UTC Power

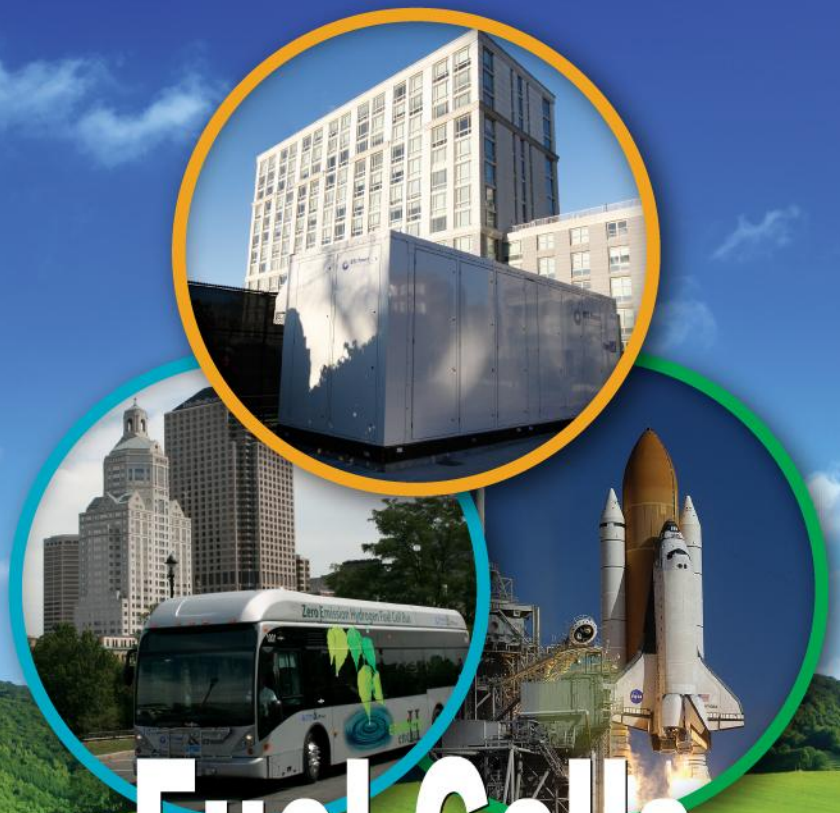
A United Technologies Company

energy

Reinvented

A Presentation on Stationary Fuel Cells

Advances in fuel processing technology



Fuel Cells

11-02-2011

UTC Power is a world leader in developing and producing fuel cells that generate energy for buildings, transportation and space & defense applications.

Sridhar Kanuri
Manager
Phosphoric Acid Fuel Cell & Fuel Processing Technology

Energy Productivity Energy Security Energy Responsibility

FUEL PROCESSING TECHNOLOGY

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Agenda

Where I'm coming from

UTC Power experience

Stationary power plant fuel processing

Transportation power plant fuel processing

Summary

UNITED TECHNOLOGIES CORP.

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Fortune 50 corporation

$54.3B in annual sales in 2010

~60% of sales are in building technologies

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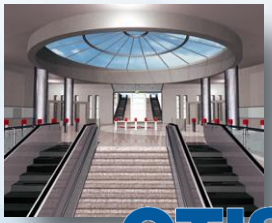


OTIS

Carrier

UTC Fire & Security

Research Center

Hamilton Sundstrand

UTC POWER

About us

- Fuel cell technology leader since 1958
- ~ 450 employees
- 768+ active U.S. patents,
  258 additional U.S. patents pending
- Global leader in efficient, reliable, and sustainable fuel cell solutions

