# Comparing Alternate Power Sources on Overall Efficiency

By: Derek Calderara

Submitted to:
Frank LaBanca, Program Director
Newtown High School Applied Science Research Program
6/15/06

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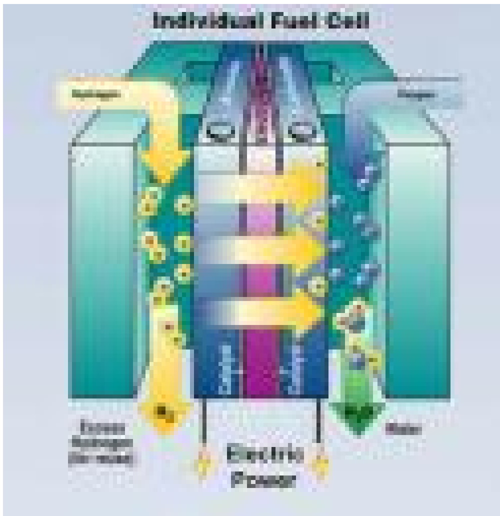
# Abstract

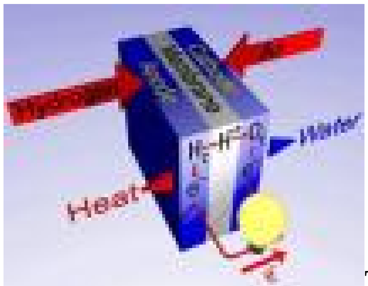
The recent energy crisis has caused a drastic increase in the search for alternate, more abundant forms of energy. Gas prices have sky rocketed in recent years, and it has become imperative for a new form of energy to be found. Not just a cheaper one, but also a cleaner one to help protect earths already damaged O-zone layer. The aim of this project will be to examine an alternate power source and determine whether or not it can efficiently replace the power of old. The alternate power source being used will be a PEM fuel cell that can generate up to three volts. Since fuel cells only use hydrogen gas to power them, and their only waste is water, they are the perfect subject for this project. The fuel cell will be attempting to replace a standard, three volt battery in an ordinary object, or in this case, an electric powered Crossman airsoft BB gun. By replacing the guns original battery with the fuel cell, it can be determined whether or not a fuel cell can efficiently replace a battery. This will be measured using Vernier Software's LoggerPro software and LabPro sampling apparatus. By attaching the fuel cell to the probes of the LabPro, the current can be measured via computer and put in to tangible numbers and graphed. So using these materials, this project will hopefully support the idea of using fuel cells as a new source of power with substantial evidence.

# Introduction



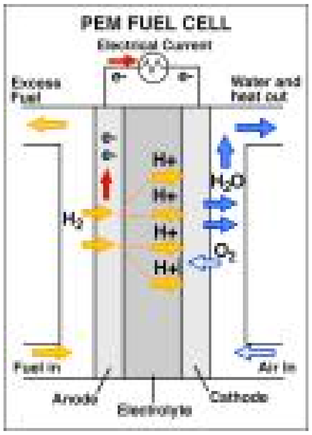

A fuel cell creates electricity using hydrogen and oxygen with different catalysts. The fuel cell harnesses chemical energy trapped in hydrogen gas and converts it into kinetic energy (electricity), without using fossil fuels or creating combustion or pollution. As an efficient, remarkably clean source of renewable energy, fuel cells can take the place of both batteries and engines to power vehicles, laptops, residential power grids, etc. The technology of fuel cells has been well researched and developed. Economic and political reasons have prevented widespread implementation. A clean power source, as part of a widespread hydrogen economy, guarantees less dependence on the dwindling supplies of fossil fuels.  It creates less greenhouse gases that contribute to global climate change, and does not explode or malfunction as frequently as engine-driven electricity.

Chemically, a fuel cell takes in hydrogen and oxygen, creates electricity, and produces by products of water and heat. The outside layers of a fuel cell are the anode plate, with a positive charge, and the cathode plate, with a negative charge. Together with the center electrolyte plate, they are catalytic environments that encourage certain electrochemical functions. The anode separates hydrogen into protons and electrons.




The electrons flow along a path, producing electrical current for a circuit. The protons move through the electrolyte to the cathode. The cathode combines oxygen with protons, as well as collecting some of the electrons in the circuit, to recombine them into water. The cathode allows water, and extra heat, to be used as additional sources of energy. Unlike at a gas station, an independent hydrogen supply doesn’t need to be the sole source of fuel in a fuel cell. In fact, one can run on rotting organic material, like vegetation, because that gives off hydrogen, too. Or hydrogen might be separated from oxygen out of water, through electrolysis, by solar or wind power. If water is used as a source of hydrogen, the fuel cell is practically immortal, as it continues the cycle from water to hydrogen to water.

