H-E-B Grocery Total Power Solution™ for Fuel Cell Powered Material Handling Equipment

PowerEdge™ Fuel Cell Hybrid Power Packs

PowerTap™ Hydrogen Refueling

Gus Block
Nuvera Fuel Cells, Inc.
5/13/2011

Project ID #
H2RA008

This presentation does not contain any proprietary, confidential, or otherwise restricted information
### Overview

#### Timeline
- **Project Start** – 08/01/09
- **Project End** – 07/31/11
- **Percent Complete**: 79% (based on calendar time through March ’11)

#### Barriers and Risks
- Operation of hydrogen and fuel cell equipment in very demanding application
- Confirming value proposition for fuel cells for material handling equipment
- Safety planning and safe operation

#### Budget
- **Total Project Funding:**
  - Overall: $3,324K
  - DOE: $1,139K
  - Cost share: $2,185K

#### Partners
- H-E-B Grocery – Host Site
- H-E-B Parkway Systems
- Airgas
- Nuvera Fuel Cells – Project Lead

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ARRA Relevance

Objective
Validate DOE market transformation activities by demonstrating:

- Fuel cell-powered forklifts operating in highly transient environments.
- A distributed natural gas-based hydrogen refilling system as a precursor to future automotive fuel cell refilling stations.

ARRA 2009 Relevance

- Stimulate use of emerging technologies – additional investment by H-E-B is anticipated, without ARRA funding.
- Develop jobs and job skills (manufacturing, product development, repair and maintenance) in clean energy growth industries.

FCT ARRA Relevance

- Project has led to improvements to make fuel cells and hydrogen refueling equipment commercially viable.

Barriers and Risks Addressed

- Use of equipment in demanding customer application and environment has uncovered substantial opportunities to improve fuel cell and hydrogen technology reliability.
- Operation and maintenance costs are being quantified.
- Proper safety planning and safe operation of all equipment.
Approach

Demanding Application

- Class-II forklifts are generally the most demanding material handling application.

- H-E-B incentivizes forklift operators to maximize the amount of product moved.

- H-E-B has optimized warehouse utilization with higher lifts & heavier pallets.

- H-E-B facility poses challenges with air quality, shock & vibration, and high ambient temperatures.

These factors resulted in challenges that emerged during the course of the project and were addressed in the previous 12 months.
## Tasks and Status - Approach

<table>
<thead>
<tr>
<th>ID</th>
<th>Task</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Build fuel cell systems and hydrogen generation and refueling station.</td>
<td>Complete (Q409)</td>
</tr>
</tbody>
</table>
| 2  | Create site-specific service plan, including training of local service providers:  
  - Parkway Systems (fuel cell systems)  
  - Airgas (hydrogen infrastructure)  | Complete (Q409)               |
| 3  | Deploy fleet  
  - 60 forklift operators received hydrogen and fuel cell training  
  - Multiple issues resulted in scale-back of fleet July – November 2010 during reliability campaign | Complete (Q410)               |
| 4  | Confirm value proposition  
  - Initial productivity assessment completed Q110  
  - Follow-up underway with process excellence group  
  - Go/No Go for fleet expansion will depend on trials with 2011 PowerEdge model RL40 (early summer 2011) | 50% Complete (Q111)           |
| 5  | Final Testing                                                        | 0% Complete                   |
| 6  | Project management                                                    | 79% Complete (Q111)           |
Site Plan - Approach

PowerTap Location

Dispenser 1

Dispenser 2

Grocery DC

Refrigerated Produce DC

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Technical Accomplishments and Progress

**RL25 Issues**

- Fleet was reduced from 14 to 4 units in July 2011
  - Root cause analysis undertaken
  - Corrective actions identified
  - Reliability campaign initiated

- **Issues Resolved**
  - Dirt
  - Shock & vibration
  - High temperatures
  - Short Absorbed Glass Mat battery life

- **Performance verified during busy season**
  - MTBF is 3-4X higher

- **Test & validate future product enhancements**
  - More robust power circuits
  - Auto-Start feature to extend battery life
  - Improved controls to extend stack life
Mean Time Between Failure (MTBF) is 3-4 times higher in Dec’10 – Feb’11 vs. Aug – Oct’10

* Feb’11 data through 2/9/11
PowerTap Issues

- High ambient temperatures reduced hydrogen generator capacity, de-rated from 56 to 45 kg/day.
  - New cooling strategy will be implemented in Summer 2011.
- Power outages cause some electrical components to fail
  - Protections/replacements implemented on case-by-case-basis.
- Local natural gas composition and water quality require more frequent replacement of desulphurizing media and RO membranes.
- Water pump speed control not robust, so target steam pressure was not consistently achieved (Sep’10), requiring manual intervention every several days.
  - New control strategy being developed.
PowerTap Reliability

PowerTap has supplied >90% of all hydrogen consumed at H-E-B since Sep’10, and is at or near 100% currently.
Technical Accomplishments and Progress

Safety

- Reviewed by and discussed DOE Hydrogen Safety Panel in December 2010 during on-site visit.
  - Focus was primarily on safety devices and design, especially on dispenser and dispenser area.
  - All recommendations will be reviewed and implemented as needed.
- Safety plan will be revised to respond to Panel comments.
  - More thorough description of the level of coordination between H-E-B and Nuvera on communication and management of near-misses, incidents and changes, was requested.
Technical Accomplishments and Progress

8 PowerEdge safety Near Misses or Non-Events identified to date.

Near Miss: An event that under slightly different circumstances could have become an Incident.

*Example:* Unplanned hydrogen release insufficient to sustain a flame.

Non-Event: A situation, occurrence, or other outcome relevant to safety that does not involve an Incident (Severity 1) or a Near-Miss (Severity 2).

*Examples:* Failed safety inspection, or an unsafe material condition beyond normal wear and tear, that if left uncorrected, could eventually compromise personal safety.

- 2 non-hydrogen fire Near Misses involving electrical interconnection and power management.
  *Primary Factor:* Design Flaw

- 3 water discharge Non-Events involving PowerEdge controls
  *Primary Factor:* Design Flaw

- 3 minor hydrogen releases (no ignition) Non-Events involving hydrogen tanks
  *Primary Factor:* Maintenance Required
4 PowerTap safety Incidents, Near Misses, or Non-Events identified to date.

- Incident: An event that results in:
  - A lost time accident and/or injury to personnel
  - Damage/unplanned downtime for project equipment, facilities, or property
  - Impact to the public or environment
  - Any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
  - Release of any volatile, hydrogen containing compound (other than HCs used as common fuels)

- 1 20-gallon hydraulic oil leak Incident involving cyclic fatigue failure of un-supported cantilevered pressure gauge
  *Primary Factor:* Design Flaw

- 2 reformate release Near Misses from PTG-50 involving 1) damaged O-ring and 2) HX structural support
  *Primary Factor:* Design Flaws

- 1 Non-Event involving movement of hydrogen tubing on roof during sustained high winds (80 mph)
  *Primary Factor:* Weather
Corrective Actions for Safety Issues

**PowerEdge**
- Regen modules were upgraded to prevent the electrical shorting.
- Water management hardware and controls software were upgraded to eliminate the excess water discharges on the warehouse floor.

**PowerTap**
- PTC compressor was upgraded to ensure all components and gauges were adequately supported against vibration.
- Structural support for the HX in the PTG was upgraded to withstand thermal cycling.
- Service procedure for replacing the filter was updated to help reduce the risk of damaging O-rings.
- Supports for the high pressure tubing running along the warehouse roof to the dispensers were upgraded to withstand wind speeds up to 120 mph.
Value Proposition

- **Cost of Ownership**
  - Assessed on $/hour basis
  - Air & Water Filters
  - Battery repair & replacements
  - Stack and cell repair & replacements
  - Desulphurizing media

- Attempting to gather data regarding reduced truck maintenance

- **Productivity**
  - 10% total productivity gain vs. batteries measured in Q110
  - Will repeat in Q111

3 Month Average
January - March 2010
Service Plan - Collaboration

Nuvera Customer Care provides safety & service training, spare parts, data analysis, warranty, and factory service support.

- H-E-B Parkway Systems is Local Service Provider for PowerEdge fuel cell systems.
  - 1\textsuperscript{st} Responder Role: Minimize customer downtime.
  - Tier-1 Service training
    - Operator training
    - Schedule maintenance
    - Basic diagnostics and repairs
  - Tier-2 Service qualification
    - Advanced qualification for safety critical repairs (high pressure/voltage).
- Nuvera is Local Service Provider for the PowerTap hydrogen refueling system.
  - Airgas Southwest personnel trained as LSPs but do not have sufficient resources to provide 24*7 service coverage.
  - Airgas SW will take over LSP role after fleet expansion (2 add’l PowerTaps).
- Airgas (Bozrah, CT)
  - Provides 24*7 monitoring of PowerTap status.

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Future Work

- Continue to operate 14-unit fleet in normal operations to gain durability and life cycle cost information on the fuel cell systems.
- Monitor and record the long term operation cost of on-site hydrogen generation.
- Compile performance data of PowerEdge and PowerTap systems.
- Assess productivity gains.
- Undertake steps necessary for fleet expansion (28 PowerEdge systems and 2 PowerTap systems)
  - Field testing of higher-power RL40 PowerEdge units
**Future Work – Fleet Expansion**

**Phase 1:** One PowerTap hydrogen refueler, and 14 PowerEdge units in produce and grocery distribution centers.

**Phase 2:** One additional PowerTap systems and 16 more PowerEdge units, completing the conversion of produce and grocery DCs.

**Phase 3:** One additional PowerTap system and 12 PowerEdge freezer units.

Phases 2 and 3 are beyond the project scope but are made possible because of the accomplishments of ARRA-funded Phase 1.
Future Work – Fleet Expansion

Go/No Go on Phase 2 depends on successful testing of higher-power PowerEdge RL40.

