Float Control of the Negative Plates in VRLA Batteries With the MAXIMIZER™

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Background

During the last five to six years, there have been numerous papers and presentations bringing attention to the various problems with VRLA batteries. There were some reports noting the high percentages of the VRLA cells failing with low capacity and correlated by means of conductance readings.[1] The C&D product had not been included in most of those studies since C&D TECHNOLOGIES did not start building what was known as 20 year design life AGM product until 1992. C&D Technologies had been building VRLA (Valve Regulated Lead-Acid) batteries since 1984 using both AGM (Absorbed Glass Mat) starved electrolyte (Liberty 1000) and a patented Prelyte™ (Gel) technology (Liberty LST).

When we discuss VRLA AGM type batteries, we first need to define what we mean when we state "20-year design life". The conventional method of predicting lead-acid battery life is based on positive grid corrosion. That is the time it takes for the positive grids to both corrode and grow to the point that this combination of loss of grid conductivity and loss of contact between the grid and active materials, results in cell capacity dropping below 80% of rated capacity. This has been the basis for life projections for flooded lead-acid batteries and is typically verified by accelerated life testing at elevated temperatures. The problem for the VRLA products is that the grid corrosion has not been the major cause of failure.

When C&D introduced the Liberty 2000 as a "20 year design life" product in 1992 we were convinced that we had addressed all the problems, especially the mechanical design and environmental problems manufacturers were having with VRLA product. We believed we truly had a product that could be expected to last 15 to 20 years. [2] This was a product designed from essentially a blank sheet of paper as primarily a Telecom standby battery. The design life is based upon the results of accelerated life tests, performed in accordance with Bellcore TR-766. To date, this product has shown excellent performance without the previously reported premature failure modes, e.g. leaks, lack of compression dry-out etc.

Since 1994, there have been several papers written which indicated there may be other causes for VRLA failures than both manufacturers and users realize.[3,4] C&D had been skeptical of some of the statements and conclusions, e.g. dry out and degradation of the negative plates, but never-the-less began extensive testing and verification of the reported problems. By testing product in the field, and verifying that more was happening to VRLA products than we could readily explain (capacity performance falling off faster than was expected or could be explained), C&D looked for better understanding and solutions. We did find that, although there was "fall off" most, if not all the loss in capacity, could be recovered by high voltage charging, and/or cycling. Much of this effort included bringing cells back to the lab for conditioning. This however, was not an acceptable answer for our customers, because while possible, it was not practical to charge the VRLA cells at the voltage levels necessary to get the cell capacity restored.

Control of the Negative Plates

For the last two years C&D has worked very closely with Mr. W.E.M. Jones and Philadelphia Scientific. This relationship involved the test and evaluation of the use of an internal catalyst and its ability to control the negative plate polarization in a VRLA battery. This paper will discuss our findings as well as provide information on the introduction of this catalyst into a production product. The results of our testing have been extremely positive, and now, we have every reason to believe we have made another major leap forward in the state-of-the-art for VRLA batteries. This has been accomplished with the introduction of the "**Maximizer™**" vent to the Liberty 2000 product line. The "**Maximizer™**" is an internal catalyst technology incorporated into patent pending vent cap designs. It is the belief of the R&D team at C&D TECHNOLOGIES, that the use of these catalyst vent caps will enable the batteries to provide a consistent high performance level. The batteries are expected to maintain a consistent level without the need for external intervention such as high voltage charging or cycling, for its design life, while enhancing the features already built into the product.

The research team believed that when a VRLA battery is designed and built well, it would perform well with minimal problems. The research team believed that by using batteries in conditions, for which they were not intended caused many of the problems with the VRLA batteries. However, since the introduction of C&D's "20 year design life product", almost six years ago, we have learned much more about the operation of VRLA products in what we would consider good operating environments. We have shown that it is possible to build a product that would not suffer from the high rate of premature failures reported on at every INTELEC conference. However, results from field-testing of product have confirmed that there is more happening to VRLA batteries in operation, then we fully understood.

One very important finding is that when a very high efficiency recombinant battery is produced, the recombining of oxygen at the negative plates of a cell will over time, result in the self-discharge of the negative plates. This condition occurs when operating at normal recommended float voltages and verifies claims made by Mr. Jones[3] and Dr. Brecht[4]. While we can verify polarization conditions on the negative plates with the use of third electrodes embedded into the cells, this is not possible with those batteries in use at customers' facilities. When we are in the field, we have been able to check string float current as well as impedance, resistance or conductance. This information does provide an indication of potential "fall off in battery performance. With the help of Mr. Tom Croda of Sprint, we were also able to determine the state of charge of cells in his test facility. We checked 10/92 vintage (550 AH cells) by putting the cells, whose impedance had risen more than expected, on open circuit. These cells were maintained at the recommended float voltage, 2.26 volts per cell. The data clearly demonstrates, that the cells are in various stages of discharge. Since these batteries were not maintaining a load it is a reasonable to assume that the discharge is occurring at the negative plates. See Table 1 below. I will not go into a discussion on tafel characteristics (the log linear slope of voltage verse current) for VRLA batteries in this paper since this topic has been covered, directly and indirectly, many times in the past. "Oxygen recombination" prevents the negative plates from reaching "top of charge", so therefore almost all the overcharge polarization in a VRLA cell is on the positive plates.

