

7

Automotive Battery Operation

LEARNING OBJECTIVES

Upon completion and review of this chapter, you should be able to:

- Identify the purpose of the battery.
- Describe battery operation.
- Explain battery capacity.
- Identify battery safety procedures.
- Explain battery ratings.

KEY TERMS

Battery
Cell
Cold Cranking Amperes (CCA)
Cycling
Electrolyte
Element
Plates
Primary Battery
Secondary Battery
Sealed Lead-Acid (SLA)
Specific Gravity
State-of-charge Indicator

INTRODUCTION

The automotive **battery** does not actually store electricity, as is often believed. The battery is a quick-change artist. It changes electrical current generated by the vehicle's charging system into chemical energy. Chemicals inside the battery store the electrical energy until it is needed to perform work. It is then changed back into electrical energy and sent through a circuit to the system where it is needed. We will begin our study of batteries by listing their functions and looking at the chemical action and construction of a battery.

Just as you are made up of a bunch of cells, so is the battery in a car. Each battery contains a number of **cells** made up of alternating positive and negative **plates**. Between each plate is a separator that keeps the plates from touching, yet lets electrolyte pass back and forth between it. The separators are made of polyvinyl chloride (PVC). An automotive battery does the following:

- Operates the starter motor
- Provides current for the ignition system during cranking

- Supplies power for the lighting systems and electrical accessories when the engine is not operating
- Acts as a voltage stabilizer for the entire electrical system
- Provides current when the electrical demand of the vehicle exceeds the output of the charging system

ELECTROCHEMICAL ACTION

All automotive wet-cell batteries operate because of the chemical action of two dissimilar metals in the presence of a conductive and reactive solution called an **electrolyte**. Because this chemical action produces electricity, it is called electrochemical action. The chemical action of the electrolyte causes electrons to be removed from one metal and added to the other. This loss and gain of electrons causes the metals to be oppositely charged, and a potential difference, or voltage, exists between them.

The metal plate that has lost electrons is positively charged and is called the positive plate. The plate that has gained electrons is negatively charged and is called the negative plate. If conductors and a load are connected between the two plates, current will flow through the conductor

and the load (Figure 7-1). For simplicity, battery current flow is assumed to be conventional current flow (+ to -) through the external circuit connected to the battery.

Primary and Secondary Batteries

There are two general types of batteries: primary and secondary. The action within a **primary battery** causes one of the metals to be totally destroyed after a period of time. When the battery has delivered all of its voltage to an outside circuit, it is useless and must be replaced. Many small dry-cell batteries, such as those for flashlights and radios, are primary batteries.

In a **secondary battery**, both the electrolyte and the metals change their atomic structure as the battery supplies current to an outside circuit. This is called discharging. The action can be reversed, however, by applying an outside current to the battery terminals and forcing current through the battery in the opposite direction. This current causes a chemical action that restores the battery materials to their original condition, and the battery can again supply current. This is called charging the battery. The condition of the battery materials is called the battery's state of charge.

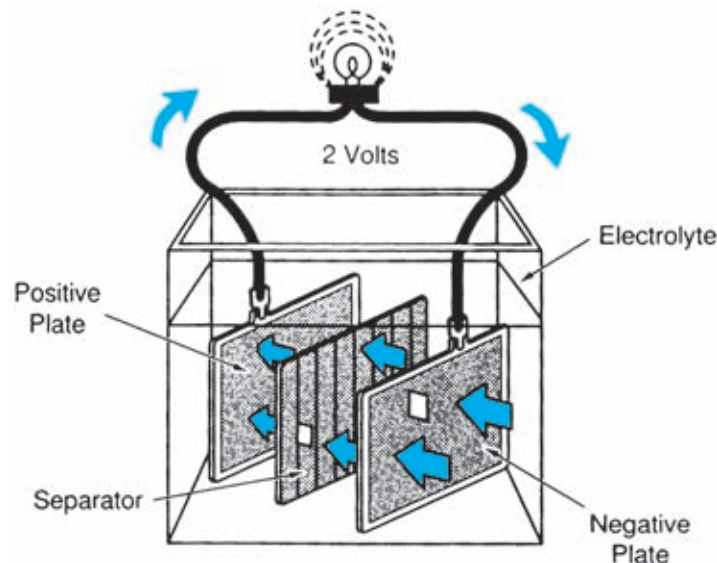


Figure 7-1. The potential difference between the two plates of a battery can cause current to flow in an outside circuit. (GM Service and Parts Operations)

Electrochemical Action in Automotive Batteries

A fully charged automotive battery contains a series of negative plates of chemically active sponge lead (Pb), positive plates of lead dioxide (PbO_2) and an electrolyte of sulfuric acid (H_2SO_4) and water (H_2O) (Figure 7-2). As the battery discharges, the chemical action taking place reduces the acid content in the electrolyte and increases the water content. At the same time, both the negative and the positive plates gradually change to lead sulphate (PbSO_4).

A discharged battery (Figure 7-2) has a very weak acid solution because most of the electrolyte has changed to water. Both series of plates

are mostly lead sulfate. The battery now stops functioning because the plates are basically two similar metals in the presence of water, rather than two dissimilar metals in the presence of an electrolyte.

During charging (Figure 7-2) the chemical action is reversed. The lead sulfate on the plates gradually decomposes, changing the negative plates back to sponge lead and the positive plates to lead dioxide. The sulfate is re-deposited in the water, which increases the sulfuric acid content and returns the electrolyte to full strength. Now, the battery is again able to supply current.

This electrochemical action and battery operation from fully charged to discharged and back to fully charged is called **cycling**.

WARNING: Hydrogen and oxygen gases are formed during battery charging. Hydrogen gas is explosive. Never strike a spark or bring a flame near a battery, particularly during or after charging. This could cause the battery to explode.

Battery Construction

There are four types of automotive batteries currently in use, as follows:

- Vent-cap (requires maintenance)
- Low-maintenance (requires limited maintenance)

- Maintenance-free (requires no maintenance)
- Recombinant (requires no maintenance)

The basic physical construction of all types of automotive batteries is similar, but the materials used are not. We will look at traditional vent-cap construction first and then explain how the other battery types differ.

