EVALUATION PROGRAM

for

SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST OF
GULTON INDUSTRIES
3.6 & 5.6 AMPERE-HOUR NICKEL CADMIUM CELLS
WITH VULCANIZED NEOPRENE TERMINAL SEALS

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 3.6 AND 5.6 AMPERE-HOUR NICKEL CADMIUM CELLS WITH VULCANIZED NEOPRENE TERMINAL SEALS

QE/C 66-69 28 JANUARY 1966

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Enclosure (1)

REPORT BRIEF

GULTON 3.6 AND 5.6 AMPERE-HOUR SEALED NICKEL-CADMIUM SECONDARY SPACECRAFT CELLS WITH VULCANIZED NEOPRENE TERMINAL SEALS

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 3.6 and 5.6 ampere-hour Secondary Spacecraft Cells with vulcanized neoprene terminal seals 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 3.6 ampere-hour and fifty 5.6 ampere-hour cells (manufacturer's ratings) were purchased from Gulton Industries, Inc., Metuchen, New Jersey by National Aeronautics and Space Administration (NASA). The terminals protrude through vulcanized neoprene seals.

II. CONCLUSIONS.

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

1. The vulcanized neoprene seals of these cells, manufactured by Gulton Industires, Inc., are satisfactory as evidenced by no leakers out of the 72 cells tested.

2. The weak point in the cell construction may be the cover to can weld as evidenced by the two leakers out of the 72 cells tested.

3. The capacity of the cells was in the acceptable range of 3.42 to 4.00 ampere-hours for the 3.6 ampere hour cells and 5.68 to 7.62 ampere-hours for the 5.6 ampere-hour cells.

III. RECOMMENDATIONS:

A. It is recommended that these Gulton Industries, Inc. 3.6 and 5.6 ampere-hour cells with vulcanized neoprene terminal seals be accepted on the basis of the acceptance test results.

RESULTS OF ACCEPTANCE TESTS

OF

3.6 AND 5.6 AMPERE-HOUR SEALED NICKEL-CADMIUM

SECONDARY SPACECRAFT CELLS

WITH VULCANIZED NEOPRENE TERMINAL SEALS

MANUFACTURED BY

GULTON INDUSTRIES, INC.

I. INTRODUCTION.

A. On 2 August 1965, this activity began acceptance tests on twenty-two 3.6 ampere-hour cells and fifty 5.6 ampere-hour cells. These tests were completed on 12 November 1965.

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.
7. 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. The cells were identified by the manufacturer's serial numbers although not consecutively. They were numbered as follows:

1. 3.6 ampere-hour (folded cover to terminal seal): 105 to 146 (22 cells).

2. 5.6 ampere-hour (folded cover to terminal seal): 101 to 151 (25 cells).

3. 5.6 ampere-hour (nonfolded seal): 101 to 143 (25 cells).

B. Both the 3.6 and 5.6 ampere-hour cells are cylindrical with average dimensions and weights as follows:

TYPE	LENGTH (Inches)	DIAMETER (Inches)	WEIGHT (Grams)
3.6 a.h. (folded cover seal)	2.271	1.313	156.9
5.6 a.h. (folded cover seal)	3.370	1.315	235.7
5.6 a.h. (nonfolded cover seal)	3.367	1.317	221.4

These weights include metal tabs for making electrical contact on the top and bottom of each cell.

C. The cell containers or cans of both sizes of cells and the cell covers are made of cold rolled steel. The positive terminal is insulated from the cell cover by a vulcanized neoprene bushing and protrudes through the bushing as a 1/8 inch projection. The vulcanized neoprene bushings used in the folded cover to terminal seals are longer than those used in the nonfolded cover to terminal seals to protrude through the sleeve formed by the inward fold at the center of the cover. This design results in a greater length of seal and affords greater protection to the seal from heat during welding of the cover to the can. The possible damage to the neoprene seal of either type cover to terminal seal, by attempting to solder electrical connections to the 1/8 inch positive terminals made it necessary to spot weld metal tabs to these terminals. Metal tabs were also spot welded to the bottom of the cans to serve as the negative terminals. Figure 1 is a photograph of these batteries.

D. The 3.6 and 5.6 ampere-hour cells were received in a partially 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 vulcanized neoprene 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 72 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. Since no capacity data was submitted by the manufacturer, it was not possible to compare the manufacturer's capacity values with those of this activity. The 3.6 ampere-hour individual cell capacities ranged from 3.42 to 4.00 ampere-hours for an average of 3.73 ampere-hours. The 5.6 ampere-hour, folded cover to terminal seal, individual cell capacities ranged from 5.68 to 7.62 ampere-hours for an average of 6.41 ampere-hours. The 5.6 ampere-hour, nonfolded cover to terminal seal, individual capacities ranged from 5.80 to 6.78 ampere-hours for an average of 6.36 ampere-hours. The cell capacities are tabulated in Tables I, II and III respectively. Their characteristic 2-hour rate discharge curves are shown in Figures 2, 3 and 4.

3. One 5.6 ampere-hour cell with the nonfolded cover to terminal seal was rejected because it was unable to accept the initial charge.

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 1.19 to 1.24 volts on the 3.6 ampere-hour cells for an average of 1.23 volts; from 1.22 to 1.24 volts on the 5.6 ampere-hour cells with the folded cover to terminal seal for an average of 1.23 volts; and from 1.19 to 1.25 volts on the 5.6 ampere-hour cells with the nonfolded cover to terminal seal for an average of 1.23 volts.

