CHAPTER 10

Ignition Systems

Learning Objectives

After studying this chapter, you will be able to:

- Describe the primary purpose of the ignition system.
- Identify the components in a typical magneto system and describe the function of each part.
- Identify the three general classifications of magneto ignition systems and explain the operation of each.
- Describe the operation of a battery ignition system.

Key Terms

Alnico
capacitive discharge ignition (CDI) system
center electrode
condenser
dry-charged batteries
dwell (cam angle)
electronic switching device
flashover
heat range
ignition advance system
ignition coil
insulator
magneto system
mechanical breaker point ignition (MBI) system
mechanical breaker points
reach
spark plug
spark plug wire
transistor-controlled ignition (TCI) system
tungsten
wet-charged batteries

Basic Ignition System Operation

The primary purpose of the ignition system of a small gasoline engine is to provide sufficient electrical voltage to discharge a spark between the electrodes of the spark plug. See **Figure 10-1**. The spark must occur at exactly the right time to ignite the highly compressed air-fuel mixture in the engine's combustion chamber.

The ignition system must be capable of producing as many as 30,000 volts to force electrical current (electrons) across the spark plug gap. The intense heat created by the electrons jumping the gap ignites the air-fuel mixture surrounding the electrodes.

The rate, or number of times per minute, at which the spark must be delivered is very high. For example, a single cylinder, four-cycle engine operating at 3600 rpm requires 1800 ignition sparks per minute. A two-cycle engine running at the same speed requires 3600 sparks per minute. In multi-cylinder engines, the number of sparks per minute for one cylinder is multiplied by the number of cylinders.

Every spark must take place when the piston is at exactly the right place in the cylinder and during the correct stroke of the power cycle. Refer to *Chapter 5* of this text. Considering the high voltage required, the precise degree of timing, and the high rate of discharges, the ignition system has a remarkable job to do.

Most small gasoline engines use magneto systems to supply ignition spark. ***Magneto systems*** produce electrical current for ignition without any

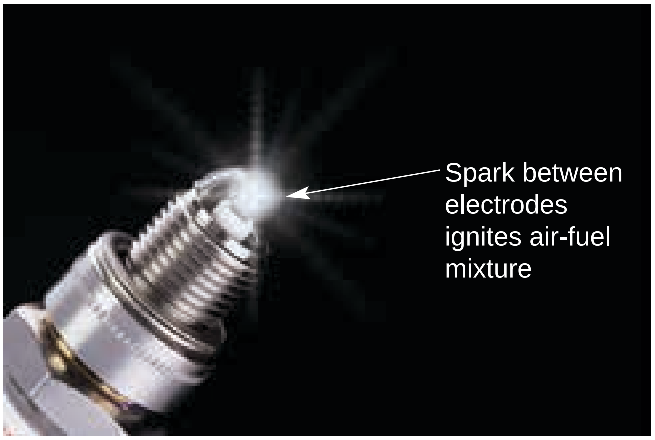

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Figure 10-1. The ignition system of a small engine works hard to produce enough voltage to force electrons to jump the spark plug gap.

outside primary source of electricity. They serve as simple and reliable ignition systems. Basic parts of a magneto system include:

- Permanent magnets.
- Spark plug.
- Spark plug wire.
- Ignition coil.
- Switching device.

A simplified magneto ignition system is shown in **Figure 10-2**. Note that the magnets are mounted in the flywheel and rotate past the coil assembly as the flywheel spins. In **Figure 10-2A**, the switching device is closed. As the magnets move past the coil, current is induced in the coils primary windings. This current causes a magnetic field to form around the primary windings. As the engine's piston nears TDC on its compression stroke, the switching device opens and the magnetic field in the primary windings collapses rapidly, inducing a high-voltage current in the secondary windings. The high voltage current travels to the spark plug, where it arcs across the spark plug gap and ignites the air-fuel mixture. See **Figure 10-2B**. An actual magneto ignition system is much more complex than the model shown here, but the basic operating principles are the same.

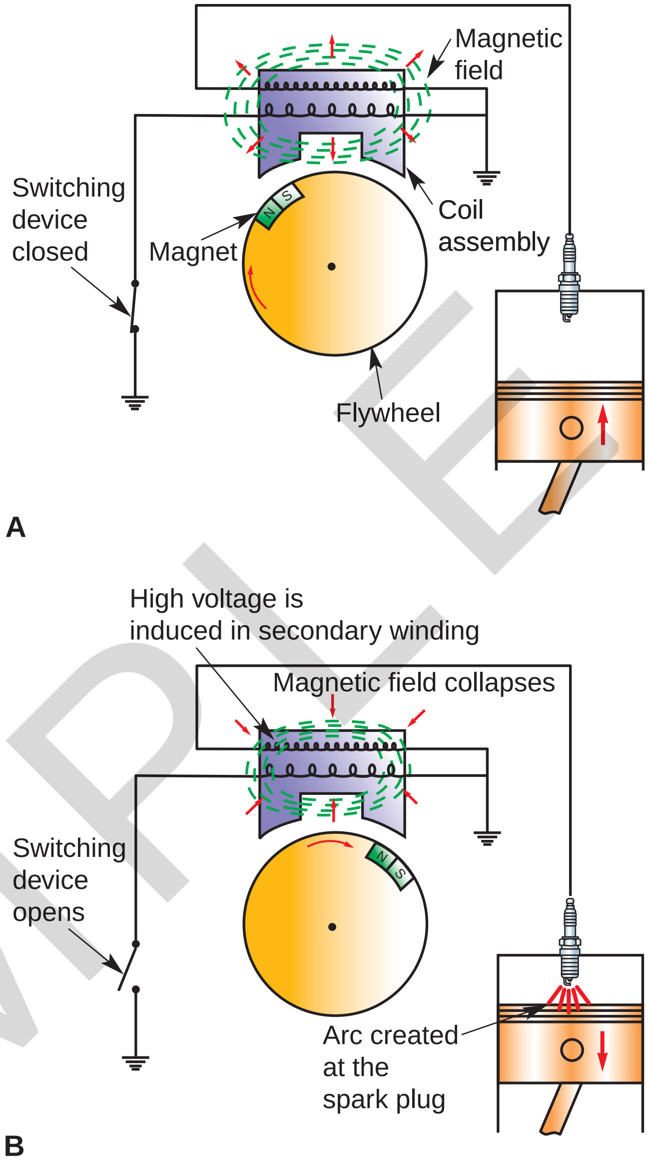

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Figure 10-2. The major parts of this small engine magneto system are the switching device, coil, flywheel magnets, spark plug wire, and spark plug.

Ignition System Components

The following sections detail the components commonly used in small engine ignition systems. An understanding of the construction and operation of these individual components will help you better understand the various systems discussed later in this chapter.

Ignition Coil

The ***ignition coil*** used in a magneto system operates like a transformer. The coil contains two separate windings of wire insulated from each other and wound around a common laminated iron core. See **Figure 10-3**. The primary winding is heavy-gage wire with fewer turns than the secondary winding, which has many turns of light-gage wire.

When electrical current is passed through the primary winding, a magnetic field is created around the iron core. When the current is stopped, the magnetic field collapses rapidly, cutting through the secondary windings. This rapid cutting of the field by the wire in the coil induces high voltage in the secondary circuit. The high secondary voltage, in turn, causes a spark to jump the spark plug gap and ignite the air-fuel mixture.

Spark Plugs

A ***spark plug*** is a device inserted into the combustion chamber of an engine that ignites the compressed air-fuel mixture. At first glance, an assortment of spark plugs may look very much alike. Actually, there are many variations. Using the correct spark plug for a given engine application can greatly increase the efficiency, economy, and service life of the engine.

Figure 10-4 shows the major parts of a typical spark plug. The terminal nut is the external contact with the ignition coil. Some terminal nuts are removable, others are not. Many of the major parts of the spark plug are used to identify the actual type of the plug. Other considerations include construction, heat rating number, and firing end construction. To learn how to identify spark plug types, use the spark plug symbols chart in **Figure 10-5**.

The spark plug ***insulator*** is usually an aluminum-oxide ceramic material, which has excellent insulating properties. The insulator must have high mechanical strength, good heat conducting quality, and resistance to heat shock. Generally, ribs on the insulator extend from the terminal nut to the shell of the plug to prevent flashover. ***Flashover*** is the tendency for current to travel down the outside of the spark plug instead of through the center electrode.