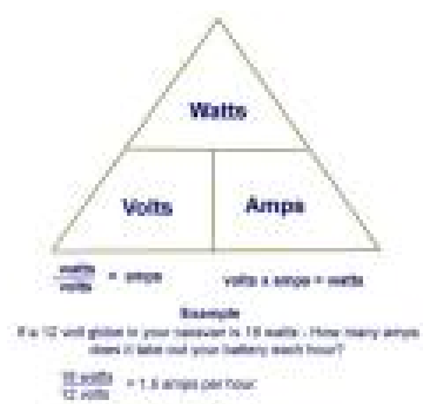
A fuel cell is flexible because it can be small and portable or larger and permanent. The cost to convert to a fuel cell-driven power grid may initially be high, but over time it will significantly reduce the costs of maintenance, repair, and fuel compared to conventional electricity generators. If one can use the resulting heat, say, to warm a house during winter, the fuel cell becomes even more cost effective.




( Christian Friedrich Schönbein)

The idea of the fuel cell was first discovered by Swiss scientist Christian Friedrich Schönbein in 1838 and was published on January 1839 in the "Philosophical Magazine". Based on this work, the first fuel cell was developed by Welsh scientist Sir William Grove. A sketch was published in 1843, but until 1959 it wasn't developed successfully. British engineer Francis Thomas Bacon was the first to do that. In 1959, a team led by Harry Ihrig built a 15 kW fuel cell tractor for Allis-Chalmers that was demonstrated across the US at state fairs. This system used potassium hydroxide as the electrolyte and compressed hydrogen and oxygen as the reactants. Later, in 1959, Bacon and his colleagues demonstrated a five-kilowatt fuel cell unit capable of powering a welding machine, which led, in the 1960s, to Bacon's patents being licensed by Pratt and Whitney from the U.S. where the concepts were used in the U.S. space program to supply electricity and drinking water.  Extremely expensive materials were used and the fuel cells required very pure hydrogen and oxygen. Early fuel cells needed to have very high operating temperatures that were a problem in many cases. However, fuel cells were seen to be desirable due to the large amounts of fuel(hydrogen & oxygen) available. Further advances in the 1980s - 90s, such as reductions in the quantity of expensive materials, have made the prospect of fuel cells in consumer applications such as automobiles much more realistic.

The average fuel cell is 80% more efficient that a gasoline powered vehicle and 30-40% more efficient than a battery powered car. Although the cost of a fuel cell car is still comparatively expensive, the price for materials is rapidly dropping.  For example, the amount of platinum needed for a fuel cell large enough to power an auto has been dramatically reduced from $30,000 to $500.  In order to compare the efficiency of a fuel cell to a battery, the measurements are required.  The units used to measure the amount of power produced are Amps ( A ), Volts ( V ) and Watts ( W ).  An amp, or ampere, is the unit of electrical current being used.  A volt is the electrical potential difference between two points in a circuit. The fundamental unit is derived as work per unit charge-(V = W/Q). One volt is the potential difference required to move one coulomb of charge between two points in a circuit while using one joule of energy.  A coulomb is the amount of electricity transported by a current of one ampere flowing for one second.  A watt is the unit for measuring electrical power. It defines the rate of energy consumption by an electrical device when it is in operation. The energy cost of operating an electrical device is calculated as its wattage multiplied by the hours of use. In single phase circuits, the energy is related to volts and amps by the formula: Volts x Amps x PF = Watts.

