MYTHS AND MISCONCEPTIONS:
EXPLORING THE MYTHS OF BATTERY LIFE. A USER'S PERSPECTIVE

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ABSTRACT

This paper will examine how cell design parameters influence battery life. It will compare a high rate design to a general purpose design and examine the influence of two parameters (plate thickness and specific gravity) on battery life. I am limiting the discussion to these two topics because they are easily explained and understood and stay away from the quagmire of flooded versus VRLA, which as been the subject of a great many previous papers. In addition, these parameters affect VRLA and flooded alike.

I will then turn to a short discussion on the influence of cell selection and how that impacts the service life of the battery. This is an important topic and one that I did not understand at all when I had to specify my first replacement battery. We will also look at the influence of the installation design on service life.

We will then examine the influence of operating temperature, number of cycles, and maintenance practices on service life.

The final discussion is on warranty and what is the warranty. In my opinion, a warranty is just an insurance policy. If a battery has a 12 year design life and comes with a 20 year warranty, what does that warranty mean?

A USER'S PERSPECTIVE

When I first started out in the battery world, I made a decision to join the IEEE Stationary Battery Committee. This was one of the best decisions of my professional career. It exposed me to group of people who have the knowledge we all want and who are willing to share. This was extremely important, as I was faced with several issues on the stationary batteries at the plant.

One of the most difficult questions that the battery engineer has to explain to the facility owner or manager is: why does that battery need to be replaced? After all, it came with a 20 year warranty. Doesn't that mean it will last for 20 years? The purpose of the paper is to build on "Got Warranty? Taking Another Look at the 20-Year Battery Warranty" presented last year by Carey O'Donnell and Chuck Finin. The paper will look at what, I believe, are four of the most prevalent myths/misconceptions in the user community concerning lead-acid battery life. I define these as:

- Battery design life is equal to warranty life.
- Battery warranty life is equal to service life.
- Cell Selection and Installation Design have little impact on service life.
- Installation, Operating and Maintenance Practices have little impact on service life.

Before we begin, we first need to agree on some basic terms:

- Design Life: The expected life of a battery cell, based the design of the cell and the manufacturer established operating conditions.

- Service Life: The life of a battery cell, based on the actual installation design, operating conditions, and maintenance practices of the installation.

- Warranty Life: The life of a battery cell, over which the manufacturer amortizes the cost of the cell. This is often unrelated to the design of the battery and can be nothing more than a marketing tool. It has no relationship whatsoever to the service life of the battery.

INFLUENCE OF CELL DESIGN ON BATTERY LIFE

In the United States, batteries come in three basic flavors: High Rate (often called UPS), Long Duration (often called Telecom), and General Purpose. These designations not only define the battery type, they also influence the life expectancy of the battery. These are the province of the battery designer.

The natural aging mechanism of a lead-acid battery is positive plate growth. In the most common design (pasted plate), the growth is caused by corrosion of the positive grid. As the grid grows, active material can shed and electrical contact between the grid and the active material is lost resulting in a loss of capacity.

There are many factors that influence the rate of positive plate growth. Among these are:

- Physical strength of the grid
- Acid concentration
- Positive Plate Polarization during float charge
- Operating temperature

While it can be argued that the battery designer cannot control plate polarization or operating practices, it is true that the design life is based on operating the battery within the parameters established by the designer.

The amount of current a particular design can produce at any point is a function of the amount of active material in contact with the electrolyte and the acid concentration in the electrolyte. When a designer is working on a high rate design, the goal is to have the maximum amount of active material in contact with the electrolyte at all times.

To increase the amount of active material in contact with the electrolyte, the designer reduces the thickness of the plates. This allows more plates in the same volume, increasing the surface area in contact with the electrolyte. Even then, it is not uncommon for manufacturers to increase the electrolyte specific gravity to 1.250 or 1.300 to improve the high rate capabilities of a cell.

The opposite is true of a long duration battery. Here, the designer uses thick grids, and electrolyte specific gravity is typically 1.215. This results in a cell with a relatively low 1 minute current but excellent, long term power production capabilities.

The general purpose battery falls in between these two extremes. Plates are thicker than high rate designs, but somewhat less thick than long duration designs. Electrolyte specific gravity is typically 1.215 to 1.250. This results in a cell with moderate, high rate capabilities and good, long term power production capabilities.

