FABRICATION AND TESTING OF
LARGE SIZE NICKEL-ZINC CELLS

by Martin Klein

ENERGY RESEARCH CORPORATION

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA Lewis Research Center

NAS3-19415
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FINAL REPORT

Contract No. NAS3-19415

FABRICATION AND TESTING OF LARGE SIZE NICKEL-ZINC CELLS

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Prepared For:
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21000 Brookpark Road
Cleveland, Ohio 44135

Date:
April, 1977
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</tr>
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1.0 INTRODUCTION

The nickel-zinc battery system offers potential advantages for electric vehicles and other applications. This program was directed at the construction and limited testing of 100 to 300 ampere-hour nickel-zinc cells. The program was divided into the following tasks:

Task I - 3 experimental 100 ampere-hour cells
TASK II A - 6 experimental 300 ampere-hour cells
B - 4 second generation experimental 300 ampere-hour cells
TASK III - Test and evaluation of the above cells
TASK IV - Fabrication of 7,300 ampere-hour cells for delivery for NASA
TASK V - Reports
TASK VI - Fabrication and delivery of 135, 300 ampere-hour cells

All the cells were constructed with Government furnished inorganic separator material, and sintered nickel positive electrodes. The cells constructed for Task II B and Task VI utilize a Government furnished injection molded cell case and cover. The cell design and fabrication procedure for the zinc negative electrodes utilized in all the cells was specified in the contract.
TASK I - Fabrication of 3 experimental 100 ampere-hour nickel-zinc cells

The 100 ampere-hour cells were constructed in accordance with the specification listed in Table I. The cell containers were fabricated from 3/8" thick polysulfone plastic. The negative electrodes were prepared according to the NASA fabrication procedure, attached is Appendix A. The separator bags for the negative electrode which utilize the inorganic separator were prepared by epoxy bonding; an ABS plastic frame to two layers of the separator material as shown in Figure 1. This technique was utilized for all the cells constructed in the program. The ABS frame thickness was selected to be equal to the nickel or zinc electrodes thickness and its absorbent separator layer.

The three 100Ahr cells were filled each with 500 cc of 31, 33 and 35% KOH containing 1% LiOH and then placed in an oven at 150°F. for 16 hours to complete the wetting cycle. After an additional 48 hours of soaking they were charged at 5.3A for 24 hours. They were then discharged at 120A, to 1.50 volts followed by draining at 10A to 1.50 volts. The charge rate was kept at 5.3A for 24 hours or to a voltage cut-off of 1.92 volts. No cell reached this cut-off during charge. Table II summarizes the results.
TABLE I

100AH Cell Specifications

<table>
<thead>
<tr>
<th>Cell Dimensions</th>
<th>100 Amp. Hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Height</td>
<td>13.0 in.</td>
</tr>
<tr>
<td>Case Height</td>
<td>12.25 in.</td>
</tr>
<tr>
<td>Case Width</td>
<td>7.0 in.</td>
</tr>
<tr>
<td>Case Depth</td>
<td>1.062 in.</td>
</tr>
<tr>
<td>No. of Electrodes</td>
<td>5 Pos/4 Neg</td>
</tr>
</tbody>
</table>

**Electrode Sizes**

- Inside Positive: 5.875 x 9.62 x 0.070 in.
- Outside Positive: 5.875 x 9.62 x 0.035 in.
- Negative: 6.125 x 9.87 x 0.067 in.

Negative Electrode Material: 113-115 grams

**Note** - Negative electrode thickness dependent upon absorber mat thickness.

**Separator Bag Size**: 6.50 x 10.25 in.

**Absorber Materials on Positive**: 2530 Polypropylene .012 thick

**Absorber Material on Negative**: ERC prepared KT (potassium titanate sheet) .010 in thick
Figure 1

SEPARATE FRAME
TABLE II

100Ahr Results

<table>
<thead>
<tr>
<th>Cell No.</th>
<th>Elec. Conc.</th>
<th>Capacities - Ahr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>**120A/*10A</td>
</tr>
<tr>
<td>100 - 1</td>
<td>31%</td>
<td>60.3/108</td>
</tr>
<tr>
<td>100 - 2</td>
<td>33%</td>
<td>60.3/109</td>
</tr>
<tr>
<td>100 - 3</td>
<td>35%</td>
<td>60.3/108</td>
</tr>
</tbody>
</table>

*Represents the sum of the two capacities

**Discharge carried out to 1.40 volts
Based on the results obtained during the initial tests, these cells were subjected to a pulse discharge cycle regime. After 4 pulse cycles were completed, the cells developed shorts and the testing was discontinued.

Dissection of the cells showed that zinc had penetrated through the bottom portion of the sealed inorganic separator bag. Evidence of zinc shorting could also be seen at the edges of the bag seal as well. Some evidence of positive plate wrapping was also seen.

The cause of the shorting in the 100Ahr cells was traced to use of inorganic separator materials from the beginning of the separator roll which had only been coated once. The normal material is prepared with a double dip coating.

**TASK II A - Construction of 6, 300 ampere-hour cells**

The six experimental 300 ampere-hour cells were constructed using 3/8" thick polysulfone fabricated cell cases as shown in Figure 2. The cell design is shown in Table III. Figure 3 shows the positive electrode utilized. The first 300 ampere-hour cell was subjected to testing and dissection before the balance of the cells were completed. The cell contained non-woven polypropylene as the separator material on the positive electrodes. Dissection of this cell revealed that the positive electrode tended to dish placing a compressive load on the separator edges. To overcome this all subsequent cells of the program contained positive electrode that had the screen side inward to reverse the bow.
Nickel-Zinc Electric Vehicle Cell

300 Amp-Hours

Case Material
3/8 = Polysulfone

Figure 2
300 Ah CELL
### TABLE III

**300AH Cell Specifications**

<table>
<thead>
<tr>
<th>Cell Dimensions</th>
<th>300 Amp. Hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Height</td>
<td>13.0 in.</td>
</tr>
<tr>
<td>Case Height</td>
<td>12.25 in.</td>
</tr>
<tr>
<td>Case Width</td>
<td>7.0 in.</td>
</tr>
<tr>
<td>Case Depth</td>
<td>2.812 in.</td>
</tr>
<tr>
<td>No. of Electrodes</td>
<td>14 Pos/13 Neg.</td>
</tr>
</tbody>
</table>

**Electrode Sizes**

| Inside Positive          | 5.875 x 9.62 x 0.070 in. |
| Outside Positive         | 5.875 x 9.62 x 0.035 in. |
| Negative                 | 6.125 x 9.87 x 0.067 in. |

**Negative Electrode Material**

113-115 grams

**Separator Bag Size**

6.50 x 10.25 in.

**Absorber Materials on Positive**

- 2530 Polypropylene
- Fuel Cell Asbestos 0.010 in. thick (Cell 5 & 6)

*As manufactured by the Pellon Corporation.

