Team 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)

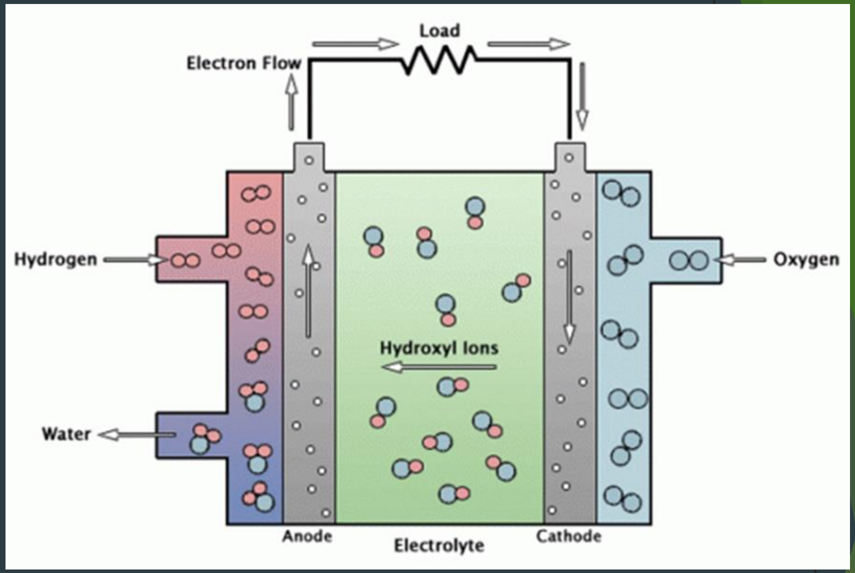

Fig. 1: Fuel Cell Operation

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%

Applications of Fuel Cells

- Automobile
  - Fuel cell to power electric motor
  - Water and heat as byproduct
  - 200-300 miles
  - 10 min recharge
- Home application
  - Power house when no sunlight
  - Extra power supplied

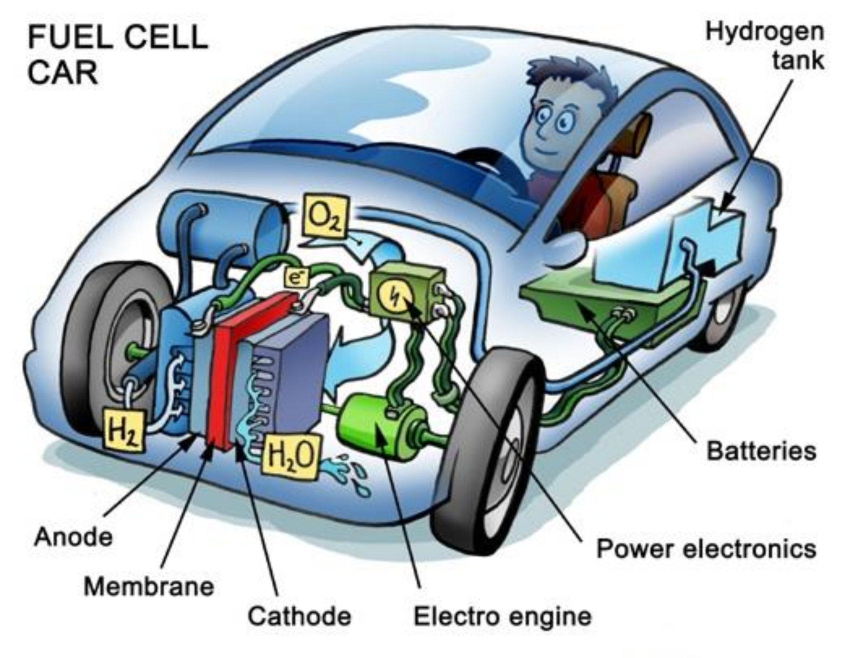

Fig. 2: Fuel cell car application

Fig. 3: FSU off grid house

Motivation

- Fuel cells in other green energy systems
  - Microalgae Bioreactor
    - Closed loop system – Water
      - Reduces need for outside water source
      - Fuel delivery is produced naturally
  - Production of Hydrogen is inefficient and costly
    - Chemically – 96%
    - Electrolysis – 4%
  - Incorporation Increases sustainability

