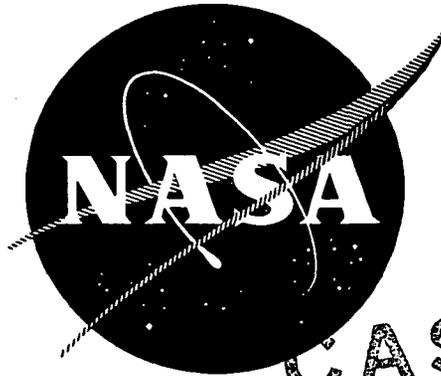


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EVALUATION PROGRAM
for
SECONDARY SPACECRAFT CELLS
ACCEPTANCE TESTS
OF
EAGLE-PICHER 100 AMPERE-HOUR
NICKEL-CADMIUM CELLS
WITH AUXILIARY ELECTRODES

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT S-23404-G

QUALITY EVALUATION LABORATORY
NAD CRANE, INDIANA

NAVAL AMMUNITION DEPOT
QUALITY EVALUATION AND ENGINEERING LABORATORY DEPARTMENT
CRANE, INDIANA 47522

EVALUATION PROGRAM
FOR
SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
EAGLE-PICHER
100 AMPERE-HOUR
NICKEL-CADMIUM CELLS
WITH AUXILIARY ELECTRODES

QEEL/C 72-126

10 MARCH 1972

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By direction

Enclosure (1)

REPORT BRIEF
EAGLE-PICHER COMPANY
100 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
WITH AUXILIARY ELECTRODES

Ref: (a) NASA P. O. S-23404-G
(b) Acceptance Test Procedure for Nickel-Cadmium Cells:
NAD 3052-TP304 Rev A, 14 May 1970

I. TEST ASSIGNMENT BRIEF

A. The purpose of this acceptance test program is to insure that all cells put into the life cycle program are of high quality by the removal 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 after the cell short test.

B. Five cells were purchased by National Aeronautics and Space Administration, Goddard Space Flight Center, from Eagle-Picher Company, Joplin, Missouri. The cells were rated at 100 ampere-hours and equipped with auxiliary electrodes. Testing of these cells was funded in accordance with reference (a).

II. SUMMARY OF RESULTS

A. The capacity of the 24 cells ranged from 103.5 to 119.0 ah. All the cells exceeded the rated capacity on all three capacity checks.

B. All cells recovered above the 1.150-volt requirement after the cell short test.

C. These cells cannot be overcharged at the c/10 rate without exceeding 1.500 volts after approximately 12 to 13 hours of charge.

D. A special resistance test was conducted on the auxiliary electrodes of these cells. This test was designed to establish the resistance value necessary which would provide maximum signal power across the auxiliary electrode. The resistance value thus established was 10 ohms.

E. One cell (S/N 3) revealed a definite leak at the negative terminal.

III. RECOMMENDATIONS

A. This activity does not recommend these 100 ampere-hour cells for further testing or for use in space. This recommendation is based on continuous difficulties encountered during overcharge requirements.

RESULTS OF ACCEPTANCE TEST
OF
100 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
WITH AUXILIARY ELECTRODES
MANUFACTURED BY
EAGLE-PICHER COMPANY

I. INTRODUCTION

A. On 12 February 1972 acceptance tests were begun on five cells manufactured by the Eagle-Picher Company, Joplin, Missouri. These tests were completed 25 February 1972.

II. TEST CONDITIONS AND PROCEDURE

A. These cells were operated within a cold plate fixture designed by Goddard Space Flight Center. The temperature of this plate was maintained at 20° C, as specified by Goddard, by using a temperature-controlled water bath to circulate water through the fixture.

1. Phenolphthalein Leak Test.
2. Three Capacity Checks.
3. Cell Short Test.
4. Phenolphthalein Leak Test.
5. Overcharge Tests, c/20 and c/10 Rates.
6. Special Resistance Test of Auxiliary electrodes (between c/20 and c/10 overcharge rates).
7. Internal Resistance.
8. Phenolphthalein Leak Test.

