QUALIFICATION TESTING OF GENERAL ELECTRIC 50 Ah NICKEL-CADMIUM CELLS WITH NEW SEPARATOR AND NEW POSITIVE PLATE PROCESSING

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ABSTRACT

Forty-two 50 Ah aerospace nickel-cadmium cells were delivered to Goddard Space Flight Center (GSFC) by General Electric (GE) in February, 1985 for the purpose of evaluating and qualifying a new nylon separator material, Pellon 2536, and the new GE Positive Plate Nickel Attack Control Passivation process. Testing began in May, 1985 at the Naval Weapons Support Center (NWSC) in Crane, Indiana with standard initial evaluation tests. Life cycling in both Low Earth Orbit (LEO) and Geosynchronous Orbit (GEO) began in July, 1985 with approximately 1200 LEO cycles complete at this writing. Early test results show that cells with positive plate passivation exhibit higher than normal charge voltage characteristics. Other aspects of performance have been nominal.

INTRODUCTION

In the early 1980s, Pellon Corporation announced that it would discontinue the manufacture of aerospace nickel-cadmium separator material, Pellon 2505 ml. That announcement meant that a new separator material would have to be found and qualified for aerospace use. Pellon 2536, very similar to 2505 ml, was chosen in 1984 as the new aerospace separator. In the meantime, GE had developed a new positive plate process to reduce the amount of attack on the nickel sintered structure during the active material impregnation. This process would also need to be qualified. Therefore, a test program was put together by the GSFC to evaluate and qualify both the separator and positive plate process. Cell fabrication for this program was initiated in early 1984 and the cells were delivered in February, 1985.

CELL DESCRIPTION

The 50 Ah nickel-cadmium cells undergoing test were activated with electrolyte during the 37th week of 1984. All cells have dual, nickel-braze, ceramic-to-metal seals and welded prismatic cases with a nominal case wall thickness of 0.0265 inch. The test group is made up of 4 cell designs: 1) NASA standard (42B050AB20), 2) old positive, new separator (42B050AB25), 3) new positive, old separator (42B050AB26), and 4) new positive, new separator (42B050AB27). Cell design data is provided in Table 1. The cells were manufactured to GE Manufacturing Control Document (MCD) 232A2222AA-84 and acceptance tested at GE to Acceptance Test Procedure P24A-PB-222 prior to delivery.

TEST OBJECTIVES

The objectives of this test program are: (1) to evaluate the effects of the new separator material, Pellon 2536, and the new GE Positive Plate Nickel Attack Control Passivation process on cell performance and life, and (2) to qualify these changes for use in NASA/GSFC spacecraft applications.

Initial Evaluation Test Results

The standard initial evaluation test used by the GSFC is outlined in Figure 1. During these tests, the cells were placed in packs of ten and set up so that each pack utilized the same charge and discharge power supplies. This set-up allowed data to be compared across the packs as must be done in a test of this nature.

Tables 2 and 3 provide an overview of data from all 3 capacity tests, 2 overcharge tests, and a charge efficiency test. Review of this data reveals that groups with positive plate passivation exhibited slightly higher peak and end-of-charge (EOC) voltages during the 35°C overcharge. Voltages were as much as 19 mV higher. Also capacity test data shows that all groups began the test with approximately the same capacity. This will allow capacity degradation to be compared directly throughout life. The highest average capacity experienced was 63.7 Ah while the lowest was 58.7 Ah.

From data not included here, it was observed that groups with positive plate passivation recovered to a lower voltage during internal short testing. These voltages were as much as 35 mV lower than expected while still well above the requirement of 1.17 v/cell after 24 hours of open circuit stand. It was also observed that data from internal resistance, charge retention, and pressure versus capacity tests compared well between all groups.

Life Cycling Evaluation Test Description

The identification of each test group and the test matrix outline is detailed in Figure 2. There are 3 cycling regimes in this test: LEO 40% DOD and 20°C (L4020), LEO 40% DOD and 0°C (L4000), and GEO 80% DOD and 20°C (G8020). All 4 cell designs are being tested in the L4020 regime while only the old positive – new separator and new positive – new separator designs are tested in the G8020 regime and only the new positive – new separator design is tested under the L4000 regime.

