A NATURALLY AGED VRLA BATTERY: 18 YEARS LATER

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ABSTRACT

The difficulties facing engineers that design long-life products are universal: The effects of what are hoped to be design improvements reveal themselves only slowly. How does one qualify a battery design, for example, without waiting for the product to naturally age? Is the design capable of going the intended life or is it inherently flawed? It is an elusive question for the telecom battery designer to answer given that most manufacturers' battery cells have not been deployed in the field for anything near their design life.

For lead-acid batteries, a traditional method of artificially aging cells involves floating sample cells at elevated temperatures in order to accelerate the chemical and electrochemical stresses. Temperatures of 40, 50, 60 and even 70 degrees C are used to simulate the passage of time, accelerate aging and assess a design.

The problem with this practice is that particularly at the higher temperatures, failure modes are introduced that would not be experienced in normal operating conditions. Water vapor transmissibility, something that is not an issue at room temperatures, (given proper material selections) becomes a problem at elevated test temperatures. Plastics behave differently, vents fail and electrode polarizations are altered. In summary, changes are introduced to the system, which are not normally experienced in the "real" world. At lower temperatures, many of these problems are avoided but the testing may take several times longer. The method is perhaps better than nothing but it is far from ideal.

GNB Industrial Power, with close to 20 years of actual experience in the deployment of large valve regulated lead acid batteries in stand-by power use, recently replaced a *naturally aged* 17-year old *Absolyte I* string that had been operated in a telecommunications environment. It was brought into our laboratories and analyzed in great detail to understand it's condition with respect to the application it was in and relative to it's original design intent. This paper presents the results of this testing.

INTRODUCTION

The subject of the investigation was a battery that was among the first commercially manufactured VRLA products GNB made. Given that GNB was a pioneer in the application of VRLA batteries in telecommunication environments, it was also one of the first batteries of its type used in that industry. This 75A25, 900-Ah battery was manufactured in 1983 and installed in a CEV in Heber, Arizona. It is known that the site experienced outages and that the battery always carried the load. When presented with the opportunity to have the battery returned for analysis, GNB made provisions for its replacement and return.

What followed was a thorough assessment of the returned string to assess its state-of-health and condition through the examination of its external, internal and electrical characteristics.

INITIAL TEST DATA

Upon receipt at the GNB Engineering Center in Lombard, Illinois, the first step was to give the battery a 17-year check-up. As part of this process, the as-received internal ohmic values (IR) open circuit voltages (OCV) and vent-opening pressures were measured and recorded.

OCV's, Vent Opening Pressures and IR's Before and After Charge

GNB Cell #	As rec'd OCV	Vent Open (psi)	Internal Resistance Before Chrg	After Chrg	% Δ
1	2.123	2.96	0.504	0.299	-41%
2	2.103	2.49	0.322	0.227	-30%
3	2.146	4.53	0.361	0.481	33%
4	2.128	1.99	0.535	0.259	-52%
5	2.120	3.38	0.416	0.396	-5%
6	2.114	4.37	0.427	0.413	-3%
7	2.113	2.84	0.460	0.347	-25%
8	2.116	3.72	0.584	0.468	-20%
9	2.094	2.54	0.333	0.241	-28%
10	2.124	3.33	0.426	0.296	-31%
11	2.131	3.63	0.633	0.556	-12%
12	2.108	2.72	0.404	0.297	-26%
13	2.117	2.86	0.538	0.380	-29%
14	2.125	3.51	0.426	0.398	-7%
15	2.109		0.443	0.325	-27%
16	2.094	3.25	0.354	0.256	-28%
17	2.138	3.10	0.617	0.514	-17%
18	2.125	2.45	0.310	0.274	-12%
19	2.115	2.97	0.570	0.391	-31%
20	2.117	3.37	0.486	0.339	-30%
21	2.118	3.26	0.524	0.404	-23%
22	2.104	3.16	0.350	0.252	-28%
23	2.107	1.99	0.380	0.274	-28%
24	2.118	2.25	0.440	0.321	-27%
min	2.094	1.987	0.310	0.227	-52%
max	2.146	4.527	0.633	0.556	33%
average	2.117	3.072	0.452	0.350	-22%

