Intelligent Energy Holdings

WORLD ECONOMIC FORUM
TECHNOLOGY PIONEER 2006

Energy Materials: Meeting the Challenge
9th October 2008

PEM Fuel Cells
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INTELLIGENT ENERGY

Clean Fuel and Power

Intelligent Energy

Intelligent Energy develop PEM Fuel Cell technology for a range of application including combined heat and power, transport and telecoms.

- 1988
  - Start of fuel cell development R&D at Loughborough University. Departments of Chemistry and Aeronautical and Automotive engineering
- 1995
  - Advanced Power Sources Ltd formed as a University spin-out company by 4 members of staff
- 2001
  - Intelligent Energy acquires Advanced Power Sources
  - 25 employees, Loughborough facility and London office
- 2008
  - 90+ employees, main site in the Innovation Centre on Loughborough University Campus.

Selected applications

Motive

In the air

On four wheels

On two wheels

DG and Portable

UPS systems (telecoms)

Remote power

Domestic and distributed power

PEM Stack Range

Air Cooled

AC32-24
Power: 250W
Size: 66 x 112 x 86
Weight: 0.9kg

AC32-48
Power: 450W
Size: 66 x 112 x 151
Weight 1.5kg

AC64-48
Power: 900W
Size: 66 x 192 x 151
Weight: 2.5kg

Evaporatively Cooled

EC200-48
Power: 4.5kW
Size: 110 x 154 x 194
Weight: 16kg

EC200-192
Power: 20kW
Size: 290 x 154 x 194
Weight: 32kg

EC600-336
Power: 75kW
Size: 550 x 440 x 194
Weight: 140kg

Air Cooled Stacks and Modules

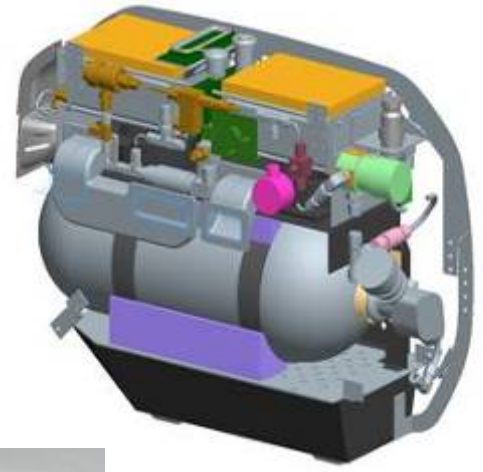
20W – 1kW (2kW+ multiple stacks)

- **Application coverage for small vehicles, mini UAVs, portable power:**
- **Requires minimal balance of plant**
- **Can be packaged with H2 supply and control system as 'slot-in /slot-out' power module**
- **Over 8,000 hour durability**

