Battery Applications and Technology

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1.0 Definitions

Active material - Constituents of a cell that participate in the electrochemical charge/discharge reaction.

Battery - Two or more cells electrically connected to form a unit. Under common usage, the term "battery" also applies to a single cell.

Capacity - Number of ampere-hours (Ah) a fully charged cell or battery can deliver under specified conditions of discharge.

Cell - Basic electrochemical unit used to store electrical energy.

Current - Flow of electrons equal to one coulomb of charge per second, usually expressed in amperes (A).

Cutoff voltage - Cell or battery voltage at which the discharge is terminated. The cutoff voltage is specified by the manufacturer and is a function of discharge rate and temperature.

Cycle - The discharge and subsequent charge of a secondary battery such that it is restored to its fully charged state.

Duty cycle - Operating parameters of a cell or battery including factors such as charge and discharge rates, depth of discharge, cycle length, and length of time in the standby mode.

Electrode - Electrical conductor and the associated active materials at which an electrochemical reaction occurs. Also referred to as the positive and negative plates in a secondary cell.

Electrolysis - Chemical dissociation of water into hydrogen and oxygen gas caused by passage of an electrical current.

Electrolyte - Medium which provides the ion transport function between the positive and negative electrodes of a cell.

Equalizing charge - Charge applied to a battery which is greater than the normal float charge and is used to completely restore the active materials in the cell, bringing the cell float voltage and the specific gravity of the individual cells back to equal values.

Float charge - Method of charging in which a secondary cell is continuously connected to a constant-voltage supply that maintains the cell in a fully charged condition.

Gassing - Evolution of gas from one or more electrodes resulting from electrolysis of water during charge or from self-discharge. Significant gassing occurs when the battery is nearing the fully charged state while recharging or when the battery is on equalizing charge.

Potential difference - Work which must be done against electrical forces to move a unit charge from one point to the other, also known as electromotive force (EMF).

Primary cell or battery - Cell or battery which is not intended to be recharged and is discarded when the cell or battery has delivered its useful capacity.

Secondary battery - A battery that after discharge may be restored to its charged state by passage of an electrical current through the cell in the opposite direction to that of discharge. (Also called storage or rechargeable.)

Separator - Electrically insulating layer of material which physically separates electrodes of opposite polarity. Separators must be permeable to ions in the electrolyte and may also have the function of storing or immobilizing the electrolyte.

Specific gravity - Ratio of the weight of a solution to an equal volume of water at a specified temperature. Used as an indicator of the state of charge of a cell or battery.

Sulfation - Formation of lead sulfate crystals on the plates of a lead-acid battery.

Terminal - External electric connections of a cell or battery, also referred to as "terminal post" or "post."

Thermal runaway - A condition that occurs in a battery (especially valve-regulated types) when charging energy results in heat generation within the battery greater than the heat dissipated, causing an uncontrolled rise in battery temperature. This can cause failure through cell dry-out, shortened life, and/or melting of the battery.

Trickle charge - Method of charging in which a secondary cell is either continuously or intermittently connected to a constant current supply in order to maintain the cell in fully or nearly fully charged condition.

Voltage - Electromotive force or potential difference, expressed in volts (V).

2.0 Overview of Batteries

2.1 Battery Cell Construction Antimony / Calcium / Selenium / Tin Alloying

The grid structure in both pasted and tubular plate batteries is made from a lead alloy. A pure lead grid structure is not strong enough by itself to stand vertically while supporting the active material. Other metals in small quantities are alloyed with lead for added strength and improved electrical properties. The most commonly alloyed metals are antimony, calcium, tin, and selenium.

