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small innovations
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micro fuel cell labs

April 28, 2005
Mr. Lucky One
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Post Mortem for the Micro Fuel Cell Testbench

Dear Mr. One:

Please find attached the document, *Post Mortem for the Micro Fuel Cell Testbench,* giving a final summary of our product for ENSC 440. The purpose of the product is to allow researchers to easily perform rigorous testing on their design of a novel micro fuel cell.

The attached document outlines the current status, timeline, and budget of the Testbench project. The attached document also includes personal comments from each of our team members on our learning experience during the project.

MFC Labs was made up of four talented individuals with expertise in various technical fields: Arash Jamshidi, Sarang Toosi, Olha Lui, and Shirin Farrahi. Please feel free to contact us at by e-mail at info@mfclabs.com for more information regarding our project.

Sincerely,

Shirin Farrahi

Shirin Farrahi
Chief Executive Officer (CEO)
Micro Fuel Cell Labs (MFC Labs)
Enclosure: *Post Mortem for the Micro Fuel Cell Testbench*

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Post Mortem for the Micro Fuel Cell Testbench

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Submitted to
Lucky One – ENSC 440
Mike Sjoerdsma – ENSC 305
School of Engineering Science
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Date: April 28, 2005

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Glossary

AC	Alternating Current
A/D	Analog to Digital
DMFC	Direct Methanol Fuel Cell
DUT	Device Under Test
NRC	National Research Council of Canada
R&D	Research and Development

1. Introduction

Our company, MFC Labs, was created with the goal of speeding up the commercialization of fuel cell technology in Canada. To achieve this goal, we created our first product, the MFC Testbench, which can provide researchers with an easy-to-use measurement system for long-term testing of fuel cell operating parameters. The MFC Testbench is also portable and stand-alone for demonstration and tradeshow purposes. The first version of the MFC Testbench is shown in Figure 1.

Figure 1: MFC Testbench

The MFC Testbench achieves our goal of speeding up the commercialization of fuel cell technology by satisfying a niche market among fuel cell researchers for equipment which can run independently and provide reliable long-term test results. This project was funded by the National Research Council of Canada (NRC).

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2. Current Status of Project

Overview

Figure 2 shows the block diagram of the MFC Labs Testbench. As shown in the block diagram, our product consists of three major sections: the MFC Testbench Block, the Software Block, and the Test Circuit Block.

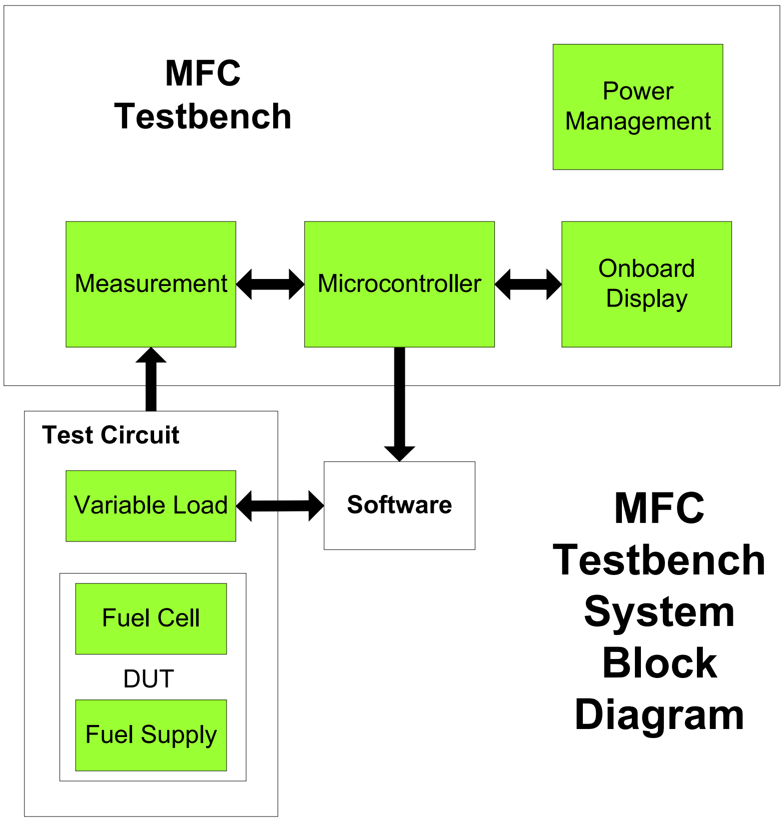

Figure 2: General block diagram of the MFC Testbench System

The MFC Testbench Block consists of the measurement, microcontroller, onboard display, and power management subunits. The measurement subunit has the task of measuring different parameters such as voltage, current, temperature, and humidity.

