

# **LEAD-ANTIMONY, LEAD-CALCIUM, LEAD-SELENIUM, VRLA, NI-CD. WHAT'S IN A NAME?**

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## **ABSTRACT**

Users are continuously bombarded by manufacturers and their representatives extolling the virtues of their products. This includes not only the products, but also the technologies employed. Without extensive research it can often be difficult for a user purchasing a new or replacement battery to separate the marketing hype from the facts.

Among many U.S. manufacturers the current buzz word is lead-selenium. Most U.S. manufacturers want us to refer to these batteries as low-antimony designs. The reason is that antimony is the primary alloy metal and selenium is a grain refiner. In truth, the same arguments can be applied to nearly all U.S. products where tin is the primary alloy metal and calcium is used as a hardener. The same is true of one U.S. manufacturer who markets their VRLA designs as "pure lead" when in reality it is a lead-tin alloy.

The attempt to paint lead-selenium with the same brush as lead-antimony makes sense in marketing space. The majority of all batteries sold are for standby service. Since lead-antimony designs are not suitable for standby service, this is done in an effort to promote lead-calcium for its superior standby characteristics. Just as lead-selenium is not the perfect battery for every application, we shall see lead-calcium has its own issues that are generally "overlooked" during marketing.

In simple terms, if the perfect battery existed, then we would not have the number of battery companies, types and technologies that exist. It is the job of the user to find the best battery for the application with the minimum life cycle cost. What this paper will attempt to do is to separate fact from fiction and present a reasonably unbiased look at the available technologies and how they fit into typical applications.

## **INTRODUCTION**

At Battcon 2008, two papers were presented that discussed the relative advantages of Lead-Calcium technologies over Lead-Antimony and Lead-Selenium<sup>1,2</sup>. Another paper was presented extolling the virtues of a new Absorbed Glass Mat/Gelled Electrolyte hybrid valve-regulated-lead-acid (VRLA) design as the solution to all our battery needs<sup>3</sup>. The purpose of this paper is not to challenge what was presented, but rather to look at the relative advantages and disadvantages of the various battery types available today and how to select a battery based on the application. The primary focus of this paper is on stationary batteries used in standby and cycling applications.

## **BATTERY HISTORY**

The most common battery used today has been in commercial use for over 130 years. First demonstrated by Gaston Planté in 1860, the venerable lead-acid battery is still the mainstay of energy storage. Over the years there have been many evolutions in the technology, but the basic chemistry has not changed.

Lead-acid battery physical plate designs have changed from solid lead to include Manchex, pasted and tubular plate designs. Separator technology has gone from wood to natural rubber, synthetic rubber and fiberglass and other synthetic fibers. Plate chemistry has changed from pure lead, to include lead-antimony, lead-calcium, lead-selenium (and its relatives) and lead-tin. The old open tank and glass battery jars have been replaced by vented cells in various plastic containers and valve-regulated designs.

The most recent lead-acid battery technology introduced was VRLA. Despite initial claims to the contrary, early valve-regulated designs suffered from short lifetimes and low reliability. As a result, designs have evolved rapidly. We have seen changes in plate alloys, internal arrangement, post seals, the addition of catalysts, the removal of catalysts, etc. all in an attempt to improve the longevity and reliability of the cells.

At the end of the 1800's, the nickel-cadmium battery became a viable product. While U.S. users are most familiar with the small AAA and AA batteries, flooded Ni-Cd designs have been in commercial use in Europe for over 100 years. Even though Ni-Cd has many advantages over lead-acid, U.S. users have only recently started embracing this technology.

More recently, new battery technologies such as the flow battery and high temperature sodium-sulfur have been developed and deployed for large energy storage applications.

The new comers to the stationary battery market are large format nickel-metal-hydride and lithium-based chemistries for stationary applications. Battery companies around the world are in research and development on large format lithium batteries for stationary applications.

The first commercial lithium based stationary battery was the Avestor lithium-metal-polymer battery. The battery is currently unavailable, but may return in the future. Other companies have subsequently entered the market with lithium-ion type batteries. The main draw back to lithium batteries is the need for very exact charge control. The other draw back is that all components of the battery are highly flammable and manufacturing tolerances are critical to prevent catastrophic failure.