The ENV motorbike

The world's first purpose–built fuel cell powered motorbike

ENV - incorporating Intelligent Energy unique engine technology

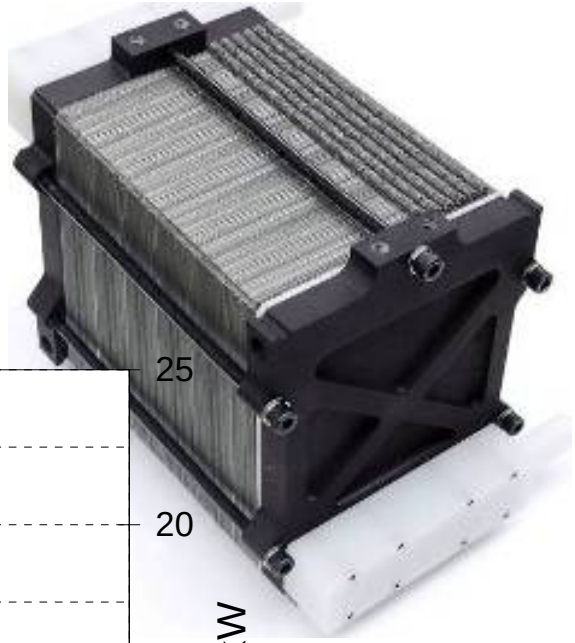


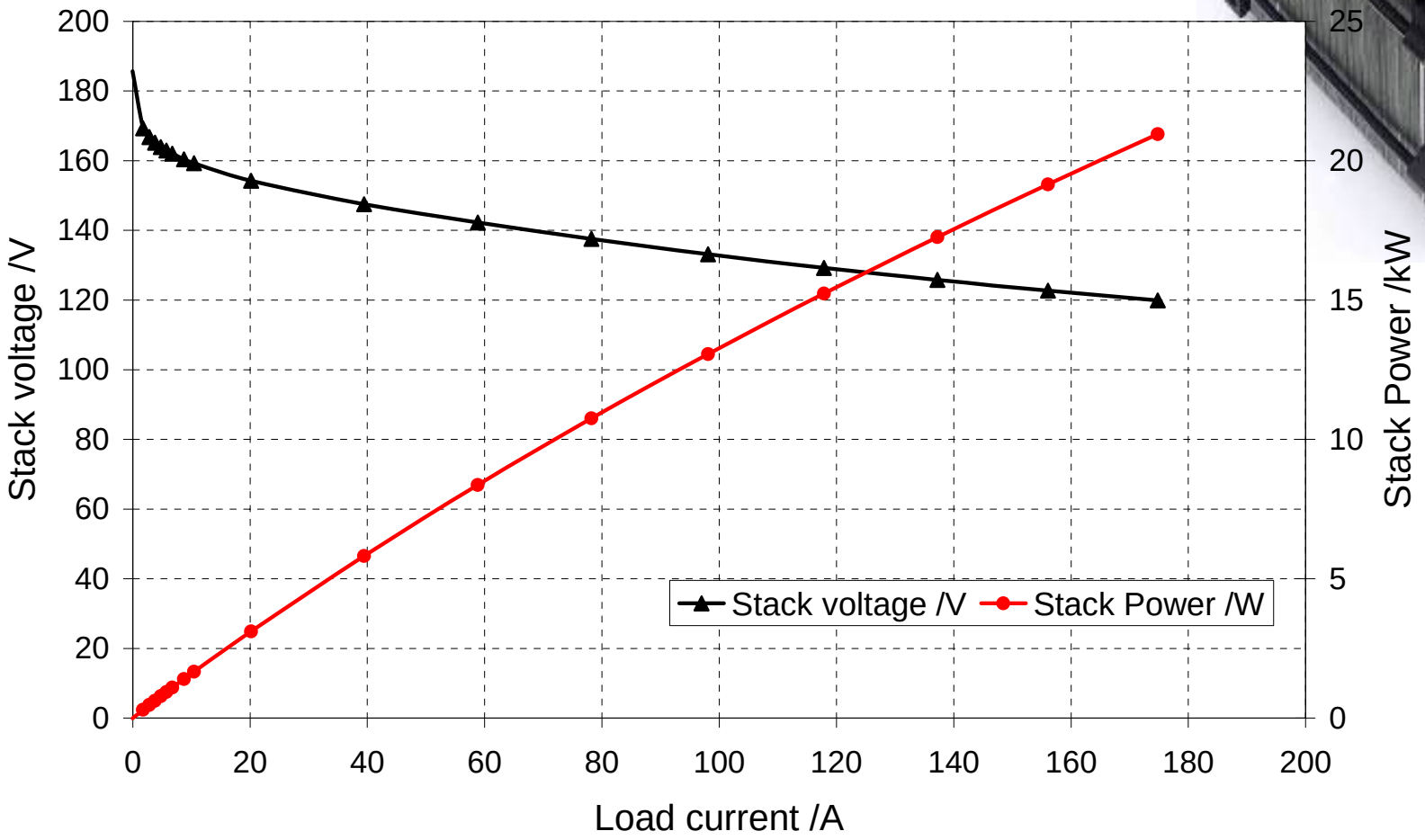
- and now powering Suzuki

High power stacks and systems

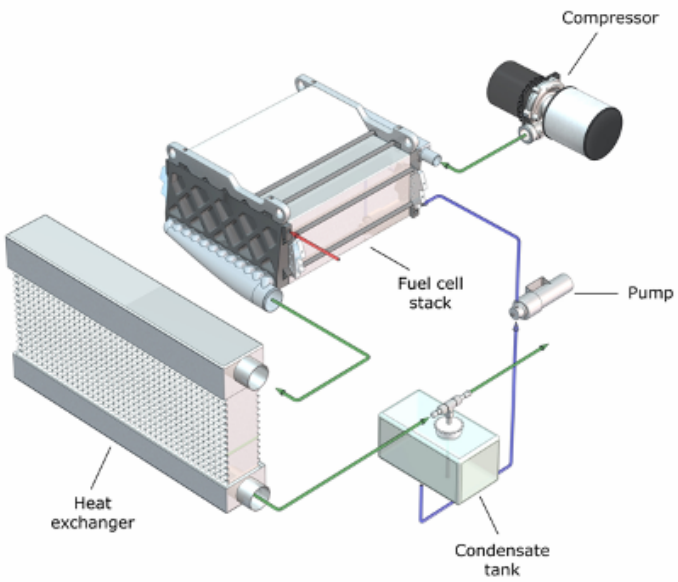
20kW PEM Fuel Cell Stack

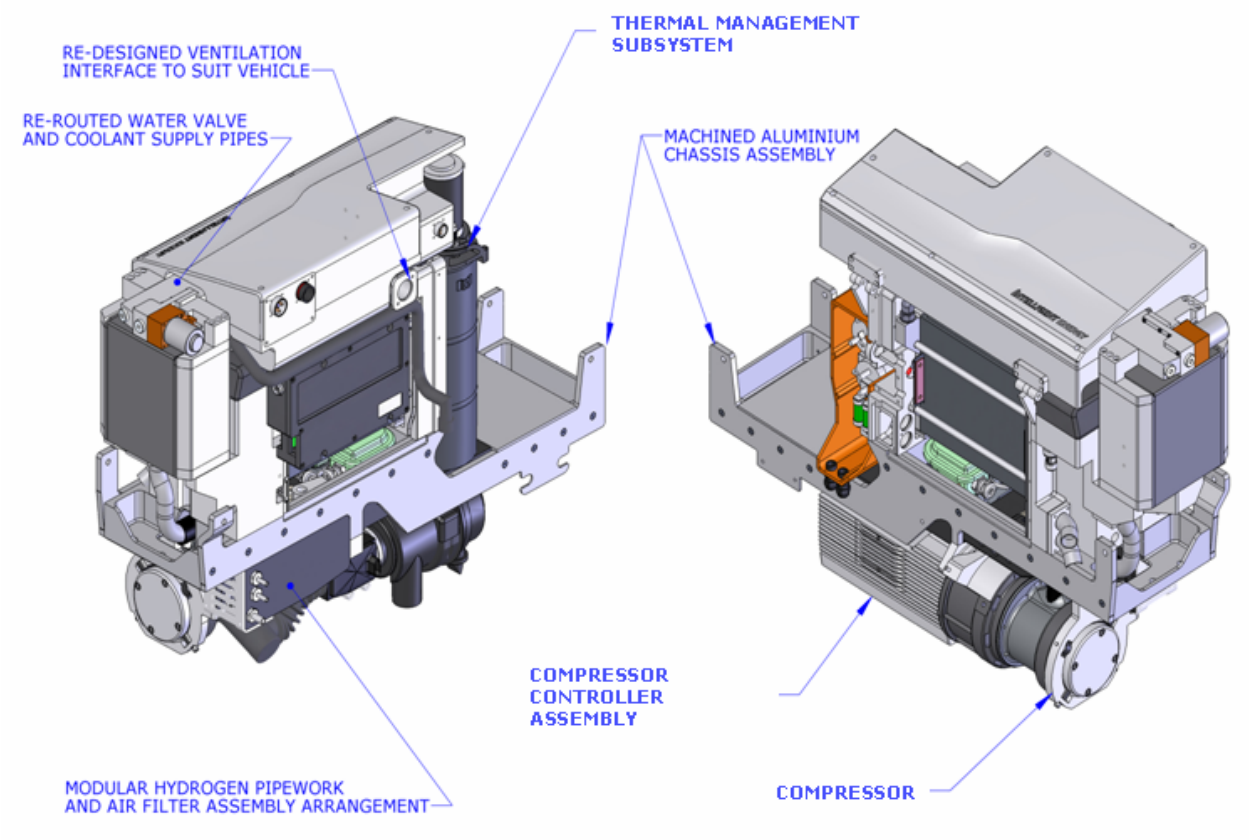
EC200-192, 290x154x194mm, 32kg





