GE Hybrid Power Generation Systems

SECA
Solid Oxide Fuel Cell Program

Sixth SECA Annual Workshop
Pacific Grove, CA
April 18-21, 2005

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Program Overview

- Overall objective
  - Demonstrate a fuel-flexible, modular 3-to-10-kW solid oxide fuel cell (SOFC) system that can be configured to create highly efficient, cost-competitive, and reliable power plants tailored to specific markets

- Period of performance
  - Phase I, October 2001 – September 2005

- Development team
  - GE Energy
    - Torrance, CA, Schenectady, NY, Greenville, SC
  - GE Global Research
    - Niskayuna, NY

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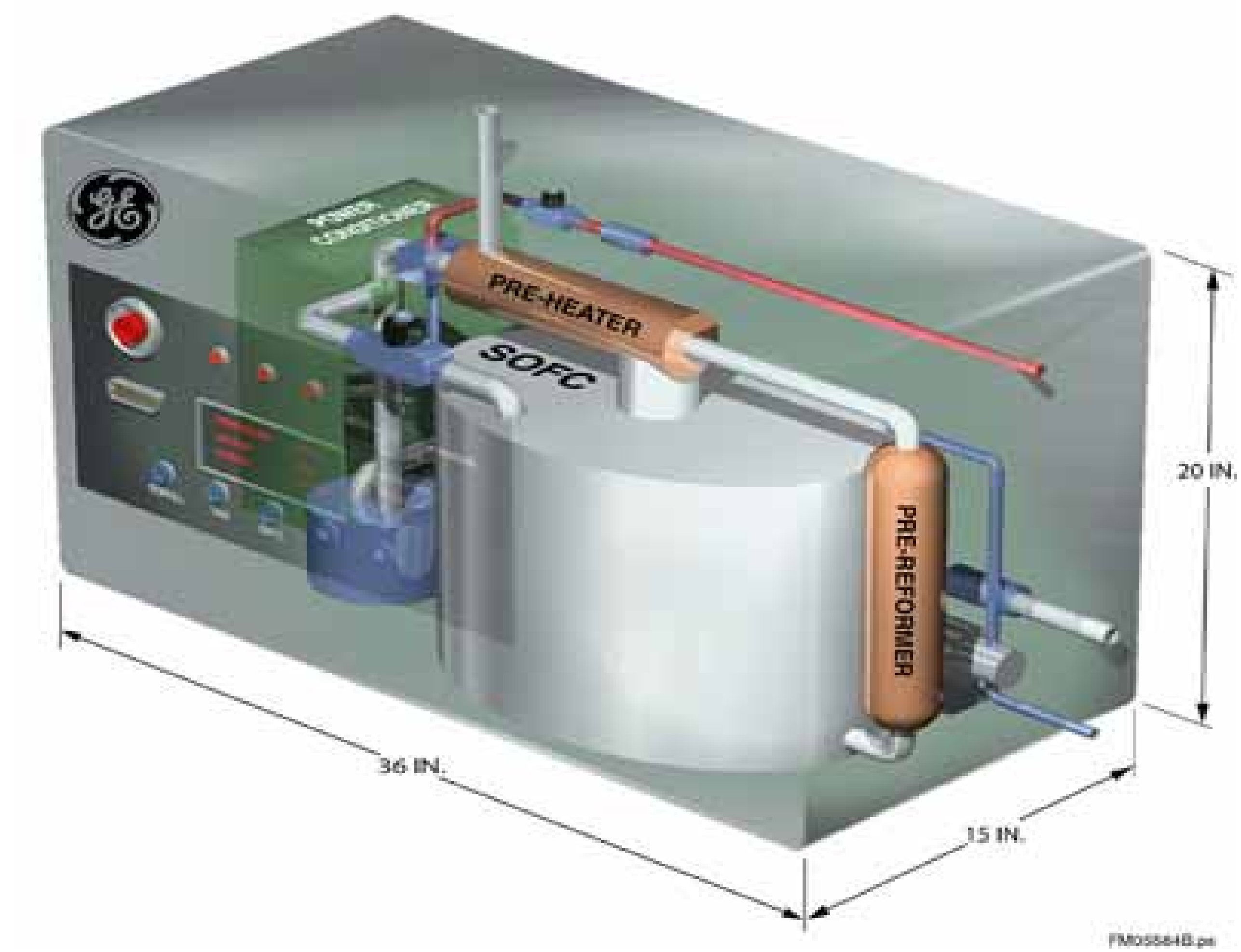
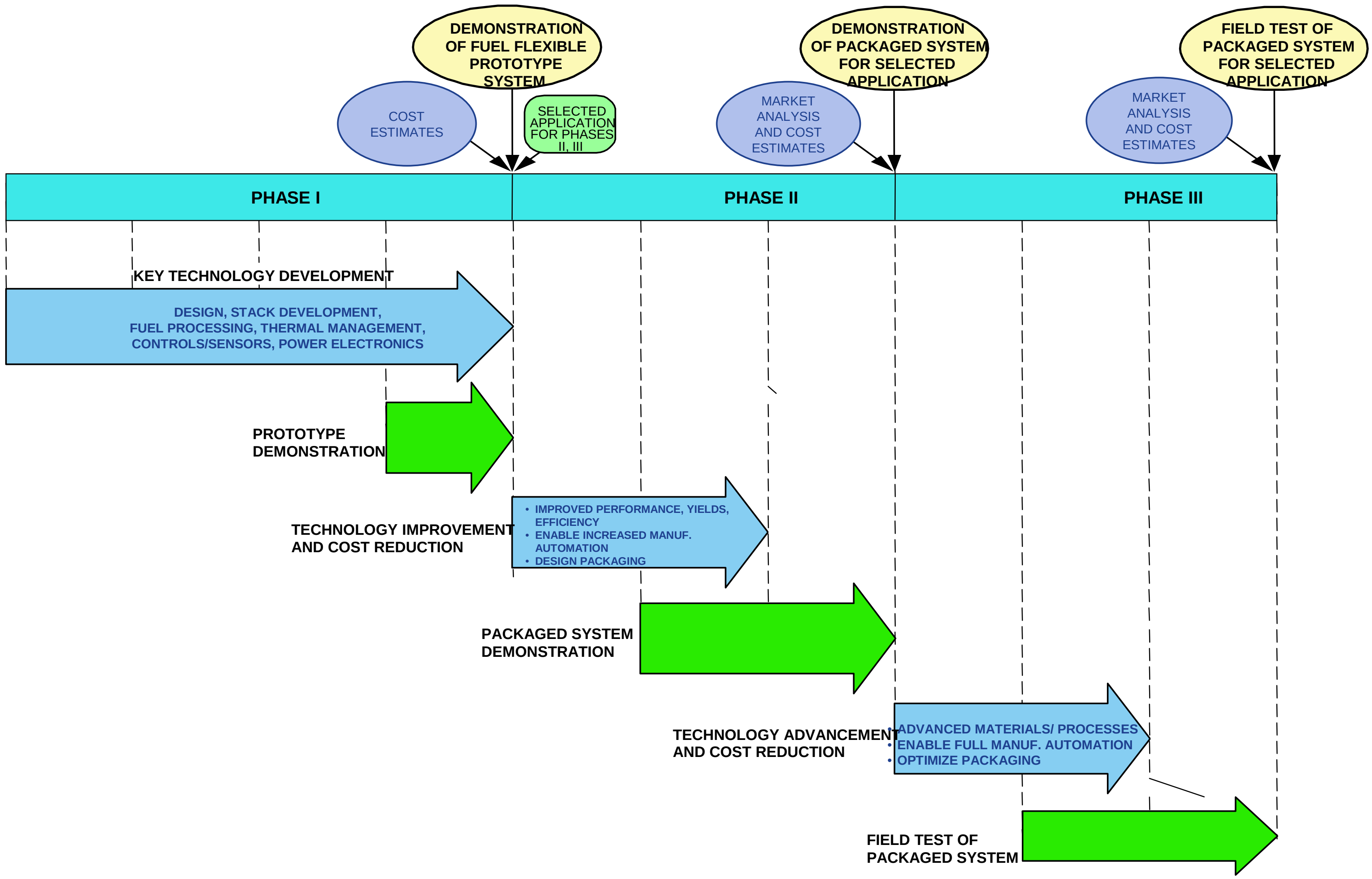
SECA SOFC System Concept



System Features

- SOFC
  - High-performance reduced-temperature cells
  - Operation on light hydrocarbons
  - Tape calendering manufacturing process
- Fuel processor
  - Low-cost, fuel-flexible fuel processor design
  - Catalytic autothermal (ATR) process
  - Pre-reforming function
- Other subsystems
  - Integrated thermal management
  - Flexible control system