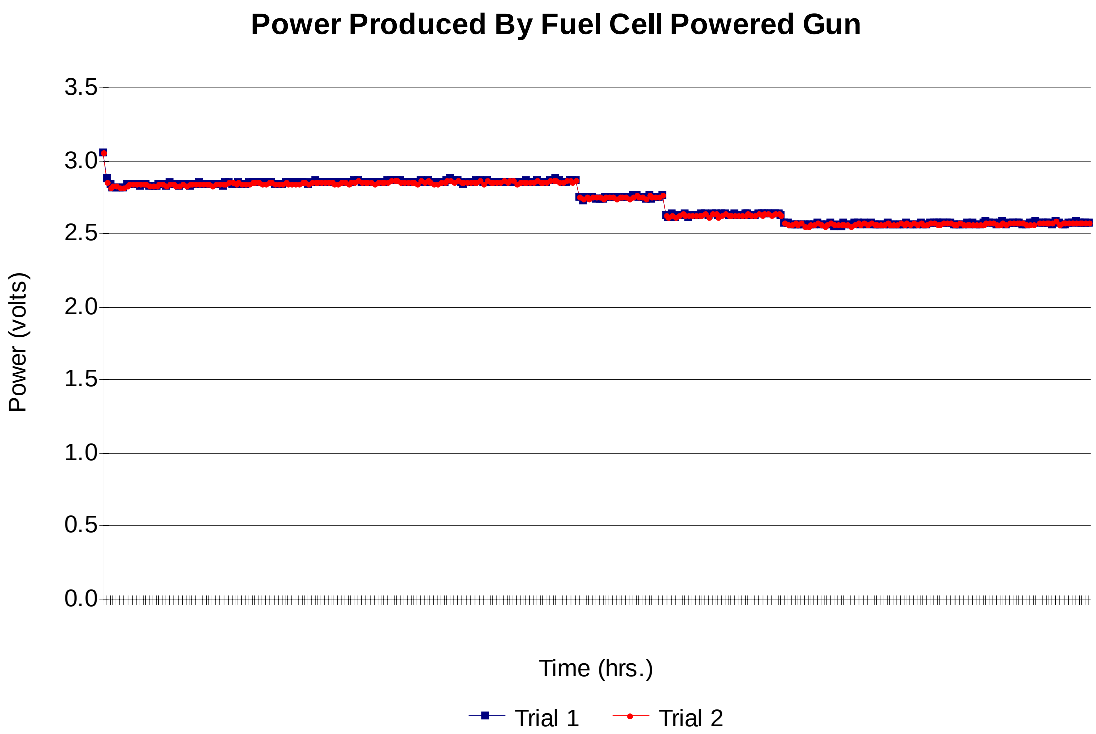


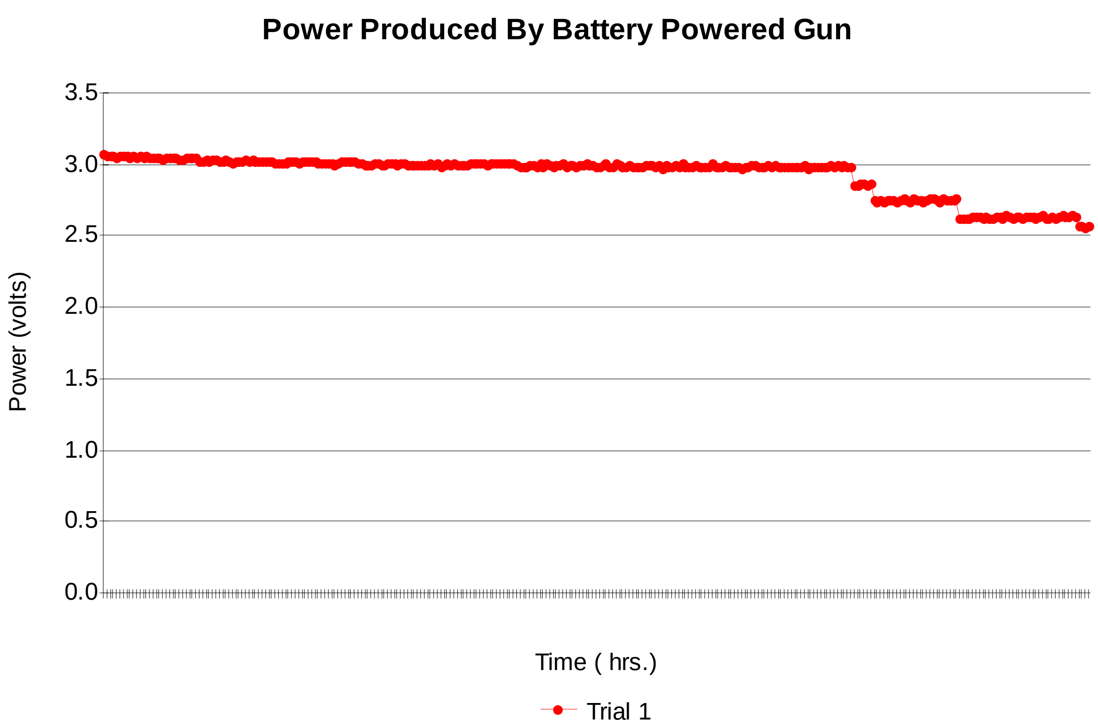
# Materials and Methods

| Chemicals/Consumables | Supplies | Equipment |
|---|---|---|
| • Hydrogen Gas<br>• Oxygen Gas<br>• Distilled Water | • Alligator Clips<br>• Test tubes<br>• Heat Sink<br>• Sun Lamp<br>• Notebook<br>• 1mm hose<br>• Wire cutters<br>• Pliers<br>• Screwdriver | • Fuel Cell Car Kit<br>• Crossman Stinger R-150 Airsoft gun<br>• Multimeter<br>• Solar Panel<br>• LoggerPro Software<br>• LabPro Sampling Apparatus<br>• Crossman gun Battery |

First, assemble the fuel cell and perform the necessary experiments in the included lab book until knowledge on how a fuel cell works is adequate. Next, fill the fuel cell with distilled water, using a syringe so no air bubbles form. Using the solar panel, perform electrolysis in the fuel cell to create hydrogen gas. Set up the air soft gun to measure the power consumed by the battery using the Lab Pro and Logger Pro software, which should be installed properly on a computer before its use. Attach the battery to the gun and the wire probes of the Lab Pro to the battery. Set the sampling time on the software to 1 1/2 hours and samples per hour to 200. Press “collect”. When the Lab Pro is finished taking data, unplug the battery and attach the fuel cell to the gun. Now, attach the wire probes of the Lab Pro to the metal plates next to the fuel cell using alligator clamps. Set the sampling time on the software to 2 hours and samples per hour to 200. Press “collect”. Repeat this step for as many trials as needed. When finished, copy and paste the data into a spreadsheet to assure that it is not lost.