**Absorber Material on Negative**

- ERC KT .010 in thick
Figure 3

NICKEL ELECTRODE

Page No. 9
This was accomplished by removing the tabs on half the positive electrodes and placing new tabs on the opposite corner. To place the new tabs it was necessary to grind off the nickel sintered active material to spot weld the tabs directly to the screen.

A further observation made on the first cells was the inorganic separator material tended to delaminate from the frame in the layers of the asbestos. To overcome this all subsequent cells contained an ABS frame around the positive electrode to provide some compression on the edge seal of the inorganic separator material. Cells 2, 3, and 4 contained two layers of 6 mil polypropylene wrapped around a positive electrode with the ABS frame. Cells 5 and 6 contained untreated asbestos absorber around the positive electrodes which was epoxy bonded to an ABS frame of equal thickness to the positive electrode.

**TASK III - Testing and evaluation of the 6 experimental 300Ahr Cells**

Table IV shows the test procedure used to test the cells.

The first 300Ahr nickel-zinc cell was filled with 1500 cc of 31% KOH + 1% LiOH and allowed to soak for 72 hours including 16 hours at 150°F prior to placing the cell on charge.
A. Cell Formation Procedures
The cells shall be formed and tested as detailed herein.

Formation Cycle No. 1 - Charge the cells at 16 amperes to 1.91-1.92 volts or for 24 hours whichever occurs first. Discharge the cells at 135 amperes (1.5ma/sq. cm) to 150 volts, then at 30 amperes to 1.50 volts.

Formation Cycle No. 2 - Same as Formation Cycle No. 1.

B. Performance-Characterization Test
Following the second formation discharge, the cells shall be charged at 16 amperes to 1.92 volts or for 24 hours whichever occurs first. The cells shall then be discharged at 360 (40ma/sq.cm), 180 (20ma/sq.cm), and 90 (10ma/sq.cm) amperes to 1.50 volts, followed by draining at 30 amperes to 1.50 volts after each test. Cells shall be charged at 16 amperes to 1.92 volts between discharges. The discharge voltage shall be continuously recorded as a function of time at the constant current drain rates.

C. Cycle Life Testing
The 300-ampere-hour cells shall be cycled continuously on the regime outlined below:
Charge Schedule:
The cells shall be charged at 20 amps until the cell voltage reads 1.92 volts. By means of a manual timer on the cycling equipment, the Contractor shall charge the cell so that on each cycle the input shall be approximately 105% of the output of the previous cycle.

Discharge Schedule:
(a) Discharge at 30 amps for 1 second  
(b) Discharge at 200 amps for 4 seconds  
(c) Stand on open circuit for 7 seconds  

Items (a) through (c) together shall constitute one discharge pulse. The discharge pulses shall be repeated until the load voltage of any cell falls to 1.5 volts.
The cell was charged at 16A for 24 hours and then discharged at 135A, 360A, 180A and 90A to 1.50 volts on each of 4 deep discharge cycled followed by draining at 30A to 1.50 volts after each cycle.

Table V shows the results of these discharges.

Following the deep discharges, the cell was placed on a pulse cycle regime. The results are shown in Table VI.

At cycle 6, the low voltage cut-off was lowered to 1.40 volts. After 3 discharge pulse cycles the cell was reaching the high voltage cut-off on charge at 1.92 volts. After 20 cycles, the ECV cut-off was raised to 2.00 volts.

Cell No. 1 failed after 43 pulse cycles and testing was discontinued. Capacity began dropping after 33 cycles and at cycle 43 capacity had fallen to 91.5Ahr. At cycle 43, the charge voltage rose to only 1.82V and after 24 hours of stand the voltage dropped to 0.1V. The cell had developed internal shorts.

Cells 2 - 6 were filled with 1550 cc of 31% KOH heat treated and placed on test. Cell #2 was initially placed on the pulse cycle test. Table VII shows the discharge results of this cell. The end of charge voltage declined after cycle 20 indicating a short. The testing was terminated after cycle 26. Cell 3-6 were initially discharged at 135 and 90 amps as shown in Table VIII - XI and then placed on cycle test.

Cell #3 shorted after 9 cycles and was dissected. The data is presented in Table XII.

Cell #3 was placed on charge stand after cycling for three days after which time the open circuit voltage dropped to 1.78 volts.
### TABLE V

**TEST RESULTS OF CELL #1**

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>5</th>
<th>30</th>
<th>60</th>
<th>110</th>
<th>120</th>
<th>150</th>
<th>190</th>
<th>215</th>
<th>240</th>
<th>250</th>
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<tbody>
<tr>
<td>Volts (135 Amp)</td>
<td>1.62</td>
<td>1.57</td>
<td>1.55</td>
<td>1.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(30 Amp)</td>
<td>1.63</td>
<td>1.62</td>
<td>1.60</td>
<td>1.58</td>
<td>1.56</td>
<td>1.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>60</th>
<th>180</th>
<th>300</th>
<th>420</th>
<th>450</th>
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<tr>
<td>Volts (360 Amp)</td>
<td>1.47</td>
<td>1.45</td>
<td>1.42</td>
<td>1.40</td>
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<tr>
<td>(30 Amp)</td>
<td>1.62</td>
<td>1.68</td>
<td>1.66</td>
<td>1.63</td>
<td>1.57</td>
<td>1.50</td>
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<table>
<thead>
<tr>
<th>Time (min)</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>55</th>
<th>65</th>
<th>90</th>
<th>120</th>
<th>180</th>
<th>240</th>
<th>300</th>
<th>370</th>
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<tbody>
<tr>
<td>Volts (180 Amp)</td>
<td>1.60</td>
<td>1.56</td>
<td>1.54</td>
<td>1.52</td>
<td>1.50</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>(30 Amp)</td>
<td>1.66</td>
<td>1.66</td>
<td>1.64</td>
<td>1.63</td>
<td>1.60</td>
<td>1.50</td>
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<td></td>
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</table>

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>5</th>
<th>60</th>
<th>120</th>
<th>180</th>
<th>205</th>
<th>240</th>
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<tr>
<td>Volts (90 Amp)</td>
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<td>1.60</td>
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<tr>
<td>(30 Amp)</td>
<td>1.55</td>
<td>1.50</td>
<td></td>
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(AH)2

