HIGH TEMPERATURE FUEL CELL (PHOSPHORIC ACID) MANUFACTURING R&D

Sridhar Kanuri
Manager,
Phosphoric acid fuel cells & fuel processing
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Agenda

PAFC cost challenge

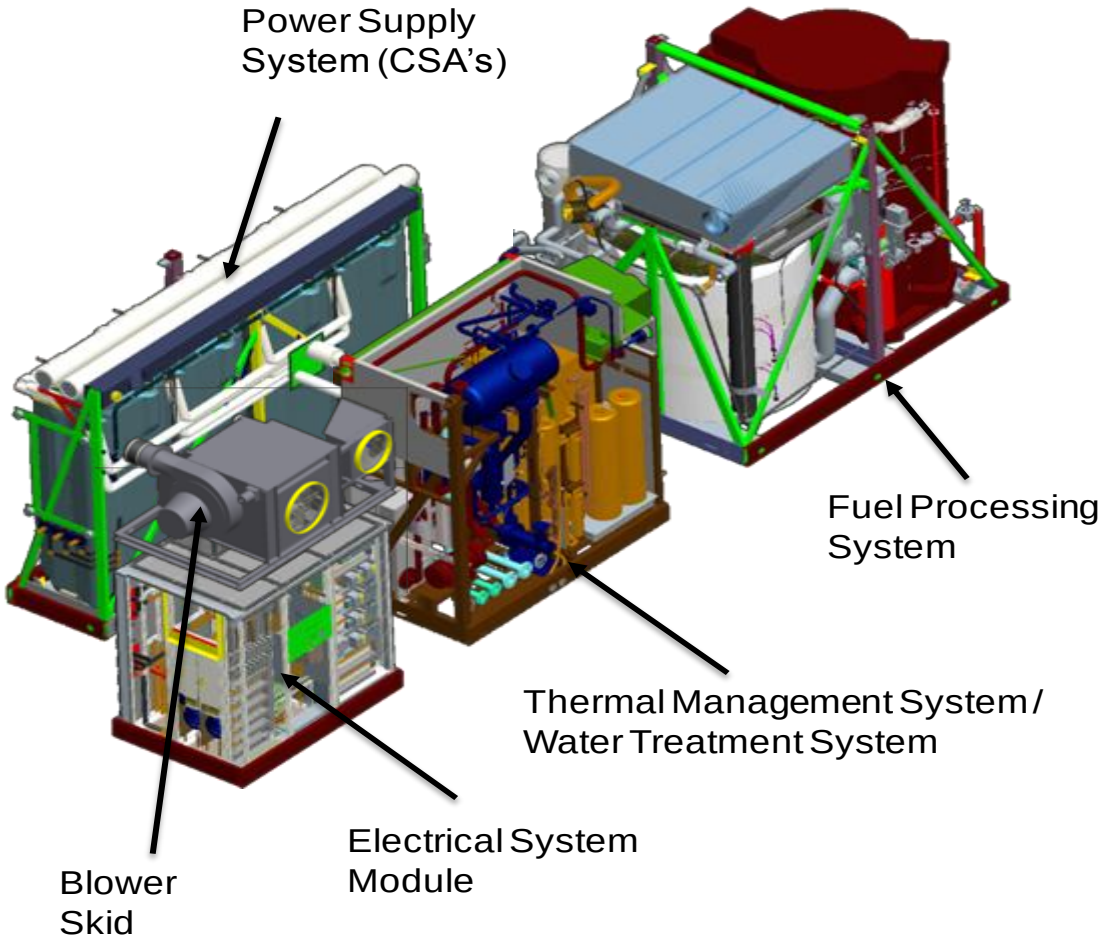
Manufacturing Cost reduction opportunities

