The Pennsylvania State University
Workforce Education and Development

Lesson Plan Template

Name of Instructor:Brian Stevens
Program Title:Automobile/Automotive Mechanics Technology/Techician
Course Title:Automotive Mechanics
Unit Title:Batteries Overview
Lesson Title:battery Function
Lesson Performance Objective:Given information on the purposes of the automotive battery,How they work, and what effects the performance of an automotive battery.
Time (length of lesson): 1 hr.
Equipment and Materials needed: Information package and question sheet.
Technical Standard(s):717,716
Academic Standard(s):CIP 47.0604 Follow information to understand battery function, Types of batteries, Safety, and battery ratings used to diagnose battery problems.
Introduction Students will learn how a battery works, How a battery is constructed, How ratings are used to diagnose battery operation.

Body: General information given on battery function, Different battery types, State of charge,Battery construction, Battery safety, How temperature effects battery operation, and battery ratings.

Summary: Given information to identify different types of batteries in order to properly replace and diagnose battery failures. Students will use this information to help understand and diagnose battery problems.

Student Assessment:

Formative Assessment(s)

Summative Assessment:

Universal Design for Learning (UDL)

Multiple Means of Engagement:

Multiple Means of Representation:

Multiple Means of Expression:

Chapter 1: Batteries Overview

Battery Function

An automotive battery is an electrochemical device that converts electrical energy into chemical energy and stores it until needed. When needed, the battery converts the stored chemical energy back into electrical energy.

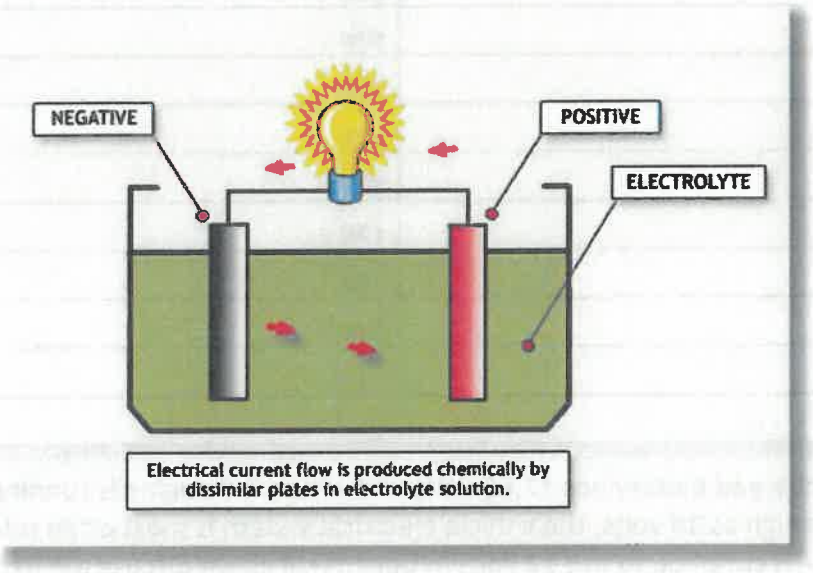
The battery serves four purposes in an automobile:

- It supplies electricity to the accessories when the engine is not running
- It supplies high current to the starter, and system voltage to the ignition system during cranking
- It provides current to the electrical systems when the demand exceeds the output of the generator
- It acts as a voltage stabilizer in the electrical system
- It acts as a "shock absorber" to smooth out the electrical surges (bumps) during the operation of the vehicle.

Automobiles generally use what is classified as a wet cell, lead-acid battery. Batteries produce current through a chemical reaction between the active materials of the plates and sulfuric acid in the electrolyte.

With many different types of batteries being used, battery charging and the correct charger is important. Using the wrong charger can damage the battery or cause fires, or explosions if directions are not followed. Batteries produce current through a chemical reaction between the active materials of the plates and sulfuric acid in the electrolyte.

Current flow in a Battery



Automotive batteries are always either charging or discharging. When a battery is supplying current to accessories or the starter, it is said to be discharging. When the engine is running at sufficient speed, the generator carries the electrical load and charges the battery, and both are said to be charging.

A battery is discharging when:

- The engine is not running (parasitic loads or self-discharging)
- The engine is running at a low rpm under conditions of high electrical demand
- There is a fault in the charging system

A battery that is nearly or completely discharged is commonly said to be "dead," "flat," or "run down." A battery in this condition will need to be recharged to full capacity in order to provide proper service. However, even though a generator will charge a battery, it is not designed to be a "battery charger." Requiring a generator to recharge a completely dead battery may cause overheating and damage to the generator.

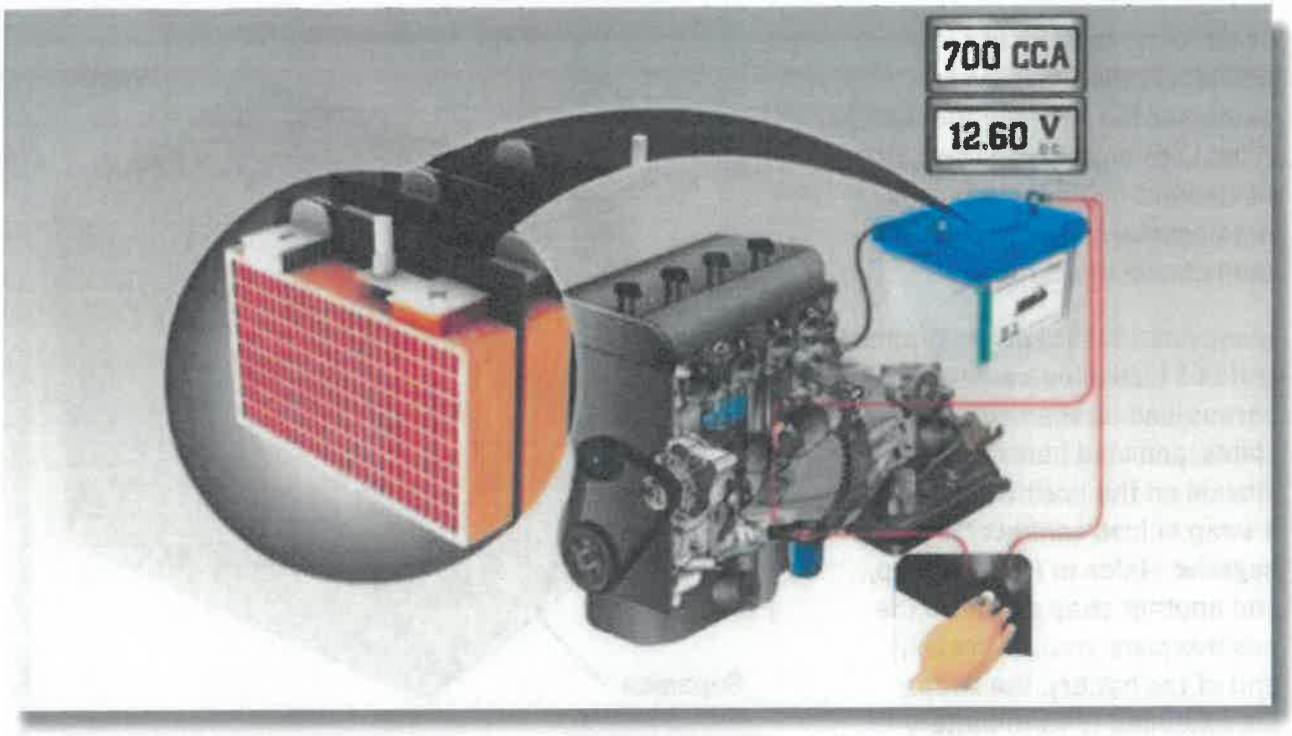
The percentage of charge on a battery can be misleading. In common terms, if a fully charged battery is 12.66 volts, then you make think that a battery with is 50% state of charge has 6.33 volts, but this is not the case. In fact, a battery measuring 12.0 volts will fail to crank many engines of cooler days. Refer to the chart below.

