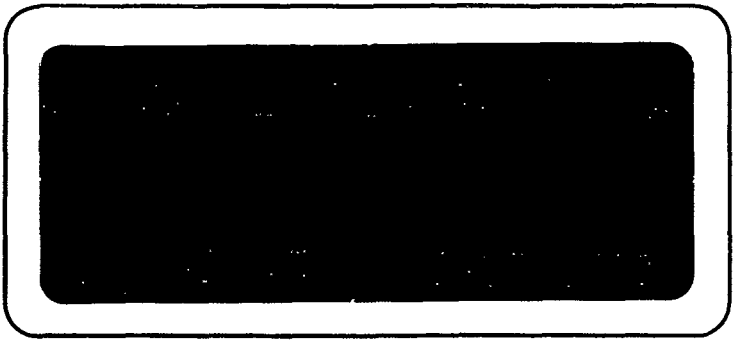

TRW SYSTEMS
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

NICKEL-CADMIUM CELL HEAT STERILIZATION

TEST PROGRAM

Phase 1
Final Report
October 1966

JPL Contract No. 951092

Subcontracted under NASA Contract NAS 7-100

TRW Systems
One Space Park
Redondo Beach, California

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS 7-100.

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PREFACE

This report was generated in accordance with the requirements of JPL Contract 951092 to summarize the work performed during Phase 1 of a nickel-cadmium cell heat sterilization test program. The objective of the work was to determine the performance characteristics of certain nickel-cadmium cells after they had been heat sterilized.

This report consists of two parts: A main volume containing the text and graphical presentation of data, and Appendix A which contains only tabulated numerical data taken during the life cycle test described herein. Because of the size of Appendix A (300 pages), it will not be given full distribution but will be available to individuals on the distribution list on request to the contractor.

ABSTRACT

Sixty cylindrical, sealed Sonotone nickel-cadmium cells rated at 4 ampere-hours and capable of heat sterilization were tested. The cells were divided into three groups: (1) twenty-one control cells (not sterilized); (2) twenty-one discharged heat sterilized cells; (3) eighteen charged heat sterilized cells. The control and discharged heat sterilized cells were further divided into sub-groups according to the stand condition (a) eight cells were charged at a constant 60 ma (floated) for various time intervals; (b) eight cells were stored on open-circuit for various time intervals before cycling; and (c) five cells were cycled with no appreciable stand time prior to the first cycle. The heat sterilization sequence consisted of three 36-hour exposures to a temperature of 145°C over a total elapsed time period of 130 hours.

All cells were mechanically and electrically inspected and tested at the beginning of the test sequence after extended cycle testing. Heat sterilization produced only minor externally discernable changes in cell appearance or dimensions.

The first test performed during Phase 1 of the work was a life cycle test consisting of one charge-discharge cycle per day for a number of days varying from 300 for sub-group (c) to a minimum of 70 for sub-groups (a) and (b). Charging rate was 400 ma to a cut-off voltage of 1.48 volts; discharge rate was 800 ma to an end voltage of 0.60 volts. Charge and discharge voltages versus time, and input and output ampere-hours were recorded for each cycle.

Capacities of control float test cells sub-groups (1) (a), all began at near 4 ampere-hours, then decreased rapidly with cycle life to end-points ranging from 3.0 after 100 cycles down to 1.0 ampere-hour after 200 or more cycles. Initial capacities of control open-circuit stand cells, sub-group (1) (b) were in the range of 3.5 to 4.0 ampere-hours. Subsequent capacity changes were severe and did not correlate with time on open-circuit stand. The average capacity of control cells that began cycling with no prior stand time, subgroup (1) (c), was 4 ampere-hours on the first life test cycle and had decreased to 2.8 ampere-hours after 100 cycles. Final capacity was 2.7 ampere-hours after 300 cycles.

The average output capacity of discharged sterilized float cells, sub-group (2) (a), was initially about 3 ampere-hours independent of how long they stood on trickle charge, and declined to between 2 and 3 ampere-hours after cycling. The capacities of all sub-group (2) (b) cells (open circuit stand) were close to 3.0 ampere-hours as each began life cycling, independent of stand time. No further change of capacity took place. The average capacity of sub-group (2) (c) cells (discharged sterilized, no stand period before cycling) began at 3 ampere-hours (compared to 4.0 before sterilization) and declined gradually to 2.8 ampere-hours after 300 cycles.

Eight of the eighteen charged sterilized cells, group (3), failed on the first cycle after heat sterilization. The surviving cells showed capacities ranging from 0.93 to 3.45 ampere-hours on the first life test cycle. Additional capacity loss during cycling ranged from 0.01 to 0.68 ampere-hour. No charged sterilized cells surviving the first cycle subsequently failed during life cycle testing.

Comparison of results of group (2) and group (3) cells with those of group (1) (control cells) shows that heat sterilization decreased the initial capacity available on cycling by about 25 percent, but that subsequent cycle life behavior of discharged sterilized cells was more stable and predictable than that of non-sterilized cells. Charged sterilized cells were subject to a high initial failure rate and further loss of capacity on cycling.

Float charging of control cells led to a more rapid rate of capacity loss on cycling than was observed with no float charging. Float charging discharged sterilized cells produced only a slightly greater rate of capacity decline than no charging of this group.

Open circuit standing of control cells led to erratic and severe capacity losses on cycling. Open circuit stand had no significant effect on discharged sterilized cells during cycling.

1. INTRODUCTION

The purpose of this report is to present the results of the test and evaluation phase of a Heat Sterilizable Nickel-Cadmium Cell Test Program performed for the Jet Propulsion Laboratory, California Institute of Technology, under JPL Contract 951092 sponsored by the National Aeronautics and Space Administration under Contract NAS 7-100.

Tests were performed on sixty (60) 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 Cell Test Statement of Work," dated February 10, 1965, and TRW Systems Test Procedure 9363.4-343, entitled "Heat Sterilization Testing of Nickel-Cadmium Cells," dated April 28, 1965.

The tests were designed to determine the capability of nickel-cadmium cells to perform after being subjected to three thirty-six hour heat sterilization cycles at 145°C. Test conditions were performed as recommended by the cell manufacturer. Included in the testing after heat sterilization were a life test, open circuit storage test, and constant current float test. Performance characteristics of non-sterilized cells and sterilized cells were compared to determine the effects induced by heat sterilization.

The tests were performed in a temperature controlled room ambient environment. An automatic battery cell test console was used for the life cycle test and provided cell protection from overvoltage/undervoltage conditions and from commercial power failures. The console was programmed to perform one charge/discharge cycle per day.

2. DEFINITION OF TERMS

2.1 Control Cell

A control cell was a cell identical to the other cells tested except that it was not subjected to the heat sterilization process.

2.2 Sterilized Cell

A sterilized cell was one that was subjected to three thirty-six hour temperature cycles from 23°C to 145°C. The exact time schedule used is described in paragraph 3.1.7.2.

2.3 Cell Charge Requirements

All charge half-cycles consisted of charging the cells at a constant current of 400 ma (or as specified herein) for a period of 14 hours or until the cell voltage increased to 1.48 volts, whichever occurred first. These values were recommended by the manufacturer for optimum performance. The following tolerances were maintained during charging:

2.3 Continued

Current Measurement:	± 5 ma
Current Regulation:	± 10 ma
Voltage Limit Setting:	1.48 ± 0.005 volts
Cell Voltage Measurement:	± 10 mv (print chart recording)
Voltage Calibration:	± 1 mv
Time Control and Data Print:	± 1 minute
Room Air Temperature:	70 ± 5°F

2.4 Cell Discharge Requirements

All discharge half-cycles consisted of discharging the cells at a constant current rate of 800 ma (or as specified herein) to an undervoltage limit of 0.6 volts. 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
Room Air Temperature:	70 ± 5°F

2.5 Cell Capacity

The cell capacity was the ampere-hours removed from the cell while being discharged at the constant current rates specified herein to a lower voltage limit of 0.6 volt. The accuracy of computations was ± 0.05 ampere-hour.

2.6 Cell Charge Efficiency

Cell charge efficiency is computed using the expression:

$$\frac{\text{Ampere-hours output x 100}}{\text{Ampere-hours input}}$$

3. PRE-HEAT STERILIZATION TEST

3.1 Mechanical Tests

3.1.1 Visual Inspection. Sixty "D" size Sonotone nickel-cadmium cells received from JPL were visually inspected for shipping damage and mechanical defects. The cells were shipped encased in styrofoam and packaged in separate boxes as shown in photographs (Figures 1 and 2). The cells were identified only by the manufacturer's serial number placed on the top of the cell by use of a vibra-tool. Comments describing the visual defects of each cell are as listed in Table 1.

3.1.1 Continued

The defects, as noted, were not considered sufficient to have an effect on the operational or functional performance of the cells. Visual inspection revealed no mechanical defects such as electrolyte leakage, distortion of cell container, cracked seals, or faulty welds.

3.1.2 Cell Weight. The weight of each cell was measured on a Sartorius single-pan balance, Type 2432. The weight measurements of each cell, as received and subsequent to the life cycle test, are as shown in Table 2. The cell weights, as received, ranged from 160.53 grams to 170.20 grams with the average being 166.20 grams. The difference between weights before and after the tests was less than 0.01 gram for all but four cells. Serial numbers 2985, 3028, 3031, and 3034 lost 0.24, 0.03, 0.28, and 0.11 gram respectively. A discussion of these data in connection with other test results appears in Section 4.

3.1.3 Cell Dimensions. Cell dimensions were measured during the pre-sterilization mechanical test and subsequent to the life cycle tests. The accuracy of measurements was $\pm$ 0.001 inch. The data are shown in Table 3. The slight difference in cell dimensions observed are believed due to non-uniformity of cell cases and points of measurement rather than from effects of tests performed.

3.1.4 Alkali Leak Test. The cells were tested for electrolyte leakage around the ceramic to metal seal and around the weld areas at the beginning and at the conclusion of life testing. The cells were checked with the following chemical indicator solution, which produces a red stain in the presence of alkalinity.

Indicator Solution

0.5 gram phenolphthalein
150 cc of 96 percent ethyl alcohol
20 cc distilled water

There was no evidence of electrolyte leakage on any of the cells during the leakage test performed prior to the heat sterilization test. At the completion of Life Cycle Testing, the test was repeated, at which time some indication of leakage was observed on all cells. The degree of leakage was considered slight on all cells.

3.1.5 Capacity and Voltage Regulation Test. The purpose of this test was to characterize the cell performance and to provide baseline data for comparison during subsequent tests. The cells were mounted in a cell holding fixture as shown in Figure 3 and placed in a Bemco Environmental Chamber. The temperature of the chamber was controlled to a tolerance of $\pm$ 1.5°F and the cells were

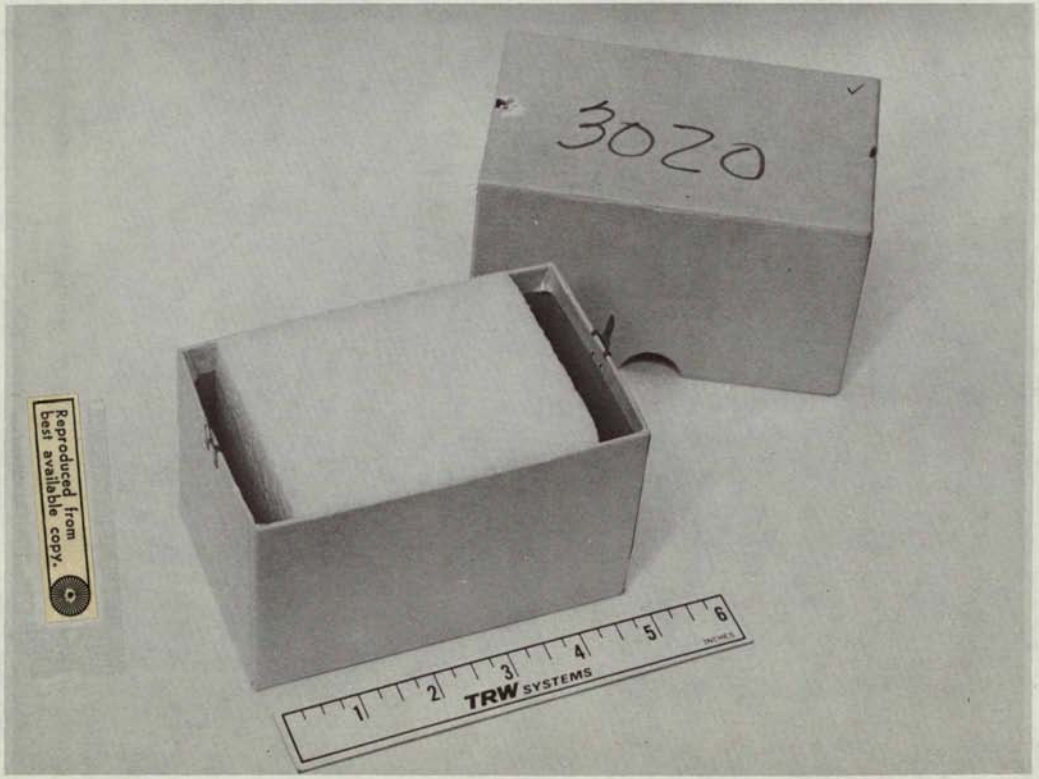


FIGURE 1

Cell Shipping Container

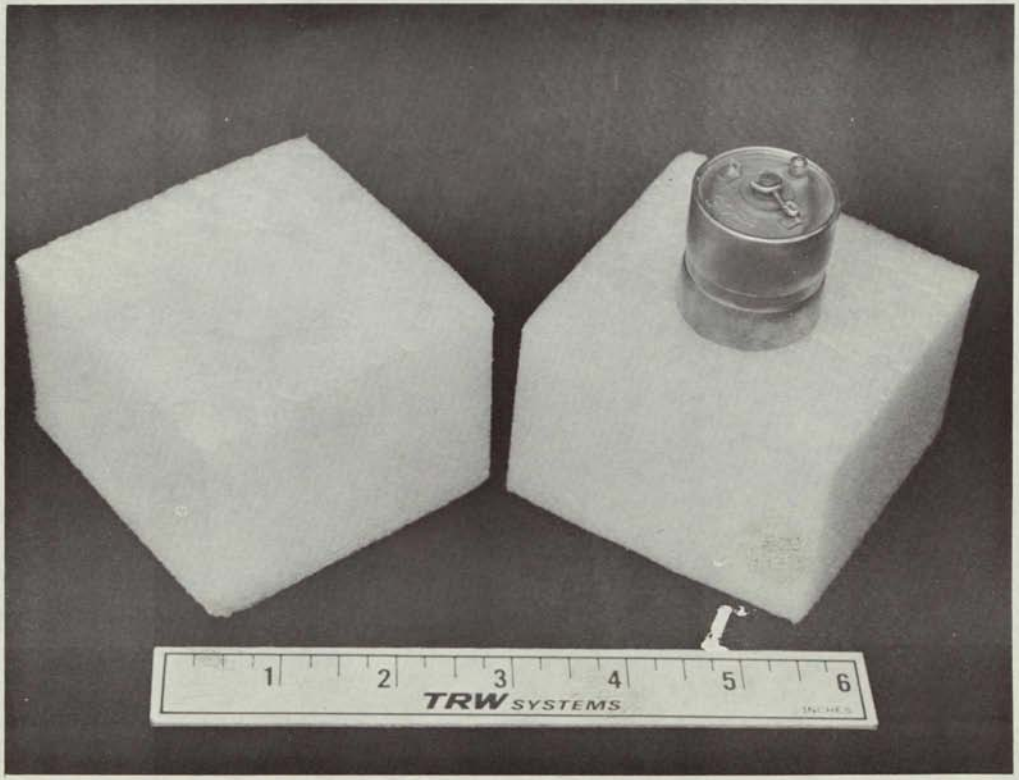


FIGURE 2

Cell Packing Material and Cell as Received

TABLE 1

VISUAL INSPECTION DATA

Cell Serial No.	Visual Inspection Comments
2966	Pin hole near negative terminal tab
2969	No defects found
2970	No defects found
2971	Top of cell slightly scratched
2972	Pin holes in top of cell
2973	No defects found
2974	Nicked near the pinch tube
2975	Top of cell slightly scratched
2979	No defects found
2980	Pin hole in top of cell under serial number
2981	Scratched near negative tab
2983	No defects found
2985	Negative terminal tab cracked
2986	Foreign substance noted near negative terminal tab
2987	Nicks in top of cell
2988	Negative terminal tab bent
2991	Pin hole in top of cell near the serial number
2992	Negative terminal tab cracked
2994	Scratches in top of cell
2996	No defects found
2997	No defects found
2998	Nicks in top of cell
2999	Nicks near the pinch tube; negative terminal tab cracked
3000	No defects found
3001	No defects found
3002	No defects found
3003	No defects found
3007	No defects found
3008	Scratches noted near the negative terminal tab
3012	Negative terminal tab cracked
3013	Foreign substance noted on top of cell
3014	No defects found
3015	Scratches noted on top of cell
3016	No defects noted
3017	No defects noted
3019	No defects noted
3020	Negative terminal tab cracked
3021	Negative terminal tab cracked
3022	Scratches noted on top of cell
3023	No defects noted
3025	Nicks noted near the negative terminal tab
3027	Negative terminal tab cracked
3028	No defects noted
3029	No defects noted

TABLE 1 (Continued)

Cell Serial No.	Visual Inspection Comments
3030	No defects noted
3031	No defects noted
3032	Discolored area near serial number
3034	Pin hole near serial number; top of cell discolored
3035	No defects noted
3037	No defects noted
3038	Negative terminal tab cracked
3039	Negative terminal tab cracked; red stain on top of cell
3042	Negative terminal tab cracked; pin hole in top of cell
3043	Pin holes on top of cell
3044	Scratches noted on top of cell
3045	Negative terminal tab cracked; pin holes in top of cell
3046	No defects noted
3047	No defects noted
3048	No defects noted
3049	Scratches noted on top of cell

TABLE 2

CELL WEIGHTS BEFORE AND AFTER TESTING

Cell Serial No.	Cell Weight (Grams) Pre-Sterilization	Post-Life Tests
2966	165.91	165.90
2969	164.70	164.70
2970	165.25	165.26
2971	168.01	168.01
2972	169.20	169.20
2973	166.66	166.66
2974	164.53	164.53
2975	163.52	163.52
2979	165.23	165.22
2980	166.97	166.96
2981	166.62	166.61
2983	166.24	166.24
2985	167.20	166.97
2986	163.85	163.85
2987	167.51	167.51
2988	168.36	168.35
2991	163.98	163.97
2992	164.97	164.97
2994	167.75	167.75
2996	167.98	167.98
2997	170.01	170.00
2998	170.20	170.20
2999	163.59	163.59
3000	164.14	164.13
3001	165.63	165.64
3002	167.18	167.18
3003	165.48	165.48
3007	166.62	166.62
3008	167.69	167.69
3012	165.09	165.09
3013	166.68	166.68
3014	167.01	167.00
3015	164.53	164.56
3016	166.05	166.05
3017	168.43	168.42
3019	165.90	168.89
3020	167.21	167.21
3021	165.33	165.32
3022	166.45	166.44
3023	167.91	167.92
3025	168.37	168.37
3027	166.95	166.95
3028	168.17	168.14
3029	168.72	168.71

TABLE 2 (Continued)

Cell Serial No.	Cell Weight (Grams) Pre-Sterilization	Post-Life Tests
3030	164.91	164.91
3031	160.53	160.25
3032	162.25	162.24
3034	162.39	162.28
3035	169.49	169.49
3037	163.39	163.38
3038	164.13	164.12
3039	164.73	164.73
3042	168.62	168.61
3043	166.15	164.16
3044	162.45	162.45
3045	168.82	168.82
3046	163.31	163.20
3047	168.39	168.40
3048	166.26	166.26
3049	167.58	167.57

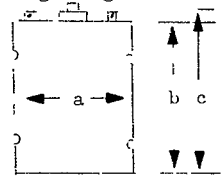
TABLE 3

HEAT STERILIZATION TESTING OF NICKEL-CADMIUM CELLS

Cell Dimensions (Pre-Sterilization and Post-Life Tests)

Test Equipment:

Vernier Caliper -- Lufkin No. 701, ± 0.001 inch accuracy
Height Gage -- Brown and Sharp No. 587, ± 0.001 inch accuracy



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

Cell Dimensions (Inches)

Cell Serial No.	Pre-Sterilization a	b	c	Post-Life a	b	c
2966	1.309	2.407	2.552	1.306	2.412	2.558
2969	1.311	2.418	2.569	1.305	2.412	2.570
2970	1.306	2.430	2.575	1.306	2.407	2.574
2971	1.306	2.402	2.554	1.307	2.404	2.557
2972	1.305	2.412	2.558	1.306	2.407	2.559
2973	1.308	2.408	2.554	1.307	2.405	2.553
2974	1.304	2.397	2.541	1.305	2.395	2.541
2975	1.308	2.416	2.565	1.308	2.407	2.565
2979	1.302	2.406	2.563	1.305	2.402	2.564
2980	1.304	2.406	2.552	1.305	2.403	2.553
2981	1.308	2.409	2.552	1.306	2.410	2.552
2983	1.308	2.419	2.567	1.305	2.421	2.568
2985	1.307	2.414	2.558	1.306	2.406	2.557
2986	1.308	2.406	2.557	1.308	2.408	2.560
2987	1.307	2.410	2.552	1.304	2.403	2.554
2988	1.305	2.418	2.563	1.308	2.415	2.562
2992	1.308	2.420	2.568	1.306	2.417	2.573
2994	1.306	2.409	2.554	1.309	2.405	2.560
2996	1.310	2.411	2.556	1.306	2.405	2.556
2997	1.306	2.409	2.555	1.308	2.400	2.554
2998	1.306	2.416	2.563	1.305	2.419	2.564
2999	1.302	2.409	2.551	1.305	2.405	2.551
3000	1.302	2.412	2.557	1.304	2.406	2.556
3001	1.304	2.407	2.556	1.305	2.407	2.564
3002	1.309	2.414	2.569	1.303	2.412	2.574
3003	1.307	2.417	2.566	1.307	2.409	2.568
3007	1.311	2.408	2.555	1.304	2.409	2.556
3008	1.306	2.411	2.557	1.307	2.410	2.557
3012	1.306	2.408	2.554	1.308	2.411	2.554
3013	1.304	2.401	2.582	1.306	2.403	2.584

TABLE 3 (Continued)

Cell Serial No.	Cell Dimensions (Inches) Pre-Sterilization a	b	c	Post-Life a	b	c
3014	1.306	2.409	2.559	1.304	2.405	2.557
3015	1.307	2.410	2.550	1.305	2.404	2.553
3016	1.308	2.416	2.559	1.306	2.416	2.558
3017	1.310	2.406	2.550	1.304	2.406	2.552
3020	1.307	2.410	2.559	1.306	2.409	2.556
3021	1.305	2.411	2.557	1.304	2.410	2.557
3022	1.308	2.415	2.558	1.306	2.416	2.557
3023	1.311	2.417	2.559	1.308	2.416	2.560
3025	1.308	2.412	2.565	1.305	2.417	2.567
3027	1.307	2.415	2.553	1.304	2.420	2.555
3031	1.311	2.420	2.555	1.305	2.418	2.555
3032	1.305	2.414	2.566	1.304	2.418	2.567
3035	1.306	2.423	2.569	1.305	2.423	2.570
3037	1.305	2.411	2.565	1.303	2.423	2.566
3039	1.305	2.406	2.548	1.304	2.418	2.549
3044	1.310	2.416	2.564	1.306	2.425	2.565
3045	1.308	2.414	2.563	1.302	2.420	2.564
3047	1.304	2.415	2.560	1.303	2.428	2.559
3048	1.305	2.415	2.548	1.304	2.422	2.551
3049	1.306	2.411	2.561	1.303	2.422	2.565
3029	1.305	2.415	2.559			
3019	1.308	2.410	2.574	No measurements made due to cell failure prior to completion of test.		
3038	1.305	2.416	2.569			
3043	1.302	2.413	2.560			
2991	1.304	2.408	2.568			
3030	1.305	2.416	2.565			
3046	1.306	2.407	2.555			
3042	1.305	2.400	2.545			
3028	1.305	2.414	2.552			
3034	1.306	2.406	2.548			

3.1.5 Continued

located so as to allow air to pass freely between them. The cells were electrically connected to the battery cell test console as shown in the schematic block diagram (Figure 4). Before beginning the programmed charge and discharge sequences, the test console was adjusted to the required test parameter accuracies as defined in Sections 2.3 and 2.4. The cells were automatically tested on an individual cell basis with overvoltage and undervoltage protection. The cycle sequence is shown in Table 4.

Tabulated data obtained from this test are shown in Table 5. Cell voltage versus time data are shown graphically in Figures 11 through 148.

Figures 11 through 130 present charge and discharge voltage data for selected test cycles for each of the 60 cells included in the program in numerical order. The odd-numbered figures show cell charge voltage versus charge time for the first and the fifth cycles of the voltage regulation test and for the first and last cycles for which the cell was on life test. Even-numbered figures numbered 12 through 130 are discharge time data for the same cycles as plotted on the charge curves.

Figures 131 through 136 are charge and discharge voltage curves for six of the test cells for cycle 2 of the pre-sterilization capacity test wherein discharge was performed at 125°F. The curves shown are typical of all cells tested.

Figures 137 through 142 show the same type of data for six cells on cycle 3 of the capacity test (32°F discharge), and figures 143 through 148 show the same type of data for cycle 4 (400 ma discharge at 75°F).

Many of the cells reached the 1.48 volt test limit on one or more of the charge half-cycles prior to completing the 14-hour charge period and were removed from the test circuit. The number and percentage of the cells that reached the voltage limit in each cycle was as follows:

	Number of Cells	Percent of Total
Cycle 1	46	77 percent
Cycle 2	50	83 percent
Cycle 3	47	78 percent
Cycle 4	33	55 percent
Cycle 5	29	48 percent

Minimum, maximum, and average values for input and output capacities for each of the five pre-sterilization cycles are shown in Table 6.

