7C: Intergovernmental Stationary Fuel Cell System Demonstration

Project ID: FC057
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Project Overview

Timeline

- Start: August 2007
- Finish: July 2010
- 95% complete

Budget

- DOE: $ 4.25M
- Cost-share: $ 4.25M
- FY 2009 funding: $1,313,363
- FY 2010 funding: $0

Barriers

- Efficiency
- Direct material cost
- Durability

Partners

- Construction Engineering Research Laboratory (CERL)
- Ballard Power Systems
- National Grid

Relevance

- To design and produce an advanced prototype PEM fuel cell system with the following features:
  - 5kW net electric output
  - Flex fuel capable—LPG, NG, ethanol
  - Reduce material and production cost and increase system and stack durability
  - Increase electrical efficiency over the existing GenSys 5U48 design
  - Increase total system efficiency by incorporating combined heat and power (CHP) capability

- To show a path to meet long term DOE objectives
  - 40% system electrical efficiency
  - 40,000 hour system/fuel cell stack life
  - $750/kW integrated system cost (w/reformer)
  - $400/kW fuel cell stack cost (direct hydrogen)

Approach

- **Concept Development** **100% complete**
  - GO/NO GO: Concept design review
- **System Definition** **100% complete**
  - GO/NO GO: System interface review
- **System Integration** **100% complete**
  - GO/NO GO: Field readiness review
- **Prototype Field Demonstration** **85% complete**
  - CERL unit demonstration rolled into 7A program using commercial GenSys unit
  - Demonstration currently being conducted at Union College Beuth House, Schenectady, NY using commercial GenSys unit
- **Project Closeout** **90% complete**

Previous Accomplishments

- Completed the analytical and design work necessary for prototype system, received a “go” decision from DOE for next phase of project
- Completed the fabrication and assembly of prototype system and began system integration testing
- Achieved system material cost reduction of 53% (in production quantities) when compared to prior year’s system material cost roll-up

Progress – National Grid Demonstration

- Installation of GenSys Blue high temp PEM fuel cell system at Union College Beuth House, Schenectady, NY
- Includes: field readiness design, build, shipping, installation, commissioning, demonstration, de-commissioning, site restoration and public/end user education
- Continues to run, providing heat and electricity
- The system is continually evaluated
- Improvements to hardware and controls will be implemented as more is learned about the system's operation

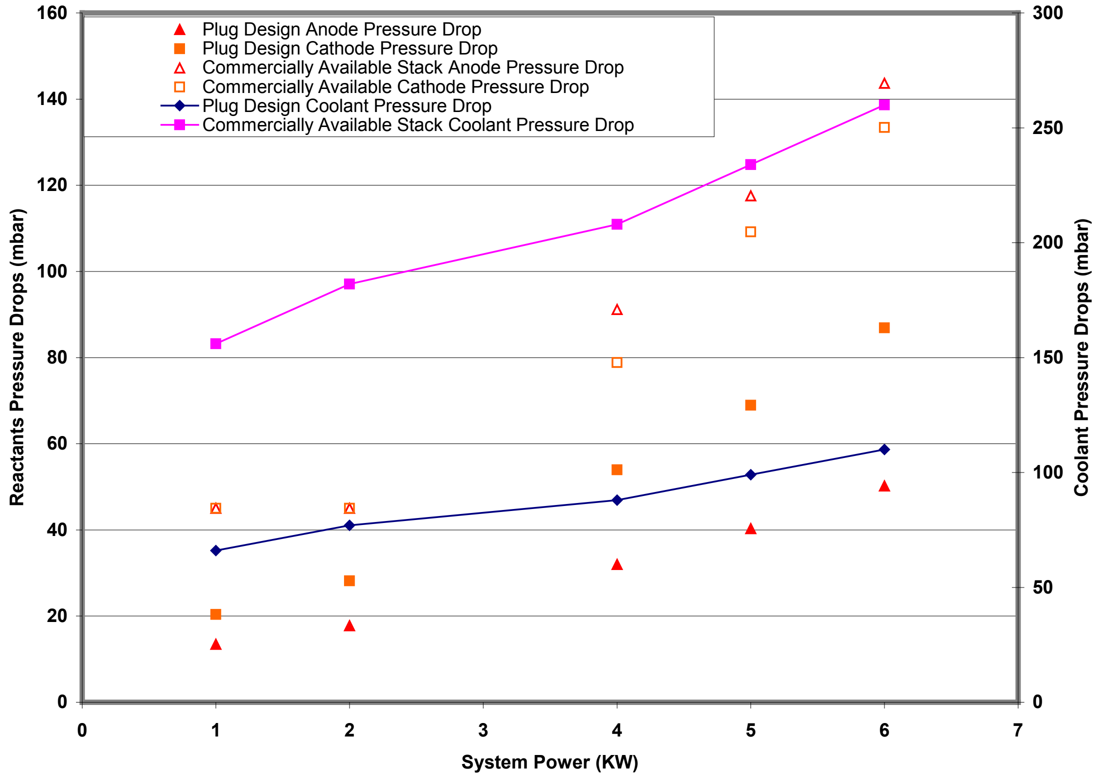
Operational Hours	1,436 since commissioning, over 2,000 hours including testing prior to installation
kWhrs Electric	1,663 in Beuth House

