Shut down

1. Turn off heating elements. (It is okay to continue with the rest of the shutdown procedure while the heating elements cool.)
2. Turn the 3-way valves to "purge."
3. Close the hydrogen main valve.
4. Turn the H_2, 3-way valve to "feed" until the main gauge on the H_2 tank indicates zero pressure, and then back off the regulator valve completely.
5. Close valve on H_2 rotameter, H_2 exhaust valve and turn H_2, 3-way valve to "purge."
6. Repeat steps 3-5 for the oxygen.
7. Turn off pumps.
8. Close the nitrogen main valve. When the main gauge on the N_2 tank indicates zero pressure back off the regulator valve completely.
9. Make sure all valves are closed and 3-way valves are turned to "purge."

Could eliminate step 2 and revise 4 accordingly.

Test Stand Leak Testing Procedure

Only Nitrogen gas is used for the procedure.
Test the connections with Fuel Cell Stack installed

1. Conduct this procedure with guidelines set forth in the Test Stand Experiment General Safety Protocol, IOP FCP-010797.
2. Connect regulator to nitrogen tank.
3. Connect the nitrogen supply line to nitrogen "inlet." (as labeled)
4. Plug any unused ports. Close all valves. Turn 3-way valves to "purge" (as labeled.)
5. Open N_2 cylinder main valve.
6. Adjust N_2 regulator to 5 psi.
7. Note tank pressure and turn off main valve. *change to high pressure gauge*
8. Wait several minutes. If the tank pressure remains constant then go to step 12. If the pressure has dropped ~~noticeably~~ then there is a leak in the system. *define*
9. Turn the main tank valve on.
10. Brush or spray soapy water on each joint in the system. *→ only need to do this if you have a leak*
    - If bubbles form then there is a leak.
    - If a fitting is leaking then tighten until the leak stops. (WARNING; it is possible to over-tighten the fittings.)
    - If the fitting is damaged or cannot seal, then replace.
    - If the joint that is leaking is at the gasket or at a sealant type joint then take apart and apply more sealant (RTV silicone sealant.)
11. Return to step 7.
12. Close the N_2 cylinder main valve and release the pressure in the system by opening the H_2 and O_2 "exhaust" (as labeled) valves. When the pressure reaches zero close the "exhaust" valves. *need better labels like anode & cathode exhaust to avoid confusion w/ H_2 & O_2 feed systems*
13. Testing the fittings from the H_2 inlet to the H_2 3-way valve. If you have already done this step then continue with step 14.
    a) Disconnect the N_2 supply line from the N_2 inlet and connect to the H_2 inlet.
    b) Test by repeating steps 5-12
14. Testing the fittings from the O_2 inlet to the O_2 3-way valve.
    a) Disconnect the N_2 supply line from the N_2 or H_2 inlet and connect to the O_2 inlet.
    b) Test by repeating steps 5-12
15. Close all valves and turn the 3-way valves to "purge".

"Standard Operating Procedures" for Compressed Gas Cylinders

#1 PROCESS	Use of compressed gas cylinders.
#2 HAZARDOUS CHEMICALS/ CLASS OF HAZARDOUS CHEMICALS	Compress gas cylinders present hazards because of the volume of gas and the pressures involved. In addition, some gases also have hazards associated with: temperature, toxicity, flammability, corrosive, or reactive. Read the MSDS and/or SOP for each gas to be used.
#3 PERSONAL PROTECTIVE EQUIPMENT	Wear safety glasses. Gloves, face shield, lab coat or apron, and/or a respirator may be required for personal protection depending on the gas and use.
#4 ENGINEERING/ VENTILATION CONTROLS	Fittings and connections shall be properly test for leaks using soapy water "snoop" or other appropriate test method. Toxic, flammable and corrosive gases shall be stored and dispensed in a fume hood or ventilated gas cabinet.
#5 SPECIAL HANDLING PROCEDURES AND STORAGE REQUIREMENTS	Read the MSDS for the gases being used. All cylinders shall be properly identified. Cylinders must be secured in an upright position at all times whether in use, transit, or storage. Safety cap must be in place when not in use. Use the proper valves and regulators for the specific gas cylinder. Store and use cylinders in a well-ventilated area away from any ignition sources. Transport large cylinders only on an approved dolly or cart.
#6 SPILL AND ACCIDENT PROCEDURES	If wearing proper protective equipment, close the gas valve. For cylinders that continue to leak, contact EH&S (3-7388).
#7 WASTE DISPOSAL	Empty non-toxic or non-corrosive gas cylinders shall be marked "Empty" or "MT" and returned to the loading dock area designated for gas cylinders. Empty gas cylinders that had contained toxic or corrosive gases shall be marked "Empty" or "MT" and stored in a fume hood or well ventilated space for pickup by the supplier. Call EH&S (5-2848 or 3-7388) for further information.

