Scale-Up of Hydrogen Transport Membranes for IGCC and FutureGen Plants

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Overview

Timeline

• Phase I Start	1 Oct 2005
• Phase II Start	1 Oct 2009
• Phase II End	30 Jun 2013

Budget ($000)

• Phase I Funding	$ 5,415
– DOE share	$ 4,330
– Contractor share	$ 1,085
• Funding in FY08	$ 1,625
– DOE share	$ 1,300
– Contractor share	$ 325
• Funding for FY09	$ 1,875
– DOE share	$ 1,500
– Contractor share	$ 375
• Phase II Funding	$40,000
– DOE Share	$31,000
– Contractor share	$ 9,000

Barriers Addressed

- Reducing hydrogen cost
- Hydrogen production from diverse pathways
- Hydrogen of sufficient purity for fuel cells

Partners

- Project lead: Eltron R&D
- Interactions: 4 membrane manufacturers
- Collaborations: 2 industrial chemical producers

DOE Project Manager – Arun Bose

DOE Contract DE-FC26-05NT42469

Program Objectives

- Develop H_2/CO_2 Separation System, which
  - Retains CO_2 at coal gasifier pressures
  - Operates near water-gas shift conditions
  - Tolerates reasonably achievable levels of coal-derived impurities
  - Delivers pure H_2 for use in fuel cells, gas turbines, and hydrocarbon processing
  - Is cost effective compared to alternative technologies for carbon capture

Approach

- Materials Development
  - Examine membrane and catalyst compositions
  - Develop preparation techniques
- Performance Screening
  - Evaluate flux, life, impurities effects using WGS composition
  - Establish range of operating conditions
- Mechanical Design
  - Assess strength of materials, embrittlement, welding techniques, et al
  - Address manufacturing costs and maintenance issues
- Process Design and Economics
  - Integrate into IGCC flow sheets – with and without co-production of H_2 & power
  - Determine methods for impurity management
  - Compare process economics versus other technologies
- Scale-up steps
  - 1.5 lbs/day H_2 production – lab scale using simulated gas compositions
  - 220 lbs/day H_2 production – using coal-based SG slipstream
  - 4 tons/day H_2 production – complete engineering data package
  - Commercial module expected to be ~ 35 TPD H_2 Production

