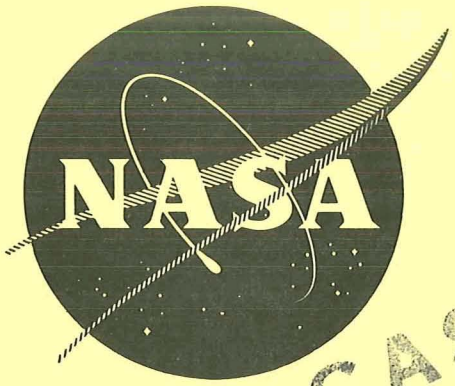

EVALUATION PROGRAM

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:
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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

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NAVAL AMMUNITION DEPOT
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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.

QE/C 70-691

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 reamining 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.

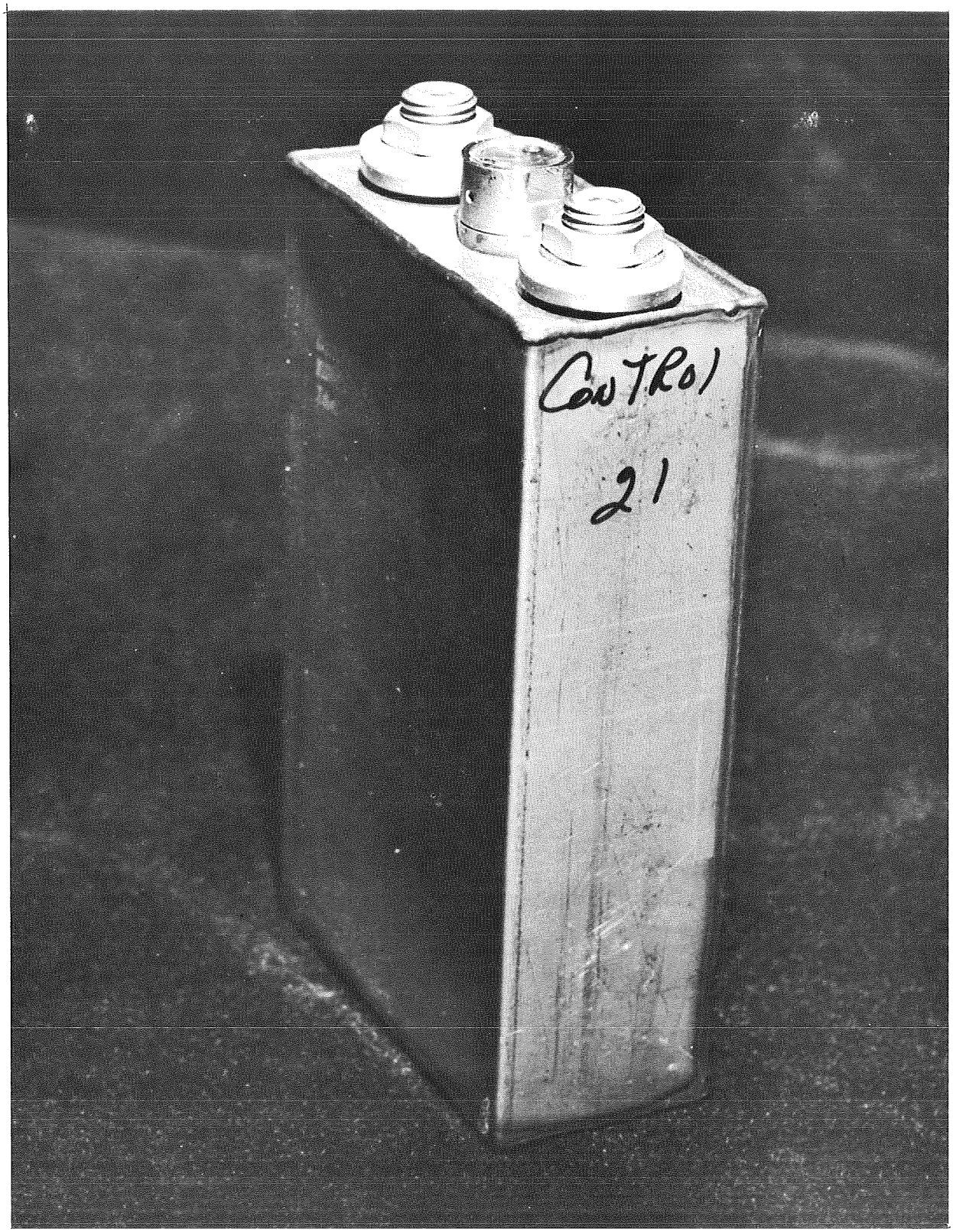
F. Internal Resistance Test:

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 LEAK TEST #1	MECHANICAL 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 LEAK TEST	MECHANICAL #1	LEAK TEST #2
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 LEAK TEST	MECHANICAL LEAK TEST #1	#2
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 TEST #1 (AH)	CAPACITY TEST #2 (AH)	CAPACITY TEST #3 (AH)	CELL SHORT TEST (VOLTS)	OVERCHARGE TEST* c/20 (VOLTS)	c/10 (VOLTS)	c/5 (VOLTS)	CELL RESISTANCE 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)

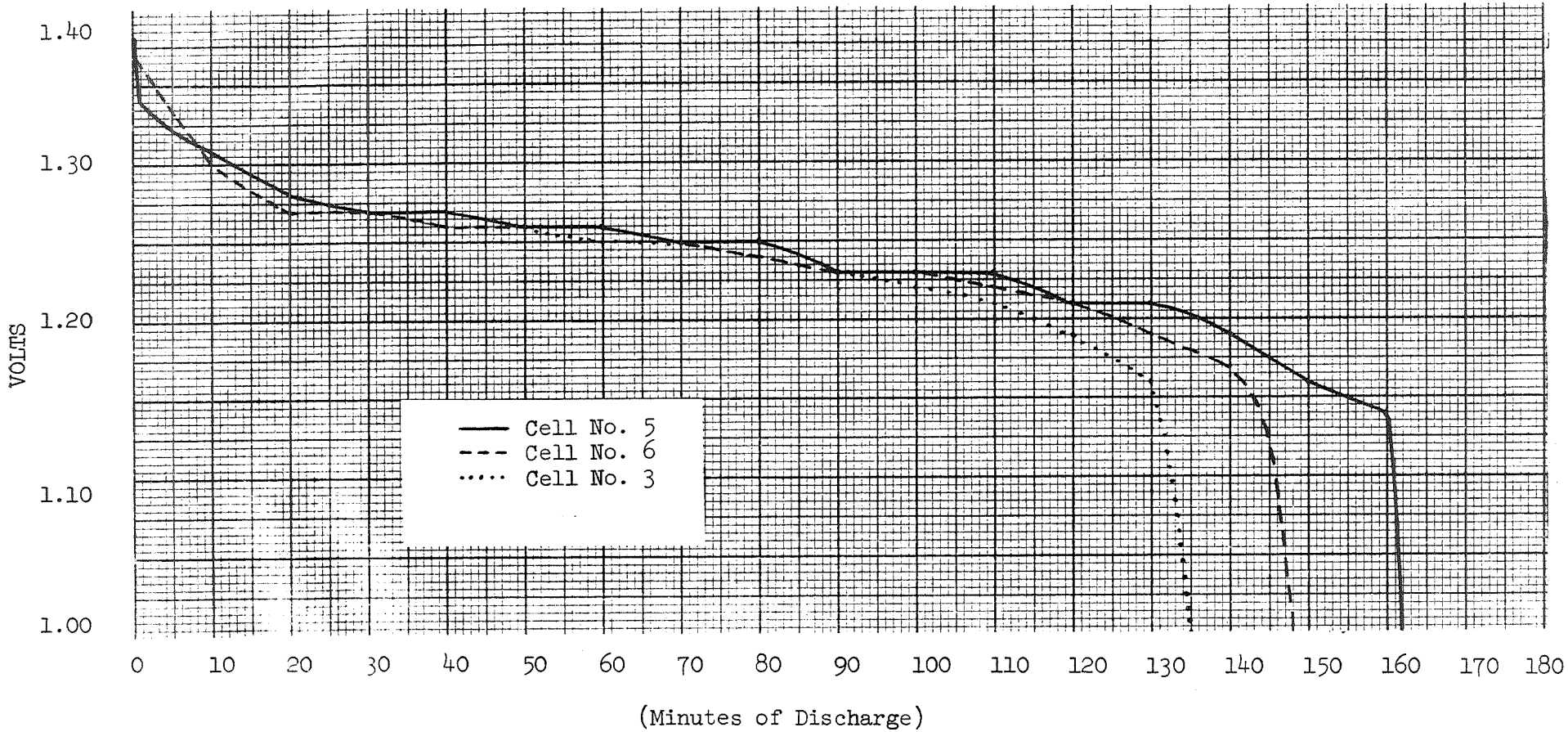
CELL SERIAL NO.	CAPACITY TEST #1 (AH)	CAPACITY TEST #2 (AH)	CAPACITY TEST #3 (AH)	CELL SHORT TEST (VOLTS)	OVERCHARGE TEST* c/20 (VOLTS)	c/10 (VOLTS)	c/5 (VOLTS)	CELL RESISTANCE CALC	METER
21	22.2	24.7	25.0	1.20	1.42	1.43	1.45	.53	1.32
23	22.5	24.0	23.8	1.20	1.41	1.42	1.45	.53	1.38
24	22.7	24.5	24.5	1.20	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

