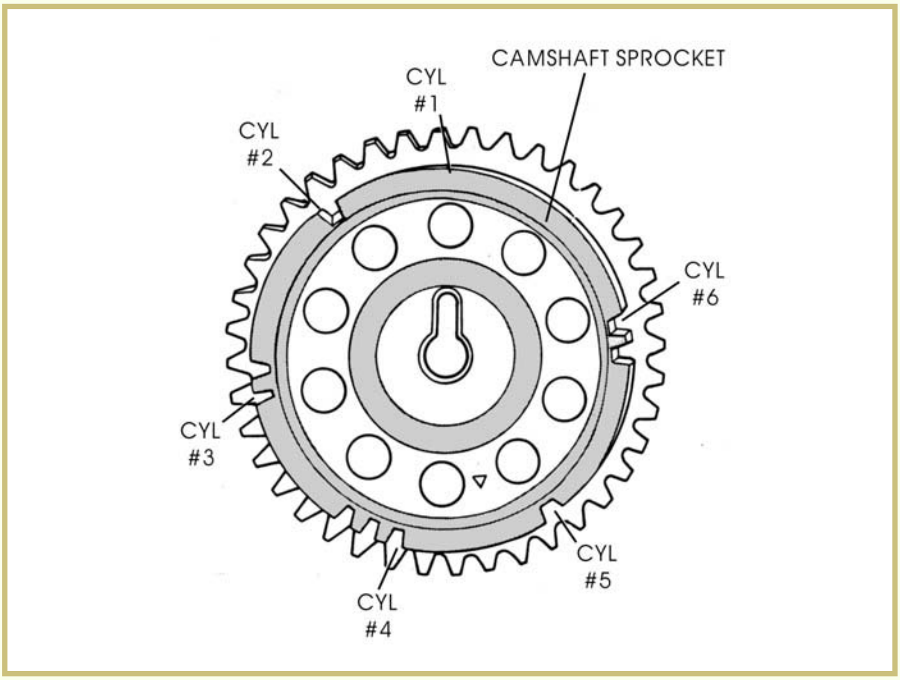



***FIGURE 72—The camshaft gear that's used in this ignition system is shown here.*** (Courtesy of Chrysler Corporation)

The firing order of this engine is 1-2-3-4-5-6. Cylinders 2 and 5 are fired together, Cylinders 3 and 6 are fired together, and Cylinders 4 and 1 are fired together.

As the engine operates, the computer uses the signals from the crankshaft position sensor to determine the current crankshaft position. The computer uses the signals from the camshaft position sensor to identify which pair of cylinders to fire. Thus, the *crankshaft sensor* tells the computer *when* to fire, and the *camshaft sensor* tells the computer *which cylinders* to fire.

As the camshaft rotates, the first single notch on the camshaft gear passes by the camshaft position sensor. The camshaft position sensor sends one signal pulse to the computer, and the computer recognizes that Cylinder 2 is approaching TDC. Then, the computer waits until the four slots in the drive plate rotate past the crankshaft position sensor. When the fourth slot passes the crankshaft position sensor, the crankshaft position sensor signals the computer that it's the right time to fire. The computer then fires the spark plugs for Cylinders 2 and 5. Cylinder 2 produces power, and Cylinder 5 produces a waste spark.

The camshaft continues to rotate, and the double notch labeled Cylinder 3 passes the camshaft position sensor. The camshaft position sensor sends two quick signal pulses to the computer, and the computer recognizes that Cylinder 3 is approaching TDC. Then, the computer waits until the four slots in the drive plate rotate past the crankshaft position sensor. When the fourth slot passes the crankshaft position sensor, the crankshaft position sensor signals the computer that it's the right time to fire. The computer then fires the spark plugs for Cylinders 3 and 6. Cylinder 3 produces power, and Cylinder 6 produces a waste spark.

The camshaft continues to rotate, and the triple notch labeled Cylinder 4 passes the camshaft position sensor. The camshaft position sensor sends three quick signal pulses to the computer, and the computer recognizes that Cylinder 4 is approaching TDC. The computer waits until the four slots in the drive plate pass the crankshaft position sensor. When the fourth slot passes the crankshaft position sensor, the crankshaft position sensor signals the computer that it's the right time to fire. The computer then fires the spark plugs for Cylinders 4 and 1. Cylinder 4 produces power, and Cylinder 1 produces a waste spark.

Next, as the camshaft continues to rotate, the single notch labeled Cylinder 5 passes the camshaft position sensor. The camshaft position sensor sends one signal pulse to the computer, and the computer recognizes that Cylinder 5 is approaching TDC. The computer waits until the four slots in the drive plate pass the crankshaft position sensor. When the fourth slot passes the crankshaft position sensor, the computer fires the spark plugs for Cylinders 5 and 2. Cylinder 5 produces power, and Cylinder 2 produces a waste spark. (Note that a single notch is used to fire both Cylinder 2 and Cylinder 5. However, since Cylinder 5 and Cylinder 2 are both fired by the same ignition coil, the computer doesn't have to distinguish between the two single notches on the camshaft gear.)

The camshaft continues to rotate, and the double notch labeled Cylinder 6 passes the camshaft position sensor. The camshaft position sensor sends two quick signal pulses to the computer, and the computer recognizes that Cylinder 6 is approaching TDC. The computer waits until the four slots in the drive plate pass the crankshaft position sensor. When the fourth slot passes the crankshaft position sensor, the computer fires the spark plugs for Cylinders 6 and 3. Cylinder 6 produces power, and Cylinder 3 produces a waste spark.

Now, look at the area of the camshaft gear that's labeled Cylinder 1. This area of the camshaft gear doesn't have notches on it. When this area passes by the camshaft position sensor, no signal is sent to the computer, and the computer recognizes that Cylinder 1 is approaching TDC. The computer waits until the four slots in the drive plate pass the crankshaft position sensor. When the fourth slot passes the crankshaft position sensor, the computer fires the spark plugs for Cylinders 1 and 4. Cylinder 1 produces power, and Cylinder 4 produces a waste spark.

At this point, the camshaft has made one complete revolution, and we're back where we started from. This process continues over and over as the engine operates, with the computer firing each of the cylinders in their proper firing order. Keep in mind that the camshaft rotates at one-half the speed of the crankshaft. Therefore, after the crankshaft has made two complete revolutions, the camshaft will have made only one revolution.

Now, let's look at one more type of direct-fire ignition system. This system uses a notched trigger wheel and a crankshaft position sensor to monitor the crankshaft position. An illustration of the wheel and sensor used in this system is shown in Figure 73.

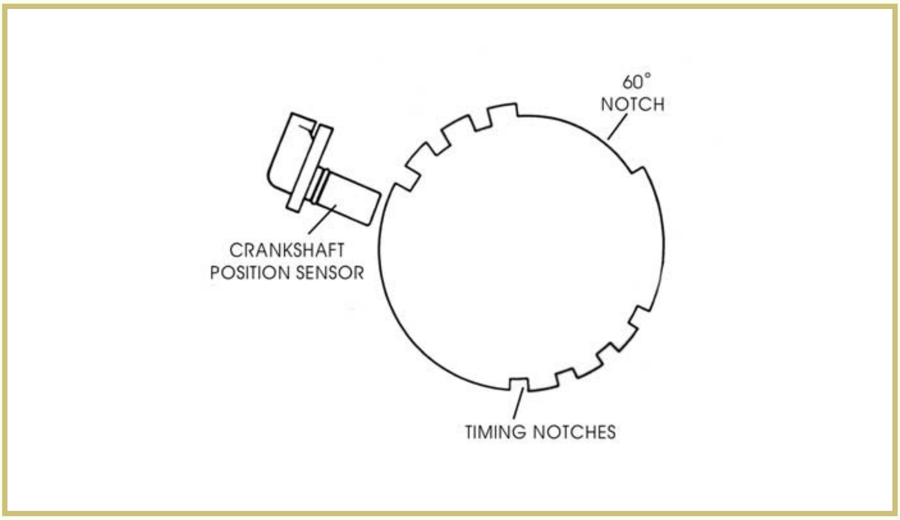



***FIGURE 73—An illustration of the wheel and sensor used in this system is shown here.*** (Courtesy of Chrysler Corporation)

Note that this trigger wheel has only two sets of four notches, because it's used in a four-cylinder engine. Since each ignition coil fires two cylinders, only two sets of crankshaft position notches are needed. The first notch on the wheel is located at 9 degrees before TDC, the second notch is located at 29 degrees before TDC, the third notch is located at 49 degrees before TDC, and the fourth notch is located at 69 degrees before TDC.

In one set of notches in the trigger wheel in Figure 73, the last notch is particularly long. In fact, the notch continues for 60 degrees of crankshaft rotation. When this long notch passes over the crankshaft position sensor, the sensor sends a very long pulse signal to the computer. When the computer receives this long signal, it recognizes that the next set of notches will be for Cylinders 1 and 4. The other set of notches corresponds to Cylinders 2 and 3.

As in most in-line, four-cylinder engines, the firing order for this engine is 1-3-4-2 (Figure 74). Therefore, the ignition coils are arranged so that Cylinder 1 and Cylinder 4 are fired by the same coil, and Cylinders 3 and 2 are fired by the other coil.

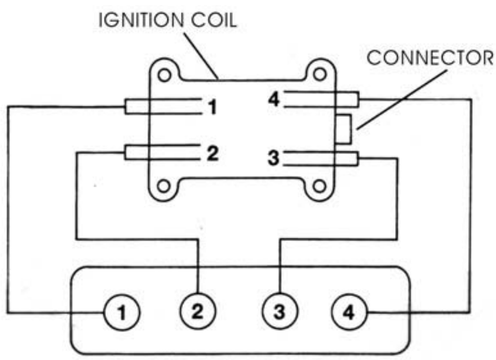



***FIGURE 74—The firing order for this in-line, four-cylinder engine is 1-3-4-2.***
(Courtesy of Chrysler Corp.)

This system uses a camshaft position sensor to help the computer identify the cylinders that are ready to fire. As in the ignition system we examined previously, the *crankshaft position sensor* in this system tells the computer *when* to fire the cylinder pairs, and the *camshaft position sensor* tells the computer *which* cylinders to fire.

However, the camshaft position sensor in this system is a little different from the other camshaft position sensor you've seen. In the previous system, the camshaft position sensor was triggered by a notched wheel on the camshaft gear. However, in this system, the camshaft position sensor is triggered by a target magnet (Figure 75).

The target magnet in this system is a magnetic disc that's attached to the end of the camshaft. The magnetic disc has four different poles spaced apart from one another. Two of the poles are north poles, and two are south poles. The camshaft position sensor is placed over the magnetic disc as shown in Figure 76. The magnetic disc then rotates with the camshaft, and the camshaft position sensor monitors the surface of the magnetic disc. Each time a north pole passes by the camshaft position sensor, the sensor sends a voltage signal to the computer. Each time a south pole passes by the sensor, no signal is sent.

The computer system uses the signals from the camshaft position sensor and the crankshaft position sensor to keep track of the cylinders that are ready to fire. For example, if the long notch on the trigger wheel passes by the crankshaft sensor, and the camshaft sensor sends no voltage signal, Cylinder 1 is ready to fire. Therefore, whenever these two conditions are met, the computer knows that Cylinder 1 is ready to fire. The computer determines the proper ignition timing and then fires Cylinder 1 and Cylinder 4. Cylinder 1 produces power, and Cylinder 4 produces a waste spark. Once the computer knows where Cylinder 1 is located, it can simply follow the engine firing order to fire the remaining cylinders.

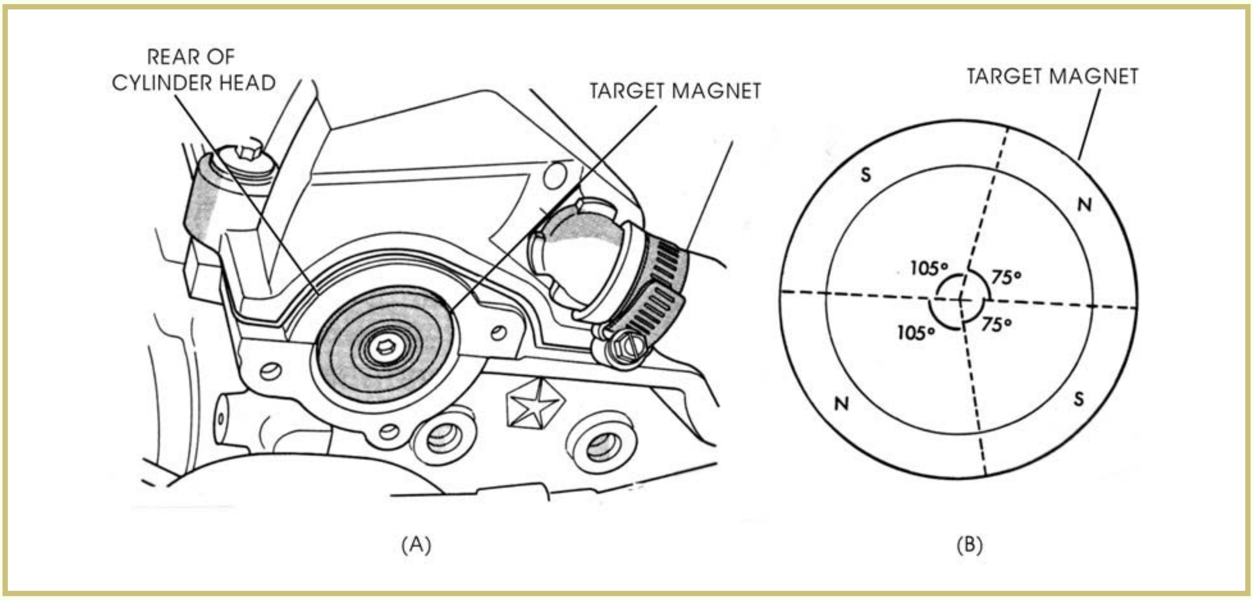



***FIGURE 75—The camshaft position sensor in this system is triggered by a target magnet (Figure 75A). The target magnet is a magnetic disc that contains four different poles (Figure 75B).*** (Courtesy of Chrysler Corporation)

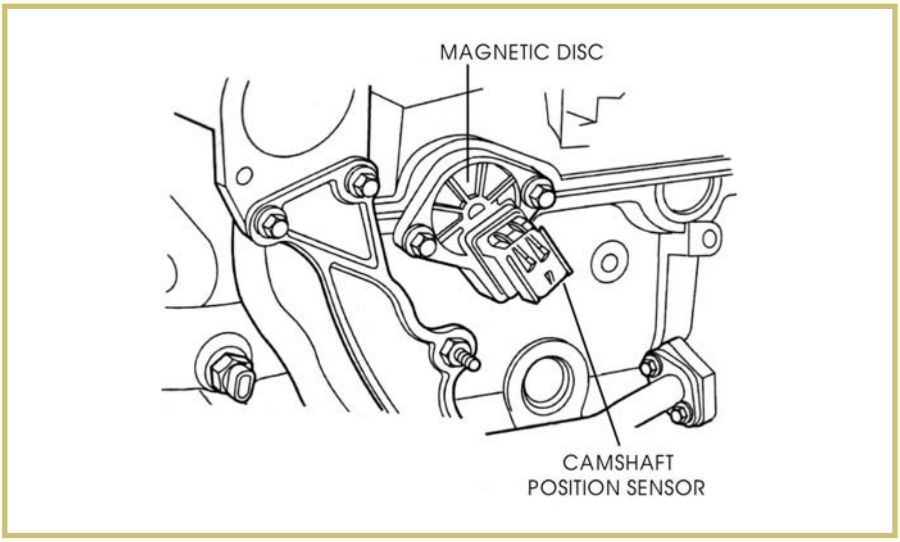



***FIGURE 76—The camshaft position sensor is placed over the magnetic disc. As the magnetic disc rotates with the camshaft, the sensor monitors the surface of the magnetic disc.*** (Courtesy of Chrysler Corporation)

In this section of your study unit, you learned about several direct-fire ignition systems in detail. As you now know, many different variations of these systems are used in modern vehicles. In fact, one manufacturer may use several types of ignition systems in its car models.

Therefore, two vehicles that were made by the same company in the same year may contain different types of ignition systems. For this reason, all technicians need to refer to service manuals to determine the exact operation of the ignition system and the location of the ignition components. In general, however, all systems operate in a similar manner. If you understand the basic principles of direct-fire ignition systems, you'll adapt easily to any system you may come across.

Now, take a few moments to review what you've learned by completing *Power Check 6*.

# *Power Check 6*

**Questions 1–5: Indicate whether the following statements are True or False.**

_____ 1. In most direct-fire ignition systems, one ignition coil is used to fire each pair of cylinders.

_____ 2. As an engine's speed increases, the spark must occur later in the engine cycle to produce the maximum power.

_____ 3. One way to control spark knock is to retard the ignition timing advance.

_____ 4. A direct-fire ignition system uses a distributor to direct the high voltage from the ignition coil to the spark plugs.

_____ 5. Some direct-fire ignition systems use two crankshaft position sensors to monitor the crankshaft position in the engine.

6. In a direct-fire ignition system, the ignition module and the ignition coils are often contained within one housing that's called a _______.

7. In a direct-fire ignition system, the ignition module takes the place of the _______.

8. A device called a ________ is used to monitor the crankshaft position at all times in a direct-fire ignition system.

9. Two common types of crankshaft position sensors are the _______ sensor and the _______ sensor.

10. In a notched trigger wheel, an extra notch that's used to identify the starting point in the firing order is called a _______.

11. A spark that fires in a cylinder without causing fuel ignition is called a _______ spark.

12. When the air-and-fuel mixture in a cylinder explodes instead of burning, a condition called _______ or _______ can occur in the engine.

**Check your answers with those on page 100.**

# SUMMARY

In this study unit, you learned how a simple circuit operates. You learned that a typical circuit includes a power source, conductors, a load, and a switch. Circuits can be closed or open. In a closed circuit, the switch is in the ON position. In an open circuit, the switch is in the OFF position.

An atom is the smallest particle of an element that still retains the properties of that element. All atoms are made up of tiny atomic particles called protons, neutrons, and electrons. Electrons have a negative charge, protons have a positive charge, and neutrons are neutral. Any substance in which electrons can move freely is called an electrical conductor.

Electrical circuits have three basic quantities associated with them: current, voltage, and resistance. Current is measured in units called amperes or amps. Voltage is a measure of the amount of electrical potential in a circuit. Resistance is the force of opposition that works against the flow of electric current in a circuit. As the resistance in a circuit increases, the current decreases. If the resistance in a circuit decreases, the current increases.

You learned that an ignition system that uses contact points is called a point-type ignition system, and an ignition system that uses an electronic triggering device is called an electronic ignition system.

You also learned about spark plugs in this study unit. You know that spark plugs allow voltage to jump across a gap, which produces a spark that ignites the engine's fuel.

Today, automobiles use electronic ignition systems rather than point-type or conventional systems. Electronic systems can tolerate very high voltages because a transistor is used to turn the primary circuit on and off. The type of triggering device used in an engine depends on the vehicle's make and model. Most engines use either a magnetic-pickup, Hall-effect, or optical triggering device.

You also learned about ignition timing in this study unit. You know that the ignition system must be timed so that it closely matches the operation of the engine. Sometimes it's necessary to change the ignition timing so that the spark plug fires earlier than a cylinder's TDC point; other times, the spark should occur after a cylinder's TDC point. As you know, this is referred to as either advancing or retarding the ignition timing.

At the end of this study unit, you learned how a direct-fire ignition system works. Then, you read some real-life examples to enhance your learning of how a direct-fire ignition system operates.

