RELIABILITY: GET REAL!
AN ALTERNATIVE VIEW FOR SELECTING THE RIGHT BATTERY

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ABSTRACT

There are so many end users who are confused over the realities of how long their batteries last or do not last. Consultants do not have time to familiarise themselves with batteries, any more than they do about any of the many other products they are expected to knit together into viable and reliable systems for their clients. They need help. Reliable batteries are available. They just cost more than the unreliable ones, but people do not always understand this.

The purpose of this paper is to encourage the end users, the electrical consulting engineers, the suppliers, and manufacturers to look at and consider the many ways in which batteries, both lead-acid and nickel-cadmium (Ni-Cd), differ from each other under identical conditions to which they are to be subjected. Reality does not provide a perfect 77^0 F scenario, along with ideal, attentive maintenance, and the battery's never seeing a discharge. The result of ignoring these facts may lead to catastrophic and costly failures, far greater than the cost differential between a less reliable battery and a more reliable one.

We experienced an interesting series of disconnects at the 2007 Conference, as summarised in the following sentences. A battery manufacturer stated that the user's application needed to be understood so that the right battery may be designed in. Shortly thereafter, a battery user cried out from the floor asking, "How do I get a good and reliable battery?" Following this, another participant wisely stated that batteries are the weak link. Clearly, the weak link depends upon the battery selected.

INTRODUCTION

It is time that batteries get the respect they are due. We must stop treating them as disposable commodities, such as those in cars or flash lights. To achieve this, we need to present batteries in a more realistic manner and not hide reality behind warranties that tend to be misunderstood by the end user. It would be better to match the right technology to the right application. If a generator costing $100K is expected to start every time, then the owner should consider not using low cost batteries and should specify a long life battery worthy of being associated with this high cost system.

There are many differences among the batteries available in the marketplace. At the very fundamental point, there is a distinct contrast between lead-acid to the nickel-cadmium technologies. This may be summarised in the following Table 1, in which the reader will note that any and all lead plates are consumed by the acid as part of the operation of the battery. The result is that lead cells will eventually collapse, producing zero volts. On the other hand, the electrolyte of Ni-Cd protects both the plates and so there is no sudden end of life. Reference Table [1].

Table 1. Basic Electrochemical Differences between Lead-Acid and Nickel-Cadmium cells.

Lead-acid Battery Internal Operation

$Pb0_2$	+	Pb	+	H_2SO_4	=	$PbSO_4$	+	$PbSO_4 + H_2O$
+ plate		- plate		acid		+ plate		- plate

Both plates react all the time with the acid (H_2SO_4)

Nickel-Cadmium Battery Internal Operation

$2NiO.OH$	$+ Cd$	$+ 2H_20$	$= 2Ni(OH)_2$	$+ Cd(OH)_2$
+ plate	- plate		+ plate	- plate

Plates do not react with the electrolyte (KOH)

FACTORS TO BE CONSIDERED

Cost of Failure

We all know that there can be tremendous costs associated with a battery failure: millions an hour in the financial world down to tens of thousands of dollars an hour at an airline check-in desk. In most cases, these costs far outweigh the absolute cost of a good battery and could be avoided through a better understanding of the range of batteries available on the part of both the consultant and the end user.

Open Circuit vs Short Circuit Failure

It is easy to forget that VRLA are known for their open circuit failure mode and that all flooded batteries are prone to short their plates out. For this and many other reasons, the VRLA is less often used in such applications as switchgear as it was five and ten years ago. The end user needs to keep these factors in mind when selecting a battery. In this way, the unexpected failure may be eliminated. Of course, when space is at such a premium and the cost of failure is not significant, then the VRLA could be used.

First Cost or Not

First cost batteries will invariably be the VRLA, despite the short life and failure mode of open circuit. Unfortunately, monitoring does not prevent this and seldom gives adequate warning. There is a misunderstanding that the VRLA is a low maintenance type of battery, which further contributes to those unexpected and costly failures. No one would consider designing in transformers with life expectations as short as 10 years. On the other end of the first cost spectrum, we have the Ni-Cd, which often cannot be justified despite hopes and wishes. However, cost of ownership over a 20 year period may possibly result in the Ni-Cd being selected. References are made to Tables 2 and 3.

Table 2. Comparing the Benefits and Drawbacks from Technology to Technology.

+ + Pros + +	Technology	- - Cons - -
Small size. Low first cost.	VRLA	3-5 yrs life experiences. Sudden death - O/C
12-15 yrs life expectation.	Pasted Plate LA	Rapid failure at end of life.
25 + yrs life expectation. No sudden failure.	Nickel-Cadmium	High first cost.
Small footprint. No maintenance.	Lithium Ion	High first cost.

Table 3. Comparison of Estimated First Year Cost Against Cost at 20 yr Operation Timeframe.

First Year	Technology	20 yrs
$4,000	VRLA	$20,000 +
$6,000	Pasted Plate LA	$15,000 +
$9,000	Nickel-Cadmium	$12,000 +
N/A	Lithium Ion	N/A

- Capacity testing is not included in the above estimates.
- IEEE recommended maintenance practices employed.
- Change outs upon cell or battery failure included.

