

N 70 40936

CR 113822



CASE FILE
COPY

EVALUATION PROGRAM
for
SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
SONOTONE 20 AMPERE - HOUR
SEALED NICKEL - CADMIUM CELLS

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT W12,397



QUALITY EVALUATION LABORATORY
NAD CRANE, INDIANA

DEPARTMENT OF THE NAVY
U. S. NAVAL AMMUNITION DEPOT
CRANE, INDIANA 47522

IN REPLY REFER TO:
3022-JDH:bc
8900

22 SEP 1970


From: Commanding Officer, Naval Ammunition Depot, Crane, Indiana
To: National Aeronautics and Space Administration, Goddard Space Flight
Center (716.2, Mr. T. J. Hennigan), Greenbelt, Maryland 20771

Subj: Report QE/C 70-691; Acceptance Test of Sonotone Corporation 20
Ampere-Hour Sealed Nickel-Cadmium Secondary Spacecraft Cells

Ref: (a) NASA Purchase Order Number W12-397

Encl: (1) Report QE/C 70-691

1. In compliance with reference (a), enclosure (1) is forwarded for
information and retention.


C. G. LYNCH
By direction

Copy to:
Distribution List

DEPARTMENT OF THE NAVY
NAVAL AMMUNITION DEPOT
QUALITY EVALUATION LABORATORY
CRANE, INDIANA 47522

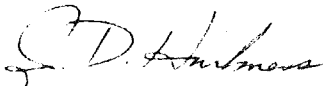
EVALUATION PROGRAM
FOR
SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
SONOTONE CORPORATION
20 AMPERE-HOUR NICKEL-CADMIUM CELLS

QE/C 70-691

28 August 1970

PREPARED BY



J. D. HARKNESS

PREPARED UNDER THE DIRECTION OF



D. G. MILEY
Manager, Electrochemical
Power Sources Branch

APPROVED BY



C. G. LYNCH
By direction

Enclosure (1)

REPORT BRIEF

SONOTONE 20 AMPERE-HOUR SEALED NICKEL-CADMIUM
SECONDARY SPACECRAFT CELLS

- Ref: (a) NASA Purchase Order No. W12,397
(b) NASA ltr BRA/VBK/pad of 25 Sept 1961 w/BUWEPS first end
FQ-1:WSK of 2 Oct 1961 to CO NAD Crane
(c) Preliminary Work Statement for Battery Evaluation Program
of August 1961

I. TEST ASSIGNMENT BRIEF

A. In compliance with references (a) and (b), evaluation of Sonotone 20 ampere-hour sealed secondary spacecraft cells was begun according to the program outline of reference (c).

B. The object of this evaluation program is to insure that these secondary spacecraft cells have sufficient quality to justify placement into the life cycle program. Information concerning performance characteristics and limitations; including cycle life under various electrical and environmental conditions, will be of interest to power system designers and users.

C. Fifty cells (25 control and 25 with springs) were purchased from Sonotone Corporation, Elmsford, New York, by NASA under contract NAS 3-6001. The goal of this contract was to study the effect of mechanical pressure on the cell plates of nickel-cadmium cells.

II. RESULTS

A. Leakage was detected in 24 cells prior to testing and in 39 cells after the completion of acceptance testing. The location of the leaks indicates a problem area in the sealing technique used on these cells.

B. The capacities of the cells were in an acceptable range of 20.7 to 27.5 ampere-hours after the third capacity test. There were no appreciable differences between the capacities of the control and spring type cells after this test.

C. There was a total of 26 cells that were removed from the overcharge test of which 20 were of the spring type. This is an indication that a mechanical pressure on the cell stack produces a higher cell voltage when a cell is in an overcharged condition.

D. The cells were placed on the life cycle program 13 May 1970.

RESULTS OF ACCEPTANCE TESTS
OF
20 AMPERE-HOUR SEALED NICKEL-CADMIUM
SECONDARY SPACECRAFT CELLS
MANUFACTURED BY
SONOTONE CORPORATION

I. INTRODUCTION

A. On 22 July 1969, this activity began acceptance tests on 50 Sonotone 20 ampere-hour cells. Twenty-five cells were of the standard sealed nickel-cadmium construction type, whereas the remaining 25 cells have the standard construction plus a constant mechanical pressure normal to the face of the nickel-cadmium stack. The goal of this contract was to study the effect of mechanical pressure on the cell plates of nickel-cadmium cells. The acceptance tests were completed on 16 April 1970 and the cells were placed on the life cycle program 13 May 1970.

II. CELL IDENTIFICATION AND DESCRIPTION

A. The cells were identified by the manufacturer's serial numbers. The 25 cells, designated as control with serial numbers in the range of 1 to 29, are of standard sealed nickel-cadmium construction. The 25 cells identified as springs, with serial numbers ranging from 34 to 74, have the standard construction plus a constant mechanical pressure (springs) normal to the face of the nickel-cadmium stack.

B. These 20 ampere-hour cells are rectangular in shape. The cases and covers are made of stainless steel. The positive and negative terminals are insulated by a teflon seal and protrude through the cell cover as threaded terminals. Each cell has a pressure relief valve, rated at 40 psig, located between the positive and negative terminals (Photograph 1).

C. The cells were measured and weighed upon receipt and then placed in restrainer plates which encompassed the entire cell case excluding the top and bottom. The plates were not removed once testing was begun. The average height (base to top of positive terminal), length, and width (all cells) were 5.446, 1.455 and 3.134 inches respectively. The average weight of the control cells was 1013.4 grams, whereas the average weight of the cells with springs was 1093.7 grams. The individual cell dimensions and weights are given in Table 1.

D. The cells were received in a discharged condition and the bottoms of the cells were convexed (bulged). One cell had convex

sides (serial no. 18). Three cells (serial nos. 2, 5 and 7) had small dents located on the side of the cell case.

III. 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. Mechanical Leak Test #1
5. Overcharge Test
6. Internal Resistance Test
7. Mechanical Leak Test #2

B. All charging and discharging was done at constant current (+ 5 percent). Cells were charged and discharged in series. The discharge of each cell was individually terminated when its voltage reached 1.00 volts.

IV. TEST PROCEDURE AND RESULTS

A. Phenolphthalein Leak Test:

1. This test is a determination of the condition of the welds and ceramic seals. The cells, when received, were sprayed with a phenolphthalein indicator solution of one-half of one percent concentration, and any coloration to pink is a determination of a leak. The location of any coloration was noted.

2. There was a total of 24 cells that leaked, and 20 of these cells were of the spring type.

3. Results of this test are shown in Table 1.

B. Capacity Test:

1. The capacity test is a determination of the cells' 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 with a 1.46 voltage limit on each cell. A total of three capacity tests were made, the cells were charged and discharged in series with the discharge of each cell individually terminated when its voltage reached 1.00.

2. The individual cell capacities ranged from 13.7 to 24.8 ampere-hours on the first capacity check, for an average of 21.95 ampere-hours. The second capacity check ranged from 21.5 to 27.2 ampere-hours, for an average of 24.48 ampere-hours. The third capacity check ranged from 20.7 to 27.5 ampere-hours, for an average of 24.6 ampere-hours. The capacities are tabulated in Table 2. Characteristic discharge curves of the third capacity test are shown in Figures 1 and 2. The curves illustrate the highest, lowest, and average ampere-hour capacities of the control and spring type cells.

