Group 16

Design and Development of Optimized Flow Channels for an Alkaline Membrane Fuel Cell Educational Kit

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Re-Introduction to AMFC Operation

- Converts chemical energy into electric potential energy
- Requires an electrolyte solution, hydrogen gas, and oxygen gas or air for operation
- Generates electricity with no harmful Bi-products
- Most electrically efficient of all the fuel cells (60% efficiency)
- Safe operating temperature for educational kit (70-100 Celsius)

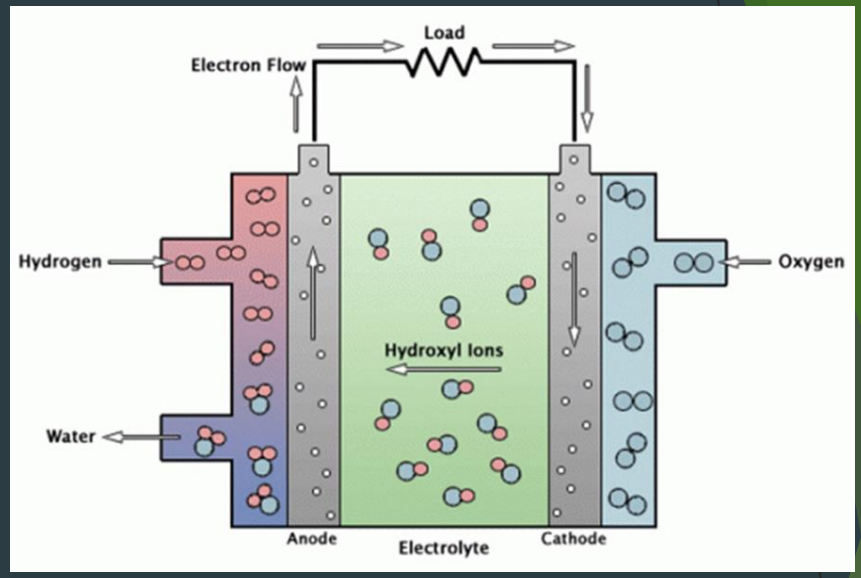


Fig. 1: Fuel Cell Operation

Table 1: Operation of various fuel cell types

Fuel Cell Type	Operating Temperature (°C)	Electrical Efficiency
Alkaline (AFC)	70 – 100	60%
Polymer Electrode Membrane (PEM)	50 – 100	25 – 58%
Phosphoric Acid (PAFC)	150 – 200	>40%
Molten Carbonate (MCFC)	600 – 700	45 – 47%
Solid Oxide (SOFC)	600 – 1000	35 – 43%

Flow Configurations

- Gas diffusion rates depend on flow configurations
  - Effective water removal – flooding decreases diffusion
  - Flow distribution – high current density increases diffusion

