RESULTS OF DEEP DOD LIFE CYCLE TESTS
AT HIGH RATES ON 12Ah NiCd CELLS

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RESULTS OF DEEP DOD LIFE CYCLE TESTS AT HIGH RATES ON 12Ah NiCd CELLS

This presentation reviews a 12Ah NiCd LEO lifecycle test that induced 47% more deep DOD cycles by mixing them with shallow DOD cycles. This test also showed how aggressive recharging to a C/D ratio of 1.15 nearly doubled performance over cycling below a C/D of 1.11.
RESULTS OF DEEP DOD LIFE CYCLE TESTS AT HIGH RATES ON 12Ah NiCd CELLS

JHU/APL spacecraft program - JANUS MISSION II

- 2 year Low Earth Orbit (LEO) mission
- Size and weight critical

Electrical Power System (EPS)

- Solar array
- Nickel cadmium (NiCd) battery
- Battery charge regulator
  - Voltage-temperature (V-T) limiting
  - Shunt excess array current

NiCd Battery

- High discharge rates (1.8C)
- Deep Depth-of-discharge (DOD)
  - 1500 cycles @ 70% DOD
  - 10000 cycles @ 20% DOD

- Little applicable performance data

⇒ Lifecycle test
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Gates Aerospace Batteries
- 12 Ampere-hour (Hr) nameplate capacity
- Pellon #2536 nylon separator

- Hermetically sealed
- Standard space qualified design
- Negative plates not teflonated
- Positive plates not passivated
- Negative terminal attached to the case

- All cells were from the same lot
- Filled in April 1988
- Short circuited
- Put in sealed plastic bags
- Refrigerated at 5° Centigrade
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The test parameters were chosen to produce the:
- Worst case eclipse, and
- Lowest battery cell voltages

95 minute cycles at ambient temperature (20° to 30° C.)
- Discharge to 70% DOD (35 minutes - actual 69.44%)
  -- C/3 rate for 15 minutes (unswitched loads)
  -- 1.8C rate for 20 minutes (switched loads)
- Charge for 60 minutes
  -- 1C rate until reach V-T limit
  -- V-T controlled taper

Relatively high end-of-charge (EOC) rates were required to fully recharge the battery in the short amount of time allowed.
### RESULTS OF DEEP DOD LIFE CYCLE TESTS AT HIGH RATES ON 12Ah NiCd CELLS

<table>
<thead>
<tr>
<th>METHOD</th>
<th>REMARKS</th>
<th># OF CYCLES</th>
<th>TOTAL 70% DOD</th>
<th>TOTAL 20% DOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contiguous 70% DOD Cycles.</td>
<td>C/D = 1.036</td>
<td>913</td>
<td>913</td>
<td></td>
</tr>
<tr>
<td>Raise VT Limit to Control C/D Ratio.</td>
<td>C/D = 1.069</td>
<td>219</td>
<td>1132</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C/D = 1.107</td>
<td>122</td>
<td>1254</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C/D = 1.146</td>
<td>1021</td>
<td>2275</td>
<td></td>
</tr>
<tr>
<td>70% DOD Cycles Interspersed with 20% DOD Cycles.</td>
<td>Above Cutoff</td>
<td>1072</td>
<td>3347</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Below Cutoff</td>
<td>583</td>
<td>3930</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20% DOD Cycles</td>
<td>695</td>
<td></td>
<td>695</td>
</tr>
<tr>
<td>20% DOD Cycles</td>
<td>C/D = 1.178</td>
<td>6104</td>
<td></td>
<td>6799</td>
</tr>
<tr>
<td>70% DOD Cycles</td>
<td>.95V Cutoff</td>
<td>100 ++</td>
<td>4030 ++</td>
<td></td>
</tr>
</tbody>
</table>
JANUS LIFE TEST - FLIGHT2

End of Discharge Voltages - After Recovery (≥1.5)

End of Discharge Voltages - Successful (≥1.2)

End of Discharge Voltages - Failures (≤0.83)

CELL VOLTAGE or RATIO

0.95 1 1.05 1.1 1.15 1.2 1.25 1.3 1.35 1.4

0 500 1000 1500 2000 CYCLE #

JANUS LIFE TEST - FLIGHT2

Recovery

After Recovery

Rest of the Time

BATTERY END OF CHARGE CURRENT IN AMPS

3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8 5

0 500 1000 1500 2000 CYCLE #

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T:0=22.8,1=27.2  V:0=0.96,1=1.49  I:0=-22.0,1=12.0
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Deep DOD LEO missions don’t usually require contiguous deep cycling, so batteries can perform better than what most life cycle tests indicate. Significantly more deep DOD cycles are obtainable if the thermal design can dissipate the heat generated by an aging NiCd overcharged to high voltages to obtain a C/D of 1.15.

This test is continuing in order to determine how many more cycles can be achieved as a function of lowering the criteria for end-of-discharge voltage. It will also investigate how high the V-T limit can be pushed before the benefit of higher EOD voltages is negated by the shortened lifetime.