# Power Check Answers

## 1

1. voltage
2. amperes
3. ohms (the unit of electrical resistance)
4. current
5. magnetic
6. ohms
7. resistance
8. True
9. False
10. True
11. False
12. True

## 2

1. firing order
2. lead-acid storage battery
3. distributor
4. secondary winding
5. spark plug gap
6. coil
7. ignition coil
8. five
9. 12
10. ignition coil
11. primary, secondary
12. distributor shaft
13. resistor
14. primary, secondary
15. boots
16. distributor cap
17. False
18. False
19. False
20. True
21. True
22. True
23. True
24. False
25. True
26. False
27. True
28. False

## 3

1. float
2. point gap
3. dwell tester
4. condenser
5. conventional
6. True
7. False
8. True
9. False
10. True

## 4

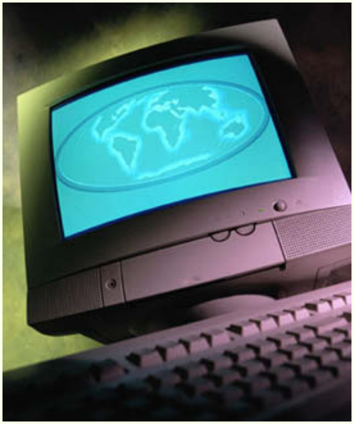
1. distributor
2. ignition module
3. shutter blades
4. False
5. True

## 5

1. advancing
2. retarding
3. vacuum-advance mechanism
4. True

## 6

1. True
2. False
3. True
4. False
5. True
6. coil pack
7. distributor
8. crankshaft position sensor
9. magnetic, Hall-effect
10. synch notch
11. waste
12. spark knock, detonation



# ONLINE EXAMINATION

For the online exam, you must use this

EXAMINATION NUMBER:

00400701

**When you're confident that you've mastered the material in your studies, you can complete your examination online. Follow these instructions:**

1. Write down the eight-digit examination number shown in the box above.
2. Click the **Back** button on your browser.
3. Click the **Take an Exam** button near the top of the screen.
4. Type in the eight-digit examination number.

Study Unit

# Ignition System Maintenance

# *Preview*

In this study unit, you'll learn how to maintain ignition systems and troubleshoot faulty ignition system components. You'll also learn how to maintain conventional and electronic ignition systems.

When you complete this study unit, you'll be able to

- Outline the steps needed to service an ignition system
- Describe how you would perform an ignition system tune-up
- Differentiate between the steps used to maintain a conventional and an electronic ignition system
- Explain how to use an oscilloscope as an automotive ignition system diagnostic tool
- List the steps used to troubleshoot ignition systems

# Contents

# Ignition System Maintenance

## IGNITION SYSTEM SERVICING

### Introduction

At this point in your program, you know that an ignition system uses electricity from a vehicle's battery, increases the battery voltage significantly, and then sends this high voltage to the spark plugs. The spark plugs produce a spark that ignites the air-and-fuel mixture that's been compressed in an engine's combustion chamber. The resulting burning of the fuel in the combustion chamber forces the piston down and gets the crankshaft turning.

Because an ignition system performs such a vital function, it's important to keep its components in working order. Any defect in the ignition system can result in a loss of engine power, a reduction in fuel mileage, and even engine failure. For this reason, the tune-up of a vehicle's ignition system is one of the most important procedures performed on an automobile. An ignition system tune-up usually involves the inspection, adjustment, and replacement of all the ignition system components, especially the spark plugs.

The servicing interval for ignition system components differs from vehicle to vehicle. The vehicle's service manual usually contains a section that lists the recommended servicing interval for a particular vehicle's ignition system. This section is called the *maintenance schedule*. The maintenance schedule contains information such as how often spark plugs, oil, and oil filters should be changed.

As you know, several basic types of ignition systems are used in automobiles. Because of the variations in the components that make up these systems, the procedures differ slightly from system to system. Let's begin by discussing how to service the components common to all ignition systems—the spark plugs, ignition coils, and spark plug wires.

### Servicing Spark Plugs

As you learned, an engine's spark plugs create sparks that ignite the air-and-fuel mixture in the combustion chambers. Because the end of a spark plug is located directly in the combustion chamber, spark plugs are exposed to very high temperatures and pressures. In addition, the high voltage from the coil is sent through the spark plug to its end. Electricity jumps from the center electrode across the air gap to the grounding electrode. The heat produced when the electricity jumps across the air gap can actually cause part of the electrode to burn or melt. Therefore, spark plugs wear out over time and need to be inspected and/or replaced periodically.

Worn or dirty spark plugs are the most common cause of sluggish performance and misfiring under acceleration. Spark plugs are normally replaced during any tune-up. In the past, spark plugs were cleaned rather than replaced if they had been used less than 12,000 miles. Spark plugs in electronic ignition systems usually last up to 30,000 miles and are replaced when an engine is tuned up.

## Removing Spark Plugs

To inspect or replace spark plugs, you must first remove them from the engine. The first step to removing spark plugs is to disconnect the spark plug wires. Each spark plug has a spark plug wire and a spark plug connector attached to it.

In most cases, the spark plug wire connector simply slips over the end of the spark plug. However, over time, it may get stuck to the spark plug. Therefore, the spark plug wire may not always pull off easily. To prevent damage to the spark plug wire, never pull on the spark plug wire itself. Instead, pull on the terminal boot that's attached to the plug. If the boot is tight, twist it gently to loosen it from the plug.

If the boot is attached to the plug very tightly or if the spark plug wire is hard to reach, it may be necessary to use a special *spark plug wire removing tool* to prevent damage to the wire. This tool usually resembles a pair of pliers, as shown in Figure 1.

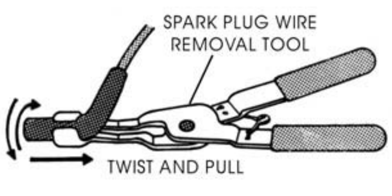



***FIGURE 1—A spark plug wire should be removed from a spark plug with a special tool like the one shown here. Using a spark plug wire removal tool will prevent damage to the wires.***

Keep in mind that when spark plug wires are reinstalled, they must be reconnected to the same plugs. This is necessary to keep the firing order in the proper sequence. For this reason, it's a good idea to mark the spark plug wires so that you can reinstall them on the correct plugs in the proper sequence. Some technicians place a piece of masking tape on each plug wire, so they can write the cylinder number on the tape.

Once the spark plug wires are disconnected, remove any dirt and debris from around the spark plugs with compressed air. Once the area around the spark plugs is clean, you're ready to remove the plugs from the cylinder head.

Remember that the spark plug insulator is usually made of porcelain. As you learned, the porcelain insulator prevents electricity from leaking out of the plug. However, porcelain is very fragile. Therefore, when removing or installing a spark plug, be careful not to damage or break the insulator. To prevent the insulator from being damaged, a specially designed socket wrench called a *spark plug socket* is used to remove a spark plug (Figure 2).

The spark plug socket closely resembles a traditional deep socket. However, unlike a deep socket, the spark plug socket has a soft rubber bushing inside that fits around the insulator to protect it from damage. As you learned, the spark plugs used in modern automobiles vary slightly in thread size, length, and design. However, the hexagon-shaped area of the spark plug comes in only two common sizes—$5/8$-inch and $13/16$-inch. Therefore, spark plug sockets are available in both the $5/8$- and the $13/16$-inch size.

As you remove the spark plugs, keep the plugs in the order in which they were removed from the engine. For troubleshooting purposes, it's

***FIGURE 2—When removing or installing a spark plug, be careful not to damage or break the spark plug insulator. A special spark plug socket should always be used to remove a spark plug.*** (Courtesy of Snap-On Tool Company, Copyright Owner)

important to know which plug came from which cylinder. If you discover a problem with one of the plugs, you may need to know which cylinder the bad plug came from in order to correct the problem.

## Inspecting the Plugs

Once the plugs have been removed, inspect them to determine their condition. The condition of a spark plug tells you a lot about how an engine is operating. In fact, many automotive technicians remove the spark plugs first when troubleshooting a faulty engine. Use the spark plug diagnostic chart in Figure 3 as a guide to identify engine problems.

Always check to make certain the spark plug is the correct type for the engine. Then, check the condition of the electrodes. A clean, new spark plug is shown in Figure 4A on page 6. Note that the bottom surface of the center electrode is flat and that the surfaces of the lower electrode are squared. A used plug in normal condition looks much the same, except the electrodes are gray or light tan from carbon deposits. (Carbon deposits are produced during normal fuel combustion.)

Next, inspect each plug for *oil fouling*. An oil-fouled plug is shown in Figure 4B. Oil fouling causes the end of a plug to be saturated with wet, sooty, black oil deposits. In a four-stroke engine, an oil-fouled plug may indicate that the piston rings aren't sealing the cylinder properly, or oil may be passing through the valve stem area. Sometimes, a clogged breather can cause an oil-fouled plug. (A breather is a vent in the crankcase.) A clogged breather may prevent the crankcase from venting properly, and, as a result, pressure builds up in the crankcase. This pressure causes oil to be pushed up past the piston rings and into the combustion chamber. The oil in the combustion chamber then fouls the spark plug. Excessive smoke at the exhaust pipe may also indicate oil fouling.

A spark plug that was fouled by excessive fuel is shown in Figure 4C. *Fuel fouling*, also called *carbon fouling*, is indicated by dry, black, fluffy deposits on the spark plug electrodes. However, the plug won't have the caked or lumpy appearance of an oil-fouled spark plug.

Fuel fouling is most often caused by an air-and-fuel mixture that's too rich. However, a blocked exhaust or faulty valve can also cause fuel fouling. If the problem is severe, you might be able to smell fuel on the spark plug.

A weak ignition can also cause fuel fouling. For instance, if the spark is weak because of a faulty cable, electronic module, coil, condenser, or because of weak points, a plug can become fuel-fouled. In addition, if the spark plug is too cold for that particular engine, it may become fuel-fouled.

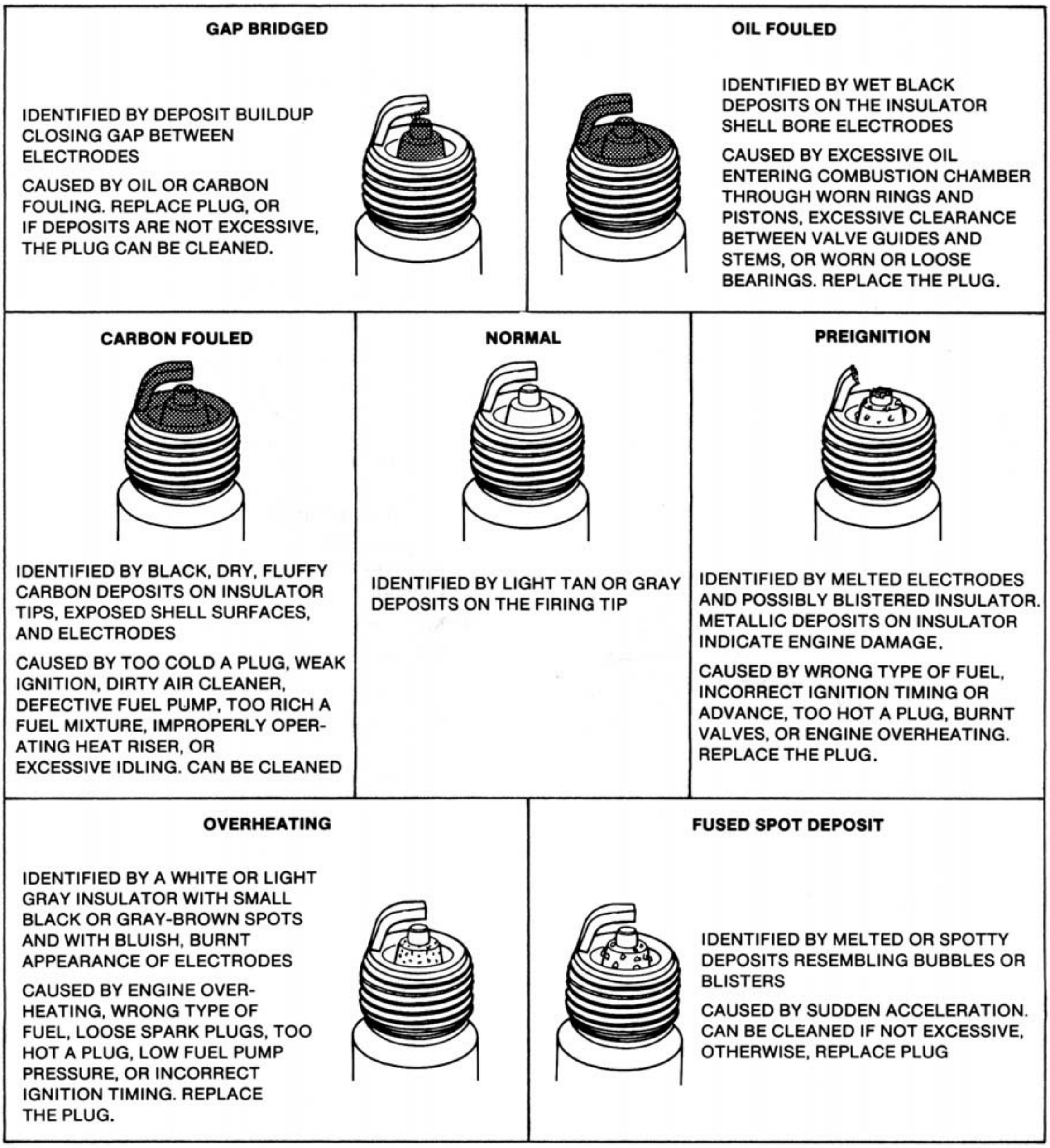



***FIGURE 3—The condition of a spark plug can tell you a lot about the engine conditions and can pinpoint the causes of poor engine performance. Use this guide to judge spark plug condition and identify engine problems.*** (Courtesy of Ford Motor Company)

Both oil fouling and fuel fouling can cause a spark plug condition known as a *bridged gap*. In this situation, carbon or oil deposits build up in the spark plug gap until it becomes completely blocked. A bridged gap seriously affects the ignition's efficiency.

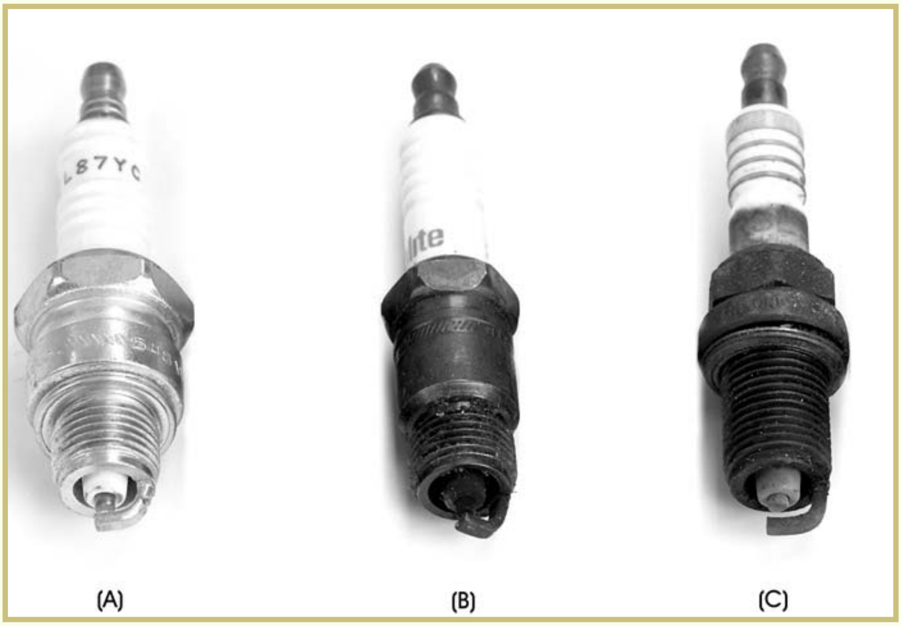



***FIGURE 4—A clean, new spark plug is shown in Figure 4A; an oil-fouled plug is shown in Figure 4B; and a plug that was fouled by excessive fuel is shown in Figure 4C.***

Note that the deposits caused by fuel and oil fouling can usually be cleaned off a spark plug, and the plug can then be reinstalled in the cylinder head. However, spark plugs are inexpensive, so it's better to replace them during an engine tune-up.

When inspecting a spark plug, you may find that the plug's electrode or insulator is damaged. In extreme situations, the electrodes may be heavily pitted and the insulator broken or cracked. This damage is usually caused by a plug that's too hot for a particular engine. A physical impact can also damage a plug. For example, if a piston or ring part breaks and hits the spark plug, you may find damaged or bent electrodes or cracked and broken insulators. Or, if the spark plug reach is too long, the piston head may strike the electrodes. The most common cause of physical damage, however, is debris or foreign objects in the cylinder. Sometimes, a bolt or washer may loosen and actually be pulled into the cylinder. The foreign object then strikes the spark plug electrodes when the piston rises.

After many hours of use, a spark plug's electrodes begin to erode. While new electrodes have flat surfaces, an electrode with an eroded center appears rounded. An electrode with an eroded side has a curve on its inside surface. Plugs with eroded electrodes should be replaced.

Plug heat ranges are changed depending on the condition of the plug that's removed from the cylinder head. For example, if a plug looks dirty, it's usually removed and a hotter plug is installed in its place. Likewise, a cooler plug is installed if the plug shows signs of heat damage such as a cracked or chipped insulator. The vehicle's service manual usually recommends the type of plug that should be used in an engine.

Always follow these recommendations to prevent the types of problems you just learned about.

Never sand, sandblast, or file a spark plug and then replace it in an engine. Using sandpaper or a file leaves tiny grooves on the electrodes. As the engine operates, these grooves either burn off or collect deposits. Also, sandblasting and filing leave tiny particles of sand or metal on the electrodes. These particles get into the engine's cylinder and cause serious damage.

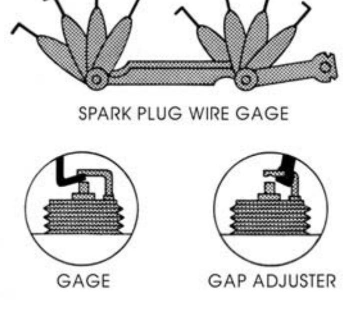
In the past, some spark plug manufacturers produced small sandblasting cleaning machines designed for their spark plugs. However, most manufacturers now advise against using these machines. Remember, spark plugs are inexpensive. If you're ever in doubt of a plug's quality, simply replace it.

## Checking the Spark Plug Gap

The next step in the spark plug inspection process is to check the spark plug gap. The width of the air gap between a spark plug's electrodes is a precision measurement that's determined by the spark plug manufacturer. In order for the plug to work properly, the gap between the electrodes must be the correct width. Therefore, before you install a spark plug in an engine, you should measure the air gap between the electrodes. The service manual usually lists the proper air gap for the spark plug.

The spark plug gap can be checked using a *gapping tool.* A gapping tool is a measuring device with small wire prongs of different thicknesses. The wire prongs are designed to measure in thousandths of an inch, and each one is labeled with its thickness. A spark plug gapping tool is shown in Figure 5. While the plug gap can also be measured with a feeler gage or a ramp gage, these tools may be less accurate.