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

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 72 cells subjected to the immersion seal test.

E. Overcharge Test:

1. 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/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 voltages of each cell at the end of each 48-hour charge rate test are shown in Tables I, II and III. Characteristic overcharge curves are shown in Figures 5, 6 and 7.

4. Two 5.6 ampere-hour cells, one folded cover to terminal seal and one nonfolded cover to terminal seal, were rejected at the end of the overcharge sequence. Both cells leaked at the weld between the cell cover and the can.

F. Internal Resistance Test:

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 values for each cell are shown in Tables I, II and III. The values for the 3.6 ampere-hour cells range from 2.92 to 8.77 milliohms; for the 5.6 ampere hour (folded cover to terminal seal) cells range from 5.64 to 11.28 milliohms; and for the 5.6 ampere-hour (nonfolded cover to terminal seal) cells range from 3.76 to 13.16 milliohms.

TABLE I
GULTON 3.6 A.H. FOLDED NEOPRENE SEAL

CELL NUMBER	WEIGHT (GRAMS)	LENGTH (INCHES)	DIAMETER (INCHES)	CAPACITY TEST (A.H.)	CAPACITY TEST (A.H.)	CAPACITY TEST (A.H.)	CELL SHORT TEST (VOLTS)	IMMERSION SEAL TEST	OVERCHARGE c/20 (VOLTS)	OVERCHARGE c/10 (VOLTS)	OVERCHARGE c/5 (VOLTS)	INTERNAL RESISTANCE (MILLIOHMS)	IMMERSION SEAL TEST
105	155.0	2.280	1.316	3.80	3.74	3.54	1.23	O.K.	1.42	1.43	1.45	2.92	O.K.
106	155.0	2.275	1.312	3.77	3.46	3.26	1.23	O.K.	1.42	1.43	1.45	2.92	O.K.
111	155.0	2.270	1.315	3.77	3.64	3.36	1.23	O.K.	1.42	1.44	1.45	2.92	O.K.
113	156.0	2.275	1.309	3.77	3.36	3.24	1.23	O.K.	1.42	1.44	1.45	2.92	O.K.
114	158.9	2.275	1.308	3.96	3.64	3.33	1.23	O.K.	1.43	1.44	1.47	8.77	O.K.
115	156.5	2.260	1.312	3.77	3.54	3.30	1.23	O.K.	1.42	1.44	1.45	5.85	O.K.
116	155.0	2.275	1.310	3.77	3.44	3.26	1.22	O.K.	1.42	1.43	1.45	2.92	O.K.
118	156.5	2.265	1.316	3.77	3.50	3.34	1.23	O.K.	1.42	1.44	1.45	2.92	O.K.
122	152.2	2.268	1.310	3.46	3.24	3.02	1.23	O.K.	1.43	1.44	1.47	5.85	O.K.
125	155.0	2.272	1.316	3.77	3.30	3.20	1.22	O.K.	1.42	1.43	1.45	2.92	O.K.
127	157.0	2.271	1.312	3.64	3.33	3.19	1.24	O.K.	1.43	1.44	1.46	5.85	O.K.
129	158.0	2.279	1.315	3.73	3.47	3.28	1.24	O.K.	1.43	1.44	1.47	5.85	O.K.
131	157.2	2.258	1.313	4.00	3.65	3.42	1.24	O.K.	1.43	1.43	1.46	8.77	O.K.
133	158.5	2.280	1.315	3.67	3.26	3.10	1.23	O.K.	1.42	1.44	1.45	2.92	O.K.
134	157.5	2.266	1.315	3.74	3.51	3.28	1.24	O.K.	1.43	1.44	1.50	5.85	O.K.
135	159.0	2.280	1.312	3.67	3.60	3.64	1.19	O.K.	1.43	1.45	1.45	5.85	O.K.
138	161.0	2.275	1.312	3.67	3.20	3.10	1.23	O.K.	1.42	1.43	1.45	5.85	O.K.
139	156.5	2.264	1.310	3.42	3.28	3.10	1.24	O.K.	1.43	1.44	1.47	8.77	O.K.
140	157.0	2.268	1.315	3.67	3.34	3.14	1.23	O.K.	1.42	1.44	1.45	2.92	O.K.
142	159.2	2.272	1.315	3.69	3.47	3.24	1.24	O.K.	1.43	1.44	1.47	8.77	O.K.
145	158.0	2.278	1.315	3.78	3.55	3.28	1.24	O.K.	1.43	1.44	1.46	8.77	O.K.
146	156.2	2.265	1.312	3.73	3.47	3.24	1.24	O.K.	1.43	1.43	1.46	5.85	O.K.