The ***center electrode*** carries the high voltage current to the spark gap. If the electrical potential is great enough to cause the current to jump the plug gap, the side electrode will complete the circuit to ground.

The sillment seal is a compacted powder that helps ensure permanent assembly and eliminates compression leakage under all operating conditions. The inside gasket also acts as a seal between the insulator and the steel shell.

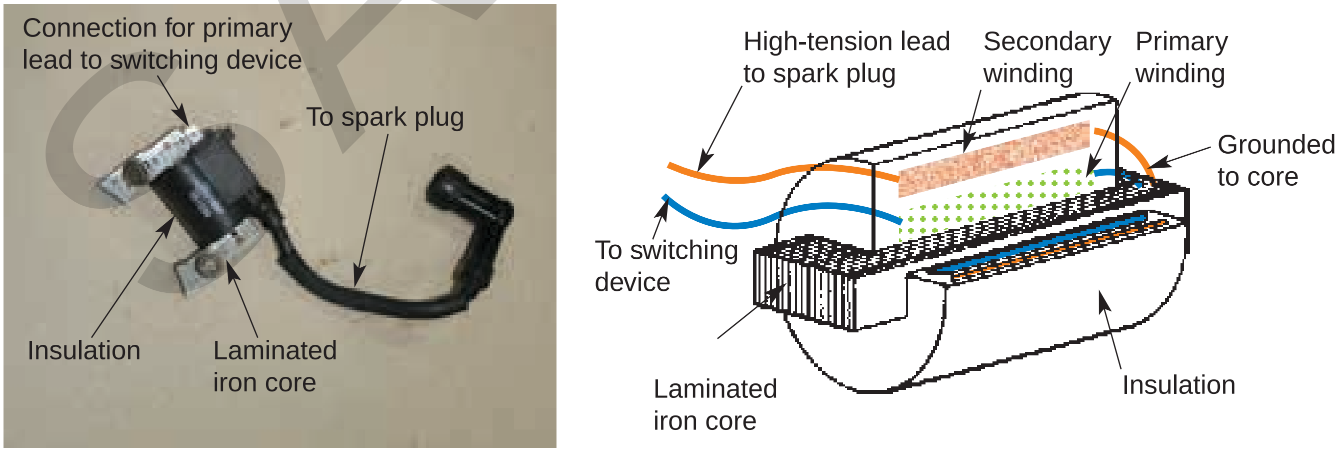

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Figure 10-3. An ignition coil functions as a step-up transformer to produce high voltage and low amperage from low voltage and high amperage. It consists of two sets of windings.

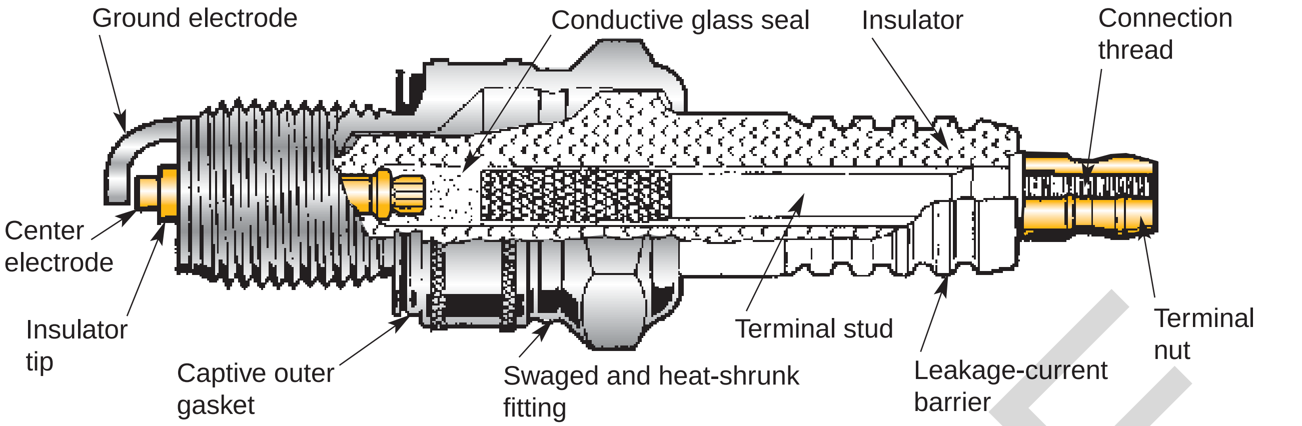

Figure 10-4. A spark plug carries high-voltage current produced by the ignition system. It also must withstand the high temperatures and shock of combustion, insulate the center electrode against current loss, and seal against compression leakage.

Spark plug ***reach*** varies with the type of spark plug. Some are long, others quite short. See **Figure 10-6**. Several standard thread sizes are commonly used. Threads on some spark plugs are metric sizes, usually 14mm.

Spark Plug Heat Transfer

Heat transfer in spark plugs is an important consideration. The heat of combustion is conducted through the plug as shown in **Figure 10-7**. Spark plugs are manufactured in various ***heat ranges*** from *hot* to *cold*. See **Figure 10-8**. Cold running spark plugs are those that transfer heat readily from the firing end. They are used to avoid overheating in engines having high combustion temperatures.

In figuring spark plug heat range, the length of the insulator nose determines how well and how far the heat travels. Spark plug A in **Figure 10-8**, for example, is a hot plug because the heat must travel a greater distance to the cylinder head. Spark plug D is comparatively colder than A. A cold plug installed in a cool running engine will tend to foul. Cool running usually occurs at low power levels, continuous idling, or in start/stop operation.

The tip of the insulator is the hottest part of the spark plug and its temperature can be related to preignition (firing of fuel charge prior to normal ignition) or plug fouling. Experiments show that if combustion chamber temperature exceeds 1750°F (954°C) in a four-cycle engine, preignition is likely to occur. If insulator tip temperature drops below 700°F (371°C), fouling or shorting of the plug due to carbon is likely to occur.

Spark Plug Wire

The ***spark plug wire*** connects the output of the ignition coil secondary windings to the spark plug. The spark plug wire is heavily insulated because it carries high voltage. If the insulation deteriorates, much of the voltage can be lost by arcing to nearby metallic parts of the engine.

Two common methods of spark plug wire connections are shown in **Figure 10-9**. Application A uses the exposed clip, which is satisfactory in uses where moisture, oil, or dirt will not get on the plug or can easily be wiped off. The boot type, shown at B, provides better plug protection.

Switching Devices

Switching devices are used in the ignition system to control the primary current to the ignition coil. The switching devices are either mechanical or electronic.

The ignition systems in some older engines use ***mechanical breaker points*** to control primary current to the coil. The breaker points generally consist of two tungsten contacts. One contact point is stationary, the other is movable. Each contact is fastened to a bracket. ***Tungsten*** is a hard metal with a high melting temperature. These characteristics