# Results


Power Produced By Fuel Cell Powered Gun
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Power (volts)
Time (hrs.)
Trial 1
Trial 2


Power Produced By Battery Powered Gun
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Power (volts)
Time ( hrs.)
Trial 1

Fuel Cell Powered Gun

| Time (hrs.) | Trial 1 | Trial 2 | | | |
|---|---|---|---|---|---|
| 0 | 3.062 | 3.057 | 0.26 | 2.842 | 2.847 |
| 0.005 | 2.881 | 2.852 | 0.265 | 2.847 | 2.842 |
| 0.01 | 2.837 | 2.822 | 0.27 | 2.847 | 2.842 |
| 0.015 | 2.817 | 2.827 | 0.275 | 2.861 | 2.861 |
| 0.02 | 2.822 | 2.827 | 0.28 | 2.852 | 2.842 |
| 0.025 | 2.817 | 2.817 | 0.285 | 2.852 | 2.842 |
| 0.03 | 2.822 | 2.822 | 0.29 | 2.852 | 2.842 |
| 0.035 | 2.842 | 2.832 | 0.295 | 2.852 | 2.847 |
| 0.04 | 2.842 | 2.842 | 0.3 | 2.852 | 2.852 |
| 0.045 | 2.842 | 2.837 | 0.305 | 2.861 | 2.852 |
| 0.05 | 2.842 | 2.837 | 0.31 | 2.847 | 2.842 |
| 0.055 | 2.832 | 2.837 | 0.315 | 2.856 | 2.861 |
| 0.06 | 2.847 | 2.847 | 0.32 | 2.866 | 2.861 |
| 0.065 | 2.847 | 2.842 | 0.325 | 2.861 | 2.856 |
| 0.07 | 2.827 | 2.827 | 0.33 | 2.856 | 2.852 |
| 0.075 | 2.832 | 2.827 | 0.335 | 2.856 | 2.852 |
| 0.08 | 2.832 | 2.832 | 0.34 | 2.852 | 2.856 |
| 0.085 | 2.842 | 2.842 | 0.345 | 2.861 | 2.861 |
| 0.09 | 2.847 | 2.847 | 0.35 | 2.852 | 2.837 |
| 0.095 | 2.827 | 2.832 | 0.355 | 2.852 | 2.847 |
| 0.1 | 2.852 | 2.847 | 0.36 | 2.856 | 2.852 |
| 0.105 | 2.842 | 2.837 | 0.365 | 2.852 | 2.852 |
| 0.11 | 2.837 | 2.832 | 0.37 | 2.852 | 2.847 |
| 0.115 | 2.832 | 2.832 | 0.375 | 2.856 | 2.861 |
| 0.12 | 2.837 | 2.837 | 0.38 | 2.871 | 2.861 |
| 0.125 | 2.842 | 2.832 | 0.385 | 2.871 | 2.866 |
| 0.13 | 2.832 | 2.837 | 0.39 | 2.856 | 2.861 |
| 0.135 | 2.837 | 2.842 | 0.395 | 2.861 | 2.856 |
| 0.14 | 2.842 | 2.842 | 0.4 | 2.861 | 2.852 |
| 0.145 | 2.856 | 2.847 | 0.405 | 2.861 | 2.856 |
| 0.15 | 2.842 | 2.837 | 0.41 | 2.861 | 2.847 |
| 0.155 | 2.842 | 2.842 | 0.415 | 2.856 | 2.852 |
| 0.16 | 2.837 | 2.837 | 0.42 | 2.852 | 2.852 |
| 0.165 | 2.837 | 2.832 | 0.425 | 2.861 | 2.856 |
| 0.17 | 2.847 | 2.837 | 0.43 | 2.871 | 2.861 |
| 0.175 | 2.842 | 2.837 | 0.435 | 2.871 | 2.866 |
| 0.18 | 2.832 | 2.837 | 0.44 | 2.871 | 2.871 |
| 0.185 | 2.852 | 2.842 | 0.445 | 2.871 | 2.871 |
| 0.19 | 2.856 | 2.856 | 0.45 | 2.866 | 2.861 |
| 0.195 | 2.847 | 2.856 | 0.455 | 2.856 | 2.852 |
| 0.2 | 2.837 | 2.842 | 0.46 | 2.861 | 2.852 |
| 0.205 | 2.852 | 2.852 | 0.465 | 2.861 | 2.856 |
| 0.21 | 2.842 | 2.847 | 0.47 | 2.852 | 2.852 |
| 0.215 | 2.842 | 2.842 | 0.475 | 2.852 | 2.847 |
| 0.22 | 2.852 | 2.847 | 0.48 | 2.866 | 2.866 |
| 0.225 | 2.856 | 2.852 | 0.485 | 2.856 | 2.852 |
| 0.23 | 2.861 | 2.856 | 0.49 | 2.871 | 2.871 |
| 0.235 | 2.861 | 2.856 | 0.495 | 2.861 | 2.861 |
| 0.24 | 2.852 | 2.847 | 0.5 | 2.852 | 2.847 |
| 0.245 | 2.852 | 2.842 | 0.505 | 2.856 | 2.842 |
| 0.25 | 2.852 | 2.852 | 0.51 | 2.856 | 2.852 |
| 0.255 | 2.861 | 2.856 | 0.515 | 2.861 | 2.861 |

