PEM ELECTROLYSER DEGRADATION MECHANISMS AND PRACTICAL SOLUTIONS
MARCH 2013

ITM POWER
Energy Storage | Clean Fuel

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ITM POWER DESIGNS AND MANUFACTURES HYDROGEN ENERGY SYSTEMS FOR ENERGY STORAGE AND CLEAN FUEL PRODUCTION

"I want to drive to my local petrol station and fill up with 50 Litres of wind..."

Peter Hoffmann

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COMPANY HISTORY

ITM Power Plc was the first Fuel Cell and Hydrogen Company to be listed on the London Stock Market. The company has successfully made the transition from an R&D company to a product supplier and is rapidly engaging with an increasing number of blue chip clients.

£10m Aim Floatation

Placing of 20,000,000 Ordinary Shares at a price of 50p

06/04

£29m Secondary Fundraising

Placing of 9,189,235 Ordinary Shares at 320p each

05/06

Appointment of Roger Putnam

Roger Putnam takes position of independent Non-Executive Director

05/06

Clean Equity Monaco Award

Awarded for excellence in the field of Environmental Technology Research

02/08

Launch of Green Box

Green Box single vehicle domestic electrolyser launched in London

06/08

New CEO Appointed

Graham Cooley joined ITM Power as CEO in 2009. Prior to that Graham was Business Development Manager in National Power Plc

06/09

ISO Accreditation

Achieved ISO 9001 for quality management systems; ISO 14001 for environmental management systems and BS OHSAS 18001 for occupational health and safety