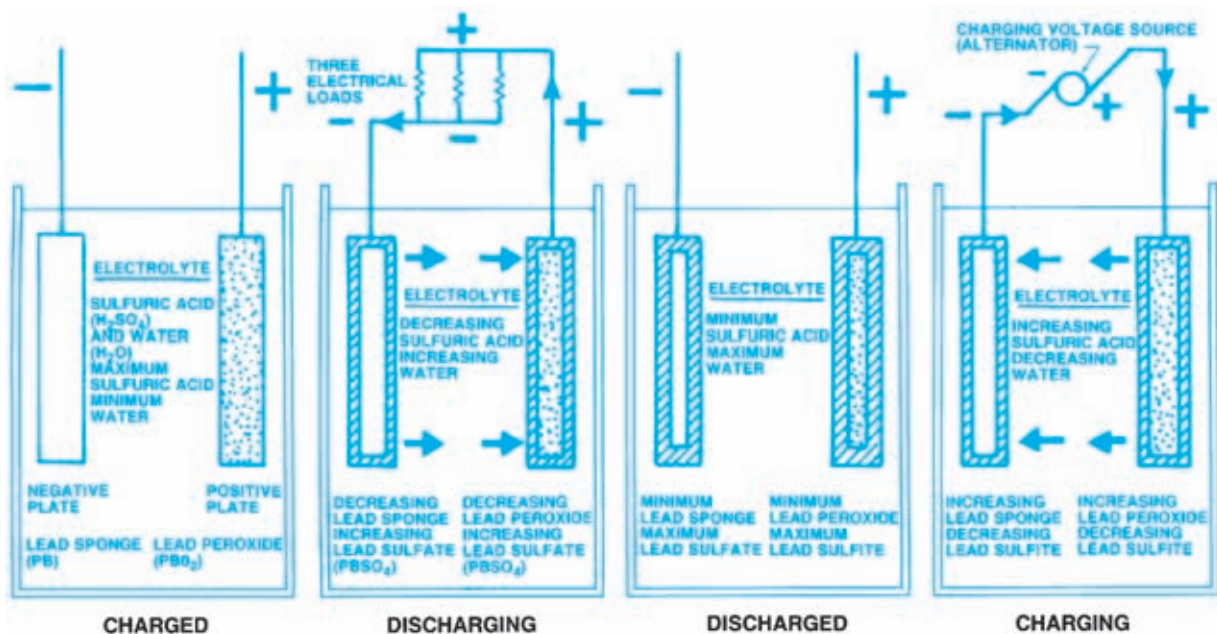


Figure 7-2. Battery electrochemical action from charged to discharged and back to charged.

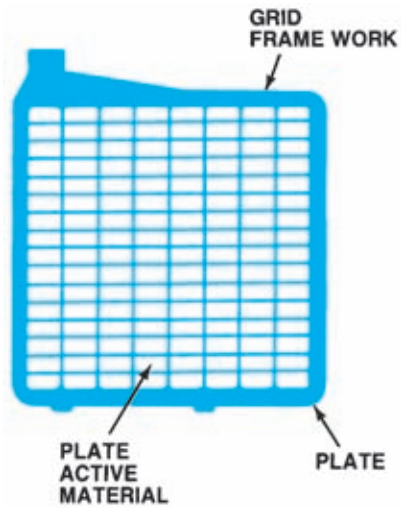


Figure 7-3. The grid provides a support for the plate active material.

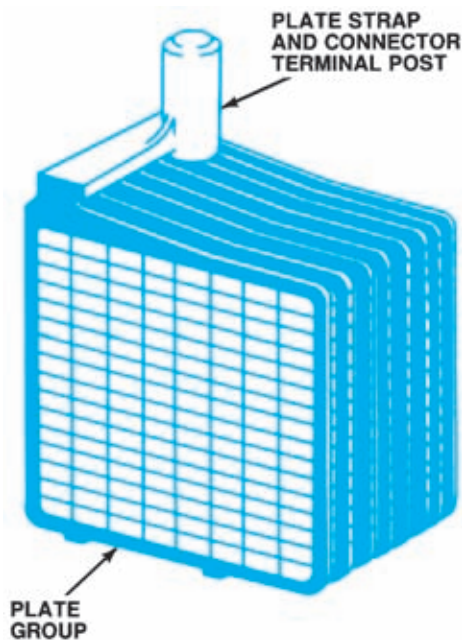


Figure 7-4. A number of plates are connected into a group.

Vent-Cap Batteries

Battery construction begins with the positive and negative plates. The plates are built on grids of conductive materials, as shown in Figure 7-3, which act as a framework for the dissimilar metals. These dissimilar metals are called the active materials of the battery. The active materials, sponge lead and lead dioxide, are pasted onto the grids. When dry, the active materials are very porous, so that the electrolyte can easily penetrate and react with them.

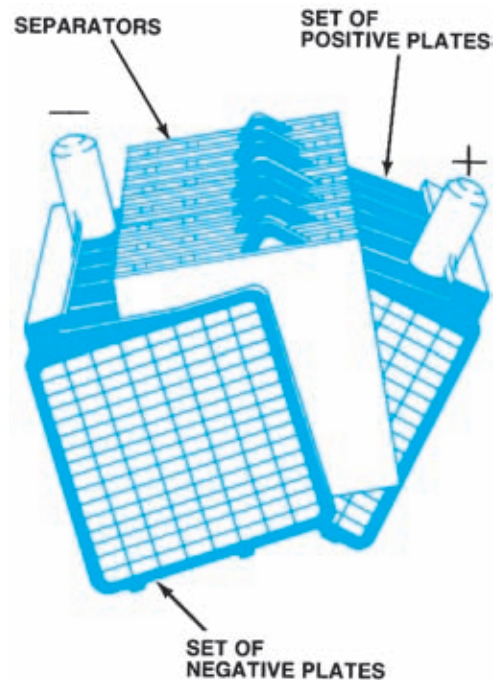


Figure 7-5. Two groups are interlaced to form a battery element.

A number of similar plates, all positive or all negative, are connected together into a plate group (Figure 7-4). The plates are joined to each other by welding them to a plate strap through a process called lead burning. The plate strap has a connector or a terminal post for attaching plate groups to each other.

A positive and a negative plate group are interlaced so that their plates alternate, Figure 7-5. The negative plate group normally has one more plate than the positive group. To reduce the possibility of a short between plates of the two groups, they are separated by chemically inert separators (Figure 7-5). Separators are usually made of plastic or fiberglass. The separators have ribs on one side next to the positive plates. These ribs hold electrolyte near the positive plates for efficient chemical action.

Other Secondary Cells

The Edison (nickel-iron alkali) cell and the silver cell are two other types of secondary cells. The positive plate of the Edison cell is made of pencil-shaped, perforated steel tubes that contain nickel hydroxide. These tubes are held in a steel grid. The negative plate has pockets that hold iron oxide. The electrolyte used in this cell is a solution of potassium hydroxide and a small amount of lithium hydroxide.

An Edison cell weighs about one-half as much as a lead-acid cell of the same ampere-hour capacity. This cell has a long life and is not damaged by short circuits or overloads. It is however, more costly than a lead-acid cell. The silver cell has a positive plate of silver oxide and a negative plate of zinc. The electrolyte is a solution of potassium hydroxide or sodium. For its weight, this cell has a high ampere-hour capacity. It can withstand large overloads and short circuits. It, too, is more expensive than a lead-acid cell.

A complete assembly of positive plates, negative plates, and separators is called an **element**. It is placed in a cell of a battery case. Because each cell provides approximately 2.1 volts, a 12-volt battery has six cells and actually produces approximately 12.6 volts when fully charged. The elements are separated from each other by cell partitions, and rest on bridges at the bottom of the case that form chambers where sediment can collect. These bridges prevent accumulated sediment from shorting across the bottoms of the plates. Once installed in the case, the elements (cells) are connected to each other by connecting straps that pass over or through the cell partitions (Figure 7-6). The cells are connected alternately in series (positive to negative to positive to negative, and so on), and the battery top is bonded onto the case to form a watertight container.

