PAFC History and Successes

John Ferro

Manager Product Development

UTC Power

A United Technologies Company

john.ferro@utcpower.com

AGENDA

Company overview and history

System description and applications

Failure modes and life analysis

Summary

UNITED TECHNOLOGIES CORPORATION

Revenues: $58.7 billion (2008)

Commercial & Residential Building Systems, Aerospace & Transportation, Industrial systems

UTC Power

Carrier

Hamilton Sundstrand

Sikorsky

UTC Fire & Security

Otis

Research Center

Pratt & Whitney

18th largest U.S. manufacturer (2009 list, *Industry Week*)

37th largest U.S. corporation (2009 list, *Fortune*)

61st largest publicly held manufacturer in the world (2009 list, *Industry Week*)

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Markets

Transportation fuel cells

Space & defense fuel cells

Stationary fuel cells

Global sales

5 continents
19 countries

PURECELL® FUEL CELL SYSTEM

Stationary fuel cell history

1976
1 MW - PAFC

1984
4.5 MW - PAFC

1991
11 MW - PAFC

PureCell™ Model 400

2009
400 kW

$290 MM from DOE for PAFC*

Main focus areas: Durability & CHP

1988 – 1992
200 kW - PAFC

1992 – Present
200 kW - PAFC

2001 - 2005
150 kW PEM

1968
4 kW- PAFC

1971 – 1973
12 kW - PAFC

1975 – 1986
40 kW - PAFC

2002 - Present
5 kW H_2 PEM

1970 1975 1980 1985 1990 1995 2000 2005 2009

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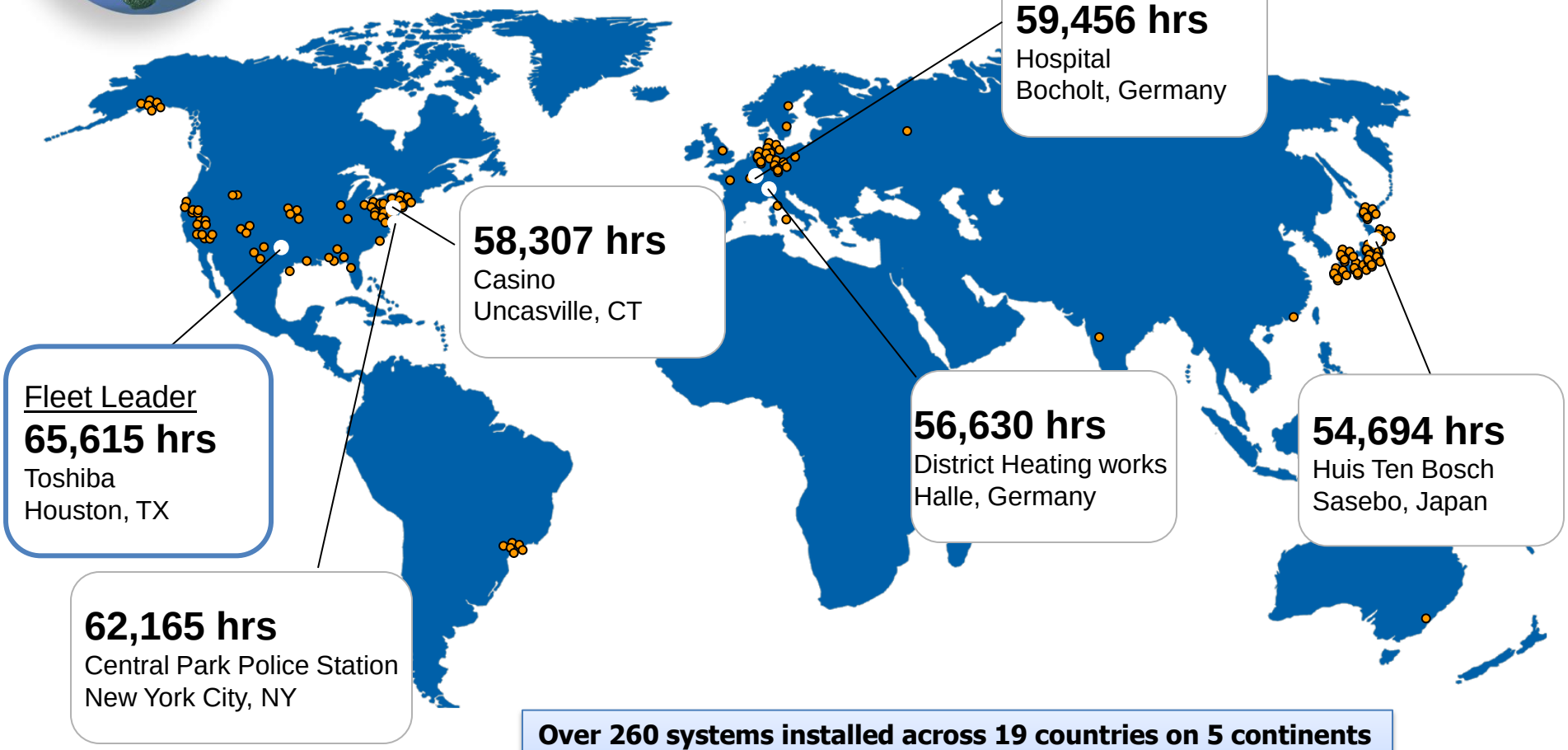
*** Reference: "FETC Perspective on the DOE Stationary Power Fuel Cell Program," Rita A. Bajura, 1997**