Chemical Spill/Gas Leak Procedure

Chemical Spills

1. … → need to assess hazard and use spill kit if appropriate
2. Call EH&S (3-7388) or (9-911).

Gas Leaks

1. If the leak is at a fitting try tightening without over tightening.
2. If the leak persists then discontinue whatever process is being conducted using the appropriate shutdown procedure.
3. If the leak is occurring at a crack or break in a line or a fitting then discontinue whatever process is being conducted using the appropriate shutdown procedure.
4. If condition persist that may be a hazard to others call EH&S (3-7388) or (9-911).

(This procedure is still in the processes of being written and modified.) ✓

Test Stand Experiment General Safety Protocol

1. A copy of this Protocol and relevant SOPs and IOPs must be available at the site where the experiment is being conducted. List the phone numbers of the principle students conducting the experiment in the space provided in item 6.
2. Wear safety glasses while working in the lab with compressed gas and/or hot water.
3. Know the location of the fire extinguishers.
4. Never leave an experiment in progress unattended. At least two people must be in the building while conducting the experiment.
5. Have emergency numbers readily available.

Fire and medical	9-911
Chemical Spill/Leak	3-7262 or if no answer 9-911
Eric Stuve	543-0156 work 527-9869 home
Brian Flinn	616-9068 work 524-1535 home
Per Reinhall	543-5628 work 365-5914 home
Enter Principle Student(s) in Charge of Experiment	
Enter Principle Student(s) in Charge of Experiment	
Enter Principle Student(s) in Charge of Experiment	

6. Review the <u>Standard Operating Procedure for Gas Cylinders</u> SOP FCP-970709
   a. Before using compressed hydrogen read the <u>Hydrogen MSDS</u>.
   b. Before using compressed oxygen read the <u>Oxygen MSDS.</u>
   c. Before using compressed nitrogen read the <u>Nitrogen MSDS.</u>

7. The test stand should be properly grounded. Make sure that static charges cannot develop within the test stand. Any device (like a pump) that may produce a electrical discharge (spark) must be kept outside of the hood.
8. Make sure fume hood is working properly.
   - Turn on hood and lower door until a 2 " gap remains.
   - Airflow should be felt/observed moving through the gap into the hood.
9. Understand the Chemical Spill/Gas Leak Procedure IOP FCP-970801
10. Leak test the system using the Test Stand Leak Testing Procedure, IOP FCP-970705
11. Understand Emergency Shutdown Procedure. IOP FCP-970711

Membrane Conditioning: Experiment 1

Date __________

Individuals conducting the experiment: ______________________________

______________________________ ______________________________

______________________________ ______________________________

Purpose

The primary goal is to condition the membrane for maximum power output. Related to this goal is to develop the fastest method to condition membranes.

Secondary goals are to determine problems associated with the test stand, fuel cell stack, and the hydration systems so improvements may be made.

Discussions with experts and literature indicate that the membrane needs to be conditioned by operating under a load for about twelve hours before the membrane achieves maximum output. Maximum conditioning should occur at maximum power output. Over the initial conditioning period the maximum power output will vary with load. The four cells in the stack will remain connected in parallel during this experiment. Every half-hour the voltage will be measured across nine resistive loads (1,5,10,25,35,50,65,80,100 ohms) from which the power output of the fuel cell can be determined. Until the next measurement series the load which has the greatest power dissipation will be left connected to the fuel cell stack.

