PAFC Cost Challenges

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AGENDA

Purecell® 400 cost challenge

Cost reduction opportunities

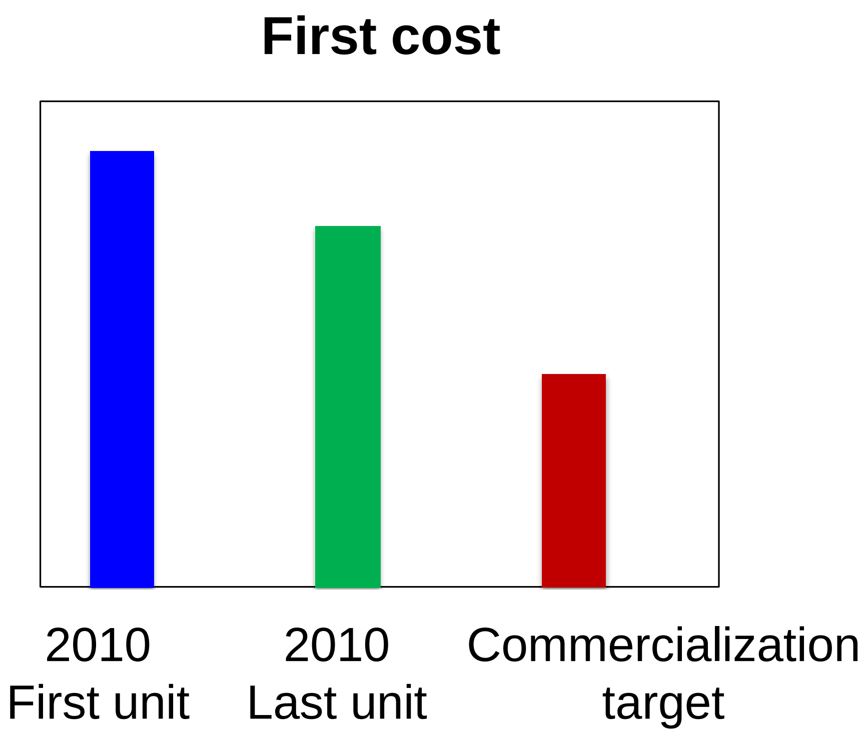
Summary

PURECELL® FUEL CELL SYSTEM

Powerplant cost

2010 cost reduction is being accomplished by incremental changes in technology & low cost sourcing

Technology advances are required to reduce further cost and attain UTC Power's commercialization targets



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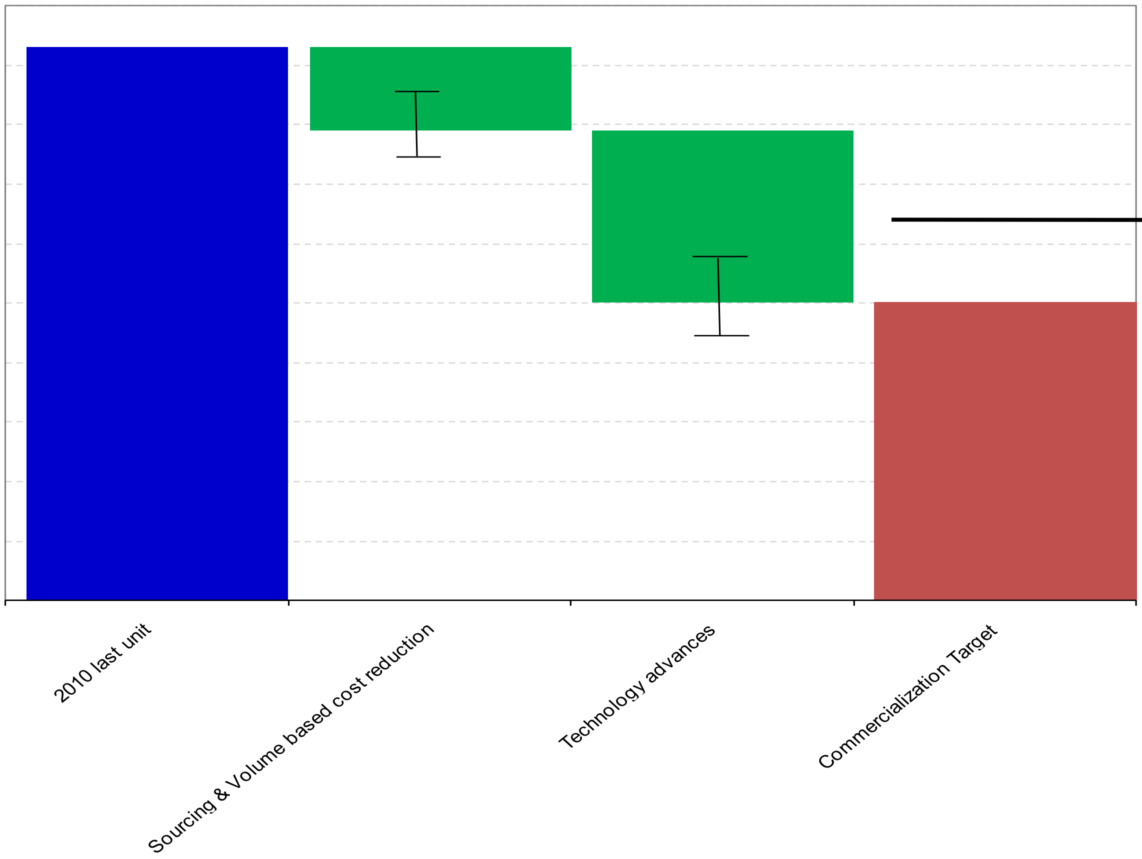
PURECELL® FUEL CELL SYSTEM

