Group 16

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

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Presentation Overview

- Project Goal Statement
- Brief Re-Introduction
- Current Design
- Functional Analysis
- Failure Analysis
- Safety Analysis
- Commercialization
- Plans for the Future

Goal Statement

- "Deliver a functioning educational alkaline membrane fuel cell kit that demonstrates the effects of flow configurations on the fuel cell's performance by the end of spring 2017 semester"

Re-Introduction to AMFC Operation

- Converts chemical energy into electric potential energy
- Requires an electrolyte solution, hydrogen gas, and oxygen gas for operation
- Generates pure water and electricity
- No greenhouse gas emitted

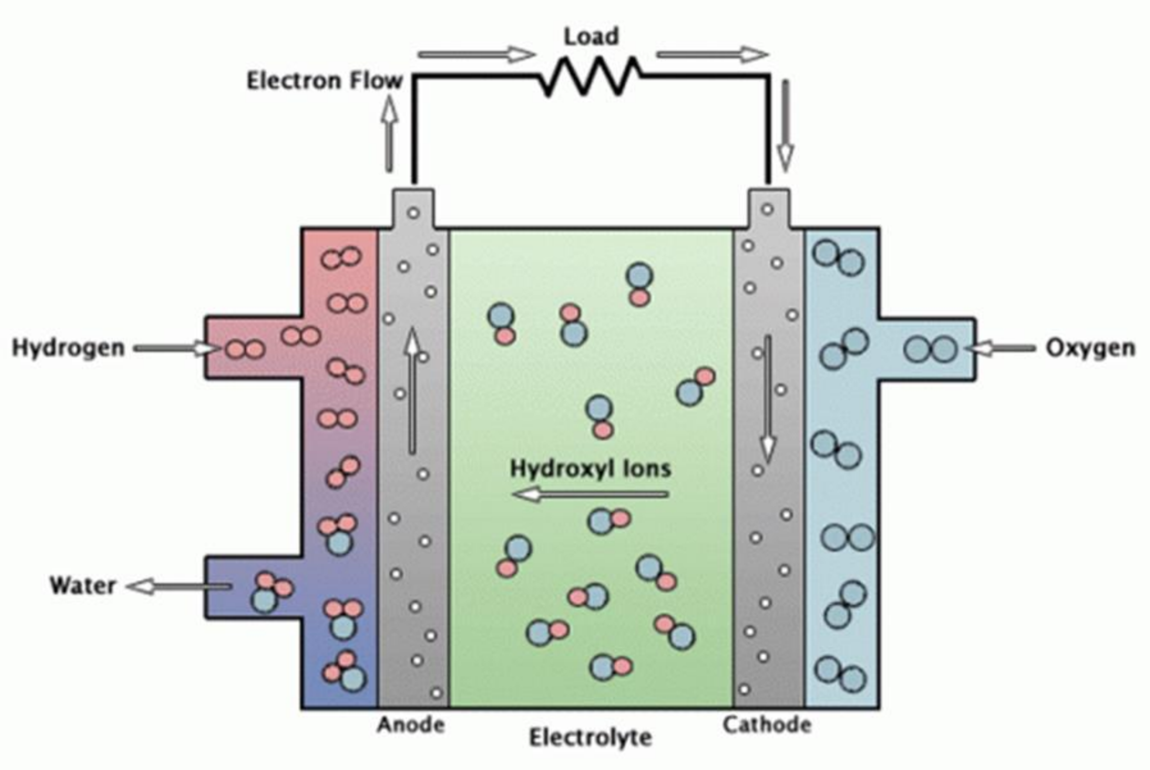


Fig. 1: Fuel Cell Operation

Current Set Up

- 200 mL Electrolysis Cylinders
- 1/8 in diameter exit
- 0.05” Wire to 9V battery
  - Producing a flow rate of 0.2678L/hr
  - Fluid Velocity of 0.036m/s
  - Very low feeding pressure and flow rate
  - Not optimal to study thermal fluids system

