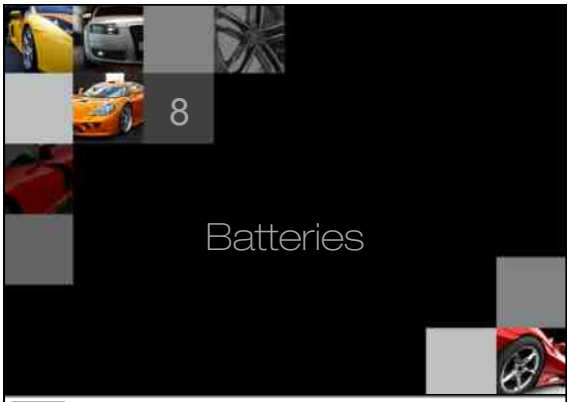








**FIGURE 8.1** Batteries are constructed of plates grouped into cells and installed in a plastic case.

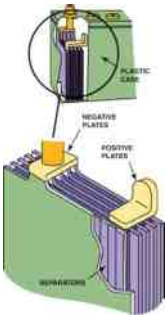








**FIGURE 8.2** A grid from a battery used in both positive and negative plates.

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.






**FIGURE 8.3** Two groups of plates are combined to form a battery element.







**FIGURE 8.4** A cutaway battery showing the connection of the cells to each other through the partition.

**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.**






**FIGURE 8.5** Chemical reaction for a lead-acid battery that is fully charged being discharged by the attached electrical load.

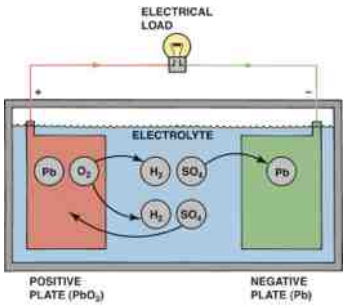








**FIGURE 8.6** Chemical reaction for a lead-acid battery that is fully discharged being charged by the attached alternator.

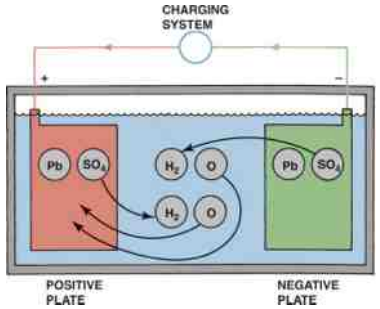


**FIGURE 8.7** An absorbed glass mat battery is totally sealed and is more vibration resistant than conventional lead-acid batteries.







**FIGURE 8.8** This battery has a rating of 1,000 amperes using the cold cranking rating and 900 amperes using the CCA (cold-cranking method).







FREQUENTLY ASKED QUESTION

**What Is Meant by "Deep Cycling" a Battery?**

**Deep cycling** is almost fully discharging of 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.

**FIGURE 8.9** (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.







**CHART 8.1** A comparison showing the relationship between battery voltage and state-of-charge.

| STATE-OF-CHARGE (SOC) | BATTERY VOLTAGE |
|---|---|
| Fully charged | 12.6 volts or higher |
| 75% charged | 12.4 volts |
| 50% | 12.2 volts |
| 25% | 12.0 volts |
| Discharged | 11.9 volts or lower |

CHART 8–1






**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.**

**FIGURE 8.10** 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.







**FIGURE 8.11** An alternator regulator battery starter tester (ARBST) automatically loads the battery with a fixed load for 15 seconds to remove the surface charge, then removes the load for 30 seconds to allow the battery to recover, and then reapplies the load for another 15 seconds. The results of the test are then displayed.







**FIGURE 8.12** 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.

**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.**






**CHART 8.2** Battery charging guidelines based on the state-of-charge of the battery and the charging rate.

| OPEN CIRCUIT VOLTAGE | STATE-OF-CHARGE (SOC) (%) | 6/10 A | 4/10 A | 2/10 A | 1/10 A | 1/20 A | 1/20 A |
|---|---|---|---|---|---|---|---|
| 12.6 | 100 | N.A. (Fully charged) | N.A. (Fully charged) | N.A. (Fully charged) | N.A. (Fully charged) | N.A. (Fully charged) | N.A. (Fully charged) |
| 12.4 | 75 | 15 min. | 20 min. | 27 min. | 35 min. | 46 min. | 90 min. |
| 12.2 | 50 | 35 min. | 45 min. | 55 min. | 75 min. | 95 min. | 180 min. |
| 12.0 | 25 | 50 min. | 65 min. | 85 min. | 115 min. | 145 min. | 280 min. |
| 11.8 | 0 | 65 min. | 85 min. | 110 min. | 150 min. | 185 min. | 370 min. |

CHART 8-2






**FIGURE 8.13** 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.

**FIGURE 8.14** This mini clamp-on digital multimeter is being used to measure the amount of battery electrical drain that is present. In this case, a reading of 20 mA (displayed on the meter as 00.02 A) is within the normal range of 20 to 30 mA. Be sure to clamp around all of the positive battery cable or all of the negative battery cable, whichever is easiest to get the clamp around.







