

Reality Checks to Commonly Heard Direct Methanol Fuel Cell Myths

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There is enormous interest in Direct Methanol Fuel Cell (DMFC) systems for low-power applications. Thousands of papers and patent applications have appeared in the literature over the last years, and virtually every major consumer electronics OEM has at least a DMFC R&D program. At the same time, the first DMFC products by SFC Smart Fuel Cell appeared on end-user markets. This paper reviews the most frequently heard opinions on inherent technical characteristics of DMFC`s and subjects them to a reality check based upon SFC`s experience with products actually being used in the market.

Myth #1: “DMFC systems suffer from methanol crossover”

REALITY CHECK: This is probably the most frequently heard myth about DMFC technology. The term “methanol crossover” describes the phenomenon associated with some of the fuel permeating through the electrolyte membrane. Hundreds of people have been working to avoid it, thousands of students have been told “DMFC does not work because of crossover“, and millions of dollars have been spent on this alleged issue.

In a slightly different context, Paul Stonehart, a famous electrochemist, commented:

Unfortunately, most of this work was uniformly useless, since it is not possible to extrapolate any of these results to operationally useful environments ... The perceptions of many academic research groups regarding important questions that need to be answered, and the realities of the marketplace are not the same.

P. Stonehart, in *Progress in Electrocatalysis – Theory and Practice, Conference Abstracts*, Ferrara, Italy, Sept 13-15th, 1993, p. 106.

This statement fits perfectly to the myth concerning methanol crossover. From an academic point of view, looking at a single cell test station in a laboratory environment, it is correct that methanol crossover has a few disadvantages: it does lead to losses in Faradaic and voltage efficiency.

In real-world environments, when you design complete integrated systems and want to ship products that make customers happy, other factors are far more important. Among these are lifetime and reliability, cold-start and freeze-start capability, water and heat management of the system under any conditions. To actually meet these requirements, it turns out that methanol crossover is not only helpful, it is absolutely necessary for any DMFC system that exists today. Active systems by SFC Smart Fuel Cell, and even passive systems, would not work without (controlled) fuel crossover, because:

- (a) Methanol crossover is a way to convert methanol into water, which is helpful in certain situations such as during start-up or under extreme outside conditions;

- (b) Methanol crossover is the most elegant way to rapidly heat up the unit;
- (c) Methanol crossover can be used to distribute the anti-freeze additive evenly across the whole stack;
- (d) Methanol crossover is quite helpful from a system control perspective.

SFC's state-of-the-art DMFC systems use active crossover control, i.e. they activate crossover when needed, and reduce it to an absolute minimum (1-2 %) when it is not desired. An off-the-shelf Nafion membrane, combined with a well-designed anode GDL structure, good fluid dynamics in the anode, and software algorithms using active crossover control fulfills all requirements.

The only scenario under which a further reduction in crossover may be beneficial is ultra-low loaded cathodes – cathodes with Pt loadings far below about 0.5 mg/cm². The more platinum loading is reduced on the cathode, the more sensitive the cathode becomes to even very small amounts of crossover. However, today's platinum loadings are already compatible with the target costs of the vast majority of DMFC applications. Again, some well managed methanol crossover is more than useful to design and supply reliable DMFC products.

Myth #2: “Methanol cannot be transported by plane”

REALITY CHECK: This is often heard, but is fully understood only by very few people. In fact, you can ship methanol onboard aircraft already, by air cargo in UN-approved packaging subject to Dangerous Goods Regulations. SFC has established a working fuel supply infrastructure such that any user which has a shipping address somewhere on the planet can be supplied with full methanol cartridges within a few days. SFC has obtained the IATA certification which allows the company to ship fuel cartridges by airplane. Companies not in possession of this certification can work with external cargo service providers who take care of the paperwork.

In the future, private end users will be allowed take methanol fuel cartridges with them into the cabin of an aircraft - and to use this equipment onboard. There has been very encouraging progress removing the regulatory hurdles. A big breakthrough was recently achieved: in December 2004, the UN Committee of Experts on the Transportation of Dangerous Goods in Geneva enacted a new global model regulation for fuel cartridges. Cartridges that comply with a safety standard will be allowed on the airplane. It is now up to other regulators and modal agencies; such as, national authorities, ICAO, IMO, and others to translate this new model regulation into enforceable regulations. This process is expected to take until 2007. Thereafter, fuel cartridges will be treated similar to other consumer goods such as toiletry articles (e.g. perfume), beverage alcohol, and other personal belongings that can be carried onboard – requiring compliance with safety standards and in reasonably limited quantities.

