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SEMI-ANNUAL TECHNICAL REPORT
1 Jan. 1965 to 1 July 1965

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Prepared by
COOK ELECTRIC COMPANY
Dayton Ohio

for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

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Authors: I. F. Luke

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ABSTRACT

10049

The object of this report is to present the technical status of the cycle-life tests, initiated under Contract NAS 5-1048, on nine (9) cell groups of spacecraft-type nickel-cadmium cells. The report includes a summary of results obtained in the cycle-life tests subsequent to cycles completed and data reported in the last Technical Report of Contract NAS 5-1048. The nine (9) cell groups include five (5) groups of cylindrical cells rated at 3.5 ampere-hours from two (2) manufacturers and four (4) groups of rectangular cells rated at 6.0 ampere-hours from another manufacturer.. Three (3) groups of cells (one from each manufacturer) are being cycled at a temperature of -10°C, one group of the rectangular cells is being cycled at 50°C and the remaining groups are being cycled at 25°C. One group of the cylindrical cells cycling with a 25% depth of discharge at 25°C failed at 12,592 life cycles during this report period. The remaining groups have completed approximately 13,500 life-cycles. The life-cycling is continuous with 60-minute charge periods and 40-minute discharge periods.

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I. INTRODUCTION

The scope of this report covers the continuation of the cycle-life tests, initiated under Contract NAS 5-1048, on nine (9) cell groups of spacecraft-type nickel-cadmium cells. One-third of the original cells in the program of Contract NAS 5-1048 had failed at the completion of approximately 8000 cycles due to the mechanical design and other problems not definable as electrochemical in nature. Cycle-life tests are continued under Contract NAS 5-9073 in order to evaluate the cycling performance capabilities of these cells over extended lengths of time under different environmental conditions.

The cells operating in the cycle-life tests consist of sealed nickel-cadmium cells from three (3) manufacturers. Included are cylindrical 3.5 AH size cells manufactured by Gould-National Batteries, Inc. and Sonotone Corp., and rectangular 6 AH size cells manufactured by Gulton Industries, Inc. Prior to the cycle-life tests the cells were subjected to a series of initial tests including visual and mechanical, capacity, electrical leakage, overcharge, internal resistance, electrolyte leakage, vibration, shock and acceleration tests. A description of the cells, procedures and results of the initial tests, and results for the first 8000 life-cycles were reported in the final Technical Report under Contract NAS 5-1048. For reference purposes, a brief summary of these previously reported results are included in Tables 1, 3 and 5. Additional cycle-life test results up to approximately 13,500 cycles and post-failure tests completed during the report period are discussed in the following section.

II. DISCUSSION

A. Cycle-Life Tests (General)

The cycle-life tests employ 100-minute repetitive charge-discharge cycles consisting of 60-minute charge periods and 40-minute discharge periods. The cycle-life tests of the nine (9) cell groups still operating at the beginning of the report period were performed at three (3) ambient temperatures and two (2) depths of discharge. The cell groups on which the cycle-life tests were continued are identified as follows:

Mfr. & Group	Depth of Discharge and Temp.
Gould-National - Group A	10% and -10°C
Gould-National - Group B	10% and 25°C
Gulton - Group A	10% and -10°C
Gulton - Group B	10% and 25°C
Gulton - Group C	10% and 50°C
Gulton - Group D	25% and 25°C
Sonotone - Group A	10% and -10°C
Sonotone - Group B	10% and 25°C
Sonotone - Group D	25% and 25°C

The percent depth of discharge for the cycle-life tests was based upon the nominal rated capacity and the discharges were accomplished at constant current rates. The percent of ampere-hours replaced during the 60-minute charge period was different for each temperature environment, but was the same percentage for cells of different manufacturers and depths of discharge at any one temperature environment. The constant current charging rates were set to replace 115% of the discharged ampere-hours at -10°C, 125% of the discharged ampere-hours at 25°C, and 150% of the removed ampere-hours at 50°C. The cells received these re-charge percentages unless during charge a cell group voltage reached the limiting

voltage established for that group. In this case, the charge equipment automatically switched to a constant voltage mode of charging at the established limiting voltage value. The cells in a cycle-life test group consisted of series-connected cells of the same manufacturer and the limiting voltage was controlled across the series-connected group.

Unless otherwise specified, cycle-life tests were continued uninterrupted until one-half of the original cells in the group failed. A cell was considered to have failed when its terminal voltage fell below 0.9 volt during the 40-minute discharge period and consistently exhibited low discharge voltages on a number of subsequent cycles.

In general, the additional cell failures which occurred during the report period resulted from mechanical design or manufacturing defects in the cells rather than from the "end-of-life" or "wearout" of a basic part of the electrochemical system. The failures were the result of poor glass-to-metal seals, pierced separators, weak welds, and shorts across ceramic insulators. Of the eighteen cells (reference Tables 2, 4 and 6) which failed during the report period, four (4) would not accept a charge and six (6) had a terminal voltage below 1.0 volt at the end of a 120-hour open circuit stand test following a 16-hour charge at a C/2 rate. Of the remaining eight (8) cells which had 120-hour-open-circuit-stand test voltages ranging from 1.08 to 1.30 volts, three were removed from test with a group failure.

1. Test Results - (Gould-National Cells)

A summary of the test results on the Gould-National cells to the end of the report period is shown in TABLE 1.

No additional group failures, as defined above, occurred during the report period, however, four (4) individual cell failures occurred in the cell group cycling with a 10% depth of discharge at 25°C. The number of life-cycles-to-failure and post-failure test data for these four cells are shown in TABLE 2. The end-of-discharge voltage of Cells No. 10 and 22 fell to 0.1 volt during cycling and the end-of-discharge of Cells No. 12 and 15 fell to 0.8 volt. The post-failure open-circuit stand voltages given in TABLE 2 are those following a 16-hour charge at a C/10 rate after removal of the cells from the cycling regime at the end of the discharge period.

The end-of-charge and end-of-discharge voltages for each group were continuously monitored with the results being recorded periodically throughout the cycle-life tests. These results along with the end-of-charge and discharge voltages for individual cells selected at random from the groups are presented in Appendix I, Figures 1 through 5 and 6 through 13 respectively. Figures 14 through 21 show the entire charge-discharge voltage measurements for representative cycles of the cells selected from each group.

TABLE 1 - Summary of Results - Gould National Cells

A. CELL SIZE: 3.5 A.H.

B. NO. OF CELLS STARTED IN TEST

1. Initial Tests: 50
2. Cycle-Life Tests: 40

C. NO. OF CELLS FAILED IN TEST

1. Initial Tests - 25
2. Cycle-Life Tests - 17 plus 12 cells stopped with group failure (27.5% of original cells remain on cycle-life)

D. TYPES OF FAILURES

1. Initial Tests

a. Electrolyte Leakage: 25 cells (50% of cells tested)
b. Electrical Leakage: 2 cells (4% of cells tested)

2. Cycle-Life Tests

a. Open-ckt.: None
b. Shorts (Direct): 5 cells (12.5% of total cells cycled)
Shorts (Capacity Loss on Open-Circuit Stand): 10 Cells (25% of total cells cycled)
c. Excessive Leakage (Dried Out): 2 cells (5% of total cells cycled)

E. NO. OF CYCLES COMPLETED

1. Group A (10% Disch. at -10°C): 12,400 cycles - Still cycling (No cell failures)
2. Group B (10% Disch. at 25°C): 14,000 cycles - Still cycling (4 cell failures)
3. Group C (10% Disch. at 50°C): 3576 cycles - Group Failure
4. Group D (25% Disch. at 25°C): 5110 cycles - Group Failu
5. Group E (40% Disch. at 25°C): 1282 cycles - Group Failure

F. NO. OF CELLS IN GROUP AT START OF CYCLE-LIFE

1. Groups A & E: 5 cells
2. Groups B, C & D: 10 cells

TABLE 2 - TEST DATA SUMMARY ON CELL FAILURES* (Gould-National Cells)

Cell No.	Charge Rate (amps)	Charge Limit (volts/cell)	Discharge Rate (amps)	Cycles to Failure	Case Distortion	Leakage Case	Leakage Seal	Post-Failure Open Circuit Voltage (volts) after 15 mins.	after 24 hrs.	after 120 hrs.	Post-Failure Capacity to 1.0 V. (AH)	to 0.6 V. (AH)
GROUP B - 10% Depth of Discharge at 25°C												
10	0.44	1.5	0.525	8,843	No	No	Slight - Cell would not accept charge					
22	0.44	1.5	0.525	10,832	No	No	Extensive - Cell would not accept charge					
12	0.44	1.5	0.525	11,332	No	No	Slight	1.37	1.29	1.08	2.5	3.0
15	0.44	1.5	0.525	13,712	No	No	Extensive	1.38	1.34	1.30	0.33	2.13

* Failures during report period

2. Test Results (Gulton Cells)

A summary of the test results on the Gulton cells to the end of the report period is listed in TABLE 3.

Two cell failures, one each in Group C cycling with 10% depth of discharge at 50°C and Group D cycling with 25% depth of discharge at 25°C, occurred during the report period. The number of life-cycles completed and post-failure test data for these two cells are summarized in TABLE 4.

The discharge voltage of Cells No. 602 and 818 during cycling fell to 0.01 volt and 0.6 volt, respectively. The post-failure open-circuit stand voltages given in TABLE 4 were measured after a 16-hour charge at a C/10 rate. The post-failure capacity determinations were made with a C/2 discharge rate immediately following another 16-hour charge at a C/10 rate after the 120-hour open-circuit stand test.

The average end-of-charge and end-of-discharge voltages for each group and end-of-charge and discharge voltages for individual cells selected at random are presented in APPENDIX II, Figures 22 through 25 and 26 through 33, respectively. Figures 34 through 41 show the charge-discharge voltage characteristics for representative cycles of cells selected from each group.

TABLE 3 - Summary of Results - Gulton Cells

A. CELL SIZE: 6 A-H

B. NO. OF CELLS STARTED IN TEST

1. Initial Tests: 50
2. Cycle-Life Tests: 40

C. NO. OF CELLS FAILED IN TEST

1. Initial Tests: 7
2. Cycle-Life Tests: 10 (75% of original cells remain on cycle-life)

D. TYPES OF FAILURES

1. Initial Tests

a. Electrolyte Leakage: 5 Cells (10% of cells tested)
b. Electrical Leakage: 2 Cells (4% of cells tested)

2. Cycle-Life Tests

a. Open-ckt.: None
b. Shorts (Direct): 6 Cells (15% of total cells cycled)
Shorts (Capacity Loss on Open-Circuit Stand): 4 Cells (10% of total cells cycled)

E. NO. OF CYCLES COMPLETED

1. Group A (10% Disch. at -10°C): 13,500 cycles - Still cycling (No cell failures)
2. Group B (10% Disch. at 25°C): 14,000 cycles - Still cycling (2 cell failures)
3. Group C (10% Disch. at 50°C): 13,800 cycles - Still cycling (4 cell failures)
4. Group D (25% Disch. at 25°C): 13,700 cycles - Still cycling (4 cell failures)

F. NO. OF CELLS IN GROUP AT START OF CYCLE-LIFE

1. All 4 Groups: 10 cells

TABLE 4 - TEST DATA SUMMARY ON CELL FAILURES* (Gulton Cells)

Cell No.	Charge Rate (amps)	Charge Limit (volts/cell)	Discharge Rate (amps)	Cycles to Failure	Case Distortion	Leakage Case	Leakage Seal	Post-Failure Open Circuit Voltage (volts) after 15 mins.	after 24 hrs.	after 120 hrs.	Post-Failure Capacity to 1.0 V. (AH)	to 0.6 V. (AH)
GROUP C - 10% Depth of Discharge at 50°C												
602	0.90	None	0.90	11,148	No	No	No - Cell would not accept charge					
GROUP D - 25% Depth of Discharge at 25°C												
818	1.88	1.5	2.22	13,355	No	No	No	1.38	1.27	0.20	2.5	2.8

* Failures during report period

3. Test Results (Sonotone Cells)

A summary of the test results on the Sonotone cells to the end of the report is shown in TABLE 5.

Sonotone Group D cycling with a 25% depth of discharge at 25°C failed during the report period. Also, the first three cell failures in the group cycling with a 10% depth of discharge at 25°C occurred near the end of the report period. The number of cycles completed and post-failure test data for these cells are summarized in TABLE 6. End-of-discharge voltages for these cells at failure ranged from 0.1 volt to 0.82 volt. The open-circuit stand voltages were measured after a 16-hour charge at a C/10 rate and the post failure capacities were determined with a C/2 discharge rate following another 16-hour charge at a C/10 rate after the open-circuit stand test.

The average end-of-charge and discharge voltages for each group and end-of-charge and discharge voltages for individual cells selected at random are presented in APPENDIX III, Figures 42 through 46 and 47 through 55, respectively. Figures 56 through 64 show the charge-discharge voltage characteristics for representative cycles of cells selected from the groups.

TABLE 5 - Summary of Results - Sonotone Cells

A. CELL SIZE: 3.5 A.H.

B. NO. OF CELLS STARTED IN TEST

1. Initial Tests: 50 Cells
2. Cycle-Life Tests: 44 Cells

C. NO. OF CELLS FAILED IN TEST

1. Initial Tests: 6
2. Cycle-Life Tests: 15 plus 12 cells stopped at group failure (39% of original cells remain on cycle-life)

D. TYPES OF FAILURES

1. Initial Tests

a. Electrolyte Leakage: 4 Cells (8% of cells tested)
b. Electrical Leakage: 2 Cells (4% of cells tested)

2. Cycle-Life Tests:

a. Open-ckt.: None
b. Shorts (Direct): 9 Cells (20% of total cells cycled)
Shorts (Capacity Loss on Open-Ckt. Stand): 6 Cells (14% of total cells cycled)

E. NO. OF CYCLES COMPLETED

1. Group A (10% Disch. at -10°C): 13,500 cycles - Still Cycling (No cell failures)
2. Group B (10% Disch. at 25°C): 14,000 cycles - Still Cycling (3 cell failures)
3. Group C (10% Disch. at 50°C): 5,545 cycles - Group Failure
4. Group D (25% Disch. at 25°C): 12,592 cycles - Group Failure
5. Group E (40% Disch. at 25°C): 6,146 cycles - Group Failure

F. NO. OF CELLS IN GROUP AT START OF CYCLE-LIFE

1. Groups A, B, C and D: 10 Cells
2. Group E: 4 Cells

TABLE 6 - TEST DATA SUMMARY ON CELL FAILURES* (Sonotone Cells)

Cell No.	Charge Rate (amps)	Charge Limit (volts/cell)	Discharge Rate (amps)	Cycles to Failure	Case Distortion	Leakage Case	Leakage Seal	Post-Failure Open Circuit Voltage (volts) after 60 mins.	after 24 hrs.	after 120 hrs.	Post-Failure Capacity to 1.0 V. (AH)	to 0.6 V. (AH)
GROUP B - 10% Depth of Discharge at 25°C												
65	0.44	1.5	0.525	13,594	No	No	No	1.34	1.28	1.26	2.2	2.4
R40	0.44	1.5	0.525	13,756	Slight	No	Slight	1.37	1.30	1.28	2.5	3.0
68	0.45	1.5	0.525	13,756	No	No	Slight - Would not accept charge					
GROUP D - 25% Depth of Discharge at 25°C												
61	1.09	1.5	1.31	11,032	No	No	No	1.28	1.16	1.0	0.1	0.14
R55	1.09	1.5	1.31	11,033	Slight	No	No	1.31	1.18	0.88	1.0	1.1
R57	1.09	1.5	1.31	11,766	Slight	No	No	1.31	1.26	1.11	1.9	2.1
R51	1.09	1.5	1.31	12,563	Slight	No	Extensive	1.30	1.24	0.91	0.9	
60	1.09	1.5	1.31	12,592	Slight	No	No	1.28	1.11	0.77	0.8	
R49	1.09	1.5	1.31	12,592**	Slight	No	Slight	1.33	1.29	1.23	1.34	
R50	1.09	1.5	1.31	12,592**	Slight	No	No	1.28	1.19	0.85	1.14	
R52	1.09	1.5	1.31	12,592**	No	No	Slight	1.31	1.25	1.13	1.1	
R53	1.09	1.5	1.31	12,592**	No	No	Slight	1.30	1.26	1.19	1.4	

* Failures during report period
** Group Failure (Cycling Stopped)

III. NEW TECHNOLOGY

(Data for this section is not applicable)

IV. PROGRAM FOR NEXT REPORTING INTERVAL

Continuation of the cycle-life tests on groups still cycling is planned for the next reporting interval. Also, completion of internal inspection and analysis of cells which have failed is planned for the next reporting interval.

V. CONCLUSIONS

At the end of this reporting period slightly more than one-half of the original cells started on the cycle-life test have failed through individual cell failures and group failures. Approximately three-fourths of the cells of one manufacturer have failed in the cycle-life tests.

The significance of the temperature environment on the cycle-life of the cells is indicated by the following data: after completion of more than 30-months of cycling with 10% depth of discharge, all of the original cells in the cycle tests at the -10°C temperature environment are still cycling, 70% of the original cells at 25°C are still cycling, and only 20% of the original cells at 50°C are still cycling.

The significance of the depth of discharge on the cycle-life of the cells at 25°C is also indicated by the test results since all cells cycled with 40% discharge have failed, 80% cycled with 25% discharge have failed and 30% cycled with 10% discharge have failed to date.

No cell failures have occurred as a result of an open-circuit. Approximately one-half of the cell failures resulted from direct shorts (such as corrosion across insulating seals and pierced separators) and the cells would not accept a re-charge after failure, or the terminal voltage dropped to zero during an open circuit stand test. Approximately another one-third of the failed cells had shorts sufficient to cause a voltage decrease to less than 1.0 volt on an open circuit stand (120 hrs.) following a re-charge.

VI. BIBLIOGRAPHY

Technical Report, Contract NAS 5-1048, "Testing and Evaluation of Spacecraft-Type Cells", bu I. F. Luke and E. A. Roeger. Prepared for Goddard Space Flight Center.

APPENDIX I

(Voltage Characteristics - Gould-National Cells)

Figure 1 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at -10°C
Gould-National Cells

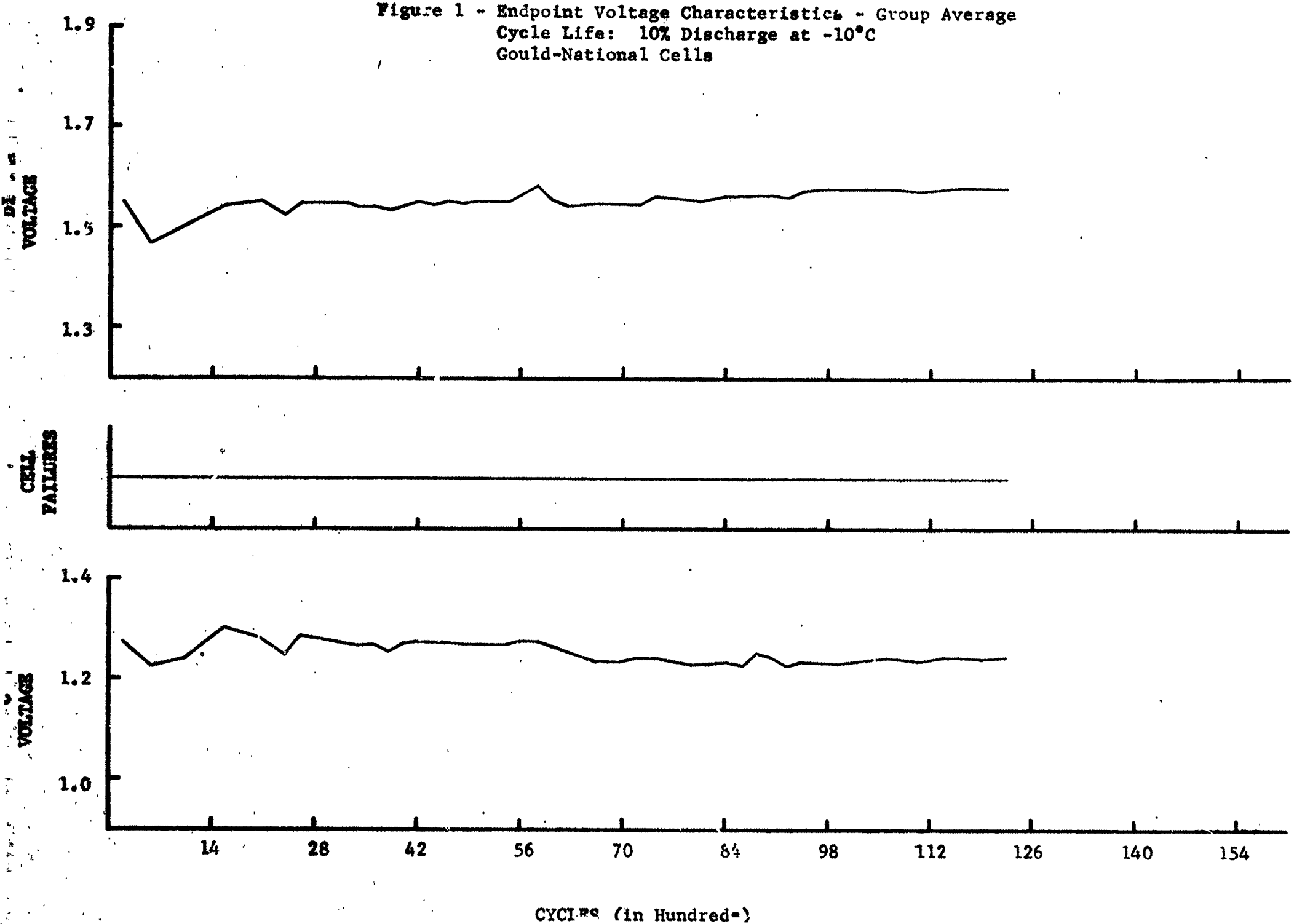


Figure 2 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at 25°C
Gould-National Cells

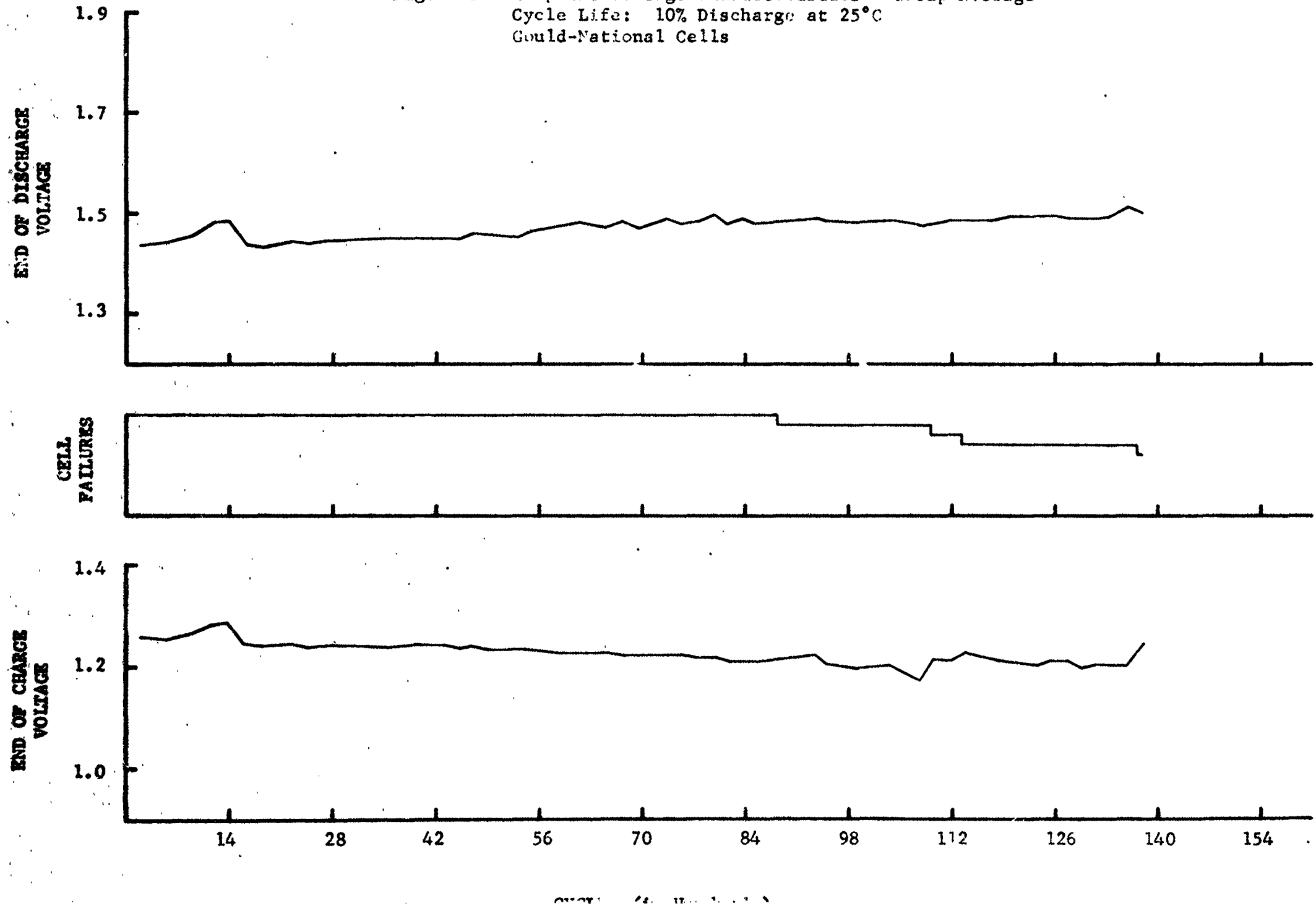


Figure 3 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at 50°C
Gould-National Cells

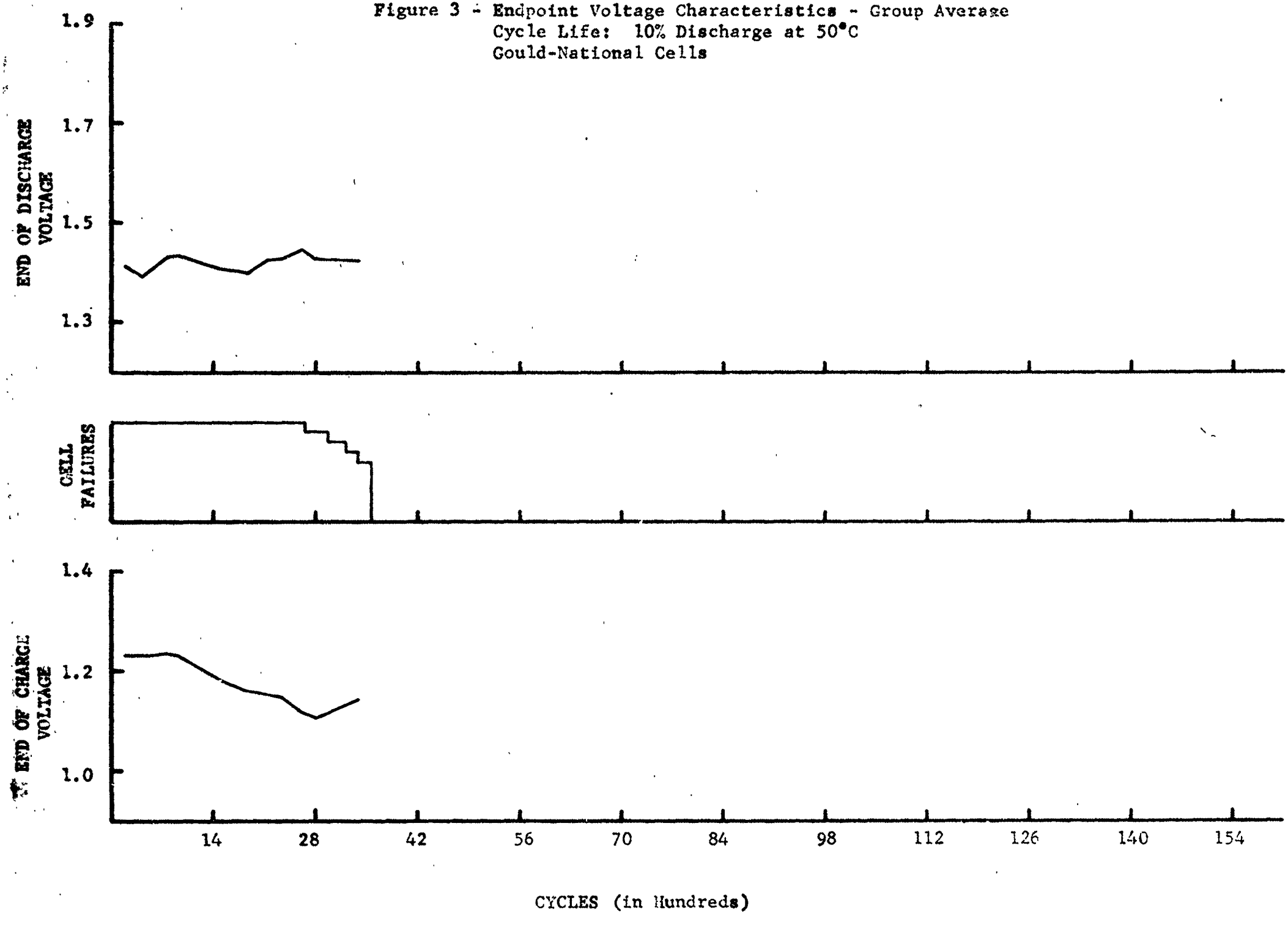


Figure 4 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 25% Discharge at 25°C
Gould-National Cells

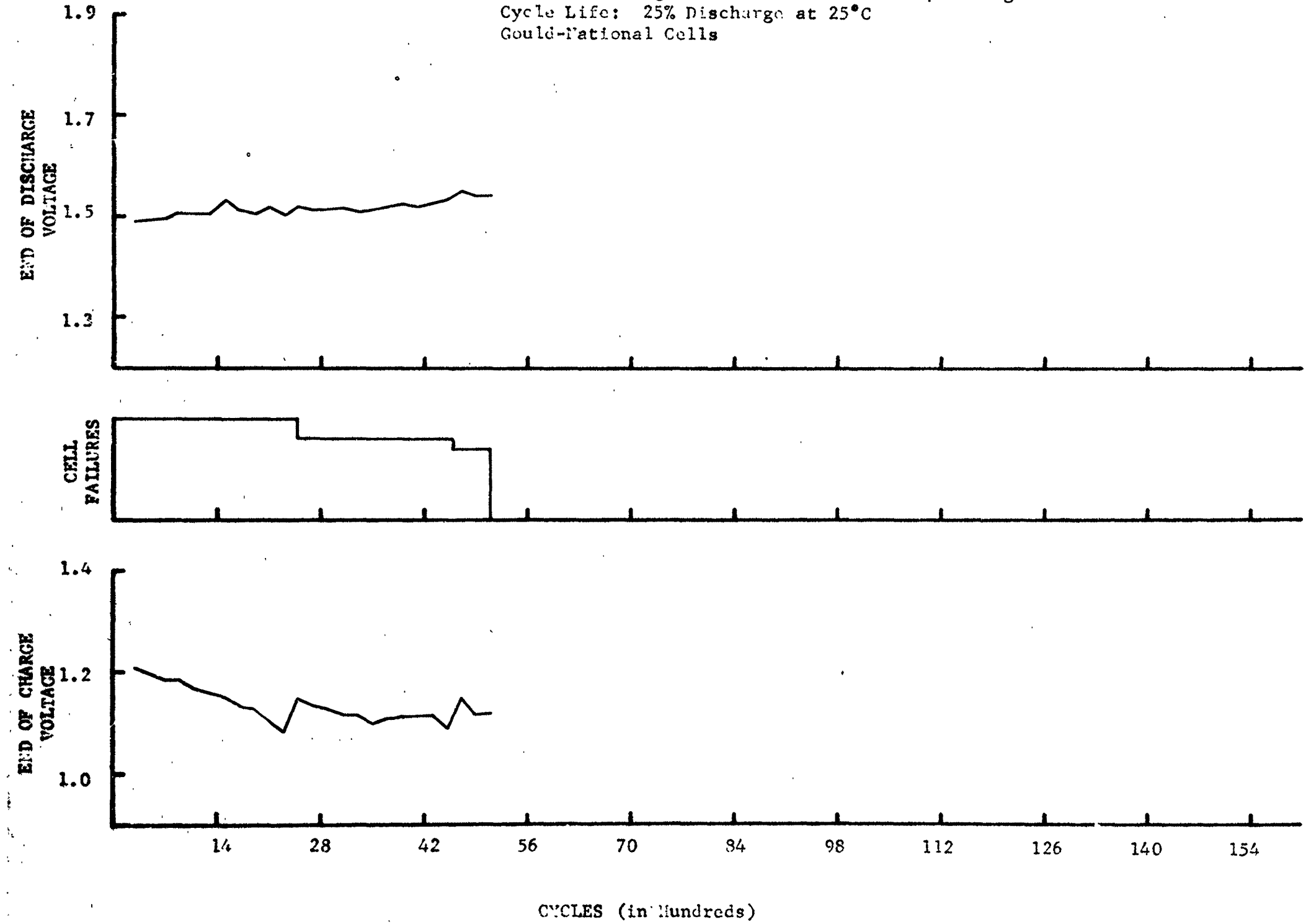


Figure 5 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 40% Discharge at 25°C
Gould-National Cells

