



# Batteries: An Introduction

An Online Continuing Education Course for Engineers

**Course Number: E-2020**

**Credit: 2 Hours / 2 PDH / 2 CPD**

# Introduction to Batteries

## Introduction

The purpose of this course is to introduce and explain the basic theory and characteristics of batteries. The batteries which are discussed and illustrated have been selected as representative of many models and types which are used in industry today. No attempt has been made to cover every type of battery in use; however, after completing this course you will have a good working knowledge of the batteries which are in general use.

First, you will learn about the building block of all batteries, the CELL. The explanation will explore the physical makeup of the cell and the methods used to combine cells to provide useful voltage, current, and power. The chemistry of the cell and how chemical action is used to convert chemical energy to electrical energy are also discussed.

In addition, the care, maintenance, and operation of batteries, as well as some of the safety precautions that should be followed while working with and around batteries are discussed.

Batteries are widely used as sources of direct-current electrical energy in automobiles, boats, aircraft, ships, portable electric/electronic equipment, and lighting equipment. In some instances, they are used as the only source of power; while in others, they are used as a secondary or standby power source.

A battery consists of a number of cells assembled in a common container and connected together to function as a source of electrical power.

## The Cell

A cell is a device that transforms chemical energy into electrical energy. The simplest cell, known as either a galvanic or voltaic cell is shown in figure 1. It consists of a piece of carbon (C) and a piece of zinc (Zn) suspended in a jar that contains a solution of water (H<sub>2</sub>O) and sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) called the electrolyte.

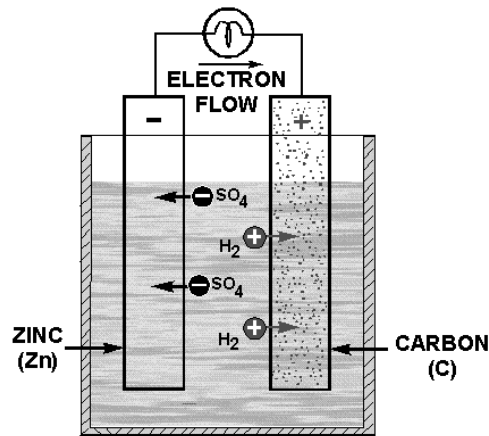


Figure 1.—Simple voltaic or galvanic cell.

The cell is the fundamental unit of the battery. A simple cell consists of two electrodes placed in a container that holds the electrolyte.

In some cells the container acts as one of the electrodes and, in this case, is acted upon by the electrolyte. This will be covered in more detail later.

### Electrodes

The electrodes are the conductors by which the current leaves or returns to the electrolyte. In the simple cell, they are carbon and zinc strips that are placed in the electrolyte; while in the dry cell (fig.2), they are the carbon rod in the center and zinc container in which the cell is assembled.

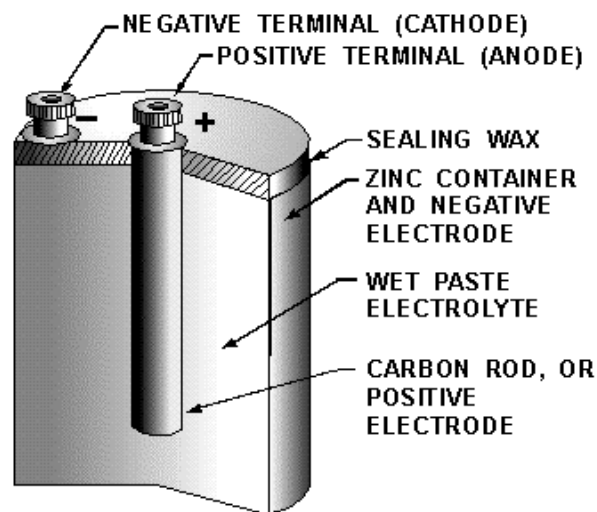


Figure 2.—Dry cell, cross-sectional view.

## **Electrolyte**

The electrolyte is the solution that acts upon the electrodes. The electrolyte, which provides a path for electron flow, may be a salt, an acid, or an alkaline solution. In the simple galvanic cell, the electrolyte is in a liquid form. In the dry cell, the electrolyte is a paste.

## **Container**

The container which may be constructed of one of many different materials provides a means of holding (containing) the electrolyte. The container is also used to mount the electrodes. In the voltaic cell the container must be constructed of a material that will not be acted upon by the electrolyte.

