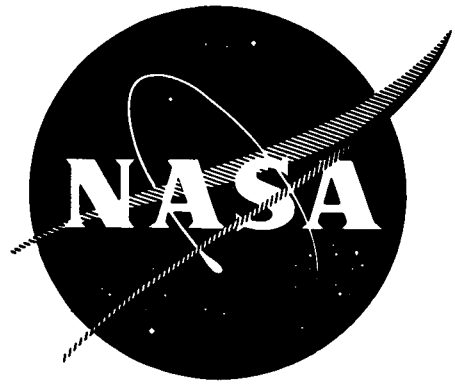

EVALUATION PROGRAM
for
SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
GENERAL ELECTRIC COMPANY
12.0 AMPERE-HOUR AUXILIARY ELECTRODE CELLS

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT W11,252B

QUALITY EVALUATION LABORATORY
NAD CRANE, INDIANA

QUALITY EVALUATION LABORATORY
UNITED STATES NAVAL AMMUNITION DEPOT
CRANE, INDIANA

EVALUATION PROGRAM FOR SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST OF

GENERAL ELECTRIC COMPANY 12.0 AMPERE-HOUR AUXILIARY ELECTRODE CELLS

QE/C 66-803 DECEMBER 1966

PREPARED UNDER THE DIRECTION OF

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Enclosure (1)

REPORT BRIEF

GENERAL ELECTRIC 12 AMPERE-HOUR AUXILIARY ELECTRODE NICKEL CADMIUM SECONDARY SPACECRAFT CELLS

Ref: (a) National Aeronautics and Space Administration Purchase Order W11,252B
(b) NASA ltr BRA/VBK/pad of 25 September 1961 w/BUWEPS first end FQ-1:WSK of 2 October 1961 to CO NAD Crane
(c) Preliminary Work Statement for Battery Evaluation Program of 25 August 1961

I. TEST ASSIGNMENT BRIEF.

A. In compliance with references (a) and (b), evaluation of General Electric 12 ampere-hour Auxiliary Electrode Secondary Spacecraft Cells was begun according to the program outline of reference (c).

B. The object of this evaluation program is to gather specific information concerning secondary spacecraft cells. Information concerning performance characteristics and limitations, including cycle life under various electrical and environmental conditions, will be of interest to power systems designers and users. Cell weaknesses, including causes of failure of present designs, will be of interest to suppliers as a guide to product improvement.

C. Thirty cells were supplied by General Electric Company, Gainesville, Florida to National Aeronautics and Space Administration (NASA) to replace those which failed prematurely on life cycle test. These cells are rated at 12 ampere-hours by the manufacturer. They include the fuel cell type auxiliary electrode for signaling and another auxiliary electrode of similar material and area for oxygen recombination making a total of four electrodes.

II. CONCLUSIONS.

A. From the results of this test, it can be concluded that:

1. The ceramic seals of these cells, manufactured by General Electric Company, are satisfactory as evidenced by no leakers out of the 30 cells tested.

2. The capacities of the cells were in the acceptable range of 15.30 to 16.92 ampere-hours.

III. RECOMMENDATIONS.

A. It is recommended that these General Electric 12 ampere-hour auxiliary electrode cells be accepted on the basis of the acceptance test results.

RESULTS OF ACCEPTANCE TESTS OF

12.0 AMPERE-HOUR NICKEL CADMIUM SECONDARY SPACECRAFT CELLS

WITH AUXILIARY ELECTRODE

MANUFACTURED BY

GENERAL ELECTRIC COMPANY

I. INTRODUCTION.

A. On 10 July 1966, this activity began acceptance tests on 30 cells. These tests were completed on 7 September 1966.

II. TEST CONDITIONS.

A. All acceptance tests were performed at an ambient temperature between 23° C and 27° C at existing relative humidity and atmospheric pressure, and consisted of the following:

1. Phenolphthalein Leak Test.
2. Capacity Test.
3. Cell Short Test.
4. Immersion Seal Test.
5. Overcharge Test.
6. Internal Resistance Test of the Auxiliary Electrode.
7. Internal Resistance Test of the Cell.
8. Immersion Seal Test.

B. All charging and discharging was done at constant current (± 5 percent). Cells were charged in series but discharged individually.

