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NICKEL-CADMIUM CELL DESIGN VARIABLE PROGRAM DATA ANALYSIS

George W. Morrow

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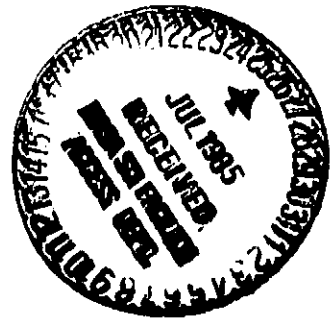

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

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INTRODUCTION

In early 1978, an extensive investigation was initiated by the National Aeronautics and Space Administration Goddard Space Flight Center (NASA/GSFC) in conjunction with the General Electric Company (G.E.) to evaluate nine of the most important nickel-cadmium (Ni-Cd) aerospace cell designs that had been used during the previous decade. The need for a comprehensive evaluation was fully recognized since a review of the cell design history indicated that the cells that were in use bore only a slight resemblance to those used in the first satellite applications. The changes that had occurred in the cells could be attributed to a number of factors: the desire to improve energy density, the need for longer life, the need to improve production yield, the desire to enhance cell performance, and the competitive drive to meet the customer's requirements. Many of the changes had been tested and evaluated by various users but there was never a systematic approach to compare the relative merits of each design. The objective of this report is, therefore, to present the test results and conclusions drawn from the Design Variable Program.

APPROACH

It was necessary to choose a test cell with a proven heritage and a physical design similar to that of other widely used aerospace cells. For these reasons the G.E. 12ah cell was selected as the Design Variable test cell. It had been used in the past with much success and because its design is much like that of the 6ah and 20ah cell designs used by the GSFC, the data collected could be adapted with confidence to those cells.

Description of Design Variables

Fight of the most frequently used designs and one proposed design were selected as the design variables to be tested in this Program. Thus, a Control group and 8 design groups of 6 cells per group were manufactured. A discussion of each group is as follows:

1. Control: This group represents G.E.'s basic aerospace design and processes as of 1978. The positives of these cells were subjected to cadmium treatment (PQ) as is indicative of G.E.'s process since 1970. The loading was somewhat lighter than normally used by G.E. during this time-frame. These lighter levels were chosen because the GSFC had recently procured 2 flight lots (IUE) with this design. The cells were manufacutred with nonwoven nylon separator (Pellon 2505) and all cells received the decarbonation treatment.

2. Teflon: These cells are identical to the control with the exception that the negatives were treated with teflon to level II. As a result these cells also contain slightly more KOH than the Control.

3. Silver: This group is identical to the Control except the negatives had silver treatment and, as with Teflon, slightly more KOH.

4. Light Loading: The plates of this group have lighter loading (less active material) than those of the previous 3 groups. These plates are from the same impregnation post as the Control but are from different spirals. The purpose of this group was to evaluate a further reduction of plate loading with respect to initial and life benefits. Though no teflon or silver treatments were used, these cells contain 5cc more electrolyte than the Control cells.

5. No PQ: This group is identical to the Control except that the positives were not subjected to the PQ treatment. The positive plates are from the same impregnation post as the Control but from different spirals. The negative plates are from the same spiral as the Control.

6. Polypropylene: This group contains all of the design parameters of the Control except that polypropylene separator material was used in place of nylon.

7. A.K.-Old Process: This design is indicative of cells made during the middle sixties, i.e., the cells are made with the plate design and processes of that era. Specifically, no PQ treatment was used, the negatives were not depleted during the flooded cell test, and there was no decarbonation. Also, the plate design was different than the Control and there was no precharge adjustment made to the cells

8. A.K.-Present Process: This group contains the same plate lot as the A.K.-Old Process. However, these cells were processed using the same aerospace procedures and practices as the Control.

9. Electrochemical: This design contains electrochemically impregnated positives. All other variables are identical to the Control. This was an early attempt by the G.E. Company to use electrochemical impregnation in cell manufacture.

Each Design Variable group contained two signal electrode cells. One signal electrode was the standard G.E. teflonated electrode that had been in use though 1983. The other electrode was of a new G.E. design and was designated the "Heart-Pacer Signal Electrode." The old G.E. standard was discontinued in 1983 and the "Heart Pacer Electrode" is now used across the board. Details concerning the design and performance of these two types of signal electrodes have been documented (REF. 5).

Test Program

The specifications of each of the designs discussed in the previous section were incorporated into a G.E. Manufacturing Control Document (MCD) following discussion and approval at the GSFC. G.E. then used this document to fabricate and acceptance test the cells. After review of the acceptance test data, the cells were accepted by the GSFC and were shipped to the NASA Battery Test Facility at the Naval Weapons Support Center (NWSC) in Crane, Indiana where the Design Variable Test Program was carried out.

The test program consisted of 2 segments (figure 1). First an Initial Evaluation Program was conducted. Initial evaluation tests were performed in order to characterize each cell, to compare initial behavior, and to detect any manufacturing defects overlooked during acceptance testing. These tests were repeated on 1 cell from each design after 1 year of cycling and on all cells remaining in each group at the end of cycling. The repetitions were carried out in order to compare performance and degradation based on the same criteria at different points during the life of the cells.

- INITIAL EVALUATION TESTS*
  - LEAK TESTS
  - CAPACITY TESTS
  - INTERNAL RESISTANCE AND SHORT TEST
  - CHARGE RETENTION TESTS
  - CHARGE EFFICIENCY TEST
  - OVERCHARGE TESTS
  - PRESSURE VS. CAPACITY TESTS
- LOW EARTH ORBIT CYCLING

*TESTS REPEATED AFTER 1 YEAR CYCLING AND AT END OF PROGRAM

Figure 1. Design Variable Test Program

The second segment and principle part of the Design Variable Program was extended cycling in the low earth orbit (LEO) regime (table 1). A higher depth of discharge (DOD) than is normally seen in Low Earth orbit (40%) was selected in order to obtain observable results as quickly as possible.

Table 1
Leo Cycling Test Regime

PARAMETER	DESCRIPTION
Temperature	20°C
Depth-of-discharge	40 percent
Orbit period	90 minutes
Charge current	9.6 amps to a voltage limit (1.453V/cell typical)
Discharge current	9.6 amps

MANUFACTURING DATA

Basic Cell Design Summary

The test cells were of the standard G.E. 12ah design and configuration. Figure 2 shows an outline of the basic cell design. The design contains 11 positive plates, 12 negative plates, and other features as follows:

1. Nickel braze, ceramic to-metal seal (positive and negative terminals),
2. Cell case wall of 0.17 in. (0.43 cm) nominal thickness.

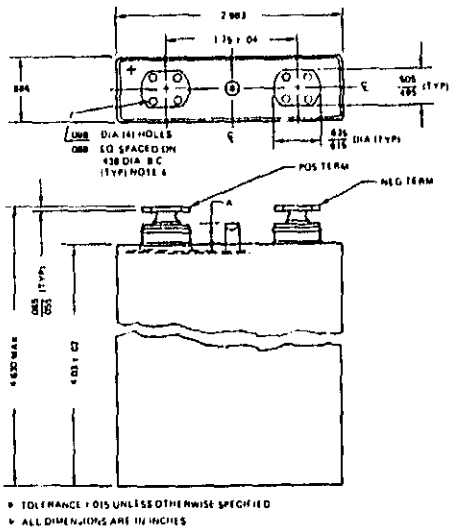

Figure 2. Cell Design Outline

The Design Variable cells were purchased rom G.E. under NASA contract #NAS5-23783 to NASA specification 74-15000, "Specification for the Manufacturing of Aerospace Nickel-Cadmium Storage Cells." A total of 54 cells were ordered. The cells were manufactured according to G.E. MCD 232 A2222AA-54, Revision 18. The G.E. catalog number for the cells was 42B012AB29.

Physical Measurements

A summary of the physical properties of the plates of each design group is shown in table 2.

Table 2
Electrode Physical Measurements

GROUP	PHYSICAL PARAMETER	POSITIVE	NEGATIVE
Typical	Length	2.998 in. to 3.001 in. (7.615 cm to 7.673 cm)	2.999 in. to 3.002 in. (7.618 cm to 7.625 cm)
Typical	Width	2.755 in. to 2.758 in. (6.998 cm to 7.005 cm)	2.754 in. to 2.758 in. (6.995 cm to 7.005 cm)
Control	Thickness (TYP)	0.027 in. (0.069 cm)	0.031 in. (0.079 cm)
Teflon		0.027 in. (0.069 cm)	0.031 in. (0.079 cm)
Silver		0.027 in. (0.069 cm)	0.031 in. (0.079 cm)
Light Loading		0.027 in. (0.069 cm)	0.031 in. (0.079 cm)
No PQ		0.027 in. (0.069 cm)	0.031 in. (0.079 cm)
Polypropylene		0.027 in. (0.069 cm)	0.031 in. (0.079 cm)
A.K.-Old		0.032 in. (0.081 cm)	0.026 in. (0.066 cm)
A.K.-Pres.		0.032 in. (0.081 cm)	0.026 in. (0.066 cm)
Electrochem		0.029 in. (0.074 cm)	0.031 in. (0.079 cm)

Electrochemical Cleaning and Testing (ECT) Data

ECT is a flooded test of temporary cells in which the capacities of the positive and negative plate are determined. Table 3 shows the average, maximum, and minimum capacities obtained for each design group.

Separator Analysis

The separator used on all groups except the Polypropylene group was Pellon 2505, Lot no. 29258, Roll no. 1. The G.E. specification for the separator was A50-PB-112. The polypropylene separator used was GAF, Lot no. 5382. The G.E. specification was A50-PB-116. To meet the requirements of 74-15000, the separator was tested as per G.E. Q.P.I. 701.07, Revision 5. A summary of the results of the separator test is shown in table 4.

KOH Quantity

The final KOH quantity varied from group to group because of the different performance properties caused by each variable and loading level. The criteria for determining the amount of KOH was to obtain the maximum KOH allowable in each group consistent with reasonable overcharge pressures.

The overcharge pressure design goal was 30 to 75 psia. The final KOH quantities and loading levels are shown in table 5.

Table 3
ECT Plate Capacity Results

GROUP	POSITIVE CAPACITY (Ah)			NEGATIVE CAPACITY (ah)			AVERAGE NEG. TO POS. RATIO
	AVG.	MAX.	MIN	AVG.	MAX.	MIN.	
Control	16.04	16.20	15.80	28.02	28.50	27.30	1.75:1
Teflon	16.04	16.20	15.80	28.02	28.50	27.30	1.75:1
Silver	16.04	16.20	15.80	28.02	28.50	27.30	1.75:1
Light Loading	13.83	14.10	13.68	24.95	25.40	24.63	1.80:1
NO PQ	15.63	15.76	15.58	27.88	28.51	27.34	1.78:1
Polyprop	16.04	16.20	15.80	28.02	28.50	27.30	1.75:1
A.K.-Old	19.78	19.96	19.67	—[1]	—[1]	—[1]	1.25:1
A.K.-Pres.	19.55	19.82	19.33	24.37	26.24	23.31	1.25:1
Electrochem	13.87	15.07	13.12	28.53	30.44	26.59	2.06:1

[1]Old plate processing: Negatives discharged for 4 hours only.

Table 4
Separator Test Results

Q.P.I. 701.07 PARAGRAPH	TEST	PELLON 2505 AVG. VALUE	GAF AVG. VALUE
5.1	Air permeability	272.4 $ft^3/min/ft^2$	174.9 $ft^3/min/ft^2$
5.4	Thickness dry	0.0147 in.	0.0117 in.
	Thickness wet	0.0139 in.	0.0117 in.
5.5	Electrolyte retention	95.2%	89.9%
	Electrolyte porosity	49.3%	36.15%
5.6	Wettability	5 min.+	0.5 min.
5.8	Tensile strength at break		
	Dry	182.52 $Kg/in.^2$	101.60 $Kg/in.^2$
	After 24 hr. soak in 34% KOH	147.38 $Kg/in.^2$	122.10 Kg/in^2
	% Organic	0.63%	0.438%
	% Inorganic	1.02%	0.00%

Table 5
KOH QUANTITY, LOADING, AND PRECHARGE

GROUP	KOH QUANTITY, CC NON 3rd/3rd	LOADING g/dm^3		PRECHARGE ADJUST[1]	
		POS.	NEG.	Ah	% EXC. NEG.
Control	40/40	2095	2180	4.6	38.4
Teflon	48/49	2095	2180	4.6	38.4
Silver	43/44	2095	2180	4.6	38.4
Light Loading	45/46	1840	1833	4.6	41.4
No PQ	40/41	2113	2180	4.6	37.6
Polypropylene	39/40	2095	2180	4.6	38.4
A.K.-Old	38/39	2130	2542	---	---
A.K.-Pres.	39/40	2130	2542	1.8	37.3
Electrochem	48/---	1276[2]	2280	5.8	39.6

[1]Based on 228 cc $O/_2$Ah.
[2]By hydrate pickup, not hydrate reduction.

Precharge

Precharge was set by the oxygen incremental venting technique. The cell procurement specification, 74-15000, required the precharge to be set to 40±5 percent of the excess negative. The final precharge adjust data is shown in table 5.

INITIAL EVALUATION TESTS

The Design Variable Cell Initial Evaluation Program was performed at the Naval Weapons Support Center in Crane, Indiana under NASA Purchase Order S-57075 AG. The initial purpose of this evaluation test program was to insure that all cells put into the life cycle program were of high quality by screening those cells found to have electrolyte leakage, internal shorts, low capacity, or the inability to recover an open-circuit voltage of 1.15 volts during the internal short test. The reevaluations at the 1 year point and at the end of cycling were done in order to compare back to the initial data.

All evaluation tests were performed at room ambient (RA) pressure and temperature (25°±2°C) with discharges at the 2-hour rate, unless otherwise specified, and consisted of the following:

a. phenolphthalein leak tests (2),
b. three capacity tests, the third at 20°C; with internal resistance measurements made during the second,
c. signal electrode characterization test,
d. charge retention test at 20°C,
e. internal short test,
f. charge efficiency test at 20°C,
g. overcharge tests at 0°C and 35°C,
h. pressure versus capacity test,
i. phenolphthalein leak test.

For a summary of the test procedure see Appendix 1.

Evaluation Test Results

The summary data sheets for the initial evaluation tests for all groups at the beginning and end of life (BOL and EOL) are provided in Appendix 2 and Appendix 3 respectively. Summary data sheets from the 1 year repetition are not available. BOL & EOL electrical performance test data is summarized in tables 6-8 and 9-11 respectively. From this summary of data, conclusions can be drawn about the performance of each design group. Discussion will be limited to the 25°C Capacity Test, 25°C Overcharge Test, and the 0°C Overcharge Test.

Table 6
Beginning of Life Initial Evaluation Test Data Averages
Control, Silver, Teflon

CHARGE/DCH. @ C/2	CONTROL			SILVER			TEFLON		
	EOC VOLTS	EOC PSIA	DCH. Ah OUT	EOC VOLTS	EOC PSIA	DCH. Ah OUT	EOC VOLTS	EOC PSIA	DCH. Ah OUT
C/20, 48 hrs., 25°C	1.453	16	16.1	1.437	19	15.5	1.441	18	16.0
C/10, 24 hrs., 25°C	1.460	37	15.3	1.453	35	14.8	1.455	41	15.0
C/10, 24 hrs., 20°C	1.469	48	14.8	1.461	42	14.2	1.465	56	14.4
C/10, 24 hrs , 20°C[1]	1.470	56	13.5	1.463	39	13.0	1.470	55	13.5
C/40, 20 hrs., 20°C[2]	1.372	4	3.7	1.373	7	4.6	1.373	6	4.2
C/20, 60 hrs., 0°C	1.496	45	14.5	1.483	36	13.9	1.493	44	14.6
C/10, 24 hrs., 35°C	1.418	37	15.9	1.417	17	16.1	1.417	31	15.9
Open Circuit									
End-of-1 week[1]	1.326	4		1.332	8		1.329	6	
24 hrs. after 16 hrs. short	1.250	4		1.257	7		1.250	6	

[1]Charge retention test [2]Charge efficiency test, 6.0 Ah input

Table 7
Beginning of Life Initial Evaluation Test Data Averages
Light Loading, No PQ Polypropylene

CHARGE	LIGHT LOADING			NO PQ			POLYPROPYLENE		
	EOC VOLTS	EOC PSIA	DCH. Ah OUT	EOC VOLTS	EOC PSIA	DCH. Ah OUT	EOC VOLTS	EOC PSIA	DCH. Ah OUT
C/20, 48 hrs., 25°C	1.441	20	14.3	1.447	13	16.3	1.443	16	16.1
C/10, 24 hrs., 25°C	1.457	29	13.7	1.455	26	16.0	1.458	39	15.5
C/10, 24 hrs., 20°C	1.466	34	13.6	1.466	52	15.0	1.471	66	15.1
C/10, 24 hrs., 20°C[1]	1.467	42	12.5	1.468	58	13.7	1.475	77	13.8
C/40, 20 hrs., 20°C[2]	1.376	10	3.9	1.375	4	4.1	1.374	6	4.3
C/20, 60 hrs., 0°C	1.491	37	13.1	1.506	37	14.8	1.497	69	14.8
C/10, 24 hrs., 35°C	1.423	35	14.1	1.402	34	14.1	1.415	24	16.0
Open Circuit									
End-of-1 week[1]	1.319	10		1.315	5		1.330	6	
24 hrs. after 16 hrs. short	1.238	10		1.259	4		1.247	6	

[1]Charge retention test [2]Charge efficiency test, 6.0 Ah input

Table 8
Beginning of Life Initial Evaluation Test Data Averages
A.K.-Old, A.K.-Present, Electrochem

CHARGE	A.K.-OLD			A K.-PRESENT			ELECTROCHEM		
	EOC VOLTS	EOC PSIA	DCH. Ah OUT	EOC VOLTS	EOC PSIA	DCH. Ah OUT	EOC VOLTS	EOC PSIA	DCH. Ah OUT
C/20, 48 hrs., 25°C	1.452	14	18.6	1.452	14	15.7	1.446	32	10.7
C/10, 24 hrs., 25°C	1.463	30	18.0	1.463	29	18.1	1.435	32	10.1
C/10, 24 hrs., 20°C	1.477	26	17.7	1.480	34	17.8	1.444	40	10.1
C/10, 24 hrs., 20°C[1]	1.477	37	15.2	1.480	40	15.4	1.443	36	9.0
C/40, 20 hrs., 20°C[2]	1.370	6	3.6	1.369	9	3.1	1.377	12	3.1
C/20, 60 hrs., 0°C	1.578	68	16.8	1.581	66	16.1	1.494	46	10.2
C/10, 24 hrs., 35°C	1.396	52	14.5	1.397	40	14.7	1.395	26	9.4
Open Circuit									
End-of-1 week[1]	1.308	7		1.308	11		1.294	13	
24 hrs. after 16 hrs. short	1.263	6		1.259	9		1.236	12	

[1]Charge retention test
[2]Charge efficiency test, 6.0 Ah input

Table 9
End of Life Initial Evaluation Test Data Averages
Control, Silver, Teflon

CHARGE	CONTROL			SILVER			TEFLON		
	EOC VOLTS	EOC PSIA	DCH. Ah OUT	EOC VOLTS	EOC PSIA	DCH. Ah OUT	EOC VOLTS	EOC PSIA	DCH. Ah OUT
C/20, 48 hrs., 25°C	1.450	34	10.7	1.438	36	10.1	1.436	44	11.5
C/10, 24 hrs., 25°C	1.461	53	10.6	1.447	52	10.4	1.450	72	11.7
C/10, 24 hrs., 20°C	1.482	54	10.4	1.457	55	10.3	1.467	74	11.4
C/10, 24 hrs., 20°C[1]	1.476	53	9.0	1.449	52	---[3]	1.465	70	9.6
C/40, 20 hrs., 20°C[2]	1.372	20	2.8	---[3]	---[3]	---[3]	1.374	16	3.8
C/20, 60 hrs., 0°C	1.510	39	9.6	---[3]	---[3]	---[3]	1.497	59	10.8
C/10, 24 hrs., 35°C	1.438	46	10.6	1.410	30	9.9	1.424	64	11.9
Open Circuit									
End-of-1 week[1]	1.303	20		---[3]	---[3]		1.296	17	
24 hrs. after 16 hrs. short	---[3]	---[3]		---[3]	---[3]		1.183	16	

[1]Charge retention test
[2]Charge efficiency test, 6.0 Ah input
[3]Shorted cells

Table 10
End of Cycling Initial Evaluation Test Data Averages
Light Loading, No PQ, Polypropylene

CHARGE	LIGHT LOADING			NO PQ[3]			POLYPROPYLENE		
	EOC VOLTS	EOC PSIA	DCH. Ah OUT	EOC VOLTS	EOC PSIA	DCH. Ah OUT	EOC VOLTS	EOC PSIA	DCH. Ah OUT
C/20, 48 hrs., 25°C	1.431	31	9.9	---	---	---	1.436	16	8.25
C/10, 24 hrs., 25°C	1.455	39	10.1	---	---	---	1.447	16	8.25
C/10, 24 hrs., 20°C	1.476	41	9.9	---	---	---	1.447	14	6.85
C/10, 24 hrs., 20°C[1]	1.471	40	8.3	---	---	---	1.444	11	---[3]
C/40, 20 hrs., 20°C[2]	1.385	19	3.7	---	---	---	1.389	4	3.4
C/20, 60 hrs., 0°C	1.512	34	9.3	---	---	---	1.505	8	5.9
C/10, 24 hrs., 35°C	1.434	32	10.5	---	---	---	1.394	9	6.7
Open Circuit									
End-of-1 week[1]	1.293	20		---	---		1.231	4	
24 hrs. after 16 hrs. short	1.183	19		---	---		---[3]	---[3]	

[1]Charge retention test
[2]Charge efficiency test, 6.0 Ah input
[3]Shorted cells

Table 11
End of Cycling Initial Evaluation Test Da... Averages
A.K.-Old, A.K.-Present, Electrochem

CHARGE	A.K.-OLD			A.K. PRESENT			ELECTROCHEM		
	EOC VOLTS	EOC PSIA	DCH. Ah OUT	EOC VOLTS	EOC PSIA	DCH. Ah OUT	EOC VOLTS	EOC PSIA	DCH. Ah OUT
C/20, 48 hrs., 25°C	1.424	21	10.4	1.470	24	13.2	1.448	21	10.6
C/10, 24 hrs., 25°C	1.520[4]	24	11.5	1.520[4]	20	12.5	1.485	19	10.5
C/10, 24 hrs., 20°C	1.520[4]	23	11.0	1.520[4]	19	11.7	1.497	18	10.1
C/10, 24 hrs., 20°C[1]	1.520[4]	22	8.8	1.520[4]	18	9.1	1.496	17	9.0
C/40, 20 hrs., 20°C[2]	1.376	20	3.6	1.385	18	4.0	1.383	17	3.4
C/20, 60 hrs., 0°C	1.602[5]	45	9.1	1.608[5]	42	9.6	1.550	41	9.0
C/10, 24 hrs., 35°C	1.412	35	12.1	1.391	37	12.1	1.472	20	10.4
Open Circuit									
End-of-1 week[1]	1.302	21		1.304	18		1.326	17	
24 hrs. after 16 hrs. short	1.197	20		---[3]	---[3]		---[3]	---[3]	

[1]Charge retention test
[2]Charge efficiency test, 6.0 Ah input
[3]Shorted cells
[4]Ah in. to 1.520 volt cut-off
[5]Voltage exceeded 1.52 volts for 2 hrs.

25°C Capacity Test Results

The room ambient capacity test consisted of a charge at the 20-hour rate for 48 hours followed by a discharge at the 2-hour rate to 0.7 volts per cell. The initial, 1 year, and end-of-cycling capacities are shown in Table 12.

This data indicates that the capacity loss for most groups to the end-of-cycling (3 to 4 years) was between 24 percent and 35 percent excluding the Polypropylene, Electrochemical and No PQ groups. Thirty-nine percent of the initial tested capacity of the Polyropylene group was lost within the first year under the LEO cycling regime. This first year capacity loss was the greatest among any of the groups as was the total capacity loss of 49 percent at the end of 3 years of cycling. Conversely, the Electrochemical group appears to have lost the least capacity with a loss of only 2 percent at the end-of-cycling. This is misleading, however, because this group remained on test for only 2.5 years (14000 cycles), and there was no 1-year test point available for comparison.

The No PQ group remained on test for 4 years (23300 cycles) and had lost the least amount of capacity of any group at the 1 year point, (only 6 percent) but could not be recharged after the end-of-cycling and, therefore no capacity data point was obtained. The other groups that remained on test for 4 years, Control and A.K.-Old Process, showed average capacity performance not only to the 1 year point showing 21 percent and 16 percent capacity losses respectively, but also to the end-of-cycling as well as mentioned above.

Table 12
Initial Evaluation Tests
25°C Capacity Test

VARIABLE	PACK NO	INITIAL (Ah)	1 YEAR (Ah)	EOL (Ah)
Control	3D	15.3	12.1	10.6 (4 yrs)
Teflon	3E	14.7	12.5	10.1 (3 yrs)
Silver	3F	15.2	12.1	11.5 (3 yrs)
Light	3G	13.9	11.6	10.1 (3 yrs)
No PQ	3H	16.0	15.1	---[2] (4 yrs)
Polypropylene	3I	15.6	9.5	8.0 (3 yrs)
AK-Old Proc	3J	17.7	14.9	11.5 (4 yrs)
AK-Pres Proc	3K	17.4	18.0	12.5 (3 yrs)
Electrochem	3L	10.8	---[1]	10.6 (2.5 yrs)

[1]No one year test.
[2]Would not accept charge.

25°C Overcharge Test Results

The 25°C overcharge test consisted of a constant current charge at the 10-hour rate for 24 hours. The initial, 1 year, and end-of-cycling end-of-charge (EOC) voltages reached during this test for all design groups are presented in Table 13. Groups 1, 2, 3, 5, 6, and 9 showed little or no change in the EOC voltage levels during life. The voltages reached by these groups were in the normal range for aerospace Ni-Cd cells and ranged from 1.454 volts to 1.465 volts. Of the groups mentioned above, the Control group showed the highest voltage each time tested followed by Polypropylene and the A.K.-Old Process group.

Group 4, Light Loading, initially had an average EOC test voltage of 1.458 volts but when the test was repeated at the 1-year point the test voltage had risen to 1.477 volts. However the EOC voltage at the end-of-cycling was again in the nominal range. Group 8, A.K.-Present Process, also showed an EOC voltage rise at the 1 year point with a voltage of 1.520 volts causing the charge to be stopped prematurely. Unlike Light Loading, however, an abnormally high EOC voltage remained at the end-of-cycling indicating that these cells were "negative limited" and had been so since before the 1 year retest. The A.K.-Old Process group, even though it was made with the same plate as Group 8, surprisingly showed no signs of being "negative limited" until the remaining cells were tested at the end-of-cycling (4 years). This difference, therefore, must be due to the differences in the plate processing techniques used on each group. Both groups initially had a lower negative to positive ratio than the other groups by design and so from the beginning possessed a strong tendency to becoming "negative limited." In addition to this, the plate forming or ECT process which permits a longer reversal time and additional precharge adjustment, caused the amount of excess negative in the group to be reduced to a much greater extent than in the old process group. The effect of less excess negative is a rise in voltage during overcharge, a condition in which cells are said to be "negative limited."

Table 13
Initial Evaluation Tests
25°C Overcharge Test

VARIABLE	PACK NO.	INITIAL EOC V	1 YEAR EOC V	EOL EOC V
Control	3D	1.462	1.465	1.461
Teflon	3E	1.455	1.457	1.447
Silver	3F	1.456	1.458	1.450
Light	3G	1.458	1.477	1.455
No PQ	3H	1.454	1.452	---[3]
Polypropylene	3I	1.459	1.457	1.450
AK-Old Proc	3J	1.459	1.419	1.520[4]
AK-Pres Proc	3K	1.458	1.520[1]	1.522[5]
Electrochem	3L	1.456	---[2]	1.480

[1]Test terminated at 23.4 Ah in. due to high voltage.
[2]No one year test.
[3]Would not accept charge.
[4]Test terminated at 17 Ah in. due to high voltage.
[5]Test terminated at 15 Ah in. due to high voltage.

0°C Overcharge Test Results

The 0°C overcharge test consisted of a constant current charge at the 20-hour rate for 60 hours. The initial EOC voltages, and the 1 year and end-of-cycling EOC and peak voltages are presented in Table 14.

The 0°C overcharge test produced contrasts of a much greater magnitude between the groups on test than did the 25°C test. Results showed that by the 1 year retest the Light Loading, No PQ, Polypropylene, A.K.-Old Process, and A.K.-Present Process groups all had higher than normal peak and EOC voltages which indicated they may have become "negative limited." In fact, the charge was stopped prematurely on each of these groups because of high voltage or pressure. By contrast, the Teflon group showed the lowest peak voltage at 1.529 volts of any group at 1 year followed by Silver at 1.546 volts and the Control at 1.552 volts.

At the end-of-cycling only the A.K.-Present Process and A.K.-Old Process groups had high EOC voltage and therefore, were the only groups which appeared to be "negative limited" at the end-of-cycling. This agreed with the results obtained during the 25°C overcharge test. The Teflon group showed many intermittent shorts during this test at the end-of-cycling and thus, the data obtained is not valid and, in fact, represents only 1 of the 4 cells; the others could not be recharged. The No PQ group possessed internal shorts prior to the start of the end-of-cycling evaluation tests as was discussed previously.

Table 14
Initial Evaluation Tests
0°C Overcharge Test

VARIABLE	PACK NO.	INITIAL EOC V	1 YEAR EOC V	1 YEAR PEAK V	EOL EOC V	EOL PEAK V
Control	3D	1.496	1.508	1.552	1.510	1.537
Teflon	3E	1.486	1.496	1.529	1.433	1.433[4]
Silver	3F	1.494	1.494	1.546	1.496	1.527
Light	3G	1.492	1.567	1.577[1]	1.512	1.542
No PQ	3H	1.508	1.599	1.600[1]	---	---[5]
Polypropylene	3I	1.497	1.578	1.583[1]	1.509	1.540
AK-Old Proc	3J	1.575	1.585	1.585[2]	1.602	1.610[1]
AK-Pres Proc	3K	1.578	1.572	1.585[2]	1.608	1.611[1]
Electrochem	3L	1.495	---	---[3]	1.506	1.539

[1]Terminated due to high voltage (voltage exceeded 1.56V for 2 hrs.).
[2]Terminated due to high pressure (>100 PSIA).
[3]No one year test.
[4]All cells in Teflon Group showed intermittent shorts.
[5]Would not accept charge.

LOW EARTH ORBIT CYCLING TEST RESULTS

Following the Initial Evaluation Test sequence discussed earlier, each design group was placed in the LEO life cycling regime outlined in Table 1. Individual cell failure criteria during cycling was defined as: end-of-discharge (EOD) voltage ≤0.75V, EOC voltage ≥1.52 V, or internal cell pressure ≥100 psig. A summary of the individual cell failures is given in Table 15 by cycle number.

Table 15
LEO Cycling Cell Failure/Removal Record

CYCLE NO.	VARIABLE	PACK NO.	FAILURE MODE/REASON FOR REMOVAL
248	AK-Old Proc	3J	Cell 4 removed - high EOC voltage (1.525V)
2008	AK-Pres Proc	3K	Cell 5 removed - high EOC voltage ≥1.52V
2459	AK-Pres Proc	3K	Cell 1 removed - high EOC voltage ≥1.52V
9022	Electrochem	3L	Cell 4 removed - low EOD voltage (−0.17V)
10200	AK-Pres Proc	3K	Cell 1a failed - low EOD voltage ≤0.75V
10268	AK-Pres Proc	3K	Cell 1a removed - shorted
14517	Teflon	3E	Cell 4 failed - low EOD voltage ≤0.75V not removed
14728	Polypropylene	3I	Cell 3 failed - low EOD voltage ≤0.75V not removed
15700	Polypropylene	3I	Cell 2 failed - low EOD voltage ≤0.75V not removed
16149	Teflon	3E	Cell 2 failed - low EOD voltage ≤0.75V not removed
21103	Control	3D	All cells failed - low EOD voltage ≤0.75V not removed

Capacity Performance

A direct comparison of capacity performance of each of the groups during cycling proved to be very beneficial to the evaluation of each design variable. Capacity checks were performed on each group at 6 month intervals through two years and then yearly to the end of cycling. In order to reduce the reconditioning effect on the capacity measurements, a progressive sequence of cells undergoing the checks was used, i.e., cell 1 at six months, cells 1 and 2 at one year, cells 1, 2 and 3 at 18 months, cells 1, 2, 3, and 4 at two years, and all cells from that point on.

The data from each capacity cycle (6 mo., 1 yr., 18 mo., 2 yrs., 3 yrs.) for all 9 design groups is presented in Figures 3 to 12. The odd numbered figures have the data from the Control, Teflon, Silver, Light and No PQ groups while the even numbered figures have the Control (for comparison), Polypropylene, A.K.-Old Process, A.K.-Present Process, and Electrochem. A 4 year capacity plot for the Control, No PQ, and A.K.-Old Process groups is shown in Figure 13. From the plots it is obvious that the above 3 groups maintained a greater amount of capacity than any of the other groups tested and of those 3, the No PQ group performed the best.

