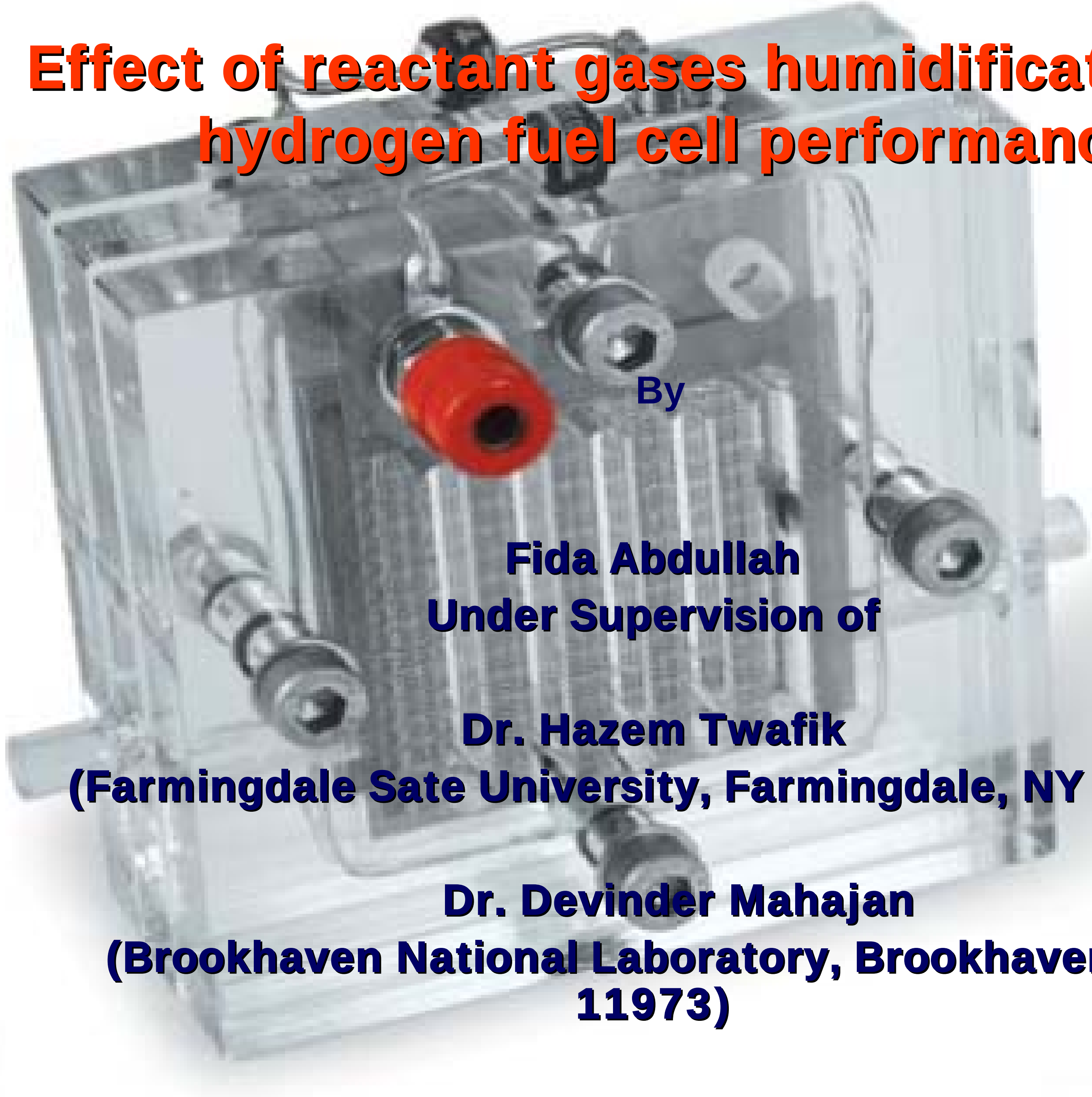

Effect of reactant gases humidification on hydrogen fuel cell performance

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Abstract

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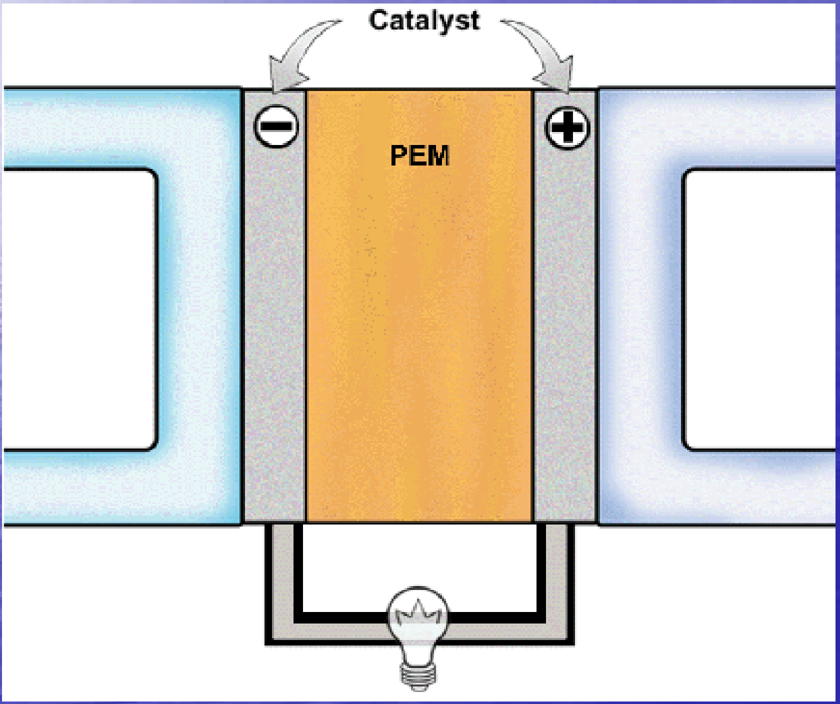
Recent experimental investigations on polymer electrolyte membranes emphasize water management as being a critical factor in the design of an efficient fuel cell. The research topic of interest aims to explore the influence of humidified air and hydrogen on the fuel cell's performance. The first half of the experiment involved the measurement of humidity and temperature entering and exiting the fuel cell, via either reactant channels across varies loads. The results indicated a substantial increase in the generated power across the variable load as the humidity of the oxygen exiting the channel increased (38.74%). The air exiting the cell plateaus at 78.13% relative humidity. A comparison of both gases under similar