EVALUATION PROGRAM

for

SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
GULTON INDUSTRIES, INCORPORATED
12 & 20 AMPERE-HOUR ADHYDRODE 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
GULTON INDUSTRIES INCORPORATED
12 & 20 AMPERE-HOUR ADHYDRODE CELLS

QE/C 67-1 21 JANUARY 1967

PREPARED UNDER THE DIRECTION OF

E. C. Bruess

E. C. BRUESS
Manager, Electrochemical

APPROVED BY

C. M. AUSTIN
By direction

Enclosure (1)

REPORT BRIEF

GULTON 12 AND 20 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM SECONDARY SPACECRAFT CELLS

Ref: (a) National Aeronautics and Space Administration Purchase Order Number 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 Gulton Industries, Inc. 12 and 20 ampere-hour Adhydrode 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. Twenty-two 12 ampere-hour and twenty 20 ampere-hour cells were purchased from Gulton Industries, Inc., Metuchen, New Jersey, by National Aeronautics and Space Administration (NASA). These cells are rated at 12 and 20 ampere-hours respectively by the manufacturer and include the adhydrode or absorption hydrogen type auxiliary electrode.

II. CONCLUSIONS.

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

1. The ceramic seals of these cells, manufactured by Gulton Industries, Inc. are satisfactory as evidenced by no leakers out of the 42 cells tested.

2. The capacities of the cells were in the acceptable range of 14.82 to 16.50 ampere-hours for the 12 ampere-hour cells and 23.30 to 28.70 ampere-hours for the 20 ampere-hour cells respectively.

III. RECOMMENDATIONS.

A. It is recommended that these Gulton Industries, Inc. 12 and 20 ampere-hour adhydrode cells be accepted on the basis of the acceptance test results.

RESULTS OF ACCEPTANCE TESTS

OF

12 AND 20 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM

SECONDARY SPACECRAFT CELLS

MANUFACTURED BY

GULTON INDUSTRIES, INC.

I. INTRODUCTION.

A. On 18 July 1966, this activity began acceptance tests on twenty-two 12 ampere-hour and twenty 20 ampere-hour cells. These tests were completed on 17 August 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 Adhydrode.
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 167 to 199, although not consecutively, for the 12.0 ampere-hour cells and from 121 to 140 consecutively for the 20.0 ampere-hour cells.

B. The 12.0 and 20.0 ampere-hour adhydrode cells are both rectangular in shape with average heights (base to top of positive terminal), lengths, widths and weights as follows:

Type	Height (Inches)	Length (Inches)	Width (Inches)	Weight (Grams)
12.0 A.H.	4.623	0.890	2.975	569.5
20.0 A.H.	7.120	0.888	2.986	925.6

The individual cell dimensions and weights are given in Tables I and II for the 12.0 and 20.0 ampere-hour cells respectively. Figure 1 is a photograph showing both the Gulton Industries, Inc. 12.0 and 20.0 ampere-hour adhydrode cells.

C. The cell containers or cans, and the cell covers are made of cold rolled steel. Both terminals on each battery type are insulated from the cell covers by ceramic seals and protrude through the cover as solder type terminals.

D. These cells, rated by the manufacturer at 12.0 and 20.0 ampere-hours respectively, were supplied in a discharged (with shorting wire) condition.

IV. TEST PROCEDURES 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. This test was performed with a phenolphthalein spray indicator solution of one-half of one percent concentration.

2. There were no signs of leakage on any of the 42 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 checks 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 adhydrode, 51 ohms resistance was used between the adhydrode and the negative terminal for the first capacity check; 24 ohms was used for the second capacity check; and an open circuit of infinite resistance was used for the third capacity check.

3. Since complete capacity data, including adhydrode 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 12 ampere-hour individual cell capacities ranged from 14.82 to 16.50 ampere-hours for an average of 15.78 ampere-hours. The 20 ampere-hour individual cell capacities ranged from 23.30 to 28.70 ampere-hours for an average of 26.20 ampere-hours. The cell capacities together with the adhydrode voltage characteristics for the 12 and 20 ampere-hour cells are tabulated in Tables III and IV respectively. Characteristic 2-hour rate discharge curves for the two types are shown in Figures 2 and 3.

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 the 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 a 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 voltages, 24 hours after removal of the shorting resistors, ranged from 1.17 to 1.20 volts for an average of 1.19 volts on the 12 ampere-hour cells and from 1.20 to 1.21 volts for an average of 1.20 volts on the 20 ampere-hour cells.

4. There were no rejects of any of the cells subjected to the cell short test. The voltage values for the 42 accepted cells are shown in Tables III and IV.

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 42 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 Tables III and IV. Characteristic overcharge voltage curves are shown in Figures 4 and 5.

F. Internal Resistance Test of the Adhydrode.

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

2. During the c/10 charge rate portion of the overcharge test; the voltage drop across the 51 ohm resistor connecting the adhydrode to the negative terminal was measured. The 51 ohm 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 adhydrode 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 resistor.
I1 = current flow in amperes through the 51 ohm resistor.
I2 = current flow in amperes through the 0.9808 ohm resistor.

3. The internal resistance value for the adhydrode of each cell is shown in Tables V and VI. The values range from 5.46 to 14.04 ohms and from 4.39 to 12.32 ohms for the 12 and 20 ampere-hour cells respectively.

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 amperes.

3. The internal resistance value for each cell is shown in Tables V and VI. The values range from 0.88 to 3.51 milliohms and from 1.58 to 2.11 milliohms for the 12 and 20 ampere-hour cells respectively.

TABLE I

GULTON 12 AMPERE HOUR CELLS

Cell Number	Height (Inches)	Length (Inches)	Width (Inches)	Weight (Grams)
167	4.636	0.891	2.965	567.1
168	4.634	0.890	2.975	564.6
169	4.616	0.887	2.972	565.8
170	4.634	0.891	2.968	564.6
171	4.629	0.890	2.980	577.4
172	4.636	0.890	2.980	569.4
173	4.630	0.890	2.975	574.8
174	4.620	0.892	2.976	572.1
175	4.612	0.897	2.976	576.1
177	4.640	0.896	2.970	567.8
178	4.627	0.885	2.982	564.2
179	4.618	0.903	2.980	580.5
180	4.620	0.886	2.975	570.7
181	4.630	0.888	2.969	577.7
182	4.600	0.891	2.984	565.9
184	4.628	0.888	2.976	566.1
186	4.614	0.888	2.975	565.0
191	4.633	0.890	2.982	563.8
192	4.610	0.886	2.970	562.9
196	4.616	0.900	2.971	576.2
198	4.589	0.884	2.972	562.9
199	4.639	0.894	2.971	573.8

