AN EXAMINATION OF HIGH RATE RECHARGE ON ABSOLYTE IIP BATTERIES

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ABSTRACT:

Power needs in the telecommunication industry are presently undergoing rapid change. The coexistence of digital and analog systems, future build-out strategies and ever increasing data and Internet traffic throughout a network makes power planning a difficult task at best. As a reaction to this uncertainty, many in the industry are oversizing power panels today so they will meet their anticipated needs tomorrow. In such cases, after an outage and when the power plant comes back on-line, large amounts of current are available to the battery. Combined with this reality is a desire by users to rapidly bring their batteries to a high state of charge after an outage or a test. Both of these situations lead the user to value a battery which can accept high recharge currents without sustaining damage.

GNB Technologies has conducted a series of tests to examine Absolyte IIP battery charge acceptance when the available current is essentially unlimited. The testing also endeavors to evaluate harmful effects on the battery such charging could have by examining heating effects, water loss, and capacity.

INTRODUCTION:

In the telecommunication industry's early years, power needs were substantial. The relays and tubes in the state of the art switching stations of the time required large amounts of electricity. As electro-mechanical switches were replaced by semi-conductors, these devices became much more power efficient and power needs decreased. As evidence of this decrease, not so long ago, the power rooms built decades before went largely unused.

Of course, that was then.

This trend toward smaller power requirements has been reversed. Today digital systems overlay existing analog ones. Wireline that always existed now sits in parallel with wireless, broad band data for Internet resulting in large fiber network build-outs, cable TV, etc. The applications multiply. They all need power.

Providers of these services are savvy but planning power requirements even a couple of years into the future under these circumstances is challenging. One reaction to the uncertainty is to oversize power panels relative to the battery in the expectation that the site will "grow into" the load. This strategy results in systems where the battery can see much larger in-rush currents after a power outage than previous designs. On the other hand, battery manufacturers generally recommend that the charge current be limited to 18 to 30 amps per hundred ampere-hours of the battery's 8-hour capacity. These competing interests can cause uncertainty for the power planner.

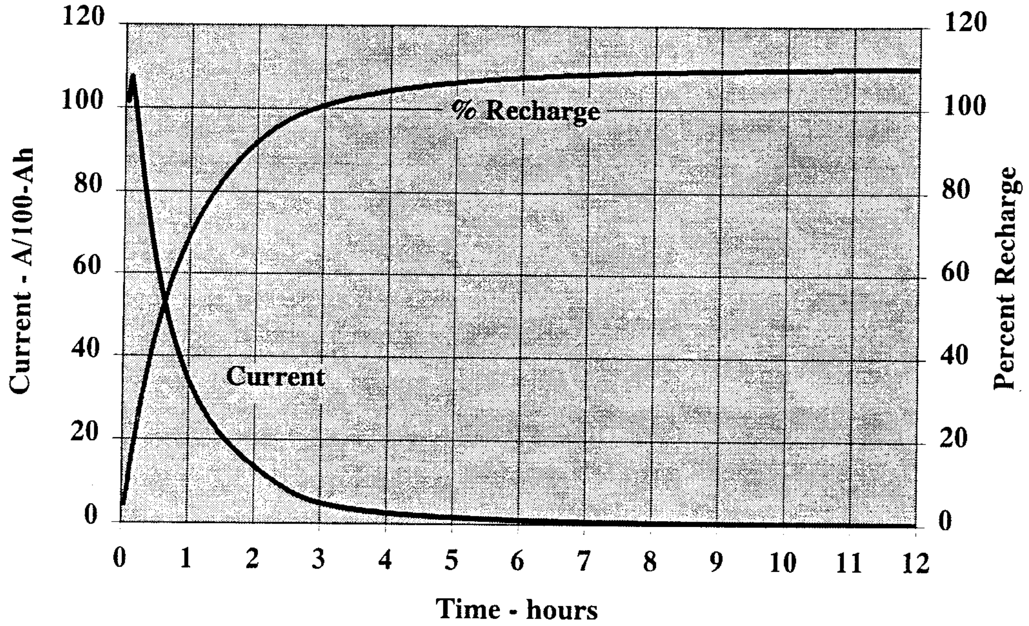
GNB Technologies has conducted a series of tests to characterize the behavior of its Absolyte battery subjected to conditions that would simulate high recharge currents. The testing also attempted to determine if the battery was harmed in any way by these large currents.