Fuel cell system design





Case Study: H2Origin

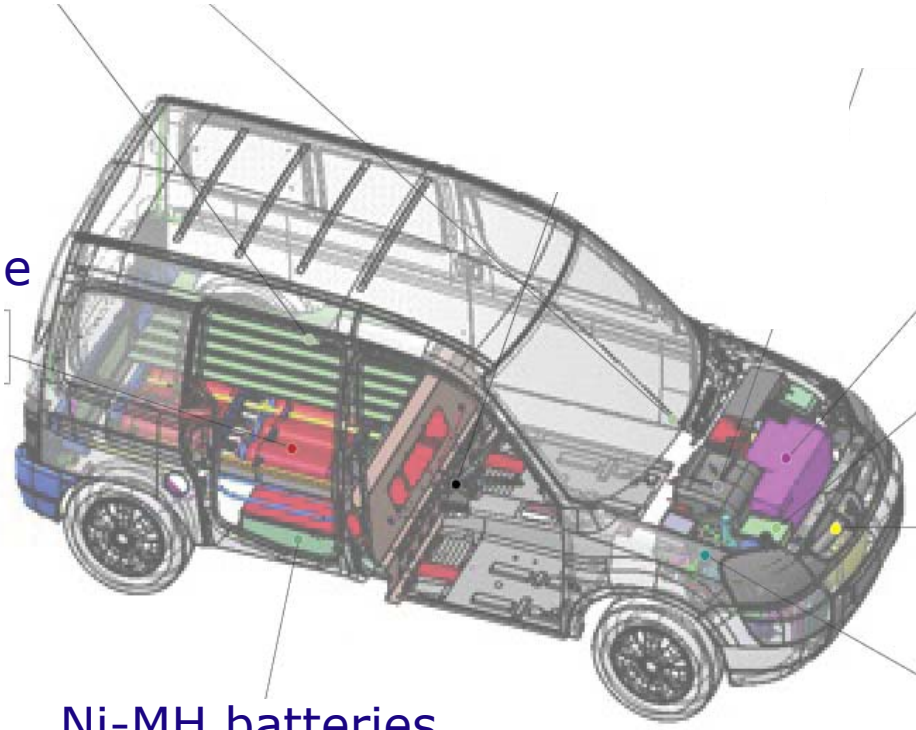
- H2Origin – an electric urban delivery vehicle with a hydrogen fuel cell system
- Programme supported by the Technology Strategy Board

INTELLIGENT ENERGY Clean fuel and power *	Project leader Fuel cell power systems
PSA PEUGEOT CITROËN	Volume manufacturer Experience in electric and fuel cell vehicles
prodrive *	Interface electronics