## **Primary Cell**

A primary cell is one in which the chemical action eats away one of the electrodes, usually the negative electrode. When this happens, the electrode must be replaced or the cell must be discarded. In the galvanic-type cell, the zinc electrode and the liquid electrolyte are usually replaced when this happens. In the case of the dry cell, it is usually cheaper to buy a new cell.

## **Secondary Cell**

A secondary cell is one in which the electrodes and the electrolyte are altered by the chemical action that takes place when the cell delivers current. These cells may be restored to their original condition by forcing an electric current through them in the direction opposite to that of discharge. The automobile storage battery is a common example of the secondary cell.

## **Electrochemical Action**

If a load (a device that consumes electrical power) is connected externally to the electrodes of a cell, electrons will flow under the influence of a difference in potential across the electrodes from the CATHODE (negative electrode), through the external conductor to the ANODE (positive electrode).

A cell is a device in which chemical energy is converted to electrical energy. This process is called ELECTROCHEMICAL action.

The voltage across the electrodes depends upon the materials from which the electrodes are made and the composition of the electrolyte. The current that a cell delivers depends upon the resistance of the entire circuit, including that of the cell itself. The internal resistance of the cell depends upon the size of the electrodes, the distance between them in the electrolyte, and the resistance of the electrolyte. The larger the electrodes and the closer together they are in the electrolyte (without touching), the lower the internal resistance of the cell and the more current the cell is capable of supplying to the load.

## Primary Cell Chemistry

When a current flows through a primary cell having carbon and zinc electrodes and a diluted solution of sulfuric acid and water (combined to form the electrolyte), the following chemical reaction takes place.

The current flow through the load is the movement of electrons from the negative electrode of the cell (zinc) and to the positive electrode (carbon). This causes fewer electrons in the zinc and an excess of electrons in the carbon. Figure 1 shows the hydrogen ions ( $H_2$ ) from the sulfuric acid being attracted to the carbon electrode. Since the hydrogen ions are positively charged, they are attracted to the negative charge on the carbon electrode. This negative charge is caused by the excess of electrons. The zinc electrode has a positive charge because it has lost electrons to the carbon electrode. This positive charge attracts the negative ions ( $SO_4$ ) from the sulfuric acid. The negative ions combine with the zinc to form zinc sulfate. This action causes the zinc electrode to be eaten away. Zinc sulfate is a grayish-white substance that is sometimes seen on the battery post of an automobile battery.

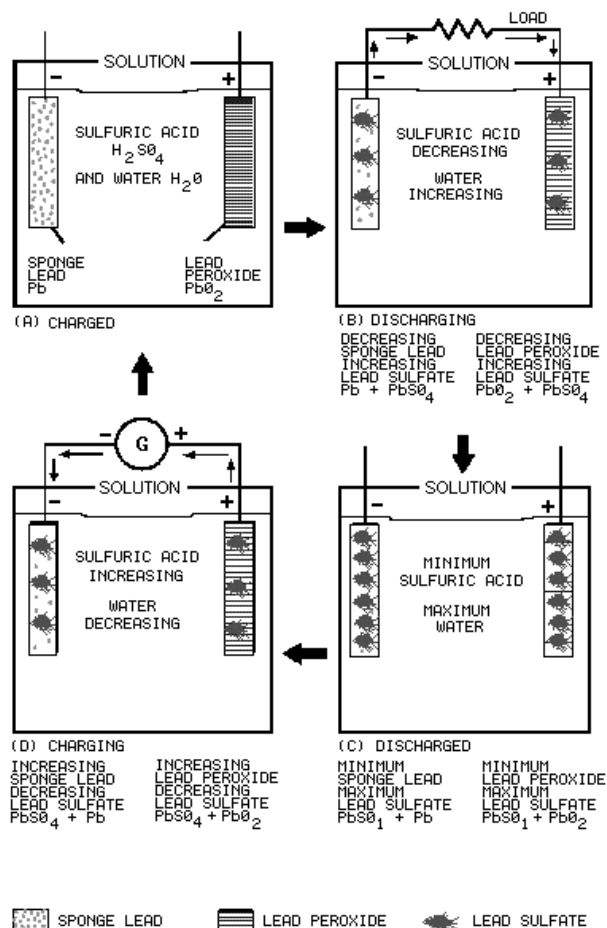
The process of the zinc being eaten away and the sulfuric acid changing to hydrogen and zinc sulfate is the cause of the cell discharging. When the zinc is used up, the voltage of the cell is reduced to zero.