Open circuit voltage (OCV) of the battery	State of charge or % of charge
12.70 to 12.80	Battery has a surface charge (is not overcharged)
12.66	100% (fully charged battery)
12.58	90%
12.51	80%
12.45	70%
12.35	60%
12.28	50%
12.20	40%
12.12	30%
12.04	20%
11.97	10%
11.89	0%

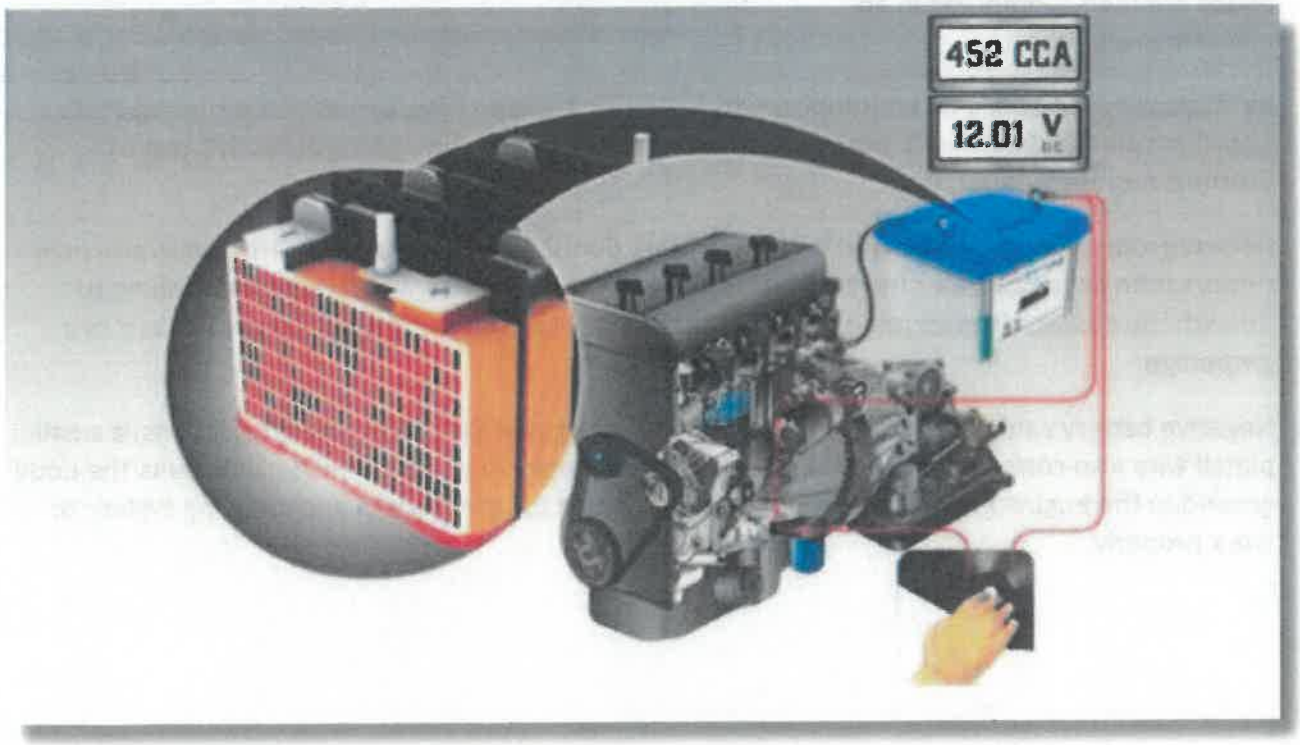
Although a fully charged battery has 12.66 volts and, when the engine is running, the charging voltage can be as high as 16 volts, the vehicle electrical system is most often referred to as a 12-volt system. We will continue to use 12 volts in our course as we discuss the battery and electrical system.

Unlike "**deep cycle**" batteries used in some RV and marine applications, an automotive battery is designed to remain at or near a full state of charge and not to be completely discharged.