12/09

Launch of First Product Range at Hannover

05/10

US Next Energy Home Refueller Design Contract

05/10

First Product Sale and Field Trial

06/10

HFuel Launched at AGM and Open Day

09/10

Lord Freeman Appointed as Non Executive Director

09/10

HPac Product Achieves CE Certification

01/11

High Power Density FC

02/11

HOST Launch at Stansted

03/11

HFuel UK Compliance

03/11

Sale of First HFuel

04/11

ITM Power GmbH Established

07/11

HFuel Cost Structure

11/11

EcoIsland Agreement

11/11

First Major EU Grant

11/11

HFuel CE Compliance

01/12

M&S Agreement

01/12

UKH2Mobility Initiative

01/12

Agreement with Boeing

02/12

MW Energy Storage

02/12

Approval to Operate and Sell HFuel in Germany

04/12

Hyundai Joins HFuel Here

04/12

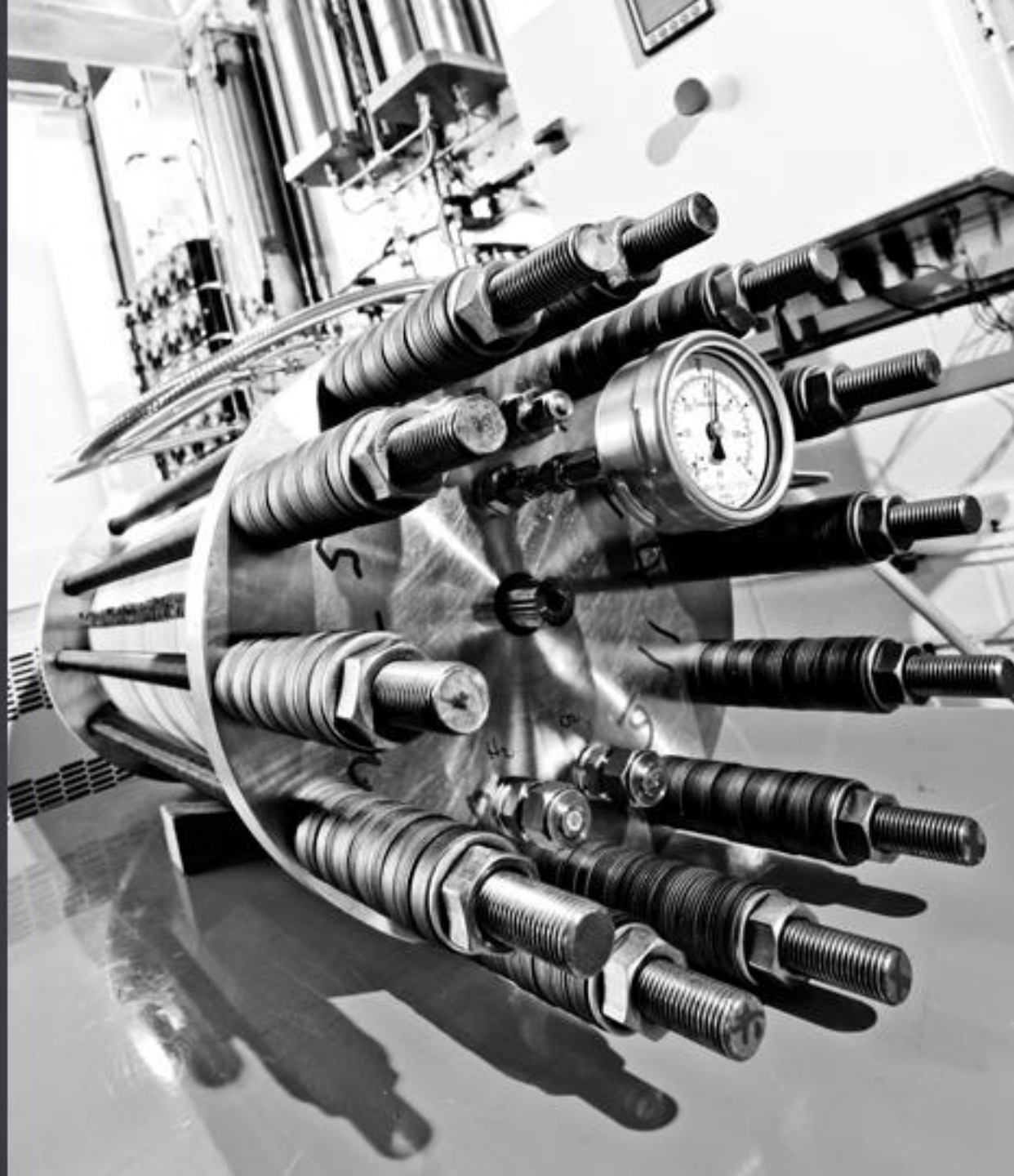2004   2005   2006   2007   2008   2009   2010   2011   2012
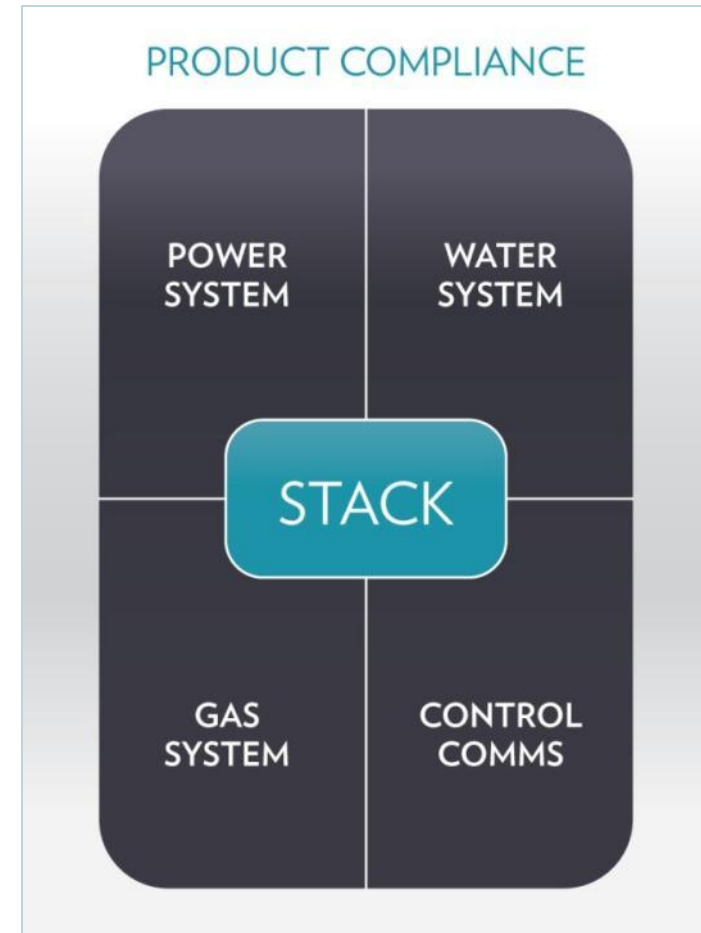
TECHNOLOGY

