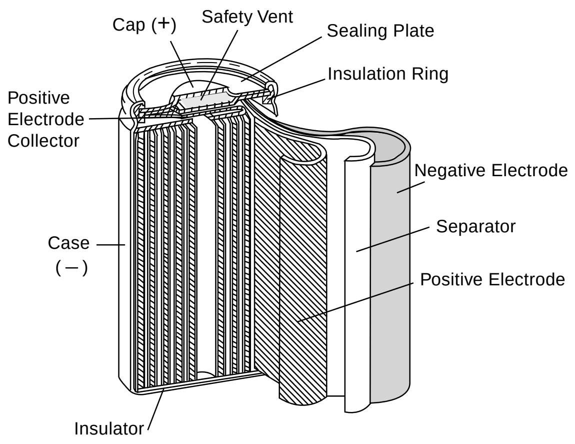
Overview

As electronic products have come to feature more sophisticated functions, more compact sizes and lighter weights, the sources of power that operate these products have been required to deliver increasingly higher levels of energy. To meet this requirement, nickel-metal hydride batteries have been developed and manufactured with nickel hydroxide for the positive electrode and hydrogen-absorbing alloys, capable of absorbing and releasing hydrogen at high-density levels, for the negative electrode. Because Ni-MH batteries have about twice the energy density of Ni-Cd batteries and a similar operating voltage as that of Ni-Cd batteries, they are expected to become a mainstay in the next generation of rechargeable batteries.

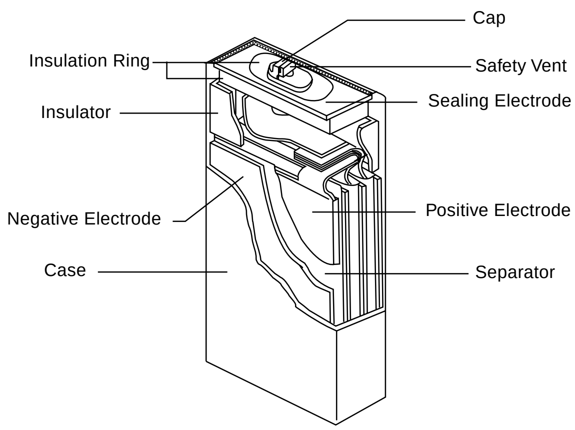
Construction

Nickel-metal hydride batteries consist of a positive plate containing nickel hydroxide as its principal active material, a negative plate mainly composed of hydrogen-absorbing alloys, a separator made of fine fibers, an alkaline electrolyte, a metal case and a sealing plate provided with a self-resealing safety vent. Their basic structure is identical to that of Ni-Cd batteries.
With cylindrical nickel-metal hydride batteries, the positive and negative plates are seperated by the separator, wound into a coil, inserted into the case, and sealed by the sealing plate through an electrically insulated gasket.
With prismatic nickel-metal hydride batteries, the positive and negative plates are sandwiched together in layers with separators between them, inserted into the case, and sealed by the sealing plate.

Structure of Nickel Metal Hydride Batteries



Cylindrical Type



Prismatic Type

Principle of Electrochemical Reaction Involved in Batteries

Hydrogen-absorbing Alloys

Hydrogen-absorbing alloys have a comparatively short history which dates back about 20 years to the discovery of NiFe, MgNi and $LaNi_5$ alloys. They are capable of absorbing hydrogen equivalent to about a thousand times of their own volume, generating metal hydrides and also of releasing the hydrogen that they absorbed. These hydrogen-absorbing alloys combine metal (A) whose hydrides generate heat exothermically with metal (B) whose hydrides generate heat endothermically to produce the suitable binding energy so that hydrogen can be absorbed and released at or around normal temperature and pressure levels. Depending on how metals A and B are combined, the alloys are classified into the following types: AB (TiFe, etc.), AB_2 ($ZnMn_2$, etc.), AB_5 ($LaNi_5$, etc.) and A_2B (Mg_2Ni, etc.). From the perspective of charge and discharge efficiency and durability, the field of candidate metals suited for use as electrodes in storage batteries is now being narrowed down to AB_5 type alloys in which rare-earth metals, especially metals in the lanthanum group, and nickel serve as the host metals; and to AB_2 type alloys in which the titanium and nickel serve as the host metals. Panasonic is now focusing its attention on AB_5 type alloys which feature high capacity, excellent charge and discharge efficiency, and excellent cycle life. It has developed, and is now employing its own $MmNi_5$ alloy which uses Mm (misch metal = an alloy consisting of a mixture of rare-earth elements) for metal A.

