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FAILURE ANALYSIS OF A 3.5 INCH, 50 AMPERE HOUR NICKEL–HYDROGEN CELL

KENNETH H. FUHR

Martin Marietta Denver Aerospace, P.O. Box 179, Denver, CO 80201 (U.S.A.)

Summary

A 3.5 in., 50 ampere hour nickel–hydrogen cell has been on a Low Earth Orbit (LEO) test regime at 10 °C and 60% depth of discharge. At cycle number 511 the Automatic Control and Data Acquisition System (ACDAS) terminated the test when the end of discharge voltage dropped below the 1.00 V cutoff. Upon removal of the stack assembly from the pressure vessel, portions of the Zircar separator were found to be completely missing. Upon further examination, portions of both the positive and the negative plates were found to be missing from their substrate and several gas screens were damaged due to excessive heat which had caused fusing. The postulated cause of failure is that free electrolyte in the cell caused oxygen channeling which resulted in localized recombination degrading the stack components and leading to a short.

Introduction

The nickel–hydrogen cell in this study was manufactured according to Hughes-Airforce specifications with recirculating electrode stack design and two layers of Zircar separators. The cell was 3.5 in. in diameter and was rated at 50 A h.

The cell was mounted on a cold plate by means of an aluminum collar; the cold plate was oriented inside an environmental chamber such that the cell was in the horizontal position. The test chamber was kept at 10 °C and the cold plate cooled to 10 °C with circulating, chilled water.

The cell was on a LEO test regime consisting of 55 min charge time, 35 min discharge time, and under test to a 60% depth of discharge. Cycling was controlled automatically on the ACDAS to permit unattended operation. During the charge phase of cycle #509 the cell voltage began deviating from the other test cells by 80 mV. During discharge on cycle #511 the cell voltage dropped below the 1.00 V cutoff and the ACDAS terminated the test. The cell was removed from the test fixture and an insulation resistance test between mounting collar and pressure vessel was performed and found to be greater than 1 MΩ. The internal impedance was found to be 1.10 mΩ compared with the initial impedance of 1.15 mΩ.

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A reconditioning charge of 5.0 A was applied for 16 h during which time the maximum voltage recorded was 1.397 V. Upon termination of the charge, the open-circuit voltage was monitored and found to decay to 1.0 V over a 3 h period. A 1 Ω resistor was placed across the terminals for 24 h to discharge the cell completely. After this time a shorting wire was placed across the terminals until a failure analysis could be performed.

Failure analysis results

The shorting wire was removed and the voltage monitored for possible signs of recovery; there was none. The cell was placed in a nitrogen glove-box and the fill tube was cut off. The cell was inverted in order to allow free electrolyte to drain out. Approximately 2 - 3 ml of electrolyte were collected. The cell was oriented with its fill tube up, evacuated and allowed to back-fill with nitrogen. This procedure was repeated for a total of four cycles in order to remove residual hydrogen gas. Finally the cell was evacuated and inverted to remove any remaining electrolyte. An additional 2 - 3 ml were obtained. The pressure vessel was opened by cutting through the walls on the cylinder side of the girth weld using a high speed cutoff wheel, making sure that penetration was deep enough to cut through the inside weld ring. The terminal hardware and the dome end of the cylinder were removed. The edges of the cylinder were deburred and the cutoff area was thoroughly cleaned to remove cutting debris.

Upon removal of the plate stack from the pressure vessel, a large, dark area was clearly visible beginning at positive plate (counting from the positive terminal end) number 15 and continuing to approximately positive plate number 38 with the major damaged area occurring from plate 15 to plate 31. Detailed examination of the plate stack assembly revealed the complete absence of separator material. Active material was noted to be missing from both the positive and negative substrate. Shorting of adjacent positive and negative plates was found in these areas. Portions of the gas screens from this area were found to be missing and the edges bordering the missing area appeared to be burned or fused together. Examination of the separator material revealed that portions were missing.

Conclusions

The cause of failure is hypothesized to be free electrolyte collecting in the bottom of the stack while the cells were under test in the horizontal position. This excessive electrolyte, in turn, resulted in oxygen channeling and caused localized recombination. The localized recombination resulted in hot spots and "popping" which destroyed the separator and plates. The popping caused plate material to be dislodged from the substrate which, in turn, caused the plate-to-plate short.