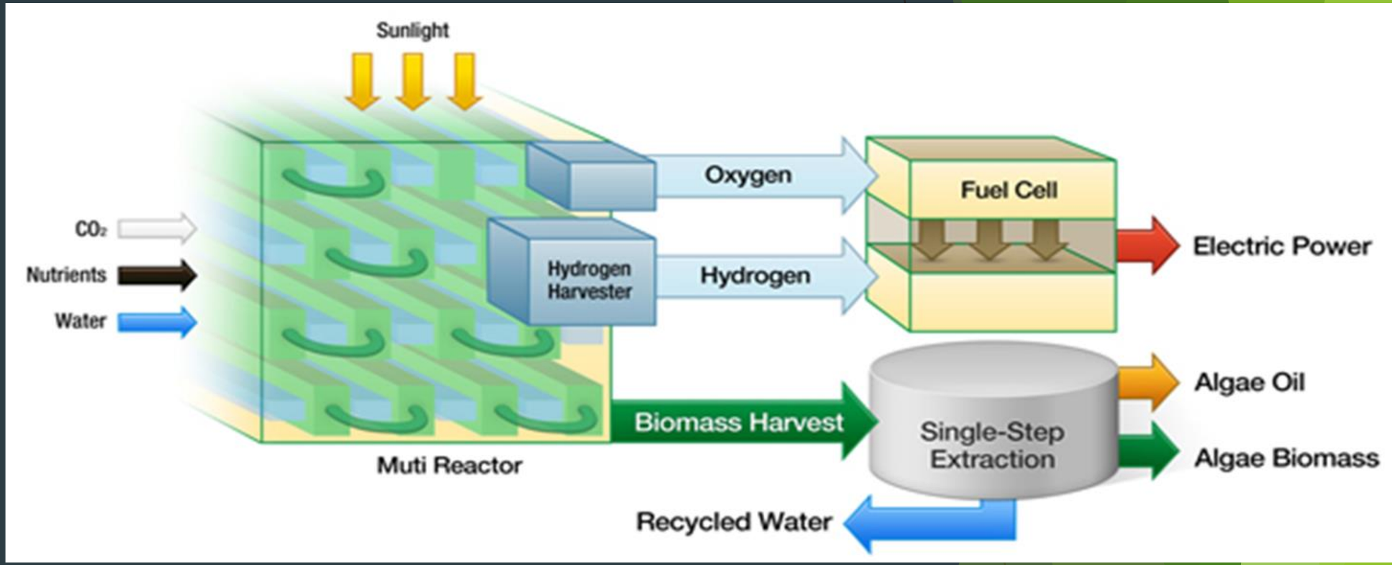

Fig. 4: Fuel cell integration with microalgae bioreactor

Education for the Future - Project Summary

- Small scale fuel cell kit for educational use
  - Demonstrate how a fuel cell operates
  - What properties effect a fuel cells performance based on flow configurations
  - Motivate the purpose and use of fuel cells

- Team 16's AMFC educational kit contains
  - Multiple flow configurations
  - Procedures for different education levels
  - Motivation to integrate into other green energy systems
  - Model for commercialization

Fig. 5: Team 16 Educational Kit

Kit Overview - Components

- HydroFILL PRO
  - Produces pure Hydrogen through electrolysis
- HydroSTIK PRO
  - Safe Hydrogen Storage Solution
    - Binds Hydrogen with a metal alloy to form solid metal Hydride
- Pressure Regulator
  - Regulates outlet pressure from HydroSTIK to 6.5 psi
- Air pump
- Measurement Set
  - Load Box
  - Multimeters
- Rubber Gaskets
- Nozzles and tubing for gas line connections
- Brackets and bolts
- Membrane and electrolyte

Fig. 6: Components in Kit

Kit Overview - Configurations

- Designed to understand importance of flow design
  - Goal is to design to minimize voltage drop
    - Concentration losses

$$\Delta V = \frac{RT}{2F} \ln\left(\frac{P_2}{P_1}\right)$$

    - Fuel losses (Internal Currents)

