Pure Lead Plus Technology for Ultra High Rate Service in UPS and Standby Power Applications

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***Abstract*—Emerging uninterrupted power supply (UPS) battery applications require longer service life with greater power all while reducing environmental footprint. Application benefits of operating stationary batteries at higher ambient temperatures can significantly reduce the total cost of ownership (TCO). Prior to recent advances in battery technology, operation of a UPS lead acid battery system at high temperatures led to a rapid and unrecoverable loss of battery capacity. The advent of the C&D Technologies, Inc. Pure Lead Plus Technology, permits longer service life at higher temperatures and higher discharge rates. In addition, the technology reduces electrolysis and oxygen recombination, operates at a lower float current, and allows for extended storage periods, which positively impacts safety, and reliability.**

Keywords—Lead Acid, Pure Lead, High Rate, UPS, VRLA, Charge Acceptance, Charge Efficiency

I. Introduction

In the marketplace, “Pure Lead” originally referred to the use of ultra-high purity lead for lead acid battery manufacturing, in both the active materials (PbO) and the POS and NEG grids. One of the first “Pure Lead” products was the AT&T™ Round Cell, which was a large flooded vented lead acid (VLA) cell manufactured by C&D Technologies until the year 2010 for telecommunications applications. Using high purity materials and high purity oxides reduced gassing reactions on float charge, thus reducing the need for watering intervals, and pure lead grids limited corrosion, particularly intergranular corrosion of the positive grid. At the time of its development, most lead acid batteries were using either antimonial alloys for the grids or high Ca alloys (Ca >0.067%)[1]. The antimonial alloys leached high levels of impurities (Sb, As, Cu, etc.) into the electrolyte which migrated to the negative electrode, causing depolarization and increased gassing, subsequently increasing service frequency. The high Ca alloys resulted in increased intergranular corrosion (IGC) rates, due to higher reactivity from the precipitation of Ca intermetallic at the grain boundaries and typical surface defects the existing casting technologies introduced into the parts. Later special production methods were developed to improve the grain structures of Ca alloys such as the use of bottom pour casters and die casting. These process methods greatly reduced IGC due to the improved casting quality of the grids.

The next generation of pure lead products were the Gates “round cell”, which was a spiral wound valve regulated lead acid (VRLA) cell. This technology relied on pure Pb grids for ease of processing the spiral cells, which requires significant mechanical deformation during the assembly of the cylindrical cell, and had the added benefit of the inherent improved IGC properties associated with Pb and PbSn alloys for the positive grid.

The next evolution in VRLA pure Pb technology was initially marketed as the MSE technology. MSE technology, introduced by C&D Technologies in 2007, relies on ultra-high purity active materials and proprietary processing methods of the active materials to make a VRLA cell act similar to a flooded cell in terms of its float charge behavior. MSE technology was released by C&D under the product brand ms-EndurII®. The resulting 2V product is one of the most robust and longest lasting 20-year design life VRLA batteries on the market today. In comparative tests, the ms-EndurII outperforms other 2V VRLA products as shown in Fig 1. C&D continues to produce ms-EndurII product and has expanded the 2V VRLA product line with the Liberty® MSE product family[1].

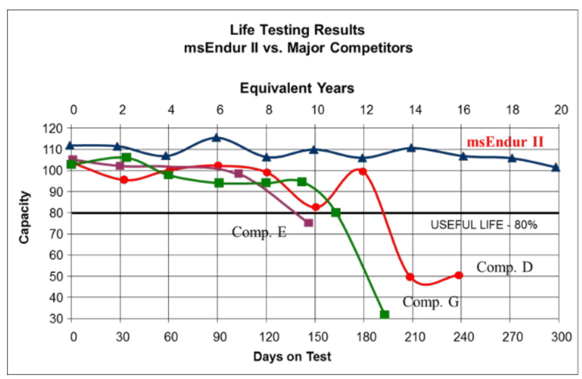

FIG 1 C&D MS-EndurII 71^{O}C Accelerated Float Life Testing Comparison to Major Competitors. Measured 8 hour rated capacity to 1.75VPC versus days on float test[2].

Since the introduction of the MSE technology, C&D Technologies has adapted the materials and processes to create two new products for the standby power market. The High Temperature (TEL-HT) series, designed for uncontrolled environments, especially in telecom applications, and the Pure Lead Plus (PLP) series. The premise for the development of the PLP was to design a battery with ultra-high-power capability, enhanced service life and increased resilience in high temperature applications.