Battery 100% Charge



Battery 50% Charge

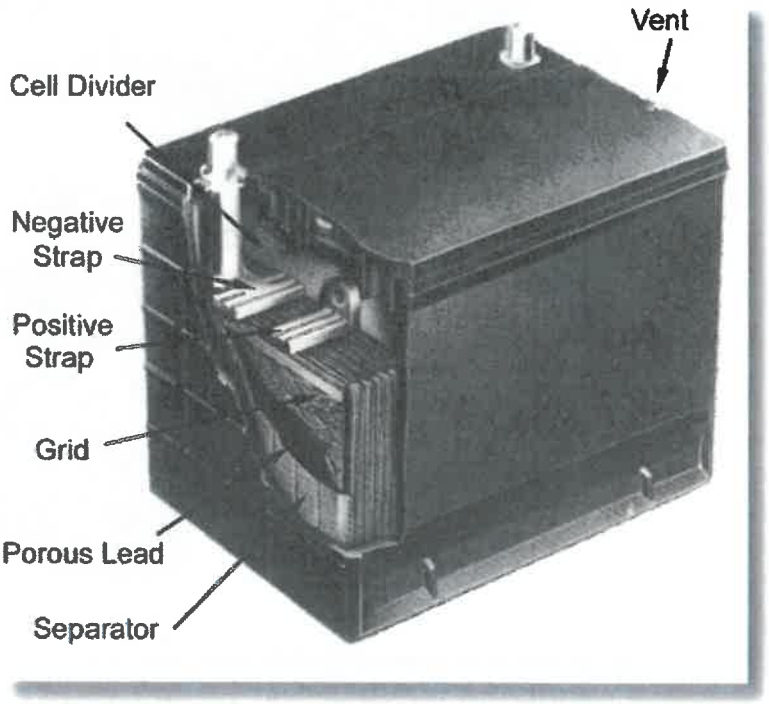


Battery Construction

A battery is made up of six individual **cells**, electrically connected in series to produce 12 Volts. Each battery cell contains an element made up of positive and negative plates, separators, and connecting straps.

Each plate consists of a stiff mesh grid of a lead alloy, coated with porous lead on the negative plates, and lead peroxide or lead dioxide on the positive plates. A strap of lead connects the negative plates to form a group, and another strap connects the positive plate group. On each end of the battery, the straps are extended to form battery terminals or posts. All of the plates are then submerged in an electrolyte solution.

Cutaway of an Automotive Battery



Battery cells are housed in a durable, vented, plastic case, and have terminals on the top ("top post") or side (side terminal). Many aftermarket batteries are equipped with both types of terminal arrangements.

Battery group sizing is established by the Battery Council International (BCI). The group size only refers to the physical size of the battery, its length, width, and height. The size has nothing to do with the available amperage of capacity of the battery; bigger does not always mean more amperage.

Negative battery cables are usually grounded to the engine block. On some applications, a small pigtail wire also connects the negative terminal to the vehicle body. The pigtail connects the body ground to the engine ground, and it must be connected for the starting and charging system to work properly.

BCI GROUP SIZES AND OVERALL DIMENSIONS

All dimensions match BCI Original Equipment Sizes and may not include handles.

BCI GRP. NO.	BCI FIG. NO.	VOLTS	MAXIMUM OVERALL DIMENSIONS in INCHES and (MM) L	W	H
1	2	6	9 (230)	7 (181)	9 (239)
2	2	6	10 (264)	7 (181)	9 (238)
2E	5	6	19 (482)	4 (105)	9 (232)
2N	1	6	10 (254)	5 (141)	8 (227)
3	2	6	11 (285)	7 (191)	9 (238)
3D	2	6	20 (518)	8 (222)	10 (254)
3EE	9	12	19 (491)	4 (111)	8 (225)
3EH	5	6	19 (491)	4 (111)	9 (249)
3ET	9	12	19 (491)	4 (111)	9 (249)
4	2	6	13 (334)	7 (181)	9 (238)
4B	8	12	21 (543)	11 (283)	10 (276)
4D	8	12	20 (527)	8 (222)	9 (249)
4DLT	16L	12	20 (508)	8 (208)	7 (202)
4EH	5	6	19 (491)	5 (127)	9 (249)
5D	2	6	13 (349)	7 (181)	9 (238)
6D	8	12	20 (527)	10 (254)	10 (260)
7D	2	6	16 (413)	7 (181)	9 (238)
8D	8	12	20 (527)	11 (283)	9 (249)
12T	10	12	7 (179)	6 (177)	7 (202)
16TF	10F	12	16 (421)	7 (181)	11 (283)
17HF	28	6	7 (187)	6 (175)	9 (229)
17TF	11L	12	17 (433)	6 (177)	7 (202)
19L	2	6	8 (266)	7 (178)	7 (181)
21	10	12	8 (208)	6 (173)	8 (222)
21R	11	12	8 (208)	6 (173)	8 (222)
22F	11F	12	9 (241)	6 (175)	9 (231)
22HF	11F	12	9 (241)	6 (175)	9 (229)
22NF	11F	12	9 (240)	5 (140)	8 (227)
22R	11	12	9 (229)	6 (175)	8 (211)
24	10	12	10 (260)	6 (173)	8 (225)
24F	11F	12	10 (273)	6 (173)	9 (229)
24H	10	12	10 (260)	6 (175)	9 (238)
24R	11	12	10 (260)	6 (173)	9 (229)
24T	10	12	10 (260)	6 (173)	9 (240)
25	10	12	9 (230)	6 (175)	8 (225)
26	10	12	8 (208)	6 (173)	7 (197)
26R	11	12	8 (208)	6 (173)	7 (197)
27	10	12	12 (306)	6 (173)	8 (225)
27F	11F	12	12 (318)	6 (173)	8 (227)
27H	10	12	11 (298)	6 (173)	9 (236)
27R	11	12	12 (306)	6 (173)	8 (225)
28	16	12	10 (260)	6 (173)	9 (240)
29H	10	12	13 (334)	6 (170)	9 (232)
29NF	11F	12	13 (330)	5 (140)	8 (227)
30H	10	12	13 (343)	6 (173)	9 (236)
31	16	12	13 (330)	6 (173)	9 (240)
33	11F	12	13 (338)	6 (173)	9 (236)
34	10	12	10 (260)	6 (173)	7 (200)
34R	11	12	10 (260)	6 (173)	7 (200)
35	11	12	9 (230)	6 (175)	8 (225)
36R	19	12	10 (263)	7 (183)	8 (206)
39	15	12	8 (206)	6 (175)	7 (178)
40R	15	12	10 (278)	6 (175)	6 (175)
41	15	12	11 (283)	6 (175)	6 (175)
42	15	12	9 (241)	6 (175)	6 (175)
43	15	12	13 (334)	6 (175)	8 (205)
45	10F	12	9 (240)	5 (140)	8 (227)