Approach - Milestones

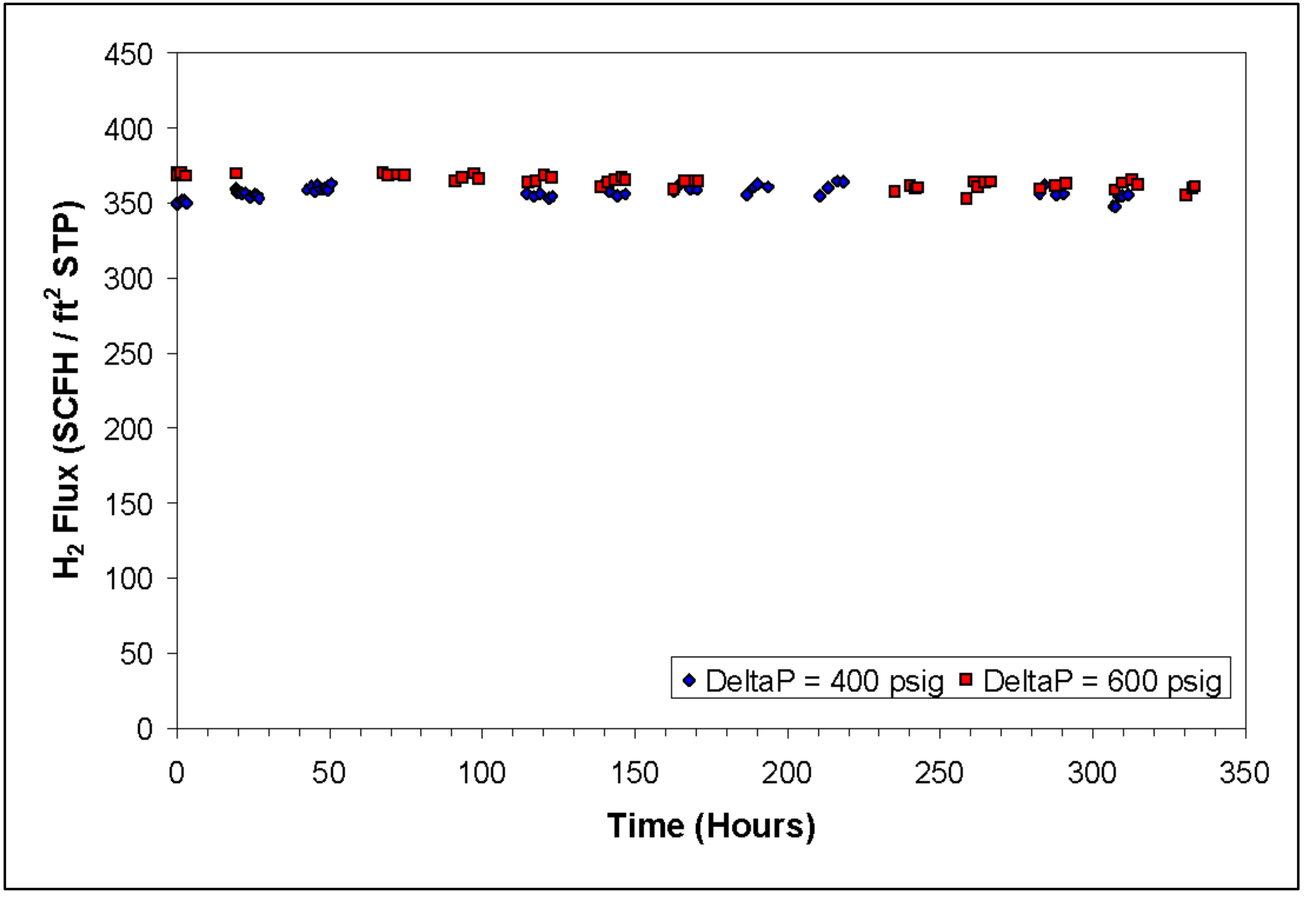
	Milestone
FY08 Q3	Select feed catalyst composition for impurity testing Status: Completed
FY08 Q4	Update process flow sheet and demonstrate improved economics utilizing HTM in coal-based IGCC plants. Status: Completed
FY09 Q1	Complete initial testing of membranes in H_2S contaminated syngas and complete initial life cycle testing of membranes with runs sufficiently long to allow an engineering assessment. Status: Completed
FY09 Q2	Develop a preliminary design basis for the PDU. Status: Completed
FY09 Q3	Procure membrane materials prepared by different manufacturers and processes for testing and evaluation Status: In progress
FY09 Q4	Select the preferred manufacturing process and catalyst deposition technique for scale-up in PDU. Status: In progress

Technical Accomplishments and Progress

1. 10 high flux alloys manufactured and tested at high differential pressures. One alloy down-selected for future testing.
2. Catalyst Development
   - H_2S
   - CO
   - Catalyst down-selected
3. Lifetime testing / stability
4. Manufacturing
5. Engineering