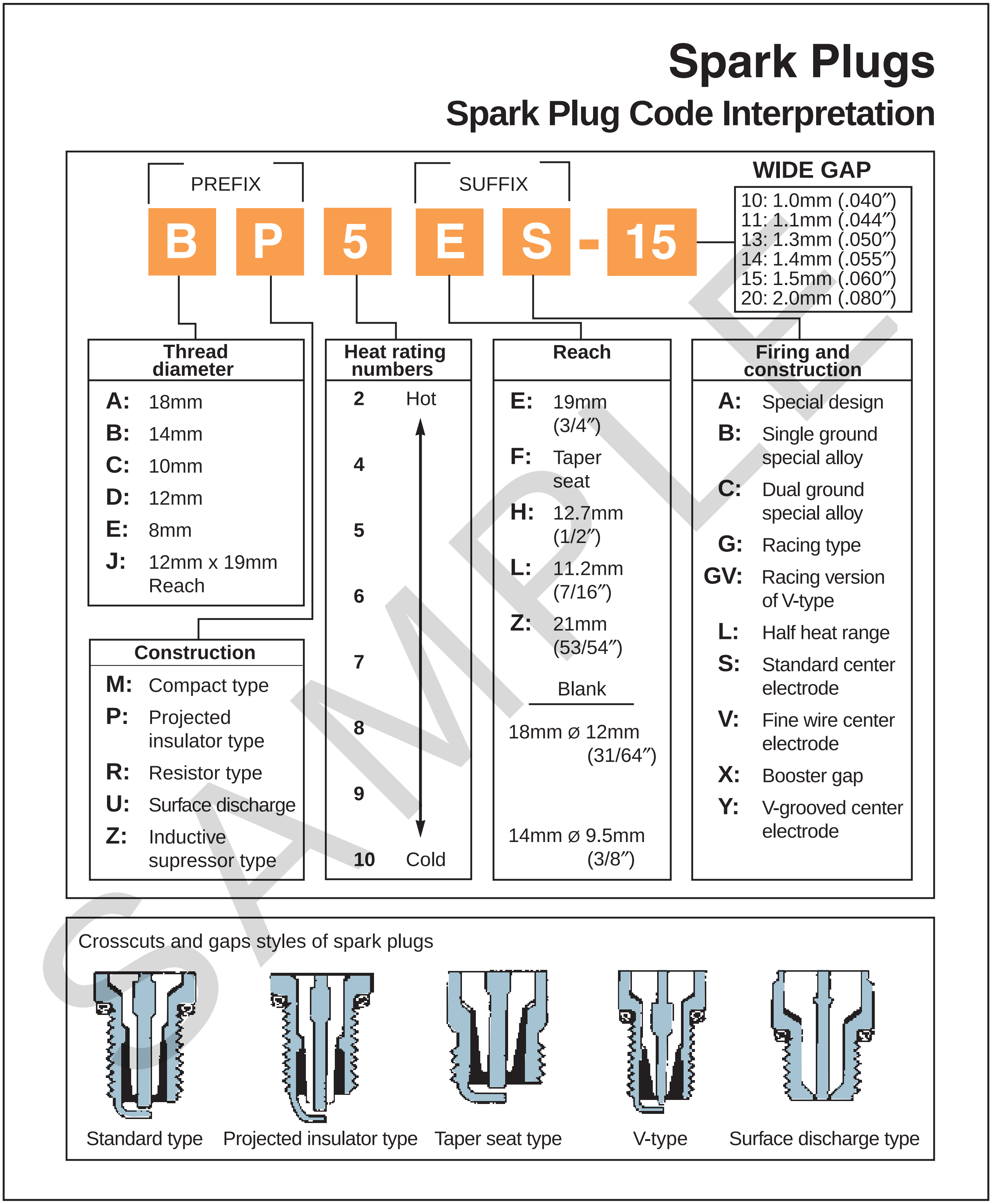

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Figure 10-5. This chart explains how to identify spark plugs.

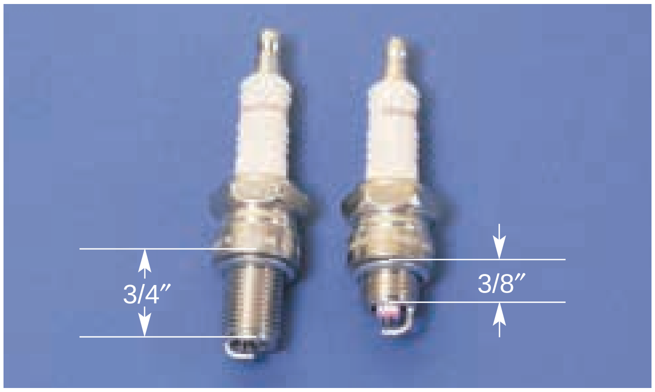

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Figure 10-6. Spark plug reach (length of thread) can vary considerably from one plug to another. Too long a reach can damage a piston. Too short a reach provides poor combustion.

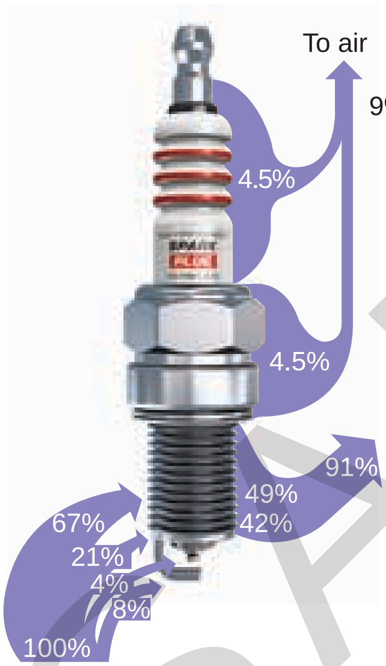

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Figure 10-7. The heat of ignition and combustion must be conducted away from critical parts of the spark plug to prevent preignition and burning of the electrodes.

are needed to withstand the continual opening and closing that takes place and the eroding effect of the arc that occurs when the points *break* (start to open).

The ignition systems in most engines use ***electronic switching devices*** to control the primary current to the coil. An electronic switching device is more dependable than a mechanical type because it has no moving parts to wear or burn out.

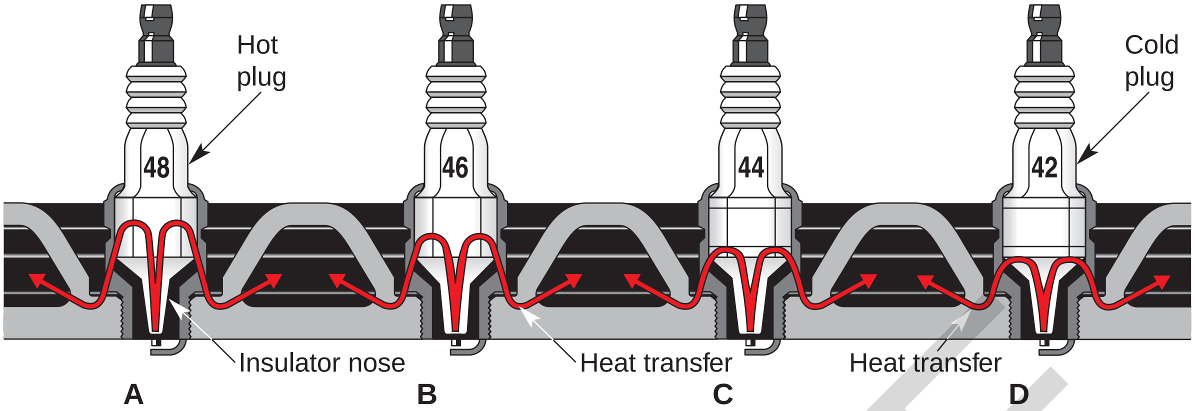
Magneto Ignition Systems

There are several types of magneto systems used on small engines. These systems are classified by the type of switching device they use to control primary current to the coil. Mechanical breaker point ignition (MBI) systems use mechanical breaker points to control current in the ignition coil. This type of system was used exclusively until the development of the solid state ignition system. Today, all ignition systems in late-model engines are of the solid state type. Solid state systems use electronic devices (transistors, capacitors, diodes, etc.) to control various ignition system functions. Solid state ignition systems provide many advantages over mechanical systems:

- Since there are no moving parts, mechanical adjustments are not required.
- No breaker points to burn, pit, or replace.
- Increase spark plug life.
- Easy starting, even with fouled plugs.
- Higher spark output and faster voltage rise.
- Spark advance is electronic and automatic. It never needs adjusting.
- Electronic unit is hermetically sealed and unaffected by dust, dirt, oil, or moisture.
- System delivers uniform performance throughout component life and under adverse operating conditions.
- Improves idling and provides smoother power under load.

The following are the three general classifications of magneto ignition systems.

1. A capacitive discharge ignition (CDI) system is a solid state (no moving parts) system that stores its primary energy in a capacitor and uses semiconductors for timing or triggering the system.
2. A transistor-controlled ignition (TCI) system is an inductive system that does not use mechanical breaker points. It utilizes semiconductors (transistors, diodes, etc.) for switching purposes.
3. A mechanical breaker point ignition (MBI) system is a flywheel magneto inductive system commonly used for internal combustion engines until the mid-1980s. It employs mechanical breaker points to time or trigger the system.



AC Spark Plug Div.; GMC

Figure 10-8. Spark plug heat transfer determines whether the plug is hot or cold. Heat is controlled by the insulator nose.

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Figure 10-9. Two common spark plug wire connectors. A—Exposed type. B—Neoprene-boot type. An exposed clip connector can be used in conjunction with a metal strip stop switch.

Note

Figure 10-10 compares these three types of magneto ignition systems. Study them carefully!

Operation of Capacitive Discharge Ignition (CDI) System

The ***capacitive discharge ignition (CDI) system*** is a solid state ignition system. It is standard equipment in many applications and has improved the reliability of modern small gasoline engines. The only moving parts in a CDI system are the permanent magnets in the flywheel. **Figure 10-11** shows a CDI module installed on a small gasoline engine. Refer to **Figure 10-12** to progressively trace current flow through the various electronic components in a typical CDI system.