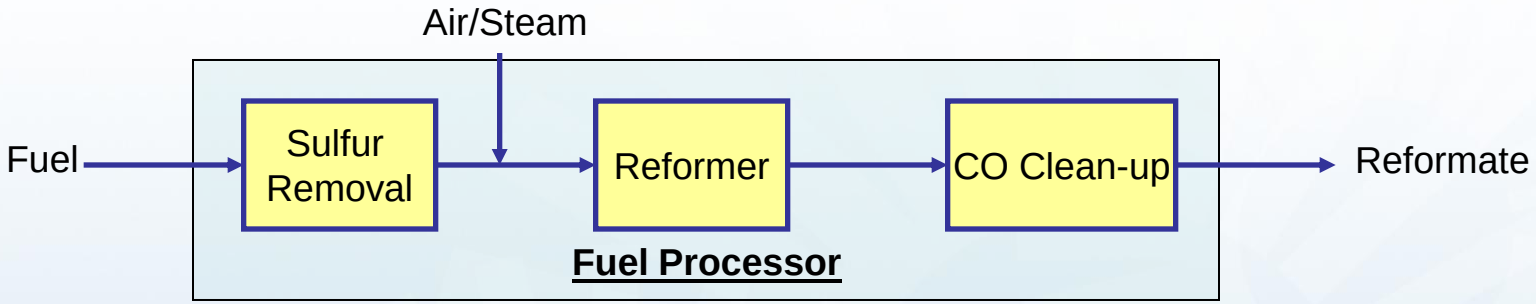
Stationary Fuel Cells

Transportation

Space & Defense

FUEL PROCESSING TECHNOLOGY

UTC Power experience



FUEL	Catalytic Partial Oxidation (CPO)	Autothermal (ATR)	Catalytic Steam (CSR)	Shift	Preferential Oxidation (<10 ppm CO)	Sulfur Removal
Natural Gas	✓		✓	✓	✓	✓
Methanol	✓	✓	✓	✓	✓	
Gasoline	✓	✓		✓	✓	✓
Diesel	✓	✓		✓		✓
Propane			✓	✓		✓
Jet Fuel		✓		✓		✓
Light Naphtha			✓	✓		✓
Landfill Gas			✓	✓		✓
Anaerobic Digester Gas (ADG)			✓	✓		✓

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Stationary fuel cell power plants

Home 1968
4 kW

1971 - 1973
12.5 kW

1983 - 1986
40 kW

1988 - 1992
200 kW

1992
200 kW

2002
5 kW

2003
150 kW

2009
400 kW

Pressurized Systems

Near Ambient Systems

1976
1 MW

1984
4.5 MW

1991
1 MW

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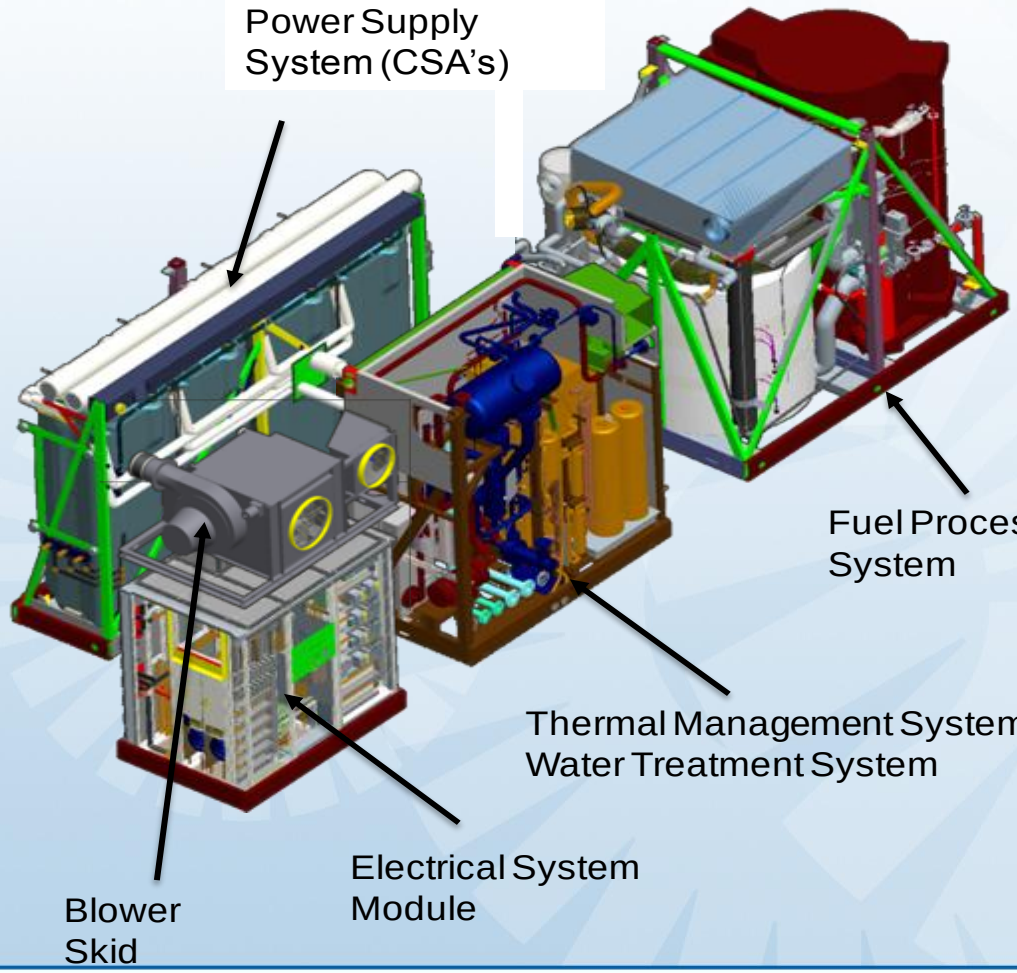
Purecell® System Model 400 overview