TABLE II
GULTON 5.6 A.H. FOLDED NEOPRENE SEAL

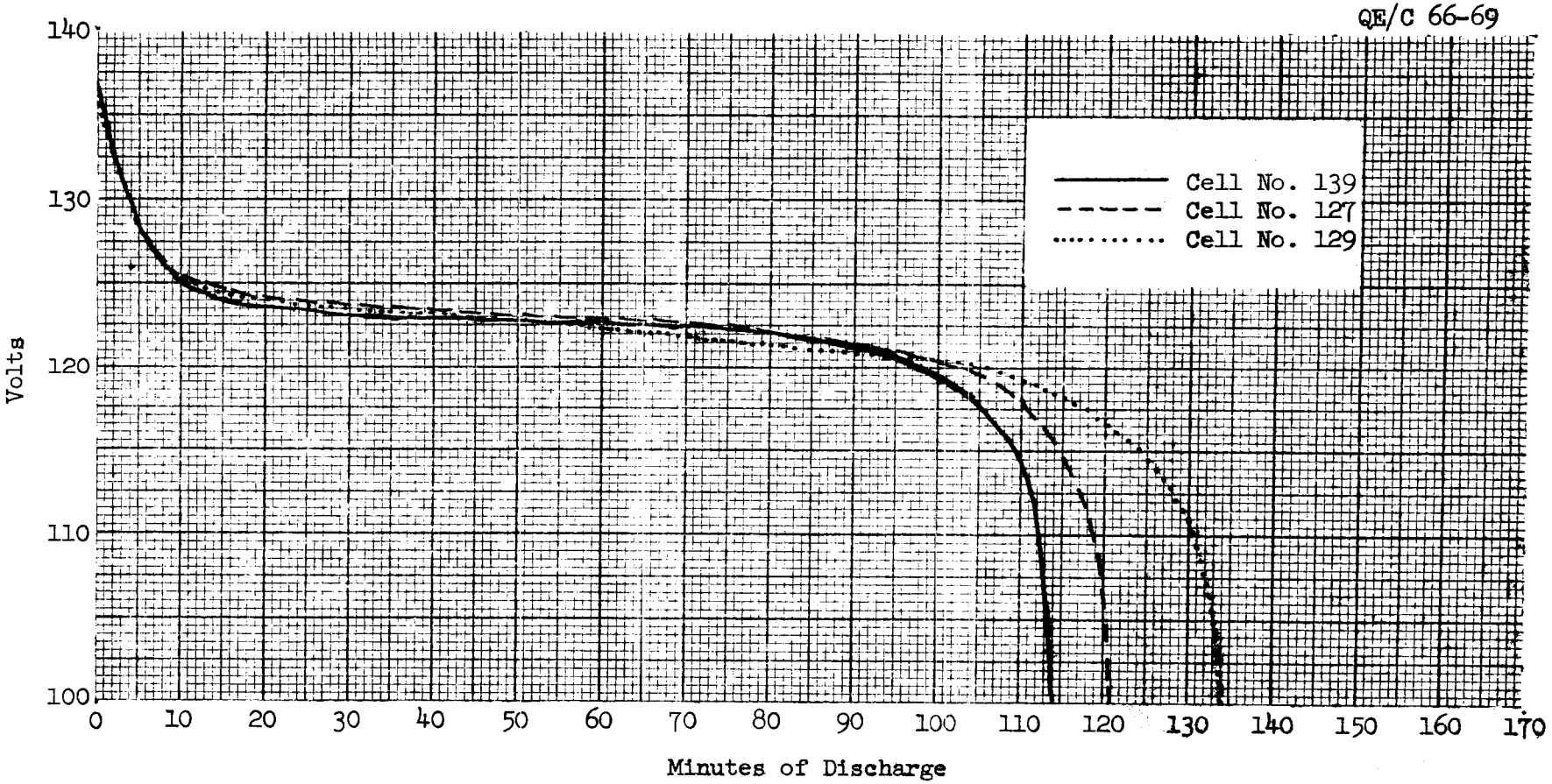
CELL NUMBER	WEIGHT (GRAMS)	LENGTH (INCHES)	DIAMETER (INCHES)	CAPACITY TEST (A.H.)	CAPACITY TEST (A.H.)	CAPACITY TEST (A.H.)	CELL SHORT TEST (VOLTS)	IMMERSION SEAL TEST	OVERCHARGE c/20 (VOLTS)	OVERCHARGE c/10 (VOLTS)	OVERCHARGE c/5 (VOLTS)	INTERNAL RESISTANCE (MILLIOHMS)	IMMERSION SEAL TEST
101	240.0	3.368	1.315	5.96	5.54	5.32	1.23	O.K.	1.42	1.44	1.45	9.40	O.K.
104	235.0	3.375	1.312	6.86	6.24	5.80	1.24	O.K.	1.41	1.43	1.43	11.28	O.K.
105	236.2	3.365	1.310	6.58	5.52	5.26	1.23	O.K.	1.40	1.44	1.44	9.40	O.K.
111	237.1	3.375	1.315	7.62	6.08	5.88	1.23	O.K.	1.40	1.41	1.42	9.40	O.K.
112	238.3	3.372	1.316	7.48	6.08	5.74	1.23	O.K.	1.40	1.41	1.43	7.52	O.K.
114	234.5	3.364	1.320	7.34	6.24	5.80	1.23	O.K.	1.40	1.41	1.42	11.28	O.K.
115	228.5	3.368	1.315	7.00	6.16	5.88	1.22	O.K.	1.40	1.42	1.43	9.40	O.K.
117	222.0	3.340	1.312	6.78	6.10	5.68	1.22	O.K.	1.42	1.43	1.44	9.40	O.K.
118	239.2	3.370	1.317	6.10	5.46	5.10	1.23	O.K.	1.41	1.42	1.43	7.52	O.K.
120	235.4	3.363	1.313	5.68	5.12	4.96	1.23	O.K.	1.41	1.42	1.44	7.52	O.K.
121	236.0	3.370	1.315	6.10	5.40	5.24	1.23	O.K.	1.41	1.43	1.44	7.52	O.K.
122	237.1	3.370	1.314	6.02	5.38	5.12	1.23	O.K.	1.41	1.42	1.44	7.52	O.K.
125	231.5	3.372	1.317	5.88	5.40	5.12	1.23	O.K.	1.41	1.42	1.44	9.40	O.K.
126	238.4	3.372	1.315	6.08	5.40	5.04	1.23	O.K.	1.41	1.42	1.44	11.28	O.K.
128	234.5	3.374	1.315	5.74	5.12	4.82	1.23	O.K.	1.41	1.42	1.43	11.28	O.K.
129	236.3	3.372	1.314	6.16	5.38	5.04	1.23	O.K.	1.41	1.42	1.43	9.40	O.K.
132	240.7	3.368	1.318	7.00	6.16	5.74	1.22	O.K.	1.41	1.42	1.44	9.40	O.K.
133	240.9	3.377	1.313	7.34	6.52	5.92	1.24	O.K.	1.41	1.42	1.43	5.64	O.K.
135	235.1	3.370	1.315	5.68	5.46	5.38	1.23	O.K.	1.42	1.43	1.44	9.40	O.K.
137	240.0	3.380	1.315	6.52	6.24	5.60	1.23	O.K.	1.42	1.43	1.44	9.40	O.K.
142	234.5	3.373	1.316	5.88	5.46	5.38	1.23	O.K.	1.42	1.43	1.44	7.52	O.K.
144	248.0	3.373	1.313	5.96	5.54	5.40	1.23	O.K.	1.42	1.43	1.44	5.64	O.K.
147	237.5	3.376	1.314	5.94	5.52	5.46	1.23	O.K.	1.42	1.43	1.44	7.52	O.K.
151	219.2	3.368	1.315	6.08	5.66	5.40	1.23	O.K.	1.42	1.44	1.45	9.40	O.K.