**FIGURE 8.15** After connecting the shut-off tool, start the engine and operate all accessories. Stop the engine and turn off everything. Connect the ammeter across the shut-off switch in parallel. Wait 20 minutes. This time allows all electronic circuits to "time out" or shut down. Open the switch—all current now will flow through the ammeter. A reading greater than specified (usually greater than 50 mA, or 0.05 A) indicates a problem that should be corrected.







**NOTE: Using a voltmeter or test light to measure battery drain is *not*. recommended by most vehicle manufacturers. The high internal resistance of the voltmeter results in an irrelevant reading that does not provide the technician with adequate information about a problem.**

**FIGURE 8.16** The battery was replaced in this Acura and the radio displayed "code" when the replacement battery was installed. Thankfully, the owner had the five-digit code required to unlock the radio.







**NOTE: Do not reinsert fuses after they have been removed as this action can cause modules to "wake up," leading to an inconclusive test.**






**FIGURE 8.17** Jump starting a 2001–2003 Toyota Prius using a 12-volt supply to boost the 12-volt auxiliary battery in the trunk.

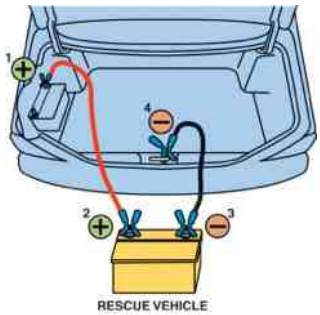


**CHART 8.3** A summary chart showing where the 12-volt and high-voltage batteries and shut-off switch/plugs are located. Only the auxiliary 12-volt batteries can be serviced or charged.

CONTINUED





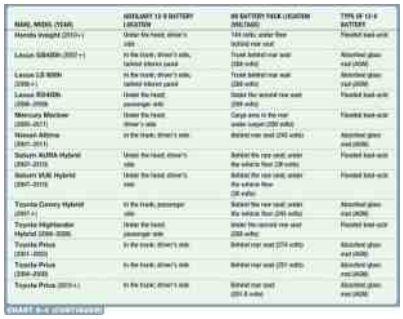
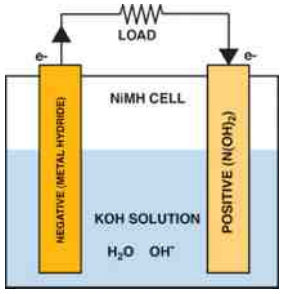








**FIGURE 8.18** An NiMH cell. The unique element in a nickelmetal hydride cell is the negative electrode. Note that the electrolyte does not enter into the chemical reaction and is able to maintain a constant conductivity regardless of the state-of-charge of the cell.



FREQUENTLY ASKED QUESTIONS

**How Many Types of Lithium-Ion Batteries Are There?**

There are numerous types of lithium-ion batteries, and the list is growing. While every component of the battery is under development, the primary difference between the various designs is the materials used for the positive electrode or **cathode.** The original Li-ion cell design used lithium cobalt oxide for its cathode, which has good energy storage characteristics but suffers chemical breakdown at relatively low temperatures. This failure results in the release of heat and oxygen, which often leads to a fire or explosion as the electrolyte ignites.

In order to make lithium-ion batteries safer and more durable, a number of alternative cathode materials have been formulated. One of the more promising cathode designs for automotive applications is lithium iron phosphate ($LiFePO_4$), which is stable at higher temperatures and releases less energy when it does suffer breakdown. Other lithium-ion cathode designs include:

- Lithium nickel cobalt oxide (LNCO)
- Lithium metal oxide (LMO)
- Nickel cobalt manganese (NCM)
- Nickel cobalt aluminum (NCA)
- Manganese oxide spinel (MnO)

Research and development continues on not only cathode design, but also anodes, separator materials, and electrolyte chemistry.



