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

![Diagram of experimental setup]
NICKEL-HYDROGEN CELL CHEMISTRY
DISCHARGE/REVERSAL

DISCHARGE

Nickel

Hydrogen

Total

2 NiOOH + 2 HOH + 2 e \rightarrow 2 Ni(OH)_2 + 2 OH^-
H_2 + 2 OH^- - 2 e \rightarrow 2 HOH

2 NiOOH + H_2 \rightarrow Ni(OH)_2

E^o = +0.5v
E^o = +0.8v
E^o = +1.3v

OVERDISCHARGE (REVERSAL) WITH HYDROGEN PRECHARGE

Nickel

Hydrogen

2 HOH + 2 e \rightarrow H_2 + 2 OH^-
H_2 + 2 OH^- - 2 e \rightarrow 2 HOH

No net reaction; H_2 recombines

E^o = -0.8v
E^o = +0.8
NICKEL-HYDROGEN CELL CHEMISTRY
OVERDISCHARGE (REVERSAL) WITH NICKEL PRECHARGE

ACTIVE NICKEL PRECHARGE PRESENT

<table>
<thead>
<tr>
<th></th>
<th>Reaction</th>
<th>E°</th>
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</thead>
<tbody>
<tr>
<td>Nickel</td>
<td>2 NiOOH + 2 HOH + 2 e → 2 Ni(OH)₂ + 2 OH⁻</td>
<td>+0.5v</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>2 OH⁻ - 2 e → 1/2 O₂ + HOH</td>
<td>-0.4v</td>
</tr>
<tr>
<td>Total</td>
<td>2 NiOOH + HOH → 2 Ni(OH)₂ + 1/2 O₂</td>
<td>+0.1v</td>
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</tbody>
</table>

ACTIVE NICKEL PRECHARGE EXHAUSTED

<table>
<thead>
<tr>
<th></th>
<th>Reaction</th>
<th>E°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel</td>
<td>2 HOH + 2 e → 2 OH⁻ + H₂</td>
<td>-0.8v</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>2 OH⁻ - 2 e → 1/2 O₂ + HOH</td>
<td>-0.4v</td>
</tr>
<tr>
<td>Total (electrochemical)</td>
<td>HOH → 1/2 O₂ + H₂</td>
<td>-1.2v</td>
</tr>
<tr>
<td>Chemical</td>
<td>1/2 O₂ + H₂ → HOH</td>
<td></td>
</tr>
</tbody>
</table>
DISCHARGE INTO REVERSAL WITH HYDROGEN PRECHARGE (C/2)

Cell Voltage (Volts)
- - - - Cell Temperature (Deg C)

CELL TEMPERATURE

DISCHARGE TIME (HOURS)

CELL VOLTAGE
DISCHARGE INTO REVERSAL WITH NICKEL PRECHARGE (C/2)
DISCHARGE INTO REVERSAL WITH NICKEL PRECHARGE (C/10)
DISCHARGE INTO REVERSAL WITH LEAK-TO-VACUUM

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

CELL VOLTAGE (VOLTS) - CELL TEMPERATURE (DEG C)

TIME (HOURS)
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.