A NiCd Never Forgets. Or Does It?

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A NiCd Never Forgets.

A lot of folklore has accumulated about memory effect and nickel-cadmium (NiCd) rechargeable batteries. It's time to separate myth from fact.

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When the conversation drifts to rechargeable batteries—NiCds in particular—someone is sure to bring up the dreaded *memory effect*. True memory effect refers to a specific type of deterioration in NiCd cell performance. It manifests itself as a reduction in cell voltage, usually in the order of a few tenths of a volt, and is brought on by many repeated shallow charge/discharge cycles (see Figure 1).

First, the Bad News about Memory Effect

The bad news is that there is much controversy surrounding the memory effect, despite decades of NiCd use in industrial and consumer products. Much of the debate surrounds the procedure of discharging NiCds before charging. Proponents argue that discharging is necessary to prevent memory effect, while opponents claim that it's just a waste of valuable cell life. (NiCds typically enjoy a life-span of about 200 complete charge/discharge cycles. More cycles are possible with less than a complete discharge.) Some dismiss both extremes and advocate an occasional discharge before charge. Unfortunately, the frequency of the procedure is still a subject of debate.

Now for the Good News

The good news is that the preponderance of evidence suggests true memory effect is very rare. It usually takes many shallow discharge cycles to *precisely* the same discharge point before memory effect occurs. (Conditions such as these were present in communications satellites, where memory effect was first observed.) Some battery manufacturers even claim their batteries exhibit no memory effect at all. For this reason, I suspect other types of battery problems are often mistaken for this phenomenon. Voltage depression is probably the most likely culprit in most cases (see Figure 2).

While it's even possible for a cell loss of only one-tenth of a volt to go unnoticed, perhaps the best news of all is this: *Even if you experience memory effect, it's neither permanent nor fatal.* One or two complete charge/discharge cycles is all it takes to restore your NiCd to original condition. (I am defining a "complete discharge" in this case as 1.0 V per cell. You'll find out why later.)

The NiCds in My Home and Shack

I've had good luck with my NiCds. In fact, the current champions around our house are the batteries in my cordless elec-

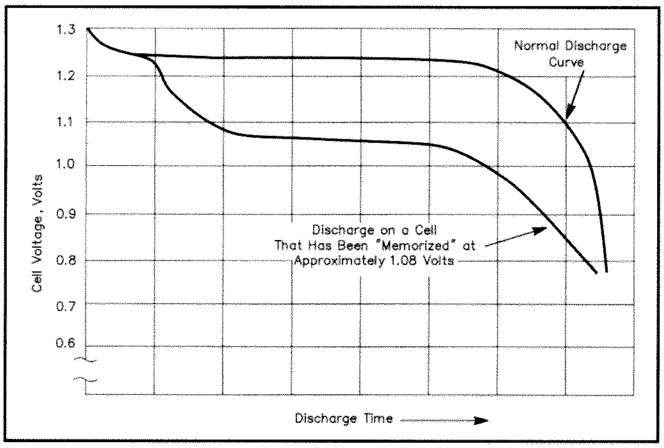

Figure 1—Discharge characteristics of a normal NiCd versus a cell with memory effect.

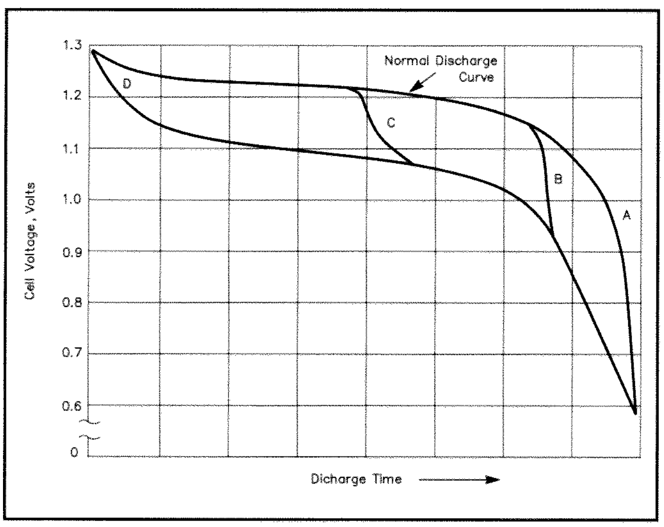

Figure 2—Voltage depression symptoms closely mimic the true memory effect. So much so, in fact, some people tend to define voltage depression and true memory effect as one phenomenon called "memory." The two, however, are quite different. Be sure to understand which of these effects, as well as any others, are considered as "memory" when you encounter other discussions on this topic. Voltage depression in NiCds is caused by long, continuous overcharging. The effect is initially limited at the end of the discharge cycle as indicated by curve B. As the length of overcharge time increases, the effect starts occurring sooner during the discharge period, such as illustrated by curve C. If the overcharge is severe enough, the discharge curve takes on the shape produced by a normal cell, but the whole curve is depressed, as shown by curve D. Voltage depression is caused by the growth of crystals inside the battery. These crystals in turn cause an increase in the battery's internal resistance. Fortunately, like the true memory effect, this is a reversible phenomenon. One or more deep discharge/charge cycles is all it takes to reverse voltage depression. It's best, however, to prevent voltage depression from occurring in the first place by not overcharging your NiCds.

Or Does It?

tric razor. They've seen daily use for almost 10 years now and they're still going strong! The following guidelines have worked well for me and represent my personal philosophy on the treatment of NiCd batteries:

❑ First and foremost, I always follow the manufacturer's instructions for any given product. The one exception I make, however, is never to intentionally discharge my NiCds until they are completely depleted. As I indicated previously, my rule of thumb is never to discharge a NiCd cell to less than 1.0 V. Discharging cells beyond this limit can lead to cell reversal and shortened battery life. See Figure 3 for a description of cell reversal.

