CONSTUCTON AND FEATURES OF ACID AND ALKALINE CELLS
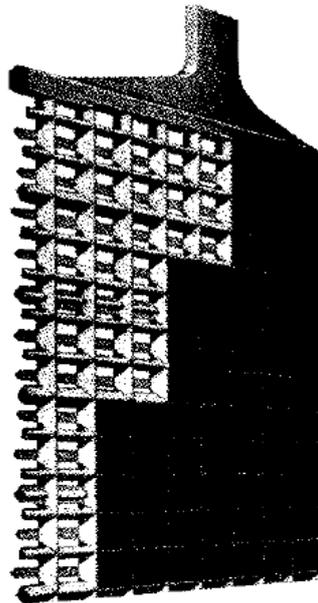
Section 12.1 will give detailed information relating to all types of industrial battery cells. Section 12.2 will point out the effects of these differences.

SECTION 12.1

12.1.1 Pasted plate lead acid batteries (Faure)

Both the positive and the negative grids of the Faure (pasted plate) lead acid battery are cast with an open lattice pattern.

Grid for pasted plate lead cells

Because of the low mechanical strength of pure lead, alloying materials are added to increase the strength of the plate. Many alloys have been used including nickel, silver, cadmium, mercury and others, singularly or in combination. Antimony in concentrations of 6% to 12%, and calcium in concentrations of less than one percent, have been most frequently used in the past several years. They lend their names to describe these two categories of stationary pasted plate lead acid batteries: The "lead antimony" battery and the "lead calcium" battery. The names can be somewhat misleading as it is frequently and incorrectly assumed that the alloying agent is one of the electrochemical couples of the cell.

In the past 20 to 25 years, considerable research and development have been accomplished in order to find more suitable alloying agents. The primary problems experienced with the antimony and the calcium alloys were the high float currents experienced with antimony alloy grids and the grid growth experienced with calcium alloy grids.
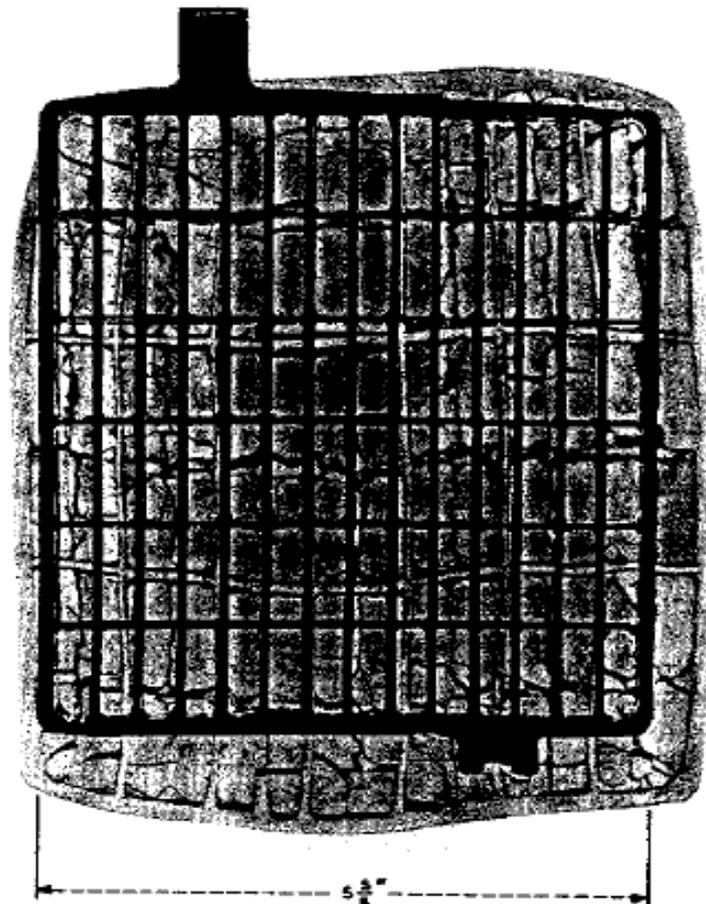
Corroded positive lead calcium plate with original
grid overlaid to indicate initial dimensions.

