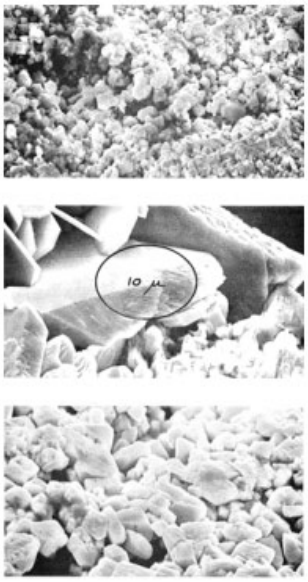
Battery University

Memory: Myth or Fact?

During the nickel-cadmium years in the 1970s and 1980s, most battery ills were blamed on “memory.” Memory is derived from “cyclic memory,” meaning that a nickel-cadmium battery could remember how much energy was drawn on previous discharges and would not deliver more than was demanded before. On a discharge beyond regular duty, the voltage would abruptly drop as if to rebel against pending overtime. Improvements in battery technology have virtually eliminated the phenomenon of cycling memory.

Figure 1 illustrates the stages of crystalline formation that occur on a nickel-cadmium cell if overcharged and not maintained with periodic deep discharges. The first enlargement shows the cadmium plate in a normal crystal structure; the middle image demonstrates full-blown crystalline formation; and the third reveals some form of restoration.



New nickel-cadmium cell. The anode (negative electrode) is in fresh condition. Hexagonal cadmium-hydroxide crystals are about 1 micron in cross section, exposing large surface area to the electrolyte for maximum performance.

Cell with crystalline formation. Crystals have grown to 50 to 100 microns in cross section, concealing large portions of the active material from the electrolyte. Jagged edges and sharp corners can pierce the separator, leading to increased self-discharge or electrical short.

Restored cell. After a pulsed charge, the crystals are reduced to 3–5 microns, an almost 100% restoration. Exercise or recondition is needed if the pulse charge alone is not effective.

Figure 1: Crystalline formation on nickel-cadmium cell. Crystalline formation occurs over a few months if battery is overcharged and not maintained with periodic deep discharges.

Courtesy of the US Army Electronics Command in Fort Monmouth, NJ

The modern nickel-cadmium battery is no longer affected by cyclic memory but suffers from *crystalline formation.*The active cadmium material is applied on the negative electrode plate, and with incorrect use a crystalline formation occurs that reduces the surface area of the active material. This lowers battery performance. In advanced stages, the sharp edges of the forming crystals can penetrate the separator, causing high self-discharge that can lead to an electrical short. The term “memory” on the modern NiCd refers to crystalline formation rather than the cycling memory of old.

When nickel-metal-hydride was introduced in the early 1990s, this chemistry was promoted as being memory-free but this claim is only partially true. NiMH is also subject to memory but to a lesser degree than NiCd. While NiMH has only the nickel plate to worry about, NiCd also includes the memory-prone cadmium negative electrode. This is a non-scientific explanation of why nickel-cadmium is more susceptible to memory than nickel-metal-hydride.

Crystalline formation occurs if a nickel-based battery is left in the charger for days or repeatedly recharged without a periodic full discharge. Since most

applications fall into this user pattern, NiCd requires a periodic discharge to one volt per cell to prolong service life. A discharge/charge cycle as part of maintenance, known as *exercise,* should be done every one to three months.Avoid over-exercising as this wears down the battery unnecessarily.

If regular exercise is omitted for six months and longer, the crystals ingrain themselves and a full restoration with a discharge to one volt per cell may no longer be sufficient. However, a restoration is often still possible by applying a secondary discharge called “recondition.” Recondition is a slow discharge that drains the battery to a voltage cut-off point of about 0.4V/cell and lower. Tests done by the US Army indicate that a NiCd cell needs to be discharged to at least 0.6V to effectively break up the more resistant crystalline formations. During this corrective discharge, the current must be kept low to minimize cell reversal and, as discussed earlier, NiCd can tolerate a small amount of cell reversal. Figure 2 illustrates the battery voltage during a discharge to 1V/cell, followed by the secondary discharge to 0.4V/cell.

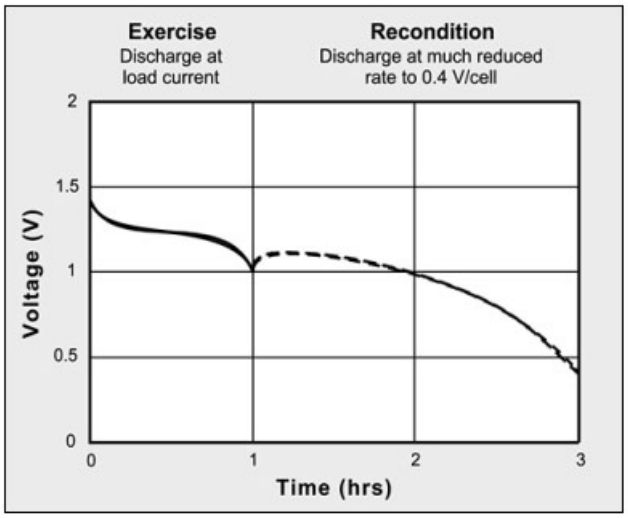


Figure 2: Exercise and recondition features of a Cadex battery analyzer

Recondition restores NiCd batteries with hard-to-remove memory. Recondition is a slow, deep dis-charge to 0.4V/cell.

Courtesy of Cadex

Recondition is most effective with healthy batteries and the remedy is also known to improve new packs. Similar to a medical treatment, however, the service should only be applied when so needed because over-use will stress the battery. Automated battery analyzers (Cadex) only apply the recondition cycle if the user-set target capacity cannot be reached.