Progress – Stack Sourcing

- Original program intent was to leverage Plug Power's supply chain and knowledge gained during Topic 3.1 work activities at Warner Robins AFB (which led to development of the "Rev 3" MEA), and expand to a fuel cell stack solution capable of meeting both DOE objectives and those required for productization
- Based on preliminary work on the TeleCOOP program Plug Power and Ballard proceeded to collaborate
- Stack integration complications occurred with the commercially available Ballard MK-1300 series stack design and DOE goals were not being met
  - High pressure drop posed issues finding applicable balance of plant components
  - High DP also posed issues in controllability of the system
  - System efficiency and turndown capability was negatively impacted by this stack design
- Improvements made by 3M in durability and cost and leveraging the production design MEA confirmed the viability of a Plug Power/3M stack solution from a material cost and superior system design perspective

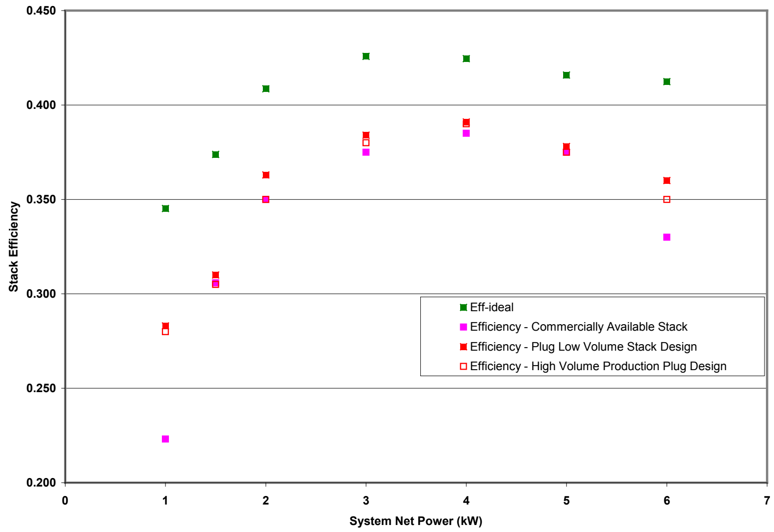
