HHO A VIABLE FOSSIL FUEL ADDITIVE

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Methods and Applications Final

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Abstract

This paper explores current HHO technologies. It concludes with the findings that an HHO cell is a viable alternative for further exploration and experimentation. Further, it finds that the cost of electric production is high in the previous experiment due to the nature of HHO cells to have a high current draw at voltages at or around auto batteries and charging systems. Alternative voltages of 30 volts or higher are recommended for use. Further findings include alternating current to be acceptable only when put through a half or full wave rectifier to create a pulse. Constant d.c. voltages are shown to have too high a cost in heat production so a pulse is recommended. An HHO cell can be tuned to have very little or even 0 current draw when the frequency of the pulse is adjusted. In this experiment, it was found that a voltage of about 30 volts at 22440 Hz was sufficient to produce 28 mL of gas per minute with a very small HHO cell that cost less than 20 dollars to produce. Finally, this technology is recommended for further study, but is not recommended for continual used as better alternatives are available.

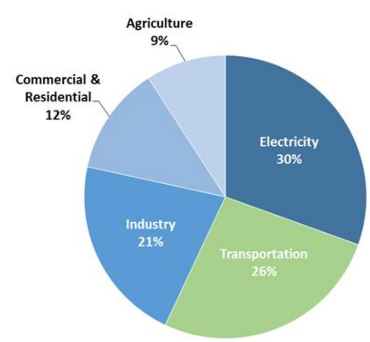
Keywords: HHO, Hydroxy, Hydroxyl, Browns Gas, Gas Cell, fuel from water, alternative fuels.

LIST OF ABBREVIATIONS AND NOMENCLATURE

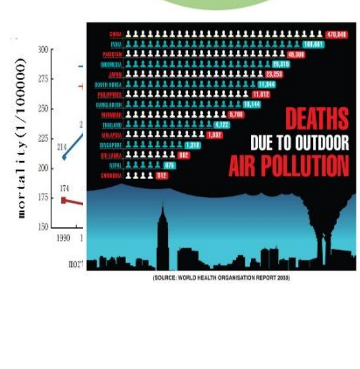
HHO : Hydroxy, Hydroxyl, BG Browns Gas, SI : Spark Ignition, CI : Compression Ignition, LPG : Liquefied Petroleum Gas, CO : Carbon monoxide, HC : Hydrocarbon, CO_2 : Carbon dioxide, NOx : Nitrogen oxide, HEV : Hybrid Electric Vehicle, H2ICE : Hydrogen fueled Internal Combustion Engine, KOH : Potassium Hydroxide, NaOH : Sodium Hydroxide, NaCl : Sodium Chloride, EEW: : Electrically Expanded Water W : Watt, SFC : Specific Fuel Consumption, HECU : Hydroxy Electronic Control Unit, TDC : Top Dead Center BDC : Bottom Dead Center, EEPROM : Electrically Erasable Programmable Read-Only Memory, F : Force, T : Torque, rev. : Revolution, Pb : Brake Power, bmep : Brake Mean Effective Pressure BSFC : Brake Specific Fuel Consumption, bth h : Thermal Efficiency, CR : Compression Ratio, AFR : Air-Fuel Ratio, EGR : Exhaust Gas Recirculation, rpm : Revolutions Per Minute, CATIA : Computer Aided Three-dimensional Interactive Application, V : Volt, A : Ampere, CCM : Cubic Centimeters per Minute, SLM : Standard Liters per Minute, DC : Direct Current, AC : Alternating Current mF : Micro Farad, MOSFET : Metal Oxide Semiconductor Field Effect Transistor, PWM : Pulse Width Modulation, f : Frequency, MAP : Manifold Absolute Pressure, ADC: Analog to Digital Converter, DAC: Digital to analog converter, PLC: Programmable Logic Controller, STP: Standard temperature and pressure: 298.15 K, 101.325 kPa

Introduction

Any business person will tell you that the problem with dependence on any non-renewable energy source such as fossil fuels is that it has no sustainability and thus in the long term it is a strategically bad plan. At best such efforts are a race, the dash for the cash until such resources run dry. We in the U.S. have, never the less chose fossil fuels as our main source of energy and use it in a spectrum ranging from the creating of electricity to travel we even use it to make our drinking glasses. Unfortunately, too often we dismiss evidence linking climate change to fossil fuel consumption. It has been so gradual that many believe it not to be true. Many are blinded to change in order to keep the common comforts. It is hard to imagine that as little as 100 years ago electric power and the internal combustion engine (ICE) was rarely heard of. Many people today deny any change in the climate, however, this is a documented truth. Cars and the pollution from cars are the single greatest polluter in our nation's cities (Tekin and Çavuşoğlu, 1997). Auto pollution comes from by-products of the combustion (exhaust) and from the vapor of the fuel itself. Since this combustion is not perfect the automobile emits several types of pollutants. These are: Hydrocarbons (HC)--unburned fuel, Nitrogen oxides NOx—under high-pressure combustion nitrogen and oxygen create various NOx. Like hydrocarbons, these interfere with the formation of ozone and contribute to acid rain, Carbon Monoxide CO—CO is a product of the incomplete combustion of fuels; when inhaled it reduces the flow of oxygen in the bloodstream, and is very dangerous to persons with heart disease, Carbon Dioxide CO_2—The EPA views this as a product of perfect combustion, though not threatening to humans CO_2 is a contributor to Global Warming as a greenhouse gas (EPA, 1994). Gasoline and diesel fuels are mixtures of HC, compounds which contain hydrogen and carbon atoms. Smog is proportional to the amount of HCs in exhaust. Many things in an engine can produce HCs such as advanced timing, or a bad catalytic converter. CO a colorless and odorless gas is a killer, CO_2 will also kill someone if there is no oxygen but CO is very dangerous for humans, this emission production has to do with combustion efficiency and fuel to air ratio. NOx is also very harmful to humans. They also contribute to smog, greenhouse emissions, and acid rain, and form toxic compounds dangerous to human. Maximum limits on NOx emissions are continually being reduced(Walsh, 2001)(Bowman, 1992). NOx, HC's and CO top the list as the worst offenders for health and smog (Musmar, 2011). Catalytic converters introduced in 1975 significantly reduced hydrocarbon and carbon monoxide emissions. However, lead inactivates the catalyst is catalytic converters so oil companies had no choice but to once again remove lead from fuel. Normal petrol combustion has the following emissions: Carbon monoxide 1-2% of volume, HC <.25% of volume, Nitrogen 71% of volume, CO_2 14% of volume, water vapor 12% of volume, NOx <.25% of volume, SOx < .03% of volume (Rajeshkumar et al, 2016).



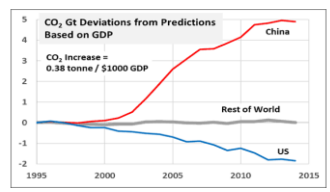
The EPA functions under The Clean Air Act of 1970 to regulate motor vehicles. This has led to devices to manage the exhaust caused by burning fossil fuels. The first regulation is through engine design, next the catalytic converter, mentioned above, to burn off HCs and CO, the Oxygen Sensor to help prevent combustion problems and finally the Exhaust Gas Recirculation (EGR) to manage NOx (EPA, 1994). Slowing down the combustion rate by EGR lowers NO and NOx to less severe levels. Greenhouse gasses come from many sources as viewed by the chart to the right which was

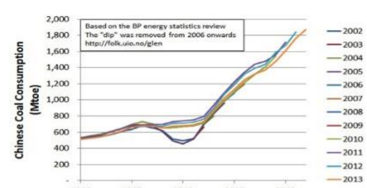


published by the EPA. We see that the production of electricity is the biggest offender, in total not just in cities, followed by transportation and then industry. According to Harper 2007, electricity is produced mainly by fossil fuels, coal and natural gas being the most widely used, however, in transportation gasoline and diesel are mostly used. Fossil fuel accounts for approx. 90% of our energy consumption. Industrialization and technology growth in-turn have spurned growth in population and economy which creates an even larger demand for fossil fuels, and this is an unending circle. Since fossil fuels cause visible damage to human life and environment this is not good (Venkataraman and Elango, 1998). Fossil fuel-based energy sources are facing increasing pressure on a host of environmental fronts, including a serious challenge for coal to meet the greenhouse gas reduction targets, but we are not likely to do enough in time to curve expected damages (Herzog et al., 2006).

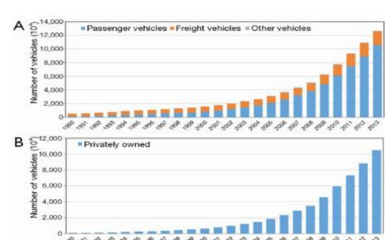
Problems

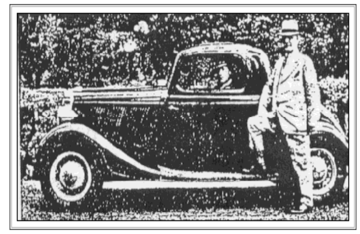
Recent changes in the world's economy afford us an opportunity to see our end if we stay on this current course. Global warming is a problem faced by the scientific community but China provides us with the best evidence to date of the negative effects of fossil fuel dependency. China used to have the lowest heart disease rate in the world. It also enjoyed the cleanest air quality, however, with China's industrial revolution we see an increase in coal-based electric plants. The industrial revolution in China is being driven by the conversion of fossil fuels to energy just like here in the U.S. As a result of the short time frame and exorbitant growth we can view china as a petri dish declaring the end results of an economy based on fossil fuels. True there seem to be correlations with the increase of fossil fuel use and greenhouse gas, but in the last ten years, this fossil fuel revolution correlates with an increase in heart disease--a number that now leads the world. Further, air quality is also reported among the worst in the world. Most residents of Chinese cities brag on the model of air purifier in their homes. Schools are closed, businesses and mass transportation stop due to dangerous air quality. There is no doubt, we can no longer ignore these facts. We must move away from fossil fuels. In addition, those countries not having these resources are facing energy crises. The use of fossil fuels has led to several environmental problems such as reduction carbon energy sources, water pollution, and habitat destruction. Meanwhile, CO_2 levels are still climbing and the greenhouse effect is growing as a function of burnt fuel along with increased acid rain (Durairai et al, 2012). All these are problems with our current source of fuel, but our biggest hurdle will be the implementation of alternative fuels sources.





Many other sources of fuel for the ICE are readily available. I even found one that shows how wood gas can be used to run any ICE (Wyer, 1905). Articles of people using many forms of biomass to operate an ICE are available now. One interesting video on YouTube that explains gasification pretty well states that his gasifier will run off anything other than glass, metal, or rocks man (Kieth, 2012). I find it amazing that most have not heard of alternative fuel sources for ICE's. Operating an engine from grass clippings is totally possible yet we make movies about it like it is an impossibility. Here is a picture from the beginning of the century of a gasifier mounted on a truck which at that time were commercially available. Yet today this information is suppressed. Charles Nelson Pogue made headlines in 1933 by driving





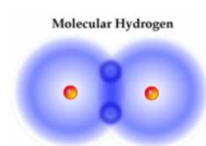
his 1932 Ford (to the right) about 200 miles on a single gallon of gas. After a demonstration conducted by the Ford Motor Company in Winnipeg-the Pogue Carb went into production. However, this required White Gas. White Gas is gasoline which contains no additives- one of the crucial factors for these carbonators to run efficiently. When oil companies found this out they began to add lead to the production gasoline. This rendered Pogue's carburetor as inefficient and unusable. Unfortunately not long after this Pogue was found dead. Once more Shell oil completed tests in 1975 that resulted in an opal getting an astounding 350 mpg by using the vapors of heated fuel to run a car (Shell, 1975), the same technology Pogue used. Amazingly all these tests were done on a private closed track with the results never being made known to the public. As a boy I recall Stanford University doing an experiment that included just re-porting a carburetor. The results, if I remember correctly, where an astounding 60mpg. Most of today's hybrids do not even come close to that. Later when lead became a problem and the Pogue carb now reported as a myth lead was removed from gasoline. The man who patented the first AC Motor, the technology that runs cellphone towers, and invented the production of alternating current was Nicola Tesla (Tesla, 1889). At that time Mr. Tesla envisioned to supply the world with free power, but J.P. Morgan pulled funding because it had no meter and could not make money. Later Edison using Tesla patents began equipping everyone with the AC current that Tesla patented through wires and meters through funding granted by, you guessed it, J.P. Morgan. If it is not known, J.P. Morgan is Morgan/Chase bank. Every time one pays the power bill one should remember that bill is brought to you by Chase Bank. We were warned about such monopolizing of power by President Eisenhower who warned against the Military Industrial Complex (MIC). It is when a corporation becomes so large that the population is basically in service to them. Eisenhower feared incoming John F. Kennedy would not have the wisdom to withstand the pressures brought by such a complex or corporation (MedHursta, 2009). When Kennedy gave his great speech in which he said, "I look forward to a great future for America - a future in which our country will match its military strength with our moral restraint". Shortly thereafter Kennedy was killed This is the first foreseen problem Walter Adam in his article points not to the MIC but to Giant Corporation as the dominator and controller of all economic environments. He points out that while they will operate outside of the law being immunized from all oversight (Adams, 1968). According to Dr. Steven Greer who produced the movies "Sirius" and "The Disclosure Project," these are one in the same.

Who are these giants of corporation? Reportedly Bank of America owns Exxon oil, Wells Fargo owns Chevron oil, J.P. Morgan/Chase owns Shell oil, and Citi-Bank owns Arco, Bp, and Tesoro oil, and all these together own the Federal Reserve—that correct the U.S. does not own the Federal reserve. From here on out we will call them the four horsemen. The MIC is their biggest customer of the four horsemen. This is the biggest problem. Though we know that the burning of fossil fuels correlates with climate change, poor air quality, sickness, and death, we have not the influence individually or economically to do much about it. These four horseman trade trillions of dollars monthly, an amount equal or exceeding our national Annual Gross Product. As a result, nations, governments, and peoples are enslaved to their domination and have little or no recourse. These companies have proved that they have little concern for anything that would create any opposition to their own economic security. How many lives have been lost in the procurement power and money by oil spills, mass killings to run pipelines, whole areas being devastated, not to mention the small threat of a simple inventor mysteriously disappearing. It seems if anyone government or person rocks the boat they can expect to be silenced by whatever means necessary, like Mr. Pogue, President Kennedy, and Tesla. So to recap, by looking at China and the EPA we see that we must move from fossil fuels to reduce negative emission, climate change, poor air quality, and to save lives. However, those that form the upper tier of the banking and oil industries are in direct opposition to this and in times past subverted any attempt. As a result, we will have to start small and work with the situation. We must come up with something that will lower emissions while still using the fossil fuels until those in opposition while allowing a retiring of fossil fuels.

Various forms of energy

"Energy is a quantity that can be assigned to every particle, object and system of objects as a consequence of the state of that particle, object or system (Harper, 2007)." Kinetic, potential, thermal, gravitational, sound, elastic, light and electromagnetic energy are all different forms of energy. The production of energy is important in all areas of the economy. To add to this, per capita, energy consumption is directly related to our standard of living (Vader and Joshi, 2005). Currently being researched by science are alternative energy sources such as solar, wind, biogas/biomass, tidal, geothermal, fuel cell, hydrogen energy, small hydropower, etc. (Alias, 2005). This paper will focus on Biodiesel, Hydrogen as (HHO) and Electric. Vegetable oils and animal fats and Algae are what is used to create Biodiesel, an alternative diesel fuel. These are renewable biological sources that are normally biodegradable and non-toxic. Biomass is a bio-source of H_2 and water that is burnable through a gasifier. Electricity is both a power that can be produced cleanly and used cleanly. All these can have low emission profiles and be environmentally beneficial (Krawczyk, 1996). However, due to these characteristics, researchers are focusing much attention on hydrogen as an alternative fuel in ICEs (Saravanan and Nagarajan, 2008).