***FIGURE 5—The spark plug gap is set with a special spark plug wire gage like the one shown here.***



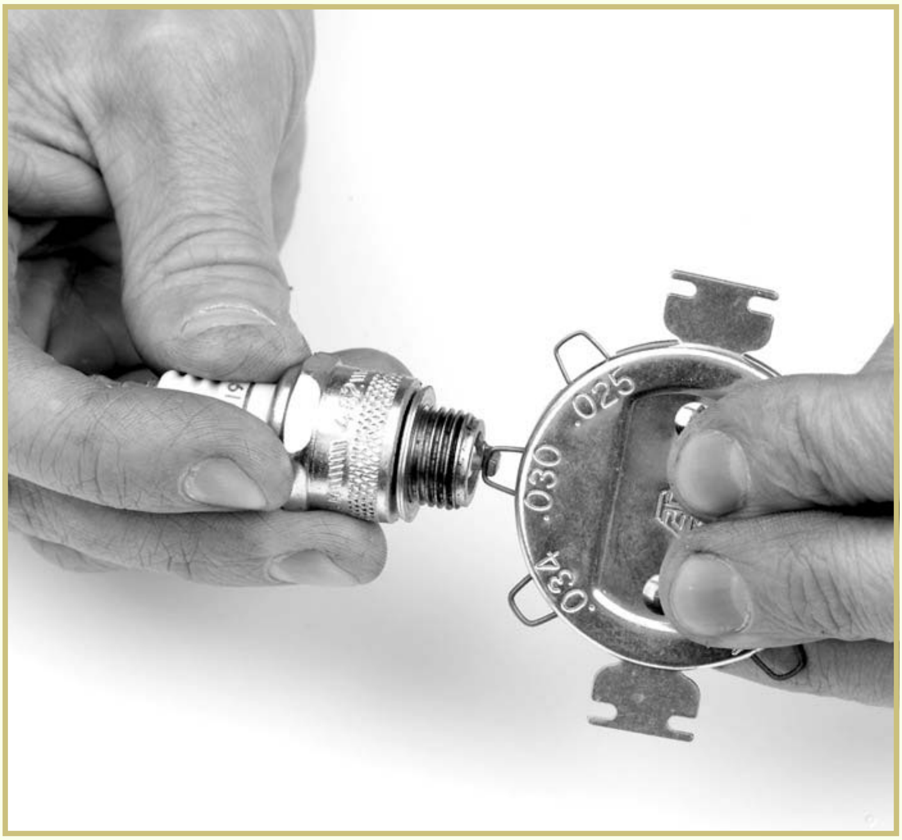



***FIGURE 6—If the gapping-tool wire slides between the electrodes with a slight resistance, you're measuring the gap correctly.***

Before you measure the plug gap, check the service manual to determine the correct gap width. Suppose the service manual lists the correct gap width as 0.030 of an inch. Find the wire on the gapping tool that's marked 0.030 and fit it into the gap between the plug's electrodes. This process is shown in Figure 6. The wire should fit snugly between the electrodes. If the gap is too large or too small, use the metal tab on the side of the gapping tool to gently bend the grounding electrode into its correct position.

A plug's gap can also be measured using a feeler gage. However, if the spark plug's electrodes are worn, the flat blades on the feeler gage may not provide an accurate reading. An illustration of this is shown in Figure 7. As you can see in this figure, when the plug electrodes are worn, the wire gapping tool provides a more accurate measurement of the gap (Figure 7B). However, if the plug electrodes are very worn, the spark plug should be replaced.

You should measure the gap of every spark plug before you install it—even a new plug. A new plug's electrodes may have been bent out of shape and need adjustment.

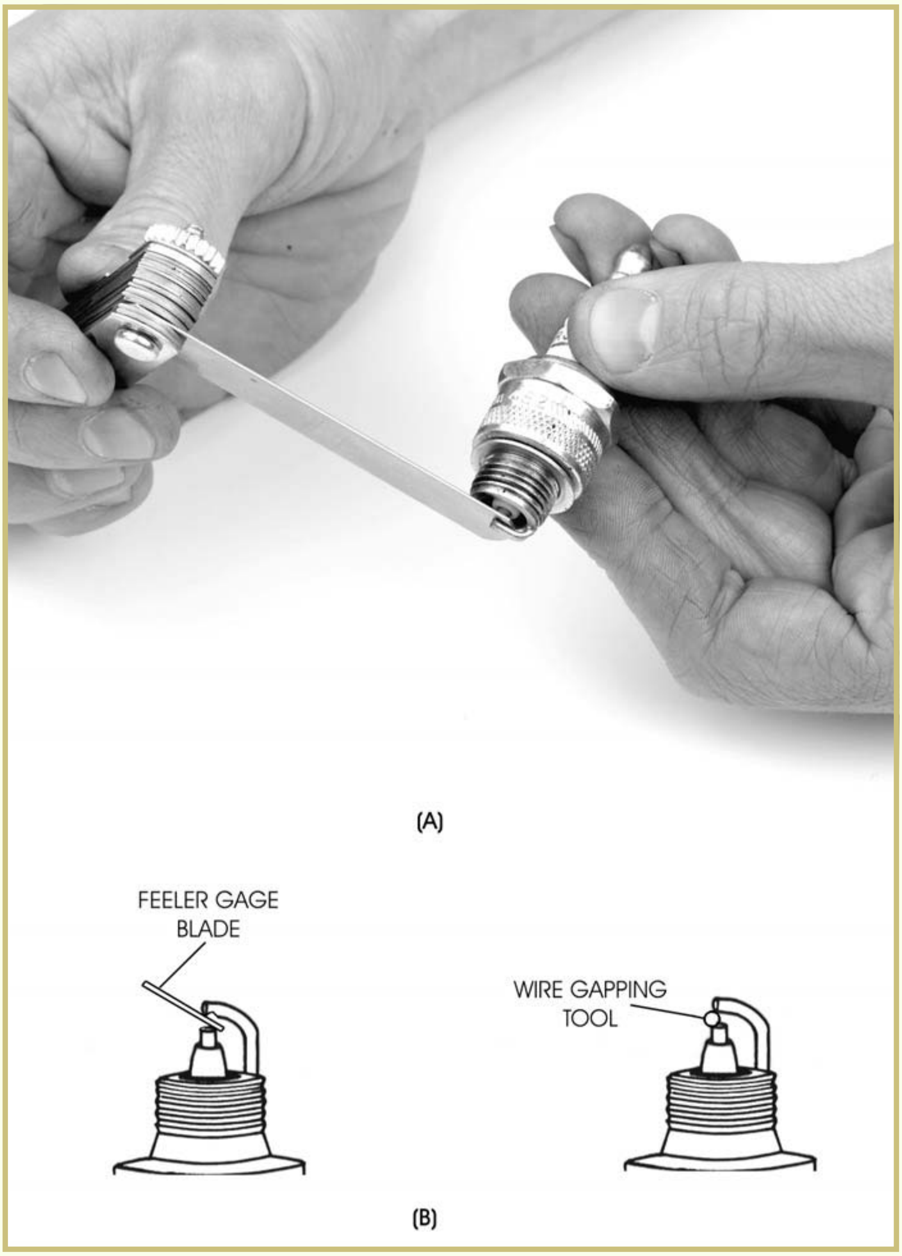



***FIGURE 7—A feeler gage can also be used to measure a plug's gap. However, the wire gapping tool provides a more accurate measurment of the gap.***

## Installing New Spark Plugs

Before installing new plugs in an engine, inspect each new spark plug to make sure it's the proper type and has the correct heat rating for the engine. All plugs installed in an engine must be the same type and have the same heat rating. Don't assume that all of the plugs in one package are the same—mistakes are sometimes made at the factory or at the parts store.

When the spark plug gap has been checked, and corrected if necessary, and the threads in the spark plug holes have been cleaned, it's time to replace the spark plug into the cylinder head. Hold the plug with your fingers and gently screw the plug into the cylinder. Don't force the plug to turn. The plug should turn at least two full turns into the cylinder head. Tighten the plug by hand until it's "hand-tight." If the spark plug uses a gasket, make sure to install a new gasket.

Now, use a spark plug socket and a torque wrench to tighten the plug into the cylinder head. A spark plug should be tightened according to the manufacturer's specifications, which are usually in the range of 15 foot-pounds. A torque wrench should be used to tighten the plug (Figure 8). Torque wrenches have special dials or gages on them that indicate the tightening force you're applying. When using a torque wrench, turn the plug socket with the torque wrench until the wrench indicates you've reached 15 foot-pounds.

It's very important that a spark plug be tightened to the proper torque specifications. If you use too little torque, the spark plug will overheat because of improper heat transfer between the plug and the cylinder head, or the spark plug may cause a compression leak between the threads. A compression leak will eventually destroy both the spark plug and the cylinder head. In contrast, if you tighten the spark plug with too much torque, the plug will be distorted and the plug gap will be changed. The plug will also be very hard to remove later. A good rule of thumb is to tighten gasketed plugs $\frac{1}{4}$ of a turn after the gasket contacts the cylinder head. Plugs without gaskets—tapered-seat types—should be tightened $\frac{1}{16}$ of a turn after the taper contacts the cylinder head.

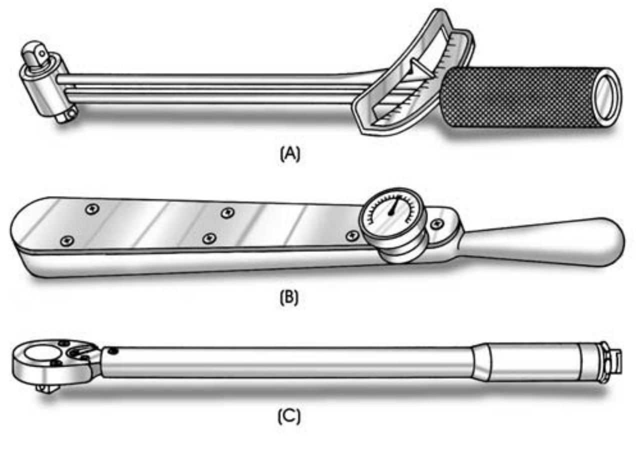



***FIGURE 8—Three types of torque wrenches are shown here.***

One of the biggest problems with spark plug installation is the possibility of cross-threading the plug. In cross-threading, the plug is screwed into the cylinder head at a slight angle, damaging the threads inside the hole in the cylinder head. Aluminum cylinder heads are very easily damaged.

If a plug is cross-threaded into the cylinder, it's possible to repair the threads. The best repair method is to remove the cylinder head and screw a tap of the appropriate size into the hole. If you don't have a tap, you can remove the cylinder head and screw a spark plug with a long reach backwards through the hole. Either method cleans the top threads, allowing you to replace the cylinder head and screw the correct plug in from the top of the cylinder head. (Use a new cylinder head gasket whenever you remove and replace the cylinder head on an engine.)

A special tool called a *thread chase* can also be used to clean damaged threads. Again, remove the cylinder head and screw in the thread chase, just as you would install the spark plug. The thread chase cuts away the faulty thread area, leaving good threads behind.

If the threads are heavily damaged, you can use a thread insert to replace the existing threads. In this case, you would drill an oversized plug hole. The insert is then threaded into the oversized hole in the cylinder head, and the spark plug is threaded into the insert.

After the plugs are installed, the final step is to reconnect the spark plug wires. Make sure that each wire is connected to the proper spark plug.

## Inspecting the Spark Plug Wires

As part of a routine inspection of the ignition system, the spark plug wires are usually checked to ensure they're in good condition. Spark plug wires usually don't wear out as fast as spark plugs, but over time wires can wear and may need to be replaced. Spark plug wires are usually inspected visually for damage and then checked with an electrical test meter to see how well they carry the voltage to the plug. Let's begin with how to perform a visual inspection.

Check the spark plug wire for cracks or other signs of damage in the insulation and conductors. When checking the wires, be sure to carefully check any area that passes close to the engine or exhaust system. It's common to find that the insulation has been worn off from rubbing against an engine part, or burned away by coming into contact with the hot exhaust manifold. Also, check each of the connectors and rubber insulation boots for any signs of damage. Any wire that's brittle, oil-soaked, or damaged in any way should be replaced.

Keep in mind that wires that appear to be in good condition on the outside may be damaged or broken inside. A damaged wire may have too much resistance, and the high voltage from the ignition system may not reach the spark plug and fire the plug properly. If the spark plug wire insulation is worn away, electricity may arc across to a metal engine part. If the wire is very worn or broken, it may not carry any electricity at all past the broken area.

If electricity doesn't reach a spark plug, the air-and-fuel mixture in that cylinder won't be ignited. Thus, that cylinder won't produce any power, which reduces the overall power produced by the engine. When one or more cylinders doesn't fire, the condition is called *engine miss* or *misfire*. A misfire can cause a dramatic loss of engine power and may also cause the engine to vibrate and run unevenly. Think of it this way—if just one of the cylinders in a four-cylinder engine misfires, the engine loses $\frac{1}{4}$ its power.

Use a multimeter to check for excessive resistance in a wire. Excessive resistance in a wire limits the wire's ability to carry voltage to the spark plug.

The exact procedure for using a multimeter depends on the type of meter. The multimeter will come with printed instructions that explain how to use its different functions. However, the following is a general procedure for checking a spark plug wire with a multimeter:

*Step 1:* Disconnect the spark plug wire from the spark plug and from the distributor cap or ignition coil. Figure 9 shows one type of wire connection you may find in a distributor cap. Most plug wires pull off of the spark towers of the distributor cap. If these wires must be replaced, the distributor cap must be removed and the wire ends compressed for removal.

*Step 2:* Set the multimeter to its ohmmeter function. (Multimeters are often called ohmmeters when they're set to this function.)

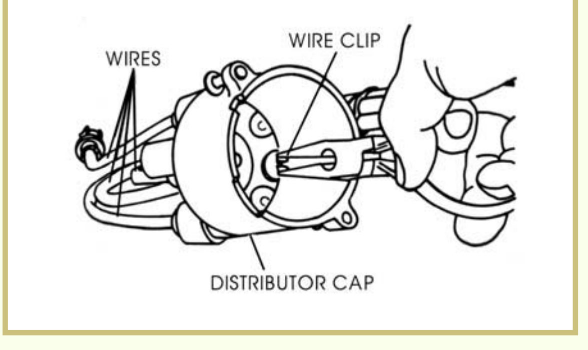



***FIGURE 9—Before some spark plug wires can be removed from a distributor cap, a wire clip inside the distributor cap must be compressed.*** (Courtesy of Chrysler Corporation)

*Step 3:* Attach the multimeter's test leads to both ends of the spark plug wire as shown in Figure 10.

*Step 4:* Read the measured resistance on the multimeter display.

In most cases, a spark plug wire should have approximately 4,000

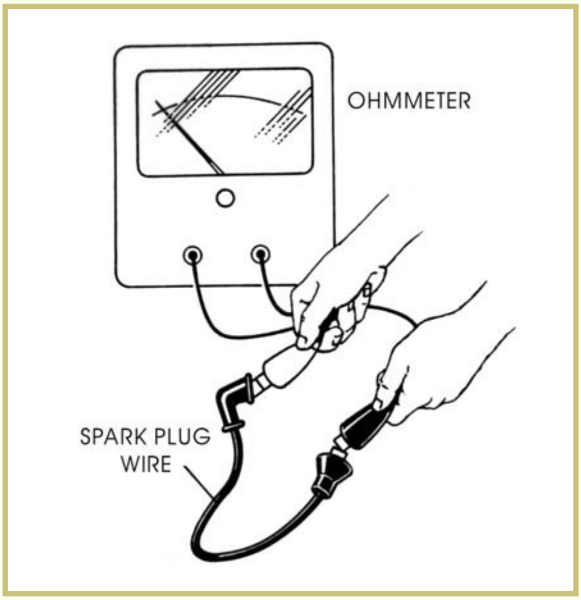



***FIGURE 10—To measure the resistance of a wire, set the meter to the ohmmeter function and attach the leads to the ends of the wire as shown here.***

ohms (Ω) of resistance per foot of wire. In other words, a wire that's two feet long should have a resistance of about 8,000 ohms. Remember, though, that these are only approximate resistance values. A wire can have a little more or less resistance and still be usable. However, if the resistance value of a wire is much higher than the approximate values provided here, the wire will greatly limit the amount of electricity that can pass through to the spark plug. In this situation, the wire should be replaced.

When testing spark plug wires, you may sometimes get a resistance reading that's so high the meter can't measure it. This type of reading is called an *infinite reading*. An infinite reading usually indicates that the spark plug wire is broken somewhere along its length, so electricity can't flow through the wire. Any wire that produces an infinite resistance reading must be replaced.

Once the wires have been inspected, they can be reinstalled in the engine. Remember that spark plug wires must be reinstalled in their original positions in order to maintain the proper firing order in the engine. If all the wires need to be tested, or if you're installing a new set of wires, it's a good idea to check and reinstall the wires one at a time to be sure they're placed in their proper positions. Another method is to draw a sketch of the wiring layout before you remove the wires. Later, you can refer to the sketch to determine how to correctly reinstall the wires.

When you're removing or replacing spark plug wires, you may notice that plastic *wire holders* are placed at various locations. These wire holders are simply small brackets that are snapped over the plug wires. Wire holders keep the wires neat and prevent them from becoming tangled. In addition, wire holders keep the wires spaced apart to ensure that no voltage can jump from one wire to another. The holders also prevent the wires from rubbing against sharp edges on the engine, or from coming into contact with the hot exhaust system. Because the wire holders perform such important functions, it's important that the wires be placed back into the holders when they're reinstalled.

## Testing Ignition Coils

As you know, automotive ignition coils vary in size and shape, depending on the manufacturer and the type of ignition system. However, even though ignition coils may look different on the outside, they're all constructed in much the same way.

The inspection and testing of the ignition coil is similar to that of spark plug wires. First, check the ignition coil visually for any damage. Then, test the condition of the coil windings using a multimeter.

Let's review the visual inspection process. First, carefully examine the plastic insulating material near the terminal areas. This material can be brittle at times, so check for cracks and breaks. Cracked insulating material can cause electrical problems that prevent the coil from working properly. Also, make sure that the coil is clean and free of dirt and oil. Dirt or oil on the outside of a coil allows electricity to flow along the coil surface from one terminal to the other. This causes electricity to bypass the coil windings and prevent the coil from producing a spark. If a coil is damaged in any way, it should be replaced.

Once the coil has been visually inspected, check the coil with a multimeter to determine the condition of the coil windings. In most situations, you won't need to check a coil with a multimeter unless you suspect a problem. In other words, a multimeter test isn't a part of normal maintenance—a visual check of the coil is enough. To check an ignition coil with a multimeter, follow these steps.

*Step 1:* Remove the coil from the vehicle or, at the very least, disconnect the wires connected to the coil.

*Step 2:* Set the multimeter to its ohmmeter function.

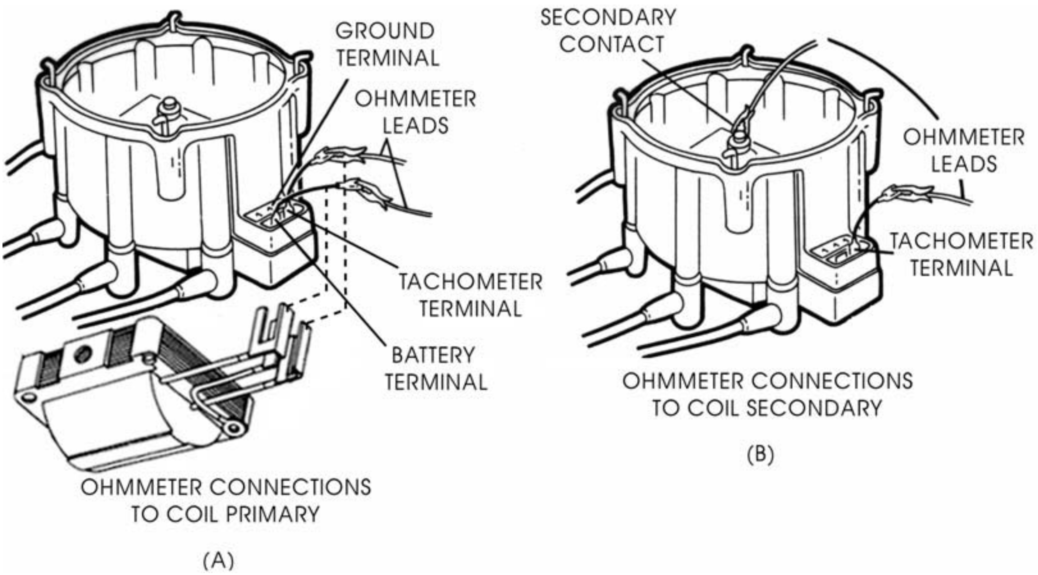



***FIGURE 11—To check the primary coil winding, place one meter lead on each of the primary-winding terminals as shown in Figure 11A. To check the secondary windings, place one meter lead on either of the primary-winding terminals, and the other meter lead on the secondary-winding connector, as shown in Figure 11B. In this figure, the test is being performed on an ignition coil that's located in the distributor cap.***

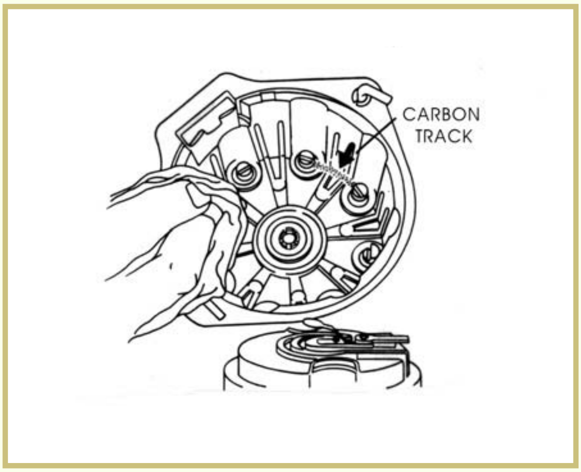
*Step 3:* First, check the coil's primary winding. Place one of the multimeter test leads on one of the primary-winding terminals, and place the other multimeter lead on the other primary-winding terminal (Figure 11A). Since you're measuring the amount of resistance in the coil winding, it doesn't matter which multimeter lead is placed on which primary terminal.