parameters was made. The oxygen's substantial increase in humidity was matched by a slight increase (2.36%) from the exiting hydrogen side. The second part of the experiment involved conventional methods of external-humidification of the oxygen gas. Comparison of humidified oxygen versus non-humidified oxygen was made and a 17% increase in power output was recorded when oxygen was humidified. Since the results yielded a slight change (2.36%) in the exiting hydrogen humidity, the consequent step was the humidification and circulation of 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.

Research Objectives

- To explore influence of reactant-gases humidity on hydrogen fuel cell
- To examine the influence of each gas humidification on the fuel cell power output and performance
- To develop a control system for fuel cell water management.

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%.

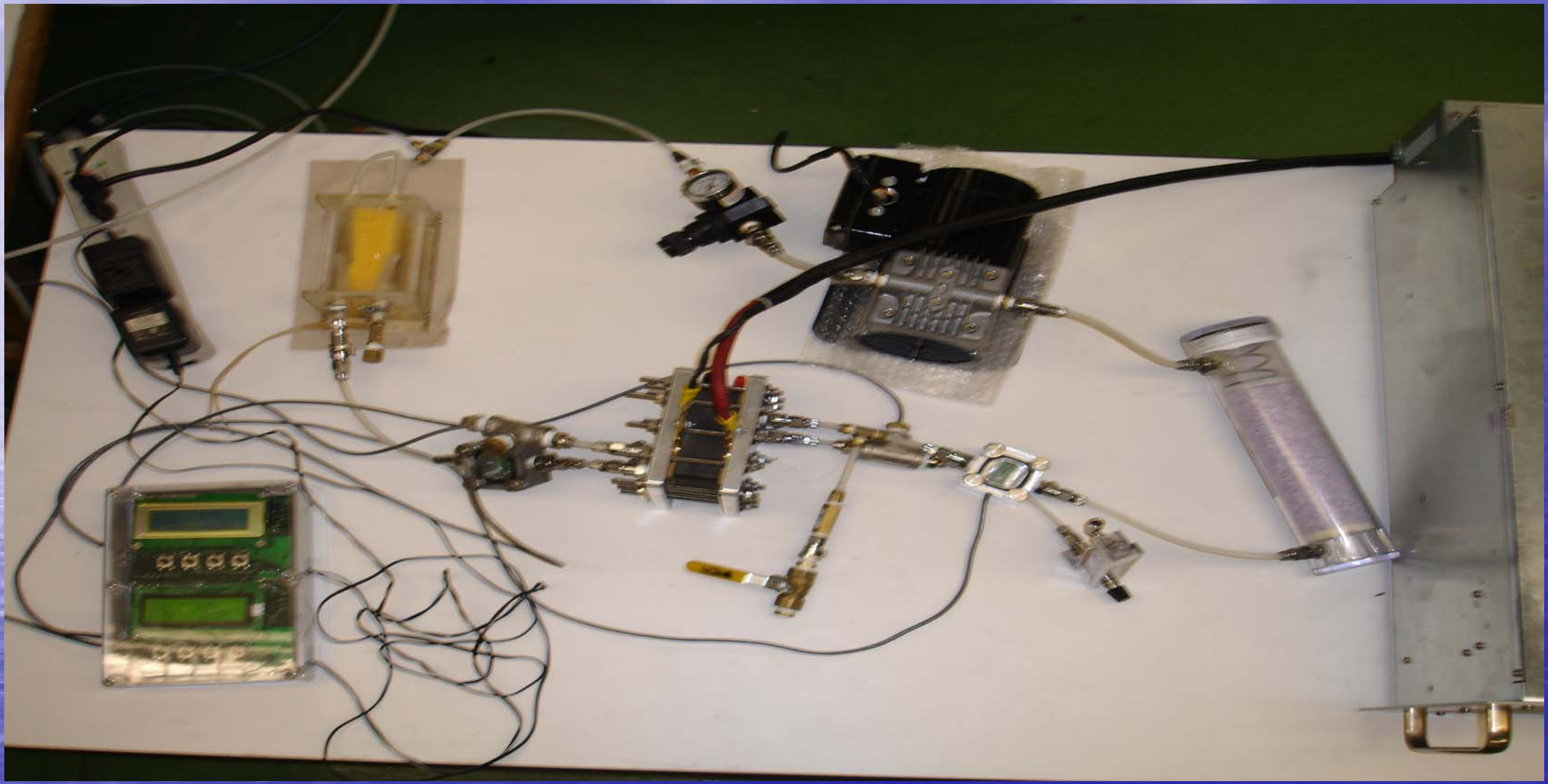
What is compelling about humidification?