BCI GRP. NO.	BCI FIG. NO.	VOLTS	MAXIMUM OVERALL DIMENSIONS in INCHES and (MM) L	W	H
46	10F	12	10 (273)	6 (173)	9 (229)
47	28	12	9 (242)	6 (175)	7 (190)
48	24	12	10 (278)	6 (175)	7 (190)
49	24	12	13 (353)	6 (175)	7 (190)
50	10	12	13 (343)	5 (127)	10 (254)
51	10	12	9 (230)	5 (129)	8 (223)
51R	11	12	9 (230)	5 (129)	8 (223)
52	10	12	7 (186)	5 (147)	8 (210)
53	14	12	13 (330)	4 (119)	8 (210)
54	19	12	7 (186)	6 (154)	8 (212)
55	19	12	8 (219)	6 (154)	8 (212)
56	19	12	10 (254)	6 (154)	8 (212)
57	22	12	8 (205)	7 (183)	6 (177)
58	26	12	10 (255)	7 (183)	6 (177)
58R	19	12	10 (255)	7 (183)	6 (177)
59	21	12	10 (255)	7 (195)	7 (196)
60	12	12	13 (332)	6 (160)	8 (225)
61	20	12	7 (182)	6 (162)	8 (225)
62	20	12	8 (225)	6 (162)	8 (225)
63	20	12	10 (258)	6 (162)	8 (225)
64	20	12	11 (296)	6 (162)	8 (225)
65	21	12	12 (306)	7 (192)	7 (192)
66	13	12	12 (306)	7 (192)	7 (194)
67R	38	12	9 (231)	6 (175)	6 (175)
70	17	12	8 (206)	7 (180)	7 (196)*
71	17	12	8 (206)	7 (179)	8 (216)
72	17	12	8 (206)	7 (179)	8 (210)
73	17	12	9 (230)	7 (179)	8 (216)
74	17	12	10 (260)	7 (184)	8 (222)
75	17	12	9 (230)	7 (180)	7 (196)*
76	17	12	13 (334)	7 (180)	8 (216)*
78	17	12	10 (260)	7 (180)	7 (196)*
79	35	12	12 (307)	7 (180)	7 (188)
85	11	12	9 (230)	6 (173)	8 (203)
86	10	12	9 (230)	6 (173)	8 (203)
90	24	12	9 (242)	6 (175)	6 (175)
91	24	12	11 (278)	6 (175)	6 (175)
92	24	12	12 (315)	6 (175)	6 (175)
93	24	12	13 (353)	6 (175)	6 (175)
94R	24	12	12 (315)	6 (175)	7 (190)
95R	24	12	15 (392)	6 (175)	7 (190)
96R	15	12	9 (242)	6 (173)	6 (175)
97R	15	12	9 (252)	6 (175)	7 (190)
98R	15	12	11 (283)	6 (175)	7 (190)
99	34	12	8 (207)	6 (175)	6 (175)
99R	24	12	8 (210)	6 (175)	6 (175)
100	35	12	10 (260)	7 (179)	7 (188)
101	17	12	10 (260)	7 (179)	6 (170)
121R	11H	12	8 (222)	7 (178)	8 (216)
124R	11H	12	10 (276)	7 (178)	6 (194)
151R	28	12	7 (188)	6 (125)	8 (225)
GC2	2	6	10 (264)	7 (183)	10 (270)*
U1	10	12	7 (197)	5 (132)	7 (186)
U1R	11	12	7 (197)	5 (132)	7 (186)
U2	10	12	8 (160)	5 (132)	7 (181)

* Height may vary with different terminal types
* Maximum height dimension shown includes batteries with raised quarter cover design. Flat-top design model height minus quarter cover is reduced by approximately .3 inch (10 mm)

Acid fumes and water vapor are formed and released during the chemical reactions of charging. This **gassing** causes the loss of electrolyte. Conventional batteries have removable vent caps that permit the electrolyte levels to be checked and topped off as well as to allow chemical testing. "Maintenance free" batteries are designed to minimize gassing and therefore not as accessible.

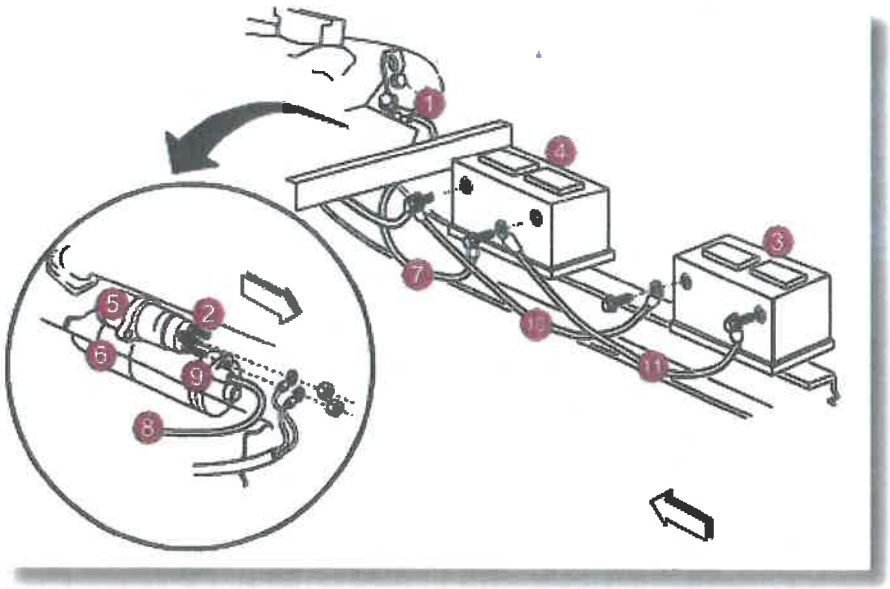
When filling a cell in the battery, only distilled water is used. Tap or drinking water will damage the cells in the battery. Gasses that are released are explosive, so no sparks or open flames may be near a battery. Explosions are very rare, but can happen; when they do, severe personal injury and property damage are highly likely.

Between the positive and negative plates are separators, which are constructed to keep the plates from touching each other and shorting. The separators are porous, to allow electrolyte to circulate freely and permit the chemical process to take place.

Each battery cell is a separate unit that produces 2.1 volts. A "12 volt" automotive battery contains six cells connected in series for a total of 12.6 volts.