III. CELL IDENTIFICATION AND DESCRIPTION.

A. Cells were identified by the manufacturer's serial numbers which were from 3-7 to 7-13 although not consecutively.

B. The 12.0 ampere-hour auxiliary electrode cell is rectangular in shape with an average height (base to top of positive terminal), length and width of 4.662, 1.098 and 3.025 inches respectively. The average weight is 579.7 grams. The individual cell dimensions and weight are given in Table I. Figure 1 is a photograph of a General Electric Company 12.0 ampere-hour auxiliary electrode cell.

C. The cell container or can, and the cell cover are made of stainless steel. Both terminals are insulated from the cell cover by a ceramic seal and protrude through the cover as 1/4-20 threaded posts. The auxiliary signaling electrode connection is extended externally as a solder tab on the cell cover while the auxiliary recombination electrode is connected internally to the negative plates.

D. These cells, rated by the manufacturer at 12.0 ampere-hours, were supplied in a discharged condition.

IV. TEST PROCEDURE AND RESULTS.

A. Phenolphthalein Leak Test.

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

2. There were no signs of leakage on any of the 30 cells subjected to the leak test.

B. Capacity Test.

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 tests were made at this activity. The cells were discharged individually, but were recharged in series.

2. In order to gather data on the characteristics of the auxiliary electrode, 51 ohms resistance was used between the auxiliary electrode and the negative terminal for the first capacity check; 24 ohms was used for the second capacity check; and an open circuit or infinite resistance was used for the third capacity check.

3. Since complete capacity data, including auxiliary electrode characteristics with the three resistance values, was not submitted by the manufacturer, it was not possible to compare the

manufacturer's results with those of this activity. The individual cell capacities ranged from 15.30 to 16.92 ampere-hours for an average of 15.75 ampere-hours to 1.00 volt. The cell capacities together with the auxiliary electrode voltage characteristics are tabulated in Table II. Characteristic 2-hour rate discharge curves are shown in Figure 2.

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 individual cell was loaded with a resistor of value giving c/1 to c/5 discharge rate and allowed to stand 16 hours with the resistor acting as a shorting device. At the end of 16 hours, the resistors were removed and the cells were placed on open circuit stand for 24 hours. Any cell whose voltage did not recover to 1.15 volts or higher was rejected.

3. The open circuit cell voltage, 24 hours after removal of the shorting resistors, ranged from 1.19 to 1.24 volts for an average of 1.20 volts.

4. There were no rejects of any of the cells subjected to the cell short test. The voltage values for the 30 accepted cells are shown in Table II.

D. Immersion Seal Test.

1. The immersion seal 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 and cause of leaks.

2. The cells were placed under water in a bell jar container. A vacuum of 20 inches of mercury was held for 3 minutes. Cells discharging a steady stream of bubbles were considered rejects.

3. There were no rejects in the 30 cells subjected to the immersion seal test.

E. Overcharge Test.

1. The overcharge tests were performed to determine the steady state voltage at specific rates. The test specified a series of constant current charges at c/20, c/10 and c/5 rates, for a

minimum of 48 hours at each charge rate or until the increase of the "on-charge" voltage was less than 10 millivolts per day.

2. The cells were monitored hourly throughout the test. Charging was to be discontinued on cells which exceeded 1.50 volts while on charge. There was no need to remove any cells from the charging sequence.

3. The steady state voltage of each cell at the end of each 48-hour charge rate test is shown in Table II. Characteristic overcharge voltage curves are shown in Figure 3.

F. Internal Resistance Test of the Auxiliary Electrode.

1. This test was performed to determine the internal resistance of the auxiliary signaling electrode.

2. During the c/10 charge rate portion of the overcharge test; the voltage drop across the 51 ohm resistor connecting the auxiliary electrode to the negative terminal was measured. The 51 ohms resistor was then shunted with a one ohm resistor for 5 to 10 seconds and the voltage drop across the two parallel resistors (0.9808 ohms) was measured. The internal resistance of the auxiliary electrode in ohms was calculated according to the following formula:

$$R = \frac{V1 - V2}{I2 - I1}$$

where V1 = voltage drop, in volts, across the 51 ohm resistor
V2 = voltage drop, in volts, across the 0.9808 ohm resistors
I1 = current flow, in amperes, through the 51 ohm resistor
I2 = current flow, in amperes, through the 0.9808 ohm resistors.

