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NICKEL HYDROGEN COMMON PRESSURE VESSEL BATTERY DEVELOPMENT

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The nickel hydrogen battery has become the battery of choice for satellite power systems. Because of its superior energy density and long cycle life, it is replacing nickel cadmium systems in space applications. In general, nickel hydrogen chemistry has shown a greater tolerance for depth of discharge with a lower effect on cycle life than nickel cadmium [1].

To date all nickel hydrogen batteries that have flown in space have been of the individual pressure vessel (IPV) form. The fully integrated IPV cell system in a battery assembly reduces the specific energy density from 55 wh/kg at the cell level to 34 wh/kg at the battery level [2] (Figure 1). The next natural step in the maturing development of nickel hydrogen battery systems is to combine all of the cells into a common pressure vessel (CPV). In 1984, Johnson Controls and COMSAT Laboratories started on the development of the CPV nickel hydrogen battery. This work has evolved into a range of products to serve both the terrestrial and extra-terrestrial markets. Today Johnson Controls is producing multicell CPV nickel hydrogen batterie from 7 Ah to 190 Ah and voltages in excess of 50 all in one vessel. This approach to putting all the cells in one vessel reduces the volume and weight over a more typical IPV installation. The actual differences vary with the power requirements and installation space available. A comparable nickel hydrogen battery installation for an Intelsat I-7A satellite can save as much a 36 kg when using a CPV instead of an IPV.

There are three different diameter batteries being produced today in the CPV design by Johnson Controls, 5", 10" and 12" (Figure 2). Designs for a 2.5" and 7.5" diameter have been established. As the system voltage requirements change, it is a simple process of adding another cell stack to the CPV design which will add to its total length only. Cell shapes are offered in several different shapes from full circles (disc shape) (Figure 3) and half circles (Figure 4) to rectangular (Figure 5). Each application dictates what cell shape should be used. In th case of our 190 Ah stationary battery, weight and size were of no importance since the batte are intended to be buried in the ground for good thermal stability, low cost was the main driver in this application. In keeping with that objective, we used a thin wall stainless steel hydrogen barrier liner and end domes that are epoxy bonded on and the entire vessel is over-wrapped with the lower cost filament "E" glass. This gave us a vessel with a 5:1 safety factor and a very desirable failure mode on over pressure. The cells have 90 mil thick positives, are retangular in shape and they fit into a standard automotive container made of polypropylene.

For the aircraft starting battery the requirement was to weigh less than the nickel cadmium battery presently used and provide improved reliability. The weight savings was only 3 kg but the cycle life reliability has gone up more than 10 times. This battery used a 10" diameter and the half circle cell design to provide the shortest discharge path for the cell connections. We provide

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in excess of 1000 A for 90 seconds because of the short intercell connection which have an internal resistance of less than 1.35 millivolts per cell.

Our 5" diameter battery is generally offered in full circle cell form. We have made batteries from 12 volts to 28 volts (10 to 22 cells) and can go higher if needed.

The CPV battery can be provided with specific energy densities of 55 wh/kg or more if needed.

In all the designs we use a heat fin which is generally aluminum or copper. This fin picks up the heat from the broad surface of the cell and conducts it to the wall of the vessel. This patented feature is one of the key design factors that permits the CPV battery to meet all operating thermal demands. Temperature differentials are kept to less than 10°C between any extreme point in the assembly and it can be altered by simply changing the thickness of the fin.

Each cell is enclosed in a double layer, three part plastic enclosure which has two gas vent ports to hold the moisture and KOH in and allow the hydrogen gas to pass through.

The typical air force back-to-back cell configuration is used (Figure 6). Our minimum cell arrangement is two positive and two negative catalyst plates which we call a module. If more amphours are required, more modules will be connected in parallel as required.

We generally use a negative precharge but can provide a positive precharge to prevent damage from 100% depth of discharge.