Powerplant cost

Cost reduction



- Alternate electrolyte
- Active catalyst
- Low cost manufacturing
- Low cost HEXs
- Non NH_3 producing FPS

Significant technology advances are required to meet commercialization targets

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Alternate electrolyte

Property	Desired	PAFC
Operating temperature (C)	150 – 250	150 - 250
Ionic conductivity (mho/cm)	> 0.65	0.65
Vapor pressure (atm)	~ 0	4.5×10^{-7} @ 175 C
O_2 solubility (mol/cm^3)	high	1×10^{-7} @ 175 C
Transference number	0	0.11
Anion poisoning	None	Phosphate poisons catalyst
Electrochemical stability	No decomposition products between 0 – 1.2V	H_3PO_4 is very stable
Material compatibility	Compatible with fuel cell materials (Ex: Carbon, Teflon, SiC, Catalyst)	Very compatible with fuel cell materials
Freeze tolerance	-30 C – 250 C	-30 C – 250 C

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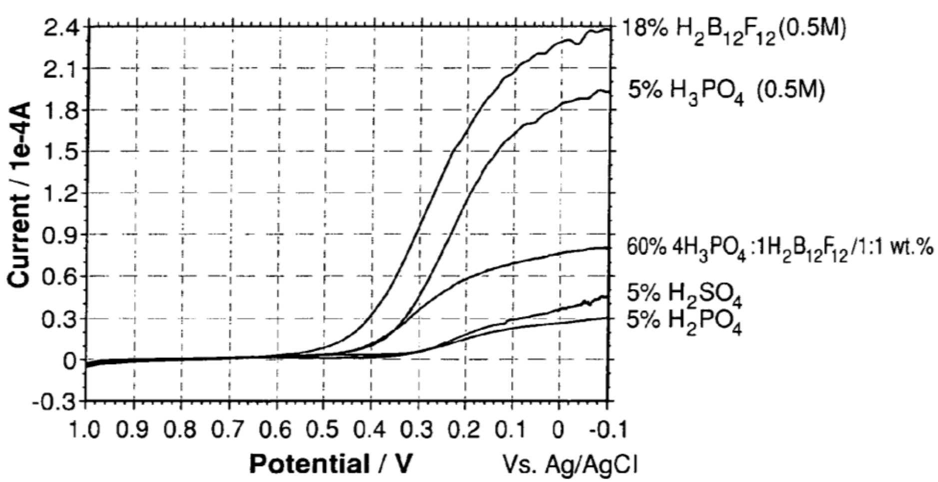
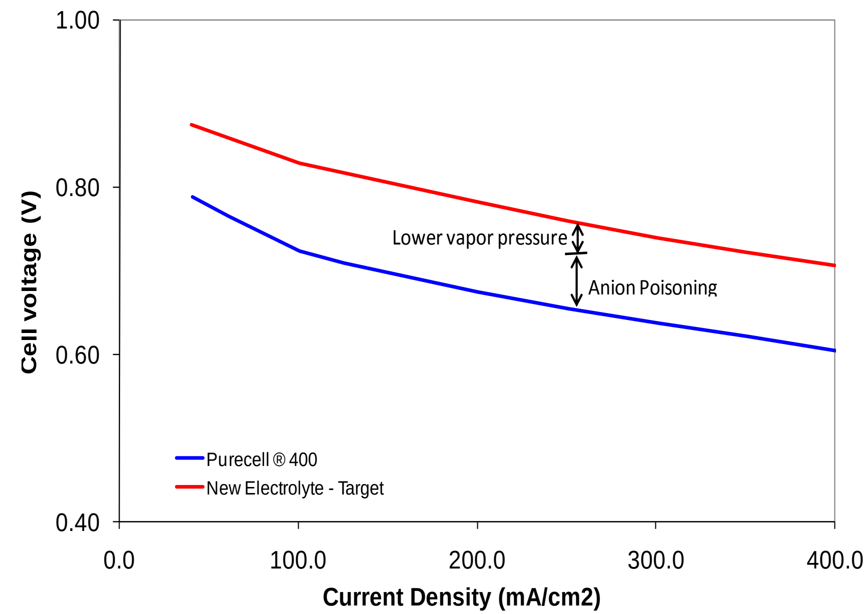
Alternate electrolyte