PURECELL® FUEL CELL SYSTEM

Worldwide fuel cell deployment and experience



Over 260 systems installed across 19 countries on 5 continents

More than 8.7 million hours of operation

More than 1.4 billion kWh of electricity generation

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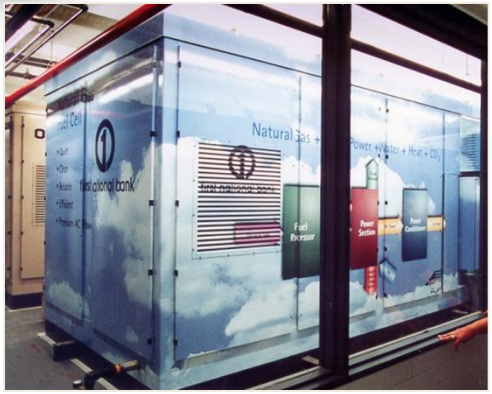
PURECELL® FUEL CELL SYSTEM

Flexible fuel cell application and varied experience

Assured Power



First National Bank of Omaha
Nebraska

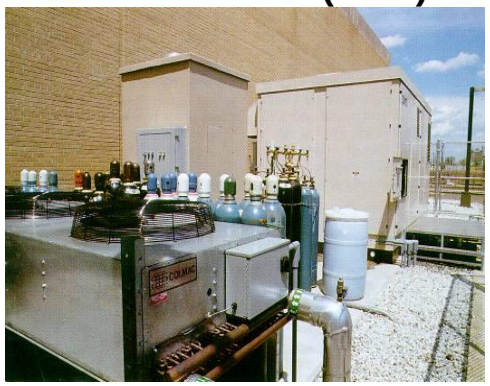
On-Line Emergency Power

Verizon Communications
New York

Green CHP Power

Whole Foods Market
Connecticut

Renewable Fuel (ADG)



Wastewater treatment plants
New York, New York

Indoor CHP Power

Mohegan Sun Resort & Casino
Connecticut

Off-Grid Power

Central Park Police Station
New York

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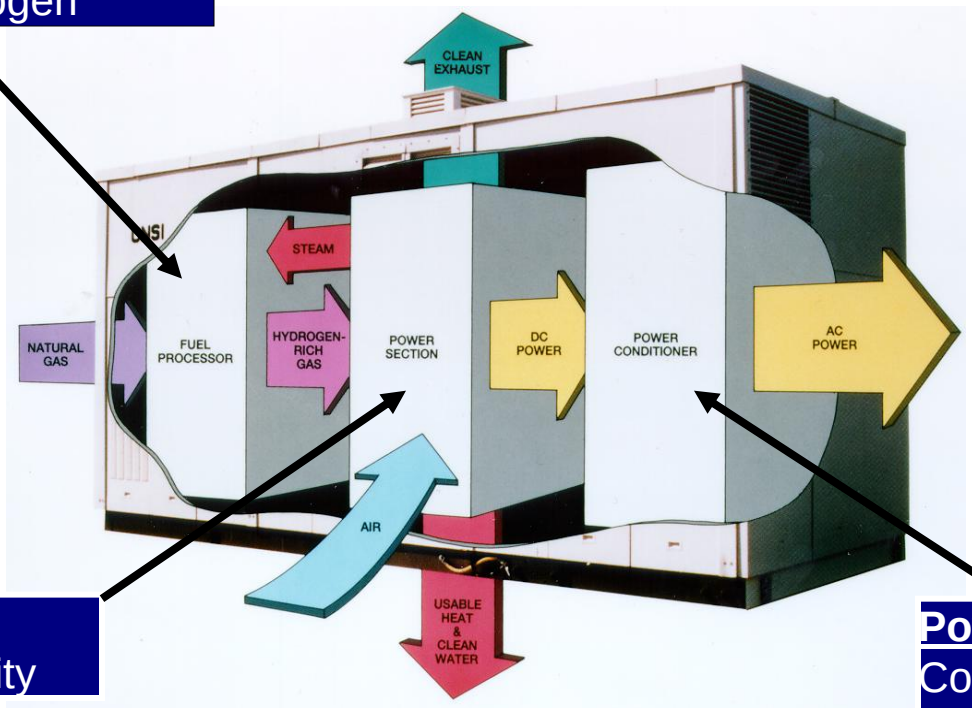
PURECELL® FUEL CELL SYSTEM