In the L4020 and L4000 regimes, the cells are discharged at a 0.8C rate (40 amps) for 30 minutes and charged at a 0.8C rate to a voltage clamp at which point the current is allowed to taper for the remainder of the 60 minute charge period. The voltage clamp is selected to allow a percent recharge (C/D) of 112 $\pm$ 2 percent. The G8020 regime is a real-time GEO regime with a 42-day eclipse period occurring twice per year. During shadow periods the cells are discharged at a 0.667C rate (33 amps). Figure 3 shows the daily discharge times for each eclipse season. Following each shadow the packs are charged at a 0.1C rate (5 amps) to 115 percent recharge (C/D) or 1.48 volts any cell, whichever occurs first. At that time the rate is reduced to a 0.17C rate (0.83 amp). During periods of continuous charge (full sun periods), the packs are trickle charged at the 0.17C rate. The packs are reconditioned to 0.75 v/cell before each eclipse season. All test packs contain 5 cells.

Life Cycle Results

At this time the L4020 packs have experienced approximately 1200 cycles while the L4000 pack has seen 800 cycles and the G8020 packs have not yet had the first eclipse season. Problems had been encountered early in cycling in controlling the pack temperatures of the L4020 packs. Pack temperatures rose to as high as 28°C. This was corrected by increasing air circulation in the environmental chambers.

As a whole, the LEO groups have exhibited slightly higher voltages than expected. Voltage clamp levels were expected to be set at GSFC level 7 or below to maintain 112% recharge at the 40% DOD. This, however, has not been the case as levels have had to be raised to 7.5 after about 800 cycles. Also, all packs are exhibiting charge voltage divergence of as much as 20 mV after the voltage is clamped. This can be seen on the typical cycle plots of Figures 3-7.

CONCLUSIONS

Slightly higher charge voltages as well as increased voltage divergence has been observed of all new positive plate test packs. This is observed most clearly in overcharge tests and LEO cycling test voltage level settings. Apart from this, all packs are performing nominally. Life cycle testing will continue to failure.

Table 1: CELL DESIGN DATA

	NASA STANDARD		OLD POSITIVE NEW SEPARATOR		NEW POSITIVE OLD SEPARATOR		NEW POSITIVE NEW SEPARATOR	
	Pos.	Neg.	Pos.	Neg.	Pos.	Neg.	Pos.	Neg.
	31069	45008	31069	45008	45046	45008	45046	45008
	59.23	130.06	59.23	130.06	60.62	130.06	60.62	130.06
Ah	78.50	149.71	78.50	149.71	74.86	149.71	74.86	149.71
	76	87	76	87	81	87	81	87
	16	17	16	17	16	17	16	17
	1.422	1.422	1.422	1.422	1.422	1.422	1.422	1.422
in.)	0.027	0.031	0.027	0.031	0.027	0.031	0.027	0.031
	12.21	15.86	12.21	15.86	12.12	15.86	12.12	15.86
	166		157		162		155	
	Pellon 2505		Pellon 2536		Pellon 2505		Pellon 2536	
	20.83		21.25		21.40		20.97	

Table 2. INITIAL EVALUATION CAPACITY TEST RESULTS

	C/20 Chr., 48 hrs., 25°C			C/10 Chr., 24 hrs., 25°C			C/10 Chg., 24 hrs., 20°C		
	Ave.	Low	High	Ave.	Low	High	Ave.	Low	High
	63.2	62.8	63.8	56.8	56.5	57.3	56.3	55.8	57.0
ew Sep.	62.7	61.8	63.8	56.6	55.3	57.3	56.1	55.3	57.8
ld Sep.	60.1	59.5	61.3	55.9	55.3	56.8	57.8	56.5	58.8
lew Sep.	59.4	58.8	60.3	55.0	54.0	58.0	56.4	54.8	58.8
ew Sep.	63.7	62.1	64.3	58.9	57.8	59.6	60.6	60.3	61.3
New Sep.	58.7	57.8	59.1	54.3	53.1	54.9	58.4	57.8	58.8
New Sep.	59.2	58.5	59.6	54.6	53.4	55.6	58.8	57.8	59.3

