6. Which terminal of the data link connector does General Motors use for Class 2 communication?
   a. 1 **c.** 3
   b. 2 **d.** 4
7. GMLAN is the General Motors term for which type of module communication?
   a. UART **c.** High-speed CAN
   b. Class 2 **d.** Keyword 2000
8. CAN H and CAN L operate how?
   a. CAN H is at 2.5 volts when not transmitting.
   b. CAN L is at 2.5 volts when not transmitting.
   c. CAN H goes to 3.5 volts when transmitting.
   d. All of the above
9. Which terminal of the OBD-II data link connector is the signal ground for all vehicles?
   a. 1
   b. 3
   c. 4
   d. 5
10. Terminal 16 of the OBD-II data link connector is used for what?
   a. Chassis ground
   b. 12 V positive
   c. Module (signal ground)
   d. Manufacturer's discretion

chapter 50 BATTERIES

OBJECTIVES: After studying Chapter 50, the reader will be able to: • Prepare for ASE Electrical/Electronic Systems (A6) certification test content area "B" (Battery Diagnosis and Service). • Describe how a battery works. • List battery ratings. • Describe deep cycling. • Discuss how charge indicators work.

KEY TERMS: AGM 542 • Ampere hour 543 • Battery Council International (BCI) 543 • CA 543 • CCA 543 • Cells 539 • Deep cycling 543 • Electrolyte 540 • Element 539 • Flooded cell batteries 542 • Gassing 539 • Gel battery 542 • Grid 538 • Low-water-loss batteries 538 • Maintenance-free battery 538 • MCA 543 • Partitions 539 • Porous lead 539 • Recombinant battery 542 • Reserve capacity 543 • Sediment chamber 538 • SLA 542 • SLI 539 • Specific gravity 540 • Sponge lead 539 • SVR 542 • VRLA 542

INTRODUCTION

PURPOSE AND FUNCTION

Everything electrical in a vehicle is supplied current from the battery. The battery is one of the most important parts of a vehicle because it is the heart or foundation of the electrical system. The primary purpose of an automotive battery is to provide a source of electrical power for starting and for electrical demands that exceed alternator output.

WHY BATTERIES ARE IMPORTANT

The battery also acts as a stabilizer to the voltage for the entire electrical system. The battery is a voltage stabilizer because it acts as a reservoir where large amounts of current (amperes) can be removed quickly during starting and replaced gradually by the alternator during charging.

- The battery *must* be in good (serviceable) condition before the charging system and the cranking system can be tested. For example, if a battery is discharged, the cranking circuit (starter motor) could test as being defective because the battery voltage might drop below specifications.
- The charging circuit could also test as being defective because of a weak or discharged battery. It is important to test the vehicle battery before further testing of the cranking or charging system.

BATTERY CONSTRUCTION

CASE

Most automotive battery cases (container or covers) are constructed of polypropylene, a thin (approximately 0.08 in., or 0.02 mm, thick), strong, and lightweight plastic. In contrast, containers for industrial batteries and some truck batteries are constructed of a hard, thick rubber material.

Inside the case are six cells (for a 12 volt battery). ● **SEE FIGURE 50–1.** Each cell has positive and negative plates. Built into the bottom of many batteries are ribs that support the lead-alloy plates and provide a space for sediment to settle, called the **sediment chamber.** This space prevents spent active material from causing a short circuit between the plates at the bottom of the battery.

A **maintenance-free battery** uses little water during normal service because of the alloy material used to construct the battery plate grids. Maintenance-free batteries are also called **low-water-loss batteries.**

GRIDS

Each positive and negative plate in a battery is constructed on a framework, or **grid,** made primarily of lead. Lead is a

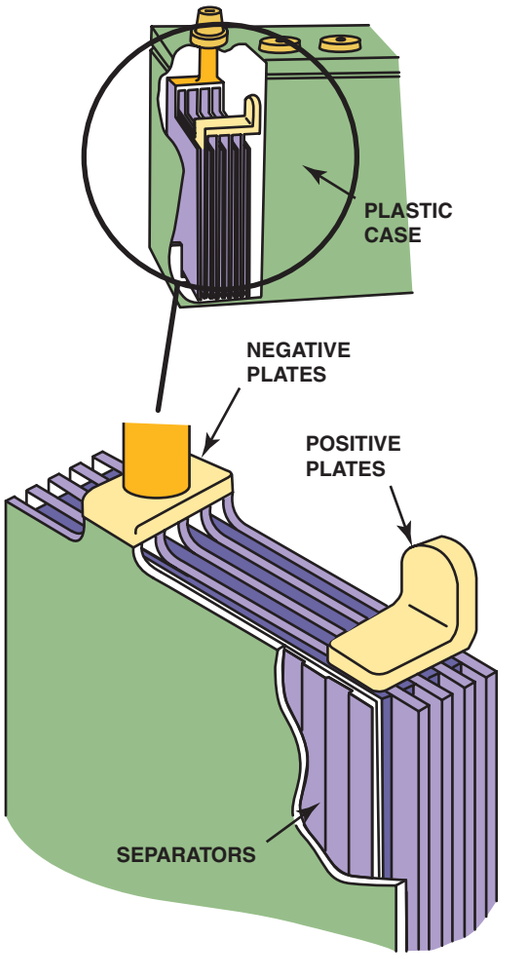

FIGURE 50–1 Batteries are constructed of plates grouped into cells and installed in a plastic case.

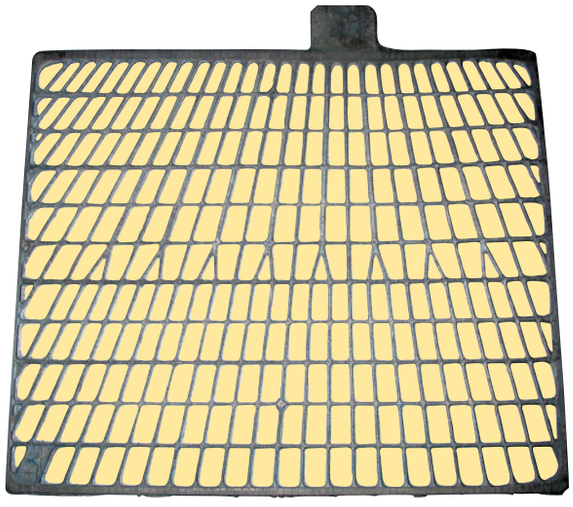

FIGURE 50–2 A grid from a battery used in both positive and negative plates.

soft material and must be strengthened for use in an automotive battery grid. Adding antimony or calcium to the pure lead adds strength to the lead grids. ● **SEE FIGURE 50–2.**

Battery grids hold the active material and provide the electrical pathways for the current created in the plate.

Maintenance-free batteries use calcium instead of antimony, because 0.2% calcium has the same strength as 6% antimony. A typical lead-calcium grid uses only 0.09% to 0.12% calcium. Using low amounts of calcium instead of higher amounts of antimony reduces **gassing.** Gassing is the release of hydrogen and oxygen from the battery that occurs during charging and results in water usage.

? **FREQUENTLY ASKED QUESTION**

What Is an SLI Battery?

Sometimes the term *SLI* is used to describe a type of battery. **SLI** means starting, lighting, and ignition, and describes the use of a typical automotive battery. Other types of batteries used in industry are usually batteries designed to be deep cycled and are usually not as suitable for automotive needs.

Low-maintenance batteries use a low percentage of antimony (about 2% to 3%), or use antimony only in the positive grids and calcium for the negative grids. *The percentages that make up the alloy of the plate grids constitute the major difference between standard and maintenance-free batteries.* The chemical reactions that occur inside each battery are identical regardless of the type of material used to construct the grid plates.

POSITIVE PLATES The positive plates have *lead dioxide (peroxides),* in paste form placed onto the grid framework. This process is called *pasting.* This active material can react with the sulfuric acid of the battery and is dark brown in color.

