INITIAL EVALUATION TESTS OF GENERAL ELECTRIC COMPANY 4.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS FOR THE AMPTE SATELLITE PROGRAM

prepared for

GODDARD SPACE FLIGHT CENTER

Contract S-57075AG

WEAPONS QUALITY ENGINEERING CENTER
NWSC Crane, Indiana

DEPARTMENT OF THE NAVY
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EVALUATION PROGRAM FOR SECONDARY SPACECRAFT CELLS

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WQEC/C 83-428

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Enclosure (1)

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REPORT BRIEF

INITIAL EVALUATION TESTS OF GENERAL ELECTRIC COMPANY 4.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS FOR THE AMPTE 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 ensure 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 to characterize the Active Magnetic Particle Tracer Explorer (AMPTE) cell design and to demonstrate the effects of specific mission parameters on cell life. These cells were selected from the AMPTE flight lot purchased by the Johns Hopkins Applied Physics Laboratory (APL) and were manufactured by the General Electric Company according to APL's Specification Number 7254-9017. (See Appendix I for a detailed cell description.) The cells were identified by the manufacturer's catalog number 42B004AB37. The cells are rated at 4.0 ampere-hours and contain dual, nickel-braze 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. Measurement of the cell containers, following test, indicated an average increase of .008 inches in the plate stack thickness.

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

Charge	Volts	ah Out
c/20 for 48 hrs @ 25°C	1.444	5.4
c/10 for 24 hrs @ 25°C	1.456	5.3
c/10 for 24 hrs @ 20°C	1.470	5.3
c/10 for 24 hrs @ 20°C*	1.470	4.9
c/40 for 20 hrs @ 20°C**	1.373	1.1
c/20 for 60 hrs @ 0°C	1.494	5.2
c/10 for 24 hrs @ 35°C	1.428	5.4

*Charge retention test
**Charge efficiency test, 2.0 ah input

C. The five cells exceeded the voltage requirement of 1.480 volts during their c/10 charges at 20°C. Their peak voltages ranged from 1.484 to 1.489 volts.

D. The average cell voltage at the end of 1 week open-circuit during the charge retention test was 1.316 volts.

E. The average ampere-hours out, during the charge efficiency test, was 1.14 which corresponds to an efficiency of 57 percent.

F. During the 0°C overcharge test, four cells exceeded the voltage requirement of 1.520 volts. Their peak voltages ranged from 1.526 (S/N 024) to 1.536 volts (S/N 016). Peak voltage of the other cell (S/N 106) was 1.519 volts.

G. Figures 1 and 2 show the average charge and discharge voltage profiles at 0°C, 20°C, and 35°C.

III. RECOMMENDATIONS

A. Although high cell voltages were observed during the c/10 charges at 20°C and the c/20 charge at 0°C, this may have been due to the non-treatment of the negative plates. It is recommended that these cells be placed on an AMPTE-type orbit life test.