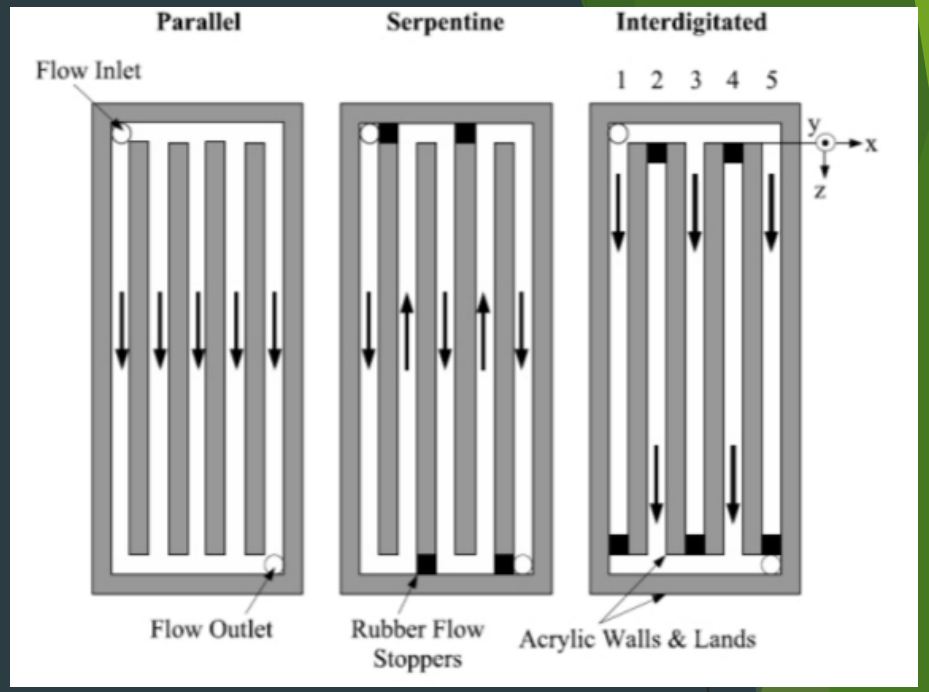


Fig. 2: Fuel cell flow configurations

Current Set up

- 200 mL Electrolysis Cylinders
  - Inconsistent and slow feeding rates
  - Poor water removal
- 1 Configuration
  - Cannot experimentally compare
- Hazardous features

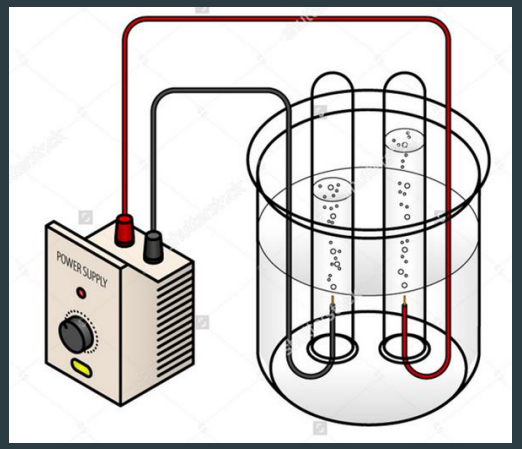


Fig. 3: Basic electrolysis set up

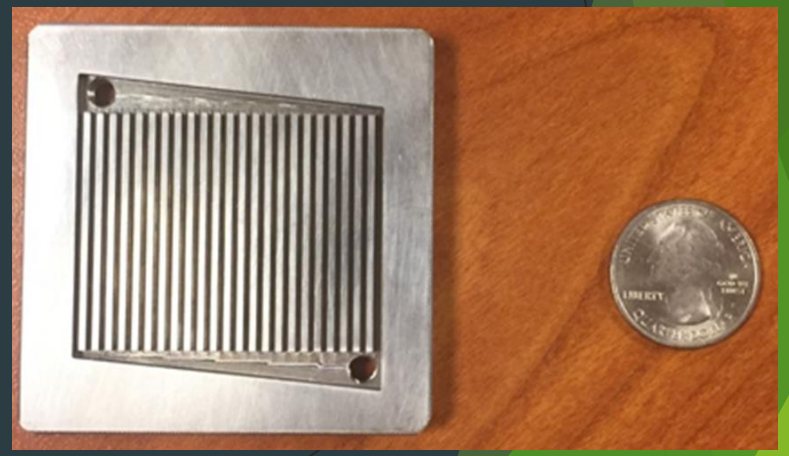


Fig. 4: Current parallel plate

Problem Statement

“The current AMFC setup does not effectively allow students to test the effects of flow configurations on fuel cell performance.”

Goal Statement and Objectives

“Deliver a safe and functioning educational alkaline membrane fuel cell kit that demonstrates the effects of flow configurations on the fuel cell’s performance for educational use”

Objectives

- Include parallel, serpentine, and interdigitated configurations to compare power outputs
- A standard operation procedure and a product specification sheet included in the kit
- A series of demonstration experiments will be designed and conducted with explanations of why certain configurations perform better than others
- Develop a model for potential commercialization of the kit.

Plan and Approach

- Communication
  - Team has enrolled in related class towards project with advisor/sponsor
    - Need to increase communication between team and advisor/sponsor
    - Increases face to face contact for improved scheduling
  - Seek help with Brazilian team

- Modifications
  - Advanced fuel delivery
    - Electrolysis machine (Hydrogen) and air pump (Oxygen)
      - Increases safety
      - Experimental consistency
  - Case packaging
    - Adjust how new components will fit in travel case