Table 3. INITIAL EVALUATION OVERCHARGE TEST AND CHARGE EFFICIENCY TEST RESULTS

	Overcharge #1 C/20 Chg., 60 hrs., 0°C		Overcharge #2 C/10 Chg., 24 hrs., 35°C		Charge Efficiency C/40 Chg., 20 hrs., 20°C		
Group	Ave. EOCV	Peak V	Ave. EOCV	Peak V	Ah In	Ah Out	Eff.
NASA Std. (Grp. 1)	1.512	1.538	1.406	1.407	29.9	17.2	69.1
Old Pos., New Sep. (Grp. 2)	1.516	1.542	1.404	1.408	24.9	16.7	67.1
New Pos., Old. Sep. (Grp. 3)	1.513	1.541	1.419	1.424	24.9	15.1	60.6
New Pos., New Sep. (Grp. 4)	1.512	1.541	1.412	1.423	25.7	16.5	64.2
Old Pos., New Sep. (Grp. 7)	1.514	1.536	1.406	1.408	24.5	16.6	67.8
New Pos., New Sep. (Grp. 8)	1.512	1.543	1.418	1.427	25.0	16.6	66.5
New Pos., New Sep. (Grp. 9)	1.511	1.545	1.418	1.425	25.0	16.5	66.0

- PHENOLPHTHALEIN LEAK TEST
- THREE CAPACITY TESTS
- INTERNAL RESISTANCE TEST
- CHARGE RETENTION TEST, 20°C
- INTERNAL SHORT TEST
- CHARGE EFFICIENCY TEST, 20°C
- OVERCHARGE TESTS, 0° and 35°C
- PRESSURE VERSUS CAPACITY TEST
- PHENOLPHTHALEIN LEAK TEST

Figure 1. INITIAL EVALUATION TEST REGIME

ORBIT	DOD	TEMP (°C)	NASA STD. CELLS	OLD POS. NEW SEP.	NEW POS. OLD SEP.	NEW POS. NEW SEP.
LEO	40	20	Group 1 42B050AB20 S/N 2-7	Group 2 42B050AB25 S/N 2-7	Group 3 42B060AB26 S/N 2-8	Group 4 42B060AB27 S/N 3-6, 11, 12
GEO	80	20		Group 7 42B050AB25 S/N 1, 8-12		Group 8 42B050AB27 S/N 1, 7-10
LEO	40	0				Group 9 42B050AB27 S/N 2, 13-16