Progress – Stack Sourcing Pressure Drop

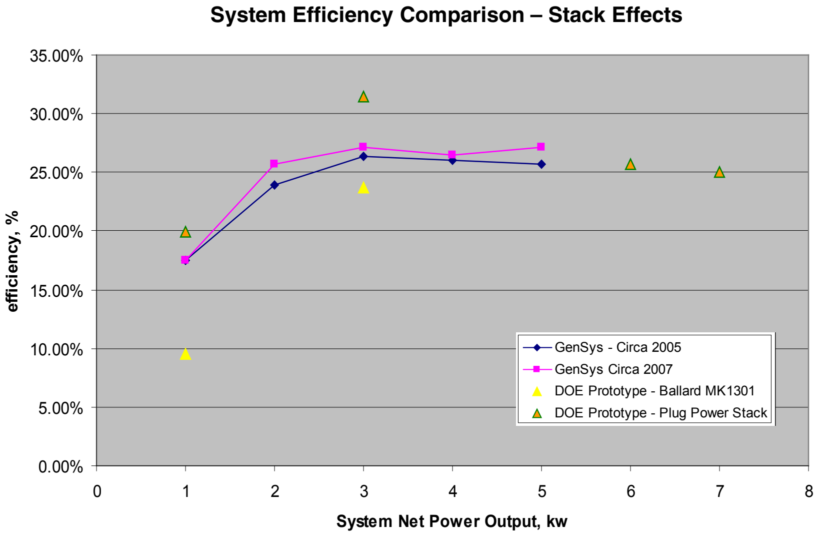
- The commercially available stack had up to 3.5x the pressure drop of the Plug Power stack design
- The higher pressure drop required for the water management method led to lower system efficiency and difficulty finding components to supply the required reactants
- Low power efficiency was also effected due to “DP floor”



Pressure drop comparisons between commercially available stack and Plug Power stack design

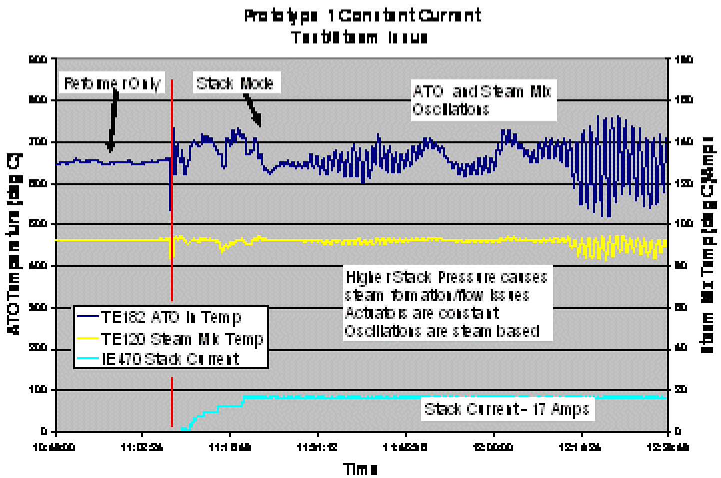
Progress – Stack Sourcing Efficiency Impacts





- The efficiency impact of the commercially available stack negated any potential gains it had in cost and durability
- The GenSys 6U48 product advantage over incumbent technology is based on superior efficiency leading to op-ex savings
- The commercially available stack was not a viable solution for a GenSys product and did not show a path to meeting DOE objectives

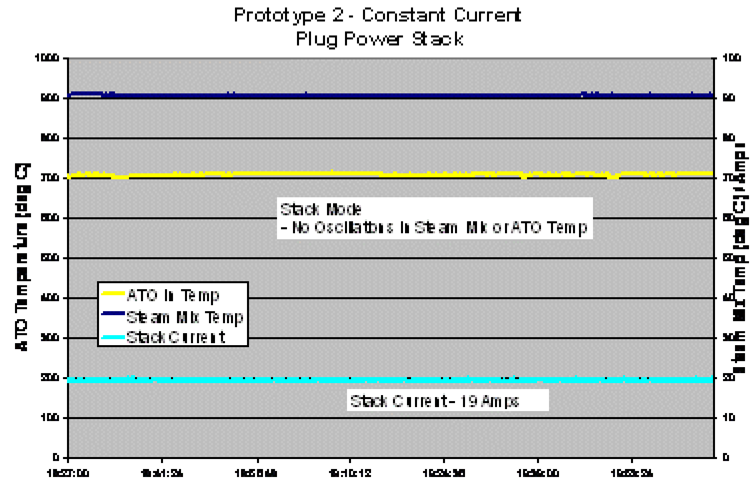
Progress – Stack Sourcing System Controls Impacts



