FABRICATION & TESTING OF NEGATIVE-LIMITED SEALED NICKEL-CADMIUM CELLS

Report No. 732-015-1

First Quarterly Report
1 July to 30 September 1973

Prepared by E. Luksha
K.C. Kohl

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10 October 1973

Jet Propulsion Laboratory
Contract No. 953680

Gould Inc., Gould Laboratories
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ABSTRACT

Negative-limited sealed nickel-cadmium cells are a possible means toward increasing the life of nickel-cadmium cells to about a decade or more. The purpose of this program is to design, construct, and test 100, 20 Ah and 100, 3Ah negative-limited sealed cells. Fifty-two cells from each group will be selected and delivered to JPL. The remaining 48 cells of each group will be tested by Gould. The cell design was completed during the first quarter. The required physical dimensions of the hardware and components necessary to produce 20 and 3 Ah cells were established. The stainless steel cans and covers have been ordered. The covers will contain two ceramic seals. The fabrication of electrodes was started. About 55% (879 electrodes) of the required cadmium electrodes has been prepared. About 44% of the porous nickel substrates (plaques) required for the preparation of the nickel oxide electrodes has been completed.

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I. INTRODUCTION

The sealed version of todays nickel-cadmium cell is a unique one. In terms of high-rate performance, over a wide range of ambient conditions, calendar life, cycle life, mechanical properties, etc., it is unsurpassed. In spite of its impressive performance features it has limitations where really long life (say 10 years) is required. Sealed nickel-cadmium cells with useful lives in this range are being actively pursued for aero-space applications, medical implantations, just to mention the prominent ones. In the past decade or so the nickel-cadmium cell has been developed to a point where it may be possible that gas loss from the cell is the most important life limiting phenomenon in the system.[1] The gassing that normally occurs in such cells, particularly on the positive electrode[2] during charge and overcharge can result in gas loss from the cell via diffusion. Also pressure and temperature fluctuation associated with the overcharge of the cell can damage its hermetic seals.

Gould Inc. has done work under subcontract with JPL in the past which was directed at minimizing the above-mentioned difficulties and thereby increase the life of the system to the desired level. An essentially 'non-gassing' negative-limited nickel-cadmium cell was developed.[4,5] The 'non-gassing' approach involved essentially three changes in the design of conventional nickel-cadmium batteries. These were:

1. Change the ratio of positive to negative active material in the cells so that the cells become negative limited.
2. Use a grid material for the cadmium electrode that has a high over-potential for the hydrogen evolution reaction so that the onset of hydrogen gassing would be signaled by a relatively large voltage step.
3. Incorporation of a miniature electronic charge control device that will be used externally to each cell to end the charge using the voltage step as a signal.

During work on parts 1 and 2 (ref 4) the concept of a negative-limited 'non-gassing' nickel-cadmium battery was demonstrated by constructing and testing practical size experimental cells of approximately 25 Ah capacity. Thirty cells were constructed and tested (ref 5) for 500 cycles using an accelerated regime approximating a 90-minute orbit period. Three groups of 10 cells each were tested at 0°, 25°, and 40°C. The test program clearly showed that the negative-limited nickel-cadmium cell was a very promising avenue leading to a practical, long-lived secondary cell.

The technology developed in the above-referenced program is being applied in the present work, which is made up of the following tasks:

- Cell design and hardware fabrication
- Component and cell construction
- Cell testing

for 100, 3 Ah and 100, 20 Ah aerospace type cells. Fifty-two cells of each size will be delivered to JPL. The remaining 48 cells will undergo varying tests including a 1000 cycle life test.

II. RESULTS AND DISCUSSION

A. Cell Design and Hardware Fabrication

1. Cell Design

The required physical dimensions of the hardware and components necessary to produce 20 Ah and 3 Ah cells was established. The numerical values are given in Table 1. The cadmium electrodes are identical to the ones employed in an earlier study.[5] The nickel electrode to be employed in this work was increased in thickness from 50 to 65 mils while maintaining the same loading per $in.^3$ in order to increase the positive/ negative active material ratio. The separator thickness was also increased from 10 to 18 mils in an effort to improve the overall separation and perhaps improve electrolyte distribution.

