

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

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Abstract

The 3.5 inch, 50 ampere-hour nickel-hydrogen cell was on a Low Earth Orbit (LEO) test regime and was being cycled 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 volt 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 negative plates were found to be missing from its substrate and several gas screens were damaged due to excessive heat which caused fusing. The postulated cause of failure is free electrolyte in the cell which caused oxygen channelization resulting in localized recombination which degraded the stack components leading to a short.

Introduction

The subject nickel-hydrogen cell was manufactured according to the Hughes-Airforce specifications with the recirculating electrode stack design using two layers of zircar separators. The cell is 3.5 inches in diameter and is rated at 50 ampere-hours.

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

The cell was on a LEO test regime consisting of 55 minutes charge time, and 35 minutes discharge time and was being tested 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 millivolts. During discharge on cycle #511 the cell voltage dropped below the 1.00 volt 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 one megaohm. The internal impedance was found to be 1.10 milliohms compared to the initial impedance of 1.15 milliohms.

A reconditioning charge of 5.0 amps was applied for 16 hours during which time the maximum voltage recorded was 1.397 volts. Upon termination of the charge, the open circuit voltage was monitored and found to decay to 1.0 volt over a three hour period. A one ohm resistor was placed across the terminals for twenty-four hours to completely discharge the cell. After this time a shorting wire was placed across the terminals until the failure analysis could be performed.

Failure Analysis Results

The shorting wire was removed and the voltage was monitored for possible signs of recovery of which 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. Approximately 2-3 milliliters of electrolyte were collected. The cell was orientated with fill tube up and 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. The vacuum line was again attached to the cell and it was evacuated and inverted to remove any remaining electrolyte. An additional 2-3 milliliters were obtained. The cell was then mounted in a lathe and a high speed motor with a Norton A364 reinforced carborundum wheel attached to the motor shaft was mounted on the tool post of the lathe. The pressure vessel was opened by cutting through the walls on the cylinder side of the girth weld making sure penetration of the cutoff wheel was deep enough to cut through the inside weld ring. The terminal hardware was removed and the dome end of the cylinder was 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 (Figure 1) beginning at positive plate (counting from 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 (Figure 2). 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 (Figures 3 & 4). 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 of the missing area appeared to be burned or fused together (Figure 5). Examination of the separator material also revealed portions of it to be missing, (Figure 6).

Conclusions

The cause of failure is hypothesized to be free electrolyte collecting in the bottom of the stack when the cells were being tested in the horizontal position. This excessive electrolyte in turn results in oxygen channelization causing localized recombination. The localized recombination results in hot spots and "popping" which destroys the separator and plates. The popping causes plate material to be dislodged from the substrate which in turn caused the plate to plate short.

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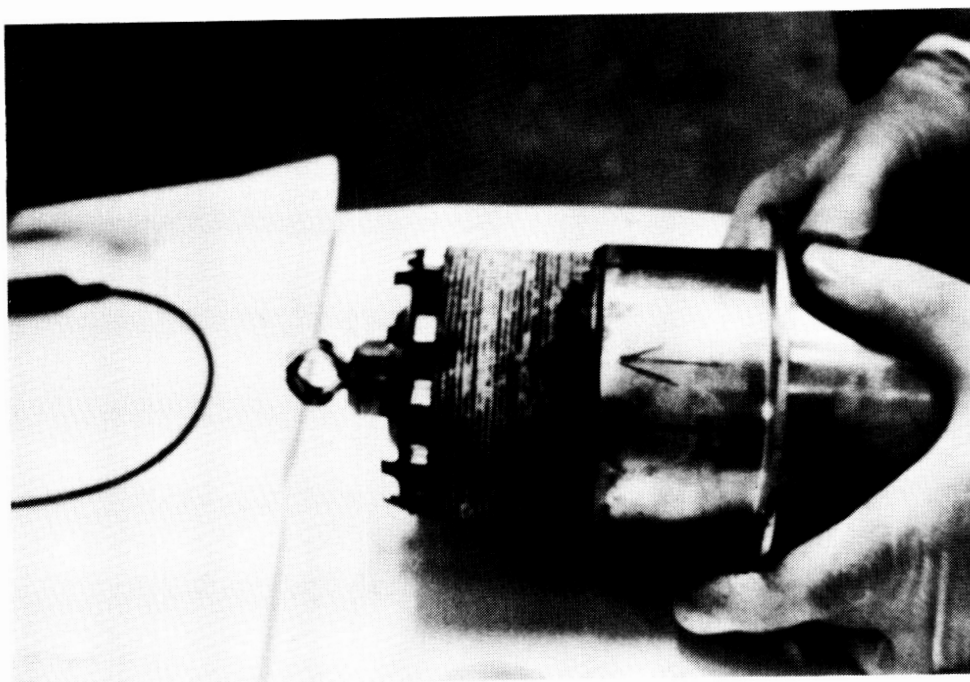


