HYDROGEN, MAGNETS AND THE PROTIUM PROJECT

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Over the past one and a half years, the University of Birmingham (together with contributions from alumni), British Waterways, Tempus, Less Common Metals and EMPA (Switzerland), have invested money and materials to the value of around £100K in the design, construction and now, operation of a canal boat of the future (Figure 1). This boat is powered by a combination of a metal hydride solid state hydrogen store, a proton exchange membrane (PEM) fuel cell, a lead acid battery stack and a NdFeB permanent magnet electric motor. The schematic of this system is shown in Figure 2.

The boat, called the Ross Barlow, encapsulates very effectively, the hydrogen and magnets research interests at the University of Birmingham and at EMPA in Switzerland. Not only does hydrogen provide the fuel for the PEM fuel cell but also provides the means (the HD-process) of manufacturing the NdFeB magnets.

Waterways transport is inherently efficient and the weight of the metal hydride store can readily be compensated by the removal and redistribution of the existing ballast from the twelve tonne canal boat. Thus the use of hydrogen in this context is expected to become commercially viable at a much earlier stage than in automotive applications where the weight and volume of the hydrogen store are both critical factors and remain a major challenge for the future.

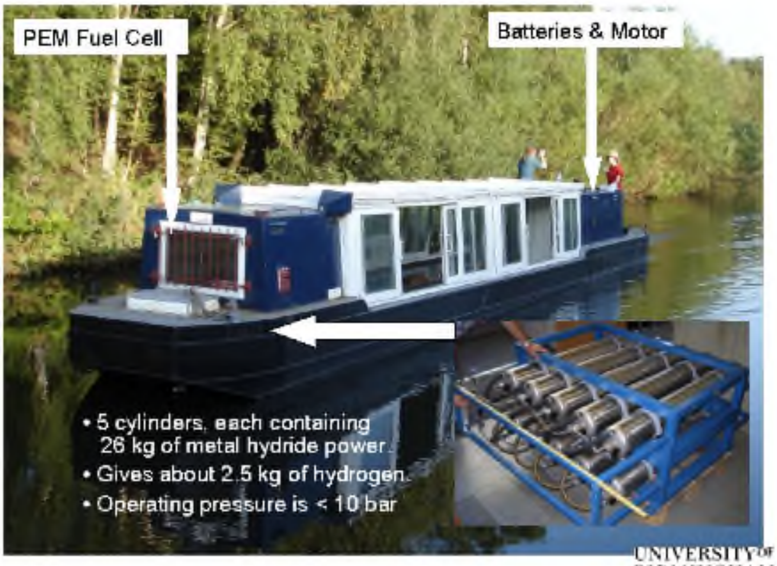

Figure 1 Canal boat of the future

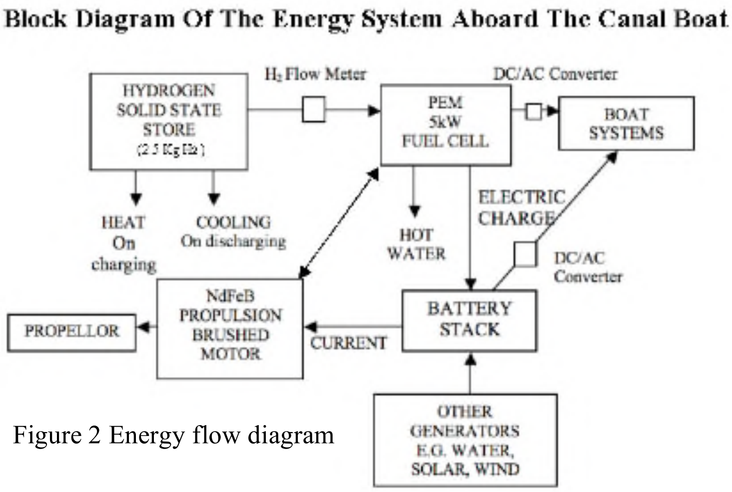

Figure 2 Energy flow diagram

Figure 3 Conversion process

The Protium project began with the provision of a standard maintenance boat by British Waterways and over the past one and a half years the craft has been converted to a passenger/display boat (Figure 3) by replacing the standard diesel engine with an all electric propulsion system and by enclosing the middle portion of the vessel.