Principle of Electrochemical Reaction Involved in Batteries

Nickel-metal hydride batteries employ nickel hydroxide for the positive electrode similar to Ni-Cd batteries. The hydrogen is stored in a hydrogen-absorbing alloy for the negative electrode, and an aqueous solution consisting mainly of potassium hydroxide for the electrolyte. Their charge and discharge reactions are shown below.

Positive electrode : $Ni(OH)_2 + OH^- \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftarrows}} NiOOH + H_2O + e^-$

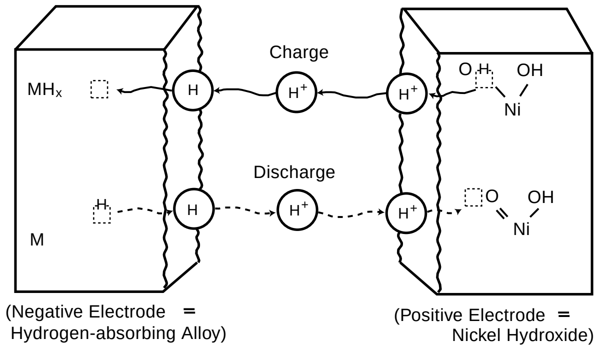
Negative electrode : $M + H_2O + e^- \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftarrows}} MH_{ab} + OH^-$

Overall reaction : $Ni(OH)_2 + M \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftarrows}} NiOOH + MH_{ab}$

(M : hydrogen-absorbing alloy; H_{ab} : absorbed hydrogen)

As can be seen by the overall reaction given above, the chief characteristics of the principle behind a nickel-metal hydride battery is that hydrogen moves from the positive to negative electrode during charge and reverse during discharge, with the electrolyte taking no part in the reaction; which means that there is no accompanying increase or decrease in the electrolyte. A model of this battery's charge and discharge mechanism is shown in the figure on the following page. These are the useful reactions taking place at the respective boundary faces of the positive and negative electrodes, and to assist one in understanding the principle, the figure shows how the reactions proceed by the transfer of protons (H^+).

The hydrogen-absorbing alloy negative electrode successfully reduces the gaseous oxygen given off from the positive electrode during overcharge by sufficiently increasing the capacity of the negative electrode which is the same method employed by Ni-Cd batteries. By keeping the battery's internal pressure constant in this manner, it is possible to seal the battery.



Schematic Discharge of Ni-MH Battery

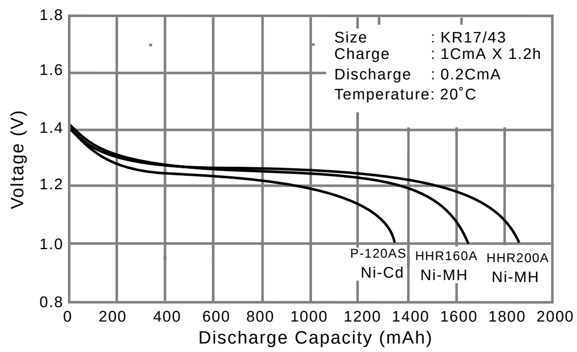
Features

- **Similarity with Ni-Cd batteries**

These batteries have similar discharge characteristics to those of Ni-Cd batteries.

- **Double the energy density of conventional batteries**

Nickel-metal hydride batteries have approximately double the capacity compared with Panasonic's standard Ni-Cd batteries.