* Received funding from Technology Strategy Board

System in H2Origin

H2Origin architecture

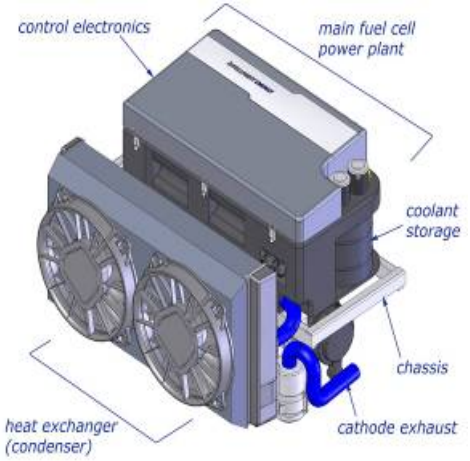


System in Vehicle

Fuel cell London taxi

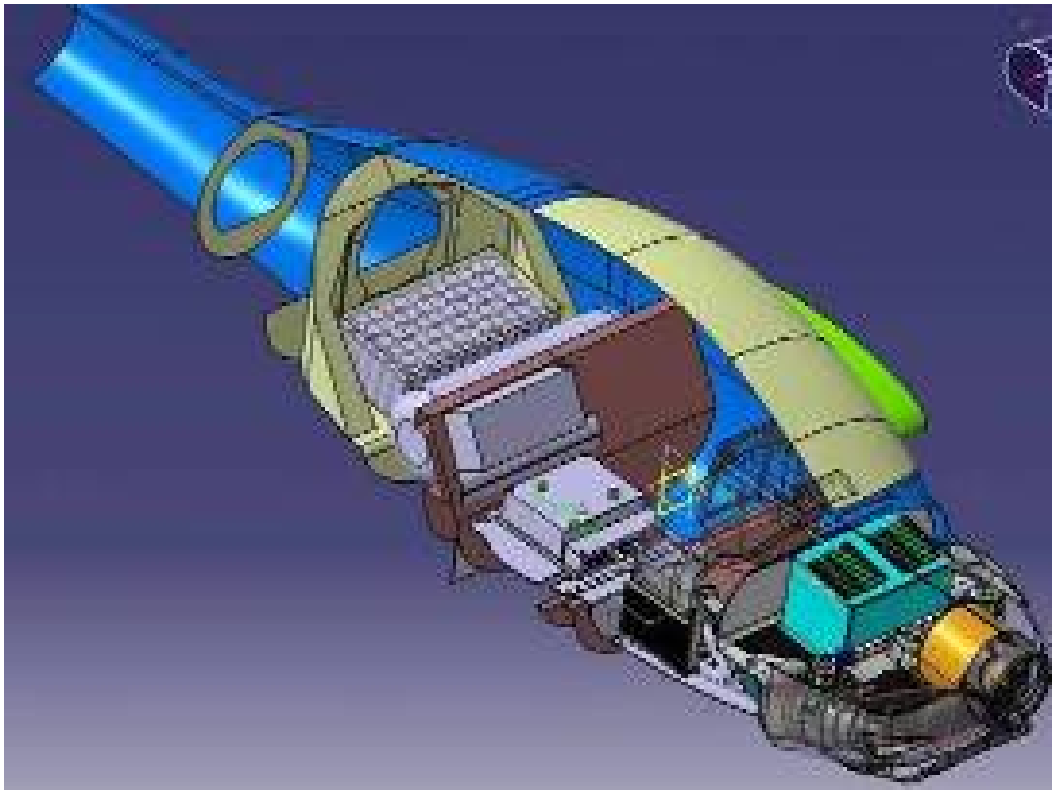
Integrate 30kW PEM fuel cell 90kW hybrid powertrains into LTI TX4 taxis.

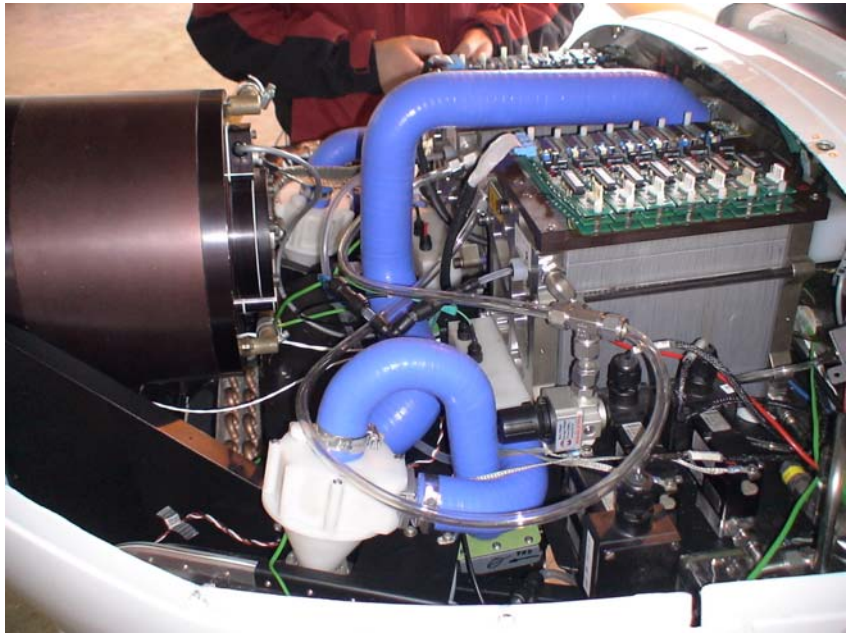
Programme supported by the Technology Strategy Board

