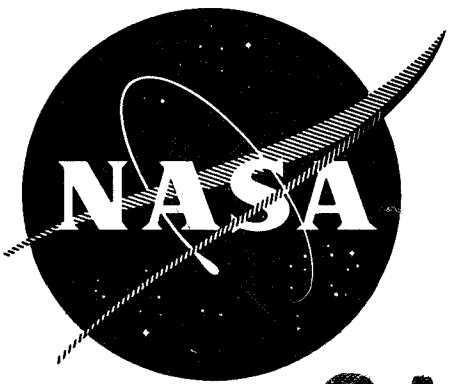




# EVALUATION PROGRAM

# for

# SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
GENERAL ELECTRIC COMPANY

6.0 AMPERE-HOUR NICKEL-CADMIUM CELLS
W/ SIGNAL & RECOMBINATION ELECTRODES

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT W12,397

QUALITY EVALUATION LABORATORY

NAD CRANE, INDIANA

**DEPARTMENT OF THE NAVY**
**NAVAL AMMUNITION DEPOT**
**CRANE, INDIANA 47522**

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29 JUN 1971

From: Commanding Officer, Naval Ammunition Depot, Crane, Indiana
To: National Aeronautics and Space Administration, Goddard Space Flight Center (761.2, Mr. T. J. Hennigan), Greenbelt, Maryland 20771

Subj: Report QE/C 71-187; Acceptance Test of General Electric Company 6.0 Ampere-Hour Nickel-Cadmium Secondary Spacecraft Cells with Signal and Recombination Electrodes

Ref: (a) NASA Purchase Order W12,397

Encl: (1) Report QE/C 71-187

1. In compliance with reference (a), enclosure (1) is forwarded for information and retention.

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# EVALUATION PROGRAM FOR SECONDARY SPACECRAFT CELLS

## ACCEPTANCE TEST OF GENERAL ELECTRIC COMPANY 6.0 AMPERE-HOUR NICKEL-CADMIUM CELLS

QE/C 71-187 1 JUNE 1971

PREPARED BY

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Enclosure (1)

# REPORT BRIEF
# 6.0 AMPERE-HOUR NICKEL-CADMIUM SECONDARY SPACECRAFT CELLS WITH SIGNAL AND RECOMBINATION ELECTRODES MANUFACTURED BY GENERAL ELECTRIC COMPANY

Ref: (a) NASA Purchase Order W12,397
(b) NAD Crane Test Procedure 3052-TP 304, Rev A

## I. TEST ASSIGNMENT BRIEF

A. The purpose of this acceptance test is to provide a "base line" reference, prior to life cycling, for new cells. It also provides a screening against cells that are obviously bad due to internal shorts or gross leakage. The reference is provided with regard to physical dimensions, electrolyte leakage, cell capacity, internal shorts, ability to withstand long periods of overcharge, and internal resistance measurements. All cells complete the entire series of tests. Cells are removed from individual segments of the test only if pressure or voltage limits are reached and cell damage would result from further testing during that segment.

B. The 25 cells were purchased from General Electric Company of Gainesville, Florida by the National Aeronautics and Space Administration (NASA). These cells were rated at 6.0 ampere-hours by the manufacturer. In addition to the positive and negative terminals, they have a signal electrode and a recombination electrode. Testing on these cells was funded in accordance with reference (a).

## II. SUMMARY OF RESULTS

A. The overall averages for the three capacity checks were respectively, 7.26, 7.01 and 6.82 ampere-hours.

B. The cells averaged 1.218 volts after 24 hours of open circuit during which they recovered from a dead short. These results indicate that no internal shorts existed.

C. Five of the 25 cells had to be removed from the c/10 overcharge due to high cell voltage. The time-on-charge at this rate varied from 5 to 14 hours (see Table I).

D. Internal resistance was measured across the cell terminals, the signal electrodes, and the recombination electrodes. The average resistances are: cell, 2.85 milliohms; signal electrode, 52.0 milliohms; and recombination electrode, 71.2 milliohms.

**E.** Eleven of the 25 cells showed electrolyte leakage during one or more of the three leak tests. A summary of these tests is found in Table I.

