Design and Development of an Alkaline Membrane Fuel Cell Educational Kit for High School and College Level Laboratory Demonstration

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Abstract

Alkaline membrane fuel cells are a promising source of power in today's market. However, efficient fuel cells are usually made in a large scale. Our project aims to design a fully functional alkaline membrane fuel cell that is small enough to be used as an educational tool kit for different purposes. With supervision from the team advisor at Florida State and working with our team in Brazil, appropriate schedules and a plan of action have been made in order to start the design making process of this kit. The next steps include collection of necessary data in order to begin designing and modeling of the fuel cell and a cost analysis in order to create a realistic budget.

1 Introduction

The objective of this project is to create a functional fuel cell educational kit designed for educational purposes. Fuel cells nowadays are used due to their lack of emission of environmental pollutants to create electrical energy to provide a sufficient source of power. One of the advantages are that fuel cells are scalable such that the fuel cell can be stacked to provide the amount of power needed.

The issue with project is that we need a smaller scale fuel cell the size of a small kit. In addition, the cost of the materials to design this fuel cell poses a problem due to our budget. Finding and using the materials purchased as inexpensively and sparingly as possible will provide the best balance between the budget and detailed testing to improve the efficiency of our design. Also, in order improve the efficiency of the cell, pure oxygen is optimal to use with the cell. A better way to filter off the oxygen supply to remove carbon dioxide is needed to guarantee a fully optimized fuel cell. Further constraints/issues will be later discussed in the report.

2 Project Definition

2.1 Background research

Fuel cell technology has been increasingly recognized in the field of alternative energy as a clean option for future power generation. For this reason, an educational kit using an alkaline membrane fuel cell is to be created to demonstrate the technology and spread interest in the concept to future engineers.

This project aims to build on the research previously conducted on alkaline membrane fuel cells (AMFC) by the engineering departments of both Florida State University and Universidade Federal do Paraná. Professors such as Juan Ordonez (FSU) and Jose Vargas (UFPR) were able to produce and validate a dynamic model to predict the response of a single AMFC according to the variation of physical properties, as well as design and operating parameters[1]. Using this model, the fuel cell of the educational kit will be optimized to lower overhead costs and increase functionality.

Though similar kits already exist in today's market involving other types of fuel cells, this kit will be the first to use an AMFC to power the system. Alkaline membrane technology has shown promising characteristics when compared to other forms of fuel cells, such as a higher current density, lower cost electrolyte and higher operating temperatures, which should allow for the production of a more accessible and affordable educational kit[2]. There are also some disadvantages that will bring some different challenges to the design as seen in the table below. First, the reaction taking place in the fuel cell has an intolerance to CO_2 which will hurt the efficiency overall[1]. Also, pure H_2 and O_2 must be used as fuel for the chemical reaction to take place within the fuel cell. These problems have been addressed previously in larger scale designs and will soon be addressed for our smaller scale design as well.

Advantages	Disadvantages
• Inexpensive catalysts: - Nickel at the anode - Silver at the cathode • No expensive polymer membrane is necessary – liquid alkaline solution as electrolyte • Liquid electrolyte may enable a simple cooling of the stack • Activation overvoltage is less than with an acid electrolyte	• High corrosivity of the electrolyte • Electrolyte must be reconcentrated during long time • Intolerance to CO_2 $CO_2 + 2OH^- \rightarrow CO_3^{2-} + H_2O$ • Must use pure H_2 and O_2

Table 1. Advantages and Disadvantages of Alkaline Membrane Fuel Cells[1]

2.2 Need Statement

The sponsor for FIPSE Team 3 is Florida State University, however the needs are being conveyed through Florida State University Associate Professor Dr. Juan Ordonez. Currently the alkaline membrane fuel cell is set up in a laboratory in CAPS building, the size of the setup is in the neighborhood of 70 ft^2. Florida State and Dr. Ordonez would like for the entire setup to be inside of a portable case. This means shrinking the setup roughly 30 times its current size. By making the alkaline membrane fuel cell fit into a suitcase Florida State University hopes to create a prototype of an educational alkaline membrane fuel cell kit that students can learn with. The team plans to deliver a fully operational alkaline membrane fuel cell prototype kit smaller than a standard suitcase by March 22, 2015.

“The current AMFC setup is too large and immobile to be a portable educational kit alkaline membrane fuel cell.”

2.3 Goal Statement & Objectives

“Deliver a fully functional alkaline membrane fuel cell in a portable case to Florida State University by the end of the spring 2015 semester.”

- All contained components accessible for teaching purposes
- Reliable fully operational alkaline membrane fuel cell powering a small visible fan with LEDs
- Packet containing any specifications used, any engineering drawings used, and all components used including acquisition information

- Storage and distribution – the size and availability of the kit should be optimized
- Cost reduction and manufacturing – the kit should be affordable for the customers and be affordable to manufacture
- CO_2 poisoning – Filter off incoming oxygen supply to reduce/remove CO and CO_2
- Precipitate and liquid formation – Formation of potassium carbonate (if exposed to CO_2) and water in fuel cell through chemical reactions

2.4 Constraints

Before the use of fuel cells can be considered a practical means of energy production we must meet some specific constraints that are put in place for the design to succeed.