This table represents a large quantity of numerical data but a glance at the averages and extremes is instructive:

- All vent-opening pressures met the then-current specification of 1.0-psi minimum. The minimum vent opening pressure since 1985 has been 3.0-psi. (There is no value for cell 15 as its vent was sacrificed to make a fixture for testing the others.)
- Generally the as-received OCV's (and hence specific gravities) were lower than normal for a fully charged cell, indicating that the string might have self-discharged in the warm Arizona environment between decommissioning and receipt in the test lab.
- In response to the indicated low state of charge, the cells were boosted as a 24-cell string at 2.35 VPC for 48 hours and floated at 2.25 VPC for 72 hours more. After-charge Internal Resistance (IR) values declined an average of 22% from received although one cell's IR actually increased 33%.

INTERNAL EXAMINATION

In order to assess the battery's aging processes, positive grids from sample cells were examined. Over the years, GNB has published data in various professional papers relating grid corrosion rates to battery design and actual life. One paper calculated the grid corrosion rate of an *Absolyte IIP* cell in float service for 5 years to be 0.036 mm/year[1]. Since the corrosion rate is a function of grid surface area, which is itself not constant, the overall rate of corrosion can be expected to decline as the available surface area decreases. The observed corrosion rate of a five-year old cell therefore, disproportionately represents the relatively large one-time corrosion associated with curing and formation at a time when the grid surface area is at its maximum. Hence, it is not surprising that the average corrosion rate of this 17-year old *Absolyte I* was found to be 0.017 mm/year, significantly less than the previously stated rate but very close to experimental accelerated life results of .020 to 0.028 mm/year. Polished photomicrographs of the positive grid cross sections appear below.

Significantly, the separator was highly saturated despite its advanced age and the low-humidity environment in which it was operated. Dryout resulting from water vapor transmissibility, excessive gassing or consumption from grid corrosion did not cause failure in this VRLA product. The negatives were also fully saturated, exhibited good shine and generally had the appearance of charged plates.

In terms of growth on length and width, the following was calculated from tear down grids:

Absolyte I Grid Measurements

Measurements of an approximately 15 year-old 75A Absolyte I cell taken 12 May 2000.

75A Specification		Average Measurements	Growth	% Growth
length non-lug side	18.500	18.886	0.386	2.1%
length lug side	18.754 calculated	18.967	0.213	1.1%
Width	5.564	5.784	0.220	3.9%
thickness	0.190	0.199	0.009	4.9%

ELECTRICAL TESTING

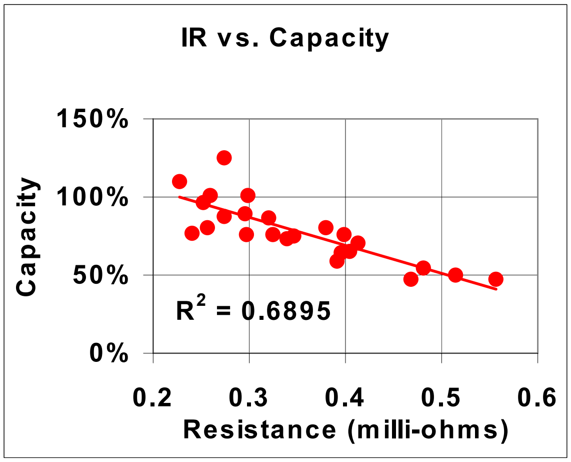
After the conditioning charge discussed above, the string was discharged at its 8-hour and 3-hour to 1.75 VPC rates and recharged with 110% of the ampere-hours removed. This data is tabulated below.