- **Cycle life equivalent to 500 charge and discharge cycles**

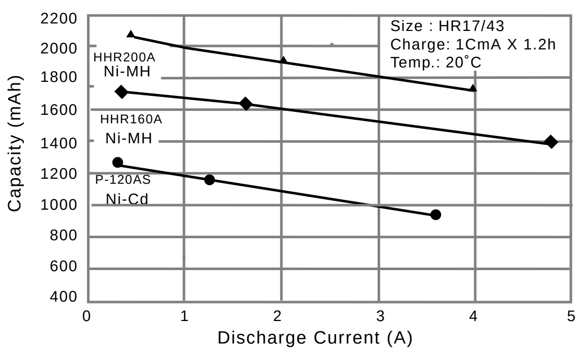
Like Ni-Cd batteries, nickel-metal hydride batteries can be repeatedly charged and discharged for about 500 cycles. (example: IEC charge and discharge conditions)

- **Rapid charge in approx. 1 hour**

Nickel-metal hydride batteries can be rapidly charged in about an hour using a specially designed charger.

- **Excellent discharge characteristics**

Since the internal resistance of nickel-metal hydride batteries is low, continuous high-rate discharge up to 3CmA is possible, similar to Ni-Cd batteries.



Five Main Characteristics

As with Ni-Cd batteries, nickel-metal hydride batteries have five main characteristics: charge, discharge, storage life, cycle life and safety.

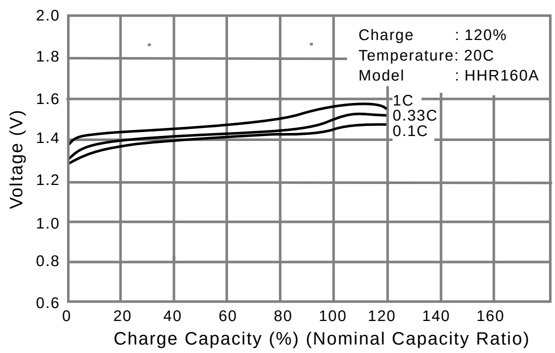
- **Charge characteristics**

Like Ni-Cd batteries, the charge characteristics of nickel-metal hydride batteries are affected by current, time and temperature. The battery voltage rises when the charge current is increased or when the temperature is low. The charge efficiency differs depending on the current, time, temperature and other factors.

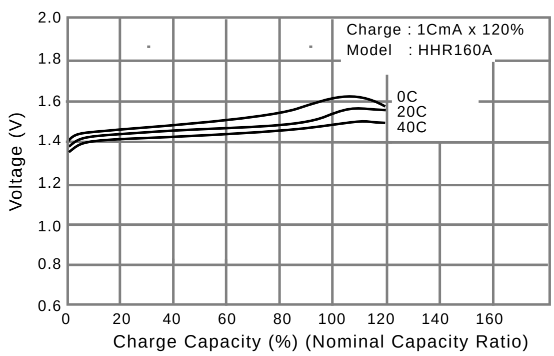
Nickel-metal hydride batteries should be charged at a temperature ranging from 0°C to 40°C using a constant current of 1C or less. The charge efficiency is particularly good at a temperature of 10°C to 30°C. Repeated charge at high or low temperatures causes the battery performance to deteriorate. Furthermore, repeated overcharge should be avoided since it will downgrade the battery performance.

Refer to the section on recommended charge methods for details on how to charge the batteries.