HYDROGEN ENERGY SYSTEMS FOR ENERGY STORAGE AND CLEAN FUEL PRODUCTION

HYDROGEN ENERGY SYSTEMS

Customers buy products which are complete systems

- Power system
- Water system
- Gas system
- Control and communications system
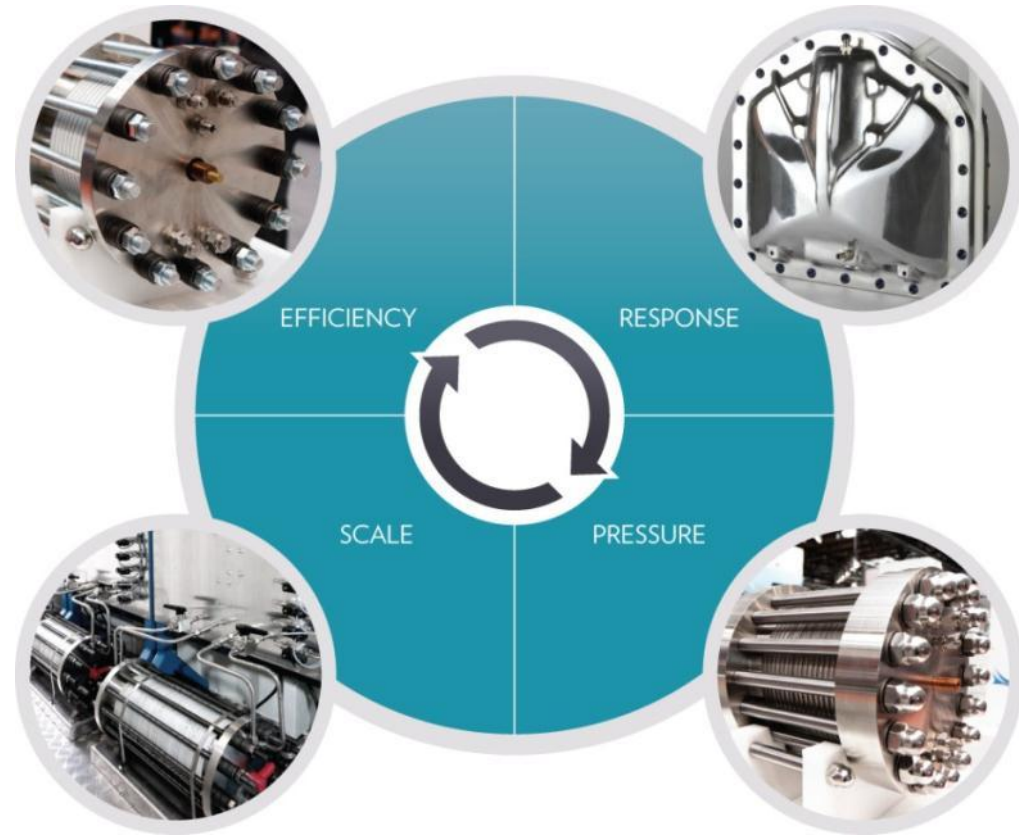- At the heart of each system is a stack

PRODUCT COMPLIANCE

POWER SYSTEM | WATER SYSTEM
STACK
GAS SYSTEM | CONTROL COMMS

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CORE TECHNOLOGY

An electrolyser stack is at the heart of every hydrogen energy system
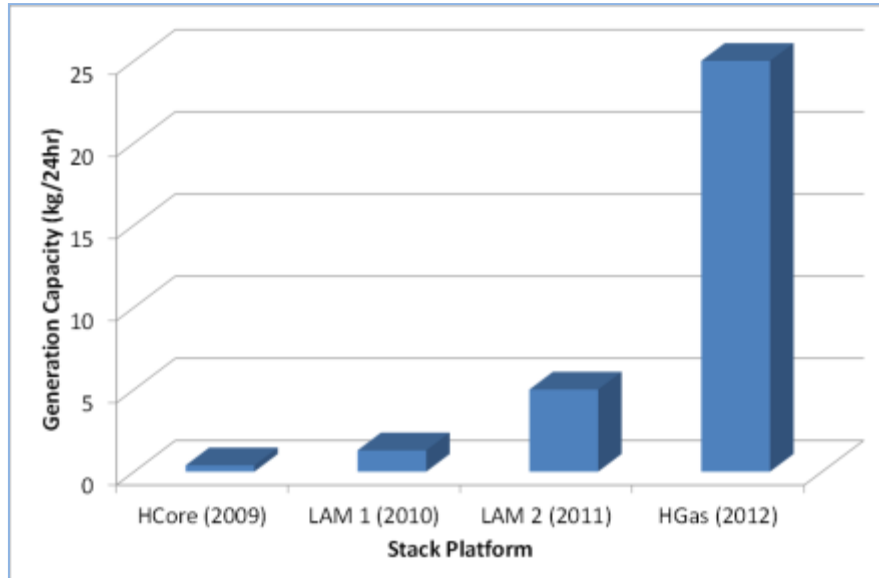
- Efficiency
- Response time
- Scale
- Pressure
- Cost