Figure 2: LIFE CYCLING TEST MATRIX

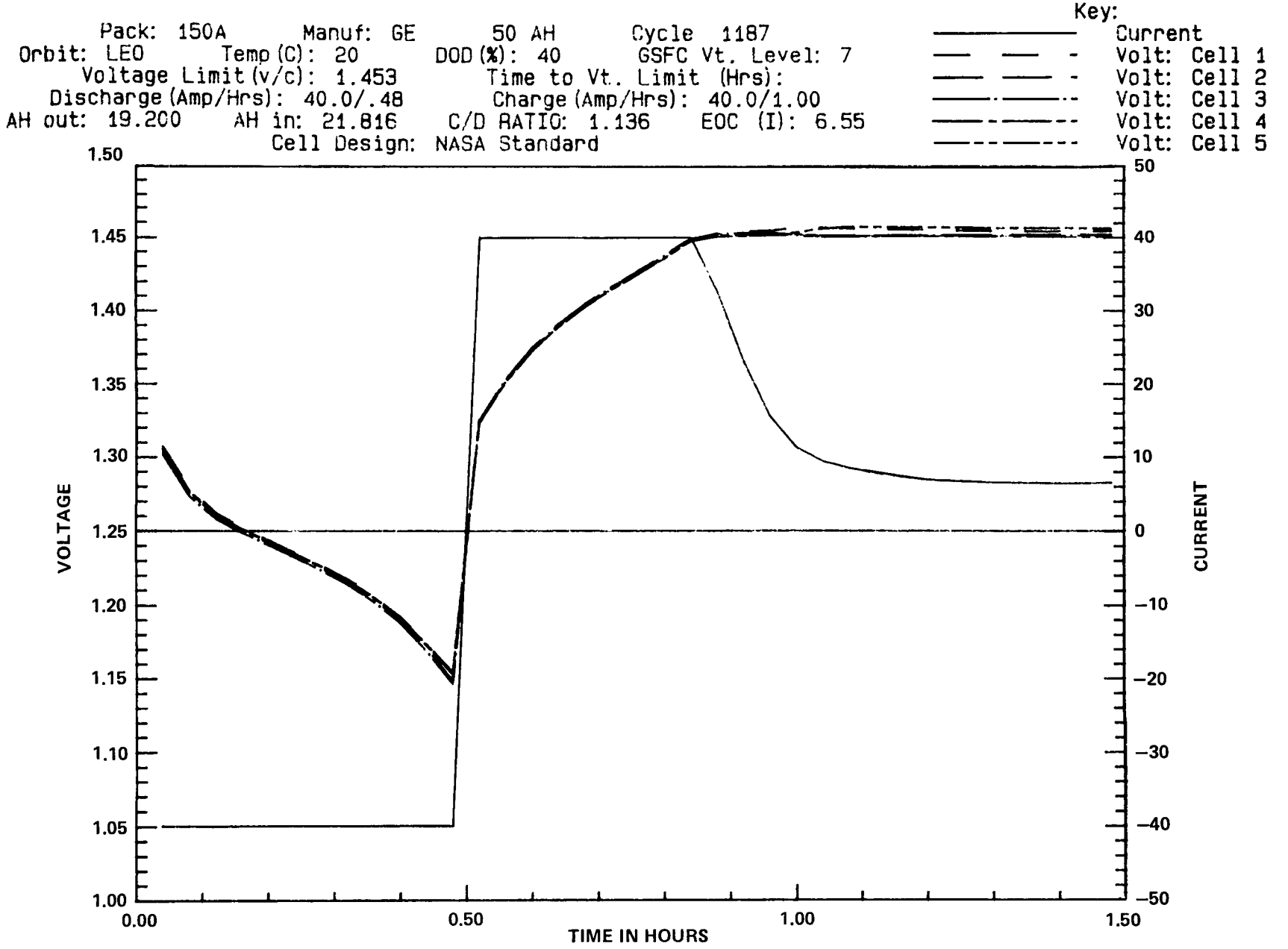

Figure 3. REQUALIFICATION-LIFE CYCLING