B. On 26 December 1983, one 5-cell pack (Pack 4H) began life test.

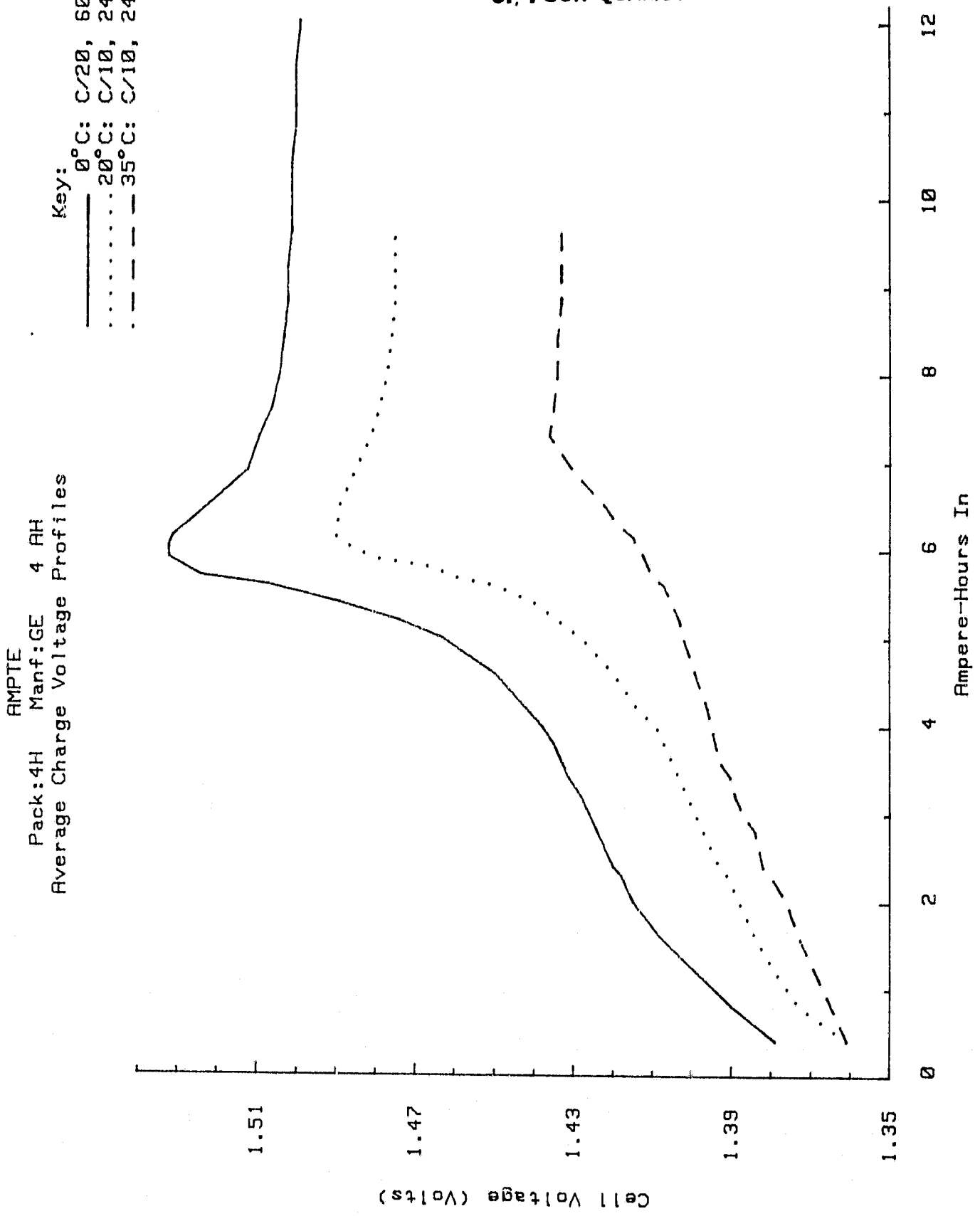

Figure 1

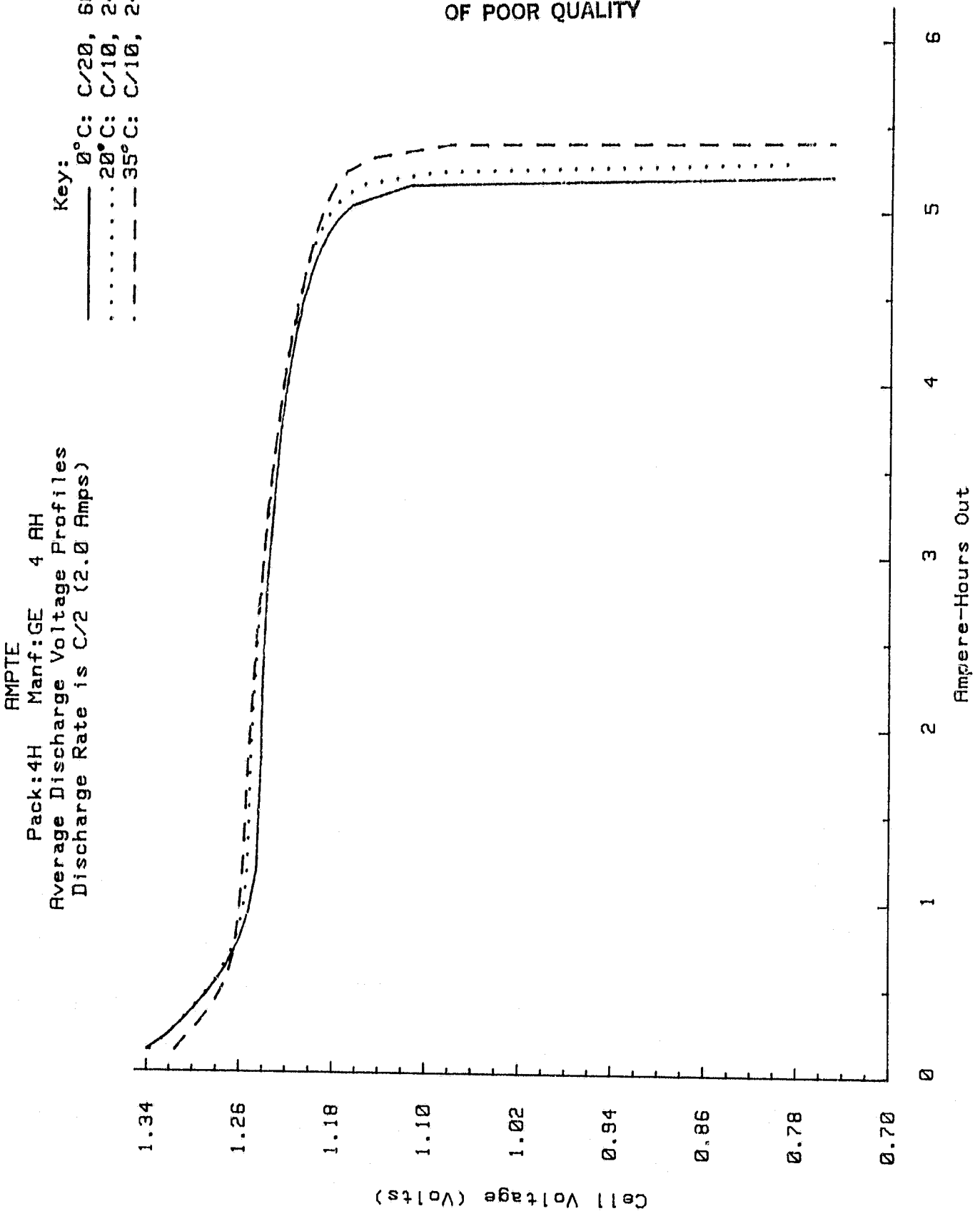

Figure 2

RESULTS OF INITIAL EVALUATION TESTS OF GENERAL ELECTRIC COMPANY 4.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS FOR THE AMPTF 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 the second charge/discharge test.

3. Charge retention test, 20°C.

4. Internal short test.

5. Charge efficiency test, 20°C.

6. Overcharge tests, 0° and 35°C.

7. 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 (04190441-016 to 106 non-inclusive - L01) and catalog number 42B004AB37. The cells were also identified with the APL part number 7254-9017A. Each cell was individually restrained during test.

B. The 4.0 ampere-hour cell is rectangular with an average weight and physical dimensions as follows:

Weight (g)	Height (in.)	Thickness (in.) (Pre/Post-Test) Edge	Center	Width (in.)
199.6	2.722	.812	.785/.794	2.144

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 V:

A. Measurement of the cell containers, following test, indicated an average increase of .008 inches in the plate stack thickness.

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

Charge	Volts	ah Out
c/20 for 48 hrs @ 25°C	1.444	5.4
c/10 for 24 hrs @ 25°C	1.456	5.3
c/10 for 24 hrs @ 20°C	1.470	5.3
c/10 for 24 hrs @ 20°C*	1.470	4.9
c/40 for 20 hrs @ 20°C**	1.373	1.1
c/20 for 60 hrs @ 0°C	1.494	5.2
c/10 for 24 hrs @ 35°C	1.428	5.4

*Charge retention test
**Charge efficiency test, 2.0 ah input

C. The average internal resistance at the end-of-charge (Cycle 1) was 4.4 milliohms and at the end-of-discharge (Cycle 2) it was 4.3 milliohms.

D. The five cells exceeded the voltage requirement of 1.480 volts during their c/10 charges at 20°C. Their peak voltages ranged from 1.484 to 1.489 volts.

