Evaluation of Lead-Carbon Devices
DOE Energy Storage Program
Contract # 407411

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Participants

- **MeadWestvaco**
  - Developing carbons for energy storage
  - Lab scale and battery testing

- **DOE Energy Storage Program and Sandia National Labs**
  - Verification and battery testing
  - Analytic Support

- **NorthStar Battery Company**
  - Manufacturing and Battery Testing
  - Battery Expertise

- **ETA**
  - Testing
  - System Estimates

- **WPS Energy**
  - Valuation
Program Overview

Phase 1
- Evaluate lead based energy storage technologies
- Develop carbon for lead based technologies
  - Increase cycle life for some applications
  - Improve charging characteristics

Phase II
- Select best technology for 1MW utility demonstration
History

1. Lead Carbon Asymmetric
   - Research Cells
2. Evaluation of carbon modified lead acid batteries
   - Research Cells
   - 2 battery trials (250 Batteries)
3. Testing of Batteries and cells under several tests
Utility Market Opportunity

10 seconds to 20 minutes charge/discharge requires device that has capacitor and battery properties.
Carbons Under Review

- Activated Carbon
- Graphite
- Carbon Black

- Activated Carbon: 50µm
- Graphite: 6µm
- Carbon Black: 180nm
Current Theories

- Activated Carbon
  - Pore Former (Acid Reservoir)
  - Increase Capacitance
- Graphite
  - Conductivity
- Carbon Black
  - Conductivity
## Properties

<table>
<thead>
<tr>
<th>Carbon</th>
<th>Surface Area (m²/g)</th>
<th>Capacitance (F/g)</th>
<th>Conductivity (ohm-cm)</th>
<th>Pore Volume (cc/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite</td>
<td>1-20</td>
<td>1-5</td>
<td>0.001-0.1</td>
<td>0-0.1</td>
</tr>
<tr>
<td>Activate Carbon</td>
<td>500-2000</td>
<td>50-200</td>
<td>0.5-2.0</td>
<td>0.5-1.3</td>
</tr>
<tr>
<td>Carbon Black</td>
<td>50-1700</td>
<td>5-100</td>
<td>0.1</td>
<td>0.1-0.3</td>
</tr>
</tbody>
</table>
Standard Negative Electrode

Secondary Electron Image (SEI) in SEM
Battery Build

- **Negative activate material (NAM) modifications**
  - **Standard**  Standard Battery Formulation
  - **MWV 0** 2% C-black and 2% graphite (Hammond-ALABC)
  - **MWV 1** 4% activated carbon
    - A-type Activated Carbon
  - **MWV 2** 4% activated carbon and 1.5% C-black
    - A-type Activated Carbon
  - **MWV 3** 3% activated carbon
    - B-type Activated Carbon
  - **MWV 4** 3% activated carbon and 1.5% C-black
    - B-Type Activated Carbon
PSoC Screening test on 30Amphr Batteries

![Graph showing capacity degradation over cycles for different MWV types.]

- MWV0 curve remains stable.
- MWV1 curve shows initial drop followed by slight recovery.
- MWV2 curve displays significant drop and recovery pattern.
- STD curve shows a consistent decline.

% Initial Capacity vs Cycle
PSoC Screening test on 50AmpHr Batteries
Simulated Utility algorithm

- Develop algorithm based on real data supplied by WPS Energy
- Profile developed
  - 30-80% SOC operation
  - same Ah balance as actual duty
  - SOC adjustment every 24 h
  - recharge 1-2 times per week
- Laboratory cycling of MWV0 and Standard
Fast Charge Cycle 108% Cycling

Charge Current

Discharge Current

Carbon modified batteries has 8 cycles compared to 1 for standard product
Carbon modified batteries have an increase in current at all voltages.
Gas lost and float current at 2.45 volts per cell

<table>
<thead>
<tr>
<th>Battery</th>
<th>Gassing rate to Standard</th>
<th>Float current to Standard</th>
<th>Molar Ratio H2:0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>1</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td>MWV0</td>
<td>22</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>MWV1</td>
<td>20</td>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td>MWV3</td>
<td>2</td>
<td>10</td>
<td>3</td>
</tr>
</tbody>
</table>
Conclusion

- Carbon additives increase cycle life under some conditions.
- Carbon improves charging characteristics.
- Carbon increases gas evolution and float currents.
Future Work

- Build new batteries with improved carbons
- Verify mechanisms for carbon effect
  - Develop new carbons
- Standardizing testing of batteries
- Develop actual system cost for Utility Demonstration
Thanks to Those Involved

NORTHSTAR
BATTERY COMPANY

MeadWestvaco
Leading with Imagination

Electric Transportation Applications

Sandia National Laboratories

WPSenergy.com
A WPS Resources Company