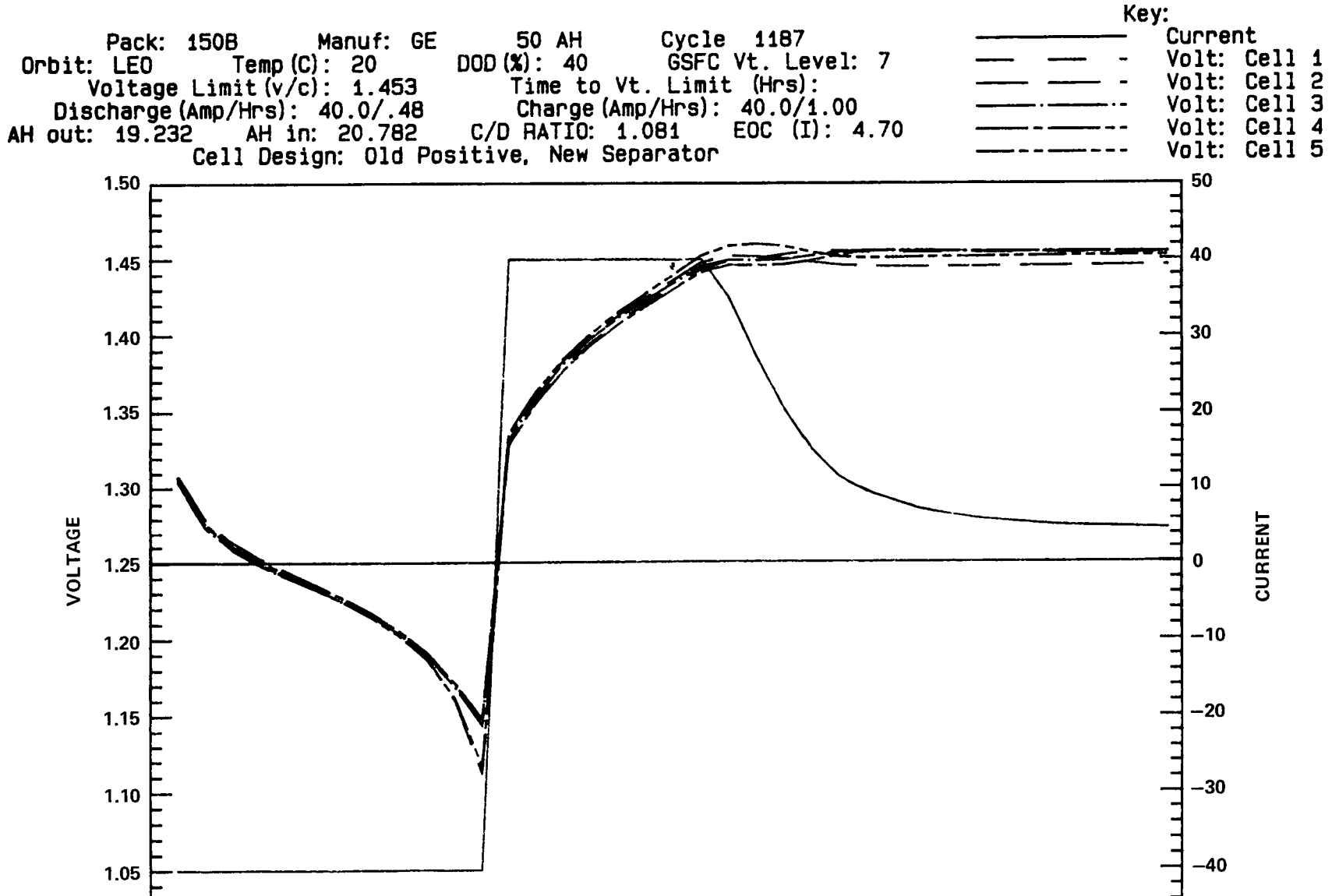

Figure 4. REQUALIFICATION-LIFE CYCLING

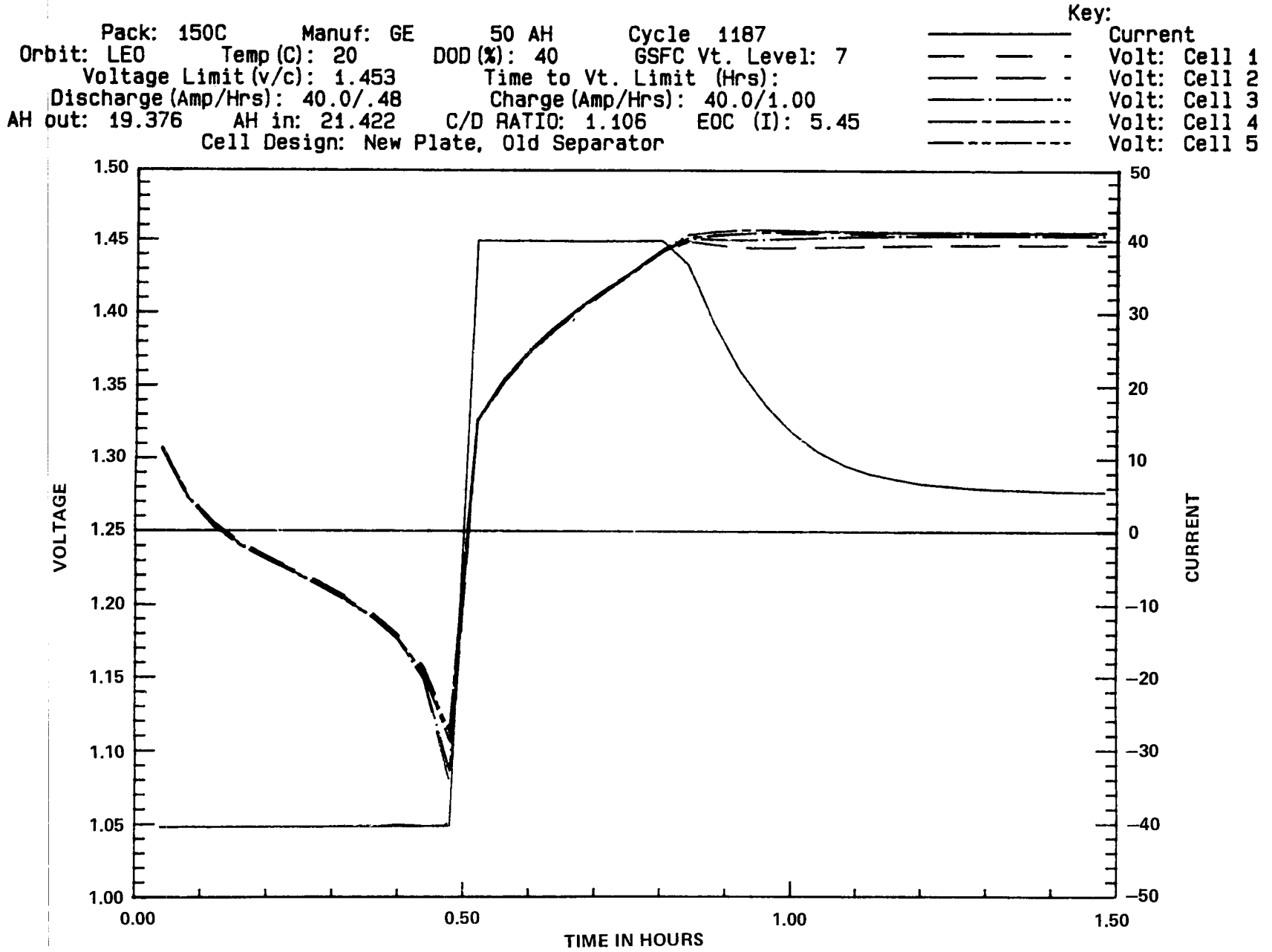