NEGATIVE PLATES The negative plates are pasted to the grid with a pure **porous lead,** called **sponge lead,** and are gray in color.

SEPARATORS The positive and the negative plates must be installed alternately next to each other without touching. Nonconducting *separators* are used, which allow room for the reaction of the acid with both plate materials, yet insulate the plates to prevent shorts. These separators are porous (with many small holes) and have ribs facing the positive plate. Separators can be made from resin-coated paper, porous rubber, fiberglass, or expanded plastic. Many batteries use envelope-type separators that encase the entire plate and help prevent any material that may shed from the plates from causing a short circuit between plates at the bottom of the battery.

CELLS **Cells** are constructed of positive and negative plates with insulating separators between each plate. Most batteries use one more negative plate than positive plate in each cell; however, many newer batteries use the same number of positive and negative plates. A cell is also called an **element.** Each cell is actually a 2.1 volt battery, regardless of the number of positive or negative plates used. The greater the number of plates used in each cell, the greater the amount of *current* that can be produced. Typical batteries contain four positive plates and five negative plates per cell. A 12 volt battery contains six cells connected in series, which produce 12.6 volts ($6 \times 2.1 = 12.6$) and contain 54 plates (9 plates per cell $\times$ 6 cells). If the same 12 volt battery had five positive plates and six negative plates, for a total of 11 plates per cell ($5 + 6$), or 66 plates (11 plates $\times$ 6 cells), then it would have the same voltage, but the amount of current that the battery could produce would be increased. ● **SEE FIGURE 50–3.**

The amperage capacity of a battery is determined by the amount of active plate material in the battery and the area of the plate material exposed to the electrolyte in the battery.

PARTITIONS Each cell is separated from the other cells by **partitions,** which are made of the same material as that used for the outside case of the battery. Electrical connections between cells are provided by lead connectors that loop over the top of the partition and connect the plates of the cells together. Many batteries connect the

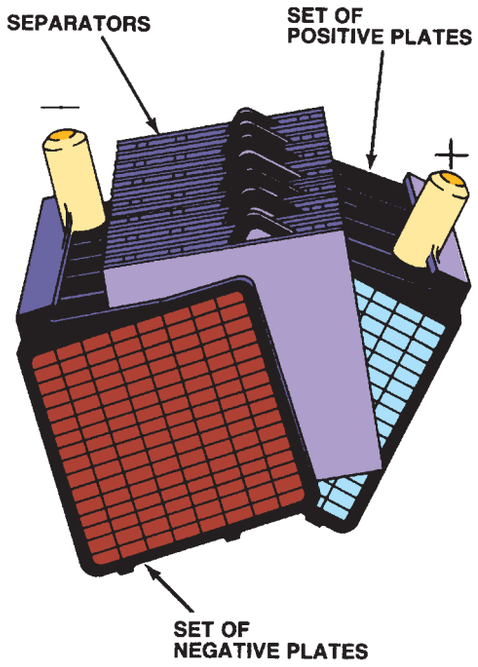

FIGURE 50–3 Two groups of plates are combined to form a battery element.

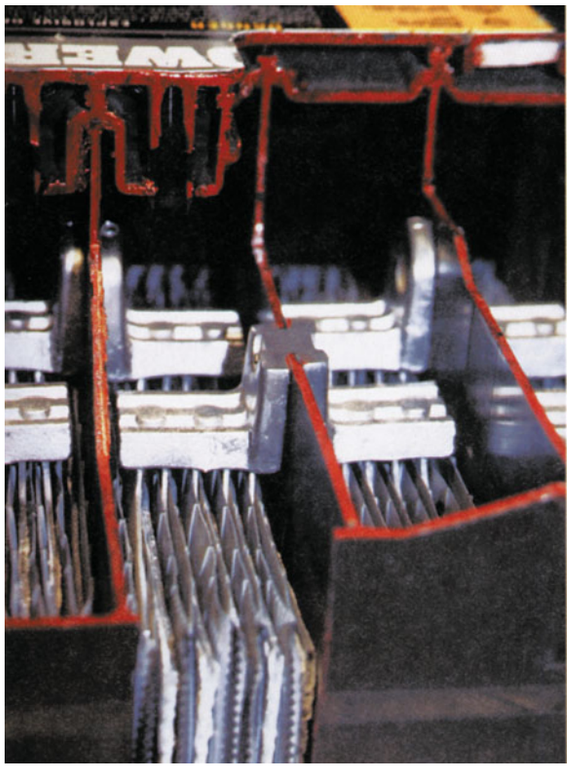

FIGURE 50–4 A cutaway battery showing the connection of the cells to each other through the partition.

cells directly through the partition connectors, which provide the shortest path for the current and the lowest resistance. ● **SEE FIGURE 50–4.**

ELECTROLYTE

Electrolyte is the term used to describe the acid solution in a battery. The electrolyte used in automotive batteries is a solution (liquid combination) of 36% sulfuric acid and 64% water. This electrolyte is used for both lead-antimony and lead-calcium (maintenance-free) batteries. The chemical symbol for this sulfuric acid solution is H_2SO_4.

H_2 = Symbol for hydrogen (the subscript 2 means that there are two atoms of hydrogen)

S = Symbol for sulfur

O_4 = Symbol for oxygen (the subscript 4 indicates that there are four atoms of oxygen)

Electrolyte is sold premixed in the proper proportion and is factory installed or added to the battery when the battery is sold. Additional electrolyte must *never* be added to any battery after the original electrolyte fill. It is normal for some water (H_2O) in the form of hydrogen and oxygen gases to escape during charging as a result of the chemical reactions. The escape of gases from a battery during charging or discharging is called gassing. Only pure distilled water should be added to a battery. If distilled water is not available, clean drinking water can be used.

HOW A BATTERY WORKS

PRINCIPLE INVOLVED

The principle of how a battery works is based on a scientific principle discovered years ago that states:

- When two dissimilar metals are placed in an acid, electrons flow between the metals if a circuit is connected between them.
- This can be demonstrated by pushing a steel nail and a piece of solid copper wire into a lemon. Connect a voltmeter to the ends of the copper wire and nail, and voltage will be displayed.

A fully charged lead-acid battery has a positive plate of lead dioxide (peroxide) and a negative plate of lead surrounded by a sulfuric acid solution (electrolyte). The difference in potential (voltage) between lead peroxide and lead in acid is approximately 2.1 volts.

DURING DISCHARGING

The positive plate lead dioxide (PbO_2) combines with the SO_4, forming $PbSO_4$ from the electrolyte and releases its O_2 into the electrolyte, forming H_2O. The negative plate also combines with the SO_4 from the electrolyte and becomes lead sulfate ($PbSO_4$). ● **SEE FIGURE 50–5.**

FULLY DISCHARGED STATE

When the battery is fully discharged, both the positive and the negative plates are $PbSO_4$ (lead sulfate) and the electrolyte has become water (H_2O). As the battery is being discharged, the plates and electrolyte approach the completely discharged state. There is also the danger of freezing when a battery is discharged, because the electrolyte is mostly water.

CAUTION: Never charge or jump start a frozen battery because the hydrogen gas can get trapped in the ice and ignite if a spark is caused during the charging process. The result can be an explosion.