TABLE II

GULTON 20 AMPERE HOUR CELLS

Cell Number	Height (Inches)	Length (Inches)	Width (Inches)	Weight (Grams)
121	7.130	0.895	2.989	931.5
122	7.109	0.889	2.988	922.0
123	7.128	0.885	2.980	921.3
124	7.128	0.889	2.988	918.2
125	7.104	0.894	2.991	928.7
126	7.100	0.884	2.986	921.7
127	7.118	0.890	2.986	929.5
128	7.112	0.894	2.993	920.0
129	7.125	0.885	2.986	920.4
130	7.108	0.889	2.975	935.5
131	7.120	0.889	2.977	923.1
132	7.125	0.883	2.985	927.2
133	7.107	0.890	2.984	926.7
134	7.129	0.880	2.983	917.3
135	7.135	0.889	3.000	931.3
136	7.141	0.889	2.982	931.0
137	7.110	0.884	2.980	932.2
138	7.136	0.885	2.994	923.8
139	7.104	0.894	2.992	923.7
140	7.123	0.884	2.990	925.6

GULTON 12 A.H. 3RD ELECTRODE

QE/C 67-1

TABLE III

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
167	1.42	0.0032	14.28	1.46	0.0178	16.02	1.44	0	16.02	1.19	1.40	0.340	0.0067	1.42	0.390	0.0076	1.42	0.629	0.0123
168	1.42	0.0001	14.10	1.46	0.0040	15.72	1.44	0	15.60	1.19	1.40	0.377	0.0074	1.41	0.539	0.0106	1.41	0.725	0.0142
169	1.42	0.0041	13.62	1.46	0.0153	15.42	1.44	0	15.48	1.19	1.40	0.410	0.0080	1.41	0.560	0.0110	1.42	0.753	0.0148
170	1.42	0.0006	13.20	1.46	0.0175	15.12	1.44	0	14.52	1.18	1.40	0.540	0.0106	1.41	0.701	0.0137	1.41	0.806	0.0158
171	1.42	0.0004	12.42	1.46	0.0167	15.60	1.44	0	15.12	1.18	1.40	0.560	0.0110	1.41	0.769	0.0151	1.42	0.837	0.0164
172	1.41	0.0013	12.00	1.47	0.0160	15.78	1.45	0	15.42	1.19	1.40	0.410	0.0080	1.42	0.549	0.0108	1.42	0.676	0.0133
173	1.41	0.0004	12.60	1.46	0.0144	16.02	1.44	0	15.90	1.19	1.40	0.400	0.0078	1.41	0.690	0.0135	1.42	0.830	0.0163
174	1.42	0.0013	12.78	1.46	0.0158	15.78	1.44	0	15.72	1.19	1.40	0.450	0.0088	1.41	0.612	0.0120	1.42	0.740	0.0145
175	1.43	0.0031	13.92	1.46	0.0166	15.48	1.45	0	14.52	1.19	1.40	0.584	0.0115	1.42	0.741	0.0145	1.42	0.811	0.0159
177	1.43	0.0023	13.80	1.46	0.0171	15.48	1.44	0	15.00	1.17	1.40	0.510	0.0100	1.41	0.671	0.0132	1.42	0.801	0.0157
178	1.43	0.0018	13.92	1.45	0.0153	14.82	1.44	0	14.40	1.19	1.40	0.430	0.0084	1.42	0.561	0.0110	1.43	0.676	0.0133
179	1.40	0.0051	15.78	1.44	0.0150	15.48	1.43	0	14.40	1.20	1.41	0.399	0.0078	1.43	0.666	0.0131	1.43	0.815	0.0160
180	1.44	0.0056	15.78	1.44	0.0155	15.30	1.43	0	14.58	1.18	1.41	0.474	0.0093	1.43	0.616	0.0121	1.42	0.755	0.0148
181	1.40	0.0043	15.78	1.44	0.0154	16.08	1.44	0	15.18	1.18	1.41	0.460	0.0090	1.42	0.567	0.0111	1.41	0.697	0.0137
182	1.40	0.0057	15.60	1.45	0.0162	15.78	1.44	0	14.70	1.20	1.41	0.547	0.0107	1.42	0.717	0.0141	1.41	0.808	0.0158
184	1.40	0.0051	15.90	1.44	0.0100	16.38	1.44	0	15.60	1.19	1.41	0.510	0.0100	1.42	0.656	0.0129	1.41	0.767	0.0150
186	1.44	0.0059	15.78	1.44	0.0168	15.18	1.43	0	14.70	1.17	1.41	0.446	0.0087	1.42	0.651	0.0128	1.41	0.802	0.0157
191	1.44	0.0068	15.60	1.44	0.0186	14.58	1.43	0	13.68	1.20	1.41	0.660	0.0129	1.42	0.793	0.0155	1.41	0.828	0.0162

TABLE III (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
192	1.43	0.0057	15.90	1.45	0.0168	15.60	1.44	0	14.82	1.18	1.41	0.528	0.0104	1.42	0.733	0.0144	1.42	0.820	0.0161
196	1.40	0.0054	16.20	1.44	0.0148	15.72	1.44	0	14.52	1.19	1.41	0.395	0.0077	1.42	0.626	0.0123	1.41	0.797	0.0156
198	1.40	0.0047	16.02	1.44	0.0164	15.72	1.44	0	15.00	1.19	1.41	0.459	0.0090	1.43	0.623	0.0122	1.42	0.748	0.0147
199	1.40	0.0045	16.02	1.45	0.0138	16.50	1.45	0	15.72	1.20	1.41	0.340	0.0067	1.43	0.455	0.0089	1.43	0.699	0.0137