| | | | | | |
|---|---|---|---|---|---|
| 0.52 | 2.866 | 2.871 | 0.8 | 2.764 | 2.754 |
| 0.525 | 2.876 | 2.866 | 0.805 | 2.773 | 2.769 |
| 0.53 | 2.866 | 2.861 | 0.81 | 2.759 | 2.759 |
| 0.535 | 2.866 | 2.871 | 0.815 | 2.759 | 2.749 |
| 0.54 | 2.861 | 2.861 | 0.82 | 2.739 | 2.744 |
| 0.545 | 2.847 | 2.852 | 0.825 | 2.769 | 2.764 |
| 0.55 | 2.856 | 2.856 | 0.83 | 2.744 | 2.749 |
| 0.555 | 2.856 | 2.861 | 0.835 | 2.754 | 2.749 |
| 0.56 | 2.861 | 2.861 | 0.84 | 2.754 | 2.754 |
| 0.565 | 2.866 | 2.856 | 0.845 | 2.769 | 2.764 |
| 0.57 | 2.871 | 2.871 | 0.85 | 2.627 | 2.627 |
| 0.575 | 2.856 | 2.847 | 0.855 | 2.617 | 2.617 |
| 0.58 | 2.871 | 2.871 | 0.86 | 2.637 | 2.627 |
| 0.585 | 2.856 | 2.861 | 0.865 | 2.617 | 2.617 |
| 0.59 | 2.852 | 2.856 | 0.87 | 2.627 | 2.632 |
| 0.595 | 2.856 | 2.861 | 0.875 | 2.632 | 2.637 |
| 0.6 | 2.856 | 2.856 | 0.88 | 2.637 | 2.632 |
| 0.605 | 2.856 | 2.866 | 0.885 | 2.617 | 2.622 |
| 0.61 | 2.861 | 2.852 | 0.89 | 2.627 | 2.632 |
| 0.615 | 2.856 | 2.866 | 0.895 | 2.627 | 2.627 |
| 0.62 | 2.861 | 2.866 | 0.9 | 2.627 | 2.627 |
| 0.625 | 2.856 | 2.847 | 0.905 | 2.642 | 2.632 |
| 0.63 | 2.861 | 2.861 | 0.91 | 2.637 | 2.637 |
| 0.635 | 2.856 | 2.861 | 0.915 | 2.627 | 2.617 |
| 0.64 | 2.866 | 2.861 | 0.92 | 2.637 | 2.642 |
| 0.645 | 2.852 | 2.852 | 0.925 | 2.637 | 2.637 |
| 0.65 | 2.861 | 2.856 | 0.93 | 2.632 | 2.617 |
| 0.655 | 2.871 | 2.866 | 0.935 | 2.637 | 2.632 |
| 0.66 | 2.861 | 2.861 | 0.94 | 2.642 | 2.637 |
| 0.665 | 2.861 | 2.852 | 0.945 | 2.627 | 2.627 |
| 0.67 | 2.856 | 2.861 | 0.95 | 2.632 | 2.632 |
| 0.675 | 2.866 | 2.871 | 0.955 | 2.637 | 2.632 |
| 0.68 | 2.871 | 2.871 | 0.96 | 2.632 | 2.632 |
| 0.685 | 2.876 | 2.871 | 0.965 | 2.632 | 2.627 |
| 0.69 | 2.866 | 2.856 | 0.97 | 2.637 | 2.632 |
| 0.695 | 2.852 | 2.852 | 0.975 | 2.642 | 2.642 |
| 0.7 | 2.861 | 2.866 | 0.98 | 2.627 | 2.622 |
| 0.705 | 2.866 | 2.866 | 0.985 | 2.622 | 2.622 |
| 0.71 | 2.871 | 2.856 | 0.99 | 2.642 | 2.637 |
| 0.715 | 2.871 | 2.866 | 0.995 | 2.637 | 2.627 |
| 0.72 | 2.754 | 2.754 | 1 | 2.642 | 2.637 |
| 0.725 | 2.734 | 2.739 | 1.005 | 2.642 | 2.642 |
| 0.73 | 2.754 | 2.754 | 1.01 | 2.637 | 2.632 |
| 0.735 | 2.749 | 2.744 | 1.015 | 2.642 | 2.637 |
| 0.74 | 2.759 | 2.754 | 1.02 | 2.646 | 2.642 |
| 0.745 | 2.739 | 2.749 | 1.025 | 2.627 | 2.632 |
| 0.75 | 2.739 | 2.749 | 1.03 | 2.578 | 2.573 |
| 0.755 | 2.739 | 2.739 | 1.035 | 2.578 | 2.568 |
| 0.76 | 2.749 | 2.749 | 1.04 | 2.568 | 2.563 |
| 0.765 | 2.759 | 2.759 | 1.045 | 2.563 | 2.573 |
| 0.77 | 2.759 | 2.754 | 1.05 | 2.568 | 2.568 |
| 0.775 | 2.749 | 2.739 | 1.055 | 2.563 | 2.573 |
| 0.78 | 2.759 | 2.759 | | | |
| 0.785 | 2.749 | 2.754 | 1.06 | 2.559 | 2.554 |
| 0.79 | 2.754 | 2.754 | 1.065 | 2.559 | 2.554 |
| 0.795 | 2.749 | 2.744 | 1.07 | 2.568 | 2.559 |

| | | | | | |
|---|---|---|---|---|---|
| 1.075 | 2.568 | 2.559 | 1.285 | 2.563 | 2.563 |
| 1.08 | 2.578 | 2.578 | 1.29 | 2.568 | 2.563 |
| 1.085 | 2.563 | 2.563 | 1.295 | 2.568 | 2.578 |
| 1.09 | 2.559 | 2.554 | 1.3 | 2.568 | 2.568 |
| 1.095 | 2.563 | 2.563 | 1.305 | 2.578 | 2.568 |
| 1.1 | 2.578 | 2.573 | 1.31 | 2.568 | 2.563 |
| 1.105 | 2.554 | 2.563 | 1.315 | 2.573 | 2.563 |
| 1.11 | 2.563 | 2.559 | 1.32 | 2.563 | 2.568 |
| 1.115 | 2.554 | 2.563 | 1.325 | 2.563 | 2.568 |
| 1.12 | 2.573 | 2.559 | 1.33 | 2.573 | 2.563 |
| 1.125 | 2.568 | 2.563 | 1.335 | 2.588 | 2.583 |
| 1.13 | 2.563 | 2.554 | 1.34 | 2.583 | 2.573 |
| 1.135 | 2.573 | 2.568 | 1.345 | 2.578 | 2.573 |
| 1.14 | 2.573 | 2.573 | 1.35 | 2.568 | 2.568 |
| 1.145 | 2.563 | 2.568 | 1.355 | 2.573 | 2.568 |
| 1.15 | 2.578 | 2.573 | 1.36 | 2.588 | 2.583 |
| 1.155 | 2.568 | 2.568 | 1.365 | 2.563 | 2.568 |
| 1.16 | 2.578 | 2.573 | 1.37 | 2.578 | 2.578 |
| 1.165 | 2.568 | 2.568 | 1.375 | 2.573 | 2.573 |
| 1.17 | 2.563 | 2.563 | 1.38 | 2.573 | 2.578 |
| 1.175 | 2.568 | 2.563 | 1.385 | 2.573 | 2.573 |
| 1.18 | 2.563 | 2.568 | 1.39 | 2.568 | 2.573 |
| 1.185 | 2.578 | 2.578 | 1.395 | 2.563 | 2.568 |
| 1.19 | 2.568 | 2.568 | 1.4 | 2.573 | 2.563 |
| 1.195 | 2.563 | 2.563 | 1.405 | 2.578 | 2.568 |
| 1.2 | 2.559 | 2.559 | 1.41 | 2.593 | |
| 1.205 | 2.568 | 2.573 | 1.415 | 2.573 | 2.578 |
| 1.21 | 2.563 | 2.568 | 1.42 | 2.573 | 2.573 |
| 1.215 | 2.578 | 2.573 | 1.425 | 2.583 | 2.583 |
| 1.22 | 2.568 | 2.563 | 1.43 | 2.573 | 2.578 |
| 1.225 | 2.568 | 2.573 | 1.435 | 2.568 | 2.578 |
| 1.23 | 2.563 | 2.568 | 1.44 | 2.588 | 2.588 |
| 1.235 | 2.583 | 2.583 | 1.445 | 2.573 | 2.563 |
| 1.24 | 2.563 | 2.559 | 1.45 | 2.568 | 2.573 |
| 1.245 | 2.563 | 2.568 | 1.455 | 2.568 | 2.573 |
| 1.25 | 2.578 | 2.583 | 1.46 | 2.578 | 2.578 |
| 1.255 | 2.573 | 2.578 | 1.465 | 2.573 | 2.583 |
| 1.26 | 2.573 | 2.568 | 1.47 | 2.588 | 2.578 |
| 1.265 | 2.573 | 2.568 | 1.475 | 2.573 | 2.573 |
| 1.27 | 2.573 | 2.578 | 1.48 | 2.578 | 2.578 |
| 1.275 | 2.578 | 2.578 | 1.485 | 2.578 | 2.578 |
| 1.28 | 2.573 | 2.578 | 1.49 | 2.578 | 2.578 |

