

Low-Cost Hydrogen Distributed Production System Development

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June 10, 2008

PD1

Overview

Timeline

- July 1, 2005
- June 30, 2008
- Complete

Budget

- Total project funding
 - \$3.46M DOE funds
 - \$1.89M contractor share
- \$450,000 DOE funds in FY05
- \$400,000 in FY06
- \$1,997,361 in FY07
- \$609,354 in FY08

Barriers

- **Barriers addressed**
 - Fuel Processor Capital Costs.
 - Fuel Processor Manufacturing
 - Operation and Maintenance (O&M)
 - Feedstock Issues.
 - Control and Safety

Partners

- Süd-Chemie, Inc.

Objectives

Execute on the following specific goals as part of the overall plan to overcome the barriers identified by the USDOE and to meet the USDOE technical targets in terms of cost and energy efficiency

- Design, build and test a 565 kg/day hydrogen plant for 99.999% pure hydrogen to meet DOE hydrogen \$3/kg cost target for SMR and PSA
- Develop a catalyst suite based on our current technology suitable for use with fuel grade ethanol to facilitate renewable hydrogen production

Milestones

- ***Commissioned first 565 kg/hr prototype (HGM5001) plant at field site 10/07***
- ***3,889 production hours on HGM5001 as of May 12, 2008***
- ***Demonstrated sub-scale advanced HGM reactor 1/08***
- ***Shipped 2nd generation 565 kg/hr prototype (HGM5002) 2/08***
- ***Operated EtOH catalysts 1,900 hours***

Approach

First steps – analysis and bench scale experiments

- Catalyst improvements - done
- Balance of plant improvement - done
- Advanced reactor design - done

Second step - integration and test improved technology in the existing HGM-2000 platform

1. Incremental improvements - done
2. Obtain long-term test data (eventually in commercial test fleet) - done
3. Make ongoing progress towards USDOE goals - done

Final deliverable

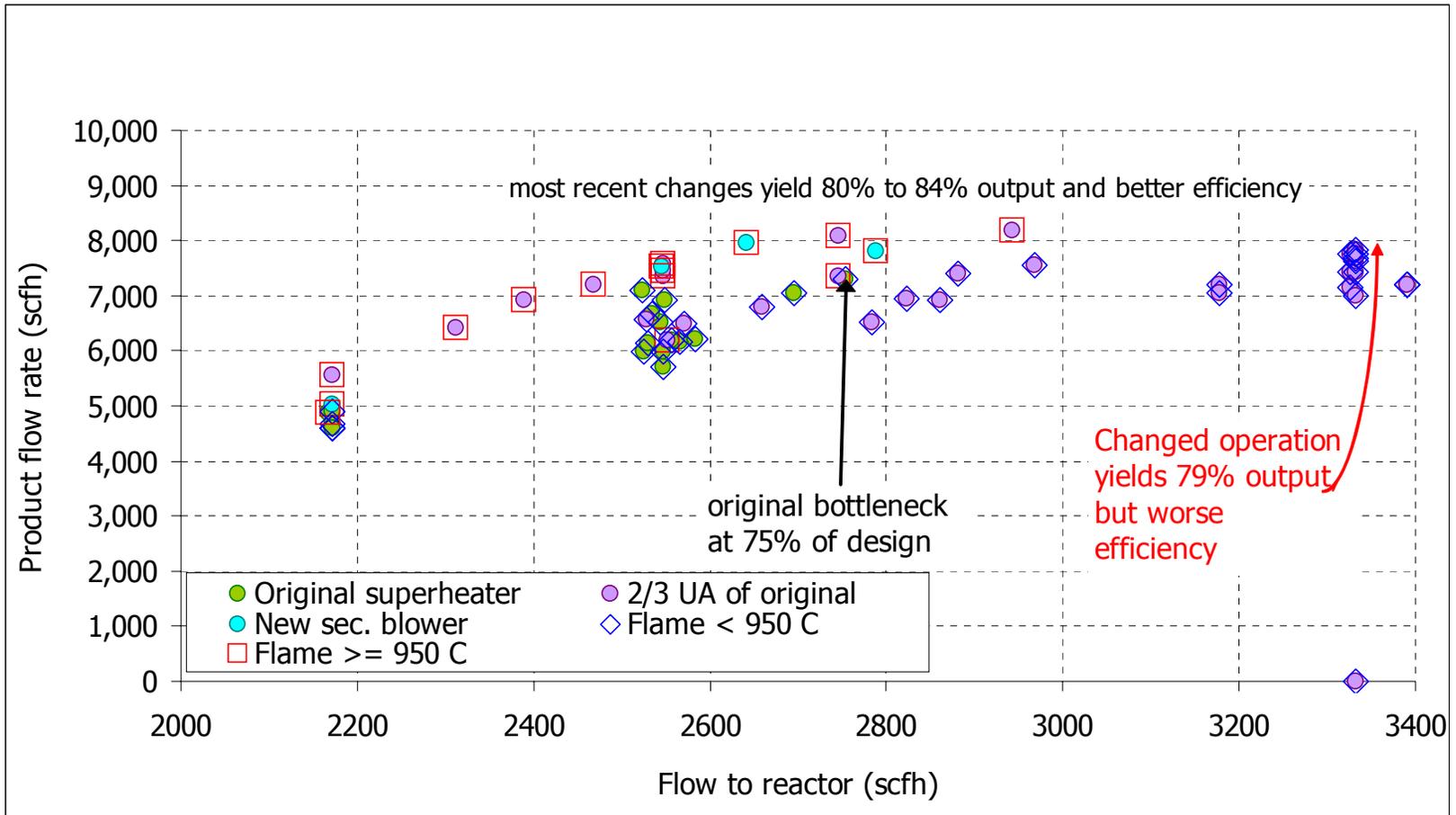
1. Design 565 kg/day plant using DFMA, FMEA and other best practices based on lessons learned from second step – done
2. Construct first 565 kg/day plant – done
3. Test first 565 kg/day plant - done
4. Redesign 565 kg/day plant based on test results and DFMA - done
5. Test second 565 kg/day plant – in process