ENERGY RESEARCH CORPORATION
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<tr>
<th>CYCLE NO.</th>
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<th>CAPACITY</th>
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<tbody>
<tr>
<td>1</td>
<td>16A for 24 hrs</td>
<td>1.885</td>
<td>945</td>
<td>218</td>
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</tr>
<tr>
<td>2</td>
<td>16A for 16 hrs</td>
<td>1.900</td>
<td>1359</td>
<td>314</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16A for 22 1/4</td>
<td>1.920</td>
<td>1349</td>
<td>311</td>
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</tr>
<tr>
<td>4</td>
<td>16A for 20 1/2</td>
<td>1.920</td>
<td>1306</td>
<td>303</td>
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</tr>
<tr>
<td>5</td>
<td>16A for 20 3/4</td>
<td>1.920</td>
<td>1232</td>
<td>284</td>
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<tr>
<td>6</td>
<td>16A for 18 1/4</td>
<td>1.920</td>
<td>1527</td>
<td>354 Low limit is changed to 1.400V</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>16A for 21 3/4</td>
<td>1.920</td>
<td>1214</td>
<td>280 1.495V stop discharging manually</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>16A for 18</td>
<td>1.920</td>
<td>1390</td>
<td>322</td>
<td></td>
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<tr>
<td>9</td>
<td>16A for 21 1/2</td>
<td>1.920</td>
<td>1367</td>
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</tr>
<tr>
<td>10</td>
<td>16A for 21 1/4</td>
<td>1.920</td>
<td>1357</td>
<td>313</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>16A for 21</td>
<td>1.920</td>
<td>1332</td>
<td>308</td>
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<td>12</td>
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TABLE VII
NICKEL-ZINC 300Ahr CELL NO. 2
Pulse Discharge

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TABLE VIII

TEST RESULTS OF CELL #3

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<td>1.56</td>
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(All)
### TABLE IX

**TEST RESULTS OF CELL #4**

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**Note:** The figures in parentheses indicate the values at 30 and 90 Amps.
TABLE X

TEST RESULTS OF CELL #5

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<td>1.62</td>
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<tr>
<td>Volts (90 Amps)</td>
<td>1.60</td>
<td>1.59</td>
<td>1.56</td>
<td>1.52</td>
<td>1.50</td>
<td>1.61</td>
<td>1.54</td>
<td>1.50</td>
</tr>
<tr>
<td>(30 Amps)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE XI

TEST RESULTS OF CELL #6

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>30</th>
<th>45</th>
<th>65</th>
<th>80</th>
<th>135</th>
<th>180</th>
<th>340</th>
<th>370</th>
<th>470</th>
<th>(AH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volts (135 Amp)</td>
<td>1.52</td>
<td>1.52</td>
<td>1.51</td>
<td>1.50</td>
<td></td>
<td></td>
<td>1.65</td>
<td>1.64</td>
<td>1.60</td>
<td>1.58</td>
</tr>
<tr>
<td>(30 Amp)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
<th>180</th>
<th>200</th>
<th>230</th>
<th>260</th>
<th>(AH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volts (90 Amps)</td>
<td>1.59</td>
<td>1.58</td>
<td>1.57</td>
<td>1.56</td>
<td>1.54</td>
<td>1.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(30 Amps)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.58</td>
<td>1.5</td>
<td>(360)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE XII

**NICKEL-ZINC 300 Ahr CELL NO. 3**

<table>
<thead>
<tr>
<th>Cycle No.</th>
<th>Charge</th>
<th>ECV</th>
<th>Pulse</th>
<th>Capacity Ahr</th>
<th>End of Discharge Voltage 1.4V</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16A for 19 hrs.</td>
<td>1.935</td>
<td>1090</td>
<td>252</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>16A for 20 1/2</td>
<td>2.02</td>
<td>962</td>
<td>222</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16A for 18 hrs.</td>
<td>2.00</td>
<td>812</td>
<td>187</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>16A for 15 1/2</td>
<td>2.00</td>
<td>755</td>
<td>175</td>
<td>Valve Closed</td>
</tr>
<tr>
<td>5</td>
<td>16A for 16 hrs.</td>
<td>1.95</td>
<td>912</td>
<td>211</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>16A for 16 hrs.</td>
<td>1.90</td>
<td></td>
<td></td>
<td>·shorted· OCV 1.800V 3 days standing to 1.73 volts</td>
</tr>
<tr>
<td>7</td>
<td>16A for 16 hrs.</td>
<td>1.88</td>
<td>909</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>16A for 16 hrs.</td>
<td>1.90</td>
<td>971</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>16A for 14 hrs.</td>
<td>2.0</td>
<td>109</td>
<td>25</td>
<td>Check shorting</td>
</tr>
</tbody>
</table>
When current was applied, the cell voltage dropped to 1.40 volts. Zinc penetration could be seen in many areas over the separator face, but was most prominent along the bottom portion of the separator. Zinc was also seen growing through the epoxy sealed separator frames along the edges. Considerable zinc erosion was noted along the top portions of the negative plate and shape change was estimated at about 25% which is high considering the short cycle life.

Cycle testing was terminated on Cell #4 after the capacity decayed below 150Ahr as shown in Table XIII. Dissection of this cell also showed zinc shape change and zinc penetration through the separator.

Cells #5 & 6 with the asbestos on the positive electrode exhibited better performance and were cycled 39 times. A gradual capacity decay was observed as shown in Tables XIV and XV.

**TASK IV - Fabrication of 7, 300Ahr Cells for Delivery to NASA**

Seven cells were fabricated for delivery to NASA-LEWIS in polysulfone fabricated cases with asbestos absorbers on the positives. Additional epoxy was placed along the edges of the separator frame to prevent zinc growth along the seal area. The cells were filled with 1550 cc of 31% KOH.
TABLE XIII

NICKEL-ZINC 300Ahr CELL NO. 4

<table>
<thead>
<tr>
<th>Cycle No.</th>
<th>Charge</th>
<th>ECV</th>
<th>No. Pulse</th>
<th>Capacity Ahr</th>
<th>End of Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16A for 19 hrs.</td>
<td>1.920</td>
<td>1033</td>
<td>238</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>16A for 18 1/2</td>
<td>2.01</td>
<td>1131</td>
<td>261</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16A for 18 hrs.</td>
<td>2.00</td>
<td>1013</td>
<td>233</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>16A for 15 1/2</td>
<td>2.00</td>
<td>817</td>
<td>189</td>
<td>Valve closed</td>
</tr>
<tr>
<td>5</td>
<td>16A for 16 hrs.</td>
<td>2.00</td>
<td>1152</td>
<td>266</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>16A for 16 hrs.</td>
<td>2.00</td>
<td>780</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>16A for 16 hrs.</td>
<td>2.00</td>
<td>1187</td>
<td>274</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>16A for 16 hrs.</td>
<td>2.01</td>
<td>971</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>16A for 14 hrs.</td>
<td>2.01</td>
<td>769</td>
<td>178</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>16A for 14 1/2</td>
<td>2.00</td>
<td>755</td>
<td>174</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>16A for 15 2/3</td>
<td>2.00</td>
<td>688</td>
<td>159</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>16A for 10 hrs.</td>
<td>2.00</td>
<td>641</td>
<td>148</td>
<td></td>
</tr>
</tbody>
</table>

