| | | | |
|---|---|---|---|
| 4/15/97 | KRH | 5. Connect the $H_2$; $O_2$, and $N_2$ supply lines to their respective tanks of compressed gas. | |
| 4/16/97<br>"<br>10:41 am | KRH<br>"<br>KF | 6. Start the test using the start-up procedure found in Test Stand Start-up/shutdown Procedure IOP FCP-970704. | |
| 10:41 am | KRH<br>KF | 7. Adjust the exhaust valves until the initial exhaust pressures. | See note 1. |
| 10:41 am | KF | 8. Wire the fuel cell in parallel and connected to the 1-ohm load. | |
| 11:00 | | 9. Start recording data on the <u>Stack Experiment Membrane Conditioning</u> 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. | |
| ~~3:14~~<br>3:17 | KF | 13. Finish the experiment with the shutdown procedure found in Test Stand Start-up/shutdown Procedure IOP FCP-970704. | |
| 3:25 | KRH | 14. Disconnect the supply lines from the inlet lines for the $H_2$, $O_2$, and $N_2$. | OK to leave connect if experiment will be cont. on another day Yes / for time |
| | | 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. |

4/16

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.

# Stack Experiment: Membrane Preconditioning

Date: 8/16/97 Start Time: 11:00 am Finish Time: 12:00 pm

Persons Conducting Experiment Kevin Honger

Karen Fleckner

| | 1 | 2 | 3 |
|---|---|---|---|
| time | 11:00 am | 11:30 am | 12:00 |
| $H_2$, pressure, psi Exhaust | 5 | 5.1 | 5.0 |
| $O_2$, pressure, psi Exhaust | 8 | 8.1 | 7.6 |
| $H_2$, Rotameter, % | ≈ 55 | 50 | 65 |
| $O_2$, Rotameter, SCFM(air) | 5 | 2.5 | 6 |
| $H_2$, Hydration temp., °C | 72.6 | 75.7 | 74.5 |
| $O_2$, Hydration temp., °C | ~~69.0~~ 70 | 73.6 | 72.0 |
| Thermocouple 1, °C $H_2$ Exhaust | 64.0 | 68.3 | 69.4 |
| Thermocouple 2, °C $O_2$ Exhaust | 64.2 | 69.0 | 73.5 |
| Thermocouple 3, °C Water Bath | 76.3 | 81.5 | 80.8 |
| Thermocouple 4, °C Air Temp in Hood | 22.8 | 22.8 | 22.8 |

| Resistance load, ohms R | Volts V | Power $V^2/R$ $10\times^{-3}$ | Volts V | Power $V^2/R$ $10\times^{-3}$ | Volts V | Power $V^2/R$ $10\times^{-3}$ |
|---|---|---|---|---|---|---|
| 1 | 0.037 | 1.369 | 0.038 | 1.444 | 0.035 | 1.225 |
| 5 | 0.177 | 6.266 | 0.153 | 4.682 | 0.141 | 3.976 |
| 10 | 0.277 | 7.673 | 0.247 | 6.101 | 0.233 | 5.429 |
| 25 | 0.430 | 7.396 | 0.400 | 6.400 | 0.383 | 5.868 |
| 35 | 0.482 | 6.638 | 0.456 | 5.941 | 0.437 | 5.436 |
| 50 | 0.536 | 5.746 | 0.512 | 5.243 | 0.496 | 4.920 |
| 65 | 0.569 | 4.981 | 0.548 | 4.620 | 0.534 | 4.387 |
| 80 | 0.592 | 4.381 | 0.573 | 4.104 | 0.562 | 3.948 |
| 100 | 0.617 | 3.807 | 0.600 | 3.600 | 0.590 | 3.481 |

Comments: Note overall power drop from reading 1 to 2.

After measurement 2: Adjusted ~~Changed~~ $H_2$ back to 5 psi flow at 62%
$O_2$ " " 7.5 flow at 6 SCFM

- Again: a drop from reading 2 to 3.

