NICKEL-HYDROGEN CELL
REVERSAL CHARACTERISTICS

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NICKEL-HYDROGEN CELL REVERSAL CHARACTERISTICS

NICKEL-HYDROGEN CELL REVERSAL CHARACTERISTICS ARE BEING STUDIED AS PART OF A TRW PROGRAM DIRECTED TOWARDS DEVELOPMENT OF A HIGH CURRENT BATTERY CELL BYPASS SWITCH.
CELL BYPASS SWITCH

- OPEN CIRCUIT FAILURE MODE CONSIDERED CREDIBLE FOR NICKEL-HYDROGEN CELLS
- BYPASS PROTECTION TRADITIONALLY PROVIDED BY DIODES
- DIODE APPROACH IS POWER LIMITED
  - THERMAL DISSIPATION
  - UNAVAILABILITY OF LARGE FLIGHT QUALIFIED DIODES
- BYPASS WITH A SWITCH IS PREFERRED FOR LARGE CELLS
  - LOWER DISSIPATION
  - LIGHTER
BYPASS SWITCH APPROACH

Passive fuse wire actuated bypass switch

Thermostatically actuated bypass switch
NICKEL-HYDROGEN CELL REVERSAL CHARACTERISTICS

- Characterization of the switch includes understanding
  - how long it will take to actuate
  - at what voltage it will actuate

- Characteristics of the fuse links, diode, resistor, and thermostat are easily determined

- Reversal characteristics of nickel hydrogen cells must also be known if the switch actuation characteristics are to be determined
EXPERIMENTAL

- DETERMINE NICKEL HYDROGEN CELL REVERSAL VOLTAGE TRAJECTORIES
  - HYDROGEN AND NICKEL PRECHARGED CELLS
  - NOMINAL AND MINIMUM RATES
  - CELL LEAKING INTO VACUUM (SPACE)

- TEST INSTRUMENTATION
EXPERIMENTAL (CONT'D)

- EP RNH 65-17 CELL, IN THERMAL SLEEVE, ON COLD PLATE AT 5 ± 2 DEG C
  - ZIRCAR SEPARATOR, WALL WICK
  - BACK-TO-BACK STACK CONFIGURATION

- LEAK TO SPACE SIMULATED BY VENTING CELL TO VACUUM
NICKEL-HYDROGEN CELL CHEMISTRY
DISCHARGE/REVERSAL

DISCHARGE

Nickel
2 NiOOH + 2 HOH + 2 e → 2 Ni(OH)$_2$ + 2 OH$^-$

Hydrogen
H$_2$ + 2 OH$^-$ - 2 e → 2 HOH

Total
2 NiOOH + H$_2$ → Ni(OH)$_2$

E° = +0.5v
E° = +0.8v
E° = +1.3v

OVERDISCHARGE (REVERSAL) WITH HYDROGEN PRECHARGE

Nickel
2 HOH + 2 e → H$_2$ + 2 OH$^-$

Hydrogen
H$_2$ + 2 OH$^-$ - 2 e → 2 HOH

No net reaction; H$_2$ recombines

E° = -0.8v
E° = +0.8
**NICKEL-HYDROGEN CELL CHEMISTRY**

**OVERDISCHARGE (REVERSAL) WITH NICKEL PRECHARGE**

### ACTIVE NICKEL PRECHARGE PRESENT

<table>
<thead>
<tr>
<th>Component</th>
<th>Reaction</th>
<th>Standard Cell Potential ($E^\circ$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel</td>
<td>$2 \text{ NiOOH} + 2 \text{ HOH} + 2 \text{ e} \rightarrow 2 \text{ Ni(OH)}_2 + 2 \text{ OH}^-$</td>
<td>$+0.5 \text{ v}$</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>$2 \text{ OH}^- + 2 \text{ e} \rightarrow \frac{1}{2} \text{ O}_2 + \text{ HOH}$</td>
<td>$-0.4 \text{ v}$</td>
</tr>
<tr>
<td>Total</td>
<td>$2 \text{ NiOOH} + \text{ HOH} \rightarrow 2 \text{ Ni(OH)}_2 + \frac{1}{2} \text{ O}_2$</td>
<td>$+0.1 \text{ v}$</td>
</tr>
</tbody>
</table>

### ACTIVE NICKEL PRECHARGE EXHAUSTED

<table>
<thead>
<tr>
<th>Component</th>
<th>Reaction</th>
<th>Standard Cell Potential ($E^\circ$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel</td>
<td>$2 \text{ HOH} + 2 \text{ e} \rightarrow 2 \text{ OH}^- + \text{ H}_2$</td>
<td>$-0.8 \text{ v}$</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>$2 \text{ OH}^- - 2 \text{ e} \rightarrow \frac{1}{2} \text{ O}_2 + \text{ HOH}$</td>
<td>$-0.4 \text{ v}$</td>
</tr>
<tr>
<td>Total (electrochemical)</td>
<td>$\text{ HOH} \rightarrow \frac{1}{2} \text{ O}_2 + \text{ H}_2$</td>
<td>$-1.2 \text{ v}$</td>
</tr>
<tr>
<td>Chemical</td>
<td>$\frac{1}{2} \text{ O}_2 + \text{ H}_2 \rightarrow \text{ HOH}$</td>
<td></td>
</tr>
</tbody>
</table>
DISCHARGE INTO REVERSAL WITH HYDROGEN PRECHARGE (C/2)
DISCHARGE INTO REVERSAL WITH NICKEL PRECHARGE (C/2)
DISCHARGE INTO REVERSAL WITH NICKEL PRECHARGE (C/10)
DISCHARGE INTO REVERSAL WITH LEAK-TO-VACUUM

CELL VOLTAGE (VOLTS)

CELL TEMPERATURE (DEG C)

TIME (HOURS)

CELL VENTED TO VACUUM
C/2 DISCHARGE
C/10 CHARGE
C/5 CHARGE
TRICKLE CHARGE
C/2 REVERSAL
NICKEL ELECTRODE EXHAUSTED
TEST TERMINATED AT -2.5 VOLTS
VOLTAGE TRAJECTORY
END OF DISCHARGE AND REVERSAL

LINEAR REGRESSION
Voltage = -62.3 x Time + 92.5
R^2 = 0.97
Slope = -1038 mv/min

LINEAR REGRESSION
Voltage = -12.1 x Time + 21.8
R^2 = 0.99
Slope = -202 mv/min

LINEAR REGRESSION
Voltage = -18.9 x Time + 37.7
R^2 = 0.99
Slope = -315 mv/min
COMPOSITE VOLTAGE TRAJECTORY CURVES

MINIMUM AND MAXIMUM ESTIMATED RATES OF VOLTAGE DECREASE

THE SHADED AREA SHOWS THE REGION IN WHICH THE BYPASS SWITCH WILL CLOSE FOR A GIVEN COMBINATION OF MECHANICAL, THERMAL, AND ELECTRICAL PROPERTIES.