

## IMPROVED SPECIFIC ENERGY NI-H<sub>2</sub> CELL

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### ABSTRACT

Significant improvements in specific energy for Ni-H<sub>2</sub> battery cells have been and will be achieved. Current flight cell designs in operation on multiple satellites have achieved a specific energy of 52 Whr/Kg (this value may be compared to 45 Whr/Kg for advanced, light-weight Ni-Cd space cells). Battery cells operating at increased pressures (600 to 900 psi) have been manufactured and successfully tested demonstrating a specific energy of 63 Whr/Kg. Further optimization of electrode substrate and cell terminal/conductor assembly designs will permit achievement of specific energies between 75-80 Whr/Kg. Energy density (outline volume) will be improved from 49 Whr/L to 73 Whr/L.

### INTRODUCTION

To achieve a Ni-H<sub>2</sub> battery cell offering a specific energy of 75-80 Whr/Kg, system design optimization was undertaken in the following specific areas which evolved from previous work (1): 1. The specific energy of the electrode stack was increased primarily through the enhancement of the specific capacity of the positive electrode. 2. Pressure vessel mass savings were achieved through size reduction associated with higher pressure operation and weld ring/center rod redesign. 3. The weight consumed by the electrical feedthru/current conductor assemblies was reduced by more efficient, shorter path designs.

This paper discusses the results of design validation testing and planned design validation steps to be undertaken.

The "Intelsat" type Ni-H<sub>2</sub> battery cell design has been chosen for expository purposes. However, it should be recognized portions of the improved technology could be applied to the "Air Force" type Ni-H<sub>2</sub> battery cell design with equal benefit.

## DESIGN OPTIMIZATION

### ELECTRODE STACK

Negative electrode design improvement has been achieved by the simple reduction of platinum catalyst loading. A reduction of 67% from the current flight production level produced the electrode thickness and mass improvements presented in Table I (17 and 28% reduction respectively).

With respect to design validation, work was initiated in this technology in 1974 with the goal of component cost reduction. Comparative testing reported in 1975 (2) demonstrated equivalent performance and these results were subsequently corroborated by multiple Ni-H<sub>2</sub> and Ag-H<sub>2</sub> cell production and testing. More recently, COMSAT Laboratories reported equivalent performance (3) with a platinum loading reduction of 94% of current flight production levels.

Planned validation for this component and the remaining design improvements discussed below will involve 75-80 Whr/Kg specific energy battery cell production for qualification and life testing. This activity is now in the tooling and part procurement phase.

A major advance was achieved with respect to the positive electrode. As indicated in Table I, a small increase (17%) in sinter substrate (nickel) thickness permitted a 5% increase in sinter porosity. Since the sinter substrate contributes more than 60% of the finished electrode weight but occupies only 20% of the volume, a small increase in porosity translates into a significant mass savings.

The resulting increase in void volume (vv) allows the further deposition of active material without violating the present, proven flight level limit. The measured capacity of the conventional "Intelsat" positive electrode is increased by 35%. In fact the weight of the additional active material is almost exactly off-set by the reduction of nickel sinter permitting the statement the specific capacity of the positive electrode has been increased by 35%.

Design validation has been successfully carried through sinter substrate mechanical strength characterization, and finished electrode dynamic stress and boilerplate performance cycling.

When these advanced electrode technologies are combined into a stack, a shorted stack (25%) offering higher capacity per unit mass is achieved (33% increase in specific energy) as presented in Table I. An initial analysis might indicate the specific energy at the stack level should be higher because of the component count reduction (37%). However, the electrolyte level associated with the positive electrode group remains unchanged and the total cell electrolyte is reduced by only 12%.

## PRESSURE VESSEL

Figure 1. presents a photograph of the redesigned pressure vessel weld ring. This light-weight design offers enhanced dynamic load tolerance in the critical cell longitudinal axis. In addition, the design is intended to specifically accommodate the more universal "dual stack" cell assembly technique.

