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

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## Abstract

The current Gantt chart shown in this report provides a detailed timeline for the goals that we have put in place for the rest of the project. Based off this Gantt project we are currently on track with these goals. The team in Brazil is currently performing the needed testing in order to determine the most optimized size for the fuel cell. We have also determined a budget based off the required components and it is currently within are projections. Due to a recent the recent decision to not use a simple fan for our demonstration the team is currently brainstorming some new ideas and will be determining there feasibility in the near future. One problem we have encountered so far is based off some of the data that Brazil has recently obtained the scaling originally estimated for the fuel cell was too small and will need to be increased.

# 1 Introduction

The objective of this project is to create a functional alkaline membrane fuel cell educational kit. Fuel cells have a number of key advantages over other energy storage solutions. These key advantages include no environmental pollutants. This issue grows by the year and as the world continues to be exposed to the importance of eliminating environmental pollution solutions like fuel cells will become more commonplace. The fuel cell simply turns chemical potential into useable work. Current solutions to small portable devices often include batteries, essentially the fuel cell is a battery however is does not have any post use waste, so there is nothing to dump out of anything to throw away after. Also the advantage of the fuel cell is the energy companies use to manufacture batteries stems from fossil fuels at some point in the process. Just like a battery fuel cells can vary in size and power output based on the needed operation.

Now that the fuel cell benefits are clear, the purpose for this joint venture is to create a prototype of a small educational alkaline membrane fuel cell that can potentially be mass produced and sold to classrooms all over. The market for this alkaline membrane fuel cell rests on two key components. First this is an alkaline membrane fuel cell which is a different technology than the standard hydrogen fuel cells in many of the currently produced kits. Second the educational kit will be made for the sole purpose of catching student’s interest into the world of renewable engineering. Capturing young students interest into the fields of engineering is always a difficult task, this cell will allow teachers to engage their students and hopefully peak their interest, and what teacher does not want to do that..?

There are several key challenges with the design of a totally new alkaline membrane fuel cell kit. Primarily the issues come from three areas, one the technology of alkaline membrane fuel cells are different from the cells commonly produced outside of laboratories. The key is to migrate this alkaline membrane technology into a market saturated with hydrogen fuel cells. The other area of challenge is the physical constraints. The educational kit needs to be portable and portable would assume portable for all types of professors. This means the kit needs to a manageable size and weight. As mentioned prior the alkaline membrane technology is a laboratory technology with very large heavy setups. Finally the unseen challenge with this project is to create a stable safe setup that is chemically stable under reasonable circumstances. Laboratories that currently contain this technology have expensive in depth sensors that ensure there are no chemical issues in the area, this safety needs to be incorporated into the educational kit.

# 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:<br>- Nickel at the anode<br>- Silver at the cathode<br>• No expensive polymer membrane is necessary – liquid alkaline solution as electrolyte<br>• Liquid electrolyte may enable a simple cooling of the stack<br>• Activation overvoltage is less than with an acid electrolyte | • High corrosivity of the electrolyte<br>• Electrolyte must be reconcentrated during long time<br>• Intolerance to $CO_2$<br>$CO_2 + 2OH^- \rightarrow CO_3^{2-} + H_2O$<br>• 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 visual aid (yet to be determined)
- 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
- Creation of a thorough safety and installation manual to be put onto an instructional dvd included with the kit

# 3 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

## 3.1 Design Specifications

The overall design specifications given to us so far are very open ended and are currently still being determined by the team members in Brazil. This is due to the fact that the current goal of the project is to simply design an educational kit using the AMFC technology. This leaves us with many different options that we are currently looking at. Currently we have decided as a team to keep the size of the kit to that of an averaged sized briefcase to ensure portability. Also, the overall stresses acting on the kit should not exceed the standard stress experienced when carrying it from one location to another. Also, due to the sensitivity of the fuel cell being used it will not be expected to experience being dropped without some kind of damage. Since we are producing electricity from the fuel cell and it will be small in scale the expected power output will range between 1.5 to 2 volts. Finally, no specific weight has currently been determined but it will be expected to remain light enough for non-restricted portability.

## 3.2 Performance Specification

Our end product is expected to integrate the AMFC technology into an easy to use education kit. The main specification is that the fuel cell will need to have an output that is at least 1 volt to power a device that can be used for demonstrative purposes. The maximum voltage that we currently hope to achieve while remaining in a reasonable scale is around 2 volts. This will range from a fan to if possible a remote control car. We are currently determining if the remote control car is a reachable goal. Also, the kit will display how much compressed gas is left in the canisters as well as detecting possible leaks. The ratios for the gases consumed vs the electrical output are needed and are currently being determined by the Brazil team.