As the flywheel magnets rotate across the CDI module laminations, they induce a low voltage alternating current (ac) in the charge coil. The ac passes through a rectifier and is changed to direct current (dc), which travels to the capacitor, where it is stored.

When the silicon controlled rectifier is triggered, the 300V dc stored in the capacitor travels to the spark coil. At the coil, the voltage is stepped up instantly to a maximum of 30,000V. This high voltage current is discharged across the spark plug gap.

In **Figure 10-13**, the flywheel magnets rotate approximately 351° before passing the CDI module laminations and inducing a small electrical charge

Comparisons	Mechanical Breaker Ignition System	Transistor Controlled Ignition System	Capacitor Discharge Ignition System
Abbreviation	MBI	TCI	CDI
Circuit type	Conventional	Solid state	Solid state
Energy source	Primary current of ignition coil	Primary current of ignition coil	Stored in capacitor
Trigger switch	Breaker contacts	Power transistor	Thyristor
Secondary voltage	Standard	Standard	Higher
Spark duration	Standard	Standard	Shorter
Rise time*	Standard	Standard	Shorter
Maximum operating speed	Standard	Higher	Higher
Maintenance	Regap and retime	None	None

*Rise time–time required for maximum voltage to occur.

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Figure 10-10. This chart compares mechanical breaker point, transistor-controlled, and capacitor discharge ignition systems.

in the trigger coil. At starting speeds, this electrical charge is just great enough to turn on the silicon controlled rectifier (SCR) in a retarded firing position (9° BTDC). This provides for easy starting.

In **Figure 10-14**, when the engine reaches approximately 800 rpm, advanced firing begins. The flywheel magnets travel approximately 331°, at which time enough voltage is induced in the trigger coil to energize the silicon controlled rectifier in the advanced firing position (29° BTDC).

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Figure 10-11. The CDI ignition module is compact and maintenance free. The only moving parts in a CDI system are the flywheel magnets.

Note

On some small engines equipped with electronic fuel injection, the engine control unit (ECU) calculates the proper ignition timing based on engine operating conditions. In these systems, engine sensors feed information on engine operation to the ECU. The ECU then prompts the ignition module to fire the spark plugs at the proper time based on the sensor inputs. These systems provide precise control of spark timing for improved engine operating efficiency.

Operation of Transistor-Controlled Ignition (TCI) System

The individual components that make up the ***transistor-controlled ignition (TCI) system*** are given in a chart in **Figure 10-15**. Study the function of each part carefully.

There are a variety of transistor-controlled circuits. Each has its own unique characteristics and modifications. **Figure 10-16** illustrates a typical circuit for a transistor-controlled ignition. Refer to this circuit as its principles are described in the following section.

As the engine flywheel rotates, the magnets on the flywheel pass by the ignition coil. The magnetic

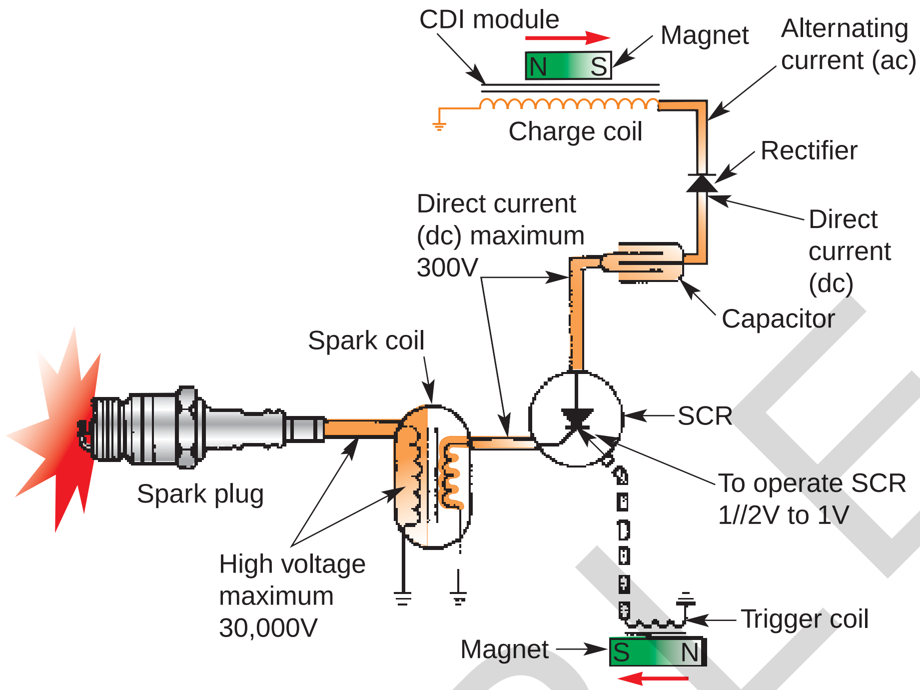

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Figure 10-12. The flywheel magnets induce a low-voltage alternating current in the charge coil. As the alternating current passes through the rectifier, it is changed to direct current. The direct current continues to the capacitor, where it builds up a charge. When the capacitor nears its full charge, the flywheel magnets induce a small current in the trigger coil. The current briefly activates the silicon controlled rectifier (SCR), which allows the 300V stored in the capacitor to discharge through the primary windings of the spark coil. This induces a much higher voltage in the secondary windings, which fires the spark plug.

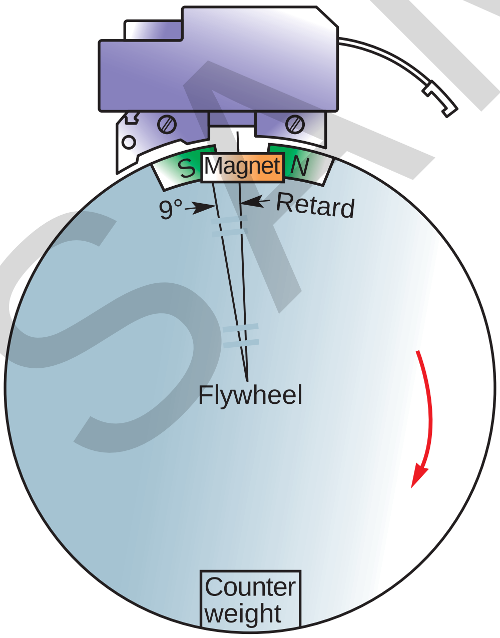

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Figure 10-13. At low speeds, the flywheel magnets induce a small current in the trigger coil, which turns on a silicon rectifier at 9° BTDC for easy starting.

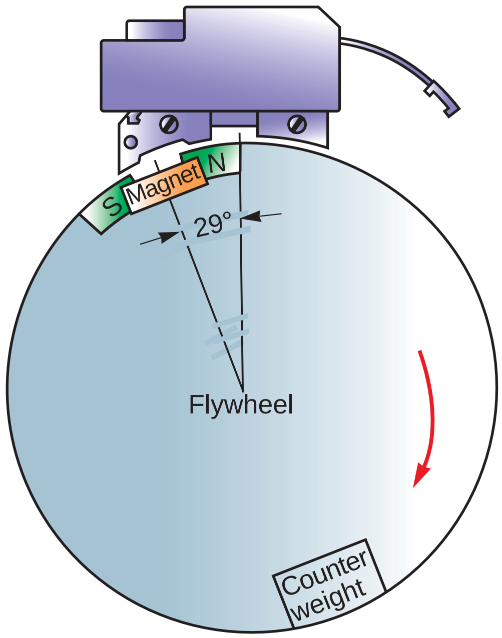

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Figure 10-14. At 800 rpm, stronger trigger coil current turns on the silicon rectifier at 29° BTDC for satisfactory ignition during normal engine operation.

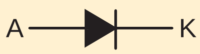
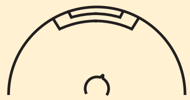
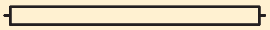
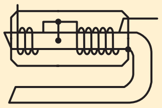
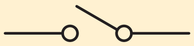
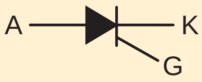
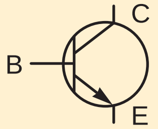
Diode (D1, D2)		Allows one-way current from Anode "A" to Cathode "K" as rectifier.
Flywheel		Provides magnetic flux to primary windings of ignition coil.
High-tension lead		Conducts high voltage current in secondary windings to spark plug.
Ignition coil		Generates primary current, and transforms primary low voltage to secondary high voltage.
Ignition switch		No spark across gap of spark plug when switch is at "STOP" position.
Resistor (R1, R2)		Resists current flow.
Spark plug		Ignites fuel-air mixture in cylinder.
Thyristor (S)		Switches from blocking state to conducting state when trigger current/voltage is on gate "G."
Transistor (T, T1, T2)		Very small current in the base circuit (B to E) controls and amplifies very large current in the collector circuit (C to E). When the base current is cut, the collector current is also cut completely.

