AN IMPROVED VALVE-REGULATED FLOODED LEAD-ACID CELL (VR-FLA) MADE POSSIBLE WITH A HYGROSCOPIC CATALYTIC VENT CAP.

Will Jones
Owner
Philadelphia Scientific
Montgomeryville, PA

Duncan Jones
Managing Director
Philadelphia Scientific–UK
Bolton, UK

Trevor Alden
Director - Catalysts
Philadelphia Scientific
Montgomeryville, PA

Abstract

Lead-acid batteries continue to provide high-value standby power for millions of applications. Most users believe they are limited to two categories; Vented Flooded Lead acid (FLA) and Valve-Regulated lead-acid (VRLA). A FLA will vent gases that are formed during recharge while the VRLA has a safety vent, and gas recombination occurs internally. No battery type is perfect for every application. In many applications, users have moved from the traditional FLA/flooded battery to using more expensive and less robust options to reduce maintenance and gassing.

Is it possible to create a different type of cell…the Valve-Regulated Flooded Lead-Acid Cell (VRFLA)? A safe flooded lead acid cell with zero measurable water loss and zero measurable gas output. This could not be simply achieved by putting a pressure vent on to a flooded cell as gas would still be vented out as the cell pressurised. It was also not practical to use any existing gas recombiner accessory as they are not 100% efficient (particularly in high temperatures) and can be damaged with high gassing rates.

Work started to develop a new vent design that would make this possible. This paper introduces the result of over four years of development work on a new category of battery made possible by the unique application of an internal catalyst in a flooded cell.

This paper describes an overcharge tolerant catalytic device that recombines gases back into water ***vapor*** within a semi-sealed environment and allows a flooded lead-acid battery to operate with zero measurable water loss and zero measurable gas output. The VR-FLA Battery is made possible with this new device and may be the answer for applications that want the robust performance of a flooded cell but with zero measurable water loss and zero measurable gas output.

Standby Battery Basics

Standby batteries primarily store energy for emergency use and are rarely discharged. As a result, they remain on float charge most of their life. When choosing the best standby battery, the best one is usually the one that has the lowest net lifetime cost per year in the application. The net lifetime cost must consider the battery cost, life expectancy, maintenance cost, environmental control costs (air-conditioning), and end of life cost.

Lead-Acid Standby Battery Evolution

To achieve the lowest lifetime cost, several lead acid chemistries have evolved.

1. **Flooded Lead-Antimony** cells have long been the baseline. They have good cyclability and temperature resilience but have high gassing rates, requiring frequent watering and significant ventilation.
2. **Flooded Lead-Calcium** cells were developed to reduce gassing rates. This reduces the maintenance and ventilation, but in doing so reduces cyclability.
3. **AGM VRLA and GEL VRLA** batteries eliminate watering and gassing but are more expensive to manufacture.

Existing Catalyst Vents in Batteries

This is not the first time catalysts were investigated to be in lead acid batteries. Edison used them going back to the very early 1900's. Since then, several companies have created recombining vent products of which many are still on the market today. For many years, the author's company has continuously produced and developed internal catalysts for VRLA batteries. As a result, they have a particular expertise in the behavior of catalysts and understand the challenges to success.

Design Principals

Objectives in this development were to create a cell vent cap that was:

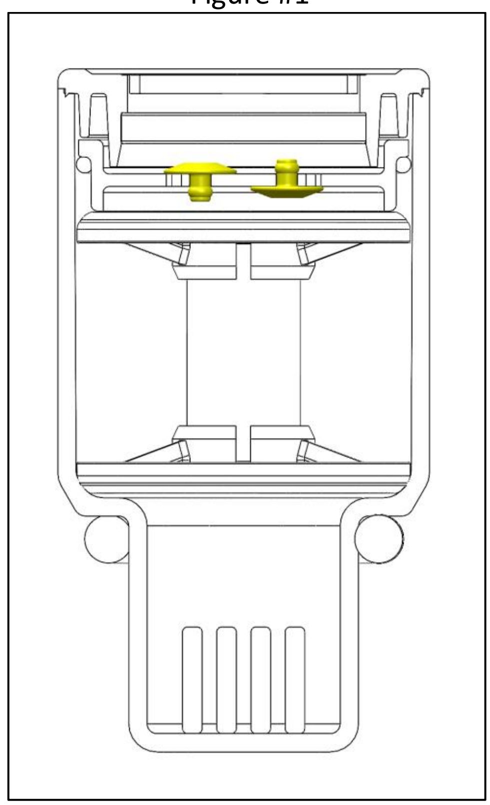
1. **Virtually 100% efficient**: Allowing an FLA cell to have zero measurable water loss and zero measurable gas output.
2. **Intrinsically Safe**: Tolerant to reasonable periods of overcharge, self-limiting during periods of extreme overcharge, and safe from external spark/ignition.
3. **Protected from Poisons**: Ability to withstand normal catalyst poisons within a cell during its lifetime.

Design Features

During the development we found several separate design solutions that were required to achieve our design principles.

- **Valve regulating the cell**. To ensure all gas is recombined, the cell needs to be sealed. Without a seal a percentage of uncombined gases will always escape. During our tests it was discovered that our vent could be a very low-pressure seal as increasing the release pressure made no improvement in efficiency. Sealing the cell also eliminates water loss from evaporation as the atmosphere within the headspace is humid. It was also found that a second safety vent was required to prevent an undesirable vacuum in the cell in certain circumstances. This second low-pressure vent allows air to be pulled back into the cell. Under normal operation neither of these vents are operational. The vent design creates a sealed cell but provides a safety vent in the vent of overpressure and an event in to manage negative pressure.

Figure #1



- **Hygroscopic vapor absorption**. Existing catalytic device designs have relied on large external chambers or exaggerated surface area moldings to create the largest possible condensing surfaces. The intent is that condensate then drips back into the cell. This can be effective when the ambient environment is colder than the battery, but this is rarely the case. This concept was to bring the catalyst inside the cell and intentionally eliminate as much of the vent plug's external chamber volume as possible. The catalyst is then working within the headspace of the cell and is not external. The result of this logic reversal is that the hygroscopic property of the electrolyte absorbs the water vapor as quickly as it can be produced.

Figure #2

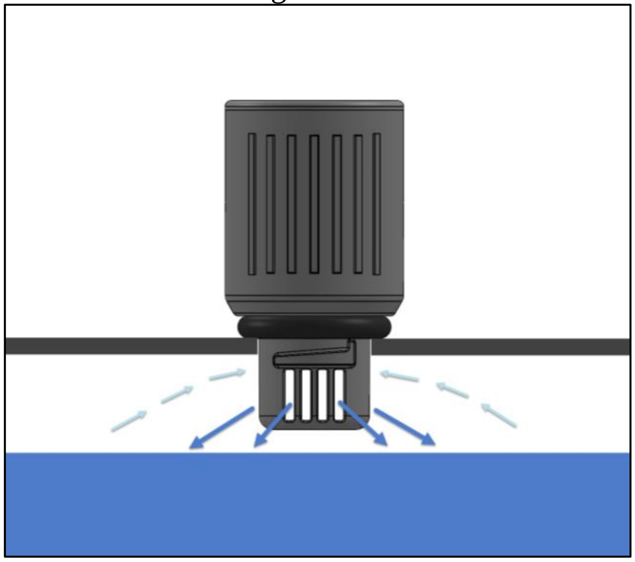
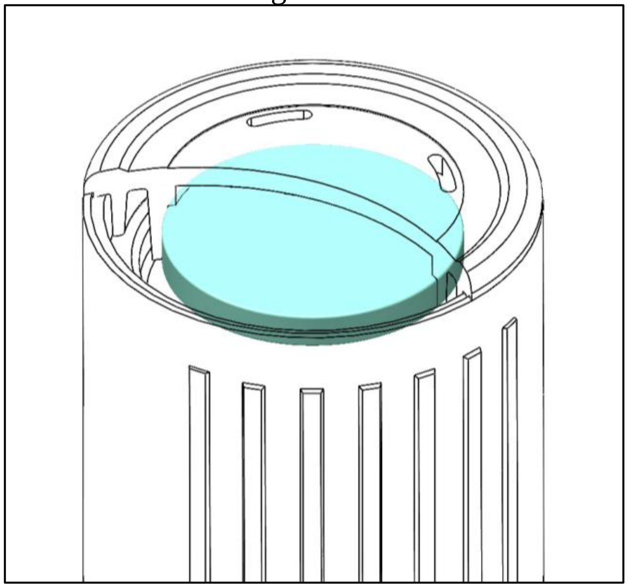