The need for water cooling systems for nickel-metal-hydride batteries operating in a continuous charge mode seems to be slowing development in this area and further development is not expected near term. This technology seems more at home in cycling or transportation applications such as hybrid vehicles where the battery does not operate in a continuous charge mode.

Changes in battery technology have been spurred by the desire to improve over one or more characteristics of the original lead-acid battery. As each change in lead-acid battery technology has achieved performance improvements, it has also introduced undesirable characteristics. The development of alternate technologies seeks to address the inherent limitations in lead-acid technology but as the technologies are deployed, we find that each has its pros and cons and so the search for the perfect battery continues.

The advanced battery technologies discussed above have been covered in multiple papers at Battcon and the expertise in these areas is still primarily the province of the manufacturers. The focus of this paper on the three most common technologies, the venerable vented lead-acid battery, the VRLA battery and the Ni-Cd battery.

## **LEAD-ACID BATTERY TECHNOLOGY REVIEW**

### **Plate Configurations**

There are five basic plate configurations used to produce lead-acid batteries

1. Pasted – The active material is contained in a supporting grid that provides the current path (Faure-1881)
2. Tubular – The active material is contained in an insulated electrolyte permeable tube through which extends a lead alloy rod that provides the current path. Tubular plates were originally referred to as “ironclad” plates.
3. Planté – A solid lead plate where the active material is formed on the surface of the plate (Gaston Planté 1860). Modern plates are normally scored with a grid to increase surface area.
4. Manchester – An alloy plate, either lead-antimony or lead-calcium, with round openings into which are inserted rolled up corrugated pure lead strips. The active material is formed on the corrugated lead strips. Batteries using this plate design are typically referred to as Manchex batteries<sup>5</sup>.
5. Round cells – Pure lead conically shaped grids are stacked horizontally in a cylindrical jar.

Pasted and tubular plate designs dominate the market. Round, Planté and Manchester plates are limited to use in pure lead batteries which have a very small market share.

Today, the most common negative plate is the pasted plate. Even if a battery is marketed as a tubular plate, Manchex or Planté battery, it nearly always has a pasted negative. The reason is simple economics. Pasted plates are inexpensive and easy to manufacture.

The solid lead Planté and the round cell have the longest life and are the most resistant to damage by elevated temperatures.

The Manchester plate is a hybrid design. While typically marketed as a pure lead design the grid is normally either a lead-antimony or lead-calcium alloy. The grid alloy results in a Manchex battery having operational characteristics somewhere between a Planté and a pasted plate design using the same grid alloy. The advantage of Manchester plates is the larger surface area for active material formation which gives them larger capacity and higher current capabilities than a similar size Planté battery.

Pasted plates are the most commonly used plates. The aging characteristics and resistance to damage by elevated temperatures are directly proportional to the thickness of the plate grid and to the type of alloy used in the grid. In pasted plates the lead oxide is mixed with expanders and binding agents to improve utilization of the active material. The paste is then forced into the plate by a rolling mill.

Tubular plates are composed of a series of small vertical pockets of non-conductive electrolyte permeable materials. A thin lead-alloy rod runs down the center of each pocket and the pockets are filled with the active material before they are sealed. The life and resistance to elevated temperature damage of tubular plate designs depends on the thickness of the rod, the alloy type and the ability of the pocket material to resist damage from internal pressure. Tubular plates are typically filled with dry lead oxide powder without expanders.

### **Plate Alloys**

There are five basic plate alloys used today.

1. Pure Lead used in standby long duration batteries with low current demands
2. Lead-Antimony used for cycling applications and often for heavy equipment starting batteries
3. Lead-Calcium (dominates the U.S. market) for flooded standby and VRLA designs
4. Lead-Selenium (dominates the European market) for flooded standby and cycling applications
5. Lead-Tin for VRLA

### Pure Lead

The pure lead battery has the advantage of being very long lived and reasonably resistant to damage by elevated temperatures and over charging. However, it has very low power density and is not able to produce large currents.