C. Cell Short Test:

1. The cell short test is a means of detecting slight shorting conditions which may exist in a cell 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 0.5 ohm resistor across the cell terminals for 16 hours. At the end of 16 hours, the resistors were removed and the cells were placed on open circuit stand for 24 hours.

3. The open circuit cell voltage, 24 hours after removal of the 0.5-ohm resistors, ranged from 1.08 to 1.22 volts, for an average of 1.20 volts.

4. There were no rejects of any of the cells subjected to the short test. The open circuit voltage values for the cells are shown in Table 2.

D. Mechanical Leak Tests (#1 and #2):

1. This test is a means of detecting leakage of a seal or weld. The test was performed prior to the overcharge test (test #1) and after the internal resistance test (test #2) to determine the presence and location of leaks.

2. The cells were placed in a vacuum chamber and subjected to a vacuum of 40 microns Hg or less for 24 hours.

3. The cells were removed after 24 hours and the phenolphthalein leak test, procedure described in IV.A.1., was repeated.

4. There were 38 cells that indicated a leak prior to the overcharge test. Thirty-four of these cells indicated leaks located around the seal or the pressure relief valve. There were 39 cells that indicated a leak after the internal resistance measurements, of which 28 cells showed the location of the leak around the seal or pressure relief valve.

5. Results of these tests are shown in Table 1.

E. Overcharge:

1. The overcharge tests were performed to determine the steady state voltage of each cell at specified rates. The steady state voltage is a result of equilibrium between oxygen being produced as charging proceeds and being recombined by the charged negative plates.

2. The test specified three consecutive 48-hour constant current charges; the first at the c/20 rate; the second at the c/10 rate, and the third at the c/5 rate. The cells were monitored hourly throughout the test and charging was to be discontinued on any cell that exceeded 1.48 volts.

3. There was a total of 26 cells that were removed from the overcharge test in which 20 were of the spring type. There were five spring type cells removed during the c/10 overcharge test while the others were removed during the c/5 overcharge test.

4. The steady state voltage at the end of each charging sequence is shown in Table 2. Characteristic overcharge voltage curves are shown in Figures 3 and 4.

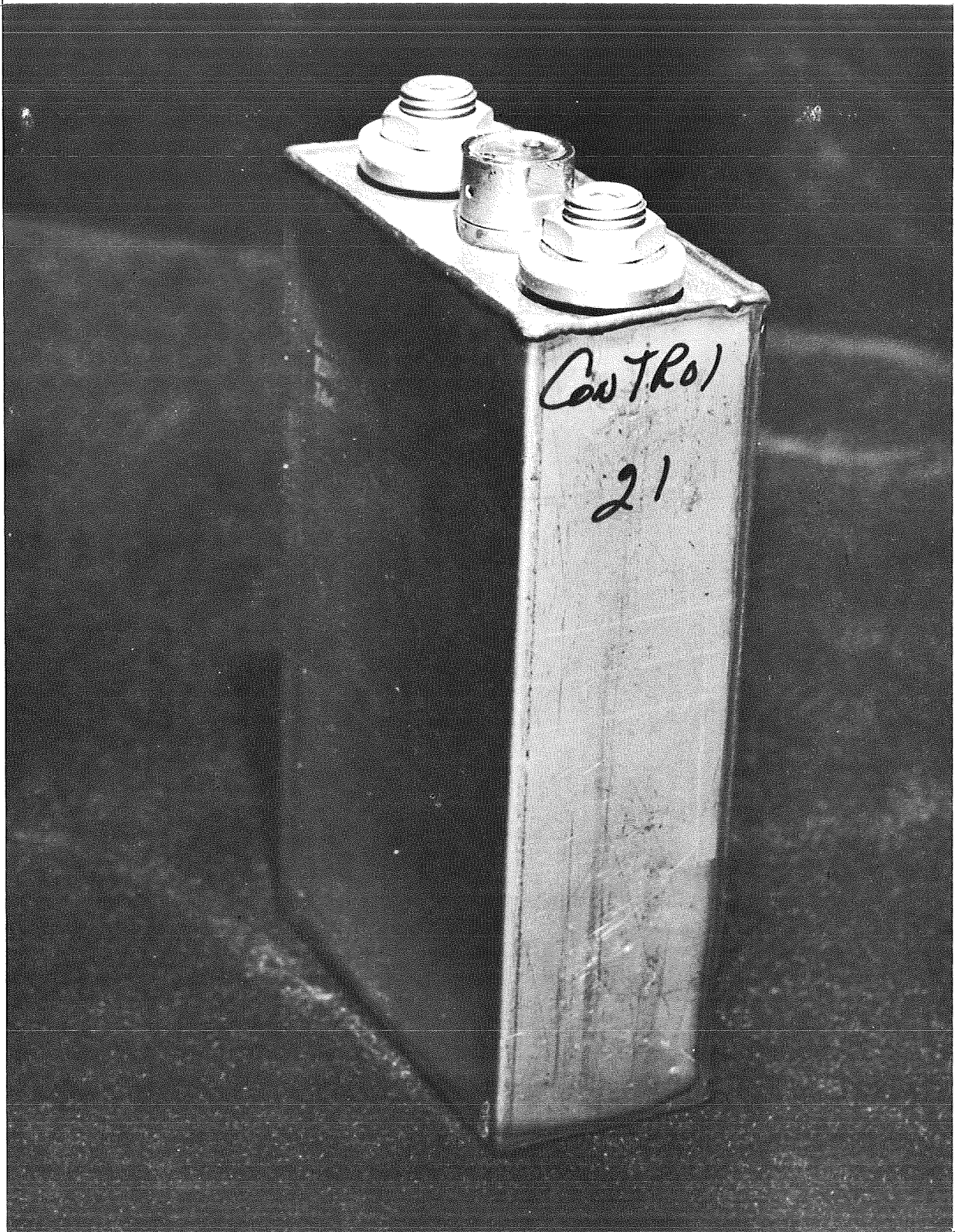
F. Internal Resistance Test:

1. At the completion of the overcharge test, the cells were returned to the c/20 charge rate and given a short pulse (5 to 10 seconds) at the rate of c/1 in amperes. The cell voltages, V_1 , immediately prior to the pulse; and V_2 , 5 milliseconds after the initiation of the pulse, were read on a CEC high speed oscillograph (direct print) recorder--16.0 inches of paper per second. The internal resistance of the cell in ohms was calculated according to the formula:

$$R = \frac{V_2 - V_1}{I_c - I_c/20}$$

V_1 and V_2 are in volts, I_c and $I_c/20$ are in amperes.

2. Due to the number of significant figures in the voltage measurements (as read from the chart paper), the error in the calculated resistance values may be as large as 10 milliohms. Therefore, in addition to calculating the internal resistance of the cells, the internal resistance was also measured directly through the use of a Hewlett-Packard milliohmmeter (Model 4328A). The results of both methods are shown in Table 2. Values determined by the calculation method ranged from 0.53 to 1.05 milliohms for an average of 0.69 milliohms. The values measured by the milliohmmeter ranged from 1.15 to 1.47 milliohms for an average of 1.29 milliohms.



