Nickel Cadmium Battery Cell

The nickel–cadmium battery (Ni–Cd battery) (commonly abbreviated NiCd or NiCad) is a type of rechargeable battery using nickel oxide hydroxide and metallic cadmium as electrodes.

The abbreviation *NiCad* is a registered trademark of SAFT Corporation, although this brand name is commonly used to describe all Ni–Cd batteries. The abbreviation *NiCd* is derived from the chemical symbols of nickel (Ni) and cadmium (Cd).

There are two types of Ni–Cd batteries: sealed and vented. This article mainly deals with sealed cells.

Applications:

Sealed Ni–Cd cells may be used individually, or assembled into battery packs containing two or more cells. Small cells are used for portable electronics and toys, often using cells manufactured in the same sizes as primary cells. When Ni–Cd batteries are substituted for primary cells, the lower terminal voltage and smaller ampere-hour capacity may reduce performance as compared to primary cells. Miniature button cells are sometimes used in photographic equipment, hand-held lamps (flashlight or torch), computer-memory standby, toys, and novelties.

Specialty Ni–Cd batteries are used in cordless and wireless telephones, emergency lighting, and other applications. With a relatively low internal resistance, they can supply high surge currents. This makes them a favourable choice for remote-controlled electric model airplanes, boats, and cars, as well as cordless power tools and camera flash units. Larger flooded cells are used for aircraft starting batteries, electric vehicles, and standby power.

Voltage:

Ni–Cd cells have a nominal cell potential of 1.2 volts (V). This is lower than the 1.5 V of alkaline and zinc–carbon primary cells, and consequently they are not appropriate as a replacement in all applications. However, the 1.5 V of a primary alkaline cell refers to its initial, rather than average, voltage. Unlike alkaline and zinc–carbon primary cells, a Ni–Cd cell's terminal voltage only changes a little as it discharges. Because many electronic devices are designed to work with primary cells that may discharge to as low as 0.90 to 1.0 V per cell, the relatively steady 1.2 V of a Ni–Cd cell is enough to allow operation. Some would consider the near-constant voltage a drawback as it makes it difficult to detect when the battery charge is low.

Ni–Cd batteries used to replace 9 V batteries usually only have six cells, for a terminal voltage of 7.2 volts. While most pocket radios will operate satisfactorily at this voltage, some manufacturers such as Varta made 8.4 volt batteries with seven cells for more critical applications.

12 V Ni–Cd batteries are made up of 10 cells connected in series.

Battery characteristics

Comparison with other batteries:

Recently, nickel–metal hydride and lithium-ion batteries have become commercially available and cheaper, the former type now rivaling Ni–Cd batteries in cost. Where energy density is important, Ni–Cd batteries are now at a disadvantage compared with nickel–metal hydride and lithium-ion batteries. However, the Ni–Cd battery is still very useful in applications requiring very high discharge rates because it can endure such discharge with no damage or loss of capacity.

Advantages:

When compared to other forms of rechargeable battery, the Ni–Cd battery has a number of distinct advantages:

- The batteries are more difficult to damage than other batteries, tolerating deep discharge for long periods. In fact, Ni–Cd batteries in long-term storage are typically stored fully discharged. This is in contrast, for example, to lithium ion batteries, which are less stable and will be permanently damaged if discharged below a minimum voltage.
- Ni–Cd batteries typically last longer, in terms of number of charge/discharge cycles, than other rechargeable batteries such as lead/acid batteries.
- Compared to lead–acid batteries, Ni–Cd batteries have a much higher energy density. A Ni–Cd battery is smaller and lighter than a comparable lead–acid battery. In cases where size and weight are important considerations (for example, aircraft), Ni–Cd batteries are preferred over the cheaper lead–acid batteries.