Fig. 2a: Electrolysis Cylinder

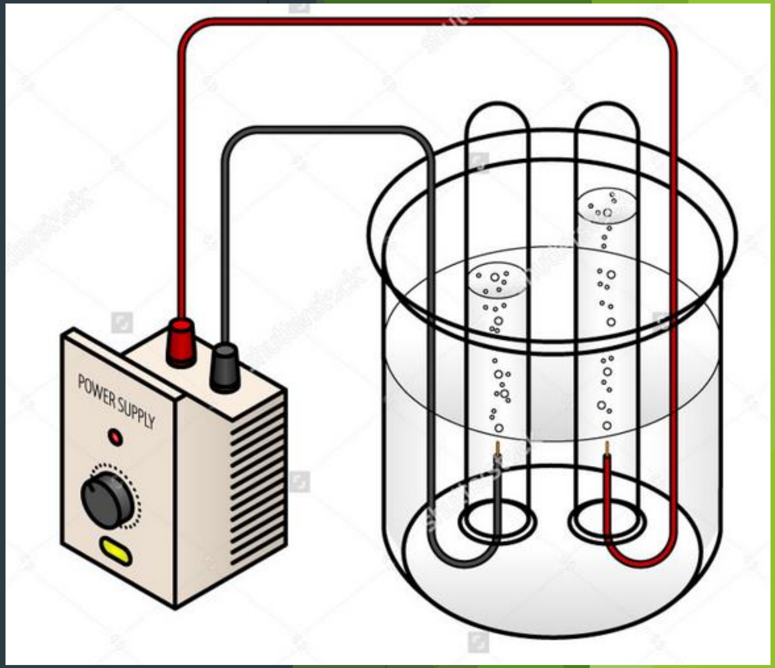


Fig. 2b: Electrolysis Operation

Parallel Configuration

- Lowest pressure drop
    - No minor losses
    - Multi-path design
- Does not require a high flow rate for operation
- Current max voltage 0.561V produced
    - Ideal 1.23V

Fig. 3: Parallel Configuration

Serpentine Configuration

- Higher pressure drop compared to parallel
  - Minor losses-22 bends in current design
  - One path continuous flow
  - Steady contraction loss
- Higher flow rate desired for optimal functionality