Summary

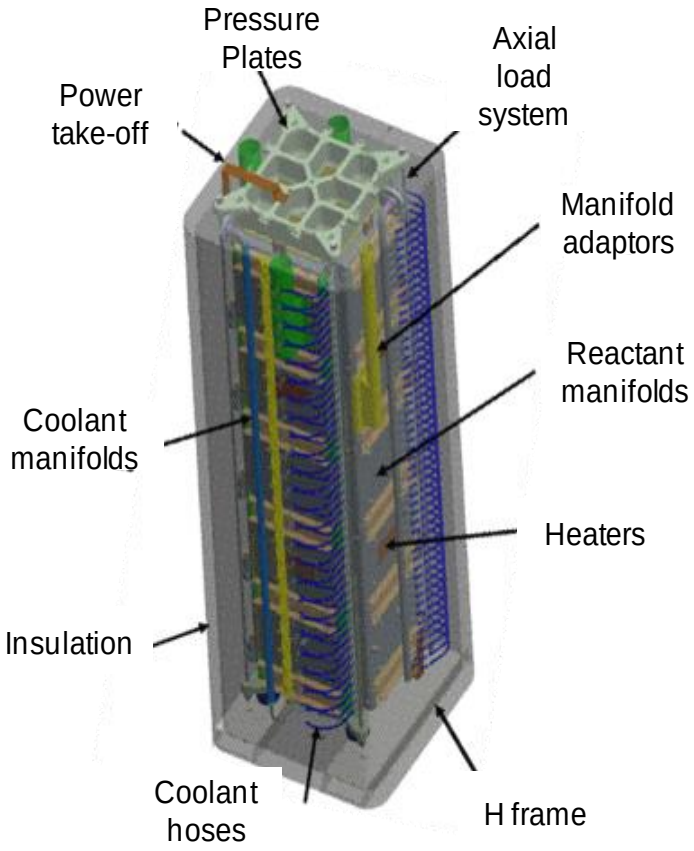
PAFC SYSTEM OVERVIEW

Overview

Powerplant modules



Cell stack Assembly



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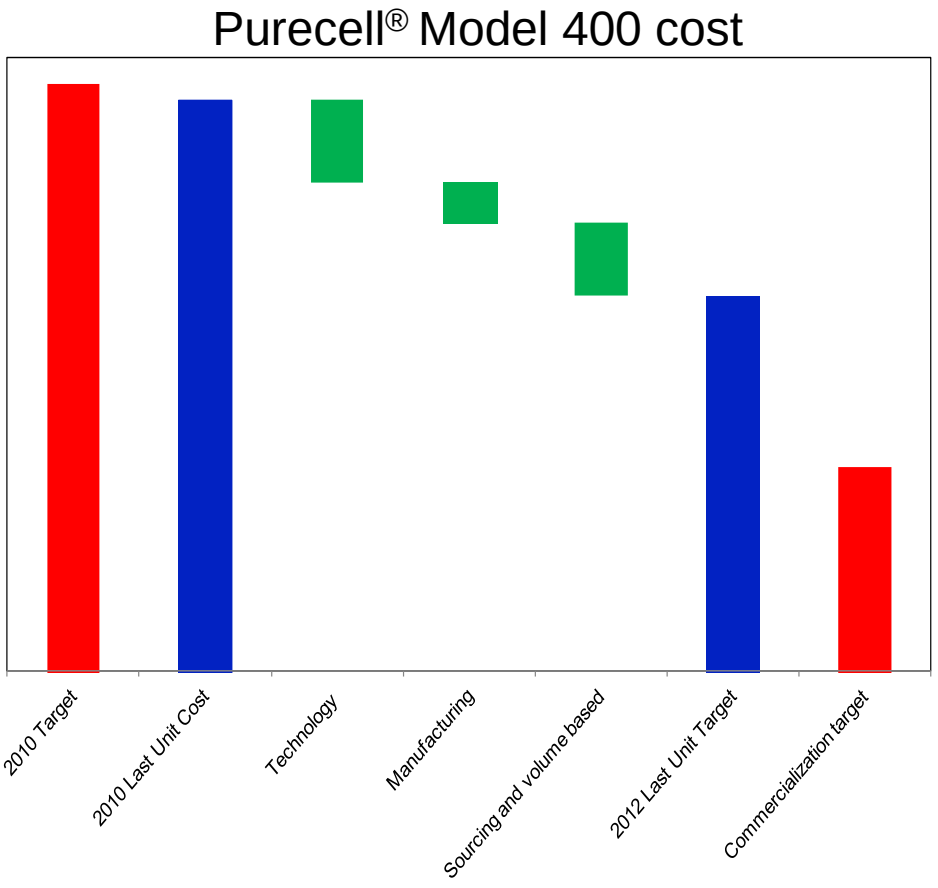
PURECELL® MODEL 400 SYSTEM

