How to Store Batteries

The recommended storage temperature for most batteries is 15°C (59°F); the extreme allowable temperature is –40°C to 50°C (–40°C to 122°F) for most chemistries. While lead acid must always be kept at full charge during storage, nickel- and lithium-based chemistries should be stored at around a 40 percent state-of-charge (SoC). This level minimizes age-related capacity loss while keeping the battery in operating condition and allowing self-discharge.

Finding the 40 percent SoC level is difficult because the open circuit voltage (OCV) of batteries does not lend itself well to state-of-charge estimations. For lack of better methods, voltage is nevertheless used as a rough fuel gauge indicator. The SoC of Li-ion is roughly 50 percent at 3.80V/cell and 40 percent at 3.75V/cell. Allow Li-ion to rest 90 minutes after charge or discharge before taking the voltage reading to get equilibrium.

SoC on nickel-based batteries is especially difficult to measure. A flat discharge curve, agitation after charge and discharge, and voltage change on temperature contribute to the fluctuations. Since no other estimation tool exists that is practical, and the charge level for storage is not all too critical for this chemistry, simply apply some charge if the battery is empty, and then make sure that the battery is kept in a cool and dry storage.

Storage will always cause batteries to age. Low temperature and partial SoC only slow the effect. Table 1 illustrates the *recoverable capacity* of lithium- and nickel-based batteries at various temperatures and charge levels over one year. The recovered capacity is defined as the available battery capacity after storage with a full charge.

Temperature	**Lead acid** at full charge	**Nickel-based** at any charge	**Lithium-ion** (Li-cobalt)	
			40% charge	100% charge
0°C	97%	99%	98%	94%
25°C	90%	97%	96%	80%
40°C	62%	95%	85%	65%
60°C	38% (after 6 months)	70%	75%	60% (after 3 months)

Table 1: Estimated recoverable capacity when storing a battery for one year
Elevated temperature hastens permanent capacity loss. Depending on battery type, lithium-ion is also sensitive to charge levels.

Lithium-ion batteries are often exposed to unfavorable temperatures, and these include leaving a cell phone in the hot sun or operating a laptop on the power grid. Elevated temperature and allowing the battery to sit at the maximum charge voltage for expended periods of time explains the shorter than expected battery life. Elevated temperature and excessive overcharge also stresses lead and nickel-based batteries. All batteries must have the ability to relax after charged, even when kept on float or trickle charge.

Nickel-metal-hydride can be stored for about three years. The capacity drop that occurs during storage can partially be reversed with priming. Nickel-cadmium stores well, even if the terminal voltage falls to zero volts. Field tests done by the US Air Force revealed that NiCd stored for five years still performed well after priming cycles. It is believed that priming becomes necessary if the voltage drops below 1V/cell. Primary alkaline and lithium batteries can be stored for up to 10 years with minimal capacity loss.

You can store a sealed lead acid battery for up to two years. Since all batteries gradually self-discharge over time, it is important to check the voltage and/or specific gravity, and then apply a charge when the battery falls to 70 percent state-of-charge. This is typically the case at 2.07V/cell or 12.42V for a 12V pack. (The specific gravity at 70 percent charge is roughly 1.218.) Some lead acid batteries may have different readings and it is best to check the manufacturer's instruction manual. Low charge induces sulfation, an oxidation layer on the negative plate that inhibits current flow. Topping charge and/or cycling may restore some of the capacity losses in the early stages of sulfation.

Sulfation may prevent charging small sealed lead acid cells, such as the Cyclone by Hawker, after prolonged storage. If seemingly inactive, these batteries can often be reactivated by applying a higher than normal voltage. At first, the cell voltage under charge may go up to 5V and absorb only a small amount of current. Within two hours or so, the charging current converts the large sulfate crystals into active material, the cell resistance drops and the charge voltage gradually normalizes, and at a voltage of 2.10–2.40V the cell is able to accept a normal charge. To prevent damage, set the current limit to a very low level. Do not attempt to perform this service if the power supply does not allow setting current limiting. Read about Charging with a Power Supply.

Simple Guidelines for Storing Batteries

- Primary batteries store well. Alkaline and primary lithium batteries can be stored for 10 years with moderate loss capacity.
- Remove battery from the equipment and store in a dry and cool place.
- Avoid freezing. Batteries freeze more easily if in discharged state.
- Charge lead acid before storing and monitor the voltage or specific gravity frequently; apply a boost if below 2.10V/cell or an SG below 1.225.

- Nickel-based batteries can be stored for five years and longer, even at zero voltage; prime before use.
- Lithium-ion must be stored in a charged state, ideally 40 percent. This assures that the battery will not drop below 2.50V/cell with self-discharge and fall asleep.
- Discard Li-ion if the voltage has stayed below 2.00/V/cell for more than a week.

Caution :	When charging an SLA with over-voltage, current limiting must be applied to protect the battery. Always set the current limit to the lowest practical setting and observe the battery voltage and temperature during charge. In case of rupture, leaking electrolyte or any other cause of exposure to the electrolyte, flush with water immediately. If eye exposure occurs, flush with water for 15 minutes and consult a physician immediately. *Wear approved gloves when touching electrolyte, lead and cadmium. On exposure to skin, flush with water immediately.*