3. The internal resistance value for the auxiliary electrode of each cell is shown in Table III. The values range from 0.463 ohms to 3.674 ohms.

G. Internal Resistance Test of the Cell.

1. This test was performed to determine the internal resistance of the cell.

2. At the completion of the overcharge test, the cells were returned to the c/20 charging rate and given a short pulse (5-10 seconds) at the rate of c in amperes. The cell voltages, V1, immediately prior to the pulse; and V2, 5 milliseconds after the

pulse, were read on a suitable recording instrument. A CEC high speed oscillograph recorder (28.8 inches of tape per second) was used. The internal resistance of the cell in ohms was calculated according to the following formula:

$$R = \frac{V2 - V1}{Ic - Ic/20}$$

V1 and V2 are in volts, Ic and Ic/20 are in ampers.

3. The internal resistance values for each cell is shown in Table III. The values range from 1.75 to 2.63 milliohms.

TABLE I

CELL NUMBER	HEIGHT (INCHES)	LENGTH (INCHES)	WIDTH (INCHES)	WEIGHT (GRAMS)	CELL NUMBER	HEIGHT (INCHES)	LENGTH (INCHES)	WIDTH (INCHES)	WEIGHT (GRAMS)
3-7	4.664	1.100	3.028	572.0	6-3	4.616	1.100	3.020	580.7
3-8	4.668	1.105	3.032	572.8	6-4	4.669	1.104	3.028	581.6
4-6	4.655	1.100	3.011	576.1	6-5	4.667	1.100	3.018	581.5
4-7	4.665	1.108	3.032	577.6	6-6	4.681	1.090	3.030	586.8
5-1	4.692	1.104	3.010	586.3	6-7	4.685	1.100	3.028	584.7
5-2	4.662	1.100	3.012	583.1	7-2	4.688	1.096	3.028	574.5
5-3	4.688	1.092	3.025	586.6	7-3	4.650	1.092	3.032	574.3
5-6	4.615	1.088	3.012	582.1	7-4	4.658	1.091	3.033	574.6
5-7	4.657	1.100	3.010	587.4	7-5	4.688	1.092	3.029	575.9
5-8	4.669	1.100	3.012	584.0	7-6	4.656	1.092	3.037	575.6
5-9	4.668	1.097	3.007	580.9	7-7	4.652	1.091	3.034	574.4
5-10	4.654	1.100	3.029	588.8	7-9	4.652	1.100	3.037	576.5
5-11	4.612	1.100	3.030	584.2	7-10	4.670	1.100	3.038	577.2
5-12	4.660	1.094	3.008	581.4	7-11	4.650	1.100	3.034	576.2
6-1	4.660	1.096	3.021	579.2	7-13	4.682	1.100	3.036	574.7
					Ave. of 30 Cells	4.662	1.098	3.025	579.7