- 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)

Why not control humidity by manipulating operation parameters?

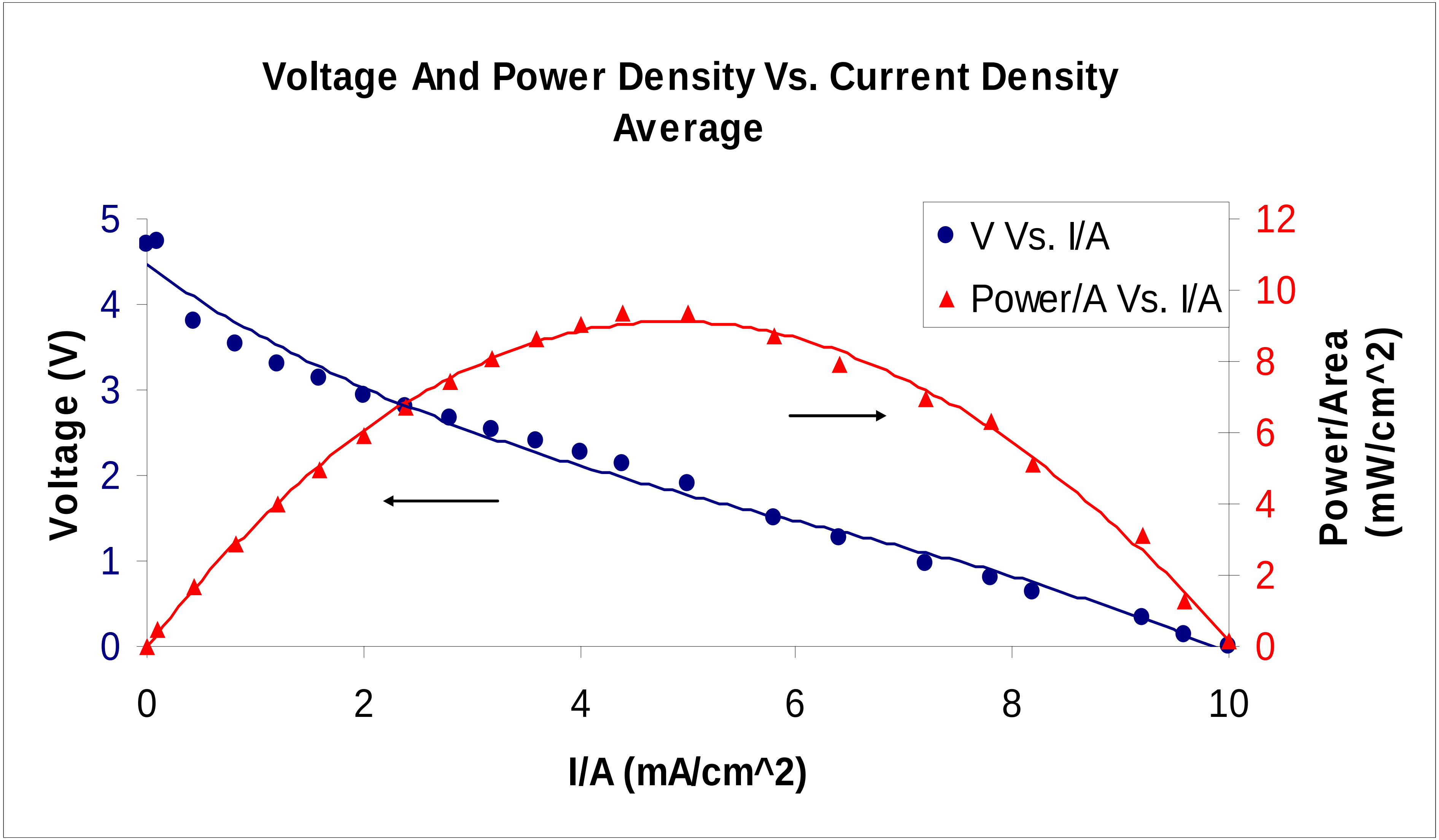
- Raising Temperature- The drying affect of air is non-linear in it's relationship to temperature. Raising the temperature would yield in substantial water lost. This is due to the Psat (Saturated vapor pressure).
  - Relative humidity = Pw/ Psat , the rapid rise in Psat as temperature rises yields humidity lost. Example- a moderately drying situation, say 70% relative humidity, at ambient temperature, can be fiercely drying when heated to about 60 C.
- Lowering Temperature- As temperature decreases, humidity increases. Lowering the temperature dramatically to gain humidity would yield losses in voltage which is an impractical tradeoff
- Lowering the air flow rate and hence stoichiometric relationship would reduce cathode performance
- Increasing the pressure- would take more energy to run the compressor and increase parricide energy

