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PROJECT SPECIFICATION

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PEM Fuel Cell Battery

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Table of Contents

1 PROJECT SPECIFICATION OVERVIEW

1.1 Executive Summary

Due to the growing concerns on the depletion of petroleum-based energy resources and climate change, fuel cell technologies have received much attention in recent years owing to their high efficiencies and low emissions. Factors such as durability and cost still remain as the major barriers to fuel cell commercialization. [Y. Wang, Ken S. Chen, Jeffrey Mishler, Sung Chan Cho, Xavier Cordobes Adroher, A Review of Polymer Electrolyte Membrane Fuel Cells: Technology, Applications, and Needs on Fundamental Research, Applied Energy 88 (2011) 981-1007].

Our research team consists of undergraduate Mechanical and Aerospace Engineering seniors and will be working on the study of proton exchange membrane (PEM) fuel cells. A fuel cell is an electrochemical device that converts chemical energy from a fuel into electricity through a chemical reaction involving an oxidizing agent such as oxygen.

The PEM fuel cell generates electricity by electrochemical reactions in the anode as well as the cathode. In order to speed up the chemical reactions, PEM fuel cells utilize a catalyst. The best catalyst researched to date is platinum. When the protons reach the cathode, they react with the oxygen and electrons to produce water, which is the only waste product produced by the fuel cell. Meanwhile, the electrons generated in the anode travel in an external circuit, creating the electrical output of the fuel cell. There are no harmful emissions as there is no combustion of the fuels.

A PEM hydrogen fuel cell has a practical efficiency of up to 60%, which leads to as little as 40% of the energy inputted becoming excess heat. However, fuel cells are negatively affected by variations in temperature. This research will look into a way of keeping the PEM fuel cells a consistent temperature, as well as utilizing the waste heat in a portable system. Two main ways of cooling, with air and with water, will be focused on. During this time, investigation will begin on which type of medium best cools the PEM fuel cells, as well as finding the best operating temperature for cells to achieve maximum efficiency. After this is done, research will be carried out to determine how much heat is removed from each fuel cell and whether or not this heat can be viably used for other purposes.

Another focus of this design project will be to maintain the water that is discharged from the fuel cell. Preliminary testing will be done on the fuel cells to determine the quantity of the discharged water as well as its temperature under various conditions. There are two cases that will be looked into regarding the temperature of the waste water: 1) low temperature waste water and 2) medium temperature waste water. Since the fuel cells that will be used are considered low temperature fuel cells, it is highly unlikely that the water will be discharged at a high temperature. For case 1, the low temperature waste water will be utilized for potential cooling for various systems. As for case 2, the focus of the medium temperature waste water will be on potential heating for smaller systems that do not require high temperatures. Depending on the amount of water discharged from the fuel cell will determine whether or not a third case will be introduced. The possible third case may be investigated will be to use the water to spin a rotor to generate additional electricity if there is a significant amount of discharged water from the fuel cell.

2 Product Description

The main objective of the project is to produce a more efficient hydrogen energy fuel cell. To help the team understand how a fuel cell works, testing and analyzing of a PV Panel and electrolyzer will be done. In order for a PEM fuel cell to produce electricity, you need two inputs: hydrogen gas (H_2) and oxygen (O_2). The oxygen can be used from the one present in the atmosphere while hydrogen gas has to be synthesized because it is not naturally occurring. For our project, we will be using an electrolyzer in order to create hydrogen gas. An electrolyzer takes water (H_2O) as an input and splits it into hydrogen gas (H_2) and oxygen molecules (O_2). In order for the electorlyzer to carry out this function, an electric current is needed. To obtain a current, we will be harvesting power from the sun through the use of monocrystalline solar panels. An electrolyzer, commonly called HHO dry cell or HHO generator converts electrolytes such as distilled water, NaOH, and KOH into HHO fuels consumed by fuel cell batteries that generate electric power and clean water. It uses a chemical process called electrolysis which passes a current through water and decomposes it to hydrogen and oxygen. With the electric current, the positively charged hydrogen ions migrate to the negatively charged cathode and then reduction takes place, forming hydrogen atoms. The hydrogen atoms then combine to form the gaseous hydrogen molecules, (H_2) which is used as a replacement for fuel and other things. The same process takes place for the oxygen ions but instead they form on the positively charged anode.