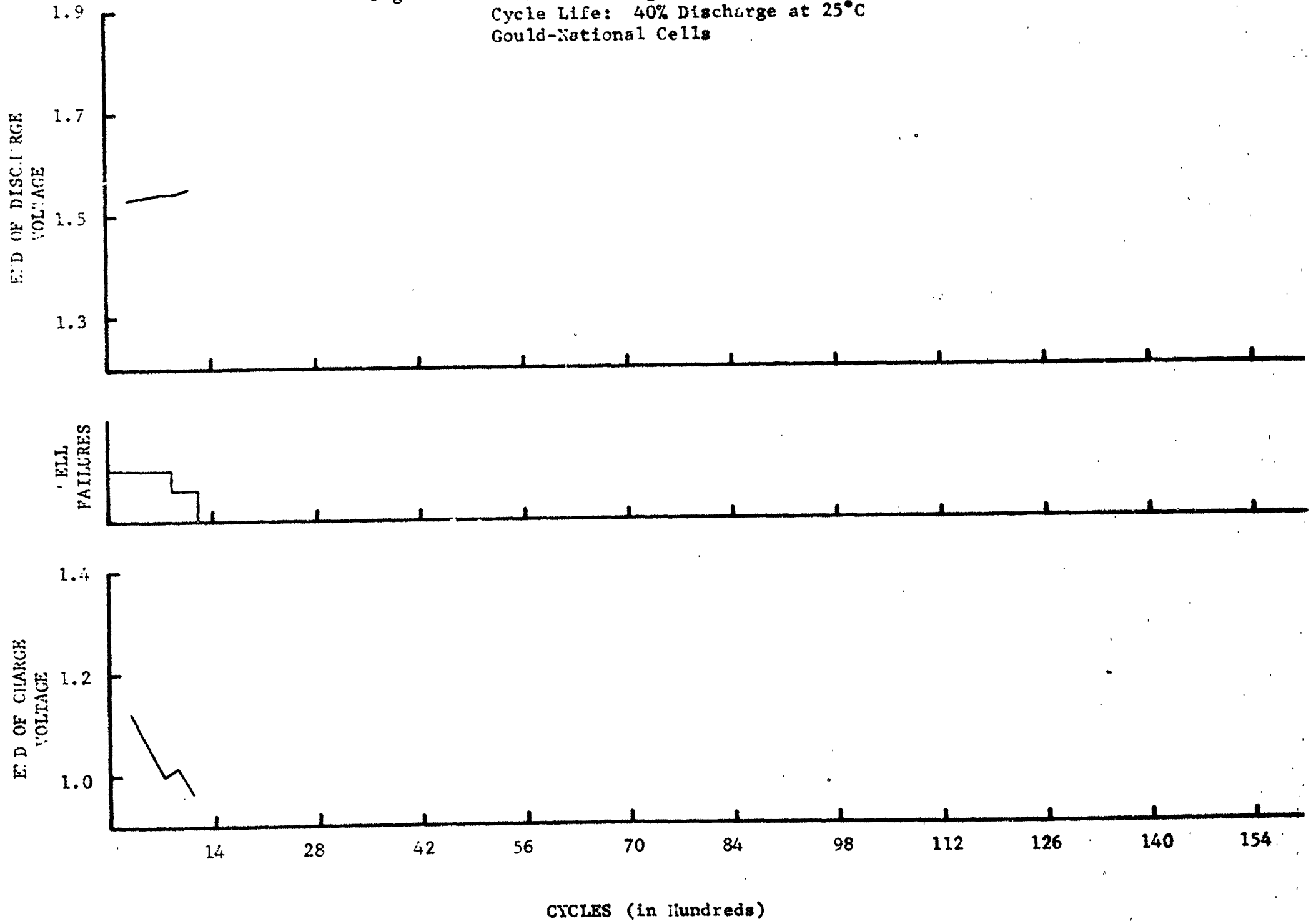


Figure 6 - Endpoint Voltage Characteristics - Cell #35
Cycle Life: 10% Discharge at -10°C
Gould-National Cell

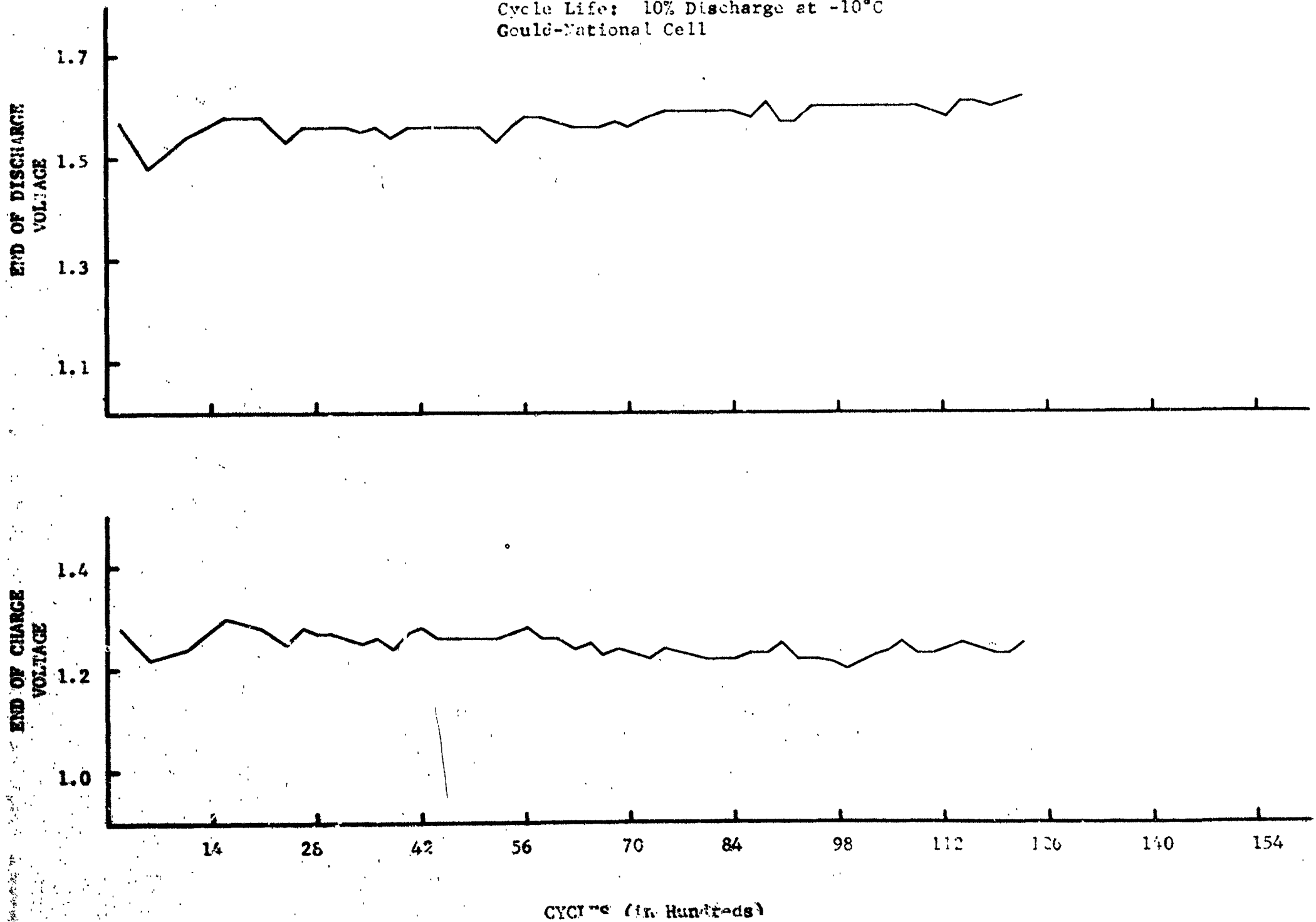


Figure 7 - Endpoint Voltage Characteristics - Cell #9
Cycle Life: 10% Discharge at 25°C
Gould-National Cell

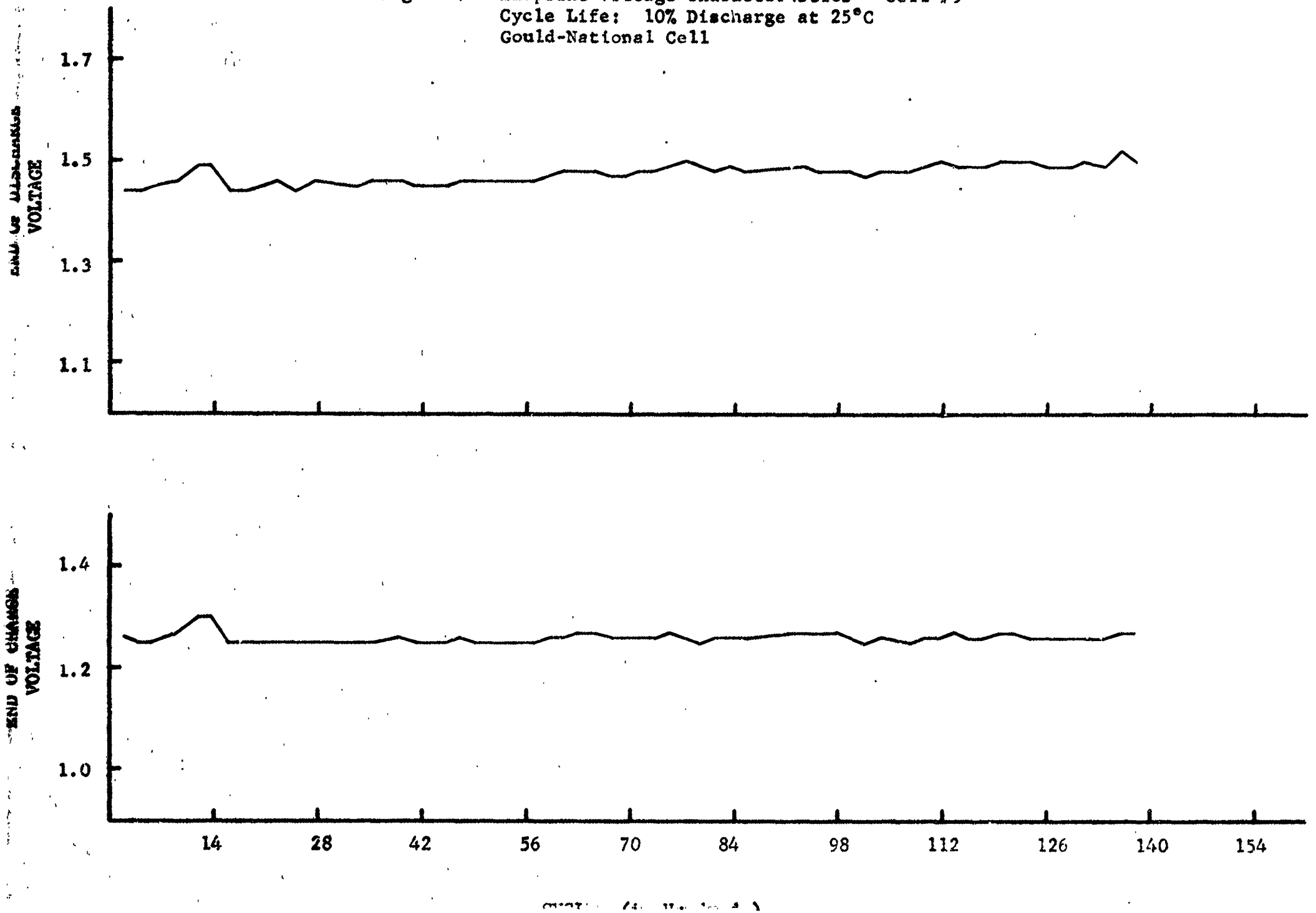


Figure 8 - Endpoint Voltage Characteristics - Cell #22
Cycle Life: 10% Discharge at 25°C
Gould-National Cell

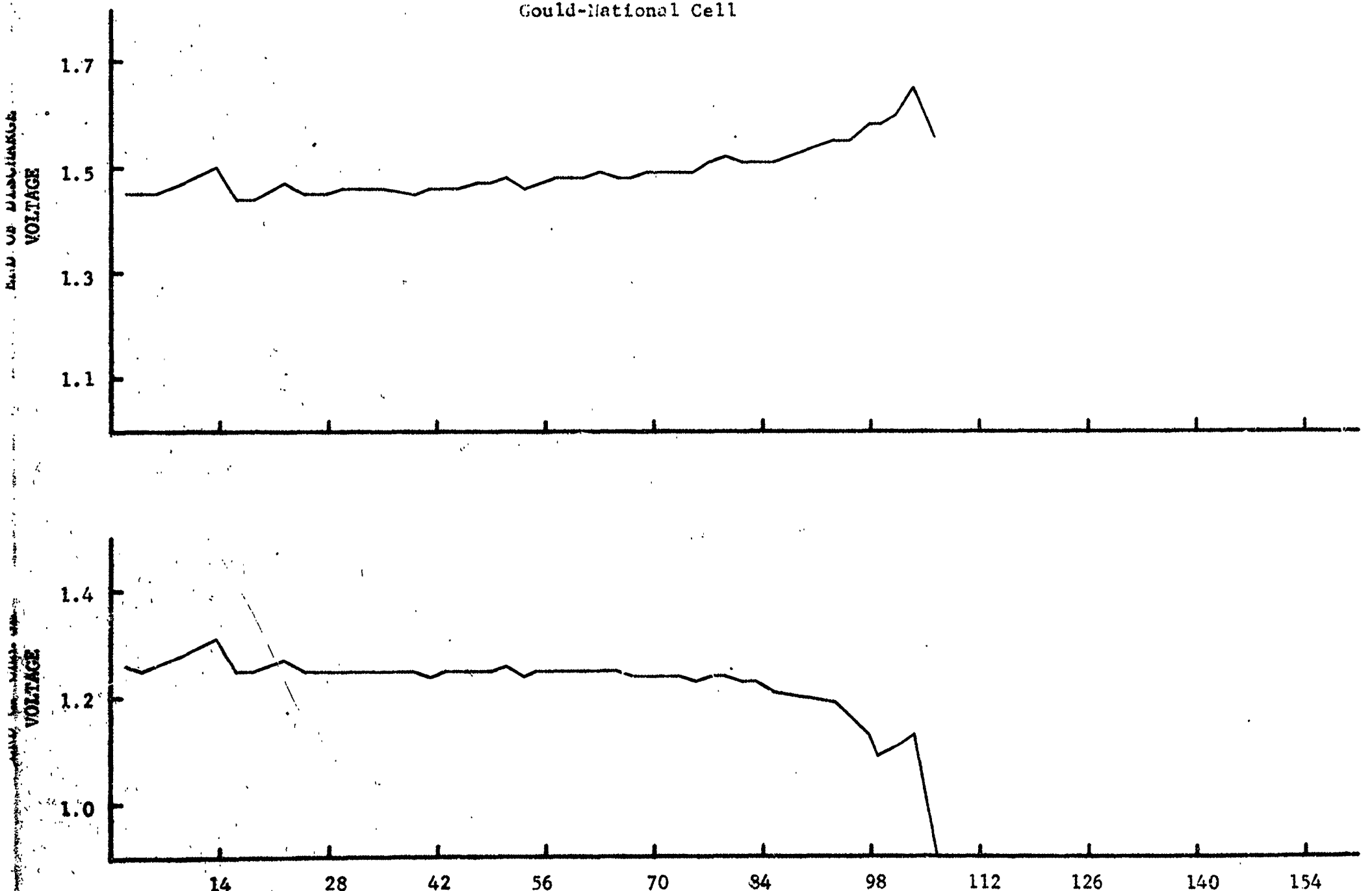


Figure 9 - Endpoint Voltage Characteristics - Cell #21
Cycle Life: 10% Discharge at 50°C
Gould-National Cell

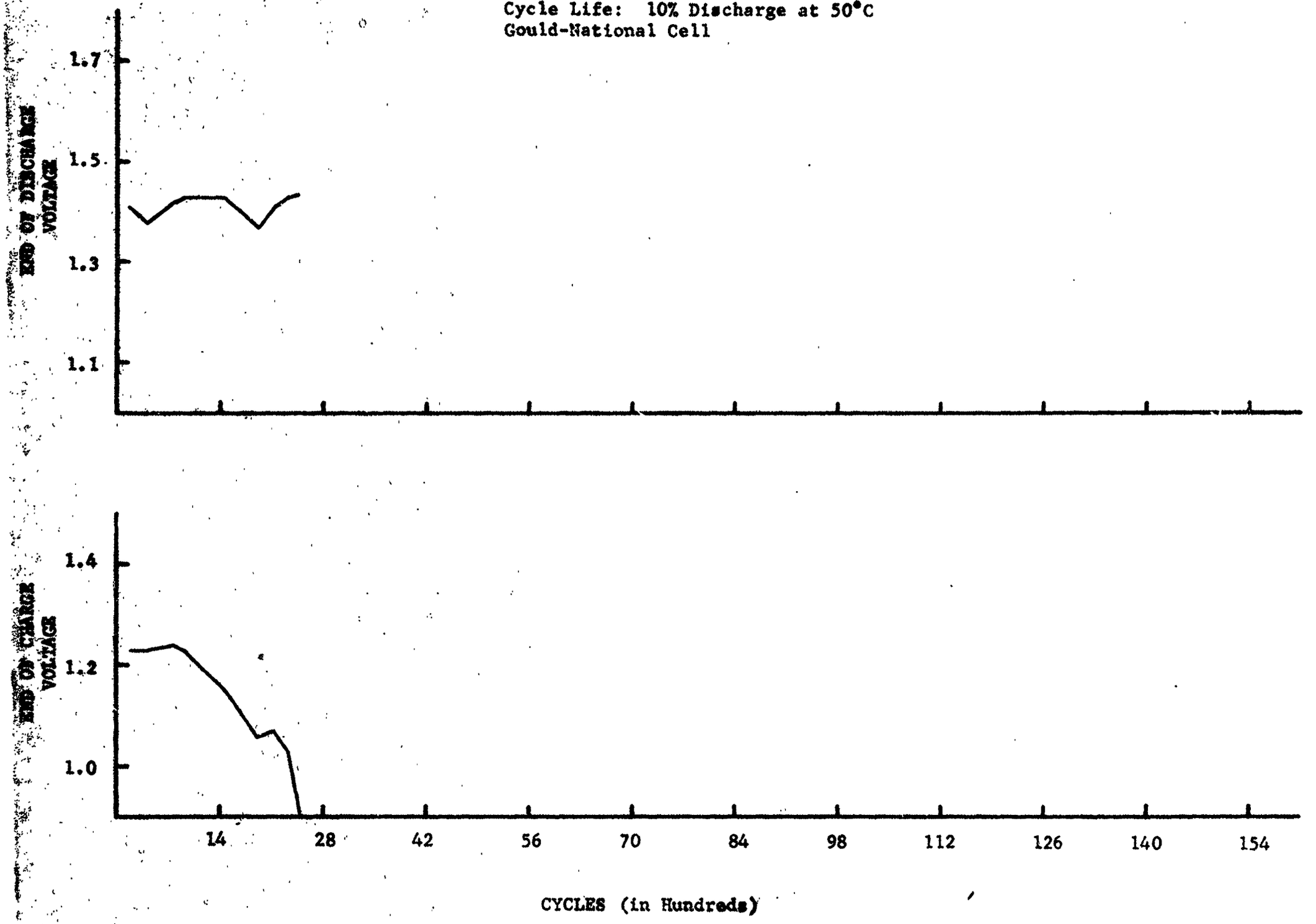


Figure 10 - Endpoint Voltage Characteristics - Cell #28
Cycle Life: 10% Discharge at 50°C
Gould-National Cell

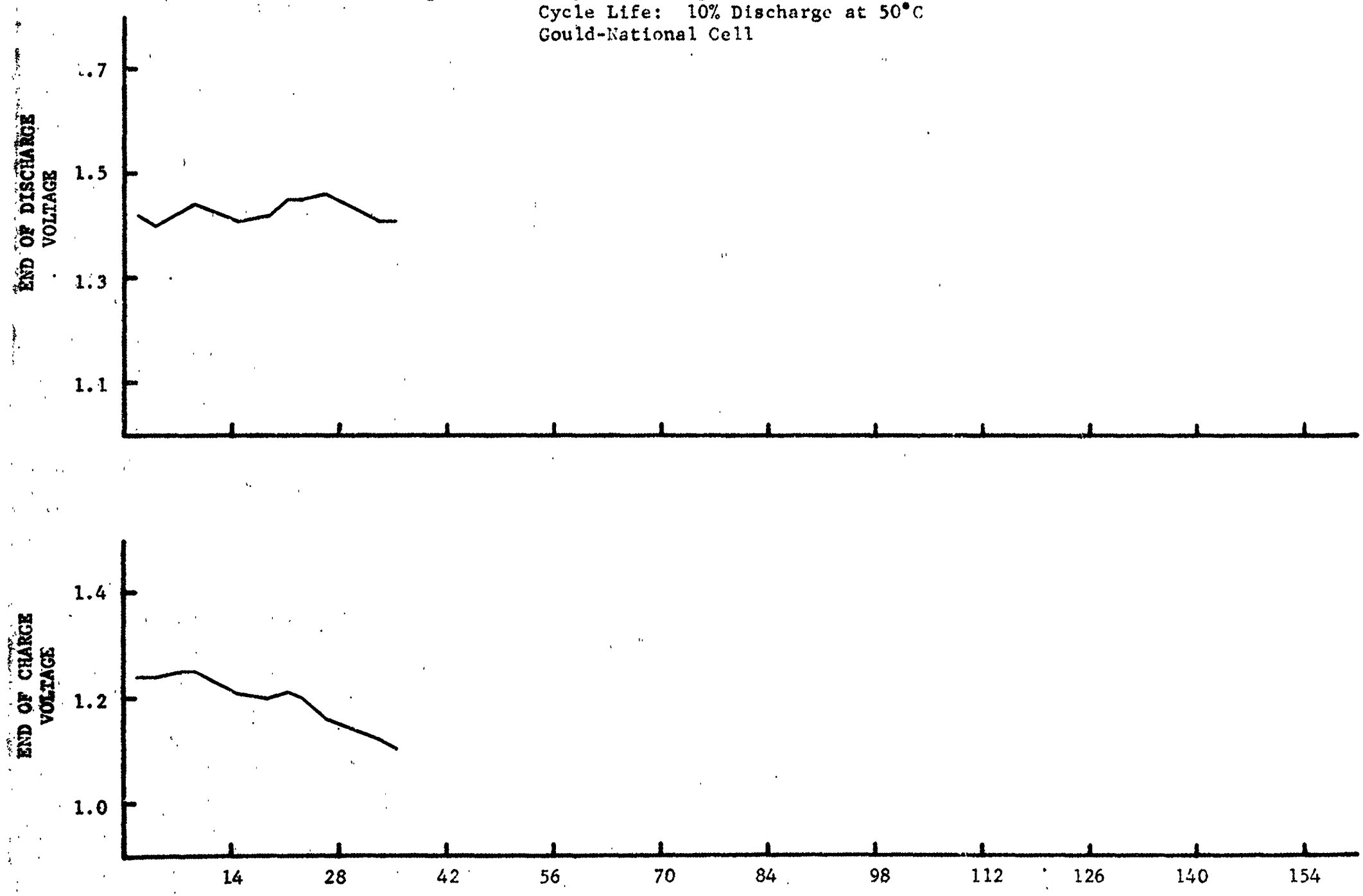


Figure 11 - Endpoint Voltage Characteristics - Cell #3
Cycle Life: 25% Discharge at 25°C
Gould-National Cell

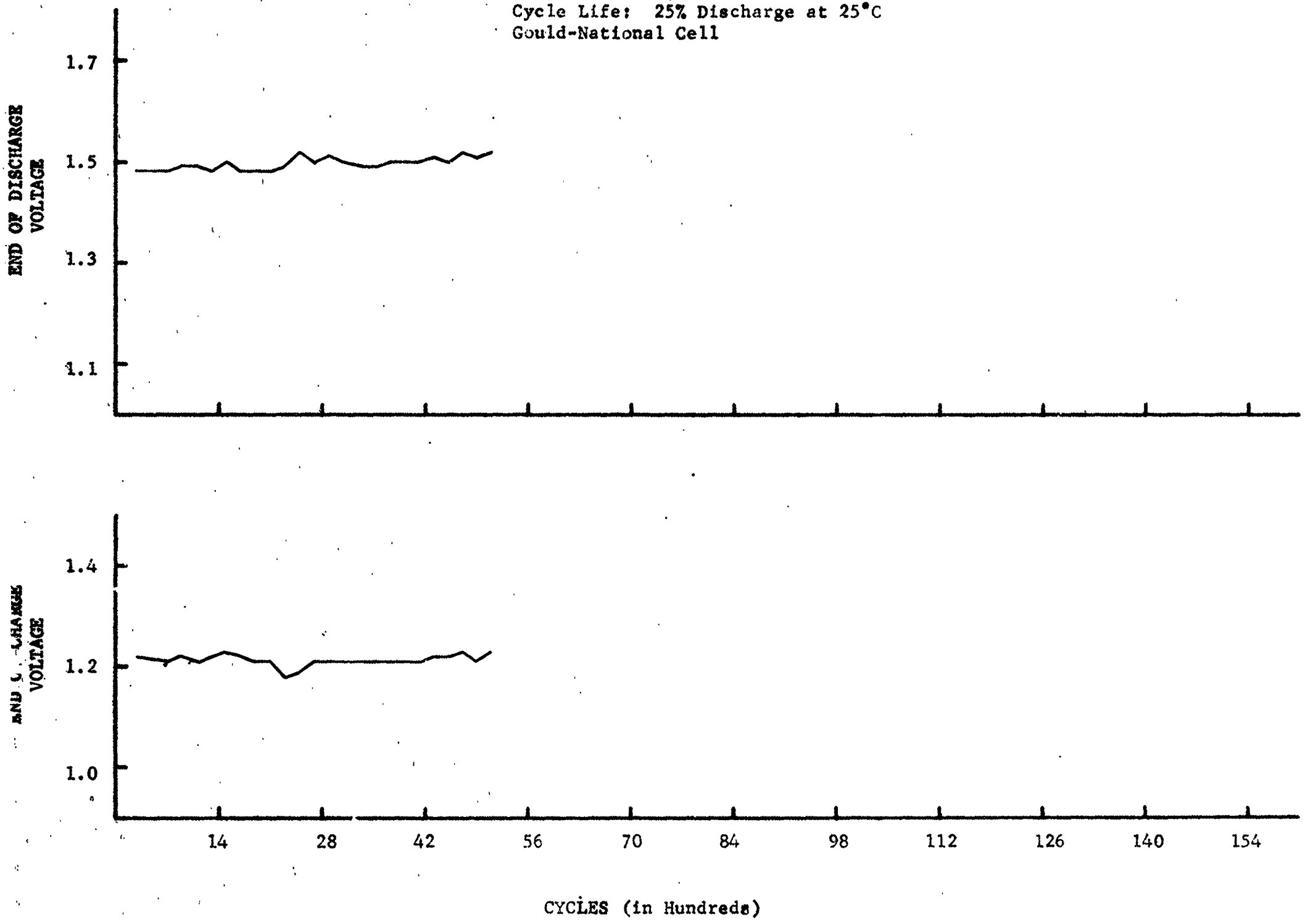


Figure 12 - Endpoint Voltage Characteristics - Cell #13
Cycle Life: 25% Discharge at 25°C
Gould-National Cell

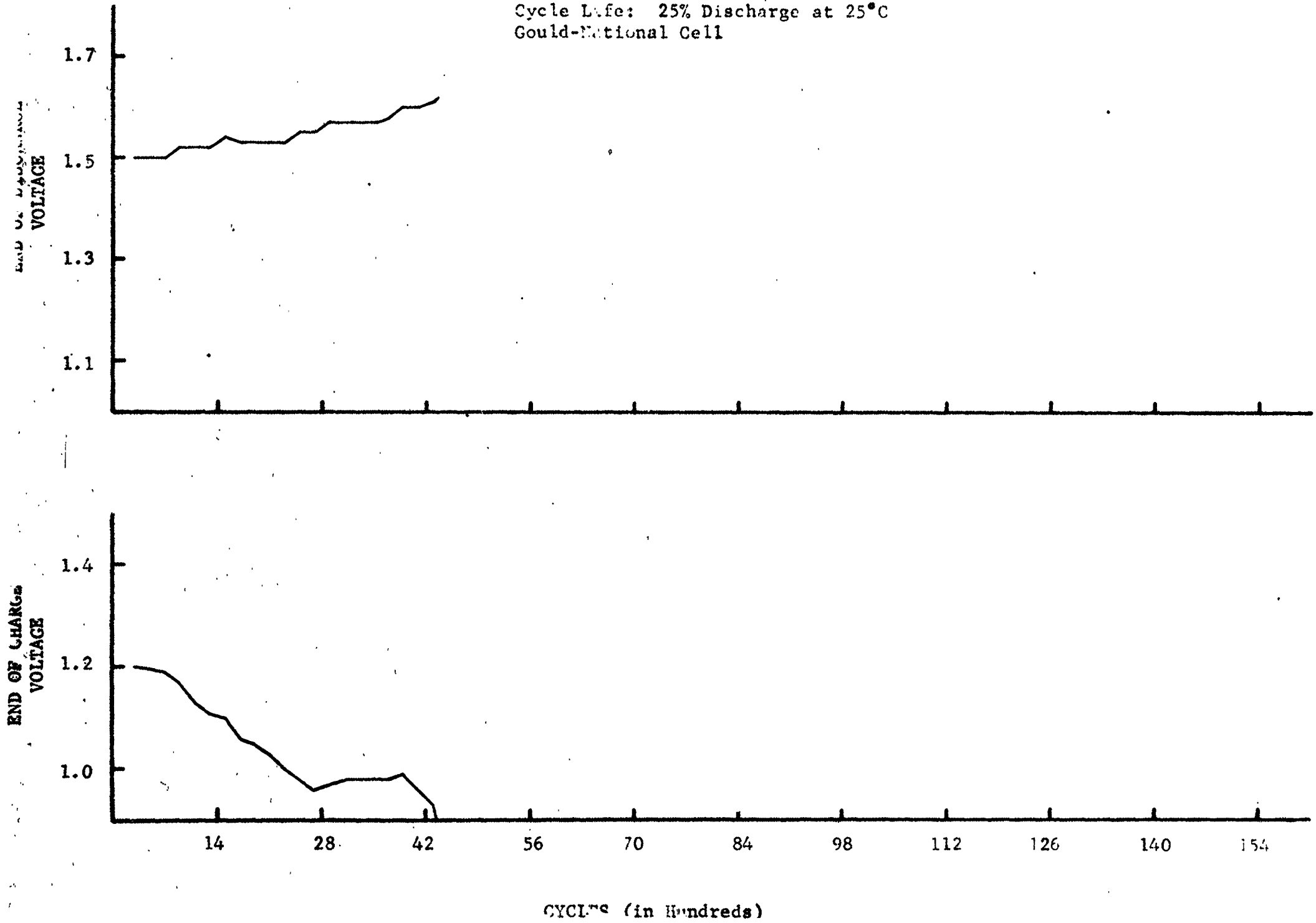


Figure 13 - Endpoint Voltage Characteristics - Cell #49
Cycle Life: 40% Discharge at 25°C
Gould-National Cell

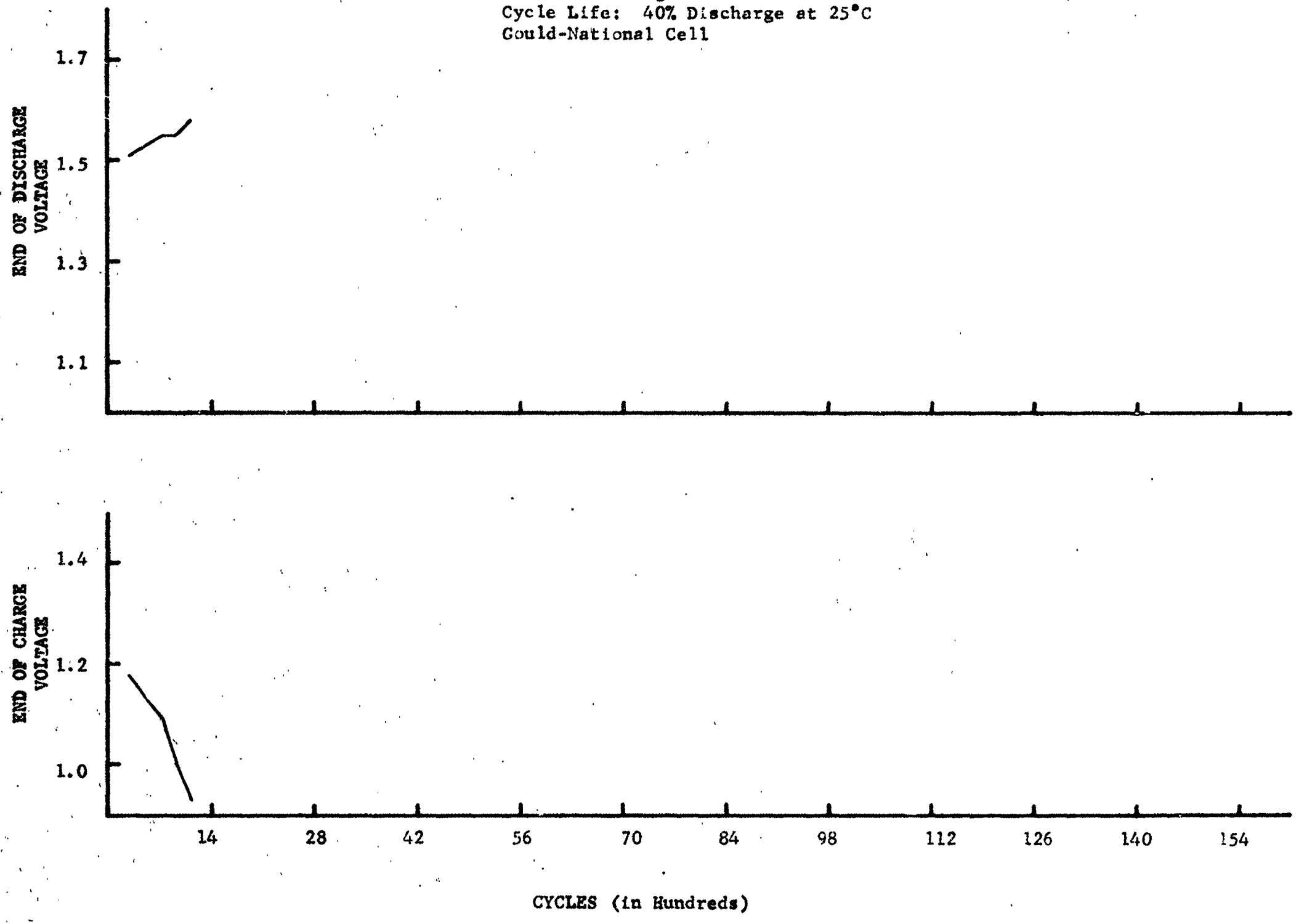


Figure 14 - Charge-Discharge Voltage-Characteristics - Cell #35
Cycle Life: 10% Discharge at -10°C
Gould-National Cell