GULTON 20 A.H. 3RD ELECTRODE QE/C 67-1

TABLE IV

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
121	1.41	0.0050	24.20	1.44	0.0180	25.80	1.45	0	25.30	1.20	1.42	0.426	0.0084	1.44	0.556	0.0109	1.44	0.664	0.0130
122	1.42	0.0063	24.00	1.44	0.0181	25.50	1.43	0	25.00	1.20	1.42	0.427	0.0084	1.43	0.535	0.0105	1.43	0.634	0.0124
123	1.43	0.0073	23.80	1.44	0.0185	24.20	1.43	0	23.70	1.20	1.42	0.459	0.0090	1.44	0.587	0.0115	1.43	0.725	0.0142
124	1.44	0.0084	23.30	1.44	0.0176	22.50	1.44	0	22.20	1.20	1.42	0.487	0.0095	1.43	0.603	0.0118	1.43	0.749	0.0147
125	1.41	0.0048	24.00	1.45	0.0183	26.70	1.44	0	26.20	1.20	1.42	0.467	0.0092	1.43	0.604	0.0118	1.42	0.732	0.0144
126	1.42	0.0070	24.00	1.44	0.0188	24.80	1.44	0	24.30	1.20	1.42	0.460	0.0090	1.43	0.553	0.0108	1.43	0.685	0.0134
127	1.41	0.0050	24.20	1.45	0.0183	26.50	1.45	0	26.20	1.20	1.42	0.455	0.0089	1.43	0.562	0.0114	1.42	0.700	0.0137
128	1.44	0.0088	23.30	1.44	0.0172	22.50	1.43	0	21.80	1.20	1.42	0.507	0.0099	1.43	0.631	0.0124	1.43	0.760	0.0149
129	1.44	0.0079	23.30	1.43	0.0192	23.50	1.44	0	22.80	1.20	1.42	0.500	0.0098	1.43	0.627	0.0123	1.42	0.762	0.0149
130	1.41	0.0053	24.20	1.44	0.0208	25.70	1.44	0	25.00	1.20	1.42	0.500	0.0098	1.44	0.633	0.0124	1.43	0.771	0.0151
131	1.40	0.0051	23.80	1.45	0.0183	27.30	1.44	0	26.20	1.20	1.41	0.365	0.0072	1.43	0.490	0.0096	1.43	0.602	0.0118
132	1.40	0.0050	24.00	1.45	0.0175	27.50	1.44	0	26.30	1.20	1.41	0.377	0.0074	1.42	0.497	0.0097	1.43	0.592	0.0116
133	1.40	0.0051	24.00	1.45	0.0183	27.50	1.44	0	26.50	1.20	1.41	0.374	0.0073	1.42	0.522	0.0102	1.42	0.666	0.0131
134	1.43	0.0062	24.00	1.45	0.179	26.50	1.44	0	25.30	1.20	1.41	0.351	0.0069	1.42	0.476	0.0093	1.42	0.599	0.0117
135	1.40	0.0045	23.70	1.45	0.0183	27.70	1.44	0	24.00	1.21	1.42	0.410	0.0080	1.43	0.539	0.0106	1.42	0.626	0.0123
136	1.40	0.0050	24.00	1.45	0.0183	27.30	1.44	0	26.20	1.20	1.41	0.369	0.0072	1.42	0.505	0.0099	1.42	0.630	0.0124
137	1.40	0.0050	24.00	1.46	0.0167	28.70	1.45	0	27.30	1.20	1.41	0.348	0.0068	1.42	0.507	0.0099	1.42	0.656	0.0129
138	1.40	0.0049	24.00	1.45	0.0175	27.80	1.44	0	26.70	1.20	1.41	0.370	0.0072	1.42	0.507	0.0099	1.42	0.634	0.0124
139	1.40	0.0052	24.00	1.44	0.0188	27.30	1.44	0	26.00	1.20	1.41	0.446	0.0087	1.42	0.569	0.0112	1.42	0.674	0.0132
140	1.43	0.0053	24.00	1.45	0.0170	27.20	1.44	0	25.70	1.20	1.42	0.378	0.0074	1.43	0.505	0.0099	1.43	0.603	0.0118

TABLE V

GULTON 12 AMPERE HOUR CELLS

Cell Number	Auxiliary Electrode Resistance (ohms)	Cell Resistance (Milliohms)
167	10.05	1.75
168	5.46	1.75
169	6.51	1.75
170	6.53	1.75
171	5.86	1.75
172	7.18	1.75
173	10.02	2.63
174	4.69	2.63
175	5.95	2.63
177	6.34	1.75
178	6.89	2.63
179	10.02	1.75
180	6.43	1.75
181	5.99	1.75
182	6.77	0.88
184	6.61	2.63
186	13.29	2.63
191	7.75	2.63
192	14.04	3.51
196	10.30	1.75
198	6.86	2.63
199	6.76	1.75

TABLE VI

GULTON 20 AMPERE HOUR CELLS

Cell Number	Auxiliary Electrode Resistance (ohms)	Cell Resistance (Milliohms)
121	12.32	2.11
122	6.23	2.11
123	6.49	2.11
124	5.52	2.11
125	5.38	1.58
126	5.13	2.11
127	5.46	1.58
128	6.07	1.58
129	6.45	1.58
130	6.26	1.58
131	5.61	2.11
132	4.71	1.58
133	4.84	2.11
134	4.39	2.11
135	5.25	2.11
136	4.70	2.11
137	4.55	2.11
138	4.79	2.11
139	5.69	2.11
140	5.15	2.11