TABLE 1. COMPONENT DIMENSIONS FOR NEGATIVE-LIMITED SEALED NICKEL-CADMIUM CELLS

Type	No.	H (In.)	W (In.)	T (In.)	Loading ($g/in.^3$)
		3 Ah Size	(4 Ah Actual)		
Nickel Electrode	7	2.25	1.75	0.065	31.6
Cadmium Electrode	6	2.25	1.75	0.015	60.7
Pellon	14	2.50	2.00	0.018	–
		20 Ah Size	(25 Ah Actual)		
Nickel Electrode	9	5.50	3.50	0.065	31.6
Cadmium Electrode	8	5.50	3.50	0.015	60.7
Pellon	18	5.75	3.75	0.018	–

2. Hardware Fabrication

Stainless steel cans and covers (type 304L) are presently being fabricated in the necessary sizes to accommodate the above-described components. The covers will be constructed with two ceramic seals; one is to be silver plated and will service the cadmium electrode. Provisions were made for attaching Trerice pressure gauges (tubes and sockets fabricated from 316 stainless steel) and a rupture disc type safety device to the fill tube. During preliminary testing of the cells, measurements of cell pressure and capacity will be made. The attachments will be removed from the 52 cells selected from each group for delivery and the fill tube will be sealed. The attachments will be retained on cells tested by Gould. Ceramaseal Corp. will provide the ceramic seals. The detailed engineering drawings for the hardware required for this program are shown in Appendix I.

All exterior hardware items have been ordered with delivery already complete or expected as noted.

Items received:

- Pressure release device including rupture disc
- Fittings for attaching gauges and pressure release device

Items pending:

- Pressure gauges – ship 10/12/73
- Cover assemblies – ship 12/4/73
- Cans – ship 11/30/73
- Plating of terminal – depends upon cover delivery

B. Electrode Fabrication

1. Cadmium Electrodes

Electrodeposited cadmium electrodes which earlier work (ref 4,5) indicated were best suited for use in negative-limited cells are presently being constructed.

Electrodes are being prepared using a laboratory version of a proprietary production process where by a cadmium active mass is deposited on a 5 Ag 7 – 4/0 expanded silver sccreen (Exmet Corp.). These electrodes are being prepared in 2.25 x 1.75 in. and 5.50 x 3.50 in. sizes. They are 0.014 – 0.016 inches thick and have average $Cd(OH)_2$ loadings of 0.91 g/in.^{2} Electrical formation steps associated with the manufacturing process is being employed here to screen the electrode capacities to assure that electrodes of closely balanced capacities will be assembled in cells. In addition all electrodes are being very carefully visually examined for physical defects. Presently 586 of the large and 293 of the small cadmium electrodes have been prepared. Thus the cadmium electrode manufacturing portion of the work is about 55% complete based on the estimate that a total of 1600 electrodes will be required.

2. Nickel Electrodes

Nickel electrodes of a type identical in construction except for thickness to those previously used (ref 4,5) are being constructed. Inco type 287 powder is first dried in a vacuum oven for one hour at 210°C. After removal from the oven, the powder is cooled in a dry room. The powder is then placed in a set of standard sieves and processed on a Ro-Tap shaker for 15 minutes. The 1.04 g/cc (Scott Densiometer, the -37μ fraction) fraction is stored in a dry room until used. A portion of the powder is sprinkled into a 6 x 12 in. mold containing a 20-mesh wire-woven nickel screen. The powder is removed from the mold and sintered in a vacuum furnace for 10 minutes at 1675°F.

The plaques thusly prepared will be first cut into the appropriate sizes for the 20 Ah and 3 Ah cells, coined, and then current collector tabs will be welded on. The thickness of the plaques will be in the range of 63 mils.

The plaques will be impregnated using one of Gould's private processes, to a loading of 1.925 $\pm$ 0.056 g/cc.

The electrodes prepared in this way were shown to be extremely uniform (ref 4). For the purpose of the present work it is sufficient to screen electrode weights and thicknesses to assure the desired level of uniformity. Formed electrodes will be carefully inspected and rejected if physical defects like blisters are apparent.