PHOTOGRAPH 1

TABLE I
CONTROL CELLS

CELL SERIAL NO.	HEIGHT (Inches)	LENGTH (Inches)	WIDTH (Inches)	WEIGHT (Grams)	PHENOL- PHTHALEIN LEAK TEST	MECHANICAL #1	LEAK TEST #2
1	5.410	1.430	3.127	1022.3			Leaked
2	5.429	1.422	3.129	1002.2		Leaked	Leaked
3	5.432	1.434	3.135	1007.4	Leaked	Leaked	Leaked
4	5.484	1.425	3.130	1007.6		Leaked	Leaked
5	5.450	1.435	3.144	1029.5			
6	5.439	1.448	3.140	1011.8		Leaked	
8	5.455	1.430	3.132	1013.5		Leaked	Leaked
9	5.480	1.432	3.138	1014.0		Leaked	Leaked
10	5.464	1.423	3.134	1026.4		Leaked	Leaked
11	5.448	1.424	3.130	1002.4		Leaked	Leaked
13	5.440	1.420	3.164	1009.1			Leaked
14	5.455	1.421	3.147	1027.8			
15	5.460	1.435	3.156	1019.5			Leaked
16	5.476	1.420	3.152	1027.6		Leaked	
17	5.426	1.436	3.140	1005.1		Leaked	Leaked
18	5.431	1.432	3.166	982.5		Leaked	Leaked
20	5.456	1.419	3.165	1004.6		Leaked	
21	5.454	1.422	3.135	1019.0			
23	5.425	1.425	3.143	1016.9			Leaked
24	5.452	1.420	3.135	1003.2			Leaked

TABLE I (CONT)
CONTROL CELLS

CELL SERIAL NO.	HEIGHT (Inches)	LENGTH (Inches)	WIDTH (Inches)	WEIGHT (Grams)	PHENOL- PHTHALEIN	MECHANICAL #1	LEAK TEST #2
					LEAK TEST		
25	5.460	1.429	3.152	1014.8	Leaked		Leaked
26	5.479	1.419	3.161	1021.2	Leaked	Leaked	
27	5.472	1.423	3.155	1021.9		Leaked	Leaked
28	5.456	1.415	3.141	1013.1		Leaked	Leaked
29	5.461	1.410	3.134	1012.4	Leaked		Leaked

SPRING CELLS

34	5.430	1.485	3.125	1097.8			
35	5.435	1.479	3.120	1078.9	Leaked		Leaked
37	5.425	1.475	3.120	1088.5	Leaked		Leaked
38	5.455	1.483	3.125	1092.8			Leaked
39	5.425	1.485	3.125	1094.9	Leaked		Leaked
41	5.460	1.453	3.130	1069.4	Leaked	Leaked	Leaked
42	5.450	1.492	3.125	1096.0	Leaked		
44	5.440	1.435	3.125	1085.1	Leaked		
45	5.435	1.490	3.120	1100.2	Leaked		
46	5.468	1.545	3.116	1094.1	Leaked		
47	5.435	1.492	3.115	1103.4	Leaked		
49	5.445	1.500	3.120	1071.4		Leaked	
50	5.450	1.480	3.125	1078.1		Leaked	

TABLE I (CONT)
SPRING CELLS

CELL SERIAL NO.	HEIGHT (Inches)	LENGTH (Inches)	WIDTH (Inches)	WEIGHT (Grams)	PHENOL- PHTHALEIN	MECHANICAL #1	LEAK TEST #2
					LEAK TEST		
51	5.432	1.480	3.125	1098.0	Leaked	Leaked	Leaked
52	5.435	1.525	3.125	1100.5	Leaked	Leaked	
53	5.440	1.520	3.125	1107.8	Leaked	Leaked	
57	5.435	1.493	3.125	1101.9			
58	5.445	1.540	3.122	1090.0	Leaked		
59	5.456	1.520	3.119	1077.9	Leaked		
61	5.445	1.463	3.125	1107.9	Leaked		
70	5.425	1.445	3.136	1101.8	Leaked		
71	5.436	1.450	3.125	1091.3	Leaked	Leaked	Leaked
72	5.425	1.460	3.125	1113.4	Leaked		Leaked
73	5.430	1.455	3.125	1103.4	Leaked		Leaked
74	5.433	1.455	3.130	1098.5	Leaked		Leaked

TABLE II
CONTROL CELLS

CELL SERIAL NO.	CAPACITY	CAPACITY	CAPACITY	CELL				CELL RESISTANCE	
	TEST #1 (AH)	TEST #2 (AH)	TEST #3 (AH)	SHORT TEST (VOLTS)	OVERCHARGE c/20 (VOLTS)	TEST* c/10 (VOLTS)	TEST* c/5 (VOLTS)	CALC	METER
1	24.0	24.5	24.3	1.20	1.42	1.42	1.42	1.05	1.35
2	24.0	24.7	24.3	1.20	1.42	1.43	1.43	1.05	1.40
3	22.8	22.8	22.5	1.20	1.42	1.42	1.42	.53	1.47
4	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	24.3	25.7	27.0	1.21	1.42	1.43	1.48 (42)	1.05	1.42
6	24.8	25.2	24.7	1.21	1.41	1.42	1.42	.53	1.37
8	24.7	25.7	25.8	1.20	1.42	1.42	1.44	1.05	1.37
9	24.5	25.3	26.7	1.20	1.41	1.42	1.42	1.05	1.34
10	24.7	25.5	26.8	1.20	1.41	1.42	1.42	.53	1.30
11	23.7	24.7	26.0	1.20	1.41	1.42	1.42	1.05	1.37
13	23.2	24.7	24.8	1.20	1.42	1.42	1.46	.53	1.24
14	23.0	25.5	25.8	1.20	1.42	1.42	1.45	.53	1.28
15	22.8	25.2	25.3	1.22	1.42	1.42	1.48 (25)	.53	1.23
16	23.3	25.7	26.0	1.20	1.42	1.42	1.45	.53	1.30
17	20.7	23.5	23.8	1.20	1.42	1.44	1.48 (47)	.53	1.25
18	21.7	23.7	23.7	1.20	1.42	1.42	1.47	.53	1.30
20	20.7	23.8	23.8	1.20	1.42	1.42	1.47	.53	1.36

NA--Not Available

*Number in () is the time, in hours, that the cell was on that sequent of the overcharge test before exceeding the voltage limit of 1.48 volts

TABLE II (CONT)