Myth #3: “Methanol is toxic and flammable, so it is very dangerous“

REALITY CHECK: The first part of this statement is true, the second one not necessarily. Methanol as a substance is toxic and flammable. In contrast, methanol properly packaged in cartridges that meet or exceed applicable safety standards is very safe to handle. Today's methanol cartridges for entry markets already fulfill the highest applicable safety standards,

such as UN approval and the German TÜV (organization analogous to UL in USA) GS label (meaning “safety tested”). Therefore, SFC’s methanol cartridges are not classified as mere containers for methanol, but as a consumer article, based upon their safety features (e.g. patented safety valve) and the rationale that users do not come into contact with the content. Consumer cartridges for mass markets will also fulfill CPSC (consumer protection and safety commission) and other requirements, including child resistancy.

In many ways, methanol cartridges are actually safer than batteries. Modern batteries store a huge electrical energy potential which, upon a single event such as a short circuit, can be released very quickly and typically leads to a fire. In the case of fuel cartridges, three separate events must occur in proper sequence to cause a similar accident. First there must be a rupture of the cartridge body that leads to leakage. Second, there must be access to enough oxygen for combustion before the methanol evaporates; and, finally, an adequate ignition source to start a fire must occur.

In summary, industry has developed safe methods for supplying methanol, managing the toxicity and flammability of the content of fuel cartridges. Cartridges will meet and exceed all applicable safety standards.

Myth #4: “DMFC system efficiency is too low for consumer applications”

REALITY CHECK: This is a myth in almost all DMFC markets. DMFC system efficiencies are typically between 20 and 30 % (methanol in → DC power out) which, for power conversion systems in the power range of 10 – 250 Watts, is an exceptionally high number. It will be almost impossible for any competing technology to exceed this proven efficiency, with the only exception of hydrogen fuel cells. Most significantly, DMFC system efficiencies have already been quantified on real world operating units in very advanced stages up to commercially available products. Whereas, the values for some competing technologies that have been publicly announced, are merely theoretical values that still need to be proven in mature consumer ready systems. Also, DMFC systems achieve this efficiency with neat methanol (100 %, undiluted) as its fuel, which maximizes systems energy density.

Again, reliability and ruggedness are top priority parameters of any product design. Hence, it is wise to focus on these, and implement certain safety margins in system design and component selection, which typically leads to minor efficiency losses compared to best-case theoretical studies.

The main point is, however, this: the only important parameters for market-driven products are customer benefits. In case of DMFC systems, these are typically reflected by the advantages in these important parameters such as:

- is it available today?
- is it cost effective?
- weight, volume, form factor of device and cartridge
- runtime per cartridge
- lifetime, reliability, ruggedness
- low noise generation, low detectability, zero environmental impact.

Users never have a direct advantage of system efficiency. They judge product suitability based upon their direct benefits, which are only partially related to efficiency. It is certainly true that $(100\% \text{ minus system efficiency})$ times overall power consumption gives waste heat. However, one must carefully examine the mechanisms and temperature gradients required to reject this waste heat. For DMFC systems, significant portions of this waste heat is simply taken up to vaporize product water (in both the anode and cathode exhaust streams). Therefore, this heat does not need to be rejected nor does it lead to heat exchanger or thermal signature issues. SFC systems maximize the temperature gradient along which the remaining waste heat is rejected, which minimizes size, weight, and cost of the heat exchanger.

System efficiency is certainly related to runtime per cartridge, as a more efficient conversion efficiency gives longer runtime per cartridge. However, the following example may illustrate a very typical situation:

System X has a 28 % efficiency and a single cartridge lasts for 3 days non-stop. System Y has a 30 % efficiency, the same cartridge then lasts marginally longer – but this unit is significantly more expensive because it is more complex, it is much less reliable, and has limited operational flexibility such as inability to operate at zero load or partial loads, and cannot be turned off instantly, etc.

Which of the two systems should the commercial or military customer prefer?

In summary, efficiency alone is never the single decision parameter. The nature of energy converters is that trade-offs between several parameters must be found. Thus, a focus on reliability, availability, cost, compactness, and user operability occurs. This is particularly true for low-power markets, such as portable power for consumer electronics and military applications.