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ADVANCES IN NICKEL HYDROGEN TECHNOLOGY

AT

YARDNEY BATTERY DIVISION

A PRESENTATION BY

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TO THE

1986 GODDARD BATTERY WORKSHOP

AT

NASA GODDARD SPACE FLIGHT CENTER

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INTRODUCTION

This presentation outlines the current major activities in nickel hydrogen technology being addressed at Yardney Battery Division. It covers five basic topics:

1. An update on life cycle testing of ManTech 50 AH NiH₂ cells in LEO regime.
2. An overview of the Air Force/Industry briefing on the Yardney ManTech program.
3. Nickel electrode process upgrading.
4. 4 1/2" cell development.
5. Bipolar NiH₂ battery development.

1. UPDATE ON LIFE CYCLE TESTING OF MANTECH 50AH NIH₂ CELLS IN LEO REGIME

A year ago at the 1985 Goddard Workshop Yardney reported in a short informal briefing on the effort to date in LEO regime life cycle testing on Yardney ManTech cells which were the prototypical output of Phase II of the ManTech Program (Fig. 1). This depicted the testing of two cells to 5000 cycles at 80% depth of discharge including, in the first 1000 cycles, efforts to optimize charge/discharge ratios and fine tune the computerized test and data acquisition systems. The consensus among several of those in the NiH₂ technological community at that point was that the 80% DOD was overly rigorous and unrealistic.

Therefore, when we restarted cycle testing we did so at 60% Depth of Discharge. Also, by this time we were delivering cells to customers representing the final configuration coming out of the ManTech Program, that is to say, Phase III cells. These vary from the prototype Phase II cells only in areas of mechanical design. The number, type, and arrangement of electrochemical elements remained unchanged. We added one of these Phase III cells to the test group as we restarted testing.

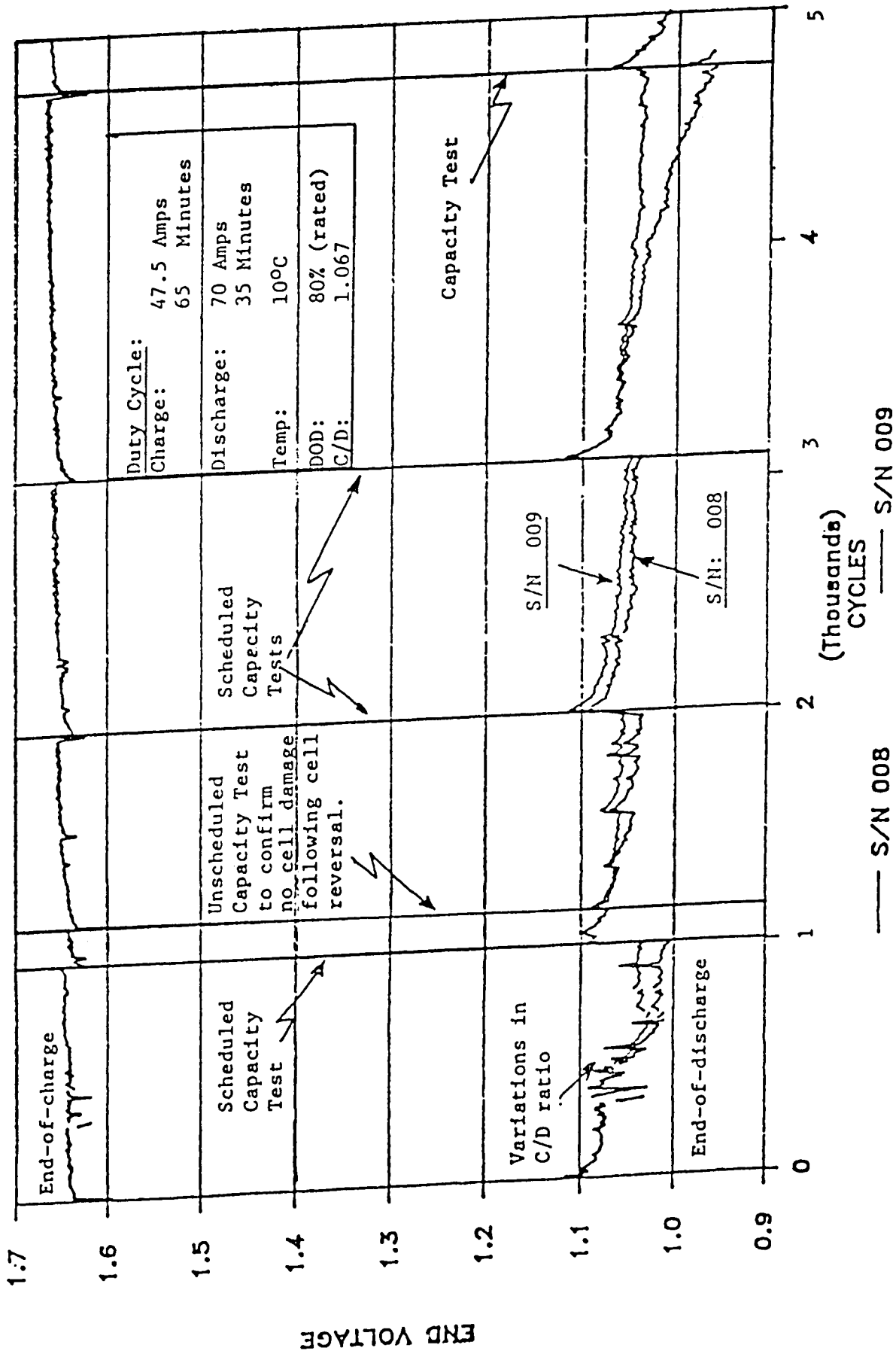


Figure 1. YNH-50-1 Cells (5-Apr-84 to 24-May-85).

We did not recondition or recharacterize the cells at 6000 cycles but did so at 7000 and 8000. As can be seen in Figure 2 cell 008 was the poorer performer of the group. This is attributed to test system problems encountered during the first 5000 cycles. In addition to power failures which interrupted testing at the most inopportune times the cells were at least once driven into reversal as a result of test system malfunctions.

Testing has proceeded to about 8900 cycles of which approximately 8800 cycles are represented here. During the current recharacterization we have decided to explore some other characteristics of these cells.

One of these was cell impedance at various temperatures and states of charge (Figure 3). It is of interest that at 0°C impedance values converged and as temperature is increased charged cells have a greater impedance while discharged ones exhibit less impedance. It should be noted that these values were taken at 40 Hz.

A second peripheral investigation was in regard to what is sometimes referred to as the "double knee phenomenon" which cells exhibit during discharge. The three ManTech test cells had been maintained for a sustained period (10-14 days) at less than 10 mV and were then charged at a C/10 rate for 20 hours and discharged. The first discharge was at C/25 and exhibited no "double knee" phenomenon (Figure 4). Repeating the same test 3 days later exhibited a genesis of the phenomenon (Figure 5). A retest at a C/10 rate discharge shows a slightly more pronounced display (Figure 6). A repeat of the test at a discharge rate of C/2 exhibits a more substantive but less pronounced characteristic (Figure 7). Finally, at a C rate discharge the differentiation of the two "knees" has almost disappeared (Figure 8). These characteristics illustrate an inherent dependency of the positive electrode active nickel structure on prior cycle history and rate of discharge. We are continuing to evaluate this phenomenon relative to cell performance.

Additionally, radiographic examinations were made to determine positive plate growth. Less than .002"/plate was noted on cells S/N 008 and 009 in the first 5000 cycles. No measurable growth was discerned in the subsequent 3800 cycles.

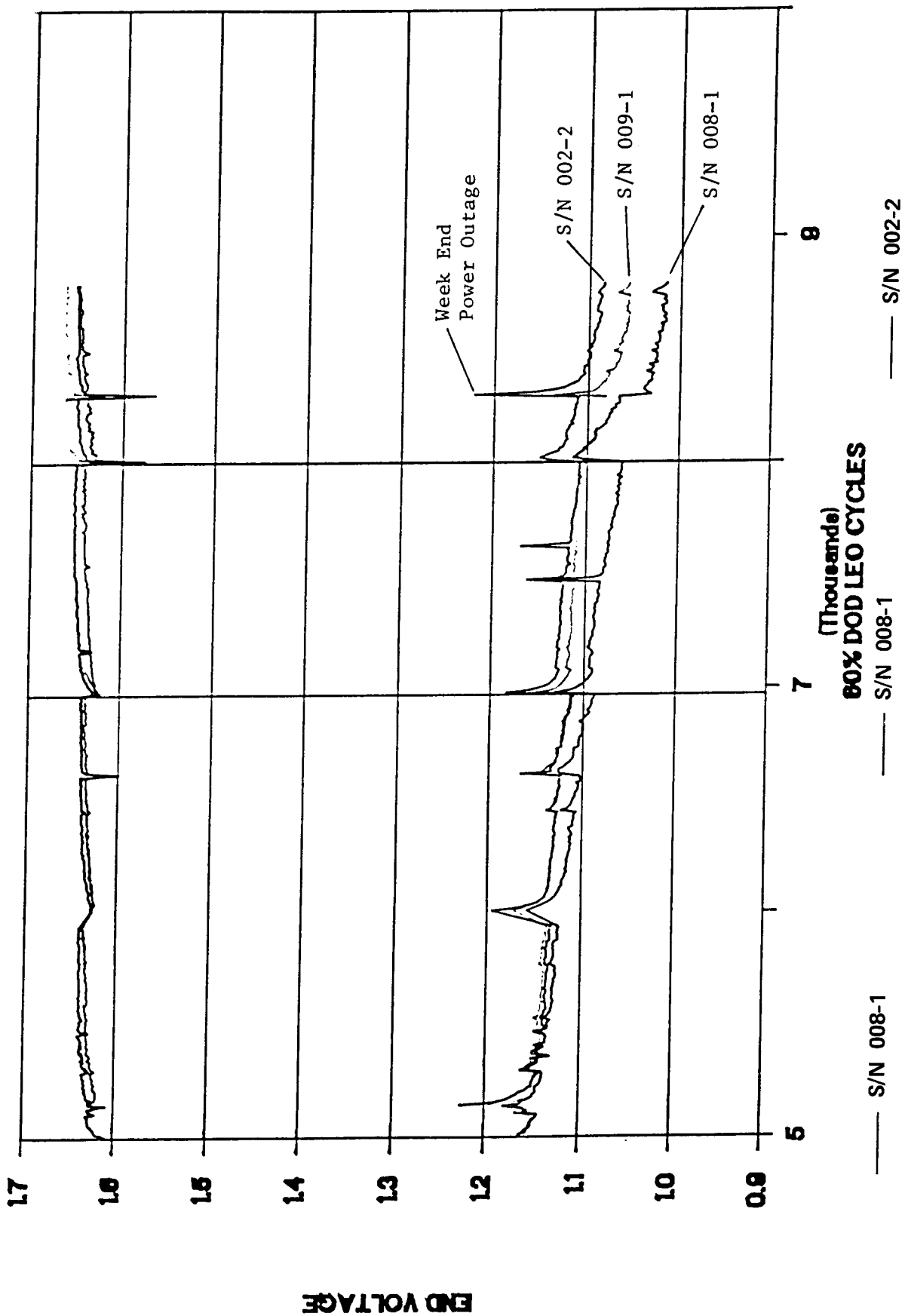
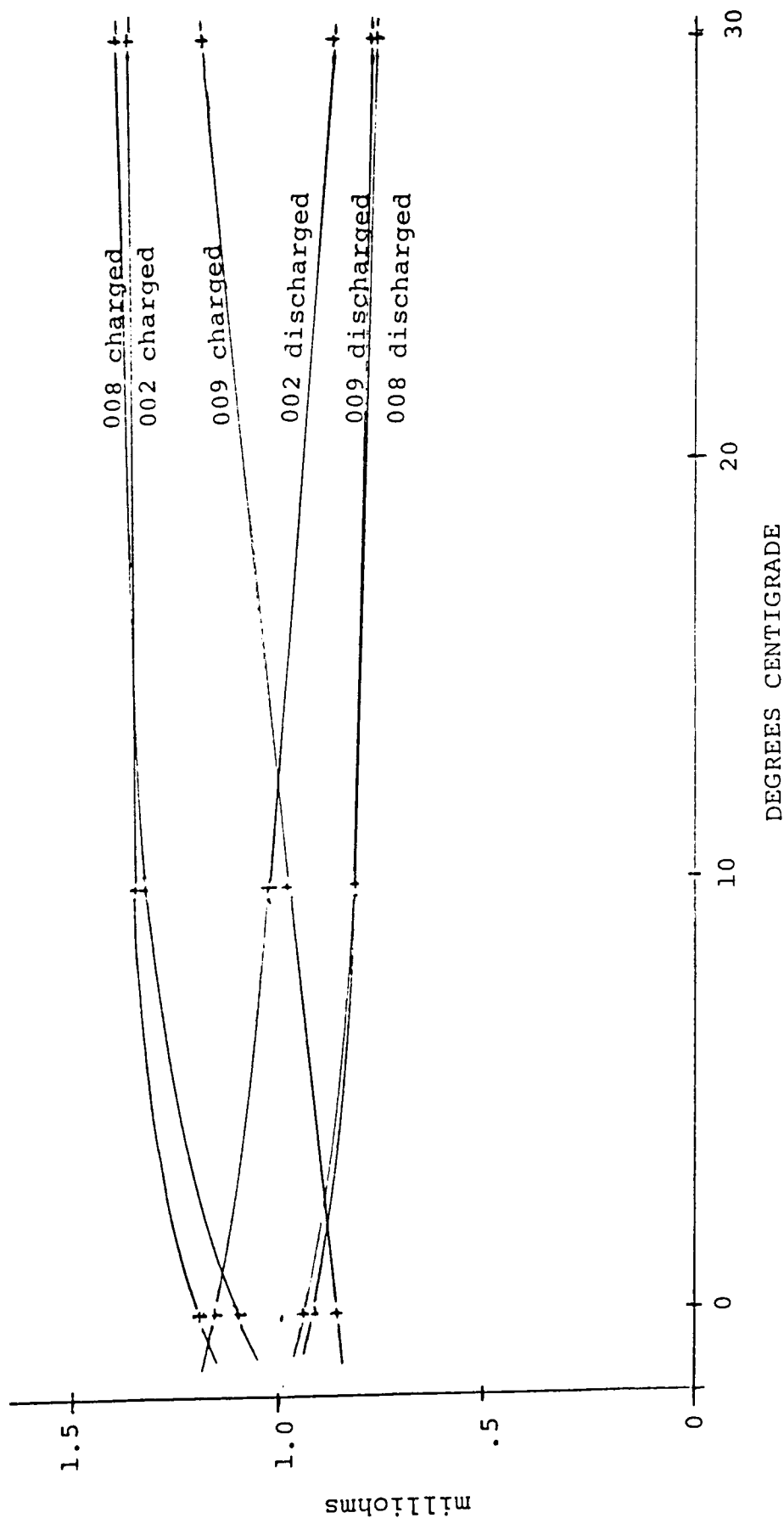


Figure 2. YNH-50 Cells (22-Sep-86).



Cells 008 and 009 after 9000 LEO cycles (5K @ 80% and 4K @ 60% DoD).
 Cell 002 after 4000 LEO cycles @ 60% DoD.

Measurements made with a Keithley Model 503 milliohmmeter at 40 Hz.

Figure 3. Impedance of NiH₂ Cells at Various Temperatures when Fully Charged and Fully Discharged.

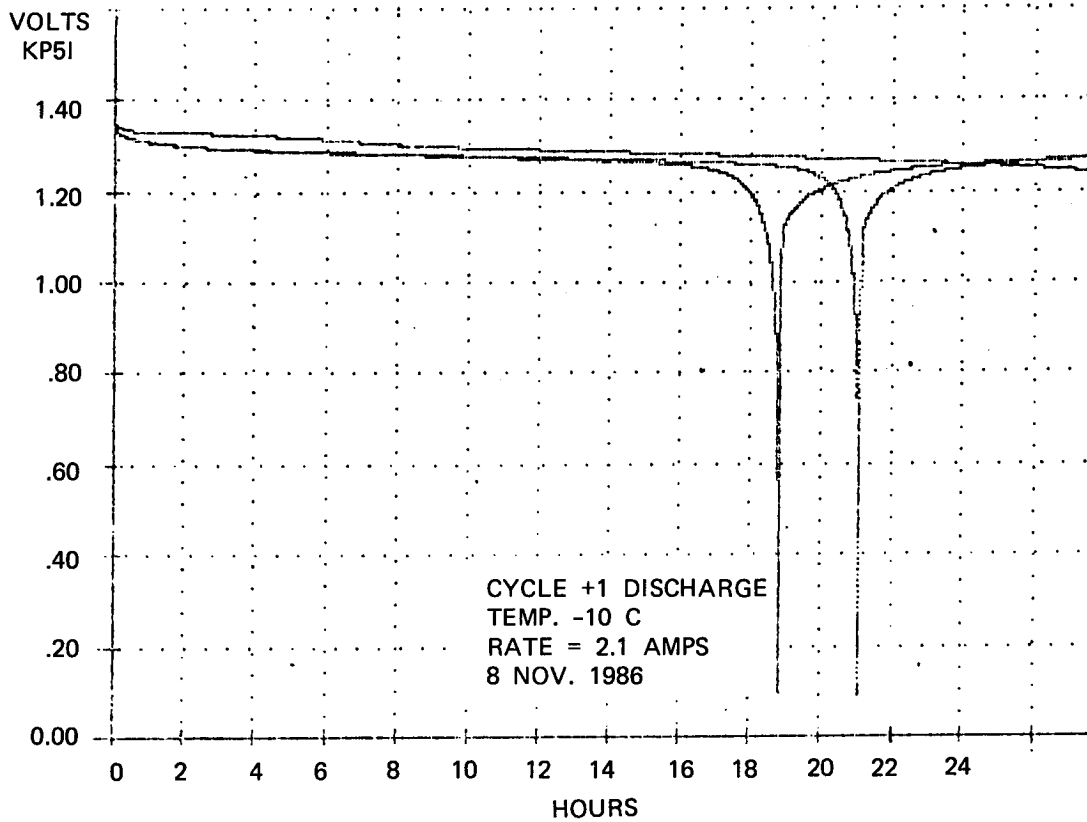


Figure 4.

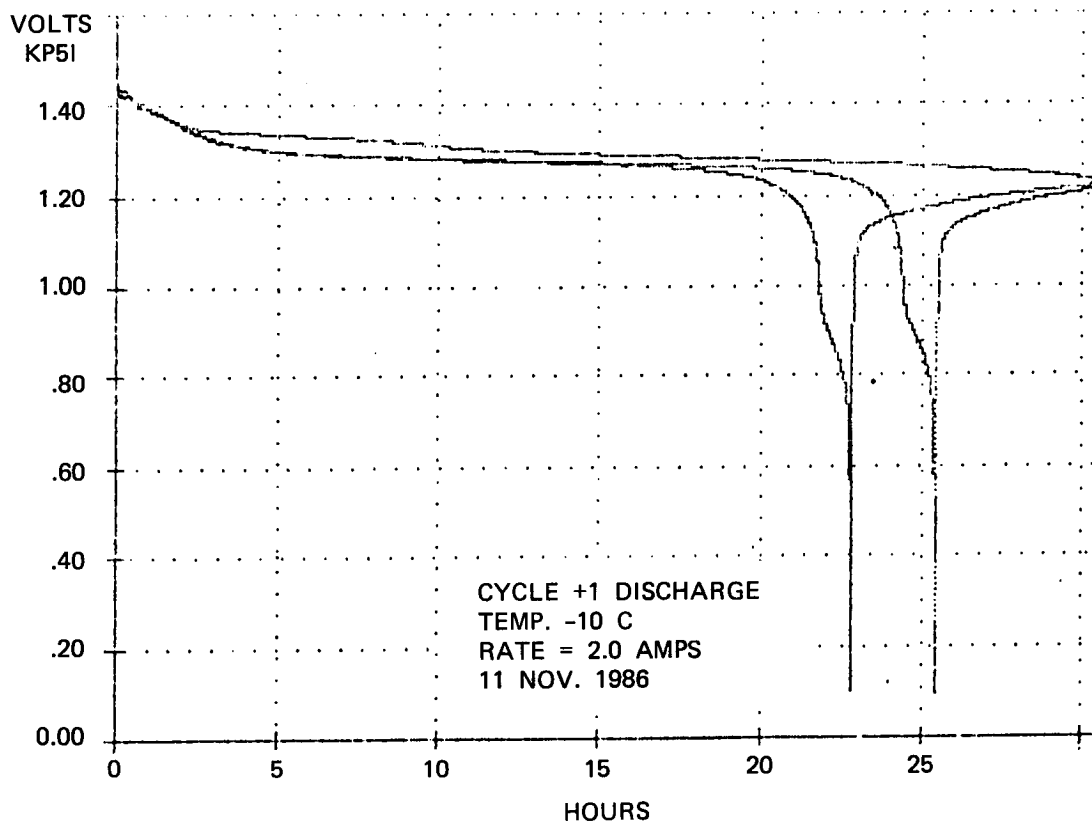


Figure 5.

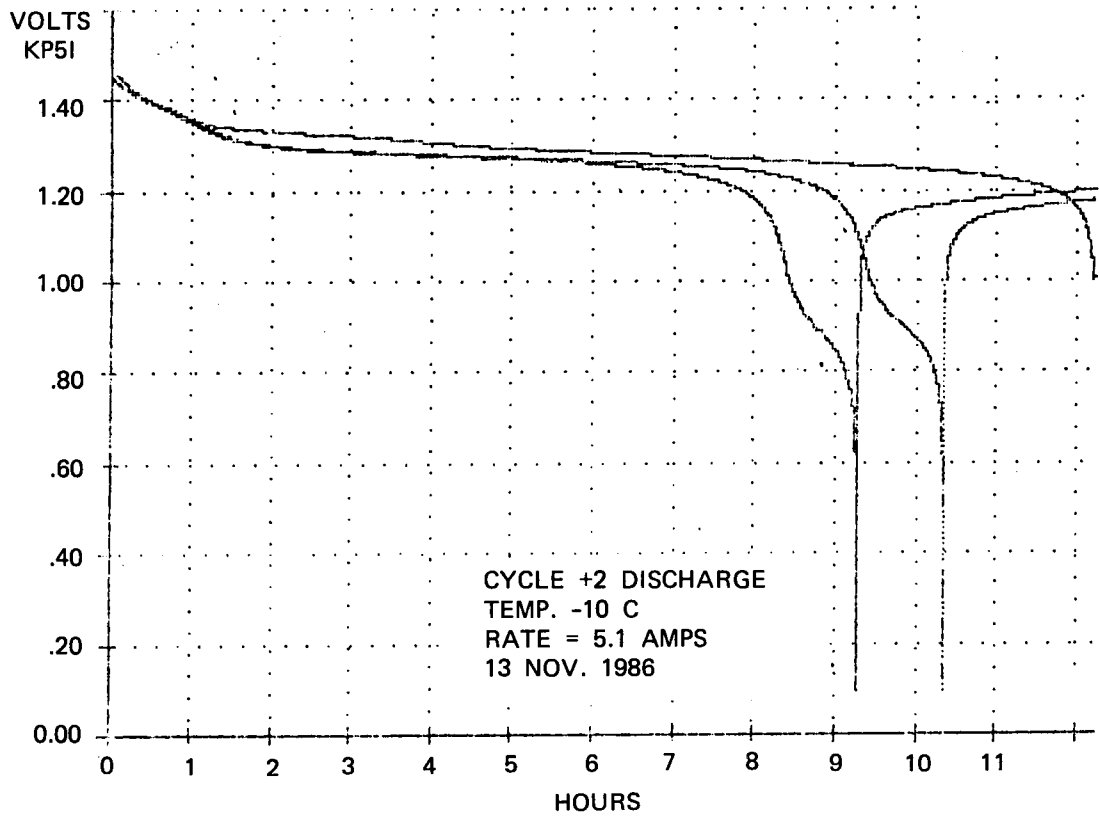


Figure 6.

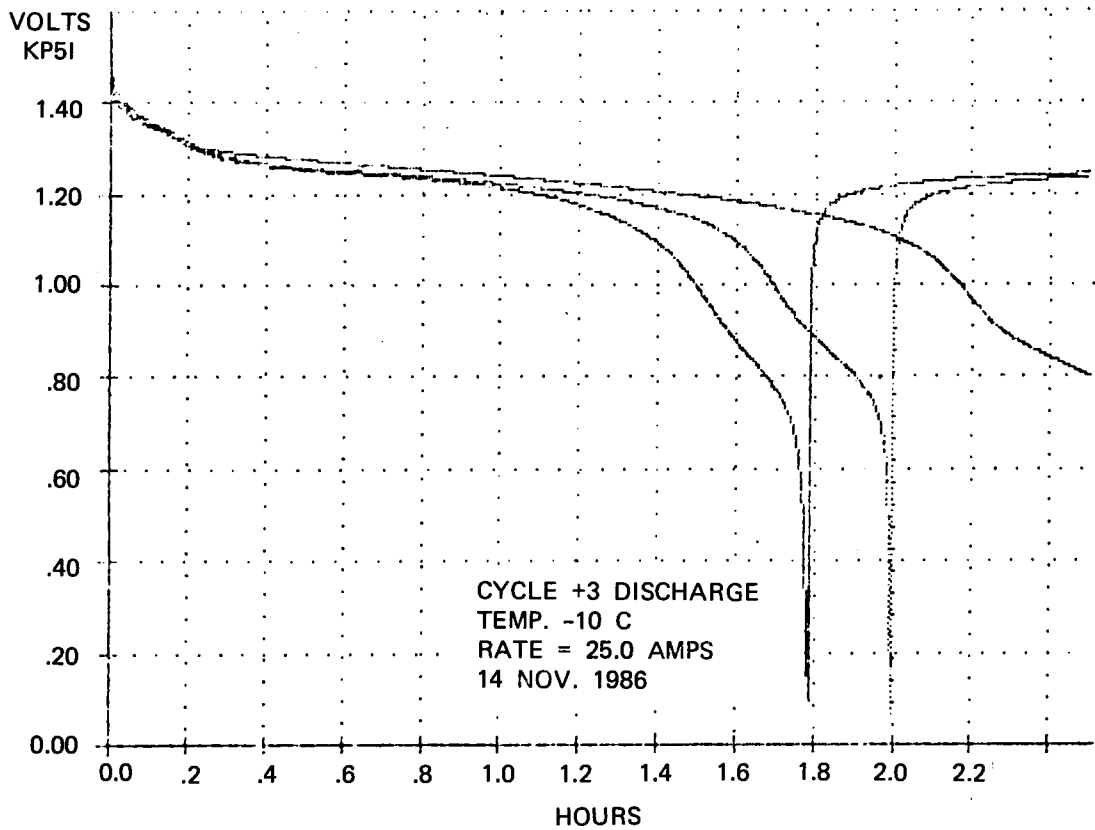


Figure 7.

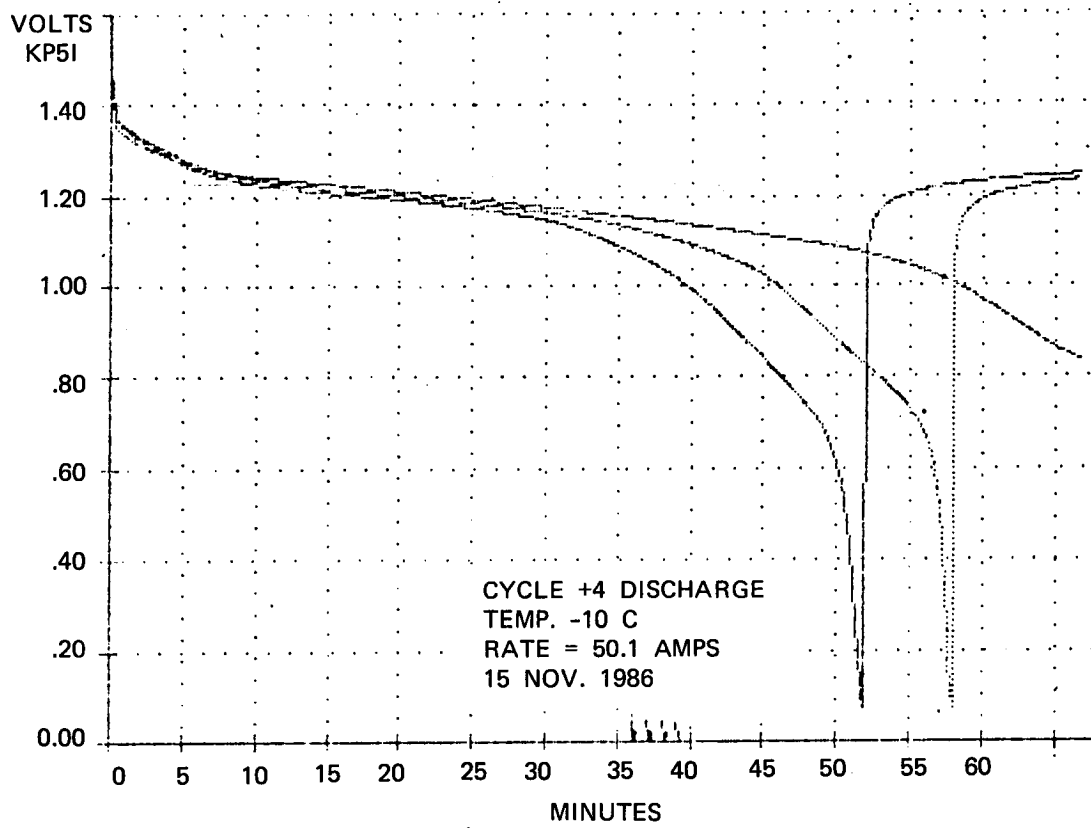


Figure 8.

2. OVERVIEW OF THE AIR FORCE/INDUSTRY BRIEFING ON THE YARDNEY/MANTECH PROGRAM

As some of you are aware we are at this time completing our contract with Wright Patterson Materials Lab for the application of manufacturing technology to the baseline Air Force 3 1/2", 50 AH cell. While the ITAR regulations prevent an in-depth technical discourse in this forum we can give a very brief overview of the project.

This program, initiated in 1981, while encountering several problematical delays, has resulted in a number of technical break-throughs, including the reduction in platinum loading of the negative without loss of performance, the improvement in structural accommodation to plate growth and, most importantly, a reduction in price from the baseline cell of from 30 to 50% or more depending on production lot size.

In addition to the prototype cells coming out of the program and being tested at Yardney we have delivered cells to the Wright Patterson Materials Lab, and to Don Warnock's group at Wright Patterson both of which cell lots are now on test at the Naval Weapons Support Center, Crane, Indiana. Additional cell lots in the Phase III configuration have been produced for other customers as well.

3. NICKEL ELECTRODE PROCESS UPGRADING

Within Yardney's new dedicated NiH_2 manufacturing facility a substantial effort has been directed at nickel positive manufacturing techniques. The Yardney positive process includes a wet slurry-type plaque which is sintered in a reducing atmosphere and electrochemical impregnated (EI) by the Pell Blossom process. New plaque pulling, sintering and EI equipment are providing superior control of those phases of the operation.

These efforts are now providing positive plates which meet stringent requirements of thickness growth and blistering when subjected to a 200 cycle high rate stress test. This test consists of 10 C charge for 12 minutes and a 10 C discharge for 8 minutes at room temperature. Criteria for acceptance are a maximum of 3 mil thickness growth and less than 3% of the plate area blistered for the standard 31 and 35 mil thick electrodes.

4. 4 1/2" CELL DEVELOPMENT

In May of 1985 Yardney embarked on a cooperative effort with Ford Aerospace Corporation to develop a 4 1/2 inch diameter nickel-hydrogen cell with a nominal rating of at least 220 AH in a LEO regime. The design is a tandem stack, floating core type, typical of Yardney's 3 1/2 inch Air Force arrangement, but incorporating wall wick recombination and back-to-back electrodes. Mechanically the structure is a 35% scale-up variant of 3 1/2 inch components employed in the ManTech and Air Force cells. The program was somewhat accelerated in order to produce light-weight cells for performance evaluation in less than six months. Figure 9 identifies some of the improved design features employed in this cell.

A series of characterization tests were carried out on five of these cells to determine the effect of temperature between 0 and 36°C. The temperature was controlled by fluid transfer in manifolded sleeves clamped to the cylindrical section of each pressure vessel. These temperature trials, which were conducted as the first cycles, demonstrated that the best capacity is at 10°C for an average value of 243 AH. After 150 LEO cycles this early capacity increased to an average value of 259 AH above 1.0 volts.

Figure 10 illustrates the end of charge and discharge voltage trends for this initial cycle series. Continued life testing is now being planned for several of these cells.

Figure 11 shows the characteristic curves of voltage for the rating cycle of all five cells. Figures 12 and 13 indicate the consistency of discharge performance between cells from the 5th to the 150th cycle.

In early 1986 Yardney responded to customer interest to produce 100 AH LEO regime, 4 1/2 inch diameter cells. This design also employs a tandem stack, floating core; however, the stack elements are arranged in a conventional recirculating sequence. The pressure vessel wall is coated with zirconium oxide in the common Air Force practice, and no platinum catalyst is incorporated for wall recombination. Assembly of the first 100AH

CELL DESIGN FEATURES
YARDNEY 4 1/2" MODEL YNH-HRWRTS220

- 4 1/2" DIA. CYL. x 18 3/8 LOA
- MANTECH/MILSTAR GROWTH VARIANT(1.35 SCALE-UP)
- BACK-TO-BACK ELECTRODES (.031" MANTECH THICKNESS)
- ZIRCAR AND ASBESTOS SEPARATOR
- WELD RING w/MINIMAL "WIDTH"
- SIMPLIFIED CENTER SUPPORT PLATE
- BELLEVILLE SPRING STROKE MAXIMIZED
- RECOMBINATION & MAJOR HEAT SOURCE ON WALLS
- ANTI-TWIST TERMINAL

Figure 9.

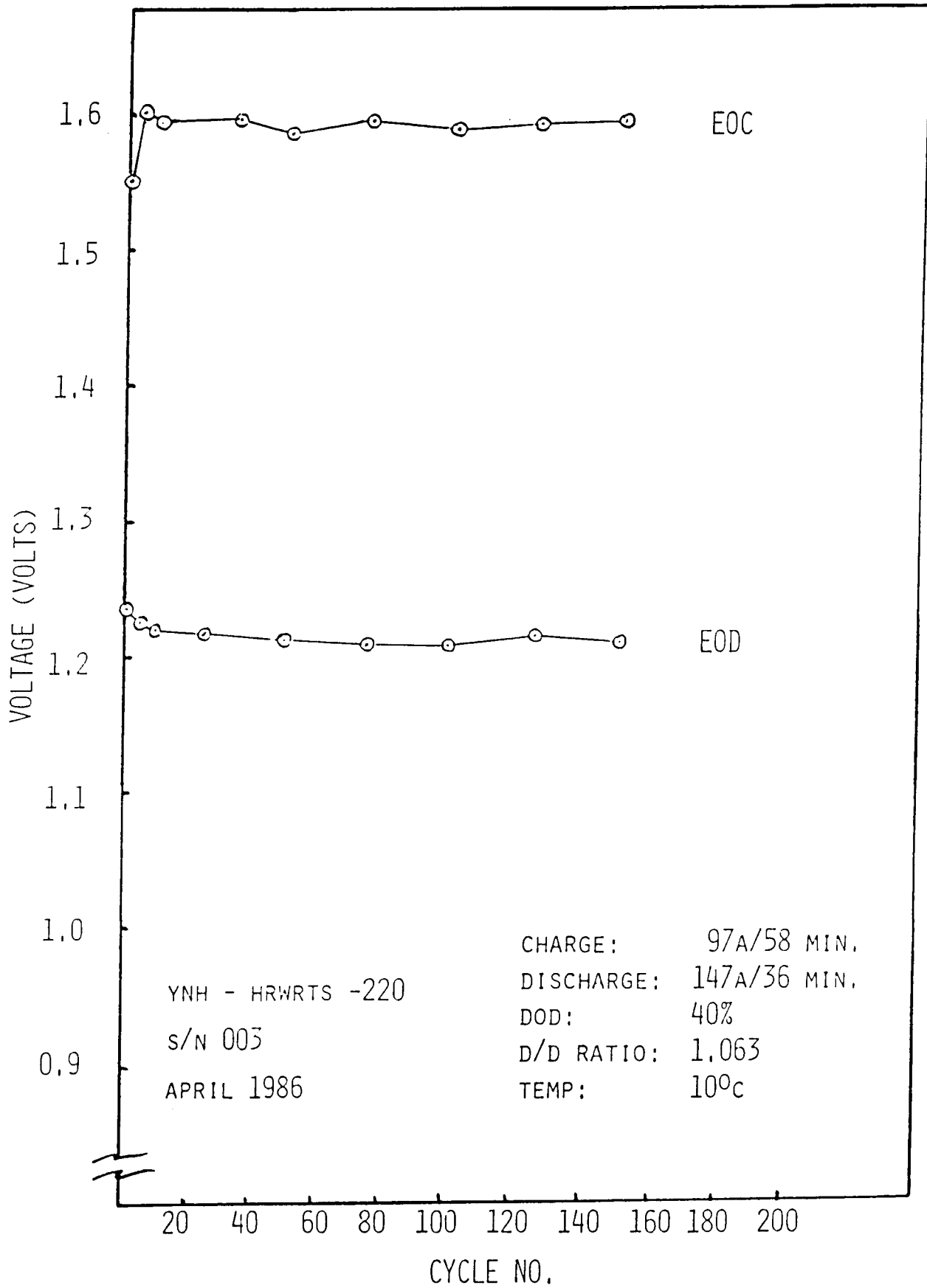


Figure 10. LEO Life Cycle Data Summary.

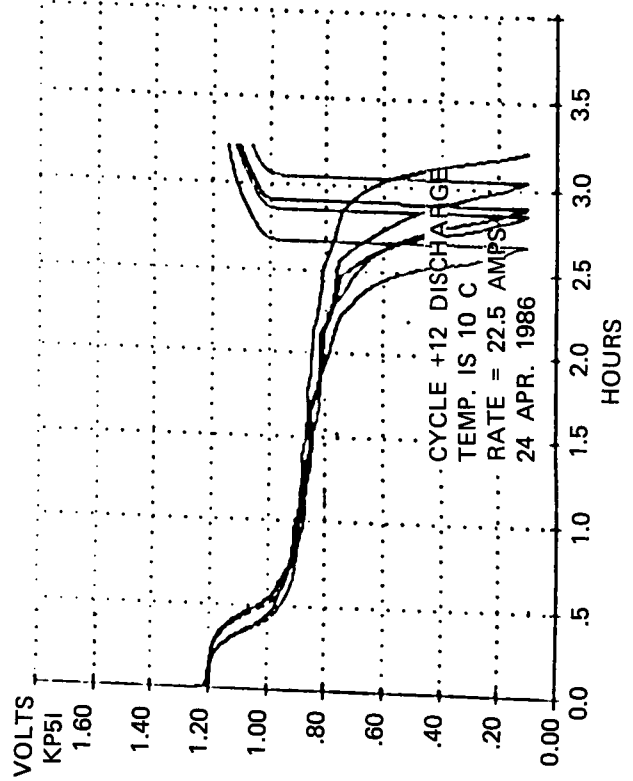
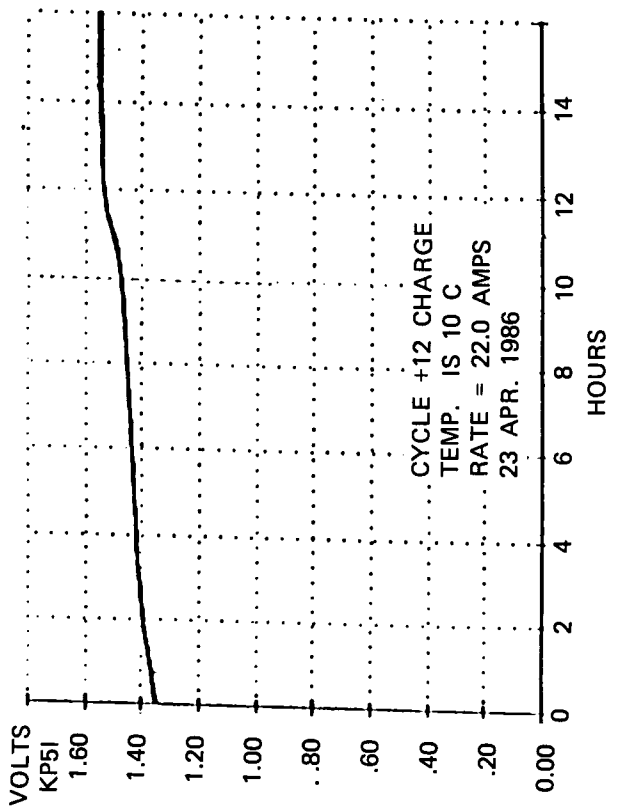
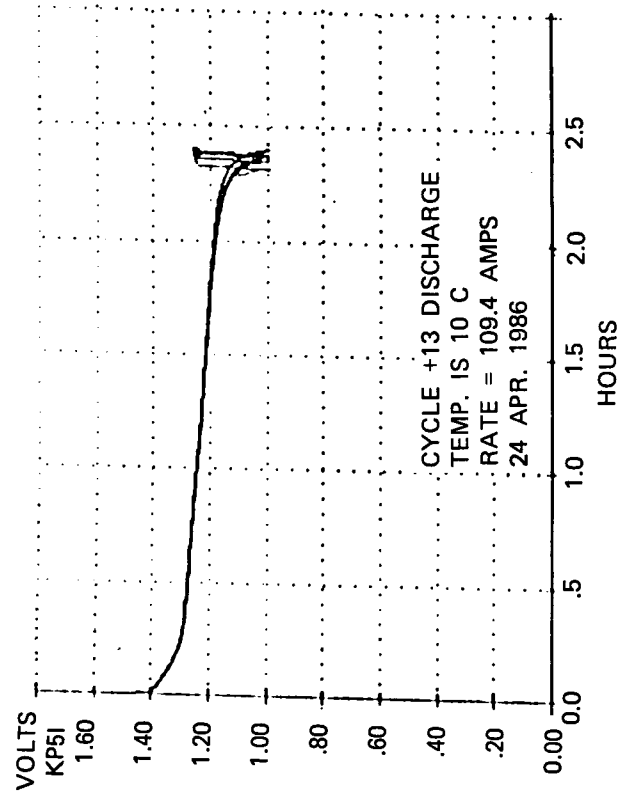


Figure 11.

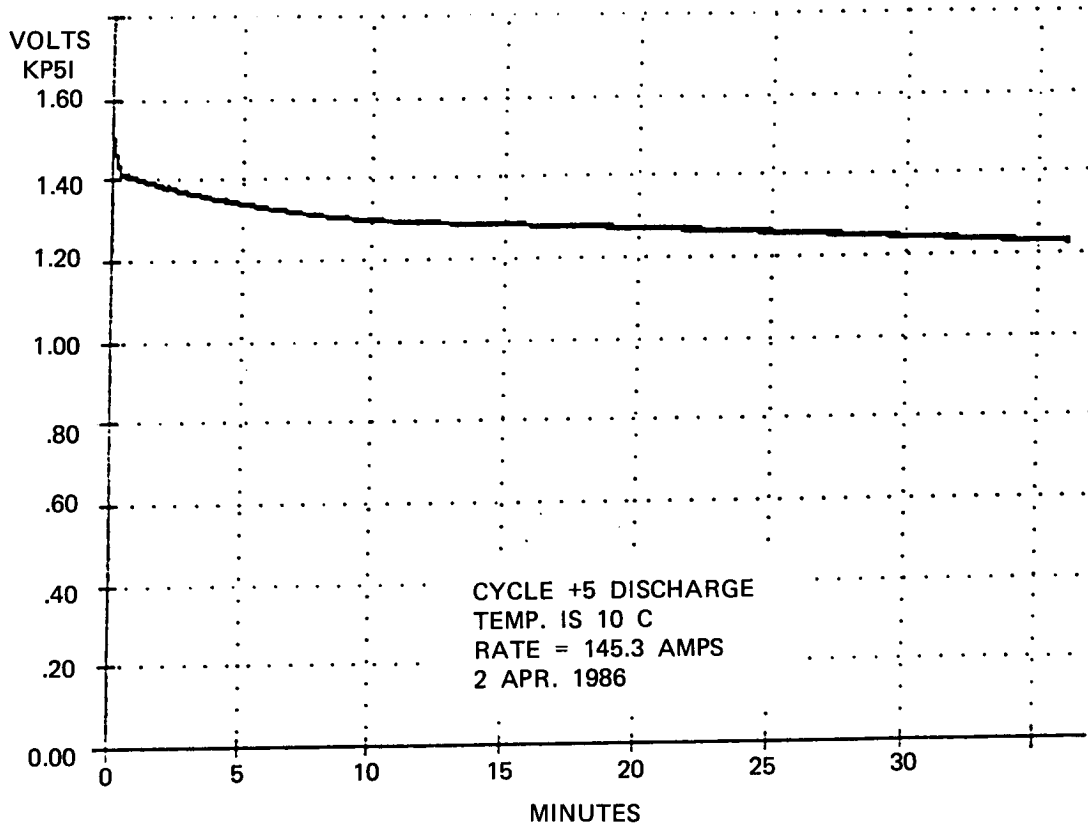


Figure 12.

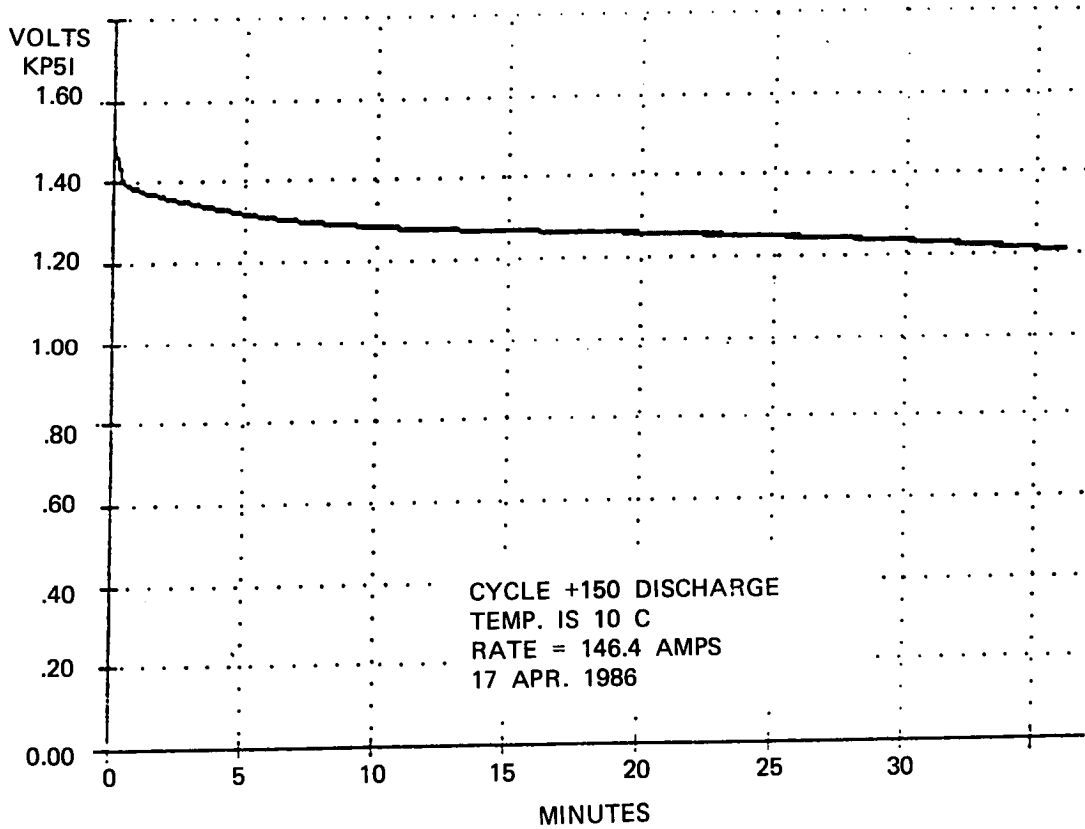


Figure 13.

units is currently underway and characterizations tests are scheduled for December 1986.

