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Validation Test of 125 Ah Advanced Design IPV Nickel-Hydrogen Flight Cells

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ABSTRACT

An update of validation test results confirming the advanced design nickel-hydrogen cell is presented. An advanced 125 Ah individual pressure vessel (IPV) nickel-hydrogen cell was designed. The primary function of the advanced cell is to store and deliver energy for long-term, Low-Earth-Orbit (LEO) spacecraft missions. The new features of this design, which are not incorporated in state-of-the-art design cells, are: (a) use of 26 percent rather than 31 percent potassium hydroxide (KOH) electrolyte, (b) use of a patented catalyzed wall wick, (c) use of serrated-edge separators to facilitate gaseous oxygen and hydrogen flow within the cell, while still maintaining physical contact with the wall wick for electrolyte management, and (d) use of a floating rather than a fixed stack (state-of-the-art) to accommodate nickel electrode expansion due to charge/discharge cycling. The significant improvements resulting from these innovations are extended cycle life; enhanced thermal, electrolyte, and oxygen management; and accommodation of nickel electrode expansion. Six 125 Ah flight cells based on this design were fabricated by Eagle-Picher. Three of the cells contain all of the advanced features (test cells) and three are the same as the test cells except they do not have catalyst on the wall wick (control cells). All six cells are in the process of being evaluated in a LEO cycle life test at the Naval Weapons Support Center, Crane, IN, under a NASA Lewis Research Center contract. The catalyzed wall wick cells have been cycled for over 19 000 cycles with no cell failures in the continuing test. Two of the noncatalyzed wall wick cells failed (cycles 9588 and 13 900).

INTRODUCTION

As part of an overall effort to advance the technology of nickel-hydrogen batteries for use in a space power system, an advanced design for an IPV battery cell was conceived (1). The intent of this effort was to improve cycle life at moderate to deep-depths-of-discharge (40 to 80 percent). The approach was to review IPV nickel-hydrogen cell designs and results of cycle life test conducted in-house and by others to identify areas where improvements could result in a longer cycle life (2-8). Design philosophies were developed relative to oxygen and electrolyte management requirements (9). The feasibility of the advanced design was demonstrated using 6 Ah boiler plate cells and 31 percent KOH electrolyte (10). Recently, a breakthrough in LEO cycle life using state-of-art design boiler plate cells, 26 percent KOH and an accelerated cycle regime was achieved under a NASA Lewis Research Center contract with Hughes (11-13).

The purpose of this experiment is to validate the advanced cell using flight hardware containing 26 percent KOH and compare cells containing the catalyzed wall wick to cells without it. Six 125 Ah capacity flight cells based on the advanced design were fabricated by Eagle-Picher Joplin, MO. Three of the cells contain all of the advanced features (test cells) and three are the same as the test cells except they do not have catalyst on the wall wick (control cells). They are undergoing real time LEO cycle life testing at the Naval Weapons Support Center (NWSC), Crane, IN, under a NASA Lewis contract. In this report, validation test results which were presented at the 1992 IECEC will be updated (14).

EXPERIMENTAL

Test Facility

The facility is capable of testing 45 battery packs with maximum of 10 cells electrically connected in series per pack. Each pack has its own charge and discharge power supply which is controlled by a computer that is programmed to satisfy the particular test requirements. During testing, each pack is scanned every 2.4 min to compare data such as voltage, temperature and pressure with programmed limits. If a parameter is out of limit, an alarm will be initiated and a message will be typed out identifying the cell and parameter. The data is recorded on a 132 MB disk drive and, if requested, can be obtained in report form. The cell temperature during a test is controlled by a recirculating cooler that circulates a solution of water and ethylene glycol through a cooling plate.

Cell Description

The six cells are 125 Ah capacity advanced flight IPV nickel-hydrogen cells. They were fabricated by Eagle Picher, Joplin, MO, according to NASA Lewis specifications using nickel electrodes fabricated at Eagle Picher, Colorado Springs, CO, and were impregnated with active material by the alcoholic Pickett process (15). Three of the cells (test cells) contain all of the advanced design features as described in reference 1. The other three cells (control cells) are the same as the test cells except they do not have catalyst on the wall wick. All six cells contain 26 rather than 31 percent KOH electrolyte.