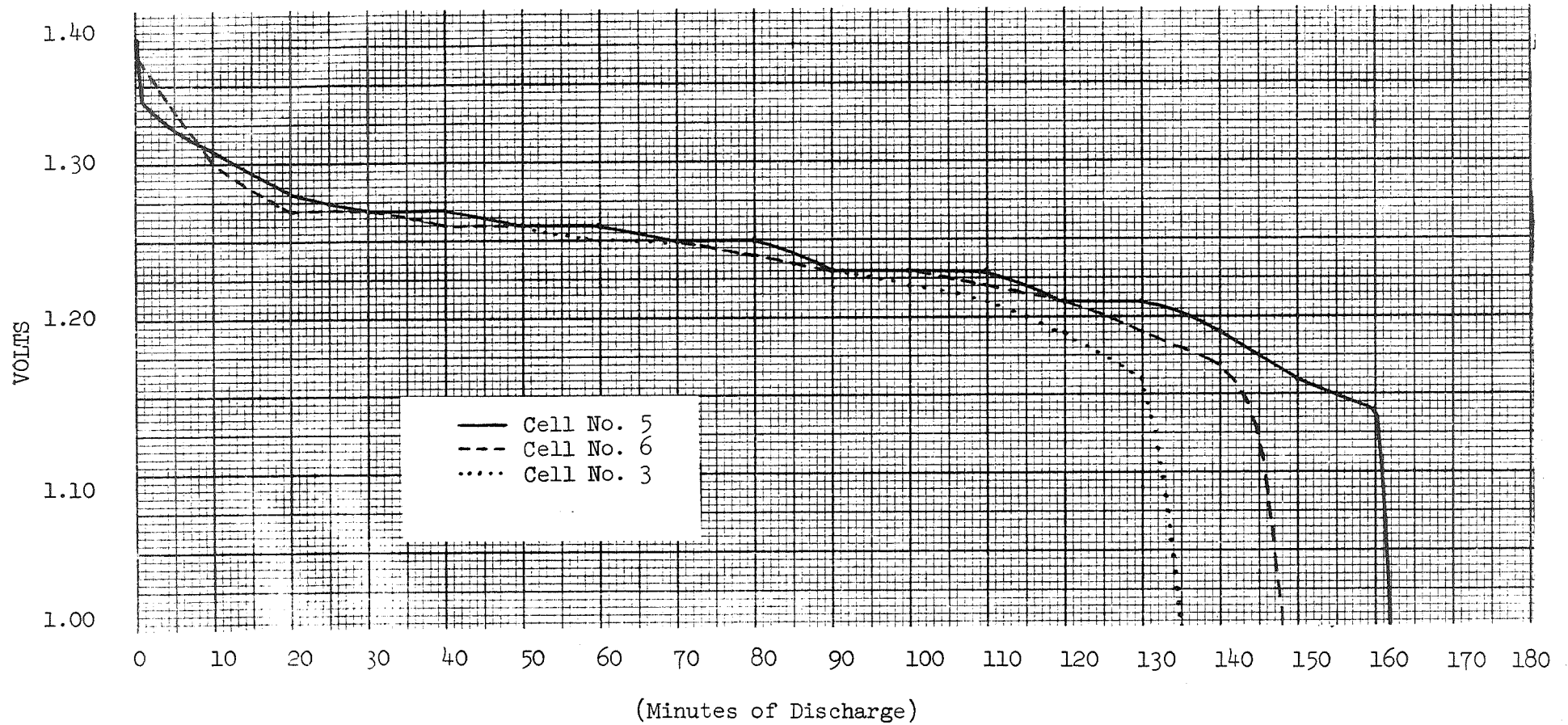
CELL SERIAL NO.	CAPACITY	CAPACITY	CAPACITY	CELL				CELL RESISTANCE	
	TEST #1 (AH)	TEST #2 (AH)	TEST #3 (AH)	SHORT TEST (VOLTS)	OVERCHARGE c/20 (VOLTS)	TEST* c/10 (VOLTS)	TEST* c/5 (VOLTS)	CALC	METER
21	22.2	24.7	25.0	1.20	1.42	1.43	1.45	.53	1.32
23	22.5	24.0	23.8	1.20	1.41	1.42	1.45	.53	1.38
24	22.7	24.5	24.5	1.20	1.41	1.42	1.48 (47)	.53	1.30
25	22.8	24.2	23.7	1.22	1.42	1.43	1.46	1.05	1.31
26	22.2	24.3	23.8	1.22	1.43	1.43	1.47	1.05	1.28
27	22.0	24.2	23.7	1.22	1.42	1.43	1.48 (46)	.53	1.26
28	22.7	24.8	23.8	1.22	1.43	1.43	1.48 (21)	.53	1.34
29	23.0	24.5	24.0	1.22	1.43	1.43	1.46	1.05	1.32
SPRING CELLS									
34	22.2	23.2	23.5	1.22	1.42	1.43	1.48 (47)	.53	1.22
35	15.2	22.7	23.3	1.20	1.42	1.42	1.46	.53	1.20
37	13.7	22.3	23.3	1.21	1.42	1.43	1.48 (33)	.53	1.18
38	14.3	23.8	23.5	1.20	1.42	1.43	1.44	.53	1.21
39	14.3	23.2	23.7	1.21	1.42	1.42	1.48 (45)	.53	1.28
41	14.2	22.3	23.2	1.21	1.42	1.43	1.48 (32)	1.05	1.39
42	17.3	22.0	22.5	1.21	1.43	1.44	1.48 (14)	.53	1.40
44	18.2	21.5	22.5	1.21	1.43	1.42	1.47	1.05	1.38
45	20.5	22.2	21.2	1.20	1.43	1.45	1.48 (4)	1.05	1.40

*Number in () is the time, in hours, that the cell was on that segment of the overcharge test before exceeding the voltage limit of 1.48 volts