- In consumer applications, Ni–Cd batteries compete directly with alkaline batteries. A Ni–Cd cell has a lower capacity than that of an equivalent alkaline cell, and costs more. However, since the alkaline battery's chemical reaction is not reversible, a reusable Ni–Cd battery has a significantly longer total lifetime. There have been attempts to create rechargeable alkaline batteries, or specialized battery chargers for charging single-use alkaline batteries, but none that has seen wide usage.
- The terminal voltage of a Ni–Cd battery declines more slowly as it is discharged, compared with carbon–zinc batteries. Since an alkaline battery's voltage drops significantly as the charge drops, most consumer applications are well equipped to deal with the slightly lower Ni–Cd cell voltage with no noticeable loss of performance.
- The capacity of a Ni–Cd battery is not significantly affected by very high discharge currents. Even with discharge rates as high as 50C, a Ni–Cd battery will provide very nearly its rated capacity. By contrast, a lead acid battery will only provide approximately half its rated capacity when discharged at a relatively modest 1.5C.
- Nickel–metal hydride (NiMH) batteries are the newest, and most similar, competitor to Ni–Cd batteries. Compared to Ni–Cd batteries, NiMH batteries have a higher capacity and are less toxic, and are now more cost effective. However, a Ni–Cd battery has a lower self-discharge rate (for example, 20% per month for a Ni–Cd battery, versus 30% per month for a traditional NiMH under identical conditions), although low self-discharge NiMH batteries are now available, which have substantially lower self-discharge than either Ni–Cd or traditional NiMH batteries. This results in a preference for Ni–Cd over NiMH batteries in applications where the current draw on the battery is lower than the battery's own self-discharge rate (for example, television remote controls). In both types of cell, the self-discharge rate is highest for a full charge state and drops off somewhat for lower charge states. Finally, a similarly sized Ni–Cd battery has a slightly lower internal resistance, and thus can achieve a higher maximum discharge rate (which can be important for applications such as power tools).

Disadvantages:

- The primary trade-off with Ni–Cd batteries is their higher cost and the use of cadmium. This heavy metal is an environmental hazard, and is highly toxic to all higher forms of life. They are also more costly than lead–acid batteries because nickel and cadmium cost more.
- One of the biggest disadvantages is that the battery exhibits a very marked negative temperature coefficient. This means that as the cell temperature rises, the internal resistance falls. This can pose considerable charging problems, particularly with the relatively simple charging systems employed for lead–acid type batteries. Whilst lead–acid batteries can be charged by simply connecting a dynamo to them, with a simple electromagnetic cut-out system for when the dynamo is stationary or an over-current occurs, the Ni–Cd battery under a similar charging scheme would exhibit thermal runaway, where the charging current would continue to rise until the over-current cut-out operated or the battery destroyed itself. This is the principal factor that prevents its use as engine-starting batteries. Today with alternator-based charging systems with solid-state regulators, the construction of a suitable charging system would be relatively simple, but the car manufacturers are reluctant to abandon tried-and-tested technology.

Availability:

Ni–Cd cells are available in the same sizes as alkaline batteries, from AAA through D, as well as several multi-cell sizes, including the equivalent of a 9 volt battery. A fully charged single Ni–Cd cell, under no load, carries a potential difference of between 1.25 and 1.35 volts, which stays relatively constant as the battery is discharged. Since an alkaline battery near fully discharged may see its voltage drop to as low as 0.9 volts, Ni–Cd cells and alkaline cells are typically interchangeable for most applications.

In addition to single cells, batteries exist that contain up to 300 cells (nominally 360 volts, actual voltage under no load between 380 and 420 volts). This many cells are mostly used in automotive and heavy-duty industrial applications. For portable applications, the number of cells is normally below 18 cells (24V). Industrial-sized flooded batteries are available with capacities ranging from 12.5Ah up to several hundred Ah.

Nickel-metal hydride battery:

A **nickel–metal hydride cell**, abbreviated **NiMH** or **Ni-MH**, is a type of rechargeable battery. It is very similar to the nickel–cadmium cell (NiCd). NiMH use positive electrodes of nickel oxyhydroxide (NiOOH), like the NiCd, but the negative electrodes use a hydrogen-absorbing alloy instead of cadmium. A NiMH battery can have two to three times the capacity of an equivalent size NiCd, and their energy density approaches that of a lithium-ion cell.