Grid growth is even more of a problem when the battery is exposed to temperatures above 77° F or when the battery is discharged more than 15% or more often than three times per year.

One of the most promising of the new grid alloys is itself an alloy of selenium and less than 2% antimony. This grid commonly described as "low antimony" or "lead selenium" has low float currents desired in float application batteries while providing the capability to be deep discharged, cycled or operated at elevated temperatures.

In pasted plate construction, a thick slurry of lead oxides and sulfuric acid is forced into the open lattice work. This was originally a hand pasting operation from whence the term "pasted plate" was derived. Plates are then dried prior to assembly and "formed" by an electrochemical process to activate the positive and negative electrodes. A microporous rubber or plastic separator is placed between each positive and negative plate.

After mechanical assembly, when the posts are brought through the cover with suitable glands, seals and nuts, the cells are ready for filling with electrolyte and initial charge. The cells can be shipped wet and charged, ready for service, or dry charged with liquid electrolyte separate.

12.1.2 Planté type lead acid battery

The original lead acid electrochemical couple was developed by Gaston Planté in the late 1800's. All lead acid batteries with a pure lead active material in the positive electrode carry the name "Planté" or "Planté type". During the formation process, the pure lead at the plate surface is changed to lead oxide, constituting the active material of the positive plate. The Planté plate is made in two different constructions depending upon the manufacturer. One construction starts with essentially an alloy grid cast with circular holes. A strip of corrugated pure lead rolled into a spiral is forced into the holes of the plate. The other type of Planté positive plate starts with a blank of pure lead which has usually been combed to expand its surface area.
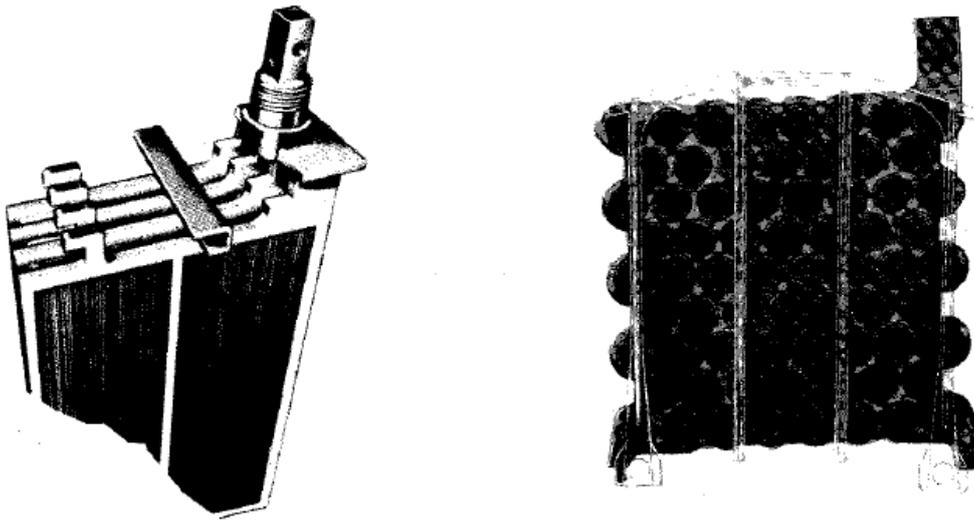
Planté type plate

The negative plate of the Planté battery is the familiar pasted plate with an alloy grid.

With either design of positive Planté plate, a microporous separator insulates it from its pasted plate negative neighbor. As with the Faure battery, the Planté battery is designed with outside negative plates. Plate strap burning, post assembly, suspension of the element in the jar and other features closely approximate the construction of the Faure, or pasted plate battery.

