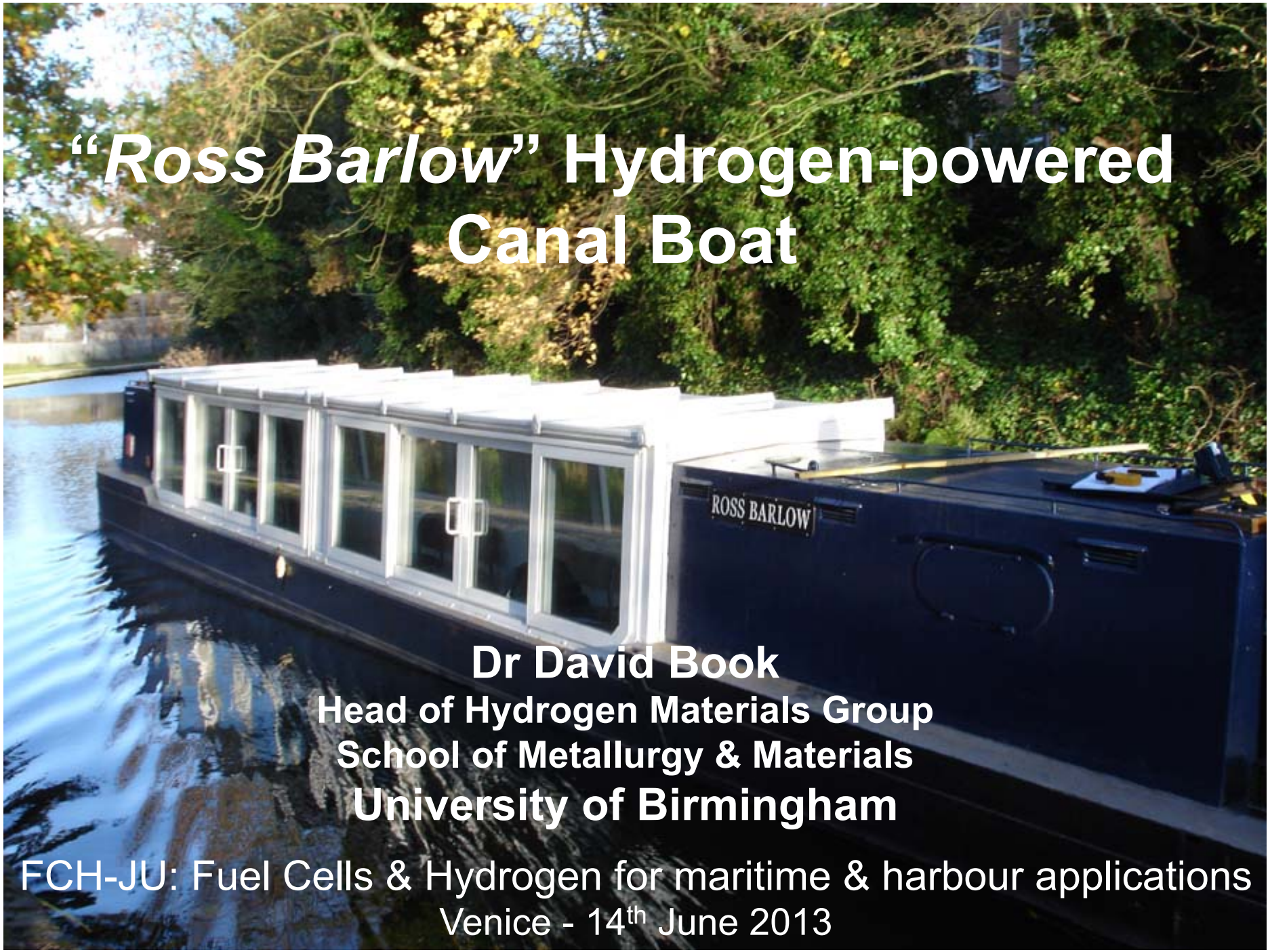

"*Ross Barlow*" Hydrogen-powered Canal Boat

Dr David Book
Head of Hydrogen Materials Group
School of Metallurgy & Materials
University of Birmingham

FCH-JU: Fuel Cells & Hydrogen for maritime & harbour applications
Venice - 14th June 2013

Project Coordinator: Professor Rex Harris


Edinburgh
Manchester
Birmingham
Bristol
London

University of Birmingham

- Founded in 1900 as the original “redbrick” university

- Clock Tower was modelled on the Torre del Mangia in Siena
- The mosaics are by Salviati Burke and Co. of Venice

Hydrogen and Fuel Cell Research

Metallurgy & Materials

Dr. D. Book

H2 Storage, Separation Membranes, H2 Processing of Materials

Prof. R. Harris (H)

Hydrogen Fuel Cell System Integration & H2 Storage

Dr. A. Walton

Hydrogen Processing of Magnets

Dr. J.D. Speight

Hydrogen Separation Membranes

Dr. A.J. Davenport

Corrosion of Bipolar Plates

www.hydrogen.bham.ac.uk

Chemical Engineering

Prof R. Steinberger-Wilkens

SOFC, PEMFCs, Stacks & systems

Prof K. Kendall (H)

SOFC & Nanotechnology

Dr N. Rees

PEMFCs

Dr A. Dhir

Hydrogen Generation

Drs. Leeke, Santos & Bushra Al-Duri

H2 production & Biorefining of Biomass using Supercritical Water

www.fuelcells.bham.ac.uk

Chemistry

Dr. P. Anderson

Hydrogen Storage

Prof. P. Slater

Materials for SOFC

Prof. C. Greaves

Materials for SOFC

Biosciences

Prof. L. Macaskie

Bio-Hydrogen Production

Physics

Prof. R. Palmer

H2 Photocatalysis

Electrical Eng

Dr. S. Hillmansen

Hydrogen in Railways

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Fuel Cells (Chemical Engineering)


Microtubular SOFC

Microcabs & H2 fueling stations

SOFC Testing System

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

SWARM

Demonstration of Small 4-Wheel
fuel cell passenger vehicle Applications in
Regional and Municipal transport

>90 small passenger FC vehicles & infrastructure in: British Midlands; Brussels region & Wallonia; & Weser-Ems region in NW Germany.

Professor Robert Steinberger-Wilckens

www.fuelcells.bham.ac.uk

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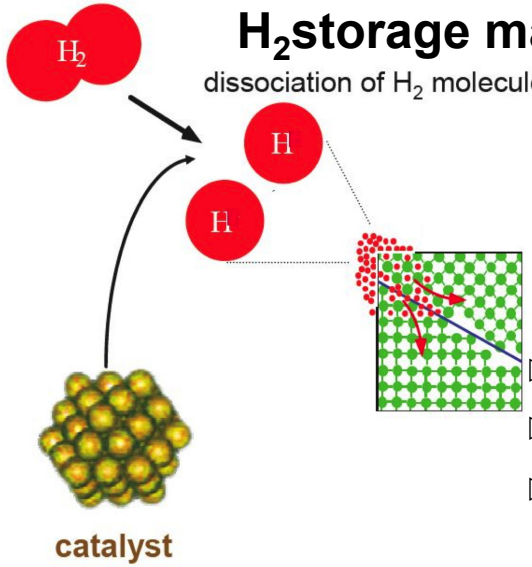
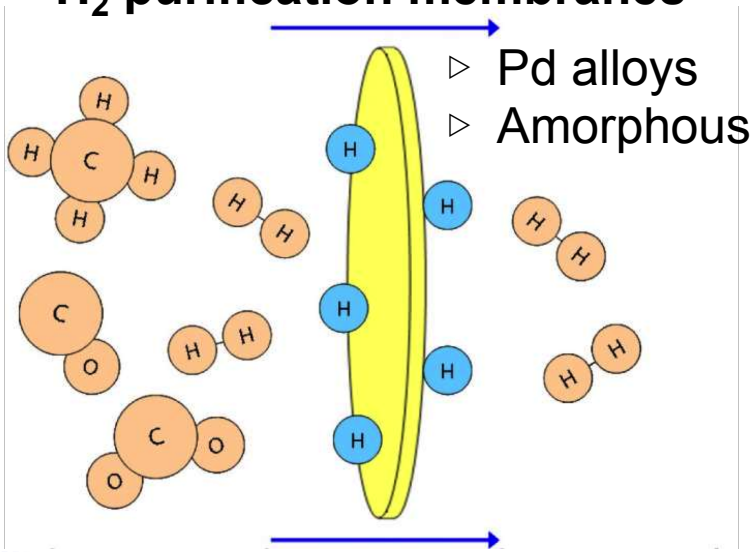
Hydrogen (Metallurgy & Materials)

