DOE Hydrogen Program

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Integrated hydrogen production, purification and compression system

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Project ID # PD3

Overview

Timeline

- Project start date - April 1, 2005
- Project end date - June 31, 2008*
- Percent complete: 45

* *Revised with extension*

Barriers addressed

- Production Barriers
  - Fuel Processor Capital Costs
  - Operation and Maintenance
- Delivery Barriers
  - Reliability and Costs of Hydrogen Compression

Budget

- Total project funding - $3,840,009
  - DOE share: $2,854,202
  - Team share: $985,807
- Funding received to date
  - $306,339 (FY05); $600,000 (FY06)
- Funding for FY07 - $948,892

Partners

- Key partners:
  - MRT
  - HERA USA
- Other collaboration/interactions:
  - Safety experts
  - Product certification experts
  - Pd membrane suppliers

Program Objectives

- **Goal**: To demonstrate a low-cost option for producing FCV quality hydrogen that can be adopted to meet the ultimate DOE cost and efficiency targets for distributed production of hydrogen
- **Objective**: To develop a fuel processor system that directly produces high pressure, high-purity hydrogen from a single integrated unit
  - **Task 1(FY05):** Perform a detailed techno-economic analysis, verify feasibility of the concept and develop a test plan
  - **Task 2 (FY06-07):** Build and experimentally test a Proof of Concept (POC) integrated reformer / metal hydride compressor (MHC) system
  - **Task 3(FY07-08):** Build an Advanced Prototype (AP) system with modifications based on POC data and demonstrate at a commercial site
  - **Task 4 (FY08):** Complete final product design capable of achieving DOE 2010 H2 cost and performance targets

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Approach

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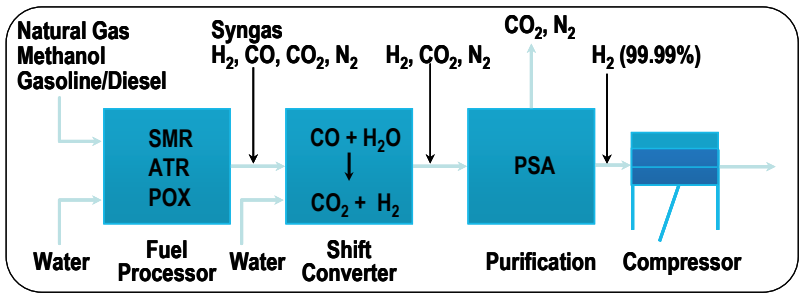
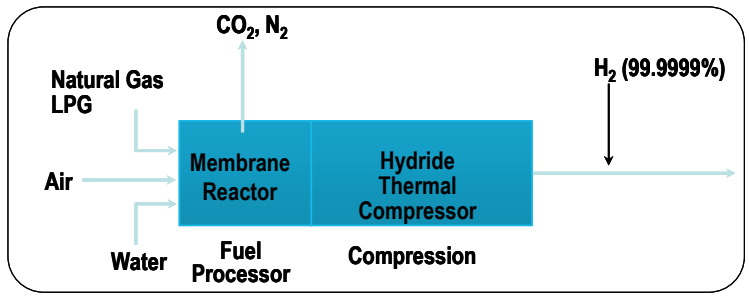
Integrate the membrane reformer developed by Membrane Reactor Technology (MRT) with the metal hydride compressor (MHC) developed by HERA USA in a single package



Conventional



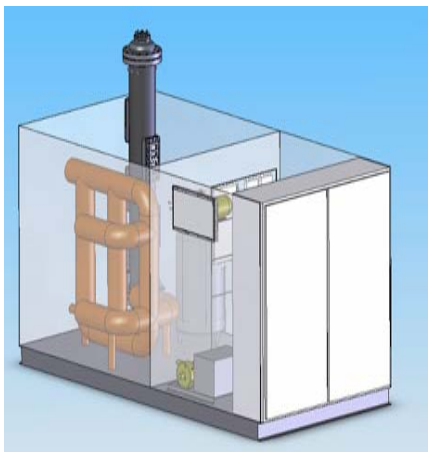
Proposed System

- Lower capital cost compared to conventional fuel processors by reducing component count and sub-system complexity.
- Increase efficiency by:
  - directly producing high-purity hydrogen using high temperature, H2 selective membranes; increased flux due to suction provided by the hydride compressor
  - improved heat and mass transfer due to inherent advantages of fluid bed design
  - equilibrium shift to enhance hydrogen production in the reformer by lowering the partial pressure of hydrogen in the reaction zone
  - using excess heat from reformer to provide over 20% of compression energy