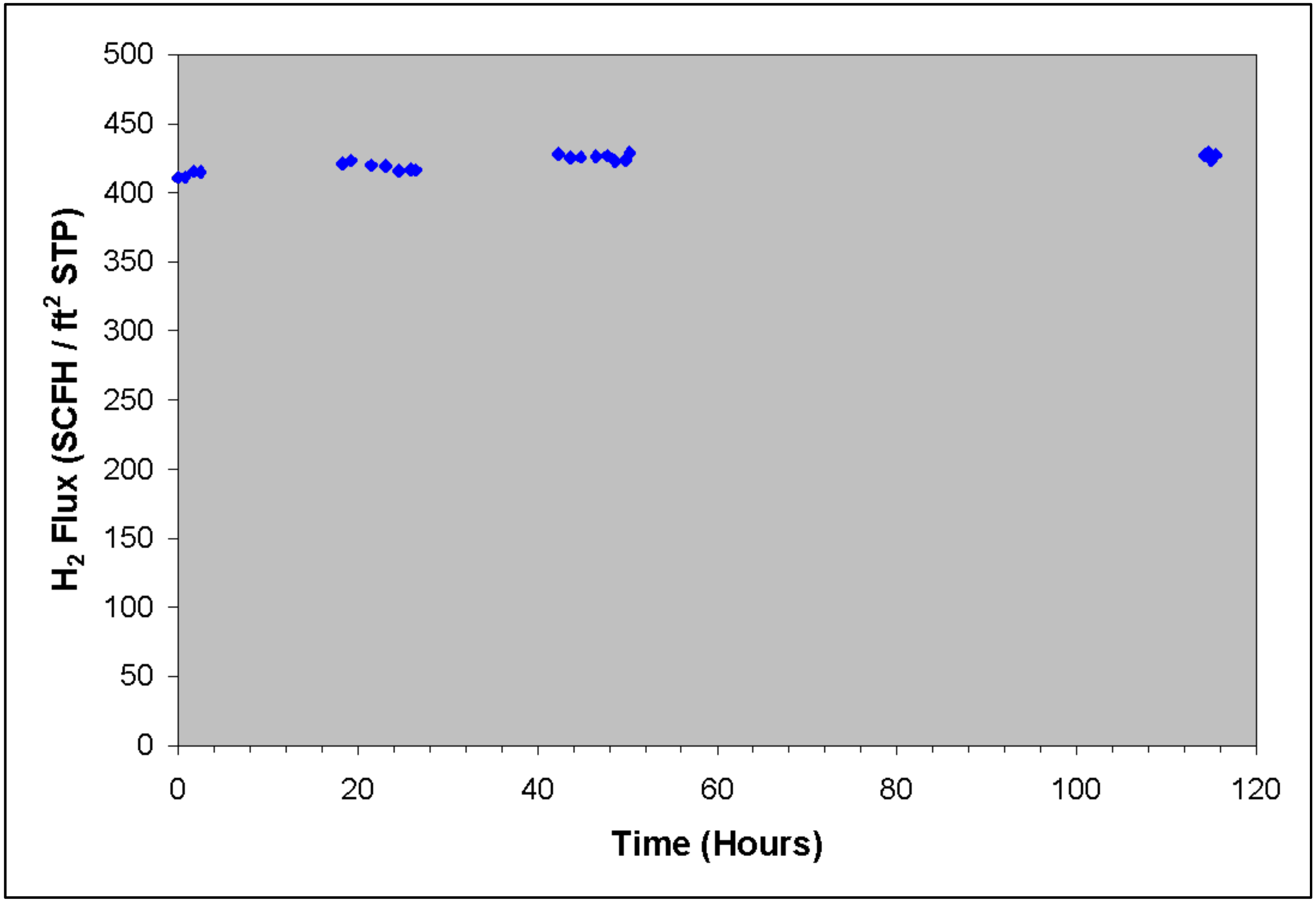
Technical Accomplishments and Progress 1 - Substrate

- 10 low-cost alloys tested
- 1 down-selected
- High Flux
- Stable at High ΔP
- 340°C