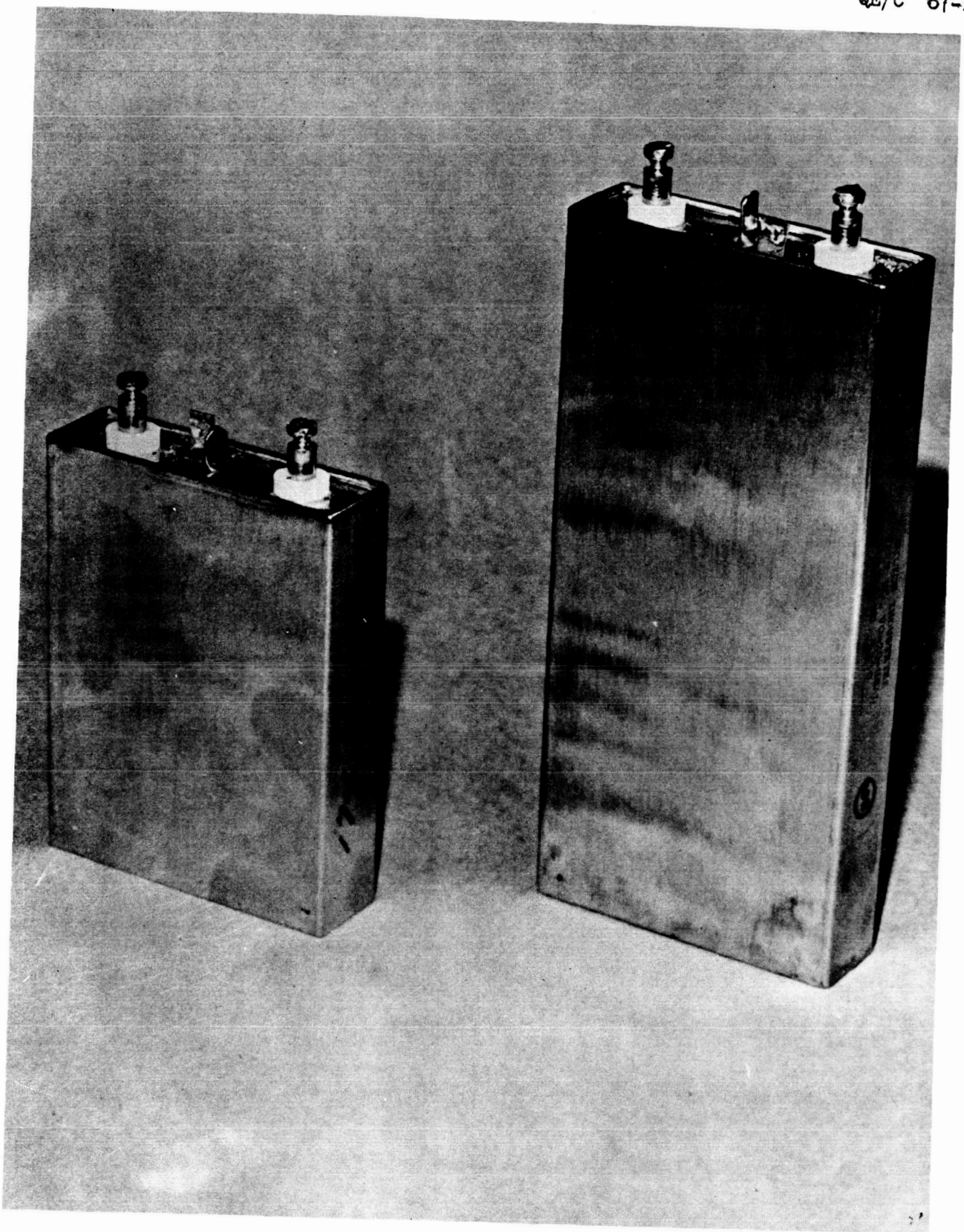
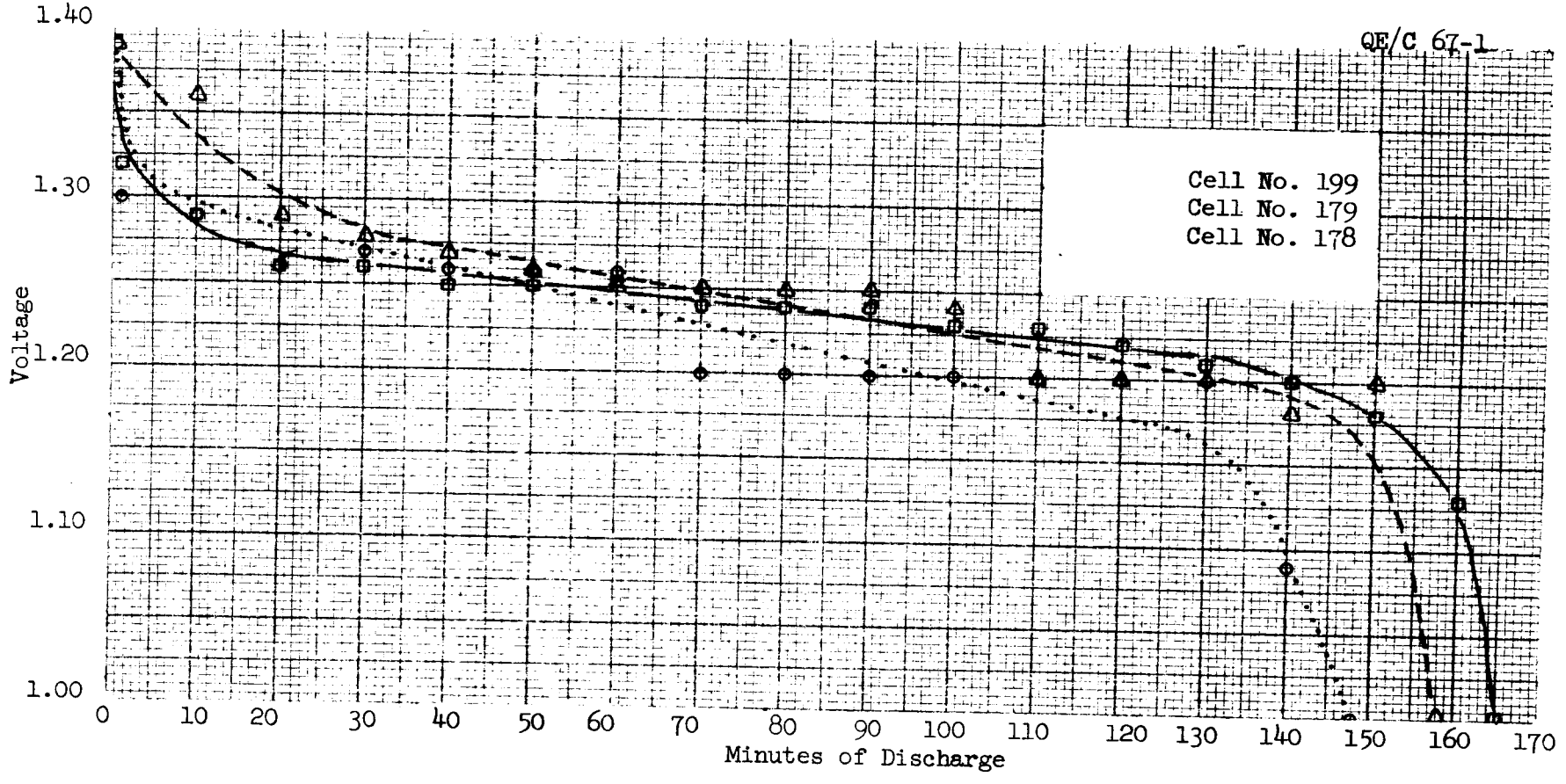