H_2storage materials



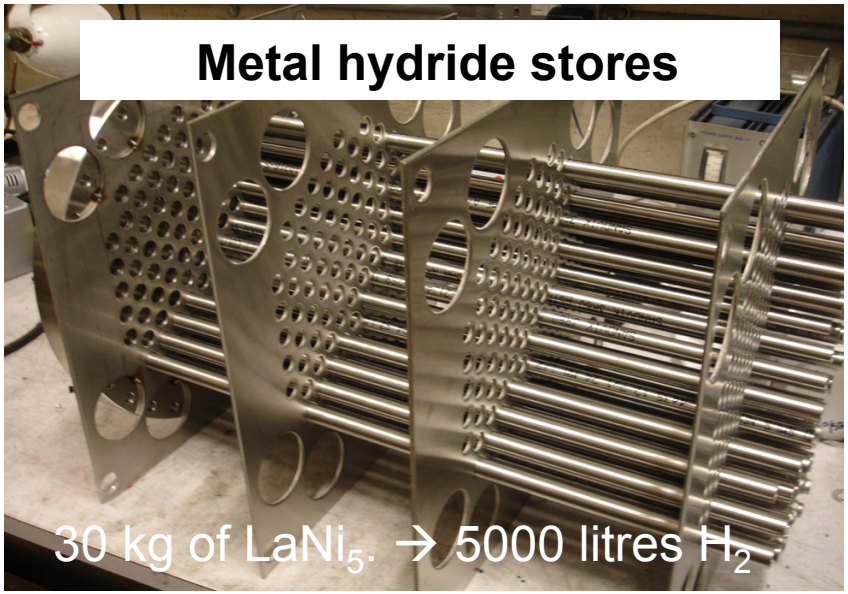
- Nano-Mg
- Borohydrides
- Metal hydrides

H_2 purification membranes

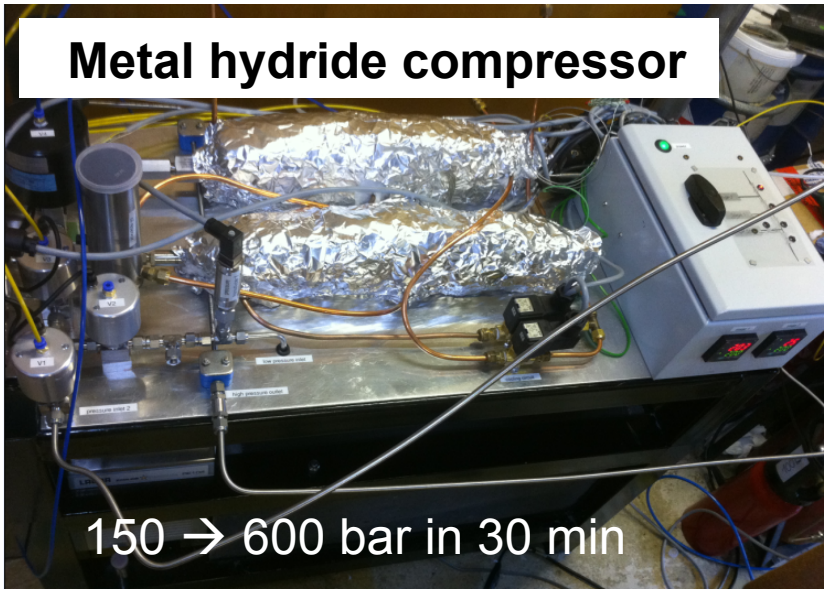


- Pd alloys
- Amorphous TM

Metal hydride stores



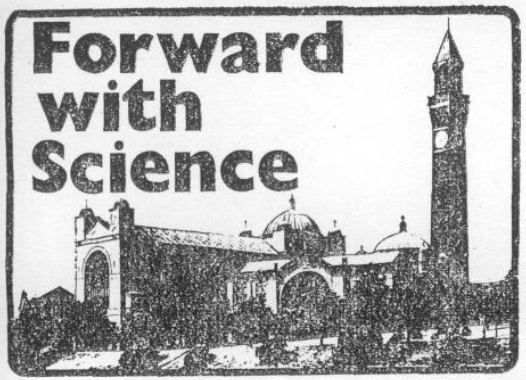
Metal hydride compressor



Dr David Book **www.hydrogen.bham.ac.uk**

UNIVERSITY OF BIRMINGHAM

Birmingham Evening Mail - 27 June 1979



Vroom into the future—on hydrogen

A FUNKY moped is one of the surprises in store for visitors to the Department of Physical Metallurgy at Birmingham University on Saturday.

The little Honda, of doubtful vintage, has been modified by researcher Dr. Rex Harris to run on a few handfuls of fine grey powder.

More precisely, it is the hydrogen gas given off by the powder that takes the place of petrol.

The remarkable thing is that any car or other motor vehicle could be adapted today quite simply to run on hydrogen with only minor modifications to the engine.

Will hydrogen be the car fuel of the future?

Dr. Harris thinks it may be.

Support

He and his team have been working for several years, with the support of industry and the Science Research Council, on a range of new man-made materials known as inter metallic alloys.

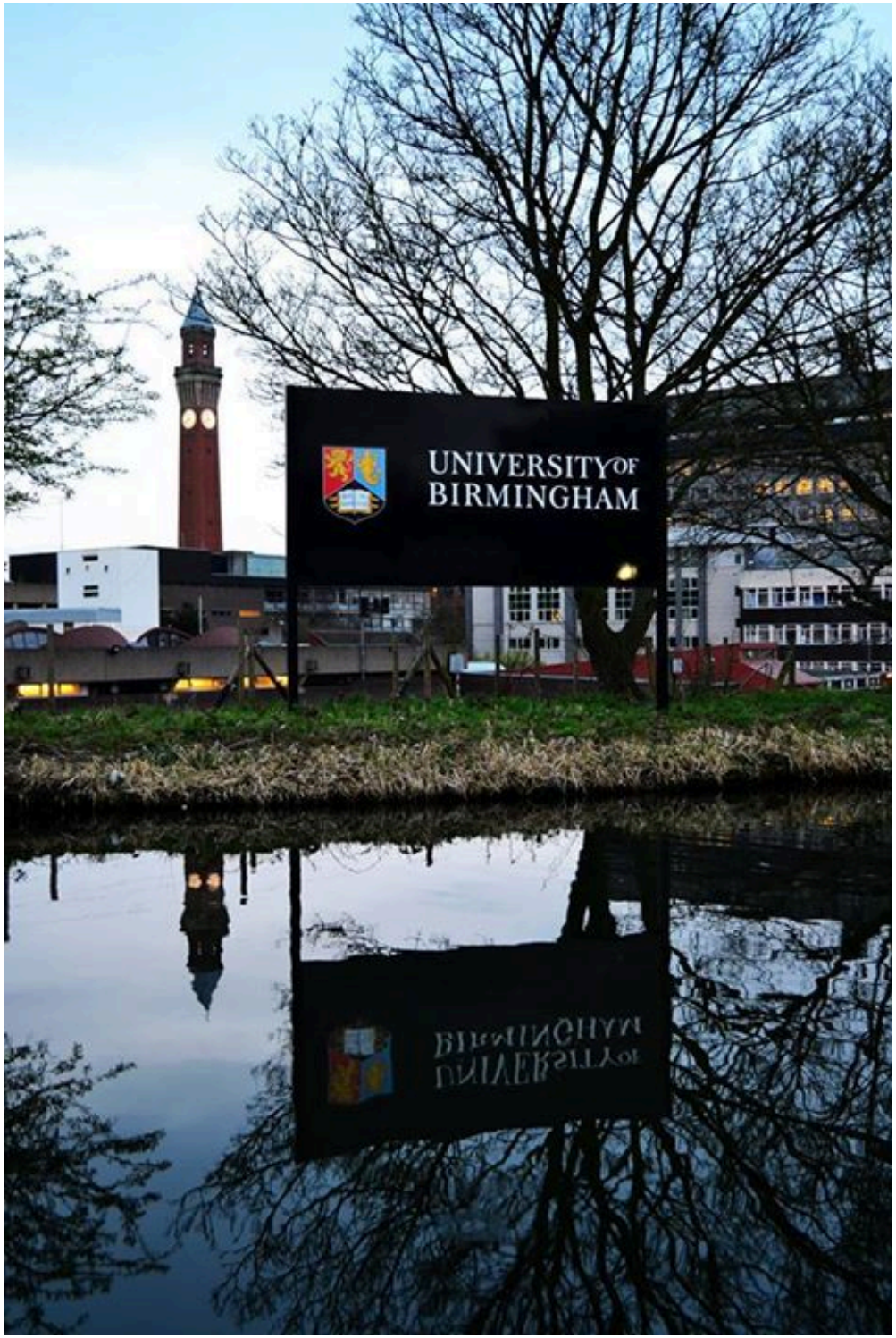
Dr. Harris's grey powder is one of these — magnesium nickel alloy — and