The test cell design is illustrated in figure 1. The new features of this design, which are not incorporated in the state-of-the-art Air Force/Hughes or Comsat/Intelsat cells, are: (a) use of 26 percent rather than 31 percent KOH electrolyte, (b) use of catalyzed wall wick, (c) use of serrated edge separators, and (d) use of a floating rather than a fixed stack (SOA). The 26 percent electrolyte is used to chemically recombine the oxygen generated at the end of charge and on overcharge with hydrogen to form water. State-of-the-art nickel hydrogen cells recombine the oxygen on the catalyzed hydrogen electrode surface in the stack. The catalyzed wall wick should improve oxygen and thermal management (16). The serrated edge separators are used to facilitate gaseous oxygen and hydrogen flow within the cell, while still maintaining physical contact with the wall wick for electrolyte management. The floating stack accommodates some of the nickel electrode expansion due to charge/discharge cycling. This is accomplished by use of Belleville disk springs located at each end of the stack. The significant improvements resulting from these innovations are extended cycle life, enhanced oxygen, thermal and electrolyte management, and accommodation of some of the nickel electrode expansion.

Measurements and Procedures

The quantities measured every 2.4 min for each cell during charge and discharge and their accuracies are: current (±2.0 percent), voltage (±0.001 percent), pressure (±1 percent), and temperature (±1 percent). Charge and discharge ampere-hour capacities were calculated from current and time. The charge to discharge ratio (ampere-hours into cell on charge to ampere-hours out on discharge) are calculated from the charge and discharge ampere-hour capacities. Cell charge and discharge currents are calculated from measured voltage across a shunt, using an integrating digital voltmeter. Cell voltage is measured, also using an integrating digital voltmeter. Cell pressure is measured using a strain gauge located on the cell dome. The temperature is measured using a thermistor located on the center of the pressure vessel dome. The thermistor is mounted using a heat sink compound to insure good thermal contact.

After completion of activation testing by the manufacturer, the precharge hydrogen pressure was set to 0 psig (14.5 psia) with the nickel electrodes in the fully discharged state. After completion of the acceptance testing, the cells were discharged at the C/10 rate (12.5 A) to 0.1 V or less and the terminals were shorted. The cells were shipped to NWSC, Crane, where they were stored open circuit, discharge, 0 °C for 52 days. After storage, the discharge ampere-hour capacity acceptance test was repeated. The capacity was measured after charging the cells at the C/2 rate (62.5 A) for 2 hr, then C/10 for 6 hr, followed by a 0.5 hr open circuit stand. The discharge capacity was measured to 1.0 V for each of the following rates: C/2, C, 1.4C, and 2C.

Prior to undergoing cycle life testing, the capacity retention after a 72 hr open circuit stand (10 °C) was measured for all cells. For the cycle life test, the cells were connected electrically in series to form a six cell pack. The cycle regime is a 90 min LEO orbit consisting of a 54 min charge at a constant 0.69C rate (87 A) followed by 36 min discharge at C rate (125 A). The charge to discharge ratio was 1.04. The depth-of-discharge was 60 percent of name plate capacity (125 Ah). During the cycle life test, the cooling plate temperature was maintained at 10±2 °C. Cell failure for this test was defined to occur when the discharge voltage degrades to 1.0 V during the course of the 36 min discharge.

RESULTS AND DISCUSSION

Cell Performance

For a representative 125 Ah advanced catalyzed wall wick nickel-hydrogen flight battery cell, the voltage and pressure during charge and discharge are shown in figure 2 (beginning of life). The discharge rate was 0.69C (87 A) and the temperature was a nominal 10 °C. The mid discharge voltage was 1.248 V. The pressure, as expected, varies linearly with the state-of-charge. It should be noted, however, that the pressure could increase with charge/discharge cycling causing a shift in the state-of-charge curve.

The effect of discharge rate on ampere-hour capacity for a representative cell of each type is shown in figure 3. The capacity decreased slightly (1 percent) over the range of C/2 to 1.4C, (175 A) after which point it decreases rapidly. In a nickel-hydrogen cell, the gaseous hydrogen comes into contact with the nickel electrodes resulting in a capacity loss due to self discharge. The capacity retention of the cells after a 72 hr open circuit stand at 10 °C is shown in figure 4. The data shows that there is no significant difference in capacity retention between the catalyzed and wall wick cells. For the catalyzed wall wick cells, on the average, it is 84 percent, and for noncatalyzed wall wick cells, it is 85 percent.

