EVALUATION PROGRAM

for

SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
GULTON INDUSTRIES, INC.
(5.0 AMPERE-HOUR NIMBUS CELLS)

prepared for
GODDARD SPACE FLIGHT CENTER

CONTRACT W11,252B

QUALITY EVALUATION LABORATORY

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CRANE, INDIANA

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ACCEPTANCE TEST OF GULTON INDUSTRIES, INC. 5.0 AMPERE-HOUR NIMBUS CELLS

QE/C 65-460 23 June 1965

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Enclosure (1)

QE/C 65-460

REPORT BRIEF

GULTON INDUSTRIES FIVE AMPERE-HOUR NIMBUS 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. five ampere-hour nickel cadmium Nimbus 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 purchased from Gulton Industries, Inc., Metuchen, New Jersey by National Aeronautics and Space Administration (NASA). These cells are rated at five ampere-hours by the manufacturer and are similar to those used in the Nimbus satellite program.

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 30 cells tested.

2. Internal shorting is a weak point in the Gulton Industries. Inc. five ampere-hour Nimbus cell construction as evidenced by five rejects out of 35 cells tested.

3. The capacity of the cells was in the acceptable range of 5.00 to 6.63 ampere-hours to 1.00 volt.

III. RECOMMENDATIONS.

A. It is recommended that an investigation be made to determine the causes of and methods to eliminate what appears to be an internal shorting problem.

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RESULTS OF ACCEPTANCE TESTS

OF

FIVE AMPERE-HOUR NIMBUS NICKEL CADMIUM SECONDARY SPACECRAFT CELLS

MANUFACTURED BY

GULTON INDUSTRIES, INC.

I. INTRODUCTION.

A. On 17 March 1965, this activity began acceptance tests on 30 cells. These tests were completed on 20 May 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. Conditioning Cycle.
3. Capacity Test.
4. Cell Short Test.
5. Immersion Seal Test.
6. Overcharge Test.
7. Internal Resistance Test.
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. The cells were identified by the manufacturer's serial numbers which were from 170 to 298, although not consecutively.

B. The five ampere-hour Nimbus cell is cylindrical in shape with a convex base. A threaded stud is fastened to the base to facilitate heat sink mounting. The cell has an average length (base, excluding the threaded stud, to top of the container) of 3.373 inches and

average diameter of 1.277 inches. The average weight was 195.7 grams. Figure 1 is a photograph of a Gulton Industries, Inc. five ampere-hour Nimbus cell.

C. The cell container or can, and the cell cover are made of stainless steel. Two stainless steel tabs, welded to the cover, serve as the contacts for the negative terminal. The positive terminal is insulated from the cell cover by a ceramic seal and protrudes through the cover as a solder type terminal. Two solder tabs are welded to the terminal.

D. These cells, rated by the manufacturer at five ampere-hours, 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 ceramic seal on receipt of the cells. The test was performed prior to any other tests using a phenolphthalein solution of one half of one percent concentration.

2. There were no signs of leakage on any of the 35 cells subjected to the leak test.

B. Capacity Test:

1. Prior to the capacity tests, the cells were given a preconditioning cycle. This cycle consisted of a 48-hour charge at 250 milliamperes followed by a 2.5 ampere discharge to a cutoff of 1.00 volt per cell and then shorted out through a 1-ohm resistor for 16 hours.

2. 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. Because of instrumentation requirements on the Nimbus satellite, capacities were measured to 1.15 volts per cell in addition to the 1.00 volt cutoff. 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.

3. 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 individual cell capacities ranged from 4.38 to 6.18 ampere-hours for an average of 5.03 ampere-hours to 1.15 volts and from 5.00 to 6.63 ampere-hours for an average of 5.46 ampere-hours to 1.00 volt. The cell capacities are tabulated

in Table I. Characteristic 2-hour rate discharge curves are shown in Figure 2.

4. One cell was rejected because it would not accept its 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 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 1.18 to 1.24 volts for an average of 1.20 volts.

4. There were three rejects among the 34 cells subjected to the cell short test. The voltage values for the 30 accepted cells are shown in Table I.

5. One cell, after passing the initial cell short test, was later found to be shorted when it was mounted in a battery pack.

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

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 value for each cell is shown in Table I. The values range from 4.21 milliohms to 37.89 milliohms.

