



Hydrogen: The clean fuel of the future?

Price
30p

Some history

The biggest drawback to the development of hydrogen as a fuel is the public perception of it being an explosive uncontrollable gas following the destruction of the airship Hindenburg in New York in 1937. Hydrogen is, however, comparable with methane (natural gas) and petrol from the point of view of danger and it used to make up over 50% of the old town gas supplies. If a substance is capable of being used as a fuel, inevitably it is potentially dangerous.

Throughout the 19th century various people worked with hydrogen both for use in internal combustion engines and in fuel cells. In fact hydrogen was considered safer than petrol at one time, but the invention of the carburettor made petrol safer to handle and led Otto to develop the modern petrol powered internal combustion engine.

Sir William Grove, a Welsh solicitor invented the fuel cell in 1839 and the work was developed further in the 1880s by Brenner and Mond. However, the invention of the dynamo by Michael Faraday and the further development of power stations as central sources of electricity coupled with cheap fossil fuel discouraged further serious development of fuel cells for many years.

The pros and cons of hydrogen

As a fuel, hydrogen has many advantages, mainly that it is so clean, the combustion product being water. On a weight for weight basis it releases far more energy in its reaction with oxygen than any other fuel, though on a volume basis it is more than 3000 times as dilute, which means that it has to be highly compressed to make it manageable. Liquid hydrogen is not an option for ordinary use because it needs massive cooling and special equipment.

Nonetheless, throughout the 1920s and 1930s many automobile engineers, led among others by Sir Harry Ricardo, continued work with hydrogen. Indeed with a high compression ratio the hydrogen powered internal combustion engine was very efficient. However all heat engines come up against the Carnot cycle which limits



Hydrogen filling station, Reykjavik

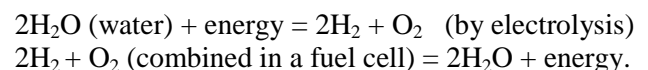
efficiency for all intents and purposes to 50% maximum, and often very much less.

The fuel cell does not have this limitation and could theoretically be 100% efficient. F T Bacon was the British scientist who worked single handedly on the hydrogen cell through the '40s to '60s and developed the cell which provided power in the Gemini capsules of the American manned space programme.

Whilst fossil fuels are cheap and easily accessible there is little incentive to develop the more expensive hydrogen as a fuel. However, it is believed fossil fuel use is contributing to global warming so hydrogen is a potential alternative. Moreover its source, water, is inexhaustible.

Production of hydrogen

Hydrogen can be obtained in various ways but the most elegant route is by electrolysis: the passing of an electrical current through water. The process is reversible:



Ideally the electricity needs to be derived from non carbon sources, eg wind turbines, solar cells, or even nuclear energy.

All fossil fuels are hydrocarbons (i.e. contain both carbon and hydrogen atoms) so hydrogen can also be obtained chemically from them. Natural gas (methane or CH_4) is the favoured source.

Using hydrogen

BP is currently designing a large, 350 MW, hydrogen fuelled power station at Peterhead, Aberdeenshire, where gas will be split into hydrogen and CO_2 . The hydrogen will be burnt to produce electricity and the CO_2 transported 240 km by undersea pipeline and injected into the Miller oil field increasing its yield by some 40 M barrels and extending its life by 15-20 years. BP have a similar project in Carson, California.

The greater potential seems to be in fuel cells. These could be developed for micro-generation in the home but more interest is being shown for use in motor vehicles where, apart from bio fuels, there are no other non-fossil alternatives. Hydrogen can also be used as an energy 'store'. The supply of renewable energy by wind, wave or solar cells is variable, and this will limit penetration into the wholesale electricity market unless the variability can be evened out by storage. Currently an American company is planning to build 2 wind/hydrogen 'farms' (one in the Baltic, the other in California) with the intention of selling

An ALDES Briefing Note

August 2006

This briefing note is based on a presentation at the 2000 Spring Conference given by Ken Cosslett. It should be technically accurate. If you see errors or have comments please contact the secretary, Richard Balmer, at 79 Links Drive, Solihull, B91 2DJ, or richard_balmer@blueyonder.co.uk

electricity at peak times and generating hydrogen 'off peak'. This is an important initiative because it will test the technology and give a good indication of costs.