Storage Test

The effect of storage (52 days, discharged, open circuit, 0 °C) on the capacity of the six, 125 Ah flight IPV nickel-hydrogen cells is summarized in the figure 5. The spread in the data shows no significant capacity loss for either the catalyzed or noncatalyzed wall wick cells due to the 52 day storage. Actually, there was a slight average increase in capacity for both the catalyzed and noncatalyzed wall wick cells.

Cycle Test

The influence of LEO cycling at 60 percent DOD on the end of discharge voltage for the 125 Ah catalyzed wall wick IPV nickel-hydrogen flight cells is summarized in figure 6. After 19 000 cycles, there has been no cell failure in the continuing test. The influence of cycling on the end-of-charge pressure for the catalyzed wall wick cells is shown in figure 7. No pressure for cell 2 is available because the cell had a bad strain gauge. For cells 1 and 3, the pressure increased relatively rapidly up to about cycle 1400, then decreased to a steady state valve. The average pressure increase at cycle 1400 is about 11 percent higher than at the beginning of life.

The influence of LEO cycling at 60 percent DOD on the end of discharge voltage for the 125 Ah noncatalyzed wall wick IPV nickel-hydrogen flight cells is shown in figure 8. Two of the three cells failed (cycles 9588 and 13 900). The failure was characterized by degradation of end of discharge voltage to 1.0 V. The cells did not fail due to an electrical short. The influence of cycling on the end-of-charge pressure for the noncatalyzed wall wick cells is shown in figure 9. The pressure for the three cells increased up to about cycle 2000, then decreased. The average pressure increase at cycle 2000 is about 9 percent higher than at the beginning of life.

The cycle life testing will continue until cell failure. A post-cycle teardown and failure analysis will be conducted to evaluate the cause of failure. This information will be used to effect further improvements.

CONCLUDING REMARKS

Validation testing of NASA Lewis 125 Ah advanced design IPV nickel-hydrogen flight cells is being conducted at NWSC, Crane under a NASA Lewis contract. This consists of characterization, storage and cycle life testing. There was no capacity degradation after 52 days of storage with the cells in the discharged state, on open circuit, 0 °C, and a hydrogen pressure of 14.5 psia. The catalyzed wall wick cells have cycled for over 19 000 cycles with no cell failures in the continuing test. Two of the noncatalyzed wall wick cells failed (cycles 9588 and 13 900). These results indicate that the advanced design is an improvement.

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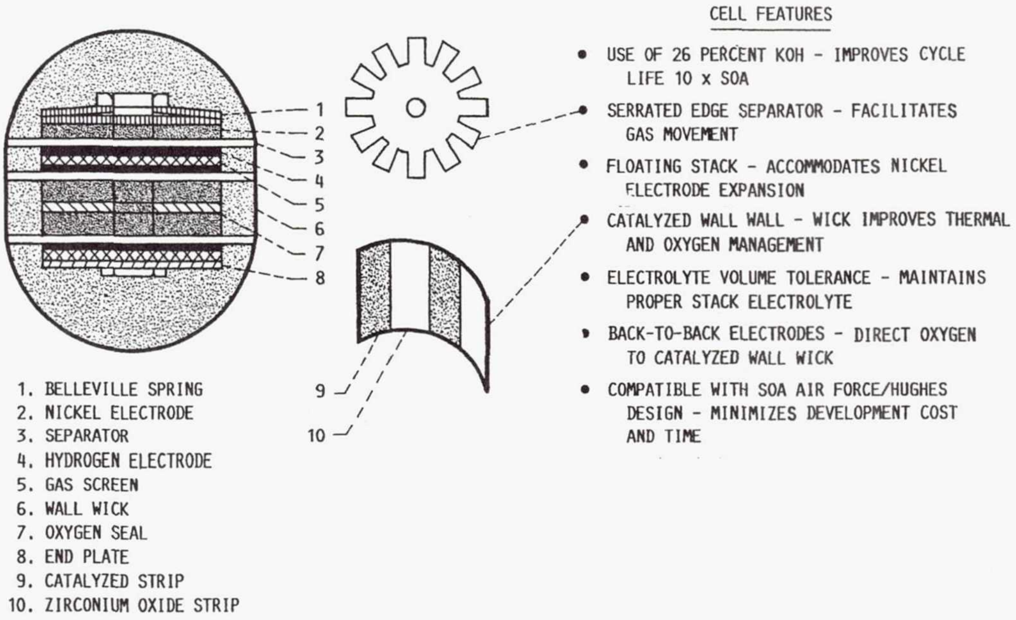