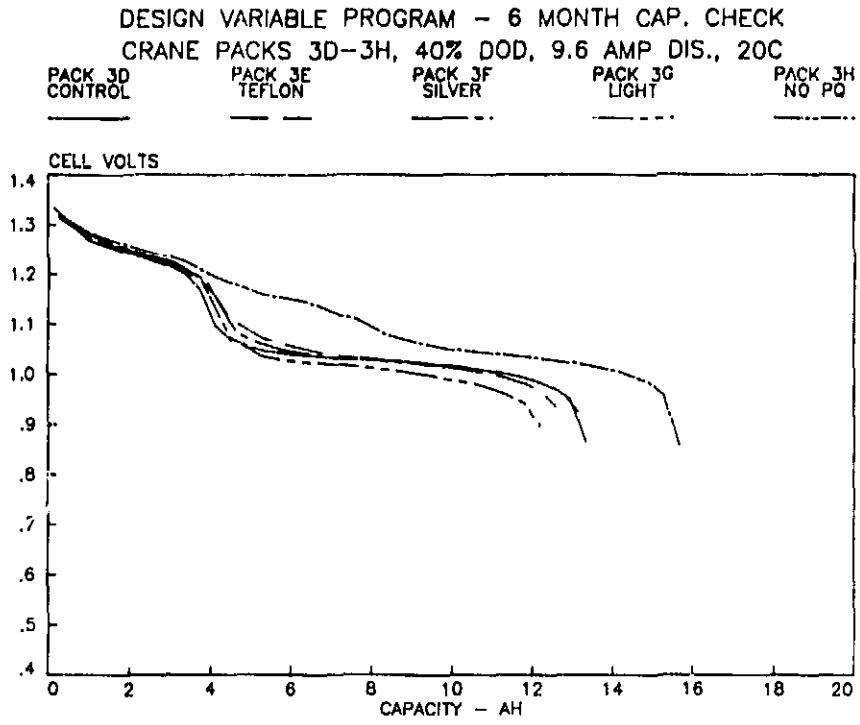

Figure 3. 6-Month Capacity Check 3D-3H

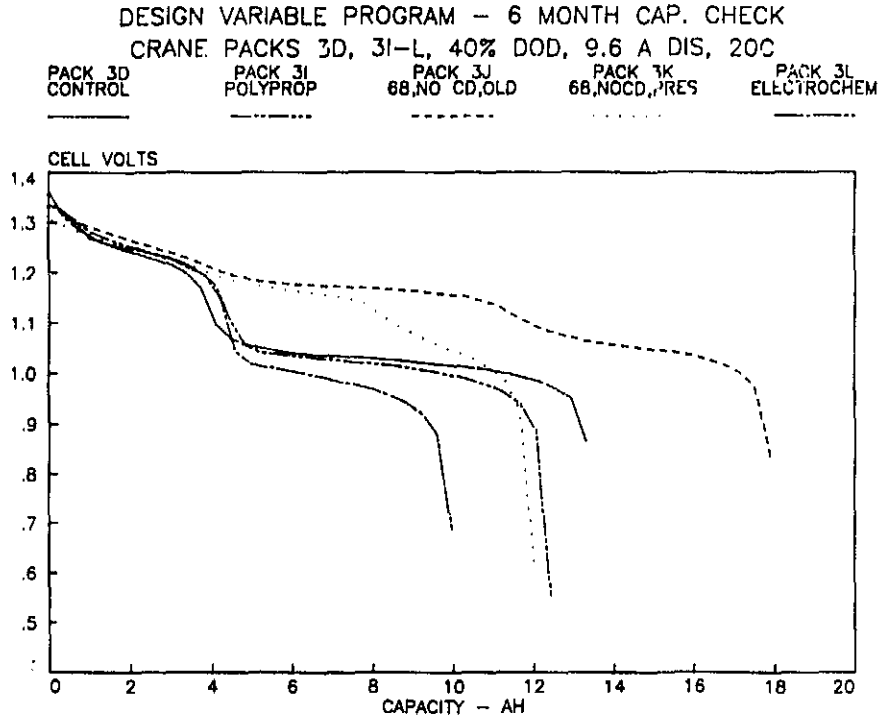

Figure 4. 6-Month Capacity Check 3D, 31-3L

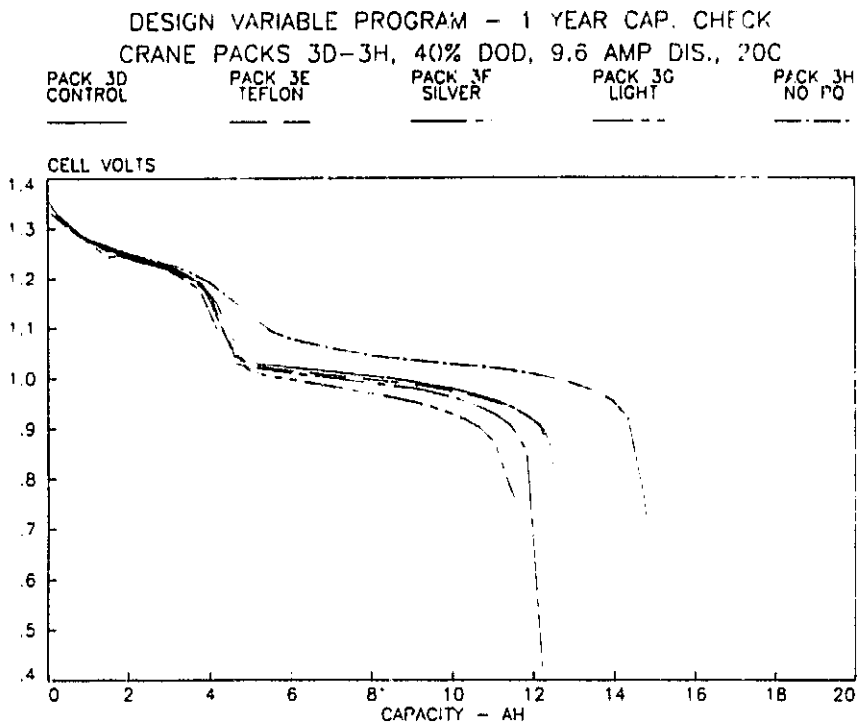

Figure 5. 1 Year Capacity Check 3D-3H

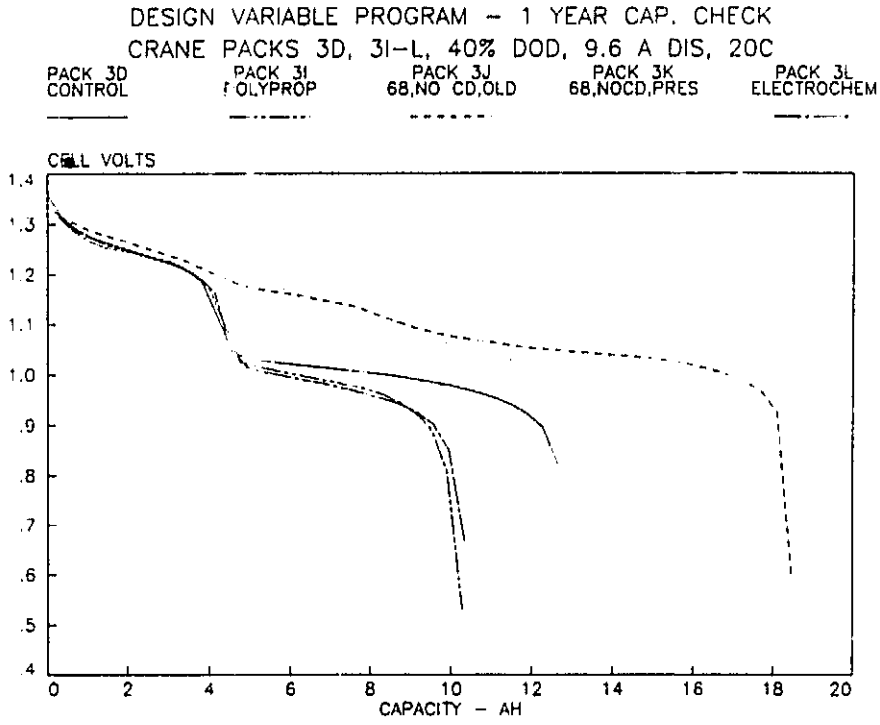

Figure 6. 1 Year Capacity Check 3D, 31-3L

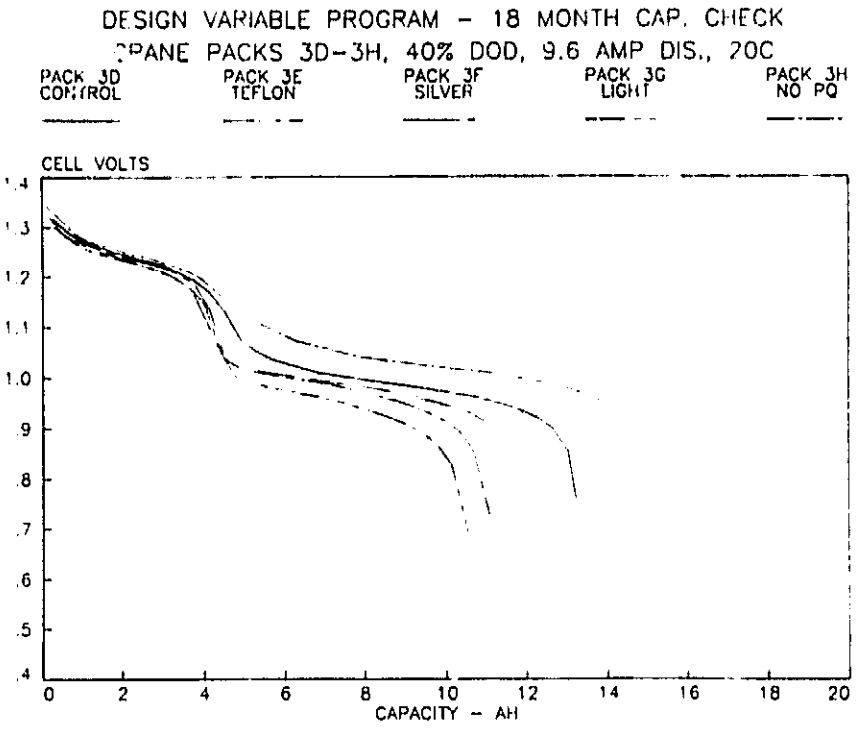

Figure 7. 18 Month Capacity Check 3D-3H

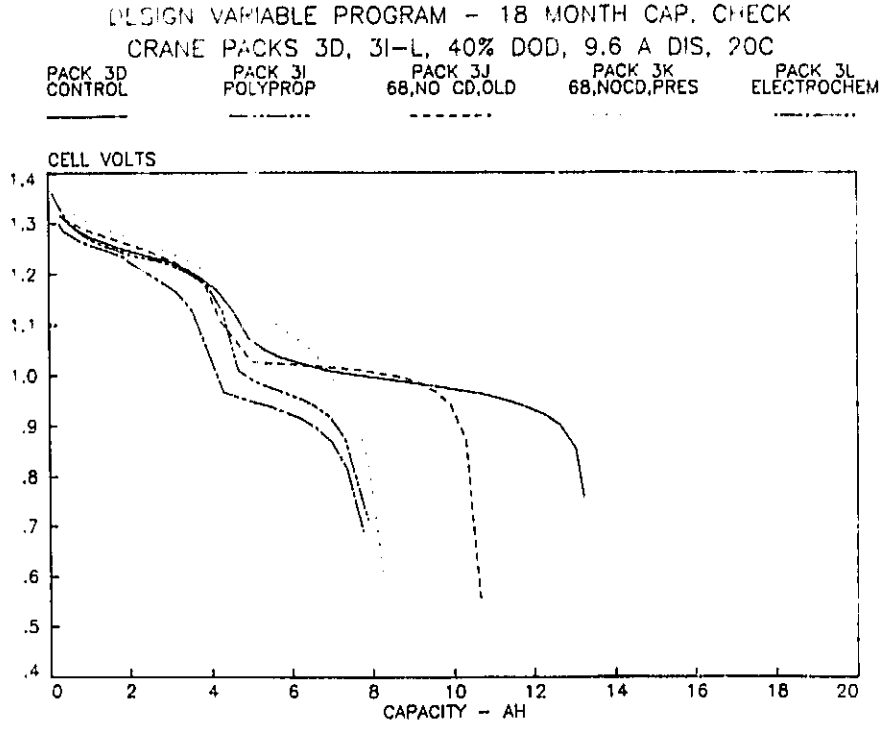

Figure 8. 18 Month Capacity Check 3D, 31-3L

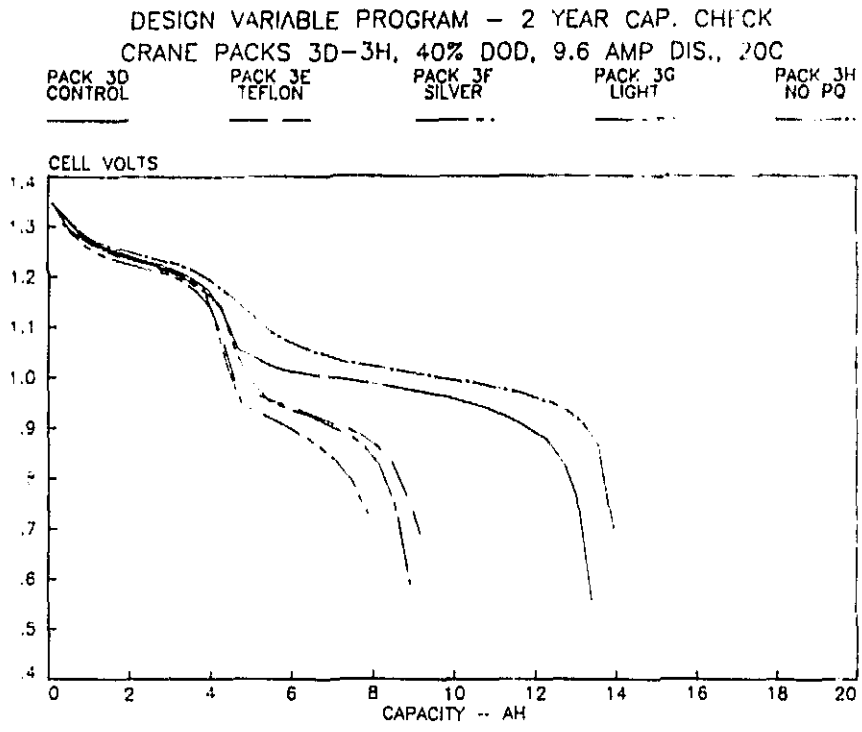

Figure 9. 2 Year Capacity Check 3D-3H

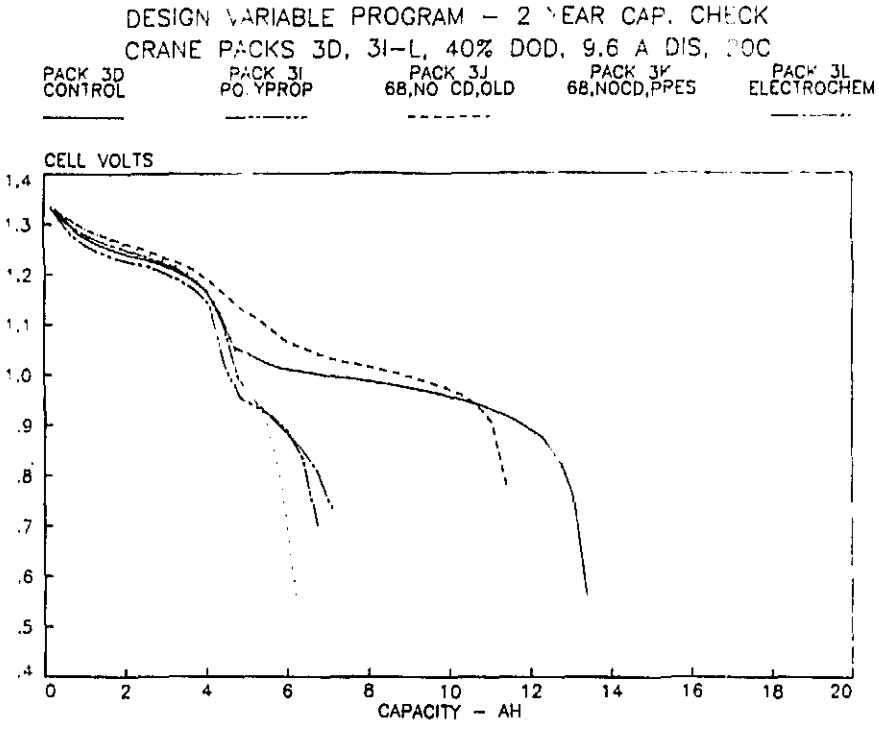

Figure 10. 2 Year Capacity Check 3D, 31-3L

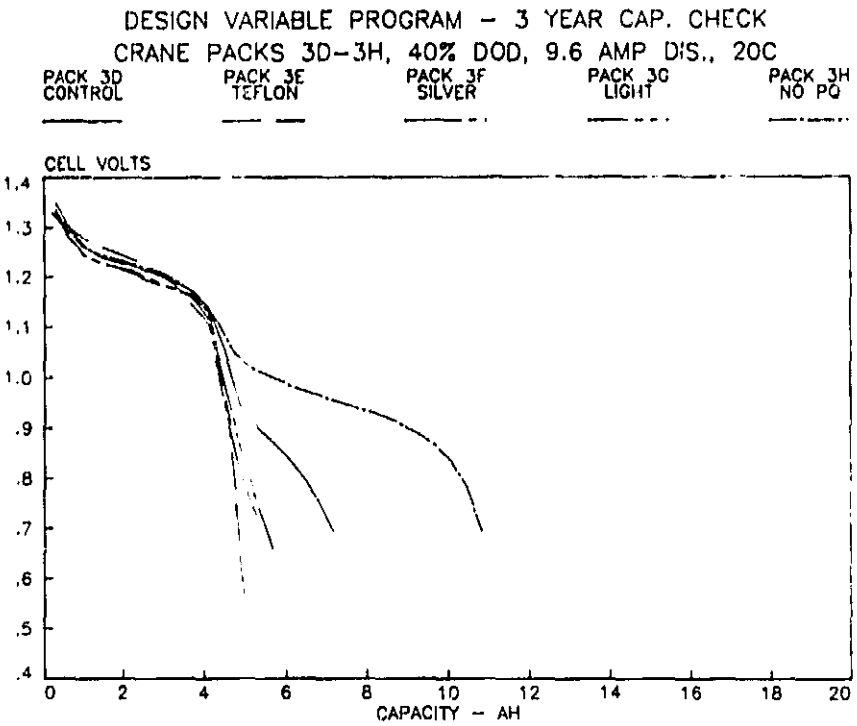

Figure 11. 3 Year Capacity Check 3D-3H

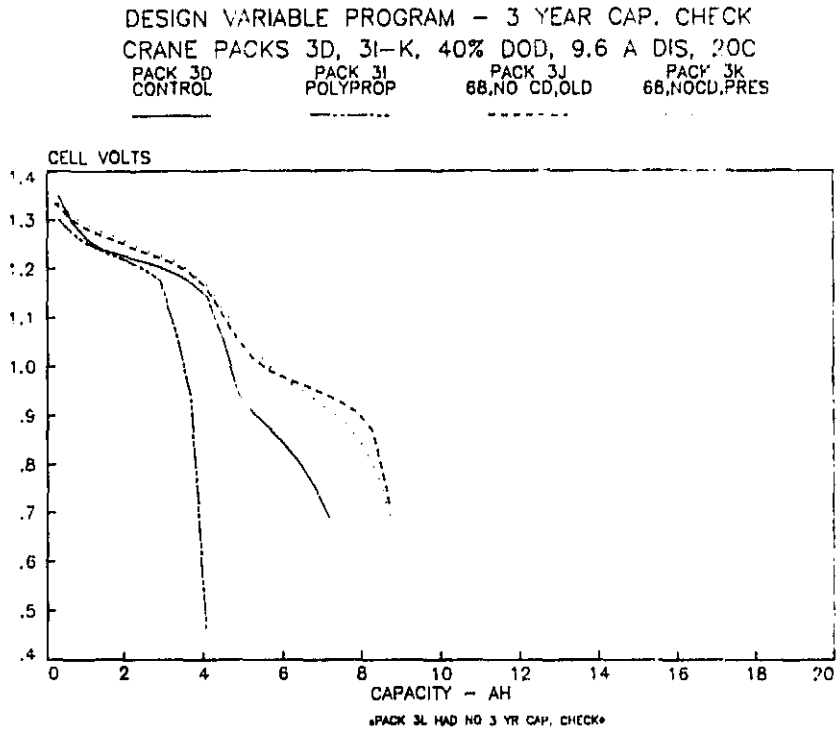

Figure 12. 3 Year Capacity Check 3D, 31-3K

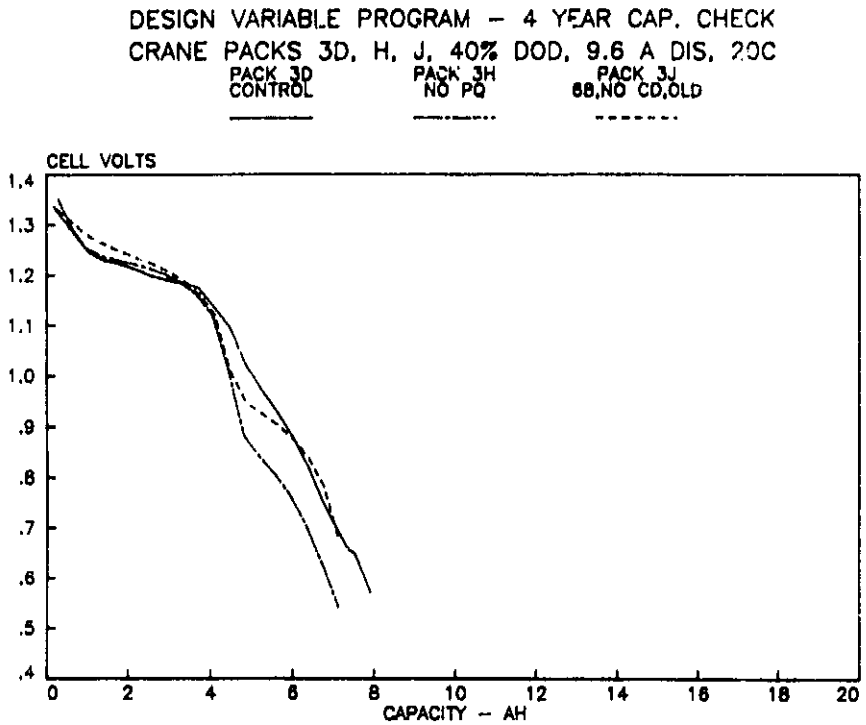

Figure 13. 4 Year Capacity Check 3D, 3H, 3J

A more accurate and objective representation of the capacity performance is presented in Figures 14 and 15 where the percent of initial capacity is plotted versus the number of cycles. These plots decisively show that the No PQ group, from the beginning, lost the least amount of capacity on a percentage basis than any other group. This group lost only 15 percent of its initial capacity during 3 years of cycling. This is compared to the Control group loss of 35 percent in 3 years and the A.K.-Old Process Group loss of 40 percent in 3 years. The Silver and Teflon groups lost 59 percent and 65 percent of their initial capacities respectively in 3 years while the Electrochem group lost only 22 percent in 2.5 years. The capacity lost percentages quoted here do not necessarily agree with the percentages calculated from the Initial Evalaution Test data. The discrepancies are a result of the different discharge current levels used. All discharges during the Initial Evaluation Program were at the 2-hour rate while those performed during the cycling capacity tests were at the 1.3-hour nominal cycling rate. Also, since the capacity discharges during the Initial Evaluation Program followed a deep discharge in a previous test, the data could reflect a slight reconditioning effect.

Plots of capacity checks by individual pack are included in Appendix 4. From the plots, capacity loss trends can be observed.

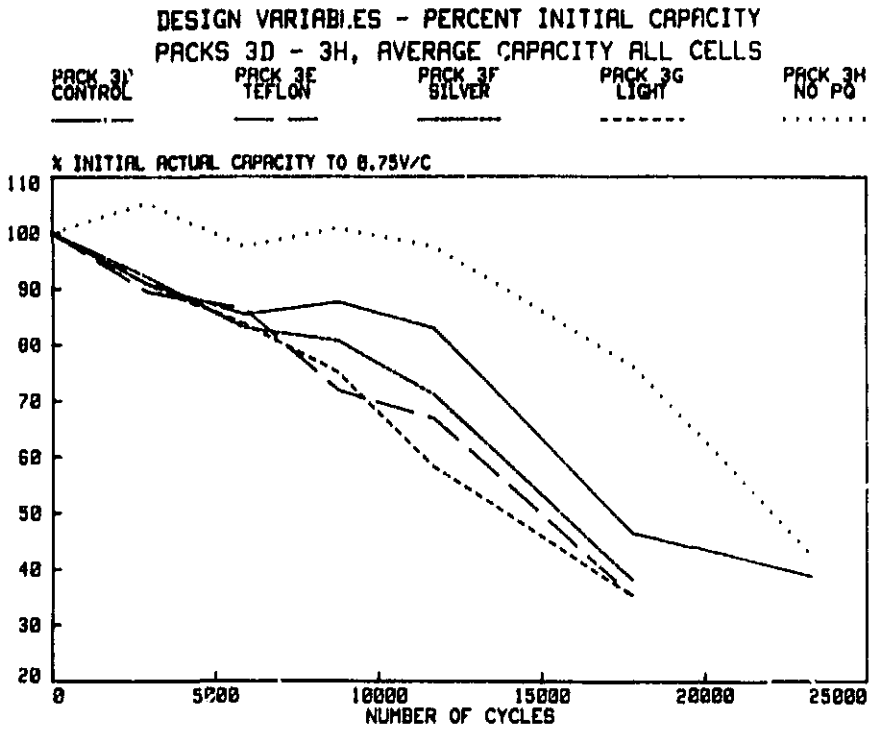

Figure 14. Percent Initial Capacity 3D-3H

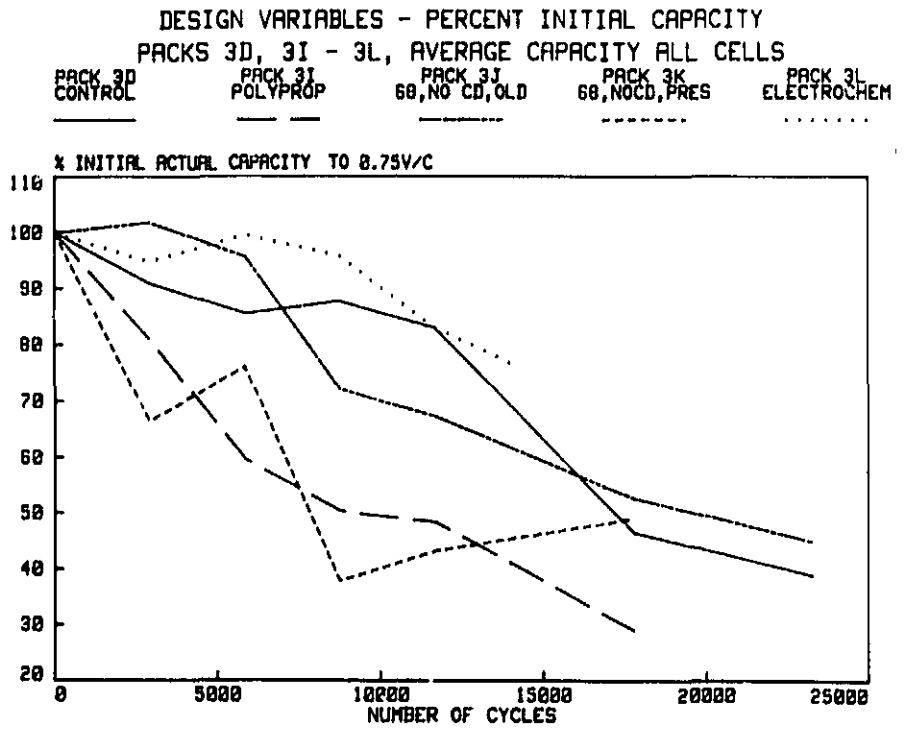

Figure 15. Percent Initial Capacity 3D, 31-3L

Endpoint Data

A comparison of average EOD voltages throughout life for all design groups is shown on Figures 16 and 17. These figures serve to reassert that the No PQ group outperformed all others. It maintained an EOD voltage of 1.14 volts/cell from cycle 7500 through cycle 19000 after slowly declining from a BOL EOD voltage of 1.21 volts/cell and before beginning a sharp decline near the end of cycling. The A.K.-Old Process group performed well, maintaining an EOD voltage of 1.12 volts/cell before declining at approximately 17000 cycles. The Control group also provided adequate performance after a sharp decline at BOL, maintaining an EOD voltage of approximately 1.03 volts/cell throughout most of its cycle life.

The Silver, Electrochem, and Teflon groups did not perform quite as well. The EOD voltage of the Silver group parallelled that of the Control until approximately cycle 11000 when a steady voltage decline began, culminating with an EOD voltage of 0.94 volt/cell at the end of cycling (17300 cycles). The EOD voltage of the electrochemical group declined sharply during the first 1500 cycles to 1.06 volts/cell. This voltage was then maintained by the pack until removal from test. The Teflon group showed a steady EOD voltage decline throughout life. The EOD voltage at the end of cycling was 0.89 volt/cell.

The A.K.-Present Process, Light, and Polypropylene groups displayed the worst performance of any of the 9 groups tested. The data shown on Figure 17 for the A.K.-Present Process group would indicate that it performed adequately but because of numerous cell failures (Table 15) and pack imbalance, this data is misleading. The Light Loading group exhibited a steady voltage decline during life to 0.87 volt/cell. The Polypropylene group had a very sharp voltage decline to 1500 cycles and ended cycling with an EOD voltage of 0.90 volt/cell after two cell failures.

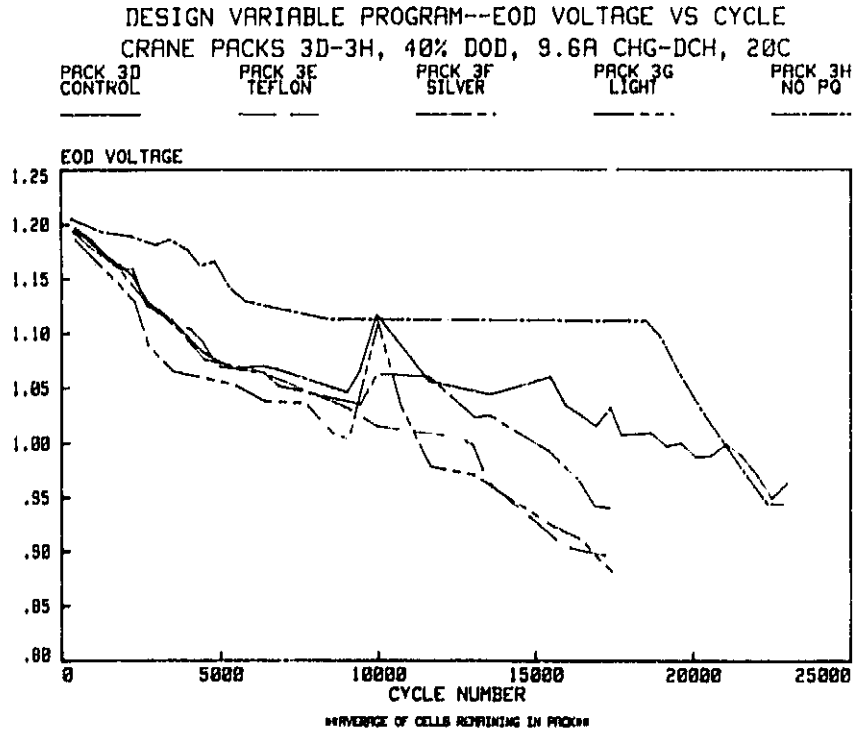

Figure 16. EOD Voltage vs Cycle 3D-3H

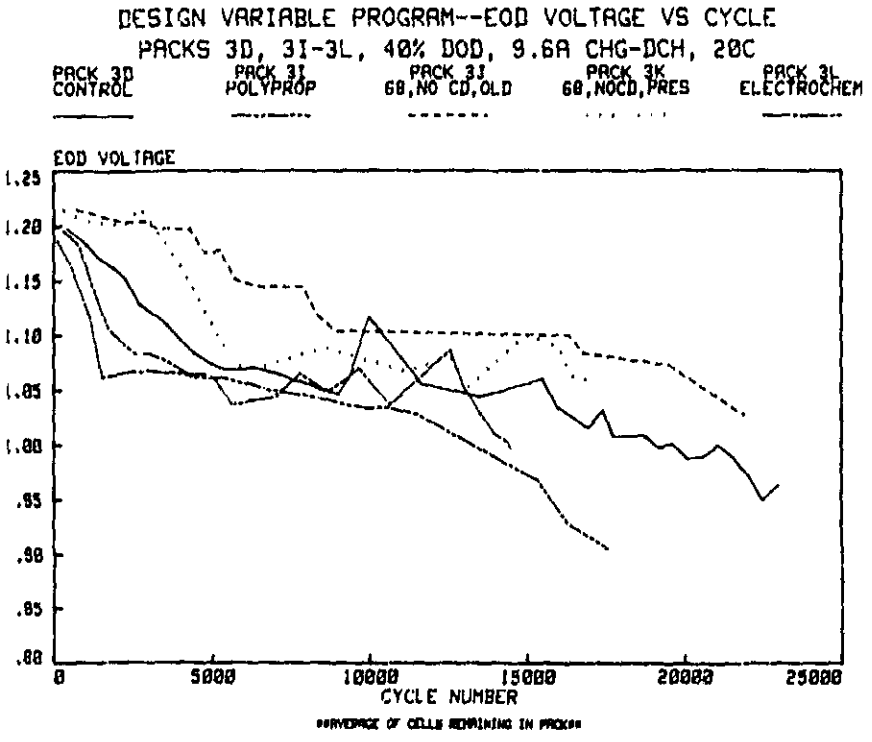

Figure 17. EOD Voltage vs Cycle 3D, 3I-3L

Plots of EOC current and percent recharge versus cycle number for each group are shown on Figures 18-26. A nominal percent recharge of 115 percent was to be maintained throughout life by adjusting the charge voltage limit of each pack. As the plots show, 115 percent recharge was not maintained. However, all groups were maintained at a percentage adequate to assure that full charge was achieved with a difference between groups of 5 percent or less. Therefore, all groups were maintained at approximately the same state throughout life. Figures 18-26 also provide a record of changes in the voltage limit for each pack.

Typical cycle plots for each pack at 6 points during cycle life are provided in Appendix 5. Average cell voltage, current, pressure, and signal electrode voltage are plotted versus cycle time.

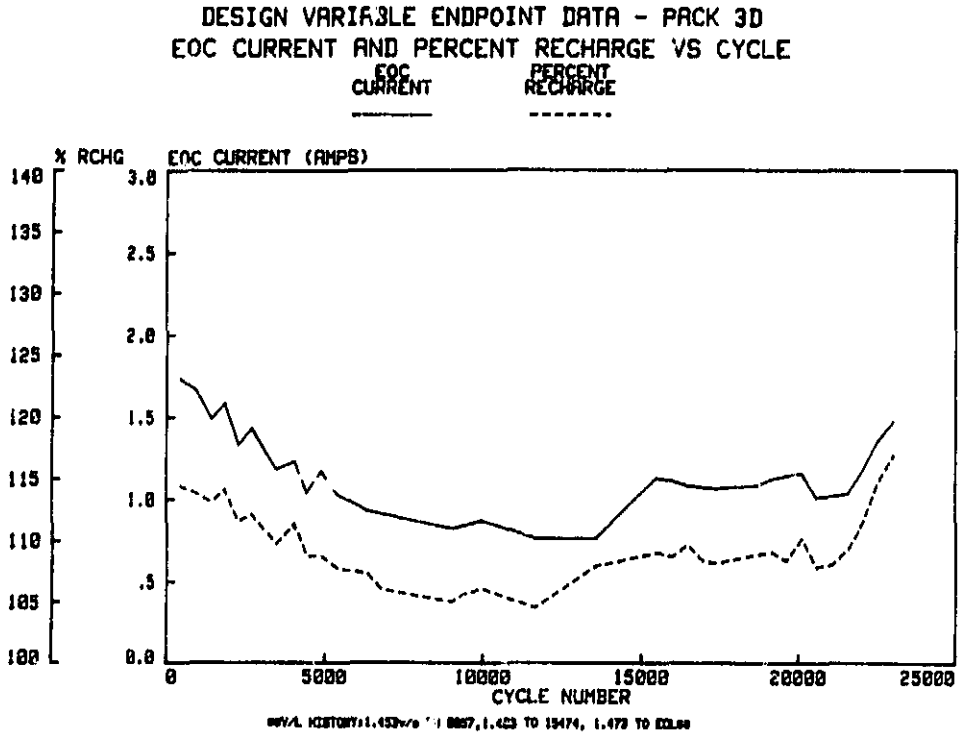

Figure 18. EOC Current & % Recharge vs Cycle 3D

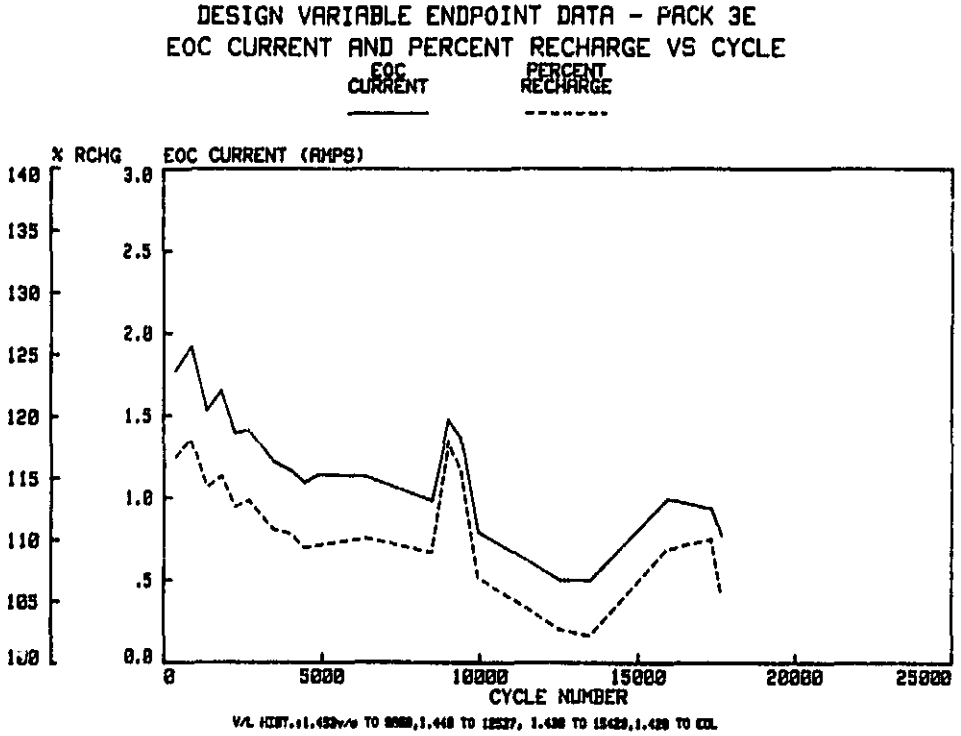

Figure 19. EOC Current & % Recharge vs Cycle 3E

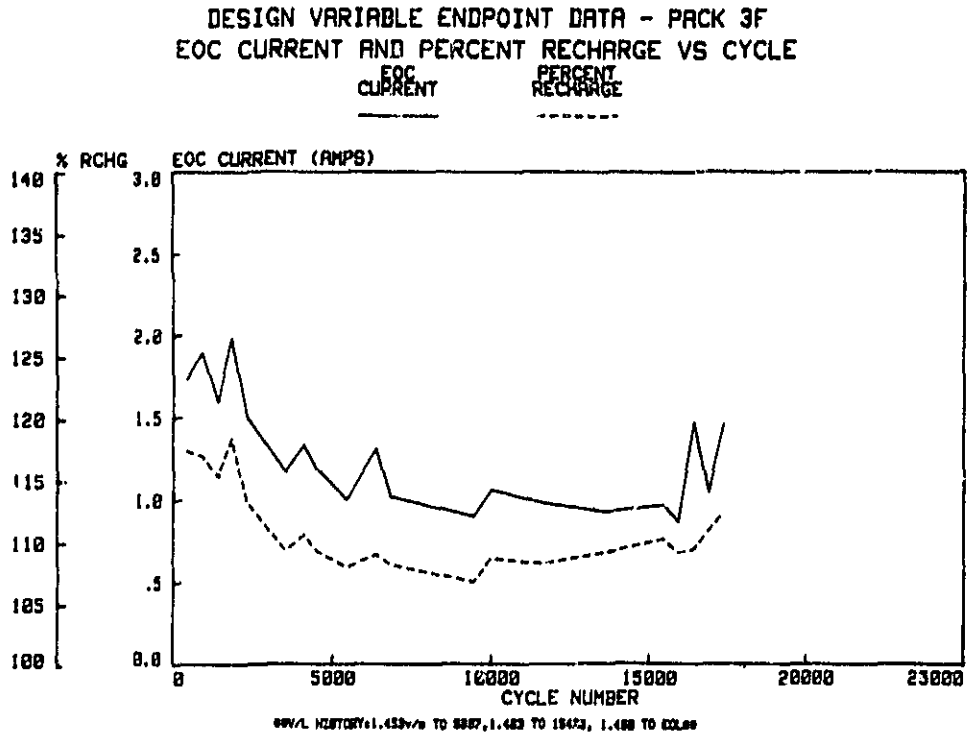

Figure 20. EOC Current & % Recharge vs Cycle 3F

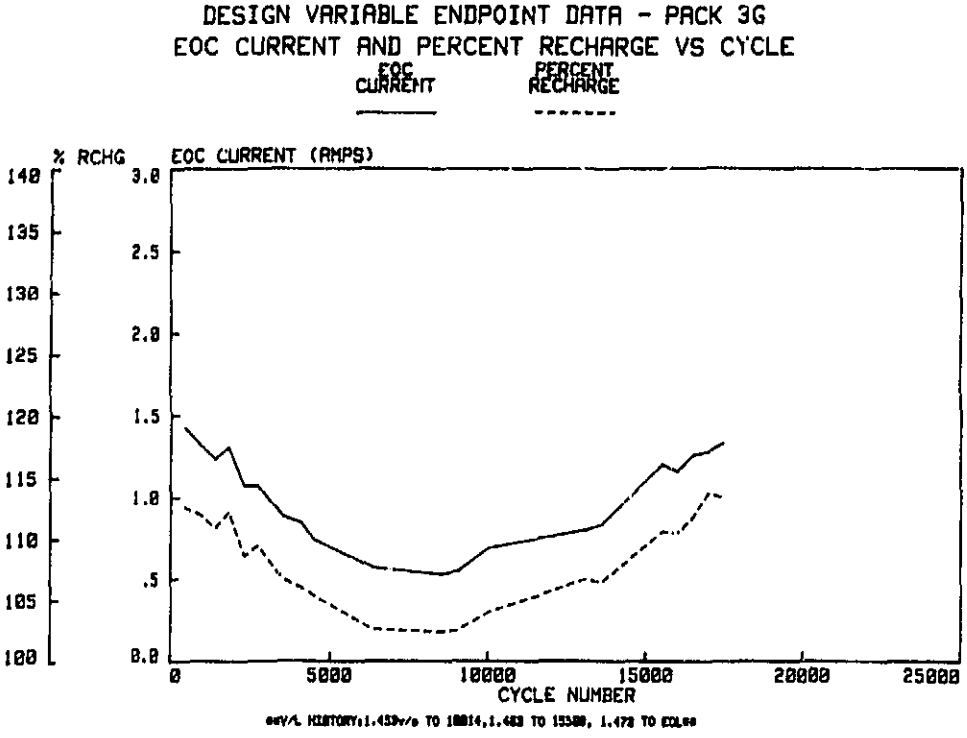

Figure 21. EOC Current & % Recharge vs Cycle 3G

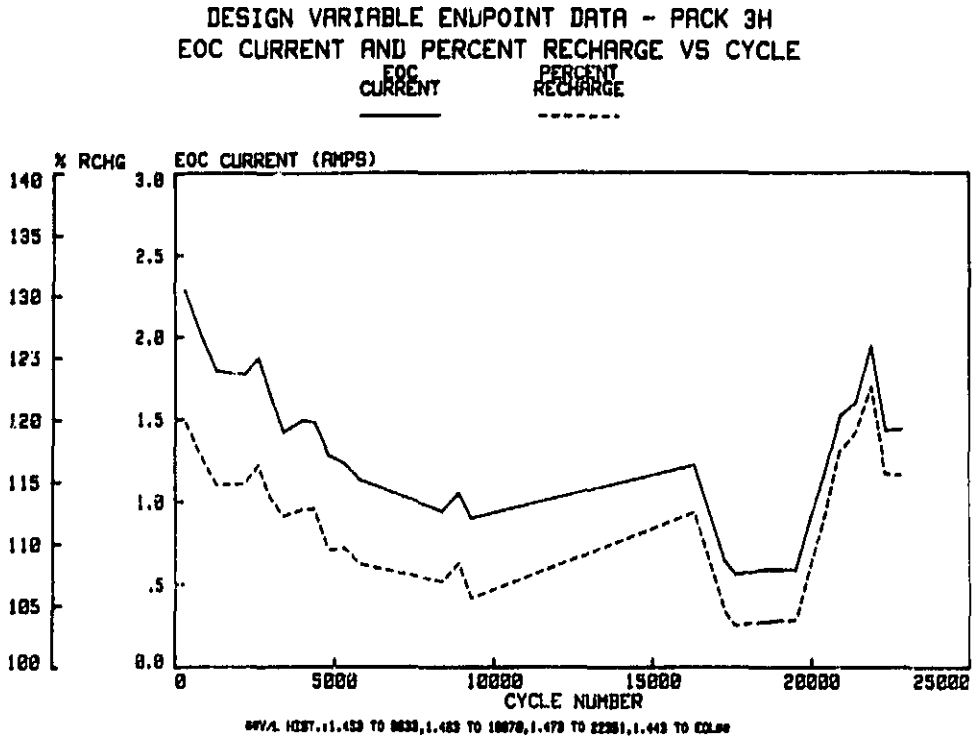

Figure 22. EOC Current & % Recharge vs Cycle 3H

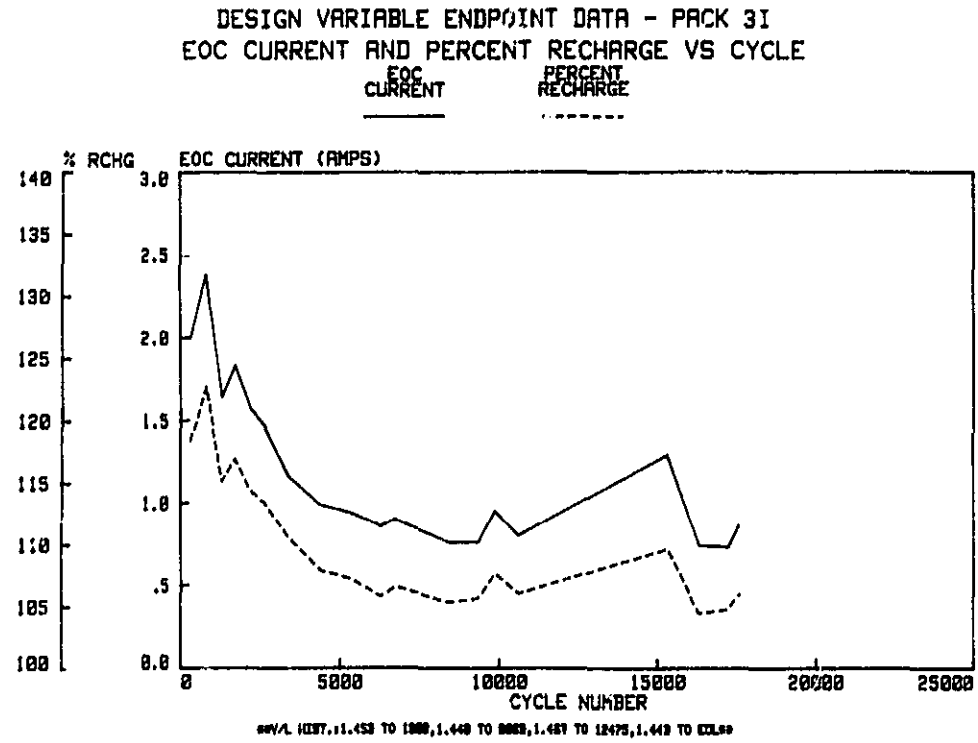

Figure 23. EOC Current & % Recharge vs Cycle 3I

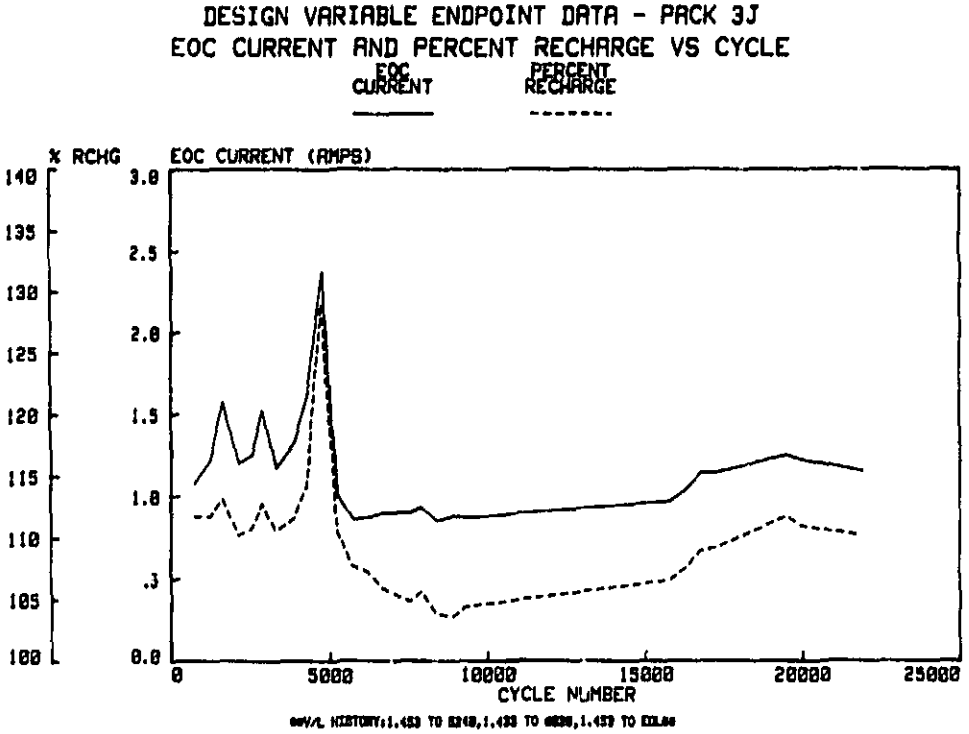

Figure 24. EOC Current & % Recharge vs Cycle 3J

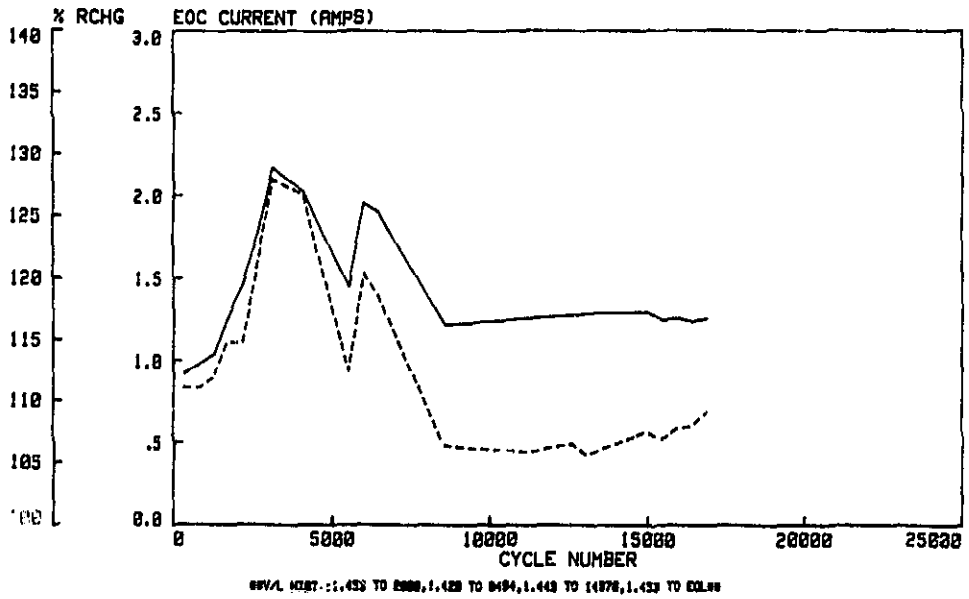

Figure 25. EOC Current & % Recharge vs Cycle 3K

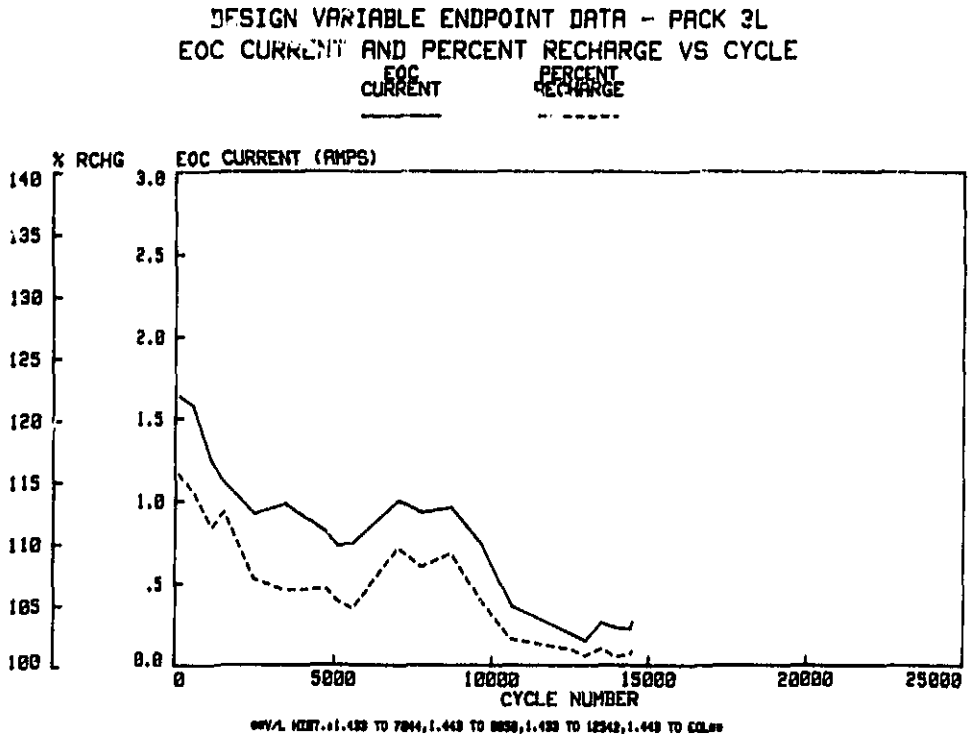

Figure 26. EOC Current & % Recharge vs Cycle 3L

CONCLUSIONS

The No PQ group outperformed all other Design Variable Program groups in both the areas of capacity retention and EOD voltage. This performance was rivaled only by the Control group that had PQ but no other treatment and the 1968 A.K.-Old Process group which did not have PQ treatment. The failure of the No PQ group to accept charge at the end of cycling did leave doubts about its performance. Inability to accept a charge is an indication that hard shorts had developed between the plates in all cells, a condition caused by excessive cadmium migration.

The Electrochemical group exhibited a capacity loss on a percentage basis lower than that of most other test groups, especially during the Initial Evaluation Tests, and above average active material utilization. It did not perform at the same level as the No PQ group, however, and had a very low BOL capacity as a result of the low positive plate loading level it possessed. Undoubtedly, the cause of the low positive loading level was that this was an early attempt by G.E. to use electrochemical impregnation in cell manufacture. Because of the indications of decreased capacity loss and enhanced active material utilization with this design, and in light of the advances made in this technology during the past 6 years, this process should be reevaluated with respect to aerospace energy storage programs.

Teflon and silver treatments enhance the rate of oxygen recombination and thus allow a greater amount of electrolyte to be added to the cells. The use of one or the other of these treatments was strongly recommended by G.E. and previous acceptance test and life test data indicated that these treatments improved cell performance and life. On the contrary, these groups showed very poor performance. The Teflon group had the highest capacity loss and the lowest end of cycling EOD voltages of any group discussed thus far. It also exhibited intermittent shorts at the end of cycling (17300 cycles) which is an indication of excessive cadmium migration, a condition teflon supposedly helps prevent. The merits of this design should clearly be reevaluated.

The Polypropylene, Light Loading, and 1968 A.K.-Present Process groups exhibited poor performance in all aspects of the test program. The Polypropylene group showed excessive capacity loss, low EOD voltage and two cell failures. The data did indicate, however, adequate performance if polypropylene separators were the only alternative because of mission requirements. Light loading levels in theory will reduce plate swelling and in turn reduce the drying of the separator yielding longer cycle life. This theory can be taken to the extreme and the data shows that was the case in this test. The Light Loading group showed very low capacity and EOD voltage from the beginning of life indicating that loading levels were too low for the physical design of the cell. The 1968 A.K.-Present Process group displayed performance to be expected when utilizing an early plate design with current processing techniques. The cells were very unbalanced and although averaged data looked good, overall performance because of cell problems and failures was poor.

From the above observations and conclusions regarding each design group, it is clear that cells manufactured with the fewest plate additives and treatments performed best (No PQ and Control). The worst performance among the present cell designs came from groups with the most additives and treatments (Teflon and Silver). Also, electrochemical impregnation proved itself to be a viable alternative and perhaps, because of its characteristics, a preferred manufacturing process for nickel-cadmium aerospace cells.

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3. NASA/GSFC SP 74-15000, "Specification for the Manufacturing of Aerospace Nickel-Cadmium Storage Cells," January 1974.

4. General Electric Company Manufacturing Control Document 232 A2222 AA-54, Rev. 18.

5. Morrow, G., *1983 GSFC Battery Workshop Proceedings*, NASA CP 2331, pages 385-399.

6. General Electric Company Separator Specification A50-PB-112.

7. General Electric Company Separator Specification A50-PB-116.

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9. "Initial Evaluation Tests of General Electric Company 12.0 Ampere-Hour Nickel-Cadmium Spacecraft Cells with Design Variables," Weapon Quality Engineering Center, NWSC Crane, Ind., 1979.

