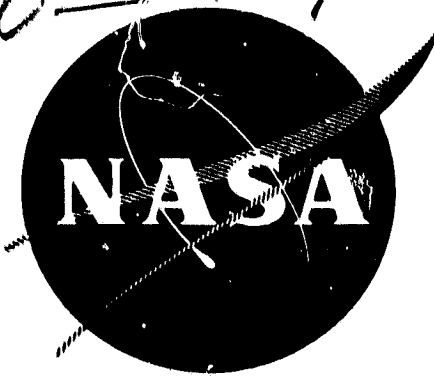


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160014



(NASA-CR-160014) EVALUATION PROGRAM FOR SECONDARY SPACECRAFT CELLS: INITIAL EVALUATION TESTS OF GENERAL ELECTRIC COMPANY 6.0 AMPERE HOUR NICKLE CADMIUM SPACECRAFT CELLS FOR THE (Naval Weapons Support Center, G3/44

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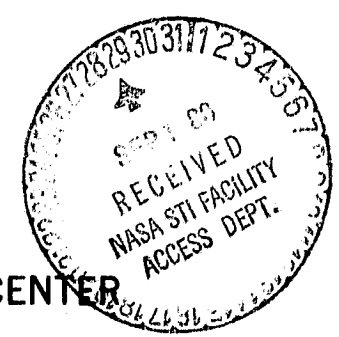
**INITIAL EVALUATION TESTS  
OF  
GENERAL ELECTRIC COMPANY  
6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS  
FOR THE  
DYNAMIC EXPLORER SATELLITE PROGRAM**

prepared for

**GODDARD SPACE FLIGHT CENTER**

Contract S-57075AG

**WEAPONS QUALITY ENGINEERING CENTER  
NWSC Crane, Indiana**



DEPARTMENT OF THE NAVY  
NAVAL WEAPONS SUPPORT CENTER  
WEAPONS QUALITY ENGINEERING CENTER  
CRANE, INDIANA 47522

EVALUATION PROGRAM  
FOR  
SECONDARY SPACECRAFT CELLS  
  
INITIAL EVALUATION TESTS  
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WQEC/C 80-128

09 APR 1980

PREPARED BY

*J. D. Harkness*

J. D. HARKNESS

PREPARED UNDER THE DIRECTION OF

*D. E. Mains*

D. E. MAINS, Manager  
Satellite & Shipboard Battery Branch

APPROVED BY

*Morris L. Robertson*

MORRIS L. ROBERTSON  
Manager, Electrochemical Power  
Sources Division

REPORT BRIEF  
INITIAL EVALUATION TESTS  
OF  
GENERAL ELECTRIC COMPANY  
6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS  
FOR THE  
DYNAMIC EXPLORER SATELLITE PROGRAM

Ref: (a) NASA Purchase Order S-57075AG  
(b) Initial Evaluation Test Procedure for Nickel-Cadmium Sealed  
Space Cells: NAD 3053-TP324; 10 Apr 1973

## I. TEST ASSIGNMENT BRIEF

A. The purpose of this evaluation test program is to insure that all cells put into the life cycle program are of high quality by the screening of cells found to have electrolyte leakage, internal shorts, low capacity, or inability of any cell to recover its open-circuit voltage above 1.150 volts during the internal short test.

B. The ten cells were provided by the National Aeronautics and Space Administration, Goddard Space Flight Center (GSFC), to NAVWPNSUPPCEN Crane for evaluation in the two predicted Dynamic Explorer (DE) Satellite Flight profiles. The cells were purchased by GSFC, under NASA Purchase Order Number S-63727B from the General Electric Company. The cells were manufactured at the same time and from the same materials as the first lot of cells manufactured for RCA for the DE Program. They were manufactured in accordance with "Product Specification Hermetically Sealed Nickel-Cadmium Battery Cell", RCA PS No. 2295143, Revision A. The General Electric catalog number is 42B006AB60. (See Appendix I for detailed cell description) The cells were identified by the manufacturer's serial numbers and RCA's part number 2295143-1. These cells are rated at 6.0 ampere-hours, contain dual, nickel-braze ceramic seals and four cells have pressure transducers. Testing was funded in accordance with reference (a).