Hydrogen energy



Though H_2 has been looked at for an alternative because it enhances engine efficiency and produces less pollution (Boretti, 2010), the expensive to include in manufacture is too high (White et al, 2006). H_2 can be produced from electrolysis of water, coal gasification, from biomass, and solar photoelectrolysis (Saravanan and Nagarajan, 2008). However, though H_2 is one of the most common elements in the universe it is found rarely in nature by itself. Using H_2 can theoretically extend the lean limit--the least amount necessary to burn-- of a fuel mixture, by simply adding a small amount of hydrogen to a liquid or gaseous fossil fuel. This makes a more complete combustion, improves efficiency and the decrease in operating temperatures lowers NOx (Jingding et al., 1998)(Stebar and Parks, 1974). To add to this during ultra-lean operation NO_x formation rates are so low that engine out emissions are near zero **(**Das, 1991). On the other hand, there are several problems with using H_2 alone as a fuel, foremost of which is the cost of production.

Brown's Gas

Brown's Gas is a mixed form of H_2 that is easily produced at a fraction of the cost of pure H_2. Brown's Gas has a few aliases: Hydroxy, HHO, and H_2O_2 to name a few. Basically, it is the vapor from the water after electrolysis. Hydroxy gas (Brown's Gas) is a mixture of monoatomic and diatomic hydrogen and oxygen referred to as "Electrically Expanded Water (EEW)" or "Santilli Magnecules". Browns gas has a cool flame about 130°C yet is able

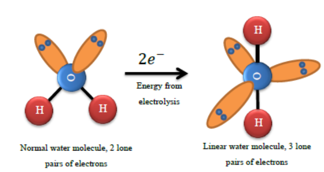


Figure 1: Rydberg clusters containing water molecules with highly energized electrons, but unenergized nuclei[4].

to melt just about anything. Although the flame is cool Brown's Gas can fuse brick, steel, sublimate tungsten, glaze quarts, and neutralize nuclear waste. This Gas burns with a clean flame. It uses no atmospheric oxygen and creates only pure water as its combustion product. (Michrowski, 1993). This gas cannot be stored safely it is very volatile and highly explosive at standard temperatures and pressures when mixed with air (Cameron, 2012). As a result, the forming and implementation must be done without ever storing or pressurizing the gas, i.e., it must be used as it is produced. This necessitates the need for a production unit or--HHO cell--for every application. When water is electrolyzed (when an electric current is passed through) Rydberg clusters may be formed. Clusters of hydrogen and oxygen including water molecules in the "highly energized trigonal-by pyramidal geometry, monatomic and diatomic hydrogen, free electrons and oxygen" (Eckman, 2010). Rydberg clusters are in solids and liquids and are very stable for hours. In the case of HHO or Brown's Gas, these clusters have shown a life span of about 10 (Santilli, 2006). The make use of the hydrogen bond, a relatively weak bond when compared to the covalent bond (Mccarthy, 2008).

HHO Cells

There are two types of HHO cells currently. The Dry Cell where only the centers of the plates have electrolyte and the Wet Cell where the entire plates are submerged. The advantages for the dry cell water is less, generated heat is smaller due to the circulation between cell and reservoir and easy access for testing plate voltages. The electric current used is also smaller because less of the power is converted into heat. The plate usage are is only 60% versus 100% in a wet cell.

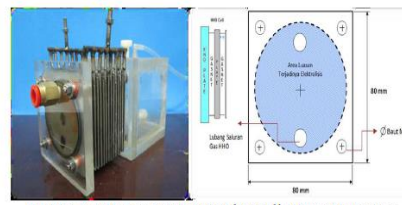


Figure 3. HHO gas Generator dry Cell type a.Generator construction b.Electrodes area

The Wet Cell is a generator with the electrodes fully immersed in the electrolyte. The advantages of the wet cell type gas production has more quantity, the flow is stable, construction and maintenance is easier (Bambagn et al, 2016).

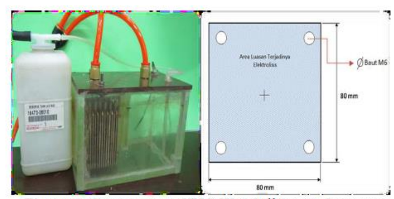
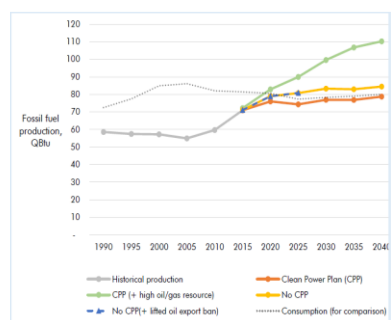


Figure 4. Generator gas HHO Wet Cell type a.Generator

Stakeholders

Since HHO production is not centralized, and storage is dangerous, it cannot be metered and monopolized. As a result, such technology will be in offense to the four horseman stakeholders because they cannot sell it which in turn cuts into profits. It is Tesla's dilemma all over again. Since the population at large is our other stakeholder let us hope that we have better luck than him. Remember Tesla died bankrupt and alone in a small apartment after all his patents were stolen and used for profit. Although his science is still changing the world today, after all, who does not have a cell phone? My only solution to this problem is that the changes be small. Unable to address the first foreseen problem more than that, we will concentrate on the other foreseen problems. Stockholm environment institute suggests we might begin by simply limiting the amount of permitted fossil fuel licenses we allow. In their declaration that avoiding dangerous climate change requires rapid transition away from fossil fuels and that a full phase-out of global fossil fuel consumption – particularly coal and oil—will have to be completed within the next 50 years (Rogelj et al, 2015), reports a tentative reduction in CO_2 emission by simply limiting the permitted extractions of fossil fuels. Under such a policy coal production in the U.S. would steadily decline. To add to this oil and gas



extraction would drop as well. They conclude the phasing out of federal leases for fossil fuel extraction would reduce global CO_2 emissions by 100 million tons per year. These findings suggest that policy-makers should give greater attention slowing down the expansion of fossil fuel supplies. Fossil fuel expansion is at an all-time high and are only moving upwards (Rystad, 2015). Investments like this will lock in long-term fuel supplies while trying the population to fossil revenues (Erickson et al. 2015).

Internal Combustion Fundamentals.

The engine used mostly powered by burning fossil fuel is the internal combustion Engine (ICE). These come in two main models the spark ignition (SI) known as a gasoline engine, and the compression-ignition (CI) engine known as the diesel engine. Each of these come in a range of styles and types. The four stroke, the two-stroke, and rotary are among these types; the stroke is defined as how many times the piston travels up and down in one cycle. We will be dealing with the four stroke models mostly to help us understand engine fundamentals (Kahraman, 2005; Haywood, 1998). The following pictures are from Haywood, 1998.

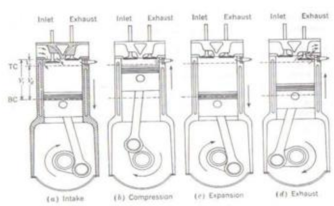


Figure 3.1. Cross-section schematic of a four stroke SI engine (Heywood, 1998)

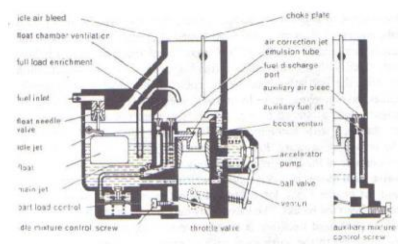


Figure 3.2. Cross section of a single barrel carburetor (Heywood, 1998)

The picture on the left references the four stroke per cycle, and the picture on the right is two typical types for fuel carburetion. Basically, fuel travels through the carburetor or injector to the cylinder on the intake down stroke. The fuel is compressed on the following compression upstroke. Combustion occurs either due to spark on SI engines of compression on CI engines which pushes the piston down on the combustion stroke and the leftovers and evacuated on the last upstroke called the exhaust stroke. Then the process repeats (Haywood, 1998). In our literature reviews, engine torque will normally be measured with a dynamometer. The engines output shaft is coupled to the dynamometer much like a transmission is to an auto. Then torque coefficient is found using an equation.

P (kW) = 2p w (rev / s) ´ T (Nm) x 10-3 brake mean effective pressure (bmep).

where,

$$bmep\ (kPa) = \frac{P_b\ (kW) \times n_r\ x\ 10^3}{V_d\ (dm^3) \times \omega\ (rev/s)}$$

When doing the math it is found that a perfect energy conversion is not attainable. The best that is found is about 96% (Kahraman, 2005; Haywood, 1998) (Yilmaz, 2010).

Electrons, Water and Conductivity

Water H_2O is a compound that is most important in life. Because of this, I am against using water hydrolysis as a formal means of producing power. I much prefer reclamation and the recycling of Biomass and human and animal waste as the formal means of producing H_2, HHO, Methane, or other usable sources of fuel. However, that being said let the research go on. Water consists of a compound of 2 molecules hydrogen H_2 and one molecule Oxygen. When separated we have $2H_2O \rightarrow 2H_2 + O_2$. Since this is so

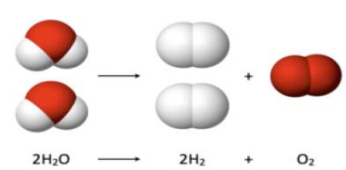


Figure 1. Decomposition of water molecules into HHO Gas

simple and lite, compared to the much heavier petroleum, we have a much greater bang for the buck. Water can be turned into HHO gas through electrolysis (Durairai et al, 2012). Hydrogen has a calorific value of 120MJ/kg, a value that is much greater than gasoline, diesel or natural gas (Verhelst, 2009). Electrolysis is achieved by passing an electric current through two electrodes submerged in water. Electrolysis occurs when DC electron flows from a cathode to the anode via an electrolytic solution (Bureau, 2011). However, this produces heat so to reduce heat often an electrolyte is used as a catalyst which reduces heat. A bubbler unit must be used to prevent flashback. Hydrogen at or above 2500psi can easily lead to a blast. Using DC current the electrodes are have two poles; a positive--the anode, and negative-- the cathode. The following reactions are found:

Base equilibrium reaction:
Cathode (Reduction) $2H_2O(l)+2e^- \rightarrow H_2(g)+2OH^-(aq)$
Anode (Oxidation) $4OH^-(aq) \rightarrow O_2(g)+2H_2O(l)+4e^-$
Overall reaction $2H_2O(l) \rightarrow 2H_2(g)+O_2(g)$
Acid equilibrium reaction:
Cathode (reduction) $2H^+ (aq) + 2e^- \rightarrow H_2 (aq)$
Anode (Oxidation) $2H_2O (l) \rightarrow O_2 (g) +4H^+ (aq) +4e^-$
(Bambagn et al, 2016)

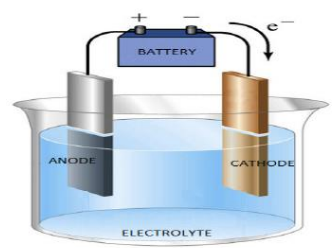


Figure 2. Schematic hydrolysis process of water

Bio Diesel

Biodiesel is diesel fuel made from vegetable oils, animal fats, recycled restaurant greases, algae, and other biomass. It is normally safe, biodegradable, and produces fewer air pollutants than petroleum-based diesel. Biodiesel can be used in its pure form or blended with petroleum diesel. Bio Diesel production Transesterification can be performed by continuous or batch systems. It is a process where vegetable oil or other biomass is reacted with alcohol or methanol and is catalyzed by bases, acids or enzymes to form esters and glycerol. The viscosity of the oil is changed to something that is very close to petroleum diesel (Durairai et al, 2012). Drop in replacement for diesel or CI engine of biodiesel with HHO is thought to be a valid alternative for the workhorses of our nation.

Literature Review

In this study and review, we will be looking at one of the enduring alternatives to gasoline and diesel. However, the idea, for now, is not to replace gasoline, nor improve mileage so drastically that it would warrant attention by those in opposition. Hydrogen has been researched for a long time. We will examine data from a NASA experiment with Hydrogen to see what effects on mileage and emission it will have when using it as an additive to common ICE fuels. Physical and environmental factors according to this and other studies will be reviewed. Some of the reviews will be of the smaller nature just answering specific questions, while others will be presented more extensively as to provide template information and background for further exploration. Both results in support of and against the hypothesis that HHO offers an acceptable alternative fuel source will be reviewed.

The papers in the following literature review offer answers to the many initial hurdles. In reviewing this literature I am looking for answers to the following questions. 1. Can H_2 burn in an engine? 2. Is it real--can one produce a burnable form of H_2 from water easily and cheaply? 3. Does HHO have significant data supporting the decrease of auto emission to warrant further study? 4. Is it true that one can build and HHO cell at little cost? 5. How does design affect production? 6. At what amperage and voltage values is a Cell likely to operate best at? 7. Will HHO cells operate with A.C. or D.C. best, or what happens if one uses a D.C. to carry A.C.? 8. What happens to production when the frequency is changed?

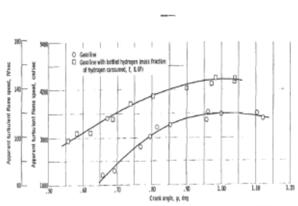
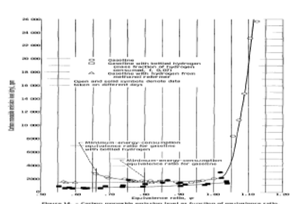
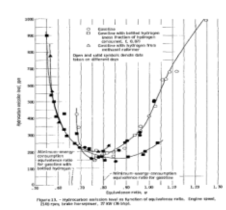
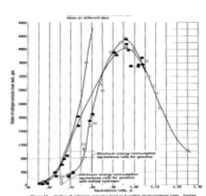
Q. Can H_2 burn in an engine?

Rudolf A. Erren *made hydrogen-fueled engines in the 1920s* including trucks and buses. Allies of World found a submarine and even torpedoes converted by Erren to hydrogen power (Erren and Campbell, 1933). Since drinkable water is the exhaust hydrogen and oxygen as fuel they have been considered for the submarine since the end of the world wars (King and Rand, 1955).

Robert Zweig *converted a pickup truck to run on H_2*. It still operates and can be seen at The American Hydrogen Association where it is displayed in public exhibits (Zweig, 1992).

NASA, in 1977, done an experiment using a multi-cylinder engine to *extend the efficient lean operating range of gasoline by adding hydrogen*. It was hypothesized that the lean mixture –ratio combustion in internal combustion engines-- has the potential of producing low emissions and higher efficiency for several reasons. This list is directly out of their paper: 1. Excess oxygen in the charge further oxidizes unburned hydrocarbons and carbon monoxide. 2. Excess oxygen lowers the peak combustion temperatures, which inhibits the formation of oxides of nitrogen. 3. The lower combustion temperatures increase the mixture specific heat ratio by decreasing the net dissociation losses. 4. As the specific heat ratio increases, the cycle thermal efficiency also increases, the cycle thermal efficiency also increases which gives the potential for better fuel economy. NOx is produced by high combustion engines. Lee and Brehob indicated slightly increased hydrocarbon emissions will come from higher compression ratios. It is believed that a 10% increase in efficiency is possible (Lee and Brehob, 1971). In order to provide a basis for comparison, the engine was operated with varying amounts of hydrogen to gasoline ratios. Torque was measured at 55mph.