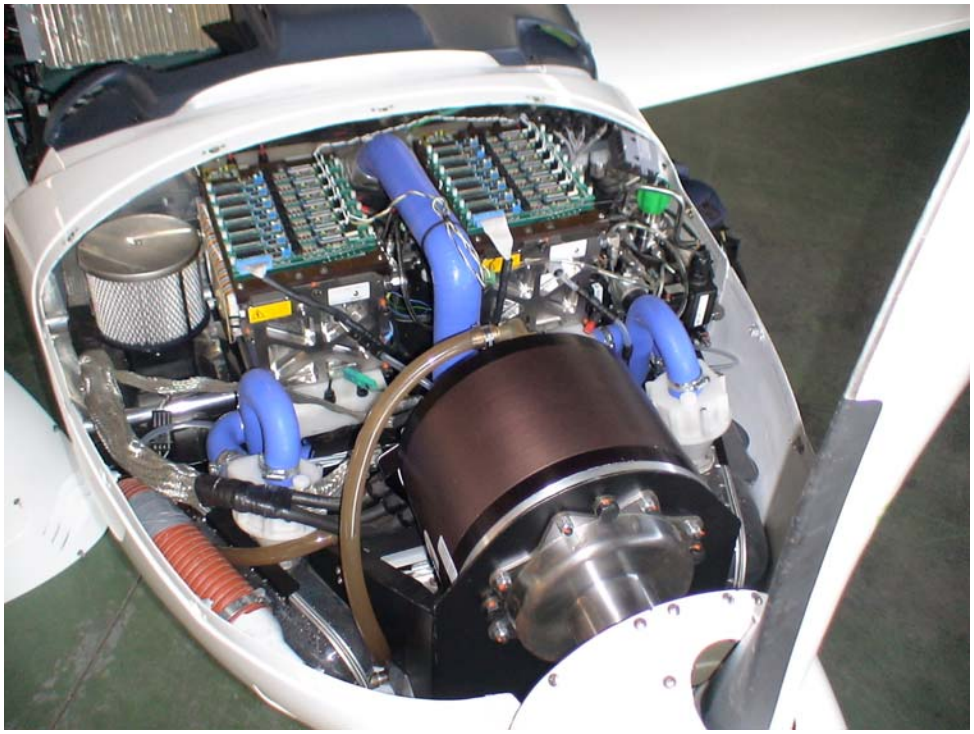


30kW fuel cell system (preliminary)		
Performance	Net power	30.0kW
	Efficiency	50% lhv
	Output	240 to 400V DC
	Noise	TBC
Fuel	Hydrogen	99.99% pure
	Pressure	3.0 barg
	Consumption	<360 SLPM
Physical	Length x width x height	TBC
	Ambient temperature range	-20°C to 40°C
	Mass	TBC