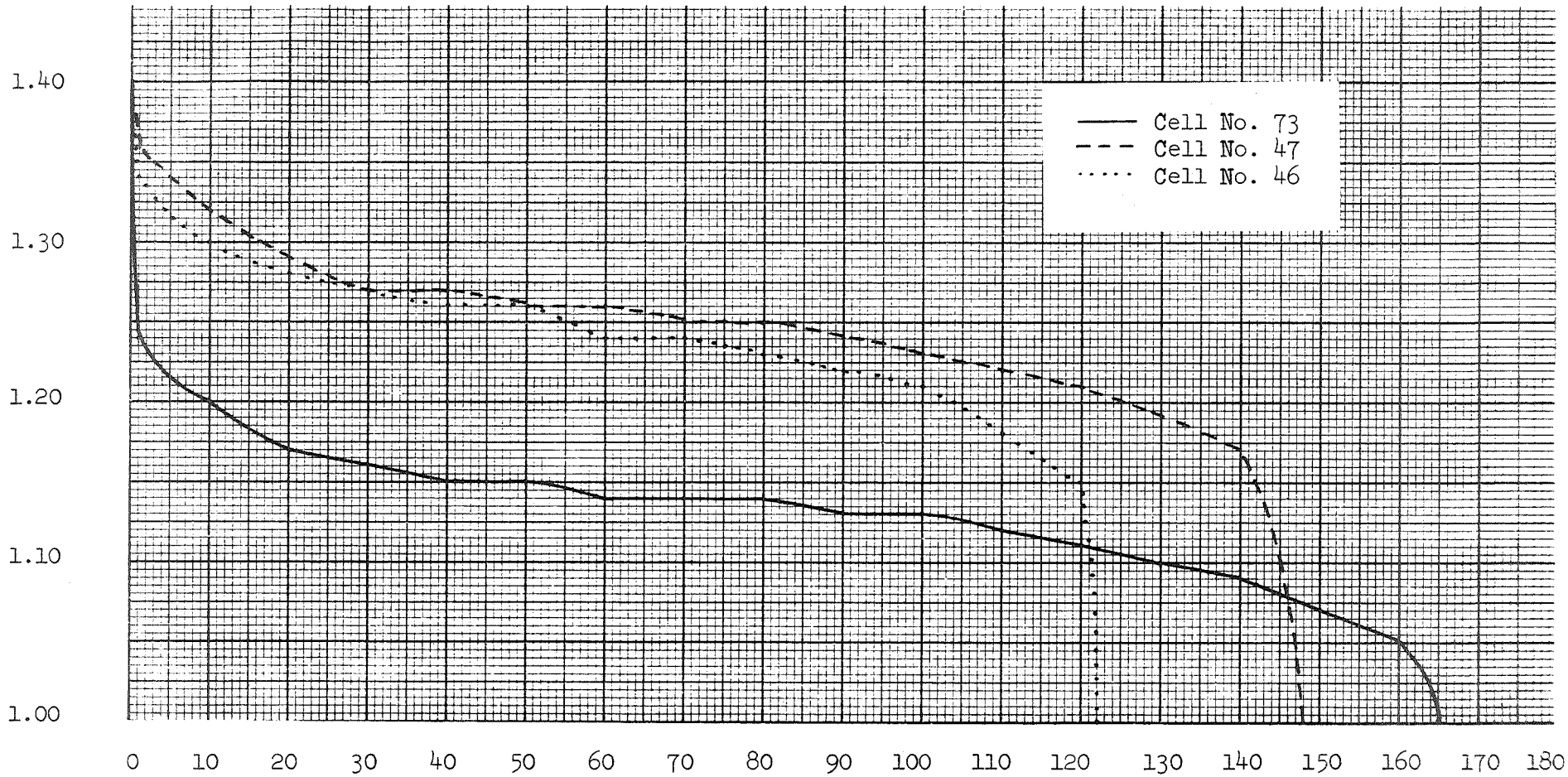
CELL SERIAL NO.	CAPACITY TEST #1 (AH)	CAPACITY TEST #2 (AH)	CAPACITY TEST #3 (AH)	CELL SHORT TEST (VOLTS)	OVERCHARGE TEST* c/20 (VOLTS)	c/10 (VOLTS)	c/5 (VOLTS)	CELL RESISTANCE CALC	CELL RESISTANCE METER
46	17.0	22.0	20.7	1.19	1.43	1.47	1.48 (5)	1.05	1.31
47	23.5	24.7	24.7	1.21	1.41	1.43	1.48 (41)	.53	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)