$$\text{Gas usage} = \frac{I}{2F} \text{ moles s}^{-1}$$

  - Serpentine
  - Parallel
  - Digital

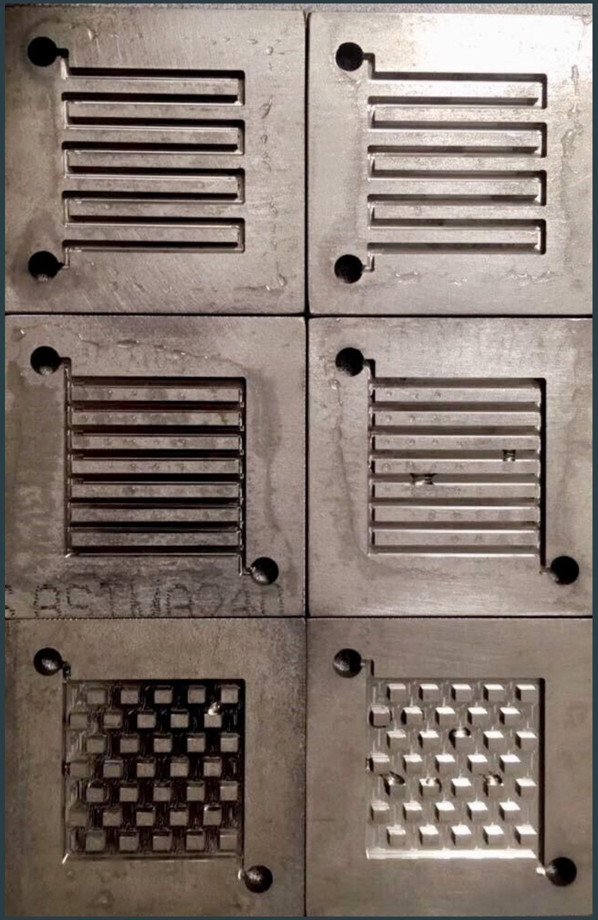

Fig. 7: Cell Configurations

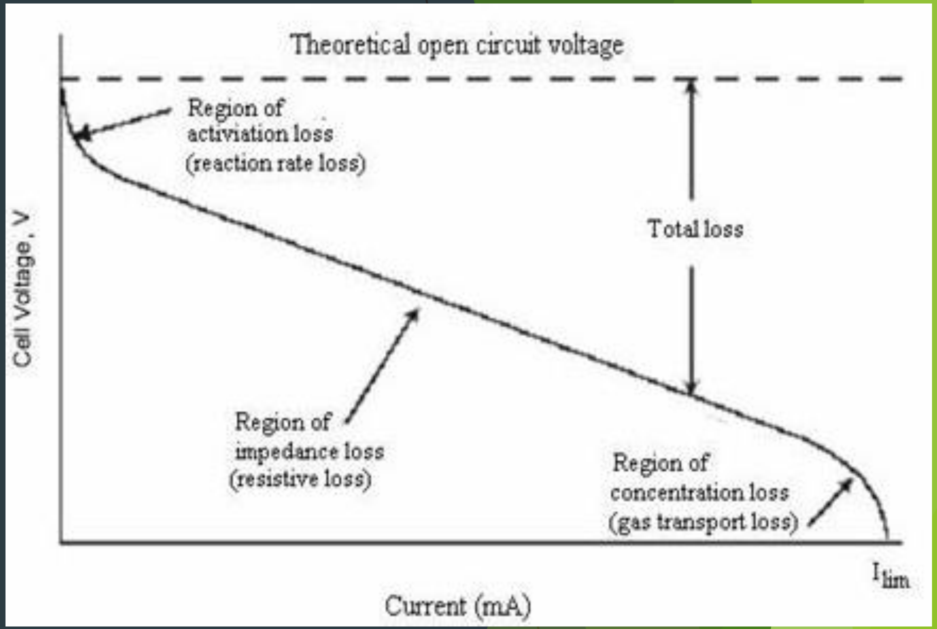

Fig. 8: Voltage Drop due to losses

Material Selections

- Produce a quality kit for longevity, reliability, purpose
  - Polycarbonate bracket
    - Protects cell with impact strength 16 ft-lbs/in
    - Transparent material
  - Stainless Steel Plate
    - Corrosion resistant
  - Rubber Gasket
    - Seals cell
    - Protects membranes