Power plant cost

Cost reduction is being accomplished by incremental changes in technology and manufacturing



Closing commercialization gap

- Continuous manufacturing methods for cell components
- Low cost FPS & high temperature BOP components
- Technology advances
- Volume based cost reductions

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Current manufacturing cost reduction initiatives at UTC Power

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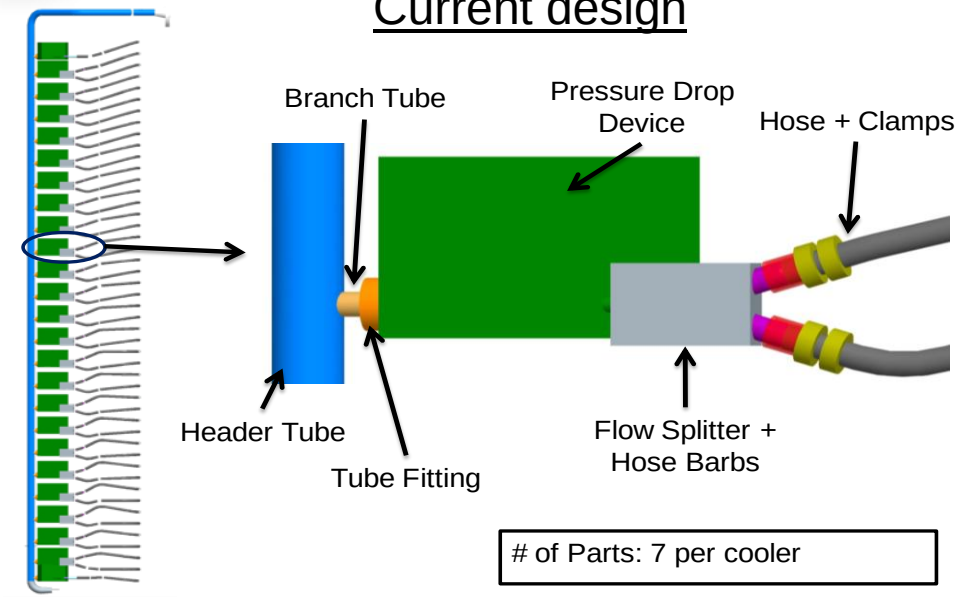
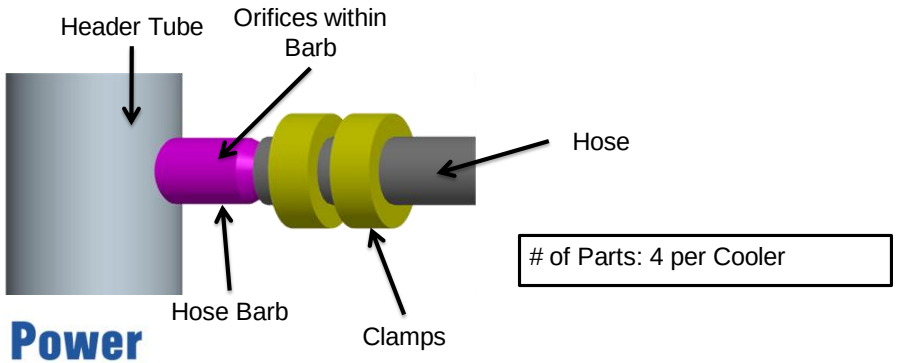
DFA - Manufacturing cost reduction