Our first CPV battery design for space application in concert with Comsat Laboratories was a 10" diameter, half circle cell 24 A, 32 volt (26 cell) design. It lasted 18 months and performed 7,000 cycles at 44% depth of discharge in a LEO cycle of 16 cycles per day at 10°C ambient. This battery experienced a premature failure because of an assembly error. Two of the plastic (single layer at this time) cell enclosures had been cut open during cell insertion in a heat transfer assembly we no longer use. It was felt by all involved in the program that if a plastic enclosure ever leaked, the KOH would bridge the cells and the battery would fail in a very short time. Surprisingly there was no recognized evidence of this assembly defect for over a year and a half of cycling and it wasn't until the DPA at Comsat, after 7,000 cycles, that the truth was known. This heat transfer housing design is no longer used and the new design has eliminated the threat of this type of error completely. Only the first prototype battery used the difficult to assemble design.

Our present design uses an open disk which allows the cell to be set into a shallow cavity and subsequent cells are stacked on each other with the total number based on the battery voltage required (Figure 7). This approach not only eliminates the assembly error threat but also more readily assures equal contact pressure to the heat fin between each cell which further assures balanced heat transfer. These heat fin dishes with their appropriate cell stacks are held together with tie bars which in turn are connected to the vessel weld rings at each end of the tube.

All batteries can be activated with the KOH and placed in a boiler plate vessel for check out prior to final welding into the Inconel 718 vessel. A CO_2 laser weld is used to seal the dome and tube assembly to the weld ring.

We have passed the 2 minute - 3 axis - 19.5 g random vibration test and thermal vacuum.

All of the design features are intended to provide ease of assembly which enhances reliability and lower cost. Johnson Controls continues to develop the CPV technology for all its markets and their mutual benefit.

References:

[1] IECEC paper, The NASA Research and Technology Program On Batteries, Gary L. Bennett, 25th IECEC, August 1990 (Page 80).

[2] IECEC paper, Some Initial Tests Carried Out On Nickel Hydrogen Cells With Regard To Their Usage On The Olumpus Space Craft, P. Leggett and A. Sepers, 20th IECEC, August 1985 (Page 1.331).