1st Prototype plant HGM5001

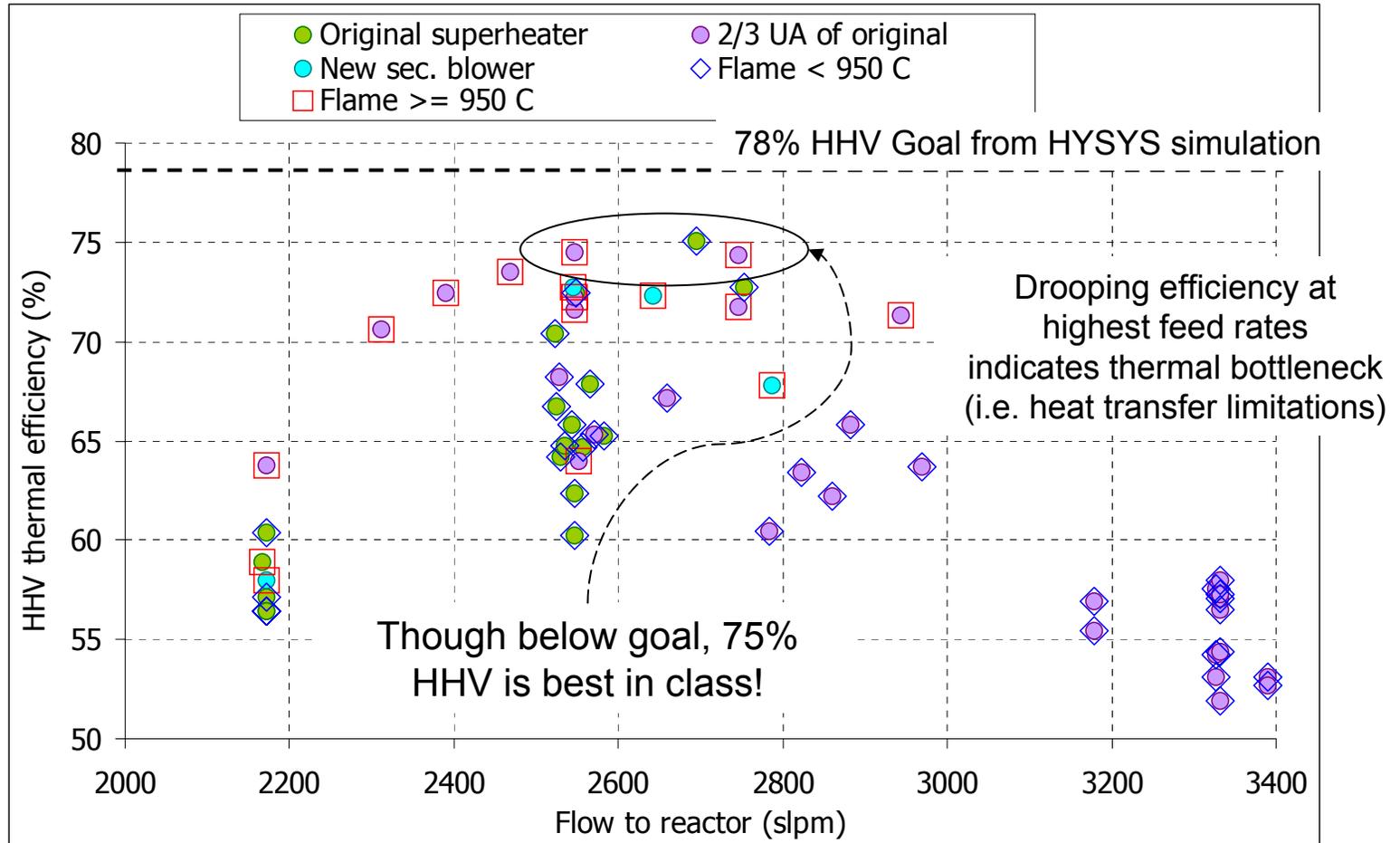
- On time and under budget
- Over 3800 runtime hours
- Achieved 84% of target output flow rate
- HHV thermal efficiency 96% of target value
- Bill of material cost meets goal



