Why Discharge?

Why use a discharger?
There are two good reasons:

1. It can save you money.
2. It extends the life of your packs and improves their performance.

Your battery packs are expensive and anything you can do to extend their life will help you to maximize your investment. Along with a good charger and proper storage, CamLight Systems' 2-Stage Pack Dischargers and Auto-Cutoff Modules are designed to extend the life of your NiCd and NiMH packs by conditioning the cells and insuring that they retain as much capacity as possible over the years.

Not using a discharger that automatically turns off at the correct voltage (approx. 0.9V/cell) can lead to:

- Over-discharging and reversal of one or more cells, damaging the pack. This causes loss of capacity, high self-discharge rates and reduced voltage under load. This damage is cumulative and may not be immediately noticeable or the damage might mistakenly be attributed to other causes.
- Under-discharging and the loss of capacity and voltage depression resulting from unwanted large cadmium crystal growth

We still have packs from 1992 being used here at CamLight Systems, charged/discharged several hundred times, and it's the combination of proper charging, discharging with the right value load to a known cutoff voltage, and proper storage that makes this possible. Omit any of these three things and the life of your packs will be shortened.

How does proper discharging help?
Regularly scheduled discharging of your packs down to a known cutoff voltage (typically around 0.9V/cell) helps to "condition" the cells in the pack, i.e, it helps to create the smaller cadmium crystals that increase the cell's voltage under load. It also reduces the presence of other alloys with lower electro-chemical potential, i.e., lower voltage levels.

Under normal use, and moderate to high charging currents, the cadmium that is deposited during a charge is deposited as very small crystals with a large surface area. This larger surface area is important because it exposes more of the cadmium to the electrolyte and decreases the cell's internal resistance, thereby increasing the cell's voltage under load. CamLight Systems' 2-Stage Pack Dischargers and Auto-Cutoff Modules make this easy.

Unfortunately, over time these small crystals want to join together to produce larger crystals. These larger crystals decrease the surface area of the cadmium and are harder to dissolve while discharging. This leads to higher internal resistance and voltage depression under load. Three things help these large crystals to form:

1. **Slow charging** – While good for initially forming new cells, it shouldn't be the standard method of charging. Slow charging encourages slow crystal growth and this aids in the formation of large crystals.
2. **High temperature** – Crystal growth speeds up as the temperature increases.
3. **Time** – More time between full discharges means that the crystals have more time to combine and grow larger.

These larger crystals can actually grow enough to puncture the separator inside the cell (shorting it out internally) and cause the cell to self-discharge much faster than normal.

Using your battery packs without discharging them completely converts only some of those larger crystals back to the desirable smaller size when you charge them. The remaining larger crystals now have even more time to join together and increase the internal resistance of your cells. A proper (complete) discharge and recharge converts all of the cell's cadmium to smaller crystals, reducing the internal resistance and allowing you to maximize the current you can draw from the pack. It also helps to increase the voltage of the pack while under load.

How else can a discharger help me?
Using a discharger with known cutoff voltage levels will consistently bring your packs down to the same voltage level every time. This makes it easy to:

- Track and log the capacity of your packs to better know when to replace them.
- Recondition "tired" packs to bring back most, if not all, of their original capacity and voltage under load by converting the cadmium back to smaller crystals.

If the discharger has adjustable loads, you can easily and accurately:

- Test the efficiency of the cells at different current levels making it easy to know how hard you can push them.
- Measure the temperature of the pack at various discharge current levels to test different shrink-wrapping, mounting and cooling strategies.
- Test the useful run times of your packs at various discharge current levels.
- Compare different chemistries (NiCd vs. NiMH) and cell capacities at various discharge current levels to pick the best pack for each of your applications.

Over-discharging and its effect
While discharging until the cells in a pack are "empty" (to approximately 0.9V/cell) is good, discharging them any further is not better. In fact, it can destroy cells in your pack.

Not all of the cells in your pack are identical. As the pack ages the cells become more and more unbalanced (different voltage or charge levels between the cells) and some cells can "empty" before others during a discharge if the pack's voltage is brought too low. If these already-discharged cells are discharged even more, they are subjected to what is essentially a reversed-polarity charge. This causes excess gas to be produced which builds up pressure in the cell, possibly forcing the gas to escape through the cell's safety vents. This causes a loss of water and damages the cell.

Discharging must be stopped before this reversal (and the damage it causes) can occur. Accepted cutoff values for NiCd/NiMH packs range from 0.8V/cell to 1.1V/cell, depending on the discharge current level (the higher the discharge current level, the lower the cutoff should be). All of CamLight Systems' 2-Stage Pack Dischargers and Auto-Cutoff Modules have per-cell cutoffs in this range. We recommend 0.9V/cell as a standard. It is low enough to make sure all of the useful charge in a pack is removed without being so low as to risk cell-reversal due to over-discharging.