The physical strength of the grid is a function of two basic elements**,** the first being the strength of the lead alloy and the second being the amount of grid metal. High rate designs with thin grids have the least amount of strength, while long duration designs have the highest grid strength.

We can now see how the design impacts the life of the battery. Thick grids have the strength to resist the growth caused by corrosion. Thin grids do not. The higher the specific gravity gains short circuit capabilities but sacrifices life due to the increase in corrosion rate.

My experience and contact with other users suggests the following for flooded, pasted plate lead-calcium designs (based on installations with good design, operating conditions and maintenance practices):

High Rate Batteries:	12 to 15 years expected life
General Purpose Batteries:	20+ years of expected life
Long Duration Batteries:	25+ years of expected life

For lead-antimony designs, there is much more variation, but, in general, life expectancy is 3 to 5 years less than the same design lead-calcium battery.

As can be seen**,** not all batteries are designed to deliver the same service life, even if they have the same warranty life.

INFLUENCE OF CELL SELECTION AND INSTALLATION DESIGN ON SERVICE LIFE

The province of the system designer is proper selection of the battery for the service conditions. The majority of installations today use lead-calcium designs. This battery type is excellent for float operation. The down side is that it has a relatively short cycle life (typically 80 to 100 cycles).

Lead-antimony, on the other hand, does not perform as well in float service. This is due to antimony transfer from the positive grid to the negative plate. The higher initial float current (~5 times that of lead-calcium) and the fact that antimony transfer increases float current cause these batteries to consume more water. This leads to increased maintenance, with a maintenance frequency that increases with time in service. The good news is that lead-antimony has an excellent cycle life. So for installations that require a high number of cycles, it is the preferred choice.

Lead-selenium (also called low-antimony) is advertised has having a lower float current than traditional lead-antimony designs that remains stable over life. There are differing technical opinions on these claims, so, for the purposes of this paper, we will confine the discussion to lead-calcium and lead-antimony.

The type of cell selected also has much to do with the service life. As has been discussed, a high rate design has a shorter expected service life than a general purpose or long duration. However, the load profile that a battery must supply is the usually the deciding factor.

In some instances, high rate designs are selected for applications that can be served by a general purpose design. This is usually done when a high initial rate is required and the physical space the battery is located in is relatively small. In these instances, it is not uncommon to find a high rate battery installed with a relatively long load profile of several hours. The other advantage is that the high rate battery will have a lower cost than the general purpose battery.

The other factors that the installation designer may have control over are the operating conditions. In the US, batteries are rated at 25°C or 77°F. In Europe, the design is 20°C. In my experience, this is one of the most misunderstood battery parameters in the user community. Even if a user has a basic understanding of the influence of temperature on battery life, they may believe that it is the room temperature. Or that it is the average room temperature.

In reality, the operating temperature is the internal cell temperature. While ambient temperature influences cell temperature, it is not the only determinant. Cell temperature in a well ventilated room with uniform air temperatures and adequate air flow around the cells normally runs 1 to 2°F above ambient temperature. In a room with localized temperature gradients caused by such things as an outer wall exposed to very high or low temperature, direct sunlight on a portion of the room or a localized heat source, the battery can be exposed to very large extremes in cell temperature resulting in uneven aging of the cells.

For Valve Regulated Lead-Acid (VRLA) batteries, air flow is of great importance. In VRLA designs, the recombination reaction at the negative plate produces heat that must be dissipated to the environment. If adequate air flow around the cells is not provided, or if the air flow is restricted, then localized hot spots can develop within the battery. At the least, these hot cells will age at a more rapid rate. At the worst, they can pull the battery into thermal runaway and in the worst case scenario result in a fire.

One of the issues that is becoming more common in turnkey projects is the lack of aging margin being used in battery sizing. Unless the purchase specification explicitly details aging factors, competitive pressures force vendors to leave them out. The impact to the project is that it keeps the cost at a minimum. The impact to users is that a battery without any aging margin will have to be replaced when capacity falls below 100%. Facility managers don’t like us to replace perfectly good batteries because the design was incorrect. It is our job to prevent this from occurring.