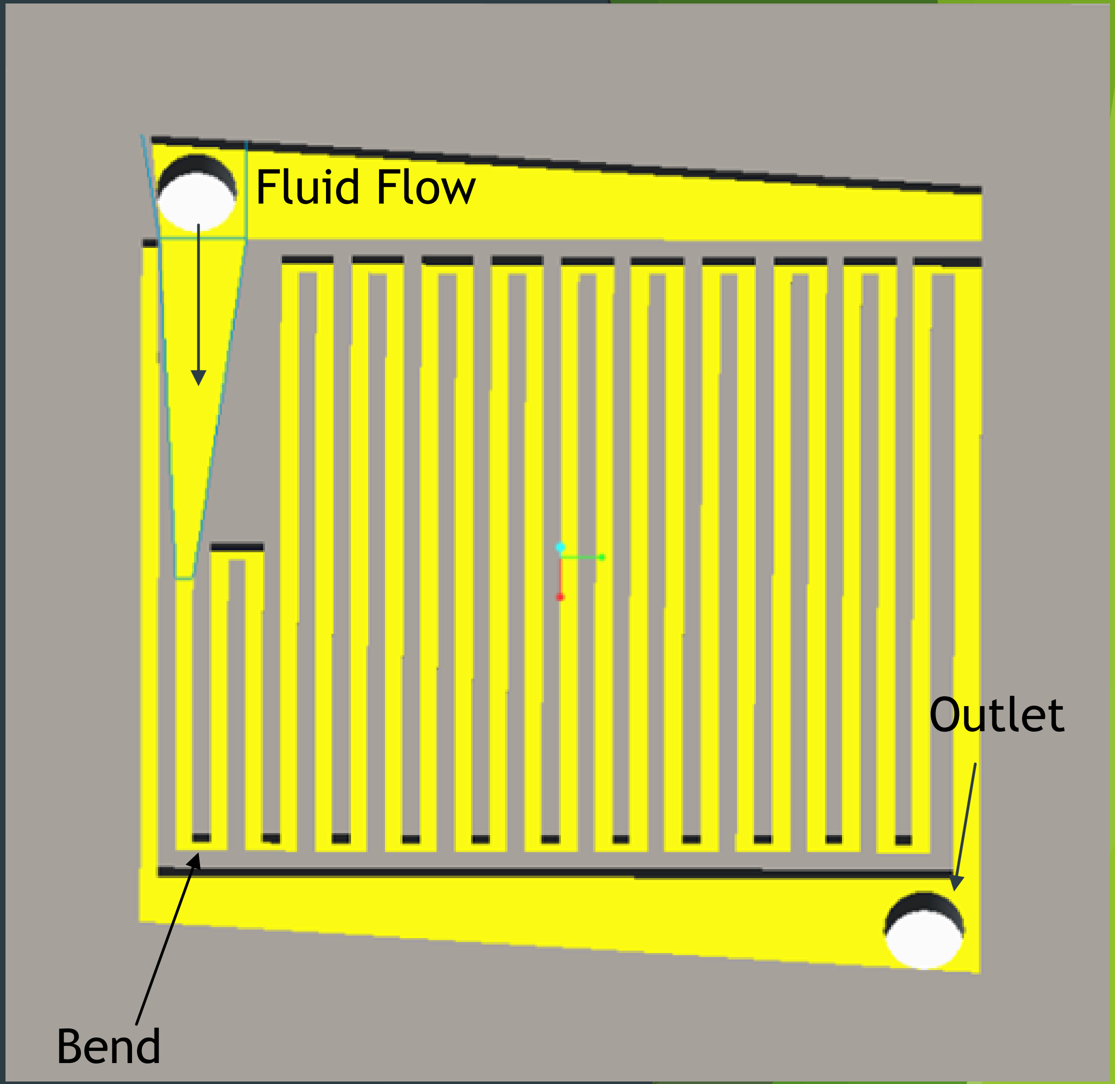


Fig. 4: CAD Serpentine Configuration

Tristan Walter
Design and Development of AMFC Kit

Interdigitated Configuration

- Highest Pressure drop compared to parallel and serpentine design
  - Minor losses-22 bends
  - Dead Ends
    - Forces fluid to lateral diffuse over channel walls for high diffusion rate
    - Potentially flooding
    - High pressure drop
- Higher flow rate required for optimal functionality

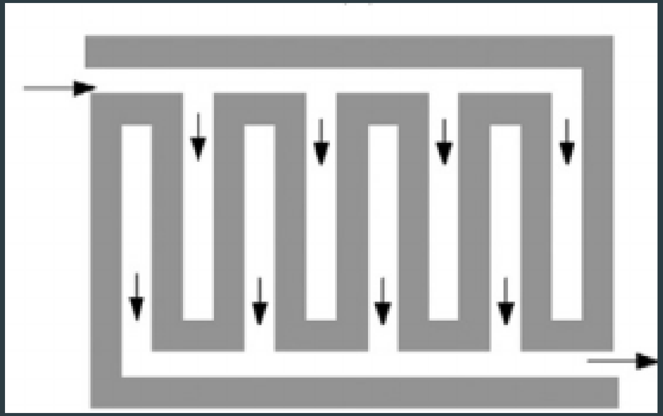


Fig. 5a: Interdigitated Configuration flow

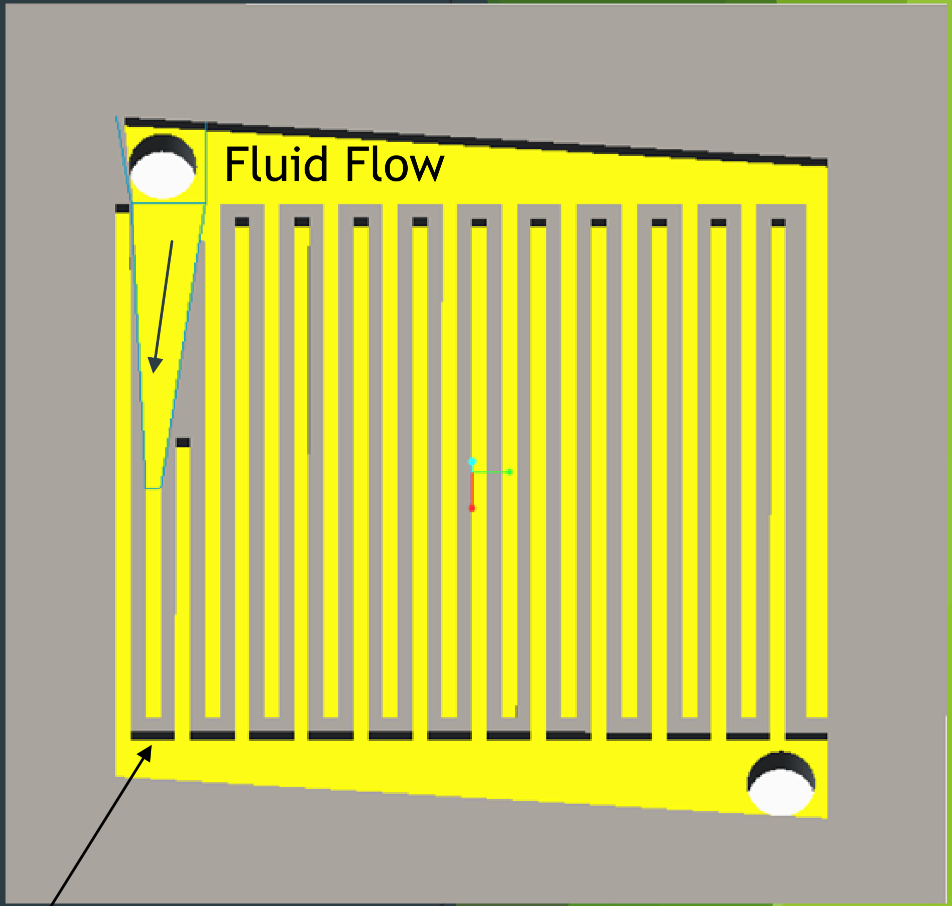


Fig. 5b: CAD Interdigitated Configuration

Dead End

Effects of Low Flow Rate on High Pressure Drop Configurations

- Heat distribution and Heat transfer
    - Fluid temperature will dissipate quicker through system
    - Max Heat ≈393.15 K (Shown in Fig. 6 in red)