In Figure 1 you will notice that the zinc electrode is labeled negative and the carbon electrode is labeled positive. This represents the current flow outside the cell from negative to positive.

The zinc combines with the sulfuric acid to form zinc sulfate and hydrogen. The zinc sulfate dissolves in the electrolyte (sulfuric acid and water) and the hydrogen appears as gas bubbles around the carbon electrode. As current continues to flow, the zinc gradually dissolves and the solution changes to zinc sulfate and water. The carbon electrode does not enter into the chemical changes taking place, but simply provides a return path for the current.

## Secondary Cell Chemistry

As stated before, the differences between primary and secondary cells are, the secondary cell can be recharged and the electrodes are made of different materials. The secondary cell shown in Figure 3 uses sponge lead as the cathode and lead peroxide as the anode. This is the lead-acid type cell and will be used to explain the general chemistry of the secondary cell. Later in the course when other types of secondary cells are discussed, you will see that the materials which make up the parts of a cell are different, but that the chemical action is essentially the same.



**Figure 3.—Secondary cell.**

Figure 3 view A shows a lead-acid secondary cell that is fully charged. The cathode is pure sponge lead, the anode is pure lead peroxide, and the electrolyte is a mixture of sulfuric acid and water.

Figure 3 view B shows the secondary cell discharging. A load is connected between the cathode and anode; current flows negative to positive as shown. This current flow creates the same process as was explained for the primary cell with the following exceptions.

In the primary cell the zinc cathode was eaten away by the sulfuric acid. In the secondary cell the sponge-like construction of the cathode retains the lead sulfate formed by the chemical action of the sulfuric acid and the lead. In the primary cell the carbon anode was not chemically acted upon by the sulfuric acid. In the secondary cell the lead peroxide anode is chemically changed to lead sulfate by the sulfuric acid.

When the cell is fully discharged it will be as shown in figure 3 view C. The anode and cathode retain some lead peroxide and sponge lead, but the amounts of lead sulfate in each is maximum. The electrolyte has a minimum amount of sulfuric acid. With this condition no further chemical action can take place within the cell.

As you know, the secondary cell can be recharged. Recharging is the process of reversing the chemical action that occurs as the cell discharges. To recharge the cell, a voltage source, such as a generator, is connected as shown in figure 3 view D. The negative terminal of the voltage source is connected to the cathode of the cell and the positive terminal of the voltage source is connected to the anode of the cell. With this arrangement the lead sulfate is chemically changed back to sponge lead in the cathode, lead peroxide in the anode, and sulfuric acid in the electrolyte. After all lead sulfate is chemically changed, the cell is fully charged as shown in figure 3 view A. Once the cell has been charged, the discharge-charge cycle may be repeated.

## Polarization of the Cell

The chemical action that occurs in the cell while the current is flowing causes hydrogen bubbles to form on the surface of the anode. This action is called POLARIZATION. Some hydrogen bubbles rise to the surface of the electrolyte and escape into the air; some remain on the surface of the anode. If enough bubbles remain around the anode, the bubbles form a barrier that increases internal resistance. When the internal resistance of the cell increases, the output current is decreased and the voltage of the cell also decreases.

A cell that is heavily polarized has no useful output. There are several methods to prevent polarization or to depolarize the cell.

One method uses a vent on the cell to permit the hydrogen to escape into the air. A disadvantage of this method is that hydrogen is not available to reform into the electrolyte during recharging. This problem is solved by adding water to the electrolyte, such as in an automobile battery. A second method is to use material that is rich in oxygen, such as manganese dioxide, which supplies free oxygen to combine with the hydrogen.

A third method is to use a material that is rich in calcium. The calcium releases hydrogen during discharge, so that the cell is practically depolarized.

## Local Action

When the external circuit is closed, the chemical action within the cell starts. The zinc, carbon, lead, and arsenic impurities within the zinc electrode in which current flows are also active. The chemical action continues even though the zinc is not in contact with the electrolyte.

Local action may be prevented by coating the zinc with mercury, or by adding a small amount of mercury to the manufacturing process. The treatment of zinc with mercury is many times more effective than the treatment with mercury weighing less than mercury. The removal of these impurities from the zinc plate is called "depolarization."

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