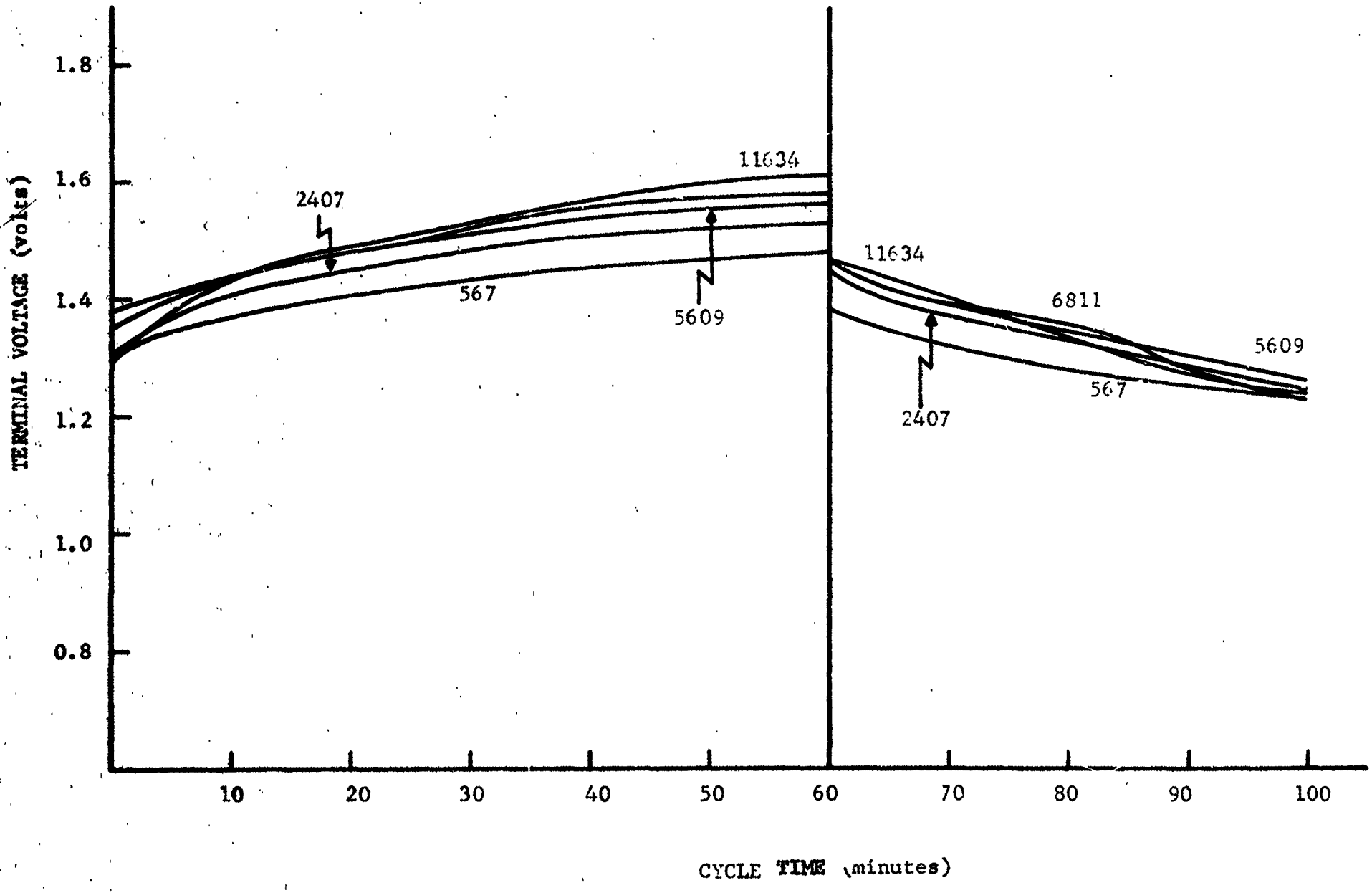


Figure 15 - Charge-Discharge Voltage Characteristics - Cell #9
Cycle Life: 10% Discharge at 25°C
Gould-National Cell

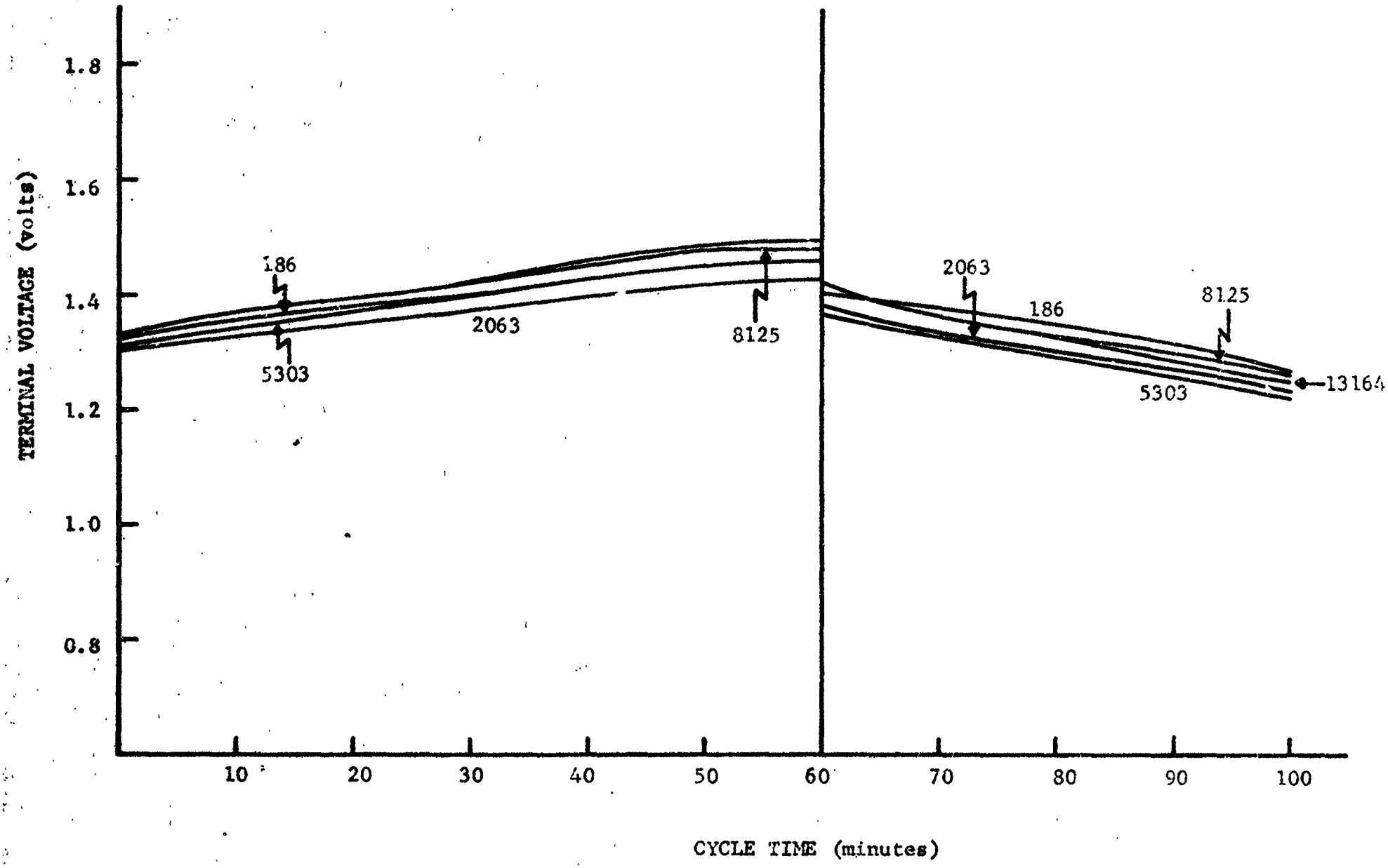


Figure 16 - Charge-Discharge Voltage Characteristics - Cell #22
Cycle Life: 10% Discharge at 25°C
Gould-National Cell

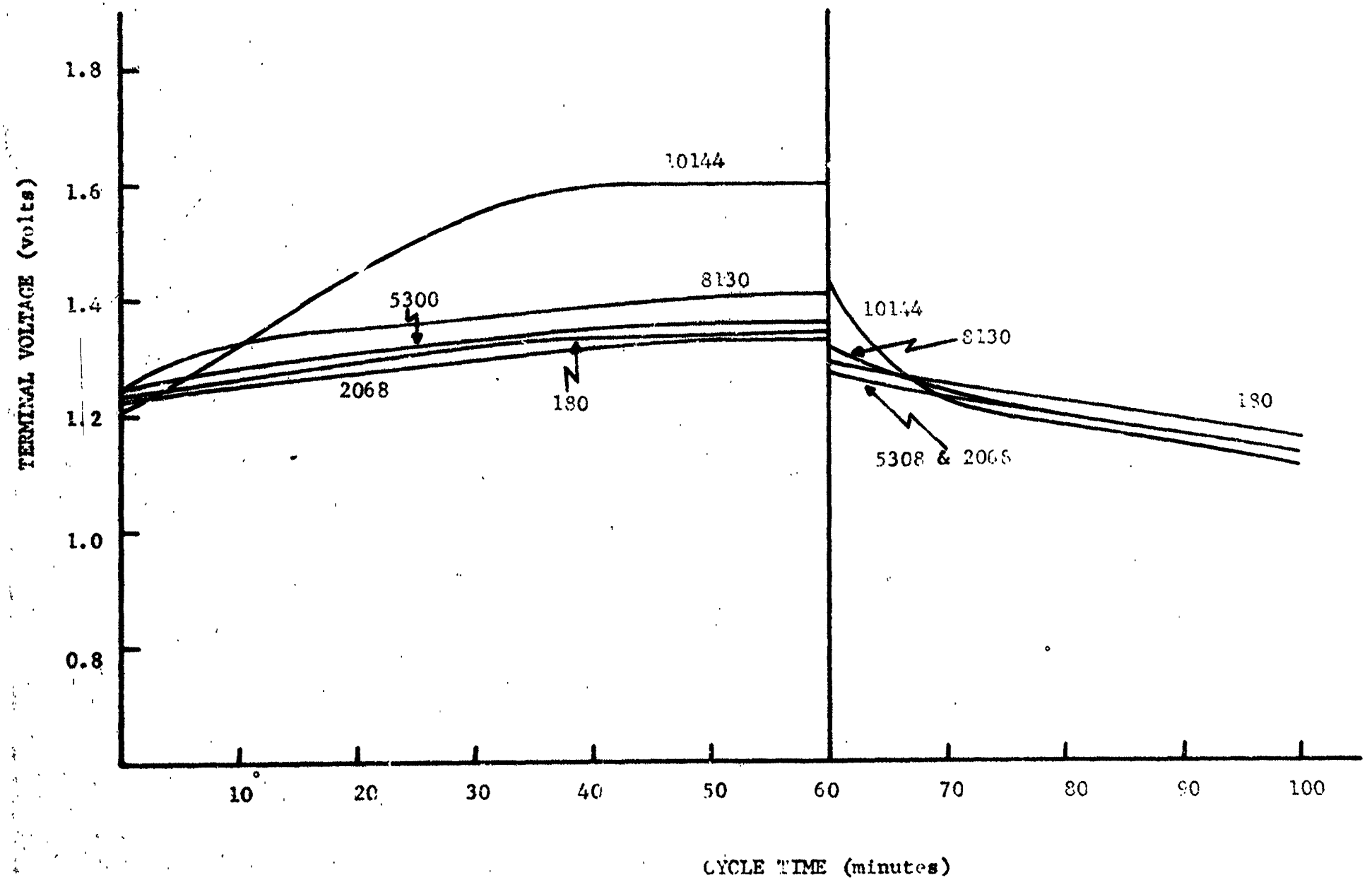


Figure 17 - Charge-Discharge Voltage Characteristics - Cell #21
Cycle Life: 10% Discharge at 50°C
Gould-National Cell

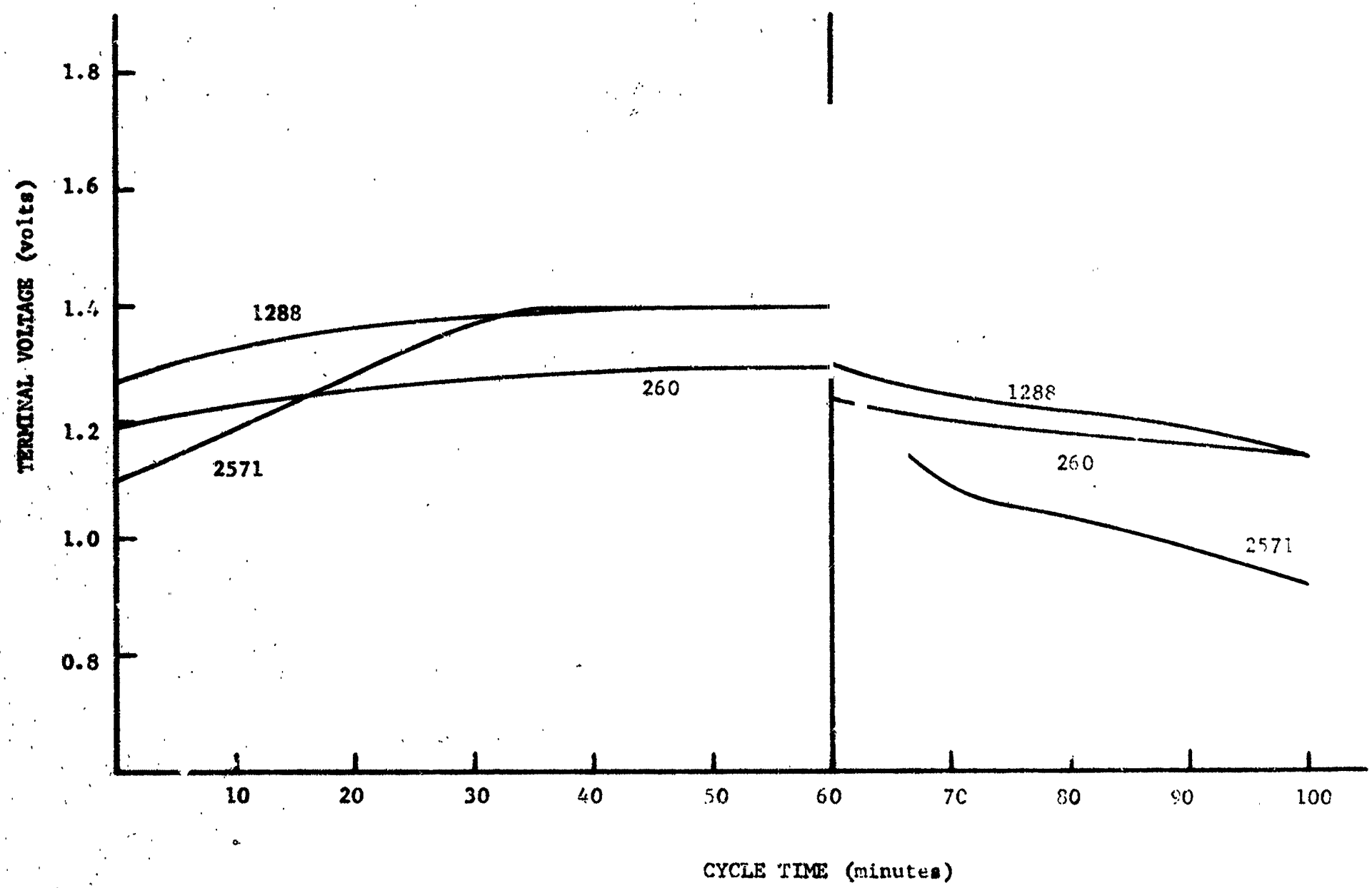


Figure 18 - Charge-Discharge Voltage Characteristics - Cell #28
Cycle Life: 10% Discharge at 50°C
Gould-National Cell

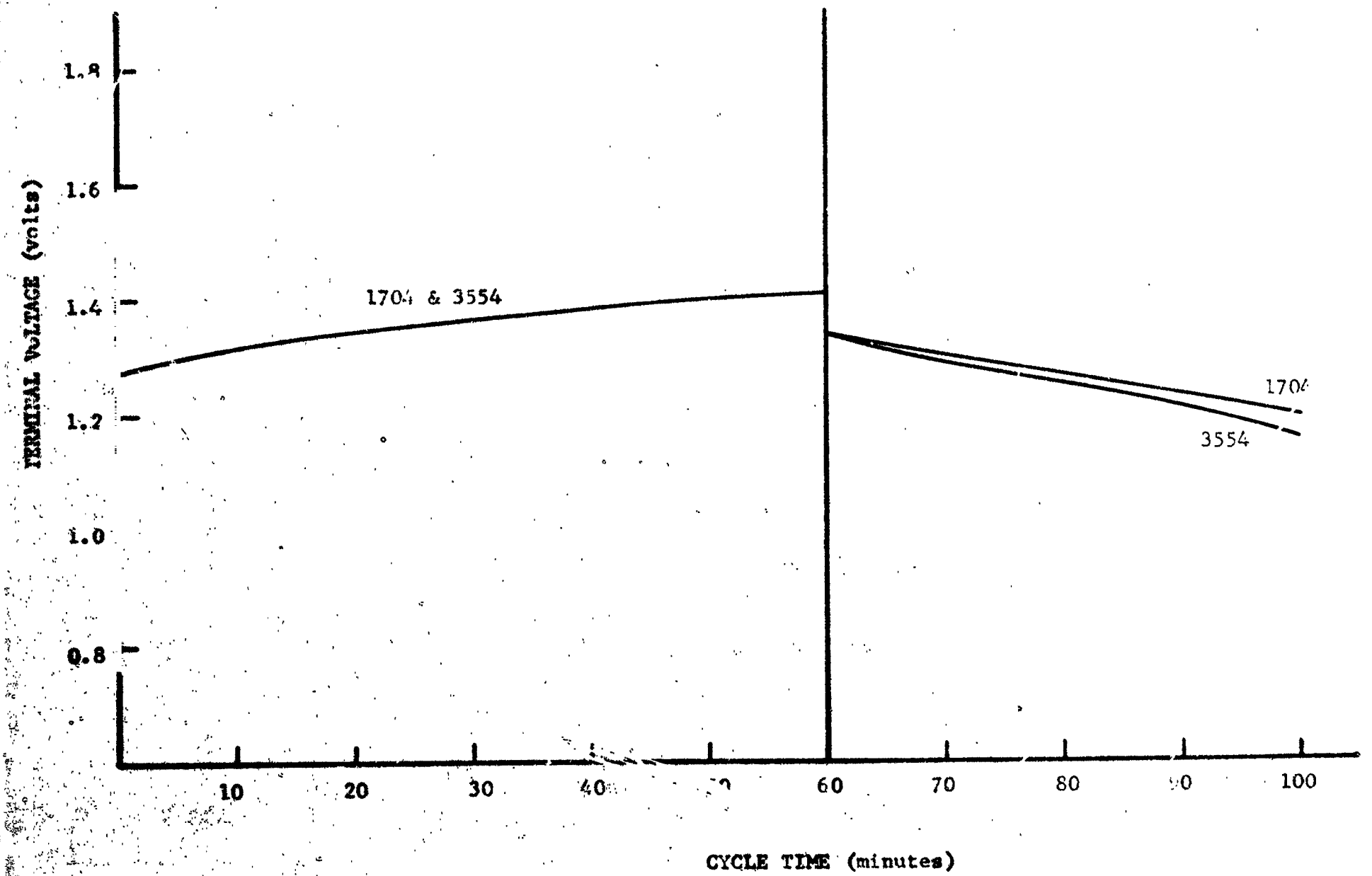


Figure 19 - Charge-Discharge Voltage Characteristics - Cell #3
Cycle Life: 25% Discharge at 25°C
Gould-National Cell

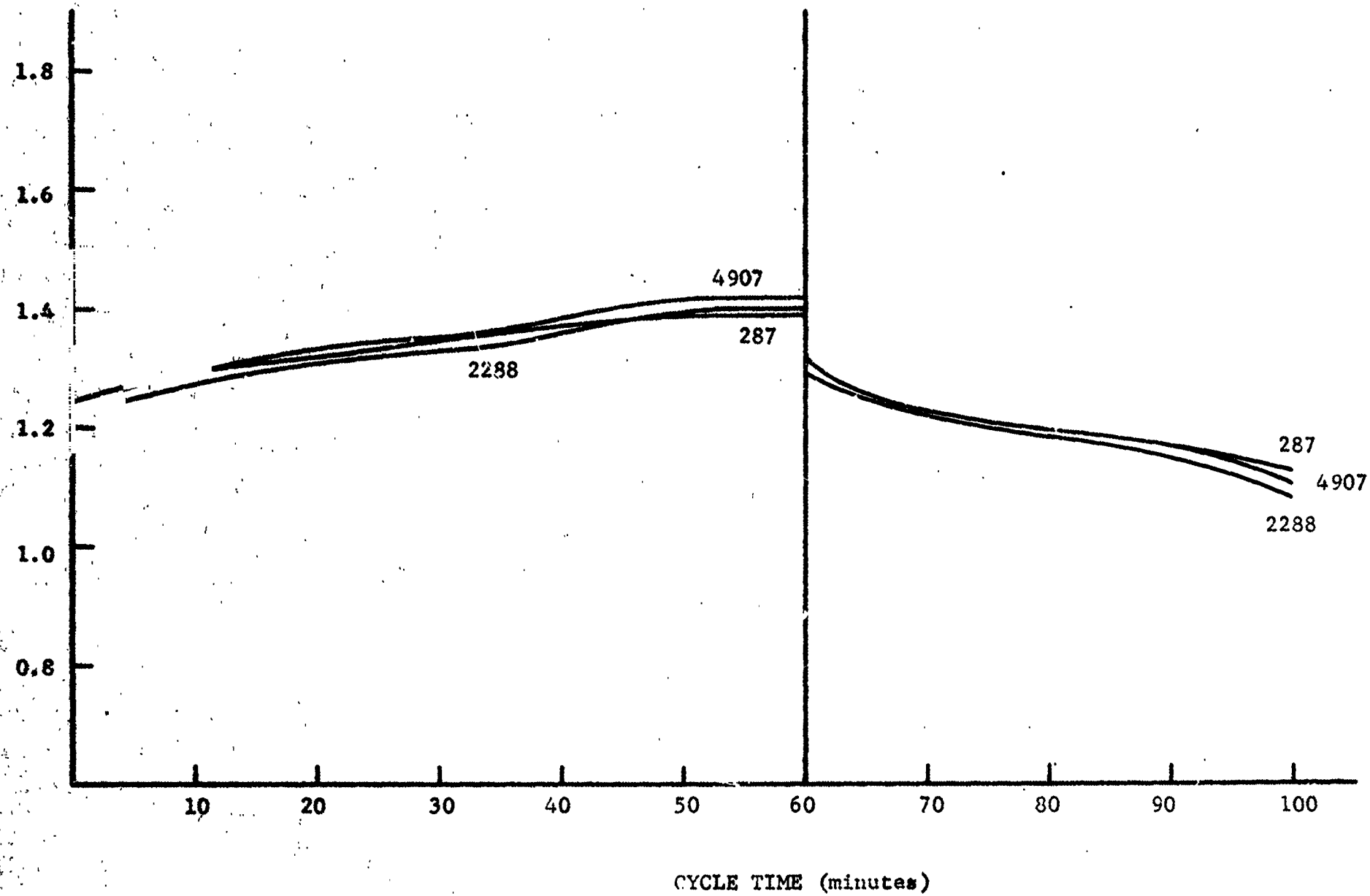


Figure 20 - Charge-Discharge Voltage Characteristics - Cell #13
Cycle Life: 25% Discharge at 25°C
Gould-National Cell

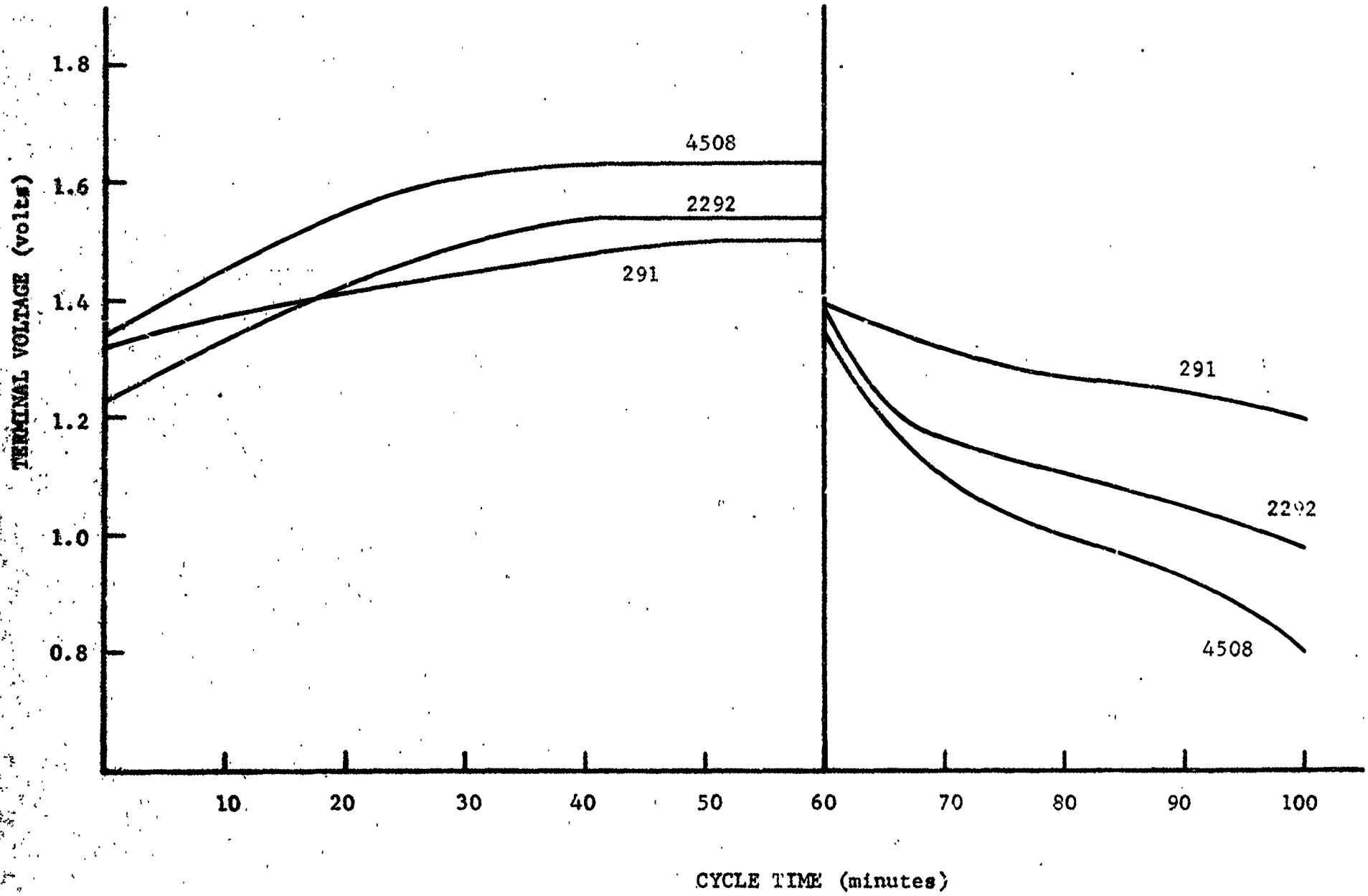
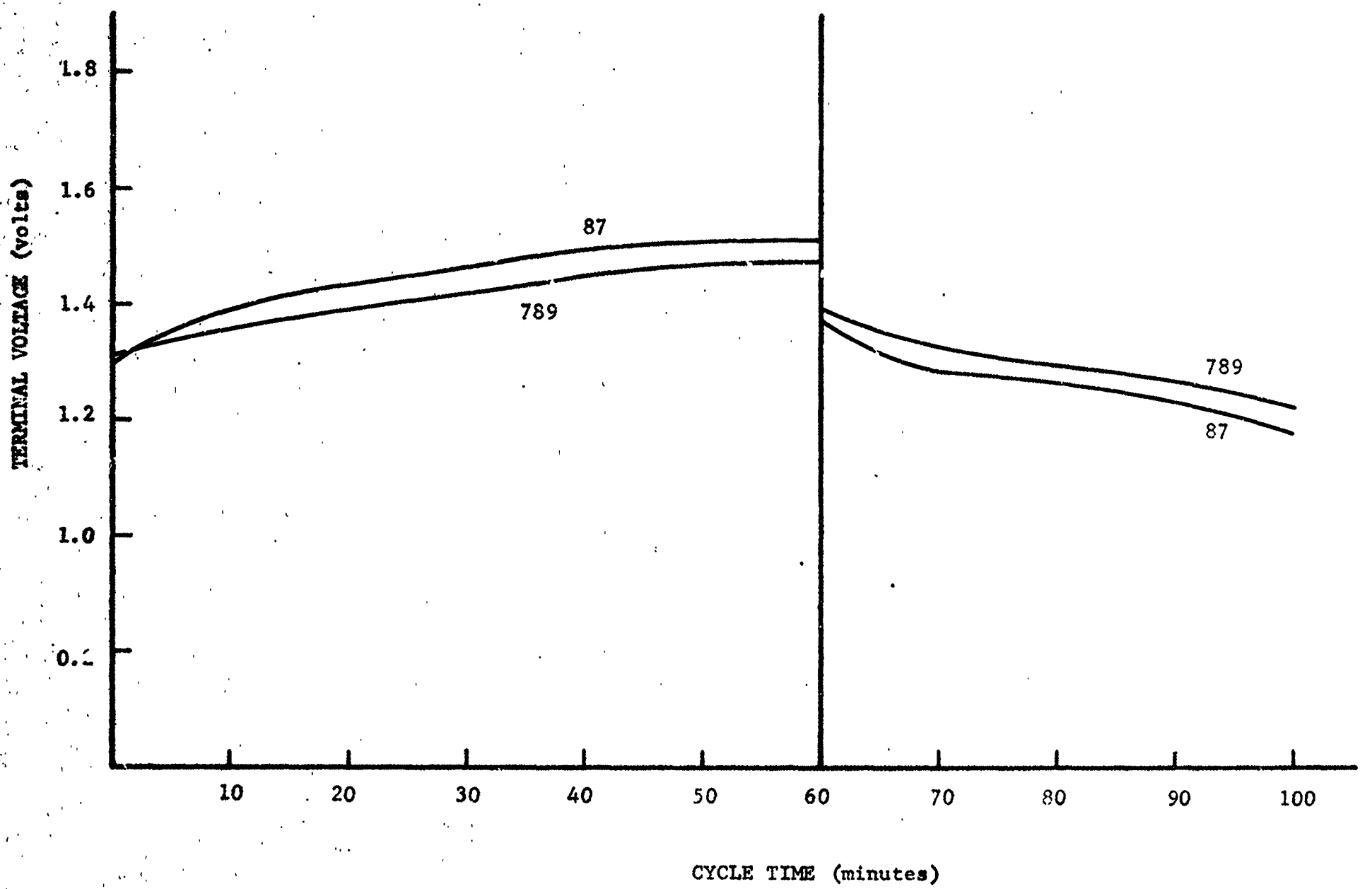


Figure 21 - Charge-Discharge Voltage Characteristics - Cell #49
Cycle Life: 40% Discharge at 25°C
Gould-National Cell



APPENDIX II

(Voltage Characteristics - Gulton Cells)

Figure 22 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at -10°C
Gulton Cells