Experimental Setup

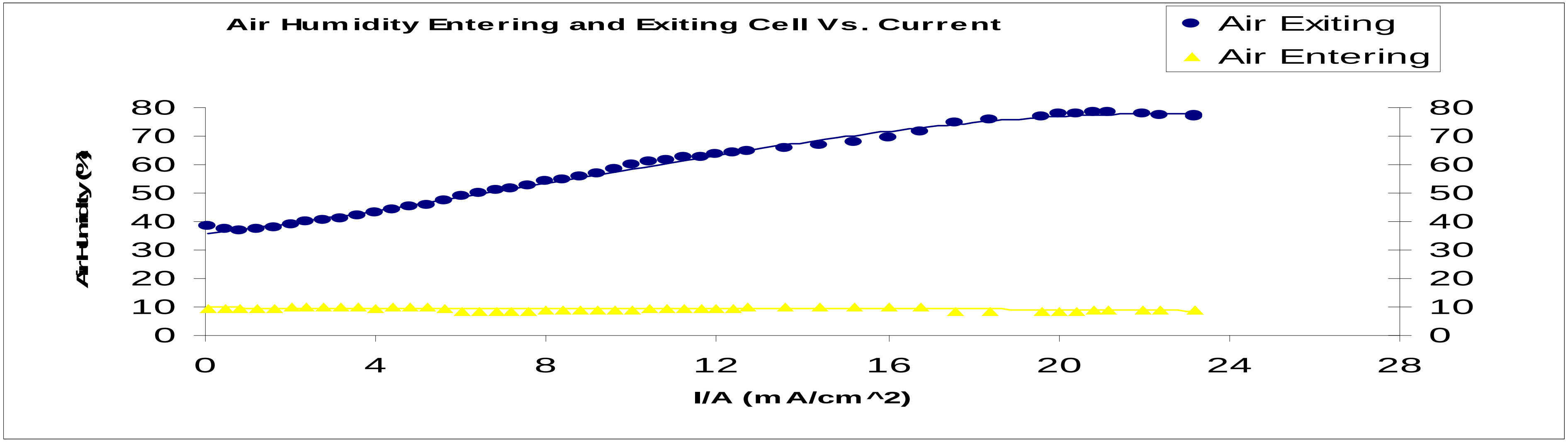


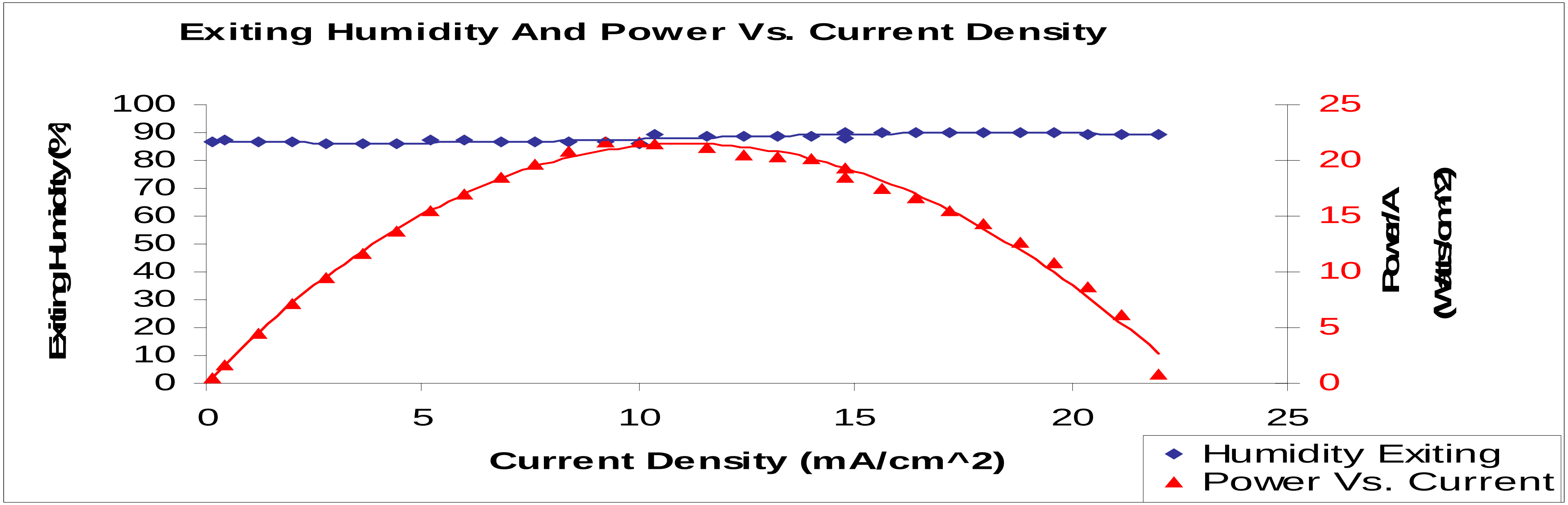
External humidification is necessary to optimize performance. Therefore, the reactant gases are humidified directly before entering the fuel cell. The hydrogen and air are humidified by circulating through humidifiers. The gas molecules carry some water with them and ultimately pass that water along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