C. Test limits specify those values at which a cell is to be terminated from charge or discharge. Requirements are referenced to as normally expected values based on past performance of aerospace nickel-cadmium cells with demonstrated life characteristics. A requirement does not constitute a limit for discontinuance from test.

## II. SUMMARY OF RESULTS

A. Measurements of the cell containers, following test, indicated an increase of .002 inches in the plate stack thickness of one cell (S/N 160).

B. Average end-of-charge voltages and pressures, and capacity output in ampere-hours (ah) were as follows:

<u>Charge</u>	<u>Volts</u>	<u>PSIA</u>	<u>ah Out</u>
c/20 for 48 hrs @ 25° C	1.430	32	7.0
c/10 for 24 hrs @ 25° C	1.440	69	6.8
c/10 for 24 hrs @ 20° C	1.448	80	6.4
c/10 for 24 hrs @ 20° C*	1.446	84	5.8
c/40 for 24 hrs @ 20° C**	1.373	3	2.6
c/20 for 60 hrs @ 0° C	1.474	91	6.2
c/10 for 24 hrs @ 35° C	1.407	27	7.2

\*Charge retention test.

\*\*Charge efficiency test, 3.0 ah input

C. High pressures were exhibited by the four pressure transducer cells during their c/10, 24 hour charges at 25°C and 20°C. Three cells exceeded the requirement of 65 psia at 25°C and all 4 cells exceeded this requirement during both charges at 20°C.

D. During the 0°C overcharge test, two cells were discontinued from charge when their pressure reached the test limit of 100 psia and the other two pressure transducer cells exceeded the pressure requirement of 65 psia. Peak voltages, for all cells, during charge ranged from 1.499 to 1.511 volts.

E. The cells delivered 86% of the input capacity during the 20°C charge efficiency test.

F. The average cell voltage at the end of 1 week open-circuit-stand, during the charge retention test, was 1.318 volts.

G. The 24-hour average cell voltage following the 16-hour shunt period, during the internal short test, was 1.248 volts.

H. The cells, with pressure transducers, reached a pressure of 20 psia before reaching the voltage limit of 1.550 volts during the pressure versus capacity test. The average ampere-hours in and voltage at this pressure were 8.6 ah and 1.512 volts respectively. The cells did not exhibit a pressure decay during the last 30 minutes of the 1-hour open-circuit-stand period. Average capacity out was 7.2 ampere-hours.

### III. RECOMMENDATIONS

A. Although pressures were greater than what normally has been exhibited by General Electric cells in the past, it is recommended that these cells be placed on life test simulating the predicted DE flight profiles.

B. In March 1980, two packs (22D and 22E) began life test. Pack 22D simulates the DE-A flight profile at 25°C and pack 22E simulates DE-B at 10°C.

RESULTS OF  
INITIAL EVALUATION TESTS  
OF  
GENERAL ELECTRIC COMPANY  
6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS  
FOR THE  
DYNAMIC EXPLORER SATELLITE PROGRAM

I. TEST CONDITIONS AND PROCEDURE

A. All evaluation tests were performed at room ambient (RA) pressure and temperature ( $25^{\circ} \pm 2^{\circ}$  C), with discharges at the 2-hour rate, and in accordance with reference (b), unless otherwise specified, and consisted of the following:

1. Phenolphthalein leak tests (2).
2. Three capacity tests, third at  $20^{\circ}$  C; with internal resistance measurements during second charge/discharge.
3. Charge retention test,  $20^{\circ}$  C.
4. Internal short test.
5. Charge efficiency test,  $20^{\circ}$  C.
6. Overcharge tests,  $0^{\circ}$  and  $35^{\circ}$  C.
7. Pressure versus capacity test.
8. Phenolphthalein leak test.

(See Appendix II for summary of test procedure).

II. CELL IDENTIFICATION AND DESCRIPTION

A. The cells were identified by the manufacturer's serial numbers (02950333-113 to 161 non-inclusive-L01), and RCA's part number 2295143-1. The cells were placed in a temporary pack configuration for initial testing (Pack 559X). Each cell was individually restrained and four cells (S/N's 113, 115, 121 and 151) had pressure transducers.