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Figure 10-15. Study the components of transistor-controlled ignition systems.

field around the magnets induces current in the primary windings of the ignition coil.

The base circuit of the ignition system has current flow from the coil primary windings, common grounds, resistor (R1), base of the transistor (T1), emitter of the transistor (T1), and back to the primary windings of the ignition coil.

Current flow for the collector circuit in **Figure 10-16** is from the primary windings of the coil, common grounds, collector of transistor (T1), emitter of transistor (T1), and back to the primary windings.

When the flywheel rotates further, the induced current in the coil primary increases. When the current is high enough, the control circuit turns on and begins to conduct current. This causes transistor (T2) to turn on and conduct. A strong magnetic field forms around the primary winding of the ignition coil.

The trigger circuit for this ignition system consists of the primary windings, common grounds,

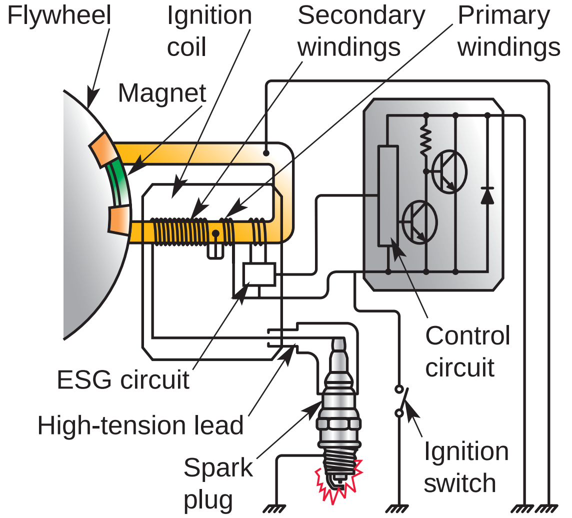

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Figure 10-16. Study how this transistor circuit is used to operate the ignition coil. Note differences and similarities.

control circuit, base of transistor (T2), and emitter of transistor (T2).

When transistor (T2) begins to conduct current, the base current flow is cut. This causes the collector circuit to shut off, and the transistor (T1) stops conducting current.

When transistor (T1) stops conducting, current stops flowing through the primary of the ignition coil. This causes the primary magnetic field to collapse across the secondary windings of the ignition coil. High voltage is then induced into the secondary winding to fire the spark plug.

The secondary circuit includes the coil secondary windings, spark plug wire, spark plug, and common grounds returning to the coil secondary.

When the ignition switch is off, the primary circuit is grounded to prevent the plug from firing. Diode (D1) is installed in the circuit to protect the TCI module from damage.

The ESG circuit shown in **Figure 10-16** is used to retard the ignition timing. At high engine rpm, the ESG circuit conducts. This bypasses the trigger circuit and delays when the current reaches the base of transistor (T2).

Operation of the Mechanical Breaker Point Ignition (MBI) System

For many years, the ***mechanical breaker point ignition (MBI) system*** supplied the ignition spark on most small engines. Major components and operation of a typical MBI system are illustrated in **Figure 10-17**. The coil, condenser, and breaker points may be found inside or outside of the flywheel. This varies with engine type, but the principles of operation remain basically the same.

The ***condenser*** plays an important part in MBI system operation. Its primary purpose is to prevent current from arcing across the breaker point gap as the points open. If arcing were to occur, it would burn the points and absorb most of the magnetic energy stored in the ignition coil. Not enough energy would be left in the coil to produce the necessary high voltage surge in the secondary circuit. The condenser absorbs current the instant the breaker points begin to separate. Since the condenser absorbs most of the current, little is left to form an arc between the points.

Magnets are usually cast into the flywheel and cannot be removed. They are strong permanent magnets made of ***Alnico*** (aluminum, nickel, cobalt alloy) or a ceramic magnetic material.

The breaker points in the MBI system are mechanically actuated, opened by the cam and closed by the breaker point spring. As the flywheel turns, the magnets pass over the legs of the laminated core of the coil. When the north pole of the magnet is over the center leg of the coil, the magnetic lines of force move down the center leg through the coil, across the bottom of the lamination, and up the side leg to the south pole. See **Figure 10-17**.

As the flywheel continues to turn, the north pole of the magnet comes over the side leg and the south pole is over the center leg of the core. Now the lines of force move from the north pole down through the side leg, up through the center leg and coil, and to the south pole. At this point, the lines of force have reversed direction.

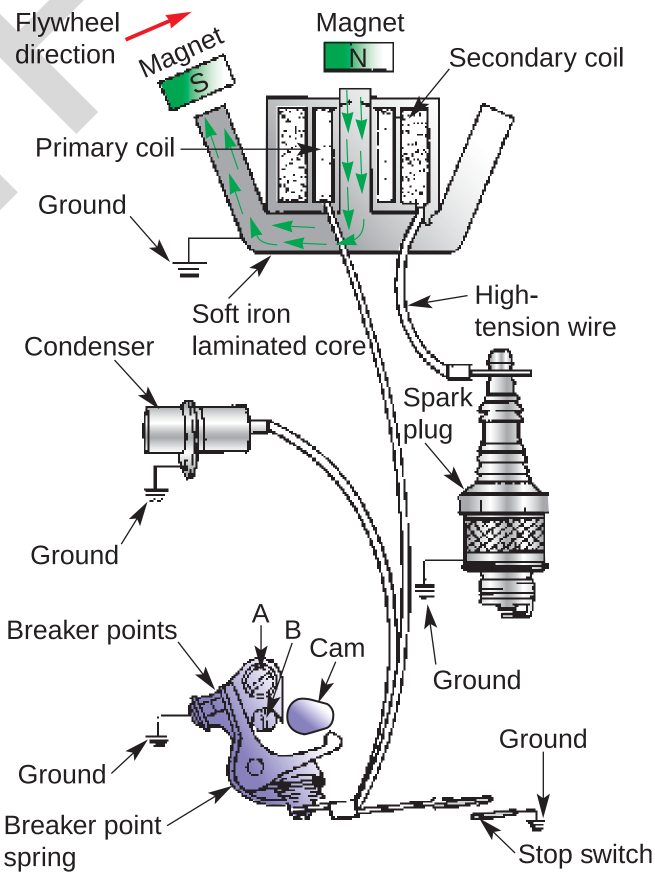

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Figure 10-17. Typical MBI system. As the magnets on the flywheel align with the legs on the core, a magnetic field is established through the core.

Figure 10-18 shows the field reversal taking place in the center leg of the core and coil. The reversal induces low-voltage current in the primary circuit through the breaker points. Current flowing in the primary winding of the coil creates a primary magnetic field of its own, which reinforces and helps maintain the direction of the lines of force in the center leg of the lamination. It does this until the magnets' poles move into a position where they can force the existing lines of force to change direction in the center leg of the lamination. Just before this happens, the breaker points are opened by the cam.

Opening of the points breaks the primary circuit, and the primary magnetic field collapses through the turns of the secondary winding. See **Figure 10-19**.