There is only one pure lead VRLA on the market, and it is limited to very small sizes.

Note: There are companies that market “pure lead” VRLA batteries in large sizes. The “pure lead” designation in this case refers to the purity of the lead used to produce the battery<sup>4</sup>. In reality, the batteries use a lead-tin plate alloy and pasted plates.

### Lead-Antimony (Antimony content greater than 2%)

In an effort to improve the power density and current capability, early developers experimented with different plate designs and types of alloys. The first successful alloy was lead-antimony. The addition of antimony makes lead stronger and so allowed for taller plates. It also accelerated the development of pasted and tubular plate designs.

Today, antimony alloys dominate the market for cycling applications and due to ease of production are common in developing nations. The dominance of antimony alloys in the cycling market is based on the fact that the alloy is extremely resistant to distortion or damage from repeated discharge and recharge cycles. In our daily lives we encounter these most frequently as “deep cycle batteries” for boats, golf carts, fork lifts etc.

Lead-Antimony alloys are not well suited for stand-by service. The phenomenon of antimony-poisoning where antimony from the grid alloy forms small discharge points on the negative plate surface is a direct result of continuous charging. This results in a continuously increasing float current and water consumption over the life of the battery. The rate of antimony-poisoning is directly related to the operating temperature, charging voltage and the antimony content of the alloy.

The decline in production of antimony designs in Europe and the U.S. has been driven by the steady increase in reliability of the electrical grid. With increased reliability of the normal power source the number of discharge and recharge cycles drops. This results in the battery spending the majority of its time on float charge. Under these conditions, antimony-poisoning takes over and causes a rapid increase in maintenance and shortened battery life.

The high float current of lead-antimony alloys makes them unsuitable for use in VRLA batteries.

### Lead-Calcium

In 1935, manufacturers began the successful development of lead-calcium alloys<sup>6</sup>. Calcium alloys are not susceptible to a similar phenomenon like antimony-poisoning and so perform better on continuous charge in standby applications. Lead-calcium alloys currently dominate the American market.

The major disadvantage is that lead-calcium alloys are unable to withstand a large number of discharge and recharge cycles. As such they are unsuitable for cycling service. Even repeated shallow cycles (less than 20%) can rapidly age the battery.

Calcium does not readily mix with lead making lead-calcium alloys difficult to manufacture. If the process is not controlled properly, the alloy content between plates can vary. This can result in some of the grids having too high of a calcium content. Calcium tends to deposit at the grain boundaries and over time corrosion of the calcium results in plate growth and ultimately determines the life of the battery. If the content of the calcium is too high, grid corrosion is accelerated which results in accelerated plate growth, shortened life and in extreme cases, the grids can grow to the point they crack the container.

Another issue a manufacturer faces is large variations in individual cell voltage (ICV) during float operation<sup>9</sup>. Lead-antimony designs typically float within a very narrow ICV range. This is most often attributed to the relatively high float current of lead-antimony alloys and the fact that antimony stabilizes the polarity of the positive plates. Lead-calcium alloys have very low float currents and it is believed the low float current and lack of antimony are responsible for the large variation in negative plate polarization that causes large variations in ICVs.

In extreme cases ICV variation can result in a gradual loss of capacity in low voltage cells. To achieve acceptable ICV variation, some manufacturers add platinum salts to the high voltage cells in a string to depolarize the negative plate. The user needs to be aware of this fact, because after about 8 years the platinum becomes locked in the negative plate. If a new cell is added to an existing string that is more than 8 years old and platinum was added to the new cell, then new cell ICV may be below that required to maintain charge and the cell will sulfate. If platinum was used in manufacture and the battery is more than 8 years old, replacement cell orders should specify that no platinum is to be added to the cell.

The limited cycle ability and ICV variations have driven nearly continuous development in lead-calcium alloys. Gone are binary alloys composed of lead and calcium. The primary constituents of today's alloys are lead and tin (tin content is typically less than 2%). The calcium content has been remained at less than 0.1% and is typically around 0.05%. To improve the alloy properties, many modern alloys add aluminum to the mix as a grain refiner.