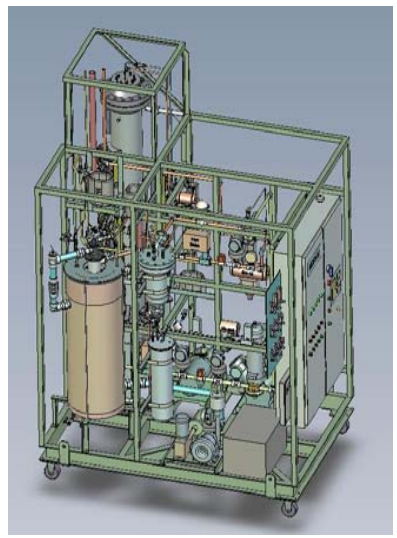
Technical Accomplishments, Progress and Results

Completed detailed design for Proof of Concept prototype (POC)

- P&ID finalized for construction
- HAZOPS completed in June 06
- Safety Plan revised
- Components re-sourced and procured
- Fabricators selected for custom equipment
- 3D models generated



Concept to Reality



Technical Accomplishments, Progress and Results

Reformer Skid Assembly

Prototype Basis

- ❑ Pros:
  - Independent Skids
  - Greater accessibility
  - Ideal for component testing and optimization
- ❑ Cons:
  - Increased equipment costs due to higher classification zones
  - Minimal integration
  - Need for redundant systems

Reformer Skid Dimensions

LENGTH:	9’
WIDTH:	6’
HEIGHT:	9’-6” (12’ including reactor)

Technical Accomplishments, Progress and Results

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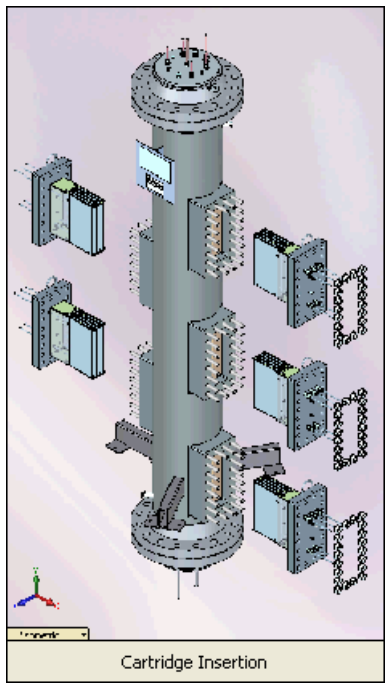
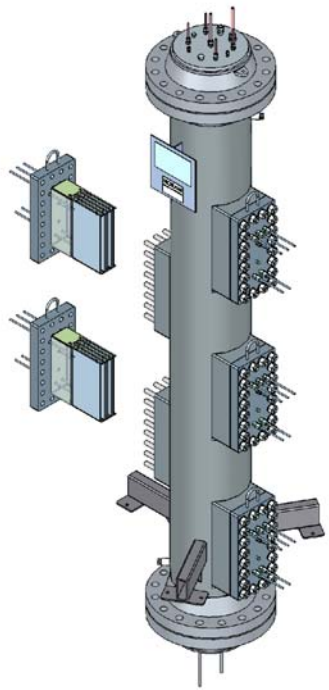
Novel Auto-thermal Fluidized Bed Membrane Reformer (FBMR) Assembly

- Detailed mechanical design completed
  - New design enables use of lower cost metals to address rising metal costs
  - Membrane access vastly improved
- FBMR fabricated and installed