DURING CHARGING

During charging, the sulfate from the acid leaves both the positive and the negative plates and returns to the electrolyte, where it becomes normal-strength sulfuric acid solution. The positive plate returns to lead dioxide (PbO_2), the negative plate is again pure lead (Pb), and the electrolyte becomes H_2SO_4. ● **SEE FIGURE 50–6.**

SPECIFIC GRAVITY

DEFINITION

The amount of sulfate in the electrolyte is determined by the electrolyte's **specific gravity,** which is the ratio of the weight of a given volume of a liquid to the weight of an equal volume of water. In other words, the more dense the liquid is, the higher its

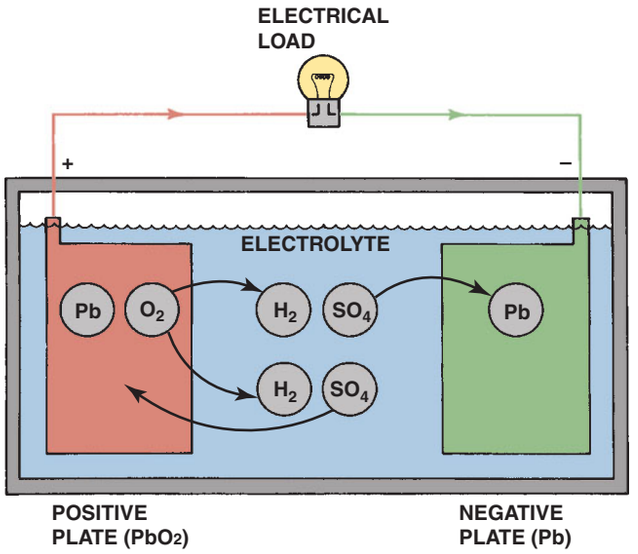

FIGURE 50–5 Chemical reaction for a lead-acid battery that is fully charged being discharged by the attached electrical load.

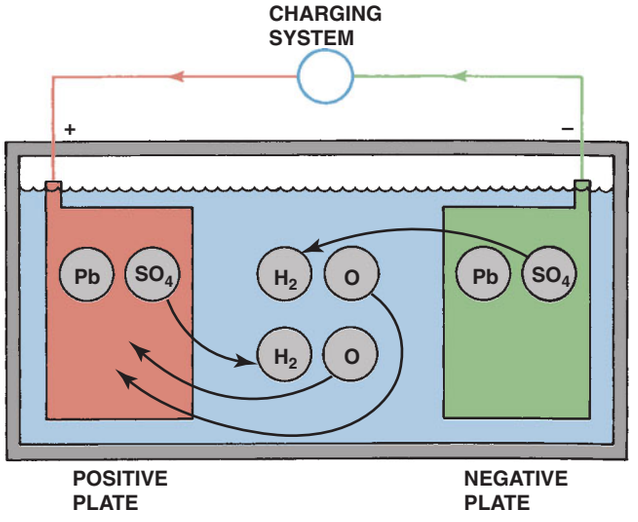

FIGURE 50–6 Chemical reaction for a lead-acid battery that is fully discharged being charged by the attached generator.

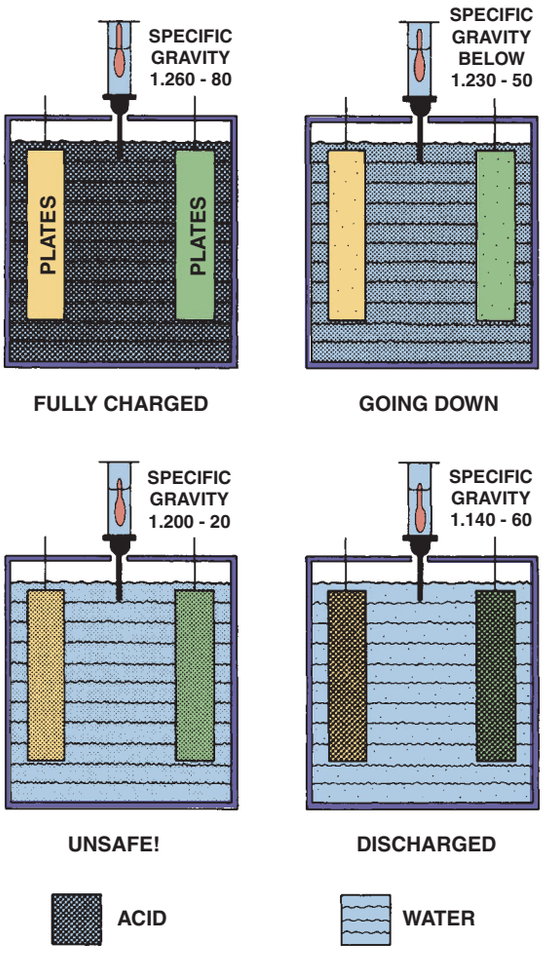

FIGURE 50–7 As the battery becomes discharged, the specific gravity of the battery acid decreases.

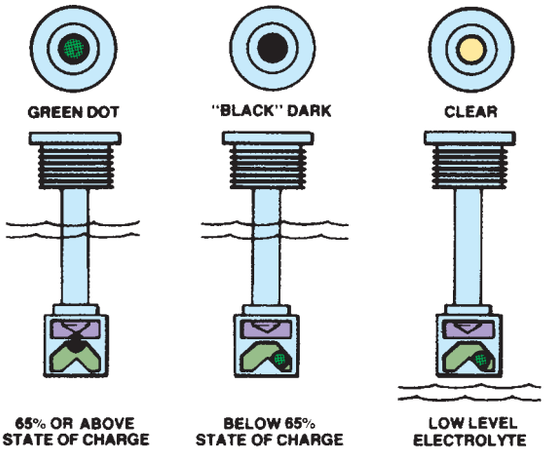

FIGURE 50–8 Typical battery charge indicator. If the specific gravity is low (battery discharged), the ball drops away from the reflective prism. When the battery is charged enough, the ball floats and reflects the color of the ball (usually green) back up through the sight glass and the sight glass is dark.

FREQUENTLY ASKED QUESTION

Is There an Easy Way to Remember How a Battery Works?

Yes. Think of the sulfuric acid solution in the electrolyte being deposited, then removed from the plates.

- **During discharge.** The acid (SO_4) is leaving the electrolyte and getting onto both plates.
- **During charging.** The acid (SO_4) is being forced from both plates and enters the electrolyte.

specific gravity. Pure water is the basis for this measurement and is given a specific gravity of 1.000 at 80°F (27°C). Pure sulfuric acid has a specific gravity of 1.835; the *correct* concentration of water and sulfuric acid (called electrolyte—64% water, 36% acid) is 1.260 to 1.280 at 80°F. The higher the battery's specific gravity, the more fully it is charged. ● **SEE FIGURE 50–7.**

CHARGE INDICATORS Some batteries are equipped with a built-in state-of-charge indicator, commonly called *green eyes.* This indicator is simply a small, ball-type hydrometer that is installed in one cell. This hydrometer uses a plastic ball that floats if the electrolyte density is sufficient (which it is when the battery is about 65% charged). When the ball floats, it appears in the hydrometer's sight glass, changing its color. ● **SEE FIGURE 50–8.**

Because the hydrometer is only testing one cell (out of six on a 12 volt battery), and because the hydrometer ball can easily stick

SPECIFIC GRAVITY	STATE OF CHARGE	BATTERY VOLTAGE (V)
1.265	Fully charged	12.6 or higher
1.225	75% charged	12.4
1.190	50% charged	12.2
1.155	25% charged	12.0
Lower than 1.120	Discharged	11.9 or lower

CHART 50–1

A comparison showing the relationship among specific gravity, battery voltage, and state of charge.

in one position, do not trust that this is accurate information about a state of charge (SOC) of the battery.