Three main sections – fuel processor, stacks, & power conditioner

Fuel Processor
Converts fuel to hydrogen

Fuel Input
98.9 Nm^3/hr natural gas



Electric Output:
400 kW, 480 V, 60 Hz
400 kW, 400 V, 50 Hz

Fuel Cell Stack
Generates DC electricity

Power Conditioner
Converts DC power to high quality AC power

Internal heat exchanger provides:
1.50MM BTU/hr @ 60C, or
0.68MM BTU/hr @ 121C with balance at 60C

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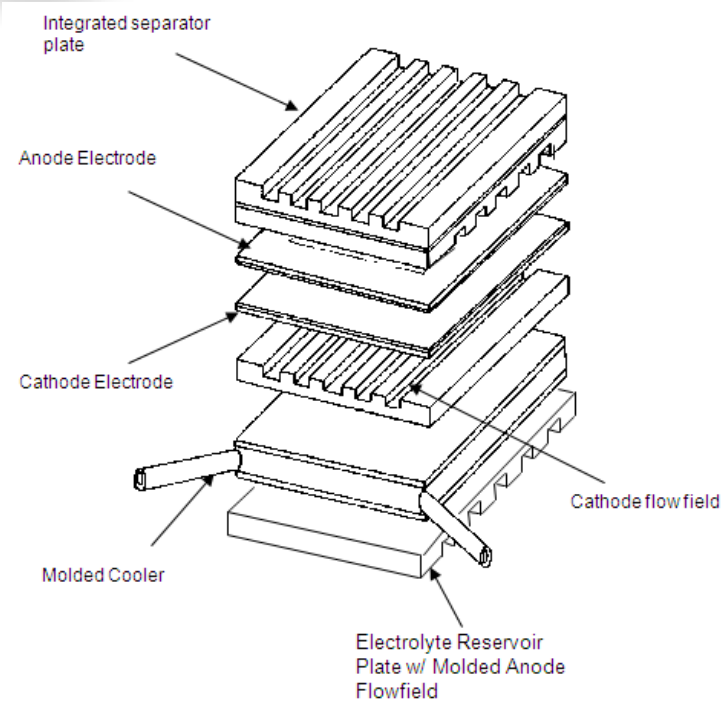
PURECELL® FUEL CELL SYSTEM

Cell stack assembly

Repeat assembly



8 cells per substack

34 substacks per CSA

Cell stack assembly (CSA)

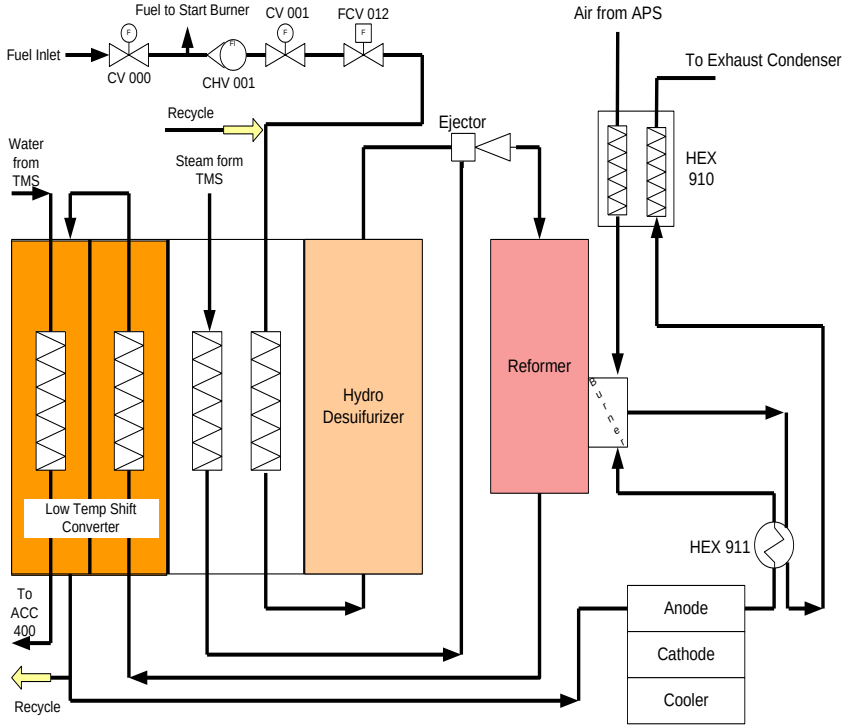
Molded carbon Teflon® composite for bipolar plates and coolers