To ensure high performance and reliability, Nuvera is upgrading key sub-systems and utilizing a disciplined testing and qualification process.
Summary

- H-E-B’s demanding operation has helped Nuvera understand how to develop a more robust product.
- Nuvera has incorporated all of these learnings into the design & controls of the products for Phase 2 for H-E-B as well as for future customers.
- H-E-B is realizing a significant productivity gain.
- Job creation:
  - 1 job associated with PowerTap maintenance
  - 2 jobs associated with PowerEdge maintenance
- Hydrogen infrastructure
  - On-site generation a unique feature of the project
  - Directly relevant to the establishment of automotive hydrogen infrastructure
Technical Back-Up Slides
# PowerEdge Fuel Cell System

## Product Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>RL25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Power (30 sec)</td>
<td>25 kW</td>
</tr>
<tr>
<td>Voltage</td>
<td>36 VDC</td>
</tr>
<tr>
<td>Operating Current Range(^1)</td>
<td>-400A to 1150A</td>
</tr>
<tr>
<td>Energy Storage Capacity(^2)</td>
<td>35.7 kWh</td>
</tr>
<tr>
<td>Size - In. (mm)</td>
<td>38.2 in. x 20.1 in. x 30.8 in. (970 mm x 510 mm x 781 mm)</td>
</tr>
<tr>
<td>Target Weight - lbs (kg)</td>
<td>2600 lbs (1155 kg)</td>
</tr>
<tr>
<td>Refueling Time</td>
<td>120 sec</td>
</tr>
<tr>
<td>Hydrogen Storage</td>
<td>1.0 kg</td>
</tr>
<tr>
<td>Hydrogen Pressure</td>
<td>5075 psig (350 bar)</td>
</tr>
<tr>
<td>Hydrogen Port</td>
<td>SAE J-2600 H35, CE 0036</td>
</tr>
<tr>
<td>Ambient Operating Temperature(^3)</td>
<td>25 to 95°F (-4 to 35°C)</td>
</tr>
<tr>
<td>Environment</td>
<td>Indoor Use Only</td>
</tr>
<tr>
<td>Emissions</td>
<td>Water Vapor</td>
</tr>
</tbody>
</table>

### Notes:
1. Actual lower limit is dependent on truck upper voltage threshold (value shown based on 440V)
2. Based on LHV of H\(_2\) at 5075 psig (350 bar), 15°C, and 1 hr battery discharge rate
3. System must be stored and started above freezing conditions (4°C, 39°F minimum)
# PowerTap Hydrogen Infrastructure

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<table>
<thead>
<tr>
<th>PowerTap Hydrogen Generator</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Hydrogen Production</td>
<td>50 kg/day</td>
</tr>
<tr>
<td>Hydrogen Purity</td>
<td>99.995%</td>
</tr>
<tr>
<td>Natural Gas Consumption</td>
<td>7.5 MBTU/day</td>
</tr>
<tr>
<td></td>
<td>222 Nm³/day</td>
</tr>
<tr>
<td>Water Consumption</td>
<td>2400 l/day</td>
</tr>
<tr>
<td>Electrical Consumption</td>
<td>9 kW average</td>
</tr>
<tr>
<td>Size</td>
<td>12 ft x 4 ft x 9 ft</td>
</tr>
<tr>
<td></td>
<td>3.66 m x 1.22 m x 2.74 m</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-4°F to 104°F (-20°C to 40°C)</td>
</tr>
<tr>
<td>Standards Compliance</td>
<td>Designed for CSA, CE</td>
</tr>
<tr>
<td>Environment</td>
<td>Outdoor</td>
</tr>
<tr>
<td>Emissions¹</td>
<td>NOₓ: &lt;15 ppm</td>
</tr>
<tr>
<td></td>
<td>CO: &lt;50 ppm</td>
</tr>
<tr>
<td></td>
<td>SOₓ: undetectable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PowerTap Hydrogen Station</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaseous Hydrogen Source</td>
<td>Steam reformer, electrolyzer or delivered via tube trailer or liquid hydrogen</td>
</tr>
<tr>
<td>Dispensing Rate</td>
<td>500 – 1000 gram/minute</td>
</tr>
<tr>
<td>Dispensing Pressure</td>
<td>5000 psig (350 bar)</td>
</tr>
<tr>
<td>Storage Capacity</td>
<td>Configurable from 12 – 128 kg</td>
</tr>
<tr>
<td>Compressor</td>
<td>Hydraulically driven intensifier</td>
</tr>
<tr>
<td>Electrical Consumption</td>
<td>12 kW average</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-4°F to 104°F (-20°C to 40°C)</td>
</tr>
<tr>
<td>Standards Compliance</td>
<td>System Designed to: CSA HGV4 &amp; NFPA 52</td>
</tr>
<tr>
<td></td>
<td>Dispenser Nozzle: SAE J2600-H35</td>
</tr>
<tr>
<td></td>
<td>Type A Compliant</td>
</tr>
<tr>
<td>Environment</td>
<td>Compression and Storage: Outdoor</td>
</tr>
<tr>
<td></td>
<td>Dispenser: Indoor or Outdoor</td>
</tr>
</tbody>
</table>