The typical specific energy for small NiMH cells is about 100 W·h/kg, and for larger NiMH cells about 75 W·h/kg (270 kJ/kg). This is significantly better than the typical 40–60 W·h/kg for Ni–Cd, and similar to the 100-160 W·h/kg for Li-ion. NiMH has a volumetric energy density of about 300 W·h/L (1080 MJ/m^3), significantly better than nickel–cadmium at 50–150 W·h/L, and about the same as li-ion at 250-360 W·h/L.

NiMH batteries have replaced NiCd for many roles, notably small rechargeable batteries. NiMH batteries are very common for AA (penlight-size) batteries, which have nominal charge capacities (*C*) ranging from 1100 mA·h to 3100 mA·h at 1.2 V, measured at the rate that discharges the cell in five hours. Useful discharge capacity is a decreasing function of the discharge rate, but up to a rate of around 1×*C* (full discharge in one hour), it does not differ significantly from the nominal capacity.[4] NiMH batteries normally operate at 1.2 V per cell, somewhat lower than conventional 1.5 V cells, but will operate most devices designed for that voltage.

About 22% of portable rechargeable batteries sold in Japan in 2010 were NiMH. In Switzerland in 2009, the equivalent statistic was approximately 60%. This percentage has fallen over time due to the increase in manufacture of li-ion batteries: in 2000, almost half of all portable rechargeable batteries sold in Japan were NiMH.

One significant disadvantage of NiMH batteries is a high rate of self-discharge; a NiMH battery will lose as much as 3% of its charge per week of storage. In 2005 a **low self-discharge NiMH battery** (LSD) was developed. LSD NiMH batteries significantly lower self-discharge, but at the cost of lowering capacity by about 20%.

History

The first consumer grade NiMH cells for smaller applications appeared on the market in 1989, the culmination of over two decades of research and development

The earliest pioneering work on NiMH batteries — essentially based on sintered Ti_2Ni+TiNi+x alloys for the negative electrode and NiOOH-electrodes for the positives — was performed at the Battelle-Geneva Research Center starting after its invention in 1967. The development work was sponsored over nearly two decades by Daimler-Benz in Stuttgart, Germany, and by Volkswagen AG within the framework of Deutsche Automobilgesellschaft, now a subsidiary of Daimler AG. The batteries showed high specific energy up to 50 W·h/kg (180 kJ/kg), power density up to 1000 W/kg and a reasonable life of 500 charge cycles (at 100% depth of discharge). Patent applications were filed in European countries (priority: Switzerland), United States and Japan and the patents transferred to Daimler-Benz.

Interest grew in the 1970s with the commercialization of the Nickel–hydrogen battery for satellite applications. Hydride technology promised an alternative much less bulky way to store the hydrogen. Research carried out by Philips Laboratories and France's CNRS developed new high-energy hybrid alloys incorporating rare earth metals for the negative electrode. However, these suffered from the instability of the alloys in alkaline electrolyte and consequently insufficient cycle life. In 1987, Willems and Buschow demonstrated a successful battery based on this approach (using a mixture of $La_{0.8}Nd_{0.2}Ni_{2.5}Co_{2.4}Si_{0.1}$) which kept 84% of its charge capacity after 4000 charge-discharge cycles. More economically viable alloys using mischmetal instead of lanthanum were soon developed and modern NiMH cells are based on this design.

Ovonic Battery Co. in Michigan altered and improved the Ti-Ni alloy structure and composition according to their patent[10] and licensed NiMH batteries to over 50 companies worldwide. Ovonic's NiMH variation consisted of special alloys with disordered alloy structure and specific multicomponent alloy compositions. Unfortunately, linked to their composition, the calendar and cycle life of such alloys always remains very low, and all NiMH batteries manufactured at the present time consist of AB_5-type rare earth metal alloys.

Positive electrode development was done by Dr. Masahiko Oshitani from GS Yuasa Company, who was the first to develop high-energy paste electrode technology. The association of this high-energy electrode with high-energy hybrid alloys for the negative electrode led to the new environmentally friendly high-energy NiMH cell.