TABLE III
GULTON 5.6 A.H. NONFOLDED NEOPRENE SEAL

CELL NUMBER	WEIGHT (GRAMS)	LENGTH (INCHES)	DIAMETER (INCHES)	CAPACITY TEST (A.H.)	CAPACITY TEST (A.H.)	CAPACITY TEST (A.H.)	CELL SHORT TEST (VOLTS)	IMMERSION SEAL TEST	OVERCHARGE c/20 (VOLTS)	OVERCHARGE c/10 (VOLTS)	OVERCHARGE c/5 (VOLTS)	INTERNAL RESISTANCE (MILLIOHMS)	IMMERSION SEAL TEST
101	226.0	3.370	1.320	6.30	6.52	6.08	1.19	O.K.	1.42	1.44	1.45	7.52	O.K.
102	223.0	3.375	1.318	6.44	5.74	5.60	1.24	O.K.	1.42	1.44	1.45	11.28	O.K.
103	222.5	3.356	1.315	6.44	6.10	5.82	1.22	O.K.	1.42	1.44	1.45	11.28	O.K.
107	214.0	3.368	1.316	6.78	5.96	5.36	1.24	O.K.	1.40	1.42	1.44	13.16	O.K.
111	219.5	3.373	1.317	6.38	5.60	5.66	1.23	O.K.	1.42	1.44	1.46	9.40	O.K.
112	216.5	3.365	1.317	6.36	5.80	5.74	1.23	O.K.	1.42	1.44	1.46	11.28	O.K.
114	220.5	3.365	1.315	6.44	6.02	5.94	1.22	O.K.	1.42	1.44	1.46	9.40	O.K.
115	224.0	3.370	1.318	6.36	5.80	5.60	1.23	O.K.	1.42	1.46	1.45	11.28	O.K.
116	217.0	3.365	1.315	6.24	5.54	5.52	1.23	O.K.	1.42	1.44	1.46	11.28	O.K.
117	216.0	3.370	1.319	6.38	5.60	5.60	1.23	O.K.	1.42	1.46	1.46	11.28	O.K.
118	214.0	3.372	1.315	6.36	5.60	5.60	1.23	O.K.	1.42	1.44	1.45	13.16	O.K.
119	208.0	3.370	1.315	5.80	5.40	5.12	1.21	O.K.	1.42	1.44	1.45	9.40	O.K.
120	214.5	3.360	1.315	6.44	5.74	5.74	1.22	O.K.	1.42	1.44	1.46	9.40	O.K.
122	215.0	3.365	1.318	6.36	5.60	5.60	1.23	O.K.	1.42	1.44	1.46	11.28	O.K.
123	215.5	3.370	1.318	6.50	6.72	5.46	1.24	O.K.	1.41	1.44	1.44	9.40	O.K.
130	231.5	3.365	1.315	6.58	6.30	5.96	1.23	O.K.	1.41	1.44	1.44	5.64	O.K.
132	224.0	3.370	1.315	6.30	5.60	5.40	1.24	O.K.	1.41	1.44	1.44	5.64	O.K.
133	223.5	3.365	1.315	6.30	5.60	5.40	1.24	O.K.	1.41	1.44	1.44	3.76	O.K.
135	228.0	3.365	1.320	6.38	5.80	5.52	1.24	O.K.	1.42	1.44	1.44	7.52	O.K.
136	233.5	3.365	1.320	6.38	5.32	4.98	1.25	O.K.	1.41	1.42	1.43	11.28	O.K.
137	224.0	3.370	1.315	6.08	5.80	5.52	1.24	O.K.	1.42	1.44	1.44	9.40	O.K.
141	228.5	3.363	1.320	6.22	5.54	5.40	1.24	O.K.	1.42	1.43	1.43	7.52	O.K.
143	232.5	3.370	1.317	6.02	5.60	4.98	1.24	O.K.	1.42	1.44	1.44	7.52	O.K.


