

High Specific Energy, High Capacity Nickel-Hydrogen Cell Design

James R. Wheeler
Eagle Picher Industries, Joplin MO

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Abstract

A 3.5 inch rabbit-ear-terminal nickel-hydrogen cell has been designed and tested to deliver high capacity at a C/1.5 discharge rate. Its specific energy yield of 60.6 wh/kg is believed to be the highest yet achieved in a slurry-process nickel-hydrogen cell, and its 10°C capacity of 113.9 AH the highest capacity yet made at a discharge rate this high in the 3.5 inch diameter size. The cell also demonstrated a pulse capability of 180 amps for 20 seconds. Specific cell parameters, performance and future test plans are described.

Cell Description

A program was desired to maximize power and specific energy for 3.5 inch diameter nickel-hydrogen cells while still retaining the long-cycle life and ruggedness of the positive slurry electrode. Eagle-Picher designed the cells as part of a joint project with a major aerospace company. We have now completed and tested a 100 ampere-hour cell design in two separator versions. One version has a single layer of asbestos separator for each positive electrode, and one has a single Zircar separator, but they are otherwise identical and were made from the same lots of electrodes and other components. Four Zircar cells and three asbestos cells were built and activated with a standard solution of KOH.

A photograph of a sample cell (both versions are externally the same) and a table of weight and dimensions are provided by Figure 1 and Table 1. All of the cells were equipped with strain gage pressure monitors.



Figure 1

CELL DESCRIPTION	TYPE SEPARATOR	
	Single Zircar	Single Asbestos
Weight (grams)*	2279	2236
Cell Length (in) Dome to Dome	10.97	10.97
Cell Length (in) Overall	11.56	11.56

* strain gage weight subtracted (17g)

Table 1

The internal cell design is a dual stack with a back-to-back electrode configuration and continuous leads to rabbit-ear terminals. The rabbit-ear terminal is a feature which permits a shorter battery height and therefore a shorter thermal path when the cells are vertically mounted. Thus, the high specific energy can be further improved at the battery level by reducing the length of the cell sleeve mountings and cell inter-connections. If the cells are mounted parallel to a baseplate, the rabbit-ear terminals help there as well because the cells can be rotated to minimize the length of the interconnects.

The positive electrodes are only slightly thicker and more porous than Eagle-Picher's standard high-bend-strength slurry plaque, but are still approximately double the bend-strength of dry sinter. A catalyzed wall wick is incorporated for improved thermal operation and gas management, making the cell suitable for either LEO or GEO applications. The electrolyte levels for the two versions are about the same, with the single Zircar version holding, on average, only 1% more per cell than the single asbestos version.

The pressure vessel is Inconel 718. MEOP translates to a minimum burst safety factor of 2.5. The actual maximum pressure reached by the highest Zircar version cell under conditions of severe overcharge was 3% greater than the value for the asbestos.

Cell Testing

The cells were tested to the customer's performance specification. Performance data are summarized in Tables 2 and 3.

CAPACITIES TO 1.0V (AH) AT 68 AMPS	SEPARATOR TYPE	
	Zircar	Asbestos
30°C	81.3	82.9
20°C	99.1	99.7
10°C	113.9	111.3
0°C	117.6	113.1
-10°C	115.6	108.2

Table 2

Standard capacity charges were 9 amps for 16 hours. The discharge rate used was C/1.5, or 68 amps. Average discharge voltage performance for each type of cell is shown by the curves in Figure 2. Mid-discharge values (45 minutes) are comparable to those achieved in shorter 3.5 inch cells, indicating a good cross-section of internal bussing. The voltage advantage of Zircar over asbestos is apparent, and is essentially the same for the single Zircar configuration as would be expected from a double Zircar design.