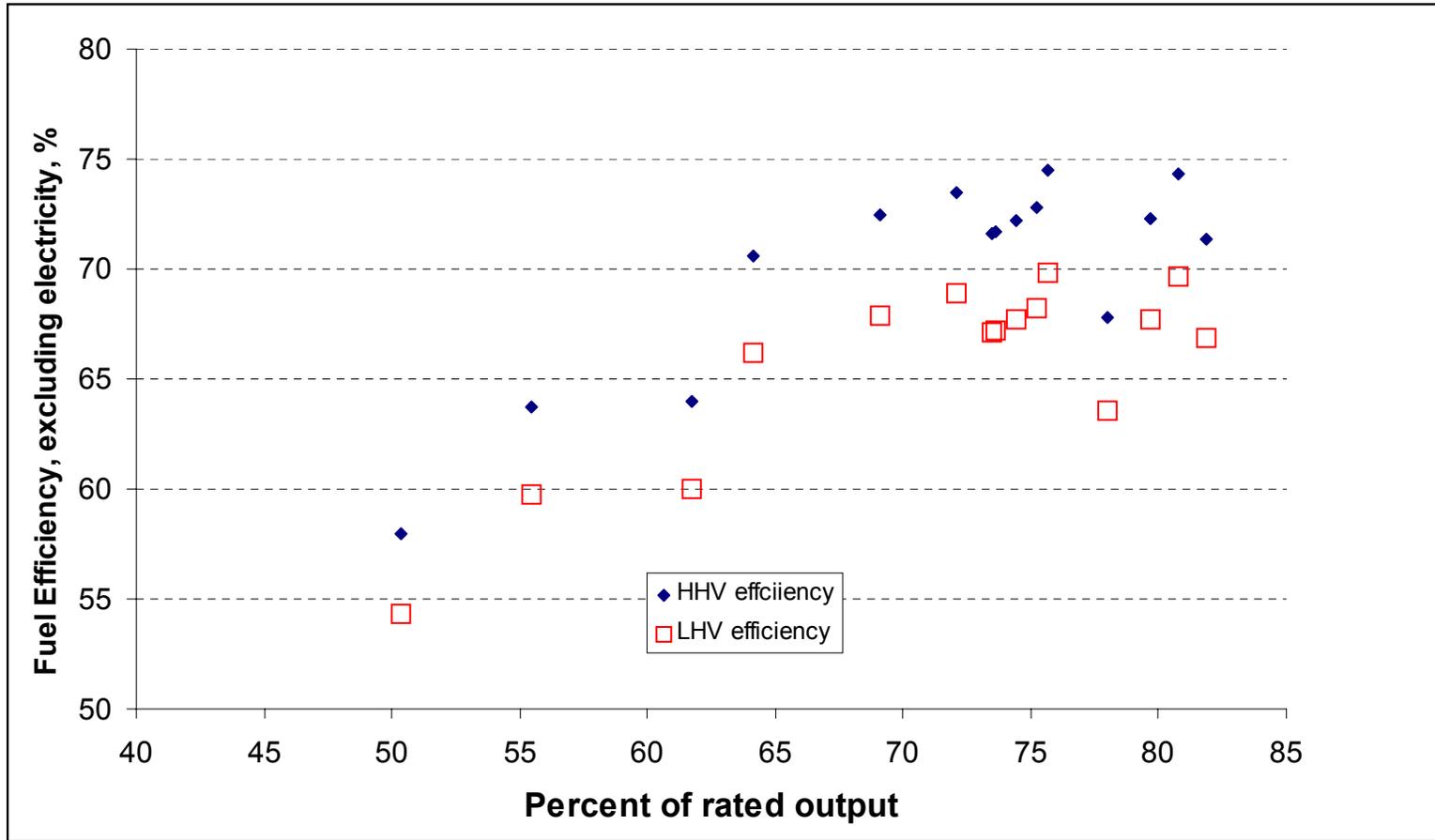
Output data for HGM 5001



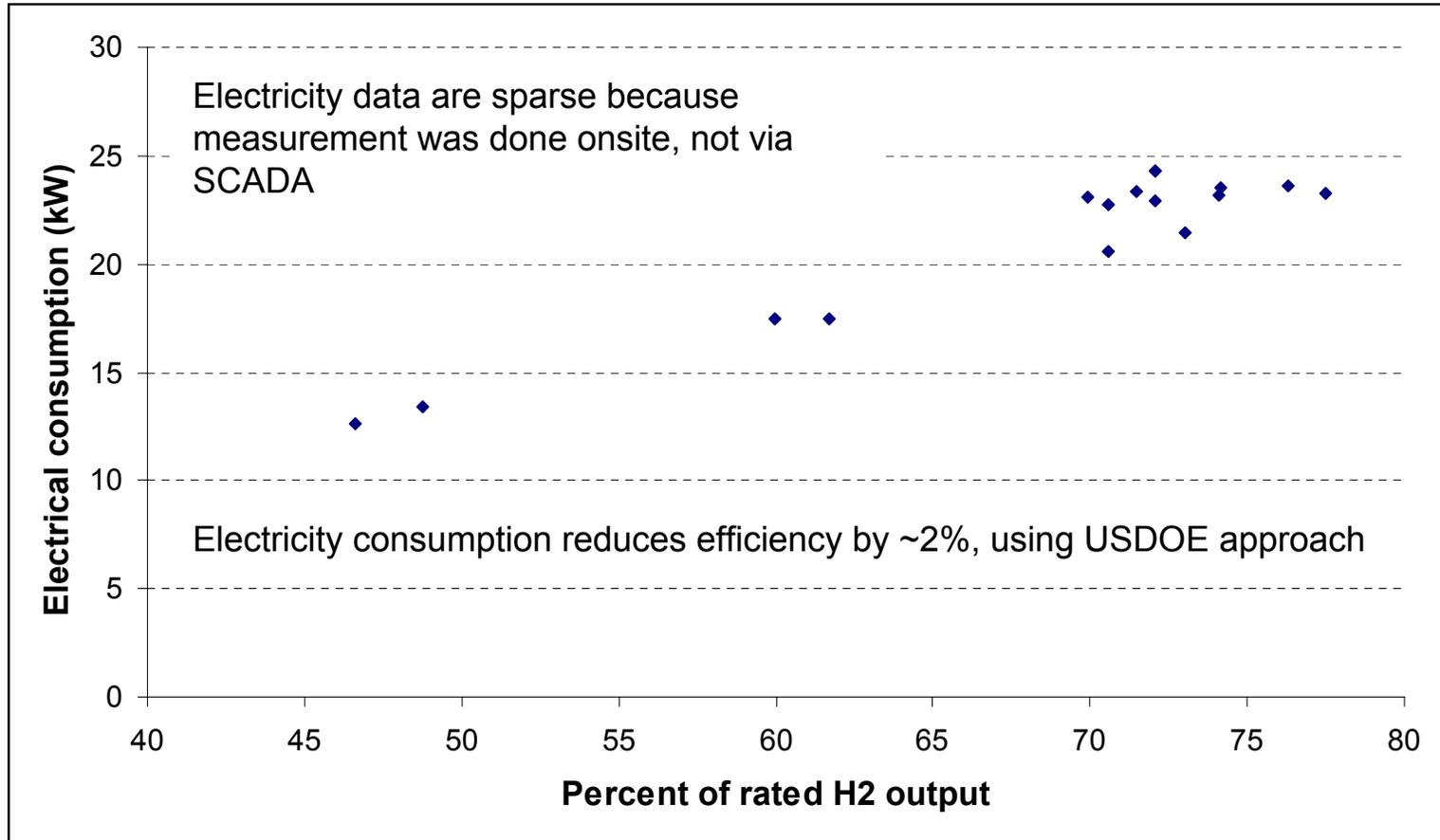
1st prototype thermal efficiency



Efficiency data at optimized operating