STACK SCALE UP

The stack is key to reliable scale up

- 2009: HCore;   0.4kg/day
- 2010: LAM1;   1.3kg/day
- 2011: LAM2;   5.0kg/day
- 2012: HGas;   25kg/day

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CE MARKED PRODUCTS

HBOX SOLAR
HPAC 10
HPAC 40
HFUEL

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COMPLIANCE

Product compliance is now an area of considerable expertise

ISO
- ISO 9001
- ISO 14001
- ISO 18001

CE Marking
- PED
- LVD
- MD
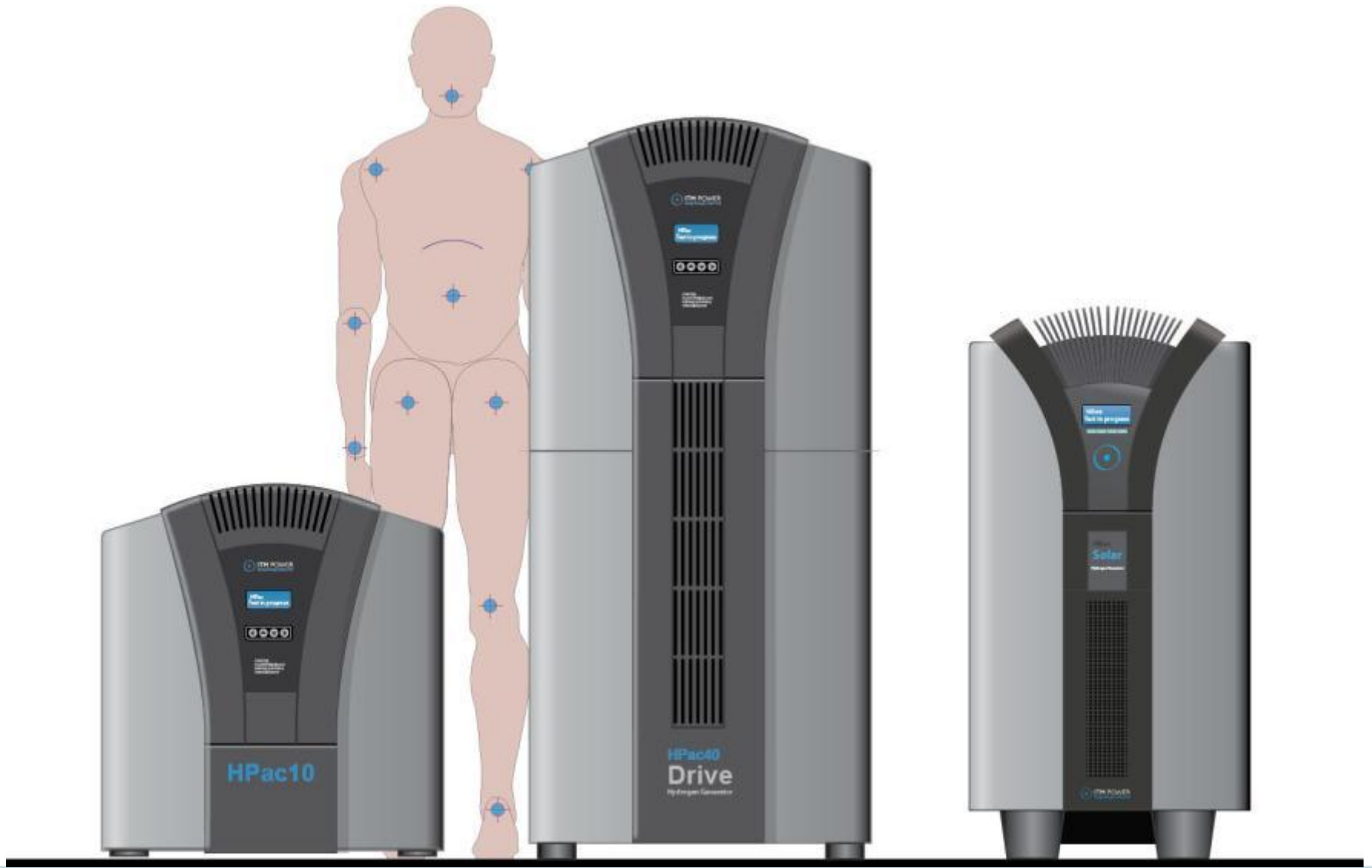- EMC

Compliance
- HAZOPS
- HSE
- Fire Service
- Planning

Product Standards
- BSI PVE 3/8
- ISO/TC 197