End of Discharge Voltage 1.4V
### TABLE XIV

**NICKEL-ZINC 300Ahr CELL NO. 5**

<table>
<thead>
<tr>
<th>Cycle No.</th>
<th>Charge</th>
<th>ECV</th>
<th>No. Pulse</th>
<th>Capacity Ahr</th>
<th>End of Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16A for 19 hrs.</td>
<td>1.93</td>
<td>1090</td>
<td>252</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>16A for 24 hrs.</td>
<td>1.96</td>
<td>1518</td>
<td>351</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16A for 20 hrs.</td>
<td>1.92</td>
<td>1413</td>
<td>326</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>16A for 19 hrs.</td>
<td>1.90</td>
<td>1324</td>
<td>306</td>
<td>Valve Closed</td>
</tr>
<tr>
<td>5</td>
<td>16A for 19 hrs.</td>
<td>1.92</td>
<td>1339</td>
<td>310</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>16A for 19 hrs.</td>
<td>1.95</td>
<td>1222</td>
<td>282</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>16A for 16 hrs.</td>
<td>1.89</td>
<td>1200</td>
<td>277</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>16A for 16 hrs.</td>
<td>1.90</td>
<td>1105</td>
<td>255</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>16A for 19 hrs.</td>
<td>1.94</td>
<td>1286</td>
<td>297</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>16A for 17 1/2</td>
<td>1.98</td>
<td>1105</td>
<td>255</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>16A for 15 1/4</td>
<td>2.00</td>
<td>1200</td>
<td>277</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>16A for 11 hrs.</td>
<td>1.90</td>
<td>743</td>
<td>172</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>16A for 17 hrs.</td>
<td>2.00</td>
<td>1131</td>
<td>261</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>16A for 16 hrs.</td>
<td>2.00</td>
<td>1129</td>
<td>261</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>16A for 16 hrs.</td>
<td>2.00</td>
<td>1157</td>
<td>267</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>16A for 18 3/4</td>
<td>2.00</td>
<td>1218</td>
<td>281</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>16A for 17 1/4</td>
<td>2.00</td>
<td>1156</td>
<td>267</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>16A for 16 3/4</td>
<td>2.00</td>
<td>1108</td>
<td>255</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>16A for 15 1/2</td>
<td>2.00</td>
<td>1088</td>
<td>253</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>16A for 15 hrs.</td>
<td>2.00</td>
<td>991</td>
<td>229</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>16A for 14 hrs.</td>
<td>2.00</td>
<td>1019</td>
<td>235</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>16A for 14 3/4</td>
<td>2.00</td>
<td>1015</td>
<td>234</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>10A for 18 hrs.</td>
<td>1.95</td>
<td>831</td>
<td>192</td>
<td>Accident at Power Supp.</td>
</tr>
<tr>
<td>24</td>
<td>16A for 16 hrs.</td>
<td>2.00</td>
<td>1008</td>
<td>233</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>16A for 15 hrs.</td>
<td>2.00</td>
<td>968</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>16A for 13 1/2</td>
<td>2.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Page No. 25**
<table>
<thead>
<tr>
<th>Cycle No.</th>
<th>Charge</th>
<th>ECV</th>
<th>Pulse</th>
<th>Capacity Ahr</th>
<th>End of Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>16A for 15 1/2</td>
<td>2.01</td>
<td>896</td>
<td>229.6</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>16A for 15 1/2</td>
<td>2.10</td>
<td>816</td>
<td>188.5</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>16A for 11</td>
<td>2.00</td>
<td>696 30A</td>
<td>232.8</td>
<td>160.8Ah + 232.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>666 130A</td>
<td></td>
<td>72 Ah + 232.8</td>
</tr>
<tr>
<td>31</td>
<td>16A for 11 hrs.</td>
<td>2.00</td>
<td>666</td>
<td>153.8</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>16A for 10 1/2</td>
<td>2.10</td>
<td>530</td>
<td>122.4</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>16A for 10 1/4</td>
<td>2.10</td>
<td>516</td>
<td>119.2</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>16A for 8 hrs.</td>
<td>2.10</td>
<td>631</td>
<td>145.76</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>16A for 9 1/2</td>
<td>2.10</td>
<td>522</td>
<td>120.58</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>16A for 8 hrs.</td>
<td>2.10</td>
<td>492</td>
<td>113.7</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>16A for 8 1/4</td>
<td>2.10</td>
<td>448</td>
<td>103.48</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>16A for 16 hrs.</td>
<td>2.10</td>
<td>508</td>
<td>117.3</td>
<td>shorted voltage didn't get 2.00V, on charge</td>
</tr>
</tbody>
</table>
**TABLE XV**

**NICKEL-ZINC 300Ahr CELL NO. 6**

<table>
<thead>
<tr>
<th>Cycle No.</th>
<th>Charge</th>
<th>DCV</th>
<th>Pulse</th>
<th>Capacity Ahr</th>
<th>End of Discharge Voltage 1.4V</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16A for 19 hrs.</td>
<td>1.91</td>
<td>1271</td>
<td>294</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>16A for 24 hrs.</td>
<td>1.92</td>
<td>1581</td>
<td>351</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16A for 20 hrs.</td>
<td>1.92</td>
<td>1413</td>
<td>326</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>16A for 19 hrs.</td>
<td>1.89</td>
<td>1324</td>
<td>306</td>
<td>Valve closed</td>
</tr>
<tr>
<td>5</td>
<td>16A for 19 hrs.</td>
<td>1.90</td>
<td>1339</td>
<td>310</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>16A for 19 hrs.</td>
<td>1.91</td>
<td>1222</td>
<td>282</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>16A for 16 hrs.</td>
<td>1.89</td>
<td>1200</td>
<td>277</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>16A for 16 hrs.</td>
<td>1.89</td>
<td>1105</td>
<td>255</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>16A for 19 hrs.</td>
<td>1.94</td>
<td>1286</td>
<td>297</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>16A for 17 1/2</td>
<td>1.93</td>
<td>1105</td>
<td>255</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>16A for 15 2/3</td>
<td>1.94</td>
<td>1200</td>
<td>277</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>16A for 11 hrs.</td>
<td>1.90</td>
<td>743</td>
<td>172</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>16A for 17 hrs.</td>
<td>1.95</td>
<td>1131</td>
<td>261</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>16A for 16 hrs.</td>
<td>1.95</td>
<td>1109</td>
<td>256</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>16A for 20 hrs.</td>
<td>2.00</td>
<td>1341</td>
<td>309</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>16A for 18 3/4</td>
<td>1.98</td>
<td>1250</td>
<td>289</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>16A for 17 1/4</td>
<td>1.97</td>
<td>1156</td>
<td>267</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>16A for 17 3/4</td>
<td>1.98</td>
<td>1105</td>
<td>255</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>16A for 15 1/2</td>
<td>1.96</td>
<td>1088</td>
<td>251</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>16A for 15 hrs.</td>
<td>1.96</td>
<td>991</td>
<td>229</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>16A for 16 hrs.</td>
<td>2.00</td>
<td>1019</td>
<td>235</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>16A for 15 hrs.</td>
<td>2.00</td>
<td>1180</td>
<td>273</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>10A for 18 hrs.</td>
<td>1.95</td>
<td>831</td>
<td>192</td>
<td>Accident at Power Supp.</td>
</tr>
<tr>
<td>24</td>
<td>16A for 16 hrs.</td>
<td>2.00</td>
<td>1008</td>
<td>233</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>16A for 15 hrs.</td>
<td>2.00</td>
<td>968</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>16A for 13 1/2</td>
<td>2.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycle No.</td>
<td>Charge</td>
<td>ECV</td>
<td>Pulse</td>
<td>Capacity Ahr</td>
<td>End of discharge Voltage 1.4V</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------</td>
<td>-----</td>
<td>-------</td>
<td>--------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>28</td>
<td>16A for 15 1/2</td>
<td>2.01</td>
<td>896</td>
<td>229.6</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>16A for 15 1/2</td>
<td>2.10</td>
<td>816</td>
<td>188.5</td>
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<tr>
<td>30</td>
<td>16A for 11 hrs.</td>
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<td>696</td>
<td>160.8</td>
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<td>16A for 13 hrs.</td>
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<tr>
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<td>117.3</td>
<td>Shorted, voltage didn't get to 2.0V on charge</td>
</tr>
<tr>
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<td>16A for 16 hrs.</td>
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</tbody>
</table>
TASK II B - 2nd Generation Test Cells