B. The 6.0 ampere-hour cell is rectangular with an average weight and physical dimensions as follows:

Weight (g)*	Height (in)	Edge	Thickness (in)		Width (in)
			Pre-Test Center	Post-Test Center	
282.2	3.175	.839	.839	.839	2.146

\*Does not include pressure transducer cells (4).

C. The cell containers and covers are made of stainless steel. The positive and negative terminals are insulated from the cell cover by dual, nickel-braze, ceramic-to-metal seals and protrude through the cover as solder-type terminals.

III. RESULTS - The following was condensed from Tables I through VI.

A. Measurement of the cell containers, following test, indicated an increase of .002 inches in the plate stack thickness of one cell (S/N 160).

B. Average end-of-charge voltages and pressures, and capacity output in ampere-hours (ah) were as follows:

<u>Charge</u>	<u>Volts</u>	<u>PSIA</u>	<u>ah Out</u>
c/20 for 48 hrs @ 25° C	1.430	32	7.0
c/10 for 24 hrs @ 25° C	1.440	69	6.8
c/10 for 24 hrs @ 20° C	1.448	80	6.4
c/10 for 24 hrs @ 20° C*	1.446	84	5.8
c/40 for 20 hrs @ 20° C**	1.373	3	2.6
c/20 for 60 hrs @ 0° C	1.474	91	6.2
c/10 for 24 hrs @ 35° C	1.407	27	7.2

\*Charge retention test

\*\*Charge efficiency test, 3.0 ah input

C. The average internal resistance at the end-of-charge (Cycle 1) was 3.6 milliohms and at the end-of-discharge (Cycle 2) it was 3.2 milliohms.

D. Three of the 4 cells, having pressure transducers, exceeded the pressure requirement of 65 psia during the c/10 charge for 24 hours at 25° C. All four cells exceeded this requirement during their c/10 charges, for 24 hours at 20° C.

E. Two pressure transducer cells were discontinued from charge during the 0°C overcharge test when their pressure reached the test limit of 100 psia. The other 2 pressure transducer cells exceeded the requirement of 65 psia. Peak voltages, for all the cells, during charge ranged from 1.499 (S/N 155) to 1.511 volts (S/N 113).

F. The cells delivered 86% of the input capacity during the 20° C charge efficiency test.

G. The average cell voltage at the end of 1 week open-circuit-stand, during the charge retention test, was 1.318 volts.

H. The 24-hour average cell voltage following the 16-hour shunt period, during the internal short test, was 1.248 volts.

I. The cells, with pressure transducers, reached a pressure of 20 psia before reaching the voltage limit at 1.550 volts during the pressure versus capacity test. The average ampere-hours in and voltage at this pressure were 8.6 ah and 1.512 volts respectively. The cells did not exhibit a pressure decay during the last 30 minutes of the 1-hour open-circuit-stand period. Average capacity out was 7.2 ampere-hours.

TABLE I  
MEASUREMENT AND LEAK TEST DATA

SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)			WIDTH (Inches)	PHENOLPHTHALEIN LEAK TESTS												
			MINIMUM EDGE	CENTER MAXIMUM (Pre-Test)	CENTER MAXIMUM (Post-Test)		INITIAL		PRE HI VAC		POST TEST								
							Terminals	Other	Terminals	Other	Terminals	Other							
113	297.0 *	3.173	.839	.840	.840	2.145													
115	298.4 *	3.173	.839	.839	.839	2.146													
121	297.9 *	3.173	.840	.840	.840	2.145													
151	297.8 *	3.175	.839	.839	.839	2.148													
153	282.2	3.178	.839	.839	.839	2.145													
155	283.0	3.176	.839	.839	.839	2.146	NO LEAKS				NO LEAKS								NO LEAKS
156	281.1	3.180	.841	.841	.841	2.145													
159	282.3	3.176	.837	.837	.837	2.147													
160	283.2	3.173	.838	.838	.840	2.147													
161	281.6	3.178	.839	.839	.839	2.146													
+	includes Swagelok fittings																		