The commercially available stack, without design changes, was unable to improve efficiency or control stability

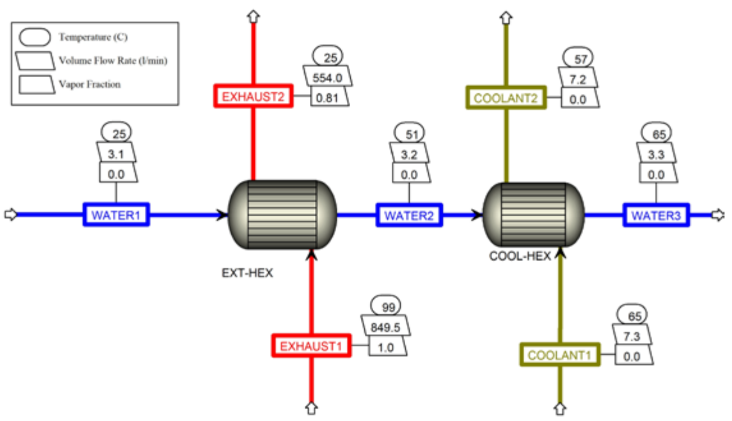
Commercial

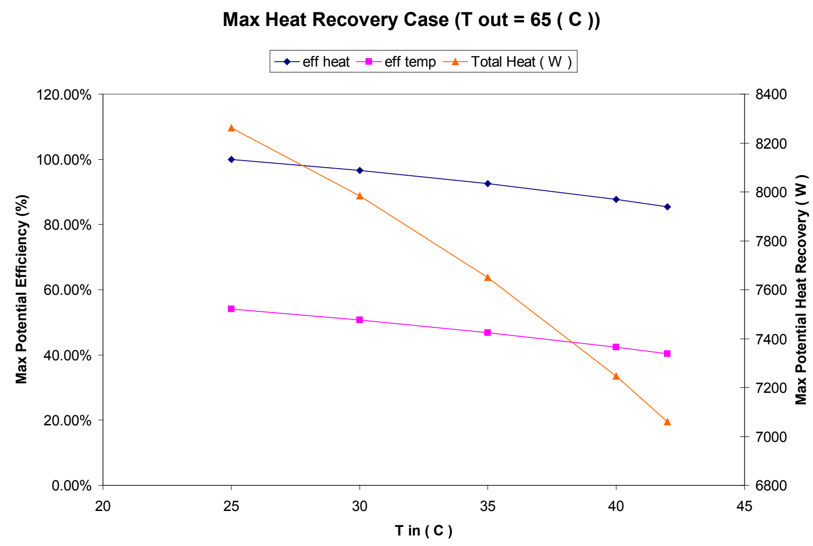
Plug Power



In addition to efficiency impacts, the commercially available stack resulted in a system that was much more unstable (reformer/ stack interaction) due to its higher pressure drop

