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

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Deliverable Name: Interim Design Report

Sponsor: FIPSE

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Team Bios

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FSU Team Leader

Collin Heiser is currently a senior of mechanical engineering at Florida State University and will be graduating in the spring of 2015 with a specialized track in thermal fluids. He's had a project management internship with Jarden Consumer Solutions in previous summers and effectively brings that experience to the project.

Benjamin Richardson – (jbr10@my.fsu.edu)
Brazil Team Leader

Ben is a senior graduating from Florida State University in May, 2015 with a Bachelor of Science in Mechanical Engineering. He is currently working in Curitiba, Brazil at Universidade Federal do Paraná performing research using a prototype alkaline membrane fuel cell with a team of American and Brazilian students.

Bryan Anderson – (banderson40@gmail.com)
Financial Advisor

Bryan is a senior graduating in May of 2015 with his BS in Mechanical Engineering. He works as the team's financial advisor ensuring the project is allocating their resources in the most productive way. Bryan hopes to use his degree to analyze the social fabric that governs the world's finances.

Mustafa Nek – (mn11h@my.fsu.edu)
FSU Assistant Mechanical Engineer/Web Master

Mustafa is a senior in mechanical engineering with a thermal fluids track. As a tutor in math and sciences for Florida State University, he believes success is a part of hard diligent work as everything can be a challenge. His knowledge with web development makes him a great web editor.

Nicole Alvarez – (nda10@my.fsu.edu)
Brazil Assistant Mechanical Engineer

Nicole is currently studying mechanical engineering at FSU and has held internship positions with Rolls-Royce and Pratt & Whitney. Her work within and outside of school has grown her interest to pursue a career in the aerospace industry.

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Abstract

The project that we have been working on focuses on the FSU developed alkaline membrane fuel cell. Our team has been tasked with designing and proving the practicality of this device. This is important for FSU because if a proof of concept like this can be made from scratch it will help prove that a device such as this one deserves further funding and research in order to pave the way for a new cleaner energy source. We plan on doing this by making some design changes to some of the existing cells like overall size and making changes to the gas channels. With the team working in Brazil we have so far collected crucial data in order to support some of the changes that we will make to the existing cell design. We have also designed the portable casing needed for safe transport. Finally, the parts that are needed to begin the manufacturing of the cell have been ordered so machining can begin early next semester.

1 Introduction

This section of the report introduces the background research in order to gain an understanding of the AMFC and some of its advantages over other cells. Also, the needs statement that is explained as well as the goals and objectives the team has set for the project. Finally, the constraints for the design are discussed.

1.1 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.

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 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]. Based off some of the data that was gathered we have determined some of the advantages and disadvantages of using this kind of cell and have displayed the results below in table 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. 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
• 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 Need Statement

The sponsor for FIPSE Team 3 is Florida State University and our advisor is Dr. Ordonez who has been assisting us in reaching the overall goal of the project. 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."

1.3 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."

We have determined a number of objectives that we hope to accomplish this semester. First, we want to have all of the components need be easily accessible for teaching purposes while at the same time having a reliable fully functional alkaline membrane fuel cell powering a visual aid. Also, we will have an informational packet that will contain any technical instructions needed to operate the fuel cell so the teachers using it will understand the proper procedure. The design for our kit must also have optimized dimensions for easy transportation storage and distribution.

Since this kit will be used for educational purposes we want to keep the budget within reason in order to be affordable to teaching staff.

1.4 Constraints

In the design process there a few constraints that we must consider in order have an operating cell and a successful kit. One of the constraints is that the active surface area of the cell will be limited based off the size of the platinum electrode sheets. These are the most expensive part of the project so in order to maintain a reasonable budget the active surface area for the cell will remain small. The size that is currently being looked is at around 1.96 in^2. Another design constraint is that the entire kit must be below 20 lbs. to ensure portability. Also, it is crucial that all of the components we design fit inside a standard briefcase of around 1.4 ft^2 – 2.0 ft^2. Proper seals will be needed to ensure that gas leaks to not occur. In order to prevent the cell from shorting out the design must consider that the bipolar plates do not come into physical contact with each other.

2 Design and Analysis

This section of the report will focus on the design aspect of the project. We will discuss some of the different components needs as well as the three different design ideas we have drawn. Also, we will give an overview of our selection process for the final design and our final choices.

2.1 Functional Analysis

Fuel Storage Tanks

There will be two fuel storage tanks, one will contain diatomic oxygen and the other will contain diatomic hydrogen gas. They will both have an excess flow valve, a solenoid valve, and a pressure release vent port. The tanks will be sized to fit into the suitcase as well as the amount needed to perform the test. The tanks will have cylindrical sidewalls and hemispherical ends to remove any pressure concentration points, as seen in Fig. 1. The gas storage tanks will be selected to tolerate the 30 psig pressure that the gasses will need be stored at. Since these are combustible gasses stored under pressure, safety is the primary concern.

Figure 1. Gas Storage Tanks

Fuel Cell

The primary function of the Alkaline Membrane Fuel Cell is converting energy from the reaction between diatomic hydrogen and oxygen into usable electrical energy. The system consists of seven control volumes; two input valves, two body plates, an anode, a cathode, and an electrolyte. The electrolyte we will be using is a 40% concentration of potassium hydroxide (KOH) contained between two platinum cloth sheets that act as the anode and cathode. The interior of the fuel cell consists of channels to increase the surface area of the reaction and also guide the water produced as a byproduct out of the fuel cell. At this stage of design, it is projected that the body of the fuel cell will be made of Aluminum 2024 to reduce weight and increase heat transfer, which will in turn speed up the reaction. From previous tests conducted with steel, we were able to obtain values of 0.818 V and 6.68 A. However, with our new design we can expect higher voltage and current outputs.

2.2 Design Concepts

We have decided on three different concepts for our fuel cell design. The first design that we came up with involves the fuel cell being placed on a stand that is separate from the case during operation and can be seen below in Figure 2.