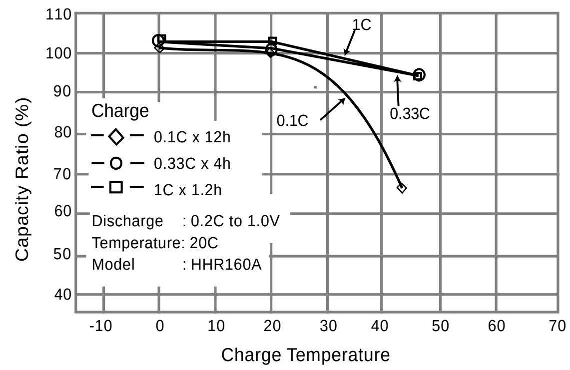
- Charge characteristics



- Charge temperature characteristics at 1C charge



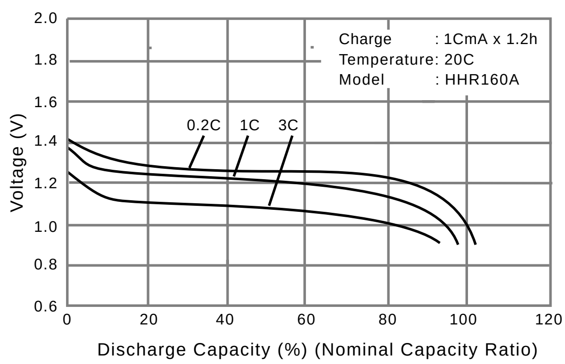
- Charge temperature characteristics at various charge rates



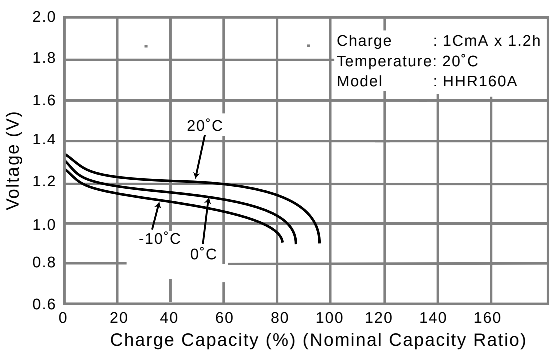
- **Discharge characteristics**

The discharge characteristics of nickel-metal hydride batteries are affected by current, temperature, etc., and the discharge voltage characteristics are flat at 1.2V, which is almost the same as for Ni-Cd batteries. The discharge voltage and discharge efficiency decrease in proportion as the current rises or the temperature drops. As with Ni-Cd batteries, repeated charge and discharge of these batteries under high discharge cut-off voltage conditions (more than 1.1V per cell) causes a drop in the discharge voltage (which is sometimes accompanied by a simultaneous drop in capacity). The discharge characteristics can be restored by charge and discharge to a discharge end voltage of down to 1.0V per cell.

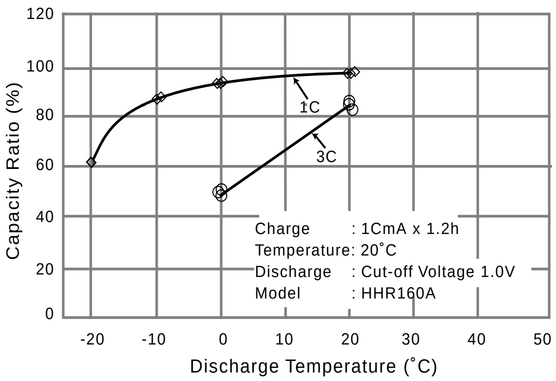
- Discharge characteristics



- Discharge temperature characteristics at 1C discharge



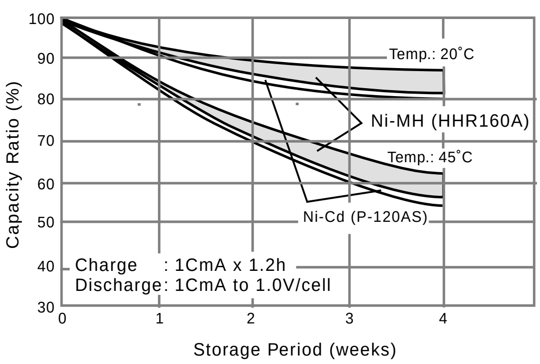
- Discharge temperature characteristics



Storage characteristics

These characteristics include self-discharge characteristics and restoration characteristics after long-term storage. When batteries are left standing, their capacity generally drops due to self-discharge, but this is restored by charge.