- Why optimize?
    - Higher flow rates allow for higher heat transfer rates
    - High current density

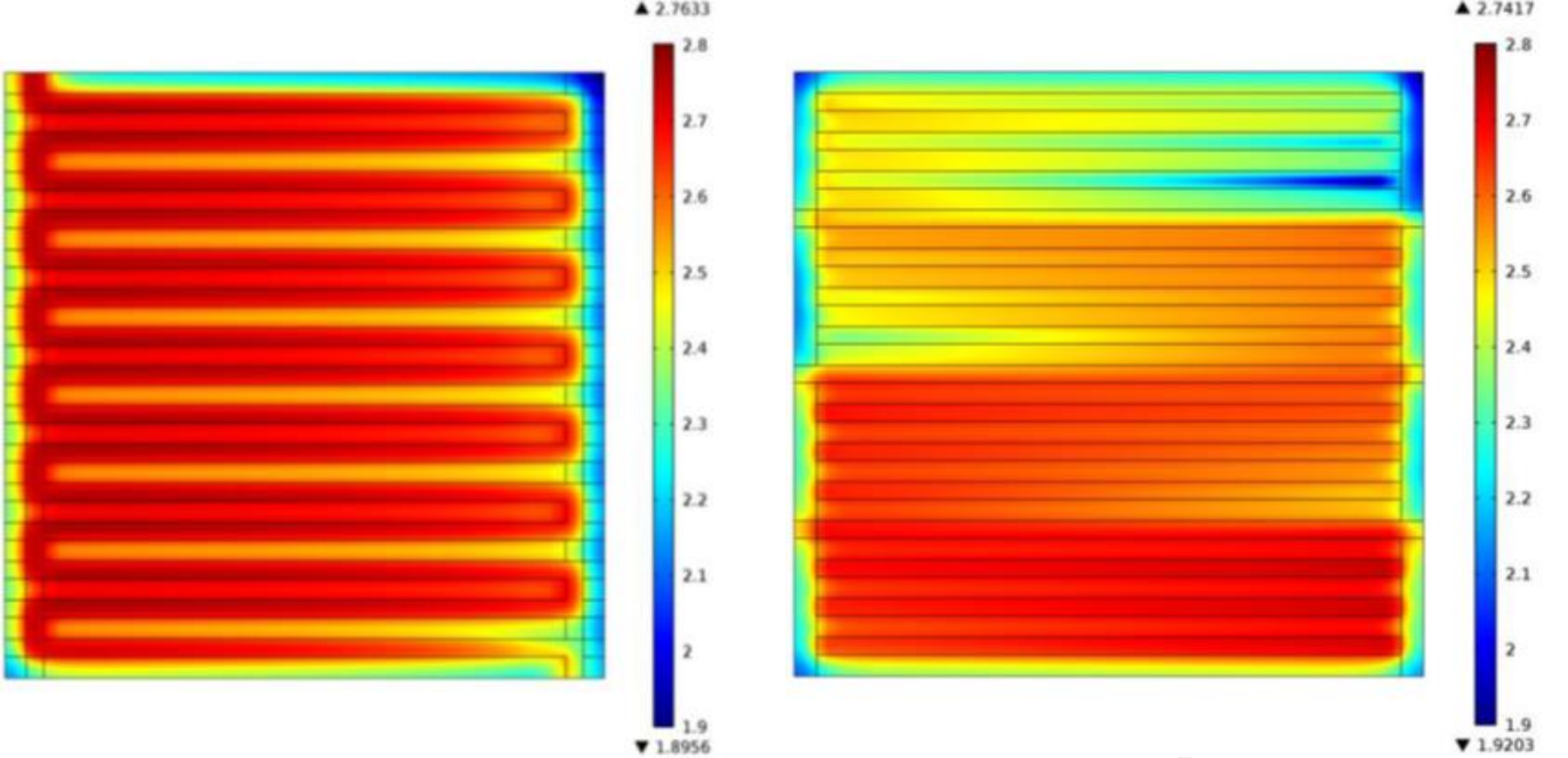


Fig. 6: Thermal Imaging Interdigitated (left) Serpentine (Right)

Effects of Low Flow Rate on High Pressure Drop Configurations

- Low feeding pressure
  - Thermal fluids system has energy losses – Head loss
  - Cannot overcome these losses to allow for fluids to move through system

$$\mathrm{Re} = \frac{\rho v D}{\mu}$$

Eqn. 1: Reynolds Number

- Low Reynolds number
  - Current set up produces RE=0.42
  - No empirical formula to find appropriate friction factor
  - Cannot study pressure drop in the thermal fluid system

$$f = \frac{24}{\mathrm{Re}}(1 - 1.3553a + 1.9467a^2 - 1.7012a^3 + 0.9564a^4 - 0.2537a^5)$$

Eqn. 2: R.K. Shah and A.L. London friction factor

Analysis

- How much feeding pressure is required for a respectable flow rate?
  - New velocity selected to received respected RE
    - 6.0 m/s results in RE = 56.45
    - R.K. Shah and A.L. London equation used for f
    - **Geankoplis table**
    - **Geankoplis friction loss**
    - ΔP=0.1663psi

Table 1: **Geankoplis table of friction losses for non-tubulent flow**

Re	50	100	200	400	1000	Turbulent
K_f	17	7	2.5	1.2	0.85	0.75

$$\sum F = \frac{V^2}{2}\left(\frac{4fL}{D_h} + K_f\right)$$

Eqn. 3: **Geankoplis friction loss (Energy Balance)**

$$\frac{\Delta P}{\rho} = \sum F$$

Eqn. 4: ΔP is proportional to the sum of frictional losses

Results

- New flow rate of $1.2384 * 10^{-4} \frac{m^3}{s}$ (Fluid Velocity = 6.0m/s) results in ΔP=0.1663psi for current serpentine design
- Must produce a feeding pressure > 0.1663psi
  - Increase Electrolysis reaction
  - Pump

Increasing Pressure and Future Steps

- Increasing Electrolysis Reaction
  - Add salt to distilled water in cylinders- increases conductivity
  - Thicker wire- increases current
  - Use larger battery- increases voltage
  - Use pressure gage to measure if this pressure is achievable
- Pump
  - Pump selection will allow for an exact desired flow rate
  - Adds more components to system
  - Electrolysis method cannot be used

Fig. 7: Pressure Gage used to measure pressure on cylinder

Design for Commercialization

- Kit’s main use is for educational use
  - Easy to disassemble and replace with different flow plates
  - Safe design
  - Maximize simplicity and reliability of the design
  - Transportability
  - All parts and directions included

Failure Analysis

Table 2: 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	Electrolysis Components	No Gas Production	Dead Battery, Poor Electrical Connections	No Bubbling	Visual Inspection, Testing Battery	No Power Generation	Requires Replacement
5	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

Safety Analysis

- AMFC operates at max temperatures of 100°C - 120°C
- Improving design to make more stable
- Prevent fuel cell from moving during operation