As with all experiments conducted on the test stand, fuel cell stack, and hydration systems, problems should be carefully recorded. If a solution is readily apparent it should also be noted.

Apparatus and Materials

- Test Stand
- Assembled fuel cell stack.
- Hot water pump, heats and pumps water through the heated bath.
- (2) Variac
- Peristaltic pump

- Hydrogen gas cylinder
- Oxygen gas cylinder
- Nitrogen gas cylinder
- De-ionized water
- Stack Experiment: membrane Preconditioning (FRM FCP-970804) and Stack Experiment: General (FRM FCP-970712) forms as needed.

Initial Values

Variable	Setting desired
N_2 Regulator, psi	20
H_2 Regulator, psi	
O_2 Regulator, psi	
Hot Water Bath Temperature, °C	85
H_2 (Heating tape) variac, %	100
O_2 (Heating tape)variac, %	100
H_2 Rotameter, %	
O_2 Rotameter, SCFM	
Load (resistance), ohms	1
H_2 Exhaust pressure, psi	
O_2 Exhaust pressure, psi	

Procedure

Date/time procedure completed	Initials	Procedure	Comments
		1. Read this entire procedure before conducting experiment.	
		2. Place test stand in hood with the front facing the room.	
		3. Place fuel cell stack in the bath container and connect the appropriate fittings.	
		4. Conduct Test Stand Leak Testing Procedure IOP FCP-970705.	

		5. Connect the H_2, O_2, and N_2 supply lines to their respective tanks of compressed gas.	
		6. Start the test using the start-up procedure found in Test Stand Start-up/shutdown Procedure IOP FCP-970704.	
		7. Adjust the exhaust valves until the initial exhaust pressures. ?	See note 1.
		8. Wire the fuel cell in parallel and connected to the 1-ohm load.	
		9. Start recording data on the Stack Experiment Membrane Conditioning form FRM FCP-970804.	The data will be collected every half-hour. See note 2.
		10. Calculate which load is producing the most power. Adjust the potentiometer so the fuel cell is producing the maximum power.	See note 3.
		11. Repeat steps 7 and 8 every half-hour; continue until the fuel cell has operated for 8 hours.	
		12. Conduct the General Stack experiment for one data set.	
		13. Finish the experiment with the shutdown procedure found in Test Stand Start-up/shutdown Procedure IOP FCP-970704.	
		14. Disconnect the supply lines from the inlet lines for the H_2, O_2, and N_2.	
		15. Before leaving make sure that the test stand is in a safe condition.	
		16. Prepare a graph showing volts versus current density	See note 4.

Not if another experiment will follow soon

<u>Notes</u>

1. To acquire the proper exhaust pressure the rotameters should be fully opened and the regulators adjusted greater than the exhaust pressure.
2. The data is recorded by the following method.
   - Record time
   - Record the values of rotameters, hydration temperatures, thermocouples 1-4
   - Record the voltage across the 1-ohm load. Change the load to 5-ohms and wait a few seconds until the voltage settles and record voltage. Repeat for the 10, 25, 35, 50, 65, 80, & 100-ohms loads.
3. From the voltages recorded from step 7 calculate the power produced by the fuel cell by the following equation:

   $$P = V^2 / R$$

   Adjust the load across the fuel cell to that which is dissipating the most power.
4. Calculate the size of the reaction area of the total stack (cells wired in parallel) in cm^2 and divide into the current output of the stack. The result will be the amount of current per cm^2 or current density. Then plot voltage versus current density.

Stack Experiment: Membrane Conditioning, Record Sheet

Date: ___/___/___ Start Time: _________ Finish Time: _________

Persons Conducting Experiment ____________________ ____________________

____________________ ____________________ ____________________

time						
H_2, Exhaust pressure, psi						
O_2, Exhaust pressure, psi						
H_2, Rotameter, %						
O_2, Rotameter, SCFM(air)						
H_2, Hydration temp., °C						
O_2, Hydration temp., °C						
Thermocouple 1, °C						
Thermocouple 2, °C						
Thermocouple 3, °C						
Thermocouple 4, °C						