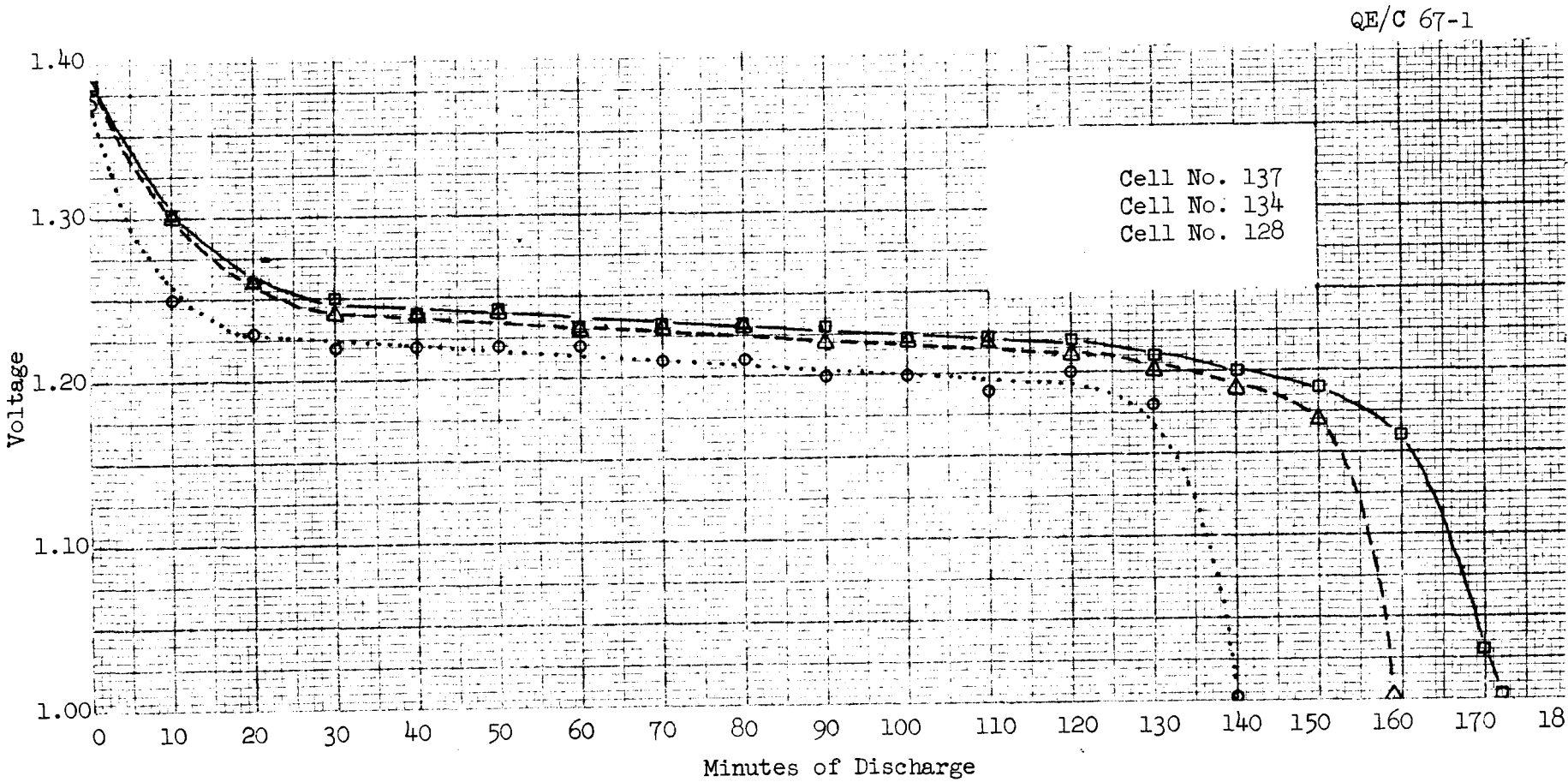
FIGURE 1



CHARACTERISTIC 2-HOUR RATE DISCHARGE

GULTON 12 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM SEALED CELLS

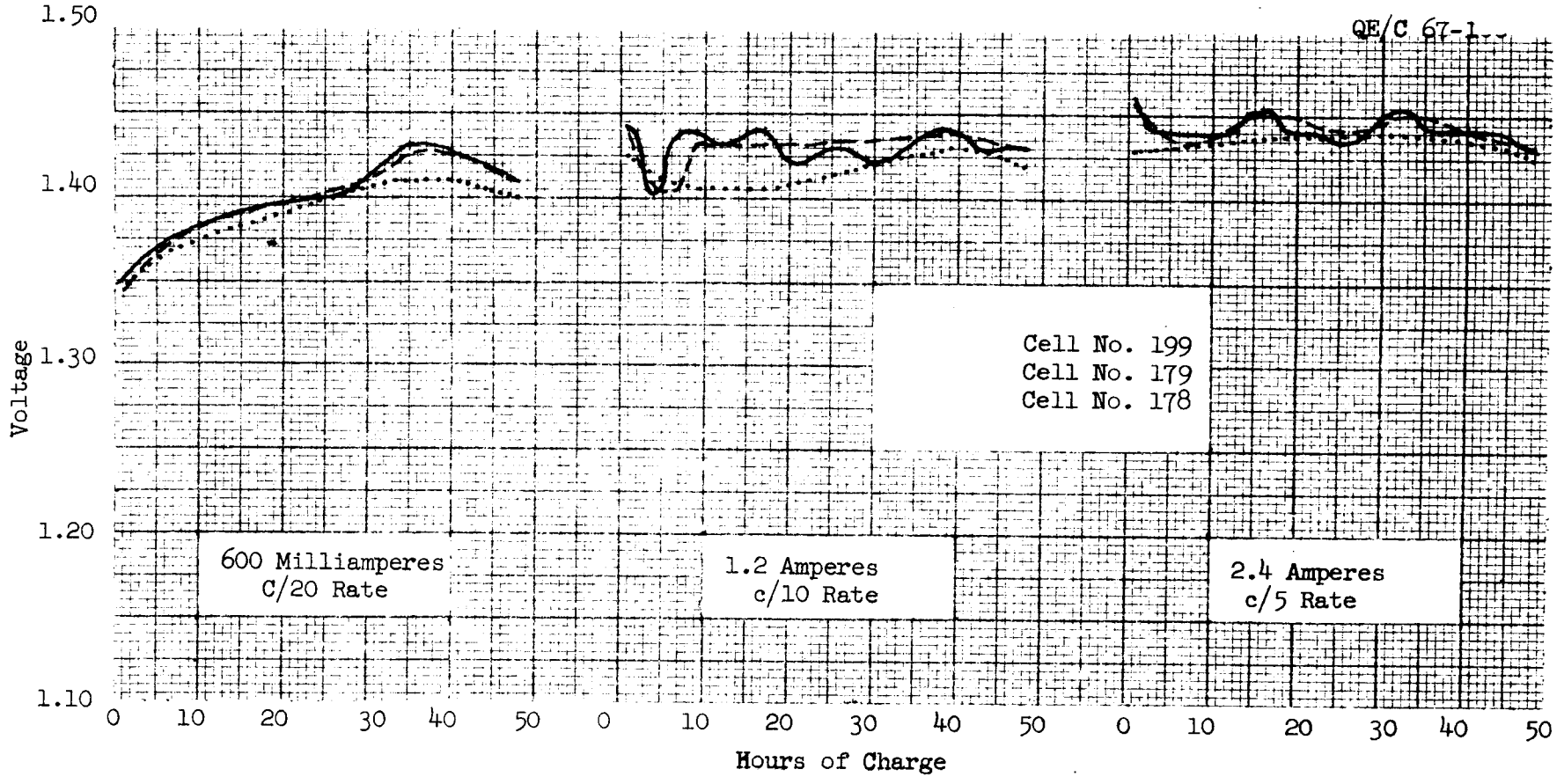
FIGURE 2



CHARACTERISTIC 2-HOUR RATE DISCHARGE

GULTON 20 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM SEALED CELLS

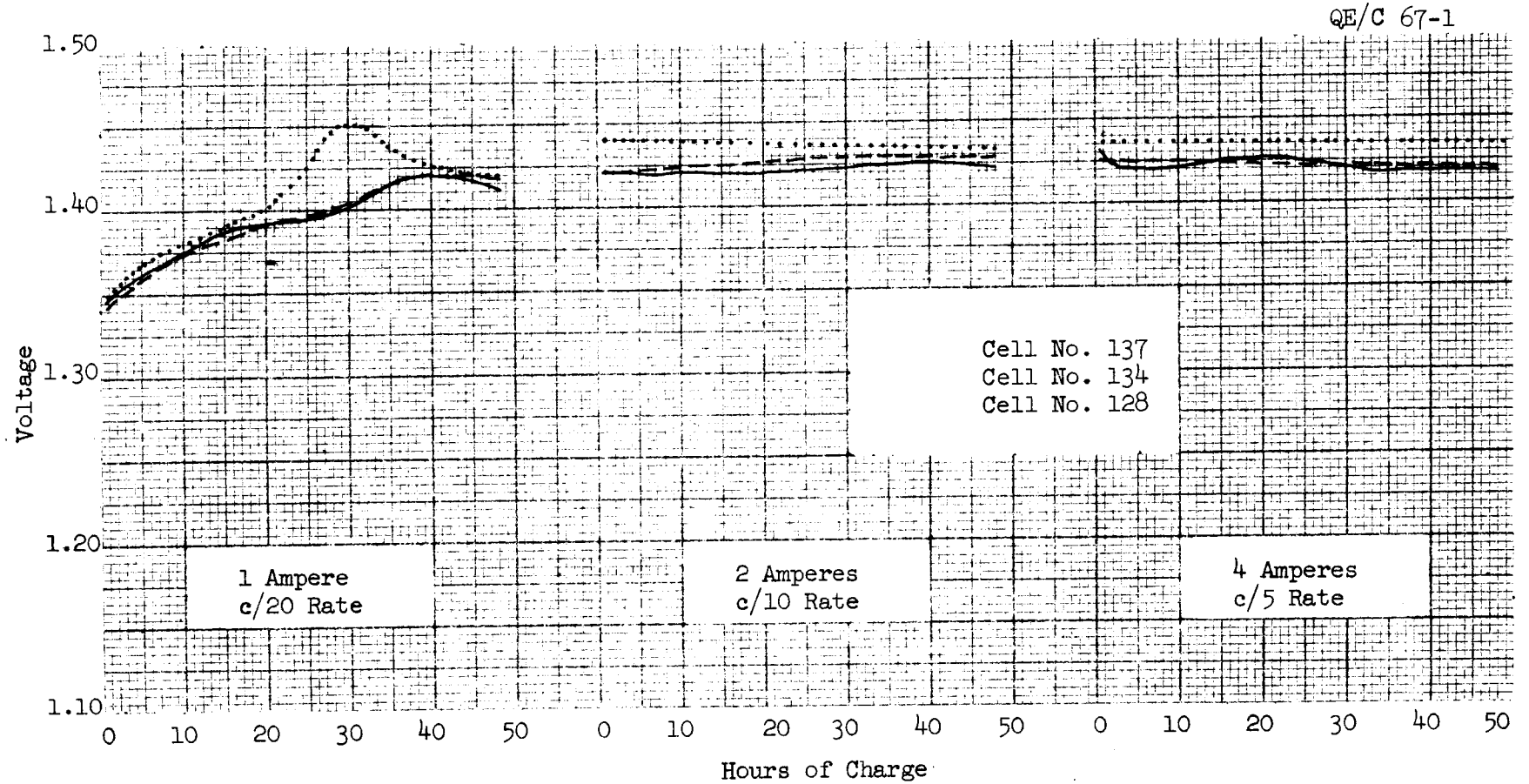
FIGURE 3



CHARACTERISTIC 48-HOUR OVERCHARGE CURVES

GULTON 12 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM SEALED CELLS

FIGURE 4



CHARACTERISTIC 48-HOUR OVERCHARGE CURVES

GULTON 20 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM SEALED CELLS

FIGURE 5

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, MS-234), 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
17	National Aeronautics and Space Administration, Lewis Research Center (Mr. R. R. Miller, MS-500-202), 21000 Brookpark Road, Celveland, Ohio 44135
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

34 Natick Laboratories, Clothing and Organic Materials Division (Mr. Robert N. Walsh and Mr. G. A. Spano), Natick, Massachusetts 01760