TEST ONE: SINGLE MODULE TESTING, MULTIPLE CURRENTS

The first test was designed to characterize the voltage and current acceptance behavior of an Absolyte IIP module. The battery tested was a single, series-connected, six-cell 264-Ah 50A11 module. The charge voltage was always 2.35 VPC although a number of different current limits were imposed. The testing also attempted to determine if the cells were sustaining damage from the high recharge currents. This was done by monitoring weight loss that would signal a decrease in saturation (i.e. water loss), impedance, and most importantly, capacity throughout the testing. In addition, temperature stability (i.e. signs of thermal runaway) and external physical appearance were observed.

After discharging the 12 volt module 100% at its 8-hour rate, the battery was recharged at 2.35 VPC and with a current limit of 50, 100 and 150 amperes per 100 ampere-hours of capacity at the 8-hour rate respectively. Also examined were the behaviors at 12, 24, 36 and 72 A/100-Ah. A total of 9 cycles were put on the battery with six of them at 50 amps per 100 A-h or higher. A typical recharge curve at 150 A/100-Ah of available current follows:

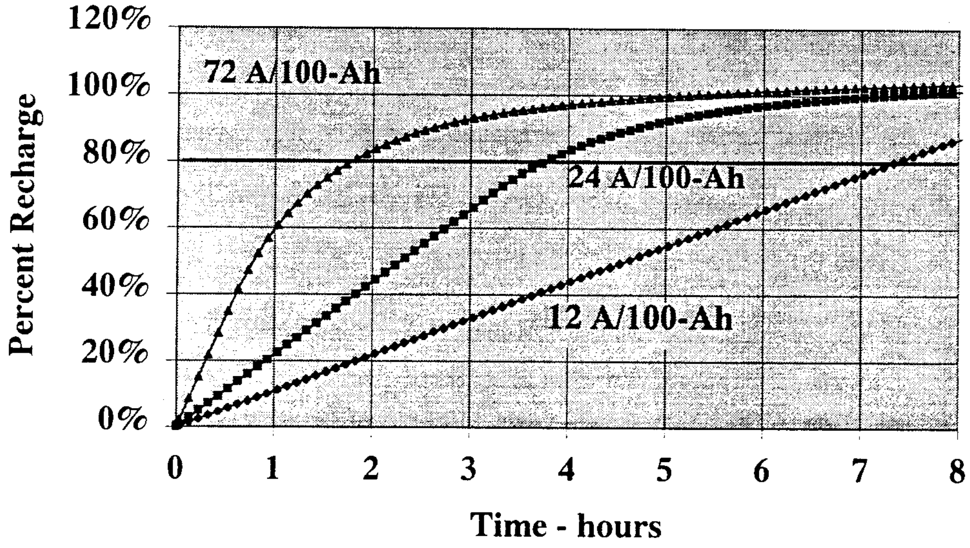
Recharge Behavior at 2.35 VPC 150 A/100-Ah



As expected, the period of time that the battery accepts the highest charge current is brief. Charge efficiency is very high during this time and the state of charge rises rapidly. As the battery become "full", its charge acceptance decreases and its current asymptotically approaches float level for the given voltage. It is interesting to note, that although 150 A/100-Ah was available, this battery only accepted 109 A/100-Ah. The data indicates that the cell's internal resistance limited the amount of current that it could accept.