By shifting the fulcrum stress to a more centralized location, a lighter weight hollow center rod may be utilized. Total mass savings for these redesigned components is estimated to be 30%.

The redesigned weld ring has been validated by a centralized dynamic loading technique. If the photograph of Figure 1. is observed closely, the permanent deformation of the current weld ring design, after the same level of testing, can be noted.

The reduced length and corresponding pressure vessel mass savings associated with increased cell nominal operating pressure (900 psi) is straight forward and has been the subject of previous papers (1). The present vessel is quite conservatively designed with a nominal burst pressure in excess of 3,000 psi and an estimated yield pressure in excess of 2,700 psi.

Design validation has been accomplished via hydraulic pressure cycling at Eagle-Picher and through a fracture analysis performed for Eagle-Picher by Martin Marietta Aerospace, Denver, Colorado.

## ELECTRICAL FEEDTHRU/CURRENT CONDUCTORS

To minimize the number of current conductors (electrode leads) required, the reduced stack component design described above is further enhanced as depicted in Figure 2. The "notched" lead access and reduced "wall gap" (0.20 cm to 0.10 cm) accommodates a 12% increase in electrode area. A 33% increase in electrode edge perimeter is also accommodated enhancing the heat rejection capability of the electrode stack.

Figure 2. further depicts elimination of the busbar arrangement in preference for the more mass efficient, continuous lead design.

Figure 3. offers an overview comparison between the current and advanced cell designs. Shown are the internally mounted, 45° off-set electrical feedthru's considerably reducing the current conductor path length. The feedthru design features a redundant sealant (teflon), hydraulic seal mechanism.

Also shown is the relative reduction in pressure vessel length and the continuous lead, electrode stack conductor arrangement. A 50% mass savings with respect to the electrical conductors and a 17% mass savings with respect to the reduced pressure vessel size are projected. In addition, an overall outline volume reduction of 33% is achieved.

Design validation of the basic concepts associated with the 0.10 cm wall gap, continuous lead design and the hydraulic seal is assumed as the result of the successful work conducted by the Hughes Aircraft Company, Technology Division, El Segundo, California under the Air Force "Nickel-Hydrogen Battery Advanced Development Program" (4).

### CONCLUSION

This paper has summarized design optimization activities which have evolved and validated the necessary technology to produce Ni-H<sub>2</sub> battery cells exhibiting a specific energy of 75-80 Whr/Kg (energy density approximately 73 Whr/L). Final design validation is currently underway with the production of battery cells for qualification and life testing.

The significance of the progress which has already been achieved is shown in Table II which begins with state-of-the-art, light-weight Ni-Cd. The photograph presented in Figure 4, shows two 70 Ah rated cells (nominal capacity 80 AH) mounted in aluminum thermal collars in preparation for life cycle testing. The pressure vessels for these cells are approximately 1 cm shorter than current flight production 50 AH rated cells and the measured specific energy is 63 Whr/Kg.

## REFERENCES

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4. Stadnick, S. J. et al (Hughes Aircraft Company): Nickel-Hydrogen Battery Advanced Development Program. AFWAL-TR-80-2-44, April 1980, Aero Propulsion Laboratory, Air Force Wright Aeronautical Laboratories, Air Force Systems Command, Wright-Patterson Air Force Base, OH 45433.