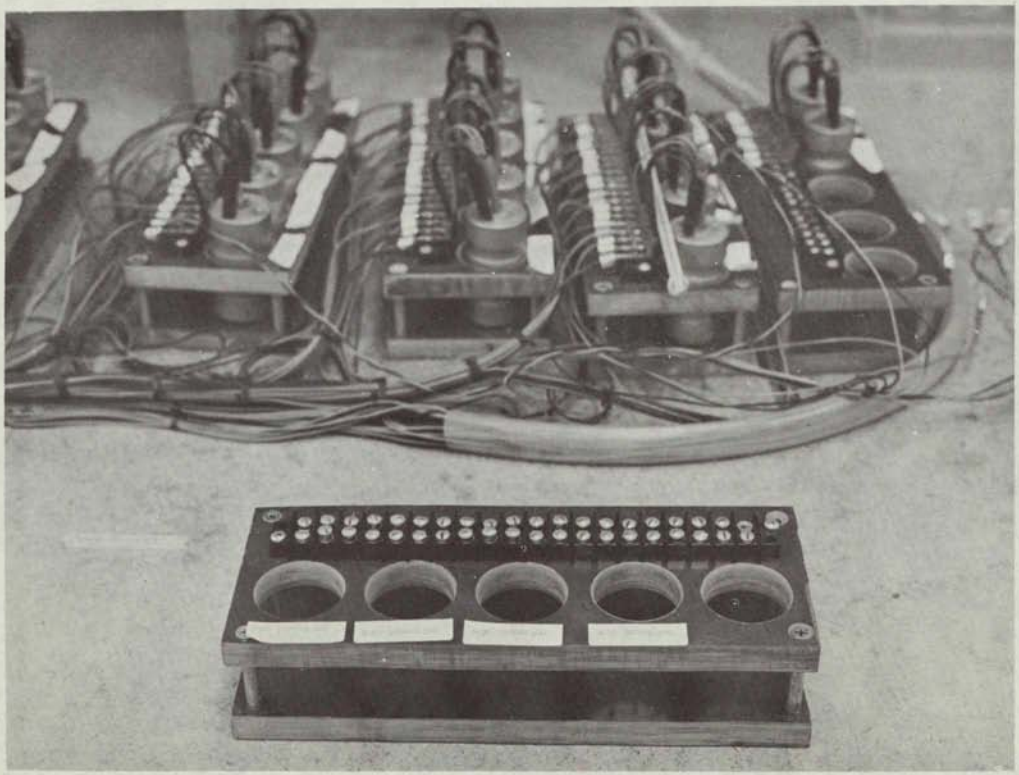
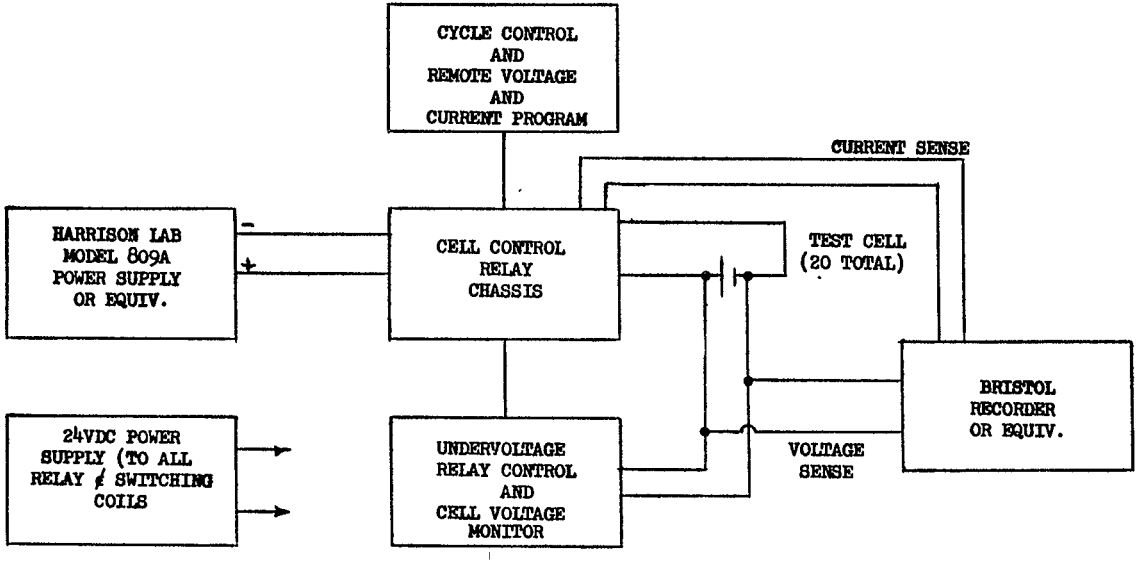


FIGURE 3

Cell Holding Fixture

FIGURE 4



SCHEMATIC BLOCK DIAGRAM

BATTERY CELL TEST CONSOLE

TABLE 4.

CAPACITY AND VOLTAGE REGULATION REQUIREMENTS

Cycle Number		Rate (ma)	Temperature ($^{o}F \pm 1.5^{o}F$)	Time (Hours)	Voltage Limit (Volts dc)
1	Charge	400	75	14	1.48
	Discharge	800	75	6.5	0.6
2	Charge	400	75	14	1.48
	Discharge	800	125	6.5	0.6
3	Charge	400	75	14	1.48
	Discharge	800	32	6.5	0.6
4	Charge	400	75	14	1.48
	Discharge	400	75	13	0.6
5	Charge	400	75	14	1.48
	Discharge	800	75	6.5	0.6
	Discharge	1 ohm shunt	$70 \pm 10^{o}F$	(24)	0.0

NOTES: (a) The discharge times were programmed to allow the maximum capacity cell to reach the undervoltage setting prior to the next charge sequence. All cells completed the specified discharge before starting the next charge sequence.

(b) For each temperature change, the cells were allowed to stabilize for four (4) hours prior to beginning the next sequence.

(c) After the cycle 5 discharge as shown, a 1-ohm, 5-watt resistor was connected across the terminals of each cell for a 24-hour period, followed by a shorting wire which remained on the cells until removal is later designated herein for subsequent tests.

TABLE 5

CAPACITY AND VOLTAGE REGULATION TEST
(Paragraph 5.5 of Procedure 9363.4-343)

Charge Rate: 400 milliamperes for 14.0 hours or 1.48 volts whichever occurs first
Discharge Rate: 800 milliamperes to an undervoltage limit of 0.6 volt

Cell S/N	Cell Capacity - Input and Output (Ampere-Hours)									
	Cycle 1		Cycle 2		Cycle 3		Cycle 4		Cycle 5	
	Input	Output	Input	Output	Input	Output	Input	Output	Input	Output
2966	5.54*	4.17	4.37*	4.17	4.45*	3.97	4.37*	4.19	4.50*	4.11
2969	5.41*	3.97	4.24*	3.99	4.37*	3.75	5.60	4.19	4.62*	3.95
2970	5.54*	4.12	4.28*	4.07	4.39*	3.91	4.28*	4.09	4.41*	4.04
2971	5.37*	4.07	4.35*	4.04	4.45*	3.89	4.33*	4.09	4.41*	3.97
2972	5.51*	4.23	4.58*	4.17	4.64*	4.07	4.87*	4.27	4.69*	4.19
2973	5.29*	3.85	5.01*	3.87	4.11*	3.60	3.99*	3.80	4.13*	3.72
2974	5.41*	3.85	4.19*	3.77	4.07*	3.55	3.95*	3.75	4.09*	3.68
2975	5.27*	3.92	4.25*	3.88	4.17*	3.67	4.05*	3.85	4.18*	3.80
2979	5.21*	3.89	4.17*	3.88	4.21*	3.71	4.29*	3.97	4.33*	3.89
2980	5.18*	3.95	4.19*	3.89	4.19*	3.71	5.60	4.17	4.67*	4.00
2981	5.60	4.15	5.60	4.24	4.69*	3.51	5.60	4.35	5.60	4.09
2983	5.60	4.01	5.60	4.08	4.68*	3.57	5.60	4.16	5.60	3.95
2985	5.60	4.28	5.60	4.28	5.03*	4.08	5.60	4.37	5.60	4.28
2986	5.17*	3.43	3.59*	3.53	3.76*	2.48	5.60	3.97	4.13*	3.41
2987	5.60	4.27	4.63*	4.24	4.65*	4.12	4.85*	4.32	4.73*	4.24
2988	5.60	4.21	5.60	4.27	4.55*	4.01	4.39*	4.15	4.59*	4.09
2991	5.60	4.16	4.97*	4.25	4.59*	3.96	5.60	4.41	5.60	4.32
2992	5.60	4.13	4.41*	4.11	4.51*	3.75	5.60	4.33	5.60	4.12
2994	5.15*	3.78	3.89*	3.77	3.91*	3.49	3.97*	3.79	3.91*	3.63
2996	5.31*	4.00	4.14*	4.00	4.20*	3.80	4.15*	4.03	4.19*	3.80
2997	5.60	4.20	4.57*	4.13	4.43*	3.93	4.27*	4.08	4.39*	3.99
2998	5.60	4.13	4.87*	4.21	4.56*	3.85	4.34*	4.20	5.60	4.17
2999	5.60	3.97	4.44*	3.93	4.17*	3.48	4.13*	4.00	4.35*	3.93
3000	5.60	4.20	4.51*	3.15	4.47*	3.95	4.37*	4.11	4.50*	4.05

*Denotes cells that reached 1.48 volts prior to the scheduled 14.0 hour termination of charge.

TABLE 5 (Continued)

	Cell Capacity - Input and Output (Ampere-Hours)									
	Cycle 1		Cycle 2		Cycle 3		Cycle 4		Cycle 5	
S/N	Input	Output	Input	Output	Input	Output	Input	Output	Input	Output
3001	5.03*	3.83	4.19*	3.91	4.34*	3.05	5.60	4.24	5.60	4.08
3002	5.05*	3.93	4.29*	3.88	4.31*	3.72	4.07*	3.92	4.42	3.93
3003	5.27*	4.15	4.80*	4.07	4.48*	3.91	4.15*	4.05	4.42*	4.05
3007	5.20*	4.05	4.45*	3.97	4.48*	3.81	4.15*	3.95	4.42*	3.95
3008	5.25*	4.05	5.60	4.09	5.60	3.91	5.60	4.12	5.60	4.07
3012	5.07*	3.93	4.32*	3.92	4.37*	3.28	3.73*	4.01	5.60	4.05
3013	5.21*	4.09	4.45*	4.01	4.50*	3.75	4.22*	4.10	5.60	4.13
3014	5.21*	4.16	4.52*	4.04	4.55*	3.89	4.37*	4.15	5.60	4.19
3015	5.21*	4.04	4.50*	3.97	4.55*	3.81	4.29*	4.03	5.60	4.24
3016	5.21*	4.07	4.50*	4.07	4.81*	3.71	5.60	4.41	5.60	4.29
3017	5.26*	4.09	4.45*	4.07	4.49*	3.92	4.25*	4.12	4.67*	4.16
3019	4.80*	3.64	4.01*	3.68	3.99*	3.43	3.65	3.66	3.94*	3.63
3020	5.24*	4.13	4.51*	4.07	4.56*	3.55	4.15*	4.16	5.60	4.23
3021	5.21*	4.13	4.51*	4.08	4.63*	3.81	5.60	4.33	5.60	4.16
3022	4.69*	3.63	3.97*	3.53	3.97*	3.40	3.67*	3.53	4.93*	3.55
3023	4.95*	3.81	4.17*	3.77	4.23*	3.55	5.60	4.02	5.60	3.91
3025	5.57*	4.35	4.70*	4.24	4.69*	4.09	4.42*	4.25	4.75*	4.28
3027	4.91*	3.83	4.21*	3.81	4.27*	3.25	3.73*	3.91	4.41*	3.87
3028	5.43*	4.29	4.69*	4.21	4.73*	3.62	5.60	4.51	5.60	4.35
3029	4.95*	3.73	4.19*	3.79	4.00*	3.33	3.91*	3.82	5.60	4.11
3030	5.43*	4.20	4.59*	4.13	5.60	3.56	5.60	4.47	5.60	4.25
3031	4.80*	3.63	4.33*	3.76	5.60	3.13	5.60	3.93	5.60	3.69
3032	4.76*	3.67	4.11*	3.73	5.60	3.23	5.60	4.03	5.60	3.75
3034	4.93*	3.77	4.17*	3.83	4.26*	3.59	4.15*	3.91	4.31*	3.80
3035	5.48*	4.28	5.60	4.27	5.60	3.95	5.60	4.41	5.60	4.21
3037	5.04*	3.89	4.26*	3.87	4.32*	3.61	3.99*	3.91	4.29*	3.77
3038	5.38*	4.19	4.62*	4.11	5.60	3.63	5.60	4.36	5.60	4.08
3039	5.56*	4.32	5.60	4.28	5.60	3.79	5.60	4.41	5.60	4.16
3042	5.60	4.40	5.60	4.45	5.60	4.16	5.60	4.60	5.60	4.40
3043	4.93*	3.79	4.32*	3.83	5.60	3.44	5.60	4.09	5.60	3.87
3044	4.69*	3.65	4.11*	3.71	4.15*	3.39	5.60	3.94	5.60	3.65
3045	5.20*	4.08	4.48*	4.01	5.60	3.88	5.60	4.25	5.60	4.07
3046	5.60	4.40	5.60	4.49	5.60	4.31	5.60	4.66	5.60	4.49
3047	5.60	4.56	5.60	4.67	5.60	4.48	5.60	4.82	5.60	4.68
3048			4.37*	3.97	4.50*	3.81	4.41*	4.09	4.99*	4.11
3049			4.73*	4.12	5.60	4.16	5.60	4.41	5.60	4.31

*Denotes cells that reached 1.48 volts prior to the scheduled 14.0 hour termination of charge.

3.1.5 Continued

TABLE 6

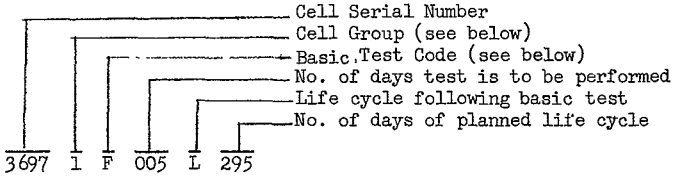
PRE-STERILIZATION CYCLE CAPACITY DATA SUMMARY

Cycle No.	Input Min.	Input Ave.	Input Max.	Output Min.	Output Ave.	Output Max.	Average Charge Efficiency
1	4.69	5.29	5.60	3.63	4.04	4.56	78%
2	3.59	4.58	5.60	3.53	4.01	4.67	88%
3	3.76	4.66	5.60	2.48	3.71	4.48	80%
4	3.65	4.82	5.60	3.53	4.08	4.82	85%
5	3.94	5.03	5.60	3.13	4.03	4.48	80%

As all cells that charged for the full 14 hours received 5.6 ampere-hours input, the figure appears in the "Input Maximum" column for all cycles.

In cycle 5, test parameters are the same as in cycle 1. The differences observed between the first and fifth cycles were insignificant. Capacity values from cycle 5 were used as a reference for comparison with data obtained during subsequent tests.

3.1.6 Cell Grouping and Identification. Following the capacity and voltage regulation tests, cell groups were selected for the tests described in the remainder of this report. Each cell was identified as a member of a test group by serial number which was included in a 13-character alpha-numeric code combination defining all the test operations performed on the cell during this program. An example of test code is as follows:



Code Legend

Cell Groups

1. Control
2. Discharged sterilization
3. 40% charged sterilization
4. 70% charged sterilization
5. Fully charged sterilization

Test Codes

F - Float
S - Stand
D - Discharge
C - Charge
L - Life cycling

3.1.6 Continued

A flow diagram of the test program describing the test steps is shown in Figure 5.

The cells, by serial number and test code, are as shown in Table 7.

The cells will be referred to in this report by only the serial number (first four digits of the identification code).

3.1.7 Heat Sterilization Test

3.1.7.1 Preparation of Cells For Heat Sterilization. After the fifth discharge cycle of the pre-sterilization electrical tests (See Section 3.1.5), all cells were shorted by strapping the terminals with a wire. Twenty-one of the cells, as indicated in Part 2 of Table 7, remained in the shorted condition throughout the heat sterilization process. Eighteen additional cells, shown in Section 3 of Table 7, were treated as follows. The short circuits were removed and the cells were series-connected to the battery test console. The cells were charged at 400 milliamperes for 14 hours or until the voltage limit (1.48 volts) was reached. Six of the cells remained at full charge; six cells were discharged at 800 milliamperes for 1.5 hours (30 percent of rated capacity withdrawn); and six cells were discharged at 800 milliamperes for 3.0 hours (60 percent of rated capacity withdrawn). The depth of discharge figures used here are based on the rated capacity and were calculated by use of the following formula:

Percent depth of discharge = 20 (hours discharged at 0.8 ampere)

The data from the pre-sterilization cell electrical charge preparation procedure are shown in Table 8.

The cells were then placed in cell holding fixtures (Figure 3) and located in a Bemco Temperature Chamber as shown diagrammatically in Figure 6.

3.1.7.2 Heat Sterilization Test. The heat sterilization process was initiated and the test sequence as outlined in Table 9 was followed, holding the temperatures to the tolerance as specified.

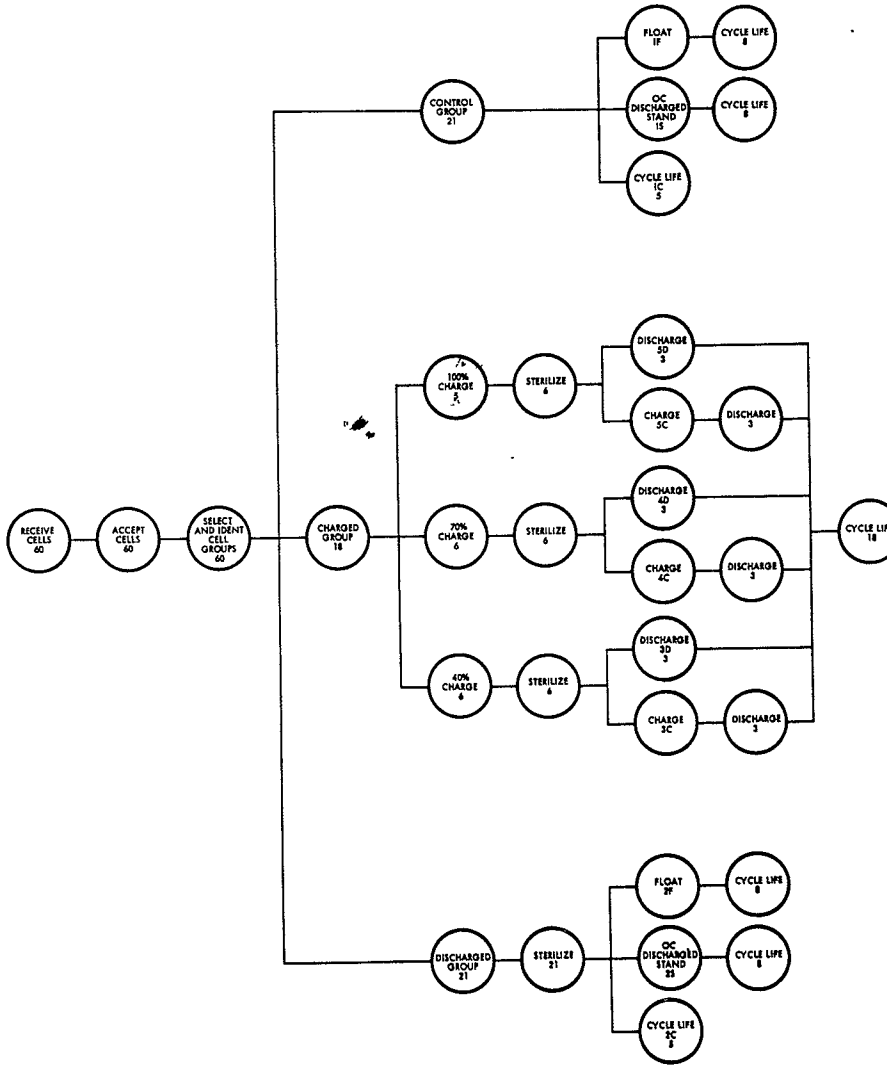


FIGURE 5: Cell Flow Diagram
Heat Sterilization Testing of Nickel-Cadmium Cells

TABLE 7

CELL SERIAL NUMBER AND TEST CODE IDENTIFICATION

1. Control Cells (Non-Sterilized, 21 total)

   a. Float Test

29661F005L295	29791F117L183
29701F019L281	29811F170L130
29721F042L258	29851F230L070
29741F075L225	29871F300L000

   b. Open-Circuit Stand Test (Discharged)

29911S005L295	30011S117L183
29941S019L281	30031S170L130
29971S042L258	30081S230L070
29991S075L225	30131S300L000

   c. Cycle Life Test (300 day)

30151C000L300	30191C000L300
30161C000L300	30201C000L300
30171C000L300	

2. Discharged Sterilized Cells (21 total)

   a. Float Test

29692F005L295	29802F117L183
29712F019L281	29832F170L130
29732F042L258	29862F230L070
29752F075L225	29882F300L000

   b. Open-Circuit Stand Test (Discharged)

29922S005L295	30022S117L183
29962S019L281	30072S170L130
29982S042L258	30122S230L070
30002S075L225	30142S300L000

   c. Cycle Life Test (300 day)

30212C000L300	30252C000L300
30222C000L300	30272C000L300
30232C000L300	

3. Charged Sterilized Cells (18 total)

   a. Full Charge Sterilized (begin life on discharge sequence)

30285D00L300	30305D00L300
30295D00L300	

b. Full Charged Sterilized (Begin life on charge sequence)

30315C000L300 30345C000L300
30325C000L300

c. 70% Charged Sterilized (Begin life on discharge sequence)

30354D000L300 30384D000L300
30374D000L300

d. 70% Charged Sterilized (Begin life on charge sequence)

30394C000L300 30434C000L300
30424C000L300

e. 40% Charged Sterilized (Begin life on discharge sequence)

30443D000L300 30463D000L300
30453D000L300

f. 40% Charged Sterilized (Begin life on charge sequence)

30473C000L300 30493C000L300
30483C000L300

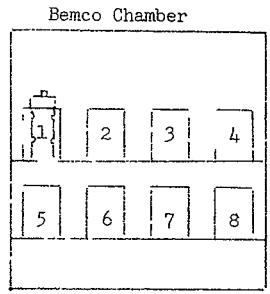
TABLE 8

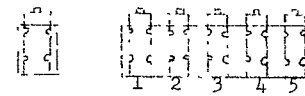
PRE-STERILIZATION ELECTRICAL CHARGE PREPARATION

Cell Serial Number	End-of-Charge Voltage (Volts)	Input Capacity (A-H)	End-of-Discharge Voltage (Volts) at 800 ma After		Open-Circuit Voltage Before Heat Sterilization (vdc)
			1.5 Hr.	3.0 Hr.	
3028	1.480	5.21	---	---	1.354
3029	1.480	4.62	---	---	1.348
3030	1.480	5.01	---	---	1.352
3031	1.480	4.57	---	---	1.347
3032	1.480	4.58	---	---	1.344
3034	1.480	4.53	---	---	1.346
3035	1.473	5.60	1.251	---	1.297
3037	1.480	4.56	1.251	---	1.302
3038	1.480	5.05	1.251	---	1.302
3039	1.480	5.21	1.253	---	1.303
3042	1.471	5.60	1.253	---	1.303
3043	1.471	5.60	1.253	---	1.300
3044	1.471	5.60	---	1.217	1.281
3045	1.471	5.60	---	1.230	1.285
3046	1.473	5.60	---	1.232	1.290
3047	1.472	5.60	---	1.243	1.291
3048	1.480	4.83	---	1.233	1.289
3049	1.480	5.09	---	1.235	1.289

FIGURE 6

CHAMBER-CELL LOCATION DURING HEAT STERILIZATION TEST





Cell Holding Fixture

Cell Mounting Fixture	Cell Position	Cell Serial Number
1	1	2969
	2	2971
	3	2973
	4	2975
	5	2980
2	1	2983
	2	2986
	3	2988
	4	2992
	5	2996
3	1	2998
	2	3000
	3	3002
	4	3007
	5	3012
4	1	3014
	2	3021
	3	3022
	4	3023
	5	3025
5	1	3027
	2	3028*
	3	3029*
	4	3030*
	5	3031
6	1	3032
	2	3034*
	3	3035
	4	3037
	5	3038*
7	1	3039
	2	3042*
	3	3043*
	4	3044
	5	3045
8	1	3046*
	2	3047
	3	3048
	4	3049

*Failed prior to test completion

3.1.7.2 Continued

TABLE 9

HEAT STERILIZATION TEST SEQUENCE

Heat Sterilization Cycle No.	Task Performed and Temperature (Temp. Tolerance: ± 2°C)	Time (Hours)
1	At 23°C, start temperature increase	0
	Increase temperature from 23°C to 145°C	3.0
	Stabilization at 145°C	36.0
	Decrease temperature from 145°C to 23°C	2.25
	Stabilization at 23°C	2.0
2	Increase temperature from 23°C to 145°C	3.25
	Stabilization at 145°C	36.0
	Decrease temperature from 145°C to 23°C	3.25
	Stabilization at 23°C	2.25
3	Increase temperature from 23°C to 145°C	3.25
	Stabilization at 145°C	36.0
	Decrease temperature from 145°C to 23°C	3.5

The temperature of the cells was monitored continuously during the entire heat sterilization process. The temperature was not allowed to increase from room ambient to 145°C in less than one hour or decrease from 145°C to room temperature in less than two hours.