BIRMINGHAM University welcomes visitors to its annual open day on Saturday. MAURICE ROTHEROE, with the aid of Information Officer Maurice Cheesewright, today takes a look at another futuristic project there.

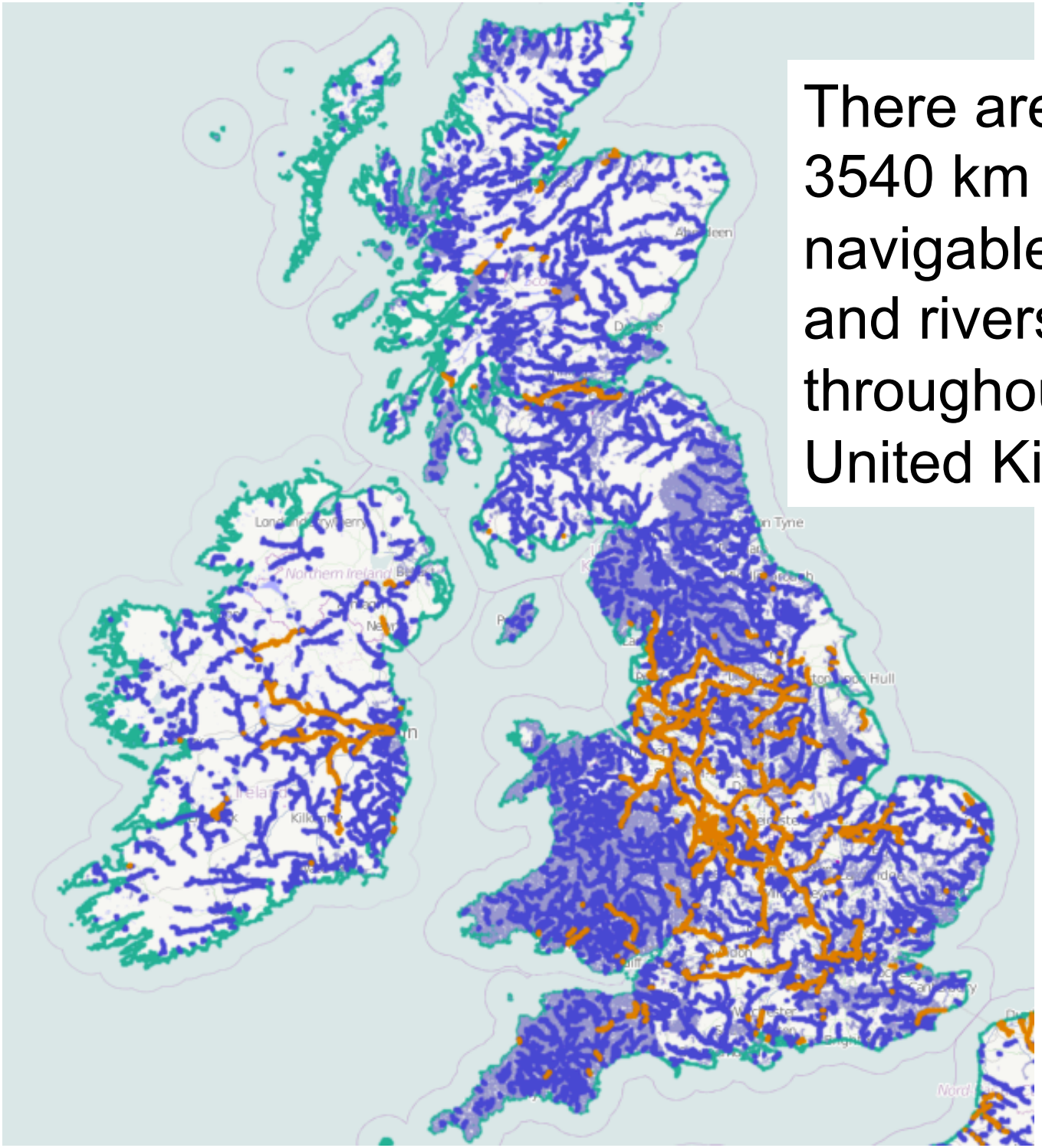
FUNKY MOPED . . . Dr. Harris with his hydro gen-powered bike. The cylinder contains powder which release stored hydrogen to give about two hours' running.

In the past, a small ICE motorbike was converted to run on hydrogen (from a hydride store)

What other opportunities are there to demonstrate hydrogen energy…?



A canal runs through the middle of the university campus!



There are about 3540 km of navigable canals and rivers throughout the United Kingdom.

Orange = man-made canals

- The network is navigable in its entirety by a narrowboat (2.1 m wide) less than 17 m
- The speed limit for the majority of inland waterways in the UK is 6.4 kph.

Canals in Birmingham (UK)