10. Morrow, G., *1984 GSFC Battery Workshop Proceedings*, NASA CP 2382, pages 208-227.

Appendix 1

Initial Evaluation Test Procedure

INITIAL EVALUATION TEST PROCEDURE

A. Phenolphthalein Leak Tests:

1. This test is a determination of the condition of the welds and ceramic seals on receipt of the cells and following the last discharge of the cells (Cycle #8).

2. The cells were initially checked with a one-half of one percent phenolphthalein solution applied with a cotton swab and then placed in a vacuum chamber and exposed to a vacuum of 40 microns of mercury or less for 24 hours. Upon removal they were rechecked for leaks and then received a final check following test completion. The requirement is no red or pink discoloration which indicates a leak.

B. Capacity Tests:

1. The capacity test is a determination of the cells' capacity at the C/2 discharge rate to 0.75 volt per cell, where C is the manufacturer's rated capacity. This type discharge follows all charges of this evaluation test.

2. The charges for the capacity tests are as follows:

   a. C/20, 48 hours, room ambient (RA), Cycle 0, with a test limit of 1.52 volts or pressure of 100 psia.

   b. C/10, 24 hours, RA, Cycle 1, with a test limit of 1.52 volts or 100 psia pressure and a requirement of maximum voltage (1.48) or pressure (75 psia).

   c. C/10, 24 hours, 20°C, Cycle 2, with the same limits and requirements as the charge of Cycle 1.

C. Internal Resistance:

1. Measurements are taken across the cell terminals 1/2 hour before the end-of-charge (EOC) on Cycle 1, and 1 and 2 hours after the start-of-discharge of Cycle 2. These measurements were made with a Hewlett-Packard milliohmeter (Model 4328A).

D. Special Charge Retention Test, 20°C:

1. This test is to establish the capacity retention of each cell following a 7-day open-circuit-stand in a charge mode.

2. The cells are charged at C/10 for 24 hours with a test limit of 1.52 volts or 100 psia pressure. They then stand on open-circuit for 7 days, with the requirement that the open-circuit voltage of each cell, following this period, is within ±5 millivolts of the average cell voltage. The cells are then discharged and 80 percent capacity out of that obtained in Cycle 3 is required.

E. Internal Short Test:

1. This test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials, or damage to element in handling or assembly.

2. Following completion of the third capacity discharge, the cells are shunted with a 0.5-ohm, 3-watt resistor for 16 hours. At the end of 16 hours the resistors are removed and the cells stand on open-circuit-voltage (OCV) for 24 hours. A minimum voltage of 1.15 is required at the end of the 24 hours.

F. Charge Efficiency Test, 20°C:

1. This test is a measurement of the cells' charge efficiency when charged at a low current rate.

2. The cells are charged at C/40 for 20 hours with a test limit of 1.52 volts or 100 psia pressure. They are then discharged and the requirement is that the minimum capacity out equals 55 percent of capacity in during the preceding charge.

G. Overcharge Test #1, 0°C:

1. The purpose of this test is to determine the degree to which the cells will maintain a balanced voltage, and to determine the cells' capability to be overcharged without overcharging the negative electrode.

2. The cells are charged at C/20 for 60 hours. The test limits are cell voltages of 1.56 or greater for a continuous time period of 2 hours or pressures of 100 psia. The requirement is a voltage of 1.520 or a pressure of 75 psia. The cells are then discharged and 85 percent capacity out of that obtained in Cycle 3 is required.

H. Overcharge Test #2, 35°C:

1. This test is a measurement of the cells' capacity at a higher temperature when compared to its capacity at 20°C. This test also determines the cells' capability of reaching a point of pressure equilibrium; oxygen recombination at the negative plate at the same rate it is being generated at the positive plate.

2. The cells are charged C/10 for 24 hours with a test limit of 1.52 volts or 100 psia pressure and a requirement of 1.45 volts or 75 psia pressure. The cells are then discharged and 55 percent capacity out of that obtained in Cycle 3 is required.

I. Pressure versus Capacity Test:

1. The purpose of this test is to determine the capacity to a pressure and the pressure decay during charge and open circuit stand respectively.

2. Each cell is charged at C/2 to either a pressure of 20 psia or a voltage of 1.550. Recordings are taken on each cell when it reaches 5, 10, 15 and 20 psia pressure. The cells then stand OCV for 1 hour with 30-minute recordings and then are discharged, shorted out and leak tested.

Appendix 2

Initial Evaluation Test-Summary Data Sheets-BOL

Table I
Measurement and Leak Test Data

	SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)			WIDTH (Inches)	PHENOLPHTHALEIN LEAK TESTS								
								INITIAL			POST HI V.:C			POST TEST		
				EDGE MINIMUM	CENTER MAXIMUM (Pre-Test)	CENTER MAXIMUM (Post-Test)		Terminals		Other	Terminals		Other	Terminals		Other
								+	−		+	−		+	−	
Group 1	001	769.6*	4.559	.893	.898	.895	2.993									
	002	520.3	4.553	.893	.893	.898	2.992									
	003	509.5	4.554	.898	.896	.899	2.991									
	004	770.2*	4.543	.893	.894	.897	2.987									
	005	774.3*	4.544	.890	.898	.898	2.987									
	006	774.4*	4.544	.890	.893	.893	2.986									
Group 4	001	767.3*	4.549	.892	.899	.893	2.991									
	002	509.7	4.565	.891	.890	.894	2.991									
	003	509.1	4.563	.895	.893	.895	2.989									
	004	760.4*	4.547	.895	.900	.893	2.986									
	005	765.4*	4.539	.890	.891	.890	2.999									
	006	762.0*	4.548	.891	.891	.895	2.991	NO LEAKS			NO LEAKS			NO LEAKS		
Group 7	001	771.0*	4.539	.898	.919	.911	2.983									
	002	773.4*	4.549	.897	.909	.915	2.985									
	003	519.6	4.549	.896	.906	.922	2.984									
	004	521.6	4.553	.891	.917	.929	2.984									
	005	778.0	4.545	.899	.916	.923	2.987									
	006	777.8*	4.535	.899	.932	.919	2.995									
Group 8	001	521.0	4.557	.894	.910	.916	2.983									
	002	770.8*	4.552	.892	.916	.922	2.987									
	003	519.3	4.553	.896	.912	.919	2.981									
	004	767.8*	4.556	.892	.920	.911	2.984									
	005	774.8*	4.541	.896	.909	.928	2.967									
	006	772.9*	4.557	.891	.909	.922	2.984									

*-Has Pressure Transducer

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Table I
Measurement and Leak Test Data

	SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)			WIDTH (Inches)	PHENOLPHTHALEIN LEAK TESTS								
								INITIAL			POST HI VAC			POST TEST		
				EDGE MINIMUM	CENTER MAXIMUM (Pre-Test)	CENTER MAXIMUM (Post-Test)		Terminals		Other	Terminals		Other	Terminals		Other
								+	−		+	−		+	−	
Group 2	001	538.8	4.560	.891	.898	.898	2.989									
	002	534.5	4.571	.890	.898	.898	2.989									
	003	793.6*	4.559	.899	.902	.902	2.990									
	004	789.6*	4.560	.895	.902	.902	2.989									
	005	791.6*	4.561	.897	.898	.898	2.991									
	006	790.5*	4.564	.895	.898	.898	2.989									
Group 3	001	524.1	4.567	.891	.901	.903	2.989									
	002	790.7*	4.564	.893	.904	.904	2.992									
	003	775.4*	4.583	.891	.895	.896	2.984									
	004	524.6	4.563	.889	.898	.904	2.987									
	005	783.7*	4.567	.894	.902	.905	2.987									
Group 5	001	766.6*	4.577	.895	.902	.903	2.982	NO LEAKS			NO LEAKS			NO LEAKS		
	002	516.3	4.576	.892	.902	.903	2.985									
	003	772.3*	4.571	.897	.904	.904	2.984									
	004	516.4	4.576	.889	.902	.904	2.986									
	005	770.8*	4.561	.889	.898	.901	2.985									
	006	768.4*	4.560	.891	.897	.900	2.984									
Group 6	001	520.0	4.563	.896	.897	.899	2.987									
	002	771.0*	4.606	.896	.902	.903	2.987									
	003	770.0*	4.567	.896	.900	.902	2.987									
	004	519.6	4.559	.892	.903	.903	2.987									
	005	774.7*	4.565	.896	.898	.898	2.984									
	006	775.6*	4.564	.890	.895	.897	2.987									

*–Has Pressure Transducer

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Table I
Measurement and Leak Test Data

SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)			WIDTH (Inches)	PHENOLPHTHALEIN LEAK TESTS								
							INITIAL			POST HI VAC			POST TEST		
			MINIMUM	MAXIMUM (Pre-Test)	MAXIMUM (Post-Test)		Terminals		Other	Terminals		Other	Terminals		Other
							+	−		+	−		+	−	
001	830.8*	4.567	.911	.925	.928	2.996									
002	808.8*	4.599	.909	.922	.924	3.002									
003	553.9	4.567	.903	.970	.924	2.998	NO LEAKS			NO LEAKS			NO LEAKS		
004	558.7	4.585	.911	.928	.931	2.995									
005	555.7	4.573	.904	.920	.922	2.999									

Group 9

*–Has Pressure Transducer

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Table II
Capacity Data

	SERIAL NUMBER	Capacity Test 1—CHG. C/20, 48 hrs., (RA)						Capacity Test 2—CHG. C/10, 24 hrs., (RA)						Capacity Test 3 (20°C)—CHG. C/10, 24 hrs.					
		END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE		
		CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)
Group 1	001	1.456		19	16.4		1	1.462		27	15.3		2	1.469		43	14.6		5
	002	1.456			16.4			1.462			15.3			1.469			14.5		
	003	1.456			16.4			1.462			15.3			1.469			14.6		
	004	1.447		16	15.4		1	1.462		28	15.5		14	1.471		42	15.1		6
	005	1.455	.818	15	16.4	−.086	3	1.457	.623	41	14.9	.152	7	1.468	.593	55	14.6	.154	11
	006	1.447	.541	14	15.4	−.095	10	1.457	.725	51	15.3	.052	3	1.470	.703	53	15.1	.257	19
Group 4	001	1.442		23	14.3		8	1.458		33	13.6		8	1.466		37	13.4		10
	002	1.442			14.3			1.458			13.9			1.467			13.7		
	003	1.441			14.3			1.457			13.6			1.465			13.7		
	004	1.441		15	14.3		10	1.456		25	13.6		11	1.465		30	13.7		11
	005	1.441	.813	24	14.3	−.039	12	1.455	.064	30	13.6	−.002	13	1.466	.560	38	13.4	120	13
	006	1.441	.362	18	14.1	−.015	6	1.456	.396	26	13.6	.061	7	1.467	.390	32	13.7	.143	9
Group 7	001	1.451		22	18.6		5	1.464		35	18.4		9	1.476		45	17.7		16
	002	1.450		17	18.6		7	1.464		33	18.4		12	1.476		49	17.7		21
	003	1.454			18.6			1.465			18.4			1.478			18.0		
	004	1.452			18.1			1.465			17.9			1.476			17.4		
	005	1.452	.750	6	18.6	−.013	0	1.459	.421	21	17.0	.061	0	1.481	.452	27	17.3	.052	7
	006	1.453	.663	12	18.9	.001	5	1.459	.739	31	17.7	.352	11	1.476	.745	37	18.0	.329	17
Group 8	001	1.451			18.8			1.464			18.4			1.477			17.9		
	002	1.453		11	19.1		0	1.470		32	18.6		7	1.489		40	18.0		17
	003	1.449			18.8			1.462			18.4			1.474			17.9		
	004	1.453		14	18.8		6	1.463		32	18.4		10	1.477		38	17.8		17
	005	1.453	.779	16	18.8	.039	6	1.458	.516	25	17.4	.082	8	1.479	.508	27	17.8	.051	10
	006	1.453	.321	16	18.6	−.011	6	1.460	.379	28	17.4	.052	14	1.482	.346	32	17.5	.050	18

Table II
Capacity Data (Cont)

	SERIAL NUMBER	Capacity Test 1—CHG. C/20. 48 hrs., (RA)						Capacity Test 2—CHG. C/10. 24 hrs., (RA)						Capacity Test 3—(20°C) CHG. C/10. 24 hrs.					
		END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE		
		CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS PSIA)	CAt AC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)
Group 2	001	1.438			15.5			1.455			14.7			1.462			14.2		
	002	1.437			15.5			1.452			14.9			1.459			14.2		
	003	1.435		16	15.3		5	1.453		36	14.7		6	1.460		41	14.1		12
	004	1.434		26	15.5		6	1.452		45	14.7		11	1.460		54	14.2		16
	005	1.436	.347	19	15.5	−.006	11	1.452	.456	32	14.9	− 037	11	1.460	.467	39	14.2	.079	12
	006	1.437	.348	14	15.7	.008	10	1.453	.414	27	14.9	.036	10	1.460	.413	33	14.3	.055	12
Group 3	001	1.442			16.1			1.456			15.2			1.467			14.5		
	002	1.442		20	15.9		6	1.455		52	14.8		9	1.465		65	14.2		14
	003	1.441		21	16.1		10	1.455		37	15.1		11	1.465		53	14.5		14
	004	1.441			15.9			1.456			15.1			1.466			14.5		
	005	1.441	.453	12	15.9	.032	1	1.455	.548	35	14.9	.070	2	1.465	.540	51	14.5	.115	4
Group 5	001	1.446		8	16.3		0	1.454		23	16.0		0	1.464		50	15.0		4
	002	1.448			16.2			1.454			16.0			1.465			15.0		
	003	1.445		16	16.2		5	1.455		32	16.0		6	1.465		61	15.0		10
	004	1.448			16.3			1.455			16.2			1.466			15.0		
	005	1.446	.310	15	16.2	.007	0	1.457	.405	27	16.0	−.004	8	1.468	.366	53	15.0	.050	11
	006	1.447	.460	12	16 3	−.015	3	1.455	.511	23	16.0	−.002	4	1.466	.555	45	15.0	.101	16
Group 6	001	1.441			16.0			1.459			15.6			14.71			14.9		
	002	1.445		15	16.0		6	1.461		57	15.4		6	1.472		95	14.9		19
	003	1.443		25	16.0		12	1.457		43	15.4		12	1.472		83	14.6		16
	004	1.444			16.0			1.458			15.4			1.472			14.6		
	005	1.442	.262	13	16.1	−.002	5	1.457	.409	33	15.4	−.001	3	1.471	.409	56	15.7	.026	4
	006	1.442	.442	10	16.3	−.048	2	1.457	.536	21	15.6	−.024	1	1.470	.553	30	15.9	−.043	2
Group 9	001	1.449		26	10.4		7	1.438		26	9.8		8	1.444			9.6		11
	002	1.446		38	10.8		19	1.437		38	10.0		20	1.446			10.1		22
	003	1.444			10.8			1.436			10.2			1.443			10 2		
	004	1.444			10.8			1.433			10.2			1.443		34	10.2		
	005	1.445			10.8			1.433			10.2			1.443		46	10.2		

Table III
Internal Resistance and Short Test Data

	SERIAL NUMBER	INTERNAL RESISTANCE (MILLIONS)			INTERNAL SHORT TEST		
		END-OF-CHARGE	ONE HOUR AFTER START-OF-DISCHARGE	TWO HOURS AFTER START-OF-DISCHARGE	AFTER 16 HR SHORT	AFTER 24 HOUR OCV STAND	
					CELL	CELL	PRESS
GROUP 1	001	2.4	2.3	2.2	.058	1.252	1
	002	2.3	2.3	2.3	.059	1.252	
	003	2.1	2.2	2.2	.058	1.252	
	004	2.3	2.1	2.2	.058	1.250	1
	005	2.3	2.1	2.1	.058	1.249	4
	006	2.2	2.1	2.1	.057	1.247	8
GROUP 4	001	2.2	2.3	2.2	.017	1.240	9
	002	2.3	2.3	2.2	.020	1.237	
	003	2.2	2.2	2.3	.020	1.240	
	004	2.3	2.3	2.3	.015	1.234	11
	005	2.1	2.2	2.2	.025	1.239	13
	006	2.2	2.2	2.1	.025	1.239	6
GROUP 7	001	2.3	2.2	2.3	.102	1.264	6
	002	2.4	2.3	2.4	.091	1.264	10
	003	2.4	2.4	2.4	.085	1.262	
	004	2.4	2.3	2.3	.091	1.264	
	005	2.4	2.4	2.4	.088	1.260	0
	006	2.5	2.4	2.4	.095	1.262	7
GROUP 8	001	2.2	2.1	2.1	.093	1.261	
	002	2.2	2.1	2.1	.091	1.257	6
	003	2.2	2.2	2.2	.084	1.261	
	004	2.2	2.1	2.2	.082	1.257	10
	005	2.3	2.2	2.3	.084	1.261	8
	006	2.3	2.1	2.2	.083	1.259	12

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Table III
Internal Resistance and Short Test Data (Cont)

	SERIAL NUMBER	INTERNAL RESISTANCE (MILLIONS)			INTERNAL SHORT TEST		
		END-OF-CHARGE	ONE HOUR AFTER START-OF-DISCHARGE	TWO HOURS AFTER START-OF-DISCHARGE	AFTER 16 HR SHORT	AFTER 24 HOUR OCV STAND	
					CELL	CELL	PRESS
GROUP 2	001	2.6	2.8	2.8	.059	1.258	
	002	2.9	3.0	3.0	.062	1.255	
	003	2.9	2.9	3.0	.057	1.258	4
	004	2.8	3.1	3.0	.061	1.258	5
	005	3.0	3.0	3.1	.062	1.258	11
	006	2.9	3.0	3.1	.066	1.254	9
GROUP 3	001	2.6	2.7	2.8	.051	1.249	
	002	3.1	3.0	3.1	.050	1.250	6
	003	2.9	3.0	2.9	.057	1.251	10
	004	2.9	3.0	3.1	060	1.252	
	005	2.8	3.0	3.1	.051	1.248	1
GROUP 5	001	2.6	2.8	3.0	.054	1.261	0
	002	3.0	3.1	3.1	.056	1.259	
	003	3.0	3.2	3.1	.047	1.260	5
	004	3.0	3.1	3.1	.049	1.258	
	005	3.0	3.1	3.0	.054	1.259	8
	006	2.9	2.9	3.1	.048	1.256	4
GROUP 6	001	2.9	2.9	3.0	.057	1.249	
	002	3.4	3.2	3.1	.047	1.248	6
	003	3.1	3.1	3.1	.044	1.251	12
	004	3.4	3.2	3.2	.045	1.251	
	005	3.2	3.1	3.2	.043	1.247	3
	006	3.2	3.1	3.1	.042	1.235	2
GROUP 9	001	3.2	3.1	N/A	.027	1.232	8
	002	3.1	3.1	N/A	.021	1.238	16
	003	3.1	3.0	N/A	.029	1.236	
	004	3.0	3.0	N/A	.024	1.237	
	005	3.2	3.1	N/A	.030	1.238	

N/A - Not applicable.

Table IV
Charge Retention Test Data

	SERIAL NUMBER	END-OF-CHARGE			24 HR. OCV			1 WEEK OCV			END-OF-DISCHARGE		
		CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)
GROUP 1	001	1.469		52	1.367		2	1.326		1	13.5		1
	002	1.470			1.368			1.326			13.0		
	003	1.469			1.367			1.326			13.5		
	004	1.471		50	1.369		2	1.328		2	13.5		1
	005	1.468	.559	60	1.365	.010	5	1.324	.001	4	13.5	−.001	4
	006	1.471	.734	63	1.367	.099	10	1.324	.012	8	13.7	−.042	8
GROUP 4	001	1.468		40	1.366		9	1.320		9	12.5		9
	002	1.467			1.365			1.317			12.5		
	003	1.466			1.366			1.320			12.5		
	004	1.466		34	1.365		11	1.315		11	12.5		10
	005	1.467	.558	46	1.364	.007	13	1.321	.000	13	12.5	−.005	13
	006	1.467	.425	46	1.365	.051	7	1.321	.005	7	12.5	−.137	7
GROUP 7	001	1.476		41	1.346		8	1.309		7	15.3		6
	002	1.476		44	1.345		14	1.309		11	15.1		11
	003	1.477			1.344			1.309			15.4		
	004	1.476			1.344			1.308			14.9		
	005	1.478	.403	25	1.341	.018	5	1.306	.001	1	14.9	−.003	0
	006	1.480	.733	36	1.345	.248	10	1.309	.021	7	15.5	−.084	7
GROUP 8	001	1.479			1.344			1.309			15.4		
	002	1.486		49	1.344		18	1.308		9	15.6		8
	003	1.473			1.344			1.309			15.4		
	004	1.478		46	1.343		20	1.308		12	15.4		11
	005	1.481	.490	28	1.342	.020	12	1.308	.002	9	15.4	−.006	9
	006	1.484	.319	37	1.341	.035	23	1.306	.013	15	15.2	.004	14

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Table IV
Charge Retention Test Data (Cont)

	SERIAL NUMBER	END-OF-CHARGE			24 HR. OCV			1 WEEK OCV			END-OF-DISCHARGE		
		CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)
GROUP 2	001	1.465			1.371			1.334			12.9		
	002	1.462			1.370			1.331			13.0		
	003	1.463		38	1.370		5	1.332		5	13.0		5
	004	1.463		46	1.370		6	1.333		6	13.0		5
	005	1.462	.849	38	1.370	.005	11	1.334	.001	11	13.0	−.017	11
	006	1.463	.414	32	1.370	.064	10	1.330	.004	9	13.2	−.024	9
GROUP 3	001	1.471			1.369			1.329			13.6		
	002	1.470		63	1.369		7	1.327		6	13.5		6
	003	1.469		52	1.369		11	1.330		11	13.5		11
	004	1.469			1.370			1.330			13.4		
	005	1.469	.531	51	1.370	.008	1	1.331	.000	1	13.4	−.005	1
GROUP 5	001	1.466		53	1.352		0	1.313		0	13.7		0
	002	1.467			1.352			1.314			13.7		
	003	1.468		64	1.354		6	1.316		5	13.7		5
	004	1.469			1.352			1.314			13.7		
	005	1.471	.342	60	1.358	.025	10	1.319	.002	9	13.7	−.012	8
	006	1.469	.568	53	1.353	.053	4	1.314	.010	4	13.7	−.014	4
GROUP 6	001	1.475			1.371			1.330			13.7		
	002	1.479		92	1.372		7	1.331		6	13.7		6
	003	1.475		92	1.370		13	1.330		12	13.5		12
	004	1.475			1.370			1.330			13.5		
	005	1.473	.424	74	1.370	.009	3	1.329	.000	3	13.7	−.093	3
	006	1.473	.587	48	1.370	.094	2	1.327	.005	2	14.5	−.059	2
GROUP 9	001	1.443		31	1.323		8	1.286		8	8.3		8
	002	1.445		41	1.332		17	1.296		17	9.0		16
	003	1.442			1.329			1.295			9.1		
	004	1.443			1.330			1.296			9.3		
	005	1.442			1.330			1.296			9.1		

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Table V
Charge Efficiency and Overcharge Data

	SERIAL NUMBER	Charge Efficiency (20°C)						Overcharge Test (0°)						Overcharge Test (35°C)					
		END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE		
		CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)
Group 1	001	1.372		1	3.9		1	1.496		40	14.5		14	1.418		37	15.9		3
	002	1.373			3.9			1.496			14.5			1.419			15.9		
	003	1.372			3.9			1.496			14.5			1.418			15.9		
	004	1.371		1	3.4		1	1.496		39	14.6		14	1.416		36	16.1		3
	005	1.372	.006	4	3.9	−.005	4	1.495	.409	49	14.3	.119	21	1.417	.655	36	15.6	.068	6
	006	1.371	.046	8	3.4	.040	8	1.497	.519	50	14.6	.235	27	1.419	.748	39	16.0	.239	13
Group 4	001	1.377		9	3.9		9	1.490		38	12.8		18	1.424		40	14.1		11
	002	1.376			3.9			1.492			13.0			1.424			14.2		
	003	1.376			3.9			1.490			13.3			1.423			14.2		
	004	1.376		11	3.9		10	1.490		32	13.3		17	1.424		29	14.1		13
	005	1.376	.005	13	3.9	.001	12	1.491	.300	40	13.0	.090	22	1.421	.640	34	14.0	.042	13
	006	1.376	.025	7	3.9	.000	7	1.492	.562	37	13.0	.134	17	1.424	.716	35	14.1	.279	10
Group 7	001	1.370		6	4.0		6	1.576*		64	16.6		55	1.396		51	14.5		32
	002	1.370		10	3.5		10	1.578*		70	16.8		61	1.396		54	14.6		37
	003	1.370			3.5			1.578*			16.8			1.396			14.5		
	004	1.370			3.8			1.578*			16.6			1.396			14.6		
	005	1.371	.025	0	3.5	.018	0	1.582*	.206	65	16.6	.013	58	1.396	.192	42	14.0	.032	31
	006	1.369	.191	7	3.5	.122	7	1.575*	.629	71	17.1	.276	64	1.395	.706	59	14.6	.123	38
Group 8	001	1.368			3.1			1.578*			16.2			1.398			15.1		
	002	1.370		6	2.9		6	1.590*		62	16.4		28	1.401		27	15.4		19
	003	1.368			3.1			1.579*			16.2			1.398			15.1		
	004	1.369		10	3.1		10	1.583*		70	16.0		38	1.398		36	14.7		29
	005	1.368	.077	3	3.1	.015	8	1.578*	.281	58	16.0	.004	42	1.395	.364	44	14.0		32
	006	1.368	.058	12	3.1	.046	12	1.577*	.240	73	16.0	.016	56	1.394	.324	52	13.9		37

9ND-NADC (SP 11/73) *Charge terminated because of high cell voltage, average AH_{in}: Group 7 (21.8) Group 8 (22.0) WQEC/C 79-114

Table V
Charge Efficiency and Overcharge Data

	SERIAL NUMBER	Charge Efficiency (20°C)						Overcharge Test (0°)						Overcharge Test (35°C)					
		END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE		
		CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)
Group 2	001	1.373			4.7			1.486			13.7			1.418			16.0		
	002	1.372			4.4			1.482			13.9			1.417			16.1		
	003	1.373		4	4.8		4	1.481		36	13.7		15	1.417		17	16.0		5
	004	1.373		5	4.7		5	1.481		43	13.9		19	1.416		19	16.1		7
	005	1.373	.001	11	4.7	.000	11	1.480	.372	37	13.7	.079	13	1.417	.282	19	16.0	.002	12
	006	1.372	.025	9	4.5	.005	9	1.485	.303	28	14.2	.156	12	1.415	.297	14	16.2	.079	10
Group 3	001	1.373			4.0			1.494			14.7			1.420			16.0		
	002	1.372		6	4.3		6	1.494		52	14.5		17	1.416		33	15.8		8
	003	1.373		10	4.1		10	1.492		41	14.7		17	1.417		32	16.0		12
	004	1.373			4.3			1.493			14.6			1.417			15.8		
	005	1.373	.001	1	4.2	−.027	1	1.492	.386	40	14.6	.124	8	1.417	.544	28	15.7	.013	2
Group 5	001	1.375		0	4.5		0	1.505		32	14.9		10	1.398		29	13.4		0
	002	1.375			4.1			1.508			14.8			1.397			13.1		
	003	1.375		5	4.1		5	1.503		40	14.8		18	1.404		38	15.0		7
	004	1.375			4.0			1.509			15.1			1.400			13.8		
	005	1.376	.032	8	4.1	.007	8	1.502	.142	43	14.6	.031	20	1.410	.525	33	15.6	.024	10
	006	1.375	.080	4	4.0	.015	4	1.509	.343	31	14.8	.115	10	1.400	.602	35	13.9	.124	5
Group 6	001	1.374			4.2			1.497			14.9			1.416			16.1		
	002	1.374		6	4.2		6	1.499		83	15.0		33	1.415		25	15.9		7
	003	1.374		12	4.4		12	1.496		80	14.6		33	1.415		35	15.9		14
	004	1.374			4.4			1.498			14.2			1.415			15.8		
	005	1.374	.004	3	4.3	.002	3	1.495	.239	65	14.9	.054	25	1.415	.339	20	16.1	.009	6
	006	1.374	.063	2	4.2	.035	2	1.496	.484	49	15.2	.152	14	1.415	.491	15	16.1	.065	4
Group 9	001	1.377		8	2.9		8	1.492		42	9.6		24	1.397		27	9.3		11
	002	1.378		16	3.1		16	1.494		49	10.2		28	1.398		26	9.6		13
	003	1.376			3.1			1.497			10.4			1.397			9.3		
	004	1.377			3.1			1.495			10.6			1.393			9.5		
	005	1.377			3.1			1.492			10.4			1.393			9.3		

Table VI
Pressure vs. Capacity Test Data

Serial No.	001	004	005	006	001	004	005	006	001	002	005	006	002	004	005	006
Start-of-Charge, Press.	1	2	4	10	10	12	13	8	19	20	9	18	7	14	15	19
AH in to 5 PSIA	18.4	18.3	17.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cell (volts)	1.520	1.505	1.476													
Aux (volts)			.297													
AH in to 10 PSIA	18.9	18.7	18.4	N/A	N/A	N/A	N/A	15.8	N/A		20.2	N/A	20.5	N/A	N/A	N/A
Cell (volts)	1.540	1.528	1.520					1.489			1.521		1.526			
Aux (volts)			.592					.309			.067					
AH in to 15 PSIA	19.1	19.0	18.6	19.0	16.0	16.4	15.6	16.3	N/A		N/A	N/A	21.0	20.3	N/A	N/A
Cell (volts)	1.545	1.536	1.530	1.534	1.498	1.514	1.479	1.517					1.546	1.513		
Aux (volts)			.631	.505			.364	.379								
AH in to 20 PSIA	19.5	19.3	19.1	19.3	16.7	16.9	16.3	16.4	18.6		N/A	20.2	N/A	21.2	21.2	19.0
Cell (volts)	1.548	1.543	1.545	1.542	1.528	1.530	1.520	1.522	1.469			1.492		1.549	1.539	1.473
Aux (volts)			.681	.572			.582	.401				2.68			.307	.090
AH in to V/L (1.55V)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		20.9	N/A	21.2	N/A	N/A	N/A
Aux (volts)											.165					
Press (PSIA)											14		19			
30 Min OCV, Cell	1.415	1.419	1.412	1.420	1.415	1.415	1.415	1.416	1.383		1.386	1.382	1.387	1.386	1.385	1.384
Aux (volts)			.506	5.37			.482	.488			.077	.266			.143	.076
Press (PSIA)	27	24	26	27	N/A	N/A	N/A	N/A	N/A		20	20	22	23	22	20
1 hour OCV, Cell	N/A	1.409	N/A	1.411	1.403	1.403	1.400	1.403	1.378		1.380	1.378	1.379		1.378	1.378
Aux (volts)				.526			.468	.321			.055	.261			.086	.077
Press (PSIA)		21		27	24	22	21	23	21		14	20	22	23	22	20
EOD AH out	15.9	15.5	15.4	15.3	13.6	13.6	13.6	13 6	15.3		17.2	16.5	17.6	17.6	17.6	15.3
Aux (volts)			.111	.224			.007	.114			.003	.087			.003	.031
Press (PSIA)	3	3	6	13	12	13	14	6	20		13	18	19	21	20	20

N/A-Not Applicable Group 1 Group 4 Group 7 Group 8

N/A-Not Applicable

Table VI
Pressure vs. Capacity Test Data

Serial No.	003	004	005	006	002	003	005	001	003	005	006	002	003	005	006
Start-of-Charge, Press.	4	5	1	5	1	4	4	0	5	6	4	5	4	2	3
AH in to 5 PSIA	15.0	N/A	18.4	N/A	18.1	16.7	17.4	19.6	N/A	N/A	17.4	N/A	15.7	18.2	18.2
Cell (volts)	1.441		1.499		1.507	1.459	1.477	1.532			1.465		1.444	1.492	1.492
Aux (volts)			.237				.163				.183			.137	.370
AH in to 10 PSIA	18.1	17.9	19.1	18.1	18.6	18.4	18.4	19.7	18.8	18.8	19.1	18.4	18.2	18.6	18.6
Cell (volts)	1.496	1.484	1.514	1.495	1.529	1.514	1.520	1.536	1.508	1.518	1.519	1.510	1.495	1.515	1.514
Aux (volts)			.325	.279			.321			.498	.402			.197	.428
AH in to 15 PSIA	18.8	18.8	19.5	18.8	18.8	18.8	18.8	20.1	19.3	19.3	19.6	18.9	18.9	18.9	18.9
Cell (volts)	1.516	1.512	1.515	1.513	1.536	1.533	1.536	1.545	1.530	1.539	1.540	1.526	1.522	1.522	1.520
Aux (volts)			.378	.354			.488			.578	.458			.223	.456
AH in to 20 PSIA	19.3	19.3	19.9	19.5	19.1	19.1	19.1	20.3	19.7	19.6	19.9	19.1	19.1	19.1	19.2
Cell (volts)	1.518	1.518	1.514	1.519	1.540	1.538	1.540	1.548	1.540	1.545	1.545	1.530	1.527	1.526	1.523
Aux (volts)			.411	.387			.547			.601	.504			.253	.526
AH in to V/L (1.55V)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aux (volts)															
Press (PSIA)															
30 Min OCV, Cell	1.411	1.411	1.408	1.412	1.415	1.415	1.413	1.406	1.406	1.407	1.406	1.418	1.417	1.416	1.417
Aux (volts)			.384	.328			.493			.340	.435			.286	.463
Press (PSIA)	23	22	18	19	26	26	26	24	27	24	23	26	27	23	21
1 hour OCV, Cell	1.402	1.401	1.401	1.403	1.407	1.406	1.405	1.397	1.396	1.397	1.396	1.408	1.406	1.405	1.407
Aux (volts)			.342	.304			.467			.278	.408			.267	.470
Press (PSIA)	21	20	13	16	25	26	24	21	24	22	21	25	25	21	17
EOD AH out	15.6	15.6	15.6	15.6	15.7	15.7	15.7	16.1	15.9	15.9	15.9	15.8	15.8	15.8	15.8
Aux (volts)															
Press (PSIA)	8	8	2	7	4	8	7	0	7	8	5	8	7	4	4
			Group 2			Group 3				Group 5				Group 6	

N/A-Not Applicable

Table VI
Pressure vs. Capacity Test Data

Serial No.	004	005														
Start-of-Charge, Press.	8	9														
AH in to 5 PSIA	N/A	N/A														
Cell (volts)																
Aux (volts)																
AH in to 10 PSIA	12.0	12.2														
Cell (volts)	1.469	1.457														
Aux (volts)	N/A	N/A														
AH in to 15 PSIA	13.0	13.2														
Cell (volts)	1.482	1.478														
Aux (volts)																
AH in to 20 PSIA	13.5	13.7														
Cell (volts)	1.491	1.478														
Aux (volts)																
AH in to V/L (1.55V)	N/A	N/A														
Aux (volts)																
Press (PSIA)																
30 Min OCV, Cell	1.379	1.380														
Aux (volts)																
Press (PSIA)	23	22														
1 hour OCV, Cell	1.370	1.370														
Aux (volts)																
Press (PSIA)	21	21														
EOD AH out	10.1	10.3														
Aux (volts)																
Press (PSIA)	11	13														

Group 9

N/A-Not Applicable

Table VII

Group 1
9ND-NADC (SP 11/73)

Special Resistance Characteristic Data on the Auxiliary Electrodes

SERIAL NO	005		006		POWER - 005		POWER - 006				AVERAGE	
OHMS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	MILLIWATTS
10,000	.928	19	.891	16	.086		.079					
5,000	.916	18	.804	16	.168		.129					
2,000	.895	18	.762	16	.401		.290					
1,000	.870	18	.717	17	.757		.514					
500	.840	18	.568	18	1.411		.645					
200	.785	18	.426	18	3.081		.907					
100	.732	18	.311	17	5.358		.967					
50	.676	17	.211	17	9.140		.890					
20	.571	17	.122	16	16.302		.744					
10	.479	17	.079	17	27.944		.624					
5	.381	17	.038	16	29.032		.288					
2	.238	16	.017	16	28.322		.144					
1	.168	16	.008	17	28.22		.064					
0.5	.111	14	.003	16	24.642		.018					
0.2	.079	14	.001	16	31.205		.005					
0.1	.066	14	.001	17	43.560		.010					

Note: All pressures in PSIA.

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$$\text{POWER} = \frac{V^2}{R} \text{ Watts } 10^3 \frac{\text{Milliwatts}}{\text{Watt}} : \text{Milliwatts}$$

Table VII

Group 4 Special Resistance Characteristic Data on the Auxiliary Electrodes (Cont)

9ND-NADC (SP 11/73)

SERIAL NO	005		006		POWER - 005		POWER - 006				AVERAGE	
OHMS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	MILLIWATTS
10,000	.907	20	.739		.082		.055					
5,000	.896	20	.670		.161		.089					
2,000	.874	20	.543		.381		.147					
1,000	.845	20	.420		.714		.176					
500	.814	20	.280		1.325		.157					
200	.755	20	.131		2.850		.086					
100	.703	20	.074		4.942		.055					
50	.648	19	.049		8.398		.048					
20	.544	19	.027		14.797		.036					
10	.449	19	.017		20.160		.029					
5	.347	19	.011		24.082		.024					
2	.705	19	.009		21.013		.040					
1	.142	18	.005		20.164		.025					
0.5	.082	18	.002		13.448		.008					
0.2	.049	18	.001		12.005		.005					
0.1	.037	17	.001		13.690		.010					

Note: All pressures in PSIA.

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$$\text{POWER} = \frac{V^2}{R} \text{ Watts} \quad 10^3 \frac{\text{Milliwatts}}{\text{Watt}} : \text{Milliwatts}$$

Table VII

Group 7 Special Resistance Characteristic Data on the Auxiliary Electrodes (Cont)

9ND-NADC (SP 11/73)

SERIAL NO	005		006		POWER - 005		POWER - 006				AVERAGE	
OHMS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	MILLIWATTS
10,000	.884	19	.817	25	.078		.067					
5,000	.871	19	.815	25	.152		.133					
2,000	.845	19	.814	25	.357		.331					
1,000	.811	19	.802	25	.658		.643					
500	.767	19	.754	25	1.177		1.137					
200	.697	19	.646	25	2.429		2.087					
100	.634	19	.544	25	4.019		2.96					
50	.559	19	.420	25	6.250		3.53					
20	.430	19	.252	25	9.25		3.18					
10	.323	19	.116	25	10.43		1.35					
5	.221	19	.090	25	9.77		1.62					
2	.117	19	.042	25	6.84		.882					
1	.070	19	.024	25	[illegible]		.576					
0.5	.043	19	.014	25	3.69		.392					
0.2	.025	19	.008	25	3.13		.320					
0.1	.019	19	.006	25	3.61		.360					

Note: All pressures in PSIA.

WQEC/C 79-114

$$\text{POWER} = \frac{V^2}{R} \text{ Watts} \quad 10^3 \frac{\text{Milliwatts}}{\text{Watt}} : \text{Milliwatts}$$

Table VII

Group 8 Special Resistance Characteristic Data on the Auxiliary Electrodes (Cont)

9ND-NADC (SP 11/73)

SERIAL NO.	005		006		POWER - 005		POWER - 006				AVERAGE	
OHMS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	MILLIWATTS
10,000	.889	22	.821	24	.079		.067					
5,000	.876	22	.759	24	.153		.115					
2,000	.849	22	.654	24	.360		.214					
1,000	.815	22	.523	24	.664		.274					
500	.771	22	.380	24	1.189		.289					
200	.707	22	.221	24	2.499		.244					
100	.652	22	.149	24	4.251		.222					
50	.588	22	.091	24	6.915		.166					
20	.482	22	.049	24	11.616		.120					
10	.385	22	.029	24	14.823		.084					
5	.283	22	.012	24	16.018		.029					
2	.163	21	.006	24	13.285		.018					
1	.103	21	.005	24	10.609		.025					
0.5	.066	20	.003	24	8.712		.048					
0.2	.040	20	.000	24	8.000		.000					
0.1	.031	19	.000	24	9.61		.000					

Note: All pressures in PSIA.