Table I. ADVANCED ELECTRODE DESIGNS

ADVANCED ELECTRODE DESIGNS

NEGATIVE ELECTRODE

PLATINUM LOADING	67% DECREASE
ELECTRODE THICKNESS	17% DECREASE
ELECTRODE MASS	28% DECREASE

POSITIVE ELECTRODE

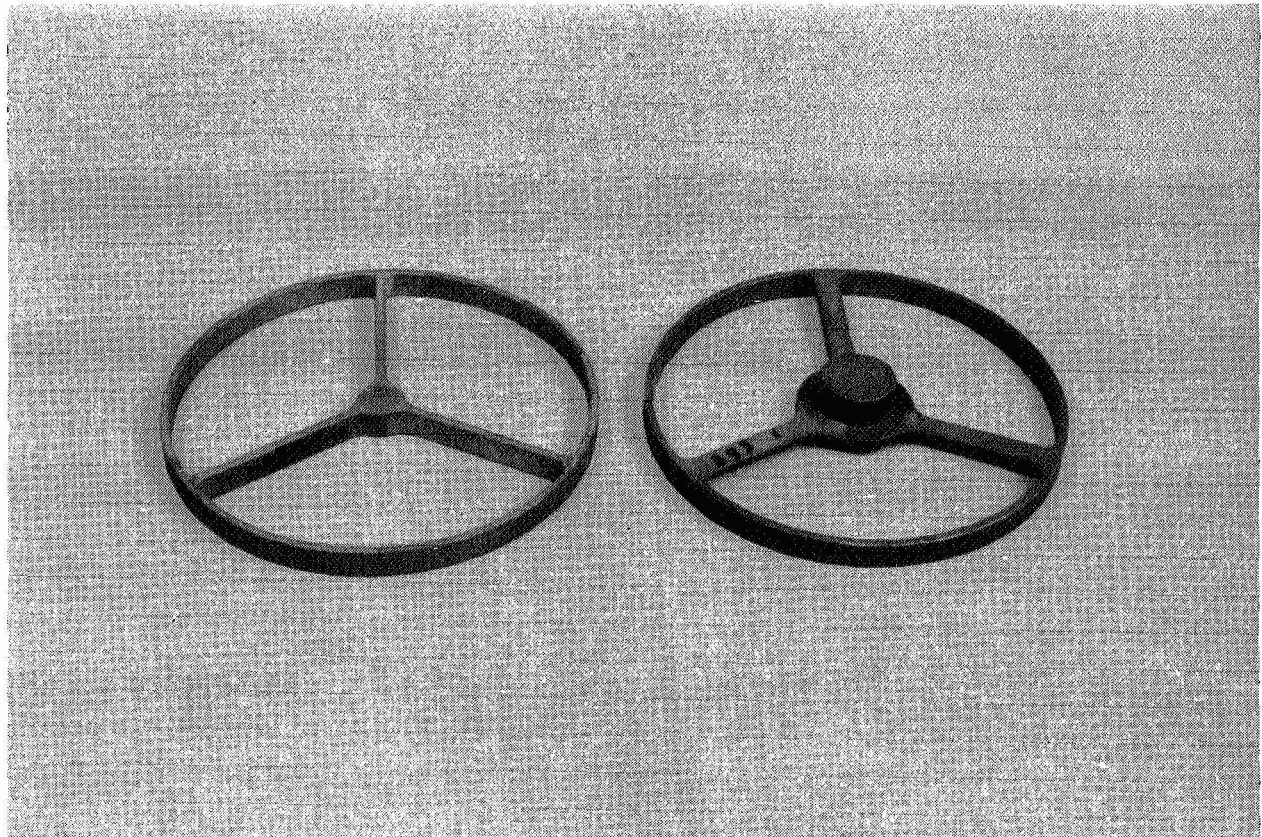
SINTER THICKNESS	17% INCREASE
SINTER POROSITY	5% INCREASE
ELECTRODE LOADING	NO CHANGE
ELECTRODE CAPACITY	35% INCREASE

STACK SPECIFIC CAPACITY	33% INCREASE
STACK COMPONENT COUNT	37% DECREASE
STACK LENGTH	27% DECREASE

Table II. BATTERY CELL SPECIFIC ENERGY

BATTERY CELL SPECIFIC ENERGY

LIGHT-WEIGHT NI-CD	45 WHR/KG
CURRENT (600 PSI) NI-H <sub>2</sub>	52 WHR/KG
HIGHER PRESSURE (900 PSI) NI-H <sub>2</sub>	63 WHR/KG
ADVANCED (900 PSI) NI-H <sub>2</sub>	75-80 WHR/KG