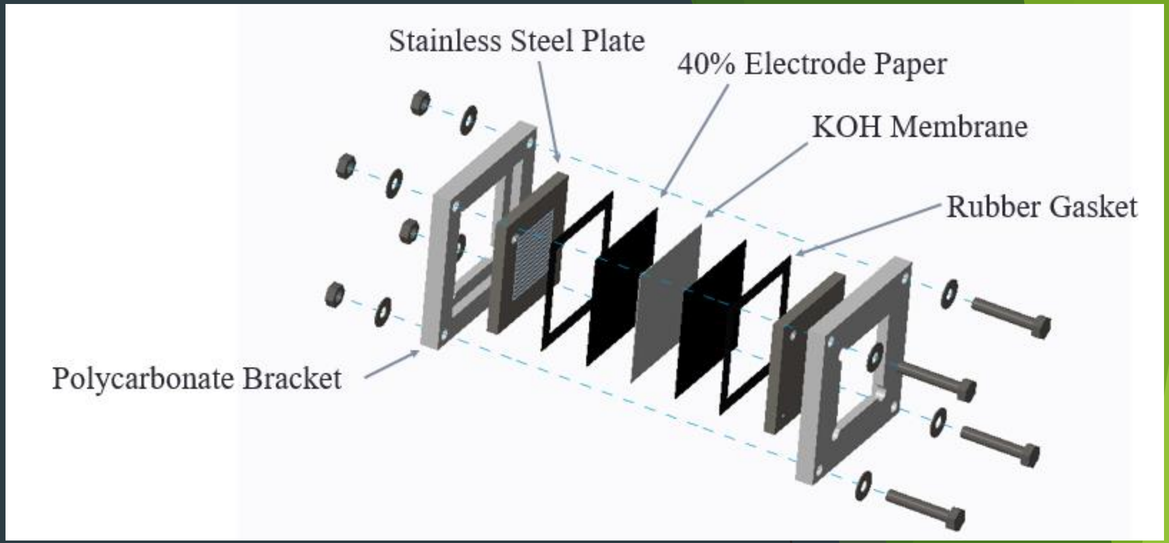

Fig. 9: Exploded view of fuel cell

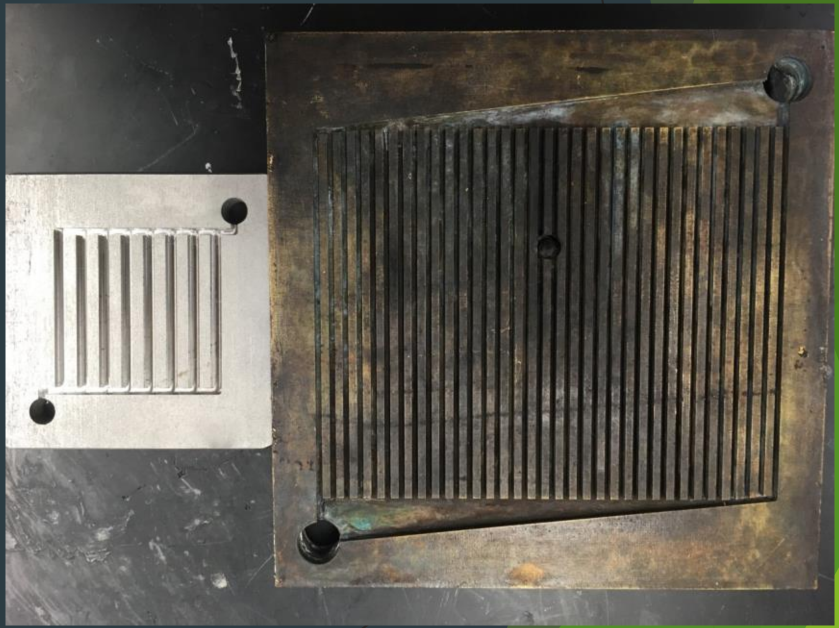

Fig. 10: Team 16 stainless steel plate and brass plate

Experimental Setup

- Charge Hydrostik pro
- Soak membrane in KOH solution
- Assemble fuel cell
- Connect air pump to cathode
- Connect Hydrostik to regulator and connect to anode
- Run banana plugs from cell to port 1
- Connect multimeter 1 in voltage port
- Connect multimeter 2 in current port
- Connect water waste tubes from cell to cylinders

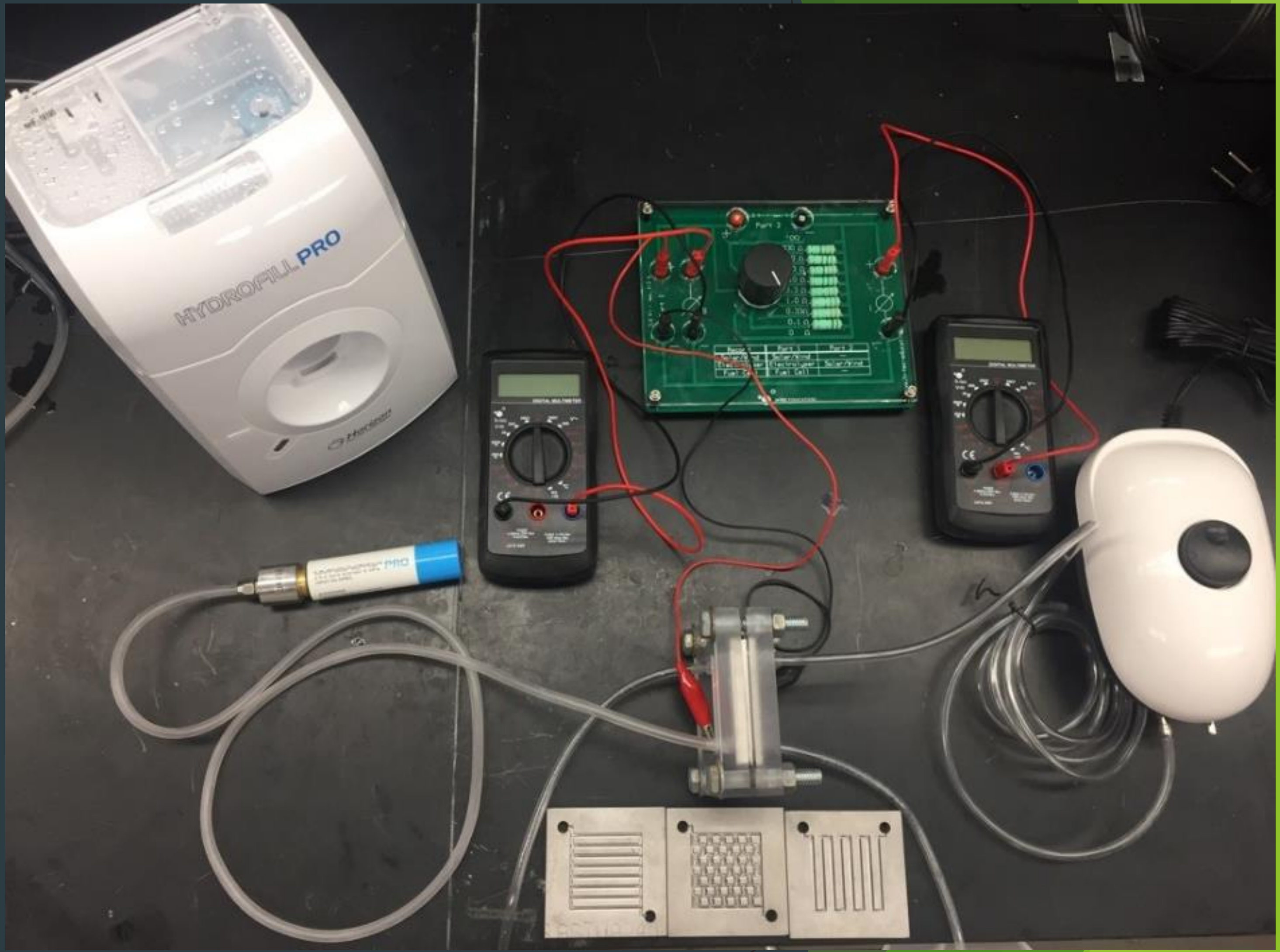

Fig. 11: Experimental Setup

Testing

- Measure voltage
- Vary resistance to produce different voltages and currents
- Run test after 10 min of fuel cell operation
- Construct I-V curve and plot power
  - Power is calculated from P=IV