There are various factors that affect the efficiency of the electrolyzer. The main factors that affect the efficiency are the distance between the plates, the surface area of the plates, and the voltage across. Other factors come into play as well, such as waste heat, current leak, and water flow through the device. Through various tests, we aim to design an electrolyzer that can minimize energy loss, and ultimately have a significantly high performance. Testing for the electrolyzer will be done by adjusting for maximum performance. To do so, various parameters will be tested, one at a time, and then adjust the settings to the optimum parameters to obtain the maximum efficiency result for the given electrolyzer. We will first test for optimum voltage by keeping all other parameters at a constant. Voltage affects how much of the water has been converted into hydrogen for a given volume flow rate. After obtaining results for this voltage, we will then keep every parameter at a constant and adjust the current. Current determines the conversion process with respect to time. Then we keep the voltage and current at the optimum constant and run a third test to check for the optimum efficiency of the electrolyzer. Through careful testing and analysis of the PV Panel and electrolyzer, optimization of the PEM fuel cell will occur next.

To optimize the PEM fuel cell, it must first be evaluated based on its performance; from this information, logical conclusions will be made about the desired operating conditions. Fuel cell performance relies on a large range of aspects. Fuel cell type, electrode size, operating temperature and pressure are among the many factors that determine the power output and efficiency of a fuel cell. The PEM fuel cell used in this project will be fed a steady supply of hydrogen gas and oxygen and assessed in Professor Yun Wang's laboratory [Yun Wang, PhD; Liem Pham; Guilherme Porto Salerno de Vasconcellos; Marc Madou, Fabrication and Characterization of Micro PEM Fuel Cells using Pyrolyzed Carbon Current Collector Plates, Journal of Power Sources, 195 (2010) 4796-4803.] [J. Mishler, Y. Wang, R. Lujan, R. Mukundan, and R. L. Borup, An Experimental Study of Polymer Electrolyte Fuel Cell Operation at Sub-Freezing Temperatures, Journal of The Electrochemical Society, 160 (6) F514-F521 (2013)]. An E-load system will be used to measure the current density and cell voltage. The efficiency of the hydrogen fuel cell is obtained by comparing the theoretical energy yield of a given amount of hydrogen gas (fuel) to the amount of energy converted and put out by the fuel cell setup. It is imperative that the team collect this data under different environmental conditions, such as the fuel cell temperature and pressure of the hydrogen gas and oxygen input as well as the water byproduct. Optical microscopy techniques will be applied to the proton exchange membrane so that the team may be able to visualize the microscopic flow of hydrogen protons through the membrane. Through this technique we wish to observe the flow patterns of the hydrogen protons through the membrane and locate the areas in the membrane that are most prone to proton “flooding.”

Altering the operational conditions will lead to conclusions as to what optimum conditions allow for the most efficient fuel cell. Such conditions include altering the temperatures, pressures, flow rates, and also managing the water content. Some conditions may indirectly affect other conditions however such as is the case with large reactant flows, low humidity, high temperatures, and low pressures, which all result in a water deficit. A water surplus could also occur if there is a relatively small reactant flow, high humidity, low temperature, and high pressures. Without adequate water management, an imbalance will occur between water production and water removal from the cell. Another key condition that will be monitored is the amount of diluents in hydrogen if it is to be bought from a vendor. This is because hydrogen, after being reformed can carry small amounts of carbon monoxide (CO) and some tests show that even 10ppm of CO can impact cell performance by blocking hydrogen from catalyst sites. If hydrogen is collected by electrolysis we will be able to try and reduce as much diluents as possible so as to avoid CO poisoning.

After the research phase has been completed, the team will design a fuel cell apparatus that aims to promote and maintain the aforementioned optimum operational conditions. The components and assembly of the device will first be drafted on the 3-Dimensional CAD program Solidworks. The design will then be carried out through the combined use of the fabrication facilities at the University of California, Irvine. Any necessary welding and metal fabrication will take place in the metal shop in ET 151. Due to the complexity of this technology, utmost care must be taken when fabricating new devices or modifying the existing fuel cell. Sensitive fabrication and other processes will be carried out within Professor Yun Wang’s research laboratory.

3 Appendix

http://app.knovel.com/web/toc.v/cid:kpFCSEE002/viewerType:toc/root_slug:fuel-cell-systems-explained-2nd-edition/url_slug:fuel-cell-systems-explained?b-q=fuel%20cells&b-group-by=true

Fuel Cell Handbook

http://www.fuelcelltoday.com/about-fuel-cells/technologies/pemfc

No. 10, in *An EPRI/GRI Fuel Cell Workshop on TechnologyResearch and Development, *April 13-14, 1993, Stonehart Associates, Madison, Connecticut, 1993.

S. Gottesfeld, “Polymer Electrolyte Fuel Cells: Transportation and Stationary Application,”