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# NOAA 26.5 Ah LEO CHARACTERIZATION TEST

George W. Morrow
Goddard Space Flight Center
Greenbelt, MD 20771

## ABSTRACT

Five General Electric (GE) 26.5 Ah NOAA-G flight nickel-cadmium cells were obtained from RCA-Astro Electronics to undergo performance characterization testing at the Goddard Space Flight Center (GSFC). This lot of cells was manufactured with passivated positive plate, to control nickel structure attack during active material impregnation, and less electrolyte than normal (< 3cc/Ah). The cells were tested in a parametric Low Earth Orbit (LEO) cycling regime that had previously been used to test and characterize GSFC standard 50 Ah cells. Life cycle testing at the Naval Weapons Support Center (NWSC) in Crane, Indiana followed. The results of the test showed nominal performance in comparison with previous test data on the standard 50. Life cycle testing in the NOAA orbital regime is continuing at NWSC.

## INTRODUCTION

The NOAA-G spacecraft battery cell flight lot was manufactured by GE in Gainesville, Florida. GE fabricated these cells using a new positive electrode processing step designed to increase the strength of the electrode by reducing attack on the nickel sintered structure by active material impregnation solutions. This passivation process reduces the void volume of the cell, thus reducing the amount of electrolyte that can be added. Questions about the reliability of cells with this new processing step and less electrolyte brought about characterization testing by the GSFC.

Characterization was accomplished by subjecting 5 cells to a parametric LEO cycling regime developed to characterize GSFC standard 50 Ah cells. Data was then compared between the cell designs. Following the characterization test, the cells were shipped to NWSC for life cycle evaluation.

## TEST OBJECTIVES

The objectives of this test program were: (1) to study the behavior of aerospace cells manufactured with GE positive trode nickel attack control passivation, (2) to compare this behavior to that of cells without passivation, and (3) to charrize the performance of these cells in a typical NOAA orbit with the same charge voltage levels as the NOAA-F spacecraft.

### Description

The cells tested are GE 26.5 Ah aerospace nickel-cadmium cells containing third (signal) electrodes. They were manufacl with teflonated negative electrodes, cadmium treated positive electrodes, and positive electrode nickel attack control ration. The cells were manufactured to GE Manufacturing Control Document (MCD) 232A2222AA-80 and are desigl Catalog Number 42B030AB10/11. The cells are from NOAA lot 11 activated in February 1984 and acceptance tested E Acceptance Test Procedure P24A-PB-222 prior to shipment to RCA.

### Performance Characterization Test Description

'he cells were tested in a series connected 5-cell pack separated and isolated by 3/8-inch aluminum plates followed by -inch PVC sheets. The pack was held by 3/8-inch stainless steel bolts torqued to 30 lb/in$^2$. The cell bottoms were filled RTV to provide a flat, thermally conductive surface. The pack was wired with individual cell voltage monitors and 5 ocouples. The thermocouples were located on the tops of cells 1, 3, and 5 and on the broadface center of cells 2 and

4. For the test, the pack bottom was coated with thermal grease and placed on an active thermal cooling plate in a Tenney environmental chamber.

The parametric test regime is shown in Figure 1. Four charge rates (0.2C, 0.3C, 0.5C, 0.8C) and 4 discharge rates (0.1C, 0.2C, 0.5C, 0.8C) were chosen for the test. The discharge rates coupled with a discharge time of 30 minutes resulted in depths of discharge (DOD) of 5, 10, 25, and 40 percent. Three charge voltage levels were chosen (GSFC 3, 5, 7) as were 3 temperatures (0, 10, 20°C). The charge voltages corresponding to each temperature are shown in Figure 2.

During the test, 8 cycles of each of the 13 charge-discharge combinations, shown in Figure 1, were completed at each temperature and voltage level. Before each temperature or voltage level change, 16 stabilization cycles were run. A stabilization cycle consisted of one 30-minute discharge at 0.5C followed by a 60-minute voltage limit taper charge at 0.5C to GSFC voltage level 6 at 20°C. Eight hundred stabilization cycles were also run prior to test startup to stabilize pack characteristics. The entire parametric test consisted of approximately 1900 cycles.

## RESULTS

Throughout the test each set of 16 stabilization cycles was compared to chart the state of the pack. End-of-discharge (EOD) voltage remained constant throughout the test as did the end-of-charge (EOC) taper current level and C/D recharge ratio. This is shown on Figure 3. Capacity performance was also very good considering the varying conditions experienced. A precycling capacity measurement provided 33.2 Ah from the cells at an average plateau voltage of 1.24 v/cell, while a post-cycling capacity check yielded 30.1 Ah capacity at an average plateau voltage of 1.22 v/cell. Capacity test data is provided in Figure 4.

Parametric test data was plotted in the form of percent recharge (C/D) versus voltage level and C/D versus charge current level. This data was plotted against data from the standard 50 Ah cells under the same conditions. The trends of these plots compare very well as can be seen in the sample plots of Figures 5 – 13. Actual numerical data cannot be directly compared because of differences in cell design. Trend data is expected to compare very well for all aerospace nickel-cadmium cells regardless of design as is the case here. Poor correlation of trend data between cell designs may indicate problems related to manufacture and fabrication of the cells.

Data from this test also indicates that the cells exhibit slightly lower voltage characteristics than the 50 Ah cells to which they were compared. Full recharge was reached in almost all cases at both voltage levels 5 and 7. There was, therefore, no indication of slightly higher voltages as might have been expected from cells with low amounts of electrolyte.

### NOAA Regime Test Results

Following the LEO performance characterization test, the cells were cycled in a parametric regime with characteristics similar to those experienced on the NOAA-F spacecraft. The pack was discharged for 35 minutes at 0.42C and charged for 69 minutes to RCA voltage levels 1, 2, 3, and 4 at 10°C. Eight cycles at each voltage level were performed with 16 stabilization cycles between each voltage level change. Full recharge ($>$106% C/D) was reached at RCA levels 3 and 4. In all other aspects, the cells performed nominally.

### Life Cycle Test at NWSC

In June 1985 following all testing at the GSFC, the cells were sent to NWSC to undergo life cycle testing. The life cycle regime is detailed in Figure 14. The cells have performed nominally since the start of testing and have undergone approximately 1200 cycles at the time of this writing. The initial voltage level of 1.47 v/cell has provided approximately 106% C/D as is shown in the typical cycle plots of Figures 15 – 18.

## CONCLUSIONS

LEO performance characterization tests have shown that the capacity and voltage performance of these cells is nominal. Also, parametric test data trend plots show that these cells react in a manner consistent with other aerospace nickel-cadmium cells when subjected to various charge-discharge currents, charge voltage levels, and temperatures. Further, these tests have shown that these cells obtain full recharge with the same range of charge voltage levels as experience predicts.

Parametric tests using the voltage levels and charge-discharge currents of the NOAA-F spacecraft indicate that these cells will perform satisfactorily under those conditions. Lastly, life cycle data during the first 1200 cycles of simulated LEO operation shows no abnormal or unexpected behavior. In light of the above findings, the cells should perform nominally in orbit. No problems are foreseen and no concern exists with regard to the low electrolyte levels or the positive plate nickel attack control passivation.

| CHARGE RATE | | DISCHARGE RATE | | | |
|---|---|---|---|---|---|
| | | 0.1C | 0.2C | 0.5C | 0.8C |
| | 0.2C | X | X | | |
| | 0.3C | X | X | X | |
| | 0.5C | X | X | X | X |
| | 0.8C | X | X | X | X |

- 8 CYCLES AT EACH CONDITION
- DISCHARGE TIME: 30 MINUTES
  CHARGE TIME: 60 MINUTES
- VOLTAGE LIMITS: GSFC 3, 5, 7
- TEMPERATURES: 0, 10, 20° C

NOTE: 16 BASELINE CYCLES RUN BETWEEN EACH VOLTAGE LIMIT/TEMPERATURE TEST TO STABILIZE PACK

Figure 1. LEO PERFORMANCE CHARACTERIZATION REGIME

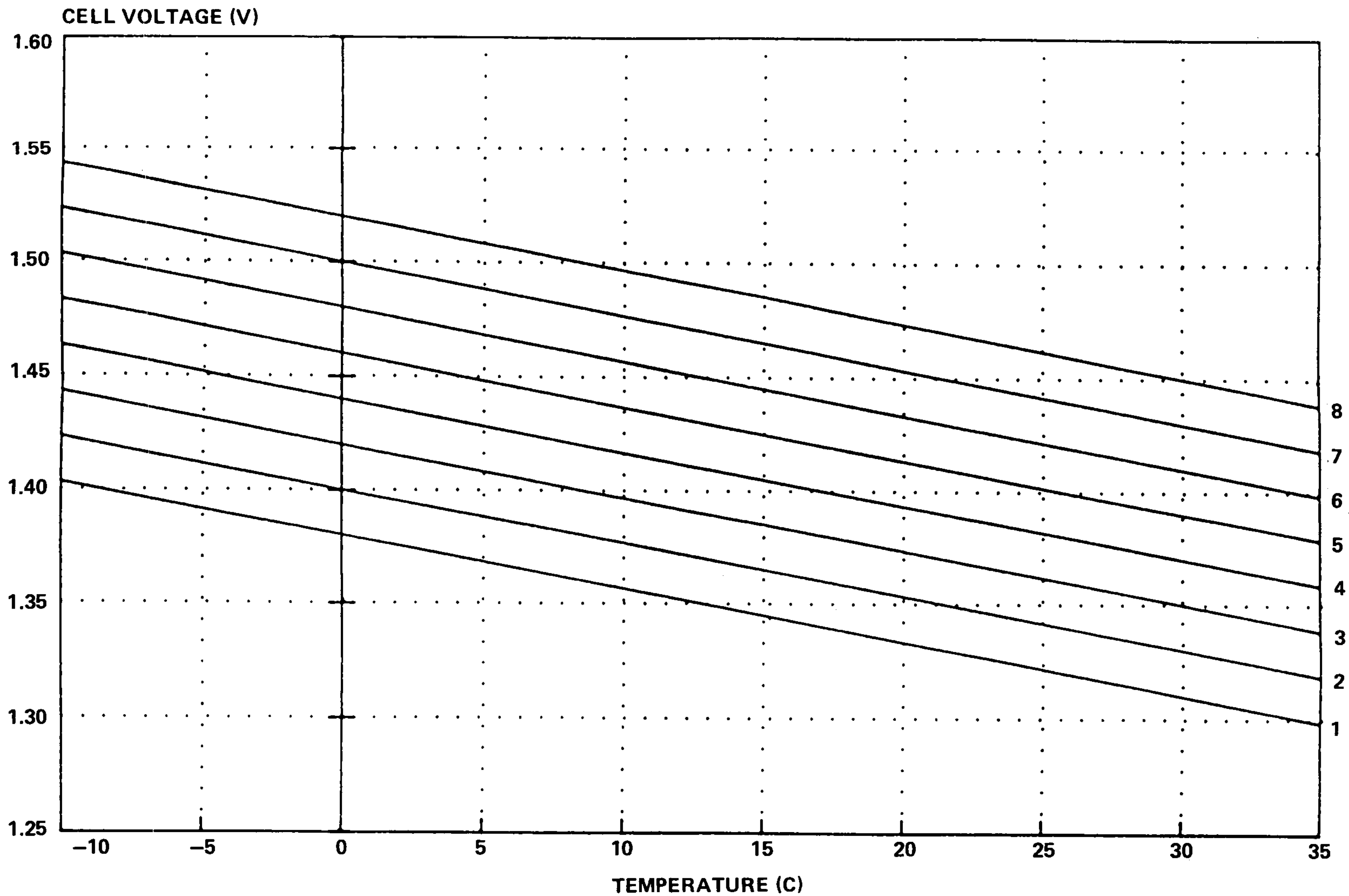


Figure 2. NASA/GSFC STANDARD Ni-Cd VOLTAGE/TEMPERATURE CHARGE CHARACTERISTICS ON A CELL BASIS

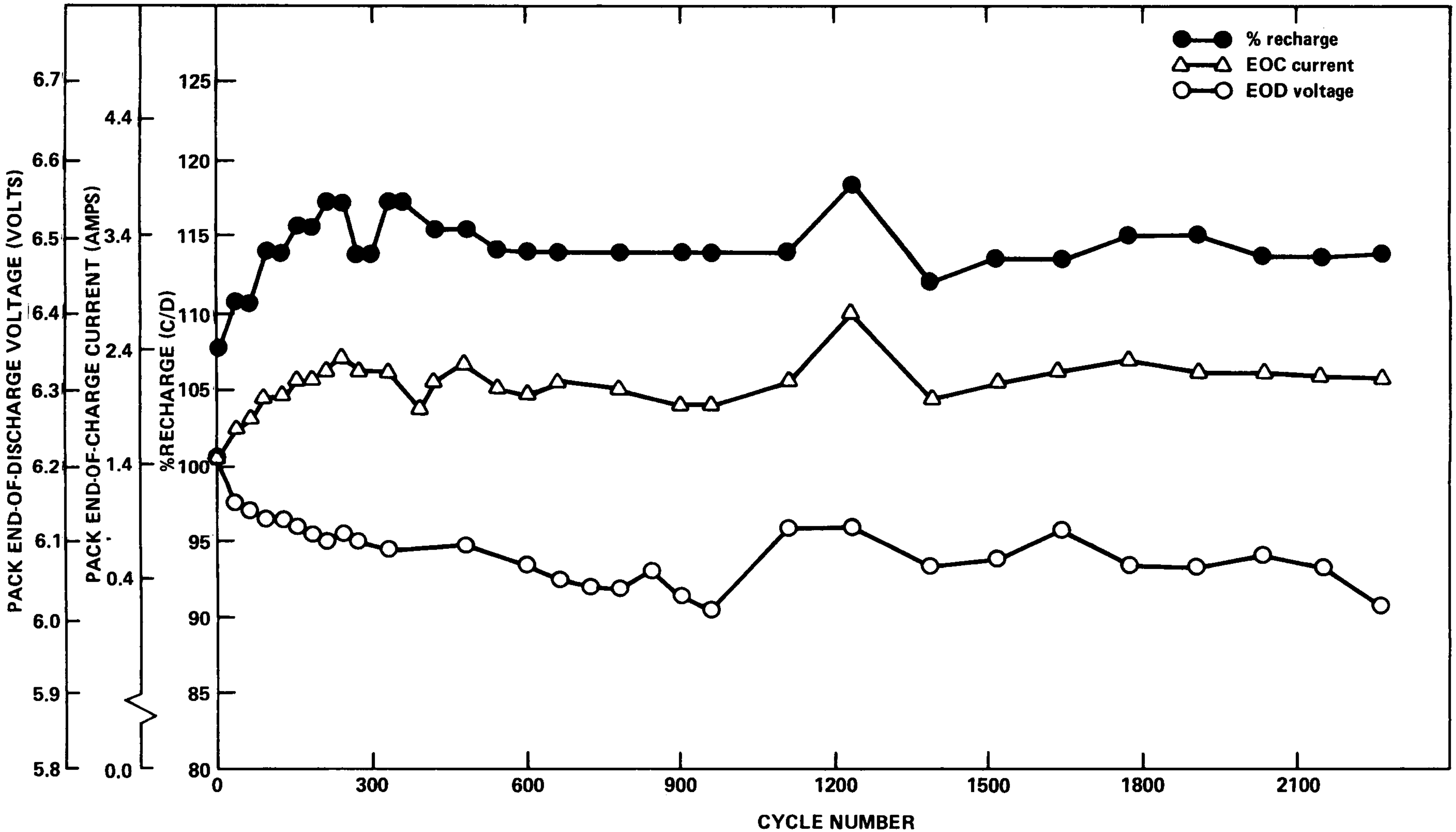


Figure 3. NOAA 26.5 Ah PARAMETRIC LEO CYCLING TEST
% RECHARGE, EOD VOLTAGE, EOC CURRENT, VS CYCLE
25% DOD, GSFC $V_T6$=1.433 V/CELL, 20°C
CYCLES 0 TO 965 BURN-IN, 966-2300 TEST

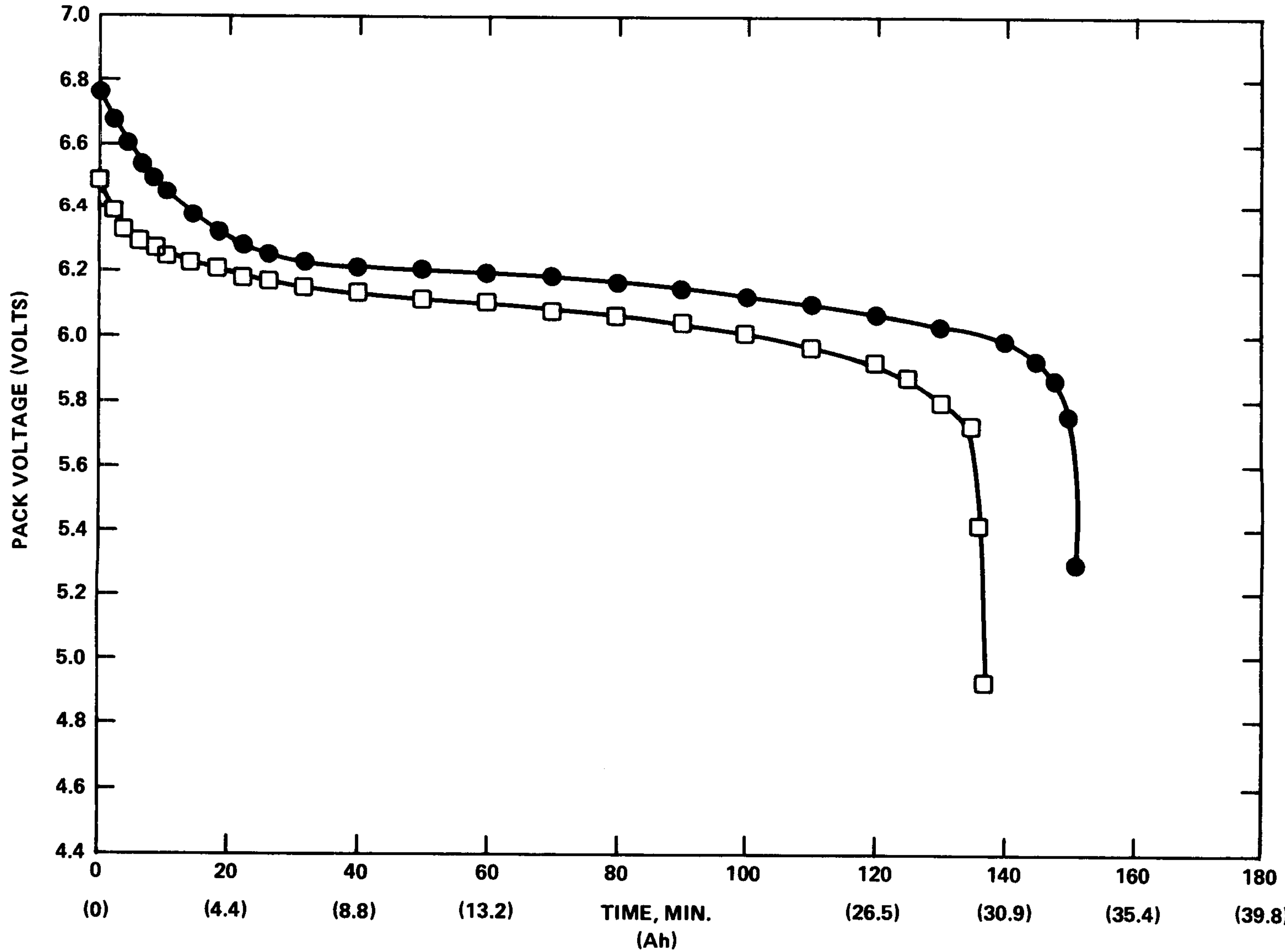


Figure 4. NOAA 26.5 Ah LEO CYCLING TEST
PRECYCLING CAPACITY VS POSTCYCLING CAPACITY
0.5C DCH TO 0.75V FIRST CELL
TEMPERATURE: 23 °C

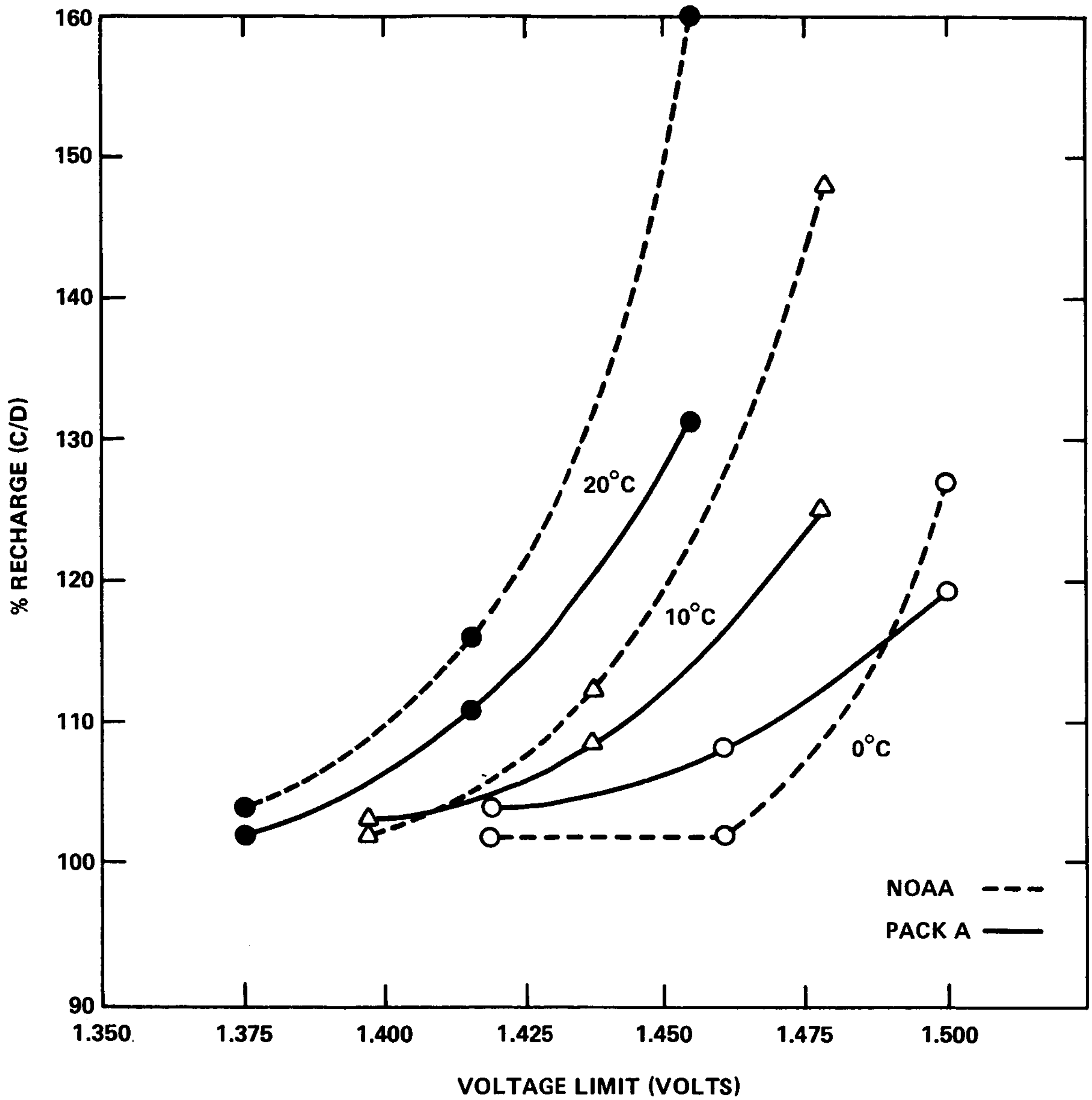


Figure 5. NOAA 26.5 Ah VS PACK A 50 Ah
CHARGE CURRENT: 0.2C
10% DEPTH OF DCH

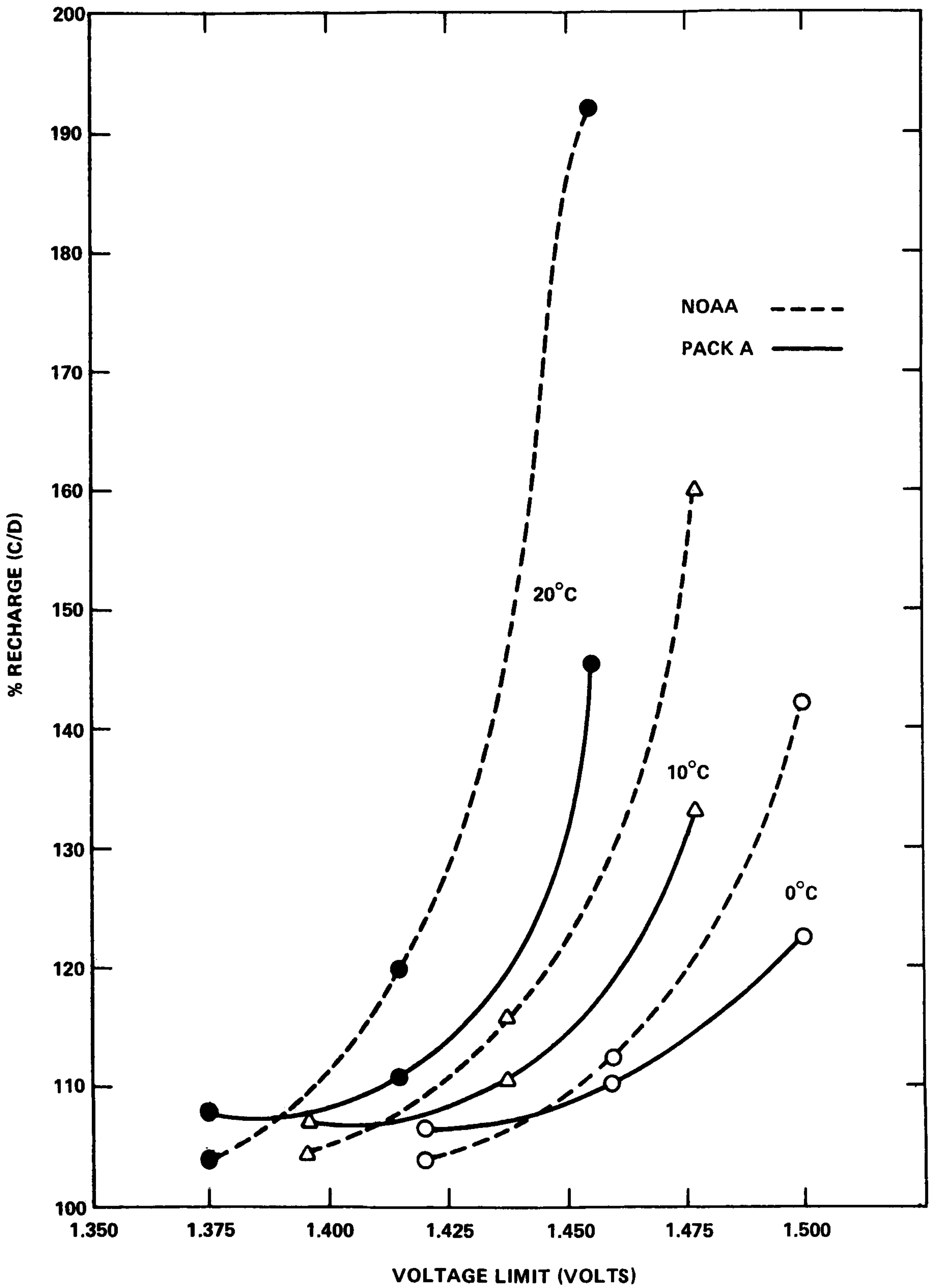


Figure 6. NOAA 26.5 Ah VS PACK A 50 Ah
CHARGE CURRENT: 0.5C
10% DEPTH OF DCH

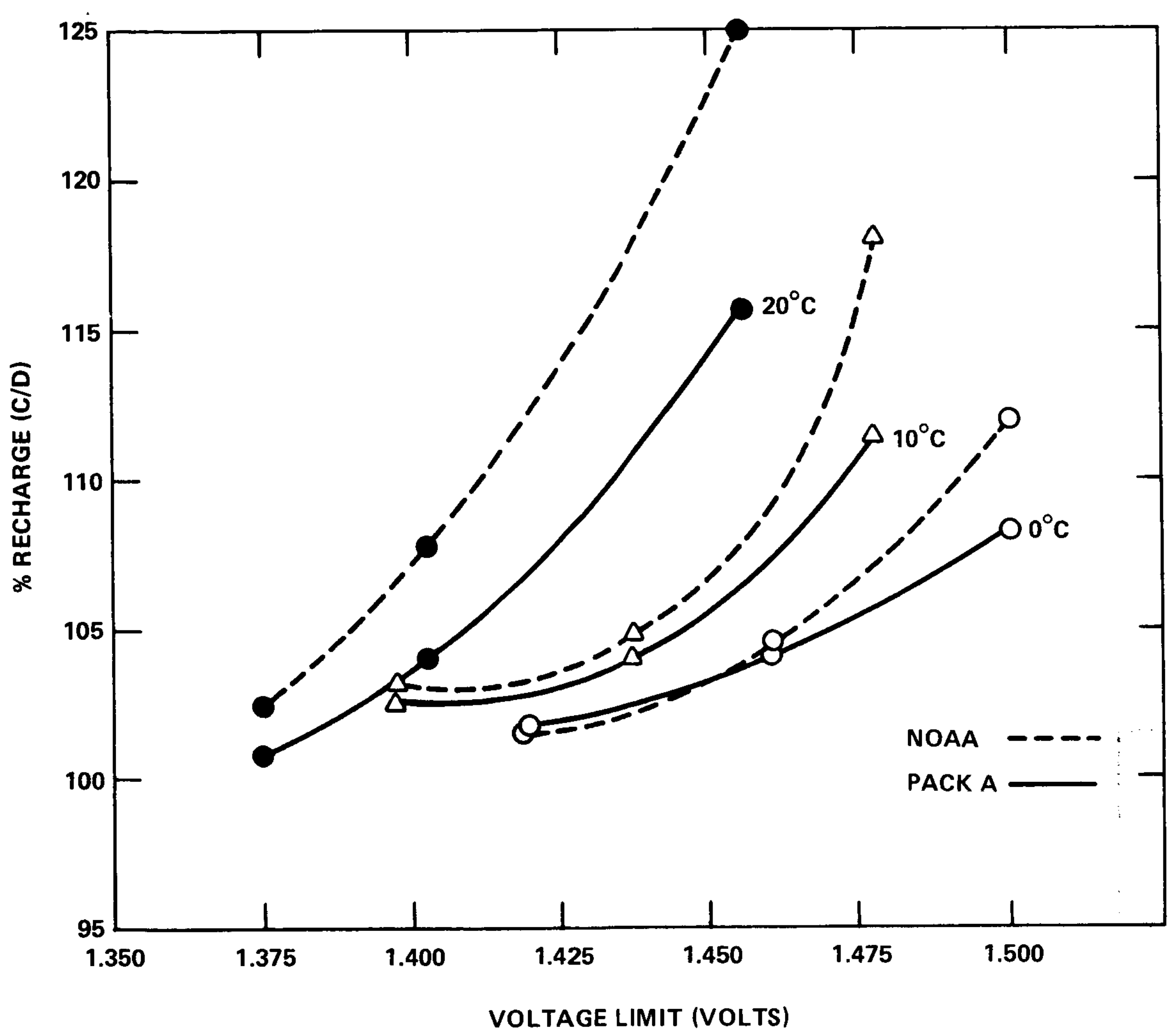


Figure 7. NOAA 26.5 Ah VS PACK A 50 Ah CYCLING TEST
% RECHARGE VS VOLTAGE LIMIT
CHARGE CURRENT: 0.5C
25% DEPTH OF DISCHARGE