Table 1 shows the accuracies and ranges of parameters measured by the MFC Testbench when connected to a fuel cell under test. The data in Table 1 has been validated by test results which are outlined in detail in the MFC Labs project binder.

Table 1: Ranges and Accuracies of Fuel Cell Measured Parameters

Parameter	Range	Accuracy
Voltage	0 – 2V	± 0.05 V
Current	10 – 100 mA	± 5 mA
Temperature	0 – 50 °C	± 1 °C
Humidity	0 – 100 %RH	± 3 %RH
Fuel Flow	10 – 100 mL/min	± 10% FS

MFC Testbench Block

The microcontroller receives the information from the measurement block and either displays the data on the onboard display module or sends the data through an RS232 connection to the software module for long term data logging purposes. The MFC Testbench can be powered from either an AC adaptor or a battery. The power unit also provides power to different modules of the MFC Testbench, provides an accurate voltage reference for the analog to digital converter, and has extra protective circuitry for the battery, AC adaptor and the analog to digital converter. Figure 3 shows the arrangement of the MFC Testbench subunits before integration into a box.

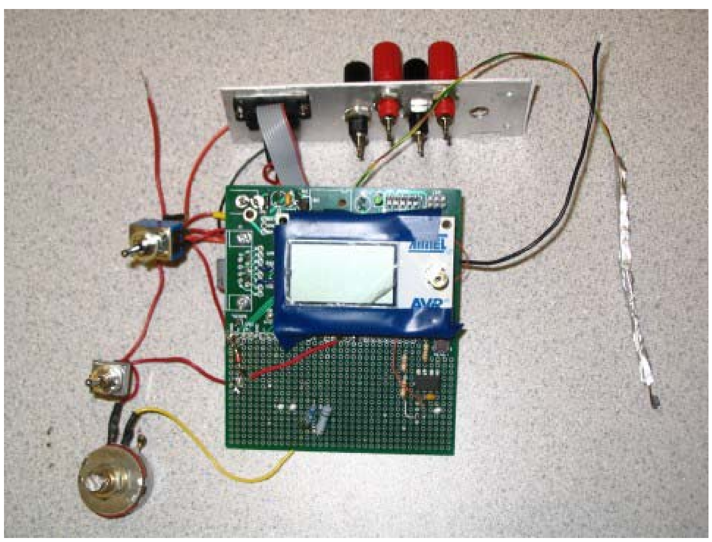

Figure 3: MFC Testbench Before Integration into a Box

The mechanical box shown in Figure 1 provides several important features for the MFC Testbench including durability and portability. It also allows the user to easily interface with the other system components including the fuel cell under test, the electronic load, and the computer interface as shown in Figure 4.

