Notes on the Nickel-Cadmium Battery

Peter D. Hiscocks

Department of Electrical and Computer Engineering
Ryerson Polytechnic University

phiscock@ee.ryerson.ca

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1 Introduction

These are notes on the properties and charging of Nickel-Cadmium (NiCad) batteries.

1.1 Reference [1], section 14.0

Open Circuit Voltage The open circuit voltage of a NiCad under loaded conditions is about 1.2 volts per cell, compared to about 1.5 volts for an Alkaline, Zinc Cloride or LeClanche cell. Consequently, a device designed to operate off 6 Alkaline AA cells (9VDC) would require 8 NiCad cells.

Float Voltage The *float* voltage of a Nicad cell is about 1.4 volts, so the battery charger must supply a much larger voltage than this to charge the battery. To charge an 8 cell, 9.6 volt battery would require something in excess of 11.2 volts.

Charge Capacity C The typical size for an 'AA' sized cell is 600 to 900mA-H. This capacity also applies to the 7.2 and 9.6 RC batteries used in radio controlled cars and planes, which are made up of AA sized cells.

Charging Rate Nicads can be charged continuously at a rate of 0.1C, ie, 60 mA for a 600 mA-H battery. Typically, you need to charge 140%C to recharge the battery. For example, a 600mA-H battery would require a recharge of 840mA-H (ie, 14 hours at 60mA) to recharge the battery.

Constant Voltage Charging This doesn't work for Nicads. Use constant current. Don't hold the battery at a constant *float* voltage, allow the terminal voltage to change.

Fast Charging The battery may be charged at a constant current rate of CC if the temperature is monitored and the charging shut off when the battery gets hot.

Series and Parallel Nicad batteries are often connected in series but should never be connected in parallel.

1.2 Reference [2]

Self Discharge The discharge is about 10% in the first 24 hours and 10% every 30 days thereafter.

Maximum Load Current 20C (eg 12Amps for 600mA-H battery, which is why these are excellent batteries for battery-powered aircraft and cars.)

Optimum Load Current 1C (eg, 600mA for 600mA-H battery).

Internal Resistance Varies, but typically 0.1 .

Number of Charge-Discharge Cycles Over 1000 cycles if properly maintained.

Discharged Condition Typically about 1 volt per cell, or 8 volts for a 9.6 volt battery. Discharging beyond the cutoff voltage should be avoided. Otherwise, cell reversal may occur, causing the cell to vent and possible short-circuit.

Repeated Discharge Cycling The Nicad is the least affected of battery types by full discharge cycles.

Slow Charger Applies a fixed charge rate of 0.1C for as long as the battery is connected.

Typical charge time about 12 to 14 hours.

No switch necessary, but the battery should be removed when it is lukewarm to the touch.

Quick Charger Applies a fixed charge rate of 0.3C.

Typical charge time about 3 to 6 hours.

Requires a cutoff control.

Leads to better battery life than a slow charger if the charge is controlled correctly.

Fast Charger Applies a fixed charge rate of 1C.

Typical charge time about 1 hour. (Actually, about 66 minutes, allowing for a 91% charging efficiency.)

Requires a cutoff control.

Leads to extended battery life if the charge is controlled correctly.

Venting If overcharged, the Nicad battery will vent excess pressure. Some electrolyte is lost and the seal may leak afterwards. A white powder will accumulate near at vent opening.

Charging Cutoff by Temperature Sensing (Paraphrased from the reference) *Commercial fast-chargers are often not designed in the best interests of the battery. This is especially true of Nicad chargers that measure the battery's charge state solely through temperature sensing. Charge termination by temperature sensing is not accurate. Thermistors exhibit broad tolerances: their positioning with respect to the cells is not consistent. Ambient temperature and exposure to the sun while charging also affect the accuracy of full charge detection. To prevent the risk of premature cut-off and assure full charge under most conditions, charger manufacturers use 501C as the recommended temperature cut-off. Although a prolonged temperature above 451C is harmful to the battery, a brief temperature peok above that level is often unavoidable.*

Charging Cutoff by Temperature Gradient Sensing The Ω gradient (rise in temperature vs time) is sensed. A temperature rise of 11 per minute with an absolute temperature cutoff of 601C is works well. This method only works with a Fast Charger.

Charging Cutoff by Negative Delta V Sensing The terminal voltage of a Nicad battery drops 10 to 30mV per cell just after full charge is reached. (This would be 80 to 240mV for an 8-cell battery.) The charge rate must be at least 0.5C. The signature may be obscured if different cells in the battery reach full charge at different times. The charger must also sense temperature as a safety measure.