- BSI GEL 105
- ISO/TC 105

CE MARKED PRODUCTS

FROM TECHNOLOGY TO PRODUCTS

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HFUEL PLATFORM
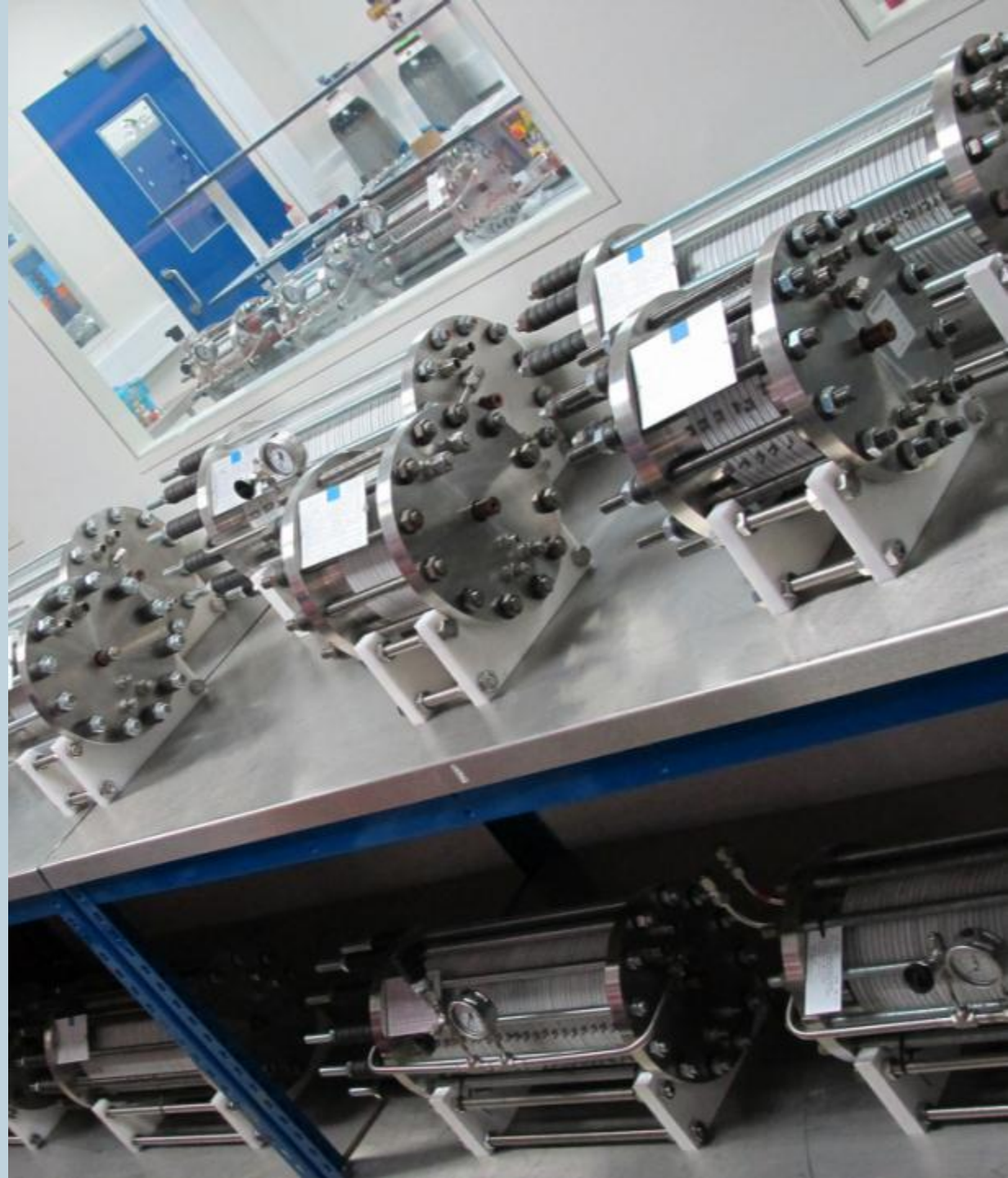
A fully compliant hydrogen refuelling system for small fleets

- From 5kg/day to 400kg/day
- CE compliance achieved for integrated system
- Modular at both stack and container levels

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MEASURING DEGRADATION

STACKS
SYSTEMS
TESTING

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DEGRADATION OF MEMBRANES, CATALYSTS AND MEA'S

- Performed in small scale single cell tests.