II. High Rate UPS Application Failure modes

The definition of a high-power, short duration discharge, standby power system has traditionally been synonymous with reduced service life, when compared to longer duration systems, especially as it relates to warranty. The trade-off between power and service life for VRLA batteries is institutionalized within the industry to the extent that IEC 60896-21 (2004) provides guidelines for service life, Section 6.16 Requirement for the impact of a stress temperature of 55°C or 60°C (Section 6.16.2 Table 20) where the requirement at a fifteen minute (4C) discharge rate is approximately 50% of the three hour (C/3) discharge. As the aging factors within a VRLA cell are a function of operating temperature, the logical conclusion of the IEC requirement is that aging factors impact the high power capability of a VRLA cell, having twice the impact as compared to the lower rate discharge performance.

This relationship is well understood as one of the primary consequences of aging within VRLA cells is the increase of the cell's internal resistance. From this premise, it is easy to calculate the influence the aging factor has on the cell at specific discharge rates.

Equation 1. $V = I * R$
Equation 2. $R = R_o + R_{age}$

Based on these equations, the impact of aging at a C/3 rate versus a 4C rate should have a relative increased influence of ~12 times. For most aging mechanisms, the consequence to the cell is increased internal resistance. Furthermore, most aging mechanisms directly or indirectly influence each other, leading to the well-established non-linear performance versus time curve for VRLA cells. At high discharge rates, this non-linear behavior becomes even more pronounced. Fig 2 illustrates the typical performance versus service life for a VRLA cell at high discharge rates.

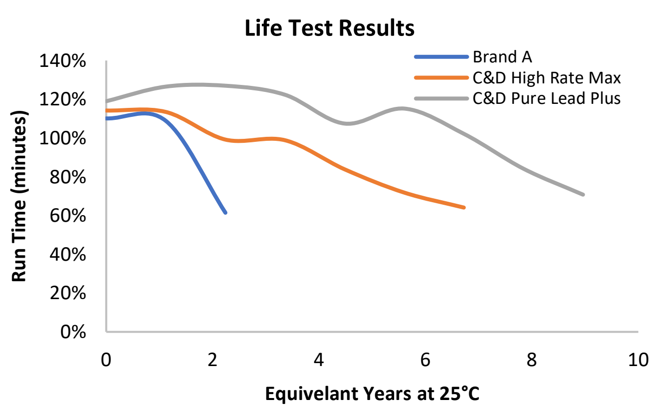

FIG 2 60°C Accelerated Float Life Testing Comparison to Major Competitors. Measured 15 Min rated capacity to 1.67VPC versus days on float test[1].

The mechanisms which cause reduced service life of a UPS VRLA battery are shown in Table 1. Although simplistic, the table illustrates the interrelationship between the mechanism and the general trend towards increased cell resistance for all of them either directly or indirectly.

Table 1. Typical Aging Mechanisms and Consequences for Standby VRLA batteries

	Aging Mechanism	Direct Consequences	Indirect Consequences
1.	Positive Grid Corrosion – Intergranular Corrosion	Electrolyte consumption, Decreased Conductivity	Increased Resistance
2.	Electrolyte Consumption	Dry-out, Decompression	Increased Resistance, Increased Recombination
3.	Increased Recombination	Negative De-polarization, Positive Polarization	Increased Current Acceptance
4.	Increased Current Acceptance	Increased Positive Grid Corrosion (See point 1)	Increased Resistance, Electrolyte Consumption (see point 2)

III. Influence of pure Lead Plus and MSE technology

Oxides used in VRLA batteries have a significant and direct impact on battery performance and service life. C&D uses a proprietary Ball Mill Oxide made with ultra-high purity positive and negative active materials in addition to specialized processing techniques. This recipe creates a well-balanced cell that operates with reduced float current, as shown in Fig 3 & 4,