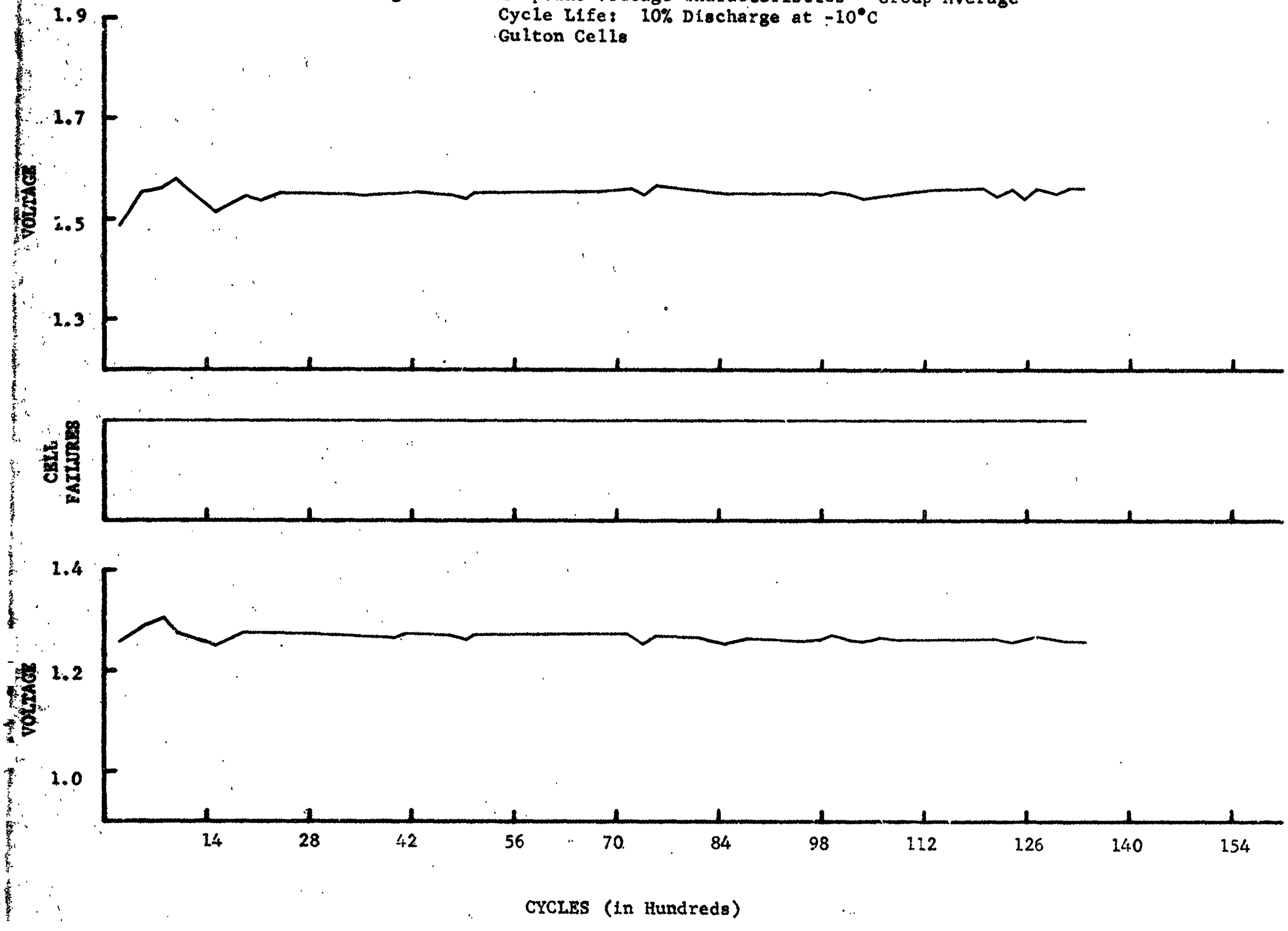


Figure 23 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at 25°C
Gulton Cells

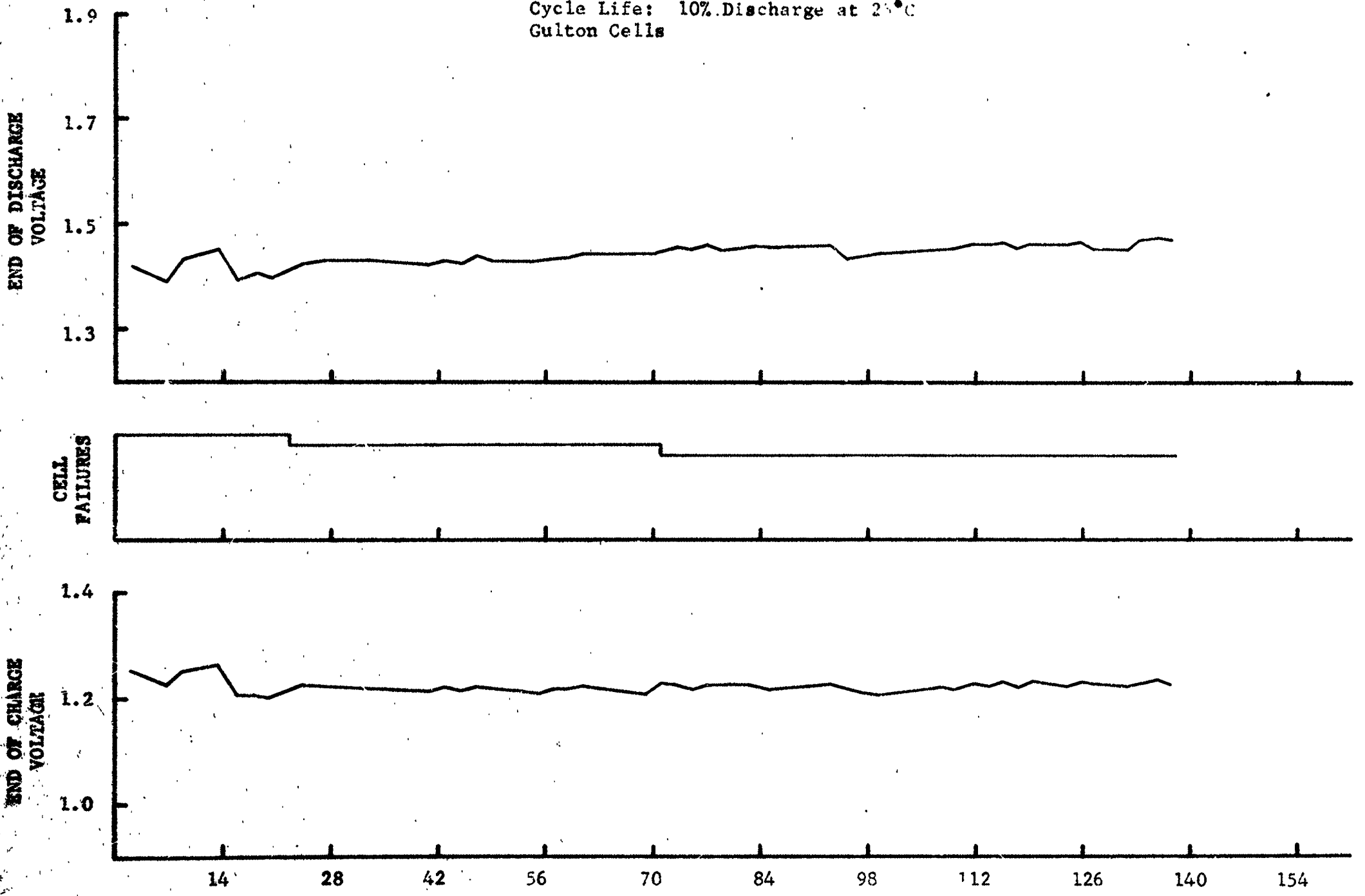


Figure 24 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at 50°C
Gulton Cells

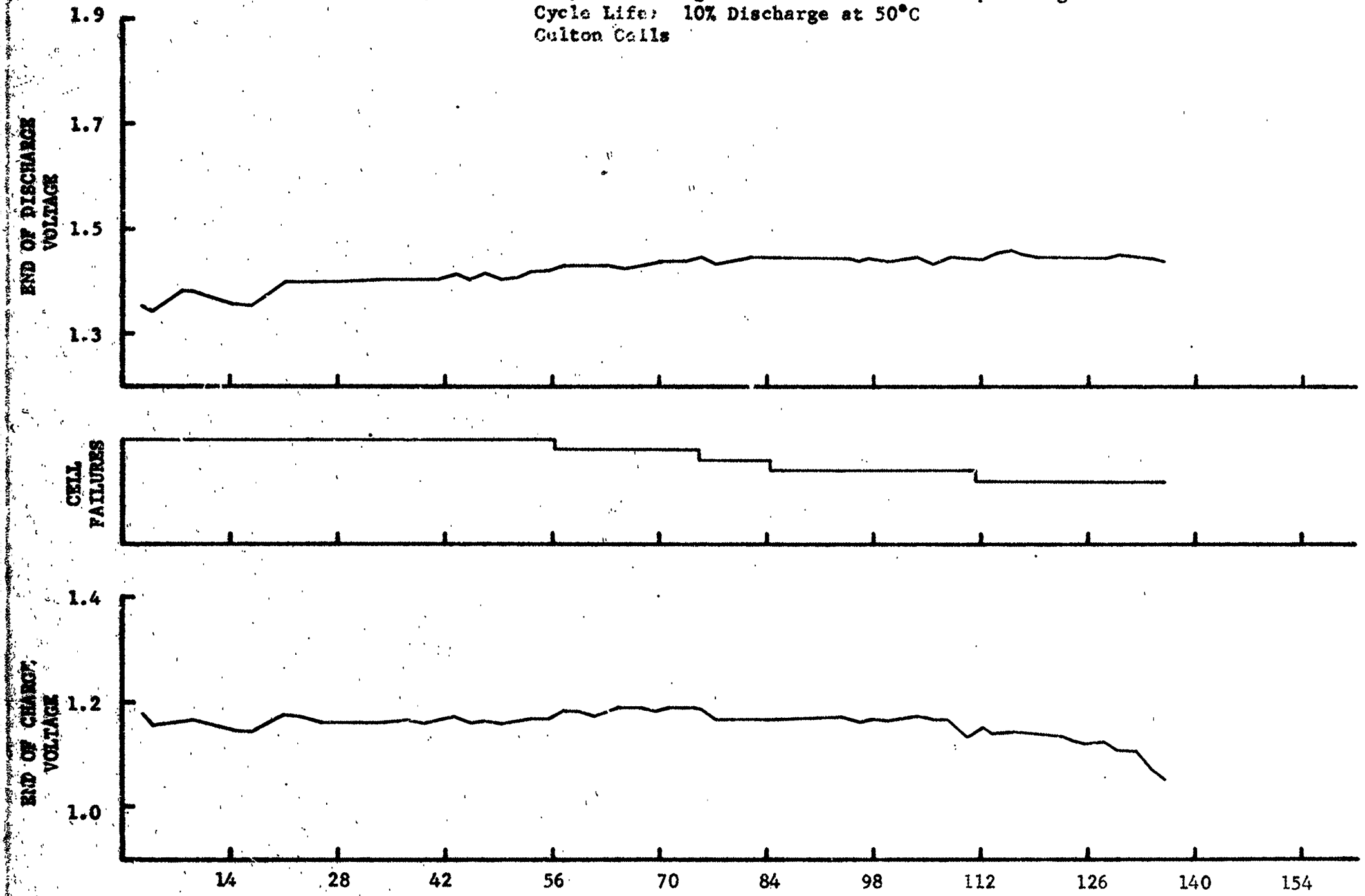


Figure 25 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 25% Discharge at 25°C
Gulton Cells

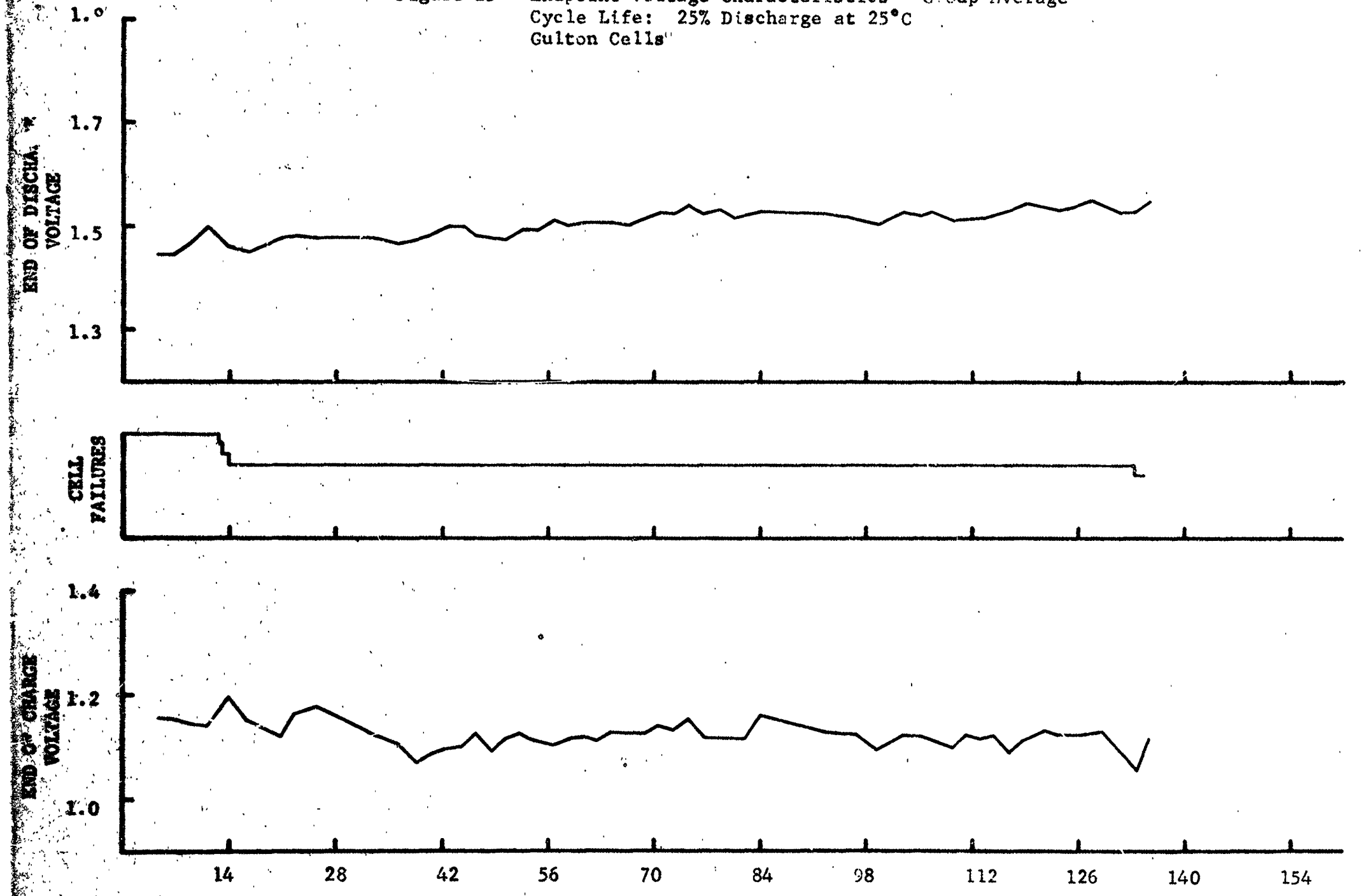


Figure 26 - Endpoint Voltage Characteristics - Cell #620
Cycle Life: 10% Discharge at -10°C
Gulton Cell

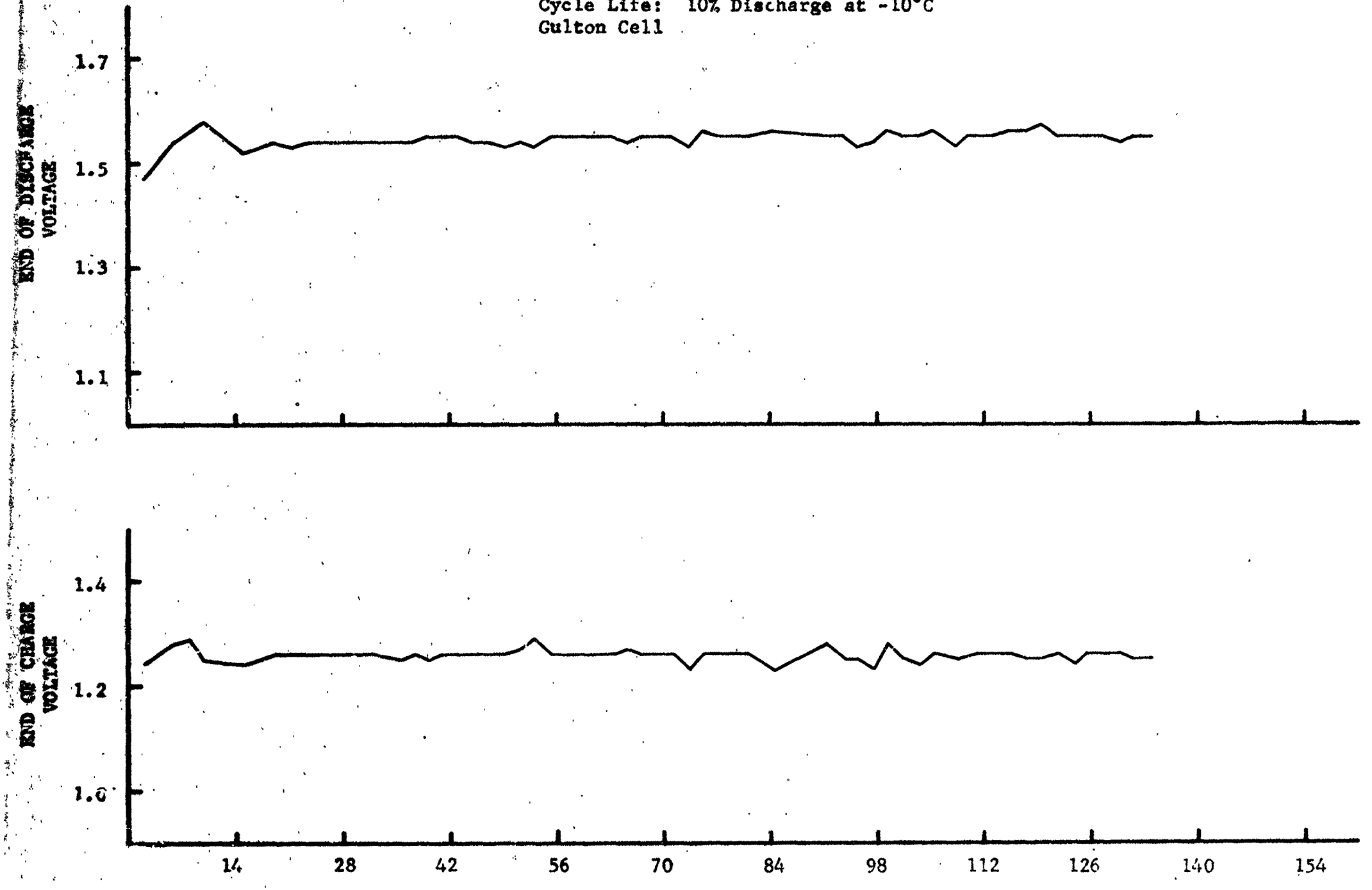


Figure 27 - Endpoint Voltage Characteristics - Cell #783
Cycle Life: 10% Discharge at -10°C
Gulton Cell

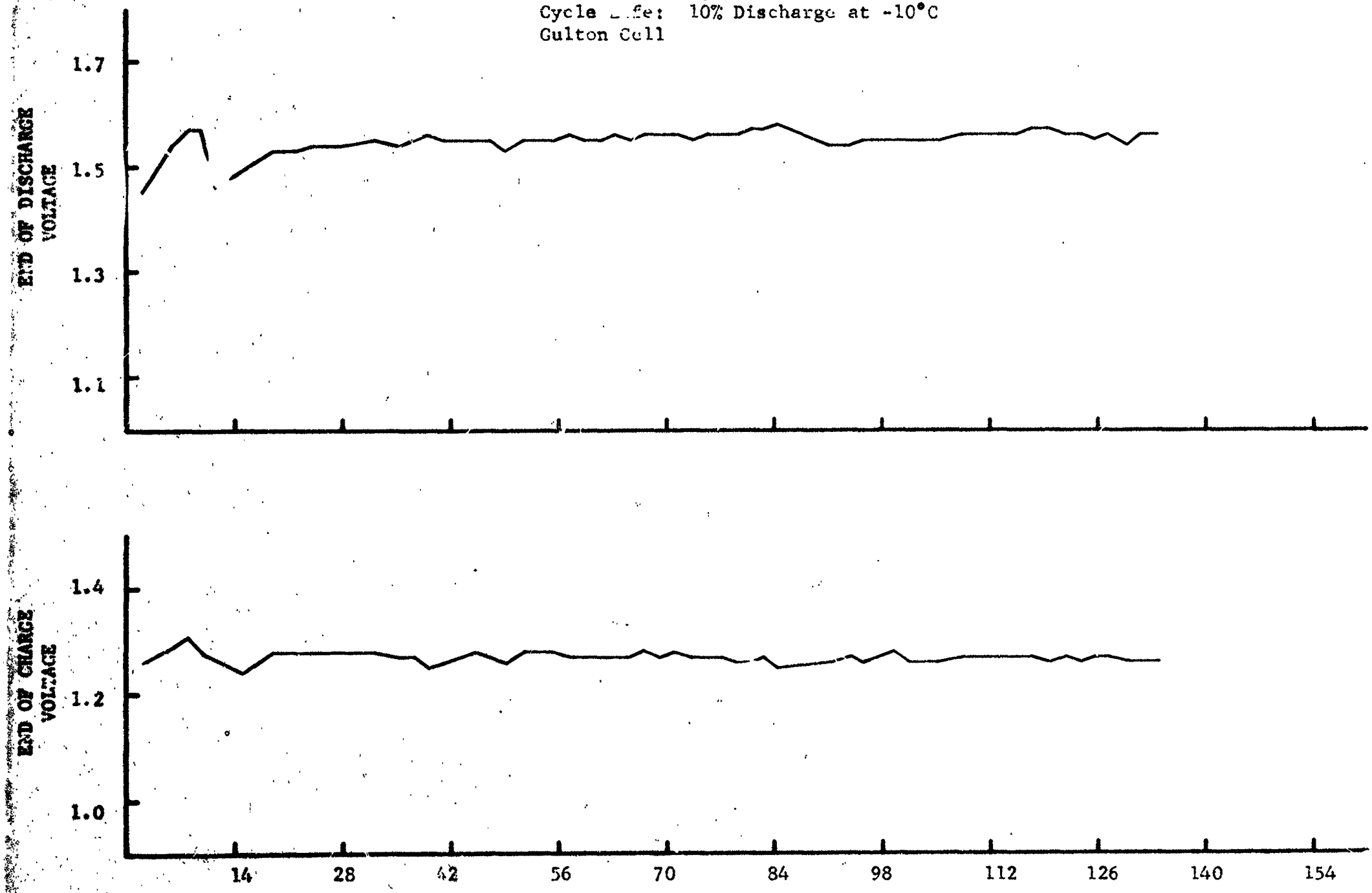


Figure 28 - Endpoint Voltage Characteristics - Cell #638
Cycle Life: 10% Discharge at 25°C
Gulton Cell

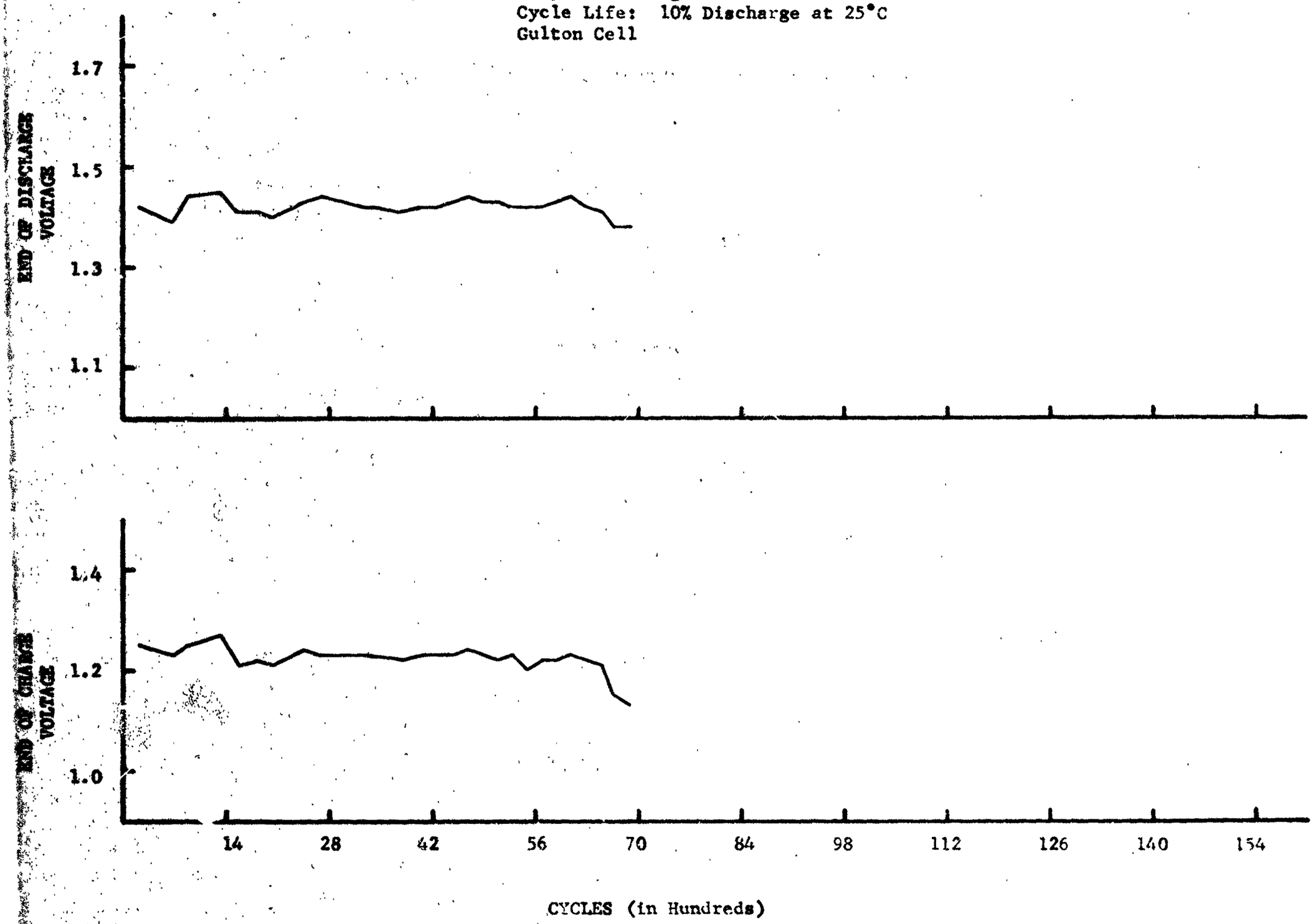


Figure 29 - Endpoint Voltage Characteristics - Cell #622
Cycle Life: 10% Discharge at 25°C
Gulton Cell

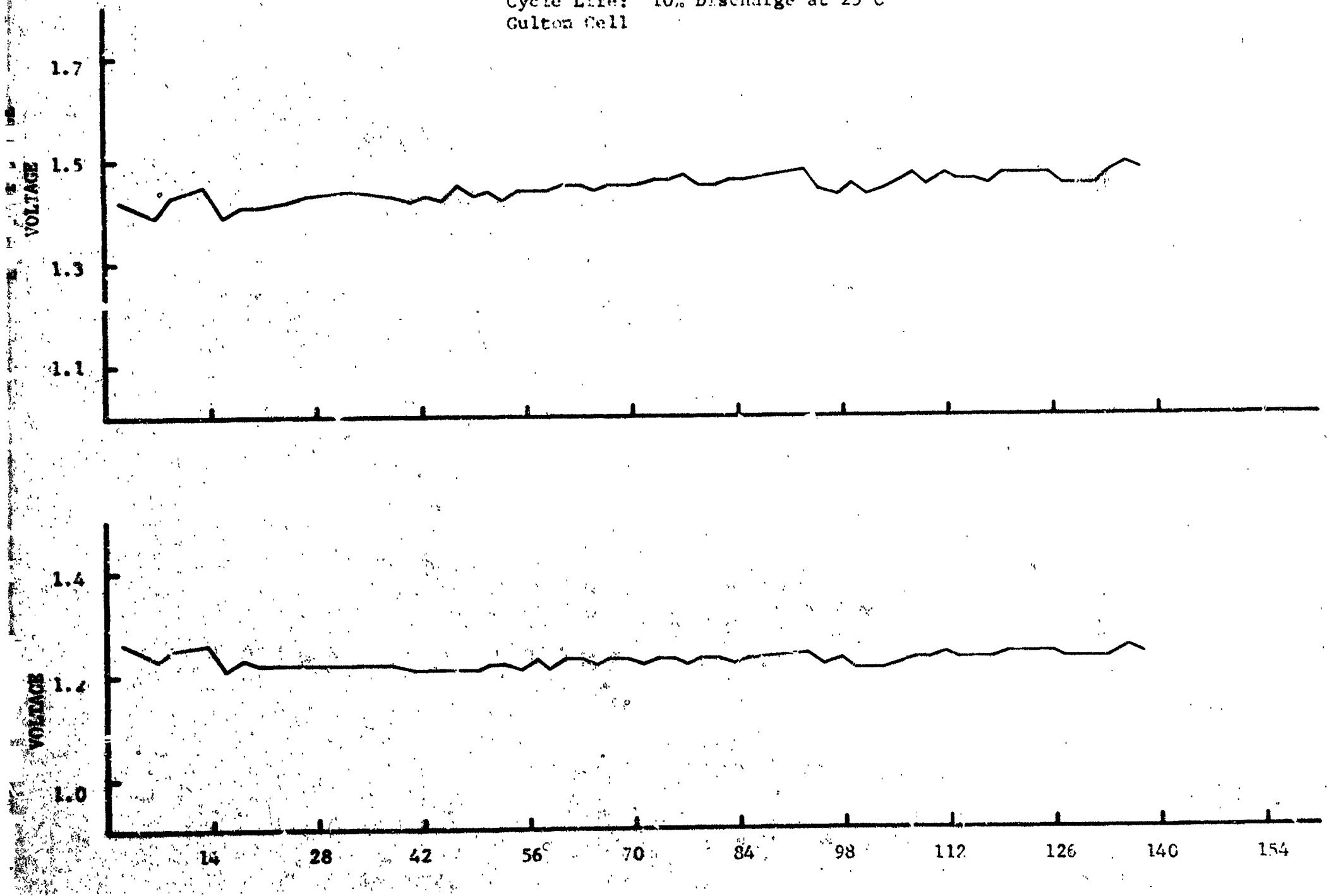


Figure 30 - End Point Voltage Characteristics - Cell #602
Cycle Life: 10% Discharge at 50°C
Gulton Cell

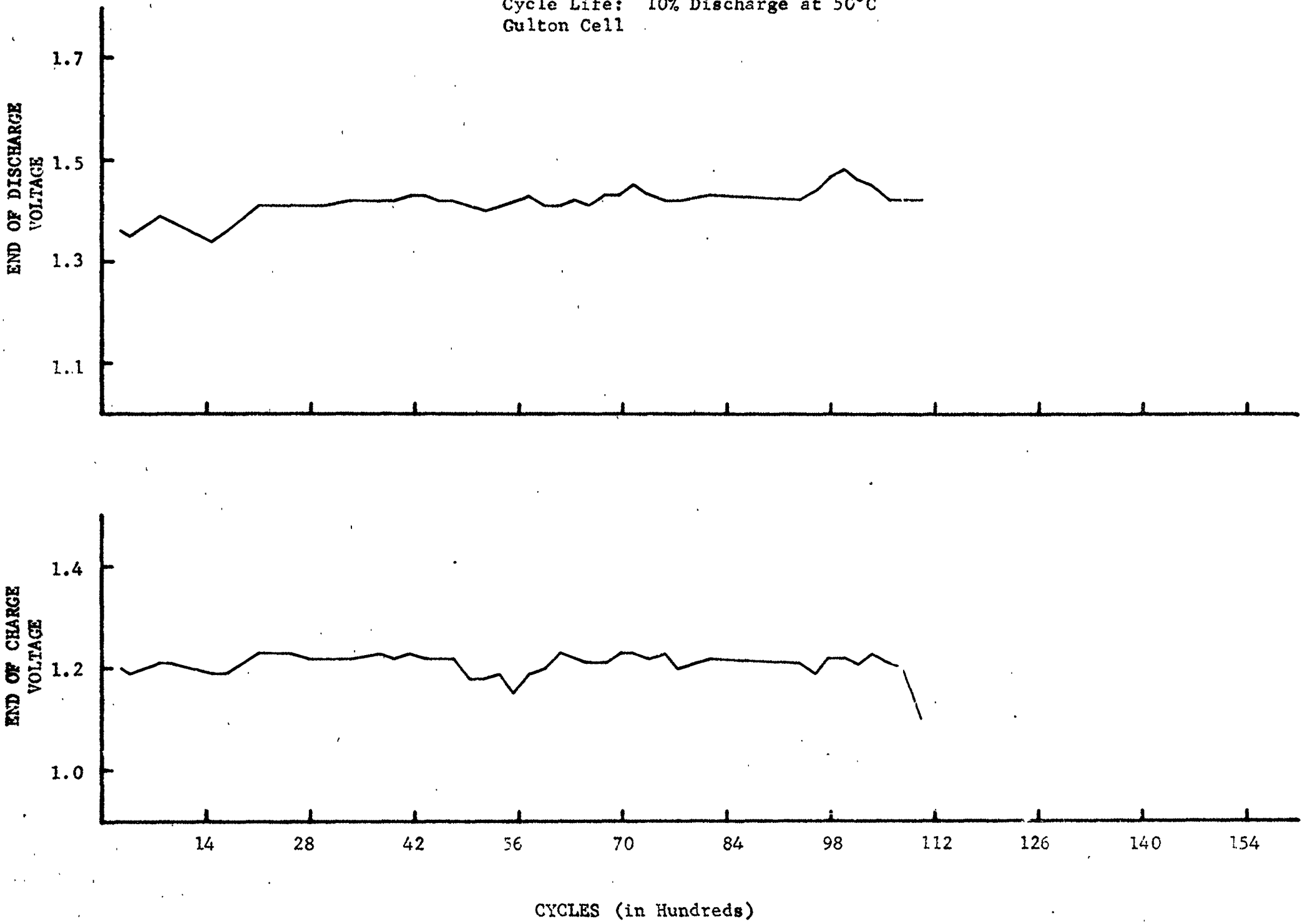


Figure 31 - Endpoint Voltage Characteristics - Cell #779
Cycle Life: 10% Discharge at 50°C
Gulton Cell