# RESULTS OF ACCEPTANCE TESTS OF 6.0 AMPERE-HOUR NICKEL-CADMIUM SECONDARY SPACECRAFT CELLS WITH SIGNAL AND RECOMBINATION ELECTRODES MANUFACTURED BY GENERAL ELECTRIC COMPANY

## I. INTRODUCTION

A. On 2 December 1970, testing was begun on 25 cells in accordance with reference (b). These tests were completed on 19 January 1971. Table I summarizes the results.

## II. TEST CONDITIONS

A. All acceptance tests were performed at an ambient temperature between 23° C and 27° C at existing relative humidity and atmospheric pressure, and consisted of the following:

1. Physical measurement.

2. Three capacity tests.

3. Cell short test.

4. Overcharge tests at c/20 and c/10.

5. Internal resistance tests of cell, signal electrode and recombination electrode.

6. Three leak tests: initial, after capacity tests, and after overcharge tests.

B. Appendix I gives the details of the test procedure.

## III. CELL IDENTIFICATION AND DESCRIPTION

A. The cells were identified by the manufacturer's catalog number, 42B006AB29. They were placed into packs according to the manufacturer's serial numbers. Table II lists these numbers along with the physical dimensions and cell weights.

B. These cells are rectangular with a stainless steel cell cover and container. Both terminals are insulated from the cell cover by ceramic seals and protrude through the cover as solder type terminals. The signal electrode, which is used for charge control, is welded to a wire that protrudes through a hole in the cell cover. This hole is potted to seal the cell. The recombination electrode is welded to the inside of the container, and its terminal is a stainless steel tab welded to the outside.

IV. RESULTS--The following data was condensed from Table I.

A. Capacity Tests:

1. The capacities of all 25 cells exceeded the manufacturer's rated capacity--ranging from 6.40 to 7.59 ampere-hours. The average capacity for the three respective capacity tests were 7.26, 7.01 and 6.82 ampere-hours.

B. Cell Short Test:

1. All cells indicated they were free of internal shorts by recovering, in excess of 1.150 volts, during a 24-hour open circuit period following a dead short across the terminals. The open circuit voltages ranged from 1.171 to 1.228 volts, averaging 1.218 volts.

C. Overcharge Test:

1. Five cells had to be removed from the c/10 overcharge due to high cell voltage--exceeding 1.500 volts. The time-on-charge at the c/10 rate varied from 5 to 14 hours for these five cells.

D. Internal Resistance:

1. Internal resistance was measured across the cell terminals, across the signal electrode (from signal electrode terminal to negative terminal), and across the recombination electrode (from recombination electrode terminal to negative terminal). All values were consistent for a given set of measurements. The resistances across the cell terminals ranged from 2.67 to 3.21 milliohms, averaging 2.85 milliohms. The resistances across the signal electrodes ranged from 43.0 to 68.0 milliohms, averaging 52.0 milliohms. The resistances across the recombination electrodes ranged from 47.5 to 122.0 milliohms, averaging 71.2 milliohms.

E. Leak Tests:

1. Eleven of the 25 cells showed electrolyte leakage during one or more of the three leak tests. The leakage was more prevalent

around the positive terminal and the signal electrode terminal. Most leakage was slight and discovered following the capacity tests and/or the overcharge tests.