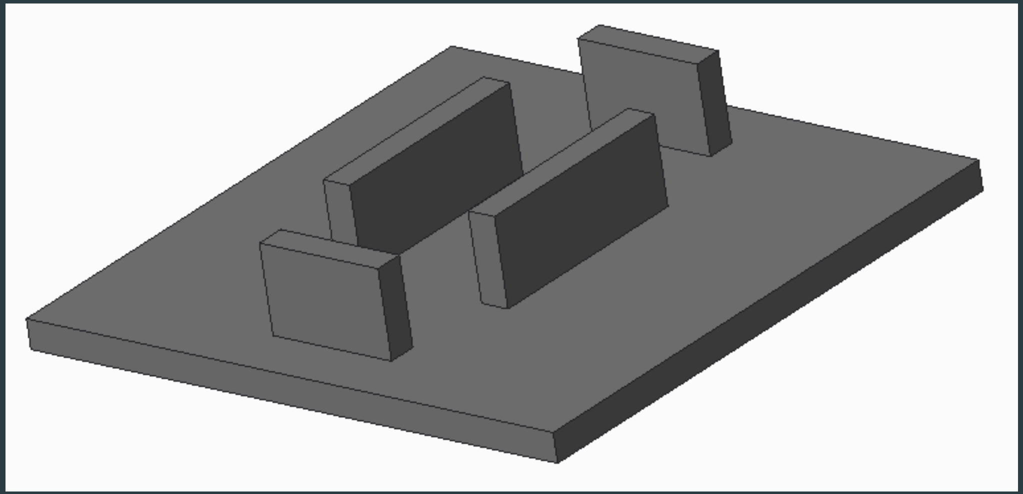


Fig. 8: CAD drawing of fuel cell stand

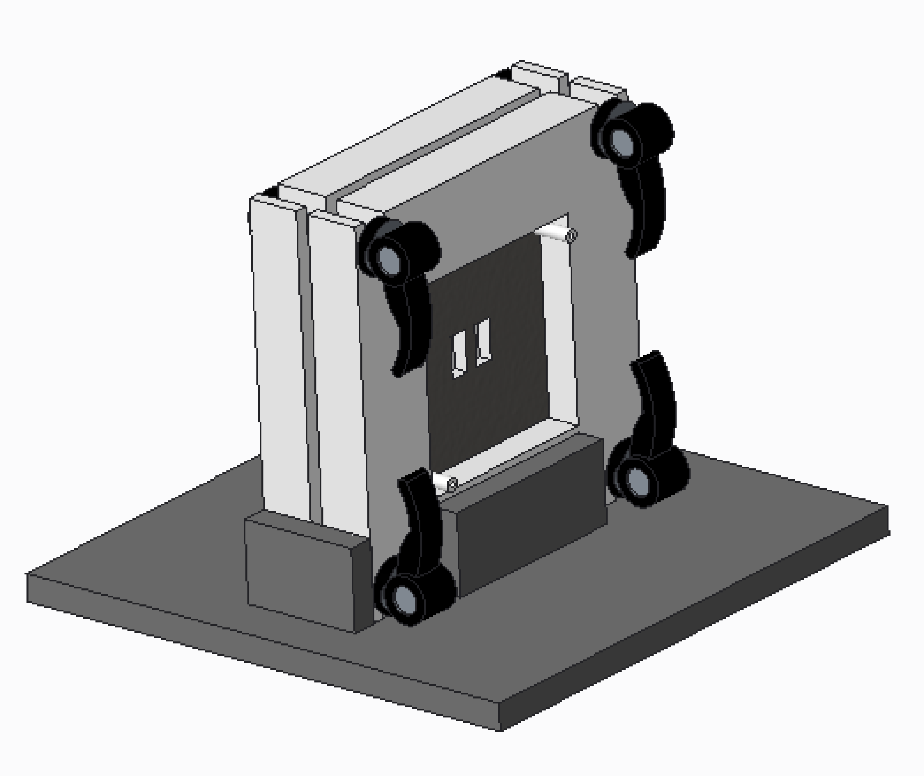


Fig. 9: CAD drawing of fuel cell in stand

Maximizing Simplicity

- Old design relied on bolts for assembly
- New design assembled with quick release bicycle skewers
- Skewers will be customized in order to fit design

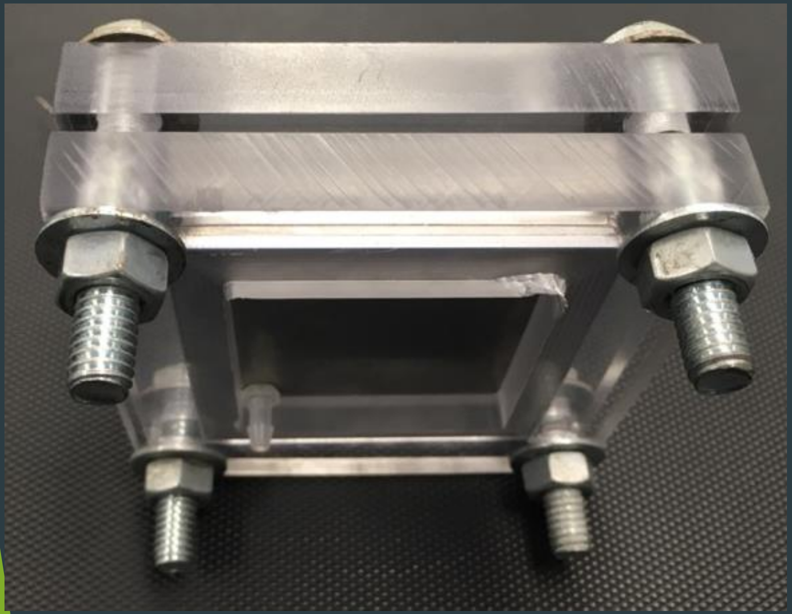


Fig. 10: Current design using bolts

Fig. 11: Quick release skewer

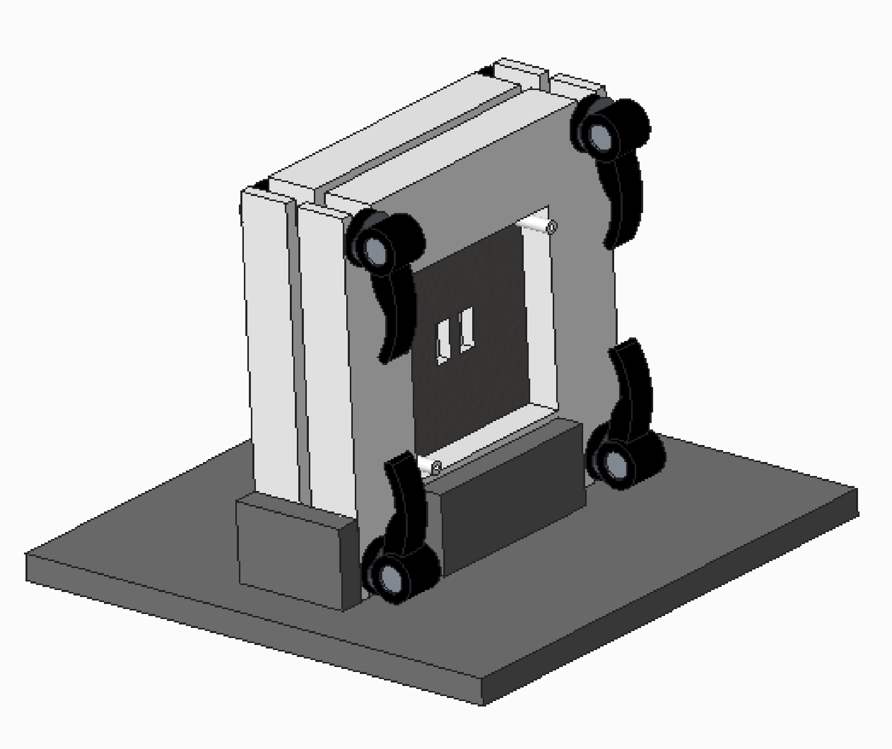


Fig. 12: CAD drawing of new design

Maximizing Testing Reliability

- Old Design relied on spliced wires to measure power generation
- Could produce inconsistent measurements
- New Design features integrated connection points to facilitate alligator clips

