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NOVEL CATALYTIC MICROCHANNEL FUEL PROCESSING TECHNOLOGY

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Solutions for a changing planet

Objectives and Budget

Develop a microchannel fuel processor for the production of clean hydrogen from fossil fuels using catalytic steam reforming and advanced separations technology.

- **Achieve DOE cost and efficiency targets for hydrogen production through microchannel design and advanced thermal management**
- **Develop and test 2nd generation components**
- **Demonstrate integrated multi-kW system**

TOTAL CONTRACT BUDGET: $1,069,698 = $850,229 (DOE) + $219,649 (Contractor Share)
PHASE III BUDGET: $ 375,287 = $300,229 (DOE) + $ 75,058 (Contractor Share)

Technical Barriers and Targets

Fuel Processor Capital Costs – **2010 target of $0.24 per kg H2**
Operation and Maintenance – **75% Target primary energy efficiency**
Feedstock and Water Issues – **Fuel-flexible reformer & water recycle**
Control & Safety – **optimized operations, e.g. on-off cycling; enhanced consumer safety**

Approach:

Develop a commercially viable product by

- **integrating novel micro-structured devices to increase thermal & chemical efficiency, and reduce coking, – reactor, heat exchanger, injector**
- **developing sulfur-tolerant catalyst for multiple fossil & renewable fuels**
- **using advanced hydrogen-permeable membrane for purification**

Project Timeline

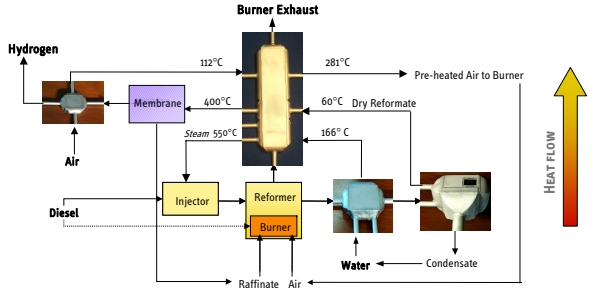
7/99 PHASE I 9/00	PHASE II 10/02	PHASE III 10/04
Component design; feasibility established with methanol	>1000 hr catalyst test with n. gas 1 kW demonstration	Components/system optimized 10 day multi kW demonstration

DOE Hydrogen, Fuel Cells, and Infrastructure Technologies Program Review Meeting 2004

Technical Accomplishments

Micro-Structured System Components Integrated for High Efficiency

Thermal zones with tight integration is key to successful system optimization.



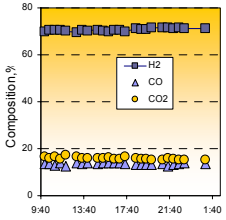
Schematic of the InnovaGen® Fuel Processor with Heat Exchangers

Proprietary Catalyst and Support Foils Developed for Microchannel Reactor

- **Reforms multiple fuels**
- **Highly reactive**
- **Sulfur tolerant**

granulate (300-500 µm) catalysts

foil catalysts (4.0"×0.35" × 0.012")



Steam Reforming Results for Diesel

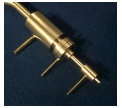
Diesel Reforming Conditions
T=850°C
H_2O/C=5.14
GHSV=165,300 hr^{-1}
Sulfur = 3.5 ppm

Methane Reforming Conditions
T=850°C
H_2O/C=2.82
GHSV=237,000 hr^{-1}

SAFETY PROCEDURES IMPLEMENTED: HAZOP, FMEA, MOC

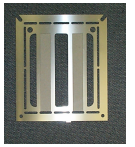
Proprietary Micro-Structured Steam Reformer Components Developed

- **Demo of 1 kW-sized reformer is underway**
- **Projected efficiency = 65% for natural gas**



Fuel Injector
Reduces coke formation, the #1 reforming problem

Heat Exchanger
1 of 4 types that reduce thermal loss

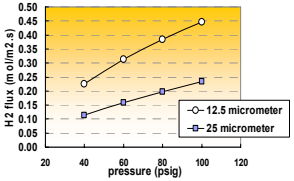


Individual Reactor shim plate
1 of 5 types that are diffusion bonded

5-kW Micro-Channel Reactor with Integrated Burner
40% smaller than conventional reactor

Hydrogen Purification Rate Doubled using Enhanced Pd-Alloy Membrane

Dimensions
2.5 x 2.5 inches
Thickness
11~14 micrometers
Flux
2.4 LPM pure H_2
1.0 LPM H_2 from reformate



SUMMARY: The use of micro-structured components has allowed development of a smaller, less costly, more efficient fuel processing system by improving thermal management and residence time compared to conventional technology.

Interactions & Collaborations

- **Agreements with heat exchanger manufacturer and membrane housing manufacturer**
- **Teaming agreements with several systems integrators**
- **Catalyst evaluation performed at Washington Statue University**
- **Microchannel modeling performed at University of Florida**
- **Collaboration with PNNL for control system development**
- **Presentations and Publications: 2004 Fuel Cell Seminar & 15th Annual U.S. Hydrogen Conference**