TABLE I

CAPACITY CHECKS

| Serial Number | END OF DISCHARGE Ampere-Hours | Signal Electr Voltage | Recomb Electr Voltage | Vacuum Inches Hg. | Ampere-Hours | Signal Electr Voltage | Recomb Electr Voltage | Vacuum Inches Hg. | Ampere-Hours | Signal Electr Voltage | Recomb Electr Voltage | Vacuum Inches Hg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 002 | 7.30 | -0.014 | -0.022 | 21 | 7.20 | -0.022 | -0.030 | 21 | 7.11 | -0.002 | 0.029 | 22 |
| 003 | 7.30 | -0.039 | -0.026 | 20 | 7.26 | -0.027 | -0.030 | 21 | 6.99 | -0.003 | 0.032 | 22 |
| 004 | 7.14 | -0.041 | -0.007 | 21 | 6.99 | -0.012 | -0.014 | 26 | 6.90 | -0.003 | 0.030 | 25 |
| 005 | 7.25 | -0.043 | -0.031 | 18 | 6.99 | -0.044 | -0.015 | 19 | 6.81 | +0.003 | 0.032 | 20 |
| 006 | 7.25 | -0.056 | -0.036 | 19 | 6.96 | -0.011 | -0.006 | 20 | 6.81 | +0.012 | -0.031 | 21 |
| Pack Avg. | 7.25 | | | | 7.08 | | | | 6.92 | | | |
| 007 | 7.50 | -0.051 | -0.031 | 22 | 7.41 | -0.007 | -0.024 | 22 | 7.20 | +0.005 | -0.020 | 23 |
| 008 | 7.50 | +0.278 | +0.861 | 19 | 7.29 | +0.474 | +0.892 | 4 | 6.99 | -0.012 | -0.024 | 20 |
| 009 | 7.26 | -0.042 | -0.044 | 28 | 6.81 | -0.019 | -0.037 | 28 | 6.69 | -0.015 | -0.037 | 25 |
| 011 | 7.20 | -0.014 | -0.035 | 25 | 6.84 | -0.004 | -0.032 | 27 | 6.81 | +0.003 | -0.030 | 23 |
| 013 | 7.29 | -0.018 | -0.054 | 15 | 6.96 | -0.015 | -0.029 | 15 | 6.90 | -0.014 | -0.031 | 15 |
| Pack Avg. | 7.35 | | | | 7.06 | | | | 6.92 | | | |
| 014 | 7.59 | -0.060 | -0.042 | 29 | 7.26 | +0.003 | -0.013 | 21 | 7.20 | -0.001 | -0.031 | 21 |
| 015 | 7.59 | -0.012 | -0.050 | 9 | 7.26 | -0.007 | -0.017 | 10 | 7.00 | -0.003 | -0.028 | 10 |
| 016 | 7.29 | -0.027 | -0.037 | 27 | 6.99 | -0.022 | -0.023 | 26 | 6.70 | -0.012 | -0.029 | 25 |
| 018 | 7.35 | -0.019 | -0.046 | 21 | 7.11 | -0.018 | -0.037 | 21 | 6.80 | -0.016 | -0.033 | 21 |
| 019 | 7.56 | -0.021 | -0.046 | 23 | 7.14 | -0.018 | -0.026 | 22 | 7.10 | -0.013 | -0.039 | 22 |
| Pack Avg. | 7.48 | | | | 7.15 | | | | 6.96 | | | |
| 020 | 7.14 | -0.014 | -0.057 | 25 | 7.05 | -0.014 | -0.027 | 21 | 6.60 | -0.013 | -0.023 | 21 |
| 021 | 7.29 | -0.046 | -0.040 | 25 | 7.29 | -0.011 | -0.019 | 23 | 6.84 | -0.011 | -0.019 | 23 |
| 022 | 7.26 | -0.020 | -0.044 | 19 | 7.14 | -0.018 | +0.026 | 17 | 6.60 | -0.017 | -0.031 | 19 |
| 023 | 7.11 | -0.020 | -0.048 | 20 | 6.99 | -0.017 | -0.036 | 21 | 6.50 | -0.017 | -0.036 | 22 |
| 025 | 7.14 | -0.019 | -0.049 | 10 | 7.14 | -0.009 | -0.027 | 10 | 6.70 | -0.011 | -0.025 | 10 |
| Pack Avg. | 7.19 | | | | 7.12 | | | | 6.65 | | | |
| 047 | 7.14 | -0.028 | -0.034 | 21 | 6.85 | 0.006 | -0.025 | 22 | 6.90 | 0.013 | -0.026 | 21 |
| 050 | 7.20 | -0.020 | -0.025 | 31 | 6.85 | 0.003 | -0.022 | 30 | 6.85 | 0 007 | -0.025 | 30 |
| 066 | 6.85 | -0.012 | -0.019 | 26 | 6.40 | -0.007 | -0.029 | 24 | 6.45 | 0.000 | -0.030 | 25 |
| 067 | 7.00 | -0.021 | -0.035 | 22 | 6.65 | -0.018 | -0.035 | 21 | 6.65 | -0.015 | -0.032 | 21 |
| 068 | 6.90 | -0.023 | -0.037 | 21 | 6.45 | -0.018 | -0.035 | 20 | 6.45 | -0.009 | -0.034 | 20 |
| Pack Avg. | 7.02 | | | | 6.64 | | | | 6.66 | | | |
| Overall Avg | 7.26 | | | | 7.01 | | | | 6.82 | | | |