Carbon substrates coated with catalyst layers

Cell active area = 0.5 m^2

PURECELL® FUEL CELL SYSTEM

Fuel processing system



FPS converts fuel into a hydrogen-rich, sulfur-free, gas for CSA

CSA provides required heat for the endothermic fuel processing steam reforming

PURECELL® FUEL CELL SYSTEM

Mohegan Sun facility

Maximum Efficiency = $\left(\frac{200+88+132}{494}\right)$ **= 85%**

Efficient use of high grade and low grade heat

Customer needs heating all year long

Effective integration

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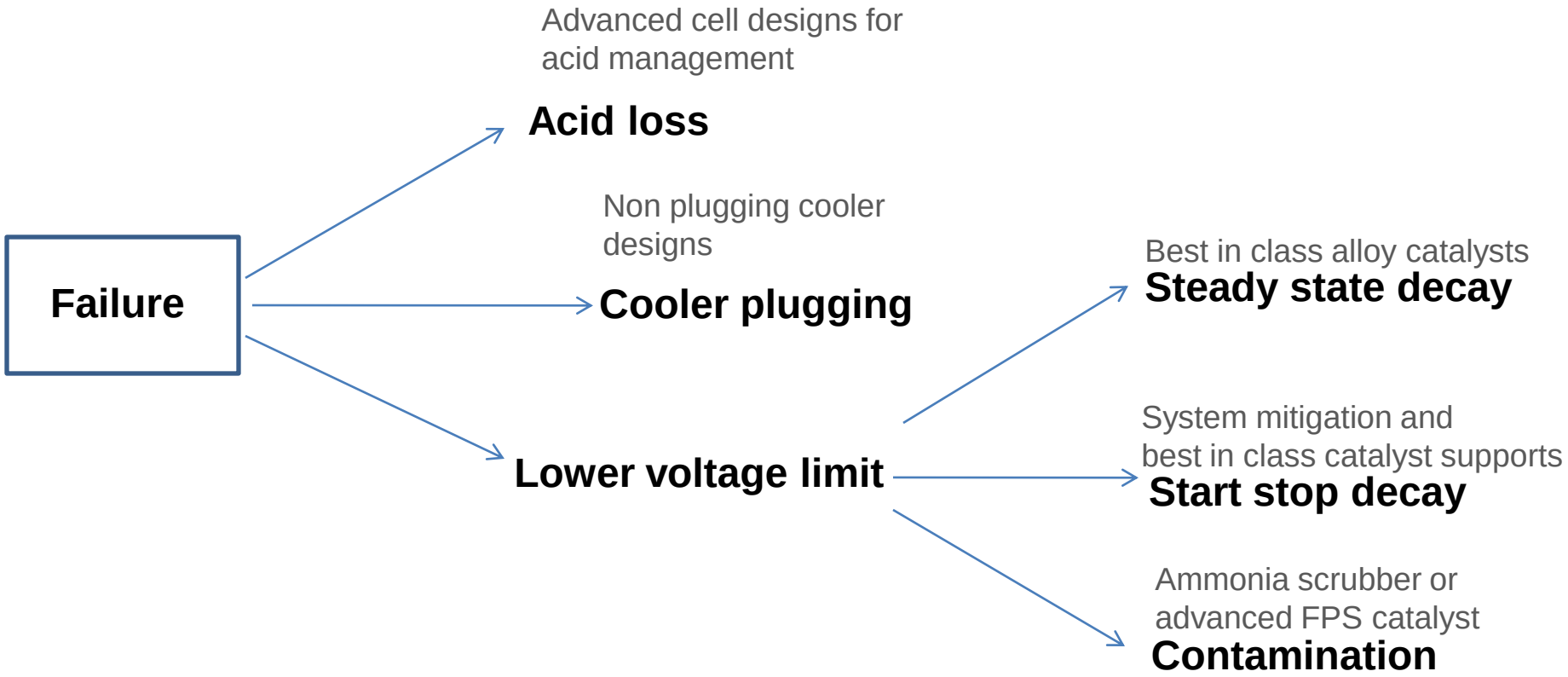
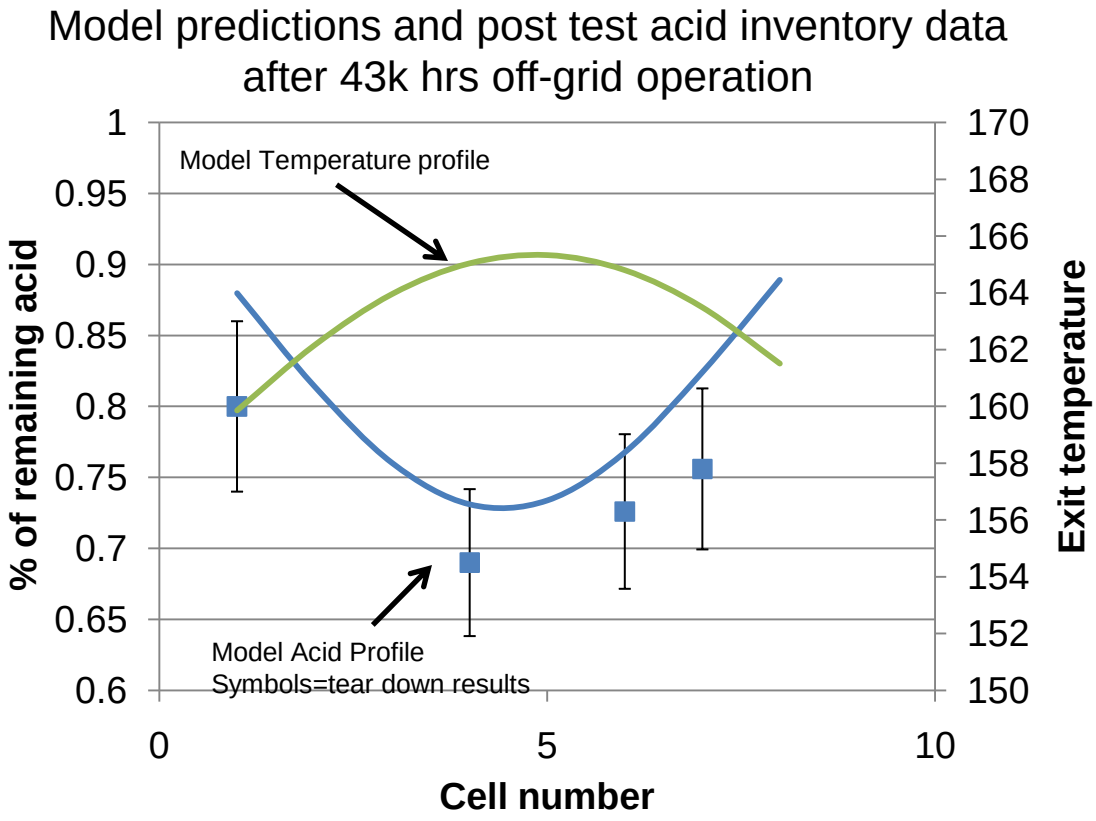
PURECELL® FUEL CELL SYSTEM