TABLE II (CONT)
SPRING CELLS

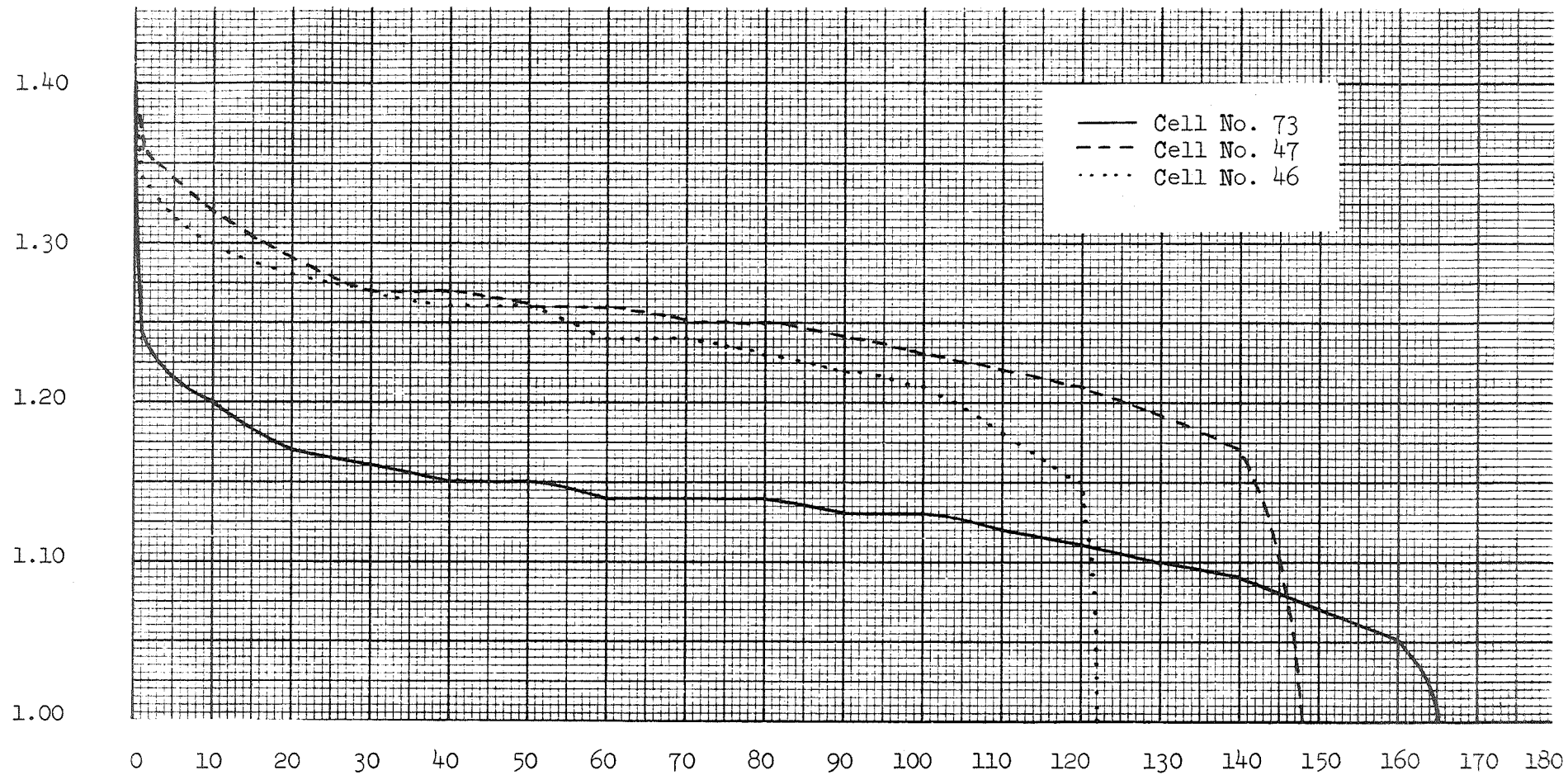
CELL SERIAL NO.	CAPACITY	CAPACITY	CAPACITY	CELL	OVERCHARGE TEST*			CELL RESISTANCE CALC	RESISTANCE METER
	TEST #1 (AH)	TEST #2 (AH)	TEST #3 (AH)	SHORT TEST (VOLTS)	c/20 (VOLTS)	c/10 (VOLTS)	c/5 (VOLTS)		
46	17.0	22.0	20.7	1.19	1.43	1.47	1.48 (5)	1.05	1.31
47	23.5	24.7	24.7	1.21	1.41	1.43	1.48 (41)	.53	1.23
49	24.0	24.7	24.7	1.21	1.42	1.43	1.48 (14)	.53	1.27
50	24.3	25.5	25.5	1.21	1.42	1.43	1.48 (45)	.53	1.17
51	23.3	25.0	25.2	1.21	1.42	1.43	1.48 (40)	.53	1.20
52	23.3	24.5	24.8	1.22	1.42	1.45	1.48 (9)	.53	1.20
53	23.5	25.2	25.5	1.21	1.41	1.43	1.48 (39)	.53	1.28
57	22.7	24.2	24.7	1.22	1.42	1.43	1.48 (37)	.53	1.30
58	24.3	24.3	24.7	1.21	1.41	1.41	1.47	1.05	1.15
59	23.7	25.0	25.2	1.21	1.42	1.43	1.47	.53	1.25
61	22.8	24.8	25.0	1.21	1.41	1.44	1.48 (11)	1.05	1.27
70	24.0	26.8	26.7	1.14	1.43	1.48	(15)	.53	1.20
71	24.0	26.8	27.0	1.11	1.43	1.48	(8)	.53	1.27
72	24.2	27.0	27.2	1.14	1.43	1.48	(9)	.53	1.28
73	24.0	27.2	27.5	1.12	1.44	1.48	(10)	.53	1.24
74	24.2	27.2	27.0	1.08	1.43	1.48	(9)	.53	1.20

*Number in () is the time, in hours, that the cell was on that segment of the overcharge test before exceeding the voltage limit of 1.48 volts



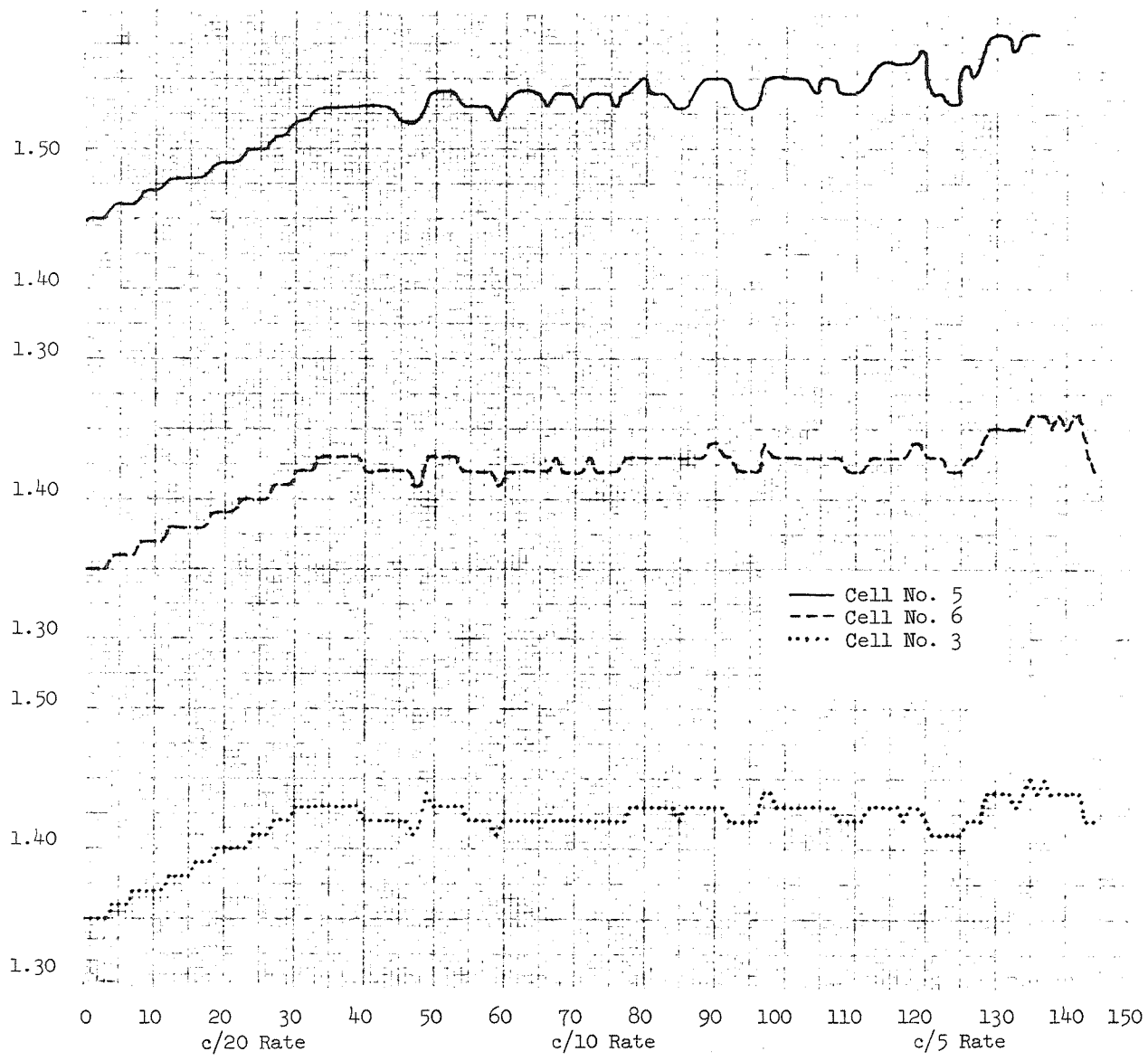
CHARACTERISTIC DISCHARGE, THIRD CAPACITY TEST
SONOTONE 20 AMPERE-HOUR SEALED NICKEL-CADMIUM (CONTROL)