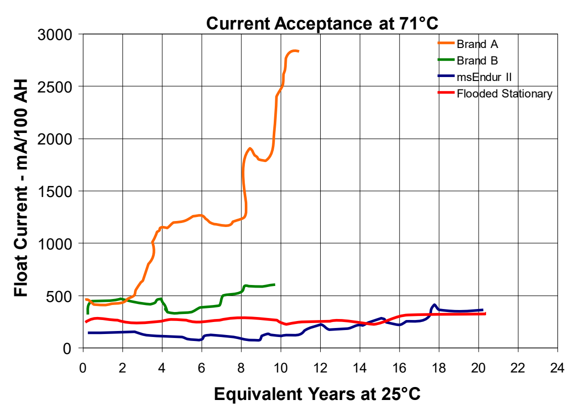

FIG 3 C&D MS-EndurII 71°C Accelerated Float Life Testing Comparison of current acceptance during float test. Comparison of MSE technology (ms-EndurII) versus PbCa VLA technology (Flooded Stationary), competitive VRLA products (Brand A & B).

similar to a flooded cell, slowing grid corrosion and limiting water loss. Extended service life is a function of the lower corrosion rate of the positive grid alloy and the shift in polarization of the electrodes resulting from the engineering of the active materials. The net effect is that Pure Lead Plus formula extends service life.

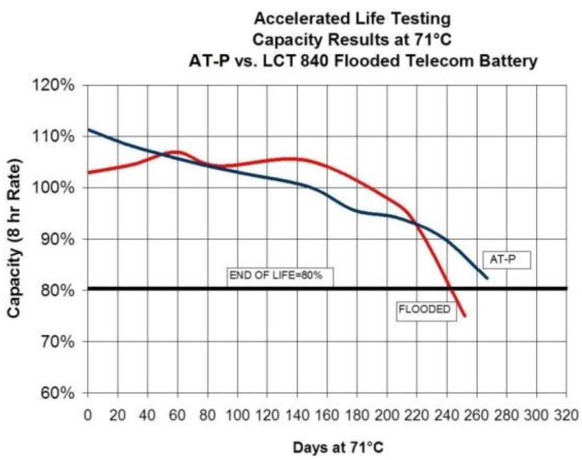

Fig 4 C&D ms-EndurII float life Current versus Flooded.

PLP technology was developed using MSE technology as a basis for negative active material and a modified positive active material with negligible levels of impurities. For 12V UPS applications, the higher power capability is a function of both lower resistance design of the cell components and lower float current of the cell. Fig 5 illustrates float currents of PLP battery compared to a typical UPS VRLA battery.

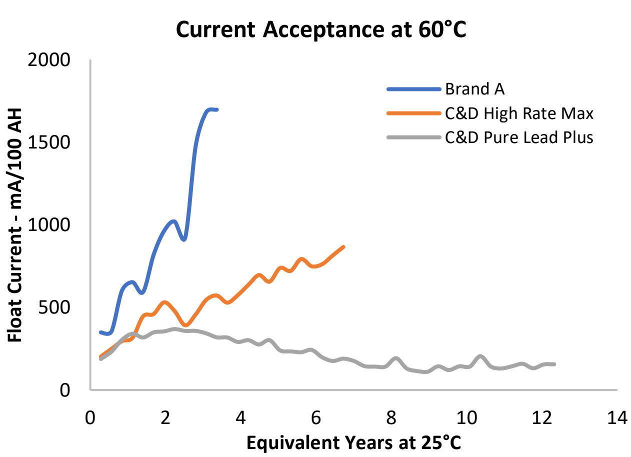

FIG 5 60^{O}C Current Acceptance Comparison to Major Competitors[1].

IV. Application Benefits and Considerations

The Pure Lead Plus technology changes the fundamental way in which the cell operates. The effect on the active material are measurable and the results are tangible

- High density large pore structure in the active materials through proprietary plate manufacturing process
- Low corroding positive grid alloys
- Improved life characteristics by reducing the current required during float service
- Eliminates negative plate discharge/sulfation
- Slows cell dry out
- Maintains cell compression
- Reduces risk of thermal runaway
- Slows grid corrosion & grid growth

V. Economics

In numerous case studies, the economic benefits of using PLP batteries has been demonstrated to be comparable or better in cost and performance with other battery technologies, such as, lithium ion. In addition, the benefits of using field tested and proven designs can limit the risk associated with using newer battery technologies and unproven system designs in mission critical applications.

Table II demonstrates the benefits of using PLP technology versus standard VRLA batteries. Normalizing systems based on Rated Capacity, initial capital cost and calculating the cost per Wh used, in terms of $/Wh, the PLP technology can provide a significantly lower cost solution on a total cost of ownership basis. Furthermore, the end of life value of the PLP batteries can be up to 30% of the replacement battery cost or, in more practical terms, cover removal and replacement cost of the battery including shipping and labor. In addition, the recyclability value, or possibly cost of disposing of newer battery technologies, can be a significant concern.