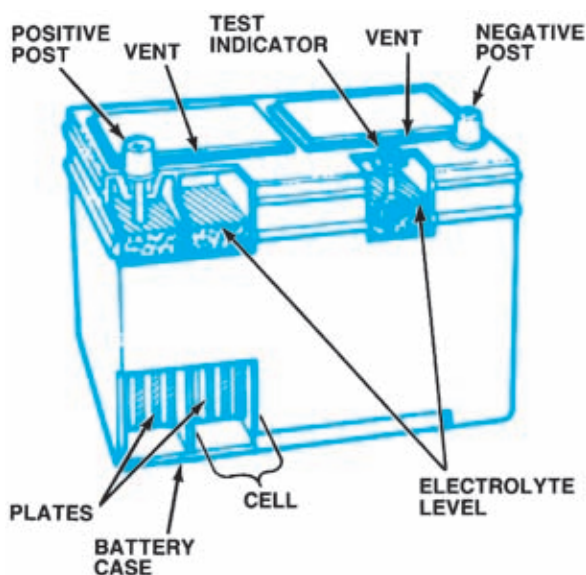


Figure 7-6. A cutaway view of an assembled battery. (DaimlerChrysler Corporation)

Vent caps in the battery top provide an opening for adding electrolyte and for the escape of gases that form during charging and discharging. The battery is connected to the car's electrical system by two external terminals. These terminals are either tapered posts on top of the case or internally threaded connectors on the side. The terminals, which are connected to the ends of the series of elements inside the case, are marked positive (+) or negative (-), according to which end of the series each terminal represents.

Sealed Lead-Acid (SLA) Batteries

Most new batteries today are either partially sealed, *low-maintenance* or completely sealed, *maintenance-free* batteries. Low-maintenance batteries provide some method of adding water to the cells, such as the following:

- Individual slotted vent caps installed flush with the top of the case
- Two vent panel covers, each of which exposes three cells when removed
- A flush-mounted strip cover that is peeled off to reveal the cell openings

Sealed lead-acid (SLA) batteries have only small gas vents that prevent pressure buildup in the case. A low-maintenance battery requires that water be added much less often than with a traditional vent-cap battery, while a SLA battery will never need to have water added during its lifetime.

These batteries differ from vent-cap batteries primarily in the materials used for the plate grids. For decades, automotive batteries used antimony as the strengthening ingredient of the grid alloy. In low-maintenance batteries, the amount of antimony is reduced to about three percent. In maintenance-free batteries, the antimony is eliminated and replaced by calcium or strontium.

Reducing the amount of antimony or replacing it with calcium or strontium alloy results in lowering the battery's internal heat and reduces the amount of gassing that occurs during charging. Since heat and gassing are the principal reasons for battery water loss, these changes reduce or eliminate the need to periodically add water. Reduced water loss also minimizes terminal corrosion, since the major cause of this corrosion is condensation from normal battery gassing.

In addition, non-antimony lead alloys have better conductivity, so a maintenance-free battery has about a 20 percent higher cranking performance rating than a traditional vent-cap battery of comparable size.

Recombinant Batteries

More recently, completely sealed maintenance-free batteries were introduced. These new batteries do not require—and do not have—the small gas vent used on previous maintenance-free batteries. Although these batteries are basically the same kind of lead-acid voltage cells used in automobiles for decades, a slight change in plate and electrolyte chemistry reduces hydrogen generation to almost nothing.

During charging, a vent-cap or maintenance-free battery releases hydrogen at the negative plates and oxygen at the positive plates. Most of the hydrogen is released through electrolysis of the water in the electrolyte near the negative plates as the battery reaches full charge. In the sealed maintenance-free design, the negative plates never reach a fully charged condition and therefore cause little or no release of hydrogen. Oxygen is released at the positive plates, but it passes through the separators and recombines with the negative plates. The overall effect is virtually no gassing from the battery. Because the oxygen released by the electrolyte recombines with the negative plates, some manufacturers call these batteries “recombination” or recombinant electrolyte batteries.

Recombination electrolyte technology and improved grid materials allow some sealed, maintenance-free batteries to develop fully charged, open-circuit voltage of approximately 2.1 volts per cell, or a total of 12.6 volts for a six-cell 12-volt battery. Microporous fiberglass separators reduce internal resistance and contribute to higher voltage and current ratings.

In addition, the electrolyte in these new batteries is contained within plastic envelope-type separators around the plates (Figure 7-7). The entire case is not flooded with electrolyte. This eliminates the possibility of damage due to sloshing or acid leaks from a cracked battery. This design feature reduces battery damage during handling and installation, and allows a more compact case design. Because the battery is not vented, terminal corrosion from battery gassing and electrolyte spills or spray is also eliminated.

The envelope design also catches active material as it flakes off the positive plates during discharge. By holding the material closer to the plates, envelope construction ensures that it will be more completely redeposited during charging. Although recombinant batteries are examples of advanced technology, test and service requirements are basically the same as for other maintenance-free, lead-acid batteries. Some manufacturers caution,



Figure 7-7. Many maintenance-free batteries have envelope separators that hold active material near the plates.

however, that fast charging at high current rates may overheat the battery and can cause damage. Always check the manufacturer’s instructions for test specifications and charging rates before servicing one of these batteries.

BATTERY ELECTROLYTE

For the battery to become chemically active, it must be filled with an electrolyte solution. The electrolyte in an automotive battery is a solution of sulfuric acid and water. In a fully charged battery, the solution is approximately 35 to 39 percent acid by weight (25 percent by volume) and 61 to 65 percent water by weight. The state of charge of a battery can be measured by checking the specific gravity of the electrolyte.

WARNING: When lifting a battery, excessive pressure on the end walls could cause acid spill through the vent caps, resulting in personal injury. Lift with a battery carrier or with your hands at opposite corners. For more information, see the “Battery Safety” section in Chapter 7 of the *Shop Manual*.

Specific gravity is the weight of a given volume of liquid divided by the weight of an equal volume of water. Since the acid is heavier than water, and water has a specific gravity of 1.000, the specific gravity of a fully charged battery is greater than 1.000 (approximately 1.260 when weighed in a hydrometer). As the battery discharges, the specific gravity of the electrolyte decreases because the acid is changed into water. The specific gravity of the electrolyte can tell you approximately how discharged the battery has become:

- 1.265 specific gravity: 100% charged
- 1.225 specific gravity: 75% charged
- 1.190 specific gravity: 50% charged
- 1.155 specific gravity: 25% charged
- 1.120 specific gravity or lower: discharged

These values may vary slightly, according to the design factors of a particular battery. Specific gravity measurements are based on a standard temperature of 80°F (26.7°C). At higher temperatures, specific gravity is lower. At lower temperatures, specific gravity is higher. For every change of 10°F, specific gravity changes by four points (0.004). That is, you should compensate for temperature differences as follows:

- For every 10°F above 80°F, add 0.004 to the specific gravity reading.
- For every 10°F below 80°F, subtract 0.004 from the specific gravity reading

When you study battery service in Chapter 7 of the *Shop Manual*, you will learn to measure specific gravity of a vent-cap battery with a hydrometer. See the section on “Inspection, Cleaning and Replacement” for more information.

STATE-OF-CHARGE INDICATORS

Many low-maintenance and maintenance-free batteries have a visual **state-of-charge indicator** or built-in hydrometer installed in the battery top. The indicator shows whether the electrolyte has

fallen below a minimum level, and it also functions as a *go/no-go* hydrometer.

The indicator shown in Figure 7-8 is a plastic rod inserted in the top of the battery and extending into the electrolyte. In the design used by Delco (now Delphi), a green plastic ball is suspended in a cage from the bottom of the rod. Depending upon the specific gravity of the electrolyte, the ball will float or sink in the cage, changing the appearance of the indicator “eye” from green to dark. When the eye is dark, the battery should be recharged.