Poor connection at stack (adjust screws)
cells 2 & 3 open circuit voltage ≈ 0.45–0.5 volts
" 1 & 4 " " " ≈ 0.815
after adjusting screws on 2 & 3 all cell were at ≈ 0.815 volt oc.
add $H_2O$ to $O_2$ Hydration at 12:10 pm

# Stack Experiment: Membrane Preconditioning

Date: 8/16/97 Start Time: 12:30pm Finish Time: 2:00

Persons Conducting Experiment: Kevin Houger, Karen Fleckner

| Reading | 4 | 5 | 6 |
|---|---|---|---|
| time | 12:30 pm | 1:30 | 200 |
| $H_2$, pressure, psi | 5 | 5 | 5 |
| $O_2$, pressure, psi | 7.5 | 7.5 | 7.5 |
| $H_2$, Rotameter, % | 65 | 65 | 65 |
| $O_2$, Rotameter, SCFM(air) | 6.5 | 6 | 6 |
| $H_2$, Hydration temp., °C | 73.6 | 72.5 | 73.9 |
| $O_2$, Hydration temp., °C | 67.8 | 66.4 | 67.2 |
| Thermocouple 1, °C | 72.6 | 67.4 | 66.8 |
| Thermocouple 2, °C | 68.1 | 66.1 | 66.9 |
| Thermocouple 3, °C | 82.6 | 74.8 | 78.7 |
| Thermocouple 4, °C | 22.8 | 22.5 | 22.6 |

| Resistance load, ohms R | Volts V | Power $V^2/R$ $10^{-3}$ | Volts V | Power $V^2/R$ $10\times^{-3}$ | Volts V | Power $V^2/R$ $10\times^{-3}$ |
|---|---|---|---|---|---|---|
| 1 | 0.042 | 1.764 | 0.051 | 2.601 | 0.052 | 2.704 |
| 5 | 0.188 | 7.069 | 0.212 | 8.989 | 0.220 | 9.680 |
| 10 | 0.280 | 7.840 | 0.320 | 10.240 | 0.325 | 10.563 |
| 25 | 0.436 | 7.604 | 0.464 | 8.612 | 0.472 | 8.911 |
| 35 | 0.482 | 6.638 | 0.514 | 7.431 | 0.516 | 7.607 |
| 50 | 0.540 | 5.832 | 0.562 | 6.317 | 0.561 | 6.294 |
| 65 | 0.570 | 4.998 | 0.593 | 5.410 | 0.590 | 5.355 |
| 80 | 0.596 | 4.440 | 0.616 | 4.743 | 0.612 | 4.682 |
| 100 | 0.617 | 3.807 | 0.638 | 4.070 | 0.635 | 4.032 |

Comments: – power increase from reading 3 to 4 – after contact (electrical) were adjusted.

Skipped 1:00 measurement – $O_2$ Hydration water line needed fixed and DI water added

– significant increase in power out – 10.240

## Stack Experiment: Membrane Preconditioning

Date: 8/16/97 Start Time: 2:33 Finish Time: 3:00

Persons Conducting Experiment

| time | 2:30 | 2:40 | 3:00 |
|---|---|---|---|
| $H_2$, pressure, psi | 5 | 5 | 5 |
| $O_2$, pressure, psi | 7.6 | 7.8 | 7.5 |
| $H_2$, Rotameter, % | 65 | 65 | 65 |
| $O_2$, Rotameter, SCFM(air) | 6 | 6 | 6 |
| $H_2$, Hydration temp., °C | 75.3 | 74.5 | 75.1 |
| $O_2$, Hydration temp., °C | 70.0 | 69.2 | 67.0 |
| Thermocouple 1, °C | 73.9 | 75.6 | 75.9 |
| Thermocouple 2, °C | 69.4 | 70.0 | 70.7 |
| Thermocouple 3, °C | 83.2 | 83.8 | 84.0 |
| Thermocouple 4, °C | 22.7 | 22.7 | 22.6 |