Ultra low emission electric aircraft

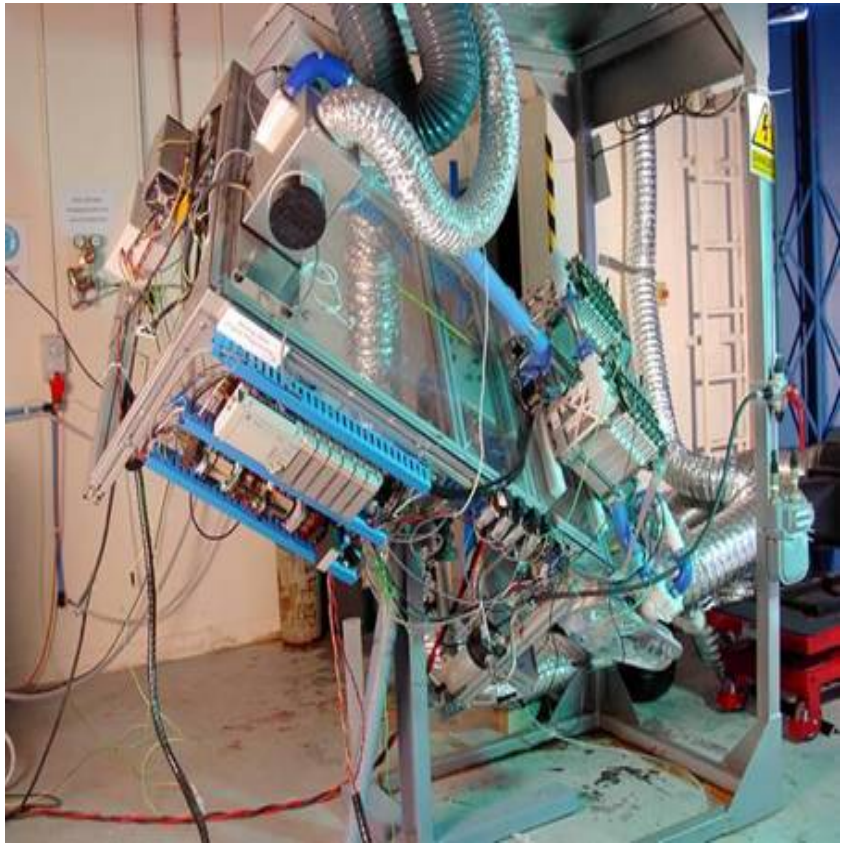


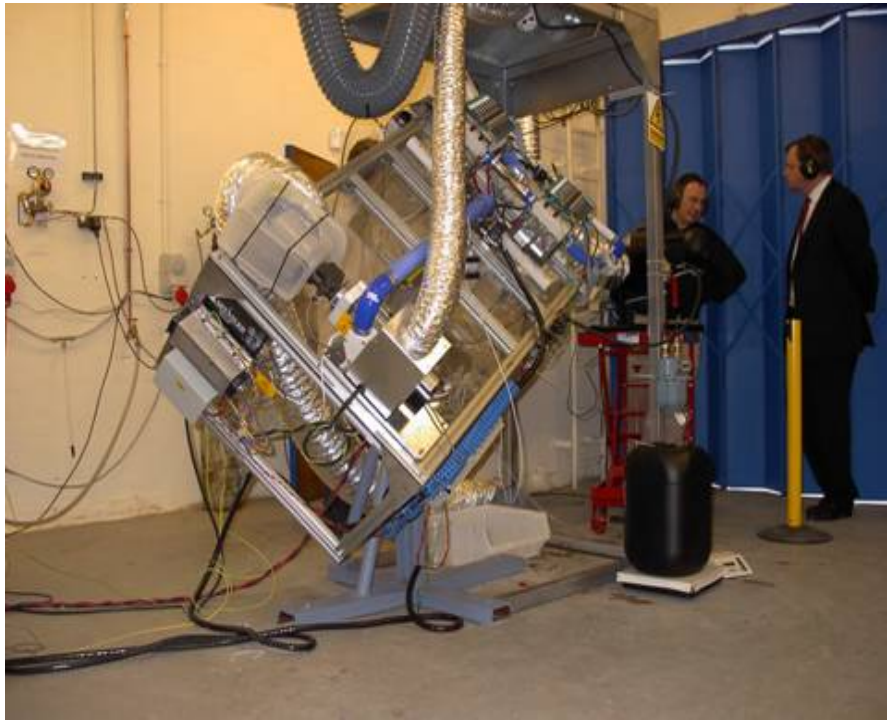




Fuel cell system operation

Maximum pitch & lateral inclination

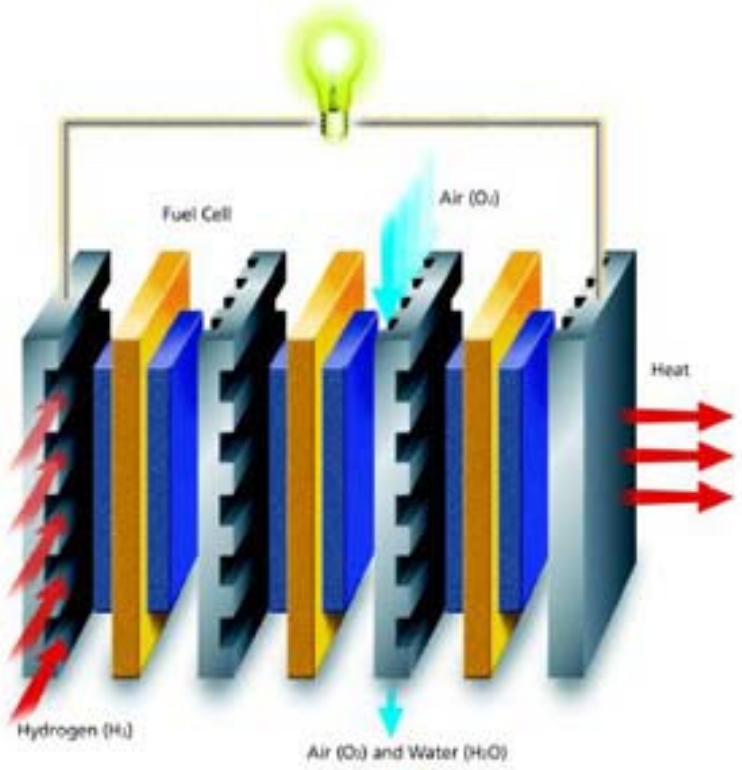




Materials selection

