USABC Li-Ion PHEV Contract – P.O. 08-2047

U.S. Department of Energy Merit Review

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Johnson Controls – Saft
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JCS PHEV System Development

Project ID: es_06_engstrom

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Overview

Timeline
- Project Start – June, 2008
- Project Finish – June, 2010
- Percent Complete – 38%

Budget
- Total Project Funding - $8,211K
  - JCS Share 50%
- Funding Received in CY08
  - $1080K
- Funding for CY09
  - $2,012K (on track)

Barriers
- System energy density of present systems is too low
- Cycle-life in charge-depleting and charge-sustaining modes
- High cost of meeting performance targets

Partners
- Johnson Controls and Saft
- USABC Program Lead: Renata Arsenault
- DOE Contract Manager: David Howell
Objectives

• Develop Lithium-Ion PHEV Systems for 10 and 40 mile all-electric range applications.

• Demonstrate cell and system designs to meet program USABC targets.

• Report on thermal management modeling approaches for air-cooled and liquid cooled approaches.

• Characterize cathode technologies and other materials for PHEV applications.
Milestones

• Ship Baseline 10-mile all-electric range system for testing – Complete
• Submit abuse tolerance test summary for materials selections – In Progress
• Deliver baseline high-energy cells for testing (June, 2009) – In Progress
• Deliver cell technology performance characterization comparison (July, 2009) – In Progress
• Deliver 10 and 40-mile thermal management design review summary (Oct, 2009) - In Progress
Approach

• Cell design development will leverage existing hardware and focus on materials selection to optimize performance.

• System development approach will utilize core sub-assemblies and strategically address those areas which will best improve the energy density and cost.

• Manufacturing study to improve design and assembly efficiencies.
Technical Accomplishments/Progress/Results

- Assisted USABC in assessing alternate abuse tolerance testing methods
- Development of core PHEV system software
- Thermal Management model development for air and liquid cooling applications
- Development of alternate cell technologies for comparison
- Updated Cost Model
- Identification of assembly process improvements
Future Work

2009
• Continue to refine cell performance for 10 and 40-mile applications
• Develop 10-mile design for optimized cost/size
• Complete study of various cell technologies for performance and reliability.

2010
• Build and deliver 10-mile design
• Develop and deliver 40-mile design

JCS Advanced Power Solutions
Summary

• JCS has built research teams in Europe, North America and Asia with experience on a broad range of battery technologies.

• Ability to leverage years of Automotive Experience and a world-class supply base with parent company.

• Used USABC HEV development program to get head start in this PHEV program for systems design/development and manufacturing.

• Cell manufacturing capability developed in US.
### Summary Table

#### USABC Goals for Advanced Batteries for PHEV's

(End of Life Energy Storage Systems for PHEVs)

<table>
<thead>
<tr>
<th>Characteristics - EoL</th>
<th>units</th>
<th>High Power/ Energy Ratio Battery</th>
<th>High Energy/Power Ratio Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref. Equivalent Electric Range</td>
<td>miles</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Peak Pulse Discharge Power - 2 Sec</td>
<td>kW</td>
<td>50</td>
<td>46</td>
</tr>
<tr>
<td>Peak Pulse Discharge Power - 10 Sec</td>
<td>kW</td>
<td>45</td>
<td>38</td>
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<tr>
<td>Peak Regen Pulse Power - 10 Sec</td>
<td>kW</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>Available Energy for CD (Charge Depleting) Mode, 10 kW Rate</td>
<td>kWh</td>
<td>3.4</td>
<td>11.6</td>
</tr>
<tr>
<td>Available Energy for CS (Charge Sustaining) Mode</td>
<td>kWh</td>
<td>0.5</td>
<td>0.3</td>
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<tr>
<td>Max. round-trip energy Efficiency (USABC HEV cycle)</td>
<td>%</td>
<td>90</td>
<td>90</td>
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<tr>
<td>Cold Cranking power at -30 Deg C, 2 Sec - 3 Pulses</td>
<td>kW</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>CD Life/Discharge Throughput</td>
<td>Cycles/MWh</td>
<td>5000 / 17</td>
<td>5000 / 58</td>
</tr>
<tr>
<td>CS HEV Cycle Life, 50 Wh Profile</td>
<td>Cycles</td>
<td>300,000</td>
<td>300,000</td>
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<tr>
<td>Calendar Life, 35 Deg C</td>
<td>year</td>
<td>15</td>
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<tr>
<td>Maximum System Weight</td>
<td>kg</td>
<td>80</td>
<td>120</td>
</tr>
<tr>
<td>Maximum System Volume</td>
<td>Liter</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>Maximum Operating Voltage</td>
<td>Vdc</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Minimum Operating Voltage</td>
<td>Vdc</td>
<td>&lt;0.55 x Vmax</td>
<td>&lt;0.55 x Vmax</td>
</tr>
<tr>
<td>Maximum Self-Discharge</td>
<td>Wh/day</td>
<td>50</td>
<td>50</td>
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<tr>
<td>System recharge Rate at 30 Deg C</td>
<td>kW</td>
<td>1.4 (120V/15A)</td>
<td>1.4 (120V/15A)</td>
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<tr>
<td>Unassisted Operating &amp; Charging Temperature Range</td>
<td>Deg C</td>
<td>-30 to + 52</td>
<td>-30 to + 52</td>
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<tr>
<td>Survival Temperature Range</td>
<td>Deg C</td>
<td>-46 to + 66</td>
<td>-46 to + 66</td>
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<td>Maximum System Production Price, @ 100k units/year</td>
<td>$</td>
<td>$1,700.00</td>
<td>$3,400.00</td>
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</tbody>
</table>

Preliminary results planned for late 2009.