Figure 1.



Figure 2.

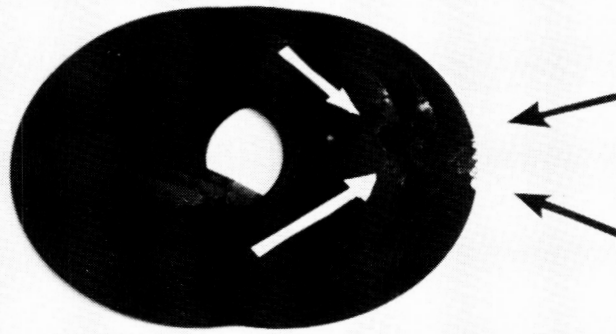


Figure 3.

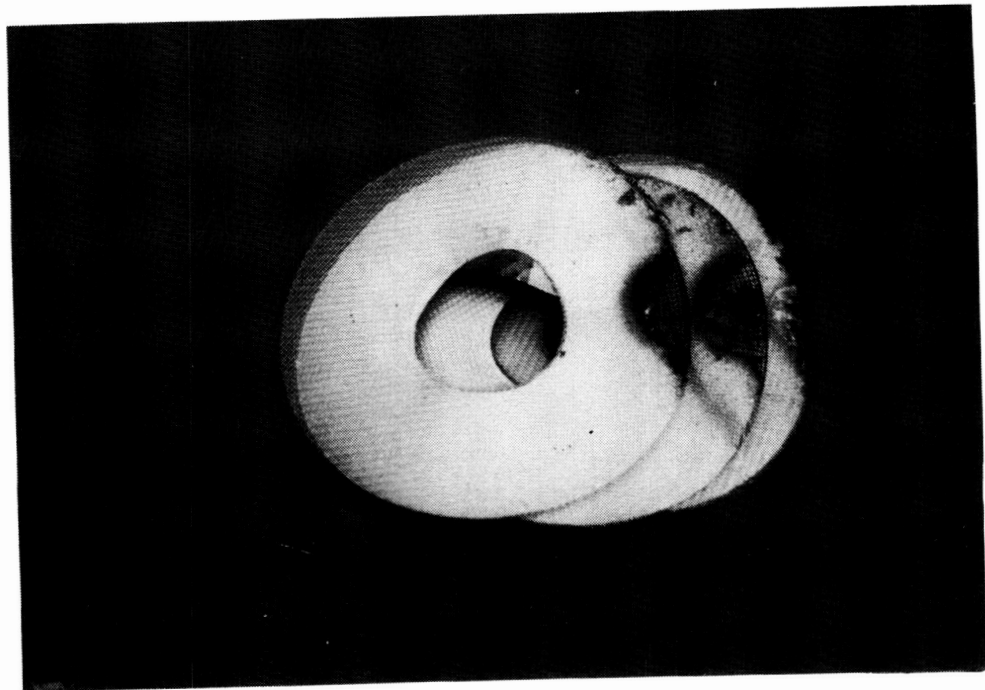


Figure 4.