E. The average cell voltage at the end of 1-week open-circuit, during the charge retention test, was 1.316 volts.

F. The 24-hour average cell voltage following the 16-hour shunt period, during the internal shunt test, was 1.213 volts.

G. The average ampere-hours out, during the charge efficiency test, was 1.14 which corresponds to an efficiency of 57 percent.

H. During the 0°C overcharge test, four cells exceeded the voltage requirement of 1.520 volts. Their peak voltages ranged from 1.526 (S/N 024) to 1.536 volts (S/N 016). Peak voltage of the other cell (S/N 106) was 1.519 volts.

APPENDIX I

CELL DESCRIPTION

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CELL DESCRIPTION

Cell History and Description

These cells were selected from the AMPTE flight lot purchased by the Johns Hopkins Applied Physics Laboratory (APL), and were manufactured by the General Electric Company according to APL's Specification Number 7254-9017. The General Electric catalog number is 42B004AB37 and the cells were activated in August 1982. Some of the pertinent cell design features and manufacturing data are as follows:

Dual ceramic seals	
Low profile construction	
Plate treatment:	Positive - nickel-attack-control
	Negative - none
Separator:	Pellon 2505
Loading:	Positive - Post No. 17135 - 12.47 gm/dm^2
	Negative - Post No. 250764 - 15.46 gm/dm^2
Final KOH Quantity:	15 to 16 cc of 31 percent KOH
Precharge setting:	1.26Ah
Average ECT:	5.88Ah positive
	10.63Ah negative

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.

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 (1.480 volts) 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 milliohmeter (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 cell's 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.

TABLE I

MEASUREMENT AND LEAK TEST DATA

SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)			WIDTH (Inches)	PHENOLPHTHALEIN LEAK TESTS								
							INITIAL			POST HI VAC			POST TEST		
			EDGE	CENTER (Pre-Test)	CENTER (Post-Test)		Terminals		Other	Terminals		Other	Terminals		Other
							+	-		+	-		+	-	
016	200.1	2.723	.811	.785	.794	2.140		↑			↑			↑	
024	200.2	2.727	.813	.788	.801	2.144		↑			↑			↑	
061	199.0	2.723	.811	.787	.794	2.151	NO	LEAKS		NO	LEAKS		NO	LEAKS	
098	200.3	2.718	.812	.789	.795	2.140		↓			↓			↓	
106	198.6	2.719	.811	.778	.785	2.146		↓			↓			↓	

TABLE II
Capacity Data

SERIAL NUMBER	Capacity Test 1 -- CHG, C/20, 48 hrs., 25°C						Capacity Test 2 -- CHG, C/10, 24 hrs., 25°C						Capacity Test 3 -- CHG, C/10, 24 hrs., 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)
016	1.446			5.50			1.458			5.38			1.472			5.28		
024	1.441			5.34			1.453			5.22			1.467			5.20		
061	1.444			5.22			1.457			5.06			1.470			5.00		
098	1.442			5.50			1.455			5.38			1.468			5.36		
106	1.445			5.58			1.456			5.54			1.471			5.52		

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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
016	4.4	4.3	4.4	.007	1.208	
024	4.5	4.2	4.2	.004	1.216	
061	4.4	4.3	4.3	.018	1.223	
098	4.4	4.2	4.3	.006	1.210	
106	4.5	4.3	4.4	.003	1.210	

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. ELECT. (VOLTS)	PRESS. (PSIA)
016	1.472			1.352			1.315			5.00		
024	1.468			1.352			1.315			4.92		
061	1.470			1.353			1.317			4.60		
098	1.469			1.353			1.318			5.00		
106	1.471			1.353			1.316			5.16		

TABLE V
Charge Efficiency and Overcharge Data

SERIAL NUMBER	Charge Efficiency -- CHG, C/40, 20 hrs., 20°C						Overcharge Test 1 -- CHG, C/20, 60 hrs., 0°C						Overcharge Test 2 -- CHG, C/10, 24 hrs., 35°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)
016	1.374			1.14			1.499			5.16			1.426			5.44		
024	1.373			1.14			1.490			5.16			1.427			5.36		
061	1.374			1.14			1.496			5.00			1.428			5.20		
098	1.372			1.14			1.490			5.32			1.429			5.44		
106	1.373			1.14			1.495			5.32			1.427			5.60		

9ND-NADC (SP 11/73)