The results indicated that flame Speed was increased significantly. In leaner mixtures mixing hydrogen with gasoline reduced emissions favorably even NOx was reduced by a factor of 19, however, engine performance reduced also. At the useable performance settings, the NOx values actually increased. At an idle Hydrocarbon are slightly higher and Carbon Monoxide dropped. It should be noted that JPL conducted similar experiments with the same results. Please refer to the data in the graphs. The conclusion of the review, positive, H_2 can burn in an engine (Lee and Brehob, 1971).

Q. Is it real--can one produce a burnable form of H_2 from water easily and cheaply?

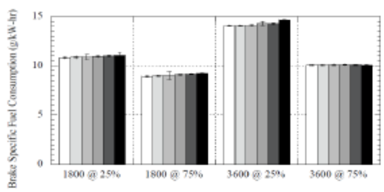
Two different researchers have shown that HHO can reduce diesel consumption (Yilmaz, 2010) (Bari, 2010). However, another team found a reduction in engine efficiency (Birtas, 2011). As a result, the University of Southern Queensland attempted to *validate the effects of onboard HHO addition on fuel economy and emissions in a 28kW diesel generator*. The results, HHO was shown to increase diesel consumption proportional to the rate of injection – up to a 5.2% increase at 55% load with 6L/min of HHO addition. The addition of water and HHO reduced Oxides of nitrogen (NOx) emissions up to 11.8%. It was found that the thermal losses in the engine stage would outweigh the economy gains from onboard HHO addition. To accurately automate and data-log the experiment an industrial control system was used.

Review,

Adnan et al found gaseous hydrogen injection rate of 20L/min at standard temperature and pressure (STP) doubled oxides of nitrogen (NOx) emission. Also due to the amount of current used in this experiment the generator is left with only about 29% of the engines power available for useful work, this dramatically increasing diesel consumption (Adnan et al, 2009). The Bose and Maji supported these findings and showed NOx emissions increased 70% and 90% at 20% and 40% load respectively due to hydrogen injection. The efficiency of the diesel engine increased due to the increased lean limit and flame speed due to the properties of hydrogen combustion (Bose, Maji, 2009). Lilik tested the effects of smaller ratios of hydrogen injection shown in Table 1. H_2 had a negative impact. The hydrogen injection in the turbo diesel engine had the opposite effect on diesel consumption showing a decrease in fuel economy (Lilik, 2010).

Table 1: Change in NOx emissions and BSFC on a 2.5L turbo diesel at 1800r/min

Parameter	2.5% FE H_2 25% Load	2.5% FE H_2 75% Load	5% FE H_2 25% Load	5% FE H_2 75% Load
NO	-16.9%	-3.4%	-24.2%	-5.4%
NO_2	+53.3%	+72.1%	+68%	+87.1%
BSFC	+0.3%	+0.4%	+0.6%	+0.6%



Brake specific fuel consumption of the four modes tested, with □ 0%, ■ 2.5%, ■ 5%, ■ 7.5%, ■ 10% and ■ 15% hydrogen substitution on an energy basis.

Figure 2: Brake specific fuel consumption for a 2.5L turbo diesel engine, courtesy Lilik [9].

It was felt that a small rate of water injection could offset cylinder temperatures created from hydrogen and therefore reduce NOx emissions. As a result, Yilmaz et al injected small rates of HHO instead of H_2 into a diesel engine. Experiments performed showed positive results in improving the fuel efficiency of the engines. Tauzia et al compared the effects of EGR and water injection. This was more effective for reducing NOx emissions. NOx was reduced by 50%. Either water injection alone or onboard HHO addition alone both appear to reduce fuel economy of the diesel engines (Tauzia et al, 2010). Cameron found that there are no reliable indicators that onboard HHO has the potential to decrease diesel fuel consumption in a naturally aspirated generator based on the literature reviewed. The problem seemed to be the amount of energy it took to make the HHO was offsetting the contributing factors. He further found that HHO needs to be produced onboard and on-demand and factors of fuel and efficiency are connected to the water content in HHO and added water injection.

Template and design,

A sodium hydroxide salt solution was used for an electrolyzer. A dry cell design with dead plates for higher voltage electrolysis was manufactured to perform an experiment to prove the effects of onboard HHO and water addition to a diesel generators to enhance performance. A PLC system was used for the sake of repeatability. The key results of the test include HHO additions, water injection, and generator load along with the diesel fuel consumption and total NOx emissions. The plates in the electrolyzer are set up the same as in a car battery. The end plates were supplied *12.5-14V DC* resulting *in a 2.08V to 2.33V* drop across each successive plate in the electrolyzer. The total amperage rating was *18A connected in series and 30A electrolyzers connected in series*. Water was pumped in at 10% of the fuel consumption, it then was converted to steam and injected into the intake. A voltage over the potential of typically *0.6V above the 1.48V* thermo-neutral voltage is required for any significant current o flow at STP. This is due to a low reaction rate, the activation energy barrier, electrical resistance of the electrolyte and electrodes, and bubble formation (Zeng, Zhang, 2010).

Final Results,

HHO on-demand did not reduce diesel consumption. As the rate of HHO production increased so did the energy required to run the electrolyzer, resulting in a net loss. HHO and water injection reduced NOx between 1.3% and 11.8%. At 30% engine load, NOx was most affected by HHO injection, when combined with water injection there was a total reduction of 11.8% NOx emissions.

Table 6: Energy requirements for on-board electrolysis

H2-O2 (l/min)	RMS Voltage	RMS Current	Electrical Power	Energy of production	Thermal efficiency
2	242.0V	2.1A	513W	4.27Wh/L	50.5%
4	239.9V	3.9A	943W	3.93Wh/L	55.0%
6	237.7V	6.0A	1426W	3.96Wh/L	54.5%

Financial Analysis,

No financial feasibility

The problems I found here point toward the amount of electricity it takes to produce enough HHO respectively reported being 120W Electrolysis and 43W Electrolysis (Cameron, 2012). However, the gains of the water injection to alleviate the problem of high NOx is a great find. Also noted it the design of the HHO Cell.

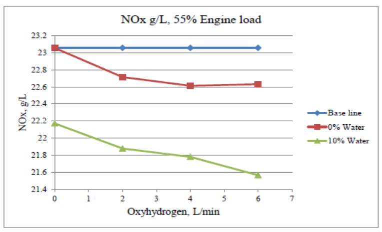


Figure 24: The effects of HHO and water injection on NOx at 55% engine load.

Appendix G: Logged Data – Exhaust Emissions

Exhaust Emissions Data (Averaged)

Load (kW)	Water	HHO (L/min)	CO(g/L)	O2(g/L)	NOx(g/L)	AFR(--)	LDA(--)	Eff(%)
9.91	0%	0	5.6	5728.1	17.33	47.4	3.3	99.6
9.91	0%	2	4.8	5724.0	16.80	47.4	3.3	99.6
9.91	0%	4	4.9	5773.7	16.29	47.7	3.3	99.6
9.91	0%	6	5.8	5783.5	15.91	47.7	3.3	99.5
9.91	10%	0	5.5	5723.8	17.11	47.4	3.3	99.6
9.91	10%	2	5.7	5723.4	16.43	47.4	3.3	99.5
9.91	10%	4	4.9	5789.2	15.66	47.8	3.3	99.6
9.91	10%	6	5.4	5796.0	15.28	47.8	3.3	99.5
19.1	0%	0	6.3	2578.5	23.06	29.3	2.0	99.6
19.1	0%	2	6.3	2614.3	22.72	29.5	2.0	99.6
19.1	0%	4	6.3	2619.8	22.61	29.6	2.0	99.6
19.1	0%	6	6.2	2621.1	22.63	29.6	2.0	99.6
19.1	10%	0	6.3	2546.4	22.17	29.1	2.0	99.6
19.1	10%	2	5.6	2553.9	21.88	29.2	2.0	99.6
19.1	10%	4	5.8	2562.9	21.78	29.2	2.0	99.6
19.1	10%	6	5.7	2563.0	21.56	29.2	2.0	99.6

On-board HHO Test

HHO (L/min)	Load (kW)	Diesel (g/h)	EGT (C)	Water Injection	Relative humidity	IAT (K)
0.0	9.91	3430.0	216.7	0%	16.1	297.4
2.0	9.91	3488.4	223.3	0%	13.3	299.3
4.0	9.91	3543.5	229.7	0%	11.8	301.1
6.0	9.91	3623.1	236.4	0%	11.0	302.4
0.0	9.91	3393.9	228.0	10%	9.6	304.8
2.0	9.91	3470.8	231.3	10%	9.0	305.5
4.0	9.91	3555.0	234.5	10%	9.3	305.1
6.0	9.91	3639.0	238.6	10%	9.0	304.8
0.0	19.1	5173.5	324.5	0%	6.0	310.6
2.0	19.1	5277.8	329.3	0%	5.5	311.6
4.0	19.1	5365.3	335.8	0%	5.0	312.3
6.0	19.1	5466.3	342.5	0%	4.9	313.1
0.0	19.1	5205.3	332.2	10%	4.4	313.9
2.0	19.1	5309.3	335.2	10%	4.1	314.2
4.0	19.1	5391.4	339.4	10%	4.2	314.3
6.0	19.1	5507.9	345.0	10%	4.3	314.5

External Supplied HHO Test

HHO (L/min)	Load (kW)	Diesel (g/h)	EGT (K)	Water Injection	Relative humidity	IAT (K)
0.0	9.91	3423.5	225.9	0%	8.6	303.9
2.0	9.91	3407.4	227.7	0%	8.0	305.3
4.0	9.91	3385.4	229.3	0%	7.6	306.5
6.0	9.91	3372.9	230.3	0%	6.9	307.3
0.0	9.91	3412.6	230.4	10%	6.8	307.6
2.0	9.91	3417.6	230.3	10%	7.3	306.8
4.0	9.91	3405.9	229.7	10%	7.3	306.8
6.0	9.91	3399.6	229.9	10%	7.4	307.0
0.0	19.1	5198.2	326.0	0%	4.4	313.4
2.0	19.1	5184.4	327.6	0%	3.5	315.3
4.0	19.1	5157.0	330.4	0%	2.9	317.3
6.0	19.1	5165.8	332.8	0%	3.0	317.8
0.0	19.1	5237.6	333.5	10%	3.0	317.0
2.0	19.1	5229.8	334.0	10%	3.3	316.8
4.0	19.1	5212.6	333.7	10%	3.1	317.0
6.0	19.1	5206.1	334.0	10%	3.3	317.0

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Q. Does HHO have significant data supporting the decrease of auto emission to warrant further study?

Stebar and Parks investigated the effects of hydrogen-supplementation and a very low NOx and CO emissions were achieved. Also, significant thermal efficiency improvements resulted from the extension beyond isooctane lean limit operation (Stebar and Parks, 1974).

Masood et al test results showed that the *hydrogen–diesel co-fueling solved the drawback of lean operation* of hydrocarbon fuels such as diesel. This reduced misfires, improved emissions, performance and fuel economy (Masood et al., 2006).

Ji and Wang studied hydrogen–gasoline mixtures in engines and concluded that wide flammability and fast burning velocity of hydrogen yielded reduced CO and HC emissions at idle and lean conditions (Wang, Ji 2009).

Rajeshkumar et al in this paper *introduced four methods to reduce the exhaust emissions.* 1. Adding additives. 2. HHO technology 3. Charcoal absorption to reduce the CO, HC and 4. A NaOH silencer to reduce more than two-thirds or carbon dioxide. The result showed fossil fuel was much nearer to complete combustion which intern ensures that there are no unburned hydrocarbons. Oxidation of the partially oxidized carbon i.e. CO was also more completely oxidized CO_2 (Rajeshkumar et al, 2016).

Masood et al studies found that though power output of an engine was 20% more than for a gasoline engine and 42% more when using a carburetor. Studies further suggested this will lead to *higher NOx emissions for injection of H_2 alone* (Masood et al., 2007).

Jingding studies have shown that if mixtures are made lean and spark timing is retarded *NOx can be reduced below the current standards for emissions* (Jingding, 1998).

Bambagn et al manufactured a PWM to control temperature. Instead of water injection to cool the cylinder, it was thought that Pulse width modulation temperatures might be controlled better. A PWM is an electronic circuit that is able to regulate current input by quickly turning the current on and off. This duty cycle and frequency can be set and adjusted (Ghiffari, 2013). One goal is to keep the Cell below 60° C (Musmar et al, 2011). The objective of this study is to see if these advantages remained with original engine specifications. A Dry Cell HHO device was used and optimization of PWM was done by varying the duty cycle of pulse width modulation i.e. 20%, 40%, 80%, and 100%. A venturi style mechanism mounted intake was used to port HHO. Measured was the effects of HHO gas on the performance and the temperature of the Cell. The results show optimum performance is generated by a PWM system with a 40% duty cycle. Documented increase BMEP, thermal efficiency, engine torque, power. The thermal efficiency increased respectively to 2.27%, 2.76%, and 3.05% while the performance increased by 6.55%, 7.65%, and 15.50%. The electrolyte used is an alkaline solution of KOH. The HHO Gas generator is composed of two basic components. Tube generator and a power source (battery). A Dry cell type generator with a separated bubbler and water fill (Bambagn et al, 2016).

The Performance parameters (taken directly from the study) (Bambagn et al, 2016).

1. Generator Power Input. The Formulation to find the input power is P=VxI. Watts=volts x amps.
2. HHO Gas production= measured by a gas flow meter.
3. Specific Energy Input defined as the amount of energy required to process the electrolysis of water in kjoule to produce 1kg of HHO gas.
4. Generator efficiency, the ratio of useful energy to the energy supplied to the system.
5. Generator HHO Temperature
6. The PWM system. PWM is an electronic circuit to control the amount of electric Current that enters the equipment and to avoid excessive power dissipation in the battery. Also, Voltage is regulated by percentage of pulse width to the period of a square signal in the form of a periodic voltage applied to the motor as a power source. PWM signal can be constructed using analog methods using op-amp circuit or by using a digital method that could be affected by the resolution of the PWM itself. PWM electronic circuits can be make using a 555 timer ic or IC LM324N. Timer IC is one type of timer that has the ability PWM controller with pulse width control features 0 to 100%. Mosfet drivers are needed to the use of PWM.

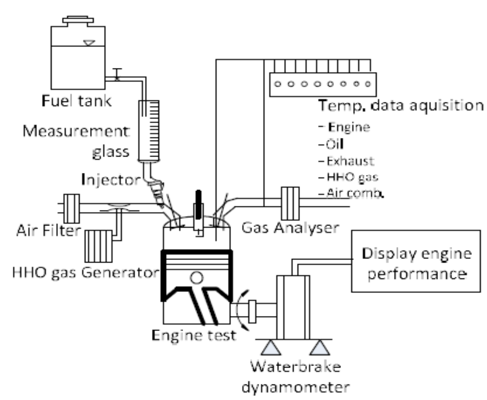
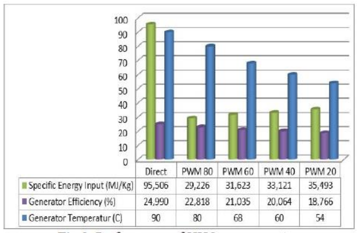


Fig. 7. Schematic diagram of the experimental setup

Results

Generator temp was maintained at 60 ° C. Application of HHO gas generator in point above on standard ignition timing engine produce in an increase of performance such as torque, power, BMEP and thermal efficiency respectively of 2.27%, 2.76%, and 3.05% and decrease of bsfc 7.76% (Bambagn et al, 2016).



