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Fuel Cells – The Modern Necessity of Fuel

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Abstract - Day by day questions that were debated yesterday are now increasingly becoming critical issues that we deal today. Researchers work day and night to come up with a solution to such problem. Fuel cell technology has been around for many years, this technology has been accepted by all the major automotive industry as the answer for the future. This paper specifically deals with the automotive use of fuel cell as an alternative power train to the internal combustion engine for mass-market use. It looks at the progress made by the industry to date and clearly explains some of the major, technological, fuel and infrastructure issues facing both the industry and society on the road to a fuel cell-based hydrogen economy.

Index Terms – Fuel Cell Design, Challenges, Technologies, Safety

I. INTRODUCTION

In hydrogen fuel cell the future, the concept of having hydrogen fuel cell electric vehicles is compelling. Fuelled by pure hydrogen gas they produce zero local emissions, enjoy relative mechanical simplicity with sealed-for-life drive motors and their positive environmental impact not just on urban air quality, but also noise pollution would be substantial. The potential for integrating automotive power trains with domestic and de-centralized power generation is substantial and fully supports the need to address the world's alarming demand for energy in a way that fossil fuel technologies never could.

The end game is easy to visualize, but the fuel cell industry is encumbered with more than overcoming a huge technical task. It also has to succeed in motivating governments and society sufficiently to support the massive changes in economy and infrastructure needed with all the attendant costs that entails.

II. FUEL CELL DESIGN

An individual PEM (proton exchange membrane) cell consists of a fluro polymer membrane sandwiched by two, electrically conductive separator plates containing channels for the passage of gas and coolant liquid. The membrane is coated on both sides with a platinum catalyst layer, which form the electrodes of the cell (anode and cathode).

Hydrogen is supplied under pressure to one separator plate while air is pumped through the other. On the hydrogen side, the catalytic coating (anode) ionizes the hydrogen splitting it into protons and electrons. The protons then migrate through the membrane leaving the electrons to be collected in the separator, generating electrical current of between 0.6 and 1.0 volts when the circuit is closed. Having passed through the membrane, the hydrogen protons combine with oxygen electrons to form water, the only by-product of the reaction apart from heat. As many cells as necessary are connected in series to produce the desired total voltage (up to around 400 volts) and are known collectively as a 'stack'.

III. TECHNICAL CHALLENGES

Technical challenges are considerable and the advantages of simplifying fuel cell design (with so many individual cells in a stack) considerable. Some issues requiring further attention include:

- Robustness and life (especially of the fuel cell membrane)
- Start up time
- Start up in very low ambient temperatures
- Management of residual internal moisture in very low ambient temperatures
- Reduction of manufacturing complexity and cost.

IV. TECHNOLOGIES

All automotive fuel cell systems for tractive use are of the PEM type. PEM fuel cell stacks usually operate under pressure, intake air pressure being provided by air pump. UTC favors an ambient system, which operates at just above atmospheric pressure. Advantages lie in the fact that sealing of the stack and manifolds is a less demanding task and in noise, mainly because of the absence of a higher-pressure blower. A disadvantage of a low pressure stacks is the size, they are usually larger than pressurized stacks because of the need for greater internal surface area. Technologies such as UTC, PEM, V-3 etc are in use by various car manufacturers.

V. REFORMING LIQUID FUEL

Research is also going o into reforming (extracting) hydrogen from liquid fuels such as methanol or gasoline, which means equipping vehicles with fuel processors (reformers) to provide a supply of pure hydrogen to the fuel cell. Although the concept contradicts the concept of a zero emission fuel cell vehicle, extracting hydrogen from 'dirty' fossil fuel is seen as one way of bridging the gap between a hydrocarbon-based infrastructure and a fully developed hydrogen infrastructure. In the process of reforming the fuel is mixed with air and water, then passes over a series of catalysts that 'cracks' the hydrogen from the carbon, which is emitted as Carbon Dioxide. However, the hydrogen stream has to be cleaned before it reaches the fuel cell stack as any traces of carbon monoxide can destroy a fuel cell's proton exchange membrane.