FIGURE 1



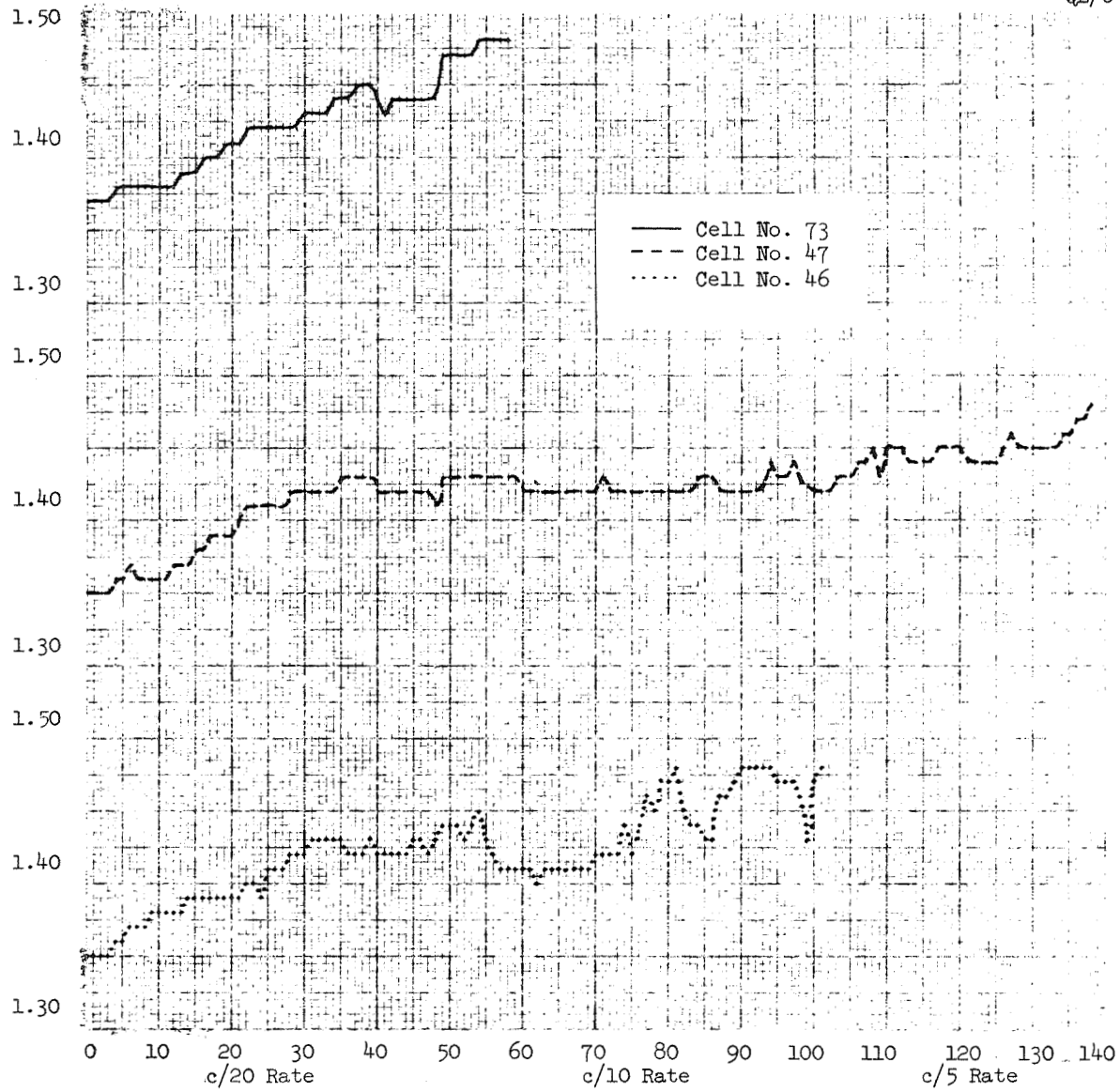
(Minutes of Discharge)
CHARACTERISTIC DISCHARGE, THIRD CAPACITY TEST
SONOTONE 20 AMPERE-HOUR SEALED NICKEL-CADMIUM (SPRING)

FIGURE 2



CHARACTERISTIC OVERCHARGE CURVES (CONTROL)

FIGURE 3



CHARACTERISTIC OVERCHARGE CURVES (SPRINGS)

FIGURE 4

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 SAC), Washington, D. C. 20546
- 9-11 National Aeronautics and Space Administration, Scientific and Technical Information Center: Input, P. O. Box 33, College Park, Maryland 20740
- 12 National Aeronautics and Space Administration, (Dr. Steven J. Glassman, Code UT), Washington, D. C. 20546
- 13 National Aeronautics and Space Administration, Goddard Space Flight Center (Mr. Joseph Sherfey, Code 735), Greenbelt, Maryland 20771
- 14 National Aeronautics and Space Administration, Goddard Space Flight Center (Mr. Gerald Halpert, Code 735), Greenbelt, Maryland 20771
- 15 National Aeronautics and Space Administration, Goddard Space Flight Center (Mr. Louis Wilson, Code 450), Greenbelt, Maryland 20771
- 16 National Aeronautics and Space Administration, Langley Research Center (Mr. John L. Patterson, MS-472), Hampton, Virginia 23365
- 17 National Aeronautics and Space Administration, Langley Research Center (Mr. M. B. Seyfert, MS-112), Hampton, Virginia 23365
- 18 National Aeronautics and Space Administration, Lewis Research Center (Dr. Louis Rosenblum, MS 302-1), 21000 Brookpark Road, Cleveland, Ohio 44135
- 19 National Aeronautics and Space Administration, Lewis Research Center (Mr. Harvey Schwartz, MS 309-1), 21000 Brookpark Road, Cleveland, Ohio 44135