See Appendix I for detailed test procedure.

III. CELL IDENTIFICATION AND DESCRIPTION

A. The cells were identified by the manufacturer's serial numbers (3 through 11)--not consecutive.

B. The 100 ampere-hour cell is square with an average height, width and length of 8.273, 7.325 and 1.435 inches, respectively.

The average weight was 3694.2 grams. Individual measurements and averages are listed in Table I.

C. The cell containers and the cell covers are made of stainless steel. The positive and negative terminals were insulated from the cell covers by ceramic seals and protrude through the cover as solder type terminals. The auxiliary electrode terminal consists of a stainless steel tab welded to the cell cover. (See Photograph 1)

IV. RESULTS--The following data was condensed from Tables II through IV.

A. The average capacity for the three capacity checks was: 113.6, 110.7 and 108.5 ampere-hours respectively. It should be noted that these cells were never charged (c/10 rate) beyond 13 hours due to high cell voltages.

B. The average recovery voltage was 1.222 volts.

C. End-of-Overcharge Voltage:

1. Cell voltages increased rapidly after 13 hours of charge at the c/10 rate. The current was therefore reduced stepwise to c/40 to remain below the 1.500 voltage limit. The cell voltages ranged from 1.458 to 1.499 volts under these conditions.

2. After the initial c/10 conditioning charge, reference (b) called for a c/20 charge for an additional 16 hours. This c/20 rate was never possible. The cells were maintained at the c/40 rate (established in the previous step) for 1 hour. Increasing cell voltages necessitated a further stepwise reduction of the overcharge current to c/125. The voltage ranged from 1.428 to 1.504 volts under these conditions.

3. No attempt was made to return to the c/10 rate or to maintain the overcharge at c/125 as previously established. This was in accordance with instructions from Goddard Space Flight Center.

D. Special Test for Determining the Resistance Giving Maximum Signal Power from the Auxiliary Electrode:

1. This test was conducted following the c/125 overcharge and prior to the c/10 overcharge (never performed) on two of the five cells. See Appendix I for details. Table IV shows 10 ohms as the resistance value giving the maximum power in millivolts across the auxiliary electrode.

E. Internal Resistance Averaged:

1. 1.3 milliohms across the cell terminals.
2. 5.6 milliohms across the auxiliary electrode.

F. Leak Tests:

1. One cell (S/N 3) revealed a definite leak at the negative terminal.

APPENDIX I

I. TEST PROCEDURE

A. Phenolphthalein Test:

1. The phenolphthalein leak test is a determination of the condition of the welds and ceramic seals on receipt of the cells. This test was performed prior to any other tests, with a phenolphthalein spray indicator solution of one-half of one percent concentration.

B. Capacity Tests:

1. The capacity test is a determination of the cell capacity at the $c/2$ discharge rate, where c is the manufacturer's rated capacity to a cutoff voltage of 1.00 volt per cell. The discharge was made after a 1-hour open circuit period following the 16-hour charge at the $c/10$ rate. A total of three capacity checks was made at this activity. The cells were discharged individually, but were recharged in series.

2. The auxiliary electrodes were without resistors until the resistance characterization was conducted during the overcharge tests following the $c/20$ rate and just prior to the $c/10$ rate. These tests precisely determined the correct resistance for the auxiliary electrode.

C. Cell Short Test

1. The cell short 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 third capacity discharge test, each cell was loaded with a 0.05 ohm, 10 watt resistor for 16 hours. At the end of 16 hours, the shorting resistors were removed and the cells were placed on open circuit stand for 24 hours. Any cell whose voltage did not recover the 1.150 volts or higher was considered as failing this portion of the acceptance test.

D. Leak Test

1. The leak test is a means of detecting leakage of a seal or weld. The test was performed before and after the overcharge test sequence to determine the presence of leaks.

