Steady State Water Model for Polymer Electrolyte Membrane Fuel Cells

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Proper humidification in polymer electrolyte membrane fuel cells (PEMFCs) is essential for steady power delivery. An excess of water can lead to flooding of the electrodes while a deficiency of water leads to membrane dehydration. Both of these situations dramatically decrease fuel cell performance.

A steady state water balance model for PEMFCs was developed. The basis for the model is that the water produced by reaction at the cathode must balance the water carried out in the exhaust streams from the cathode and anode. In the simplest configuration the anode and cathode are modeled as continuously stirred tank reactors whose concentrations are uniform and equal to that of the outlet. At low current densities the water distribution within the membrane is considered to be uniform and the water vapor in the gases at the anode and cathode and in equilibrium with the water in the membrane.

A very simple PEM fuel cell was constructed that shows the existence of multiple steady states. If the membrane is not sufficiently hydrated at start-up it is impossible to achieve a reasonable steady-state current output from the cell. The model was used to predict the ideal operating conditions to achieve a steady state or a balance between the rate of water production and rate of water removal. Only at such a condition can high performance of a PEMFC be sustained over long periods of time. The rate of water production and removal are expressed as functions of relative humidity in the cell. It was found that at 80°C with no inlet gas humidification, three steady state conditions exist (Fig. 1). At higher temperatures (130-140°C) which is the desired operating range for PEMFCs operating on reformed fuel, either humidification of the inlet gas streams or increasing inlet gas pressures is necessary to achieve a balance between the rate of water production and the rate of water removal.

Increasing the inlet gas pressures increases the rate of water production and the amount of energy produced, but higher gas pressures may lead to higher fuel and energy costs. On the other hand, humidification of the inlet gases dilutes the inlet gas streams lowering the rate of energy production.

Since maintaining a high rate of energy production is the ultimate objective, different conditions for were investigated to achieve the same energy production rate. It was found that for the same rate of water production or energy production, less inlet gas pressure is necessary in the case of humidified gas streams. It is necessary to combine increased inlet gas pressures with inlet humidification to minimize economic and energy losses while maximizing the rate of energy production.

Using the conditions predicted by the model, experimental tests are in progress to prove the validity of this model.

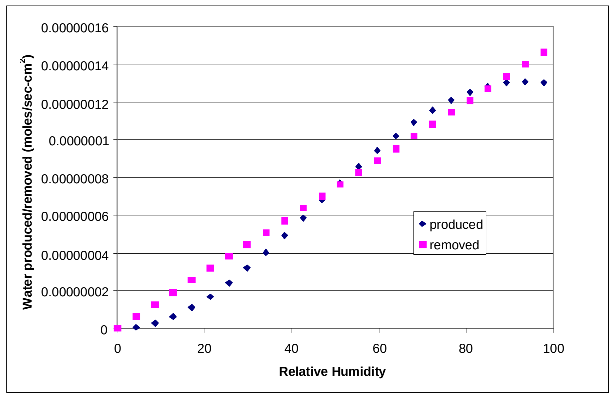

Figure 1. Water Balance Model Results at 80°C

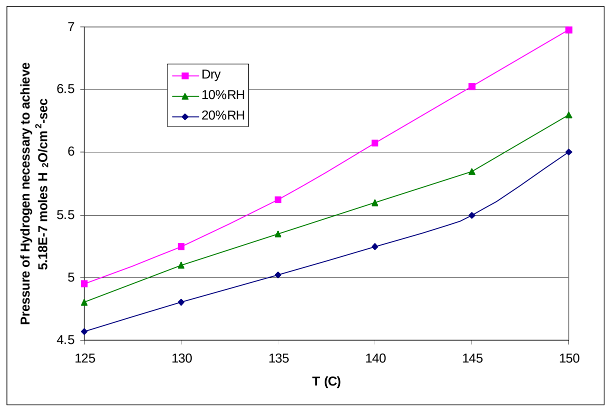

Figure 2. Comparison of Operating Conditions Necessary for Same Rate of Energy Production