Basic Reliability

As presented at the 2005 Conference, reference [1], we saw a strong and convincing case that the reliability of a battery of the "short circuit failure" style increases as the number of cells in series increases. The reverse occurs with the VRLA battery and even parallel strings do not raise the system reliability too much when compared to a single string of a flooded battery. Within the short circuit failure class of vented cells, it was demonstrated that a single string of a Ni-Cd battery will be significantly more reliable than a flooded lead-acid battery of the same voltage. Even a second redundant parallel string in the lead-acid battery will not match the Ni-Cd reliability.

Impact of Temperature – High and Low

It is well known that low temperatures slow up the internal chemical reactions in any battery; the degrees of reduced performance vary according to the technology. For example, at temperatures around freezing, a VRLA may need capacity compensation of 20%. The lead-calcium cell using 1.215 specific gravity acid will require a doubling of capacity, while the Ni-Cd will need about 18% increased capacity.

At the other end of the temperature range, high temperature is the killer of all batteries. There will be no surprise to find out that this impact varies from one technology to another. Lead acid at 95^{0}F will experience a 50% shortened life, while Ni-Cd will have a 16-18% shortening of life. IEEE 450, Annex H offers a method for calculating the impact of high temperatures on a lead acid battery. Reference [2]

Life Expectations

"Expected Life under Site Specific Conditions." This phrase is offered as the new mantra for our battery world.
This should be the rationale used by all parties, manufacturers and end users alike. We know that warranties give an expectation for the battery if and when the battery is maintained at 77^{0}F and that maintenance records be forthcoming if and when claims or concerns are raised. Outside these mandates, there is little to fall back on. A warranty is a sort of baptism to which a battery is subjected to in this country; it is a marketing feature, not a benefit.

In Europe, guarantees are made for extended expectations and may be negotiated often with a price adder. Reality towards to the VRLA may be found at www.eurobat.org , reference [3], wherein one may drill down to the VRLA section. There on will find that the VRLA fall into four groups. with "life expectations" ranging from 2 to 12 years now. That dream for a 20 year lasting VRLA is a ways off. Flooded or vented lead acid batteries are generally accepted as lasting some 12 to 15 years before being replaced.

On the side of the Ni-Cd, there are examples of batteries with 60% capacity at 40 years and others still working at 28 years. Some of these have been removed from service for the only reason that it was deemed that they were old. Regrettably, no capacity testing was used in making this determination.

Maintenance

This is an area in which it seems to be acceptable to cut back on and save costs for the user. This is usually decided upon by those who do not appreciate the importance of reliable batteries, as they classify them as disposable items. Maintenance recommendations from IEEE, references [4, 5, and 6] are based upon experiences and are generated to ensure the best performance and life expectations. They are serious documents, developed over the years to help users get the best out of their systems. If the user really wants to reduce maintenance, then the selection should be steered to a battery which does not need the same attention.

Design Guide

A good design guide, reference [7], should be developed for any and all organisations and operations and take into account all of the subjectivities and sensitivities of batteries, so that the end user and the consultant may make wiser selections. When considering the combined effects and impacts of failure modes, end of life failure, temperature, and real life expectations, the employment of life cycle costing could lead to an upgrade in battery selection.

Specifications

After due diligence has been performed and an electrical engineer has selected the appropriate battery, then the subsequent specification needs to be developed. This should be tight and specific to ensure that the system integrity is delivered with no possibility of an alternative battery being inserted without the awareness or approval of the aforementioned engineer.

SUMMARY

The owner is to be encouraged to educate him or herself on the differences of the various battery technologies and to select a corporate policy regarding the type of battery technologies their company should employ. The owner should write strong specifications to ensure the right product is employed. It is also recommended they establish internal experts, if they do not already exist.

The battery industry should be encouraged to step away from warranties. Reliability needs to be reviewed with respect to the cost of failure and first cost. Over the long term, it is anticipated that the battery industry will be routinely charging for recycling lead batteries, which will result in higher product costs.

In closing, knowledge is paramount to understanding what may be expected from a DC backup system, so that even UPS systems could employ longer living and more reliable batteries. This latter issue should be under the control of the user's demand or specification and not left to the preference of the UPS OEM. Please do not forget that "cost of failure."

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REFERENCES

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[5] IEEE 450 *Recommended Practice for Maintenance, Testing and Replacement of Vented Lead-Acid Batteries for*
[6] IEEE 1106 *Recommended Practice Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium*
[7] Battery Design Guide by R N Pocock; submitted to Construction Specifications Institute (CSI) - 2006.

SUGGESTED FURTHER READING

[1] IEEE 1187 *Recommended Practice for Installation and Design of Valve-Regulated Lead-Acid Batteries (VRLA) Storage Batteries for Stationary Applications.*
[2] IEEE 1189 *Guide for Selection of Valve-Regulated Lead-Acid Batteries (VRLA) for Stationary Applications*.
[3] IEEE 485 *Recommended Practice for Sizing Lead-Acid Batteries for Storage Applications*
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