	08/11/97 O.C.Volts	08/01/97 O.C.Volts	07/30/97 O.C.Volts	07/25/97 Voltage
1	2.139	2.100	2.183	2.265
2	2.126	2.091	2.175	2.256
3	2.134	2.089	2.172	2.252
4	2.147	2.089	2.173	2.269
5	2.159	2.138	2.201	2.299
6	2.136	2.083	2.180	2.262
7	2.143	2.092	2.182	2.263
8	2.149	2.124	2.185	2.288
9	2.148	2.090	2.174	2.254
10	2.123	2.074	2.167	2.243
11	2.126	2.076	2.166	2.245
12	2.130	2.072	2.172	2.252
13	2.138	2.079	2.175	2.257
14	2.156	2.104	2.180	2.260
15	2.137	2.077	2.170	2.249
16	2.139	2.080	2.172	2.252
17	2.146	2.085	2.175	2.256
18	2.143	2.087	2.182	2.260
19	2.150	2.101	2.191	2.275
20	2.151	2.129	2.191	2.291
21	2.135	2.083	2.175	2.257
22	2.129	2.082	2.172	2.250
23	2.140	2.081	2.174	2.253
24	2.159	2.113	2.187	2.272
String Average	2.141	2.092	2.178	2.262

Table 1

While it is possible to reverse this degradation with periodic boost charging, this solution is not easily accomplished, and in most cases it is not possible without taking a battery string off line. These cells were boost charged at 59 volts or 2.46 volts per cell for approximately 24 hours. After taking the open circuit readings a few days later, it is noted that the cells have improved but they are still not fully charged. A look at the impedance readings also shows some improvement. See Table 2 below.

Cell Number		1	2	3	4	5	6	7	8	9	10	11	12
07/25/97	**AC mOhms**	0.600	0.677	0.731	0.594	0.697	0.733	0.594	1.100	0.491	0.508	0.536	0.446
08/09/97	**AC mOhms**	0.360	0.641	0.744	0.671	0.878	0.338	0.551	0.453	0.453	0.493	0.513	0.448

Cell Number		13	14	15	16	17	18	19	20	21	22	23	24
07/25/97	**AC mOhms**	0.490	0.510	0.701	0.611	0.651	0.556	0.500	0.602	0.596	0.705	0.592	0.649
08/09/97	**AC mOhms**	0.481	0.507	0.644	0.556	0.596	0.384	0.344	0.827	0.580	0.711	0.624	0.416

		String Average
07/25/97	**AC mOhms**	0.620
08/09/97	**AC mOhms**	0.551

Table 2

High rate "boost charging" has been done many times in C&D's labs on groups of high impedance cells that were brought back from the field. In our labs, we typically charge at 2.5 volts per cell for approximately 24 hours. We have been able to improve both cell capacities and cell impedance. However, the cells would drop off again over the ensuing months or years.

We have now found that with the use of an internal catalyst, the VRLA product now has the potential to live up to its hype. At C&D this is being accomplished with the introduction of the Maximizer™ to the Liberty 2000 product.

The MAXIMIZER™

There have been a number of papers presented at recent technical symposiums that explain the actions of a catalyst when used with a lead-acid battery. One of the most recent is by Mr. Jones[5]. Catalyst vents have been used for years for both flooded lead-acid as well as flooded NiCad batteries to prolong watering intervals. **The Maximizer™ vent that is on the Liberty 2000 product is internal to the VRLA cell and has four distinct direct benefits to the product along with a number of indirect benefits.** Some of the test results that follow have been gathered to verify our beliefs both in our laboratories and in the field.

Four Major Benefits of the Maximizer™

1. PERFORMANCE IS IMPROVED THROUGHOUT LIFE

The fact that some of the oxygen is being recombined at the catalyst and not at the negative plates **allows the negative plates to achieve and maintain a full state of charge**. C&D has verified the increase in negative plate polarization with third electrode measurements as shown on Figure 1.