Dual Batteries in Parallel

1. Chassis Ground
2. Start Solenoid Interconnect (OEM)
3. Secondary Battery (Diesel)
4. Battery
5. Start Solenoid
6. Starter Motor
7. Negative Battery Cable
8. Positive Battery Cable
9. Secondary Positive Battery Cable (Diesel)
10. Secondary Negative Battery Cable (Diesel)



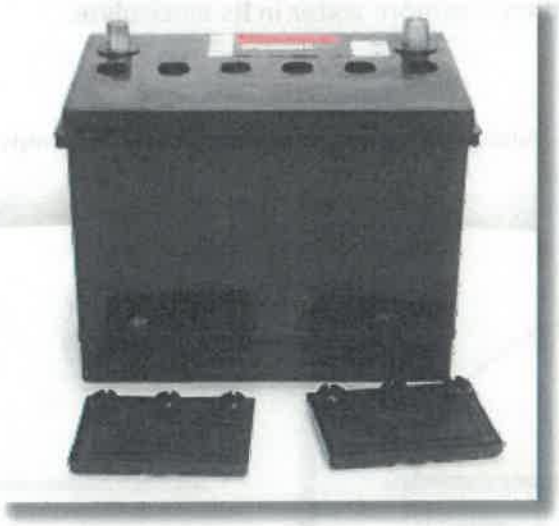
Many diesel applications use two 12-volt batteries connected in parallel (positive to positive and negative to negative) to provide the high current required to crank a diesel engine. Batteries connected in this fashion still supply 12 volts but have twice the current capacity of a single battery. Two 12-volt batteries, connected in series (positive to negative) will produce a 24 volts system. Heavy duty trucks and some large equipment operate on a 24-volt system.

Other Types of Batteries

Many batteries are marketed as "Maintenance-Free," meaning water should not need to be added during the life of the battery. The plates in these batteries tend to be slightly shorter to allow them to be submerged deeper in electrolyte.

Some Maintenance-Free batteries do not have removable covers or caps. Others do, to allow for the addition of water in case of overcharging or severe conditions, and to permit hydrometer testing. These batteries should not require additional water, but if the electrolyte **can** be checked, it **should** be checked approximately every six months.

Top Post Battery With Vent Caps Removed



Gel Cell and Absorbent Glass Mat (AGM) Batteries

Recent innovations in battery technology include Gel Cell, and Absorbent Glass Mat (AGM) designs. These designs do not use liquid electrolyte like conventional automotive batteries. Gel Cell batteries were developed for use in mining equipment and have good resistance to shock and vibration.

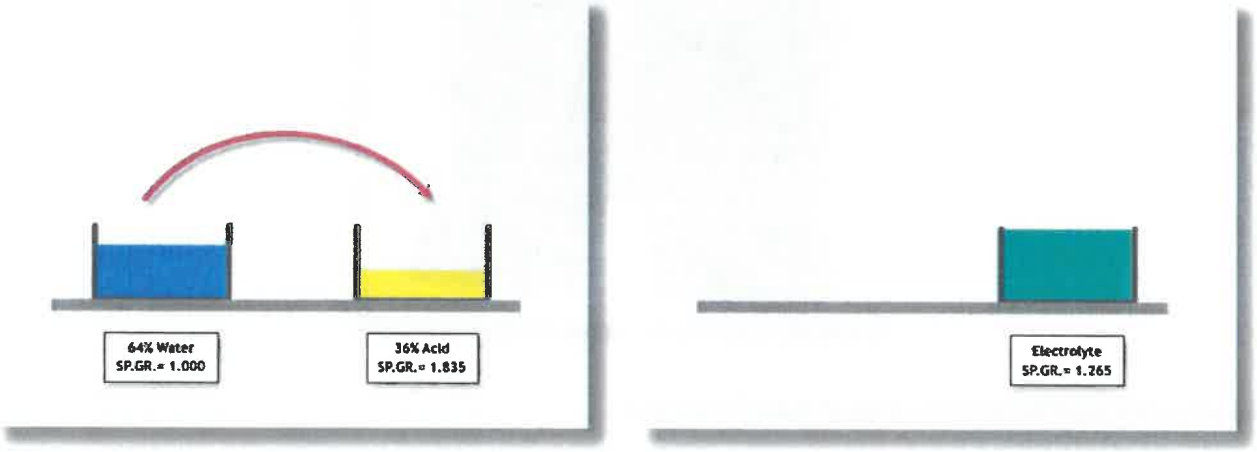
In AGM batteries, the elements are compressed. The plates are thinner, allowing for more plates per cell. They are heat-resistant, and may last three times longer than Wet Cell batteries. The Gel Cell and AGM designs have not yet seen widespread usage, due to their higher cost.

ELECTROLYTE

Electrolyte and Specific Gravity

Specific gravity is a measure of the density or weight of a fluid, when compared to water. Water has a specific gravity of 1.000, and pure sulfuric acid has a specific gravity of 1.835, meaning it is 1.835 times heavier than water. The electrolyte in batteries contains 64% water and 36% acid, which gives it a specific gravity of 1.265 to 1.270, when fully charged (this is often expressed as "twelve seventy," etc.). If the electrolyte is accessible, its specific gravity can be checked with a **hydrometer**. As a battery discharges, its electrolyte contains less acid and more water, which means that a hydrometer's float will not rise as high in the hydrometer barrel. Some maintenance free batteries even have a hydrometer built into one of its cells. We will cover those, and other forms of hydrometer testing, later in the section. For now, keep in mind that acid is heavier than water, and a discharged battery has more water in its electrolyte.