Based on the dissection analysis of cells number 1 to 6, it was decided to modify the design somewhat from the 7 cells delivered to NASA. To evaluate these charges, 4 additional cells were assembled and tested prior to the completion of the Final 135 cells.

The new design featured the following modifications:

1. The use of the molded cell case and cover with a 12 negative, 13 positive electrode configuration.
2. Two layers of 6 - 7 mil thick Pellon 2533 polypropylene on the positive electrodes in place of the untreated asbestos. This material was heat sealed along 2 vertical edges to form open top bags.
3. The frame thickness on the positive electrodes were decreased by .02" to compensate for thickness build-up due to epoxy on the negative plate frames.

The four cells were filled with 1450 cc of electrolyte subjected to four characterization cycles and then put on life test on the pulsed discharge. The charge and discharge results are presented in Table XVI. The four cells were run in series on discharge and the discharge was stopped when one cell reached 1.4V.

The cells were cycled on the normal pulse discharge regime for a total of 34 cycles. The results of this testing is shown in Table XVII. Cells were recharged and given one discharge at 90 amps at cycle 18 and 35 as shown in Table XVIII and IXX. Discussions with NASA Technical Representatives revealed that there may have been a problem with the pellon polypropylene...
<table>
<thead>
<tr>
<th>Cell Type: Contract No.</th>
<th>Initial Cycle Results of Cells 8-11</th>
<th>Charge Date: Discharge Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>300Ah Ni-Zn</td>
<td>3/23</td>
<td>3/24</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Cycle No.</th>
<th>Formation</th>
<th>Charge Current</th>
<th>V-Reading Interval</th>
<th>Charge Time</th>
<th>Discharge Time</th>
<th>Discharge Current</th>
</tr>
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<tbody>
<tr>
<td>1</td>
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<td>2.56</td>
<td>1.487</td>
<td>1.528</td>
<td>1.545</td>
</tr>
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<td></td>
<td>1.576</td>
<td>2.39</td>
<td>1.497</td>
<td>1.539</td>
<td>1.553</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.658</td>
<td>2.25</td>
<td>1.497</td>
<td>1.540</td>
<td>1.551</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.694</td>
<td>2.16</td>
<td>1.497</td>
<td>1.540</td>
<td>1.551</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.712</td>
<td>2.10</td>
<td>1.497</td>
<td>1.540</td>
<td>1.551</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.731</td>
<td>2.25</td>
<td>1.497</td>
<td>1.540</td>
<td>1.551</td>
</tr>
</tbody>
</table>

|           |           | 1.576           | 2.39              | 1.497       | 1.539          | 1.553             |
|           |           | 1.658           | 2.25              | 1.497       | 1.539          | 1.553             |
|           |           | 1.712           | 2.10              | 1.497       | 1.539          | 1.553             |
|           |           | 1.731           | 2.25              | 1.497       | 1.539          | 1.553             |

|           |           | 1.576           | 2.39              | 1.497       | 1.539          | 1.553             |
|           |           | 1.658           | 2.25              | 1.497       | 1.539          | 1.553             |
|           |           | 1.712           | 2.10              | 1.497       | 1.539          | 1.553             |
|           |           | 1.731           | 2.25              | 1.497       | 1.539          | 1.553             |

|           |           | 1.576           | 2.39              | 1.497       | 1.539          | 1.553             |
|           |           | 1.658           | 2.25              | 1.497       | 1.539          | 1.553             |
|           |           | 1.712           | 2.10              | 1.497       | 1.539          | 1.553             |
|           |           | 1.731           | 2.25              | 1.497       | 1.539          | 1.553             |
### TABLE XVI
(continued)

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<th>Contract No.</th>
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<td>Cell Type:</td>
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<td>Discharge Date:</td>
<td>3/30 3/31/76</td>
</tr>
<tr>
<td>Charge Date:</td>
<td>3/29 3/30</td>
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<tr>
<td>Charge Current:</td>
<td>16A</td>
</tr>
<tr>
<td>Discharge Current:</td>
<td>360A ~ 1.4V</td>
</tr>
<tr>
<td>V-Reading Interval:</td>
<td>30A ~ 1.5V</td>
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<td>Cut Off Voltage:</td>
<td>60 min.</td>
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<th>10</th>
<th>11</th>
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<tbody>
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<td>24 hrs.</td>
<td>24 hrs.</td>
</tr>
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**Time**

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<tr>
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<td>15:26</td>
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3/31 |

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<th>326</th>
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<td>326</td>
<td>326</td>
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<tr>
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<td>326</td>
<td>326</td>
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<td>326</td>
</tr>
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<td>OCV (v)</td>
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**Time**

Start at 8:40

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8:51

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13:51

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18:21

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**Discharge Time**

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<th>327.5</th>
<th>327.5</th>
<th>327.5</th>
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<tbody>
<tr>
<td>Va (v)</td>
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<tr>
<td>Cell Type</td>
<td>300Ah Ni-Zn</td>
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<tr>
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<td>-------------</td>
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</tr>
<tr>
<td>Contract No.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Name of Test</td>
<td>V + Cap. determ.</td>
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<td>Cycle No.</td>
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<table>
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<tr>
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<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge Time</td>
<td>24 hrs.</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
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<td>OCV (v)</td>
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<td>1.872</td>
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<td>1.877</td>
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<td>Discharge Date</td>
<td>4/6/76</td>
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<td></td>
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<td>Charge Date</td>
<td>4/5 ~ 4/6/76</td>
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<td></td>
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</tr>
<tr>
<td>Charge Current</td>
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<tr>
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<td>V-Rounding Interval</td>
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<td>Cutt Off Voltage</td>
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</tr>
<tr>
<td>Discharge Time</td>
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<td>350</td>
<td>350</td>
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<tr>
<td>Va (v)</td>
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</table>
TABLE XVII

