Water Balance in Polymer-Electrolyte Fuel Cells with Counter Flowing Air and Fuel

R. M. Darling
United Technologies Research Center (UTRC)
East Hartford, CT, 06108, USA

Understanding and controlling the movement and accumulation of water in polymer-electrolyte fuel cells (PEFCs) has long been recognized as key to improving performance and durability. State-of-the-art cells use thin (< 25 μm) membranes that provide low resistance and rapid water movement. The water activities of the fuel and air streams at a particular location in the active area approach equilibrium because of this rapid water movement.

An approach that has been successfully applied to plan fuel-cell experiments and organize results is based on the concept of an exit relative humidity function. The exiting relative humidity is calculated from a steady-state mass balance on water and the assumption that the water activities of the air and fuel and leaving the cell are in equilibrium. This approach leads to a function that depends on the compositions, flows, and pressures of the air and fuel entering the cell and the temperature of the cell. Figure 1 shows the correlation between resistance and relative humidity for a large single cell. The resistance is nearly constant for RH > 1 and increasing for RH < 1.

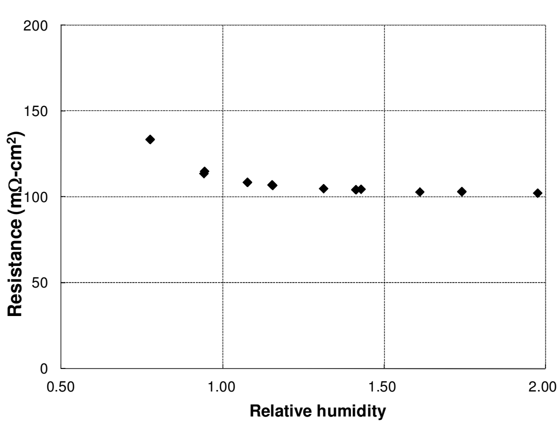

Figure 1: Correlation of resistance to relative humidity.

The approach outline above does not yield correct predictions for the effect of dry fuel flow when the fuel and air are fed to the cell counter-currently. The exiting relative humidity decreases as more dry gas is added to the cell. However, performance is often observed to increase when the flow of dry gas is increased to a cell operating at RH < 1.

This deficiency can be understood by comparing the fuel cell to a multi-stage equilibrium separator with multiple feed points. While this approach is approximate and does not replace more detailed and sophisticated models of water balance, it suggest an instructive way to plot and interpret water collection measurements.

Figure 2 shows a series of water balance measurements for a large cell operating with dry fuel and air. The abscissa is the ratio of dry fuel to total dry gas; the ordinate is the fraction of water that exits in the fuel stream. The straight line is the fractional separation predicted by the exiting relative humidity calculation. The data is divided into two series depending on whether condensation is likely or not. When condensation is not expected, the data lies below the straight line for low fuel flows and above the line for high fuel flows. This behavior is consistent with a multi-stage separator, as indicated by the dashed curve in figure 2.

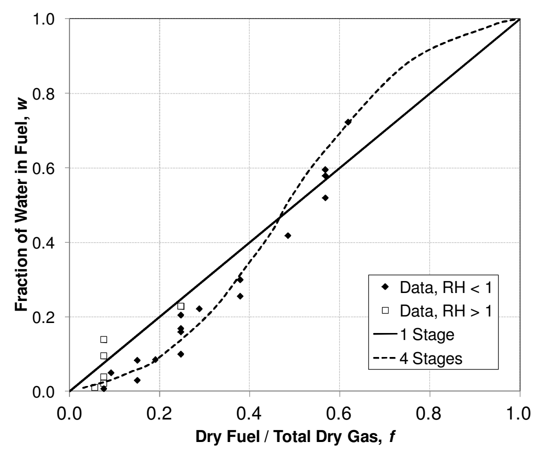

Figure 2: Water balance for large cell with counter-flowing air and fuel.

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