	Direct	PWM 80	PWM 60	PWM 40	PWM 20
Specific Energy Input (MJ/Kg)	95,506	29,226	31,623	33,121	35,493
Generator Efficiency (%)	24,990	22,818	21,035	20,064	18,766
Generator Temperatur (C)	90	80	68	60	54

Fig.8. Performance of HHO gas generator

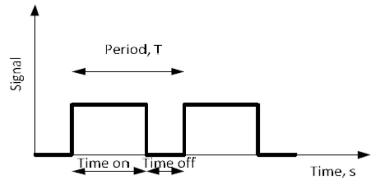


Figure 5. Duty cycle of pwm system

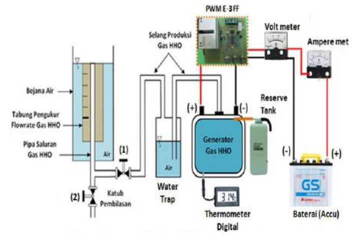


Fig 6. Assembly of HHO gas generator

Yimaz et al at Mutah University *showed that a mixture of HHO, air, and gasoline cause a reduction in emission pollutants and enhancement in engine efficienc*y. Emission of NO and NOx were reduced by an astounding 50%. Moreover, carbon monoxide concentrations were reduced by 20%. While fuel consumption was reduced by 20-30 (Yimaz et al, 2010).

Template and design,

The fuel cell used in this research is basically an electrolyte cell which decomposes water into HHO. The heat generated is due the electrolysis process so a sodium bicarbonate is added to accelerate the decomposition. HHO has a caloric value three times that of gasoline. Plates of stainless steel are used to prevent degradation. The effect of adding HHO gas to the air/fuel mixture on the carbon monoxide concentration is presented, in fig 4. Using a blend of HHO gas reduces the presence of CO.

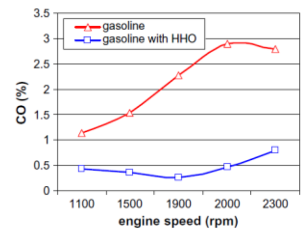


Fig. 4. Variation of carbon monoxide concentration with engine speed.

The conclusion from the study shows that HHO cell may be integrated easily with existing engine systems. Further, that the combustion efficiency has been enhanced when HHO gas has been introduced, consequently reducing fuel consumption. Concentrations of nitrogen oxide have been reduced by 50%. Carbon monoxide has been reduced to 20%. NOx concertation was reduced to about 54%. Finally, HC concentrations were highly affected by the engine speed and the presence of HHO (Yimaz et al, 2010).

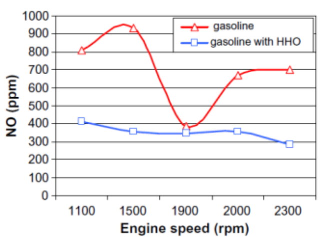


Fig. 5. Variation of nitrogen oxide concentration with engine speed.

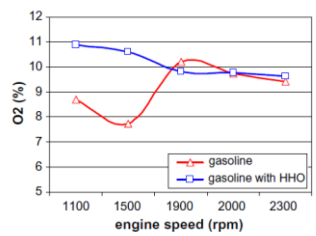


Fig. 7. Variation of oxygen concentration in the exhaust with engine speed.

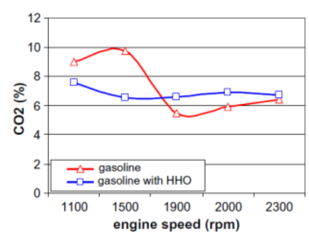


Fig. 8. Variation of carbon dioxide concentration in the exhaust with engine speed.

Q. Is it true that one can build and HHO cell at little cost?

Cunningham et al made researches *on methods and apparatus for enhancing combustion* in an ICE through electrolysis and produced hydrogen along with oxygen yielding an enhanced combustion at low engine loads for all types of engines (Cunningham et al, 1992).

Ammar A presents work in *the design of a device attached to the engine to integrate an HHO production system with the gasoline engine*. He states this device can be easily installed in any engine compartment.

Review,

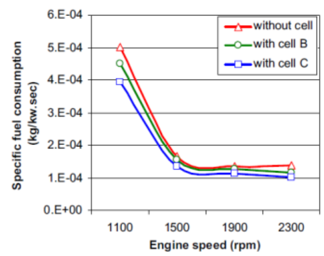
Studies at Mutah University include the reduction of cylinder liner wear, the filtration process, fuel mixing processes, as well as the introduction of the HHO fuel cell (FC). In the theoretical background, in "Properties of hydrogen" Momirlan *elaborated upon the hydrogen H_2 technology*, economics and the environmental impact on the world at the end of the 20th century. In the 21st century studies have been centering on browns gas or HHO (Momirlan, Veziroglu, 2002).

Dunn in his paper talked about how the decisions made today will likely determine which countries and companies *seize the enormous political power and economic prizes* associated with the hydrogen age now downing (Dunn, 2002).

Schulti et al done studies on acceptance, risk perception and customer satisfaction gave suggestions on *how to use marketing methods*, education projects, and product exposure in order to attain the successful introduction of hydrogen as an alternative fuel (Schulti et al, 2004).

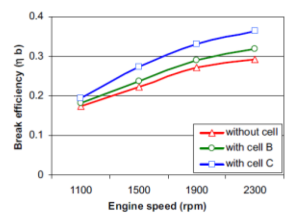
Hekkert et al discusses the role of governments in the transition to hydrogen (Hekkert et al, 2005).

Template and Design,



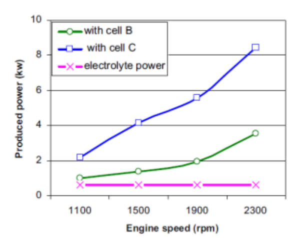
The type cells used in this experiment was a Wet Cell filled with water and *sodium bicarbonate*. Two cells were constructed being the same type with different configurations FCb and FCc. Cell FCc is half the dimension of cell b, with an electrode placed closer.

Results, (list is taken directly from study)

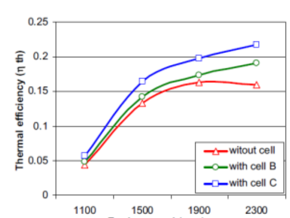


1. An increase in efficiency of about 3% for cell b and 8% for cell c.
2. Fuel consumption was reduced especially with cell c.
3. fig 10 shows a reduction in exhaust gasses this leads to better combustion and cleaner gas
4. Increased power.

Conclusions,



1. The use of HHO in gasoline engines enhances combustion efficiency, consequently reducing fuel consumption and thereby decreasing pollution.
2. The optimal size of the FC is when the service area of an electrolyte needed to generate sufficient amount of HHO is twenty times that of the piston surface area. Also, the volume of water needed in the cell is about one and a half that of the engine capacity.



The FC which can be used in simple, easily constructed, and easily integrated with existing engines at low costs, about 15 dollars per cylinder. How does design affect production?
(Ammar, 2010)

HHO with Diesel Design

Durairai et al wrote a paper dealing with *bio-diesel and HHO gas from hydrolysis*. This report states that the using of water powered biodiesel results in a substantial reduction in emission. Preheating the air improves the thermal efficiency. This is a strange finding since most CI engines make use of an intercooler to cool the air and prevent run away. The main focus deals with implementation of oxy-hydrogen as a duel fuel with biodiesel (Durairai et al, 2012).

Biodiesel

Biodiesel is a clean burning mono-alkyl ester-based fuel very close the consistency of fossil-based diesel but is made from renewable sources such as vegetable oils and animal fats.

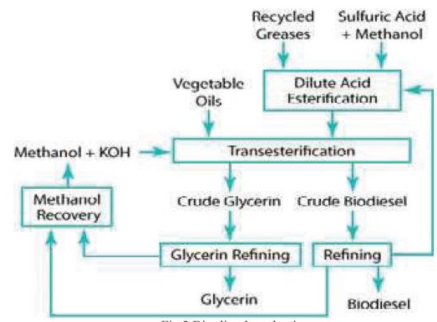


Fig.2.Bio-diesel production

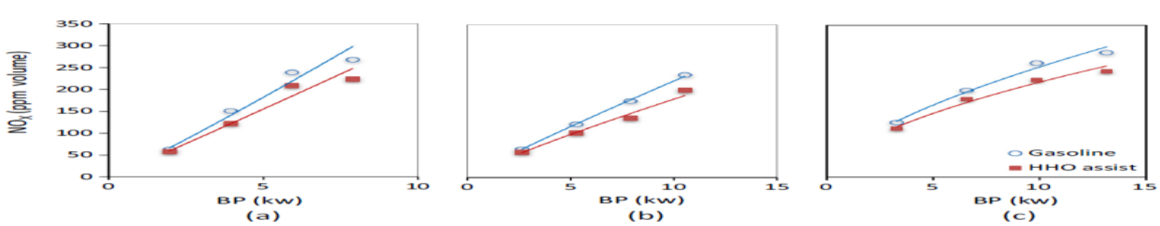
Findings. (list is taken from original paper) (Durairai et al, 2012).

1. The HHO/Bio-diesel shows evidence of producing low emissions and higher thermal efficiency.
2. Reduces the formation of unburned hydrocarbons and reduces the unburned fuel in the combustion chamber.
3. Due to this the combustion process will be done in an efficient manner and the hydrogen is four times highly effective when compared to ordinary fuels.
4. Due to this it will increase the combustion reaction and lead to an increase in efficiency and torque, and horsepower.
5. The HHO compounds will be used to reduce the formation of CO2 and CO and other harmful compounds produced in the engine and increase in mileage and performance of the engine.
6. Heat energy is recovered from the exhaust gasses which causes lower heat addition, thus improving engine thermal efficiency.
7. NOx emission is reduced with the exhaust heat recovery system. Higher inlet air temperature is caused the lower ignition delay, which is responsible for lower NOx formation with air preheating. Uniform or better combustion will occur due to the pre-heating of inlet air, which also causes lower engine noise.
8. Due to better evaporation and shorter ignition delay, there is less fuel adhering to the combustion chamber wall and therefore a small amount of fuel accumulated in the combustion chamber before ignition is started which may produce low NOx emission as well as low noise vibration.

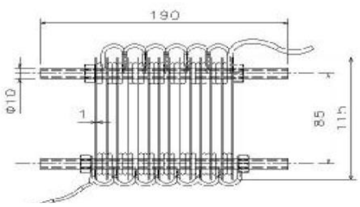
Q. At what amperage and voltage values is a Cell likely to operate best at, what is a good design?

Mohamed et al in this experiment attempts to *find the optimal number of neutral plates, the distance between them, and type and quantity of the catalysts*. Looking at sodium hydroxide NaOH, and potassium hydroxide KOH. NOx, CO and NOx emission were measured. *Using 2 neutral plates with a 1mm distance* and 6 g/L of KOH a maximum productivity was established of 18L/h (Mohamed et al, 2015).

Bhavesh et al did a study of the effect that changing the compression ratio has on a Diesel/HHO powered CI engine. Emission characteristics and combustion characteristics under 5 different loads were measured and graphed. The results show small changes. Conclusion inconclusive (Bhavesh et al, 2016).



Yilmaz at the Cukurova University in *his study on the best catalyst* for HHO compared KOH(aq), NaOH(aq), NaCL(aq). Various electrode designs were evaluated. Molecular bonds are weakened by the use of Catalysts. Hydroxy gas is used as a supplementary fuel in both SI and Ci engines without modifications. The effect on HC, CO, as well as on the specific fuel consumption (SFC) is investigated NaOH was found to be the best Catalyst (Yilmaz, 2010). High corrosion resistance is considered, therefore, electrodes are made of stainless. *There are not dead plates in this design*. The power conversion equations is:



P =V x I =12 V x 10.6 A=127.2 W @ 0.13 kW

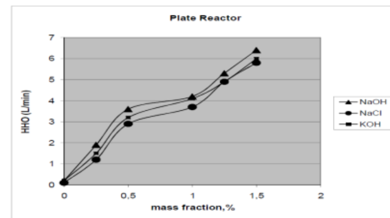


Figure 4.4. Variation of HHO flow rate with catalysts mass fraction

Three cells were tested: a cylinder, a wire electrode cell, and a plate cell. *The most efficient is the NaOH catalyst with the plate type electrode.* Using a1% NaOH solution by mass. It is found that too much volume of HHO at low speed causing saturation and reduced engine performance. An electronic control unit (HECU) is serially connected to the HHO system. Conditions. *The electronic control unit is designed and manufactured to decrease HHO flow rate by decreasing voltage and current.* Experiments depict that voltage around 7.1 V and current around 5.4 Amps are suitable. Review show the most common method is pulse width modulation (PWM). *The newly designed PWM (NonPLC) takes advantage of the 555 IC timer chip which is available easily* (Millman and Grabel, 1987).

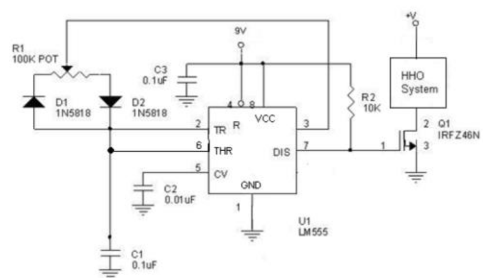


Figure 4.15. The schematic diagram for the 555 PWM circuit (DPRG, 2005)

Results and discussion

An average of 32.4% improvement in engine torque is obtained. Further, 27% increase in engine power is achieved. A gain of 16.3% is achieved in SFC by using HHO system. A reduction of 6.7% in HC emissions. A reduction of 14.4% in CO emissions. A 19.1% increase in total engine torque is obtained. A reduction of 5% in HC and 13.5% in CO emission at an engine speed of 1750 rpm.

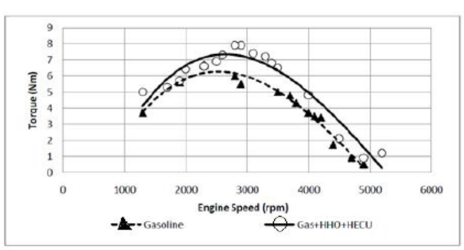


Figure 5.1. Variation of engine torque with engine speed

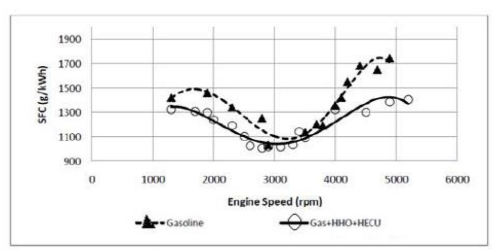


Figure 5.2. Variation of SFC with engine speed

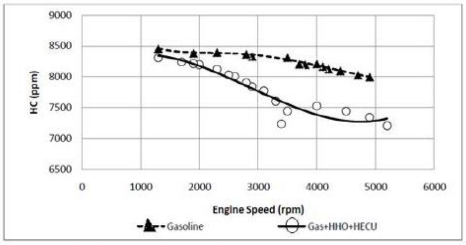


Figure 5.3. Variation of HC emissions with engine speed

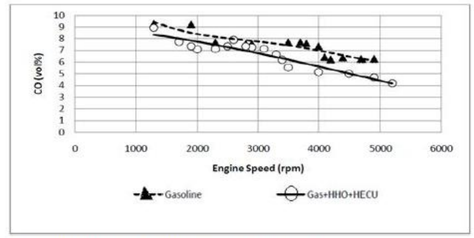


Figure 5.4. Variation of CO emissions with engine speed

Conclusions (directly from paper) (Yilmaz, 2010).

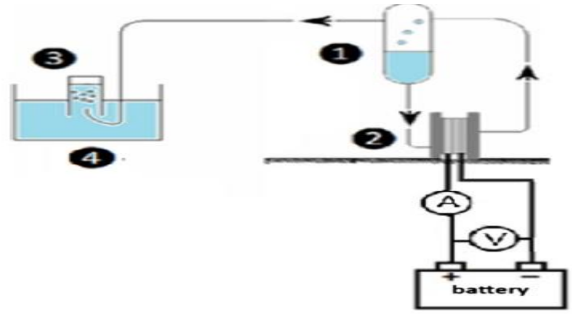
The results of this experimental study are summarized as follows:

1. At mid and higher engine speeds, the HHO system with diesel fuel and gasoline yields higher engine torque output compared to pure diesel and gasoline fueled engine operation unless HECU is added to the system. High burning velocity and low ignition energy of HHO-air mixture minimize the effect of the weakened in cylinder charge flow and increased residual gas fraction which blocks the fuel to be fast and completely burnt at high speeds. Also, high burning velocity of HHO yields higher resistance against knocking which provides higher compression ratio (CR) and increased thermal efficiency. However, increased CR may cause pre-ignition and this can be minimized by direct HHO injection into the cylinder. At low engine speeds, low lean flammability limits of HHO causes challenges at higher equivalence ratios. Due to the long opening time of intake manifold at low speeds, high volume occupation (reduced volumetric efficiency) of HHO becomes inevitable. Since minimum ignition energy of HHO-air mixture is a decreasing function of equivalence ratio till stoichiometric (richer) conditions, torque is reduced after HHO addition. A control unit has to be used to obtain appropriate electrolysis voltage and current (gas flow rate) to terminate the impairments of HHO gas at low speeds.
2. Uniform and improved mixing of HHO-air and oxygen content of HHO stimulate combustion which has a major effect on SFC by using an adequate capacity HHO system. Wide flammability range, high flame speed and short quenching distance of HHO yield gasoline and diesel fuel to be combusted completely under high-speed conditions without HECU and low-speed conditions with HECU.
3. High burning velocity, wide flammability range, oxygen content, and absence of carbon make HHO gas an appropriate fuel addition in obtaining adequate combustion which yields reputable reduction of HC and CO emissions when a sufficient HHO system is used at mid and higher speeds of the engine without HECU and low-speed conditions with HECU.
4. A control unit, which decreases electrolysis voltage and current automatically when the engine speed decreases under 1750 rpm for CI and 2500 rpm for SI (critical speeds for this experimental study), has to be designed and manufactured to eliminate the impairments of HHO enriched diesel fuel combustion at low speeds and to provide energy economy.
5. The average power increment in test engines during experiments is bigger than the electrical power consumed and fuel economy obtained with the aid of HHO system as well. This indicates that the system is efficient.

Wang et al have conducted a number of experiments investigating H_2/gasoline blends. Their results are outlined in their studies (Wang et al, 2009,2011,2011,2011,2012,2014).

HHO design

The generator used consists of a separation tank, an HHO cell, with continuous flow. This style is referred to as a Dry Cell. Stainless steel electrodes were used, 16 electrodes 16x20x.2 cm thick. Configured as shown. *__Neutral plates divide the voltage while all plates carry the same amperage__*. The space between the plates was reduced to 1mm by the use of rubber gaskets. The voltage ranged from 12-14 volt DC. HHO cell results. It is found that 6g/L of KOH as catalyst gives better efficiency (Notice different from the last study who said NaOH was best). It is found the 4g/L of NaOH gives better thermal efficiency compared to other NaOH. The Picture shows the results comparing 6g/L KOH to 4g/L of NaOH. It is found that the KOH gives the **highest efficiency.**



(a)

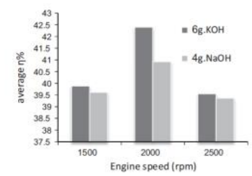
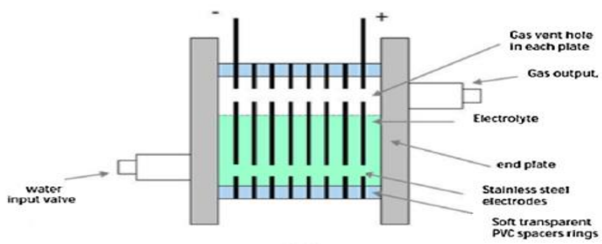
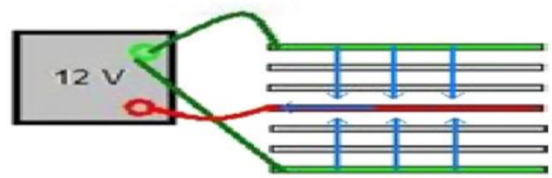


Figure 7 Average efficiencies for using concentrations of 6 g KOH and 4 g NaOH per liter at different engine speed.



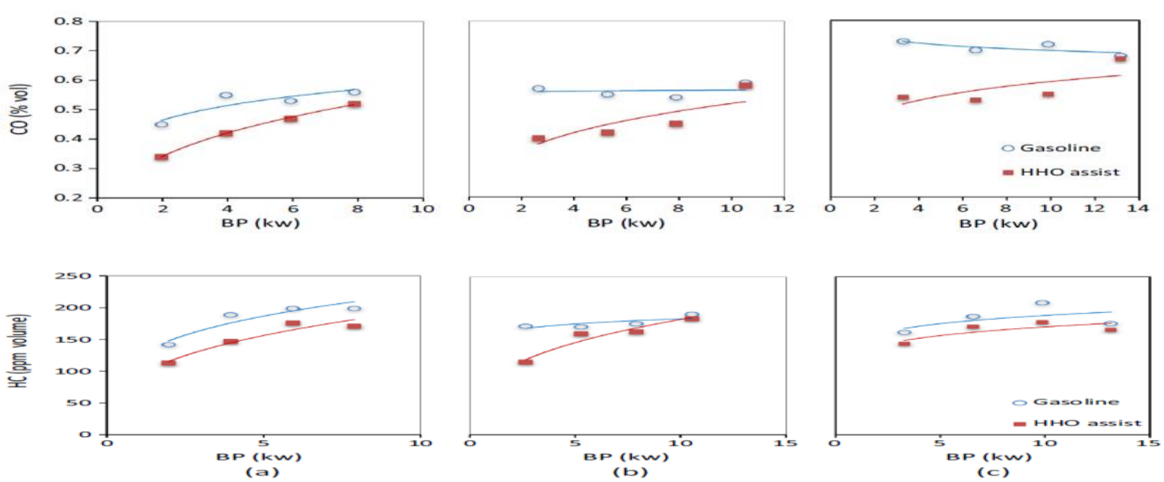
(a)



(b)

Engine emissions,

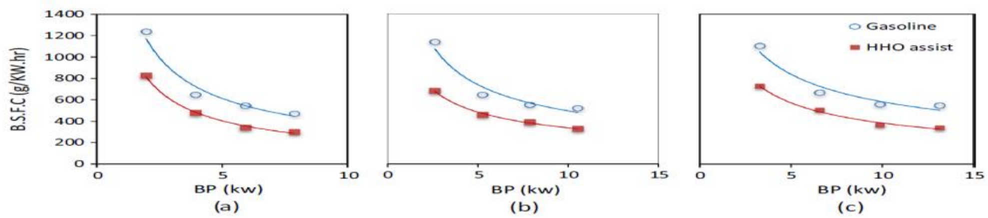
NOx is expected to increase, however, it is noted that when the *__gasoline mixture is leaned out__* to accommodate for the HHO there is a reduction in NOx as well.



Conclusion (taken directly from paper) (Wang et al, 2014).

1. HHO cell can be integrated easily with existing engine systems.
2. The engine thermal efficiency has been increased up to 10% when HHO gas has been introduced into the air/fuel mixture, consequently reducing fuel consumption by up to 34%
3. The concentration of NOx, CO, and HC gasses has been reduced to almost 15%, 18%, 14% respectively on average when HHO is introduced into the system.
4. The best available catalyst was found to be KOH, with a concentration of 6g/L.
5. The proposed design for separation tank takes into consideration the safety precaution needed

Widhiyanuriyawan did an experiment using simple $NaHCO_3$ in a water solution. He used six pieces Stainless Steel for electrodes. The results indicated that distilled water consumed 353.52 Watts to produce Brown's gas of 0.00123 l/s. However, if $NaHCO_3$ (baking soda and water) was added into



: 9 Effect of varying the engine dynamometer load on BSFC; (a) 1500 rpm, (b) 2000 rpm, and (c) 2500 rpm.

distilled water with the mass fraction of 1.33% consumed power decreased to 27.89 Watts and Brown's gas was produced 0.0017 l/s. The efficiency of distilled water had the greatest efficiency only 5.53% by using current of 2 Ampere and power reached 31.043Watts. This is a 1400% power drop and a net increase in production (Widhiyanuriyawan, 2016).

Literature Review Summation.

1. Yes H_2 and HHO can be burned in an engine. Erren and Campbell in 1920 were successful.
2. Yes HHO can be produced from electrolysis for little cost (Yull Brown patent, in 1977).
3. Though H_2 alone is not suitable as an alternative fuel source for a drop-in replacement, in the future it is still a viable alternative due to the weight to power ratio, however, engines design specifically for H_2 would have to be engineered, in the meantime HHO with the water content that it has will reduce all emissions and enhance power and torque when the fossil fuels are leaned out to accommodate for the HHO, with the addition of a control unit to control the flow rate into the intake for this reason more experimentation is advised Lee and Brehob in 1971 showed H_2 to be an insufficient drop in replacement for fossil fuel(Lee and Brehob, 1971).
4. Engineering an HHO cell seems to be inexpensive, however, after the experiment, we will further elaborate on our findings, is it possible to build an HHO cell for 20 dollars or less.
5. Design effects production.
    i. All studies use Plexiglas or a material that does not have a substantial risk if flashback occurs. As a result in our main experiment, we will be using plastic (Bambagn et al, 2016).
    ii. According to reviews, it is found that the electrode plate is the best choice, due to increased volume and these plates should be stainless steel (Millman and Grabel, 1987).

iii. It is found that the dead plate or blank plate design is the best to provide insulation for electric currents (Millman and Grabel, 1987).
iv. It is found that $NaHCO_3$ is the best catalyst for the following reasons (Widhiyanuriyawan, 2016) (Yimaz et al, 2010).
   a. KOH is not readily available, and production of it is time-consuming and hazardous when compared to baking soda and water.
   b. NaOH is mostly derived from a chemical reaction that emits chlorine gas which is hazardous to humans.
   c. The benefits for reducing power requirements as well as the increase in productivity is desirable.
v. It is found that gas measurement can be done by water displacement.
vi. It is found that because of cost and ease the Wet Cell type is preferable.

6. Most experiments were done at 12-14 volts DC, some went up to 35v. These studies show 14 volts at 2 amps was the preferred volts and amp, however, for a perfect reaction amperage should be much lower (Zeng, Zhang, 2010).

Q. 7. Will HHO cells operate with A.C. or D.C. best, or what happens if one uses a D.C. to carry A.C.?
Will be determined in the experiment.

Q. 8. What happens to production when A.C. frequency is changed?
Will be determined in the experiment.

Conclusion

For a complete answer to questions 4, 7 and 8 it is advised to continue experimentation, further, it is felt that the next step in the process is to find what effect in any production of HHO from electrolysis has under different electrical energy forums.

Experiment Hypothesis

1. With increased voltage amount their sound be a net gain of production of HHO due to the increased electron count. A voltage over the potential of typically *0.6V above the 1.48V* (Zeng, Zhang, 2010).
2. A.C. voltage may show and increase in production amount as the poles of the current reverse making it possible for all electrodes to be more efficient due to a more efficient use of surface area. Millman and Grabel were able to change production rates with their PWM.
3. A frequency in Hz of the current that matches the resident frequency of either the electrode or the aqueous solution should cause the hydrogen bonds to break more readily. Millman and Grabel were able to change temperature and keep it below 60° C with their PWM.
4. An A.C. current carried by a D.C. voltage should increase production due to the increased force breaking the Hydrogen bonds Eckman states that the Hydrogen bond is weak so any added stress to this bond should be effective (Eckman, 2010).
5. An Audio signal carried by a D.C. voltage should cause greater production as the audio frequency draws nearer to the resident frequency of the electrode or the aq solution do to vibration. Bambagn et al state that the Pulsing of current was effective in weakening Hydrogen bonds (Bambagn et al, 2016). Any added stress to this bond should be effective in weakening the bond and increasing production (Eckman, 2010).

Stages

This experiment will be carried out in stages.
Stage one: Engineer and HHO Cell as cheaply as possible to verify Q. 4.
Stage two. Engineer a Cell that is safe in the case of flashback and test outputs D.C. volts and amps from 1V to 20V.
Stage three: Test various voltages above 20V at varying Amperages.
Stage four: Test with A.C. Voltage 0-20V low Amperages.
Stage five: Test High A.C. Voltages Varying Amperage.
Stage Six: Audio signals from an amplifier as a power source set at different frequencies.
Stage Seven: Repeat stage 6 using both full and half wave rectifiers using as much at the info from the other stages as possible to guide the settings.

Methods

Data for stage one is visibly observed with the eye, and given by store receipt.

Data for Stages 2-5 will be gathered by 3 Digital Multi Meters, and a temperature reading Device. And a Graduated Bottle to read volumetric production of HHO.

Data for Stages 6-8 will include all previous data recording devices, with the addition of an Oscilloscope app for frequency reading.

Stage one: The Mission is to Engineer or Build an HHO Wet Cell as cheaply as possible using products from local hardware stores. Assemble using decided configurations from the literature review and hypothesis. The purpose of this experiment is to make observations of gas production, i.e. is gas produced? D.C. Voltages from 1v dc to 20 v dc. Will be used. Also, a test with pure tap water vs $NaHCO_3$ (aq) will be compared visually. Funding for this stage is supplied by Jeffery Morse.

Stage two. Engineer a Cell that is safe in the case of flashback. We will use the 6 g/L amount in Mohammad's tests of $NaHCO_{3\,(aq)}$ and test volumetric outputs using the water displacement method. D.C. volts and amps from 1V to 25V produced by a variable power supply. Three DVMs will read A.C. volts, D.C. Volts, and Amperage. Data will be recorded for Temperature, Volts, Amps, and Volume of HHO produced. Also, a run with distilled water will be done for baseline comparison. Also, a run with Tap water only will be run for a baseline comparison.

Stage thee: Using the setup from stage two Test various voltages above 20V D.C. at varying Amperages will be recorded. Also, one test using an in-circuit spark gap.

Stage four: Using current set up a test with A.C. Voltage 0-20V low Amperages.

Stage five: Test High A.C. Voltages Varying Amperage (fire and explosive precautions for this experiment will include shielding and fire protection).

Stage six: Test A.C. a small A.C. generator must be constructed to vary Hz.

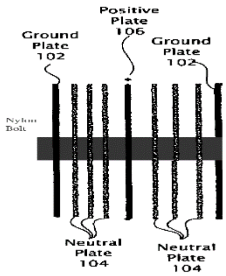
Stage Seven: Repeat stage 6 using both full and half wave rectifiers using as much at the info from the other stages as possible to guide the settings.