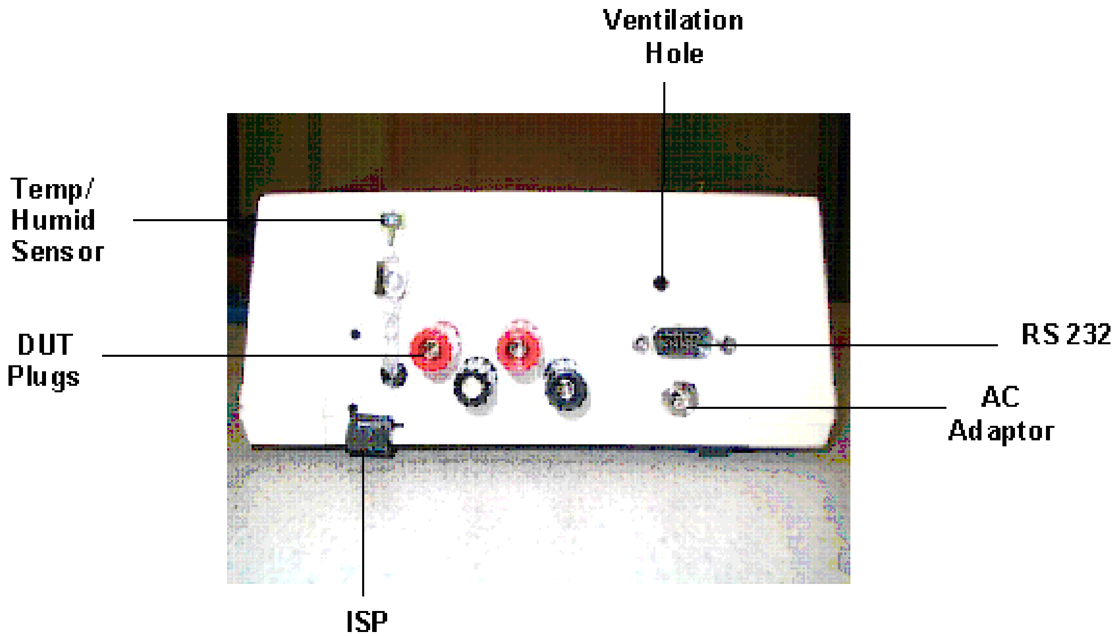

Figure 4: Back view of the MFC Testbench after integrating with the box

Software Block

The software module has the task of communicating with the variable load to provide for long-term data logging and to control the load seen by the fuel cell. The communication between the software and the variable electronic load is also done through RS232. In addition, the software receives the voltage, current, temperature, and humidity information from the microcontroller for long-term data logging purposes. Figure 5 shows a snapshot of the data logging software.

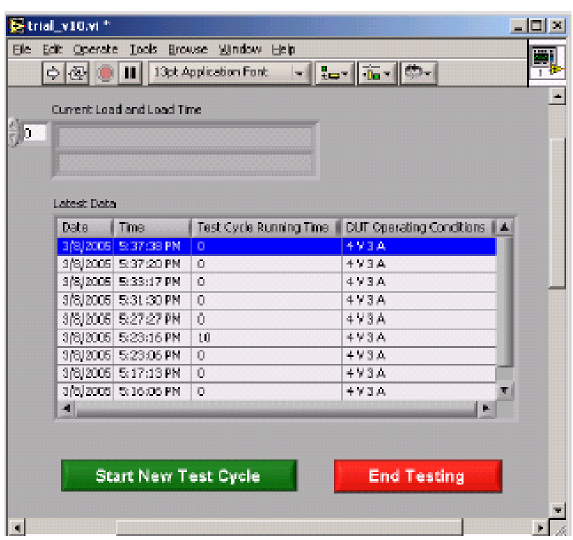

Figure 5: MFC Testbench Software

Test Circuit Block

Figure 6 shows the overall arrangement of the test circuit. As can be seen from Figure 6, the DUT is connected to a switching circuit that switches between the manual and electronic load options. There are also connections from different points of the circuit to the analog to digital converter (A/D) for measurement purposes.

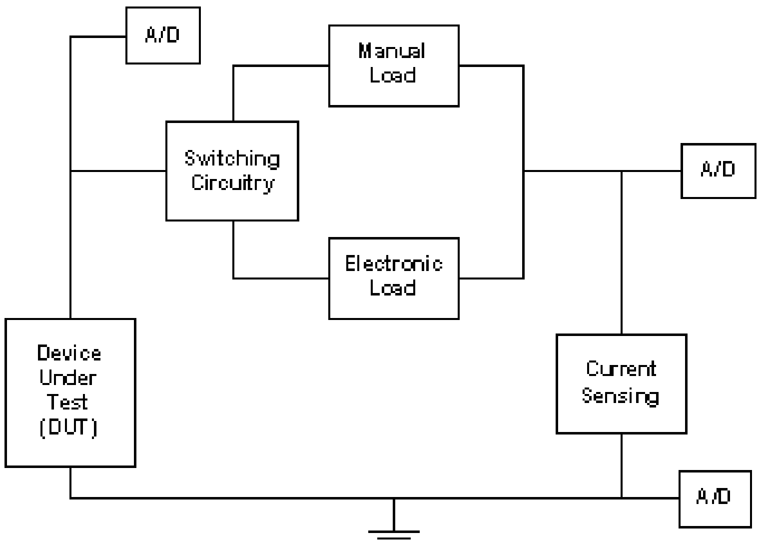

Figure 6: Overview of the Test Circuit

The DUT section consists of two modules: the DMFC and the Fuel Supply. The Fuel Supply module has the task of providing fuel for the fuel cell and also monitoring the flow. Figure 7 shows the overall arrangement of the fuel supply section.

