Valve Regulated Lead-Acid Battery Degradation
How A Single Bad Battery Can Cause Thermal Runaway

Most data center professionals are aware of thermal runaway and the damage it can cause to their Uninterruptible Power Supply (UPS), its batteries, and potentially the room or building in which they are housed. Some, however, are not aware that a single bad battery can cause a tremendous amount of damage when left unmonitored. Johnston Technologies has seen many cases in which, with proper maintenance and monitoring, a disaster could have been avoided. This white paper will detail what steps can be taken in order to avoid a dangerous thermal runaway condition.

To begin, we will detail how a valve regulated lead-acid (VRLA) battery works standalone, and in a UPS battery cabinet.

Valve Regulated Lead-Acid Batteries

This paper is meant to detail the VRLA gel batteries, which differ from the wet-cell batteries used in more industrial applications. These VRLA gel batteries have positive and negative lead plates contained in a plastic enclosure with electrolyte, or battery acid. This electrolyte is the same chemical makeup as the wet-cell batteries, just in a solid, gel-like substance.

When the battery undergoes a discharge, the battery contents create a chemical reaction that produces lead sulphate and water. Oppositely, charging these batteries produces lead and acid. If the charge exceeds the amount of energy the battery can withstand, some of the battery contents will be wasted by decomposing the water into hydrogen and oxygen. If the pressure becomes too great, the batteries will release these gases by way of the safety vent built into the enclosure.

A few of our UPS products utilize a different setup, however, the majority of our products that exist in the field have these batteries hooked up in series-parallel. Meaning, each battery in a cabinet is hooked up in a series, with additional cabinets hooked up in a parallel system. This is what we’ll be focusing on for the rest of the paper. If one battery were to fail in a cabinet, the whole cabinet will prove useless. The rest of the cabinets will have to handle the electrical load and as a result, reduce runtime.
That isn’t the only negative impact when a battery fails. Unless the breaker in that specific battery cabinet were opened or tripped (turned off), the charger will continue to provide voltage to the batteries. Furthermore, the voltage provided to the batteries will remain the same despite one of the batteries failing. This will inherently raise the voltage in the remaining “good” batteries. The increase in voltage will increase the temperature in jar. Left unattended, this heat will open the battery and eventually create a thermal runaway condition.

**Thermal Runaway**

Thermal runaway is defined by Wikipedia as,

> “Where an increase in temperature changes the conditions in a way that causes a further increase in temperature, often leading to a destructive result”


Since these VRLA batteries are sealed, the increase in temperature can cause the jar to explode even with the safety vent. As more batteries continue to fail, the hotter the remaining batteries will get. This is thermal runaway.

Once it has begun, all the batteries in the cabinet are compromised and need to be replaced immediately. What is left is a dangerous situation that needs to be handled by professionals only. The battery acid that has spilled should alone discourage anyone from attempting to rectify the situation.

**How to Prevent Thermal Runaway**

Preventing thermal runaway can be achieved in multiple ways. Regular monitoring and maintenance of the UPS batteries is a necessity. These proactive measures can diagnose any issues well before thermal runaway and can help increase the life of the batteries.
The industry standard is for a bi-yearly battery test of voltage and internal resistance of every jar. These tests will take a snapshot of the quality of each jar. They will identify jars that are beginning to age and give the customer a plan of action. If one or two jars are aging, replacing just those jars is recommended. If up to 10% of the jars are aging, a full battery replacement is recommended. This is due to the negative affect the 10% have caused to the remaining batteries.

The best solution for the scenario where only a few have degraded, a battery on-site spare (B.O.S.S.) cabinet is recommended. A B.O.S.S. cabinet keeps a couple of batteries charged and ready for immediate installation on-site, minimizing mean time to repair.

Another common monitoring solution is by installing a Cellwatch™ battery monitoring system. These advanced systems constantly monitor each jar and send the reports directly to the designated party. The best feature of these systems is the new thermal runaway prevention design. When the system detects a thermal runaway situation, the system alarms the user and if no action is taken, trips the battery breaker. This action will not only isolate the cabinet from the others, but stops the charger from making the situation worse than it already is. It also adheres to the fire code, NFPA 1 Chapter 52.

**NFPA 1 Chapter 52**

Chapter 52 of NFPA 1 directly relates to a stationary storage battery system, in other words, a UPS. Any VRLA stationary storage battery systems having an electrolyte capacity of more than 100 gallons in sprinklered buildings or 50 gallons in unsprinklered buildings used for facility standby power, emergency power, or uninterrupted power supplies must be in accordance with chapter 52.

Chapter 52 states that a VRLA battery system must satisfy seven requirements for it to be in compliance with NFPA 1. Those seven require the batteries to have:

1. Safety Caps (must be Self-Resealing Flame-Arresting Caps)
2. Thermal runaway protection
3. Neutralization prevention capabilities on-site
4. Ventilation
5. Signage within battery cabinet indicating relevant electrical, chemical, and fire hazard
6. Seismic braces in seismically active areas
7. Fire detection in battery system room

*Feel free to read our previous white paper, NFPA 1 Chapter 52, for more detail of this code.*
As you can see, thermal runaway protection is listed as a step needed in protecting the building from an uninterruptible power supply. As previously mentioned, a battery monitoring system from Cellwatch™ would satisfy this fire code requirement.

**Proper Battery Installation**

Proper installation of VRLA batteries can help lengthen the life of the UPS batteries. According to IEEE 1657 standards, each battery needs to be:

1. Tested for both voltage and internal resistance. We recommend using an Alber Cellcorder™. This device not only allows you to test the batteries, but to produce reports on the batteries that clearly show how the batteries are holding up over a period of time also.
2. Clean the terminals with a terminal cleaner and scrub them with a Brillo™ pad. Scrubbing the terminals removes any dirt or residue left on the terminals from the manufacturing plant.
3. Have non-oxidant grease applied to the terminals. This grease creates a non-harmful barrier between the hardware and battery terminal, reducing any corrosion that may build up.
4. Apply a battery terminal protector to all battery hardware. This also helps reduce any corrosion that may build during the life of the battery.
5. Torque the battery hardware to 110 inch-pounds (or to manufacturer’s specifications) during installation.

These preventative measures are meant to possibly increase the life of the battery, but is not a guarantee. Many different factors can affect the life of the UPS batteries.

**Other Factors that Degrade Batteries**

Many different factors determine the life of a battery. To have an exact time frame of a battery’s life is difficult to predict. However, there are some common occurrences that decrease battery life.

One of the more common issues in UPS batteries is operating temperature. The recommended operating temperature for elongating battery life is 77°F. Every 15°F rise in temperature cuts the life of the battery in half. Keep in mind that this is not the ambient temperature of the room, just the temperature at which the batteries operate.
A more difficult factor to control is battery discharge. Each time the battery discharges, the life of the battery dwindles. Since this is the purpose of the UPS is to handle an outage, there is not a lot you can or would want to do about how many discharges the batteries take.

**Battery Investment**

The UPS and it’s batteries should be viewed as an investment. The more care and attention you give to the batteries, the longer the investment will last. These systems are designed to provide backup power to critical equipment, some of which is very costly. Maintaining this equipment is crucial for the unit itself, but also for the devices that it is designed to protect. Hiring the right professionals to install, monitor, and maintain the UPS and batteries is vital to the life of the unit.