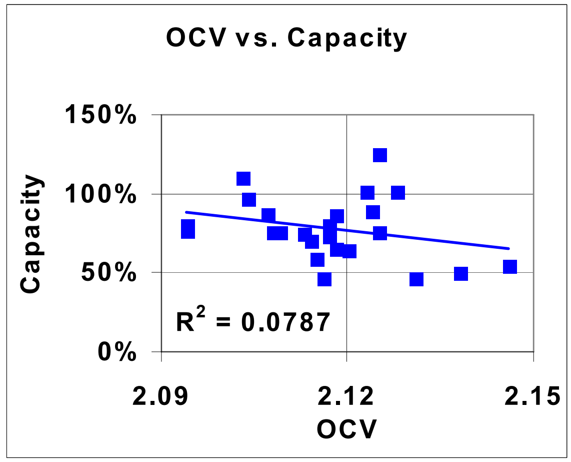
Internal Resistance and Capacity

GNB Cell #	Int. Res.	Measured Capacity 8-hour	3-hour
1	0.299	101%	96%
2	0.227	110%	100%
3	0.481	55%	33%
4	0.259	101%	33%
5	0.396	65%	96%
6	0.413	71%	53%
7	0.347	75%	54%
8	0.468	47%	75%
9	0.241	77%	78%
10	0.296	89%	93%
11	0.556	47%	30%
12	0.297	76%	78%
13	0.380	81%	77%
14	0.398	76%	57%
15	0.325	76%	80%
16	0.256	80%	83%
17	0.514	50%	36%
18	0.274	125%	108%
19	0.391	59%	39%
20	0.339	73%	81%
21	0.404	66%	58%
22	0.252	97%	100%
23	0.274	88%	87%
24	0.321	86%	79%
min	0.227	47%	30%
max	0.556	125%	108%
average	0.350	63%	48%

From this data, several points become apparent:

- As would be expected with an aged battery, the 8-hour performance was better than the 3-hour capacity.
- Although capacities varied a good deal, 71% of cells exceeded 70% and 42% exceeded 80% rated capacity.
- There was a fairly good overall correlation between internal resistance and capacity but a poor one between as-received OCV's and capacity.





DISCUSSION OF INITIAL RESULTS

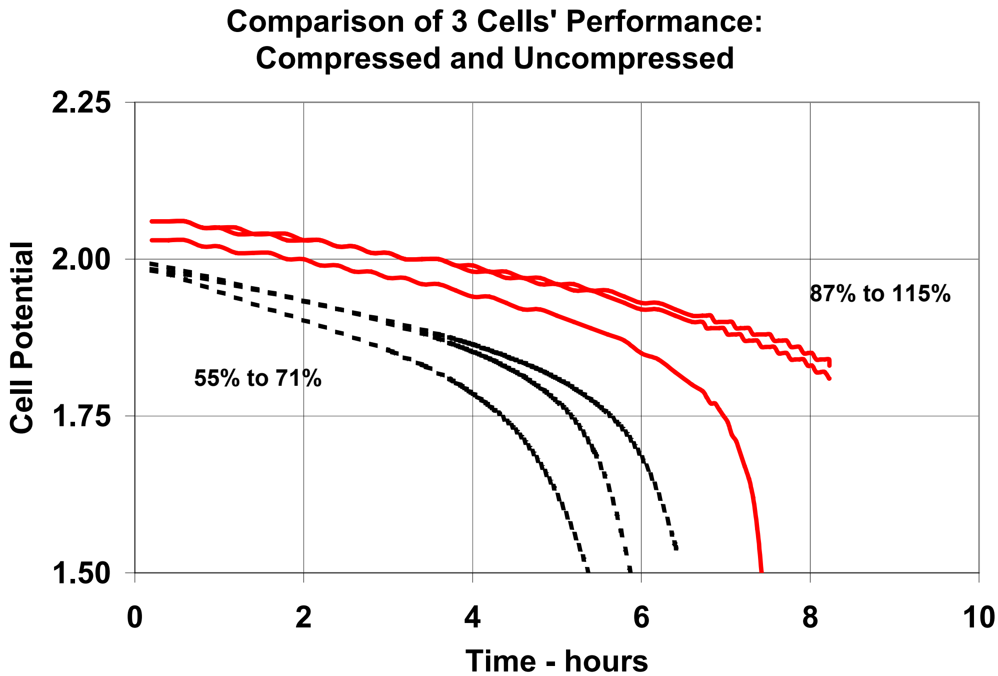
Having close to 20 years experience with Absorbed Glass Mat (AGM) VRLA cells, GNB has learned the importance of the various components contained within this complex electrochemical system. One key system performance element is the behavior of the glass mat separator during the life of the product. The glass mat separator serves three key functions in the cell. First, since it absorbs, wicks and holds most of the electrolyte, it allows for the ionic transport that is vital to electrical performance and life. Second, the separator is the medium through which oxygen transport occurs and is thus crucial to the recombination cycle. Third, because there is no reservoir of free electrolyte within the system to maintain electrical continuity, the separator must maintain intimate contact with the entire surface of the positive and negative electrodes. If this contact is lost, the internal resistance will increase (often dramatically) and the cell electrical performance will suffer.