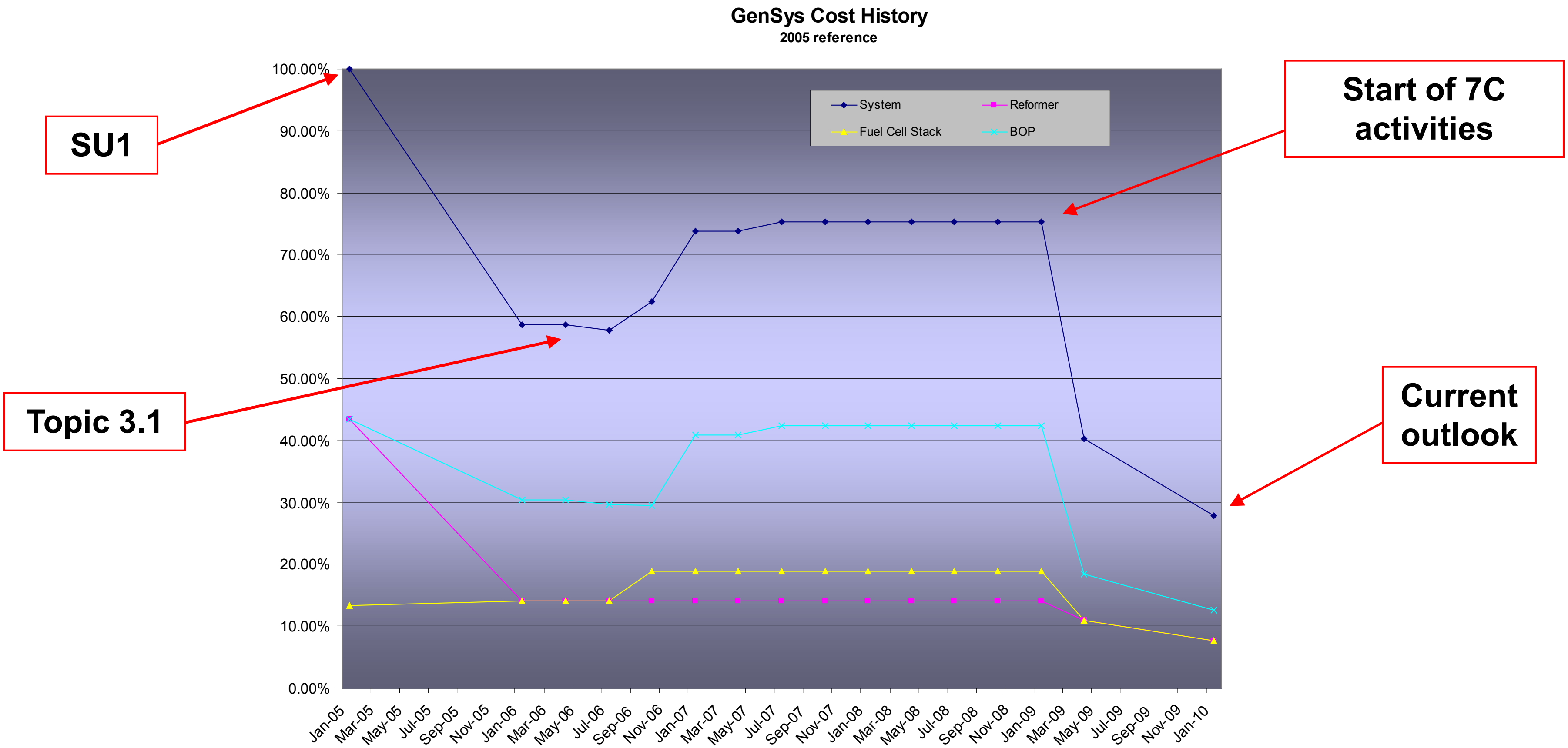
Progress – LT PEM for CHP Applications





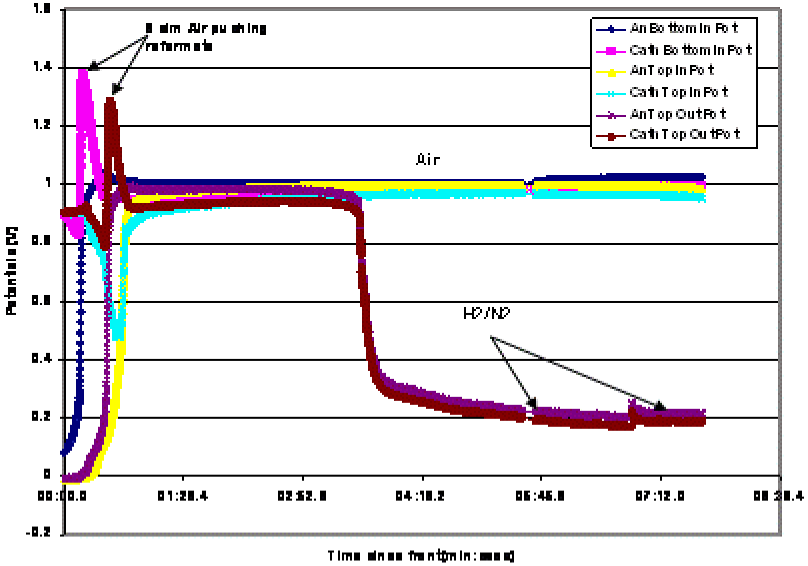
- Using a low temp PEM system in a CHP application has been studied for both the maximum heat recovery and maximum output temperature based on the existing design
  - 8200 W (28,250 BTU/hr) are available at a of temperature 65C (150F)
  - The maximum outlet temperature of 77C (170F) is possible with 5050 W available
