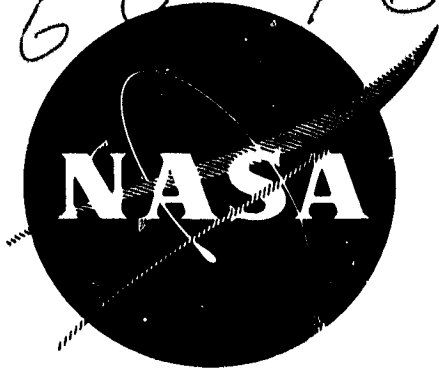


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NASA CR-160016



INITIAL EVALUATION TESTS
of
GENERAL ELECTRIC COMPANY
40.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
for the
TRACKING DATA RELAY SATELLITE SYSTEM

(NASA-CR-160016) EVALUATION PROGRAM FOR SECONDARY SPACECRAFT CELLS: INITIAL EVALUATION TESTS OF GENERAL ELECTRIC COMPANY 40.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS FOR THE (Naval Weapons Support Center, 63/44 32503) NSG-31833 UNCLAS

prepared for
GODDARD SPACE FLIGHT CENTER

Contract S-53742AG

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
40.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
FOR THE
TRACKING DATA RELAY SATELLITE SYSTEM

WQEC/C 78-416

21 December 1978

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

D. G. Miley

D. G. MILEY

Enclosure (1)

REPORT BRIEF
INITIAL EVALUATION TESTS
OF
GENERAL ELECTRIC COMPANY
40.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
FOR THE
TDRSS SATELLITE

Ref: (a) NASA Purchase Order S-53742AG, Modification Number 17
(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 five cells were provided by the National Aeronautics and Space Administration, Goddard Space Flight Center (GSFC), to NAVWPNSUPPCEN Crane for evaluation on a synchronous orbit life test. The cells were manufactured for TRW at the same time and from the same materials as Engineering Cells (Lot 1) manufactured for the Tracking Data Relay Satellite System (TDRSS) program. They were manufactured in accordance with TRW Part/Material Control Document "Battery Cells 40 ah", Number 8E011 and General Electric MCD 232A2222AA-80. (See Appendix I for detailed cell description). The cells were identified by the manufacturer's catalog numbers 42B040AB03-G1 and G2. These cells are rated at 40.0 ampere-hours, contain double ceramic seals, and the G2 type cells (2) 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 average increase of .006 inches in the plate stack thickness.

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	1.438	39	51.2
c/10 for 24 hrs @ 25° C	1.447	80	48.5
c/10 for 24 hrs @ 20° C	1.467	80	50.1
c/10 for 24 hrs @ 20° C*	1.467	85	44.5
c/40 for 20 hrs @ 20° C**	1.369	7	14.5
c/20 for 60 hrs @ 0° C	1.493	68	47.1
c/10 for 24 hrs @ 35° C	1.401	58	49.4

*Charge retention test

**Charge efficiency test, 20.0 ah input

C. Three cells exceeded the voltage requirement of 1.48 volts during both c/10 charges at 20° C. Their peak voltages were 1.480 to 1.482 volts.

D. All cells exceeded the voltage requirement of 1.52 volts during the 0° C overcharge test although their end-of-charge voltages were below 1.50 volts. Peak voltages were 1.523 to 1.527 volts.

E. The pressure requirement of 65 psia was exceeded by both pressure transducer cells during the c/10 charges at 25° C and 20° C and also during the 0° C overcharge test.

F. The average cell voltage at the end of one week open-circuit-stand, during the charge retention test, was 1.312 volts.

G. The 24-hour average cell voltage following the 16-hour short period, during the internal short test, was 1.236 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 61.5 ah and 1.537 volts respectively. The cells exhibited a pressure decay of 2 psia during the last 30 minutes of the 1-hour open-circuit stand. Average capacity out was 51.3 ampere-hours.

III. RECOMMENDATIONS

A. Manufacturing processes and controls should be such to prevent swelling of the plate stack, thereby preventing cell case distortion.

B. It was recommended that these cells be placed on a synchronous orbit life test.

C. In December 1978, one pack (232A) began synchronous orbit life test with its first eclipse season.

RESULTS OF
INITIAL EVALUATION TESTS
OF
GENERAL ELECTRIC COMPANY
40.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
FOR THE
TDRSS SATELLITE

I. TEST CONDITIONS AND PROCEDURE

A. All evaluation tests were performed at Room Ambient (RA) pressure and temperature ($25^{\circ}\text{C} \pm 2^{\circ}\text{C}$), 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, catalog numbers and TRW's Part/Material Control Document Number 8E011-001Z-001 Revision B. The manufacturer's numbers are as follows:

<u>Catalog</u>	<u>Serial</u>
42B040AB03-G1	02660303-001 to 003-01
42B040AB03-G2	02660303-004 and 005-01

The cells were placed in a temporary pack configuration for initial testing (Pack 547X). Each cell was individually restrained and two cells (S/Ns 004 and 005) had pressure transducers.

B. The 40.0 ampere-hour cell is rectangular with an average weight and physical dimensions as follows:

<u>Weight (g)*</u>	<u>Height (in.)</u>	<u>Edge</u>	<u>Thickness (in.)</u>		<u>Width (in.)**</u>	
			<u>Pre-Test Center</u>	<u>Post-Test Center</u>	<u>Edge</u>	<u>Center</u>
1457.0	6.591	1.303	1.304	1.310	3.406	3.445

* - Does not include pressure transducer cells (2)

** - Cells received having convex sides.

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

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

A. Measurements of the cell containers, following test, indicated an average increase of .006 inches in the plate stack thickness.