RDE of aqueous acids at 1400 RPM



(Ref: US 2007/0048605 A1)

Performance Analysis



Literature shows significant potential for using alternate electrolytes for fuel cells

Eliminating anion poisoning and using electrolytes that have very low vapor pressure result in improving power plant efficiency by ~6 points and/or reducing power plant cost by ~ 15% - 20%.

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Alternate electrolyte – H_3PO_4 additives

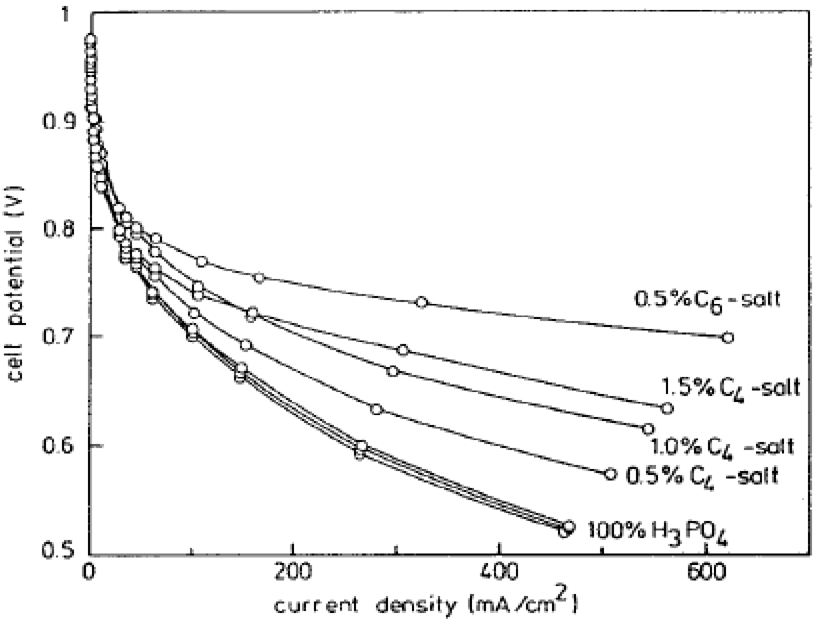


Fig. 8. Polarization curves for electrolyte modified by addition of C_6-salt and C_4-salt (fuel, H_2; oxidant, O_2; electrolyte, 100% H_3PO_4; and temperature, 190°C).