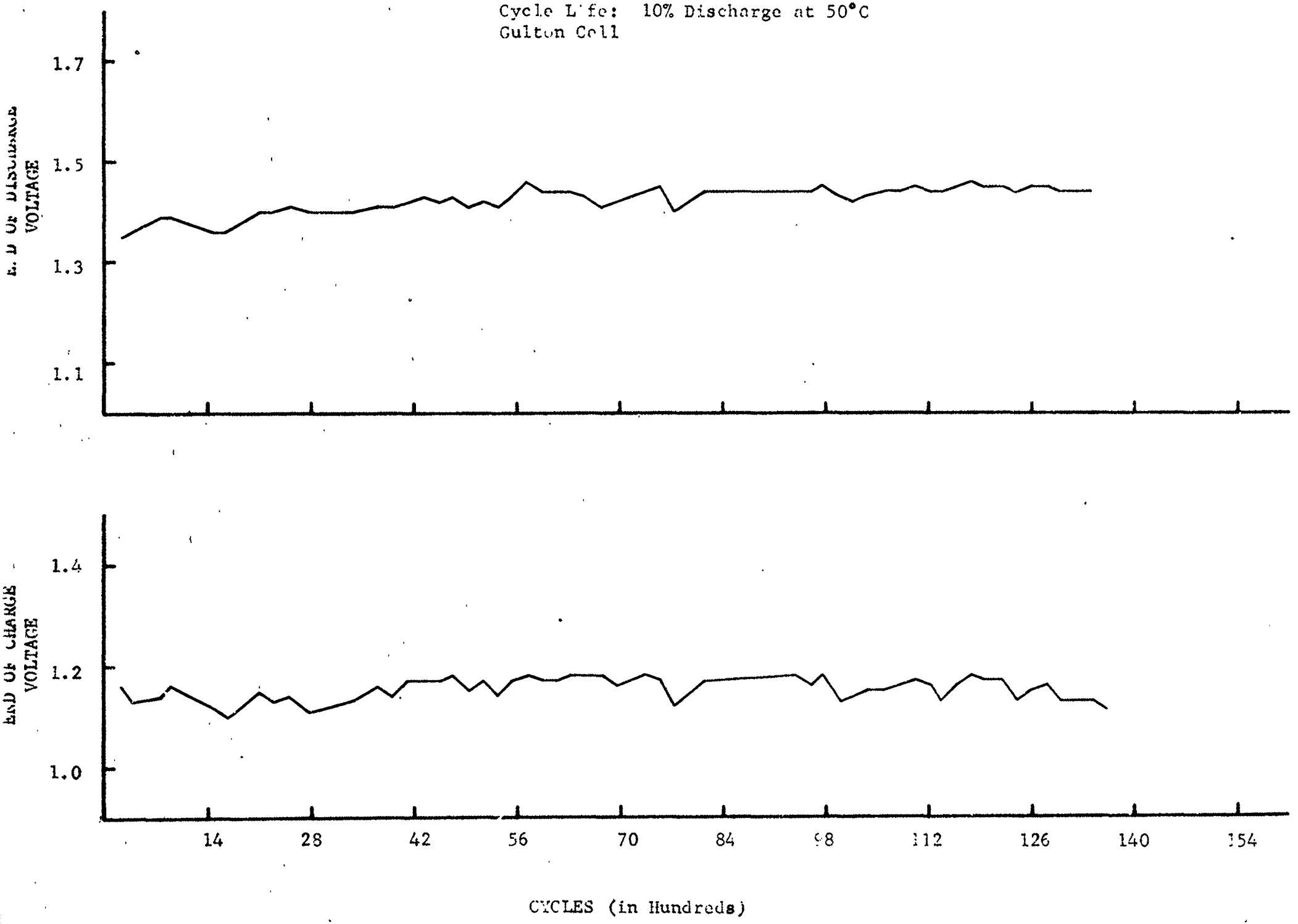


Figure 32 - Endpoint Voltage Characteristics - Cell #660
Cycle Life: 25% Discharge at 25°C
Gulton Cell

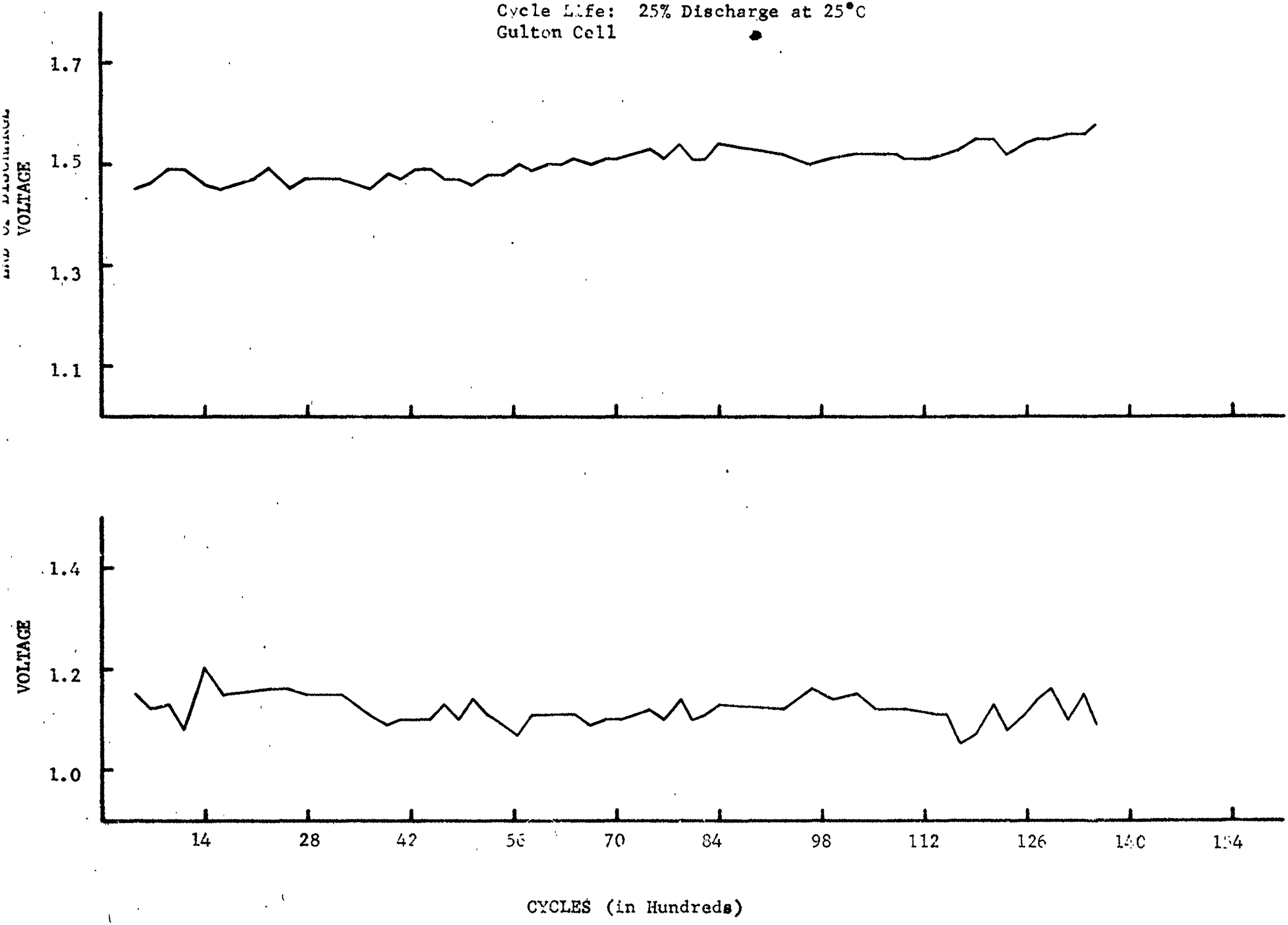


Figure 33 - Endpoint Voltage Characteristics - Cell #918
Cycle Life: 25% Discharge at 25°C
Gulton Cell

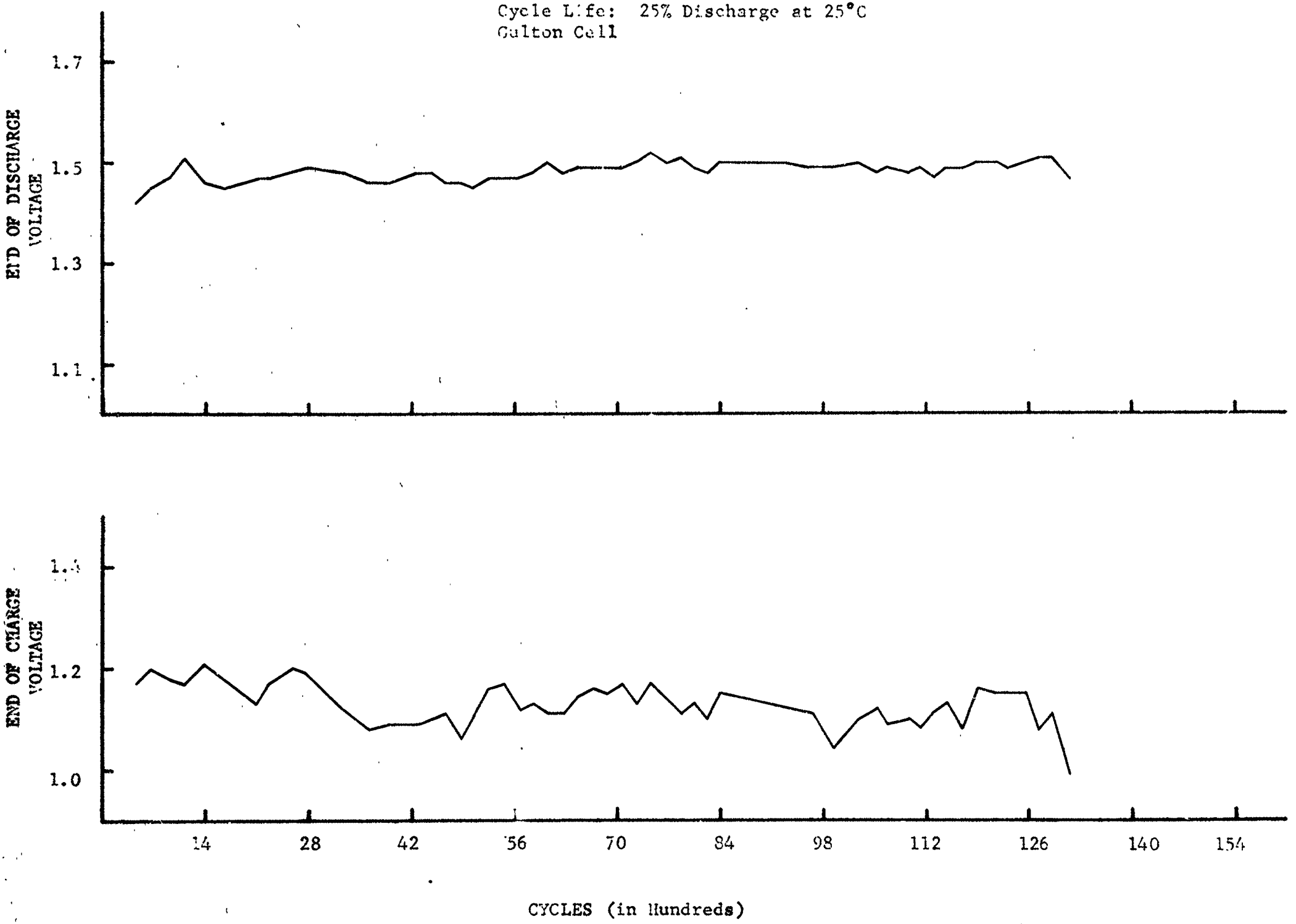


Figure 34 - Charge-Discharge Voltage Characteristics - Cell #620
Cycle-Life: 10% Discharge at -10°C
Gulton Cell

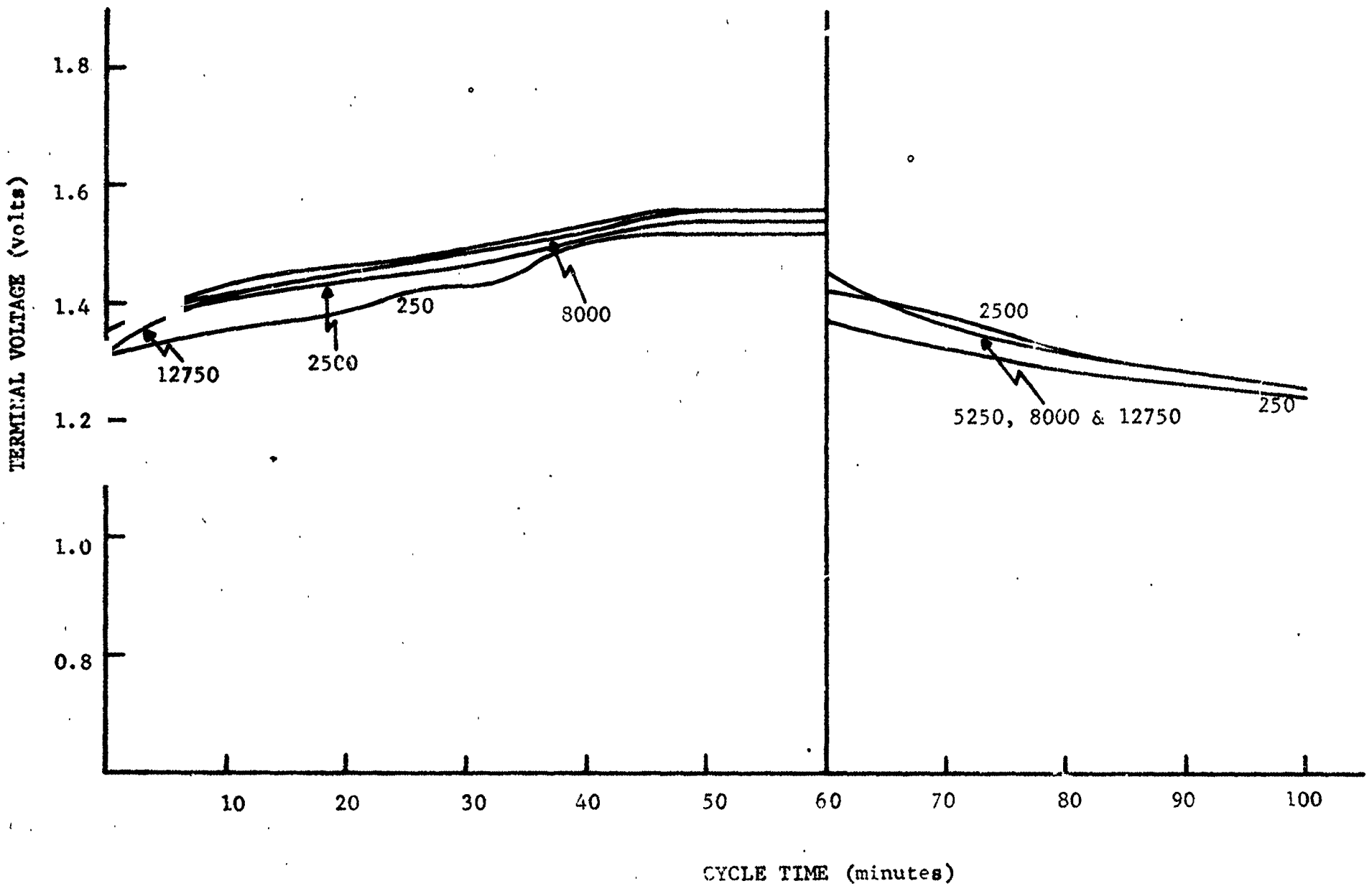


Figure 35 - Charge-Discharge Voltage Characteristics - Cell #783
Cycle Life: 10% Discharge at -10°C
Gulton Cell

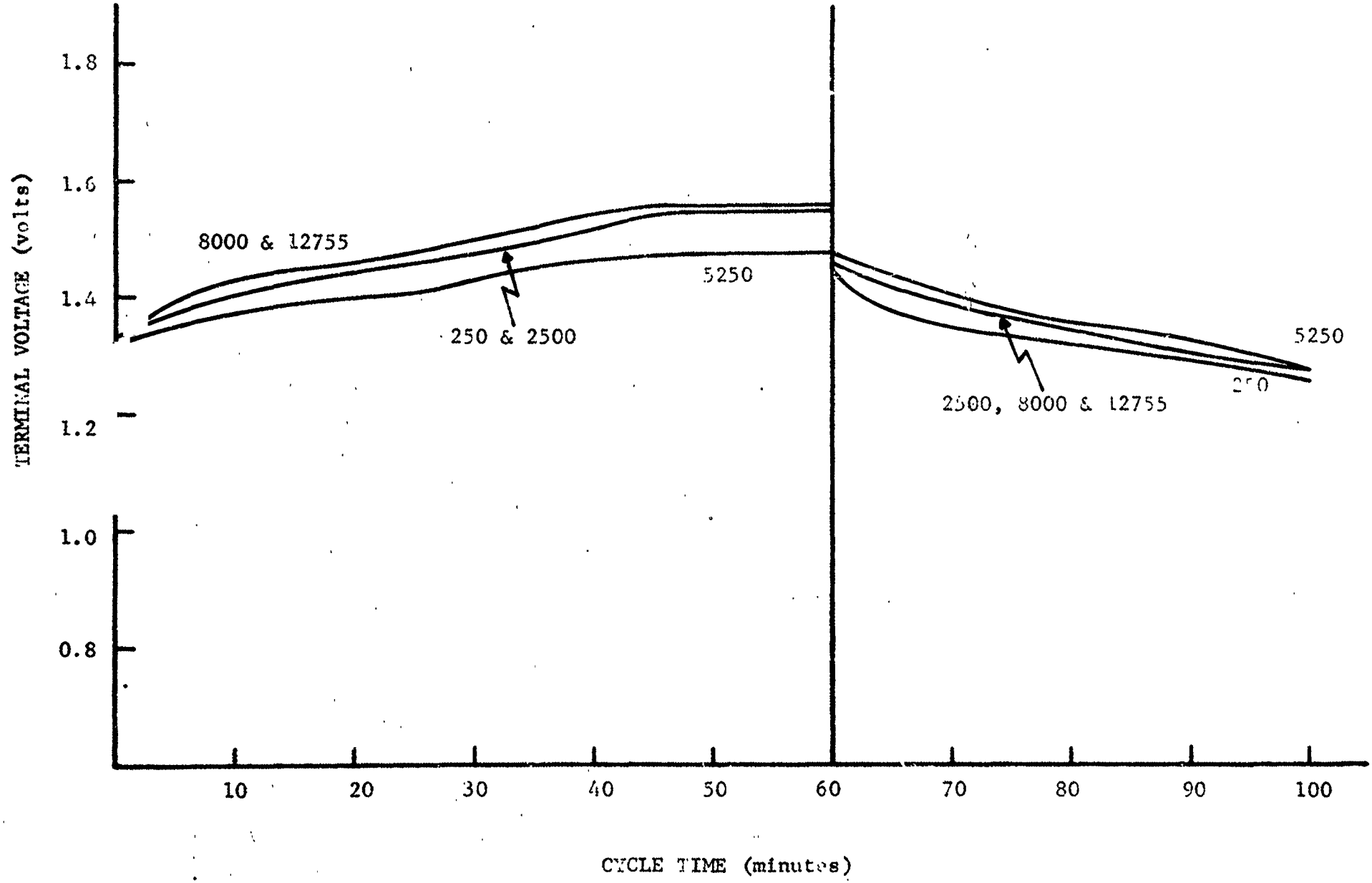


Figure 36 - Charge-Discharge Voltage Characteristics - Cell #638
Cycle Life: 10% Discharge at 25°C
Gulton Cell

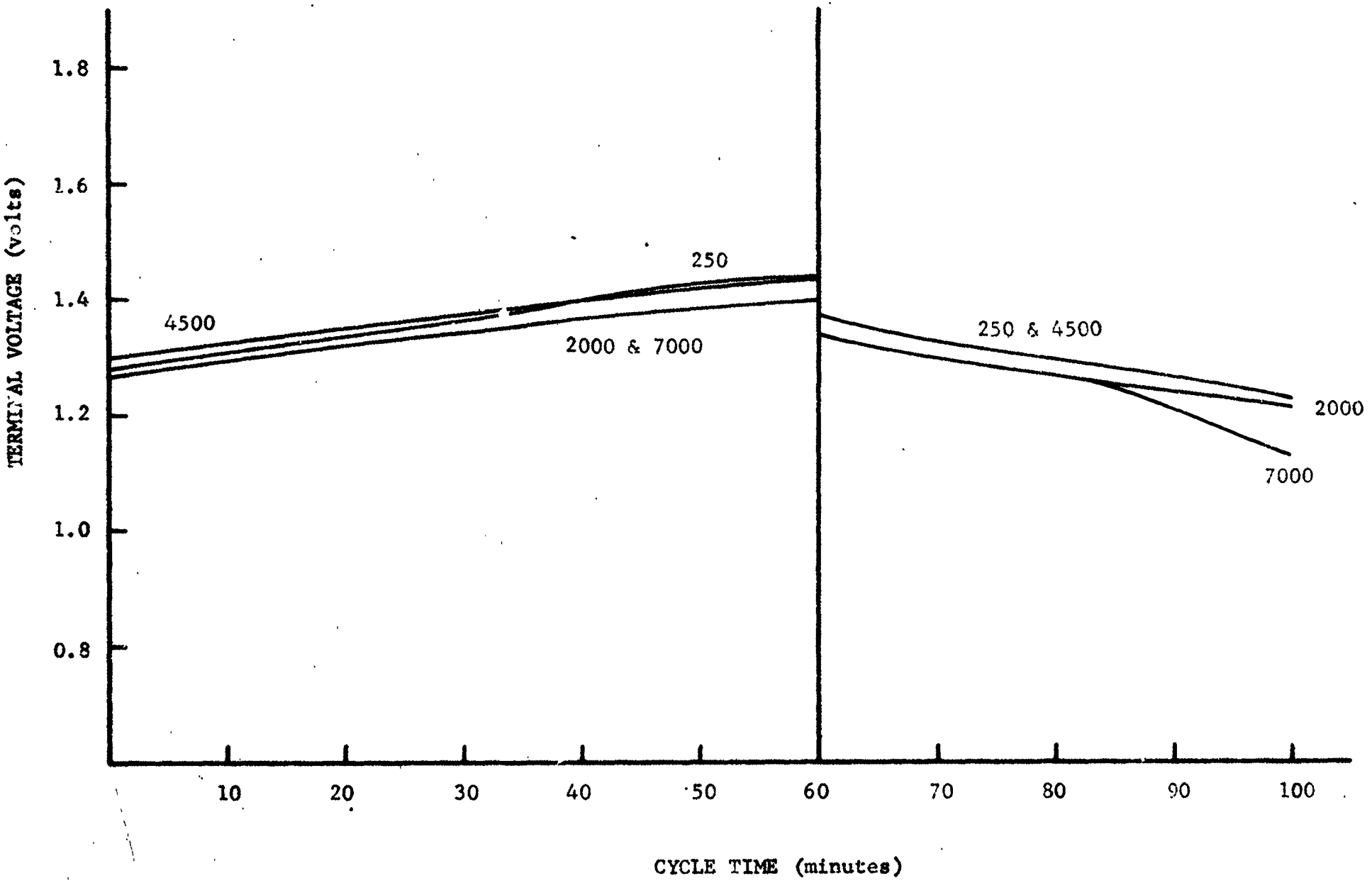


Figure 37 - Charge-Discharge Voltage Characteristics - Cell #822
Cycle Life: 10% Discharge at 25°C
Gulton Cell

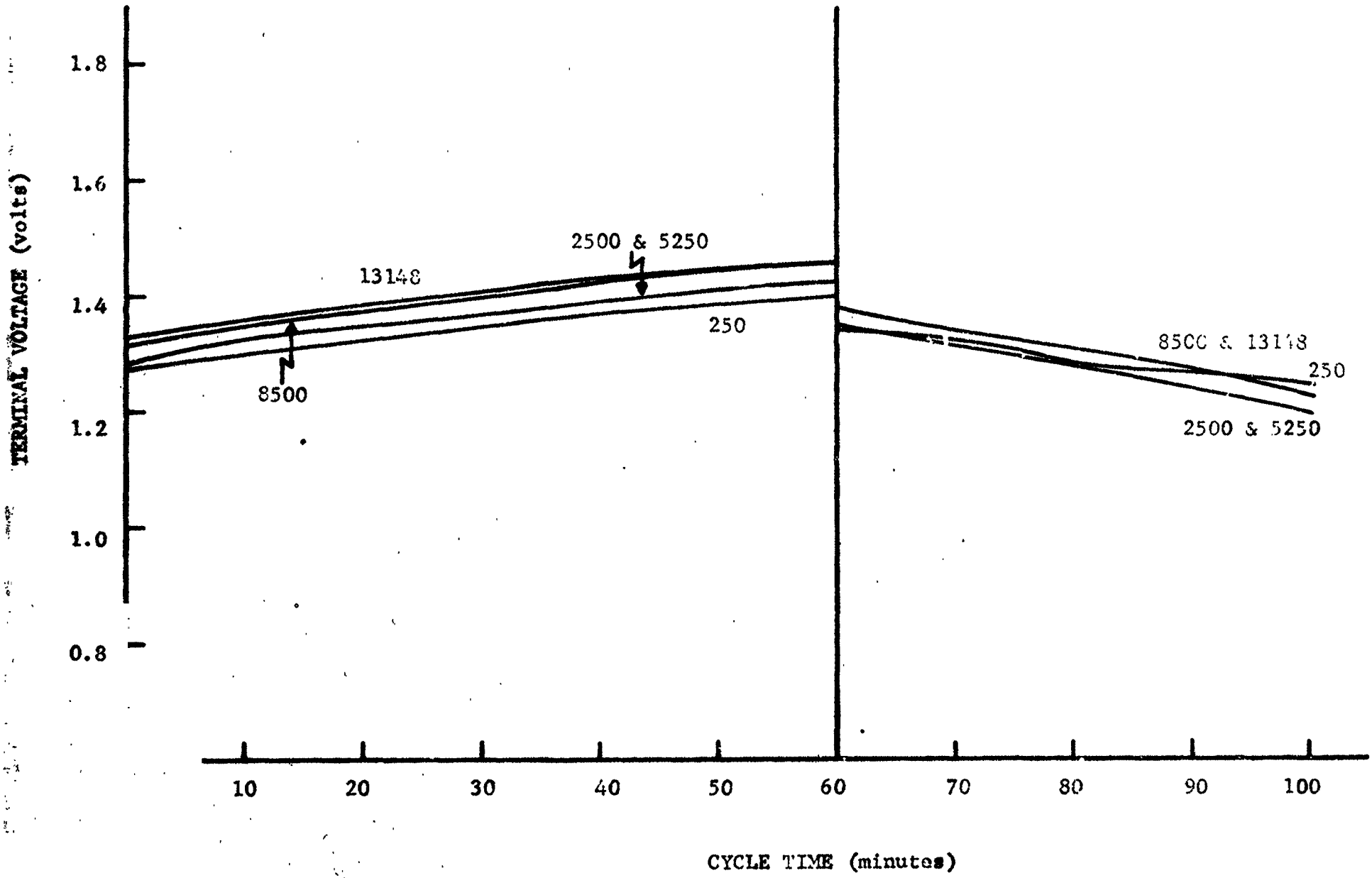


Figure 38 - Charge-Discharge Voltage Characteristics - Cell #602
Cycle Life: 10% Discharge at 50°C
Gulton Cell

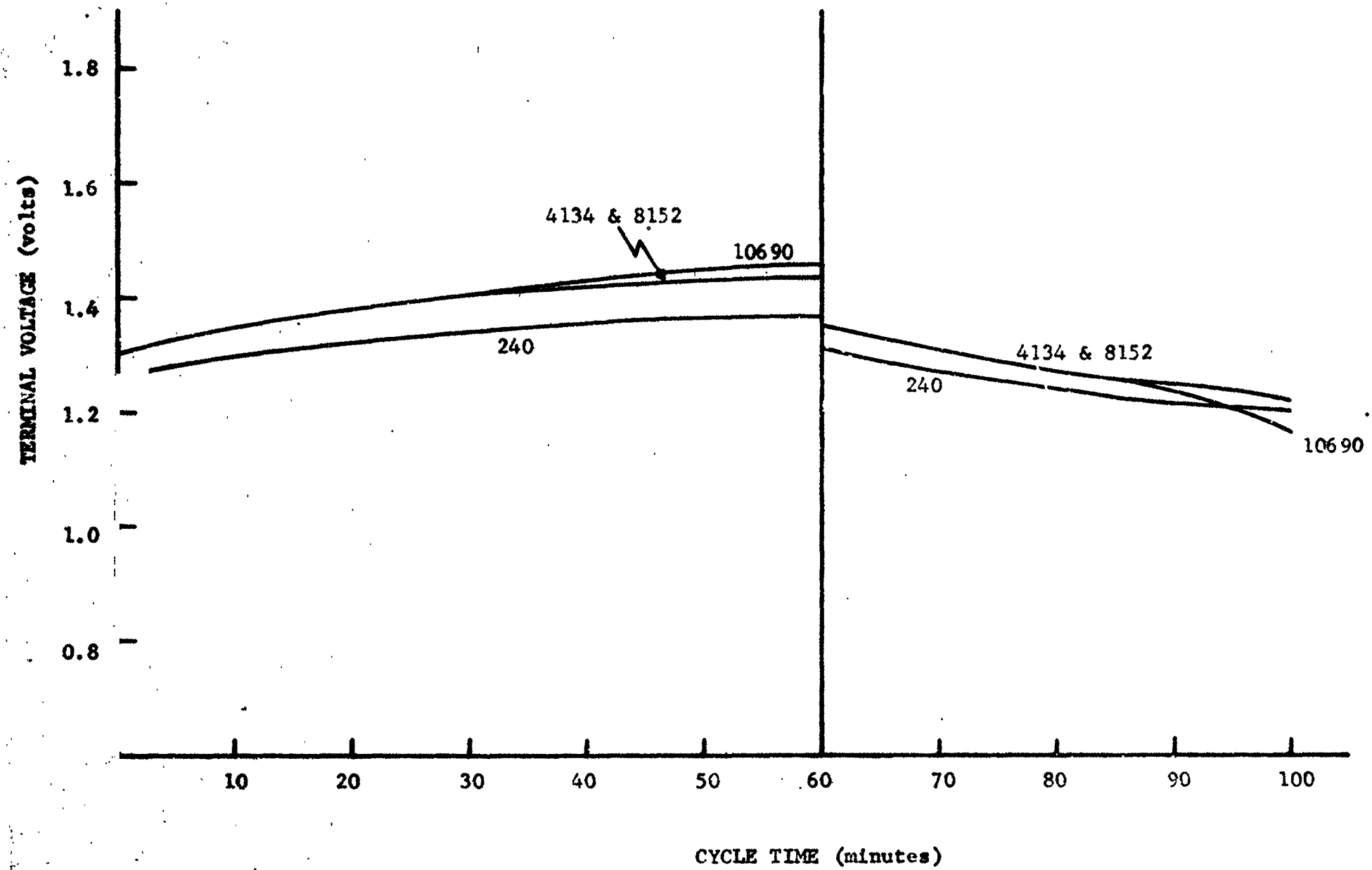


Figure 39 - Charge-Discharge Voltage Characteristics - Cell #779
Cycle Life: 10% Discharge at 50°C
Gulton Cell