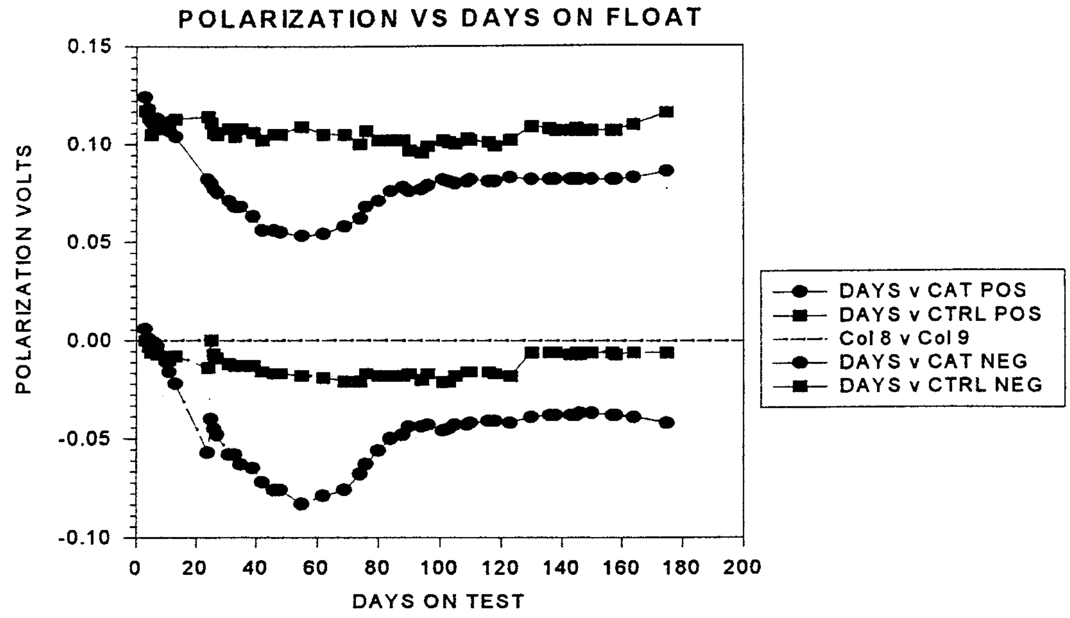

Figure 1

It is not easy to observe improvement in negative plate performance with cells in use at customer locations. However, the improvement in cell impedance, resistance or conductance as well as string current, can be easily monitored. Below in Table 3, are before and after readings from three sites that had the Maximizer™ vent caps installed in the field. One of the sites was the Sprint Test Lab. While not shown in the table below, the current is being monitored at the San Mateo site. Prior to the addition of the Maximizer™ vents the current had been at 690 milliamps. A day after the catalyst was instaled the current was down to 590 milliamps. Mr. Croda had informed me on March 24, 1998 that the current had decreased to 360 milliamps.

This would indicate that the cells have continued to improve and charge back from the reduced state of charge.

Cell	San Mateo 02/11/98 AC mOhms w/Catalyst	HD-500 Mfg 10/92 02/10/98 AC mOhms	Plymouth 3/11/98 AC mOhms	HD-1300 Mfg 11/93 3/16/98 AC mOhms	Coatsville 3/11/98 AC mOhms	HD-700 Mfg 7/92 3/16/98 AC mOhms	Plymouth 3/11/98 AC mOhms	HD-700 Mfg 7/94 3/16/98 AC mOhms
1	0.322	0.796	0.214	0.141	.0147	0.127	0.594	0.166
2	0.334	0.754	0.209	0.144	0.177	0.127	0.211	0.169
3	0.338	0.852	0.174	0.133	0.202	0.120	0.184	0/173
4	0.322	0.817	0.157	0.120	0.149	0.118	0.146	0.157
5	0.389	1.022	0.191	0.168	0.203	0.174	0.190	0.158
6	0.320	0.885	0.195	0.144	0.224	0.194	0.194	0.172
7	0.327	0.650	0.209	0.168	0.281	0.179	0.205	0.175
8	0.397	1.506	0.192	0.134	0.184	0.168	0.216	0.149
9	0.328	0.522	0.180	0.130	0.177	0.138	0.154	0.138
10	0.332	0.576	0.174	0.129	0.217	0.135	0.165	0.135
11	0.327	0.601	0.155	0.114	0.202	0.141	0.131	0.154
12	0.327	0.502	0.083	0.127	0.178	0.134	0.124	0.147
13	0.327	0.538						
14	0.330	0.568						
15	0.332	0.763						
16	0.332	0.669						
17	0.321	0.669						
18	0.321	0.716						
19	0.316	0.740						
20	0.978	0.935						
21	0.332	0.722						
22	0.343	0.929						
23	0.332	0.728						
24	0.332	0.899						
String Average	0.361	0.765	0.178	0.138	0.208	0.153	0.210	0.156

Table 3

2. POSITIVE GRID CORROSION IS REDUCED EXTENDING LIFE

At constant potential float, this increase in the potential at the negative is complemented by a **corresponding decrease in the float potential at the positive plates**. The decrease at the positive has also been verified with the use of third electrodes as shown on Figure 1. The effect of polarization on positive grid corrosion had been the result of a number of past studies. See Figure 2 below.