Battery Powered Gun

| Time (hrs.) | Trial 1 |
|---|---|
| 0 | 3.071 |
| 0.005 | 3.066 |
| 0.01 | 3.062 |
| 0.015 | 3.062 |
| 0.02 | 3.052 |
| 0.025 | 3.057 |
| 0.03 | 3.057 |
| 0.035 | 3.057 |
| 0.04 | 3.052 |
| 0.045 | 3.057 |
| 0.05 | 3.052 |
| 0.055 | 3.057 |
| 0.06 | 3.047 |
| 0.065 | 3.057 |
| 0.07 | 3.047 |
| 0.075 | 3.042 |
| 0.08 | 3.052 |
| 0.085 | 3.052 |
| 0.09 | 3.032 |
| 0.095 | 3.047 |
| 0.1 | 3.047 |
| 0.105 | 3.047 |
| 0.11 | 3.047 |
| 0.115 | 3.032 |
| 0.12 | 3.032 |
| 0.125 | 3.042 |
| 0.13 | 3.042 |
| 0.135 | 3.047 |
| 0.14 | 3.042 |
| 0.145 | 3.027 |
| 0.15 | 3.027 |
| 0.155 | 3.037 |
| 0.16 | 3.022 |
| 0.165 | 3.032 |
| 0.17 | 3.032 |
| 0.175 | 3.018 |
| 0.18 | 3.022 |
| 0.185 | 3.037 |
| 0.19 | 3.027 |
| 0.195 | 3.013 |
| 0.2 | 3.022 |
| 0.205 | 3.018 |
| 0.21 | 3.018 |
| 0.215 | 3.032 |
| 0.22 | 3.027 |
| 0.225 | 3.032 |
| 0.23 | 3.027 |
| 0.235 | 3.022 |
| 0.24 | 3.022 |
| 0.245 | 3.027 |
| 0.25 | 3.022 |
| 0.255 | 3.018 |
| 0.26 | 3.013 |
| 0.265 | 3.008 |
| 0.27 | 3.013 |
| 0.275 | 3.008 |
| 0.28 | 3.022 |
| 0.285 | 3.027 |
| 0.29 | 3.018 |
| 0.295 | 3.013 |
| 0.3 | 3.018 |
| 0.305 | 3.022 |
| 0.31 | 3.018 |
| 0.315 | 3.018 |
| 0.32 | 3.018 |
| 0.325 | 3.008 |
| 0.33 | 3.013 |
| 0.335 | 3.013 |
| 0.34 | 3.013 |
| 0.345 | 3.003 |
| 0.35 | 2.998 |
| 0.355 | 3.013 |
| 0.36 | 3.018 |
| 0.365 | 3.018 |
| 0.37 | 3.018 |
| 0.375 | 3.018 |
| 0.38 | 3.018 |
| 0.385 | 3.013 |
| 0.39 | 3.008 |
| 0.395 | 2.998 |
| 0.4 | 2.998 |
| 0.405 | 2.993 |
| 0.41 | 3.003 |
| 0.415 | 3.003 |
| 0.42 | 2.998 |
| 0.425 | 2.998 |
| 0.43 | 3.003 |
| 0.435 | 3.013 |
| 0.44 | 3.008 |
| 0.445 | 2.993 |
| 0.45 | 3.003 |
| 0.455 | 3.013 |
| 0.46 | 2.993 |
| 0.465 | 2.993 |
| 0.47 | 2.998 |
| 0.475 | 2.993 |
| 0.48 | 2.998 |
| 0.485 | 2.993 |
| 0.49 | 2.998 |
| 0.495 | 3.008 |
| 0.5 | 2.993 |
| 0.505 | 3.013 |
| 0.51 | 2.988 |
| 0.515 | 2.993 |
| 0.52 | 3.008 |

| | | | |
|---|---|---|---|
| 0.525 | 2.998 | 0.805 | 2.979 |
| 0.53 | 3.013 | 0.81 | 2.983 |
| 0.535 | 2.998 | 0.815 | 2.988 |
| 0.54 | 2.993 | 0.82 | 2.993 |
| 0.545 | 2.998 | 0.825 | 2.993 |
| 0.55 | 2.998 | 0.83 | 2.993 |
| 0.555 | 3.013 | 0.835 | 2.979 |
| 0.56 | 3.008 | 0.84 | 2.993 |
| 0.565 | 3.003 | 0.845 | 2.974 |
| 0.57 | 3.003 | 0.85 | 2.998 |
| 0.575 | 3.003 | 0.855 | 2.983 |
| 0.58 | 2.998 | 0.86 | 2.983 |
| 0.585 | 3.003 | 0.865 | 2.993 |
| 0.59 | 3.003 | 0.87 | 2.988 |
| 0.595 | 3.008 | 0.875 | 3.003 |
| 0.6 | 3.008 | 0.88 | 2.988 |
| 0.605 | 3.008 | 0.885 | 2.983 |
| 0.61 | 3.003 | 0.89 | 2.988 |
| 0.615 | 3.008 | 0.895 | 2.993 |
| 0.62 | 3.003 | 0.9 | 2.988 |
| 0.625 | 2.993 | 0.905 | 2.979 |
| 0.63 | 2.988 | 0.91 | 2.988 |
| 0.635 | 2.979 | 0.915 | 2.979 |
| 0.64 | 2.988 | 0.92 | 3.003 |
| 0.645 | 2.993 | 0.925 | 2.979 |
| 0.65 | 2.998 | 0.93 | 2.988 |
| 0.655 | 2.983 | 0.935 | 2.983 |
| 0.66 | 3.003 | 0.94 | 2.998 |
| 0.665 | 2.983 | 0.945 | 2.983 |
| 0.67 | 3.008 | 0.95 | 2.983 |
| 0.675 | 2.998 | 0.955 | 2.988 |
| 0.68 | 2.988 | 0.96 | 2.988 |
| 0.685 | 2.993 | 0.965 | 2.974 |
| 0.69 | 2.993 | 0.97 | 2.988 |
| 0.695 | 3.003 | 0.975 | 2.983 |
| 0.7 | 2.988 | 0.98 | 2.998 |
| 0.705 | 2.998 | 0.985 | 2.993 |
| 0.71 | 2.993 | 0.99 | 2.979 |
| 0.715 | 2.988 | 0.995 | 2.983 |
| 0.72 | 2.998 | 1 | 2.988 |
| 0.725 | 2.998 | 1.005 | 2.993 |
| 0.73 | 3.003 | 1.01 | 2.983 |
| 0.735 | 2.998 | 1.015 | 2.993 |
| 0.74 | 2.998 | 1.02 | 2.988 |
| 0.745 | 2.983 | 1.025 | 2.988 |
| 0.75 | 2.988 | 1.03 | 2.983 |
| 0.755 | 2.998 | 1.035 | 2.988 |
| 0.76 | 3.003 | 1.04 | 2.983 |
| 0.765 | 2.988 | 1.045 | 2.979 |
| 0.77 | 2.988 | 1.05 | 2.983 |
| 0.775 | 3.003 | 1.055 | 2.983 |
| 0.78 | 2.993 | 1.06 | 2.993 |
| 0.785 | 2.983 | 1.065 | 2.974 |
| 0.79 | 2.988 | 1.07 | 2.979 |
| 0.795 | 2.993 | 1.075 | 2.983 |
| 0.8 | 2.983 | 1.08 | 2.979 |