Power Plant Modules



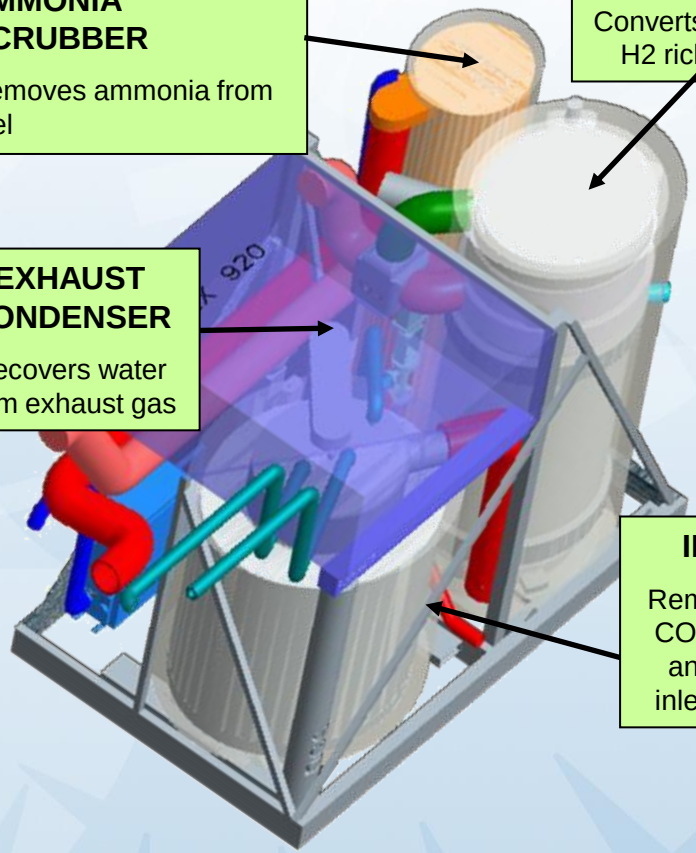
Fuel Processing System

AMMONIA SCRUBBER
Removes ammonia from fuel

REFORMER
Converts fuel to H2 rich gas

EXHAUST CONDENSER
Recovers water from exhaust gas

ILS
Removes CO from anode inlet gas



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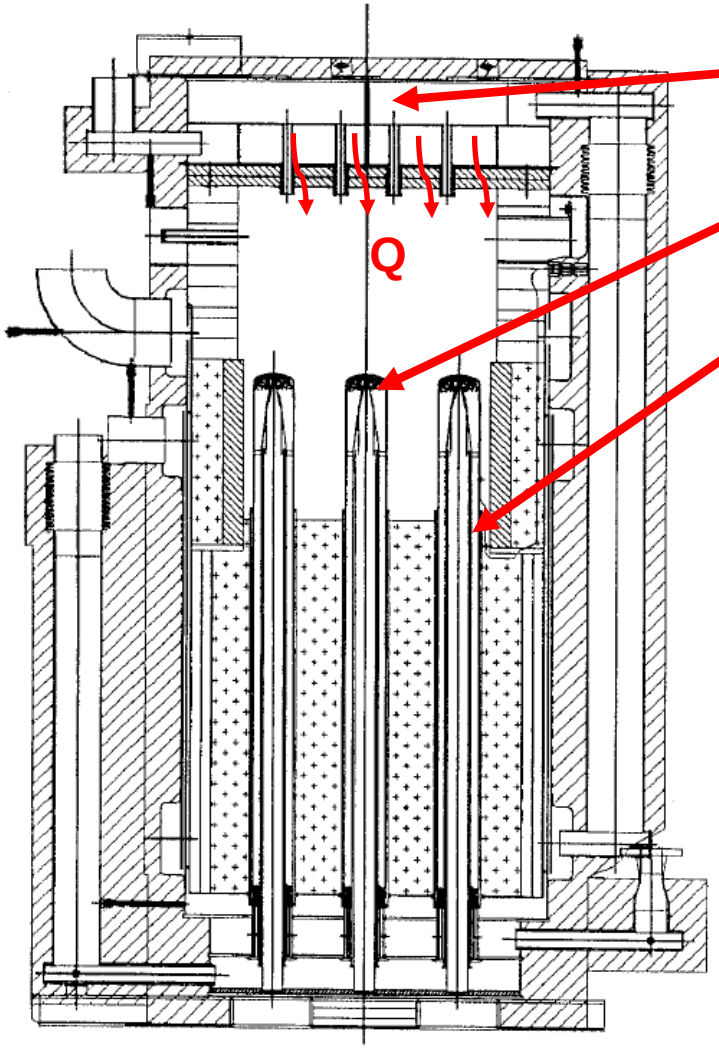
PureCell® System Model 400 catalytic steam reformer



Anode exhaust burner

Steam reforming and shift