FIGURE 1: 26-CELL CPV BATTERY AND IPV EQUIVALENT

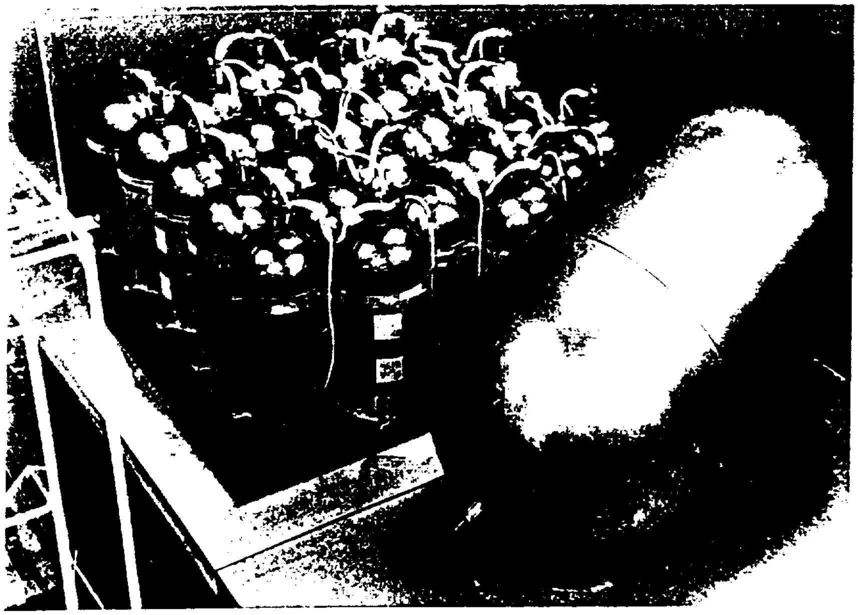

FIGURE 2: VARIETY OF CPV BATTERIES CURRENTLY IN PRODUCTION

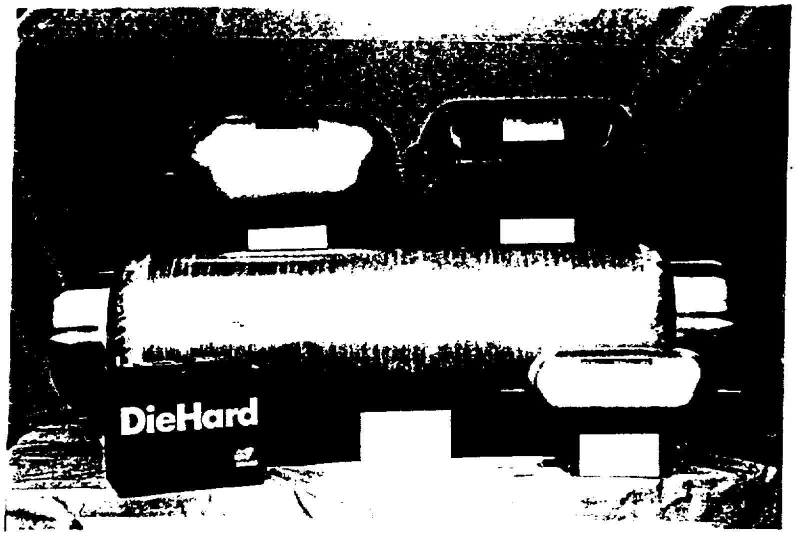

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FIGURE 3: 5" CIRCULAR CPV CELL