Hydrogen fuelled transport

The major motor manufacturers have been developing experimental vehicles since the early 1990's. Ballard, the Vancouver based company, working in conjunction with Daimler Chrysler, have delivered 30 EvoBus Citaros which are being used in 10 European cities. Elsewhere Johnson Matthey, the British company making catalysts, are cooperating with Ballard. They are using methanol (CH_3OH) which is broken down to hydrogen and carbon dioxide with the hydrogen used in the fuel cell. Although the methanol is currently derived from a fossil source, use of a fuel cell increases efficiency. By using fuel cells to supply batteries which then drive the vehicle, the demands of a 70 kW electric motor for example can be met with an 8 kW fuel cell working continuously.

Methanol has an advantage because it is easier to transport a liquid than a compressed gas. However, Ballard use compressed hydrogen in their buses. Both the BMW 745h and the earlier 750hL have back up petrol supply, but are designed to use liquid hydrogen. This is stored in a cooled 140 litre tank, about 3 times the volume of a conventional one, though this will still give a range of only 400 km. Other pure hydrogen systems compress the gas to over 300 atmospheres pressure. (Road tyres have a pressure a little over 2).

High pressure and low temperature systems are technically exacting to bring into mass production, and consume about half the available energy. They also carry health and safety risks so much work has been carried out over the last 30 years on storing hydrogen in special metals or chemical solutions. A water based solution of sodium borohydride is being studied. The solution would be run through a catalytic chamber splitting it into hydrogen and sodium metaborate. The metaborate would be recovered and re-converted at a depot using renewably generated hydrogen.

The carbon structures developed through nanotechnology may provide particularly efficient forms of mechanical storage. It has been suggested such structures might carry up to 70% of hydrogen. If true, a 25 litre 'tank' fully charged with hydrogen would give an ordinary saloon car a range of 5000 miles on one filling! Watch this space!

Current outlook

Fuel cell powered transport is in the development stage. A great deal of expertise is being employed to find ways to reduce the weight and cost penalties of fuel cell systems and to work out the optimum way to carry fuel on board. In the absence of surplus renewable energy it is currently thought that producing hydrogen from natural gas gives the greatest reduction in CO_2 emissions (about 70%).

Though a few experimental cars are being put on the road, it is probable that the first production vehicles will be buses and other vehicles which operate within and around town centres. Not only is the weight penalty less important but

they need to remain close to a base where hydrogen is always available. All new fuels (e.g. LPG and natural gas) face the chicken and egg problem of developing a distribution network across the country (and indeed the continent) when demand is in its infancy. However it is becoming possible to 'top up' with hydrogen at more and more places including 30 in the USA (over half in California) and one at Hornchurch, Essex. Recently Shell has opened a station in Washington DC for 6 vehicles running to New York. Even so it seems likely that the first fuel celled motor cars will be hybrids: that is have supplementary petrol systems.

Amongst all this interesting news however, it is right to sound a note of caution. Some 20 years ago motor manufacturers began serious work on electrically powered cars. California required every manufacturer selling more than 35,000 cars a year in the state to include 4% with 'zero' emissions or face a penalty of \$5,000/unsold car. Success depended crucially on finding a low weight, low cost alternative to the old lead acid battery. Despite the funding and the actual and long term incentives, the search failed and consumer enthusiasm weakened. California plans to keep up the pressure for clean technology and hopes that the fuel cell will achieve what the battery did not, but it is in the process of reducing the 4% requirement to 2%.

Moreover, cost can not be ignored. The promising Citaros (see above) will have a range of only 300 km and a top speed of 50 mph. With their 250 kW fuel cell engines they will cost over £800,000 each. Some form of cross subsidy is going to be necessary to increase the demand for hydrogen vehicles so that volumes can increase and manufacturing costs come down. Lastly, hydrogen fuel will be more expensive, though a German study claims converting biomass could produce hydrogen *cheaper* than the taxed cost of petrol, if not the untaxed cost.

There is no doubt hydrogen fuelled vehicles can be built. The question is whether consumers will pay the higher price and, if not, whether governments will provide sufficient tax carrots and sticks to enable the technology to achieve a commercial breakthrough. One disincentive is that governments will lose fuel tax revenues and have to compensate by raising taxes elsewhere.

Conclusion

That the world will run out of fossil fuels and will need alternatives is fact, though when this will be is conjecture. That demands to tighten emission standards from power stations and vehicles will continue, despite escalating costs, is also certain. That some cities around the world have already begun to ban conventional vehicles at certain times, is merely the beginning of a trend which will create a market for zero emission vehicles. In all this hydrogen offers a potential, though challenging and expensive, solution. We are even further away from the day when hydrogen will be 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.