The role of the glass mat separator on VRLA-AGM cell float and cycle life has become better understood in recent years as the topic has been explored in numerous technical studies and reports. For its own part, GNB has previously reported on separator behavior and asserts that separator functionality can make *the* difference between VRLA cells that do and do not perform at their rated capacities and for their design lives.

Separator compression loss can be manifested in two primary ways. The first occurs when the fibers of the glass mat experience slippage or other rearrangement such that the separator material acquires a permanent set resulting in loss of spring back force exerted against the plate. Separator characteristics (like fiber surface area and furnish) or design properties (such as percent compression and saturation) can influence the degree of slippage. The other primary means that compression loss occurs is from lack of proper mechanical support to the cell wall. The internal cell pressure that all VRLA cells operate with can cause the jar material to deflect. It was suspected that one or both of these means of compression loss was at play with these cells.

CAPACITY RECOVERY: OVERCOMING COMPRESSION LOSS

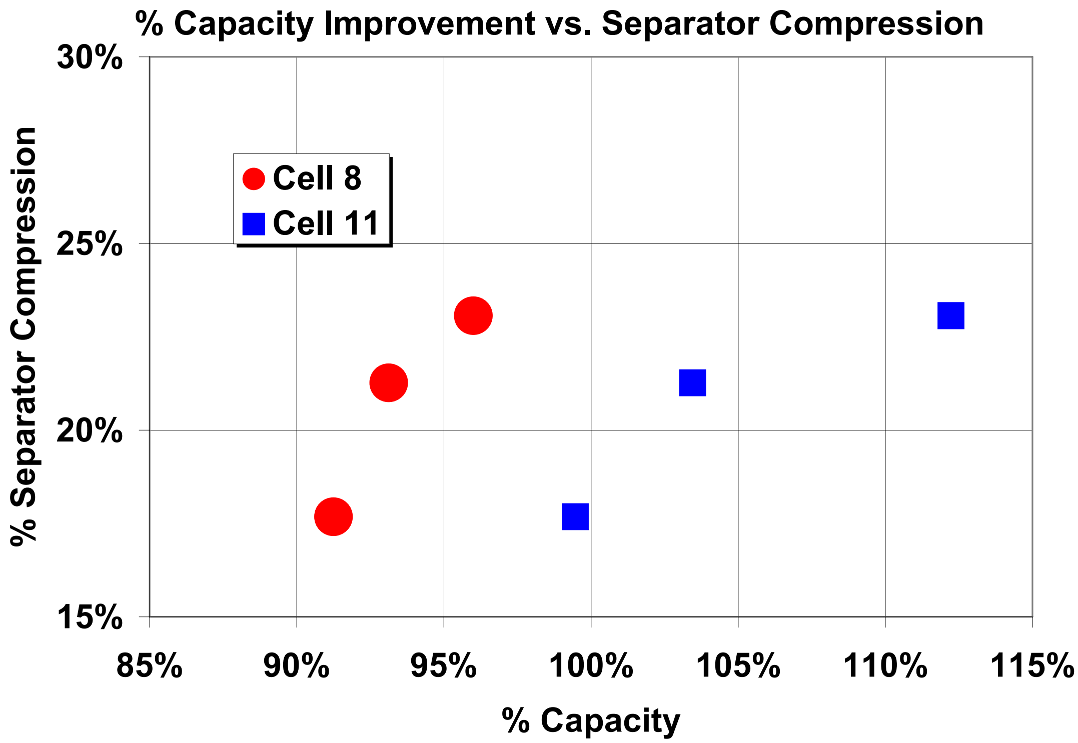
These early three-cell *Absolyte I* trays did not have steel partitions between the cells. This means that cells with lower vent opening pressures relative to its neighbors experienced more support and increased compression. Capacities of such cells tended to be better. In order to remove these interactions, a test was devised involving three of the poorer performing cells. The three cells were removed from the *Absolyte I* trays and put in a compression fixture to simulate the uniform jar wall support they would receive in a partitioned *Absolyte IIP* tray. An 8-hour discharge was performed on these cells as before. The capacity increase observed was significant.