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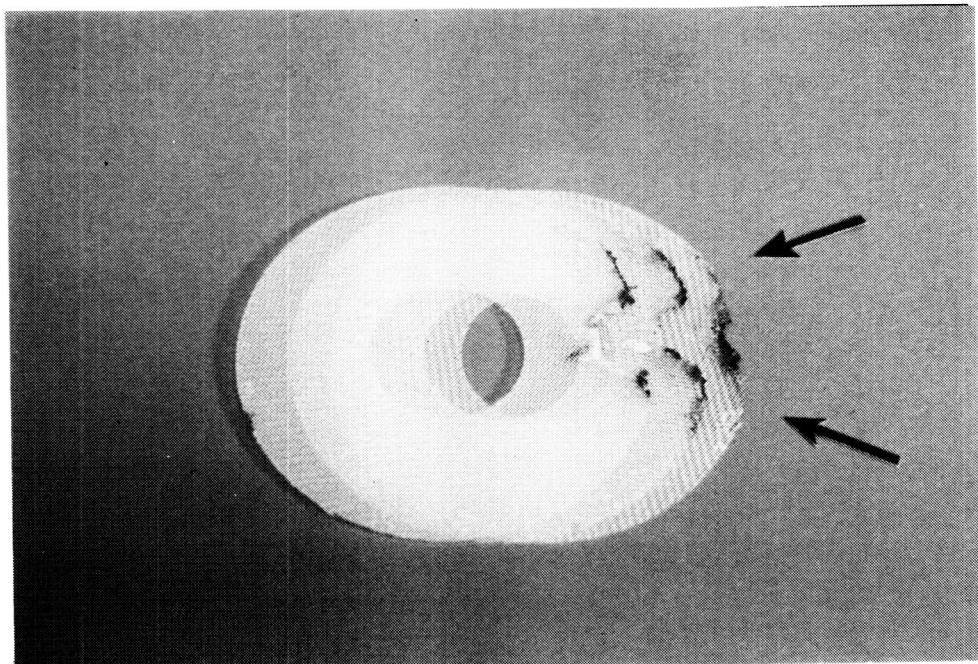


Figure 5.

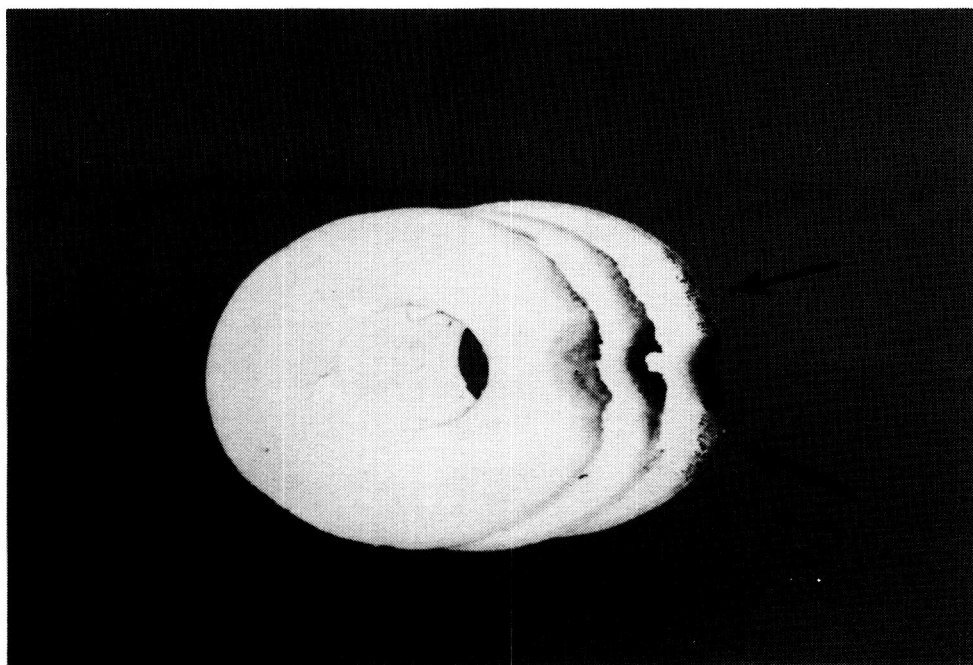


Figure 6.