SOLAR POWERED HHO BROWN GAS FUEL CELL

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ABSTRACT

HHO is a mixture of hydrogen and oxygen gas produced by water electrolysis that is purported to increase efficiency of internal combustion engines when fed into the air intake. Available data indicates that this is true. This report attempts to determine whether HHO gas injection can serve as a cost-effective method for reducing vehicle fuel costs. The results of eight investigations are analyzed. In all studies, the method of determining the effect of hho on fuel consumption is roughly the same. Fuel consumption of a diesel engine on a dynamometer test stand is measured at different hoe gas feed rates. In this way, tests are performed under a relatively controlled set of conditions. The additional amount of energy produced per mass units of hydrogen gas was calculated at various speeds and loads. This determination, called a yield value, wan useful for comparing results against various thresholds. A yield of approximately 9 mega joules per grain of h2 is needed for cost effective reduction of vehicle fuel costs. Only three of the eight investigations met this requirement. a restricted hho feed rate was one factor common to the three investigations with higher yield values. a wet cell reactor of similar design was also used. the issue of whether there might be some variability in the composition of the hho gas itself is also addressed.

1. INTRODUCTION:

There has been much conjuncture in the public domain as to the effects on fuel economy of hydrogen on-demand systems made for internal combustion engines, as is evident with a simple search on the internet. There is little solid experimental evidence from controlled repeatable tests quantitatively proving the economy enhancing effects of on-board HHO for naturally aspirated or turbo diesel engines. Two independent sets of researchers have shown experimentally that HHO on-board can reduce diesel consumption [1, 2], while another team found a reduction in engine efficiency [3]. To the authors knowledge no on–board testing has been performed under a controlled environment where the systems variables and environmental conditions are accurately controlled and corrected for. On-board HHO addition means HHO produced by taking a portion of the engines power to crack water into a small volume of HHO to be fed back into the air intake as a fuel saving additive. This study will experimentally verify the economy and emissions effects of adding small rates of HHO produced on-demand by a diesel generators own power combined with 0% water injection and 10% water injection.

Research Objectives

The rationale behind the research objectives are derived from the research gap in testing hydrogen on demand by other researchers, as well as the need to experimentally prove or disprove the validity of the claims of hydrogen on demand vendors.

The experimental research objectives of this research include;

- Experimentally test the effect on fuel consumption and exhaust emissions of adding 0L/min to 6L/min of HHO to a constant speed 28kW diesel generator under two loading conditions - 30% and 55% of the engines rated load.
- Accurately automate and data-log the experiment with an industrial control system, where water injection rate, HHO production and generator load are the independent variables.
- Optimize HHO and water injection ratios to yield lowest brake specific fuel consumption, if HHO is shown to have a positive effect on fuel economy.
- Record and discuss the effects of HHO on oxides of nitrogen (NOx) emissions.
- Discuss the financial feasibility of on-board HHO, if HHO proves to reduce diesel consumption.

2. LITERATURE SURVEY

BROWN'S GAS is created via the process of water electrolysis where the hydrogen and oxygen are allowed to stay mixed. Water contains a ratio of 2 parts hydrogen to one part oxygen bonded in a tetrahedral molecular arrangement with two lone pairs of electrons and two bonding pairs of electrons connecting the hydrogen atoms to the central oxygen atom. BROWN'S GAS is created via the process of water electrolysis where the hydrogen and oxygen are allowed to stay mixed. Water contains a ratio of 2 parts hydrogen to one part oxygen bonded in a tetrahedral molecular arrangement with two lone pairs of electrons and two bonding pairs of electrons connecting the hydrogen atoms to the central oxygen atom.

The extra energy stored in one litre of HHO due to Rydberg clusters is theorized to be 600±34J. Rydberg clusters are most common in solids and liquids and are typically stable from nanoseconds to hours. In the case of HHO or Brown's Gas these clusters have shown a life span of 11 minutes [4]. Due to these highly energizedclustersHHOcontainsmuchmoreenergythaneq uivalentstoichiometric

Adnan et al. found gaseous hydrogen injection rate of 20L/min at standard temperature and pressure (STP) doubled oxides of nitrogen (NOx) emission at 1500r/min in a 7.4kW 406cm3 naturally aspirated Yanmar diesel engine, with a compression ratio of 19.3:1. The engine load or power output was not stated. The cylinder peak pressure increased 11% and delayed the peak pressure event 10° in the combustion stroke, indicated power increased 33% at 1500r/min. The power gain would correspond to a reduction of fuel consumption all things being equal. If the hydrogen was produced on-demand at 4.4Wh/L then the added load would be 5.3kW, leaving around 29% of the engines power for useful work, and most likely dramatically increasing diesel consumption.