Program Features



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Phase I Requirements

PARAMETER	PHASE I REQUIREMENTS
POWER RATING (net)	3Kw - 10 kW
COST	$800/kW
EFFICIENCY (AC or DC/LHV)	Stationary-35%
STEADY STATE TEST @ NORMAL OPERATING CONDITIONS	1500 hrs
	80% avalability
	Delta Power = 2% degradation/500 hrs at a constant stack V with R >= 0.95
TRANSIENT TEST	10 cycles
	Delta Power = 1% degradation after 10 cycles at a constant stack voltage
TEST SEQUENCE	1) Steady state 1000 hours
	2) Transient test
	3) Steady state 500 hours
FUEL TYPE	Operate the prototype on either a commercial commodity, or a representative fuel. Utilize external or internal primary fuel reformation or oxidation
MAINTENANCE INTERVAL	> 1000 hours
DESIGN LIFETIME	Not less than 40,000 operating hours for stationary applications

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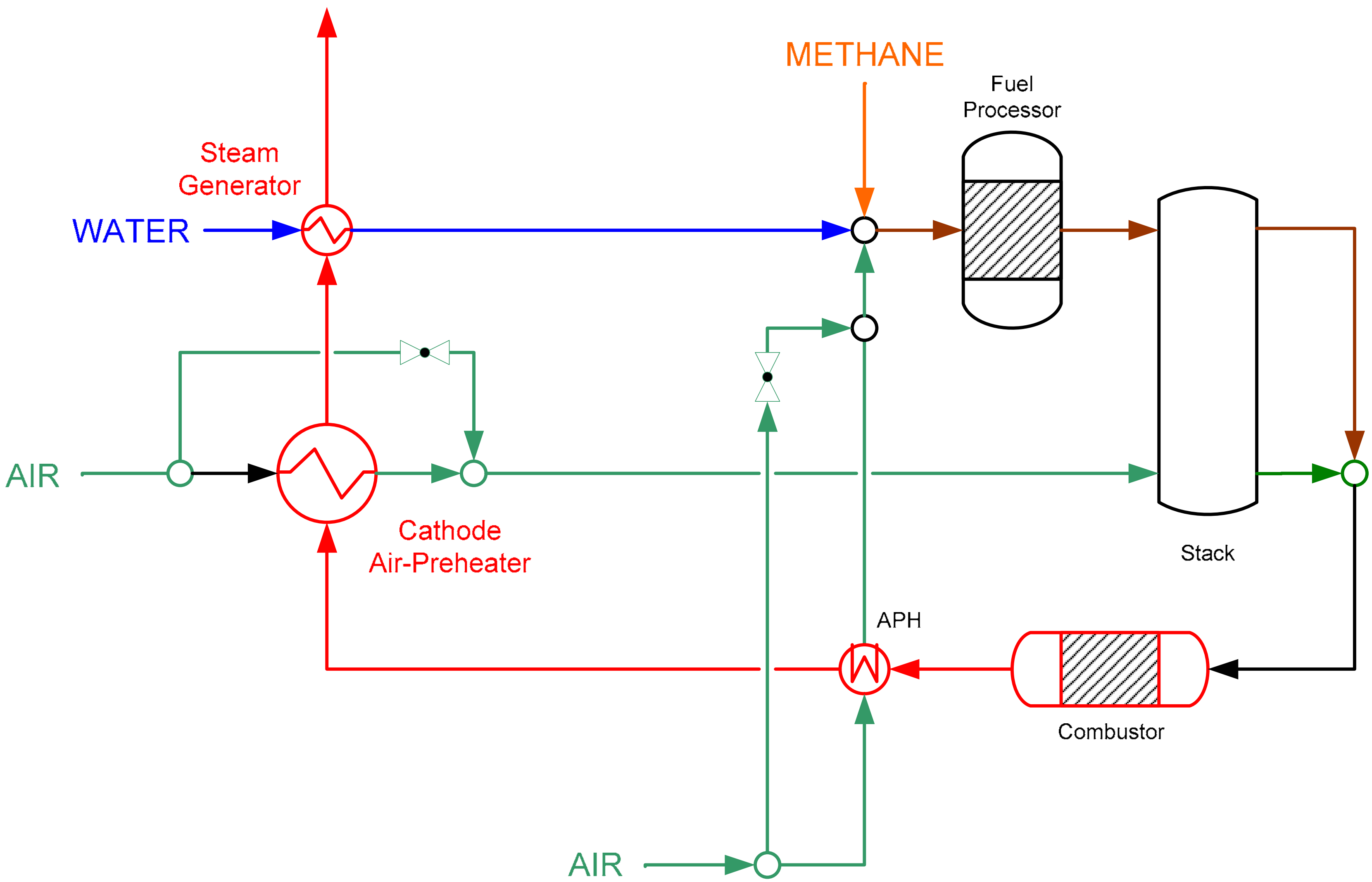
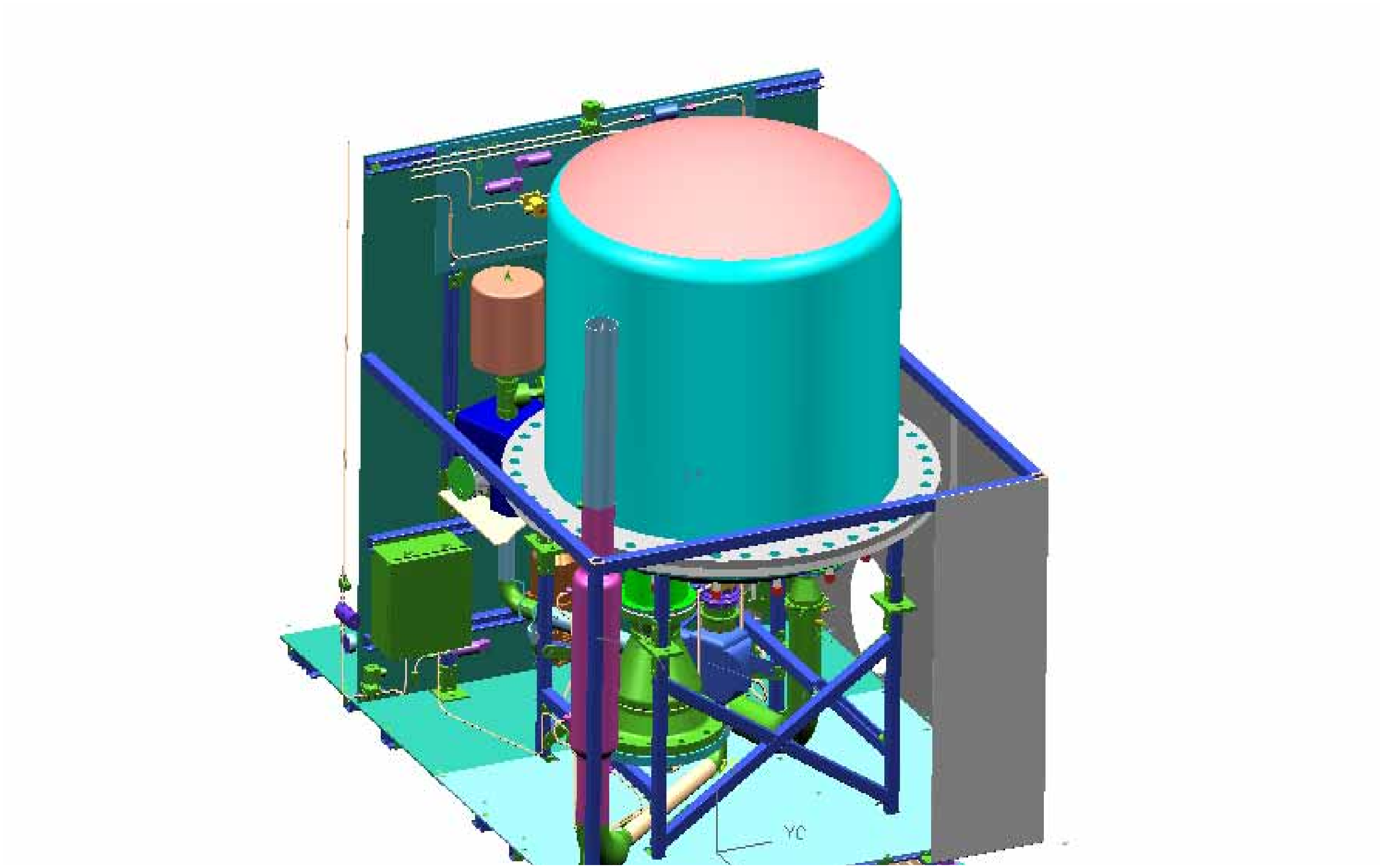
Prototype System Schematic



Prototype System



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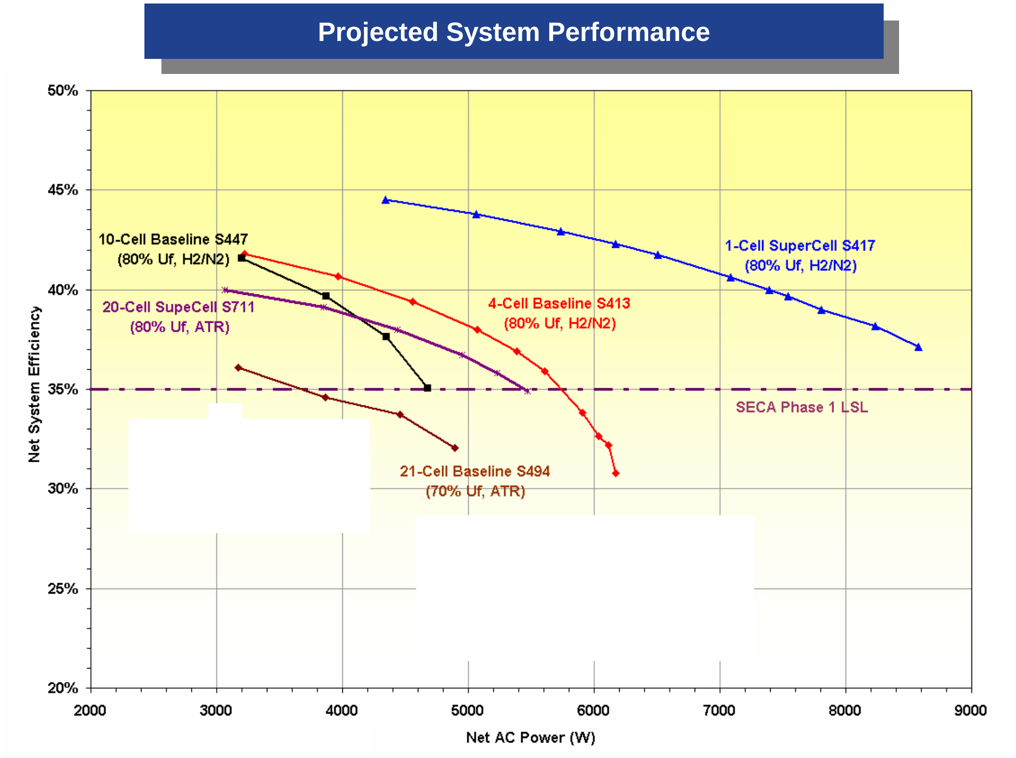
Estimated System Performance

– Performance Keys
  - Stack performance
  - Heat loss
  - Auxiliary power
  - Pressure drop
– 35% is well within reach
– Improved cell enables efficiencies meeting SECA Phase III goal of 40%
– Opportunities remaining to improve system performance



Stack Requirements

- Stack Performance:
  - Power density: 0.3W/cm^2
  - Stack LHV efficiency: 47% on ATR fuel
    - Average cell voltage: 0.7V
    - Fuel utilization: 80%

- Cell Performance:
  - Power density: 0.3W/cm^2
  - Cell LHV efficiency: 51.7% on ATR fuel
    - Cell Voltage: 0.7V
    - Fuel Utilization: 88%

- Cell Component:
  - Total ASR: < 560 mohm-cm^2

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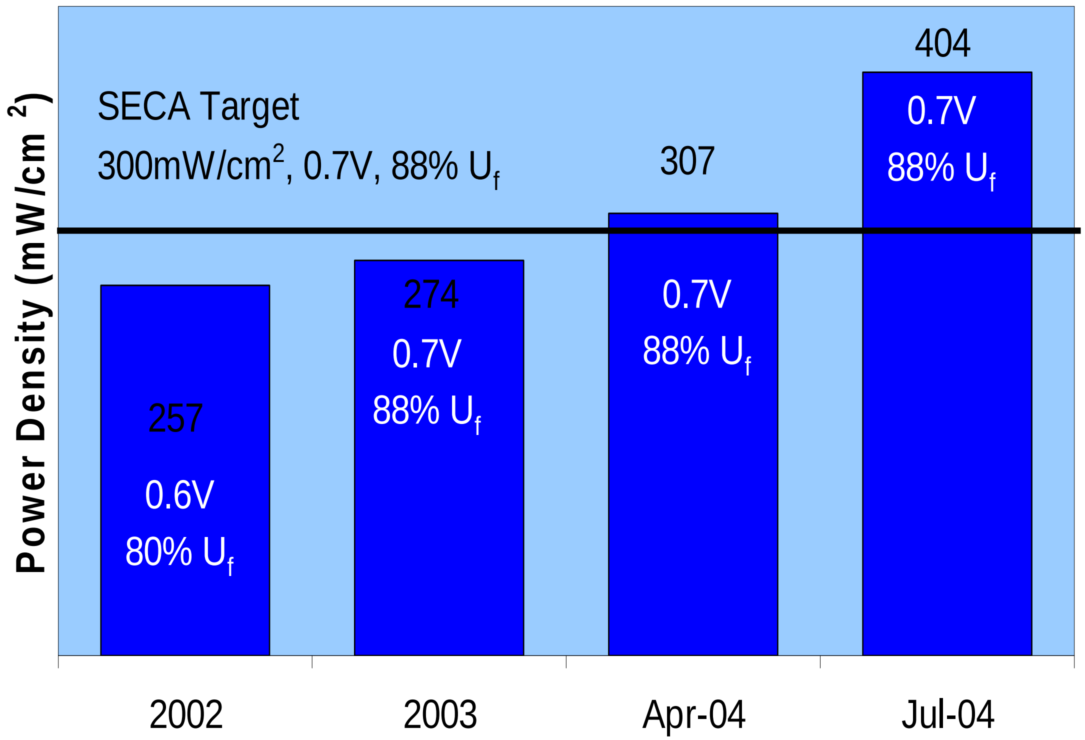
SOFC Cell Performance

- Performance exceeding target
- Fuel utilization of up to 95% demonstrated
- Internal reforming demonstrated