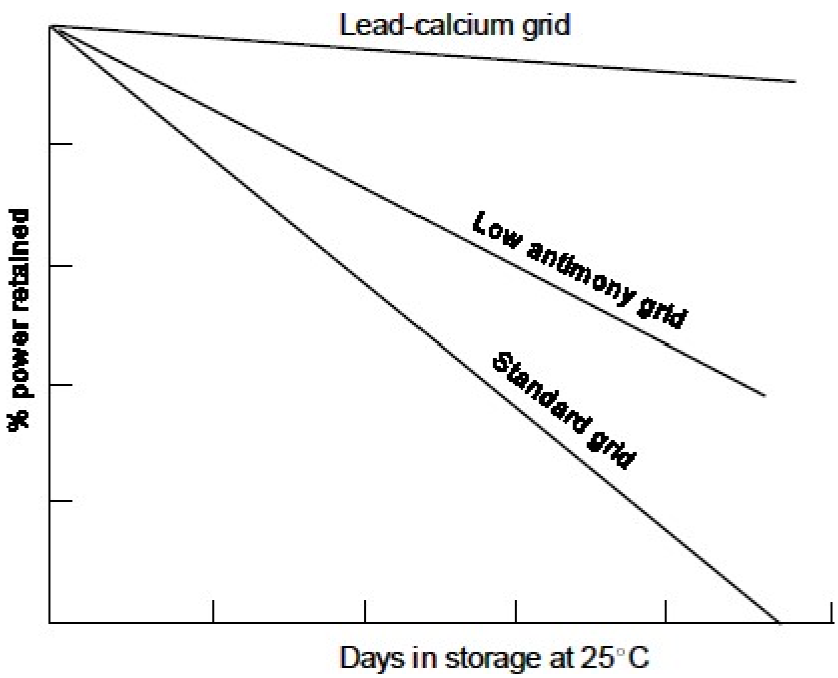
The two most common alloys used today to harden the grid are antimony and calcium. Batteries with these types of grids are sometimes called "lead-antimony" and "lead-calcium" batteries. Tin is added to lead-calcium grids to improve cyclability. The major differences between batteries with lead-antimony and lead-calcium grids are as follows:

1. Lead-antimony batteries can be deep cycled more times than lead-calcium batteries.

2. Flooded lead-antimony batteries require more frequent maintenance as they near end-of-life since they use an increasing amount of water and require periodic equalization charges.

3. Lead-calcium batteries have lower self-discharge rates as shown in the illustration below and therefore, will draw less current while on float charge than lead-antimony batteries.

4. Lead-calcium positive plates may grow in length and width because of grid oxidation at the grain boundaries. This oxidation is usually caused by long-term overcharging, which is common to UPS and other batteries on constant-float changing. Grids may grow in size sufficiently to cause buckling or rupture of their containers.



Another type of grid alloy is lead-selenium. In reality, this battery is actually a low lead-antimony grid with a slight amount of selenium. Lead-selenium has characteristics that fall somewhere between lead-calcium and lead-antimony.

When pure lead is mixed with an alloy there may be undesirable characteristics introduced in the performance of the battery. Modern day battery manufacturers try to reduce the amount of antimony and calcium by introducing doping agents such as selenium, cadmium, tin, and arsenic. When batteries containing arsenic and antimony are charged (especially overcharged) the poisonous gases arsine (AsH_3) and stibine (SbH_3) may be released.

2.2 Capacity and Battery Ratings

In general terms, the *capacity* of a cell/battery is the amount of charge available expressed in *ampere-hours* (Ah). An ampere is the unit of measurement used for electrical current and is defined as a coulomb of charge passing through an electrical conductor in one second. The capacity of a cell or battery is related to the quantity of active materials in it, and the amount of electrolyte and the surface area of the plates. The capacity of a battery/cell is measured by discharging at a constant current until it reaches its terminal voltage (usually about 1.75 volts). This is usually done at a constant temperature, under standard conditions of 25C (77F). The capacity is calculated by multiplying the discharge current value by the time required to reach terminal voltage.

The most common term used to describe a battery's ability to deliver current is its *rated capacity*. Manufacturers frequently specify the rated capacity of their batteries in ampere-hours at a specific discharge rate. For example, this means that a lead-acid battery rated for 200 Ah (for a 10-hour rate) will deliver 20 amperes of current for 10 hours under standard temperature conditions (25C or 77F).
Alternatively, a discharge rate may be specified by its charge rate or C-rate, which is expressed as a multiple of the rated capacity of the cell or battery. For example, a battery may have a rating of 200 Ah at a C/10 discharge rate. The discharge rate is determined by the equation below:

$$C/10 \text{ rate (amperes)} = 200 \text{ Ah}/10 \text{ h} = 20 \text{ amperes.}$$

Battery capacity varies with the discharge rate. The higher the discharge rate, the lower the cell capacity. Lower discharge rates result in higher capacity. Manufacturer's literature on batteries will normally specify several discharge rates (in amperes) along with the associated discharge time (in hours). The capacity of the battery for each of these various discharge rates can be calculated as discussed above.

The rated capacity for lead-acid batteries is usually specified at the 8-, 10-, or 20-hour rates (C/8, C/10, C/20). UPS batteries are rated at 8-hour capacities and telecommunications batteries are rated at 10-hour capacities.

2.3 Sizing and Selection of Batteries

A simple duty cycle diagram is shown below: