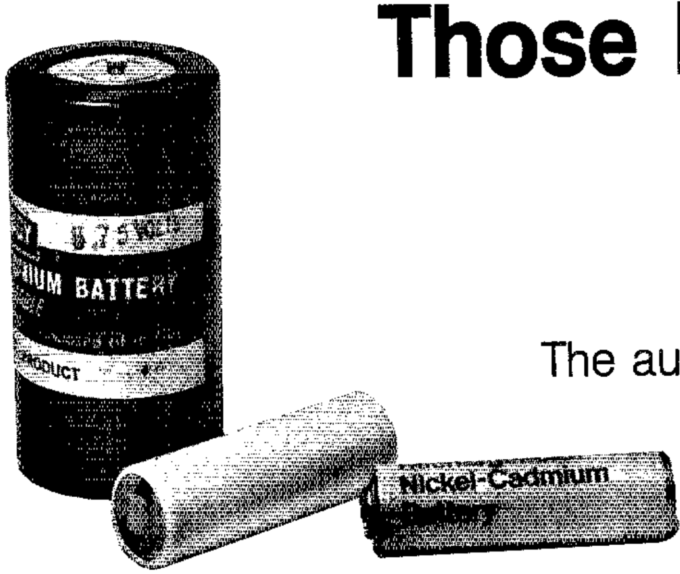

Those NiCad Batteries and How to Charge Them!

The author explains the nature of NiCad batteries. He also shows how to charge them sensibly with a home-built charger that works better than store-bought units.

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Nickel cadmium batteries (NiCads) are remarkable devices! They have been in use for more than 50 years. They can be used and recharged hundreds of times. The internal resistance of NiCad batteries is low and remains low until the end of the discharge cycle, and the output voltage remains fairly constant during the discharge period. Typical voltage is 1.3 for a freshly charged cell. It decreases to about one volt at the end of the discharge cycle. If the discharge continues, the output voltage falls rapidly from this point. Higher-voltage batteries or power packs are realized by connecting one or more cells in series.

Sealed cylindrical cells and batteries that are most commonly found in Amateur Radio equipment are made something like a capacitor. Thin, sintered electrodes of sheet nickel hydroxide and cadmium hydroxide are isolated from each other by a porous separator sheet. A limited amount of potassium hydroxide serves as the electrolyte. The three sheets and the electrolyte are rolled together, then placed in the cylindrical steel case. An insulating seal ring separates the positive cover from the negative case.

The chemical reaction of the nickel cadmium cell is:

$$Cd + 2NiOOH + 2H_2O \underset{\text{Discharged}}{\overset{\text{Charged}}{\rightleftharpoons}} Cd(OH)_2 + 2Ni(OH)_2 \quad \text{(Eq. 1)}$$

Notice that the reaction can go in either direction. If current from a charging source flows in the proper direction, it will drive the reaction backward toward the charge direction and in effect will recharge the electrodes. What is not clear from the equation, though, is that during the final part of a charge cycle, and during periods of overcharge, NiCads generate gas. Oxygen is generated at the nickel (positive) electrode and hydrogen is generated at the cadmium (negative) electrode as each reaches full charge. If the charging rate is about 1 C (defined later) the pressure and temperature inside a cell will soar at full charge, and the cell will be damaged or destroyed. Since the cells are sealed, the pressure must not become excessive. The cells have vents that will release pressure when it exceeds 150 to 300 psi, but such venting shortens the life of a cell. The manufacturers avoid the generation of hydrogen gas by making the positive electrode smaller than the negative one, so that the positive electrode becomes fully charged first. Oxygen is generated at this positive electrode at full charge, but this gas can migrate back to the negative electrode, with which it reacts, preventing the negative electrode from charging further. This also prevents it from becoming fully charged and producing hydrogen. The NiCad cell can be overcharged indefinitely then, without being damaged, owing to this protective mechanism (well, in theory, anyway).

Another interesting fact about the NiCad that makes it different from other types of batteries is that the terminal voltage is at maximum around 75° F (24° C). The voltage decreases as the temperature goes above or below that temperature. Similarly, the internal resistance is smallest at 75° F, and it increases as the temperature goes above or below that temperature. Because of this characteristic and for other reasons, a NiCad should be operated inside of the temperature range of 32° F to 105° F (0 to 40° C).