INFLUENCE OF OPERATING CONDITIONS ON SERVICE LIFE

IEEE 450 contains a graph that shows the influence of operating temperature on battery life. An unfortunate number of users are not familiar with this graph. The graph shows that, for every 15 degree rise above 77°F, a flooded battery loses half of its available life. This means that if a battery starts with a maximum life of 20 years, then operation at 92°F electrolyte temperature will reduce its life to 10 years. If the temperature is increased to 107°F, the life drops to 5 years. This holds true for a high rate design, except the life is much shorter. For a 12 year expected service life, the life drops to 6 years at 92°F and 3 years at 107°F. These figures are for continuous operation at elevated temperatures. Unfortunately, battery manufacturers have not developed a way to characterize the effects of frequent hot and cold cycles, which more the norm. The fundamental fact remains, however: heat is bad for battery life. Whenever possible and economically justifiable, the battery should be located in an air-conditioned space, even if the equipment it supports is not.

Even if a user understands the impact of temperature**,** a battery may still have a shorter life. Temperature can be unequal across the battery to the point that cells age at significantly different rates. Because heat rises, typical causes (besides those already mentioned) are racks with more than 2 tiers and uneven temperature gradients from the floor to the ceiling. The impact of this uneven aging is often found when either a discharge test is performed or when the battery is required to fulfill its design function. Under these conditions, the aged cells in the string become the limiting factor in the battery to produce energy. This often results in reduced duty times or the need to jumper cells during a discharge test.

These unexpected situations often leave the battery manager with the difficult task of explaining to the facility manager the need to spend significant sums to replace multiple cells in a battery that. in theory. should have years of available life.

A lesser understood operating condition is the impact of cycles on battery life. Most lead-calcium batteries are rated for 80 to 100 cycles. (In this instance, a cycle is defined as a discharge of greater than 80% of available battery capacity followed by a recharge.) This can leave the user with idea that multiple small discharges are not detrimental to battery life. In reality, these discharges are damaging. While the battery can withstand more of these shallow discharges, they do accelerate the aging of the battery and result in loss of life. The most difficult thing for the battery manager is to estimate this type of operating condition's effect on battery life.

While it is easy to quantify the impact of temperature on battery life, the same is not true for cycles. The impact of cycles on battery life is highly dependent on the frequency of the discharges, the depth of the discharge, and how quickly the battery is recharged following the discharge. While a lead-calcium battery may be initially selected for a particular facility, if the site is subjected to frequent power disturbances (hence battery discharge / recharge cycles), then the battery should be replaced with a battery more suited to cycling operation such as a lead-antimony or lead-selenium design.

The other critical operating condition is the maintenance practices to which the battery is subjected. A continuous over charge of .01volts per cell has a similar impact as operating the battery at 80°F. For a typical 48 volt battery with 24 cells, this results in a 0.24 volt increase in overall string voltage. Failure to maintain individual cell voltages above critical voltage can cause cells to self discharge and sulfate. In extreme cases, this can lead to the plates expanding until the jar ruptures**,** creating an open circuit in the battery. Even if this does not occur, a failed cell creates a high resistance condition that significantly reduces the battery's ability to produce power. High resistance terminal connections have failed and caused battery fires on multiple occasions.

A more insidious problem can develop from water quality. Water is routinely added to flooded battery cells to make up for losses associated with electrolysis and evaporation. If the water quality is bad, then contaminants are introduced that can poison the cells and cause rapid cell failure. If the water quality is marginal, then this condition may take years before it makes itself evident.

Air quality is also a potential issue. The build up of dust on the battery cover in the presence of humidity can result in tracking. An even worse impact is if the battery is exposed to an environment where the dust is conductive. Tracking creates external shorts and can cause individual cells to fail. While some users may feel that the common horizontal arrangement of posts in VRLA designs makes them immune to tracking, this is not the case. This is because the vent is normally located with the posts and can release small amounts of acid, which do not dry but attract moisture and dust.

As can be seen**,** the quality of the maintenance program has a very large influence on battery life and the ability of the battery to perform its design function. While the recommendations of IEEE 450 are written without regard to cost, at a minimum an effective maintenance program should contain the elements called out with the frequency based on the availability of resources, the type of battery in use, and the other operating conditions to which the battery is subjected.