12.1.3 Tubular positive plate design lead acid battery.

The positive grid of the tubular plate lead acid battery is formed of similar alloys to that used in its pasted plate counterpart. The grid is cast as a number of thin, parallel rods bridged at one end. Originally, a rigid plastic, perforated cylinder surrounded the entire length of each thinly cast rod. A later development was the woven cylindrical tube of glass or plastic fiber, which took the place of the rigid, perforated cylinder. Powdered lead oxide active material is filled into the space between the central rod of the grid and the sleeve. Plastic caps seal the tube ends. The negative plate of the tubular construction battery is the familiar pasted plate.
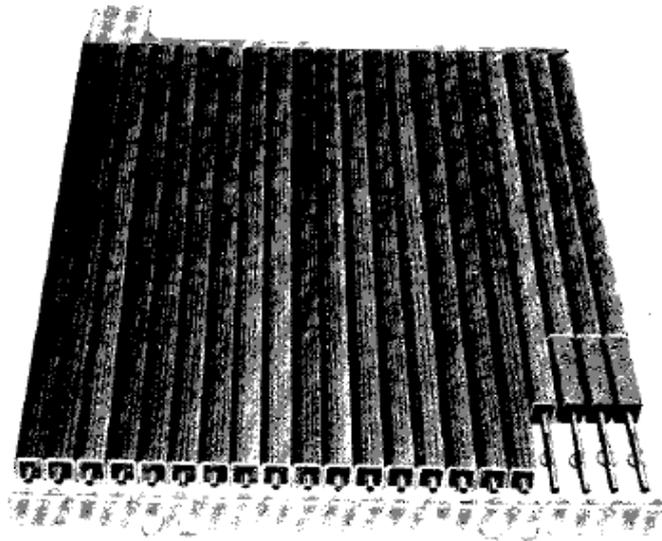
Tubular plate construction

Plate tabs molded on the grid are burned to the plate group strap in a manner similar to that previously described. The post hardware and glands are assembled with the cover. The cover is then sealed to the container. The entire plate group rests on supporting ribs molded in the bottom of the container. Some designs use support for the element near the top of the cell by having the group strap rest on a ledge molded in the upper jar wall.

12.1.4 Maintenance free lead acid batteries

The lead acid battery is manufactured in basically two different types, "wet flooded" and "maintenance free". The maintenance free type is also manufactured in two different versions, "gelled electrolyte" and "absorbed glass mat" (AGM).

The technology of both versions of the maintenance free lead acid battery is identical in that they are both recombinant type batteries which have "positive limited" plate groups operating in the "oxygen cycle".

In any type of lead acid battery, the positive plate is lead oxide and the negative is sponge lead. The resultant voltage difference will cause pressure to make electrons flow from one plate to the other if they are connected. This electron flow causes a chemical reaction inside the battery. When discharged, much of the acid is changed to water and both plates have been reduced to lead sulfate. The chemical reaction caused by discharging can be reversed by making electrons flow in the opposite direction with a battery charger.

During recharge, oxygen is released at the positive plate and upon full charge of the negative plate, hydrogen is released at the negative plate. These gases are obtained by decomposition of the water that is mixed with the acid to form the electrolyte. Both gases are vented outside the battery and must be properly dispersed because of the explosive nature of hydrogen. In the standard lead acid battery, the water loss has to be replaced on a regular maintenance schedule to prevent the plates from drying out.

In the maintenance free "recombinant" battery, the negative plate is designed to be what the industry calls "positive limited", because the chemical reaction of discharging is stopped when the positive plate is exhausted. On recharge, the negative plate never reaches the point in the chemical reaction where it is charged enough to cause hydrogen gas emission.

The oxygen generated at the positive plate makes its way to the negative plate via the void paths in the separator. This oxygen creates a positive pressure inside the battery jar that is a few p.s.i. above ambient. For this reason, a relief valve is provided in case a malfunction should occur, such as a runaway charger. This valve is constructed so that it will reseal once the pressure returns to normal.

At the negative plate the oxygen combines with the lead in the negative plate to form lead dioxide. The lead dioxide reacts with the acid in the electrolyte to form lead sulfate and water. This water replaces the water that was consumed at the positive plate to make oxygen. Thus, no additional water need be added and the case can be sealed with the pressure relief valve.