In terms of the amount of time that it takes to recharge a battery at higher vs. lower available charge currents, the difference is significant. For example from the data below, 80% recharge at 12 A/100-Ah available current takes about 7.3 hours—nearly twice the amount time it takes with 24 A/100-Ah available (3.8 hours), and over four times that with 72 A/100-Ah (1.8 hours). If rapidly returning the battery to a high state of charge is desired, higher available charge current is clearly beneficial.

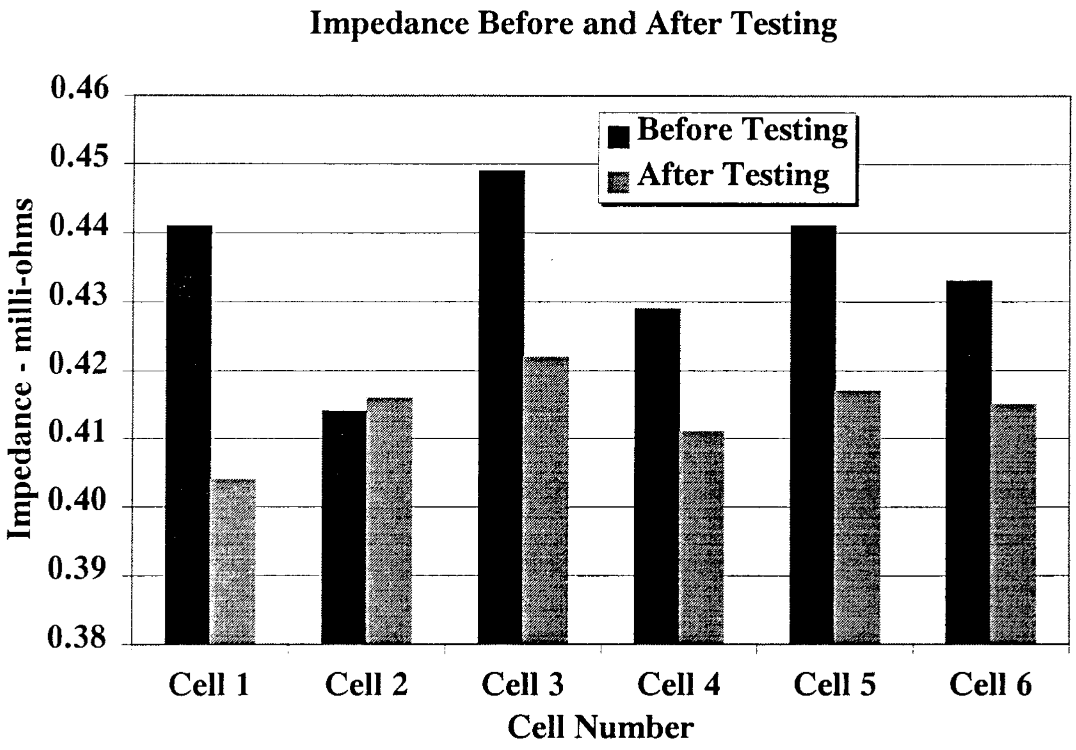
Recharge Time with 12, 24 and
72 A/100 A-h Available Charge Current



During these tests indicators of battery health did not suggest that the battery was harmed by the high in-rush charge currents. Impedance at the finish of testing *decreased* from initially recorded values an average of 5%. As these were brand new cells from the plant, it was expected that their relative cell saturation would be high and some water loss would be normal. Indeed after some initial loss, the saturation decrease stopped. The higher and lower numbers from trial to trial suggest the changes were so small that our equipment could not accurately measure the minute amounts of water lost. Impedance and saturation change data is presented below. Lastly and most importantly, capacities at the 8-hour rate, before and after testing increased from 100% to 106%.