| Resistance load, ohms R | Volts V | Power $V^2/R$ $10^{-3}$ | Volts V | Power $V^2/R$ $10^{-3}$ | Volts V | Power $V^2/R$ $10^{-3}$ |
|---|---|---|---|---|---|---|
| 1 | 0.059 | 3.481 | 0.069 | 4.761 | 0.063 | 3.699 |
| 5 | 0.211 | 8.904 | 0.212 | 9.00 | 0.212 | 9.00 |
| 10 | 0.315 | 9.923 | 0.316 | 9.99 | 0.316 | 9.986 |
| 25 | 0.463 | 8.575 | 0.463 | 8.575 | 0.465 | 8.649 |
| 35 | 0.515 | 7.578 | 0.512 | 7.490 | 0.515 | 7.578 |
| 50 | 0.560 | 6.272 | 0.556 | 6.183 | 0.558 | 6.227 |
| 65 | 0.593 | 5.410 | 0.586 | 5.283 | 0.587 | 5.301 |
| 80 | 0.616 | 4.743 | 0.610 | 4.651 | 0.611 | 4.667 |
| 100 | 0.636 | 4.045 | 0.630 | 3.970 | 0.632 | 3.994 |

Comments: Redo on 2:30 reading to verify power drops.

with ~~cells in series & 10 ohm load.~~ full cell

# Membrane Conditioning: Experiment 1

Date 8/18/97

Individuals conducting the experiment: Kevin Hauger

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 |
| $H_2$ 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 | | 1. Read this entire procedure before conducting experiment. | |
| | | 2. Place test stand in hood with the front facing the room. | 8/16/97 From Experiment |
| | | 3. Place fuel cell stack in the bath container and connect the appropriate fittings. | |
| | | 4. Conduct Test Stand Leak Testing Procedure IOP FCP-970705. | |

| | | | |
|---|---|---|---|
| 8/15/97 | | 5. Connect the $H_2$, $O_2$, and $N_2$ supply lines to their respective tanks of compressed gas. | |
| 5/16/97 End 12:20 | | 6. Start the test using the start-up procedure found in Test Stand Start-up/shutdown Procedure IOP FCP-970704. | [illegible] |
| | | 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 <u>Stack Experiment Membrane Conditioning</u> 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.

Cell Area cm^2 55.44000

Membrane Conditioning:Experiment 08/16/97

11:00am

| resistance | volts | current | current density | power |
|---|---|---|---|---|
| 1 | 0.037 | 0.03700 | 6.674E-04 | 1.369E-03 |
| 5 | 0.177 | 0.03540 | 6.385E-04 | 6.266E-03 |
| 10 | 0.277 | 0.02770 | 4.996E-04 | 7.673E-03 |
| 25 | 0.430 | 0.01720 | 3.102E-04 | 7.396E-03 |
| 35 | 0.482 | 0.01377 | 2.484E-04 | 6.638E-03 |
| 50 | 0.536 | 0.01072 | 1.934E-04 | 5.746E-03 |
| 65 | 0.569 | 0.00875 | 1.579E-04 | 4.981E-03 |
| 80 | 0.592 | 0.00740 | 1.335E-04 | 4.381E-03 |
| 100 | 0.617 | 0.00617 | 1.113E-04 | 3.807E-03 |

11:30am

| resistance | volts | current | current density | power |
|---|---|---|---|---|
| 1 | 0.038 | 0.03800 | 6.854E-04 | 1.444E-03 |
| 5 | 0.153 | 0.03060 | 5.519E-04 | 4.682E-03 |
| 10 | 0.247 | 0.02470 | 4.455E-04 | 6.101E-03 |
| 25 | 0.400 | 0.01600 | 2.886E-04 | 6.400E-03 |
| 35 | 0.456 | 0.01303 | 2.350E-04 | 5.941E-03 |
| 50 | 0.512 | 0.01024 | 1.847E-04 | 5.243E-03 |
| 65 | 0.548 | 0.00843 | 1.521E-04 | 4.620E-03 |
| 80 | 0.573 | 0.00716 | 1.292E-04 | 4.104E-03 |
| 100 | 0.600 | 0.00600 | 1.082E-04 | 3.600E-03 |