3. METHODOLOGY

Construction

This research project had a large experimental portion requiring fabrication of a few different components. The components included manufacture of intake and exhaust manifolds for the engine, plumbing the diesel supply and metering system, rebuilding of electrolyser, and calibrating the electrolyser. Oxyhydrogen as an additive Hydrogen is highly explosive at standard temperatures and pressures when mixed with air. There are eight layers of safety redundancy in the hydrogen system making it almost impossible even to cause any injuries.

1. Small volume of HHO storage. The hydrogen and oxygen are produced on demand, so the only storage is in the supply lines and the gas void in the electrolyte tank and molecular sieve. The maximum storage/worst case scenario is around 1L stored in the bubbler flash back arrestor. The energy in 1L of HHO could be calculated as the HHV of the stored volume of hydrogen

Mass of hydrogen in 1L at STP;

$$m_{H_2} = \frac{p \cdot V \cdot MW}{R \cdot T}$$

$$= \frac{101325 \times 667 \times 10^{-6} \times 2.016}{8.3145 \times 298.15} = 55.0mg$$

Where is the mass of hydrogen

p is the pressure of air [Pa]

V is volume of gas [m3]

MW is the molecular weight of hydrogen [gmol−1]

R is the ideal gas constant [jk−1 mol−1]

T is the temperature [K]

Energy in 1 litre of HHO in terms of the product of the higher heating value of hydrogen () and equation (3.1);

$$E_{H2} = m_{H_2} \cdot HHV_{H_2}$$

$$= 55.0 \times 10^{-6} \times 141.86 \times 10^{3} = 7.8\ kJ$$

Where is the higher heating value of hydrogen [J/g]

This is the equivalent to the energy contained in 0.17g of diesel.

2. HHO injection below flammability limit. The maximum rate of HHO injection is 6L/min. The test engine is a 3.9L four stroke engine operating at 1500r/min. Volume of air drawn in by the engine per minute is determined by the engine displacement, and engine speed assuming there are no pumping losses:

$$fuel\ air\ ratio\ (volume) = \frac{V_{HHo}}{V_e} \cdot \frac{2}{3} \cdot 100\%$$

$$= \frac{6}{2925} \cdot \frac{2}{3} \cdot 100\% = 0.137\%$$

3. No ignition source inside system. There are no spark energy sources inside the HHO system. The control of HHO production being open loop, so there are no sensors in the HHO supply or production zones.

High auto ignition temperature of 585°C. The hottest part of the exhaust pipe was measured at 440 under full load, so this is ~140 below the flammability limit. There is no mechanism to allow HHO to be vented to the exhaust manifold in any case of failure.

Leak tested. The system was tested for hydrogen flow at the electrolyte tank and then at the bubbler where the gas leaves the system. The seals in the flash back arrestor where leak proofed with Vaseline for easy of servicing.

1. **Hydrogen is highly dissipative.** Hydrogen is 14 times lighter than air rising at 20m/s.
2. **Room ventilation.** USQ's engine laboratory is fully ventilated, even if it was sealed the hydrogen would dissipate out of the room quicker then it could be produced.
3. **Emergency stop isolation.** The emergency stop button (E-stop) breaks power to the diesel supply valve, and makes a separated isolated contact to the PLC control system. On activation the DC electrical supply to the water electrolyser is isolated, preventing a more production of HHO. The main supply relay is supplied from generators 24V DC PLC power supply, which is only active when the engine is running.

Operation:

A hazard operability assessment was conducted before the experimental equipment was installed on the diesel generator set as per Appendix B: Experiment HAZOP. Two academic staff (one having RPEQ registration) and an electrical technician where present to review all plant and procedure to be used in the experiment that differed from standard procedure. All risks identified were reduced

to acceptable levels primarily through procedural safeguards and having hearing and eye protection. Safe operation of the experiment mainly involved operators understanding the correct start, run, stop and emergency shutdown procedures for the equipment.

4. Experimental SETUP

The experiment is designed to automatically cycle four rates of HHO injection, two rates of water injection at two engine loads. Primary goals of the experimental design include;

- Repeatability oftests
- Accurate control over the input/system variables
- Adjustment for environmental conditions such as ambient air temperature and relative humidity
- Steady state engine operating conditions – constant 1500 r/min engine speed and stable exhaust gas temperatures.