Results Stage One: Cost

1. 9 Stainless Steel washers ½ x 2 inches. .65 cents each at Lowes.
2. 1 nylon bolt ½ by 4 inches from Home Depot $1
3. 4 nylon nuts for bolts .65 cents each
4. 9 nylon washers for spacers. .20 cents each
5. 1 old olive jar and lid, free
6. Old speaker wire I had laying around.
7. 1 tablespoon Baking Soda free.

Total cost: Less than $20.00.

Build:



The first negative power lead is slide on the nylon bolt and then the first plate washer slides on the nylon bolt, 3 nylon washer for spacers then each of the three neutral stainless washers with nylon washer spacers in between. Then a nylon bolt for distance. The Positive Plate washer and electric supply line with another nylon bolt on top of that, then three neutral plate washers, a spacer, and the last negative plate washer and supply line, lastly the final nylon nut to hold it together. A whole in the top for ventilation and electric access.

Results stage one:

1. Using Distilled water NO visible gas is produced.
2. Using Water with a tablespoon of Bicarbonate visible gas is produced.
3. It is noted that with increased DC voltage more production is seen.

Conclusions stage one:

1. A simple HHO was achieved at a cost less than $20 U.S.
2. Production rises with D.C. voltage.
3. Due to the nature of HHO, it is recommended to abandon glass as a casing in case of an explosion.
4. Since Q4 is "True", and production of HHO is visible with bicarbonate solution it is recommended to proceed to stage two.

Method: Stages two and three

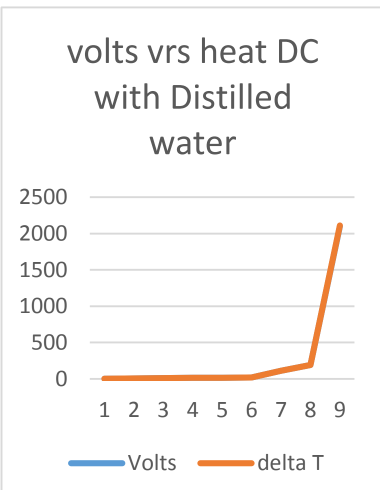
Stage two. Engineer a Cell that is safe in the case of flashback. We will use the 6 g/L amount in Mohammad's tests of $NaHCO_{3\,(aq)}$ and test volumetric outputs using the water displacement method. D.C. volts and amps from 1V to 20V produced by a variable power supply. Three DVMs will read A.C. volts, D.C. Volts, and Amperage. Data will be recorded for Temperature, Volts, Amps, and Volume of HHO produced. Also, a run with distilled water will be done for baseline comparison. Also, a run with Tap water only will be run for a baseline comparison.

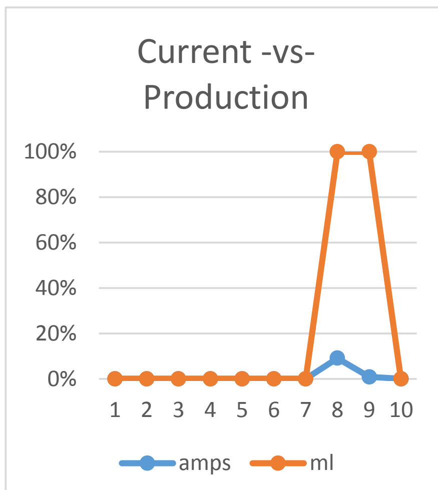
Design

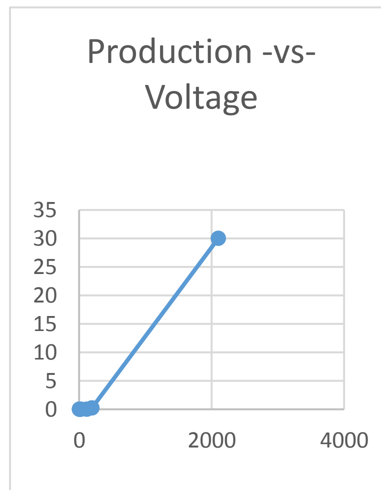
1. We used the cell assembly made in the last stage and placed it in a sealed plastic water bottle with contact points for electricity and an exhaust spout. The bottle was purchased at the Goodwill for less than 1 dollar.
2. The water displacement device was made from an old chain fuel mixture container graduated at 15, 30 and 45 Ml. At the HHO is produced it passes through the hose to the main section of the white container forcing water into the top mixture reservoir.

Measurements

1. We used a variable d.c. power supply from 1-25v. For lower voltages, and higher voltages were created through running the supply voltage through a transformer, also we used a 2100 volt transformer with a half wave rectifier to achieve kilovolts.
2. We used voltmeters at the output of the supply as well as voltmeters on the posts of the cell for reading. Further, we used amp meters in both places. For kilovolt measurements, a resistance was added to the probes to allow for higher voltage measurement.
3. Please refer to the appendix for the data tables on all charts.





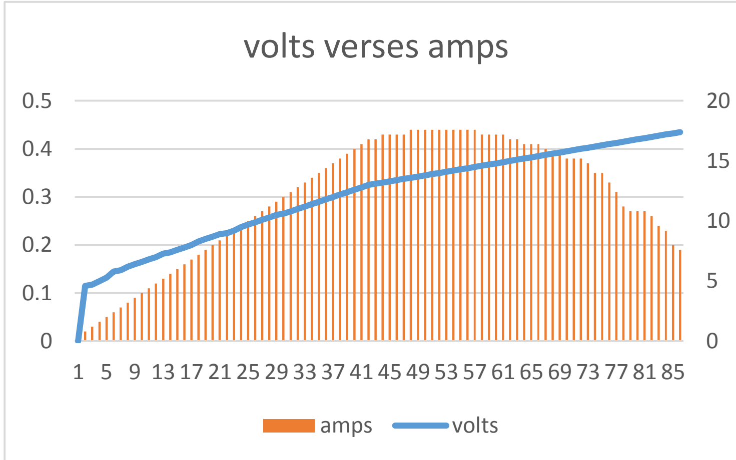


Results Stages two and three: appendix A:

Results from stages two and three show that only a very high voltage will produce HHO gas from distilled water. Further the temperatures created would be a challenge to manage. One note is that there seems to be some correlation between the increase in amperage and the production of HHO. It is recommended that before proceeding to stage four measurement be taken of values voltage versus amperage. Conclusion HHO cell is not economically useful under this condition using distilled water, the costs outway the benefits.

Results from voltage versus amp review: appendix B.

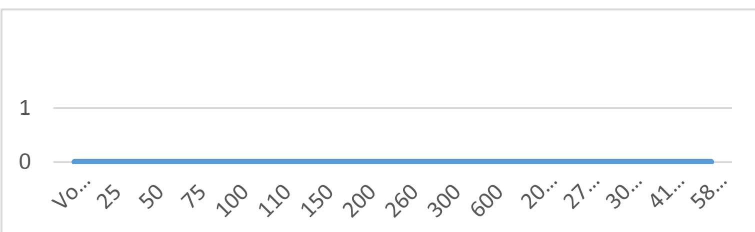
1. It is found that the greatest draw on a power source is from 12 to 16 volts.
2. The graph indicates that at some voltage greater than 20 volts it may be possible to have a low current drain.



Conclusions stages two and three:

Most studies show that this technology is not economically sound, however, after doing a power requirement review it is found that this technology may be profitable. It seems that most studies have been performed at a voltage from 10-17 volts, though this is the normal voltage of an auto charging system this is also the highest area of the current requirement for this cell. However, stage three showed that the higher the d.c. voltage supplied, the more heat produced, also the net benefit is not great enough to support the production of high voltages at amperages above 2 amps. Recommendation to continue to the next stage.

Stages four and five, appendix C & D:



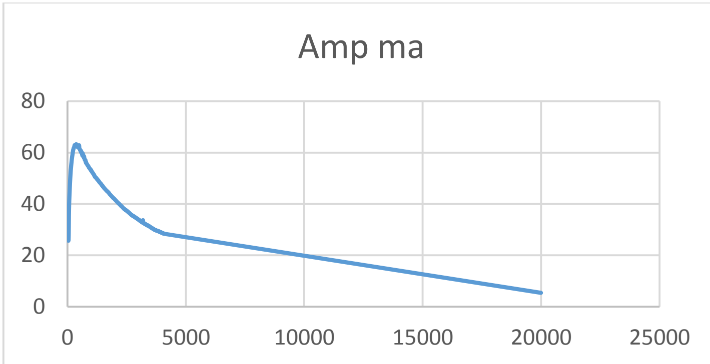
Results Stages four and five: A.C. power will not produce HHO in the cell. Though it was thought that the cathode and anode would oscillate, the net result is that they never polarize, as a result no production is done.

Conclusion Stages four and five

Alternating current will not work to produce HHO gas in an HHO cell. The recommendation is to go on to step six.

Stage Six

The use of an audio amp to provide an A.C. signal at the resonant frequency of the cell. The resonance frequency is found by recording the metal of the cell after being struck. Then the file is analyzed with an audio frequency analyzer to determine resonant frequencies. The resonance frequencies are found to be 46.7. 53, and 127 Hz. A signal from a frequency generator was running through an audio amplifier, in this way an alternating current at the desired frequency was obtained.

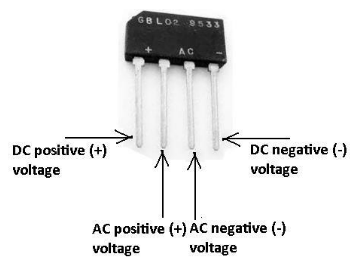


Results stage six: appendix E.

1. Since an audio signal is an A.C. current it made no difference what frequency was supplied, no HHO was produced. Recommendation to go on to stage seven.
2. It was found that as frequency increased voltage decreased.

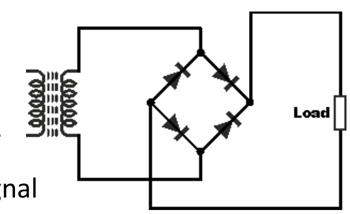
Conclusion stage six:

Since the studies show that continuous D.C. voltage produces too great a delta T, and no production is made from any audio frequency it is recommended to continue to stage seven.



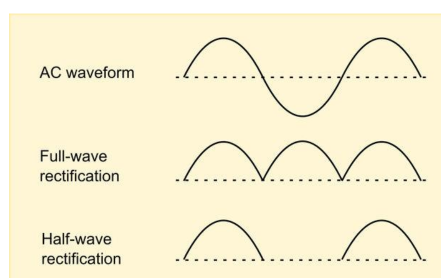
Stage Seven. Audio Signal through a full wave rectifier.

A full wave rectifier if a diode bridge that in essence splits the positive and negative portions of the alternating wave. It then inverts the negative portion to positive. The end result is a positively charged pulse at twice the frequency rate.

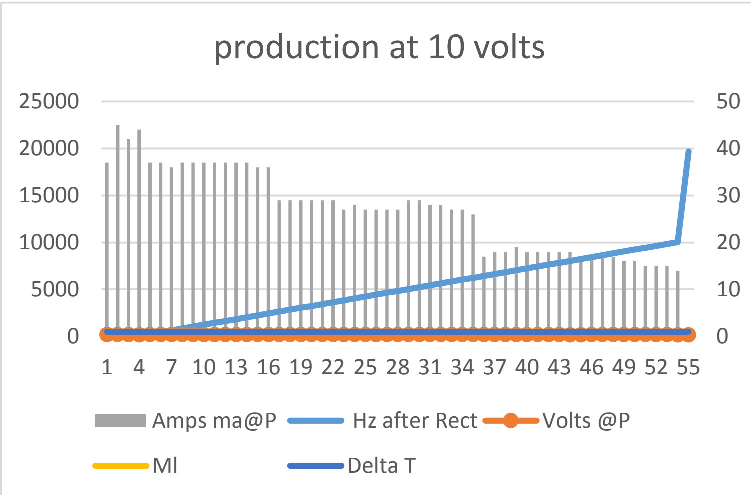


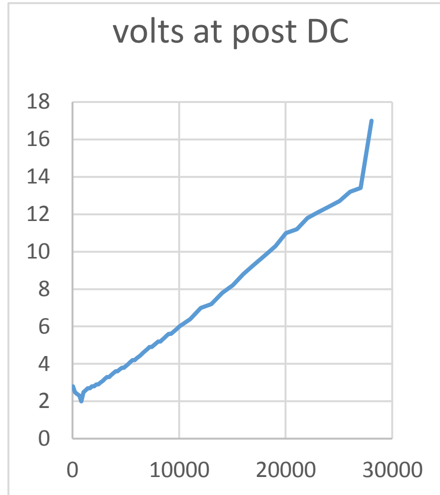
Results stage seven: appendix G, voltage values with full wave rectifier.

It first is noticed that the voltage value of the rectified audio signal follows the characteristics of the continuous d.c. voltages studied in stages two and three as shown in the Volts at post-DC graph to the right. As a result, it may be possible to find a frequency that will have a very small current draw.



Results stage seven a: Production and current results of using an audio signal through a full wave rectifier with the voltage held at 10 volts. Appendix G.



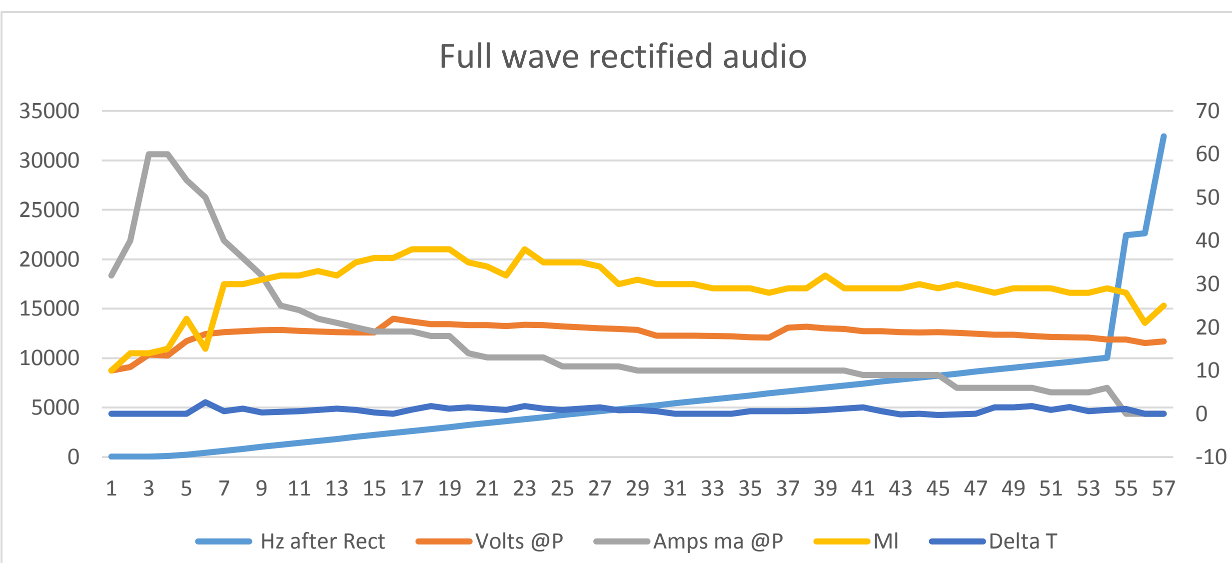


Discussion

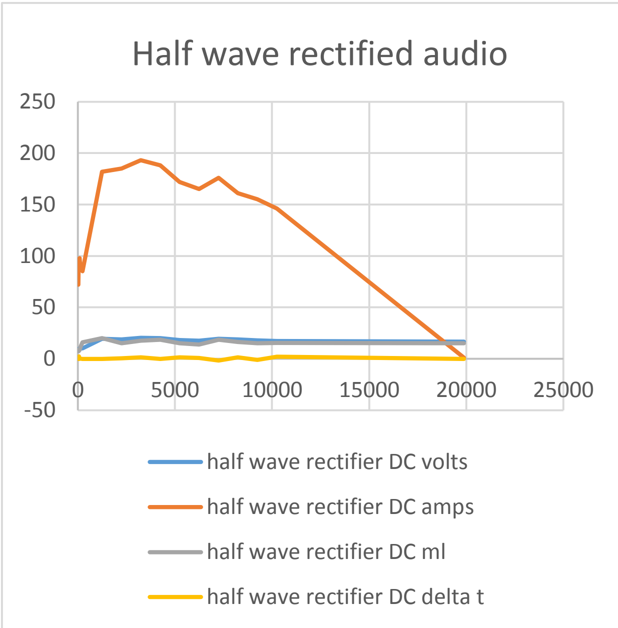
It is shown that voltage seems to be the deciding factor on production. No matter what Hz the production value was stable at 7.5 mL per minute. An unexpected outcome is a drastic reduction in current needed. Current has dropped to 50 milliamps or less, also it is noticed that at extremely high frequencies production remains the same but amperage draw drops to zero. This is very promising and greatly reduces the cost of producing HHO. However, 7.5 mL per minute is not enough production to sustain need.

