Hydrogen: The clean fuel of the future?

Price 30p

Interest in the use of hydrogen as a fuel has grown rapidly in the last decade. Already several exciting technologies have been proven. The task now is to refine them, reduce costs and find 'green' ways to produce the hydrogen needed.

Some history

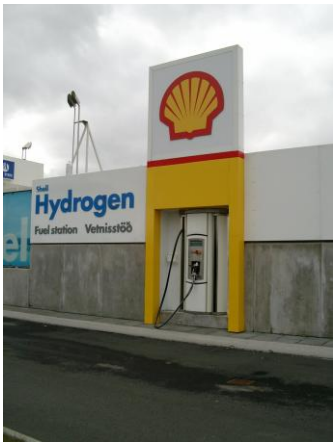
Historically reluctance to use hydrogen lies in the public perception that it is an explosive uncontrollable gas following the destruction of the airship Hindenburg in New York in 1937. Hydrogen is actually 'only' as dangerous as methane (natural gas) and petrol and used to make up over 50% of the old town gas supplies. Clearly any fuel can be dangerous.

Throughout the 19th century various people worked with hydrogen and it was considered safer than petrol until the invention of the carburettor made petrol safer to handle and led Otto to develop the modern petrol powered internal combustion engine. The fuel cell, whereby hydrogen combines with oxygen in air in the presence of a catalyst to produce electricity, was actually invented in 1839 by Sir William Grove, a Welsh solicitor and developed further in the 1880s by Brenner and Mond before losing out to the invention of the dynamo by Michael Faraday, the growth of power stations as central sources of electricity and the era of cheap fossil fuel.

The pros and cons of hydrogen

As a fuel hydrogen has many advantages. It is clean, the combustion product being water. By weight it releases more energy in its reaction with oxygen than any other fuel though by volume it is over 3000 times as dilute. This means it must be highly compressed or turned into liquid using huge cooling equipment.

Nonetheless through the 1920s and 1930s many automobile engineers, led among others by Sir Harry Ricardo, continued work with hydrogen. They found that a hydrogen powered internal combustion engine could be 50% efficient - the effective limit of that kind of engine. The fuel cell could, theoretically, be 100% efficient. It was a British scientist F T Bacon, working single handedly on the fuel cell through the '40s to '60s, who developed those powering the Gemini capsules of the American space programme.



Hydrogen filling station, Reykjavik

Even so there was no point developing costly hydrogen systems while fossil fuels were cheap. Higher prices and recognition of global warming is changing the position.

Production of hydrogen

Hydrogen can be obtained in various ways. The simplest route is by electrolysis: passing an electrical current through water. The process is reversible:

$2H_2O$ (water) + energy = $2H_2 + O_2$ (by electrolysis)

$2H_2 + O_2$ (combined in a fuel cell) = $2H_2O$ + energy.

Ideally the electricity needs to be derived from non carbon sources, eg wind turbines, solar cells, or nuclear energy. However all fossil fuels are hydrocarbons (i.e. contain both carbon and hydrogen atoms) so hydrogen can also be obtained chemically from them. Natural gas is the favoured source.

Using hydrogen

Hydrogen can be burnt directly as a high quality, very clean fuel to produce electricity in power stations just like coal or gas. It can also be used as an energy 'store'. Wind, marine or solar sources of electricity are variable so producing hydrogen at times of surplus and using it to generate electricity when output drops would balance supply and increase the total renewable energy that could be used. There are a number of small projects already using the wind-hydrogen option: in the Baltic at Lolland, Greece (Karatea), Norway, America, the Isle of Unst in the Shetlands and one or two other places. At Lolland the oxygen from the electrolysis is used in the local sewage treatment works and the hydrogen in a micro-CHP plant producing 2 kW of electricity and 6.5 kW of heat. At Unst some of the hydrogen fuels a car as well as providing heat and power. Costs are high and can only be contemplated in small remote communities.

The great attraction of hydrogen is for use in vehicles where, apart from bio-fuels, there are no non-fossil alternatives.

Hydrogen fuelled transport

Most major motor manufacturers have been researching hydrogen powered vehicles, either using fuel cells or as a petrol replacement, since the early 1990's. In January

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This briefing note is based on a presentation at the 2000 Spring Conference given by Ken Cosslett and updated since. It should be technically accurate. If you see errors or have comments please contact Richard Balmer, email richardbalmer162@btinternet.com

2004 33 fuel cell powered EvoBus Citaro buses produced by Ballard the Vancouver based company and Mercedes/Daimler Chrysler, began a 2 year trial in 10 European cities and Perth, Australia. The trial was extended by a year with some change of cities (Beijing was a joiner). Transport for London (TfL) have now ordered 8 hydrogen fuelled buses made by the Wright Group in Northern Ireland. Two, operating out of the Stratford depot which holds the hydrogen, were on the RV1 route before Christmas 2010 with the remainder due in 2011. They cost £0.8 M each. 15 London taxis are imminent and Tarmac, the contractors, are testing 2 modified Ford Transits as part of another trial using ITM Power's technology with 4 other companies.

