EAGLE EYE TECHNICAL NOTE

Title	**VRLA Batteries in Heat**
Document No.	**TN-02-16-22-1**

Revision History

Date	Revision	Change Description	Author(s)
2/16/22	0	Original document	JAB

VRLA Batteries in Heat.

Overview.

Heat is detrimental to Valve-Regulated Lead-Acid (VRLA) battery operation and life. And, like all stationary batteries, they should be operated in an environment that allows for natural air movement and ventilation around the battery.

It is important to maintain the battery at approximately 77ºF (25ºC). If this is not possible, and the battery is operated at a much higher or lower temperature, then the battery charger should incorporate automatic temperature compensation of the charging voltage in order to prevent over or under-charging. Over-charging will cause over-heating and could result in thermal runaway. Under-charging will result in loss of battery capacity and eventual failure.

Some Definitions.

Before delving into the body of this technical article, let's look at some definitions.

- **Battery.** This term refers to one or more single or multi-cell units connected in series or series-parallel to form a battery string or plant.
- **Charge Voltage Temperature Compensation.** This is where the temperature is measured at the battery negative-most terminal and is used to adjust the charger output voltage in order to keep a constant float current flowing through the battery.
- **Over-charging.** This is when the charging current is above the manufacturer recommended level for the particular battery and could lead to thermal runaway.
- **Under-charging.** This is when the battery is not receiving enough current to overcome the natural self-discharge of the battery. This could lead to the formation of lead sulfate crystals (sulfation) of the battery lead plates.
- **Thermal Runaway.** This occurs when the battery is being overcharged, either through too high a charging voltage being applied or the battery being operated in a higher-than-recommended ambient temperature.
- **Exothermic Reaction.** A process or chemical reaction causing the release of heat. Batteries generate heat both during charging and discharge.

Heat Generation.

Heat generation calculations during the various battery charge and discharge regimes is complex, and there are many variables and "it depends." Both heating and gassing will vary according to battery chemistry, type, charge voltage/current, ambient temperature, and operation. The operational mode could be:

- Initialization/Freshening charge.
- Standby/Float charging.

- Boost/Equalize charge.
- Discharge.
- Recharge.

By far, the most common operational mode is constant voltage float charging, where the battery is maintained at a voltage slightly above the open-circuit voltage and is calculated to overcome the battery's natural losses and maintain it in a fully charged condition. The Institute of Electronics and Electrical Engineers (IEEE) defines standby/float application as follows:

> "The float operating mode occurs when a constant voltage is applied to the battery terminals sufficiently to maintain an approximately constant state of full charge. The standby float operating mode can be detected by observing the float/equalize mode of the chargers. Most batteries in stationary applications (with the exception of cycling batteries, such as photovoltaic (PV) solar applications, or constant current charging schemes) spend more than 99% of the time on float."

Calculating Heat Generation.

For lead-tin or lead-calcium AGM VRLA batteries, the following equations apply to batteries being operated in standby/float application.

$$q_W = 0.34 \times I \times n_c$$

where $I = C_8 \times 0.00121$

or $I = P_{15} \times 0.326$

q_W is the total heat produced in watts
I is the current through each string in Amperes
C_8 is the 8-hour ampere-hour rating of a lead-acid cell to 1.75 V at 25 °C
P_{15} is the 15-minute kW/cell rating of a lead-acid cell to 1.67 V at 25 °C
n_c is the number of cells in the battery plant

Examples:

Say the battery is rated at 1000 Ah at the 8-hour rate. There are two parallel 48-Volt, 24-cell strings for a total of 48 cells.

q_w = 0.34 x 1000 x 0.00121 x 48 = 19.7472 Watts.

Say the battery is rated at 400 Watts per-cell (0.400 kW per-cell) at the 15-minute rate. There are two parallel 480-Volt strings of 240 cells each for a total of 480 cells.

q_w = 0.34 x 0.4 x 0.326 x 480 = 21.2813 Watts.

Temperature Compensation Factor.

Battery manufacturers will provide a “compensation” voltage that should be applied to the nominal float voltage in order to maintain an acceptable charge current to the battery. This is typically 1.7mV per °F (3mV per °C) above or below the nominal voltage. This is subtracted from the recommended float voltage if the temperature is above the nominal or added to the recommended float voltage if below the nominal for the battery.

Example:

A battery is being operated in an environment where the temperature at the negative most post is 90 °F (32.2°C). If the recommended nominal temperature is 77°F (25°C), then the battery is being operated at 13°F (7.2°C) above that recommended temperature. Based upon the above:

1.75mV x 13(°F) = 22.75mV which should be subtracted from the recommended float voltage. Say the recommended float voltage is 2.27 Volts-per-cell, then the temperature compensated float voltage would be 2,27V – 22,75mV = 2.247 Volts-per cell.

Battery Capacity and Heat.

If temperature compensated charging is not applied, what will happen to the battery capacity? Well, if partially or constantly operated in an environment above or below the recommended operating temperature, the battery will exhibit the following:

- Above the nominal temperature, the battery capacity will increase but the life of the battery will be shortened.
- Below the nominal temperature, the battery capacity will be decreased but the battery life will be extended.

Let's put some numbers to the life aspect. It is generally recognized that for every 18°F (10°C) above the recommended nominal of 77°F (25°C) in which the battery is being operated, that the life will be decreased by 50%. In other words, if a battery is being constantly operated at 95°F (35°C), its life will be cut in half.

Battery Storage and Heat.

As temperature had a significant effect on battery storage time, the ideal temperature of a storage location should be between 15C (60F) and 30C (85F). High temperature can significantly increase self-discharge, and consequently, the period required between freshening charges. It should be noted that if batteries are stored in a warehouse on storage racks that may be several meters (feet) high, temperature stratification can occur where the upper batteries may be at a higher temperature than the lower ones. Batteries should not be stored in direct sunlight or be subject to wide ambient temperature fluctuations.

The Arrhenius equation, which was developed in 1889 by the Nobel Prize winning Swedish scientist Svante Arrhenius, states that an increasing temperature produces an exponential increase in reaction rate. This is important when applied to a stationary battery in storage. For example, a battery that is stored at a temperature of 10C (18F) above the ideal 25C (77F) will self-discharge twice as quickly as a battery being stored at the ideal temperature. The same will apply to a lowering of the self-discharge rate of batteries stored at a temperature below the nominal.

Even though storage below the ideal storage temperature will decrease the self-discharge rate, one has to be careful that the storage temperature is not so low as to cause the electrolyte to freeze. The freezing point of the sulfuric acid electrolyte is dependent upon the concentration of the sulfuric acid. The higher the concentration, the lower the freezing point. Most stationary batteries have a° Specific Gravity (SG) of between 1.215 and 1.32, but this is the case only for a fully charged battery. As the battery becomes discharged, the SG decreases and consequently the freezing point rises. Water freezes at 32°F (0°C), so unless the battery is completely discharged, the freezing point will be some value below this. A lower temperature will greatly slow down the self-discharge, but if the SG of the electrolyte has decreased sufficiently, the freezing point will be raised. The requirements for a freshening charge will be covered in a forthcoming Eagle Eye technical note

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