NiH$_2$ LEO Cycle Life Study

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Mantech Cell Cycle Test History

- Mantech Cells on Duty Cycle Test at 41 °F at Various Load Levels Since 1996
  - Generic LEO Load Profile with Peak Load Test for Minimum Voltage Test
  - Concern With Spacecraft is Low Bus Voltage Trip into Safe-Mode
  - Reconditioning Scheduled Annually During Cycling
  - Also Perform Reconditioning to Maintain Voltages Above Minimum Requirement
    - 19 - 22 Cells in Series Configuration

- Lot 1 Slurry Process Cells Added 3/96 - Completed 35.2K Cycles

- Lot 2, 3 Slurry Process Cells Added 9/97 - Completed 26.7K Cycles

- HST Dry Sinter Cells (3) added 9/97
  - Previously Cycled 6 Years at MSFC (~33K Cycles) - Unknown Storage History
  - Removed From Test 10/00 (16K + ~33K Cycles) - Cold Storage @ EPT

- Lot 5 Slurry Process Cells Added 10/98 - Completed 21.0K Cycles

- Lot 6 Slurry Process Cells Added 10/00 - Completed 10.5K Cycles
## Eagle Picher Cell Life Test

### Load Profiles

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<td>3/21/02 -</td>
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Mantech Life Test Day #667
S/N 101 Cell Data (Dec. 31, 1997)

Battery VT = 33.6 V
Cell Life Study
HL8 Test Profile

Mantech Life Test Day #922
S/N 101 Cell Data (Sept 13, 1998)

Battery VT = 33.2 V

The graph shows the cell potential (V) and current (A) over time (hours) for HL8 Test Profile. The cell potential is plotted on the left y-axis, ranging from 0.80 to 1.60 V. The current is plotted on the right y-axis, ranging from -40 to 120 A. The x-axis represents time in hours, ranging from 0 to 24 hours.

Key points:
- Battery VT = 33.2 V
- Cell data collected on September 13, 1998
- The graph indicates the periodic charging and discharging cycles of the cell.
Mantech Life Test Day #922
S/N 101 Integrated Capacity (Sept 13, 1998)
Cell Life Study
HL10M Test Profile

Mantech Life Test Day #1269
S/N 101 Cell Data (Sept 8, 1999)

Battery VT = 32.8 V
Mantech Life Test Day #1269
S/N 101 Strain Gauge (Sept 8, 1999)
Cell Life Study
HL12M Test Profile

Battery VT = 32.8 V

Ma nte c h Life Test Day 1462
S/N 101 Cell Data (3/24/2000)

Potential (V)
Volts

Current (A)
Amps

Time (Hours)

0 4 8 12 16 20 24

0 20 40 60 80 100 120

0 10 20 30 40

0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6

Battery VT = 32.8 V
Cell Life Study
HL12M Test Profile

Maintech life Test Day 1462
S/N 101 Strain Gauge Data (3/24/2000)

Capacity (AH)

Time (Hours)
Cell Life Study
HL14R Test Profile

Maintech Life Test Day 1972
S/N 101 Cell Data (9/28/2001)

Battery VT = 32.8 V
Cell Life Study
HL15R Test Profile

Mantech Life Test DAY2345
S/N 101 Strain Gauge Data (10/24/2002)

Capacity (AH)

Time (Hours)
HST Orbital Capacity Trend

IECEC-2002
HST Recondition Capacity Comparison
Battery 4 Orbital vs S/N 204 Ground

BATTERY LETDOWN
Battery 4 vs S/N 204

Battery Voltage (V)

0 10 20 30 40 50 60 70 80 90

Battery 4 (A-h) Out

26.37V

1.3K Cycle HL8

16.2K Cycle HL12M

10.5K Cycle HL10M

5.5K Cycle HL8

6.9 Ah

2002 NASA Aerospace Battery Workshop
HST Recondition Capacity Comparison
Battery 4 Orbital vs S/N 204 Ground

BATTERY RECONDITION
Battery 4 vs S/N 204

Battery Voltage (V)

Battery 4 (A-h) Out

- Batt4 Recondition 9-02
- 1.3K Cycles 50 °F 15 A Cap 1-98
- 5.5K Cycles 50 °F 15 A Cap 9-98
- 10.5K Cycles VT Recdn 41 °F 9-99
- 13.5K Cycles VT Recdn 41 °F 3-00
- 5.5K Cycle HL8 50°F 15 A Cap
- 1.3K Cycle HL8 50°F 15 A Cap
- 61.9 Ah
- 10.5K Cycle HL10M VT
- 13.5K Cycle HL12M VT
50 °F Capacity Test Comparison
Cycle Life Test

Cycle Life Test - 5.5K Cycles
50 °F Capacity Test

- S/N 101 5.5K Cycles
- S/N 200 33K + 5.5K Cycles
- S/N 204 33K + 5.5K Cycles
- S/N 285 33K + 5.5K Cycles

Cell Potential (V) vs. Capacity (AH)
HST Recondition Capacity Comparison
Battery 3 & 4 Orbital vs S/N 204 Ground

Battery 3 & 4

HST Battery 3 & 4
~8 Ah DOD
68K Cycles On Orbit

S/N 204
33K HST Cycles (MSFC 1990-6)
~7 Ah DOD
VTP-771 Cycles (1996-7)
9.6 Ah DOD
12 Ah DOD

S/N 204 Letdown
S/N 204 Recondition

Battery 3
Battery 4
S/N 204 Letdown
S/N 204 Recondition

HST Recondition Capacity Comparison
Battery 3 & 4 Orbital vs S/N 204 Ground

Cycle Number
Capacity (Ah)
Battery Model Impedance Prediction

![Graph showing cell impedance vs. state of charge depletion for dry sinter and slurry processes.](image)

IECEC-2002
Flight Spare Battery Pulse Discharge

IECEC-2002
Flight Spare Battery Cell Potential Distribution

IECEC-2002
Flight Spare Battery Cell Impedance Distribution

State of Charge Depletion (Ah)

Resistance (ohm)

IECEC-2002
AC Impedance - GEO Ground Cycling (RNH 76-11 Dry Sinter)

Interpretation of Results
- Decrease in Active Surface (R2, C2)
- Electrode Surface Effect (R2, C2)
- No Difference at High-Frequency (R1 - No Separator Difference)
- Inductive Effects Ignored

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<tr>
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<tr>
<td>Seasons</td>
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<td>C2, farads</td>
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• This Work Was Supported by NASA Contract Mod 593 Dated 2 June 1987
  • Directed LMSC to Design, Develop and Deliver Nickel-hydrogen Battery Modules
  • For the Hubble Space Telescope Low Earth Orbit Mission
    • Per NAS 8-32697 and NAS 5-5000.

• LMMSO Wishes to Acknowledge the Technical Support From
  • HST Program Office for Orbital Data
  • NASA/MSFC for Ground Test Data.