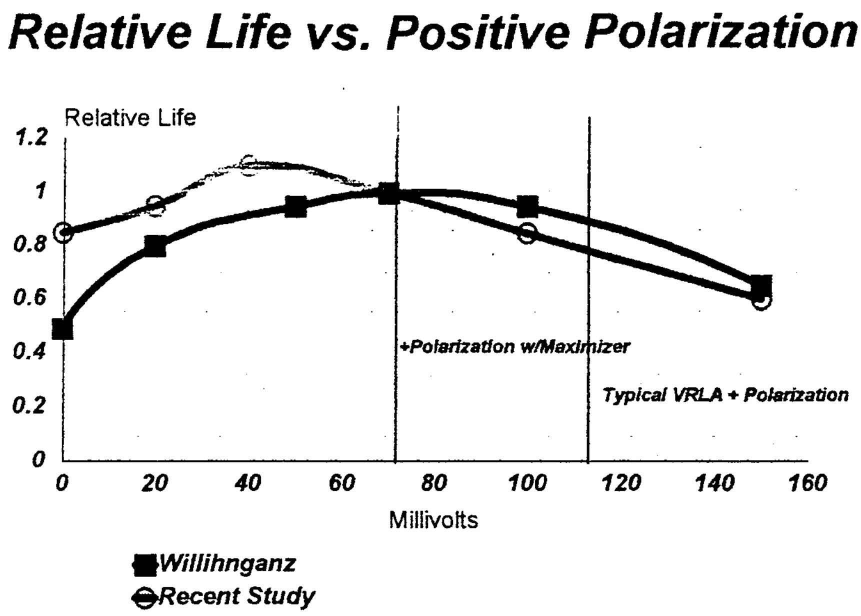

Figure 2

3. WATER LOSS IS NO LONGER A MAJOR CONCERN FOR VRLA

The VRLA cell recombines most of the oxygen given off by the positive plates of a cell in a fully charged state. However, water is still lost from the cell due to the loss of hydrogen given off from:

a) Corrosion of the positive grids
b) Self-discharge of the negative plates due to the high level of recombination at the negatives.

Hydrogen will be released through periodic venting by the safety vent or lost through the jar walls. **The catalyst recombines the hydrogen and some of the oxygen given off at the positive plates, thereby greatly reducing the water loss from a VRLA cell.**

4. REDUCES POTENTIAL FOR THERMAL RUNAWAY

The reduction in the percent of recombination occurring at the negative **plates reduces the current of recombination and the current required by the battery**. There is no reduction in total recombination efficiency as the oxygen not recombined at the negative is recombined at the catalyst. There is a corresponding **reduction in exothermic heat generation.** See current vs. time for catalyst cells as compared with non-catalyst cells shown in Figure 3.

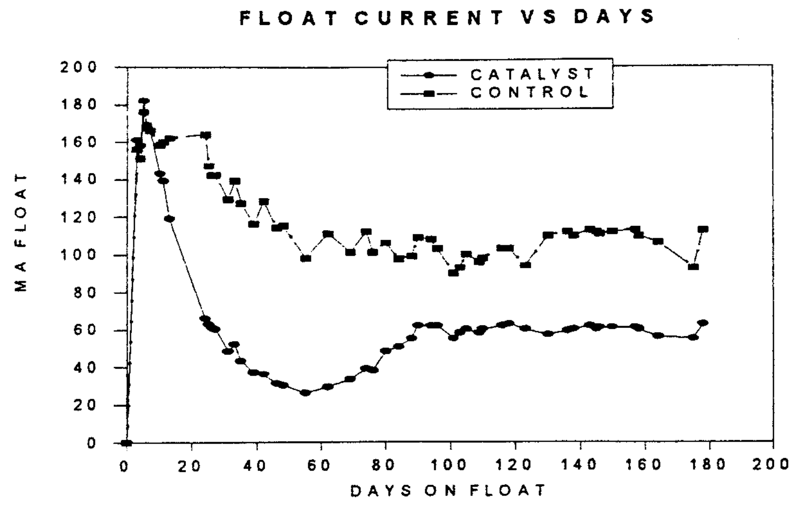

Figure 3

The results to date show the MAXIMIZER™ is a tremendous improvement in the state-of-the-art for VRLA batteries. However, it must be re-emphasized that all previous recommendations and concerns for VRLA products are still valid and that misuse, high temperature operation etc. will still have more detrimental effects on VRLA products then on flooded lead-acid batteries.

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