Figure #3



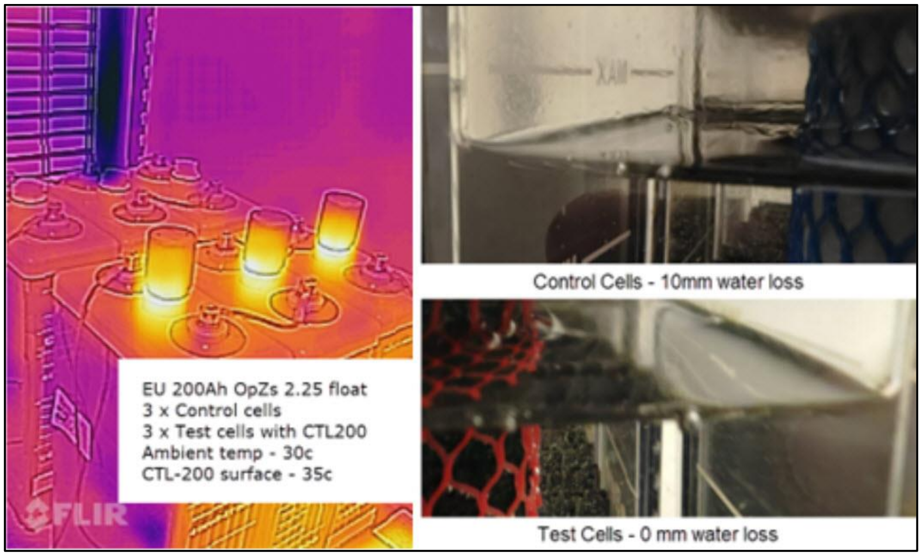
- **Prevention of external spark ignition**. There are several design features that keep a cell safe from external ignition. An anti-flame frit is located at the top of the vent plug, above the safety vents which prevents any external spark from entering the cell. In addition, both safety vents are normally closed in operation, further reducing any chance of ignition from external sources. Finally, the catalyst operation ensures that any combustible gases are recombined as they are produced so the headspace atmosphere is not normally flammable.

- **Self-limiting**. Any catalytic device must be safe during periods of unexpected gassing. Due to normal events such as boost charge and equalization, gassing rates are higher than on float. On occasion, failed cells or incorrect charger calibration can cause much higher gassing rates. If catalytic material were to be directly exposed to gasses the reaction rate is not limited and can get hot enough to cause issues. The solution is to completely enclose the catalytic material within a dense but porous ceramic container. The thickness and the porosity define the amount of gas that can pass through the catalyst limiting maximum recombination and therefore maximum temperature. The ceramic catalyst body is held centrally in the chamber by two ultra-high temperature carriers. The device can support full recombination at 5 amps and will remain thermally stable at even higher charging rate with no deformities or detrimental effects. At higher gassing rates the recombination rate is choked, maintaining a safe temperature, but the cell loses water as the cell is creating more gas than can be recombined.

Figure #4

- **Poison Protection.** Poisons (such as Arsene and Stibene) can be present in gas created during charging which can damage the effectiveness of the catalytic active material. The material inside the ceramic container includes a poison filtration compound which absorbs poisons before these gases can damage the active material. This is only relevant for lead-antimony and lead-selenium.