The better the cells are matched in a pack (i.e., the pack is balanced), and the longer they stay that way, the less you have to worry about cell reversal during a discharge. The cells will each discharge at the same rate and their voltages will stay matched. This helps prevents cell reversal since no cell is being brought down to zero volts ("emptied") before the others and damaged as a result. You can accidentally over-discharge such a pack with much less fear of damaging one or more cells.

All packs will become more and more unbalanced as they age. Moderate to high current charging and discharging to approximately 0.9V/cell can help keep your packs balanced as long as possible. If your pack configuration and size allows it, occasionally discharging each cell (individually) to 0.0V and then charging the cells together as a pack is the best way to maintain this balance. In between these zero-volt discharges, keep discharging your packs to approximately 0.9V/cell.

When should I discharge?
You should not discharge your packs after every use. They only have a limited life (especially some NiMH packs) and you don't need to condition the packs every time you use them.

We recommend the following:

- Discharge to 0.8V/cell to 1.0V/cell (choose the lower cutoff for higher discharge rates to compensate for voltage drops cause by internal cell resistance) every 3-4 weeks.

- Discharge before storing the packs for more than 2 weeks.
- If the packs are not being used, cycle (charge/discharge) them 1-2 times every 3-4 weeks.

Additional tips:

- Don't leave the packs on a trickle charge for a long time. This will cause large crystal growth that leads to voltage depression.
- Don't overcharge the cells. Use a peak-detection charger at a moderate to high rate, but avoid overheating the pack.
- Don't store, charge, or discharge them at over 85°F. (30°C.).
- Don't discharge below 0.8V/cell. The cell is essentially completely discharged at approximately 0.9V/cell to 1.0V/cell. If you do go below 0.8V/cell, immediately start a trickle charge, at a 0.1C rate or lower, until the pack has charged up a bit (at least 0.2AH). Then complete the charge normally and do a standard discharge to 0.8V/cell or higher.

Fast vs. slow discharging

There's a lot of debate over the merits of discharging your packs at the same current level you use them. We feel it's a good idea for the following reasons:

- You can easily measure the capacity of your packs during a discharge at the same current level you use them.
- It's often a lot faster.

But, there's a downside to fast discharging. The internal resistance of the cell causes the voltage of the pack to drop more and more as higher and higher discharge currents are used. This makes the pack appear to be discharged, even though a significant amount of charge may still be left in the cells.

You can fully discharge a pack by slowly discharging it (typically at a 1C rate or lower), but that takes a very long time. Or, you can do a quick higher-current discharge down to a known cutoff value and then a second lower-current discharge to minimize the voltage drop due to the cell's internal resistance. This ensures a complete discharge and better helps to condition the pack, increase its voltage under load, and increase its life expectancy.

All of CamLight Systems' Pack Dischargers use 2-Stage discharging to give you the shortest discharge time while still ensuring a complete discharge.

Heat is the enemy

Fast discharging has a lot of benefits but it can cause damage to your packs if you're not careful. Simply put, heat is bad. You might have seen packs get so hot that their heat shrink melted (or worse) and they appeared OK, but they're not. While high-quality cells are more resistant to damage from heat than ever before, they're not invulnerable. The cell can leak gasses formed during fast discharging and plate or separator warping or damage can occur. It might not be obvious at first, but over time the damage will lower the pack's capacity and voltage under load, eventually leading to the failure of one or more cells.

But, a lot of times we don't have much of a choice while using the pack. The discharge current level often needs to be high to get the performance we need out of the device using the pack. Just be aware that the temperature of the cells is much, much higher inside that pack than it is outside of the shrink wrap and do whatever you can to cool them quickly. But, do not refrigerate your packs before using them or cool them with anything other than air! A cold cell will not perform well and can very easily be damaged by localized heating inside the cell as it's used. In addition, cooling them too fast (e.g., using water or carbon-dioxide) will just cause warping or other physical damage to the cell as the inside of the cell is still very hot.

To help maximize the life of your packs:

- Keep the discharge current level low enough to prevent overheating whenever you can. Let the temperature of the cells tell you how high a discharge current level they can safely handle. Most manufacturers set the safe temperature limit during discharge to 130°F. (55°C.) or so, with a maximum of 150°F. (66°C.) set by manufacturers of some cells. This doesn't mean that the outside surface of the shrink wrap should stay below this temperature. The cell itself needs to stay below this level to maximize its life.

- As much as possible, cool them with fast moving air as they are being used. Add space between the cells to allow for better air flow.
- Don't store them above 85°F. (30°C.) or below 32°F. (0°C.).

Can you exceed the rated maximum temperatures and have the cell survive? Of course. Just be aware that a little bit of the pack's performance might be lost, and its life expectancy shortened, each time you do.

Be sure to read our **Tech Tips** that give you other ways to help extend the life of your packs and maximize their performance.

Check our web site at
www.camlight.com
for our list of dealers and the latest information on our current and upcoming products.