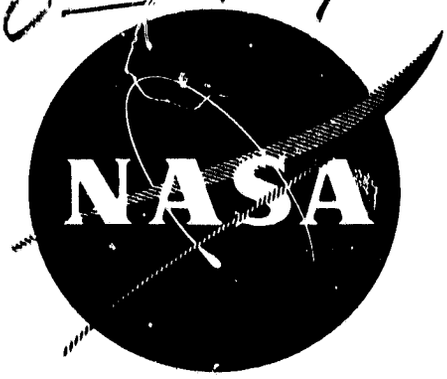

INITIAL EVALUATION TESTS OF GENERAL ELECTRIC COMPANY 6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS FOR THE DYNAMIC EXPLORER SATELLITE PROGRAM

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

WQEC/C 80-128

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Enclosure (1)

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) Initail 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 (GFSC), 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:

Charge	Volts	PSIA	ah Out
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° ± 2° 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° C; with internal resistance measurements during second charge/discharge.

3. Charge retention test, 20° C.

4. Internal short test.

5. Charge efficiency test, 20° C.

6. Overcharge tests, 0° and 35° 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:

			Thickness (in)		
			Pre-Test	Post-Test	
Weight (g)*	Height (in)	Edge	Center	Center	Width (in)
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:

Charge	Volts	PSIA	ah Out
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								
							INITIAL			PRE HI VAC			POST TEST		
			MINIMUM EDGE	CENTER MAXIMUM (Pre-Test)	CENTER MAXIMUM (Post-Test)		Terminals		Other	Terminals		Other	Terminals		Other
							+	-		+	-		+	-	
113	299.0 *	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														

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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		
	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)
113	1428		38	6.9		10	1437		80	6.7		28	1456		92	6.4		43
115	1429		30	7.1		5	1438		71	6.9		23	1449		80	6.6		40
121	1427		28	7.0		5	1439		65	6.8		20	1448		76	6.5		34
151	1429		33	6.9		11	1438		60	6.7		20	1450		72	6.3		29
153	1432			7.1			1440			6.8			1448			6.4		
155	1427			6.9			1439			6.7			1445			6.3		
156	1432			7.0			1439			6.8			1447			6.4		
159	1434			6.9			1443			6.7			1448			6.3		
160	1431			7.0			1440			6.7			1443			6.4		
161	1432			7.1			1442			6.8			1445			6.5		

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TABLE III
INTERNAL RESISTANCE AND SHORT TEST DATA

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SERIAL NUMBER	INTERNAL RESISTANCE (MILLIOHMS)			INTERNAL SHORT TEST		
	END-OF-CHARGE	ONE HOUR AFTER START-OF-DISCHARGE	TWO HOURS AFTER START-OF-DISCHARGE	AFTER 16 HR SHORT	AFTER 24 HOUR OCV STAND	
				CELL	CELL	PRESS
113	3.3	3.3	3.1	.038	1.248	8
115	3.4	3.2	3.0	.032	1.247	1
121	3.5	3.4	3.2	.033	1.249	0
151	3.4	3.2	3.2	.036	1.249	2
153	3.6	3.4	3.3	.031	1.245	
155	3.7	3.6	3.2	.037	1.248	
156	3.7	3.6	3.2	.031	1.244	
159	3.8	3.4	3.4	.032	1.249	
160	3.8	3.5	3.3	.034	1.248	
161	3.8	3.6	3.4	.033	1.249	

TABLE IV
CHARGE RETENTION TEST DATA

SERIAL NUMBER	END-OF-CHARGE			24 HR. OCV			1 WEEK OCV			END-OF-DISCHARGE		
	CELL (VOLTS)	AUX. ELECT. (VOLTS)	PRESS. (PSIA)	CELL (VOLTS)	AUX. ELECT. (VOLTS)	PRESS. (PSIA)	CELL (VOLTS)	AUX. ELECT (VOLTS	PRESS. (PSIA)	CAPAC-ITY (AH)	AUX. FLECT. (VOLTS)	PRESS. (PSIA)
113	1.457		94	1.354		12	1.320		8	5.8		8
115	1.447		85	1.352		9	1.319		1	5.9		1
121	1.445		78	1.352		6	1.320		0	5.9		0
151	1.444		79	1.353		10	1.320		2	5.8		2
153	1.445			1.351			1.317			5.9		
155	1.443			1.351			1.317			5.7		
156	1.446			1.352			1.318			5.9		
159	1.447			1.351			1.318			5.7		
160	1.442			1.349			1.317			5.8		
161	1.445			1.351			1.318			5.9		

TABLE V
Charge Efficiency and Overcharge Data

SERIAL NUMBER	Charge Efficiency (20°C) END-OF-CHARGE CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	END-OF-DISCHARGE CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	Overcharge Test (0°) END-OF-CHARGE CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	END-OF-DISCHARGE CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	Overcharge Test (35°C) END-OF-CHARGE CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	END-OF-DISCHARGE CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)
113	1372		[illegible]	25		8	1473 *		[illegible]	[illegible]		33	1468		[illegible]	[illegible]		2
115	1372		1	25		1	1467		[illegible]	25		45	1469		[illegible]	[illegible]		[illegible]
121	1372		0	26		[illegible]	1472		[illegible]	65		[illegible]	[illegible]		25	72		[illegible]
151	1373		2	26		2	[illegible] *		[illegible]	[illegible]		[illegible]	[illegible]		23	[illegible]		[illegible]
153	1373			26			1473			[illegible]			[illegible]			73		
155	1372			26			1470			[illegible]			[illegible]			72		
156	1373			25			1472			62			[illegible]			72		
159	1373			25			1477			[illegible]			[illegible]			72		
160	1373			26			[illegible]			62			1469			72		
161	1373			26			1474			62			[illegible]			[illegible]		

* - Ampere-Hours In: S/N 113 ([illegible])
S/N 151 ([illegible])

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TABLE VI
PRESSURE VS. CAPACITY TEST DATA

Serial No.	113	115	121	151											
Start-of-Charge, Press.	6	1	0	1											
AH in to 5 PSIA	NA	8.1	8.3	7.7											
Cell (volts)		1.481	1.491	1.469											
Aux (volts)	NA	NA	NA	NA											
AH in to 10 PSIA	7.6	8.4	8.5	8.2											
Cell (volts)	1.459	1.504	1.506	1.498											
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)	NA	NA	NA	NA											
Aux (volts)															
Press (PSIA)															
30 Min OCV, Cell	1.398	1.402	1.401	1.400											
Aux (volts)															
Press (PSIA)	24	25	25	26											
1 hour OCV, Cell	1.390	1.391	1.390	1.390											
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											

NA - Not Applicable

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APPENDIX I

CELL DESCRIPTION

APPENDIX I
CELL DESCRIPTION

Cell 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^2

negative: 15.46 to 16.02 g/dm^2

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"

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 ± 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.