GENERAL ELECTRIC 12.0 AMPERE-HOUR 3RD ELECTRODE

TABLE II

CELL NUMBER	END OF CHARGE WITH 51 OHM RESISTOR		CAPACITY NO. 1	END OF CHARGE WITH 24 OHM RESISTOR		CAPACITY NO. 2	END OF CHARGE WITH NO RESISTOR		CAPACITY NO. 3	CELL SHORT TEST	c/20 OVERCHARGE			c/10 OVERCHARGE			c/5 OVERCHARGE		
	Volts	Amps		Volts	Amps		Volts	Amps			CELL VOLTAGE	THIRD ELECTRODE Volts	THIRD ELECTRODE Amps	CELL VOLTAGE	THIRD ELECTRODE Volts	THIRD ELECTRODE Amps	CELL VOLTAGE	THIRD ELECTRODE Volts	THIRD ELECTRODE Amps
3-07	1.43	0.0010	15.30	1.40	0.0368	13.38	1.39	0	9.90	1.20	1.38	0.873	0.0171	1.38	0.897		1.39	0.932	
3-08	1.42	0.0007	15.42	1.40	0.0329	13.38	1.38	0	9.90	1.20	1.38	0.813	0.0159	1.38	0.829		1.38	0.860	
4-06	1.39	0.0008	15.48	1.39	0.0376	11.52	1.38	0	7.02	1.24	1.36	0.891	0.0175	1.37	0.928		1.39	0.948	
4-07	1.40	0.0007	15.72	1.38	0.0376	13.62	1.38	0	9.48	1.20	1.36	0.893	0.0175	1.36	0.913		1.39	0.938	
5-01	1.41	0.0003	15.78	1.41	0.0371	16.08	1.39	0	13.08	1.21	1.36	0.888	0.0174	1.36	0.898		1.39	0.920	
5-02	1.41	0.0003	15.78	1.40	0.0370	16.02	1.38	0	11.28	1.22	1.36	0.870	0.0171	1.35	0.886		1.39	0.913	
5-03	1.42	0.0002	15.90	1.42	0.0367	16.68	1.39	0	13.32	1.20	1.37	0.871	0.0171	1.36	0.879		1.38	0.899	
5-06	1.42	0.0003	15.90	1.42	0.0365	16.92	1.39	0	13.62	1.21	1.37	0.867	0.0170	1.36	0.881		1.39	0.895	
5-07	1.42	0.0003	15.90	1.41	0.0363	16.68	1.39	0	13.32	1.20	1.37	0.864	0.0169	1.36	0.883		1.38	0.912	
5-08	1.42	0.0003	15.90	1.42	0.0373	16.92	1.40	0	14.40	1.21	1.37	0.890	0.0175	1.37	0.913		1.41	0.936	
5-09	1.42	0.0004	15.30	1.41	0.0363	14.20	1.38	0	9.50	1.21	1.37	0.886	0.0174	1.36	0.896		1.37	0.913	
5-10	1.42	0.0003	15.30	1.41	0.0360	15.10	1.38	0	10.70	1.20	1.37	0.877	0.0172	1.37	0.888		1.37	0.898	
5-11	1.42	0.0005	15.30	1.41	0.0366	14.29	1.39	0	10.10	1.20	1.37	0.887	0.0174	1.38	0.913		1.38	0.919	
5-12	1.42	0.0004	15.30	1.42	0.0370	15.00	1.38	0	10.80	1.20	1.38	0.894	0.0175	1.37	0.918		1.38	0.937	
6-01	1.42	0.0008	15.30	1.41	0.0356	14.20	1.38	0	10.20	1.20	1.38	0.867	0.0170	1.38	0.863		1.38	0.855	