Other manufacturers use either the “Delco Eye” under license, or one of several variations of the design. One variation contains a red ball and a blue ball side by side in the cage. When the specific gravity is high, only the blue ball can be seen in the “eye”. As the specific gravity falls, the blue ball sinks in the cage, allowing the red ball to take its place. When the battery is recharged, the increasing specific gravity causes the blue ball to move upward, forcing the red ball back into the side of the cage.

Another variation is the use of a small red ball on top of a larger blue ball. When the specific gravity is high, the small ball is seen as a red spot surrounded by blue. As the specific gravity falls, the blue ball sinks, leaving the small ball to be

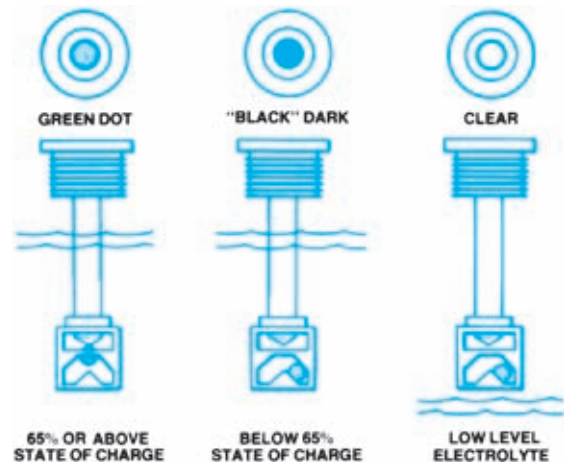


Figure 7-8. Delco (Delphi) “Freedom” batteries have this integral hydrometer built into their tops. (Delphi Corporation)

seen as a red spot surrounded by a clear area. The battery then should be recharged.

If the electrolyte drops below the level of the cage in batteries using a state-of-charge indicator, the “eye” will appear clear or light yellow. This means that the battery must be replaced because it has lost too much electrolyte. For more information, see the “Battery Testing” section in Chapter 7 of the *Shop Manual*.

WET-CHARGED AND DRY-CHARGED BATTERIES

Batteries may be manufactured and sold as either wet-charged or dry-charged batteries. Before maintenance-free batteries became widely used, dry-charged batteries were very common. A wet-charged battery is completely filled with an electrolyte when it is built. A dry-charged battery is shipped from the factory without electrolyte. During manufacture, the positive and negative plates are charged and then completely washed and dried. The battery is then assembled and sealed to keep out moisture. It will remain charged as long as it is sealed, and it can be stored for a long time in any reasonable environment. A dry-charged battery is put into service by adding electrolyte, checking the battery state of charge, and charging if needed.

Even when a wet-charged battery is not in use, a slow reaction occurs between the plates and the electrolyte. This is a self-discharging reaction, and will eventually discharge the battery almost completely. Because this reaction occurs faster at higher temperatures, wet-charged batteries should be stored in as cool a place as possible when not in use. A fully charged battery stored at a room temperature of 100°F (38°C) will almost completely discharge after 90 days. If the battery is stored at a temperature of 60°F (16°C), very little discharge will take place.

BATTERY CHARGING VOLTAGE

Forcing current through it in the direction opposite from its discharge current charges a battery. In an automobile, the generator or alternator

supplies this charging current. The battery offers some resistance to this charging current, because of the battery’s chemical voltage and the resistance of the battery’s internal parts. The battery’s chemical voltage is another form of counterelectromotive force (CEMF) that you studied in Chapter 4.

When a battery is fully charged, its CEMF is very high. Very little charging current can flow through it. When the battery is discharged, its CEMF is very low, and charging current flows freely. For charging current to enter the battery, the charging voltage must be higher than the battery’s CEMF plus the voltage drop caused by the battery’s internal resistance.

Understanding this relationship of CEMF to the battery state of charge is helpful. When the battery is nearly discharged, it needs, and will accept, a lot of charging current. When the battery is fully charged, the high CEMF will resist charging current. Any additional charging current could overheat and damage the battery materials. Charging procedures are explained in Chapter 3 of your *Shop Manual*. See also the section on “Battery Testing” in Chapter 7 of the *Shop Manual*.

The temperature of the battery affects the charging voltage because temperature affects the resistance of the electrolyte. Cold electrolyte has higher resistance than warm electrolyte, so a colder battery is harder to charge. The effects of temperature must be considered when servicing automotive charging systems and batteries, as we shall see later in this chapter.

BATTERY SELECTION AND RATING METHODS

Automotive batteries are available in a variety of sizes, shapes, and current ratings. They are called “starting batteries” and are designed to deliver a large current output for a brief time to start an engine. After starting, the charging system takes over to supply most of the current required to operate the car. The battery acts as a system stabilizer and provides current whenever the electrical loads exceed the charging current output. An automotive battery must provide good cranking power for the car’s engine and adequate reserve power for the electrical system in which it is used.

Manufacturers also make 12-volt automotive-type batteries that are not designed for automotive use. These are called “cycling batteries” and are designed to provide a power source for a vehicle or accessory without continual recharging. Cycling batteries provide a constant low current for a long period of time. They are designed for industrial, marine, and recreational vehicle (RV) or motor home use. Most of their current capacity is exhausted in each cycle before recharging.

The brief high current flow required of a starting battery is produced by using relatively thin plates, compared to those used in a cycling battery. The thicker plates of the cycling battery will provide a constant current drain for several hours. Using a starting battery in an application calling for a cycling battery will shorten its life considerably, as we shall see later in the chapter. The use of a cycling battery to start and operate a car will cause excessive internal heat from the brief but high current draw, resulting in a shorter service life.

Test standards and rating methods devised by the Battery Council International (BCI) and the Society of Automotive Engineers (SAE) are designed to measure a battery’s ability to meet the requirements of its intended service.

The BCI publishes application charts that list the correct battery for any car. Optional heavy-duty

the ignition system until the engine starts. This requires a high discharge over a very short time span. Cold engines require more power to turn over, but batteries have difficulty delivering power when it is cold. **Cold cranking amperes (CCA)** are an important measurement of battery capacity because they measure the discharge load, in amps, that a battery can supply for 30 seconds at 0°F while maintaining a voltage of 1.2 volts per cell (7.2 volts per battery) or higher. The CCA rating generally falls between 300 and 970 for most passenger cars; it is identified as 300 CCA, 400 CCA, 500 CCA, and so on. The rating is typically higher for commercial vehicles. For more information about cold cranking amps, see the section on “Battery Testing” in Chapter 7 of the *Shop Manual*. Some batteries are rated as high as 1,100 CCA.

Cranking Amps (CA)

Cranking amps (CA) represent the discharge load (in amps) that a fully charged battery can supply for 30 seconds at 32°F while maintaining a voltage of 1.2 volts per cell (7.2 volts per 12 volt battery) or higher.

NOTE: CA (Cranking Amps) is nearly the same as CCA (Cold Cranking Amps), but the two ratings should not be confused. CCA is rated at 0°F. CA, on the other hand is measured at a temperature of 32°F. The difference in temperature will produce a considerable amount of additional current when measured as a CA rating.

batteries are normally used in cars with air conditioning or several major electrical accessories or in cars operated in cold climates. To ensure adequate cranking power and to meet all other electrical needs, a replacement battery may have a higher rating, but never a lower rating, than the original unit. The battery must also be the correct size for the car, and have the correct type of terminals. BCI standards include a coding system called the group number. BCI battery rating methods are explained in the following paragraphs.