Resistance load, ohms R	Volts V	Power V^2/R	Volts V	Power V^2/R	Volts V	Power V^2/R	Volts V	Power V^2/R	Volts V	Power V^2/R	Volts V	Power V^2/R
1												
5												
10												
25												
35												
50												
65												
80												
100												

Comments:

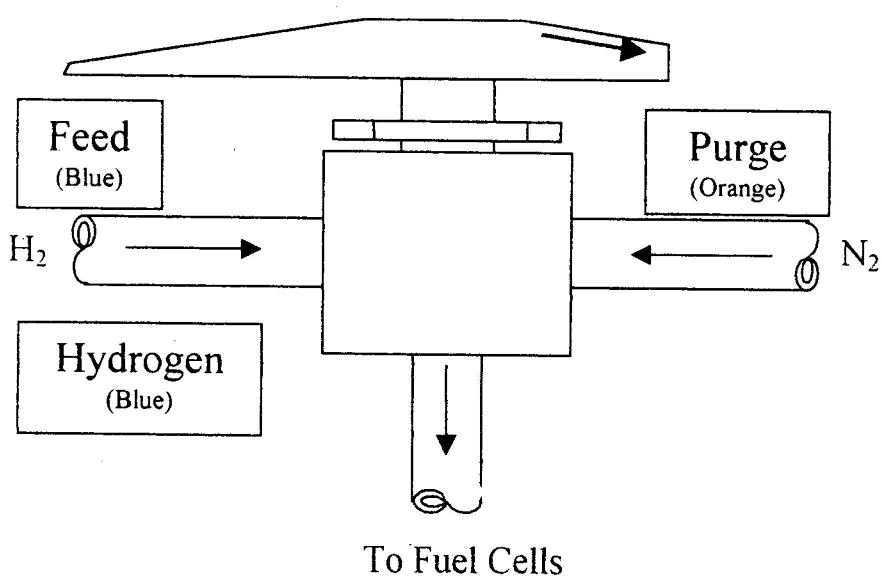
Standards for Labeling Experiments

Labeling, and definitions.

The copper lines, hoses, and other vessels that hold or transport gases or water will be labeled in the following way.

Color	Material being contained or transported
blue	Hydrogen being transported to stack.
yellow	Oxygen being transported to stack.
orange	Nitrogen
red	Hydrogen being transported from stack.
violet	Oxygen being transported to stack.
green	Water
white	

On the test stand the 3-way valves will be labeled with an orange label with the word "Purge" in the direction the handle points for allowing nitrogen to flow through the stack. The 3-way valve that control the hydrogen will be labeled with a blue label with the word "Hydrogen". A blue label with the word "feed" used when the valve is turned to allow hydrogen to flow. The 3-way valve that control the oxygen will be labeled with a yellow label with the word "Oxygen". A yellow label with the word "feed" used when the valve is turned to allow oxygen to flow. See figure below.



Definitions

Back off the regulator- Adjusting the regulator screw counter-clockwise until the flow of gas is zero (or the regulator valve is closed). Typically in a regulator adjusting the screw CW increases the flow and CCW reduces the flow.

Close- means a valve is turned off to stop or reduce flow, typically clockwise.

CW- clockwise

CCW- counter-clockwise

Open- means a valve is turned on to allow flow, typically counter-clockwise.

Main valve- is the valve on the gas cylinder that prior to the regulator.

Variac- is a variable AC voltage device.

RVC
MSDS
SOP
anode
cathode
Nafion
MEA

Standards for All Documents: Minimum Requirements

where is this from?

This standard applies to original documents being published by the Fuel Cell Project.

