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## MULTI-MISSION Ni-H<sub>2</sub> BATTERY CELLS FOR THE 1990's

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A sufficient production, test and operational database is now available to permit design technology optimization for the next decade. The evolved battery cell design features standardized technology intended to support multiple type missions (e.g. both GEO and LEO). Design analysis and validation test cells demonstrate that improved performance plus attractive specific-energy characteristics will be achieved.

### INTRODUCTION

In the year 1988 Eagle-Picher Industries (EPI) surpassed the production point of 10,000 space type Ni-H<sub>2</sub> battery cells. Approximately 25,000,000 battery cell hours of space flight operation have now been accumulated. Multiple test cell groups continue to undergo real-time and accelerated life testing. Real-time GEO testing has now exceeded 13 years and LEO testing over six (6) years. Accelerated LEO testing has exceeded 40,000 cycles.

Several design technologies evolved in the accumulation of this extensive data-base. Performance comparisons and post-test destructive physical analysis (DPA) have proven useful in the evaluation of the advantages and disadvantages of the various design technologies. Sufficient data is therefore available to propose a more standard, optimized battery cell design capable of supporting multiple types of missions for the next decade.

### BATTERY CELL DESIGN

The following design summary proposes a baseline cell design. If optional technology is available which has been tested and proven, then it is noted in parenthesis.

#### Pressure Vessel (PV)

A single girth weld design is proposed with opposing axial compression terminal seals as shown in Figure 1. (For volume critical or other special applications, the terminals may be located at 45° off-set positions on either the same PV end or at opposing ends.)

In accordance with MIL-STD-1522A, EPI has established and qualified an "in-house" fracture critical vessel inspection capability which permits customizing the cell design maximum-expected-operating-pressure (MEOP) and vessel wall thickness for the specific mission application.

### Electron Beam Welding

All PV joining will be accomplished by the electron beam (EB) process. EPI has procured a FERRANTI Sciaky 60 KV, 250 mA EB welder for "in-house" capability and control. A large vacuum chamber was selected to permit equipment modifications for high precision, multiple cell self-indexing, fully automated welding.

### Electrode Stack

The electrode stack will feature "pineapple slice" geometry for optimum thermal, mechanical and electrical characteristics (refer to Figure 1). The positive electrodes will be configured in a "back-to-back" arrangement. Depending upon capacity the design will feature a single or dual stack arrangement. For capacities of 50 Ampere-Hours (A-H) or less, a single stack is generally used.

### PV Wall Coating

The PV will feature a porous zirconium oxide wall coating to serve as an electrolyte return (wick) and reservoir. (A combination electrolyte transport and catalyzed wall coating design for enhanced gas management is also offered.)

### Positive Electrode

A high mechanical strength (1500 psi minimum), slurry sinter positive electrode is utilized for long term dimensional stability. An electrode thickness of 0.03 inches (0.076 cm) is incorporated to maximize the quantity of electrodes and thus minimize operational current densities. A moderate active material loading level of 1.65 grams/cm<sup>3</sup> of void volume is specified.

### Negative Electrode

A standard teflonated catalyzed electrode with a platinum loading of 8 milligrams/cm<sup>2</sup> is featured. (Platinum loading reductions of up to an order of magnitude are also available).

### Separator

In consideration of long term availability, electrolyte reserve provisions and low impedance (particularly at lower temperatures), a two (2) layer zirconium oxide (Zircar) material design is featured. (A combination asbestos/Zircar design is also available. In addition, for mass critical missions a single layer asbestos or Zircar design is offered.)

### Electrolyte

A 31% potassium hydroxide solution will be incorporated in the standard cell. (For missions with a large number of cycles or high depths of discharge, a 26% solution is offered for positive electrode stress reduction.)

### Gas Management

The more open structural characteristics of the Zircar separator material poses additional problems with respect to oxygen gas management (reference Figure 2). The proposed cell design will incorporate provisions which are intended to

redirect the oxygen gas flow away from the positive electrode-to-separator interface during overcharge.

### Stack Growth Accommodations

To accommodate potential electrode stack dimensional growth and to maintain appropriate stack load under dynamic stress, a spring type device is employed. The device incorporated in the proposed cell design offers significant advantages over the Belleville washer design employed in several cell types. The spring constant for the proposed device can be reproducibly controlled and maintained in the manufacturing process. In addition, load uniformity is maintained over much greater length of travel at approximately one fourth the mass of equivalent Belleville washers.