configuration for 1st prototype



HGM 5001 electricity consumption



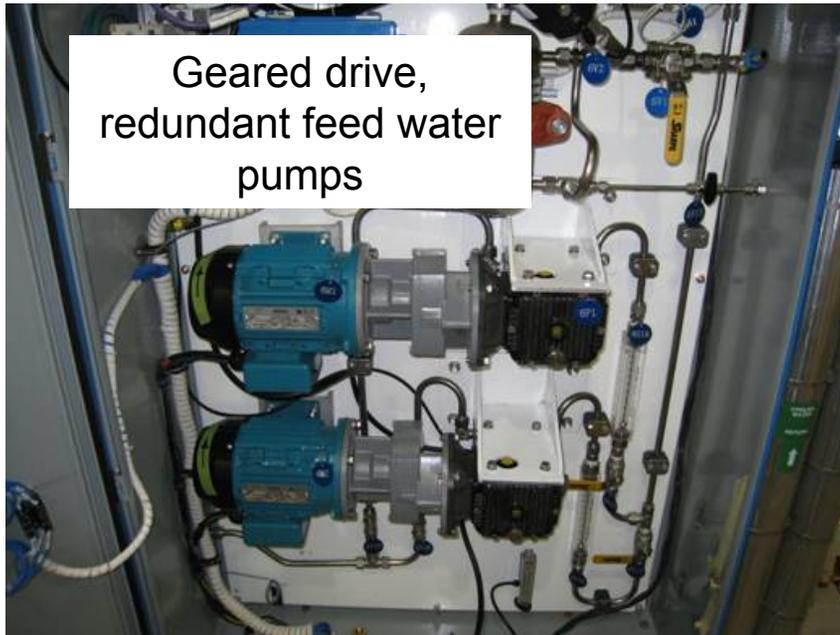
Root cause of shortfall in output and efficiency compared to program goals