GULTON
IDEAS IN ACTION
R 360 FRS
SN 140
GULTON
IDEAS IN ACTION
R 560 FRS
SN 101

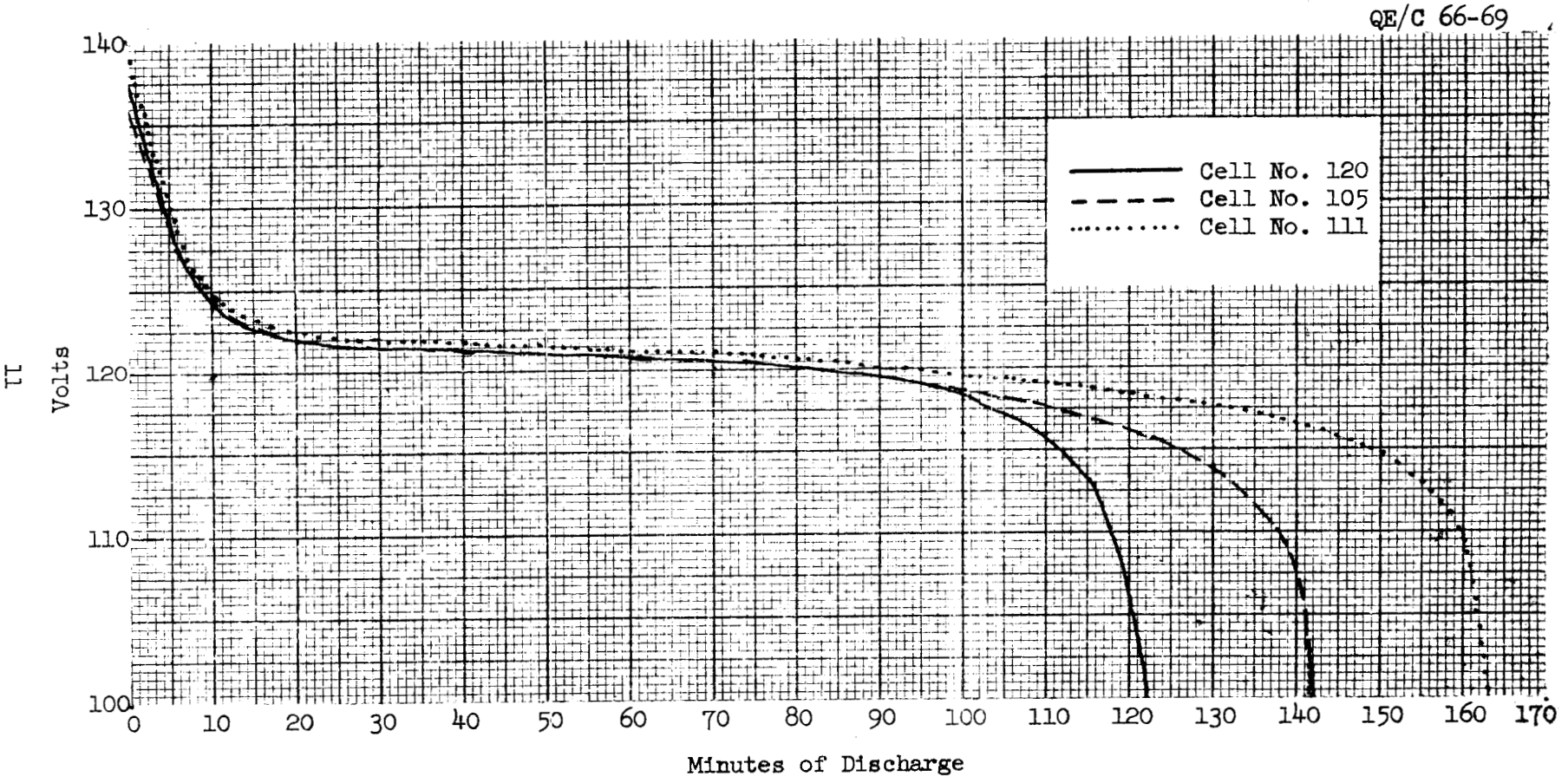
FIGURE 1



CHARACTERISTIC 2-HOUR RATE DISCHARGE CURVES

GULTON 3.6 AMPERE-HOUR NICKEL CADMIUM SEALED CELLS
(with folded neoprene seal)