Initial Test Procedure

Initially the test cycle was designed to be fully automated, where the PLC stepped through the engine through three loads, having water injection rates incremented up to 25% of the diesel consumption, as well as stepping through sixty rates of HHO injection from 0-6L/min. This gave a total of 1500 system states. All sensors were programmed to be read every 100ms with the average value logged every 500ms. The data was processed immediately after each automated test into three dimensional surface plots of fuel consumption and exhaust gas temperature versus HHO injection and water injection.

Final Test Procedure

The final test cycle involved running the engine with fixed input variables for the time the engine took to drain 100g of diesel – about 70 seconds at the 55% engine loading. This represents a 700x greater time base for acquiring diesel consumption data for a given combination of input variables compared to the previous test cycle used. The test procedure in this final experimental structure involved the operator setting the load and water injection rate then allowing the PLC to step through four discrete increases in HHO injection from 0L/min to 6L/min. There were a total of four test cycles, running HHO injection with and without 10% water injection at 30% and 55% engine load.

Optimized Testing

The engine test included six main subsystems;

1. Water electrolyser subsystem
2. Water injection subsystem
3. Generator resistive load bank
4. NOx exhausts gas analysis subsystem
5. Diesel supply subsystem
6. Automated control and data logging subsystem

The selection process for each subsystem was based on balancing accuracy and reliability of control, availability of parts, simplicity of design, time constraints and replication of equivalent HHO products or concepts in the public domain.

HHO Subsystem

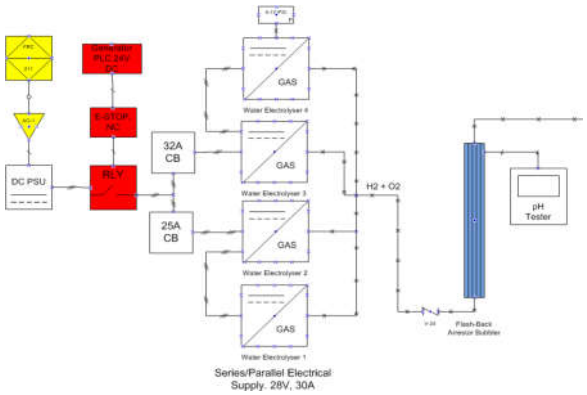


Figure 5: P&ID for the Water electrolyser

Principle of Operation

The HHO subsystem consists of an array of water electrolysers, programmable low voltage (up to 33V) DC power supply, a bubbler flash back arrestor and an electrical safety interlock. The plates in the electrolyser are set up the same as in a car battery.

Electrically the electrolyser is the same as over charging a battery – hydrogen and oxygen are produced. There are effectively 13 stainless steel plates

or tubes with 12 spaces containing electrolyte. The two end plates of the water electrolysers were supplied 12.5-14V DC, depending on the required current on HHO addition rate, resulting in a 2.08V to 2.33V drop across each successive plate in the electrolyser. When the voltage is supplied current flows, work is done in the form of splitting water into hydrogen and oxygen and waste heat. HHO production is directly proportional to current flow, so the greater the current supplied to the electrolysers, the greater the production of HHO in linear proportion.

Electrolyser Control

The water electrolyser had its current supplied from a Sorenson XG 1700 series 33V, 50A DC programmable power supply. The power supply's current was controlled by a 0-10V DC signal from a PLC DAC output. Four6-cell electrolysers were used – two were rated at 18A and two were rated at 30A. To reduce the current at full HHO production, the cells were run in series/parallel. The 18A electrolysers were connected in series with each other and the 30A electrolysers were connected in series with each other. These two sets of electrolysers connected in parallel (Figure 5) so as two both have 25-28V. The cables and electrolysers were protected by the DC power supply's current limiting function, and by two DC circuit breakers rated at 25A and 32A. The system could be isolated by manually activating the emergency stop button. This would break the current to the solenoid relay, and send a control signal to the PLC notifying the program that there was a fault.

Calibration

Calibration and measurement of HHO volumetric injection rate seems to be a missing factor in the HHO literature reviewed [1, 2]. Flow rate measured with a flow meter designed for air was found to show only 75% of the actual flow rate for HHO. This discrepancy was discovered by taking measurements with the HHO equipment flowing gas through a RMB series Dwyer flow meter in series with an inverted bucket in water.

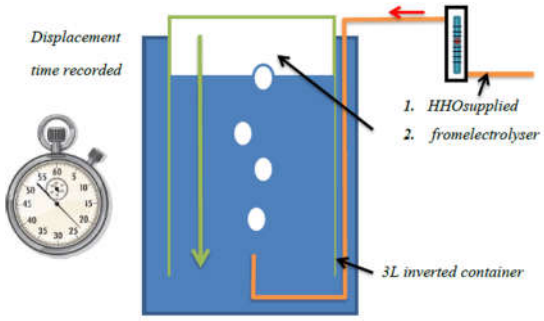


Figure 6: Representation of gas volume calibration setup.

