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High-Rate/High-Temperature Capability of a Single-Layer Zircar-Separator Nickel-Hydrogen Cell

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Abstract

A 50 ampere-hour nickel-hydrogen cell with a single-layer Zircar separator stack design was fully charged and then discharged at a 2C current rate to an end voltage of 1 volt. This extreme test resulted in high temperatures which were recorded at three locations on the cell, i.e., the cell wall, the boss (barrel of the compression seal), and a terminal. The results provide new information about the high-temperature and high-discharge-rate capabilities of nickel-hydrogen cells. This information also adds to the growing data base for single-layer zirconium-oxide-cloth (Zircar) separator cell designs.

Cell Description

The cell used in the tests described here is a 3½ inch-diameter RNH 50-49Z ManTech design with a nominal capacity of 50 Ah. A typical cell is shown in figure 1.

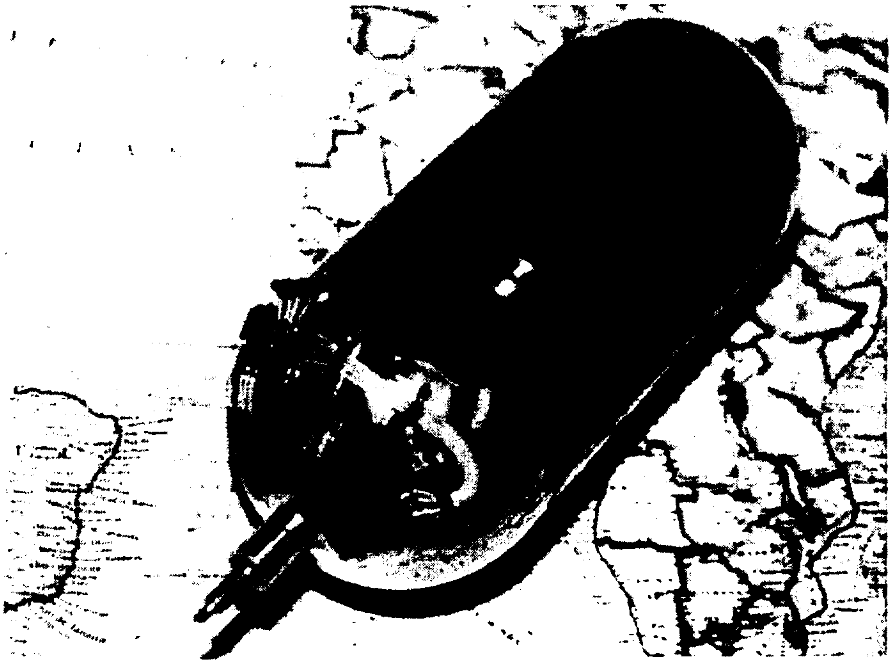

Figure 1. RNH 50-49 Nickel Hydrogen Cell

By "ManTech" is meant an Eagle Picher design which uses pineapple-slice-shaped electrodes and stack elements, a central polysulfone core, continuous nickel-foil leads on electrodes, and a wall-wick to ensure a recirculating path to return and equilibrate electrolyte throughout the cell stack. Other features include a spring washer for uniform stack compression, a small wall gap and separator/electrolyte contact with the cell wall to facilitate heat transfer. One feature in this cell that makes it slightly different from other ManTech production cells is the application of a thin, plated coating of gold to the hemispheres on either end. The purpose of this is to lower the thermal emittance of the normally-cooler cell ends and thereby reduce the thermal gradient within the cell.

The development cell chosen for this test differs from the production version in that its stack contains one layer of zirconium-oxide cloth per positive electrode instead of one layer of asbestos. The cell was constructed with a production lot and all other materials were identical to those in the production cells. This design is notable for having the highest ratio of conductor resistance to area of electrode of any other 3.5-inch diameter size cell currently in production at Eagle Picher. The reason for this is weight-savings. The design, with either separator, successfully met all acceptance-test requirements.

Test Design

The test described here was performed primarily to confirm the 2C current-carrying rating of a ¼-inch nickel terminal in a 50 Ah nickel-hydrogen cell. Secondary objectives were to confirm the survivability of the terminal seals and the cell itself at high rates and temperatures, and to test the robustness of single-layer Zircar separator under the same conditions.

The test was conducted in the open air of an air-conditioned test laboratory, and no special effort was made to cool it during this period of testing. The cell was instrumented with thermocouples on the cell wall (opposite the cell stack), on the boss (barrel of the compression seal), and on the tip of the negative terminal. It was given a standard charge (5.25 amps for 16 hours) and then discharged to 0.7 volts at 100 amps. Capacity was measured to 1.0 volts, and also to 0.7 volts in anticipation of the voltage depression caused by high current and the resultant high IR drop in stack and leads.

The cell was then shorted down to below 0.1 volts with a 0.2 ohm resistor, and the test was repeated. The discharge rate the second time was increased to 125 amps to provide an over-test and to increase performance confidence. To detect any leakage which might result from the softening of the Nylon terminal seals by the high test temperatures, a phenolphthalein leak test was performed on the terminal seals at the end of all charges and discharges.

Following the high-rate cycles the cell was given a phenolphthalein leak check, placed in a cooling cart and given a standard cycle using the same charge regime as before, but a normal 30 amp discharge. This was intended to indicate whether any performance decline had resulted from the testing.

Test Results

The cell delivered appropriately good capacity on all cycles. No leaks occurred despite temperatures as high as 189°F. See tables 1 and 2 for summaries of capacity and temperature. A graph of the thermocouple temperatures on the second high-rate cycle are shown in figures 2 and 3. The plots for the first cycle were similar, but not quite so high. The evident late rise in the terminal temperature in figure 3 was due to a connection problem with the thermocouple.

Table 1
Cell Capacity (Ah)

	0.7 volts	1.0 volts
Test 1 (100 amps)	60.0	53.3
Test 2 (125 amps)	55.6	41.6
Standard 10°C (30 amps)	------	64.4

Table 2
Thermocouple Temperature (°F)

	100 amp discharge	125 amp discharge
Negative Terminal	110	143
Boss (seal)	156	176
Cell Wall	189	188

Conclusions

The warm starting temperature and the selection of a cell with thin leads made it a severe test. Despite the fact that the test cell has electrode leads lighter than any other Eagle Picher production cell, it performed well at the 2C and 2.5C rates without any decline in performance at a normal temperature. The final standard capacity of 64.4 Ah compares favorably, within normal test variance, with the cell's original 10°C ATP capacity of 65.2 Ah. Finally, its Nylon seals did not leak despite exposure to at least 176°F.

The results support the conclusion that this type of cell, including its single Zircar separator design, and the Ziegler Nylon compression seal are robust under harsh conditions. The seal withstood a temperature of 176°F and the cell a temperature of 189°F. The actual temperatures internal to the seal and cell stack were certainly higher than this, although they could not be measured directly.

It is generally recognized that temperature has some effect on the cycle life of batteries in general,[1] and it should be reassuring that this type of cell can endure this kind of exposure with no apparent degradation of performance. The presence of the wall wick in the design affords a mechanism to re-distribute any water displaced by the temperature extremes. While a judgment about the long-term effects of high temperatures is not within the scope of this paper, there is no reason to expect the ultimate cycle life to be degraded by a short-term exposure as in the test described here, particularly since this cell design has a wall wick to redistribute any electrolyte which might be displaced by temperature gradients during testing.

Acknowledgments

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[1] David Linden, *Handbook of Batteries and Fuel Cells,* para. 3.2.6, p. 3-9, McGraw Hill, 1984.