FIGURE 2

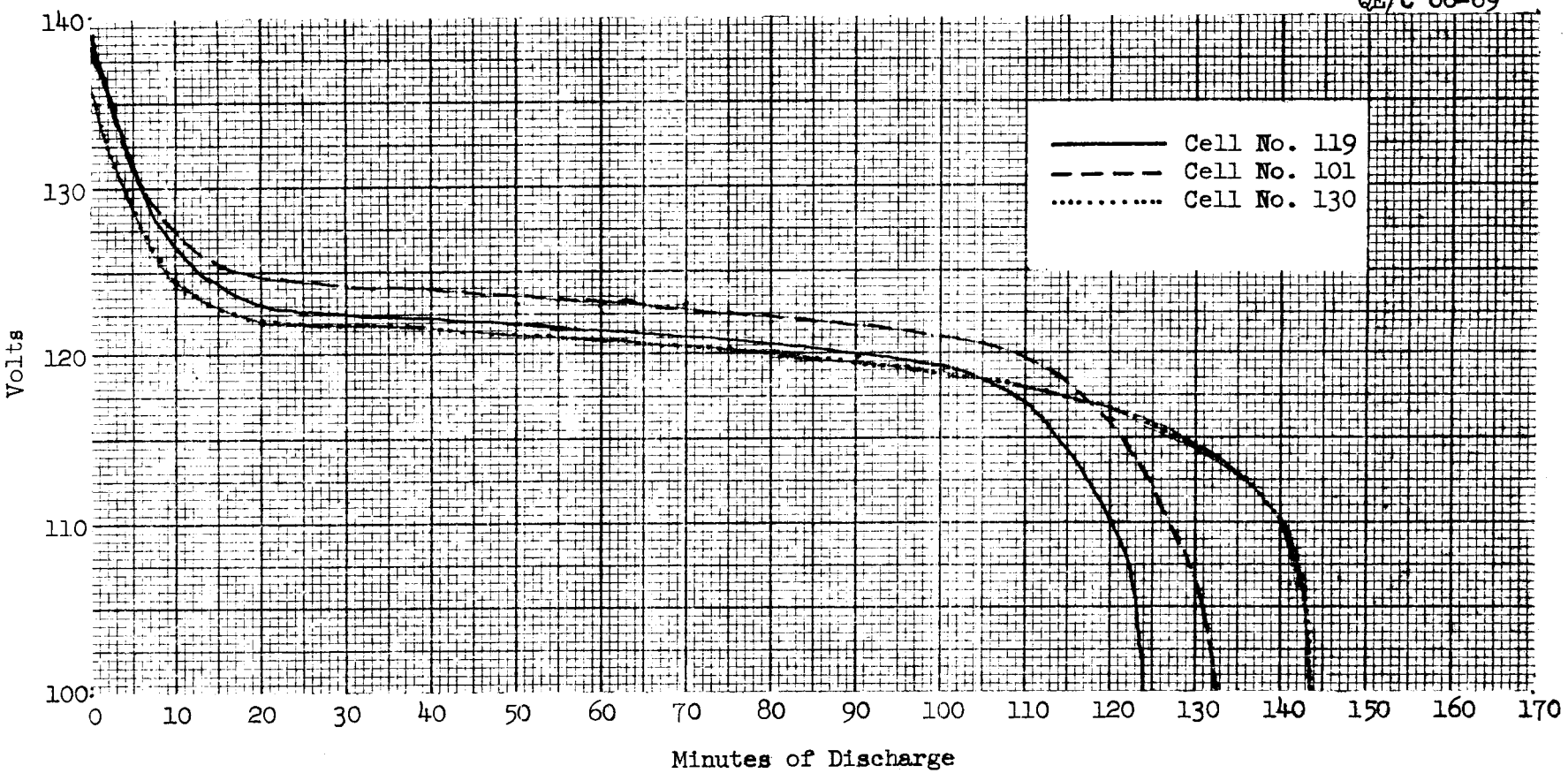


CHARACTERISTIC 2-HOUR RATE DISCHARGE CURVES

GULTON 5.6 AMPERE-HOUR NICKEL CADMIUM SEALED CELLS
(with folded neoprene seal)