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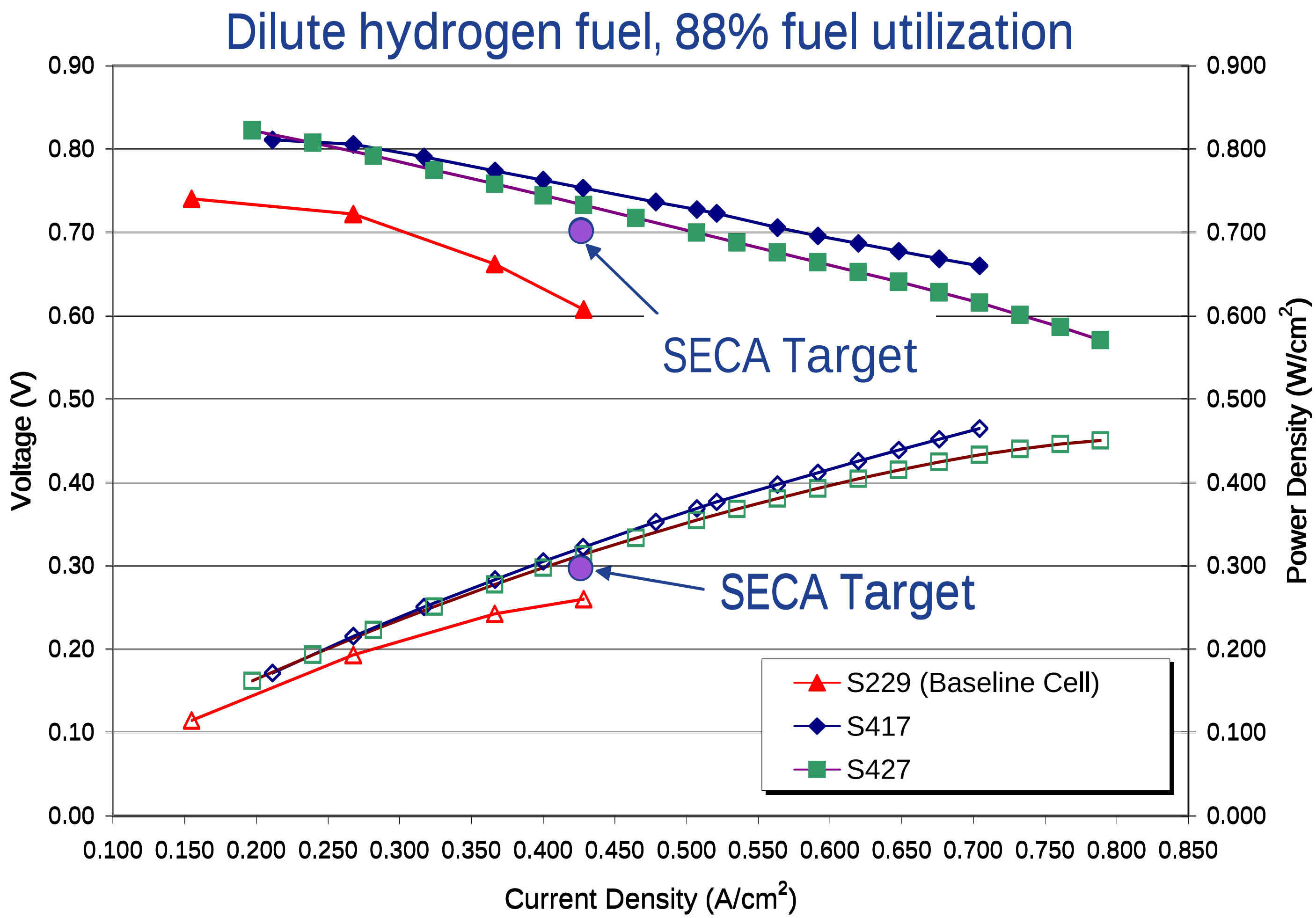
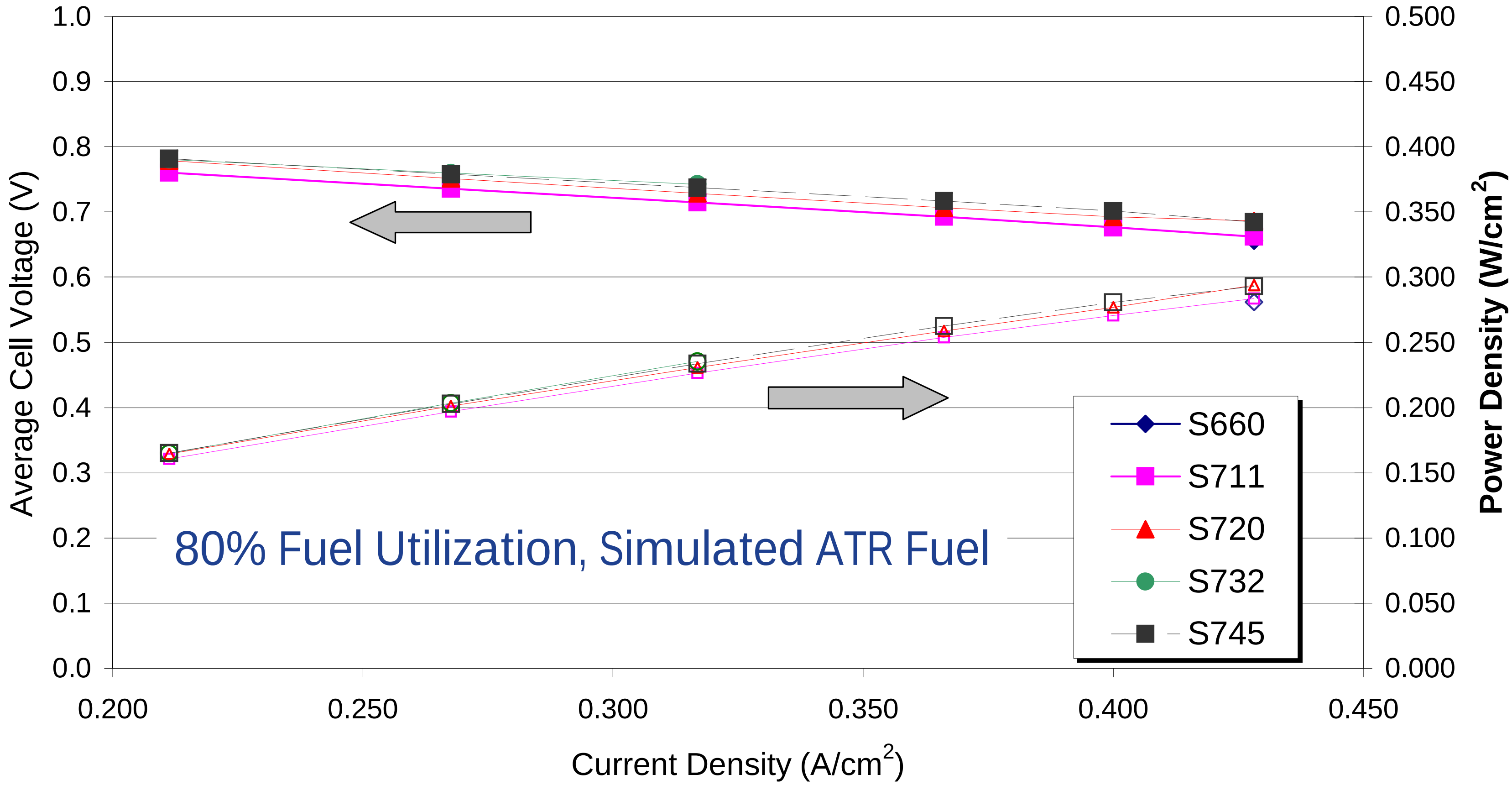
Cell Module Performance Improvement



Stack Performance



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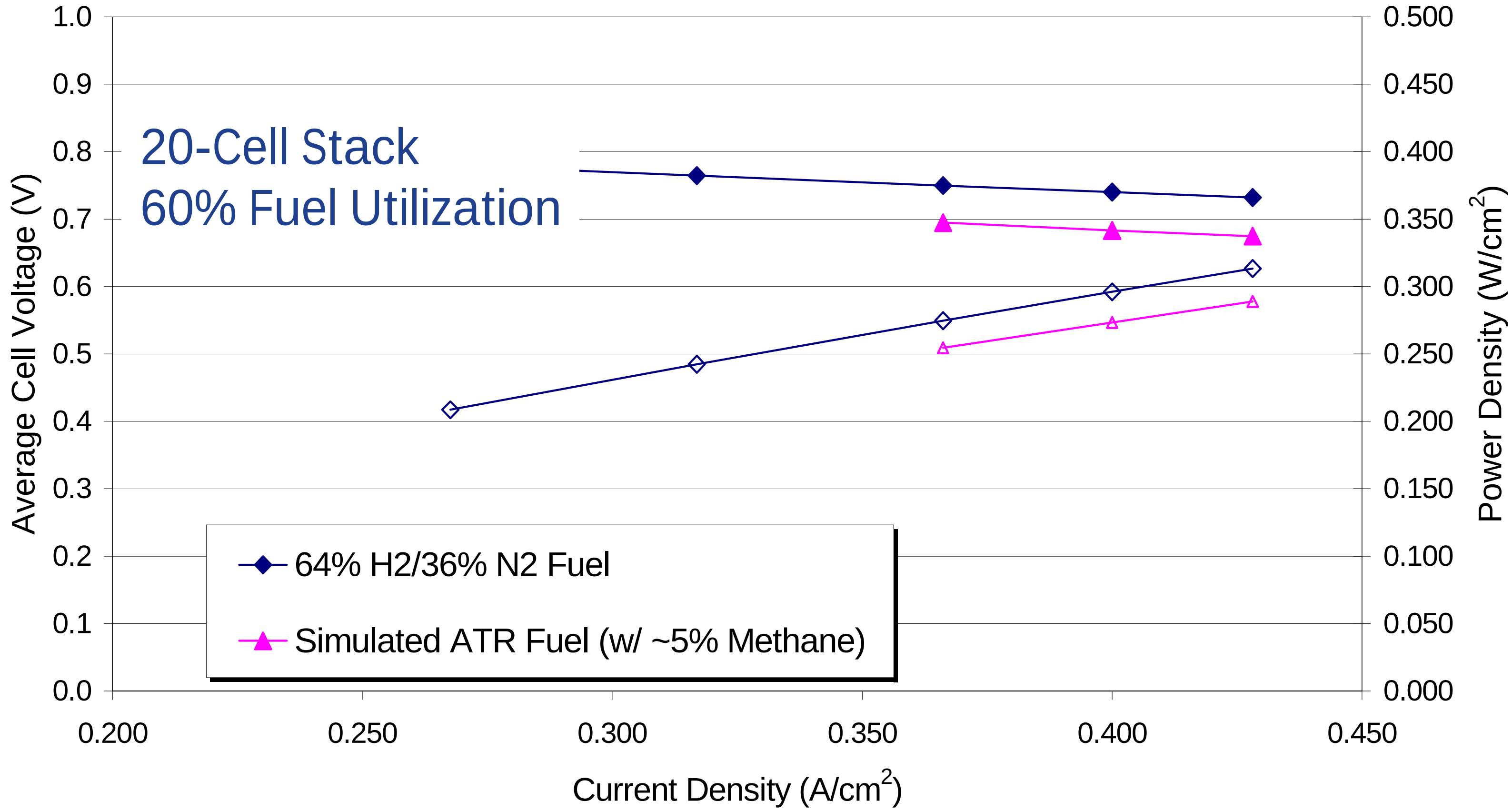
Stack Performance with Reformate