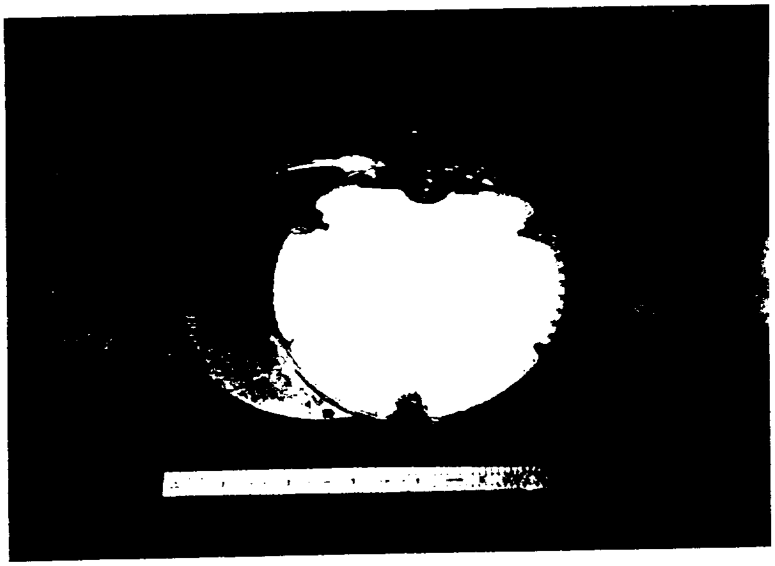

FIGURE 4: 10" SEMI-CIRCULAR CPV CELL

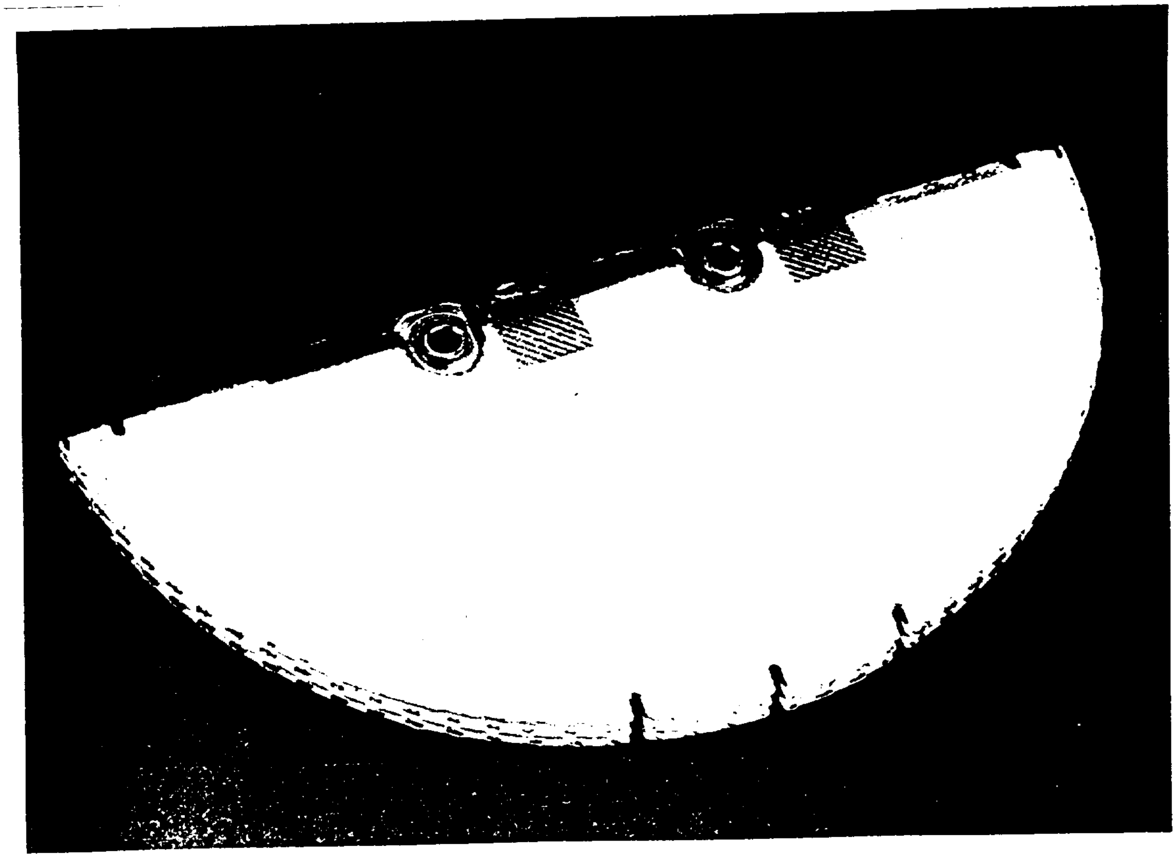

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FIGURE 5: RECTANGULAR CPV CELL MODULE AND COMPONENTS