The extremely low float current of lead-calcium alloys made them the first choice for VRLA battery designs and they are still the most common alloys used today.

### Lead-Selenium (Antimony content less than 2%) also referred to as "Low-Antimony"

While American manufacturers focused on lead-calcium alloys for standby applications, European manufacturers developed low antimony alloys. In order to reduce the antimony-poisoning issue and improve standby operation, developers reduced the antimony content of the alloy. In order to reduce the antimony-poisoning rate to an acceptable level for standby service, developers were forced to reduce the antimony content to less than 2%.

Unfortunately, an antimony content of less than 2% results in a very hard alloy that is nearly impossible to cast making it unsuitable for use in a battery plate<sup>8</sup>. In an effort to achieve a castable alloy, developers experimented with adding different elements as grain refiners. The most common commercial cell today is based on a lead-selenium alloy. While selenium is not the only element used to create low-antimony alloy plates, the performance differences between the various alloys are small enough that we will use lead-selenium to represent this class of batteries in this paper.

Lead-selenium alloys typically have antimony contents of around 1.5% and selenium contents of less than 0.05%.

In terms of performance, lead-selenium alloys fall somewhere in between the characteristics of lead-antimony and lead-calcium cells<sup>9</sup>. They have 5 to 10 times the cycle capability of lead-calcium alloys and about 70% that of lead-antimony alloys. Float current is typically higher than lead-calcium but much less than lead-antimony. While float current still increases over the life of the battery the change does not impact standby operation or significantly increase water use. Even though lead-selenium alloys have much lower float current than lead-antimony, they do not suffer from wide variations in ICVs like lead-calcium.

The higher float current of lead-selenium type alloys limits their use in VRLA batteries.

### Lead-Tin

In an effort to reduce the potential for thermal runaway in VRLA batteries much research has been done in the area of plate alloys. A recent development is a nearly pure lead plate with a very low quantity of tin added<sup>4</sup>. This alloy is often marketed as “pure lead”. The “pure lead” marketing phrase refers to the purity of the lead used to produce the battery.

### **Plate Formation Techniques**

Formation is process of turning the red lead oxide paste into lead-dioxide and pure lead. It is accomplished by placing the plates in an electrolyte or electrolytic solution and applying a voltage. The formation process generates heat which must be dissipated.

Flooded cells in the U.S. are normally formed in the jar. That is, the unformed plates are assembled into a plate pack with the retention mats, separators and end caps and then placed in the jar. The cells are cooled during the formation process by placing them in a water bath. Typically European cells are vat formed. Vat formation involves lowering the unformed plates into a vat of electrolyte or an electrolytic solution and then applying the formation voltage. The plates are cooled by circulating the electrolyte through a heat exchanger. The plates are then rinsed and dried prior to being assembled into a cell.

Vat formation results in the most uniform plate formation and 100% initial cell capacity. The trade off is cost. Vat formation is typically more expensive than jar formation and a properly jar formed cell can easily make 100% capacity at the factory. The risk with jar formation is overheating of the plates during manufacture resulting in shortened cell life and warranty claims. As we can see like most things dealing with lead-acid battery technology there are advantages and disadvantages to both types of plate formation.

### **Positive Plate Support Methods**

The original design for batteries was to support the both the positive and negative plates off the bottom of the container. The negative plate is always bottom supported in vented batteries. The difference is in how the positive plate is supported.

The normal aging mechanism for a lead-acid battery is positive plate growth. There are two ways to compensate for this plate growth. The first is support the plate off the bottom of the container and design the post seal to allow the post to grow up through the seal. While most U.S. manufacturers limit bottom supported positive plates to smaller size batteries, it is common for all sizes of European batteries. This is why European batteries typically have more space between the top of the plates and the container cover.

The other method is to suspend the positive plates from the tops of the negative plates. This is accomplished by forming one or more loops on the top of the positive plates through which non-conductive fibrous rods are passed. The rod(s) then rest on a non-conductive support plate that rests on the top of the negative plates. In this design the positive plates are designed to grow down toward the bottom of the jar.