WQEC/C 79-114

$$\text{POWER} = \frac{V^2}{R} \text{ Watts} \quad 10^3 \frac{\text{Milliwatts}}{\text{Watt}} \cdot \text{Milliwats}$$

Appendix 3

Initial Evaluation Test-Summary Data Sheets-EOL

Table I
Measurement and Leak Test Data

	SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)			WIDTH (Inches)	PHENOLPHTHALEIN LEAK TESTS								
								INITIAL			POST HI VAC			POST TEST		
				EDGE	CENTER* (Pre-Test)	CENTER** (Post-Test)		Terminals		Other	Terminals		Other	Terminals		Other
								+	−		+	−		+	−	
Group 1	003				.899	.974										
	005				.898	.914										
Group 2	006				.893	.909										
	002				898	.999										
Group 3	003				.902	.891										
	006				.898	.894										Press Fitting
	002				.904	.904										
Group 4	003				.896	.899										
	004				.904	.985										
	005				.905	.898										
Group 6	003				.895	.930										
	004				.893	.894										
	005				.890	.890										
	006				.895	.891										
Group 7	003				.902	.894										
	004				.903	.887										
	005				.898	.895										
	006				.897	.877										
Group 8	001				.911	.910										
	002				.915	.928										
	003				.922	.990										
Group 9	003				.919	.995										
	004				.911	.928										
	002				.924	.919										
	004				.731	.785										
	005				.922	.969										

*–Followed Initial Evaluation Tests **—Followed Post Evaluation Tests

Table II
Capacity Data

	SERIAL NUMBER	Capacity Test 1—CHG. C/20. 48 hrs., (RA)						Capacity Test 2—CHG. C/10. 24 hrs., (RA)						Capacity Test 3 (20°C)—CHG. C/10 24 hrs.,					
		END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE		
		CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)
Group 1	003	1.452			10.7			1.462			10.6			1.484			10.4		
	005	1.449	.348	34	10.7	.008	20	1.460	.401	54	10.6	.023	18	1.481	.352	55	10.4	.024	21
	006	1.449	.501	35	10.7	.105	25	1.461	.608	52	10.6	.114	25	1.482	.553	53	10.4	.120	25
Group 2	002	1.434			8.7			1.452			9.7			1.459			9.7		
	003	1.443		40	10.8		19	1.448		59	10.7		23	1.[illegible]2		61	10.5		28
	006	1.437	.326	32	10.9	.080	20	1.440	.361	44	10.9	.069	23	1.451	.355	49	10.8	.053	24
Group 3	002	1.436		48	11.2		13	1.451		80	11.3		17	1.469		83	11.0		21
	003	1.438		46	11.3		19	1.450		77	11.4		25	1.467		78	11.0		28
	004	1.436			11.7			1.450			11.9			1.468			11.7		
	005	1.436	.210	37	11.9	.016	18	1.450	.288	58	12.2	.012	20	1.466	.219	60	12.0	.013	22
Group 4	003	1.441			10.1			1.456			10.2			1.478			10.1		
	004	1.401		28	9.8		21	1.452		35	10.0		22	1.474		36	9.9		22
	005	1.444	.158	38	9.8	.023	24	1.457	.207	50	9.8	.026	25	1.478	174	52	9.7	.024	26
	006	1.438	.343	27	9.9		16	1.454	.387	33	10.2		18	1.476	.352	34	10.1	.013	18
Group 6	003	1.420		5	5.8		5	1.442		6	5.7		6	1.397		6	3.1		6
	004	1.445			10.7			1.455			11.2			1.473			9.9		
	005	1.445	.023	32	9.2	.013	14	1.459	.050	36	9.1	.029	13	1.476	.040	31	8.2	.020	13
	006	1.432	.330	11	7.3	.107	5	1.433	.285	7	7.0	.058	5	1.442	.237	4	6.2	.005	4
Group 7	001	1.428		18	9.5		18	1.520*		25	11.3		24	1.520**		23	10.8		22
	002	1.422		24	12.8		24	1.520*		23	12.5		23	1.521**		22	11.8		22
Group 8	003	1.423			8.9			1.521*			10.7			1.521**			10.4		
	003	1.500			13.6			1.523*			12.8			1.521**			11.9		
Group 9	004	1.440		24	12.9		24	1.521*		20	12.3		20	1.523**		19	11.4		19
	002	1.432		21	10.3		19	1.520*		19	9.7		18	1.521**		18	8.9		18
	004	1.456			11.0			1.470			11.2			1.487			11.1		
	005	1.456			10.5			1.468			10.6			1.483			10.4		

9ND-NADC (SP 11/73)

*AH_{in} to 1.520 Volts: Grp 7, S/N 001 (17.1 AH), S/N 002 (16.8 AH), S/N 003 (17.5 AH); Grp 8, S/N 003 (17.5 AH), S/N 004 (17.0 AH); Grp 9, S/N 002 (13.5 AH)

**AH_{in} to 1.520 Volts: Grp 7, S/N 001 (14.7 AH), S/N 002 (15.3 AH), S/N 003 (14.3 AH); Grp 8, S/N 003 (15.2 AH), S/N 004 (14.6 AH); Grp 9, S/N 002 (11.4 AH)

Table III
Internal Resistance and Short Test Data

	SERIAL NUMBER	INTERNAL RESISTANCE (MILLIONS)			INTERNAL SHORT TEST		
		END-OF-CHARGE	ONE HOUR AFTER START-OF-DISCHARGE	TWO HOURS AFTER START-OF-DISCHARGE	AFTER 16 HR SHORT	AFTER 24 HOUR OCV STAND	
					CELL	CELL	PRESS
GROUP 1	003	3.1	3.2	N/A	.019	1.168	
	005	3.2	3.3	N/A	.017	.017	17
	006	3.0	3.2	N/A	.023	1.175	22
GROUP 2	002	3.4	3.0	N/A	.000	.000	
	003	3.7	3.0	N/A	.000	.000	16
	006	2.9	2.6	N/A	.000	.000	20
GROUP 3	002	2.8	2.9	N/A	.015	1.190	13
	003	2.9	2.9	N/A	.013	1.186	18
	004	3.1	3.2	N/A	.013	1.178	
	005	2.7	3.2	3.4	.010	1.177	17
GROUP 4	003	3.0	3.1	N/A	.012	1.187	
	004	3.3	3.4	N/A	.016	1.179	19
	005	3.6	3.7	N/A	.014	1.187	22
	006	2.9	3.0	N/A	.012	1.180	16
GROUP 6	003	3.1	8.5	N/A	.008	.055	6
	004	6.1	5.0	N/A	.008	.012	
	005	4.0	5.6	N/A	.033	1.193	3
	006	5.2	5.6	N/A	.011	1.170	3
GROUP 7	001	3.3	3.1	N/A	.011	1.194	19
	002	3.2	3.1	4.0	.012	1.206	21
GROUP 8	003	3.0	3.1	N/A	.011	1.191	
	003	3.3	3.3	3.8	.003	.004	
	004	4.0	3.3	3.8	.005	.007	18
GROUP 9	002	2.8	3.0	N/A	.015	1.200	17
	004	3.0	2.9	N/A	.012	1.206	
	005	2.9	2.8	N/A	.013	1.207	

N/A - Not applicable - cells did not last 2.0 hrs. on discharge. (9N-NADC (SP 11/73)

Table IV
Charge Retention Test Data

	SERIAL NUMBER	END-OF-CHARGE			24 HR. OCV			1 WEEK OCV			END-OF-DISCHARGE		
		CELL (Volts)	AUX. ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX. ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX. ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX. ELECT (Volts)	PRESS (PSIA)
GROUP 1	003	1.477			1.364			1.300			8.9		
	005	1.475	.372	53	1.367	.010	19	1.303	.000	18	9.1	−.045	18
	006	1.476	.574	53	1.369	.011	24	1.305	.007	23	9.1	−.035	22
GROUP 2	002	1.449			1.269			0.000			0.0		
	003	1.452		58	1.302		18	1.254		16	4.0		16
	006	1.445	.341	45	1.309	.020	22	1.275	.008	21	6.8	−.014	21
GROUP 3	002	1.466		80	1.361		15	1.300		14	9.5		14
	003	1.464		75	1.358		20	1.290		19	9.0		19
	004	1.465			1.359			1.297			9.8		
	005	1.465	.224	56	1.360	.005	19	1.299	.000	19	10.0	−.012	18
GROUP 4	003	1.471			1.360			1.299			8.6		
	004	1.469		36	1.350		21	1.290		20	7.9		19
	005	1.472	.184	51	1.364	.004	23	1.297	.000	23	8.4	−.002	22
	006	1.470	.351	34	1.353	.004	16	1.287	.001	16	8.1	−.059	16
GROUP 6	003	1.413		6	1.254		6	1.080		6	0.0		6
	004	1.466			1.315			1.280			6.1		
	005	1.472	.025	23	1.347	.012	4	1.298	.001	3	7.1	.002	3
	006	1.424	.169	3	1.288	.011	3	1.264	.002	3	3.7	−.043	3
GROUP 7	001	1.521*		22	1.345		23	1.302		21	8.7		20
	002	1.521*		22	1.348		22	1.308		22	10.2		22
	003	1.520*			1.341			1.295			7.6		
	*AH_{in} to 1.520 volts: S/N 001 (14.45), S/N 002 (14.92 AH), S/N 003 (14.04 AH)												
GROUP 8	003	1.521*			1.356			1.313			9.8		
	004	1.522*		18	1.339		18	1.295		18	8.5		18
	*AH_{in} to 1.520 volts; S/N 003 (14.99 AH), S/N 004 (14.31 AH)												
GROUP 9	002	1.522*		17	1.363		17	1.326		17	8.1		17
	004	1.486			1.369			1.322			9.7		
	005	1.481			1.370			1.326			9.1		

*AH_{in} to 1.520 volts: S/N 002 (11.06 AH)

Table V
Charge Efficiency and Overcharge Data

	SERIAL NUMBER	Charge Efficiency—CHG. C/40, 20 hrs., 20°C						Overcharge Test 1—CHG. C/20, 60 hrs., 0°C						Overcharge Test 2—CHG. C/10, 24 hrs., 35°C					
		END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-CHARGE		
		CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)
Group 1	003	1.371			2.8			1.514			9.6			1.439			10.6		
	005	1.373	.002	17	2.8	−.001	17	1.508	.192	37	9.7	−.020	20	1.436	.441	45	10.6	.017	21
	006	1.371	.014	22	2.8	−.018	22	1.509	.333	40	9.6	.110	26	1.438	.665	47	10.6	.088	26
Group 2	002	.007			0.0			.013			0.0			1.422			8.5		
	003	.014		16	0.0		16	1.433		15	5.3		15	1.408		32	10.4		21
	006	.015	.002	20	0.0	.002	20	.033	.000	19	0.0	.000	19	1.401	.255	28	10.8	.045	23
Group 3	002	1.376		13	3.7		13	1.498		66	10.5		29	1.425		74	11.6		20
	003	1.375		18	3.7		18	1.496		61	10.4		34	1.424		68	11.6		25
	004	1.373			3.8			1.497			11.0			1.425			12.2		
	005	1.374	.001	17	4.0	.000	17	1.4[illegible]	.089	50	11.2	.014	27	1.423	.421	47	12.3	.002	22
Group 4	003	1.385			3.8			1.519			9.4			1.436			10.6		
	004	1.386		19	3.6		19	1.510		31	9.1		22	1.432		30	10.3		24
	005	1.385	.001	23	3.6	.000	23	1.508	.096	41	9.1	.017	28	1.437	.259	38	10.3	.024	25
	006	1.384	.012	16	3.8	−.013	16	1.510	.274	29	9.4	.082	18	1.432	.356	28	10.6	.049	19
Group 6	003	1.399		6	3.3		6	1.510		6	5.9		6	1.412		7	7.3		7
	004	1.394			3.3			1.496			5.1			1.367			3.5		
	005	1.379	.002	3	3.7	−.003	3	1.514	.014	15	6.8	.003	9	1.426	.031	16	10.0	.011	6
	006	1.382	.014	3	3.3	−.062	3	1.500	.203	4	5.7	.013	4	1.369	.205	3	6.0	.021	3
Group 7	001	1.376		19	3.7		19	1.598*		38	9.1		36	1.418		35	12.1		33
	002	1.372		21	3.4		21	1.612*		52	9.4		48	1.404		35	12.5		32
Group 8	003	1.379			3.7			1.597*			8.9			1.415			11.7		
	003	1.388			4.0			1.603*			9.7			1.402			12.5		
	004	1.381		18	4.0		18	1.613*		42	9.5		41	1.379		37	11.7		34
Group 9	002	1.386		17	3.5		17	1.638*		41	7.4		20	1.520**		20	9.1		19
	004	1.384			3.4			1.507			10.1			1.450			11.3		
	005	1.380			3.4			1.505			9.4			1.447			10.8		

9ND-NADC (SP 11/73)

*—Removed from charge because of high voltage (AH_{in}): Group 7, S/N 001 (14.1), S/N 002 (14.4), S/N 003 (13.8); Group 8, S/N 003 (14.7), S/N 004 (14.2); Group 9, S/N 002 (11.5)

**—Removed from charge because of high voltage after 12.5 AH_{in}

Table VI

Pressure vs. Capacity Test Data

Serial No.	005	006		003	006		002	003	005		004	005	006			
Start-of-Charge, Press.	6	10		7	9		3	8	8		6	14	8			
AH in to 5 PSIA	N/A	N/A		N/A	N/A		12.3	N/A	N/A		N/A	N/A	N/A			
Cell (volts)							1.489									
Aux (volts)				N/A			N/A	N/A			N/A					
AH in to 10 PSIA	12.1	N/A		11.4	10.7		13.0	12.0	13.0			N/A	10.9			
Cell (volts)	1.537			1.487	1.468		1.520	1.490	1.505				1.509			
Aux (volts)	.339				.145				.264				.343			
AH in to 15 PSIA	12.5			12.1	12.6		13.4	12.7	13.5			9.7				
Cell (volts)	1.557			1.519	1.547		1.538	1.518	1.531			1.472				
Aux (volts)	.392				.387				.341			.098				
AH in to 20 PSIA				12.8			13.5	13.0	13.8			11.4				
Cell (volts)				1.539			1.542	1.527	1.544			1.548				
Aux (volts)									.386			.221				
AH in to V/L (1.55V)	12.5	12.3			12.9		N/A	N/A	N/A		11.4		11.5			
Aux (volts)	.392	.462			.418								.392			
Press (PSIA)	16	14			18						6		13			
30 Min OCV, Cell	1.407	1.406		1.398	1.396		1.402	1.402	1.403		1.396	1.397	1.396			
Aux (volts)	.278	.402			.288				.301			.153	.260			
Press (PSIA)	16	18		21	16		25	21	23		6	19	12			
1 hour OCV, Cell	1.397	1.397		1.385	1.385		1.391	1.391	1.393		1.388	1.389	1.389			
Aux (volts)	.238	.342			.255				.273			.131	.224			
Press (PSIA)	12	18		17	14		19	18	19		6	17	11			
EOD AH out	9.6	9.4		10.0	10.2		10.9	10.6	11.6		9.0	9.0	9.4			
Aux (volts)	−.021	.122			.111				.048			.026	.064			
Press (PSIA)	7	13		10	10		6	11	9		6	15	9			
	Group 1			Group 2			Group 3				Group 4					

N/A-Not Applicable

Table VI
Pressure vs. Capacity Test Data

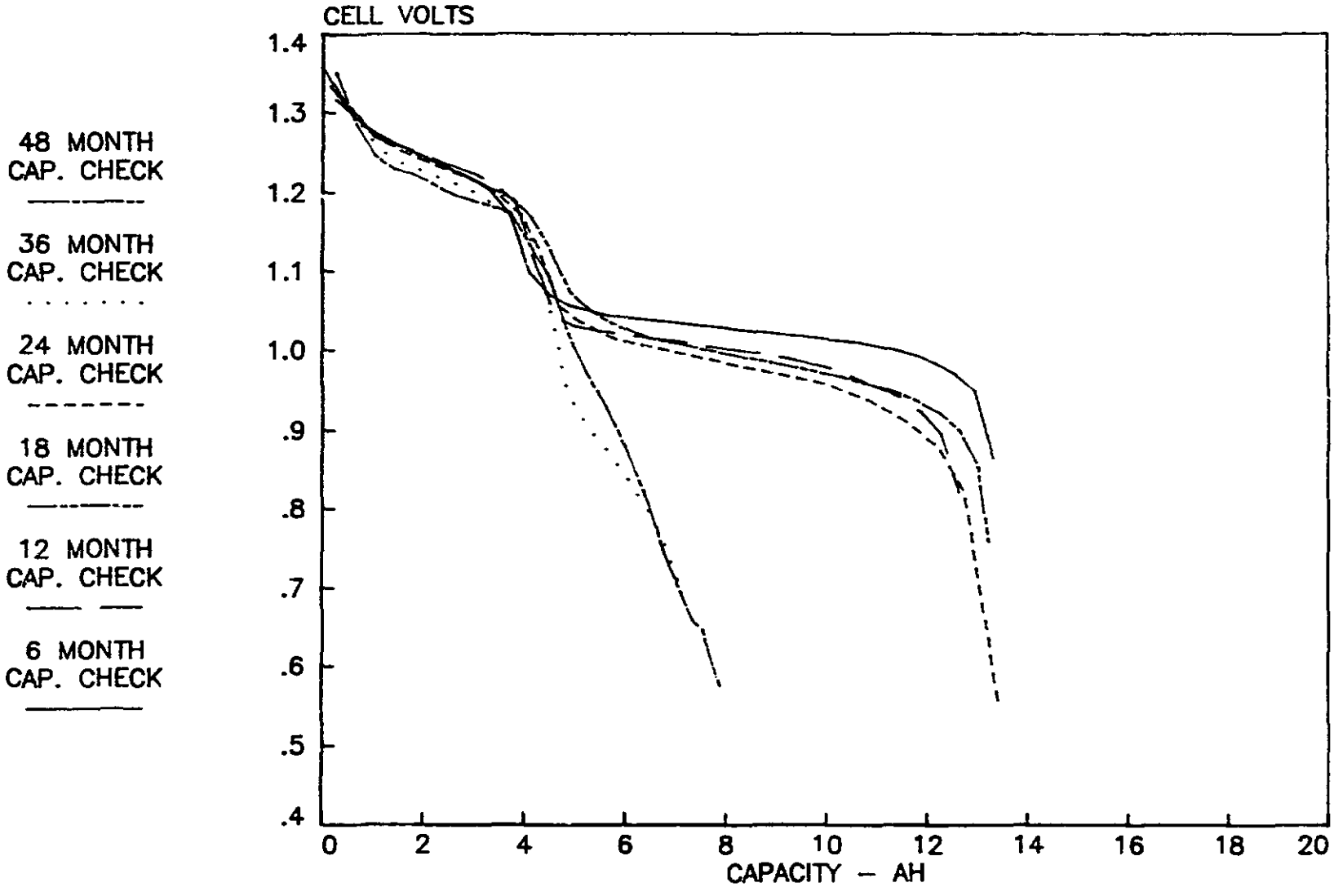
Serial No.	003	005	006		001	002		004		002						
Start-of-Charge, Press.	8	6	4		7	9		8		17						
AH in to 5 PSIA	N/A	N/A	7.6		N/A	N/A		N/A		N/A						
Cell (volts)			1.538													
Aux (volts)	N/A		.203		N/A	N/A		N/A		N/A						
AH in to 10 PSIA		11.4			14.5	13.7				N/A						
Cell (volts)		1.544			1.556	1.515										
Aux (volts)		.204														
AH in to 15 PSIA										N/A						
Cell (volts)																
Aux (volts)																
AH in to 20 PSIA																
Cell (volts)																
Aux (volts)																
AH in to V/L (1.55V)	6.6	11.8	8.5		14.5	14.5		13.7		10.5						
Aux (volts)		.027	.246													
Press (PSIA)	8	14	9		10	10		8		18						
30 Min OCV, Cell	1.367	1.391	1.368		1.400	1.396		1.391		1.391						
Aux (volts)		.018	.122													
Press (PSIA)	8	10	9		10	10		8		18						
1 hour OCV, Cell	1.355	1.381	1.355		1.393	1.388		1.382		1.384						
Aux (volts)		.017	.100													
Press (PSIA)	8	8	9		9	10		8		18						
EOD AH out	4.9	9.1	6.3		11.6	11.7		11.3		8.1						
Aux (volts)		.003	−.080													
Press (PSIA)	8	7	9		8	10		8		18						
	Group 6				Group 7			Group 8		Group 9						

N/A-Not Applicable

Appendix 4

Capacity Checks by Individuals Pack

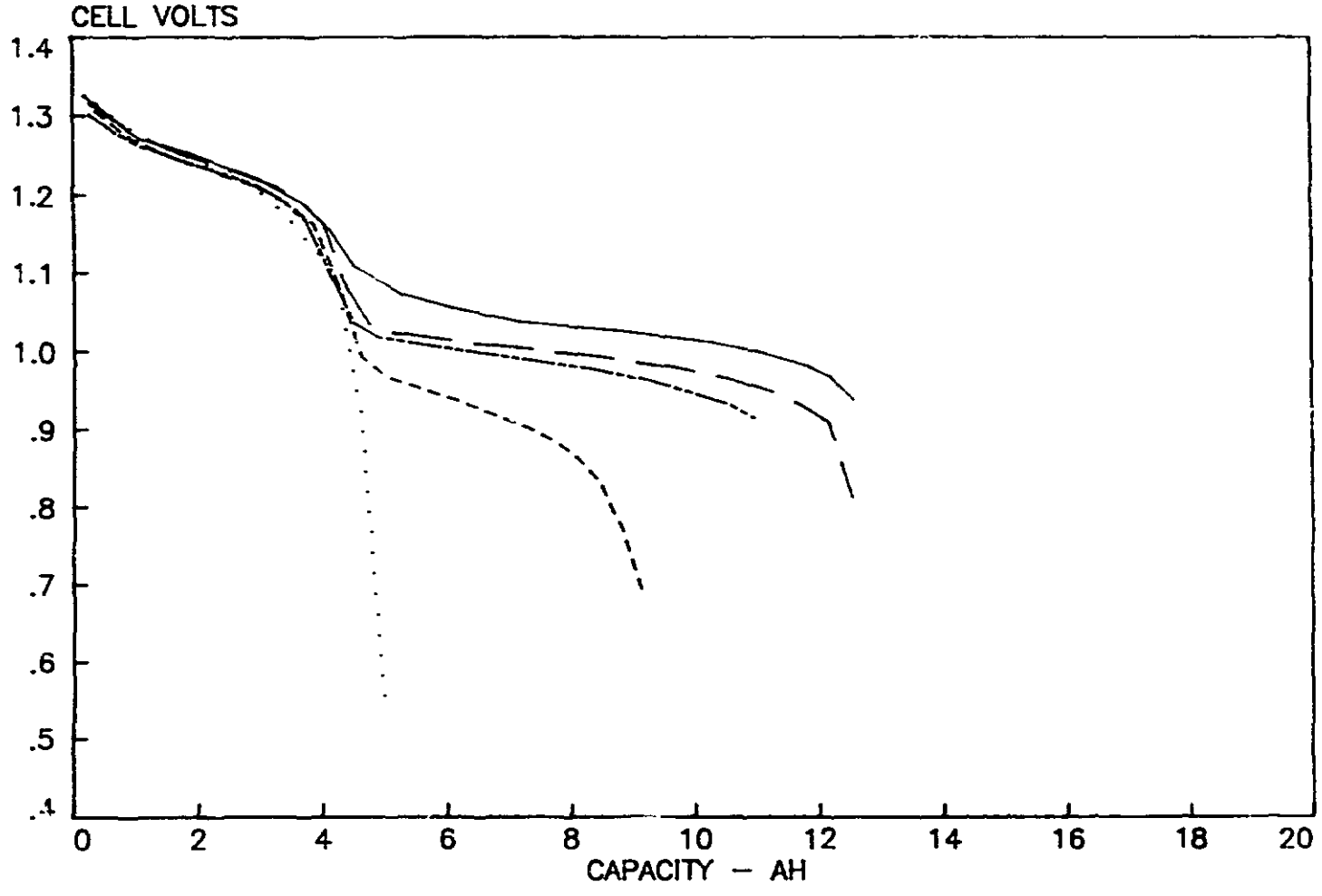
DESIGN VARIABLE PROGRAM – CAP CHECKS BY PACK
CRANE PACK 3D, 40% DOD, 9.6 AMP DIS., 20 C



DESIGN VARIABLE PROGRAM – CAP CHECKS BY PACK

CRANE PACK 3E, 40% DOD, 9.6 AMP DIS., 20C

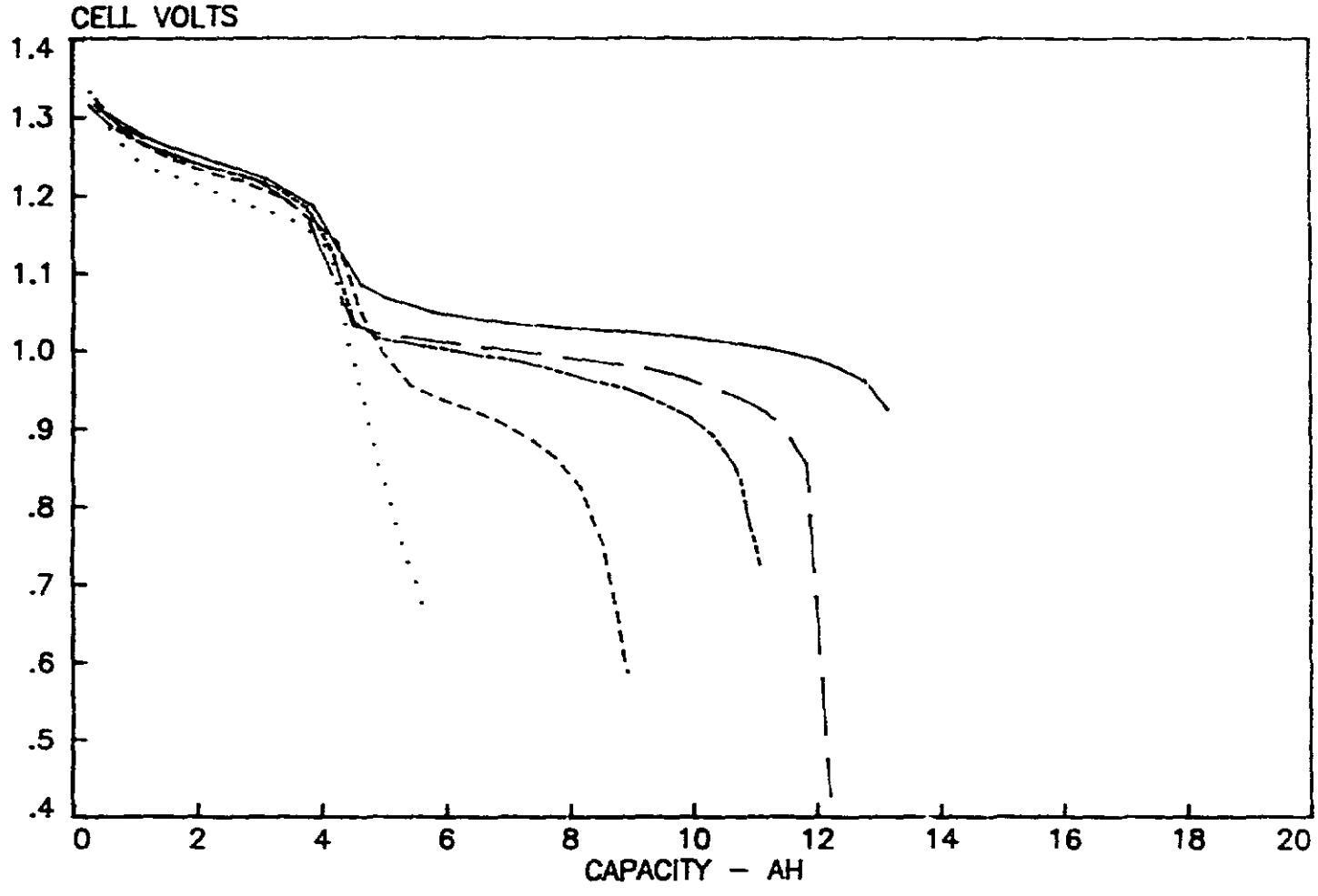
6 MONTH CAP. CHECK ——— 12 MONTH CAP. CHECK — — 18 MONTH CAP. CHECK ———— 24 MONTH CAP. CHECK - - - - - - - 36 MONTH CAP. CHECK . . . . . .



DESIGN VARIABLE PROGRAM – CAP CHECKS BY PACK

CRANE PACK 3F, 40% DOD, 9.6 AMP DIS., 20C

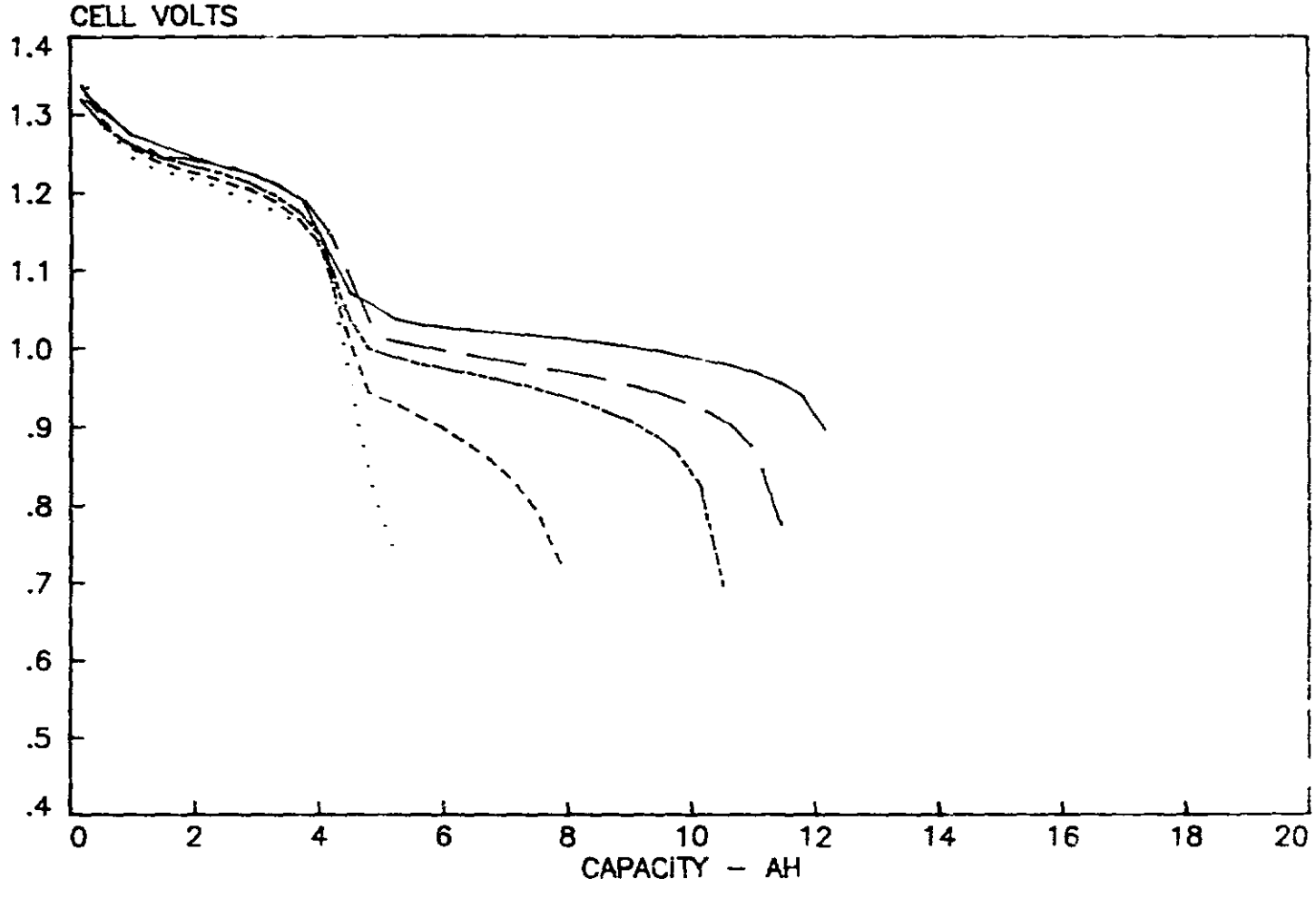
6 MONTH CAP. CHECK ———— 12 MONTH CAP. CHECK — — 18 MONTH CAP. CHECK ———··· 24 MONTH CAP. CHECK - - - - - - - 36 MONTH CAP. CHECK . . . . . .



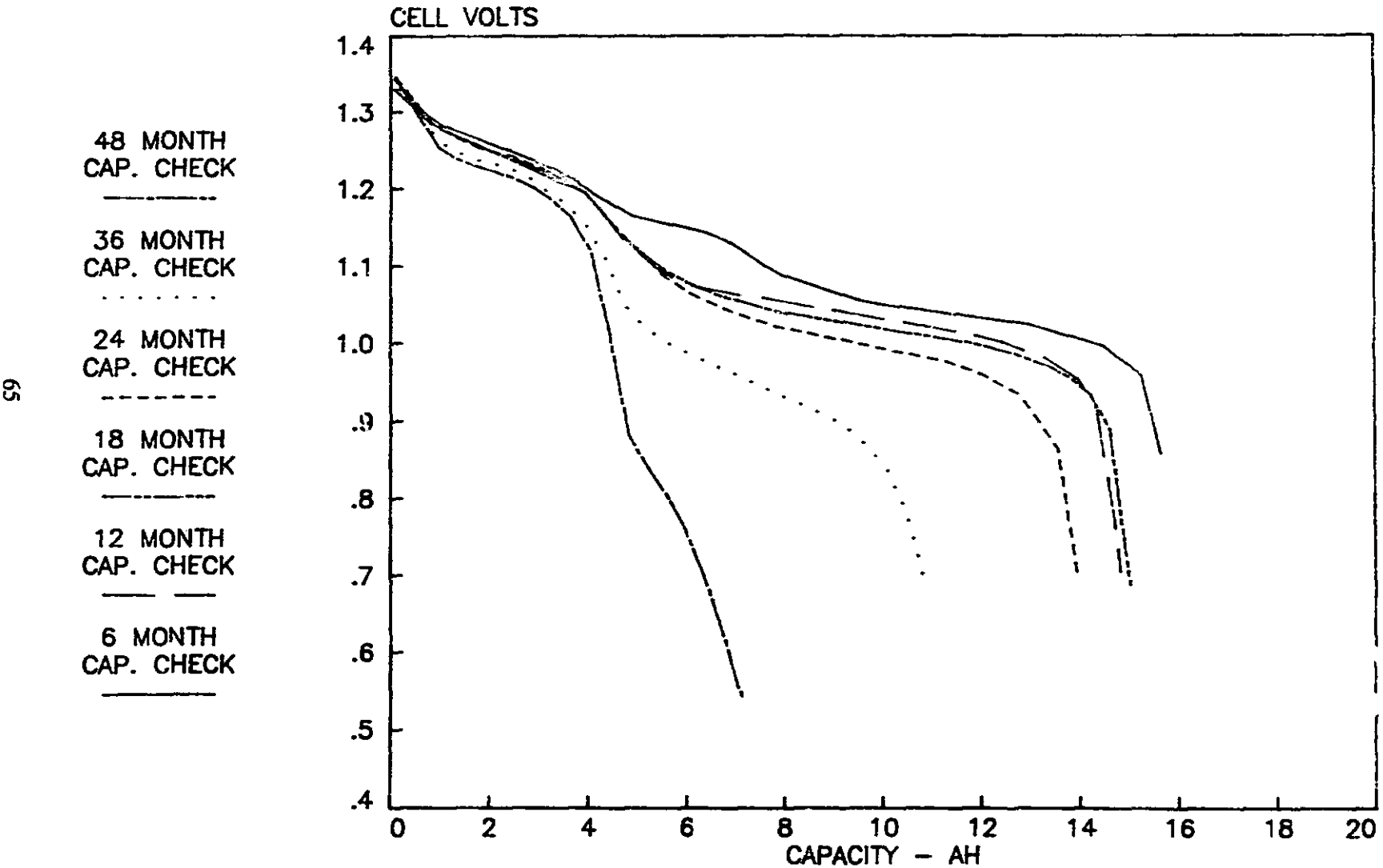
DESIGN VARIABLE PROGRAM – CAP CHECKS BY PACK

CRANE PACK 3G, 40% DOD, 9.6 AMP DIS., 20C

6 MONTH CAP. CHECK ——— 12 MONTH CAP. CHECK — — 18 MONTH CAP. CHECK ———— 24 MONTH CAP. CHECK - - - - - - 36 MONTH CAP. CHECK . . . . . .



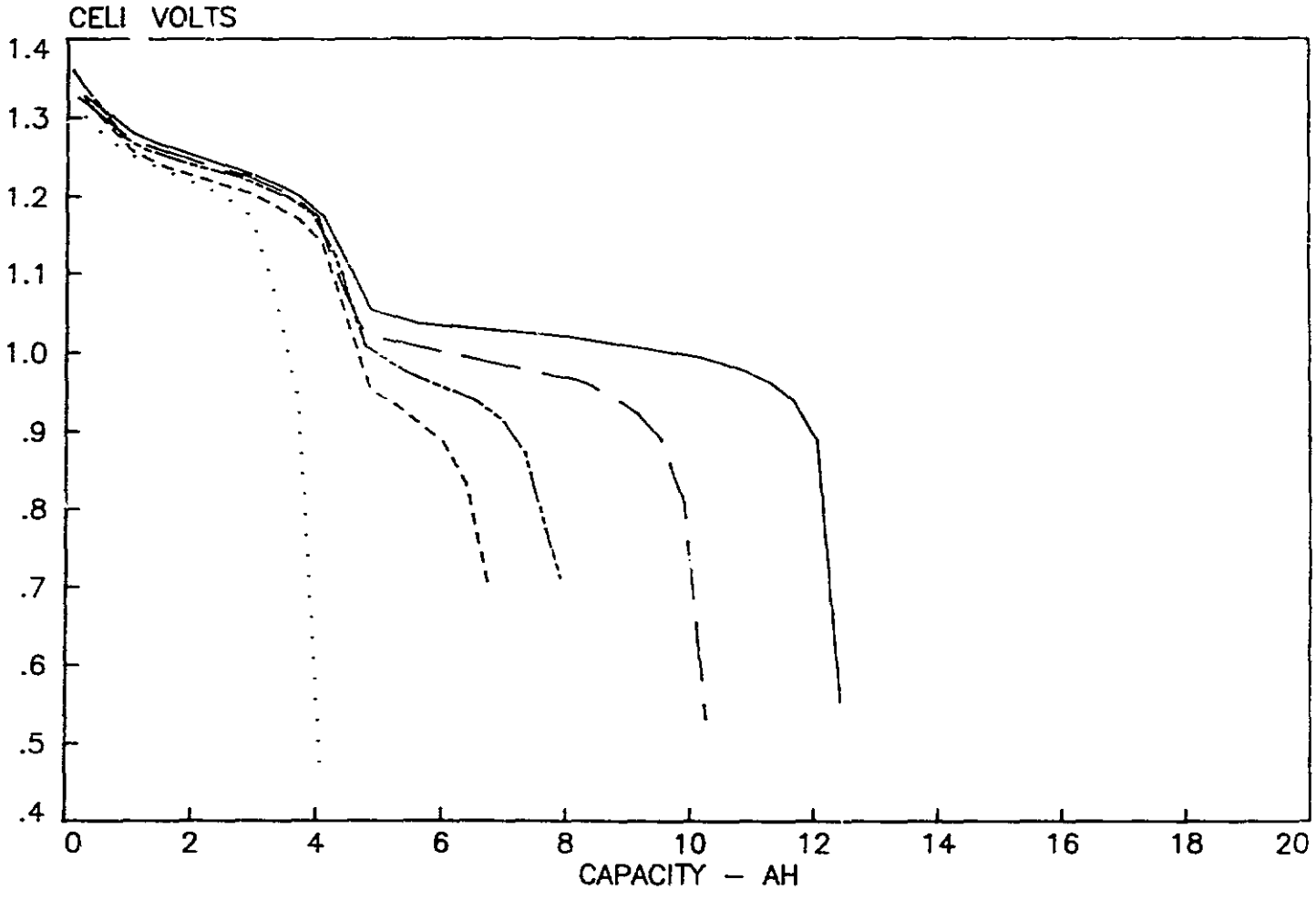
DESIGN VARIABLE PROGRAM – CAP CHECKS BY PACK
CRANE PACK 3H, 40% DOD, 9.6 AMP DIS., 20 C



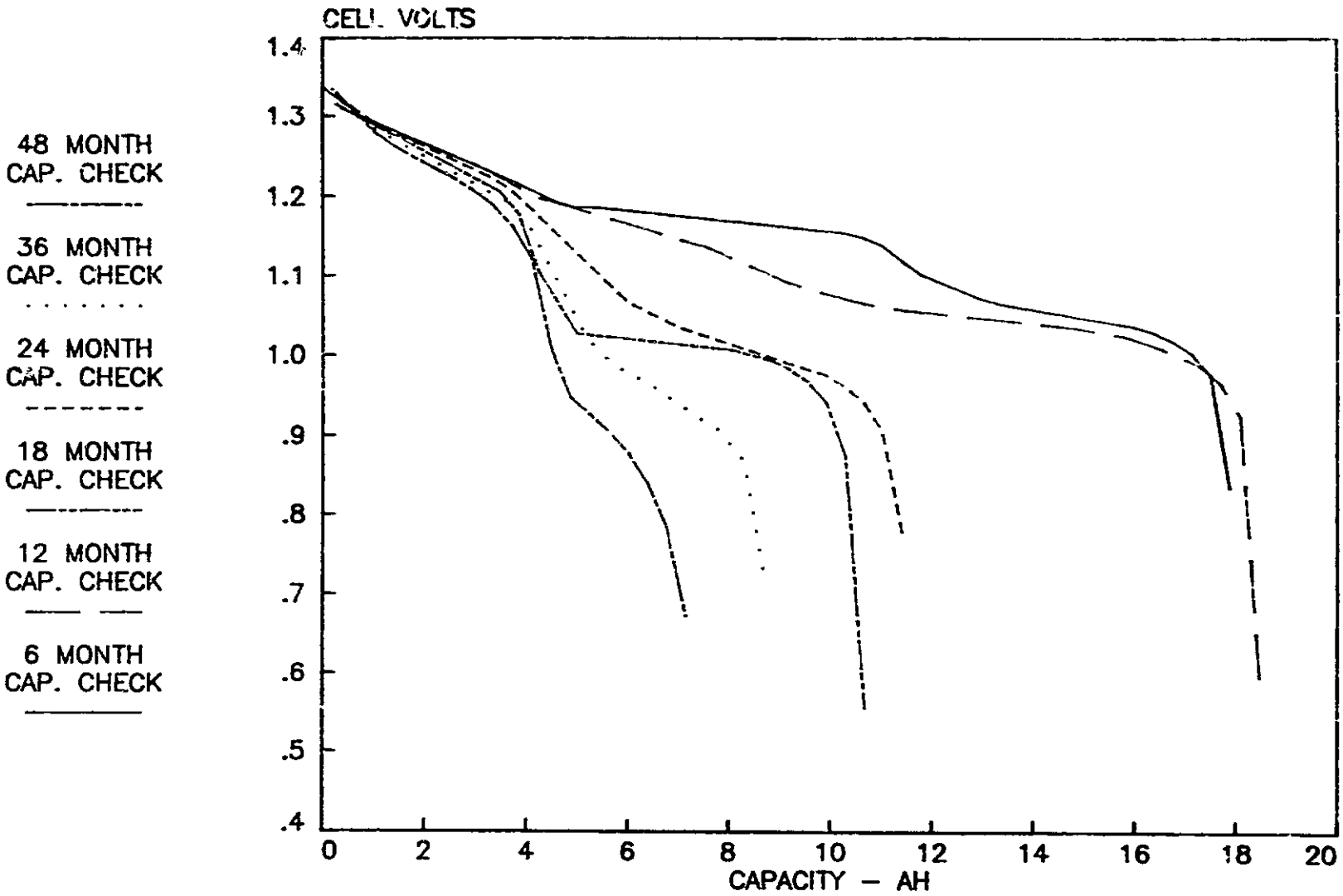
DESIGN VARIABLE PROGRAM – CAP CHECKS BY PACK

CRANE PACK 31, 40% DOD, 9.6 AMP DIS., 20 C

6 MONTH CAP. CHECK ——— 12 MONTH CAP. CHECK — — 18 MONTH CAP. CHECK —·—·— 24 MONTH CAP. CHECK - - - - - - - 36 MONTH CAP. CHECK . . . . . .



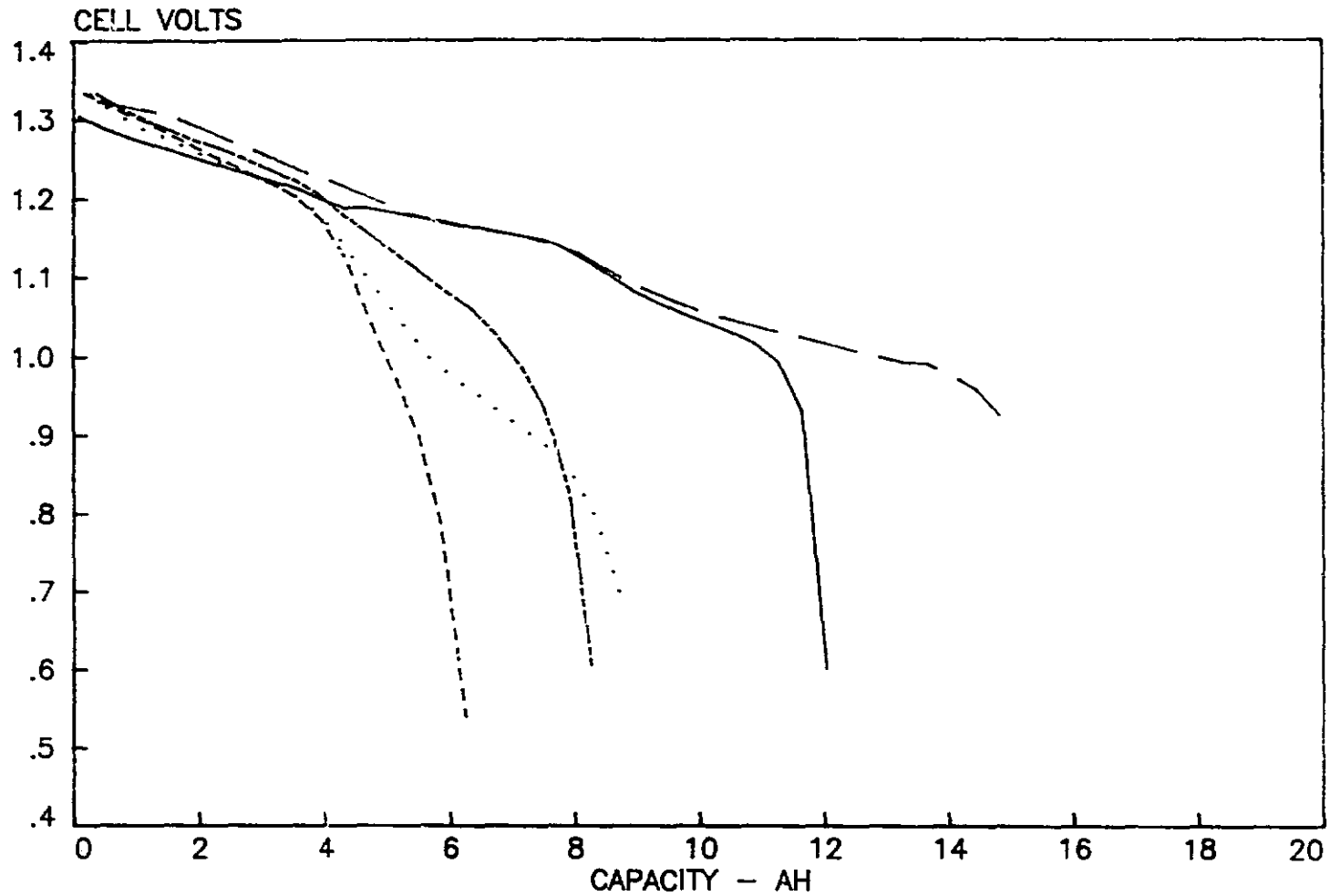
DESIGN VARIABLE PROGRAM – CAP CHECKS BY PACK
CRANE PACK 3J, 40% DOD, 9.6 AMP DIS., 20 C



DESIGN VARIABLE PROGRAM – CAP CHECKS BY PACK

CRANE PACK 3K, 40% DOD, 9.6 AMP DIS., 20 C

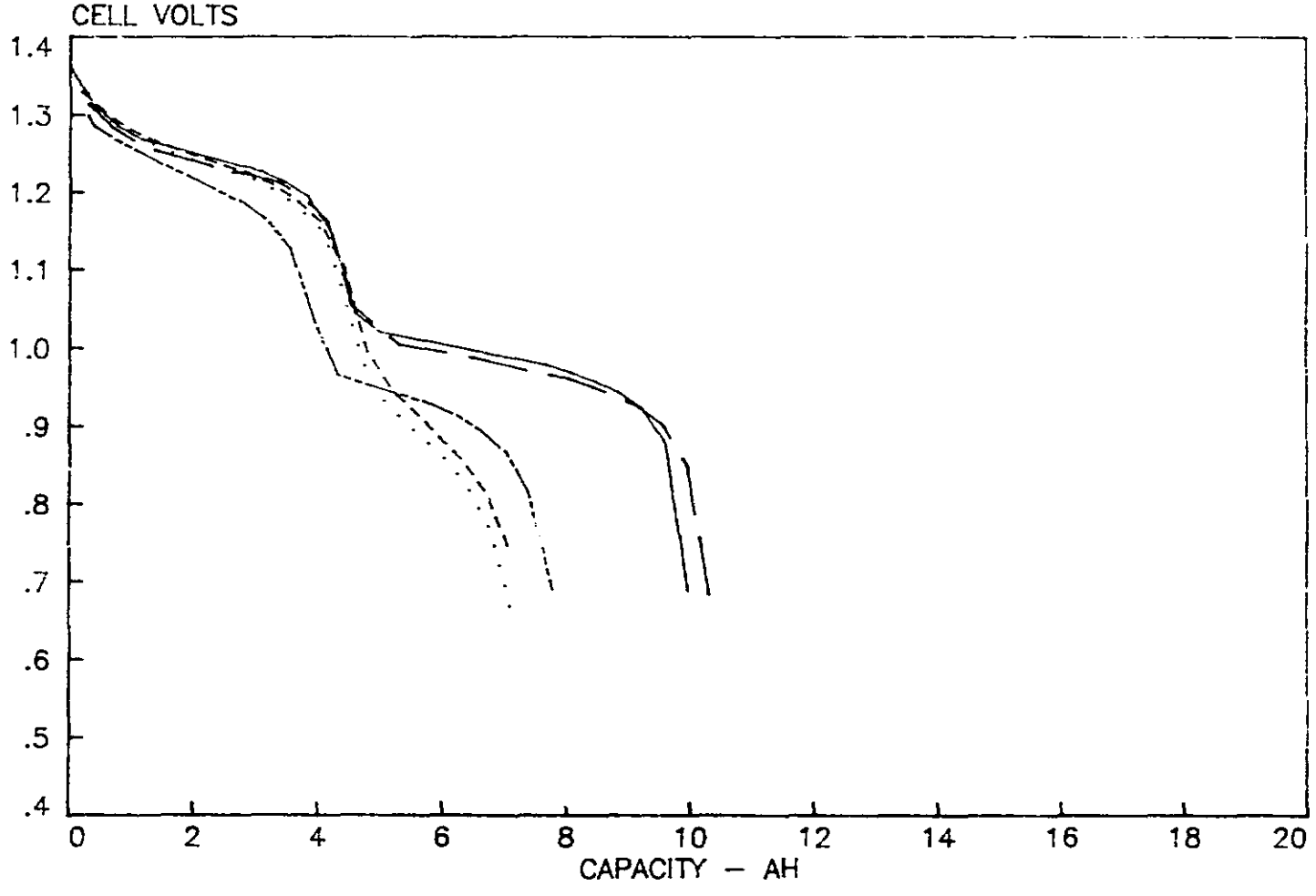
6 MONTH CAP. CHECK ——— 12 MONTH CAP. CHECK — — 18 MONTH CAP. CHECK —·—·— 24 MONTH CAP. CHECK - - - - - - 36 MONTH CAP. CHECK . . . . . .