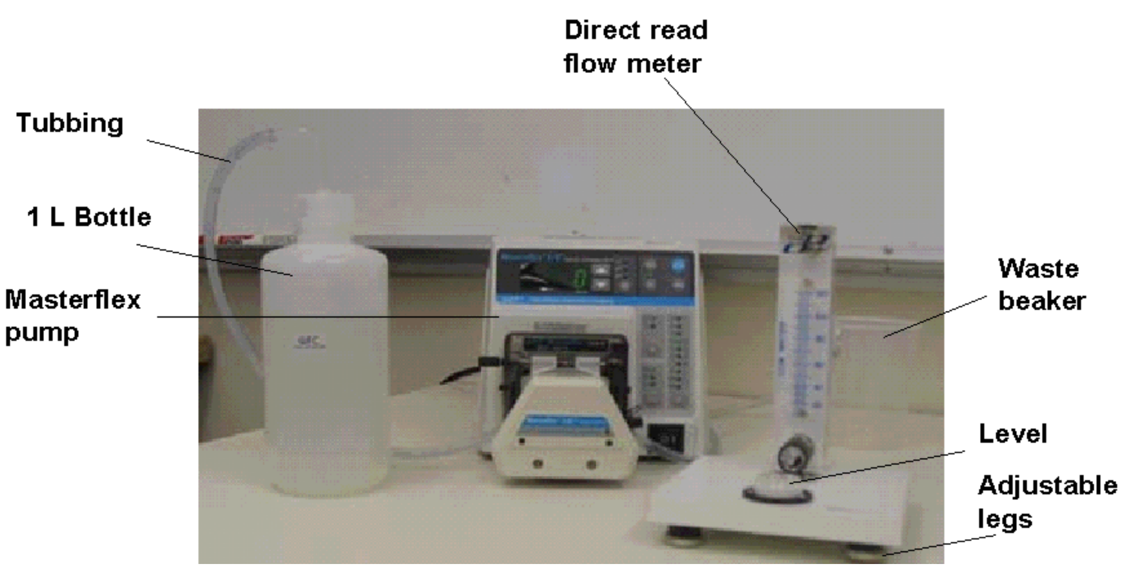

Figure 7: The Fuel Supply Module

Design Revisions

Several design changes were made since our design specifications were submitted [2]. These changes have been outlined and justified in the MFC Labs project binder.

3. Timeline

Table 2 presents a comparative analysis of the MFC Testbench project's major milestones and explains the reasons for any delays experienced.

Table 2: Comparative Analysis of Milestones

Task Name	Original date	Actual date	Comments
Project proposal	25-Jan-05	25-Jan-05	
Oral presentation/Progress report	14-Feb-05	8-Feb-05	E-mailed Mike our progress report
Software	21-Feb-05	14-Mar-05	Delays in getting Labview software installed
Variable Load Blocks	21-Feb-05	3-Apr-05	Delays in ordering at NRC, no documentation included, software provided didn't work, and extra cable had to be ordered
Functional Specs	22-Feb-05	22-Feb-05	
Measurement block	28-Feb-05	24-Mar-05	Everything was on time, except the current sensor
Power management block	28-Feb-05	1-Mar-07	The part was lost in shipping
Design Specs	11-Mar-05	14-Mar-05	Had an extension because of team member's absence
Preliminary demo	14-Mar-05	17-Mar-05	Actual date was scheduled by Lucky
Methanol supply = Fuel Flow	25-Mar-05	1-Apr-05	NRC provided incompatible pump and tubing
Group Presentation	11-Apr-05	26-Apr-05	Exams period

Table 3 presents a comparative analysis of the original, reviewed, and actual schedules. Any discrepancies from the original schedule submitted in our proposal [1] are highlighted in red.