## Post Seals

The post seal is one of the items that can make or break the long term reliability of a battery cell. Flooded batteries using bottom supported positive plates usually have a post seal that allows for growth of the positive post upward through the seal. Flooded top supported positive plate designs usually have a static design involving o-rings and compression fittings or a welded seal.

VRLA designs use a variety of post seal types. These batteries operate at a positive internal pressure, so post seal design and assembly are critical attributes. Since positive plate growth is unavoidable and the internal pressure must be maintained, most VRLA batteries use a static seal design and provide space within the container to allow for plate growth.

## Separators

In flooded lead-acid batteries there are two basic types of separators used today. The first is micro-porous rubber. The second is micro-porous synthetic rubbers/plastics. These have replaced the original wood separators. In general natural rubber separators are considered the best alternative (they are also the more expensive option). The reason is they have less resistance to current flow. This enables the battery to produce higher current levels and for very short duration discharges (15 minutes or less), can have a minor impact on the available amp-hours.

### VALVE REGULATED LEAD ACID (VRLA) BATTERIES

Let me preface this discussion with a simple admission of bias. I am a “wet-head”, I only use VRLA designs when I cannot figure out a cost effective way to install a flooded battery. The reason is simple: Reliability”. I have yet to meet a VRLA battery that can match a flooded battery in this most critical attribute.

VRLA batteries were introduced in the 1970s as “maintenance free” designs. We found out soon afterwards, that this claim was not true. Early designs were plagued by a multitude of problems. While current designs are vastly improved, reliability remains a question mark.

Accelerated age testing of battery cells is an expensive proposition which most manufacturers are unwilling to invest in without some reasonable expectation of a return on the investment. In addition, accelerated age testing has not proven reliable for VRLA due to the many failure modes other than positive grid growth. As a result, users are left with the job of age testing new designs. Since batteries are very long lived devices, it often takes years before a problem shows up. As VRLA designs have been and continue to undergo rapid design changes, it is hard to predict future performance based on past performance. As a result, with VRLA batteries it is more difficult to separate fact from marketing hype

There are two basic technologies, absorbed glass mat (AGM) and gelled electrolyte (gel cell). In AGM batteries the electrolyte is immobilized in a sponge type separator that is wrapped around the plates. In a gel cell the electrolyte is immobilized in a silica gel. There are proponents of both types and even a recent introduction that is a hybrid combining AGM and Gel technologies. The differences are relatively minor. Gel cells have lower float currents and better heat transfer capabilities, while AGM cells have superior high-rate performance and lower gassing rates. The focus should usually be on the reliability of the battery and its suitability for the application rather than on whether it is AGM or gel.

VRLA batteries give off very little gas during normal operation which makes them suitable for installation in normally occupied spaces or close to sensitive equipment. They also have higher energy density than a flooded battery and require less floor space. On the down side, they are susceptible to thermal runaway, open circuit failure which renders the battery inoperable and typically have much shorter lifetimes than their flooded brothers.

### COMPARISON OF EUROPEAN AND U.S. BUILT LEAD-ACID BATTERIES

The information presented in this section, is of a necessity general in nature. However there are sufficient similarities among manufacturers to make such comparisons possible. Since there are few differences between a U.S. or European built Ni-Cd battery, the discussion will be limited to lead-acid designs.

- 1. Plate Configuration** – The majority of U.S. manufacturers of flooded lead-acid batteries use pasted positive plates. European manufacturers tend to use tubular positive plates for low and medium rate batteries. Both Europe and U.S. rely on pasted plates for high rate applications and negative plates.