ADVANCED WELD RING

CURRENT WELD RING

Figure 1



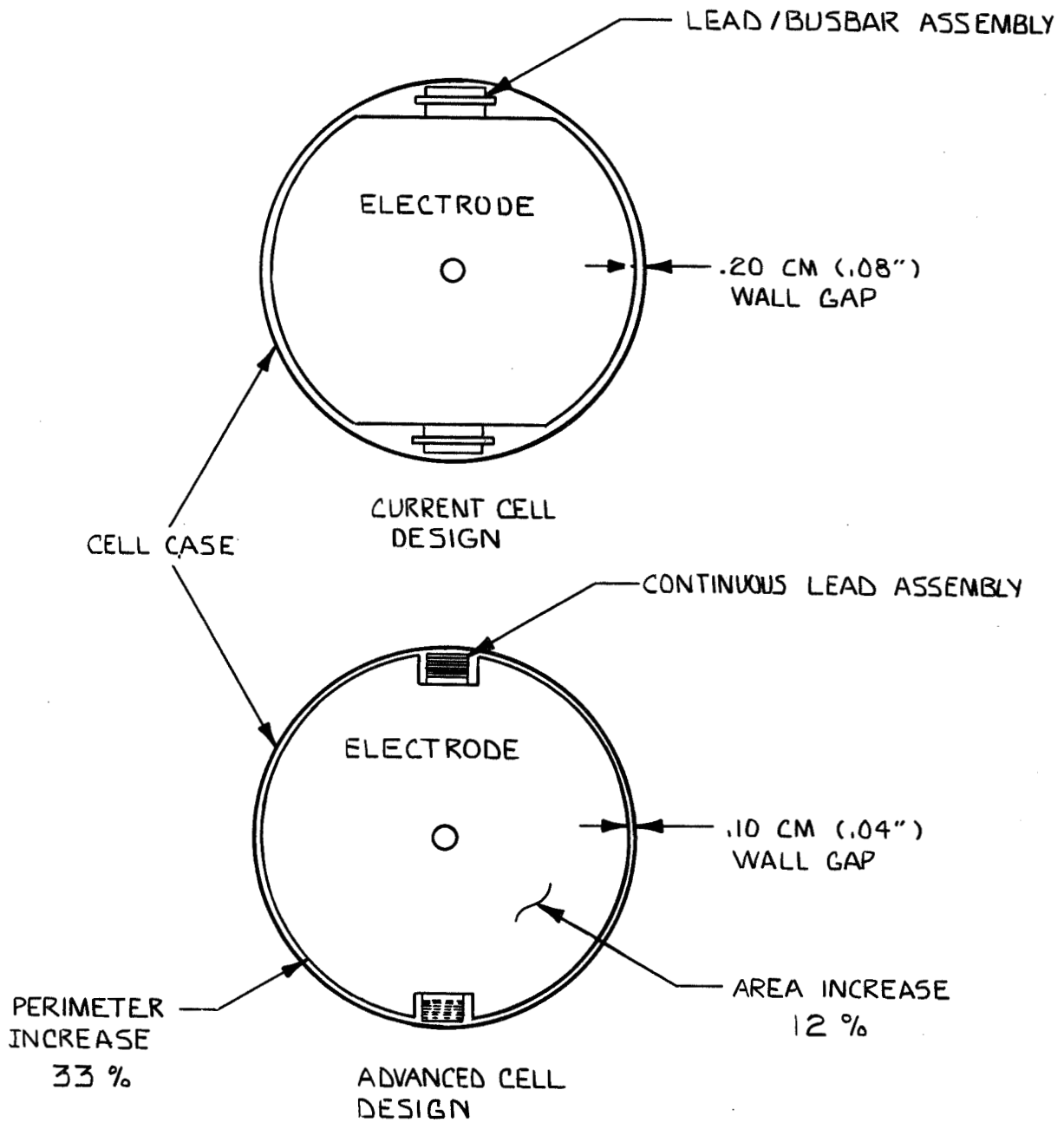
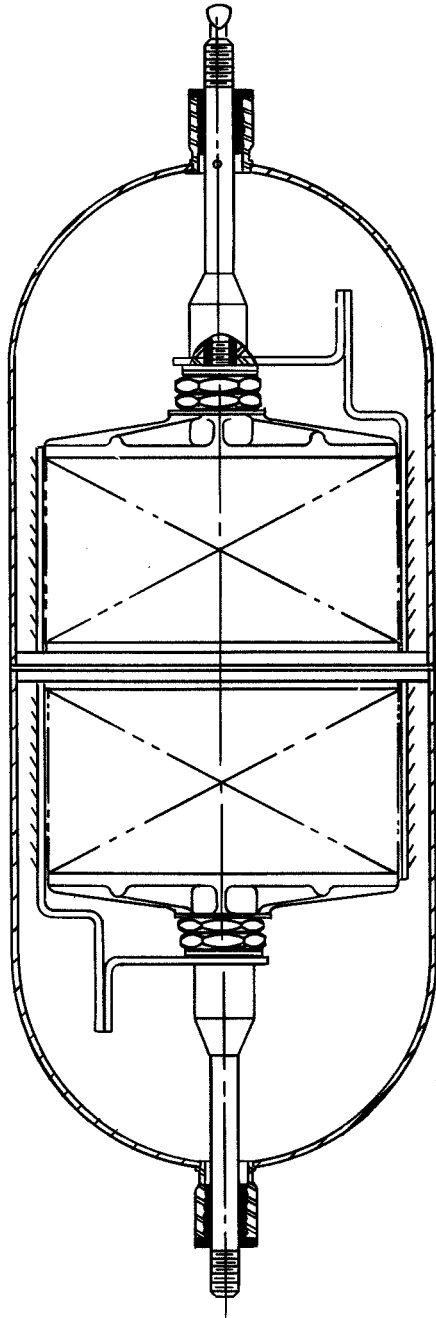