At the completion of the third temperature cycle, the cells were removed from the Bemco chamber and prepared for the life cycle test, float test and the open circuit stand test.

3.1.7.3 Post-Sterilization Visual Examination. The cells were visually inspected and compared with the control cells. Other than a slight brownish coloration of the metal case, there appeared to be no detectable discrepancies such as cracked insulators, alkali leakage or bulging of the cell cases. A comparison of a heat sterilized and a control cell is shown in Figure 7.

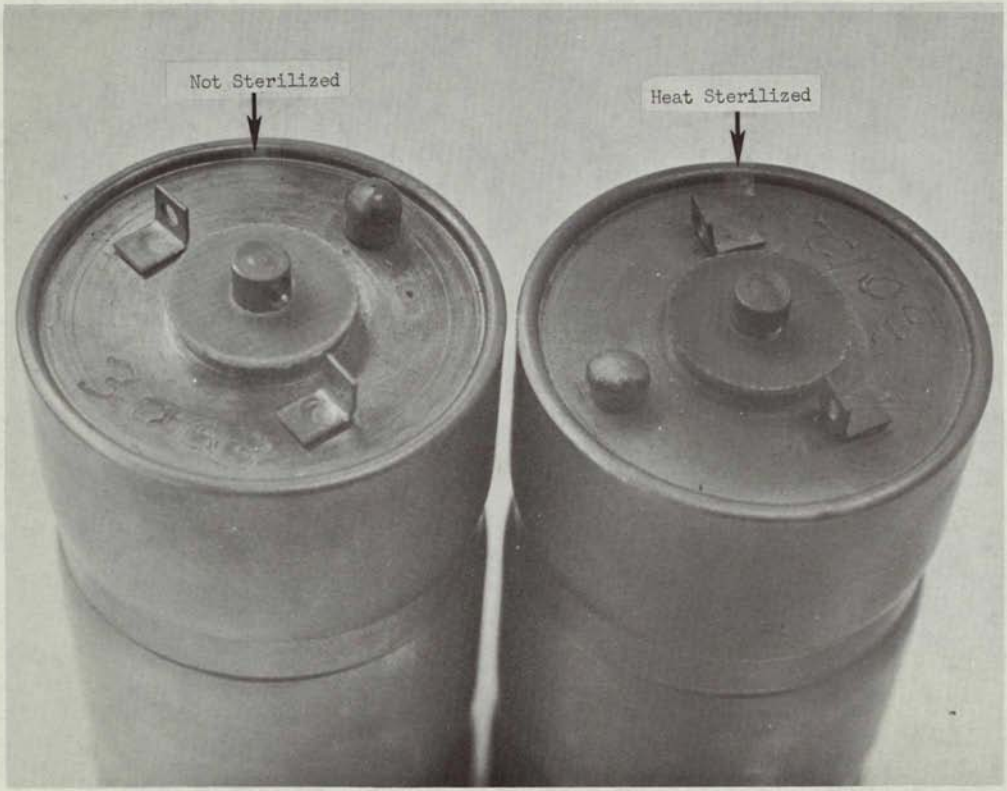


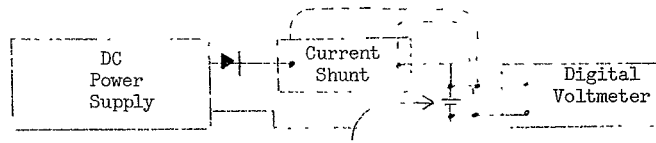
FIGURE 7

Cell Appearance Before (Left) and After Heat Sterilization

3.1.7.4 Post Sterilization Open Circuit Voltage. The open circuit voltage of each cell that was either fully charged or partially charged prior to heating was measured after sterilization. These voltages are shown in Table 10. Because of these low voltages, indicating a low state of charge, the cycle life test was begun with a charge half-cycle rather than with a discharge for the cells so designated in the original test procedure.

3.1.8 Float Test. After completion of the heat sterilization test, sixteen cells (8 control and 8 discharged sterilized cells) were connected in series as shown in the following schematic.

FLOAT TEST SCHEMATIC BLOCK DIAGRAM



The cells were charged as described in paragraph 2.3, followed by a 60 ma overcharge for the duration of the test. Voltage and current measurements were monitored once each working day. Maximum, minimum, and average voltages observed are shown in Table 11. The fluctuations were random in nature and were attributed to changes in room temperature.

Float test cells were removed from float in pairs (one control cell and one discharged sterilized cell) on the following schedule of days after sterilization: 5, 18, 42, 76, 117, 170, and 230.

Immediately after removal of each pair of cells from the float test, the cells were connected to the battery test console and cycled for the duration of the life test described in paragraph 3.1.10.

3.1.9 Open Circuit Stand Test. Immediately after the sterilization test, sixteen cells (8 control previously shorted and 8 discharged sterilized cells) were placed on open circuit and allowed to stand (discharged condition) at room temperature (70° ± 5°F).

Cells were removed from the stand test on the same schedule as described in paragraph 3.1.8 and the open circuit voltage of each cell was measured. The voltage of the control cells ranged from 0.52 volt to 1.20 volts whereas the voltage of the discharged sterilized cells were all less than 0.1 volt. After this measurement, the cells were connected to the test console and subjected to the remainder of the life cycle test.

TABLE 10

OPEN-CIRCUIT VOLTAGE OF CHARGED STERILIZED CELLS

AFTER HEAT STERILIZATION

Cell Serial Number	*Open-Circuit Voltage (vdc)
30285D000L300	0.057
30295D000L300	0.000
30305D000L300	0.000
30315C000L300	0.000
30325C000L300	0.562
30345C000L300	0.000
30354D000L300	0.534
30374D000L300	0.095
30384D000L300	0.000
30394C000L300	0.108
30424C000L300	0.000
30434C000L300	0.612
30443D000L300	0.093
30453D000L300	0.103
30463D000L300	0.043
30473C000L300	0.084
30483C000L300	0.028
30493C000L300	0.049

*Measurements recorded immediately before beginning the life cycle test (34 hours after removal from the temperature chamber).

TABLE 11

FLOAT TEST VOLTAGE MEASUREMENT SUMMARY

Number of Cells	Days on 60 ma Float Test	Float Cell Voltage Min.	Max.	Avg.
16	1	1.424	1.461	1.440
14	6	1.406	1.454	1.437
14	18	1.403	1.460	1.435
12	27	1.403	1.465	1.436
12	36	1.398	1.458	1.430
10	47	1.397	1.461	1.430
10	53	1.383	1.450	1.414
10	57	1.397	1.465	1.432
10	62	1.392	1.455	1.422
10	67	1.387	1.451	1.420
10	71	1.390	1.452	1.421
8	77	1.402	1.460	1.429
8	83	1.406	1.473	1.439
8	88	1.386	1.447	1.417
8	95	1.388	1.457	1.417
8	103	1.384	1.447	1.416
8	109	1.388	1.449	1.418
8	115	1.396	1.466	1.430
6	118	1.393	1.459	1.428
6	123	1.376	1.436	1.406
6	129	1.377	1.440	1.407
6	136	1.383	1.447	1.414
6	143	1.377	1.443	1.409
6	147	1.377	1.442	1.409
6	152	1.372	1.444	1.408
6	157	1.378	1.441	1.409
6	161	1.384	1.453	1.418
6	167	1.384	1.448	1.415
4	172	1.381	1.438	1.405
4	175	1.381	1.440	1.401
4	179	1.382	1.439	1.406
4	182	1.388	1.446	1.412
4	186	1.386	1.444	1.410
4	192	1.386	1.445	1.410
4	196	1.380	1.436	1.404
4	203	1.385	1.443	1.410
4	207	1.385	1.442	1.408
4	213	1.383	1.440	1.407
4	217	1.390	1.447	1.413
4	221	1.388	1.445	1.411
4	228	1.404	1.458	1.427
2	234	1.416	1.460	1.438
2	238	1.414	1.462	1.438
2	243	1.411	1.458	1.435
2	248	1.414	1.462	1.438
2	252	1.402	1.454	1.428
2	258	1.395	1.455	1.425
2	263	1.410	1.461	1.435
2	269	1.417	1.464	1.440
2	273	1.411	1.460	1.435
2	278	1.417	1.462	1.439
2	284	1.394	1.423	1.403
2	288	1.402	1.454	1.428
2	293	1.400	1.455	1.427
2	300	1.412	1.457	1.434

3.1.10 Life Cycle Test

3.1.10.1 Test Procedure. The life cycle test consisted of subjecting cells to one charge/discharge cycle per day for a number of days which varied from one cell group to another with a maximum of 300 days and a minimum of 70 days. Life test cycles were performed at a room temperature (70° ± 5°F) at the charge/discharge rates defined in paragraphs 2.3 and 2.4.

The cells as scheduled by the test procedure, were series-connected to the automatic test console which provided programming of the charge-discharge sequences. The electrical test schematic block diagram was as shown in Figure 4. Photographs of the life test setup are shown in Figures 8 and 9.

The end of charge voltage and the input and output capacity for each cell was measured for each cycle during the life test.

3.1.10.2 Life Cycle Test Results. The tabulated data obtained for each cycle of the life cycle test are contained in Appendix A to this report. Cell voltage versus time data for the first and last cycles that each cell was on are shown graphically in Figures 11 through 130. Note that the "first cycle on test" is not necessarily the "first cycle of the test," as many cells were on stand tests during part of the Life Cycle Test. The Life Cycle Test cycle number at which each cell was put on the Life Cycle Test is indicated on the individual figures. This information is also provided by the test code as described in Section 3.1.6 and Table 7.

Data for cell input and output capacities and end-of-charge voltages versus days in cycle life test are shown graphically in Figures 149 through 196. Data points for every fifth cycle are plotted as well as those for each of the five capacity test cycles for reference. Consideration of these curves provides the following information:

a) The control cells for each of the three types (float, open-circuit stand, and 300-day cycle) behaved similarly on both charge and discharge. Behavior at the beginning of cycle testing was similar to that of the first and fifth pre-sterilization cycles. Discharge capacity was near the rated value at the beginning but decreased continuously as cycling continued. The nature and extent of the capacity change varied with the pre-treatment received (see below).

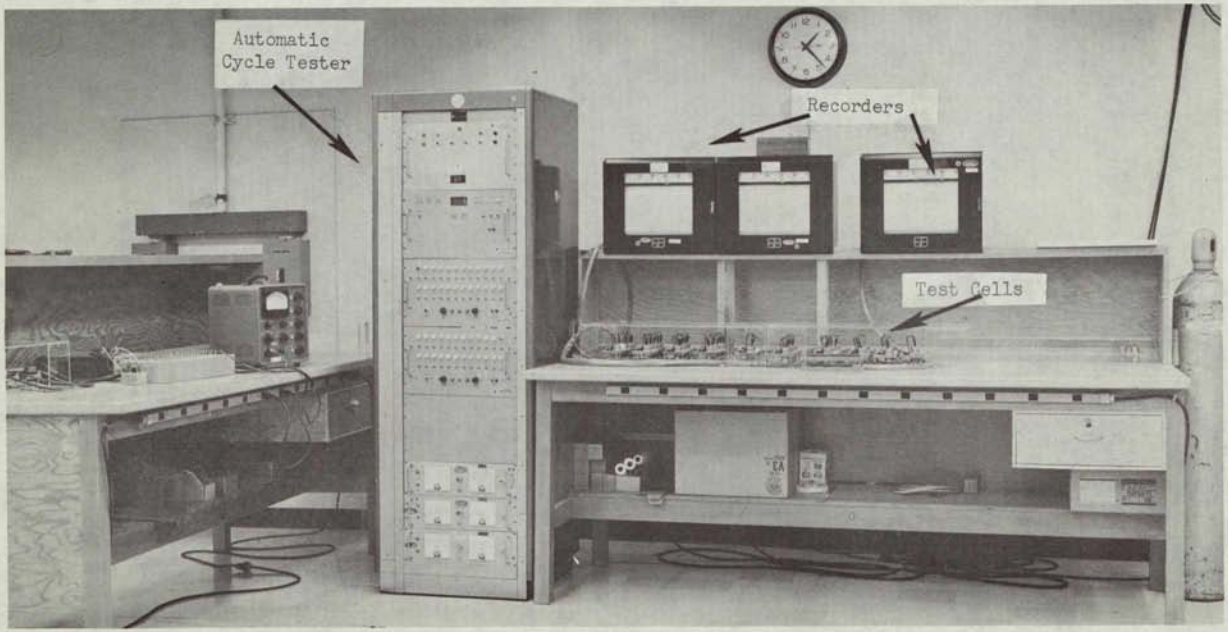


FIGURE 8

Over-All View of Test Area

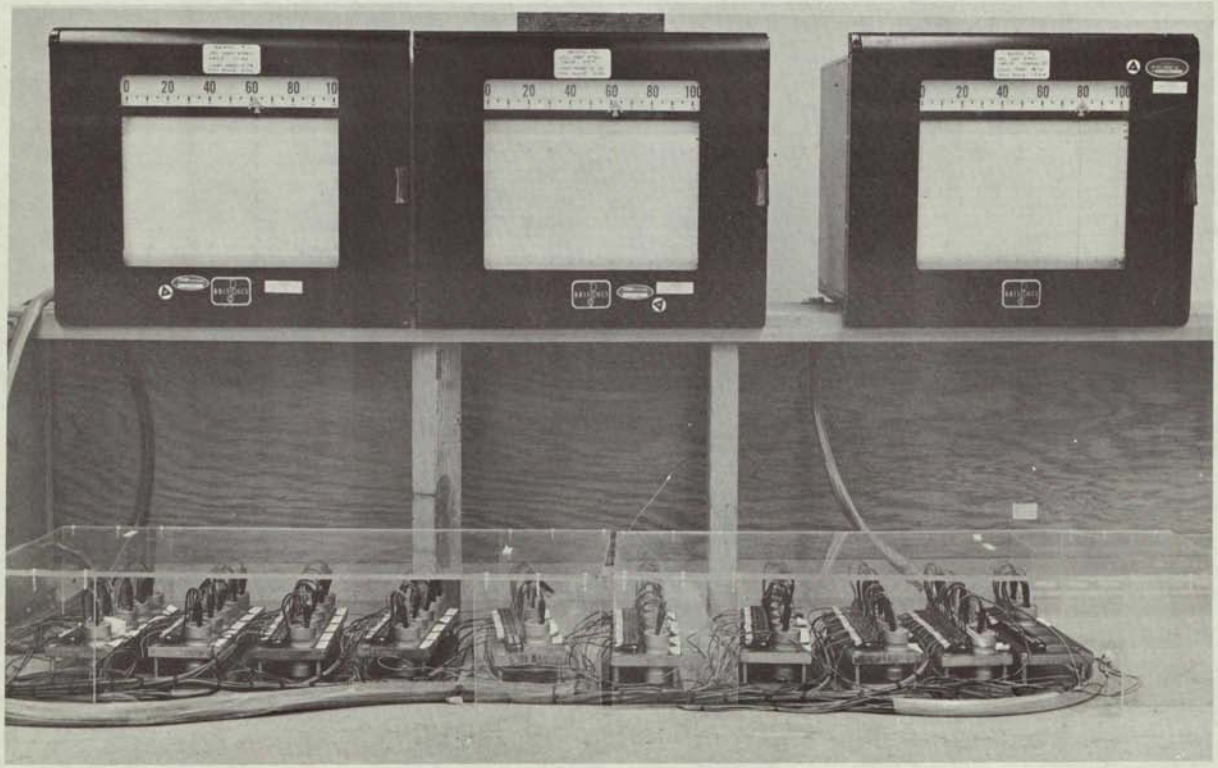


FIGURE 9

Close-Up View of Cell Fixtures and Recorders

3.1.10.2 Continued

b) Float (Trickle Charge) Test Cells. The voltage characteristics of both control and discharged sterilized float test cells were essentially the same as those of non-floated control cells after the same number of cycles. End-of-charge voltage consistently reached 1.48 volts throughout the test. For control cells floated up to 76 days, output capacity decreased relatively rapidly at first, then more slowly to 40 to 60 percent of the rated capacity at the end of 300 days. However, for control cells floated 118 days or longer, the rate of capacity decrease was much less, resulting in a residual of about 80% of rated capacity at the end of the test.

For discharged sterilized cells that were floated between heat sterilization and cycle testing, output capacities started at about 3 ampere-hours. For discharged-sterilized cells floated up to 76 days, the capacity did not decrease appreciably below the 3 ampere-hour level during cycling. For cells floated 118 days and longer, capacities decreased gradually to about 2 ampere-hours at the end of the 300-cycle test.

c) Open-Circuit Stand Test Cells. Immediately after open-circuit stand, the charge voltage of open-circuit stand control cells and open-circuit stand discharged-sterilized cells was significantly higher during the first half of the charge period than was that of the cell average during the five cycles of the Capacity and Voltage Regulation Test. See, for example, charge voltage plots for cell numbers 3000, 3002, 3007, and 3012, Figure numbers 57, 61, 65, and 69. In some cases, this higher voltage behavior disappeared after continued cycling while in other cases, it became more pronounced. Little difference was seen between control cells and discharged-sterilized cells in this respect. High initial charge voltage after inactive stand has been observed for other types of nickel-cadmium cells by the contractor and has been described in report STL 2315-6005-RU000, Volume I, pages 3-51 to 3-56, prepared under Contract NAS 5-899.

Output capacities on life cycles began close to 3 ampere-hours and remained substantially constant throughout the remaining cycle test. Starting capacity and behavior pattern appeared independent of stand time.

Output capacity behavior of control open-circuit-stand cells was not consistent. Control cells standing up to 21 days prior to cycling lost more than 50% of initial capacity by the end of the 300-cycle test. Control cells standing 42, 76, and 118 days showed a relatively smaller loss rate and levelled out at 3 ampere-hours. Control cells standing 169 and 231 days again showed rapid rate of loss with cycling. Sterilized-discharged cells subjected to open-circuit stand prior to cycling all showed capacities of about 3 ampere-hours at the start of cycling and did not change further.

d) 300-Day Life Cycle Cells. Both end-of-charge voltage and input/output capacity behavior varied from cell to cell in this group. This behavior is summarized in Table 12.

Output capacities of all cells subjected to 300 days of life testing are tabulated in detail in Appendix A and are plotted versus cycle number in Figures 177 through 196. Capacity data are summarized for every hundreth cycle in Table 13. It may be seen that the output capacity of the control cells ranged from 3.64 to 4.16 ampere-hours for an average of 4.01 on cycle number 1, decreased to an average of 2.84 by cycle number 100, and ended the test with a range of 1.71 to 3.27, average 2.70 ampere-hours. The significance of the latter average value is questionable because of the large spread of individual capacity values. If the lowest value (1.71) is omitted from the sample, the average of the three remaining cells is 3.05 ± 0.22 ampere-hours.

The output capacities of discharged sterilized 300-day test cells ranged from 2.20 to 3.29 for an average of 3.03 ampere-hours on cycle number 1 and ended the test ranging from 1.56 to 3.53 for an average of 2.82 ampere-hours. In this group, one cell, serial number 3022, was not representative. If this cell is omitted from the sample, the averages are 3.24 for cycle number 1 and 3.27 for cycle number 300.

The difference between the average of capacities of discharged-sterilized cells and those of control cells from cycle number 100 on throughout the test is small and is not considered significant in view of the small sample and the normal variability between cells. The significant observations are (a) that the discharged sterilized cells began the cycle life test at about 80 percent of the pre-sterilization average (4.03 ampere-hours, see Table 6) and did not change in capacity for 300 cycles; (b) that the control cells began the life test at the same average as previously measured (4.01 versus 4.03 ampere-hours) and decreased in capacity within 100 cycles to about 75 percent of the original value; and (c) that the final capacities were the same for both groups of cells.

3.1.10.2 Continued

d) Continued

Six cells each were sterilized in a (a) full charged, (b) 30 percent discharged, and (c) 60 percent discharged condition as described in paragraph 3.1.7.1. Of these, four out of six of the fully (100 percent) charged cells, three out of six of the 30 percent discharged (70 percent charged), and one out of six of the 60 percent discharged (40 percent charged) cells responded abnormally on the initial cycle of the life test. The behavior observed is summarized in Table 14.

TABLE 12

LIFE-CYCLE BEHAVIOR SUMMARY

300-Day Cells (Uncharged)

Cell Number and Type	End-Of-Charge Voltage	Output Capacity
Control Cells		
3015	1.48 volts throughout	Log-type decrease to 2 ampere-hours
3016	Up and down, 1.43 - 1.48 volts	Decreased to 3 ampere-hours, then constant
3017	1.48 volts to 100 days, then 1.44 volts	V - gradual decrease to 3.5 ampere-hours
3019	1.48 volts throughout	Rapid decrease to failure
3020	Started at 1.46 volts; decreased to 1.44 volts	Rapid decrease to 3 ampere-hours then no further change
Discharged-sterilized Cells		
3021	Constant at 1.48 volts	Gradual decrease from 3.5 - 2.5 ampere-hours
3022	Constant at 1.48 volts	Graudal decrease from 2.5 - 1.75 ampere-hours
3023	1.48 volts to 250 days, then decrease to 1.45 volts	Gradual decrease from 3.3 - 3.0 ampere-hours, then increase to 3.5 ampere-hours
3025	Constant at 1.48 volts	Gradual decrease from 3.4 - 3.0 ampere-hours
3027	Similar to 3023	Similar to 3023

TABLE 13

OUTPUT CAPACITY DATA SUMMARY FOR 300-DAY CYCLE LIFE CELLS

	Pre-Sterilization Cycle Number		After Sterilization Life Cycle Number			
	1	5	1	100	200	300
Control Cells						
3015	4.04	4.24	4.08	2.33	2.03	1.71
3016	4.07	4.24	4.05	3.01	3.15	3.04
3017	4.09	4.16	4.16	3.21	3.65	3.27
3019	3.64	3.63	3.64	*	---	---
3020	4.13	4.23	4.13	2.84	2.81	2.83
Average	4.00	4.11	4.01	2.84	2.91	2.70
Discharge-Sterilized						
3021	4.13	4.16	3.29	3.12	2.91	2.75
3022	3.63	3.55	2.20	2.24	1.81	1.56
3023	3.81	3.91	3.24	3.03	3.11	3.53
3025	4.35	4.28	3.14	3.32	3.19	3.03
3027	3.83	3.87	3.29	2.67	2.95	3.28
Average	3.94	3.96	3.03	2.87	2.77	2.82
Fully Charged-Sterilized						
3031	3.63	3.69	0.93	1.00	1.03	0.92
3032	3.67	3.75	2.37	2.13	2.13	2.13
Average	---	---	1.65	1.56	1.58	1.52
70% Charged-Sterilized						
3035	4.28	4.21	2.32	2.19	2.11	1.99
3037	3.89	3.77	1.93	1.61	1.49	1.36
3039	4.32	4.16	2.44	2.00	1.89	1.76
Average	---	---	2.23	1.93	1.83	1.70
40% Charged-Sterilized						
3044	3.65	3.65	3.05	2.69	2.63	2.55
3045	4.08	4.06	3.47	3.11	2.95	2.79
3047	4.56	4.68	1.88	1.99	1.88	1.76
3048	4.09	4.11	1.87	1.95	1.72	1.55
3049	4.20	4.31	2.61	2.57	2.37	2.28
Average	---	---	2.57	2.46	2.31	2.18

*Failed on cycle 41

3.1.10.2 Continued

d) Continued

TABLE 14

SUMMARY OF ABNORMAL CHARGE BEHAVIOR AFTER STERILIZATION

Cell Number	Percent Charged	Voltage at End of Charge	Subsequent Output Capacity
3028	100	1.47	less than 0.1 A-H
3029	100	0.00	---
3030	100	0.00	---
3034	100	0.00	---
3038	70	0.03	0.0
3042	70	0.00	---
3043	70	Immediate overvoltage	---
3046	40	" "	---

End of charge voltage and capacity data for the surviving operable charged sterilized cells placed on the life cycle test is shown in Figures 187 through 196. Output capacities prior to sterilization and at 100-cycle intervals during the 300-cycle test are presented in Table 15.

The large variations from cell to cell within groups precludes averaging the values. It is apparent that a substantial loss of capacity resulted from sterilization in a charged state and that further losses during the life cycle test occurred but were small (Table 15). There appears to be only a rough correlation between the loss of capacity and the degree of charge at the time of heat sterilization, greater loss occurring at greater percentage charge.

TABLE 15

OUTPUT DATA SUMMARY FOR CHARGED STERILIZED CELLS ON LIFE TEST

Cell Number	Percent Charged	Capacity (A-H) Pre-Sterilization	Output Capacity at Cycle Number 1	100	200	300	Capacity Loss Pre-Sterilization to Cycle No. 1	Capacity Loss Cycle 1 to Cycle 300
3031	100	3.69	0.93	1.00	1.03	0.92	2.56	0.01
3032	100	3.75	2.37	2.13	2.13	2.13	1.38	0.24
3035	70	4.21	2.32	2.19	2.11	1.99	1.89	0.33
3037	70	3.77	1.93	1.61	1.49	1.36	1.84	0.57
3039	70	4.16	2.44	2.00	1.89	1.76	1.72	0.68
3044	40	3.65	3.05	2.69	2.63	2.55	0.60	0.50
3045	40	4.05	3.47	3.11	2.95	2.79	0.60	0.65
3047	40	4.68	1.88	1.99	1.88	1.76	2.79	0.13
3048	40	4.11	1.87	1.95	1.72	1.55	2.23	0.33
3049	40	4.31	2.61	2.57	2.37	2.28	1.70	0.33

3.1.10.2 Continued

e) Generally, low output capacity was associated with low input capacity for a given cycle. This was true of pre-sterilization cycles as well as for the cycle life test. Low input ampere-hours resulted when the charge voltage limit was reached before the 14-hour time limit. In most cases where the capacity had decreased to a fraction of the original value at the end of the 300-day test, either the charge voltage reached 1.48 volts in a similar fraction of the 14-hour maximum period, or a peak occurred in the charge voltage curve at some value less than 1.48 volts, indicating that the cell was fully charged (to the limit of its charge acceptance capability) prior to the end of the 14-hour period. Often in such cases, the charge voltage was well above that of cells accepting a full 5.6 ampere-hours at all times after the first hour of charging.

f) Charge efficiency was 85 percent or greater for most cycles and all cells cycled except numbers 3001, 3016, 3017, and 3020. These were control cells for which charge efficiency varied from 60 to 75 percent during the cycle life test.