- Self discharge characteristics

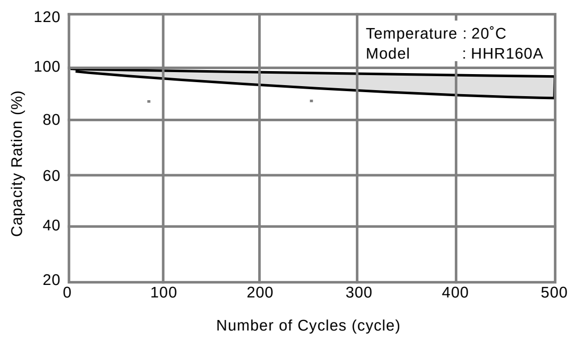


Self-discharge is affected by the temperature at which the batteries are left standing and the length of time during which they are left standing. It increases in proportion as the temperature or the shelf-standing time increases. Panasonic's nickel-metal hydride batteries have excellent self-discharge characteristics that are comparable to those of Ni-Cd batteries.

Cycle Life Characteristics

The cycle life of these batteries is governed by the conditions under which they are charged and discharged, temperature and other conditions of use. Under proper conditions of use (example: IEC charge and discharge conditions), these batteries can be charged and discharged for more than 500 cycles.

- Cycle life characteristics



Safety

When the internal pressure of these batteries rises due to overcharge, short-circuiting, reverse charge or other abuse or misuse, the self-resealing safety vent is activated to prevent battery damage. Panasonic's nickel-metal hydride batteries have similar safety characteristics as Panasonic Ni-Cd batteries.

CHARGE METHODS FOR NICKEL METAL HYDRIDE BATTERIES

Charge is the process of restoring a discharged battery to its original capacity. In order for a battery to be usable for a long period of time, it must be charged via the proper charge method. Various methods are used to charge rechargeable cells, but Panasonic recommends the charge methods described below to charge its nickel-metal hydride batteries.

(1) Rapid charge current: 1CmA (rapid charge temperature range: 0°C to 40°C). In order to exercise proper control to stop rapid charge, it is recommended that batteries be charged at over 0.5CmA but less than 1CmA. Charging batteries at a current in excess of 1CmA may cause the safety vent to be activated by a rise in the internal pressure of the batteries, thereby resulting in electrolyte leakage. When the temperature of the batteries is detected by a thermistor or other type of sensor, and their temperature is under 0°C or over 40°C at the commencement of the charge, then trickle charge, rather than rapid charge, must be performed. Rapid charge is stopped when any one of the values among the types of control described in (4), (5), (6), and (11) reaches the prescribed level.

(2) Allowing a high current to flow to excessively discharged or deep-discharged batteries during charge may make it impossible to sufficiently restore the capacity of the batteries. To charge excessively discharged or deep-discharged batteries, first allow a trickle current to flow, and then proceed with the rapid charge current once the battery voltage has risen.

(3) Rapid charge start voltage: Approx. 0.8V/cell
Rapid charge transition voltage restoration current: 0.2 ~ 0.3 CmA

(4) Upper battery voltage limit control: Approx. 1.8V/cell. The charge method is switched over to trickle if the battery voltage reaches approximately 1.8V/cell due to trouble or malfunctioning of some kind.

(5) ΔV value: 5 to 10mV/cell. When the battery voltage drops from its peak to 5 to 10mV/cell during rapid charge, rapid charge is stopped, and the charge method is switched over to trickle charge.

(6) dT/dt value: Approx. 1 to 2°C/min. When a rise in the battery temperature per unit time is detected by a thermistor or other type of temperature sensor during rapid charge, and the prescribed temperature rise is sensed, rapid charge is stopped and the charge method is switched over to trickle charge.

(7) TCO: 55°C (for A, AA and D size), 50°C (for QA, AAA and prismatic size), 60°C (for L-A, L-fatA and SC size). The cycle life and other characteristics of batteries are impaired if the batteries are allowed to become too hot during charge. In order to safeguard against this, rapid charge is stopped and the charge method is switched over to trickle charge when the battery temperature has reached the prescribed level.