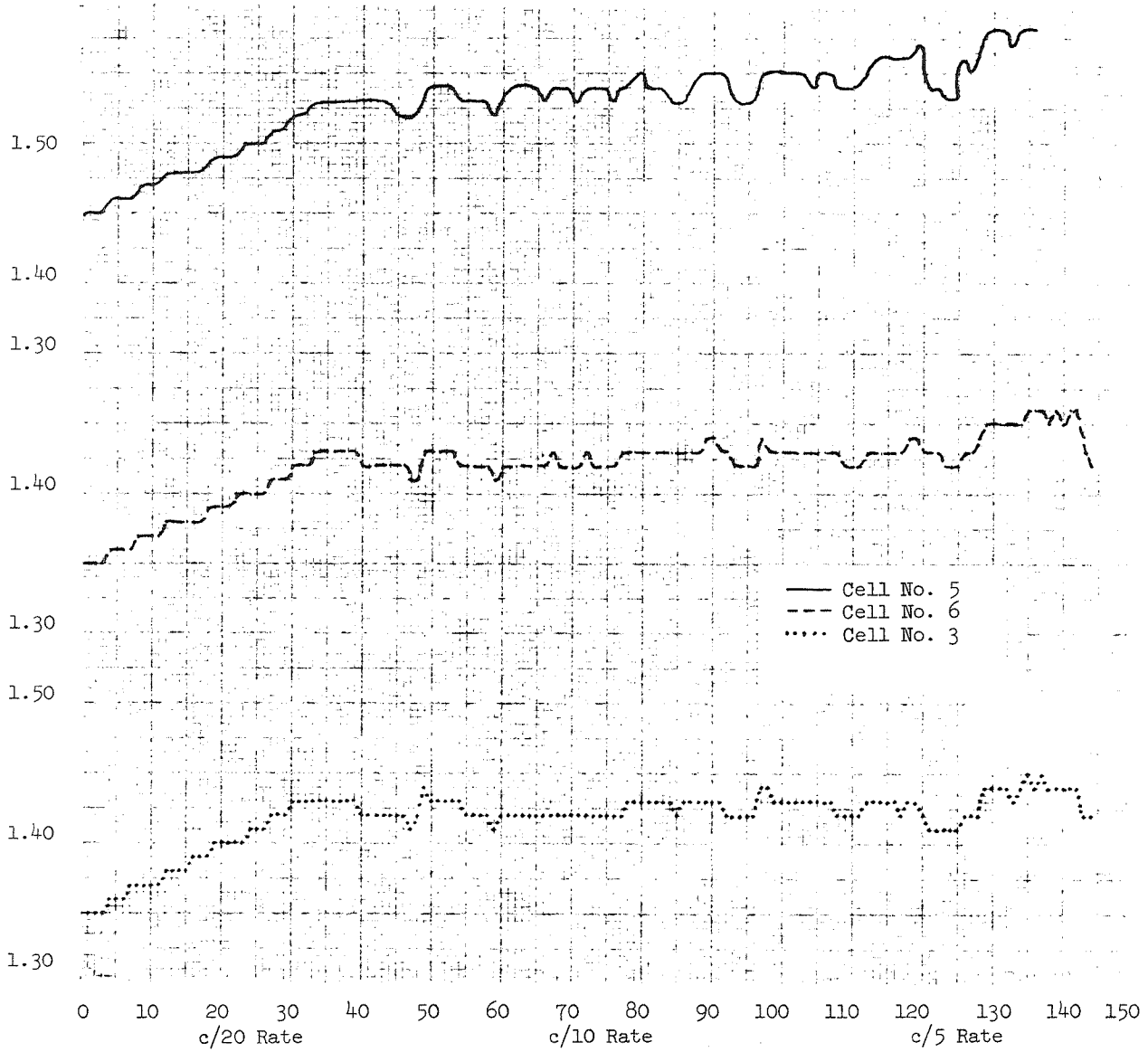
FIGURE 1



(Minutes of Discharge)