- Low heat exchanger UA products
- Steam generator and economizer shortfall was predicted as of last year's meeting
- Reactor shortfall in heat transfer performance was unexpected

Process improvements for 2nd prototype, HGM 5002

	Surface area	Flue side Reynold's number	Process side Reynold's number	Other
Reactor	same	Increased 50%	same	5X lower mechanical stresses
Steam generator	Increased 11%	Increased 20%	same	Designed with wall-wetting features
Economizer	Increased 39%	Increased 20%	same	Designed for 10% quality

Machinery improvements



Small compromises in BOM cost and Power consumption have been made for HGM 5002 to maximize reliability

Packaging improvements



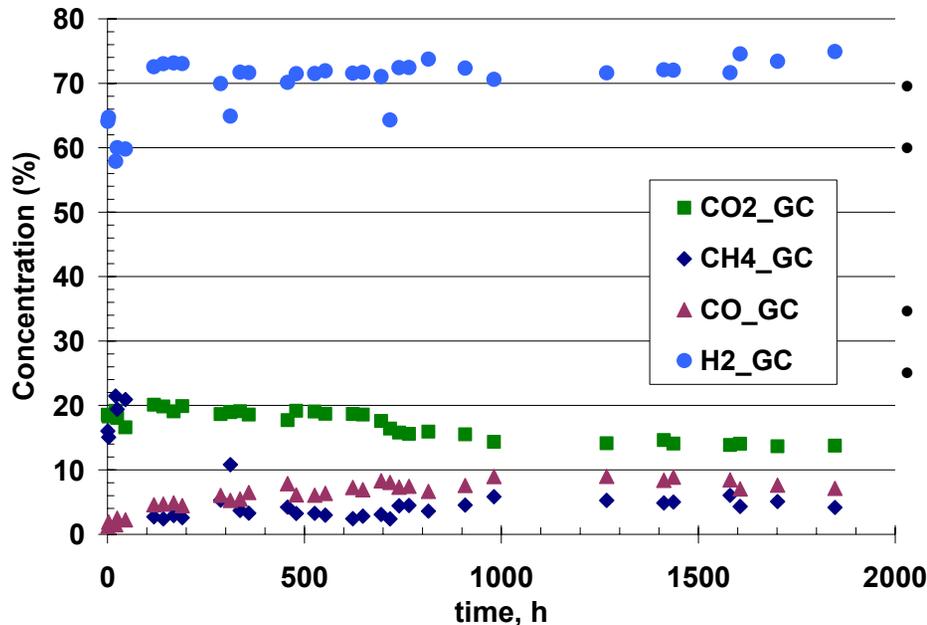
- Major focus on reducing clutter, aiding access for service
- Remedying any points of subtle vibration, or weakness of mounting points (step proofing)

2nd prototype HGM5002 being installed at field site



- Commissioning underway, but no test data as of May 15
- less than 12 months from start of redesign to commissioning

Ethanol Reforming



- Microreactor aging test.
- Ethanol pre-reforming catalyst followed by standard HGM SMR, WGS catalysts.
- Ethanol column reflux feed
- Complete ethanol conversion in the pre-reforming section

- 1900 hr test under the conditions matching that of HGM unit
- Demonstrated reforming of ethanol with standard fuel additives

Next steps:

- Long term microreactor testing with fuel grade ethanol E95/E85.
- Dual fuel (ethanol/PSA waste gas) burner testing.
- Ethanol based HGM unit construction and testing.

Future Work

- **Commercialize 565 kg/hr hydrogen plant (not using USDOE funds)**
- **Continue EtOH testing, extending to denatured fuel ethanol**
- **Conduct design for fuel supply and combustor systems**
- **Test burner system**

Summary

Distributed Hydrogen Generation Targets			
Production Parameter	Units	System Target	Achieved by 5/12/08
Hydrogen Output	Kg/day	565	475
System efficiency	% LHV	>67.5	67-68%
Parts Cost	\$	<\$350,000	Proprietary
Field test time	hours	2,500	3,889
Ethanol Reforming Target			
Catalyst test time	hours	>1,000	1,900