AF Ni-Cd Cell Qualification Program

S. Hall and H. Brown NSWC CRANE
G. Collins and W. Hwang Aerospace Corporation
AIR FORCE NI-CD PROGRAM
OVERVIEW OF TEST PROGRAM

PURPOSE

GENERIC QUALIFICATION OF AEROSPACE NICKLE-CADMIUM CELLS

MULTIPLE MANUFACTURES
MULTIPLE DESIGNS
INCLUDES CELLS FROM PREVIOUS PROGRAM
HIGH AND LOW ORBIT LIFE CYCLING

CHARACTERIZE BEGINNING OF LIFE PERFORMANCE
<table>
<thead>
<tr>
<th>TYPE</th>
<th>TEMPERATURE</th>
<th>ORBIT</th>
<th>DISCHARGE</th>
<th>CHARGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>6351A</td>
<td>20 DEGREES CENTIGRADE</td>
<td>100 MINUTES</td>
<td>36.0 AMPS FOR 34 MINUTES, 40% DOD</td>
<td>25.0 AMPS WITH V/T TAPER AT V/T 7.5 (1.464 V/C)</td>
</tr>
</tbody>
</table>

50 A/H-NI-CD, HUGHES
<table>
<thead>
<tr>
<th>TYPE</th>
<th>50 A/H NI-CD, HUGHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMPERATURE</td>
<td>5 DEGREES CENTIGRADE</td>
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<tr>
<td>ORBIT</td>
<td>96 MINUTES</td>
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<tr>
<td>DISCHARGE</td>
<td>25.0 AMPS FOR 30 MINUTES, 25%DOD</td>
</tr>
<tr>
<td>CHARGE</td>
<td>25. AMPS WITH V/T TAPER AT V/T 5.5 (1.458 V/C)</td>
</tr>
<tr>
<td>MONTHS</td>
<td>A/HO</td>
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<tr>
<td>--------</td>
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</tr>
<tr>
<td>6</td>
<td>36.3</td>
</tr>
<tr>
<td>12</td>
<td>33.8</td>
</tr>
<tr>
<td>18</td>
<td>38.0</td>
</tr>
</tbody>
</table>
ANNUAL TRENDPLOT
Pack: 6321H Manf: HUGHES 21.0 AH
Orbit: LEO Temp (C): 20 DOD(%): 40.0
Discharge(Amp/Hrs): 15.0/0.56 Charge(Amp/Hrs): 10.5/1.12

TEST DATA AS OF OCTOBER 23, 1993

1. START LIFE-CYCLING, V/T 5.5 (1.424 V/C).
2. CYCLE 1851, V/T INCREASED TO 8.0 (1.434 V/C).
CONCLUSIONS OF RESULTS FOR "SUPER NICD" CELLS

* THERE IS A STORAGE/HANDLING ISSUE

* 50 Ah, 40% DOD PACK HAS INCREASING E0CV DIVERGENCE

* BEGINNING OF LIFE CAPACITY FADE NOT DETRIMENTAL TO CYCLE LIFE
ANNUAL TRENDPLOT

Pack: 63505  Manf: SAFT  50.0 AH
Orblt: LED  Temp (C): 20  DOD(%): 40.0
Discharge(Amp/Hrs): 35.3/0.56  Charge(Amp/Hrs): 25.0/1.12

TEST DATA AS OF OCTOBER 23, 1993

Cells Cycling

1. START OF LIFE CYCLING, V/T 6.0 (1.434 V/C).
2. CYCLE #775, INCREASED TO V/T 6.5 (1.444 V/C) DUE TO LOW EOD'S.
3. CYCLE #1125, INCREASED TO V/T 7.0 (1.454 V/C) DUE TO LOW EOD'S.
4. CYCLE #1513, INCREASED TO V/T 7.5 (1.464 V/C) DUE TO LOW EOD'S.
5. CYCLE #2020, INCREASED TO V/T 8.0 (1.474 V/C) DUE TO LOW EOD'S.
6. CYCLE #3076, INCREASED TO V/T 8.5 (1.484 V/C) DUE TO LOW EOD'S.
ANNUAL TRENDPLOT

Pack: 63515 Manf: SAFT 50.0 AH
Orbit: LEO Temp (C): 0 DOD(%): 25.0
Discharge(Amp/Hrs): 25.0/0.50 Charge(Amp/Hrs): 25.0/1.10

