HEAT STERILIZED NICKEL-CADMIUM CELL ELECTRICAL PERFORMANCE INVESTIGATION

Phase III

Final Report

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PREFACE

This report was generated in accordance with the requirements of JPL Purchase Order No. CA-388009 to summarize the work during Phase III of a heat sterilizable nickel-cadmium cell test program. The objectives of this work were to compare the electrical performance of nickel-cadmium cells capable of heat sterilization, both control (unsterilized) and heat sterilized cells, with variation in discharge rate (C/5, C/2 and C) and temperature (32°F, 75°F and 110°F), and to compare this electrical performance with cells tested under Phase I.

This report was prepared by R.F. Fogle and R.N. Richards, who acted as Project Engineers for TRW. W. R. Scott was the Project Director. Mr. Winfield Yeaney was the Technical Representative for JPL.

ABSTRACT

The results of the "Heat Sterilizable Nickel-Cadmium Cell Electrical Performance Investigation" (Phase III) showed that initially a greater percentage (73 percent) of the sterilized cells had a higher capacity than comparable nonsterilized cells. At the termination of the test, only 45 percent of the sterilized cells showed a higher capacity than comparable nonsterilized cells. A comparison of the Phase III capacity data with that of Phase I testing showed that the final capacities of Phase I were comparable with the initial capacities of Phase III, that is, a greater percentage (73%) of the sterilized cells showed higher capacities than comparable nonsterilized cells. There were some cells which exhibited irregularities of input and output capacities, that is, they showed high input capacities coupled with low output capacities or low input capacities coupled with almost equal output capacities. A higher percentage of the cells showing these irregularities had not been subjected to sterilization. In phase I testing, a high input capacity reflected itself in a high output capacity and a low input capacity reflected itself in a low output capacity. The effect of increasing the discharge rate at a specific temperature resulted in decreasing the output capacity. In general, the input capacities increased as the temperature increased. The output capacities for a given discharge rate were low at 32°F (2.23 ampere hours), were a maximum at 75°F (3.51 ampere hours) and then fell off at 110°F (2.07 ampere hours). One cell (nonsterilized) failed during the Phase III testing but it is doubtful the failure resulted from the cycle regime.

1.0 SUMMARY

1) All cells subjected to this test program showed a negative leak test at the termination of cycling.

2) Cell dimensions and weights measured at the termination of this test program were the same as those at the termination of Phase I testing.

3) The cycling sequence produced one cell failure. Cell S/N 3017 started to show a decline in both input and output capacities at about cycle number thirty (30). This decline continued and the cell was removed from test at cycle number thirty-six (36). This cell was an unsterilized cell which had been subjected to the life cycling only of Phase I testing.

4) At the termination of Phase I, 73 percent of the sterilized cells ultimately selected for Phase III testing showed higher capacities than non-sterilized cells which had been subjected to the same test conditions. For sterilized cells showing higher capacities the range was from 1.3 to 163 percent higher with an average of 51 percent. The average output capacities for the sterilized cells was 2.94 ampere hours, and that for the non-sterilized was 2.62 ampere hours. At the initiation of Phase III, 81 percent of the sterilized cells showed higher capacities; but the capacity range had decreased to 0.9 to 41 percent higher with an average of 16.6 percent. The average output capacity was 3.56 ampere hours for sterilized cells and 3.32 ampere hours for non-sterilized cells. At the termination of Phase III testing, only 45 percent of the sterilized cells showed a higher capacity than comparable cells which had not been sterilized. For sterilized cells showing higher capacities, the range was from 12 to 28 percent higher with an average of 20 percent. The average output capacity was 2.07 ampere hours for sterilized cells and 1.99 ampere hours for non-sterilized cells.

5) At the termination of this test, all cells, except those which had been on open circuit or float charge for 300 days during Phase I testing, exhibited output capacities in the vicinity of two (2) ampere-hours. The 300 day open circuit and float charge cells exhibited output capacities of approximately 2.4 ampere-hours. The reason for the slightly higher capacities of these cells may be that they had experienced only one charge-discharge cycle during Phase I testing, while the other cells received from 70 to 300 cycles.

6) Comparison of the initial capacities (10th cycle, 75°F, and 0.800 ampere discharge rate) with the final capacities (64th cycle, same conditions of temperature and rate) shows that there was little or no decrease of cell capacity for cells which completed the test.

SUMMARY (Continued)

7) In general, the input capacities increased as the temperature was increased. The output capacities for a given discharge rate were low at 32°F, were at a maximum at 75°F, and then fell off again at 110°F. The average output capacity of the cells of 0.800 amperes discharge rate was 2.23 ampere hours at 32°F (cycle 27), 3.51 ampere hours at 75°F (cycle 10), and 2.07 ampere hours at 110°F (cycle 42).

8) The effect of increased discharge rate at a given temperature results in decreasing the output capacity. This effect was more pronounced at 32°F and 110°F than at 75°F.

2.0 INTRODUCTION

The purpose of this report is to present the results of the test and evaluation phase of a Nickel-Cadmium Heat Sterilization Cell Characterization Test Program performed for the Jet Propulsion Laboratory, California Institute of Technology, under JPL Contract CA-388009 sponsored by the National Aeronautics and Space Administration under Contract NAS 7-100.

Tests were performed on thirty-one (31) 4.0 ampere-hour "D" size Sonotone nickel-cadmium cells capable of heat sterilization in accordance with the program as outlined in JPL's "Nickel-Cadmium Testing, Contract 951092, Modification 2 Statement of Work", dated 30 August 1966, and TRW Systems Test Procedure 9363.4-343, entitled "Heat Sterilization Testing of Nickel-Cadmium Cells," dated 28 April 1965, as modified by Purchase Order CA-388009, dated 10 November 1966.

The tests were designed to determine the effect of varying the rate and temperature of discharge on cells and to compare the performance of the cells under these conditions with the performance of Phase I (Nickel-Cadmium Cell Heat Sterilization Test Program).

The cells used in this test were cells that had survived the Phase I testing, which included life test, open circuit storage test and constant current float test. Performance characteristics of non-sterilized and sterilized cells were compared to determine the effects of the variables of this test.

The temperature of the cells was regulated by placing them in a temperature-controlled forced air chamber. An automatic battery cell test console (same as used in the Phase I testing) was used for cycling the cells and provided cell protection from overvoltage/undervoltage conditions and from commercial power failures. The console was programed to perform one charge/discharge cycle per day.

3.0 DEFINITION OF TERMS

The test items used were cells which had successfully completed Phase I of this program. Cell identification is specified in Section 3.1.6 of the Phase I Final Report of JPL Contract 95102. All cells used in this test program were of cylindrical construction, had a niminal capacity of 4 ampere hours, and were manufactured by the Sonotone Corporation.

3.1 Control Cell

A control cell was a cell which had not been subjected to heat sterilization during Phase I.

3.2 Sterilized Cell

A sterilized cell was a cell which had been subjected to three (3) thirty-six hour temperature cycles from 23°C to 145°C during Phase I. The exact time schedule of the sterilization cycles is described in Section 3.1.7.2 of the Phase I Final Report.

3.3 Cell Charge Requirements

All cells were charged at a constant current of 400 ma for a period of 14 hours or until the cell voltage increased to 1.55 volts at 32°F, 1.52 volts at 75°F (which is a deviation from Phase I Testing), 1.46 at 110°F, whichever occurred first. The above end of charge were selected from a linear plot of voltage versus temperature of similar type cells. The following tolerances were maintained during charging:

Current measurement	± 5 ma
Current regulation	± 10 ma
Voltage Limit Setting	1.55 ± 0.005 Vdc at 32°F 1.52 ± 0.005 Vdc at 75°F 1.46 ± 0.005 Vdc at 110°F
Cell voltage measurement	± 10 MV (print chart recording)
Voltage calibration	± 1 MV
Time control and data print	± 1 minute
Chamber temperature	32° ± 3°F 75° ± 3°F 110° ± 3°F

3.4 Cell Discharge Requirements

The cells were discharged at a constant current rate of 0.800 ampere, 2.0 amperes, 4.0 amperes and 6.0 amperes to an undervoltage limit of 0.6 volt. The following tolerances were maintained during discharging:

Current measurement	± 5 ma
Current regulation	± 10 ma
Voltage limit setting	0.60 ± 0.01 volt
Cell voltage measurement	± 10 MV (print chart recording)
Voltage calibration	± 1 MV
Time control and data print	± 1 minute
Chamber temperature	32° ± 3°F 75° ± 3°F 110° ± 3°F

4.0 CELL CHARACTERIZATION TESTS

The purpose of this test was to determine if the cell capacities measured at the termination of Phase I could be maintained after cycling at various temperature/discharge-current combinations.

4.1 Cell Characterization Test Set-Up

The test fixture and recording equipment used in this test were the same as that used in Phase I, life cycle testing. The reader is referred to Phase I Final Report for a detailed description of the test fixture.

4.2 Cell Preparation Characterization Testing

4.2.1 Cell and Cycle Identification

4.2.1.1 Cell Identification

For the purpose of this testing and presentation of data, the following identification was used. This identification was based on the test sequence the cells experienced in Phase I testing.

HS - Heat sterilized

NS - No sterilization

F - Float charge

OC - Open Circuit stand

L - Life cycled

Numerals - Number of days subjected to float charge, open circuit stand and life cycles.

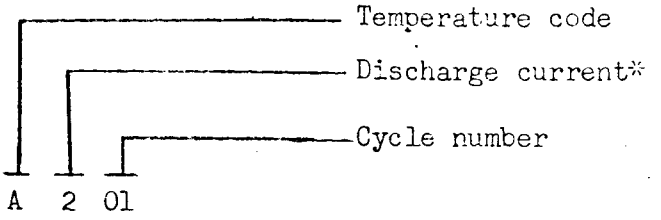
NOTE: All cells in this test that were sterilized, were sterilized in the discharged state.

Example: HS - F270 - L30

The above example shows that the particular cell was sterilized, then float-charged for 270 days, and then life cycled 30 days during Phase I testing. Since all cells in this test received the same treatment, no further identification was made.

4.2.1.2 Cycle Identification

Since the charge portion of each cycle was at the same rate and the discharge portion was at different rates, the discharge half-cycle was used for the identification of each cycle. Each cycle was identified by a four (4) character alpha-numeric code combination defining all the parameters of discharge half-cycles. An example of the test code is as follows:



*As specified in section 3.4.

Code Legend

Temperature Code

A - 75°F test temperature
B - 32°F test temperature
C - 110°F test temperature

4.2.2 Cell Positioning

The cells were placed in the holding fixtures for placement in the Temperature Chamber. The position of the cells in the holding fixture is given in Figure 1.

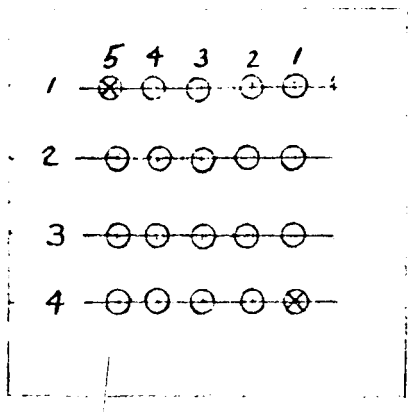
4.2.3 Temperature Recording

To determine the effect of cell temperature on the various discharge rates of the test sequence, thermocouples were placed on two of the test cells. The thermocouples were taped to the top of two cells with glass fiber tape. One cell (S/N 3015, not heat sterilized, was cycled three-hundred (300) days during Phase I life cycle testing. The other temperature-monitored cell (S/N 3021) also had been life cycled 300 days during Phase I testing, but was subjected to heat sterilization. As can be seen from Figure 1, these cells were in positions 1 and 5 of holding fixture number 1.

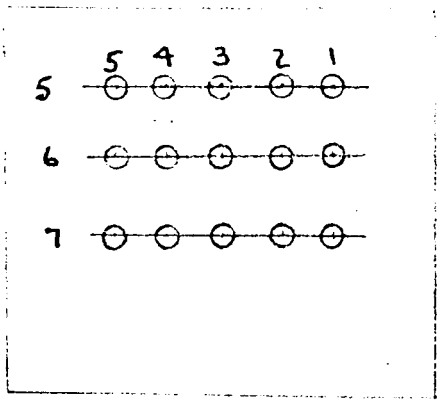
In addition to monitoring the temperature of two of the test cells, the temperature of the Environmental Chamber was also monitored. All-temperatures (two cells and chamber) were recorded on a Multi-point Strip Chart Recorder. The temperatures were maintained within the limits specified in Sections 3.3 and 3.4.

FIGURE 1

Chamber Cell Location During Characterization Testing



Top view Bemco Chamber showing top layer holding fixtures



Top view Bemco Chamber showing bottom layer holding fixtures

⊗ Indicates cells to which thermocouples were attached.

Cell Mounting Fixture	Cell Position	Cell S/N	Cell Mounting Fixture	Cell Position	Cell S/N
1	1	3015	5	1	2975
	2	3016		2	2999
	3	3017		3	3000
	4	3020		4	2979
	5	3021		5	2980
2	1	3022	6	1	3001
	2	3023		2	3002
	3	3025		3	2981
	4	2966		4	2983
	5	2969		5	3003
3	1	2992	7	1	3007
	2	2972		2	2987
	3	2973		3	2988
	4	2997		4	3013
	5	2998		5	3014
4	1	2974			

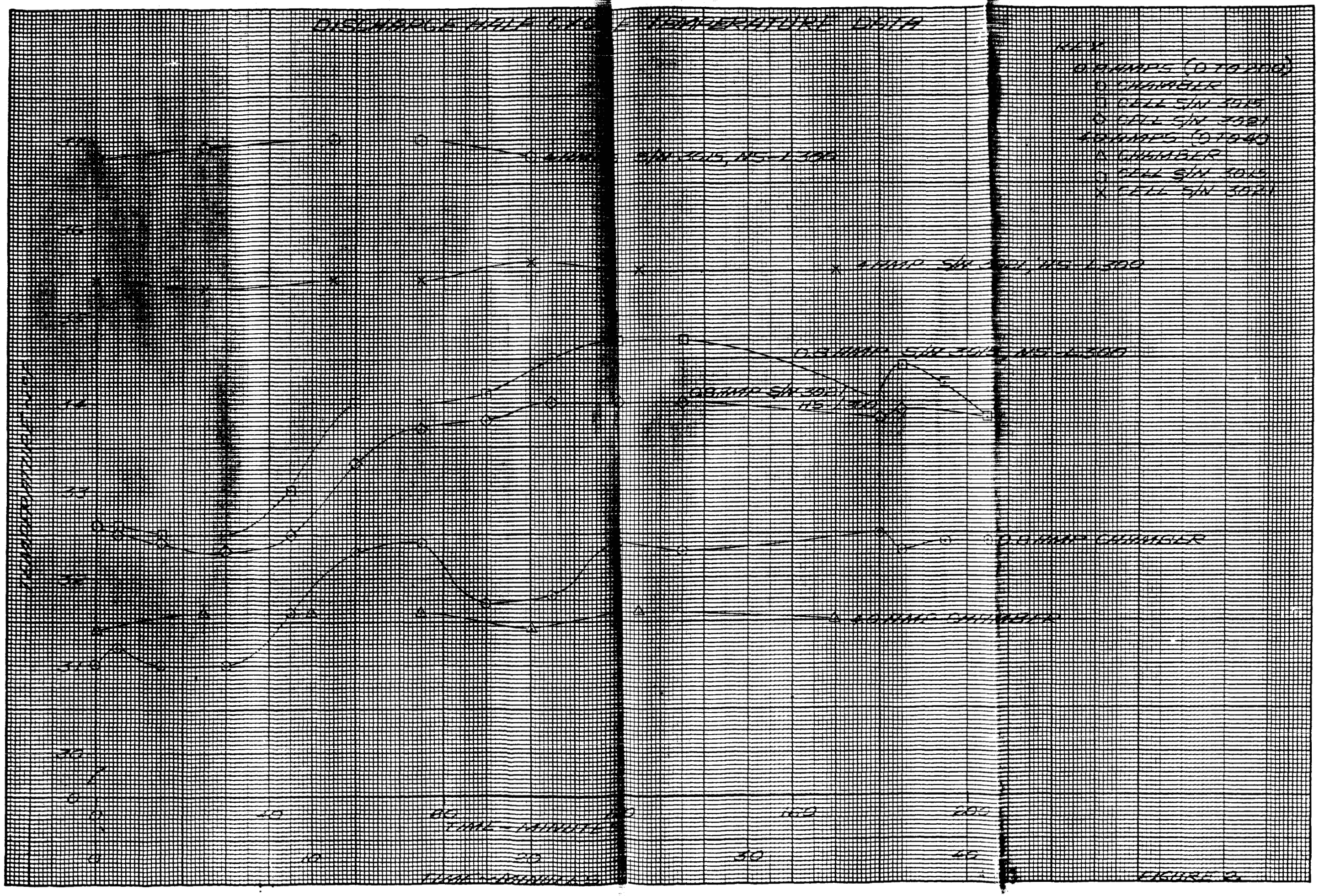

DISCHARGE HALF CYCLE TEMPERATURE DATA
KEY
0.8 AMPS (0 TO 200)
CHAMBER
CELL S/N 3015
CELL S/N 3021
4.0 AMPS (0 TO 40)
CHAMBER
CELL S/N 3015
CELL S/N 3021
4 AMP S/N 3015, NS-L300
4 AMP S/N 3021, NS-L300
0.8 AMP S/N 3015, NS-L300
0.8 AMP S/N 3021, NS-L300
0.8 AMP CHAMBER
4.0 AMP CHAMBER
TEMPERATURE
TIME - MINUTES
0
40
80
120
160
200
10
20
30
40

FIGURE 2

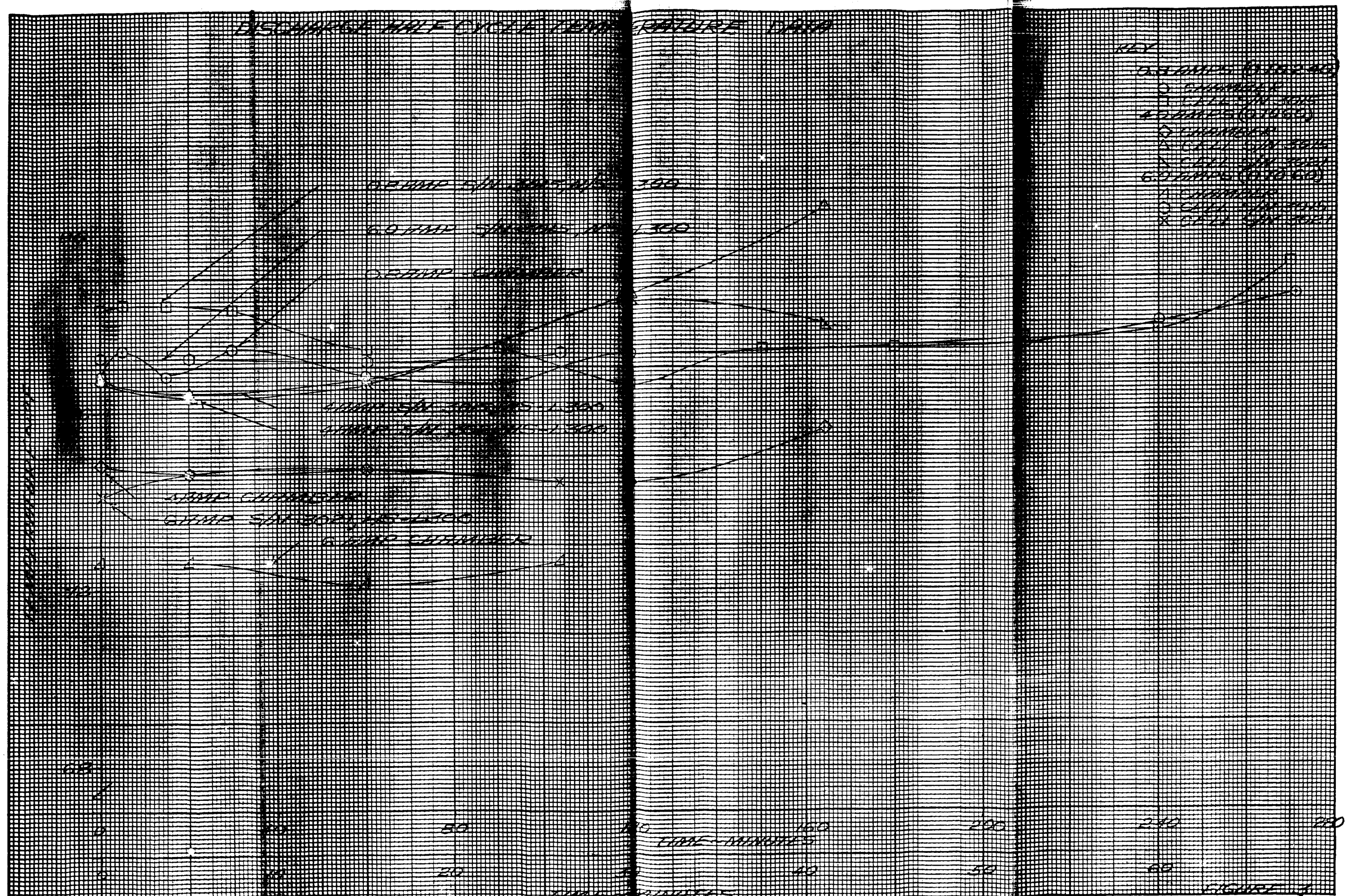

DISCHARGE HALF CYCLE TEMPERATURE DATA
KEY
0.8 AMPS (0 TO 240)
CHAMBER
CELL S/N 3015
4.0 AMPS (0 TO 60)
CHAMBER
CELL S/N 3015
CELL S/N 3021
6.0 AMPS (0 TO 60)
CHAMBER
CELL S/N 3015
CELL S/N 3021
0.8 AMP S/N 3015, N/S 1300
6.0 AMP S/N 3015, N/S 1300
0.8 AMP CHAMBER
4 AMP S/N 3015, N/S 1300
4 AMP S/N 3021, N/S 1300
4 AMP CHAMBER
6 AMP S/N 3021, N/S 1300
6 AMP CHAMBER
0
80
160
200
240
280
TIME ~ MINUTES
0
20
40
50
60
TIME ~ MINUTES

FIGURE 3

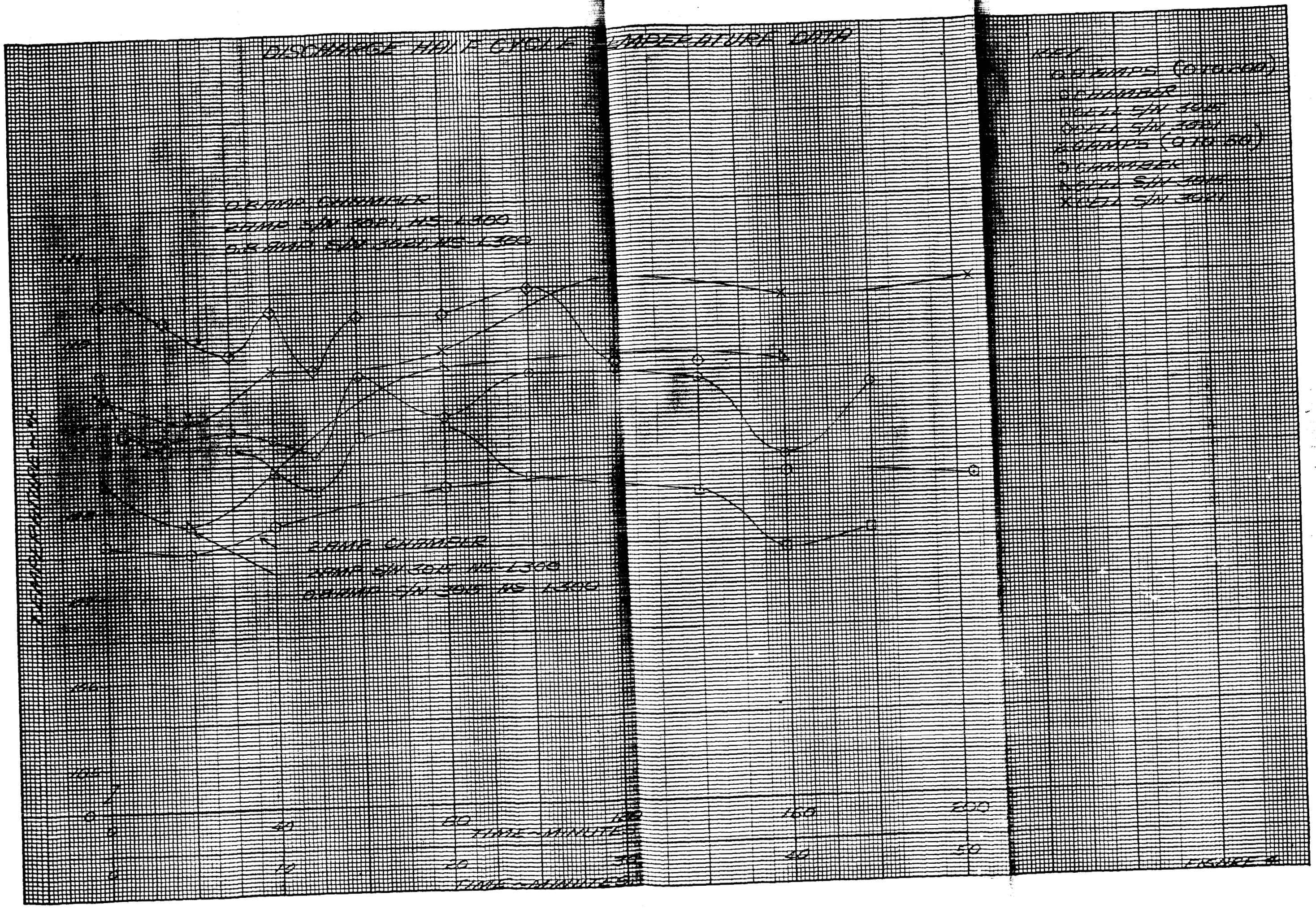

DISCHARGE HALF CYCLE TEMPERATURE DATA
0.8 AMP CHAMBER
2 AMP S/N 3021, NS-L300
0.8 AMP S/N 3021, NS-L300
2 AMP CHAMBER
2 AMP S/N 3015 NS-L300
0.8 AMP S/N 3015 NS-L300
TEMPERATURE
TIME ~ MINUTES
0
40
80
120
160
200
10
20
30
40
50
KEY
0.8 AMPS (0 TO 200)
CHAMBER
CELL S/N 3015
CELL S/N 3021
2 AMPS (0 TO 50)
CHAMBER
CELL S/N 3015
CELL S/N 3021

FIGURE 4

4.3 Characterization Cycle Testing

4.3.1 Test Procedure

As mentioned in Section 4.1, the test setup was identical to the one used in Phase I, life cycle testing, and the reader is referred to the Final Report of this Phase I for a detailed description of the setup. The test cells were on open circuit in the charged state for three months between Phase I and this test.

The cells were placed in the cell holding fixtures and then placed in a Bemco Environmental Chamber. The temperature of this chamber was controlled to a tolerance of $\pm$ 3.0°F as indicated by Figures 2, 3 and 4. These figures are a plot of temperature versus time for the various test temperatures and rates of discharge. The cells were series-connected to the automatic test console which provided programming of the charge-discharge sequence. Before beginning the programmed charge and discharge sequences, the test console was adjusted to the required test parameter accuracies as defined in Sections 3.3 and 3.4. The cycling test consisted of subjecting the cells to one charge/discharge cycle per day as per the test matrix of Table 1. As shown by the test matrix, when the test temperature was changed, the cells were placed on a twenty-four (24) hour open circuit stand just prior to making the change. Figure 5 is a plot of the open circuit voltage for the 24 hour period between cycles 23 and 24 (75°F). When the test temperature was changed, the cells remained on open circuit stand for 4 hours before resumption of cycling to allow the cells to reach the new temperature. Also, prior to starting a test sequence at a new temperature the voltage limit setting on the test console was changed to that specified in Section 3.3. The sixth (6th) cycle of the test sequence was a reconditioning cycle. Following the discharge to the voltage limit as specified in Section 3.4, the cells were shorted with a 1 ohm resistor for sixteen (16) hours. After the shorting, the test sequence as per matrix of Table 1 was continued. This reconditioning cycle was employed to attempt to erase any residual effects from Phase I life cycle testing. As shown by the test matrix, a ten-day open circuit stand was initiated at the termination of the discharge of the 65th cycle. The open circuit voltage of the cells was checked periodically during this open circuit stand, and the data are presented in Table 2. The end of charge voltage, voltage prior to charge, and the input and output capacity for each cell was measured for each cycle during the cell characterization test.

4.3.2 Cell Characterization Test Results and Discussion

A summary of the output capacities of the cells for each cycle is presented in Table 3. Table 4 is a summary log of the output capacities. In this table the output capacity data for the first and last cycle at each temperature discharge-current combination are given.

TABLE 1

CELL CHARACTERIZATION TEST MATRIX

Cycle No.	Temp. °F	Discharge Current (Amps.)	Discharge Voltage Limit (vdc)	Charge Current (Amps.)	Charge Voltage (a) Limit (vdc)
1 - 5	75	0.80	0.60	0.400	1.52
6 (b)	75	0.80	0.00	0.400	1.52
7 - 11	75	0.80	0.60	0.400	1.52
12 - 16	75	2.00	0.60	0.400	1.52
17 - 21	75	4.00	0.60	0.400	1.52
22 - 23	75	0.80	0.60	0.400	1.52
-	Open Circuit Stand 24 hours			-	
24 - 28	32	0.80	0.60	0.400	1.55
29 - 33	32	2.00	0.60	0.400	1.55
34 - 38	32	4.00	0.60	0.400	1.55
-	Open Circuit Stand 24 hours			-	
39 - 43	110	0.80	0.60	0.400	1.46
44 - 49	110	2.00	0.60	0.400	1.46
50 - 53	110	4.00	0.60	0.400	1.46
-	Open Circuit Stand 24 hours			-	
54 - 57	75	0.80	0.60	0.400	1.52
58 - 61	75	6.00	0.60	0.400	1.52
62 - 65	75	0.80	0.60	0.400	1.52
-	Open Circuit Stand 10 Days			-	
66 - 68	110	2.00	0.60	0.400	1.46

(a) Charge to voltage limit or fourteen (14) hours, whichever occurs first

(b) Recondition Cycle - Followed by a direct short for 16 hours.

TABLE 2

HEAT STERILIZABLE NICKEL-CADMIUM CELL CHARACTERIZATION TEST

Voltage Measurements on Ten Day Open Circuit Stand

Cell Serial No.	Code	Open Circuit Voltage 1st Day	2nd Day	5th Day	6th Day	7th Day	8th Day	10th Day
3015	NS-L300	1.334	1.290	1.285	1.285	1.285	1.285	1.278
3016	NS-L300	1.334	1.291	1.285	1.284	1.284	1.283	1.276
3017(a)	NS-L300	-	-	-	-	-	-	-
3020	NS-L300	1.336	1.290	1.286	1.286	1.285	1.285	1.279
3021	HS-L300	1.336	1.294	1.287	1.286	1.286	1.284	1.276
3022	HS-L300	1.340	1.286	1.278	1.278	1.277	1.276	(b)
3023	HS-L300	1.342	1.292	1.285	1.284	1.283	1.282	1.275
3025	HS-L300	1.338	1.290	1.283	1.281	1.281	1.281	1.274
2966	NS-F5-L295	1.336	1.289	1.286	1.285	1.285	1.285	1.278
2969	HS-F5-L295	1.336	1.287	1.281	1.280	1.279	1.279	1.274
2992	HS-05-L295	1.336	1.293	1.285	1.284	1.283	1.282	1.276
2972	NS-F42-L258	1.327	1.288	1.283	1.283	1.282	1.282	1.275
2973	HS-F42-L258	1.333	1.283	1.276	1.276	1.275	1.275	1.267
2997	NS-042-L258	1.330	1.290	1.286	1.285	1.286	1.286	1.278
2998	HS-042-L258	1.341	1.292	1.284	1.283	1.281	1.280	1.274
2974	NS-F75-L225	1.320	1.278	1.275	1.275	1.275	1.276	1.270
2975	HS-F75-L225	1.330	1.292	1.280	1.285	1.282	1.283	1.280
2999	NS-075-L225	1.333	1.293	1.287	1.290	1.287	1.286	1.285
3000	HS-075-L225	1.345	1.293	1.284	1.289	1.287	1.287	1.284
2979	NS-F117-L183	1.344	1.294	1.284	1.287	1.286	1.285	1.283
2980	HS-F117-L183	1.340	1.285	1.279	1.280	1.276	1.276	1.273
3001	NS-0117-L183	1.342	1.294	1.290	1.290	1.290	1.288	1.286
3002	HS-0117-L183	1.356	1.291	1.282	1.285	1.284	1.283	1.279
2981	NS-F170-L130	1.346	1.292	1.288	1.286	1.286	1.285	1.282
2983	HS-F170-L130	1.345	1.292	1.283	1.284	1.283	1.283	1.282
3003	NS-0170-L130	1.337	1.296	1.292	1.290	1.290	1.290	1.288
3007	HS-0170-L130	1.346	1.290	1.283	1.283	1.283	1.283	1.281
2987	NS-F300-L1	1.341	1.294	1.286	1.287	1.287	1.287	1.285
2988	HS-F300-L1	1.348	1.288	1.281	1.282	1.280	1.281	1.283
3013	NS-0300-L1	1.347	1.294	1.287	1.287	1.287	1.287	1.282
3014	HS-0300-L1	1.354	1.294	1.286	1.287	1.287	1.286	1.282

(a) Cell failed prior to ten day open circuit stand test

(b) No reading could be obtained, investigation showed a loose connection

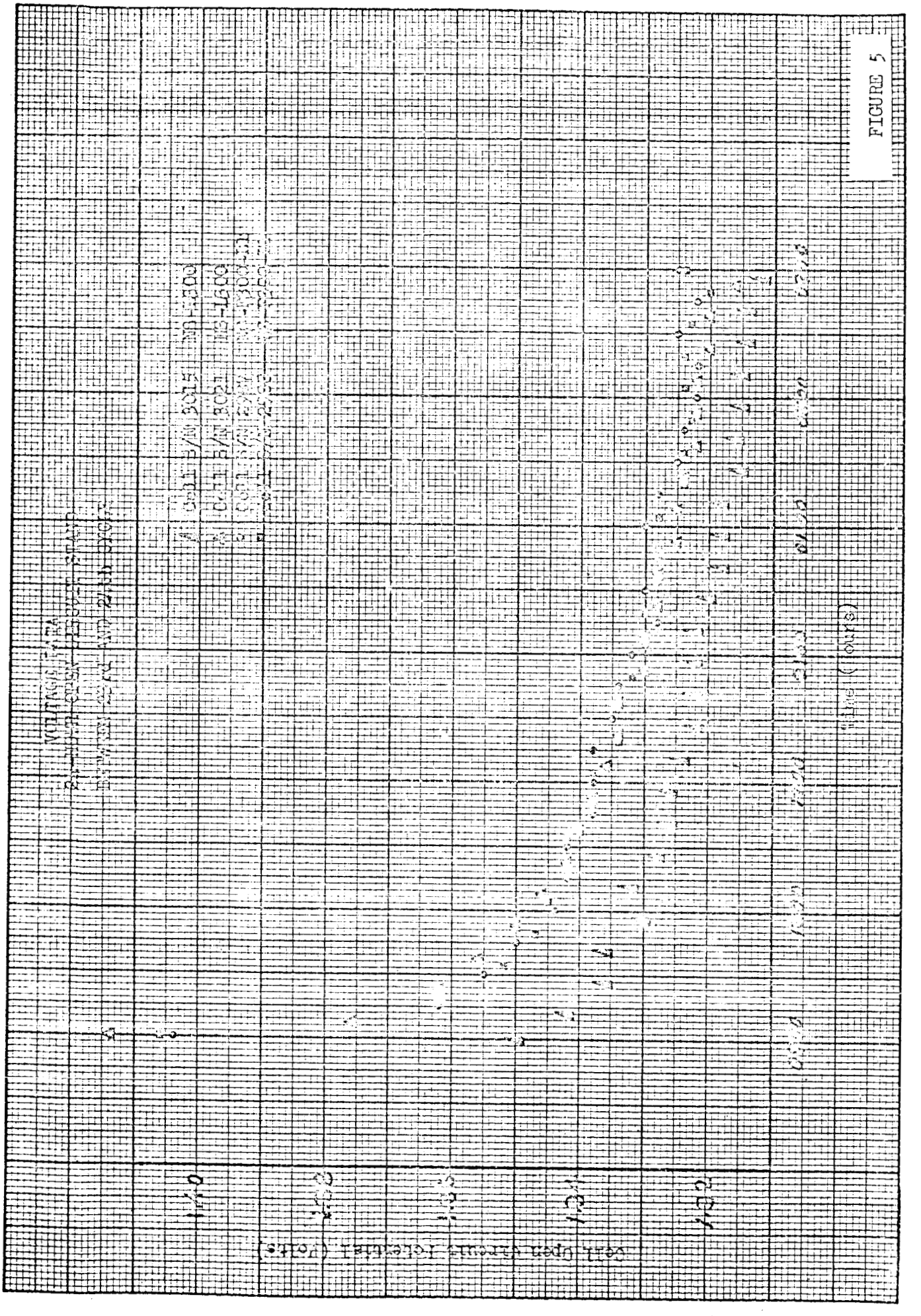


FIGURE 5

TABLE 3

HEAT STERILIZABLE NICKEL-CADMIUM CELL

CHARACTERIZATION TEST

Capacity Output Summary Table

Cell Serial No.	Pre-Sterilization Cycle 5	Output Capacity (ampere-Hours) Characterization Test Cycles: Cycle A.801	Cycle A.802	Cycle A.803	Cycle A.804	Cycle A.805	Cycle A.806	Cycle A.807
Control Cells (300-Day Life)								
3015	4.24	1.12	2.20	2.78	3.22	3.48		3.34
3016	4.29	3.06	2.84	3.16	3.24	3.26		3.61
3017	4.16	0.85	2.69	3.20	3.41	3.49		3.08
3020	4.23	2.68	2.57	2.74	2.89	2.94		3.38
Discharged Sterilized Cells (300-Day Life)								
3021	4.16	2.17	3.08	3.21	3.52	3.66		3.85
3022	3.55	0.73	2.30	2.81	3.14	3.25		3.36
3023	3.91	3.22	3.61	3.54	3.72	3.72		3.96
3025	4.28	2.36	3.12	3.32	3.65	3.76		3.81
Cells from Previous 5-Day Stand (295-Day Life)								
2966	4.11	1.46	2.89	3.08	3.08	3.05		3.01
2969	3.95	2.28	3.30	3.56	3.81	3.92		3.90
2992	4.12	3.37	3.49	3.50	3.62	3.64		3.84
Cells from Previous 42-Day Stand (258-Day Life)								
2972	4.19	1.42	2.69	3.00	3.42	3.68		3.70
2973	3.72	2.61	3.25	3.18	3.48	3.54		3.54
2997	3.99	1.18	2.58	3.22	3.58	3.82		3.57
2998	4.17	3.10	3.64	3.65	3.77	3.82		3.74
Cells from Previous 75-Day Stand (225-Day Life)								
2974	3.68	0.60	2.38	2.41	2.76	3.14	Recorder malfunction	3.29
2975	3.80	1.68	3.21	3.16	3.42	3.52		3.36
2999	3.93	0.05	3.09	3.18	3.45	3.53		3.68
3000	4.05	2.16	3.36	3.32	3.58	3.70		3.90
Cells from Previous 117-Day Stand (183-Day Life)								
2979	3.89	2.38	3.41	3.44	3.68	3.98		3.92
2980	4.00	0.05	3.02	3.14	3.41	3.48		3.58
3001	4.08	3.20	3.36	3.26	3.36	3.32		3.62
3002	3.93	3.00	4.00	3.57	3.76	3.80		3.97
Cells from Previous 170-Day Stand (130-Day Life)								
2981	4.09	2.69	3.72	3.68	3.84	3.89		3.98
2983	3.95	2.69	3.82	3.53	3.70	3.76		3.85
3003	4.05	0.81	3.16	3.45	3.81	3.61		3.34
3007	3.95	2.26	3.54	3.20	3.38	3.20		3.52
Cells from Previous 300-Day Stand (0-Day Life)								
2987	4.24	3.85	4.62	4.10	4.33	4.41		4.33
2988	4.09	2.70	3.56	3.00	3.16	3.18		3.32
3013	4.13	4.20	4.62	3.98	4.14	4.10	4.14	4.26
3014	4.19	3.90	4.66	4.00	4.14	4.12	4.16	4.13

HEAT STERILIZABLE NICKEL-CADMIUM CELL

CHARACTERIZATION TEST

Capacity Output Summary Table 3 (Continued)