TABLE I (Cont.)

| Serial Number | Cell Short Test Volts* | END OF c/20 OVERCHARGE Voltages Cell | Signal Electr | Recomb Electr | Pressure (PSIG)** | END OF c/10 OVERCHARGE Voltages Cell | Signal Electr | Recomb Electr | Pressure (PSIG)** | INTERNAL RESISTANCE TEST (milliohms) Cell | Signal Electr | Recomb Electr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 002 | 1.202 | 1.472 | 0.451 | 0.449 | 8 | 1.484 | 0.518 | 0.605 | 3 | 2.76 | 43.0 | 53.8 |
| 003 | 1.208 | 1.484 | 0.372 | 0.408 | 14 | 1.496 | 0.461 | 0.506 | -1 | 2.83 | 47.8 | 56.5 |
| 004 | 1.208 | 1.482 | 0.398 | 0.452 | 1 | 1.495 | 0.467 | 0.502 | 9 | 2.84 | 50.8 | 60.2 |
| 005 | 1.205 | 1.472 | 0.386 | 0.505 | 10 | 1.471 | 0.397 | 0.574 | -8 | 2.72 | 45.0 | 77.5 |
| 006 | 1.204 | 1.480 | 0.430 | 0.459 | 0 | 1.515c | 0.474 | 0.399 | +47 | 2.71 | 46.0 | 70.0 |
| Pack Avg | 1.205 | | | | | | | | | 2.77 | 46.5 | 63.6 |
| 007 | 1.212 | 1.451 | 0.361 | 0.320 | 4 | 1.504d | 0.520 | 0.462 | 39 | 2.67 | 45.9 | 84.1 |
| 008 | 1.214 | 1.439 | 0.355 | 0.404 | -11 | 1.503d | 0.550 | 0.639 | 11 | 2.74 | 58.0 | 60.1 |
| 009 | 1.229 | 1.428 | 0.251 | 0.389 | -21 | 1.460 | 0.362 | 0.782 | -18 | 2.82 | 45.4 | 77.3 |
| 011 | 1.210 | 1.432 | 0.318 | 0.407 | -20 | 1.461 | 0.385 | 0.779 | 10 | 2.71 | 50.2 | 86.2 |
| 013 | 1.221 | 1.441 | 0.283 | 0.341 | -10 | 1.474 | 0.414 | 0.673 | 1 | 2.68 | 44.1 | 83.9 |
| Pack Avg | 1.217 | | | | | | | | | 2.72 | 48.7 | 71.7 |
| 014 | 1.217 | 1.439 | 0.358 | 0.317 | -12 | 1.47 | 0.531 | 0.571 | 5 | 2.80 | 51.0 | 59.5 |
| 015 | 1.171 | 1.488 | 0.351 | 0.182 | +15 | 1.521a | 0.495 | 0.251 | 51 | 2.89 | 53.9 | 96.3 |
| 016 | 1.202 | 1.436 | 0.243 | 0.393 | -22 | 1.491 | 0.440 | 0.688 | 3 | 2.96 | 48.8 | 75.8 |
| 018 | 1.176 | 1.460 | 0.269 | 0.343 | -16 | 1.526 | 0.406 | 0.415 | 20 | 2.71 | 45.0 | 89.0 |
| 019 | 1.198 | 1.482 | 0.273 | 0.270 | -11 | 1.532b | 0.448 | 0.214 | 52 | 2.69 | 50.0 | 68.3 |
| Pack Avg | 1.193 | | | | | | | | | 2.81 | 49.7 | 77.8 |
| 020 | 1.228 | 1.474 | 0.352 | 0.242 | -12 | 1.502 | 0.003 | 0.222 | 35 | 2.71 | 67.5 | 60.2 |
| 021 | 1.206 | 1.447 | 0.367 | 0.321 | -18 | 1.470 | 0.451 | 0.626 | -2 | 2.83 | 49.9 | 67.0 |
| 022 | 1.233 | 1.448 | 0.342 | 0.261 | -9 | 1.488 | 0.540 | 0.475 | 11 | 2.80 | 48.0 | 69.1 |
| 023 | 1.227 | 1.444 | 0.213 | 0.316 | -19 | 1.473 | 0.408 | 0.597 | 8 | 2.79 | 51.2 | 87.0 |
| 025 | 1.219 | 1.447 | 0.198 | 0.264 | -7 | 1.467 | 0.354 | 0.529 | 0 | 2.77 | 51.9 | 122.0 |
| Pack Avg | 1.223 | | | | | | | | | 2.78 | 54.3 | 81.1 |
| 047 | 1.218 | 1.451 | 0.292 | 0.248 | -18 | 1.505 | 0.309 | 0.244 | 8 | 3.21 | 68.0 | 47.5 |
| 050 | 1.205 | 1.439 | 0.306 | 0.295 | -30 | 1.479 | 0.415 | 0.586 | -20 | 3.15 | 46.2 | 54.0 |
| 066 | 1.225 | 1.491 | 0.249 | 0.104 | -10 | 1.521 | 0.388 | 0.074 | 41 | 3.07 | 72.5 | 73.0 |
| 067 | 1.218 | 1.472 | 0.239 | 0.287 | -19 | 1.526 | 0.393 | 0.080 | 36 | 3.15 | 57.0 | 79.0 |
| 068 | 1.225 | 1.461 | 0.233 | 0.312 | -18 | 1.519 | 0.166 | 0.175 | 36 | 3.15 | 60.2 | 56.0 |
| Pack Avg | 1.218 | | | | | | | | | 3.17 | 60.8 | 61.9 |
| Overall Avg | 1.218 | | | | | | | | | 2.85 | 52.0 | 71.2 |