Vary Resistance

Multimeter-Current

Port 1: Fuel Cell

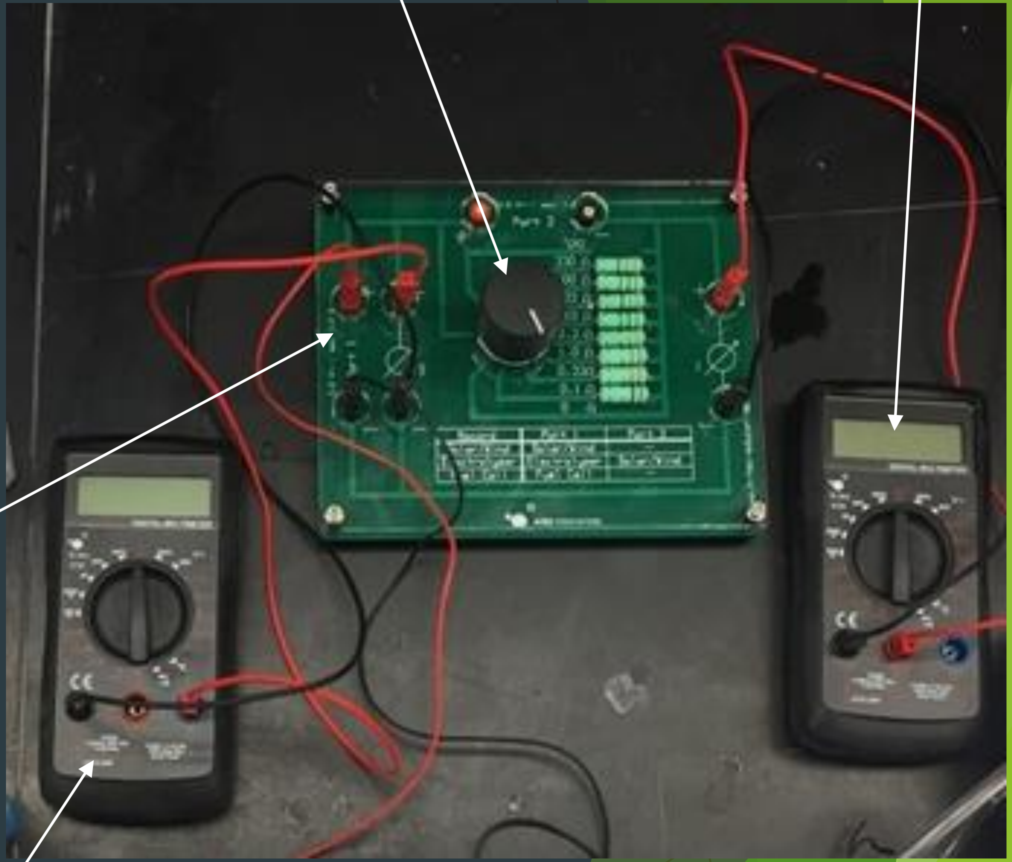

Fig. 12: Measurement Tools

Multimeter-Voltage

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Results

