Electrolyzer Manufacturing Progress and Challenges

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Outline

- Proton Commercialization Status: PEM Electrolysis
- Current Manufacturing Limitations: Stack
  - Cost Breakdown
  - Approaches
- Current Manufacturing Limitations: System
  - Cost Breakdown
  - Approaches
- Potential Impact
- Summary and Conclusions
Proton Energy  

- World leader in Proton Exchange Membrane (PEM) electrolyzer technology
- Founded in 1996 – changed name from Proton Onsite in April 2011 to reflect product expansion.
- ISO 9001:2008 registered
- Over 1,500 systems operating in 62 different countries.

Headquarters in Wallingford, CT

Cell Stacks  Complete Systems  Turnkey Solutions  Military Applications
Capabilities

- Complete product development, manufacturing & testing
- Containerization and hydrogen storage solutions
- Turnkey product installation and integration
- World-wide sales and service
- Broad understanding of PEM Electrolysis systems and markets

Proton Production Floor
Markets and Products

Power Plants  Heat Treating  Semiconductors  Laboratories  Government

Steady History of Product Introduction

1999: GC 300-600 mL/min

2000: S-Series 1-2 kg/day

2003: H-Series 4-12 kg/day

2006: StableFlow Hydrogen Control System

2009: Outdoor HPEM

2010: Lab Line

2011: C-Series, 65
Manufacturing Needs: Overview

• Cost reduction areas defined for both stack and system
  – Over 50% decrease achievable

• Opportunities in material substitution, automation, and scale up
  – Collaborations established with key partners

• Roadmap developed for technology
  – Have shown cell scale feasibility
  – Need investment in manufacturing implementation
Cell Stack Cost Breakdown

- Highest cost areas: flow fields/separators, MEA, and labor
Comparison to PEM Fuel Cell Stack

PEM Fuel Cell

- Similar materials of construction: PFSA membranes, noble metal catalysts
- Electrolysis membrane is fully hydrated, no RH cycling concerns
  - Have to withstand high pressure differential (200-2400 psi) and high sealing loads
- Stack materials have to withstand ~2 V potentials – particular concern for O₂ catalyst and flow fields
- Longer lifetime expectations (competing with gas cylinders)
Cell Stack Needs

- 50% reduction in bipolar assembly cost
  - Reduction of metal content in bipolar assembly
  - Reduction in bipolar assembly process time
- Increased part yield from suppliers
- Automation of MEA fabrication for electrolysis-specific MEAs
- Order of magnitude reduction in catalyst loading
- 30% reduction in membrane thickness
- Online quality control measurements
## Manufacturing Goals: Examples

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<tr>
<th>Part</th>
<th>Current</th>
<th>End Goal</th>
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<tr>
<td>MEA</td>
<td>Manual CCM process</td>
<td>Roll to roll coating</td>
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<tr>
<td>Flow Field</td>
<td>Multi-piece manual assembly</td>
<td>Single piece high speed manufacture</td>
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<tr>
<td>Gaskets</td>
<td>Single piece die cut</td>
<td>Roll stamping</td>
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<td>Quality control</td>
<td>Individual part measurement</td>
<td>Inline measurement</td>
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<tr>
<td>Bipolar assembly</td>
<td>Metal plate</td>
<td>Laminate or composite</td>
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Leveraging Fuel Cell Technology

- PEM electrolyzer cost reduction will follow the maturation of PEM fuel cells
- Materials of construction derived from the fuel cell supply chain
- Innovation needed to leverage existing fuel cell technology in electrolysis cell
  - Incremental funding over fuel cell investment
- Technical challenges are understood; will grow as fast as the markets emerge
• Highest cost areas: cell stacks, power supplies/electronics, and assembly labor
• Cell stacks represent larger fraction of cost with scale up
• Enclosure and custom parts still much higher than typical “appliance”
System Needs

- Utilization of off the shelf components
  - Electronics
  - Enclosures
- Investment in high speed tooling/molds
- Increased production volumes through strategic/subsidized deployment
- Investment in larger scale balance of plant
- Conversion to all DC input
Impact of Scale Up on Balance of Plant Cost

BoP represents ~2/3 of product cost at 12 kg/day
Resulting Hydrogen Cost Progression

Based on $0.05/kWh electricity

$10
$8
$6
$4
$2
$0

$/kg H2, H2A model

65 kg/day
200 kg/day system, pre-production
200 kg/day system, full production*

*Assumes volumes of 500 units/year
Conclusions

• PEM electrolysis is at the tipping point for manufacturability
  – Sustainable business at current level
  – Can make huge impact with continued progress

• Labor component is still very high
  – Investment in volume manufacturing equipment needed
  – Need collaborative technology development with supply chain especially for cell stack cost reductions

• Larger systems are pathway to DOE targets