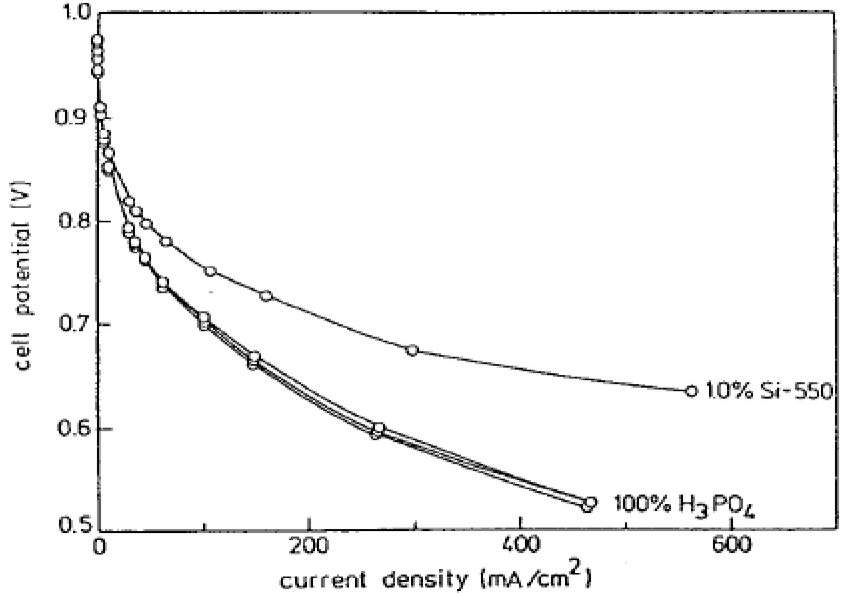


Fig. 10. Polarization curves for electrolyte modified by addition of Si-550 (fuel, H_2; oxidant, O_2; electrolyte, 100% H_3PO_4; temperature, 190°C).

H3PO4 modifications using additives have been shown to improve performance

Ref: Xiao Gang et. Al, "Electrolyte additives for phosphoric acid fuel cells, J. Electrochem. Soc., Vol. 140, No. 4, April, 1993

PURECELL® FUEL CELL SYSTEM

Anode catalysts

Primary requirements for PAFC anode:

- Stable in operating temperatures between 150 C & 225C
- CO tolerant
- Stable surface area
- Low Pt usage / kW: (PAFC: 2.4 g/kW vs. PEM: 0.03 g/kW)

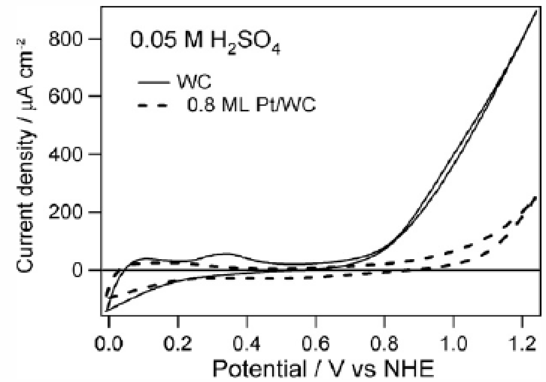
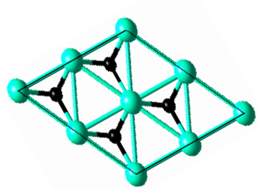


Fig. 4. Cyclic voltammetry curves of WC and 0.8 ML Pt/WC surfaces exposed to 0.05 M H_2SO_4.

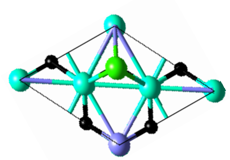
Opportunities:

High mass activity catalysts & low Pt loaded anodes

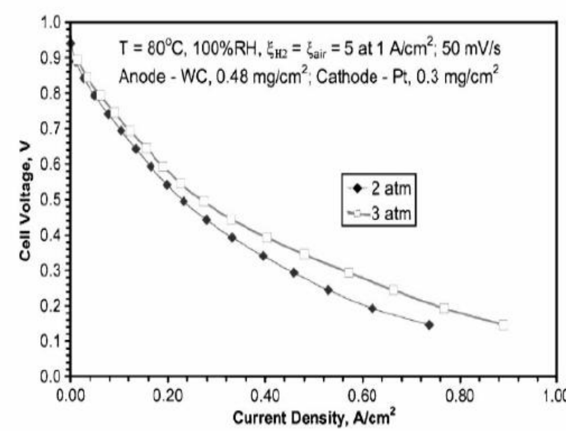
Research indicates transition metal carbides are significantly active toward HOR and are CO tolerant



● W ● C



● W ● C ● Pt ● Ta



H_2 / Air Polarization curves of WC based anode in 5 cm² cell

Ref: D.J.Ham & J.S.Lee, "Transition metal carbides and nitrides as electrode materials for low temperature fuel cells

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Cathode catalysts

Primary requirements for PAFC cathode:

Stable in operating temperatures between 150 C & 225C

Stable surface area

High mass activity

Low Pt usage / kW: (PAFC: 5.2 g/kW vs. PEM: 0.13 g/kW)