Failure modes



PURECELL® FUEL CELL SYSTEM

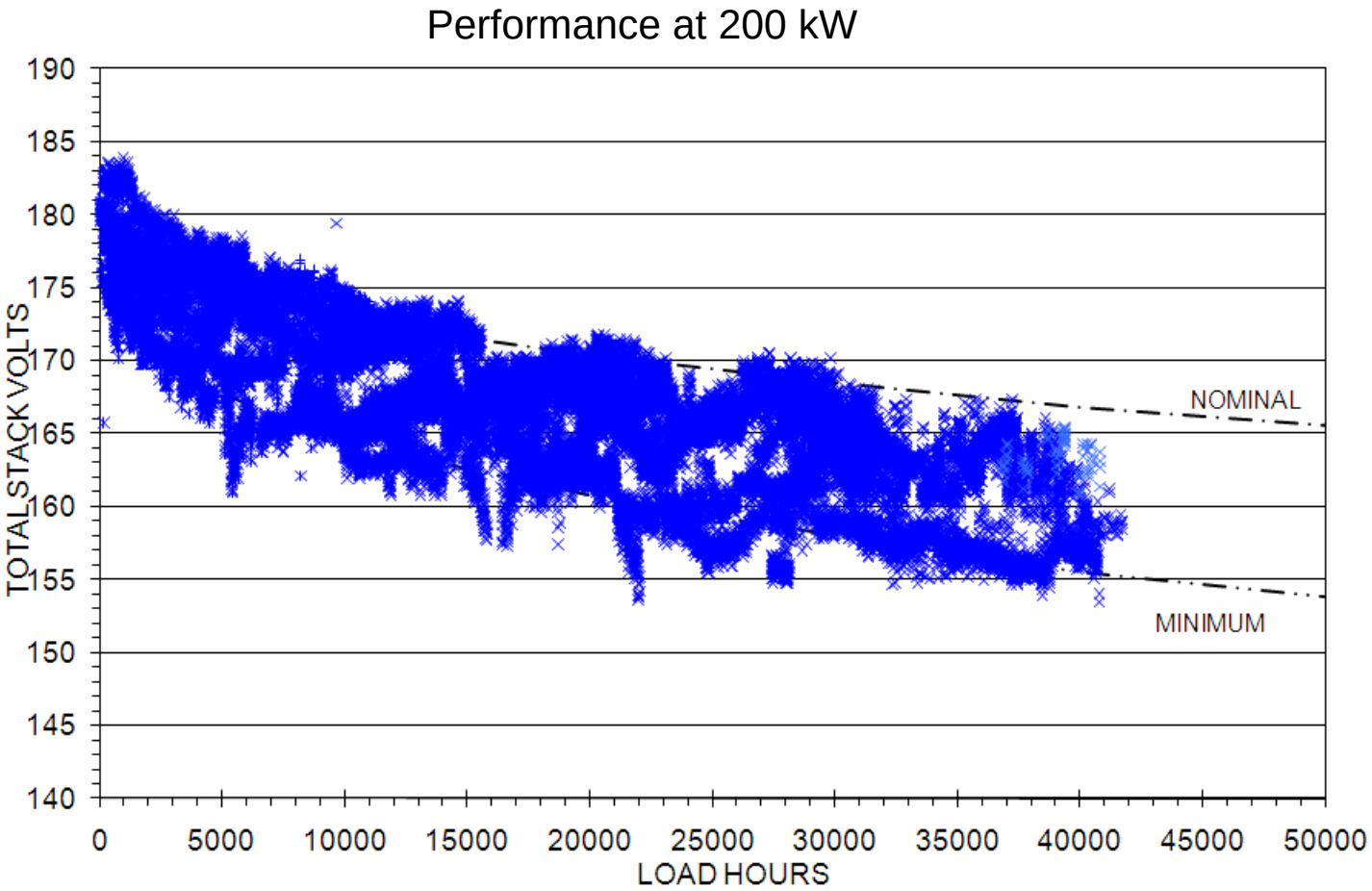
Post test acid inventory



Understanding of acid movement fundamentals is the key enabler for product performance