2. **Plate Alloys** – The use of lead-selenium type alloys for standby service allows European manufacturers to produce taller jars with a smaller cell foot print. This is due to the higher float current of antimony designs that limits electrolyte stratification. U.S. manufacturers primarily use calcium based alloys for standby service. The low float current limits jar height unless an “air bubbler” is used to keep the electrolyte mixed. Both use lead-antimony for cycling service batteries.
3. **Plate Formation** – European manufacturers typically use vat formation for flooded batteries while most U.S. manufacturers use jar formation.
4. **Positive Plate Support** – European manufacturers tend to produce bottom-supported positive plate designs for all flooded cell sizes. U.S. manufacturers tend to use top supported designs for large flooded designs with bottom supported positives limited to small cell designs.
5. **Post Seals** – For flooded batteries, static type seals are common in the U.S. while sliding types are common in European designs.
6. **Separators** – Separator designs and materials are similar for both.

### NICKEL CADMIUM (NI-CD) BATTERIES

Ni-Cd batteries have been around nearly as long as lead-acid. Commercial products have been available since around 1900<sup>7</sup>. Pocket plate designs are typically used for long to high current types, while fiber plates are used for extremely high current short demand applications like engine starting.

While Ni-Cd batteries typically cost many times what a comparable lead-acid does, their characteristics make them ideal for many applications. Their advantages over lead-acid designs include:

- High resistance to damage by over charging
- Very small loss in capacity at low temperatures
- Much greater resistance to loss of life when operated at high temperatures
- No dip in voltage during the first minute of discharge
- Stainless Steel interconnecting hardware does not loose compression or corrode
- Lower water consumption
- Lower maintenance cost
- No rapid decrease in capacity after reaching a certain point in battery life

The above list may make Ni-Cd seem the best battery available however, like all things the advantages come with a cost including:

- Very high initial cost, which can exceed 10 times that of a comparable lead-acid battery (the normal range is 3-4 times that of lead-acid)
- Limited places to recycle used cells (cadmium is highly carcinogenic)
- Potassium-hydroxide electrolyte requires retraining of maintenance staff and keeping boric acid solution at the battery location
- Memory - When maintained on charge for extended periods the memory affect results in a temporary loss of battery capacity. This can require over-sizing of the battery for standby applications.

### SO WHAT BATTERY IS RIGHT FOR MY APPLICATION?

I've presented a lot of data now comes the time to break it down into simpler terms. Since it is impossible to address every possible scenario in which a battery will be used, this will be a high level overview but should be a help. Most of what is presented is my opinion based on my experience as a user. This does not make it right or wrong, so take it as what it is, the opinion of an informed user who has spent time studying the subject with an open mind.

1. **Low temperature applications** – Ni-Cd is hard to beat. Ni-Cd suffers virtually no capacity loss at low temperatures. As a result, you need a much smaller battery than a lead-acid to do the same job which can offset the higher cost of the Ni-Cd. Throw in the lower maintenance costs and this can be an easy decision.
2. **High temperature applications** – Ni-Cd holds the edge here. Ni-Cd loss of life at high temperatures is less than vented lead-acid but may be cost prohibitive. This is one of the applications where life cycle cost is a key for selecting a battery type. In my opinion, vented lead-calcium and lead-selenium come in second and third as far as the best choice, but they can easily win the life cycle cost analysis. For standby applications, VRLA and lead-antimony are not suitable for high temperature applications. VRLA because of dry out and lead-antimony because of antimony poisoning. As a result both battery types are easily driven into thermal runaway.
3. **Engine starting** – Ni-Cd shines in this application but can be cost prohibitive. Lead-acid works well here and easily wins the initial cost battle but can just as easily lose the life cycle cost war. The following real world example is provided as an illustration of this point. Please be aware that if the operating conditions were much milder, the solution would have been a better lead-acid battery.

Case Study 1:

Problem:

Fire pump starting batteries are failing every 6 months and require weekly maintenance. The most recent failure was an explosion that splashed a maintenance worker in the face. In addition, the frequent fire pump failures to start are causing plant insurance premiums to rise. There are three fire pumps and each has two 100% redundant starting batteries.

Operating Conditions:

The plant is located in southern Texas. The batteries are located in the same rooms with the diesels in a concrete block and tin roof building. To facilitate rapid starts, the engine blocks are maintained at 140°F. With no ventilation except when the engine is operating, the room temperature is always above 110°F. The existing batteries are mounted in open racks which allow for easy maintenance.