Cold Cranking Amperes (CCA)

The primary duty of the battery is to start the engine. It cranks, or rotates, the crankshaft while it maintains sufficient voltage to activate

Reserve Capacity Rating

Reserve capacity is the time required (in minutes) for a fully charged battery at 80°F under a constant 25-amp draw to reach a voltage of 10.5 volts. This rating helps determine the battery’s ability to sustain a minimum vehicle electrical load in the event of a charging system failure. The minimum electrical load under the worst possible conditions (winter driving at night) would likely require current for the ignition, low-beam headlights, windshield wipers, and the defroster at low speed. Reserve capacity is useful for measuring the battery’s ability to power a vehicle that has small, long-term parasitic electrical loads but enough reserve to crank the engine.

Battery reserve capacity ratings range from 30 to 175 minutes, and correspond approximately to

the length of time a vehicle can be driven after the charging system has failed. The reserve capacity of a battery can be used to judge how much electrical drain in milliamperes could be acceptable using the reserve capacity in minutes divided by 4. For example, a battery with an RC rating of 120 minutes should have a maximum battery drain of 30 mA ($120 \div 4 = 30$).

■ Historical Ampere-Hour Rating

The oldest battery rating method, no longer used to rate batteries, was the ampere-hour rating. This rating method was the industry standard for decades. It was replaced, however, years ago by the cranking performance and reserve capacity ratings, which provide better indications of a battery's performance. The ampere-hour method was also called the 20-hour discharge rating method. This rating represented the steady current flow that a battery delivered at a temperature of 80°F (27°C) without cell voltage falling below 1.75 volts (a total of 10.5 volts for a 12-volt battery). For example, a battery that continuously delivered 3 amperes for 20 hours was rated as a 60 ampere-hour battery ($3 \text{ amperes} \times 20 \text{ hours} = 60 \text{ ampere-hours}$).

■ Historical Watt-Hour Rating

Many years ago, batteries were rated in watt hours. A watt hour is the drain of a battery equal to one watt, which is one volt times one amp for a period of one hour or any combination of wattage and time. The watt hour rating of the battery was measured at 0°F (−18°C).

Battery Size Selection

Battery size and weight are major factors for the design engineer. A typical battery can weigh about 50 pounds and takes space in the vehicle. Powertrain and electronic design engineers want the vehicle to have enough capacity for automatic headlights, which remain on for several minutes after the engine is turned off, as well as to provide the electrical power to start the engine under all extremely low temperature conditions. Due to vehicle packaging considerations, the battery can be located under the hood, behind the front bumper, under the rear seat, or in the trunk area. The battery selected must of course be able to fit into the vehicle and use the same cable converter as the original, as well as be able to be held down in the

vehicle. There are several different types of hold-downs including:

- Bracket over the top of the battery
- Bottom bracket that wedges into a notch at the base of the battery

When selecting a battery, check the weight of the battery in the size that fits the vehicle. A heavier battery has more lead and is likely to outperform a lighter battery of the same size and type of construction.

Group Number

Manufacturers provide a designated amount of space, usually in the engine compartment, to accommodate the battery. Since battery companies build batteries of various current-capacity ratings in a variety of sizes and shapes, it is useful to have a guide when replacing a battery, because it must fit into the space provided. The BCI size group number identifies a battery in terms of its length, width, height, terminal design, and other physical features.

BATTERY INSTALLATIONS

Most automobiles use one 6-cell, 12-volt battery installed in the engine compartment. Certain factors influence battery location as follows:

- The distance between the battery and the alternator or starter motor determines the length of the cables used. Cable length is important because of electrical system resistance. The longer the cables, the greater the resistance.
- The battery should be located away from hot engine components in a position where it can be cooled by airflow.
- The battery should be in a location where it can be securely mounted as protection against internal damage from vibration.
- The battery should be positioned where it can be easily serviced.

The decrease in size of late-model vehicles has resulted in lighter, smaller batteries with greater capacity. The use of new plastics and improved grid and plate materials has contributed to the new battery designs.

Some older cars and a few new imported and domestic models have the battery located in the trunk. For example, the battery used with the Ford Escort diesel is mounted in the trunk beneath a trim cover and encased in a protective bag (Figure 7-9). The bag will retain battery acid in case of an accident that might damage it. A tube and seal assembly connected to the battery vents allows gassing to the atmosphere.



This venting device should be inspected periodically and replaced, if necessary, because proper venting is essential for safety. Such locations require the use of long cables of heavy-gauge wire. The size of such cables offsets their greater length in keeping resistance manageable, but increases cost and weight while reducing convenience.

Late-model GM diesel cars and Ford light trucks use two 12-volt batteries connected in parallel (Figure 7-10). Both battery positive

Figure 7-9. This Ford Escort diesel battery is encased in a protective bag and housed in the trunk.

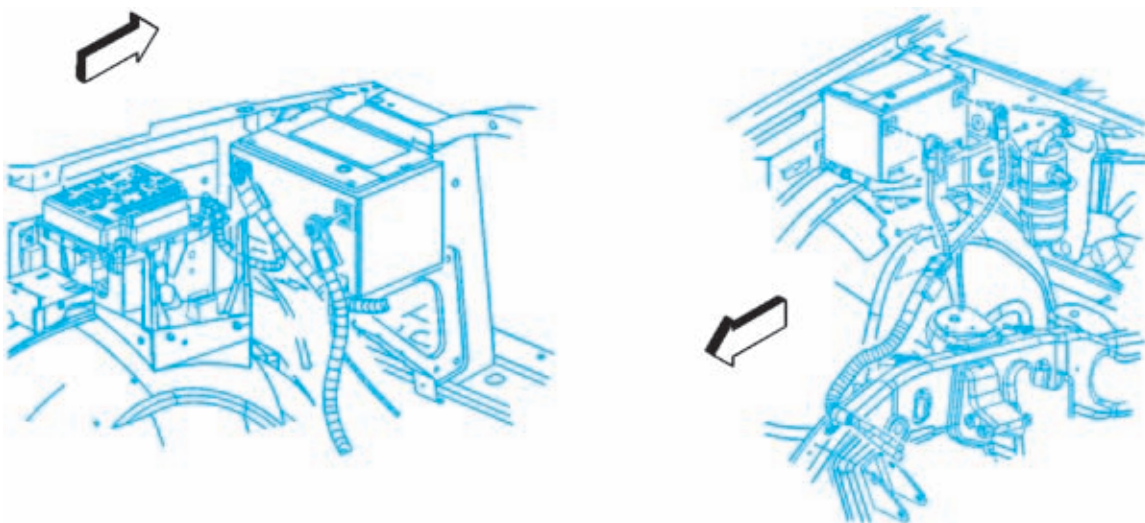


Figure 7-10. Diesel vehicles generally have two 12-volt batteries for better cranking with a 12-volt starter. (GM Service and Parts Operations)

terminals are connected to each other and to the positive battery cable attached to the starter motor (GM) or to the relay (Ford). The battery terminals are connected to each other in a similar manner, and to the ground cable. The use of a parallel installation doubles the current available for starting the high-compression diesel without increasing system voltage. If the batteries were connected in series, the voltage would double. Both batteries are charged simultaneously by the alternator. For more information, see the section on “Battery Changing” in Chapter 7 of the *Shop Manual*.