1. Titles lengths must not be more than two six-inch lines of 14 pt. boldfaced Times New Roman font (1).
2. Indexing, follow the example below (2):

DOC	FCP	-	970703		
Category			Indexing number		
IOP- Initial Procedure SOP- Standard Operating Procedure DOC- Documents i.e. reports, recommendations, unable to classify FRM- Forms i.e. data record sheets, equipment sign-out sheets, etc. DRW- Drawings, placards, labels EXP- Experiment. procedures	Fuel Cell Project	-	Year	Month	Most recent document produced during current month

3. The index number must appear on all pages of the document in the footer to the left of the page number on the right side of the page (3). Example DOC FCP-970703 (page #).
4. To reserve an indexing number go to the Overview section of the <u>Fuel Cell Resource</u> manual and sign in the reservation sign up sheet for the current month.
5. Revisions within the current month as the index number will not require a new number. Revisions made to published document in a later month will require a new indexing number.
6. Label the revision with the indexing number followed by the word revision inside of square brackets. The revision label will be placed before the current indexing number in the footer. Example: [DOC FCP-970703 revision] DOC FCP-970807 (page #).
7. Page numbers must appear all pages on the right side of the footer with the following format: page # / # of pages inside of parentheses (1). Example (1 / 2) means page 1 of 2 pages total.
8. All documents must use the following fonts (4):
   - Times New Roman
   - Arial
   - Courier New

what's the fourth?

9. At least two paper copies and one electronic copy of each document will be made.
   - One paper document (the latest revision) will be placed in the appropriate section of the Fuel Cell Resources manual.
   - The other paper copy (original and/or all revisions) placed in ascending order of the indexing number in the Documents section the current Annual Reports binder (5).
   - Save one copy with in a Microsoft Word or Rich Text format.

Notes

1. Titles may use a different font (see item 8); enter title in the desired font, change it to 14 point *Times New Roman* and boldface, if the title is more than two lines then it is too long.
2. Exception, Material Safety and Data Sheets, MSDS.
3. Exception, Quarter and Special Requested Reports follow the guidelines presented in DOC FCP-970706.
4. Exception, signs, drawings and labels may use other fonts so long that is easily readable.
5. Exception, place the Quarter Reports for each group will have their own section as labeled.

Standards for Quarter and Special Requested Research Reports

Special requested research reports are those presenting results from specific research requested by the project and will have a specified timeline. Must meet minimum standards see DOC FCP-970807.

1. Each report will have the following sections in the order listed:
   - ~~Title page~~
   - Cover letter (optional or as required)
   - Abstract or Summary (optional or as required)
   - Title page
   - Table of Contents
   - List of Tables
   - List of Figures
   - Glossary (optional)
   - Introduction
   - Topic of research (each topic will have its own discussion and conclusion before moving to the next topic.)
     - Discussion
     - Conclusions
   - Recommendations
   - References
   - Acknowledgments
   - Appendix A, B, etc.
2. Margins: left margin will be 1.25 inches, right margin 1-1.25 inches, top and bottom margins 1 inch.
3. Follow block paragraph style.
4. Line spacing will be double spacing.
5. Font size will be 12 point for the body of the report, abstract, and/or summary. Titles must be at least the same point size as the body of the report.
6. Page numbers on the top right corner beginning with the introduction ending with the last page of Acknowledgments.

7. Pages prior to the introduction with the exception of the first title, cover letter and Table of Contents pages will be number with i, ii, iii, iv,... starting with the title page.
8. Table titles will be placed above the table. Tables will be number sequentially if there is more than one table.
9. Figure titles will be placed below the figure and will be number sequentially if there is more than one figure.
10. Tables and figures, sources are placed below the table or figure; the location of the information used in the creation of tables and figures must clearly be identified (1).
11. The following may be placed in the Appendices:
    - Raw data collected from experiments (2)
    - Hand calculations
    - Hand drawn sketches
    - Reference information that will provide clarity to the report

    Other information will be placed in the body of the report
12. The indexing number will be placed at the bottom center of the second title page.

Notes:

1. If the source of information is raw data then the data must be clearly identified and placed in an Appendix. If the information is extrapolated from published sources then the sources will be referred to in the References section and the relevant pages from that source must be copied and placed in an Appendix. If the table or graph is a direct copy from another published source then the source must be referred to in the References section of the report.
2. Tables and figures may be considered raw data if they are not directly cited and are used to generate new tables and figures or if they only confirm information already presented in the report.

   Example: If several graphs show maxim~~ums~~a and you produce a table comparing the maximums, the graphs may be placed in an Appendix but the table will be placed in the body of the report. The table will cite the graphs as the source. The graphs cannot be cited elsewhere in the report or they must be included in the body of the report.