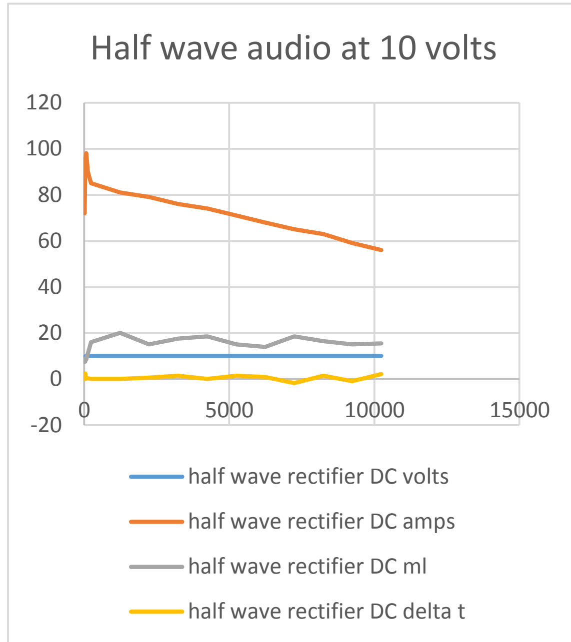
Results stage seven b: Production and current results of using an audio signal through a full wave rectifier with only Hz being changed and voltage and amperage being the result of the given Hz. Appendix H.

Discussion stage seven b: Again the results show that at 22440 Hz current draw drops to zero. While the production did reduce by 2 mL per minute this is an acceptable loss to have the net cost drop so



radically. Delta T (temperature increase) is also lower at this point. The other alternative is to use a Pulse Width Modulator, and from our research, the current reduction can also be achieved.





Results stage seven c: Half-wave rectified audio signal.

Discussion stage seven c:

The Half wave rectifier required much more current to operate, also the current never reached 0 but got very close at .1 amp. The production also never went about 20 mL per minute.

Conclusion stage seven c:

The half wave does not function as good with its limitations of never making it to zero amp draw. Further, any delta T offset that would have been gain from the longer interval is lost in the increased current draw. Finally, this model may be usable due to the decrease in production costs in installation as only one diode is required.

Final Analysis and Discussion

HHO has been looked at as an alternative additive to fossil fuels to help relieve the stresses caused by used of such fuels as well as hardships caused by the limitation of supply. Several questions were posed at the beginning of this paper and an effort has been made to determine if HHO is economically and real world alternative. Through the stages one through seven we have found many answers to these questions. An HHO cell was engineered for less than 20 dollars American. Many answers came through the literature review as it was found that H_2 can burn in engines, usually needing the timing changed to function properly. It has further been shown in the literature review that HHO does significantly reduce all auto emissions. Also found is that design does indeed affect production, and it is recommended that experiments in design continue. This experiment centered more on the problem of the cost of creating the electricity nullifying any net gain from the use of the cell. It was found that no alternating current by itself can create the polarization needed for the electrodes of the cell to produce HHO. To add to this we found that D.C. voltages around the voltages of auto batteries and charging systems are in the range of the highest current draw, as a result voltages above 20 volts and below 100 volts are suggested, in this experiment about 30 volts was good. Further, it was found that a full wave rectifier outperformed the half wave by reducing current requirements by a factor of about eight of the half wave rectifier, however, it should be noted that both outperform our literature review current requirements by a factor of about 100. It was further noted that it is possible through the manipulation of frequency to tune the cell to have a 0 current draw. This reduces the cost of production to almost nothing. The frequency that was found to lower the current to zero was about 22440 Hz while production of 28 mL of HHO gas was measured. This is not the highest on the chart for production but should be sufficient to do the job while keeping the cost of electricity to almost nothing.

Interpreting the data

The findings show that HHO is a viable alternative additive to fossil fuels and is an excellent candidate for further study. the production electrical net cost is so low that a small solar panel would be able to supply the need, or if ran off the battery, the zero amp draw would allow one to produce HHO for long periods of time without recharging. This is a game changer for this technology. HHO can easily increase mileage while lowering emissions on an auto, the problem of the big money not liking it may be reduced as it can be used as an additive and not a replacement until such a time the people of the world are allowed without danger to use a free technology.

Final conclusions

1. Can H_2 burn in an engine? YES!
2. Is it real--can one produce a burnable form of H_2 from water easily? YES!
3. Does HHO have significant data supporting the decrease of auto emission to warrant further study? YES!
4. Is it true that one can build and HHO cell at little cost? YES!
5. How does design affect production? The design does affect production.
6. At what amperage and voltage values is a Cell likely to operate best at? About 30 volts or about, at Zero amps.
7. Will HHO cells operate with A.C. or D.C. best, or what happens if one uses a D.C. to carry A.C.? HHO cells will not operate on A.C. but a pulsed D.C. charge is preferable over a continuous charge.
8. What happens to production when the frequency is changed? The voltage and amperage are affected as well as production. It is possible to tune a cell using frequency so it will produce HHO gas with a gross electrical current cost of zero.

Recommendations

It is recommended to further experiments using PWM's and high voltages. Further, it is recommended cell design continue to be experimented with. Lastly using a D.C. pulsed wave to carry and A.C. frequency is yet to be tested. This is a technology that should be distributed only on a temporary basis. Using water as a source of fuel is not really a good idea as it is the lifeblood of everything on the planet. Once more recycling biomatter in a gasifier is just as efficient and we have tons of that. Grass clipping to run your car is something that is renewable as well as an efficient means of disposal. To make pellets from biomatter is an easy process and the gas is burnable in most vehicles especially CI engines.

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Appendix

A. D.C. Voltages in distilled water.

d.c.	Volts	amps	ml	by sight	minutes	delta T
	2	0	0	no	0	0
	5	0	0	no	0	0
	9	0	0	no	0	0
	12	0	0	no	0	0
	15	0	0	no	0	0
	20	0	0	no	0	0
	112	0	0	no	0	0
	190	0.02	2	yes	20	2
	2100	0.25	30	yes	2	10

B. D.C Volt versus Amps Comparison.

Volts:amps

0:0	4.6:0.02	4.7:0.03	5:0.04	5.3:0.05	5.8:0.06
5.9:0.07	6.2:0.08	6.4:0.09	6.6:0.1	6.8:0.11	7:0.12
7.3:0.13	7.4:0.14	7.6:0.15	7.8:0.16	8:0.17	8.3:0.18
8.5:0.19	8.7:0.2	8.9:0.21	9:0.22	9.2:0.23	9.5:0.24
9.7:0.25	9.9:0.26	10.1:0.27	10.3:0.28	10.5:0.29	10.6:0.3
10.8:0.31	11:0.32	11.2:0.33	11.4:0.34	11.6:0.35	11.8:0.36
12:0.37	12.2:0.38	12.4:0.39	12.6:0.4	12.8:0.41	13:0.42
13.1:0.42	13.2:0.43	13.3:0.43	13.4:0.43	13.5:0.43	13.6:0.44
13.7:0.44	13.8:0.44	13.9:0.44	14:0.44	14.1:0.44	14.2:0.44
14.3:0.44	14.4:0.44	14.5:0.44	14.6:0.43	14.7:0.43	14.8:0.43
14.9:0.43	15:0.42	15.1:0.42	15.2:0.41	15.3:0.41	15.4:0.41
15.5:0.4	15.6:0.39	15.7:0.39	15.8:0.38	15.9:0.38	16:0.38
16.1:0.37	16.2:0.35	16.3:0.35	16.4:0.33	16.5:0.31	16.6:0.28
16.7:0.27	16.8:0.27	16.9:0.27	17:0.26	17.1:0.24	17.2:0.23
17.3:0.2	17.4:0.19				

C. Data from test with A.C. voltages and Distilled Water

A.C	Volts	current to supply	current at the cell	Ml/min	production	time
	9	0.001	0	0	no	20 min
	50	2	0	0	no	20 min
	75	2	0	0	no	20 min
	85	3	0	0	no	20 min
	110	3	0	0	no	20 min
	2100	4	0	0	no	20 min
	50000	4	0	0	no	20 min

D. Data from the test with A.C. voltages with electrolyte.

AC with 6g/liter sodium bicarbonate

Volt Draw	Amp Draw	Time	Ml	Delta T
25	4	2	0	0
50	7.6	2	0	0
75	8.4	2	0	0
100	7.1	2	0	0
110	5.4	2	0	0
150	12	2	0	0
200	0.96	2	0	0
260	1.2	2	0	0
300	1.5	2	0	0
600	2.6	2	0	0
2000	1.5	2	0	0
2700	3.2	2	0	0
3000	1.2	2	0	0
41000	1.8	2	0	0
58000	2.5	2	0	0

E. Audio Signal voltage and amperage with distilled water.

Hz	Amp ma	Volts	Hz	Amp ma	Volts	Hz	Amp ma	Volts	Hz	Amp ma	Volts
20	27.7	0.2	30	30	0.3	40	25.7	0.4	50	27.8	0.4
60	35.3	0.4	70	39.7	0.4	80	42.5	0.4	90	44.7	0.4
100	46.9	0.4	110	48.8	0.4	120	50.5	0.4	130	51.9	0.4
140	53.2	0.4	150	54.2	0.5	160	55.3	0.5	170	56.2	0.5
180	57.2	0.5	190	57.9	0.5	200	58.6	0.5	210	59.2	0.5
220	59.8	0.5	230	60.4	0.5	240	61	0.5	250	61.3	0.5
260	61.7	0.6	270	61.9	0.6	280	62.1	0.6	290	62.4	0.6
300	62.8	0.6	310	63	0.6	320	62.9	0.6	330	62.9	0.6
340	63	0.6	350	62.8	0.6	360	63.2	0.6	370	63.3	0.6
380	63.2	0.6	390	63	0.6	400	62.8	0.6	410	62.7	0.6
420	62.3	0.6	430	62.5	0.6	440	62.5	0.65	450	62	0.6
460	62.8	0.7	470	62.6	0.7	480	62.3	0.7	490	62.9	0.7
500	61.8	0.7	510	61.5	0.65	520	61.4	0.65	530	61.2	0.69
540	60.9	0.7	550	60.8	0.7	560	60.5	0.7	570	60.3	0.7
580	60.6	0.7	590	59.9	0.7	600	59.9	0.7	610	60.1	0.7
620	59.5	0.7	630	58.9	0.7	640	59	0.7	650	59.6	0.7
660	58.6	0.7	670	58.9	0.7	680	58.3	0.7	690	58.6	0.7
700	58.6	0.7	710	58	0.7	720	57.6	0.7	730	57.3	0.7
740	57.1	0.7	750	57	0.7	760	57.1	0.7	770	56.5	0.7

780	56.1	0.7	790	56.1	0.7	800	55.9	0.6	810	55.7	0.6
820	55.6	0.6	830	55.4	0.6	840	55.3	0.6	850	55.1	0.6
860	55	0.6	870	54.9	0.6	880	54.7	0.6	890	54.6	0.6
900	54.3	0.6	910	54.2	0.6	920	54.1	0.6	930	54	0.6
940	53.8	0.6	950	53.7	0.6	960	53.6	0.6	970	53.4	0.6
980	53.3	0.6	990	53.2	0.6	1000	53.2	0.6	1010	52.9	0.6
1020	52.8	0.6	1030	52.6	0.6	1040	52.5	0.6	1050	52.3	0.6
1060	52.2	0.6	1070	52.1	0.6	1080	51.9	0.6	1090	51.8	0.6
1100	51.7	0.6	1110	51.5	0.6	1120	51.4	0.6	1130	51.2	0.6
1140	50.9	0.65	1150	50.9	0.65	1160	50.7	0.69	1170	50.5	0.7
1180	50.4	0.7	1190	50.3	0.7	1200	50.3	0.7	1210	50.2	0.7
1220	50.1	0.7	1230	50	0.7	1240	49.8	0.7	1250	49.7	0.7
1260	49.5	0.7	1270	49.5	0.7	1280	49.4	0.7	1290	49.3	0.7
1300	49.2	0.7	1310	49.1	0.7	1320	48.9	0.7	1330	48.8	0.7
1340	48.7	0.7	1350	48.5	0.7	1360	48.4	0.7	1370	48.3	0.7
1380	48.2	0.7	1390	48.1	0.7	1400	48	0.7	1410	47.9	0.7
1420	47.8	0.7	1430	47.6	0.7	1440	47.5	0.7	1450	47.4	0.7
1460	47.2	0.7	1470	47.2	0.7	1480	47.1	0.7	1490	47	0.7
1500	46.8	0.7	1510	46.7	0.7	1520	46.6	0.7	1530	46.5	0.7
1540	46.3	0.7	1550	46.2	0.7	1560	46.1	0.7	1570	46	0.7
1580	45.9	0.7	1590	45.8	0.7	1600	45.7	0.7	1610	45.6	0.7
1620	45.5	0.7	1630	45.4	0.7	1640	45.3	0.7	1650	45.2	0.7
1660	45.1	0.7	1670	45	0.7	1680	44.9	0.7	1690	44.9	0.7
1700	44.8	0.7	1710	44.7	0.7	1720	44.6	0.7	1730	44.5	0.7
1740	44.4	0.7	1750	44.3	0.7	1760	44.2	0.7	1770	44	0.7
1780	43.9	0.7	1790	43.8	0.7	1800	43.7	0.7	1810	43.6	0.7
1820	43.5	0.7	1830	43.4	0.7	1840	43.3	0.7	1850	43.2	0.7
1860	43.1	0.7	1870	43	0.7	1880	42.9	0.7	1890	42.8	0.7
1900	42.7	0.7	1910	42.6	0.7	1920	42.5	0.7	1930	42.4	0.7
1940	42.3	0.7	1950	42.2	0.7	1960	42.2	0.7	1970	42.1	0.7
1980	42	0.7	1990	41.9	0.7	2000	41.8	0.7	2010	41.7	0.7
2020	41.6	0.7	2030	41.5	0.7	2040	41.4	0.7	2050	41.3	0.7
2060	41.2	0.7	2070	41.1	0.7	2080	41	0.7	2090	40.9	0.7
2100	40.8	0.7	2110	40.7	0.7	2120	40.6	0.7	2130	40.5	0.7
2140	40.4	0.7	2150	40.3	0.7	2160	40.2	0.7	2170	40.2	0.7
2180	40.1	0.7	2190	40	0.7	2200	39.9	0.7	2210	39.8	0.7
2220	39.7	0.7	2230	39.6	0.7	2240	39.5	0.7	2250	39.4	0.7
2260	39.3	0.7	2270	39.2	0.7	2280	39.2	0.7	2290	39.1	0.7
2300	39	0.7	2310	38.9	0.7	2320	38.8	0.7	2330	38.7	0.7
2340	38.6	0.7	2350	38.5	0.7	2360	38.4	0.7	2370	38.3	0.7
2380	38.2	0.7	2390	38.1	0.7	2400	38.1	0.7	2410	38	0.7
2420	37.9	0.7	2430	37.9	0.7	2440	37.8	0.7	2450	37.7	0.7
2460	37.6	0.7	2470	37.6	0.7	2480	37.5	0.7	2490	37.5	0.7
2500	37.4	0.7	2510	37.3	0.7	2520	37.2	0.7	2530	37.2	0.7
2540	37.1	0.7	2550	37	0.7	2560	36.9	0.7	2570	36.8	0.7
2580	36.8	0.7	2590	36.7	0.7	2600	36.6	0.7	2610	36.5	0.7
2620	36.5	0.7	2630	36.4	0.7	2640	36.3	0.7	2650	36.2	0.7
2660	36.1	0.7	2670	36	0.7	2680	35.9	0.7	2690	35.9	0.7