*Step 4:* Read the resistance value on the multimeter display. For most coils, the primary-winding resistance should be very low—usually less than 10 ohms. If the resistance reading is much higher or lower than 10 ohms, the coil is defective and needs to be replaced.

*Step 5:* Next, check the secondary windings. Place one multimeter test lead on either of the primary-winding terminals. Place the other multimeter lead on the secondary-winding connector, where the coil wire or spark plug wire would normally connect (Figure 11B). Again, it doesn't matter which multimeter lead is connected to which terminal, nor does it matter which of the two primary terminals you use.

*Step 6:* Read the resistance value on the meter display. For most coils, the secondary-winding resistance should be high—usually between 5,000 and 25,000 ohms. Again, if the resistance reading is much higher or lower than this range, the coil is defective and should be replaced.

*FIGURE 12—A distributor cap should be checked for a carbon track that will cause the engine to misfire.*




## Servicing Distributors

The procedures used to service distributors are basically the same whether an engine has a conventional, an electronic, or a computer-controlled ignition system.

The major defect found in distributor caps and rotors is *carbon tracking*. Moisture that accumulates inside the distributor causes spark flashover inside the cap, which produces a path of carbonized material between two of the cap terminals. Carbon tracking in the cap frequently causes a constant engine misfire. A carbon track looks like a dark line in the cap, as shown in Figure 12. The rotor may also develop a carbon track under the rotor input terminal due to high-resistance or old plugs or wires.

The following is a general procedure used to check the distributor cap and rotor.

*Step 1:* Remove the distributor cap. Clean the cap and inspect it for cracks, carbon tracks, and burned or corroded terminals. Replace the cap if you find any of these defects.

*Step 2:* Clean the rotor and inspect it for carbon tracks or eroded or corroded metal parts. Replace the rotor if you find any defects.

*Step 3:* At this point, if you're working on a point-type ignition system, you can service the points and condenser. If you're working on an electronic or computer-controlled ignition system, you can proceed to Step 4, since the distributors in these systems won't have any other components that require replacement or adjustment.

*Step 4:* Check the centrifugal-advance mechanism, if the distributor has one. Turn the distributor rotor as far as possible in the normal direction of distributor rotation. Then, release the rotor. The springs should return the rotor to its retarded position. If the rotor doesn't return to its retarded position readily, the distributor needs to be disassembled so the problem can be detected and corrected.

*Step 5:* Check the vacuum-advance mechanism, if the distributor has one. Apply vacuum to the vacuum-advance unit with a hand-held vacuum pump or another source of vacuum. Make sure that the plate rotates in the opposite direction to the distributor shaft rotation. Then, remove the vacuum source and make sure that the plate returns to the retarded position.

If the plate doesn't move at all, the vacuum-advance diaphragm is probably leaking. If the vacuum-advance diaphragm is leaking, the timing won't advance and the gas mileage will be very poor. Any stiffness in the plate movement also affects ignition timing. Correct any vacuum-advance problems before continuing with the tune-up.

*Step 6:* Make sure that all the distributor and coil primary-wire terminals are tight.

*Step 7:* Lubricate the distributor according to the manufacturer's instructions. Not all of the following procedures are applicable to all distributors.

In point-type ignition systems, apply a thin film of cam lubricant or a high-melting-point grease to the distributor cam. Replace the cam lubricator, if the system has one. Don't lubricate the old wick. Apply ½ drop of engine oil on the contact-point set pivot.

If the distributor has centrifugal weights under the breaker plate, remove the rotor and apply five drops of engine oil to the wick in the center of the shaft.

If the distributor has an advance mechanism at the top of the distributor shaft, lubricate the contact points of the weights and shaft with cam lubricant.

*Step 8:* Install the rotor and distributor cap. Make sure all spark plug wires are firmly pressed into the cap in the correct order, as shown in Figure 13. Remember that distributors can rotate clockwise or counterclockwise, and there isn't an exact guide as to what direction a particular distributor rotates in. To determine the direction of distributor rotation, consult the service manual, or start the engine with the distributor

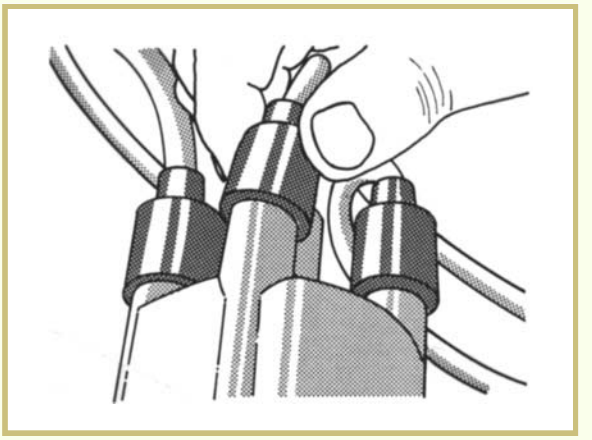


***FIGURE 13—When you install spark plug wires into a distributor cap, be sure that you press them firmly into the cap.*** (Courtesy of Chrysler Corporation)

cap off and observe the direction of rotor rotation. The spark plug wires must be reinstalled in the correct order to maintain the proper engine firing order.

## Inspecting Timing-Advance Mechanisms

Since timing-advance mechanisms are so important to proper engine operation, they should be checked whenever you service an ignition system or troubleshoot an ignition problem. Follow these steps when you check a timing-advance mechanism.

*Step 1:* Check the distributor centrifugal-advance mechanism by turning the distributor rotor as far as possible in its normal direction of rotation. Then, release the rotor and observe whether the springs return the rotor to its retarded position. If the rotor doesn't return easily, lubricate the weights and the shaft. If lubricating the weights and shaft doesn't help, disassemble the distributor, then clean and lubricate the internal parts.

*Step 2:* Check the vacuum-advance unit for free operation by turning the moveable breaker plate or distributor housing against rotation. The spring should easily return the unit to the retarded position. Correct any interference or binding. If a vacuum pump is available, you can check the vacuum diaphragm by applying a vacuum to the vacuum-advance unit input port and observing whether the breaker plate moves. If the vacuum-advance unit is defective, replace it.

Now, take a few moments to review what you've learned by completing *Power Check 1*.

# *Power Check 1*

**At the end of each section of *Ignition System Maintenance*, you'll be asked to pause and check your understanding of what you've just read by completing a "Power Check" exercise. Writing the answers to these questions will help you to review what you've studied so far. Please complete *Power Check 1* now.**

1. A special wrench called a _______ should be used to remove spark plugs to prevent damage to the insulators.

2. _______ fouling causes the end of a spark plug to be saturated with wet, sooty, black oil deposits.

3. When spark plug wires are reinstalled, they must be reconnected to the proper plugs in order to maintain the correct _______ in the engine.

4. A condition called _______ is caused when a spark plug is screwed into the cylinder head at an angle, damaging the threads inside the spark plug hole.

5. _______ fouling produces dry, black, fluffy deposits on the spark plug electrodes.

6. When carbon or oil deposits build up in a spark plug gap until it becomes completely blocked, the gap is said to be _______.

7. Damaged threads in a spark plug hole can be cleaned using a tap or a _______.

**Check your answers with those on page 65.**

# TUNING UP A CONVENTIONAL IGNITION SYSTEM

## Introduction

You learned earlier in this program that point-type ignition systems aren't used in modern cars, and that they're used only in older vehicles. However, since many of these older vehicles are still on the road, it isn't uncommon for an automotive technician to service a conventional ignition system.

As you've learned, the major difference between conventional ignition systems and electronic ignition systems is that conventional systems use contact points and a condenser in the distributor. The points and condenser will wear out over a period of time. The service manual for the vehicle lists the recommended intervals for replacement of these components.

You'll perform the following major tasks when you tune up a conventional ignition system.

1. Examine the points, clean them, and replace them if necessary.
2. Test the condenser and replace it if necessary.

## Servicing the Contact Points

The contact points are the most vital part of a conventional ignition system. They must be in working condition if the ignition system is to operate properly. A point set usually operates satisfactorily for at least 12,000 miles, sometimes longer. Although contact points were often repaired in the past, today they're usually replaced.

Use the following steps to inspect the contact points.

*Step 1:* Check the points visually for wear. Normally, contact points are gray and only slightly rough or pitted. Points in this condition don't need to be replaced.

*Step 2:* Dirty points can be cleaned with a clean, fine-cut point file. The file should be clean—not greasy or dirty—and shouldn't be used on other metals. Don't attempt to remove all roughness from the point surfaces. File off only the major rough spots or dirt.

*Note:* Don't use an emery cloth or sandpaper to clean the contact points. These materials will cause particles to embed in the point surfaces, which can cause arcing, rapid wear, and failure.

*Step 3:* If the points are burned or badly pitted, replace them. Don't attempt to file them.

If the points are burned or pitted, or if they didn't last as long as expected, it's very important to check the ignition and charging systems to determine the cause of the problem. Unless you correct the problem, the new points will burn or pit as quickly as the old ones. The most common cause of burned points is excessive primary voltage. Additionally, points are often damaged or worn out because of the following:

- A condenser that's defective or the wrong type
- A coil that's defective or the wrong type
- No resistance in the primary circuit
- A voltage regulator setting that's too high

*Step 4:* Check the alignment of the contact points with the points closed. The contacts should be aligned and contact each other evenly. Replace any misaligned points.

*Step 5:* As a preliminary adjustment before starting the vehicle, set the point gap to 0.019 inch with a feeler gage. The rubbing block should be positioned on the extreme top of the cam lobe during adjustment. Recheck the dwell after starting the engine. (Setting the point gap is discussed in detail in the following section of this study unit.)

If a set of contact points needs to be replaced, you need to remove the old set of points. To remove the contact points from the distributor, remove the electric connector and loosen the attaching screws. Some attaching screws must be completely unscrewed in order to remove the point set.

Before installing a new set of points, apply a small amount of cam lubricant to the cam and rubbing block. The grease should be applied to the rubbing block on the side away from the point faces.

Point installation is the opposite of point removal. Any ground wires should be reinstalled. The electric connectors and attaching screws should be tight. Make sure that the electric connectors don't contact the breaker plate; otherwise, the primary system will be shorted.

## Adjusting the Contact Point Gap

Contact points are adjusted by changing the distance between the point set and the distributor cam. The closer the points are to the cam, the wider they'll open. As the points are moved away from the cam, the point gap gets smaller.

To measure the point gap, crank the engine until the point set rubbing block is on the extreme top of the distributor cam lobe. Then, insert a clean 0.019-inch feeler gage for new points, or a 0.016-inch feeler gage for used points, between the two point faces. If the gage passes through the point faces with a slight drag, the point adjustment is good. Note that these feeler gage sizes are approximate. Be sure to

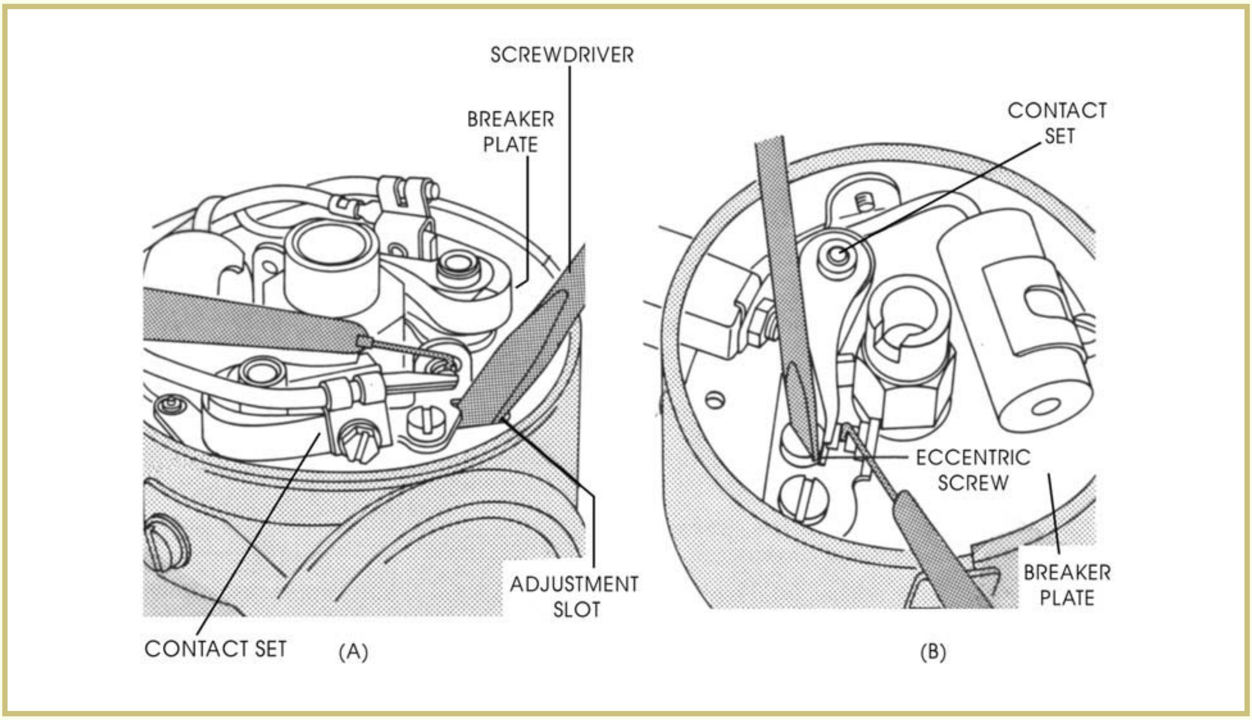



***FIGURE 14—To adjust the contact point set in Figure 14A, insert a screwdriver into the special adjustment slot. To adjust the points shown in Figure 14B, turn the eccentric screw.***

check the service manual for the exact point gap specification for a particular vehicle.

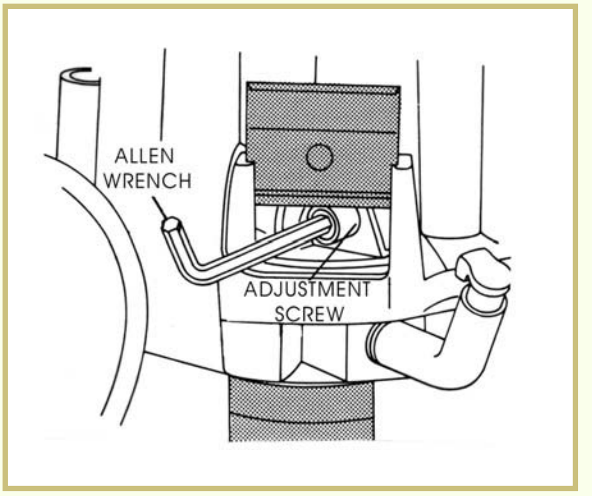
If the contact point gap needs to be adjusted, loosen the retaining screws that hold the point assembly to the breaker plate. Some contact point assemblies contain a special adjustment slot (Figure 14A), while others are adjusted by an eccentric screw (Figure 14B). If the assembly has an adjustment slot, insert a screwdriver into the slot and move the contact point assembly. If the assembly has an eccentric screw, turn the screw with a screwdriver. In either type of assembly, the distributor cap and rotor must be removed in order to make the adjustment. Once the points are adjusted, retighten the retaining screws.

Some contact point assemblies contain built-in adjustment screws. This type of assembly has a special window built into the distributor cap. Insert an Allen wrench through the metal window in the distributor cap to turn the adjustment screw (Figure 15). The gap in this type of point set can be adjusted while the engine is running.

## Testing and Adjusting the Dwell

The point gap has a direct effect on an ignition system's dwell. Remember that the dwell is the number of degrees the distributor cam rotates during the time that the contact points are closed. There are 360

***FIGURE 15—In some distributors, the contact point set has a built-in screw adjustment. To adjust the gap in this type of point set, insert an Allen wrench through the window in the distributor cap and adjust the screw. The gap in this type of contact point set can be adjusted while the engine is running.***




degrees in a circle, so the maximum dwell for any engine is 360 divided by the number of engine cylinders. Dwell is measured using a *dwell tester*. The dwell increases as the point opening decreases, and the dwell decreases as the point opening increases.

Correct dwell is important, especially during starting and low-speed operation. If the contact points are set too close together, the dwell will be too long. As a result, arcing and burning occurs, making the engine difficult to start and operate at low speeds. If points are set too far apart, the dwell will be too short. The points won't be closed long enough to allow the coil to develop a complete magnetic field. This causes a weak spark at high speeds.

Setting the dwell with a dwell meter is the preferred method of adjusting the contact points, since it's more accurate than using a feeler gage to set the point gap. The dwell should always be checked after adjusting and aligning the points.

Checking the dwell requires a dwell meter similar to the one shown in Figure 16. You should always refer to the dwell meter's instructions for proper use of the meter.

The following is a general procedure to test and adjust the dwell in a conventional ignition system.

*Step 1:* Connect the dwell meter to the engine. Connect one lead to the coil negative primary connection—the distributor side—and the other lead to a grounded location on the engine.

*Step 2:* Start the engine and observe the dwell meter. The approximate dwell should be between 45 and 60 degrees in 4-cylinder engines, between 28 and 50 degrees in 6-cylinder engines, and between 27 and 33 degrees in V-8 engines.

***FIGURE 16—An automotive dwell meter is shown here.***


*Step 3:* Slowly accelerate the engine to about 2,000 rpm and observe the dwell reading. The dwell reading should vary no more than 3 degrees when the engine is accelerated and then returned to idle. If the dwell reading varies more than 3 degrees, check for a worn distributor shaft, worn distributor bushings, or a loose breaker plate assembly.

*Step 4:* Return the engine to idle and observe the dwell reading. If the dwell reading isn't within manufacturer's specifications, the point gap needs to be adjusted. Adjust the points as described earlier, then recheck the dwell. If the dwell still isn't correct, repeat this step.

*Step 5:* Once the proper dwell is set, tighten the attaching screws.

*Step 6:* Check to make sure that the point dwell is still within specifications while the engine is running. The points must be reset if the dwell isn't within specifications. If the distributor has external adjustment points, the dwell can be set with the engine running.

## Servicing the Condenser

Condensers are usually replaced during an ignition system tune-up. A shorted or completely open condenser usually prevents the engine from starting; an overcapacity or undercapacity usually causes pitting on the breaker points.

Although an engine usually starts and runs with any good condenser, a condenser of the exact capacity helps the contact points last longer. A simple check of the condenser can be made with an ohmmeter as follows.

*Step 1:* Set the ohmmeter on the R × 1000 scale.

*Step 2:* Remove the condenser from the distributor, or remove the condenser lead from the point set.

*Step 3:* Place one ohmmeter lead on the condenser lead, and place the other ohmmeter lead on the condenser body. The ohmmeter needle should jump briefly, and then return to the infinity position. If the ohmmeter doesn't do this, replace the condenser.

A condenser can be removed easily from a distributor by disconnecting the electric wire and removing the attaching screw. To install a new condenser, simply reverse the removal process. Make sure that the condenser body is solidly grounded to the plate and that the pigtail lead doesn't contact any grounded part of the distributor. You don't need to adjust a condenser.

## Testing the Timing in a Conventional Ignition System

The proper ignition timing is critical to the proper operation of an engine. Once the points and the condenser have been replaced and/or adjusted, the ignition timing should be adjusted. Remember that changing the dwell in point-type systems changes the ignition timing, so be sure to complete all point adjustments before you set the timing.

