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Liquid hydrogen as a transportation fuel

With ever-rising petrol prices and global warming issues, alternative fuels for transportation are high up on the priority list. Hydrogen is already used for this purpose in fuel cell vehicles, but liquid-hydrogen-automobile technology is gradually coming into existence, as BMW is about to launch two liquid-hydrogen-powered cars and cryogenic-hydrogen refuelling technology is slowly introduced.

- ***Pros and cons***

Hydrogen is the lightest of the elements with an atomic weight of 1.0. Liquid hydrogen has a density of 0.07 grams per cm^3, whereas water has a density of 1.0 g/ cm^3 and petrol about 0.75 g/ cm^3. It stores approximately 2.6 times more energy per unit mass than petrol, but it requires 4 times the volume of petrol for a given amount of energy. Of course, this is further amplifieded in the case of hydrogen in the gaseous state: a full tank of such fuel would last only a few miles before the tank is empty, hence the necessity to use hydrogen in liquid form.

Hydrogen is liquefied at cryogenic temperatures and then needs to be isolated in tanks that can add weight and size to a vehicle tank. Hydrogen is also explosive when released in confined spaces such as a garage, however leaks occurring in open spaces are likely to be less dangerous than petrol as hydrogen dissipates very rapidly. This extreme volatility makes it virtually impossible to contain either in liquid or in gas form for a certain duration: H2 is the smallest molecule and eventually slips through the sides of any metal container!

Its combustion releases water vapour, which makes it very environmentally friendly, but hydrogen still requires a lot of energy to produce. This can achieved by splitting water molecules into hydrogen and oxygen through electrolysis, which requires a great deal of electricity, generating other forms of pollution. Another option is to crack methane in ultra-high temperature ovens (>1100°C), an operation that releases large quantities of CO2.

The energy cost of liquid hydrogen is even higher: it is claimed that approximately 2.12 times as much energy goes into generating and transporting liquid hydrogen by truck to a car than that can actually be used to fuel it.

(High hopes are placed on the possibility of achieving hydrogen-atom fusion in the coming decades. This process only occurs at temperatures of over 5-6 M°C, inside the sun and releases a considerable amount of energy with a limited quantity of hydrogen. Research on atomic fusion is being led at ITER, in Cadarache. Incidentally, the technology involved in achieving this result is most likely to require superconductive alloys.)

- New liquid hydrogen fuelled cars

Until recently, the method used to fuel cars with hydrogen was cell conversion, in which the hydrogen was turned into electricity through fuel cells. Contrary to fuel cell conversion, hydrogen combustion engines require liquefied hydrogen as they use larger amounts of fuel. Refuelling problems make it necessary to devise hybrid engines that can also operate on petrol.

Within the framework of its Clean Energy System, BMW is launching two liquid-hydrogen-powered car models:

The BWM 750 hl has a hybrid, 12-cylinder combustion engine that can run indefinitely on petrol or hydrogen. Linde is providing the necessary technology to store the fuel at –253°C. The vehicle can achieve a top speed of 190 km/h. The petrol tank has a 600 km range, to which the 900 km range of the hydrogen tank can be added.

The 7 Series also has a hybrid engine. The 170-l hydrogen tank can keep the hydrogen cold for 70 hours before it vents away. Even though these vehicles are fully-fledged and operational, BMW is only loaning them to selected owners.

Both vehicles obtain electricity from fuel-cell-powered batteries that can operate independently from the engine, thanks to direct hydrogen feed from the tank, enabling accessories such as air conditioning to operate independently from the engine, at low fuel cost.

- ***The refuelling issue***

For now, one of the drawbacks is the insufficient refuelling network. Those addressing the needs of fuel-cell vehicles are gradually taking off, but they only provide hydrogen in gas form. California and Norway, for instance, are both building "Hydrogen Highways," the Californian highway already comprising 23 fuel-cell stations. But liquid-hydrogen refuelling is still in its earliest stages: as an example, there are only two liquid-hydrogen stations in the entire United States, one at BMW's testing centre in Los Angeles, the other in Washington DC.

In order to respond to this new need, Linde is launching a self-contained mobile hydrogen refuelling unit in the form of a trailer. The trail H_2^{TM} can supply fuel-cell or liquid-hydrogen-combustion cars and carries up to 1000 l of cryogenic liquid. This mobile liquid-hydrogen filling station, claimed to be the first of its kind, was put into service in Munich during the World Football Cup in 2006. Linde claims the refuelling device is an essential step in the build-up of a hydrogen infrastructure. The project is supported by the state of North-Rhine-Westphalia.

www.bmwworld.com/hydrogen
http://www-formal.stanford.edu/jmc/progress/hydrogen.html