Cell Serial No.	Characterization Test Cycles Capacity Output (ampere-hours)								
	Cycle A.808	Cycle A.809	Cycle A.810	Cycle A.811	Cycle A 212	Cycle A 213	Cycle A 214	Cycle A 215	Cycle A 216
Control Cells (300-Day Life)									
3015	3.56	1.40	3.52	3.54	3.13	3.23	3.20	3.16	3.20
3016	3.41	3.34	3.21	3.20	2.86	2.96	2.90	3.00	3.06
3017	2.80	2.54	2.13	1.61		0.60	0.53	0.56	0.80
3020	3.20	3.14	3.00	3.01	2.46	2.46	2.43	2.46	2.60
Discharged Sterilized Cells (300-Day Life)									
3021	3.78	3.77	3.68	3.69	3.26	3.33	3.33	3.33	3.40
3022	3.25	3.28	3.22	3.21	2.83	2.83	2.83	2.86	0.96
3023	2.93	3.86	3.72	3.74	3.10	3.06	3.06	3.10	3.13
3025	3.80	3.81	3.76	3.76	3.43	3.46	3.43	3.43	3.46
Cells from Previous 5-Day Stand (295-Day Life)									
2966	2.92	2.90	2.85	2.88	2.80	2.73	2.70	2.70	2.73
2969	3.97	3.92	3.85	3.88	3.56	3.60	3.60	3.56	3.63
2992	3.76	3.68	3.50	3.44	2.80	2.86	2.86	2.83	0.96
Cells from Previous 42-Day Stand (258-Day Life)									
2972	3.68	3.74	3.65	3.653	3.30	3.56	3.46	3.46	3.53
2973	3.49	3.54	3.46	3.520	3.33	3.40	3.40	3.36	3.43
2997	3.77	3.82	3.74	3.720	3.40	3.53	3.46	3.46	3.53
2998	3.89	3.85	3.73	3.733	3.43	3.53	3.46	3.46	3.50
Cells from Previous 75-Day Stand (225-Day Life)									
2974	3.14	3.60	3.08	3.08	2.43	2.63	2.56	2.50	0.46
2975	3.53	3.54	3.54	3.54	2.73	0.46	3.40	3.40	3.40
2999	3.54	3.53	3.48	3.42	3.00	2.96	3.03	3.03	3.06
3000	3.81	3.42	3.74	3.73	3.76	0.33	0.10	0.06	0.10
Cells from Previous 117-Day Stand (183-Day Life)									
2979	3.88	3.84	3.78	3.77	4.03	0.43	3.30	3.33	3.33
2980	3.53	3.54	3.52	3.52	4.06	3.16	3.30	3.30	3.30
3001	3.42	3.32	3.22	3.22	3.40	3.93	0.10	0.03	1.03
3002	3.85	3.81	3.78	3.77	4.40		3.50	3.53	0.10
Cells from Previous 170-Day Stand (130-Day Life)									
2981	3.94	3.86	3.82	3.77	4.06	3.13	3.26	3.33	3.30
2983	3.77	3.72	3.66	3.66	4.10	2.50	0.86	0.76	0.30
3003	3.30	3.85	3.89	3.90	4.43	1.10	3.60	3.60	3.60
3007	3.40	3.38	3.37	3.36	3.83	0.93	3.10	3.10	3.13
Cells from Previous 300-Day Stand (0-Day Life)									
2987	4.65	4.37	4.36	4.36	3.76	4.16	4.23	4.23	1.73
2988	3.30	3.32	3.30	3.29	4.03	3.26	3.26	3.26	3.26
3013	4.21	4.17	4.10	4.06	4.40	3.53	3.46	3.43	3.36
3014	3.21	4.00	3.93	3.92	4.40	3.60	3.56	3.53	3.50

HEAT STERILIZABLE NICKEL-CADMIUM TEST

CHARACTERIZATION TEST

Capacity Output Summary Table 3 (Continued)

Cell Serial No.	Characterization Test Cycles Capacity Output (ampere-hours)								
	Cycle A 417	Cycle A 418	Cycle A 419	Cycle A 420	Cycle A 421	Cycle A.822	Cycle A.823	Cycle* B.824	Cycle B.825
Control Cells (300-Day Life)									
3015	3.06	2.93	2.93	2.73	2.80	3.50	3.40	2.52	2.54
3016	3.06	3.06	3.13	3.26	3.33	3.97	3.98	2.62	2.88
3017	0.26	0.40	0.53	0.66	0.86	2.06	1.44	0.02	0.01
3020	2.33	2.40	2.40	2.46	2.60	3.26	3.45	0.38	
Discharged Sterilized Cells (300-Day Life)									
3021	3.26	3.20	3.20	3.20	3.26	3.78	3.84	2.92	3.06
3022	2.73	2.66	2.66	3.26	2.66	3.17	3.22	2.44	2.36
3023	3.00	3.00	3.00	3.06	3.13	3.89	3.94	2.54	2.84
3025	3.26	3.20	3.20	3.26	3.33	3.74	3.80	2.88	2.98
Cells from Previous 5-Day Stand (295-Day Life)									
2966	2.60	2.46	2.46	2.46	2.40	2.65	2.70	2.38	2.45
2969	3.46	3.46	3.33	3.46	3.46	3.94	3.96	3.02	3.29
2992	2.86	2.86	2.93	2.93	3.00	3.69	3.85	2.41	2.76
Cells from Previous 42-Day Stand (258-Day Life)									
2972	3.53	3.33	3.33	3.33	3.40	3.69	3.69	3.22	3.08
2973	3.46	3.40	3.33	3.33	3.33	3.52	3.57	3.02	3.24
2997	3.53	3.40	3.40	3.33	3.26	3.70	3.42	2.84	2.90
2998	3.53	3.46	3.53	3.46	3.33	3.96	3.96	2.58	3.14
Cells from Previous 75-Day Stand (225-Day Life)									
2974	2.26	2.20	2.13	2.00	2.13	2.57	3.01	2.13	1.85
2975	3.40	3.33	3.40	3.26	3.20	3.53	3.24	2.77	2.88
2999	2.80	2.73	0.26	0.06	2.66	3.28	3.49	2.28	0.54
3000	0.20	0.13	0.06	0.06	3.26	3.77	3.76	2.60	2.76
Cells from Previous 117-Day Stand (183-Day Life)									
2979	3.26	3.26	3.40	3.33	3.26	3.78	3.85	2.78	2.14
2980	3.26	3.20	0.53	0.13	3.20	3.50	3.53	2.89	2.80
3001	0.32	0.20	2.73	2.73	2.73	3.46	3.52	2.12	2.36
3002	3.40	3.33	3.33	3.33	3.33	3.82	3.85	2.74	3.12
Cells from Previous 170-Day Stand (130-Day Life)									
2981	3.46	3.40	0.66	0.86	3.40	3.89	3.90	2.66	2.70
2983	0.26	0.73	3.40	0.06	3.40	3.52	3.05	1.40	0.32
3003	3.46	3.40	3.46	3.33	3.40	3.80	3.68	2.76	2.46
3007	3.00	2.93	2.93	2.93	2.93	3.42	3.45	2.56	2.82
Cells from Previous 300-Day Stand (0-Day Life)									
2957	1.80	0.93	4.26	4.13	4.06	4.29	4.32	3.80	3.90
2988	3.26	3.20	3.20	3.20	3.13	3.34	3.36	2.81	2.97
3013	3.26	3.20	3.20	3.26	3.26	3.98	4.01	2.66	3.14
3014	3.46	3.40	3.40	3.46	3.46	3.85	3.88	2.76	3.16

*Temperature changed from 75° to 32°F.

HEAT STERILIZABLE NICKEL-CADMIUM TEST

CHARACTERIZATION TEST

Capacity Output Summary Table 3 (Continued)

Cell Serial No.	Characterization Test Cycles Capacity Output (ampere-Hours)								
	Cycle B.826	Cycle B.827	Cycle B.828	Cycle B.229	Cycle B 230	Cycle B 231	Cycle B 232	Cycle B 233	Cycle B 234
Control Cells (300-Day Life)									
3015	2.49	2.44	0.19	0.33	0.03	2.07	1.77	1.73	1.73
3016	2.81	2.82	2.55	2.23	2.50	2.57	2.27	2.27	2.30
3017	0.01	0.01	0.01	0.03	0.03	0.03	0.07	0.07	0.07
3020	2.45	2.45	2.35	2.03	2.07	2.07	1.90	1.87	1.83
Discharged Sterilized Cells (300-Day Life)									
3021	3.12	3.12	3.12	2.96	2.93	2.87	2.63	2.57	2.53
3022	2.21	2.11	1.88	3.40	1.60	1.63	1.47	1.47	1.50
3023	2.97	2.97	2.69	2.40	2.50	2.57	2.47	2.57	2.57
3025	3.08	3.03	2.75	2.40	2.53	2.50	2.20	2.23	2.23
Cells from Previous 5-Day Stand (295-Day Life)									
2966	2.45	2.40	2.31	2.13	2.17	2.13	2.03	2.00	2.03
2969	3.28	3.15	2.95	2.73	2.83	2.77	2.57	2.60	2.53
2992	2.82	2.89	2.41	2.10	2.17	2.07	2.30	2.30	2.27
Cells from Previous 42-Day Stand (258-Day Life)									
2972	2.98	2.85	2.61	2.27	2.33	2.37	2.27	2.27	2.23
2973	3.29	3.24	3.19	3.10	1.13	3.13	3.10	3.13	3.17
2997	2.88	2.89	2.56	2.30	2.30	2.10	2.10	2.10	2.03
2998	3.22	3.19	3.00	2.77	2.83	2.87	2.73	2.83	2.83
Cells from Previous 75-Day Stand (225-Day Life)									
2974	0.01	0.05	0.01	0.07	0.07	0.07	0.03	0.03	0.03
2975	2.81	2.83	2.71	2.57	2.56	2.50	2.40	2.37	2.37
2999	0.41	0.39	0.09	0.07	0.07	0.07	0.03	0.03	0.07
3000	2.78	2.88	2.77	2.50	2.55	2.23	2.47	2.47	2.47
Cells from Previous 117-Day Stand (183-Day Life)									
2979	1.78	1.71	1.57	1.20	1.53	1.47	1.07	1.17	1.10
2980	2.65	2.61	2.48	2.23	2.23	2.10	2.00	1.97	1.93
3001	2.33	2.39	2.11	1.77	2.00	2.03	1.97	2.00	2.00
3002	3.24	3.37	3.20	2.77	2.97	2.97	2.83	2.87	2.97
Cells from Previous 170-Day Stand (130-Day Life)									
2981	2.61	2.61	2.40	2.00	2.23	2.07	2.10	2.10	2.10
2983	0.21	0.23	0.23	0.37	2.50	1.27	2.47	2.53	2.57
3003	2.21	2.16	1.96	1.47	1.73	1.63	1.47	1.43	1.37
3007	2.70	2.67	2.37	2.00	2.20	2.17	2.20	2.17	2.20
Cells from Previous 300-Day Stand (0-Day Life)									
2987	3.85	3.85	3.77	1.53	1.57	1.57	1.47	3.47	3.43
2988	2.94	2.96	2.81	2.60	2.73	2.70	2.70	2.77	2.73
3013	3.22	3.31	3.13	2.63	2.67	2.67	2.70	2.70	2.63
3014	3.22	3.31	3.19	2.83	2.90	2.83	2.87	2.87	3.57

HEAT STERILIZABLE NICKEL-CADMIUM TEST

CHARACTERIZATION TEST

Capacity Output Summary Table 3 (Continued)

Cell Serial No.	Characterization Test Cycles Capacity Output (ampere-hours)								
	Cycle B 435	Cycle B 436	Cycle B 437	Cycle B 438	Cycle* C.839	Cycle C.840	Cycle C.841	Cycle C.842	Cycle C.843
Control Cells (300-Day Life)									
3015	1.33	1.13	1.20	1.20	2.24	2.25	2.03	1.96	1.88
3016	2.07	2.13	2.13	2.20	3.20	2.40	2.12	2.00	1.88
3017	0.07	0.07	0.13	0.07	----	----	----	----	----
3020	1.60	1.60	1.47	1.67	3.47	2.31	1.93	1.87	1.75
Discharged Sterilized Cells (300-Day Life)									
3021	2.33	2.27	2.20	2.27	3.05	3.52	2.39	2.23	2.11
3022	1.07	1.00	1.07	1.13	2.21	2.13	1.89	1.83	1.75
3023	2.27	2.27	2.27	2.40	3.44	2.51	2.21	2.11	1.99
3025	1.80	1.73	1.73	1.87	2.80	2.45	2.21	2.09	1.99
Cells from Previous 5-Day Stand (295-Day Life)									
2966	1.80	1.80	1.73	1.80	2.25	2.51	2.36	2.24	2.17
2969	2.40	2.27	2.27	2.33	3.04	2.77	2.45	2.25	2.19
2992	2.00	2.07	2.07	2.07	3.21	2.56	2.23	2.11	2.03
Cells from Previous 42-Day Stand (258-Day Life)									
2972	1.93	1.80	1.80	1.80	2.63	2.51	2.28	2.11	2.08
2973	3.00	2.93	2.87	3.00	3.25	2.75	2.41	2.21	2.09
2997	1.73	1.67	1.60	1.67	2.32	2.52	2.28	2.16	2.09
2998	2.53	2.60	2.60	2.67	3.99	3.17	2.79	2.61	2.45
Cells from Previous 75-Day Stand (225-Day Life)									
2974	0.13	0.07	0.13	0.13	0.07	2.16	2.00	1.91	1.87
2975	2.20	2.13	2.07	2.20	2.76	2.75	2.59	2.48	2.37
2999	0.13	0.13	0.07	0.13	1.19	2.13	1.84	1.76	1.68
3000	2.27	2.33	1.67	2.33	3.09	2.69	2.37	2.21	2.07
Cells from Previous 117-Day Stand (183-Day Life)									
2979	0.67	0.87	0.47	0.87	2.08	2.29	2.08	1.97	1.87
2980	1.67	1.73	1.67	1.73	2.44	2.39	2.13	1.97	1.87
3001	1.80	1.80	1.67	1.80	3.25	2.53	2.24	2.12	2.01
3002	2.67	2.60	2.47	2.73	3.63	2.91	2.48	2.32	2.16
Cells from Previous 170-Day Stand (130-Day Life)									
2981	1.87	1.87	1.87	1.87	2.92	2.68	2.37	2.23	2.11
2983	2.33	2.40	2.40	2.40	3.25	2.68	2.37	2.23	2.11
3003	1.00	1.00	0.93	0.93	2.24	2.59	2.39	2.28	2.23
3007	1.73	1.73	1.73	1.73	2.84	2.53	2.29	2.13	2.03
Cells from Previous 300-Day Stand (0-Day Life)									
2987	3.20	3.13	3.13	3.07	3.68	3.28	3.03	2.88	2.81
2988	2.53	2.53	2.47	2.60	3.03	2.71	2.48	2.33	2.24
3013	2.40	2.40	2.47	2.40	4.16	3.36	3.01	2.81	2.65
3014	2.40	2.27	2.27	2.27	3.85	3.55	3.24	3.04	2.80

*Temperature changed from 32° to 110°F.

HEAT STERILIZABLE NICKEL-CADMIUM CELL
CHARACTERIZATION TEST

Capacity Output Summary Table 3 (Continued)

Cell Serial No.	Characterization Test Cycles Capacity Output (ampere-hours)								
	Cycle C 244	Cycle C 245	Cycle C 246	Cycle C 247	Cycle C 248	Cycle C 449	Cycle C 450	Cycle C 451	Cycle C 452
Control Cells (300-Day Life)									
3015	1.63	1.57	1.57	1.53	1.50	1.27	1.40	1.40	1.33
3016	1.73	1.63	1.67	1.63	1.60	1.53	1.53	1.53	1.53
3017	----	----	----	----	----	----	----	----	----
3020	1.87	1.50	1.53	1.53	1.53	1.47	1.47	1.47	1.53
Discharged Sterilized Cells (300-Day Life)									
3021	1.90	1.83	1.73	1.80	1.73	1.53	1.53	1.53	1.47
3022	1.73	1.40	1.43	1.43	1.40	1.20	1.27	1.20	1.27
3023	1.80	1.63	1.57	1.60	1.57	1.53	1.47	1.47	1.47
3025	2.10	1.73	1.73	1.70	1.70	1.53	1.53	1.53	1.47
Cells from Previous 5-Day Stand (295-Day Life)									
2966	2.00	1.97	1.93	2.00	1.93	1.73	1.80	1.80	1.80
2969	1.77	1.90	1.87	1.87	1.87	1.73	1.73	1.73	1.73
2992	1.93	1.70	1.70	1.67	1.67	1.53	1.60	1.60	1.53
Cells from Previous 42-Day Stand (258-Day Life)									
2972	1.87	1.87	1.87	1.87	1.83	1.67	1.73	1.73	1.67
2973	1.90	1.83	1.77	1.80	1.73	1.60	1.60	1.60	1.60
2997	2.20	1.70	1.70	1.77	1.77	1.53	1.60	1.60	1.53
2998	1.63	2.07	2.00	1.97	1.97	1.87	1.93	1.93	1.93
Cells from Previous 75-Day Stand (225-Day Life)									
2974	-----	1.60	1.60	1.60	0.95	1.33	1.40	1.40	
2975	2.16	2.03	1.97	1.90	1.87	1.60	1.60	1.60	1.60
2999	1.43	1.40	1.43	1.43	0.73	1.20	1.20	1.27	1.20
3000	1.90	1.83	1.83	1.80	1.73	1.53	1.60	1.60	1.53
Cells from Previous 117-Day Stand (183-Day Life)									
2979	1.63	1.57	1.57	1.50	1.53	1.33	1.33	1.33	1.33
2980	1.70	1.63	1.60	1.57	1.57	1.33	1.33	1.33	1.33
3001	1.90	1.80	1.77	1.70	1.70	1.67	1.67	1.67	1.53
3002	2.00	2.00	1.97	1.90	1.93	1.80	1.80	1.80	1.80
Cells from Previous 170-Day Stand (130-Day Life)									
2981	1.90	1.87	1.80	1.77	1.77	1.67	1.67	1.67	1.60
2983	1.87	1.83	1.80	1.77	1.77	1.67	1.67	1.67	1.67
3003	2.07	2.03	2.00	1.97	1.97	1.80	1.80	1.80	1.80
3007	1.87	1.83	1.80	1.77	1.73	1.60	1.80	1.60	1.60
Cells from Previous 300-Day Stand (0-Day Life)									
2987	2.67	2.60	2.57	2.53	2.50	2.33	2.40	2.33	2.33
2988	2.03	2.00	1.97	1.93	1.97	1.80	1.80	1.80	1.80
3013	2.33	2.23	2.17	2.10	2.07	1.87	1.93	1.93	1.93
3014	2.43	2.33	2.23	2.20	2.17	2.07	2.07	2.07	2.07

HEAT STERILIZABLE NICKEL-CADMIUM CELL

CHARACTERIZATION TEST

Capacity Output Summary Table 3 (Continued)

Cell Serial No.	Characterization Test Cycles Capacity Output (ampere-hours)								
	Cycle C 453	Cycle* D.854	Cycle D.855	Cycle D.856	Cycle D.857	Cycle D 658	Cycle D 659	Cycle D 660	Cycle D 661
Control Cells (300-Day Life)									
3015	1.33	1.33	3.33	3.55	3.52	3.20	2.70	2.60	2.60
3016	1.47	1.24	3.71	3.99	3.88	3.80	3.30	3.30	3.40
3017	---	---	---	---	---	---	---	---	---
3020	1.53	1.15	3.37	0.107	---	1.00	0.20	0.20	3.00
Discharged Sterilized Cells (300-Day Life)									
3021	1.53	1.25	3.35	3.24	3.12	2.90	2.20	2.20	2.20
3022	1.20	1.11	3.08	3.19	3.16	3.00	2.40	2.60	2.40
3023	1.47	1.21	3.56	3.81	3.84	3.80	3.20	3.20	3.20
3025	1.47	1.35	3.44	3.64	3.67	3.50	3.00	3.00	3.00
Cells from Previous 5-Day Stand (295-Day Life)									
2966	1.80	1.59	2.76	2.75	2.67	2.80	2.10	2.20	2.20
2969	1.73	1.35	3.60	3.75	3.68	3.70	3.30	3.30	3.30
2992	1.53	1.36	3.23	3.52	3.57	3.60	2.90	3.00	3.00
Cells from Previous 42-Day Stand (258-Day Life)									
2972	1.67	1.57	3.60	3.83	3.83	3.90	3.20	3.20	3.20
2973	1.67	1.36	3.36	3.51	3.49	3.40	3.20	3.20	3.20
2997	1.53	1.41	2.96	2.88	2.77	2.81	2.20	2.20	2.20
2998	1.93	1.40	3.88	3.95	3.83	3.90	3.40	3.60	3.60
Cells from Previous 75-Day Stand (225-Day Life)									
2974	1.40	1.41	3.11	3.17	3.19	3.20	2.40	2.50	2.40
2975	1.60	1.20	3.40	3.15	2.92	3.00	2.50	2.40	3.00
2999	1.20	1.11	0.89	0.88	0.92	0.60	2.60	2.60	2.60
3000	1.53	1.35	3.47	3.64	3.67	3.50	3.10	3.10	3.20
Cells from Previous 117-Day Stand (183-Day Life)									
2979	1.33	1.15	3.51	3.83	3.85	3.80	3.20	3.30	3.30
2980	1.33	1.03	3.19	3.36	3.39	3.60	3.10	3.10	3.10
3001	1.53	1.31	3.61	3.88	3.81	3.60	3.00	3.10	3.10
3002	1.73	1.40	3.79	3.88	3.87	3.80	3.10	3.30	3.30
Cells from Previous 170-Day Stand (130-Day Life)									
2981	1.53	1.27	3.75	3.99	3.97	4.10	3.40	3.50	3.50
2983	1.67	1.32	3.48	3.64	3.36	3.80	3.30	3.40	3.40
3003	1.80	1.56	3.43	3.24	2.99	2.70	3.00	3.00	3.00
3007	1.60	1.41	3.28	3.37	3.36	3.30	2.80	2.90	2.90
Cells from Previous 300-Day Stand (0-Day Life)									
2987	2.33	2.11	4.08	4.23	4.25	4.40	3.90	3.90	3.90
2988	1.80	1.57	3.25	3.43	3.37	3.60	3.10	3.10	3.00
3013	1.93	1.65	3.72	3.91	3.88	3.80	3.30	3.20	3.20
3014	2.13	1.65	3.63	3.80	3.75	3.60	3.20	3.20	3.20

*Temperature changed from 110° to 75°F.

HEAT STERILIZABLE NICKEL-CADMIUM CELL

CHARACTERIZATION TEST
Capacity Output Summary Table 3 (Continued)

Cell Serial No.	Characterization Test Cycles Capacity Output (Ampere-Hours)							
	Cycle D.862	Cycle D.863	Cycle D.864	Cycle D.865	Cycle E 266 (b)	Cycle E 267	Cycle E 268	Cycle E 269
Control Cells (300-Day Life)								
3015	3.49	3.63	3.56	3.53	2.83	2.13	1.90	1.80
3016	3.95	4.12	4.05	3.97	3.10	2.13	1.90	1.77
3017	---	---	---	---	---	---	---	---
3020	3.57	3.91	3.88	3.89	3.17	1.97	1.77	1.67
Discharged Sterilized Cells (300-Day Life)								
3021	2.95	3.04	3.05	3.04	2.23	2.40	2.03	1.93
3022	3.17	3.23	3.24	3.25	---	---	---	1.87
3023	3.85	3.99	4.01	4.01	3.30	2.20	1.97	1.93
3025	3.76	3.77	3.80	3.83	2.60 (a)	2.30	2.00	2.03
Cells from Previous 5-Day Stand (259-Day Life)								
2966	2.51	2.60	2.61	2.81	2.20	2.27	2.10	2.13
2969	3.96	4.04	4.04	4.03	3.27	2.57	2.23	1.80
2992	3.45	3.75	3.76	3.79	2.70	2.17	1.90	1.97
Cells from Previous 42-Day Stand (258-Day Life)								
2972	3.64	3.52	3.52	3.55	2.67	2.27	2.03	1.93
2973	3.55	2.66	3.67	3.64	2.93	2.43	2.13	1.87
2997	2.65	3.67	2.67	2.75	2.00	2.27	2.00	1.77
2998	4.15	4.19	4.12	4.08	3.43	2.83	2.40	2.27
Cells from Previous 75-Day Stand (255-Day Life)								
2974	2.99	3.25	3.32	3.33	2.47	2.07	1.87	1.80
2975	2.99	3.16	3.05	2.99	2.10	2.50	2.23	2.10
2999	2.99	3.53	3.56	3.59	2.30 (a)	2.07	1.83	1.67
3000	2.99	3.81	3.83	3.85	2.90	2.50	2.20	2.10
Cells from Previous 117-Day Stand (183-Day Life)								
2979	2.99	3.96	3.96	3.99	2.93	2.27	1.97	1.83
2980	2.99	3.53	3.55	3.57	1.83	2.23	1.97	1.80
3001	2.99	3.96	3.93	3.91	2.65 (a)	2.27	2.00	1.87
3002	2.99	3.99	3.97	4.00	3.10	2.67	2.30	2.17
Cells from Previous 170-Day Stand (130-Day Life)								
2981	2.99	4.05	3.99	4.01	3.10	2.47	2.17	2.03
2983	2.99	3.79	3.79	3.81	2.70	2.47	2.13	2.00
3003	2.99	3.47	3.40	3.28	2.27	2.37	2.17	2.07
3007	2.99	3.45	3.44	3.45	2.50	2.33	2.07	2.00
Cells from Previous 300-Day Stand (0-Day Life)								
2987	2.99	4.08	4.03	4.01	3.10	2.83	2.63	2.53
2988	2.99	3.43	3.44	3.45	2.73 (a)	2.50	2.30	2.17
3013	2.99	4.16	4.13	4.15	3.23	2.73	2.40	2.23
3014	2.99	4.07	4.04	4.03	3.20	2.93	2.63	2.50

(a) Estimated values from charts, estimated value within ± 0.07 ampere-hours of actual value.

(b) Temperature changed from 75° to 110°F.

Inspection of the data of Table 4 for the first discharge cycle shows that 81 percent of the cells which had been sterilized in Phase I testing had higher capacities than comparable cells which had not been sterilized. The capacities of the sterilized cells showing higher values ranged from 0.9 percent to 41 percent higher with an average of 17 percent. This phenomena was also observed to a much greater degree at the termination of Phase I. At the termination of Phase I, 73 percent of sterilized cells had higher capacities than comparable cells which had not been sterilized. The capacities ranged from 1.3 percent to 136 percent higher with an average of 51 percent. Further inspection of Table 4 shows that the cycle sequence used in the Phase III testing reduced or tended to reverse this phenomena. At the conclusion of Phase III, only 45 percent of the sterilized cells showed a higher capacity than comparable cells which had not been sterilized. For the sterilized cells showing higher capacities, the range was from 12 percent to 28 percent with an average of 20 percent. It is possible the reconditioning cycle performed during the 6th cycle of the electrical performance investigation contributed to the temporary reduction or reversal of the phenomena noted at the termination of Phase I and initiation of Phase III.

Since the temperature and discharge rate of Phase I testing was the same as that used for the first eleven (11) cycles of the characterization testing, a comparison of the output capacities for the last discharge half cycle of Phase I with the first discharge half cycle of the characterization (Phase III) testing is presented in Table 5. In Phase I, the discharge half-cycle was performed immediately after each corresponding charge half-cycle. The first discharge half-cycle for Phase III characterization testing was performed fifty-two (52) days after the associated charge half-cycle, which was performed at the termination of Phase I testing. The data of Table 5 shows, in general, a decrease in discharge capacity for those cells placed on open circuit stand for fifty-two (52) days in the charged state. Several cells showed a very slight increase in capacity on standing, which could possibly be the result of the particular cells accepting a larger charge on the final charge half-cycle than they had during the previous charge cycles of Phase I testing. Two cells, S/N 2966 and 3017, showed decreases of 1.88 and 2.42 ampere-hours respectively. Note that one of the cells, S/N 3017, which showed a sizeable decrease (2.42 ampere-hours) in capacity on open circuit stand, failed at approximately the thirtieth (30th) cycle. This cell apparently had a high internal impedance as it would reach end of charge voltage immediately when placed on charge.

The end of charge voltage, input capacity and output capacity versus cycle number for each cell are shown graphically in Figures 6 through 36. In these graphs, a minimum of two cycles are plotted for each temperature-discharge rate combination. This data shows that the input capacities increased as the temperature increased. The output capacities for a given discharge rate is low at 32°F, increases to a maximum at 75°F, then falls off again at 110°F. The low input and output capacities at 32°F are typical for nickel-cadmium cells.

TABLE 4

Summary Log Output Capacities

S/N	Code	Discharge Half-Cycle	2nd	5th	7th	11th	12th	16th	17th	21st	22nd	23rd	24th	28th	29th	33rd	34th	38th	39th	43rd	44th	49th	50th	53rd	54th	57th	58th	61st	62nd	65th	66th	69th
			75°F										32°F						110°F						75°F							110°F
			0.800 amp				2.0 amp		4.00 amp	0.800 amp			0.800 amp		2.00 amp		4.00 amp		0.800 amp		2.00 amp	4.00 amp			0.800 amp		6.00 amp		0.800 amp		2.00 amp
3015	NS-L300	1.12	2.20	3.48	3.35	3.55	3.13	3.20	3.07	2.80	3.51	3.40	2.52	0.19	0.33	1.73	1.73	1.20	2.04	1.88	1.63	1.27	1.40	1.33	1.33	3.52	3.20	2.60	3.49	3.53	2.83	1.80
3016	NS-L300	3.07	2.84	3.27	3.61	3.20	2.87	3.07	3.07	3.33	2.97	3.99	2.63	2.55	2.23	2.27	2.26	2.20	3.20	1.88	1.73	1.53	1.53	1.47	1.24	3.88	3.80	3.40	3.95	3.97	3.10	1.77
3017	NS-L300	0.85	2.69	3.49	3.08	1.61	---	0.80	0.27	0.87	2.07	1.44	0.03	0.01	0.03	0.07	0.07	0.07	---	---	---	---	---	---	---	---	---	---	---	---	---	---
3020	NS-L300	2.68	2.57	2.95	3.39	3.01	2.47	2.60	2.33	2.60	3.27	3.45	---	2.35	2.03	1.87	1.87	1.67	3.47	1.75	1.87	1.47	1.47	1.53	1.15	L.C.	1.00	3.00	3.57	3.89	3.17	1.67
3021	HS-L300	2.17	3.08	3.67	3.85	3.69	3.27	3.40	3.27	3.27	3.79	3.84	2.92	3.12	2.97	2.57	2.57	2.27	3.05	2.11	1.50	1.53	1.53	1.53	1.25	3.12	2.89	2.20	2.95	3.04	2.23	1.93
3022	HS-L300	0.73	2.31	3.25	3.36	3.21	2.83	2.97	2.73	2.67	3.17	3.23	2.44	1.88	1.40	1.47	1.47	1.13	2.21	1.75	1.73	1.20	1.27	1.20	1.11	3.16	3.00	2.40	3.17	3.25	---	1.87
3023	HS-L300	3.23	3.61	3.72	3.96	3.75	3.10	3.13	3.00	3.1[illegible]	3.89	3.95	2.55	2.69	2.40	2.57	2.57	2.40	3.44	1.99	1.80	1.53	1.47	1.47	1.21	3.84	3.80	3.20	3.85	4.01	3.30	1.93
3025	HS-L300	2.36	3.12	3.76	3.81	3.76	3.43	3.47	3.27	3.33	3.75	3.80	2.88	2.75	2.46	2.23	2.23	1.8[illegible]	2.80	1.99	2.10	1.53	1.53	1.47	1.35	3.67	3.50	3.00	3.76	3.83	2.60*	2.03
2966	NS-F5-L295	1.47	2.89	3.05	3.01	2.88	2.80	2.73	2.60	2.40	2.65	2.71	2.39	2.31	2.13	2.00	2.00	1.80	2.25	2.17	2.00	1.73	1.80	1.80	1.59	2.67	2.80	2.20	2.51	2.81	2.20	2.13
2969	HS-F5-L295	2.28	3.31	3.92	3.91	3.88	3.57	3.63	3.47	3.47	3.95	3.96	3.03	2.95	2.73	2.60	2.60	2.33	2.04	2.19	1.77	1.73	1.73	1.73	1.35	3.68	3.70	3.30	3.96	4.03	3.27	1.80
2992	HS-05-L295	1.43	3.49	3.6[illegible]	3.84	3.44	2.80	2.97	2.87	3.00	3.69	3.85	2.41	2.41	2.10	2.30	2.30	2.07	3.21	2.03	1.93	1.53	1.60	1.53	1.36	3.57	3.60	3.00	3.45	3.79	2.70	1.97
2972	NS-F42-L258	2.61	2.69	3.68	3.71	3.65	3.30	3.53	3.53	3.40	3.69	3.89	3.23	2.61	2.27	2.27	2.27	1.80	2.63	3.08	1.87	1.67	1.73	1.67	1.57	3.83	3.90	3.20	3.64	3.55	2.67	1.93
2973	HS-F42-L258	0.60	3.25	3.55	3.51	3.52	3.33	3.43	3.47	3.33	3.52	3.57	3.03	3.19	3.10	3.13	3.13	3.00	3.25	2.09	1.90	1.60	1.60	1.67	1.36	3.49	3.40	3.20	3.55	3.64	2.93	1.87
2997	NS-042-L258	1.68	2.58	3.83	3.57	3.72	3.40	3.53	3.53	3.27	3.71	3.43	2.84	2.56	2.30	2.10	2.10	1.67	2.32	2.09	2.20	1.53	1.60	1.53	1.41	2.77	2.80	2.20	2.65	2.75	2.00	1.77*
2998	HS-042-L258	2.39	3.64	3.83	3.75	3.73	3.43	3.50	3.53	3.33	3.96	3.96	2.59	3.00	2.77	2.83	2.83	2.67	3.99	2.45	1.63	1.87	1.93	1.93	1.40	3.83	3.90	3.60	4.15	4.08	3.43	2.27
2974	NS-F75-L225	0.05	2.39	3.15	3.29	3.08	2.43	2.47	2.27	2.13	2.57	3.01	2.13	0.01	0.07	0.03	0.03	0.13	0.67	1.87	---	1.33	1.40	1.40	1.41	3.19	3.20	2.40	2.99	3.33	2.47	1.80
2975	HS-F75-L225	2.69	3.21	3.52	3.36	3.55	2.73	3.40	3.40	3.20	3.53	3.24	2.77	2.73	2.57	2.37	2.37	2.20	2.76	2.37	2.17	1.60	1.60	1.60	1.20	2.92	3.00	3.00	↑	2.99	2.10	2.10
2999	NS-075-L225	2.69	3.09	3.53	3.68	3.42	3.00	3.07	2.80	2.67	3.28	3.49	2.28	0.29	0.07	0.03	0.03	0.13	1.19	1.68	1.43	1.20	1.20	1.20	1.11	0.92	0.60	2.60		3.59	2.30*	1.67
3000	HS-075-L225	3.85	3.36	3.71	3.91	3.73	3.77	0.10	0.20	3.27	3.77	3.76	2.60	2.80	2.50	2.47	2.47	2.33	3.09	2.07	1.90	1.5[illegible]	1.60	1.53	1.35	3.67	3.50	3.20		3.85	2.90	2.10
2979	NS-F117-L183	2.71	3.41	3.99	3.92	3.77	4.03	3.33	3.27	3.27	3.79	3.85	2.79	1.57	1.20	1.17	1.17	0.87	2.08	1.87	1.63	1.33	1.33	1.33	1.15	3.85	3.80	3.30		3.99	2.93	1.83
2980	HS-F117-L183	3.37	3.03	3.48	3.59	3.52	4.07	3.30	3.27	3.20	3.51	3.53	2.89	2.48	2.23	1.97	1.97	1.73	2.44	1.87	1.70	1.33	1.33	1.33	1.03	3.39	3.60	3.10		3.57	1.83	1.80
3001	NS-0117-L183	1.19	3.36	3.32	3.63	3.23	3.40	1.03	0.32	2.73	3.47	3.52	2.12	2.11	1.76	2.00	2.00	1.80	3.25	2.01	1.90	1.67	1.67	1.53	1.31	3.81	3.60	3.10		3.91	2.63*	1.87
3002	HS-0117-L183	3.11	4.00	3.80	3.97	3.77	4.40	0.10	3.40	3.33	3.83	3.85	2.75	3.20	2.77	2.87	2.87	2.73	3.63	2.16	2.00	1.80	1.80	1.73	1.40	3.87	3.80	3.30		4.00	3.10	2.17
2981	NS-F170-L130	0.05	3.72	3.89	3.99	3.77	4.07	3.30	3.47	3.40	3.89	3.91	2.67	2.40	2.00	2.10	2.10	1.87	2.92	2.10	1.90	1.67	1.67	1.53	1.27	3.97	4.10	3.50		4.01	3.10	2.03
2983	HS-F170-L130	2.16	3.83	3.76	3.85	3.67	4.10	0.30	0.27	3.40	3.52	3.05	1.40	0.23	0.37	2.53	2.53	2.40	3.25	2.11	1.87	1.67	1.67	1.67	1.32	3.63	3.80	3.40		3.81	2.70	2.00
3003	NS-0170-L130	3.20	3.16	3.61	3.35	3.91	4.43	3.60	3.47	3.40	3.80	3.69	2.76	1.96	1.47	1.43	1.43	0.93	2.24	2.23	2.07	1.80	1.80	1.80	1.56	2.99	2.70	3.00		3.28	2.27	2.07
3007	HS-0170-L130	3.00	3.55	3.20	3.52	3.36	3.83	3.13	3.00	2.93	3.43	3.45	2.56	2.37	2.00	2.17	2.16	1.73	2.84	2.03	1.87	1.60	1.60	1.60	1.41	3.36	3.30	2.90		3.45	2.50	2.00
2987	NS-F300-L1	0.81	4.63	4.41	4.33	4.36	3.76	1.73	1.80	4.07	4.29	4.32	3.80	3.77	3.53	3.47	3.47	3.07	3.68	2.81	2.67	2.33	2.40	2.33	2.11	4.25	4.40	3.90		4.01	3.10	2.53
2988	HS-F300-L1	2.27	3.56	3.19	3.32	3.29	4.03	3.27	3.27	3.13	3.35	3.36	2.81	2.81	2.60	2.77	2.77	2.60	3.03	2.24	2.03	1.80	1.80	1.80	1.57	3.37	3.60	3.00		3.45	2.73*	2.17
3013	NS-0300-L1	4.20	4.63	4.11	4.27	4.07	4.40	3.37	3.27	3.27	3.99	4.01	2.67	3.13	2.63	2.70	2.70	2.40	4.16	2.65	2.33	1.87	1.93	1.93	1.65	3.88	3.80	3.20		4.15	3.23	2.23
3014	HS-0300-L1	3.91	4.67	4.12	4.13	3.92	4.40	3.50	3.47	3.47	3.85	3.88	2.76	3.19	4.83	2.87	2.87	2.27	3.85	2.80	2.43	2.07	2.07	2.13	1.65	3.75	3.60	3.20		4.03	3.20	2.50

Bristol Malfunction

Reconditioning Cycle

24-hr. open circuit stand

24-hr. open circuit stand

24 hr. open circuit stand

10-day open circuit stand

*Values estimated from charts, estimated value within ± 0.07 ampere-hours of actual value.

TABLE 5

Comparison of Final Output Capacity Phase I with

Initial Output Capacity Characterization Testing*

S/N	Code	Phase I Output Capacity Amp. Hrs.	Characterization Test Output Capacity Amp. Hrs.	ΔC **	% Change
3015	NS-L300	1.71	1.12	-0.59	-34.5
3016	NS-L300	3.04	3.06	+0.02	+00.7
3017	NS-L300	3.27	0.85	-2.42	-74.0
3020	NS-L300	2.83	2.68	-0.15	- 5.3
3021	HS-L300	2.75	2.17	-0.58	-21.1
3022	HS-L300	1.56	0.73	-0.73	-46.8
3023	HS-L300	3.53	3.23	-0.30	- 8.5
3025	HS-L300	3.03	2.36	-0.67	-22.1
2966	NS-F5-L295	2.35	1.47	-1.88	-80.0
2969	HS-F5-L295	2.97	2.28	-0.69	-23.2
2992	HS-05-L295	3.45	2.37	-0.08	- 2.3
2972	NS-F42-L258	2.03	1.43	-0.60	-29.6
2973	HS-F42-L258	3.15	2.61	-0.54	-17.1
2997	NS-042-L258	1.80	1.18	-0.62	-34.4
2998	HS-042-L258	3.04	3.11	+0.07	- 2.3
2974	NS-F75-L225	1.07	0.60	-0.47	-43.9
2975	HS-F75-L225	2.36	1.68	-0.68	-28.8
2999	NS-075-L225	0.95	0.05	-0.90	-94.7
3000	HS-075-L225	2.49	2.16	-0.33	-13.3
2979	NS-F117-L183	3.00	2.39	-0.61	-20.3
2980	HS-F117-L183	1.88	0.05	-1.83	-97.3
3001	NS-0117-L183	3.00	3.20	+0.20	+ 6.6
3002	HS-0117-L183	3.44	3.00	-0.44	-12.8
2981	NS-F170-L130	3.04	2.69	-0.35	-11.5
2983	HS-F170-L130	3.16	2.69	-0.47	-14.9
3003	NS-0170-L130	1.65	0.81	-0.84	-50.9
3007	HS-0170-L130	2.71	2.27	-0.44	-16.2
2987	NS-F300-L1	4.45	3.85	-0.60	-13.5
2988	HS-F300-L1	3.27	2.71	-0.56	-17.1
3013	NS-0300-L1	4.19	4.20	+0.01	+00.2
3014	HS-0300-L1	3.91	3.70	-0.21	- 5.4

* The cells were on open circuit charge stand for 3 months between Phase I and Phase III testing.

** Change in input capacity between last discharge half cycle of Phase I and the first discharge half cycle of characterization testing (- sign denotes decrease and - size denotes an increase).

The high input and low output capacity observed at 110°F is also normal for nickel-cadmium cells, as is the observed decrease in output capacity at a given temperature as the discharge rate is decreased. This effect is more noticeable at 32°F and 110°F.