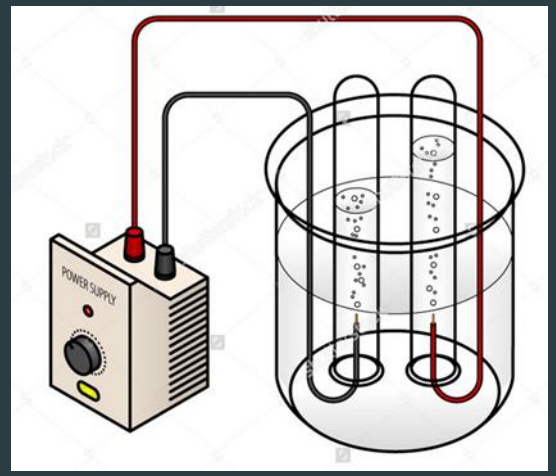


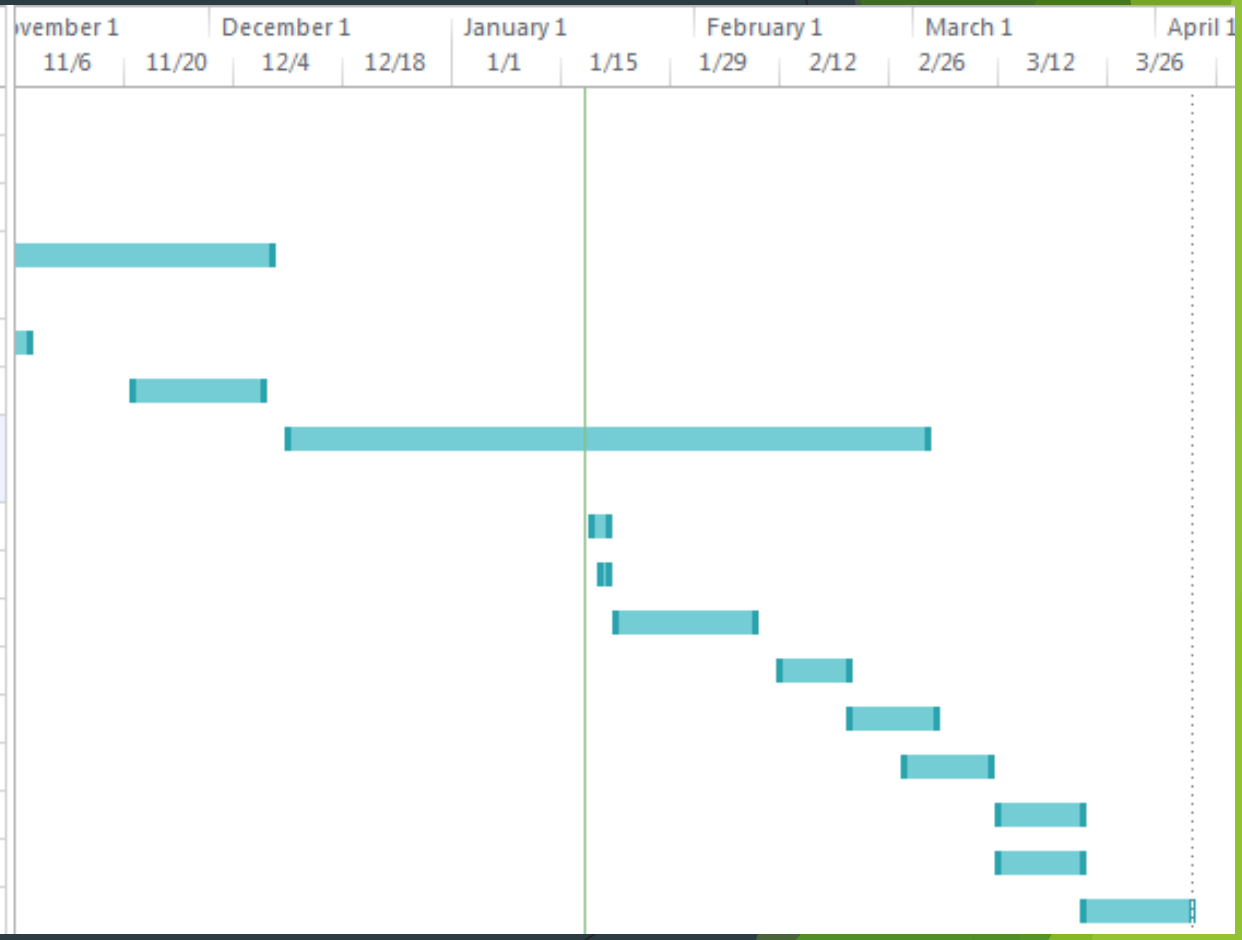
Fig. 5: Example of Old Electrolysis Setup