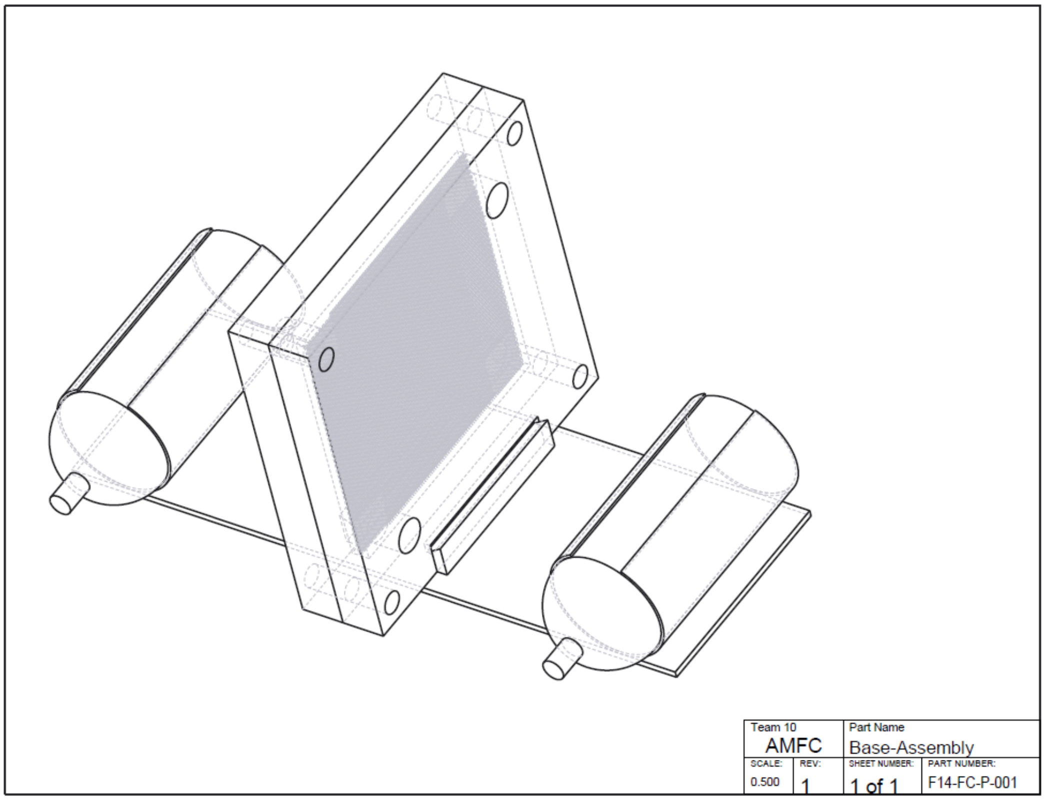


Figure 2. Cell Separate From Case Design

The cell itself will clip in to a plastic base that will result in it being upright and mostly stable. Also, the compressed gas canisters will be locked in to the same base as the cell. Another important thing to note with this design is that everything will be stored in the case. Within the case will be a foam that functions as padding and will be cut to our required dimensions. Our second design uses the same dimensions for the fuel cell as the first. This design can be seen in Figure 3 and does away with the plastic base being used to support the fuel cell from the first design.

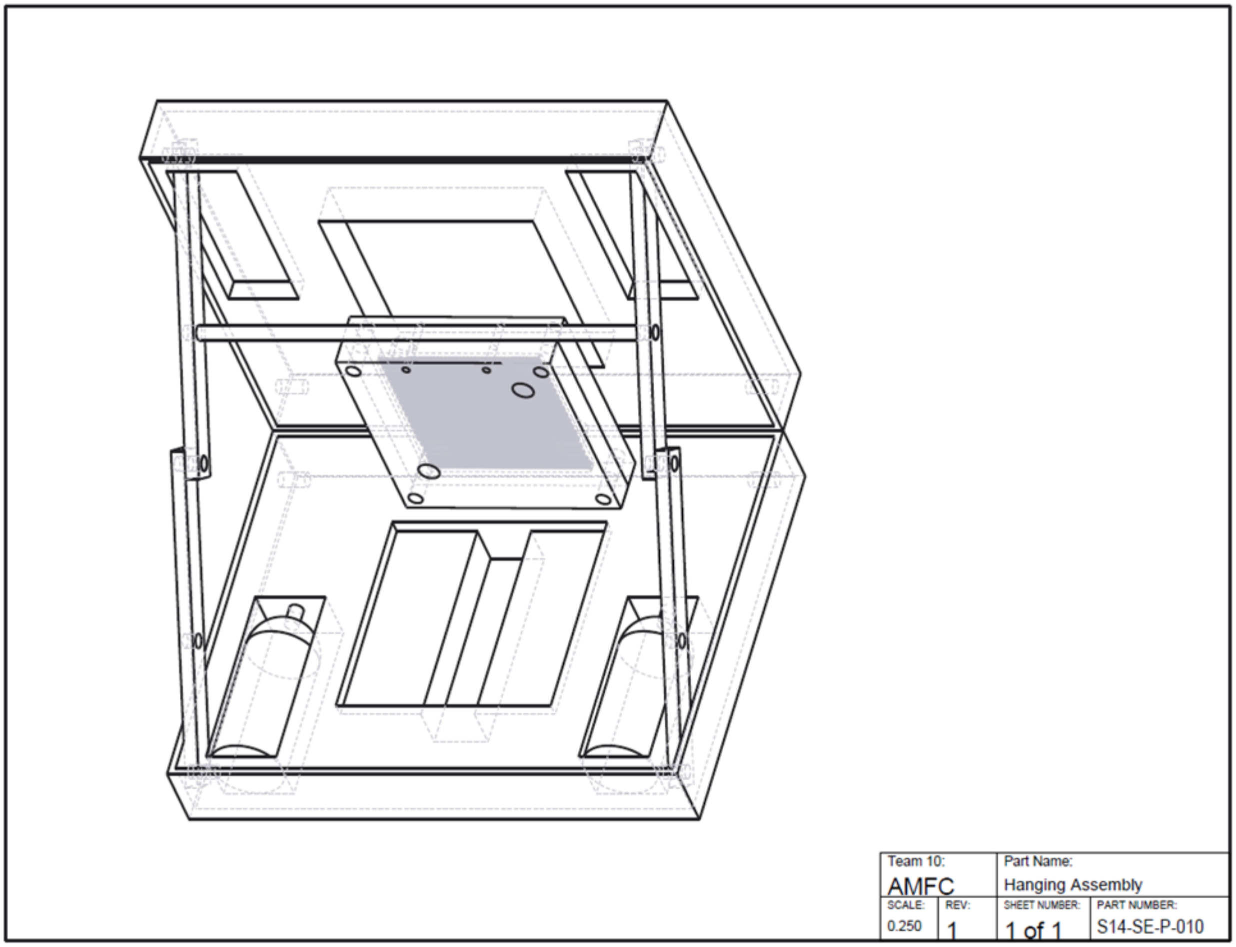


Figure 3. Hanging Fuel Cell Design

Instead of this base fuel cell is being hung by a support pole that is being supported by the side arms of the case. These arms fold in as the case closes and stay locked while the case is opened until they are manually unlocked by the user. This allows the fuel cell to be easily supported from within the case itself. Also, this lets the user quickly assemble the setup with little work. This design also works because the fuel cell does not have to be completely stationary during operation so the swaying caused by the hanging will not affect performance. The fuel cell will have two holes drilled into the top to allow for a hanger to thread through. Our third design takes advantage of the foam in the case to support the cell during operation as seen in Figure 4.

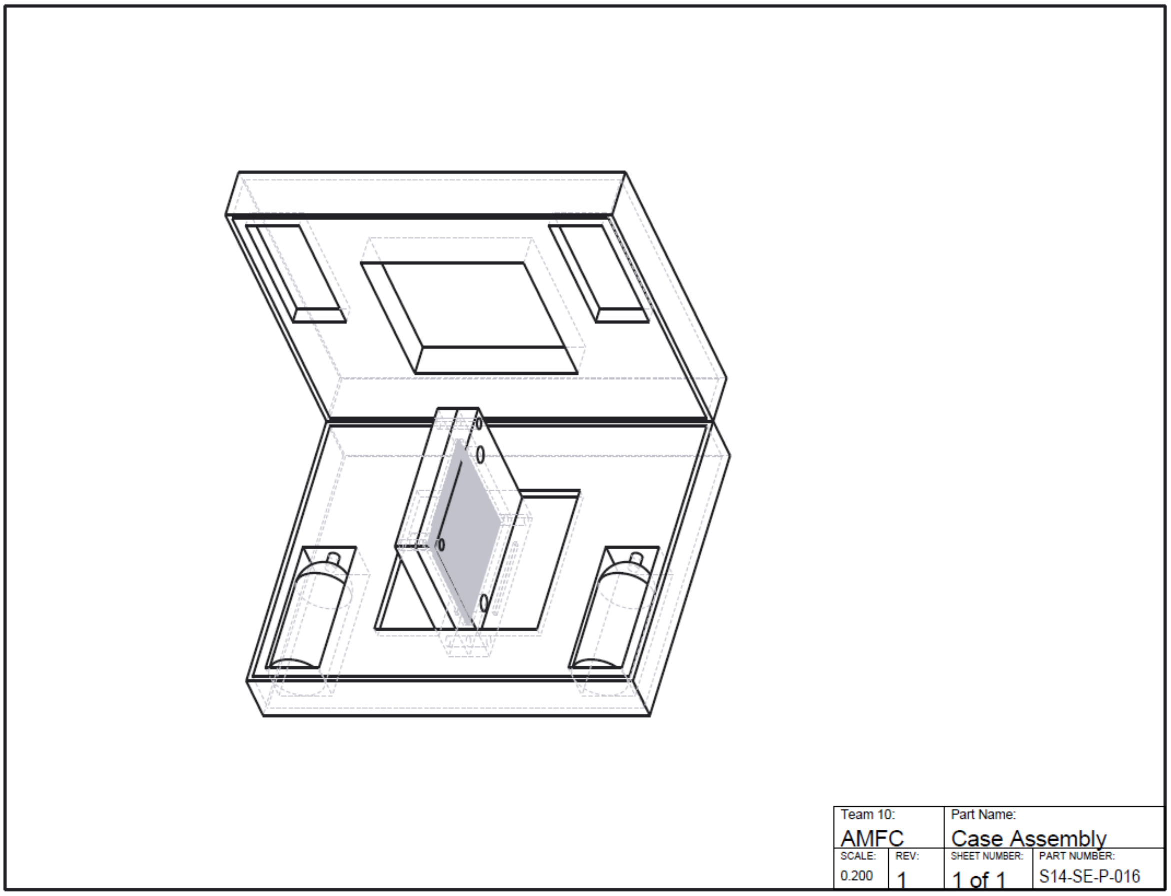


Figure 4. Mounted to Case Design

There is an indent in the foam where the cell can rest and it does not affect the cell while it is being stored. The tanks for this design are in the case as well. It is important to consider that with all three of these designs there are many things that need to be considered. First, since we are still gathering data for the fuel cell the official sized used has not yet been determined. This means that for all of the designs we will have to change a majority of the dimensions to accommodate this. Also, when looking at the fuel cell it is important to consider that it needs to remain perfectly sealed. This means that we can still make holes in the outer part of the cell in our designs as long as it is still sealed. So as a result the dimensions of the outer edge material of the cell will change depending on the size of the holes that are needed.

The benefit of each of these design ideas is that they are relatively easy to manufacture. Actually the only major manufacturing issue that we would run into would be trying to produce the plastic base mentioned in the first design. This is due to the fact that it has very unique dimensions and will have to be 3D printed. This is a problem due to our budget being slightly restrictive as it is now. The foam that is in the case can be cut manually by us to any dimensions needed so that will not be a problem. Also, the case will be purchased separately so no additional manufacturing will be needed. For our second design we will need to manufacture the arms that are supporting the case and fuel cell. The design for these arms is simple and can be easily manufactured in the engineering machine shop. The third design actually involves no additional manufacturing due to the foam being the support. Finally, if any changes need to be made to the fuel cell they can be done in the machine shop without issue.

2.3 Evaluation of designs

Seen below in table two is a selection matrix that represents some of the pros and cons of the three different designs discussed. This data was decided after determining some of the most important aspects that the cell and case design needs to be considered successful. After weighing the pros and cos of each design we have decided to use the assembly that is hanging from the case itself.

Design	Portability	Safety	Affordability	Machinability	Ease of Use	Weighted Sum
Tanks Included, Mounted to Case	5	3	3	3	4	66
Seperate Assembly From Case	3	5	4	4	4	73
Assembly Hangs from Case Mount	5	3	3	5	5	74
Weight	4	5	3	2	4	

table 2. Selection matrix comparing three different designs over five weighted design criteria.

2.3.1 Evaluation Method

The educational kit being produced in this project is unique in the fact that the design of the fuel cell itself and its accompanying parts doesn't have much room for fluctuation other than scalability; most other factors can be adjusted during assembly, such as electrolyte concentration and gas input pressures. Though adjustments of these aspects can be harmful or beneficial on performance, in our final design they will remain adjustable to allow the instructor or consumer to further understand the functionality of an Alkaline Membrane Fuel Cell and review how each parameter influences the reaction. However, three different design concepts were still able to be created based on how the educational kit would be packaged or contained when shipped/operated. After deliberation with our sponsor and the reviewing the needs stated in the project proposal, the five criteria found in table 2 were determined to be the most important aspects or standards of the AMFC educational kit that would be used to influence design selection.

This AMFC educational kit would ideally be used in an educational setting, teaching any interested parties about the possibilities and benefits associated with the alternative energy source. In order to make the fuel cell marketable and competitive, it was determined that safety should be the paramount concern when considering design concepts. Other criteria relative to the consumer, such as portability and ease of use were weighted higher than the aspects pertaining to the fuel cell construction in order to ensure proper functionality and durability of the educational kit and its components.

2.3.2 Selection of optimum Design

Of the three design concepts being considered, it was determined that the Alkaline Membrane Fuel Cell and its associated components would be better utilized by creating a kit that encompassed both the tanks and the fuel cell, with the assembly hung from a crossbeam running across the open case. This design reduces some of the frustration involved in the machining and streamlining of the kit for mass production as well as allowing for increased portability with one, self-contained kit. There are some trade-offs however, since including the tanks within the case allows for the possible transportation of combustible contents under pressure if proper safety measures aren't followed. This also increases the overall cost of the kit since more space is required within the case for the oxygen and hydrogen tanks, though the decrease in machining cost due to the simplicity of the packaging could offset some of this difference. One of the major advantages to this design concept is the reduction in area needed to operate the educational kit, as well as the ability to more easily demonstrate each step in the assembly of the Alkaline Membrane Fuel Cell. Also it is important to note that even though this has been selected as the final design the dimensions have not yet been finalized. This is due to the fact that the fuel cell size is still being determined based off of factors like performance and budget. Though with the recent return of the team members from Brazil we expect to have this complete within the first few weeks of the spring semester.

3 Risk and Reliability Assessment

Being an educational kit, our first and foremost concern is providing a safe and reliable design to get prospective engineers interested in fuel cell technology. There are certain risks inherent in the use of an Alkaline Membrane Fuel Cell that will need to be taken into consideration or overcome in order for the completion of this project next spring, whether they are performance risks or pose a hazard to the consumer.

3.1 Performance Risks

The potassium hydroxide solution used for the electrode in this AMFC design is corrosive, which could cause a problem with the long term reliability of the design if not handled properly. Our team hopes to mitigate this issue with the use of stainless steel bipolar plates, however the possibility of corrosion still looms with any impurities in the plate material, or at working fluid inlets/outlets. The functioning prototype that exists at UFPR does show signs of corrosion at the aforementioned locations, though it has continued to remain operational over extended use without diminishing performance which is promising.

3.2 Safety Risks

Likely to be our most significant risk, the storage of the working fluids (O_2 and H_2) is a paramount concern when developing our final project. One design consideration requires these gases to be compressed in storage tanks at high pressures within the educational kit. Both diatomic oxygen and hydrogen are combustible at high temperatures, and additionally hydrogen burns clear making it difficult to contain in case of combustion. There are safety measures that can be taken to significantly reduce this risk such as pressure relief valves and pressure regulation valves, however we are also considering removing the need for compressed gas storage and its associated risk depending on feasibility.

A less significant, yet nonetheless important risk arises from the nature of the chemical reaction taking place within the fuel cell. As the atomic bonds are broken between the oxygen and hydrogen atoms in the diatomic gases heat is generated within each control volume, the intensity of which is dependent on the proximity to the reaction as can be seen in the following Results and Discussion section. After several tests with the prototype at Univseridade Federal do Paraná, no excessive heat generation that would pose a hazard to the operator or anyone in proximity was observed.

4 Procurement

There are no active purchase orders, however this does not mean that the team is behind schedule. Currently certain components of the educational kit are under further analysis, the cause for the further analysis is the need to get as much correct as possible the first time around. The budget does not allow for miscalculation, especially for the stainless steel components. The following materials are ready to be ordered once design dimensions have been unanimously approved. Stainless 304 Steel for the bi polar plates (Item # 1NZR4), Raw aluminum 2024 flat stock (Item # 2EYL7) for supports and crossbeam. Case and foam inserts (BP-990) are also ready for order as soon as the final design is certain. The tricky components to purchase are the compressed gases, to combat this challenge, our advisor and sponsor Dr. Juan Ordonez is aware of the need and we will determine the needed supplies by the end of January. The other needed components mentioned in the budget summary are being looked into further. The KOH solution and the sheets specifications along with suppliers are being finalized by the Brazilian part of the team.

Machining will be necessary for the metal components within the educational kit. The team has spoken to the FSU machine shop and they have been made aware of the needed components. Once the materials have arrived next semester the materials will be sent to the machine shop along with detailed engineering drawings. The foam insets will be made custom by the team once the full design is set, that way each component of the kit fits securely within the padded case.

Though no orders have been placed yet, the team is confident in the timeline feasibility and are set up to have a strong spring semester cumulating in a successful alkaline membrane fuel cell educational kit prototype.

5 Communications

Our team effectively communicated throughout the semester to keep track of our progress and our goals. The main form of communication between members at FSU were text messages and phone/skype calls, which proved to be the most effective method to get ahold of each member. Due to our circumstances, approximately half our team is located in Curitiba, Brazil, conducting research and tests on the alkaline membrane fuel cell. Thus, our communication was setup through both text messages and video calls. The text messaging application known as WhatsApp was used to communicate with the Brazil members. Email was also used to communicate less urgent information.

Although our communication with our advisor has not been as frequent as expected, meetings have been set up when our advisor has been available. Any updates and concerns with the project have mainly been sent through email.

6 Environmental and Safety Issues

The educational kit and its comprising parts do not pose a risk on the environment. The KOH solution can be disposed of once it is diluted properly. While handling the KOH solution the user will need to be wearing gloves. If contact is made with the skin simply wash them as soon as possible. Some people can get a slight reaction to the KOH if contact is made. This would involve having some slight redness and itching of the skin. Since the current plan is to ship the KOH in pellet form and have the user mix the solution themselves there is little risk of leaking during the transportation process. Also, the sell will be sealed during operation to prevent leaking during this stage as well.

The transportation of the oxygen and hydrogen is another important safety concern when dealing with the case. The gas that will be transported will be under very low pressures so from a safety standpoint there will be no issue. Transportation will be limited to ground transportation since these gasses will not be allowed on planes. Also, the tanks will need to stay away from any fires in order to limit the risk of ignition which is very low. Another thing that we have considered when dealing with the gasses is leaking. Since we will be not using very much gas for our application as well as them being stored under such low pressure if there is a leak the gasses will quickly dissipate into the air and cause no effect on the room or its occupants.

Since we will be dealing with a device that produces electricity there is naturally a safety concern. The two bipolar plates will not be making contact with each other so there will be no risk of a short. Also, the wiring that will be used to power our device will be insulated properly. Overall the components are safe to use as long the user is properly educated on the procedure. A detailed pamphlet and DVD will be provided with the kit to demonstrate proper use and disposal of the fuel cell components. The product produced by our team will not in any way be produced and distributed without taking every precaution necessary to prevent harm to the public and the environment.

7 Project Management

Methodology is a key part of the product in order to produce an alkaline membrane power cell with portable capabilities. A good representation for our methodology can be seen below in Figure 5.

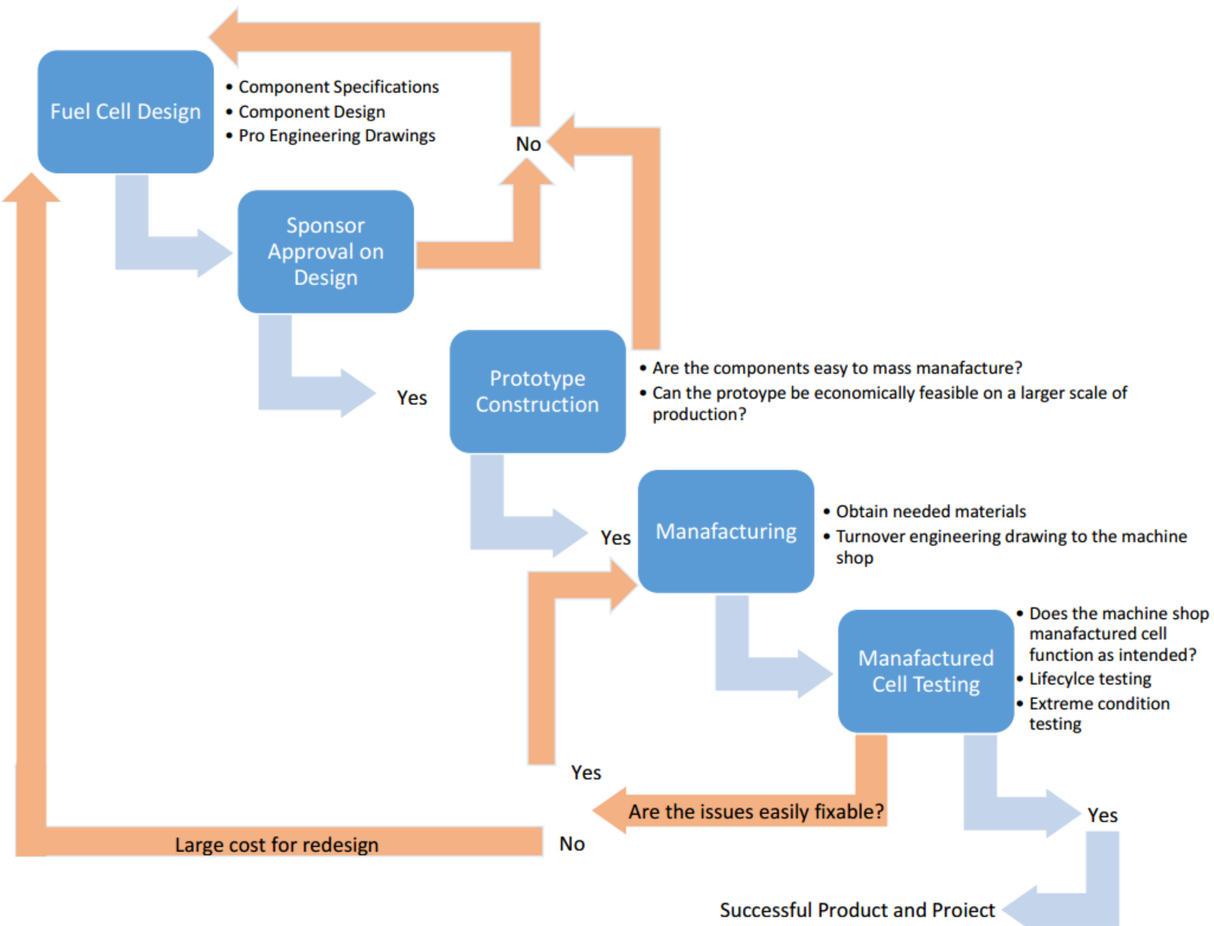


Figure 5. Methodology Block Diagram

At first, our goal was to understand the technology behind these fuel cells, this includes research of previous advancements in fuel cell technologies as well as understanding the basic theory behind the chemical energy transfers that occurs. Also, before testing occurred we made sure to understand the proper gas ratios needed in order to not damage the equipment being used. Now that the team has a grasp on the theory and background of AMFC technology, the next step is to verify the design process fits what is needed. The design process has been a joint effort with Brazil to ensure that the designs meet and exceed the expectations. Within each design flexibility has been included so that when construction occurs, any issues will have so room to maneuver and fit together seamlessly. The team is still in the design phase, and ahead of schedule on it. Below is a flow diagram outlining the requirements each stage has and the path for the future. After each milestone the team will ensure each objective is met before continuing, if the objective has been met the work will flow down, if the objectives are not met then the project flows up until the objectives can be met.