TEST DATA AS OF OCTOBER 23, 1993

Cells Cycling

Cycle Numbers

1. STARTED LIFE-CYCLING, V/T B (1.480 V/C).
1. Shadow #1, lowered VL to 1.414 V/C due to high per-cent recharge.
2. Shadow #1, during Cycle # 25, a system problem occurred that caused the A/H to be read as 21,474 A/H. The pack was then recharged with a V/L for 202 hours.
3. Shadow #3, The DOD was adjusted to 80%.
4. Cycle #218, lowered to VT4 (1.394 V/C) due to cells warming at EOC.
5. Cycle #248, raised to VT4.5 (1.404 V/C) due to EOD volts.
6. Cycle #307, lowered to VT4 (1.394 V/C) due to warming at EOC.
7. Cycle #339, raised to VT4.5 (1.404 V/C) due to low EOD volts.
8. Cycle #409, started pack using true VT control.
9. Cycle #428, raised to VT5 (1.414 V/C) due to low EOD.
10. Shadow #3, due to chamber problems, the pack remained in DCV 28 days during Shadow Day #38.
11. Cycle #1087, raised to VT5.5 (1.424 V/C) due to low EOD.
1. Shadow #1, VT 5 (1.414 V/C).
2. Shadow #4, DOD changed from 68 to 80 per cent recharge.
3. Shadow #6, VT 4.5 (1.404 V/C) due to cells warming during charge.
4. During Shadow #9, the pack was using a 2 step V/T. The first ten days and the last nine days of the shadow period were at VT 4.0 (1.394 V/C). During days 11 thru 33 (mid-shadow) the pack ran at VT 4.5 (1.404 V/C).
5. Shadow #10, voltage clamp changed to voltage/temperature controlled voltage limit at VT 5 (1.414 V/C).
6. Shadow #20, due to chamber problems, the pack remained in OCV 28 days during Shadow Day #7.
7. Shadow #23, increased to VT 5.5 (1.414 V/C), due to low EOD.
CONCLUSIONS OF RESULTS FOR SAFT CELLS

* C/D HIGHER THAN THAT OF PRE-1986 GATES CELLS
* LEO RESULTS VERIFY GENERIC QUALIFICATION OF V0S A (UP TO 40 Ah) CELLS
* RECOMMEND A NEW TERMINAL DESIGN FOR 40Ah CELLS
ANNUAL TRENDPLOT

Pack: 6335A Manf: GATES 35.0 AH
Orbit: LEO Temp (°C): 20 DOD(%): 40.0
Discharge(Amp/Hrs): 25.0/0.56 Charge(Amp/Hrs): 17.5/1.12

TEST DATA AS OF OCTOBER 23, 1993

1. LIFE CYCLING STARTED AT VT 4.0 (1.380 V/C).
2. VT'S WERE INCREASED FROM 4.0 TO 8.0 IN 1/2 VT INCREMENTS DUE TO LOW EOD'S AND % RECHARGE.
3. A PERCENT OF RECHARGE INCREASE WAS NOTICED AFTER EXTENDED OPEN CIRCUIT TIMES DURING CHAMBER PROBLEMS.
4. CYCLE #3840, IT WAS NOTICED THAT ALL CELL CASES WERE SWOLLEN DUE TO HIGH PERCENT OF RECHARGE (117%).
5. CYCLE #6073, PACK SLIGHTLY RECONDITIONED WHEN TEST SYSTEM WENT DOWN. VOLTAGE STEADILY INCREASED THE NEXT 25 CYCLES AND THEN DECLINED.
ANNUAL TRENDPLOT

Pack: 6335B Manf: GATES 35.0 AH
Orbit: GPS Temp (°C): 20 DOD(%): 41.4
Discharge(Amp/Hrs): 15.8/0.92 Charge(Amp/Hrs): 03.5/9.50

TEST DATA AS OF OCTOBER 23, 1993

1. STARTED LIFE CYCLING AT V/T 4.0(1.380 V/C).
2. VT'S WERE ADJUSTED FROM 4.0 TO 5.0, IN INCREMENTS OF 1/2 VT, DUE TO
   LOW EOD'S.
3. CYCLE #528, PACK WAS RECONDITIONED WITH A/HO 20.12.
4. CYCLE #684, DECREASED TO V/T 4.5(1.404 V/C) DUE TO HIGH EOC TEMP....
5. CYCLE #733, INCREASED TO V/T 5.0(1.414 V/C) DUE TO LOW EOD.
6. CYCLE #862, INCREASED TO V/T 5.5(1.424 V/C) DUE TO LOW EOD.
7. CYCLE #1005, PACK WAS RECONDITIONED WITH A/HO 19.0.
8. CYCLE #1374, INCREASED TO V/T 6.0(1.434 V/C) DUE TO LOW EOD.
9. CYCLE #1508, PACK WAS RECONDITIONED WITH A/HO 23.7.
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RESULTS FOR GATES CELLS

* 35 Ah CELL, 40% DOD & 20 C: EODV > 0.987 AT 9443 CYCLES

* 35 Ah CELL, 41.4% DOD & 20 C: EODV > 1.094 AT 1495 CYCLES
ACCELERATED 10.4 HOUR GPS ORBIT

* 50 Ah CELL, 40% DOD & 20 C: TESTING JUST BEGAN