Adding Water and Sulfuric Acid to make Electrolyte



Chemical Reactions while Discharging and Charging

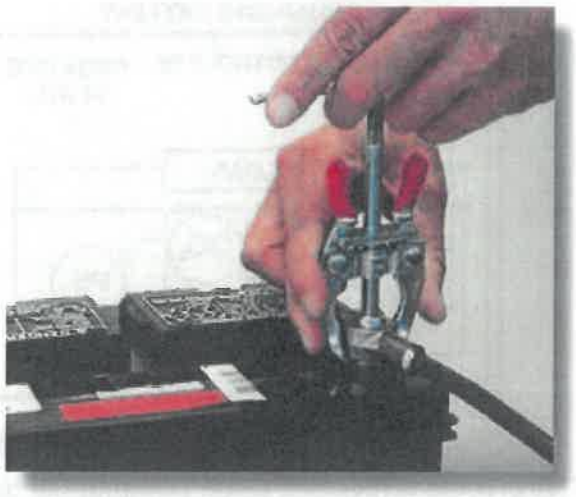
In a fully-charged battery, the active materials in the positive and negative plates are distinctly different in chemical composition, and the electrolyte has a high acid content. Positive plates contain a compound of lead and oxygen (PbO_2), while negative plates contain lead (Pb). The electrolyte is composed of water (H_2O) and sulfuric acid (H_2SO_4). Sulfuric acid is a compound of hydrogen, sulfur and oxygen.

As a battery begins to discharge, the composition of the plates becomes more similar, and the water content of the electrolyte increases. Lead sulfate ($PbSO_4$) is formed on both the positive and negative plates, trapping the oxygen and sulfur, and leaving water molecules behind (left side of illustration). The voltage potential of a battery is dependent on the dissimilarity of the active materials in the positive and negative plates. As the lead sulfate content in the plates increases, the voltage and available current decreases.

The following guidelines will help to reduce the chance of arcing or sparks:

- The ground terminal of a battery should always be disconnected **first** and reconnected **last.**
- Connect battery chargers to a battery **before** plugging in the charger.
- When jump-starting a vehicle, always follow the proper procedure. **Do not** connect the jumper cable to the negative battery terminal of the vehicle you are jump-starting! The correct procedure to follow when jump-starting will be presented later in this section.
- **Do not** attempt to charge, jump-start, or load test a battery with a broken or loose post, a cracked case, or one in which the electrolyte is frozen.

Proper Removal of a Ground Cable



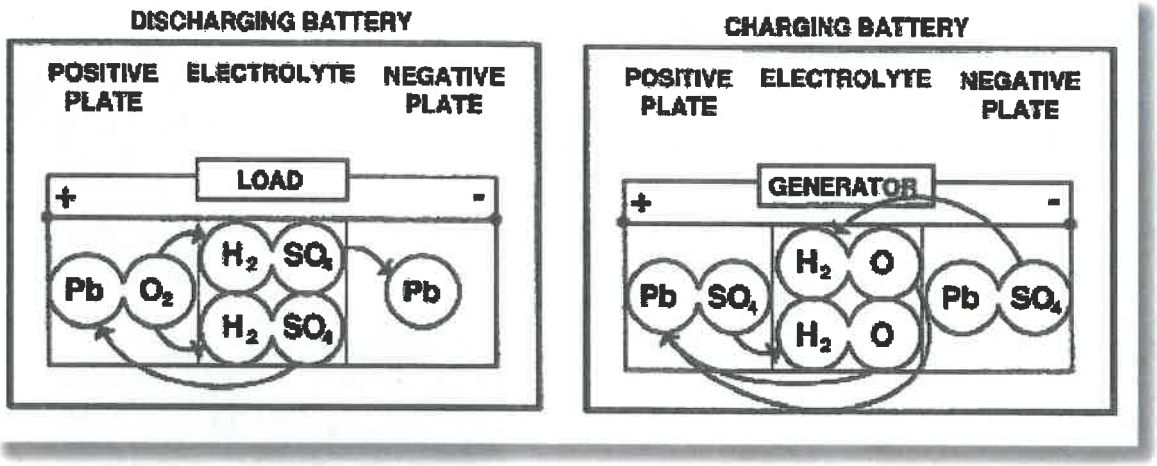
Accidentally shorting the positive battery terminal, or any system voltage source, to ground with a tool or metal object can cause severe burns. Metal jewelry can be heated to its melting point in seconds. In addition, even a brief short of this nature can damage the PCM and other electronic components.

Using a Clamp Spreading Tool

Never hammer on a battery terminal or cable end, or attempt to remove a cable by prying. To avoid damage to the battery or terminals, and possible personal injury, use a clamp spreading tool if the clamp doesn't seat at the bottom of the post. Also, a proper cable clamp puller should be used to remove stubborn clamps. Avoid contact with the white, flaky, or powdery corrosion that builds up around battery terminals and trays. This substance is sulfate and/or sulfide; it is corrosive and can cause chemical burns.

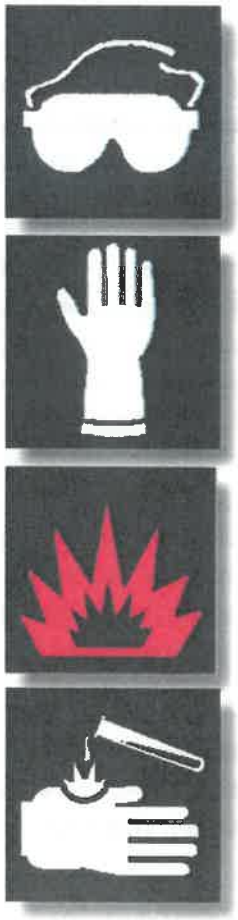
Always follow all general safety guidelines for servicing motor vehicles with regard to adequate venilation, working around hot or moving parts, proper use of the parking brake, gear selector, wheel blocks, and disabling fuel or ignition systems. Refer to the equipment User's Manual and/ or vehicle Service Manual for the applicable procedures.

Charging and Discharging Processes



This process is reversed when charging the battery. Current applied to the battery causes the lead sulfate residing on the plates to release its oxygen into the electrolyte. This release increases the acid content of the electrolyte, and returns the plates to their original compositions (right side of illustration).

Battery Safety



Batteries can explode, and they have enough power to arc weld. Always respect the power of a battery, even a "dead" battery. **The sulfuric acid in electrolyte is extremely corrosive and can cause severe chemical burns to the skin and eyes.** It will also damage painted surfaces and many other materials, including clothing. Always wear approved **safety glasses** when working around batteries. The use of **rubber gloves** is recommended when working with electrolyte.

You should know the locations of all fire extinguishers and the First Aid Kit. First Aid Kits should contain a bottle of sterile, acid-neutralizing eyewash. Larger facilities often have an emergency shower and eyewash station located in the battery storage and service area.

Batteries release explosive hydrogen and oxygen gasses. A battery can explode, rupture its case, and spray acid in all directions. As such, you should always avoid creating sparks around a battery.