Concepts for Improved mass activity

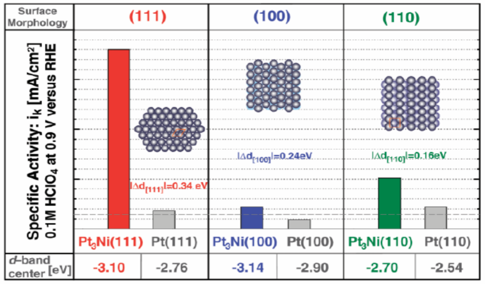
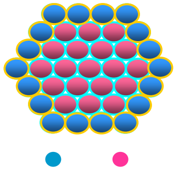


Fig. 3. Influence of the surface morphology and electronic surface properties on the kinetics of ORR. RRDE measurements for ORR in $HClO_4$ (0.1 M) at 333 K with 1600 revolutions per minute on $Pt_3Ni(hkl)$ surfaces as compared to the corresponding Pt(*hkl*) surfaces (a horizontal dashed gray line marks specific activity of polycrystalline Pt) are shown. Specific activity is given as a kinetic current density i_k, measured at 0.9 V versus RHE. Values of *d*-band center position obtained from UPS spectra are listed for each surface morphology and compared between corresponding $Pt_3Ni(hkl)$ and Pt(*hkl*) surfaces.

New synthesis
(3X mass activity)

Pt V Co

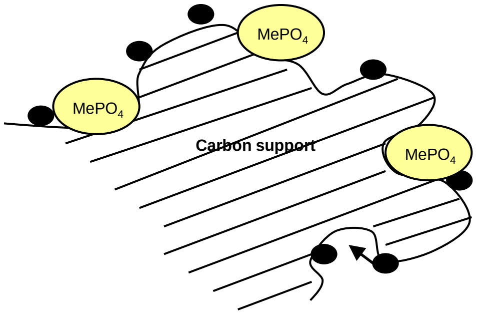
New structure
(10X mass activity)

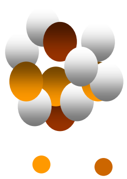


Pt Pd

Ref: Vojislav R. Stamenkovic, et. al, "Improved oxygen reduction activity on Pt3Ni(111) via increased surface site availability.

Concepts for surface area stabilization





Pt Ir Co

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PURECELL® FUEL CELL SYSTEM

Low cost manufacturing – Electrodes

Current process of PAFC electrode manufacture is capital intensive

PAFC electrode manufacturing

CATALYST FLOC DRYING

MICROPULVERIZOR

CLOUD TOWER

COMPACTION ROLLER [1]

SINTERING OVEN

COMPACTION ROLLER [2]

FINISHED PART

Low cost electrode manufacturing concepts

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

Using emulsions to obtain a uniform dispersion of Catalyst & Teflon® with subsequent wet deposition of catalyst layer and drying

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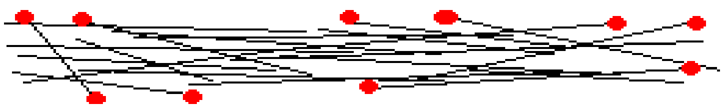
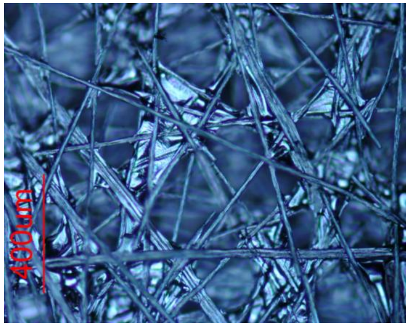
Low cost materials / manufacturing – GDLs

PAN-based (long)—Today





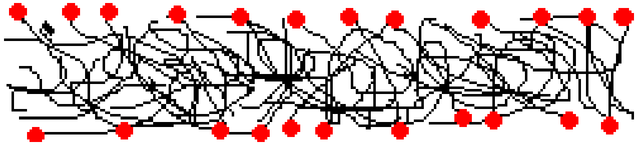
Primary requirements for PAFC GDL

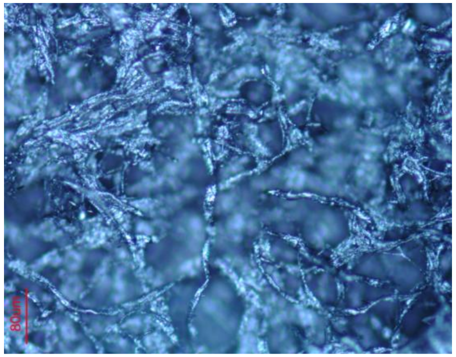
Density	~ 0.6 g/cc
Electrical resistivity:	< 0.08 mV/mil
Thermal conductivity	> 400 BTU/hr-ft^{2}-^{0}F
Flex strength	> 2200
Corrosion resistance	< 40 mA/g