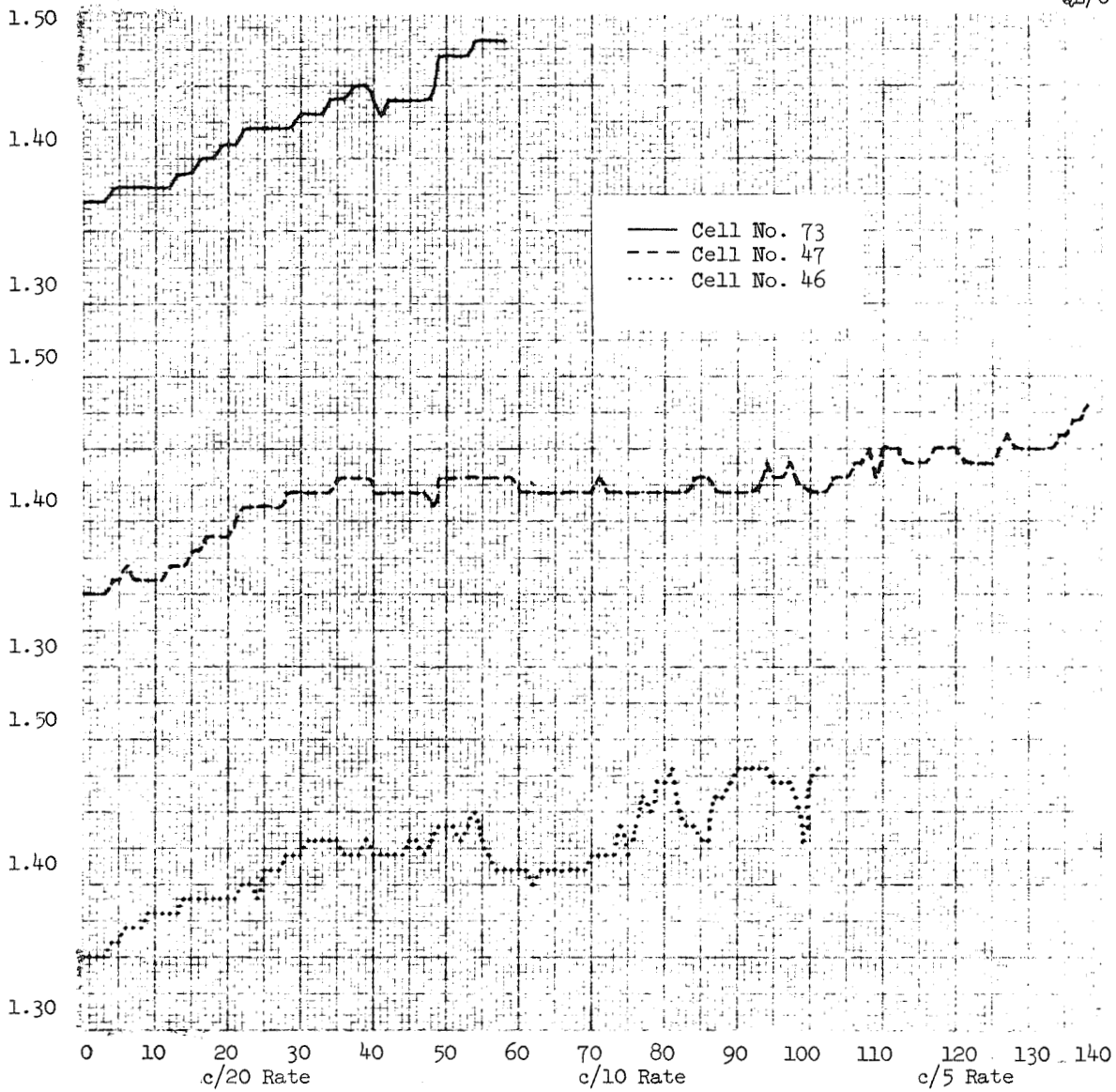
CHARACTERISTIC DISCHARGE, THIRD CAPACITY TEST
SONOTONE 20 AMPERE-HOUR SEALED NICKEL-CADMIUM (SPRING)

FIGURE 2



CHARACTERISTIC OVERCHARGE CURVES (CONTROL)

FIGURE 3



CHARACTERISTIC OVERCHARGE CURVES (SPRINGS)

FIGURE 4

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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

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24 National Aeronautics and Space Administration, Electronics Research Center (Code CPE, Dr. Sol Gilman), 575 Technology Square, Cambridge, Massachusetts 02139

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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

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