2. The cells were placed in a vacuum chamber and exposed to a vacuum of 40 microns of mercury or less for 24 hours. The cells were then removed from the vacuum chamber and sprayed with phenolphthalein. Pink or redish discolorations would indicate leakage.

E. Overcharge Test

1. The purpose of this test is basically threefold:

a. To determine the degree to which a pack of cells maintain a balanced voltage.

b. To determine the cells capability of reaching a point of chemical equilibrium--oxygen recombination with the negative (cadmium) plate.

c. To test the integrity of the seals as the pressure increases.

2. The overcharge tests were performed to determine the steady state voltage at specified rates. The test specified a series of constant current charges at c/10, c/20 and c/10 for a minimum of 16 hours at each charge rate. The first c/10 rate serves to establish a condition of overcharge.

3. The cells were monitored hourly throughout the test. Charging was to be discontinued on cells which exceeded 1.500 volts or 100 psig.

4. The special resistance characterization tests for the auxiliary electrodes were conducted following the c/20 overcharge and prior to the c/10 overcharge. The cells were maintained on charge at c/125 throughout the special resistance test in order to maintain the voltage limit. The tests were conducted on the cells with pressure gauges and consisted of the following:

a. A decade resistance box was hooked across the auxiliary electrode of each cell (auxiliary electrode terminal to negative terminal) such that the resistance could be conveniently and precisely varied.

b. The pressure was maintained as close to ambient (0 psig) as possible throughout the test. No alteration of the c/125 charge rate was necessary for these cells to maintain this condition. The temperature was room ambient.

c. The sequence of resistance charges (ohms) were: 10,000, 5000, 2000;1000, 500, 200;100, 50, 20;10, 5, 2;1, 0.5, 0.2;and 0.1. A period of approximately 5 minutes was allowed for the equilibrium of the auxiliary electrode voltage to re-establish itself after each resistance change. This equilibrium was verified by observation of a strip chart recorder monitoring the auxiliary electrode voltage of each cell.

d. Data thus obtained was converted to power units in millivolts as illustrated at the foot of Table IV. The resistance value giving the maximum power of the auxiliary electrode signal is thus chosen for the auxiliary electrode resistance.

F. Internal Resistance;

1. Immediately following the overcharge test, the internal resistance was measured across the cell terminals and across the auxiliary electrodes (from auxiliary electrode terminal to negative terminal). These measurements were made with a Hewlett-Packard milliohmmer (Model 4328A).

G. Leak Test:

1. Following the internal resistance measurements, the cells were still in a charged state. The cells were discharged at $c/2$ to 0.00 volt and shorted prior to the final leak test. The shorted cells were then placed in a vacuum chamber and the procedure described in paragraph I.D.2. was repeated.

TABLE II
CAPACITY CHECK DATA

QEEL/C 72-126

SERIAL NUMBER	FIRST CAPACITY CHECK						SECOND CAPACITY CHECK						THIRD CAPACITY CHECK					
	END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE		
	** CELL (Volts)	AUX ELECT (Volts)	PRESS *	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS *	** CELL (Volts)	AUX ELECT (Volts)	PRESS *	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS *	** CELL (Volts)	AUX ELECT (Volts)	PRESS *	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS *
3	1.500	0.834		114.0	0.540		1.500	0.835		113.5	0.650		1.503	0.938		111.5	0.657	
6	1.500	0.838	+14	106.0	0.586	+10	1.523	0.815	+15	103.5	0.654	+9	1.525	0.956	+17	105.0	0.638	+7
8	1.500	0.868	-20	117.5	0.675	-29	1.533	0.862	-20	114.0	0.660	-27	1.547	0.969	-7	109.0	0.656	-23
10	1.500	0.769		111.5	0.591		1.533	0.841		106.5	0.643		1.514	0.954		103.5	0.655	
11	1.500	0.865		119.0	0.652		1.500	0.922		116.0	0.657		1.500	0.952		113.5	0.654	
Average				113.6						110.7						108.5		
** All cells reached the 1.500 voltage limit prior to the required 16 hours of charge at the % rate. The times to 1.500 volts are noted below in hours and minutes.																		
3	11:34						12:59						13:20					
6	11:00						12:04						12:55					
8	11:55						12:55						12:55					
10	11:34						12:55						12:55					
11	11:53						13:02						13:20					

Negative values are interpreted as inches of mercury vacuum, while positive values are psig.