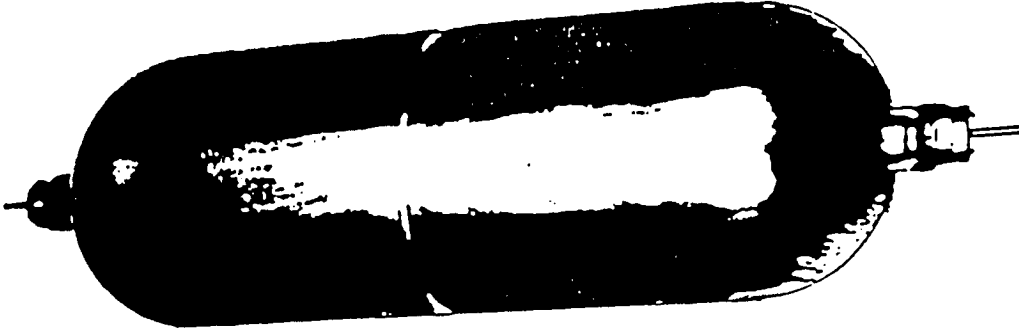
Figure 14 depicts the relative size of 50 and 70 AH 3 1/2" cells and 100 and 220 AH 4 1/2" cells.

5. BIPOLAR ACTIVITIES

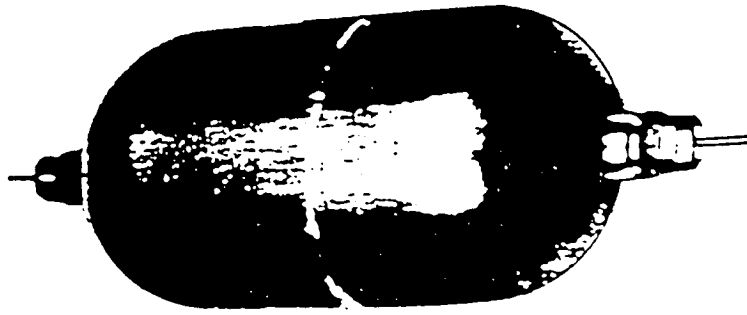
Yardney is in the third year of development regarding a 75 AH bipolar experimental battery for space applications. This NASA program is organized to evaluate a baseline design and its variants. Ford Aerospace Corporation is the prime contractor and Yardney has responsibility for the stack development. The design is inherently modular in nature, lending itself to high capacities and voltages depending on cell stack arrangement within a common pressure vessel. The program objectives include development of thick electrodes and evaluation of designs for heat removal within a context of simplicity and consequent ease of manufacturability.

The basic electrode is .080 inches thick with an area of 4 x 16 inches. Three such electrodes are ganged together in individual frames on a common "bi-polar" heat conducting plate at each cell level. A model was built early in the program to represent a full-scale section only one-sixth in length, with electrodes 4 x 8 inches. Thermal path lengths and mechanical details remained the same for the model as for the prototype size. Figure 15 shows the 10-cell model manufactured by Yardney with the cooling plates in place. This model was characterized for capacity at approximately 10°C by charging and discharging at various combinations of rates. These results are shown in the form of a carpet plot on Figure 16. It can be seen that capacity to 1.0 volts varies in a continuous manner with best results relating to optimum charge rates between C/2 and C for discharges between C/4 and 2C, respectively. After the characterization series, LEO cycles were run at 80% and 60% DOD for a total of approximately 380 cycles. The model was then torn down and inspected. In general, the cells appeared in good condition with the exception of one shorted cell attributed to the mechanical design. Figure 17 illustrates the first 75 AH stack built to this design for thermal and performance evaluation in a specially designed pressure vessel at Ford Aerospace Corporation.

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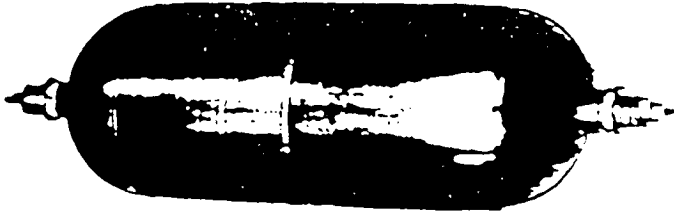


YHII-IIRTSNR220-1



YHII-IIRTS100-1

YHII-IIRTS100-1



YHII-IIRTS70-1



YHII-IR50-2

Figure 14.

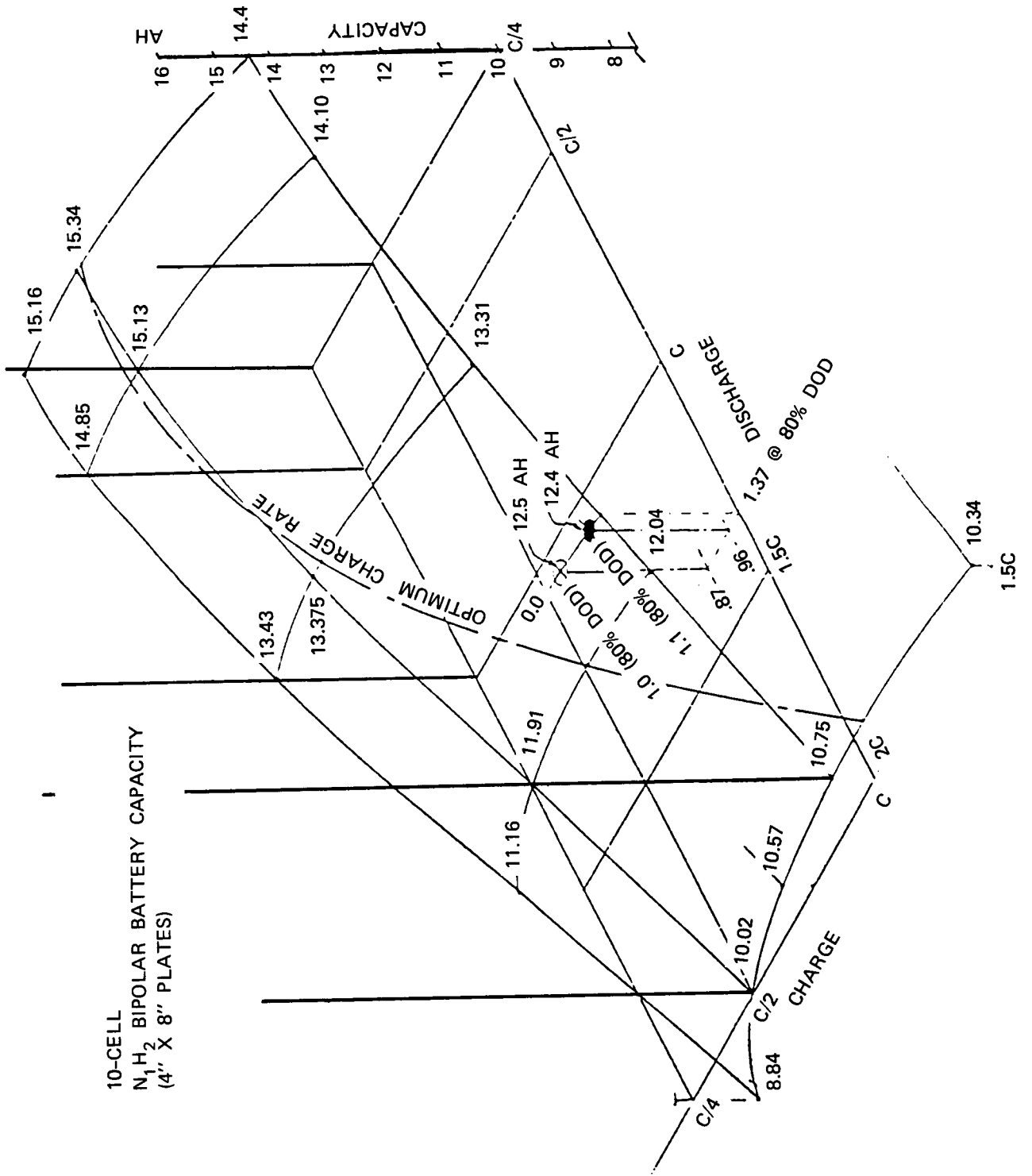


Figure 15.