TABLE II  
Capacity Data

SERIAL NUMBER	Capacity Test 1				Capacity Test 2				Capacity Test 3 (20°C)						
	END-OF-CHARGE	END-OF-DISCHARGE		END-OF-CHARGE	END-OF-DISCHARGE		END-OF-CHARGE	END-OF-DISCHARGE		END-OF-CHARGE	END-OF-DISCHARGE				
	AUX ELECT (Volts)	CELL (Volts)	PRESS (PSIA)	AUX ELECT (Volts)	CELL (Volts)	PRESS (PSIA)	AUX ELECT (Volts)	CELL (Volts)	PRESS (PSIA)	AUX ELECT (Volts)	CELL (Volts)	PRESS (PSIA)	AUX ELECT (Volts)	CELL (Volts)	PRESS (PSIA)
113	1428	38	10	6.9	1437	80	6.7	28	1452	92	6.4	49			
115	1428	30	5	7.1	1438	71	6.9	23	1449	80	6.6	40			
121	1429	28	5	7.0	1439	65	6.8	20	1448	76	6.5	34			
151	1429	33	11	6.9	1438	60	6.7	20	1450	72	6.3	29			
153	1432			7.1	1445		6.8		1458		6.4				
155	1427			6.9	1439		6.7		1445		6.2				
156	1432			7.0	1439		6.6		1447		6.4				
159	1434			6.9	1443		6.7		1448		6.3				
160	1421			7.0	1440		6.7		1443		6.4				
161	1432			7.1	1442		6.8		1445		6.5				

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END-100 (SP 11/73)







TABLE VI  
PRESSURE VS. CAPACITY TEST DATA

Serial	113	115	121	151
Start-of-Charge, Press.	6	1	0	1
AH in to 5 PSIA	N/A	2.1	2.3	7.7
Cell (volts)	1.481	1.491	1.469	
Aux (volts)	N/A	N/A	N/A	N/A
AH in to 10 PSIA	7.6	8.5	8.5	8.2
Cell (volts)	1.459	1.504	1.506	1.458
Aux (volts)				
AH in to 15 PSIA	8.2	8.6	8.6	8.4
Cell (volts)	1.492	1.512	1.512	1.508
Aux (volts)				
AH in to 20 PSIA	8.4	8.7	8.7	8.6
Cell (volts)	1.505	1.515	1.516	1.512
Aux (volts)				
AH in to V/L (1.55V)	N/A	N/A	N/A	N/A
Aux (volts)				
Press (PSIA)				
30 Min OCY, Cell	1.598	1.492	1.491	1.460
Aux (volts)				
Press (PSIA)	24	25	25	24
1 Hour OCY, Cell	1.590	1.391	1.390	1.310
Aux (volts)				
Press (PSIA)	23	28	25	26
EOD AH out	7.1	7.2	7.2	7.1
Aux (volts)				
Press (PSIA)	13	14	12	14
N/A - Not Applicable				

WQEC/C 80-128

APPENDIX I  
CELL DESCRIPTION

APPENDIX I  
CELL DESCRIPTIONCell History and Description

Twelve 6AH cells were purchased by GSFC under Purchase Order Number S-63727B from the General Electric Company. Four cells were fitted with SWAG-LOC caps. All cells were manufactured at the same time and from the same materials as the first lot of cells manufactured for RCA for the DE program. These cells were manufactured in accordance with "Product Specification Hermitically Sealed Nickel-Cadmium Battery Cell," RCA PS #2295143, Revision A. The General Electric catalog number is 42B006AB60. Pertinent cell design features and manufacturing data are as follows:

Number of Plates: 10 positive, 11 negative

Two GE nickel-braze, ceramic-to-metal seal

Plate Dimensions: positive: 2.170" x 1.968" x .027" nominal

negative: 2.170" x 1.978" x .031" nominal

Negative plate is Teflon treated

Plate Loading: positive: 12.19 to 12.89 g/dm<sup>2</sup>

negative: 15.46 to 16.02 g/dm<sup>2</sup>

KOH Quantity: 28cc of 31% KOH

Precharge: 2.67 AH

Separator: Pellon 2505

Cell Case (welded) Dimensions: 3.180" x 2.134" x .830"

Case Wall Thickness: .019"  $\pm$  .003

Overall Cell Height Including Terminals: 3.629"

WQEC/C 80-128

APPENDIX II  
TEST PROCEDURE



## APPENDIX II

## I. TEST PROCEDURE

## A. Phenolphthalein Leak Tests:

1. This test is a determination of the condition of the welds and ceramic seals on receipt of the cells and following the last discharge of the cells (Cycle 8).