A LOOK AT WARRANTY

The previous sections have examined the impact of conditions beyond the control of the manufacturer that affect the service life of the battery. We have also explained why not all cells are created with equal design life. So how does all this affect the warranty life of the battery?

In the United States, nearly all flooded lead-acid batteries are sold with a twenty year warranty whether or not there is a reasonable expectation that the battery will last twenty years. This is because we as consumers have come to expect the twenty year warranty. In Europe, the opposite is true. Almost no batteries are sold with twenty year warranties. So, what is the difference? In reality, the difference is that U.S. manufacturers use the twenty year warranty as a marketing tool. It has little to do with the actual design life of the battery.

So, let us ask ourselves as users: what can we do?

There are several things:

1. Quit insisting on twenty year warranties for high rate products or VRLA designs that have no reasonable expectation of a twenty year service life. All the manufacturer is doing is banking our money, knowing they will be giving some of it back. This is like an insurance policy, where the manufacturer is the winner. Work with the vendor to obtain a reasonable warranty that provides the necessary coverage and eliminates the excessive coverage and its associated cost.

2. Make reasonable warranty claims. The warranty is specific about the operating conditions and maintenance requirements. When we fail to meet these requirements, we must shoulder the burden for short battery life. For this reason, we need to ensure we understand the warranty requirements and keep the necessary records to support warranty claims.

3. Ensure we understand how cell selection, installation design, operating conditions, and maintenance practices affect the service life of the battery. When we do this, we can maximize the life of our batteries. If necessary and economically viable, we can modify the installation to extend the life. This will enable us to be able to tell the difference between what is a warranty claim due to manufacturing defects or errors and what is shortened service life based on design, operating conditions, and maintenance practices.

4. Be involved in the selection of the battery for the installation. A turnkey project is an easy one to manage, but it may result in a design that has no margin and where battery life has been sacrificed at the expense of keeping the cost down. This may result in our 20 year battery having only a 8-10 year service life before capacity falls below the value needed for the battery to perform its design function. This is not a warranty issue. This is a failure on the part of the battery manager to ensure that the facility manager understands that the lowest price up front has a significant impact on the maintenance cost of the installation.

   The most recent bid for our facility was for a 30kVA UPS system with the battery sized at a 1.0 aging margin, a 1.0 design margin, 77 degrees operating temperature, and a 0.8 power factor. We, as the facility battery manager, have to break this chain of cheap bidding. For a standard 120 volt UPS, we should insist on a reasonable operating temperature (65°F for an air conditioned space is reasonable), a 1.25 aging margin so we can get the maximum life out of the battery, and, in the case of 120 volt UPS, a 0.9 or higher power factor, which is more typical of a 120 volt system.

5. If a user is going to rely on internal cell ohmic values to determine when a cell or battery needs to be replaced, then ensure this acceptable to the battery vendor and is spelled out in writing in the warranty. Few standard warranties recognize internal ohmic measurements as a valid reason for a warranty claim.

CONCLUSION

We have seen how battery design life is not equal to warranty life. High rate and VRLA designs typically have life times less than the warranty period. In these cases, the warranty is simply a marketing tool that adds cost to the battery. We as consumers need to start making reasonable a warranty period part of our specifications when we purchase these products.

We have seen how battery service life is almost never equal to warranty life. Even for designs where it is reasonable to expect the service life to exceed the warranty life, the service can be reduced by operating conditions and maintenance practices. In many cases, it is not cost justifiable to operate the battery in manner that will enable it to meet its warranty life.

We have reviewed how cell selection and installation design impact service life. We as consumers have to ensure that the persons designing the installation are knowledgeable of the factors that impact battery life and take these into account when designing the installation. This is especially true for ensuring that the correct sizing margins are included in the design process.

We have discussed some of the ways in which operating and maintenance practices impact service life. We as users need to ensure that our maintenance practices and operating conditions are matched to the type of battery and follow the battery manufacturer's recommendations and/or IEEE recommended practices for the type of battery. We need to use our knowledge to forecast a reasonable service life for the battery. This will enable us to replace an aged battery before it can no longer perform its design function.