Anode exhaust preheater

$CH_4 + H_2O \rightarrow CO + CO_2 + 3H_2$
$CO + H_2O \rightarrow CO_2 + H_2$
$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$

External to CSR reactor:

- Steam generator
- Additional shift
- Prox
- Thermal management

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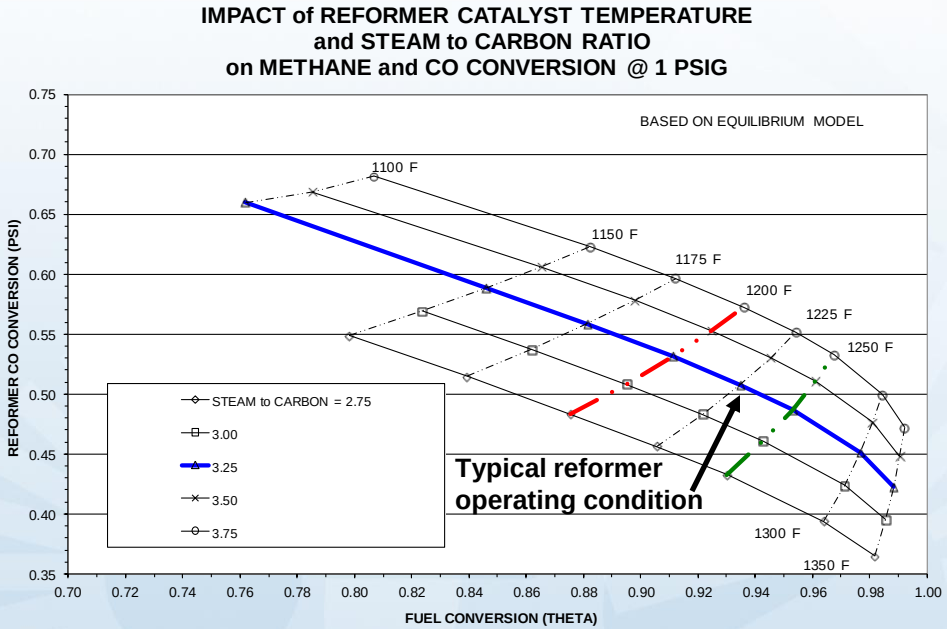
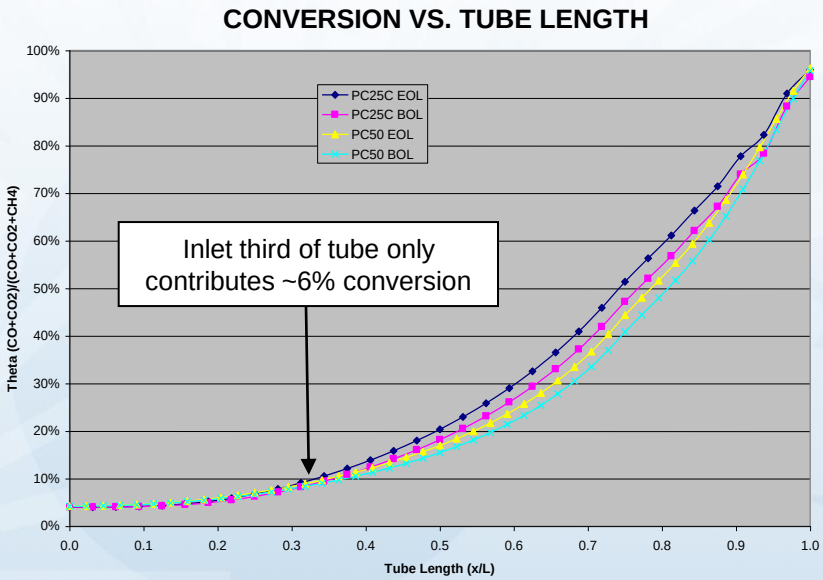
PureCell® System Model 400 reformer design





