Thermal Runaway of Valve Regulated Lead-Acid (VRLA) Batteries, Causes and Hazards

INTRODUCTION

This paper will detail the causes and dangers of VRLA battery Thermal Runaway. Concerns about VRLA batteries generally center on two issues: Safety and Reliability. To understand the capabilities and limitations of VRLA technology, we first need to understand VRLA design and operation. All products eventually come to an end of useful life. We will explore when that will occur in VRLA batteries and how that life can be extended or reduced by installation and maintenance practices.

VRLA THEORY OF OPERATION

The valve regulated lead-acid battery is designed to prevent the release into the external air of gasses produced as a byproduct of electrochemical action. The VRLA operates by exchanging oxygen molecules between positively charged lead plates and negatively charged plates, ultimately forming water and hydrogen gas. Because water cannot be added, the recombination of water with acid contained in the battery is crucial to the life and health of a VRLA battery. Any factor that increases the rate of evaporation or loss will reduce the life of the battery. Such factors can include battery container material heat dissipation capabilities, overcharging, undercharging, ambient operating or storage temperatures, battery age and the number of discharge/recharge cycles.

VRLA LIFE EXPECTANCY

The term "life expectancy" has been controversial within the battery community. If we disregard "warrantied life" which is a marketing term, there are two commonly used terms with different meanings that, regrettably, are often used interchangeably.

Design Life: is used by manufacturers as a measure of comparison. It is a theoretical figure. It is used as a short-hand method of comparison, as in "5 year," "10 year," and "20 year" battery, and is the basis for pro-rated warranties.

Service Life: is the actual time from the installation of the battery until its capacity falls below 80% of its nominal rating. Service life implies a replacement interval shorter than the design life. The end of useful life for VRLA batteries can be as much as 50% below its design life and in extremely harsh operating environments as low as 20%. When VRLA batteries are properly maintained, and monitored, they frequently achieve 70 - 80% of design life.

FACTORS THAT CAN EFFECT VRLA BATTERIES

A. **Battery Design** Variations from one battery manufacturer to another
B. **Charging Voltage** Under & Over Charging
C. **Environmental** Room Temperature, ventilation, and battery location
D. **Cycling Profile** Number of Discharge and Recharge cycles
E. **Battery Age** Have the batteries past their service life or even design life
F. **Essential Maintenance** Are the batteries being trended or monitored to obtain actionable information

THERMAL RUNAWAY

On standby batteries, Thermal runaway is a very destructive and serious condition if not identified in the earliest stages. If thermal runaway is ignored, injury to personnel and severe damage to the battery as well as surrounding equipment can occur resulting in costly repairs. In all cases, thermal runaway can lead to abrupt system failure and disruption of service if not detected. A proactive method must be instituted to deal with a thermal runaway condition. Furthermore, as described in the International Fire Code (IFC), VRLA battery systems shall be provided with a listed device or other approved method to preclude, detect and control thermal runaway (IFC 608.3)(2).

1. What causes Thermal Runaway?

When a VRLA battery's "Float voltage" is kept elevated or the battery is over-charged, almost all of this unneeded energy generates heat. A well designed installation allows the heat to escape and thermal equilibrium is maintained, so there are no problems. However, if the rate of heat generated exceeds the heat dissipated, the battery temperature will rise. Higher temperature causes an increased current draw by the battery (float/charge current). More current creates more heat until the electrolyte (Acid within the battery) vaporizes (dry-out) within the battery at 259 degrees Fahrenheit. Pressure builds up inside the battery until the vents open and allow the release of oxygen and potentially explosive concentrations of hydrogen gas. Buildup of internal pressure and softening the case material has been known to cause container bulging or rupture.

2. So how does this apply to OLD batteries?

Batteries that are reaching or have exceeded the service life are at a significantly elevated risk of Thermal Runaway. This is due to the inevitable rise of internal resistance and the deterioration of the internal materials exceeding the rated number of discharge/recharge cycles. Because of this deterioration, the battery can be subject to long duration or even an increase in recharging current, which results in more heat. As we stated before, Thermal Runaway is generated when the internal heat of the battery exceeds the ability of the battery to dissipate heat.

As batteries age the open circuit voltage (T**he voltage the battery carries without being**

charged) of the battery decreases. For example, a new battery will have an open circuit voltage of 12.5VDC, after 5 years that open circuit voltage can decrease to 11VDC or even 10.8VDC. Because of the decrease in the open circuit voltage, the battery requires a longer duration or increase in charging current which results in more heat.

CONCLUSION

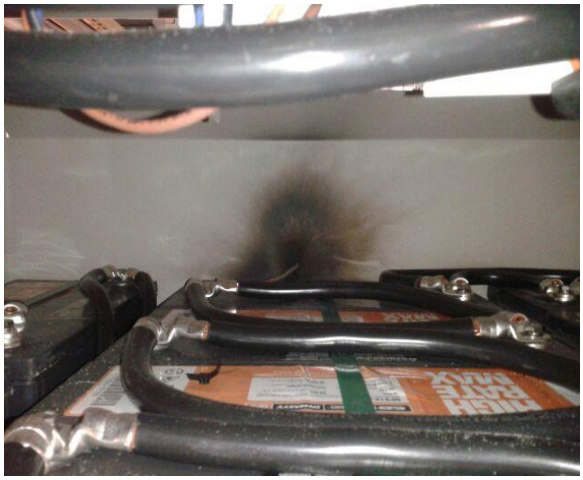
When properly applied and maintained, VRLA batteries such as those used in small and medium-sized critical power backup systems can give reliable performance for three to five years or longer (depending upon battery selection). Battery dry-out is a major problem resulting from the heat generated by extended charging duration and excessive recharge current. The result is the premature end of battery service life or the catastrophic failure known as "**Thermal Runaway**". Preventative maintenance combined with continuous battery monitoring systems can detect and enable proactive response to conditions which cause premature cell failure and Thermal Runaway.

VRLA batteries are safe to use in data centers and network rooms when properly installed and maintained. Neglect, abuse, excessive temperatures and lack of maintenance and monitoring can create conditions that could result in catastrophic failure, including fire and explosion. Proper cooling and ventilation, continuous monitoring and a preventative maintenance program can all contribute to safer operation and longer battery life.

See below for photographs of batteries that have exploded and ignited due to Thermal Runaway.

Fire due to Thermal Runaway

Short Circuit due to Thermal Runaway



Container Destruction due to Thermal Runaway

Explosion due to Thermal Runaway