- Further improvements in quality of heat are possible at the expense of electrical efficiency
- Plug Power is investigating the viability of a LT CHP system based on the GenSys system architecture

Accomplishments – System Material Cost

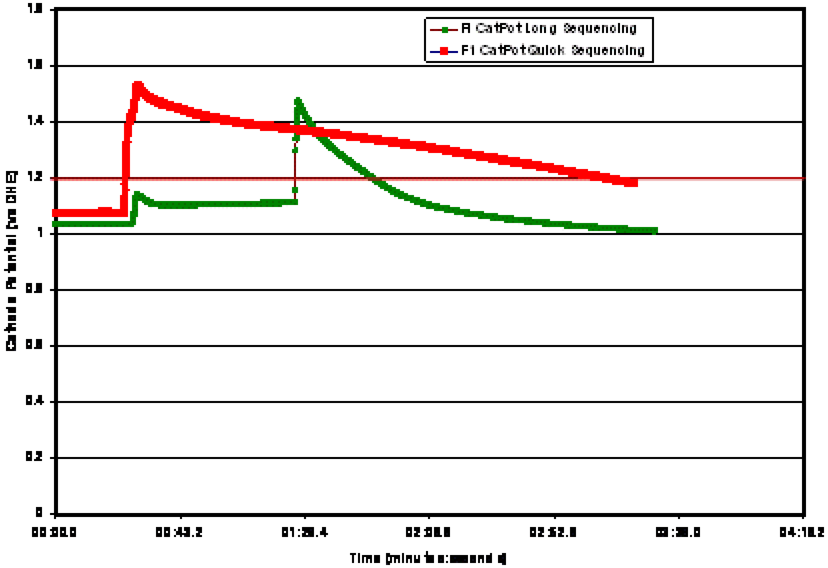


- Material cost of GenSys system has been reduced by 63% due to design activities related to this program
- Fuel cell stack material costs reduced 59%
  - Expect additional 15% cost reduction once design is fully tooled