35 Harry Diamond Laboratories (Mr. Nathan Kaplan), Room 300, Building 92, Connecticut Avenue and Van Ness Street, N. W., Washington, D. C. 20438

36 Army Materiel Command, Research Division (Mr. John W. Crellin, Code AMCRD-RSCM-T-7), Washington, D. C. 20315

37 Army Materiel Command, Development Division (Mr. Marshall D. Aiken, Code AMCRD-DE-MO-P), Washington, D. C. 20315

38 U. S. Army TRECOM (Dr. R. L. Echols, Code SMOFE-PSG), Fort Eustis, Virginia 23604

39 U. S. Army TRECOM (Mr. Leonard M. Bartone, Code SMOFE-ASE), Fort Eustis, Virginia 23604

40 U. S. Army Mobility Command, Research Division (Mr. O. Renius, Code AMSMO-RR), Center Line, Michigan 48090

41 Office of Naval Research (Head, Power Branch, Code 429), Washington, D. C. 20360

42 Office of Naval Research, Department of the Navy (Mr. H. W. Fox, Code 425), Washington, D. C. 20360

43 Naval Research Laboratory (Dr. J. C. White, Code 6160), Washington, D. C. 20360

44 U. S. Navy, Marine Engineering Laboratory (Mr. J. H. Harrison), Annapolis, Maryland 21402

45 Commander, Naval Air Systems Command (Code 5368A, Mr. Whitewell T. Beatson), Department of the Navy, Washington, D. C. 20360