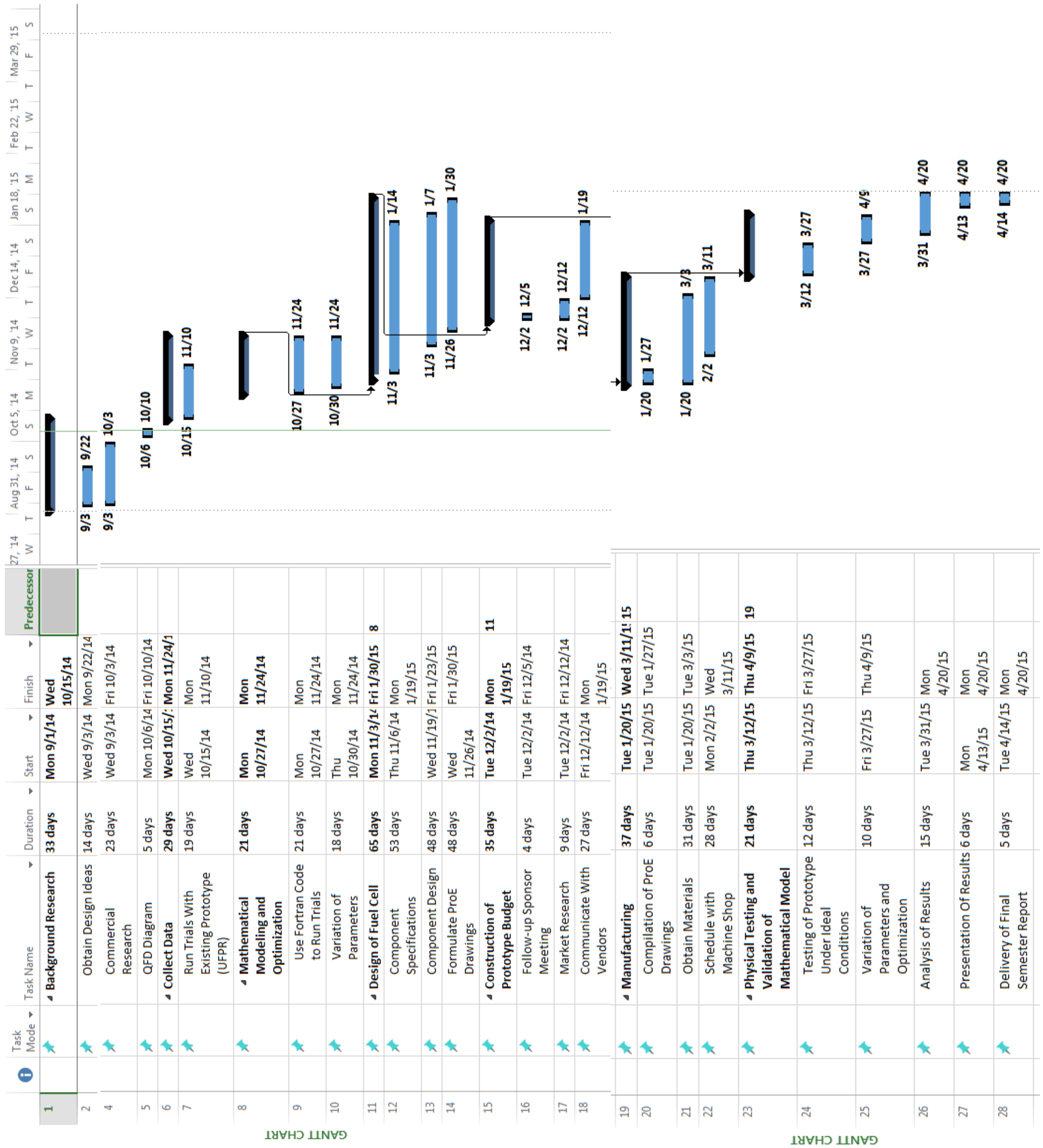
7.1 Schedule

The Gantt chart shown in Figure 6 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 reviewed the current technical reports on the cell to obtain a better understanding of what is needed to make a successful kit. Also, during this time we met frequently with Dr. Ordonez in order to address some of the questions and concerns that we had.

Then, after enough information was gathered we communicated with our team in Brazil to help gather and understand the data that they were gathering while testing an existing fuel cell design. From this data we managed to determine the ideal membrane concentrations as well as some important data points that we can compare are tests to when we perform them in the spring.

Now the team is finalizing the design of the fuel cell. This is a joint operation between Brazil and FSU. This has been difficult and holds as a continually changing process. This includes components and there specifications along with engineering drawings for each. The timeframe for the design portion is 65 days long. The timeline for the design phase has been ahead of schedule due to dynamic team communication amongst FSU and Brazil members. The team has currently decided on a finalized design concept. This is important because the dimensions of the design will be changing based on the finalized dimensions of the fuel cell. Also, the team has taken this design idea to our sponsor and it has gotten the necessary approval.

As this was taking place other team members spoke with vendors in order to more accurately obtain a shipping timeline for the materials needed and to adjust the budget in case any unexpected expenses occur.



	Task Name	Duration	Start	Finish	Predecessors
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	
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/	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	
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 6. Gant Chart

7.2 Budget

The Alkaline Membrane Fuel Cell educational kit has a budget of one-thousand dollars. This budget brings forth some serious challenges. Though the goal is to develop an AMFC kit as financially prudent as possible, often when developing such a product a much larger budget is allotted for the initial designs and prototypes. This is because designing a kit that can be produced on a larger scale requires a great deal of design and optimization work. Each part must be engineered without error because there is not enough room in the budget to make major errors. When discussing the budget there are two core groups of cost, primarily the single time purchases that will ideally last the life of the product, then those that are consumed during the process which must be purchases cyclically. The single time purchases consist of structural kit components including the case ($55), the foam inserts ($35), the structural supports and crossbeam ($63), the bi polar plates ($202), and the tubing/wiring ($11). This is a conservative budget with extra anticipated costs built in the budget to ensure design flexibility. The bi polar plates are a large portion of the budget however this is a good investment as stainless steel takes care of the corrosion issue experienced in Brazil with using brass. The other group of costs, the recurring, will be budgeted for all test runs during the optimization stage as well as the initial prototype. After that point the recurring costs will be the responsibility of the investing party. The anode and cathode sheets ($TBD), the KOH solution ($10), hydrogen gas ($TBD), and the oxygen ($15) all will be recurring costs. Not including the few costs that are still being finalized, the total cost is $381. This is much higher than desired but a seemingly realistic budget to produce a working prototype.