2700	35.8	0.7	2710	35.7	0.7	2720	35.6	0.7	2730	35.6	0.7
2740	35.5	0.7	2750	35.5	0.7	2760	35.4	0.7	2770	35.4	0.7
2780	35.3	0.7	2790	35.3	0.7	2800	35.2	0.7	2810	35.1	0.7
2820	35.1	0.7	2830	35	0.7	2840	34.9	0.7	2850	34.9	0.7
2860	34.8	0.7	2870	34.8	0.7	2880	34.7	0.7	2890	34.6	0.7
2900	34.6	0.7	2910	34.5	0.7	2920	34.4	0.7	2930	34.4	0.7
2940	34.3	0.75	2950	34.3	0.75	2960	34.2	0.75	2970	34.1	0.75
2980	34.1	0.75	2990	34	0.75	3000	33.9	0.75	3010	33.8	0.75
3020	33.8	0.75	3030	33.7	0.75	3040	33.6	0.75	3050	33.6	0.75
3060	33.5	0.75	3070	33.5	0.75	3080	33.4	0.75	3090	33.3	0.75
3100	33.3	0.75	3110	33.2	0.75	3120	33.1	0.75	3130	33.1	0.75
3140	33	0.75	3150	32.9	0.75	3160	32.8	0.75	3170	32.8	0.75
3180	32.8	0.75	3190	33.7	0.75	3200	32.7	0.75	3210	32.6	0.75
3220	32.6	0.75	3230	32.5	0.75	3240	32.4	0.75	3250	32.4	0.75
3260	32.3	0.75	3270	32.3	0.75	3280	32.2	0.75	3290	32.2	0.75
3300	32.1	0.75	3310	32.1	0.75	3320	32	0.75	3330	31.9	0.75
3340	31.9	0.75	3350	31.8	0.75	3360	31.8	0.75	3370	31.7	0.75
3380	31.7	0.75	3390	31.6	0.75	3400	31.6	0.75	3410	31.5	0.75
3420	31.5	0.75	3430	31.4	0.75	3440	31.4	0.75	3450	31.3	0.75
3460	31.3	0.75	3470	31.2	0.75	3480	31.2	0.75	3490	31.1	0.75
3500	31	0.75	3510	31	0.75	3520	30.9	0.75	3530	30.8	0.75
3540	30.8	0.75	3550	30.7	0.75	3560	30.7	0.75	3570	30.6	0.75
3580	30.5	0.75	3590	30.5	0.75	3600	30.4	0.75	3610	30.4	0.75
3620	30.3	0.75	3630	30.3	0.75	3640	30.2	0.75	3650	30.1	0.75
3660	30.1	0.75	3670	30	0.75	3680	30	0.75	3690	30	0.75
3700	29.9	0.75	3710	29.9	0.75	3720	29.8	0.75	3730	29.8	0.75
3740	29.7	0.75	3750	29.7	0.75	3760	29.7	0.75	3770	29.6	0.75
3780	29.6	0.75	3790	29.6	0.75	3800	29.5	0.75	3810	29.5	0.75
3820	29.5	0.75	3830	29.4	0.75	3840	29.4	0.75	3850	29.4	0.75
3860	29.3	0.75	3870	29.3	0.75	3880	29.2	0.75	3890	29.2	0.75
3900	29.2	0.75	3910	29.1	0.75	3920	29.1	0.75	3930	29	0.75
3940	29	0.75	3950	29	0.75	3960	28.9	0.75	3970	28.9	0.75
3980	28.8	0.75	3990	28.8	0.75	4000	28.8	0.75	4010	28.7	0.75
4020	28.7	0.75	4030	28.6	0.75	4040	28.6	0.75	4050	28.5	0.75
4060	28.5	0.75	4070	28.5	0.75	4080	28.4	0.75	20000	5.4	0.8

F. Audio Signal with Full Wave Rectifier, Voltages at Cell electrodes.
Hz: hz after full wave: volts at post DC

20	40	2.8:	120	240	2.5:	220	440	2.4:	320	640	2.3
420	840	2	520	1040	2.5	620	1240	2.6	720	1440	2.7
820	1640	2.7	920	1840	2.8	1020	2040	2.8	1120	2240	2.9
1220	2440	2.9	1320	2640	3	1420	2840	3.1	1520	3040	3.2
1620	3240	3.3	1720	3440	3.3	1820	3640	3.4	1920	3840	3.5
2020	4040	3.6	2120	4240	3.6	2220	4440	3.7	2320	4640	3.8
2420	4840	3.8	2520	5040	3.9	2620	5240	4	2720	5440	4.1

2820	5640	4.2	2920	5840	4.2	3020	6040	4.3	3120	6240	4.4
3220	6440	4.5	3320	6640	4.6	3420	6840	4.7	3520	7040	4.8
3620	7240	4.9	3720	7440	4.9	3820	7640	5	3920	7840	5.1
4020	8040	5.2	4120	8240	5.2	4220	8440	5.3	4320	8640	5.4
4420	8840	5.5	4520	9040	5.6	4620	9240	5.6	4720	9440	5.7
4820	9640	5.8	4920	9840	5.9	5020	10040	6	5520	11040	6.4
6020	12040	7	6520	13040	7.2	7020	14040	7.8	7520	15040	8.2
8020	16040	8.8	8520	17040	9.3	9020	18040	9.8	9520	19040	10.3
10020	20040	11	10520	21040	11.2	11020	22040	11.8	11520	23040	12.1
12020	24040	12.4	12520	25040	12.7	13020	26040	13.2	13520	27040	13.4
14020	28040	17									

G. Production and current results from an audio signal through a full wave rectifier. With voltage held at 10 Volts.

Hz from source	Hz after Rectifier	Volts @P	Amps @P	Ml	Delta T	Visual	Time
20	40	10	0.37	15	0	yes	2
23.5	47	10	0.45	15	0	yes	2
26.75	53.5	10	0.42	15	0	yes	2
63.75	127.5	10	0.44	16	0	yes	2
120	240	10	0.37	15	0.3	yes	2
220	440	10	0.37	15	0.3	yes	2
320	640	10	0.36	15	0	yes	2
420	840	10	0.37	15	-0.3	yes	2
520	1040	10	0.37	15	0.6	yes	2
620	1240	10	0.37	15	0.3	yes	2
720	1440	10	0.37	15	0	yes	2
820	1640	10	0.37	15	0	yes	2
920	1840	10	0.37	15	-0.3	yes	2
1020	2040	10	0.37	15	0	yes	2
1120	2240	10	0.36	15	0.6	yes	2
1220	2440	10	0.36	15	0	yes	2
1320	2640	10	0.29	15	0.3	yes	2
1420	2840	10	0.29	15	0	yes	2
1520	3040	10	0.29	15	0.3	yes	2
1620	3240	10	0.29	15	0	yes	2
1720	3440	10	0.29	15	0	yes	2
1820	3640	10	0.29	15	0.3	yes	2
1920	3840	10	0.27	15	0	yes	2
2020	4040	10	0.28	15	0	yes	2
2120	4240	10	0.27	15	0	yes	2
2220	4440	10	0.27	15	0	yes	2
2320	4640	10	0.27	15	0	yes	2
2420	4840	10	0.27	15	0	yes	2
2520	5040	10	0.29	15	0	yes	2

2620	5240	10	0.29	15	0	yes	2
2720	5440	10	0.28	15	0	yes	2
2820	5640	10	0.28	15	0.2	yes	2
2920	5840	10	0.27	15	0	yes	2
3020	6040	10	0.27	15	0	yes	2
3120	6240	10	0.26	15	0	yes	2
3220	6440	10	0.17	15	0	yes	2
3320	6640	10	0.18	15	0	yes	2
3420	6840	10	0.18	15	0	yes	2
3520	7040	10	0.19	15	0	yes	2
3620	7240	10	0.18	15	0	yes	2
3720	7440	10	0.18	15	-0.6	yes	2
3820	7640	10	0.18	15	0.4	yes	2
3920	7840	10	0.18	15	0	yes	2
4020	8040	10	0.18	15	0.9	yes	2
4120	8240	10	0.17	15	0.9	yes	2
4220	8440	10	0.17	15	0.2	yes	2
4320	8640	10	0.17	15	0	yes	2
4420	8840	10	0.17	15	0	yes	2
4520	9040	10	0.16	15	-0.2	yes	2
4620	9240	10	0.16	15	-0.3	yes	2
4720	9440	10	0.15	15	-0.3	yes	2
4820	9640	10	0.15	15	0	yes	2
4920	9840	10	0.15	15	0	yes	2
5020	10040	10	0.14	16	0	yes	2
9840	19680	10	0	16	0	yes	2

H. Production and current results from an audio signal through a full wave rectifier.

Hz from source	Hz after Rect	Volts @P	Amps ma @P	Ml	Delta T	Visual	Time
20	40	10	32	10	0	yes	1
23.5	47	10.8	40	14	0	yes	1
26.5	53	13.7	60	14	0	yes	1
63.75	127.5	13.5	60	15	0	yes	1
120	240	16.8	54	22	0	yes	1
220	440	18.4	50	15	2.7	yes	1
320	640	18.9	40	30	0.6	yes	1
420	840	19.1	36	30	1.2	yes	1
520	1040	19.3	32	31	0.3	yes	1
620	1240	19.4	25	32	0.5	yes	1
720	1440	19.2	24	32	0.6	yes	1
820	1640	19	22	33	0.9	yes	1
920	1840	18.9	21	32	1.2	yes	1

1020	2040	18.8	20	35	0.9	yes	1
1120	2240	18.8	19	36	0.3	yes	1
1220	2440	22	19	36	0	yes	1
1320	2640	21.3	19	38	1	yes	1
1420	2840	20.7	18	38	1.8	yes	1
1520	3040	20.7	18	38	1.2	yes	1
1620	3240	20.5	14	35	1.5	yes	1
1720	3440	20.5	13	34	1.2	yes	1
1820	3640	20.3	13	32	0.9	yes	1
1920	3840	20.6	13	38	1.8	yes	1
2020	4040	20.5	13	35	1.2	yes	1
2120	4240	20.2	11	35	0.9	yes	1
2220	4440	20	11	35	1.2	yes	1
2320	4640	19.8	11	34	1.5	yes	1
2420	4840	19.6	11	30	0.8	yes	1
2520	5040	19.4	10	31	0.9	yes	1
2620	5240	18.1	10	30	0.6	yes	1
2720	5440	18.1	10	30	0	yes	1
2820	5640	18.1	10	30	0	yes	1
2920	5840	18	10	29	0	yes	1
3020	6040	17.9	10	29	0	yes	1
3120	6240	17.7	10	29	0.6	yes	1
3220	6440	17.6	10	28	0.6	yes	1
3320	6640	19.9	10	29	0.6	yes	1
3420	6840	20.1	10	29	0.7	yes	1
3520	7040	19.8	10	32	0.9	yes	1
3620	7240	19.6	10	29	1.2	yes	1
3720	7440	19.1	9	29	1.5	yes	1
3820	7640	19.1	9	29	0.6	yes	1
3920	7840	18.9	9	29	-0.1	yes	1
4020	8040	18.8	9	30	0	yes	1
4120	8240	18.9	9	29	-0.3	yes	1
4220	8440	18.7	6	30	-0.1	yes	1
4320	8640	18.5	6	29	0	yes	1
4420	8840	18.3	6	28	1.5	yes	1
4520	9040	18.3	6	29	1.5	yes	1
4620	9240	18	6	29	1.8	yes	1
4720	9440	17.8	5	29	0.9	yes	1
4820	9640	17.7	5	28	1.6	yes	1
4920	9840	17.6	5	28	0.6	yes	1
5020	10040	17.2	6	29	0.9	yes	1
11220	22440	17.2	0	28	1.1	yes	1
11320	22640	16.4	0	21	0	yes	1
16220	32440	16.7	0	25	0	yes	1

I. Half-wave rectified audio signal at 10 volts.

half wave rectifier DC

Hz	volts	amps	ml	time	delta t
20	8	0.72	7.5	1	0
40	9.5	0.92	7.5	1	1
46.67	9.7	0.94	8	1	2.4
53	9.9	0.96	9	1	0
80	10	0.98	8.5	1	0.3
127.5	10	0.9	11	1	0.3
240	10	0.85	16	1	0
1240	10	0.81	20	1	0
2240	10	0.79	15	1	0.6
3240	10	0.76	17.5	1	1.5
4240	10	0.74	18.5	1	0
5240	10	0.71	15	1	1.5
6240	10	0.68	14	1	0.9
7240	10	0.65	18.5	1	-1.8
8240	10	0.63	16.5	1	1.5
9240	10	0.59	15	1	-0.9
10240	10	0.56	15.5	1	2.1

J. Half-wave rectified audio signal with Hz determining volts and amps.

half wave rectifier DC

Hz	volts	amps	ml	time	delta t
20	8	0.72	7.5	1	0
40	9.5	0.92	7.5	1	1
46.67	9.7	0.94	8	1	2.4
53	9.9	0.96	9	1	0
80	10	0.98	8.5	1	0.3
127.5	10	0.9	11	1	0.3
240	10	0.85	16	1	0
1240	19.4	1.82	20	1	0
2240	18.8	1.85	15	1	0.6
3240	20.5	1.93	17.5	1	1.5
4240	20.2	1.88	18.5	1	0
5240	18.1	1.72	15	1	1.5
6240	17.7	1.65	14	1	0.9
7240	19.6	1.76	18.5	1	-1.8
8240	18.9	1.61	16.5	1	1.5
9240	18	1.55	15	1	-0.9

10240	17.2	1.46	15.5	1	2.1
19882	16.6	1	15	1	0