But what if you can't conveniently measure the cell voltages? A typical example is the electric toothbrush that my wife recently purchased. It came with instructions to initially charge the batteries, but not to recharge them until they are depleted. The manual also recommends a complete discharge once a year or so. While I may leave the charger unplugged for a few days at these times, I'll be sure to reconnect it before the NiCds are completely dead.

❑ Second, in the absence of instructions to the contrary, I only recharge when convenient or necessary. I find the normal variations of the charge/discharge regime of most appliances to be more than adequate to prevent the onset of memory effect. (And yes, I do occasionally forget to start recharging an appliance before the batteries run out!) I also use this as a guideline for appliances that feature automatic shut-down at a predetermined voltage level, but I admit to having only minimal experience with such devices.

❑ And third, only if I suspect or encounter memory effects do I intentionally discharge my batteries to the 1.0 V level. Remember, this effect is neither permanent nor fatal. Why subject NiCds to unnecessary and life-shortening stress, especially when such a simple procedure will reverse it?

Discharge Before Charge

You may have seen NiCd chargers that have a discharge-before-charge feature. These devices enable you to conveniently discharge NiCds to a predetermined level before charging them. Although I do not recommend using a discharge feature to prevent the onset of memory effect (only as a last resort, if you suspect memory effect), the discharge feature can help correct NiCd *cell imbalance*. This problem occurs when multiple cells connected in series have unequal charges.

Imbalance can be promoted by the use of a *peak*-type full-charge detector (see Figure 4). If some, but not all, of the cells achieve full capacity during a charge cycle, a voltage peak can still be generated. This peak tricks the charger into shutting off, even though some cells are not yet at full charge. Cell imbalance is a rather common problem with NiCds—far more common than memory effect.

To properly balance NiCds, first discharge and recharge them in the normal fashion. Then, once the initial charge is complete, continue to trickle charge your battery until you are certain all cells are at full charge.

Another problem associated with fast chargers is overcharging. If a fast charger fails to detect that full capacity on even a single cell has been reached, charging continues and cell *outgassing* can occur. Loss of cell capacity always accompanies cell outgassing.

You can find more about NiCds and the memory effect by reading "Getting the Most Out Of Nickel-Cadmium Batteries" by Ken Stuart, W3VVN, in February 1992 *QST* and "A Microcomputer-Controlled NiCd Battery Charger" by Tim Ahrens, WA5VQK, in August 1990 *QST*. Two other good sources of information are: *Maintenance-Free Batteries*, by D. Berndt, published by John Wiley & Sons, and *Rechargeable Batteries Applications Handbook*, by the Technical Marketing Staff of Gates Energy Products Inc, published by Butterworth-Heinemann, a division of Reed Publishing.

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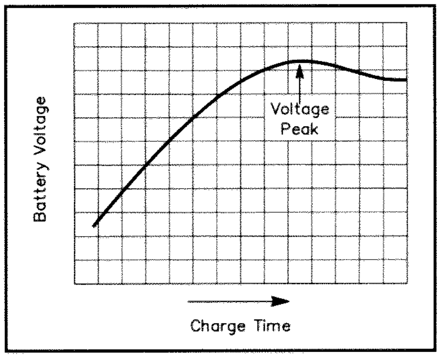

Figure 4—The terminal voltage of a NiCd cell increases as the cell is charged. Once the cell is fully charged, though, the terminal voltage drops slightly. Many of the so-called rapid or fast chargers detect this drop and automatically stop or reduce the charge rate. Two other techniques used to detect full charges in NiCds are time and temperature. Only NiCds that are specified as suitable for fast charging should be used in this type of charger.

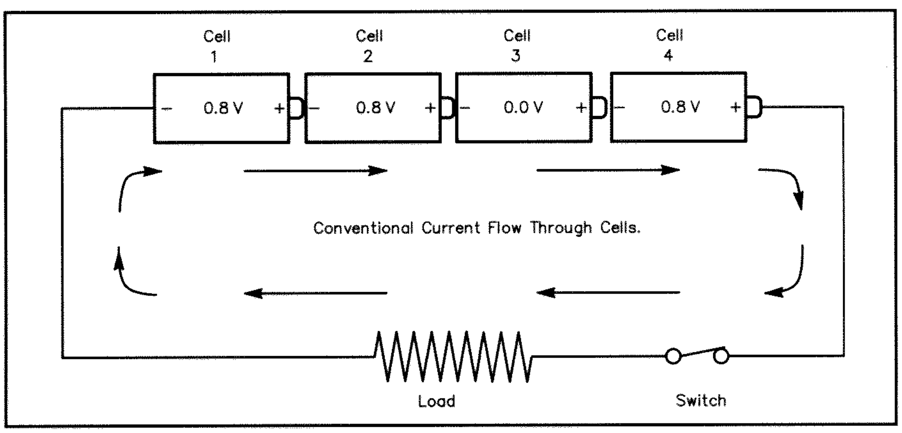

Figure 3—NiCd battery packs should not be discharged to a level less than 1.0 V per cell. Overdischarging a series-connected battery pack can lead to cell reversal—a phenomenon detrimental to NiCd longevity. During overdischarge, differences in individual cell capacity can lead to one cell becoming depleted before the others. In the example shown, cell 3 is completely discharged, while cells 1, 2 and 4 are still at 0.8 V. At this point, the current generated by the remaining active cells will "charge" cell 3, *but in reverse polarity*. Cell reversal can lead to outgassing and permanent damage to NiCds. If you accidentally overdischarge your NiCds and experience a cell reversal, try recharging the pack for the full time recommended by the manufacturer. One or two occurrences of cell reversal probably won't destroy the pack, but try not to let it happen again.