- Weigh under 20 lbs. to ensure portability
- Have all components of an alkaline membrane fuel cell contained within a standard sized suitcase (1.4 ft^2 – 2.0 ft^2)
- Filter off almost all of the CO and CO_2 in the system to prevent CO_2 poisoning

2.5 Methodology

Methodology is a key part of the product in order to produce an alkaline membrane power cell with portable capabilities. First, our goal is to understand the technology behind these fuel cells. We will research previous advancements in fuel cell technologies as well as understanding the basic theory behind the chemical energy transfers that occurs. Also, before testing we must understand the proper gas ratios needed in order to not damage the equipment being used. Once a proper understanding of the background material is thoroughly researched and understood we will begin the design process. The design process will be a joint effort between the team in the United States and in the team that will be in Brazil during the fall. The steps to complete this in order to achieve our objectives are summarized below:

- Mathematical modeling and optimization
- Design of fuel cell geometry
- Construction of the prototype budget
- Manufacturing
- Testing for fit and validation of the mathematical model
- Analysis of results
- Presentation of results
- Delivery of Final Semester Report

2.6 Schedule

The schedule shown below is representative of the goals that we currently have as determined by the Brazil team based off of the limited time they will have access to the equipment in Brazil

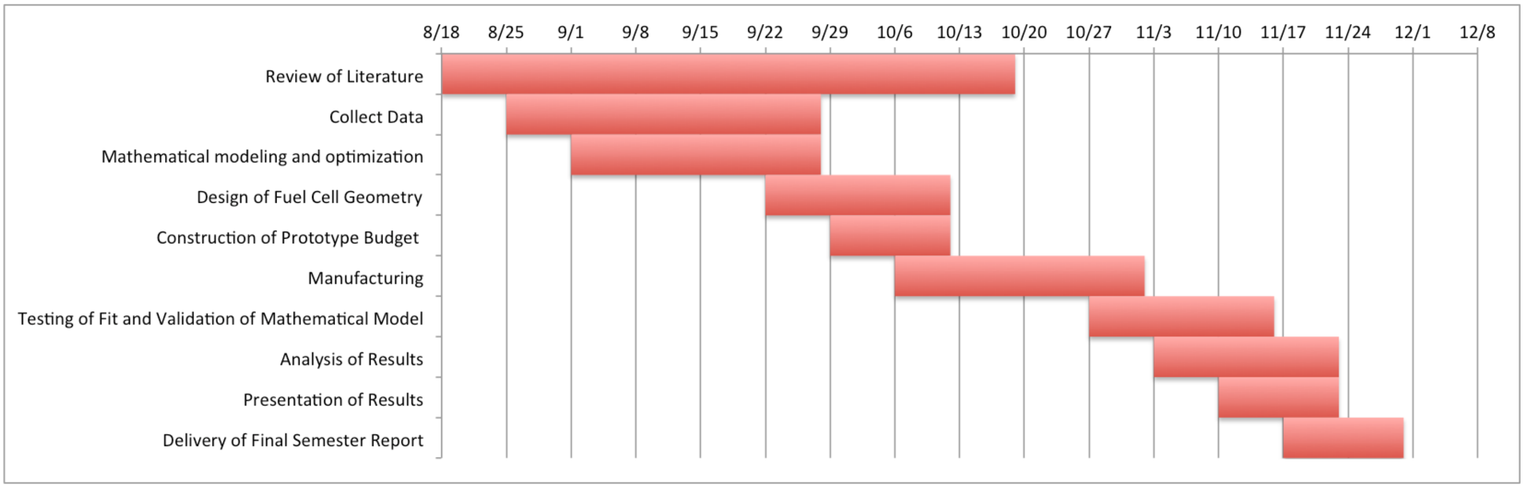

Figure 1. Gant Chart as determined by Brazil Team

3 Conclusion

This projects main goal is to develop an alkaline membrane fuel cell that has some level of portability to it. By the end of the spring 2015 semester we hope that the design prototype will be functional and able to power a small electronic device like a fan or light. Also, since the device is also to be used for educational purposes the design will be easy to use. While working with the team in Brazil and assuming there are no major issues in the overall design process we hope to have a working prototype completed or at least close to completion by the end of the fall 2014 semester in order to allow the team ample time to perform tests which will give us maximum efficiency.

4 References

[1]Vargas, J.V C., and J. C. Ordonez. "Alkaline Membrane Fuel Cell (AMFC) Modeling and Experimental Validation." *Journal of Power Sources* (2012): 1-15.*Www.elsevier.com/locate/jpowsour*. Elsevier, 11 Apr. 2012. Web. 15 Sept. 2014.

[2]Ordonez, Juan, and Jose Vargas. *Design and Development of an Alkaline Membrane Fuel Cell (AMFC) Educational Kit for High School and College Level Laboratory Demonstration*. Tallahassee: Florida State Univeristy, n.d. PDF.

[3]Kreuer, K.-D. "2." *Fuel Cells: Selected Entries from the Encyclopedia of Sustainability Science and Technology*. N.p.: n.p., 2013. 9-27. Web. 26 Sept. 2014. <http://www.springer.com/978-1-4614-5784-8>.