Cell Capacity

The capacity (C) of a NiCad cell is stated in ampere hours or in milliampere hours. A 500-milliampere/hour cell has a C equal to 500. It means, for example, that you may discharge the cell at a 50-mA rate for 10 hours, or at a 500-mA rate for one hour, but the capacity decreases with increasing discharge rates. The term C has another meaning. It can define the charging or discharging current. A 1-C discharge rate means a discharge current of 500 mA for a battery rated at 500 mA/hours, while a 0.1-C charging rate implies a charging current of 50 mA (0.1 × 500). Hence, C defines a certain milliampere/hour capacity, or a charging or discharging current based on that milliampere/hour rating.

Charging Characteristics

Now that the basic theory of NiCad cells has been reviewed, how can the cell be recharged sensibly so that we can approach a thousand or so recharge cycles? First, the charging rate must be limited to 0.1 C. As the charging rate exceeds 0.1 C, the oxygen generated as the cell nears full charge does not diffuse and react quickly enough at the negative electrode. The internal pressure will build up, and damage will take place. A 0.1-C charging rate implies a 10-hour charging time (0.1 C × 10 = 1 C), but the battery is not 100% efficient. It is necessary to put in 140 to 160%

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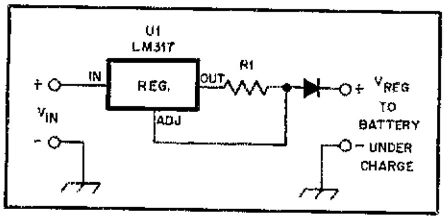

Fig. 1 — Circuit for a simple constant-current battery charger. The series diode can be a 1-A, 50-PRV silicon rectifier. U1 is a three-terminal regulator.

of the charge. Now you can see where the familiar 14- to 16-hour charging time comes from. It is typical for completely charging the NiCad battery.

A battery consists of two or more cells in series. Because no two cells have exactly the same capacity, one cell will become discharged before the rest. When this happens, the weak cell will be *reverse-polarized* by the remaining cells. When this happens, oxygen will be generated at the cadmium electrode and hydrogen at the nickel electrode. Not only will the gas pressure soar, but the internal resistance will increase, and heating will take place. Manufacturers have introduced clever schemes to suppress this generation of gas in the reverse-voltage case, but the protection is effective up to discharge rates of only 0.1 C. Since the discharge rate may be in excess of 0.1 C, you should stop discharging a NiCad battery when the potential drops below 1 volt per cell. Some battery-powered amateur gear has low-voltage indicators. Cease operation when that condition is observed.

NiCad batteries can supply large pulse and dc discharge currents because of their low internal resistance. The inquisitive reader might wonder why a cell may be discharged at rates of several C safely, yet charging them at those rates can be destructive. The reason is related to the gas and heat that is generated at or near the full-charge condition, as we discovered. Quick chargers do exist, but special NiCads are used. The "quick chargers" generally measure the temperature of the cell or battery. As the temperature climbs (near the end of the charge), a temperature sensor turns the charger off or reduces the charging rate to a "trickle" charge. Such chargers and special batteries are not commonly found in Amateur Radio equipment.

Chargers for the NiCad Battery

If you enjoy building electronic circuits, you can save some money and end up with a better charger than many that you can buy! A charger can be built for a few dollars, plus some components that you probably have in your shack. A simple charger, using a constant current that is equal to 0.1 C, can be realized by using an LM317, which is a three-terminal, adjustable (positive) voltage regulator. The

