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**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**

prepared for

**GODDARD SPACE FLIGHT CENTER**

**Contract S-49693B**

(NASA-CR-163924) 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

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

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

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TRACKING DATA RELAY SATELLITE SYSTEM

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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-496938, Modification Number 17  
(b) Initial Evaluation Test Procedure for Nickel-Cadmium Sealed Space Cells: NAD 3053-TP324

## 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. These cells were manufactured at the same time and from the same materials as Lot 2 cells 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 number 42B040AB03. These cells are rated at 40.0 ampere-hours and contain double ceramic seals. 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 .019 inches in the plate stack thickness of only those cells without pressure transducers. Also, the narrow sides of those cells containers became convex during testing.

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	1.448	29	53.7
c/10 for 24 hrs @ 25° C	1.459	70	52.0
c/10 for 24 hrs @ 20° C	1.467	68	50.0
c/10 for 24 hrs @ 20° C*	1.464	78	45.3
c/40 for 20 hrs @ 20° C**	1.373	4	16.4
c/20 for 60 hrs @ 0° C	1.500	75	50.1
c/10 for 24 hrs @ 35° C	1.398	29	49.6

\*Charge retention test

\*\*Charge efficiency test, 20.0 ah input

C. One cell (S/N 145) exceeded the voltage requirement of 1.48 volts during the first c/10 charge at 20° C. Four cells exceeded this requirement during the second c/10 charge at 20° C.

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 1.51 volts. Peak voltages were 1.539 to 1.545 volts.

E. The pressure requirement of 65 psia was exceeded by one pressure transducer cell (S/N 146) during the first c/10 charge at 20° C. Both pressure transducer cells exceeded this pressure requirement during the c/10 charge at 25° C, the second c/10 charge at 20° C, and 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 1.316 volts.

G. The 24-hour average cell voltage following the 16-hour short period, during the internal short test, was 1.240 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 61.2 ah and 1.548 volts respectively. The cells exhibited a pressure decay of 4 psia during the last 30 minutes of the 1-hour open-circuit stand. Average capacity out was 52.0 ampere-hours.

### III. RECOMMENDATIONS

A. Manufacturing processes and controls should be such to prevent cell case distortion.

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

C. In April 1980, one pack (232B) 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  $20^{\circ}\text{C}$ , with internal resistance measurements during second charge/discharge.
3. Charge retention test,  $20^{\circ}\text{C}$ .
4. Internal short test.
5. Charge efficiency test,  $20^{\circ}\text{C}$ .
6. Overcharge tests,  $0^{\circ}$  and  $35^{\circ}\text{C}$ .
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 E. The manufacturer's numbers are as follows:

<u>Catalog</u>	<u>Serial</u>
42B040AB03	02670304 S/N 02-141 to 145

The cells were placed in a temporary pack configuration for initial testing (Pack 560X). Each cell was individually restrained and two cells (S/Ns 145 and 146) 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>
1.449.8	6.588	1.307	1.311	1.330	3.405	3.433

\*Does not include pressure transducer cells (2) which indicated no increase in plate stack thickness and whose width (narrow side) were not convex following test.

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 .019 inches in the plate stack thickness of only those cells without pressure transducers. Also, the narrow sides of these cells' containers became convex during testing.

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	1.448	29	53.7
c/10 for 24 hrs @ 25° C	1.459	70	52.0
c/10 for 24 hrs @ 20° C	1.467	68	50.0
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c/40 for 20 hrs @ 20° C**	1.373	4	16.4
c/20 for 60 hrs @ 0° C	1.500	75	50.1
c/10 for 24 hrs @ 35° C	1.398	29	49.6

\*Charge retention test

\*\*Charge efficiency test, 20.0 ah input

C. The average internal resistance at the end-of-charge (Cycle 1) was 2.5 milliohms and during discharge (Cycle 2) it was 2.4 milliohms.

D. One cell (S/N 145) exceeded the voltage requirement of 1.48 volts during the first c/10 charge at 20° C. Four cells exceeded this requirement during the second c/10 charge at 20° C.

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 1.51 volts. Peak voltages were 1.539 to 1.545 volts.

F. The pressure requirement of 65 psia was exceeded by one pressure transducer cell (S/N 146) during the first c/10 charge at 20° C. Both pressure transducer cells exceeded this pressure requirement during the c/10 charge at 25° C, the second c/10 charge at 20° C, and 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 1.316 volts.

H. The 24-hour average cell voltage following the 16-hour short period, during the internal short test, was 1.240 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 the voltage at this pressure were 61.2 ah and 1.548 volts respectively. The cells exhibited a pressure decay of 4 psia during the last 30 minutes of the 1-hour open-circuit stand. Average capacity out was 52.0 ampere-hours.



TABLE I  
MEASUREMENT AND LEAK TEST DATA

SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)			WIDTH (Inches)	PHENOLIC TIE-UP LEAK TESTS						
			EDGE MINIMUM	MAXIMUM (Pre-Test)	MAXIMUM (Post-Test)		INITIAL		POST HI VAC		POST TEST		
							Terminals	Other	Terminals	Other	Terminals	Other	
141	1.447.8	6.583	1.304	1.324	3.406/3.429	+	-	+	-	+	-	-	-
142	1.452.1	6.596	1.322	1.341	3.406/3.430								
144	1.445.6	6.600	1.309	1.326	3.405/3.427								
145 *	1.834.3	6.598	1.299	1.305	3.404/3.404								NO LEAKS
146 *	1.833.0	6.563	1.303	1.310	3.407/3.407								NO LEAKS
*	Cells have pressure	tender...											











APPENDIX I  
CELL DESCRIPTION

## APPENDIX I

## CELL DESCRIPTION

Cell History and Description

Five, 40 ah cells were purchased by the GSFC, under Purchase Order Number S-49693B, from the General Electric Company. These cells were manufactured at the same time and from the same materials as (Lot 2) cells 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. This cell lot consists of two plate lots (2A and 2B). 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 2A): Positive 01049 13.36 gm/dm<sup>2</sup>  
Negative 02013 16.46 gm/dm<sup>2</sup>

Loading (Lot 2B): Positive 01056 13.49 gm/dm<sup>2</sup>  
Negative 02003 16.47 gm/dm<sup>2</sup>

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

Precharge (Lot 2): 14.4 ah

Separator: Pellon 2505

Interelectrode spacing: .0085" nominal

Flooded cell tests (Lot 2A): Average Positive 55.78 ah  
Average Negative 92.74 ah

Flooded cell tests (Lot 2B): Average Positive 55.62 ah  
Average Negative 94.64 ah

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

Case thickness: .019"

Height to top of terminals: 6.669" maximum



APPENDIX II  
TEST PROCEDURE

## APPENDIX II

## 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 cell's 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 cell's 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 cell's 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 cell's capacity at a higher temperature when compared to its capacity at 20° C. This test also determines the cell's 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.