12:00pm

| resistance | volts | current | current density | power |
|---|---|---|---|---|
| 1 | 0.035 | 0.03500 | 6.313E-04 | 1.225E-03 |
| 5 | 0.141 | 0.02820 | 5.087E-04 | 3.976E-03 |
| 10 | 0.233 | 0.02330 | 4.203E-04 | 5.429E-03 |
| 25 | 0.383 | 0.01532 | 2.763E-04 | 5.868E-03 |
| 35 | 0.437 | 0.01249 | 2.252E-04 | 5.456E-03 |
| 50 | 0.496 | 0.00992 | 1.789E-04 | 4.920E-03 |
| 65 | 0.534 | 0.00822 | 1.482E-04 | 4.387E-03 |
| 80 | 0.562 | 0.00703 | 1.267E-04 | 3.948E-03 |
| 100 | 0.590 | 0.00590 | 1.064E-04 | 3.481E-03 |

12:30pm

| resistance | volts | current | current density | power |
|---|---|---|---|---|
| 1 | 0.042 | 0.04200 | 7.576E-04 | 1.764E-03 |
| 5 | 0.188 | 0.03760 | 6.782E-04 | 7.069E-03 |
| 10 | 0.280 | 0.02800 | 5.051E-04 | 7.840E-03 |
| 25 | 0.436 | 0.01744 | 3.146E-04 | 7.604E-03 |
| 35 | 0.482 | 0.01377 | 2.484E-04 | 6.638E-03 |
| 50 | 0.540 | 0.01080 | 1.948E-04 | 5.832E-03 |
| 65 | 0.570 | 0.00877 | 1.582E-04 | 4.998E-03 |
| 80 | 0.596 | 0.00745 | 1.344E-04 | 4.440E-03 |
| 100 | 0.617 | 0.00617 | 1.113E-04 | 3.807E-03 |

1:30pm

| resistance | volts | current | current density | power |
|---|---|---|---|---|
| 1 | 0.051 | 0.05100 | 9.199E-04 | 2.601E-03 |
| 5 | 0.212 | 0.04240 | 7.648E-04 | 8.989E-03 |
| 10 | 0.320 | 0.03200 | 5.772E-04 | 1.024E-02 |
| 25 | 0.464 | 0.01856 | 3.348E-04 | 8.612E-03 |
| 35 | 0.514 | 0.01469 | 2.649E-04 | 7.548E-03 |
| 50 | 0.562 | 0.01124 | 2.027E-04 | 6.317E-03 |
| 65 | 0.593 | 0.00912 | 1.646E-04 | 5.410E-03 |
| 80 | 0.616 | 0.00770 | 1.389E-04 | 4.743E-03 |
| 100 | 0.638 | 0.00638 | 1.151E-04 | 4.070E-03 |

2:00pm

| resistance | volts | current | current density | power |
|---|---|---|---|---|
| 1 | 0.052 | 0.05200 | 9.380E-04 | 2.704E-03 |
| 5 | 0.220 | 0.04400 | 7.937E-04 | 9.680E-03 |
| 10 | 0.325 | 0.03250 | 5.862E-04 | 1.056E-02 |
| 25 | 0.472 | 0.01888 | 3.405E-04 | 8.911E-03 |
| 35 | 0.516 | 0.01474 | 2.659E-04 | 7.607E-03 |
| 50 | 0.561 | 0.01122 | 2.024E-04 | 6.294E-03 |
| 65 | 0.561 | 0.00863 | 1.557E-04 | 4.842E-03 |
| 80 | 0.590 | 0.00738 | 1.330E-04 | 4.351E-03 |
| 100 | 0.612 | 0.00612 | 1.104E-04 | 3.745E-03 |