GENERAL ELECTRIC 12.0 AMPERE-HOUR 3RD ELECTRODE

TABLE II (contd)

CELL NUMBER	END OF CHARGE WITH 51 OHM RESISTOR		CAPACITY NO. 1	END OF CHARGE WITH 24 OHM RESISTOR		CAPACITY NO. 2	END OF CHARGE WITH NO RESISTOR		CAPACITY NO. 3	CELL SHORT TEST	c/20 OVERCHARGE			c/10 OVERCHARGE			c/5 OVERCHARGE		
	Volts	Amps		Volts	Amps		Volts	Amps			CELL VOLTAGE	THIRD ELECTRODE Volts	THIRD ELECTRODE Amps	CELL VOLTAGE	THIRD ELECTRODE Volts	THIRD ELECTRODE Amps	CELL VOLTAGE	THIRD ELECTRODE Volts	THIRD ELECTRODE Amps
6-03	1.42	0.0006	15.30	1.41	0.0356	14.80	1.38	0	10.80	1.19	1.38	0.865	0.0170	1.37	0.871		1.38	0.891	
6-04	1.42	0.0005	15.30	1.42	0.0348	14.89	1.39	0	11.30	1.19	1.39	0.858	0.0168	1.38	0.855		1.38	0.869	
6-05	1.42	0.0004	15.30	1.41	0.0354	15.00	1.39	0	11.20	1.20	1.39	0.882	0.0173	1.38	0.883		1.38	0.887	
6-06	1.42	0.0005	15.40	1.41	0.0359	13.90	1.38	0	9.50	1.20	1.38	0.876	0.0172	1.37	0.877		1.37	0.880	
6-07	1.42	0.0003	15.40	1.41	0.0360	14.50	1.39	0	10.90	1.20	1.39	0.875	0.0172	1.38	0.873		1.38	0.873	
7-02	1.43	0.0003	15.50	1.45	0.0347	15.70	1.44	0	15.60	1.20	1.41	0.886		1.43	0.923		1.44	0.950	
7-03	1.43	0.0005	15.60	1.45	0.0342	15.60	1.44	0	15.50	1.20	1.41	0.891		1.43	0.927		1.43	0.954	
7-04	1.43	0.0005	15.60	1.45	0.0348	15.70	1.44	0	15.70	1.20	1.41	0.880		1.42	0.926		1.43	0.958	
7-05	1.43	0.0003	15.40	1.45	0.0068	15.80	1.44	0	15.80	1.19	1.42	0.839		1.42	0.898		1.41	0.922	
7-06	1.43	0.0003	15.60	1.45	0.0360	15.70	1.44	0	15.70	1.19	1.41	0.885		1.41	0.906		1.40	0.920	
7-07	1.43	0.0004	15.50	1.45	0.0357	15.70	1.44	0	15.60	1.20	1.41	0.875		1.41	0.899		1.42	0.920	
7-09	1.43	0.0003	15.60	1.45	0.0312	15.90	1.44	0	15.90	1.19	1.41	0.846		1.41	0.869		1.40	0.888	
7-10	1.43	0.0005	15.60	1.45	0.0283	16.00	1.44	0	16.00	1.19	1.41	0.882		1.41	0.912		1.40	0.930	
7-11	1.43	0.0006	15.50	1.44	0.0570	15.30	1.44	0	15.90	1.19	1.42	0.891		1.42	0.911		1.42	0.934	
7-13	1.43	0.0003	15.60	1.46	0.0365	16.00	1.44	0	15.80	1.20	1.41	0.878		1.42	0.904		1.42	0.914	