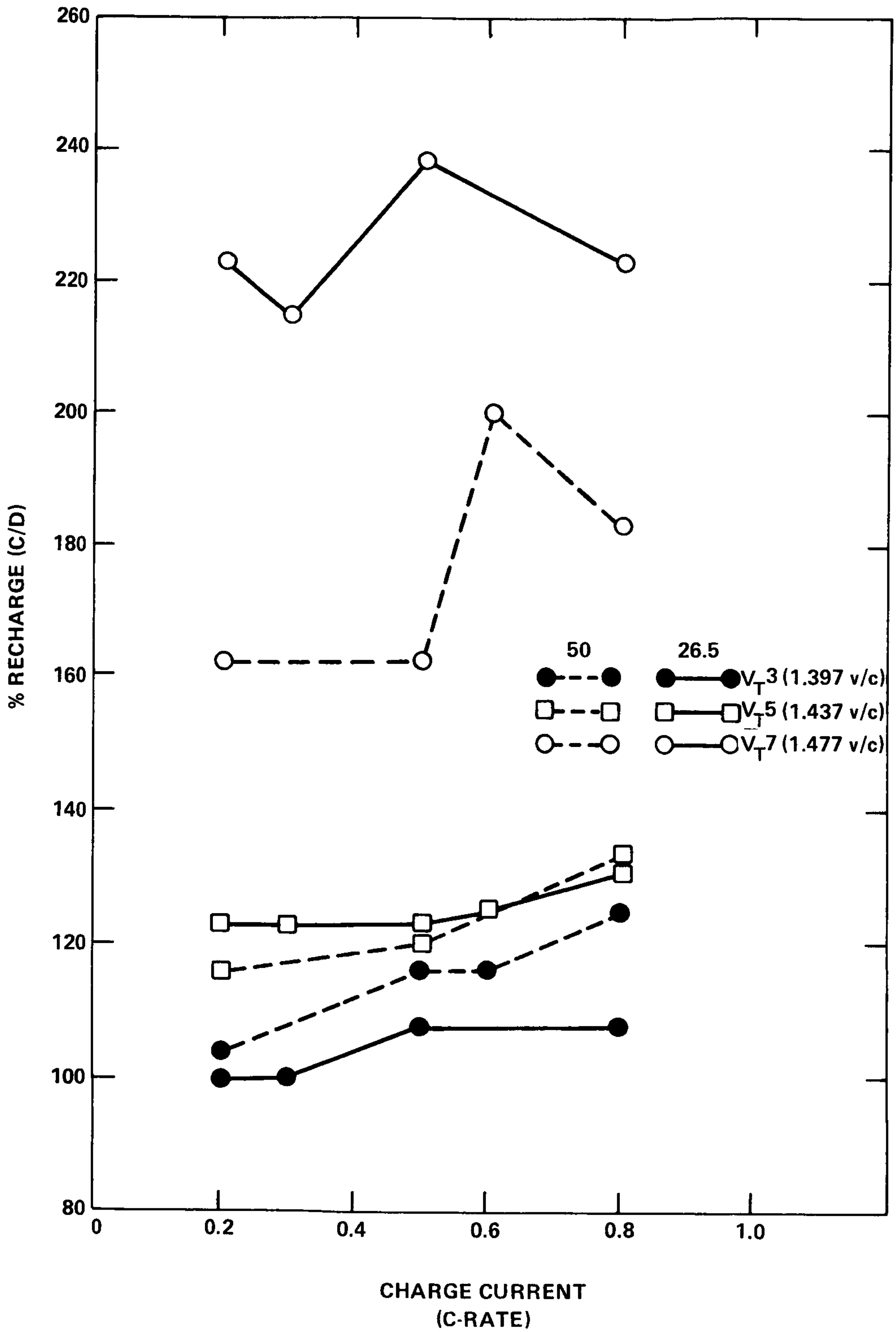


Figure 8. PACK A 50 Ah VS NOAA 26.5 Ah LEO CYCLING TEST
% RECHARGE VS CHARGE CURRENT
5% DEPTH OF DCH
TEMPERATURE: 10°C

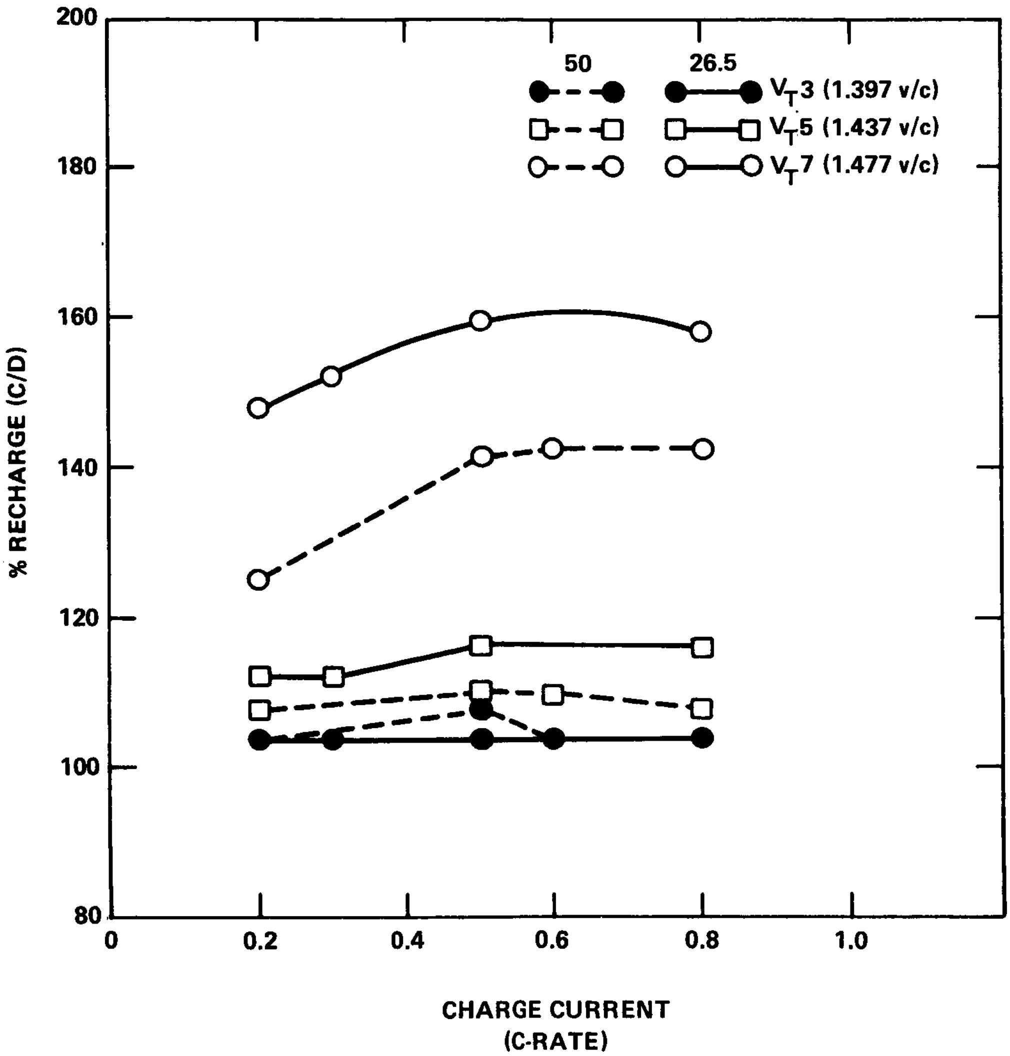


Figure 9. PACK A 50 Ah VS NOAA 26.5 Ah LEO CYCLING TEST
% RECHARGE VS CHARGE CURRENT
10% DEPTH OF DISCHARGE
TEMPERATURE: 10°C

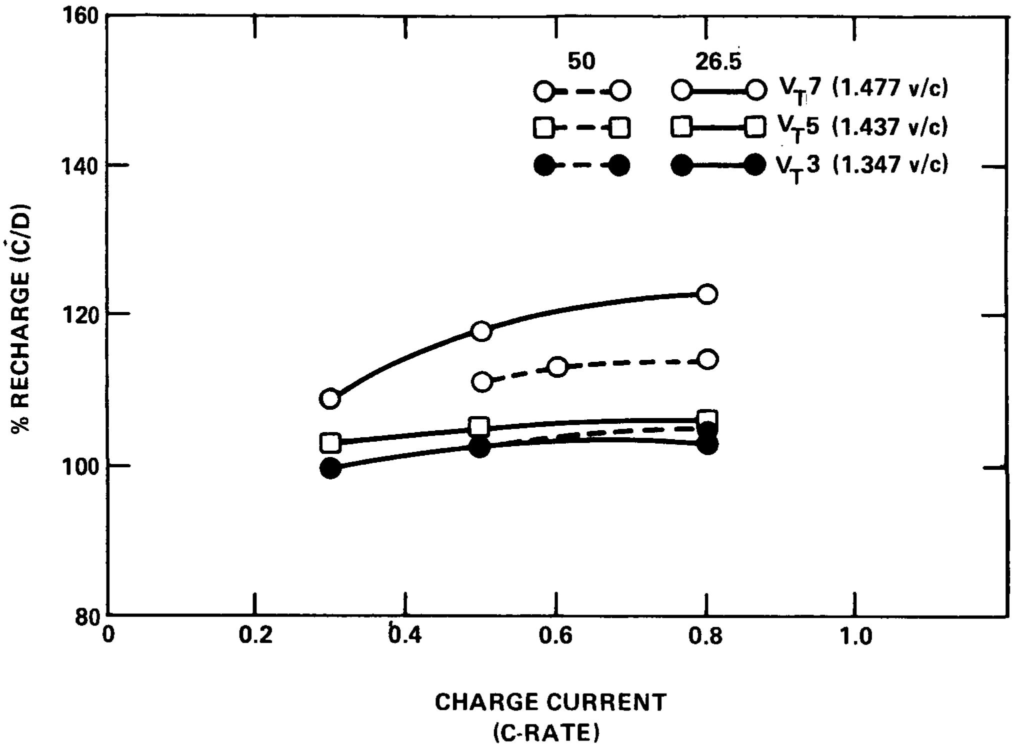


Figure 10. PACK A 50 Ah VS NOAA 26.5 Ah LEO CYCLING TEST
% RECHARGE VS CHARGE CURRENT
25% DEPTH OF DISCHARGE
TEMPERATURE: 10°C

