PRESENTATION TO
1991 NASA AEROSPACE BATTERY WORKSHOP
OCTOBER 29-31, 1991
U.S. SPACE & ROCKET CENTER
HUNTSVILLE, AL

PULSED POWER MOLTEN SALT BATTERY

CONTRACT NO. F33615-88-C-2911

AERO PROPULSION LABORATORY
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INTRODUCTION

CHLORINE CATHODES

UNIT CELL DEVELOPMENT

CELL STACK DEVELOPMENT

SUMMARY
INTRODUCTION

PHASE II PROGRAM GOALS

- Develop and demonstrate a Li/Al/chlorine molten salt battery design
- Develop improved chlorine cathodes
- Develop unit cell design
- Demonstrate a stack/battery design
INTRODUCTION

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SUMMARY
CHLORINE CATHODES

- Uniform Pore Size Distribution
- Good Permeability to Chlorine
- Activated Surface
- Electrochemical Activation
ADSORBED - CHLORINE CATHODE

IR-free Cell Polarization (V)

Current Density (Amp/sq.cm)

10ms 100ms 1 sec 5 sec
Fig. 5 Discharge characteristics for a Li-Al/carbon 8-9-2 absorbed chlorine cell under test cycle 1 regime, 250 mA for 200 sec followed by 1 A current.
LI-AL/CHLORINE CELL 450°C

500 mA 200 sec discharge
2 A 5 sec pulse

Capacity (Amp-Hours)
Cathode Performance Summary

- Single Pulsing
- Repetitive Pulsing
- Steady State Discharge
- 200 sec Steady State Load + 5 sec Pulse
- Steady State Load + 100, 10 ms pulses
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SUMMARY
Cell Development

- **Test Hardware**
  - Glass Enclosure Cell
  - Anode Wafer in Stainless Steel or Ni Cup, Nickel leads
  - Cathode rests on EB salt wafer backed by graphite current collector
  - Chlorine fed to the wafer-ambient pressure

- **Test Regime**
  - Steady discharge load + 400 10 ms pulses + 200 100 ms pulses
20 A 10 ms pulse on top of 4 A steady

TEKTRONIX 2221

ΔV2 = 0.56V

AUTO PLOT

SREF

ΔT = 0, 10 ms

SAVF

10

PEAKDET

2 ms

Tek

1991 NASA Aerospace Battery Workshop

Advanced Technologies Session
20A/100ms pulse on top of 4A steady 200th pulse (bottom)

<table>
<thead>
<tr>
<th>$\Delta U2 = 1.36\text{V}$</th>
<th>AUTO PLOT</th>
<th>SREF</th>
<th>$\Delta T = 98.0\text{ms}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>SAVE</td>
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</tbody>
</table>

1V PEAKDET 20ms

Tek
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SUMMARY
1. Anode Current Collector
2. Li-Al Anode
3. Salt Wafer
4. Carbon Cathode
5. Grafoil
6. Nickel Cup
7. Cathode Current Collector with Chlorine Feed Tube
### 100-ms Pulse Data for a 5-Cell Stack

**Diagram Details:**
- **Device:** TEKTRONIX 2221
- **Plot:**
  - Voltage change: $\Delta V_2 = 3.6\text{V}$
  - Auto Plot: SREF A
  - Time delay: $\Delta T = 0.8\text{ms}$
  - Peak detected: 20 ms

**Notes:**
- All#12-146
- 20A, 100ms pulse after 4A discharge
- Trial 1
- Date: 11-7-92

**Additional Remark:**
- 1991 NASA Aerospace Battery Workshop

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**Advanced Technologies Session**

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Delivered Energy</td>
<td>56 Wh</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>96 V</td>
</tr>
<tr>
<td>No. of Cells</td>
<td>40</td>
</tr>
<tr>
<td>Open Circuit Voltage</td>
<td>134 V</td>
</tr>
<tr>
<td>Capacity</td>
<td>0.56 Ah</td>
</tr>
<tr>
<td>Weight</td>
<td>1.34 kg</td>
</tr>
<tr>
<td>Volume</td>
<td>1.32 L</td>
</tr>
<tr>
<td>Current Density</td>
<td>0.25 A/sq. cm</td>
</tr>
<tr>
<td>Pulsing</td>
<td>1.00 A/sq.cm</td>
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</table>
# POWER DENSITY

4A DC, 24A PULSE REGIME

<table>
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<tr>
<th></th>
<th>kW/kg 10 ms</th>
<th>kW/kg 100 ms</th>
<th>kW/L 10 ms</th>
<th>kW/L 100 ms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cell</strong></td>
<td>3.9</td>
<td>3.2</td>
<td>4.3</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>Stack (5-cell)</strong></td>
<td>3.9</td>
<td>3.1</td>
<td>4.3</td>
<td>3.4</td>
</tr>
<tr>
<td><strong>Battery</strong></td>
<td>1.7</td>
<td>1.4</td>
<td>1.7</td>
<td>1.4</td>
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<tr>
<td>ENERGY DENSITY</td>
<td>Wh/L</td>
<td>Wh/kg</td>
<td></td>
<td></td>
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<tr>
<td>---------------</td>
<td>------</td>
<td>-------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CELL 1 cycle</td>
<td>112</td>
<td>102</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 cycle</td>
<td>201</td>
<td>183</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STACK</td>
<td>104</td>
<td>95</td>
<td></td>
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<tr>
<td>BATTERY</td>
<td>43</td>
<td>42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4A & C, 24 A PULSE REGIME
INTRODUCTION

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- Carbon Cathodes with chlorine work well
- Li-Alloy/chlorine at 450 deg. C, 1 atm
  - High Power capability
  - High energy density
  - DC + pulsing - 600 pulses
  - No initial peak
- Can go to red heat without burn-up
SUMMARY

• Electrochemical performance at the cell and cell stack level under demanding test regime

• Engineering and full prototype development for advancing this technology is warranted
Nickel-Hydrogen Technologies Session

Organizers: Joe Stockel
Office of Research & Development

Michelle Manzo
NASA Lewis Research Center