The longer term aim is to supply the boat with "green" electricity and with "green" hydrogen so that the project will become completely sustainable and will have totally eliminated all the atmospheric, water and noise pollution associated with the boat. Perhaps the most novel aspect of the Ross Barlow is the solid state store which contains 133 kgs of powdered Ti-V-Mn-Fe alloy which, when fully charged, will store around 2.5 kgs of hydrogen (28 cubic metres at standard temperature and pressure). There are five storage units and in each one the metal powder is contained within seven stainless steel tubes which are surrounded by a water jacket (Figure 4) which provides heat when desorbing the hydrogen to the fuel cell and cooling when the store is being charged. The temperature is maintained by means of a water pump and heat exchanger. The most attractive feature of the store is that the operating pressure is less than 10 bar and the 5 units together store the equivalent of 4 fully charged standard gas cylinders at a pressure of 200 bars. To our knowledge, this is by far the largest solid state hydrogen store being employed in any transport application within the UK. The Protium project, therefore, will provide an excellent opportunity to assess the performance of such a store in a working environment.

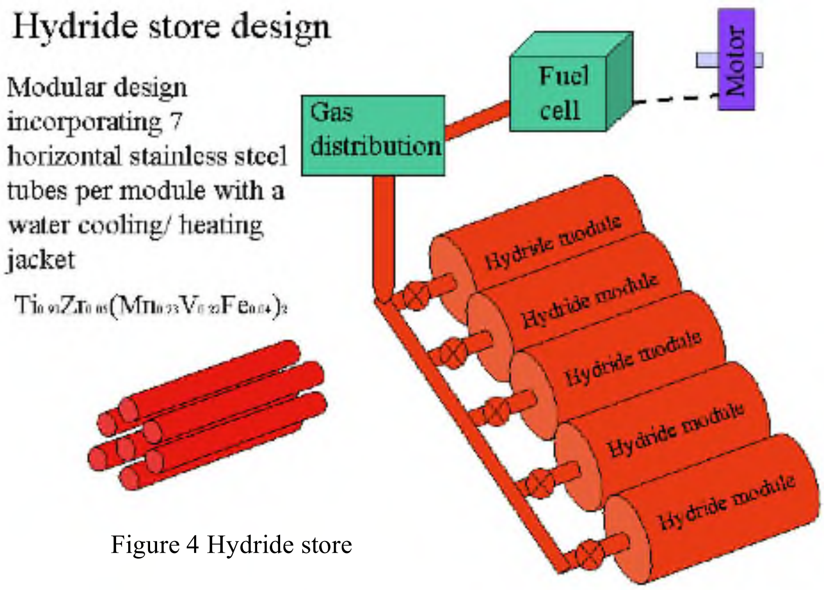

Figure 4 Hydride store

Why not power the boat solely by hydrogen? The reason is that there are advantages in employing a hybrid system. One of these is that, for most of the time, the fuel cell can be employed to charge the batteries at a steady rate and this avoids subjecting the fuel cell to surges in demand, hence extending its lifetime. In addition, the batteries can also be topped-up from a range of sustainable primary energy sources such a wind, hydro and solar. Practically this is much easier and more energy efficient compared with generating hydrogen from these sources. There is also some possibility of regenerative charging of the batteries.

The highly efficient (~90%), high torque, permanent magnet electric motor (Figure 5) makes very effective use of the energy stored in the metal hydride and in the battery stack. As stated earlier, the NdFeB sintered magnets have been manufactured by the Hydrogen Decrepitation process and this synergy is described in the educational material associated with the project. Another important on-board application for NdFeB magnets is in the guidance system where the conventional tiller can be substituted by a permanent magnet actuator.

The complete hybrid energy system is monitored continuously and controlled by computer software designed to achieve maximum efficiency and hence maximum range between the refuelling cycles. It is anticipated that this software will be modified as a result of the experience gained during the coming year. The reliability and longevity of the solid state store will be of particular interest and the powder material will need to be examined in the research laboratories to see if there is any evidence of degradation and hence loss of capacity. At a later stage, one of the storage units will be employed to test new storage materials developed in the associated research laboratories.