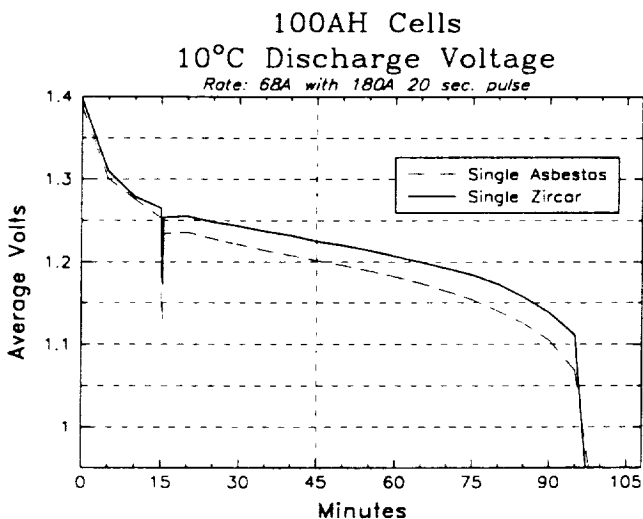


Figure 2

Testing (See Figure 2) also included a 180 amp pulse test. The test was nominally a 10°C capacity test (16

hour, 9 amp charge), with the pulse conducted 15 minutes after start of the discharge. Pulse duration was 20 seconds. Minimum terminal voltages reached at the end of the pulse were 1.17 V for the Zircar version cells, and 1.13 V for the asbestos cells.

The Zircar version achieved 60.1 watt-hours per kilogram at 10°C to 1.0 V at a discharge rate of C/1.5 (68 amps). (Watt-hour values were measured by the automated data collection software, not calculated on mid-point voltages.) In the same test the asbestos version achieved 59.0 watt-hours per kilogram. (Of course capacities would have been somewhat greater and discharge voltage higher at a more-normal C/2 rate.)

PERFORMANCE DATA	TYPE SEPARATOR	
	Zircar	Asbestos
180 Amp Pulse, Minimum Voltages	1.173	1.130
WH/Kg	60.1	59.0
WH/Kg*	60.6	59.4
* Strain gage weight subtracted		

Table 3

If the strain gages had not been installed, the values would be 60.6 wh/kg and 59.4 wh/kg respectively. These are believed to be the highest energy densities yet achieved at the cell level for nickel-hydrogen cells with slurry-process positive electrodes.

The evolution of size and power of slurry-type cells at Eagle-Picher is shown in Figure 3. This progression has been chronological, from small to large, over the last 10 years.

Capacity retention was measured by charging the cells for 16 hours at 9.0 amps and 10°C, and, after an open circuit stand of 72 hours, discharging at 68 amps to 1.0 V. The percentages of capacity retained, when compared to the standard 10°C test, were 84.6% for Zircar, and 85.8% for asbestos.

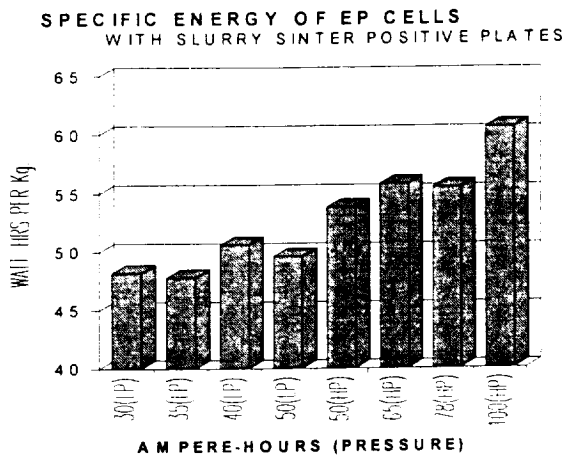


Figure 3

Conclusions

By using single-layer separator and slightly thicker, more-porous positive electrodes, specific energies of 3.5 inch nickel-hydrogen cells can exceed 60 Watt-hours per kilogram and provide good, all-around performance, even at discharge rates of C/1.5. At lower current densities, performance would of course be even better.

Also, it is shown that the 3.5 inch cell can be made to yield capacities above 110 AH. This is important to spacecraft designers who are requiring larger-capacity batteries for many applications. If these demands can be satisfied by a 3.5 inch design, thermal characteristics will be better than with a thicker cell.

Using our activation process, the electrolyte quantity for single layer Zircar is just slightly larger than the single layer asbestos version, and this augers well for cycle life. At Eagle Picher, single-layer Zircar cells have exceeded 13,400 cycles at a depth of discharge of 15%. That test is continuing.

Plans

Three cells of each version are presently undergoing characterization testing at the facilities of a major aerospace corporation, and then will undergo qualification and life testing. Characterization testing includes 100 amp discharge cycles, which have reportedly been completed with capacities comfortably above 100 AH. Life testing is planned for up to 15 years and will be to a GEO regime (real-time eclipse cycling to an 80% depth of discharge with shortened sun-times).