Ni-Zn 300Ah CELL NO. 8-11

<table>
<thead>
<tr>
<th>Cycle No.</th>
<th>Charge</th>
<th>ECV</th>
<th>No. Pulse</th>
<th>Capacity Ah</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16A, 24 hrs.</td>
<td>7.824</td>
<td>1486</td>
<td>343.3</td>
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<tr>
<td>2</td>
<td>16A, 24 hrs.</td>
<td>7.795</td>
<td>1460</td>
<td>337.2</td>
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<tr>
<td>3</td>
<td>16A, 24 hrs.</td>
<td>7.822</td>
<td>1415</td>
<td>326.8</td>
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<tr>
<td>4</td>
<td>16A, 24 hrs.</td>
<td>7.824</td>
<td>1400</td>
<td>323.4</td>
</tr>
<tr>
<td>5</td>
<td>16A, 24 hrs.</td>
<td>7.85V</td>
<td>1394</td>
<td>322.0</td>
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<tr>
<td>6</td>
<td>16A, 24 hrs.</td>
<td>7.82V</td>
<td>1381</td>
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<tr>
<td>7</td>
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<td>7.911</td>
<td>1371</td>
<td>316.70</td>
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<td>16A, 21.25</td>
<td>8.02</td>
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<td>19 hrs.</td>
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<td>273.9</td>
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<td>1105</td>
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<td>Cycle No.</td>
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<td>No. Pulse</td>
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<td>10</td>
<td>11</td>
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**Discharge Time**

- Co (Ah): 225
- Va (v): 171.9
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<table>
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<tr>
<td>Co (Ah)</td>
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Notes: V-Reading Interval: 15 min. Cutt Off Voltage: 1.30V
material utilized in these cells. Apparently the non-woven polypropylene material contained some wetting agents that could be dilatorius to cell performance. On the basis of this, it was decided to hot water wash the pellon prior to incorporation in the final cells.

Leak testing of the molded 300Ahr cell cases revealed approximately a 50% leakage rate at the ultrasonic welded plugs in the bottom of the cell cases. It was therefore, decided to sandblast and place epoxy sealing cement over the plugs in all of the cell containers.

**TASK VI - 135 Deliverable Cells**

The final cells were constructed in two groups. The first 65 cells contained NASA IO separator material. The second group of 75 cells was constructed with a new more flexible asbestos coated separator material also supplied by NASA designated K19. All the cells were filled with 1450 cc of 31% KOH and shipped to NASA LEWIS.
Operation Title: PROCEDURE FOR ANALYSIS OF MERCCURIC OXIDE CONTENT OF NEGATIVE ELECTRODE POWDER MIXES

1. EQUIPMENT REQUIRED

1.1 100 ml pyrex beaker.
1.2 Triple beam balance, Sargent S-3435, or equal.
1.3 Drying oven, electric, thermostatically controlled, 105° C.
1.4 Plain Scheibler Desiccators with active desiccant.
1.5 Stainless steel spatula.
1.6 250 cc narrow neck Erlenmeyer flask, pyrex.
1.7 Burette clamp and stand.
1.8 25 ml capacity Geissler burette.

2. MATERIALS REQUIRED

2.1 0.1 normal standard potassium thiocyanate solution (KCN).S.
2.2 Ferric indicator solution (saturated solution of Iron (ic) ammonium sulfate.
2.3 7.5 molar solution of nitric acid (HNO₃) (1:1).

3. ANALYTICAL PROCEDURE

3.1 Using a triple beam balance weigh out 10 grams ± 1 gram of the negative electrode mix to be analyzed for mercuric oxide content into a 100 ml pyrex beaker.

3.2 Transfer the sample in the beaker to a thermostatically controlled electric oven set at 105° C. Allow the sample to remain in this oven for at least 4 hours.

3.3 Remove the sample from the oven and transfer rapidly to a desiccator with active desiccant. Allow to cool off in the desiccator.

3.4 Weigh out 5.00 ± 0.01 grams of the dried sample using a triple beam balance and transfer all of the sample to a 250 cc Erlenmeyer flask.
Operation Title: PROCEDURES FOR ANALYSIS OF MERCURIC OXIDE CONTENT OF NEGATIVE ELECTRODE LÖDNER MIXES

3.5 Add 50 cc of 7.5 mol/l nitric acid (1:1) to the Erlenmeyer flask and gently swirl the liquid until the sample has dissolved. It is important that all of the sample be completely dissolved.

3.6 Add distilled water to the solution in the Erlenmeyer flask so that the entire amount of liquid in the flask is approximately 100 cc.

3.7 Add 1.5 cc of Ferric indicator solution to the solution in the flask.

3.8 Cool the contents of the flask to 12° C. This may be done by inverting the flask in water at 50° F, that may be obtained from refrigerated drinking fountains.

3.9 Keeping the solution temperature lower than 15° C, titrate with 0.1 N potassium thiocyanate standard solution, proceeding very slowly near the endpoint, until a distinct reddish brown color persists on vigorous shaking. Use a 25 cc Geissler burette for this titration.

3.10 Record the number of cc of 0.1 N KCNS required to completely react with the mercury in the sample.

4. CALCULATIONS

4.1 One cubic centimeter of 0.1 normal KCNS solution is equivalent to 0.010830 gram of mercuric oxide (HgO).

4.2 a) cc of 0.1 N KCNS x 0.010830 = grams HgO in sample.

b) grams HgO in sample x 100

5.00 grams

5. REFERENCES

5.1 "Treatise on Analytical Chemistry" by Kolthoff and Elving, Part II, Volume 3, pp 367-308.
OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: PROCEDURE FOR PREPARATION OF NEGATIVE MIX

1. OBJECTIVE OF OPERATION

The purpose of this operation is to blend together desired quantities of zinc oxide and mercuric oxide powders to form a homogeneous material for use in the fabrication of zinc electrodes.