## 3.3 Budget

With the current budget for the project set at $1000. The main concern is the large cost of the electrode sheets containing a percentage of platinum. As seen in table 2 the cost for the sheets are significantly larger than any current estimated cost at this time.

| Team 10 Project Budget | | | |
|---|---|---|---|
| Parts | Brand | Price | Quantity |
| KOH electrolyte | HHN-Hydro<br>Tech Premium Electrolyte | $11.90 | 8 Oz |
| Chromatography Paper | Whatman Cellulose chromatography paper | $55.70 | 50 sheets 20x20cm |
| electrode sheets platinum-carbon | 0.5 mg/cm^2 60% platinum on Vulcan paper | $275.00 | 20x20cm |
| | **Total** | **$342.60** | |

Table 2. Current Estimated Budget

This cost is based off of the assumption that only one sheet of the electrode paper will be necessary. We will be performing multiple tests in order to maximize efficiency and during this process the electrode paper can easily get damaged. It is also important to note that the numbers shown above to not reflect the costs of the bipolar plates. This is due to the fact that the final design has not been finalized and the plates will need to be machined accordingly. Though the plates are not expected to be very costly so it is not a budgetary concern at this point.

# 4 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

## 4.1 Schedule

The Gantt chart is designed to keep the team on pace to finish successfully, a large component of staying on pace is visualizing the steps needed to get to success.

The first large block of time is the background research. During the background research phase, the team will review current fuel cells to grasp a better understanding of what is needed to make a successful alkaline membrane educational kit. The members will focus on design inspiration while continuing communication with our sponsor. The expected timeframe for the background research is 33 days. This allows the team to feel comfortable as well as knowledgeable about fuel cells.

After the 33 days of background research the team in Brazil will begin to collect necessary data using the existing prototype (UFPR). The purpose of this is to use the functional fuel cell in Brazil to compile data needed to reduce the amount of calibration/testing on the future AMFC educational kit. The timeline for the data collection is an expected 19 days, enough for multiple runs and analysis.

Once the data is compiled, the mathematical modeling and optimization begins. This will also predominately occur in Brazil so that small parameters can be adjusted on the currently existing model to optimize the power output vs. consumption for the alkaline membrane fuel cell educational kit. The parameter adjustment will include coding with Fortran, which is what the fuel cell setup in Brazil uses. This is expected to take three weeks.

Next is the Design of the fuel cell, this is a joint operation between Brazil and FSU. This is expected to be difficult and a continually changing process. This includes components, components specifications, along with engineering drawings for each. The timeframe for the Design portion is 65 days long. The team expects to have this started during November, but not completed until the spring semester.

The stages to success that follow the Design are a prototype budget, manufacturing of the kit, and finally ensuring the kit works as intended. These tasks are all set as spring semester tasks and more likely subject to date and length changes. Following the Gantt chart is vital to success and having such an organized and detailed outline will be pivotal.

## 4.2 Resource Allocation

Due to the unique situation of having the team split between two different locations resource allocation is very important. The background research is expected to be done equally by all members of the team so everyone has a good understanding of the technologies being used. The Brazil team currently has the facilities to perform the data collection so James will be heading this process. While this is taking place the data will be sent to the team located at FSU for further analysis. After the appropriate data is obtained the FSU team mainly Collin and Mustafa will be creating a design that uses the fuel cell technology for educational purposes. This will consist of ProE drawings and the appropriate component specifications. Then Mac will lead the budget for the prototype. After the design and budget is completed the prototype construction will begin. This will be led by the James and will be supported by all team members. Finally, once the construction of the prototype is complete all group members will be performing tests to optimize the power output for the final results.

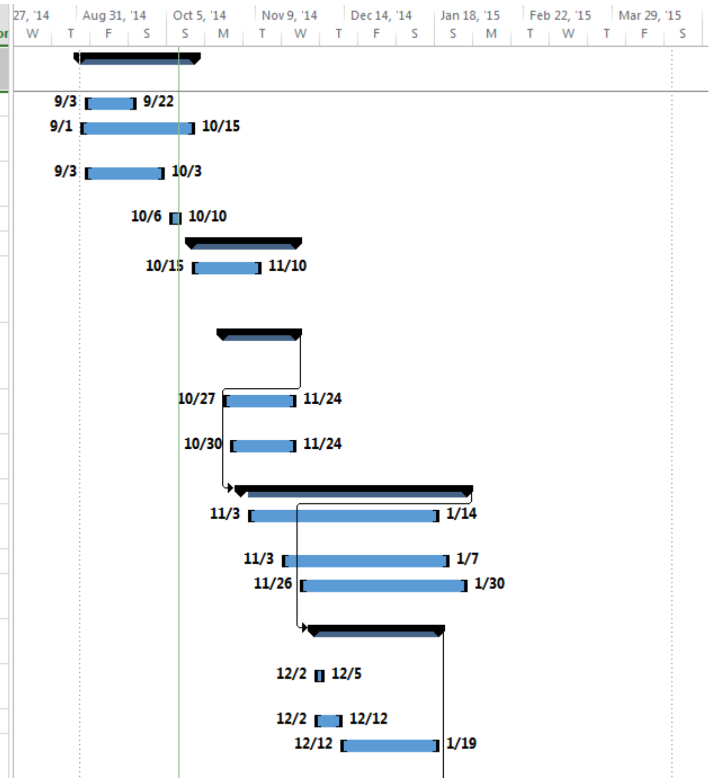
# 5 Conclusion

Now that a more formal Gantt chart has been constructed the team has a good visual on the current goals that need to be met for the project. With the Brazil team currently performing the data collection on schedule we are on track to begin the overall design by November. Recently after discussing the overall project with the team we have come to the conclusion that a simple fan demonstration will lack a certain degree of excitement and will not meet the overall goals the sponsor has laid out for us. In our free time we have currently begun brainstorming ways to make this possible and will have multiple ideas prepared when we begin the formal design in November. The one issue we have run into so far is that the overall output for the fuel cell has fallen below our initial estimates and we are increasing the overall scale as a result. This will not change the fact that the final device will still maintain its required amount of portability. Overall we are still on track to meet the deadlines we have laid out in the Gantt chart.