- Multiple tests performed on each variation.

- Measured as standard:

  - Voltage rise

  - Electrochemical Impedance Spectroscopy (and other electrochemical techniques)

  - Water analysis (ICP-MS, TOC, Conductivity, pH)

- Allows fundamental development studies

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ACCELERATED DURABILITY TESTING

Lifetime tests are not feasible for the evaluation of new electrolyser materials

- Membrane chemical degradation (Fenton's reagents)

- Three electrode CV cycling (catalyst)

- High current densities

- High temperatures

- Monitoring membrane degradation chemically

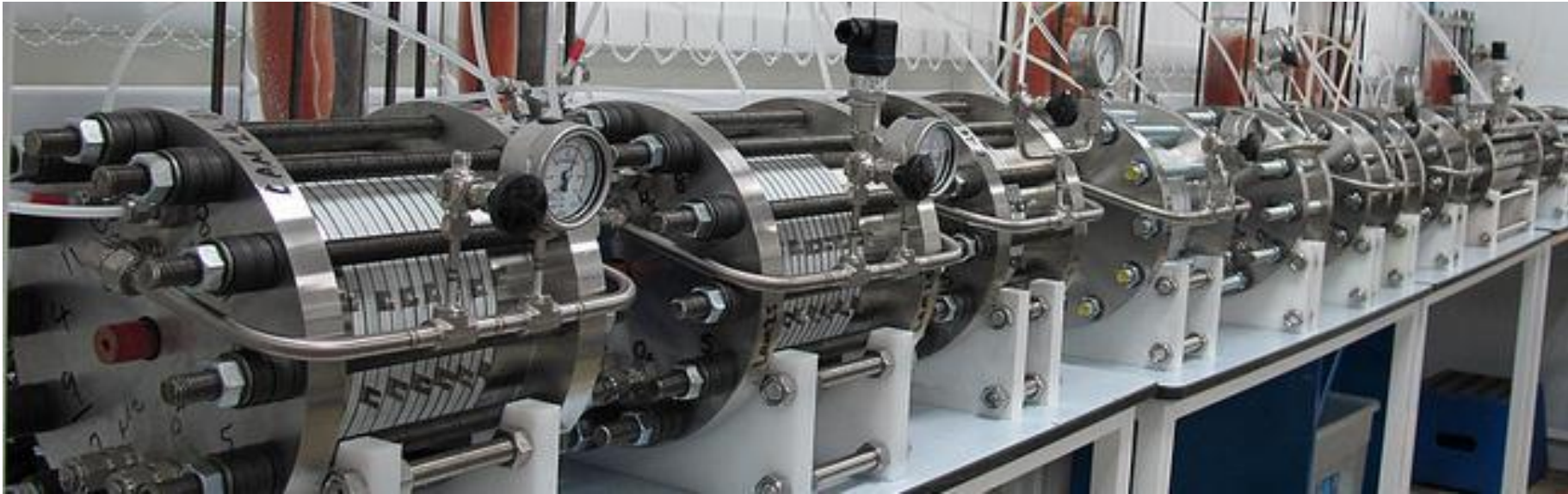- Chemical degradation additives

- Electrochemical corrosion testing
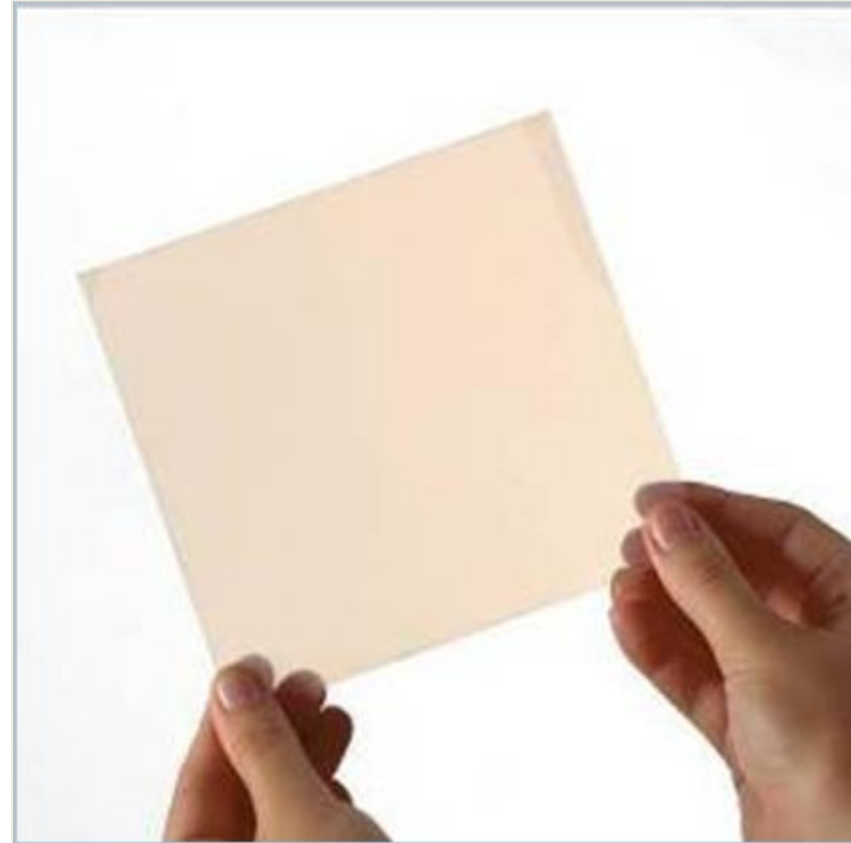
STACK TESTING