Memory Effect *Crystals form on the plates of a Nicad battery if it is overcharged or if it is not fully discharged. A periodic discharge to 1 volt per cell is essential to prevent the buildup of crystalline formation on the cell plates.* This applies to all nickel-based batteries, but is most critical for the Nicad battery. *Nicad batteries in regular use and on standby mode should be exercised once a month. No further service is necessary. If no exercise is applied to a Nicad battery for three months or more, the crystals ingrain themselves, making them more difficult to break up.*

Reconditioning A method for reconditioning a Nicad battery:

- Charge the battery.
- Discharge the battery to 1 volt per cell, at a 1C rate.
- Further discharge the battery to 0.4 volts per cell at a trickle current (not specified) to avoid cell reversal damage.
- Recharge the battery.

A study on Nicad battery use found:

- Charge-and-use resulted in a 45% battery failure rate.
- Charge, exercise and use resulted in a 15% battery failure rate.
- Reconditioning the batteries resulted in a 5% battery failure rate.

Guidelines

- Do not leave the battery in a charger for more than a day after the full charge is reached.
- Do not discharge the battery before recharging it.
- Once a month, apply a full discharge cycle or run the battery down in the equipment.
- Avoid elevating the temperature of the battery. The charger should heat the battery only briefly.

1.3 Reference [3]

From the reference, page 20, **Battery Management**:
Fast chargers for Nicad and NiMH batteries often .. rely on cell temperature to determine when to terminate charging.

In Nicad batteries, charging is an endothermic process, so a Nicad battery pack will either remain at the same temperature or cool slightly during charging. When the battery becomes overcharged, its temperature will begin to rise quickly, indicating that the charging current should be turned off. (See the figure.)

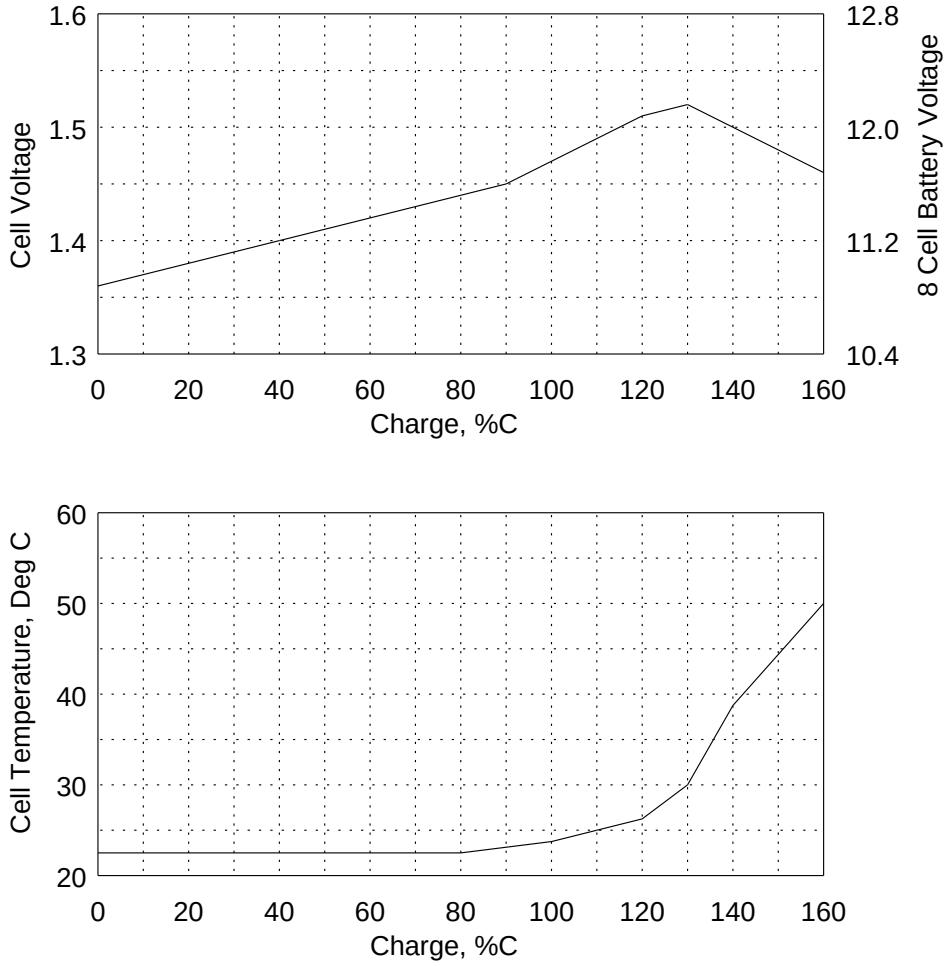

Figure 1: Nicad Battery Charging Curves

References

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[2] *Batteries in a Portable World*
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[3] *National Semiconductor's Temperature Sensor Handbook*
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