Cell Without Any External Humidification

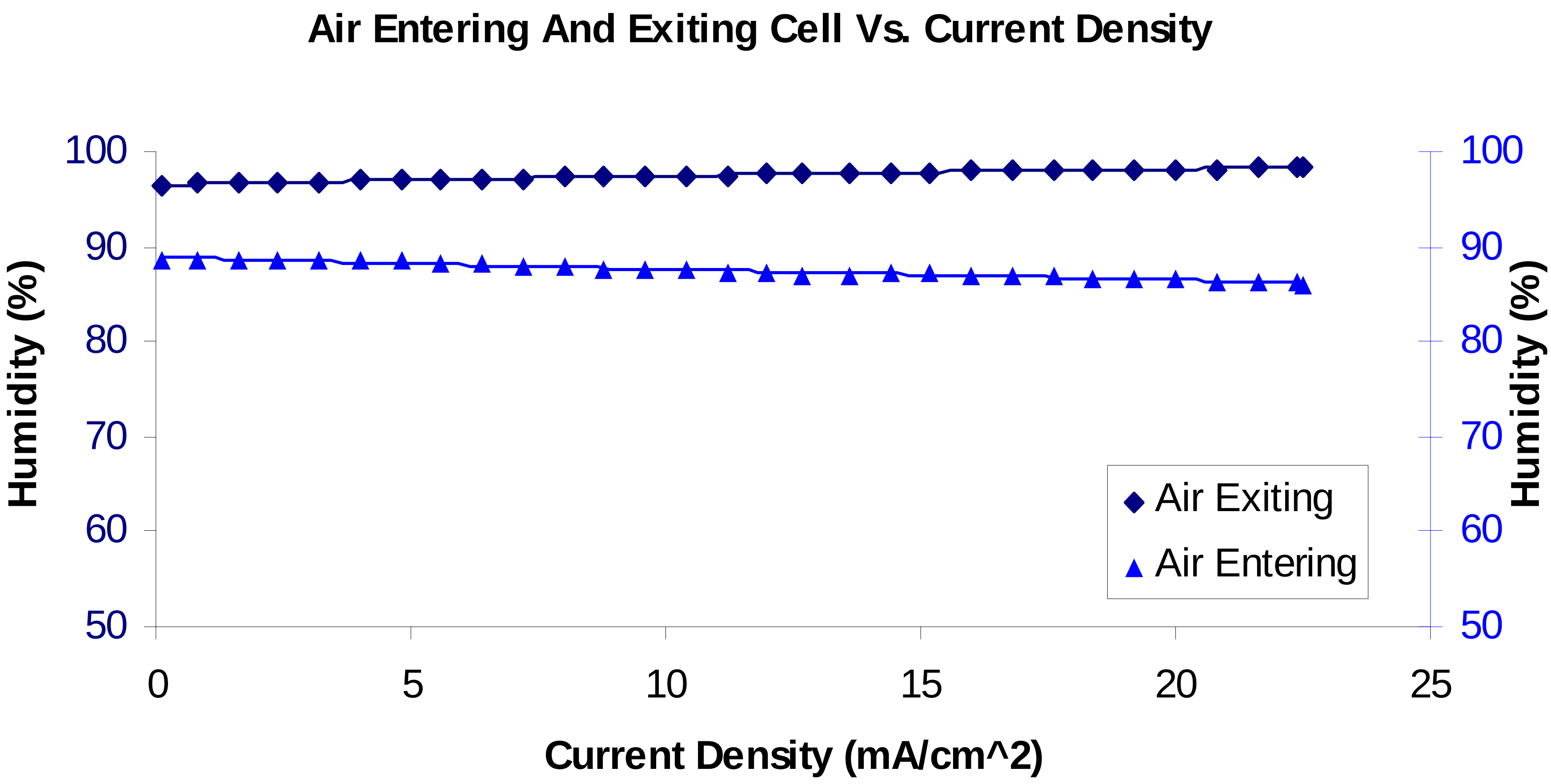


Investigating the Humidity of Dry Reactant Gases



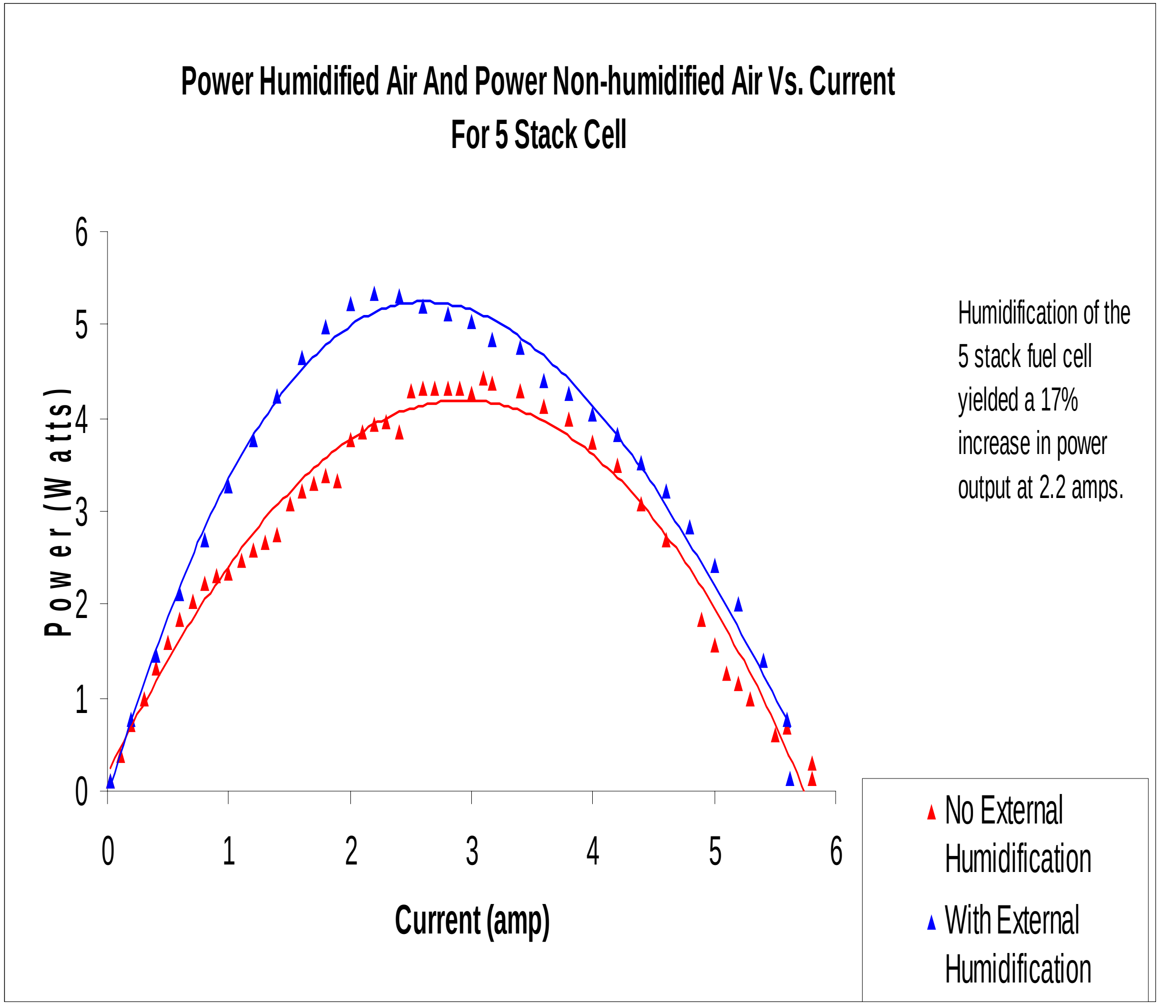


Humidified Air Entering and Exiting Fuel Cell

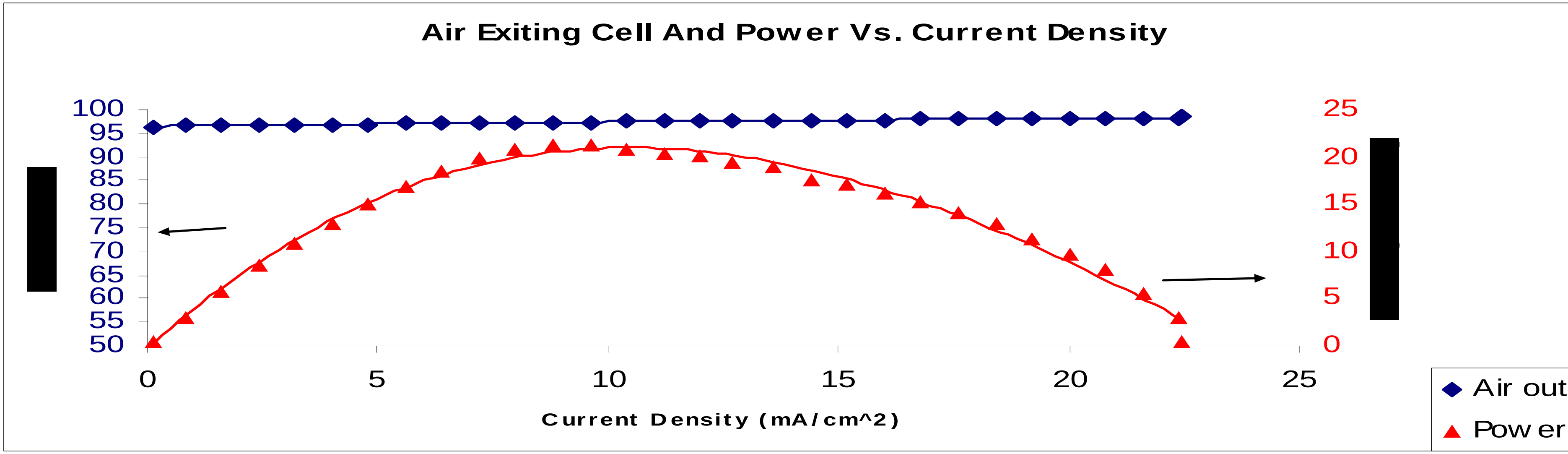