DESIGN VARIABLE PROGRAM – CAP CHECKS BY PACK

CRANE PACK 3L, 40% DOD, 9.6 AMP DIS., 20 C

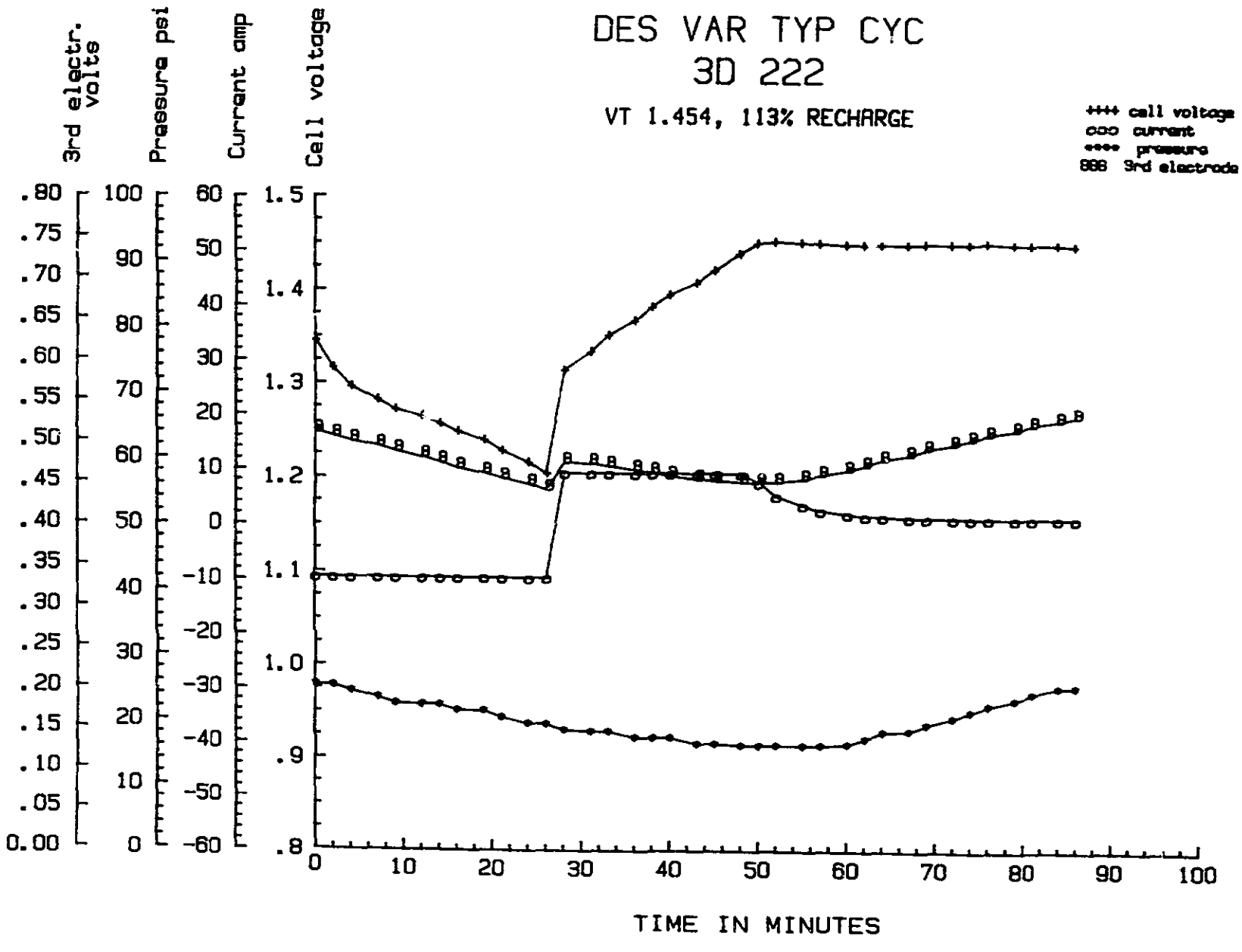
6 MONTH CAP. CHECK ———— 12 MONTH CAP. CHECK — — 18 MONTH CAP. CHECK ·—·—·— 24 MONTH CAP. CHECK - - - - - - - 30 MONTH CAP. CHECK . . . . . .

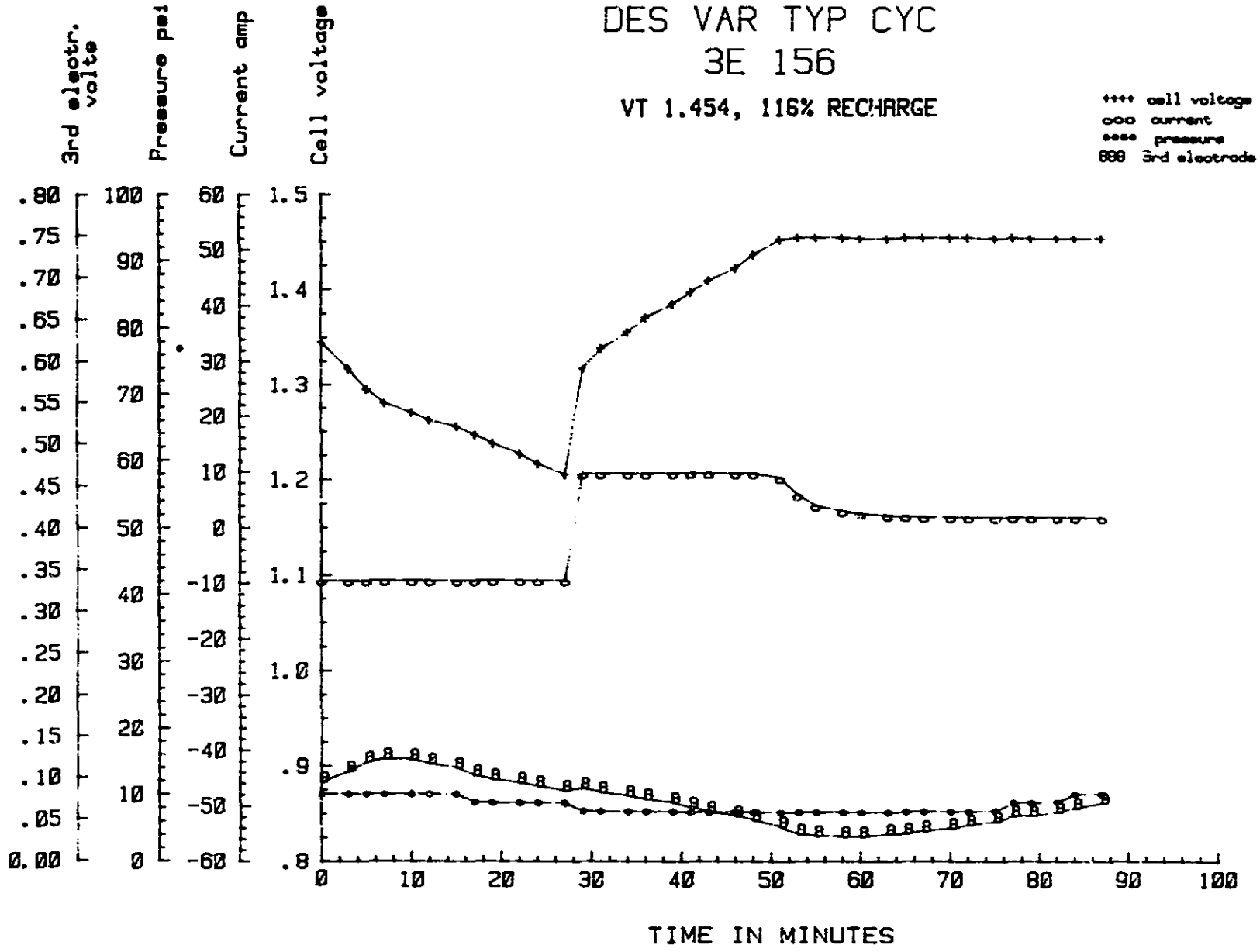


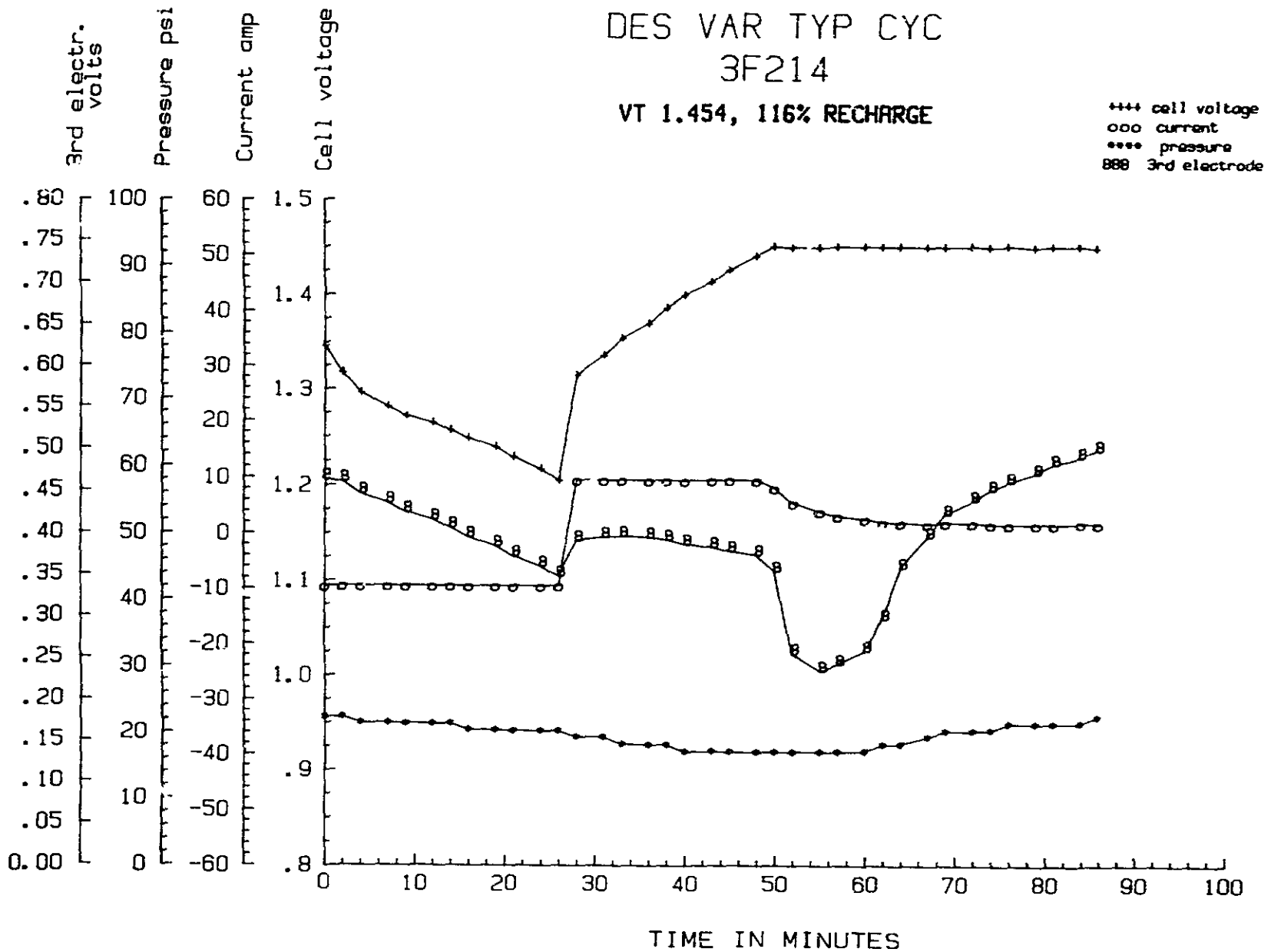
•NO 36 MONTH CHECK•

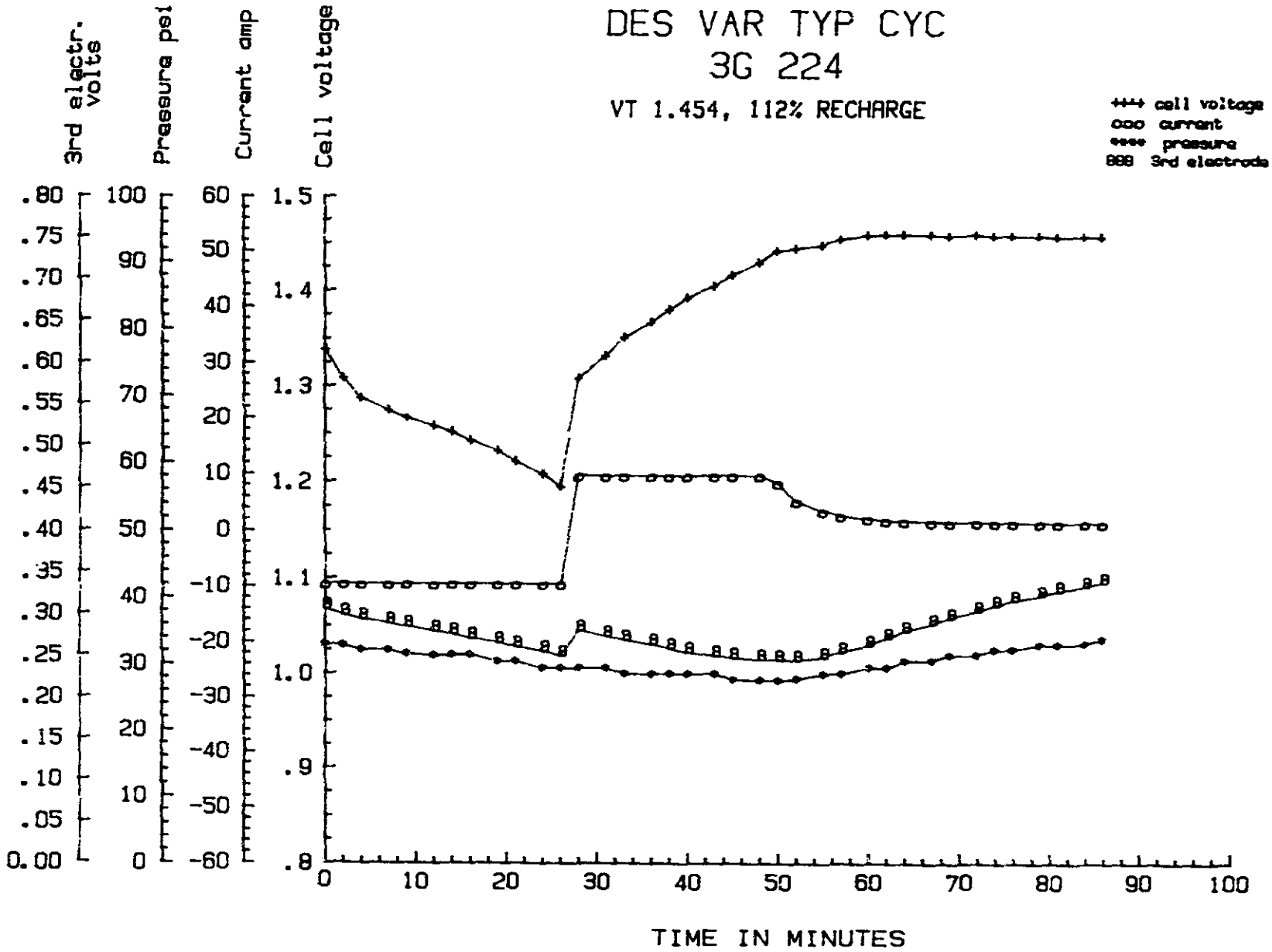
Appendix 5

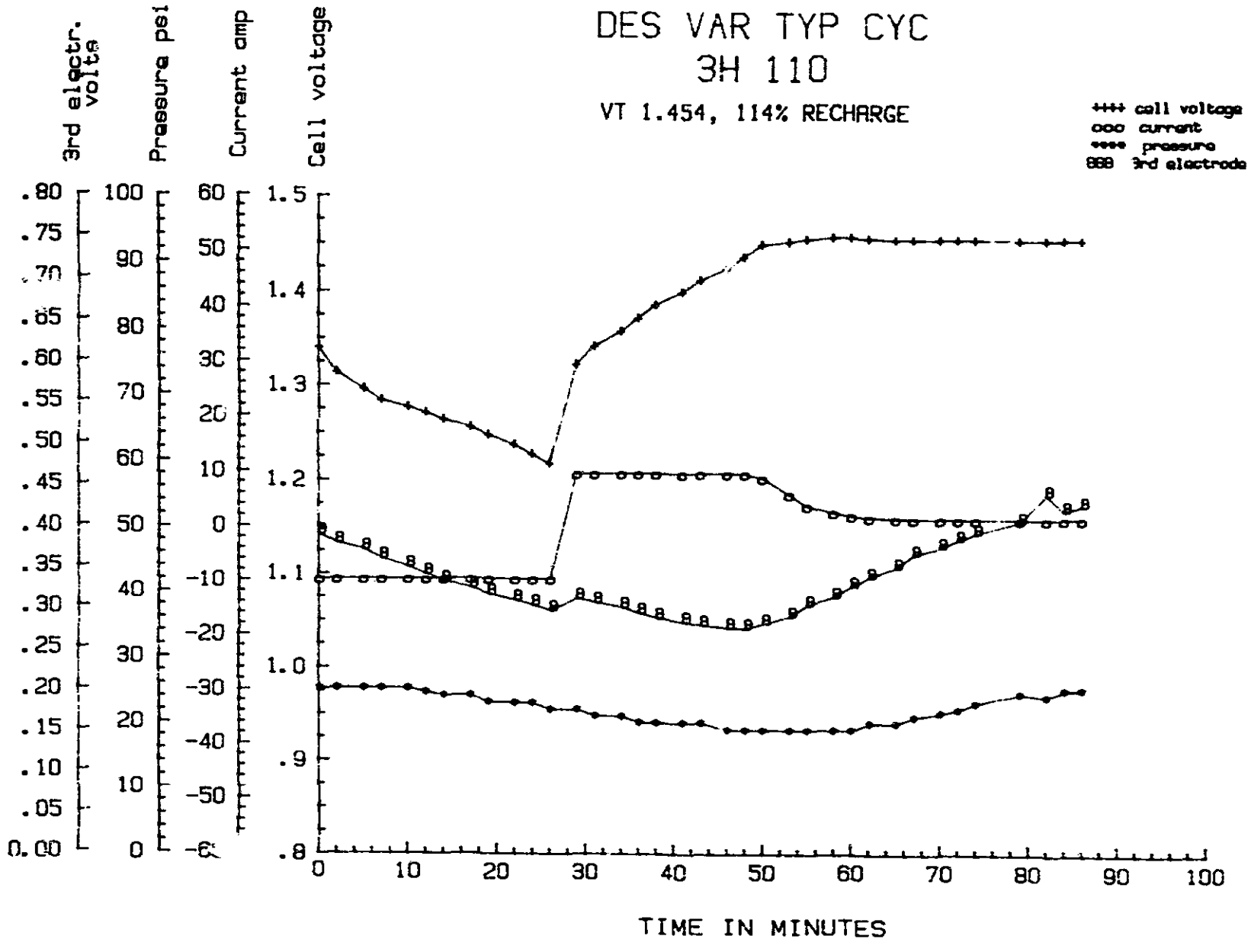
Typical Cycle Plots

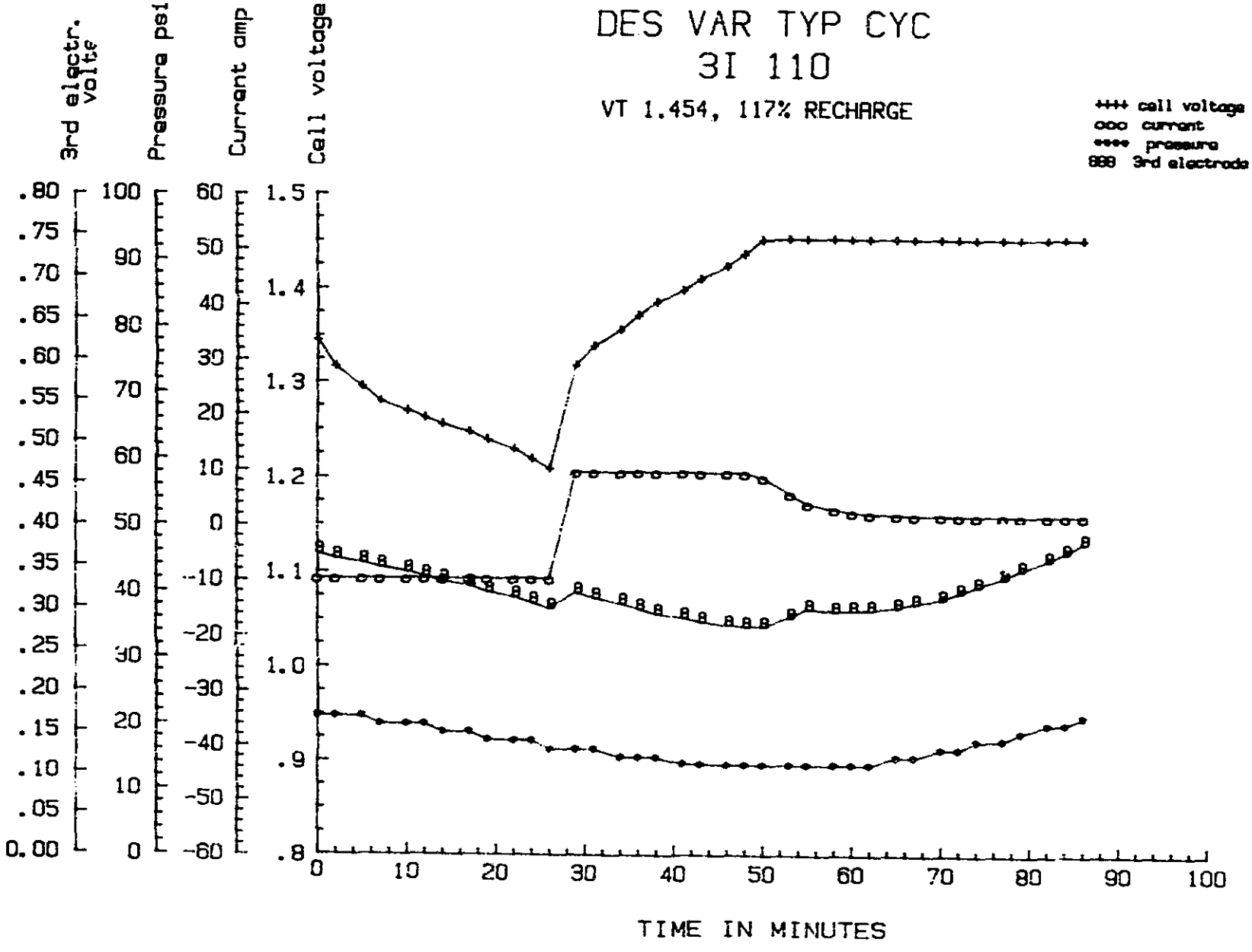

DES VAR TYP CYC
3D 222
VT 1.454, 113% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
.80
.75
.70
.65
.60
.55
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
0.00
100
90
80
70
60
50
40
30
20
10
0
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
0
10
20
30
40
50
60
70
80
90
100
TIME IN MINUTES

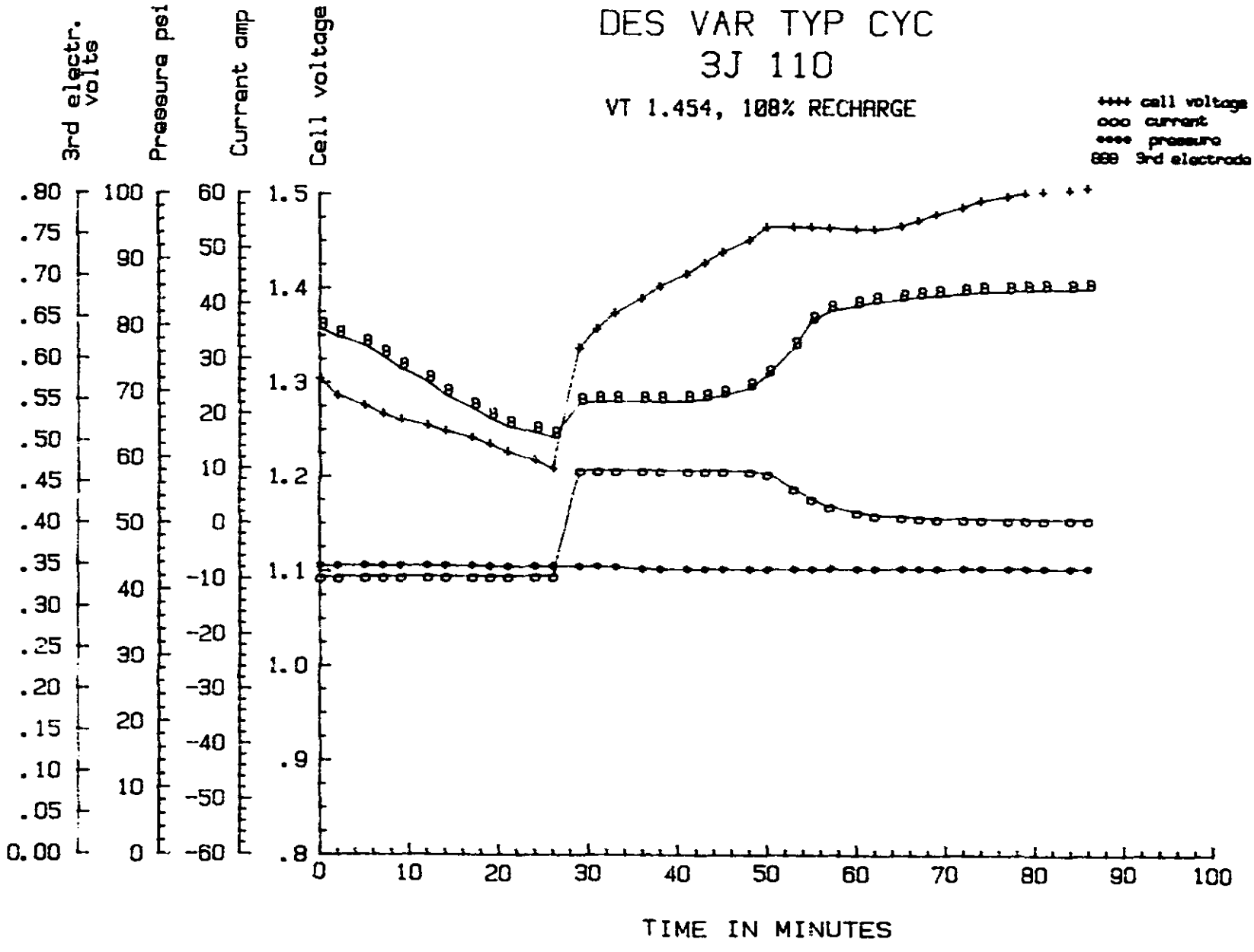

DES VAR TYP CYC
3E 156
VT 1.454, 116% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd elect. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

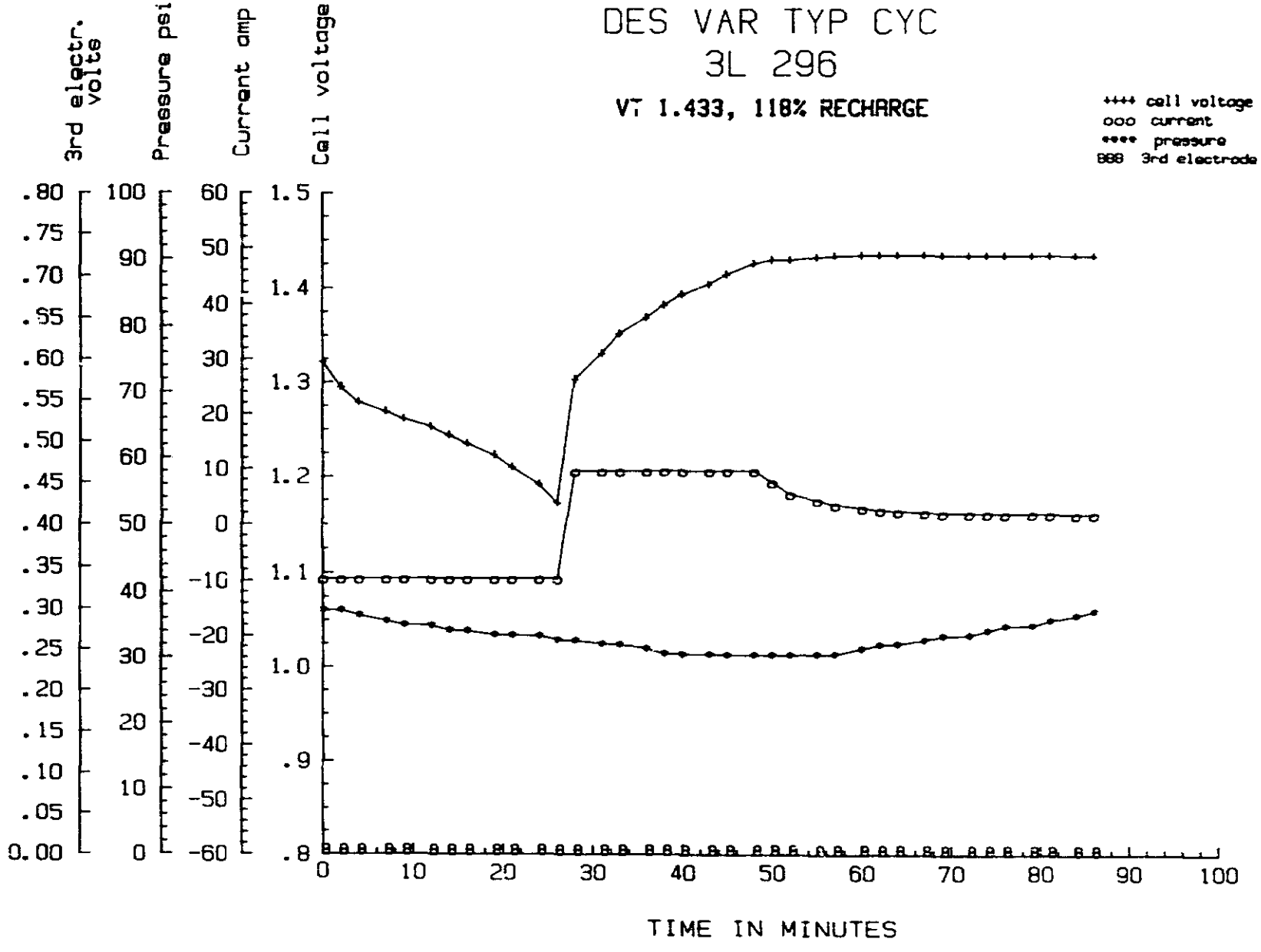

DES VAR TYP CYC
3F214
VT 1.454, 116% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

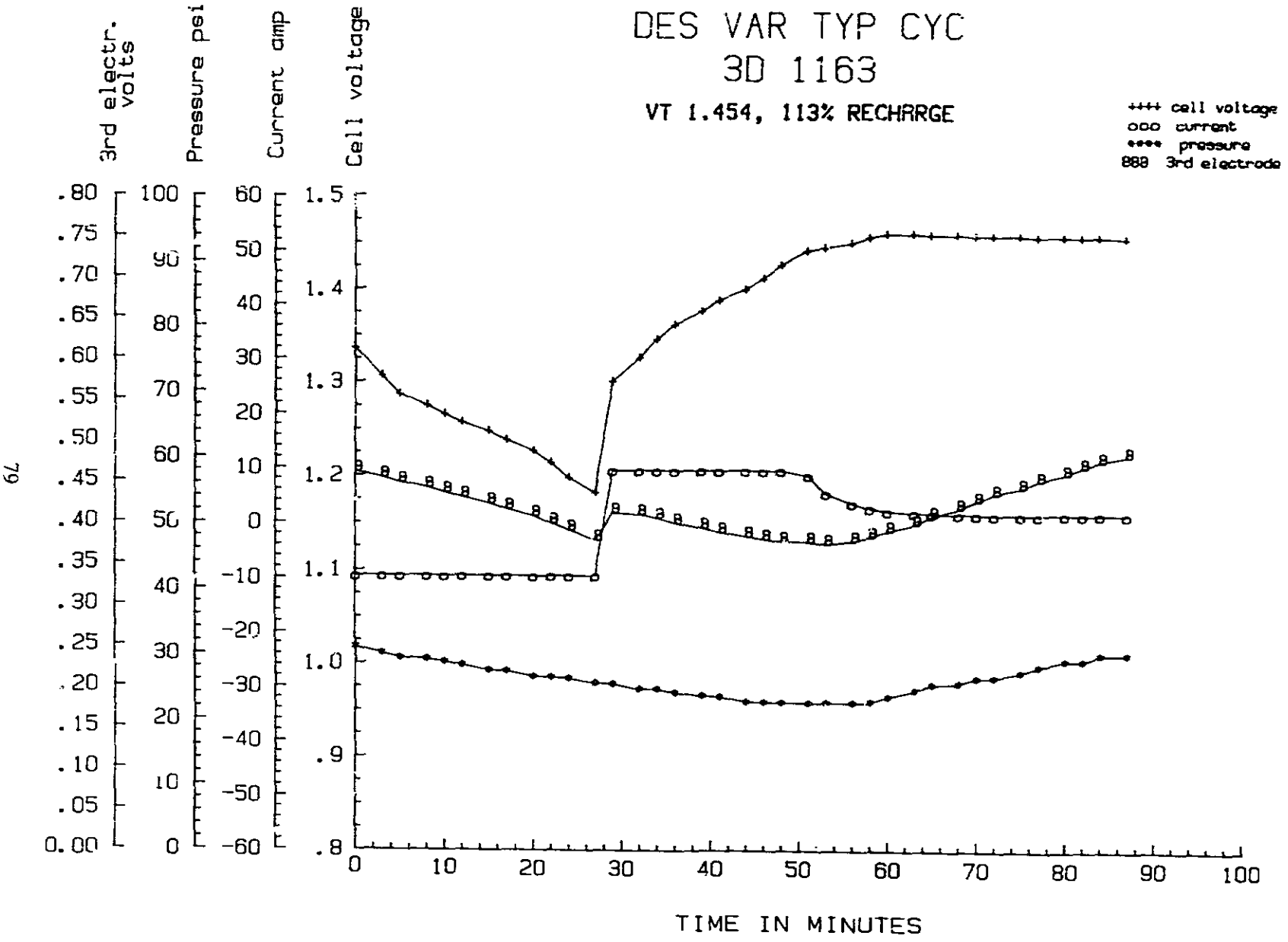

DES VAR TYP CYC
3G 224
VT 1.454, 112% RECHARGE
+++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd elactr. volts
Pressure psi
Current amp
Cell voltage
.80
.75
.70
.65
.60
.55
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
0.00
100
90
80
70
60
50
40
30
20
10
0
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
0
10
20
30
40
50
60
70
80
90
100
TIME IN MINUTES

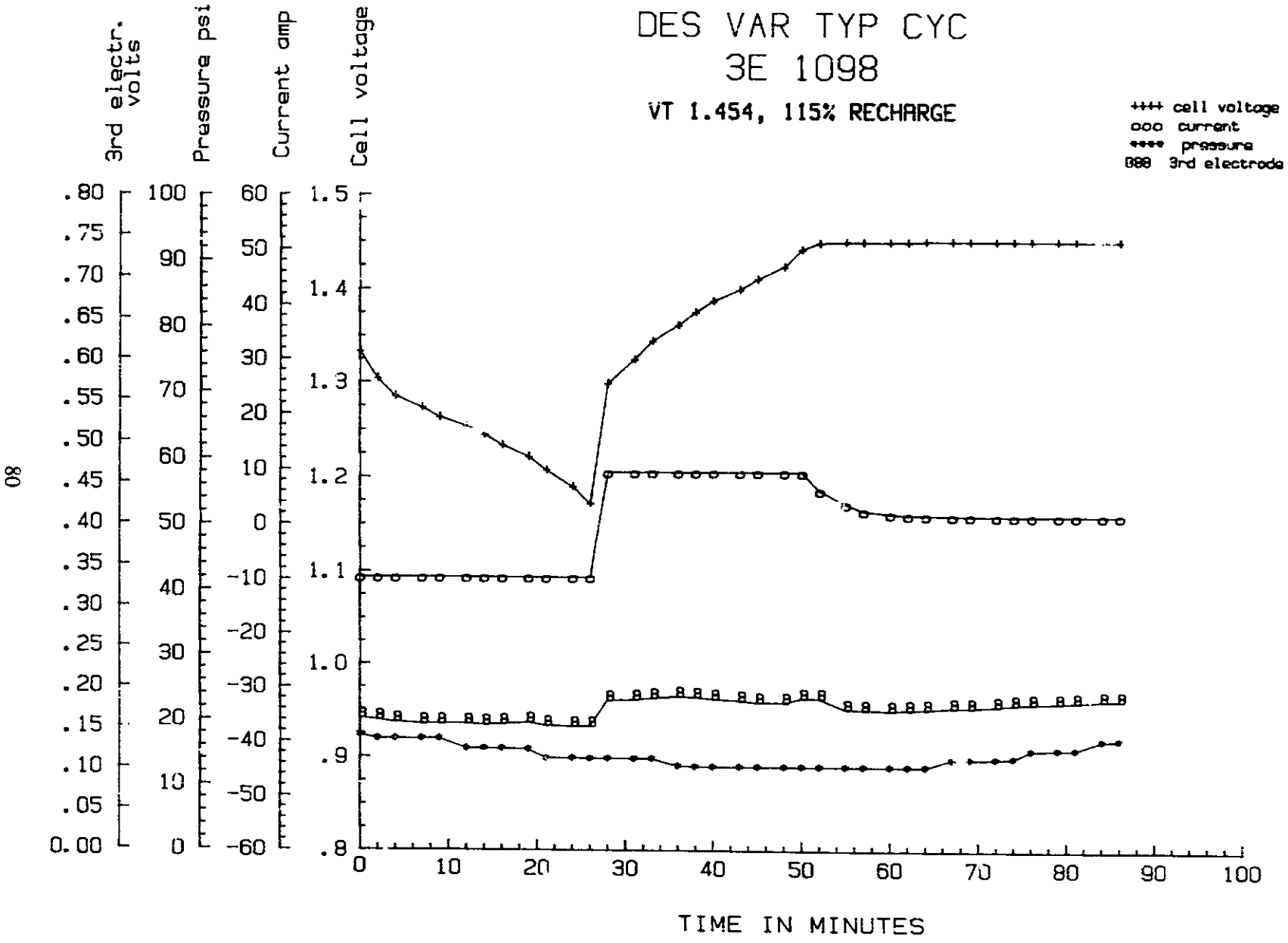

DES VAR TYP CYC
3H 110
VT 1.454, 114% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd elactr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

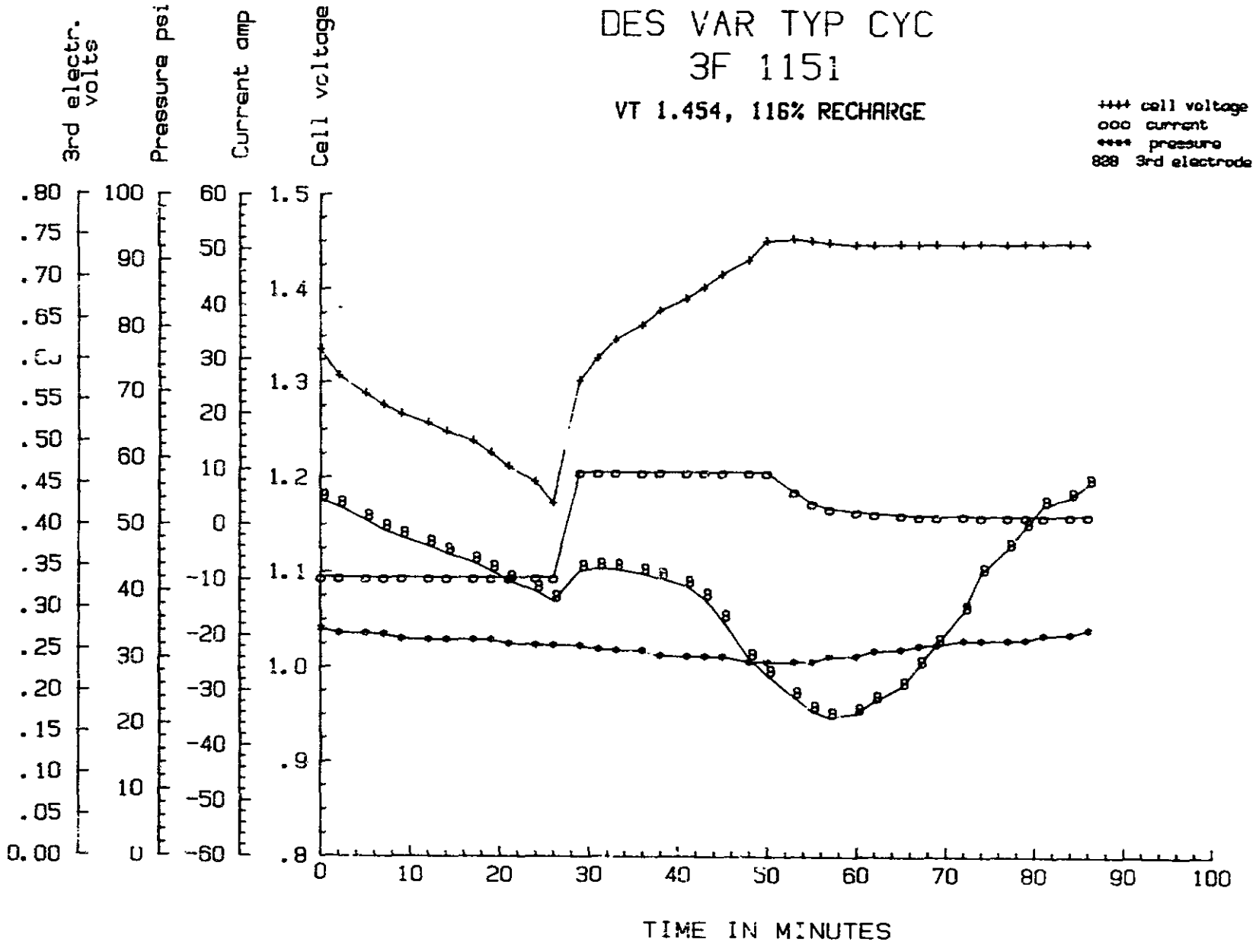

DES VAR TYP CYC
3I 110
VT 1.454, 117% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

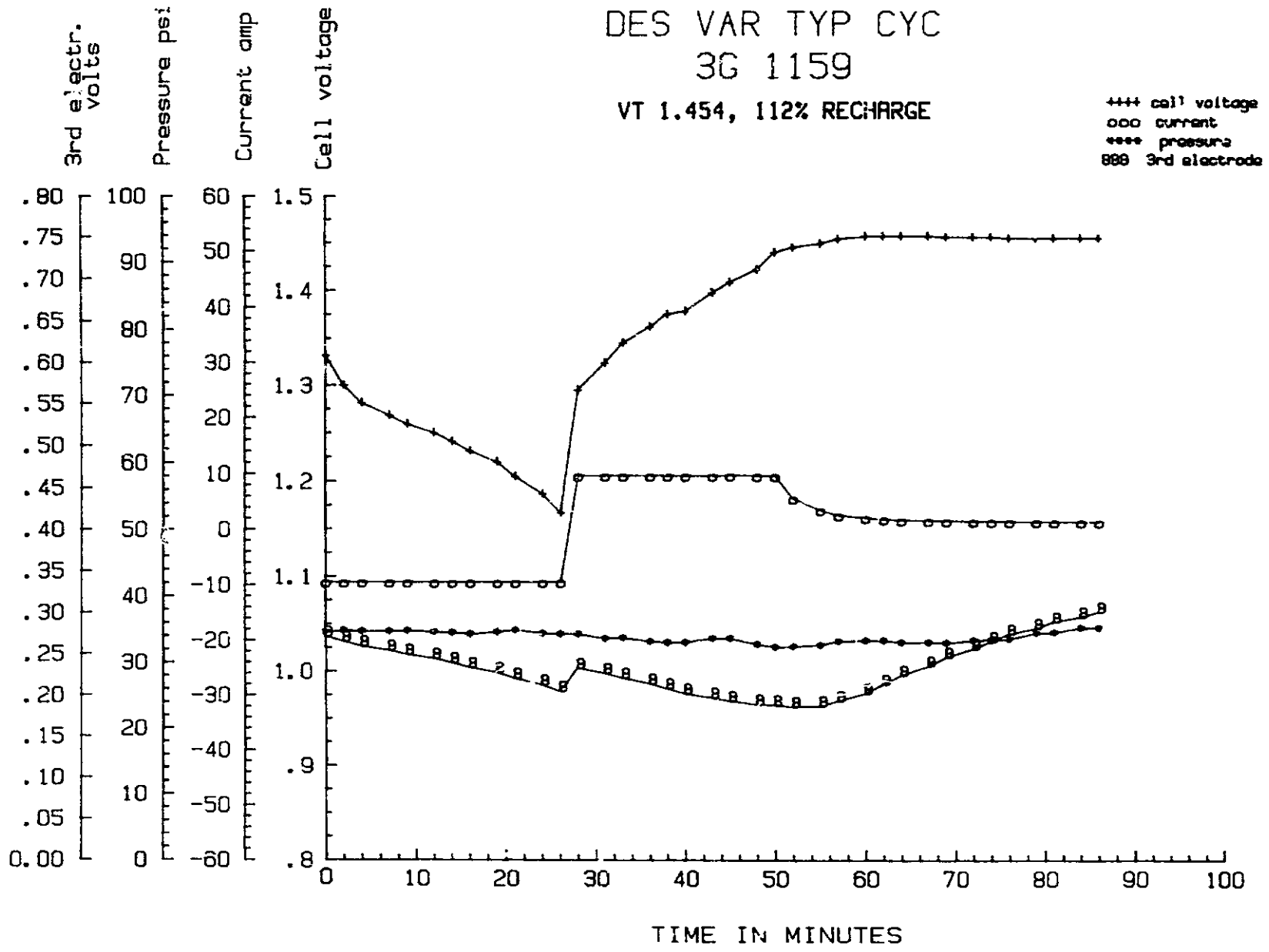

DES VAR TYP CYC
3J 110
VT 1.454, 108% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
.80
.75
.70
.65
.60
.55
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
0.00
100
90
80
70
60
50
40
30
20
10
0
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
0
10
20
30
40
50
60
70
80
90
100
TIME IN MINUTES