Procedure for Nafion Membrane Preparation and Ink Application

Date ____/____/____

Persons preparing membrane: ________________ ________________

________________ ________________

Procedure	Comments
1. Carefully read this procedure, the laboratory safety manual, and all appropriate MSDS's before you begin this process!	
2. Cut Nafion 117 membrane to fit the Lexan plates in excess approximately 0.25-inch for border. This allows for fluctuations in membrane size that can change with hydration and dehydration. should measure dry weight	
3. Under a hood, boil cut membrane in 3% by weight aqueous peroxide solution for 1 hour. This will clean membrane as well as saturate it with water. measure wet weight	
4. Boil membrane under hood in 1M sodium chloride solution for 1 hour.	
5. Remove membranes and submerge in a large beaker of deionized water and cover with aluminum foil.	

UNCLEAR

check out!

6. Measure Nafion solution from Aldrich, 5% solublized Nafion by weight and 10% platinum by weight on carbon black Vulcan XC 72-R from Electrosysthesis Company in a 1:3 ratio by mass. This should be done in a hood while wearing glove and protective eyewear and making sure to have a bottle of deionized water close by. — Good	
7. Add Nafion solution to the platinum catalyst in glass beaker.	
8. With a dropper, carefully add isopropanol and mix with a glass-stirring rod until mixture becomes a slurry and more liquid in appearance.	
9. With a dropper, add glycerol and mix with a glass-stirring rod. You want to do this process slowly as isopropanol will dilute the mixture and glycerol will thicken it. The desired consistency should still be a thick slurry. Once proper consistency is reach with minimal clumps of catalyst, cover beaker with parafilm and sonicate for 15 minutes.	

10. Add 25% to 50% excess of Tetrabutylammonium Hydroxide solution (TBOH), 1M from Aldrich to the Nafion and platinum catalyst mixture. This step is needs further investigation as a 1:3 or 1:1 molar ratio needed to be calculated, but additional information needs to known. Until the necessary information is found a 1:1 ratio will be used, that is to say that TBOH must react with every sulfonate group in the Nafion solution. See sample calculations (Appendix C, Fuel Cell Project-Quarter Report, Summer 1997) for amount of TBOH determined. Be sure that this is done in a hood with gloves and protective eyewear.	
11. Mix solution with a glass stirring-rod to help remove any clumps in the solution. Cover with parafilm and sonicate for 15 minutes.	
12. Remove beaker from the sonicator and check to see if the mixture has the consistency of ink. This mixture will eventually go into an airbrush for application on the membrane so it needs to thin and well mixed to avoid clogging up the apparatus. At this point you will if the mixture is at desired consistency then go on to step 13. If not, add isopropanol if mixture is too thick or glycerol if mixture is too thin. Usually, the thinner the liquid, the easier the airbrush step of the membrane preparation will be.	

13. Set up the airbrush apparatus in the hood. It is recommended at this time to wear a mask that will cover your mouth and nose from inhaling the atomized solution.	
14. Using gloves so as not to corrupt the clean membranes, remove the membranes from the deionized water. Let as much of the water run off as possible because excess water on the membrane will make the application of the ink difficult.	
15. Place the semi-dry membrane into the Lexan mold and secure with two C-clamps. The C-clamps should be placed adjacent to each other along either edge of the Lexan. The C-clamps can be used as a make shift easle which will help to keep the membrane/mold steady as you airbrush.	
16. Use the airbrush or a blowdryer to remove any excess water. Be sure to pay attention to water that gets trapped between the edges of the lexan and the membrane so the ink won't run under the mold and make one continuos inkpad. sp get membrane weight	
17. Once water is sufficiently removed from the membrane, fill ink in the airbrush cup, cover, and begin to apply ink liberally to the membrane using the lexan mold like a stencil. Apply to one side of the membrane until completely covered then the otherside. membrane weight	