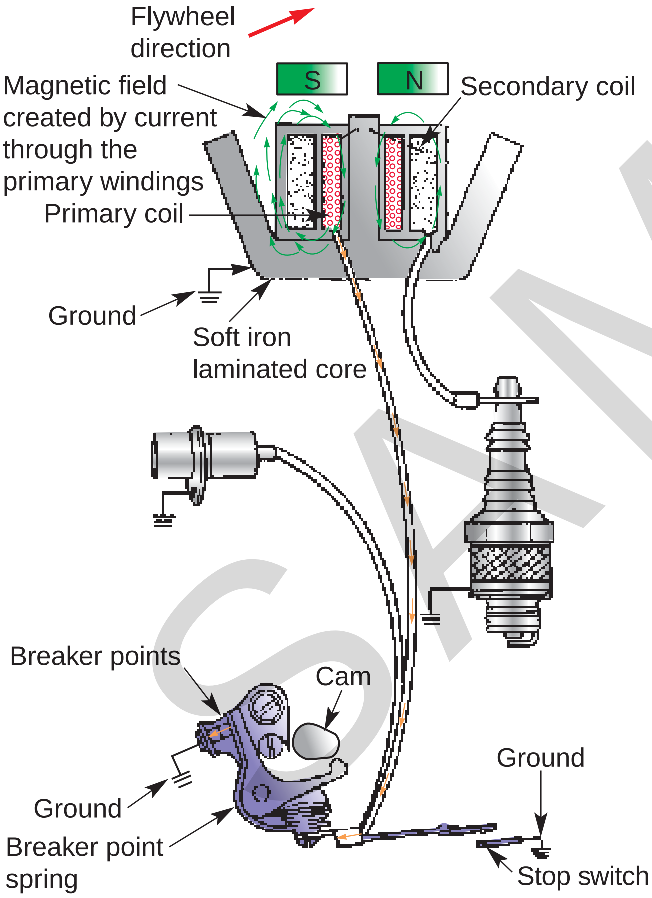

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Figure 10-18. The change in the magnetic field through the core induces a voltage in the primary circuit. Since the breaker points are closed, the current is able to flow through the circuit. The current through the primary windings builds a magnetic field that passes through the secondary windings.

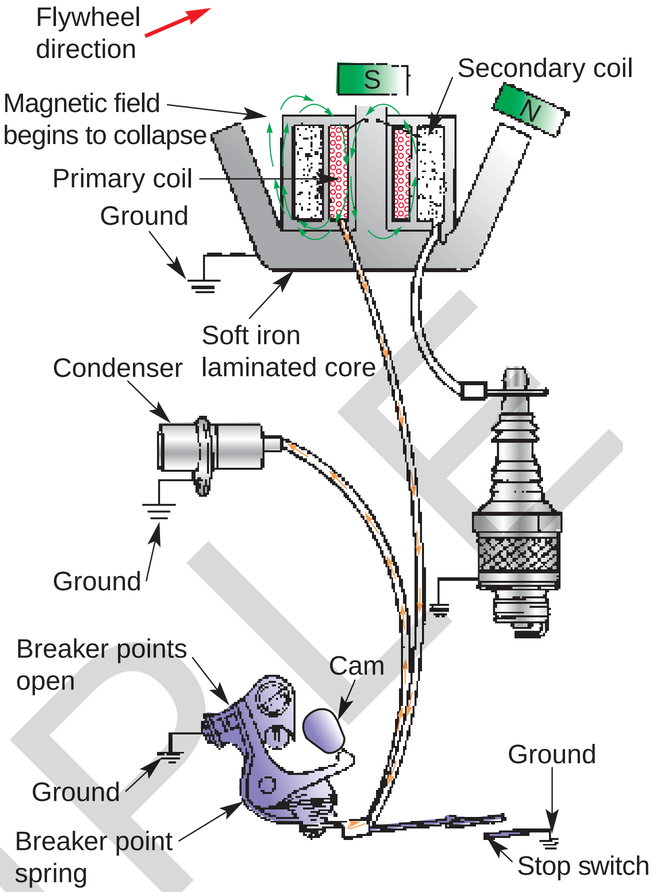

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Figure 10-19. When the breaker points open, the magnetic field around the primary windings collapses quickly through the secondary windings. This induces high voltage in the secondary windings, which is required to fire the spark plug. The field collapse also cuts through the primary windings, where it induces a moderate voltage that is absorbed by the condenser.

The condenser makes the breaking of the primary current as instantaneous as possible by absorbing the surge of primary current to prevent arcing between the breaker points.

As the magnetic field collapses through the secondary winding of the coil, high voltage is induced in the secondary winding. At exactly the same time, the charge stored in the condenser surges back into the primary winding, **Figure 10-20**, and reverses the direction of current in the primary windings. This change in direction sets up a reversal in direction of the magnetic field cutting through the secondary and helps increase the voltage in the secondary circuit. The high-voltage potential causes secondary current to arc across the spark plug gap.

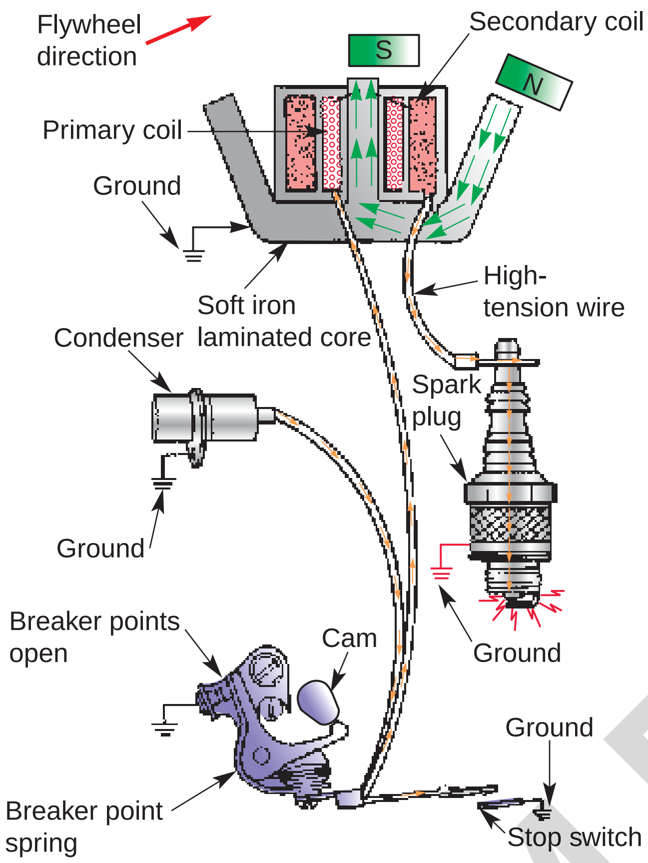

Figure 10-20. The spark plug fires, and the condenser discharges voltage back into the primary circuit.

Dwell (cam angle) is the time the breaker points stay closed during one revolution of the cam. Dwell is measured in degrees of cam rotation from the point of closing to the point of opening. There is an inverse relationship between the breaker point gap setting and dwell time. With a wider breaker point gap setting, dwell decreases. A narrower gap setting increases dwell.

Remember that the cam is driven directly from the crankshaft. When the breaker points open, the spark plug fires. Obviously, then, changing the point setting can also change spark timing. The engine manufacturer specifies which gap setting is best (usually between .020″ to .030″) and the number of degrees before top dead center (BTDC) that the spark should occur.

Some MBI systems have mechanical ***ignition advance systems*** that retard occurrence of spark for starting. For intermediate- and high-speed operation, the system causes the spark to occur earlier in the cycle.

Magneto Ignition Systems for Two-Cylinder Engines

The magneto systems used in two-cylinder engines must fire the spark plug in each cylinder at the correct time. This is accomplished in one of two ways. Some systems use two coil assemblies to fire the plugs. These assemblies are mounted near the flywheel and are located 180° apart. As the magnets in the flywheel move past each assembly, the corresponding spark plug fires at the proper time.

Other two-cylinder engines use a waste-spark system to fire the spark plugs. In this type of system, the coil assembly has two secondary outputs and fires both spark plugs at the same time. The spark occurs when the piston in one cylinder is on its compression stroke and the piston in the other cylinder is on its exhaust stroke. The spark that occurs during a cylinder's exhaust stroke has no effect on engine operation and is, therefore, considered a "waste" spark.

Battery Ignition Systems

The battery ignition system has a low-voltage primary circuit and a high-voltage secondary circuit. Like the magneto system, it consists of a coil, solid state switching device (or points and condenser), and spark plug. The basic difference is that the source of current for the primary circuit is supplied by a lead-acid battery. See **Figure 10-21**.

When the ignition switch is turned on, current flows from the positive post of the battery to the ignition coil. Current traveling through the primary windings of the coil builds up a magnetic field. See **Figure 10-22**. During this time, the switching device is closed. Ignition at the plug is not required, so the current returns to the battery through the common ground.

Then, at the exact time when ignition at the plug is required, the switching device opens. Current flow stops abruptly, causing the magnetic field surrounding the coil to collapse. See **Figure 10-23**. This rapid change of magnetic flux causes voltage to be induced in every turn of the secondary windings.