Opportunities:

Low cost Carbon composite fibers, Carbonized cellulose based fibers & cotton based fibers, low cost manufacturing techniques etc. represent significant cost reduction opportunity for H_3PO_4 fuel cells

Cellulose-based





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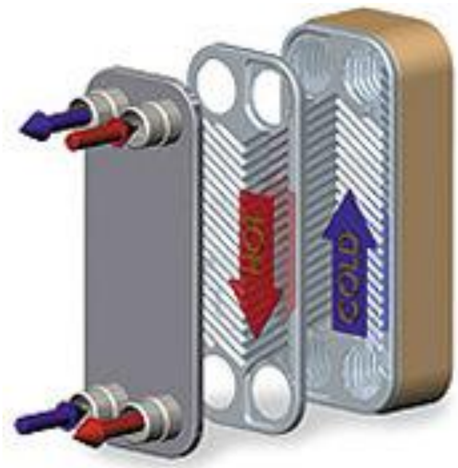
PURECELL® FUEL CELL SYSTEM
Low cost HEXs

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

Advantages:

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



Brazed plate HEX

Low cost radiators

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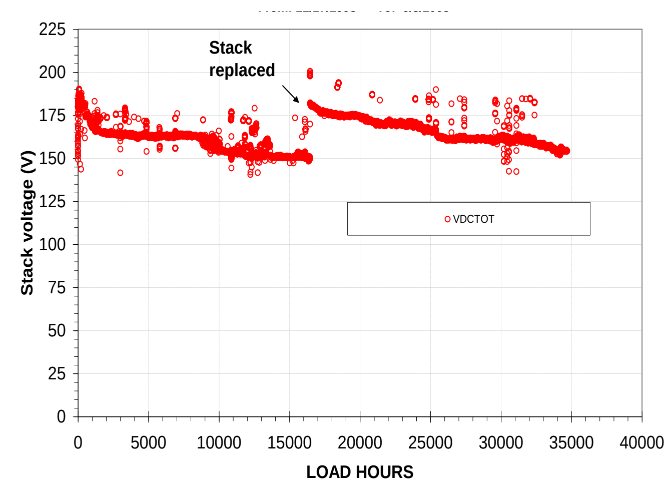
PURECELL® FUEL CELL SYSTEM

Non NH_3 producing FPS

Impact of NH_3 on performance

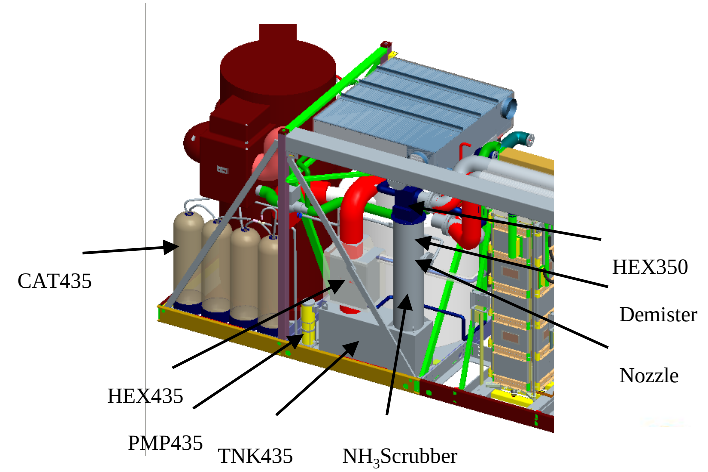


Requirement: NH_3 < 250 ppb

N_2 in natural gas produces NH_3 which poisons cathode catalyst

Purecell® 400 employs a scrubber to remove NH_3 from fuel stream

Purecell ® 400 ARD



Future concepts:

Investigate non NH_3 producing FPS catalysts

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Summary

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

Incremental improvements in technology are currently being worked / implemented by industry

Accelerated commercialization requires increased investment in technology