4. GENERAL DISCUSSION

4.1 Pre-Sterilization Capacity and Cell Weight

The data in Table 2 show that the variation of cell weights was 10 grams at 6 percent of the mean cell weight, whereas Table 6 shows that the variation in output capacities was 0.93 ampere-hour or 23 percent of the mean on Cycle 1 of the Capacity and Voltage Regulation Test and 1.35 ampere-hours or 33 percent of the mean on Cycle 5 of that test. Figure 10 shows a plot of Cycle 5 capacity data versus cell weight. Although well scattered, there is a general trend toward higher capacity at higher cell weights as is observed with other types of nickel-cadmium cells. The spread in capacities is somewhat greater than the 15 - 20 percent range currently observed in single lots of prismatic nickel-cadmium cells.

Correlation between low cell weight and low capacity after repeated cycling with or without sterilization is poor. However, the cell with the lowest weight (less than 161 grams), serial number 3031, was one that produced only 1 ampere-hour at the end of cycle testing. Output capacity appeared to be more a function of charge input than of the other variables.

4.1 Continued

Although all of the curves included in this report for the Capacity and Voltage Regulation Test cycles (Figures 11 - 148) may not make a direct contribution to the immediate objectives of this study, the data is of general interest in characterizing the preformance of cylindrical nickel-cadmium cells and will be of value in determining the exact input needed, output power expected, heat dissipation, voltage versus ampere-hours and voltage output, etc. usually required for design of batteries should these cells be used.

4.2 Open-Circuit Voltage Measurements

Open-circuit voltage measurements on electrochemical cells are of questionable significance, but large and consistent differences can be used to indicate relative states of charge. The data in Table 8 shows three levels quite clearly although the difference between the 30 and 60 percent discharged cells was only about 10 millivolts. As the maximum open-circuit voltage of these charged sterilized cells after heat sterilization was 0.6 volt, it appears that all experienced the loss of most of the useful charge energy during the sterilization process.

The inability of nickel-cadmium cells to hold a charge at elevated temperatures is well known and is attributed to thermal decomposition of nickel oxides. The sterilization temperature used in this study was considerably higher than that to which these cells are normally subjected and as a result, one or more additional degradative processes may have occurred, including direct thermal decomposition of the separator material, oxidation of separator material by nickel oxides, hydrolysis of separator material by the electrolyte, and changes in state or pore structure in the plates. These processes could be followed by the deposition of degraded separator material on the plate active surfaces in such a way that some electrochemical activity is permanently lost.

Control cells (unheated) that were shorted out for a number of days then allowed to stand on open-circuit for extended periods showed open-circuit voltages at the end of the stand period as high as 1.14 volts, whereas cells heat-sterilized while shorted and then allowed to stand on open-circuit showed no voltages above 0.1 volt at the end of varying stand times. As open-circuit voltages were below 0.1 volt on cells standing only five days after sterilization, it appears that heating accelerates the process of complete discharge of externally shorted cells.

The process of discharge of a cell having a metallic short across the terminals must be different from the process of self-discharge on open circuit. In the former case, both the normal electrochemical and chemical dissipation of the charged condition occur, with chemical processes accounting for a larger fraction of the total as the temperature increases. In the case of a cell on open circuit, only chemical (self)

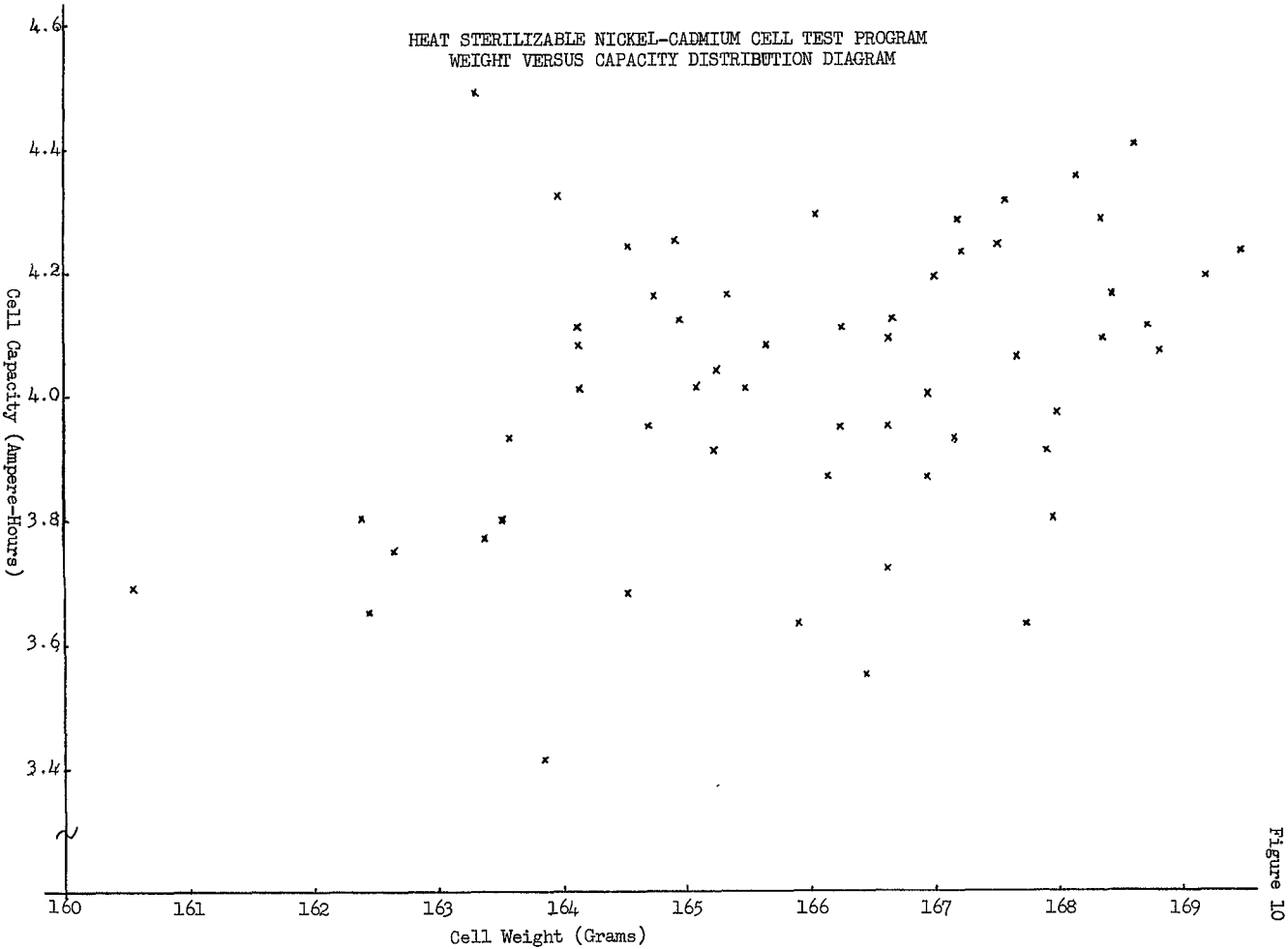

HEAT STERILIZABLE NICKEL-CADMIUM CELL TEST PROGRAM
WEIGHT VERSUS CAPACITY DISTRIBUTION DIAGRAM
Cell Capacity (Ampere-Hours)
4.6
4.4
4.2
4.0
3.8
3.6
3.4
160
161
162
163
164
165
166
167
168
169
Cell Weight (Grams)

Figure 10

4.2 Continued

discharge can take place (unless the cell has an internal metallic short). From the rise in voltage observed after removal of external shorting connections from the control cells, it is apparent that a long period of shorting is required at room temperature to discharge completely all of the charged material. This suggests the possibility that a simple, rapid discharge of a cell, even though carried to zero volts, may leave enough charged material in the cell to cause trouble on heat sterilization if the cell is not also shorted externally and allowed to stand for some time before being treated.

4.3 Failure of Cells to Accept Charge

Of those twenty-eight cells placed on charge following sterilization, eight did not accept charge (see Table 14). Five did not develop voltage significantly above 0.0 volt and were apparently shorted internally; two went immediately to the voltage limit without appreciable input indicating internal high impedance; and one reached an end-of-charge voltage in the normal range (1.47 volts) but delivered very little output. All these cells were among those that had been sterilized in the charged state. No such immediate failures occurred among cells sterilized in the discharged condition.

4.4 Life Cycle Test Behavior

The single most striking observation from the life cycle test was that on the average, sterilized cells either did not decline in capacity or decline only at a relatively low constant rate as cycle life increased. Non-sterilized cells (controls), on the other hand, generally decreased sharply in capacity early in cycle life and most of them continued to decrease at a lesser rate throughout the test. The latter behavior pattern has been observed frequently with nickel-cadmium cells and was not unexpected. The cause of the decrease has not been clearly established, but is probably due to a combination of degradative factors including (a) change in the grain size of active material on the plates; (b) conversion of electroactive compounds to non-electroactive compounds, especially conversion of cadmium hydroxide to cadmium carbonate on the negative plate; (c) physical loss of active material from the plates, as by ploughing and migration into the separator; and (e) increase in the resistivity of the plates and/or separator.

Inasmuch as a secondary cell can only deliver on discharge what is put in on charge (over any group of several cycles), and because the output capacities observed during the life cycle test varied directly with input with a ratio of output/input ampere-hours greater than 0.85 on the average, it may be more productive to discuss the effect of cell treatment on input rather than on output. As described in Section 3, most of the capacity decline during cycling of control cells occurred when the charge voltage limit was reached before the 14-hour time

had elapsed, and thus the input was less than the maximum 5.60 ampere-hours otherwise available. The data shows that the time to reach 1.48 volts on charge decreased as output capacity decreased. Thus, the use of the fixed voltage limit resulted in less and less useful energy input as cycle life increased.

A useful comparison of output capacity data from the five different cycles of the Capacity and Voltage Regulation Test can be made by selecting from Table 5 only cells receiving the full 5.60 ampere-hours input, as shown in Table 16.

TABLE 16

PRE-STERILIZATION DATA FOR CELLS RECEIVING MAXIMUM INPUT

Cycle No.	Discharge Temperature	Input (Ampere-Hours)	No. of Cells*	Average Output (Ampere-Hours)
1	75°F	5.60	14	4.22
2	125°F	5.60	10	4.31
3	32°F	5.60	13	3.82
4	75°F	5.60	27	4.30
5	75°F	5.60	31	4.13

*Out of a total of 60.

These data show that output was increased by discharging at a higher temperature and decreased by discharging at a lower temperature than that at which the cell was charged. These relationships have been demonstrated for other cells. They are not apparent from data in Table 6 where all cells are averaged regardless of charge input.

One approach to analyzing the effect of a fixed voltage limit on charging is as follows: Consider the cell voltage on charge (V_c) to consist of the sum of two components -- one the true potential difference between electrodes on charge (E_c) and the other the internal iR drop ($i_c R_i$) produced across the internal ohmic resistance R_i by the flow of charging current i_c:

$$V_c = E_c + i_c R_i$$

The term E_c more truly reflects the charge condition than does V_c but only the latter can be measured at the cell terminals. If i_c, R_i, temperature, and other variables remain constant, then V_c can be used as a reliable index of E_c by emperical calibration. If, however, R_i increases as a result of any of the degradative factors mentioned above, V_c becomes a correspondingly poorer indicator of E_c. Furthermore, below a certain value of E_c, depending on i_c and the temperature, the cell will not assume its maximum charge state even after an extended charge time. Hence, for any fixed limiting value for V_c, different conditions will lead to different output capacities.

4.4 Continued

The presence of high ohmic resistance is indicated by a charge voltage curve that is higher than that for cells with the normally low resistance over the entire charge period. This behavior was shown by many of the sterilized cells but not by the control cells (after the first few cycles where such is normal after periods of inactivity).

The above is an oversimplification directed only at the effect of internal resistance. A loss of real capacity, as by a change of state or inactivation of some active material orginally present, can lead to the same end result without an appreciable increase in internal ohmic resistance. Depending on the cause, some fraction of the capacity loss may be recovered by low-rate cycling provided that the fixed cycle routine can be interrupted at intervals involving not too many cycles or too much loss of capacity.

The above discussion may serve as a background for consideration of the behavior of the different sterilized cells during the cycle life test. The relevant data are summarized in Tables 12 and 14, Section 3. An explanation for the constant input and output capacities observed can only be postulated at this time pending further investigation. The primary effect of elevated temperature is to increase the rate of all chemical processes in the cell. Thus, certain changes that may require months to take place at room temperature may have been completed during the sterilization process, thereby reaching a relatively stable state that did not undergo much additional change during the subsequent cycling period. One such effect might be the thermal and oxidative decomposition of the separator followed by coating of a portion of the plate area with the decomposition products. The latter materials of interest here would be resinous organic substances of relatively high molecular weight that could effectively block access of electrolyte to solid surfaces to which they might adhere.

Although very little applicable information is available on the effects of exposure of non-woven polypropylene separator material to 145°C, there is little question that the structure of the material can be seriously damaged at this temperature. Just how much damage may occur over a limited exposure time is likely to vary from cell to cell. The data from this test program shows that the loss of input/output capacity for discharged sterilized cells did not differ greatly from cell to cell. However, in view of the random nature of the degradation processes involved, the uniformity observed in cyclic behavior is difficult to account for. It may be that some change of state in one of the plates has gone to completion and accounts for the 25% capacity loss observed.

4.4 Continued

The additional destructive effect of charged plates is apparent from the 50% failure rate of charged sterilized cells, the low capacities of surviving cells, and the wide range of capacities on cycling after sterilization of 100 percent, 70 percent, and 40 percent charged cells.

5. SUMMARY AND CONCLUSIONS

It is clear that nickel-cadmium cells of the type tested cannot withstand the sterilization process as performed while the cells are in a charged condition without a high probability of subsequent failure or erratic or abnormal behavior. Sterilization in the discharged-shorted condition produced a general and immediate loss of about 25 percent of initial capacity, but continued cycling showed little additional loss in capacity and consistent charge-discharge characteristics up to end of the 300-cycle test conducted.

Trickle charging cells or allowing cells to stand on open circuit for varying periods of time prior to start of cycling had only minor and temporary effects on cell performance, both for controls and sterilized cells. Charging after any form of inactive stand was more difficult for the first several cycles, but this effect disappeared on continued cycling.

Thus, within the 300-cycle test limitations used on this program, sterilization of discharged and shorted cells did not produce serious damage to the cells from an electrical performance standpoint, provided a certain de-rating can be tolerated.

Whether or not internal changes were produced that would begin to show up on longer cycling or on a different type of cycling is not known. Information bearing on this point will be obtained by extending the cycling period on certain cells, using different cycling parameters, and performing dissection of cells and analysis of cell components.

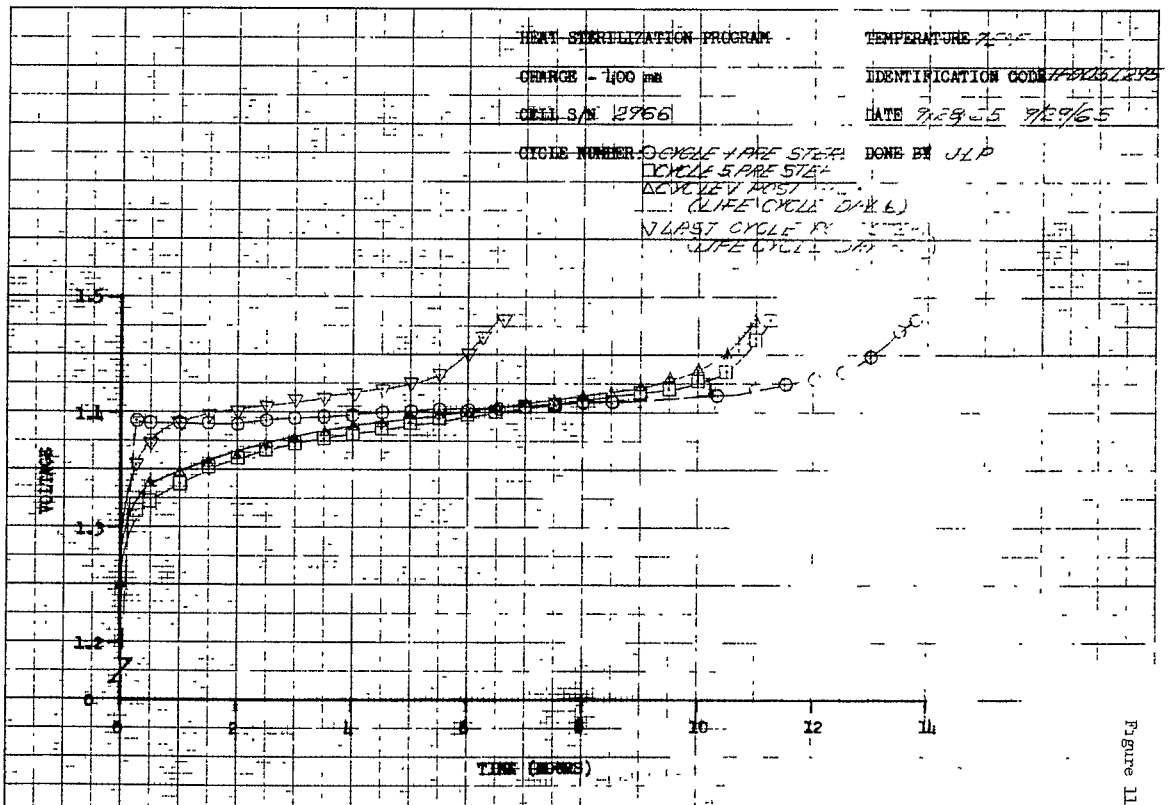


Figure 11

HEAT STERILIZATION PROGRAM
DISCHARGE - 800 ma
CELL S/N 2266
CYCLE NUMBER
TEMPERATURE 75 °F
IDENTIFICATION CODE 1/2025/285
DATE 9/27/65
DONE BY J.L.P.
VOLTAGE
TIME

Figure 12

HEAT STERILIZATION PROGRAM
TEMPERATURE 135°
CHARGE - 400 ma
IDENTIFICATION CODE 2500B1294
CELL S/N 2869
DATE 9/29/65-9/29/65
CYCLE NUMBER
○ CYCLE 1 PRE STER. DONE BY JLP
□ CYCLE 5 PRE STER.
△ CYCLE 1 POST STER (LIFE CYCLE DAY 6)
▽ LAST CYCLE POST STER (LIFE CYCLE DAY 30+)
VOLTAGE
1.5
1.4
1.3
1.2
0
2
4
6
8
10
12
TIME (HOURS)

Figure 13

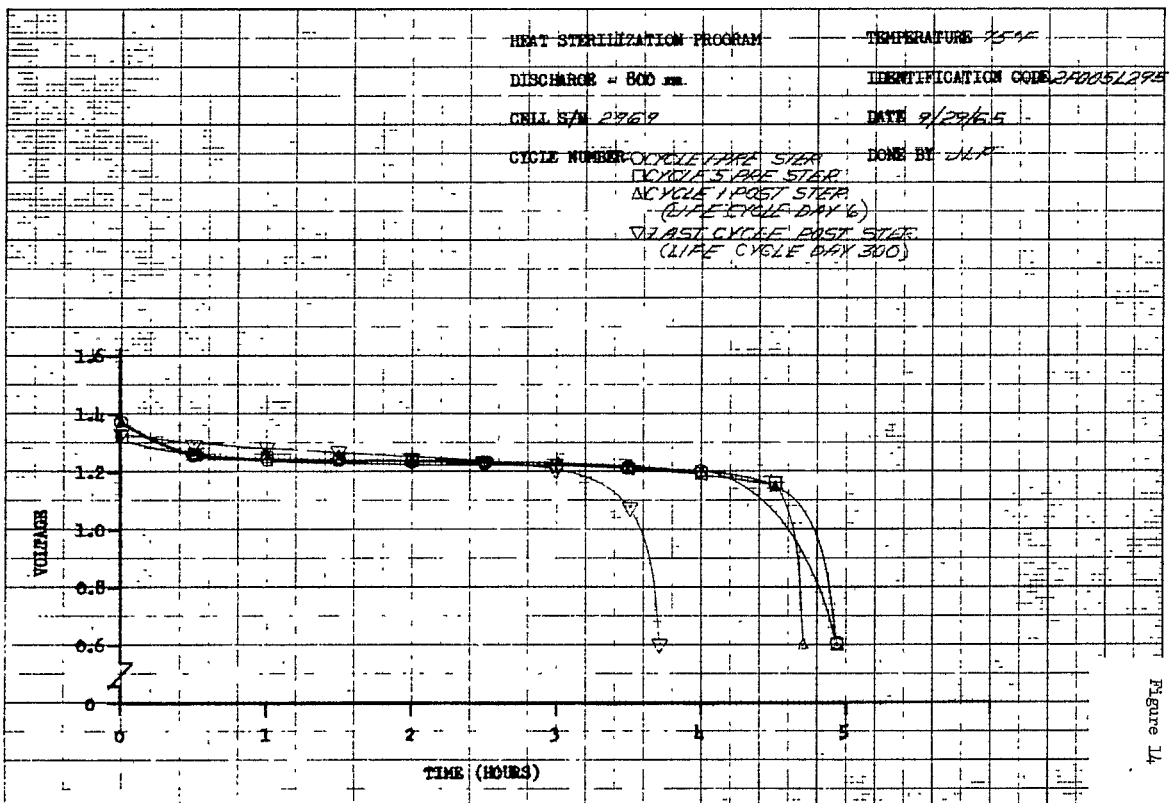


Figure 14

Figure 15

HEAT STERILIZATION PROGRAM
DISCHARGE - 800 ma
CELL S/N 2910
CYCLE NUMBER ○CYCLE 1 PRE STER.
□CYCLE 5 PRE STER.
△CYCLE 1 POST STER.
(LIFE CYCLE DAY 1)
▽LAST CYCLE POST STER.
(LIFE CYCLE DAY 300)
TEMPERATURE 75°F
IDENTIFICATION CODE 1F01R2287
DATE 9/29/65
DONE BY JKP
VOLTAGE
1.6
1.4
1.2
1.0
0.8
0.6
0
1
2
3
4
5
TIME (HOURS)

Figure 16

HEAT STERILIZATION PROGRAM
TEMPERATURE 75°C
CHARGE - 400 ma
IDENTIFICATION CODE
CELL S/N 2997
DATE 9/29/65 - 9/29/65
CYCLE NUMBER ○ CYCLE 1 PRE STEP. DONE BY JKP
□ CYCLE 5 PRE STEP
△ CYCLE 6 POST STEP
(CURE CYCLE DAY)
▽ LAST CYCLE POST STEP
(CURE CYCLE DAY 300)
VOLTAGE
1.5
1.4
1.3
1.2
0
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 17.

Figure 18

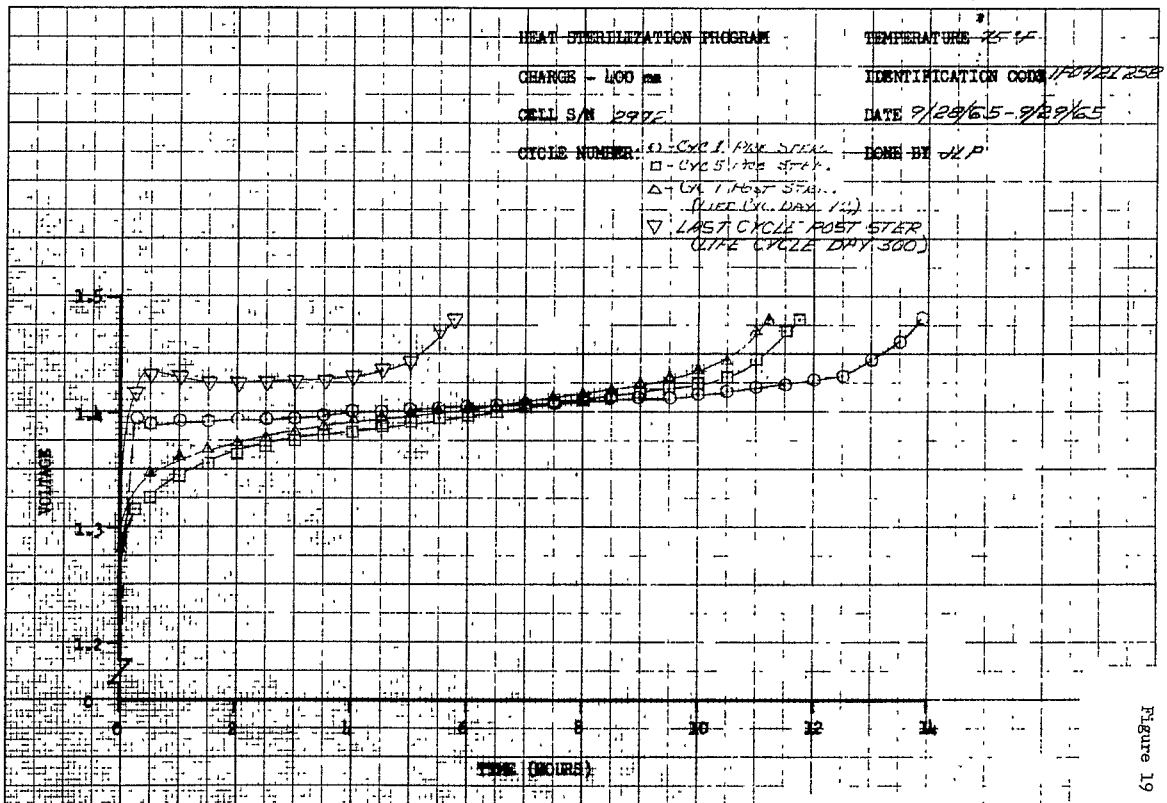


Figure 19

HEAT STERILIZATION PROGRAM
DISCHARGE - 800 ma
CELL S/N 2902
CYCLE NUMBER:
TEMPERATURE 25°C
IDENTIFICATION CODE IF0424L25B
DATE 9/28/65
DONE BY VLP
⊙ - CYCLE 2 PRE STER.
□ - CYCLE 5 PRE STER.
△ - CYCLE 1 POST STER.
(TIME CYCLE DAY 42)
▽ LAST CYCLE POST STER.
(TIME CYCLE DAY 300)
VOLTAGE
1.6
1.4
1.2
1.0
0.8
TIME (HRS)
1
2
3
4
5
6

Figure 20

HEAT STERILIZATION PROGRAM
TEMPERATURE 125°F
CHARGE — 400-ma
IDENTIFICATION CODE 270X27258
CELL S/N 2973
DATE 9/25/65 - 9/29/65
CYCLE NUMBER: ○ - CYC. 1 PRE STER.
□ - CYC. 5 PRE-STER.
△ - CYL. 1 POST STER. (CURE CYC. DAY 42)
▽ LAST CYCLE PAST STER (CURE CYCLE DAY 300)
DONE BY JHP
VOLTAGE
1.5
1.4
1.3
1.2
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 21

Figure 22

Figure 23

Figure 24

HEAT STERILIZATION PROGRAM
TEMPERATURE 75°F
CHARGE - 400 ma
IDENTIFICATION CODE 2995, 2995
CELL S/N 2995
DATE 9/28/65-9/29/65
CYCLE NUMBER: ○ = CYC 1 PRE STER. DONE BY HCO
□ = CYC 5 PRE STER.
AC CYCLE / POST STER.
(NEXT CYCLE DUE 7TH)
▽ LAST CYCLE POST STER.
(NEXT CYCLE DUE 30TH)
VOLTAGE
1.5
1.4
1.3
1.2
0
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 25

Figure 26

Figure 27

Figure 28.