TABLE III

AUXILIARY ELECTRODE RESISTANCE

CELL NO.	OHMS	CELL RESISTANCE (MILLIOHMS)	CELL NO.	OHMS	CELL RESISTANCE (MILLIOHMS)
3-07	0.603	1.75	6-03	1.102	1.75
3-08	3.674	1.75	6-04	1.424	2.63
4-06	0.645	1.75	6-05	1.189	2.63
4-07	0.635	2.63	6-06	1.108	2.63
5-01	0.470	1.75	6-07	0.927	2.63
5-02	0.707	1.75	7-02	0.734	1.75
5-03	0.697	1.75	7-03	0.727	1.75
5-06	0.619	2.63	7-04	0.811	2.63
5-07	0.988	2.63	7-05	0.900	2.63
5-08	0.463	1.75	7-06	0.901	2.63
5-09	0.949	1.75	7-07	0.866	1.75
5-10	0.884	2.63	7-09	0.727	1.75
5-11	0.621	1.75	7-10	0.784	1.75
5-12	0.638	2.63	7-11	0.800	1.75
6-01	1.239	2.63	7-13	0.789	1.75

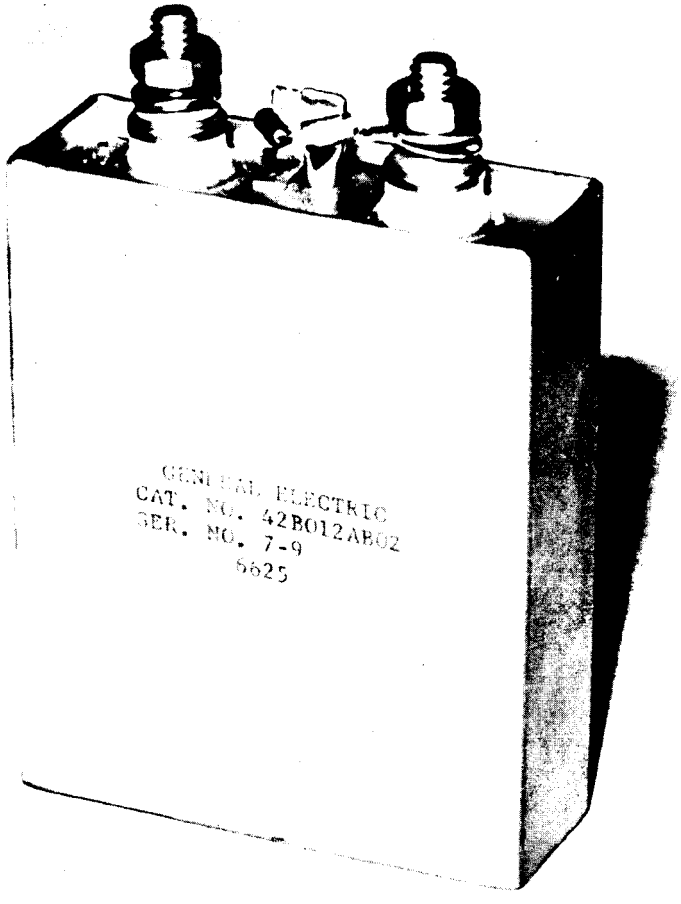
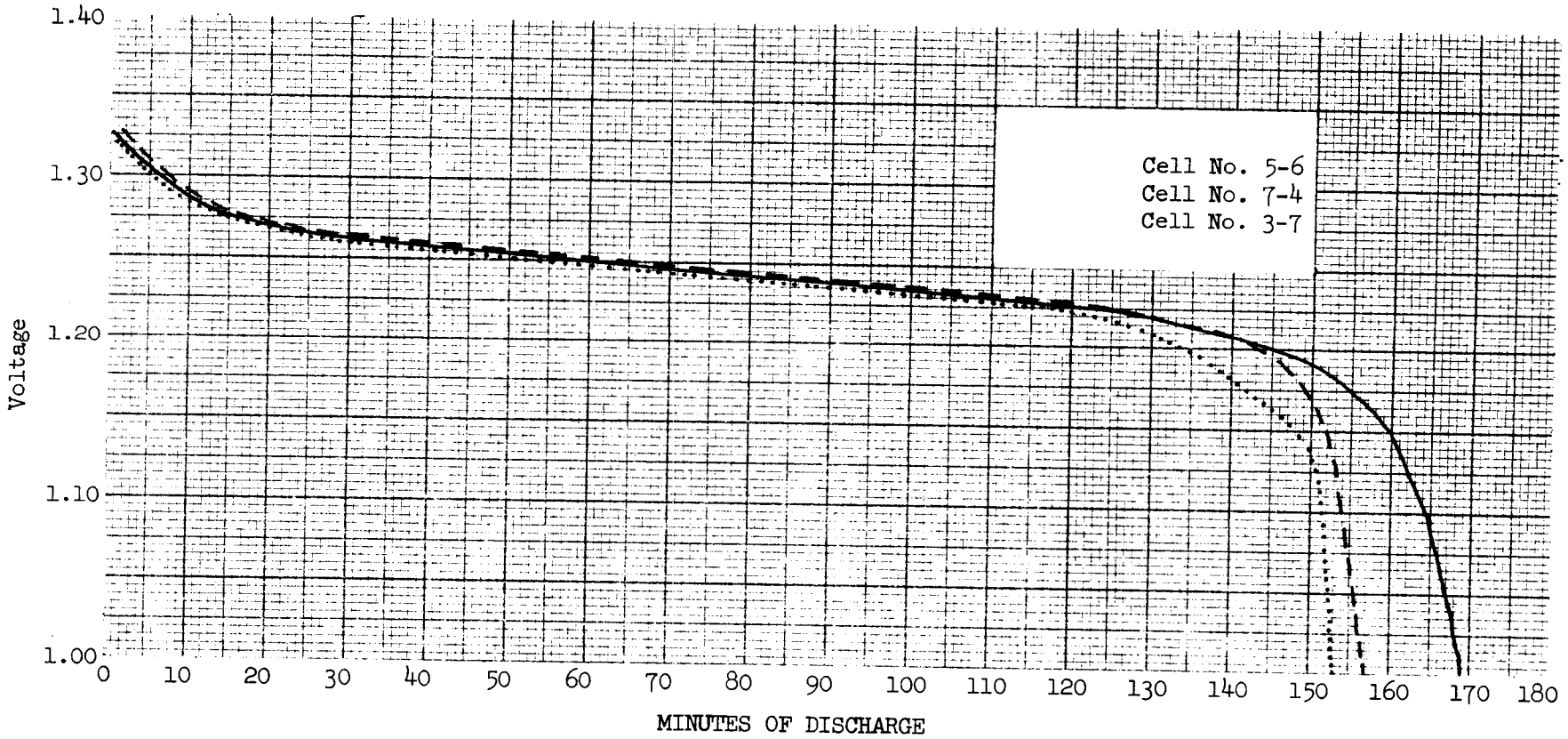