Elsewhere Johnson Matthey, the British company making catalysts, are cooperating with Ballard using methanol (meths) which is a liquid and so easier to handle. This is broken down to hydrogen and carbon dioxide with the hydrogen used in the fuel cell. Although methanol (CH_3OH) is currently produced from fossil sources, its use in a fuel cell increases overall efficiency. The fuel cells charge batteries which provide the current to drive the vehicle. The demands of a 70 kW electric vehicle motor for example can be met with an 8 kW fuel cell working continuously. Honda has now put its FCX Clarity on limited sale (about 200) in California and Japan (the only places with a minimal network of hydrogen fuel stations). It has a range of 270 miles and a 2.0 litre performance but costs upwards of £50,000 and needs a fuel tank of 171 litres (about 3 times normal) with hydrogen stored at about 340 atmospheres pressure.

Ballard also use compressed hydrogen in their buses but BMW, who have developed the use of hydrogen via their 750hL and 745h 7- series models and now the Hydrogen 7 version of their 760iL, use liquid hydrogen burnt directly in a 'petrol' engine. Hydrogen has to be compressed to 300+ atmospheres (road tyres have a pressure a little over 2) and liquid hydrogen has to be cooled to –253°C. Both are technically exacting and carry cost and other penalties. BMW's Hydrogen 7 only does 125 miles on the hydrogen fuel and requires a back up petrol supply. The combined fuel tanks occupy 170 litres space and some 250 kg weight is added. A further problem is that hydrogen will 'boil off ' in less than a day without use to maintain the refrigeration, and garages need venting lest a spark ignites any trapped hydrogen. Even so BMW have proved hydrogen can work as a simple fuel and have leased 100 Hydrogen 7s to prominent people to generate publicity and experience.

Ways to store hydrogen safely and conveniently continue to be sought and much work has been carried out over the last 30 years using special metals or chemical solutions. A water based solution of sodium borohydride is being studied. The solution would be pumped through a catalytic chamber in the vehicle to split it into hydrogen and sodium metaborate. The metaborate would be recovered at a depot and re-converted using renewably generated hydrogen. The carbon structures developed through nanotechnology may provide particularly efficient forms of mechanical storage.

Current outlook

Apart from cost the greatest challenge is to find a cheap way of producing hydrogen renewably. TfL are pragmatic enough to recognise that 'green-ness' depends on the reduction of CO_2 from 'well to wheel'. Early calculations suggest the 8 hydrogen buses will reduce the CO_2 emitted by only 50% due to the problems making and handling hydrogen before it reaches the 'tank'.

Like all new fuels (e.g. LPG and natural gas) hydrogen faces the chicken and egg problem of developing a distribution network across the country (and indeed the continent) when demand is in its infancy, but the number of garages is increasing with the EU and the USA on a par and Taiwan is developing a market with, admittedly small, reusable canisters. Buses and other municipal vehicles could well be all hydrogen because they remain relatively close to their depots but it seems likely that hydrogen fuelled cars will have to have petrol back up, unless an idea from Honda works. Honda believe a compact unit, smaller than a fridge, could be installed in the home and produce hydrogen directly from the gas supply.

Cost of course can not be ignored. The new London buses cost over £800,000 each and though this may be justified to bring down pollution in urban hot spots major subsidies will be needed to expand the market. As to the cost of hydrogen fuel itself, this is unclear. Electrolysis is known to use a lot of energy and be expensive although a German study claims converting biomass could produce hydrogen *cheaper* than the taxed cost of petrol, if not the untaxed cost.

Conclusion

Acknowledgement that action must be taken to slow global warming, whilst the world still desperately desires the convenience and pleasure afforded by both personal and public transport, is concentrating the minds of vehicle manufacturers wonderfully. That the global supply of oil is being squeezed and cleaner air demanded is increasing the pressure. Hydrogen powered urban transport (buses, taxis and delivery vans) able to access a limited number of hydrogen garages and using fuel cell technology should slowly come into major cities here and overseas. The possibility of having hydrogen piped to every house through the gas main to be burnt for heating and to generate electricity and be available there, on tap, to top up the car is much less certain - exciting perhaps but still a dream.