FIGURE 3

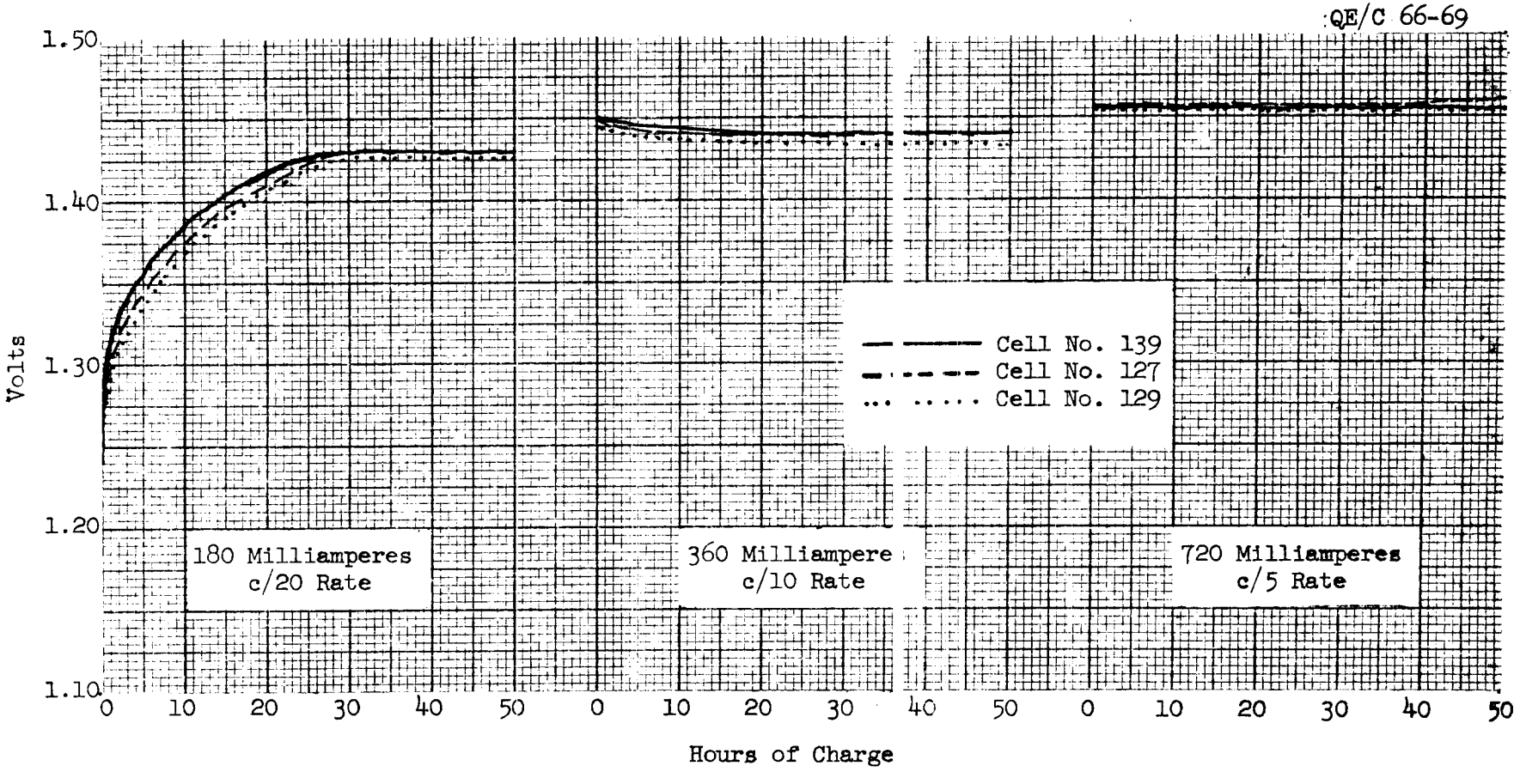
QE/C 66-69



CHARACTERISTIC 2-HOUR RATE DISCHARGE CURVES

GULTON 5.6 AMPERE-HOUR NICKEL CADMIUM SEALED CELLS
(with nonfolded neoprene seal)