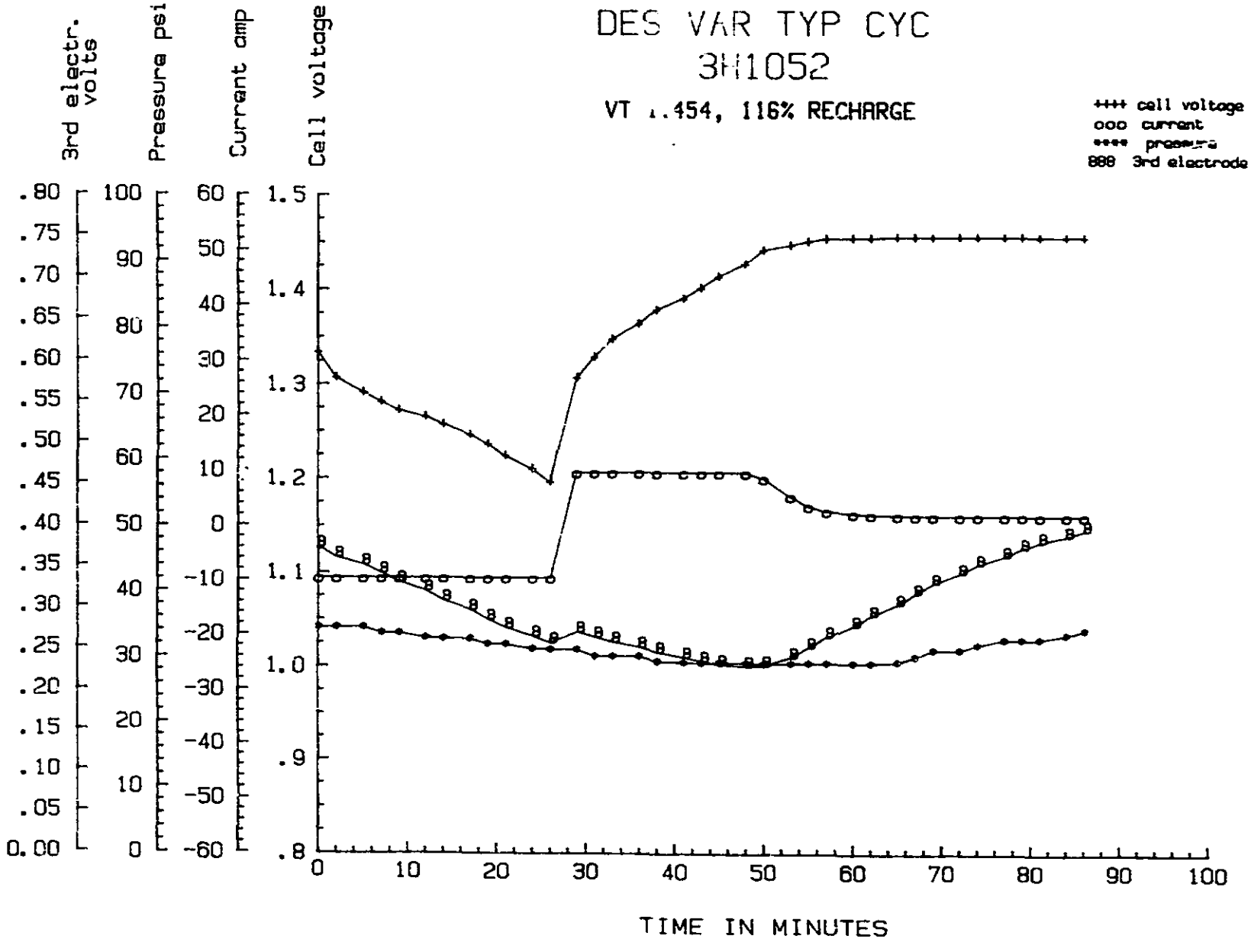

DES VAR TYP CYC
3L 296
VT 1.433, 118% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volte
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

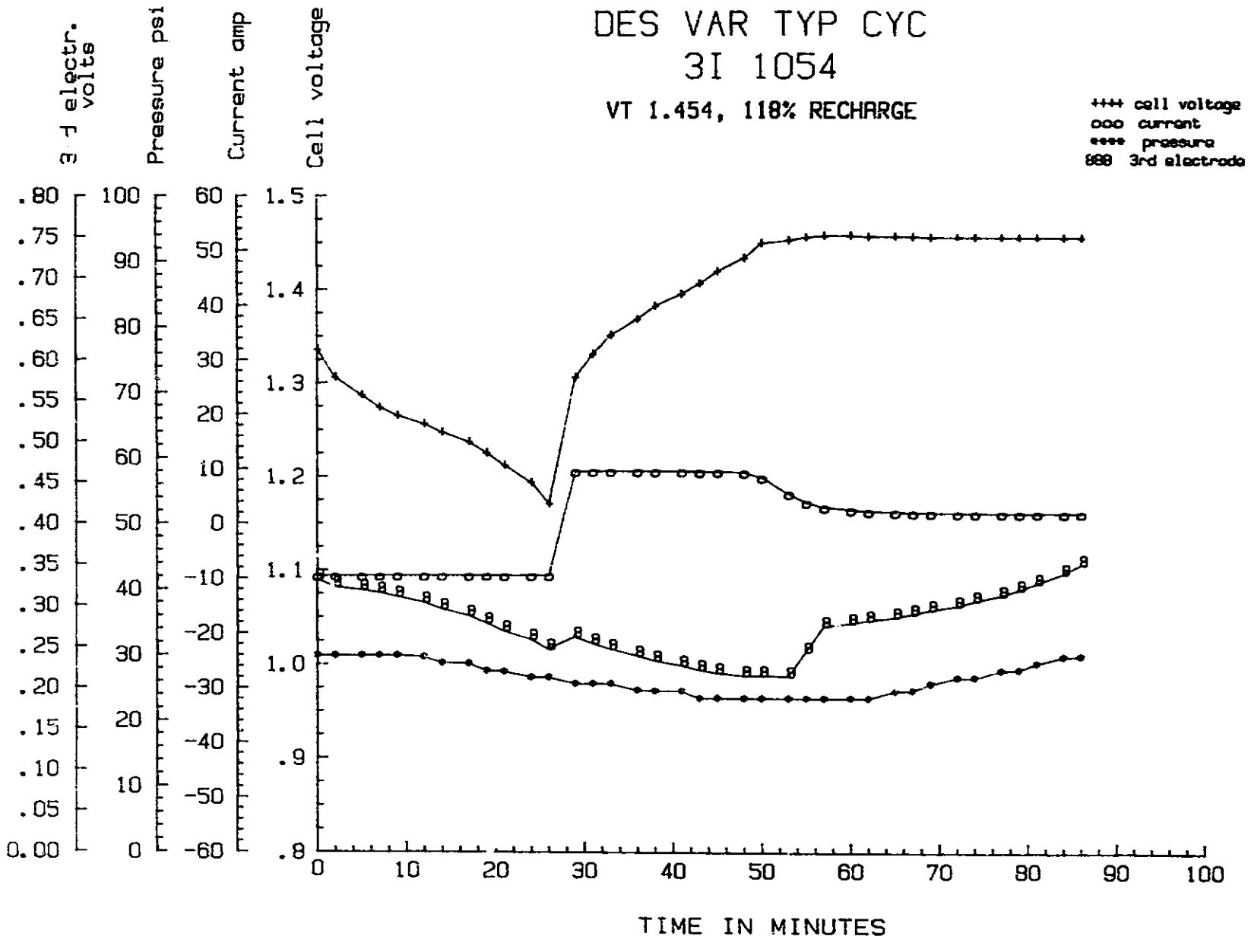

DES VAR TYP CYC
3D 1163
VT 1.454, 113% RECHRGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
.80
.75
.70
.65
.60
.55
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
0.00
100
90
80
70
60
50
40
30
20
10
0
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
0
10
20
30
40
50
60
70
80
90
100
TIME IN MINUTES

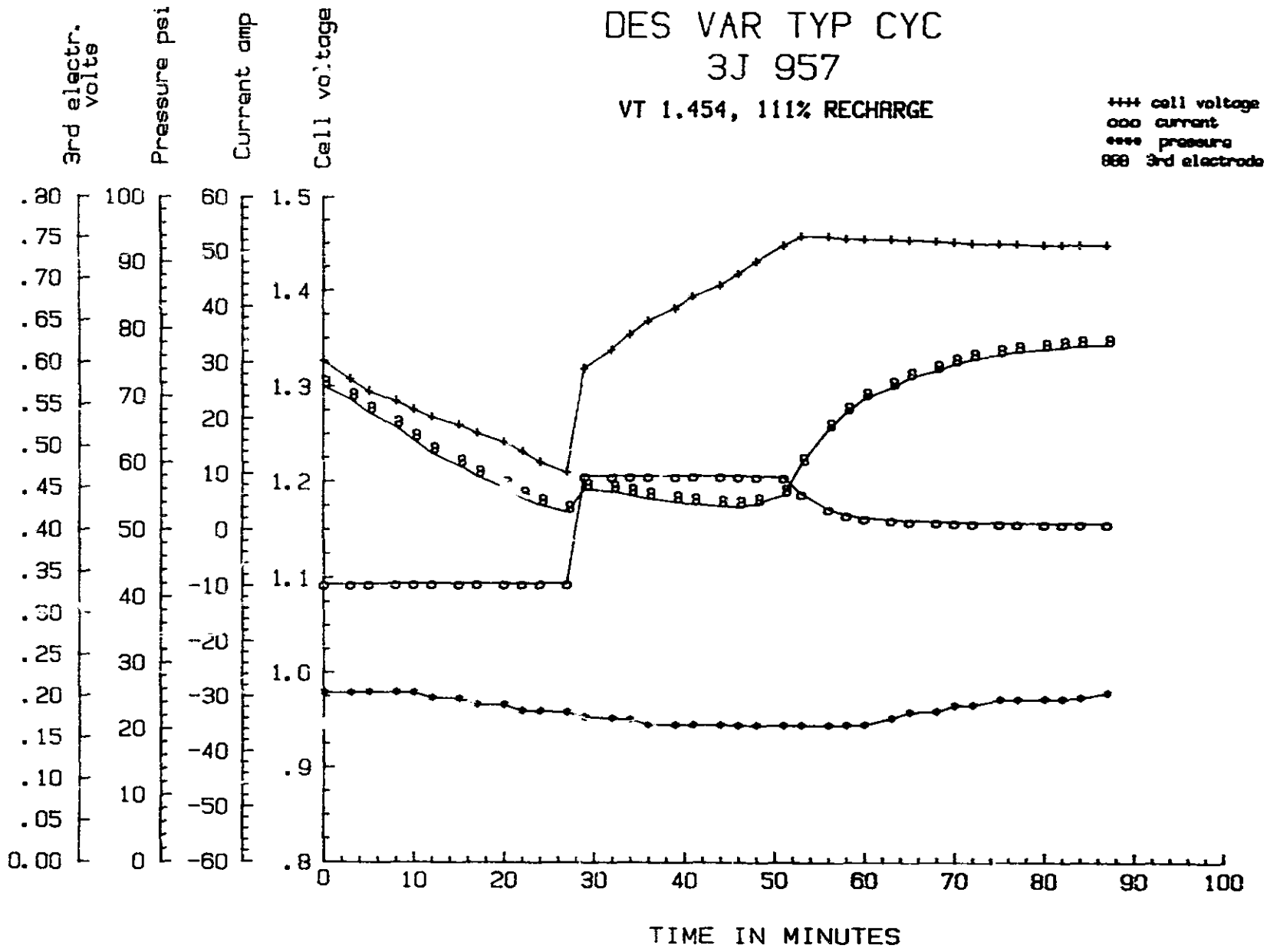

DES VAR TYP CYC
3E 1098
VT 1.454, 115% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

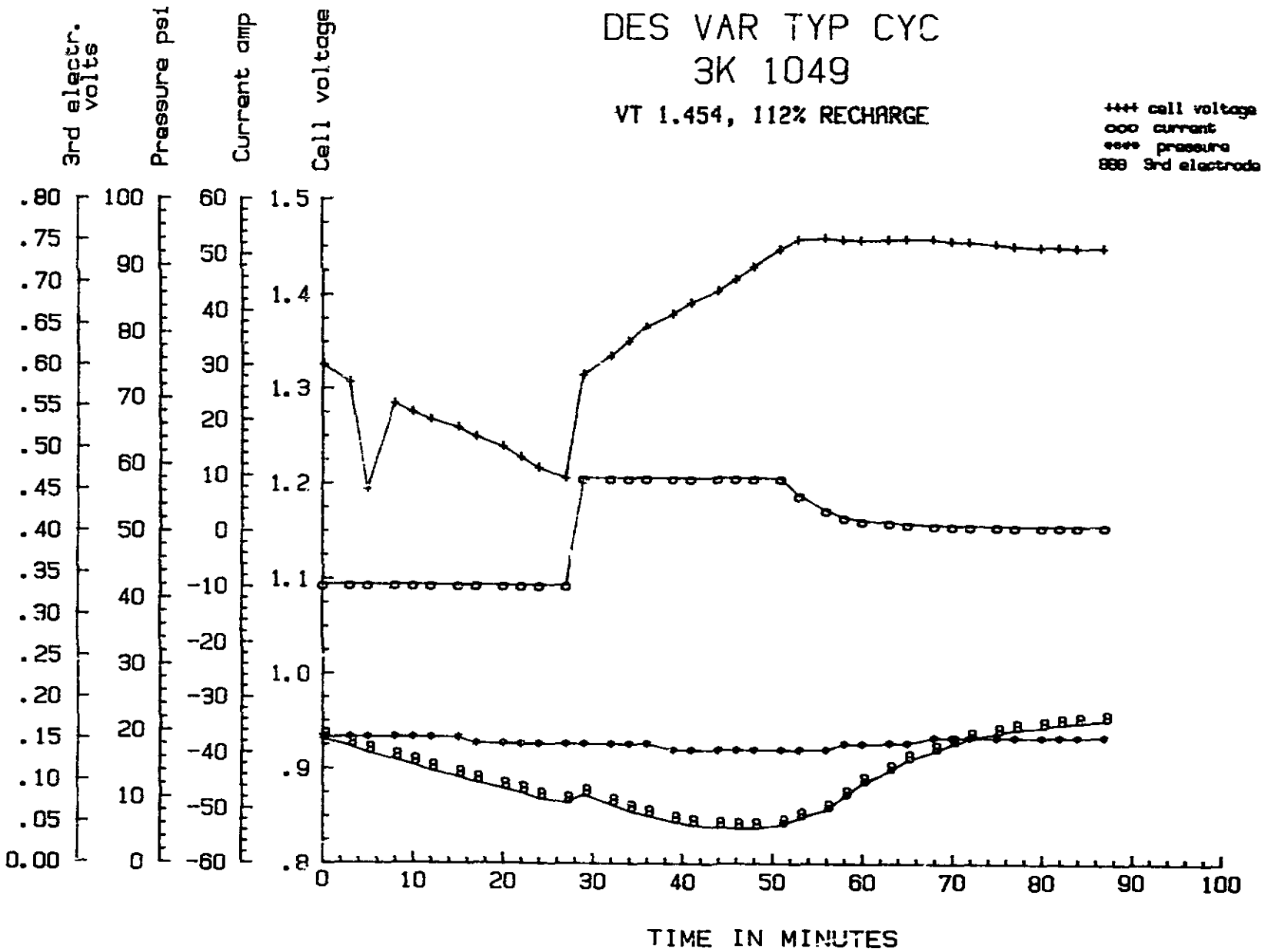

DES VAR TYP CYC
3F 1151
VT 1.454, 116% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
.80
.75
.70
.65
.60
.55
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
0.00
100
90
80
70
60
50
40
30
20
10
0
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
0
10
20
30
40
50
60
70
80
90
100
TIME IN MINUTES

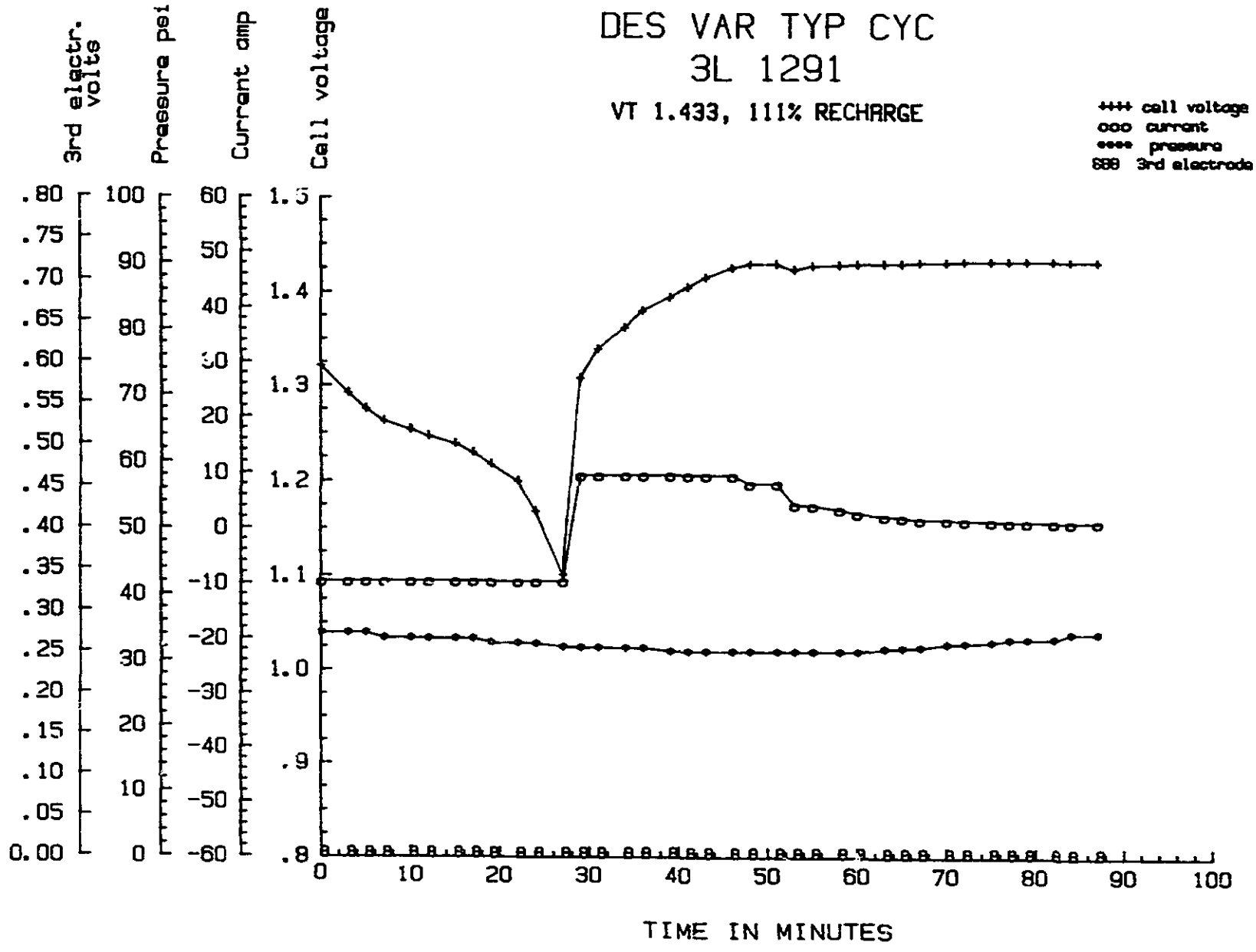

DES VAR TYP CYC
3G 1159
VT 1.454, 112% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

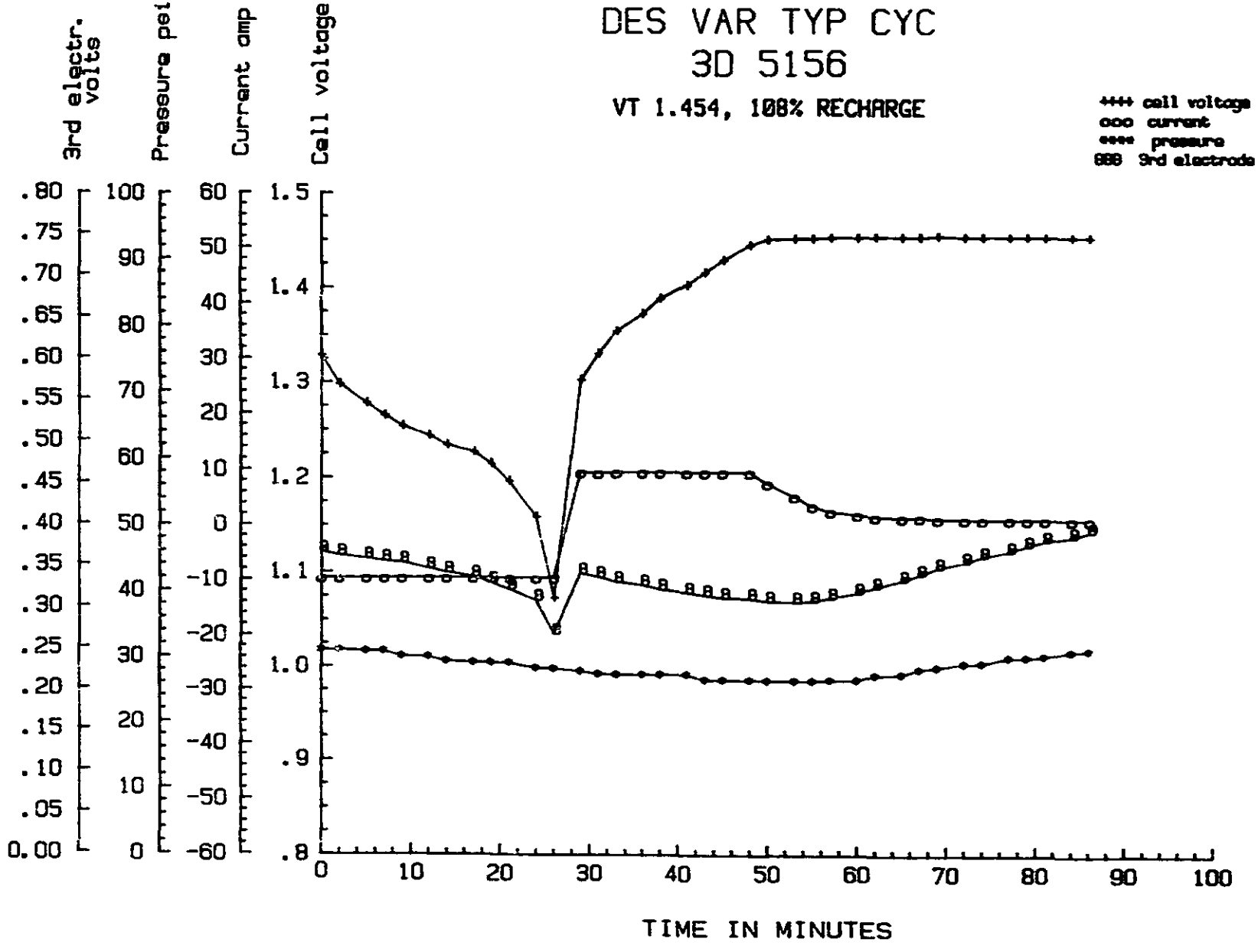

DES VAR TYP CYC
3H1052
VT 1.454, 116% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

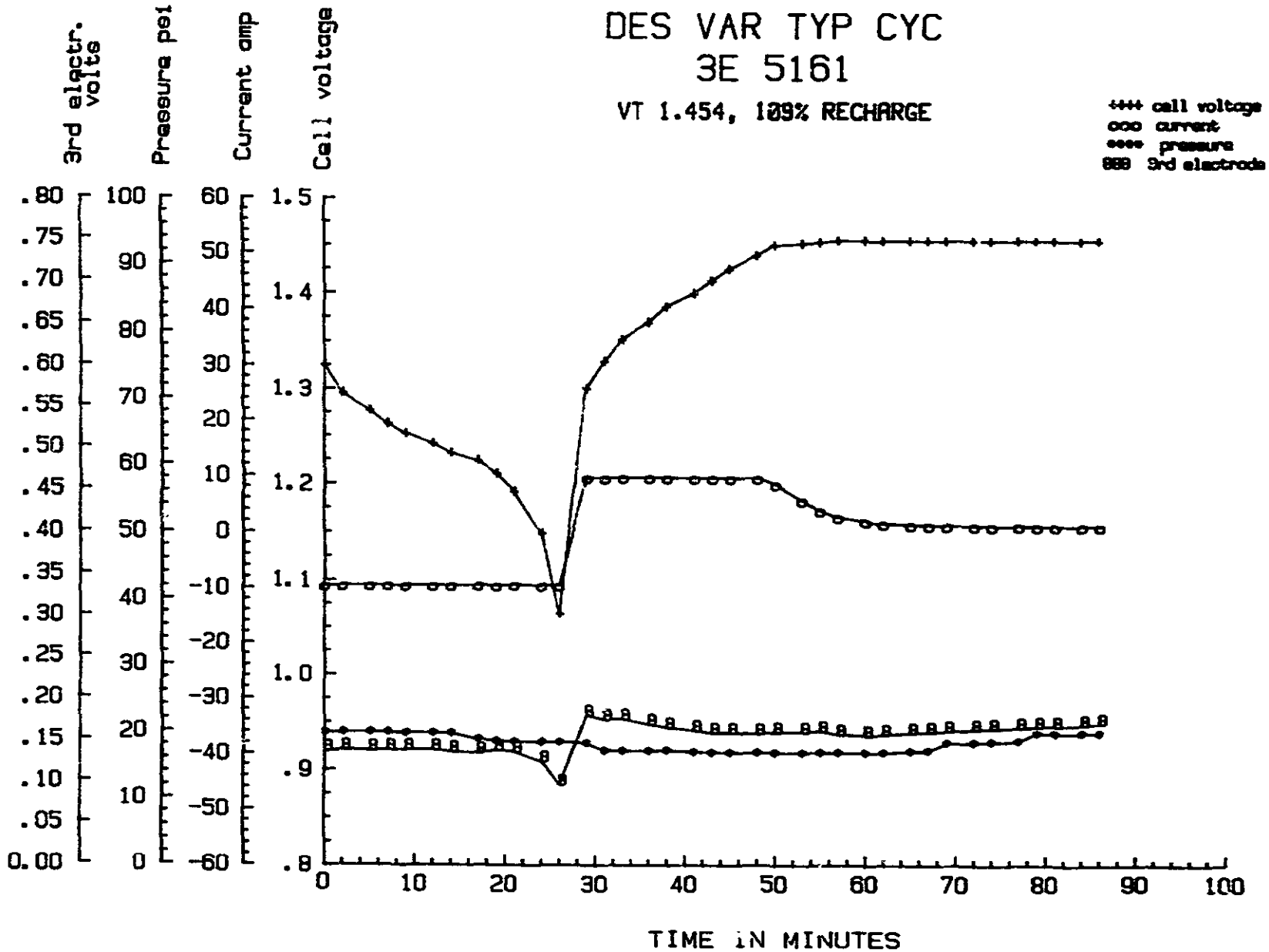

DES VAR TYP CYC
3I 1054
VT 1.454, 118% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

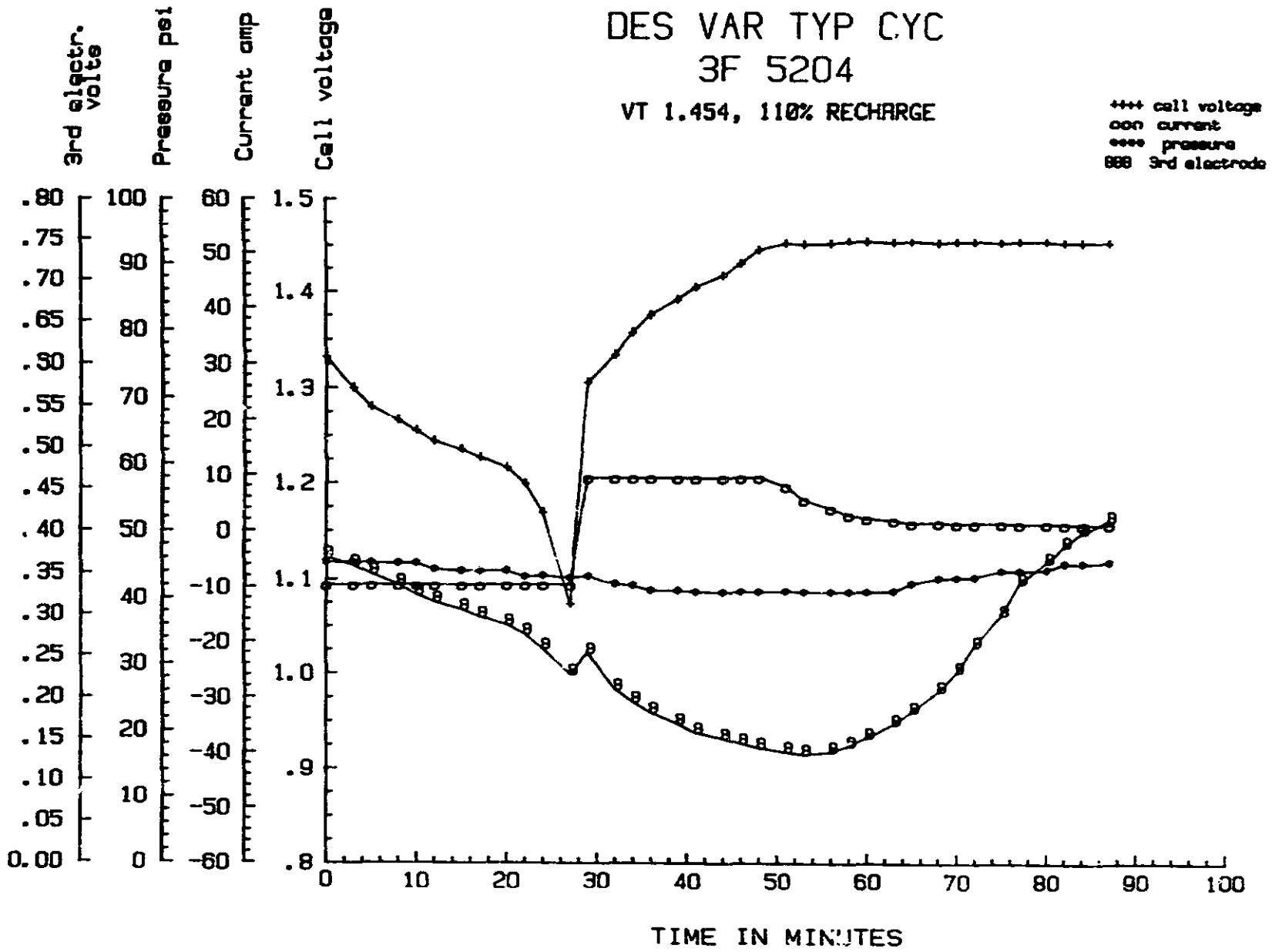

DES VAR TYP CYC
3J 957
VT 1.454, 111% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3K 1049
VT 1.454, 112% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3L 1291
VT 1.433, 111% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd elactr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3D 5156
VT 1.454, 108% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3E 5161
VT 1.454, 109% RECHARGE
++++ cell voltage
oooo current
**** pressure
888 3rd electrode
3rd elactr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3F 5204
VT 1.454, 110% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
.80
.75
.70
.65
.60
.55
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
0.00
100
90
80
70
60
50
40
30
20
10
0
60
50
40
30
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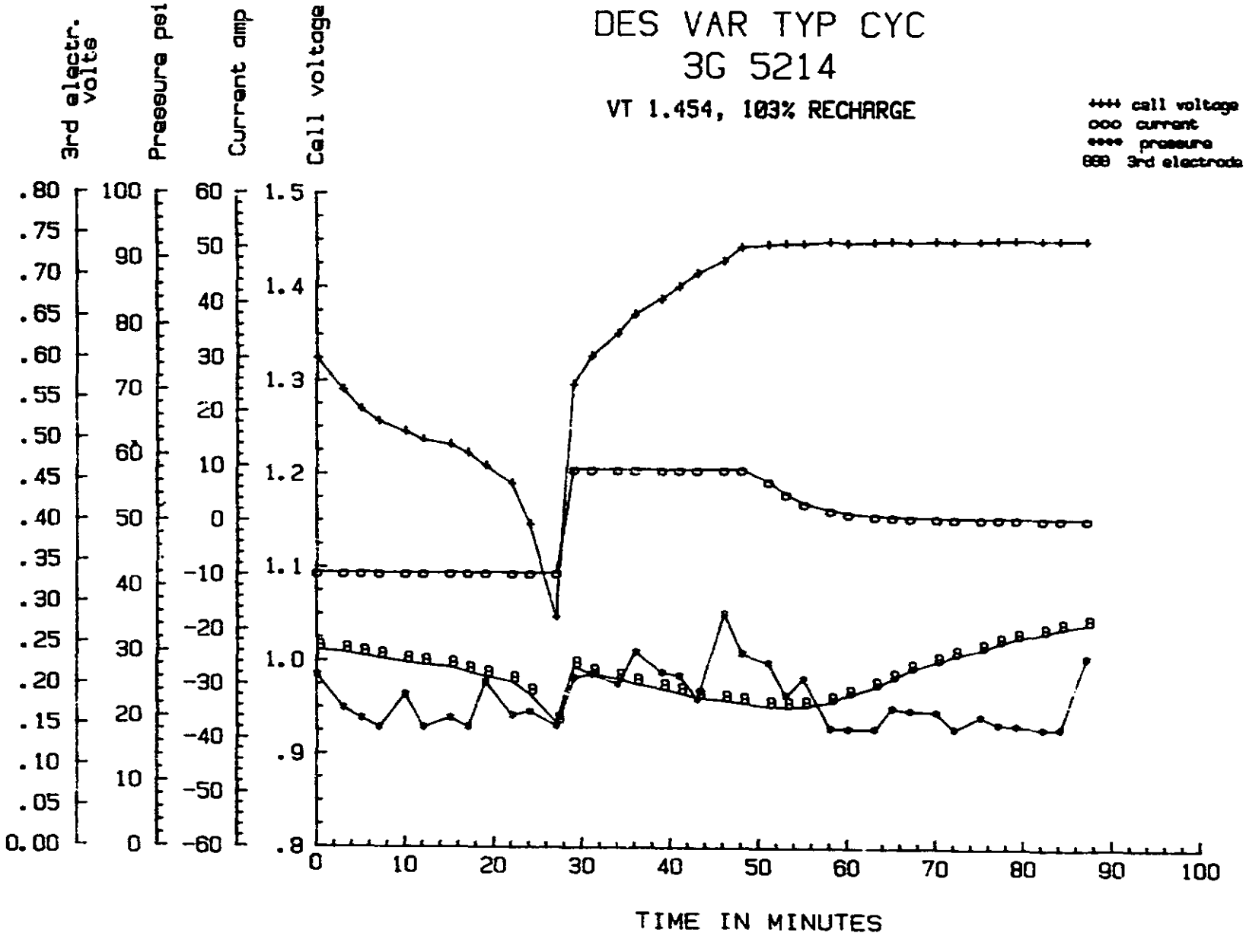
10
0
-10
-20
-30
-40
-50
-60
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
0
10
20
30
40
50
60
70
80
90
100
TIME IN MINUTES