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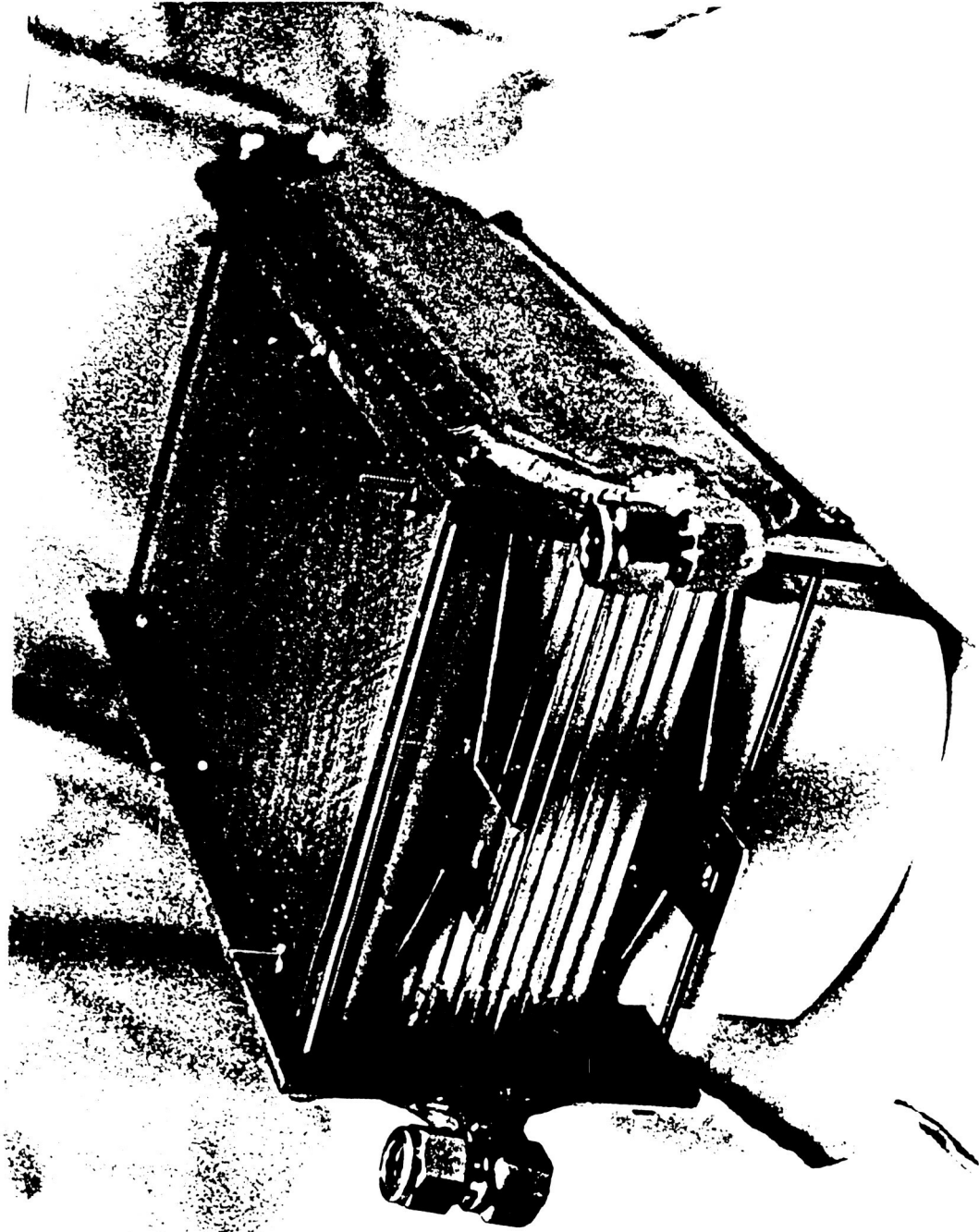


Figure 16.

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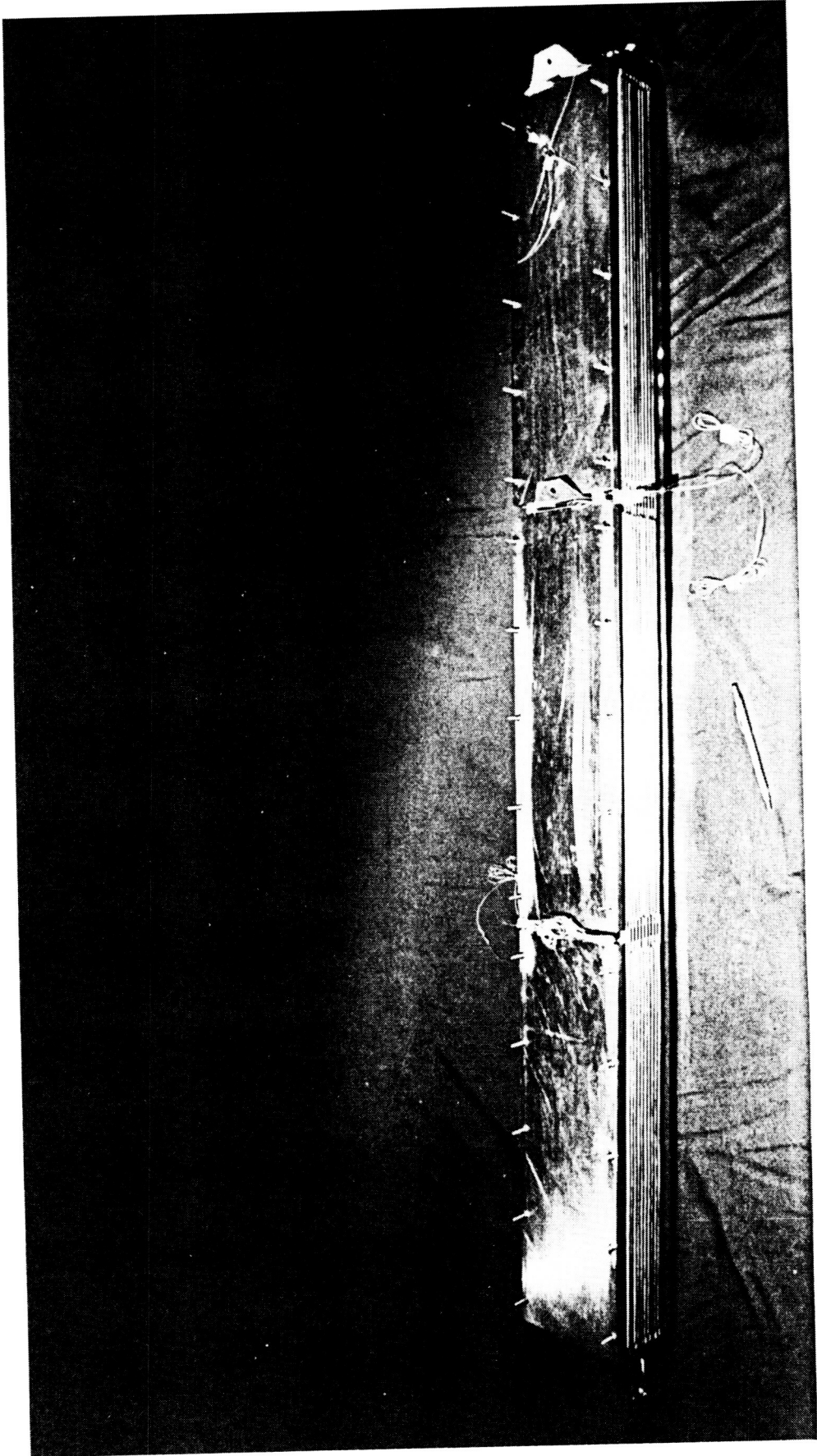


Figure 17. 75 AH NiH₂ Battery.