PURECELL® FUEL CELL SYSTEM

Fleet decay performance



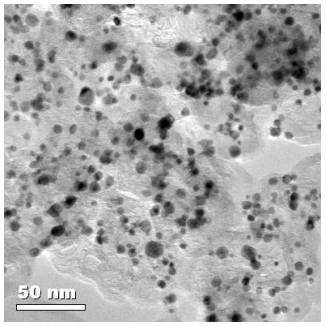
Performance band due to operational and site characteristics

PURECELL® FUEL CELL SYSTEM

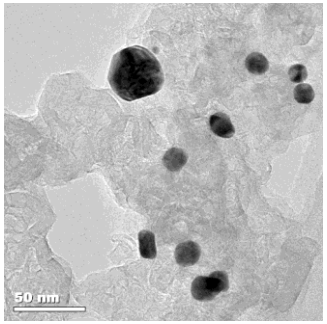
Catalyst decay

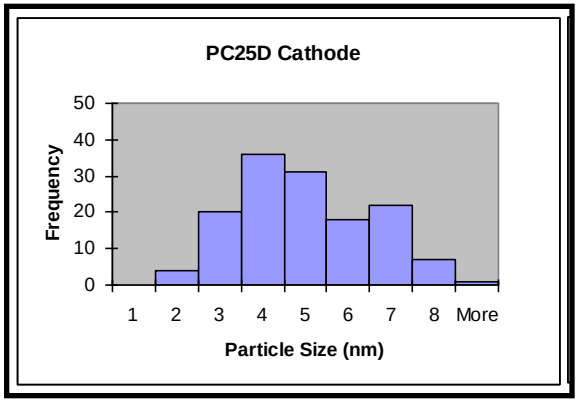
Analysis of field operated components demonstrates catalyst agglomeration

