MINIMIZING MASS-TRANSPORT LOSSES IN PEM FUEL CELLS

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The key to minimizing mass-transport losses in PEM fuel cells is effective water management within the cell. The optimum operating condition for a PEM cell is fully saturated reactants without excessive liquid water. Thorough humidification is required to minimize ohmic losses and maximize membrane life. However, the presence of liquid water can restrict gas access and result in higher mass-transport losses. It is very difficult to maintain this fully saturated, but not flooded, condition across the entire active area of a practical cell operating at practical reactant utilizations due to the water being produced in the cell, gas consumption, and temperature variations. Even if this precarious balance can be approached under certain operating conditions, it can be difficult to maintain this ideal state under the variety of conditions and transients that a fuel-cell stack is required to undergo for most applications.

UTC Fuel Cells' proprietary PEM stack technology effectively overcomes this difficult water-management challenge in a passive manner [1]. Bipolar plates with fine pores are kept filled with water by flowing water at a lower pressure inside the plates than the reactant streams flowing on the exterior surfaces of the plates. The water in the plates provides humidification in regions that are under-saturated and removes excess liquid water due to the pressure differential. This unique driving force for water removal eliminates the need to utilize other water-removal methods (*e.g.*, serpentine flow channels with high pressure drops and flow velocities and/or carefully controlled temperature gradients to promote vapor removal) that have adverse effects on the system's efficiency and energy balance. Continued optimization of this water-management system has recently yielded performance with greatly reduced mass-transport losses. As shown in Fig. 1, these improvements have resulted in cells that can be operated at very high power densities even at relatively low air stoichiometry (*e.g.*, > 9 kW/m^2 at 1.25 air stoichiometry). These results are especially advantageous for applications that demand high power density, as well as simple/compact systems that operate in water balance under a variety of conditions (*e.g.*, transportation).

It should be noted that the improvements described here are analogous to the other major advances that have had a significant impact on the performance of PEM cells. Namely, the development of catalyst layers with high performance and reduced catalyst loadings [2] and the availability of reinforced membranes with excellent performance and durability (*e.g.*, like those offered by W.L. Gore [3]). None of these improvements have relied on brand-new materials, instead these improvements all consist of existing materials (*e.g.*, carbon-supported catalysts, *PFSA*, and *e-PTFE*) that have been modified and combined to form more optimum structures. The development of these engineering solutions, along with optimized operating conditions, has made PEM fuel cells more commercially attractive than ever before. Undoubtedly, these engineering improvements will continue and, fortunately, they tend to occur at a much faster rate than the introduction of brand-new types of materials and/or fuel cells. For example, PEM fuel cells were invented in the 1950's [4] and the first Nafion®-based PEM fuel cell was tested in 1966.

References

1. C. Reiser, *U.S. Patent 5,700,595* (1997).
2. I.D. Raistrick , *U.S. Patent 4,876,115* (1989).
3. B. Bahar, *et al.*, *U.S. Patent 5,547,551* (1996).
4. W.T. Grubb, *U.S. Patent 2,913,511* (1959).

Figure 1. Load calibration results for a 400-cm^2 single cell operating at various air stoichiometries. Cell conditions at 2 A/cm^2 and 1.25 air stoichiometry: air inlet / exit P = 24.7 kPa / ambient, air inlet / exit T = ambient / 76.4 C, and coolant inlet / exit T = 61.6 C / 80.7 C.