NICKEL HYDROGEN CAPACITY LOSS

J. GUANARD - D. PAUGAM - Y. BORTHOMIEU

US SPACE AND ROCKET CENTER
HUNTSVILLE - AL

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CONTENT

. CELL DESIGN

. DEFINITIONS

. EXPERIENCE

. PRELIMINARY CONCLUSIONS
CELL DESIGN

. GENERAL: "COMSAT" DESIGN

. POSITIVE ELECTRODE
  . SINTERED NICKEL - SLURRY PROCESS - PERFORATED STEEL GRID
  . AQUEOUS ELECTROCHEMICAL IMPREGNATION
  . LOADING 1.7 g/cm² OF VOIDS - COBALT 5%

. NEGATIVE ELECTRODE
  . ACTIVE CHARCOAL 5% PLATINUM CATALYST ON NICKEL GRID
  . TEFLOM HYDROPHOBIC LAYER

. ELECTRODES STACK
  . BACK TO BACK STACKING
  . SEPARATOR: NON WOVEN POLYAMID FELT
  . GAS SCREEN: WOVEN POLYAMID
  . CENTRAL TIE ROD

. CELL
  . HYDROGEN (NEGATIVE) PRECHARGE 3 BARS (40 PSI)
  . KOH 31% (STANDARD)
  . MAXIMUM OPERATING PRESSURE 75 BARS (1040 PSI)
DEFINITIONS

REFERENCE CAPACITY AT 21 ± 3° C

A) . 5 Ω RESISTORS FOR 16 HOURS
B) CHARGE 7.7 H AT C/5
C) DISCHARGE C/2 TO 1 VOLT
D) C/5 TO .5V

TOTAL CAPACITY : CAPACITY TO 1V + CAPACITY 1V - .05V

AVERAGE VALUES : CAPACITY 1V TO .5V (D) 15% - 20% OF TOTAL

2ND PLATEAU OR CAPACITY LOSS

IF CAPACITY 1V TO .5V (D) > 20 - 25% OF TOTAL
**EXPERIENCE : 1 - BOILER PLATES 8 AH**

**FLOODED ELECTROLYTE CAPACITY**

<table>
<thead>
<tr>
<th></th>
<th>MM V 1 COBALT 5%</th>
<th>MM V 2 COBALT 10%</th>
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</thead>
<tbody>
<tr>
<td><strong>A) PRECHARGE H₂ 3 BARS (40 PSI)</strong></td>
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</tr>
<tr>
<td>REFERENCE CAPACITY (AH)</td>
<td>10.8 AH</td>
<td>13.2 AH</td>
</tr>
<tr>
<td>2ND PLATEAU AH (%)</td>
<td>7.7</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>2.3 (23%)</td>
<td>2.2 (23%)</td>
</tr>
<tr>
<td><strong>B) PRECHARGE 30 BARS (400 PSI)</strong></td>
<td></td>
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<tr>
<td>INITIAL : REFERENCE CAPACITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2ND PLATEAU</td>
<td>7.6</td>
<td>8.1</td>
</tr>
<tr>
<td></td>
<td>2.8 (26.9%)</td>
<td>2.4 (22.8%)</td>
</tr>
<tr>
<td><strong>C) PRECHARGE 3 BARS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REFERENCE CAPACITY</td>
<td>6.4</td>
<td>7.2</td>
</tr>
<tr>
<td>2ND PLATEAU</td>
<td>3.4</td>
<td>2.9 (28.7%)</td>
</tr>
<tr>
<td></td>
<td>6.2</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>3.7 (37.4%)</td>
<td>3.3 (32%)</td>
</tr>
<tr>
<td></td>
<td>9.2 AH</td>
<td>11.2</td>
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</tbody>
</table>

--- Storage under H₂ pressure increases capacity loss
--- Effect of H₂ pressure seems reduced in high cobalt content cell
**EXPERIENCE : 2 - VHS 50 BL - L1**

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>A) ACCEPTANCE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REFERENCE CAPACITY</td>
<td>49.6 AH</td>
<td></td>
</tr>
<tr>
<td>2ND P.</td>
<td>16</td>
<td>(24.4%)</td>
</tr>
<tr>
<td><strong>B) STORAGE 3 MONTHS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REFERENCE CAPACITY</td>
<td>52.5 AH</td>
<td></td>
</tr>
<tr>
<td>2ND P.</td>
<td>7.3</td>
<td>(12%)</td>
</tr>
<tr>
<td><strong>C) GEO CYCLING</strong></td>
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<td></td>
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<tr>
<td>70% DOD - 10°C</td>
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<td></td>
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<tr>
<td>CAPACITY MEASUREMENT</td>
<td></td>
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<tr>
<td>AFTER EACH SHADOW PERIOD</td>
<td></td>
<td></td>
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<tr>
<td>SHADOW 4</td>
<td>54.5</td>
<td>(12.1%)</td>
</tr>
<tr>
<td>SHADOW 13</td>
<td>50.8</td>
<td>(19%)</td>
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<tr>
<td>7.5</td>
<td>(12.1%)</td>
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<tr>
<td><strong>---» INITIAL CAPACITY LOSS RECOVERED AFTER STORAGE 3 MONTHS.</strong></td>
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<tr>
<td><strong>---» NORMAL BEHAVIOR IN CYCLING.</strong></td>
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</table>
## EXPERIENCE: 3 - VHS 90 CM - L1