Recondition is only effective on working batteries. Best results in recovery are possible when applying a full discharge every 1–3 months. If exercise has been withheld for 6–12 months, the capacity may not recover fully, and if it does the pack might suffer from high self-discharge caused by a marred separator. Older batteries do not restore well and many get worse with recondition. When this happens, the battery is a ripe candidate for retirement.

Results of Battery Maintenance

After the Balkan War in the 1990s, the Dutch Army began servicing its arsenal of nickel-cadmium batteries that had been used for the two-way radios. The technicians in charge wanted to know the remaining capacity and how many batteries could be restored to full service using battery analyzers (Cadex). The army knew that allowing the batteries to sit in the chargers with only two to three hours of use per day during the war was not ideal, and the tests showed that the capacity on some packs had dropped to a low 30 percent. With the recondition function, however, nine out of 10 batteries could be restored to 80 percent and higher. The army uses 80 percent as a threshold for usability. At time of service, the nickel-cadmiumbatteries were two to three years old.

To analyze the effectiveness of battery maintenance further, the US Navy carried out a study to find out how user pattern affects the life of nickel-cadmium batteries. For this, the research team responsible for the program established three battery groups. One group received charge only (no maintenance); another was periodically exercised (discharge to 1V/cell); and a third group received recondition. The 2,600 batteries studied were used for Motorola two-way radios deployed on three US aircraft carriers. Table 3 summarizes the test results, including the cost factor.

Maintenance method	Annual % of batteries requiring replacement	Annual battery cost (US$)
Charge-and-use only	45%	$40,500
Exercise	14%	$13,500
Recondition	5%	$4,500

Table 3: Replacement rates of nickel-cadmium batteries
Exercise and recondition prolong battery life by three- and ninefold respectively.

GTE Government Systems, the organization that conducted the test, learned that with *charge-and-use* the annual percentage of battery failure was 45 percent; with exercise the failure rate was reduced to 15 percent; and with recondition only 5 percent failed. The GTE report concludes that a battery analyzer featuring exercise and recondition costing US$2,500 would return the investment in less than one month on battery savings alone.

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If you have a suggestion or would like to report an error, please use the "contact us" form or email us at: BatteryU@cadex.com. We like to hear from you but we cannot answer all inquiries. We recommend posting your question in the comment sections for the Battery University Group (BUG) to share.

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Comments

On March 10, 2011 at 11:09am

Isidor wrote:

This article has been updated as of March 10, 2011 with new information.

On March 28, 2011 at 3:11pm

maghsoud safari javid wrote:

thanks a lot for your teaching

On November 13, 2011 at 5:46am

Mark McElroy wrote:

As a chemist(not a pharmacist) I find the technical information extremely interesting, and as a rechargeable battery user, very useful too.

On February 25, 2012 at 12:49pm

Andy Ritchie wrote:

Excellent article. detailed and succinct, and very informative. I appreciate the thoroughness with which you discuss both the causes of memory and the research in the area of battery memory and health. I especially like the cost/failure-analysis portion at the end.

On May 16, 2012 at 2:50pm

Felix wrote:

I love ur detailed explaination

On May 17, 2012 at 12:39am

Mark McElroy wrote:

Not a comment but a question. I have recently had installed photo voltaic solar panels. The problem with PVs is that most of their output cannot be used by the household. So, and maybe this is for the future, we need cheap rechargeable batteries to store the excess for use when needed. What is the state of research on affordable, convenient, and small storage batteries for PV users? I live in the UK.

On December 20, 2013 at 1:58pm

john garrettt wrote:

Hello! Im looking to use telephone wire as a discharge unit for cell packs for the reconditioning process. I'm not techy at all so please understand. Currently Im using 2000 foot of phone wire and Im having pretty good luck…. What Id like to know is… Am I on the right track deleting the cell pack to almost 0 and zapping with a charger to get it going? They work ok but could they be better? Thank you and Merry Christmas.

On September 20, 2014 at 1:53am

David Zuccaro wrote:

This explanation doesn't quite hang together. During discharge Cadmium hydroxide crystals are formed, not removed, (Cadmium metal is oxidised to cadmium hydroxide) so it does not make sense to say that failing to fully discharge causes the formation of large crystals. The opposite should be true. There must be something missing from this explanation.

On August 3, 2015 at 8:48am

Joe wrote:

I have a battery for a cordless weed whacker (lawn/garden trimmer) that is NiCd, but the instructions says to charge it periodically every 3 months though. No where in the instructions does it mention that they are NiCd batteries though. I can only assume that the instructions were written by someone incompetent assuming they were Li batteries or else that all batteries in general should be kept charged. Is this a silly assumption? Is it possible that these NiCd batteries should be charged every 3 months even if not in use?

On October 26, 2015 at 7:43am

Barrett wrote:

Great article! You mentioned a US Navy study. Where can I find that study?

On May 26, 2016 at 6:21am

mahmoud moradi wrote:

Thank you very much nice training

On July 1, 2016 at 10:33am

Nigel Anderson wrote:

The idea of a battery “university” is substantially detracted from when You, various manufacturers and other armchair Asbergers actually DISAGREE about the correct charging procedure!!!

Yaesu, for example recommends against “topping up” a NiMh, where as others claims that doing so actually improves battery health:

http://www.thomasdistributing.com/Battery-and-Charger-FAQs_ep_46-1.html

On September 24, 2016 at 1:44pm

Jay wrote:

Thank you for the information.