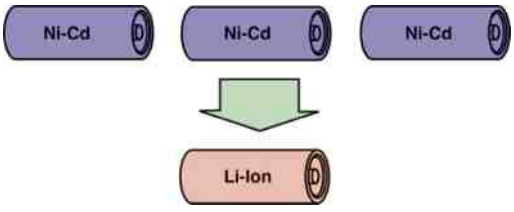



**NOTE: Early lithium-ion battery designs have experienced problems with thermal runaway, which has led to fire and even explosions. Li-ion battery packs in automotive applications must be designed with cooling and safety systems that will prevent overheating and isolate cell failures.**






**FIGURE 8.19** One advantage of a lithium-ion cell is that it produces 3.6 volts, whereas an NiMH or Ni-Cd cell only produces 1.2 volts.



**FREQUENTLY ASKED QUESTION**

**What Were the Causes of Lithium-Ion Battery Failure?**

Three major factors are responsible for failure of lithium-ion batteries:

- Operating the cells outside their required voltage range (2 to 4 volts)
- Operating the cells outside their required temperature range (0°C to 80°C)
- Short circuits (internal or external)

For these reasons, lithium-ion battery packs in automotive applications require precise battery management using specialized cooling and safety systems.






**FREQUENTLY ASKED QUESTIONS**

**How Is an Alkaline Battery Different from a Lead-Acid Battery?**

Lead-acid batteries use sulfuric acid as the electrolyte that acts as the medium between the battery's positive and negative electrodes. Acids have a pH that is below 7, where pure water has a pH of exactly 7. If electrolyte from a lead-acid battery is spilled, it can be neutralized using a solution of baking soda and water (an alkaline solution).

Alkaline batteries use an electrolyte such as potassium hydroxide, which has a pH greater than 7. This means that the electrolyte solution is basic, which is the opposite of acidic. If an alkaline battery's electrolyte is spilled, it can be neutralized using a solution of vinegar and water (vinegar is acidic). Both nickel-cadmium (Ni-Cd) and nickel-metal hydride (NiMH) batteries are alkaline battery designs.






**FIGURE 8.20** Zinc-air batteries are recharged by replacing the zinc anodes. These batteries are also considered to be a type of fuel cell, because the positive electrode is oxygen taken from atmospheric air.

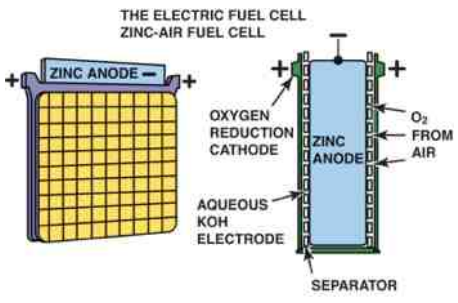


**FIGURE 8.21** Sodium-metal-chloride batteries are also known as ZEBRA batteries. These batteries are lightweight (40% of the weight of lead-acid) and have a high energy density.

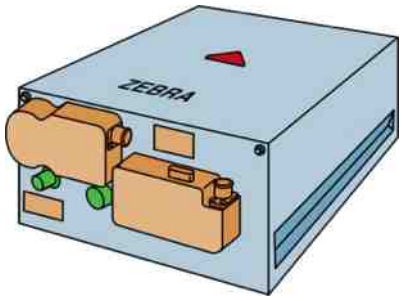








**CHART 8.4** Secondary-type battery comparison showing specifications and limitations.

SECONDARY BATTERIES COMPARISON

| BATTERY TYPE | NOMINAL VOLTAGE (V) PER CELL | THEORETICAL SPECIFIC ENERGY (WH/KG*) | PRACTICAL SPECIFIC ENERGY (WH/KG*) | MAJOR ISSUES |
|---|---|---|---|---|
| Lead-Acid | 2.1 | 252 | 35 | Heavy, low cycle life, toxic materials |
| Nickel-Cadmium | 1.2 | 244 | 50 | Toxic materials, cost |
| Nickel-Metal Hydride | 1.2 | 275–600 | 80 | Cost, high self-discharge rate, memory effect |
| Lithium-Ion | 3.6 | 766 | 120 | Safety issues, calendar life, cost |
| Zinc-Air | 1.1 | 1,320 | 170 | Low power, limited cycle life, bulky |
| Sodium-Sulfur | 2.0 | 792 | 100 | High temperature battery, safety, low power electrolyte |
| Sodium-Nickel-Chloride | 2.3 | 787 | 90 | High temperature operation, low power |

*Specific energy is measured in Watt-hours/kilogram

CHART 8-4