TABLE III

QEEL/C 72-126

SERIAL NUMBER	CELL SHORT TEST Recovery Voltage after 24 Hours (Volts)	END OF CHARGE VOLTAGE AT:									INTERNAL RESISTANCE MEASUREMENT (Milliohms)	
		c/10 CONDITIONING RATE			c/20 CONDITIONING RATE			c/10 CONDITIONING RATE			CELL	AUX ELECT
		* CELL (Volts)	AUX ELECT (Volts)	PRESS *	** CELL (Volts)	AUX ELECT (Volts)	PRESS *	*** CELL (Volts)	AUX ELECT (Volts)	PRESS *		
3	1.223	1.443	0.898		1.428	0.875					1.3	7.6
6	1.228	1.462	0.908	+8	1.449	0.892	+1				1.6	4.9
8	1.210	1.499	0.923	+13	1.504	0.914	+6				1.3	4.4
10	1.224	1.458	0.909		1.442	0.892					1.2	5.9
11	1.224	1.477	0.932		1.481	0.924					1.1	5.2
Average:	1.222										1.3	5.6
* Cell voltages increased rapidly after 13 hours of charge at the $\frac{1}{10}$ rate. The current was therefore reduced stepwise to $\frac{1}{40}$ to maintain the 1.500 voltage limit.												
** The charge rate was maintained at $\frac{1}{40}$ for one hour. Increasing cell voltages necessitated a further stepwise reduction of the overcharge current to $\frac{1}{125}$.												
*** Upon completion of the auxiliary electrode resistance characterization at the end of the " $\frac{1}{20}$ " overcharge rate, the overcharge was terminated.												