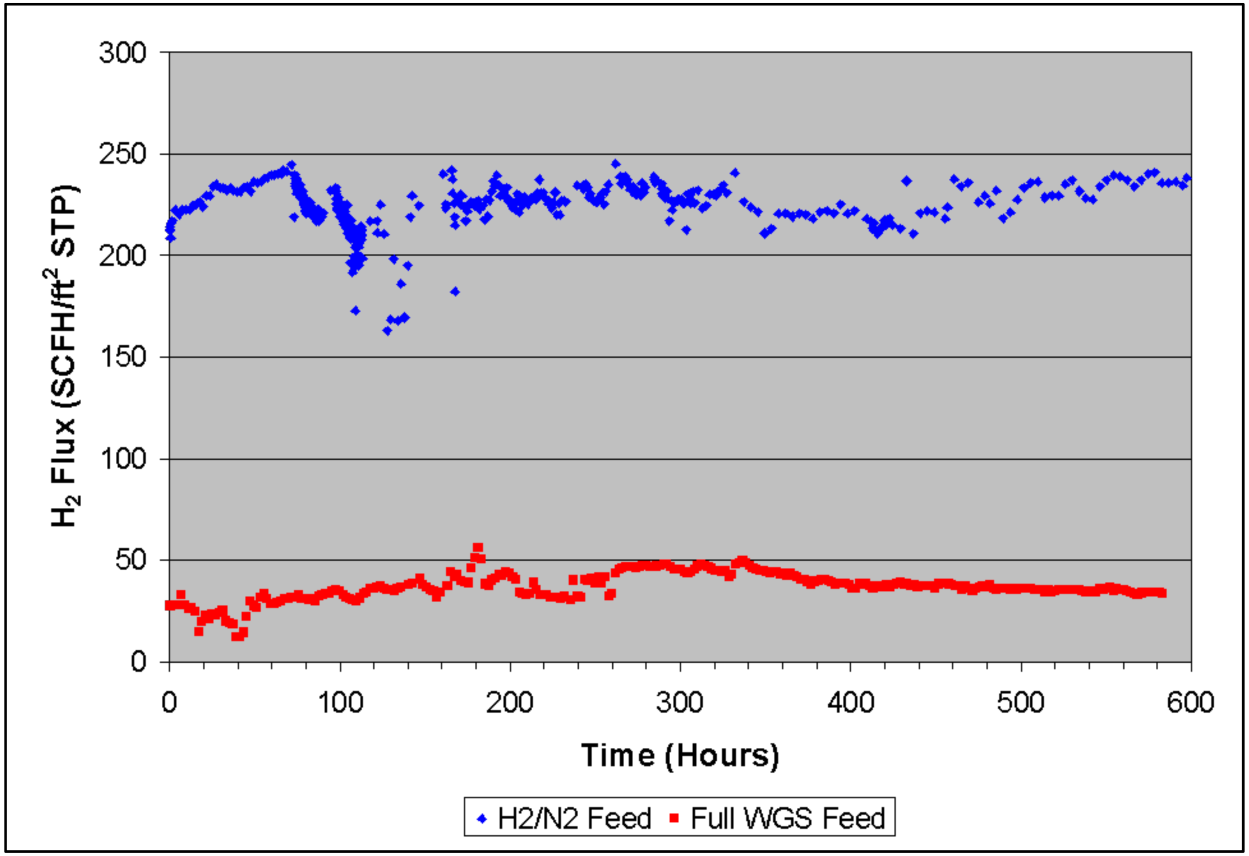
Technical Accomplishments and Progress 2 - Catalyst

- Demonstrated tolerance to 20 ppm H_2S
- Baseline tested at 340°C & ΔP = 400 psig
- To be tested under NETL Protocol Test 1 & 2 (simulated WGS and H_2S containing feed streams)



Technical Accomplishments and Progress 3 - Lifetime Testing

- 2 Reactors
- Completed 10 tests between 600 and 1300 hours
- 340^{o}C
- ΔP = 400 psig



Technical Accomplishments and Progress 4 – Manufacturing Collaborations

- Membrane Substrate Manufacturing
  - Four Manufacturers
- Membrane Catalyst Deposition
  - Evaluating 5 different techniques internally and externally with collaborator
- Assembly
  - Weld testing with collaborator

Technical Accomplishments and Progress 5 - Engineering

- H_2 Transport Resistance Model
  - Parameters developed
  - Tool for interpreting system differences
- PDU Design Basis Developed
  - Specific to membrane scale-up
  - Site factors to be determined
- Process Economics Updated

Economic Results Summary

Pre-combustion Gas Cleaning & CO_2 Capture Method	2-Stage Selexol	Cold Gas Cleaning & Eltron Membrane	Warm Gas Cleaning & Eltron Membrane	Improvement
Thermal Efficiency	27.4%	32.0%	33.6%	6.2%
% CO_2 Captured	90%	90%	95%	5.0%
Cost of Electricity ($/MWh)	115.5	114.5	106	9.5

Future Work

- Focus near term on scale-up work with commercial suppliers on manufacturing of full-size alloy membranes
- Perform life testing on new materials as required
- Understand impacts of contaminants
- Maintain and improve techno-economic models
- Design, build & operate 220 lb/day PDU – 2010+ Goal