2. MATERIALS REQUIRED

2.1 Zinc oxide - Horsehead® U.S.P. - 12 grade; New Jersey Zinc Company; in 50 lb. cartons.

2.2 Mercuric oxide - Analytical Reagent grade; Mallinckrodt; in 1 lb. bottles.

3. EQUIPMENT REQUIRED

3.1 Balance, 20 kg. capacity, Ohaus Model 1119 or equivalent.

3.2 Balance, triple beam, Sargent S-3435 or equivalent.

3.3 Mixer, U.S. Stoneware "Universal" lab mixer, with rotor/hedral mixing units.

3.4 Drying oven, Despatch, Model LDB-1-67 or equivalent.

3.5 Tray, stainless steel, 12" x 20" x 2-1/2".

3.6 Spatula, stainless steel.

3.7 Scoop, plastic.

3.8 Beaker, plastic, 100 ml. capacity.

3.9 Jar; one gallon capacity; brown glass.

4. DETAILED OPERATIONAL PROCEDURES

4.1 Place a stainless steel tray on the 20 kg. balance and tare it.

4.2 Using a plastic scoop, transfer 3920 g. of zinc oxide from its container to the tray.

4.3 Place a plastic beaker on the triple beam balance and tare it.
Operation Title: PROCEDURE FOR PREPARATION OF NEGATIVE MIX

4.4 Using a stainless steel spatula, transfer 80 g. of mercuric oxide from its container to the beaker.

4.5 Add both the zinc oxide and the mercuric oxide to one side of the rotatory blender, alternating small amounts of each so that the mercuric oxide is somewhat dispersed throughout the zinc oxide.

4.6 Put the top on the blender and turn the blender on. Let it run for 15 minutes, then turn it off.

4.7 Carefully remove the blender cover, and with a stainless steel spatula gently scrape any powder which had adhered to the blender walls off the walls. Replace the blender cover.

4.8 Turn the blender on and let it run for 45 minutes. Turn it off.

4.9 Remove the blender cover and transfer the contents of the blender to a stainless steel tray.

4.10 Place the tray containing the mixture on a shelf in the Despatch oven and allow it to dry overnight at approximately 70°C. Transfer the material to one gallon brown glass jars. Place caps on the jars.

5. DISPOSITION OF PRODUCT

The negative mix is now ready for analysis according to BFDO 1001. If mercury content is correct the mix is ready for use in electrode fabrication.

6. SAFETY CONSIDERATIONS

Mercuric oxide is an accumulative poison and should not be ingested. The operator must keep this material off his skin, and must wash his hands and arms thoroughly after exposure to mercuric oxide.
OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: MOLD DRESSING OF NEGATIVE ELECTRODES

1. OBJECTIVE

To make a negative electrode of a given size, weight and thickness by pressing mix around a collector grid.

2. MATERIAL REQUIREMENTS

2.1 Negative mix from BFDO #1013.
2.2 Welded negative electrode grid from BFDO #1012.
2.3 Potassium titanate absorbers from BFDO #1011.
2.4 P.V.A. solution from BFDO #1017.

3. EQUIPMENT REQUIREMENTS

3.1 Three-piece mold.
3.2 Hydraulic press, Wabash Model #100-15 SWAC or equivalent.
3.3 Tamping tool.
3.4 Shim stock.
3.5 Burgess Sprayer, Model VS-855.
3.6 Spray hood.
3.7 Kimwipes.
3.8 Acetone.
3.9 Vernier calipers, Helios.
3.10 Throw-away filter mask, 3M brand.
3.11 Rubber or plastic gloves.
3.12 Kimtowels.

4. OPERATIONAL DETAILS

4.1 Clean base plate with Kimwipe and place on work table.

A-5
Operation Title: MOLD FILLING OF NEGATIVE ELECTRODES

4.2 Wipe surface of base plate that will come in contact with mix with piece of Kimwipe dipped in acetone.

4.3 Clean mold with Kimwipe and position on base plate, matching base plate pins with pin holes in mold.

4.4 Tab slot in mold should be positioned toward operator.

4.5 Place one piece of potassium titanate on Kimtowel against backboard of spray hood.

4.6 Spray P.V.A. solution from BFDO #1017 on one surface of potassium titanate paper.

4.7 Remove piece of potassium titanate paper from spray hood and position in bottom of mold, wet side up.

4.8 Pour 1/2 of prepared cup of negative mix into mold on top of potassium titanate paper.

4.9 Spread mix evenly with tamping tool. The care taken in the even spreading of the mix is directly related to the final thickness and quality of the finished electrode.

4.10 Prepare collector grid assembly by handforming the grid so that it will lie flat.

4.11 Place collector grid assembly carefully on mix in mold, threading tab through tab slot. It is important that grid lie flat on mix.

4.12 Pour remainder of mix into mold on top of collector grid assembly. Material weighed per BFDO #1013.

4.13 Spread mix evenly over grid assembly with tamping tool. The care taken in the even spreading of the mix is directly related to the final thickness and quality of the finished electrode.

4.14 Repeat 4.5 - 4.6.

4.15 Remove second piece of potassium titanate paper from spray hood and place on top of mix in mold, wet side down.

4.16 Clean punch with Kimwipe. Wipe surface of punch that will come in contact with mix with Kimwipe dipped in acetone.

4.17 Insert punch very slowly into mold, to prevent blowout of mix.
Operation Title: MOLD PRESSING OF NEGATIVE ELECTRODES

4.18 Place mold assembly in center of bottom platen of press.
4.19 Place 0.339 shims on each side of mold.
4.20 To turn on press throw main switch on back right side of press. Push power on button at front right side of press.
4.21 Set pressure gauge to 40 tons.
4.22 Set timer to 35 seconds.
4.23 Press two green buttons marked "close" simultaneously to close press. Do not release the green buttons until the press stops. The pre-selected pressure will stop the press automatically and then the green buttons must be released. After the pre-set time interval the press will open.
4.24 When press opens, let the lower platen travel down a workable distance then stop by pressing green buttons once simultaneously.
4.25 Remove shims from mold and place on platens.
4.26 Remove mold assembly and place on work table in an inverted position.
4.27 Remove base plate by carefully lifting off of mold and electrode.
4.28 Place heel and thumb of each hand on either side of mold and press down, being careful not to touch edge of electrode. Hold will drop leaving electrode free on top of punch.
4.29 Pick up electrode by tab and check thickness with Vernier calipers.
4.30 Place electrode flat on area set aside for the drying of the electrode.
4.31 Before the next step the electrode must dry overnight at room temperature.

5. DISPOSITION OF PRODUCT

The electrodes are now ready for the inspection operation per DFDO #1015.
6. **SAFETY CONSIDERATIONS**

6.1 The two palm buttons are designed to prevent any injury to the operator's hand and arms since the press stops if both palm buttons are not pressed simultaneously.

6.2 A filter mask and rubber or plastic gloves should be worn during this operation.
Operational Title:  INSPECTION OF NEGATIVE ELECTRODES

1. OBJECTIVE

The objective of this operation is to insure that negative electrodes are mechanically acceptable and are 2.80" ± 0.015" in width and 3.625" ± 0.015" in length (excluding the tab extension). The measurement of thickness and the weighing of each electrode will be described in BFDO #1015.

2. MATERIAL REQUIREMENTS

Negative electrodes from operation BFDO #1014.

3. EQUIPMENT REQUIREMENTS

Vernier calipers.

4. OPERATIONAL DETAILS

4.1 There will be 100% inspection of electrodes for mechanical acceptability. Every tenth electrode will be checked for width and length.