### 80 A-H CELL DESIGNS

Battery cells rated at 80 A-H are being produced and validation cells have been placed on test. This program may serve as an example for projecting mass and volume characteristics for the proposed cell design. Figures 3 through 6 represent summaries of computer projections for the most influential technology option, separator type and design.

The design analysis of the proposed Ni-H<sub>2</sub> battery cell was performed on a TRS-80, Model 100 portable computer. The specific application software was coded in an extended version of BASIC. The program constructs a detailed model of the cell design via established electrochemical, physical and material performance formulas.

The 80 A-H cells for a program have now progressed sufficiently to permit model accuracy verification.

<u>Attribute</u>	<u>Model Accuracy</u>
Mass	0.2%
Capacity	0.2%
Length	0.1%

### CELL TEST DATA

Typical battery cell conditioning and Acceptance Test data are presented in Tables 1 and 2, respectively. To permit a level of performance comparison, data was selected for a single layer asbestos and a single layer Zircar separator cell design.

These same two (2) test cell groups are part of a larger test cell group now undergoing real-time GEO life cycle testing in accordance with the test profile presented in Figure 7. Typical end-of-discharge voltage (EODV) performance is compared graphically in Figure 8.

### CONCLUSION

A multi-mission Ni-H<sub>2</sub> battery cell has been produced and is successfully undergoing validation testing. The cell design has assimilated the optimal, space flight proven technology which has evolved from a 15 year, 10,000 production unit, 25,000,000 flight cell hour database. Its standardized features should now support missions through the 1990's with minimal need for design requalification and dedicated cycle life testing.

**TABLE 1. Performance Comparison of 80 Ampere-Hour Cells During Sealed Conditioning Cycles\***

Cycle	EOC V		1 Hr DV		Cap. (A-H)	
	#1	#2	#1	#2	#1	#2
1	1.535	1.534	1.220	1.233	88	86
2	1.527	1.525	1.218	1.233	85	85
3	1.537	1.533	1.215	1.234	84	85

- Notes:
- \* Charged C/10 for 16 hours, discharged C/2, 10°C.
  - 1. Design #1 = Asbestos Separator, 8 cells on test.
  - 2. Design #2 = Zircar (1) Separator, 3 cells on test.
  - 3. All data values are group averages.

**TABLE 2. Performance Comparison of 80 Ampere-Hour Cells During Acceptance Test Cycles\***

Test	EOC V		1 Hr DV		Cap. (A-H)	
	#1	#2	#1	#2	#1	#2
25°C	1.491	1.486	1.204	1.211	73	71
-5°C	1.595	1.585	1.140	1.188	82	84
10°C	1.530	1.515	1.185	1.205	87 (77)**	86 (84)**

- Notes:
- \* Charged C/10 for 16 hours, discharged C/1.6.
  - \*\* Discharge to 1.1 volts.
  - 1. Design #1 = Asbestos Separator, 8 cells on test.
  - 2. Design #2 = Zircar (1) Separator, 3 cells on test.
  - 3. All data values are group averages.
  - 4. Cells were subjected to 30 "burn-in" cycles between Conditioning and Acceptance Testing. Cycle = 12 hour; 75% DOD in 1.2 hours, 1.25 C/D return in 10.8 hours, 10°C.