That increased compression improved the capacities so markedly strongly suggested that the typical failure modes were not at work here. This is to say that if the cells had dried out or experienced a debilitating amount of positive grid corrosion, capacities would not be restored by increased compression. Furthermore, if negative plate self-discharge was the cause of these cells' lowered capacities, then the condition was not permanent. However, this is contrary to what much literature on the subject indicates, at least without high voltage boosts [2,3]. A more likely explanation in our view, is that the decreased capacity was due to the separator fiber slippage and / or poor physical support of the jar wall, phenomena on which GNB has extensively reported.

COMPRESSION: HOW MUCH?

Another test that dealt with compression and capacity attempted to answer the question, "how much is enough?" In this experiment two low capacity cells were put in the compression fixture with the ram just touching. The cells were discharged, recharged and the ram brought down further. This process was repeated and the capacity improvement was mapped as a function of compression.



Both of these cells had capacities of 47% in the original characterization. They finished at 96% and 100%. It is interesting to note that after the capacity topped out and the ram was brought back to the original flush position, the performance did not degrade for the two more discharges conducted.

LONG TERM FLOAT

Six of the cells exhibiting higher capacity numbers have been put on long term float. Current, voltage, half-cell potentials and temperature are being monitored. Periodic capacity tests will be performed. GNB will report on this test as it proceeds.

CONCLUSION

A very valuable battery was returned to GNB's test facility for evaluation. It was valuable because it represents a naturally aged 17 (now 18)-year old VRLA battery. From the evaluation, GNB was able to make several important assertions.

- While the battery appeared to be self-discharged, it accepted recharge at normal boost voltages.
- Observed low capacities appear to be the result of separator decompression. Increased compression dramatically improved capacities.
- Grid corrosion rates were less than projections made by extrapolating from newer cells and close to those based on accelerated life testing.

VRLA battery users have seen many problems since the introduction of the technology. Manufacturers have implemented many improvements to address these shortfalls. Like any new technology, there is a learning curve and it can be painful. The success of this 18 year-old battery should prove heartening to users and manufacturers alike. We feel that the preceding data should prove one important fact: THE TECHNOLOGY IS CAPABLE!

REFERENCES

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2. B. Dick, T. Noveske, A. Williamson, "Impact of the Internal Catalyst on VRLA Batteries One Year Later", BATTCON '99, paper 15.
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