In Phase I testing, the output capacity reflected the behavior of the input capacity: that is, if a low input capacity was observed, a corresponding low output capacity resulted and vice-versa. The previous statement refers only to cells of Phase I which were used in Phase III testing. Also in Phase I testing, both the input and output capacities remained fairly constant after the 50th cycle. The initial capacities of Phase III testing which were at the same temperature and rates (75°F, 400 ma charge half cycle and 800 ma discharge half cycle) are in general comparable to those observed at the termination of Phase III. Inspection of Figures 6 through 36, and the data presented in Table 3 show that the final capacities at 75°F, 400 ma charge and 800 ma discharge (cycle 54 through 57, and 62 through 65) of same of the cells exhibit both lower input and output when compared to the initial capacities at the same temperature and rates of Phase III testing. In addition, these final capacities are erratic, in that, in some cases high input capacities resulted in low output capacities, and low input capacities resulted in approximately equivalent output capacities. The cells which showed a notable reduction in both input and output capacities during Phase III testing are presented in Table 6. The initial capacities of Phase III testing (cycles 1 through 11) were compared with the final capacities at the same temperature and rates (cycles 54 through 57 and cycles 62 through 65). The data presented in Table 6 are average values.

The average reduction in input capacities of the cells presented in Table 6 was 23.3 percent while the average reduction for the output capacities resulting from the Phase III test parameters was 15.5 percent.

Although all the cells experienced relatively low input and output capacities during Phase III testing at 32°F, several cells exhibited exceptionally low input and output capacities. These cells are presented below:

1) S/N 3015 (NS-L300) - Figure 6
2) S/N 2974 (NS-F75-L225) - Figure 21
3) S/N 2999 (NS-075-L225) - Figure 23
4) S/N 2983 (HS-F170-L130) - Figure 30

TABLE 6

REDUCTION OF INPUT AND OUTPUT CAPACITY

Cell S/N	Code	Reference Figure	Input Capacity Initial AH	Input Capacity Final AH	% Input Redunction %	Output Capacity Initial AH	Output Capacity Final AH	% Output Redunction %
3020	NS-L300	9	5.60	5.20	- 7.1	2.99	2.50	-16.4
3021	HS-L300	10	5.60	4.05	-27.7	3.58	3.00	-16.2
2966	NS-F5-L295	14	3.73	3.24	- 8.8	2.96	2.66	-10.1
2997	NS-042-L258	19	5.60	3.46	-38.2	3.54	2.82	-20.4
2975	HS-F75-L225	22	5.60	3.46	-38.2	3.18	2.98	- 6.5
2999	NS-075-L225	23	5.60	3.40	-39.3	3.43	2.04	-40.5
3003	NS-0170-L130	31	4.95	3.96	-17.7	3.59	3.10	-13.7
2987	NS-F300-L1	33	5.60	5.09	- 9.1	4.39	3.98	- 9.3

The negligible input capacities observed at 32°F for the above cells resulted from the end of charge voltage being reached shortly after the initiation of the charge half cycle, indicating a rather high resistive path within the cells. However, this resistive path was transitory in nature, in that, it disappeared after several cycles at 32°F or when the test temperature was increased.

During the first 24 cycles, Cell S/N 3017 (NS-L300 - Figure 9) showed an average input capacity of about 5.6 ampere hours which is identical with the input capacity observed at the termination of Phase I. The output capacity of this cell during the first 24 cycles was very erratic, varying from approximately 3.1 ampere hours to 0.25 ampere hours with an average (from Figure 8) of about 1.61 ampere hours. This cell at the termination of Phase I testing exhibited a rather constant output capacity of approximately 3.5 ampere hours. The average output capacity of this cell during the first 24 cycles was 54 percent less than the average output capacity observed at the termination of Phase I. After the 24th cycle, the cell would not accept a charge. The cell would reach end of charge voltage immediately when placed on charge.

Seventh-five percent (75%) of the cells which exhibited erratic capacity during Phase III testing had not been subjected to heat sterilization. This tends to confirm one observation of Phase I testing that sterilized cells show a greater degree of stability than unsterilized cells. Thus, within the test conditions of Phase I and III, indications are that sterilization imparts some degree of stabilization. In addition, Phase III testing showed that for any given temperature-discharge rate combination, the output capacity was higher for cells which had been subjected to sterilization. Figures 37 and 38 show the variance of output capacity for sterilized and nonsterilized cells with temperature and discharge rate respectively. The output capacities given in the Figures 37 and 38 are the average values for the cycles shown. The cycles chosen for this presentation were the final cycles at the specific temperature and discharge rate.

Figures 39 through 50 show more dramatically the effect of decreased capacity at a given temperature as the discharge rate is increased. The data in these graphs show the discharge voltage versus time at constant temperature for the various discharge rates. The graphs show the discharge curves to the end of discharge voltage as specified in Section 3.3. The last cycle performed at the specific temperature-discharge rate combination was used in making the plot. Four cells were chosen for the presentation of this data based on their typical output capacities at the termination of the characterization testing and the number of cycles performed on each during Phase I testing. The four cells and their Phase I history used in making these graphs are presented below:

Serial Number	Phase I History
3015	No sterilization, life cycles 300 days
3021	No sterilization, life cycles 300 days
3987	No sterilization, float charged 300 days, 1 cycle
2988	Heat sterilized, float charged 300 days 1 cycle

The above four cells were also used for the graphic presentation of the effect of temperature at constant discharge rate, Figures 51 through 62. Here again, the effect of low capacities at 32°F increasing to a maximum at 75°F, then falling off again at 110°F is shown.

The ten (10) day open circuit stand voltages presented in Table 4 show that all cells had about the same open circuit voltage at the beginning, and very little decrease was observed during the ten day stand.

Figure 63 presents voltage data for a typical 24 hour cycle. Cell S/N 3021 was used for the presentation of this data. The data shown was taken from the 10th cycle which was at 75°F with a 400 ma charge half cycle and a 800 ma discharge half cycle. The data shows voltage data for one complete cycle, including the voltages for the charge half cycle, discharge half cycle and open circuit stand.

Figure 64 shows the variation of temperature of the test chamber, cell S/N 3015, and cell 3021 (these cells were temperature monitored with thermocouples) for a charge half-cycle at 32°F, 75°F and 110°F. The cycles used for this presentation are the final cycle performed at the specific temperature. Figures 2, 3 and 4 present similar data for the various discharge rates.

5.0 POST CHARACTERIZATION TEST

The cells used in this test were leak checked, weighed and dimensionally measured at the termination of Phase I and since the cells had been essentially inactive, having been on open circuit stand between Phase I and Phase III, these measurements were not repeated upon initiation of Phase III. However, these tests were made at the termination of Phase III.

5.1 Mechanical Tests

5.1.1 Visual Inspection

At the termination of this Phase (III) the thirty-one (31) cells under test were visually inspected for evidence of leaks, case bulge due to pressure build-up and any other defects. This inspection revealed no changes in cell appearance from the previous inspection made at the termination of Phase I.

5.1.2 Cell Weight

The weight of each cell was measured on a Sartorius single pan balance, Type 2432, at the termination of this Phase (III). The weight measurements of each cell, as measured at the termination of Phase I and this phase (III) are recorded in Table 8. As can be seen from the data, except for cell having S/N 2966, there was little change in weight between the Phase I and Phase III weights as measured. Cell having S/N 2966 showed a weight loss of 0.57 grams, seven (7) cells showed a weight loss of 0.01 gram, two (2) cells showed a weight loss of 0.04 gram, and twenty (20)cells showed no weight loss. If water is assumed to be responsible for any loss in weight, a loss in excess of 0.1 gram is considered significant as the original weight of electrolyte solution is assumed to be 13 grams.

5.1.3 Cell Dimensions

Cell dimensions were measured at the termination of this phase (III). The accuracy of the measurements was $\pm$ 0.001 inch. The data are shown in Table 8. Also, presented in Table 8 for comparison purposes are the measurements made at the termination of the life cycle test of Phase I. The slight differences between the two sets of data are believed to be due to non-uniformity of cell cases and the points of measurements rather than from effect of the tests performed.

5.1.4 Alkali Leak Test

The cells were tested for electrolyte leakage around the ceramic to metal seal and around the weld areas at termination of Phase III. The cells were checked with the following chemical indicator solution, which produces a red stain in the presence of alkalinity.

TABLE 7

CELL WEIGHTS BEFORE AND AFTER TESTING

Cell Serial No.	Cell Weight (Grams) Post-Life Cycle [a]	Post-Characterization	ΔW [b]	% Change
2966	165.90	165.33	-0.57	-0.35
2969	164.70	164.69	-0.01	~ -0.01
2972	169.20	169.20	0.00	0.00
2973	166.66	166.66	0.00	0.00
2974	164.53	164.53	0.00	0.00
2975	163.52	163.52	0.00	0.00
2979	165.22	165.22	0.00	0.00
2980	166.96	166.96	-0.04	~ -0.02
2981	166.61	166.61	0.00	0.00
2983	166.24	166.24	0.00	0.00
2987	167.51	167.51	0.00	0.00
2988	168.35	168.35	0.00	0.00
2992	164.97	164.97	0.00	0.00
2997	170.00	170.00	0.00	0.00
2998	170.20	170.20	0.00	0.00
2999	163.59	163.58	-0.01	~ -0.01
3000	164.13	164.13	0.00	0.00
3001	165.64	165.63	-0.01	~ -0.01
3002	167.18	167.18	0.00	0.00
3003	165.48	165.48	0.00	0.00
3007	166.62	166.62	0.00	0.00
3013	166.68	166.68	0.00	0.00
3014	167.00	166.99	-0.01	~ -0.01
3015	164.56	164.52	-0.04	~ -0.02
3016	166.05	166.05	0.00	0.00
3017	168.42	168.42	0.00	0.00
3020	167.21	167.20	-0.01	0.01
3021	165.32	165.32	0.00	0.00
3022	166.44	166.43	-0.01	0.01
3023	167.92	167.91	-0.01	0.01
3025	168.37	168.36	-0.01	0.01

(a) Cell weight measured at termination of Phase I testing.

(b) Difference in weight between post cycle and post characterization; negative sign denotes a loss of weight.

TABLE 8

HEAT STERILIZABLE NICKEL-CADMIUM CELL CHARACTERIZATION TEST

Cell Dimensions (Post Life Cycle Test - Post Characterization)

Test Equipment:

Veriner Caliper - - Luflkin No. 701 ± 0.001 inch accuracy
Height Gage -- Brown and Sharp No. 587 ± 0.001 inch accuracy

a - diameter of cell
c - top of ceramic to high point of base

Cell Serial No.	Cell Dimensions (Inches) Post Life Cycle a	Post Life Cycle c	Post Characterization a	Post Characterization c
2966	1.306	2.558	1.306	2.550
2969	1.305	2.570	1.305	2.571
2972	1.306	2.559	1.308	2.560
2973	1.307	2.553	1.306	2.553
2974	1.305	2.541	1.305	2.544
2975	1.308	2.565	1.305	2.570
2979	1.305	2.564	1.305	2.565
2980	1.305	2.553	1.305	2.555
2981	1.306	2.552	1.306	2.555
2983	1.305	2.568	1.301	2.569
2987	1.304	2.554	1.305	2.556
2988	1.308	2.562	1.306	2.567
2992	1.306	2.573	1.308	2.572
2993	1.308	2.554	1.305	2.557
2998	1.305	2.564	1.304	2.571
2999	1.305	2.551	1.304	2.553
3000	1.304	2.556	1.306	2.556
3001	1.305	2.564	1.304	2.559
3002	1.303	2.574	1.302	2.570
3003	1.307	2.568	1.310	2.572
3007	1.304	2.556	1.306	2.556
3013	1.306	2.584	1.302	2.586
3014	1.304	2.557	1.300	2.561
3015	1.305	2.553	1.306	2.555
3016	1.306	2.558	1.306	2.561
3017	1.304	2.552	1.305	2.553
3020	1.306	2.556	1.307	2.560
3021	1.304	2.557	1.305	2.557
3022	1.306	2.557	1.300	2.559
3023	1.308	2.560	1.309	2.560
3025	1.305	2.567	1.302	2.565

Indicator Solution

0.5 gram phenophthalein
250 cc of 96 percent ethyl alcohol
20 cc distilled water

There was no evidence of alkalinity on any of the cells which had been subjected to the Phase III characterization testing.

6.0 CONCLUSIONS

The end of charge voltage-temperature-discharge rate combinations used in the cell characterization test program resulted in altering the cell output capacities from that observed at the termination of Phase I testing. At the termination of Phase I testing, approximately 73 percent of the sterilized cells showed a higher output capacity than comparable cells which had not been sterilized. The capacities of the sterilized cells ranged from 1.3 percent to 163 percent higher with an average of 51 percent. At the start of Phase III (Characterization Test Program), the output capacities were similar to those observed at the termination of Phase I. At the start of Phase III, approximately 83 percent of the sterilized cells had a higher capacity than comparable cells which had not been sterilized. The capacities of the sterilized cells ranged from 0.9 percent to 41 percent higher with an average of about 17 percent, which is lower than that observed at the termination of Phase I testing. At the termination of Phase III, only 45 percent of the sterilized cells showed higher capacity than comparable cells which had not been sterilized. The capacities of the sterilized cells ranged from 12 percent to 28 percent higher with an average of 20 percent. The reduction from approximately 80 percent at the start of Phase III testing to about 45 percent at the termination of Phase III of sterilized cells showing higher capacities than comparable nonsterilized cells could have resulted from either the test parameters of temperature and discharge rates used in Phase III testing, or possibly from the cell reconditioning performed during the 6th cycle.

Cell S/N 3017 failed during the electrical performance investigation test program. The cell would not accept a charge in that it would reach end of charge voltage immediately upon being placed on charge, indicating a high internal impedance. It is doubtful that the cycle sequence of temperature and discharge rate variation used in this testing was the primary cause of failure. This cell has been selected for failure analysis to attempt to determine the cause of failure.

Input capacity was found to increase as the temperature increased. Output capacity was low at 32°F, was at maximum at 75°F, and low again at 110°F. The average output capacity of the cells at 0.800 ampere discharge rate was 2.23 ampere hours at 32°F (cycle 27), 3.51 ampere hours at 75°F (cycle 10) and 2.07 ampere hours at 110°F (cycle 42).

An increase in the discharge rate at a given temperature tended to reduce the output capacity.

In general, the appearance and physical integrity of the cells remained unchanged during the cell characterization test program, indicating no physical damage was caused by the cycle sequence of varying temperature and discharge rates.

Several cells exhibited negligible input and output capacities during 32°F testing. These cells would reach end of charge voltage immediately when placed on charge indicating a high internal impedance. However, this high impedance was transitory in nature as it returned to normal either after several cycles at 32°F or when the temperature was raised to the 110°F test temperature.

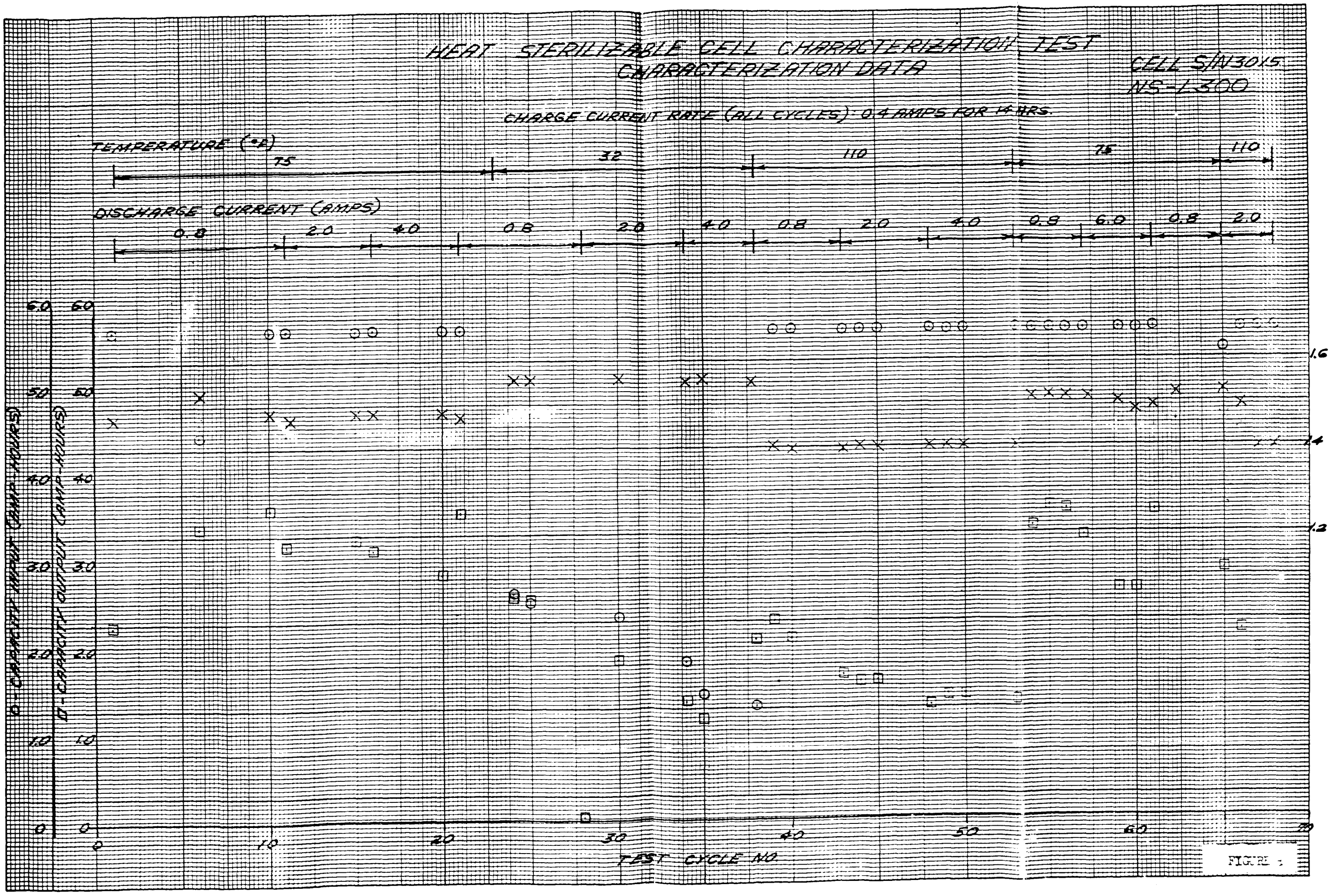

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 3015
NS-L300
CHARGE CURRENT RATE (ALL CYCLES) 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
□ - CAPACITY OUTPUT (AMP-HOURS)
6.0
60
5.0
50
4.0
40
3.0
2.0
2.0
1.0
1.0
0
0
0
10
20
30
40
50
60
70
TEST CYCLE NO.
END OF CHG VOLT.
1.6
1.4
1.2

FIGURE 1

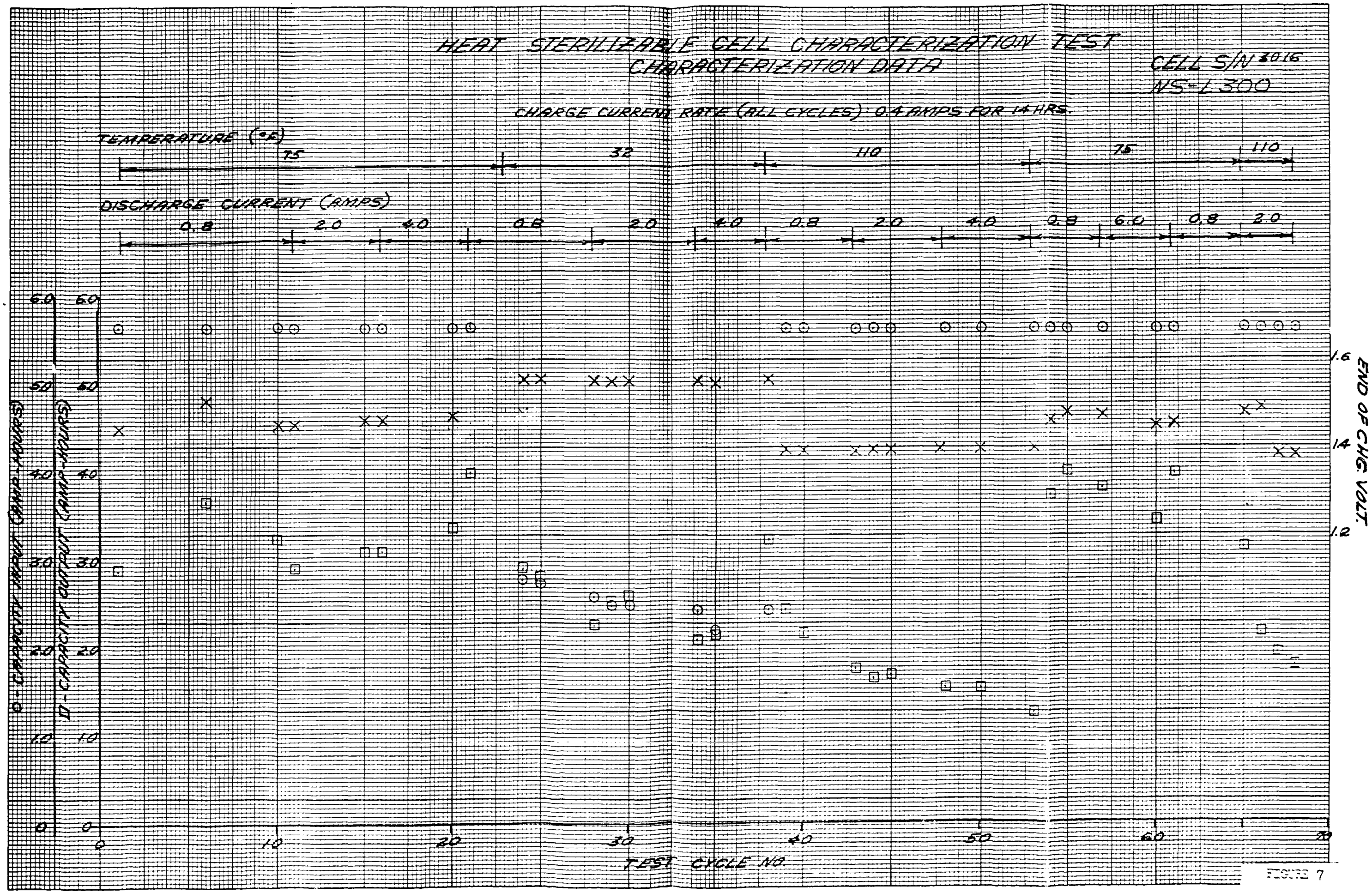

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 3016
NS-L300
CHARGE CURRENT RATE (ALL CYCLES) 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOUR)
□ - CAPACITY OUTPUT (AMP-HOUR)
6.0
5.0
4.0
3.0
2.0
1.0
0
60
50
40
30
20
10
0
1.6
1.4
1.2
END OF CHG. VOLT.
10
20
30
40
50
60
70
TEST CYCLE NO.

FIGURE 7

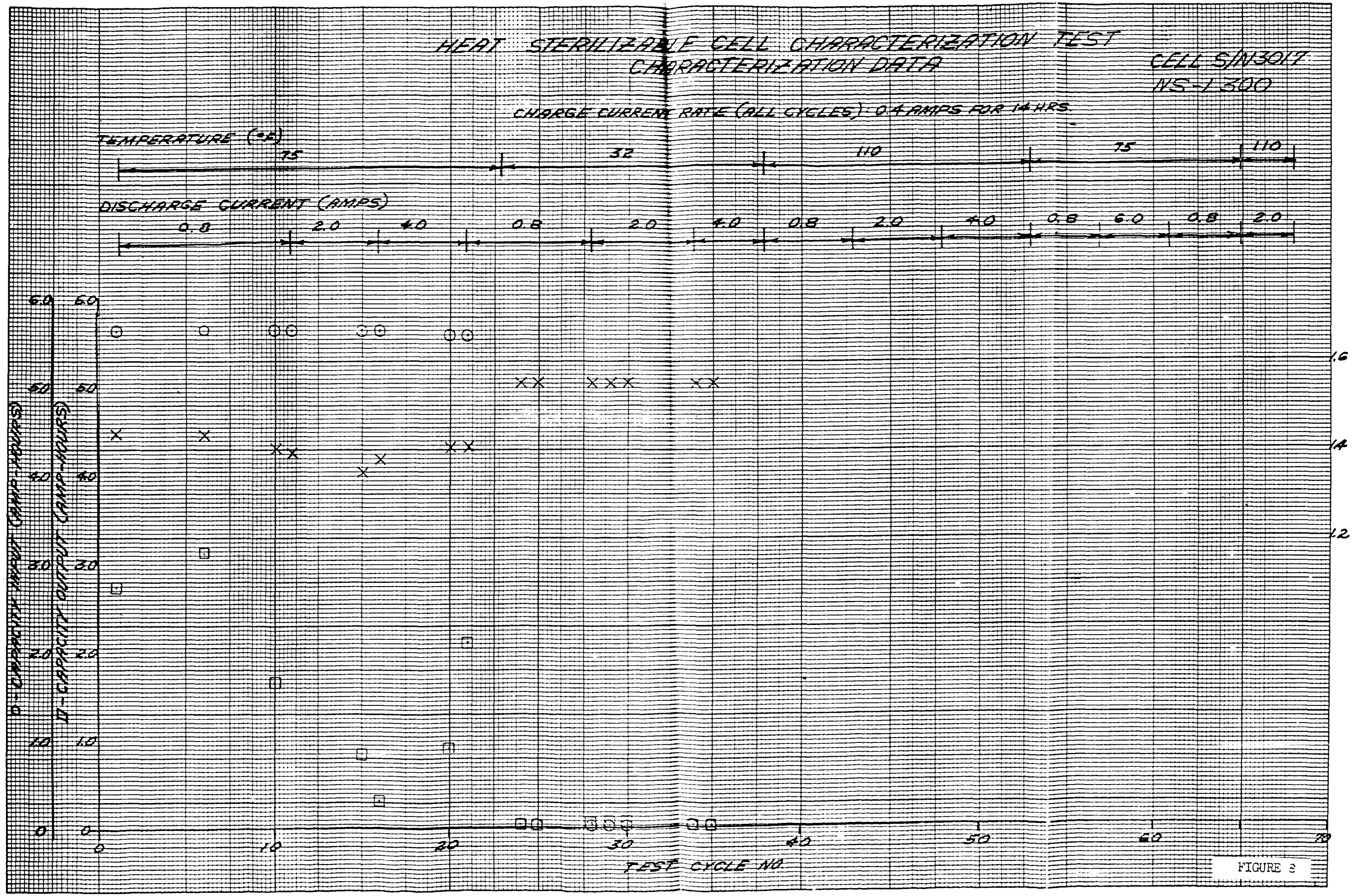

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N3017
NS-1300
CHARGE CURRENT RATE (ALL CYCLES) - 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
X - CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
1.6
1.4
1.2
END OF CHG VOLT.
0
10
20
30
40
50
60
70
TEST CYCLE NO.

FIGURE 3

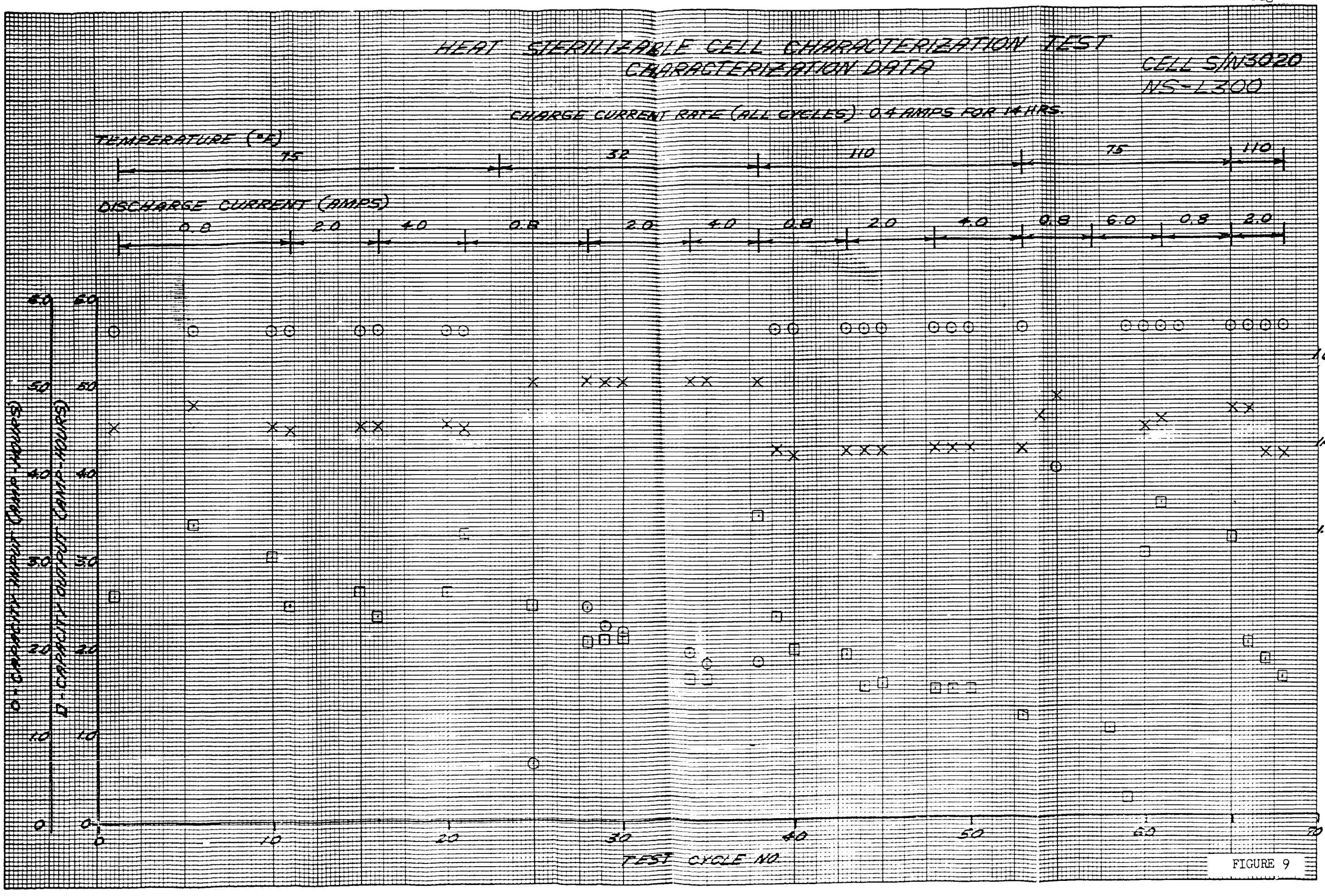

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N3020
NS-L300
CHARGE CURRENT RATE (ALL CYCLES) 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
□ - CAPACITY OUTPUT (AMP-HOURS)
END OF CHG VOLT.
TEST CYCLE NO.
0
10
20
30
40
50
60
70
1.2
1.4
1.6

FIGURE 9

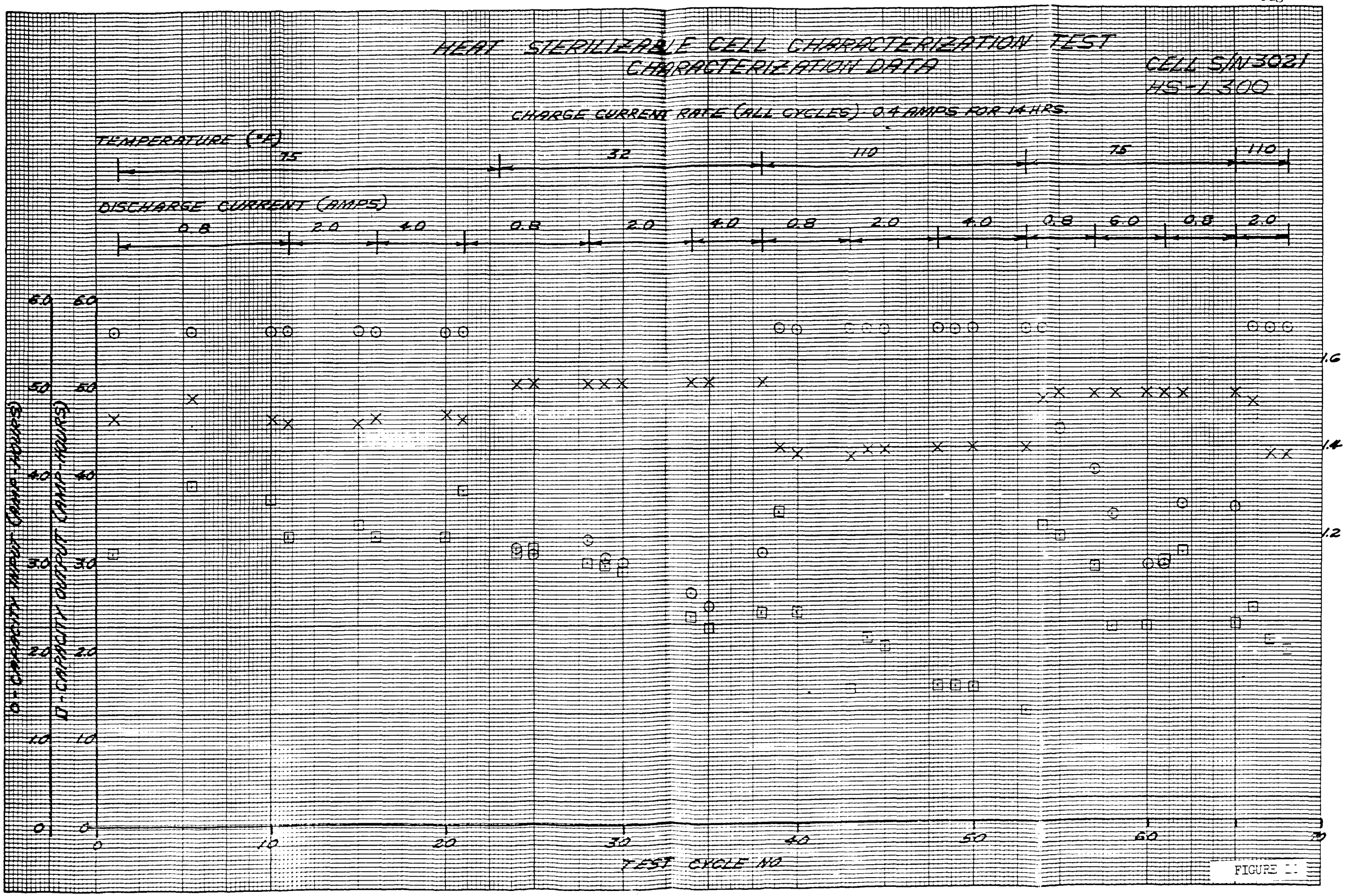

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 3021
HS-L300
CHARGE CURRENT RATE (ALL CYCLES) 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
X - CAPACITY OUTPUT (AMP-HOURS)
END OF CHG. VOLT.
TEST CYCLE NO
0
10
20
30
40
50
60
70
1.0
2.0
3.0
4.0
5.0
6.0
1.2
1.4
1.6

FIGURE 11

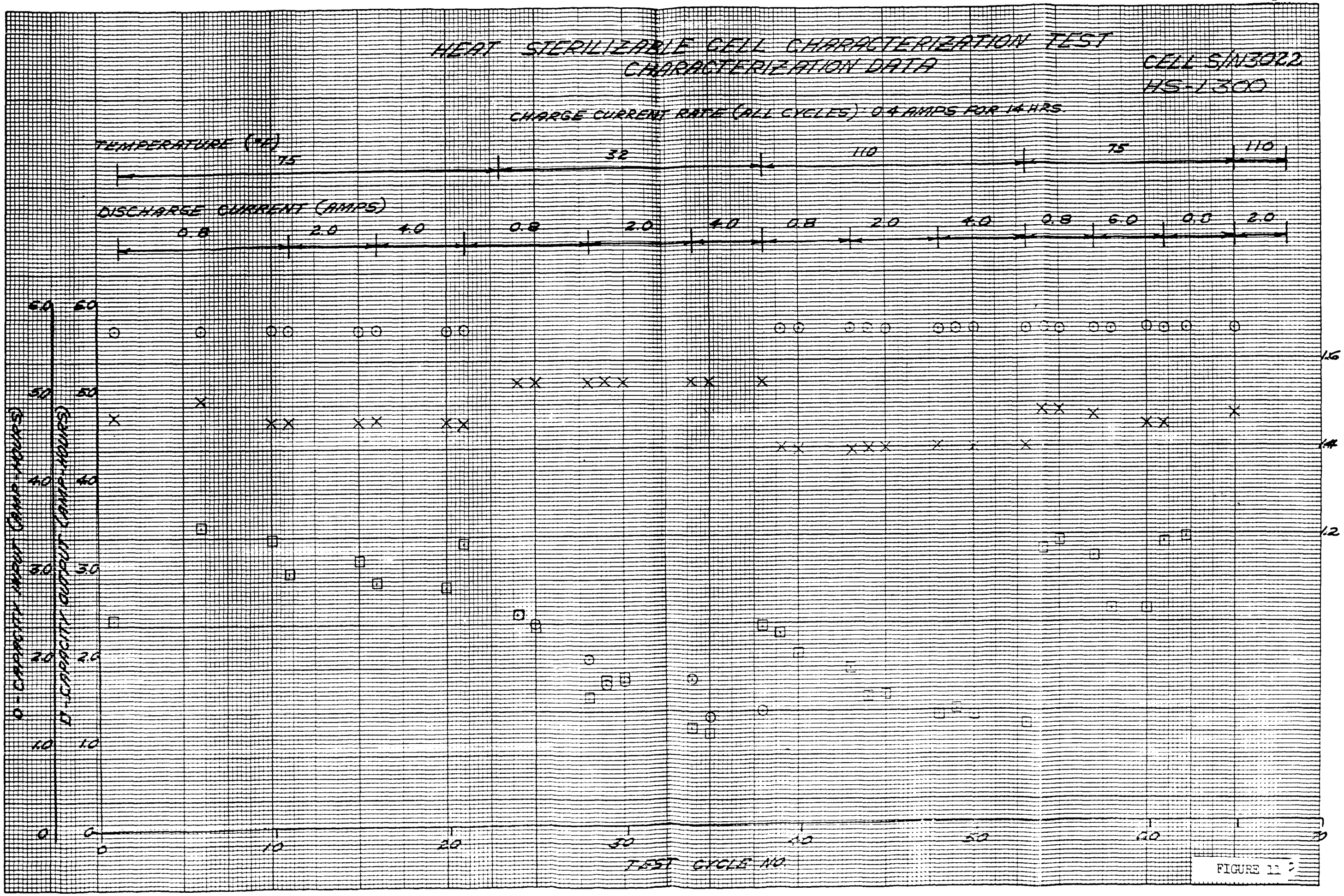

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N3022
HS-1300
CHARGE CURRENT RATE (ALL CYCLES) 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
□ - CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
END OF CHG. VOLT.
1.6
1.4
1.2
0
10
20
30
40
50
60
70
TEST CYCLE NO.