Values of specific gravity, state of charge, and battery voltage at 80°F (27°C) are given in ● **CHART 50–1.**

VALVE REGULATED LEAD-ACID BATTERIES

TERMINOLOGY There are two basic types of **valve regulated lead-acid (VRLA),** also called **sealed valve-regulated (SVR)** or **sealed lead-acid (SLA),** batteries. These batteries use a low-pressure venting system that releases excess gas and automatically reseals if a buildup of gas is created due to overcharging. The two types include the following:

- **Absorbed glass mat.** The acid used in an **absorbed glass mat (AGM)** battery is totally absorbed into the separator, making the battery leakproof and spillproof. The battery is assembled by compressing the cell about 20%, then inserting it into the container. The compressed cell helps reduce damage caused by vibration and helps keep the acid tightly against the plates. The sealed maintenance-free design uses a pressure release valve in each cell. Unlike conventional batteries that use a liquid electrolyte, called **flooded cell batteries,** most of the hydrogen and oxygen given off during charging remains inside the battery. The separator or mat is only 90% to 95% saturated with electrolyte, thereby allowing a portion of the mat to be filled with gas. The gas spaces provide channels to allow the hydrogen and oxygen gases to recombine rapidly and safely. Because the acid is totally absorbed into the glass mat separator, an AGM battery can be mounted in any direction. AGM batteries also have a longer service life, often lasting 7 to 10 years. Absorbed glass mat batteries are used as standard equipment in some vehicles such as the Chevrolet Corvette and in most Toyota hybrid electric vehicles. ● **SEE FIGURE 50–9.**
- **Gelled electrolyte batteries.** In a gelled electrolyte battery, silica is added to the electrolyte, which turns the electrolyte into a substance similar to gelatin. This type of battery is also called a **gel battery.**

Both types of valve-regulated, lead-acid batteries are also called **recombinant battery** design. A recombinant-type battery means that the oxygen gas generated at the positive plate travels through the dense electrolyte to the negative plate. When the oxygen reaches the negative plate, it reacts with the lead, which consumes the oxygen gas and prevents the formation of hydrogen gas. It is because of this oxygen recombination that VRLA batteries do not use water.

FIGURE 50–9 An absorbed glass mat battery is totally sealed and is more vibration resistant than conventional lead-acid batteries.

CAUSES AND TYPES OF BATTERY FAILURE

NORMAL LIFE Most automotive batteries have a useful service life of three to seven years; however, proper care can help increase the life of a battery, but abuse can shorten it. The major cause of premature battery failure is overcharging.

CHARGING VOLTAGE The automotive charging circuit, consisting of an alternator and connecting wires, must be operating correctly to prevent damage to the battery.

- Charging voltages higher than 15.5 volts can damage a battery by warping the plates as a result of the heat of overcharging.
- AGM batteries can be damaged if charged at a voltage higher than 14.5 volts.

Overcharging also causes the active plate material to disintegrate and fall out of the supporting grid framework. Vibration or bumping can also cause internal damage similar to that caused by overcharging. It is important, therefore, to ensure that all automotive batteries are securely clamped down in the vehicle. The shorting of cell plates can occur without notice. If one of the six cells of a 12 volt battery is shorted, the resulting voltage of the battery is only 10 volts (12 − 2 = 10). With only 10 volts available, the starter *usually* will not be able to start the engine.

BATTERY HOLD-DOWNS All batteries must be attached securely to the vehicle to prevent battery damage. Normal vehicle vibrations can cause the active materials inside the battery to shed. Battery hold-down clamps or brackets help reduce vibration, which can greatly reduce the capacity and life of any battery. ● **SEE FIGURE 50–10.**

BATTERY RATINGS

Batteries are rated according to the amount of current they can produce under specific conditions.

COLD-CRANKING AMPERES Every automotive battery must be able to supply electrical power to crank the engine in cold weather and still provide battery voltage high enough to operate the ignition

FIGURE 50–10 A typical battery hold-down bracket. All batteries should use a bracket to prevent battery damage due to vibration and shock.

FIGURE 50–11 This battery has a cranking amperes (CA) rating of 1,000. This means that this battery is capable of cranking an engine for 30 seconds at a temperature of 32°F (0°C) at a minimum of 1.2 volts per cell (7.2 volts for a 12 volt battery).

FREQUENTLY ASKED QUESTION

What Determines Battery Capacity?

The capacity of any battery is determined by the amount of active plate material in the battery. A battery with a large number of thin plates can produce high current for a short period. If a few thick plates are used, the battery can produce low current for a long period. A trolling motor battery used for fishing must supply a low current for a long period of time. An automotive battery is required to produce a high current for a short period for cranking. Therefore, every battery is designed for a specific application.

FREQUENTLY ASKED QUESTION

What Is Deep Cycling?

Deep cycling is almost fully discharging a battery and then completely recharging it. Golf cart batteries are an example of lead-acid batteries that must be designed to be deep cycled. A golf cart must be able to cover two 18-hole rounds of golf and then be fully recharged overnight. Charging is hard on batteries because the internal heat generated can cause plate warpage, so these specially designed batteries use thicker plate grids that resist warpage. Normal automotive batteries are not designed for repeated deep cycling.

system for starting. The cold-cranking ampere rating of a battery is the number of amperes that can be supplied by a battery at 0°F (−18°C) for 30 seconds while the battery still maintains a voltage of 1.2 volts per cell or higher. This means that the battery voltage would be 7.2 volts for a 12 volt battery and 3.6 volts for a 6 volt battery. The cold-cranking performance rating is called **cold-cranking amperes (CCA).** Try to purchase a battery with the highest CCA for the money. See the vehicle manufacturer's specifications for recommended battery capacity.

CRANKING AMPERES The designation **CA** refers to the number of amperes that can be supplied by a battery at 32°F (0°C). This rating results in a higher number than the more stringent CCA rating. ● **SEE FIGURE 50–11.**

MARINE CRANKING AMPERES **Marine cranking amperes (MCA)** is similar to cranking amperes and is tested at 32°F (0°C).

RESERVE CAPACITY The **reserve capacity** rating for batteries is *the number of minutes* for which the battery can produce 25 amperes and still have a battery voltage of 1.75 volts per cell (10.5 volts for a 12 volt battery). This rating is actually a measurement of the time for which a vehicle can be driven in the event of a charging system failure.

AMPERE HOUR **Ampere hour** is an older battery rating system that measures how many amperes of current the battery can produce over a period of time. For example, a battery that has a 50 amp-hour (A-H) rating can deliver 50 amperes for one hour or 1 ampere for 50 hours or any combination that equals 50 amp-hours.

BATTERY SIZES

BCI GROUP SIZES Battery sizes are standardized by the **Battery Council International (BCI).** When selecting a replacement battery, check the specified group number in service information, battery application charts at parts stores, or the owner's manual.

TYPICAL GROUP SIZE APPLICATIONS

- **24/24F (top terminals).** Fits many Honda, Acura, Infinity, Lexus, Nissan, and Toyota vehicles.
- **34/78 (dual terminals, both side and top posts).** Fits many General Motors pickups and SUVs, as well as midsize and larger GM sedans and large Chrysler/Dodge vehicles.
- **35 (top terminals).** Fits many Japanese brand vehicles.
- **65 (top terminals).** Fits most large Ford/Mercury passenger cars, trucks, and SUVs.
- **75 (side terminals).** Fits some General Motors small and midsize cars and some Chrysler/Dodge vehicles.
- **78 (side terminals).** Fits many General Motors pickups and SUVs, as well as midsize and larger GM sedans.

Exact dimensions can be found on the Internet by searching for BCI battery sizes.

REVIEW QUESTIONS

1. Why can discharged batteries freeze?
2. What are the battery-rating methods?
3. Why can a battery explode if it is exposed to an open flame or spark?