<table>
<thead>
<tr>
<th></th>
<th>QUALIFICATION TESTS</th>
<th>QUALIFICATION TESTS + REVERSAL</th>
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<tbody>
<tr>
<td></td>
<td><strong>REFERENCE CAPACITY (AH)</strong></td>
<td><strong>REFERENCE CAPACITY</strong></td>
</tr>
<tr>
<td></td>
<td>2ND P.</td>
<td>2ND P.</td>
</tr>
<tr>
<td>A) ACCEPTANCE</td>
<td>100 AH</td>
<td>100 AH</td>
</tr>
<tr>
<td></td>
<td>19.5 (16%)</td>
<td>19.5 (16%)</td>
</tr>
<tr>
<td></td>
<td>1 VOLT 72.3 AH</td>
<td></td>
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<tr>
<td></td>
<td>2ND P. 5.7 (7%)</td>
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<tr>
<td></td>
<td><strong>REFERENCE CAPACITY</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>98.8</td>
<td>91.5 (28%)</td>
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<tr>
<td></td>
<td>26 (21%)</td>
<td>36 (28%)</td>
</tr>
<tr>
<td></td>
<td>98</td>
<td>90</td>
</tr>
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<td></td>
<td><strong>STORAGE 3 DAYS - CHARGED CELL</strong></td>
<td><strong>ON PROGRESS</strong></td>
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<tr>
<td></td>
<td><strong>STORAGE 2 MONTHS</strong></td>
<td><strong>NORMAL BEHAVIOR</strong></td>
</tr>
<tr>
<td></td>
<td><strong>CYCLING GEO</strong></td>
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<tr>
<td></td>
<td>80 % DOD 10°C</td>
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<td></td>
<td><strong>EFFECT OF REVERSAL TO BE CONFIRMED</strong></td>
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<tr>
<td></td>
<td><strong>NO CAPACITY LOSS DURING STORAGE</strong></td>
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TYPICAL DISCHARGE CURVE WITH AND WITHOUT "SECOND PLATEAU"

CELL VOLTAGE (V)

DISCHARGED CAPACITY (Ah)

90CM L1

90CM L2
**EXPERIENCE : 4 - VHS, 90 CM - L2**

<table>
<thead>
<tr>
<th>A) ACCEPTANCE</th>
<th>B) BURN-IN CYCLES (50 CYCLES)</th>
<th>C) TENTATIVE RECOVERY PROCEDURE</th>
<th>D) STORAGE 2 MONTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>REFERENCE CAPACITY (AH)</td>
<td>97.8 AH</td>
<td>88 AH</td>
<td>91</td>
</tr>
<tr>
<td>2ND PLATEAU</td>
<td>21.6 AH (18%)</td>
<td>34.5 AH (28%)</td>
<td>23%</td>
</tr>
<tr>
<td>L</td>
<td></td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>86</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>23°C</td>
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<td></td>
</tr>
<tr>
<td>REFERENCE CAPACITY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2ND P</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>STOR 15 DAYS OPEN CIRCUIT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DISCHARGED OPEN CIRCUIT</td>
<td>23°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EFFECT OF RECOVERY PROCEDURE NOT PROVEN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO CAPACITY LOSS DURING LONG STORAGE</td>
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</tbody>
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| A) ACCEPTANCE REFERENCE CAPACITY (AH) | 108 AH | 21 |
| B) STORAGE 5 DAYS CHARGED CELL OPEN CIRCUIT DISCHARGE 1 VOLT | 58 AH | 2.2 AH | 3.7% |
| C) 2 MONTHS TESTING VIBRATIONS - OVERCHARGE 3 GEO CYCLES | 100 AH | 2.9 |
| D) 10 MONTHS STORAGE 0°C - 23°C | REFERENCE CAPACITY | 99 | 25 | (20%) |

2ND PLATEAU DOES NOT EXIST AFTER CHARGE RETENTION NO CAPACITY LOSS DURING LONG STORAGE
PRELIMINARY CONCLUSIONS

CAPACITY LOSS - 2ND PLATEAU PHENOMENA

- NOT OBSERVED DURING LONG STORAGE (> 1 MONTH)
- OBSERVED DURING ELECTRICAL FORMATION
- FAVOURED BY HIGH HYDROGEN PRESSURE AND LOW VOLTAGE
- CAPACITY LOSS SEEMS REDUCED IN CELLS WITH HIGH COBALT CONTENT
- WHEN OBSERVED, ALL SHORT TIME TENTATIVE RECOVERY ACTIONS HAD MORE DETRIMENTAL THAN BENEFICIAL EFFECT.
- DOES NOT AFFECT THE CELL BEHAVIOR IN CYCLING GEO 80% DOD AND LEO 40% DOD.