BATTERY INSTALLATION COMPONENTS

Selecting and maintaining properly designed battery installation components is necessary for good battery operation and service life.

Connectors, Carriers, and Holddowns

Battery cables are very large-diameter multistrand wire, usually 0 to 6 gauge. Diesel engine vehicles generally use the larger 0, while gasoline engine vehicles use 6. A new battery cable should always be the same gauge as the one being replaced.

Battery terminals may be tapered posts on the top or internally threaded terminals on the side of the battery. To prevent accidental reversal of battery polarity (incorrectly connecting the cables), the positive terminal is slightly larger than the negative terminal. Three basic styles of connectors are used to attach the battery cables to the battery terminals:

- A bolt-type clamp is used on top-terminal batteries, Figure 7-11. The bolt passes through the two halves of the cable end into a nut. When tightened, it squeezes the cable end against the battery post.
- A bolt-through clamp is used on side-terminal batteries. The bolt threads through the cable end and directly into the battery terminal, Figure 7-12.



Figure 7-11. The most common type of top terminal battery clamp.

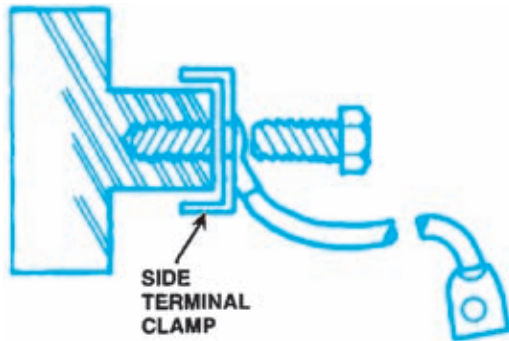


Figure 7-12. The side terminal clamp is attached with a bolt. (DaimlerChrysler Corporation)

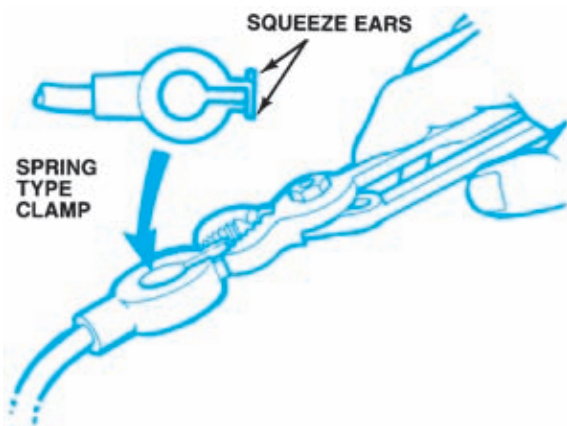


Figure 7-13. The spring-type clamp generally is found on non-domestic cars.

- A spring-type clamp is used on some top-terminal batteries. A built-in spring holds the cable end on the battery post (Figure 7-13).

Batteries are usually mounted on a shelf or tray in the engine compartment, although some manufacturers place the battery in the trunk, under the seat, or else where in the vehicle. The shelf or tray that holds the battery is called the carrier (Figure 7-14). The battery is mounted on the carrier with brackets called holddowns (Figures 7-14 and 7-15). These keep the battery from tipping over and spilling acid. A battery must be held securely in its carrier to protect it from vibration that can damage the plates and internal plate connectors. For more information, see the section on “Battery Cable Service” in Chapter 7 of the *Shop Manual*.

■ **WARNING: Don't Pull The Plugs**

Do you make a practice of removing the vent plugs from a battery before charging it? Prestolite says you shouldn't, at least with many late-model batter-

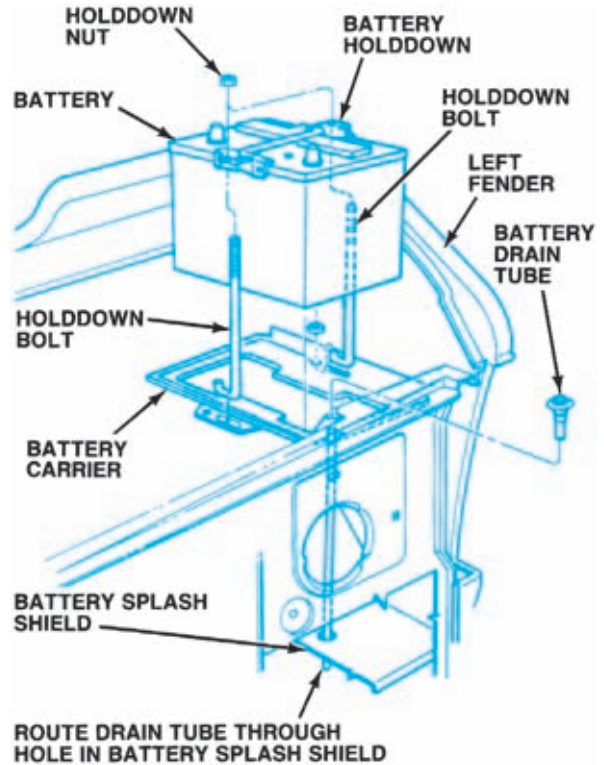


Figure 7-14. A common type of battery carrier and holddown.

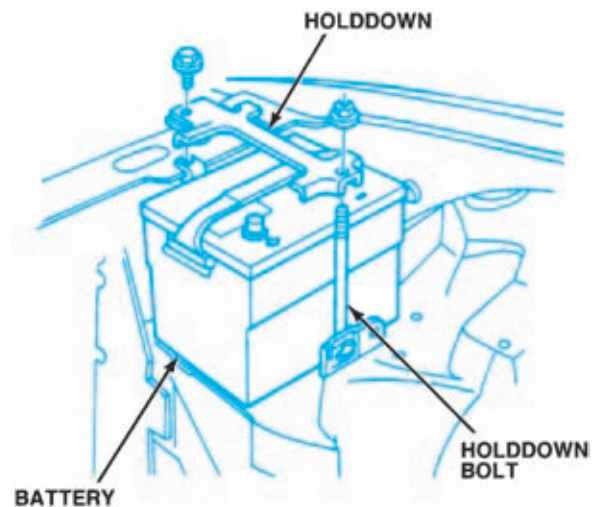


Figure 7-15. Another common battery holddown.

ies. “A great number of batteries manufactured today will have safety vents,” says Prestolite. “If these are removed, the batteries are open to external sources of explosion ignition.” Prestolite recommends that, on batteries with safety vents, the vent plugs should be left in place when charging.