Table 3. Comparative analysis of the schedules

Task Name	Start Date	Planned Completion Date	Reviewed Completion Date (2/03/05)	Actual Completion Date
Research				
Methanol fuel cell	1-Jan-05	31-Jan-05	31-Jan-05	31-Jan-05
Market research	3-Jan-05	11-Jan-05	11-Jan-05	11-Jan-05
LabVIEW research	18-Jan-05	31-Jan-05	31-Jan-05	31-Jan-05
Fluid flow for methanol	17-Feb-05	7-Mar-05	7-Mar-05	7-Mar-05
Microcontroller Development system	24-Jan-05	27-Jan-05	27-Jan-05	27-Jan-05
Concept				
Concept design	4-Jan-05	25-Jan-05	25-Jan-05	25-Jan-05
Concoept selection	10-Jan-05	25-Jan-05	25-Jan-05	25-Jan-05
Detail design				
Functional specs	24-Jan-05	31-Jan-05	31-Jan-05	31-Jan-05
Hardware design specs	31-Jan-05	14-Feb-05	14-Feb-05	14-Feb-05
Software design specs	24-Jan-05	4-Feb-05	4-Feb-05	4-Feb-05
Module design				
Ordering parts	24-Jan-05	7-Feb-05	7-Feb-05	7-Feb-05
Test plans	25-Jan-05	28-Jan-05	28-Jan-05	28-Jan-05
Testing parts/mock FC	6-Feb-05	21-Feb-05	7-Mar-05	7-Mar-05
Late ordering	11-Feb-05	25-Feb-05	4-Mar-05	4-Mar-05
LabView program	31-Jan-05	14-Feb-05	14-Mar-05	14-Mar-05
Measurement block	7-Feb-05	28-Feb-05	7-Mar-05	24-Mar-05
Variable Load	14-Feb-05	28-Feb-05	14-Mar-05	3-Apr-05
Power Menagement	24-Feb-05	28-Feb-05	7-Mar-05	7-Mar-05
Prototype Integration/testing				
Integration of blocks	14-Feb-05	11-Mar-05	11-Mar-05	1-Apr-05
Mechanical assembly	25-Feb-05	4-Mar-05	8-Mar-05	1-Apr-05
Methanol supply/FC connection	4-Mar-05	25-Mar-05	25-Mar-05	1-Apr-05
Debugging/prototype modification	7-Mar-05	11-Apr-05	11-Apr-05	11-Apr-05
Documentation/website	3-Jan-05	22-Apr-05	22-Apr-05	28-Apr-05

The first review of the schedule took place on March 2 when we were preparing for our preliminary demo. At that time we were on target for completing the major system blocks with several exceptions. The testing of parts and late ordering tasks had to be re-scheduled due to unexpected delays of placing orders through our sponsor, NRC. The measurement block was completely functional with the exception of the current sensing circuit, which was added two days after the preliminary demo on March 17. The variable load block had to be re-scheduled again due to complications with ordering. The power management block was re-scheduled once due to an integral part lost in shipping from the

United States. Consequently, the delays in module design tasks caused delays in integration of blocks, mechanical assembly and methanol supply. The average delay was approximately one week, but we were able to catch up with schedule by April 11 when we were able to complete debugging and prototype modification as originally planned. Our final demonstration and post mortem were rescheduled for April 26 and 28 respectively due to our team members' exam times and the instructor's availability.

Overall, we learned to allow more flexible time for ordering parts when dealing with a third party, such as NRC, and also to plan for alternative actions when parts get lost in shipping.

4. Budget

Table 3 presents a comparative cost analysis of our planned cost for the MFC Testbench as outlined in our proposal and our actual cost. We came under budget in both research and development (R&D) and product cost. R&D costs include parts which were purchased and not used as well as labels, printing, faxing, and other operating costs. The product cost includes all components which were purchased and used inside the MFC Testbench box. The major external component purchased was an electronic load which increased our budget by $493.69 above what was originally project, causing our total cost to exceed the projected amount. We feel that an electronic load is a useful and versatile piece of equipment and will benefit our client in many other projects. Hence, we feel that this purchase is justified.

Table 4. Comparative cost table.

	R&D	Product	External components	Total
Projected cost	**$705**	**$615**	**N/A**	**$966**
Actual Cost	**$595.78**	**<$370.67**	**$493.69**	**$1089.47**

We learned that in an engineering project there might be unforeseen expenses for necessary equipment. Hence, it is a good idea to include a contingency fund in projected plan. In our proposed budget we had 20 % contingency plan which helped us to minimize the impact of unforeseen equipment purchasing.