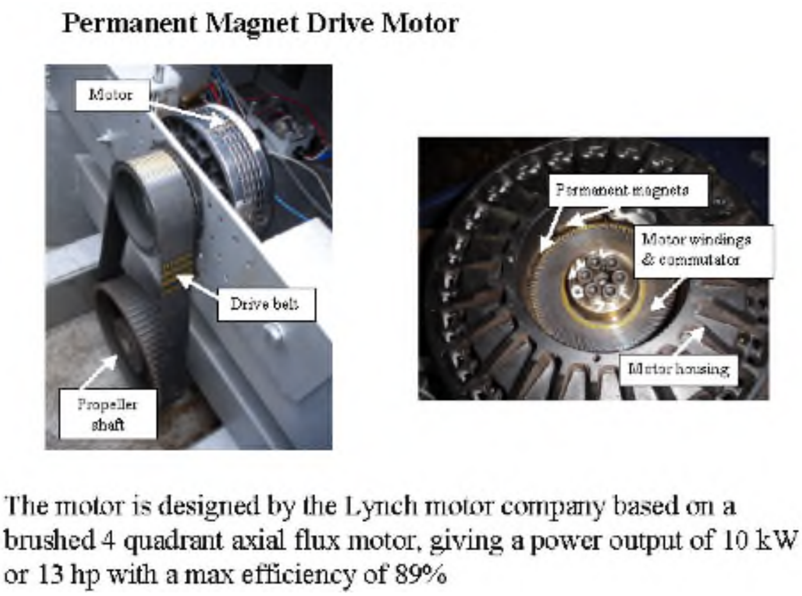

Figure 5 Permanent magnet propulsion motor

Another major objective of the project is to develop (possibly in collaboration with other hydrogen based transport projects) the necessary local scale hydrogen infrastructure and this should provide a catalyst and a model for a much larger scale operation throughout the inland waterways network with Birmingham as the hub. A further development over the coming year will be the provision of “green” hydrogen from the wind/electrolysis plant at Beacon Energy near Loughborough and hydrogen from a local source of waste biomass.

The Ross Barlow has an extensive display area and this will be employed to exhibit a range of fuel cell and energy efficient devices. Birmingham has been designated a Science City and we hope the boat can be used to promote engagement with science and to promote hydrogen as a fuel of the future. Global warming apart there is still the urgent need to find an alternative to oil which will be in very short supply by 2050.

Over the coming year, the Protium consortium (see below) will analyse the commercial prospects for this technology and, depending on the operational experience, set up an appropriate structure to exploit the in-house “know-how”. One of the objectives will be to design and build a hydrogen-hybrid canal boat from scratch and to examine a wider range of water-based transport. This could provide an ideal “early adopter” market for hydrogen/battery solutions.

The Protium Partnership is well qualified for these tasks and consists of the University of Birmingham (coordination, hydrogen storage and fuel cells), University of Sheffield (permanent magnets and actuators), Less Common Metals (materials for hydrogen stores), Beacon Energy (green hydrogen technologies), BOC Ltd (assistance with hydrogen refuelling facilities), Tempus (hardware and software for control systems), British Waterways (canal infrastructure), EMPA (fuel cells and hydrogen stores), Black Country Housing Association (energy efficiency and storage). There are also strong links to the EPSRC funded Sustainable Hydrogen Energy Consortium (UK-SHEC) and the Framework 6, EC programme, Novel Efficient Solid State Storage for Hydrogen (NESSHY). It is hoped that these programmes will provide new generations of hydrogen storage materials for trials on the boat.

Finally, why did we name the boat the Ross Barlow (Figure 6)? Ross was a postgraduate student who worked on the project in the early stages of its development and he was an enthusiastic supporter of all things sustainable. Tragically, he died in a hang gliding accident in March 2005 at the age of 25. With the strong support of his family, we decided to name the boat after him as a lasting tribute to a remarkable young man.

Figure 6 The Ross Barlow

Ross Barlow