DES VAR TYP CYC
3G 5214
VT 1.454, 103% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd elactr. volts
Pressure psi
Current amp
Cell voltage
.80
.75
.70
.65
.60
.55
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
0.00
100
90
80
70
60
50
40
30
20
10
0
60
50
40
30
20
10
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-10
-20
-30
-40
-50
-60
1.5
1.4
1.3
1.2
1.1
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.9
.8
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30
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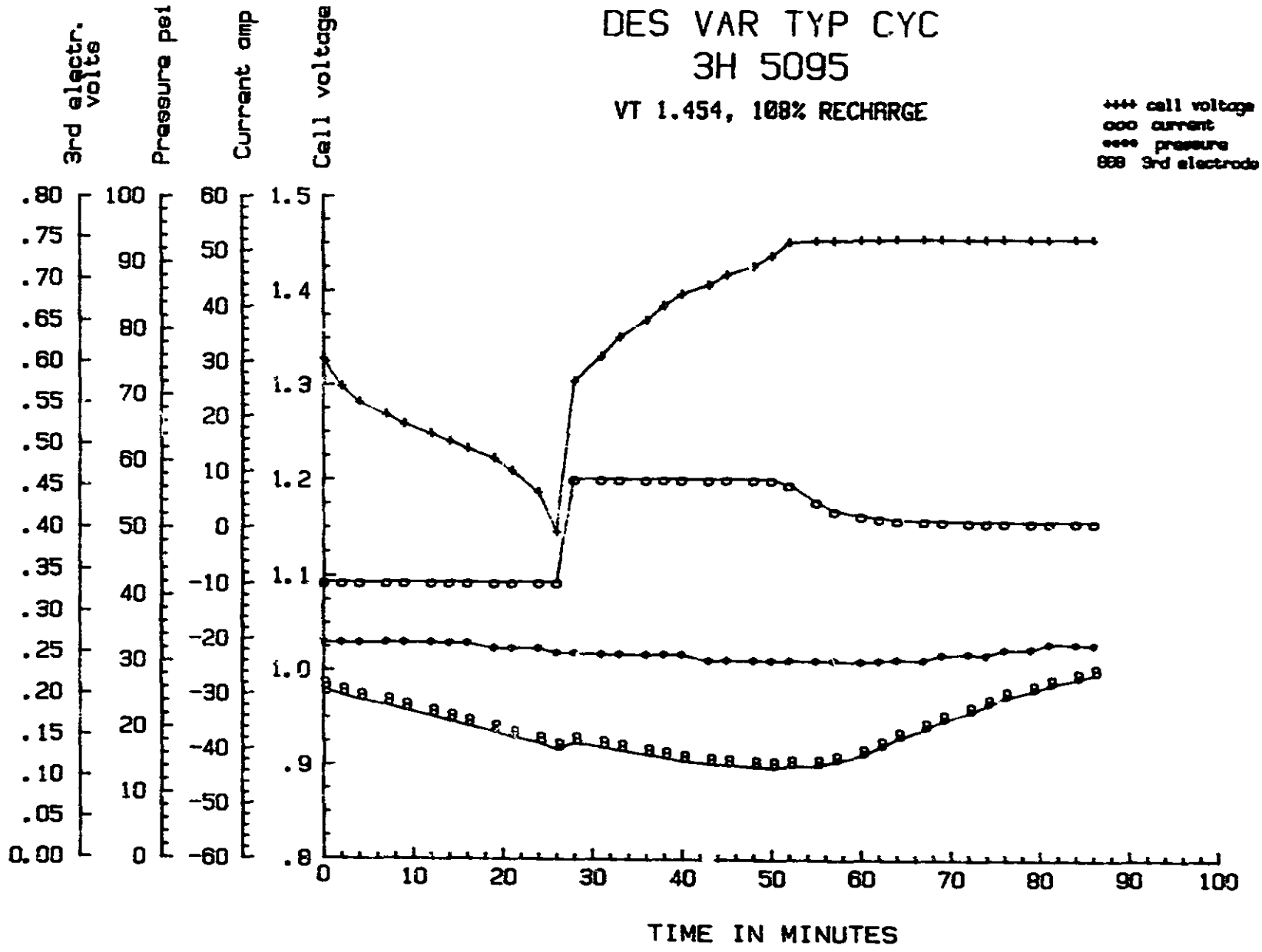
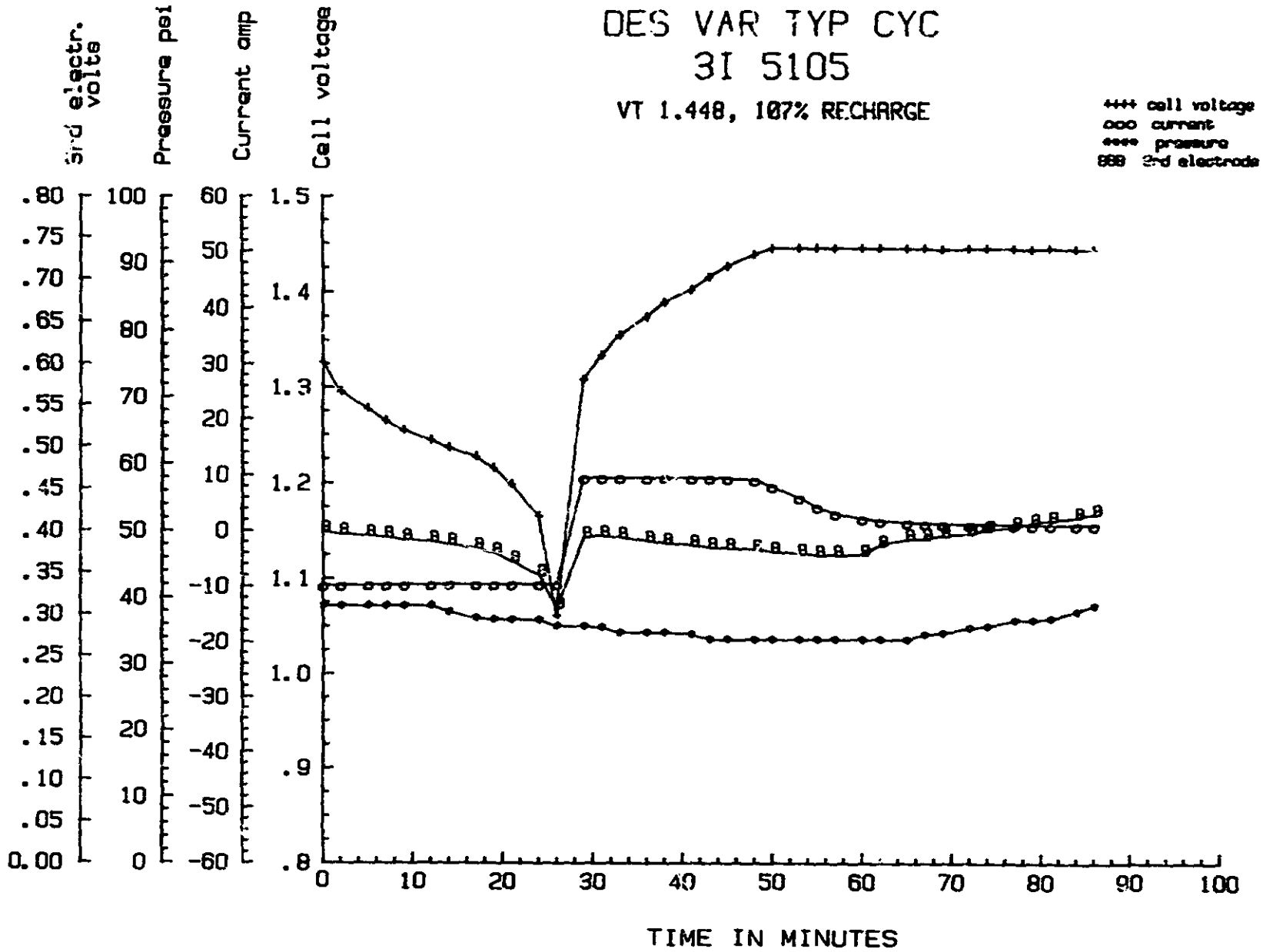
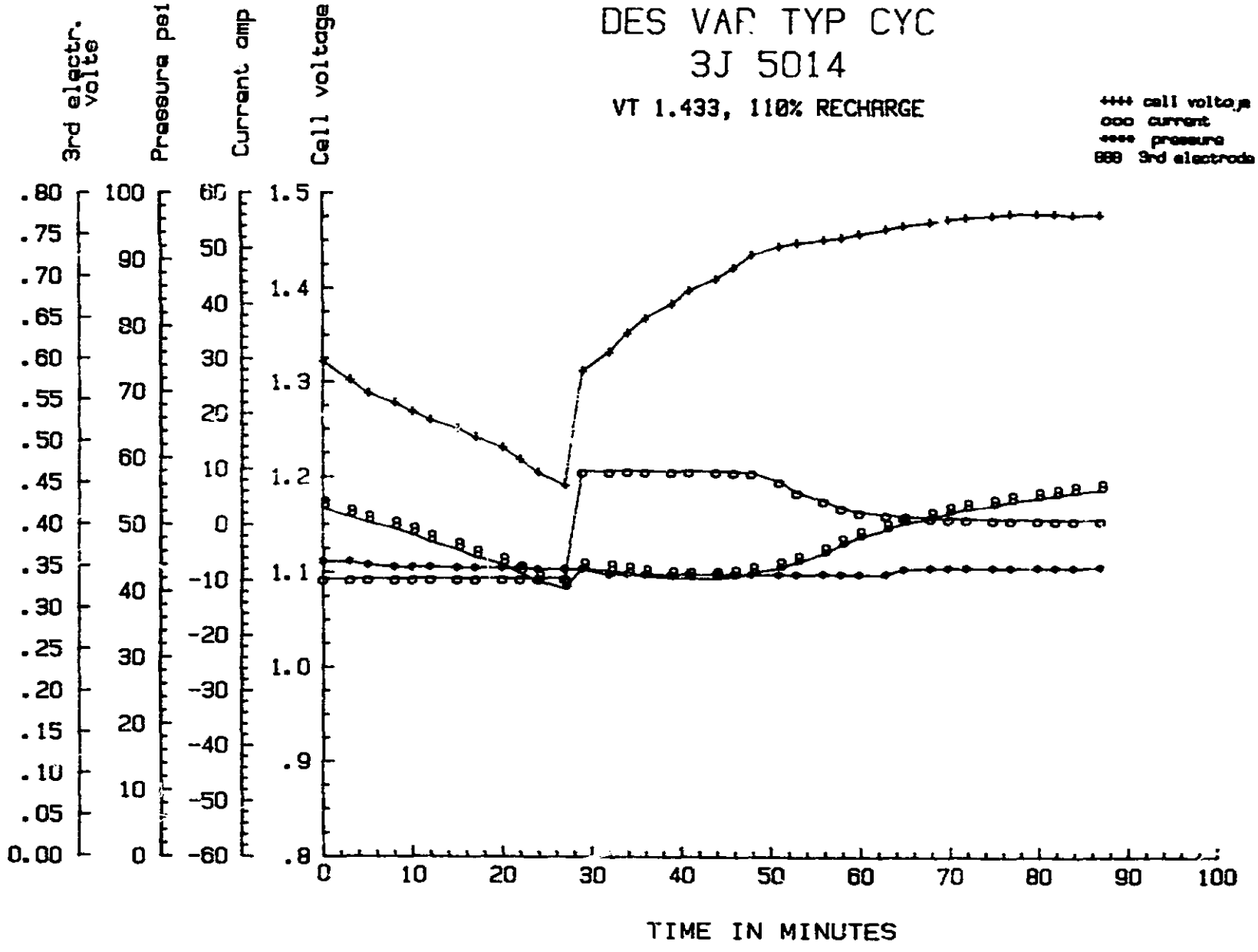
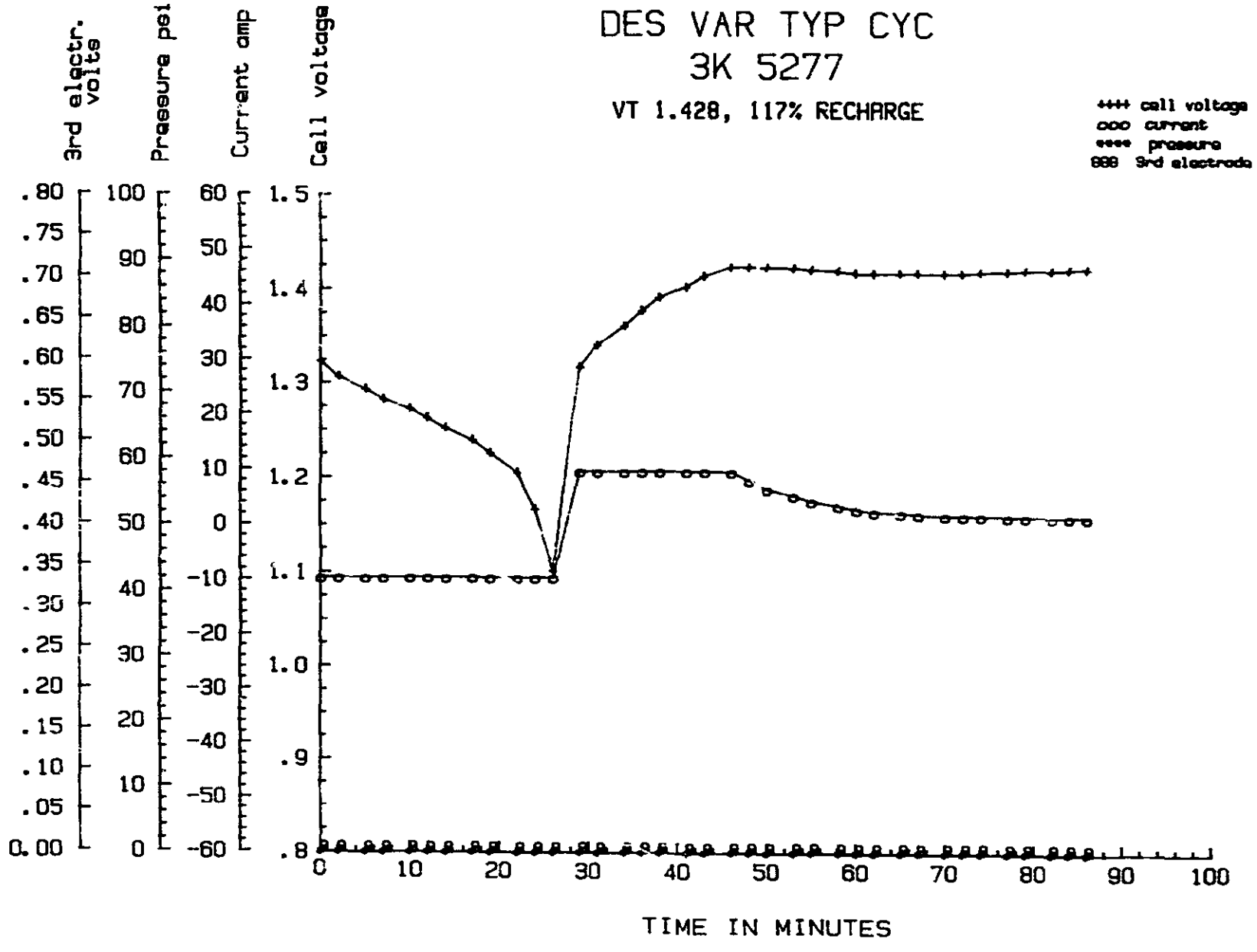
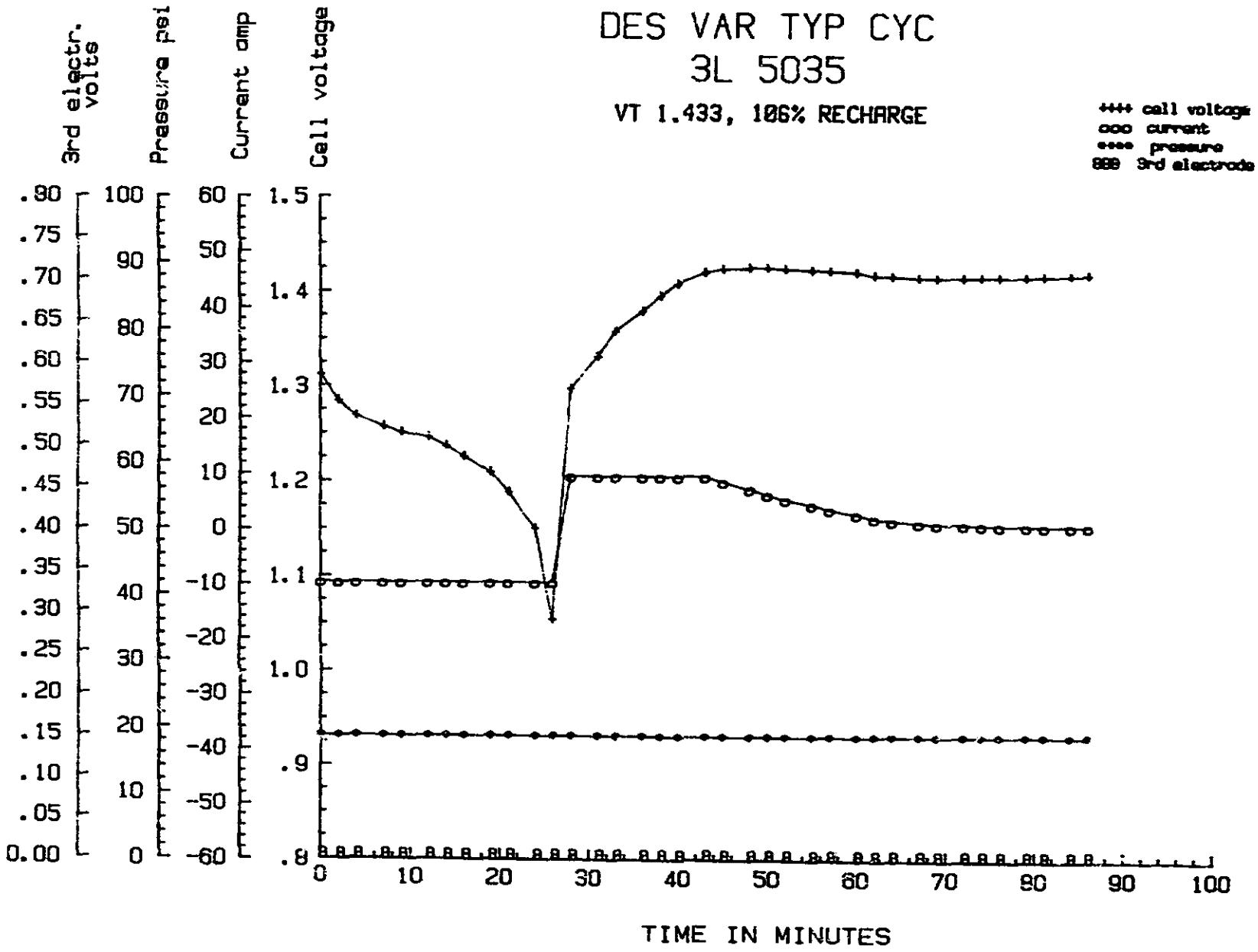
50
60
70
80
90
100
TIME IN MINUTES

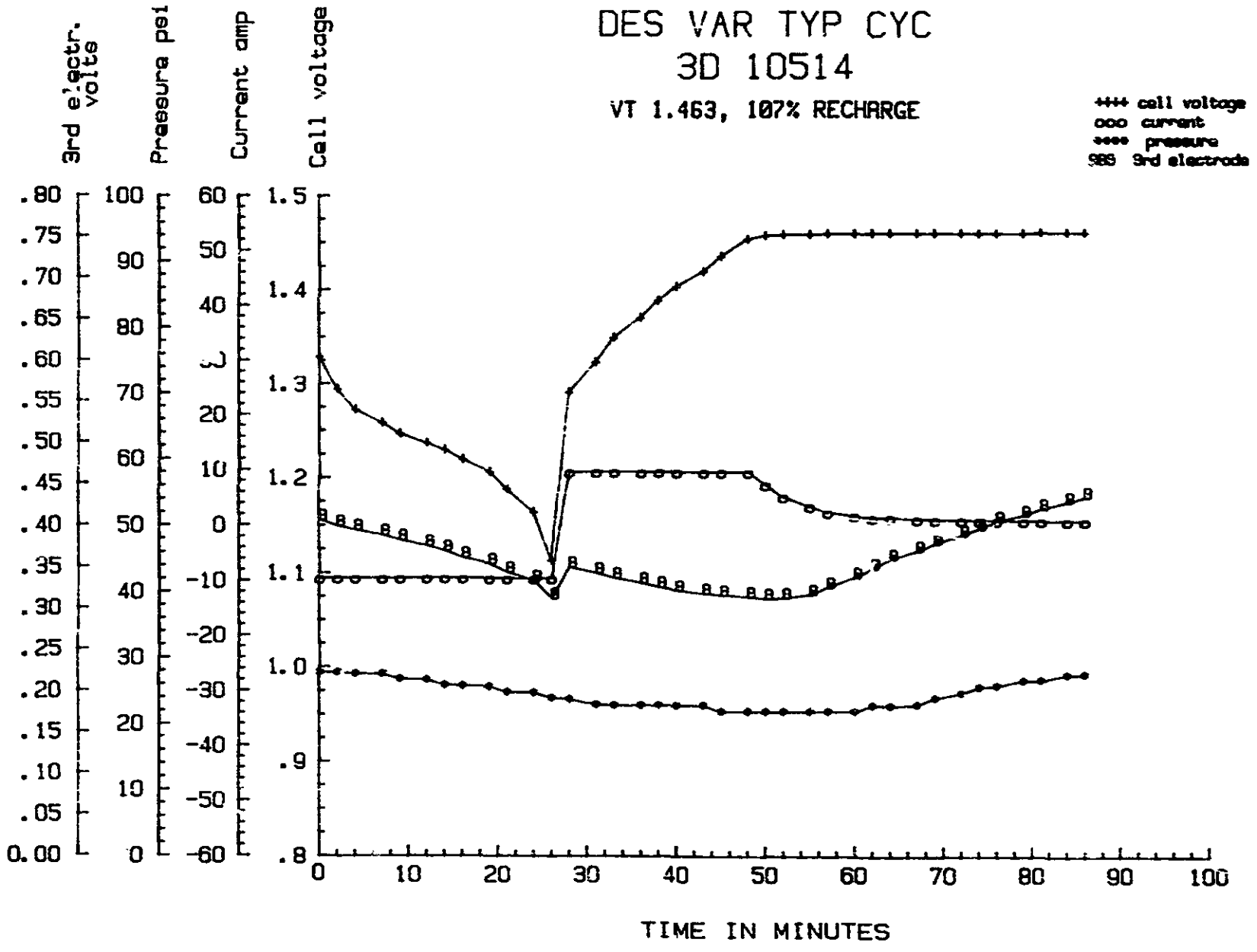

DES VAR TYP CYC
3H 5095
VT 1.454, 108% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

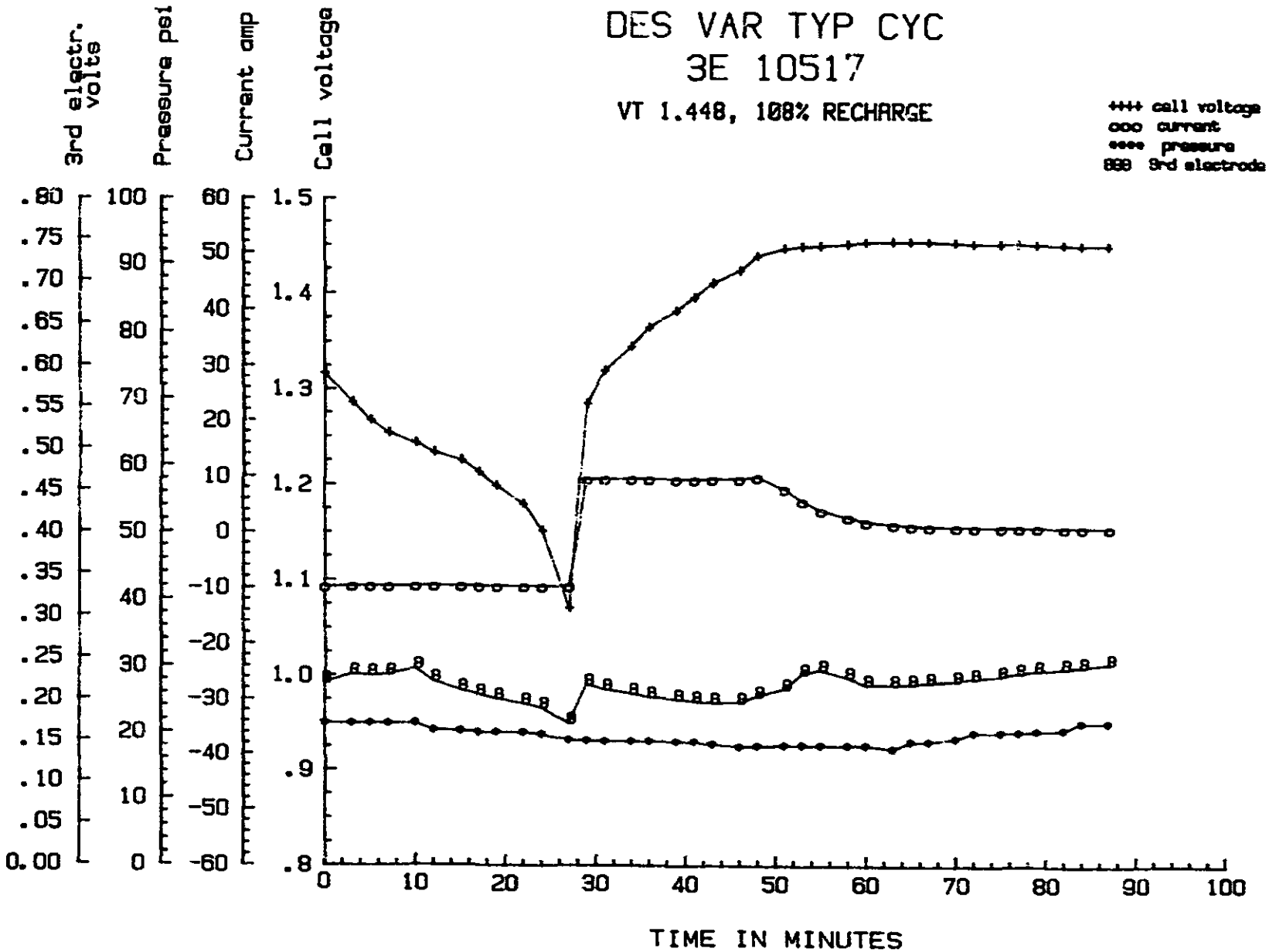

DES VAR TYP CYC
3I 5105
VT 1.448, 107% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

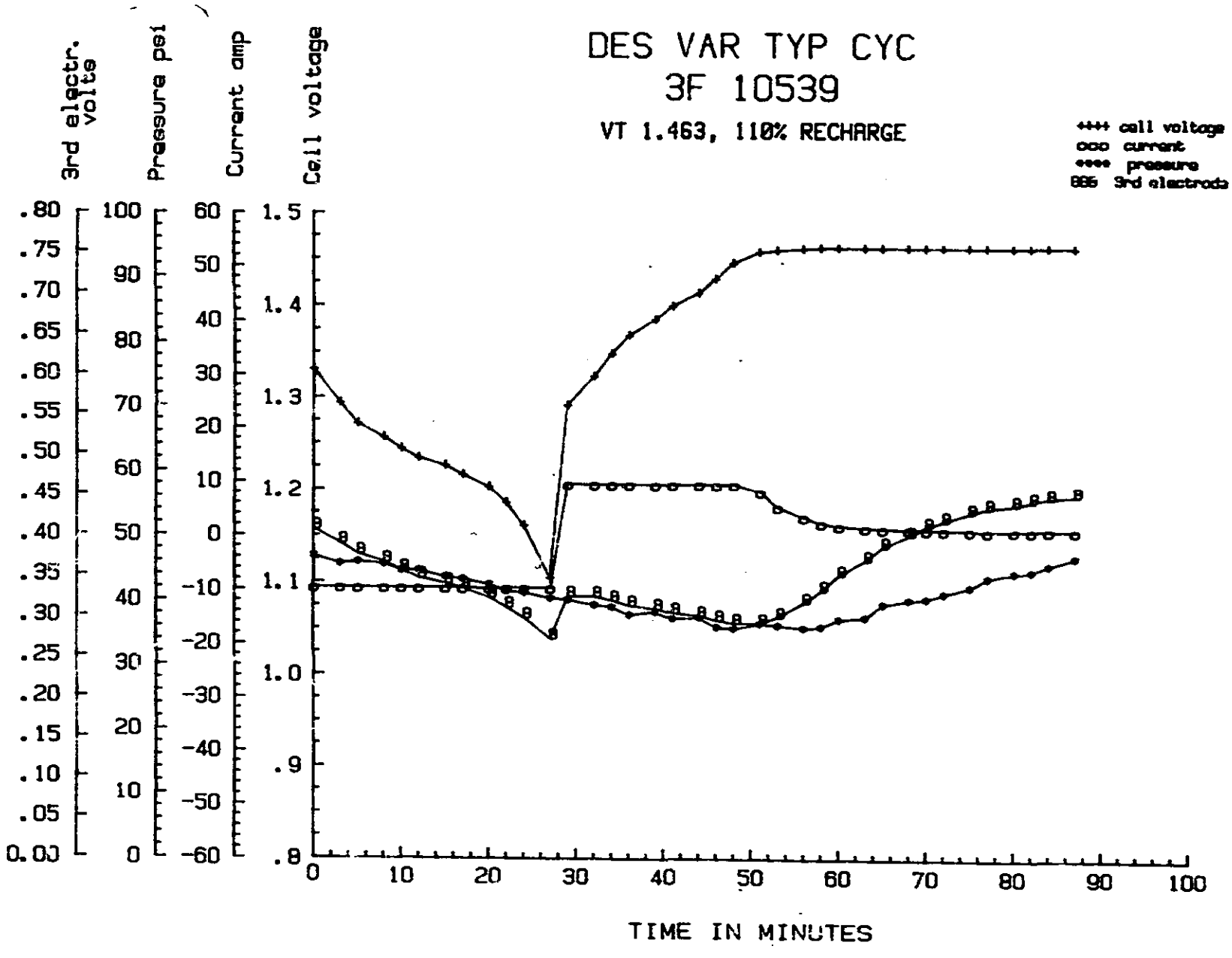

DES VAR TYP CYC
3J 5014
VT 1.433, 110% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

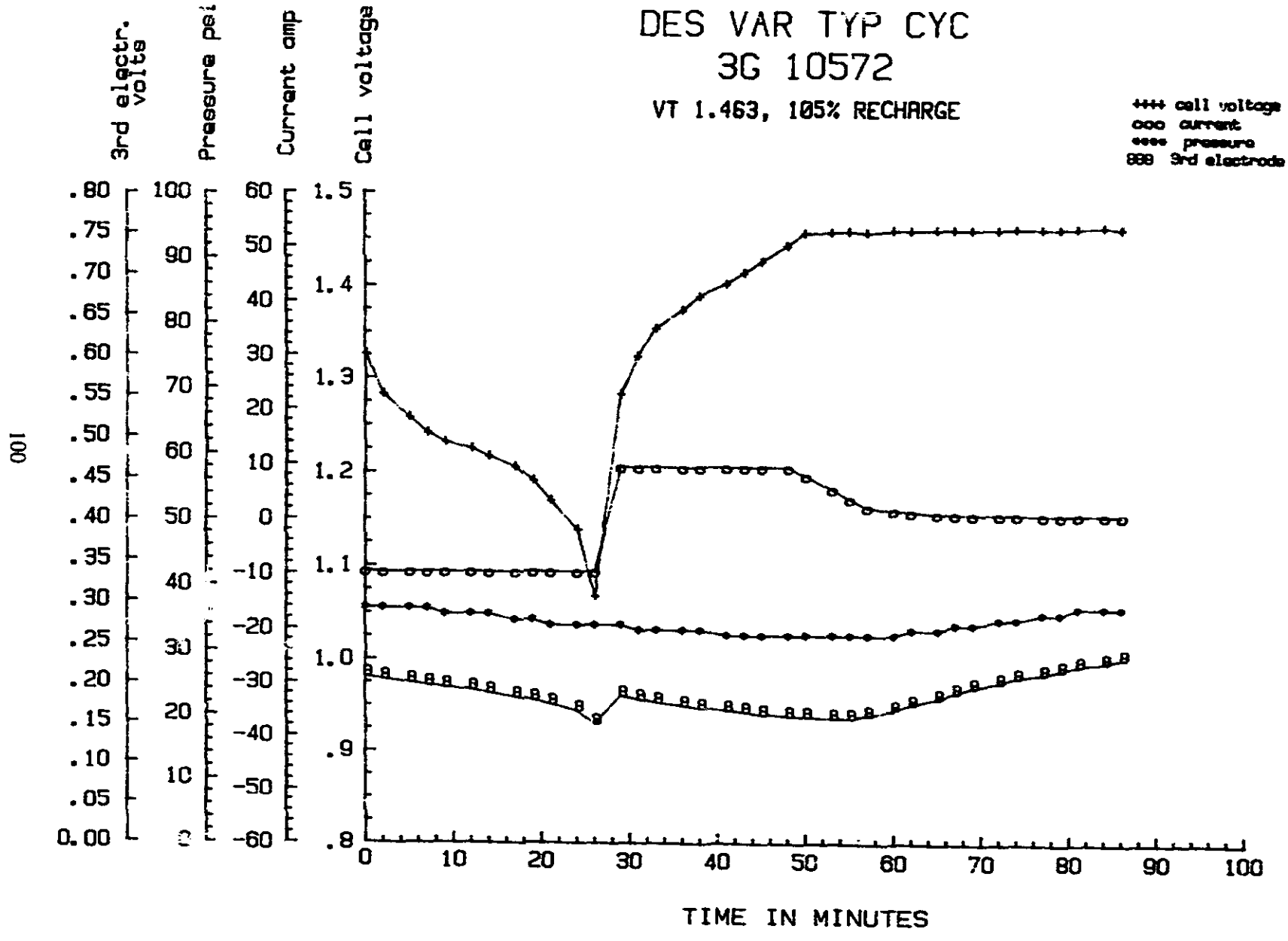

DES VAR TYP CYC
3K 5277
VT 1.428, 117% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

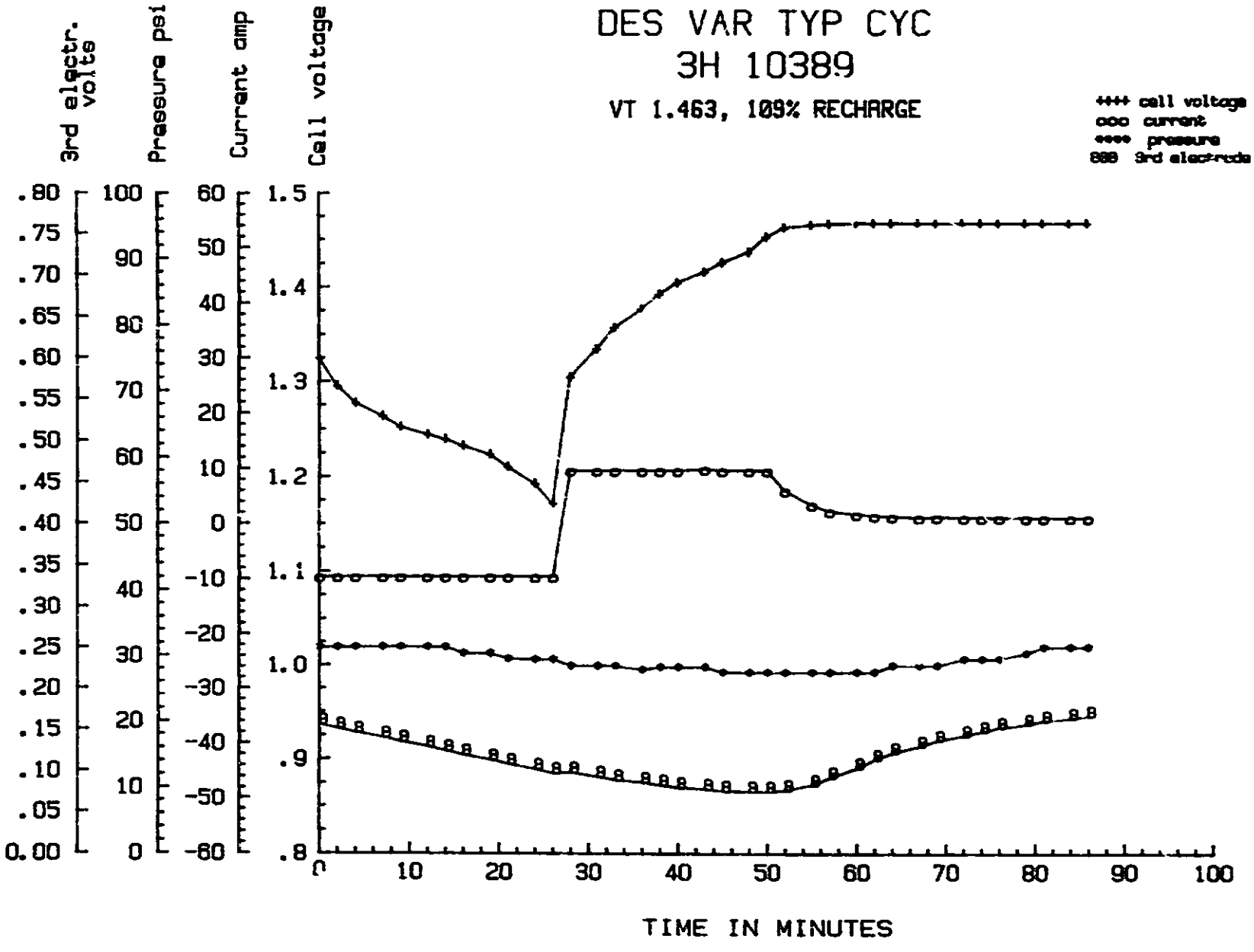

DES VAR TYP CYC
3L 5035
VT 1.433, 106% RECHARGE
++++ cell voltage
ooo current
**** pressure
3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3D 10514
VT 1.463, 107% RECHARGE
++++ cell voltage
ooo current
**** pressure
999 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3E 10517
VT 1.448, 108% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3F 10539
VT 1.463, 110% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3G 10572
VT 1.463, 105% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3H 10389
VT 1.463, 109% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd elqctr. volts
Pressure psi
Current amp
Cell voltage
.80
.75
.70
.65
.60
.55
.50
.45
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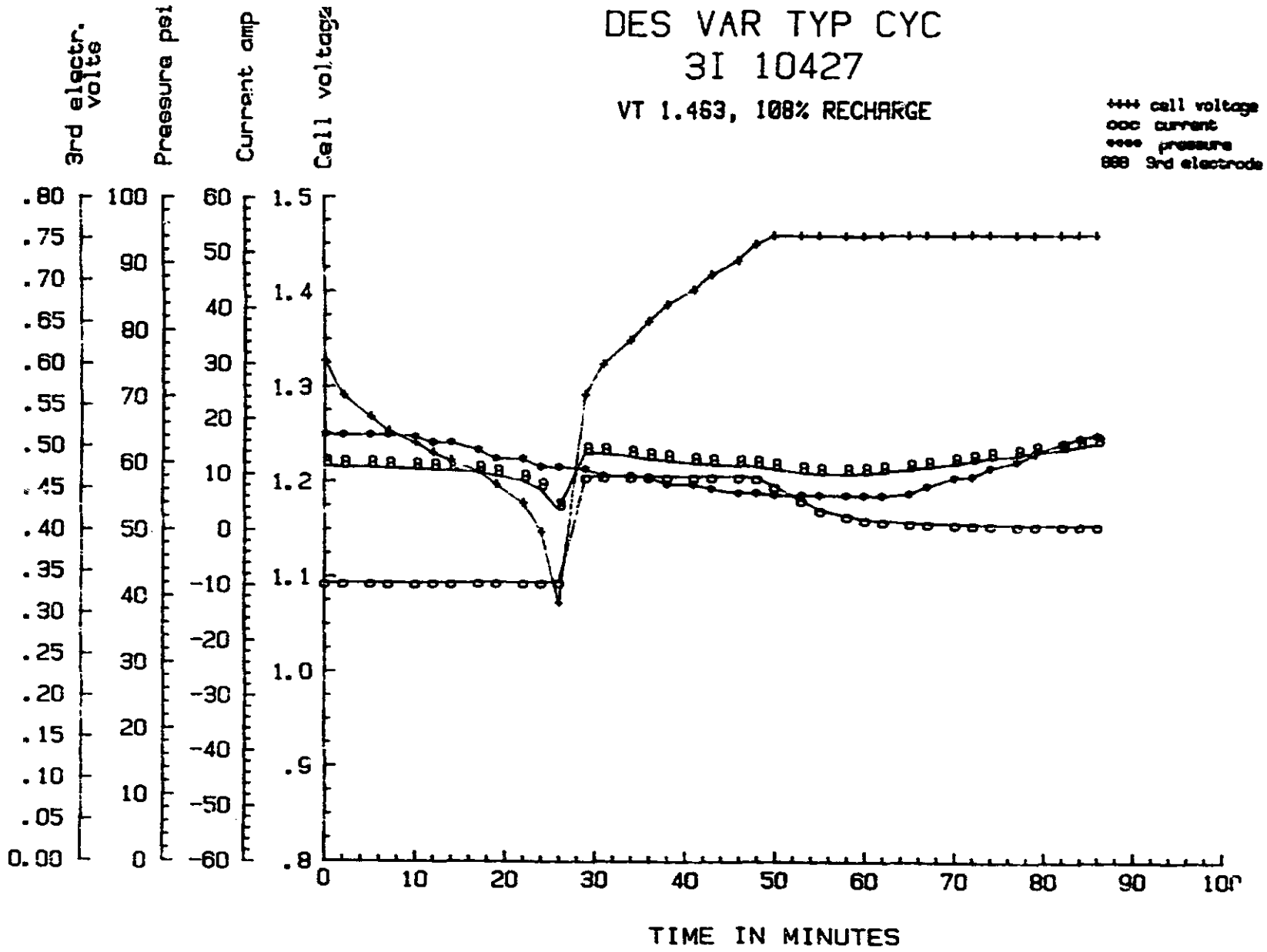
90
100
TIME IN MINUTES


DES VAR TYP CYC
3I 10427
VT 1.463, 108% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volte
Pressure psi
Current amp
Cell voltage
.80
.75
.70
.65
.60
.55
.50
.45
.40
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.30
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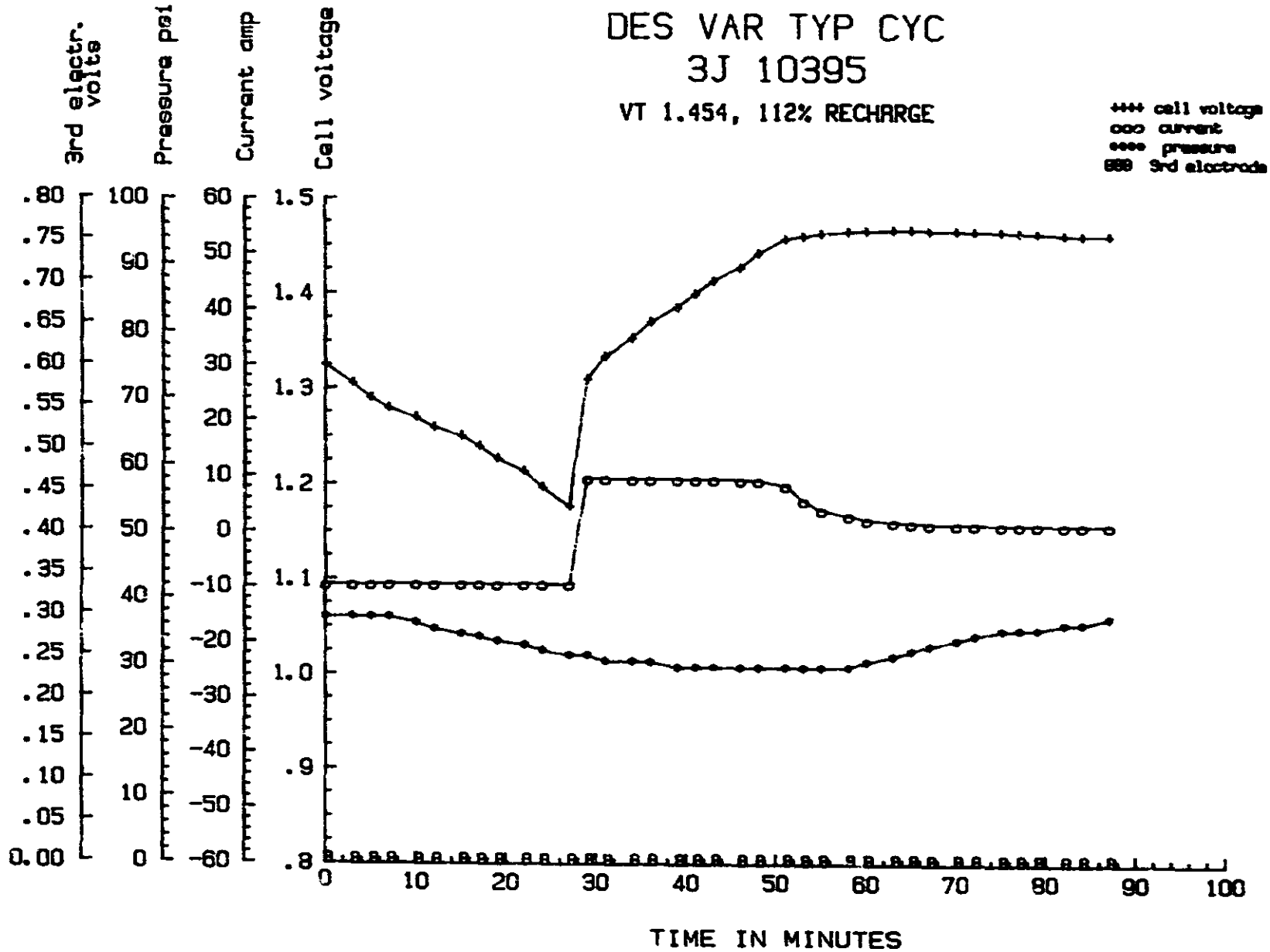
TIME IN MINUTES


DES VAR TYP CYC
3J 10395
VT 1.454, 112% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
.80
.75
.70
.65
.60
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.50
.45
.40
.35
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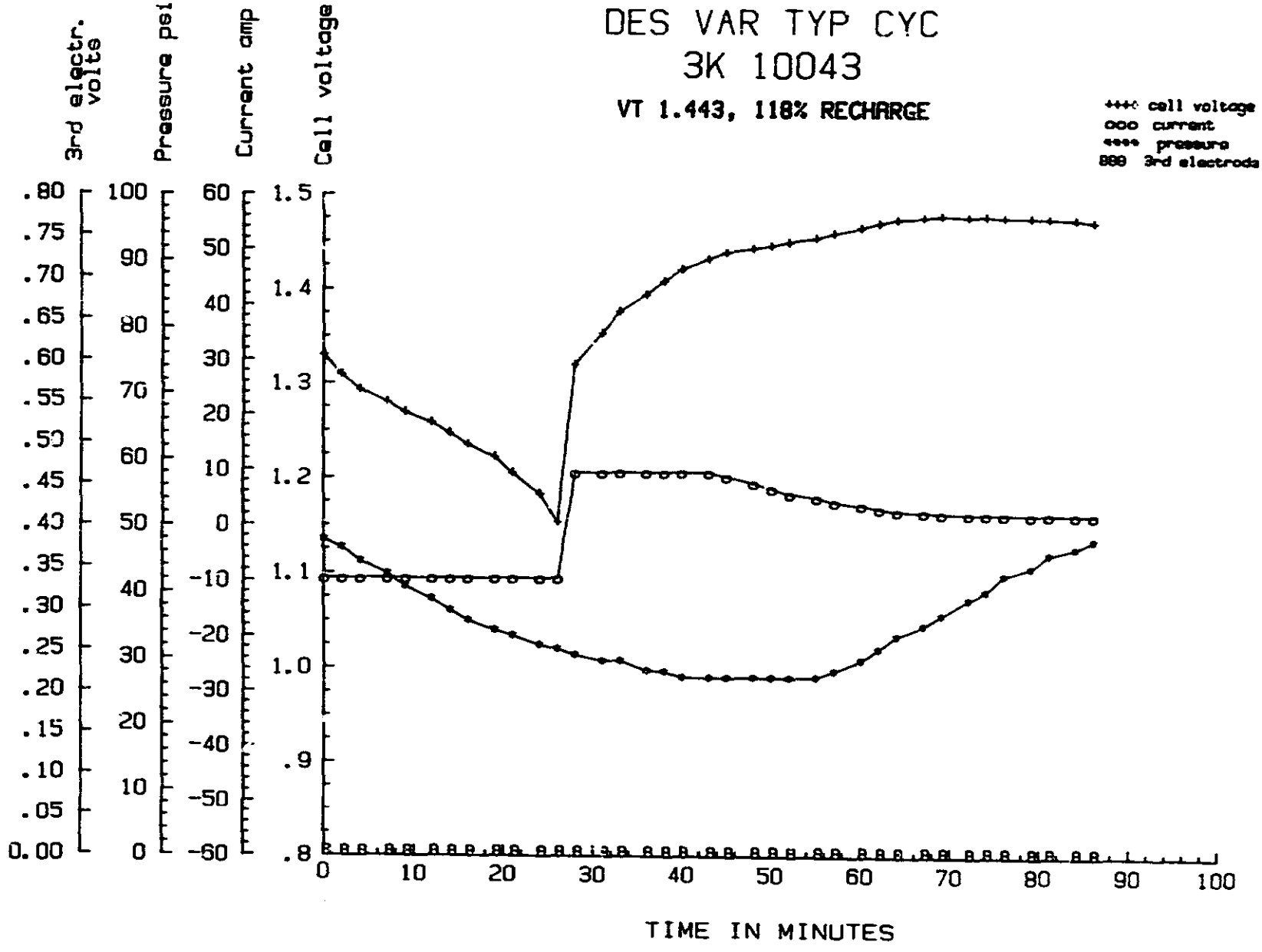
60
70
80
90
100
TIME IN MINUTES


DES VAR TYP CYC
3K 10043
VT 1.443, 118% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
.80
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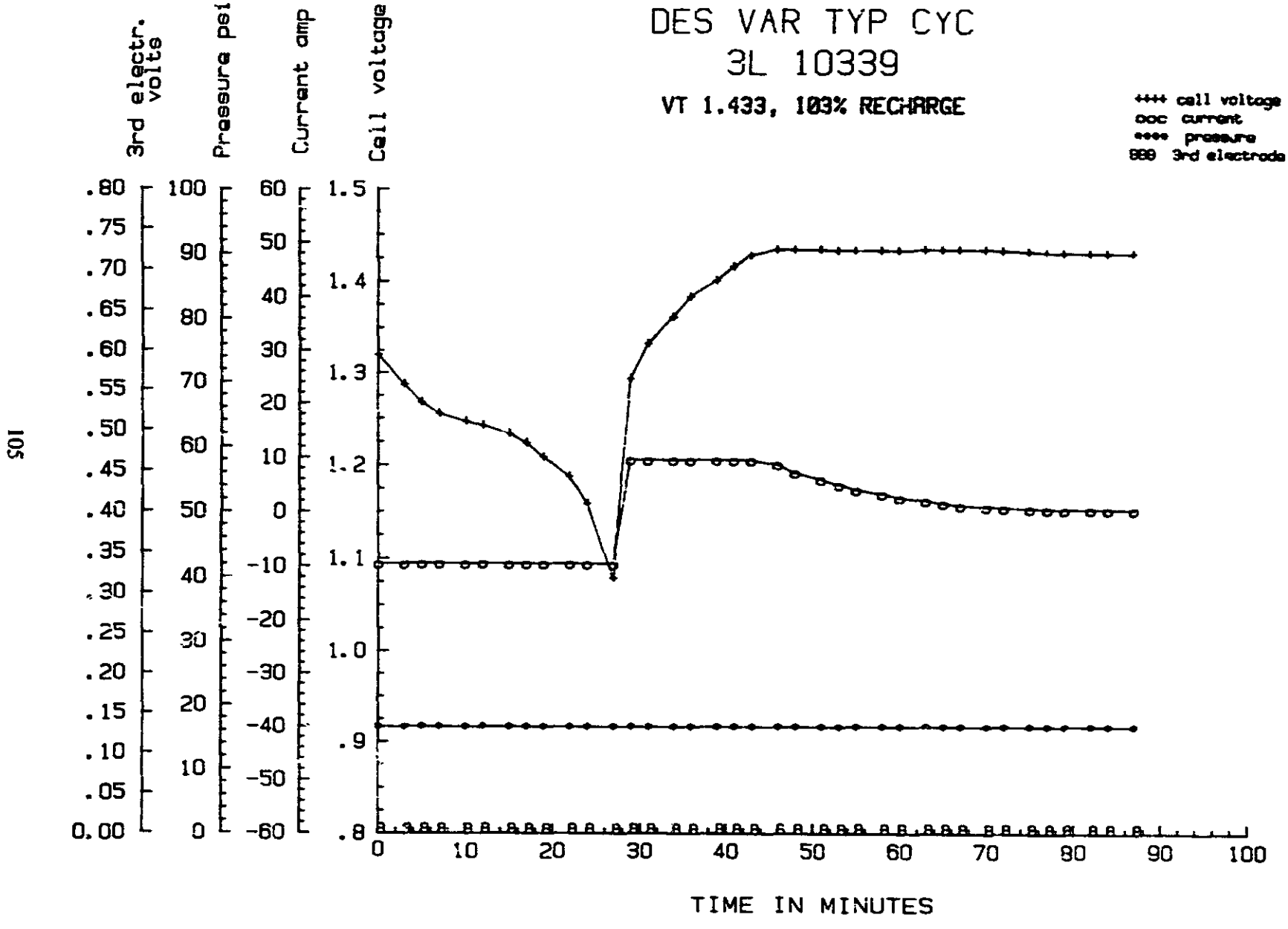
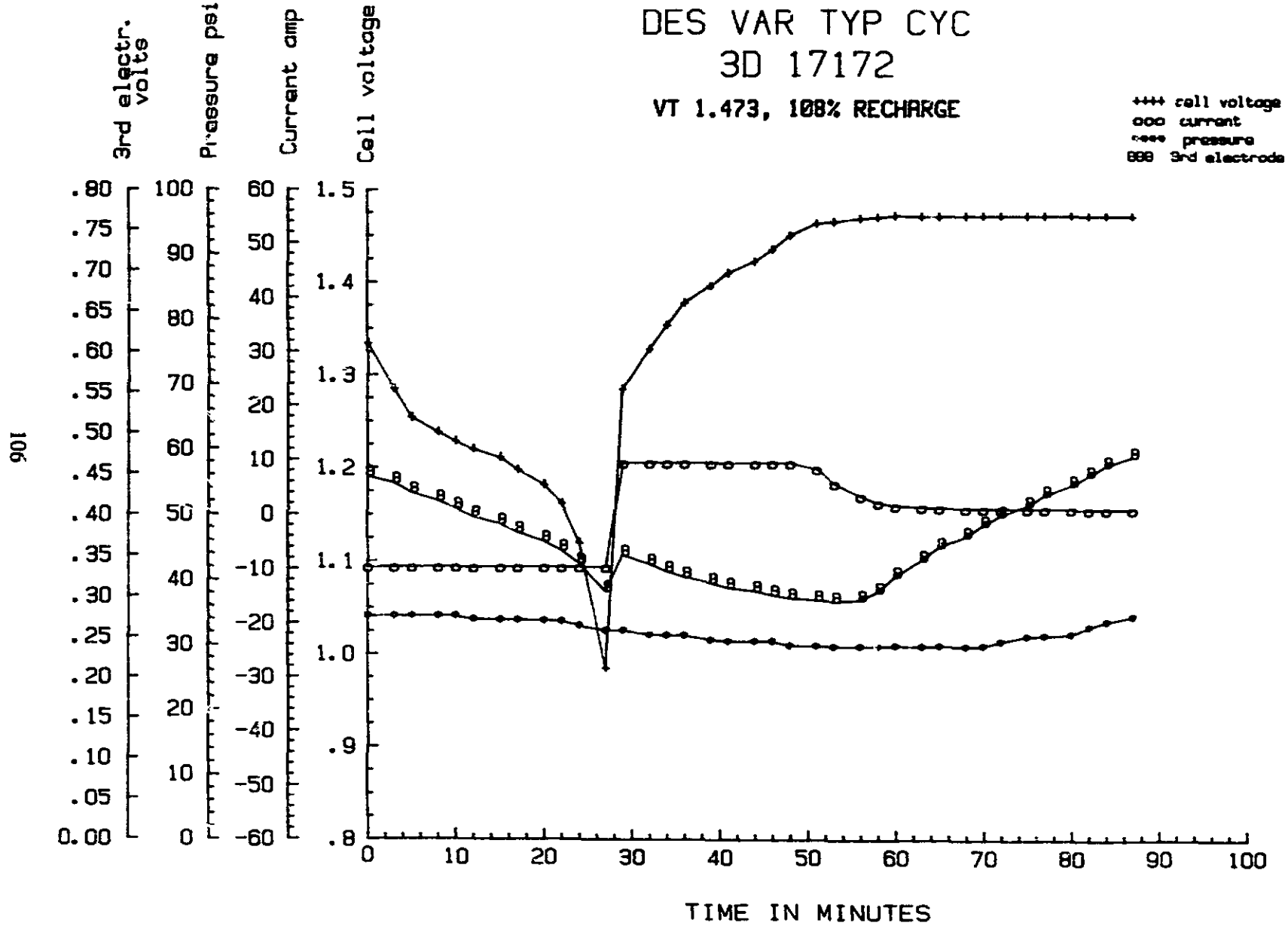
100
TIME IN MINUTES