a out after 5 hours at c/10 due to high cell voltage
b out after 6 hours at c/10 due to high cell voltage
c out after 11 hours at c/10 due to high cell voltage
d out after 14 hours at c/10 due to high cell voltage
*24-Hour Recovery from dead short
**Negative gauge pressures are automatically interpreted as inches of mercury vacuum

TABLE I (Cont)

LEAK TEST

| SERIAL NUMBER | NO LEAKS | + POST | - POST | FILL TUBE | SIGNAL ELECTRODE |
|---|---|---|---|---|---|
| 002 | X | | | | |
| 003 | X | | | | |
| 004 | X | | | | |
| 005 | X | | | | |
| 006 | X | | | | |
| 007 | X | | | | |
| 008 | | V.S.(1) | | | |
| 009 | | | | | V.S.(1) |
| 011 | | | V.S.(2) | V.S.(1) | V.S.(1) |
| 013 | X | | | | |
| 014 | X | | | | |
| 015 | | V.S.(2,3)c | | | V.S.(2,3) |
| 016 | X | | | | |
| 018 | X | | | | |
| 019 | | | | | V.S.(2,3) |
| 020 | | V.S.(1) | | | V.S.(2) |
| 021 | X | | | | |
| 022 | X | | | | |
| 023 | X | | | | |
| 025 | | L(2) | | | L(2,3) |
| 047 | | V.S.(2) | | V.S.(2) | V.S.(1,2) |
| 050 | | V.S.(2) | | | |
| 066 | X | | | | |
| 067 | | | | V.S.(1) | V.S.(1,2) |
| 068 | | L(2) | L(2) | V.S.(1), L(2) | V.S.(1), L(2) |

X= no leaks V.S.=very slight leak L=strong indication of leakage
(1) initial leak test (2) leak test following capacity checks (3) leak test following overcharge