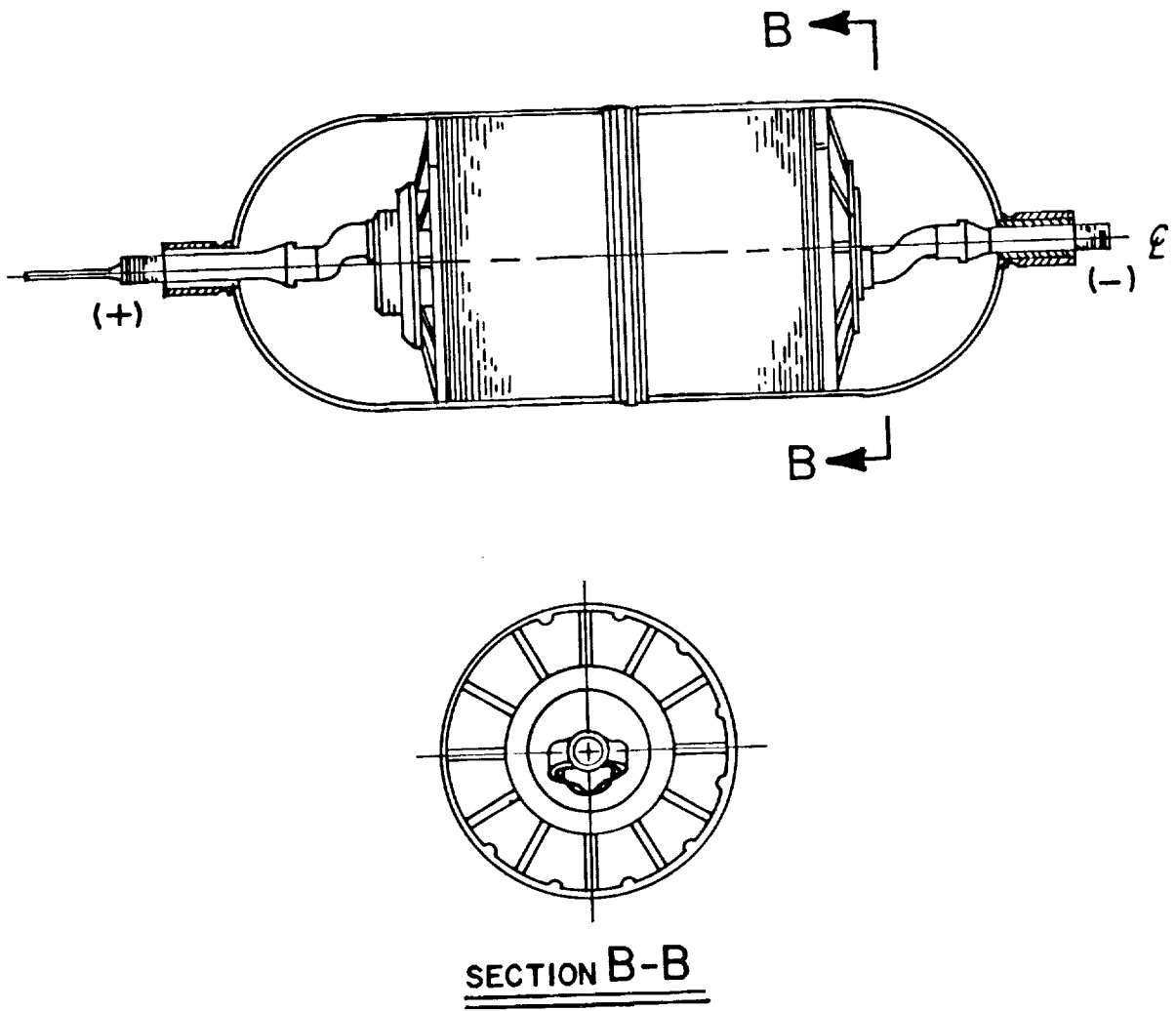


Figure 1. EPI "Mantech" Design

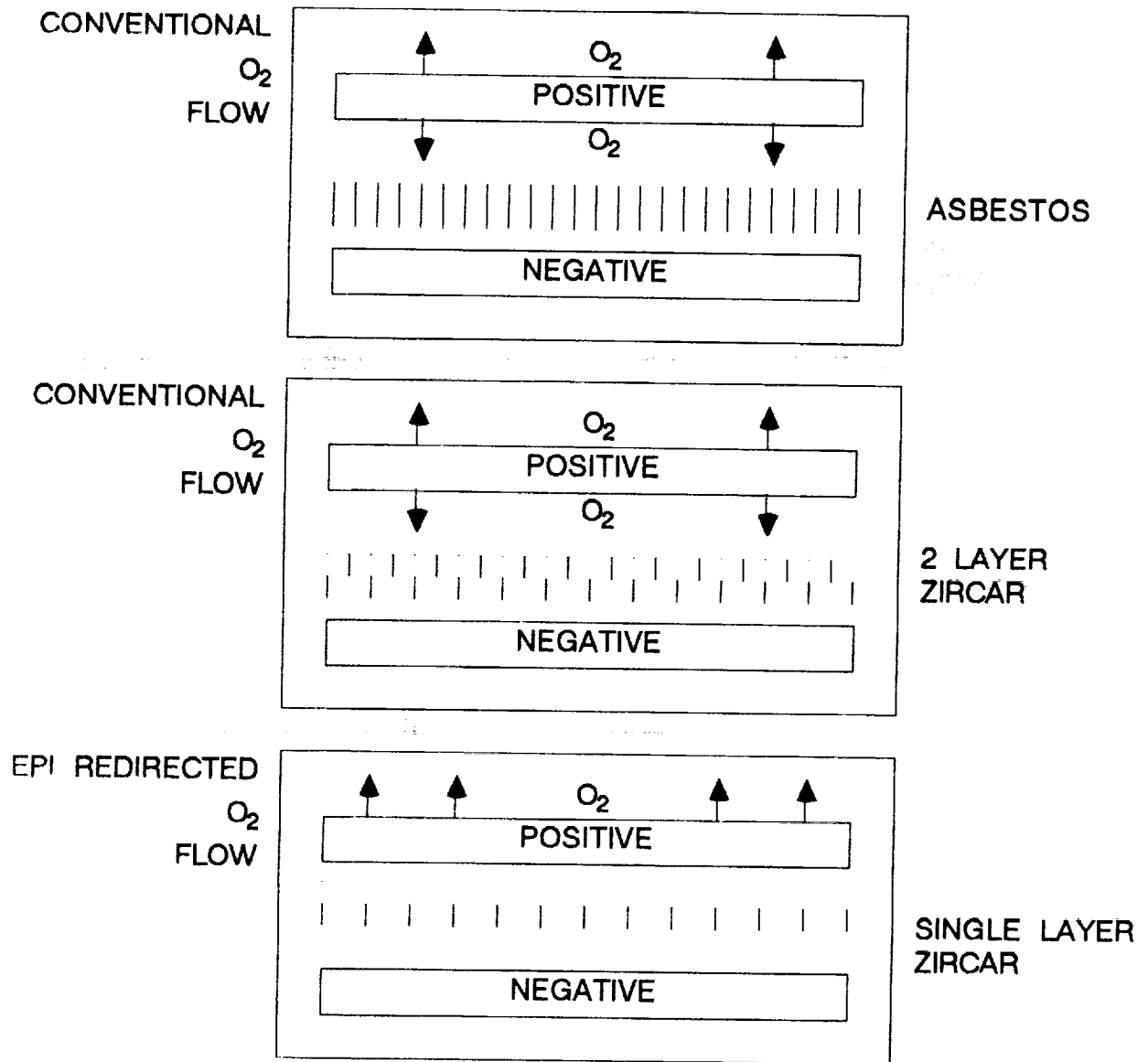


Figure 2.  $\text{NiH}_2$  Separator Design Technology

<u>Battery Cell Design Parameters (Input):</u>		<u>Value:</u>
1.	Rated Cell Capacity (A-Hr)	80.000
2.	Cell Capacity Margin (%)	10.000
3.	Cell Residual Capacity (%)	25.000
⋮		
<u>Battery Cell Design Features (Output):</u>		<u>Value:</u>
1.	Nominal Cell Mass (Gms)	1991.280
2.	Nominal Cell Capacity (A-Hr)	88.476
3.	Cell Specific Energy (W-Hr/Kg)	54.207
4.	Pressure Vessel Length (in)	10.123
5.	Total Cell Length (in)	13.373
6.	Total Cell Length (cm)	33.968
7.	Cell Diameter (in)	3.506
8.	Cell Diameter (cm)	8.905
⋮		

Figure 3. Baseline 80AH Rated (2 Layer Zircar Separator) Cell Design

<u>Battery Cell Design Parameters (Input):</u>		<u>Value:</u>
1.	Rated Cell Capacity (A-Hr)	80.000
2.	Cell Capacity Margin (%)	10.000
3.	Cell Residual Capacity (%)	25.000
⋮		
<u>Battery Cell Design Features (Output):</u>		<u>Value:</u>
1.	Nominal Cell Mass (Gms)	1947.790
2.	Nominal Cell Capacity (A-Hr)	88.476
3.	Cell Specific Energy (W-Hr/Kg)	55.417
4.	Pressure Vessel Length (in)	10.021
5.	Total Cell Length (in)	13.271
6.	Total Cell Length (cm)	33.707
7.	Cell Diameter (in)	3.506
8.	Cell Diameter (cm)	8.905
⋮		

