Fuel Cells and Electric Forklift Trucks

Steve Medwin
The Raymond Corporation
June 14, 2011
Agenda

- The Raymond Corporation
- Fuel Cells for Forklifts
- Truck Compatibility
- Pros and Cons
- Usage in North America
- Conclusions
The Raymond Corporation

- Founded in 1922
  - Design, manufacture, sell & service electric forklift trucks
- Purchased by Toyota Industries in 2000
  - Now part of Toyota Material Handling Group (TMHG)
- Started investigating fuel cells in 2004
- Fuel cells operational in factory since 2007
  - First indoor refueling in New York State
- Became independent distributor and service provider of Plug Power fuel cells in 2010
  - Raymond customers actively using fuel cells
- Evaluating new fuel cell models and exploring other energy storage systems
Greene, NY – Raymond Headquarters

Class III
- Pallet Trucks
- Walkie Stackers

Muscatine, IA

Class I & II
- VNA / Orderpicker
- Reach Trucks
- Counterbalance
- Custom Solutions

Syracuse, NY

190,000 sq. ft.
139 employees

180,000 sq. ft. (factory)
173 employees

Over 2 million parts available

30 Dealers and 108 Branches
3,779 employees
Fuel Cell Battery Replacement Systems

- Ballard™ Fuel Cell
- Energy Storage: Li-ion or supercaps
- Gas Management System
- Hydrogen Storage (with optional ballast)
- Controller
- Cooling System
- Auxiliaries
Refueling at Indoor Dispenser
Energy Source and Design of Forklift Truck

Lead-acid battery has always been critical part of design
Ensuring Compatibility Between ESS and Forklift Truck

- Industrial Truck Association (ITA) established Energy Storage System (ESS) committee to work on this issue
  - Includes fuel cells and new battery technologies
- Created Recommended Practice (RP) to facilitate the communication between truck manufacturers and ESS manufacturers
- RP describes the minimum requirements and key characteristics of the ESS as they relate to the lift truck originally designed for use with a lead acid battery
Five Critical Requirements for Energy Storage Systems

1. Size

2. Weight

3. Center of gravity

4. Power delivered

5. Power absorbed
Ideal H2 FC Customer Profile

- Larger fleet sizes (50+ trucks)
- High productivity or throughput requirements
- Multiple shifts
- Many battery changes
- High electric costs
- Local cost of hydrogen is low
- Greenfield projects provide better ROI than fleet conversions
FC Value Proposition for End Users

- Productivity increases from
  - No battery changes
  - No voltage drop as seen in batteries

- Reduced electric usage
  - No battery charging
  - Reduced peak loading

- No need for expensive battery infrastructure
  - Battery rooms, chargers, maintenance, power to building, dedicated personnel, etc.

- Environmental benefits
Factors Working Against FC Systems

- Expensive systems
- Need for “in-plant” hydrogen infrastructure
- Multiple vendors
- New technology in material handling
- Battery technology is well established
- Strong competitive technologies
Fuel Cell Forklift Truck Projects

Raymond customers using fuel cells
» Sysco Houston: 90+ trucks
» Sysco San Antonio: 116 trucks, late 2011
» UNFI Sarasota, FL: 65 trucks  
  – First fuel cell powered orderpickers
» BMW, Spartanburg, SC: 86 trucks
» Wegmans, Pottsville, PA: 90+ trucks

Plug Power customers in North America
» 1000 – 1100 units deployed in forklifts
Conclusion

- FCs commercially available for range of truck models
- Currently deployed all over North America
- System cost and hydrogen infrastructure limiting growth

- Suppliers need to drive costs down
- Truck manufacturers need to continue to test systems
- Customers need to partner with a company that will commit to delivering the best solution to fit their individual needs
Steve Medwin

steve.medwin@raymondcorp.com

www.raymondcorp.com
We have tested and approved all these truck/fuel cell configurations

Additional fuel cell units will be tested as they become available to us
# Fuel Cell and Hydrogen Costs - US

<table>
<thead>
<tr>
<th></th>
<th>FC battery replacement system cost*</th>
<th>Estimated hydrogen usage/shift (hydrogen ≈ $6 to $15/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1 SDCB</td>
<td>$32,000 to $35,000</td>
<td>2.5 to 3.5 kg/shift</td>
</tr>
<tr>
<td>Class 2 and SUCB</td>
<td>Reach &amp; SUCB: $33,000 OPR: $22,000</td>
<td>2.5 to 3.5 kg/shift</td>
</tr>
<tr>
<td>Class 3</td>
<td>$18,000</td>
<td>1 to 1.5 kg/shift</td>
</tr>
</tbody>
</table>

*Estimated list pricing

**30% federal tax credit is available**
The Raymond Corporation is now an independent distributor for the sale, rental and lease of Plug Power GenDrive™ fuel cell units in North America, Hawaii, Mexico. Raymond also will provide warranty and maintenance service on GenDrive products through our Dealer network. Raymond is a GenDrive Authorized Distributor of service parts through the PDC.
1. Size

“The maximum dimensions of the ESS are defined as the size of the battery designed to fit into a given truck as defined by the truck manufacture.”
2. Weight

“The weight of the ESS shall be within the minimum and maximum battery weight indicated on the industrial truck specification plate.”

Typical truck specification plate
3. Center of Gravity

“The location of the ESS center of gravity (CG) should be located within a cylindrical shape of radius $r$ as defined by the truck manufacturer and shaded in the figure below, with the top of the cylinder located at the volumetric center $(X,Y,Z)$ of the battery being replaced.”
4. Power Delivered

“The truck manufacturer shall specify the current and voltage delivery requirements of the industrial truck at various time durations necessary to maintain acceptable performance.”

Voltage (volts)

- $V_{1\text{max}}$
- $V_{2\text{max}}$
- $V_{3\text{max}}$
- $V_{3\text{min}}$
- $V_{2\text{min}}$
- $V_{1\text{min}}$

Current (amps)

- $I_1$
- $I_2$
- $I_3$

Time (seconds)

Nominal voltage and current must be compatible with existing truck components.
5. Power Absorbed

“The truck manufacturer shall specify the current and voltage absorption requirements of the industrial truck at various time durations necessary to maintain acceptable performance.”

![Diagram](image)

- Peaks and valleys must not damage truck components.