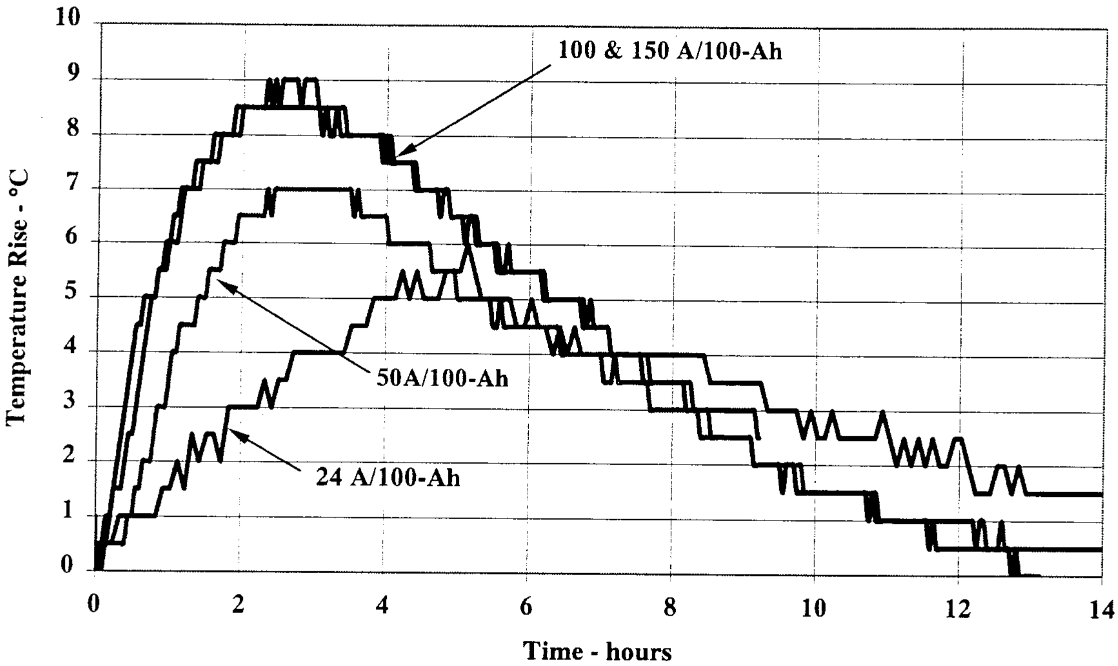
Cumulative Saturation Change

Current	Trial	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
50 A/100-Ah	**ΔSaturation1**	**-0.10%**	**-0.20%**	**-0.24%**	**-0.24%**	**-0.13%**	**-0.10%**
100 A/100-Ah	**ΔSaturation2**	**-0.17%**	**-0.30%**		**-0.30%**	**-0.27%**	**-0.17%**
150 A/100-Ah	**ΔSaturation3**	**-0.17%**	**-0.34%**	**-0.37%**	**-0.27%**	**-0.13%**	**-0.13%**
50 A/100-Ah	**ΔSaturation4**	**-0.13%**	**-0.30%**	**-0.37%**	**-0.27%**	**-0.10%**	**-0.17%**
150 A/100-Ah	**ΔSaturation5**	**-0.17%**	**-0.37%**	**-0.34%**	**-0.24%**	**-0.13%**	**-0.13%**



Examination of thermal effects is examined in more detail in the next test but it was desired to compare the temperature rise at the various available current levels during the inherently exothermic recharge process. The results presented below are hardly shocking but nonetheless informative: Lower current levels resulted in less heating. It can be surmised that the 100 and 150 A/100-Ah rises are indistinguishable because as noted earlier, the latter did not take all of the current that was available, taking not quite 10% more than the former. The data demonstrated that the heat rise was a transient effect and that the maximum 9°C temperature rise was gone in about 12 hours.