Currently, more than 2 million hybrid cars worldwide are running with NiMH batteries, e.g., Prius, Lexus (Toyota), Civic, Insight (Honda), Fusion (Ford), and others. Many of these batteries are manufactured by PEVE (Panasonic) and Sanyo.

In the EU and due to the Battery Directive, Nickel–metal hydride batteries have replaced Ni–Cd batteries for portable use by consumers.

Applications

High power Ni-MH Battery of Toyota NHW20 Prius, Japan

Nickel–metal hydride 24V battery pack made by VARTA, Museum Autovision, Altlussheim, Germany

Applications of NiMH electric vehicle batteries includes all-electric plug-in vehicles such as the General Motors EV1, Honda EV Plus, Ford Ranger EV and Vectrix scooter. Hybrid vehicles such as the Toyota Prius, Honda Insight, Ford Escape Hybrid, Chevrolet Malibu Hybrid, and Honda Civic Hybrid also use them. NiMH technology is used extensively in rechargeable batteries for consumer electronics, and it will also be used on the Alstom Citadis low floor tram ordered for Nice, France; as well as the humanoid prototype robot ASIMO designed by Honda. NiMH batteries are also commonly used in remote control cars.

Comparison with other battery types

NiMH cells and chargers are readily available in retail stores in the common sizes AAA and AA. Adapter sleeves are available to use the more common AA size in C and D applications. The sizes C and D cells are somewhat available, but are often just a AA core hidden in an outer shell, with a rating of about 2500 mA·h, much less than ordinary alkaline C and D batteries.[*citation needed*] Real NiMH C and D batteries are expensive (and the chargers are uncommon); they should be rated at least 5000 mA·h for C and 10,000 mA·h for D sizes.

PP3 (nine volt) NiMH batteries are available; these usually have an output voltage of 8.4 V (1.2 × 7) and a capacity of roughly 200 mA·h. Also available are eight-cell nine volt batteries with a nominal output voltage of 9.6 V (1.2 × 8).

NiMH cells are not expensive, and the voltage and performance is similar to primary alkaline cells in those sizes; they can be substituted for most purposes. Although alkaline cells are rated at 1.5 volts and NiMH cells at 1.2 volts, during discharge the alkaline voltage eventually drops below that of NiMH. This is particularly true for high drain applications, where the voltage of even a fresh alkaline battery can be lower than a NiMH battery while under a load. Furthermore, NiMH batteries offer a flatter discharge curve, particularly at higher current draw.

NiMH cells are often used in digital cameras and other high drain devices, where over the duration of single charge use they outperform primary (such as alkaline) batteries. Applications that require frequent replacement of the battery, such as toys or video game controllers, also benefit from use of rechargeable batteries. With the development of low self-discharge NiMHs (see section above), many occasional-use and very low-power applications are now candidates for NiMH cells.

NiMH cells are particularly advantageous for high current drain applications, due in large part to their low internal resistance. Alkaline batteries, which might have approximately 3000 mA·h capacity at low current demand (200 mA), will have about 700 mA·h capacity with a 1000 mA load. Digital cameras with LCDs and flashlights can draw over 1000 mA, quickly depleting alkaline batteries. NiMH cells can deliver these current levels and maintain their full capacity.

Certain devices that were designed to operate using primary alkaline chemistry (or zinc–carbon/chloride) cells will not function when one uses NiMH cells as substitutes. However, this is rare, as most devices compensate for the voltage drop of an alkaline as it discharges down to about 1 volt. Low internal resistance allows NiMH cells to deliver a near-constant voltage until they are almost completely discharged. This will cause a battery level indicator to overstate the remaining charge if it was designed to read only the voltage curve of alkaline cells. The voltage of alkaline cells decreases steadily during most of the discharge cycle.

Lithium ion batteries have a higher specific energy than nickel–metal hydride batteries,but they are significantly more expensive to produce. In October 2009, ECD Ovonics announced that their next-generation NiMH batteries will provide specific energy and power that are comparable to those of lithium ion batteries at a cost that is significantly lower than the cost of lithium ion batteries