The following is a general procedure you can use to adjust the timing in a conventional ignition system.

*Step 1:* Connect a timing light to the #1 spark plug and to the battery (Figure 17). Check the manufacturer's instructions for the exact connecting procedures.

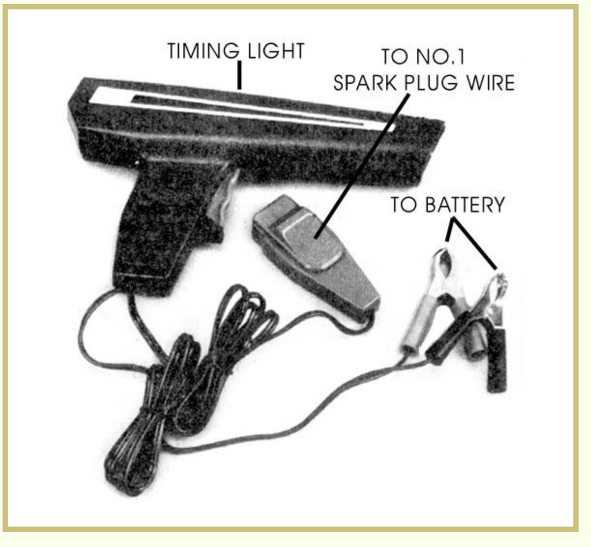



***FIGURE 17—An automotive timing light like the one shown here is used to adjust a vehicle's ignition timing.***

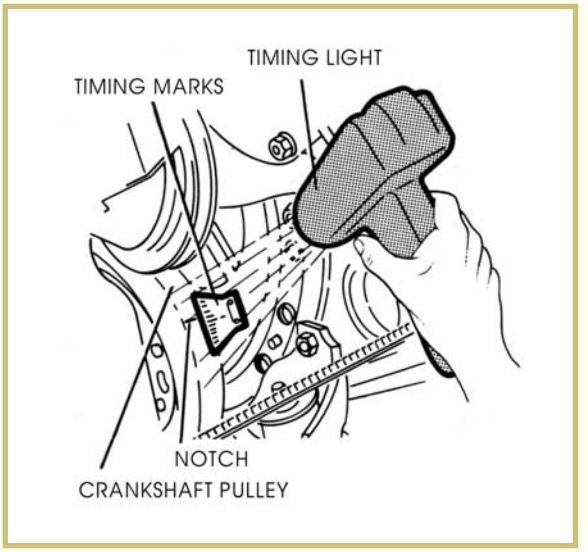



***FIGURE 18—Aim the timing light at the stationary timing marks on the flywheel housing opening or on the front of the engine.***

*Step 2:* Disconnect the spark-advance vacuum hose from the vacuum-advance unit.

*Step 3:* Plug the vacuum hose with a piece of tape, or with a suitable plug such as a golf tee.

*Step 4:* Connect a tachometer to the engine. (You may remember that a tachometer is a device used to indicate the speed of rotation.) Follow the manufacturer's instructions for connecting the tachometer. The tachometer is usually connected to the negative battery terminal on the ignition coil.

*Step 5:* Start the engine and adjust the engine idle to specifications, if necessary.

*Step 6:* Aim the timing light at the stationary timing marks on the flywheel housing opening or on the front of the engine (Figure 18). The rotating timing mark should be visible at or near the stationary timing mark. Refer to the service manual for the exact location of the timing marks.

*Note:* When setting the ignition timing on any engine that you're unfamiliar with, it's essential that you properly interpret the timing marks. On all engines, the marks are distributed on either side of the "0" (TDC) mark. If necessary, stop the engine to clean and identify the proper marks. The rotating mark in the damper or flywheel should also be cleaned and marked if necessary.

*Step 7:* Compare the timing with the timing recommended in the service manual.

*Step 8:* Adjust the timing as needed by loosening the distributor clamp bolt and rotating the distributor body until the timing light indicates the correct timing-mark alignment at the specified engine rpm.

*Step 9:* Tighten the distributor clamp bolt, and recheck the timing setting. Reset the timing if necessary.

*Step 10:* Accelerate the engine to 2,500 rpm, and observe the timing mark. If the timing mark moves approximately 15 to 20 degrees in the direction advanced, the mechanical spark-advance system is operating properly. If the timing doesn't move, the mechanical advance is sticking and should be repaired.

*Note:* The mechanical advance can often be restored to operation by lubricating the weights and shaft. Use as little lubricant as possible, to keep oil from being thrown onto the contact points.

*Step 11:* Return the engine to idle and reattach the vacuum-advance hose.

*Step 12:* Accelerate the engine to 2,500 rpm. The timing should advance farther than it did in Step 10. If it doesn't move any farther than it did with the vacuum hose disconnected, the vacuum-advance unit is defective or sticking and should be repaired.

*Note:* A leaking vacuum-advance unit must be replaced. Before replacing the vacuum-advance unit, check the vacuum hose to make sure that it isn't split or plugged, and also make sure that the hose is attached to the proper fitting on the carburetor or intake manifold and that the carburetor or intake manifold is supplying adequate vacuum.

*Step 13:* Remove the timing light.

*Note:* Always check the underhood emissions sticker or the service manual for exact instructions on how to set the timing. If the emissions sticker or service manual lists instructions different from those provided in this study unit, always follow the instructions on the sticker or in the service manual.

## Troubleshooting a Conventional Ignition System

To diagnose an ignition system problem, always proceed logically, working from simple, obvious causes to more complex problems. The troubleshooting process involves checking each individual ignition system component as well as the system as a whole.

One of the major difficulties in diagnosing ignition system problems is that the fuel and compression systems can cause similar problems. Therefore, to diagnose the ignition system, you must also check the engine fuel and mechanical systems. For example, a dead cylinder could be caused by a bad spark plug or wire, but it could also be caused by a burned valve. A hesitation in the engine when accelerating could be caused by worn spark plugs or retarded timing, but it could also be caused by a faulty carburetor accelerator pump.

The following is a general procedure used to troubleshoot ignition system problems. You can follow the steps in the order in which they're presented, or you can rearrange them to suit a particular problem.

*Step 1:* First, check the operation of the ignition primary system. To check for a spark, use a pair of insulated pliers to hold the coil wire ¼-inch from a ground point, and then crank the engine. A bright blue spark should jump from the coil wire to the ground point. If there isn't a spark, check the ignition primary side—the contact points, coil, resistor, wiring, and condenser. Also, check the battery, charging system, and the starting system to ensure that enough electricity is available to the ignition system.

*Step 2:* Next, check for any fuel system problems. If the engine has a carburetor, check for gas by looking into the carburetor air horn while working the accelerator linkage. Gas should squirt from the accelerator pump nozzle. If it doesn't, check the fuel lines, fuel filter, and pump. Also, make sure that the tank has gas in it. An internal carburetor problem could also cause engine performance problems.

*Step 3:* Then, check the condition of the ignition secondary system. If the carburetor appears to be operating and the coil sparks, check the ignition secondary for a cracked cap, a shorted rotor, or bad spark plug wires. Occasionally, an engine won't start because of worn-out, fouled, or wet spark plugs; therefore, they should also be checked.

*Step 4:* Check the ignition system for proper timing. Remove the #1 spark plug from the engine, and then crank the engine until the #1 piston comes up on its compression stroke. You should feel a rush of air out of the spark plug hole. Continue cranking the engine until the timing marks line up at TDC. Then, remove the distributor cap and check that the rotor is now under the #1 spark tower. If the engine starts but has some other problem, you can check the timing and timing advance with a timing light.

*Step 5:* If the fuel and ignition systems appear to be in good condition, the engine may have a compression problem. Check the compression with a compression tester. In a compression check, a special pressure gage is threaded into an engine's spark plug hole. The engine is then started and the amount of pressure produced is measured.

The following are some additional guidelines you can use when troubleshooting a point-type ignition system.

If an engine cranks but won't start, check the coil for a spark. If there isn't a spark, the ignition system may have any one of the following problems:

- A weak battery
- Moisture inside the distributor cap
- A defective coil
- A defective condenser
- Loose connections or broken wires in the primary circuit
- Improperly adjusted or faulty distributor points
- A broken distributor gear or drive pin

If there's a spark at the coil but the engine won't start, check for any of the following conditions:

- Moisture on high-tension wiring or spark plugs
- A cracked distributor cap
- A carbon track in the rotor, a broken rotor, or a missing rotor
- A defective or disconnected coil-to-distributor high-tension wire
- Badly retarded or advanced ignition timing

If an engine is hard to start, it usually has an ignition problem that affects engine performance after it starts. In this situation, check for any of the following:

- Worn-out, wet, or improperly gapped spark plugs
- Improperly adjusted, worn, or dirty distributor points

- Loose connections in the primary circuit
- Defective spark plug wires
- A defective or wrong-capacity condenser
- A defective coil
- A cracked distributor cap
- A carbon track in the rotor
- Retarded ignition timing

Engine misfires can be caused by burned valves or other internal engine problems. Therefore, these should also be checked. If an engine misfires, check for the following:

- Fouled or worn spark plugs
- Improperly gapped spark plugs
- Defective or disconnected spark plug wires
- A cracked distributor cap
- A carbon track in the distributor cap or rotor
- Misadjusted contact points
- A worn distributor shaft
- Reversed coil polarity

Poor performance or fuel mileage is one of the hardest problems to correct. Often, the problem isn't related to the engine, but may be caused by the fuel system, drive train, tires, brakes, or even driving habits. You can check for the following ignition system problems:

- Retarded ignition timing
- Inoperative advance mechanisms
- Worn-out spark plugs
- Reversed coil polarity

Now, take a few moments to review what you've learned by completing *Power Check 2*.

# Power Check 2

1. A point set usually operates satisfactorily for ______ miles.

2. *True or False?* The dwell can be adjusted in a conventional ignition system, using a timing light.

3. *True or False*? Burned valves, improperly gapped spark plugs, a cracked distributor cap, or a worn distributor shaft are all possible causes of engine misfires.

4. *True or False*? Poor engine performance or poor fuel mileage may be caused by retarded ignition timing or worn-out spark plugs.

5. *True or False*? To measure the point gap, you should use a 0.019-inch feeler gage for new points and a 0.016-inch feeler gage for used points regardless of what it says in the service manual.

**Check your answers with those on page 65.**

# TUNING UP AN ELECTRONIC IGNITION SYSTEM

## Introduction

As you know, the majority of modern vehicles use either distributor-type electronic ignition systems or direct-fire, distributorless systems. Although there are slight variations in the construction and design of the components, the procedures for servicing electronic ignition systems are very similar to those used for conventional systems. For example, spark plugs, spark plug wires, distributor caps, and rotors are replaced the same way. The electronic system is also timed like a conventional system.

However, there are some differences in specifications and adjustments. The internal parts in electronic-ignition distributors are more likely to rust than those in point-type distributors. This is due to the ionizing effect of higher voltages. If the inside of the distributor is rusty, the distributor cap should be replaced, since it's allowing moisture to get inside the housing.

An electronic-ignition distributor requires almost no adjustments. Although you can obtain a dwell reading, the dwell can't be adjusted.

Now, let's discuss some of the typical services and repairs required in electronic ignition systems.

## Testing the Timing in an Electronic Ignition System

You can test the ignition timing in a distributor-type electronic ignition system with a timing light just as you would test a conventional ignition system. Proper ignition timing is vital. Incorrect timing can cause sluggish performance, detonation, poor mileage, and overheating.

## Testing Ignition Coils in an Electronic Ignition System

Ignition coils, including those inside the distributor cap, can be checked by bypassing the rest of the ignition system, as follows:

*Step 1:* Disconnect the coil primary leads.

*Step 2:* Connect jumper wires from the coil primary connections to the positive and negative terminals of the battery.

*Step 3:* Hold the coil secondary wire ¼-inch from the engine block. When an ignition coil is inside the distributor cap, run a jumper wire from the center connection inside the distributor cap; hold the other end ¼-inch from the engine block.

*Step 4:* Make and break the coil circuit by removing either jumper wire from the battery. You should see a spark from the wire.

If the ignition coil doesn't produce a spark, check it for continuity and resistance with an ohmmeter as follows.

*Step 1:* Set the ohmmeter on the R × 1 setting.

*Step 2:* Place one lead on each primary terminal. Primary resistance should be less than 10 ohms.

*Step 3:* Set the ohmmeter on the R × 1000 scale.

*Step 4:* Connect one lead to any primary terminal, and the other lead in or on the coil secondary tower. Secondary resistance should be between 5,000 and 25,000 ohms.

*Step 5:* If the coil fails this test, replace it.

## Testing Electronic Ignition Modules

Ignition modules can be checked only using special testers (Figure 19). These testers are expensive and usually designed to work on a limited variety of ignition modules. Therefore, the usual methods of ignition module diagnosis are processes of elimination and substitution. For example, when an ignition system has a problem and all other components are in good condition, the problem is probably in the module. This is why it's important to check every part of the system carefully and determine that all other electronic ignition system components are working properly.

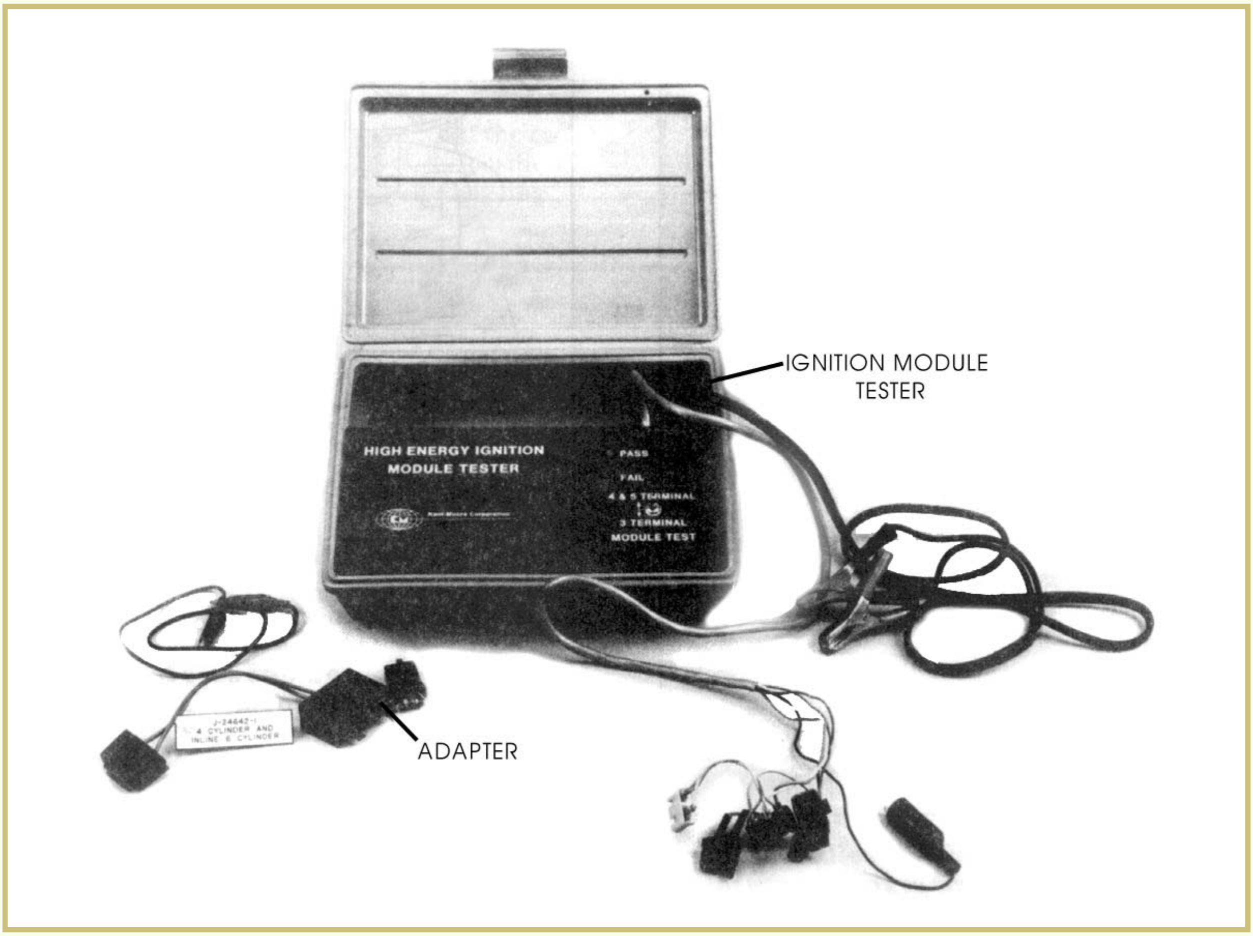



***FIGURE 19—An ignition module tester requires various adapters because of the many ignition module designs that are available.***

*Note:* A common ignition module problem is a poor ground or no ground at all. Always clean and tighten the ground connections before you replace an ignition module. Also, be aware that ground connections may be the module-attaching screws.

## Testing Magnetic Pickup Coils and Hall-Effect Switches

Pickup coils and some Hall-effect switches can be checked with an ohmmeter. (Remember that an ohmmeter is a multimeter set to the ohmmeter setting.) Usually, the coils and switches don't have to be removed from the distributor to perform the test. With some pickup coils, the air gap between the pickup coil and the trigger wheel can be adjusted. Ordinarily, air gap adjustment isn't a problem. However, it should be checked if there's a problem with the pickup coil, or if the pickup coil is removed from the distributor. If the air gap is too wide, the strength of the signal to the electronic control unit is reduced. As a result, the engine is difficult to start and the efficiency of the ignition spark is reduced during engine operation.

On some types of electronic ignition systems, the gap between the pickup coil and the trigger wheel must be checked. This clearance can be adjusted if necessary. Note that the gap should be checked only with a *nonmagnetic* feeler gage. A steel gage will stick to the permanent magnet in the pickup, and you won't be able to get a true adjustment. Brass feeler gages are available from auto supply stores and tool suppliers.

The following is a general procedure to adjust the pickup coil air gap.

*Step 1:* Check the inside of the distributor for rust. If you find any rust, replace the distributor cap.

*Step 2:* Crank the engine until one trigger wheel tooth is aligned with the pickup coil core (Figure 20).

*Step 3:* Loosen the lock screw on the mounting bracket for the pickup coil.

*Step 4:* Insert the nonmagnetic feeler gage between the tooth and the pickup coil. The gage should feel snug as it's pulled through the gap.

*Note:* Always check the service manual for the exact air gap specifications.

*Step 5:* If the clearance is incorrect, loosen the pickup-attaching screws and move the pickup assembly to adjust the gap.

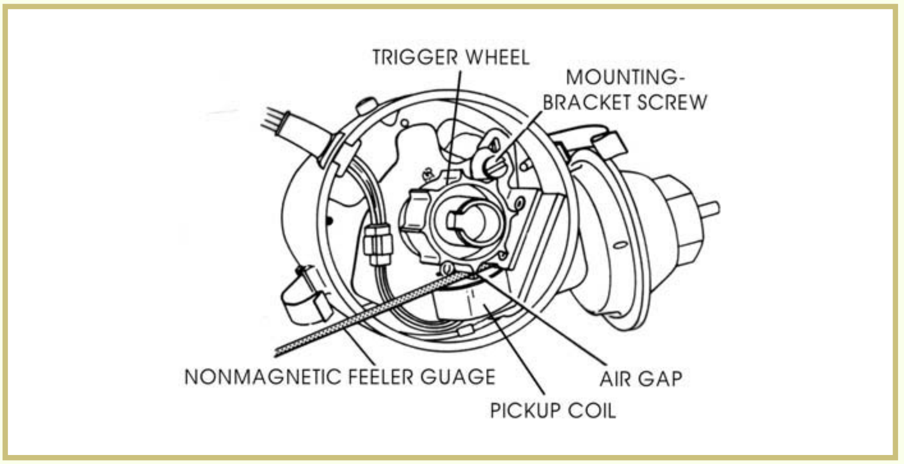



***FIGURE 20—A nonmagnetic feeler gage is used to set the air gap between the trigger wheel and the pickup coil.***

*Step 6:* Tighten the attaching screws and check the adjustment again.