Task:

Find a cost effective solution to the reliability and maintenance issues

Solution:

Replace the existing six lead-antimony starting batteries with Ni-Cd batteries.

Economic Analysis:

The cost of the engineering, installation and materials exceeded \$34,000 (the batteries for all three engines were approximately \$20,000 of the total cost. The existing lead-antimony batteries cost \$1,500 for all three engines. The reduced maintenance (including semi-annual replacements) and increased reliability resulted in a 2 year pay back for this modification.

4. **Cycling service** – Lead-antimony or VRLA are easy choices. Antimony's cycling ability is its greatest strength. The reason to include VRLA here is that one of the fundamental issues with VRLA life is depolarization of the negative plate on long term charge. If the battery is being cycled, then the negative will not become depolarized which removes this failure mechanism. If the battery is going to be on charge for long periods between cycles, then lead-selenium is an excellent choice.
5. **Standby service** – Lead-calcium or lead-selenium win the battle here. While you may hear manufacturers disparage the other technology, the reality is that both provide excellent service in this application.



6. **Confined or normally occupied spaces** – VRLA is the only choice. The gassing characteristics of flooded cells preclude them from this use.
7. **Photo-voltaic** – VRLA is a good choice. Batteries in this application spend most of their time at partial states of charge. As a result the performance characteristics and aging mechanisms are much different. Most of these are smaller applications and use 12-24 battery systems. When available, batteries specifically marketed for this service should be chosen.
8. **Uninterruptible Power Supply (UPS)** – The standard here is VRLA for smaller units and flooded for larger systems. Batteries for these applications use thin pasted positive plates to maximize contact between the active material and the electrolyte. Don't expect long life here. Thin plates typically last between 50 and 75% of their heavier cousins used in low to medium current applications. The choices here are dependent on the reliability of the primary power source. For reliable power lead-calcium or lead-selenium, frequent outages, lead-selenium or lead-antimony. When it comes to lead-antimony and lead-selenium, I choose lead-selenium for its lower maintenance at near end of life conditions.

#### Case Study 2:

##### Using the wrong battery

A UPS system was being upgraded and increased in size. The original battery was sized to provide 15 minutes of run time and a general purpose battery was chosen since it was capable of meeting the operating conditions and would provide longer operating life.

When the decision was made to increase the size of the UPS to accommodate a new computer system, the decision was made to keep the existing battery. However, the doubling of the UPS load resulted in a runtime of less than 1 minute on the existing battery.

When the battery reached end of life a comparison was made between the existing battery and one that fit in the same case but used thin plates instead of thick plates. The two batteries were rated for the same number of amp-hours. This change, which cost virtually nothing, increased the runtime on the new UPS from less than 1 minute to 10 minutes. The trade off was a reduced operating life from 20 years to 12 years, but the increased runtime trumped the loss of operating life.

9. **DC Motor Starting** – This is the same as UPS.
10. **Grid Stabilization and Large Capacity Energy Storage** – The largest battery used in this service is located in Alaska and is a Ni-Cd. Other successful applications include VRLA when the battery is kept at a partial state of charge, flow batteries and high temperature sodium-sulfur. This is an area where the technologies are rapidly changing and newer technologies have the decided edge of lead-acid.

### SUMMARY

The large number of battery types and manufacturers available to users today can make choosing the right replacement or new battery difficult. It can be hard to separate the facts from the hype. Manufacturers are quick to point out the advantages of their products and the technologies chosen. They are just as reluctant to discuss the limitations of their products and technologies or the advantages of competing technologies. So what can users do? Here are some suggestions:

Network – Get to know other users. Ask for their operating experience with a product.

Participate

Attend Battcon. It is a great place to build a network.

Attend IEEE Stationary Battery Committee meetings and get to know the folks who write the standards.

Do a paper or teach a class. I've learned more doing this than anything else.

Research – Get familiar with the different products and technologies available

Understand – Know your application including the environmental and electrical conditions of the installation

Evaluate – The battery with the lowest initial cost may have the highest life cycle cost.

## ACKNOWLEDGEMENTS

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