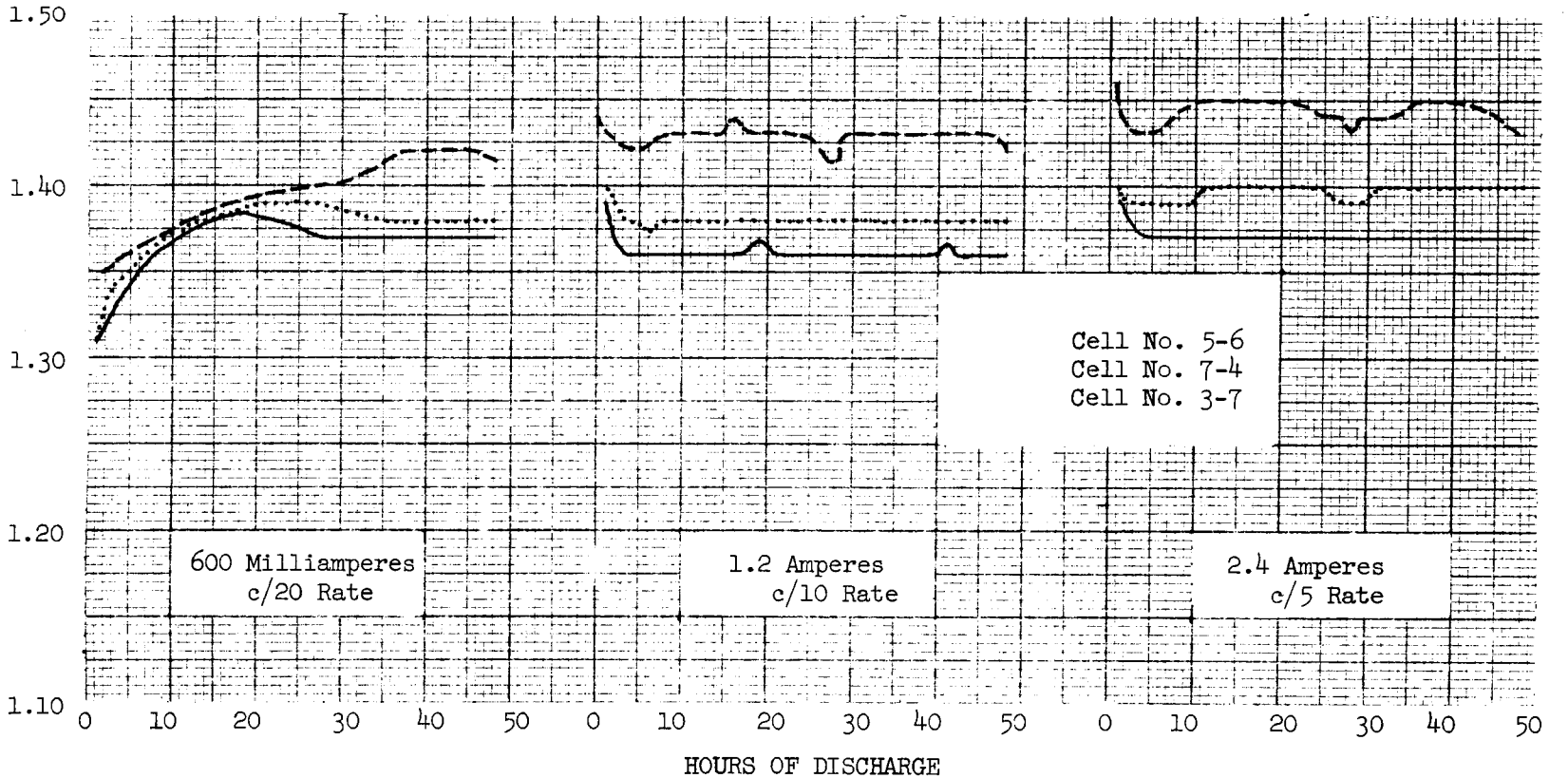
FIGURE 1



CHARACTERISTIC 2-HOUR RATE DISCHARGE

GENERAL ELECTRIC 12 AMPERE-HOUR AUXILIARY ELECTRODE NICKEL CADMIUM SEALED CELLS

FIGURE 2



CHARACTERISTIC 48-HOUR OVERCHARGE CURVES

GENERAL ELECTRIC 12 AMPERE-HOUR AUXILIARY ELECTRODE NICKEL CADMIUM SEALED CELLS

FIGURE 3

DISTRIBUTION LIST

COPY NO.	
1-6	National Aeronautics and Space Administration, Goddard Space Flight Center (Mr. Thomas Hennigan, Code 716.2), Greenbelt, Maryland 20771
7	National Aeronautics and Space Administration, (Mr. Ernst M. Cohn, Code RNW), Washington, D. C. 20546
8	National Aeronautics and Space Administration, (Mr. A. M. Greg Andrus, Code FC), Washington, D. C. 20546
9-11	National Aeronautics and Space Administration, Scientific and Technical Information Facility (NASA Representative), College Park, Maryland 20740
12	National Aeronautics and Space Administration, Goddard Space Flight Center (Mr. Joseph Sherfey, Code 735), Greenbelt, Maryland 20771
13	National Aeronautics and Space Administration, Langley Research Center, Instrument Research Division (Mr. John L. Patterson, MS234), Hampton, Virginia 23365
14	National Aeronautics and Space Administration, Langley Research Center, Instrument Research Division (Mr. M. B. Seyffert, MS 112), Hampton, Virginia 23365
15	National Aeronautics and Space Administration, Lewis Research Center (Mr. N. D. Sanders, MS 302-1), 21000 Brookpark Road, Cleveland, Ohio 44135
16	National Aeronautics and Space Administration, Lewis Research Center (Mr. R. L. Cummings, MS 500-201), 21000 Brookpark Road, Cleveland, Ohio 44135
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18	National Aeronautics and Space Administration, George C. Marshall Space Flight Center (Mr. Philip Youngblood), Huntsville, Alabama 35812
19	National Aeronautics and Space Administration, George C. Marshall Space Flight Center (Mr. Richard Boehme, Building 4487-BB), Huntsville, Alabama 35812