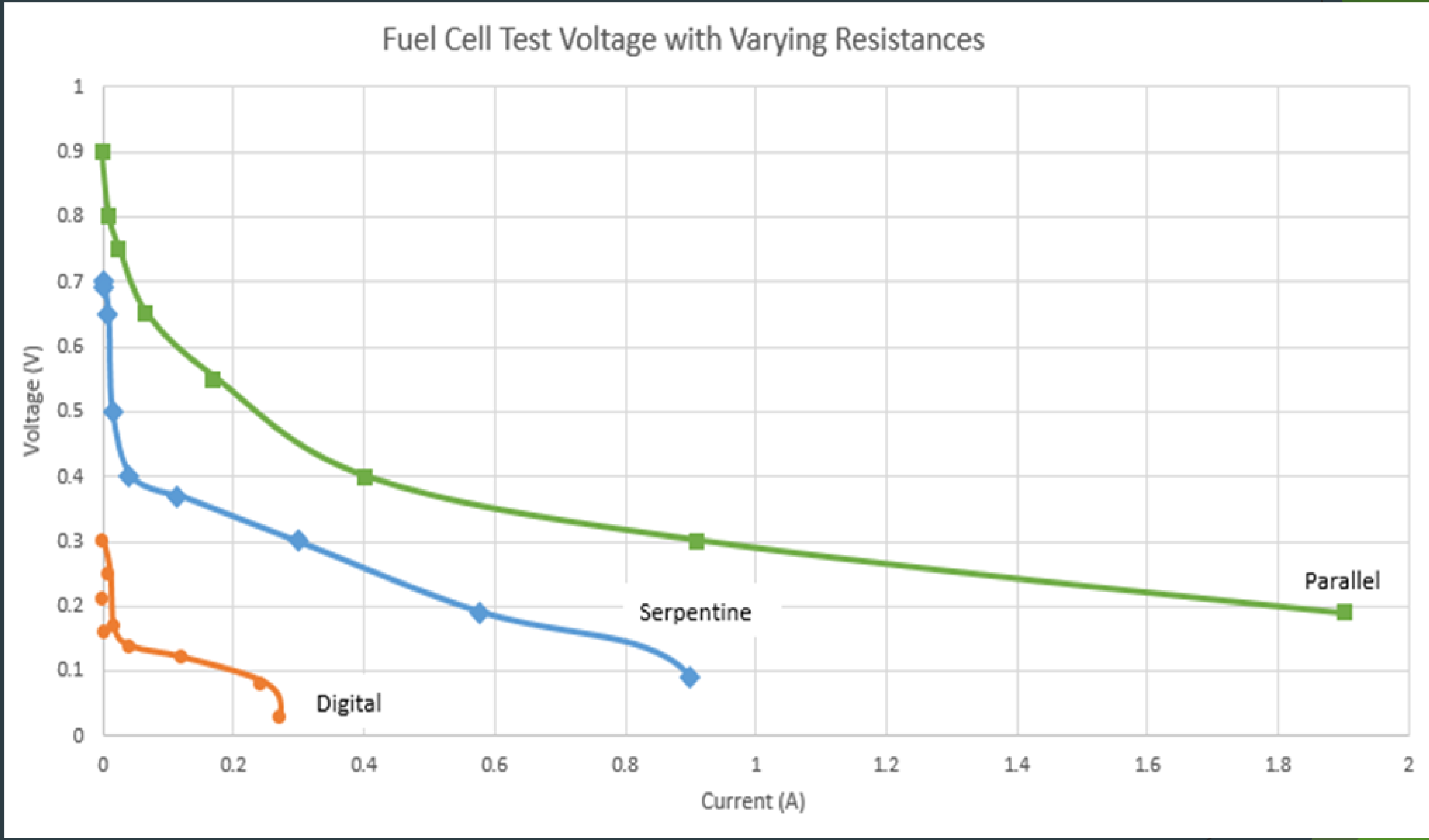

Fig. 13: Performance Curve

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Results – Continued

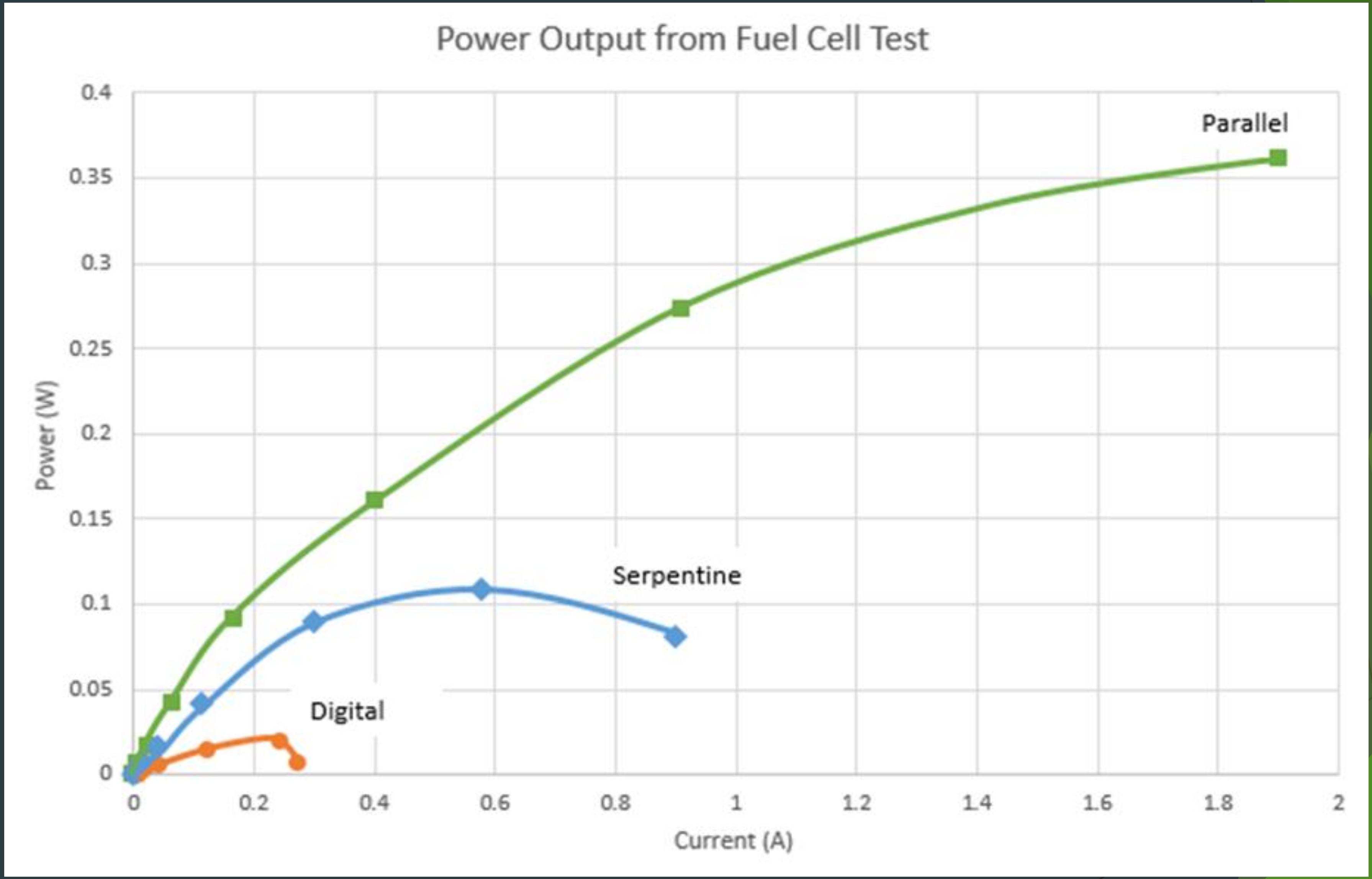

Fig. 14: Power Curve

Results Cont.