CHAPTER QUIZ

1. When a battery becomes completely discharged, both positive and negative plates become _____ and the electrolyte becomes _____.
   a. H_2SO_4 / Pb
   b. $PbSO_4$ / H_2O
   c. PbO_2 / H_2SO_4
   d. $PbSO_4$ / H_2SO_4
2. A fully charged 12 volt battery should indicate _____.
   a. 12.6 volts or higher
   b. A specific gravity of 1.265 or higher
   c. 12 volts
   d. Both a and b
3. Deep cycling means _____.
   a. Overcharging the battery
   b. Overfilling or underfilling the battery with water
   c. The battery is fully discharged and then recharged
   d. The battery is overfilled with acid (H_2SO_4)
4. What makes a battery "low maintenance" or "maintenance free"?
   a. Material is used to construct the grids.
   b. The plates are constructed of different metals.
   c. The electrolyte is hydrochloric acid solution.
   d. The battery plates are smaller, making more room for additional electrolytes.
5. The positive battery plate is _____.
   a. Lead dioxide
   b. Brown in color
   c. Sometimes called lead peroxide
   d. All of the above
6. Which battery rating is tested at 0°F (−18°C)?
   a. Cold-cranking amperes (CCA)
   b. Cranking amperes (CA)
   c. Reserve capacity
   d. Battery voltage test
7. Which battery rating is expressed in minutes?
   a. Cold-cranking amperes (CCA)
   b. Cranking amperes (CA)
   c. Reserve capacity
   d. Battery voltage test
8. What battery rating is tested at 32°F (0°C)?
   a. Cold-cranking amperes (CCA)
   b. Cranking amperes (CA)
   c. Reserve capacity
   d. Battery voltage test
9. What gases are released from a battery when it is being charged?
   a. Oxygen
   b. Hydrogen
   c. Nitrogen and oxygen
   d. Hydrogen and oxygen
10. A charge indicator (eye) operates by showing green or red when the battery is charged and dark if the battery is discharged. This charge indicator detects _____.
    a. Battery voltage
    b. Specific gravity
    c. Electrolyte water pH
    d. Internal resistance of the cells

chapter 51

BATTERY TESTING AND SERVICE

OBJECTIVES: **After studying Chapter 51, the reader will be able to:** • Prepare for ASE Electrical/Electronic Systems (A6) certification test content area "B" (Battery Diagnosis and Service). • List the precautions necessary when working with batteries. • Explain how to safely charge a battery. • Discuss how to perform a battery drain test. • Describe how to perform a battery load test. • Explain how to conduct a conductance test. • Discuss how to test batteries for open-circuit voltage and specific gravity.

KEY TERMS: Battery electrical drain test 552 • Dynamic voltage 546 • Hydrometer 547 • IOD 552 • Load test 547 • Open circuit voltage 546 • Parasitic load test 552 • Three-minute charge test 548

FIGURE 51–1 A visual inspection on this battery shows the electrolyte level was below the plates in all cells.

FIGURE 51–2 Corrosion on a battery cable could be an indication that the battery itself is either being overcharged or is sulfated, creating a lot of gassing of the electrolyte.

BATTERY SERVICE SAFETY CONSIDERATIONS

HAZARDS Batteries contain acid and release explosive gases (hydrogen and oxygen) during normal charging and discharging cycles.

SAFETY PROCEDURES To help prevent physical injury or damage to the vehicle, always adhere to the following safety procedures.

1. When working on any electrical component on a vehicle, disconnect the negative battery cable from the battery. When the negative cable is disconnected, all electrical circuits in the vehicle will be open, which will prevent accidental electrical contact between an electrical component and ground. Any electrical spark has the potential to cause explosion and personal injury.
2. Wear eye protection (goggles preferred) when working around any battery.
3. Wear protective clothing to avoid skin contact with battery acid.
4. Always adhere to all safety precautions as stated in the service procedures for the equipment used for battery service and testing.
5. Never smoke or use an open flame around any battery.

SYMPTOMS OF A WEAK OR DEFECTIVE BATTERY

The following warning signs indicate that a battery is near the end of its useful life.

- **Uses water in one or more cells.** This indicates that the plates are sulfated and that during the charging process, the water in the electrolyte is being turned into separate hydrogen and oxygen gases. ● **SEE FIGURE 51–1.**
- **Excessive corrosion on battery cables or connections.** Corrosion is more likely to occur if the battery is sulfated, creating hot spots on the plates. When the battery is being charged, the acid fumes are forced out of the vent holes and onto the battery cables, connections, and even on the battery tray underneath the battery. ● **SEE FIGURE 51–2.**
- **Slower than normal engine cranking.** When the capacity of the battery is reduced due to damage or age, it is less likely to be able to supply the necessary current for starting the engine, especially during cold weather.

BATTERY MAINTENANCE

NEED FOR MAINTENANCE Most new-style batteries are of a maintenance-free design that uses lead-calcium instead of lead-antimony plate grid construction. Because lead-calcium batteries do not release as much gas as the older-style, lead-antimony batteries, there is less consumption of water during normal service. Also, with less gassing, less corrosion is observed on the battery terminals, wiring, and support trays. If the electrolyte level can be checked, and if it is low, add only distilled water. Distilled water is recommended by all battery manufacturers, but if distilled water is not available, clean ordinary drinking water, low in mineral content, can be used.

Battery maintenance includes making certain that the battery case is clean and checking that the battery cables and hold-down fasteners are clean and tight.

BATTERY TERMINAL CLEANING Many battery-related faults are caused by poor electrical connections at the battery. Battery cable connections should be checked and cleaned to prevent voltage drop at the connections. One common reason for an engine to not start is loose or corroded battery cable connections. Perform an inspection and check for the following conditions.

- Loose or corroded connections at the battery terminals (should not be able to be moved by hand)
- Loose or corroded connections at the ground connector on the engine block
- Wiring that has been modified to add auxiliary power for a sound system, or other electrical accessory

If the connections are loose or corroded, use 1 tablespoon of baking soda in 1 quart (liter) of water and brush this mixture onto the battery and housing to neutralize the acid. Mechanically clean the connections and wash the area with water. ● **SEE FIGURE 51–3.**

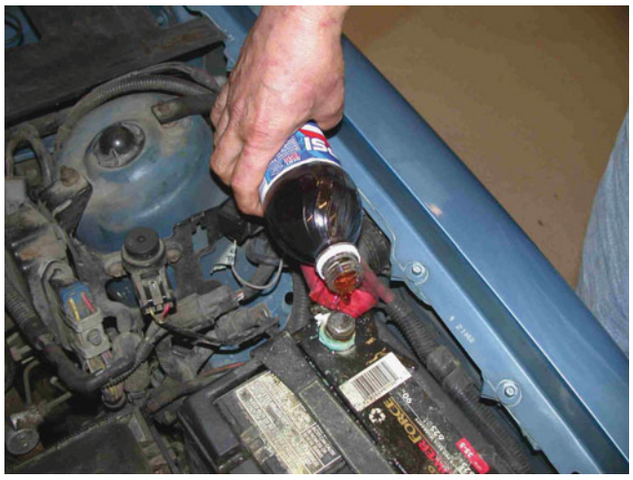

FIGURE 51–3 Besides baking soda and water, a sugar-free diet soft drink can also be used to neutralize the battery acid.

TECH TIP

Dynamic versus Open Circuit Voltage

Open circuit voltage is the voltage (usually of a battery) that exists *without* a load being applied. **Dynamic voltage** is the voltage of the power source (battery) with the circuit in operation. A vehicle battery, for example, may indicate that it has 12.6 volts or more, but that voltage will drop when the battery is put under a load such as cranking the engine. If the battery voltage drops too much, the starter motor will rotate more slowly and the engine may not start.

If the dynamic voltage is lower than specified, the battery may be weak or defective or the circuit may be defective.

BATTERY HOLD-DOWN The battery should also be secured with a hold-down bracket to prevent vibration from damaging the plates inside the battery. The hold-down bracket should be snug enough to prevent battery movement, yet not so tight as to cause the case to crack. Factory-original hold-down brackets are often available through local automobile dealers, and universal hold-down units are available through local automotive parts stores.

BATTERY VOLTAGE TEST

STATE OF CHARGE Testing the battery voltage with a voltmeter is a simple method for determining the state of charge of any battery. ● **SEE FIGURE 51–4.**

The voltage of a battery does not necessarily indicate whether the battery can perform satisfactorily, but it does indicate to the technician more about the battery's condition than a simple visual inspection. A battery that "looks good" may not be good. This test is commonly called an *open circuit battery voltage test* because it is conducted with an open circuit, no current flowing, and no load applied to the battery.