Key component of a stack

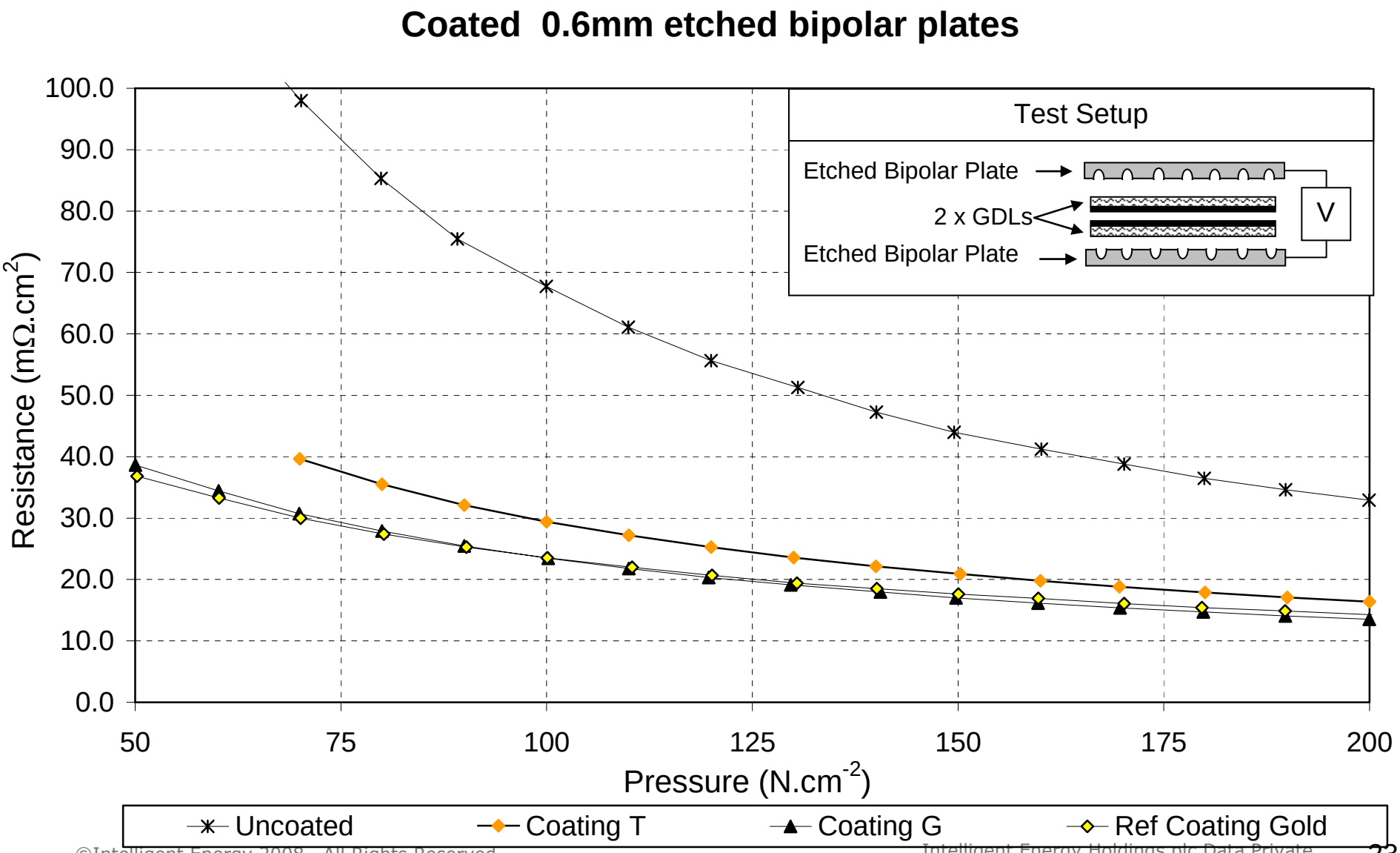
- Membranes - Typically Perfluorinated sulfonic acid (PFSA)
- Catalyst - Primarily Pt alloy based
- Gas diffusion layer – Carbon paper or cloth
- Bipolar plates – Graphite or metallic