Test Results



Float Test 1 - Results

Cell Type: EU OpZs – 200ah

Test Duration: 6 months

Temperature: 25°C

Voltage: 2.25vpc

Control Water loss: 10 mm

CTL-200 Water loss: 0 mm

Float Test 2 - Results

Cell Type: US Pb/Sb

Test Duration: 12 months

Temperature: 25°C

Voltage: 2.25vpc

Control Water loss: 20 mm

Test Water loss: 0 mm

Float Test 3 - Results

Cell Type: US Pb/Ca

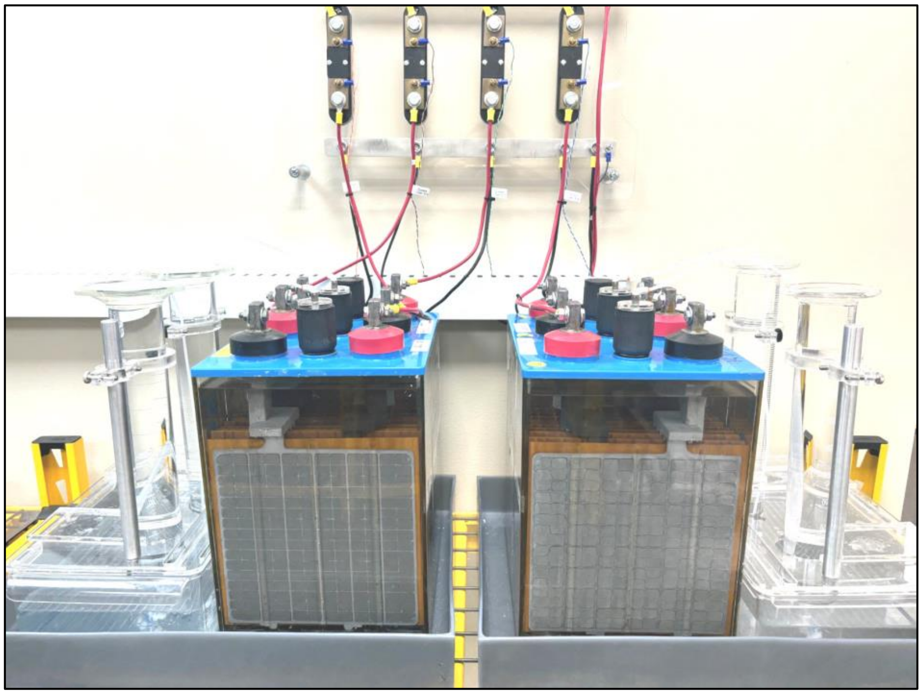
Test Duration: 8 months

Temperature: 25°C

Voltage: 2.25vpc

Control Water loss: 8 mm

Test Cells Water loss: 0 mm



Note: All lead-acid catalysts operate hot, the thermal image in "Float Test 1 - Results" shows a temperature comparison. They are not hot to the touch under normal operating conditions.

Conclusion

The standby power industry is increasingly fragmented, and no battery type is perfect for every application. Flooded batteries have long been the most resilient, but there is an understandable desire to safely avoid watering and the need for ventilation. The Valve Regulated Flooded Lead Acid battery is perhaps the best of both worlds. The resilience and cost of a flooded lead acid cell with the watering and ventilation profile of a VRLA.

In the real world there are dozens of cell sizes which could be installed in applications without guaranteed temperature control. Charging systems are often outside the control of battery manufacturers and may not have perfect temperature compensation, calibration, or charge profiles. This all results in a wide range of gas output. A vent plug device which makes the VRFLA battery possible needs to be resilient enough to handle these real-world deviations without risk or performance loss.

Our tests have demonstrated that both Lead-Antimony and Lead-Calcium standby cells can have zero measurable water loss and zero measurable gas output within float, boost and equalization phases. The tests also demonstrated that they remain safe and stable in extreme situations outside normal usage profiles.

The VRFLA battery using low-antimony alloys raises a question about the use of calcium alloys in standby applications which is well known to compromise cyclability. In some cases, the VRFLA may also be a better maintenance free option than VRLA cells.