5. Personal Comments

Throughout the completion of the MFC Testbench project, we were able to learn from each other and thus gain valuable insight into working as a team to complete a project on time and on budget. The following are our personal comments on what we learned individually.

Shirin Farrahi

The most valuable skill I learned during the implementation of the MFC Testbench was how to manage a group of people with widely varying backgrounds to work together towards achieving a common goal. Since our project was made up of many functionally separate components, I learned how to design my major system component, the MFC Testbench Software, while also considering the needs of the hardware, firmware, and mechanical sections. Finally, I gained some insight into the challenges of starting up a company with limited resources.

Arash Jamshidi

During the design and development of the MFC Labs Testbench, I had the opportunity to work with three colleagues and learn a lot of things in the process. The wide range of the ENSC 440 projects demand good management and interpersonal skills. The MFC Labs Testbench project has been a good opportunity for me to learn even more how to act within a group and discuss the solutions and problems that arise. In addition, developing a product from the first stages of the design to development, testing, etc. has helped me in better understanding the process of engineering design and development. I have also managed to learn a lot about the mechanical design and fluidics throughout this project. Furthermore, working with the microprocessor and other electronic circuitry has helped in better knowing the available components and in component selection process. At the end, the whole experience of design and development of the MFC Labs Testbench has not only added to my engineering knowledge but has also added to my interpersonal skills.

Sarang Toosi

My experience in the development of MFC Labs Testbench has helped me to become more familiar with the different stages of an engineering project. I have had the opportunity to work in different areas such as the electronic design, power design, and development and assembly of the mechanical sections. In addition to technical sections, the project has also helped me with becoming more familiar with the management and documentation aspects of a good engineering project. Learning how to keep track and organize all the design notes, schematics, and even scrap papers broaden my engineering skills. In the mechanical design of the project, I was able to test my creativity and come up with novel solution. The MFC Labs Testbench project consisted of a wide variety of equipments, including the electronics circuitry for measurement, software for data logging, and the fuel cell. Integrating and interfacing all the different sections of the project has been a valuable experience for me to become more familiar with challenges in interfacing different sections and the solutions to them. Overall, the project has been a valuable experience for me to strengthen my technical and communication skills.

Olha Lui

Participating in this project helped me to acquire a wide variety of new skills and knowledge. I learned about principle of work of direct methanol fuel cell and its important physical and chemical characteristics. As the technical lead on the fluidic part of the project, I learned how research the available fluidic equipment on the market, how to communicate with its suppliers, how to ensure that fluidic equipment meets the specifications, how to install various equipment, and how to operate and troubleshoot the fluidic system. Also, I have acquired skills of working with chemical solutions and equipment. For example, I had to ensure that all components of my fluidic system were chemically resistant to 5 % methanol solution. By participating in mechanical assembly of our MFT Testbench, I learned where to purchase the mechanical components in Lower Mainland, how to assemble the electronic components in the project box, such as installation of IC component to PCB, mounting of PCB inside the product box, machining the box to allow for component placement, and application of isolation to IC components. I learned how to operate tools in machine shop. Also I learned to work with Solid Works when preparing mechanical drawings of our product. One of the biggest components of the project was planning and documentation, where I learned how to plan schedules and budget, how to step through the project's stages such as proposal, functional specs and design specs. I also learned the importance of good organization and regular update of the project binder and the benefits of keeping a personal project log book. During the course of the four months, I also benefited from working in a group environment, learning new skills and ideas from my group members. Working in the group was also a challenge, and I learned how to communicate effectively, find compromises, plan the work, and adjust to the changes with flexibility.

6. Conclusion

The MFC Testbench is a useful device for researchers looking to take a novel fuel cell design from the research labs to a commercial product. It allows them to perform reliable testing on a fuel cell without having to burden any large, expensive fuel cell testing equipment. At MFC Labs, we are pleased to say that we have achieved our goal of helping to speed up the commercialization of novel fuel cell technology.

7. Acknowledgements

We would like to thank the following people for their help and support during the past semester: Kevin Stanley, Lilian Fan, Dr. Eva Czyzewska, Weimin Qian, Lucky One, Amir Niroumand, Gary Houghton, and Deema Annyuk.

8. References

[1] MFC Labs. *Proposal for a Micro Fuel Cell Testbench.*

[2] MFC Labs. *Design Specifications for a Micro Fuel Cell Testbench.*