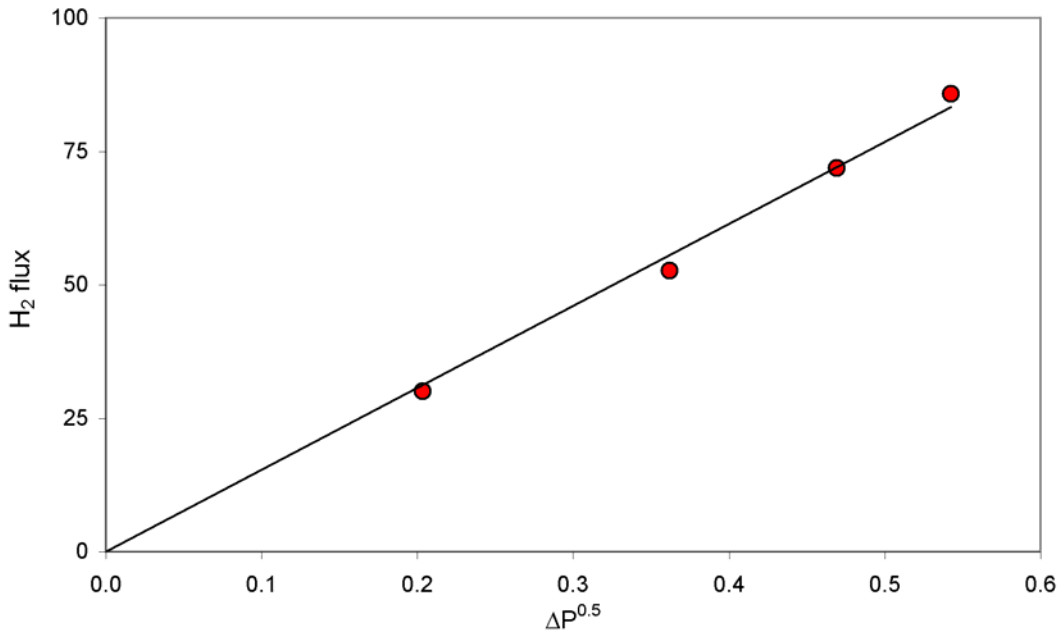




Technical Accomplishments, Progress and Results

New Membrane Design

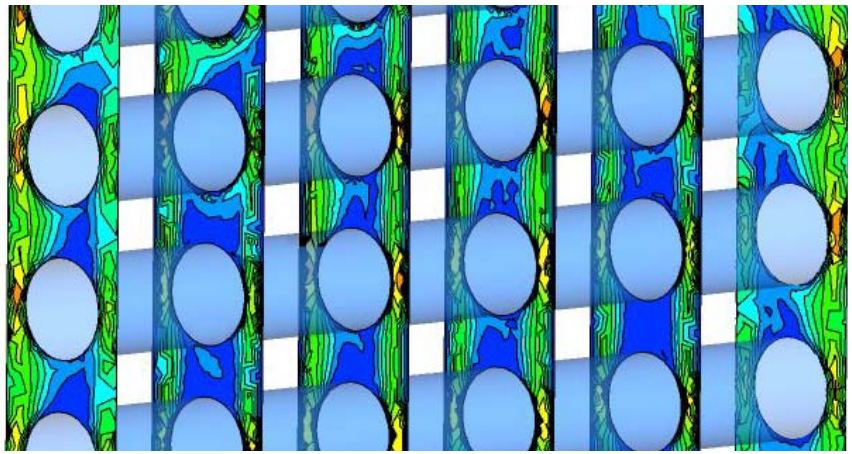
- New design incorporates efforts to reduce substrate component costs
- Membranes tested at operating temperature and pressure (550ºC, 25 bar)
- Membranes fabricated (double-sided, 25 µm foil, 6” x 11” x ¼”) for POC



Technical Accomplishments, Progress and Results

POC Vaporizer

- Single unit preheats, vaporizes & superheats a natural gas – water mixture
- Combustion air pre-heater incorporated around unit reduces overall foot print
- Detailed design effort conducted, including Computational Fluid Dynamics (CFD) modeling
- Unit fabricated and installed



CFD model shows hot air velocity gradients over HX tubes

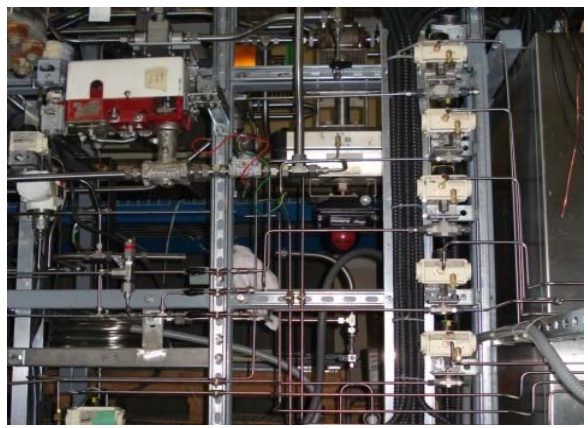
Technical Accomplishments, Progress and Results