# 6 Appendix

GANTT CHART

| | Task Mode | Task Name | Duration | Start | Finish | Predecessor |
|---|---|---|---|---|---|---|
| 1 | | **Background Research** | **33 days** | **Mon 9/1/14** | **Wed 10/15/14** | |
| 2 | | Obtain Design Ideas | 14 days | Wed 9/3/14 | Mon 9/22/14 | |
| 3 | | Communicate With Sponsors | 33 days | Mon 9/1/14 | Wed 10/15/14 | |
| 4 | | Commercial Research | 23 days | Wed 9/3/14 | Fri 10/3/14 | |
| 5 | | QFD Diagram | 5 days | Mon 10/6/14 | Fri 10/10/14 | |
| 6 | | **Collect Data** | **29 days** | **Wed 10/15/1** | **Mon 11/24/1** | |
| 7 | | Run Trials With Existing Prototype (UFPR) | 19 days | Wed 10/15/14 | Mon 11/10/14 | |
| 8 | | **Mathematical Modeling and Optimization** | **21 days** | **Mon 10/27/14** | **Mon 11/24/14** | |
| 9 | | Use Fortran Code to Run Trials | 21 days | Mon 10/27/14 | Mon 11/24/14 | |
| 10 | | Variation of Parameters | 18 days | Thu 10/30/14 | Mon 11/24/14 | |
| 11 | | **Design of Fuel Cell** | **65 days** | **Mon 11/3/1** | **Fri 1/30/15** | **8** |
| 12 | | Component Specifications | 53 days | Thu 11/6/14 | Mon 1/19/15 | |
| 13 | | Component Design | 48 days | Wed 11/19/1 | Fri 1/23/15 | |
| 14 | | Formulate ProE Drawings | 48 days | Wed 11/26/14 | Fri 1/30/15 | |
| 15 | | **Construction of Prototype Budget** | **35 days** | **Tue 12/2/14** | **Mon 1/19/15** | **11** |
| 16 | | Follow-up Sponsor Meeting | 4 days | Tue 12/2/14 | Fri 12/5/14 | |
| 17 | | Market Research | 9 days | Tue 12/2/14 | Fri 12/12/14 | |
| 18 | | Communicate With Vendors | 27 days | Fri 12/12/14 | Mon 1/19/15 | |




GANTT CHART

| | Task Mode | Task Name | Duration | Start | Finish | Predecessor |
|---|---|---|---|---|---|---|
| 19 | | **Manufacturing** | **37 days** | **Tue 1/20/15** | **Wed 3/11/1** | **15** |
| 20 | | Compilation of ProE Drawings | 6 days | Tue 1/20/15 | Tue 1/27/15 | |
| 21 | | Obtain Materials | 31 days | Tue 1/20/15 | Tue 3/3/15 | |
| 22 | | Schedule with Machine Shop | 28 days | Mon 2/2/15 | Wed 3/11/15 | |
| 23 | | **Physical Testing and Validation of Mathematical Model** | **21 days** | **Thu 3/12/15** | **Thu 4/9/15** | **19** |
| 24 | | Testing of Prototype Under Ideal Conditions | 12 days | Thu 3/12/15 | Fri 3/27/15 | |
| 25 | | Variation of Parameters and Optimization | 10 days | Fri 3/27/15 | Thu 4/9/15 | |
| 26 | | Analysis of Results | 15 days | Tue 3/31/15 | Mon 4/20/15 | |
| 27 | | Presentation Of Results | 6 days | Mon 4/13/15 | Mon 4/20/15 | |
| 28 | | Delivery of Final Semester Report | 5 days | Tue 4/14/15 | Mon 4/20/15 | |

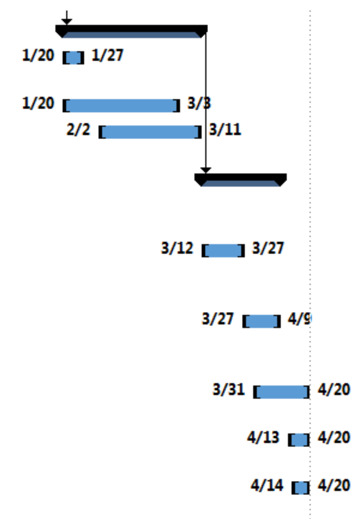



Figure 1. Gantt Chart

# 7 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.