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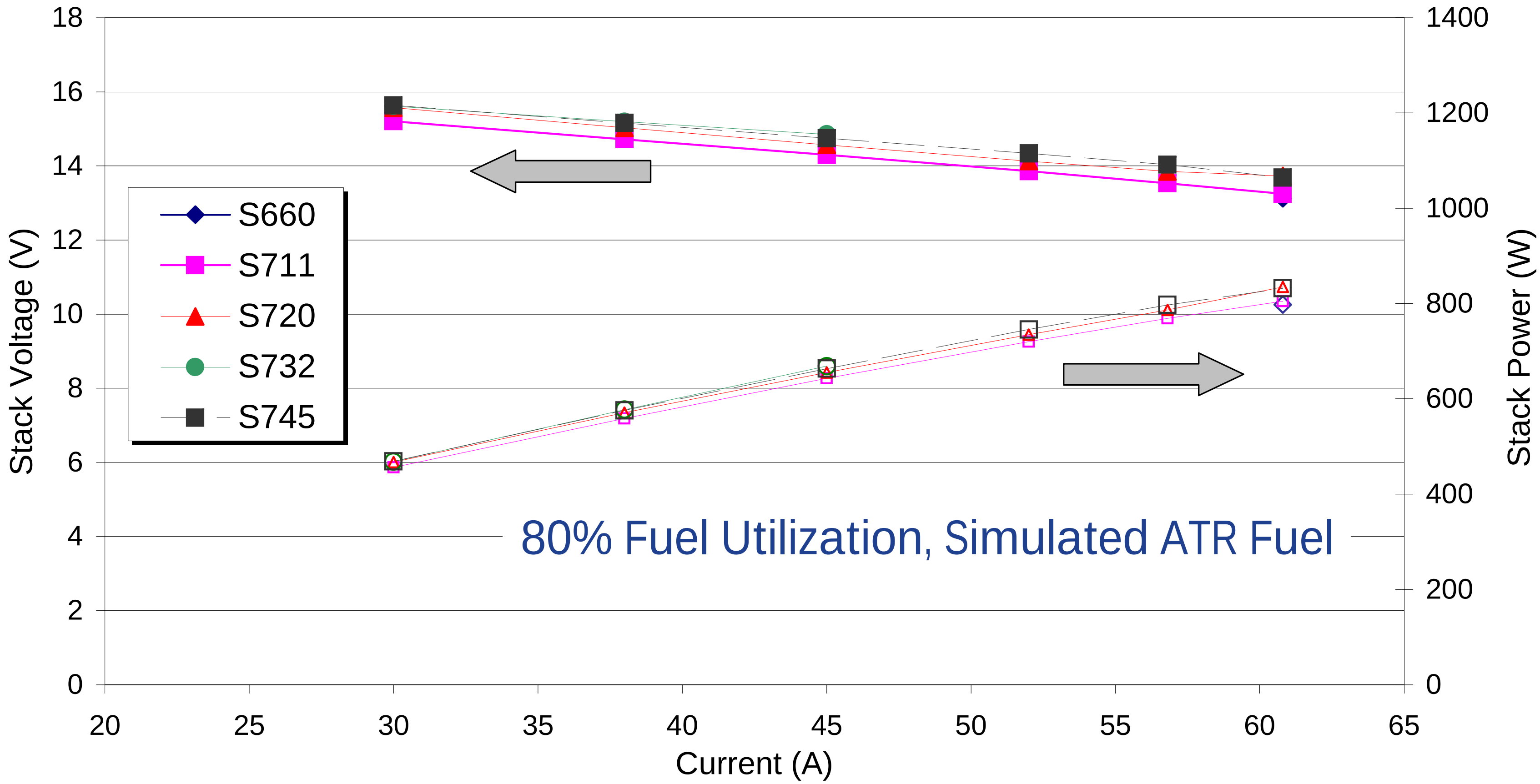
Stack (20-Cell) Performance



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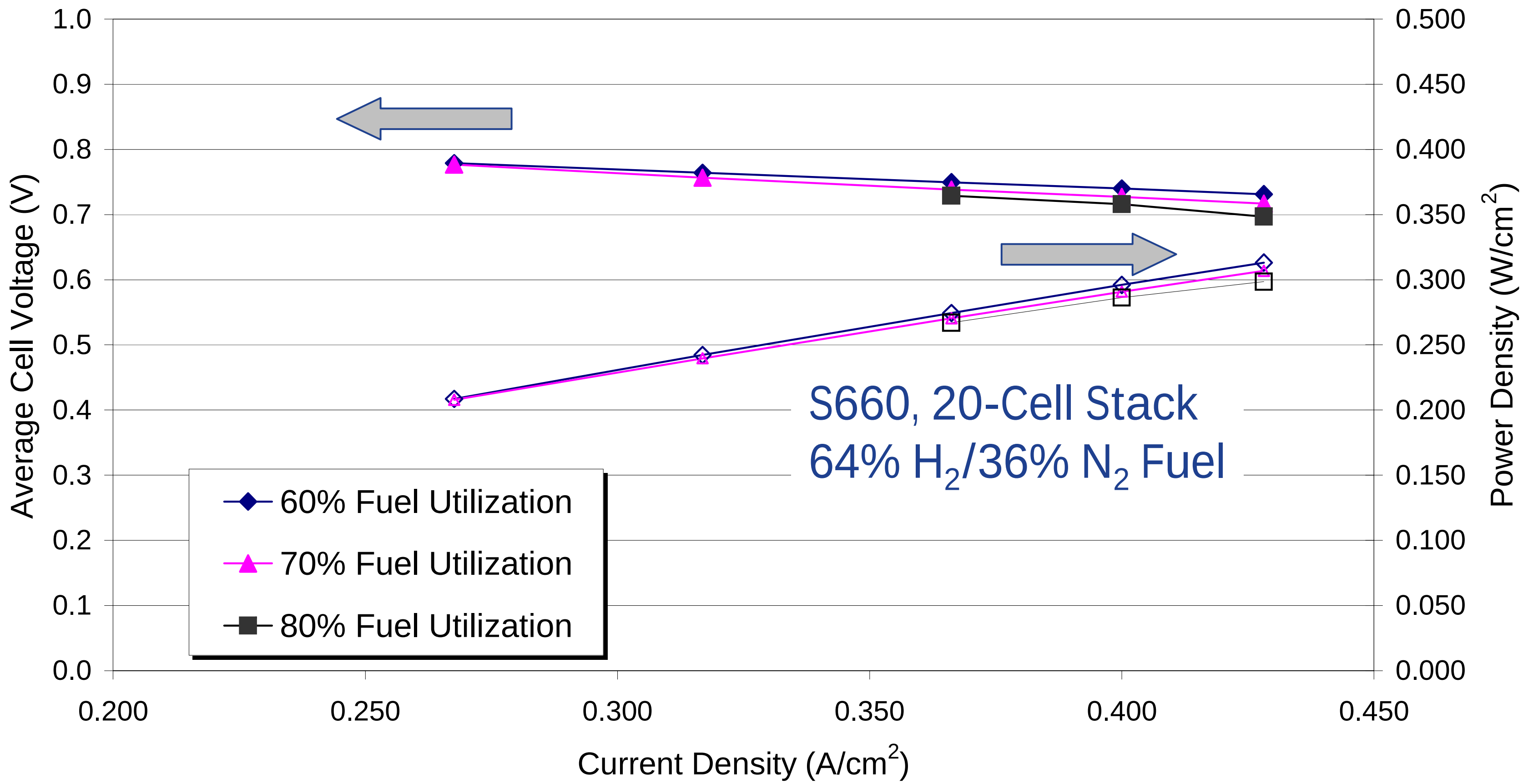
Effect of Fuel Utilization