2:30pm

| resistance | volts | current | current density | power |
|---|---|---|---|---|
| 1 | 0.059 | 0.05900 | 1.064E-03 | 3.481E-03 |
| 5 | 0.211 | 0.04220 | 7.612E-04 | 8.904E-03 |
| 10 | 0.315 | 0.03150 | 5.682E-04 | 9.923E-03 |
| 25 | 0.463 | 0.01852 | 3.341E-04 | 8.575E-03 |
| 35 | 0.515 | 0.01471 | 2.654E-04 | 7.578E-03 |
| 50 | 0.560 | 0.01120 | 2.020E-04 | 6.272E-03 |
| 65 | 0.593 | 0.00912 | 1.646E-04 | 5.410E-03 |
| 80 | 0.616 | 0.00770 | 1.389E-04 | 4.743E-03 |
| 100 | 0.636 | 0.00636 | 1.147E-04 | 4.045E-03 |

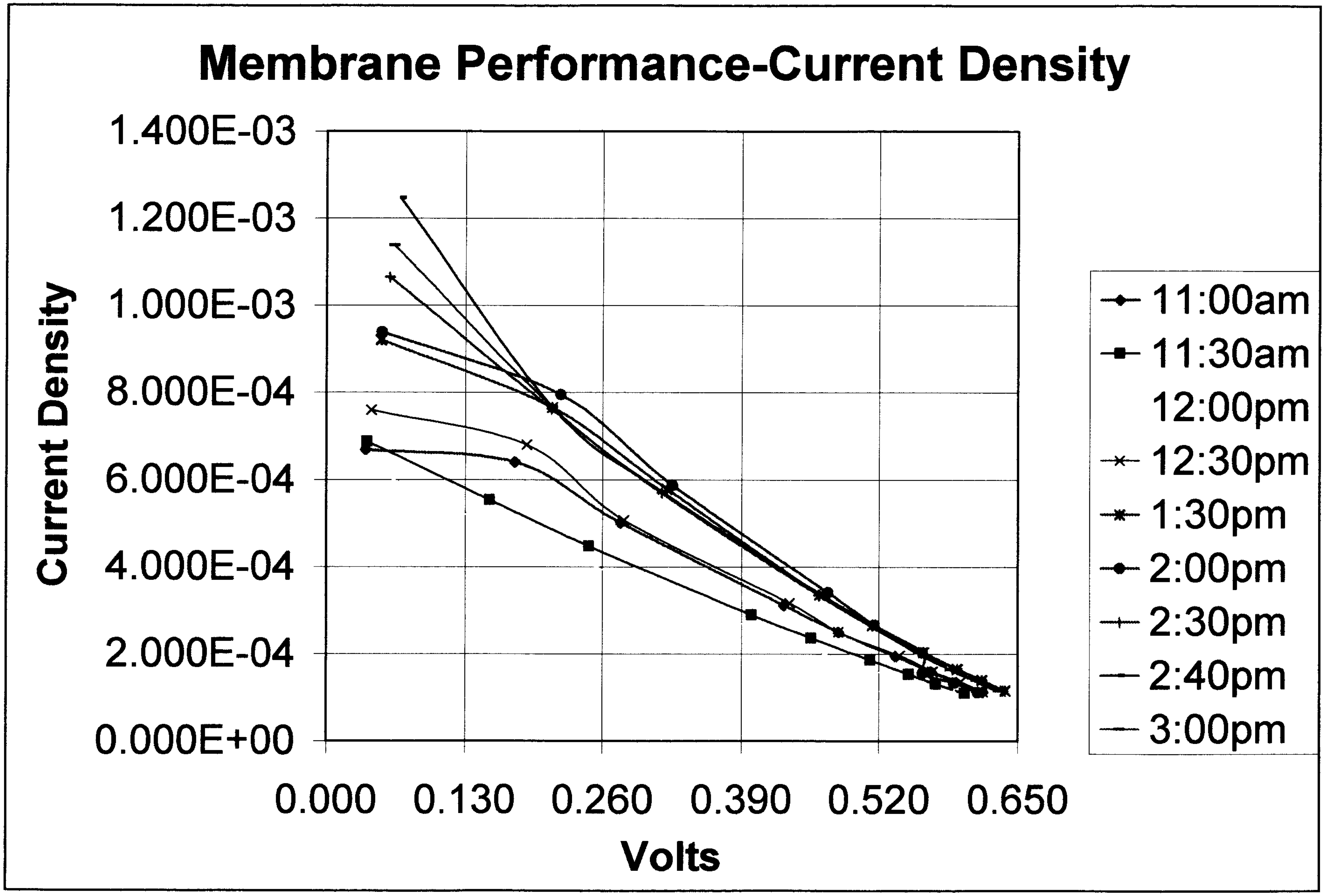
2:40pm

| resistance | volts | current | current density | power |
|---|---|---|---|---|
| 1 | 0.069 | 0.06900 | 1.245E-03 | 4.761E-03 |
| 5 | 0.212 | 0.04240 | 7.648E-04 | 8.989E-03 |
| 10 | 0.316 | 0.03160 | 5.700E-04 | 9.986E-03 |
| 25 | 0.463 | 0.01852 | 3.341E-04 | 8.575E-03 |
| 35 | 0.512 | 0.01463 | 2.639E-04 | 7.490E-03 |
| 50 | 0.556 | 0.01112 | 2.006E-04 | 6.183E-03 |
| 65 | 0.586 | 0.00902 | 1.626E-04 | 5.283E-03 |
| 80 | 0.610 | 0.00763 | 1.375E-04 | 4.651E-03 |

| | | | | |
|---|---|---|---|---|
| 100 | 0.630 | 0.00630 | 1.136E-04 | 3.969E-03 |

3:00pm