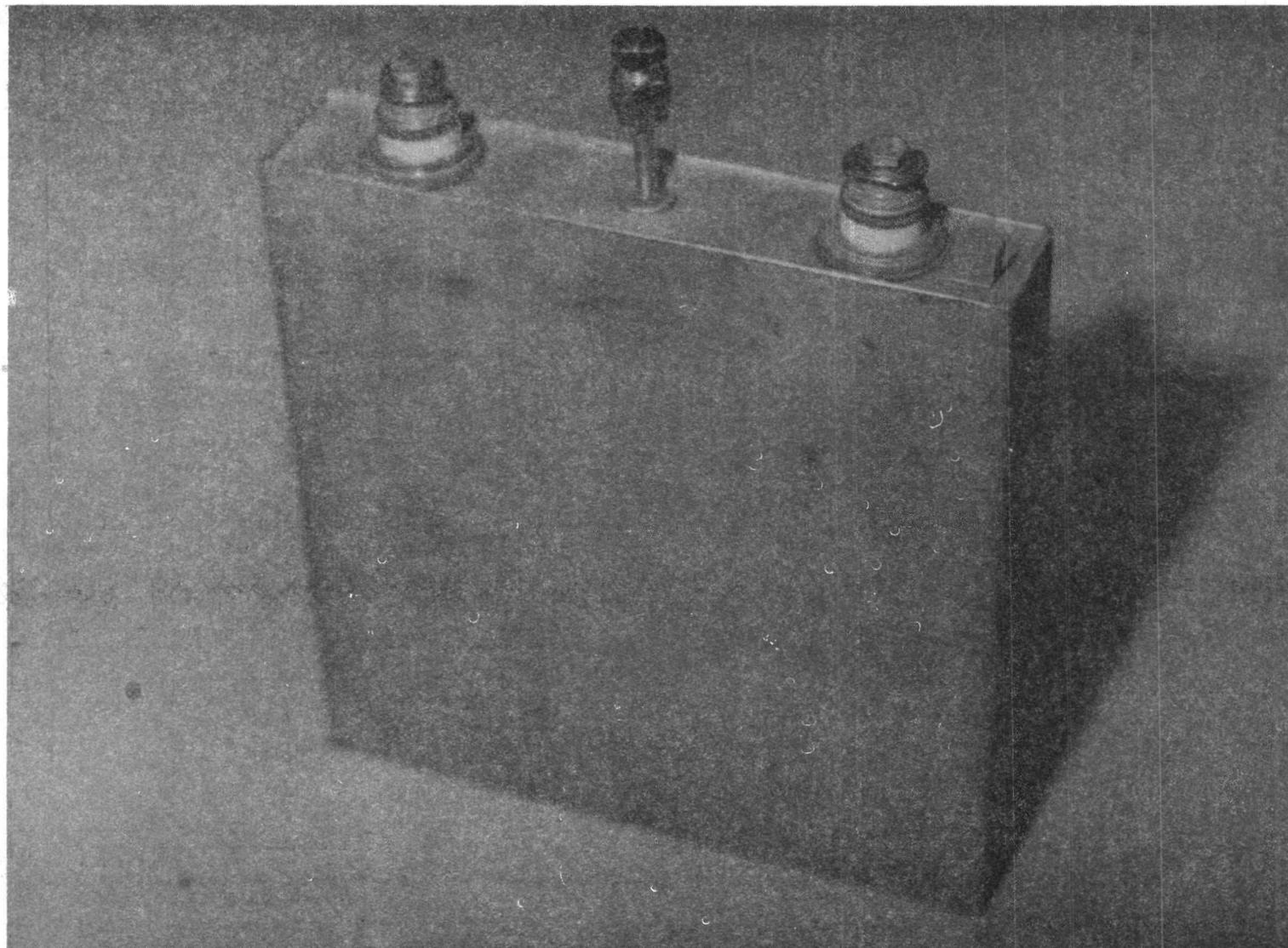
* Negative values are interpreted as inches of mercury vacuum, while positive values are psig.

TABLE IV
SPECIAL RESISTANCE TEST DATA ON THE AUXILIARY ELECTRODES

SERIAL NO.	6		8								AVERAGE		
	OHMS	VOLTS	PRESS	VOLTS	MILLIWATTS								
10,000	0.817	+1	0.786	+5								0.802	0.064
5,000	0.772	..	0.715	..								0.744	0.111
2,000	0.689	..	0.635	..								0.662	0.219
1,000	0.607	..	0.568	..								0.588	0.346
500	0.528	..	0.504	..								0.516	0.533
200	0.423	..	0.390	..								0.407	0.828
100	0.333	..	0.297	..								0.315	0.992
50	0.250	..	0.230	+6								0.240	1.152
20	0.176	..	0.162	..								0.169	1.143
10	0.130	..	0.119	..								0.125	1.563 *
5	0.088	..	0.080	..								0.084	1.411
2	0.046	..	0.041	..								0.044	0.968
1	0.024	..	0.023	..								0.024	0.576
0.5	0.012	..	0.013	..								0.013	0.338
0.2	0.005	..	0.006	+7								0.006	0.180
0.1	0.003	..	0.004	..								0.004	0.160

* Maximum wattage
across auxiliary electrode.

$$\text{POWER} = \frac{V^2}{R} \text{ Watts } 10^3 \frac{\text{Milliwatts}}{\text{Watt}} : \text{Milliwatts}$$



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Subj: Report QEEL/C 72-126; Evaluation Program for Secondary Spacecraft
Cells; Acceptance Tests of 100 Ampere-Hour Nickel-Cadmium
Spacecraft Cells with Auxiliary Electrodes Manufactured by
Eagle-Picher Company

Ref: (a) NASA P. O. S-23404-G

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