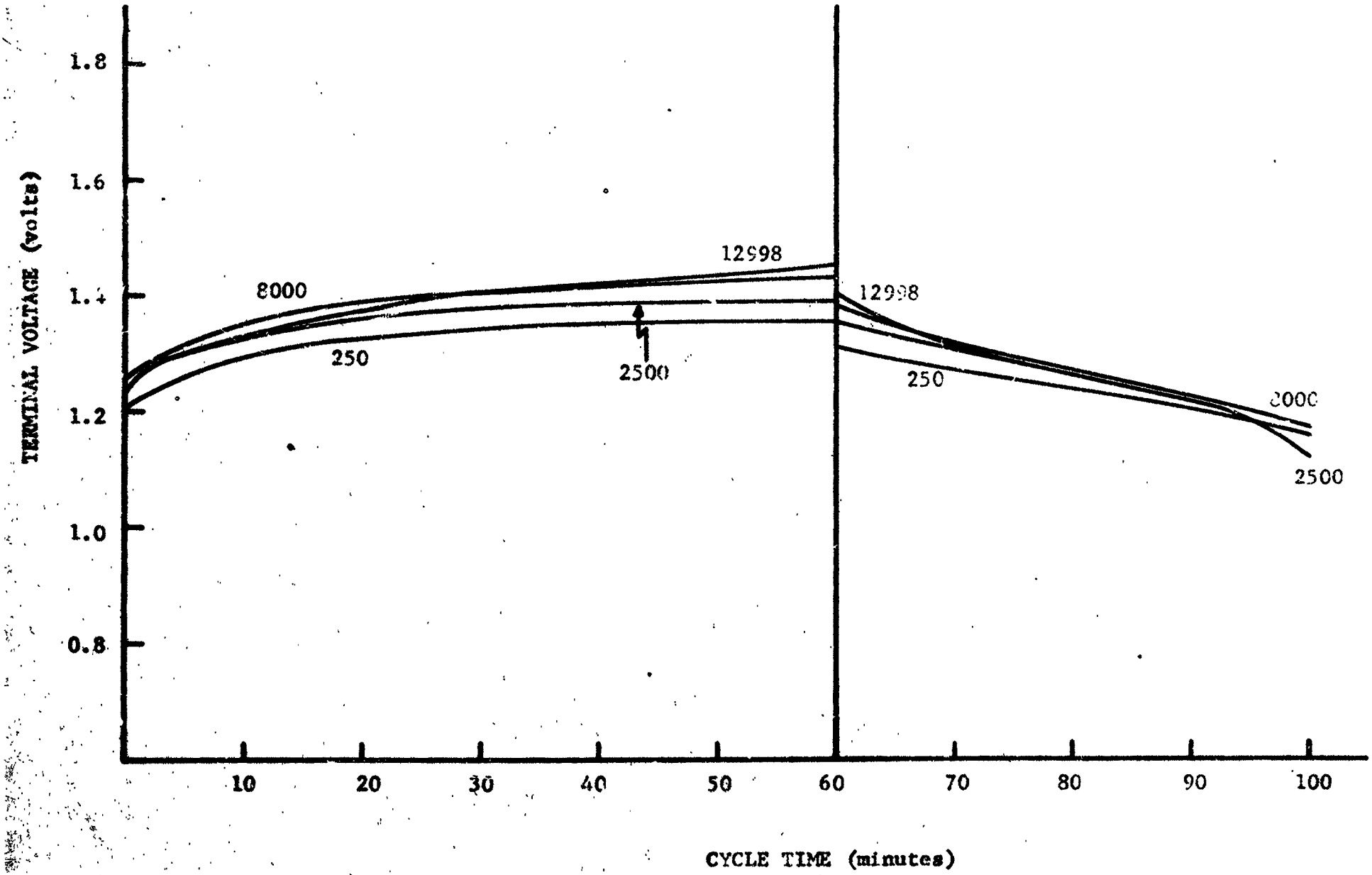


Figure 40 - Charge-Discharge Voltage Characteristics - Cell #660
Cycle-Life: 25% Discharge at 25°C
Gulton Cell

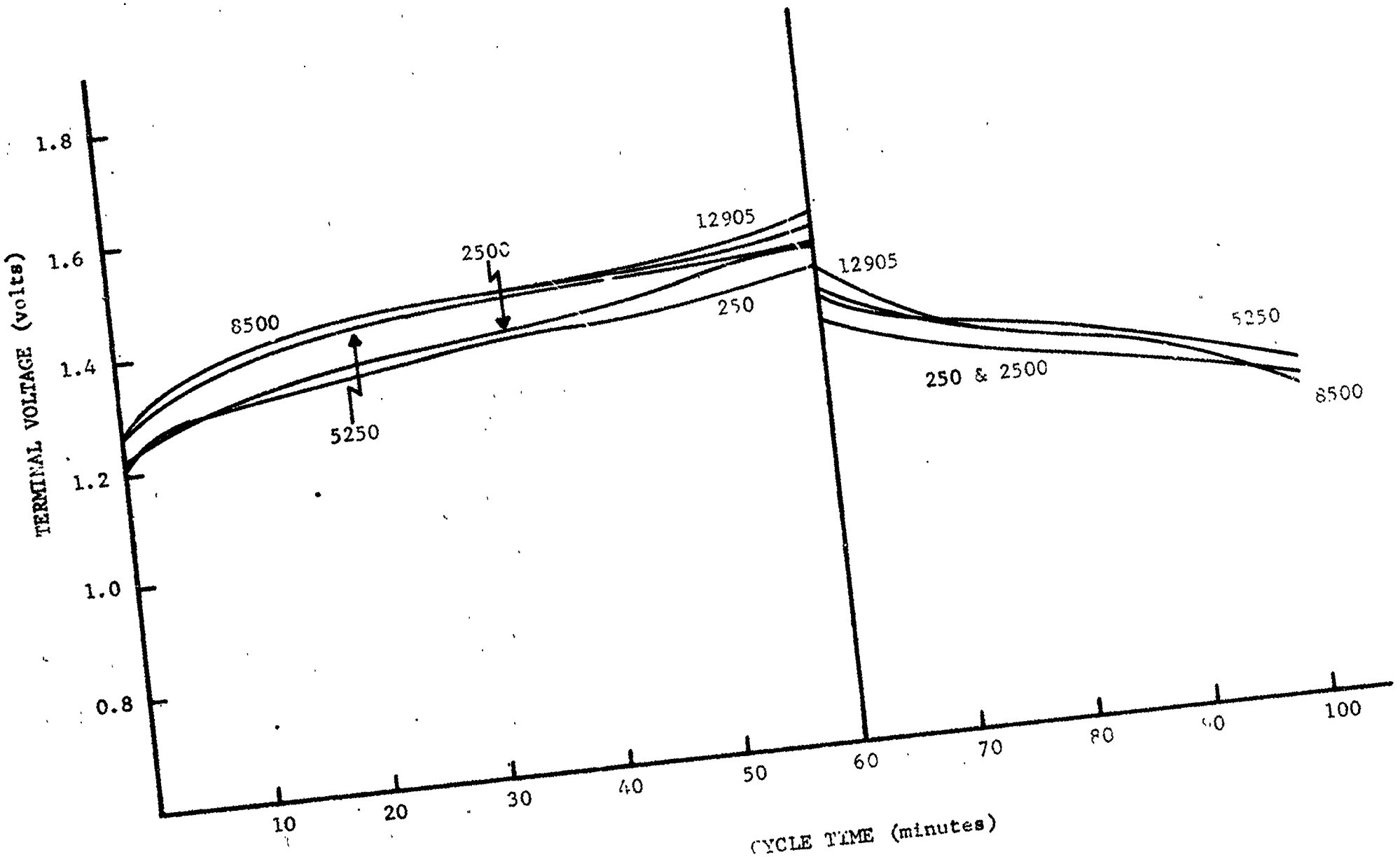
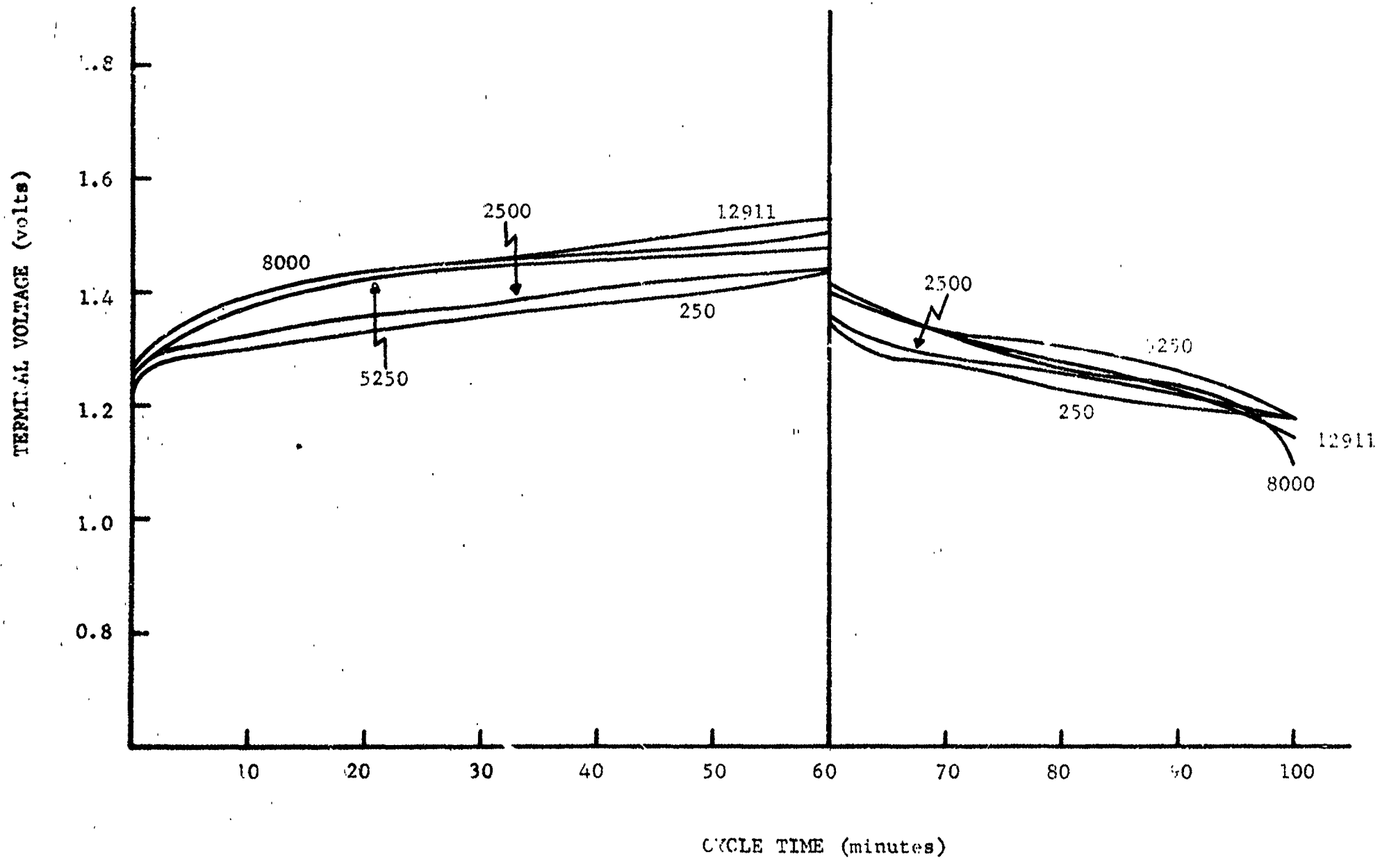


Figure 41 - Charge-Discharge Voltage Characteristics - Cell #818
Cycle Life: 25% Discharge at 25°C
Culton Cell



APPENDIX III

(Voltage Characteristics - Sonotone Cells)

Figure 42 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at -10°C
Sunotone Cells

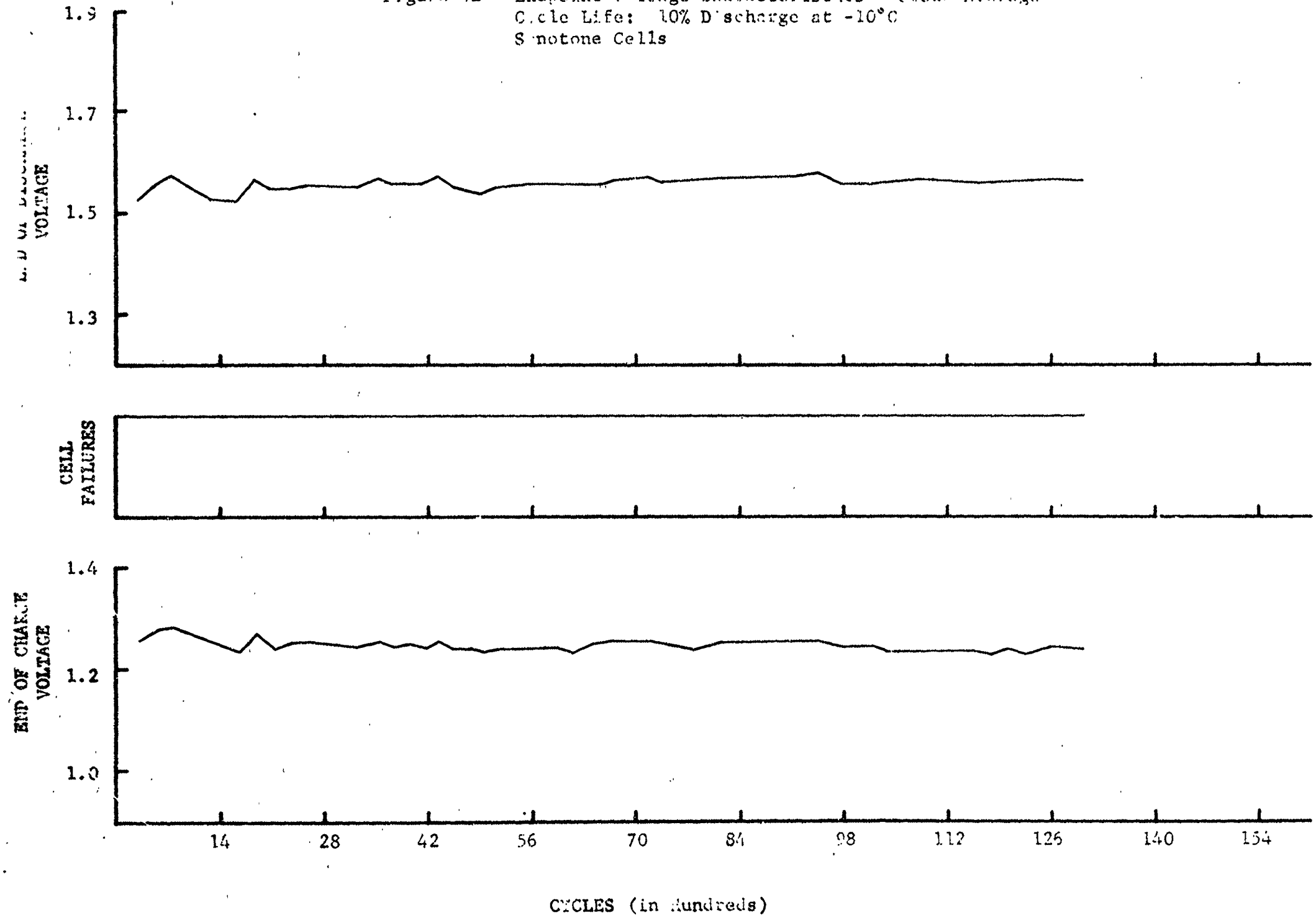


Figure 43 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at 25°C
Sonotone Cells

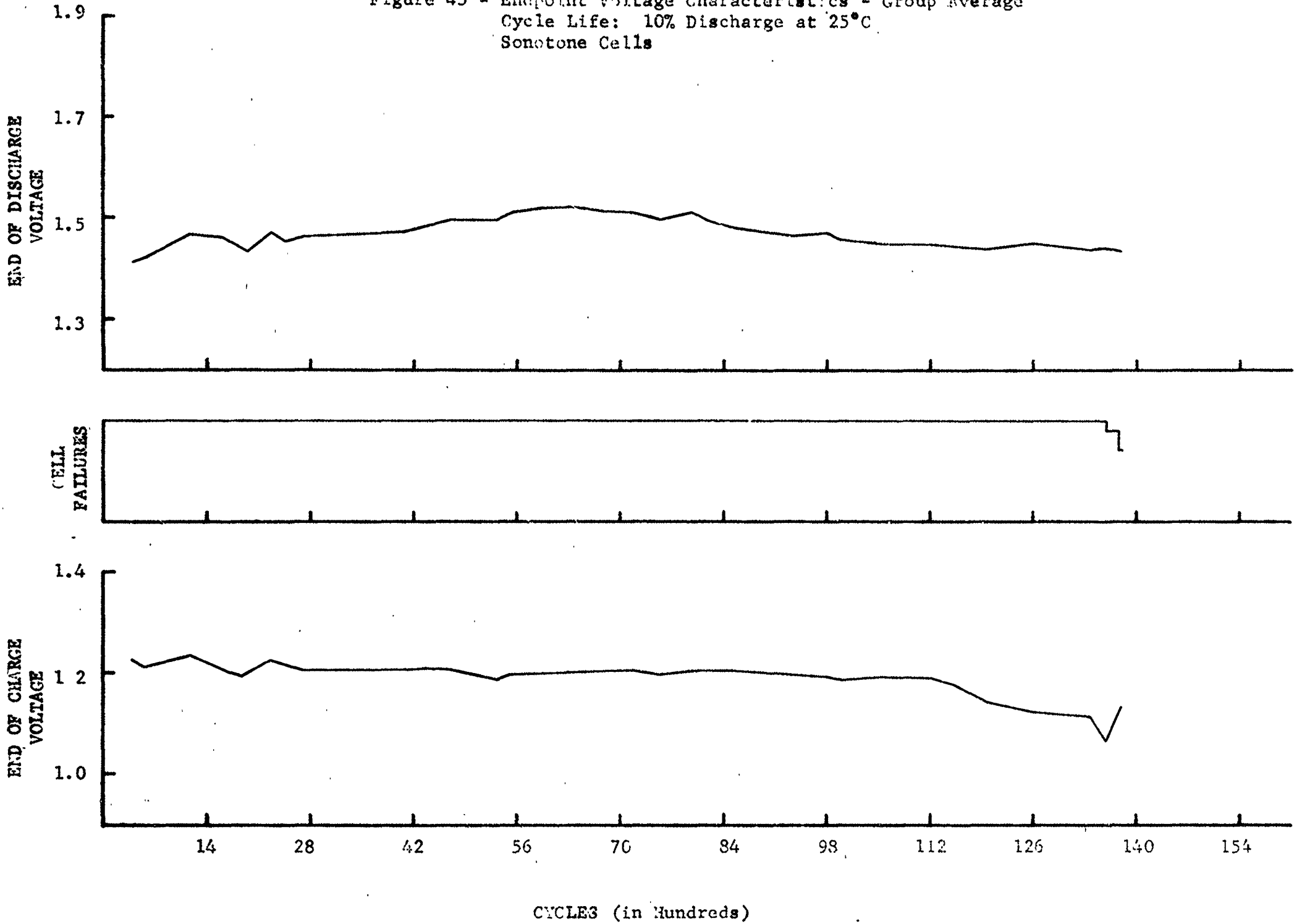


Figure 44 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at 50°C
Sonotone Cells

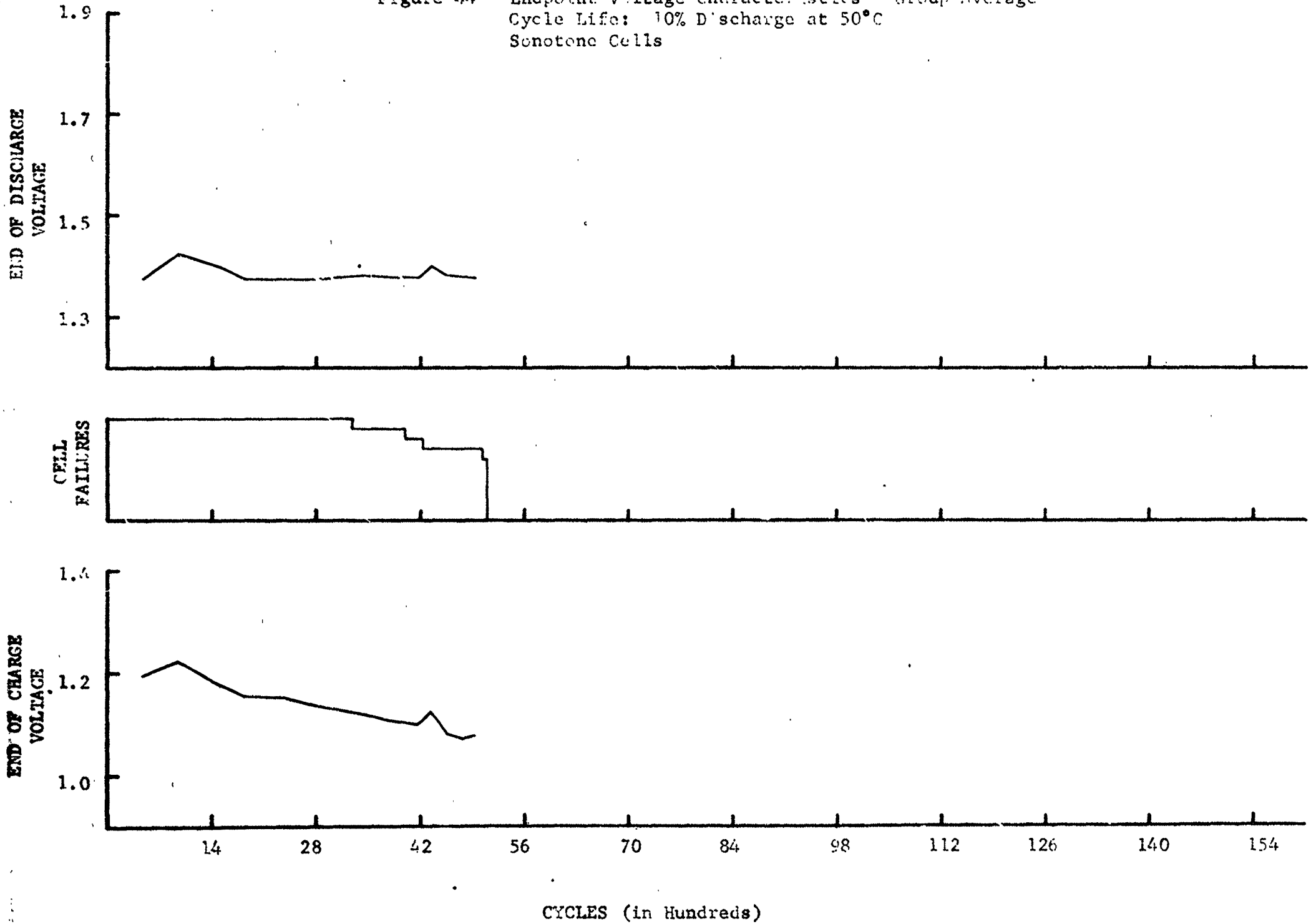


Figure 45 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 25% Discharge at 25°C
Sonotone Cells

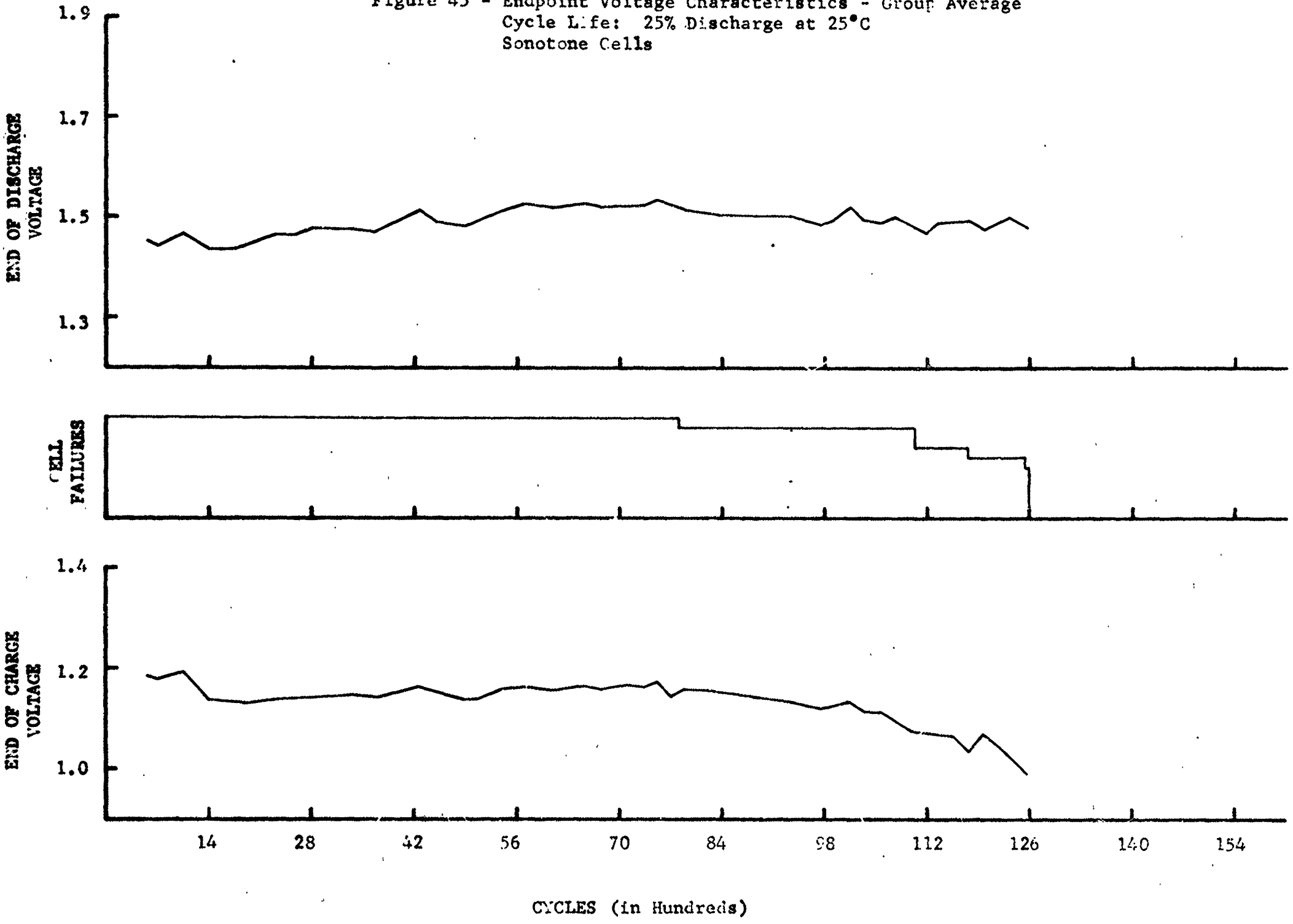


Figure 46 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 40% Discharge at 25°C
S notone Co

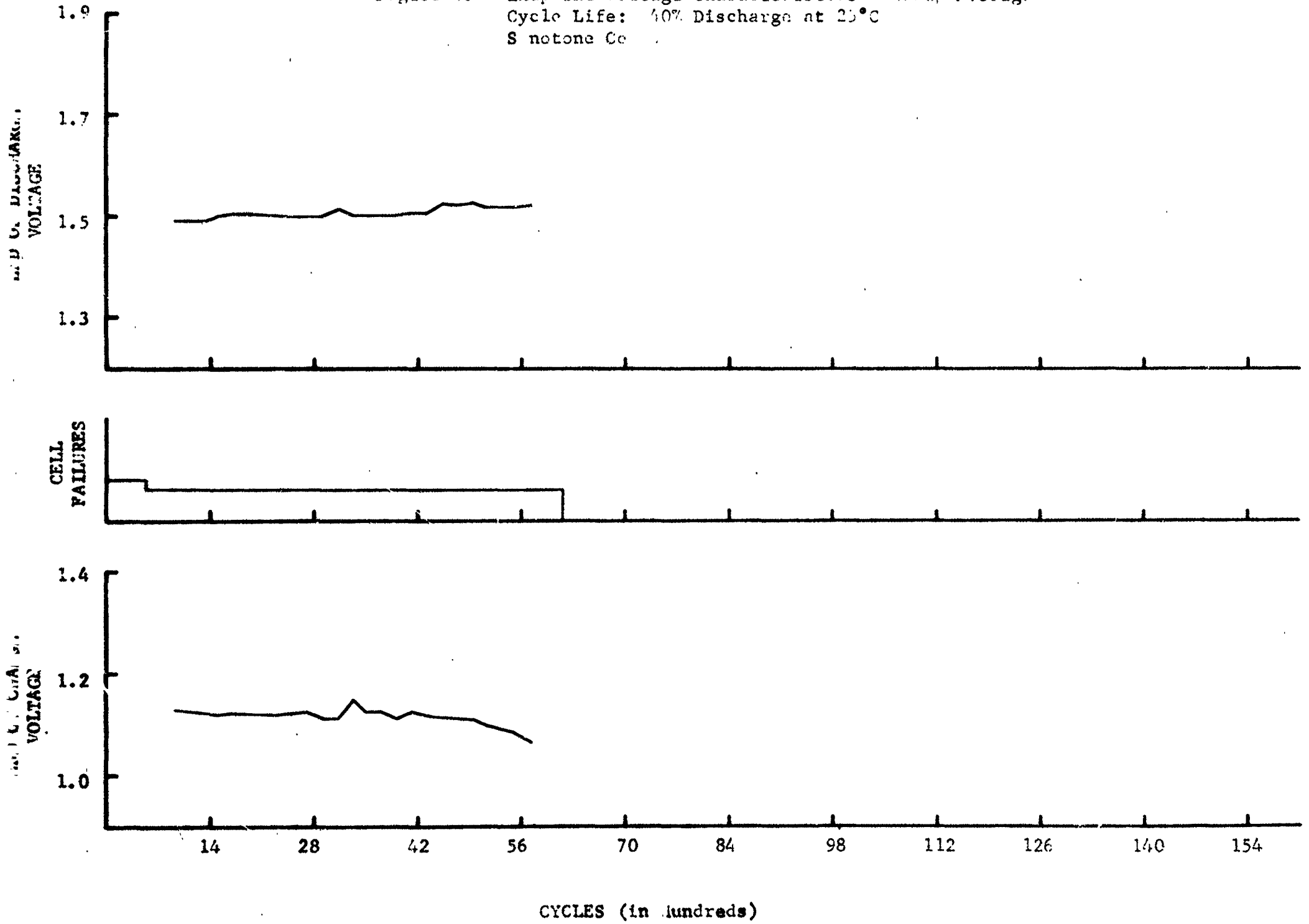


Figure 47 - Endpoint Voltage Characteristics - Cell #54
Cycle Life: 10% Discharge at -10°C
Sonotone Cell

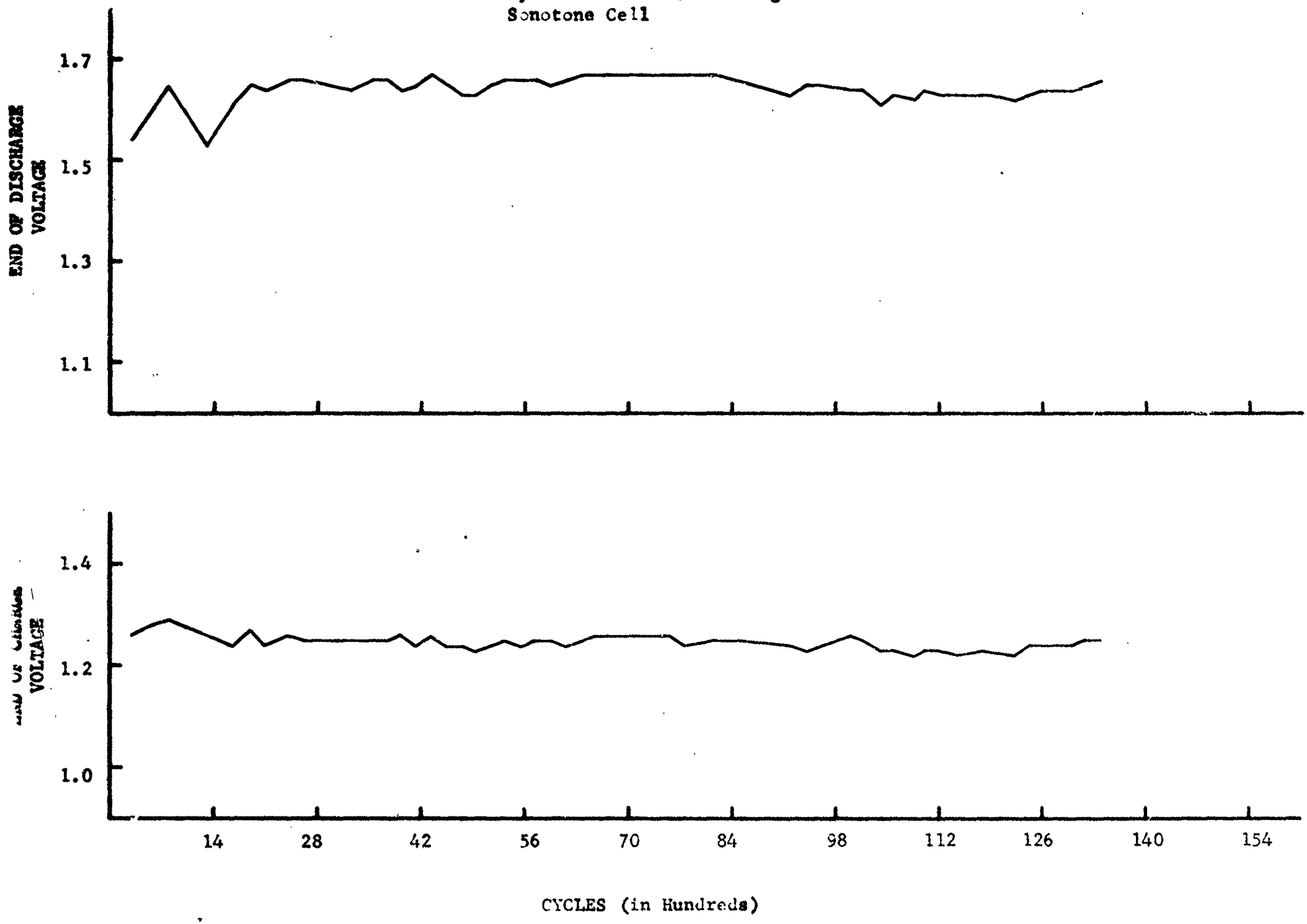


Figure 48 - Endpoint Voltage Characteristics - Cell #R38
Cycle Life: 10% Discharge at -10°C
Sonotone Cell