*Step 7:* Start the engine, and make sure that there's at least a 0.006-inch clearance between the pickup coil and each tooth.

*Step 8:* Install the distributor cap and rotor.

The pickup coil in most ignition systems can be checked with an ohmmeter. The following is a general procedure for checking a pickup coil.

*Step 1:* Set an ohmmeter on the R × 100 scale.

*Step 2:* Connect the ohmmeter leads to the pickup coil leads, and read the resistance. This step is illustrated in Figure 21A.

*Step 3:* Compare the reading to the manufacturer's specifications. The resistance should usually be between 300 and 1,500 ohms.

*Step 4:* Leave the ohmmeter leads connected, and wiggle the pickup coil leads. The reading shouldn't change.

*Step 5:* If the coil fails either of these tests, replace it.

*Step 6:* Check for a grounded pickup coil by connecting one lead of the ohmmeter to either coil pickup lead and the other lead to the distributor housing (Figure 21B). The ohmmeter should read infinity. If it doesn't, the pickup coil is grounded and should be replaced.

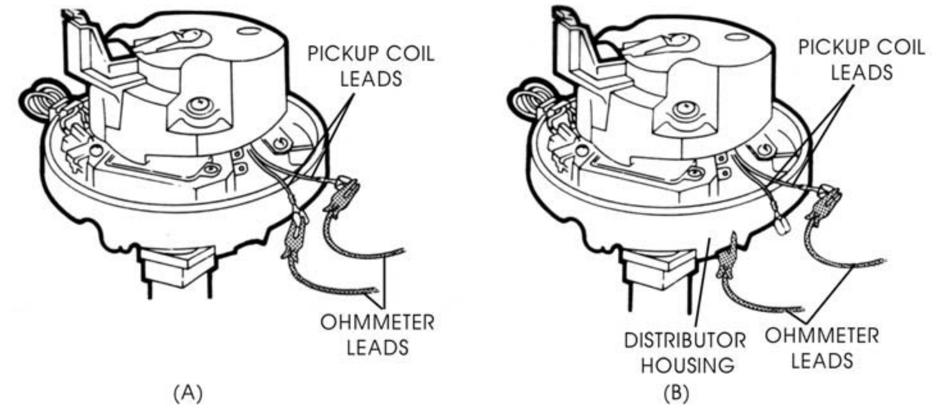



***FIGURE 21—A pickup coil is checked using an ohmmeter to measure the resistance between two pickup coil leads (Figure 21A), and the resistance between a pickup coil lead and the distributor housing (Figure 21B).***

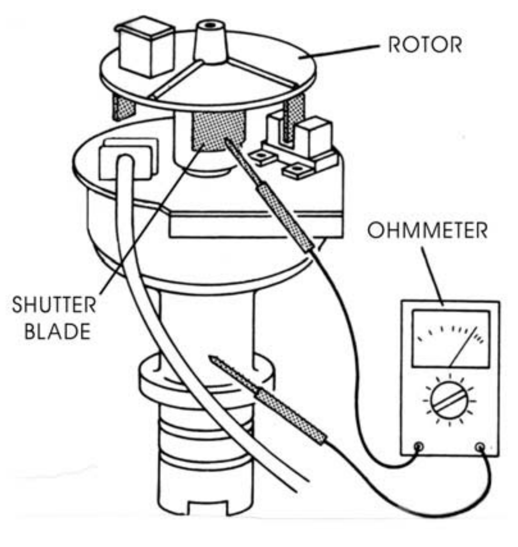
The only way to test most Hall-effect switches is to substitute a known good switch for a switch that you suspect may be malfunctioning. However, the rotor in a Hall-effect system can be checked with an ohmmeter. To test the rotor on a Hall-effect switch, follow these steps.

*Step 1:* Remove the distributor cap.

*Step 2:* Connect one lead of an ohmmeter to one of the shutter blades and connect the other lead to ground (Figure 22). Continuity should exist between the two points. If it doesn't, the shutter blades of the rotor aren't grounded.

*Step 3:* If the shutter blades aren't grounded, replace the rotor.

***FIGURE 22—You can use an ohmmeter to check the shutter blades of a Hall-effect rotor to make sure that the blades are grounded to the distributor shaft.***



*Step 4:* Repeat Steps 1 through 3 for the other shutter blades.

## Servicing the Distributor in an Electronic Ignition System

The rotor and distributor cap in an electronic ignition system are tested the same way as a rotor and distributor cap in a point-type system. However, because electronic ignition systems produce much more voltage than point-type systems, the cap and rotor in electronic systems are more prone to carbon tracking.

If the pickup coil is defective and needs to be replaced, the distributor usually has to be removed from the vehicle first. The following is a general procedure to remove and replace a distributor.

*Step 1:* Unfasten the distributor cap retaining clips or screws. Remove the distributor cap with the high-tension wires in place, and set it safely out of the way.

*Step 2:* Disconnect the vacuum hose from the distributor vacuum-advance unit.

*Step 3:* Disconnect the distributor primary-wiring connector.

*Step 4:* Scribe a mark on the distributor housing in line with the tip of the rotor (Figure 23), and mark the position of the rotor and distributor housing on the engine block.

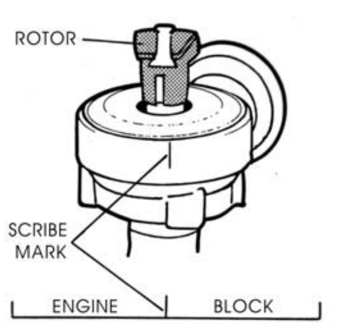
*Step 5:* Remove the distributor hold-down bolt and clamp.

*Step 6:* Withdraw the distributor carefully from the engine.

The following is a general procedure for installing a distributor.

*Step 1:* Clean the distributor-mounting area of the engine block.

***FIGURE 23—Before removing the distributor from a vehicle, mark the position of the rotor on the distributor housing and mark the position of the housing on the engine block.***



*Step 2:* Install a new distributor-mounting gasket in the counterbore of the engine block.

*Step 3:* Position the distributor in the engine.

*Step 4:* Align the rotor tip with the mark you scribed on the distributor housing. Turn the rotor approximately a ⅛-turn counterclockwise past the scribed mark.

*Step 5:* Slide the distributor down into the engine and position the housing in the original location.

*Note:* It may be necessary to move the rotor and shaft slightly at first. However, the rotor should align with the scribed marks when the distributor is down in place.

*Step 6:* Install the distributor hold-down clamp.

*Step 7:* Check the ignition timing.

If, for some reason, the engine was cranked while the distributor was removed, time the distributor as follows.

*Step 1:* Rotate the crankshaft until the #1 piston is at TDC at the end of the compression stroke. To determine when the #1 piston is on its compression stroke, remove the #1 spark plug and place your thumb over the spark plug hole. You'll feel the pressure building up in the cylinder.

*Step 2:* Align the correct initial timing with the stationary pointer and the timing mark on the crankshaft vibration damper (Figure 24). You can turn the crankshaft using the starter motor.

*Step 3:* After aligning the timing marks at the front of the engine, position the distributor in the block with the rotor at the #1 firing position and one of the trigger teeth aligned, as shown in Figure 25.

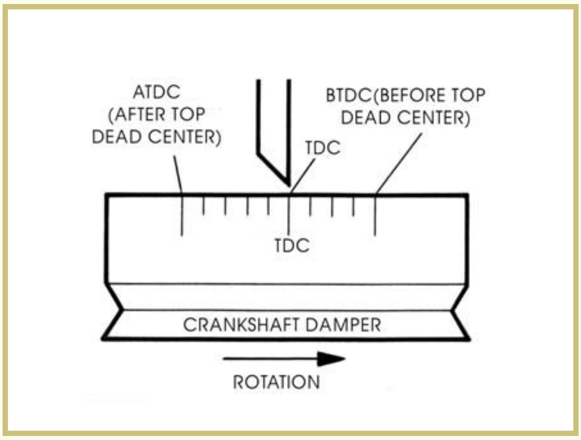



***FIGURE 24—Shown here is a typical set of timing marks that would be found on the crankshaft damper or flywheel.***

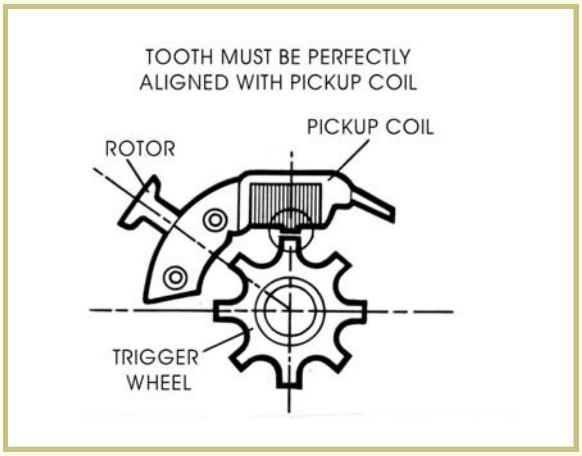



***FIGURE 25—When you're installing the distributor, make sure that one of the trigger wheel teeth aligns perfectly with the pickup coil.***

*Step 4:* Make sure that the oil pump shaft properly engages the distributor shaft. You may have to crank the engine after the distributor drive gear is partly engaged in order to engage the oil pump shaft. When the distributor drops into place, loosely install the retaining clamp and bolt. Then, revolve the distributor so that the trigger tooth is aligned properly, and tighten the clamp. Be sure that you rotate the distributor in the direction of advance.

*Step 5:* Install the distributor cap and its wires, and connect the distributor wiring connector to the vehicle wiring harness.

*Step 6:* To be sure of correct ignition timing, test the distributor timing with a timing light.

## Removing and Replacing the Magnetic Pickup Assembly

If you test the magnetic pickup assembly with an ohmmeter and find that the assembly is defective, it must be replaced. There are two basic types of pickup coils—the *single-pole type* and the *multiple-pole type*. General procedures for replacing both types of coils follow. As always, be sure to check the service manual for any variation from this general procedure.

### Replacing a Single-Pole Pickup Coil

With the distributor removed from the engine, remove the rotor. Since the trigger wheel is firmly attached to the centrifugal-advance plate sleeve, use a gear puller to remove it (Figure 26). If a gear puller isn't available, use two screwdrivers to very carefully pry the trigger wheel from its seat. As you pry, maintain equal force on each side of the trigger wheel. Remove the roll pin, stop ring, and wire retaining clip from

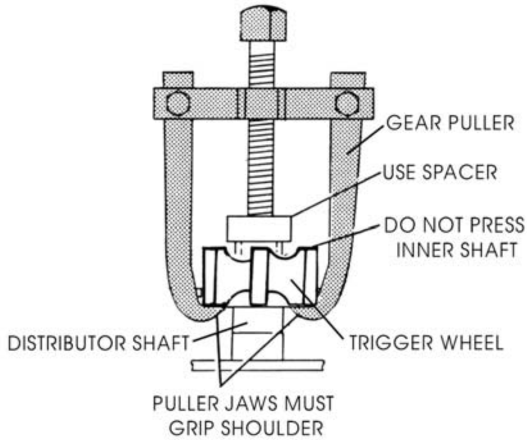



***FIGURE 26—A special gear puller like the one shown here is used to remove the trigger wheel from the distributor shaft.***

the base plate annular groove, and then remove the snap ring that secures the vacuum-advance link to the pickup assembly (Figure 27). After the ground screw is removed, lift the magnetic pickup assembly from the distributor. Lift the vacuum-advance link off the post on the pickup assembly, and move it out against the side of the housing.

Reverse this procedure when you install the new magnetic pickup assembly.

## Replacing a Multiple-Pole Pickup Coil

To replace a multiple-pole pickup coil assembly or vacuum-advance unit, you need to remove the distributor shaft from the distributor. To do this, remove the distributor from the engine, drive out the distributor gear pin, and lift the distributor shaft from the unit (Figure 28). Then, remove the screws that hold the pickup coil assembly. Remove the C washer, and then lift out the pickup coil.

Replacing the electronic module is simply a matter of disconnecting the wires and removing two module-attaching screws. Reverse the procedure to install a new module.

*Warning:* When you replace the stationary pole piece, make sure that the pole-piece mounting screws are properly seated to avoid interference between the pickup coil and the trigger wheel teeth when the distributor shaft is put back into the distributor housing.

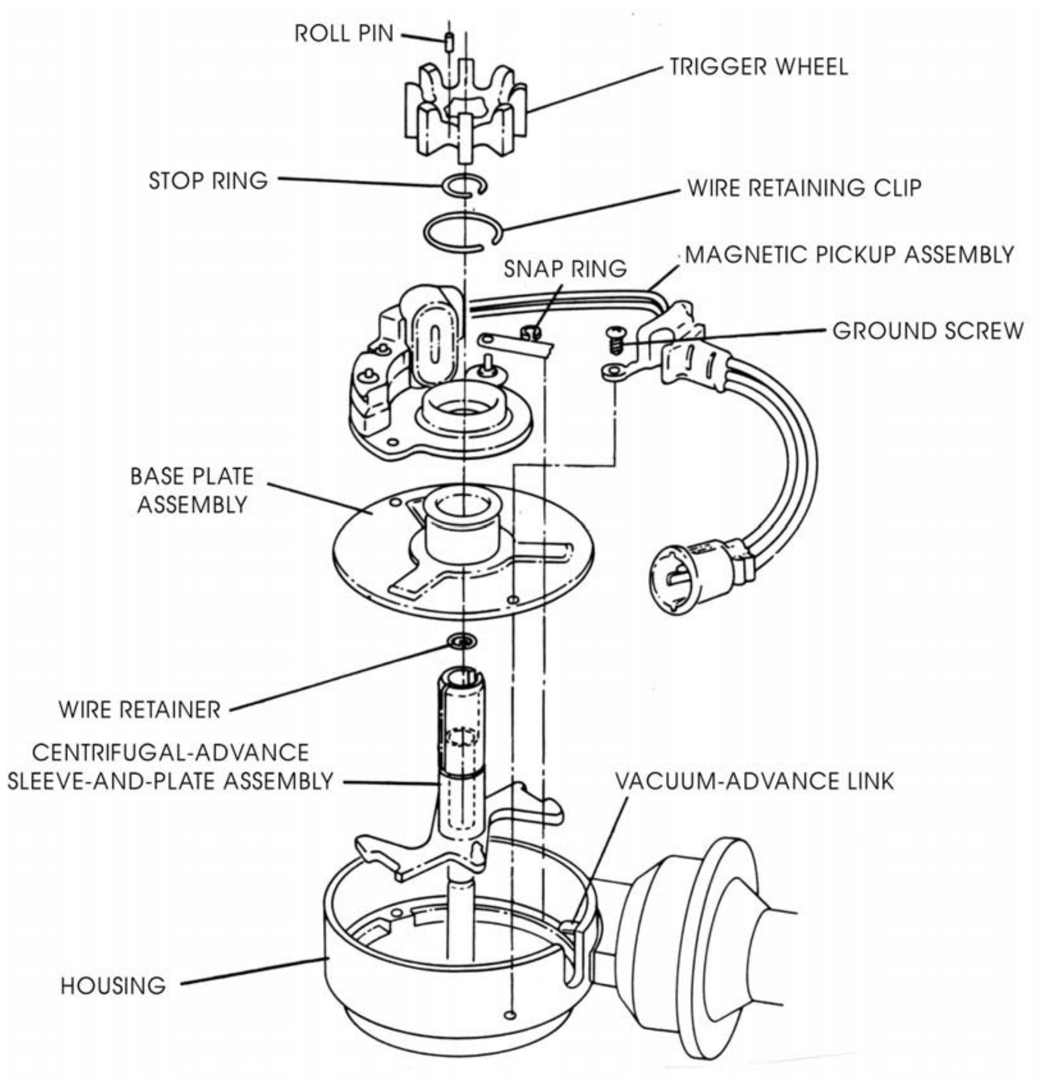



***FIGURE 27—Shown here is an exploded view of an electronic-ignition distributor that has a single-pole pickup coil.***

# Troubleshooting Electronic Ignition Systems

Electronic ignition systems have many of the same problems as point-type systems—defective coils, rotors, distributor caps, wires, and spark plugs—as well as fuel and compression system problems. To diagnose an electronic ignition system, you must check not only the ignition system, but also the engine fuel and mechanical systems.

This section concentrates on specific ignition system problems. Some electronic ignition components, such as modules, can't be checked without special testing equipment. However, pickup coils, resistors, and coils can easily be checked with an ohmmeter. Therefore, you can pinpoint problems in a nontestable part, such as a module, if you make

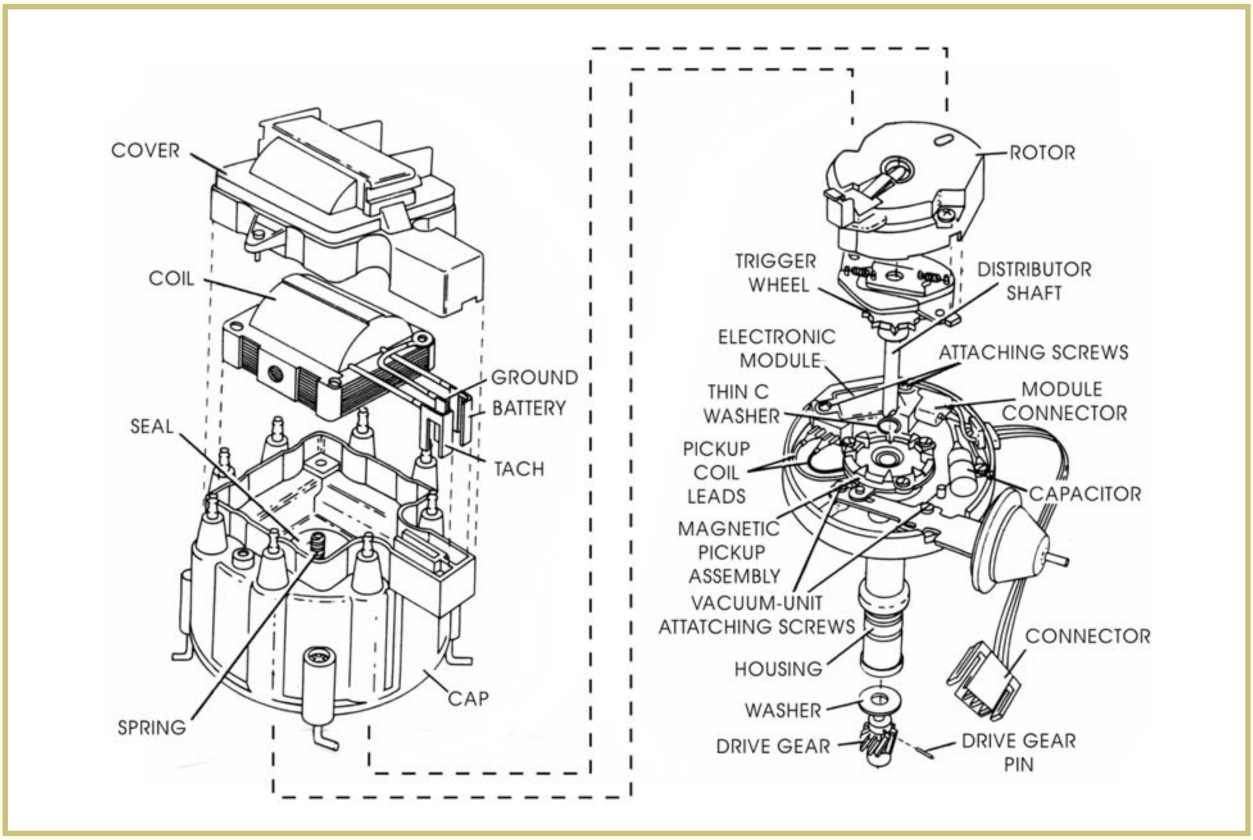



***FIGURE 28—Shown here is an exploded view of an electronic-ignition distributor that contains a multiple-pole pickup coil.***

sure all other components are in good condition. The following is a general troubleshooting procedure for electronic ignition systems. You can follow these steps in the order in which they're presented, or you can rearrange them to suit your needs.

*Step 1:* Test the vehicle's battery with a voltmeter. Connect the meter leads to the two battery terminals. A fully charged battery should produce a voltage reading of between 12 and 13 V.

