Development of a Soldier Wearable Power System (WPS)

2015 Joint Service Power Exposition

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CERDEC/CPI/Power/Power Sources
Introduction

Purpose

• Development of a Wearable Power System that provides power to all soldier borne equipment via Integrated Soldier Power & Data System.

• 1st Gen (2012)

Product Payoff

• Physical weight burden reduction (>4X) vs. batteries for dismounted soldier extended missions (72 h)

• Provides wearable power in a fightable footprint

• Provides power in a centralized power configuration

• Alternative to Conformal Wearable Battery

![Graph showing comparison of Conformal Li-ion Battery and Wearable Fuel Cell](image)
Why Alane?

Different materials available for energy storage

Selected Alane (AlH$_3$) based on high energy density, high H$_2$ product purity and H$_2$ generation process

\[
\Delta H = 6.6 \text{ kJ/mol } H_2
\]

With commercial partner have developed AlH$_3$ systems that are promising
What is Alane?

Fresh Alane (AlH$_3$)  

SEM imaging showing Alane ($\alpha$-AlH$_3$ phase) material

Spent material retains cubic shape but is porous due to H$_2$ release

Spent Alane (Al)
H₂ production (Energy) from AlH₃ decomposition

With temperature (heating) can control H₂ production following load demand.

Isothermal desorption data at different temperatures as a function of time. Solid lines are model fits. (T. Thampan et al. 2015).
AlH₃ cartridge with PEM fuel cell system was instrumented with electrical, temperature sensors

Despite high internal temperature, external temperatures remain low

Although H₂ generation from Alane requires ~ 30% net energy demonstrated

Prototype battery charger

Surface temp. are touch safe
Wearable System

With industrial partner developed 1st Gen wearable system

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Demonstrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (W)</td>
<td>20</td>
</tr>
<tr>
<td>Peak Power and Duration</td>
<td>35 W for 10 min</td>
</tr>
<tr>
<td>Energy Density for 24 hr mission</td>
<td>385 Wh/kg</td>
</tr>
<tr>
<td>Dry Weight (kg)</td>
<td>0.698</td>
</tr>
<tr>
<td>Volume (mL)</td>
<td>622</td>
</tr>
<tr>
<td>Form Factor</td>
<td>Thickness of 3.8 cm</td>
</tr>
<tr>
<td>Environmental Operating Temperature Range</td>
<td>Up to 45°C</td>
</tr>
<tr>
<td>Orientation</td>
<td>Operation: any orientation</td>
</tr>
</tbody>
</table>

Cartridge energy remaining

- AlH$_3$ cartridge compartment

Volume: 62 cm$^3$
- Weight: 68 g
- ED: ~800 Wh/kg

(T. Thampan et al. 2014)
Soldier Wearable

Developed next gen. system based on feedback

AlH₃ cartridge compartment with one quarter turn to open / close

Battery Compartment - allows energy harvesting.

Larger Fuel Cartridge

Flexible form factor

Smaller thickness profile

Easier cartridge change

One quarter turn to open/close
Thermal Images

Hottest temp is 43 C /109 F in pouch due to limited cooling, still safe to touch
Tests included:
Constant load
In pouch + Constant load
In pouch + Cycle load

Cartridge energy is ~ 600 Wh/kg (measured) vs. 800 Wh/kg (rigid systems)

<table>
<thead>
<tr>
<th>Test</th>
<th>Current (A)</th>
<th>Average Voltage (V)</th>
<th>Power (W)</th>
<th>Cartridge Energy (Wh)</th>
<th>H2 yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant Load</td>
<td>1.3</td>
<td>14.4</td>
<td>18.72</td>
<td>61 / 64</td>
<td>77%</td>
</tr>
<tr>
<td>Constant - Load / Pouch</td>
<td>1.3</td>
<td>14.5</td>
<td>18.85</td>
<td>56 / 66</td>
<td>81%</td>
</tr>
<tr>
<td>Cycle Load Pouch</td>
<td>0.3 / 2.3</td>
<td>14.8</td>
<td>4.5 / 34</td>
<td>53 / 66</td>
<td>88%</td>
</tr>
</tbody>
</table>

Preliminary cartridge ballistic testing was done. Test results provided confidence in a safe wearable system.
Soldier Evaluation

- Form factor was acceptable and lightweight
- Could be mounted in various vest locations and orientations
- Operated all end items through the use of a power manager and also battery eliminator
- “Relatively” quiet operation
- Cartridge change out was preferred vs battery change out

System can be worn under other equipment

Flexible, thin system
System worn in gap formed from normal arm position

Rigid system
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Objective</th>
<th>WPS Achieved Performance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (W)</td>
<td>≥ 20</td>
<td>20</td>
</tr>
<tr>
<td>Peak Power and Duration</td>
<td>35 W for 10 min</td>
<td>35 W for 10 min</td>
</tr>
<tr>
<td>Dry Weight Target (kg)</td>
<td>≤ 0.5</td>
<td>0.912 kg</td>
</tr>
<tr>
<td>Volume (mL)</td>
<td>≤ 650</td>
<td>743</td>
</tr>
<tr>
<td>Form Factor</td>
<td>Thickness &lt; 0.7”</td>
<td>Thickness 0.81” (L-7”, W-8”)</td>
</tr>
<tr>
<td>Environmental Operating Temperature Range</td>
<td>-20°C to +55°C</td>
<td>Up to 45°C</td>
</tr>
<tr>
<td>Orientation</td>
<td>Transportation: any orientation, Operation: any orientation</td>
<td>Operation: any orientation</td>
</tr>
</tbody>
</table>

*Performance of initial, conservative prototype to prove form-factor. Follow-on effort underway to harden system and restore specified performance.
Summary:

- Passed objective targets for nominal power, peak power, start up time
- Passed threshold requirements for weight, volume, thickness
- System is able to load follow while maintaining H$_2$ fuel control
- System can operate in a Molle pouch with an external temperature that is safe for wearable application

Follow On

- Cartridge energy density to be improved
- Improved prototype systems to be delivered 2015 Q4