TABLE I

CELL NUMBER	DIAMETER (INCHES)	HEIGHT (INCHES)	WEIGHT (GRAMS)	CAPACITY TEST (1)	CAPACITY TEST (2)	CAPACITY TEST (1)	CAPACITY TEST (2)	CAPACITY TEST (1)	CAPACITY TEST (2)	CELL SHORT TEST	IMMERSION SEAL TEST LEAKAGE	OVER-CHARGE c/20	OVER-CHARGE c/10	OVER-CHARGE c/5	INTERNAL RESISTANCE (MILLIOHMS)	IMMERSION SEAL TEST LEAKAGE
172	1.276	3.380	211.5	5.58	6.05	5.38	6.25	4.95	5.18	1.18	NONE	1.42	1.42	1.44	4.21	NONE
220	1.278	3.380	200.2	5.33	5.63	5.13	5.43	4.80	5.00	1.23	NONE	1.42	1.42	1.45	8.42	NONE
236	1.280	3.370	204.2	5.38	6.00	5.43	5.83	4.83	5.20	1.20	NONE	1.42	1.42	1.44	6.31	NONE
241	1.276	3.380	192.3	5.13	5.58	4.80	5.25	4.30	4.88	1.19	NONE	1.42	1.42	1.43	8.42	NONE
246	1.280	3.375	190.5	5.05	5.43	4.68	5.00	4.33	4.70	1.20	NONE	1.42	1.42	1.42	8.42	NONE
249	1.280	3.380	192.2	4.70	5.20	3.88	4.83	3.88	4.38	1.19	NONE	1.42	1.42	1.44	10.53	NONE
252	1.280	3.380	193.5	4.70	5.30	4.45	4.93	4.18	4.45	1.19	NONE	1.42	1.41	1.43	37.89	NONE
255	1.275	3.380	192.8	4.70	5.08	4.45	5.13	4.18	4.58	1.20	NONE	1.42	1.42	1.45	10.53	NONE
258	1.276	3.375	194.3	4.75	5.25	4.55	5.08	4.30	4.75	1.20	NONE	1.42	1.42	1.43	10.53	NONE
259	1.280	3.372	190.5	4.83	5.18	4.50	5.00	4.25	4.80	1.20	NONE	1.42	1.42	1.44	6.31	NONE
261	1.275	3.380	192.7	4.20	5.00	4.33	4.68	4.38	4.75	1.19	NONE	1.42	1.42	1.43	6.31	NONE
262	1.276	3.378	191.0	4.70	5.25	3.83	4.63	3.75	4.38	1.19	NONE	1.42	1.41	1.44	6.31	NONE
*231	1.280	3.370	286.4	5.33	6.13	5.55	5.88	5.13	5.43	1.22	NONE	1.40	1.42	1.42	6.31	NONE
*233	1.279	3.370	294.1	6.18	6.58	6.05	6.63	5.68	5.93	1.22	NONE	1.41	1.42	1.42	8.42	NONE
*235	1.279	3.370	277.5	4.58	5.30	4.13	5.08	4.18	4.50	1.24	NONE	1.41	1.42	1.42	8.42	NONE

Pressure Transducers
Capacity Test (1): To 1.15 Volts.
Capacity Test (2): To 1.00 Volt.

TABLE I (Contd)

CELL NUMBER	DIAMETER (INCHES)	HEIGHT (INCHES)	WEIGHT (GRAMS)	CAPACITY TEST (1)	CAPACITY TEST (2)	CAPACITY TEST (1)	CAPACITY TEST (2)	CAPACITY TEST (1)	CAPACITY TEST (2)	CELL SHORT TEST	IMMERSION SEAL TEST LEAKAGE	OVER-CHARGE c/20	OVER-CHARGE c/10	OVER-CHARGE c/5	INTERNAL RESISTANCE (MILLIOHMS)	IMMERSION SEAL TEST LEAKAGE
264	1.277	3.378	190.8	4.70	5.33	4.50	5.13	4.18	4.93	1.19	NONE	1.42	1.42	1.44	6.31	NONE
265	1.275	3.378	191.6	5.00	5.30	4.68	5.08	4.38	4.80	1.20	NONE	1.41	1.42	1.42	8.42	NONE
267	1.267	3.375	190.8	5.00	5.38	4.58	5.00	4.58	4.70	1.22	NONE	1.41	1.42	1.42	10.53	NONE
270	1.272	3.377	193.8	5.00	5.45	4.70	5.25	4.38	4.83	1.20	NONE	1.42	1.43	1.43	4.21	NONE
271	1.276	3.365	190.3	4.88	5.20	4.58	5.00	4.25	4.68	1.19	NONE	1.42	1.42	1.42	4.21	NONE
272	1.278	3.365	191.3	4.83	5.38	4.43	5.08	4.45	5.00	1.18	NONE	1.42	1.43	1.42	4.21	NONE
274	1.275	3.360	193.6	4.80	5.33	4.38	5.00	4.33	5.00	1.18	NONE	1.42	1.43	1.44	6.31	NONE
277	1.277	3.360	195.1	4.93	5.33	4.58	5.20	4.88	5.20	1.19	NONE	1.42	1.43	1.43	6.31	NONE
278	1.278	3.360	194.3	4.80	5.00	4.38	4.68	4.20	4.55	1.23	NONE	1.40	1.42	1.42	8.42	NONE
282	1.275	3.360	211.5	5.70	6.13	5.38	5.95	5.20	5.88	1.18	NONE	1.42	1.42	1.43	6.31	NONE
284	1.275	3.360	190.2	5.00	5.43	4.58	5.25	4.58	5.13	1.18	NONE	1.42	1.43	1.42	8.42	NONE
287	1.277	3.370	192.5	4.82	5.08	4.33	4.58	4.20	4.55	1.24	NONE	1.41	1.42	1.43	10.53	NONE
289	1.275	3.370	193.4	5.20	5.43	4.68	4.93	4.63	4.82	1.24	NONE	1.41	1.42	1.42	8.42	NONE
291	1.275	3.368	193.1	4.83	5.38	4.38	5.08	4.38	5.05	1.21	NONE	1.44	1.45	1.46	6.31	NONE
298	1.278	3.375	196.1	5.00	5.58	4.58	5.33	4.58	5.30	1.20	NONE	1.43	1.44	1.45	4.21	NONE