- Intermittent operation

- Tests performed at pressure

- Materials of construction tested

- Voltage rise, crossover monitored continuously, water analysis, EIS

- Post mortem analysis

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PRODUCT REFERENCE PLANT

HFuel and the HOST Trials

- 3 hydrogen vehicles
- 21 commercial partners
- Trials throughout the UK & Germany
- Balanced across 7 industrial sectors

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DEGRADATION MECHANISMS

TESTING AND PREVENTION

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POSSIBLE DEGRADATION MECHANISMS

- Catalyst agglomeration

- Membrane (chemical) scission

- Membrane puncture

  - Manufacture

  - Hotspots

  - Mechanical degradation

- Corrosion

- Membrane poisoning
(crosslinking by metal ions)

- Catalyst poisoning

- Balance of plant failure

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CORROSION OF M.O.C.

- Unexpected result (EIS) measured at end of life

- High frequency time constant was current dependent implying failure mode was electrochemical

- Actually due to corrosion of stack components (tunnelling was cause of current dependence)

- Corrosion caused by membrane degradation products

- Solution now implemented on all stacks
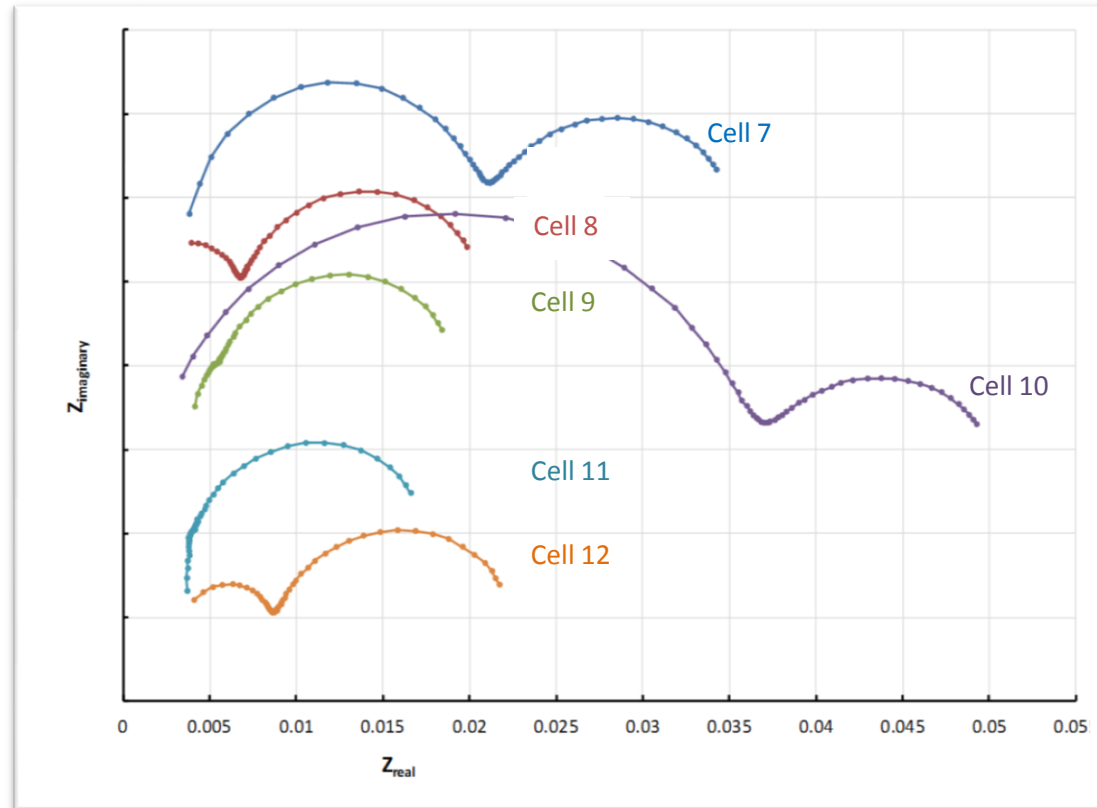
ACCELERATING DEGRADATION