The PLC span or scaling constant was determined calculating a span constant for the DAC – PLC – DC power supply interface, measuring actual gas production, and then adjusting the span constant. The initial HHO span constant for the PLC ladder logic was within 4% to 10% of the required span value, after correction the error was within -5% to +1% error. The measurement error would be due to user timing errors - ±0.5s over the shortest time base of 29s (6 L/min), giving a +-1.7% time-volume error.

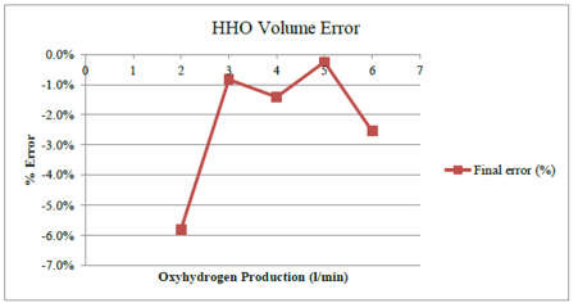


Figure 7: HHO volumetric flow rate error.

Electrolyser Performance:

The water electrolysers produced HHO at 3.1Wh/L at the DC output of the power supply, and an average of 4.06Wh/L at the 240V AC supply. The input power for the three production rates was higher due to the losses in the switching power supply in converting the higher voltage AC power to the lower voltage DC power.

100% efficient electrolysis in terms of power will be taken as 2.16Wh/L.

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%

Table : Energy requirements for on-board electrolysis

HHO Subsystem Appraisal	
Advantages	**Disadvantages**
• Water electrolyser – 4Wh/L HHO input energy • Accurate control over HHO volumetric flow rate - > ±6%error • Unfiltered HHO injection – replicates system available on the market, and does not disturb potential Rydberg clusters	• No desiccant used in final stage, leading to additional unknown water injection rates • Only DC current supplied ,effects and claims of pulsed electrolysis untested • Unknown ratio of para-hydrogen and ortho-hydrogen in injection

Table : HHO subsystem advantages and disadvantages

Water Mist Injection Subsystem

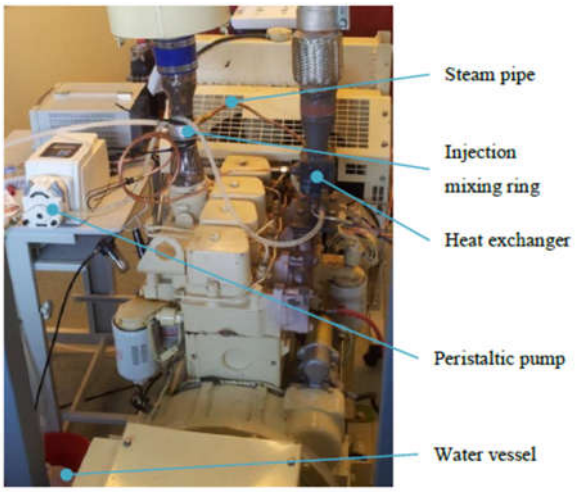


Figure 8: Water injection system layout

Water injection has benefits of reducing exhaust gas temperatures, converting heat energy into work by expanding the water into steam [12] and reducing NOx emissions because of the lower combustion temperatures [10]. Water injection may provide a means for steam cracking the diesel into lighter hydrocarbons with lower lean flammability limits – this would aid in leaner combustion. For this experiment water was injected at 0% and 10% w/w water/base line diesel consumption, at the 4 HHO injection rates.

Fig : Exhaust water-to-steam heat exchanger on the left, and internal 6mm copper pipe coil inside the unit on the right.

The peristaltic pump used in the experiment to deliver the water was a Langer Instruments model BT100-2J pump with a resolution of 0.18mL/min. The pumps head has two rollers, so the water flow had some pulsed component (Figure 10), but much of the flow variation would be attenuated as the water was heated into a gas phase then travelled through 0.5m of copper pipe before reaching the intake air manifold.

Table 8: Water injection error margin.

Load	Injection rate	Pump r/min	Maximum error
9.91kW	340g/h	3.1r/min - 334.8g/h	-1.53%
19.1kW	522g/h	4.8r/min - 518.4g/h	-0.69%

Figure 10: Voltage measurement from a Sensirion SLQ-HC60 flow meter connected to the peristaltic pump.