Figure 5. REQUALIFICATION-LIFE CYCLING

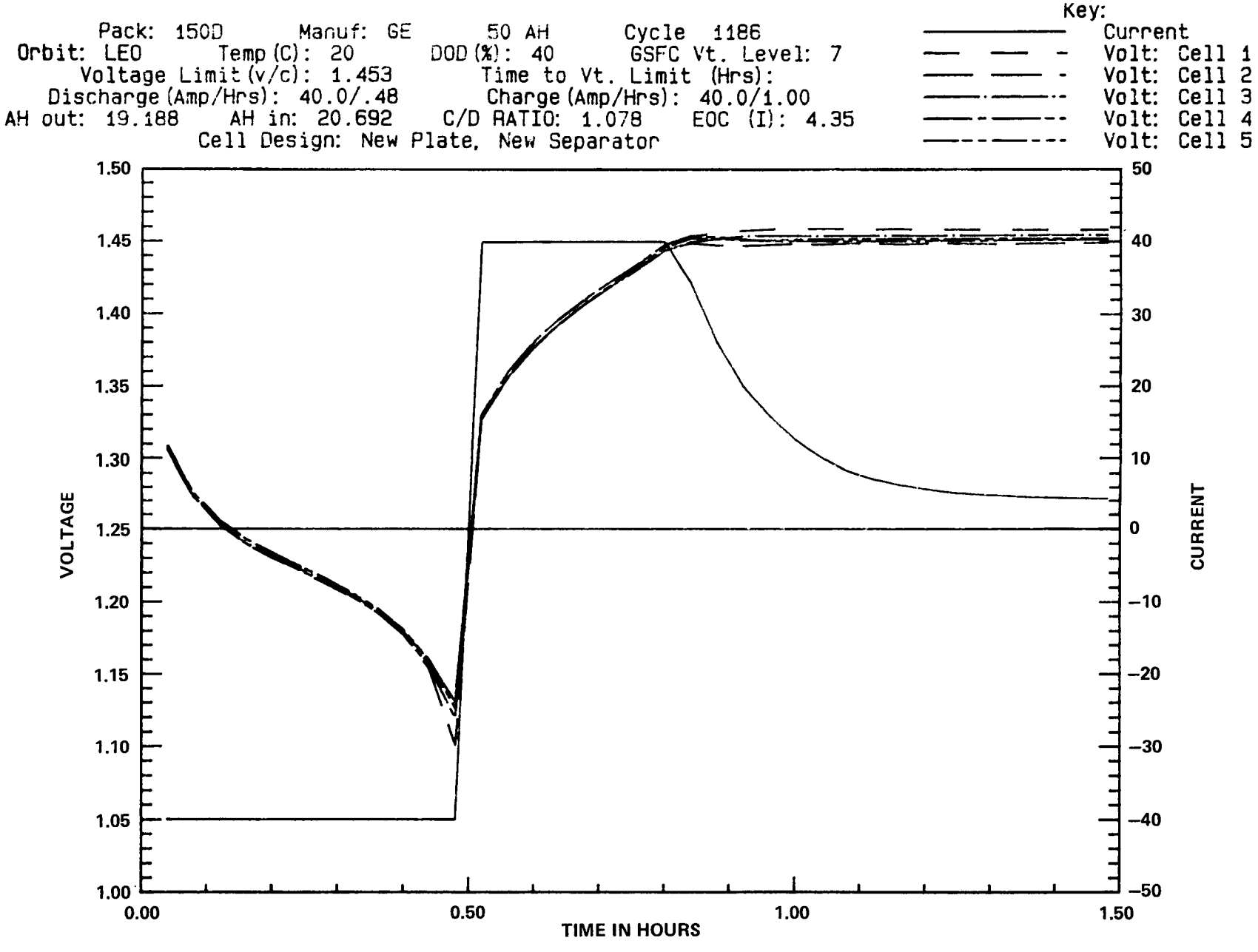