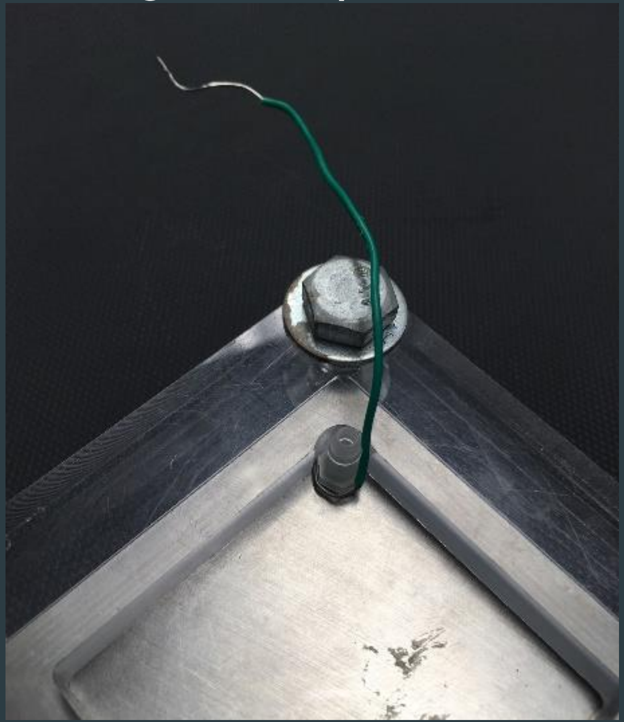


Fig. 13: Current design wiring system

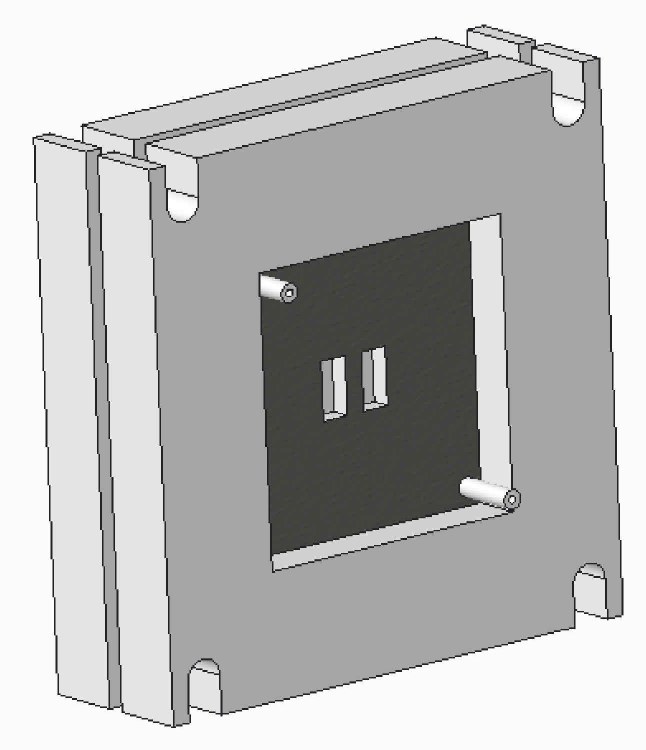
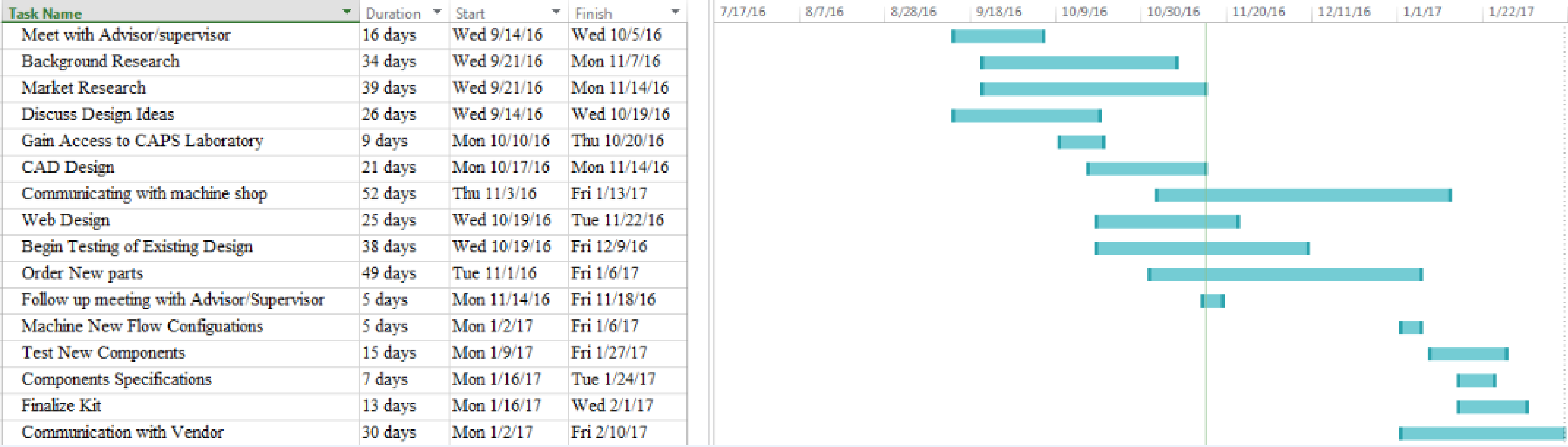


Fig. 14: CAD drawing of end plate modification

Fig. 15: Alligator clips

Gantt Chart

Table 3: Gantt Chart used to organize and plan project



Task Name	Duration	Start	Finish
Meet with Advisor/supervisor	16 days	Wed 9/14/16	Wed 10/5/16
Background Research	34 days	Wed 9/21/16	Mon 11/7/16
Market Research	39 days	Wed 9/21/16	Mon 11/14/16
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
CAD Design	21 days	Mon 10/17/16	Mon 11/14/16
Communicating with machine shop	52 days	Thu 11/3/16	Fri 1/13/17
Web Design	25 days	Wed 10/19/16	Tue 11/22/16
Begin Testing of Existing Design	38 days	Wed 10/19/16	Fri 12/9/16
Order New parts	49 days	Tue 11/1/16	Fri 1/6/17
Follow up meeting with Advisor/Supervisor	5 days	Mon 11/14/16	Fri 11/18/16
Machine New Flow Configuations	5 days	Mon 1/2/17	Fri 1/6/17
Test New Components	15 days	Mon 1/9/17	Fri 1/27/17
Components Specifications	7 days	Mon 1/16/17	Tue 1/24/17
Finalize Kit	13 days	Mon 1/16/17	Wed 2/1/17
Communication with Vendor	30 days	Mon 1/2/17	Fri 2/10/17

References

1. [4] Sommer, E.M., L.S. Martins, J.V.C. Vargas, J.E.F.C. Gardolinkski, J.C. Ordonez, and C.E.B. Marino. "Alkaline Membrane Fuel Cell (AMFC) Modeling and Experimental Validation." Journal of Power Sowers (2012): n. pag. Web. 25 Sept. 2016.
2. Paulino, Andre L.R., Eric Robalinho, Edgar F. Cunha, Rainmundo R. Passos, and Elisabete I. Santiago. "Current Distribution on PEM Fuel Cells with Different Flow Channel Patterns." (n.d.): n. pag. Https://www.comsol.com/paper/download/181391/paulino_paper.pdf. CAPES (Coordenação De Aperfeiçoamento De Pessoal De N ível Superior) and CNPq (Conselho Nacional De Desenvolvimento Científico E Tecnológico, 2013. Web. 2016.
3. Anderson, Bryan, and James Richardson. "Educational Kit for Alkaline Membrane Fuel Cell (AMFC)." Senior Design Presentation. Famu FSu College of Engineering, Tallahassee. 2016. Lecture.
4. Keith, Jason M. *CACHE Modules on Energy in the Curriculum Fuel Cells*. Rep. Houghton: Michigan Technological U, 2009. Print

Questions