TABLE II. ECONOMICS OF ENERGY STORAGE COMPARISON – UPS FLOAT APPLICATIONS

<table>
<tr><th></th><th>Pure Lead Plus</th><th>Traditional VRLA</th></tr>
<tr><td colspan="3">Battery System Parameters</td></tr>
<tr><td>12V Battery Description</td><td>UPS12-545PLP</td><td>BCI group 29 545PLP is Group 99</td></tr>
<tr><td>Rated Capacity (5 Min to 1.67vpc at 77 Deg F)</td><td>480V 888W/Batt</td><td>480V 875W/Batt</td></tr>
<tr><td>Number of Jars per 480 V System</td><td colspan="2">Qty 200 jars per System, qty 40 jars per String</td></tr>
<tr><td>Number of Strings per 480 V System</td><td colspan="2">Qty 5 Strings per System</td></tr>
<tr><td>kWb per Cabinet (5 Min to 1.67VPC)</td><td>213 kWb</td><td>210 kWb</td></tr>
<tr><td>Relative Volume and Weight Comparison</td><td colspan="2">1 to 1</td></tr>
<tr><td colspan="3">Life Cycle Comparison in Years</td></tr>
<tr><td>UPS Life Cycle Assumption</td><td colspan="2">15 Years</td></tr>
<tr><td rowspan="2">Expected Service Life in Years</td><td>8 at (25°C)</td><td>5 at (25°C)</td></tr>
<tr><td>5- 7at (35°C)</td><td>2-3 at (35°C)</td></tr>
<tr><td rowspan="2">Number of Replacements During UPS Life Cycle in Years</td><td>1 at (25°C)</td><td>2 at (25°C)</td></tr>
<tr><td>2-3 at (35°C)</td><td>5-6 at (35°C)</td></tr>
<tr><td colspan="3">System Relative Cost (15 Year UPS Life Cycle)</td></tr>
<tr><td>New System Battery Cost</td><td>110% to 115% of Traditional VRLA</td><td>Traditional VRLA = 100%</td></tr>
<tr><td>Initial Installation Cost</td><td colspan="2">Traditional VRLA System Cost</td></tr>
<tr><td>Relative Jar Cost per Replacement</td><td>57% to 61% of System Cost</td><td>49% of System Cost</td></tr>
<tr><td>Relative Labor Cost per Replacement</td><td colspan="2">Traditional VRLA System Cost</td></tr>
<tr><td rowspan="2">Total Cost of Owndership
As Percentage of New System Cost</td><td>216% to 232% at (25°C)</td><td>260% at (25°C)</td></tr>
<tr><td>362% to 387% at (35°C)</td><td>522% at (35°C)</td></tr>
</table>

Pure Lead Plus offers up to 17% cost savings at 25°C, and 30% cost savings up to 35°C

VI. CONCLUSION

The proper use of high purity materials can significantly increase the performance of a lead acid battery. The overall service life of a VRLA battery is also determined by the robustness of the design of the positive electrode and special processing of active materials.

Utilizing the Pure Lead Plus technology can reduce overall operational costs and increase service life. In accelerated life tests and actual field trials, using PLP technology in positive electrodes in conjunction with MSE technology in negative active materials, the following benefits have been achieved.

Benefits

- Longer service life at elevated temperatures
- A VRLA product which acts like a flooded cell for float currents
- Low float currents are a result of reduced positive plate polarization which reduces electrolysis of the electrolyte and oxygen recombination
- Maintains Negative polarization which prevents negative sulfation
- Operation in higher temperatures with a greatly reduced risk of thermal runaway
- Reduced POS grid corrosion and increases service life
- Reduced POS grid corrosion also maintains cell capacity in ultra-high-rate applications throughout the battery life cycle

References

1. D. Desai, Proceedings of BattCon 2019, *What is a Pure Lead Battery and why do I need one?* April Orlando, Florida 2019.

2. R. Malley, A. Williamson, Proceedings of BattCon 08, *Large Format VRLA Products for Uncontrolled Temperature Environment*, May Orlando, Florida 2008.

3. Hans, Bode,. *Lead-acid batteries*. New York: Wiley, 1977. Print.