Figure 6. REQUALIFICATION-LIFE CYCLING

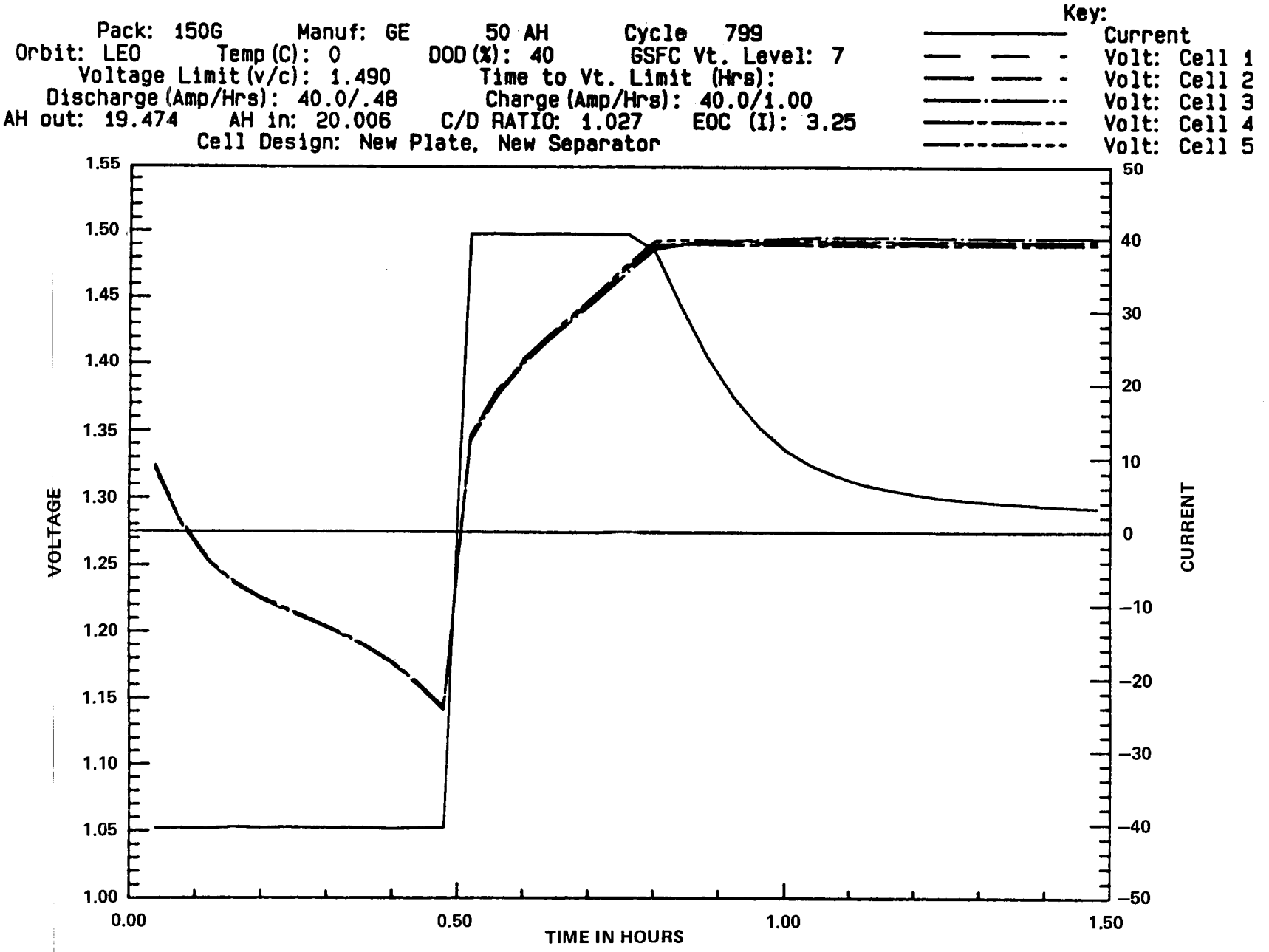

Figure 7. REQUALIFICATION-LIFE CYCLING