KEUFFEL & ESSER CO

HEAT STERILIZATION PROGRAM — TEMPERATURE 125°F

CHARGE - 400 ma — IDENTIFICATION CODE 2A1D1183

CELL S/N 2880 — DATE 9/25/65-9/25/65

CYCLE NUMBER: ○ - CYCLE PRE STER. — DONE BY JKP

□ - CYCLE PRE STER.

△ CYCLE 1 POST STER. (LIFE CYCLE DAY N/A)

▽ LAST CYCLE POST STER (LIFE CYCLE DAY 390)

VOLTAGE

1.5

1.4

1.3

1.2

0 2 4 6 8 10 12 14

TIME (HOURS)

Figure 29

Figure 30

HEAT STERILIZATION PROGRAM
TEMPERATURE
CHARGE - 400 ma
IDENTIFICATION CODE
CELL S/N 2781
DATE 9/26/65 - 9/
CYCLE NUMBER: 0 - CYC
DONE BY JLP
LAST CYCLE/1ST STER
(LAST CYCLE DRY 30M)
VOLTAGE
1.5
1.4
1.3
1.2
1.1
0
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 31

HEAT STERILIZATION PROGRAM
TEMPERATURE 75°F
DISCHARGE - 800 ma
IDENTIFICATION CODE IF170L130
CELL S/N 2891
DATE 9/29/65
CYCLE NUMBER: ○-CYC 1 PRE STER.
DONE BY JLP
□-CYC 5 PRE STER.
△CYCLE 1 POST STER.
(LIFE CYCLE DAY 62)
▽LAST CYCLE POST STER.
(LIFE CYCLE DAY 300)
VOLTAGE
1.6
1.4
1.2
1.0
0.8
0.6
0
0
1
2
3
4
5
6

Figure 32

HEAT STERILIZATION PROGRAM
CHARGE - 400 ma
CELL S/N 2983
CYCLE NUMBER: 0 - 1st PRE TEST
□ - CYC 5 PRE STER
△ CYCLE TEST STEP
(LIFE CYCLE DATA)
▽ LAST CYCLE PLOT STEP
(LIFE CYCLE OFF SET)
TEMPERATURE 75°F
IDENTIFICATION CODE 2HTOL130
DATE 9/29/65-9/29/65
DONE BY WP
VOLTAGE
1.5
1.4
1.3
1.2
0
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 33

Figure 34

Figure 35

KEUFFEL & ESSER
HEAT STERILIZATION PROGRAM
DISCHARGE - 800
CHIL S/N 2285
CYCLE NUMBER:
○ - Cyc. 1 Pre Step
□ - Cyc. 5 Pre Step
△ CYCLE 1 POST STEP (LIFE CYCLE DAY 23)
▽ LAST CYCLE POST STEP (LIFE CYCLE DAY 300)
TEMPERATURE 75°F
IDENTIFICATION CODE TE230L070
DATE 9/29/65
DONE BY DMP
VOLTAGE
1.6
1.4
1.2
1.0
0.8
0.6
0
TIME (HOURS)
1
2
3
4
5
6

Figure 36

Figure 37

Figure 38

Figure 39

Figure 40

Figure 41

Figure 42

Figure 43

Figure 44

Figure 45

Figure 16

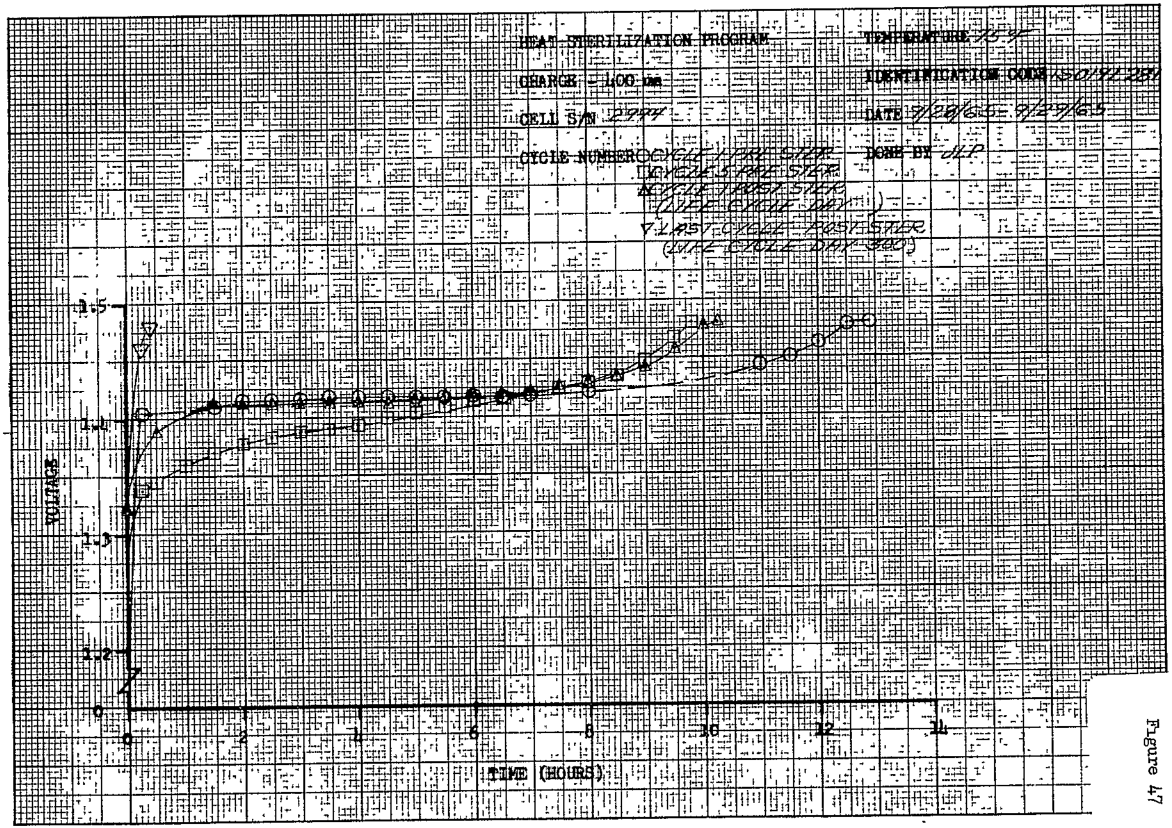


Figure 47

Figure 48

Figure 49

Figure 50

Figure 51

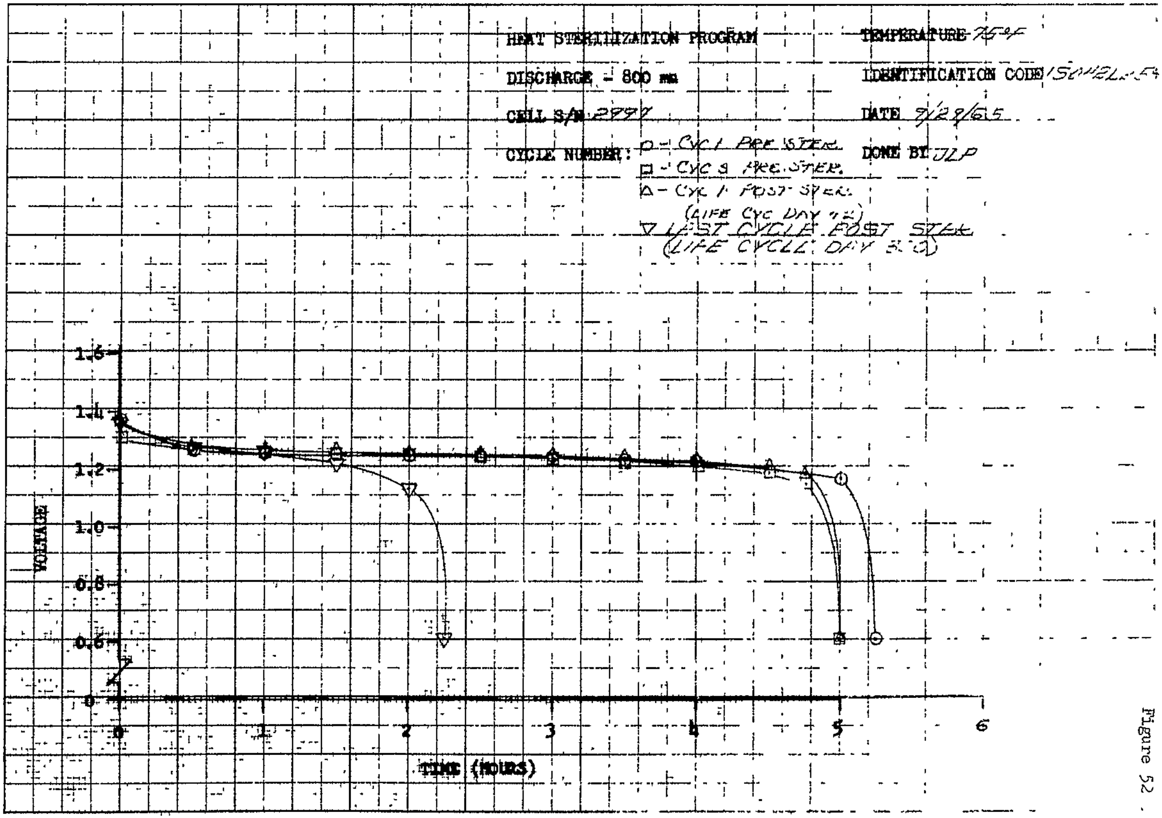

HEAT STERILIZATION PROGRAM
DISCHARGE - 800 ma
CELL S/N 2997
CYCLE NUMBER:
TEMPERATURE 75°F
IDENTIFICATION CODE
DATE 9/28/65
DONE BY JLP
VOLTAGE
TIME (HOURS)

Figure 52.

HEAT STERILIZATION PROGRAM
CHARGE - 1.09 ma
CELL S/N 2898
CYCLE NUMBER:
TEMPERATURE 75°F
IDENTIFICATION CODE 250#2250
DATE 9/29/65-9/29/65
DONE BY JAP
O - CYC 1 PRE STER.
□ - CYC 5 PRE STER.
Δ - CYC 1 POST STER. (LIFE CYC DAY 42)
▽ LAST CYCLE POST STER (LIFE CYCLE DAY 309)
VOLTAGE
1.5
1.4
1.3
1.2
0
TIME (HOURS)
2
4
6
8
10
12
14

Figure 53

HEAT STERILIZATION PROGRAM
TEMPERATURE 275°F
DISCHARGE - 800 MA
IDENTIFICATION CODE 250-12-1258
CELL S/N 2998
DATE 9/29/65
CYCLE NUMBER: ○ = CYC 1 PRE STER.
DONE BY JLP
□ - CYC 5 PRE STER.
△ - CYC 1 POST STER.
(LIFE CYC DAY 72)
▽ LAST CYCLE POST STER
(LIFE CYCLE DAY 30?)
VOLTAGE
1.6
1.4
1.2
1.0
0.8
0.6
0
0
1
2
3
4
5
6
TIME (HOURS)

Figure 54

HEAT STERILIZATION PROGRAM
TEMPERATURE 75°F
CHARGE - 400 ma
IDENTIFICATION CODE 150 251 225
CELL S/N 2999
DATE 9/28/65 - 9/29/65
CYCLE NUMBER: ○ - CYC 1 PRE STER. DONE BY JHP
□ - CYC 5 PRE STER
△ - 5TH CYCLE POST STER
(LIFE CYCLE EA. > 300)
▽ LAST CYCLE POST STER
(LIFE CYCLE EA. > 300)
VOLTAGE
1.5
1.4
1.3
1.2
0
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 55

HEAT STERILIZATION PROGRAM

TEMPERATURE 95°F

DISCHARGE - 800 ma

IDENTIFICATION CODE 50/15/L2-3

CELL S/N 2998

DATE 9/29/65

CYCLE NUMBER: ○ - CYC 1 PRE STER.

DONE BY JLP

□ - CYC 5 PRE STER.

△ CYCLE 1 POST STER. (LIFE CYCLE DAY 76)

▽ LAST CYCLE POST STER. (LIFE CYCLE DAY 300)

Figure 56

HEAT STERILIZATION PROGRAM

CHARGE - 400 ma

CELL S/N 3000

CYCLE NUMBER CYCLE 1 PRE STER.
CYCLE 2 PRE STER.
CYCLE 7 POST STER.
(LIFE CYCLE DAY 7)
LAST CYCLE POST STER.
(LIFE CYCLE DAY 30C)

TEMPERATURE 75°F

IDENTIFICATION CODE 350R2223

DATE 9/28/65-9/29/65

DONE BY JHP

Figure 57

Figure 59

HEAT STERILIZATION PROGRAM
TEMPERATURE 75°C
DISCHARGE = 800 ma
IDENTIFICATION CODE/SH/72/1
CELL S/N 3001
DATE 9/22/65
CYCLE NUMBER
DONE BY JLP
□CYCLE 1 PRE STER.
○CYCLE 5 PRE STER.
△CYCLE 1 POST STER.
(LIFE CYCLE DAY 1 HR.)
▽LAST CYCLE POST STER.
(LIFE CYCLE DAY 30 C)
VOLTAGE
TIME (HOURS)
1.6
1.4
1.2
1.0
0.8
0.6
0
1
2
3
4
5
6

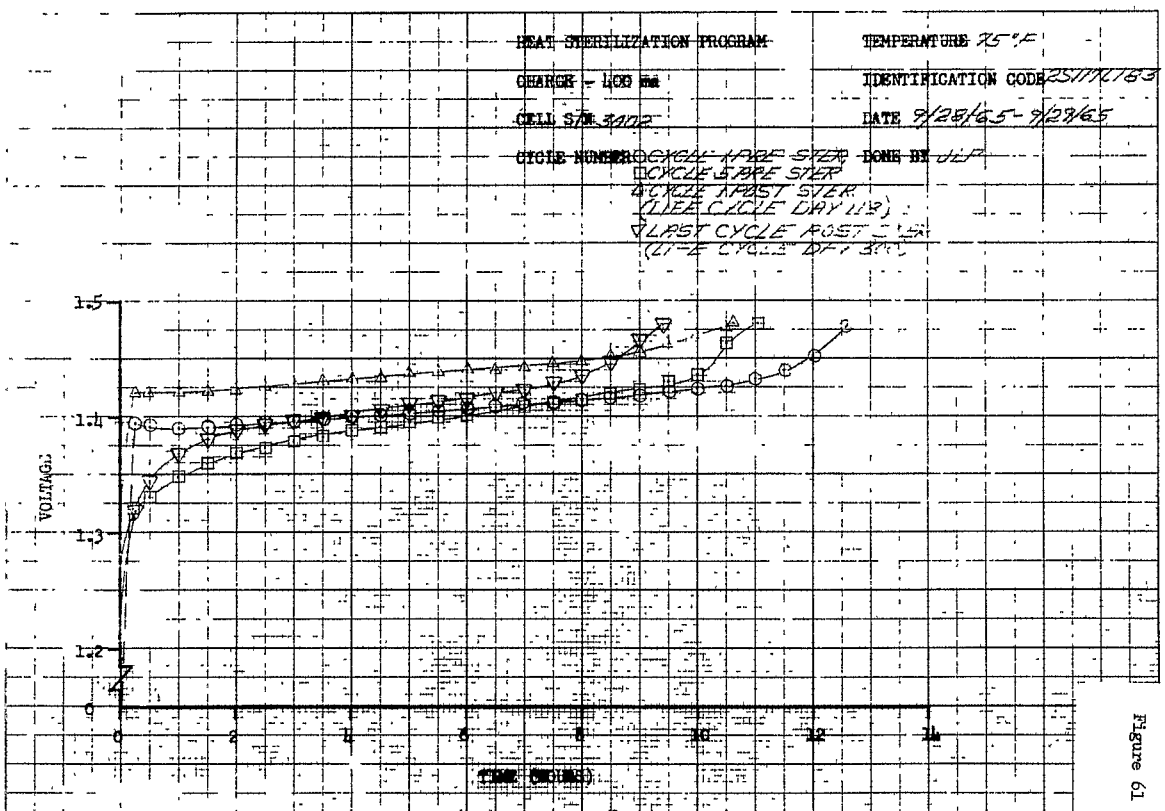


Figure 61

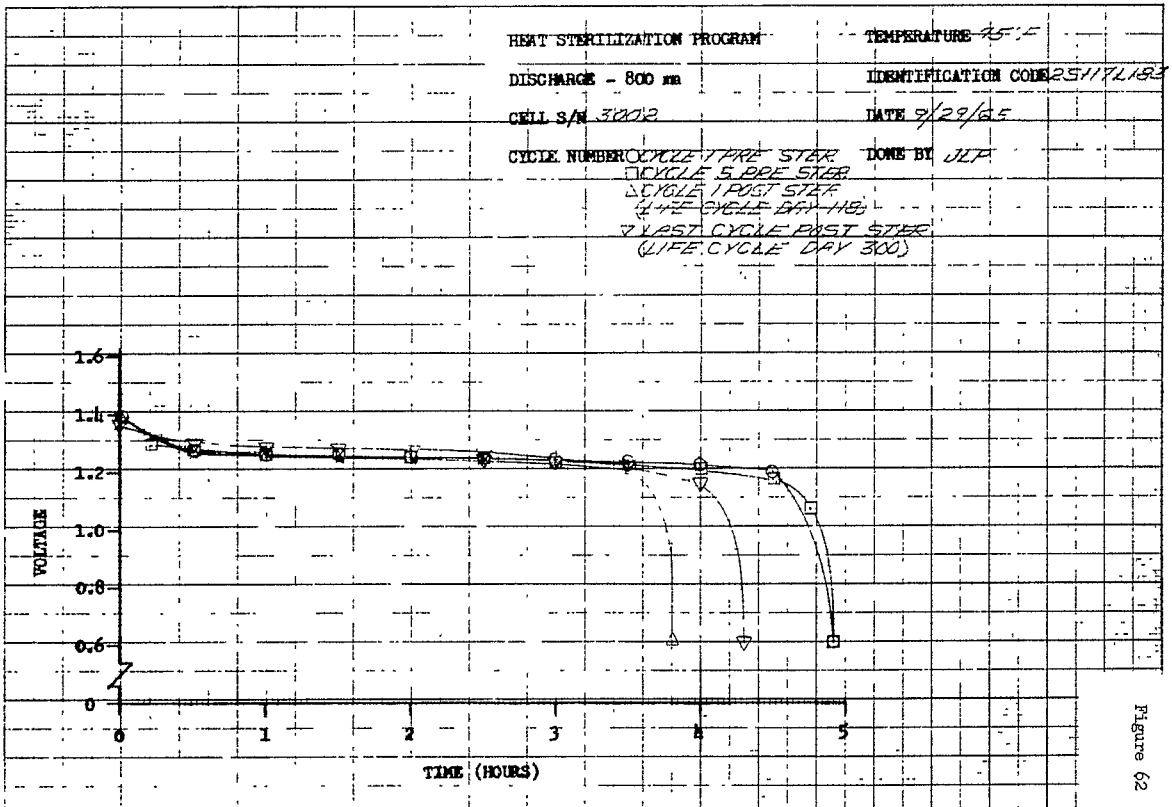

HEAT STERILIZATION PROGRAM
TEMPERATURE 45°C
DISCHARGE - 800 ma
IDENTIFICATION CODE 25117L183
CELL S/N 3002
DATE 9/29/65
CYCLE NUMBER CYCLE 1 PRE STER.
DONE BY JLP
□ CYCLE 5 PRE STER.
△ CYCLE 1 POST STER.
(4TH CYCLE DAY 118)
▽ LAST CYCLE POST STER.
(LIFE CYCLE DAY 300)
VOLTAGE
1.6
1.4
1.2
1.0
0.8
0.6
0
0
1
2
3
4
5
TIME (HOURS)

Figure 62

HEAT STERILIZATION PROGRAM
TEMPERATURE 75°F
CHARGE - 400 ma
IDENTIFICATION CODE 757102730
CELL S/N 3003
DATE 9/29/65-9/29/65
CYCLE NUMBER ○ CYCLE 1 PRE STER. DONE BY JLP
□ CYCLE 5 PRE STER
△ CYCLE 1 POST STER
(LIFE CYCLE DAY 152)
▽ LAST CYCLE POST STER
(LIFE CYCLE DAY 300)
VOLTAGE
1.5
1.4
1.3
1.2
0
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 63

HEAT STERILIZATION PROGRAM
TEMPERATURE 75°F
DISCHARGE - 800 ma
IDENTIFICATION CODE IS/70L/130
CELL S/N 3003
DATE 8/28/65
CYCLE NUMBER ○ CYCLE 1 PRE STER
□ CYCLE 5 PRE STER
△ CYCLE 1 POST STER
(LIFE CYCLE DAY 168)
▽ LAST CYCLE POST STER
(LIFE CYCLE DAY 300)
VOLTAGE
1.6
1.4
1.2
1.0
0.8
0.6
0
1
2
3
4
5
6
TIME (HOURS)

Figure 64

HEAT STERILIZATION PROGRAM
TEMPERATURE 75°F
CHARGE - 400 ma
IDENTIFICATION CODE 25°/0.2/30
CELL S/N 7001
DATE 9/24/65 - 9/29/65
CYCLE NUMBER
DONE BY J.L.P.
○ CYCLE 1 PRE STEP
□ CYCLE 5 PRE STEP
△ CYCLE 1 POST STEP (LIFE CYCLE DAY 168)
▽ LAST CYCLE POST STEP (LIFE CYCLE DAY 300)
VOLTAGE
1.5
1.4
1.3
1.2
0
6
8
10
12
14
TIME (HOURS)

Figure 65

Figure 66

Figure 67

Figure 68

Figure 69

HEAT STERILIZATION PROGRAM
TEMPERATURE 165°F
DISCHARGE - 800 ma
IDENTIFICATION CODE 25-230-220
CELL S/N 3012
DATE 9/29/65
CYCLE NUMBER ○ CYCLE 1 PRE STER DONE BY WLP
□ CYCLE 5 PRE STER
△ CYCLE 1 POST STER
(LIFE CYCLE DAY 231)
▽ LAST CYCLE POST STER
(LIFE CYCLE DAY 300)
VOLTAGE
1.6
1.4
1.2
1.0
0.8
0.6
0
0
1
2
3
4
5
TIME (HOURS)

Figure 70

HEAT STERILIZATION PROGRAM
TEMPERATURE 25°F
CHARGE - 400 ma
IDENTIFICATION CODE 15300200
CELL S/N 330/3
DATE 9/29/65 - 9/29/65
CYCLE NUMBER ○ CYCLE 1 PRE STER DONE BY WP
□ CYCLE 5 PRE STER
△ FIRST AND LAST CYCLE POST STER (SAME CYCLE)
VOLTAGE
TIME (HOURS)
0
2
4
6
8
10
12
14

Figure 71

HEAT STERILIZATION PROGRAM
TEMPERATURE 95°F
DISCHARGE - 800 ma
IDENTIFICATION CODE LS300L000
CELL S/N 3013
DATE 9/29/65
CYCLE NUMBER ○ CYCLE 1 PRE STER
□ CYCLE SPARE STER
△ FIRST AND LAST CYCLE
POST STER (SAME CYCLE)
DONE BY DLP
VOLTAGE
1.6
1.4
1.2
1.0
0.8
0.6
0
0
1
2
3
4
5
6
TIME (HOURS)

Figure 72

HEAT STERILIZATION PROGRAM

CHARGE - 400 ma

CELL S/N 3014

CYCLE NUMBER ○ CYCLE 1 PRE STER DONE BY JAP
□ CYCLE 5 PRE STER
△ FIRST AND LAST CYCLE
POST STER (SAME CYCLE)

TEMPERATURE 45°C

IDENTIFICATION CODE 5-300/000

DATE 9/28/65 - 9/29/65

VOLTAGE

1.5
1.4
1.3
1.2
1.1

0 2 4 6 8 10 12 14

TIME (HOURS)

Figure 73

HEAT STERILIZATION PROGRAM
TEMPERATURE 25°C
DISCHARGE - 800 ma
IDENTIFICATION CODE 25300L000
CELL S/N 3014
DATE 9/29/65
CYCLE NUMBER ○ CYCLE 1 PRE STER DONE BY JLP
□ CYCLE 5 PRE STER
Δ FIRST AND LAST CYCLE
POST STER (SAME CYCLE
VOLTAGE
1.6
1.4
1.2
1.0
0.8
0.6
0
0
1
2
3
4
5
6
TIME (HOURS)

Figure 74

Figure 75

Figure 76

Figure 77

Figure 78

HEAT STERILIZATION PROGRAM
TEMPERATURE 135°F
CHARGE - 400 ma
IDENTIFICATION CODE 1C0001300
CELL S/N 3017
DATE 9/24/65 - 9/27/65
CYCLE NUMBER ○ CYCLE 1 PRE STER DONE BY JLP
□ CYCLE 5 PRE STER
Δ CYCLE 7 POST STER
(LIFE CYCLE DAY 1)
▽ LAST CYCLE POST STER
(LIFE CYCLE DAY 300)
VOLTAGE
1.5
1.4
1.3
1.2
0
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 79

Figure 80

Figure 81

Figure 82

Figure 83

Figure 84

Figure 85

Figure 86

Figure 87.