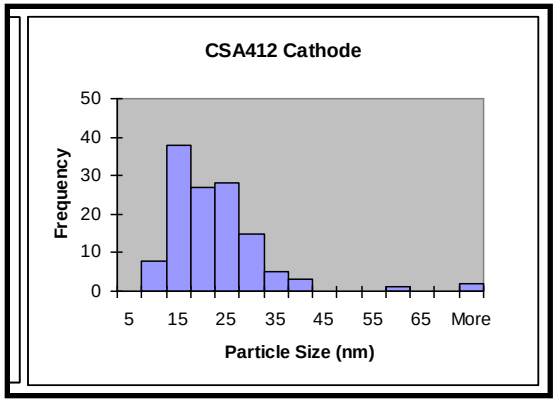
New



43,000 hr







ECA: 50 m^2/g
Average diameter: 4.5nm

ECA: 6.5 m^2/g
Average diameter: 19.9 nm

ECA=Electrochemical area

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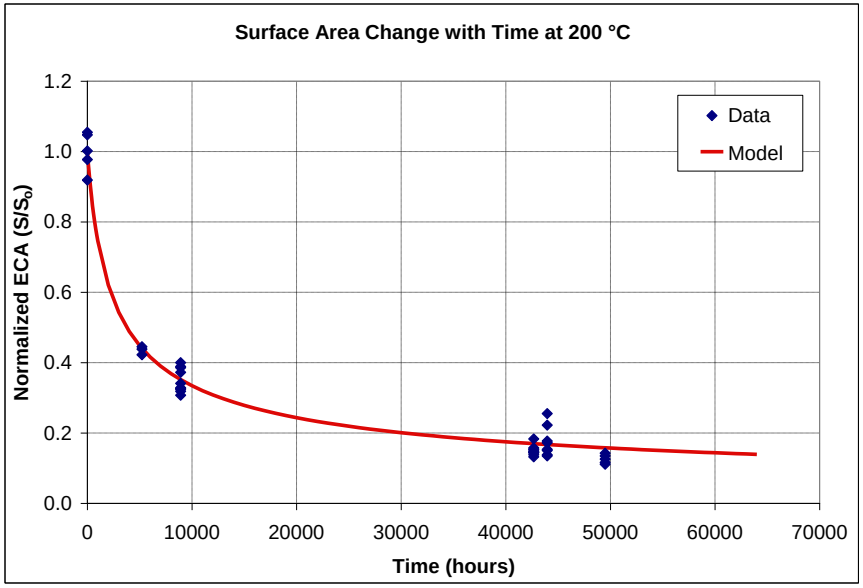
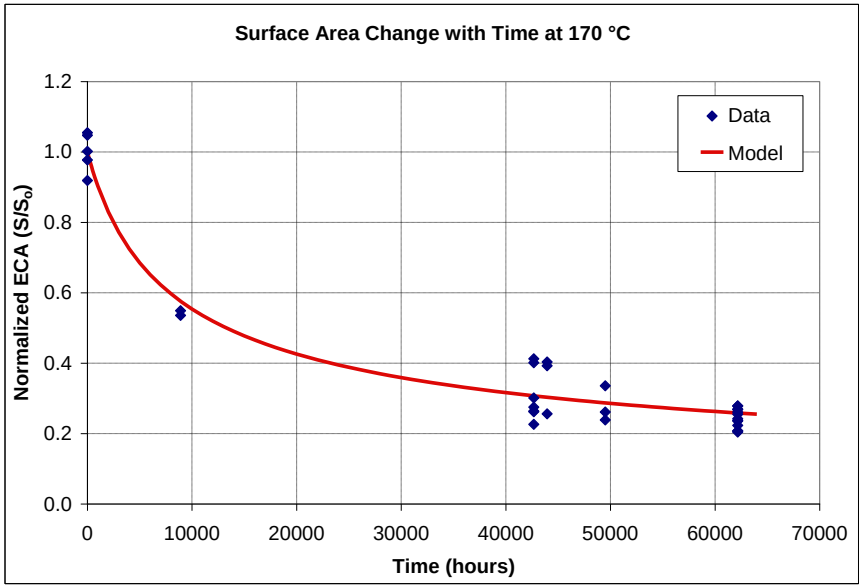
PURECELL® FUEL CELL SYSTEM

Surface Area with Time

200 °C Data vs. Model



170 °C Data vs. Model



Modeling accounts for catalyst decay mechanisms

Good model correlation with field data out to 60,000+ hours

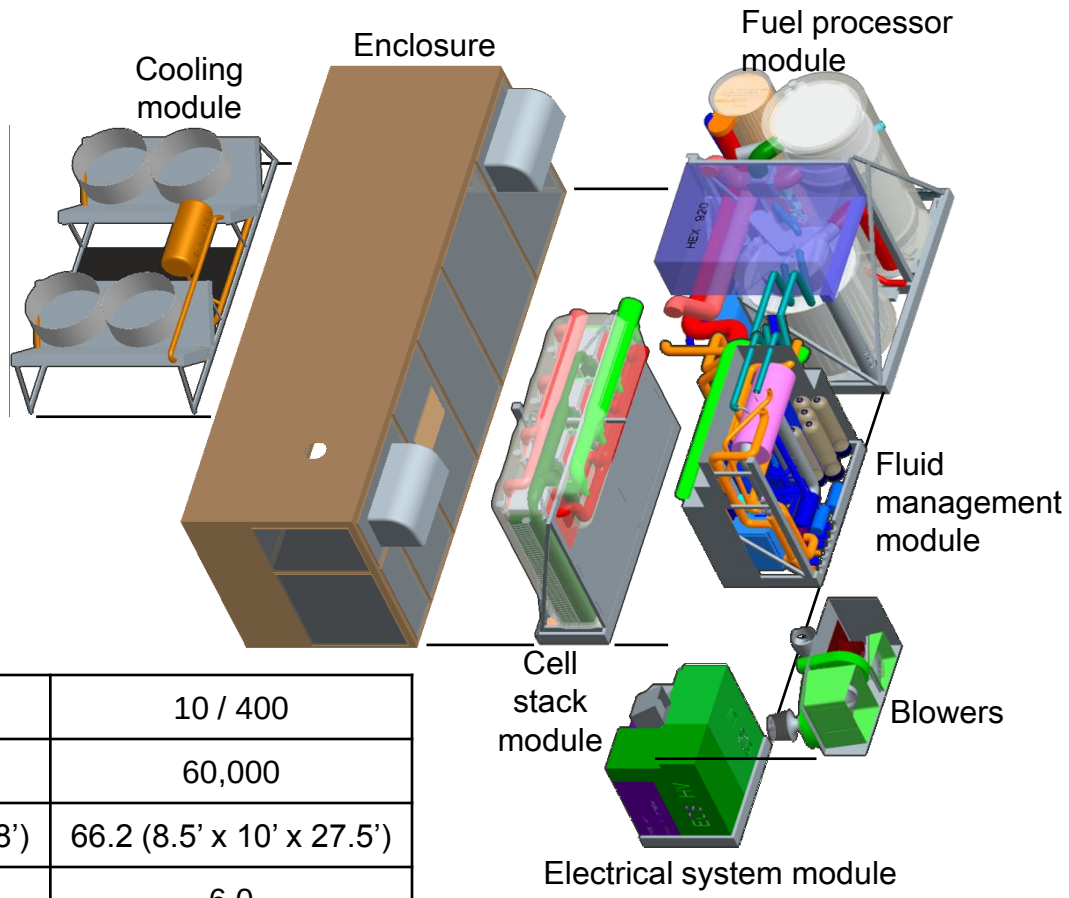
PURECELL® FUEL CELL SYSTEM

Next generation powerplant

Approach

Collaborative designs

Supply chain module sourcing



Life (years) / Power (kW)	5 / 200	10 / 400
Weight (lb)	40,000	60,000
Volume (m^3)	48.4 (9.5' x 10' x 18')	66.2 (8.5' x 10' x 27.5')
Power density (kW/m^3)	3.9	6.0