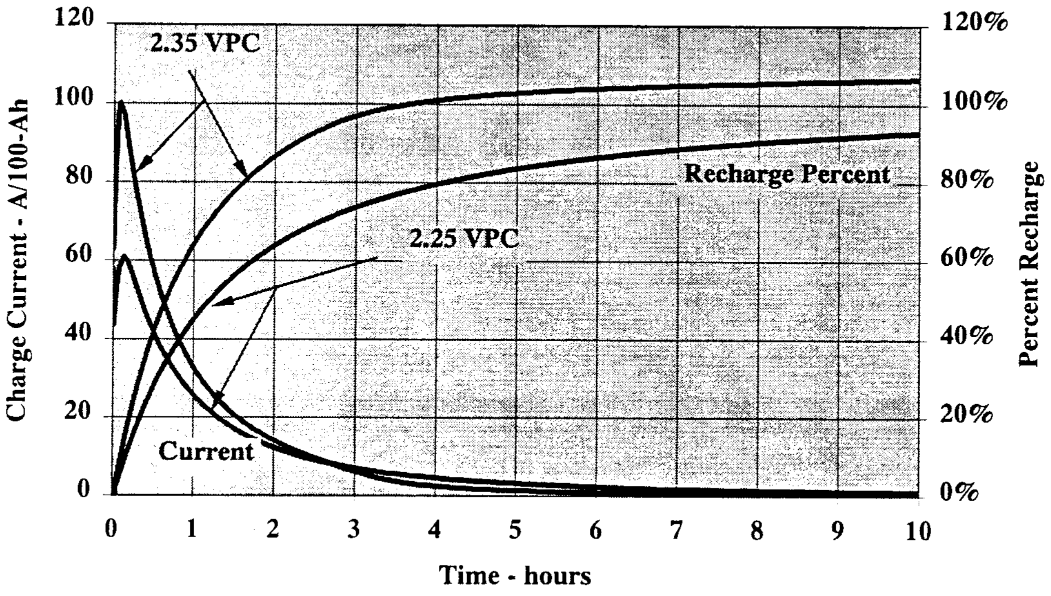
Temperature Rise at Various Charge Currents



TEST TWO: 48 VOLT SYTEM TESTING

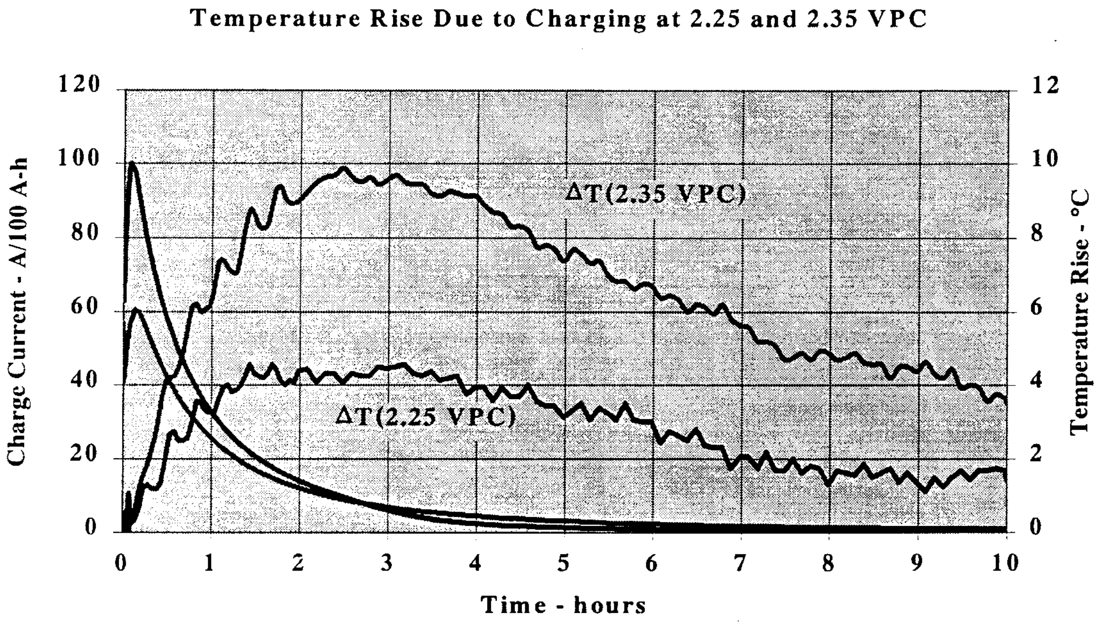
Where the first test concentrated on charge characterization at GNB's recommended equalize voltage, the second test sought to compare this charge behavior to that at the battery's recommended float voltage. It also would examine the heating effects of high charge on an entire four-module, 48 volt system, rather than just a single module. For this test, a 48 volt 50A11 264-Ah battery was again discharged to 100% depth of discharge at its 8-hour to 1.75 VPC rate. The battery arrangement consisted of six cells in a module, four modules stacked to create the system. One thermocouple was placed into each of the four modules and two thermocouples monitored ambient temperature. Recharge current was limited to 100 A/100-Ah and occurred at 2.25 VPC and 2.35 VPC. The following graph compares the rate of recharge at the two voltages.