| resistance | volts | current | current density | power |
|---|---|---|---|---|
| 1 | 0.063 | 0.06300 | 1.136E-03 | 3.969E-03 |
| 5 | 0.212 | 0.04240 | 7.648E-04 | 8.989E-03 |
| 10 | 0.316 | 0.03160 | 5.700E-04 | 9.986E-03 |
| 25 | 0.465 | 0.01860 | 3.355E-04 | 8.649E-03 |
| 35 | 0.515 | 0.01471 | 2.654E-04 | 7.578E-03 |
| 50 | 0.558 | 0.01116 | 2.013E-04 | 6.227E-03 |
| 65 | 0.587 | 0.00903 | 1.629E-04 | 5.301E-03 |
| 80 | 0.611 | 0.00764 | 1.378E-04 | 4.667E-03 |
| 100 | 0.632 | 0.00632 | 1.140E-04 | 3.994E-03 |



Membrane Performance-Current Density
Current Density
1.400E-03
1.200E-03
1.000E-03
8.000E-04
6.000E-04
4.000E-04
2.000E-04
0.000E+00
0.000
0.130
0.260
0.390
0.520
0.650
Volts
11:00am
11:30am
12:00pm
12:30pm
1:30pm
2:00pm
2:30pm
2:40pm
3:00pm

## Appendix C

Hand Calculations

Contents

# Calculations of Flow Rates for Hydrogen and Oxygen

GIVEN: $1\ AMP/cm^2$
$0.6\ VOLTS$

POWER $\wp$: $P = VI = (0.6)(1) = 0.6\ WATTS/cm^2 = 6\times10^{-4}\ \frac{KJ}{s\cdot cm^2}$

$$\dot{n} = \frac{POWER\ \wp}{\Delta G} = \frac{-6\times10^{-4}\ \frac{KJ}{s\cdot cm^2}}{-237\ \frac{KJ}{mol\ H_2}} = 2.53\times10^{-6}\ \frac{mol\ H_2}{s\cdot cm^2}$$