PureCell™ **Model 200**

PureCell™ **Model 400**

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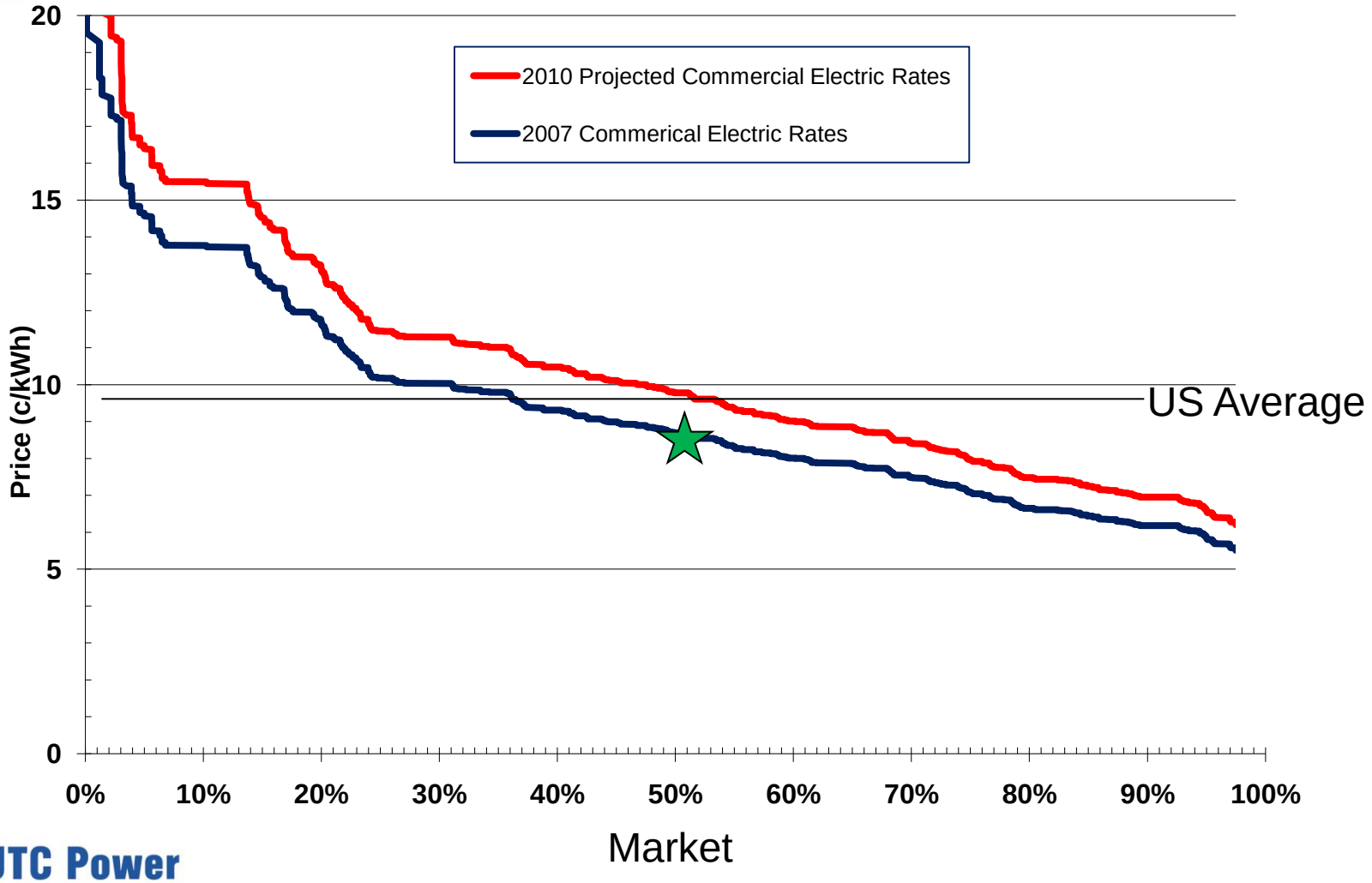
DISTRIBUTION OF U.S. GRID RATES

2007 and 2010 (projected) commercial rates



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PURECELL® FUEL CELL SYSTEM
Summary

PAFC offers high durability and total efficiency

Durability performance is driven by fundamentals based modeling and post tear down analysis correlation

PAFC has been a technical success in many market segments and applications

Next generation 400 kW powerplant leverages sound technology to close gaps to true commercialization

However, first cost is still a challenge…..