- Parallel Configuration
  - Demonstrated lowest voltage drop in concentration loss and fuel loss sections
    - Low Pressure difference – multi directional flow path
    - High contact surface area
  - Highest activation voltage
    - Electrodes reacted at the quickest rate
    - Good water removal due to design

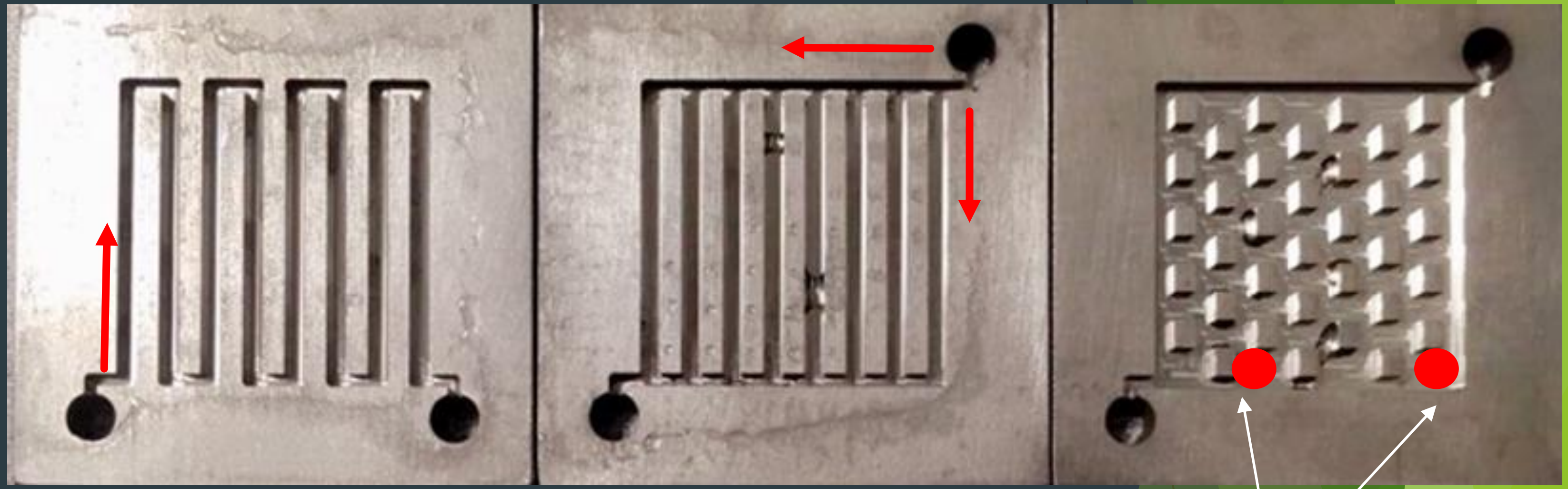

Fig. 15: Serpentine, Parallel, Digital

Educational Applications

- Designed experiments based off Florida K-12 curriculum
- Experiments meant for different educational levels
  - Junior High school
  - High school
  - College
- Hands on learning tool
- Introduction to sustainable energy

Table 2: School curriculum guide

Lessons	6th	7th	8th	9th-12th
Use data collection techniques	■	■	■	■
Organize and display data in a variety of ways	■	■	■	■
Demonstrate the use of a device to accomplish a task	■	■	■	■
Identify between independent/dependent variables		■	■	■
Investigate energy transformation between forms		■	■	■
Investigate how energy can't be created/destroyed		■	■	■
Explore the atomic theory			■	■
Differentiate chemical/physical changes			■	■
Investigate renewable/nonrenewable energy sources				■
Use scientific observation to develop scientific inferences				■
Differentiate chemical/nuclear reactions				■
Investigate relationship between current, voltage, resistance, power				■
Explore Law of Conservation of Energy in closed/isolated systems				■
Create chemical potential energy diagrams				■
Distinguish endothermic, exothermic reactions				■
Explain how factors affect rate of chemical reaction				■
Describe oxidation-reduction reactions				■
Relate basicity and hydroxyl ions and pH				■
Characterize types of chemical reactions				■
Apply mole concept/conservation of mass to calculate quantities of chemicals in reactions				■

Educational Experiments – Jr High

- Students help assemble fuel cell
- Experiment completed by a teacher
- Students tabulate and graph I – V curves
- Students will learn basic fuel cell concepts
  - Independent/dependent variables
  - Introduction to chemical reactions
  - Atomic theory

Educational Experiments – High School

- Experiment more hands on for students
- Students allowed to assemble fuel cell
- Students can operate fuel cell and take voltage measurements under adult supervision
- Basic chemistry and physics concepts
  - Investigate electrical concepts
  - Study chemical reactions involved
  - Law of Conservation of energy

Educational Experiments – College

- Students operate fuel cell in laboratory with TA
- Students can investigate the significance of different fuel cell components
  - Electrolysis
  - Stoichiometry
  - Thermodynamic Properties
  - Fuel cell properties
- Run fuel cell with different flow configurations and record/plot results
- Calculate fuel cell efficiency
- Incorporate fuel cell into microalgae bioreactor