1. BELLEVILLE SPRING
2. NICKEL ELECTRODE
3. SEPARATOR
4. HYDROGEN ELECTRODE
5. GAS SCREEN
6. WALL WICK
7. OXYGEN SEAL
8. END PLATE
9. CATALYZED STRIP
10. ZIRCONIUM OXIDE STRIP

CELL FEATURES

- USE OF 26 PERCENT KOH - IMPROVES CYCLE LIFE 10 x SOA
- SERRATED EDGE SEPARATOR - FACILITATES GAS MOVEMENT
- FLOATING STACK - ACCOMMODATES NICKEL ELECTRODE EXPANSION
- CATALYZED WALL WALL - WICK IMPROVES THERMAL AND OXYGEN MANAGEMENT
- ELECTROLYTE VOLUME TOLERANCE - MAINTAINS PROPER STACK ELECTROLYTE
- BACK-TO-BACK ELECTRODES - DIRECT OXYGEN TO CATALYZED WALL WICK
- COMPATIBLE WITH SOA AIR FORCE/HUGHES DESIGN - MINIMIZES DEVELOPMENT COST AND TIME

FIGURE 1.—NASA ADVANCED DESIGN IPV NICKEL-HYDROGEN CELL-CATALYZED WALL WICK.

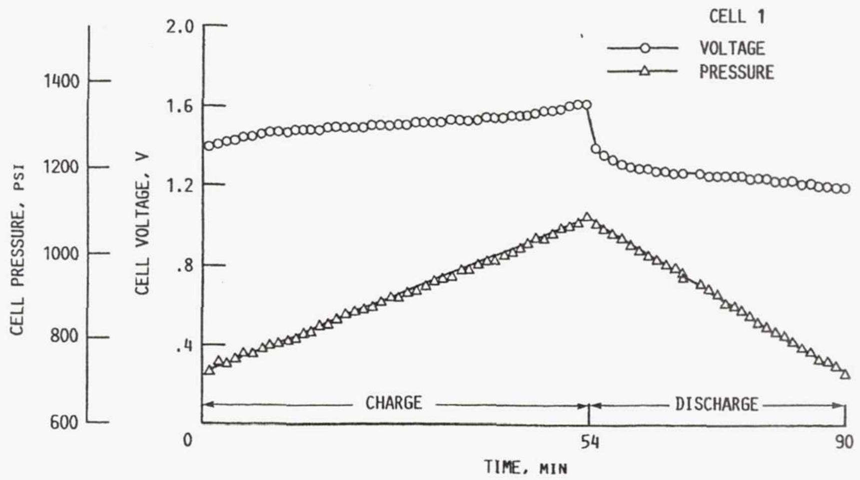

FIGURE 2.—CELL VOLTAGE AND PRESSURE DURING CHARGE AND DISCHARGE FOR A REPRESENTATIVE 125 A-hr ADVANCED CATALYZED WALL WICK IPV Ni/H_2 FLIGHT BATTERY.

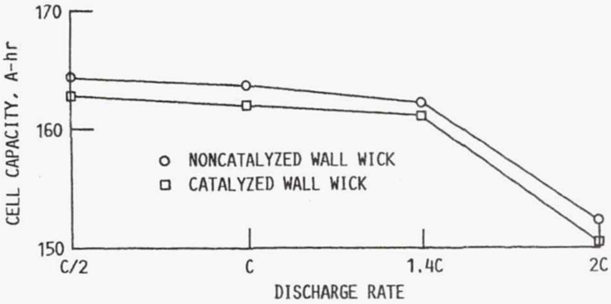

FIGURE 3.—COMPARISON OF EAGLE-PICHER 125 A-hr Ni/H_2 CELLS CATALYZED AND NONCATALYZED WALL WICK.