4.2 Inspection for mechanical acceptance.

4.2.1 Damaged or crushed edges are not acceptable.

4.2.2 There shall be no evidence of separation of the prepared mix from the DISFEX collector grid.

4.2.3 The KT paper absorber shall lie flat on each wide outer surface of the electrode and there shall be evidence of reasonable adherence of the KT paper to the electrode.

4.3 Measure width of every tenth electrode with Vernier calipers. The width should be 2.80 ± 0.015.

4.4 Measure length of every tenth electrode with Vernier calipers. The length should be 3.625 ± 0.015.

5. DISPOSITION OF PRODUCT

The electrodes are now ready for weighing, thickness measurements, and serializing per BFDO #1015.
Operation title: SLEEving AND SERIALIzING OF NEGATIVE ELECTRODES (INClUDING WEIGHIng)

1. OBJECTIVE

1.1 To record and ensure proper weight and thickness of each electrode.
1.2 To apply insulation sleeving to each electrode.
1.3 To give each electrode a traceable serial number.

2. MATERIALS REQUIRED

2.1 Pressed and inspected negative electrodes.
2.2 Heat shrinkable FEP spaghetti FEP 1ST. #3 (precut to 1/4" lengths).
2.3 White coding tapes with consecutive numbers starting with 001, EZ Code.
2.4 Traceability and inspection form.

3. EQUIPMENT REQUIREMENTS

3.1 Triple beam balance, Sargent S-3435 or equivalent.
3.2 Vernier Calipers, 6" helios.
3.3 Black ink pen.

4. OPERATIONAL DETAILS

4.1 Set balance to zero.
4.2 Pick up electrode by tab or edge and place on balance tray.
4.3 Adjust balance weights until pointer swings an equal distance on either side of zero mark.
4.4 Record weight on traceability and inspection form.
4.5 The electrode weight must fall in the range of 37.8 to 39.0 grams.
4.6 Remove electrode from balance and slide precut spaghetti down over tab until it contacts negative plate.
4.7 Attach numbered tape to end of tab.
OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: SLEEVING AND SERIALIZING OF NEGATIVE ELECTRODES
(INCLUDING WASHING)

4.8 Record number in serial number column on same line as recorded weight of electrode.

4.9 Check thickness of electrode over its entire area with a vernier caliper and record the average thickness on the traceability and inspection form on same line as serial number.

4.10 The electrode thickness must fall within the range of 86 to 90 mils.

4.11 All traceability data on form must correspond with actual data of electrode.

4.12 Electrodes are now stored in plastic boxes.

5. DISPOSITION OF PRODUCT

Electrodes are now ready for use in unit sub-assemblies. Refer to section 3.1.
OPERATIONAL WORK INSTRUCTION SHEET

Oper. title: PREPARATION OF PVA SOLUTION

1. OBJECTS OF ELATION

The purpose of this operation is to prepare a 1% solution of polyvinyl alcohol in water for use in the fabrication of zinc oxide electrodes.

2. MATERIALS

2.1 Polyvinyl alcohol - LuPont "Elvanol" Grade 51-05; in 50 lb. bags.
2.2 De-ionized water.

3. EQUIPMENT REQUIRED

3.1 Triple beam balance, Sargent 3-3475 or equivalent.
3.2 Graduated cylinder, 500 ml. capacity.
3.3 Beaker, 800 ml. capacity.
3.4 Beaker, 100 ml. capacity.
3.5 Stainless steel spatula.
3.6 Magnetic stirrer, Sargent Model H or equivalent.
3.7 Stirring bar, teflon coated, 1-1/2 in. long.

4. DETAILLED OPERATIONAL PROCEDURE

4.1 Place a 100 ml. beaker on the triple beam balance and tare it.
4.2 Weigh out 5.0 grams of Elvanol, using a stainless steel spatula to transfer the material from its bag to the beaker.
4.3 Pour 495 ml. of de-ionized water into a 500 ml. graduated cylinder.
4.4 Empty the graduated cylinder into an 800 ml. beaker.
4.5 Place the beaker containing the water on a magnetic stirrer and drop a teflon coated stirring bar into the water.
4.6 Turn the stirrer on and adjust it to a medium stirring speed.
4.7 Slowly pour the Elvanol from its beaker into the water.
OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: PREPARATION OF PVA SOLUTION

4.8 Allow the mixture to stir until all of the Elvanol has been dissolved.

4.9 Turn the stirrer off.

5. DISPOSAL OF REACTANTS

The product may be stored in glass jars with plastic lined lids, or it may be poured directly into the reservoir of the spray gun, where it will be ready for use in electrode manufacture.

6. SAFETY CONSIDERATIONS

Normal laboratory safety practices should be observed during this operation.
Calvin College
Science Building
Attn: T. L. Dirks
7175 Burton St., SE
Grand Rapids, MI 49506

Catalyst Research Corp.
Attn: F. Tepper
3308 Blair Hill Lane
Baltimore, MD 21209

Chrysler Corp.
Space Division
Attn: C. E. Thomas
Dept. 2730, P. O. Box 29200
New Orleans, LA 70189

Communications Satellite Corp.
Comsat Laboratories
Attn: R. Strauss
P. O. Box 111
Clarksburg, MD 20734

Delco Remy Division
General Motors Corp.
Attn: J. A. Keralla
2401 Columbus Ave.
Anderson, IN 46011

Dow Chemical USA
Western Division Research Lab.
Attn: C. Levine
2800 Mitchell Dr.
W masturb, CA 94598

E. I. DuPont de Nemours & Co.
Engineering Materials Lab.
Attn: J. M. Williams
Bldg. 304
Wilmington, DE 19808

Dynatech Corp.
Attn: R. L. Wentworth
17 Tudor St.
Cambridge, MA 02139

Energetics Science, Inc.
Attn: K. Blurton
Elmford, NY 10523

Energy Research Corp.
Attn: N. Klein
15 Parker Ave.
South Orange, NJ 07079

Furukawa Battery Co., Ltd.
Attn: K. Shimizu
No. 246, E-Chome
Hoshikawa-Cho
Hodogaya, Yokohama, Japan

Gates Energy Products, Inc.
Attn: D. McClelland
1050 South Broadway
Denver, CO 80217

General Dynamics
Convair Aerospace Division
Attn: R. P. Mikkelson
Dept. 623-2, P. O. Box 80647
San Diego, CA 92138

General Electric Co.
Attn: P. R. Voyentzie
P. O. Box 114
Gainesville, FL 32601

General Electric Co.
R&D Center
Attn: Whitney Library
P. O. Box 8
Schenectady, NY 12301

General Electric Co.
Space Systems
Attn: K. L. Hansan
Room M-2700, P. O. Box 555
Philadelphia, PA 19101

General Electric Co.
Attn: D. F. Schmidt
116 N. 14th St., NW
Washington, DC 20005

General Motors Research Lab.
Electrochemistry Dept.
Attn: R. G. Gunther
Warren, MI 48090