TABLE II

| CELL SERIAL NO. | WEIGHT GRAMS | HEIGHT INCHES | LENGTH INCHES | WIDTH - INCHES |
|---|---|---|---|---|
| 002 | 568.3 | 3.565 | 0.839 | 2.132 |
| 003 | 569.1 | 3.561 | 0.865 | 2.132 |
| 004 | 570.6 | 3.563 | 0.838 | 2.138 |
| 005 | 566.2 | 3.561 | 0.832 | 2.131 |
| 006 | 699.7 | 3.561 | 0.930 | 2.160 |
| 007 | 556.5 | 3.569 | 0.831 | 2.139 |
| 008 | 552.1 | 3.563 | 0.831 | 2.135 |
| 009 | 566.6 | 3.561 | 0.838 | 2.132 |
| 011 | 566.9 | 3.559 | 0.835 | 2.136 |
| 013 | 565.2 | 3.561 | 0.838 | 2.131 |
| 014 | 574.2 | 3.569 | 0.861 | 2.132 |
| 015 | 568.1 | 3.569 | 0.835 | 2.160 |
| 016 | 568.1 | 3.560 | 0.832 | 2.160 |
| 018 | 565.8 | 3.562 | 0.862 | 2.131 |
| 019 | 572.1 | 3.568 | 0.809 | 2.131 |
| 020 | 570.2 | 3.590 | 0.839 | 2.131 |
| 021 | 569.9 | 3.591 | 0.831 | 2.132 |
| 022 | 571.3 | 3.561 | 0.838 | 2.131 |
| 023 | 569.5 | 3.591 | 0.837 | 2.165 |
| 025 | 566.9 | 3.569 | 0.839 | 2.131 |
| 047 | 573.1 | 3.569 | 0.839 | 2.131 |
| 050 | 566.3 | 3.599 | 0.839 | 2.131 |
| 066 | 568.3 | 3.600 | 0.831 | 2.131 |
| 067 | 568.4 | 3.599 | 0.867 | 2.131 |
| 068 | 568.5 | 3.601 | 0.862 | 2.139 |
| AVG | 566.5 | | 0.840 | |

# APPENDIX I

I. TEST PROCEDURE

A. Phenolphthalein Leak Test:

1. The phenolphthalein leka test is a determination of the condition of the welds and ceramic seals on receipt of the cells. This test was performed prior to any other tests, with a phenolphthalein spray indicator solution of one-half of one percent concentration.

B. Capacity Tests:

1. The capacity test is a determination of the cell capacity at the c/2 discharge rate, where c is the manufacturer's rated capacity to a cutoff voltage of 1.00 volt per cell. The discharge was made after a 1-hour open circuit period following the 16-hour charge at the c/10 rate. A total of three capacity checks was made at this activity. The cells were discharged individually, but were recharged in series.

2. The signal electrodes were loaded with 330-ohm resistors and the recombination electrodes were loaded with 2.2-ohm resistors. These resistors were installed prior to the start of the capacity checks and remained throughout the test.

C. Cell Short Test:

1. The cell short test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials, or damage to element in handling or assembly.

2. Following completion of the third capacity discharge test, each cell was loaded with a 0.5-ohm, 3-watt resistor and allowed to stand 16 hours with the resistor acting as a shorting device. At the end of 16 hours, the resistors were removed and the cells were placed on open circuit stand for 24 hours. Any cell whose voltage did not recover to 1.15 volts or higher was considered as failing this portion of the acceptance test.

D. Leak Test:

1. The leak test is a means of detecting leakage of a seal or weld. The test was performed before and after the overcharge test sequence to determine the presence of leaks.

2. The cells were placed in a vacuum chamber and exposed to a vacuum of 40 microns of mercury or less for 24 hours. The cells were then removed from the vacuum chamber and sprayed with phenolphthalein. Faintly pink areas were designed as slight leakers. Darker, more obvious, discolorations of pink or red were noted as definite leakers.

E. Overcharge Test:

1. The purpose of this test is basically twofold:

a. To determine the degree to which a pack of cells maintain a balanced voltage.

b. To determine the cells capability of reaching a point of chemical equilibrium--oxygen recombination with the recombination electrode to control pressure.

2. The overcharge tests were performed to determine the steady state voltage at specified rates. The test specified a series of constant current charges at c/10, c/20 and c/10 for a minimum of 16 hours at each charge rate. The first c/10 rate serves to establish a condition of overcharge.

3. The cells were monitored hourly throughout the test. Charging was to be discontinued on cells which exceeded 1.50 volts.

F. Internal Resistance Test:

1. Immediately following the overcharge test, the internal resistance was measured across the cell terminals, across the signal electrode (from signal electrode terminal to negative terminal), and across the recombination electrode (from recombination electrode terminal to negative terminal). The measurements were made with a Hewlett-Packard milliohmmeter (Model 4328A).

G. Leak Test:

1. Following the internal resistance measurements, the cells were still in a charged state. The cells were discharged at c/2 to 0.00 volt and shorted prior to the final leak test. The shorted cells were then placed in a vacuum chamber and the procedure described in paragraph I.D.2. was repeated.

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