FIGURE 11

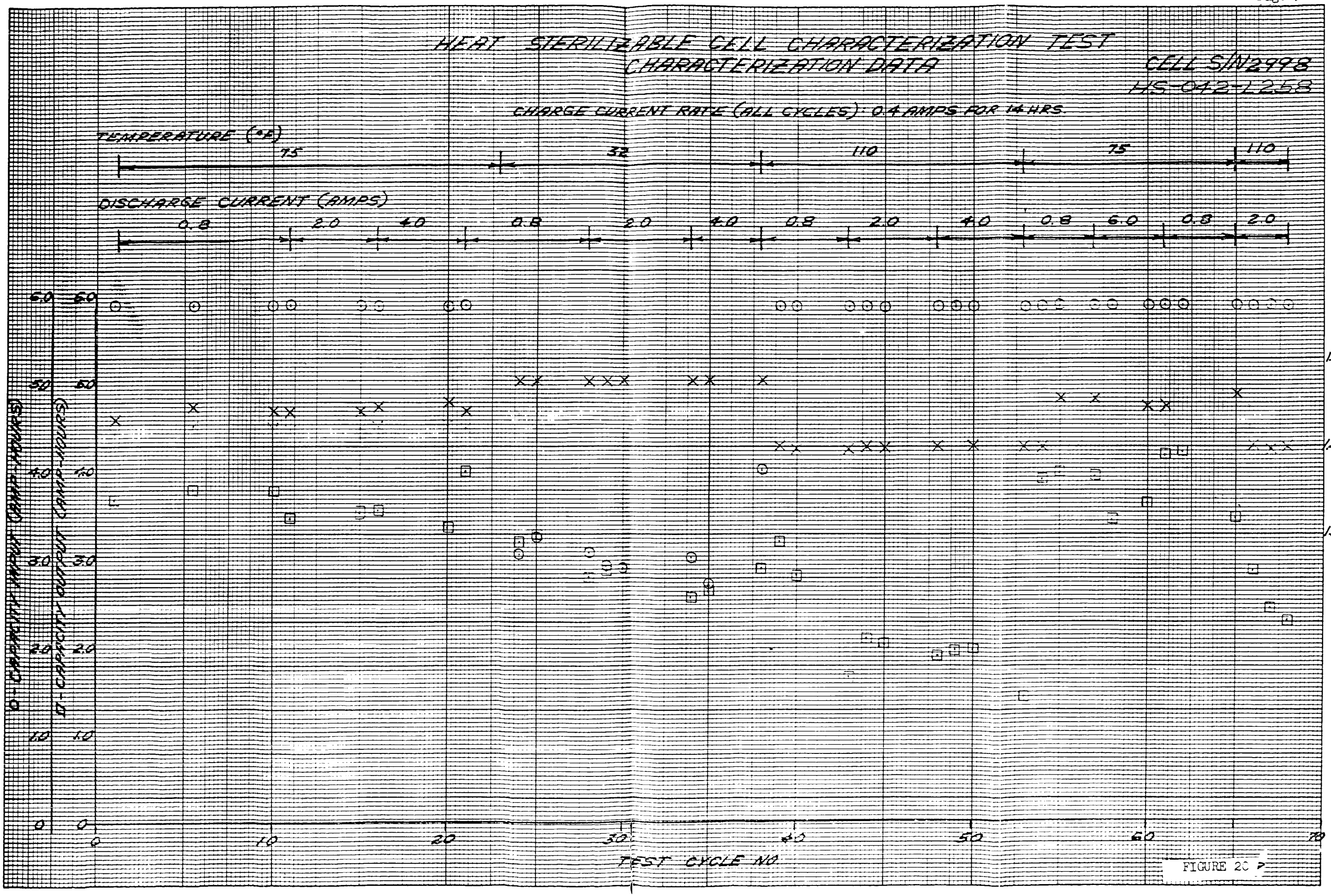

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2998
HS-042-1258
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
D-CAPACITY OUTPUT (AMP-HOURS)
C-CAPACITY INPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
60
50
40
30
20
10
0
10
20
30
40
50
60
70
TEST CYCLE NO
END OF CHG VOLT.
16
14
12

FIGURE 20

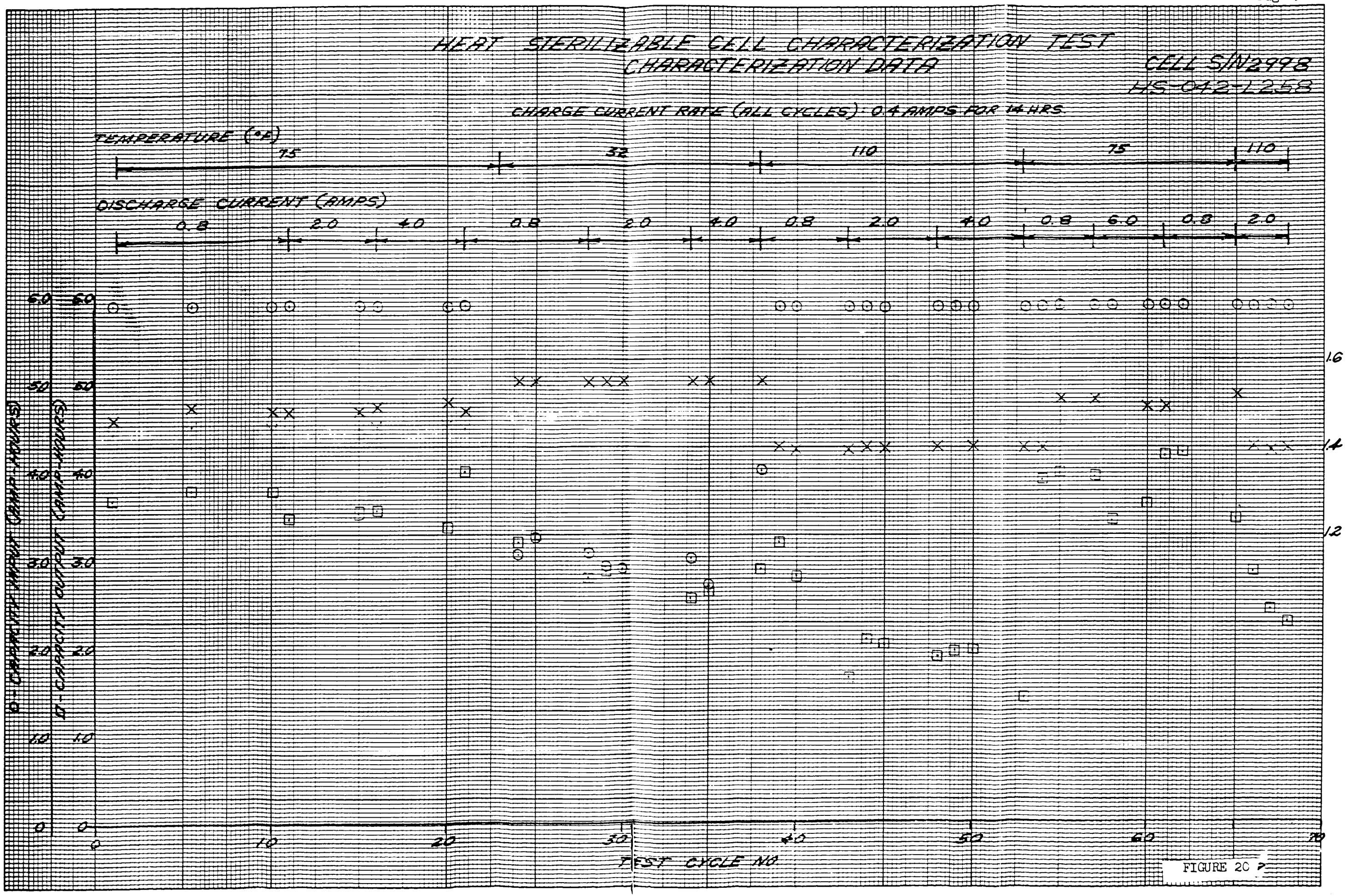

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N2998
HS-042-1258
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
Q-CAPACITY INPUT (AMP-HOURS)
Q-CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.6
1.4
1.2
END OF CHG. VOLT.
0
10
20
30
40
50
60
70
TEST CYCLE NO

FIGURE 20

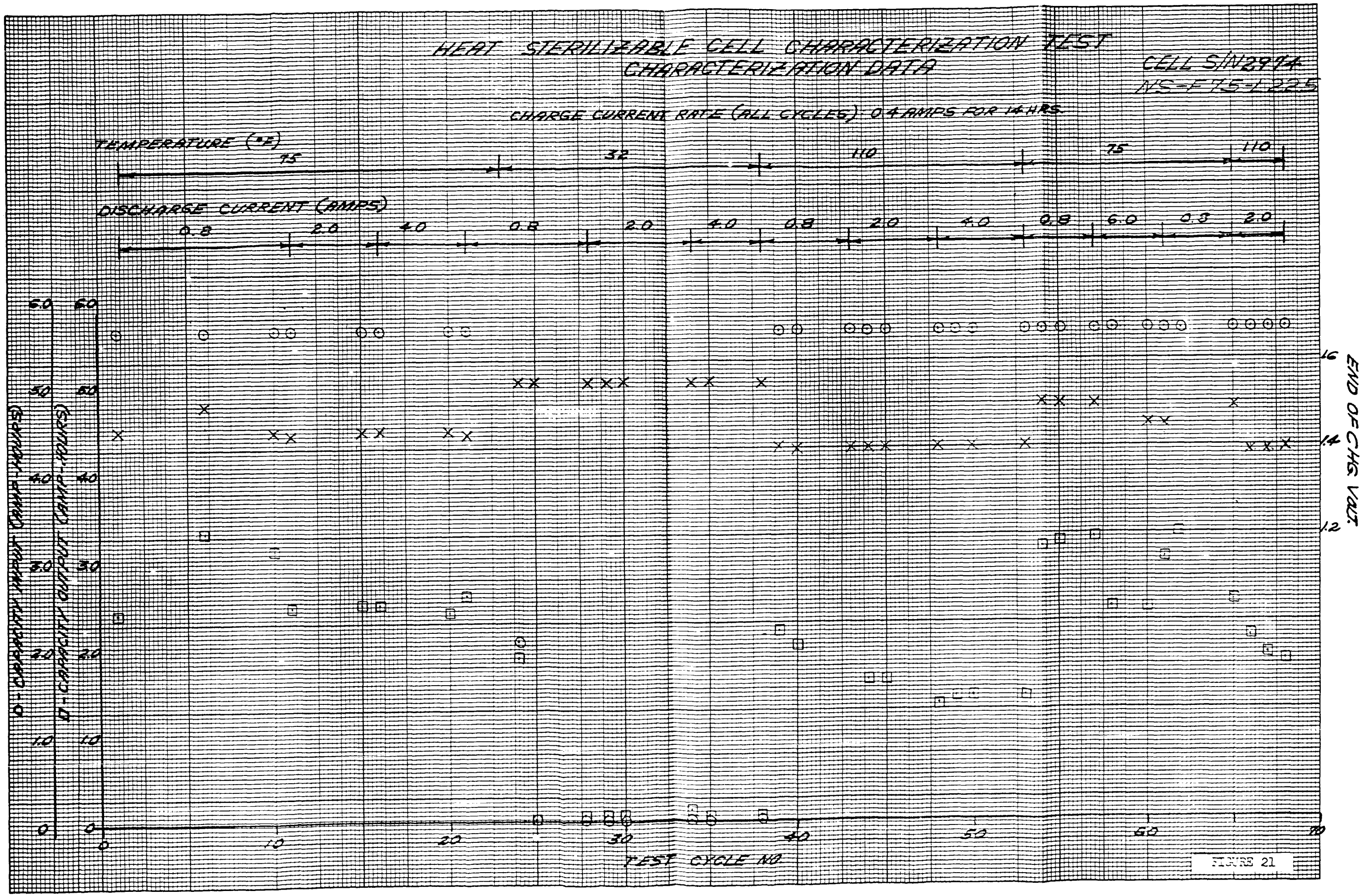

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2974
NS-F75-L225
CHARGE CURRENT RATE (ALL CYCLES) 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
D - CAPACITY INPUT (AMP-HOURS)
D - CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
END OF CHG VOLT.
1.6
1.4
1.2
0
10
20
30
40
50
60
70
TEST CYCLE NO.

FIGURE 21

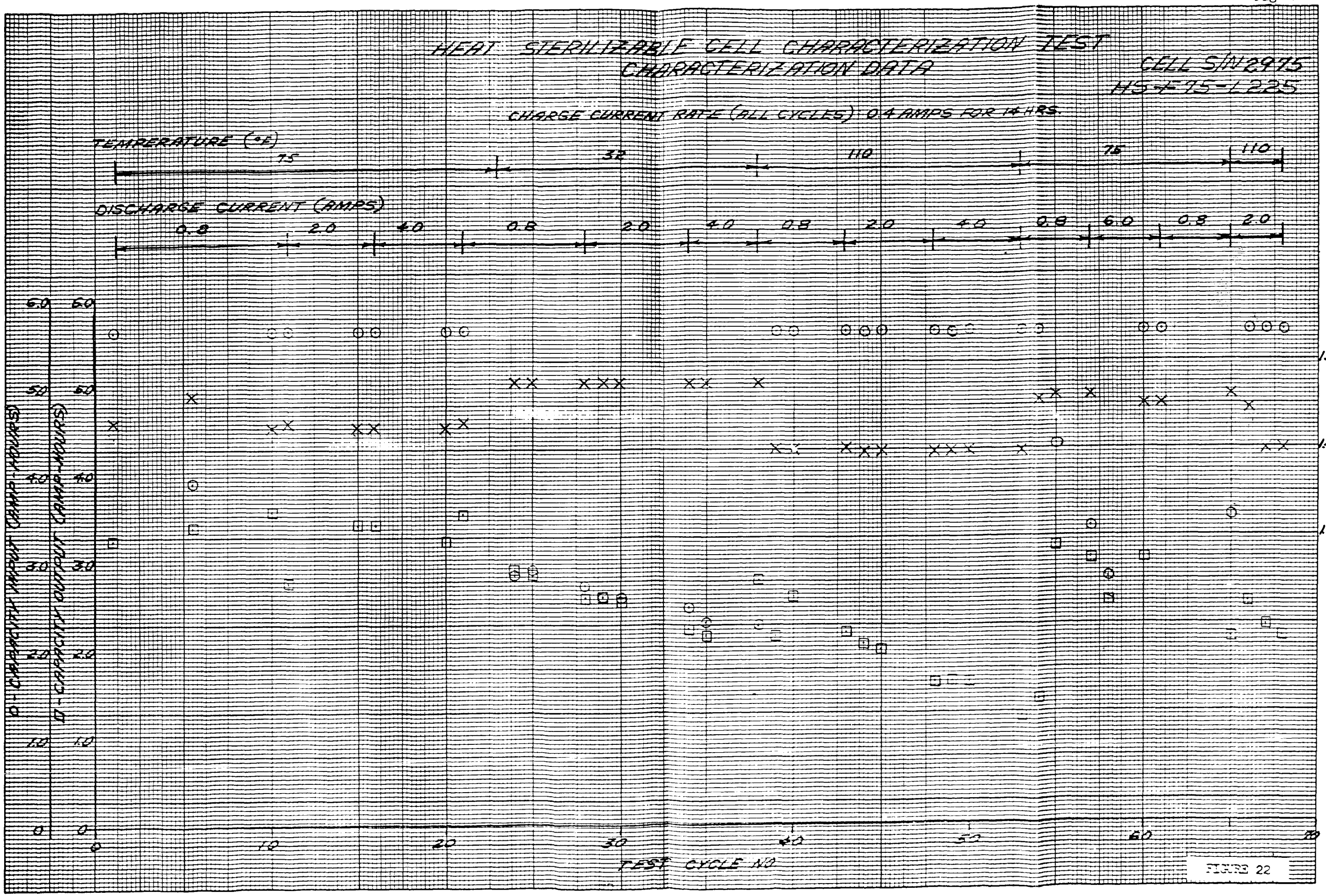

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2975
HS-735-L225
CHARGE CURRENT RATE (ALL CYCLES) 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CHARGE INPUT (AMP-HOURS)
□ - CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
60
50
40
30
20
10
0
END OF CHG. VOLT.
1.6
1.4
1.2
10
20
30
40
50
60
70
TEST CYCLE NO

FIGURE 22

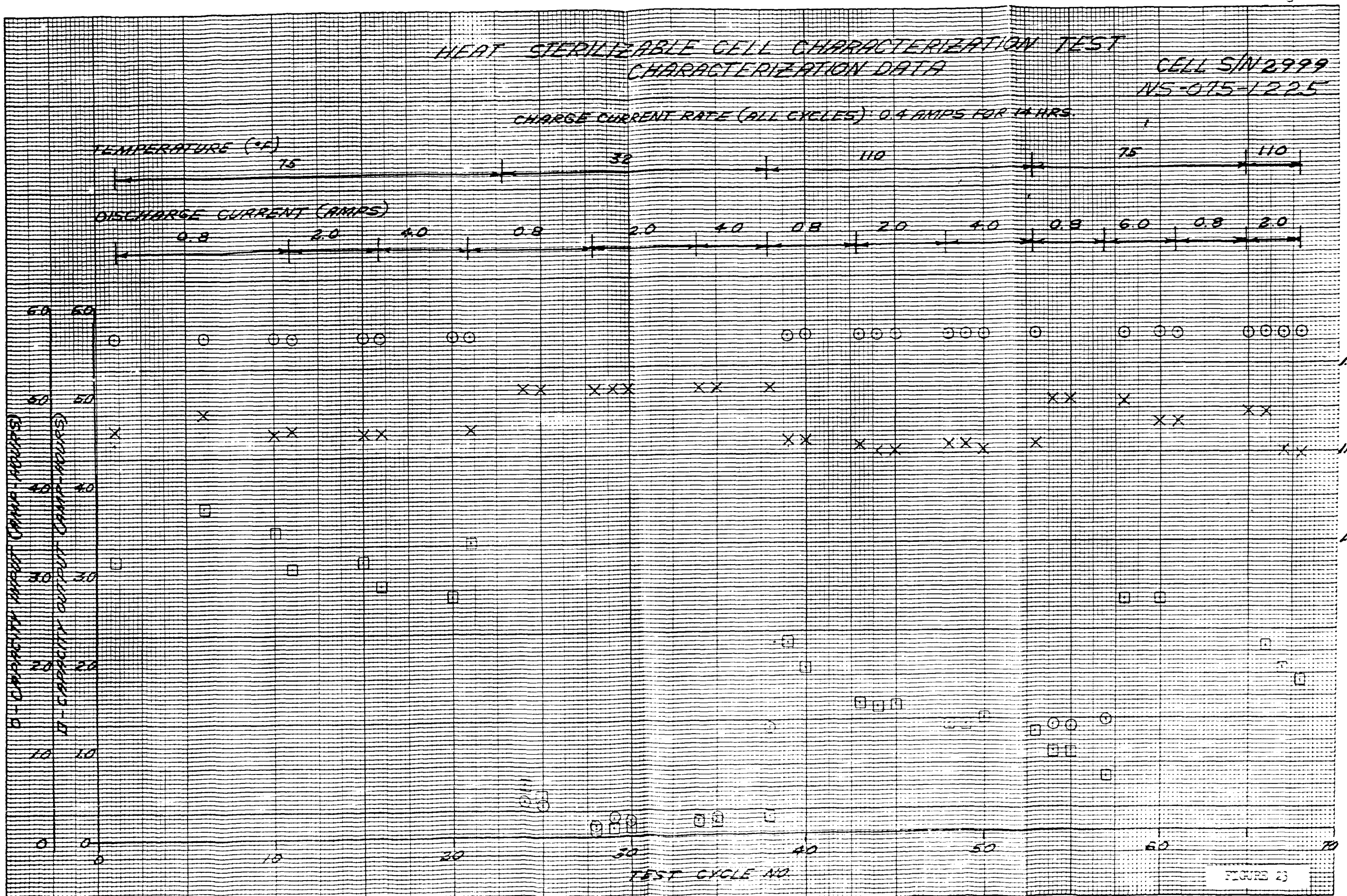

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2999
NS-075-1225
CHARGE CURRENT RATE (ALL CYCLES) 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
X - CAPACITY OUTPUT (AMP-HOURS)
END OF CHG. VOLT.
1.6
1.4
1.2
TEST CYCLE NO.
0
10
20
30
40
50
60
70

FIGURE 23

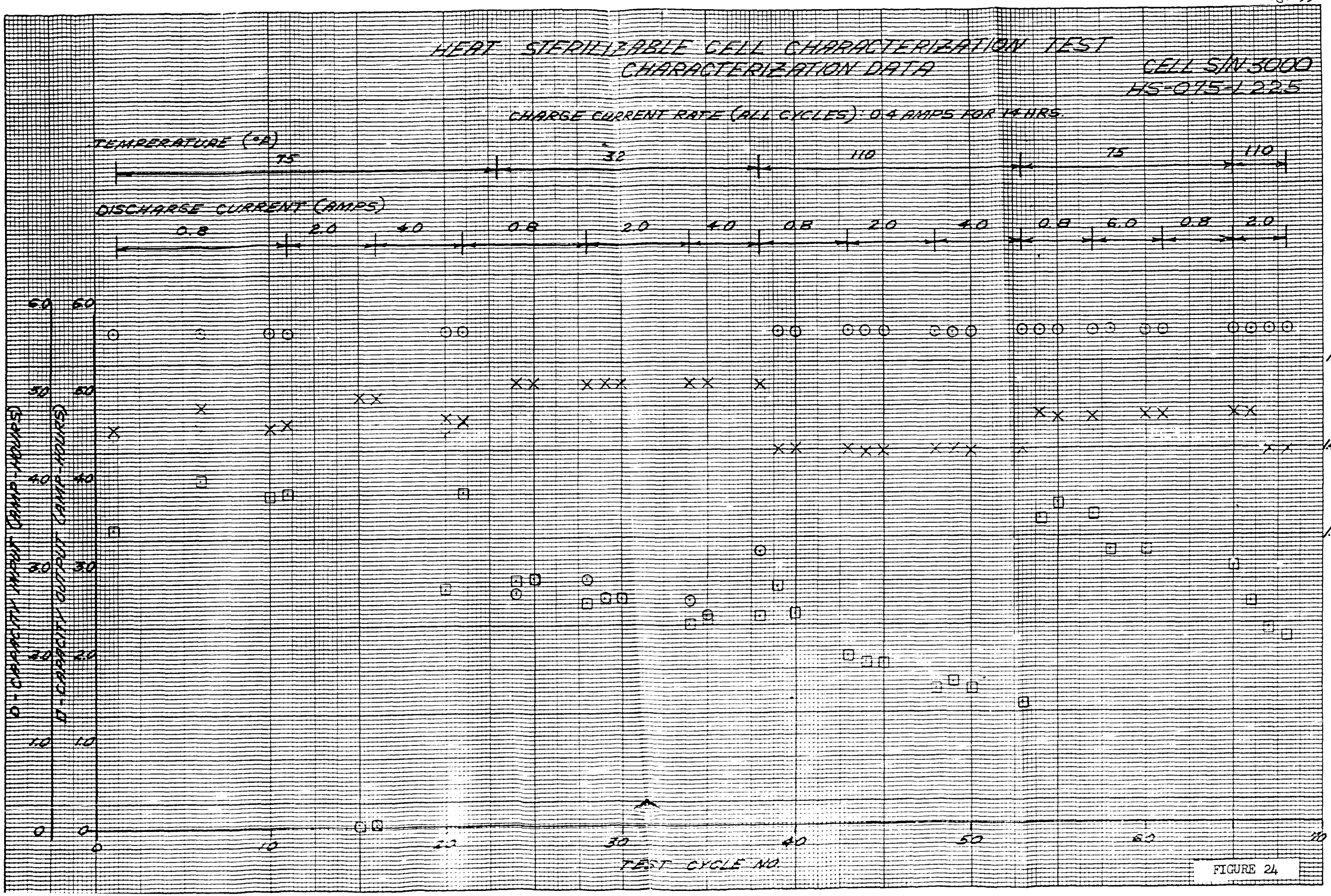
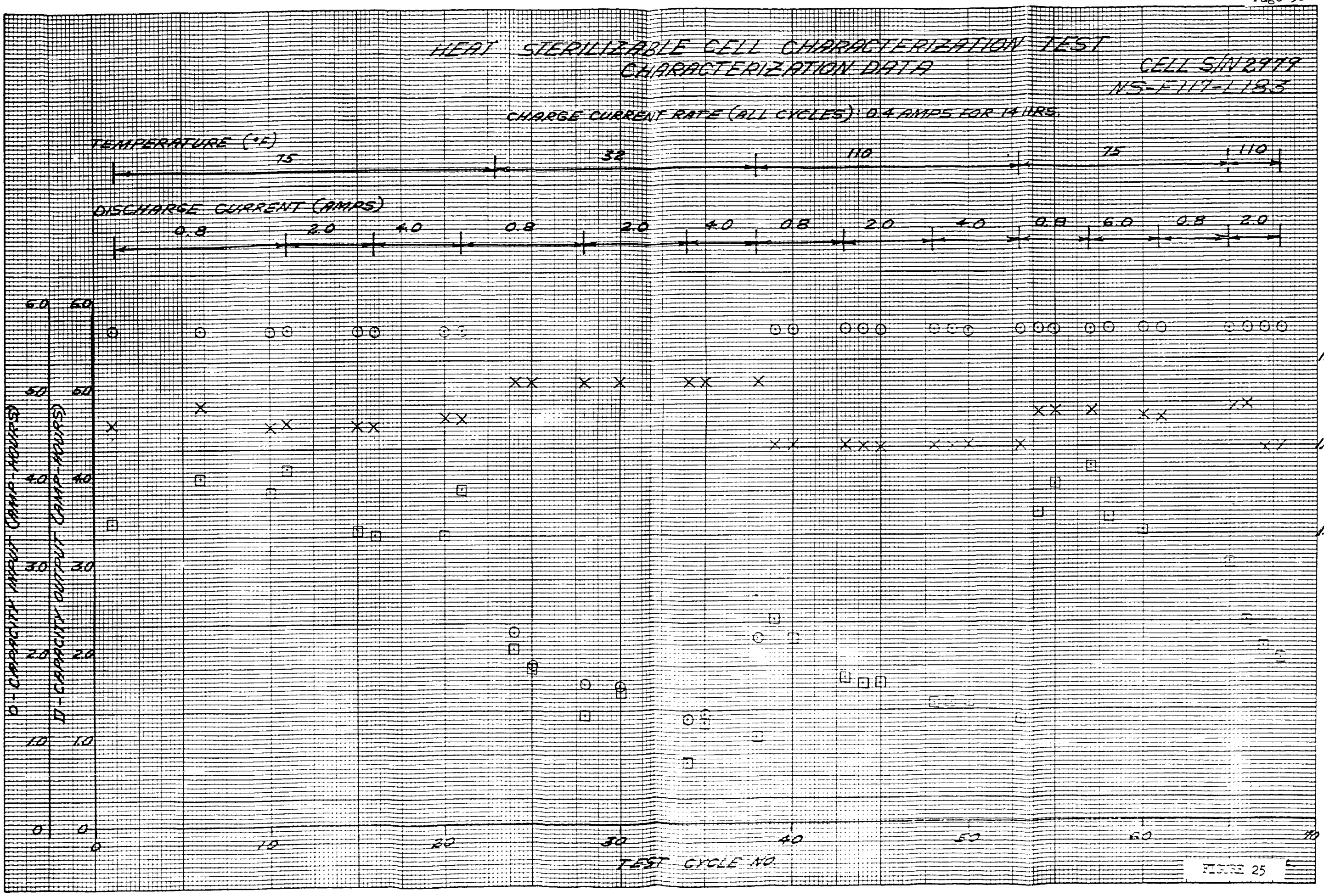

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 3000
HS-075-L225
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
□ - CAPACITY OUTPUT (AMP-HOURS)
60
50
40
30
20
10
0
END OF CHG. VOLT.
1.6
1.4
1.2
10
20
30
40
50
60
70
TEST CYCLE NO.

FIGURE 24


HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2979
NS-F117-L183
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
X - CAPACITY OUTPUT (AMP-HOURS)
END OF CHG. VOLT.
TEST CYCLE NO.
FIGURE 25

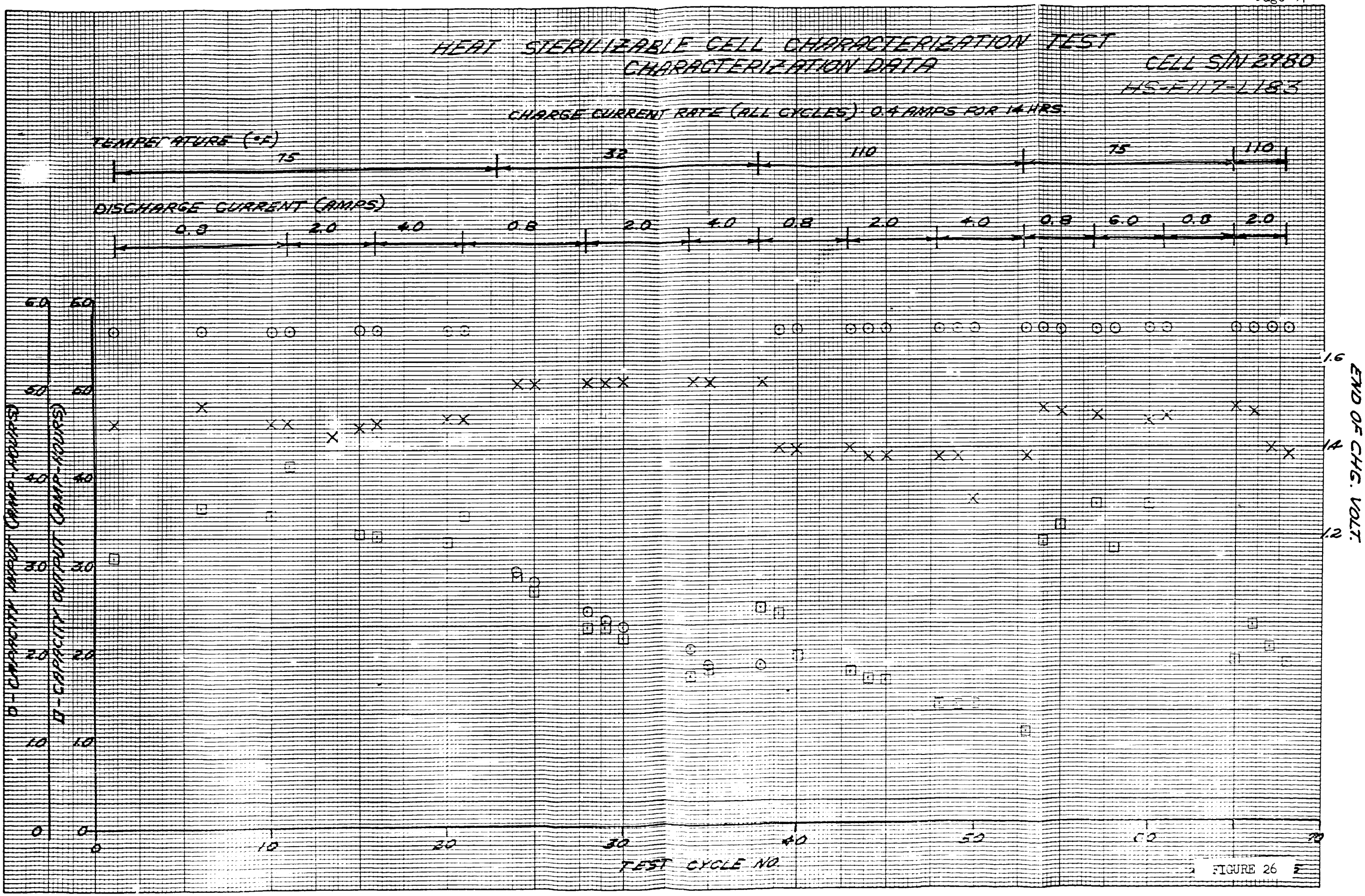

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2980
HS-F117-L183
CHARGE CURRENT RATE (ALL CYCLES) 0.4 AMPS FOR 14 HRS
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
D-CAPACITY OUTPUT (AMP-HOURS)
C-CAPACITY INPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
60
50
40
30
20
10
0
END OF CHG. VOLT.
1.6
1.4
1.2
10
20
30
40
50
60
70
TEST CYCLE NO

FIGURE 26

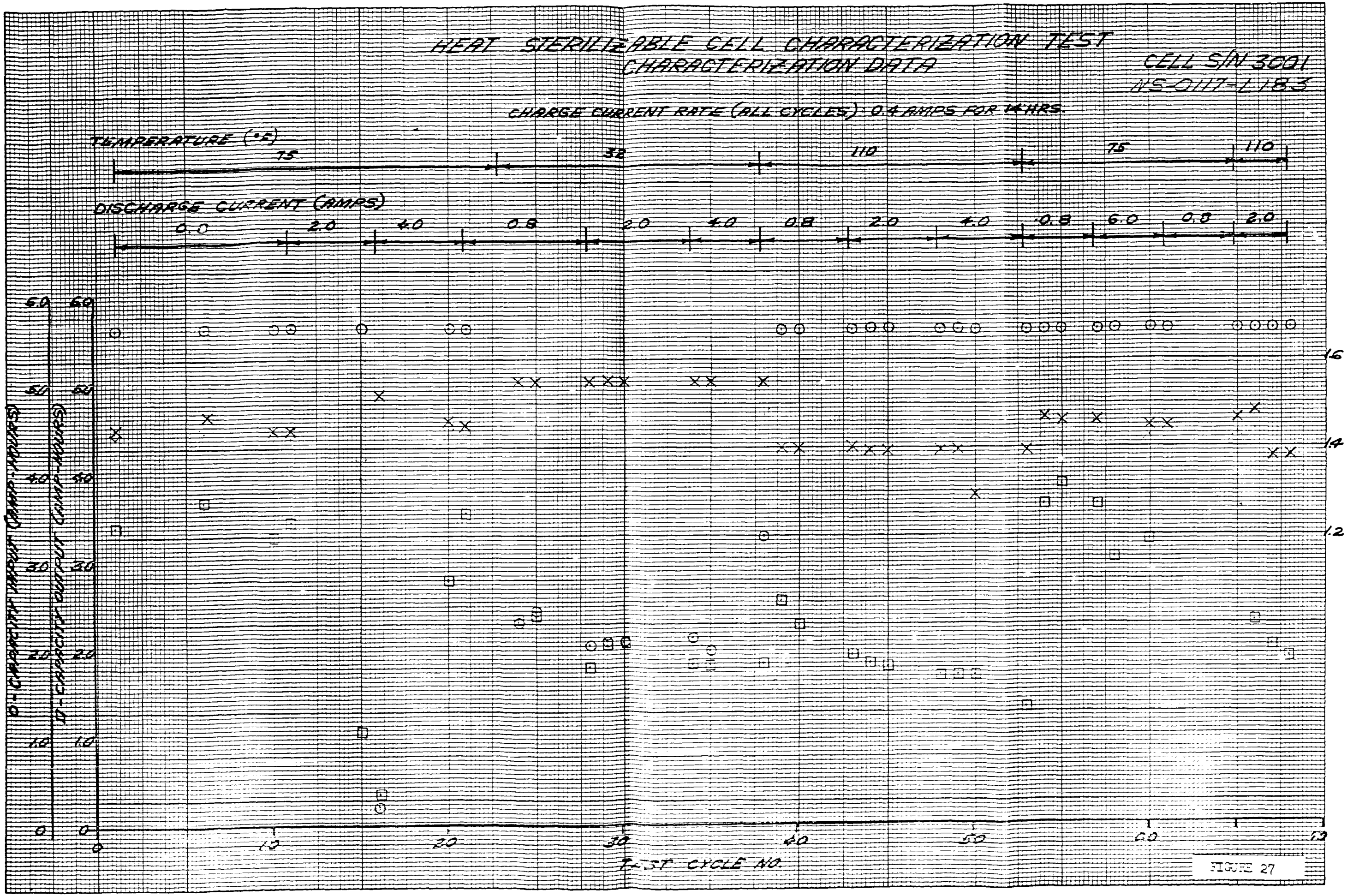

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 3001
NS-OIIT-L183
CHARGE CURRENT RATE (ALL CYCLES) 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.0
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
□ - CAPACITY OUTPUT (AMP-HOURS)
6.0
60
5.0
50
4.0
40
3.0
30
2.0
20
1.0
10
0
0
10
20
30
40
50
60
70
TEST CYCLE NO.
END OF CHG. VOLT.
1.6
1.4
1.2

FIGURE 27

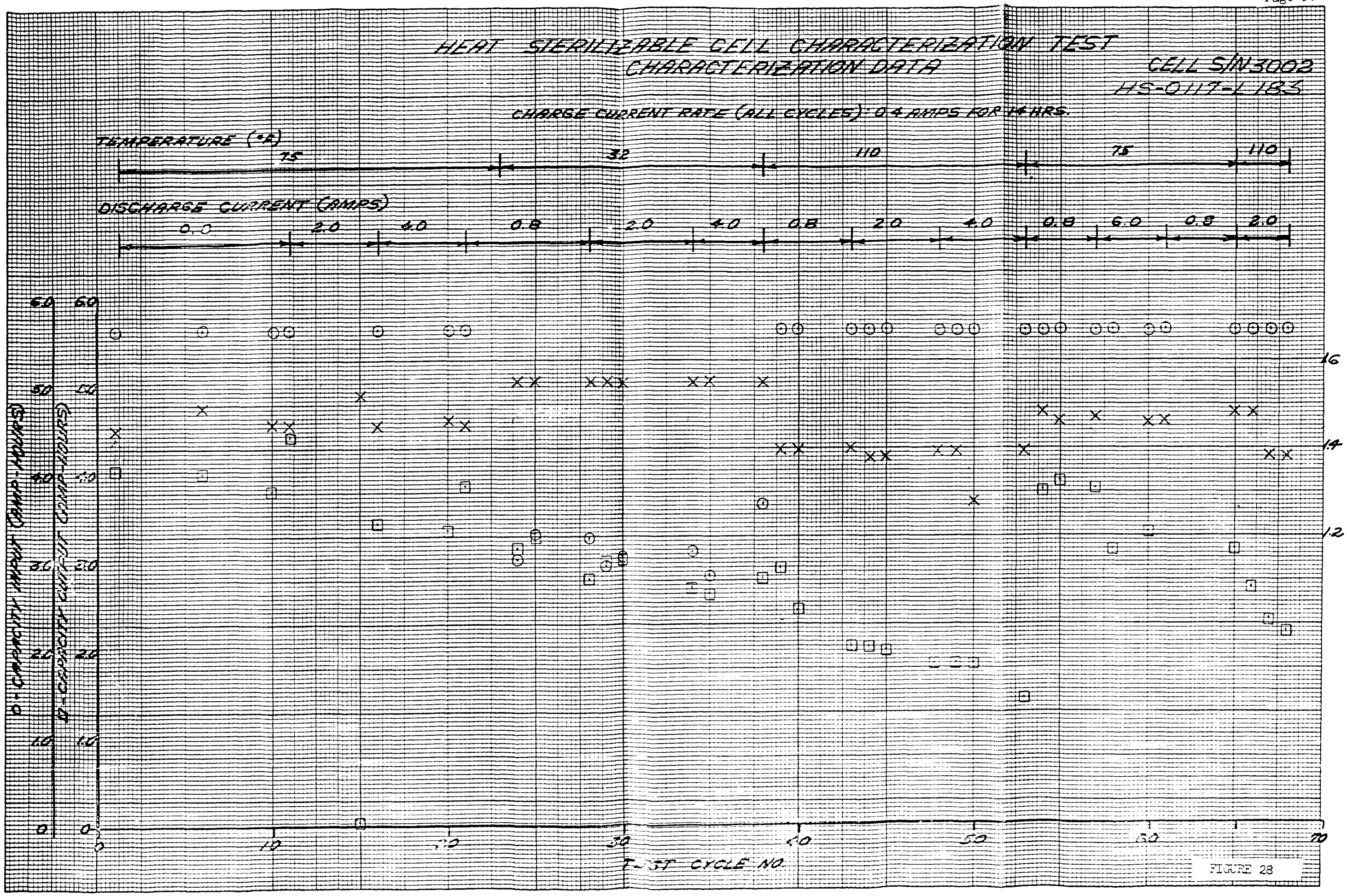

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 3002
HS-0117-L 183
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.0
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
□ - CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
1.6
1.4
1.2
END OF CHG VOLT.
0
10
20
30
40
50
60
70
TEST CYCLE NO.