Figure 2.

CURRENT CELL DESIGN  
600 PSI



ADVANCED CELL DESIGN  
900 PSI  
(20% LENGTH REDUCTION)

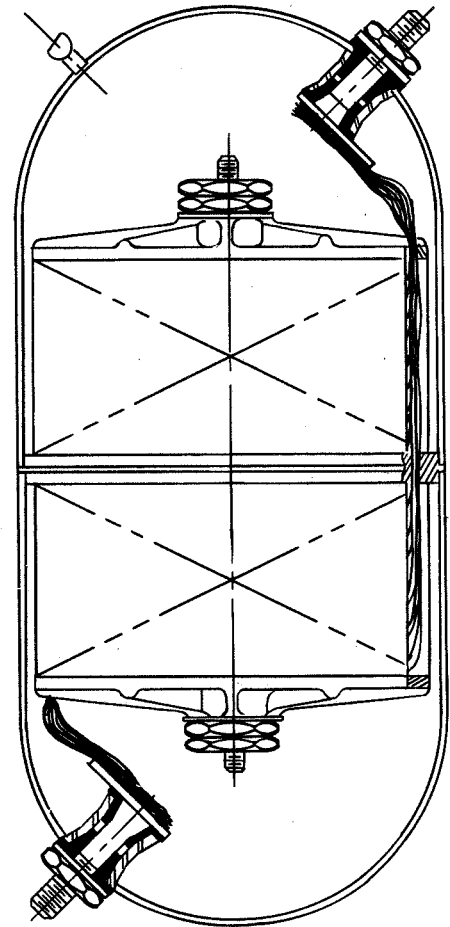


Figure 3. Projected 17% Mass Saving in Pressure Vessel and 50% Saving in Electrical Conductors. Outline Volume Reduction 33%.