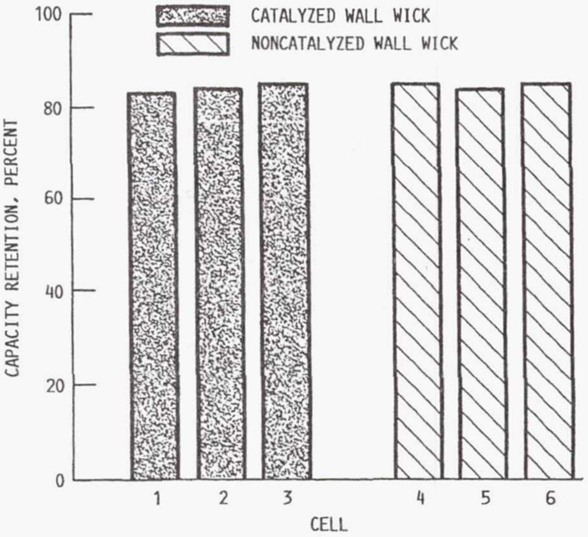

FIGURE 4.—CAPACITY RETENTION OF 125 A-hr EAGLE-PICHER ADVANCED IPV Ni/H_2 FLIGHT CELLS AFTER 72 hr OPEN CIRCUIT STAND.

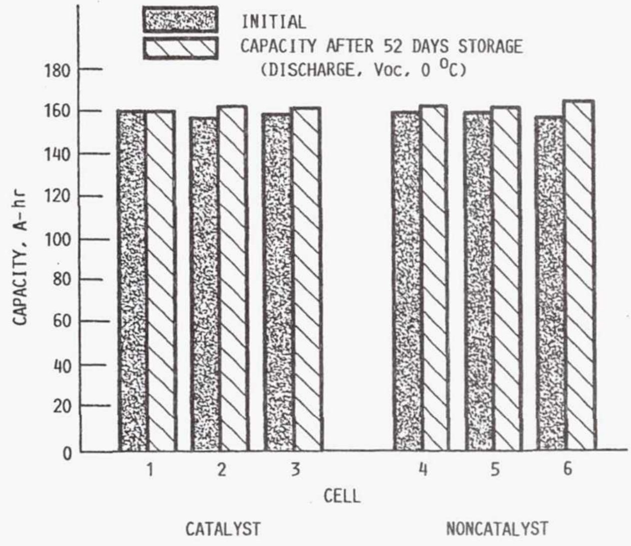

FIGURE 5.—EFFECT OF STORAGE ON CAPACITY OF 125 A-hr EAGLE-PICHER ADVANCED FLIGHT IPV Ni/H_2 CELLS, CATALYZED AND NONCATALYZED WALL WICK, 26 PERCENT KOH.

