B7 BATTERIES

NICKEL TECHNOLOGIES

Nickel-cadmium cells

Nickel-cadmium cells were invented in 1899 by a Swede by the name of Waldmar Jungner, however they were only mass produced in the early 1960s because they were so expensive. Today they are most commonly used in motorised equipment, power tools, two way radios, electric razors, commercial and industrial portable products, medical instrumentation, emergency lighting and toys.

The structure

Nickel-cadmium cells fall under the category of secondary cells which means they are rechargeable. They produce an emf of 1,2 volts. The nickel-cadmium cell (NiCD) is covered in a metal case and contains a cadmium electrode and a nickel hydroxide electrode which are separated from each other by a separator which prevents the electrode materials mixing together and reacting with each other while the cell is not in use. The electrolyte used in the nickel-cadmium cell is an alkaline electrolyte, which is often potassium hydroxide, and is not consumed in the reaction.

The reactions

The reaction at the cadmium electrode (**anode**) is:

$$Cd + 2OH^- \rightarrow Cd(OH)_2 + 2e^-$$

The reaction at the nickel hydroxide electrode (**cathode**) is:

$$2NiO(OH) + 2H_2O + 2e^- \rightarrow 2Ni(OH)_2 + 2OH^-$$

Therefore the overall reaction is:

$$2NiO(OH) + Cd + 2H_2O \rightarrow 2Ni(OH)_2 + Cd(OH)_2$$

During the recharge cycle the reaction goes in the reverse direction.

Over-charging

Overcharging a NiCD cell can damage the cell. Overcharging at the anode produces hydrogen gas and overcharging at the cathode produces oxygen gas. Because of this the anode always has a higher capacity than the cathode because the release of hydrogen gas could cause an explosion. NiCD cells therefore need to have vents to allow the release of oxygen that is formed inside the cell but once the oxygen is released the cell needs to be resealed. This complex sealing mechanism needed in the NiCD cells increases their manufacturing cost.

Advantages and disadvantages

- Compared to an alkaline cell the NiCD cell has a longer shelf-life.
- Nickel metal hydride (NiMH) cells are very similar to NiCD cells except they have a higher capacity and are less toxic but are slightly more expensive.
- NiCD cells have a low internal resistance.
- NiCD cells have a quarter of the capacity of alkaline cells.
- NiCD cells can recharge at a fast rate and the recharge reaction is endothermic so the cell does not over-heat.
- Lead-acid batteries are the most common alternative to NiCD cells. Although NiCD cells are generally much more costly than lead-acid batteries, they have a higher energy density which means they are smaller and lighter than lead-acid batteries.

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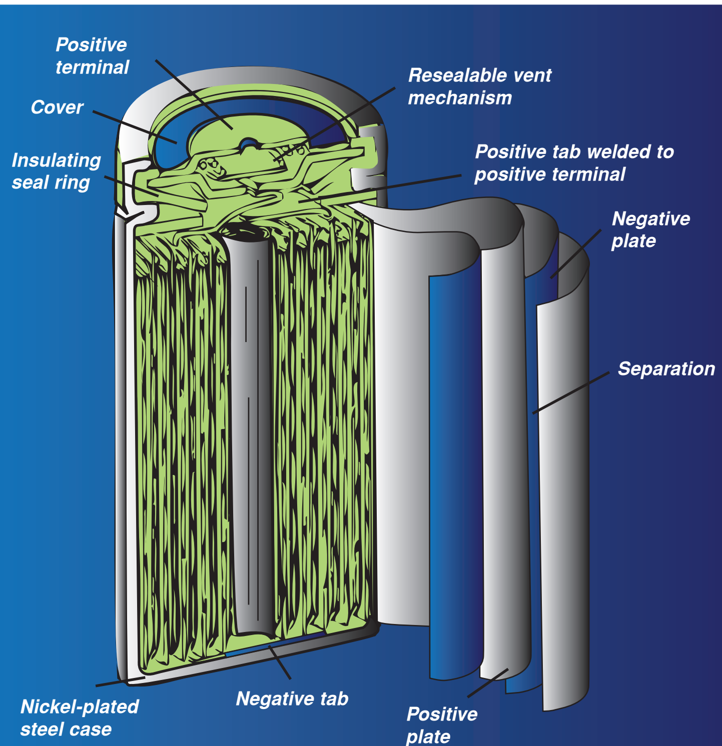

Nickel-based batteries exhibit a relatively high self-discharge. At ambient temperature, a new nickel-cadmium loses about 10% of its capacity in the first 24 hours after charge. The self-discharge settles to about 10% per month afterwards. The self-discharge increases after a nickel-based battery has been cycled for a few hundred times.