FIGURE 28

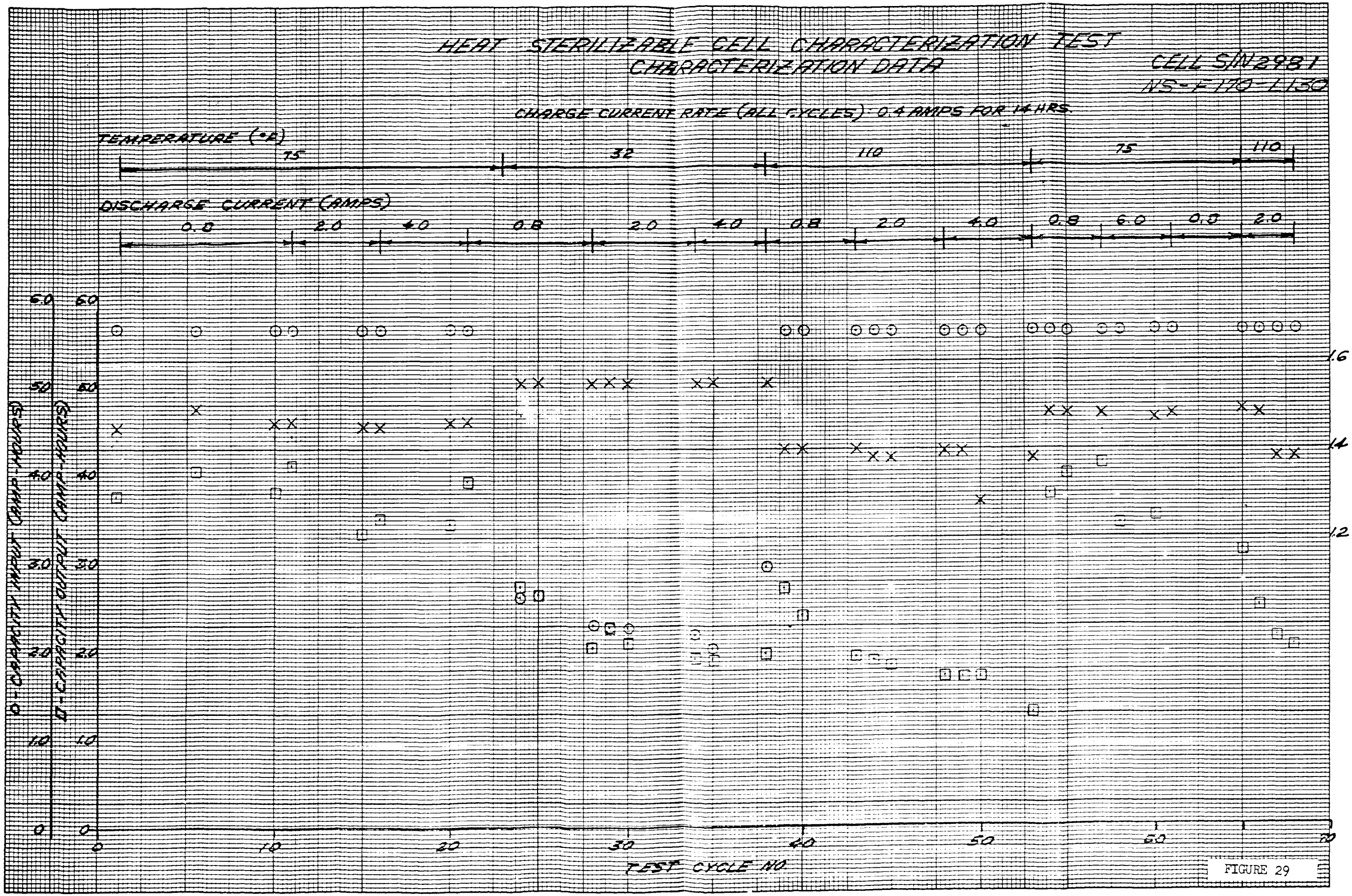

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2981
NS-F 170-L130
CHARGE CURRENT RATE (ALL CYCLES) 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
□ - CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
60
50
40
30
20
10
0
1.6
1.4
1.2
END OF CHG. VOLT.
0
10
20
30
40
50
60
70
TEST CYCLE NO

FIGURE 29

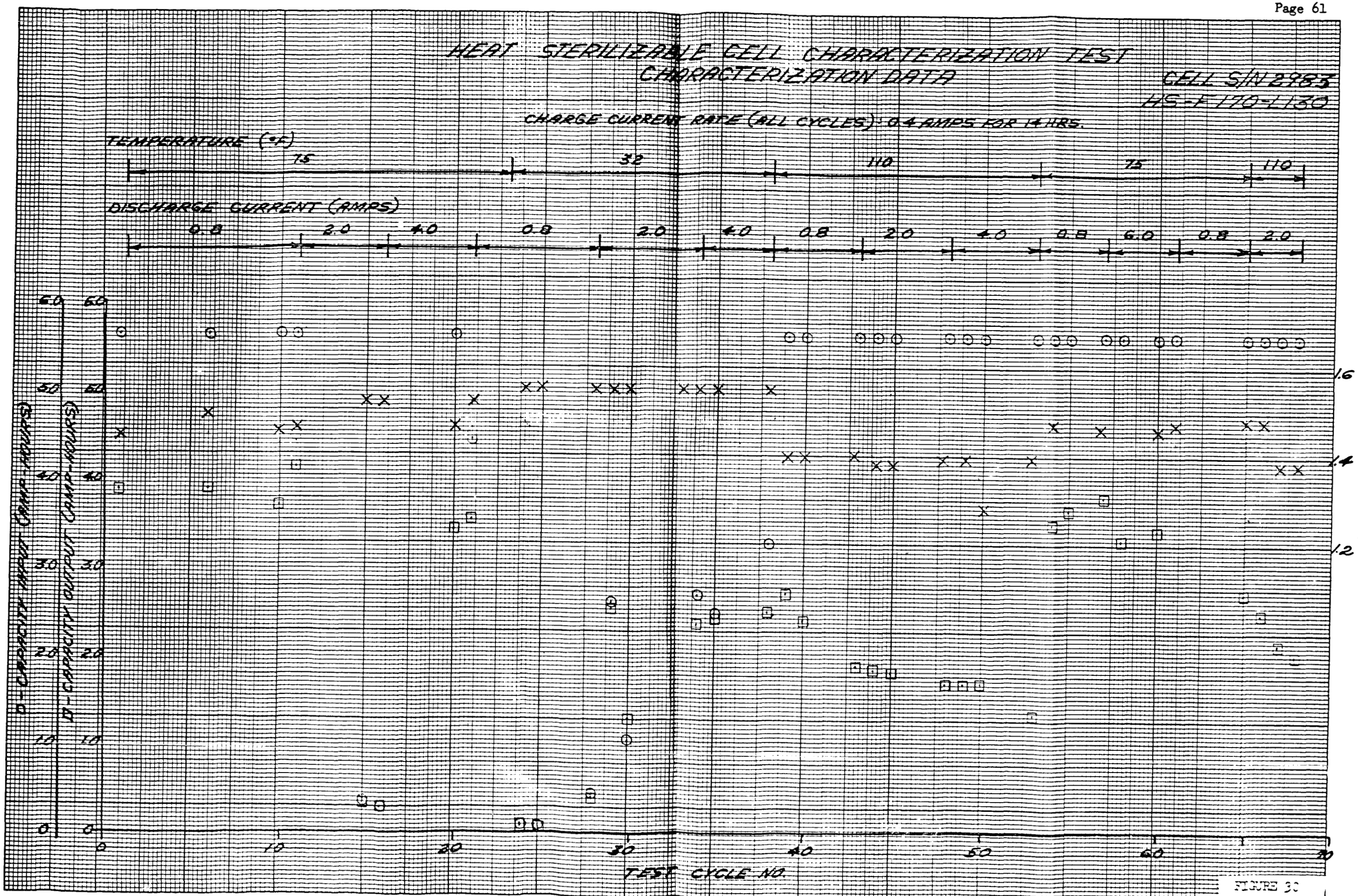

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2983
HS-F 170-L130
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
D-CAPACITY INPUT (AMP-HOURS)
D-CAPACITY OUTPUT (AMP-HOURS)
END OF CHG. VOLT.
TEST CYCLE NO.
0
10
20
30
40
50
60
70
1.2
1.4
1.6

FIGURE 30

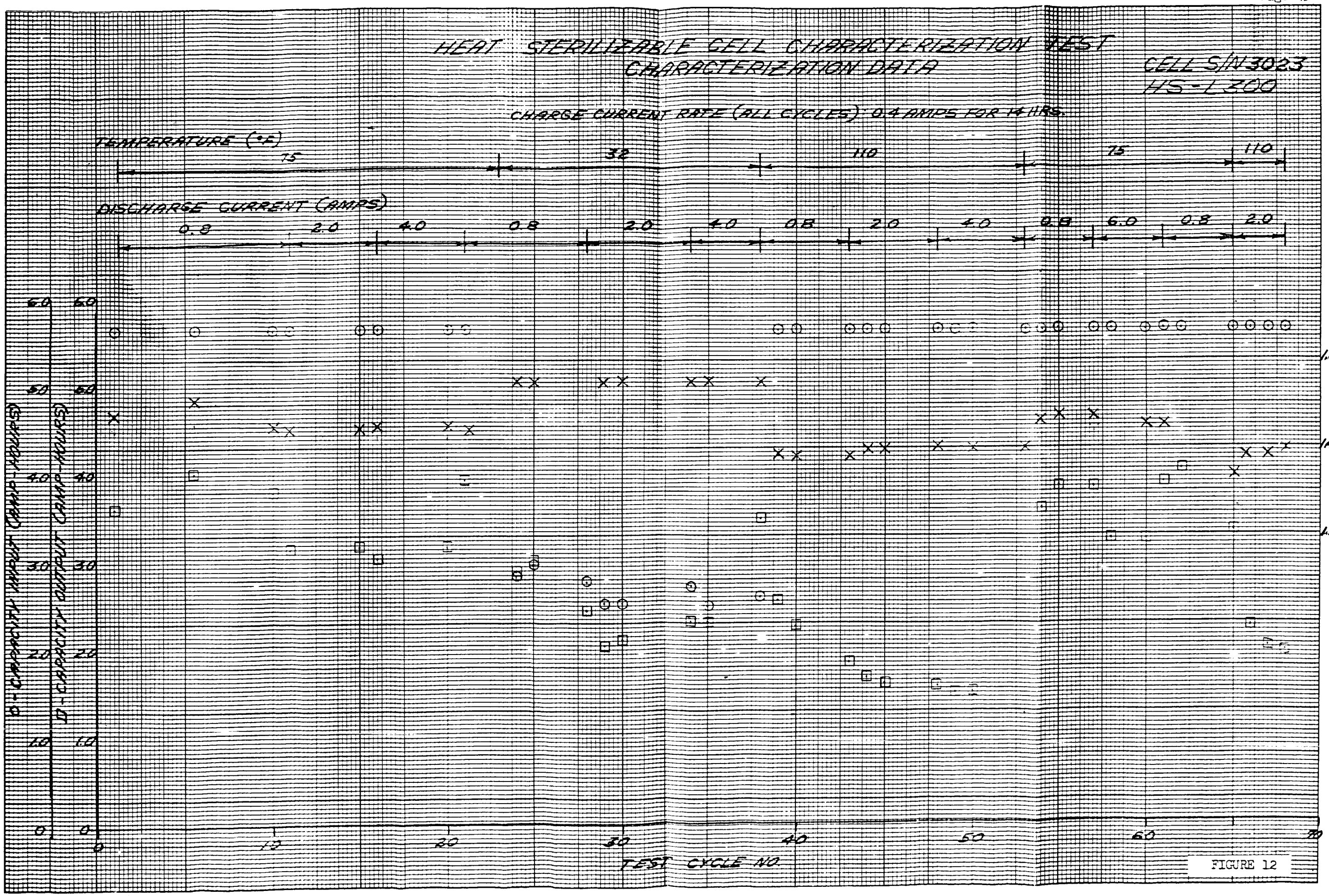

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 3023
HS-L200
CHARGE CURRENT RATE (ALL CYCLES) 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
□ - CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
60
50
40
30
20
10
0
1.6
1.4
1.2
END OF CHG. VOLT.
10
20
30
40
50
60
70
TEST CYCLE NO

FIGURE 12

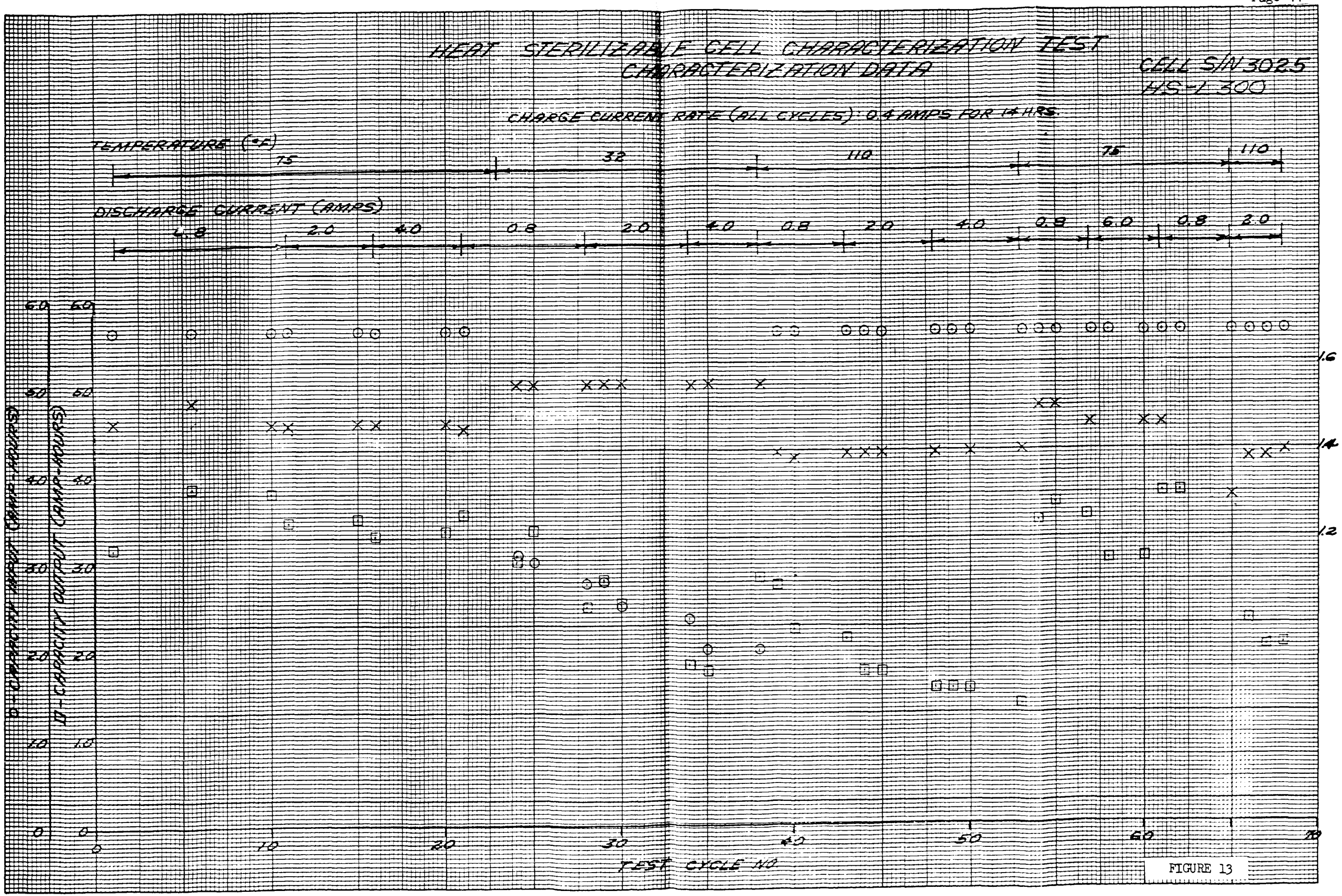

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 3025
HS-L 300
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
4.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
D-CAPACITY INPUT (AMP-HOURS)
U-CAPACITY OUTPUT (AMP-HOURS)
END OF CHG VOLT.
TEST CYCLE NO
0
10
20
30
40
50
60
70
1.0
1.2
1.4
1.6

FIGURE 13

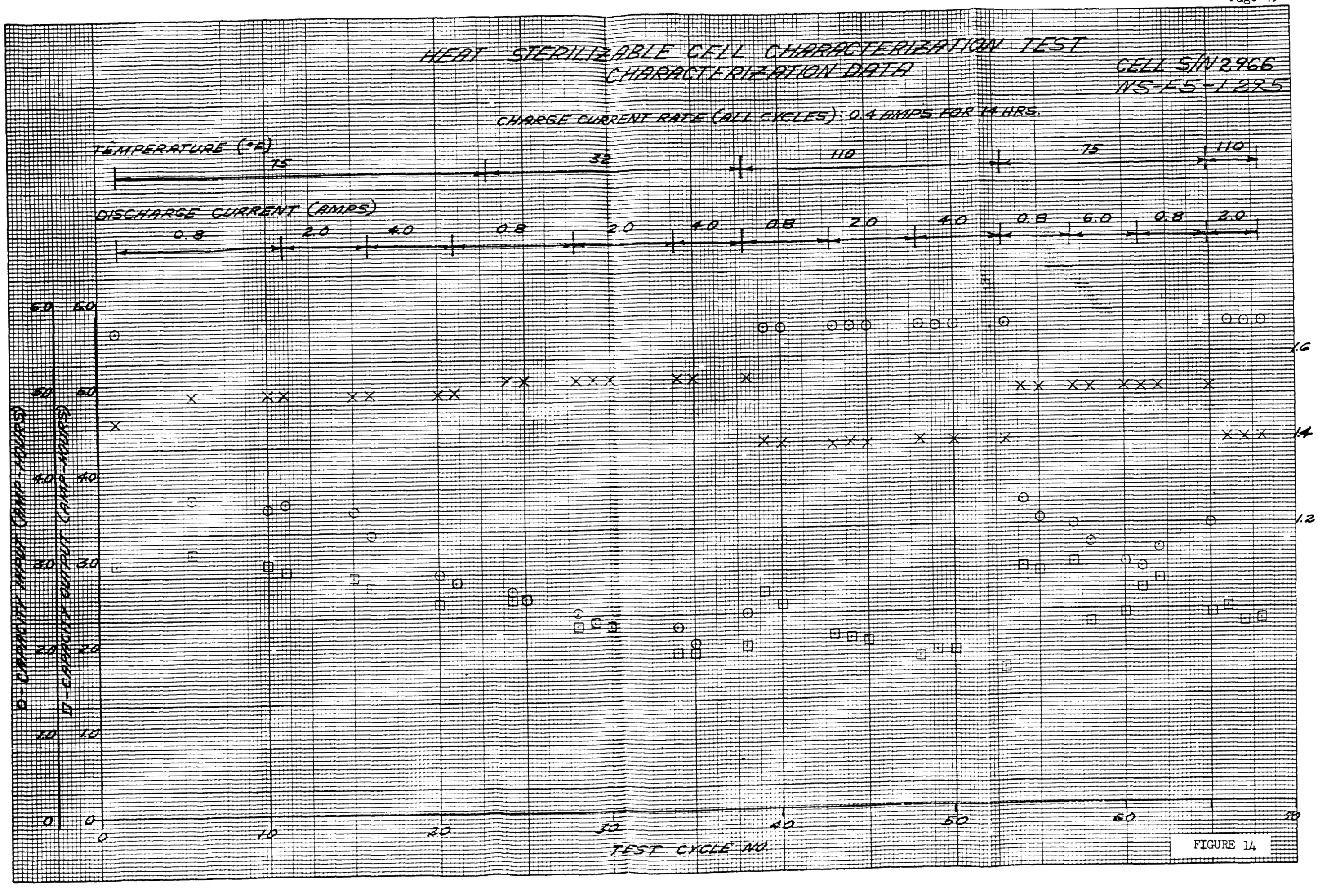

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2966
NS-F5-1225
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
Q - CAPACITY INPUT (AMP-HOURS)
Q - CAPACITY OUTPUT (AMP-HOURS)
END OF CHG. VOLT.
TEST CYCLE NO.

FIGURE 14

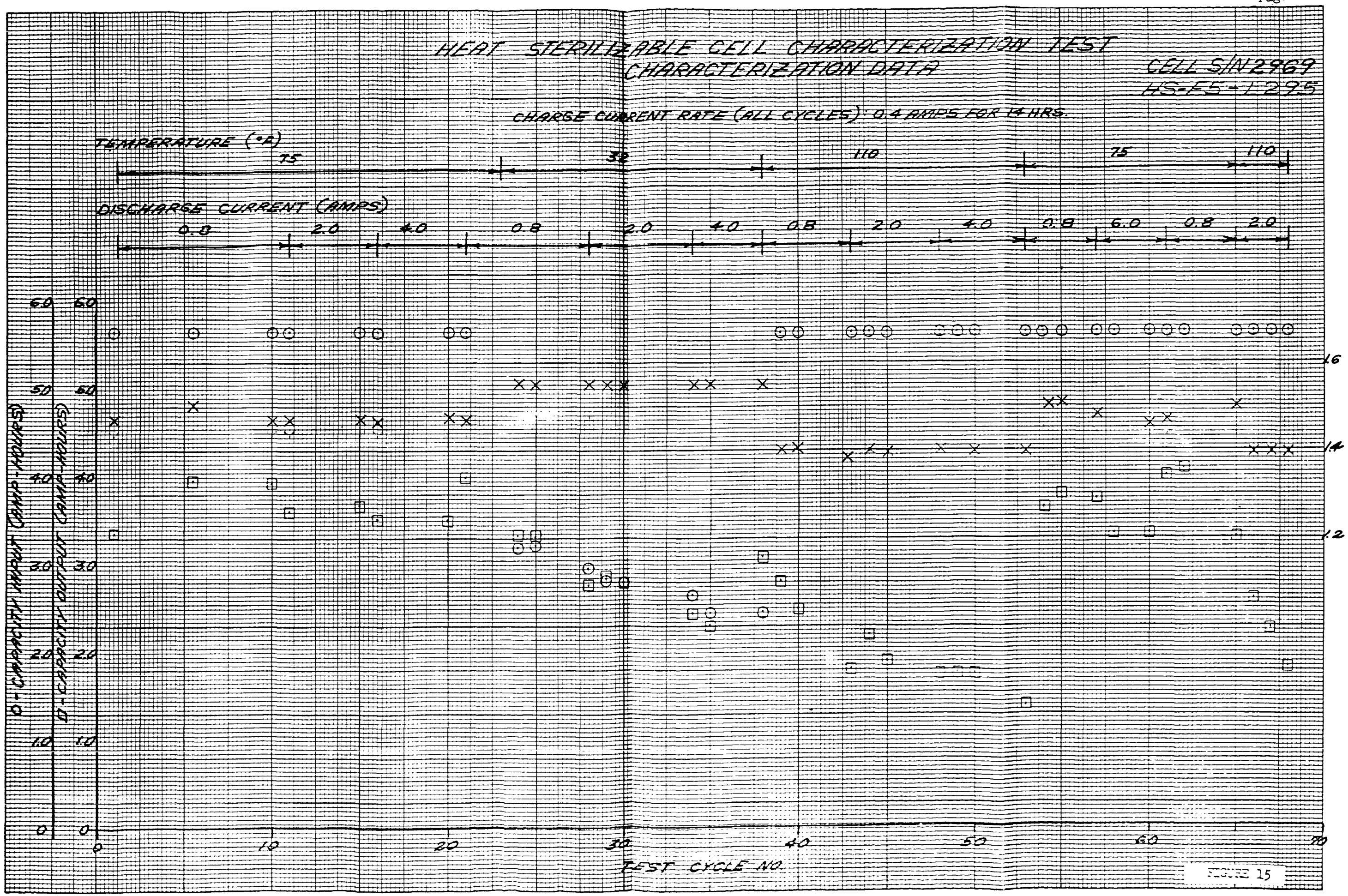

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2969
HS-F5-1295
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
□ - CAPACITY OUTPUT (AMP-HOURS)
6.0
60
5.0
50
4.0
40
3.0
30
2.0
20
1.0
10
0
0
10
20
30
40
50
60
70
TEST CYCLE NO.
1.6
1.4
1.2
END OF CHG. VOLT

FIGURE 15

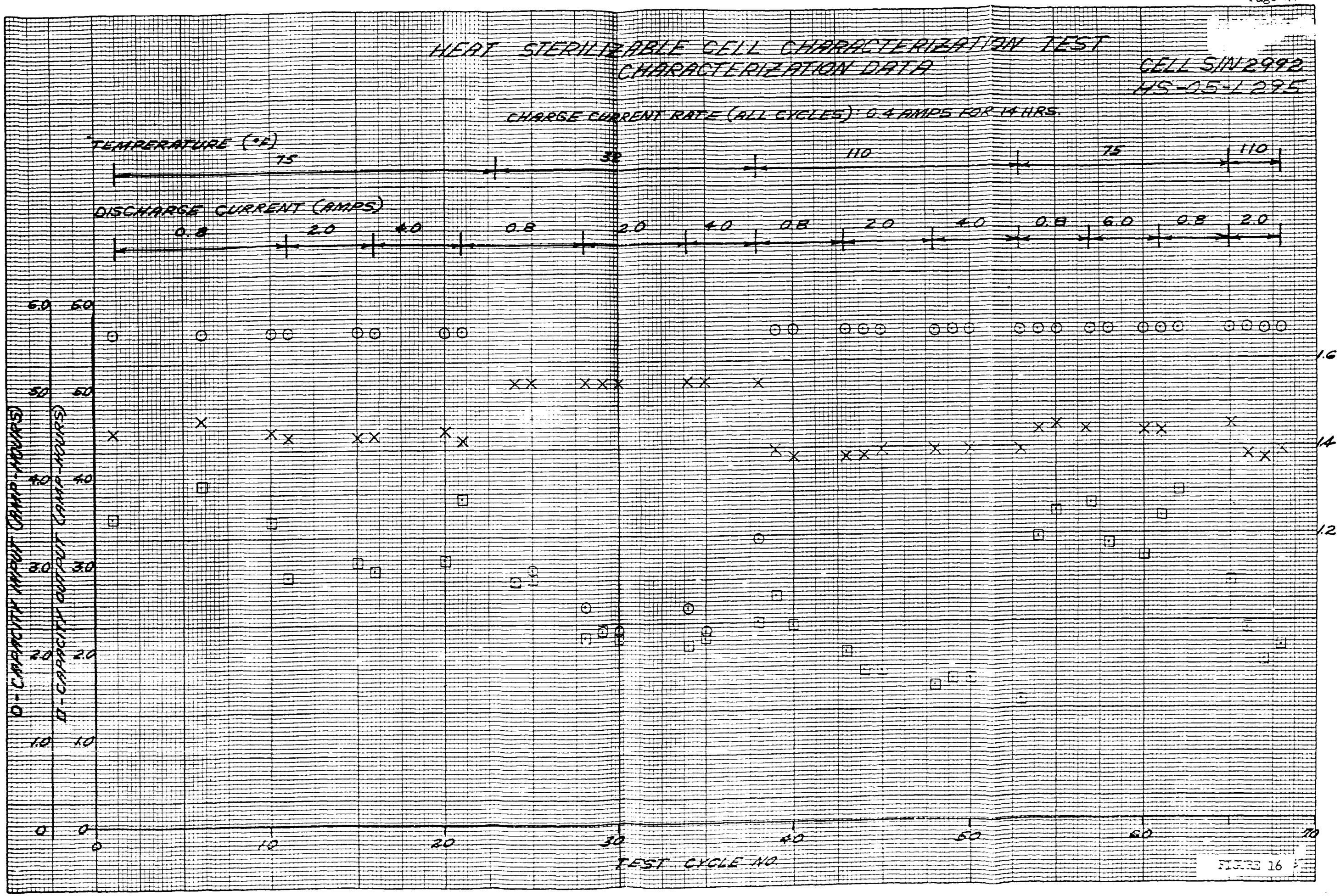

HERT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2992
HS-05-L295
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
X - CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
60
50
40
30
20
10
0
1.6
1.4
1.2
1.0
END OF CHG. VOLT.
0
10
20
30
40
50
60
70
TEST CYCLE NO.

FIGURE 16

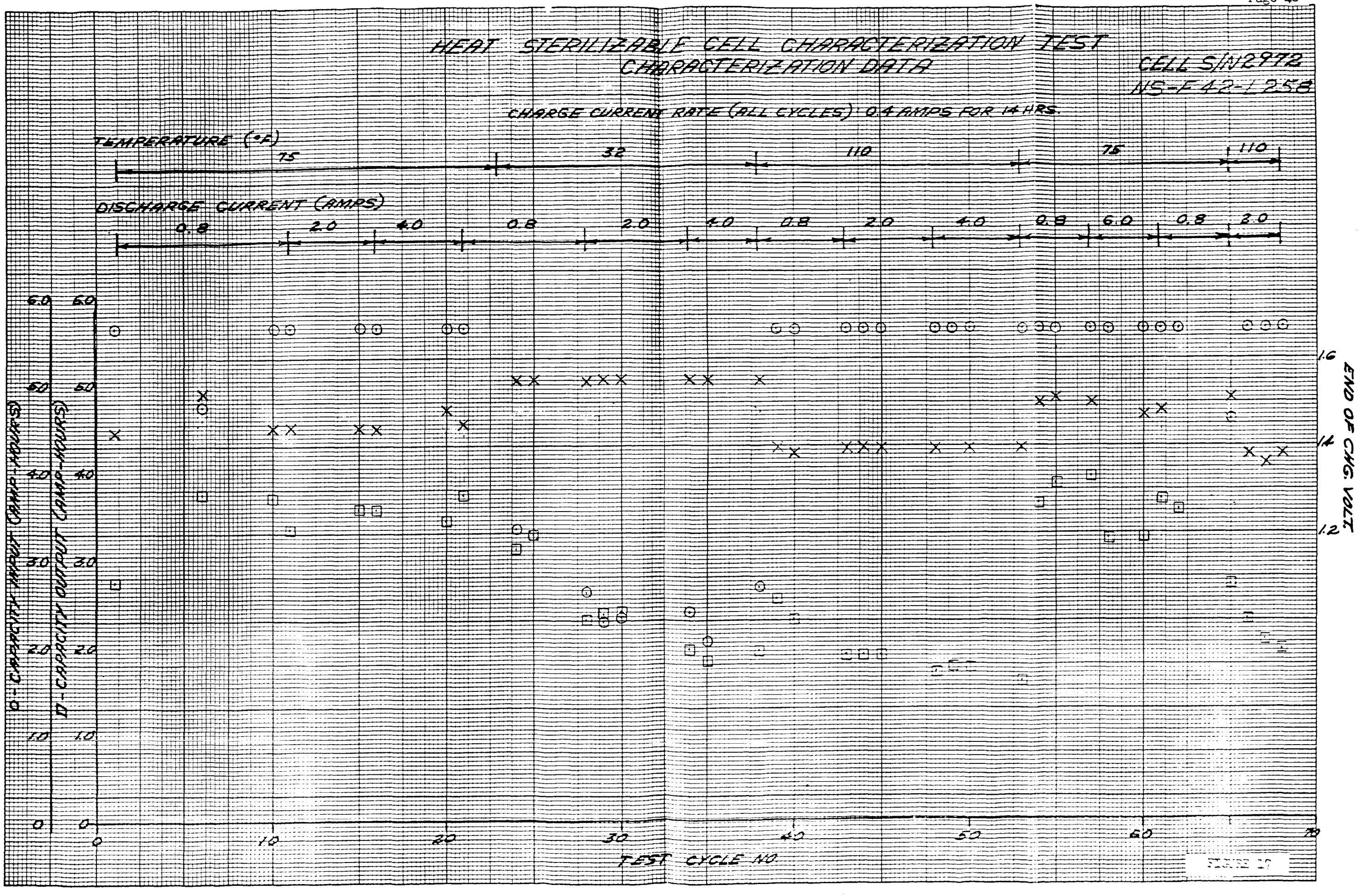

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2972
NS-F 42-1258
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
D - CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
END OF CHG. VOLT
1.6
1.4
1.2
0
10
20
30
40
50
60
70
TEST CYCLE NO

FIGURE 17

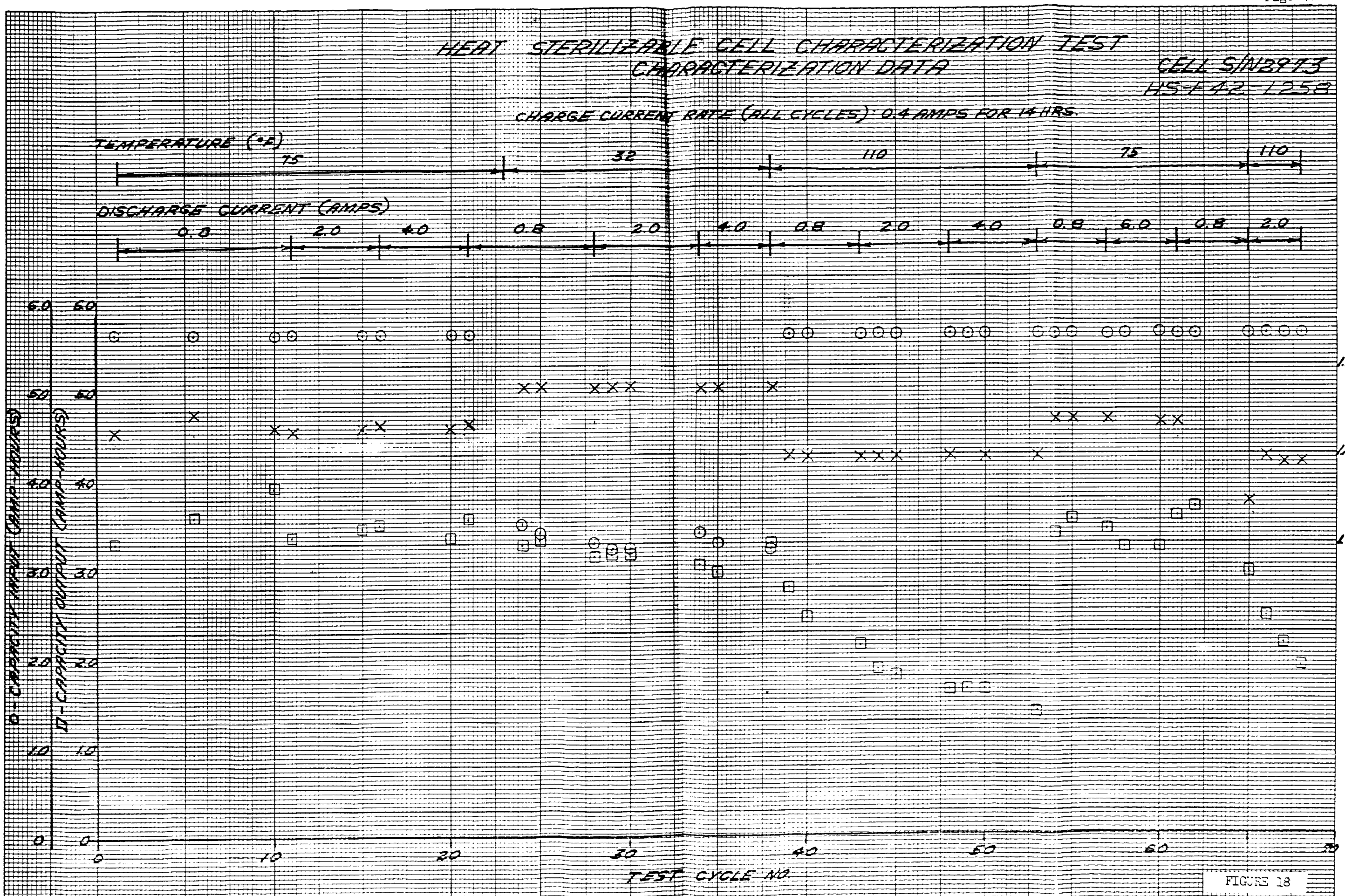

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N3973
HS-442 L258
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
X - CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
60
50
40
30
20
10
0
1.6
1.4
1.2
END OF CHG. VOLT
0
10
20
30
40
50
60
70
TEST CYCLE NO.

FIGURE 18

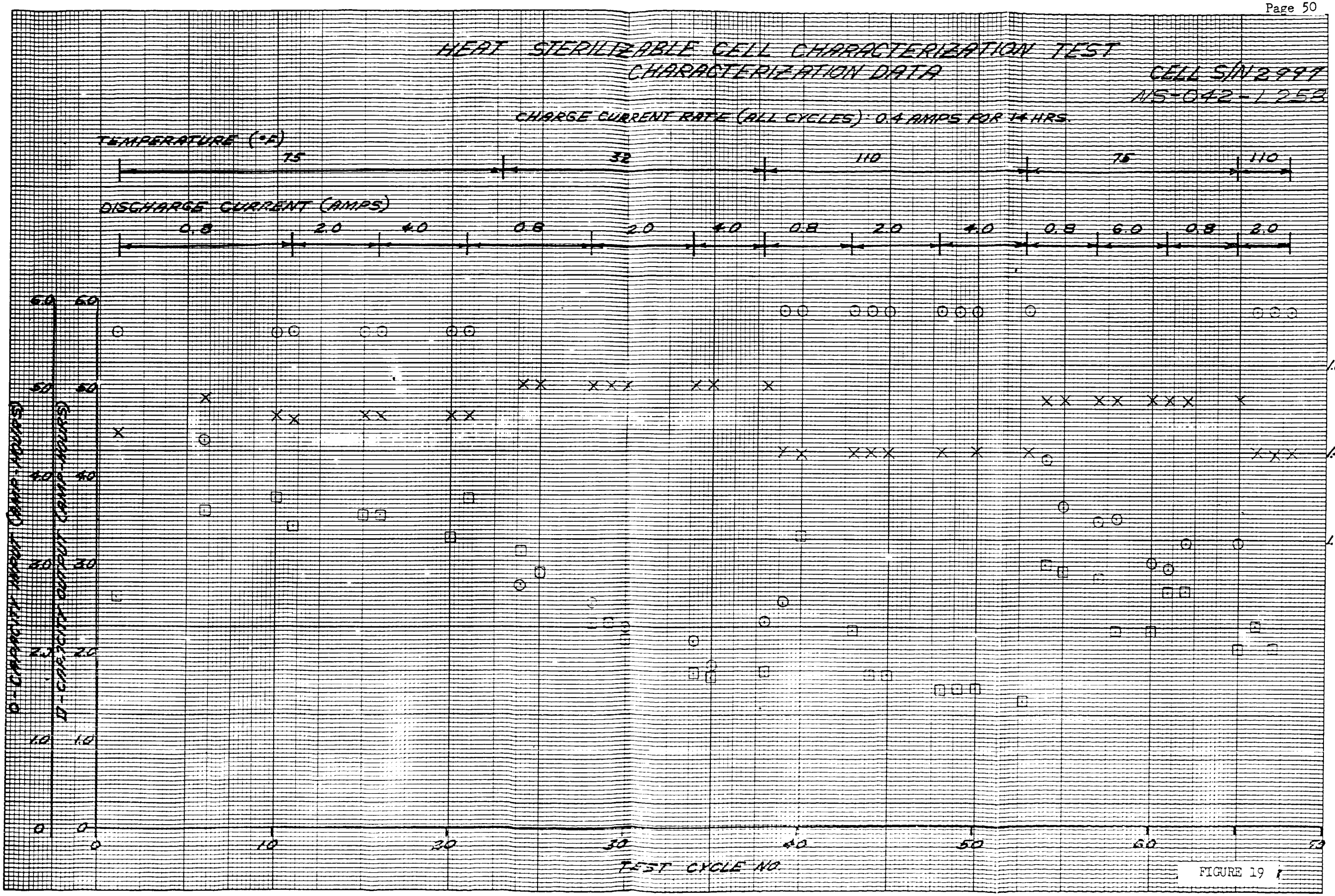
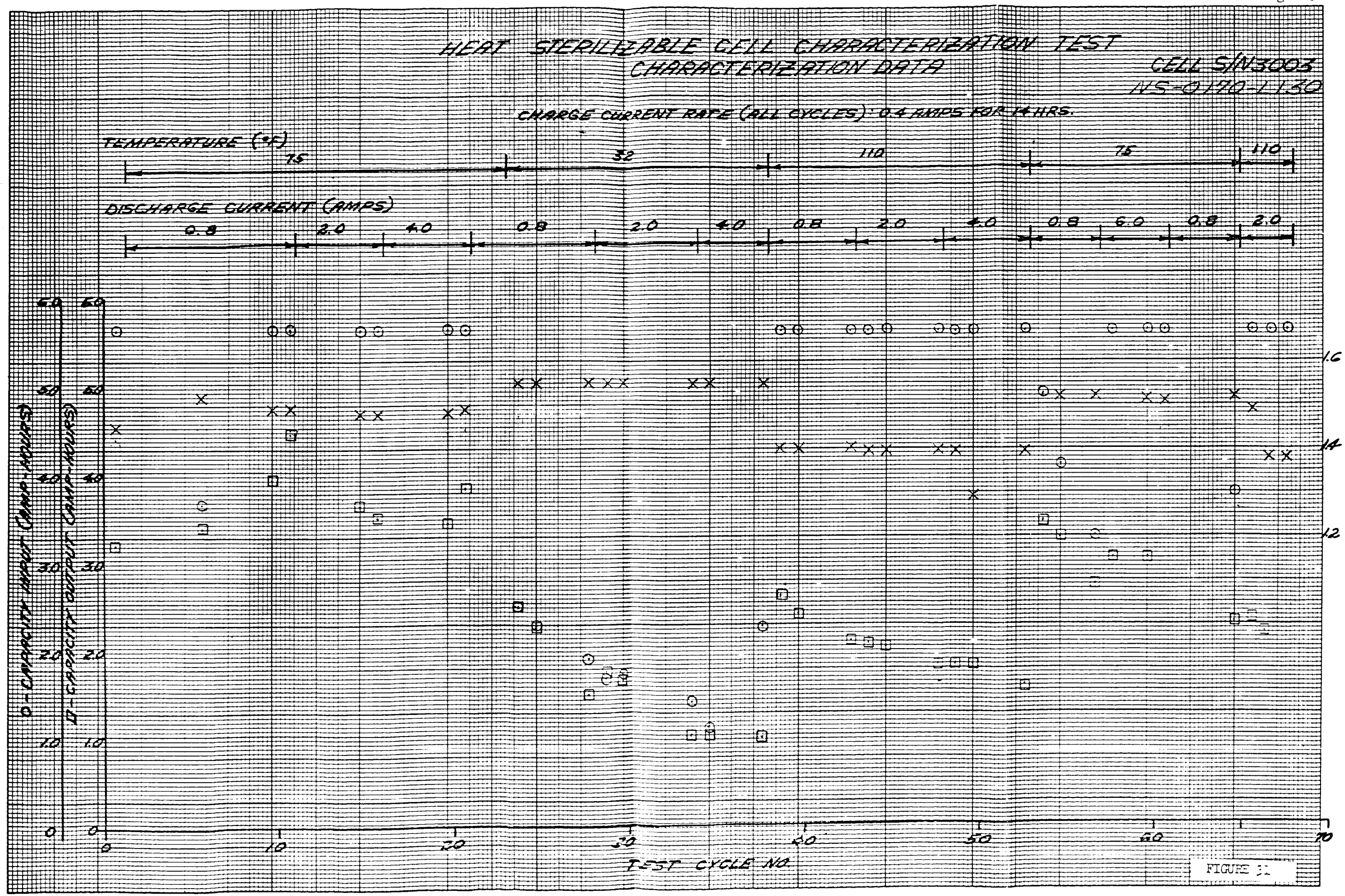

HERT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2997
MS-042-1253
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT CHARGE (AMP-HOURS)
D - CAPACITY OUTPUT DISCHARGE (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
60
50
40
30
20
10
0
10
20
30
40
50
60
70
TEST CYCLE NO.
1.6
1.4
1.2
END OF CHG. VOLT

FIGURE 19


HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N3003
NS-0170-L1.50
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O-CAPACITY INPUT (AMP-HOURS)
X-CAPACITY OUTPUT (AMP-HOURS)
60
50
40
30
20
10
0
1.6
1.4
1.2
CHG VOLT.
END OF CHG
0
10
20
30
40
50
60
70
TEST CYCLE NO.
FIGURE 31

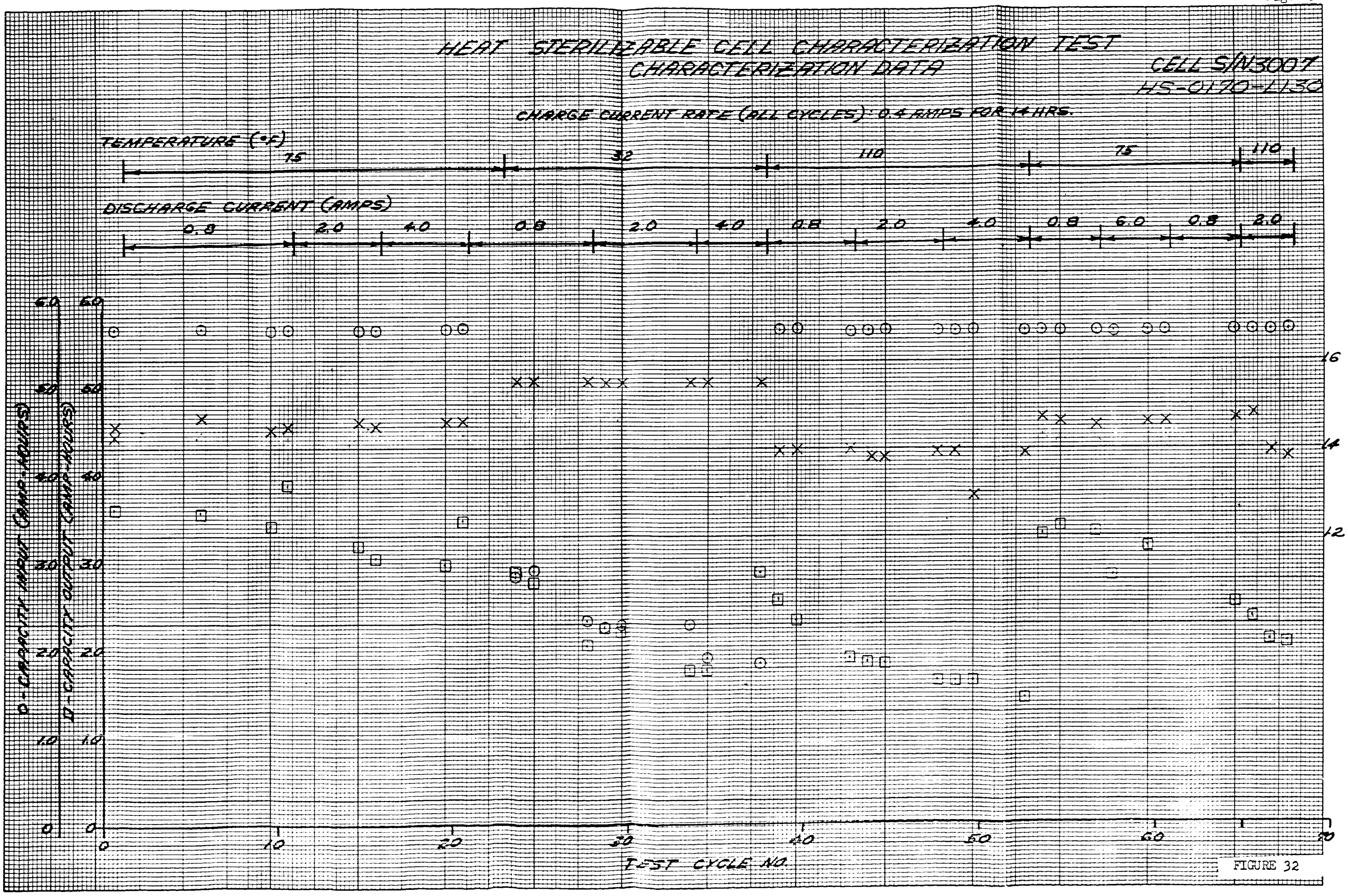

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N3007
HS-0170-L130
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
□ - CAPACITY OUTPUT (AMP-HOURS)
6.0
60
5.0
50
4.0
40
3.0
30
2.0
20
1.0
10
0
0
16
14
12
END OF CHG. VOLT.
0
10
20
30
40
50
60
70
TEST CYCLE NO.