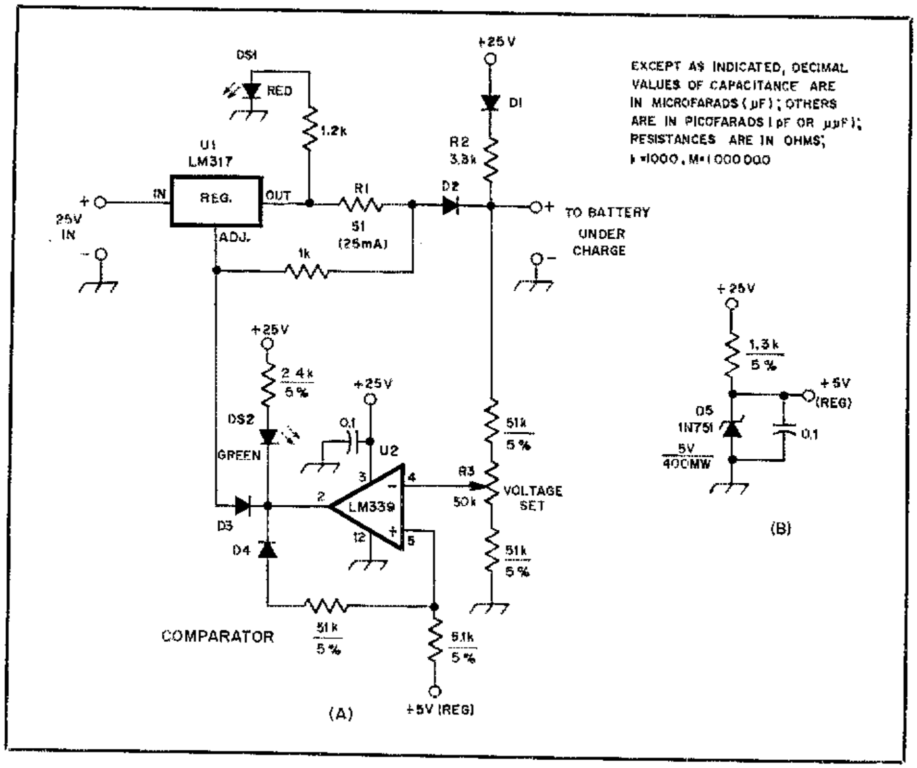

Fig. 2 — Schematic diagram of a constant-current charger with an automatic shut-down feature. R3 is adjusted to provide the maximum desired battery voltage. The capacitors are disc ceramic or Mylar. D1-D4, inclusive, are 1-A, 50-PRV silicon rectifiers. DS1 and DS2 are LEDs (see text). R3 is a linear-taper, wire-wound control. See text for details of the circuit at B.

circuit in Fig. 1 is for a constant-current charger. The regulator is available in several types of cases. Pick your favorite. The input potential should be at least 5 to 6 volts greater than the desired maximum output voltage, and it may be up to 40 volts greater. Therefore, you have a broad range of input dc voltages with which to work. The greater the voltage difference between the input and output, the greater will be the dissipation in the regulator. The charging current in milliamperes is given by:

$$\text{mA} = \frac{1200}{R1} \qquad \text{(Eq. 2)}$$

If your battery is rated at 250 mA/hr, set the current for a 25-mA charging rate. Similarly, you would set a 45-mA charging rate for a 450-mA/hr battery. These 0.1-C charging rates will require 14 to 16 hours to recharge a fully discharged battery. Overcharging should not damage them with this rate. The series diode in the schematic diagram disconnects the battery from the charger in the event that the charger is turned off, or if there is a power failure.

You can add a simple feature (Fig. 2B) that shuts down the charger when the terminal voltage of the battery reaches some fixed value. A trickle charge equal to 0.01 C to 0.03 C is supplied by resistor R2. This is the recommended "float" or leveling charging rate. The voltage comparator circuit employs 0.4 volt of hysteresis so that if the battery voltage should fall 0.8 volt below the set point, the full 0.1-C charging rate will be reinstated until the voltage reaches the desired level. A red LED (DS1) indicates that the unit is charging; the green LED indicator (DS2) shows that the battery has reached the desired (fully charged) condition. These LEDs serve only as indicators, and one or both can be eliminated.

The voltage comparator that I used is an LM339. This version has four comparators in a 14-pin DIP format, which is useful because my charger has the capability to charge several batteries independently at the same time. Just add as many constant-current regulators as you need; one LM339 will control four regulators.

All of my batteries have terminals on the bottom; they do not have connectors. I have fashioned battery supports from wood, and they have screws in the base that contact the battery terminals if the battery is inserted correctly in the blocks. A table-top charger to hold and charge an HT and spare batteries can be made with a scrap of 2- × 4-inch (51 × 102-mm) lumber and a pine board. You can decide how to connect the charger to your battery. Now go to it! Charge sensibly!