Battery Cells

We are accustomed to bringing compact and portable energy sources along with us to power all our technological devices. These energy sources—batteries—are growing smaller and smaller, with increased power outputs and increased lifetimes.

A battery is a device that converts chemical energy directly into electrical energy. As such, batteries are inherently high-efficiency devices (about 60%), while mechanical conversion devices—such as internal combustion engines—must burn a fuel to expand a gas to do work, resulting in efficiencies of 40% or less.

Within a battery the constituent chemicals are arranged so that the electrons released from one material flow through an external circuit to another part. This chemical reaction consumes the active materials within a battery cell and, when such materials are depleted, the battery can no longer produce electricity. A battery that cannot be recharged is called a *primary* battery; in a *secondary* battery, the active materials can be regenerated, allowing it to be used over and over again.

Crude primary batteries may have been used thousands of years ago. From about 250 B.C., the Parthians possibly used batteries to gold-plate some of their jewelry.

The commonly recognized discovery of the electrical battery, however, took place in Italy in the 1790s with the work of Alessandro Volta, a professor of natural philosophy at the University of Pavia. Volta put the difference in potential of metals in contact with an electrolyte. In 1800 he wrote a paper describing his "Volta pile," consisting of a disk of silver (the cathode), upon which he stacked a disk of paper, cloth, or hide soaked in a salt solution (electrolyte), a disk of zinc (the anode), then a second disk of silver, and so on. The voltage of the battery could be increased by adding more layers; after connecting a wire from the top disk of silver to the bottom disk of zinc, an electrical current would flow.

Another form of the same battery was called a "crown of cups" in which the individual cells were assembled in separate vessels. Other variations of the "voltaic pile" used tin instead of zinc, or copper instead of silver; sometimes vinegar was used as the electrolyte. Volta's battery caused a revolution in science because, for the first time ever, relatively large amounts of electric current became available for use.

In following years, many other scientists experimented with variations on the voltaic pile, many of which were attempts to reduce the drastic corrosion that occurred on the electrodes when the battery was not in use. As early as a year after Volta's first description of his battery, it was discovered that coating the electrodes with mercury helped reduce the corrosion and thus increase the shelf life of batteries.

In 1836 in England, the chemist John Daniell made a great improvement to the voltaic pile by reducing the severe polarization that occurred in the electrodes. He treated his zinc cathodes with zinc sulfate, and his copper anodes with copper sulfate, then placed a porous earthenware diaphragm between the electrodes. The Daniell cell achieved a voltage of a little more than one volt, and originally was used extensively in the telegraph industry.

In 1839, William Robert Grove introduced his two-fluid cell, which immersed an amalgamated zinc anode in dilute sulfuric acid, and a platinum cathode in strong nitric acid, with the two solutions separated by a porous pot. Shortly thereafter, the chemist Robert Wilhelm Bunsen produced a similar battery that used inexpensive carbon, rather than platinum, as the cathode, thus encouraging wider acceptance of the two-fluid cell.

Two decades later, Gaston Planté discovered the lead-acid battery, which may be charged and discharged many times, though it took another twenty years before an electric generator was developed to charge lead-acid batteries. In the interim, other batteries (primary batteries) were used to charge the lead-acid batteries (which came to be known as secondary batteries). Lead-acid cells are still used as the standard type of automobile battery.

The next major breakthrough was the creation of the "dry cell" in which the aqueous electrolyte is a paste or some other form that cannot be spilled. In the 1860s, Georges Leclanché developed a cell containing ammonium chloride electrolyte so-

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lution with a zinc anode and a manganese dioxide cathode. Once an electrical load is placed on the battery, current flows from the zinc to the cathode until most of the zinc has been used up, at which point the battery must be discarded. Originally, Leclanché's electrolyte was spillable, but a later modification immobilized it, providing the true precursor to the dry cell. Leclanché actually wrote about his development in 1868, but by that time several thousand of his batteries had been in use in railroad signal systems and telegraph lines.

The Leclanché type of dry cell is familiar as the common flashlight battery, of which more than two billion are manufactured annually. Over 90% of the dry cells produced in the United States are based on Leclanché's design. Other major types of dry cells are mercury cells and alkaline-zinc-manganese cells.

Another battery development that has become more widely used in recent years is the nickel-cadmium cell. Developed by Jungner and Berg between 1893 and 1909, the NiCd battery was similar to a cell being developed at the same time by Thomas Edison. Edison used iron in his cell for the anode, while Jungner and Berg chose cadmium; both used potassium hydroxide as the electrolyte. The NiCd battery can be recharged many times and retains a near-constant voltage during its discharge. Since NiCd cells operate well at low temperatures and can be hermetically sealed, they can withstand more abuse than any other type of battery—which makes them ideal for portable applications. NiCd batteries have gained wide use in portable, rechargeable items, from laptop computers to electric razors. There are, unfortunately, disadvantages such as "memory effects," where a NiCd battery will recharge only the amount it has been previously drained.

Battery designs continue to be improved as market pressures demand smaller, lighter, more powerful, and longer-lasting energy sources. Environmental concerns over mercury contamination are encouraging the redesign of batteries using amalgamated electrodes. Innovative battery concepts are taking advantage of exotic new materials such as aerogels. The world's need for portable power will only continue to increase, and battery designs will be forced to accommodate it. □

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