The differences in construction between the gelled electrolyte battery and the absorbed glass mat (AGM) battery result in a unique advantage to each type for different applications. In the gelled electrolyte version, the dilute sulfuric acid is blended with a silica to form a gel or paste-like substance. This gelled electrolyte is then used in a pasted plate electrode construction, complete with microporous separator, similar to that in standard wet flooded pasted plate batteries. The primary difference is that the electrode group is positive limited.

In its AGM counterpart, the positive limited electrode group is constructed without the microporous separator. All that separates the positive plate from its adjoining negative plate is the fiberglass mat which is approximately 85% saturated with liquid electrolyte. The very fine microfiber construction of this mat and its relative thin construction (usually approximately 1/8 inch) results in very low internal impedance for the cell.

The AGM battery, therefore, usually has the advantage of being smaller, lighter and more energy efficient for short discharge periods. However, it also has the disadvantage of being prone to plate shorting in conditions which cause more plate shedding, i.e. high temperatures, deep discharge cycles or numerous discharge cycles. This plate shorting is the result of a bridging of the thin glass mat by the small lead filaments that shed from the positive and negative plates of all lead acid batteries.

12.1.5 Pocket plate nickel cadmium batteries

Pocket plate nickel cadmium batteries obtain their descriptive name from a "pocket" strip in which the active material is held. These pockets are formed from very thin, finely perforated steel strips, which are formed into a shallow "U" channel.
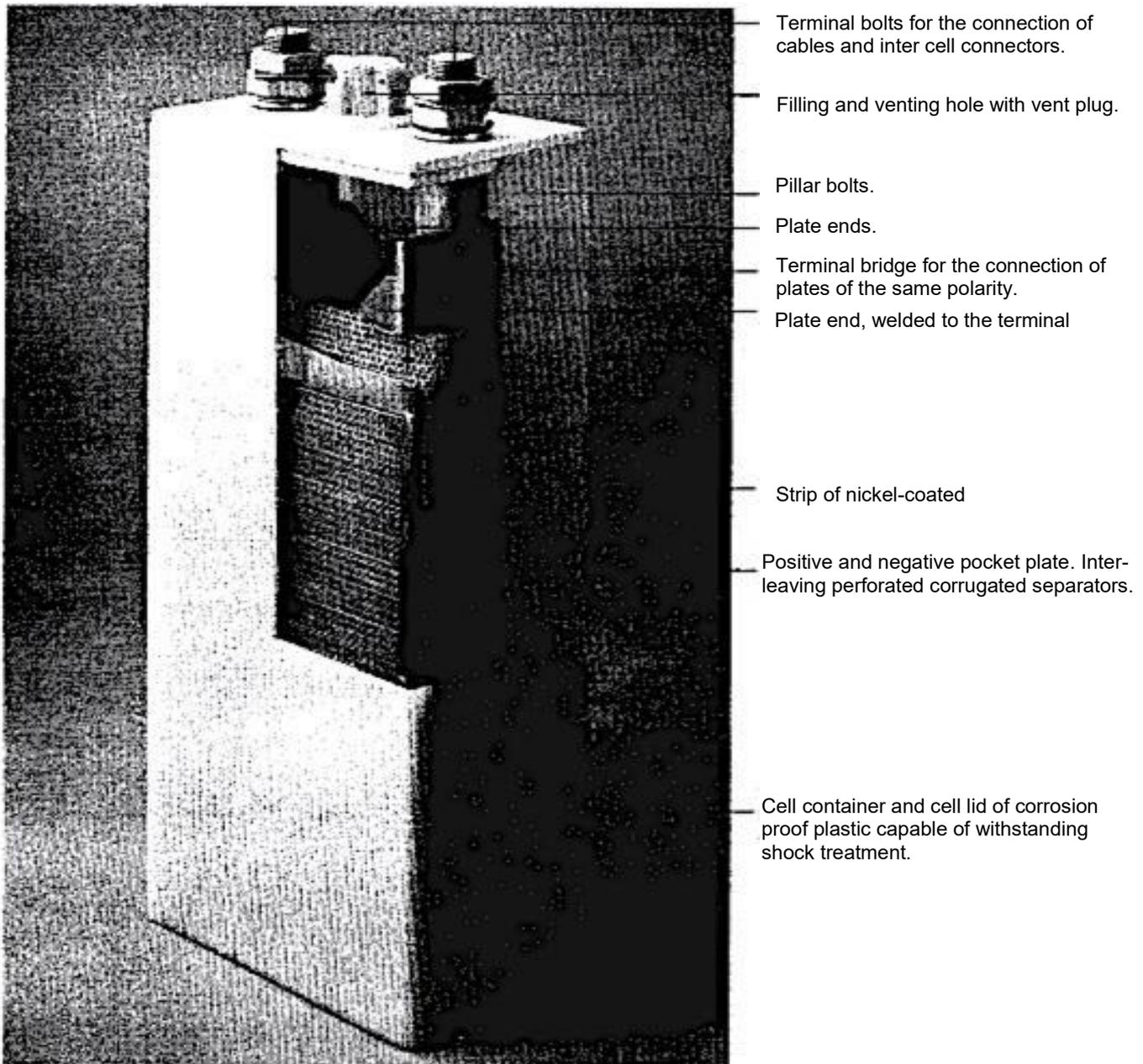