Factors that increase degradation:

- Current Density
- Temperature
- Pressure
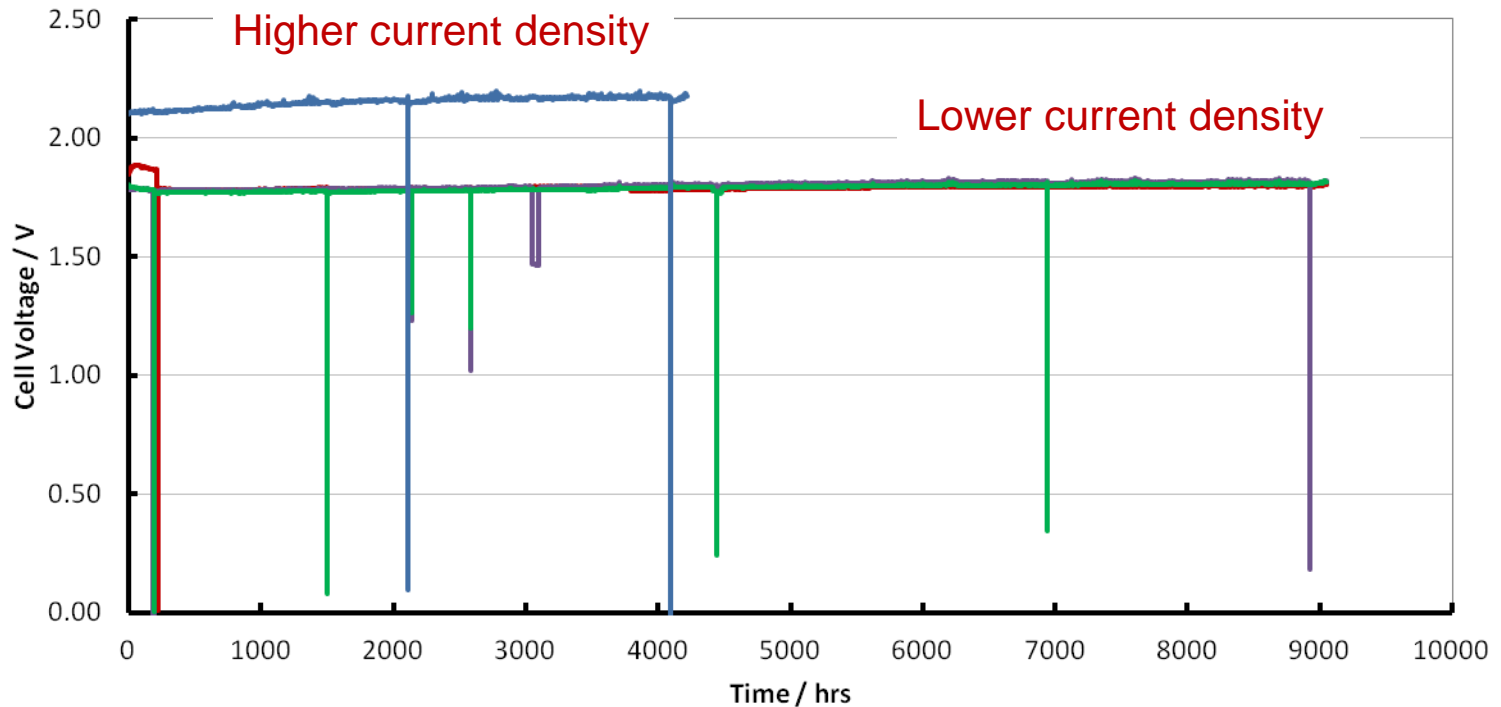
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Summary

- Degradation accelerated by temperature, current density, and pressure

- Most degradation is preventable (but solutions may be expensive)

- Degradation testing is long and expensive

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- Face Book: 154 Friends
- Twitter: 877 Followers