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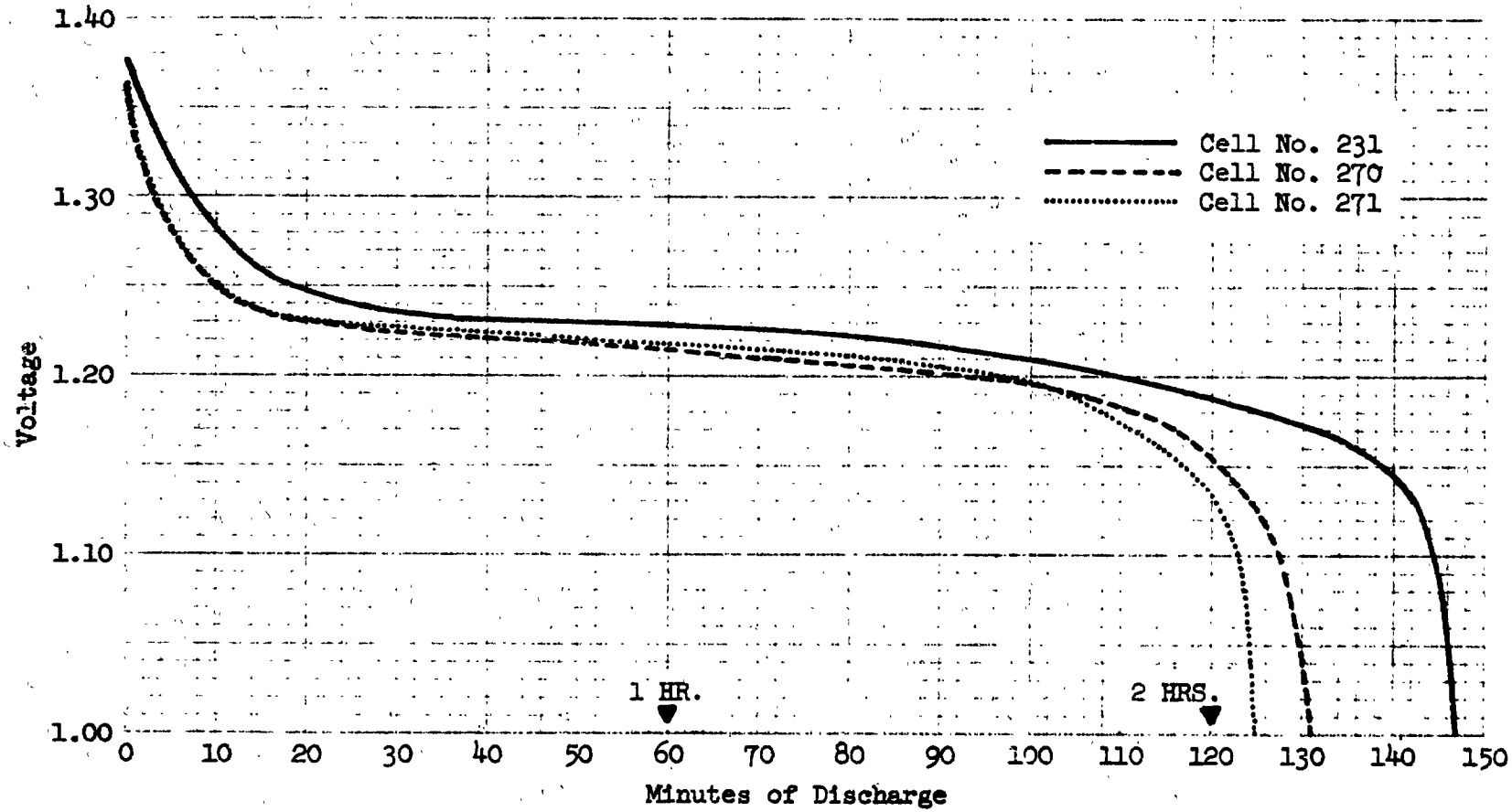
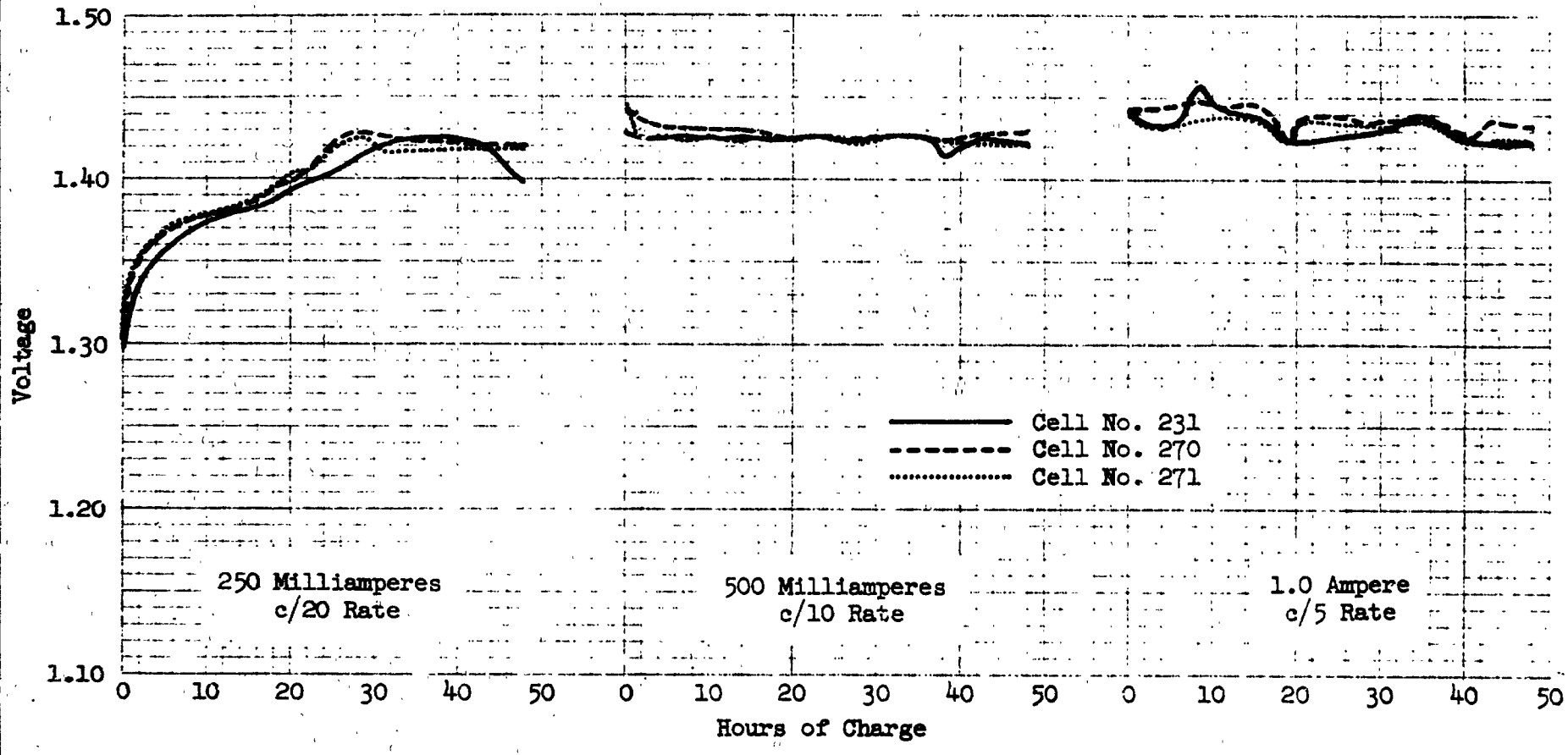
FIGURE 1



CHARACTERISTIC 2-HOUR RATE DISCHARGE CURVES

GULTON 5 AMPERE-HOUR NIMBUS NICKEL CADMIUM SEALED CELLS

FIGURE 2



CHARACTERISTIC 48-HOUR OVERCHARGE CURVES

GULTON 5 AMPERE-HOUR NIMBUS NICKEL CADMIUM SEALED CELLS

FIGURE 3

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