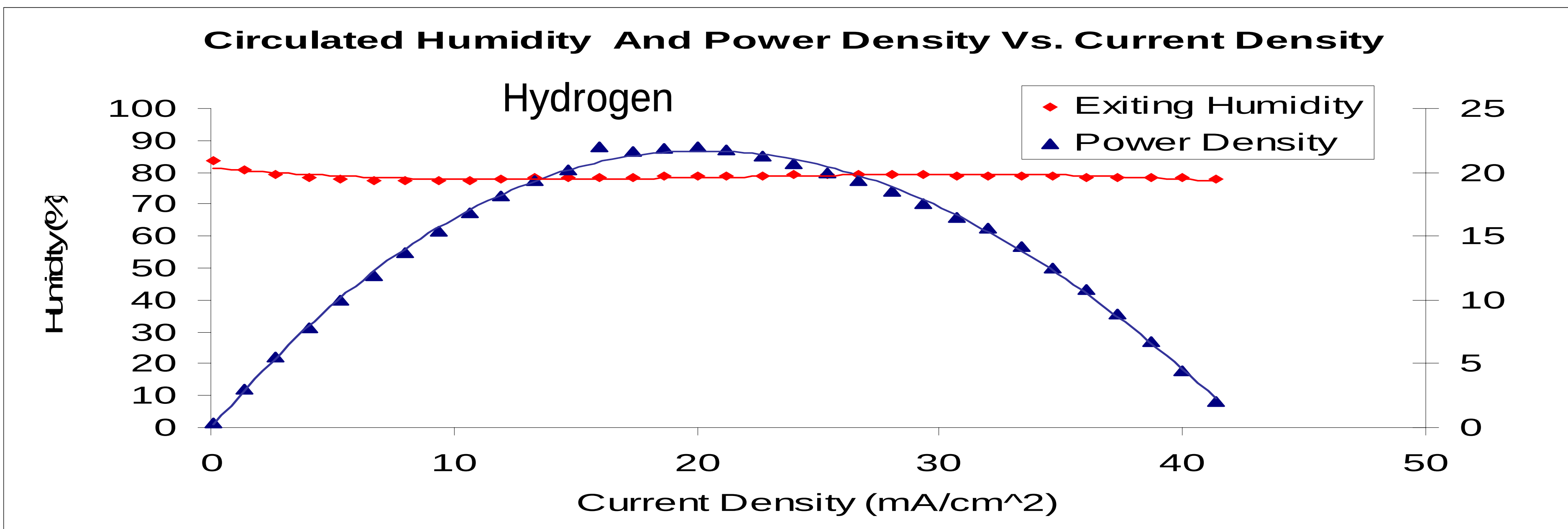
Performance Comparison Of Humidified Air Vs. Non Humidified Air

- At the anode, the reaction releases hydrogen ions and electrons whose transport is crucial to energy production. The ions build up on the anode creating a positive potential which pushes the outer ions away from the anode. The ions transfer through the electrolyte either by remaining connected through an attraction to a water molecule which travels through the electrolyte, or by transferring between water molecules.