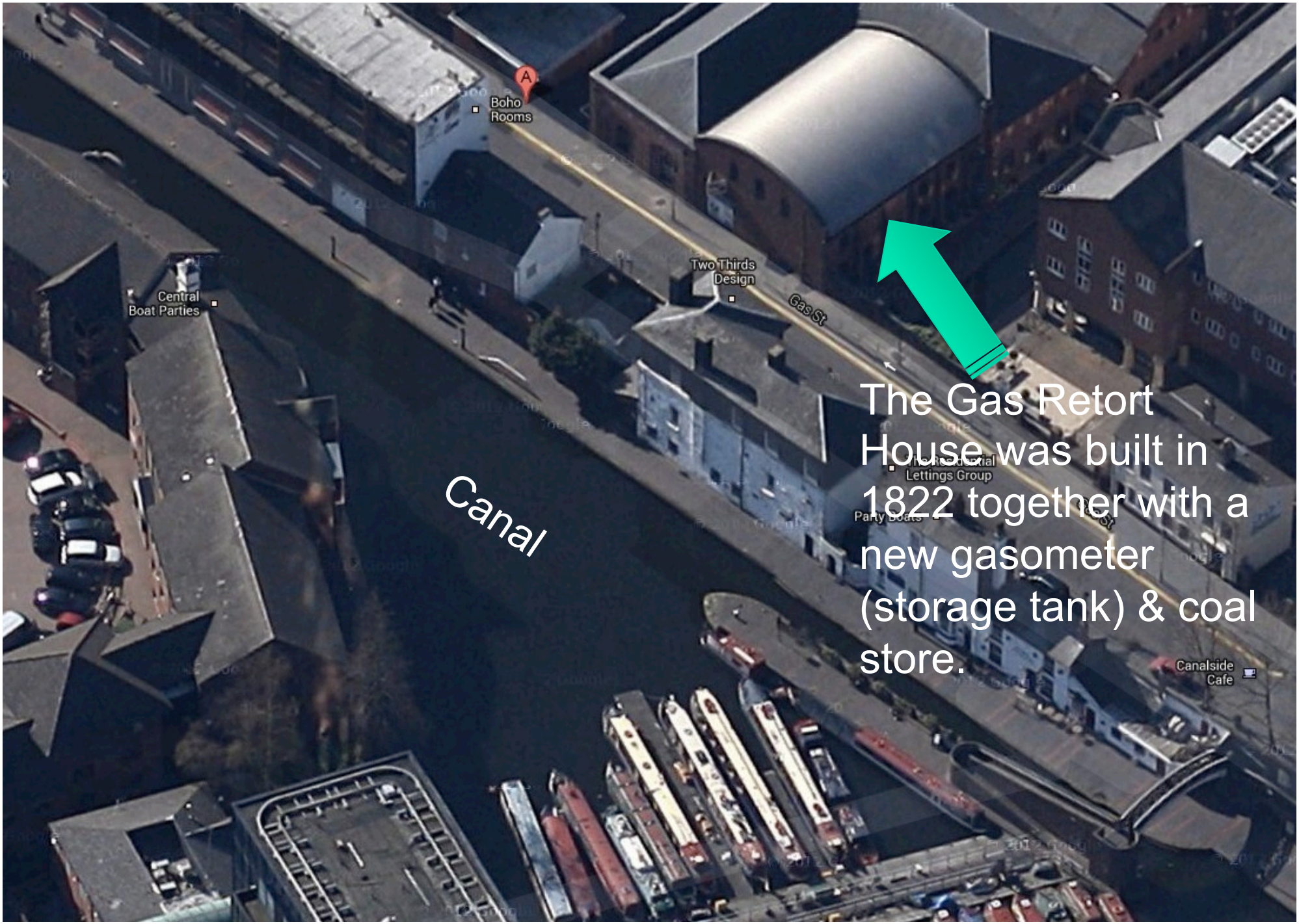
Gas Street Basin

University of Birmingham

Canal, Bournville Station, and Cadbury's Factory

From the 1760s, a large network of canals were built across Birmingham and the Black Country, to transport raw materials and finished goods.

By the 1820s an extensive canal system had been constructed; Birmingham is often described as having more miles of canals (56 km) than Venice (42 km).


A
Boho Rooms
Two Thirds Design
Gas St
Central Boat Parties
Canal
Lettings Group
Party Boats
Canalside Cafe
The Gas Retort House was built in 1822 together with a new gasometer (storage tank) & coal store.

Gas Retort House, Birmingham

Inside a retort house
(Fakenham ,Norfolk; www.geograph.org.uk/photo/1899948)

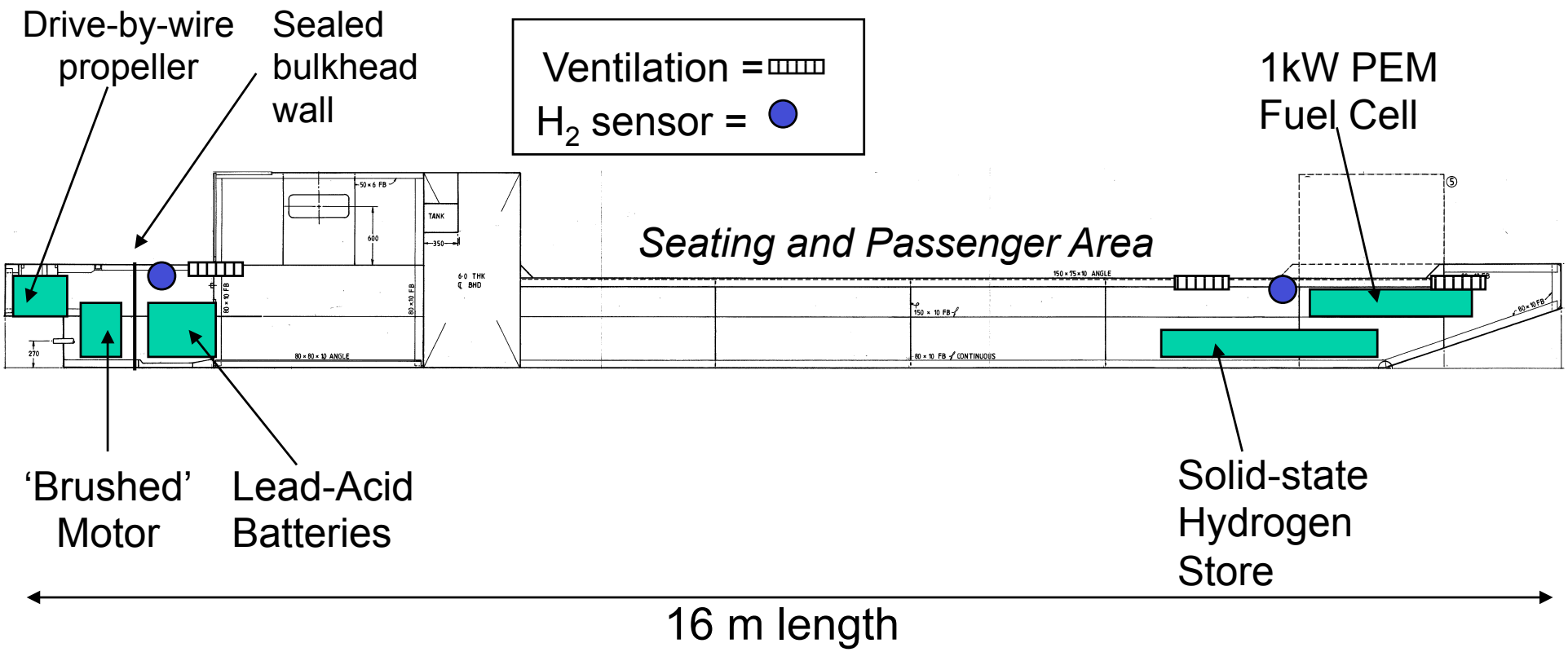
Town gas / coal gas (50% hydrogen, 35% methane, 10% CO & 5% C_2H_4) was manufactured by heating coal in the absence of air.

⇨ *Early link between canals and H_2 production!*

Why a canal boat ?