Accomplishments – Reliability Improvements Startup Sequencing



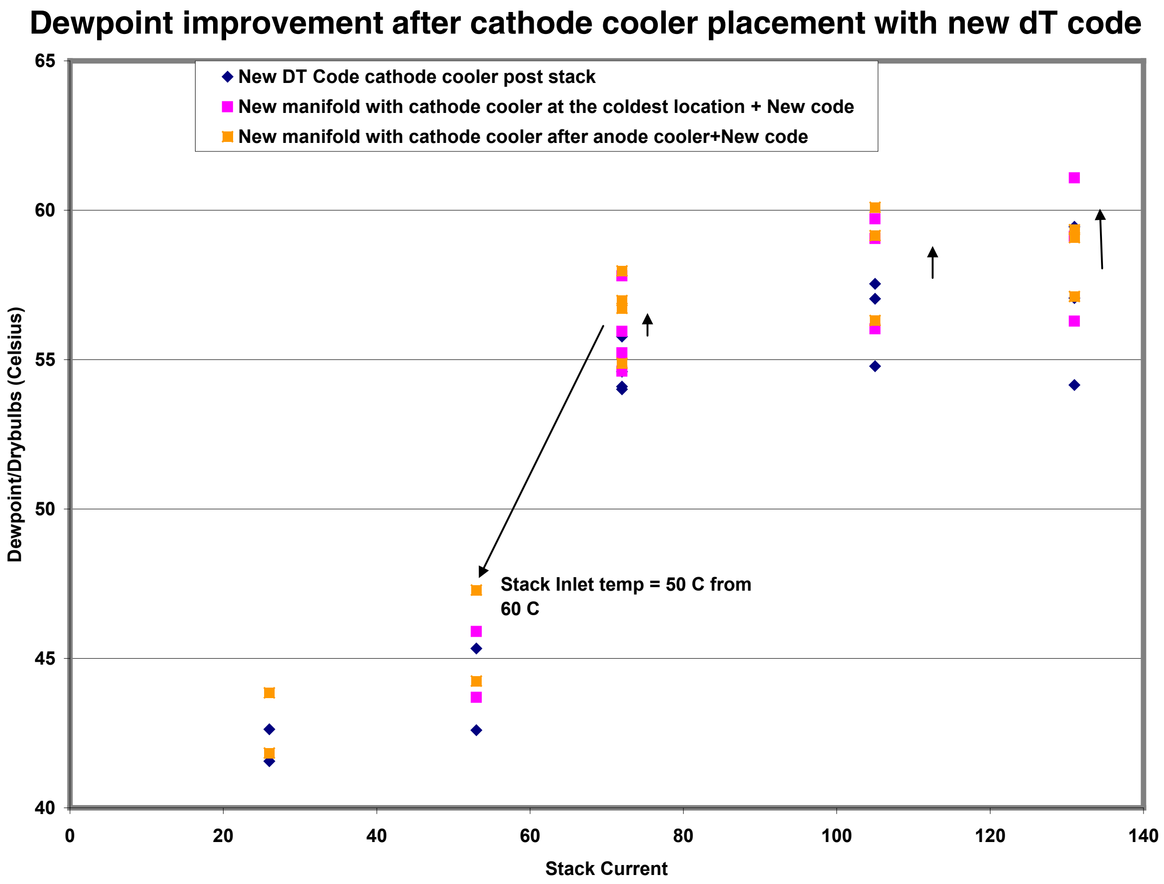
Reference electrode potential stratification as front passes by and settling after shutdown



Valve sequencing and stack reference electrode response at the same location

- In an effort to combat carbon corrosion on the MEA during H2/air front propagation at start-up, various system controls approaches were studied
- Results of these tests proved that a controls and isolation solution existed that was much less costly than an MEA materials solution
  - This allowed reduction in MEA loading leading to lower overall cost