(8) Initial delay timer: to 10 min. This prevents the -ΔV detection circuit from being activated for a specific period of time after rapid charge has commenced. However, the dT/dt detection circuit is allowed to be activated during this time. As with Ni-Cd batteries, the charge voltage of nickel-metal hydride batteries may show signs of swinging (pseudo -ΔV) when they have been kept standing for a long time or when they have discharged excessively, etc. The initial delay timer is needed to prevent charge from stopping (to prevent malfunctioning) due to this pseudo -ΔV.

(9) Trickle current: 0.033 to 0.05CmA. When the trickle current is set higher, the temperature rise of the batteries is increased, causing the battery characteristics to deteriorate.

(10) Rapid charge transfer timer: 60 min.

(11) Rapid charge timer: 90 min. (at 1C charge)

(12) Total timer: 10 to 20 hours.
The overcharging of nickel-metal hydride batteries, even by trickle charging, causes a deterioration in the characteristics of the batteries. To prevent overcharging by trickle charging or any other charging method, the provision of a timer to regulate the total charging time is recommended.
Note: The temperature and voltage of nickel-metal hydride batteries varies depending on the shape of the battery pack, the number of cells, the arrangement of the cells and other factors. Therefore Panasonic should be consulted for more detailed information on the referenced charge control values. The charge methods described previously can be applied also when both nickel-metal hydride batteries and Ni-Cd batteries are employed in a product, but Panasonic should be consulted for the control figures and other details.

- Recommended nickel metal hydride battery charge system*

(1) Rapid charge current	Max. 1CmA to 0.5CmA
(2) Rapid charge transition voltage restoration current	0.2 to 0.3CmA
(3) Rapid charge start voltage	Approx. 0.8V/cell
(4) Charge terminating voltage	1.8V/cell
(5) -ΔV value	5 to l0mV/cell
(6) Battery temperature rising rate dT/dt value	1 to 2°C/min
(7) Maximum battery temperature TCO	60°C (for L-A, L-fatA and SC size) 55°C (for A, AA and D size) 50°C (for QA, AAA and prismatic size)
(8) Initial -ΔV detection disabling timer	5 to 10 min
(9) Trickle current (after rapid charge)	0.033 to 0.05CmA
(10) Rapid charge transfer timer	60 min
(11) Rapid charge timer	90 min (at 1CmA charge)
(12) Total timer	10 to 20 hours
(13) Rapid charge temperature range	0 to 40°C

* Matching test is required because these values vary depending on rapid charge current, number of cells, configuration of battery pack, etc.

● Example of a Rapid Charge System

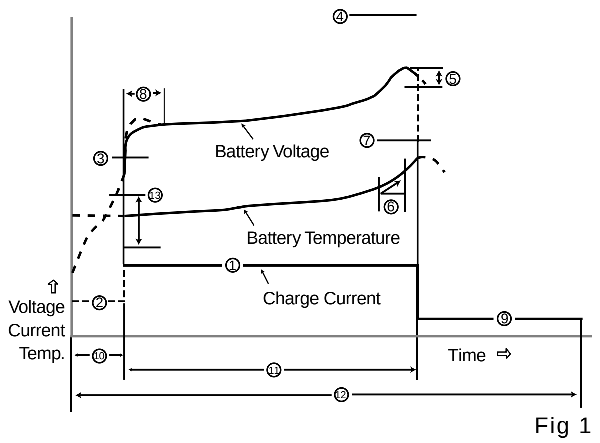


Fig 1

● Basic Pack Configuration Circuit

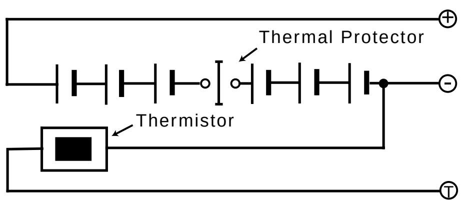


Fig 2