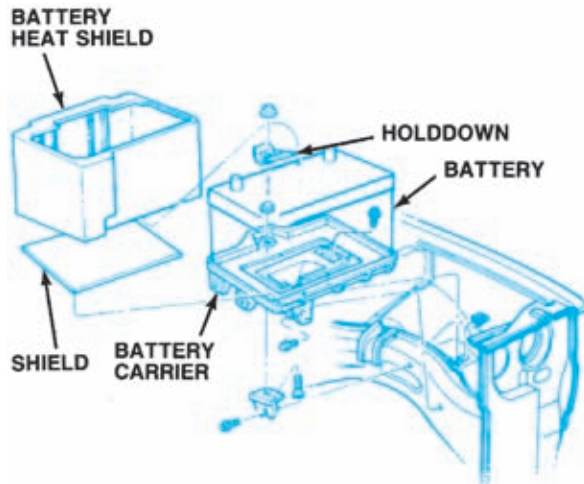


Figure 7-16. A molded heat shield that fits over the battery is used by Chrysler and some other manufacturers. (DaimlerChrysler Corporation)

Battery Heat Shields

Many late-model cars use battery heat shields (Figure 7-16) to protect batteries from high underhood temperatures. Most heat shields are made of plastic, and some are integral with the battery holddown. Integral shields are usually large plastic plates that sit alongside the battery. Heat shields do not require removal for routine battery inspection and testing, but must be removed for battery replacement.

BATTERY LIFE AND PERFORMANCE FACTORS

All batteries have a limited life, but certain conditions can shorten that life. The important factors that affect battery life are discussed in the following paragraphs.

Electrolyte Level

As we have seen, the design of maintenance-free batteries has minimized the loss of water from electrolyte so that battery cases can be sealed. Given normal use, the addition of water to such batteries is not required during their service life. However, even maintenance-free batteries will lose some of their water to high

temperature, overcharging, deep cycling, and recharging all factors in battery gassing and resultant water loss.

With vent-cap batteries, and to some extent, low-maintenance batteries, water is lost from the electrolyte during charging in the form of hydrogen and oxygen gases. This causes the electrolyte level to drop. If the level drops below the top of the plates, active material will be exposed to the air. The material will harden and resist electrochemical reaction. Also, the remaining electrolyte will have a high concentration of acid, which can cause the plates to deteriorate quickly. Even the addition of water will not restore such hardened plates to a fully active condition.

Parasitic Losses

Parasitic losses are small current drains required to operate electrical systems, such as the clock, that continue to work when the car is parked and the ignition is off. The current demand of a clock is small and not likely to cause a problem.

The advent of computer controls, however, has made parasitic losses more serious. Many late-model cars have computers to control such diverse items as engine operation, radio tuning, suspension leveling, climate control, and more. Each of these microprocessors contains random access memory (RAM) that stores information relevant to its job. To “remember,” RAM requires a constant voltage supply, and therefore puts a continuous drain on the car’s electrical system.

The combined drain of several computer memories can discharge a battery to the point where there is insufficient cranking power after only a few weeks. Vehicles with these systems that are driven infrequently, put into storage, or awaiting parts for repair will require battery charging more often than older cars with lower parasitic voltage losses.

Because of the higher parasitic current drains on late-model cars, the old test of removing a battery cable connection and tapping it against the terminal while looking for a spark is both dangerous and no longer a valid check for excessive current drain. Furthermore, every time the power source to the computer is interrupted, electronically stored information, such as radio station presets, is lost and will have to be reprogrammed when the battery is reconnected.

On engine control systems with learning capability, like GM's Computer Command Control, driveability may also be affected until the computer relearns the engine calibration modifications that were erased from its memory when the battery was disconnected. For more information, see the section on "Battery Testing" in Chapter 7 of the *Shop Manual*.

Corrosion

Battery corrosion is caused by spilled electrolyte and by electrolyte condensation from gassing. The sulfuric acid attacks and can destroy not only connectors and terminals, but metal holddowns and carriers as well. Corroded connectors increase resistance at the battery connections. This reduces the applied voltage for the car's electrical system. Corrosion also can cause mechanical failure of the holddowns and carrier, which can damage the battery. Spilled electrolyte and corrosion on the battery top also can create a current leakage path, which can allow the battery to discharge.

Overcharging

Batteries can be overcharged either by the automotive charging system or by a separate battery charger. In either case, there is a violent chemical reaction in the battery. The water in the electrolyte is rapidly broken down into hydrogen and oxygen gases. These gas bubbles can wash active material off the plates, as well as lower the level of the electrolyte. Overcharging can also cause excessive heat, which can oxidize the positive grid material and even buckle the plates. For more information, see the section on "Battery Changing" in Chapter 7 of the *Shop Manual*.

Undercharging and Sulfation

If an automobile is not charging its battery, either because of stop-and-start driving or a fault in the charging system, the battery will be constantly discharged. As we saw in the explanation of electrochemical action, a discharged plate is covered with lead sulfate. The amount of lead sulfate on the plate will vary according to the state of charge. As the lead sulfate builds up

in a constantly undercharged battery, it can crystallize and not recombine with the electrolyte. This is called battery sulfation. The crystals are difficult to break down by normal recharging and the battery becomes useless. Despite the chemical additives sold as "miracle cures" for sulfation, a completely sulfated battery cannot be effectively recharged.

Cycling

As we learned at the beginning of this chapter, the operation of a battery from charged to discharged and back to charged is called cycling. Automotive batteries are not designed for continuous deep-cycle use (although special marine and RV batteries are). If an automotive battery is repeatedly cycled from a fully charged condition to an almost discharged condition, the active material on the positive plates may shed and fall into the bottom of the case. If this happens, the material cannot be restored to the plates. Cycling thus reduces the capacity of the battery and shortens its useful service life.

Temperature

Temperature extremes affect battery service life and performance in a number of ways. High temperature, caused by overcharging or excessive engine heat, increases electrolyte loss and shortens battery life.

Low temperatures in winter can also harm a battery. If the electrolyte freezes, it can expand and break the case, ruining the battery. The freezing point of electrolyte depends upon its specific gravity and thus, on the battery's state of charge. A fully charged battery with a specific gravity of 1.265 to 1.280 will not freeze until its temperature drops below -60°F (-51°C). A discharged battery with electrolyte that is mostly water can freeze at -18°F (-28°C).

As we saw earlier, cold temperatures make it harder to keep the battery fully charged, yet this is when a full charge is most important. Figure 7-17 compares the energy levels available from a fully charged battery at various temperatures. As you can see, the colder a battery is, the less energy it can supply. Yet the colder an engine gets, the more energy it requires for cranking. This is why battery care is especially important in cold weather.

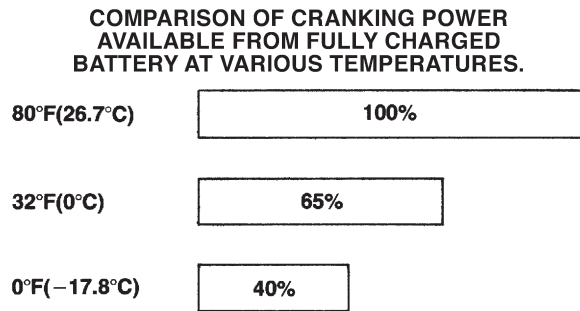


Figure 7-17. Battery power decreases as temperature decreases.

Vibration

As mentioned earlier, a battery must be securely mounted in its carrier to protect it from vibration. Vibration can shake the active materials off the plates and severely shorten a battery's life. Vibration can also loosen the plate connections to the plate strap and damage other internal connections. Some manufacturers now build batteries with plate straps and connectors in the center of the plates to reduce the effects of vibration. Severe vibration can even crack a battery case and loosen cable connections.

See the section on "Jump Starting" in Chapter 7 of the *Shop Manual*.