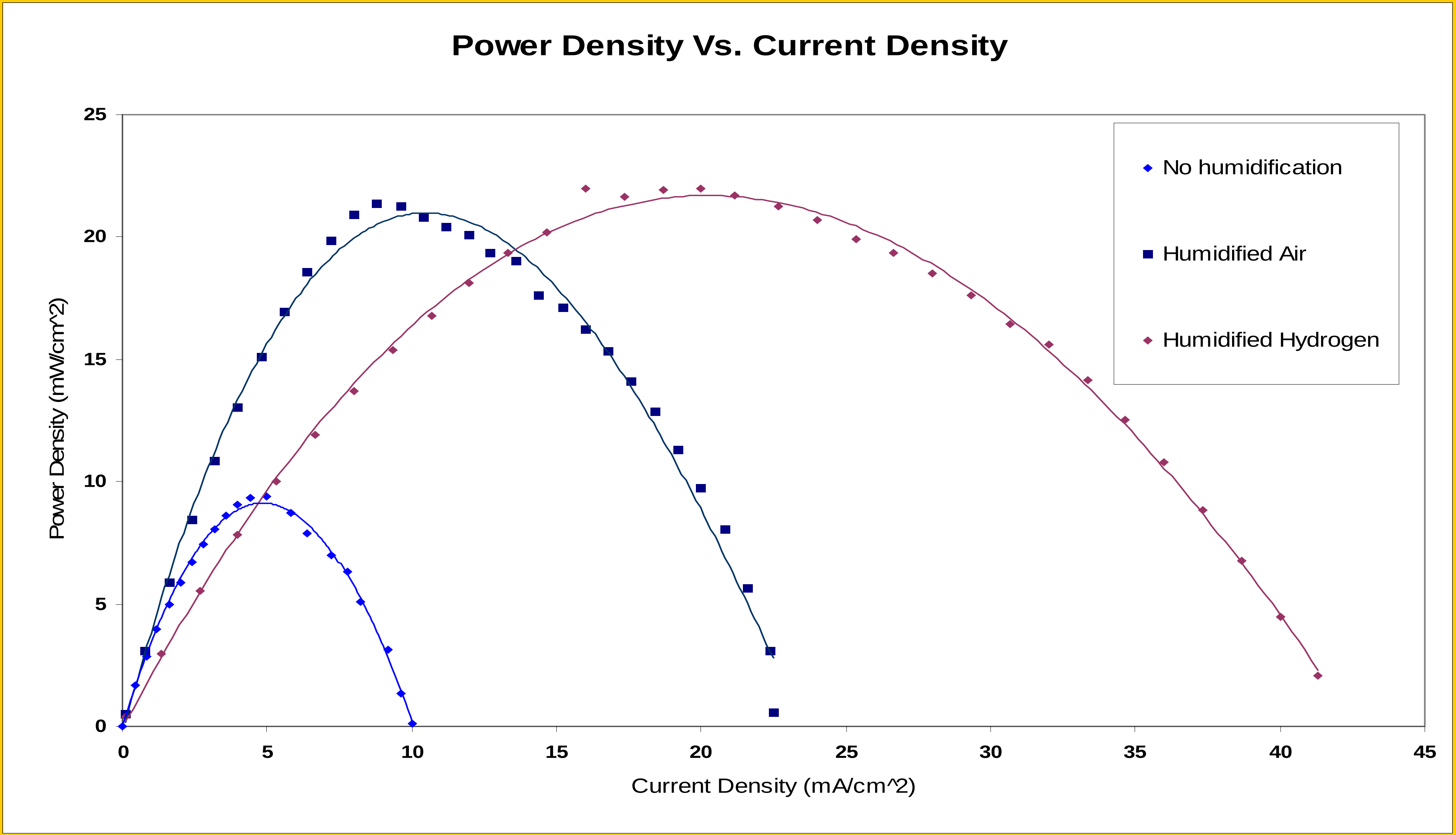


Humidification Of Reactant Gases





Power Output Comparison



CONCLUSIONS

- Humidity has been proven to be an effective parameter
- Humidification of air increased power output by 17%
- Humidification of Hydrogen exhibited more influence on the fuel cell performance than humidification of air
- Controlling humidity of reactant gases is very crucial for optimum fuel cell performance

What's Next

- Humidify air and hydrogen simultaneously and compare fuel cell performance to other scenarios.