Temperature and Ratings

Temperature, Efficiency, and Ratings

Battery Temperature and Efficiency

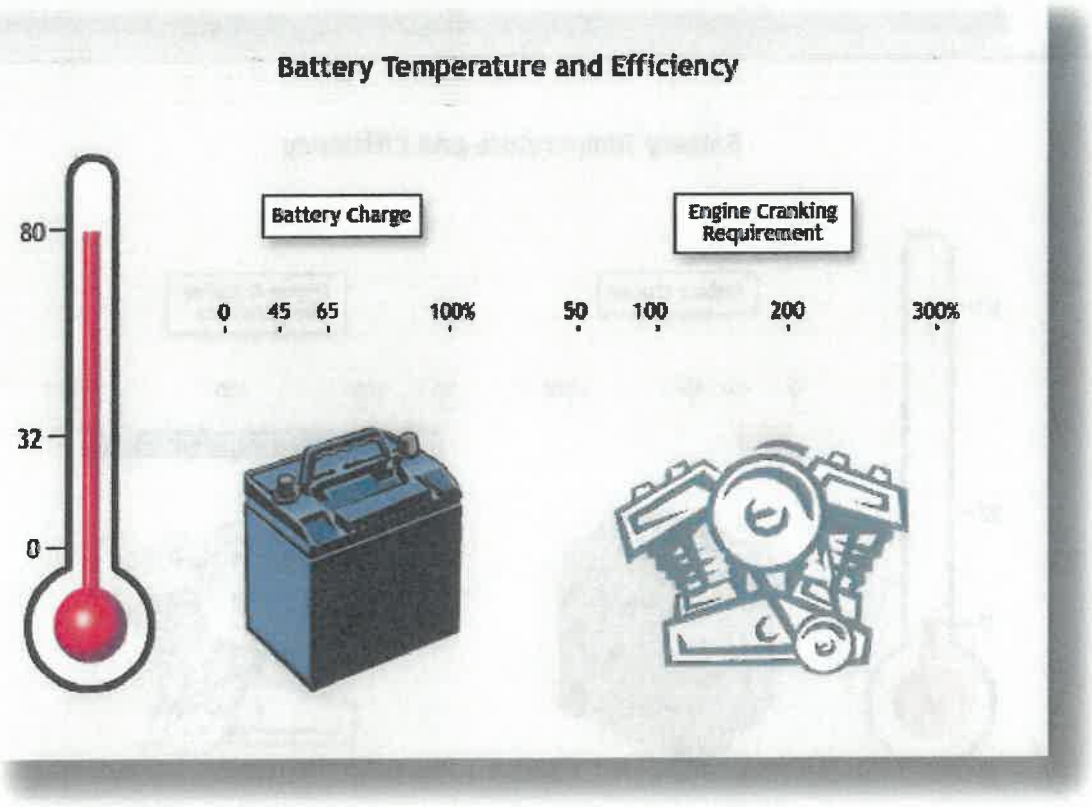
As temperatures fall, chemical reactions in a battery are slowed, and available power is reduced. At the same time, the current required by the starter to crank the engine increases, due to the thickening of the motor oil.

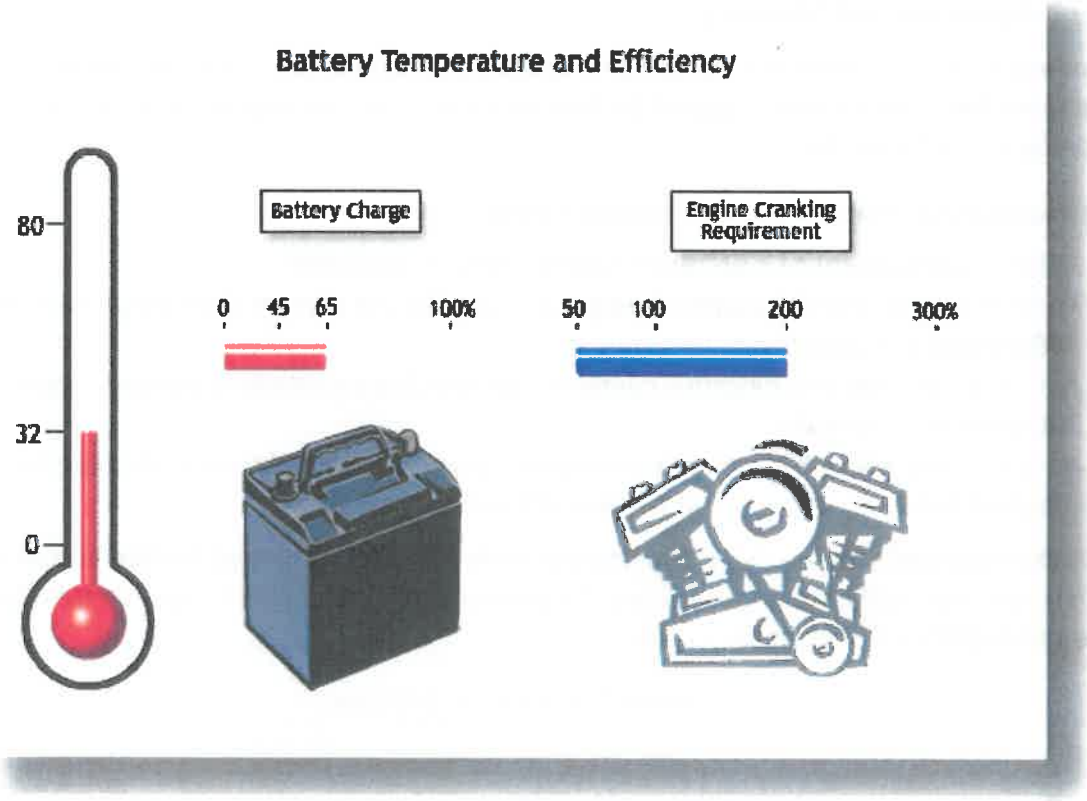
Some examples of Temperature vs. Available Power