Progress Towards DOE FutureGen Targets

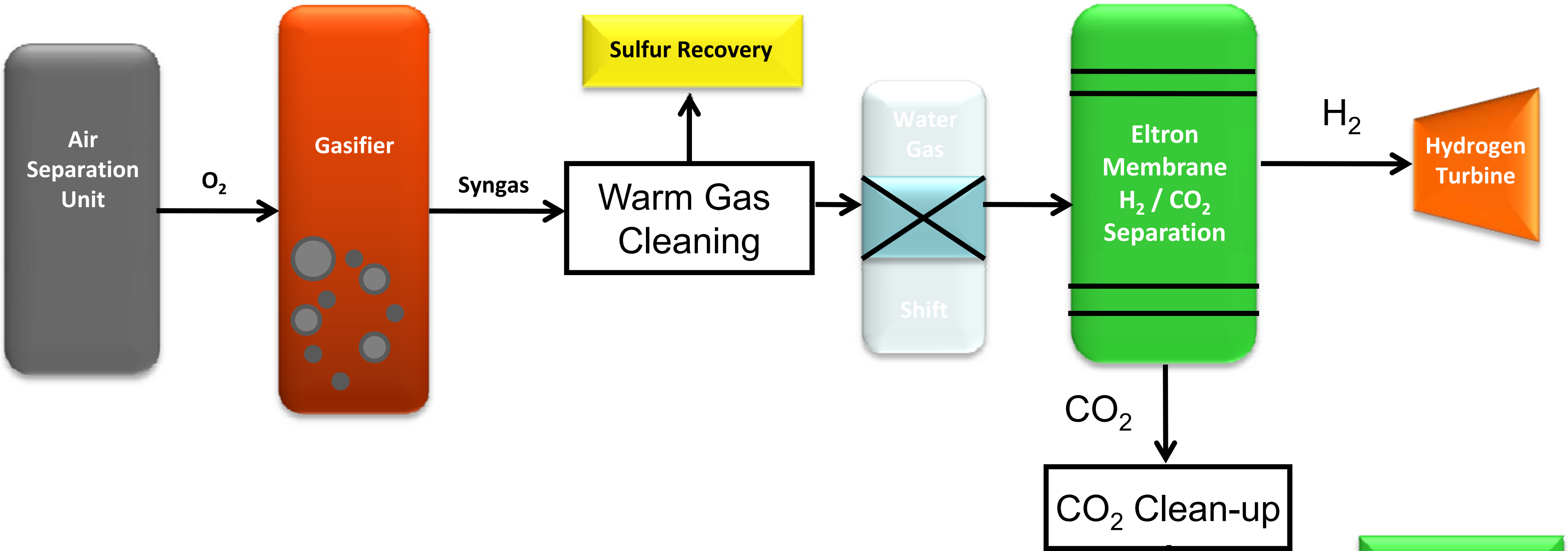
Performance Criteria	*2010 Target*	*2015 Target*	*Current Eltron Membrane*
Flux, SCFH/ ft^2	200	300	450
Operating Temperature, ^oC	300-600	250-500	250-440
Sulfur Tolerance (ppmv)	2	20	20 (prelim.)
System Cost ($/$ft^2$)	500	<250	<200
ΔP Operating Capability (psi)	400	800-1000	1,000
Carbon monoxide tolerance	Yes	Yes	Yes
Hydrogen Purity (%)	99.5	99.99	>99.99
Stability/Durability (years)	3	>5	0.9
Permeate Pressure (psi)	N/A	N/A	400

Summary

- Results demonstrate that technology is on track to meet DOE targets
  - Technical
  - Economics
- Tools are in place
  - Experimental
  - Modeling at all scales
- Flexibility in process design, including
  - Staged hydrogen recovery for polygen cases
  - Integrated water gas shift membrane reactors

Supplemental Slides

CO_2 Capture with Eltron H_2 Separation Membrane & Warm Gas Cleaning



Thermal Efficiency = 33.6%
COE = $106 / MWh