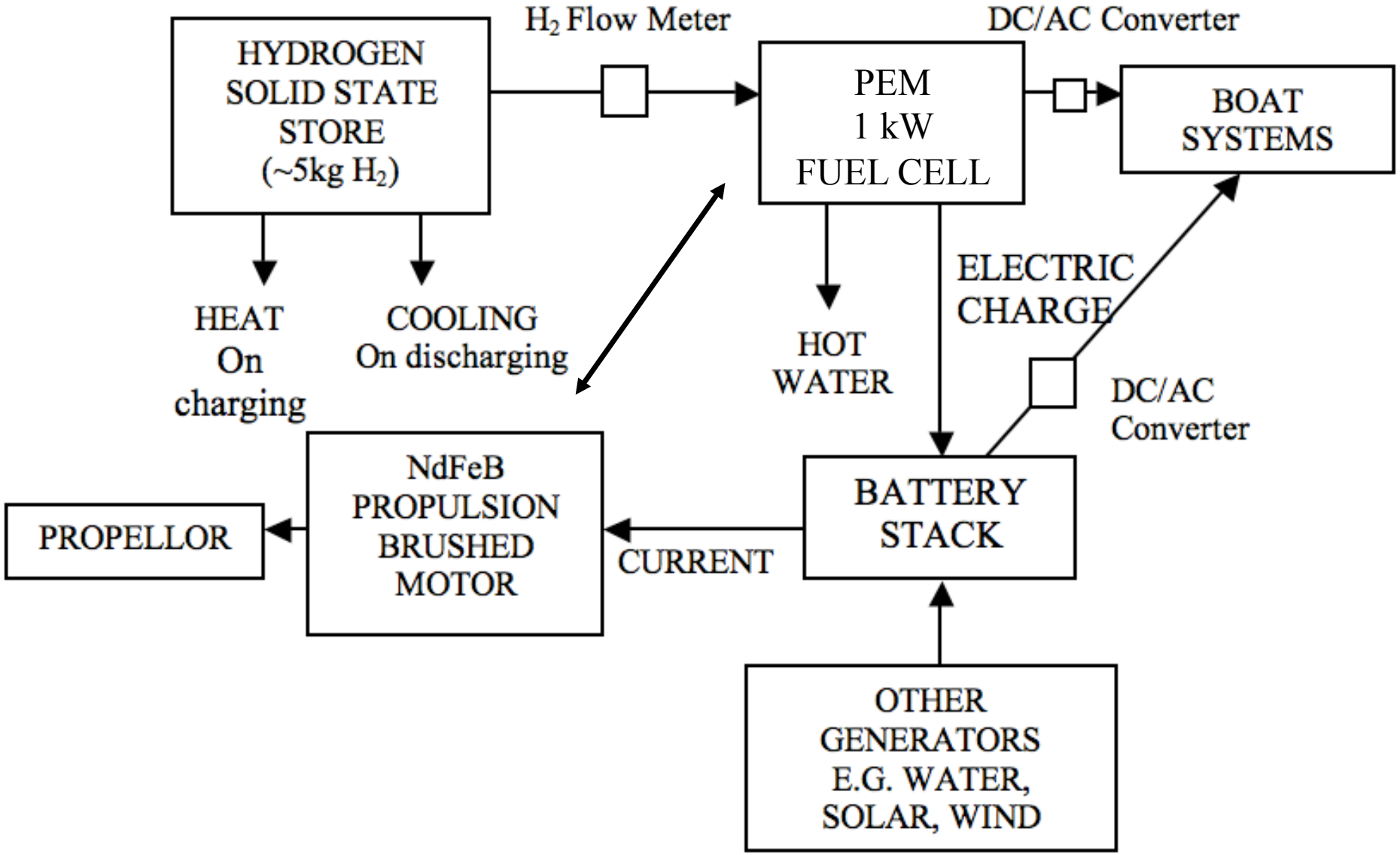
- Water-based transport is inherently efficient
- High speeds are not required (on canals)
- Weight of the hydrogen store is a small fraction of the total weight of the vessel
- The volume of the store can be compensated by the removal of existing ballast & diesel engine