46 Commander, Naval Air Systems Command (Code 520, Mr. Milton Knight), Department of the Navy, Washington, D. C. 20360

47 Commander, Naval Ordnance Systems Command (Code 044, Mr. W. S. Koontz), Department of the Navy, Washington, D. C. 20360

48 Commanding Officer, U. S. Naval Ordnance Laboratory (Mr. William C. Spindler, Code 441), Corona, California 91720

49 Commander, U. S. Naval Ordnance Laboratory White Oak (Mr. Philip B. Cole, Code WB), Silver Spring, Maryland 20919

50 Commander, Naval Ship Systems Command (Mr. C. F. Viglotti, Code 6660S), Navy Department, Washington, D. C. 20360

51 Commander, Naval Ship Systems Command (Mr. Bernard B. Rosenbaum, Code 0342), Navy Department, Washington, D. C. 20360

52 Space Systems Division, Los Angeles Air Force Station (Code SSD), Los Angeles, California 90045

53 Flight Vehicle Power Branch, Aero Propulsion Laboratory (Mr. James E. Cooper), Wright-Patterson Air Force Base, Ohio 45433

54 Air Force Cambridge Research Lab. (Commander, CRO), L. G. Hanscom Field, Bedford, Massachusetts 07131

55 Rome Air Development Center, ESD (Mr. Frank J. Mollura, (Code RASSM), Griffiss Air Force Base, New York 13442

56 National Bureau of Standards (Dr. W. J. Hamer), Washington, D. C. 20234

57 Office, DDR&E, USE & BSS (Mr. G. B. Wareham), The Pentagon, Washington, D. C. 20310

58 U. S. Atomic Energy Commission, Army Reactor, DRD, (Mr. Donald B. Hoatson), Washington, D. C. 20545

59 Aerojet-General Corporation, Chemical Products Division (Dr. S. O. Rosenberg), Azusa, California 91702

60 Aeronutronic Division, Philco Corporation, Ford Road, Newport Beach, California 92260

61 Aerospace Corporation (Library), P. O. Box 94084 Los Angeles, California 90045

62 Allis-Chalmers Manufacturing Company (Dr. P. Joyner), 1100 South 70th Street, Milwaukee, Wisconsin 53201

63 American University, Chemistry Department (Dr. R. T. Foley), Massachussets & Nebraska Avenues, N. W., Washington, D. C. 20016

64 Arthur D. Little, Inc. (Dr. Ellery W. Stone), Acorn Park, Cambridge, Massachusetts 02140

65 Atomics International Division, North American Aviation, Inc. (Dr. H. L. Recht), 8900 Desota Avenue, Canoga Park, California 91304

66 Battelle Memorial Institute (Dr. C. L. Faust), 505 King Ave., Columbus, Ohio 43201

67 Bell Laboratories (Mr. B. B. Thomas and Dr. D. A. Feder), Murray Hill, New Jersey 07971

68 The Boeing Company, P. O. Box 98124, Seattle, Washington 98124

69 Borden Chemical Company, Central Research Laboratory, P. O. Box 9524, Philadelphia, Pennsylvania 19124

70 Burgess Battery Company (Dr. Howard J. Strauss), Foot of Exchange Street, Freeport, Illinois 61032

71 C & D Batteries, Division of ELTRA Corporation (Dr. Eugene Willihnganz), Conshohocken, Pennsylvania 19428

72 Calvin College (Prof. T. P. Dirkse), Grand Rapids, Michigan 49506

73 Catalyst Research Corporation (Mr. J. P. Wooley), 6101 Falls Road, Baltimore, Maryland 21209

74 ChemCell Inc. (Mr. Peter D. Richmond), 3 Central Avenue, East Newark, New Jersey 07029

75 Dayrad Laboratories (Mr. William Ingling), 1482 Stanley Ave., Dayton, Ohio 45404

76 Delco-Remy Division, General Motors Corporation (Dr. J. J. Lander), 2401 Columbus Avenue, Anderson, Indiana 46011

77 Douglas Aircraft Company, Inc., Astropower Laboratory (Dr. Carl Berger), 2121 Campus Drive, New Port Beach, California 92663

78 Dynatech Corporation (Mr. R. L. Wentworth), 17 Tudor Street, Cambridge, Massachusetts 02138

79 Eagle Picher Industries, Incorporated (Mr. E. M. Morse), P. O. Box 47, Joplin, Missouri 64802

80 Elgin National Watch Company (Mr. T. Boswell), 107 National Street, Elgin, Illinois 60120

81 The Electric Storage Battery Company, Missile Battery Division (Mr. A. Chreitzberg), 2610 Louisburg Road, Raleigh, North Carolina 27604

82 The Electric Storage Battery Company, Carl F. Norberg Research Division (Dr. R. A. Schaefer and Mr. W. S. Herbert), 19 West College Avenue, Yardley, Pennsylvania 19068

83 Electrochimica Corporation (Dr. Morris Eisenberg), 1140 O'Brien Drive, Menlo Park, California 94025

84 Electro-Optical Systems, Inc. (Mr. E. Findl), 300 North Halstead, Pasadena, California 91107

85 Emhart Manufacturing Company (Dr. W. P. Cadogan), Box 1620, Hartford, Connecticut 06101

86 Engelhard Industries, Inc. (Dr. J. G. Cohn), 497 DeLancy St., Newark, New Jersey 07105

87 Dr. Arthur Fleischer, 466 South Center Street, Orange, New Jersey 07050

88 General Electric Company, Advanced Technology Laboratory (Dr. R. C. Osthoff and Dr. W. Carson), Schenectady, New York 12301

89 General Electric Company, Missile and Space Division, Spacecraft Department (Mr. E. W. Kipp, Room T-2513), P. O. Box 8555, Philadelphia, Pennsylvania 19101

90 General Electric Company, Battery Products Section, P. O. Box, Gainesville, Florida 32601

91 General Electric Company, Research Laboratories, (Dr. H. Liebhafsky), Schenectady, New York 12301

92 General Electric Company, Research Laboratories, P. O. Box 1088, Schenectady, New York 12301

93 General Motors, Defense Research Labs (Dr. J. S. Smatko and Dr. C. R. Russell), 6767 Hollister Street, Santa Barbara, California 93105

94 Globe-Union, Incorporated, 900 East Keefe Avenue, Milwaukee, Wisconsin 53201

95 Gould-National Batteries, Incorporated, Engineering and Research Center (Mr. J. F. Donahue), 2630 University Ave., S. E., Minneapolis, Minnesota 55418