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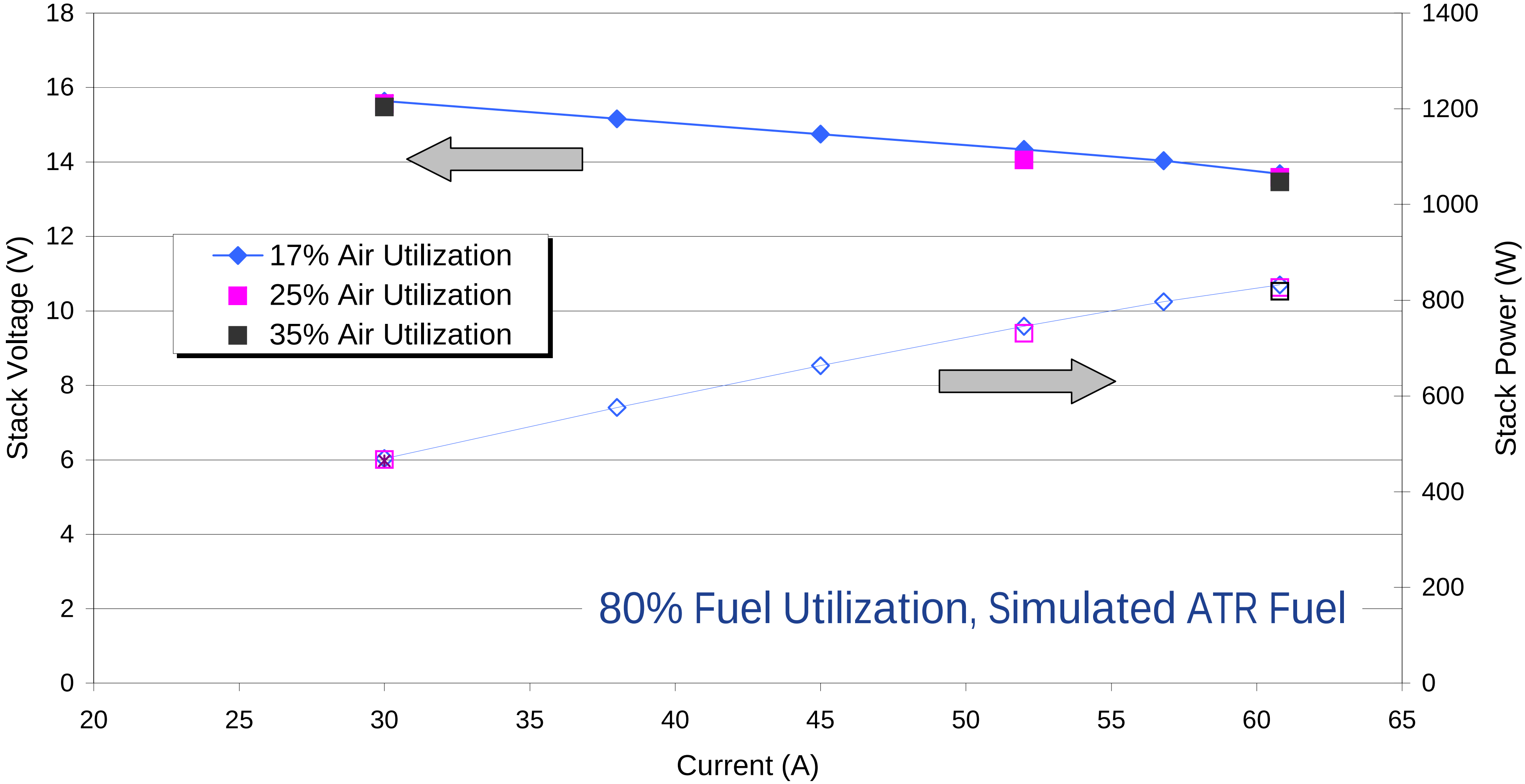
Effects of Air Flow



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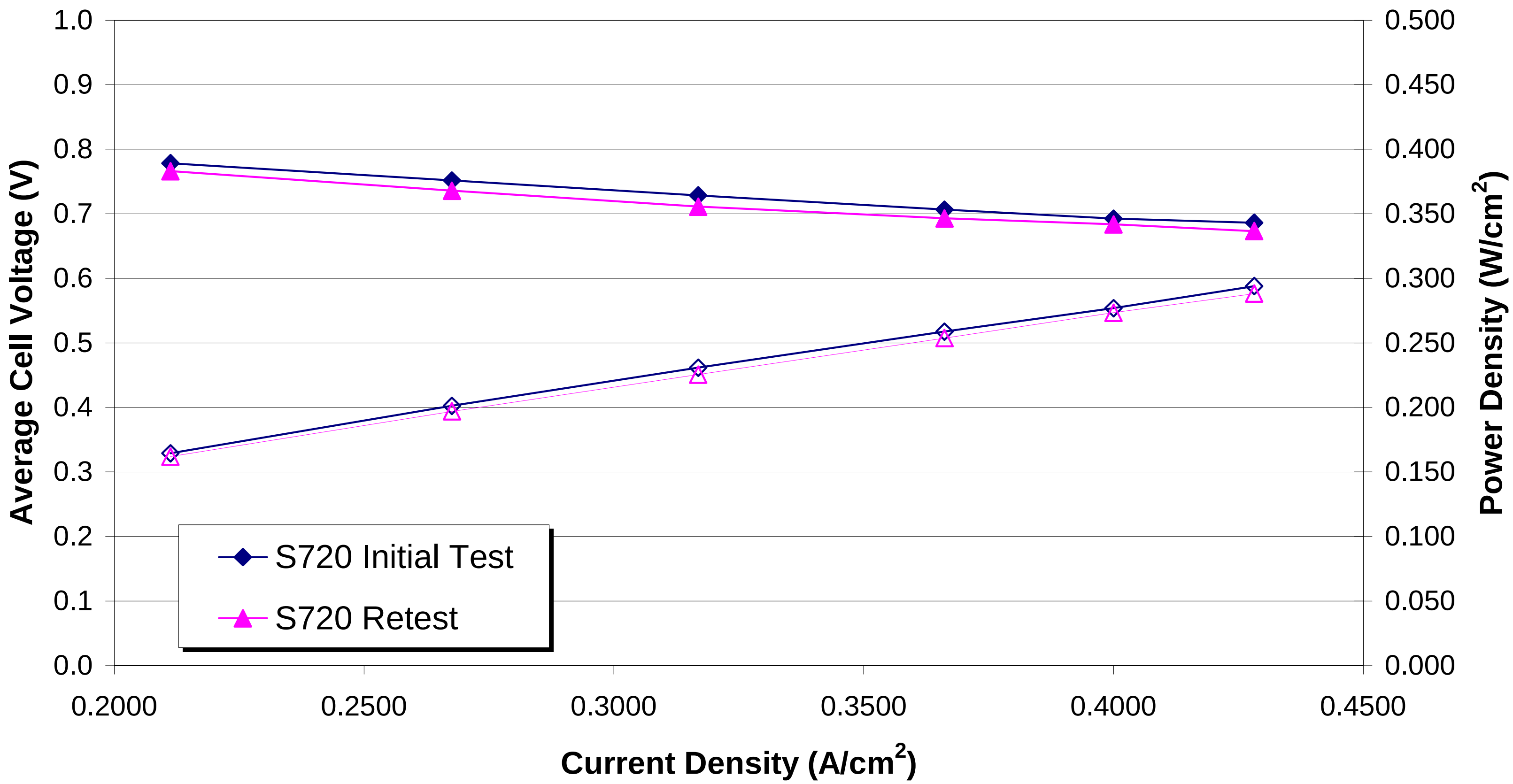
Thermal Cycle and Transport