A section from a roll of nickel plated, perforated steel strip from which the "pockets" are fabricated.
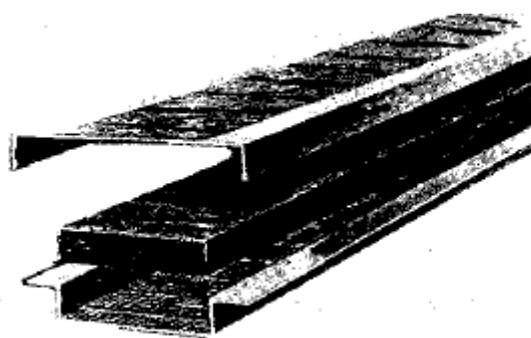
View illustrating the finished pocket with the active material contained inside.

Positive active material consisting of hydrates of nickel oxide and graphite, and negative active material consisting of cadmium oxide and a small amount of iron oxide, are filled into the positive and negative channels respectively. The open "U" channel, filled with active materials, is covered with a similar strip and is crimped to the original strip forming an endless perforated pocket. A number of pockets are interlocked edge to edge and are cut in length to approximately the plate width.

These interlocked pockets are then rolled to compress the active material and form longitudinal indentations in the plate. Each plate group is bolted or welded together. These two plate groups are interleaved and then are insulated with plastic rod or mat separators inserted into the longitudinal grooves of the plates. The insulated plate group, or element, is then inserted into the plastic container. Plastic cells are normally grouped side by side as a battery without spacing between the cells.

Terminal bolts for the connection of cables and inter cell connectors.

Filling and venting hole with vent plug.

Pillar bolts.

Plate ends.

Terminal bridge for the connection of plates of the same polarity.

Plate end, welded to the terminal

Strip of nickel-coated

Positive and negative pocket plate. Inter-leaving perforated corrugated separators.

Cell container and cell lid of corrosion proof plastic capable of withstanding shock treatment.

After mechanical assembly, the cells are put through an electrochemical formation process to convert the active materials to their charged condition. Normally, cells and batteries are shipped filled and charged, ready for service. However, they can be shipped dry and discharged if desired. Three designs are generally commercially available: extremely thin, closely spaced plates for extremely high rate discharge applications (usually less than 30 minutes); moderately thick plates, with average spacing for applications requiring the approximate internal resistance of general purpose type lead acid batteries (30 minutes to 4 hours); and fairly heavy, few plates for alarm and signal applications where the current drain is quite low, but for longer periods of time (over 4 hours).

12.1.6 Sinter plate nickel cadmium batteries

The electrodes consist of a special nickel powder sintered to form a highly porous plate approximately one millimeter thick. The sinter is strengthened by a perforated, nickel-plated steel sheet. A nickel solution is impregnated into the pores of the positive plate, and a cadmium solution into those of the negative plate. The solution in the pores is transformed into the metal hydroxides by means of a suitable process, thus forming the active masses.