- 20 National Aeronautics and Space Administration, Lewis Research Center (Dr. J. Stewart Fordyce, MS 6-1), 21000 Brookpark Road, Cleveland, Ohio 44135
- 21 National Aeronautics and Space Administration, George C. Marshall Space Flight Center (Mr. Charles B. Graff, S&E-ASTR-EP), Huntsville, Alabama 35812
- 22 National Aeronautics and Space Administration, Manned Spacecraft Center (Code EP-5, Mr. W. E. Rice), Houston, Texas 77058
- 23 National Aeronautics and Space Administration, Ames Research Center (Code PBS, M.S. 244-2, Mr. Jon A. Rubenzer), Moffett Field, California 94035
- 24 National Aeronautics and Space Administration, Electronics Research Center (Code CPE, Dr. Sol Gilman), 575 Technology Square, Cambridge, Massachusetts 02139
- 25 Jet Propulsion Laboratory (Mr. Paul Goldsmith, M.S. 198-223), 4800 Oak Grove Drive, Pasadena, California 91103
- 26 Jet Propulsion Laboratory (Mr. Alvin A. Uchiyama, M.S. 198-223), 4800 Oak Grove Drive, Pasadena, California 91003
- 27 Jet Propulsion Laboratory (Dr. R. Lutwack, M.S. 198-220), 4800 Oak Grove Drive, Pasadena, California 91103
- 28 Commanding General, U. S. Army Electro Technology Lab., Energy Conversion Research Division (MERDC), Fort Belvoir, Virginia 22060
- 29 Commanding General, U. S. Army Electronics R&D Labs, (AMSEL-KL-P), Fort Monmouth, New Jersey 07703
- 30 Commanding General, U. S. Army Electronics Command (AMSEL-ME-NMP-TB-2, Mr. A. Frink), Fort Monmouth, New Jersey 07703
- 31 U. S. Army Natick Laboratories, Clothing and Organic Materials Division (Mr. Leo A. Spano), Natick, Massachusetts 01762

- 32 Harry Diamond Laboratories (Mr. Nathan Kaplan), Room 300, Building 92, Connecticut Avenue and Van Ness Street, N.W., Washington, D. C. 20438
- 33 Chief of Naval Research (Director, Power Program, Code 473), Navy Department, Washington, D. C. 20360
- 34 Chief of Naval Research (Code 472, Mr. Harry Fox), Navy Department, Washington, D. C. 20360
- 35 Director, Naval Research Laboratory (Code 6160, Dr. J. C. White), 4555 Overlook Avenue, S.W., Washington, D. C. 20360
- 36 Officer in Charge, Annapolis Division, Naval Ship Research and Development Center (Code M760, Mr. J. H. Harrison), Annapolis, Maryland 21402
- 37 Commander, Naval Air Systems Command (Code AIR-340C, Mr. Milton Knight), Department of the Navy, Washington, D. C. 20360
- 38 Commanding Officer, Naval Weapons Center, Corona Laboratories (Code 441, Mr. William C. Spindler), Corona, California 91720
- 39 Commander, U. S. Naval Ordnance Laboratory White Oak (Code 232, Mr. Philip B. Cole), Silver Spring, Maryland 20910
- 40 Commander, Naval Ship Engineering Center (Code 6157D, Mr. C. F. Viglotti), Washington, D. C. 20360
- 41 Superintendent, Naval Observatory (Code STIC, Mr. Robert E. Trumbule, Building 52), 34th and Massachusetts Avenue, N.W., Washington, D. C. 20390
- 42 Commander, Naval Ship Systems Command (Code SHIP-03422, Mr. Bernard B. Rosenbaum), Department of the Navy, Washington, D. C. 20360
- 43 Department of the Air Force Headquarters, Aero Propulsion Laboratory (APIP-1, Mr. James E. Copper), Wright-Patterson Air Force Base, Ohio 45433
- 44 Air Force Cambridge Research Laboratory (CRE, Mr. Francis X. Doherty and Mr. Edward Raskind, Wing F), L. G. Hanscom Field, Bedford, Massachusetts 01731

- 45 Rome Air Development Center (Mr. Frank J. Mollura, Code EMEAM), Griffiss Air Force Base, New York 13442
- 46 National Bureau of Standards (Dr. W. J. Hamer), Washington, D. C. 20234
- 47-66 Director, Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314
- 67 Aerospace Corporation (Library Acquisition Group), P. O. Box 95085, Los Angeles, California 90045
- 68 American Cyanamid Company (Dr. R. A. Haldeman), 1937 W. Main Street, Stamford, Connecticut 06902
- 69 AMF, Inc. (Mr. R. A. Knight), 689 Hope Street, Stamford, Connecticut 06907
- 70 American University, Chemistry Department (Dr. R. T. Foley), Massachusetts and Nebraska Avenues, N.W., Washington, D. C. 20016
- 71 Atomics International Division, North American Aviation, Inc. (Dr. H. L. Recht), 8900 DeSota Avenue, Canoga Park, California 91304
- 72 Autonetics Division, NAR (Mr. F. F. Fogle, GF 16), P. O. Box 4181, Anaheim, California 92803
- 73 Battelle Memorial Institute (Dr. C. L. Faust), 505 King Avenue, Columbus, Ohio 43201
- 74 Bellcomm, Inc. (Mr. B. W. Moss), 955 L'Enfant Plaza North, S.W., Washington, D. C. 20024
- 75 Bell Laboratories (Mr. D. O. Feder), Murray Hill, New Jersey 07974
- 76 Dr. Carl Berger, 13401 Kootenay Drive, Santa Ana, California 92705
- 77 The Boeing Company (Mr. Sidney Gross, 2-7814, MS 85-86) P. O. Box 3999, Seattle, Washington 98124
- 78 Burgess Battery Company (Dr. Howard J. Strauss), Foot of Exchange Street, Freeport, Illinois 61032

- 79 C & D Batteries, Division of Electric Autolite Company
(Dr. Eugene Willihnganz), Conshohocken,
Pennsylvania 19428
- 80 Calvin College (Prof. T. P. Dirkse), 3175 Burton
Street, S. E., Grand Rapids, Michigan 49506
- 81 Catalyst Research Corporation (Dr. H. Goldsmith),
6101 Falls Road, Baltimore, Maryland 21209
- 82 Communications Satellite Corporation (Mr. Robert Strauss),
1835 K Street, N. W., Washington, D. C. 20036
- 83 G. & W. H. Corson, Inc. (Dr. L. J. Minnick), Plymouth
Meeting, Pennsylvania 19462
- 84 Cubic Corporation (Librarian), 9233 Balboa Avenue,
San Diego, California 92123
- 85 Delco-Remy Division, General Motors Corporation
(Mr. J. A. Keralla), 2401 Columbus Avenue, Anderson,
Indiana 46011
- 86 Eagle-Picher Industries, Inc. (Mr. E. P. Broglio),
P. O. Box 47, Joplin, Missouri 64801
- 87 E. I. du Pont Nemours and Company, Engineering Materials
Laboratory, Experimental Station, Building 304, (Mr. J. M.
Williams), Wilmington, Delaware 19898
- 88 ESB, Inc. (Director of Engineering), P. O. Box 11097,
Raleigh, North Carolina 27604
- 89 ESB, Inc., Carl F. Norberg Research Center (Dr. R. A.
Schaefer), 19 West College Avenue, Yardley,
Pennsylvania 19067
- 90 Electrochimica Corporation (Dr. Morris Eisenberg),
1140 O'Brien Drive, Menlo Park, California 94025
- 91 Electromite Corporation (Mr. R. H. Sparks), 2117 South
Anne Street, Santa Ana, California 92704
- 92 Emhart Corporation (Dr. W. P. Cadogan), Box 1620,
Hartford, Connecticut 06102