Current design



# of Parts: 7 per cooler

New design



# of Parts: 4 per Cooler

Part count:

- Before DFA: 4720 parts
- After DFA: 2688 parts
- 43% reduction

Assembly operations:

- Before DFA: 3552 operations
- After DFA: 3072 operations
- 14% reduction

Cost savings: 34%

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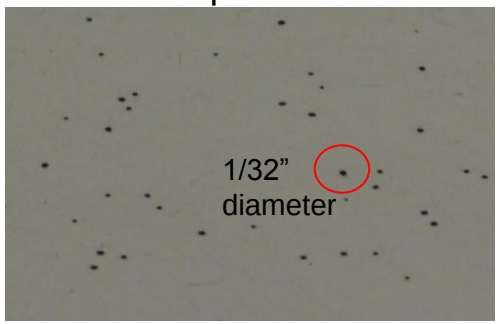
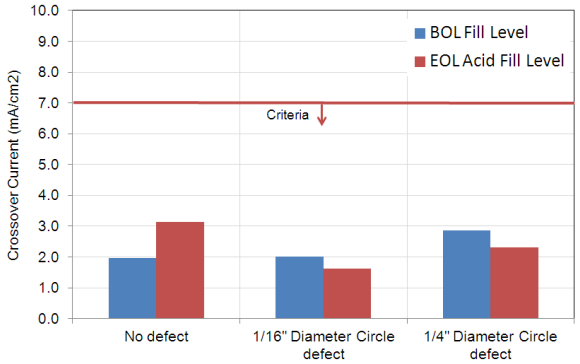
Automated inspection methods

Defects in matrix layer need touchup to prevent reactant crossover and cell shorting

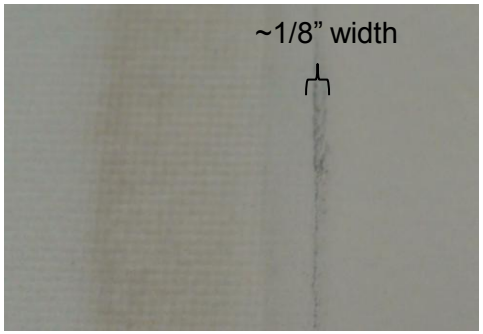
Active area pinhole defect



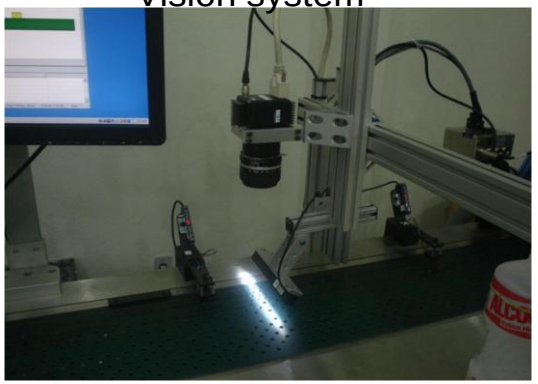
Crossover test



Leading edge defect



Vision system



Use of latest digital camera technologies to analyze defects for QC and reduction in manufacturing value add is being evaluated

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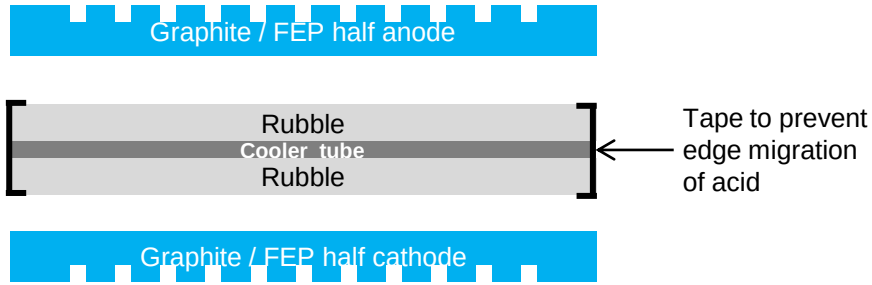
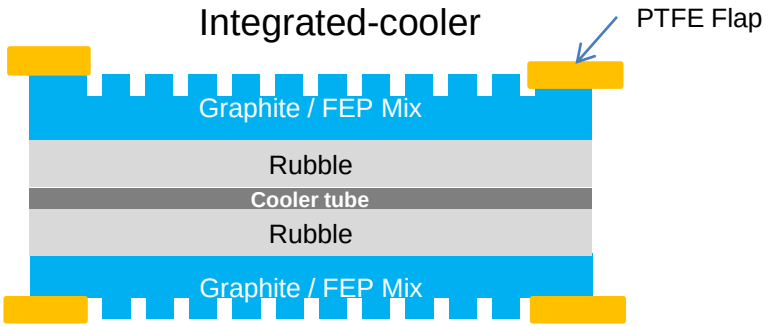
Advanced manufacturing – Integrated cooler

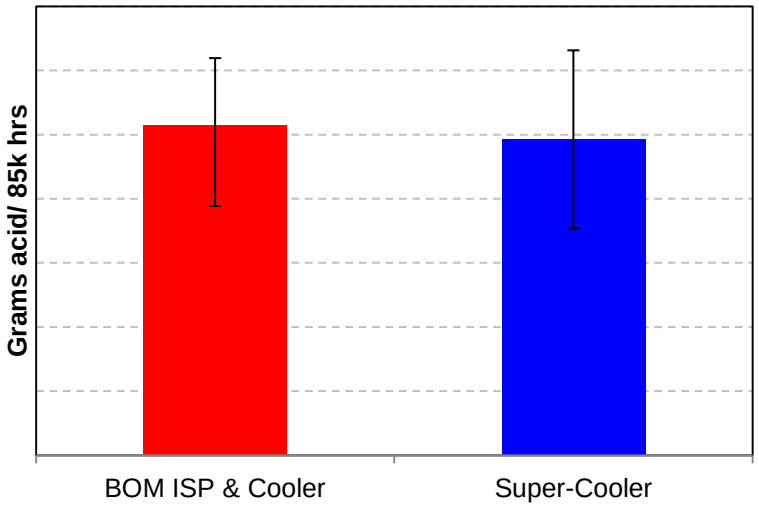
BOM cooler – Half ISP design



Integrated-cooler



Acid migration measurement



Combines three distinct components into one
Increases production capacity by ~ 10%

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Future manufacturing cost reduction opportunities