The very low internal resistance of cells with such sinter plates is due, on one hand, to the fact that the active masses are not surrounded by perforated steel sheet, so that the current paths in the electrolyte are, therefore, not constricted by the perforation openings. Apart from this, the active mass has a large surface area contact to the good-conducting carrier frame. The current flowing through the cell has only to cross very thin layers of this mass. The positive and negative plates are assembled close together to form electrode groups.
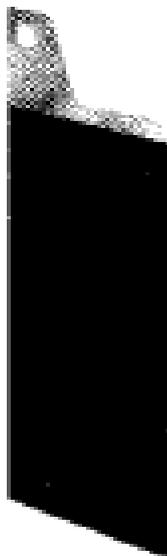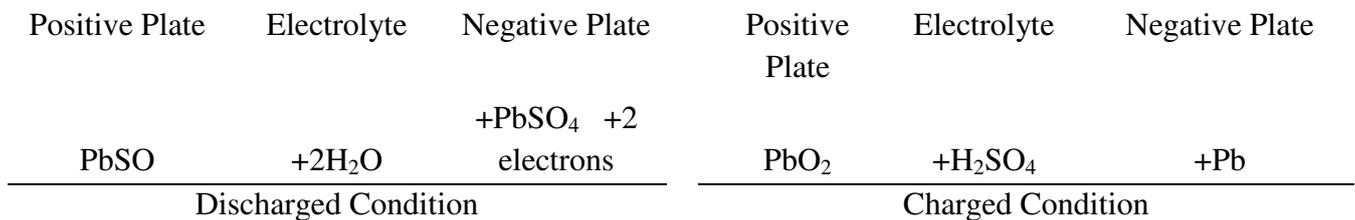

Nickel cadmium sintered plate

The sinter plate nickel cadmium battery is usually not recommended for float service applications.

SECTION 12.2

12.2.1   Performance as a function of plate design

The electrical energy which the storage battery is capable of delivering is derived from the interaction between two electrically dissimilar metals or metallic compounds. The reaction is essentially reversible and electrical energy is consumed in restoring the battery to its charged condition.

In the case of lead acid batteries, the electrolyte also takes part in the electrochemical action. A simplified version of the reaction is that on discharge the lead oxide (PbO_2) positive plate and the metallic lead (Pb) negative plate becomes lead sulfate ($PbSO_4$), with electrical energy being released as a product of this reaction. At the same time, hydrogen (H_2) contained in the sulfuric acid and the oxygen (O_2) held in the positive active material bond, producing water (H_2O) which lowers the specific gravity of the electrolyte. The formula for this chemical reaction is:

Positive Plate	Electrolyte	Negative Plate	Positive Plate	Electrolyte	Negative Plate
PbSO	$+2H_2O$	$+PbSO_4$ +2 electrons	PbO_2	$+H_2SO_4$	+Pb
Discharged Condition			Charged Condition		

When the discharged battery is charged, the chemical reaction proceeds in the reverse direction.

In alkaline systems the electrolyte takes no part in the electrochemical reaction. The higher oxides of nickel of the positive plate go to a lower valence, and the metallic cadmium becomes cadmium oxide in the negative plate during discharge. The electrolyte functions only as a current carrying medium.

CdO + 2NiO	Cd + Ni_2O_3
Discharged Condition	Charged Condition

It is obvious that the capacity of any storage cell is dependent upon the amount of positive and negative active material in the electrolyte. In the case of the lead acid battery, not only the quantity and concentration of the electrolyte, but also the diffusion of the electrolyte through the separating and insulating materials and around the plates during discharge, is of significant consequence. Conductivity of the active materials and their supporting framework also plays a part in the discharge characteristics.