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	1.438	39	51.2
c/10 for 24 hrs @ 25° C	1.447	80	48.5
c/10 for 24 hrs @ 20° C	1.467	80	50.1
c/10 for 24 hrs @ 20° C*	1.467	85	44.5
c/40 for 20 hrs @ 20° C**	1.369	7	14.5
c/20 for 60 hrs @ 0° C	1.493	68	47.1
c/10 for 24 hrs @ 35° C	1.401	58	49.4

*Charge retention test

**Charge efficiency test, 20.0 ah input

C. The average internal resistance at the end-of-charge (Cycle 1) was 3.0 milliohms and during discharge (Cycle 2) it was 2.9 milliohms.

D. Three cells exceeded the voltage requirement of 1.48 volts during both c/10 charges at 20°C. Their peak voltages were 1.480 to 1.482 volts.

E. All cells exceeded the voltage requirement of 1.52 volts during the 0° C overcharge test although their end-of-charge voltages were below 1.50 volts. Peak voltages were 1.523 to 1.527 volts.

F. The pressure requirement of 65 psia was exceeded by both pressure transducer cells during the c/10 charges at 25° C and 20° C and also during the 0° C overcharge test.

G. The average cell voltage at the end of 1 week open-circuit, during the charge retention test, was 1.312 volts.

H. The 24-hour average cell voltage following the 16-hour short period, during the internal short test, was 1.236 volts.

I. 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 61.5 ah and 1.537 volts respectively. The cells exhibited a pressure decay of 2 psia during the last 30 minutes of the 1-hour open-circuit stand. Average capacity out was 51.3 ampere-hours.

TABLE I
Measurement and Leak Test Data

SERIAL NUMBER	WEIGHT (grams)	HEIGHT (Inches)	LENGTH (Inches)			WIDTH (Inches)	PHENOLPHTHALEIN LEAK TESTS									
			EDGE MINIMUM	CENTER MAXIMUM (Pre-test)	CENTER MAXIMUM (Post-test)		INITIAL		POST HI VFC		POST TEST					
							Terminal	Other	Terminal	Other	Terminal	Other				
							+	-	+	-	+	-				
001	1464.2	6.591	1.303	1.304	1.308	3.402/3.442	-	-	-	-	-	-	-	-	-	
002	1452.3	6.591	1.302	1.303	1.311	3.406/3.434	-	-	-	-	-	-	-	-	-	
003	1454.6	6.591	1.304	1.304	1.314	3.407/3.465	No LEAKS	-	-	No LEAKS	-	-	-	No LEAKS	-	
004	1696.6	6.589	1.303	1.304	1.309	3.408/3.441	-	-	-	-	-	-	-	-	-	
005	1702.7	6.594	1.304	1.303	1.306	3.406/3.445	-	-	-	-	-	-	-	-	-	
			Cells have pressure transducers													

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TABLE II
Capacity Data

SERIAL NUMBER	Capacity Test 1						Capacity Test 2						Capacity Test 3 (20°C)												
	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	END-OF-DISCHARGE	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	END-OF-DISCHARGE	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	END-OF-DISCHARGE	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	END-OF-DISCHARGE	
00	1.438			5.10			1.447					48.2				49.7			1.461				49.7		
001	1.439			5.10			1.448					48.3				50.1			1.461				50.1		
002	1.438			5.10			1.446					48.3				50.5			1.462				50.5		
004	1.437		3.4	5.10		5	1.446		76		6	48.3			50.5			1.462			75	50.5			
005	1.437		4.4	5.12		9	1.446		83		10	49.1			50.8			1.467			84	50.8			

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TABLE IV
CHARGE RETENTION TEST DATA

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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)	CAPACITY (AH)	AUX. ELECT. (VOLTS)	PRESS. (PSIA)
001	1.468			1.357			1.313			43.7		
002	1.467			1.358			1.313			44.5		
003	1.467			1.358			1.313			44.5		
004	1.465		32	1.356		8	1.311		6	44.5		6
005	1.466		87	1.356		11	1.312		9	45.3		8

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APPENDIX I

APPENDIX I

CELL DESCRIPTION

Cell History and Description

Five, 40 ah cells were purchased by the GSFC, under Purchase Order Number S-49693D, from the General Electric Company. These cells were manufactured at the same time and from the same materials as Engineering Cells (Lot 1) manufactured for TRW for the TDRSS Program. These cells were manufactured in accordance with TRW Part/Material Control Document "Battery Cells 40 ah," Number 8E011 and General Electric MCD 232A2222AA-80. The General Electric Catalog Number is 42B040AB03. Some of the pertinent cell design features and manufacturing data are as follows:

Number of plates: 16 Positive
17 Negative

Plate Dimensions: Positive 5.40" x 3.20" x .027"
Negative 5.40" x 3.20" x .0315"

Negative Plate is Silver Treated

Loading (Lot 1): Positive 13.52 gm/dm²
Negative 16.17 gm/dm²

KOH Quantity (Lot 1): 120 cc of 31% KOH

Precharge (Lot 1): 13.4 ah

Separator: Pellon 2505

Interelectrode spacing: .0085" nominal

Flooded cell tests (Lot 1): Average Positive 55.49 ah
Average Negative 92.92 ah

Cell case dimensions: 6.24" x 3.413" x 1.308"

Case thickness: .019"

Height to top of terminals: 6.669" maximum

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APPENDIX II

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.