2. The cells were initially checked with a one-half of one percent phenolphthalein solution applied with a cotton swab and then placed in a vacuum chamber and exposed to a vacuum of 40 microns of mercury or less for 24 hours. Upon removal they were rechecked for leaks and then received a final check following test completion. The requirement is no red or pink discoloration which indicates a leak.

## B. Capacity Tests:

1. The capacity test is a determination of the cells' capacity at the  $c/2$  discharge rate to 0.75 volt per cell, where  $c$  is the manufacturer's rated capacity. This type discharge follows all charges of this evaluation test.

2. The charges for the capacity tests are as follows:

a.  $c/20$ , 48 hours, room ambient (RA), cycle 0, with a test limit of 1.52 volts or pressure of 100 psia;

b.  $c/10$ , 24 hours, RA, cycle 1, with a test limit of 1.52 volts or 100 psia pressure and a requirement of maximum voltage (1.48) or pressure (65 psia);

c.  $c/10$ , 24 hours, 20° C, cycle 2, with the same limits and requirements as the charge of cycle 1.

## C. Internal Resistance:

1. Measurements are taken across the cell terminals 0.5 hour before the end-of-charge (EOC) on cycle 1; and 1 and 2 hours after the start-of-discharge of cycle 2. These measurements were made with a Hewlett-Packard milliohmmeter (Model 4328A).

## D. Special Charge Retention Test, 20° C:

1. This test is to establish the capacity retention of each cell following a 7-day open-circuit stand in a charge mode.

2. The cells are charged at c/10 for 24 hours with the same limits and requirements as the charge of cycle 1. They then stand on open-circuit for 7 days, with the requirement that the open-circuit voltage of each cell, following this period, is within  $\pm 5$  millivolts of the average cell voltage. The cells are then discharged and 80 percent capacity out of that obtained in cycle 3 is required.

E. Internal Short Test:

1. This 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 charge retention test capacity discharge, the cells are shunted with a 0.5-ohm, 3-watt resistor for 16 hours. At the end of 16 hours the resistors are removed and the cells stand on open-circuit voltage (OCV) for 24 hours. A minimum voltage of 1.15 is required at the end of 24 hours.

F. Charge Efficiency Test, 20° C:

1. This test is a measurement of the cells' charge efficiency when charged at a low current rate.

2. The cells are charged at c/40 for 20 hours with a test limit of 1.52 volts or 100 psia pressure. They are then discharged and the requirement is that the minimum capacity out equals 55 percent of capacity in during the preceding charge.

G. Overcharge Test 1, 0° C:

1. The purpose of this test is to determine the degree to which the cells will maintain a balanced voltage, and to determine the cells' capability to be overcharged without overcharging the negative electrode.

2. The cells are charged at c/20 for 60 hours. The test limits are cell voltages of 1.56 or greater for a continuous time period of 2 hours or pressures of 100 psia. The requirement is a voltage of 1.520 or a pressure of 65 psia. The cells are then discharged and 85 percent capacity out of that obtained in cycle 3 is required.

H. Overcharge Test 2, 35° C:

1. This test is a measurement of the cells' capacity at a higher temperature when compared to its capacity at 20° C. This test also determines the cells' capability of reaching a point of pressure equilibrium; oxygen recombination at the negative plate at the same rate it is being generated at the positive plate.

2. The cells are charged at c/10 for 24 hours with a test limit of 1.52 volts or 100 psia pressure and a requirement of 1.45 volts or 65 psia pressure. The cells are then discharged with a requirement that capacity out equals 55 percent capacity out as obtained in cycle 3.

I. Pressure Versus Capacity Test:

1. The purpose of this test is to determine the capacity to a pressure and the pressure decay during charge and open-circuit stand respectively.

2. Each cell is charged at c/2 to either a pressure of 20 psia or a voltage of 1.550. Recordings are taken on each cell when it reaches 5, 10, 15 and 20 psia pressure. The cells then stand OCV for 1 hour with 30-minute recordings and then are discharged, shorted out and leak tested.