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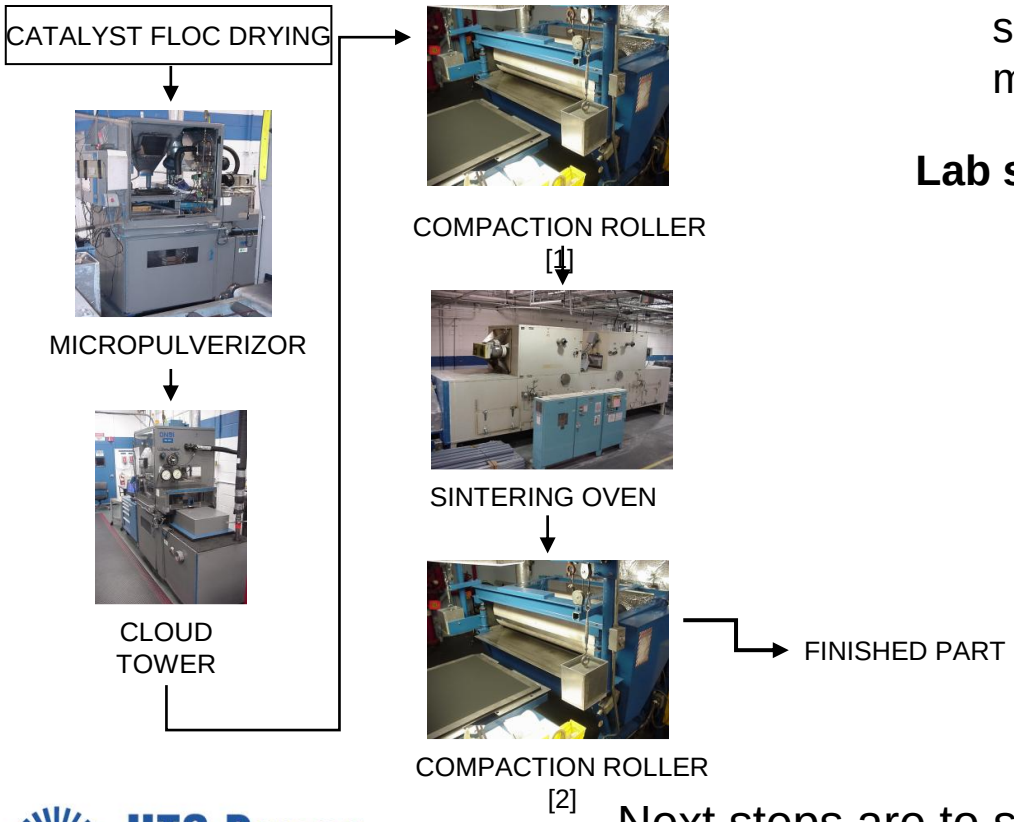
Continuous manufacturing – Advanced electrodes

Current process of PAFC electrode manufacture is capital intensive

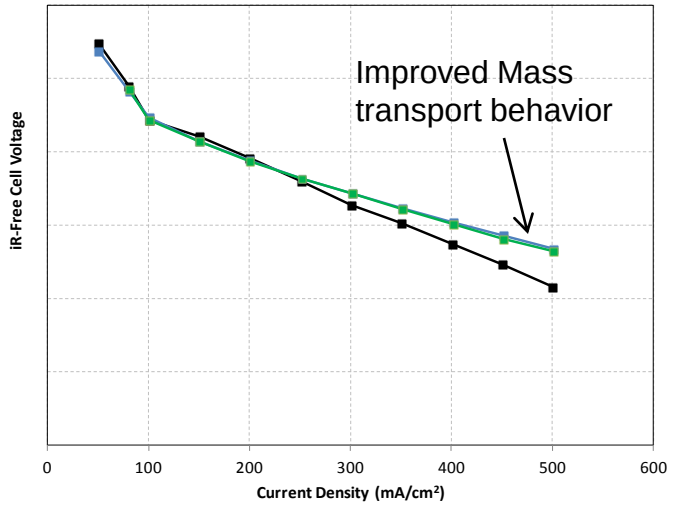
PAFC electrode manufacturing



Low cost electrode manufacturing concepts

Spraying mix of Catalyst, Teflon® directly onto a substrate with subsequent heat treatment to manufacture electrodes

Lab scale electrode manufactured using low cost manufacturing method



Next steps are to scale up using a low cost manufacturing method

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Continuous manufacturing – Net-shaped separators

Current process of PAFC flow-field and cooler manufacturing is a batch process & is labor intensive