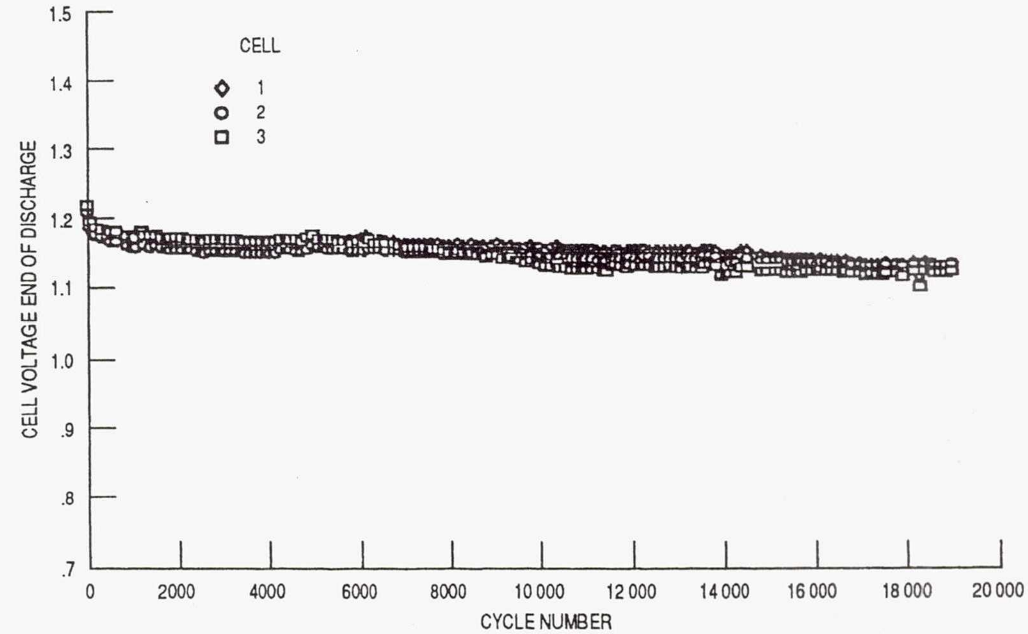

FIGURE 6.—EFFECT OF LEO CYCLING ON 125 A-hr NASA LEWIS ADVANCED CATALYZED WALL WICK IPV Ni/H_2 CELLS MANUFACTURED BY EAGLE-PICHER, 26 PERCENT KOH, 60 PERCENT DOD, 10 °C.

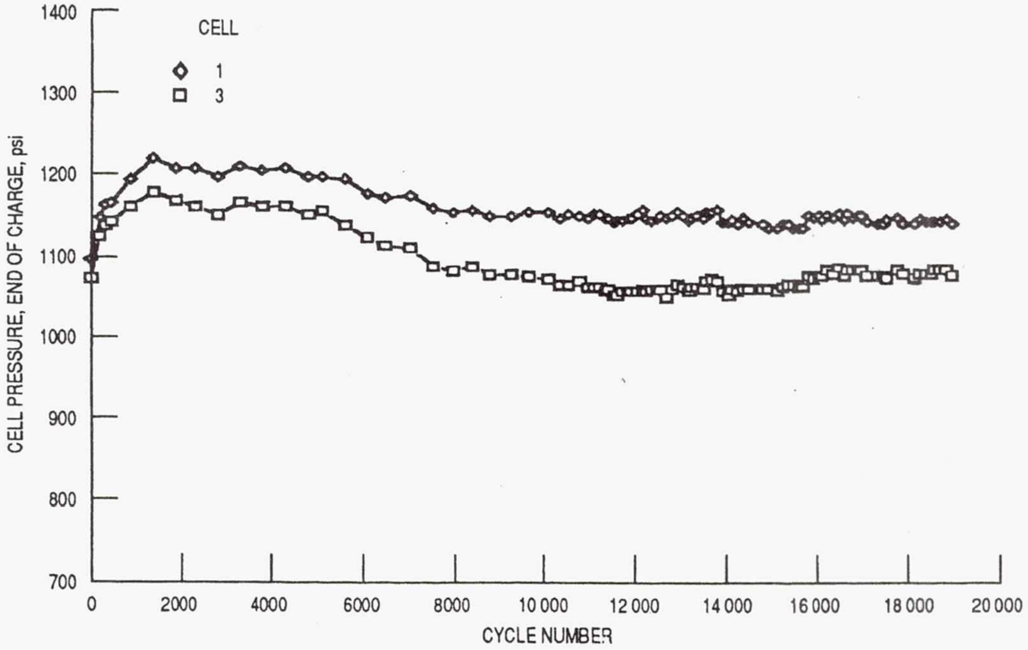

FIGURE 7.—EFFECT OF LEO CYCLING ON 125 A-hr NASA LEWIS ADVANCED CATALYZED WALL WICK IPV Ni/H_2 CELLS MANUFACTURED BY EAGLE-PICHER, 26 PERCENT KOH, 60 PERCENT DOD, 10 °C.