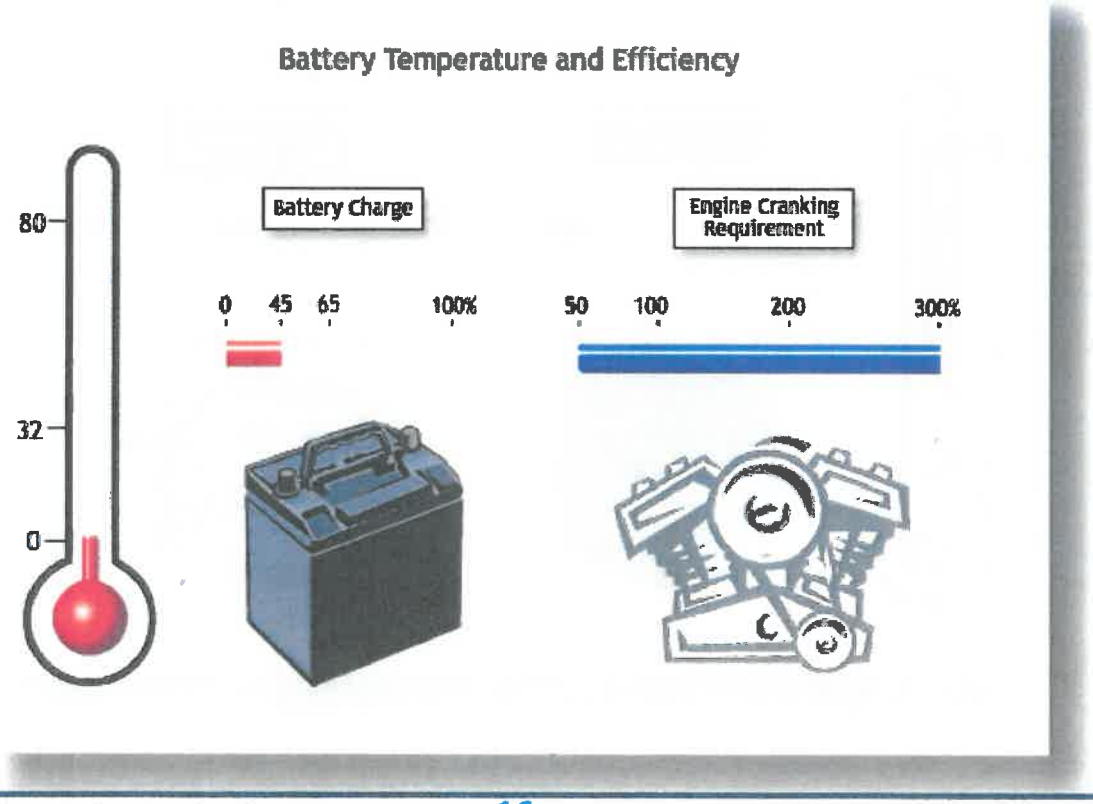
- At 80° F, 100 percent of a battery's starting power is available
- At 32° F, 65 percent of a battery's power is available, but current draw may be increased to 200 percent of normal
- At 0° F, 45 percent of a battery's power is available, but the starting power required may be 300 percent of normal
- At -20° F, only about 20 percent of a battery's power is available, while the starting power required can be more than 300 percent of normal

It is vitally important to have clean, tight connections and a fully charged battery in cold weather. Keep in mind that cold temperatures have the same effect on charging rates -- it takes longer to recharge a battery in cold temperatures.

Battery Temperature vs. Efficiency







Excessive heat also has an adverse effect on batteries, as they will self-discharge faster in a hot environment. In addition, higher-compression engines require more current to start when they are hot.

Heat and vibration are two of the main factors that shorten the life of a battery. This is why many manufacturers have moved the battery from the under-hood area to inside the passenger compartment (under the back seat) or in the trunk area. It's also true that most batteries go bad in the summer months, but continue to crank the engine until the first cold morning of fall. The battery can be tested earlier and the failure can be discovered before the customer notices a problem.

Battery Ratings

Cold Cranking Amps (CCA)

The Cold Cranking Amps rating indicates how much current (in amps) a battery can provide for 30 seconds at 0° F, while maintaining a minimum terminal voltage of at least 7.2 volts. This is the most important rating of a battery and it is used both in application specifications and in battery testing. The Cold Cranking rating is usually provided on a label or stamped into the battery case. Ratings from 350 CCA to 1000 CCA are common. The higher the number, the more powerful the battery, and the longer it will take to recharge.

Cranking Amps (CA)

The Cranking Amps rating is similar to the Cold Cranking Amps rating, except the rated temperature is 32° F, instead of 0° F. Naturally, this will yield a higher number than the CCA. This rating may be useful in comparisons of cold weather operation between batteries.

Reserve Capacity (RC)

The Reserve Capacity rating is the time (in minutes) required for a fully charged battery to reach a terminal voltage of 10.5 volts, at 80° F, when placed under a constant load of 25 amps. This rating is useful in determining how long a vehicle with a fully charged battery can travel at night with zero generator output. Typical ratings range from 90 to 200 minutes. The battery in a vehicle, with a charging system failure, will become too weak to start the engine before the reserve capacity is reached. It may, however, provide enough voltage to keep the spark plugs firing for a few minutes after this time. Reserve Capacity ratings usually appear on a battery's label.

Ampere-Hour Rating (AH)

This rating has been largely replaced by the other ratings, but is still sometimes used to calculate recharging times. The Ampere-Hour rating is a measurement of how much current a battery can produce for 20 hours at 80° F without the voltage dropping below 10.5 volts.

Japanese Industrial Standard (JIS)

Many imported vehicles from Japan or Korea are now using the JIS rating. This rating is a series of numbers and letters. The codes can be used to decipher the group size, CCAs, and weight of the battery. The codes are between 26A17 to 245H52.

Batteries Name_____

1.An automotive battery is an electrochemical device that converts _____ energy into _____ energy and stores it until needed.

2.Automotive batteries are always either charging or _____ .

3.Abattery that is nearly or completely discharged is commonly said to be_____,_____ or _____ _____.

4.A battery is made up of _____ individual cells.

5.When filling a cell in the battery, only _____ water is used.

6.Many batteries are marked as _____ _____ , meaning water should not be added during the life of the battery.

7.The electrolyte in batteries contains ____ % water and ____% acid.

8.The ground terminal of a battery should always be disconnected _____ and reconnected _____ .

9. _____ and _____ are two of the main factors that shorten the life of a battery .

10. CCA stands for.