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Shipping and Storage of Sealed Lead-Acid Batteries

This Technical Note describes ways that sealed lead-acid (SLA) batteries can fail during storage and shipping and suggests steps that manufacturers can take to prevent damage to their SLA products in the supply chain.

The Information contained in this article builds on previous Technical Notes. See also: http://www.lightingafrica.org/resources/briefing-notes.html

Introduction

Sealed or valve regulated lead-acid (SLA or VRLA, referred to here as SLA) batteries are still a common choice in off-grid lighting products. While they do not offer the high energy density of nickel metal hydride (NiMH) and lithium ion batteries, SLA batteries are inexpensive and relatively simple to use.

One disadvantage of SLA batteries is that they can be permanently damaged if stored in a discharged state. Like all batteries, lead-acid batteries slowly self-discharge even when not connected to a load. This self-discharge occurs during shipping and warehousing and while products are sitting on store shelves. If care is not taken to limit a product’s time in the supply chain, the battery may have suffered permanent capacity loss by the time the product is purchased. This damage will result in decreased run time or, in severe cases, an unusable product.

In one example of damage in the supply chain, Lighting Africa compared products purchased in stores in Kenya to those shipped directly from the manufacturer and found up to a 40% drop in battery capacity. In another case, an entire shipment of products from a major West African distributor was found to be unusable after prolonged warehouse storage.

SLA chemistry overview

All lead-acid batteries, both flooded and sealed, use lead oxide (PbO_2) for the positive electrode, metallic lead for the negative electrode, and a solution of sulfuric acid (H_2SO_4) in water as the electrolyte. As the battery discharges, sulfate ions in the electrolyte combine with lead oxide at the positive electrode and lead at the negative electrode to form lead sulfate ($PbSO_4$); when the battery is charged, these reactions are reversed. If the battery is overcharged, the water in the electrolyte is broken down into hydrogen and oxygen; flooded cells must be refilled with water periodically to restore the electrolyte level.

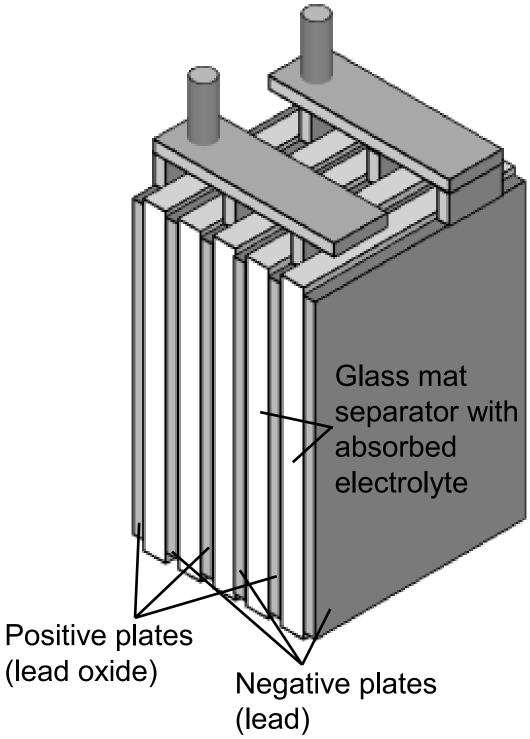

Figure 1: Construction of an AGM battery electrode stack.

There are two basic types of sealed lead-acid battery: gelled electrolyte (“gel cell”) and absorbed glass mat (AGM). In the gelled version, the liquid electrolyte is mixed with silica to form a gel; in AGM cells (Figure 1), the electrolyte is absorbed in a porous glass mat. Unlike flooded batteries, both types of SLA battery can be operated in any orientation and do not need to be refilled with water; most of the hydrogen and oxygen produced during overcharge recombine to form water.

SLA batteries are available in cylindrical and prismatic (rectangular) forms. Cylindrical cells use spirally wound lead-tin alloy electrodes, while prismatic cells use rigid lead-calcium alloy electrodes. The different electrode materials result in different performance characteristics for the two types of cells. Cylindrical cells have higher self-discharge rates and therefore shorter shelf life.

