Rechargeable batteries: NiCd and nickel-metal hydride

Part 1—More portable radio communications equipment manufacturers and users select nickel-cadmium (NiCd) batteries than any other type. Here are some comparisons between NiCd technology and a challenger.

By Isidor Buchmann

One of the common difficulties with battery-powered equipment is the gradual deterioration in performance after the first year of service.

Although fully charged, the battery's performance may have dropped to half the original capacity, resulting in unexpected down time. Without knowing the reason for the failure, the user sends in the equipment for service, only to find out that the problem has not been solved. Service centers have indicated that half of the equipment failures are battery-related.

The battery is the mystical "black box" that causes much grief, frustration and headache. One never knows whether the battery is fully charged or empty.

Has it taken a full charge, or has the *ready* indicator on the charger fooled the user, only to have the battery quit after 30 minutes of use? The battery does not reveal its mood; it does not change weight, color or shape to indicate its status. It simply keeps the user guessing.

In many ways the battery exhibits human-like characteristics: it needs good nutrition; it likes a moderate room temperature; and, in the case of the nickel-cadmium (NiCd) battery, it requires regular exercise. This article focuses on the needs of the different battery chemistries, what applications are suitable for them and how one can get the most out of them.

Nickel-cadmium battery

Among the rechargeable batteries, the NiCd remains the most popular choice.

Buchmann is the founder and chief executive officer of Cadex Electronics in Burnaby, British Columbia. He has been active in the radio communications sector and has studied the behavior of NiCd batteries in practical, everyday applications.

Some of its distinct advantages over other battery chemistries are:

(1) fast and simple charge.

(2) high number of charge-discharge cycles. (When properly maintained, the NiCd provides several thousand cycles.)

(3) excellent load performance, even at cold temperatures.

(4) simple storage and transportation. (The NiCd is accepted by most air freight companies.)

(5) easy to recharge after prolonged storage.

(6) forgiving if abused.

The NiCd is the tough and silent guy. Hard work poses no problem. It prefers fast-charge over trickle-charge and pulse-charge over dc charge.

Improved performance is achieved by interspersing discharge pulses between charge pulses during the charging process. This charge method is commonly referred to as *reflex* or *reverse load* charge.

The brief discharge currents promote the recombination of gases generated during fast-charge. This type of charge method results in a cooler and more effective charge than can be obtained with conventional dc chargers. A study done by a German battery manufacturer has shown that the reverse load charge method adds 15% to the life of the NiCd battery.

The NiCd does not like to be pampered by sitting in chargers for days and being used only occasionally for brief periods. In fact, the NiCd is the only battery type that performs best if periodically fully discharged.

All other battery chemistries prefer shallow discharges. So important is this periodic full-discharge that, if omitted, the NiCd gradually loses performance because of voltage depression or "memory effect."

Nickel-metal hydride battery

The nickel-metal hydride (NiMH) battery has been heralded as the shining star that will solve the battery problems of the 20th century and lead us into the 21st.

Although some of the claims are over-optimistic, the NiMH has distinct advantages over the NiCd.

(1) The NiMH is not affected by memory effect in the same way as the NiCd. Periodic exercise cycles may not be necessary.

(2) The NiMH provides 30% more capacity over a "standard" NiCd.

(3) The NiMH is environmentally friendly because it contains no toxic metals.

Unfortunately, the NiMH lags behind the NiCd in several aspects. For example:

(1) *Number of cycles*—The NiMH is rated for only 400 to 700 charge-discharge cycles.

It does not like to flex its muscles too hard, and the longevity of the NiMH is in direct relationship to the depth of discharge. In comparison, the NiCd can accept several thousand full discharge-charge cycles.

A GE research lab claimed that some of the NiCd batteries tested exceeded 30,000 cycles. NiCd batteries for satellite applications were designed to last for 17 years and provide 70,000 cycles.

(2) *Ease of fast-charge*—The NiMH battery does not lend itself to fast-charge as well as the NiCd.

Although a NiCd can safely be charged in 90 minutes, the NiMH will need about twice that time under the same conditions. Unlike the NiCd, the NiMH does not produce a dependable negative delta V to detect the full-charge.

A more complex algorithm for full-charge detection is needed to charge NiMH batteries if no temperature sensor is available.

(3) *Discharge current*—The maximum allowable discharge current of the NiMH

is considerably less than that of the NiCd.

Some manufacturers recommend a discharge current of 0.2C (one-fifth of the rated capacity). This shortcoming may not be critical for applications requiring only a small load, such as cellular phones. For high-power transceivers and power tools, for example, the more rugged NiCd is the recommended choice.

(4) *High self-discharge*—Both NiMH and NiCd are affected by self-discharge. The NiCd loses about 10% of its capacity within the first 24 hours, after which the self-discharge settles to about 10% per month.

For the NiMH, the self-discharge is higher as the hydrogen atoms try to escape. Selecting materials that improve bonding of the hydrogen reduces the capacity of the battery. Research engineers are faced with a compromise between an acceptable charge retention and high capacity.

(5) *Capacity*—Even though the NiMH delivers 30% more capacity than the standard NiCd, ultra-high-capacity NiCd cells now provide capacity levels similar to those of the NiMH. Tests performed by my company have shown good results with the new foam matrix NiCd cells by Panasonic. Sanyo is introducing the new *pasted* NiCd cell that is said to have similar performance to Panasonic's foam cell.

One should be aware, nonetheless, that there are compromises in increasing the capacity of the NiCd.

To obtain higher energy, more active material is packed into the cell. As a result, the internal resistance increases, which in turn reduces the maximum charge and discharge currents. The ultra-high-capacity cell tends to warm up more during fast-charge and discharge than the standard NiCd.

(6) *Stability*—Tests by my company have shown significant variations in performance between different brands of NiMH batteries.

These variations may be due to the metals used. Some NiMH batteries are based on early technologies using metal alloys such as titanium, zirconium, vanadium, nickel and chromium. Some Japanese companies are experimenting with other metals, such as the rare lanthanum.

We have had good test results with the Japanese prismatic NiMH cell used by NTT for a line of cellular phones. Stable results also have been achieved with the Motorola NiMH replacement batteries.

On the other hand, another brand of NiMH cells from the Pacific Rim does not offer the same performance.

(7) *Price*—The price of the NiMH is about 50% higher than that of the NiCd.

Price may not be a big issue when the customer requires high capacity and small size. Panasonic's foam NiCd batteries are only slightly higher-priced than the standard NiCd cells. This means that capacity-for-capacity, the foam NiCd is more competitively priced than the NiMH.

Organizations such as the military, Bell Lab and Black & Decker have made comments that NiMH chemistry is not yet fully defined. The NiMH is not new. In the '70s, this battery chemistry was tested and consequently dropped because it was considered unsuitable for the applications intended. The modern NiMH has improved and likely will maintain a strong market niche, especially in the cellular phone market.

Next: Lead-acid and lithium batteries; memory effect and self-discharge; and battery conditioning.