| | |
|---|---|
| 1.085 | 2.983 |
| 1.09 | 2.988 |
| 1.095 | 2.979 |
| 1.1 | 2.993 |
| 1.105 | 2.979 |
| 1.11 | 2.993 |
| 1.115 | 2.979 |
| 1.12 | 2.993 |
| 1.125 | 2.979 |
| 1.13 | 2.988 |
| 1.135 | 2.856 |
| 1.14 | 2.852 |
| 1.145 | 2.866 |
| 1.15 | 2.866 |
| 1.155 | 2.856 |
| 1.16 | 2.866 |
| 1.165 | 2.754 |
| 1.17 | 2.739 |
| 1.175 | 2.754 |
| 1.18 | 2.744 |
| 1.185 | 2.754 |
| 1.19 | 2.749 |
| 1.195 | 2.749 |
| 1.2 | 2.739 |
| 1.205 | 2.749 |
| 1.21 | 2.759 |
| 1.215 | 2.754 |
| 1.22 | 2.739 |
| 1.225 | 2.759 |
| 1.23 | 2.754 |
| 1.235 | 2.754 |
| 1.24 | 2.744 |
| 1.245 | 2.754 |
| 1.25 | 2.769 |
| 1.255 | 2.759 |
| 1.26 | 2.749 |
| 1.265 | 2.744 |
| 1.27 | 2.764 |
| 1.275 | 2.749 |
| 1.28 | 2.749 |
| 1.285 | 2.754 |
| 1.29 | 2.764 |
| 1.295 | 2.627 |
| 1.3 | 2.617 |
| 1.305 | 2.627 |
| 1.31 | 2.617 |
| 1.315 | 2.632 |
| 1.32 | 2.637 |
| 1.325 | 2.632 |
| 1.33 | 2.622 |
| 1.335 | 2.632 |
| 1.34 | 2.627 |
| 1.345 | 2.627 |
| 1.35 | 2.632 |
| 1.355 | 2.637 |
| 1.36 | 2.617 |
| 1.365 | 2.642 |
| 1.37 | 2.637 |
| 1.375 | 2.617 |
| 1.38 | 2.632 |
| 1.385 | 2.637 |
| 1.39 | 2.627 |
| 1.395 | 2.632 |
| 1.4 | 2.632 |
| 1.405 | 2.632 |
| 1.41 | 2.627 |
| 1.415 | 2.632 |
| 1.42 | 2.642 |
| 1.425 | 2.622 |
| 1.43 | 2.622 |
| 1.435 | 2.637 |
| 1.44 | 2.627 |
| 1.445 | 2.637 |
| 1.45 | 2.642 |
| 1.455 | 2.632 |
| 1.46 | 2.637 |
| 1.465 | 2.642 |
| 1.47 | 2.632 |
| 1.475 | 2.573 |
| 1.48 | 2.568 |
| 1.485 | 2.563 |
| 1.49 | 2.573 |

# Conclusions

The first trial attempt to run the gun on the fuel cell was not successful. Upon completing electrolysis in the fuel cell, I found that one of the alligator clips connecting the gun wires to the fuel cell and solar panel. After correcting this problem, the second trial went much better. Unfortunately, as can be seen by the data shown, the fuel cell was not as efficient as the original battery. The experiment was run for two 1 1/2 hour trials. The battery powered gun stayed at a constant power, about 3 volts, for the majority of the time. The fuel cell on the other hand, began to lose power after only 1 hour. Although the data favors the battery over the fuel cell, it does not mean that the fuel cell did not work at all. It did lose more power, but it was only tenths of a volt which is not a huge lose of power. So technically, a fuel cell could still possibly replace a battery. Perhaps with some new, better developed technology for creating the fuel cell, it will surpass the battery in efficiency and will start a new, more clean way of living.

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