Budget Analysis

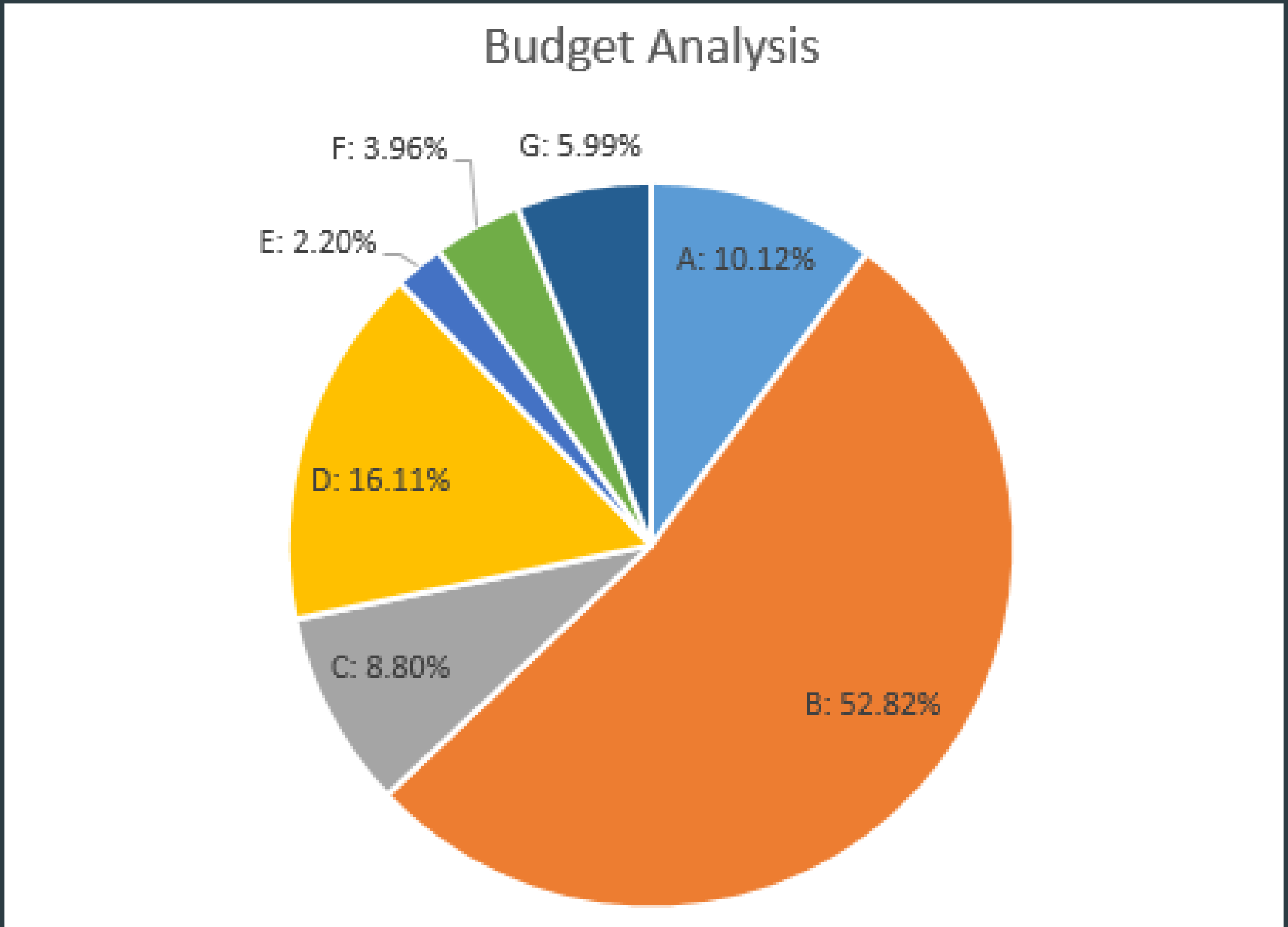

Fig. 16: Team 16 budget analysis

A: Stainless Steel
B: Hydrofill
C: Measurement Tools
D: Miscellaneous
E: Air Pump
F: Regulator
G: Over Budget

Total Cost: $1273.36

Why Team 16's Kit

- Self Sufficient gas delivery system
- Full assemble and disassemble
- Portable and transportable case
- Quality material components
- Multiple flow configurations
- Replacement materials
- Multiple experiments for different age groups

Fig. 17: Team 16's Kit

- Cannot disassemble
- Cheap material components
- No replacement parts
- No emphasis on optimization with flow channel
- One simplistic experiment
- Case is not transportable
- Cost $395

Fig. 18: Dr. FuelCell

Summary

- Parallel configuration is the most efficient with a max power output of 0.36 W
- Fuel cell reached average temperatures of 62°C after 10 minutes of testing
- The kit can be used effectively as a learning tool as early as 6th grade, with significant applications during collegiate academia
- Good material selection leads to longevity use of the kit and successful commercialization
- Fuel cells can be incorporated into other green energy systems.

Fig. 19: Team 16 kit and Brazil team kit

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Design and Development of AMFC Kit

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.

Questions