Boat Schematic



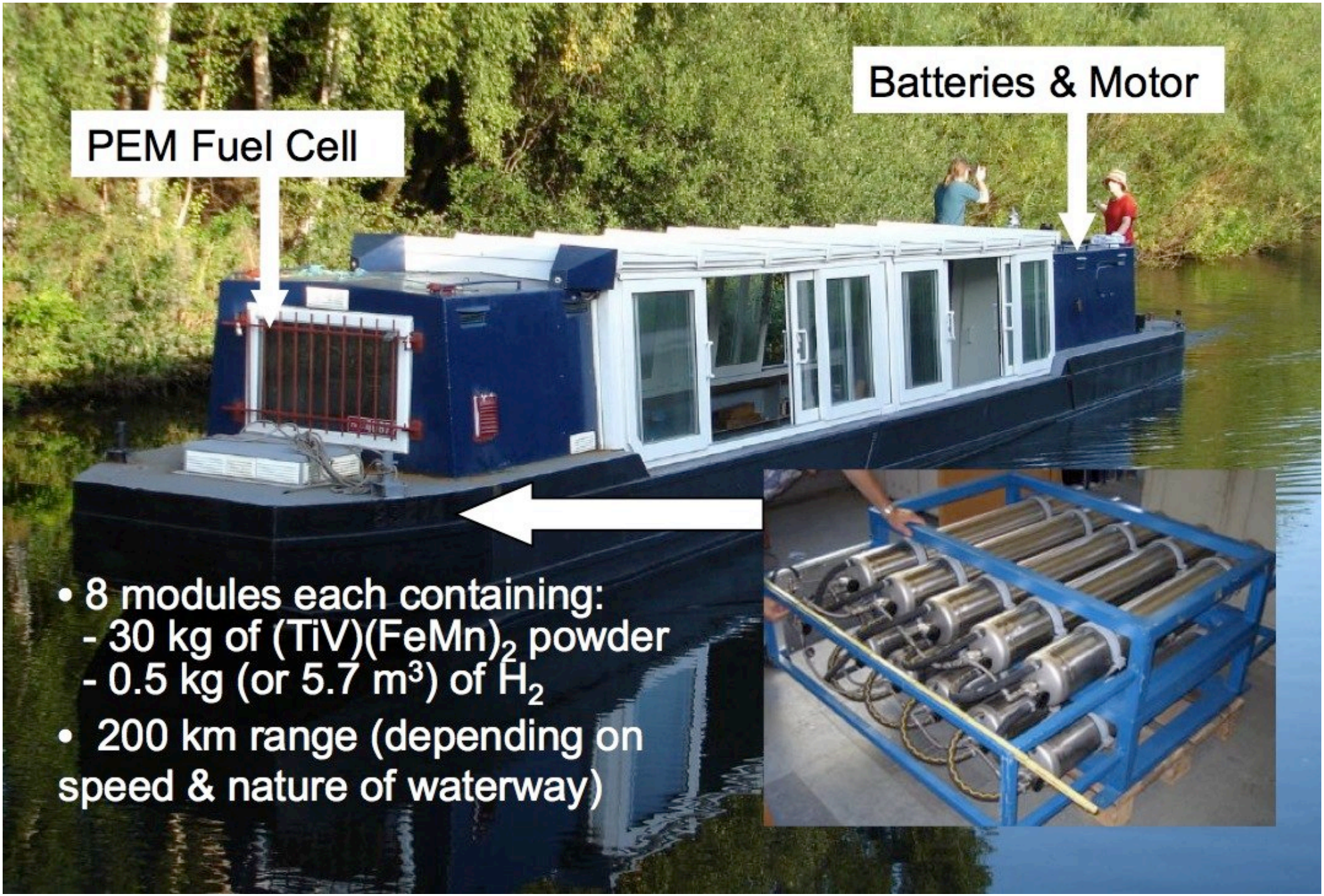
Weight ~12 tonnes

Energy System Aboard the Canal Boat



Converting the boat

Converting the boat



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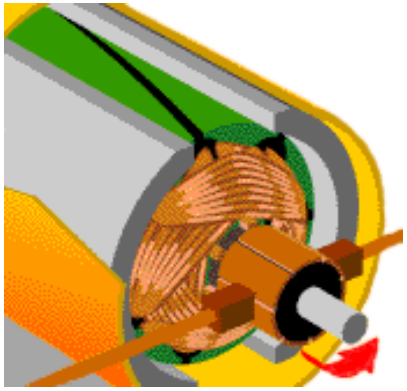
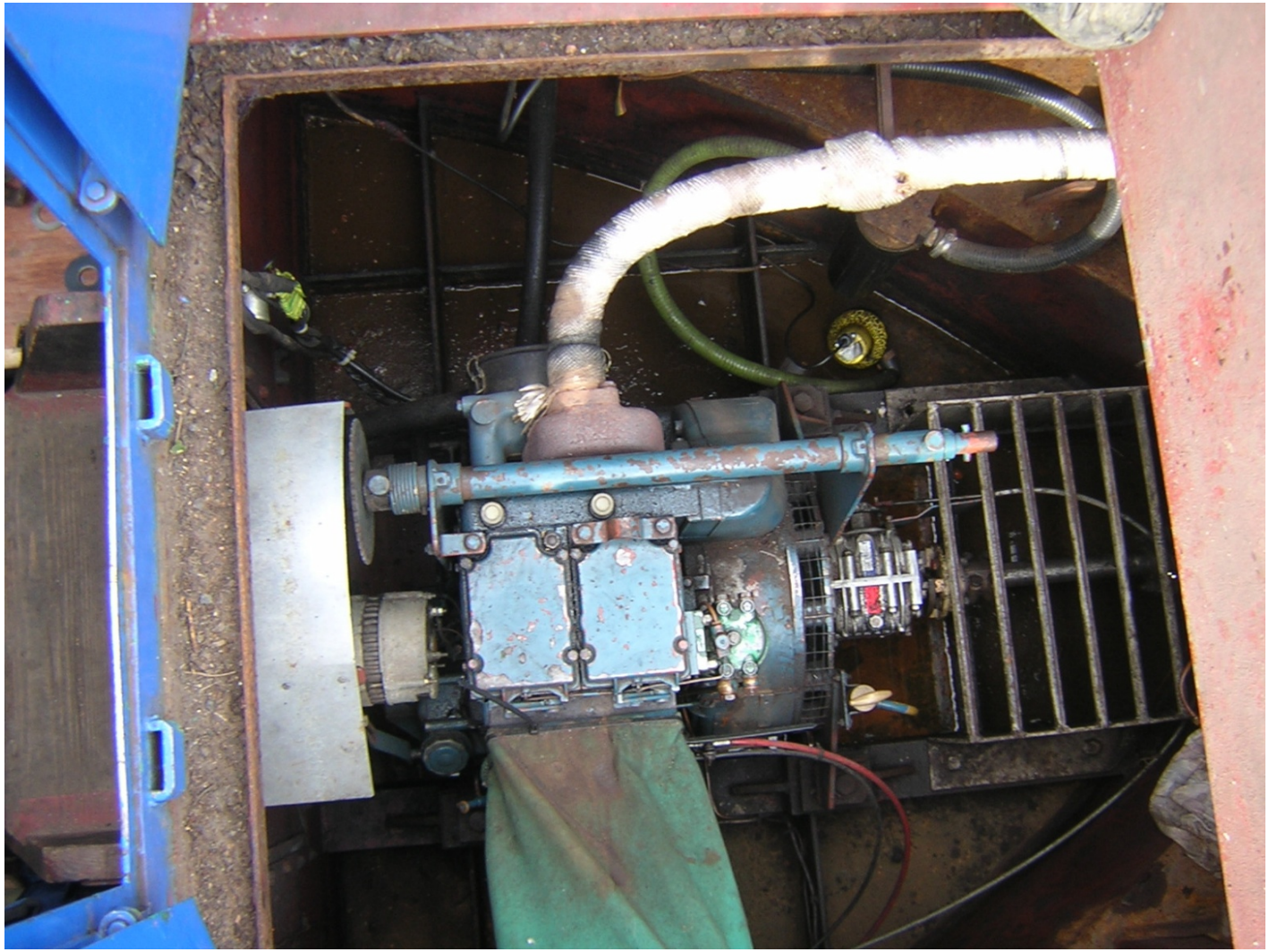
Propulsion unit