*Step 2:* Visually check the ignition primary circuit for any broken or damaged wires.

*Step 3:* Check the ignition system for spark. To check for spark, use insulated pliers to hold the coil wire ¼-inch away from a grounding source and start the engine. A bright blue spark should jump from the wire to the ground. If the coil doesn't spark, check the coil, module, and wiring, using the procedures discussed earlier.

*Step 4:* Check the fuel system operation.

*Step 5:* Check the ignition secondary system for cracked distributor caps, carbon tracks in the distributor cap, defective rotors, defective spark plug wires, and worn, fouled, or defective spark plugs.

*Step 6:* Check that the ignition system is properly timed. Remove the spark plug from the engine, and crank the engine until the #1 piston comes up on its compression stroke. Place your thumb over the spark plug hole to feel the rush of air out of the hole. Continue cranking the engine until the timing marks line up at TDC. Then, remove the distributor cap and check that the rotor is under the #1 cap tower. If the engine starts, but has another problem, the timing and timing advance can be checked with a timing light.

*Step 7:* If the fuel and ignition systems are in good condition, the engine may have a compression problem. You can check the compression with a compression tester.

Figure 29 lists some general guidelines that can be used to help diagnose a problem in an electronic ignition system.

Now, take a few moments to review what you've learned by completing *Power Check 3*.

**DIAGNOSING ELECTRONIC IGNITION SYSTEM PROBLEMS**

If an engine cranks but won't start, first check the coil for spark. If there's no spark, the ignition system could have any one of the following problems:

- A weak battery
- Too wide an air gap in the pickup coil
- A defective pickup coil
- Loose connections or broken wire in the primary circuit
- A defective ignition module
- A broken distributor gear or drive pin

If there's a spark at the coil, check for any of the following conditions:

- Moisture on high-tension wires or spark plugs
- Moisture inside the distributor cap
- A cracked distributor cap
- Carbon tracks in the rotor
- A broken or missing rotor
- A defective or disconnected coil-to-distributor high-tension wire
- Badly retarded or advanced ignition timing

If an engine is difficult to start, it may have an ignition problem. An ignition problem that causes hard starting will usually cause a performance problem once the engine starts. In such a situation, check for any of the following conditions:

- Worn-out, wet, or improperly gapped spark plugs
- Improperly adjusted pickup coil air gap
- Loose connections in primary circuit
- Defective high-tension wire
- Defective coil
- Cracked distributor cap
- Carbon tracks in rotor
- Retarded ignition timing

Engine misfiring can be caused by burned valves or by some internal engine problem. Intermittent missing is usually caused by an ignition system problem. Check for the following:

- Fouled or worn spark plugs
- Improperly gapped spark plugs
- Damaged insulation on secondary wires, or disconnected wires
- Cracked distributor cap
- Carbon tracks in distributor cap
- Carbon tracks in rotor
- Worn distributor shaft

Poor performance or fuel mileage is one of the hardest problems to correct. Often the problem isn't related to the engine, but may be caused by a problem in the fuel system, drive train, transmission, or brakes. Poor performance may also be the result of bad driving habits. If poor performance or poor mileage is observed, check for the following ignition system problems:

- Retarded ignition timing
- Inoperative advance mechanisms
- Worn-out spark plugs

***FIGURE 29—These are some general guidelines that can be used to help diagnose problems in an electronic ignition system.***

# *Power Check 3*

1. The defect that's most often found in distributor caps and rotors is _______. This condition is a frequent cause of engine misfires.

2. To check a spark plug wire for damage, use an ohmmeter to check for excessive _______ in the wire.

3. *True or False?* The rotor and distributor cap in an electronic system are tested the same way as a rotor and distributor cap in a point-type system.

4. *True or False?* In an electronic ignition system, incorrect timing can cause sluggish performance, detonation, poor mileage, or engine overheating.

5. *True or False?* The air gap in a magnetic pickup should be checked using a nonmagnetic feeler gage.

**Check your answers with those on page 65.**

# CHECKING IGNITION SYSTEM OPERATION WITH AN OSCILLOSCOPE

## Using an Oscilloscope

An *oscilloscope*, sometimes called a *scope*, is a testing instrument that's used to measure various electrical quantities in a circuit. The oscilloscope is a box-shaped device that contains a television-like screen, as well as several test leads (Figure 30). The oscilloscope's test leads are much like the test leads on a multimeter. Many modern oscilloscopes are combined with other test instruments into a single unit that's called an *engine analyzer*.


***FIGURE 30—An oscilloscope engine analyzer like the one shown here can be used to check the condition of an ignition system.*** (Courtesy of Sun Electric Corp.)

Remember that when a multimeter is connected to a circuit, the meter displays the amount of voltage, current, or resistance within the circuit. Well, an oscilloscope can do more than that—it can actually display "pictures" of the electrical quantities in a circuit. After an oscilloscope measures the electrical quantities in a circuit, it displays the measurements on its screen as a *waveform*. A waveform is a long, wavy line that runs across the oscilloscope screen. The shape of the waveform's curves tells you how a circuit is working.

You may have seen an oscilloscope being used to monitor a patient's heartbeat in a hospital. The electrical impulses produced by a person's beating heart can be measured and then displayed as a waveform on the oscilloscope screen. Each time the patient's heart beats, the waveform curves upward sharply as the oscilloscope reads the electrical signal from the heart. In between heartbeats, the waveform is a straight line.

What does this have to do with an ignition system? An oscilloscope used to measure the electricity in an ignition system circuit is very similar. If the ignition system is working properly, the waveforms have a particular shape; problems in the system also cause certain waveform shapes. The technician can observe the shape of the waveforms to pinpoint problem areas. Thus, an ignition system's distinct waveform pattern can be used to diagnose problems in the system.

An ignition system tune-up often involves a test with an oscilloscope, which can test both point-type and electronic ignition systems. An oscilloscope can measure the voltage levels in both the primary and secondary ignition systems as each spark plug fires and as the magnetic field in the coil builds up. By setting the controls on the oscilloscope, you can look at either the primary- or secondary-ignition waveforms.

Observing the oscilloscope patterns can help you diagnose many primary- and secondary-system malfunctions, such as fouled spark plugs, resistive or broken spark plug wires, cracked distributor caps, shorted rotors, defective or misadjusted points, defective or out-of-capacity condensers, reversed coil primary leads, and internal coil defects. Once you know what the correct waveform for an engine looks like, any variation in that waveform usually indicates a problem.

The oscilloscope is connected to the engine through its test leads. Usually, connections are made to the coil negative primary, to the coil secondary wire, to the #1 plug wire, and to the battery terminals. The number and kind of hookups vary among vehicles. Always consult the service manual before making any connections.

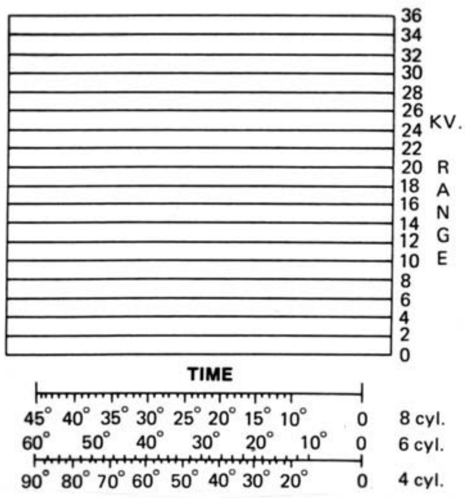
The oscilloscope controls can be adjusted to get the best possible view of a waveform. An oscilloscope usually has controls for horizontal and vertical spacing, size, brightness, and primary- or secondary-waveform selection. Most oscilloscopes also have various voltage settings to adjust the size of the waveform for the easiest viewing.

## Reading a Waveform

The waveform is a picture of voltage in relation to time. Figure 31 shows the layout of a typical oscilloscope screen. Note the markings on the screen. The horizontal lines on the screen represent voltage levels, which are measured in kilovolts. The numbers printed on the right-hand side of the lines tell you the voltage level at each horizontal line, from 0 to 36 kilovolts. (Remember that 1 kilovolt is equal to 1,000 volts.) The "time line" at the bottom of the screen represents degrees of distributor rotation.

A waveform display on an oscilloscope screen is read from left to right. By comparing the position of the waveform to the marked lines on the screen, you can determine the voltage values that the waveform represents. Whenever the waveform is above the zero line, a *positive* voltage value is indicated. Whenever the waveform is below the zero line, a *negative* voltage value is indicated.

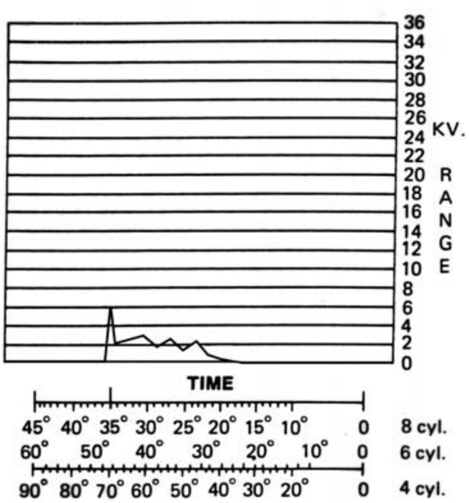
***FIGURE 31—This illustration shows a typical oscilloscope screen. The horizontal lines represent voltage levels, measured in kilovolts. The time line at the bottom of the screen represents degrees of distributor rotation.***




The waveform shown in Figure 32 is very simplified, but it will help you understand how to read an oscilloscope display. Imagine that we have an oscilloscope connected to one cylinder in the ignition system of an eight-cylinder engine, and this is the waveform the scope displays. The waveform displays a picture of the electrical activity at the cylinder as the engine runs. When the cylinder's spark plug fires, the waveform rises sharply. Thus, the "peak" in the waveform represents the spark plug fire.

Starting at the far left of the screen, the waveform is drawn along the zero line, so the waveform indicates a value of 0 kilovolts. At that point, nothing is happening, so the oscilloscope reads 0 kilovolts. Now, move to the right of the waveform. The waveform suddenly rises

***FIGURE 32—In this simplified waveform, the peak indicates the point at which the spark plug fires.***



sharply, indicating that the spark plug has fired. The highest point of this peak reaches the six-kilovolt line, so the oscilloscope is measuring six kilovolts. As you continue to move to the right, the waveform drops back down to the zero line. This waveform pattern repeats each time the spark plug fires in that cylinder.

Remember that a waveform is a representation of voltage in relation to time. The time line at the bottom of the screen indicates the number of degrees of distributor rotation. Look at the time line at the bottom of the screen in Figure 32. Note that there are three temperature lines—one line for a six-cylinder engine, one line for a four-cylinder engine, and one line for an eight-cylinder engine. Trace your finger across the time line for the eight-cylinder engine. (Our example engine has eight cylinders.) Note that the waveform peaks at the 35-degree mark. Thus, the spark plug in this cylinder fires at 35 degrees of distributor rotation.

Remember that this example is a simplified explanation of how to read a waveform. You'll look at some actual ignition system waveforms and examine the different parts of the waveforms in a later section.

# Ignition System Waveforms

Remember that an oscilloscope can be used to measure the voltage levels in both the primary and secondary ignition system circuits. By setting the controls on the scope, you can view just the primary-ignition waveforms, or just the secondary-ignition waveforms. Observing the waveforms can help you diagnose many primary- and secondary-system malfunctions. You can compare the waveform displayed on the screen with a correct waveform for the engine and look for any variations that would indicate a problem.

As you learned, an oscilloscope can be used to test both conventional and electronic ignition systems. Let's begin by discussing the waveforms for a conventional ignition system.

## The Secondary Waveform in a Conventional Ignition System

A secondary waveform is a display of the high-voltage activity in the secondary ignition system circuit. Every time the distributor points open, a voltage is produced in the secondary circuit. The voltage is then displayed as a waveform on the screen. The main use of the secondary ignition circuit waveform is to measure the amount of voltage that's needed to fire the spark plug. A typical waveform for a secondary ignition system circuit is shown in Figure 33.

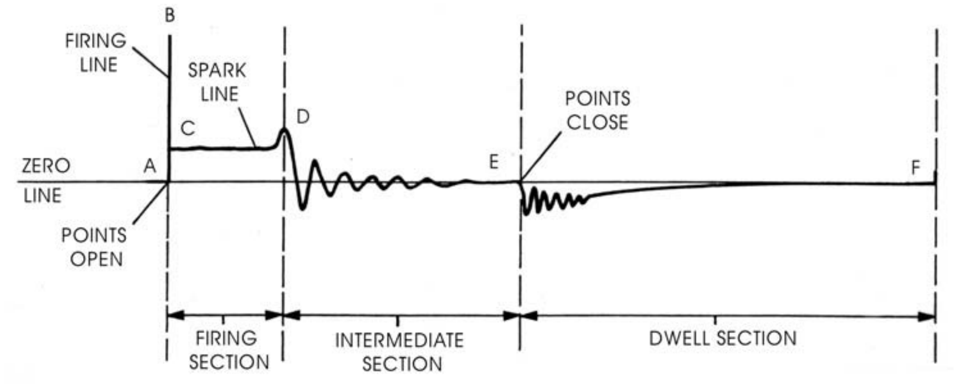



***FIGURE 33—When a point-type ignition system is operating properly, the oscilloscope will display this waveform for the secondary circuit.***

A secondary waveform is made up of three sections: the *firing section*, the *intermediate section*, and the *dwell section*. During the firing section of the waveform, the actual firing of the spark plug takes place. The firing section of the waveform is composed of the firing line and the *spark line*. The firing line is a vertical line that indicates the amount of voltage required to overcome the spark plug gap and the distributor rotor air gap. The spark line is a horizontal line that indicates the amount of voltage required to maintain the spark.

Point A in the waveform represents the exact moment at which the contact points separate, causing the magnetic field in the ignition coil to collapse. At Point B in Figure 33, the waveform rises sharply. This sharp rise illustrates the high voltage that results from the collapse of the magnetic field. The height of the firing line at Point B indicates the amount of voltage required to fire the spark plug.

After the spark plug fires, the secondary voltage in the coil drops, so the waveform drops sharply to Point C. The spark continues to bridge the spark plug gap, and the spark voltage remains at a fairly constant low value until the spark extinguishes at Point D.

Now, let's examine the intermediate section of the waveform. The intermediate section immediately follows the firing section. In Figure 33, you can see that the intermediate section contains a series of gradually diminishing *oscillations* that disappear by the time the dwell section of the waveform starts. The term oscillations refers to the small "up and down" movements of the waveform starting at Point D. These oscillations occur as the remaining ignition coil energy dissipates and gradually dies out at Point E. The oscillations result from the combined effects of the coil and the condenser in dissipating the energy.

The dwell section of the waveform illustrates the dwell portion of the ignition cycle; that is, the period of time when the contact points are closed. The dwell section begins at Point E, when the contact points close. The closing of the points causes a short downward curve in the waveform, followed by a series of small, rapidly diminishing oscillations. These oscillations represent the buildup of the magnetic field around the coil that occurs when the contact points are closed. The dwell section continues until the points open again at the beginning of the next waveform, Point F.

Secondary waveforms are very useful for showing overall ignition system operation.

## The Primary Waveform in a Conventional Ignition System

The primary waveform can be useful in detecting a problem in the ignition system's primary circuit. Since the waveform shows what's happening in the primary circuit, it can be used to locate problems relating to point condition, coil condition, and dwell in a conventional ignition system. A typical primary waveform for a point-type ignition system is shown in Figure 34.

Since any voltage variation in the ignition primary circuit is reflected in the secondary, it isn't always necessary to use a primary waveform for general ignition testing. The primary waveform has the same three basic sections as the secondary.

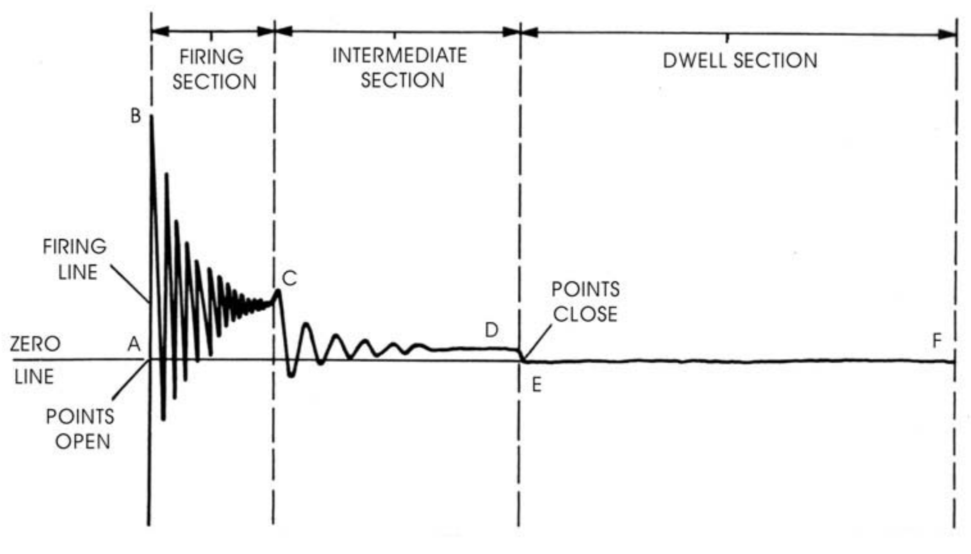



***FIGURE 34—When a point-type ignition system is operating properly, the oscilloscope will display this waveform for the primary circuit.***

The firing section shows a series of rapid oscillations that take place when the spark plug fires. Point A indicates the exact moment at which the contact points separate.

The vertical line between Point A and Point B, and the oscillations that follow Point B, represent the repeated charging and discharging of the condenser, and also the induced voltage surges in the primary circuit that occur when the spark plug is firing. When the spark jumps the spark plug gap and energy is being drained from the coil, the height of the oscillations diminish until the spark is extinguished at Point C.

The intermediate section of the waveform is a series of gradually diminishing oscillations that disappear by the time the dwell section begins. Beginning at Point C, any remaining energy in the coil dissipates and gradually dies out at Point D.

The intermediate section ends and the dwell section begins when the contact points close. The dwell section is represented by the horizontal line that extends from Point E to Point F. During this period, the contact points remain closed.

## Electronic Ignition System Waveforms

An oscilloscope can be used to check an electronic ignition system the same way it was used to check a point-type ignition system. The waveforms displayed on the screen are basically the same as those for a point-type system. Figure 35 shows a typical primary waveform for an electronic ignition system, compared with the primary waveform for a conventional ignition system. Note that the intermediate section of the electronic-system waveform is much shorter than that of the conven-

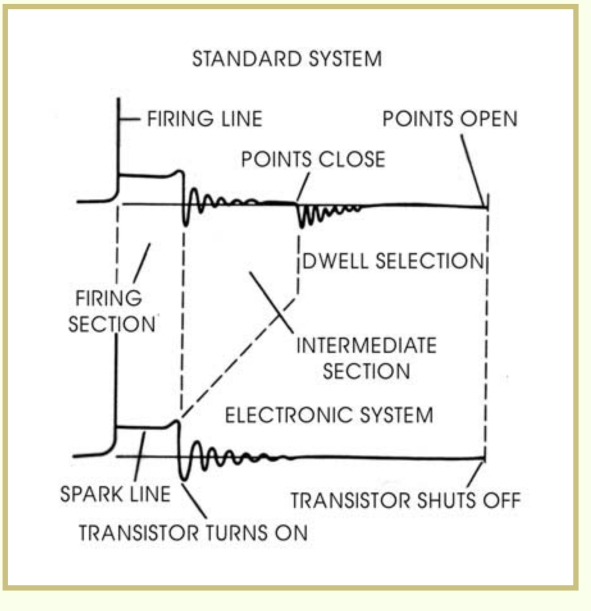



***FIGURE 35—The primary waveform of an electronic ignition system varies from that of a conventional ignition system because the electronic system uses a transistor instead of contact points to turn the primary-winding voltage on and off.***

tional system. The dwell section of the electronic-system waveform is much longer than that of the conventional system. The differences in the electronic-system waveform occur because the electronic ignition system uses a transistor instead of contact points to turn the primary-winding voltage on and off.