A cell with a matched AH capacity in active material in both positive and negative plates, and in the case of the lead acid system with the matched amount and concentration of electrolyte, would theoretically deliver the AH capacity designed into that cell. However, in actual application there are several things which prevent the attainment of the theoretical maximum capacity. The equipment which the battery operates may have a minimum permissible voltage below which it will not operate. This limits the voltage to which the cell may be discharged. Although the battery may be able to deliver further current, it is not able to produce current at a voltage usable by the connected equipment.

During discharge, the voltage of a cell will fall. The more severe the rate of discharge, the greater the rate of fall of a cell voltage. Consequently, all storage batteries are less efficient at higher rates of discharge.

In the case of the lead acid battery, the impoverishment of the electrolyte at the interface of the electrolyte and the active material, limits the attainment of full capacity. In the case of nickel cadmium batteries, it is standard practice to add fillers to the active material in order to increase conductivity for better utilization of the active material. In the pocket plate nickel cadmium battery, graphite is added to the active material for this purpose.

More efficient utilization of active material can be obtained by modifying plate design. If the plates were to be made with each active material particle on the surface of the plate only one particle thick and made with the separation between the plates at an absolute minimum, a most efficient battery would result. Not only is this difficult technically and economically, but also an extremely short cycle life would result.

High-rate performance differences resulting from differences in plate design are exemplified by the automotive-type SLI (storage, lighting and ignition) lead acid storage battery. Although the grid manufacture and pasted active material are very similar to those used in the Faure pasted plate stationary batteries, the plates are much thinner and are generally shorter. In addition, the number of plates is considerably greater for a given AH capacity cell. In the short plate, electrical energy developed at the bottom of the plate travels to the top of the plate and out the post with a minimum of voltage drop because of a shorter current path.

The SLI battery has a much larger plate surface area than the industrial-type stationary lead acid battery of the same nominal capacity. Therefore, when discharged at a given current density, amperes per AH of cell, the SLI battery will deliver much higher momentary currents than a lead acid industrial stationary battery of comparable AH capacity. The SLI battery is not recommended for float service applications because of its short life and high maintenance in continuous charging applications.

To guard against plate warpage and other undesired characteristics, there seems to be a minimum plate thickness used for lead acid industrial-type stationary cells.

It is common practice for manufacturers of industrial batteries to design two or more series of cell types which vary in plate thickness and separation, number of plates and size of current carrying parts. The extremely low internal resistance type, because of its greater number of plates, larger posts and greater labor content, is more costly per AH than its medium or relatively high internal resistance counterpart. There is a cost and performance differential between cells of the same nominal AH capacity because of these differences.

It is, therefore, encouraged by all major battery manufacturers that batteries be specified by their actual load profile and not by their AH capacity.

Table 12-1 lists data on a total of nine different industrial-grade stationary cells. The cells all have very near the same AH capacity at the 8-hour rate. However, it is easy to see from the data in the table that specifying a battery by AH capacity will result in various suppliers quoting equipment which, for the given application, may be either too large or too small, by a factor of 2 to 4 times. If the load profile is severe (large changes in current draw during the discharge period or reduced battery temperature, etc.) the difference can be even more evident.

Table 12 – 1

Battery	Eight-Hour AH Rating	Discharge in Amperes at 77° F to 1.75 v/c (Lead Acid), 1.14 v/c (Nickel Cadmium)					
		8 hr	3 hr	1 hr	1 min	10 sec	1 sec
1. Lead Planté	120	15.0	31.2	63.6	220	230	230
2. Lead Antimony	125	15.6	31.3	63.0	184	190	190
3. Lead Calcium	125	15.6	31.3	63.0	184	190	190
4. Lead Tubular	130	16.2	33.3	61.6	141	150	150
5. AGM (M.F.)	120	15.3	36.0	90.0	347	350	350
6. Gel Cell (M.F.)	120	15.1	35.3	84.0	321	321	321
7. Nickel Cadmium (L)	129	15.6	36.3	66.9			
8. Nickel Cadmium (M)	110	13.8	33.8	76.4	185	254	276
9. Nickel Cadmium (H)	120	15.0	38.4	98.0	401	550	599

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