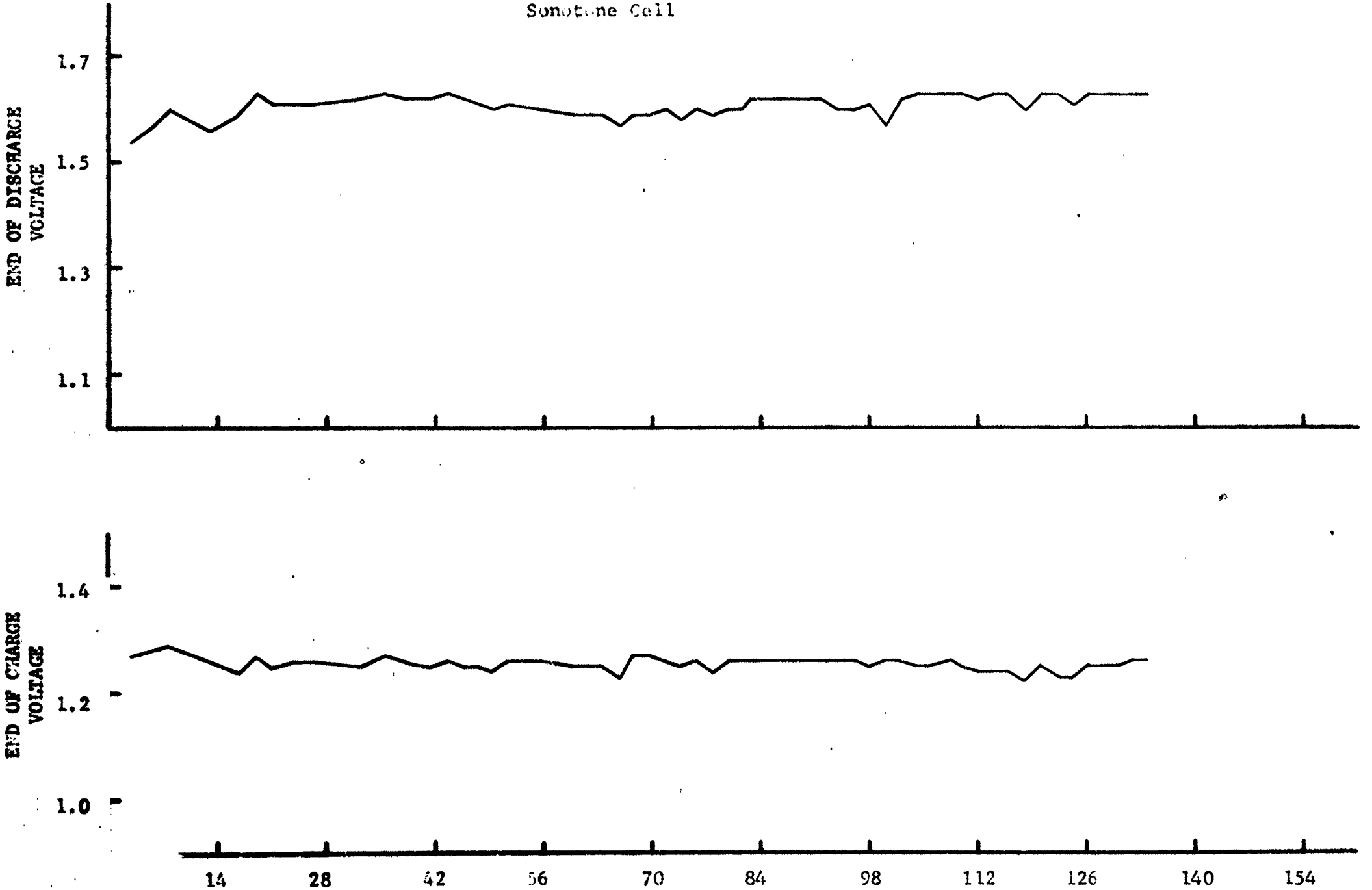


Figure 49 - Endpoint Voltage Characteristics - Cell #74
Cycle Life: 10% Discharge at 25°C
Sonotone Cell

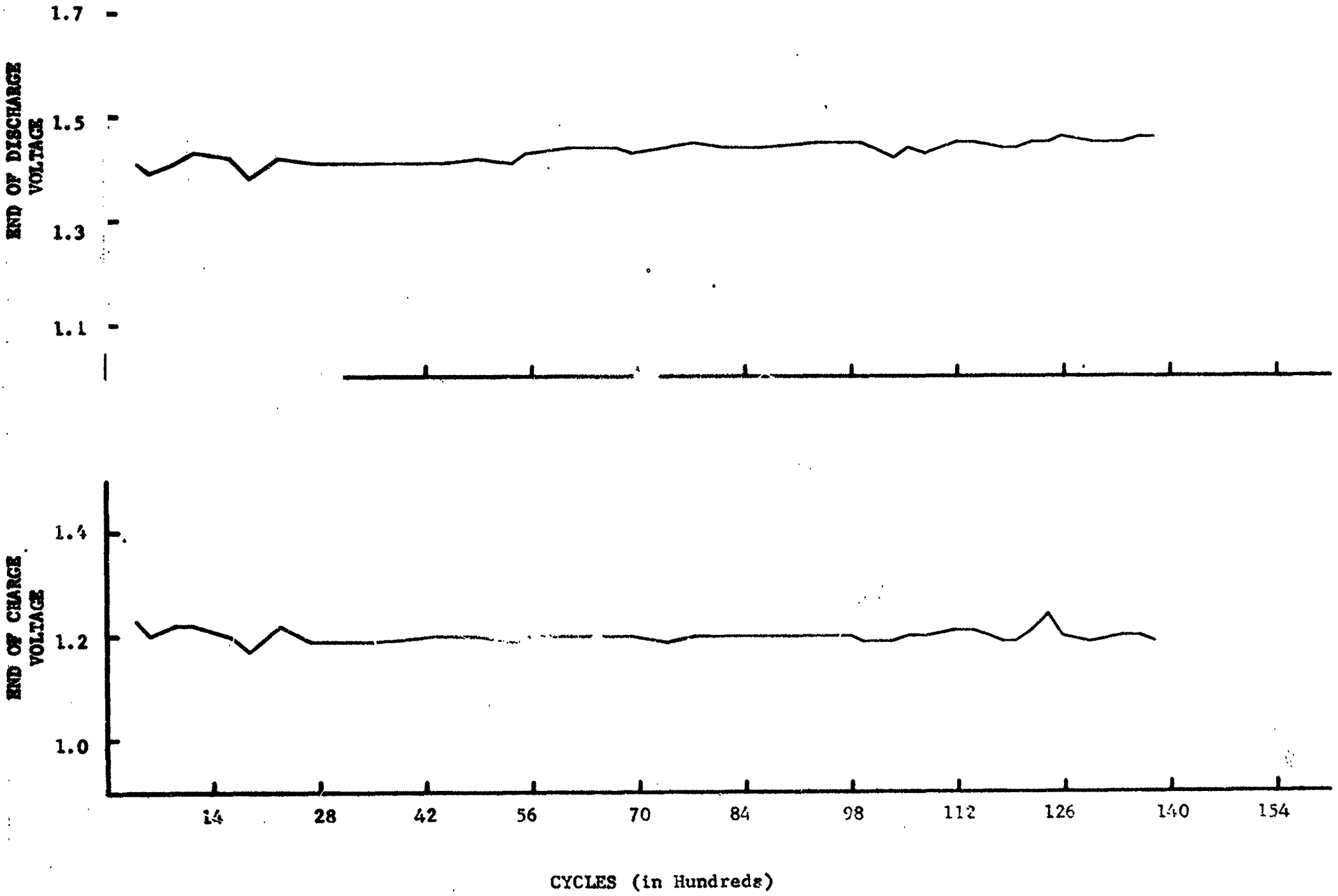


Figure 50 - Endpoint Voltage Characteristics - Cell #R39
Cycle Life: 10% Discharge at 25°C
Sonotone Cell

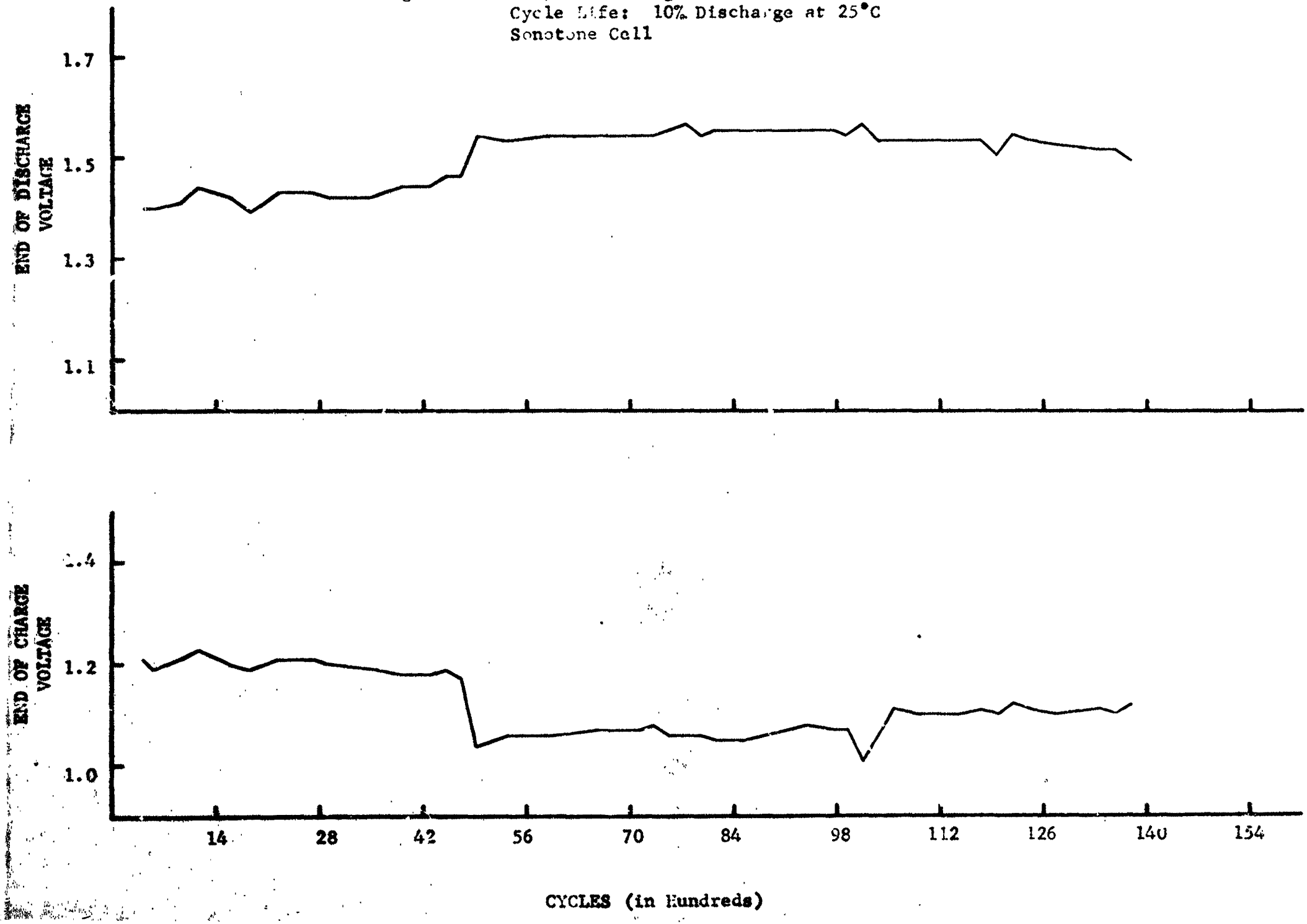


Figure 51 - Endpoint Voltage Characteristics - Cell #75
Cycle Life: 10% Discharge at 50°C
Sonotone Cell

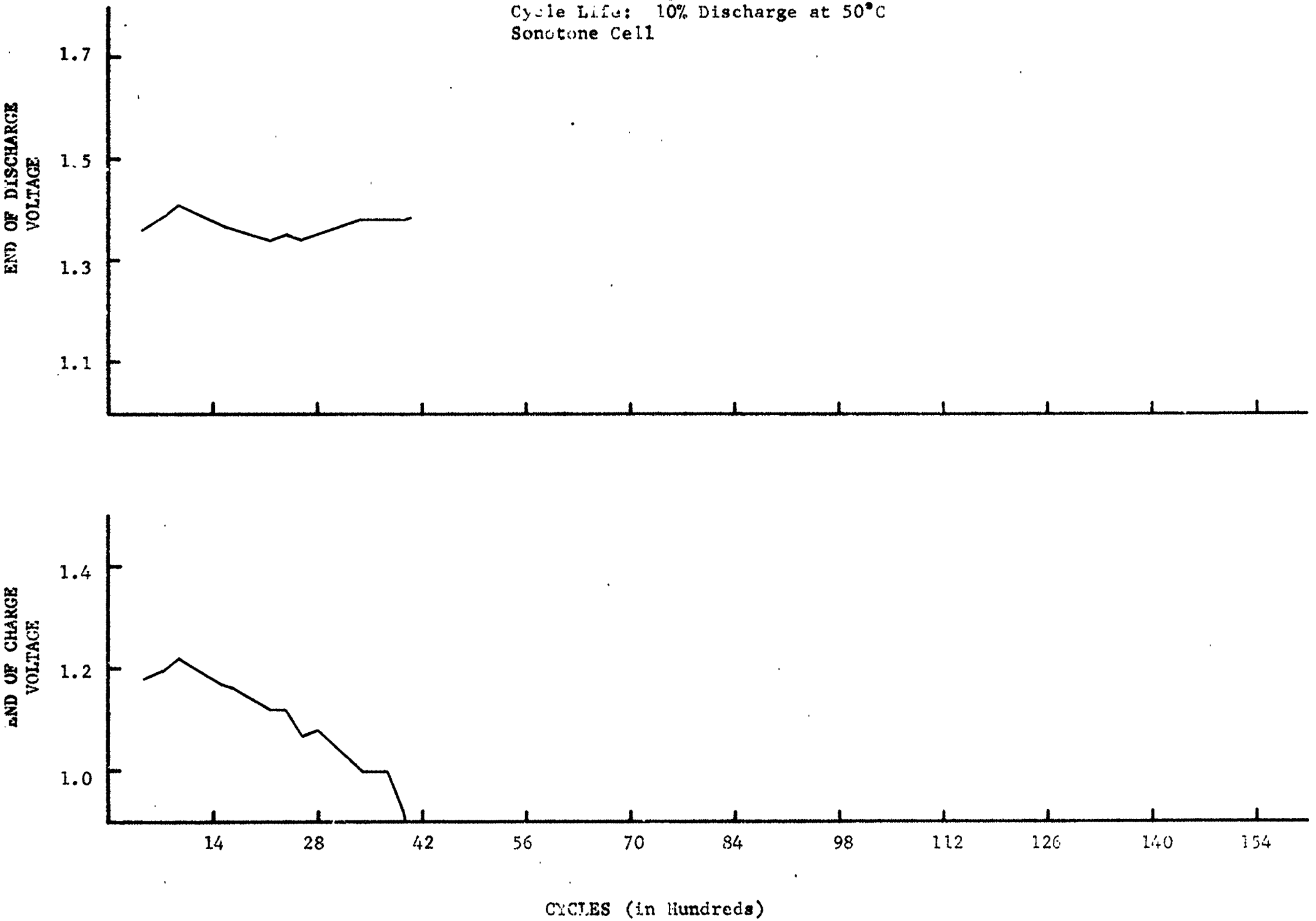


Figure 52 - Endpoint Voltage Characteristics - Cell #R48
Cycle Life: 10% Discharge at 50°C
Sonotone Cell

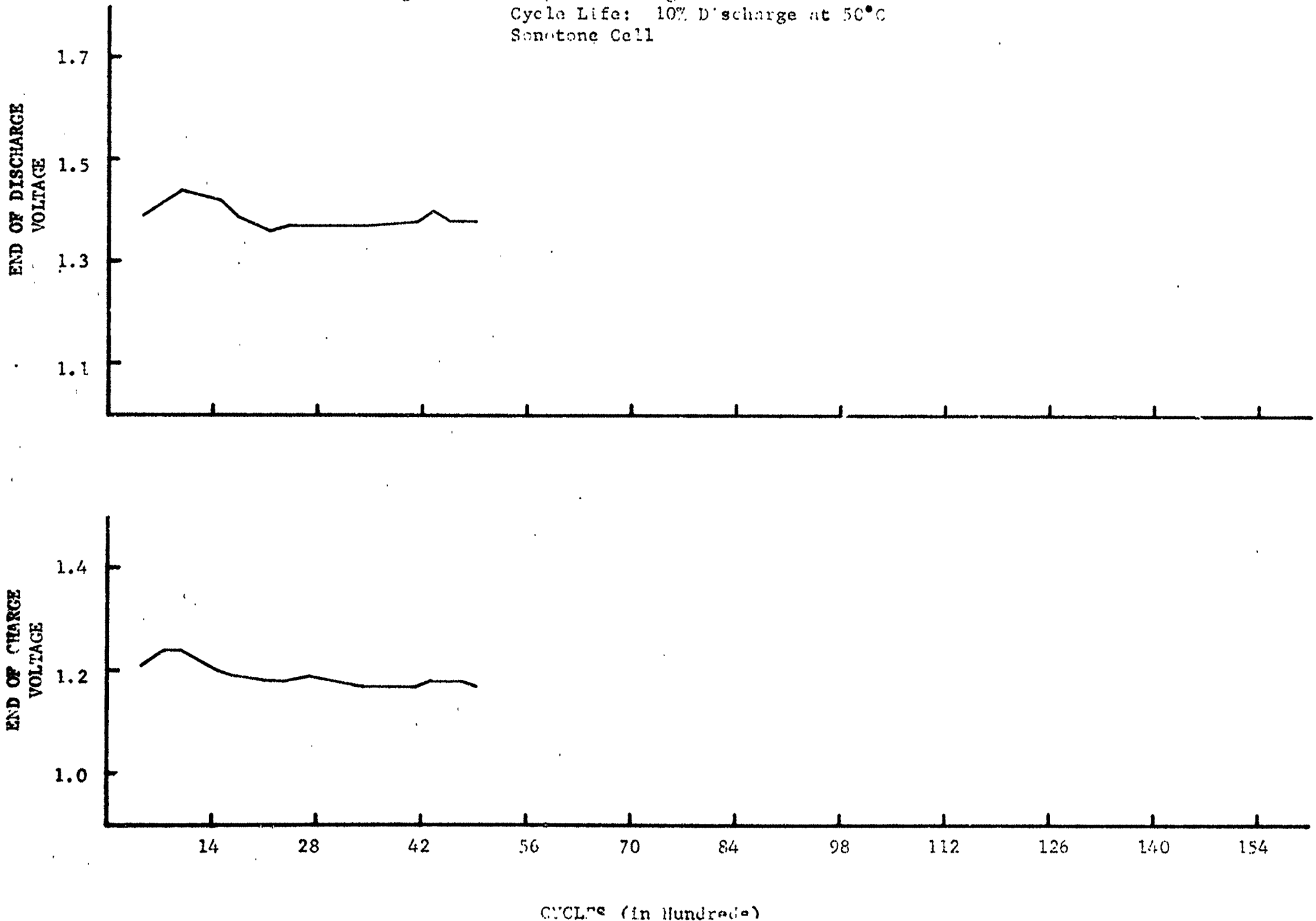


Figure 53 - Endpoint Voltage Characteristics - Cell #R49
Cycle Life: 25% Discharge at 25°C
Sonotone Cell

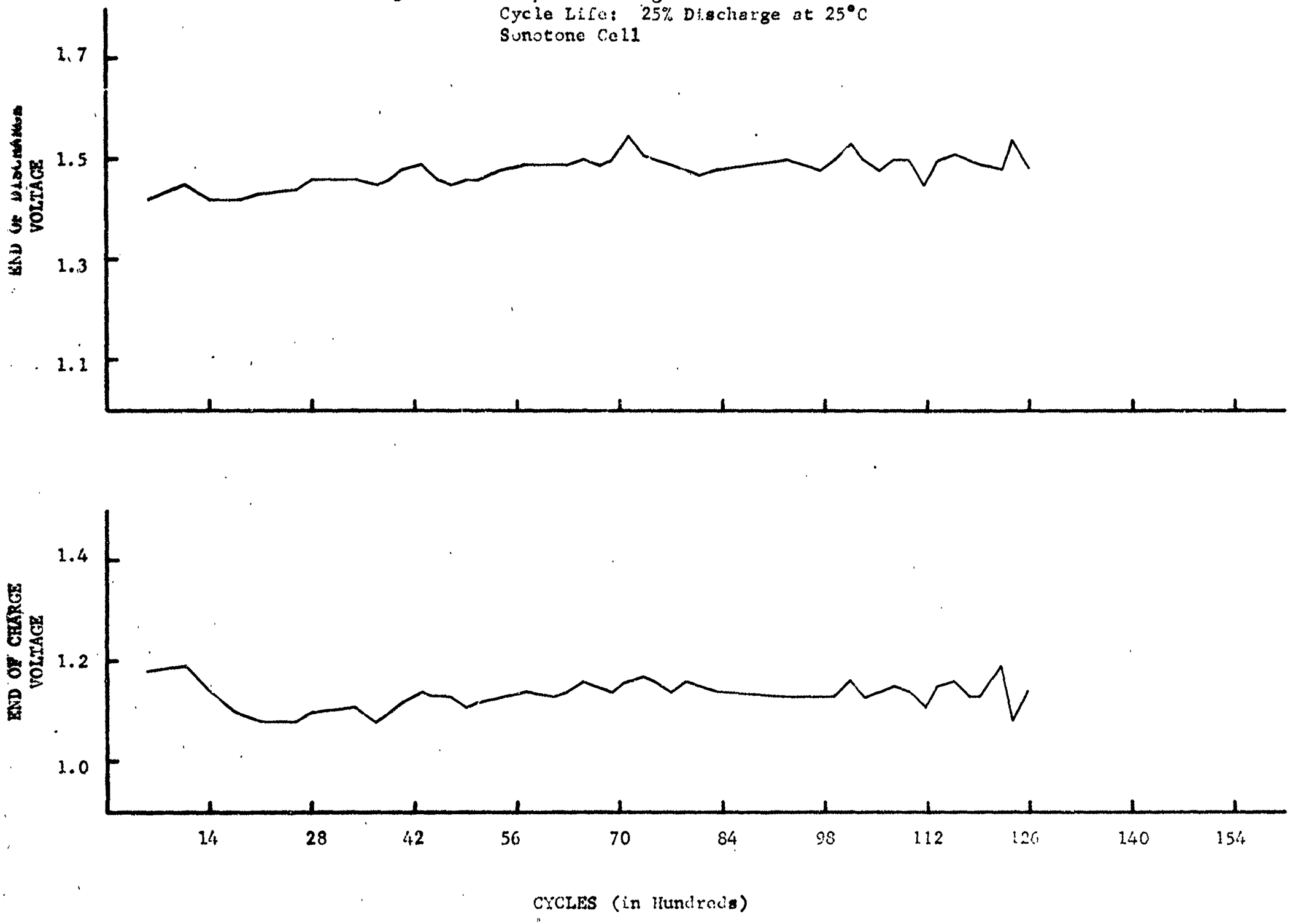


Figure 54 - Endpoint Voltage Characteristics - Cell #R57
Cycle Life: 25% Discharge at 25°C
Sonotone Cell

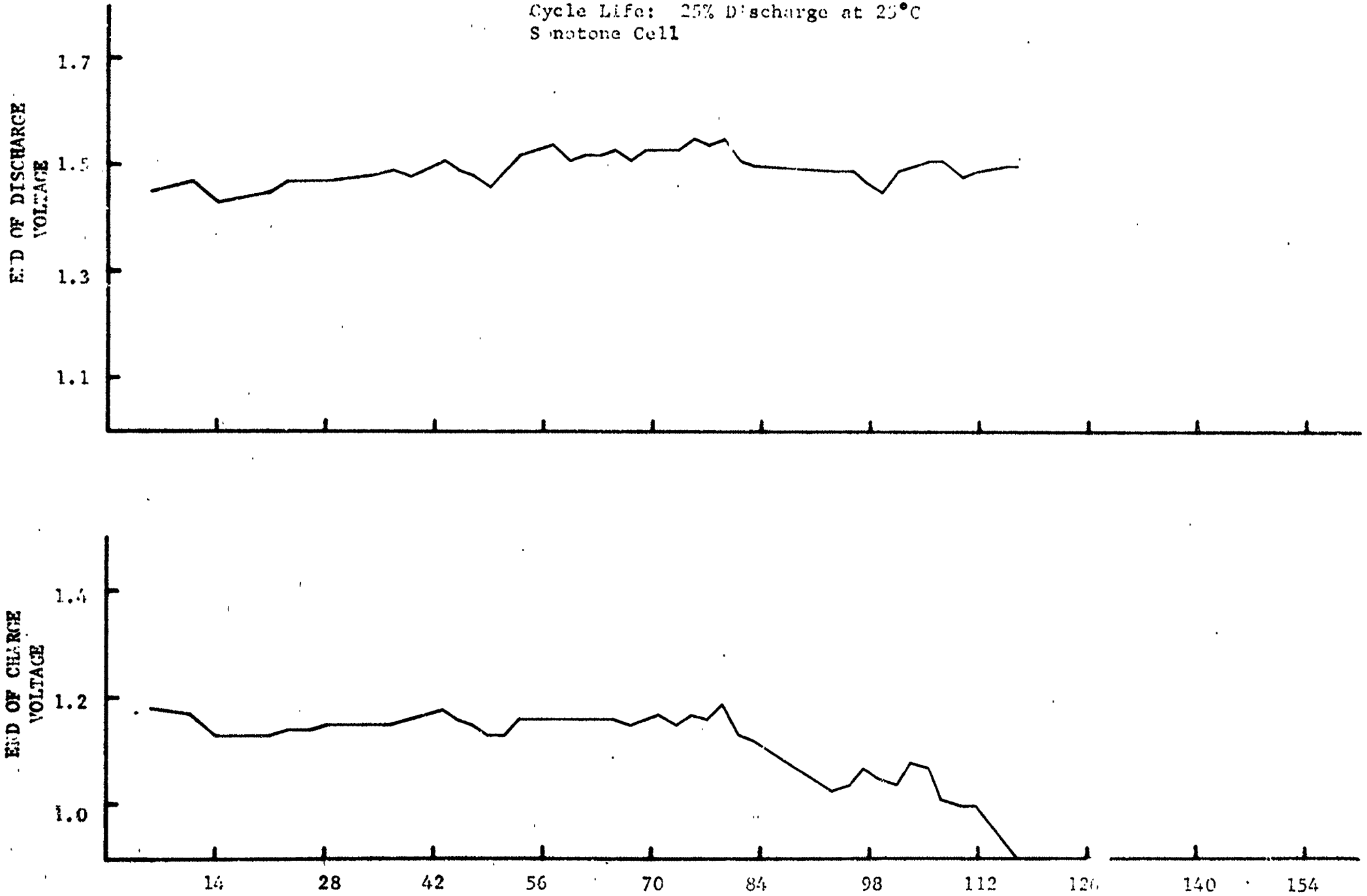


Figure 55 - Endpoint Voltage Characteristics - Cell #58
Cycle Life: 40% Discharge at 25°C
Sonotone Cell

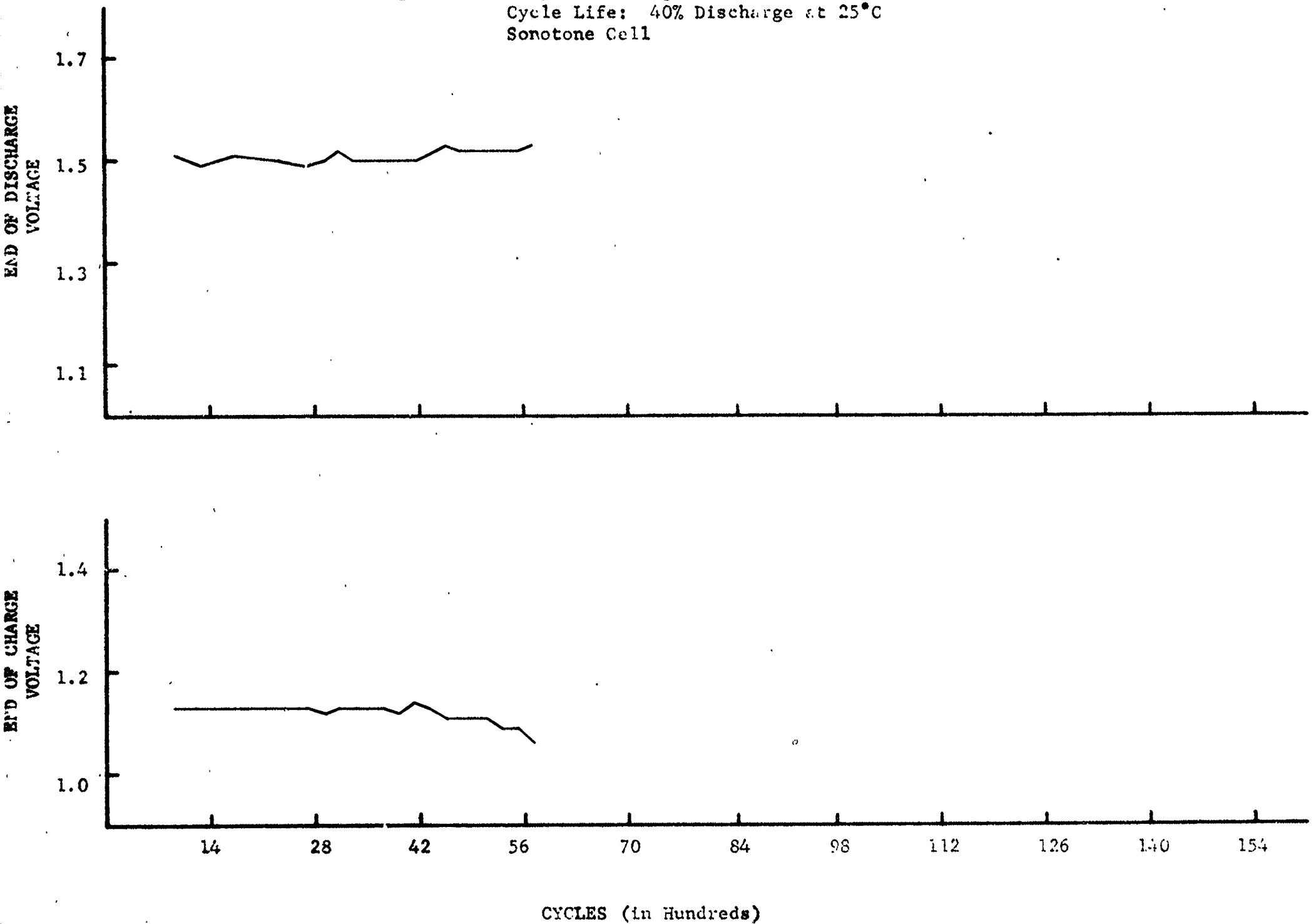


Figure 56 - Charge-Discharge Voltage Characteristics - Cell #54
Cycle Life: 10% Discharge at -10°C
Sunstone Cell