FIGURE 32

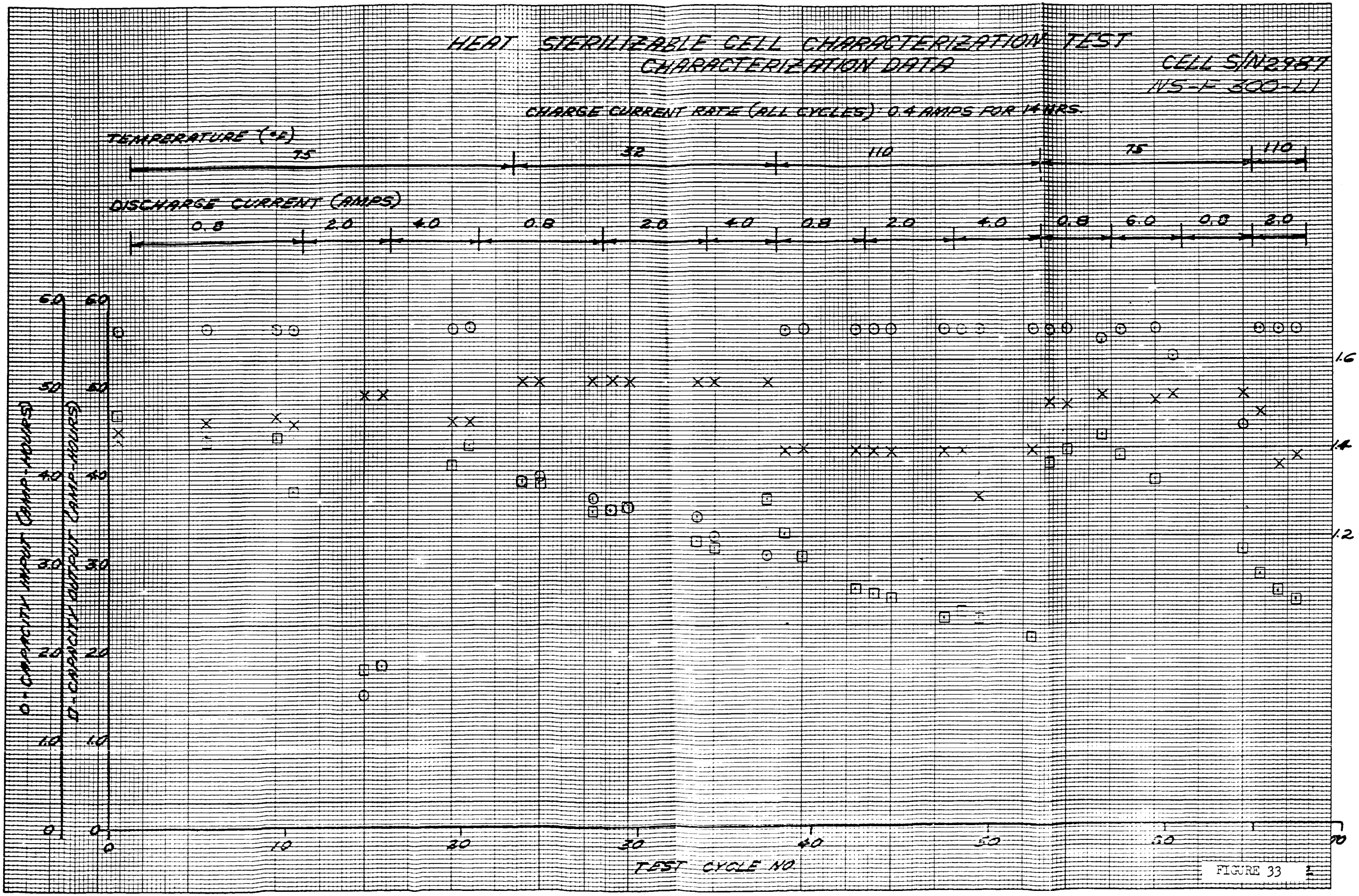

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N2987
NS-F 300-L1
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
□ - CAPACITY OUTPUT (AMP-HOURS)
END OF CHG VOLT.
TEST CYCLE NO
0
10
20
30
40
50
60
70
1.0
1.2
1.4
1.6

FIGURE 33

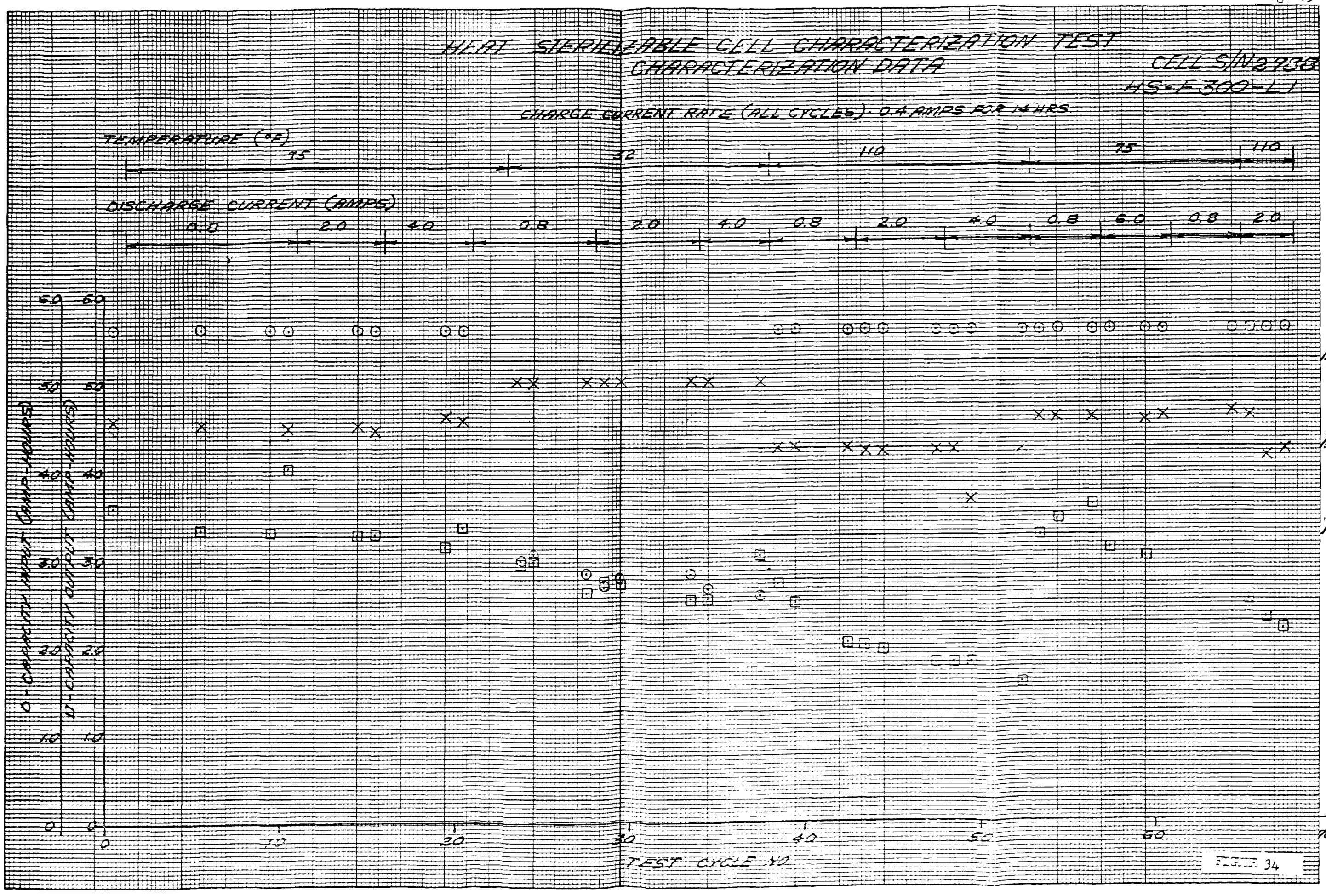
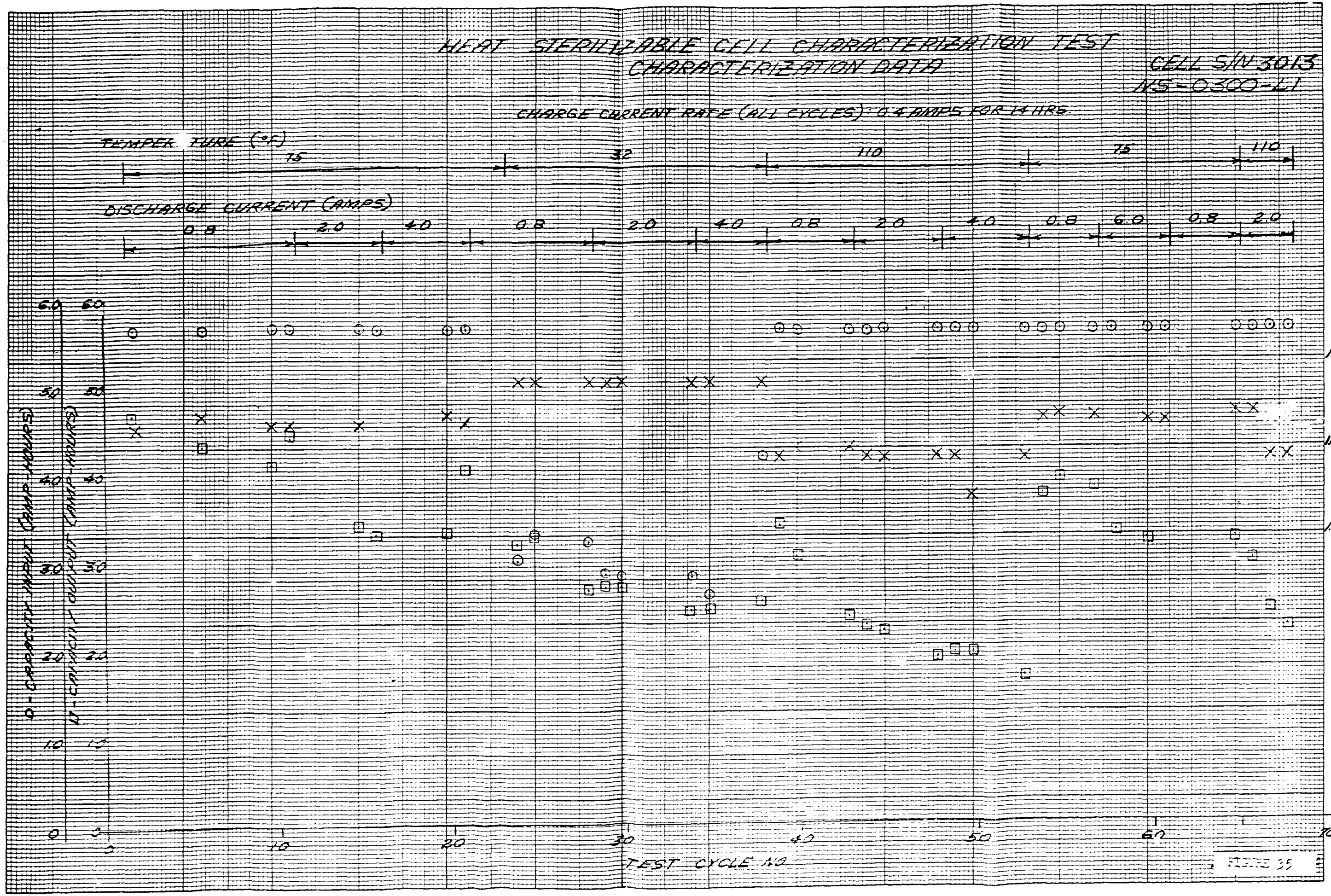

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 2933
HS-F 300-L1
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O-CAPACITY INPUT (AMP-HOURS)
Δ-CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
END OF CHG VOLT
1.6
1.4
1.2
1.0
0
10
20
30
40
50
60
70
TEST CYCLE NO

FIGURE 34


HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 3013
NS-0300-L1
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
X - CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
60
50
40
30
20
10
0
1.6
1.4
1.2
1.0
10
20
30
40
50
60
70
TEST CYCLE NO
FIGURE 35

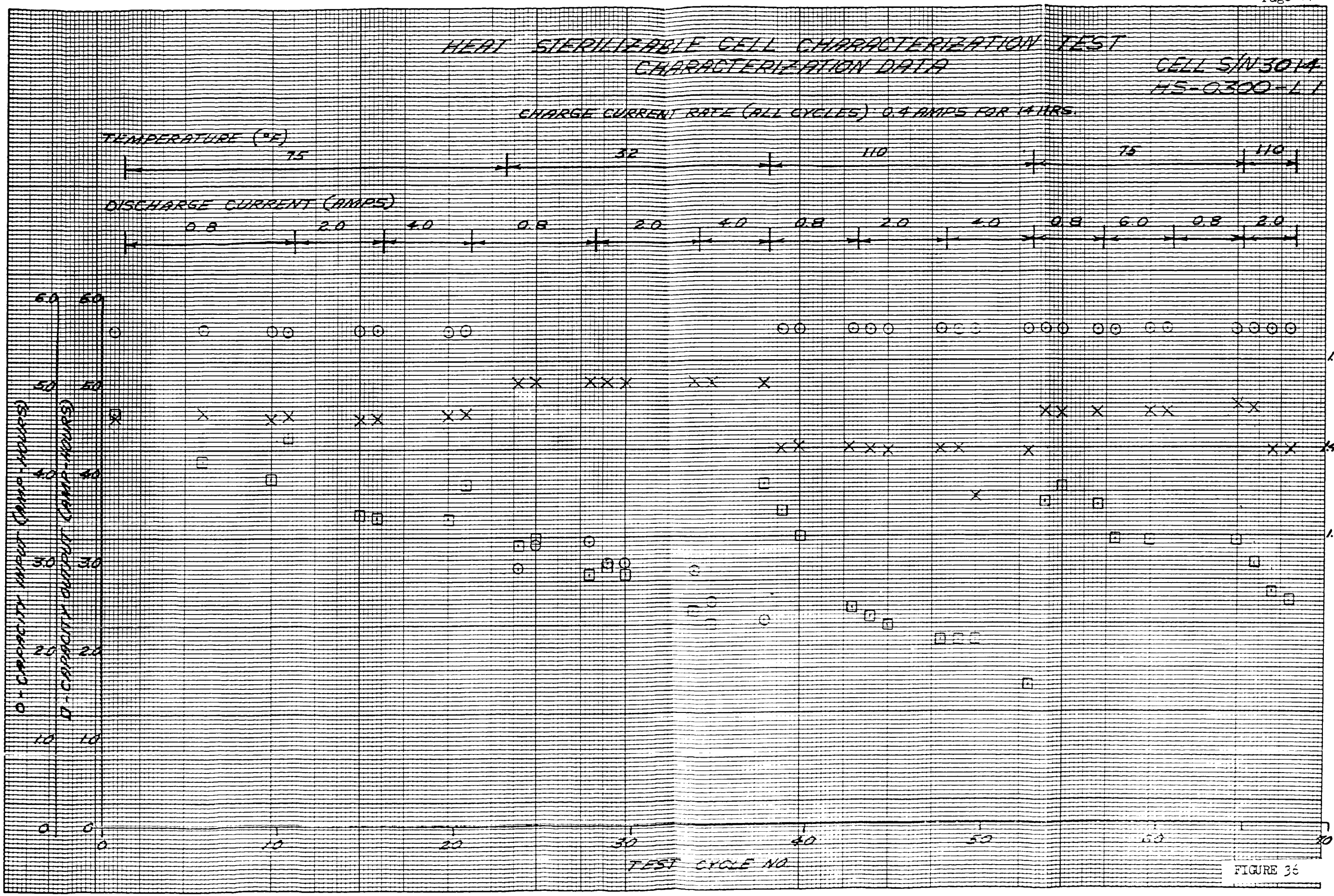

HEAT STERILIZABLE CELL CHARACTERIZATION TEST
CHARACTERIZATION DATA
CELL S/N 3014
HS-0300-L1
CHARGE CURRENT RATE (ALL CYCLES): 0.4 AMPS FOR 14 HRS.
TEMPERATURE (°F)
75
32
110
75
110
DISCHARGE CURRENT (AMPS)
0.8
2.0
4.0
0.8
2.0
4.0
0.8
2.0
4.0
0.8
6.0
0.8
2.0
O - CAPACITY INPUT (AMP-HOURS)
D - CAPACITY OUTPUT (AMP-HOURS)
6.0
5.0
4.0
3.0
2.0
1.0
0
60
50
40
30
20
10
0
10
20
30
40
50
60
70
TEST CYCLE NO.
1.6
1.4
1.2
END OF CHG VOLT.

FIGURE 36

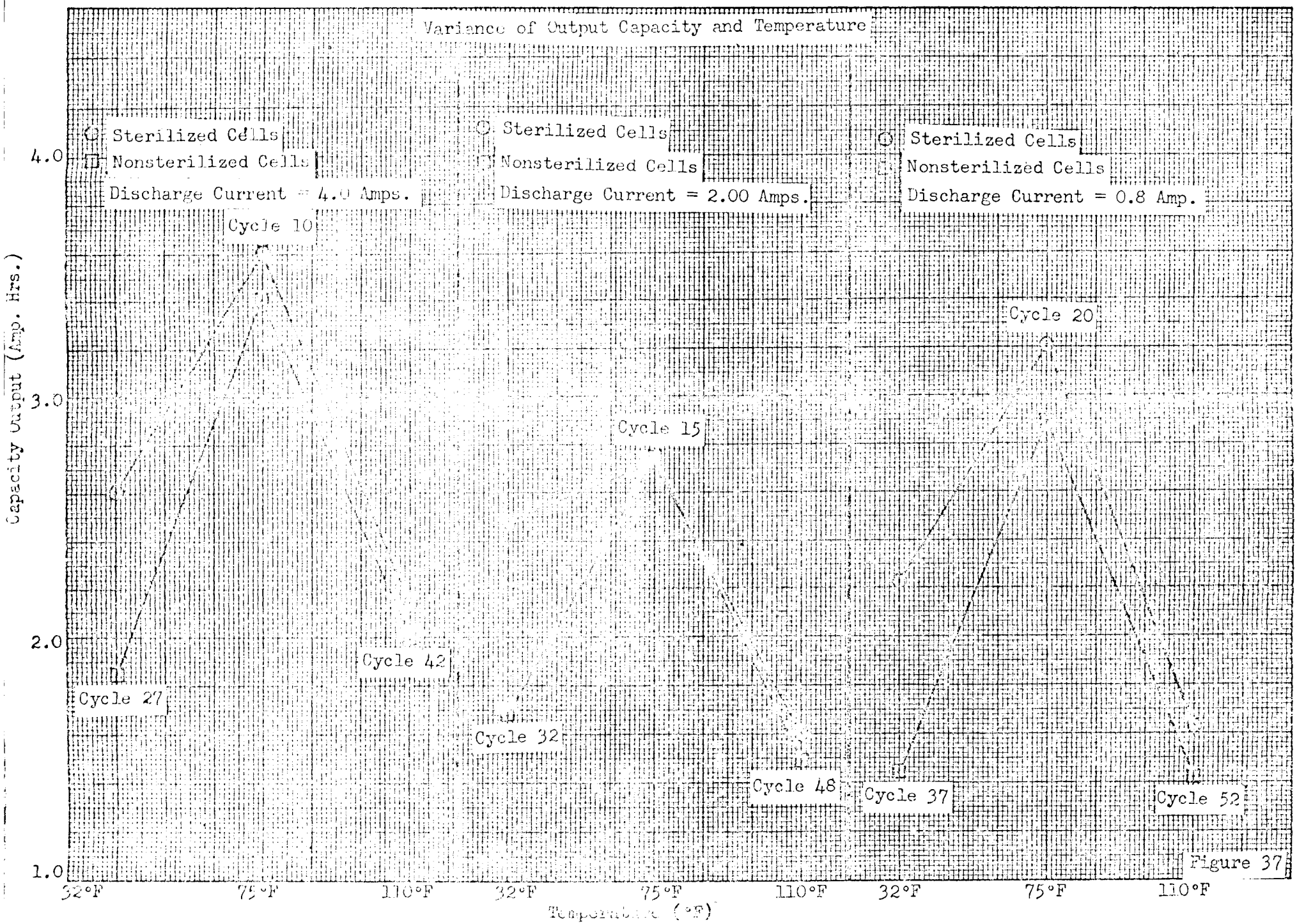

Variance of Output Capacity and Temperature
Sterilized Cells
Nonsterilized Cells
Discharge Current = 4.0 Amps.
Sterilized Cells
Nonsterilized Cells
Discharge Current = 2.00 Amps.
Sterilized Cells
Nonsterilized Cells
Discharge Current = 0.8 Amp.
Cycle 10
Cycle 27
Cycle 42
Cycle 32
Cycle 15
Cycle 48
Cycle 37
Cycle 20
Cycle 52
4.0
3.0
2.0
1.0
Capacity Output (Amp. Hrs.)
32°F
75°F
110°F
32°F
75°F
110°F
32°F
75°F
110°F
Temperature (°F)

Figure 37

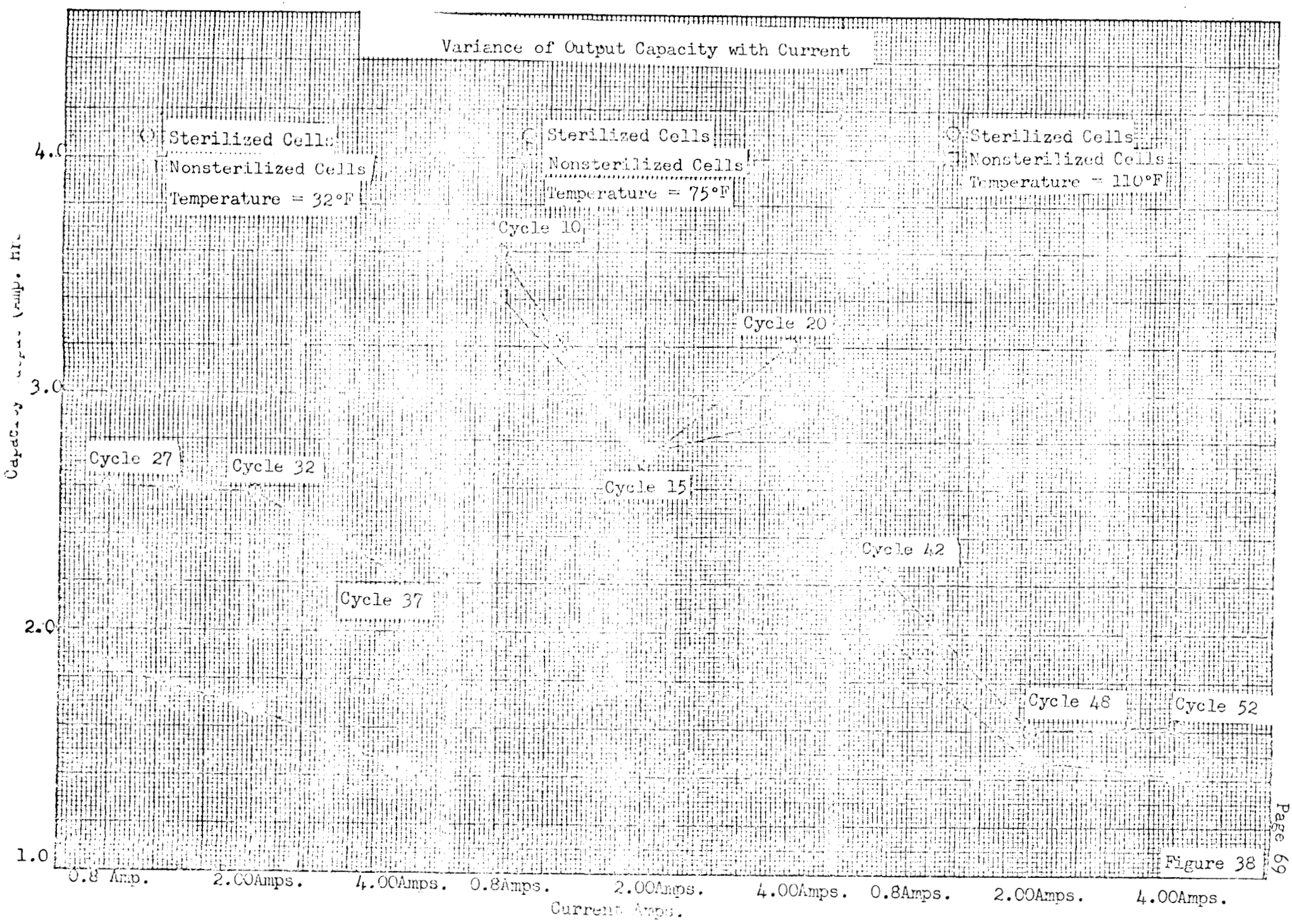

Variance of Output Capacity with Current
Sterilized Cells
Nonsterilized Cells
Temperature = 32°F
Sterilized Cells
Nonsterilized Cells
Temperature = 75°F
Sterilized Cells
Nonsterilized Cells
Temperature = 110°F
Cycle 10
Cycle 20
Cycle 27
Cycle 32
Cycle 15
Cycle 42
Cycle 37
Cycle 48
Cycle 52
4.0
3.0
2.0
1.0
0.8 Amp.
2.00Amps.
4.00Amps.
0.8Amps.
2.00Amps.
4.00Amps.
0.8Amps.
2.00Amps.
4.00Amps.
Current Amps.