Fig. 6: Image of HydroFILL filling HydroStick Pro

Gantt Chart

Table 2: Gantt Chart used to organize and plan project

Task Name	Duration	Start	Finish
Background Research	13 days	Wed 9/21/16	Fri 10/7/16
Discuss Design Ideas	26 days	Wed 9/14/16	Wed 10/19/16
Gain Access to CAPS Laboratory	9 days	Mon 10/10/16	Thu 10/20/16
Communicating with machine shop	26 days	Thu 11/3/16	Thu 12/8/16
Web Design	14 days	Wed 10/19/16	Mon 11/7/16
Begin Testing of Existing Design	13 days	Mon 11/21/16	Wed 12/7/16
Communication with Brazilian Team	60 days	Sun 12/11/16	Thu 3/2/17
Meet with Advisor/Sponsor	2 days	Thu 1/19/17	Fri 1/20/17
Communicate with Machine Shop	1 day	Fri 1/20/17	Fri 1/20/17
Purchase Components	14 days	Sun 1/22/17	Wed 2/8/17
Machine New Flow Channels	7 days	Sun 2/12/17	Mon 2/20/17
Optimize Gas Delivery System	9 days	Tue 2/21/17	Fri 3/3/17
Optimize Electrolyte Membrane	9 days	Tue 2/28/17	Fri 3/10/17
Test Flow Configurations	9 days	Sun 3/12/17	Wed 3/22/17
Conduct Mathematical Analysis	9 days	Sun 3/12/17	Wed 3/22/17
Finalize Kit	10 days	Thu 3/23/17	Wed 4/5/17



Progress Made

- Made contact with team in Brazil
- Fuel delivery issues clarified
  - Basic electrolysis method inconsistent
  - Hydrostik Pro and air pump
    - Includes electrolysis
    - Regulated flow
    - Increase safety
- Ordering correct stainless steel plates
- Drawings brought to machine shop
  - Meeting on Friday 1/20

Fig. 7: Brazilian team's lab

Failure Analysis

Table 3: Failure Analysis for educational kit

#	Name	Failure Mode	Cause	Symptoms and Local Effects	Method of Detection	Effect on System	Remarks and other Effects
1	End Plates	Oxidation, Warped, Damaged	Corrosion, Poor Thermal Management, Neglect	Reduced Diffusion, Leaking, Poor Water Vapor Management	Visual Inspection	Reduced Power Generation	Could pose a health hazard
2	Membrane	Reduced efficiency	Carbon Dioxide Poisoning, Overuse	Uneven Current Distribution	Measuring power output	Reduced Power Generation	Requires Replacement
3	Gas Delivery Tubes	Cracked, Leaking	Dry rot, Loose Connection	Leaking Gas, Reduced Diffusion	Visual Inspection	Reduced Power Generation	Requires Replacement
4	Electrode Sheets	Salt Build Up, Damaged	Carbon Dioxide Poisoning, Misuse	Uneven Current Distribution, Uneven Heat Distribution	Visual Inspection, Power Output	Reduced Power Generation	Requires Replacement
5	Electrolysis Components	No Gas Production	Dead Battery, Poor Electrical Connections	No Bubbling	Visual Inspection, Testing Battery	No Power Generation	Requires Replacement
6	Hydrostik	Electrolyzer stack poisoning	Metal ion poisoning	Red light indicator	Visual inspection	Troubleshoot mode	Requires malic acid fill to neutralize ions

Challenges

- Developing a method for supplying hydrogen and oxygen to the fuel cell
  - Direct electrolysis feed versus stored compressed feed
- Communication with sponsor/advisor
- Communication with Brazilian Team
- Machining old plate for alligator clips
- The use of old plate when comparing to new plates during testing

Future Purchases

- Stainless steel for plate configurations
- Fluke 116 Multimeter to be included in the kit
  - Capable of testing voltage, amperage, and temperature
- Load box
  - Change resistances
  - Calculate current and power output for experimental results
- Fluke 80AK-A Thermocouple adapter
- Fuel delivery
  - Petco 9902 air pump
  - Hydrofill Pro station
- Safety feature components

Fig. 8: Petco 9902 air pump

Summary

- Addition of new fuel feed components
  - Incorporates electrolysis method
  - Consistent
  - Safe
- Overall goal and objectives and goal has maintained consistent
- Overcome challenges
  - Better communication with peers
- Future purchases
  - Manufacturing parts
  - Testing

Questions