8 Results and Discussions

Since the design of the Alkaline Membrane Fuel Cell and its components remain unchanged regardless of design, the computational analysis of the system yielded the same results for each concept. Using the mathematical model in FORTRAN our team was able to predict the response of various aspects of the fuel cell, such as how the pressures of the fuels affect the generation of current and the transient behavior of temperature that occurs while the reaction takes place.

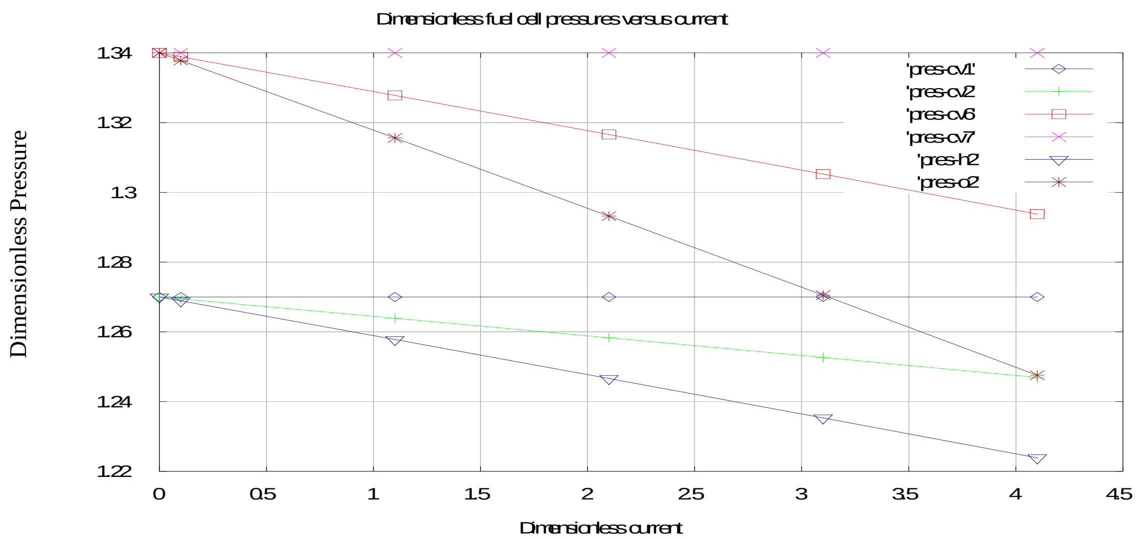


Figure 7. Dimensionless fuel cell pressure vs current

Figure 7 above depicts the theoretical pressures of select control volumes of the fuel cell, including the transient pressures of the diatomic hydrogen and oxygen gases as they flow through the fuel cell. It can be noticed that the inlet pressure of the gases (CV1 and CV7) were assumed to be constant, and yield a constant current throughout the test. However, when analyzing the other control volumes it's apparent that the pressure of the fuel is inversely related to the energy generation of the fuel cell. As pressure steadily declines, the current produced by the AMFC increases. This parameter is intentionally left alterable by use of pressure valves in order to demonstrate the effects of fuel characteristics on energy generation, however the use of lower pressures would reduce the storage tank size requirement.

As the chemical reaction between the hydrogen and oxygen takes place, heat is generated within the control volumes of the fuel cell. In order to determine whether this poses a hazard to the consumer, each control volume was analyzed separately within the response projected by the mathematical model. As seen in Figure 8 below, the overall temperature of the Alkaline Membrane Fuel Cell increases exponentially over time as the reaction takes place, however a temperature gradient is produced within the casing of the fuel cell. The temperatures at the inlets of the H2 and O2 gases (CV1 and CV7, respectively) are significantly lower than the other sections of the fuel cell due to the nature of chemical reactions, and the heat that is given off as atomic bonds are broken. Though the higher temperatures are found within the middle control volumes of the AMFC which would not be exposed, the gradient will be taken into account when forming design concepts in order to reduce the possible risk of injury to consumers.

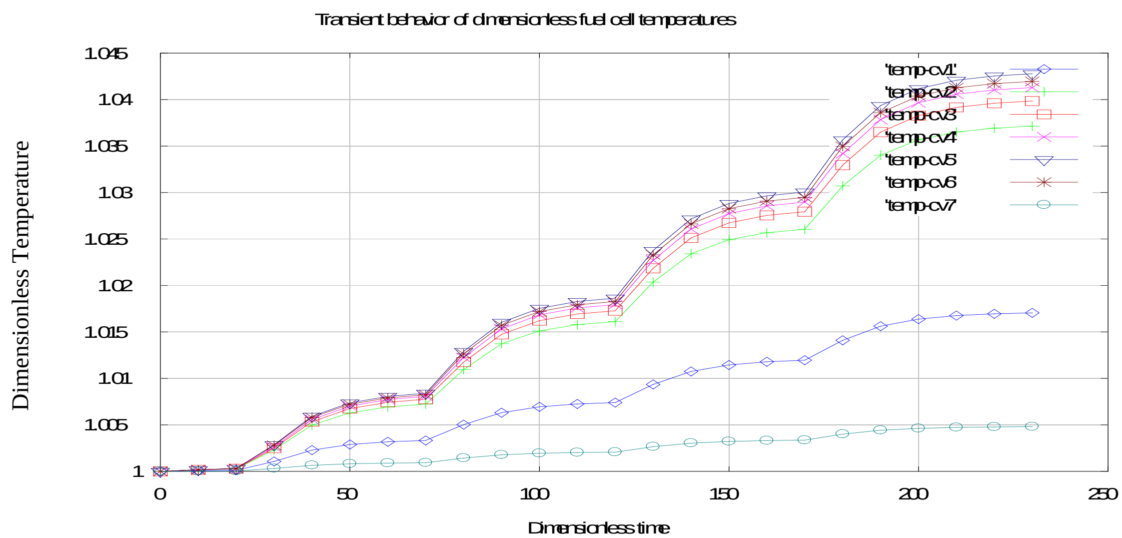


Figure 8. Transient Behavior of Dimensionless Fuel Cell Temperatures

Tests have also been done in order to determine the optimum percentage of KOH solution that is needed within the fuel cell. In order to determine this value several tests were run at different KOH percentages and the results can be seen below in Figure 9. The voltages and current were determined through the testing in order to determine the wattage. As expected the increase in current causes a decrease in voltage. Also, based off of the testing done the ideal value for the KOH is 40 % which will result with a wattage of just under 3 watts.