Figure 88

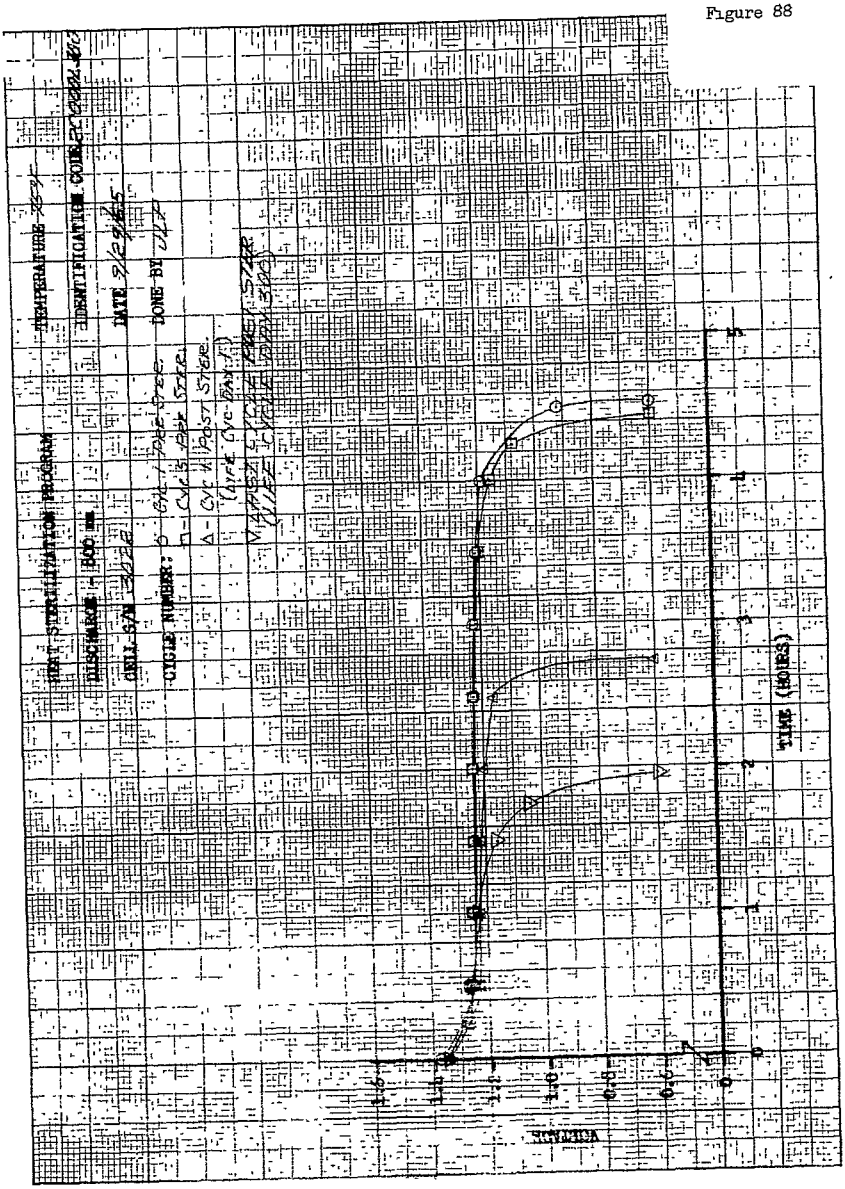


Figure 89

Figure 90

Figure 91

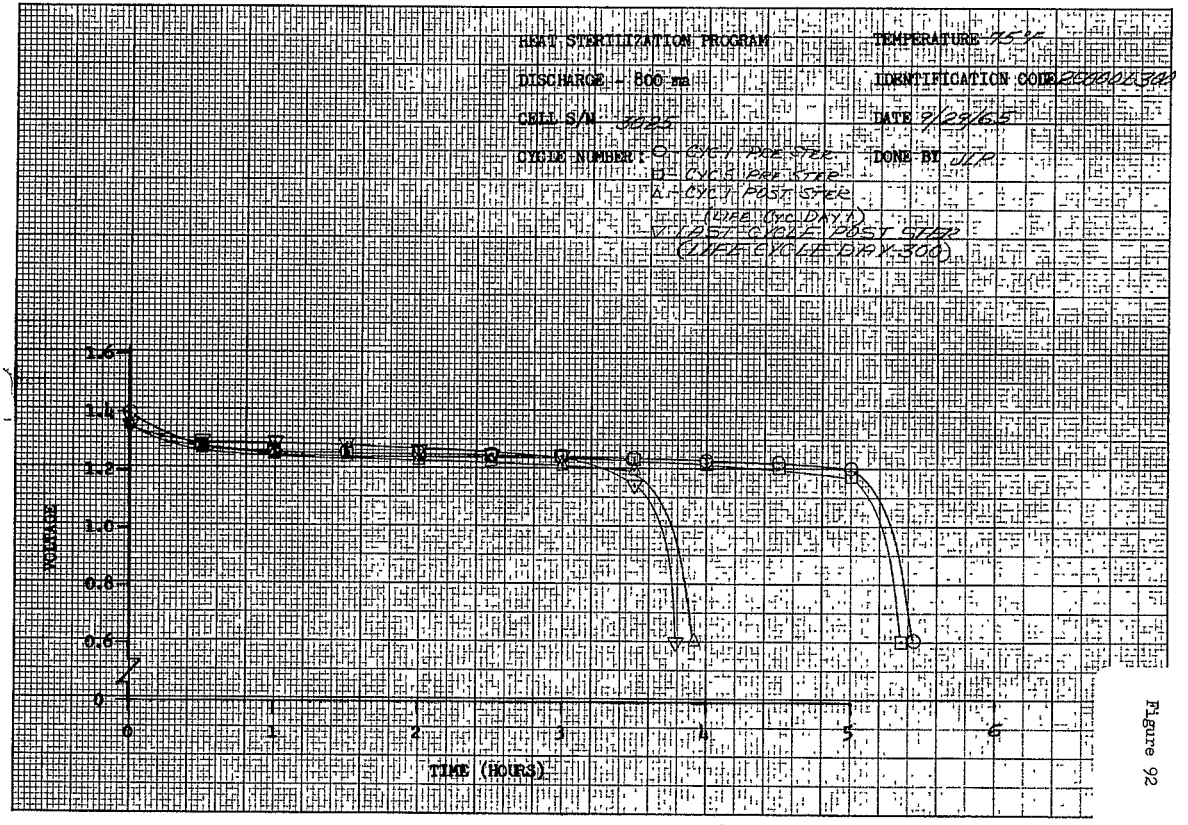


Figure 92

Figure 93

Figure 94

Figure 95

Figure 96

Figure 97

Figure 98

Figure 99

Figure 100

Figure 101

HEAT STERILIZATION PROGRAM — TEMPERATURE 95°C

DISCHARGE - 800 ma — IDENTIFICATION CODE 5000-L-300

CELL S/N 303 — DATE 9/29/65

CYCLE NUMBER: ○ - CYCLE PRE STEP — DONE BY JJD

□ - CYCLE PRE STEP

△ - CYCLE LAST STEP (LIFE CYCLE DAYS)

▽ LAST CYCLE POST STEP (LIFE CYCLE DAY 300)

Figure 102

Figure 103

HEAT STERILIZATION PROGRAM — TEMPERATURE 75°F

DISCHARGE - 800 ma — IDENTIFICATION CODE 5C9001300

CELL S/N 3015P — DATE 9/29/65

CYCLE NUMBER ○ CYCLE APRE STER DONE BY JAP

□ CYCLE 5 PRE STER

△ CYCLE 7 POST STER (LIFE CYCLE DAY 1)

▽ LAST CYCLE POST STER (LIFE CYCLE DAY 300)

VOLTAGE

1.6
1.4
1.2
1.0
0.8
0.6
0

0 1 2 3 4 5

TIME (HOURS)

140

Figure 104

HEAT STERILIZATION PROGRAM
TEMPERATURE 75°F
CHARGE - 100 ma
IDENTIFICATION CODE: 0000L300
CELL S/N 3034
DATE 8/28/65-8/29/65
CYCLE NUMBER ☒CYCLE 1 PRE STER DONE BY WLD
☐CYCLE 5 PRE STER
CELL FAILED TO RECEIVE CHARGE
AFTER NORMAL TERMINATION - REMOVED FROM
FURNACE
VOLTS
1.5
1.4
1.3
1.2
1.1
1.0
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 105

HEAT STERILIZATION PROGRAM

TEMPERATURE 75°C

DISCHARGE + 800 ma

IDENTIFICATION CODE 3[illegible]300

CELL S/N 3037

DATE 8/29/65

CYCLE NUMBER ☐CYCLE TIME SAVE ☐CYCLE SPARE SAVE

DONE BY JLP

CELL HELD TO OBTAIN OC ACCEPT CHARGE AFTER HEAT STERILIZATION – REMOVED FROM FURTHER TESTS

VOLTAGE

1.6
1.4
1.2
1.0
0.8
0.6

TIME (HOURS)

0
1
2
3
4
5

Figure 106

HEAT STERILIZATION PROGRAM
TEMPERATURE 155°F
CHARGE - 400 ma
IDENTIFICATION CODE 5200A300
CELL S/N 3055
DATE 8/28/65 - 8/29/65
CYCLE NUMBER ○ CYCLE 1 PRE STER. DONE BY JLP
□ CYCLE 5 PRE STER.
▽ CYCLE 1 POST STER.
(LIFE CYCLE DAY 1)
▽ LAST CYCLE POST STER.
(LIFE CYCLE Dr 130)
VOLTAGE
1.5
1.4
1.3
1.2
0
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 107

Figure 108

Figure 109

Figure 110

HEAT STERILIZATION PROGRAM
TEMPERATURE 25°C
CHARGE - 400 ma
IDENTIFICATION CODE 4000001300
CELL S/N 3038
DATE 9/29/65 - 9/29/65
CYCLE NUMBER: ○ - Cyc 1 pre Strc DONE BY JLP
□ - Cyc 5 pre strc
CELLS FAILED TO RECHARGE OR ACCEPT CHARGE AFTER HEAT STERILIZATION - REMOVED FROM FURTHER TESTS
VOLTAGE
1.5
1.4
1.3
1.2
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 111

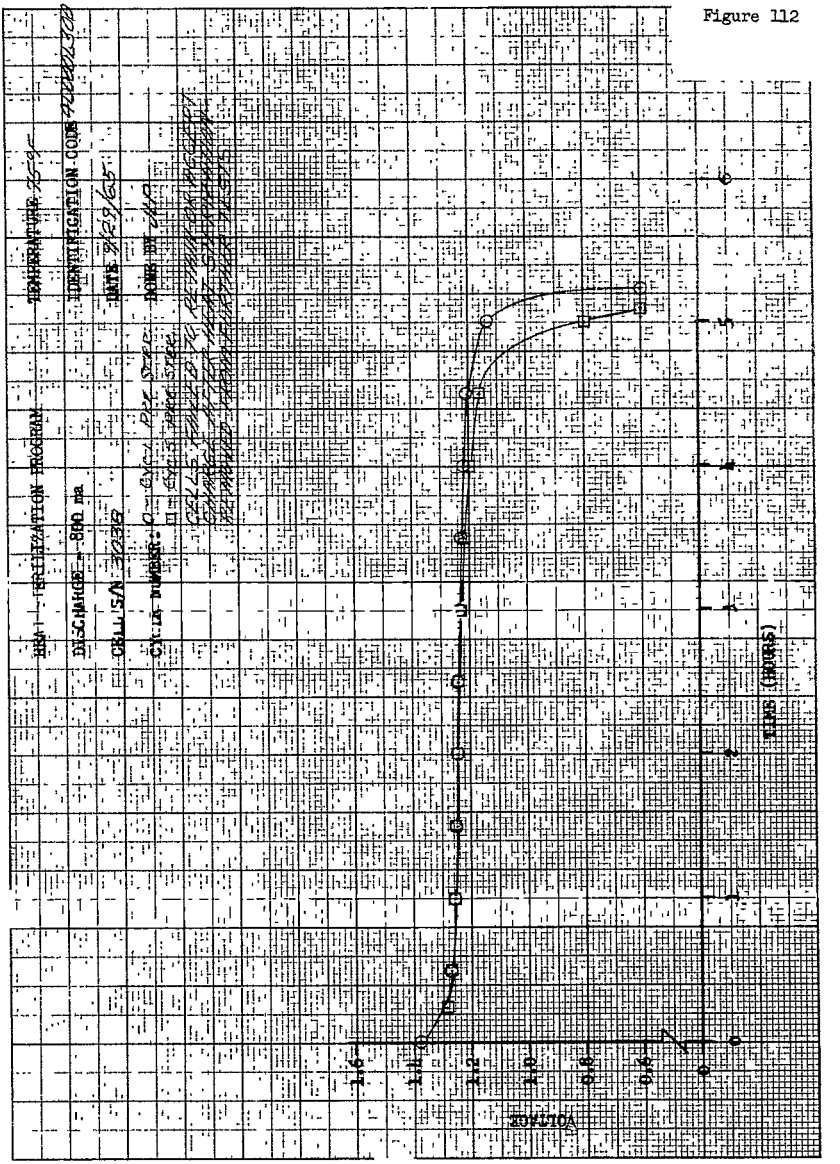


Figure 112

Figure 113

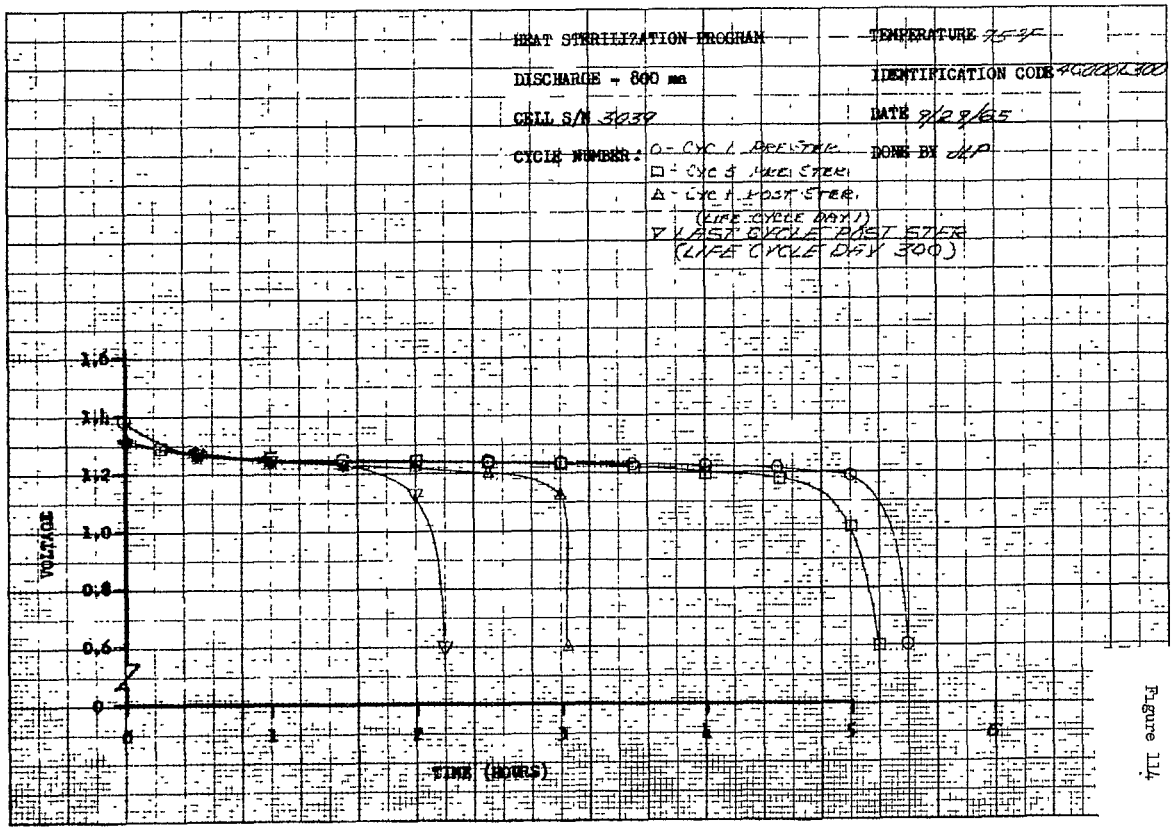


Figure 114.

Figure 115

Figure 116

HEAT STERILIZATION PROGRAM
CHARGE - 400 ma
CELL S/N 3043
CYCLE NUMBER
TEMPERATURE 75°F
IDENTIFICATION CODE TC0001300
DATE 9/28/65-9/29/65
CYCLE 1 PRE STER DONE BY JLP
CYCLE 5 PRE STER
CELL FAILED TO RETAIN OR ACCEPT CHARGE AFTER HEAT STERILIZATION-REMOVED FROM FURTHER TESTS
VOLTAGE
1.5
1.4
1.3
1.2
0
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 117

Figure 118

Figure 119

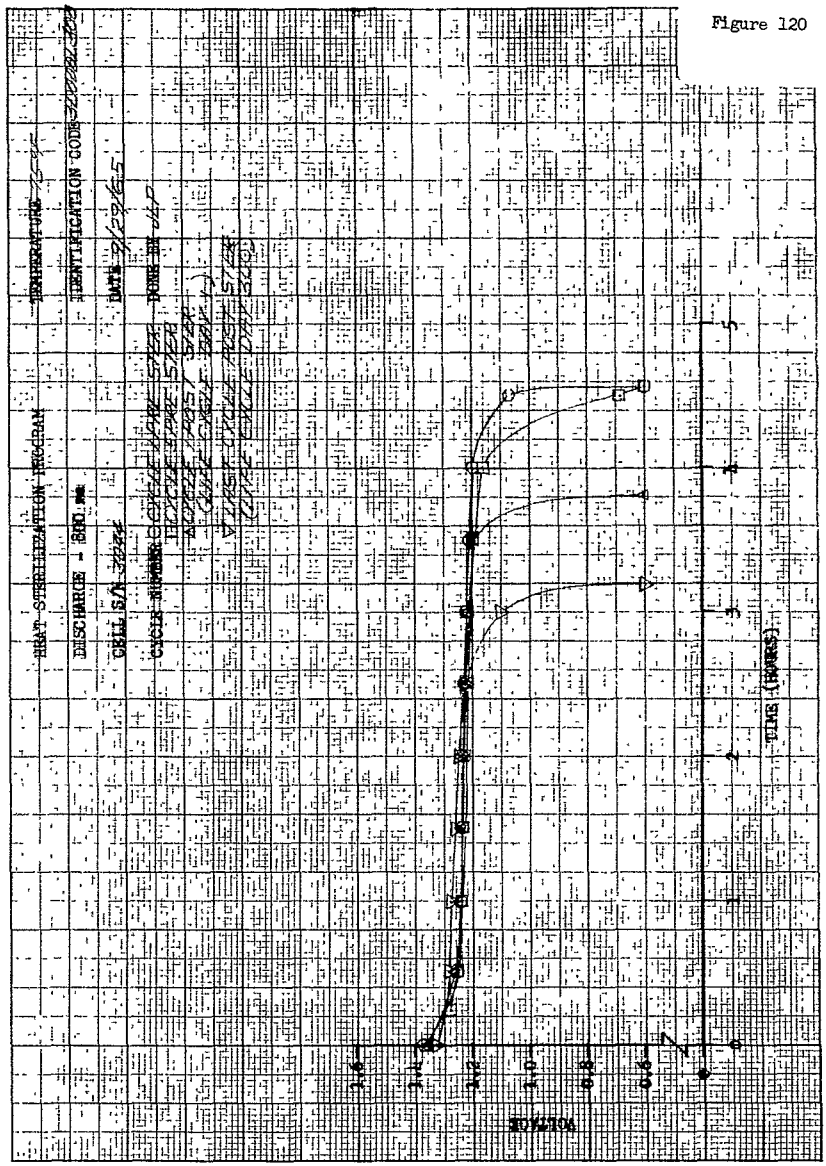


Figure 120

Figure 121

Figure 122

HEAT STERILIZATION PROGRAM TEMPERATURE 75°C

CHARGE — 100 ea IDENTIFICATION CODE XXXXXX300

CELL S/N 3046 DATE 9/27/65

CYCLE NUMBER : 9 — CYC 7 LAST STEP DONE BY JAP
CYC 5 PRE STER.
CELL FAILED TO RETAIN OR ACCEPT
CHARGE AFTER HEAT STERILIZATION
REMOVED FROM FURTHER TESTS.

