How Small Can Fuel Cells Go?

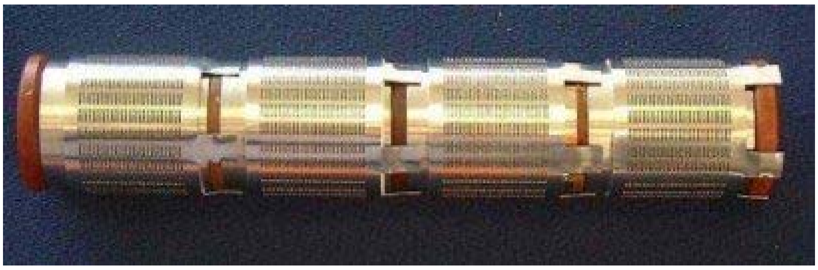
Much has been promised from fuel cells since the 1960s when they began to be used in the space industry.

For more than 40 years fuel cells have promised, and to an increasingly large degree demonstrated, a new cleaner and more efficient power source, but their introduction into mass use has always seemed 'just around the corner'. This case study highlights some of the existing obstacles and reviews some of the activities that aim to overcome them.

Fuel cells in their various forms are being developed for applications ranging from large distributed electricity generators, replacements for the petrol engine in cars, down to small-scale battery replacements for electronic devices. The larger scale applications, especially the stationary power generation systems, are the most widespread.

Sparked off by changes to the worldwide utility industry, many smaller power generation companies, and even end users themselves, are increasingly using fuel cells to generate power for community and private use. In the car industry, most car manufacturers have a fuel cell development programme and are prepared to invest heavily to get fuel cell powered cars on the road.

Portable fuel cells are trailing the field at present, and while they have some difficult technical and commercial hurdles to overcome, these difficulties are beginning to be tackled by developers.



‘Walk-man’

The two main candidates for man-portable systems are Proton Exchange Membrane Fuel Cells (PEMFCs), which run on hydrogen gas, and Direct Methanol Fuel Cells (DMFCs), which run on a mixture of methanol and water. Both types of fuel cell require oxygen in order to operate and it is usually convenient to use ambient air as the oxygen source. However, this presents a problem to the end user as the fuel cells must have air and this limits their placement in electronic devices. These air-breathing fuel cells are also affected by airborne contaminants, such as sulphur compounds and carbon monoxide (CO), which poison the catalyst, a fact often overlooked by fuel cell manufacturers.

QinetiQ has previously undertaken studies to assess the effects of air contamination in fuel cells and has identified a number of solutions.

Fuel barrier

One important technical issue that will delay the wide-scale introduction of fuel cell devices for portable power relates to the fuel itself. The hydrogen source and storage issues are pervasive across the entire spectrum of hydrogen energy devices. At present, gaseous hydrogen, obtained from compressed gas bottles or secondary metal-hydride stores, remain the most accessible means of fuelling portable power generating devices, and the source of hydrogen is almost entirely derived from fossil fuels. Apart from the environmental issues, hydrogen is difficult to store in sufficient quantity within small, lightweight containers. Consequently, although
numerous PEMFC devices exist for portable power applications, their portability or operational longevity can be severely compromised by the size and weight of the hydrogen storage and
supply apparatus.

To some extent, the hydrogen issue may recede with the emergence of miniaturised fuel reformers. Though the overall system complexity increases with the addition of a reformer in a portable PEMFC device, it will allow a wider range of fuels to be used, and these may have fewer storage problems.

Storage

Numerous approaches are being undertaken to improve the storage of hydrogen. These include further research on improving the gravimetric capacity of reversible metal hydrides and improved gas cylinders. However, it is highly unlikely that compressed gas cylinders will be acceptable for mass distributed portable electronics. Other promising approaches are focusing on the production of hydrogen from the decomposition of primary hydrides. Groups in the US and Canada have produced systems that generate hydrogen from the reaction of ammonia with hydrides such as lithium aluminium hydride and from the hydrolytic decomposition of stabilised solutions of sodium borohydride.

In the UK, QinetiQ is having success generating hydrogen from the decomposition of ammonia borane. All these decomposition methods promise much higher yields than reversible hydrides or cylinders but still require further development. The other solution to the problem of efficiently storing hydrogen is to design a fuel cell which does not require hydrogen to operate at all, but which can instead operate on a much easier to store liquid fuel - the DMFC.

A direct solution

Whereas hydrogen fuelled systems give the highest power densities, the problem of storage and refuelling of hydrogen has led to increased interest in liquid fuelled systems, such as the

DMFC. Although the DMFC has a lower power density than its hydrogen fuelled counterpart, the high energy storage of methanol has the potential to significantly raise the energy density above that of competing electrochemical power sources. Despite these advantages, the DMFC has not yet demonstrated its full potential due to the following technical issues:

- Methanol oxidation is a difficult reaction to catalyse and requires highly active and expensive catalysts with loadings considerably higher than those used in hydrogen fuel cells. Although DMFC performance is acceptable at elevated temperatures, those obtained under ambient conditions is poor and has ramifications for portable power sources.
- Conventional electrolytes used in DMFCs are permeable to methanol and this leads to a depolarising reaction on the cathode catalyst, reducing the cell performance as well as the fuel efficiency.

QinetiQ has ongoing projects focusing on the development of liquid fuel cells and is overcoming the problems described above by the application of novel membrane electrode assemblies, as well as the use of alternative liquid fuels. Outputs from these projects will be a selfcontained miniature fuel cell for portable electrical equipment (eg mobile phones) and the production and demonstration of a high performance stack.

Replacement batteries?

It may be best to think of fuel cells systems as replacements for generators rather than batteries as systems this size have the capacity for fuel storage, delivery and conversion, with the possible addition of a fuel reformer.With this in mind it is easy to see why industry has progressed further in larger scale applications.

Miniaturising a diesel generator is a difficult process, and miniaturising a fuel cell while retaining a high energy density and efficiency presents even greater difficulties. The goal of having a portable fuel cell that starts instantly and performs as efficiently and safely as a battery has been achieved by many developers. These fuel cells have found uses for certain applications and QinetiQ has recently demonstrated a fuel cell battery charger that charges laptop computer batteries. QinetiQ has also built a 50W man-portable PEMFC system and various miniature liquid fuelled fuel cells.

Clearly, the fuel cell research and development (R&D) community is growing in capability daily, and in the near future a company may announce to a startled world that it has developed a fuel cell device that is so small and discreet you could not tell it apart from conventional batteries.

However, while fuel cells systems are becoming more compact, it still may be some time before we use them like we use the common battery today. The man-portable PEMFC fuel cell worn to demonstrate both commercial and military applications.

Source: QinetiQ