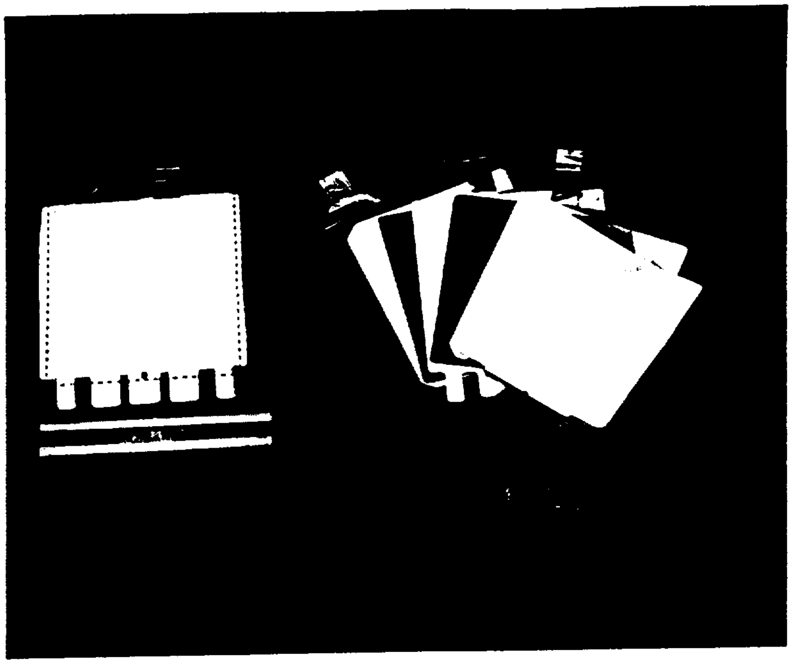
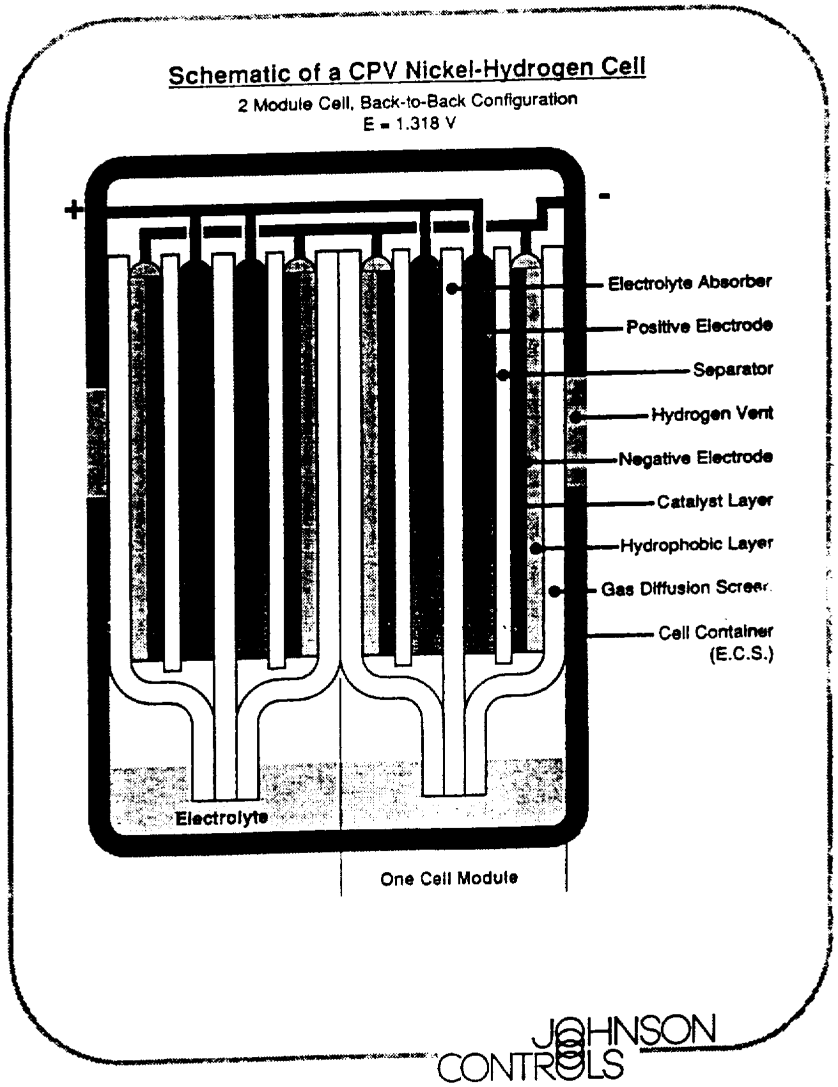


FIGURE 6:



Schematic of a CPV Nickel-Hydrogen Cell

2 Module Cell, Back-to-Back Configuration

E = 1.318 V

FIGURE 7: 22 CELL CPV LEO BATTERY STACK