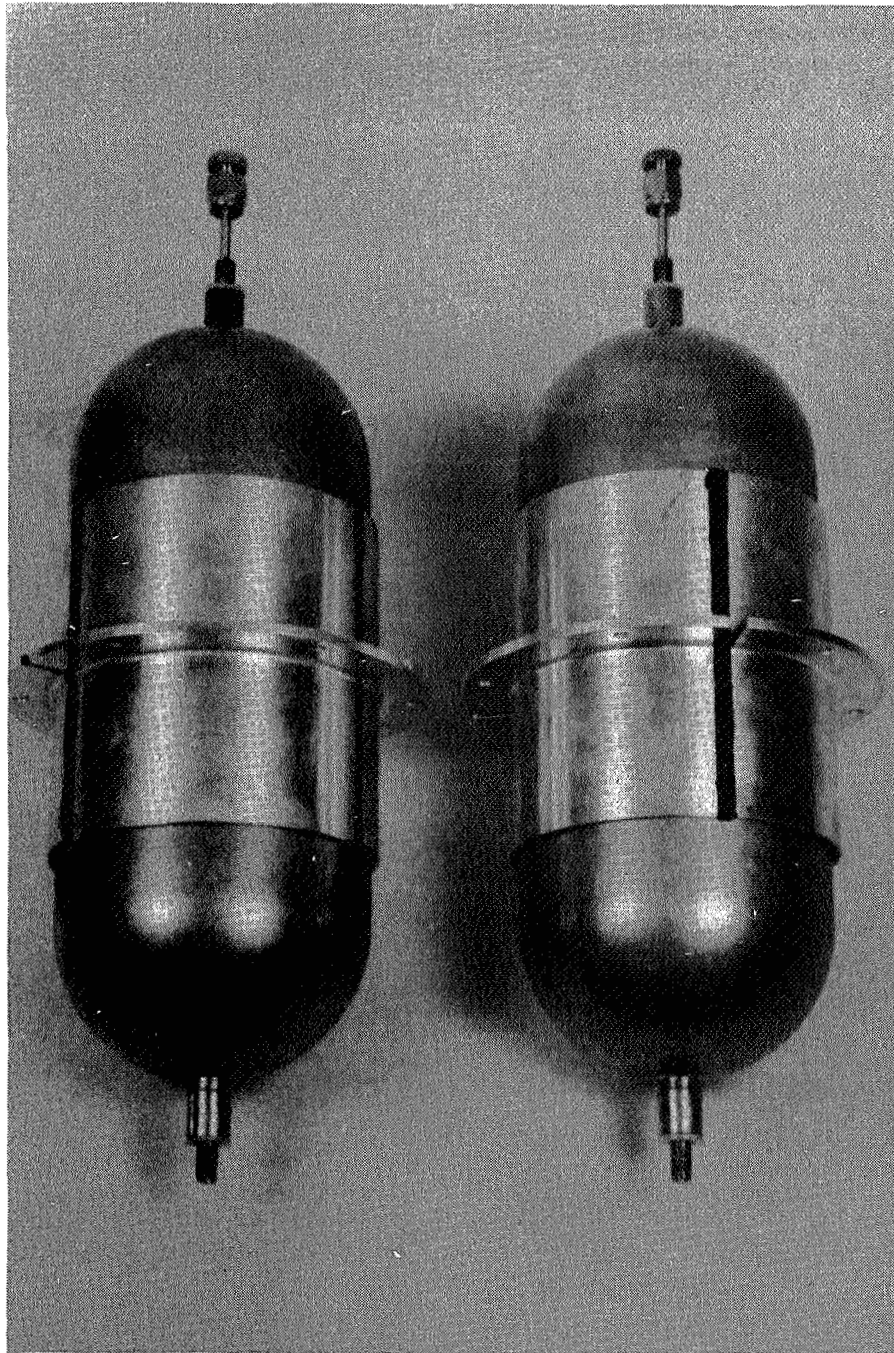


Figure 4. 70 AH Rated Cells (Nominal 80 AH), Specific Energy 63 Whr/Kg.