Need to use N_2 in the airbrush

51

18. When airbrushing is finished, let membrane dry and clean airbrush with isopropanol immediately. Be sure to fill the airbrush cup with isopropanol and let fluid run through the apparatus until it is completely clean. If this is not done properly the airbrush can be clogged and damaged. Benson Hall	
19. In room 215, heat the hydraulic press to 300 C.	
20. Remove membrane from the lexan mold and place in between two Teflon sheets and press for five minutes at 30 ATM and 300 C.	
21. Remove membrane and boil in 0.5 M Sulfuric Acid solution for 2 hour under a hood.	
22. Place membranes in deionized water and boil for two hours.	
23. Allow the water to cool. The membrane is ready for prototype. membrane weight	

Appendix B

Experiment Raw Data

Contents

- *Membrane Conditioning: Experiment 1* conducted on 8/15/97
- *Membrane Conditioning: Experiment 1* conducted on 8/16/97
- *Membrane Conditioning: Experiment 1* conducted on 8/18/97
- Raw data from *Membrane Conditioning: Experiment 1* conducted on 8/16/97 reproduced with Microsoft Excel and calculated Current, Current Density, and Power.

Membrane Conditioning: Experiment 1

Date 8/15/97

Individuals conducting the experiment: Kevin Houger

Karen Fleckner

Stopped test at 2:00 pm 8/15/97 on ~~item~~ procedure # 6

Purpose

The primary goal is to condition the membrane for maximum power output. Related to this goal is to develop the fastest method to condition membranes.

Secondary goals are to determine problems associated with the test stand, fuel cell stack, and the hydration systems so improvements may be made.

Discussions with experts and literature indicate that the membrane needs to be conditioned by operating under a load for about twelve hours before the membrane achieves maximum output. Maximum conditioning should occur at maximum power output. Over the initial conditioning period the maximum power output will vary with load. The four cells in the stack will remain connected in parallel during this experiment. Every half-hour the voltage will be measured across nine resistive loads (1,5,10,25,35,50,65,80,100 ohms) from which the power output of the fuel cell can be determined. Until the next measurement series the load which has the greatest power dissipation will be left connected to the fuel cell stack.

As with all experiments conducted on the test stand, fuel cell stack, and hydration systems, problems should be carefully recorded. If a solution is readily apparent it should also be noted.

Apparatus and Materials

- Test Stand
- Assembled fuel cell stack.
- Hot water pump, heats and pumps water through the heated bath.
- (2) Variac
- Peristaltic pump

- Hydrogen gas cylinder
- Oxygen gas cylinder
- Nitrogen gas cylinder
- De-ionized water
- Stack Experiment: membrane ~~Pre~~conditioning (FRM FCP-970804) and Stack Experiment: General (FRM FCP-970712) forms as needed.

Initial Values

Variable	Setting desired
N_2 Regulator, psi	20
H_2 Regulator, psi	5 +
O_2 Regulator, psi	7.5 +
Hot Water Bath Temperature, °C	85
H_2 (Heating tape) variac, %	100 (140 volts)
O_2 (Heating tape)variac, %	100 "
H_2 Rotameter, %	100
O_2 Rotameter, SCFM	open fully
Load (resistance), ohms	1
H_2 Exhaust pressure, psi	5
O_2 Exhaust pressure, psi	7.5

Procedure

Date/time procedure completed	Initials	Procedure	Comments
8/3/97	KRH	1. Read this entire procedure before conducting experiment.	Still being written [illegible]
4/1/97	KRH	2. Place test stand in hood with the front facing the room.	
5/15/97 1:30 PM	KRH	3. Place fuel cell stack in the bath container and connect the appropriate fittings.	
1:30 pm	KRH	4. Conduct Test Stand Leak Testing Procedure IOP FCP-970705.	