1. If the battery has just been charged or the vehicle has recently been driven, it is necessary to remove the surface charge from the battery before testing. A surface charge is a charge of higher-than-normal voltage that is just on the surface of the battery plates. The surface charge is quickly removed when the battery is loaded and therefore does not accurately represent the true state of charge of the battery.
2. To remove the surface charge, turn the headlights on high beam (brights) for one minute, then turn the headlights off and wait two minutes.

(a)

(b)

FIGURE 51–4 (a) A voltage reading of 12.28 volts indicates that the battery is not fully charged and should be charged before testing. (b) A battery that measures 12.6 volts or higher after the surface charge has been removed is 100% charged.

BATTERY VOLTAGE (V)	STATE OF CHARGE
12.6 or higher	100% charged
12.4	75% charged
12.2	50% charged
12.0	25% charged
11.9 or lower	Discharged

CHART 51–1

The estimated state of charge of a 12 volt battery after the surface charge has been removed.

SPECIFIC GRAVITY	BATTERY VOLTAGE (V)	STATE OF CHARGE
1.265	12.6 or higher	100% charged
1.225	12.4	75% charged
1.190	12.2	50% charged
1.155	12.0	25% charged
Lower than 1.120	11.9 or lower	Discharged

CHART 51–2

Measuring the specific gravity can detect a defective battery. A battery should be at least 75% charged before being load tested.

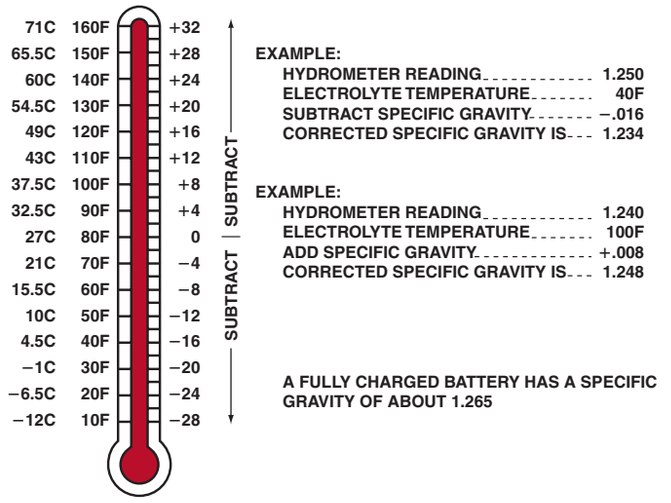

FIGURE 51–5 When testing a battery using a hydrometer, the reading must be corrected if the temperature is above or below 80°F (27°C).

FIGURE 51–6 This battery has cold-cranking amperes (CCA) of 550 A, cranking amperes (CA) of 680 A, and load test amperes of 270 A listed on the top label. Not all batteries have this complete information.

3. With the engine and all electrical accessories off, and the doors shut (to turn off the interior lights), connect a voltmeter to the battery posts. Connect the red positive lead to the positive post and the black negative lead to the negative post.

   NOTE: If the meter reads negative (−), the battery has been reverse charged (has reversed polarity) and should be replaced, or the meter has been connected incorrectly.

4. Read the voltmeter and compare the results with the state of charge. The voltages shown are for a battery at or near room temperature (70°F to 80°F, or 21°C to 27°C). ● **SEE CHART 51–1**.

HYDROMETER TESTING

If the battery has removable filler caps, the specific gravity of the electrolyte can also be checked. A **hydrometer** is a tester that measures the specific gravity. ● **SEE FIGURE 51–5.**

This test can also be performed on most maintenance-free batteries because their filler caps are removable, except for those produced by Delco (Delphi) Battery. The specific gravity test indicates the state of battery charge and can indicate a defective battery if the specific gravity of one or more cells varies by more than 0.050 from the value of the highest-reading cell. ● **SEE CHART 51–2.**

BATTERY LOAD TESTING

TERMINOLOGY One test to determine the condition of any battery is the **load test.** Most automotive starting and charging testers use a carbon pile to create an electrical load on the battery. The amount of the load is determined by the original CCA rating of the battery, which should be at least 75% charged before performing a load test. The capacity is measured in cold-cranking amperes, which is the number of amperes that a battery can supply at 0°F (−18°C) for 30 seconds.

TEST PROCEDURE To perform a battery load test, take the following steps.

STEP 1 **Determine the CCA rating of the battery.** The proper electrical load used to test a battery is half of the CCA rating or three times the ampere-hour rating, with a minimum 150 ampere load. ● **SEE FIGURE 51–6.**

STEP 2 **Connect the load tester to the battery.** Follow the instructions for the tester being used.

STEP 3 **Apply the load for a full 15 seconds.** Observe the voltmeter during the load testing and check the voltage at the end of the 15 sec. period while the battery is still under load. A good battery should indicate above 9.6 V.

FIGURE 51–7 An alternator regulator battery starter tester (ARBST) automatically loads the battery with a fixed load for 15 sec. to remove the surface charge, then removes the load for 30 sec. to allow the battery to recover, and then reapplies the load for another 15 sec. The results of the test are then displayed.

FREQUENTLY ASKED QUESTION

What Is the Three-Minute Charge Test?

A **three-minute charge test** is used to check if a battery is sulfated, and is performed as follows:

- Connect a battery charger and a voltmeter to the battery terminals.
- Charge the battery at a rate of 40 amperes for three minutes.
- At the end of three minutes, read the voltmeter.

Results: If the voltage is above 15.5 volts, replace the battery. If the voltage is below 15.5 volts, the battery is not sulfated and should be charged and retested.

This is *not* a valid test of many maintenance-free batteries, such as the Delphi Freedom. Due to the high internal resistance, a discharged Delphi Freedom battery may not start to accept a charge for several hours. Always use another alternative battery test before discarding a battery based on the results of the three-minute charge test.

STEP 4 **Repeat the test.** Many battery manufacturers recommend performing the load test twice, using the first load period to remove the surface charge on the battery and the second test to provide a truer indication of the condition of the battery. Wait 30 seconds between tests to allow time for the battery to recover. ● **SEE FIGURE 51–7.**

Results: If the battery fails the load test, recharge the battery and retest. If the load test is failed again, replacement of the battery is required.

ELECTRONIC CONDUCTANCE TESTING

TERMINOLOGY General Motors Corporation, Chrysler Corporation, and Ford specify that an electronic conductance tester be used to test batteries in vehicles still under factory warranty. Conductance is a measure of how well a battery can create current. This tester sends a small signal through the battery and then measures a part of the AC response. As a battery ages, the plates can become sulfated and shed active materials from the grids, reducing the battery capacity. Conductance testers can be used to test flooded or absorbed glass (AGM) type batteries. The unit can determine the following information about a battery.

- CCA
- State of charge
- Voltage of the battery
- Defects such as shorts and opens

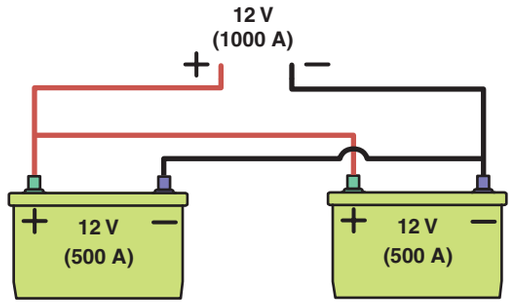

FIGURE 51–8 Most light-duty vehicles equipped with two batteries are connected in parallel as shown. Two 500 A, 12 volt batteries are capable of supplying 1,000 A at 12 volts, which is needed to start many diesel engines.