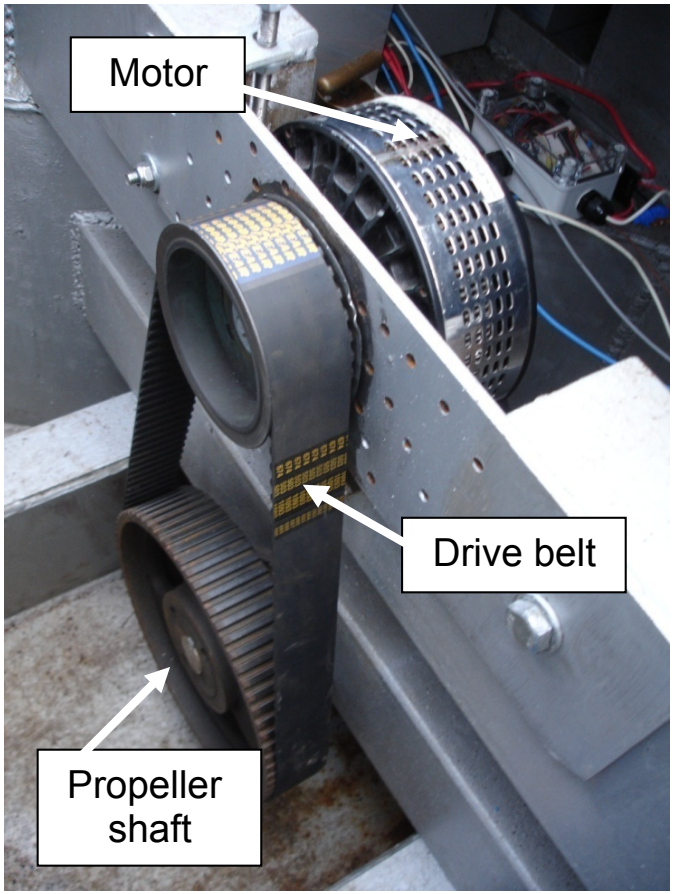


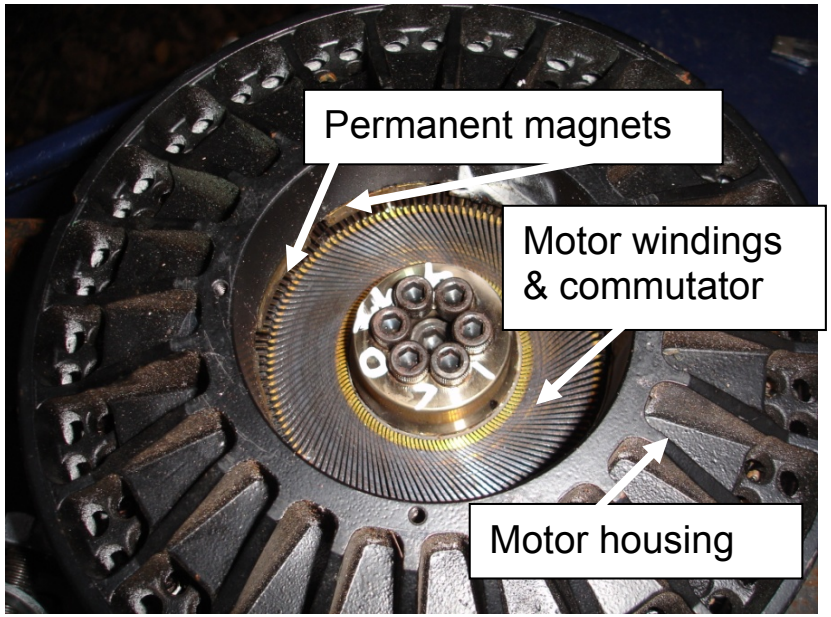
Original engine



Two cylinder diesel internal combustion engine

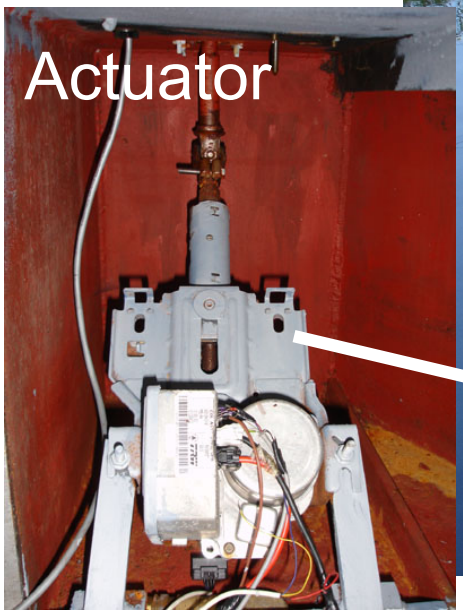
Permanent Magnet Drive Motor

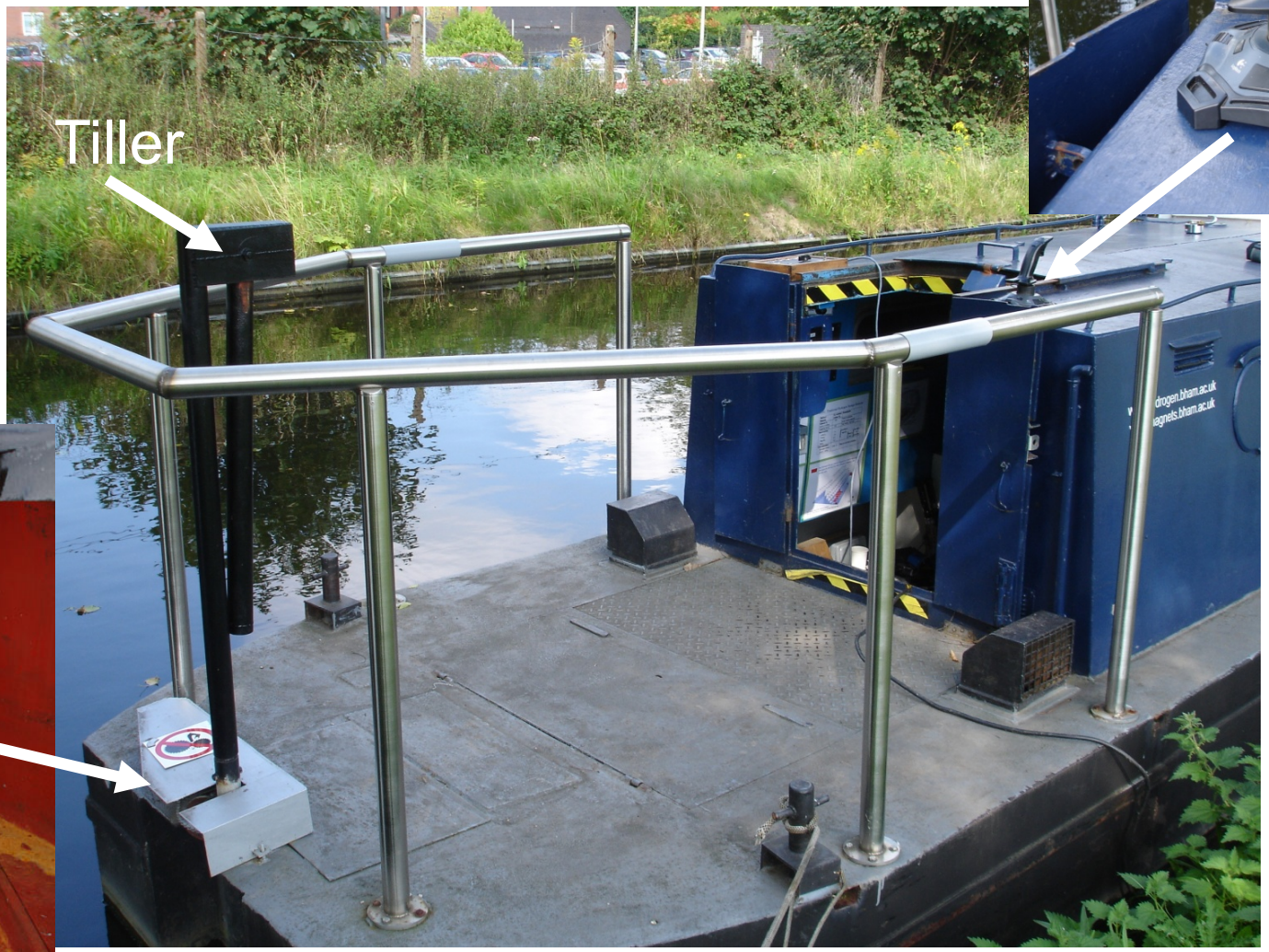




The motor is designed by the Lynch motor company based on a brushed 4 quadrant axial flux motor, giving a power output of 10 kW or 13 hp with a max efficiency of 89%

Steer By Wire Actuator

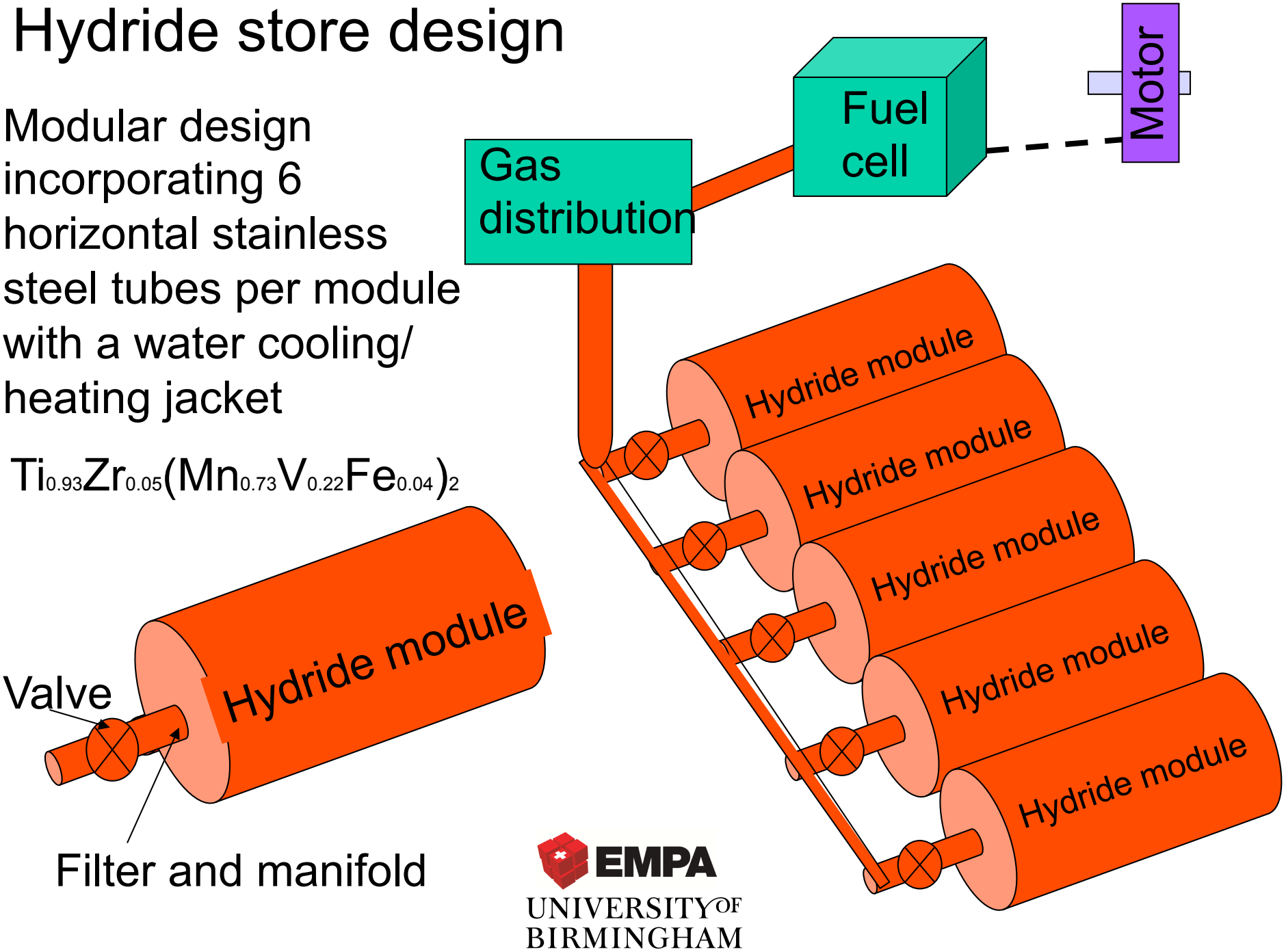




Hydride store design

Modular design incorporating 6 horizontal stainless steel tubes per module with a water cooling/ heating jacket