Figure 123

Figure 124

Figure 125

Figure 126

HEAT STERILIZATION PROGRAM
TEMPERATURE 71.9°C
CHARGE - 400 ma
IDENTIFICATION CODE 3C0802300
CELL S/N 3048
DATE 8/28/65 - 8/29/65
CYCLE NUMBER : O - CYC 1 PRE STER DONE BY JLP
□ - CYC 3 PRE STER
Δ - CYC 1 POST LIFE
(TIME CYC 1 ONLY)
▽ LAST CYCLE POST STER
(LIFE CYCLE CYC 300)
1.5
1.4
1.3
1.2
0
VOLTAGE
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 127

Figure 128

HEAT STERILIZATION PROGRAM
CHARGE - 400 ma
CELL S/N 3049
CYCLE NUMBER
TEMPERATURE 75 °F
IDENTIFICATION CODE
DATE
DONE BY JLP
CYCLE 1 PRE STAT
CYCLE 5 PRE STAT
CYCLE 1 POST STAT
(AFTER CYCLE 1 AT 1)
LAST CYCLE POST STAT
(AFTER CYCLE AT 30)
VOLTAGE
1.5
1.4
1.3
1.2
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 129

Figure 130

HEAT STERILIZATION PROGRAM

CHARGE - 400 ma

CELL S/N 2283, 2286

CYCLE NUMBER 2

TEMPERATURE 75°F

IDENTIFICATION CODE 24/90L130 2F230A090

DATE 9/29/65 - 9/30/65

DONE BY JLP

2286

2283

VOLTAGE

1.5

1.4

1.3

1.2

1.1

0

0

2

4

6

8

10

12

14

TIME (HOURS)

Figure 131

Figure 132

HEAT STERILIZATION PROGRAM

TEMPERATURE 75°F

CHARGE 400 ma

IDENTIFICATION CODE 75230200
260491300

CELL S/N 3008-3022

DATE 9/29/65-9/29/65

CYCLE NUMBER 2

DONE BY JLP

3022
3008

VOLTAGE

1.5
1.4
1.3
1.2
1.1
1.0
0

0 2 4 6 8 10 12 14

TIME (HOURS)

Figure 133

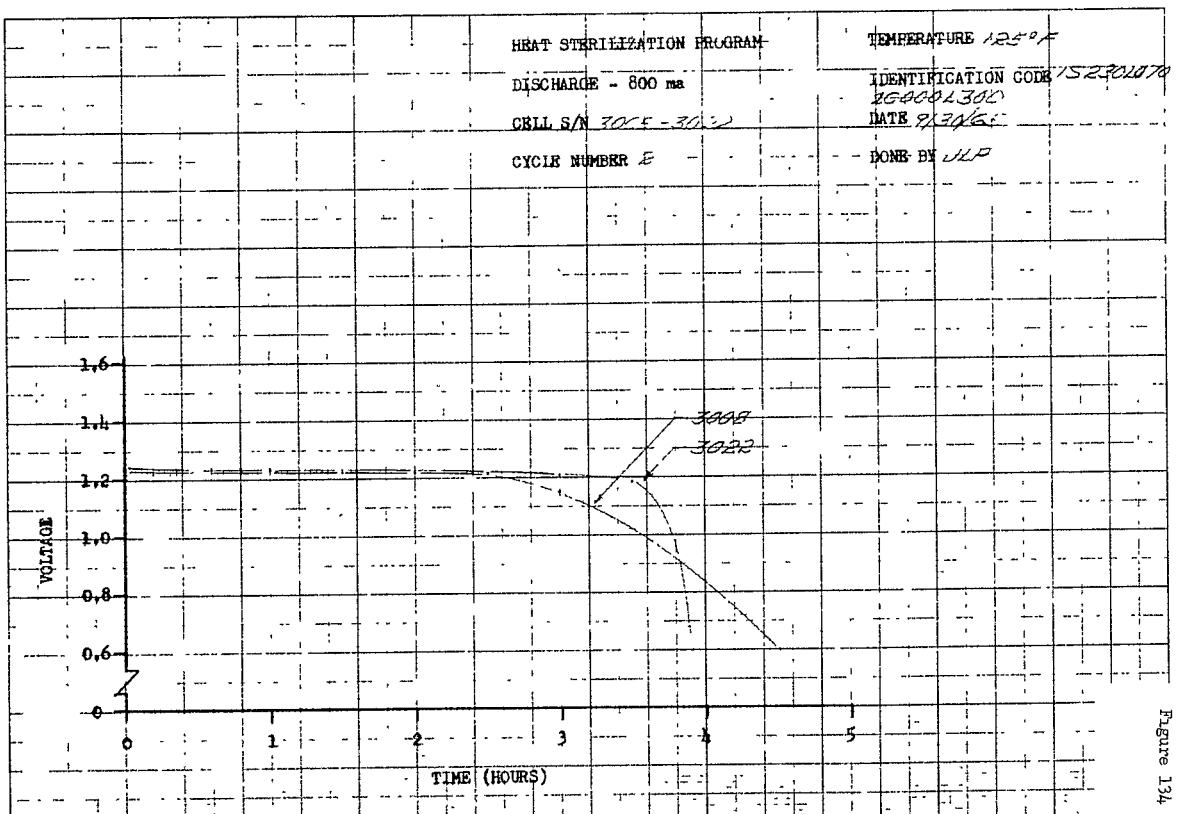


Figure 134

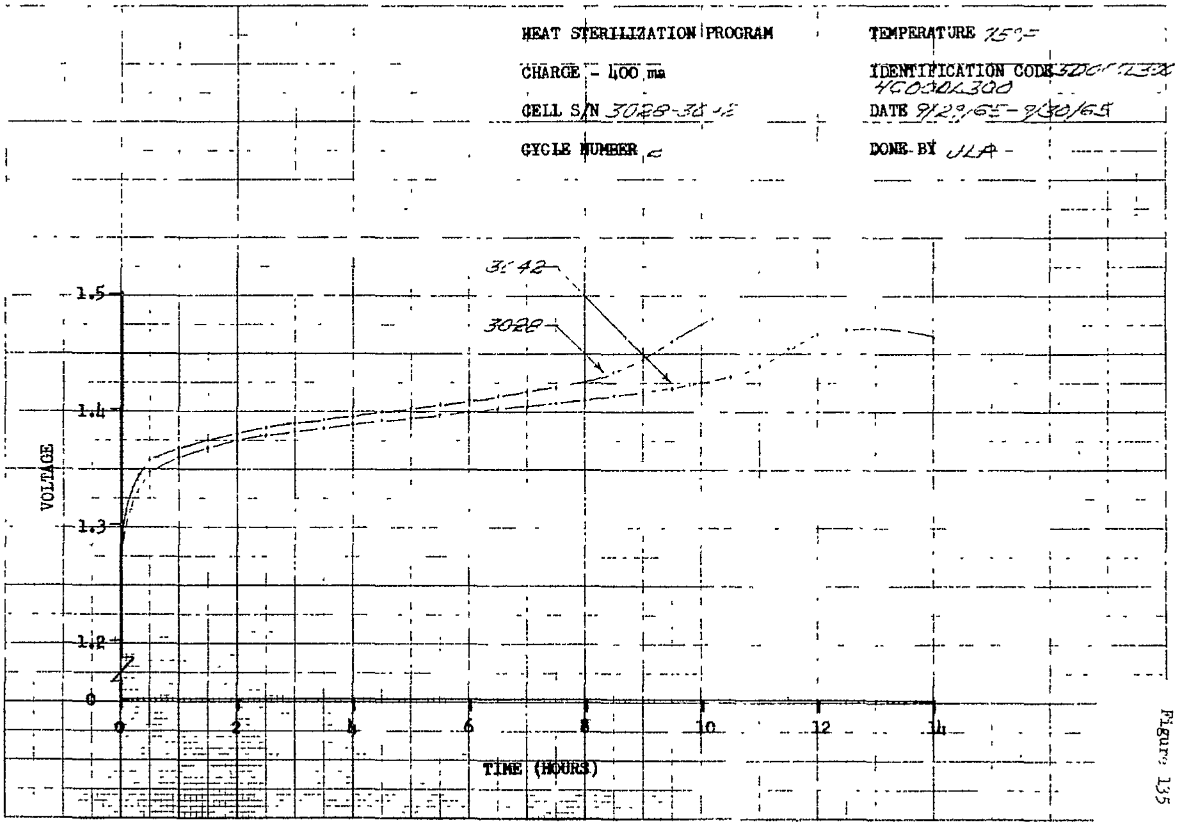

HEAT STERILIZATION PROGRAM
CHARGE - 400 ma
CELL S/N
CYCLE NUMBER
TEMPERATURE
IDENTIFICATION CODE
DATE 9/29/65-9/30/65
DONE BY JLA
3142
3028
VOLTAGE
1.5
1.4
1.3
1.2
0
0
2
4
6
8
10
12
14
TIME (HOURS)

Figure 135

Figure 136

Figure 137

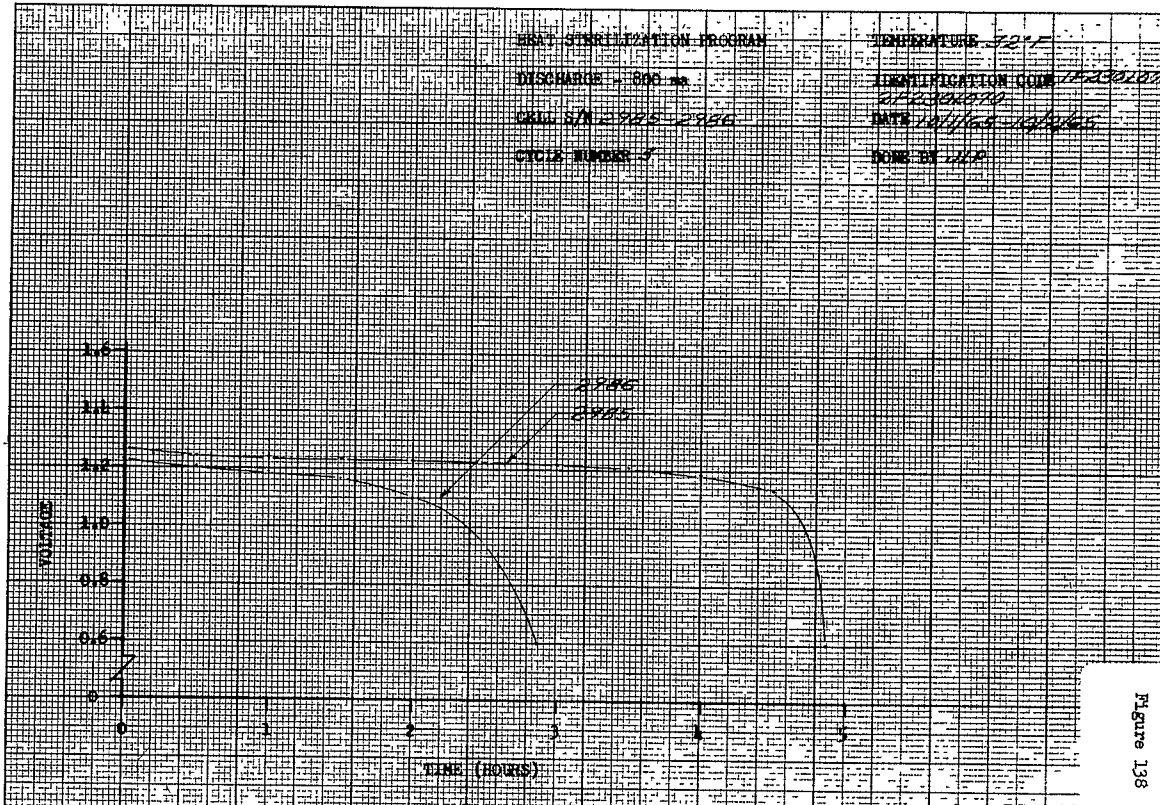


Figure 138

Figure 139

Figure 140

Figure 141

Figure 142

Figure 143

Figure 144

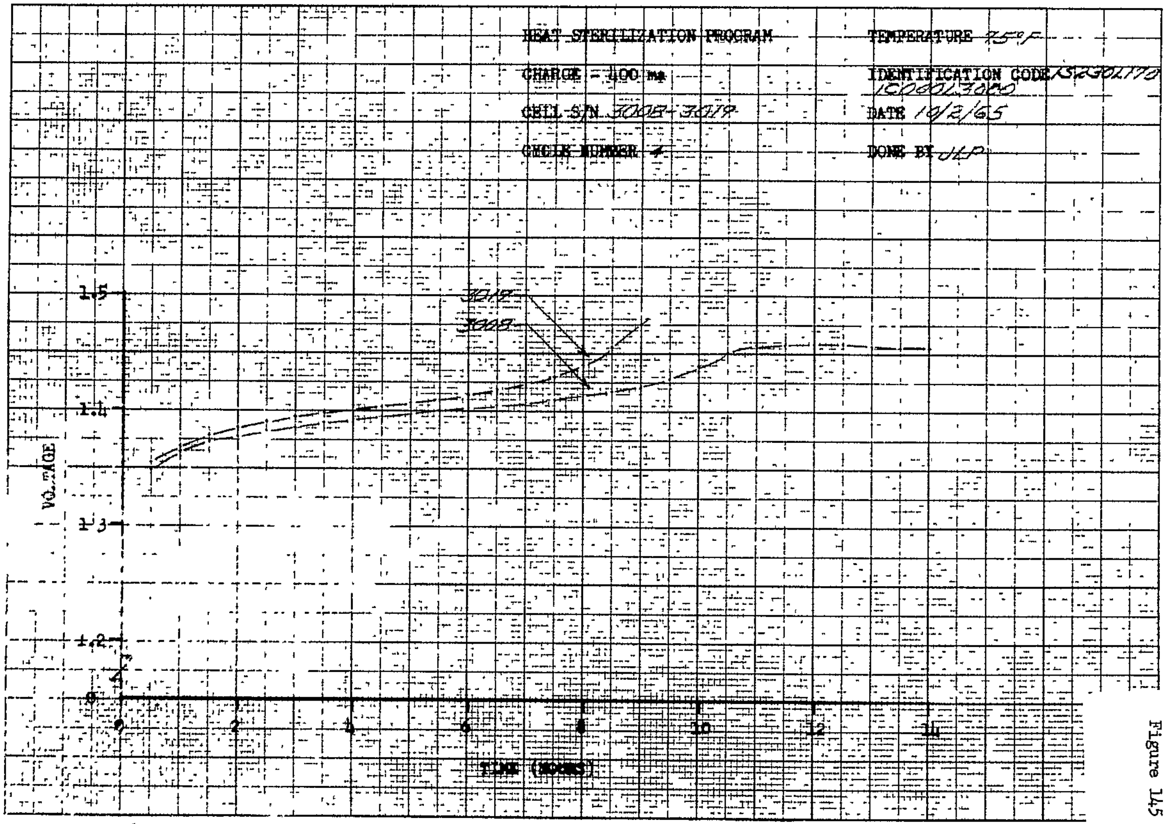


Figure 145

Figure 146

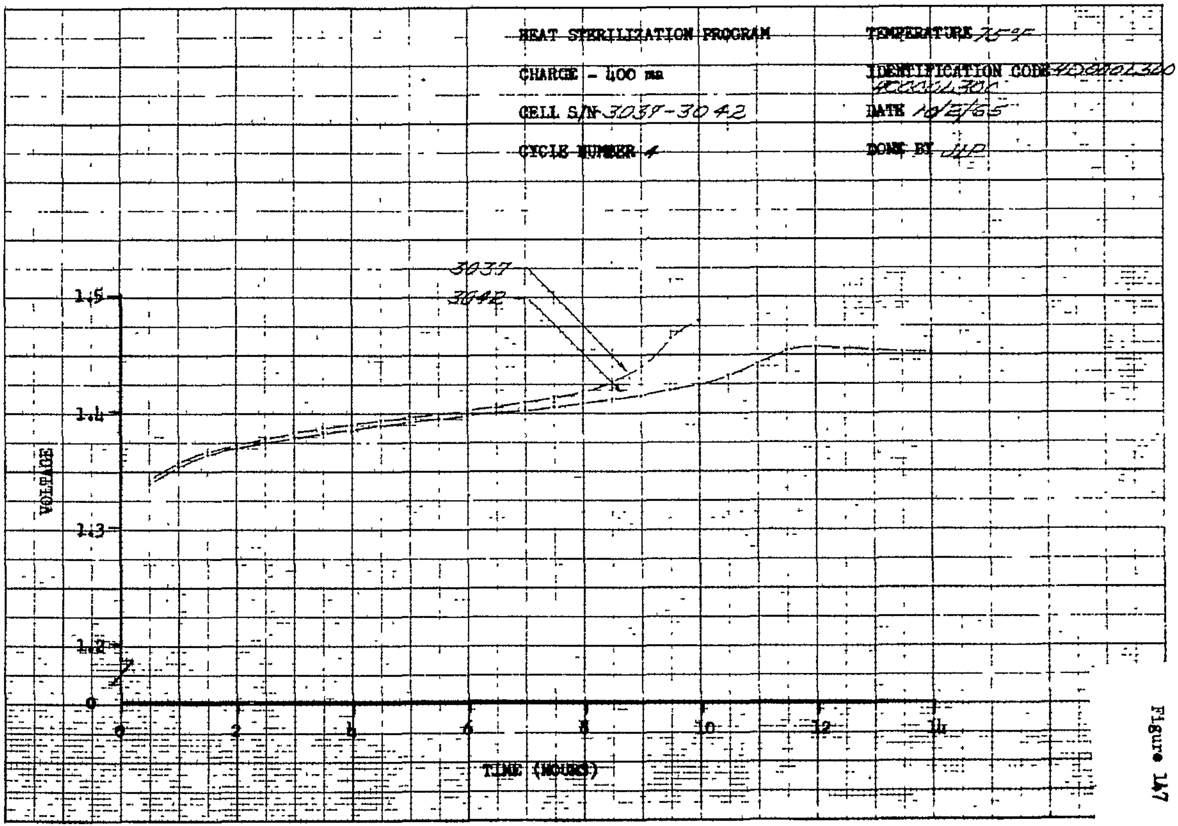


Figure 147

HEAT STERILIZATION PROGRAM

TEMPERATURE 75°F

DISCHARGE 100 ma

IDENTIFICATION CODE HDMA2300
HDMA1300

CELL S/N 3037 3042

DATE 10/2/65-10/3/65

CYCLE NUMBER 4

DONE BY JWP

3042
3037

VOLTAGE

1.6
1.4
1.2
1.0
0.8
0.6
0

0 2 4 6 8 10 12

TIME (HOURS)

Figure 148

K&E 20 X 20 TO THE INCH 359-10½G
HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 100 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
STERILIZED 6TH DAY
CELL S/N 2966
DATE 12-17-65
DONE BY JEP
KEY
INPUT CAPACITY
OUTPUT CAPACITY
END OF CHG VOLTAGE
185
CYCLE (Days)

Figure 149

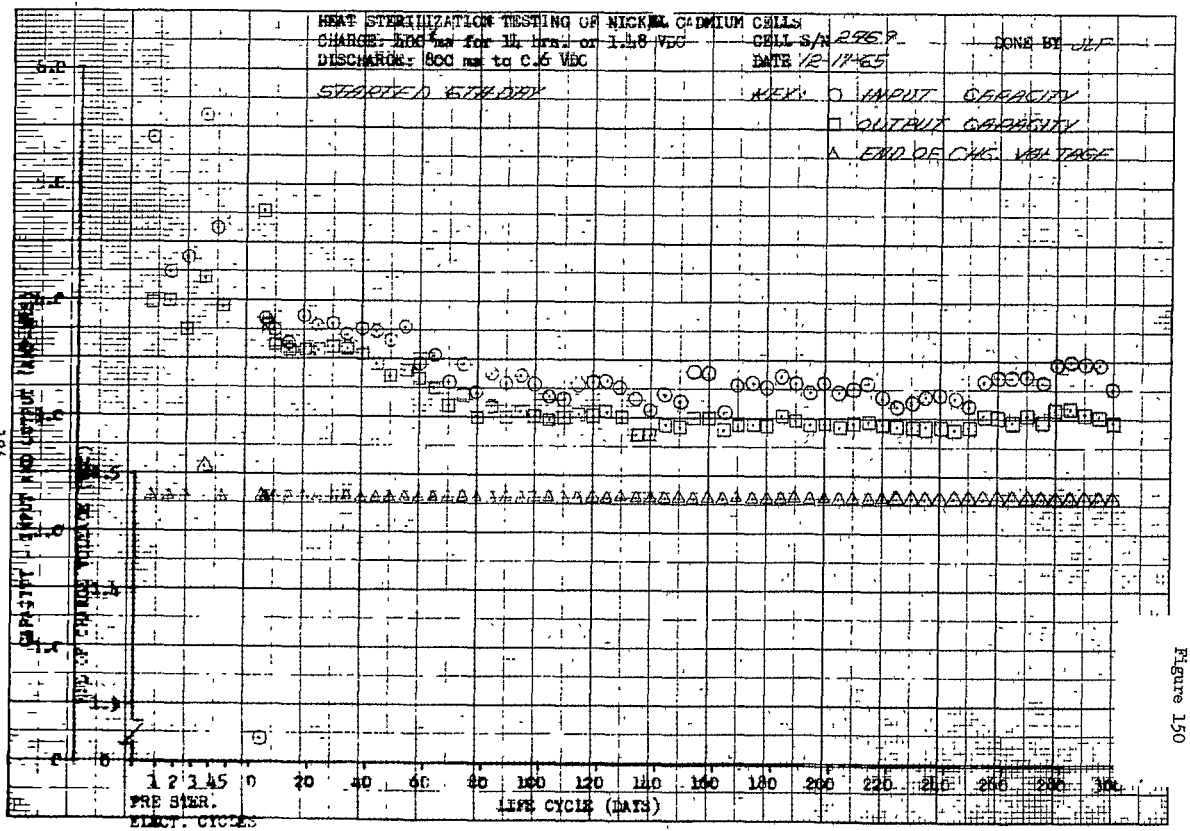


Figure 150

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 2970
DATE 12-17-65
DONE BY DEP
STERILIZE: ON 21ST DAY
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG. VOLTAGE
6.0
4.0
2.0
0
0 3 5 10 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
PRE BURN-IN ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 151

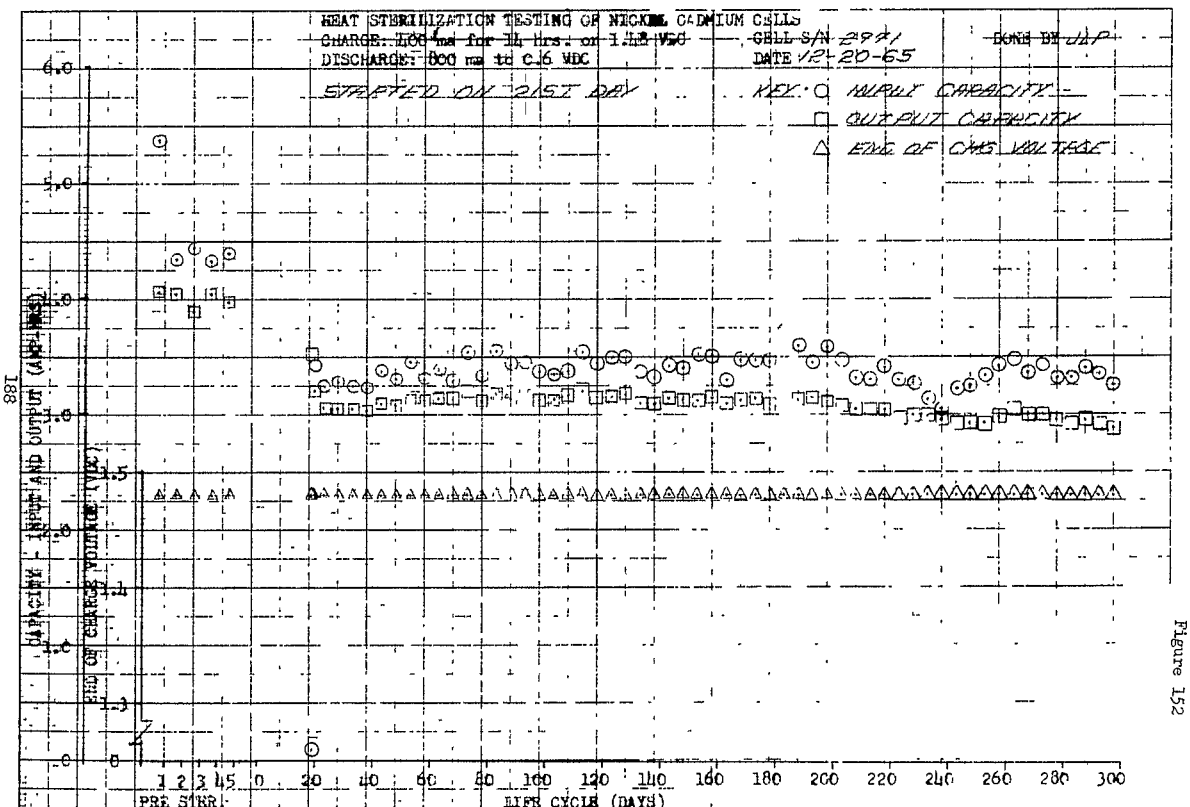

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 100 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 2941
DONE BY JAP
DATE 12-20-65
STARTED ON 21ST DAY
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG VOLTAGE
END OF CHARGE VOLTAGE (VDC)
CAPACITY (AH) OUTPUT
PRE STER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 152

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
STARTED ON #200 DRY
CELL S/N 2912
DATE 12-20-61
DONE BY JLP
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG. VOLTAGE
CAPACITY + INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE
PRE-STER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 153

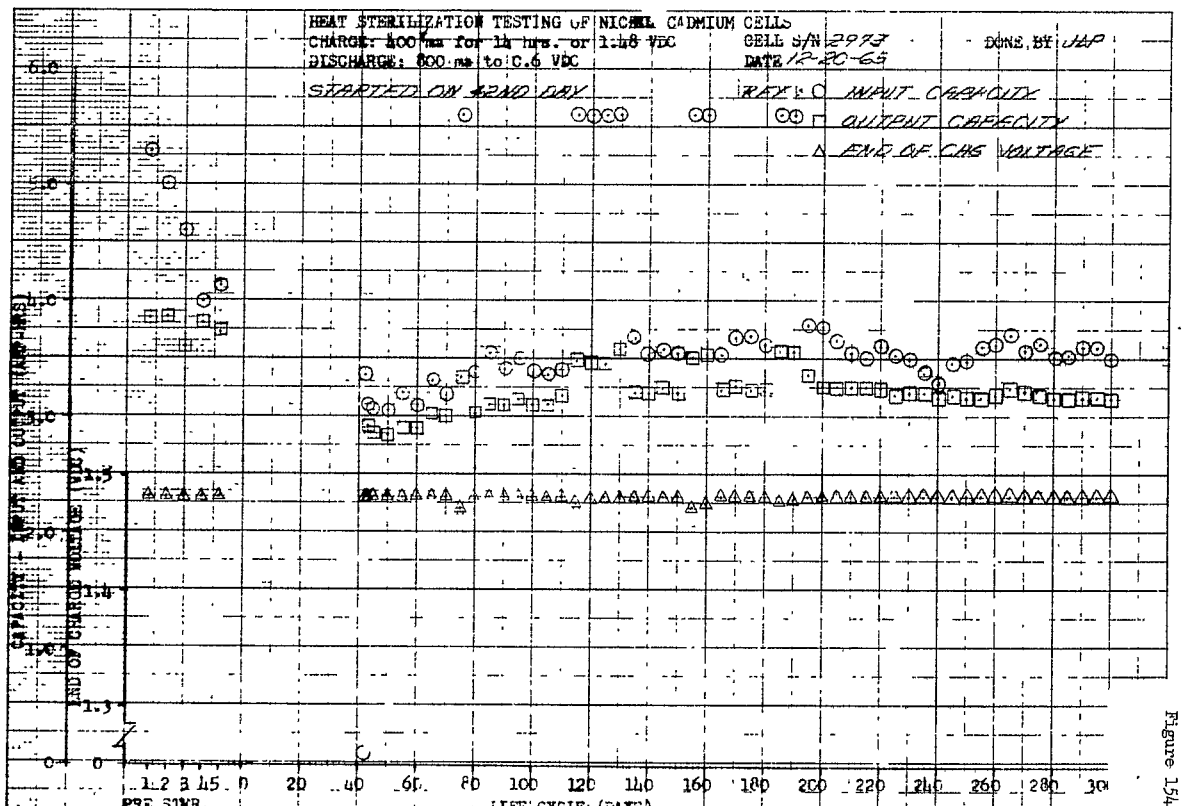


Figure 154

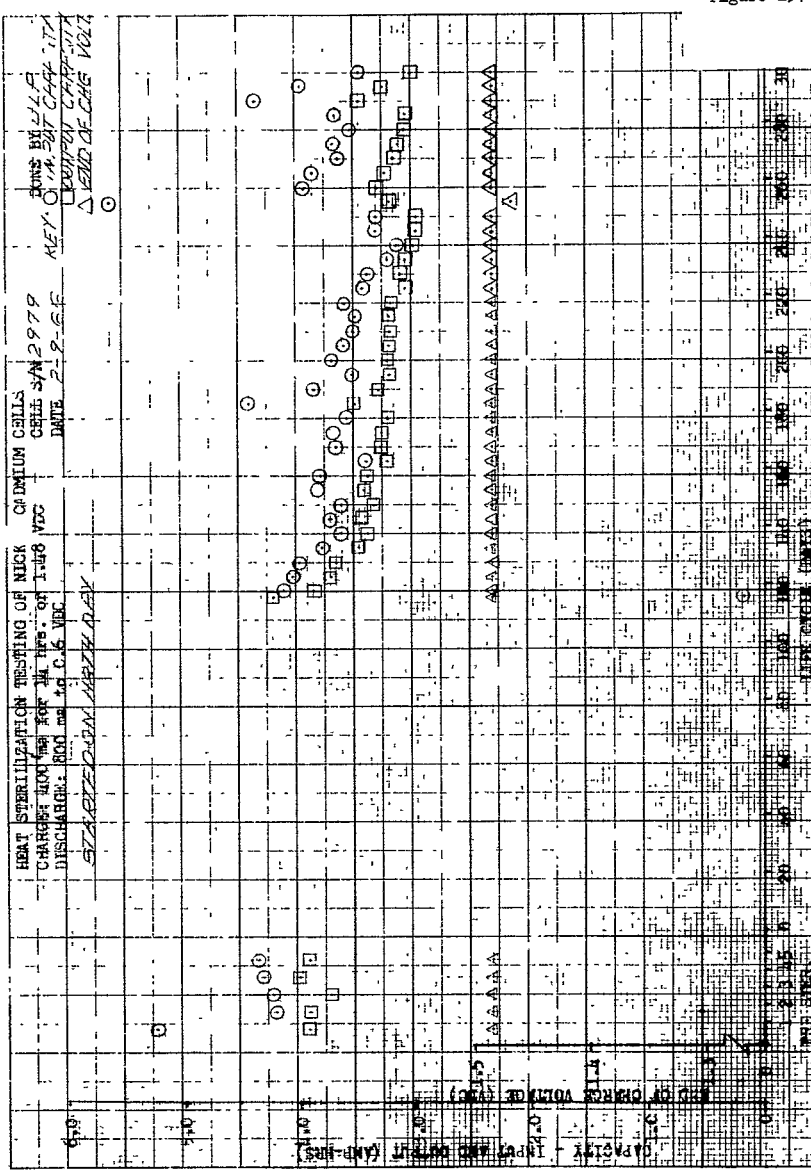
HEAT STERILIZATION TESTING OF NICK CADMIUM CELLS
CHARGE: 600 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 2774
DATE 4-24-66
STARTED 26TH DAY
KEY
INPUT CAPACITY
OUTPUT CAPACITY
END OF CHG VOLTAGE
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE
LIFE CYCLE (DAYS)
PSR 3000
ELECT. CYCLES