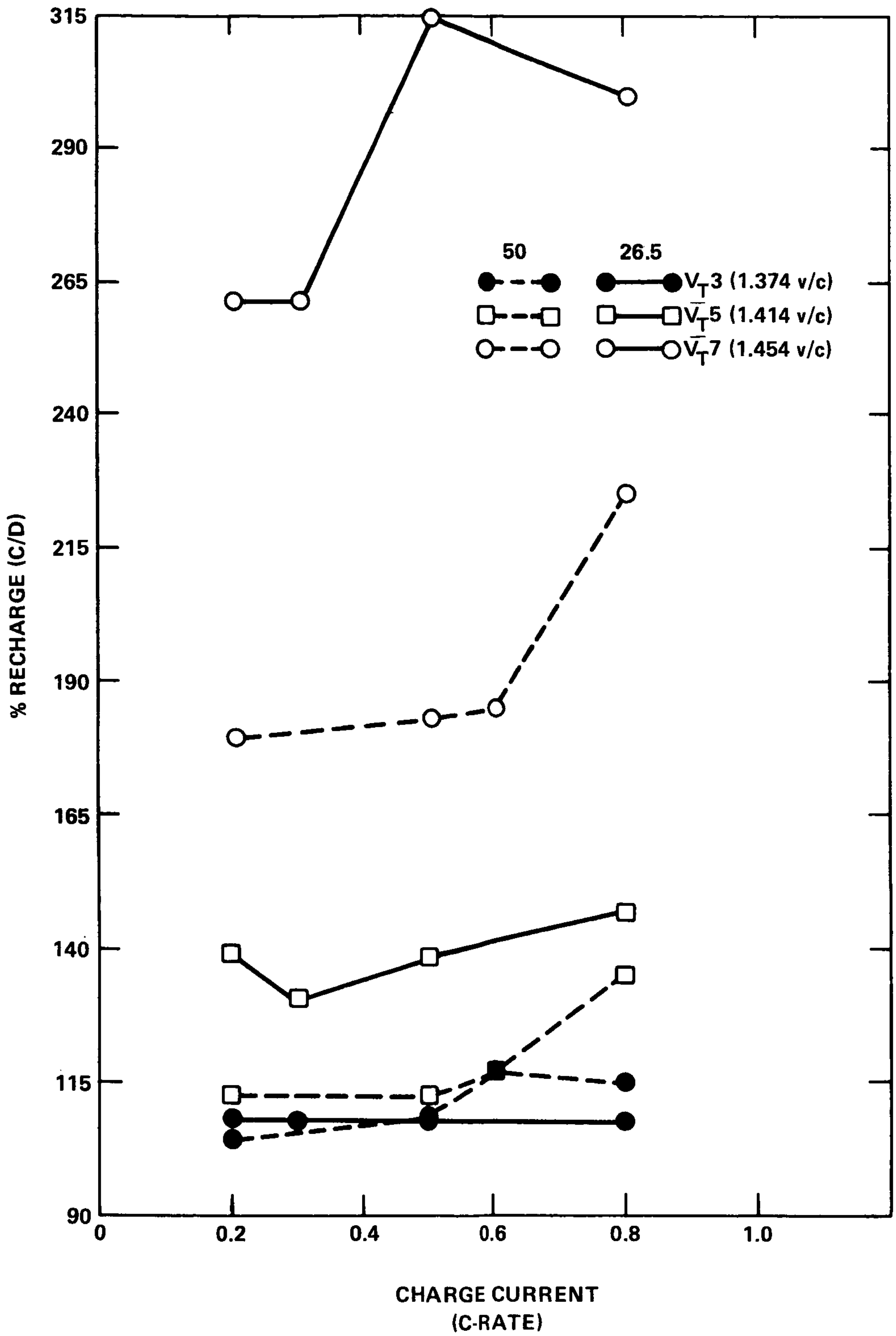


Figure 11. PACK A 50 Ah VS NOAA 26.5 Ah LEO CYCLING TEST
% RECHARGE VS CHARGE CURRENT
5% DEPTH OF DISCHARGE
TEMPERATURE: 20°C

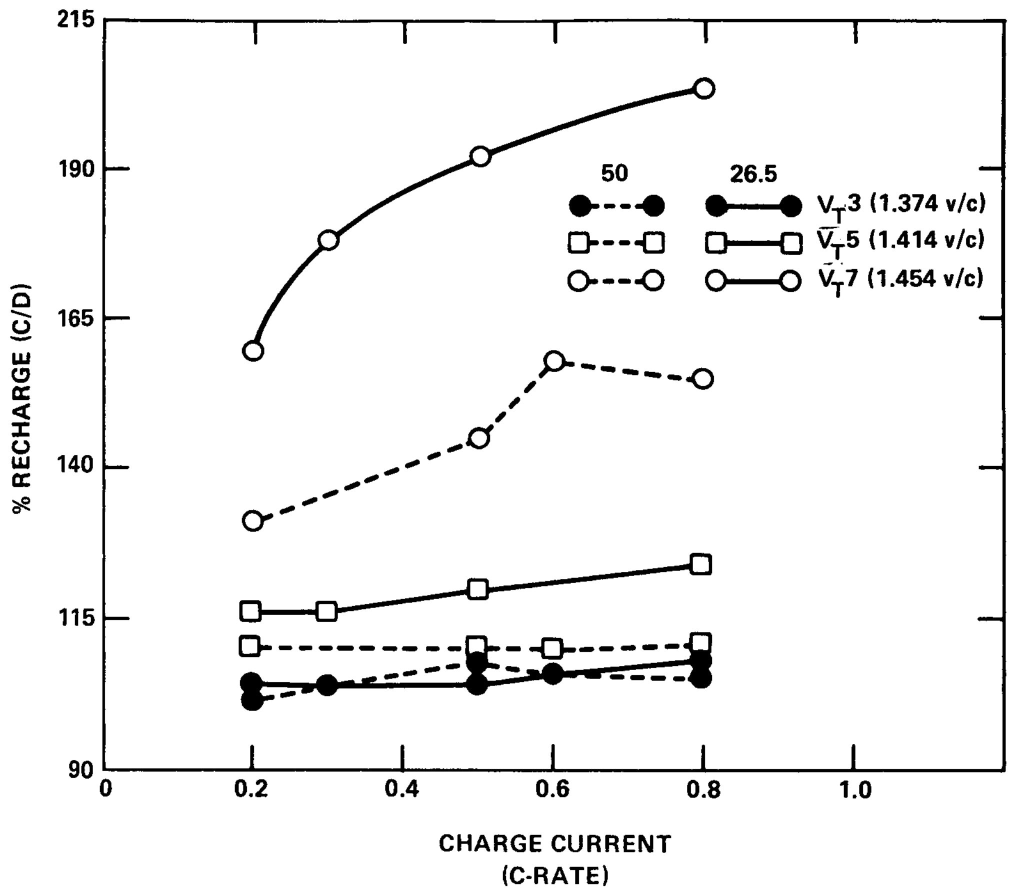


Figure 12. PACK A 50 Ah VS NOAA 26.5 Ah LEO CYCLING TEST
% RECHARGE VS CHARGE CURRENT
10% DEPTH OF DISCHARGE
TEMPERATURE: 20°C

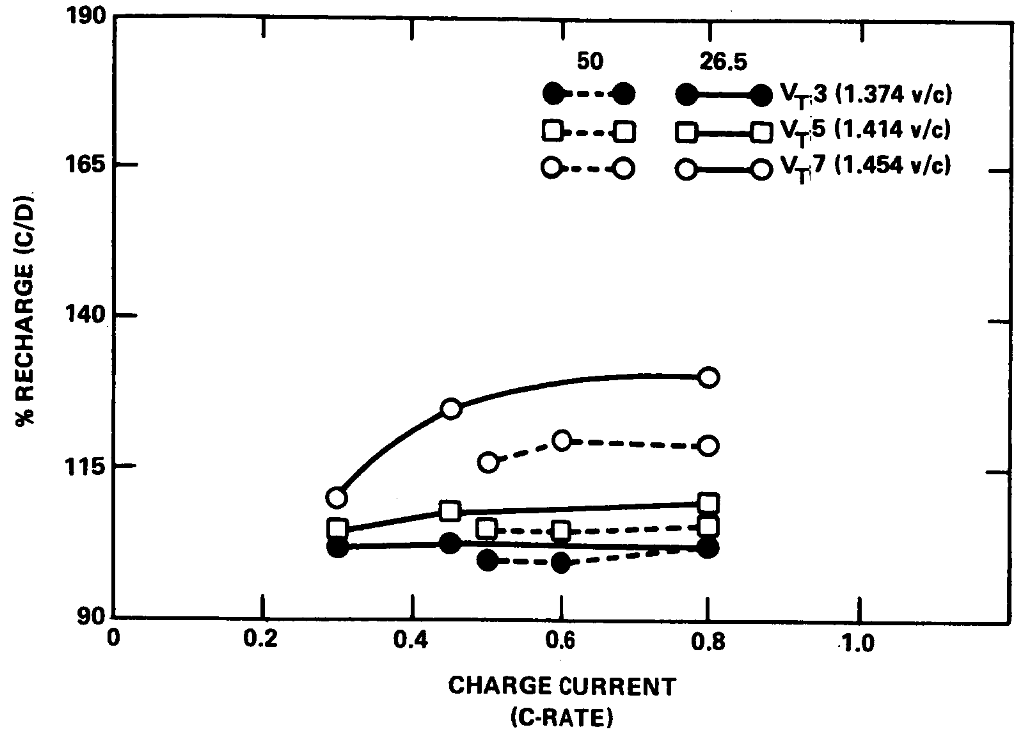


Figure 13. PACK A 50 Ah VS NOAA 26.5 Ah LEO CYCLING TEST
% RECHARGE VS CHARGE CURRENT
25% DEPTH OF DISCHARGE
TEMPERATURE: 20°C