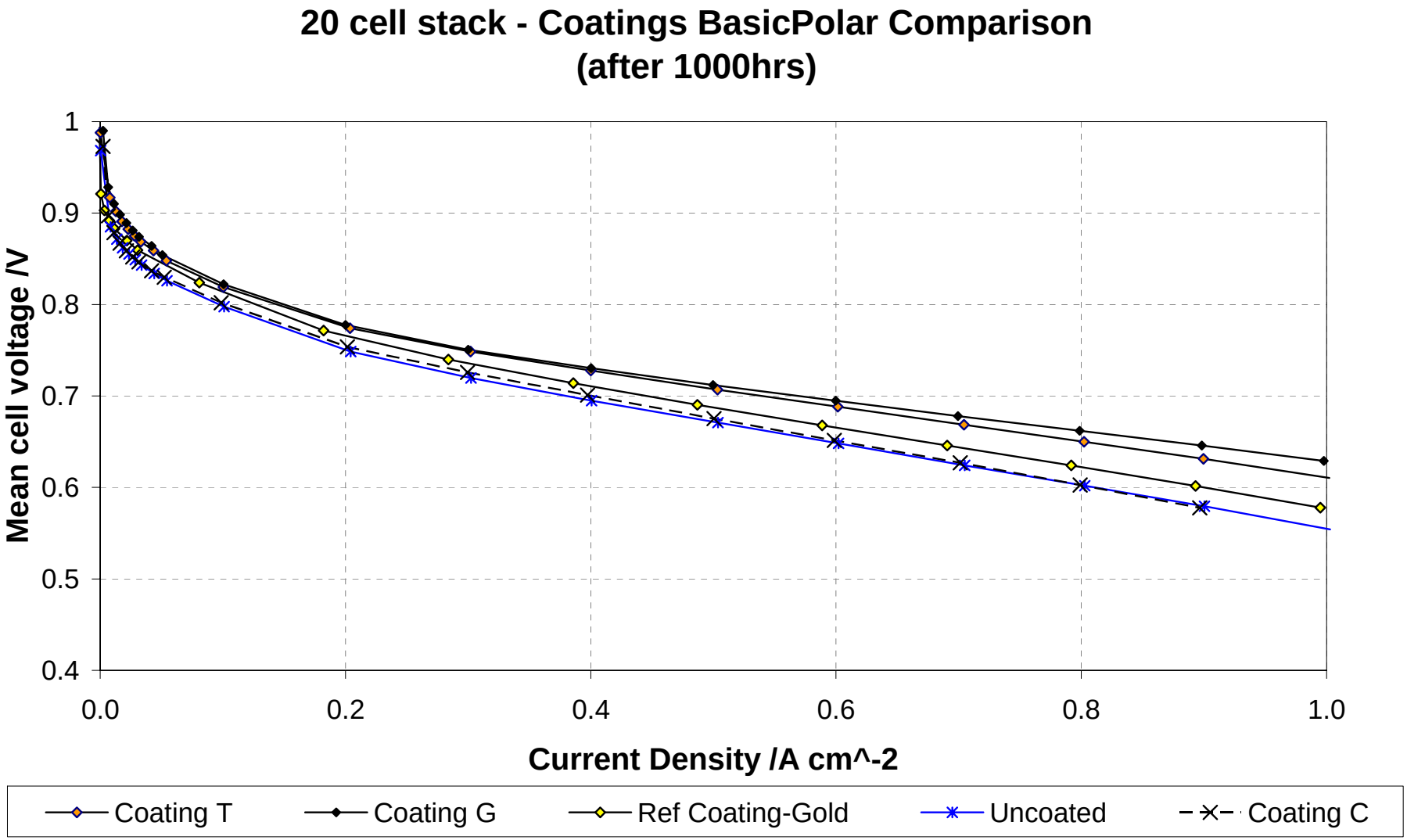
Bipolar Plate

- Present EC stack uses 0.6mm Stainless Steel Bipolar Plates
- Plate mass is approximately 110g,
  - typical stack 192 cell - 21kg for BP Plates
- Next generation pressed Stainless Steel plates 0.1mm thick
  - Plate mass 27g, 192 stack 5.2kg for BP Plates
  - Pressed SS plates amenable to mass production

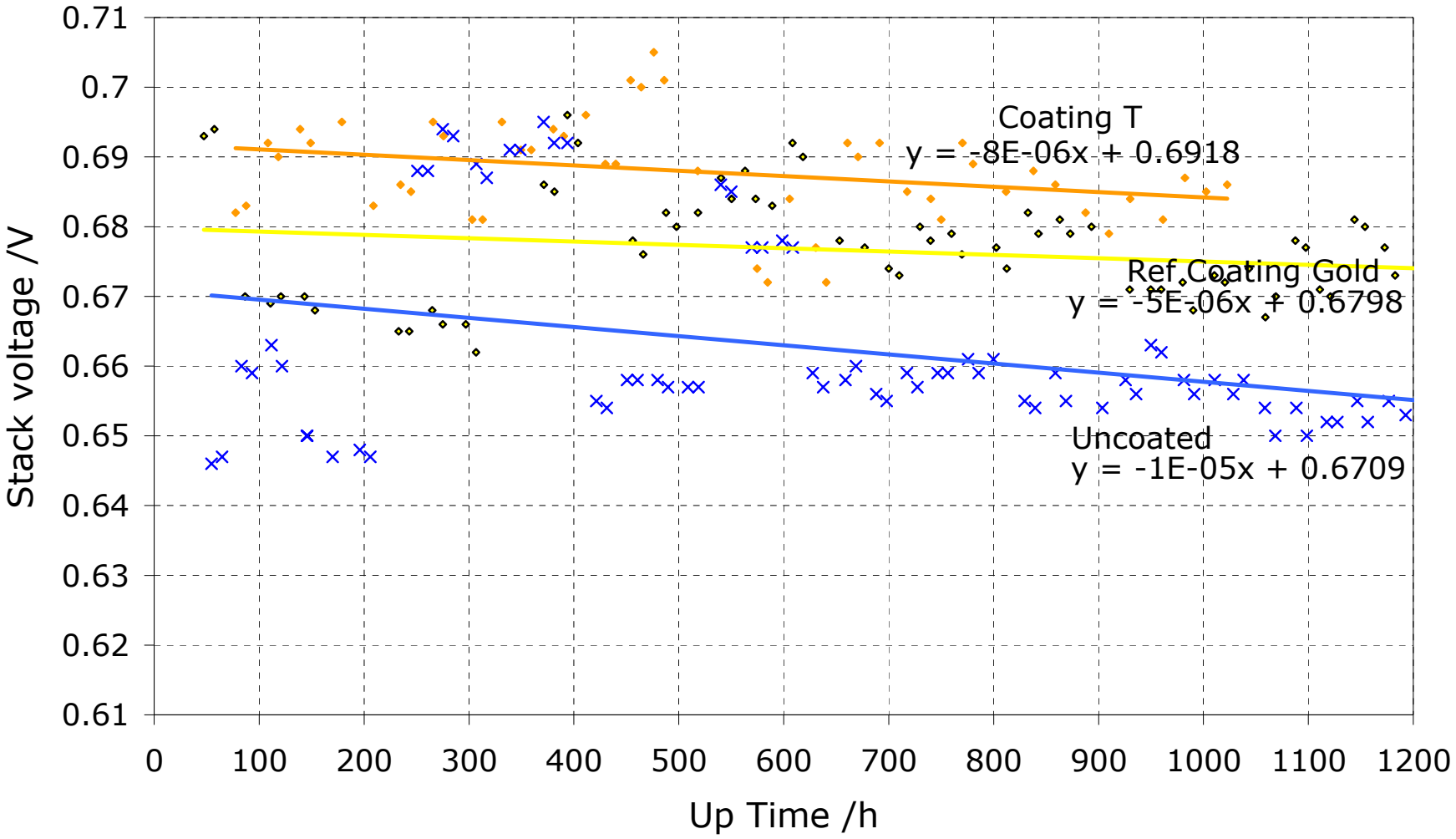
Bipolar Plate



Bipolar Plate



Influence of coating on durability in 20 Cell Stack



Summary

Bipolar plate need to have:

- High electrical conductivity
- Low gas permeability
- High corrosion resistance
- Sufficiently strong
- Have low thermal conductivity
- Low cost

- MEA can be contaminated with Fe, Cr and Ni from metallic plates

- Coating such as noble metals, nitride- or carbide-based alloys can improve corrosion resistance and improve electrical conductivity
- Methods such as CVD and PVD are commonly used to apply coatings
- Selection of plate material will depend on target application