Recharge at 2.25 and 2.35 VPC; 100 A/100 A-h Current Limit



Again nothing terribly surprising happened here. As expected, the battery at higher charge voltage recharged more rapidly. Quantitatively, how much faster the battery recharged is of interest. For example, 80% recharge occurred in less than half the time at 2.35 vs. 2.25 VPC (1.6 vs. 4.0 hours) and 90% recharge is more than 3 times faster (2.3 vs. 7.8 hours). At 2.35 VPC, the charge current merely kissed the current limit line before receding. In all, the battery only dwelled for about 3 minutes at the current limit or within 5% of it. Contrasting , at 2.25 VPC, the battery never even approached the current limit, reaching a maximum of 61 A/100-Ah. As previously concluded, the battery's internal resistance effectively self-limits the charge current even if more current is available.

As noted above, the test battery consisted of a single stack of four modules with a thermocouple placed into each module and two more monitoring ambient temperature. The difference between ambient and maximum battery temperature is depicted below. All testing occurred at a room temperature of approximately 25°C.



This portion of the testing demonstrated the intuitive notion that both temperature rise and charge acceptance is higher at a higher charge voltage. Defined as in-rush current admitted by the battery, charge acceptance at 2.25 VPC float was shown to be only 60% of what it is at 2.35 VPC while the temperature rise for the former was half that of the latter. In any event, the transient 10°C rise from ambient is not of significant concern. Within 10 hours and while still on charge at 2.35 VPC, the battery temperature had dropped to within 4°C of ambient and was decreasing at a rate of approximately 0.9°C/hour. Temperature increases on the order of 8°-10°C during 2.35 VPC recharges are typical. Having said this, it should again be emphasized that this testing occurred at approximately 25°C. More caution must be applied to a high rate charge regime when the ambient temperature is already elevated, in order to avoid the point where the heat generated exceeds the battery's ability to dissipate it. Additional studies should be conducted to evaluate the impact of initially elevated ambient conditions.

Mapping the location of the maximum temperature attained shows that the highest values occurred in interior modules, not at the top or bottom.

Maximum Attained Temperatures (°C)

module		2.35 VPC	2.25 VPC
1	Top	33.5	28.0
2		34.0	28.5
3		34.5	29.0
4	Bottom	32.5	28.0

It is important to note that as in the initial test using only a single module, these cells suffered no capacity or impedance degradation as a result of exposure to charge conditions of 2.35 VPC and currents up to 100 A/100-Ah. The final capacity of this battery system was in excess of 104% at the 8 hour rate.

SUMMARY

The two tests together reveal some interesting things about how an Absolyte IIP battery recharges from a worst case 100% depth of discharge from a controlled temperature baseline.

- A maximum in-rush charge current acceptance at a given voltage was limited by the battery. A discharged battery will not accept infinite amounts of current. Additional testing on larger capacity cells would be interesting but for the physical limitations (namely charge capacity).
- Both the current limit and charge voltage strongly affected recharge time.
- High rate recharge, up to 150 A/100-Ah, resulted in an acceptable transient temperature rise.
- The battery health indicators monitored in this test demonstrated that the GNB Absolyte IIP was not harmed by a high rate recharge practice. These indicators included impedance, water loss and capacity.