Figure 38

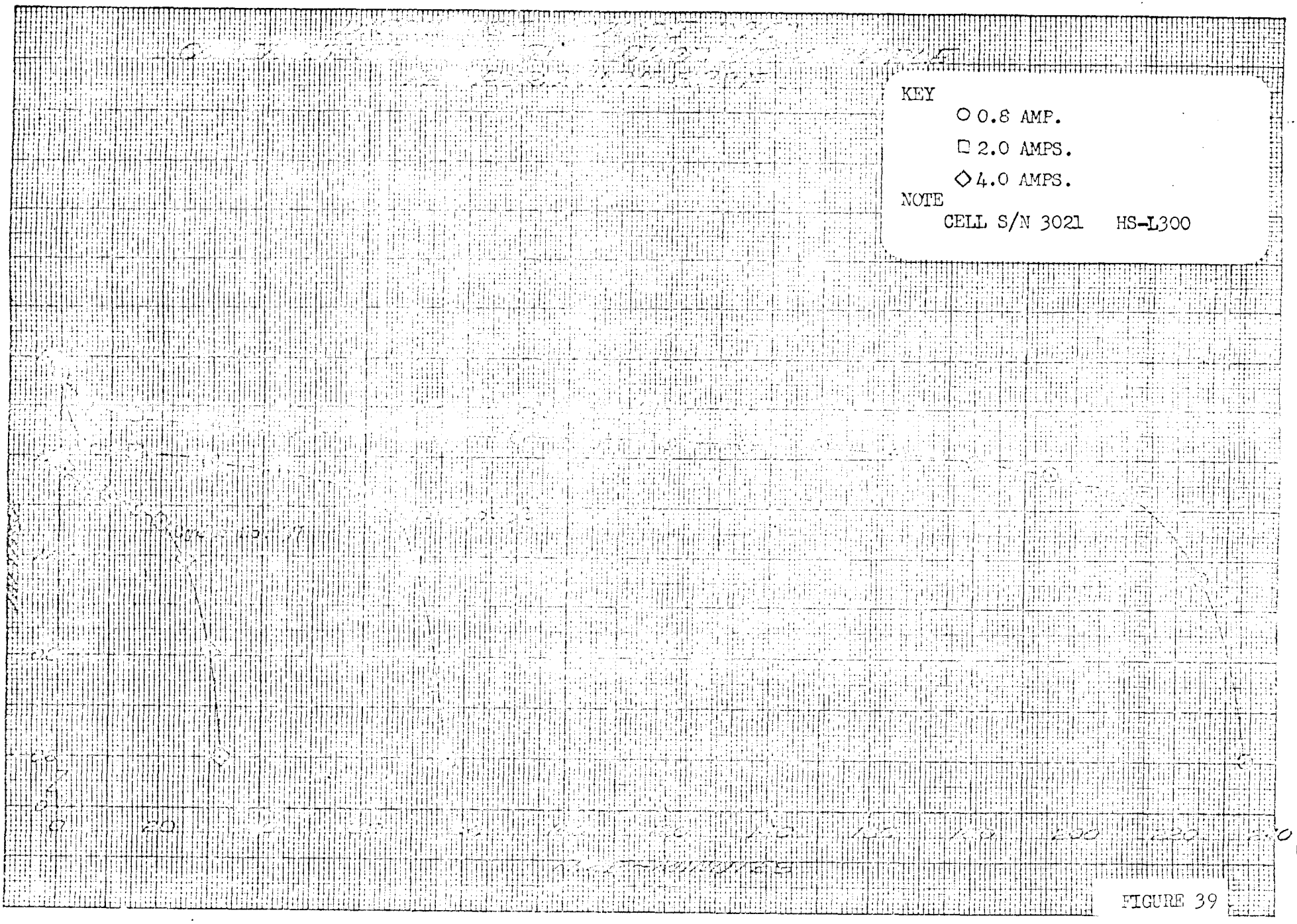


FIGURE 39

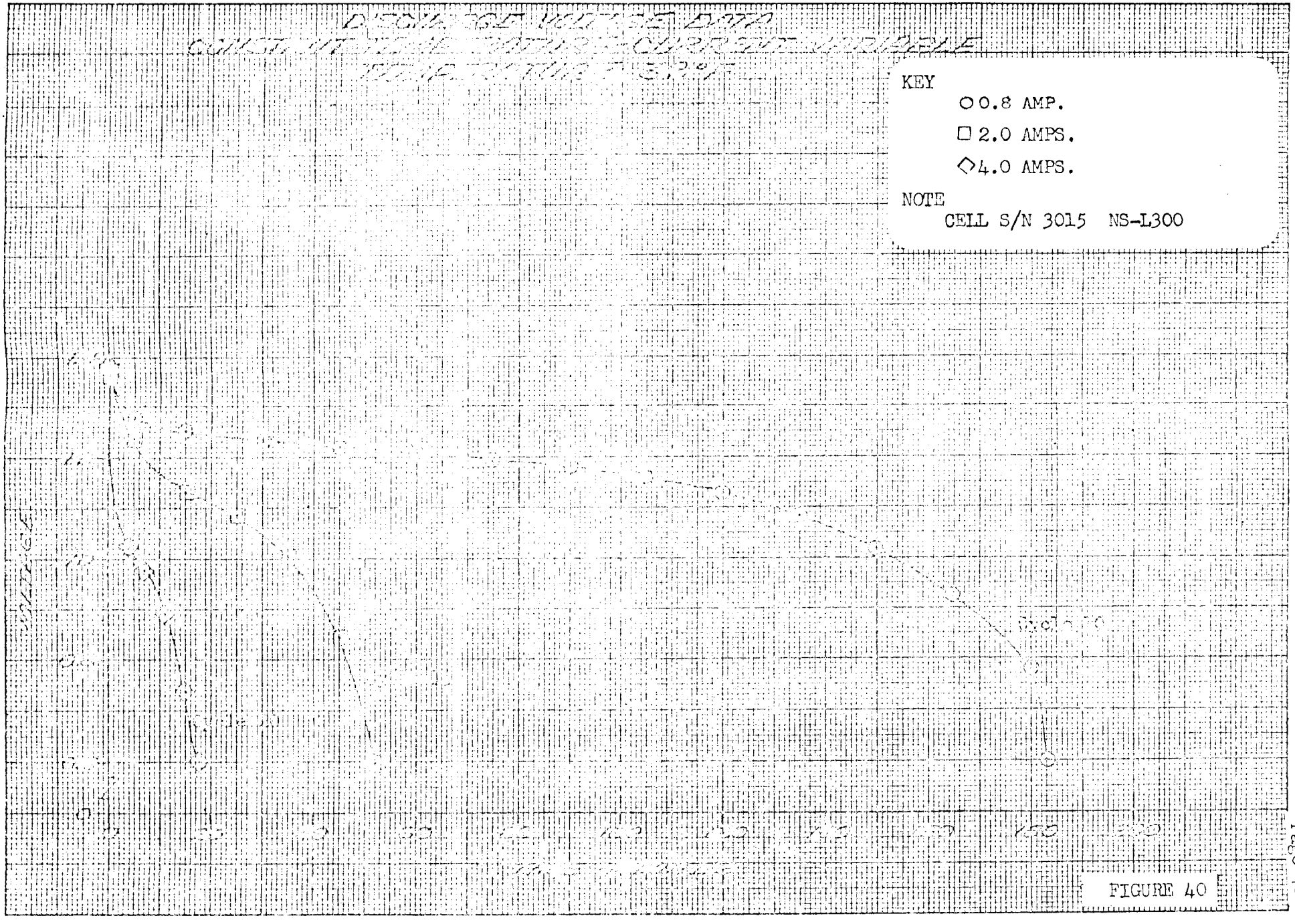


FIGURE 40

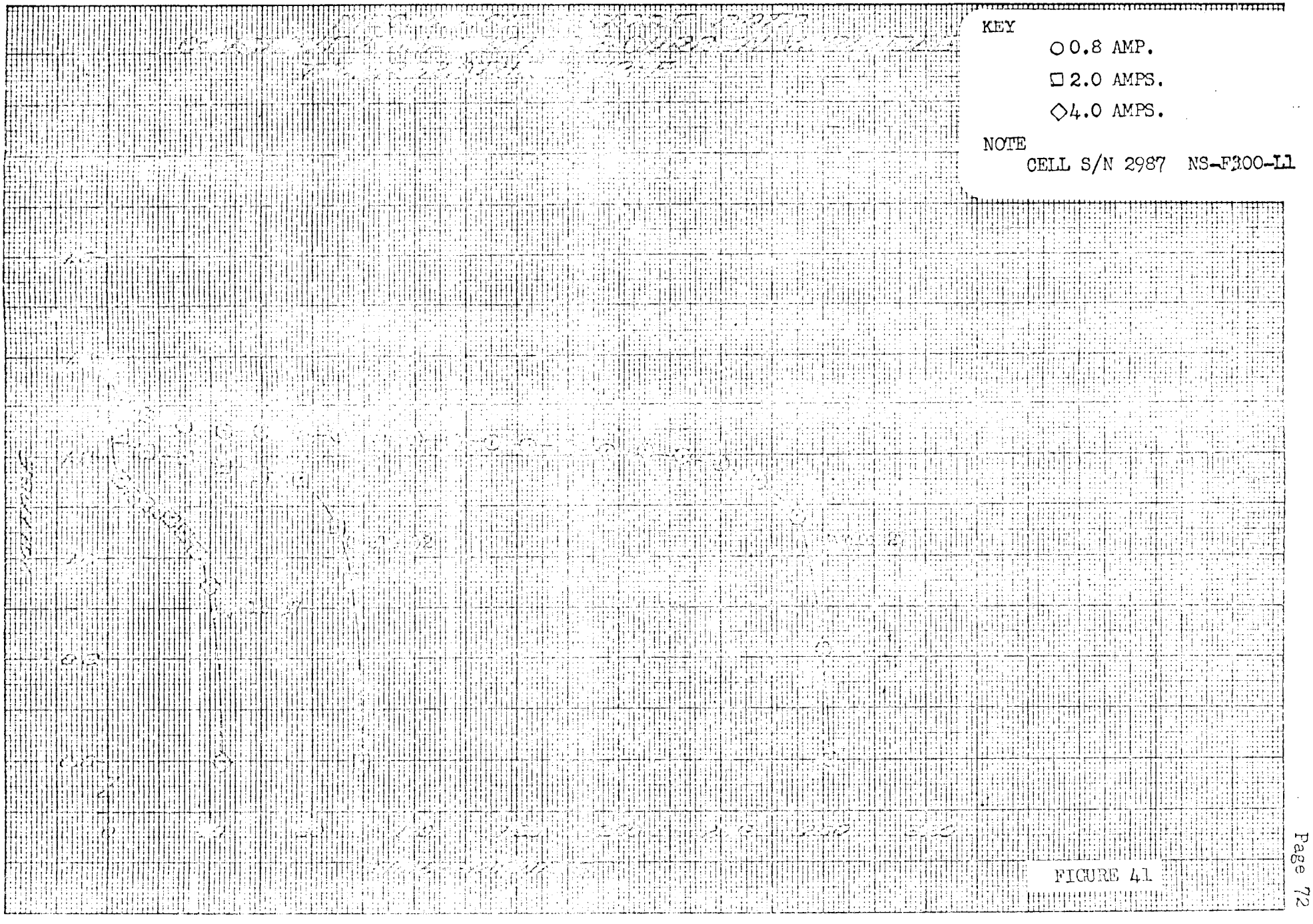


FIGURE 41

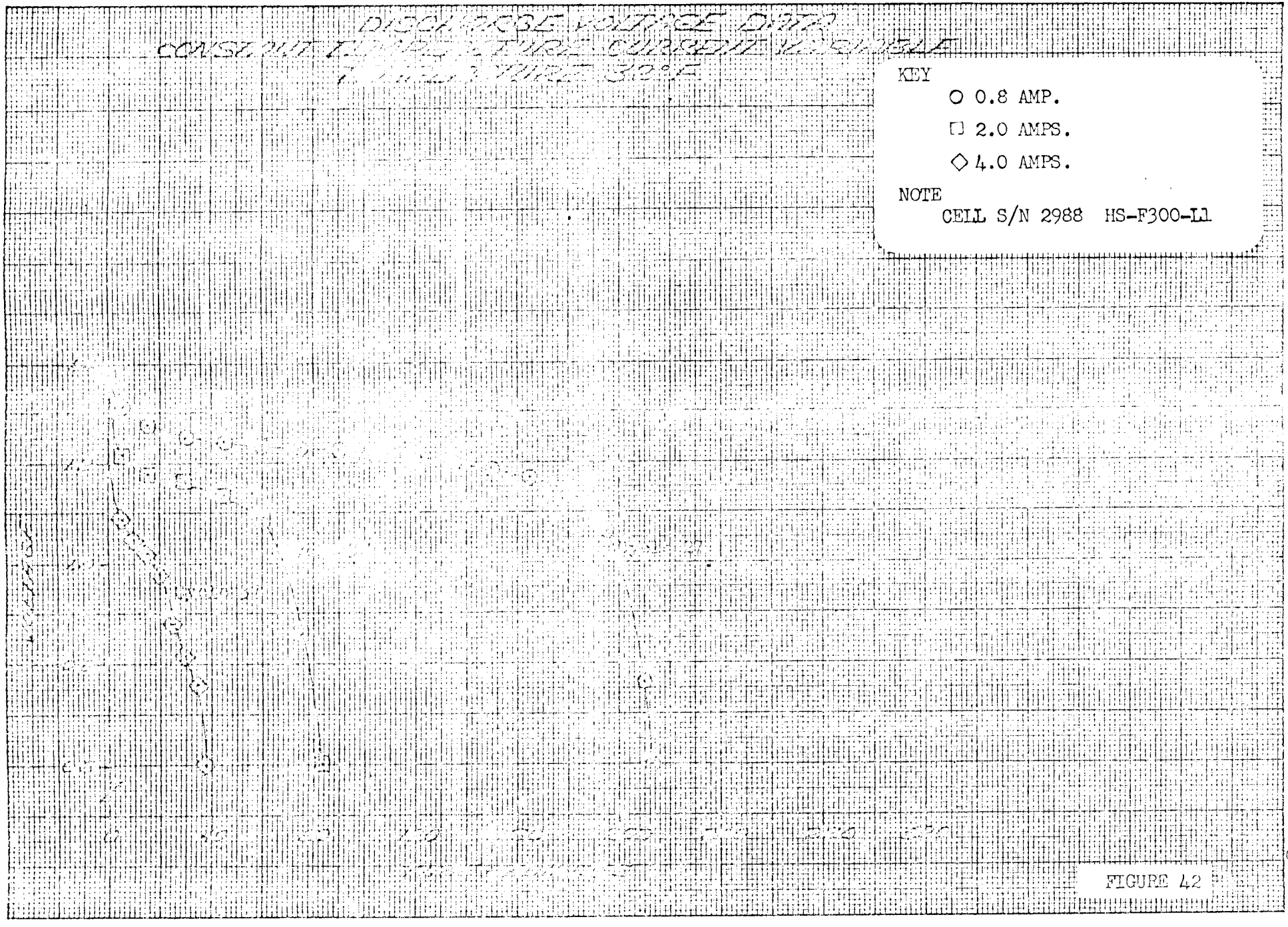


FIGURE 42

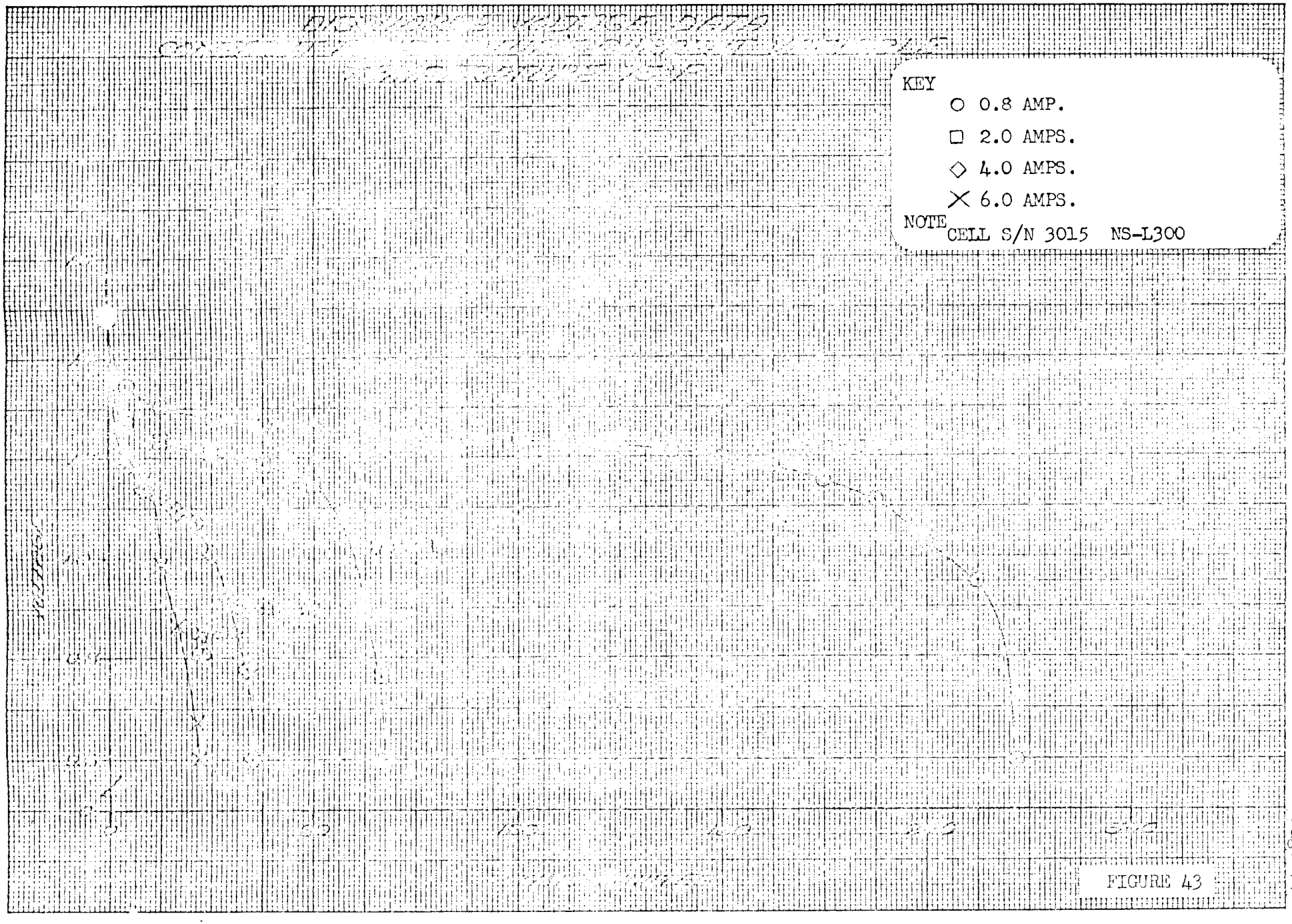


FIGURE 43

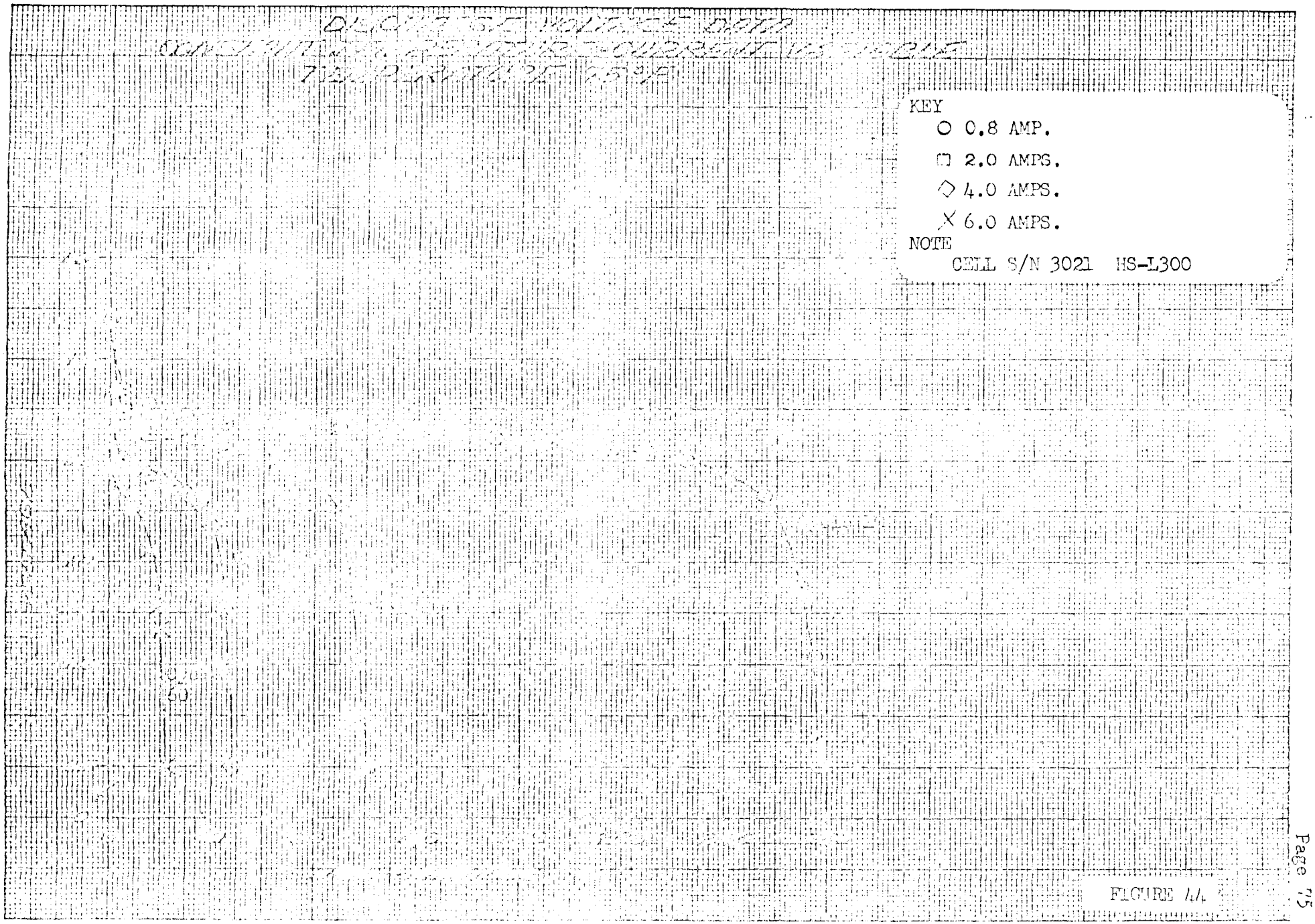


FIGURE 44

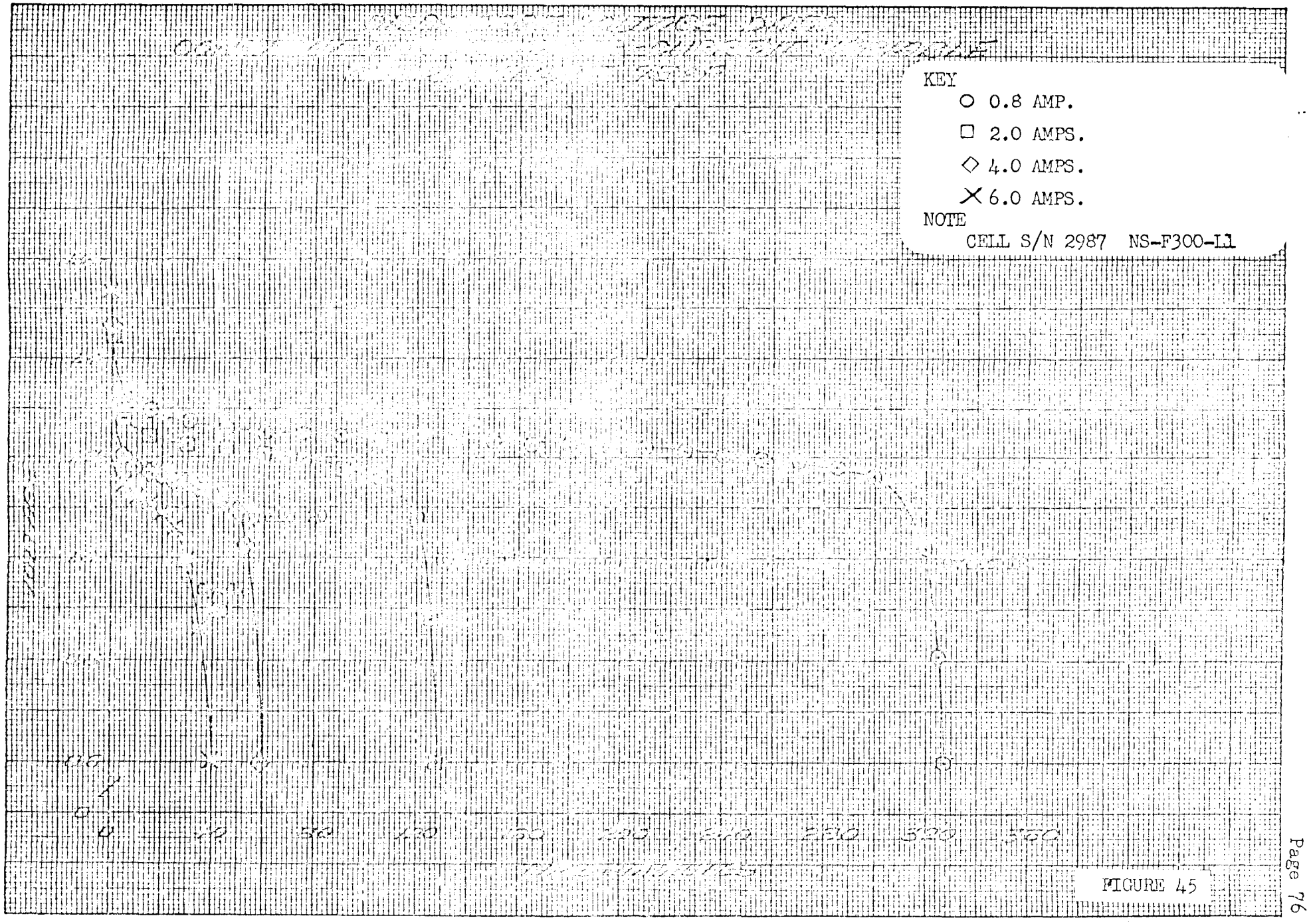


FIGURE 45

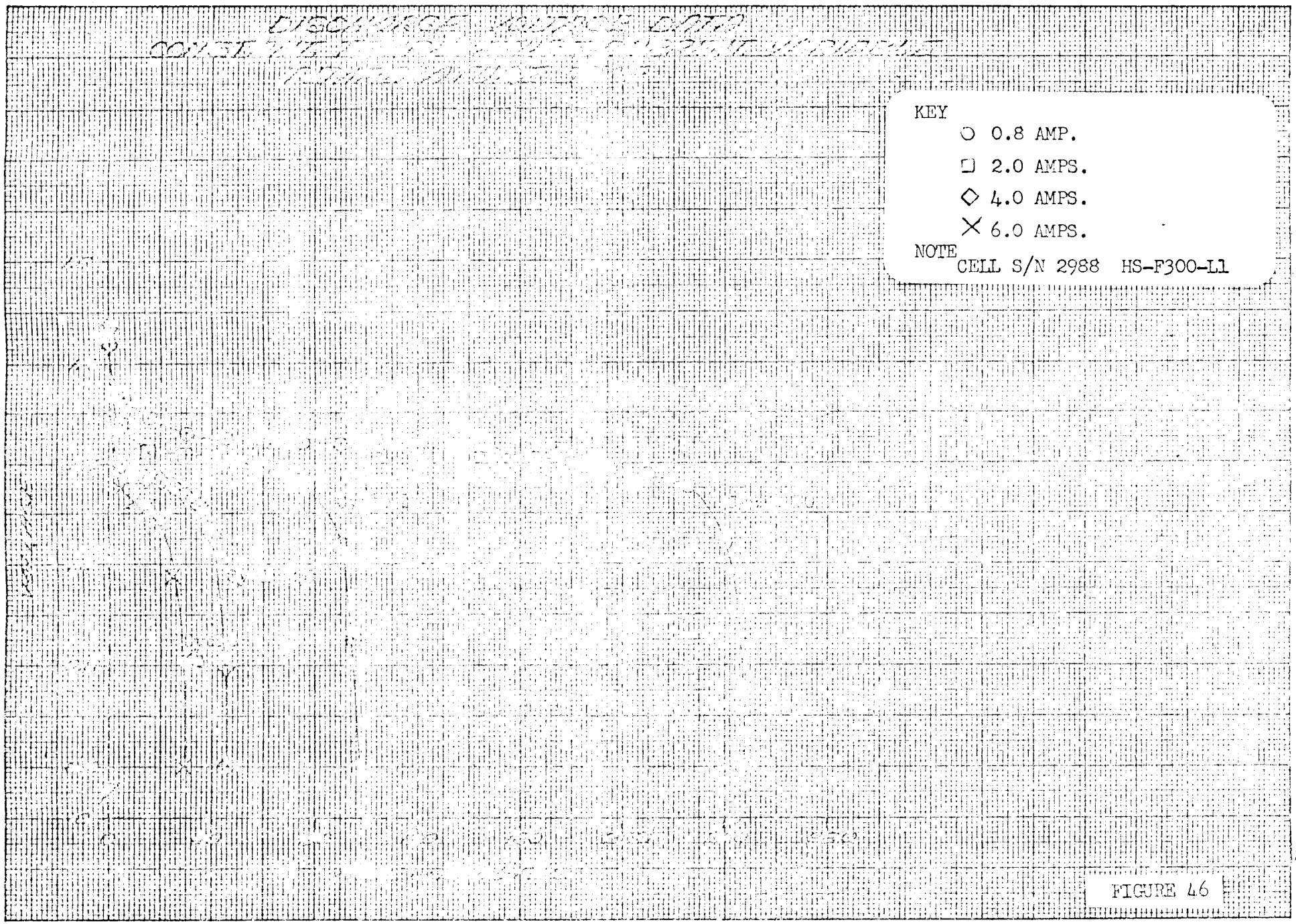


FIGURE 46

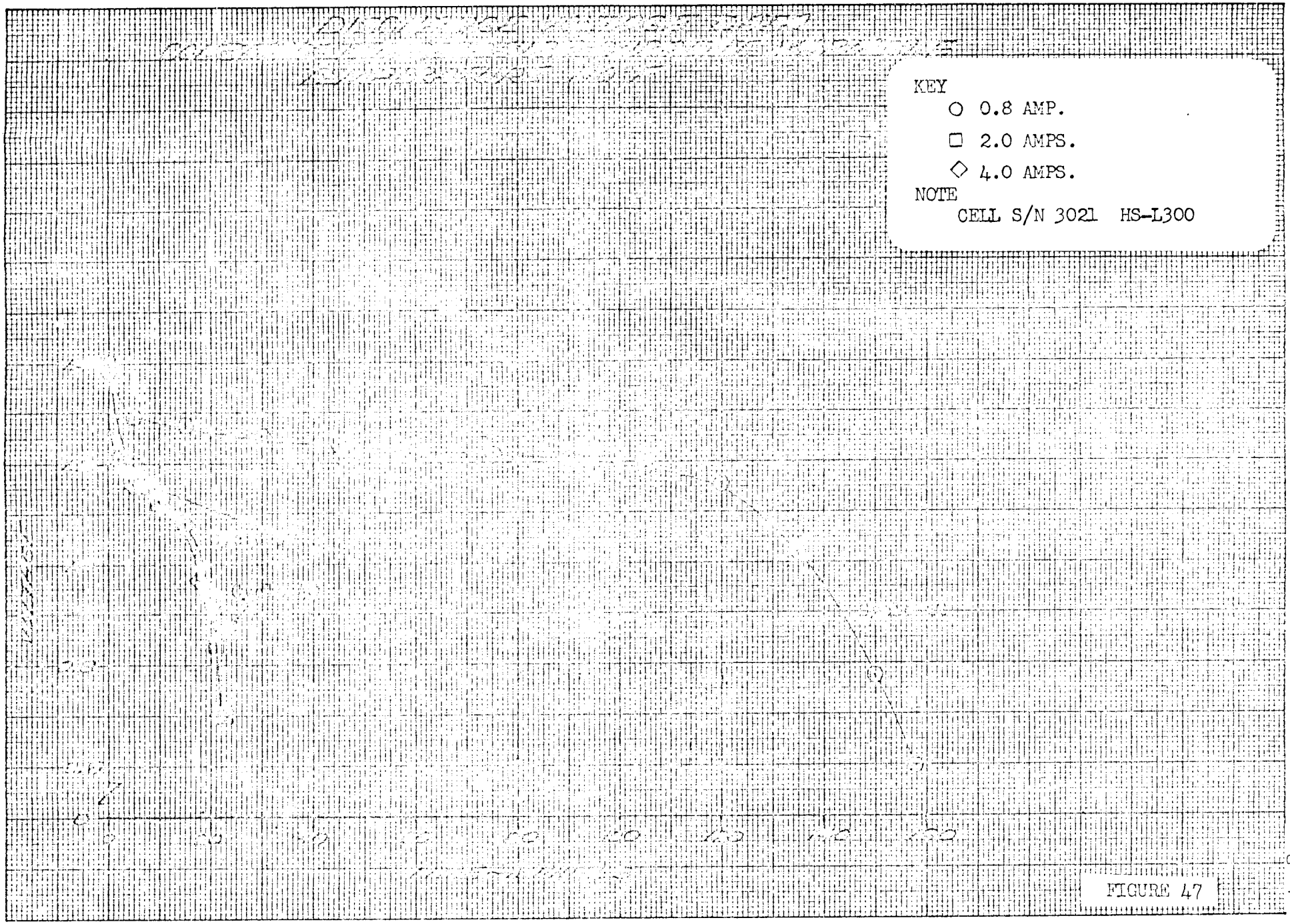


FIGURE 47

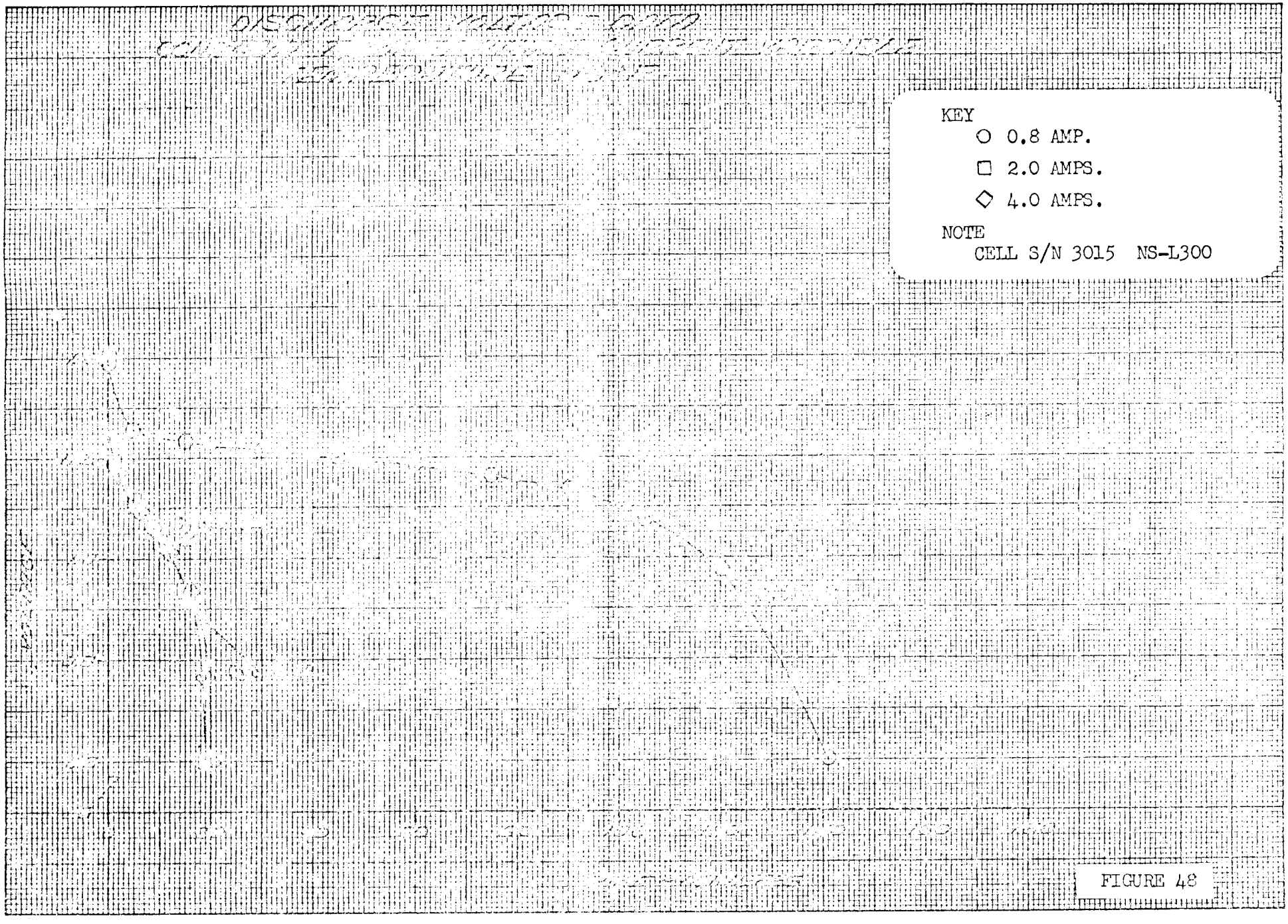


FIGURE 48

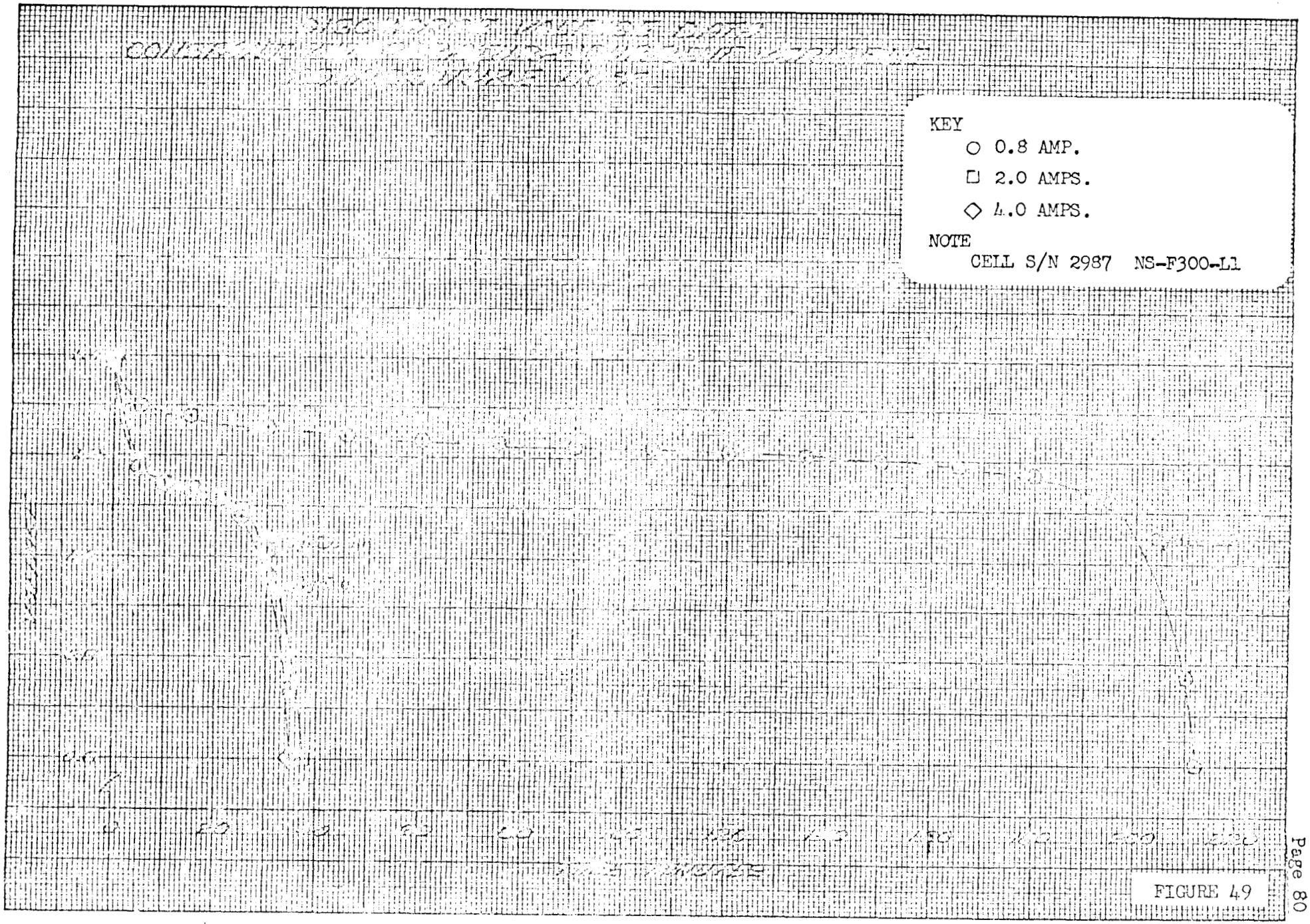


FIGURE 49

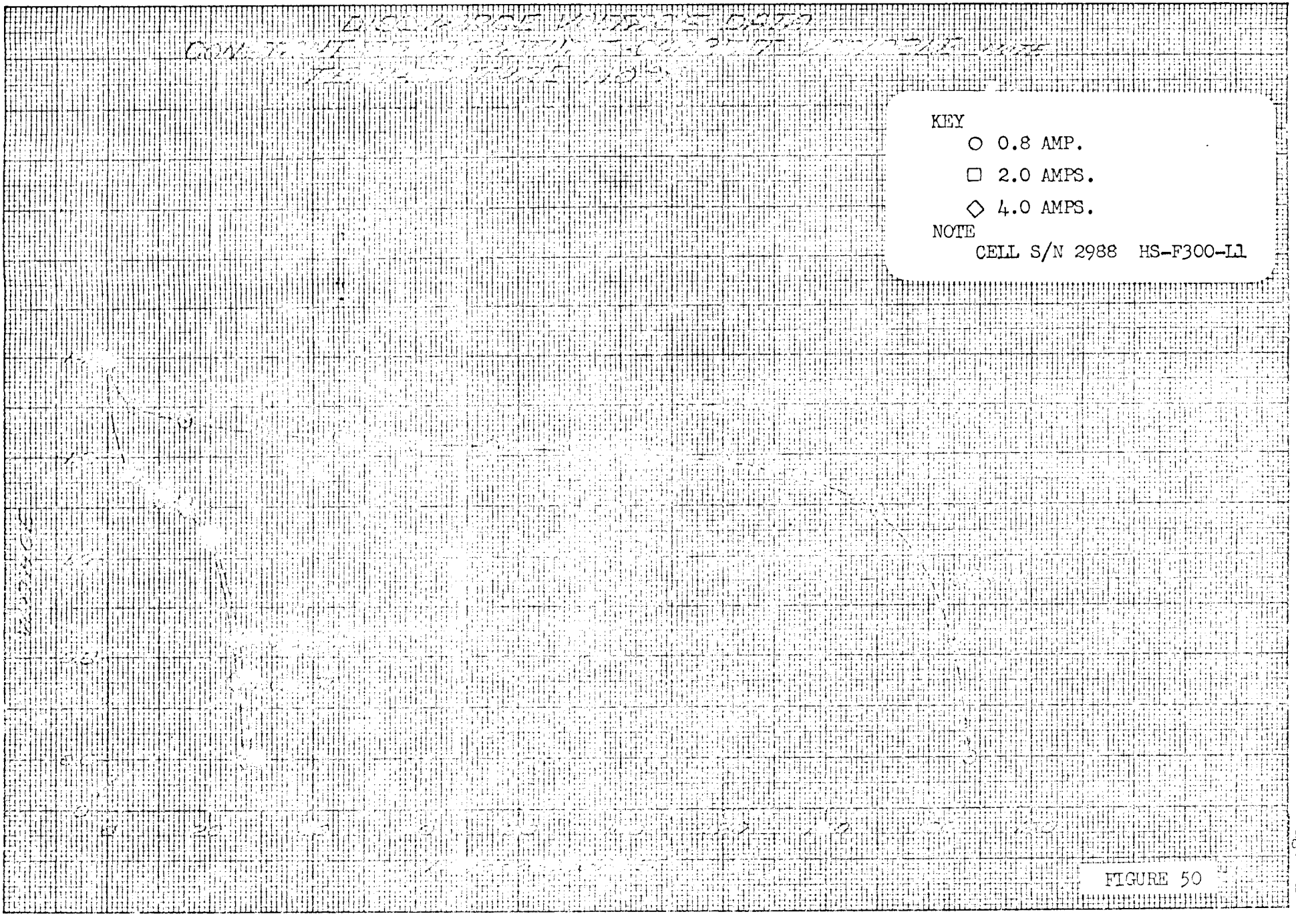


FIGURE 50

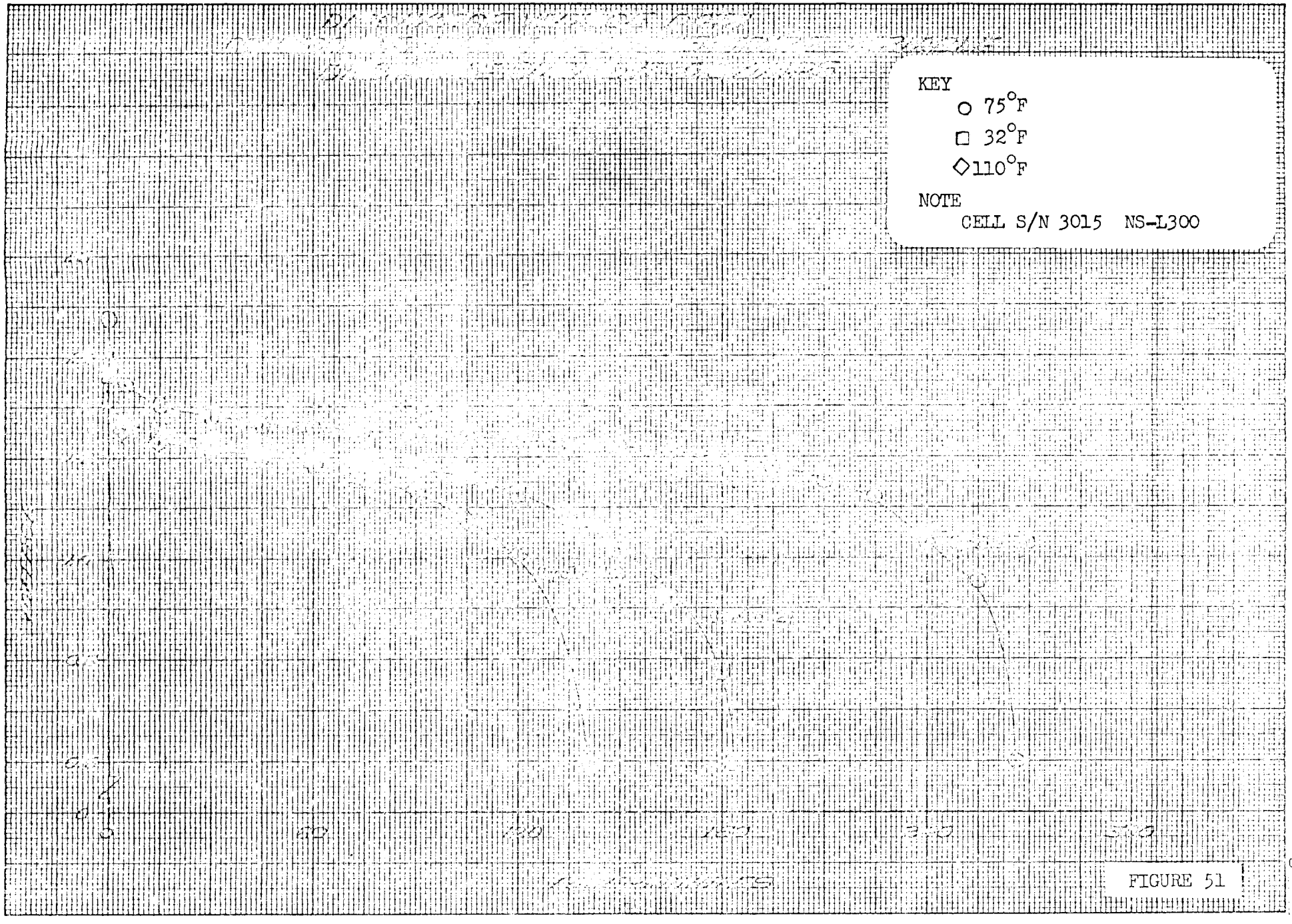


FIGURE 51

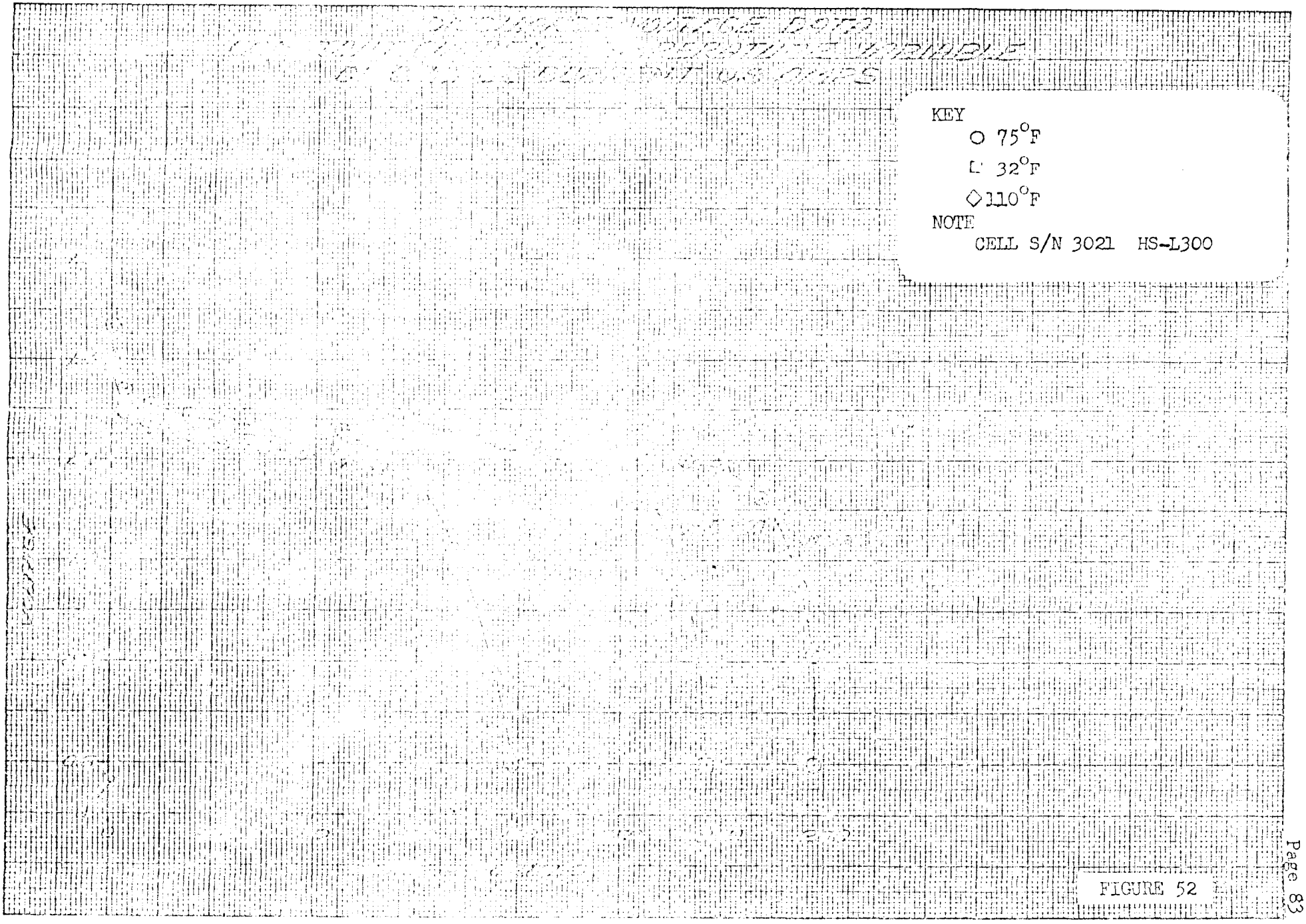


FIGURE 52

FIGURE 53

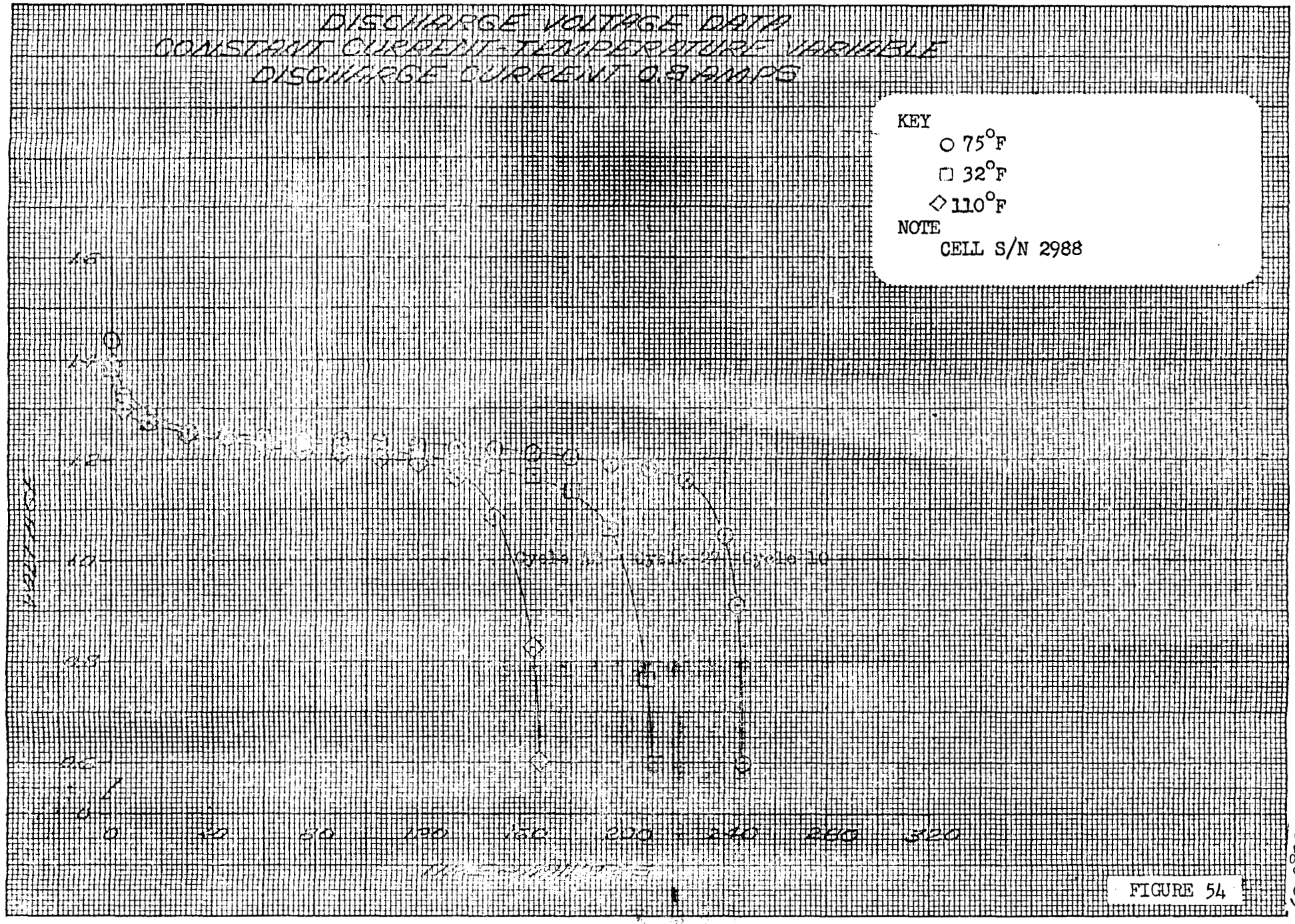

DISCHARGE VOLTAGE DATA
CONSTANT CURRENT-TEMPERATURE VARIABLE
DISCHARGE CURRENT 0.8 AMPS
KEY
○ 75°F
□ 32°F
◇ 110°F
NOTE
CELL S/N 2988
0
40
80
120
160
200
240
280
320