## Methods of Displaying Waveforms

Waveforms can be displayed on an oscilloscope screen in one of three ways: using the *superimposed method*, the *raster method*, or the *parade method*.

In a superimposed-waveform display, the waveforms for all engine cylinders are displayed simultaneously, one on top of the other, as shown in Figure 36. Superimposing the waveforms of all the engine's cylinders is a convenient way to test the ignition system for overall uniformity. By expanding the scope display horizontally between the two vertical reference lines on the screen, you can clearly view any variations in the waveform.

In the raster method of displaying waveforms, the waveforms for all engine cylinders are displayed one above the other, as shown in Figure 37. This allows the waveforms of individual ignition cycles to be displayed at full-screen width, permitting a detailed, close-up inspection of all engine cycles simultaneously. The raster method is especially helpful for examining individual cylinder waveforms when a variation is observed in a superimposed pattern.

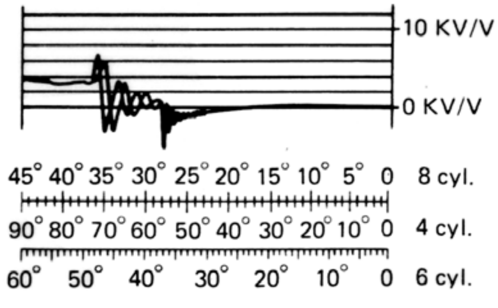



***FIGURE 36—The oscilloscope waveforms of all engine cylinders can be displayed simultaneously, one on top of the other, as shown here. This is called the superimposed method of displaying scope waveforms.***

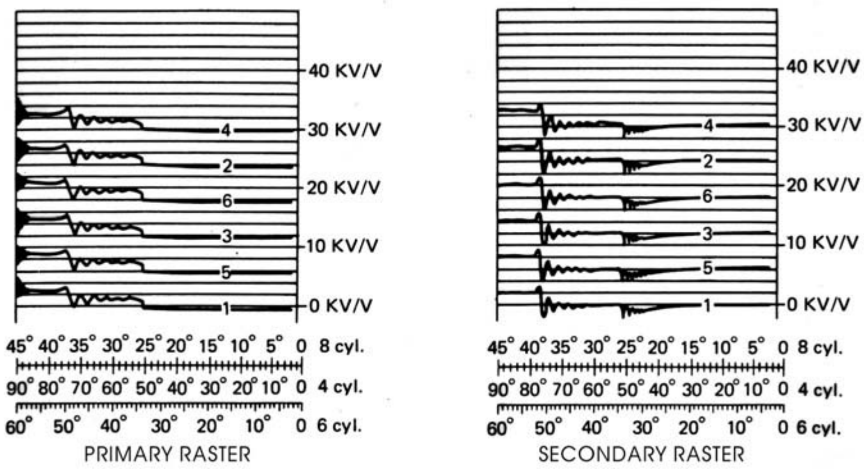
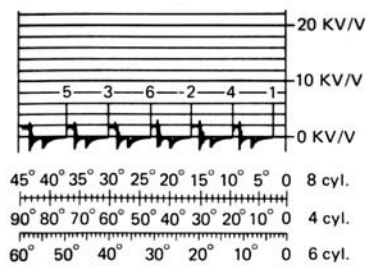



***FIGURE 37—The waveforms of all cylinders can be displayed simultaneously, one above another. This is called the raster method of displaying waveforms.***

In the parade method of displaying waveforms, the waveforms for the different cylinders are displayed one after the other in a straight line, in the order of firing. Suppose you're viewing the waveform for an engine with a 5-3-6-2-4-1 firing order (Figure 38). The parade waveform will begin on the left-hand side of the screen with the waveform for Cylinder 5. Then, the scope will show the waveforms for Cylinder 3, Cylinder 6, and so on. As you read from left to right, you can view the individual waveforms for all of the engine's cylinders in a straight line.

***FIGURE 38—In the parade method of waveform display, the waveforms for each engine cylinder are displayed on the screen from left to right, in the order of firing.***




## Performing an Engine Test with an Oscilloscope

The oscilloscope can be used to view the waveforms of both the primary and secondary circuits of an ignition system. To view a primary waveform, a primary-pickup device from the oscilloscope is connected to the primary circuit at the distributor terminal or the distributor side of the coil. To view a secondary waveform, a secondary-pickup device

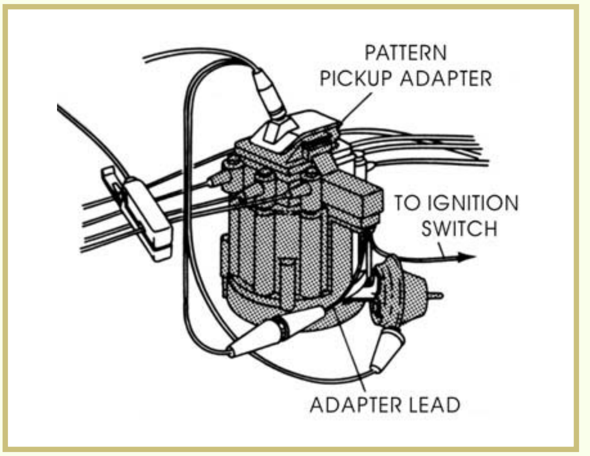



***FIGURE 39—Special adapters like the one shown here are used to attach the oscilloscope leads to an electronic ignition system.***

is connected to the secondary circuit at the coil tower. Of course, the exact procedure depends on the type of equipment you're using.

For most electronic ignition systems, the oscilloscope test connections are about the same as those for conventional ignition systems. However, some electronic ignition systems require the use of a special *secondary-waveform pickup*, a special tool that's provided with most modern test equipment. A typical adapter and hookup are shown in Figure 39.

*Note:* Oscilloscopes and other test equipment should be connected according to the instructions provided with the test equipment. Connecting the equipment in any other way could damage the test equipment or parts of the ignition system.

The following is a general procedure for using an oscilloscope to test the condition of an automotive engine with a conventional ignition system. Attachments and controls vary in different machines, so be sure to read the manufacturer's instructions provided with the equipment.

*Step 1:* Connect the oscilloscope leads to the ignition system components according to the scope manufacturer's instructions.

*Note:* Position the oscilloscope leads carefully to prevent them from becoming entangled in the engine's fans or belts.

*Step 2:* Set the oscilloscope controls to the secondary superimposed position.

*Step 3:* Start the engine and allow it to idle.

*Step 4:* Observe the waveforms in the superimposed position. Closely check the coil oscillations to diagnose a bad coil or condenser.

*Step 5:* Observe the dwell section of the waveform to diagnose the coil, condenser, or points. The dwell section in an electronic-system waveform may seem very long compared to that in a conventional-system waveform. Also, the length of the dwell section varies in high-energy ignition and computer-controlled systems.

*Step 6:* Observe the waveforms in the raster position to see all of the cylinders on the screen at once. Race the engine to observe the spark plug firing lines.

*Step 7:* Remove a plug wire to check the coil output. On some electronic ignition systems, certain plug wires must not be removed. This is to prevent the high-voltage spark from arcing down to any low-voltage components inside the distributor.

*Step 8:* Set the oscilloscope controls to the primary position.

*Step 9:* Observe the waveforms. Closely check the point-opening and point-closing signals.

*Step 10:* Compare the waveform displayed with the engine's normal waveform. If the displayed waveform doesn't match the normal waveform, the ignition system has a problem. You can then begin ignition-troubleshooting procedures to isolate the problem and correct it.

## Cylinder Balance Test

Most modern engine analyzers are designed to perform *cylinder balance tests*, which are sometimes called *dynamic compression tests*. In a cylinder balance test, the engine analyzer is used to determine whether all of the engine cylinders are producing the correct amount of power. This test can confirm a suspected problem such as a fouled plug, vacuum leak, or burned valve.

The following is a general procedure to perform a cylinder balance test.

*Step 1:* Raise the engine speed to 1,000 rpm.

*Step 2:* Use the engine analyzer to short out each cylinder, and note the engine rpm. Shorting out a cylinder should cause the rpm to drop by at least 50. If the rpm doesn't change, the cylinder wasn't producing power before it was disconnected, and the cause of the problem must be investigated.

*Note:* This test can easily be duplicated in a conventional ignition system by removing each spark plug wire with a pair of insulated pliers on a running engine with a tachometer attached. This method isn't recommended on electronic ignition systems, however, since an arc inside the cap could damage primary-circuit components.

Now, take a few moments to review what you've learned by completing *Power Check 4*.

# *Power Check 4*

1. Often, an oscilloscope is combined with other test instruments into a single testing unit that's called a (an) _______.
2. In the _______ method of displaying waveforms on an oscilloscope screen, the waveforms for the different cylinders are displayed one after the other in a straight line, in the order of firing.
3. An oscilloscope can measure electrical quantities in a circuit and display the measurements on its screen as a _______.
4. In a _______ waveform display, the waveforms of all the engine cylinders are displayed simultaneously, one on top of the other, on the oscilloscope screen.
5. *True or False?* A secondary waveform is very useful for analyzing overall ignition system operation.
6. *True or False?* A primary-circuit waveform can be used to locate problems that relate to point condition, coil condition, and dwell in a conventional ignition system.
7. *True or False?* The oscilloscope can be used only to view the waveforms for an ignition system's primary circuit.

**Check your answers with those on page 65.**

# SERVICING COMPUTER-CONTROLLED AND DIRECT-FIRE IGNITION SYSTEMS

## Computer-Controlled Ignition Systems

Computer-controlled electronic ignition systems seem complicated—and they are. However, these systems can often be diagnosed and repaired using simple test equipment and basic diagnostic procedures. Always remember that the average computer-controlled ignition system is simply an electronic ignition with a computer that controls the timing advance.

The components and operation of computer-controlled ignition systems differ greatly from vehicle to vehicle. To determine which part or area of a computer-controlled system is defective, you must understand how that particular system works. Always refer to the service manual for the exact troubleshooting procedures, since these procedures vary significantly from manufacturer to manufacturer. The following information provides some general guidelines to diagnose and repair computer-controlled systems.

Always start your diagnosis by eliminating all "noncomputer" problems. Then, proceed to check the computer system. Keep in mind that many computer systems control the fuel system as well as the spark advance. Therefore, a computer-related fuel system problem may display symptoms that are similar to those caused by a computer-related ignition problem.

Most computer-controlled electronic-ignition problems are caused by defective sensors. Therefore, in most cases, the logical procedure is to check the input sensors and wiring first, and then move on to check the computer. There are exceptions, such as when a visual check determines that a part is bad or when a performance check has pinpointed the problem area. In these cases, the components most likely to cause the problem should be checked first.

Most late-model automotive computer systems can diagnose problems, to a degree. A malfunction in any sensor or output device, or in the computer itself, is stored in the computer memory section as a *trouble code*. Stored codes can be retrieved to pinpoint the trouble area. Systems without the self-diagnostic feature are inspected using a process of elimination. This involves testing parts to determine whether or not they're defective. Then, you can determine whether the nontestable parts, such as the computer, are functioning properly. You'll learn more about computer trouble codes in a later study unit.

Some computers can be disconnected in order to determine whether the computer or something else is causing a problem. However, on other systems, disconnecting the computer accomplishes nothing, and may prevent the vehicle from running. Computers are usually disconnected or unplugged by removing the computer's fuse.

Suppose a vehicle's coil won't produce a spark. If you unplug the computer and the coil sparks, then the coil probably isn't defective and the problem is in the computer system. If the coil doesn't spark, then the problem is most likely in the ignition system itself and not in the computer system. In this instance, unplugging the computer can help you troubleshoot the engine problem.

In systems that contain a pickup coil or Hall-effect switch, the computer system can be checked using the procedures previously explained in the section on servicing electronic ignition systems. You can also use these procedures to test the remaining ignition system components, such as the coil, distributor cap and rotor, spark plugs, and spark plug wires.

## Direct-Fire Ignition Systems

As you learned, direct-fire ignition systems are computer-controlled systems. The exact design of direct-fire systems and their servicing procedures vary. Because of these variations, even experienced technicians have to rely on the repair information contained in service manuals.

You now know that many computerized ignition systems contain the ability to self-diagnose their circuits to a certain extent. Therefore, if a problem occurs in the computer-control system, the computer can often recognize the problem itself. Some people believe that a vehicle's computer system can tell the technician what the *exact* problem is. However, this isn't really true. Instead, the computer can usually only indicate that a problem exists in a certain area. The technician must then determine the cause of the problem in that area of the system.

In most cases, the computer system identifies problems by monitoring the signals it receives from its sensors. "High" and "low" limits are usually placed on the values of these signals. If any signal value from a sensor exceeds these limits, the computer recognizes that a problem exists. The computer then "tells" the technician about the problem by displaying a number called a trouble code. The technician can then look up the trouble code on a chart in the service manual and identify what problem the trouble code represents in that particular vehicle. (Details on how to retrieve trouble codes and how to service automotive computer systems will be discussed in a later study unit.)

Remember that direct-fire ignition systems contain long-lasting, reliable electronic components. Apart from regular checks of the spark plugs and spark plug wires, these ignition systems don't usually require periodic service or adjustments. Therefore, these systems are usually serviced only when a problem occurs in the system.

When servicing direct-fire ignition systems, many procedures involve using the self-diagnosing features of the computer system. However, a few other test instruments are also commonly used to diagnose problems. You've already learned about one of these instruments—the multimeter. The multimeter can be used to determine the condition of the wires and electrical connections in a direct-fire system. Using the ohmmeter function of the multimeter, you can determine if a broken wire or a defective connection is preventing electricity from flowing through the system.

Another instrument that can be used to diagnose direct-fire ignition systems is the oscilloscope. Oscilloscopes used for this purpose are smaller than ordinary oscilloscopes—usually, you can hold them in your hand. This type of oscilloscope allows you to observe the secondary waveform that shows the firing voltages for each cylinder. Because of the way the ignition system controls the coil operation, the oscilloscope can't be used to test the primary side of the ignition coil. However, by observing the secondary waveform, you can easily see if a cylinder's spark plug isn't firing, and you can measure the value of the voltage that travels to the spark plugs.

Hand-held engine analyzers are also used to test direct-fire ignition systems. The functions these analyzers perform depend on the vehicle. However, most analyzers contain a multimeter for testing electrical circuits, and also a small, television-like screen that displays the voltage pulse signals produced by the crankshaft and camshaft position sensors. Hand-held engine analyzers can be used to read digital pulse signals. In addition, most of these testers also have frequency counters that can be used to measure the time of each pulse signal. By observing these waveforms, you can often detect a problem in the system.

For example, if an engine won't start, you can test to see what signal is being produced by the crankshaft position sensor. If the crankshaft position sensor produces no pulse signal as the engine is turned over, you'll know that the sensor isn't operating properly. If the sensor doesn't produce a signal, the system won't be able to produce a spark at the spark plugs, and the engine won't run. At that point, you can check to see if the sensor is faulty or if something else—such as a broken wire or a defective trigger wheel—is causing the problem.

You just learned that hand-held engine analyzers can usually determine the frequency of the pulse signals. By determining the frequency of the signal, the tester can determine the current engine speed and display it for the technician. Some high-end testers can even monitor the signal frequency to detect ignition system misfires. If an engine cylinder isn't firing, the engine tends to slow down at the point where the power in the faulty cylinder should occur. After the next cylinder fires, the engine returns to its original speed. This slowing down of the engine also affects the signal sent to the computer, which the engine analyzer can detect.

## Troubleshooting Direct-Fire Ignition Systems

Because of the differences in direct-fire ignition systems, technicians usually follow the troubleshooting charts in the service manual when working on repairs. However, in general, problems in a direct-fire ignition system cause one of two conditions: either the engine runs and misfires, or the engine doesn't run at all.

### Engine Misfires

If the engine misfires, it usually runs unevenly and vibrates. In addition, the engine may lack power and have poor fuel mileage. In this situation, the troubleshooting procedure should begin with a visual inspection of the ignition system. Very often, the problem is caused by something simple, such as a broken or damaged spark plug wire. An obvious problem such as this is often detected quickly with a simple visual inspection of the system.

After the visual inspection, it's common to remove the spark plugs from the engine to check their condition. As you learned earlier, spark plugs that are excessively worn or damaged fail to operate and cause misfires. In addition, the condition of the spark plugs often indicates a particular problem. For example, if one spark plug is a different color, it may indicate a problem within that cylinder.

When troubleshooting engine problems, always keep in mind that the problem may be mechanical and not necessarily in the ignition system. For example, a lack of power in a cylinder may be caused by worn piston rings or a damaged valve.

Once the spark plugs have been inspected and replaced, if necessary, the ignition system is usually tested with an engine analyzer that can display the spark waveform and monitor the signals from the crankshaft and camshaft position sensors. The information gained from these tests is then compared to the specifications listed in the service manual. Once the problem is identified, the defective components can be repaired or replaced, and the system can be returned to its proper working order.

## The No-Start Condition

If an engine won't start at all, determine if the engine has spark at the spark plug. If there's a spark, then the problem is probably not in the ignition system. Instead, the problem is more likely in the fuel system or some other engine system. However, if there isn't a spark, check the computer-control system first. As you learned, you can often gain insight into the problem by analyzing the trouble codes.

After analyzing the trouble codes, use the troubleshooting charts and testing procedures outlined in the service manual to identify the exact problem. Remember that direct-fire ignition systems usually require very few, if any, adjustments. The ignition timing is controlled by the computer system. Therefore, if a problem does occur, it's probably caused by a defective component, and not worn or misadjusted components. The only components that are prone to wear in direct-fire ignition systems are the spark plugs and the spark plug wires.

Now, take a few moments to review what you've learned by completing *Power Check 5*.

# *Power Check 5*

1. Most computer-controlled ignition system problems are caused by defective _______.
2. Start with the _______ and move to the complex when dealing with computers.
3. In most computer-controlled ignition systems, the computer controls only the _______.
4. Computer _______ can be retrieved to help diagnose computer problems.
5. A computer is tested or unplugged by removing the computer's _______.
6. Voltage pulses can best be checked with a (an) _______.
7. Direct-fire ignition systems require _______ adjustments.
8. The only components of a direct-fire system prone to wear are the spark plugs and _______.

**Check your answers with those on page 65.**

# SUMMARY

Earlier in your program, you learned the importance of the ignition system in regards to engine operation. You learned that spark plugs create the sparks that ignite the air-and-fuel mixture in the combustion chambers. In this study unit, you learned how to service a vehicle's ignition system. You learned how to remove and inspect old spark plugs, and how to install new ones. In addition, you learned how to check the spark plug gap using a gapping tool. You also learned how to test the ignition coils and spark plug wires.

You now know how to tune up both a conventional ignition system and an electronic ignition system. You also know how to service and troubleshoot both types of systems.

You're familiar with an oscilloscope and you know how to read its waveforms. You know that the secondary waveform is made up of three sections: the firing section, intermediate section, and dwell section. Waveforms can be displayed on an oscilloscope using either the superimposed, raster, or parade method. You also learned how to service both a computer-controlled and direct-fire ignition system.

# Power Check Answers

## 1

1. spark plug socket
2. Oil
3. firing order
4. cross-threading
5. Fuel
6. bridged
7. thread chase

## 2

1. 12,000
2. False
3. True
4. True
5. False

## 3

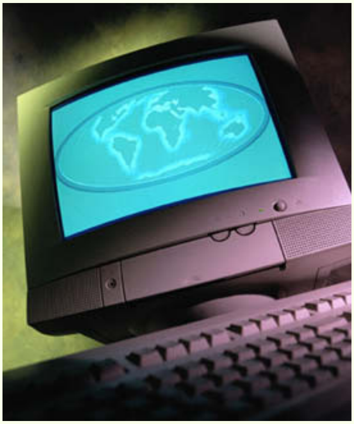
1. carbon tracking
2. resistance
3. True
4. True
5. True

## 4

1. engine analyzer
2. parade
3. waveform
4. superimposed-
5. True
6. True
7. False

## 5

1. sensors
2. easiest
3. timing advance
4. trouble codes
5. fuse
6. engine analyzer or oscilloscope
7. few
8. spark plug wires



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