The voltage built up in the secondary winding of the coil can become as high as 30,000V. The secondary windings have approximately 100 times as many turns of wire as the primary. Normally, the voltage does not reach this value. Once it becomes

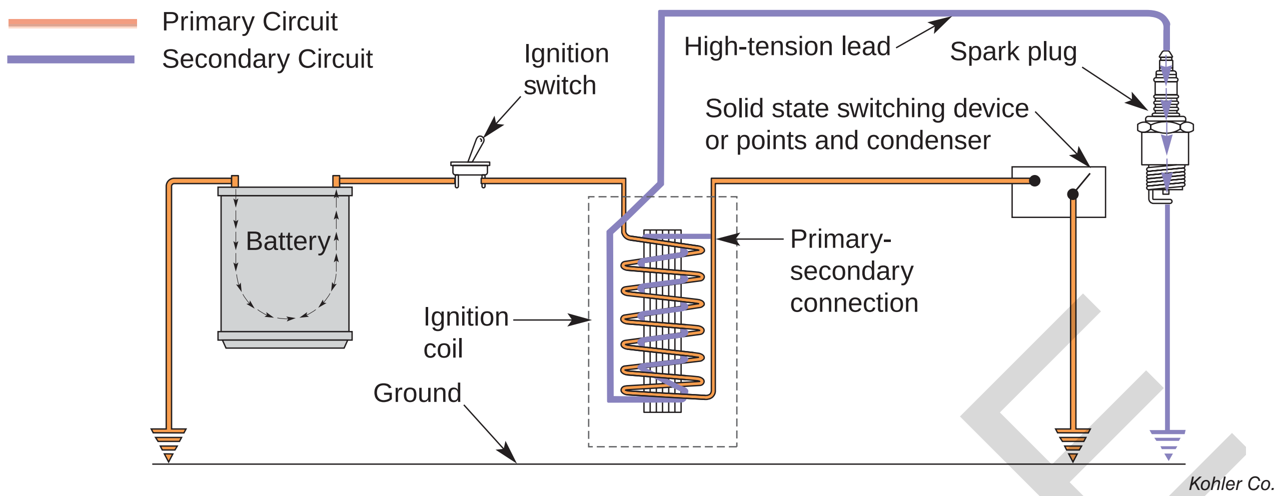

Figure 10-21. A battery ignition system is similar to a magneto system, except that the battery replaces the flywheel magnets.

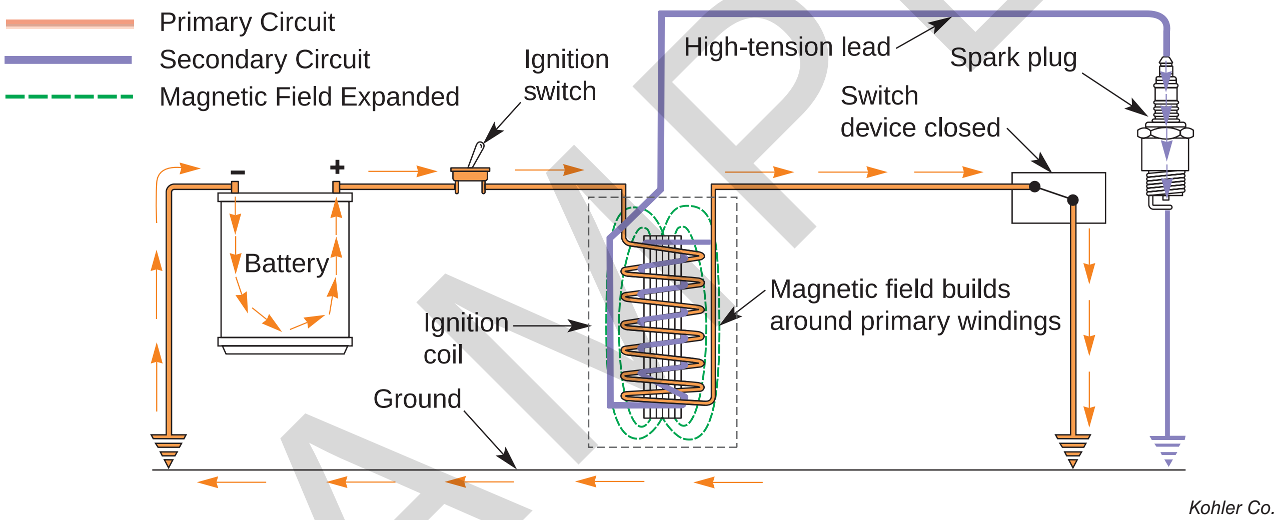

Figure 10-22. When the switching device closes in a battery ignition system, primary current builds a magnetic field around the coil.

great enough to jump the spark plug gap, the voltage drops. Usually, the amount required to jump the gap is between 6000V and 20,000V. The actual amount of voltage required depends on variables such as compression, engine speed, shape and condition of electrodes, spark plug gap, etc.

Ignition Coil

The ignition coil used in battery ignition systems serves as a step-up transformer. It increases low-voltage primary current to the high voltage required to bridge the spark plug gap. The primary and secondary windings are connected, and the common ground of the battery and primary circuit is used to complete the secondary circuit.

With this type of coil, very little primary current can flow into the secondary circuit because the secondary circuit is normally open at the spark plug gap. Primary current is just not great enough to jump the gap. Therefore, the two circuits function separately.

The primary winding of the coil consists of about 200 turns of heavy copper wire. The secondary winding has approximately 20,000 turns of very fine copper wire. Because the magnetic field collapses

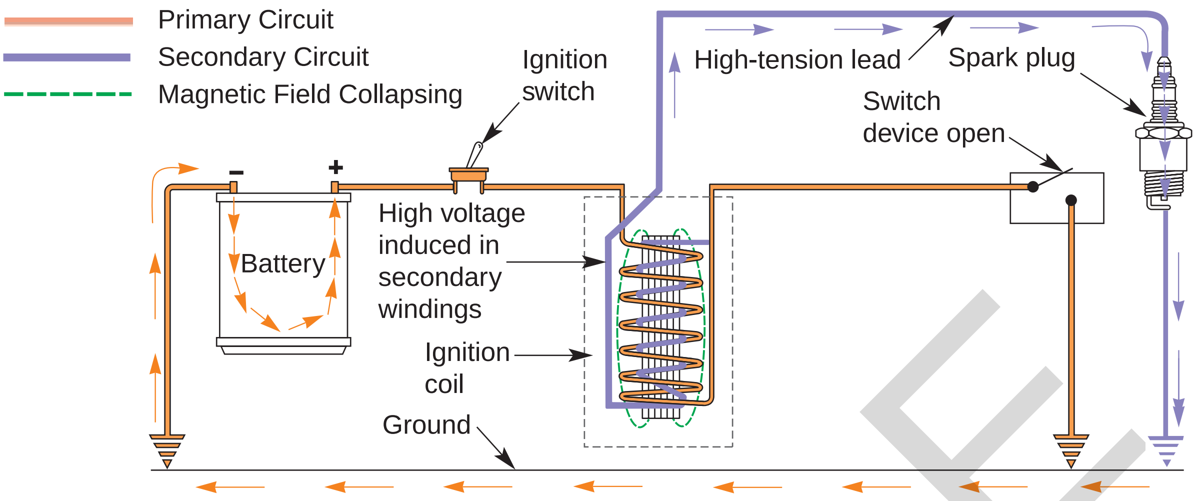

Figure 10-23. The switching device opens and the field collapses, inducing high voltage in the secondary windings of the coil.

through such a great number of conductors in the secondary, a very high voltage is developed. The amperage, however, is proportionally low. This is a typical characteristic of any transformer.

Laminated iron is used as the center core of the coil. It also forms the outer shell of the inner assembly, providing maximum concentration of the magnetic field. The inner assembly is sealed in a coil case, and the remaining space inside is filled with a special oil to minimize the effects of heat, moisture, and vibration.

The top of the coil is provided with two primary terminals. They are marked positive (+) and negative (–). The positive terminal must be connected to the positive side of the battery. The negative terminal connects to the switching device. The center tower of the coil contains the high-tension terminal.

Lead-Acid Battery

The battery is the sole source of energy for the battery ignition system of a small gasoline engine. A generator is used to replenish energy in the battery. However, the generator does not supply energy directly to the ignition system.

Lead-acid type batteries are used in battery ignition systems. The cell plates are made of lead, and a sulfuric acid and water solution serves as the electrolyte. Wet-charged or dry-charged types are available. ***Wet-charged batteries*** are supplied with the electrolyte in them, ready for use if the charge has been kept up. ***Dry-charged batteries*** must have electrolyte installed after purchase. Both types of batteries function in the same way.