High efficiency reformer > 91% efficient

Operating envelope allows for optimal sizing of CO mitigation system

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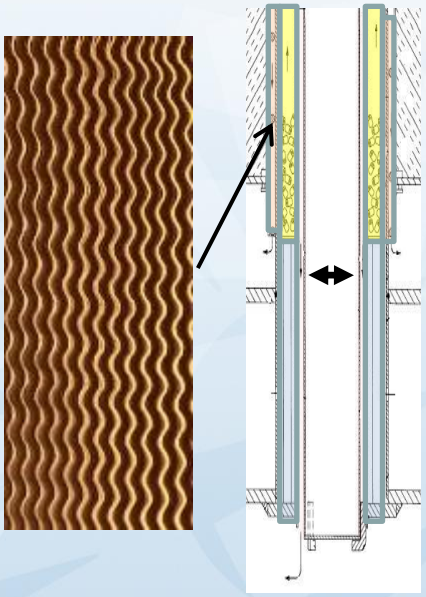
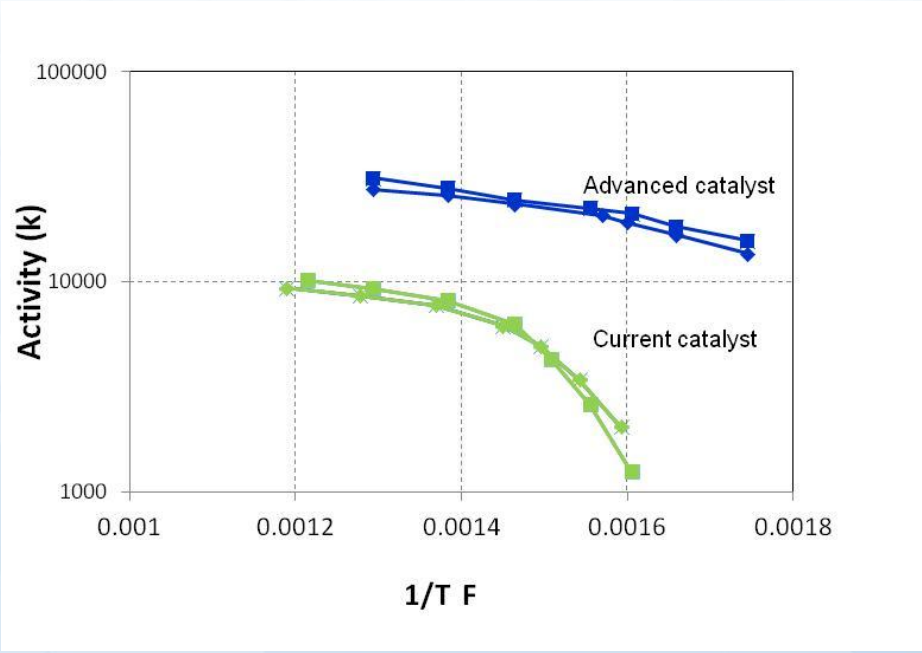
PureCell® System Model 400 advanced reformer concepts

Current Design

Low Cost Reformer



Catalyst Activity Testing



Improving reformer catalyst kinetics and heat transfer can enable significant reformer size and cost reduction