Figure 4. Option #1 80AH Rated (Asbestos / Zircar Separator) Cell Design

<u>Battery Cell Design Parameters (Input):</u>		<u>Value:</u>
1.	Rated Cell Capacity (A-Hr)	80.000
2.	Cell Capacity Margin (%)	10.000
3.	Cell Residual Capacity (%)	25.000
⋮		
<u>Battery Cell Design Features (Output):</u>		<u>Value:</u>
1.	Nominal Cell Mass (Gms)	1858.410
2.	Nominal Cell Capacity (A-Hr)	89.271
3.	Cell Specific Energy (W-Hr/Kg)	58.604
4.	Pressure Vessel Length (in)	9.643
5.	Total Cell Length (in)	12.893
6.	Total Cell Length (cm)	32.749
7.	Cell Diameter (in)	3.506
8.	Cell Diameter (cm)	8.905
⋮		

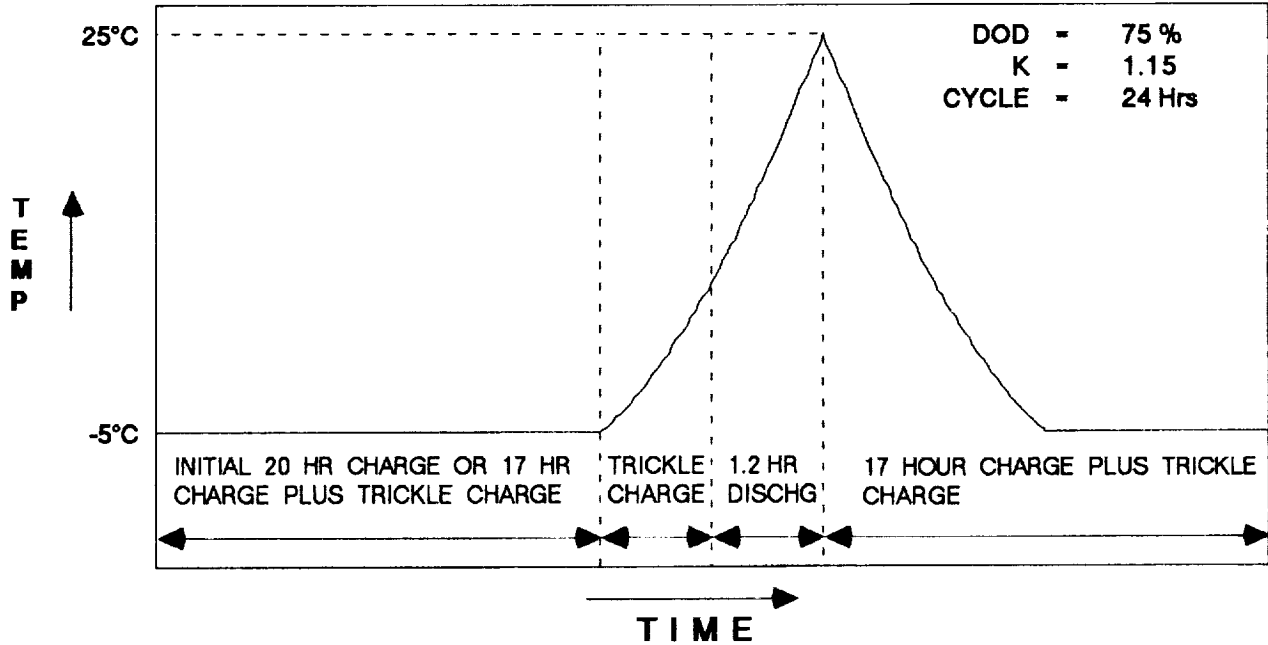
Figure 5. Option #2 80AH Rated (1 Layer Asbestos Separator) Cell Design

<u>Battery Cell Design Parameters (Input):</u>		<u>Value:</u>
1.	Rated Cell Capacity (A-Hr)	80.000
2.	Cell Capacity Margin (%)	10.000
3.	Cell Residual Capacity (%)	25.000
⋮		
<u>Battery Cell Design Features (Output):</u>		<u>Value:</u>
1.	Nominal Cell Mass (Gms)	1803.090
2.	Nominal Cell Capacity (A-Hr)	88.476
3.	Cell Specific Energy (W-Hr/Kg)	59.865
4.	Pressure Vessel Length (in)	9.505
5.	Total Cell Length (in)	12.755
6.	Total Cell Length (cm)	32.397
7.	Cell Diameter (in)	3.506
8.	Cell Diameter (cm)	8.905
⋮		

Figure 6. Option #3 80AH Rated (1 Layer Zircar Separator) Cell Design



**FIGURE 7. Cycle Test, Cell Temperature Vesus Time**



**FIGURE 8. Real-time GEO Life Cycle Test End-of-Discharge Voltage**