8/14/97	KRH	5. Connect the H_2, O_2, and N_2 supply lines to their respective tanks of compressed gas.	[illegible]
8/15/97 2:00 pm	KRH	6. Start the test using the start-up procedure found in Test Stand Start-up/shutdown Procedure IOP FCP-970704.	Stopped test will try on Saturday
		7. Adjust the exhaust valves until the initial exhaust pressures.	See note 1.
		8. Wire the fuel cell in parallel and connected to the 1-ohm load.	
		9. Start recording data on the Stack Experiment Membrane Conditioning form FRM FCP-970804.	The data will be collected every half-hour. See note 2.
		10. Calculate which load is producing the most power. Adjust the potentiometer so the fuel cell is producing the maximum power.	See note 3.
		11. Repeat steps 7 and 8 every half-hour; continue until the fuel cell has operated for 8 hours.	
		12. Conduct the General Stack experiment for one data set.	
		13. Finish the experiment with the shutdown procedure found in Test Stand Start-up/shutdown Procedure IOP FCP-970704.	
		14. Disconnect the supply lines from the inlet lines for the H_2, O_2, and N_2.	
		15. Before leaving make sure that the test stand is in a safe condition.	
		16. Prepare a graph showing volts versus current density	See note 4.

Notes

1. To acquire the proper exhaust pressure the rotameters should be fully opened and the regulators adjusted greater than the exhaust pressure.
2. The data is recorded by the following method.
    - Record time
    - Record the values of rotameters, hydration temperatures, thermocouples 1-4
    - Record the voltage across the 1-ohm load. Change the load to 5-ohms and wait a few seconds until the voltage settles and record voltage. Repeat for the 10, 25, 35, 50, 65, 80, & 100-ohms loads.
3. From the voltages recorded from step 7 calculate the power produced by the fuel cell by the following equation:

$$P = V^2 / R$$

Adjust the load across the fuel cell to that which is dissipating the most power.

4. Calculate the size of the reaction area of the total stack (cells wired in parallel) in cm^2 and divide into the current output of the stack. The result will be the amount of current per cm^2 or current density. Then plot voltage versus current density.

Membrane Conditioning: Experiment 1

Date ~~6/30~~ 8/16/97

Individuals conducting the experiment: Kevin Houger

Karen Fleckner

Purpose

The primary goal is to condition the membrane for maximum power output. Related to this goal is to develop the fastest method to condition membranes.

Secondary goals are to determine problems associated with the test stand, fuel cell stack, and the hydration systems so improvements may be made.

Discussions with experts and literature indicate that the membrane needs to be conditioned by operating under a load for about twelve hours before the membrane achieves maximum output. Maximum conditioning should occur at maximum power output. Over the initial conditioning period the maximum power output will vary with load. The four cells in the stack will remain connected in parallel during this experiment. Every half-hour the voltage will be measured across nine resistive loads (1,5,10,25,35,50,65,80,100 ohms) from which the power output of the fuel cell can be determined. Until the next measurement series the load which has the greatest power dissipation will be left connected to the fuel cell stack.

As with all experiments conducted on the test stand, fuel cell stack, and hydration systems, problems should be carefully recorded. If a solution is readily apparent it should also be noted.

Apparatus and Materials

- Test Stand
- Assembled fuel cell stack.
- Hot water pump, heats and pumps water through the heated bath.
- (2) Variac
- Peristaltic pump

- Hydrogen gas cylinder
- Oxygen gas cylinder
- Nitrogen gas cylinder
- De-ionized water
- Stack Experiment: membrane Preconditioning (FRM FCP-970804) and Stack Experiment: General (FRM FCP-970712) forms as needed.

Initial Values

Variable	Setting desired
N_2 Regulator, psi	20 → 15
H_2 Regulator, psi	5 +
O_2 Regulator, psi	7.5 +
Hot Water Bath Temperature, °C	85
H_2 (Heating tape) variac, %	100
O_2 (Heating tape)variac, %	100
H_2 Rotameter, %	100
O_2 Rotameter, SCFM	Open Fully
Load (resistance), ohms	1
H_2 Exhaust pressure, psi	5
O_2 Exhaust pressure, psi	7.5

Procedure

Date/time procedure completed	Initials	Procedure	Comments
8/15/97	KRH	1. Read this entire procedure before conducting experiment.	
"	"	2. Place test stand in hood with the front facing the room.	
"	"	3. Place fuel cell stack in the bath container and connect the appropriate fittings.	
"	"	4. Conduct Test Stand Leak Testing Procedure IOP FCP-970705.	Nitrogen Reg. set ~~at 15psi~~ at 15 psi