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Gas pretreatment skid for ADG

Removes liquid water and H2S

Powered and controlled automatically by fuel cell power plant

Switch-on-the-fly from ADG to natural gas and back

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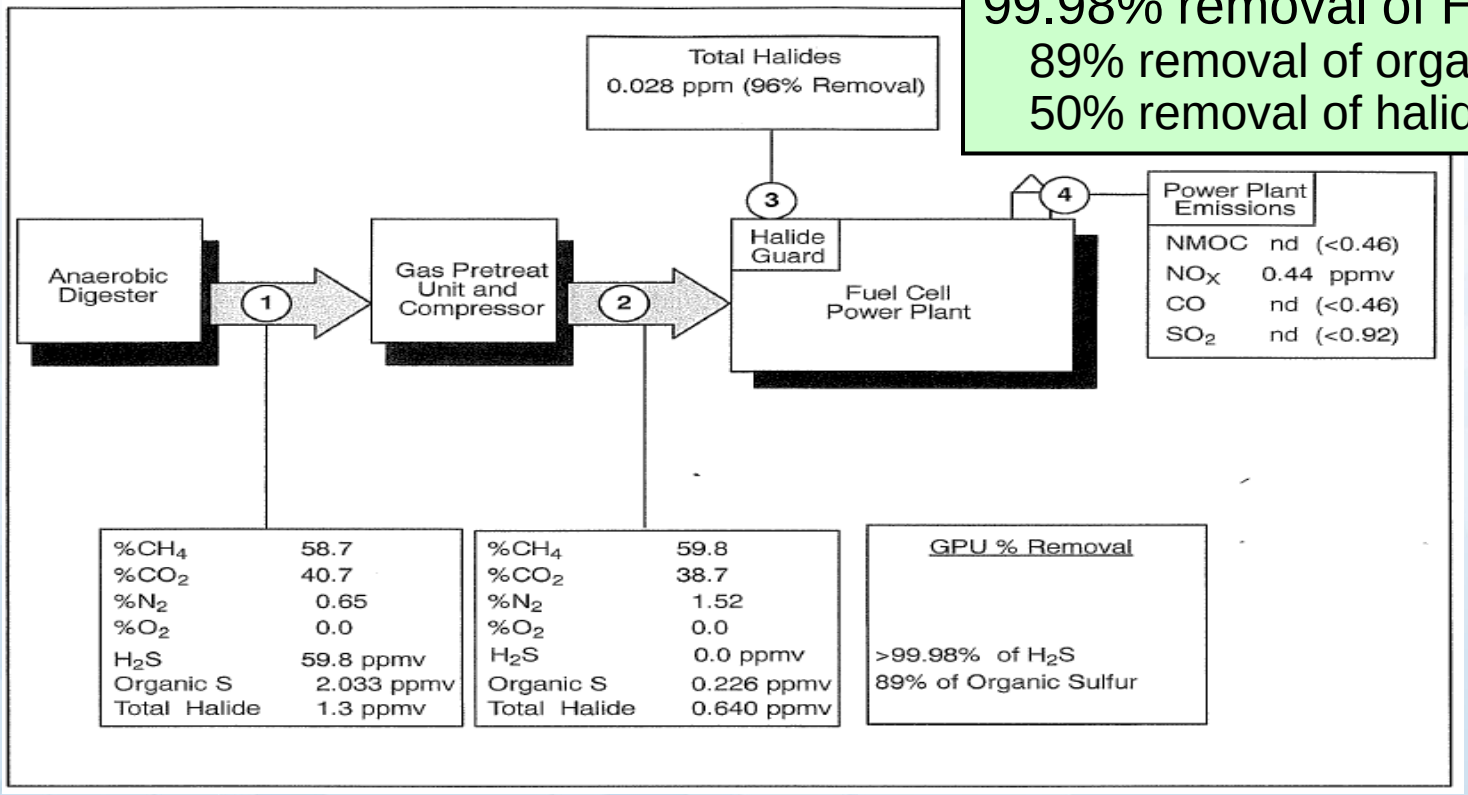
Gas pretreatment skid performance data

99.98% removal of H2S
89% removal of organic sulfur
50% removal of halides



Work sponsored by the United States EPA

Two-year demonstration test for ADG-based 200 kW fuel cell power plant was conducted from 1998-2000 at a waste water treatment plant