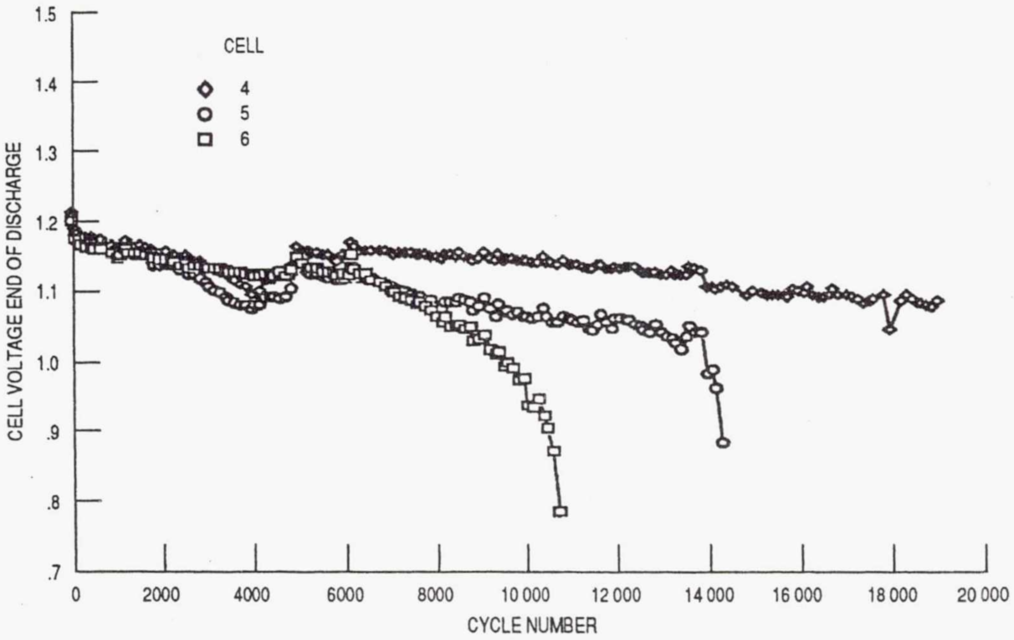

FIGURE 8.—EFFECT OF LEO CYCLING ON 125 A-hr NASA LEWIS ADVANCED NONCATALYZED WALL WICK IPV Ni/H_2 CELLS MANUFACTURED BY EAGLE-PICHER, 26 PERCENT KOH, 60 PERCENT DOD, 10 °C.

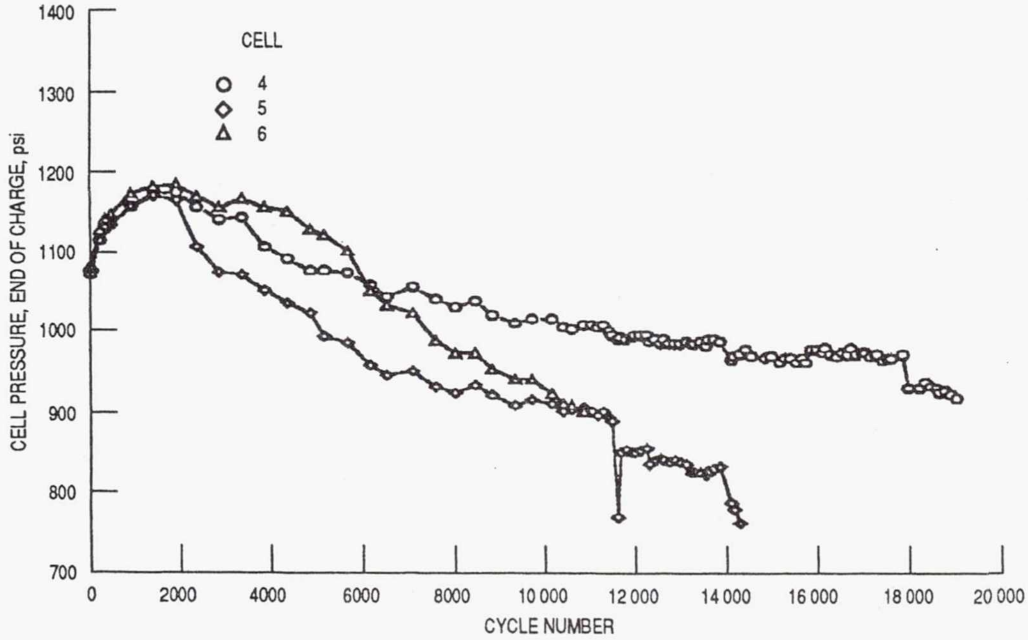

FIGURE 9.—EFFECT OF LEO CYCLING ON 125 A-hr NASA LEWIS ADVANCED NONCATALYZED WALL WICK IPV Ni/H_2 CELLS MANUFACTURED BY EAGLE-PICHER, 26 PERCENT KOH, 60 PERCENT DOD, 10 °C.

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13. ABSTRACT ***(Maximum 200 words)***

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