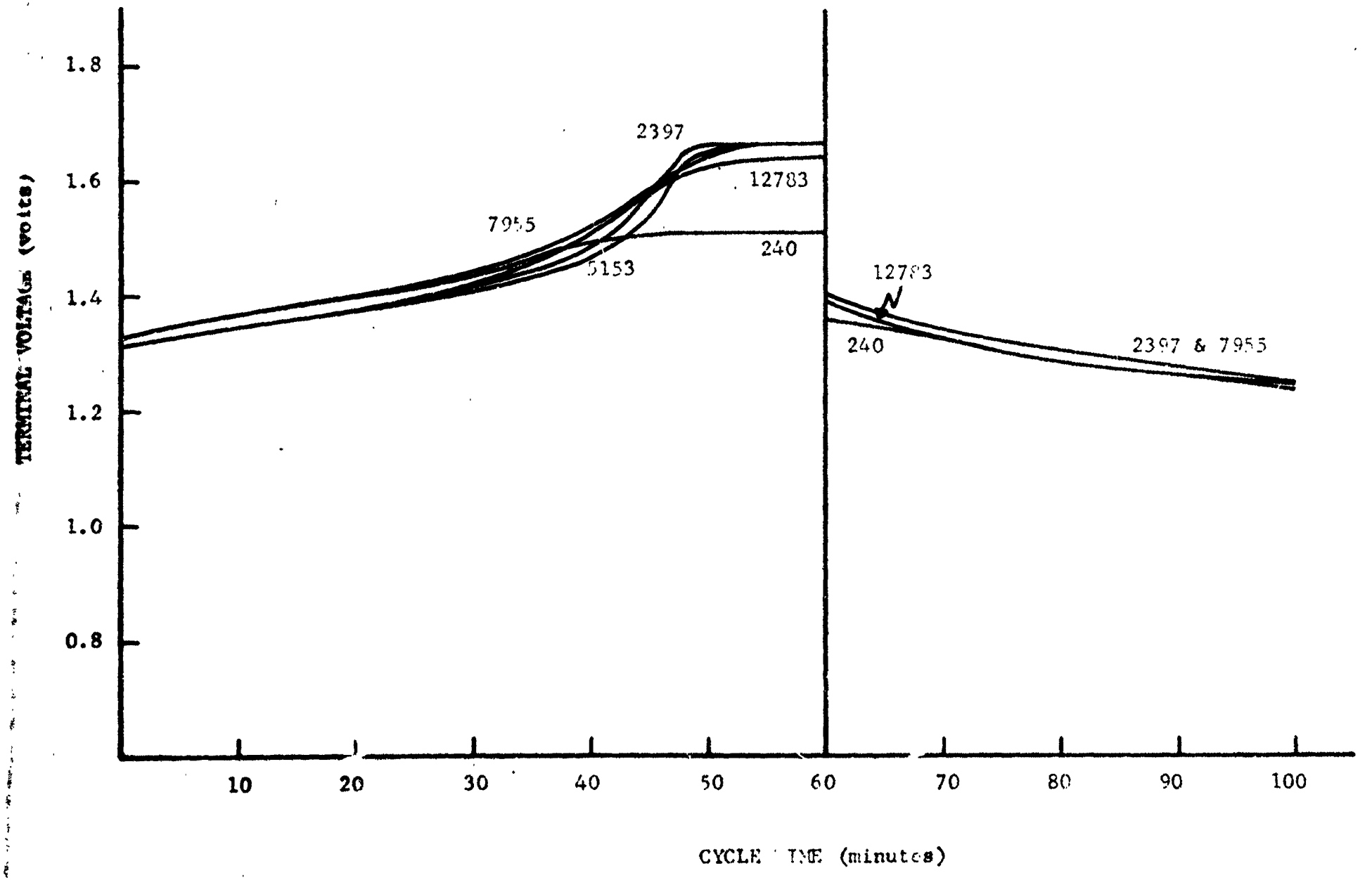


Figure 57 - Charge-Discharge Voltage Characteristics - Cell #R38
Cycle Life: 10% Discharge at -10°C
Sontone Cell

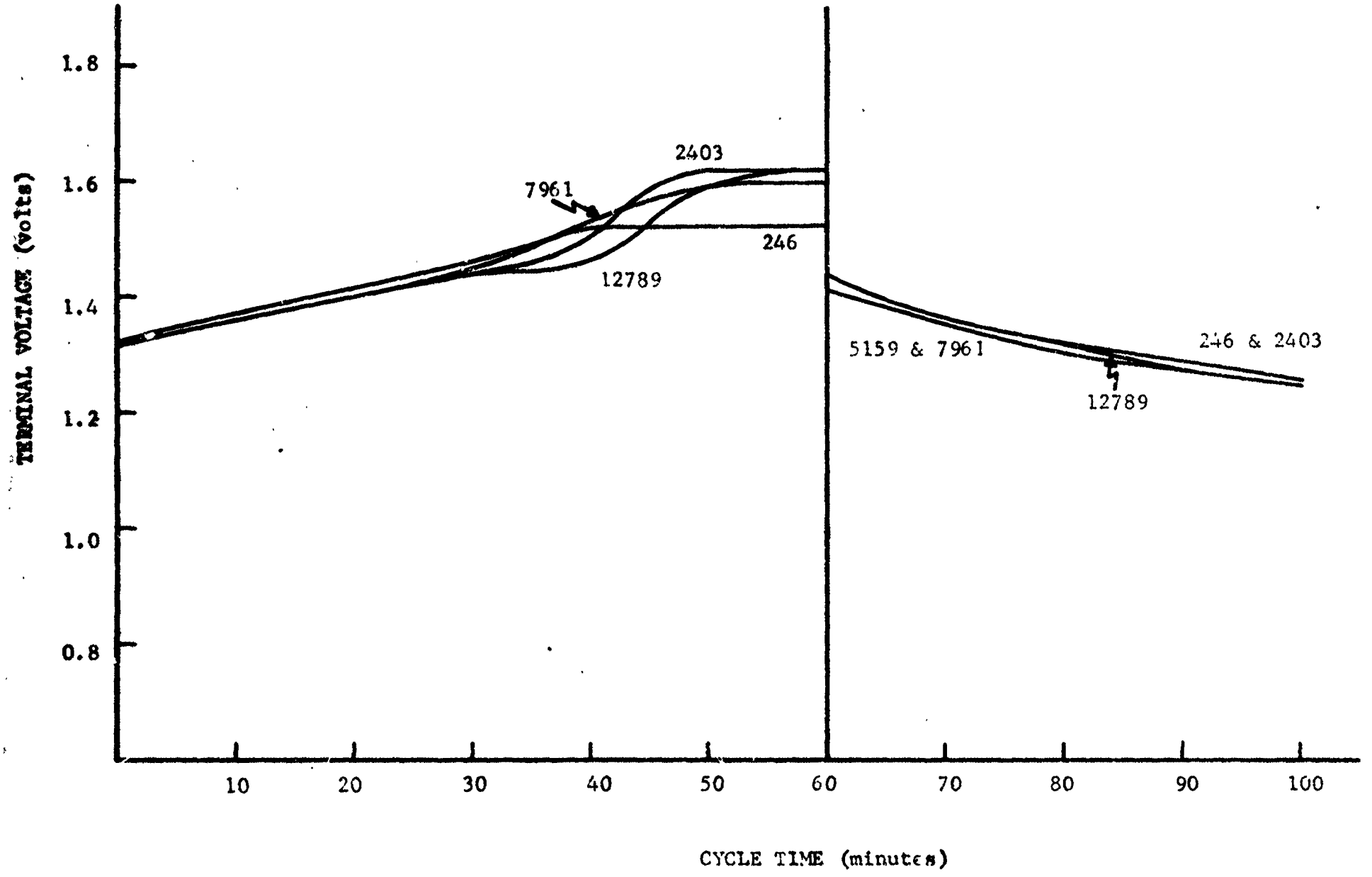


Figure 58 - Charge-Discharge Voltage Characteristics - Cell #74
Cycle Life: 10% Discharge at 25°C
Sonotone Cell

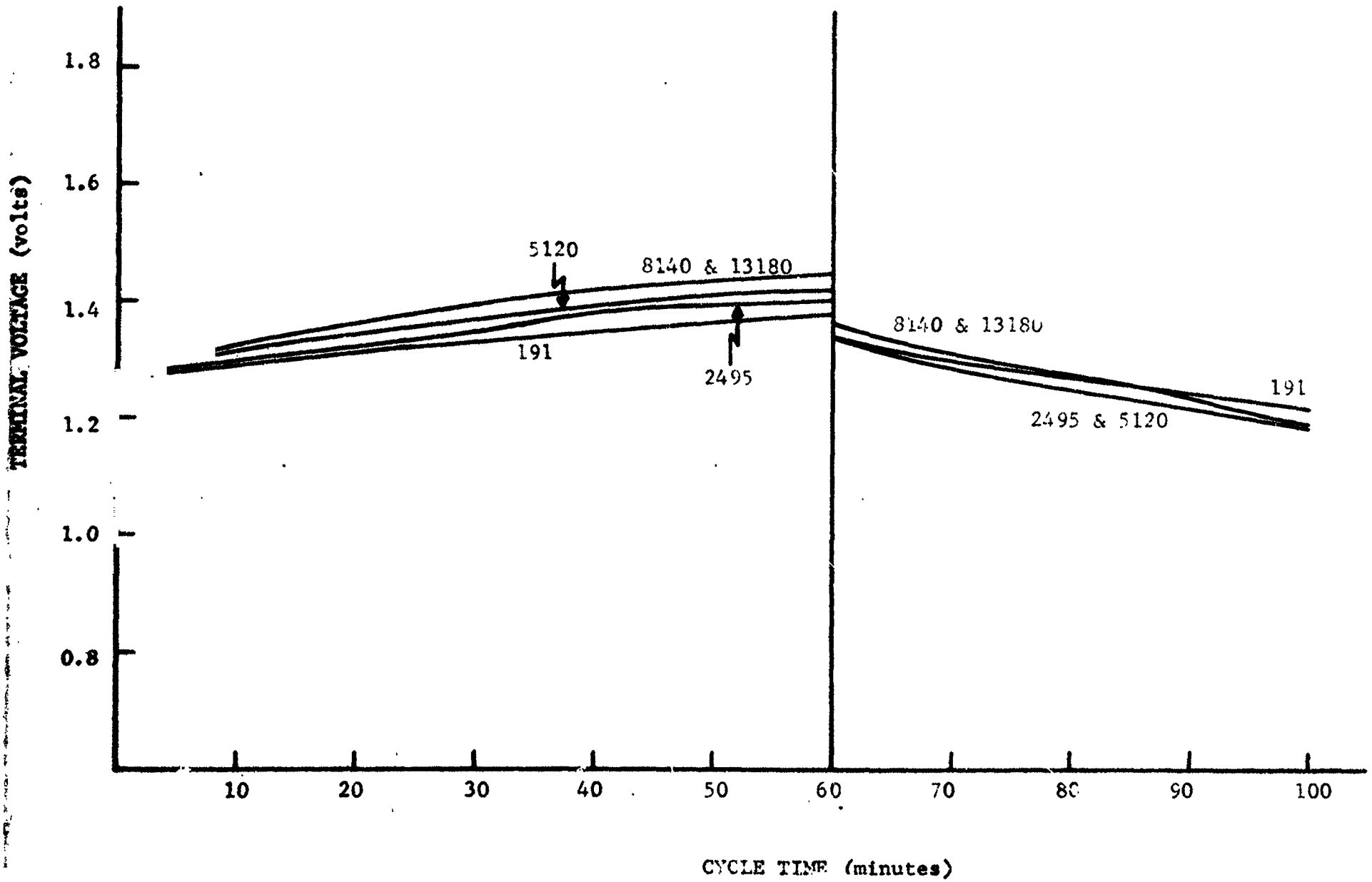


Figure 59 - Charge-Discharge Voltage Characteristics - Cell #R39
Cycle Life: 10% Discharge at 25°C
Sonotone Cell

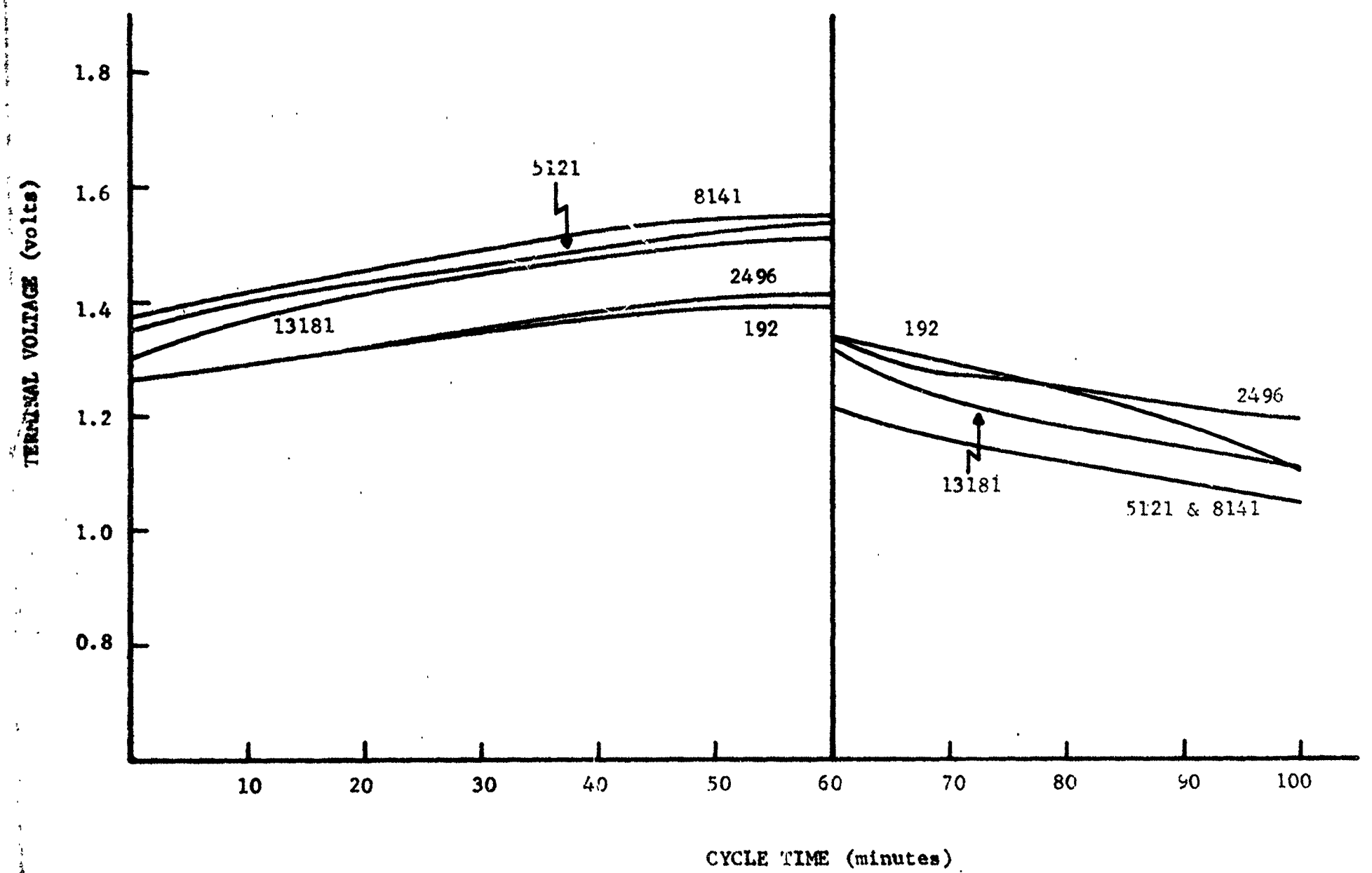


Figure 60 - Charge-Discharge Voltage Characteristics - Cell #75
Cycle Life: 10% Discharge at 50°C
Sonotone Cell

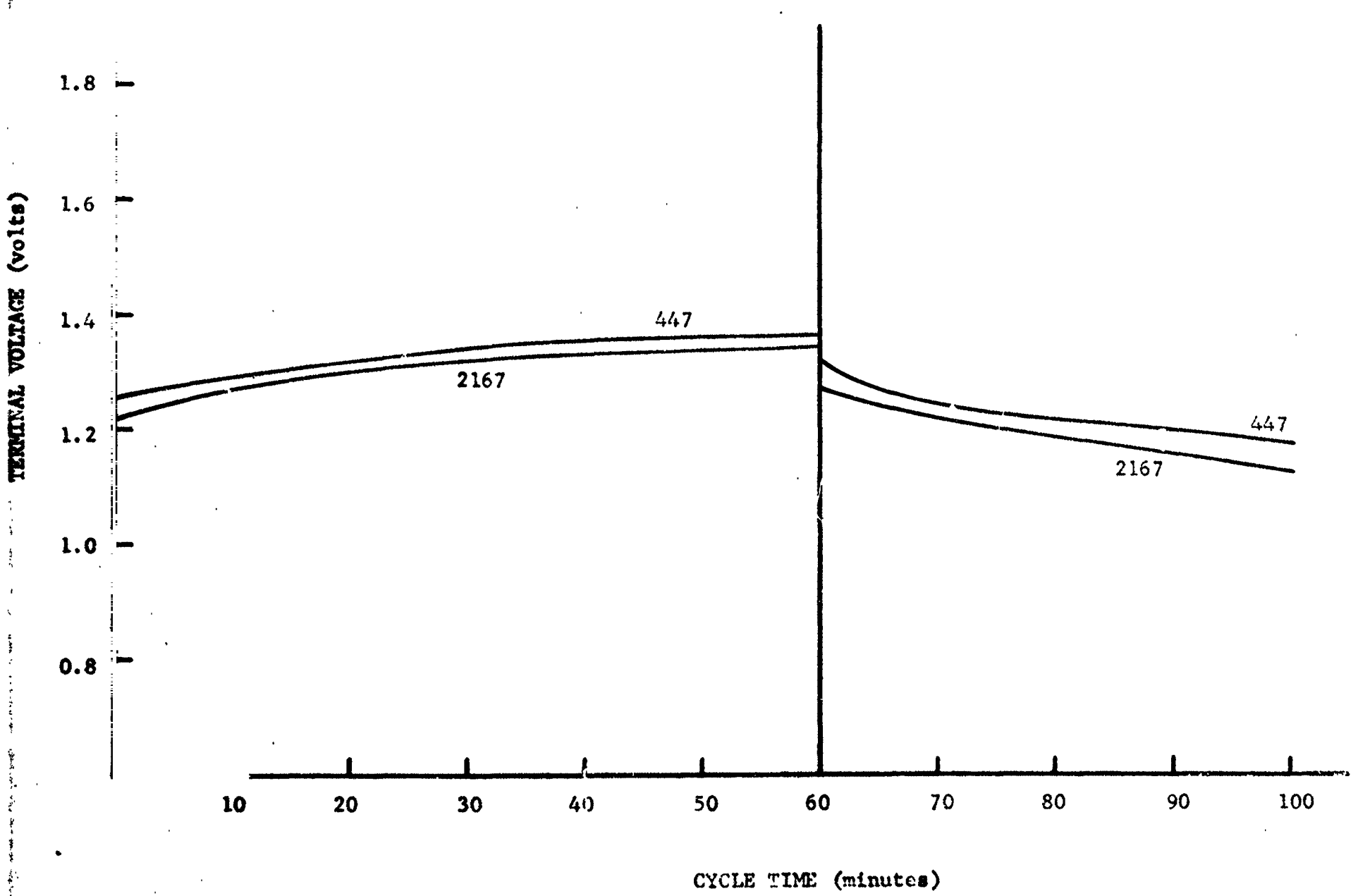


Figure 61 - Charge-Discharge Voltage Characteristics - Cell #R48
Cycle Life: 10% Discharge at 50°C
Sonotone Cell

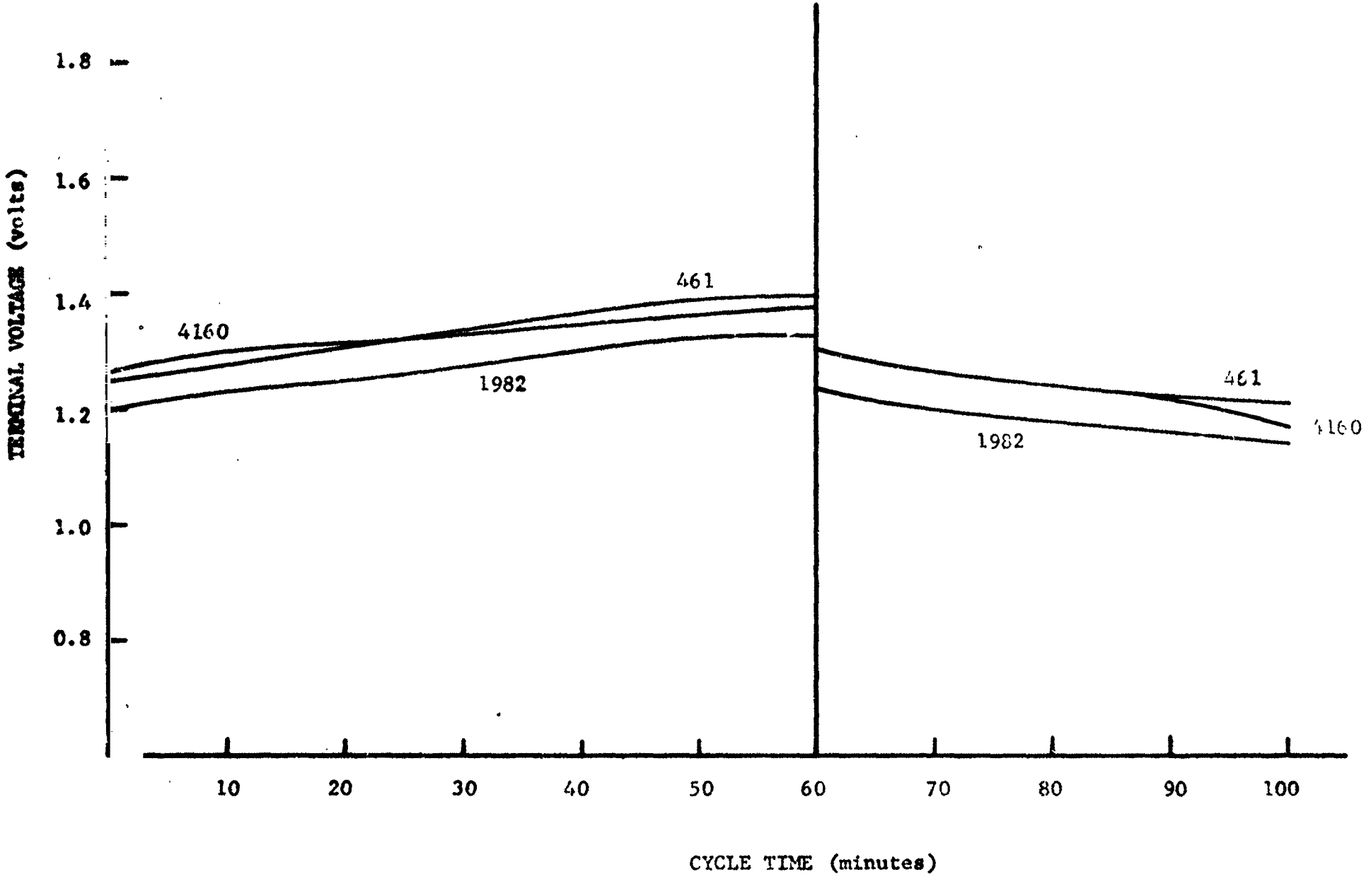


Figure 62 - Charge-Discharge Voltage Characteristics - Cell #R49
Cycle Life: 25% Discharge at 25°C
Sonotone Cell

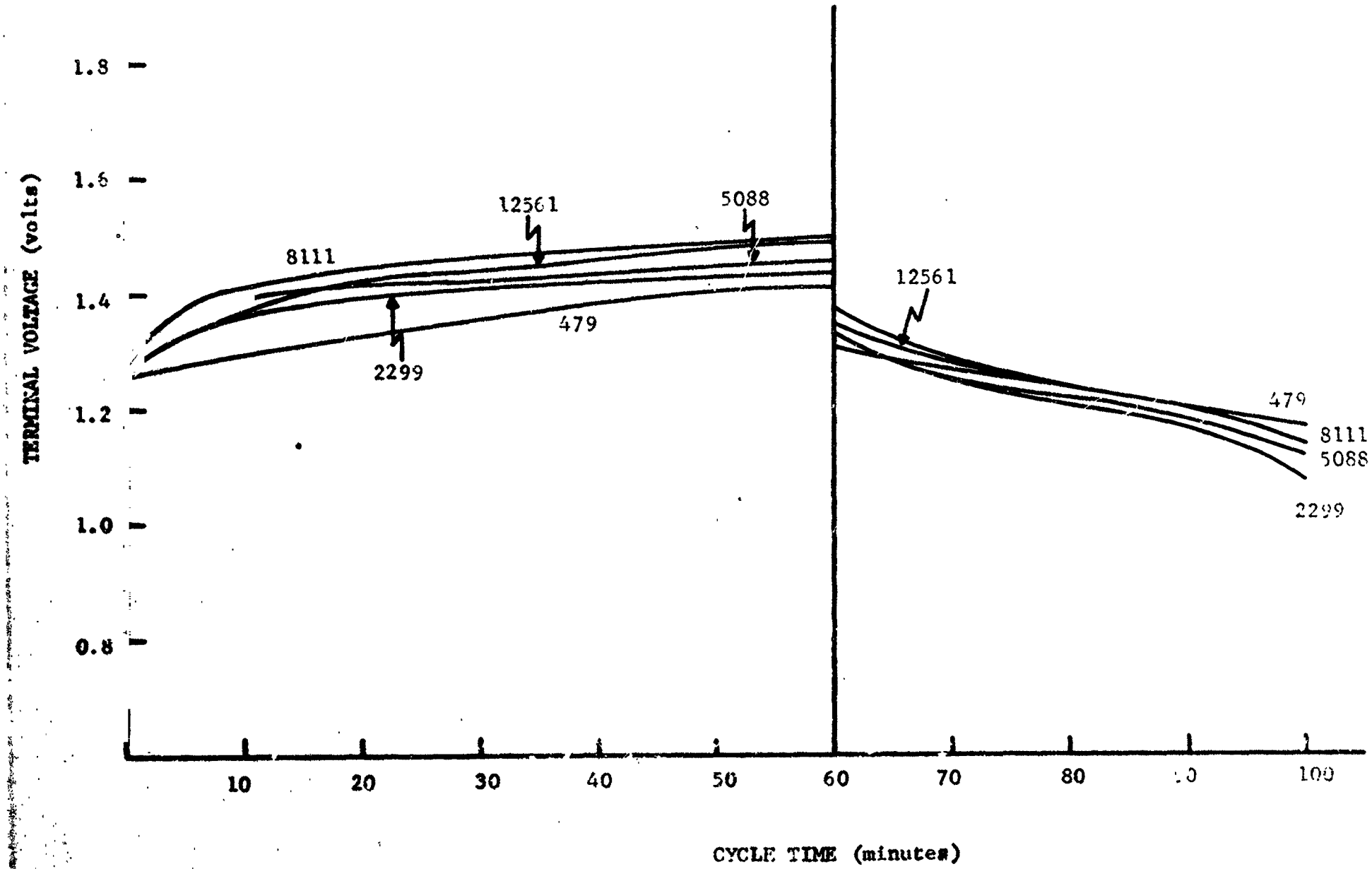


Figure 63 - Charge-Discharge Voltage Characteristics - Cell #R57
Cycle Life: 25% Discharge at 25°C
Sonotone Cell

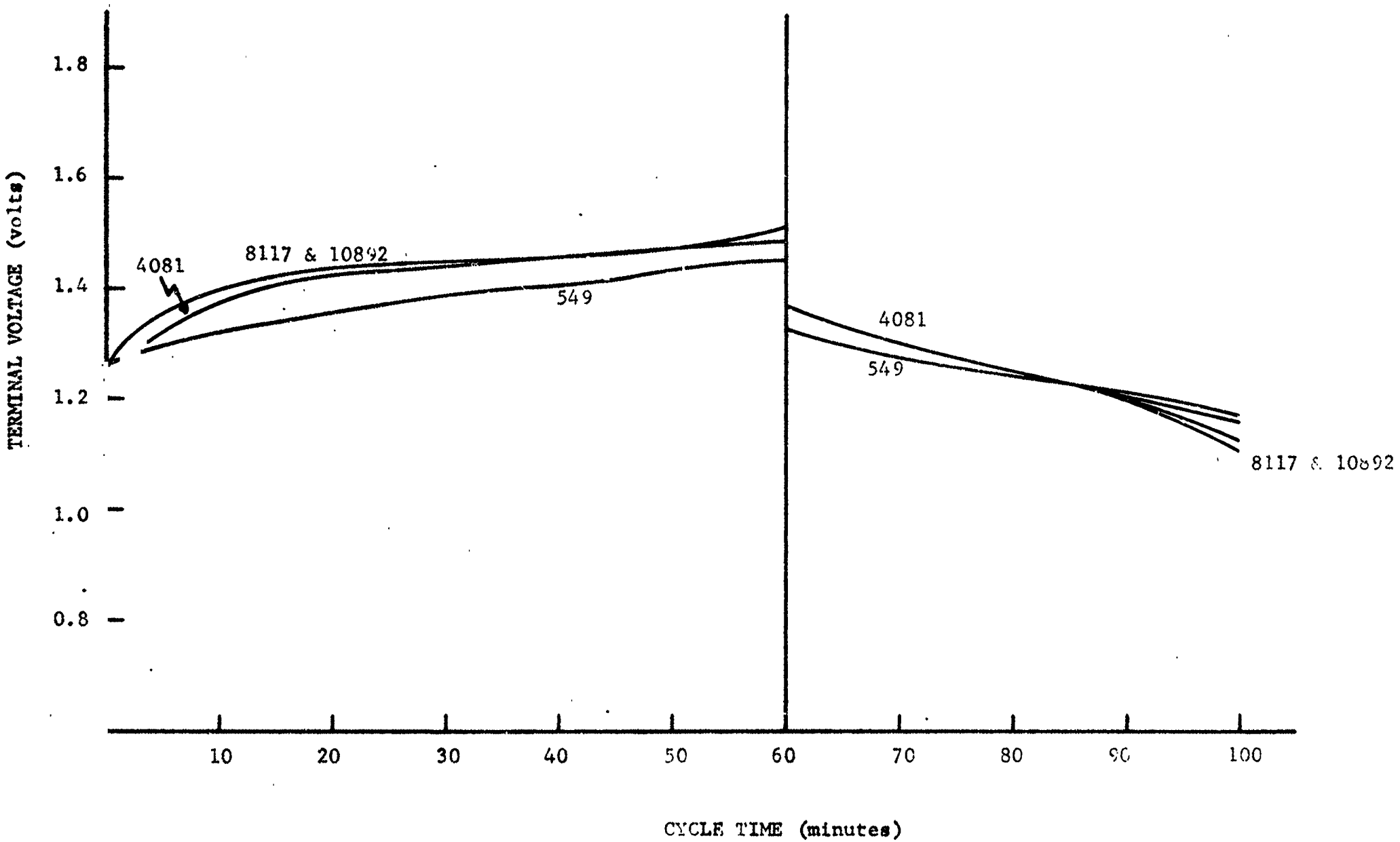
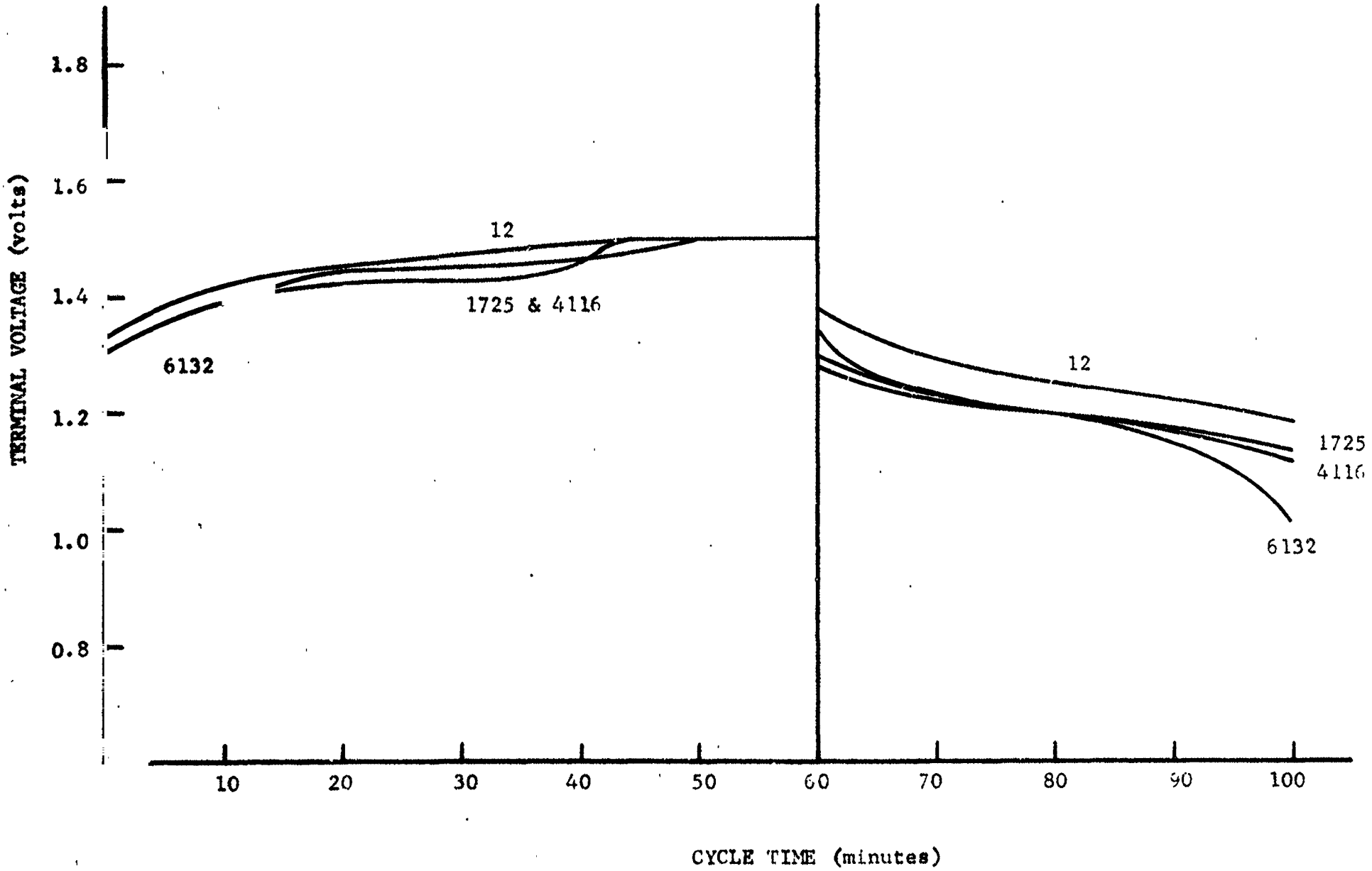



Figure 64 - Charge-Discharge Voltage Characteristics - Cell #58
Cycle Life: 40% Discharge at 25°C
Sonotone Cell