FIGURE 54

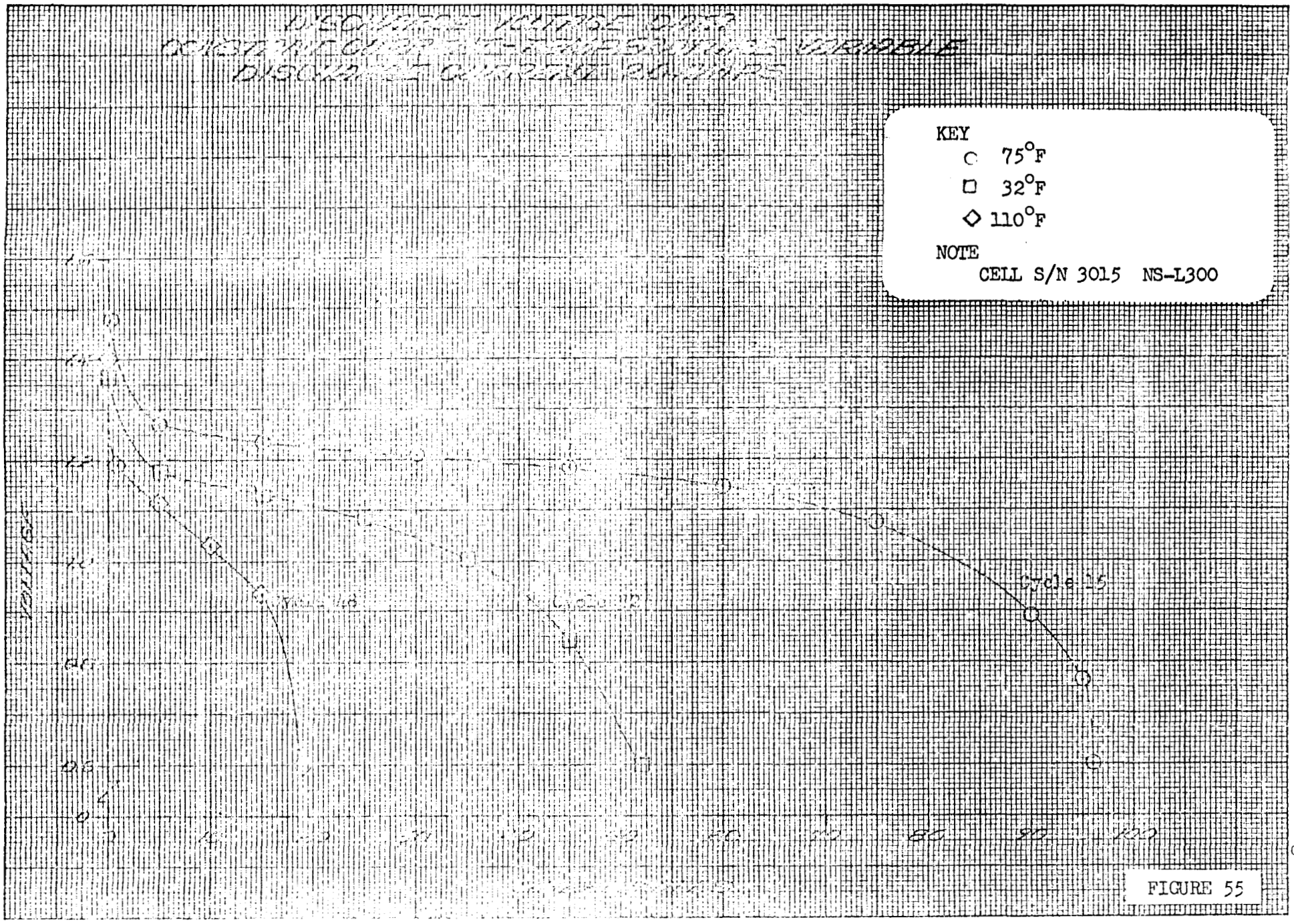


FIGURE 55

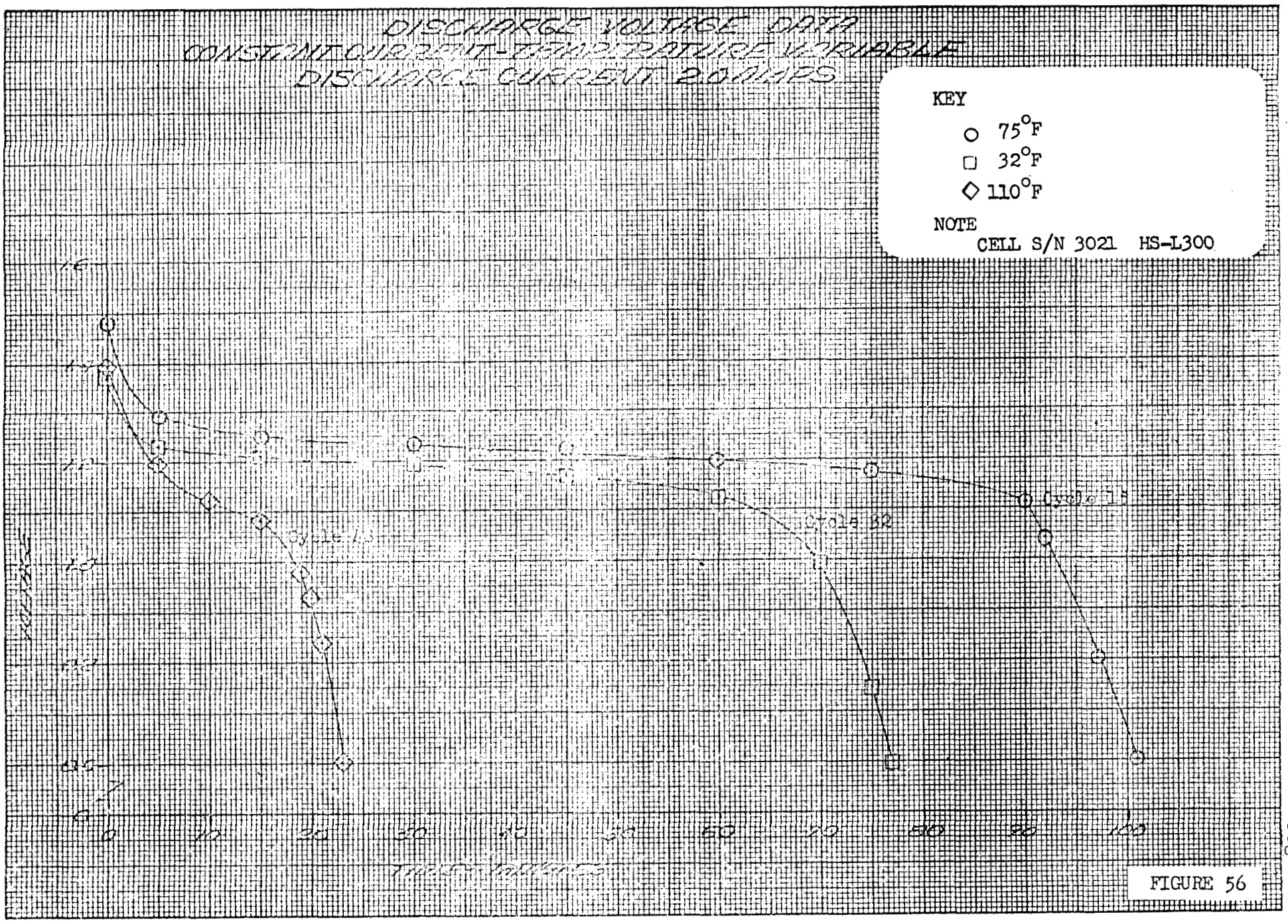

DISCHARGE VOLTAGE DATA
CONSTANT CURRENT-TEMPERATURE VARIABLE
DISCHARGE CURRENT 2.0 AMPS
KEY
75°F
32°F
110°F
NOTE
CELL S/N 3021 HS-L300
Cycle 32
Cycle 15
VOLTAGE
0
10
20
30
40
50
60
70
80
90
100

FIGURE 56

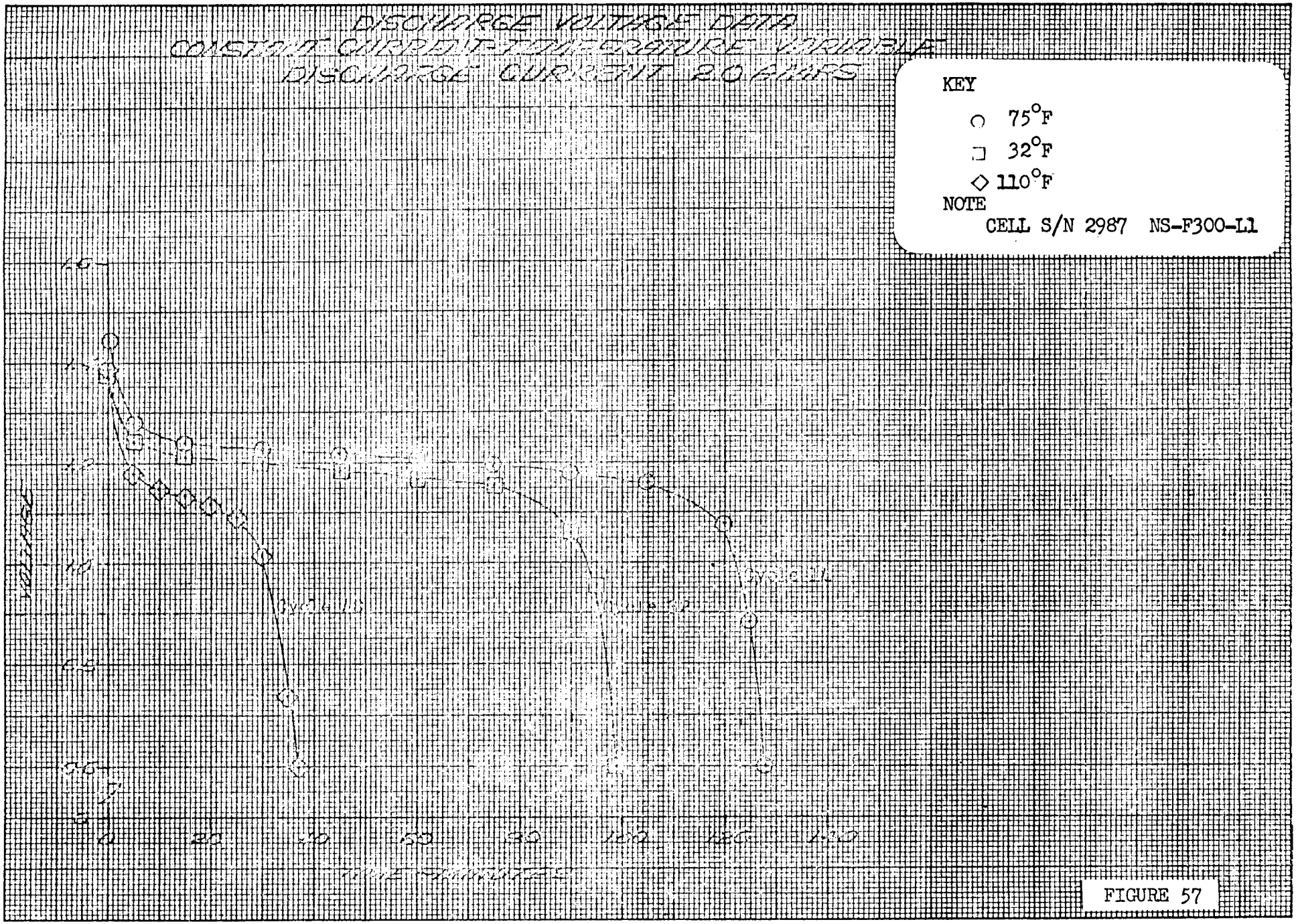

DISCHARGE VOLTAGE DATA
CONSTANT CURRENT-TEMPERATURE VARIABLE
DISCHARGE CURRENT 2.0 AMPS
KEY
75°F
32°F
110°F
NOTE
CELL S/N 2987 NS-F300-L1

FIGURE 57

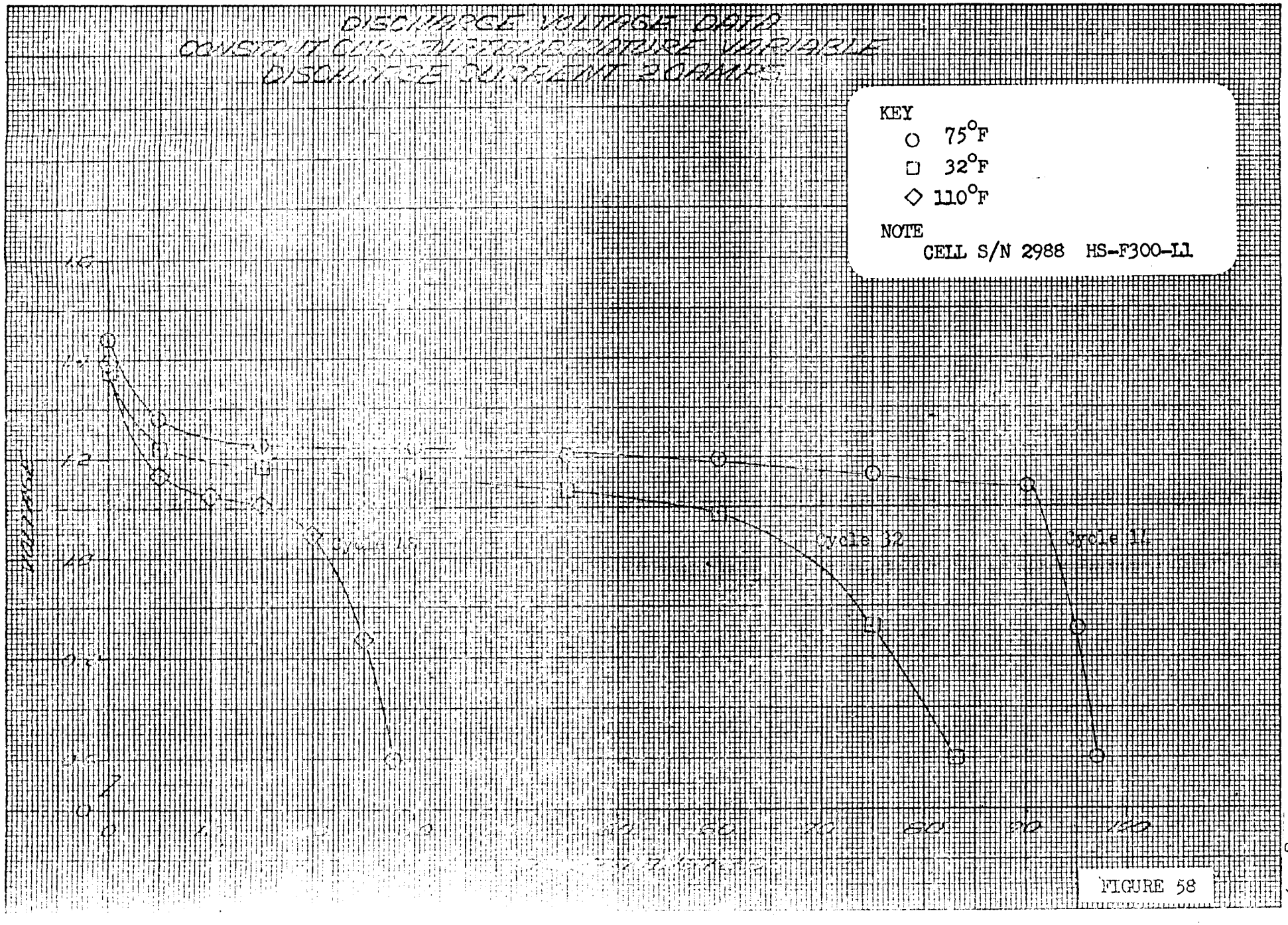

DISCHARGE VOLTAGE DATA
CONSTANT CURRENT-TEMPERATURE VARIABLE
DISCHARGE CURRENT 20AMPS
KEY
○ 75°F
□ 32°F
◇ 110°F
NOTE
CELL S/N 2988 HS-F300-L1
Cycle 15
Cycle 32
Cycle 11

FIGURE 58

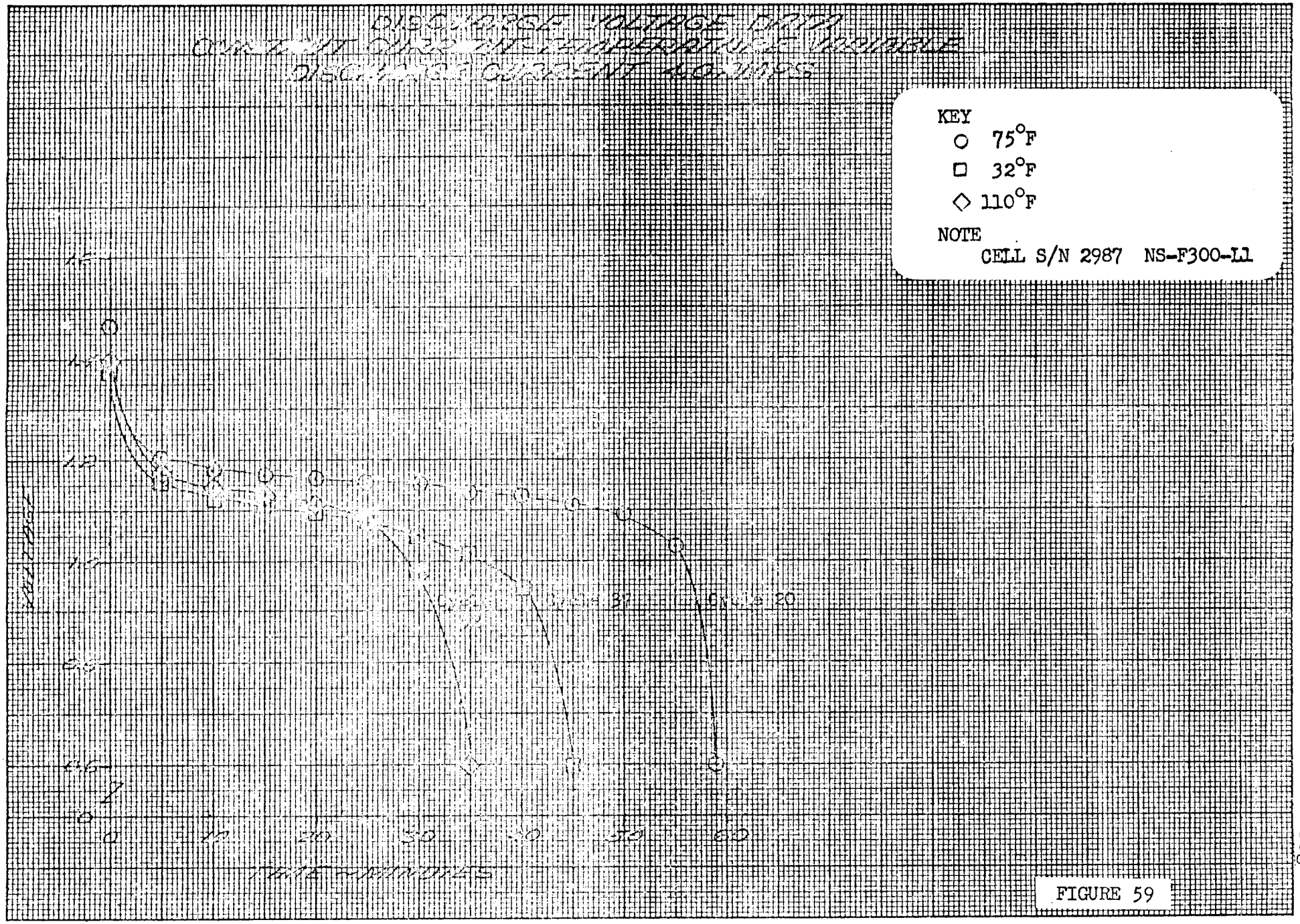


FIGURE 59

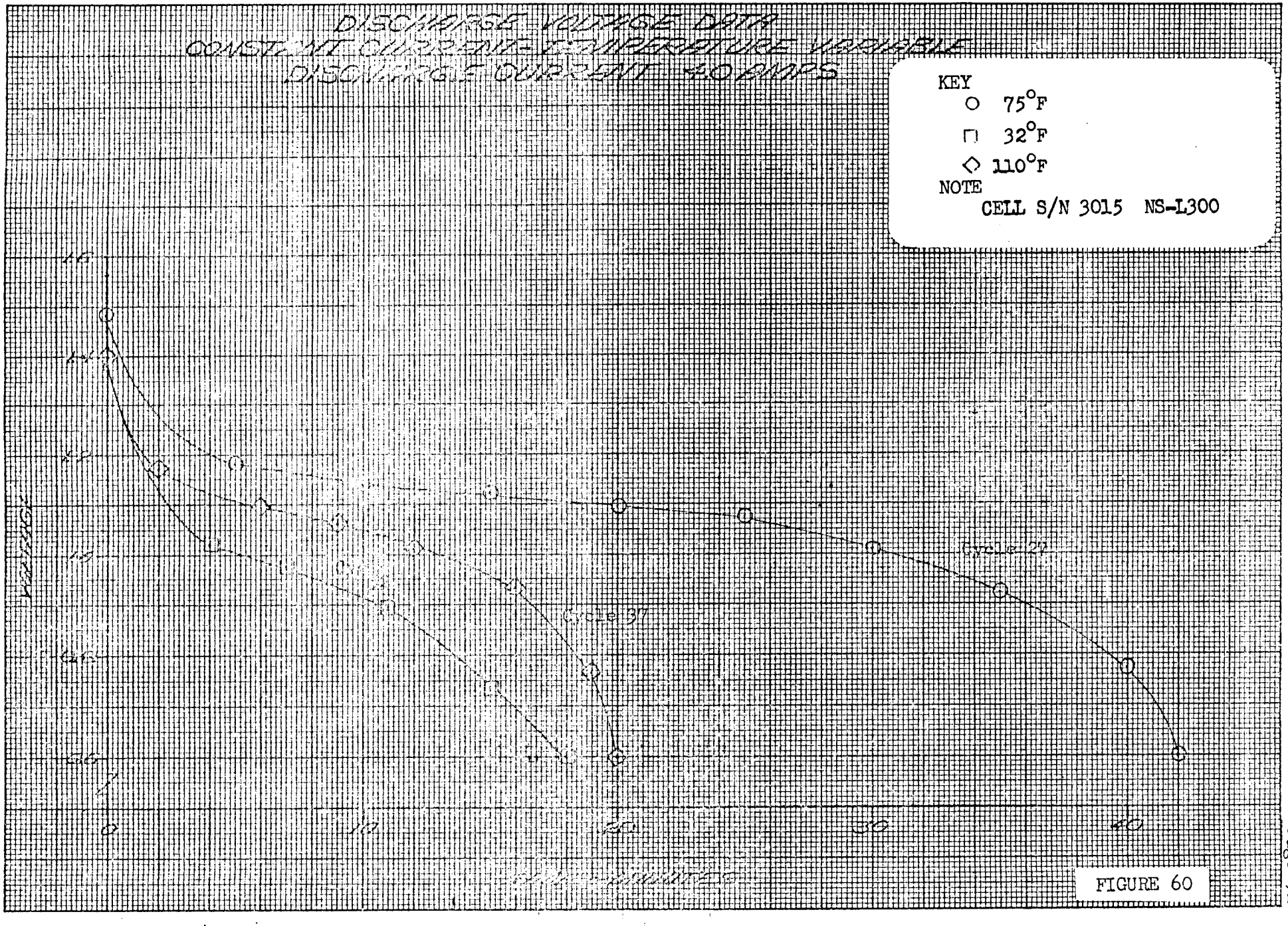

DISCHARGE VOLTAGE DATA
CONSTANT CURRENT-TEMPERATURE VARIABLE
DISCHARGE CURRENT 40 AMPS
KEY
75°F
32°F
110°F
NOTE
CELL S/N 3015 NS-L300
Cycle 27
Cycle 37
0
10
20
30
40

FIGURE 60

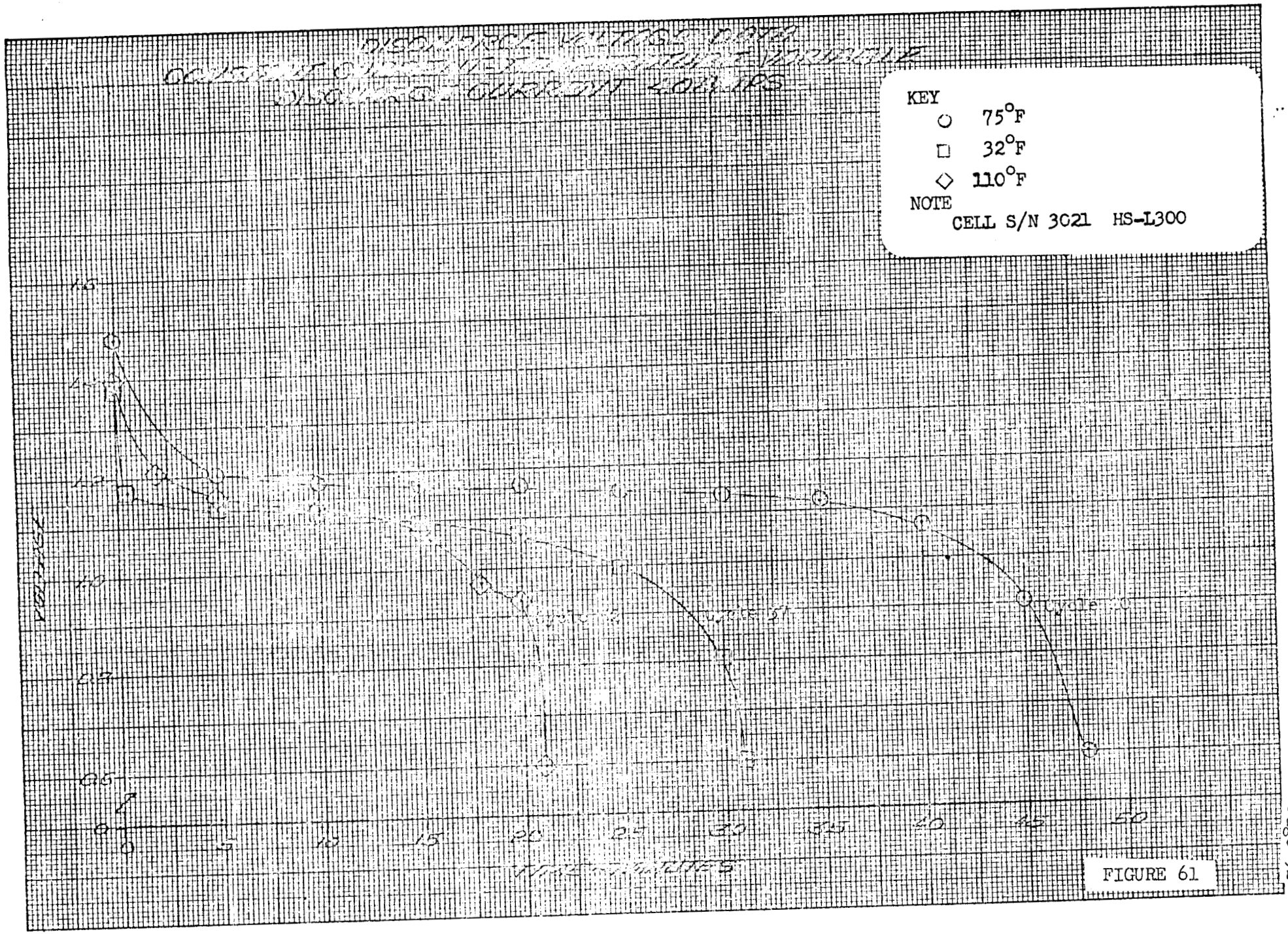


FIGURE 61

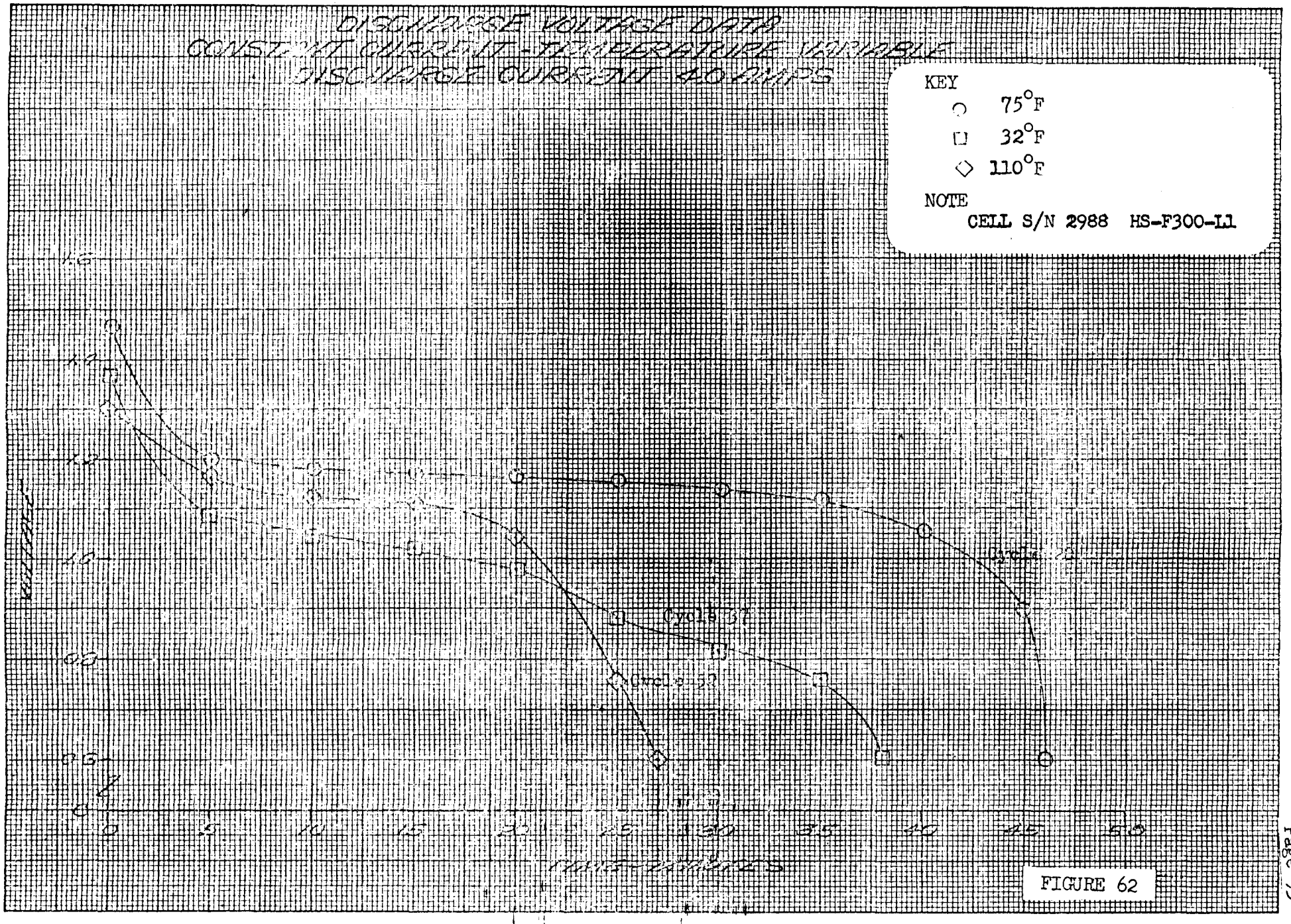

DISCHARGE VOLTAGE DATA
CONSTANT CURRENT - TEMPERATURE VARIABLE
DISCHARGE CURRENT 40 AMPS
KEY
75°F
32°F
110°F
NOTE
CELL S/N 2988 HS-F300-L1
Cycle 37
Cycle 52
VOLTAGE
TIME - MINUTES
0
5
10
15
20
25
30
35
40
45
50

FIGURE 62

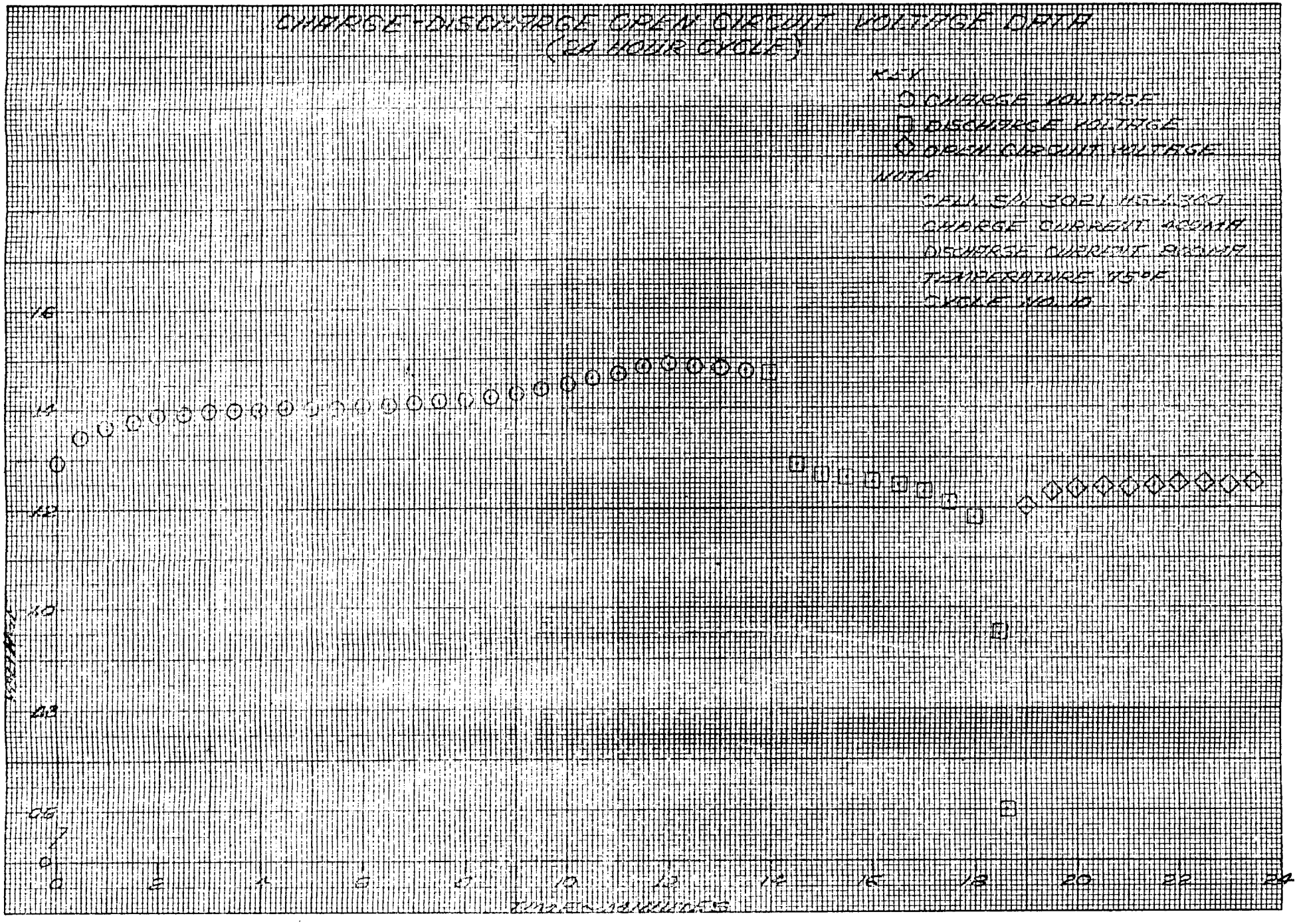

CHARGE-DISCHARGE OPEN CIRCUIT VOLTAGE DATA
(24 HOUR CYCLE)
KEY
CHARGE VOLTAGE
DISCHARGE VOLTAGE
OPEN CIRCUIT VOLTAGE
NOTE
CELL S/N 3021 HS-1300
CHARGE CURRENT 400MA
DISCHARGE CURRENT 800MA
TEMPERATURE 75°F
CYCLE NO. 10
16
14
12
10
08
06
0
0
2
4
6
8
10
12
14
16
18
20
22
24

FIGURE 63

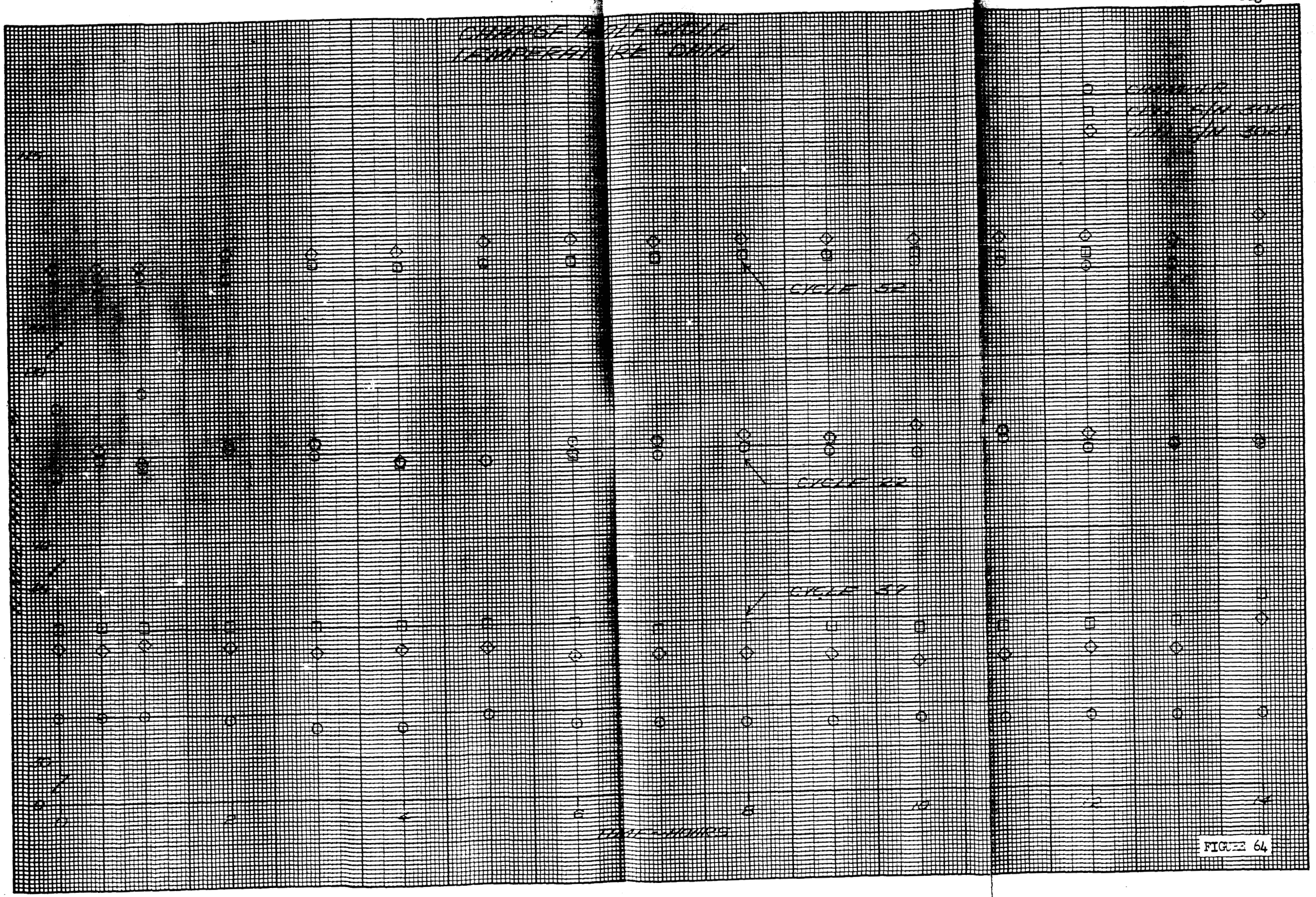


FIGURE 64