SUMMARY

Automotive batteries are lead-acid secondary batteries containing a number of electrochemical cells that can be recharged after discharging. Batteries not only store power, they generate voltage and current through the electrochemical action between dissimilar plates in the presence of an electrolyte. Each lead-acid cell generates about 2.1 volts regardless of the number of positive and negative plates. Cells are connected in series, allowing six cells to produce about 12.6 volts in a fully charged 12-volt battery. Current output of a cell depends upon the total surface

area of all the plates. Batteries with higher current or capacity ratings have larger plate areas.

The battery state of charge is determined by electrolyte specific gravity. In a fully charged battery, electrolyte should have a specific gravity of 1.260 to 1.265. Maintenance-free batteries contain calcium-alloy grids to reduce battery heat and water loss. Since such batteries are sealed, their electrolyte cannot be checked and water cannot be added to their cells.

Automotive batteries are designed for starting the engine, not for continual cycling from fully charged to discharged and back to fully charged. Batteries have cranking performance and reserve capacity ratings, and BCI group numbers indicate their size and physical characteristics. Battery service life is affected by electrolyte level, corrosion, overcharging or undercharging, cycling, vibration, and temperature variations.

■ How the Battery Got Its Name

The word "battery" means a group of like things used together. An automobile battery is a group of electrochemical cells connected and working together. Battery voltage is determined by the number of cells connected in series in the battery.

Early automobile batteries could be taken apart for service. Cases were made of wood, and the tops were sealed with tar or a similar material. The top could be opened and the plate element could be removed from a single cell and replaced with a new one.

Deep-Cycle Service

Some batteries, like those in golf carts and electric vehicles, are used for deep-cycle service. This means that as they provide electrical current, they go from a fully charged state to an almost fully discharged state, and are then recharged and used again.

Maintenance-free batteries should never be used in deep-cycle service. Deep-cycle service promotes shedding of the active materials from the battery plates. This action drastically reduces the service life of a maintenance-free battery.

Review Questions

- Which of the following occurs within an automobile battery?
 - The positive plate gains electrons and is positively charged.
 - The negative plate loses electrons and is negatively charged.
 - The positive plate loses electrons and the negative plate gains electrons.
 - The positive plate gains electrons and the negative plate loses electrons.
- Battery electrolyte is a mixture of water and:
 - Lead peroxide
 - Sulfuric acid
 - Lead sulfate
 - Sulfur crystals
- The plates of a *discharged* battery are:
 - Two similar metals in the presence of an electrolyte
 - Two similar metals in the presence of water
 - Two dissimilar metals in the presence of an electrolyte
 - Two dissimilar metals in the presence of water
- Which of the following is true about a "secondary" battery?
 - It can be recharged.
 - Neither the electrolyte nor the metals change their atomic structure.
 - One of the metals is totally destroyed by the action of the battery.
 - The action of the battery cannot be reversed.
- Which of the following does *not* occur during battery recharging?
 - The lead sulfate on the plates gradually decomposes.
 - The sulfate is redeposited in the water.
 - The electrolyte is returned to full strength.
 - The negative plates change back to lead sulfate.
- Each cell of an automobile battery can produce about _____ volts.
 - 1.2
 - 2.1
 - 4.2
 - 6
- Which of the following is true of a 6-volt automobile battery?
 - It has six cells connected in series.
 - It has three cells connected in series.
 - It has six cells connected in parallel.
 - It has three cells connected in parallel.
- The correct ratio of water to sulfuric acid in battery electrolyte is approximately:
 - 80 percent water to 20 percent sulfuric acid
 - 60 percent water to 40 percent sulfuric acid
 - 40 percent water to 60 percent sulfuric acid
 - 20 percent water to 80 percent sulfuric acid
- At 80°F, the correct specific gravity of electrolyte in a fully charged battery is:
 - 1.200 to 1.225
 - 1.225 to 1.265
 - 1.265 to 1.280
 - 1.280 to 1.300
- A specific gravity of 1.170 to 1.190 at 80°F indicates that a battery's state of charge is about:
 - 75 percent
 - 50 percent
 - 25 percent
 - 10 percent
- Which of the following materials is *not* used for battery separators?
 - Lead
 - Wood
 - Paper
 - Plastic
- Batteries are rated in terms of:
 - Amperes at 65°F
 - Resistance at 32°F
 - Voltage level at 80°F
 - Cranking performance at 0°F
- Maintenance-free batteries:
 - Have individual cell caps
 - Require water infrequently
 - Have three pressure vents
 - Use non-antimony lead alloys

14. Which of the following statements is *not* true of a replacement battery?
 - a. It may have the same rating as the original battery.
 - b. It may have a higher rating than the original battery.
 - c. It may have a lower rating than the original battery.
 - d. It should be selected according to an application chart.
15. An automobile battery with a cranking performance rating of 380 can deliver 380 amps for:
 - a. 30 seconds at 0°F
 - b. 60 seconds at 0°F
 - c. 90 seconds at 32°F
 - d. 90 seconds at 0°F
16. The principal cause of battery water loss is:
 - a. Spillage from the vent caps
 - b. Leakage through the battery case
 - c. Conversion of water to sulfuric acid
 - d. Evaporation due to heat of the charging current
17. Which of the following is *not* true of a maintenance-free battery?
 - a. It will resist overcharging better than a vent-cap battery.
 - b. It will lose water slower than a vent-cap battery.
 - c. It will produce a greater voltage than a vent-cap battery.
 - d. It has a greater electrolyte capacity than a vent-cap battery.
18. The electrolyte in a fully charged battery will generally not freeze until the temperature drops to:
 - a. 32°F
 - b. 0°F
 - c. -20°F
 - d. -50°F
19. The grid material used in a maintenance-free battery is alloyed with:
 - a. Silicon
 - b. Antimony
 - c. Calcium
 - d. Germanium
20. Low-maintenance batteries:
 - a. Have no cell caps
 - b. Have a higher proportion of sulfuric acid
 - c. Have no gas-pressure vents
 - d. Require infrequent water addition
21. Recombinant batteries are:
 - a. Rebuilt units
 - b. Completely sealed
 - c. Vented to release gassing
 - d. Able to produce a higher cell voltage
22. Which of these parts of a battery hold the electrical charge?
 - a. Side-post types
 - b. Positive and negative plates
 - c. Top-post type
 - d. Bottom plates
23. Technician A says that the battery term ampere-hour refers to stored charge capacity of a battery. Technician B says that a 75-ampere-hour charge applied to a 200-ampere-hour battery should turn the charge indicator green. Who is right?
 - a. A only
 - b. B only
 - c. Both A and B
 - d. Neither A nor B
24. On a vehicle with the two battery 12-volt system, the battery's connection is which one of the following?
 - a. Series circuit
 - b. Parallel circuit
 - c. DC circuit
 - d. AC circuit
25. During normal operation, the battery(s) perform all of the following functions, *except*:
 - a. Provides electrical energy for the accessories when the engine is not running
 - b. Acts as voltage storage for the truck electrical system
 - c. Serves as the voltage source for starting
 - d. Provides voltage for the injection solenoid when running
26. The subject of battery ratings is being discussed. Technician A says reserve capacity is a rating that represents the time in minutes that a battery can operate a truck at night with minimum electrical load. Technician B says that cranking amps (CA) is basically the same as cold cranking amps (CCA) but at a temperature of 32°F. Who is right?
 - a. A only
 - b. B only
 - c. Both A and B
 - d. Neither A nor B