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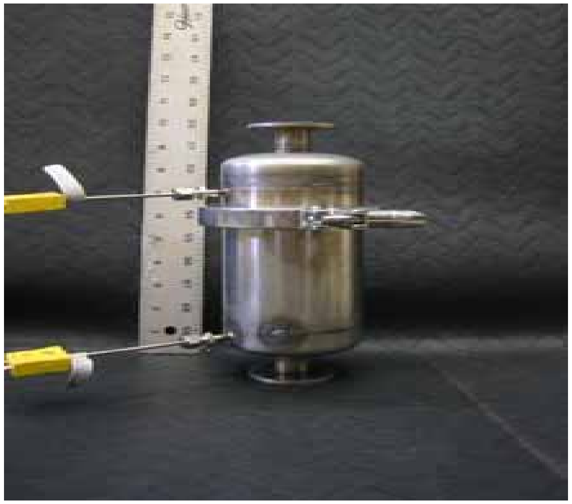
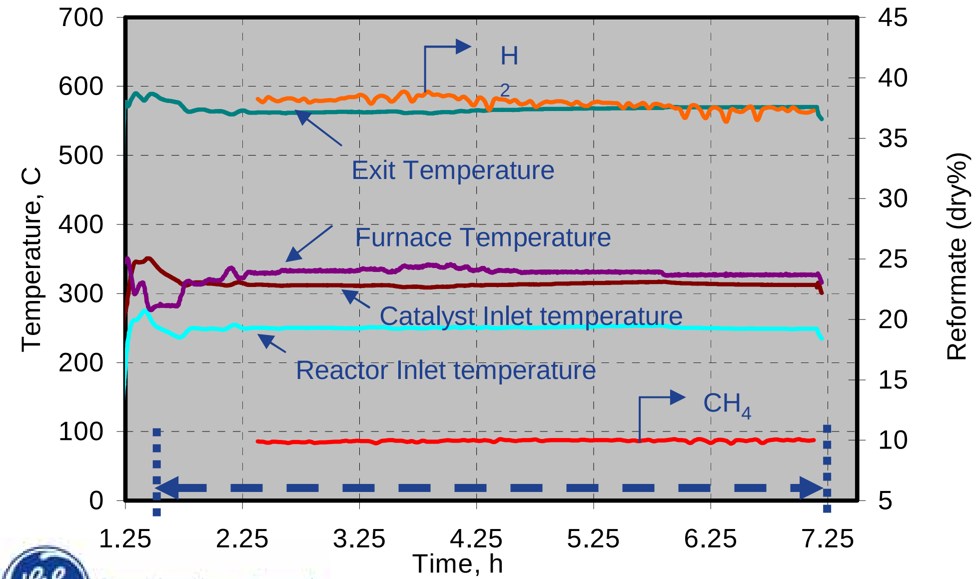
Fuel processor





- ATR fuel processor
- Ability to meet system flowdown requirements (S/C, O/C, inlet temperature, methane slip, pressure drop)
- Integration with SOFC

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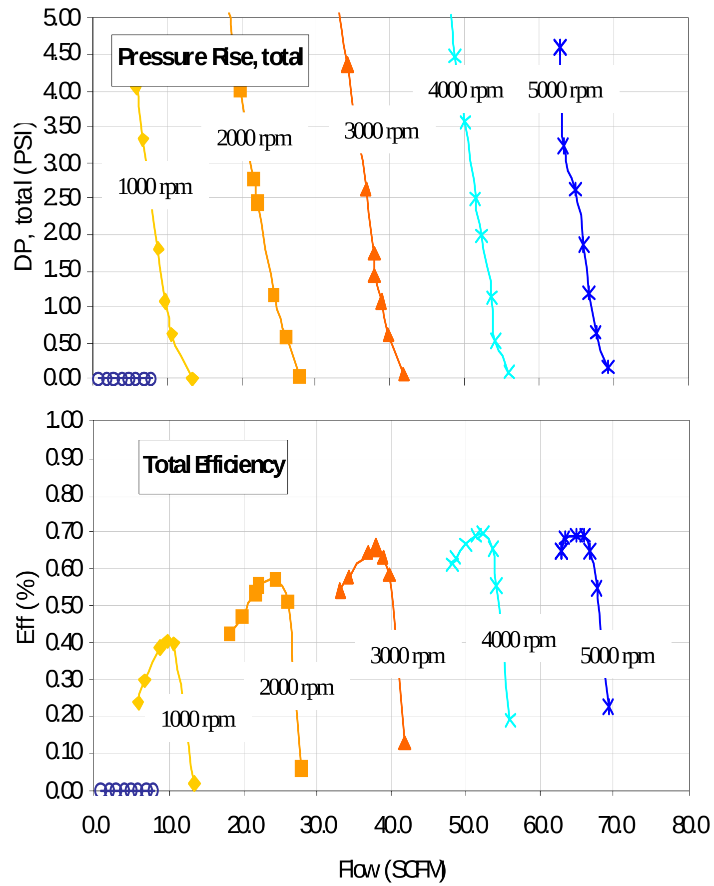
Cathode Air Blower

- Requirements
  - Efficiency requirement of 57% at design point
  - Interface and flow requirements
- Design/Selection
  - Evaluated several vendors
  - Vendor selected
    - Modified existing pumphead
    - Custom motor & controller
- Validation
  - Performance testing showed >60% efficiency at design point
  - 1000 hour endurance test completed



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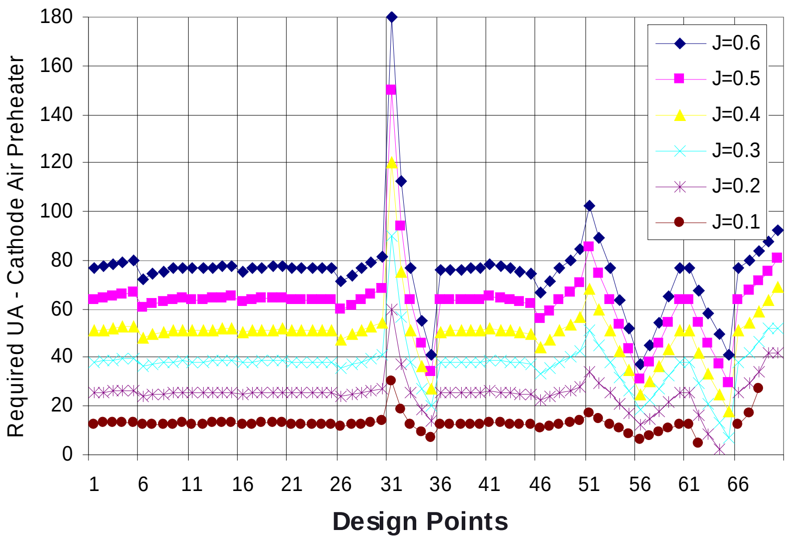
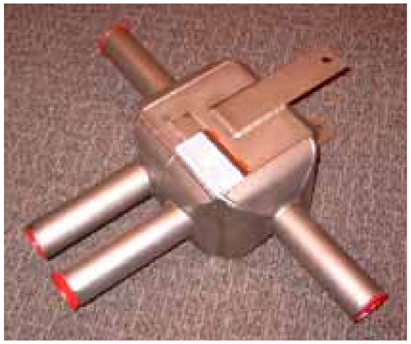
Cathode Air Preheater

- Problem Statement
  - UA requirements
  - Interface requirements
- Design/Selection
  - Included design margin to allow wide range of system operation
- Validation
  - Vendor performance predictions
  - Hot tests in system





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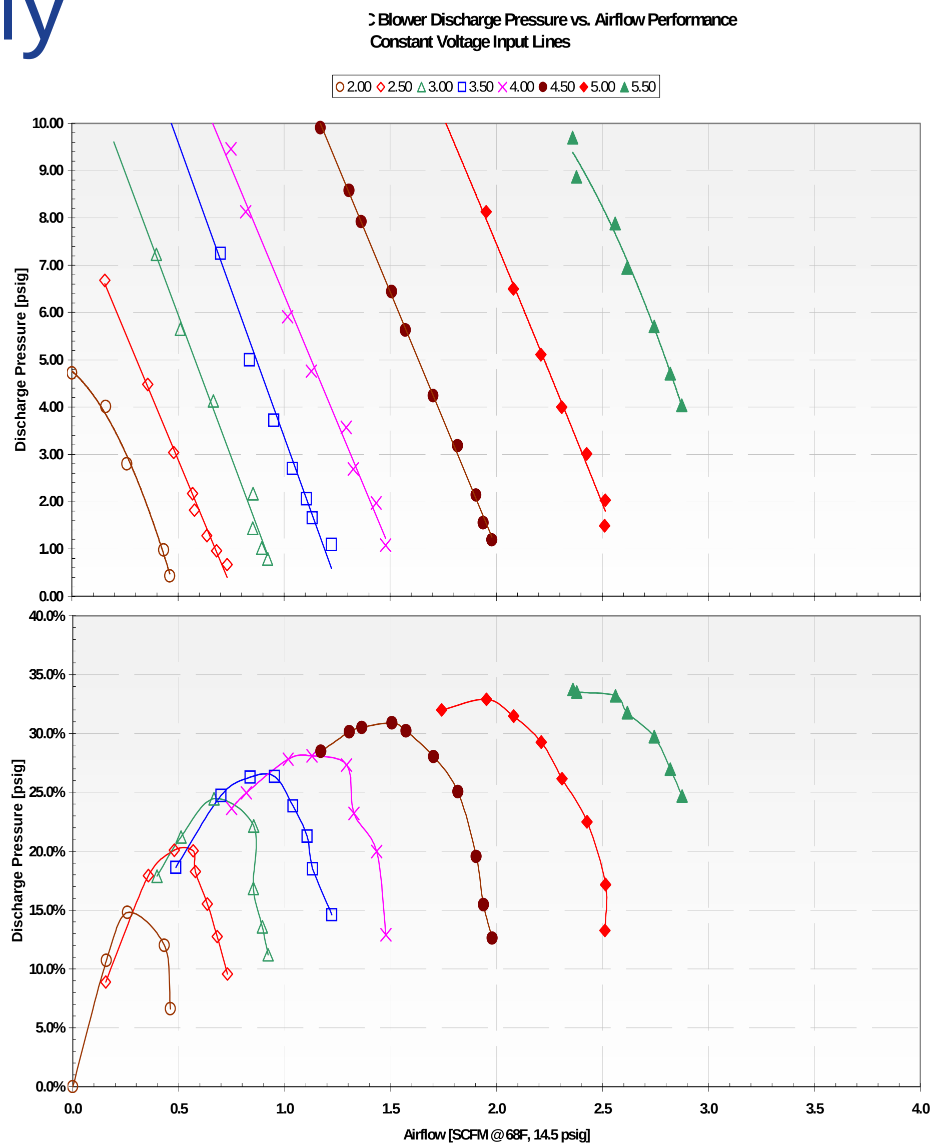
Fuel Processor Air Supply