$Ti_{0.93}Zr_{0.05}(Mn_{0.73}V_{0.22}Fe_{0.04})_2$



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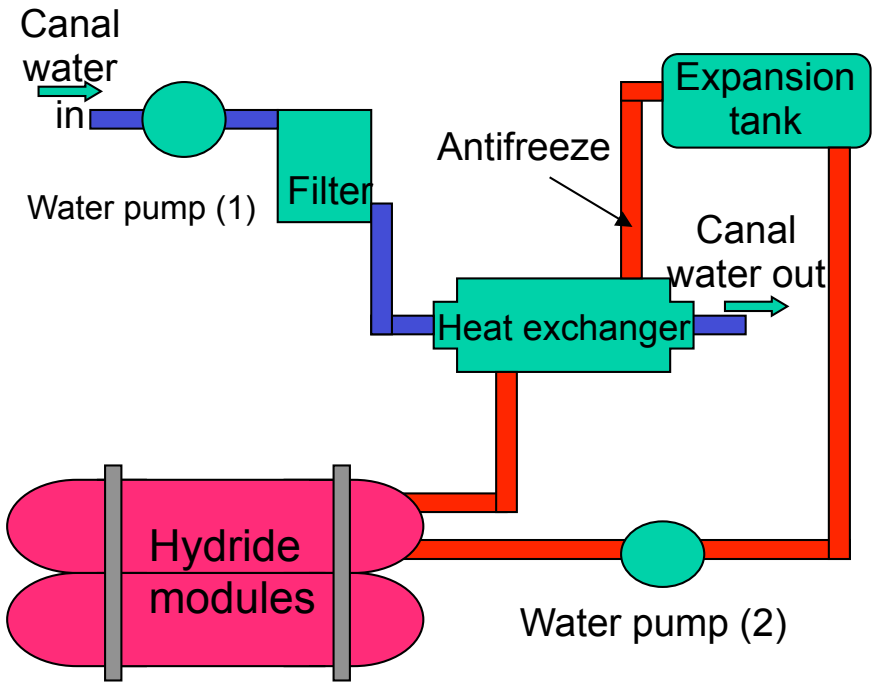
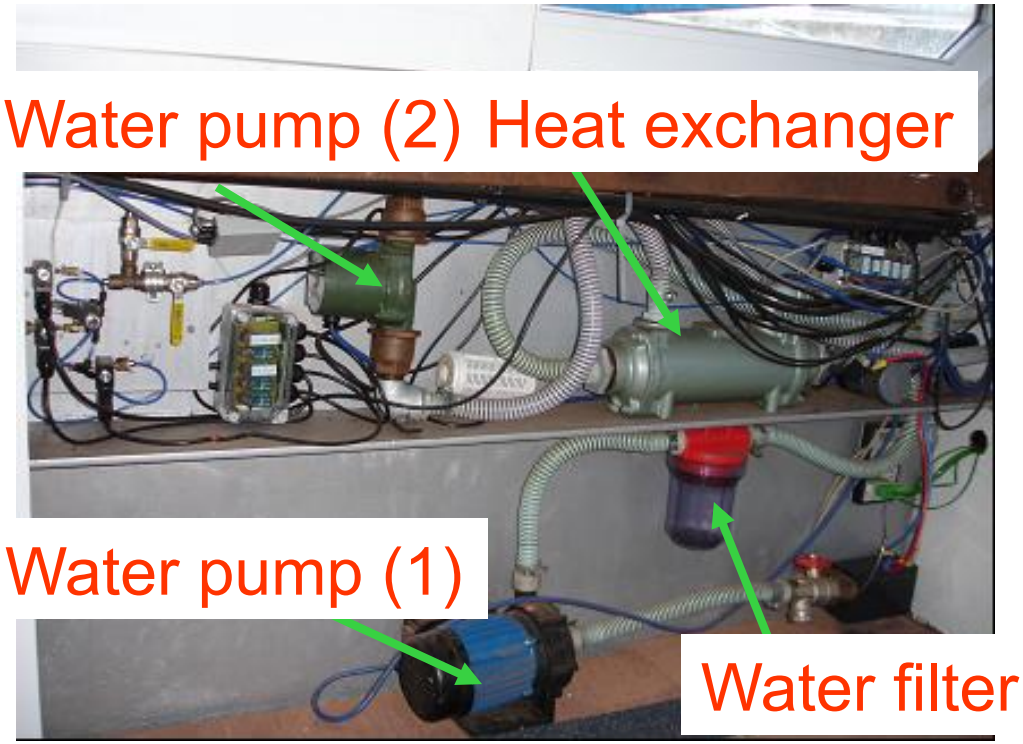
Heat exchange with canal water





Canal temperature

16 °C September
13 °C October
8 °C December
3 °C January

- ReliOn Independence 1000TM model which was designed as an (UPS), for markets such as the telecommunication industry.
- Voltage is regulated to allow charging for a 48 V system (with the max charge set to 57.6 V)
- Rated at 1 kW and operates at 65 °C with forced air cooling.
- 6 exchangeable cartridges, with each ccontaining 10 separate cells.
- For 1 kW output, average flow rate into the fuel cell is about 15 L min^{-1}.

Potential advantage of a battery/ fuel cell system

- Hydride store has a significantly faster charging rate than the batteries
- The craft will have a longer range of operations in the hybrid form before needing access to electric charging facilities
- Batteries can be “trickle-charged” using solar panels, wind and water generators. PM electric motor can also serve as a generator
- Fuel cell would prefer to operate at a constant and any load variability can be taken up by battery stack
- Hot water (~60 °C) supplied by fuel cell can be used to heat store and living space
- Unlike batteries, hydride stores will not discharge on standing idle, even for prolonged periods

Energy Storage Capabilities

- **46 kwh** can be stored in the battery stack
- **52 kwh** can be stored as hydrogen
- The batteries should not be discharged by more than **50%** whereas the store can be discharged by **~98%.**

Running trials

Further details of the boat performance:

PAPER www.rsc.org/faraday_d | Faraday Discussions View

Performance of a metal hydride store on the "Ross Barlow" hydrogen powered canal boat

A. I. Bevan,*[a] A. Züttel,[b] D. Book[a] and I. R. Harris[a]

Received 17th December 2010, Accepted 18th January 2011
DOI: 10.1039/c0fd00025f

This project involved the conversion of a British Waterways maintenance craft to a canal boat, powered by a combination of a solid-state hydrogen store, Proton Exchange Membrane (PEM) fuel cell, lead-acid battery pack and a high-efficiency, permanent magnet (NdFeB) electric motor. These replaced the conventional diesel engine thus eliminating water, noise, local and general atmospheric pollution. The "Protium" project applies modern technologies to a traditional mode of transportation. The $TiMn_2$-based metal hydride store exhibited excellent performance as an effective means of storing 4 kg of hydrogen with a suitable desorption flow rate and temperature adequate for the operation of a 1 kW PEM fuel cell in a water-based environment.

http://tinyurl.com/rossbarlow

***Future*: New hybrid H_2 narrow boat**

- Design all of the boat (rather than convert) taking into account lessons learnt
- Hydrodynamic hull design
- Light-weight materials construction
- Advanced insulation materials
- Solar PV panels to trickle charge batteries
- Improved propeller design
- Optimisation of metal hydride store design (higher volumetric density)
- Lower cost 3-5 kW PEM fuel cell, integrated with MH store water cooling

***Future*: Canal-side hydrogen generation.**

Acknowledgments

Dr Alex Bevan, University of Birmingham
Prof Andreas Züttel, EMPA Switzerland

Birmingham Science City ideasforlife

ROYAL ACADEMY OF ENGINEERING

British Waterways

- Advantage West Midlands
- Beacon Energy Ltd
- Black Country Housing Association
- BOC Ltd
- Bryte Energy
- European Commission
- Less Common Metals
- Martineau Johnson
- SHEC/EPSRC
- Solar Boat Company
- Tempus
- TRW Birmingham
- University of Birmingham
- University of Sheffield

and the following individuals:

- Mr Michael Rawlinson
- Mr John McConnell
- Mrs Jane Tyler
- Professor Rex Harris
- Professor Ian Dillamore

Greening the waterways

1-day workshop on the application of electricity & hydrogen to waterways transport

Workshop Chair: Professor Rex Harris

University of Birmingham - 27 June 2012

- Steve Hallett (ITM Power)
- Jas Singh (Auriga Energy Ltd)
- Jim Anderson (Caledonian MacBrayne)
- Ralf Plump (Germanischer Lloyd SE, Hamberg)
- Murat Gurhan (Istanbul Technical University)
- Andreas Züttel (EMPA, Switzerland)
- Sandy Taylor (Birmingham City Council)
- Sylvia and Ian Rutter (Electric Boat Association)

Videos of talks: www.greeningthewaterways.com