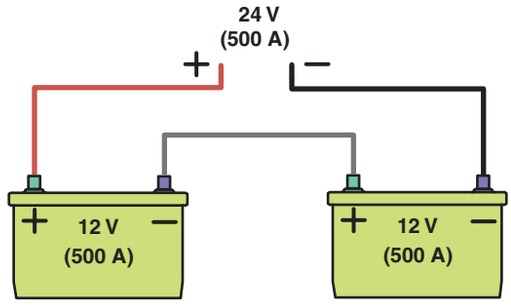

FIGURE 51–9 Many heavy-duty trucks and buses use two 12 volt batteries connected in series to provide 24 volts.

FREQUENTLY ASKED QUESTION

How Should You Test a Vehicle Equipped with Two Batteries?

Many vehicles equipped with a diesel engine use two batteries. These batteries are usually electrically connected in parallel to provide additional current (amperes) at the same voltage. ● **SEE FIGURE 51–8.**

Some heavy-duty trucks and buses connect two batteries in series to provide about the same current as one battery, but with twice the voltage, as shown in ● **FIGURE 51–9.**

To successfully test the batteries, they should be disconnected and tested separately. If just one battery is found to be defective, most experts recommend that both be replaced to help prevent future problems. Because the two batteries are electrically connected, a fault in one battery can cause the good battery to discharge into the defective battery, thereby affecting both even if just one battery is at fault.

However, a conductance tester is not designed to accurately determine the state of charge or CCA rating of a new battery. Unlike a battery load test, a conductance tester can be used on a battery that is discharged. This type of tester should only be used to test batteries that have been in service. ● **SEE FIGURE 51–10.**

TEST PROCEDURE

STEP 1 Connect the unit to the positive and negative terminals of the battery. If testing a side post battery, always use the lead adapters and *never* use steel bolts as these can cause an incorrect reading.

NOTE: Test results can be incorrectly reported on the display if proper, clean connections to the battery are not made. Also be sure that all accessories and the ignition switch are in the off position.

STEP 2 Enter the CCA rating (if known) and push the arrow keys.

STEP 3 The tester determines and displays one of the following:

- **Good battery.** The battery can return to service.
- **Charge and retest.** Fully recharge the battery and return it to service.
- **Replace the battery.** The battery is not serviceable and should be replaced.
- **Bad cell—replace.** The battery is not serviceable and should be replaced.

Some conductance testers can check the charging and cranking circuits, too.

FIGURE 51–10 A conductance tester is very easy to use and has proved to accurately determine battery condition if the connections are properly made. Follow the instructions on the display exactly for best results.

BATTERY CHARGING

CHARGING PROCEDURE

If the state of charge of a battery is low, it must be recharged. It is best to slow charge any battery to prevent possible overheating damage to the battery. Perform the following steps.

STEP 1 **Determine the charge rate.** The charge rate is based on the current state of charge (SOC) and charging rate. ● **SEE CHART 51–3** for the recommended charging rate.

STEP 2 **Connect a battery charger to the battery.** Be sure the charger is not plugged in when connecting a charger to a

SAFETY TIP

Never Charge or Jump Start a Frozen Battery

A discharged battery can freeze because the electrolyte becomes mostly water. Never attempt to charge or jump start a vehicle that has a frozen battery. When the battery freezes, it often bulges at the sides because water expands about 9% when it freezes, forming ice crystals that occupy more space than liquid water. The crystals can trap bubbles of hydrogen and oxygen that are created during the chemical processes in a battery. When attempting to charge or jump start the frozen battery, these pockets of gases can explode. Because the electrolyte expands, the freezing action usually destroys the plates and can loosen the active material from the grids. It is rare for a frozen battery to be restored to useful service.

OPEN CIRCUIT VOLTAGE	BATTERY SPECIFIC GRAVITY*	STATE OF CHARGE	CHARGING TIME TO FULL CHARGE AT 80°F**					
			at 60 amps	at 50 amps	at 40 amps	at 30 amps	at 20 amps	at 10 amps
12.6	1.265	100%	FULL CHARGE					
12.4	1.225	75%	15 min.	20 min.	27 min.	35 min.	48 min.	90 min.
12.2	1.190	50%	35 min.	45 min.	55 min.	75 min.	95 min.	180 min.
12.0	1.155	25%	50 min.	65 min.	85 min.	115 min.	145 min.	260 min.
11.8	1.120	0%	65 min.	85 min.	110 min.	150 min.	195 min.	370 min.

CHART 51–3

Battery charging guideline showing the charging times that vary according to state of charge, temperature, and charging rate. It may take eight hours or more to charge a fully discharged battery.
*Correct for temperature
**If colder, it'll take longer

FIGURE 51–11 A typical industrial battery charger. Be sure that the ignition switch is in the off position before connecting any battery charger. Connect the cables of the charger to the battery before plugging the charger into the outlet. This helps prevent a voltage spike and spark that could occur if the charger happened to be accidentally left on. Always follow the battery charger manufacturer's instructions.

battery. Always follow the battery charger's instructions for proper use.

STEP 3 **Set the charging rate.** The initial charge rate should be about 35 A for 30 minutes to help start the charging process. Fast charging a battery increases the temperature of the battery and can cause warping of the plates inside the battery. Fast charging also increases the amount of gassing (release of hydrogen and oxygen), which can create a health and fire hazard. The battery temperature should not exceed 125°F (hot to the touch).

- Fast charge: 15 A maximum
- Slow charge: 5 A maximum

● **SEE FIGURE 51–11.**

CHARGING AGM BATTERIES Charging an absorbed glass mat (AGM) battery requires a different charger than is used to recharge a flooded-type battery. The differences include:

- The AGM can be charged with high current, up to 75% of the ampere-hour rating due to lower internal resistance.
- The charging voltage has to be kept at or below 14.4 volts to prevent damage.

Because most conventional battery chargers use a charging voltage of 16 volts or higher, a charger specifically designed to charge AGM batteries must be used.

Absorbed glass mat batteries are often used as auxiliary batteries in hybrid electric vehicles when the battery is located inside the vehicle. ● **SEE CHART 51–4** for a summary of the locations of the 12 volt auxiliary battery and high-voltage battery and safety switch/plug.

TECH TIP

Charge Batteries at 1% of Their CCA Rating

Many batteries are damaged due to being overcharged. To help prevent damage such as warped plates and excessive release of sulfur smell gases, charge batteries at a rate equal to 1% of the battery's CCA rating. For example, a battery with a 700 CCA rating should be charged at 7 amperes (700 × 0.01 = 7 amperes). No harm will occur to the battery at this charge rate even though it may take longer to achieve a full charge. This means that a battery may require eight or more hours to become fully charged depending on the battery capacity and state of charge (SOC).

TECH TIP

Always Use Adapters on Side Post Batteries

Side post batteries require that an adapter be used when charging the battery, if it is removed from the vehicle. Do not use steel bolts. If a bolt is threaded into the terminal, only the parts of the threads that contact the battery terminal will be conducting all of the charging current. An adapter or a bolt with a nut attached is needed to achieve full contact with the battery terminals. ● **SEE FIGURE 51–12.**

BATTERY CHARGE TIME

The time needed to charge a completely discharged battery can be estimated by using the reserve capacity rating of the battery in minutes divided by the charging rate.

Hours needed to charge the battery =
Reserve capacity ÷ Charge current

For example, if a 10 A charge rate is applied to a discharged battery that has a 90-minute reserve capacity, the time needed to charge the battery will be nine hours.

90 minutes ÷ 10 A = 9 hours

JUMP STARTING

To jump start another vehicle with a dead battery, connect good-quality copper jumper cables or a jump box to the good battery and the dead battery, as shown in ● **FIGURE 51–13.**

When using jumper cables or a battery jump box, the last connection made should always be on the engine block or an engine bracket on the dead vehicle as far from the battery as possible. ● **SEE FIGURE 51–14.**

It is normal for a spark to be created when the jumper cables finally complete the jumping circuit, and this spark could cause an explosion of the gases around the battery. Many newer vehicles have special ground and/or positive power connections built away from the battery just for the purpose of jump starting. Check the owner's manual or service information for the exact location.