TEMPERATURE: 10°C

ORBIT: 104 minutes – 69 minutes charge
35 minutes discharge

DEPTH OF DISCHARGE: 25 percent (11.35A Constant I)

CHARGE: 7.5A Constant I
to a voltage limit and taper

VOLTAGE LIMIT: 1.47 V/Cell (initially)

Figure 14. LIFE CYCLING REGIME

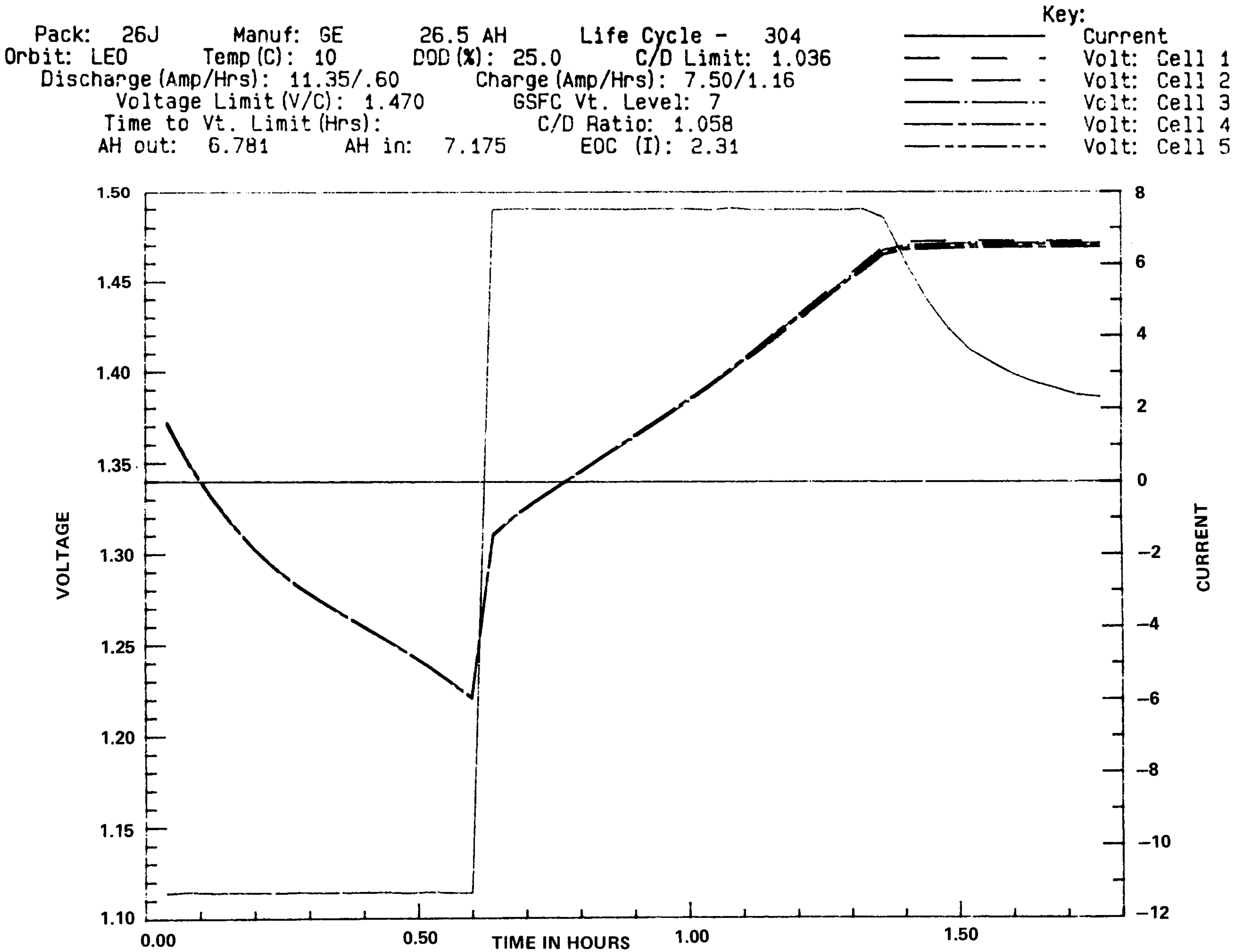