DES VAR TYP CYC
3L 10339
VT 1.433, 103% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3D 17172
VT 1.473, 108% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
.80
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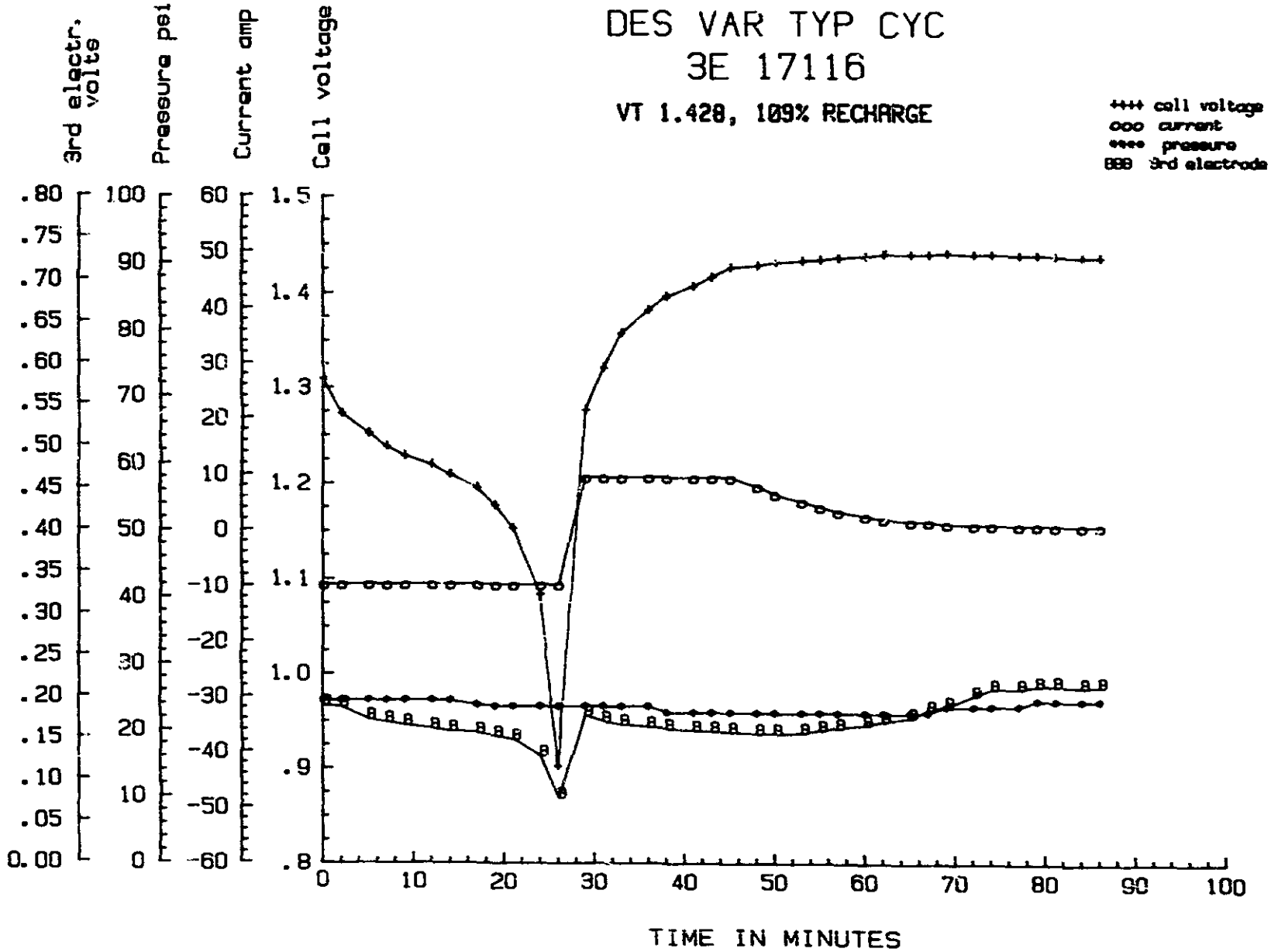
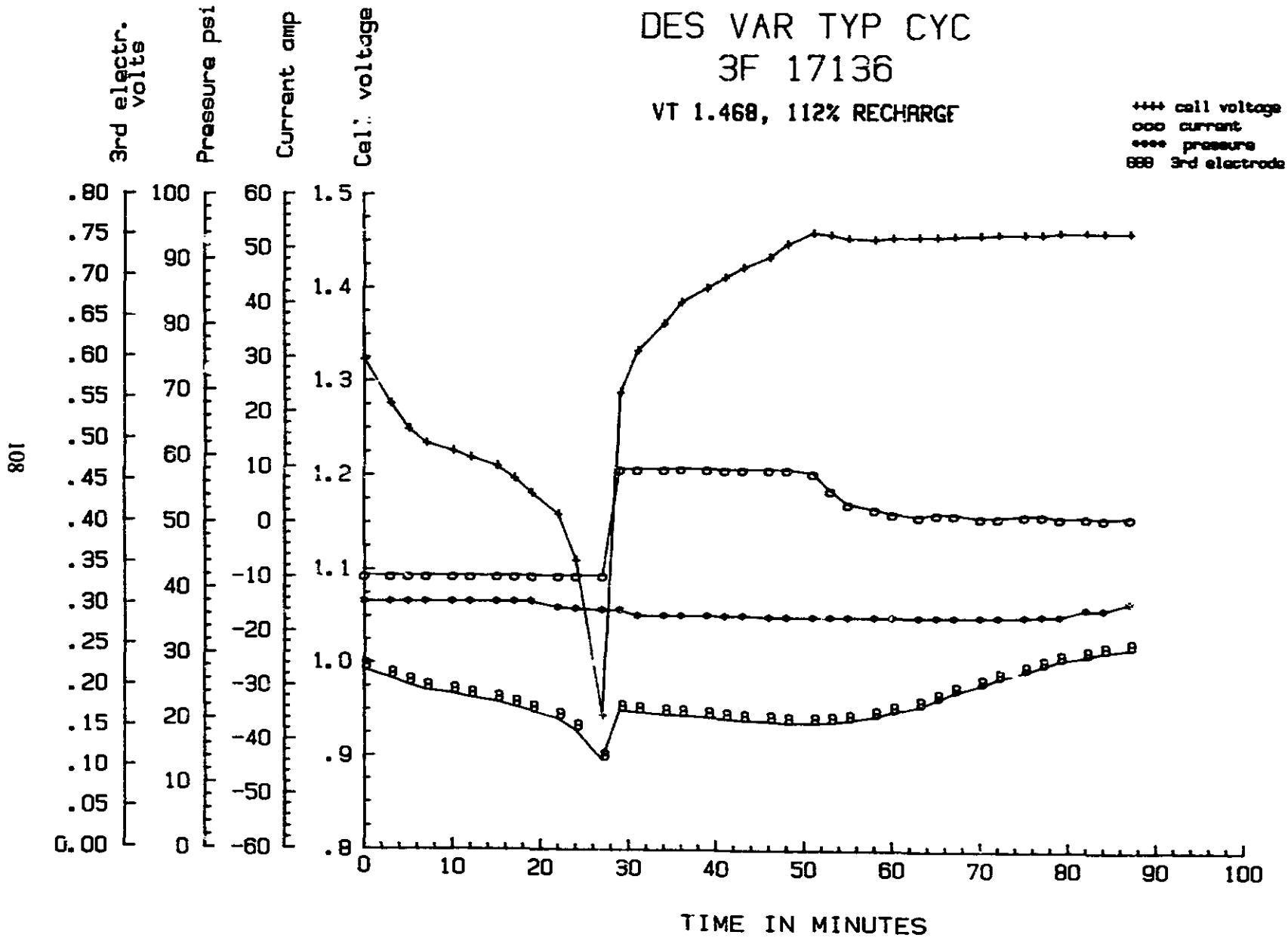
90
100
TIME IN MINUTES
106


DES VAR TYP CYC
3E 17116
VT 1.428, 109% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd elactr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3F 17136
VT 1.468, 112% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
.80
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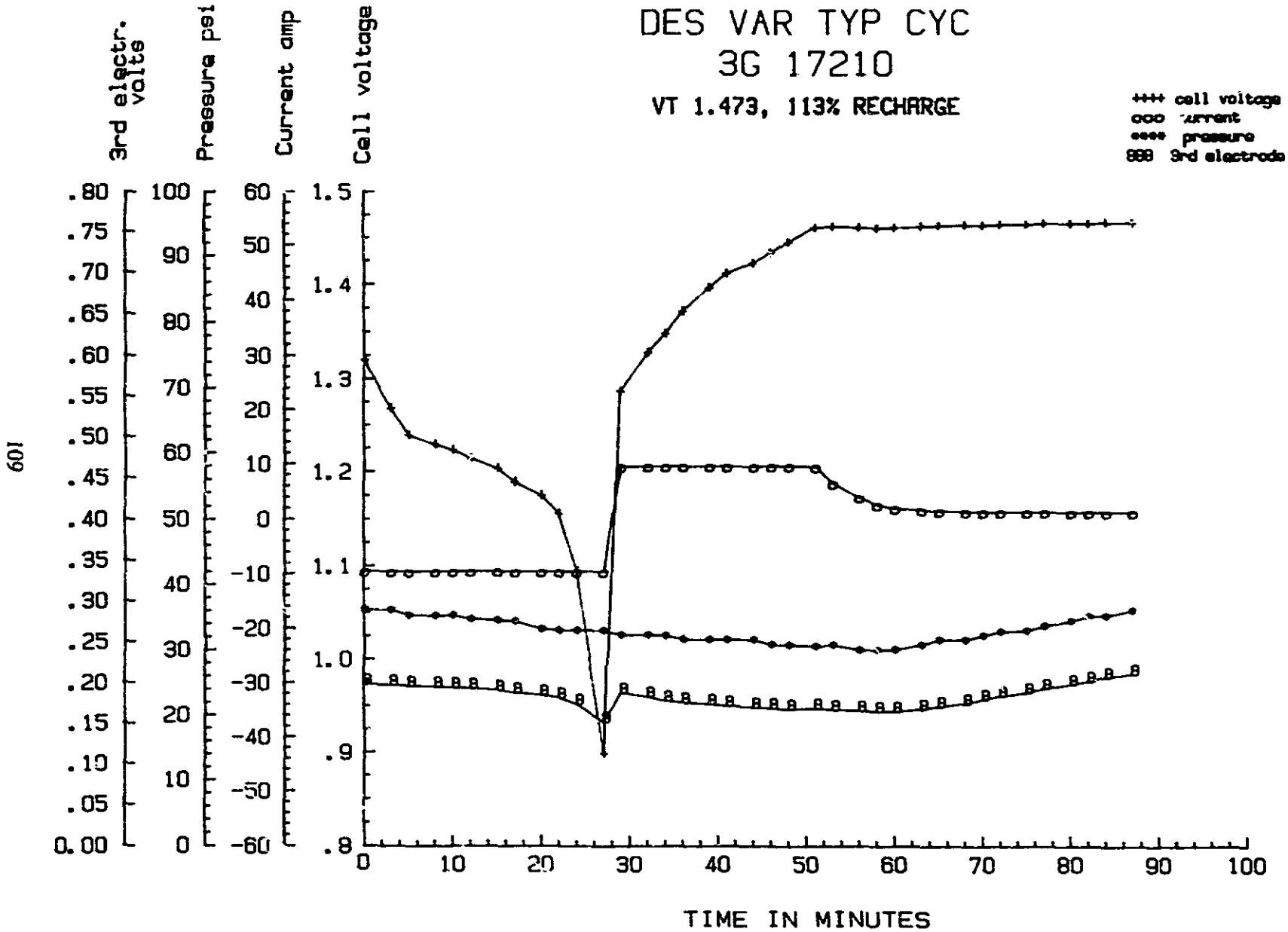
100
TIME IN MINUTES


DES VAR TYP CYC
3G 17210
VT 1.473, 113% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
.80
.75
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.65
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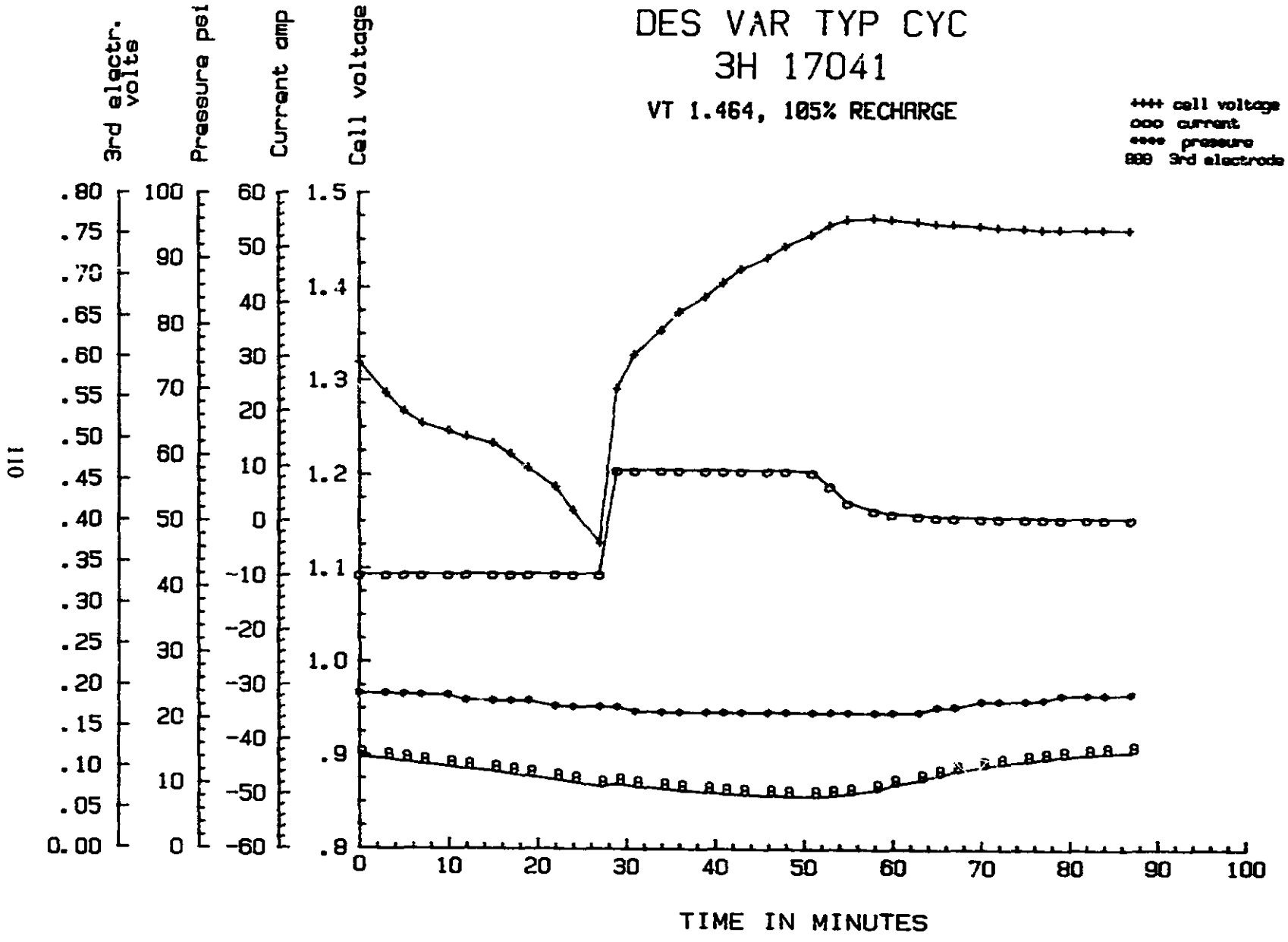
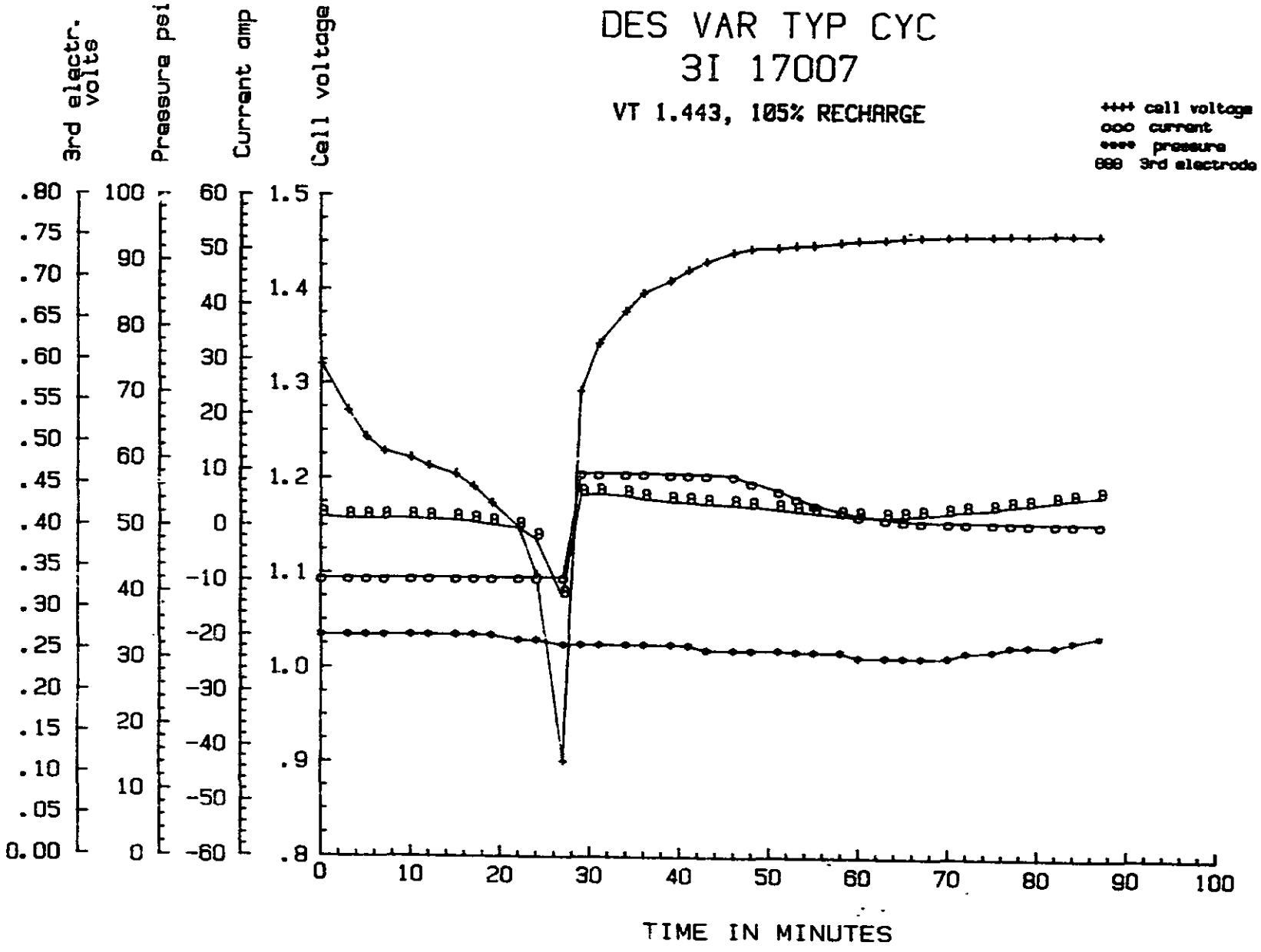
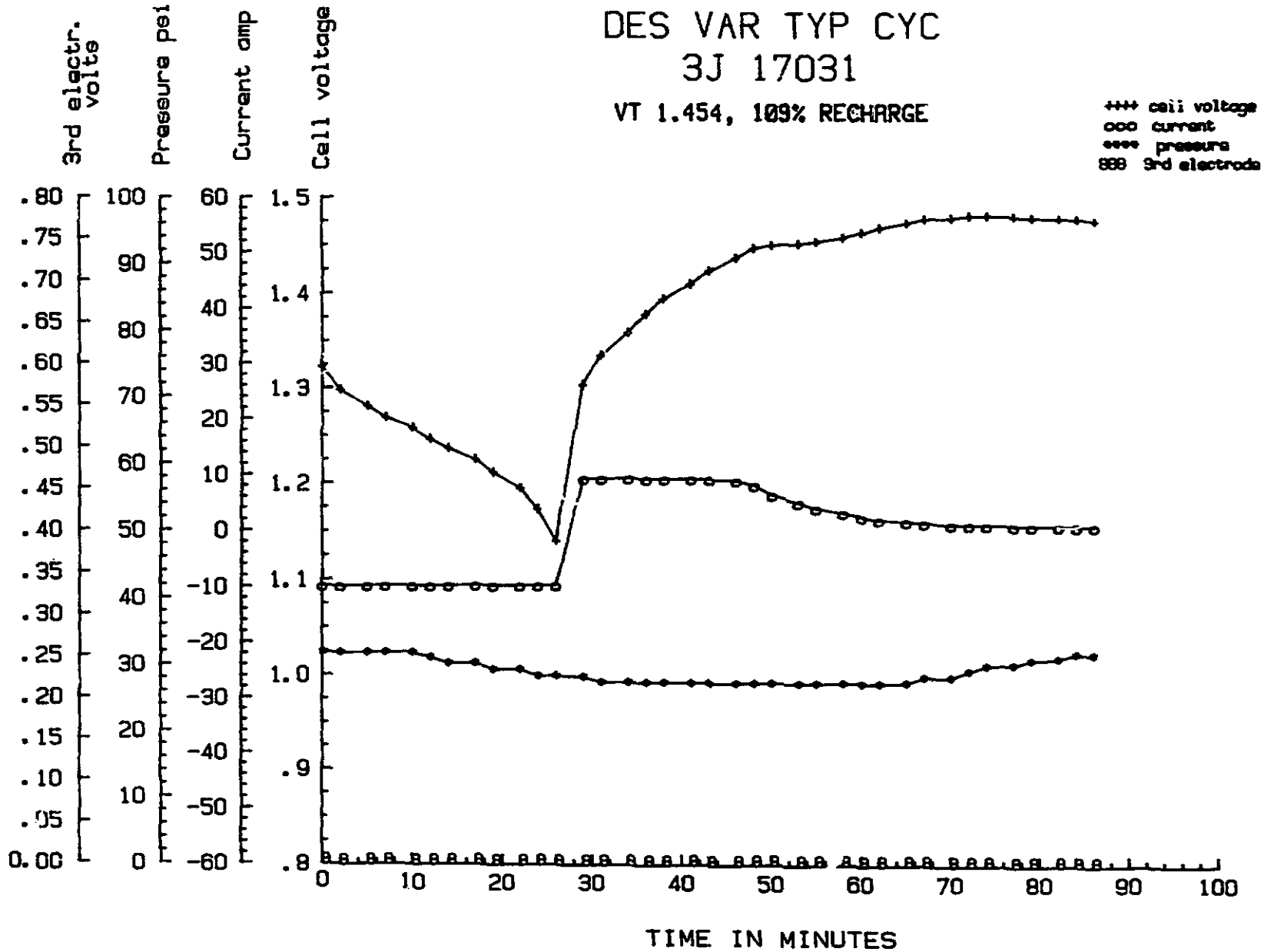
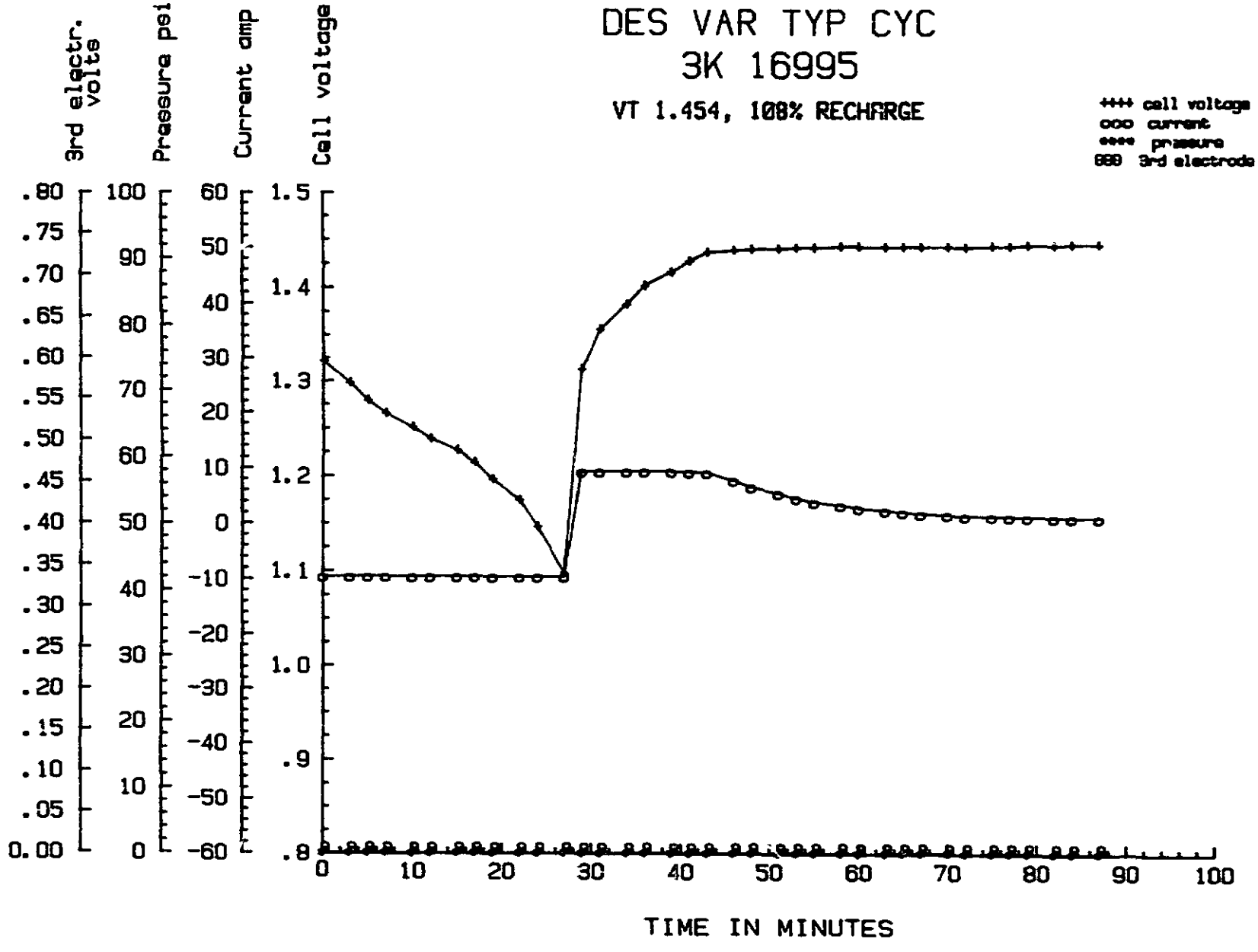
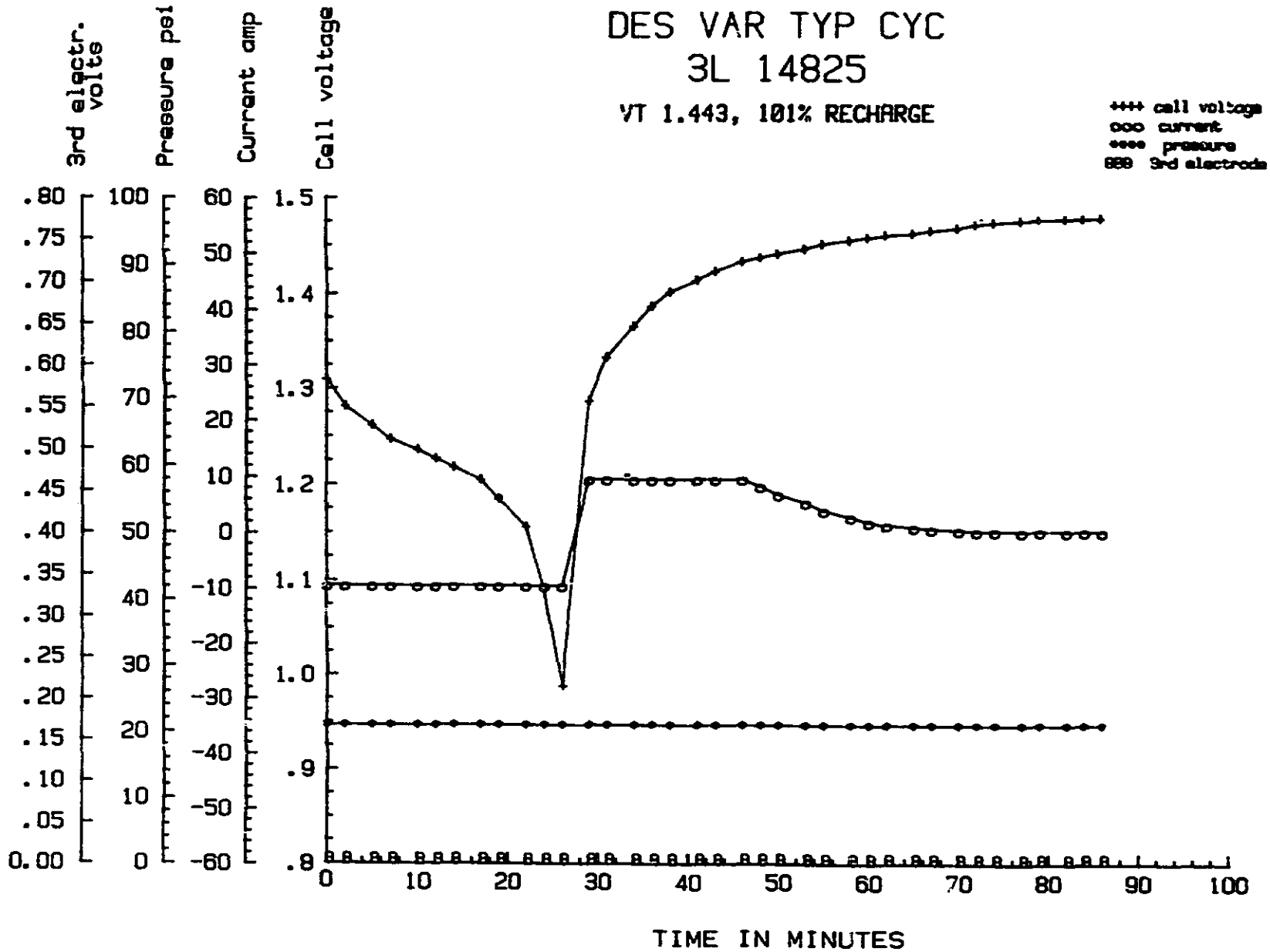
100
TIME IN MINUTES


DES VAR TYP CYC
3H 17041
VT 1.464, 105% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3I 17007
VT 1.443, 105% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3J 17031
VT 1.454, 109% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd elactr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3K 16995
VT 1.454, 108% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd elactr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3L 14825
VT 1.443, 101% RECHARGE
++++ cell voltage
ooo current
**** pressure
3rd electrode
3rd elactr. volts
Pressure psi
Current amp
Cell voltage
.80
.75
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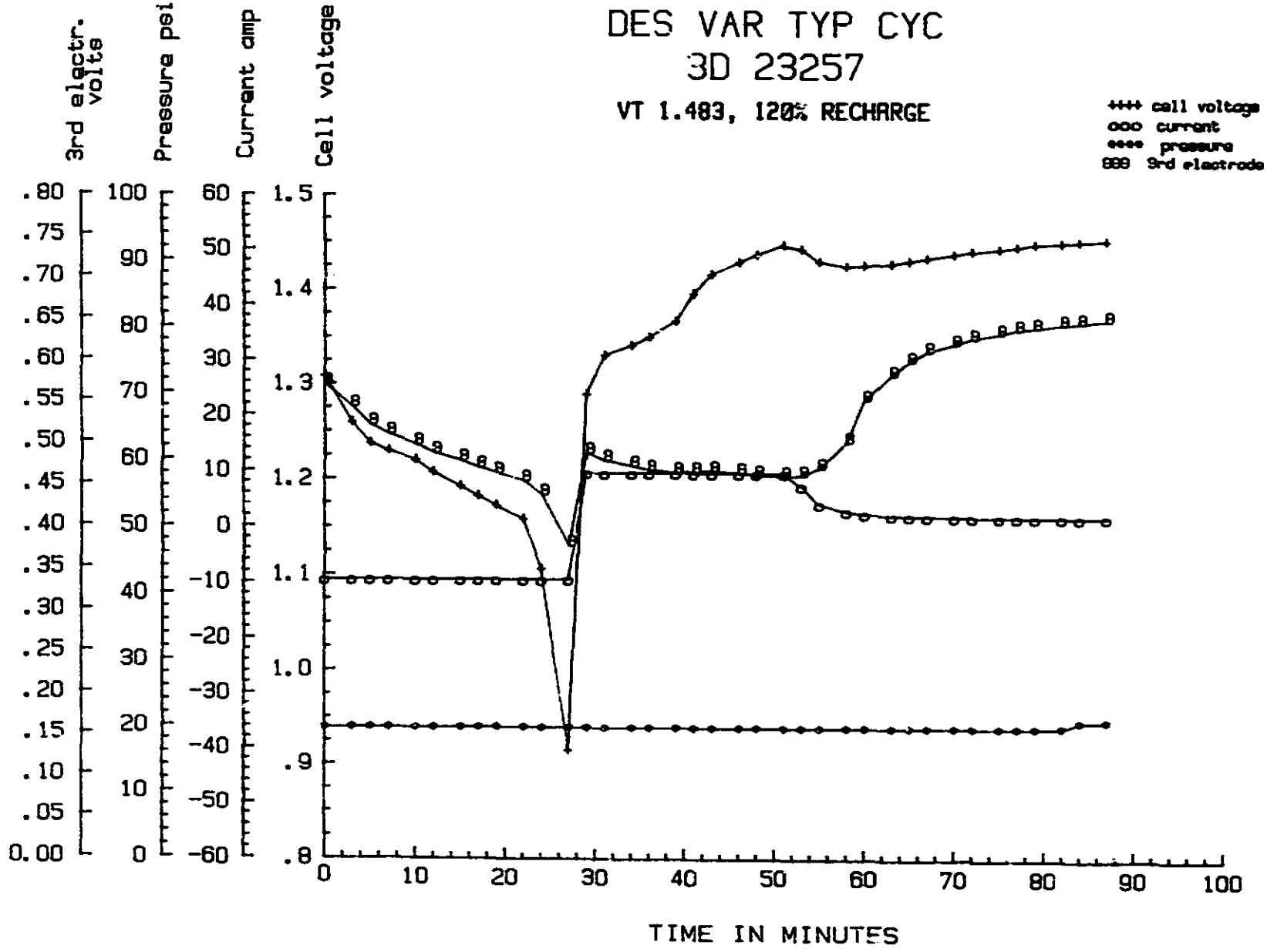
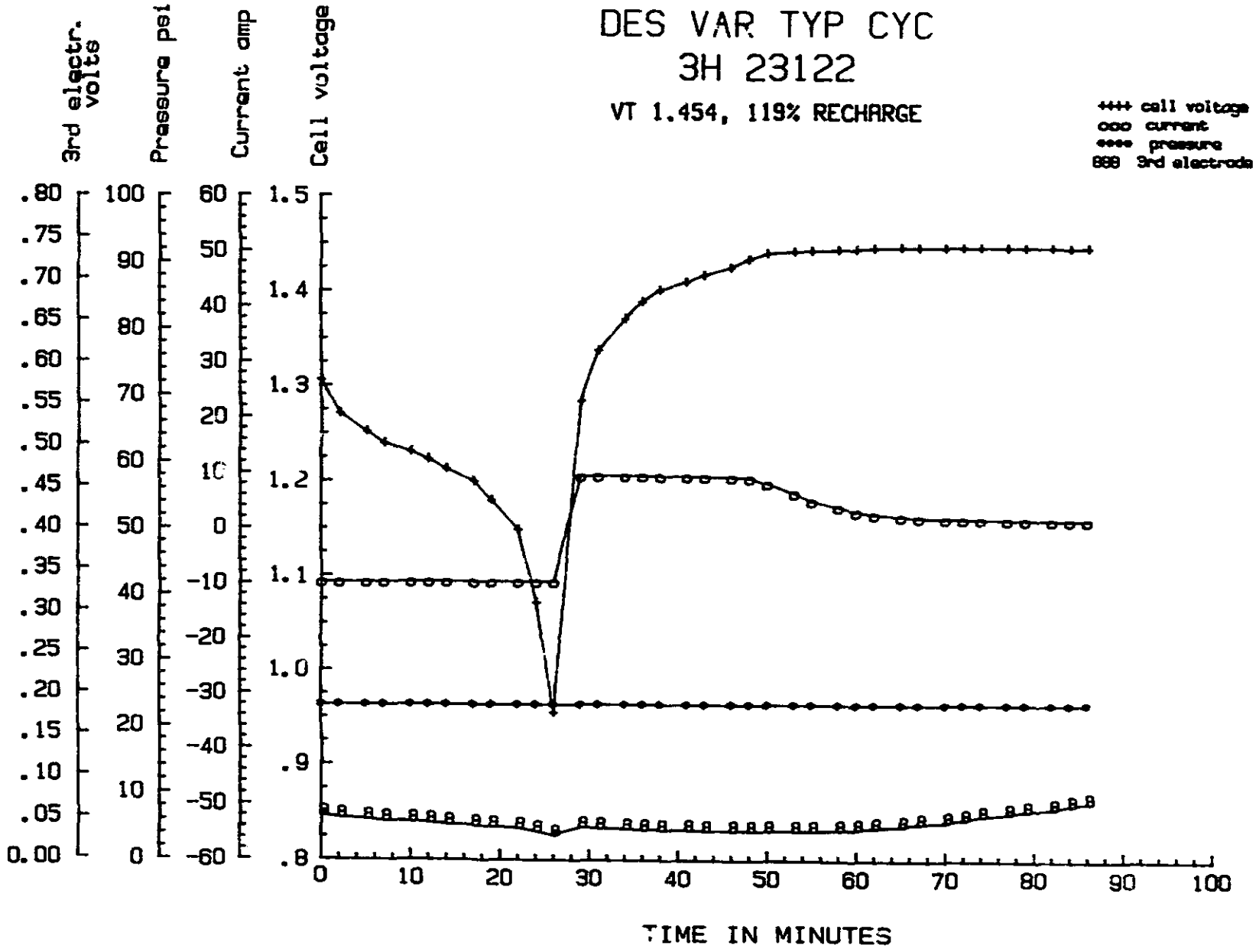
TIME IN MINUTES


DES VAR TYP CYC
3D 23257
VT 1.483, 120% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES


DES VAR TYP CYC
3H 23122
VT 1.454, 119% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
.80
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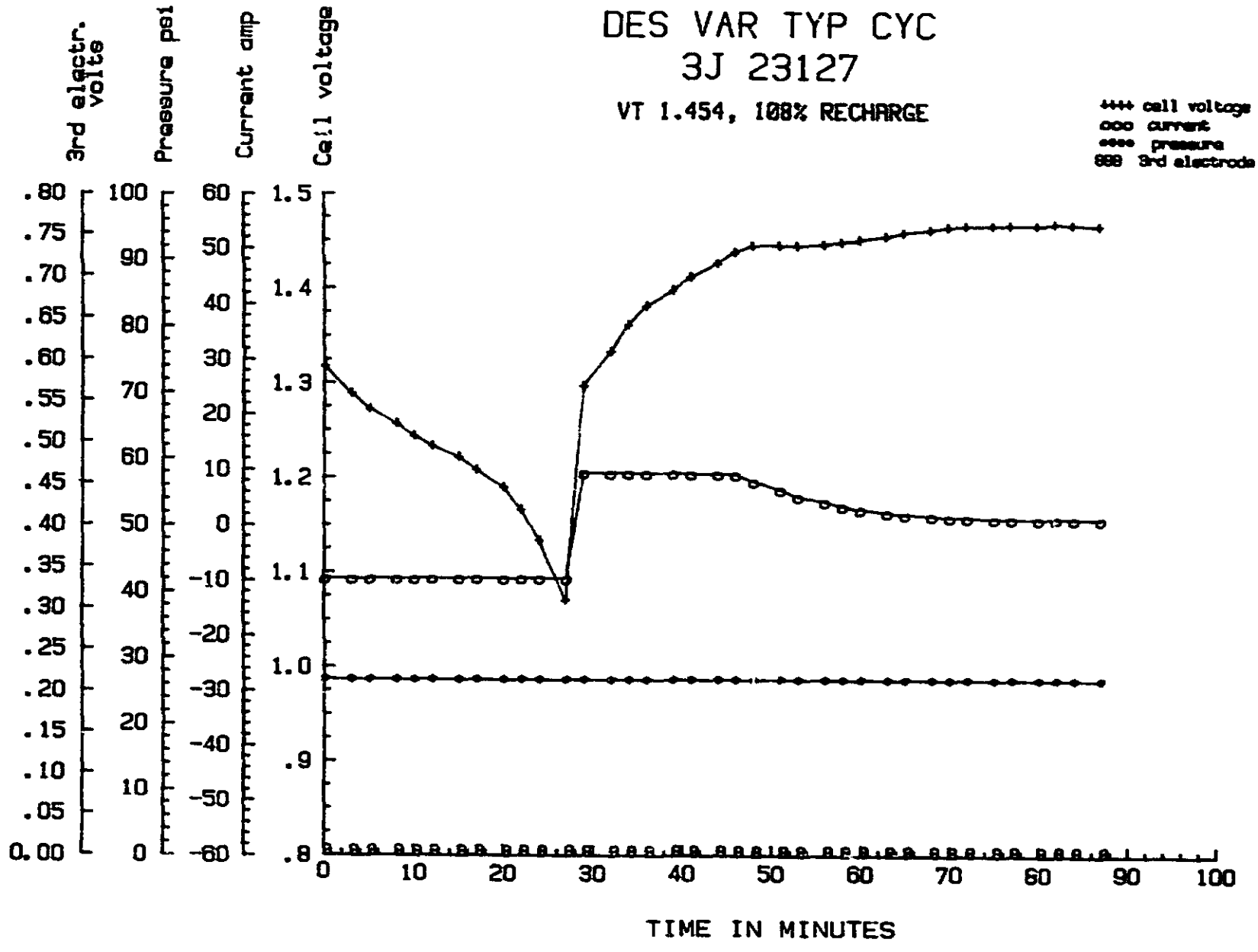
TIME IN MINUTES


DES VAR TYP CYC
3J 23127
VT 1.454, 108% RECHARGE
++++ cell voltage
ooo current
**** pressure
888 3rd electrode
3rd electr. volts
Pressure psi
Current amp
Cell voltage
TIME IN MINUTES

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15. Supplementary Notes

16. Abstract

A program was undertaken in conjunction with the General Electric Company to evaluate 9 of the more important nickel-cadmium aerospace cell designs that are currently being used or that have been used in the past 15 years. Design variables tested in this program included teflonated negative plates, silver treated negative plates, light plate loading level, no positive plate cadmium treatment, plate design of 1968 utilizing both old and new processing techniques, and electrochemically impregnated positive plates. The data acquired from these test packs in a low earth orbit cycling regime is presented and analyzed here. This data showed conclusively that the cells manufactured with no positive plate cadmium treatment outperformed all other cell designs in all aspects of the program and that the cells with teflonated negative electrodes performed very poorly.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Batteries, Electrochemical, Nickel-Cadmium Cells	Unclassifie -Unlimited Subject Category 33

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
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