FOR $H_2$:

$$\dot{V} = \frac{\dot{n}RT}{P} = \left(2.53\times10^{-6}\ \frac{mol\ H_2}{s\cdot cm^2}\right)\left(8.314\ \frac{J\ Pa\ m^3}{J\ mol\cdot K}\right)^{*}\left(293.15K\right)\left(\frac{1}{101300\ Pa}\right) = 6.09\times10^{-8}\ \frac{m^3\ H_2}{s\cdot cm^2\ electro\text{-}cataly.}$$

$\star$ $PV = WORK = E = J = Pa\cdot m^3$

CONVERT $\dot{V}$ TO SCFM:

$$\dot{V} = \left(6.09\times10^{-8}\ \frac{m^3 H_2}{s\cdot cm^2\ electro\cdot cat.}\right)\left(\frac{1\ ft}{0.3048\ m}\right)^3\left(\frac{60\ s}{1\ min}\right)\left(\frac{30.48\ cm}{1\ ft}\right)^2$$

$$\dot{V} = 0.11995\ \frac{ft^3\ H_2}{min\ ft^2\ electro\cdot cat.}$$ ✓

FOR $O_2$:

$\frac{1}{2} O_2 = 1\ mol\ H_2$

$\therefore$

$$\dot{V} = (.5)\left(0.11995\ \frac{ft^3\ H_2}{min\ ft^2\ electro\cdot cat}\right)$$

$$\dot{V} = 59.975\times10^{-3}\ \frac{ft^3\ O_2}{min\ ft^2\ electro\cdot cat}$$ ✓

## Calculations for Amount of TBOH Used

Given: for a 1-1 molar ratio of Nafion 5% by wt. solution and TBOH.

Amount of Nafion solution weighed = 1.33g

∴ Amount of Nafion = (0.05)(1.33) g = 0.0665 g of Nafion

Molecular wt of Nafion = 1100 g Nafion

∴ $0.0665 \text{ g Nafion} \times \left(\frac{1 \text{ mol Nafion}}{1100 \text{ g}}\right) = 6.045 \times 10^{-5} \text{ mol Nafion}$

For 50% excess: Need 1.5 amount of TBOH to Nafion (1:1)

∴ $(1.5)(6.045 \times 10^{-5} \text{ mol Nafion}) = 9.0682 \times 10^{-5}$ TBOH

Molecular wt of TBOH = 259.48 g

Amount of TBOH 50% in excess needed in grams:

$(9.0682 \times 10^{-5} \text{ mol TBOH})\left(\frac{259.48 \text{ g TBOH}}{1 \text{ mol}}\right) = 2.353 \times 10^{-2} \text{ g TBOH}$

Volume of TBOH 50% in excess needed:

$(2.353 \times 10^{-2} \text{ g TBOH})\left(\frac{1 \text{ ml}}{0.001 \text{ g}}\right) = 23.53 \text{ ml TBOH}$ ✓ (50% excess)

**Appendix D**

Specifics for Certain Recommendations

Contents

*Wiring Harness*

- Perform conductivity test for circuit efficiency.

*General*

- There are many possibilities to include other departments to accomplish the recommendations of this report.

*Wiring Harness*

- Perform conductivity test for circuit efficiency.

With the electrodes installed into the plates place a sheet of copper in place of the membrane. Apply a voltage through the copper plate, electrode and through the external connection. Measure the voltage drop across the electrode and ~~the~~ the connection from the electrode and external contact. Find if the voltage is increased is there a point where the thermal effects on the electrical path cause a change in resistance that limits the potential of the fuel cells. UNCLEAR

*General*

- There are many possibilities to include other departments to accomplish the recommendations of this report.

1. The material properties of some of the components of the prototype need to be further investigated which could use the aid of Material Science Students.
2. A new and improve wiring harness with the capability to change the parameters of the test and record the results could use aid of Electrical Engineers. The EE could also be used in the design of the overall safety system if it involves one switch to control solenoids that shuts down the fuel cell and fuel gases.
3. Technical Communications for maintaining the Web Site and administrating continuity of project documentation.