Current process

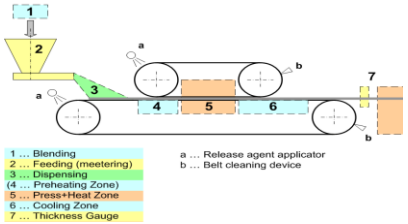
Dry powder blending

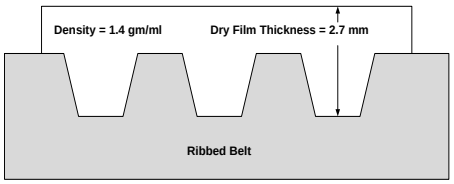
Cold & Hot Lamination

Trimming & Flow Channel Machining

Future process

Continuous screw extruder & double belt press



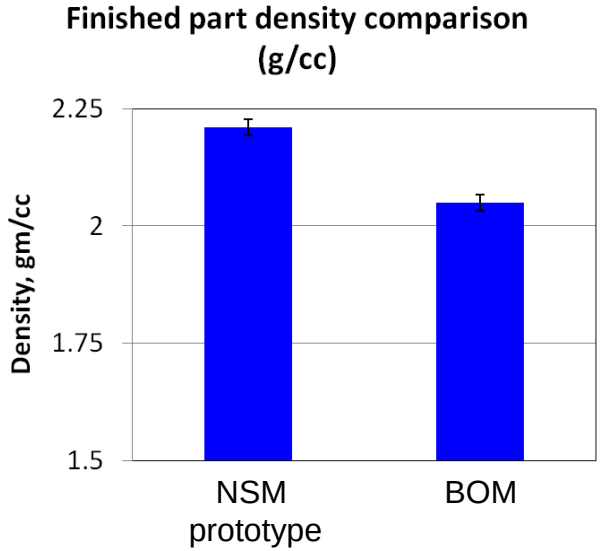


Ribbed belt system for continuous channel formation

Low cost manufacturing concepts

Continuously extrude graphite-polymer composite into a slab of desired thickness followed by net-shape molding of channels using a double-b

Lab scale bipolar plates manufactured using low cost manufacturing method



Next steps are to scaleup using a low cost manufacturing method

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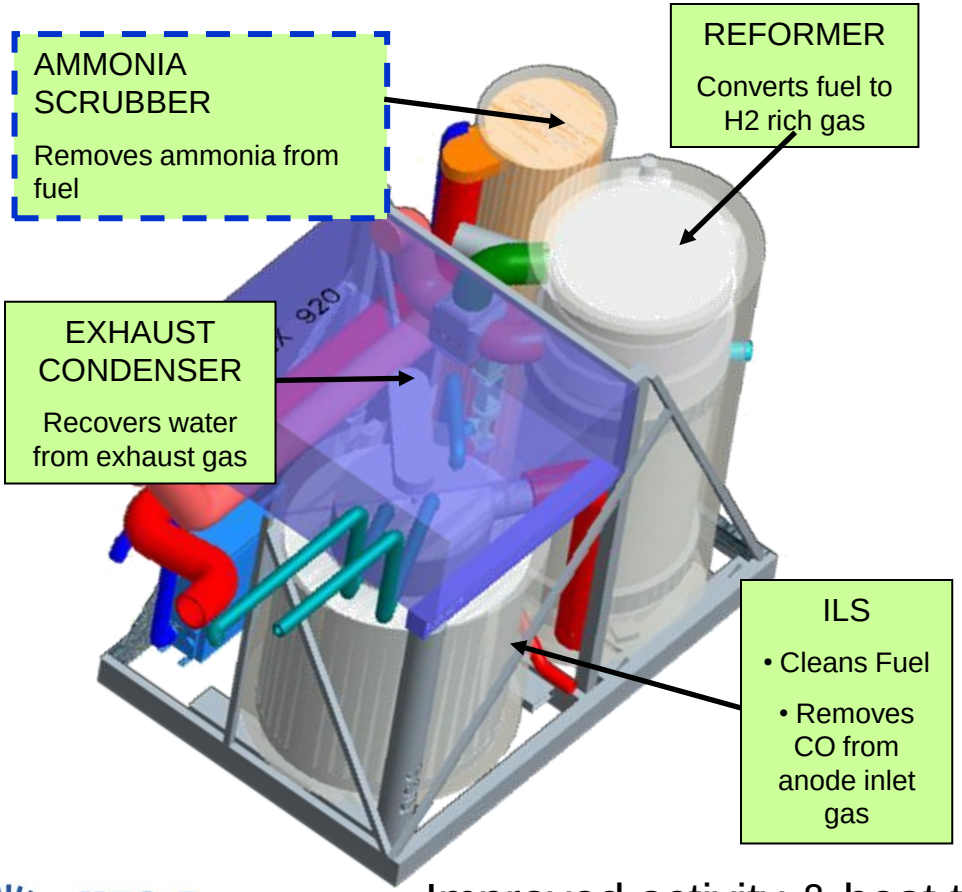
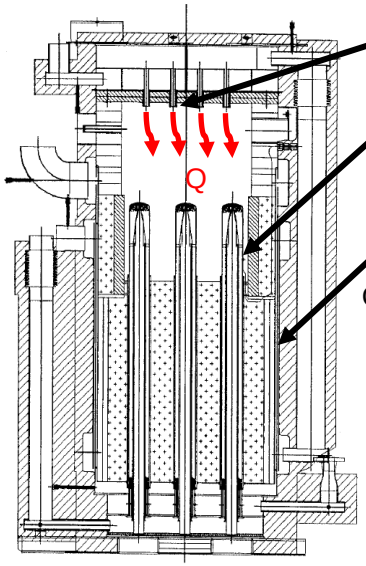
Reduced weight and volume