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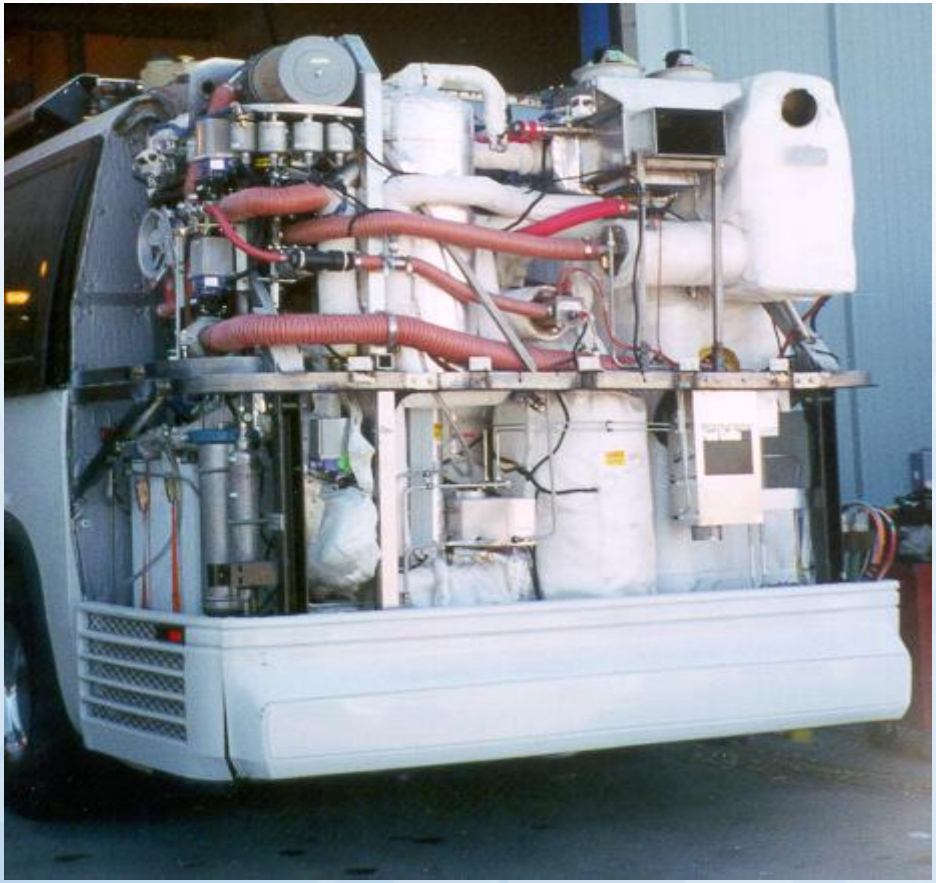
Transportation - Georgetown University bus



100 kW_e (EOL)

Methanol Fuel

- 0.05 ppmw S
- 0.05 ppmw Halides

~8,000 load hours (original stack)