Source: BatteryUniversity.com

Memory

It is commonly believed that when rechargeable batteries are not fully discharged between charge cycles that they remember the shortened cycle and are thus reduced in capacity (length of use per charge). This problem was very common with rechargeable batteries up until about 1998. With improvements in batteries and charging technology this 'Memory Effect' is becoming a thing of the past. 'Memory Effect' is the common term used to replace the more accurate term 'Voltage Depression' (VD). VD does not necessarily permanently damage a battery. It can most likely be corrected by fully charging and discharging the battery. VD can be affected by the discharge rate of a battery. Generally speaking, the depth of discharge will be less on discharges at the higher rates. The phenomenon occurs primarily in NiCD batteries. NiMH batteries are almost never affected and Li-ion batteries are never affected.

This material was obtained online from www.zbattery.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Zbattery.com. 2010. Battery Memory Effect. [Online]. Available: http://www.zbattery.com/Battery-Memory-Effect. [27 July 2010].

The effect of crystalline formation

The problem with nickel-cadmium is not so much the cyclic memory but the effects of crystalline formation. The active cadmium material is present in finely divided crystals. In a good cell, these crystals remain small, obtaining maximum surface area. With memory, the crystals grow and conceal the active material from the electrolyte. In advanced stages, the sharp edges of the crystals penetrate the separator, causing high self-discharge or electrical short. When introduced in the early 1990s, nickel-metal-hydride was promoted as being memory-free. Today, we know that this chemistry is also affected but to a lesser degree than nickel-cadmium. The nickel plate, a metal that is shared by both chemistries, is partly to blame. The stages of crystalline formation of a nickel-cadmium cell are illustrated in diagrams below. The enlargements show the cadmium plate in a proper functioning crystal structure, crystalline formation after use (or abuse) and restoration.

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Nickel-cadmium rechargeable cells in recharger

The alternative: Nickel Metal Hydride (NiMH) technology

Most NiMH designs are similar to NiCD designs, but replace the cadmium anode with a "metal hydride", based on complex metallic alloys that can store large quantities of hydrogen. The cathode is nickel oxide, the electrolyte is a solution of potassium hydroxide, stored in a polymer separator sheet.

The **anode** reaction, with "(M)" representing the metal hydride, is:

$(M)H + OH^- \rightarrow (M) + H_2O + e^-$

The **cathode** reaction is:

$NiOOH + H_2O + e^- \rightarrow Ni(OH)_2 + OH^-$

NiMH cells have a typical cell voltage of 1,2 volts, which tends to remain flat through the cell discharge cycle. They tend to have a high self-discharge rate, but are environmentally friendly, at least by the standards of storage cells.

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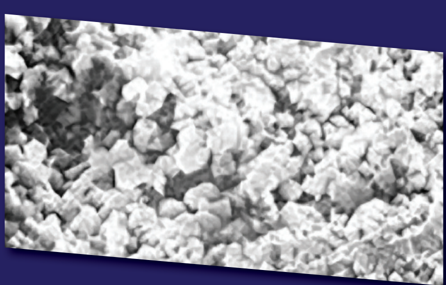
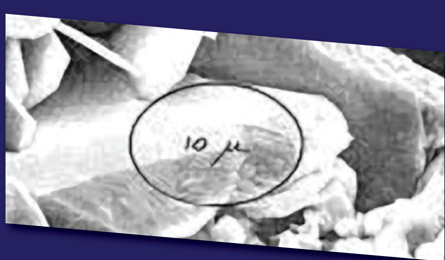
Crystalline formation on nickel-cadmium cell



New nickel-cadmium cell. The anode 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 may pierce the separator, leading to increased self-discharge or electrical short.

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

Illustration courtesy of the US Army Electronics Command in Fort Monmouth, NJ, USA.