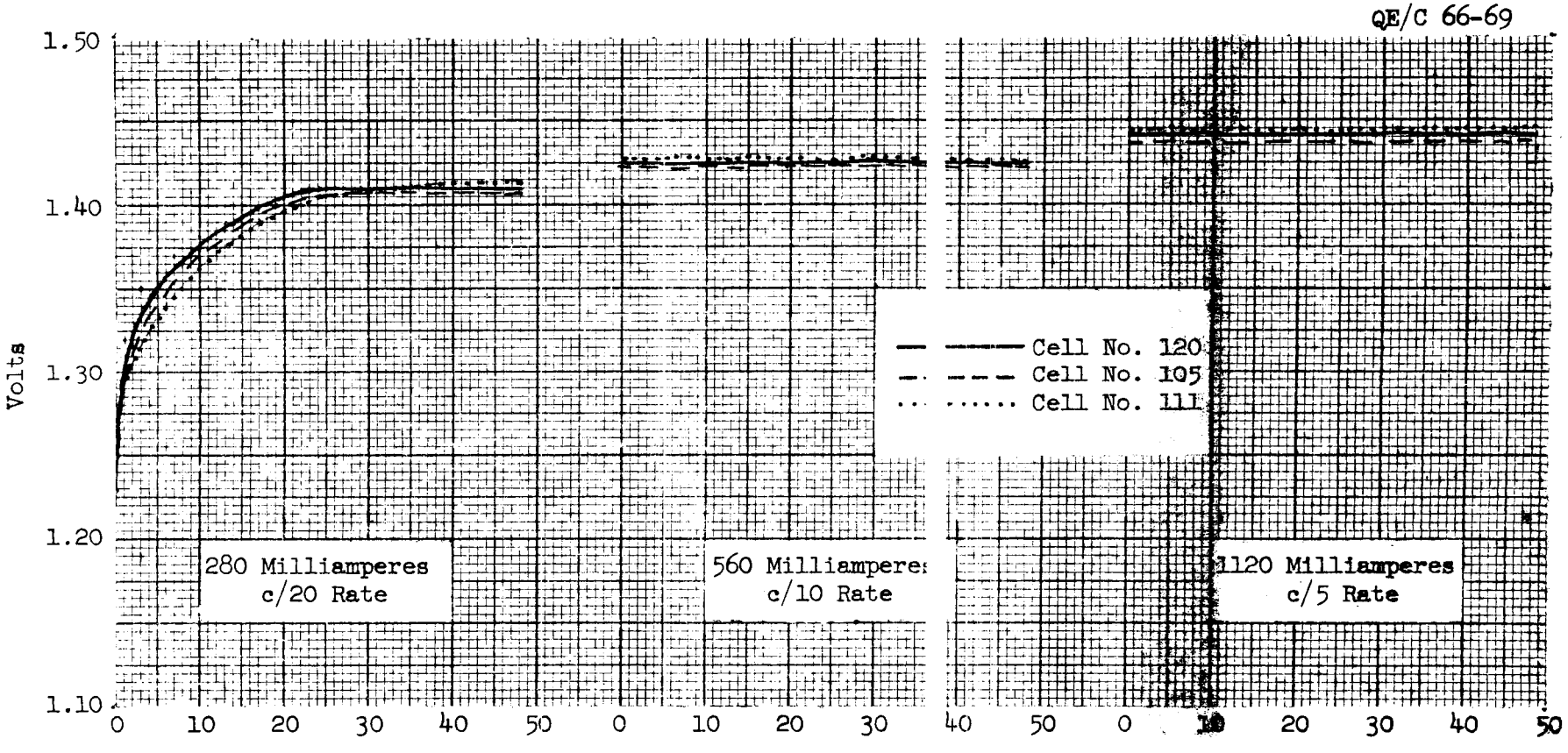
FIGURE 4



CHARACTERISTIC 48-HOUR OVER CHARGE CURVES

GULTON 3.6 AMPERE-HOUR NICKEL CADMIUM SEALED CELLS
(with folded neoprene seal)

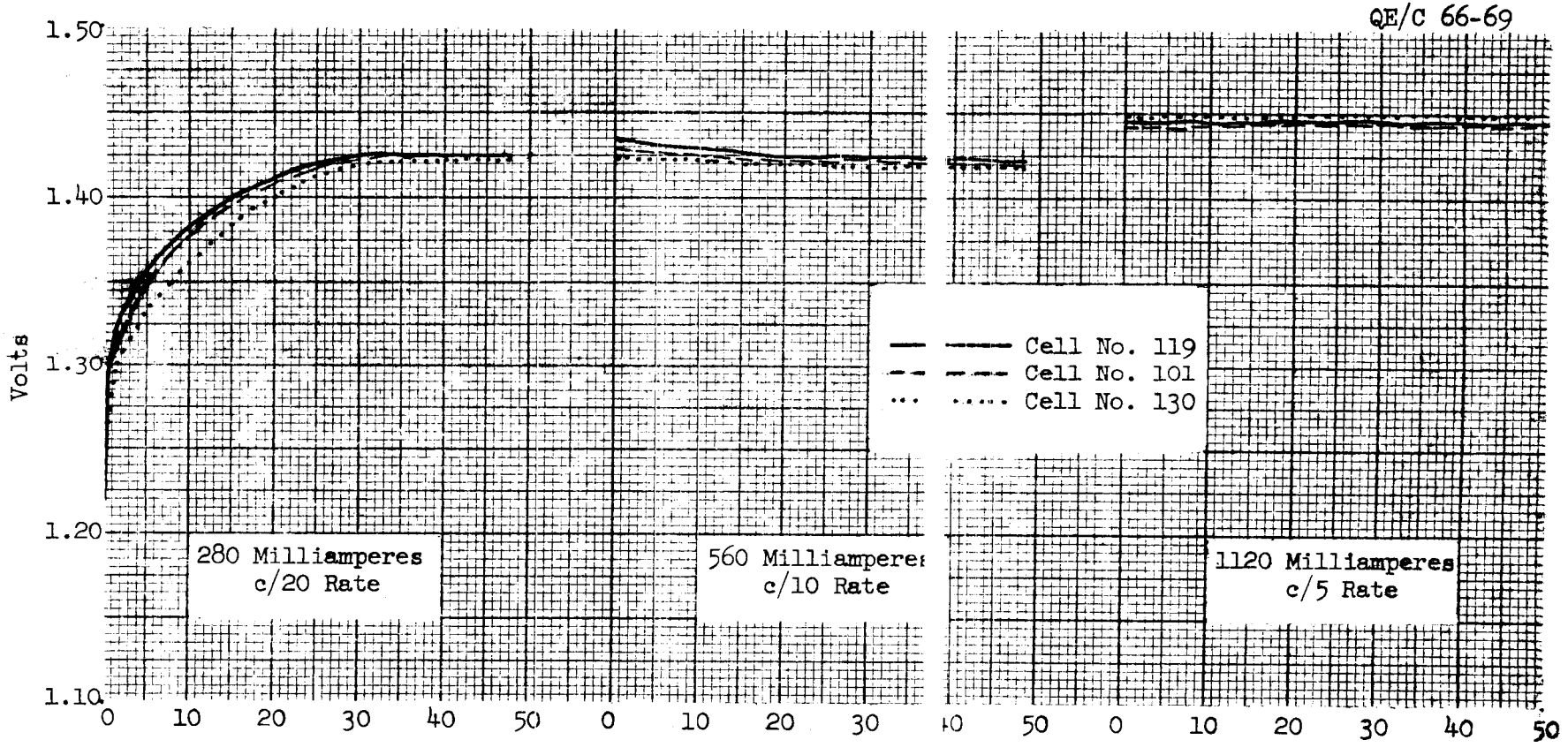
FIGURE 5



CHARACTERISTIC 48-HOUR OVERCHARGE CURVES

GULTON 5.6 AMPERE-HOUR NICKEL CADMIUM SEALED CELL
(with folded neoprene seal)

FIGURE 6



CHARACTERISTIC 48-HOUR OVER(HARGE CURVES

GULTON 5.6 AMPERE-HOUR NICKEL CA: IUM SEALED CELLS
(with nonfolded neopre: : seal)

FIGURE 7