Thus far, 200 6 x 12 in. sintered plaques have been prepared; 460 are required. When the required number of plaques are prepared, further processing will be started.

III. CONCLUSIONS

During the first quarter of the program the following tasks have been completed or are in progress:

1. The dimensions of cell hardware and components have been established.
2. Hardware specifications have been developed, and hardware construction is underway at various vendors.
3. Electrode fabrication has been started and about 55% of the cadmium electrodes required for the program have been completed. As far as the nickel electrode is concerned, about 44% of the required plaque material has been prepared.

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4. E. Luksha, D.J. Gordy, and C.J. Menard, "Non-Gassing Nickel-Cadmium Battery Electrodes and Cells", Report No. 712-122-4, Prepared for Jet Propulsion Laboratory, Contract No. 953184.

5. E. Luksha, D.J. Gordy, and C.J. Menard, "Non-Gassing Nickel-Cadmium Battery Electrodes and Cells – Testing of 25 Ah Cells", Report No. 712-122-5, Prepared for Jet Propulsion Laboratory, Contract No. 953184.

APPENDIX I.

Mechanical Drawings of Hardware Required For Negative-Limited Sealed Nickel-Cadmium Cells – 20 Ah and 3 Ah Sizes

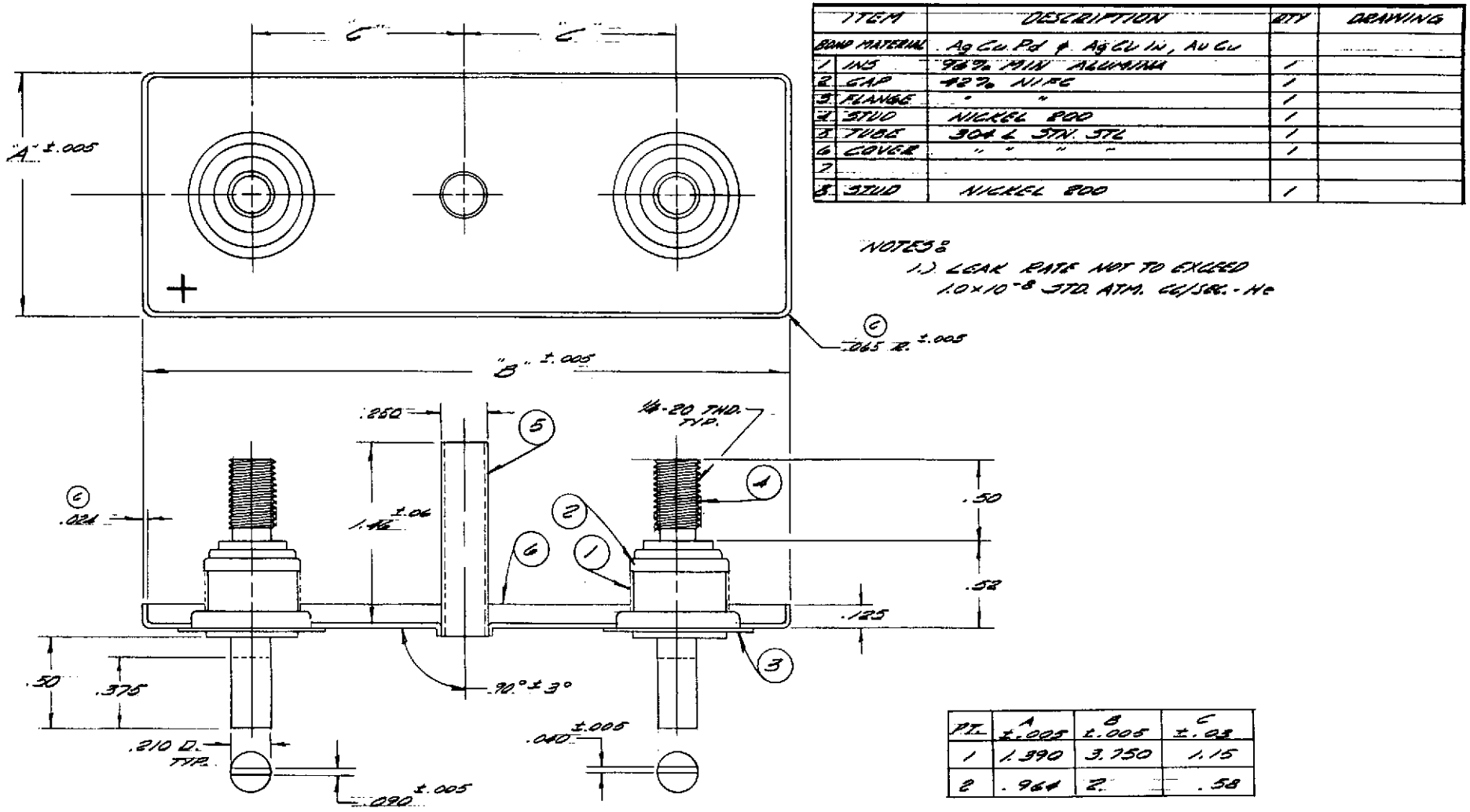
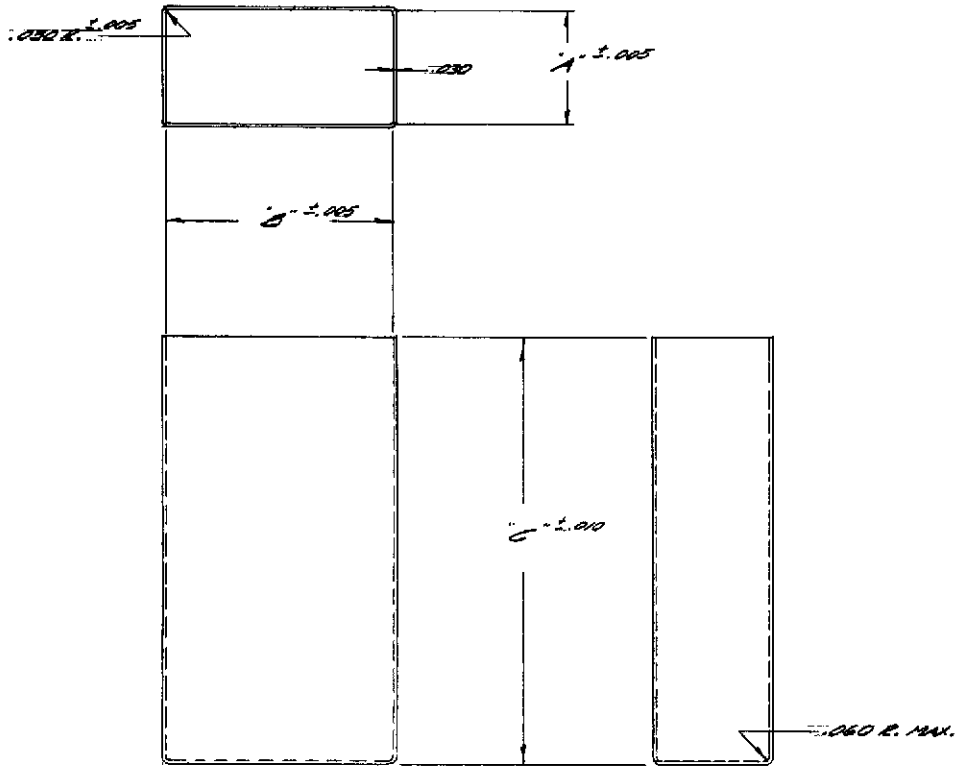


Figure 1. Stainless Steel Cover and Ceramic Seal Assembly



PT.	"A"	"B"	"C"
1	1.390	3.750	6.90
2	.964	2.850	3.65

NOTES:
1.) LEAK RATE NOT TO EXCEED 1.0×10^{-8} STD. ATM. CC/SEC. - He
2.) WELDS NOT TO BE GROUND OR POLISHED
3.) MAT'L: 304 L STAINLESS STEEL

Figure 2. Stainless Steel Cell Case