Eagle "Ep" Picher
Electronics Division
Joplin, MO

Sodium-Sulfur Program

- EPI Sodium Sulfur Program initiated in 1986.
- EPI selected by USAF as sole developer for NaS LEO cells.
- Over 200 cells constructed for a variety of applications.
- Developed a β" electrolyte production capability.
<table>
<thead>
<tr>
<th>Cell Sizes Manufactured</th>
<th>50 AH</th>
<th>40 AH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4&quot; D x 12.3&quot; L</td>
<td>600 gms (1.31 lbs)</td>
<td>500 gms (1.10 lbs)</td>
</tr>
<tr>
<td>1.4&quot; D x 9.0&quot; L</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Areas of Improvement

- Resistance
- Cathode Performance
- Parts Count
- Weight
- Seals
### Performance Improvement Demonstrated (16 Amp Discharge)

<table>
<thead>
<tr>
<th>Weight (grams)</th>
<th>Spec. Energy (Whr/kg)</th>
<th>Res. Energy Dens. (Whr/L)</th>
<th>Avg. Volts (Discharge)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>119.1</td>
<td>266.9</td>
<td>1.64</td>
</tr>
<tr>
<td>Intermediate</td>
<td>127.3</td>
<td>283.6</td>
<td>1.74</td>
</tr>
<tr>
<td>Improved</td>
<td>139.8</td>
<td>307.8</td>
<td>1.89</td>
</tr>
<tr>
<td>State-of-the-Art</td>
<td>158.5</td>
<td>334.0</td>
<td>1.95</td>
</tr>
</tbody>
</table>

EAGLE EPPICHER

Advanced Technologies Session

1992 NASA Aerospace Battery Workshop
50 AHR CELL — "IMPROVED" DESIGN

- 8,400 Cycles (>95% LEO, 60% DOD)
- On test 33 months
- Discharge resistance 8.3 milliohms (7.3 milliohms BOL)
- F1% 16.1 (14.0 BOL)
- Capacity 53.3 Ahr (52.1 BOL)
IMPROVED CELL PERFORMANCE (CAP 95% DOD)

- CYCLE 8338 F1(%) = 16.12
- CYCLE 1119 F1(%) = 13.26

VOLTS

AMPS

DISCHARGE
(25 A/2 A/25 A)

OPEN
CONSTANT CURRENT CHARGE (15 A/5 A)

CIRCUIT

MINUTES
Capacity - 50Ah "Improved" Cell

Amp Hours

40.00 42.00 44.00 46.00 48.00 50.00 52.00 54.00 56.00 58.00 60.00

Cycle #

41 768 1439 2595 2684 3012 3500 4095 4647 5141 6066 7548 7243 7669 8104
SODIUM-SULFUR GROUP

SINGLE CELL TEST MILESTONES

- Over 11,000 cycles to date
- 43 month calendar life
- 3,130 AHR/cm² in cell testing
- 5,900 AHR/cm² in sodium-sodium testing
- Discharge resistance < 5 milliohms
- F1 of less than 5 (low rate charge)
ENVIRONMENTAL TESTING ACCOMPLISHED

- Shock ............................................. 30g's, 11ms
- Acceleration ............................. 15g's, 5 min.
- Random Vibration ............. 0.25g²/Hz, 300-1200Hz (0A=19.5g RMS)
- Sine Vibration .................... 7.5g peak, 5-2000Hz
- Humidity ................................. MIL-STD-810B, Method 507
- Freeze/Thaw ......................... 20 Cycles
STATE-OF-THE-ART CELL

TYPICAL CELL PERFORMANCE (LEO 60% DOD)

- Discharge (40 A)
- Open Circuit
- Constant Potential Charge (25 A Limit)

Volts vs. Minutes

F1(%) = 12.17
ENTRY LEVEL BATTERY

- Effort funded internally 1990-1991
- Three cell module
- 1,000 cycles achieved
  Constant current charge/discharge
  Nominal 60% DOD (=30Ahr)
- 30 Whr/Kg
- Calendar life: 6 months
SODIUM-SULFUR GROUP

Advanced Systems Operation

Eagle Pitcher
Electronics Division
Joplin, MO

1992 NASA Aerospace Battery Workshop -674- Advanced Technologies Session
NEXT GENERATION BATTERY PERFORMANCE PROJECTIONS

- 35 Amp-Hour cells
- 20 cell series string
- Battery OCV: 42 Volts
- Battery working volts: 38 Volts
- Weight: 13.5 Kg
- Volume: 30 L
- Energy Density: 100 Whr/Kg, 45 Whr/L
STATE-OF-THE-ART CELL

TYPICAL THREE CELL GROUP

VOLTS

AMPS

DISCHARGE (20 A) OPEN CIRCUIT CONSTANT CURRENT CHARGE (20 A)

MINUTES
SUMMARY

Sodium Sulfur cell and battery designs continue to evolve with significant improvement demonstrated in:

- Resistance
- Rechargeability
- Cycle Life
- Energy Density
- Electrolyte Characterization