VI. FUEL AND FUEL STORAGE

Fuel for Fuel cell vehicles, its distribution and storage are the perhaps the most widely misunderstood issues surrounding fuel cell vehicles. Research is being undertaken on direct methanol fuel cell but for all practical purposes, PEM fuel cells being developed for transport all consume pure hydrogen gas and oxygen. Hydrogen is a less exotic fuel than may be supposed; even though not yet readily available to the consumer it is already produced in large quantities worldwide. 98 percent of hydrogen is reformed from natural gas and today's total capacity would meet 15 percent of global automotive needs in a fuel cell society. 45 percent of all hydrogen currently produced is used for the desulphurization of fuel, 51 percent is used in the production of ammonia for fertilizers, 3 percent by the chemical industry and 1 percent for other uses. The sources from which hydrogen gas is derived on board the vehicle could be one of three things. It may be stored cryogenically in liquid form at –253 C, in compressed gaseous form, or processed from a liquid fuel using a reformer onboard the vehicle. Liquid hydrogen storage is the traditional method used for most early fuel cell concepts. Commercial disadvantages include the difficulty and potential danger of handling liquid fuel at such low temperatures and evaporation caused by the eventual warming-up of the vacuum insulated flask. Research by GM, however, shows that this may be less of a problem for drivers using vehicles on a day to day basis and more so for weekend drivers, or those leaving vehicles for longer periods, for example in an airport car park. Research is still going on into hydrogen storage by absorption into metal hydrides, but the barriers are cost, weight, heat generation during filling, the time taken to fill a storage vessel and the speed at which hydrogen can be released when, for example, a vehicle is accelerating. Materials being tested include titanium alloy, magnesium and sodium alanate, the latter being relatively light and of lower cost. On board compressed gas storage has increasingly become the norm over the last few years thanks to the evolution of high-pressure, light weight tanks from manufacturers such as Dynetek, Impco Technologies subsidiary, Quantum and structural Composite Industries. The principle cost driver with compressed gas tanks is the carbon fiber itself. Tanks have built-in regulators so external pressures are kept to a few bar but conform to different structural types. Liquid Hydrogen carriers under investigation include methanol, ethanol and gasoline, all of which would need to be reformed to extract hydrogen either at filling stations or on-board the vehicle. Methanol can be made from coal, natural gas or from methane gas produced by fermentation of biomass. Though difficult to reform, gasoline is a real prospect as an interim fuel until a hydrogen infrastructure is developed but would need to be a specially formulated, sulphur free fuel lacking many of the additives needed for combustion engines.

VII. SAFETY

It was established in the late 1990's that the Hindenburg disaster was not caused by a hydrogen explosion, but by the use of a highly inflammable dope on the envelope. Although, like any fuel, there are dangers associated with the use of hydrogen, the consensus is that they are no greater than conventional fuels. Advantages are that it quickly disperses in the atmosphere compared to gasoline fumes, which are heavier than air. Re-fueling a car with a compressed hydrogen rig is straightforward and not unlike filling a vehicle with LPG at a commercial fuel pumps. Public use of liquid hydrogen may present greater difficulties and expense, however and may require the use of robot re-fueling stations. One of the most common areas for concern is the use of the now popular high-pressure storage vessels and fear of a catastrophic explosion. Safety tests are stringent and include testing to 2.3 times the operating pressure: Quantum's 10,000psi tank finally burst at 22,500psi. Other tests generally used include shooting at pressurized tanks with live rounds, bonfires, dropping from a crane while installed in a vehicle and subjecting them to an explosion using dynamite. The composite tanks are said to split and leak when failing rather than explode as an all-metal Type 1 tank might (e.g. LPG tanks). However, these facts do not prevent a level of concern as to their use in some quarters, even among the vehicle developers themselves. At the very least, the perceived danger may provide barriers during commercialization, despite relatively common use of CNG and LPG throughout the world, as well as the regular transport of industrial oxy-acetylene bottles by road.

VIII. INFRASTRUCTURE

It has been said that 'the most important unresolved issue with fuel cell vehicles is not the fuel cell, but the fuel, 'Or more to the point, how to distribute and supply that fuel to the point of sale. The question of fuel cell vehicles and hydrogen infrastructure is a classic catch 22 situations but I believe in particular that the car has to come first and that sufficient hydrogen stations will become available if the car meets expectation. Developing a hydrogen infrastructure involves the resolution of technical issues, economics and geography. The general consensus on manufacture is that hydrogen can be produced on a sustainable basis according to geographical resources. So, for example, solar electricity may be used in California and Gulf states, hydroelectric power in Iceland and Norway, wind farms in Europe and so on. Industrial corporations are already transporting liquid hydrogen widely using tankers and believe that to be a realistic option. But there are energy considerations in the choice of fuel. Liquefying hydrogen consumes energy but was it to be dispensed to vehicles as compressed gas, which seems likely it would need to compressed, consuming additional energy. But transporting hydrogen in compressed form is far less efficient (in terms of energy density for a given volume of tanker) than in liquid form.

IX. FUTURE

General Motors Corp. and Shell Hydrogen LLC are planning to bring a fleet of hydrogen fuel-cell vehicles and a refueling station to New York City. Ford plans to bring a new line of fuel cell-powered cars into limited production. The new generation vehicles will be sold first in Canada and later in the U.S. Ford's fuel cell cars, based on the current P2000 prototype, The other leading contender appears to be DaimlerChrysler, which has also announced plans to sell a fuel cell-powered car in 2005. The current DaimlerChrysler prototype is named the NECAR 4.

X. CONCLUSION

The pace of development since the mid-1990s has been high. Estimates of spending on fuel cell development in the private sector are between $1billion and $3 billion on fuel cell development and more is planned. Many car manufacturers have already committed further $1 billion to fuel cell. The race to reduce the cost of fuel cell stacks continues with the cost of a fuel cell power train. While environment considerations are certainly a factor, by far the biggest factor in the fuel cell vehicle's favor is the potential for new business and the profit awaiting those who claim intellectual property on designs. Almost all car manufacturers have own their own fuel ell technology. The subject of when Fuel cell will appear in numbers will begin to appear in certain markets by 2010 though it will not be until FCVs stand a chance of dominating the scene.

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