POC
Balance of Plant

Custom built
air compressor

Water pump and air blower

Low cost, compact heat exchangers

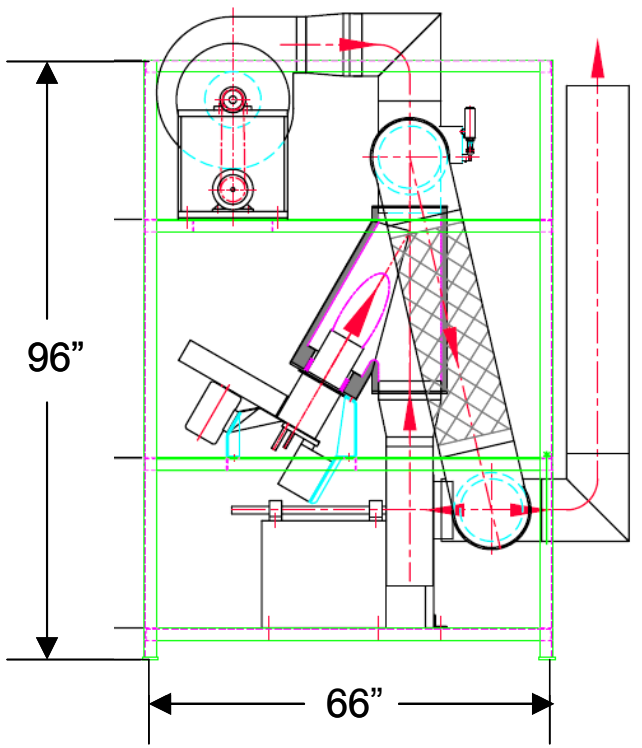


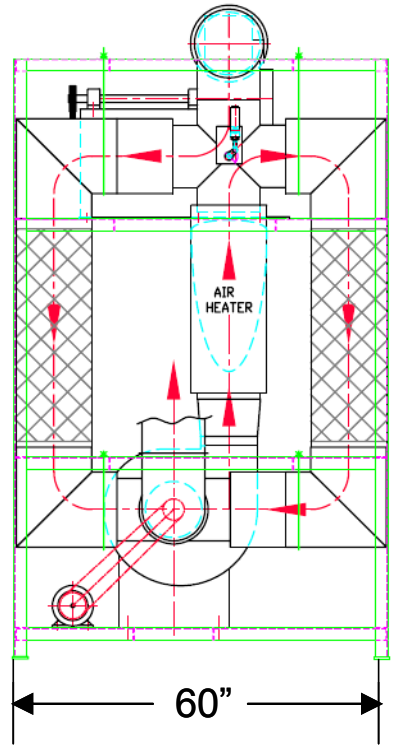
Control & safety valve rack

Technical Accomplishments, Progress and Results

Hot Air Powered MHC

- Energy provided from recirculated hot air
- Reactor off-gas provides >20% of the energy
- Inlet pressure of 7 psia maintains high flux across membranes
- Compression Ratio of 215 in a single stage
- Isothermal efficiency predicted to be >20%





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POC Technical Challenges

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- Higher metal costs (FBMR precious metal catalyst)
  - MRT working with catalyst vendor to seek alternative solutions
- Prototype membrane performance and longevity
  - Ongoing independent R&D at MRT
  - New methods to fabricate thinner, pinhole-free membranes
- Membrane and MHC interaction
  - Lab scale testing performed successfully in previous Task
  - Buffer vessels have been sized and provisions made for installation if deemed necessary
- Reliability of commercially available switching valves at 450 C
  - Custom 4-way butterfly valves sourced and being tested

Current Status & Future Work

- Current Status:
  - — Installation 90% complete (NRC Institute for Fuel Cell Innovation)
    - ➢ *MHC Skid Delayed by 2 Months*
  - — Test Plans finalized
- May 2007:
  - — Complete site installation and commission Reformer
  - — Complete MHC fabrication
- June – August 2007:
  - — Conduct performance tests – verify design parameters
  - — Install and commission MHC for one month of integrated testing
  - — Re-evaluate system economics and propose preliminary design of the next generation system (Advanced Prototype)
- September 2007:
  - — Deliverable: Report summarizing POC test results
  - — Milestone: GO/NO GO decision on next step based on POC results

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Summary

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Accomplishments

- Proof-of-concept prototype system designed, fabricated and installed
  - Novel reformer mechanical design with good membrane access
  - Prototype membrane modules (6”x11”) with lower cost substrate successfully tested at operating temperature and pressure
- Novel MHC powered by hot air designed and under construction
- Appropriate safety reviews completed
  - HAZOP completed in June 06
  - Updated Safety Plan submitted to DOE
  - Technical Risk Assessment for POC installation and operation completed

Technical Targets and Plans

- Cost and efficiency targets unchanged since last year, pending assessment and revision based on POC test results
- Complete POC performance tests, and report of results and economic assessment by September ’07
- Advanced prototype planning by September ’07
- Review results with DOE for decision on next step

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Thank you!

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Questions?

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