Lead is highly toxic even at low levels of exposure. For a discussion of the environmental and health issues associated with the use and disposal of lead-acid batteries, see the Lighting Global Eco Design Note *Battery Toxicity, Hazards, and Environmental Considerations.*

Failure modes in storage

As an SLA battery discharges, the electrolyte is depleted of sulfate ions. If the battery is discharged too deeply, the conductivity of the electrolyte decreases and the internal impedance increases, leading to low charging current and long charging times.

Depletion of the electrolyte can also cause the lead sulfate on the plates to dissolve in the electrolyte. When the battery is charged, the lead precipitates out of the solution and forms deposits in the electrolyte. These deposits can short-circuit the cell, causing it to self-discharge rapidly or stop working entirely.

Sulfation is another cause of failure in undercharged SLA batteries.[1,2] Normally, as the battery discharges, small particles of lead sulfate form on the plates; these small particles are easily converted back to lead oxide when the battery is charged. If the battery is left in a discharged state, or only partially charged, the lead sulfate can form larger crystals, which cannot be converted back to lead oxide when the battery is charged. This process leads to permanent loss of capacity. Sulfation can be prevented by periodically fully charging the battery.

In addition to gradual self-discharge, deep discharge can happen quickly if the product is accidentally turned on during shipping. This problem can be prevented by taping over the power switch or by providing a fuse that is removed during shipping and inserted at the time of purchase.

Maximum storage time

The maximum storage time for lead-acid batteries depends on temperature. At 20°C, prismatic (rectangular) SLA batteries take 16 months to discharge to 50% state of charge. At 30°C, the shelf life drops to 8-9 months; at 40°C it drops to 4-5 months.[3] Recharging is recommended after the battery reaches 50-70% of rated capacity.[3,4] Cylindrical VRLA batteries discharge faster, reaching 50% in about 7 months at 20°C and 2 months at 40°C.[3]

Some lighting products consume a small amount of "standby" current even when turned off; this "parasitic load" can deplete the battery faster than self-discharge alone. For these products, the battery must be disconnected for shipping and storage or the standby current must be taken into account when determining the maximum allowable storage time.

Preventing capacity loss

Several measures can be taken to prevent capacity loss in SLA batteries:

- Batteries should be fully charged before products are shipped.
- The time from manufacturing to end-user purchase should be limited so that the battery does not discharge below 50% capacity. The time limit depends on the expected temperature during shipping and storage; see Table 1. For prismatic cells at 35°C, the time limit is 6 months. For longer storage, batteries must be periodically recharged. Storage guidelines from the battery manufacturer should also be taken into account.
- Prolonged exposure to high temperatures should be avoided.
- Printing the manufacturing date on the product packaging allows customers to identify products with fresh batteries. Alternatively, a "best if charged by" date, calculated based on the recommended storage time, could be provided. The date should be clearly printed on the external packaging of the product.
- The product should be prevented from turning on during shipping. If the product is shipped with the battery connected, standby current should be taken into account when determining the maximum storage time.

Batteries can begin to deteriorate before they are put into products. Manufacturers should purchase only fresh batteries and not allow them to discharge before product assembly.

Table 1. Maximum allowed storage time between charges at 25°C, 30°C, and 35°C.

Temperature	Maximum storage time	
	Cylindrical cells	Prismatic cells
25°C	5 months	12 months
30°C	3.5 months	8 months
35°C	2.5 months	6 months

Shelf life can be prolonged by periodic recharging or by float charging, in which batteries are connected to a constant-voltage power supply. An SLA battery retains 80% of its rated capacity after 3-4 years of floating at 2.25-2.3 V/cell (4.5-4.6 V for a 4V battery, 6.75-6.9 V for a 6V battery, or 13.5-13.8 V for a 12V battery).[3]

Another way to prevent damage in the supply chain is to use a different battery chemistry. Nickel metal hydride (NiMH) and nickel-cadmium (NiCd) batteries are not damaged by prolonged storage. Lithium-ion batteries can be damaged if allowed to completely discharge, but are not harmed by prolonged storage at partial charge and can have low self-discharge rates, making them a good alternative as well. Two of these alternative battery types, NiMH and lithium-ion, have the additional advantage of being less toxic than lead-acid batteries.

References

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