- Requirements
  - Output pressure
  - Maximum airflow
  - DC Power
- Design/Selection
  - Reitschle-Thomas blower
- Validation
  - Performance and operability testing



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Power Conditioning Module

–Requirements

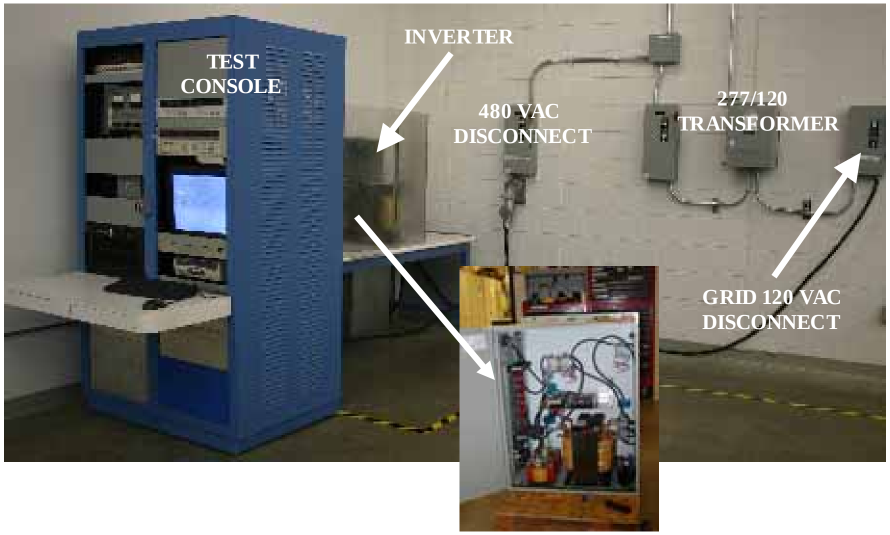
- Input: 88-153 Vdc, 80 Adc.
- Output: Single Phase, 120/240 Vac
- Efficiency: 92% LSL, 95% Target
- Operation: Grid parallel & Stand Alone mode

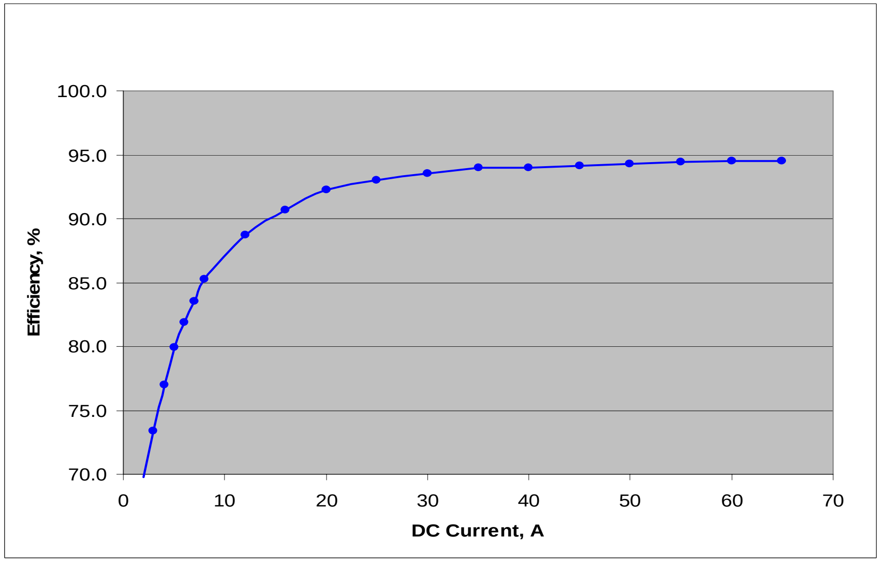
–Design/Selection

- Extensive vendor search
- Selected a supplier based on efficiency

–Validation

- Performance mapping test completed
- Faults handling and dynamic response tests completed with results as expected.





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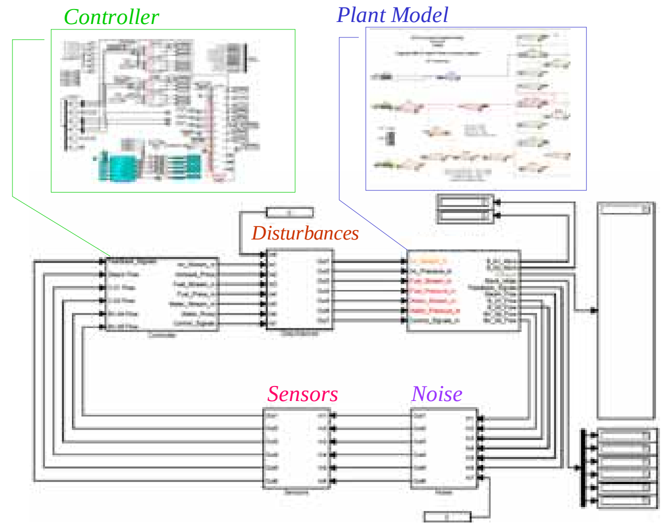
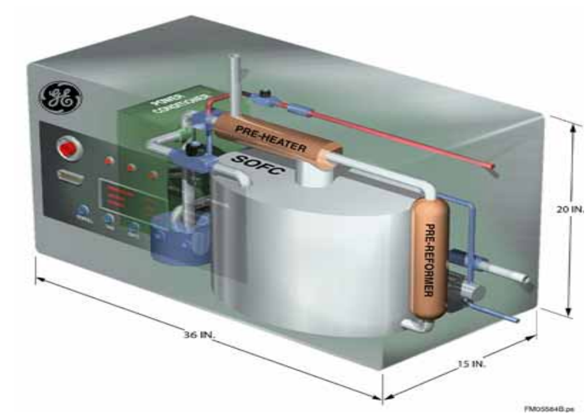
Control System Design

- Fuel Cell Dynamic Component Model Library
  - Rapid development of dynamic system models
  - Design of control systems through simulation
- Rapid prototyping tools
  - Allow for direct transfer of controls designed in simulation to control of fuel cell system
  - Advanced control and sensing techniques can be investigated through simulation trade studies
  - Most promising approaches can be easily implemented in system hardware
- Improved system operation through explicit consideration of dynamics and controllability in design





Design for Control

Control Software Development

- Control software from simulation environment updated to support real-time environment
- A full set of software has been successfully implemented on real time controller
- Meets real time requirement with significant margin to account for remaining data communication between the controller and host as well as other design changes

Software Testing/Verification

Graphical User Interface

Prototype System Assembly and Test

- Prototype system assembly completed
- System safety reviews completed
- Integrated prototype testing initiated

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Concluding Remarks

- SECA prototype system components defined, procured/developed and evaluated
- Prototype system assembly completed
- Testing being initiated

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Acknowledgments

- DOE/NETL
  - Travis Schultz, Wayne Surdoval, Mark Williams, Don Collins, Joe Strakey
- GE Fuel Cell Team

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