Fuel Cells Fueled by Alternative Fuels

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James Grieve, Introduction

• Chief Scientist, Delphi Automotive Systems (retired 2016)
  • engines, fuel cells, hybrid vehicle systems, emission controls, alternative fuels

• CTO, MicroEra Power (licensing spin-out)
  • high efficiency DG, supporting the renewable intensive grid
  • SOFC/ICE combined cycle systems (natural gas, NH3 etc.)

• Chairman, AHEAD Energy, 501(c)(3)
  • owns a test facility in Rochester, NY – in transition to a multi-user site for commercialization of fuel cell and related systems using low carbon fuels
  • promotes the use of low carbon fuels in concert with renewables.

• Board member, NH3 Fuel Association
SOFC, 3 products - each with high efficiency

Fuel in

- Electricity
- Hydrogen
- Heat
SOFC, as a fuel flexible fuel cell

• External Reforming (Gasoline, Diesel, Jet Fuel, Propane, Ethanol) vs.
• Internal Reforming (LNG, methanol, NH3)
  • Steam vs. Dry vs. Mixed (recycle) Reforming
  • Internal Reforming issues (NH3 substantially avoids these):
    - Coking of anode
    - Excessive endotherm anode inlet

• Big differences in internal reforming capability between different stack developers – Delphi had good results
• But, long term issues need evaluation (40,000 hours not 400 hours)
  • Robustness/durability impact
  • Coking, coarsening, delamination etc.
SOFC optimized for intended fuel?

- Diesel Engines and Diesel Fuels are highly co-optimized
- Gasoline Engines and Gasoline Fuels are highly co-optimized

- SOFC optimized for LNG may be different than for NH3 or methanol...
  - Stack Materials
  - Operating temperature
  - O/C ratio
  - Reforming Process
  - Fuel Utilization

- Extensive long term testing needed to optimize and understand severity factors. Many stacks needed to account for variability.

- Difference between “works in the lab” and “fieldable product” is HUGE!!!
Example: Reforming Process Options

• Process modeling (spreadsheet) to calculate Carbon Activity for Methane Cracking, Boudouard and CO Reduction reactions:

Fuel: Methane
Reforming: Internal

Carbon formation limit (COR)

Case 1: 40% anode recycle 749 °C
Case 2: Steam reforming S/C=2 693 °C
Clean Energy Commercialization Center

285 Metro Park, Rochester, NY 14623

A low-cost, open-source facility for performance and durability testing of fuel cell related components and systems

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History and Current Status:

- R&D site built by General Motors and updated by Delphi
- Proximity to three Universities: University of Rochester, Rochester Institute of Technology, and Monroe Community College
- 6 explosion-proof labs, 24/7 monitoring, gas storage and supply, Uninterrupted Power Supply, premium HVAC, fire suppression and exhaust systems lab-by-lab, oil free compressed air, deionized water
- Office space, loading docks, assembly/light manufacturing
- Owner: AHEAD Energy, 501(c)(3), in transition to a user managed facility
- USD $7-$10 million replacement cost for building and contents
Clean Energy Commercialization Center

• Tech to Market integration and validation

• Shared Infrastructure fits “Consortium Approach” and CRADA model which Dr. Satyapal discussed.
Renewable Hybrid Systems

SOFC/ICE approach brings many advantages:

- Very high efficiency at light load (SOFC-only)
- High efficiency at mid load (SOFC/ICE, ultra-lean)
- Good efficiency at high load (ICE dominant, stoich)
- Fuel flexibility (natural gas, biogas, methanol, NH3)
- Extremely low emissions (H2 assisted starts)
- No cold starts
- 24/7/365 SOFC Direct Current microgrid (supporting PV and batteries)
- ICE is dynamic, used for high value functions like Back-Up, Demand Response and Peak Shaving

SOFC Internal Combustion Engine Hybrid

Showing co-products of SOFC: Electricity, Hydrogen and Heat

- Natural Gas (or NH3)
- SOFC stack
- H₂-assisted Natural Gas (or NH3) Engine Generator
- Hydrogen
- Catalyst and Heat Recovery
- Electricity
- Heat