Battery Construction

The typical 12V battery is constructed with a hard rubber case and six separate compartments called cells. See **Figure 10-24**. There are a specific number of negative and positive plates in each

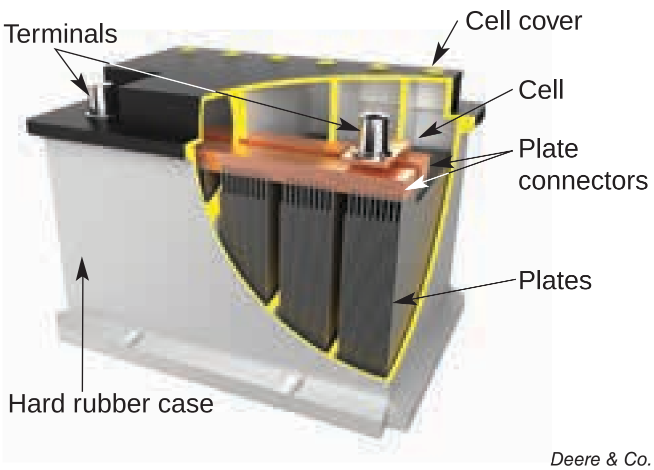

Figure 10-24. A battery provides all the current for a battery ignition system. A 12V battery has six cells, each producing approximately 2V.

cell. The greater the number of plates per cell, the higher the ampere-hour rating (capacity to provide current for a specific length of time) of the battery. The positive plates have a lead oxide covering. The negative plates have a porous or spongy surface.

Battery Voltage

In a charged battery, the lead oxide covering of the positive plate reacts with the electrolyte to generate a positive charge, and the pure lead of the negative plates reacts with the electrolyte to create a negative charge. This creates a potential difference (voltage) between the plates. All plates of a like charge are electrically connected, causing accumulative charges to be present at the positive and negative battery terminals.

Each cell of a battery in good condition contributes approximately 1.95V to 2.08V to the total charge of the battery. Six fully charged cells will produce at least 12V. If they do not, the battery must be recharged or replaced.

The Discharging/Charging Cycle

The charge in a battery remains relatively stable until a circuit is completed between the battery terminals. When this happens, current flows through the circuit and a chemical reaction takes place between plates and electrolyte as the battery attempts to equalize the potential difference between the plates.

The lead oxide (PbO_2) on the positive plates combines with the sulfuric acid (H_2SO_4) in the electrolyte to create lead sulfate ($PbSO_4$) and water (H_2O). In this reaction, each molecule of lead oxide must supply two electrons. This surrendering of electrons helps the plate stay positively charged, despite the influx of electrons through the circuit connecting the battery terminals.

A similar chemical reaction takes place at the negative plate, where the pure lead (Pb) combines with the sulfuric acid electrolyte (H_2SO_4) to form water (H_2O) and lead sulfate ($PbSO_4$). However, when this reaction is complete, there are two leftover electrons, which keep the plate negative despite the flow of electrons through the circuit to the positive plate.

As the process continues, more and more of the electrolyte is changed to water and the plates become more sulfated. Gradually, the chemical reaction becomes unable to keep up with the flow of electrons through the circuit. The voltage continues to drop as the charges on the plates equalize until the battery becomes fully discharged.

When a battery is recharged, a controlled direct current is passed through the battery in the reverse direction from normal operation. This causes a reversal in the chemical action and restores the plates and electrolyte to their original conditions.

Green Tech

Recycling Batteries

Today's lead-acid batteries typically contain a large percentage of recycled materials. This is because lead-acid batteries are recycled and some of their materials can be reused. As a result, less new material needs to go into a new battery. Automotive shops collect and send dead batteries to off-site recycling facilities. Used batteries can be stored for up to a year before being recycled. It is best to store used lead-acid batteries inside, away from the drainage system and any source of ignition. Cracked batteries should be contained, and any spills from a battery crack should be cleaned up as quickly as possible.

Summary

- The primary purpose of the ignition system is to provide sufficient voltage to discharge a spark between the electrodes of a spark plug.
- Magneto systems are self-contained systems that produce electrical current for ignition without an outside primary source of electricity. Basic magneto system parts include permanent magnets, coil, switching devices, spark plug wire, and spark plug.
- Using the correct spark plug can greatly increase engine efficiency and service life. Reach, heat range, and electrode type must all be considered.
- Most small engines are equipped with solid state ignition systems that use electronic devices in place of one or more mechanical ignition components. These systems do not require mechanical adjustments.
- The two most common solid state systems are the capacitive discharge ignition (CDI) system and the transistor-controlled ignition (TCI) system.
- The CDI system stores primary energy in a capacitor and uses semiconductor devices to trigger the ignition system.
- The TCI system is an inductive system that utilizes semiconductor devices (transistors, diodes, etc.) for switching purposes.
- The mechanical breaker point ignition system is a flywheel magneto inductive system. It employs mechanical breaker points to time the triggering of the ignition system.
- Some small engines are equipped with mechanical systems that retard and advance timing.
- Instead of a magneto, some ignition systems use a lead-acid battery to supply primary current. These systems generally employ an ignition coil.
- Because the battery is the only source of energy for battery ignition systems, a generator is used to replenish energy in the battery.

Review Questions

Answer the following questions on a separate sheet of paper using the information presented in this chapter..

Know and Understand

1. If a four-cycle engine runs at 3600 rpm, the number of sparks per minute required at the spark plug would be _____.
   A. 900
   B. 1800
   C. 3600
   D. 7200
2. Each of the following is a component of a magneto ignition system except a _____.
   A. spark plug
   B. permanent magnet
   C. switching device
   D. battery
3. The coil acts as a transformer that _____.
   A. steps down the voltage and increases the output amperage
   B. steps up the voltage and amperage
   C. steps down the voltage and amperage
   D. steps up the voltage and decreases the output amperage
4. In the ignition coil, the primary winding has _____.
   A. many turns of fine wire
   B. few turns of fine wire
   C. few turns of heavy wire
   D. many turns of heavy wire
5. *True or False?* A *cool* spark plug would have a short insulator nose.
6. The firing of the fuel charge prior to normal ignition is known as _____.
   A. preignition
   B. advance
   C. postignition
   D. fouling
7. When the switching device in the magneto is closed, _____.
   A. current is induced in the primary circuit by the flywheel magnets
   B. the spark plug fires
   C. a high voltage is induced in the secondary circuit
   D. All of the above.

8. *True or False?* Electronic switching devices are more dependable than mechanical switching devices.
9. Breaker point contacts are made of a very hard material called _____.
10. *True or False?* The only moving parts in a CDI system are the _____ in the flywheel.
11. *True or False?* The ignition advance system causes spark to occur _____ in the cycle during intermediate- and high-speed operation.
12. When breaker points are set with a wider gap, the dwell _____.
    A. becomes greater
    B. becomes less
    C. does not change
13. The amount of voltage required to jump the spark plug gap depends on _____.
    A. spark plug gap
    B. electrode condition
    C. engine speed
    D. All of the above.
14. When connecting the ignition coil in the circuit of a battery ignition system, the positive terminal of the battery must be connected to _____.
    A. the positive terminal of the coil
    B. the negative terminal of the coil
    C. either terminal of the coil
    D. None of the above.
15. A(n) is used to replenish energy in the battery used in battery ignition systems.
    A. generator
    B. magneto
    C. transformer
    D. ignition coil

Analyze and Apply

16. Describe the two major tasks performed by an ignition system.
17. What is the purpose of the ribs on the spark plug insulator?
18. Describe the operation of a waste-spark ignition system.

Critical Thinking

19. On a two-cylinder engine, what is the advantage of having an ignition coil for each cylinder rather than having a waste-spark system?
20. What advantages does a magneto ignition system have over a battery ignition system?

Suggested Activities

1. Make a visible magneto mounted on a display board or built into a clear acrylic box so that it can be manually turned with a crank. Old, but usable, engine parts can be used.
2. A workable battery ignition system can be built and mounted as a display board. Demonstrate the operation and principles involved in this system.
3. Make a collection of various kinds of spark plugs.
4. Section an old ignition coil to show the primary and secondary windings around the core.
5. Carefully open a condenser to display the lamination of aluminum foil and insulation.
6. Disassemble a magneto and demonstrate how it works.