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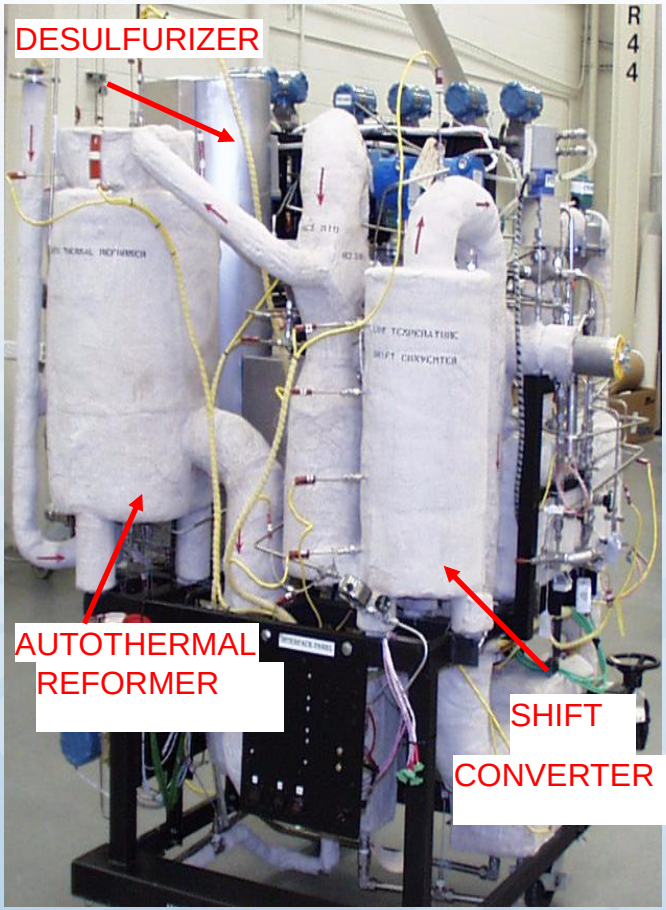
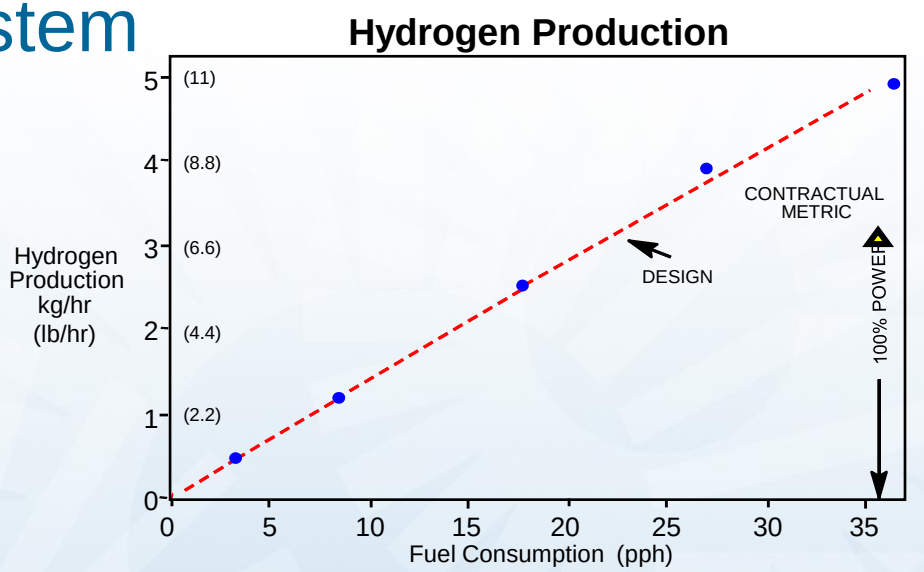
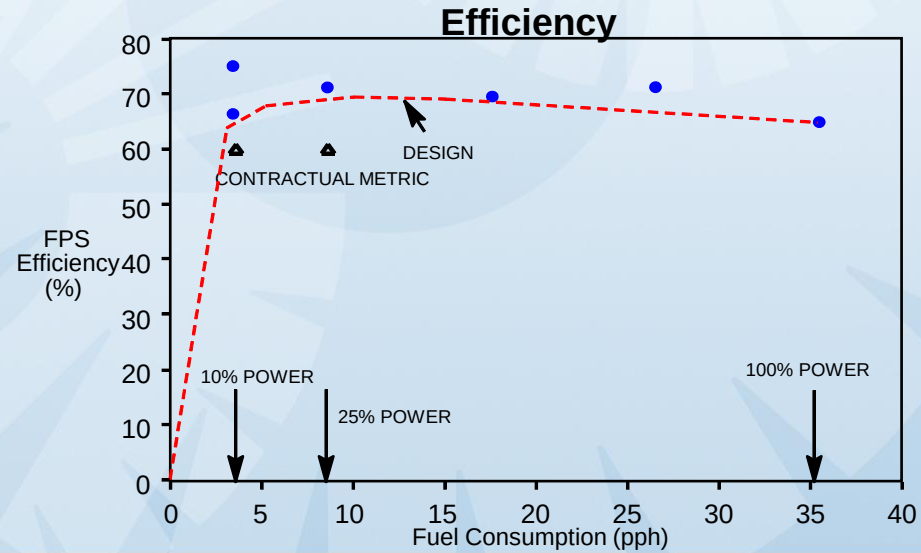
Gasoline fuel processor system







FUEL PROCESSING TECHNOLOGY

Summary

Broad background in fuel processors for fuel cell power plants

Proprietary position in desulfurization, reforming, and reformate clean-up