Figure 155

HEAT STERILIZATION TESTING OF NICK. CADMIUM CELLS
CHARGE: 400 ma for 1h hrs. or 1.45 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 2975
DATE 2-24-66
DONE BY JLP
STARTED 76TH DAY
KEY
INPUT CAPACITY
OUTPUT CAPACITY
END OF CHG VOLTAGE
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PRE-STER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 156

Figure 157


HEAT STERILIZATION TESTING OF NICK
CHARGED 400 ma for 24 hrs. at 1.40
DISCHARGE: 800 ma to 0.6 VDC
CADMIUM CELLS
CELL S/N 2979
DATE 2-2-66
KEY: ○ 1ST CHARGE
□ 2ND CHARGE
△ 3RD CHARGE
CAPACITY - Input AMP-HRS
END OF CHARGE VOLTS
CYCLES

HEAT STERILIZATION TESTING OF NICK. CADMIUM CELLS
CHARGE: 100 ma for 14 hrs. or 1.45 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 2220
DATE 2-7-66
DONE BY CHF
STARTED ON HEAT DEK
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG VOLTAGE
CAPACITY (AMP-HRS) AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PRE STER.
ELECT. CYCLE
LIFE CYCLE (DAYS)

Figure 158

HEAT STERILIZATION TESTING OF NICK. CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 2984
DATE 4-1-66
DONE BY JHP
STERILE 169TH DAY
KEY: O INPUT CAPACITY
Φ OUTPUT CAPACITY
Δ END OF CHARGE VOLTAGE
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
1.4
1.3
1.2
1.1
1.0
1 2 3 4 5 6 20 40 60 80 100 120 140 160 180 200 220 240 260 280 301
PRE STER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 159

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 100 ma for 14 hrs. or 1.18 WIG
DISCHARGE: 300 ma to C.6 VDC
CELL S/N 2993
DATE 4-1-66
DONE BY
STARTED ON TEST DAY
KEY
INPUT CAPACITY
OUTPUT CAPACITY
END OF CHG VOLTAGE
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VOLTS)
6.0
5.0
4.0
3.0
2.0
1.0
0
1 2 3 4 5
PRE STER. ELECT. CYCLES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
LIFE CYCLE (DAYS)

Figure 160

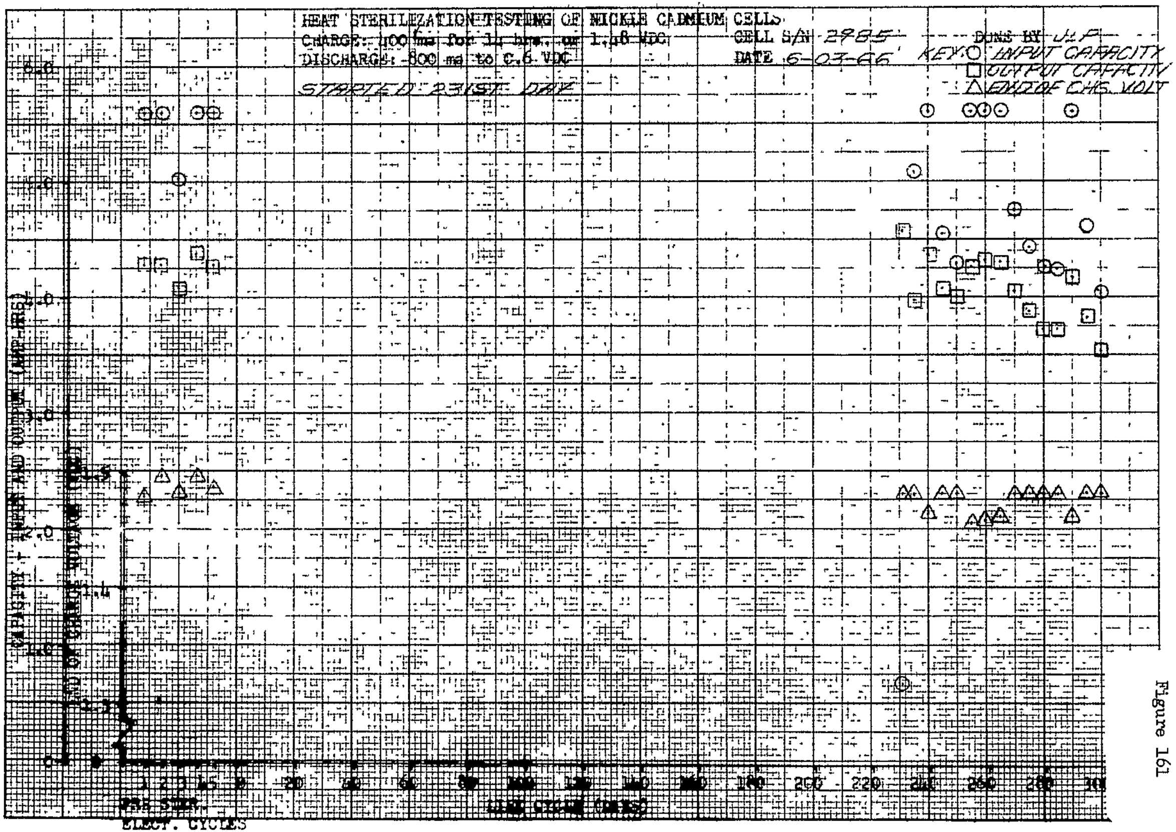

HEAT STERILIZATION TESTING OF NICKLE CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
STARTED 231ST DAY
CELL S/N 2985
DATE 6-03-66
DONE BY J.P.
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG. VOLT
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
1.5
1.4
1.3
1 2 3 4 5 10 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
PRE STER.
ELECT. CYCLES
ELEC CYCLES (DAYS)

Figure 161

HEAT STERILIZATION TESTING OF NICKLE CADMIUM CELLS
CHARGE: 100 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 500 ma to C.6 VDC
CELL S/N 2986
DATE 6-03-66
DONE BY JLP
STARTED ON 231ST DAY
KEY:
INPUT CAPACITY
OUTPUT CAPACITY
END OF CHG VOLTAGE
CAPACITY INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PRE STER.
ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 162

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 1h hrs. or 1.45 VDC
DISCHARGE: 800 ma to C.6 VDC
STARTED ON 6TH DAY
CELL S/N 2991
DATE 12-18-65
DONE BY JHP
KEY:- ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG. VOLTAGE
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
LIFE CYCLE (DAYS)
ELECT. C10125

Figure 162

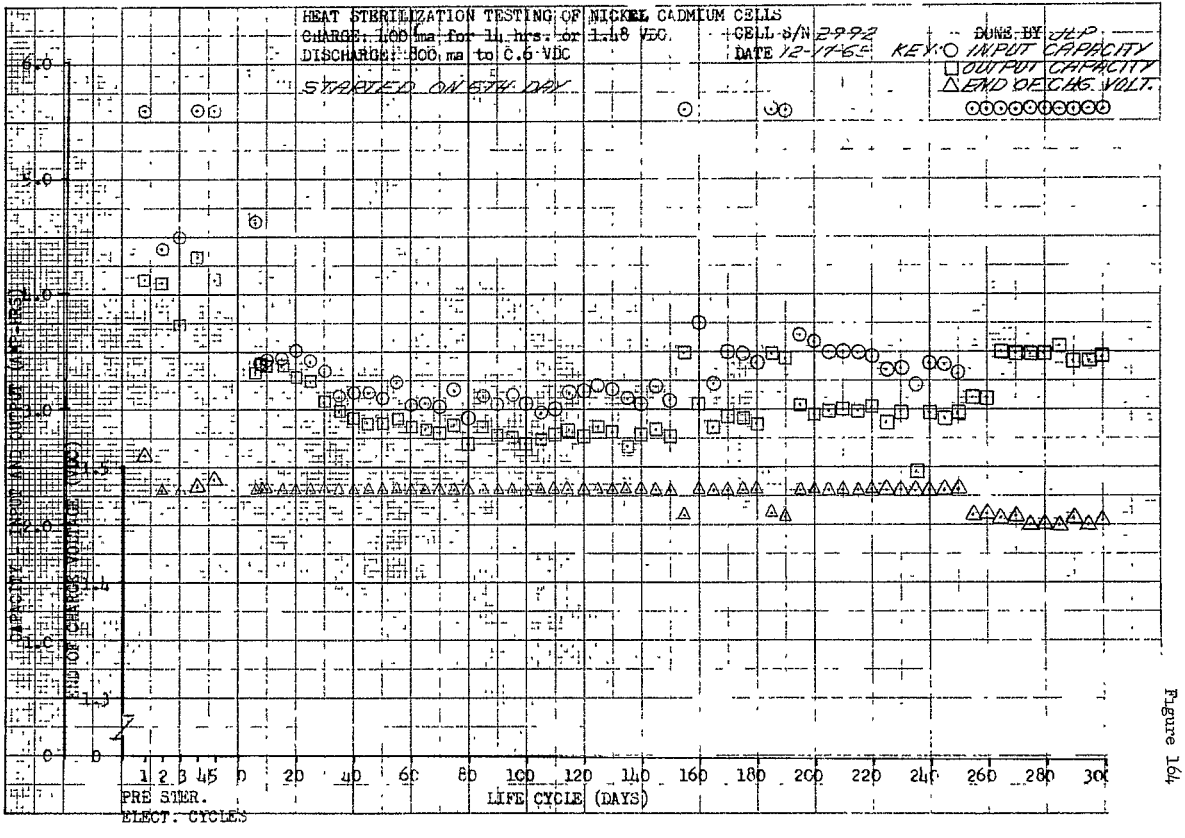


Figure 164

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 100 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 2994
DATE 12-20-65
DONE BY JLP
STERILIZATION EVERY DAY
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG VOLTAGE
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
6.0
5.0
4.0
3.0
2.0
1.0
0
0 1 2 3 4 5
PRE STER. ELECT. CYCLES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
LIFE CYCLE (DAYS)

Figure 165

Figure 166

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 2777
DATE 12-20-65
DONE BY JEP
STARTED ON 42ND DAY
KEY: INPUT CAPACITY
OUTPUT CAPACITY
END OF CHG VOLTAGE
CAPACITY INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
6.0
5.0
4.0
3.0
2.0
1.0
0
1 2 3 4 5
PRE-STER. ELECT. CYCLES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
LIFE CYCLE (DAYS)

Figure 167

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 1h hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 2298
DATE 12-20-65
DONE BY JEF
STARTED ON 42ND DAY
KEY: INPUT CAPACITY
OUTPUT CAPACITY
END OF CHG VOLTAGE
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VOLTS)
PRE STER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 168

HEAT STERILLIZATION TESTING OF NICK . CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
GELL S/N 2999
DATE 1-24-66
RUNS BY DEP
KEY ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG VOLT
START 20 DEEP DAY
CAPACITY (AMP-HRS) AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PER CENT
ELECT. CYCLES
CYCLE (DAYS)

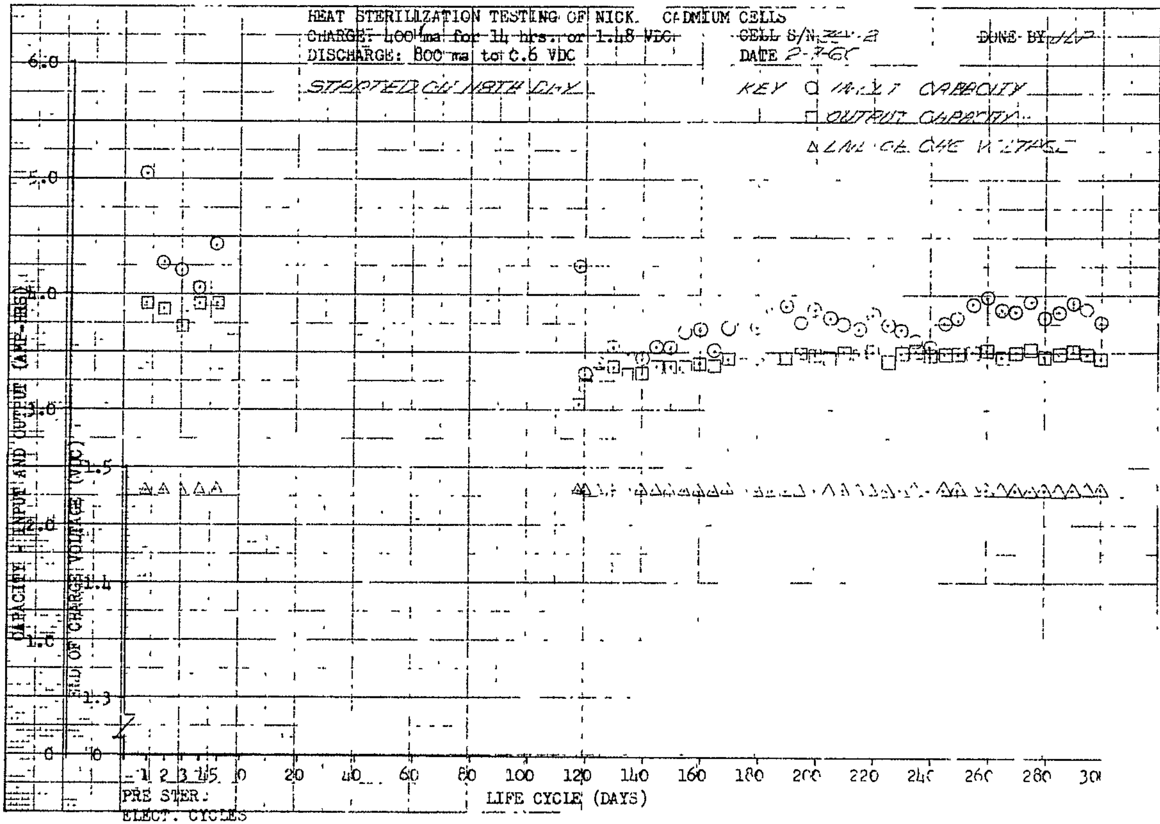
Figure 169

HEAT STERILIZATION TESTING OF NICK - CADMIUM CELLS
CHARGE: 400 ma for 1h hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
STARTED TEST DAY
CELL S/N 3800
DATE 1-24-66
DONE BY JLF
KEY
INPUT CAPACITY
OUTPUT CAPACITY
END OF CHG VOLTAGE
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PRE STER.
ELECT. CYCLE
LIFE CYCLE (DAYS)

Figure 170

HEAT STERILIZATION TESTING OF NICK CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 3004
DATE 2-7-66
DONE BY
STARTED CYCLING DAY
OUTPUT CAPACITY
END OF CHG. VOLT
CAPACITY INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PRE STER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 171



HEAT STERILIZATION TESTING OF NICK. CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N
DATE
DONE BY
KEY
INPUT CAPACITY
OUTPUT CAPACITY
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PRE STER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 172

HEAT STERILIZATION TESTING OF NICKLE CADMIUM CELLS.
CHARGE: 100 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 3003
DATE 4-1-66
DONE BY JLP
STARTED ON 16TH KEY
KEY
INPUT CAPACITY
OUTPUT CAPACITY
END OF CHG VOLTAGE
CAPACITY (AMP-HRS)
END OF CHARGE VOLTAGE
CYCLE NUMBER
LIFE CYCLE (DAYS)

Figure 173

Figure 174

HEAT STERILIZATION TESTING OF NICKLE CADMIUM CELLS
CHARGE: 400 ma for 11 hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 3005
DATE 6-03-66
DONE BY JEF
STARTED ON 231ST DAY
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG VOLTAGE
CAPACITY INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
1.4
1.3
1 2 3 4 5 0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
PRE STER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 175

HEAT STERILIZATION TESTING OF NICKLE CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 3012
DATE 6-03-66
DONE BY J.A.P.
KEY ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG. VOLT.
STARTED ON 231ST DAY
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
6.0
5.0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
1 2 3 4 5
PRE STER. ELECT. CYCLE
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
LIFE CYCLE (DAYS)

Figure 176

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 100 ma for 11 hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 3015
DATE 12-15-65
DONE BY JLF
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG. VOLTAGE
CAPACITY - AMP HRS
CHARGE VOLTAGE
DISCHARGE VOLTAGE
PRE STER. ELECT. CYCLES
LIFE CYCLES (DAYS)

Figure 177

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 100 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 3046
DATE 12-5-65
CAPACITY INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
LIFE CYCLE (DAYS)

Figure 178

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 100 ma for 1h hrs. or 1.45 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 3014
DONE BY JAF
DATE 12-16-65
OUTPUT CAPACITY
END OF CHG VOLT
6.0
5.0
4.0
3.0
2.0
1.0
0
1 2 3 4 5
PRE STER. ELECT. CYCLES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
LIFE CYCLE (DAYS)

Figure 179

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 3019
DATE 12-AG-65
DONE BY DEP
KEY: ① INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG. VOLTAGE
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
6.0
5.0
4.0
3.0
2.5
2.0
1.4
1.3
1.0
0
1 2 3 4 5
PRE STER. ELECT. CYCLES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
LIFE CYCLE (DAYS)

Figure 180

Figure 181

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 100 ma for 14 hrs. or 1.18 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 3021
DATE 12-16-65
DONE BY DLP
KEY: ⊙ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG VOLTAGE
CAPACITY INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VOLTS)
PRE STLR.
ELECT. CYCLE
LIFE CYCLE (DAYS)

Figure 182

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 3022
DATE 12-16-65
DONE BY JLP
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG. VOLTAGE
CAPACITY INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PRE STER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 183

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 1723
DATE 12-16-65
DONE BY JLP
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG. VOLTS
CAPACITY INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.4
1.3
0
1 2 3 4 5
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
PRE SUBER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 184

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 100 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 3025
DONE BY DLP
DATE 12-16-65
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG. VOLTAGE
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PRE STER.
ELECT. CYCLES
LIFE CYCLE (DAYS)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300

Figure 185

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 100 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 3027
DATE 12-16-65
RUNS BY JL
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG VOLT
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PRE STER.
ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 186

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 1h hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 3034 -
DONE BY JEP
DATE 12-16-65
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG. VOLTAGE
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PRE STER.
ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 187

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 11 hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 3032
DONE BY CLP
DATE 12-16-65
KEY · ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG. VOLTAGE
CAPACITY INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PRE STER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 188

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 100 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 7035
DATE 12-16-65
DONE BY WLP
KEY - O INPUT CAPACITY
□ OUTPUT CAPACITY
Δ END OF CHG VOLTAGE
CAPACITY (AMP-HR)
CHARGE VOLTAGE
DISCHARGE VOLTAGE
PRE STER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 189

Figure 190

Figure 191

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 600 ma for 1h hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 3014
DATE 12-16-65
DONE BY DLP
INPUT CAPACITY
OUTPUT CAPACITY
END OF CHG VOLTAGE
CAPACITY (INPUT AND OUTPUT AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PRE STER. ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 192

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 1½ hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 3045
DATE 12-17-65
DONE BY: JEP
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG VOLTAGE
CAPACITY - INPUT & OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VDC)
PER CENT ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 193

K&E 20 X 20 TO THE INCH 359-10' G

230

Figure 194

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to C.6 VDC
CELL S/N 3048
DATE 12-17-65
DONE BY
KEY · ○ INPUT CAPACITY
□ OUTPUT CAPACITY
× END OF CAPACITY
CHARGE AND DISCHARGE VOLTAGE (VDC)
6.0
5.0
4.0
3.0
2.0
1.0
0
1 2 3 4 5
PRE-SET
ELECT. CYCLES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
LIFE CYCLE (DAYS)

Figure 195

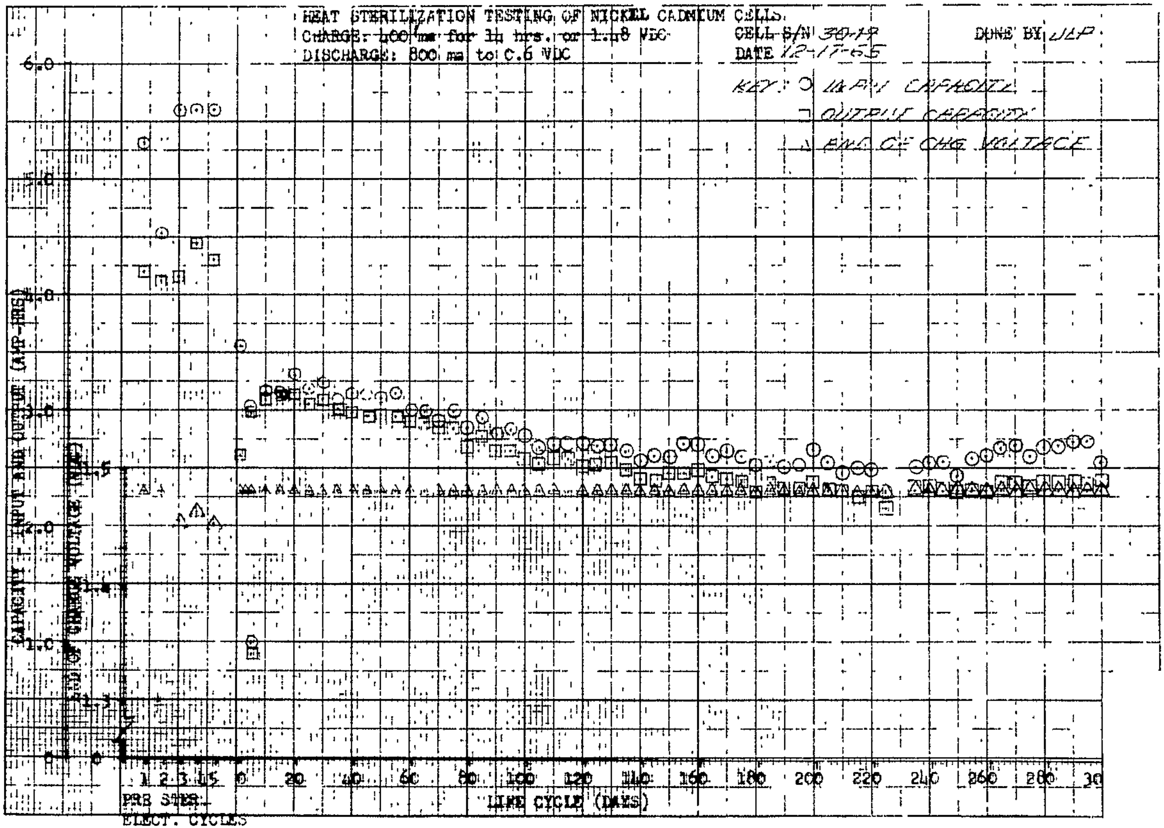

HEAT STERILIZATION TESTING OF NICKEL CADMIUM CELLS
CHARGE: 400 ma for 14 hrs. or 1.48 VDC
DISCHARGE: 800 ma to 0.6 VDC
CELL S/N 30-17
DATE 12-17-65
DONE BY JLP
KEY: ○ INPUT CAPACITY
□ OUTPUT CAPACITY
△ END OF CHG VOLTAGE
CAPACITY - INPUT AND OUTPUT (AMP-HRS)
END OF CHARGE VOLTAGE (VOLTS)
6.0
3.0
2.0
1.0
0
1.5
1.4
1.3
1 2 3 4 5
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
PRE STER.
ELECT. CYCLES
LIFE CYCLE (DAYS)

Figure 196

Figure 197