96 - 98 Gulton Industries, Alkaline Battery Division (Dr. Robert Shair), 212 Durham Avenue, Metuchen, New Jersey 08840

99 Hughes Aircraft Corporation (Mr. T. V. Carvey), Centinda Avenue and Teal Street, Culver City, California 90230

100 Hughes Aircraft Corporation (Mr. R. B. Robinson Bldg. 366, M. S. 524, El Segundo, California 90245

101 Hughes Research Laboratories Corporation, 3011 Malibu Canyon Road, Malibu, California 90265

102 ITT Research Institute (Dr. H. T. Francis), 10 West 35th Street, Chicago, Illinois 60616

103 Institute for Defense Analyses, R & E Support Division (Mr. R. Hamilton and Dr. Szego), 400 Army-Navy Drive, Arlington, Virginia 22202

104 Idaho State University, Department of Chemistry (Dr. G. Myron Arcand), Pocatello, Idaho 83201

105 Institute of Gas Technology (Mr. B. S. Baker), State and 34th Street, Chicago, Illinois 60616

106 Johns Hopkins University, Applied Physics Laboratory (Mr. Richard Cole), 8621 Georgia Avenue, Silver Spring, Maryland 20910

107 Johns Hopkins University, Applied Physics Laboratory (Mr. Louis Wilson), 8621 Georgia Avenue, Silver Spring, Maryland 20910

108 Johns Hopkins University, Applied Physics Laboratory (Document Librarian), 8621 Georgia Avenue, Silver Spring, Maryland 20910

109 Johns-Manville R & E Center (Mr. J. S. Parkinson), P. O. Box 159, Manville, New Jersey 08835

110 Leesona Moos Laboratories (Dr. H. Oswin), Lake Success Park, Community Drive, Great Neck, New York 11021

111 Livingston Electronic Corporation (Mr. William F. Meyers), Route 309, Montgomeryville, Pennsylvania 18936

112 Lockheed Missiles and Space Company (Library), 3251 Hanover Street, Palo Alto, California 93404

113 Mallory Battery Company (Mr. R. R. Clune), 60 Elm Street, North Tarryton, New York 10593

114 P. R. Mallory & Co., Inc. (Dr. Per Bro), Northwest Industrial Park, Burlington, Massachusetts 02103

115 P. R. Mallory & Co., Inc. (Technical Librarian), 3029 E. Washington Street, Indianapolis, Indiana 46206

116 Martin Company, Denver Division (P1001, Mr. R. C. Wildman), Mail No. P-6700-1 Denver, Colorado 80201

117 Melpar, Technical Information Center, 3000 Arlington Boulevard, Falls Church, Virginia 22046

118 Metals and Controls Division, Texas Instruments, Inc. (Dr. E. J. Jost), 34 Forest Street, Attleboro, Massachusetts 02703

119 Midwest Research Institute (Dr. B. W. Beadle), 425 Volker Boulevard, Kansas City, Missouri 64110

120 Monsanto Research Corporation (Dr. J. O. Smith), Everett, Massachusetts 02149

121 North American Aviation, Inc., Rocketdyne Division (Library), 6633 Canoga Avenue, Canoga Park, California 91303

122 North American Aviation, Inc. (Mr. Burton M. Otzinger), 12214 Lakewood Boulevard, Downey, California 90241

123 Dr. John Owen, P. O. Box 87, Bloomfield, New Jersey 07003

124 Paul Howard Associates Inc., Centerville, Maryland 21617

125 Power Information Center, University of Pennsylvania, Moore School Building, 200 South 33rd Street, Philadelphia, Pennsylvania 19104

126 Power Sources Division, Whittaker Corporation (Mr. M. Shaw), 9601 Canoga Avenue, Chatsworth, California 91311

127 Philco Corporation, Division of the Ford Motor Company (Dr. Phillip Cholet), Blue Bell, Pennsylvania 19422

128 Radiation Applications, Inc., 36040 37th Street, Long Island City, New York 11101

129 Radio Corporation of America, Astro Division (Mr. Seymour Winkler), Hightstown, New Jersey 08520

130 Radio Corporation of America (Mr. I. Schulman), P. O. Box 800, Princeton, New Jersey 08540

131 Radio Corporation of America (Dr. H. S. Lozier), Sommerville, New Jersey 08873

132 Republic Aviation Corporation, SMSD Division (Mr. Sam Abrahams), Farmingdale, Long Island, New York 11735

133 Southwest Research Institute (Dr. Jan Al), 8500 Culebra Road, San Antonio, Texas 78206

134 Sonotone Corporation (Mr. A. Mundel), Saw Mill River Road, Elmsford, New York 10523

135 Texas Instruments, Inc. (Dr. Isaac Trachtenberg), 13500 North Central Expressway, Dallas, Texas 75222

136 The Martin Company (Mr. Leslie Long, Mail #600), Middle-River, Maryland 21203

137 Thomas A. Edison Research Laboratory, McGraw Edison Company (Dr. P. F. Grieger), Watchung Avenue, West Orange, New Jersey 07052

138 TRW Systems, Inc. (Dr. A. Krausz, Bldg. 60, Room 929), One Space Park, Redondo Beach, California 90278

139 TRW Systems, Inc. (Dr. Herbert P. Silverman), One Space Park, Redondo Beach, California 90278

140 TRW, Inc. (Librarian), 23555 Euclid Avenue, Cleveland, Ohio 44117

141 Tyco Laboratories, Inc. (Mr. W. W. Burnett), Bear Hill, Hickory Drive, Waltham, Massachusetts 02154

142 Union Carbide Corporation, Development Laboratory Library, P. O. Box 6056, Cleveland, Ohio 44101

143 Union Carbide Corporation, Parma Research Center (Library), P. O. Box 6116, Cleveland, Ohio 44101

144 University of California, Space Science Laboratory (Dr. C. W. Tobias), Berkley, California 94270

145 Western Electric Company (Mr. R. T. Fiske), Suite 802, RCA Building, Washington, D. C. 20006

146 Westinghouse Electric Corporation, Research and Development Center, Churchill Borough, Pittsburg, Pennsylvania 15235

147 Whittaker Corporation (Mr. John Rhyne), P. O. Box 337, Newbury Park, California 91320

148 Whittaker Corporation, Power Sources Division (Mr. Burch Winder), 3850 Olive Street, Denver, Colorado 80237

149 Yardney Electric Corporation (Dr. George Dalin), 40-52 Leonard Street, New York, New York 10013