- 93 Energetics Science, Inc., 4461 Bronx Boulevard,
New York, New York 10470
- 94 Dr. Arthur Fleischer, 466 South Center Street, Orange,
New Jersey 07050
- 95 General Electric Company, Research and Development Center
(Dr. R. C. Osthoff), P. O. Box 43, Schenectady,
New York 12301
- 96 General Electric Company, Spacecraft Department
(Mr. K. L. Hanson, Room M-2614), P. O. Box 8555,
Philadelphia, Pennsylvania 19101
- 97 General Electric Company, Battery Business Section
(Mr. W. H. Roberts), P. O. Box 114, Gainesville,
Florida 32601
- 98 General Electric Company (Whitney Library), P. O. Box 8,
Schenectady, New York 12301
- 99 Globe-Union, Incorporated (Dr. Eugene Y. Weissman),
P. O. Box 591, Milwaukee, Wisconsin 53201
- 100 Gould Ionics, Inc. (Dr. J. E. Oxley), P. O. Box 1377,
Canoga Park, California 91304
- 101 Grumman Aircraft Engineering Corporation, AAP Project-
Future Missions (Mr. J. S. Caraceni, Plant 25), Bethpage,
Long Island, New York 11714
- 102 Gulton Industries, Alkaline Battery Division (Dr. H. N.
Seiger), 1 Gulton Street, Metuchen, New Jersey 08840
- 103 Honeywell, Incorporated, Livingston Electronic Laboratory
(Library), Montgomeryville, Pennsylvania 18936
- 104 Dr. P. L. Howard, Centreville, Maryland 21617
- 105 Hughes Aircraft Corporation (Mr. M. E. Ellion, Bldg. 366,
M.S. 524), El Segundo, California 90245
- 106 ITT Research Institute (Dr. H. T. Francis), 10 West 35th
Street, Chicago, Illinois 60616
- 107 Idaho State University, Department of Chemistry
(Dr. G. Myron Arcand), Pocatello, Idaho 82301

- 108 Institute for Defense Analyses (Mr. R. Hamilton),
400 Army-Navy Drive, Arlington, Virginia 22202
- 109 Institute for Defense Analyses (Dr. R. Briceland),
400 Army-Navy Drive, Arlington, Virginia 22202
- 110 International Nickel Company (Mr. William C. Mearns),
1000-16th Street, N.W., Washington, D. C. 20036
- 111 Johns Hopkins University, Applied Physics Laboratory
(Mr. Richard E. Evans), 8621 Georgia Avenue, Silver
Spring, Maryland 20910
- 112 Leeson Moos Laboratories (Dr. A. Moos), Lake Success
Park, Community Drive, Great Neck, New York 11021
- 113 Arthur D. Little, Incorporated (Dr. James D. Birkett),
Acorn Park, Cambridge, Massachusetts 02140
- 114 Lockheed Missiles and Space Company (Mr. Robert E. Corbett,
Dept. 62-14, Bldg. 154), P. O. Box 504, Sunnyvale,
California 94088
- 115 Mallory Battery Company (Mr. R. R. Clune), So. Broadway and
Sunnyside Lane, Tarrytown, New York 10591
- 116 P. R. Mallory and Co., Inc. (Dr. Per Bro), Northwest
Industrial Park, Burlington, Massachusetts 01801
- 117 P. R. Mallory and Co., Inc. (Technical Librarian),
3029 E. Washington Street, Indianapolis, Indiana 46206
- 118 Marathon Battery Company (Mr. Lou Belove), P. O. Box 247,
Cold Spring, New York 10516
- 119 Martin-Marietta Corporation (Mr. William B. Collins,
M.S. 1620 and Mr. M. S. Imamura, M.S. 8840),
P. O. Box 179, Denver, Colorado 80201
- 120 McDonnell Douglas, Inc. (Mr. A. D. Tonelli, MS 7C),
3000 Ocean Park Boulevard, Santa Monica, California 90406
- 121 McDonnell Douglas, Inc., Astropower Laboratory (Dr. George
Moe), 2121 Campus Drive, Newport Beach, California 92663
- 122 North American Rockwell Corporation, Rocketdyne Division
(Library), 6633 Canoga Avenue, Canoga Park, California 91304

- 123 Philco-Ford Corporation, Space Power and Propulsion
Department (Mr. D. C. Briggs, M.S. W-49), 3825 Fabian
Way, Palo Alto, California 94303
- 124 Portable Power Sources Corporation (Mr. Leon Schulman),
166 Pennsylvania Avenue, Mt. Vernon, New York 10552
- 125 Power Information Center, University City Science
Institute, Room 2107, 3401 Market Street, Philadelphia,
Pennsylvania 19104
- 126 Prime Battery Corporation, 15600 Cornet Street,
Santa Fe Springs, California 90670
- 127 RAI Research Corporation, 36-40 37th Street, Long Island
City, New York 11101
- 128 Southwest Research Institute (Library), 8500 Culebra
Road, San Antonio, Texas 78206
- 129 Stanford Research Institute (Dr. Fritz R. Kalhammer),
820 Mission Street, South Pasadena, California 91030
- 130 Texas Instruments, Inc., Metals and Controls Division
(Dr. E. J. Jost and Dr. J. W. Ross), 34 Forest Street,
Attleboro, Massachusetts 02703
- 131 TRW Systems, Inc. (Dr. W. R. Scott, M 2/2154),
One Space Park, Redondo Beach, California 90278
- 132 TRW Systems, Inc. (Dr. Herbert P. Silverman, R-1/2094),
One Space Park, Redondo Beach, California 90278
- 133 TRW, Inc. (Librarian), 23555 Euclid Avenue, Cleveland,
Ohio 44117
- 134 Tyco Laboratories, Inc. (Dr. A. C. Makrides), Bear Hill,
Hickory Drive, Waltham, Massachusetts 02154
- 135 Union Carbide Corporation, Development Laboratory
Library, P. O. Box 5056, Cleveland, Ohio 44101
- 136 Union Carbide Corporation, Consumer Products Division
(Dr. Robert Powers), P. O. Box 6166, Cleveland,
Ohio 44101

- 137 University of Pennsylvania, Electrochemistry Laboratory
(Prof. John O'M. Bockris), Philadelphia,
Pennsylvania 19104
- 138 Westinghouse Electric Corporation, Research and
Development Center (Dr. C. C. Hein, Contract Admin.),
Churchill Borough, Pittsburg, Pennsylvania 15235
- 139 Whittaker Corporation, Power Sources Division
(Mr. J. W. Reiter), 3850 Olive Street, Denver,
Colorado 80237