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><strong>TYPE</strong></th>
<th>50 A/H NI-CD, HUGHES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TEMPERATURE</strong></td>
<td>20 DEGREES CENTIGRADE</td>
</tr>
<tr>
<td><strong>ORBIT</strong></td>
<td>100 MINUTES</td>
</tr>
<tr>
<td><strong>DISCHARGE</strong></td>
<td>36.0 AMPS FOR 34 MINUTES, 40% DOD</td>
</tr>
<tr>
<td><strong>CHARGE</strong></td>
<td>25.0 AMPS WITH V/T TAPER AT V/T 7.5 (1.464 V/C)</td>
</tr>
<tr>
<td>Type</td>
<td>50 A/H Ni-CD, Hughes</td>
</tr>
<tr>
<td>------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Temperature</td>
<td>5 Degrees Centigrade</td>
</tr>
<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>
</tr>
<tr>
<td>--------</td>
<td>------</td>
</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

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: 6351S  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

1. STARTED LIFE-CYCLING, V/T 6 (1.480 V/C).
1. Shadow #1, lowered V/L 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 #28, lowered to VT4 (1.384 v/c) due to cells warming at EOC.
5. Cycle #248, raised to VT4.5 (1.404 v/c) due to low 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 #408, started pack using true VT control.
9. Cycle #428, raised to VT5 (1.414 v/c) due to low EOD.
10. Shadow #21, due to chamber problems, the pack remained in OCV 29 days during Shadow Day #38.
11. Cycle #1087, raised to VT5.5 (1.424 v/c) due to low EOD.

1993 NASA Aerospace Battery Workshop -531- Nickel-Cadmium Technologies Session
ANNUAL TRENDPLOT
***GEO*** AIR FORCE
TREND OF MID SHADOW
Pack: 6240S Manf: SAFT 40.0 AH
Orbit: GEO Temp (C): 20 DOO(%) 80.0
DISCHARGE (28.7 AMPS)
CHARGE (4.0 AMPS)
SHADOWS 1 THRU 28

Cells Cycling

1. Shadow # 1, VT 5 (1.414 V/C).
2. Shadow # 4, DOO changed from 88 to 80 per cent recharge.
3. Shadow # 8, 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.

1993 NASA Aerospace Battery Workshop -533- Nickel-Cadmium Technologies Session
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 #8073, 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

Plot area #1 -- keys:
Left-side:  Right-side:
□ -- High Cell  OFF
□ -- Average
□ -- Low Cell

Plot area #2 -- keys:
Left-side:  Right-side:  OFF
□ -- High Cell
□ -- Average
□ -- Low Cell

Plot area #3 -- keys:
Left-side:  Right-side:
□ -- High Cell  OFF
□ -- Average
□ -- Low Cell

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 #526, PACK WAS RECONDITIONED WITH A/HO 20.12.
4. CYCLE #524, DECREASED TO V/T 4.5(1.404 V/C) DUE TO HIGH EOD 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 23.7.
8. CYCLE #1374, INCREASED TO V/T 6.0(1.434 V/C) DUE TO LOW EOD.
9. CYCLE #1506, PACK WAS RECONDITIONED WITH A/HO 23.7.
STRESS TEST
6353G

TYPE
50 A/H LIGHTWEIGHT NI-CD, GATES

TEMPERATURE
20 DEGREES CENTIGRADE

ORBIT
100 MINUTES

DISCHARGE
35.3 AMPS FOR 34 MINUTES, 40% DOD

CHARGE
25.0 AMPS WITH V/T TAPER AT V/T 6 (1.434 V/C)
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