Figure 15. NWSC CRANE LIFE CYCLE 304 PLOT

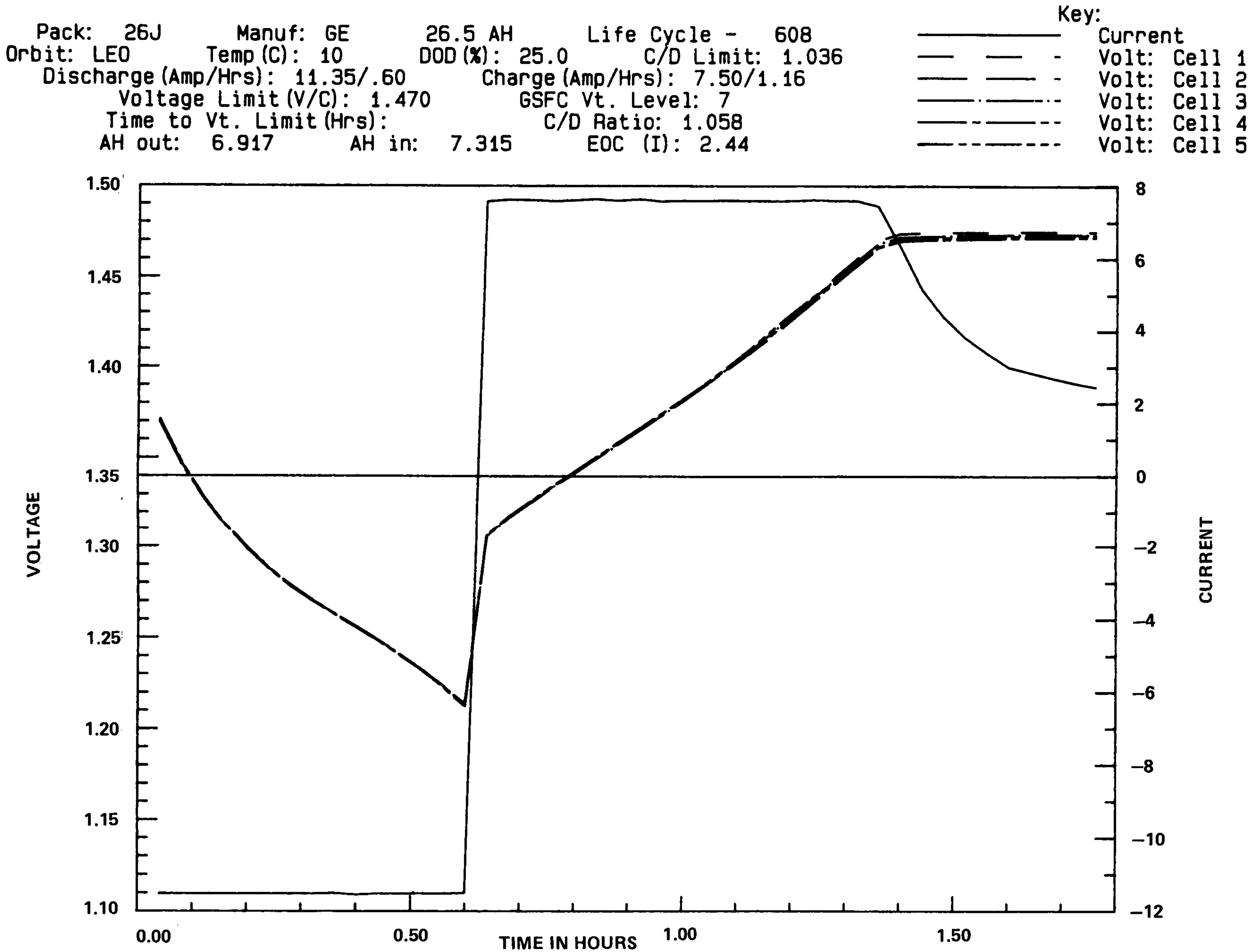


Figure 16. NWSC CRANE LIFE CYCLE 608 PLOT

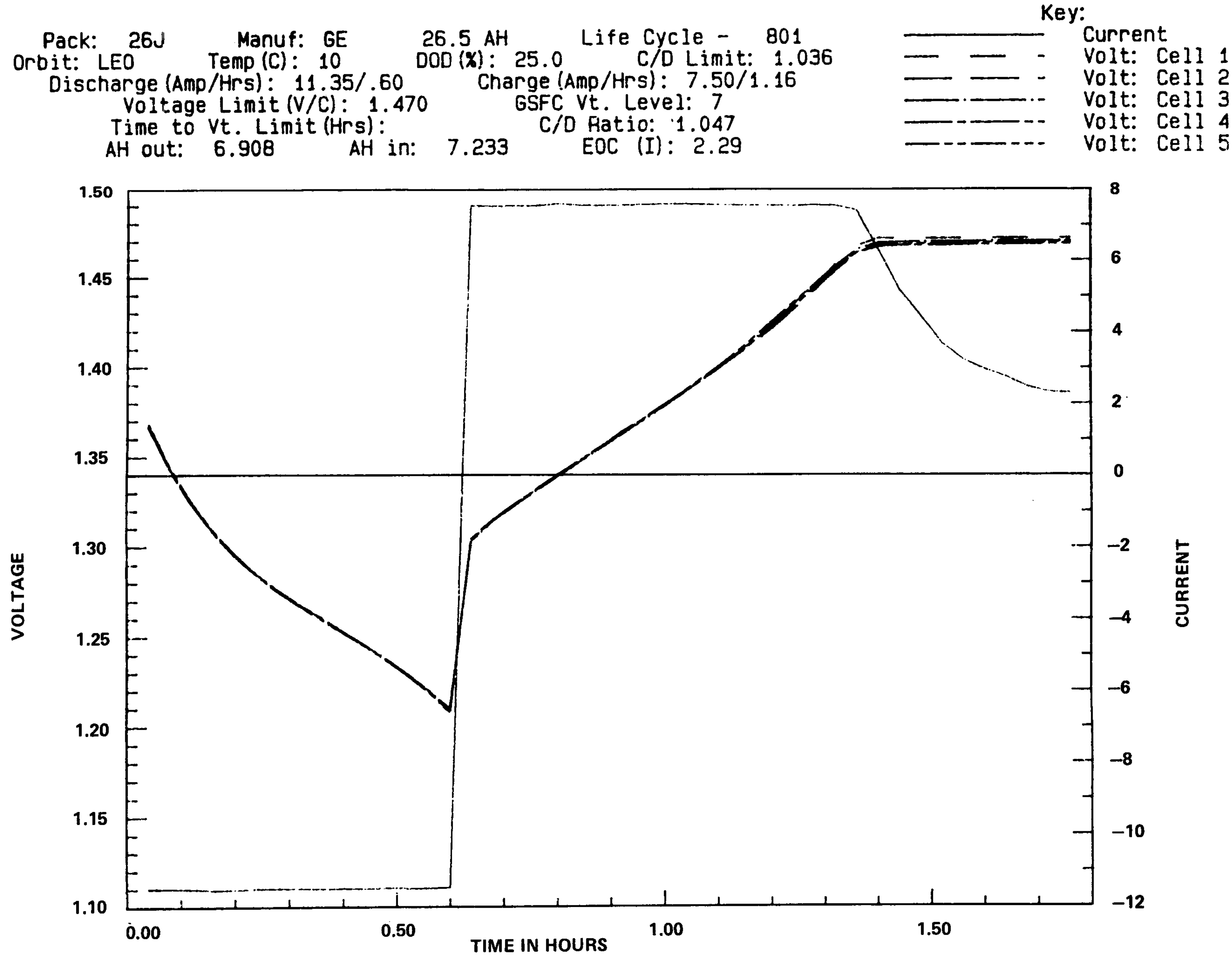


Figure 17. NWSC CRANE LIFE CYCLE 801 PLOT

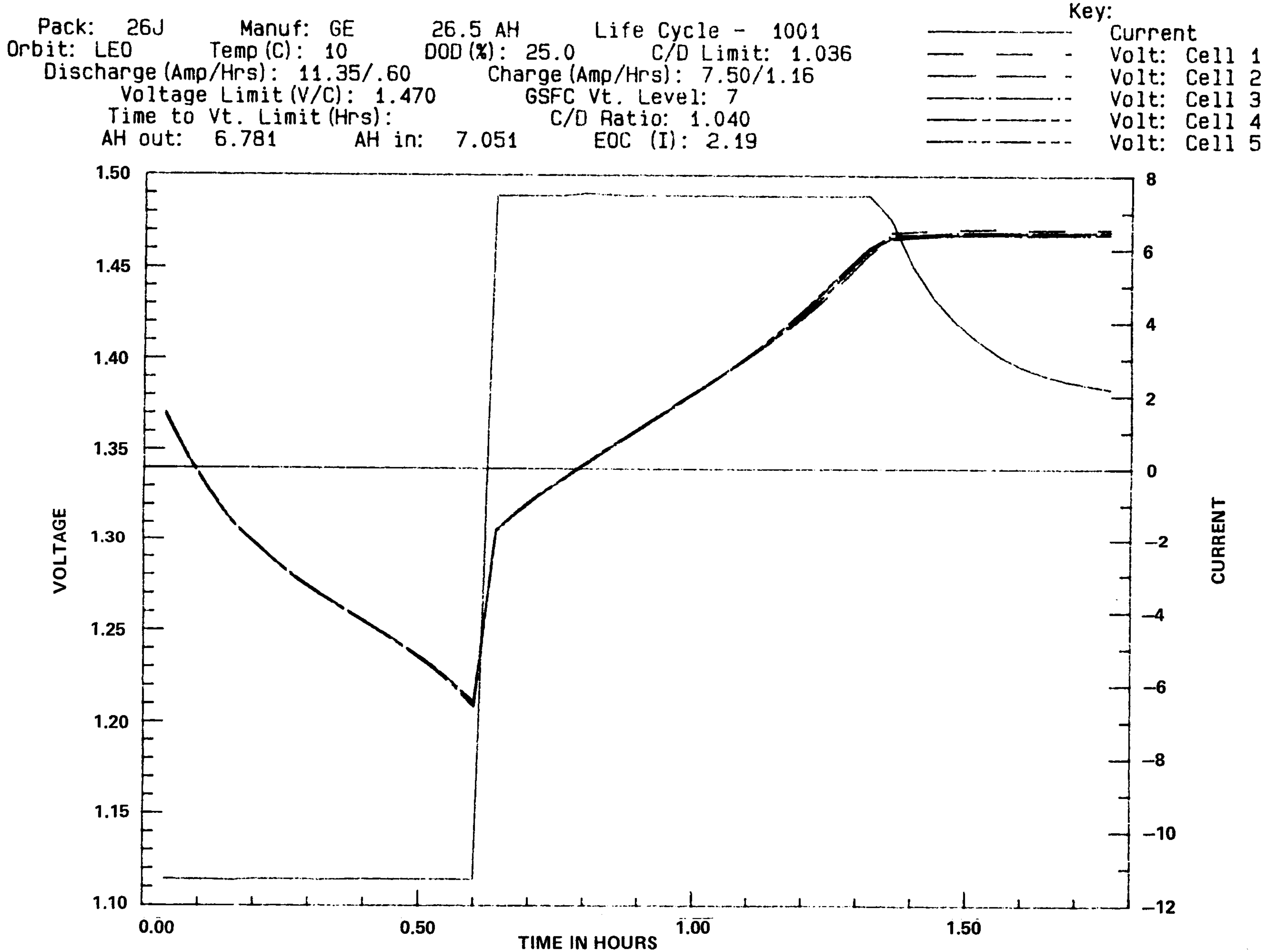


Figure 18. NWSC CRANE LIFE CYCLE 1001 PLOT