MAKE, MODEL (YEARS)	AUXILIARY 12 V BATTERY LOCATION	HV BATTERY PACK LOCATION (VOLTAGE)	TYPE OF 12 V BATTERY
Cadillac Escalade (2008+) (two mode)	Under the hood; driver's side	Under second row seat (300 volts)	Flooded lead-acid
Chevrolet Malibu (2008+)	Under the hood; driver's side	Mounted behind rear seat under vehicle floor (36 volts)	Flooded lead-acid
Chevrolet Silverado (2004–2008) (PHT)	Under the hood; driver's side	Under second row seat (42 volts)	Flooded lead-acid
Chevrolet Tahoe (two mode)	Under the hood; driver's side	Under second row seat (300 volts)	Flooded lead-acid
Chrysler Aspen (2009)	Under driver's side door, under vehicle	Under rear seat; driver's side (288 volts)	Flooded lead-acid
Dodge Durango (2009)	Under driver's side door, under vehicle	Under rear seat; driver's side (288 volts)	Flooded lead-acid
Ford Escape (2005+)	Under the hood; driver's side	Cargo area in the rear under carpet (300 volts)	Flooded lead-acid
GMC Sierra (2004–2008) (PHT)	Under the hood; driver's side	Under second row seat (42 volts)	Flooded lead-acid
GMC Yukon (2008+) (two mode)	Under the hood; driver's side	Under second row seat (300 volts)	Flooded lead-acid
Honda Accord (2005–2007)	Under the hood; driver's side	Behind rear seat (144 volts)	Flooded lead-acid
Honda Civic (2003+)	Under the hood; driver's side	Behind rear seat (144 to 158 volts, 2006+)	Flooded lead-acid
Honda Insight (1999–2005)	Under the hood; center under windshield	144 volts; under hatch floor in the rear	Flooded lead-acid
Honda Insight (2010+)	Under the hood; driver's side	144 volts; under floor behind rear seat	Flooded lead-acid
Lexus GS450h (2007+)	In the trunk; driver's side, behind interior panel	Trunk behind rear seat (288 volts)	Absorbed glass mat (AGM)
Lexus LS 600h (2006+)	In the trunk; driver's side, behind interior panel	Trunk behind rear seat (288 volts)	Absorbed glass mat (AGM)
Lexus RX400h (2006–2009)	Under the hood; passenger side	Under the second row seat (288 volts)	Flooded lead-acid
Mercury Mariner (2005+)	Under the hood; driver's side	Cargo area in the rear under carpet (300 volts)	Flooded lead-acid
Nissan Altima (2007+)	In the trunk; driver's side	Behind rear seat (245 volts)	Absorbed glass mat (AGM)
Saturn AURA Hybrid (2007+)	Under the hood; driver's side	Behind the rear seat; under the vehicle floor (36 volts)	Flooded lead-acid
Saturn VUE Hybrid (2007+)	Under the hood; driver's side	Behind the rear seat; under the vehicle floor (36 volts)	Flooded lead-acid
Toyota Camry Hybrid (2007+)	In the trunk; passenger side	Behind the rear seat; under the vehicle floor (245 volts)	Absorbed glass mat (AGM)
Toyota Highlander Hybrid (2006–2009)	Under the hood; passenger side	Under the second row seat (288 volts)	Flooded lead-acid
Toyota Prius (2001–2003)	In the trunk; driver's side	Behind rear seat (274 volts)	Absorbed glass mat (AGM)
Toyota Prius (2004–2009)	In the trunk; driver's side	Behind rear seat (201 volts)	Absorbed glass mat (AGM)
Toyota Prius (2010+)	In the trunk; driver's side	Behind rear seat (201.6 volts)	Absorbed glass mat (AGM)

CHART 51–4

A summary chart showing where the 12 volt and high-voltage batteries and shut-off switch/plugs are located. Only the auxiliary 12 volt batteries can be serviced or charged.

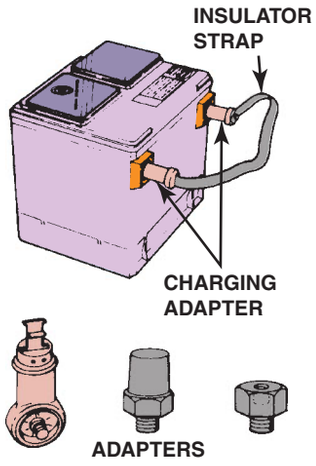

FIGURE 51–12 Adapters should be used on side terminal batteries whenever charging.

FIGURE 51–13 A typical battery jump box used to jump start vehicles. These hand-portable units have almost made jumper cables obsolete.

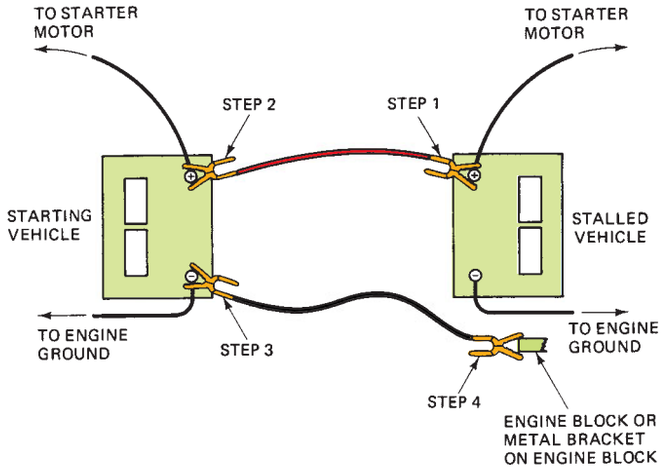

FIGURE 51–14 Jumper cable usage guide. Notice that the last connection should be the engine block of the disabled vehicle to help prevent the spark that normally occurs from igniting the gases from the battery.

FREQUENTLY ASKED QUESTION

Should Batteries Be Kept Off of Concrete Floors?

All batteries should be stored in a cool, dry place when not in use. Many technicians have been warned not to store or place a battery on concrete. According to battery experts, it is the temperature difference between the top and the bottom of the battery that causes a difference in the voltage potential between the top (warmer section) and the bottom (colder section). It is this difference in temperature that causes self-discharge to occur.

In fact, submarines cycle seawater around their batteries to keep all sections of the battery at the same temperature to help prevent self-discharge.

Therefore, always store or place batteries up off the floor and in a location where the entire battery can be kept at the same temperature, avoiding extreme heat and freezing temperatures. Concrete cannot drain the battery directly because the case of the battery is a very good electrical insulator.

TECH TIP

Look at the Battery Date Code

All major battery manufacturers stamp codes on the battery case that give the date of manufacture and other information. Most battery manufacturers use a number to indicate the year of manufacture and a letter to indicate the month of manufacture, except the letter I, because it can be confused with the number 1. For example:

A = January	G = July
B = February	H = August
C = March	J = September
D = April	K = October
E = May	L = November
F = June	M = December

The shipping date from the manufacturing plant is usually indicated by a *sticker* on the end of the battery. Almost every battery manufacturer uses just one letter and one number to indicate the month and year. ● **SEE FIGURE 51–15.**

BATTERY ELECTRICAL DRAIN TEST

TERMINOLOGY The **battery electrical drain test** determines if any component or circuit in a vehicle is causing a drain on the battery when everything is off. This test is also called the **ignition off draw (IOD)** or **parasitic load test.**

Many electronic components draw a continuous, slight amount of current from the battery when the ignition is off. These components include:

1. Electronically tuned radios for station memory and clock circuits
2. Computers and controllers, through slight diode leakage
3. The alternator, through slight diode leakage

These components may cause a voltmeter to read full battery voltage if it is connected between the negative battery terminal and the removed end of the negative battery cable. Because of