20 National Aeronautics and Space Administration, Manned Spacecraft Center, Propulsion and Energy Systems Branch (Mr. William R. Dusenbury, Building 16, Site 1), Houston, Texas 77058

21 National Aeronautics and Space Administration, Manned Spacecraft Center, Gemini Project Office (Mr. Robert Cohen), Houston, Texas 77058

22 National Aeronautics and Space Administration, Manned Spacecraft Center (Mr. Richard Ferguson, Code EP-5), Houston, Texas 77058

23 National Aeronautics and Space Administration, Manned Spacecraft Center (Mr. James T. Kennedy, Code EE-5), Houston, Texas 77058

24 National Aeronautics and Space Administration, Manned Spacecraft Center (Mr. Forrest E. Eastman, Code EE-4), Houston, Texas 77058

25 National Aeronautics and Space Administration, Manned Spacecraft Center (Mr. Barry Trout), Houston, Texas 77058

26 National Aeronautics and Space Administration, Ames Research Center, Pioneer Project (Mr. James R. Swain and Mr. A. S. Hertzog), Moffett Field, California 94035

27 National Aeronautics and Space Administration, Ames Research Center, Biosatellite Project (Mr. Jon Rubenzer), Moffett Field, California 94035

28 National Aeronautics and Space Administration, Electronics Research Center, Power Systems Laboratory (Dr. Schwartz, 575 Technology Square, Cambrdige, Massachusetts 02139

29 Jet Propulsion Laboratory (Mr. Aiji Uchiyama), 4800 Oak Grove Drive, Pasadena, California 91103

30 Commanding Officer, U. S. Army Engineer R&D Labs., Electrical Power Branch (Code SMOFB-EP), Fort Belvoir, Virginia 22060

31 Commanding Officer, U. S. Army Electronics R & D Labs., Power Sources Division (Code SELRA/SL-PS), Fort Monmouth, New Jersey 07003

32 Research Office, Rand D. Directorate, Army Weapons Command (Mr. G. Riensmith, Chief), Rock Island, Illinois 61201

33 U. S. Army Research Office (Dr. Wilhelm Jorgensen), Box CM, Duke Station, Durham, North Carolina 27706

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