Fuel processing system



Reformer

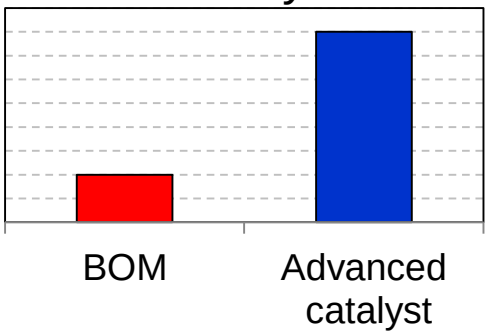


$CH_4 + H_2O \rightarrow CO + CO_2 + 3H_2$

$CO + H_2O \rightarrow CO_2 + H_2$

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

Activity



Improved activity & heat transfer can reduce the volume of FPS by ~ 50%

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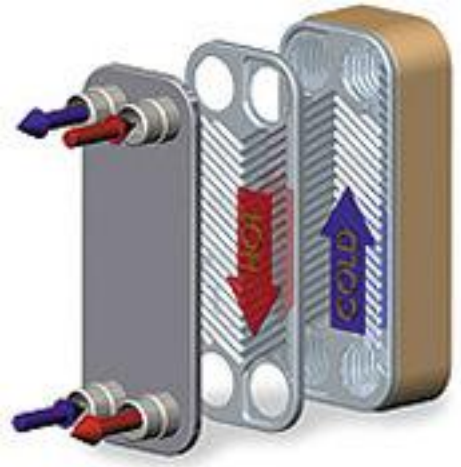
BOP – Low cost heat exchangers

Brazed plate HEXs and automotive radiators offer a significant BOP cost reduction opportunity for stationary power plants

Technology challenges involve thermal cycle stability and coating development to endure high temperature H_3PO_4 environment



Brazed plate HEX

Advantages:

- Light weight and compact
- Low pressure drop for the gas side
- Low cost due to volume production and simple structure

Low cost radiators

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Summary

First cost is a significant challenge for all stationary fuel cell power plants

Continuous high volume manufacturing techniques can enable significant cost reduction in cell component manufacturing

- Advanced electrode manufacturing
- Net shape molding of bipolar plate

Significant cost reduction opportunities exist in BOP with FPS having highest cost reduction potential

Accelerated commercialization requires investments in manufacturing R&D along with technology R&D