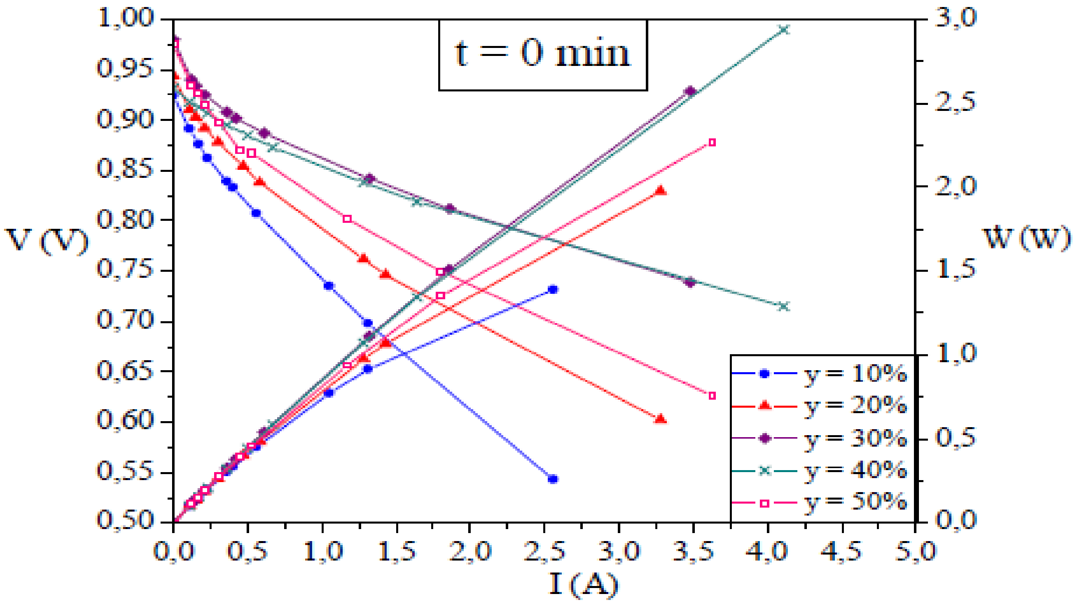


Figure 9. Output of cell with relation to KOH solution

The last test that was performed on the fuel cell is a measurement of decreasing resistances at certain times during operation. This test was done over the time of 330 minutes and the results can be seen below in Figure 10. The results were found from an open circuit to a closed circuit. Also, we can see that there is actually a drop in overall voltages after the cell has been running for around 300 minutes. This should not affect our overall results because with our application of the cell we do not plan on using it for such an extended period of time.

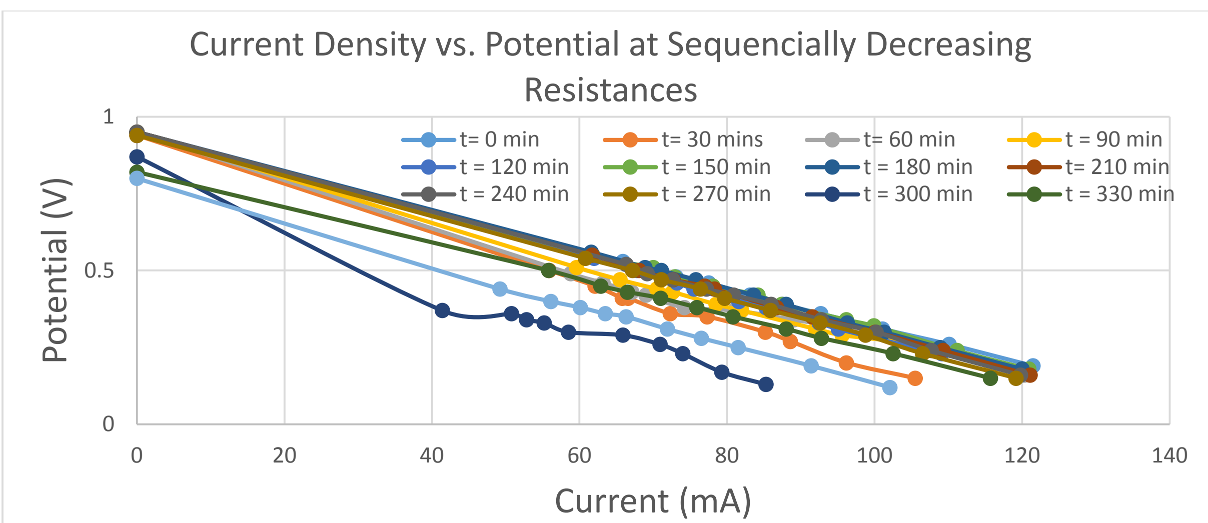


Figure 10. Current Density vs Potential at Sequentially Decreasing Resistances

9 Conclusions

Within this semester we have accomplished many things with our senior design project. First, we have finalized on our design by choosing to have the fuel cell hanging during operation. This is because it is believed to be the most reliable and stable design that will maintain these qualities through frequent use. Another thing that has been accomplished this semester is the data that has been gathered from the Brazil team. Through this data we have managed to determine that the ideal ratio for the KOH solution is 40 percent to obtain peak wattage. We have also been viewing some of the items needed for purchasing and have determined that there are some things that still need to be finalized over break before purchasing can be made. This is because the budget does not leave us very much room for error. Overall with the final design selected and purchases soon on the way the project is still very much on track to be completed by the end of the spring semester.

10 Acknowledgement

Our efforts for this project would have been impossible without the continuing assistance from our advisors and sponsors for our guidance and financial assistance.

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11 References

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