Accomplishments – Reliability Improvements Cathode Humidification



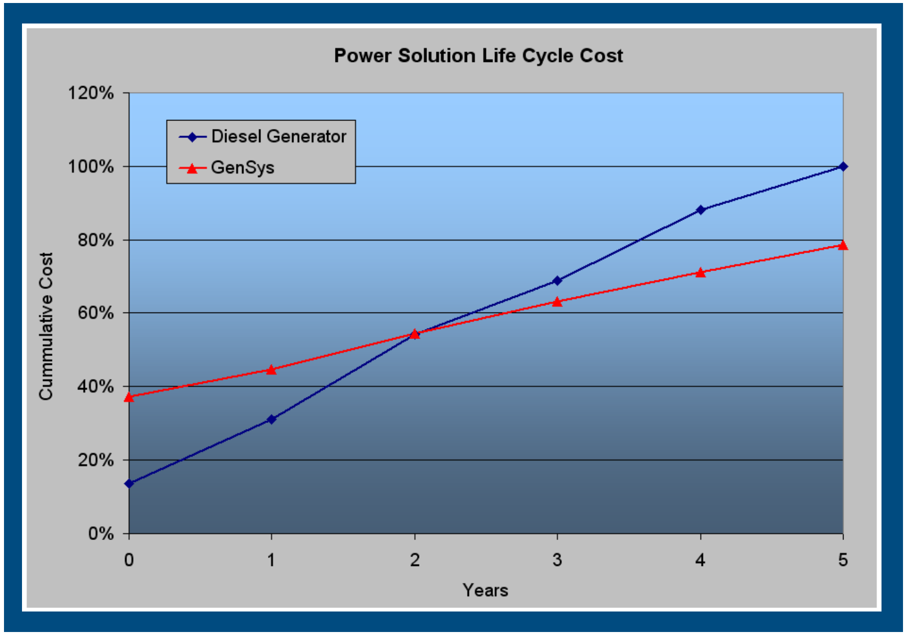
- Several different types of cathode humidifiers were studied with the goal of reducing part cost while maintaining a high cathode saturation for increased stack life

- The outcome from these tests resulted in qualification of a part that was approximately 50% of the cost of the incumbent with improved level of humidification across the operating range

Accomplishments – Commercial Viability

Total Cost of Ownership Model

Higher Efficiency → Lower OpEx → Lower Total Cost of Ownership



Note: All TCO model inputs are based on customer-supplied PO's.

Magnitude of fuel savings dwarfs the difference in the initial capital investment, offering a payback period of ~ 2 years

Accomplishments – Commercial Viability

DOE Objectives			
	Plug Power	MK-1300	DOE Target
Resulting System Efficiency (max)	33%	23%	40%
System/Stack Life (hrs)	15K	15K	40K
Stack Cost (direct hydrogen)	562 $/kw	556 $/kw	400 $/kw
System Cost	2667 $/kw	2645 $/kw	750 $/kw

Using a Plug Power stack design offers the best option for meeting commercial and DOE program objectives

Collaborations

Partners

- **Ballard Power Systems** (Sub-contract, Industry): Collaboration on how best to perform system integration of a PEM based fuel cell stack
- **Construction Engineering Research Laboratory (CERL)** (Partner, Federal): Collaboration to provide opportunity to test prototypic hardware under simulated field conditions
- **National Grid** (Partner, Utility): Collaboration to install GenSys system at Union College

Technology Transfer

- Collaboration with Ballard to improve reactant humidification, start-up and shut down protocol and operating conditions to maximize fuel cell performance and stack life
- Collaboration with CERL and National Grid provided opportunity to test fuel cell systems performance in their intended application in advance of commercial deployment

Proposed Future Work

- Union College unit will be decommissioned summer of 2011
- Due to significant system advancements DOE has agreed to closeout the 7C program and role the CERL contract obligations into the 7A program
  - Plug Power will site a commercial GenSys unit at CERL
  - The CERL unit will be counted as one of the 20 units in 7A
  - The CERL siting will use the remaining funds in the 7C program
  - Plug Power will install data acquisition equipment required for 7A in the CERL unit
  - Plug Power will complete data analysis on CERL unit as part of 7A program

Summary

Relevance: Provide the platform to improve overall system efficiency, reduce system and stack material cost, and investigate system and materials improvements necessary to increase stack performance and durability

Approach: Combine past experience and project learning to set the path for the commercial GenSys units currently in production

Technical Accomplishments and Progress:

- System integration testing complete
- Validation testing and controls complete
- Commenced prototype field demonstration

Technology Transfer/Collaborations: Active partnership with Ballard Power Systems combined industry leading knowledge in fuel cell stacks and system integration, and partnership with National Grid allowed successful installation of a high temperature system in a utility setting

Activities for Future:

- Complete Union College demonstration
- Meet CERL demonstration obligation via 7A program

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