Effect of Reactant Gases Humidification on Hydrogen Fuel Cell Performance

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Abstract

Recent experimental investigations on polymer electrolyte membranes emphasize water management as being a critical factor in the design of an efficient fuel cell. The research topic of interest aims to explore the influence of humidified air and hydrogen on the fuel cell's performance. The first part of the experiment involved the measurement of humidity and temperature entering and exiting the fuel cell, via both reactant channels across varies loads. The results indicated a substantial increase in the exiting humidity of oxygen (25.26%) despite the humidity entering the cell being relatively constant (0.68% increase). The air exiting the cell plateaus at 75.15% RH (relative humidity). A comparison of both gases under similar parameters was made. The oxygen's substantial increase in humidity was matched by a smaller increase (14.3%) from the exiting hydrogen side. The cell yielded a maximum power density of 19.43 mW/cm² and a maximum current density of 41.33 mA/cm². The second part of the experiment involved conventional methods of external-humidification of the oxygen gas. The humidified air entering the cell was not controlled and ranged from 85.63% to 78.42% RH. The humidified air exiting the cell was less volatile and yielded a slight increase of 2.11%. Comparison of humidified air versus non-humidified air was made and a 72.77% increase in power density was recorded when oxygen was humidified. Since the results in the dry cell (no humidification) yielded a slight change (14.3%) in the exiting hydrogen humidity, the consequent step was the humidification of circulated hydrogen. The hydrogen proton carries an average of one to five water molecules when passing through the polymer electrolyte membrane (electro-osmosis). Electro-osmosis could damage the fuel cell and cause a voltage drop if the polymer electrolyte membrane is too dry. Humidification of the hydrogen required a more complex apparatus consisting of a humidifier, humidity and temperature sensor, dehumidifier and hydrogen compressor for circulation. The results yielded a slighter gain in power density of 12.87%.The humidification of air proved to be more crucial in the optimization of the fuel cell via water management. The final part of the experiment was the humidification of both reactant gases. The exiting humidity of both gases yielded less difference then the previous scenarios. The humidification of both reactant gases yielded better performance then solely humidifying hydrogen but fell short of the performance of solely humidifying air. Although the maximum power density increased substantial by 54.24%, humidification of air proved to be more influential.

The Effects of Humidification

+

Maximize

Power output of fuel cell (Proton conductivity is directly proportional to the water content)

Minimize

Negative effects of electro-osmotic drag, the H+ tendency to pull water molecules with it when passing from the anode to the cathode. Typically between one to five H20 molecules are dragged by each proton (Zawodzinski et al.,1993 and Ren and Gottesfeld,2001)

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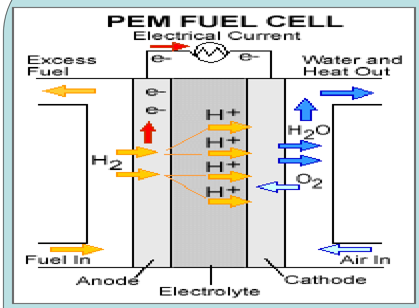
PEM



The humidified gases infiltrate the PEM after passing through the electrodes. The PEM is where the hydration is needed in order to yield optimal performance and avoid damage. If lack of hydration exists the PEM will dry and crack, causing the gases to mix directly and thus excessive thermal heating will occur. On the contrary saturation will cause the electrodes to flood and the reactant gases will not be able to reach the catalyst. These situations will yield a considerable voltage drop. Optimal humidity is just below 100%.

Experimental Apparatus

External humidification is necessary to optimize performance. Therefore, the reactant gases are humidified directly before entering the fuel cell. The hydrogen and air are humidified by circulating through humidifiers. The gas molecules carry some water with them and ultimately pass that water along to the electrode and PEM.

Results

Figure 1a

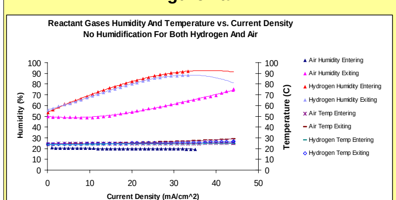


Figure 1b

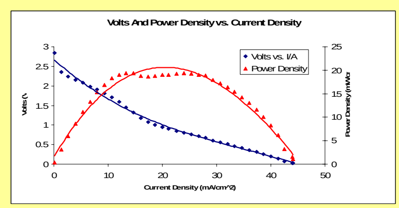


Figure 2a

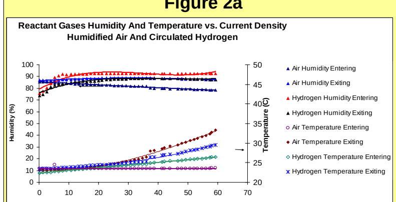


Figure 2b

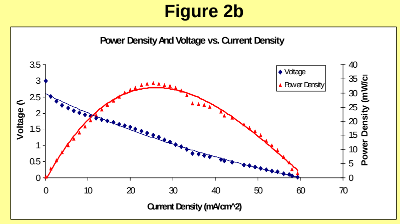


Figure 3a

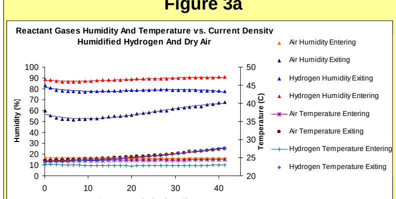


Figure 3b

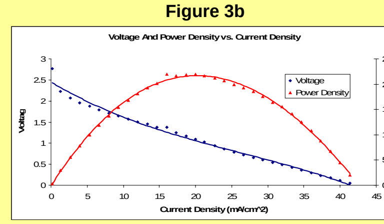


Figure 1 a & b

1a) Temperature and humidity of reactant gases entering and exiting cell without external humidification.
1b) Complimentary power density and voltage for cell without external humidification

Figure 2 a & b

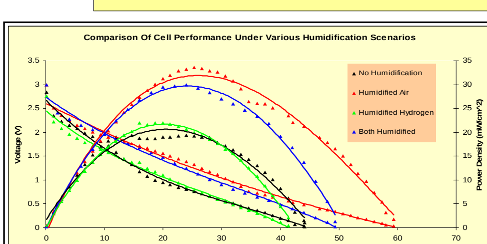
2a) Temperature and humidity of reactant gases entering and exiting cell with external humidification of air.
2b) Complimentary power density and voltage for cell with external humidification of air.

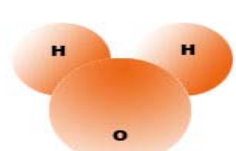
Figure 3 a & b

3a) Temperature and humidity of reactant gases entering and exiting cell with external humidification of both gases.
3b) Complimentary power density and voltage for scenario.

Figure 4

This graph compares the power output and voltage of the fuel cell under various humidification scenarios





WATER MOLECULE

Hydrogen Fuel Cell Byproduct

Conclusion

The humidity of the cell proved to be an essential factor of optimization. The dry fuel cell yielded a maximum power output of 19.43mW/cm². Once the air entering the fuel cell was humidified (85.63%-78.42%) the power output increased substantially by 72.77% to 33.57mW/cm². The consequent step was the humidification of the hydrogen entering the cell. The sole humidification of hydrogen yielded a slighter gain of 12.87% (21.93mW/cm²) in power output in comparison to the dry cell. The humidification of both reactant gases yielded a maximum power output of 29.97mW/cm², an increase of 54.24%. Although this is a substantial increase in performance, the humidification of air proved to yield larger power gains then running dry, humidifying hydrogen alone, and humidifying both.

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