Table 9: Water system design appraisal.

Water Injection Subsystem Appraisal	
Advantages	**Disadvantages**
• Accurate control over waterinjection • Good mixing of water and intakeair • Relatively long test cycle removing effects of pulses in waterinjection • Reuse of waste heat energy from exhaust	• Unknown water/steam injection temperature • Possible small reduction of air density due to displacement from water mist and increased air temperature • Water vapour mixing with engine oil • Risk rusting of piston rings if engine not purged of waterafter test

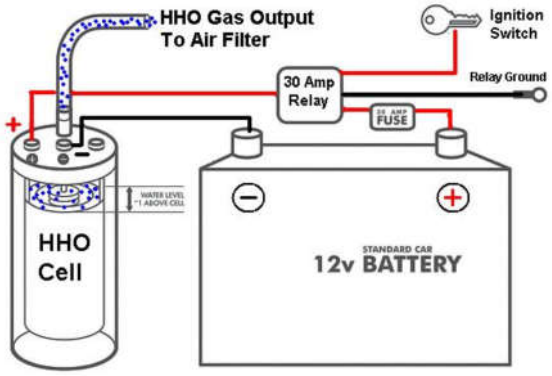
Black diagram:

Hydrogen Generators are NOT hard to build, we've seen children build these devices (under adult supervision of course). Our collection of plans and guides show you pictures and illustrations for building the HHO Generator of your choice. If you don't like the way one manual explains it, you can simply choose another. You can mix and match different designs to make a unique HHO system that is a custom fit to your vehicle.

HHO Generators are just as simple to install. With our multiple plans and videos at hand, installation becomes super easy. The eBooks include detailed pictures and diagrams to look at. The HHO gas generated from the electrolyser is sucked into your engine's air intake system as shown in the diagram below. The entire system uses your engine's vacuum pressure to suck in more HHO gas as engine speed increases.

Converting your vehicle to a Hydrogen Hybrid is simple. There is no need to modify your engine or your vehicle's computer. Once you start your car, the HHO Generator uses electricity supplied by your car's battery and Alternator to produce HHO gas (Hydrogen + Oxygen) also known as "Oxyhydrogen" or Hydroxyl Gas.

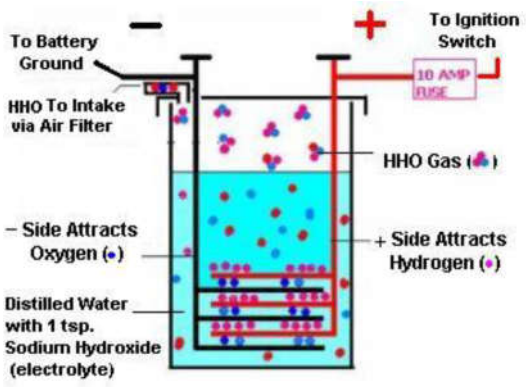
The electrical connections are just as simple. The device by-passes any complication by simply connecting the negative wire to your battery and the positive wire to your ignition switch or fuel pump. This ensures that your HHO Generator will not activate unless your vehicle is turned on. The entire system is also fully protected by an inline 30 Amp fuse, which will blow to prevent damage to your HHO cell.



After researching and testing many different HHO Generator designs of all materials, shapes and sizes, we gathered all the best designs that worked and put them

into one HUGE package called the HHOSuperPack! Through extensive testing and research, we've found the BEST Hydrogen Generators that can produce the most HHO gas while using the least amount of battery power.

HHO technology work



By placing two pieces of metal in distilled water, and applying electricity, the water (H2O) can instantly be separated into Hydrogen and Oxygen. The separated gas molecules surface and regroup to form HHO GAS, which is an unbounded mixture of Hydrogen and Oxygen.

This Hydroxyl Gas is then injected into your vehicle's air intake system as a Supplemental Fuel. HHO Gas has proven to increase mileage while improving horsepower and lowering emissions.

Experimental equipments:

Fuel of Choice

Gasoline is preferred to Diesel. Propane is preferred to Gasoline. HHO is preferred to Propane or any other fuel. HHO is the perfect fuel. In order to take advantage of the increasing ability of each fuel, more engine requirements are needed. But when engine to fuel type is evenly matched, new efficiencies are realized. Creating an evenly matched engine for HHO is uncharted. If anyone has done it, they're not sharing.

Gasoline Generator Milestone:

The first that we know of to run gasoline generators completely on HHO is Smart Scare Crow & D3adpOO1. They each posted YouTube videos. We believe this was under estimated in its importance. This is a huge HHO milestone! There is much controversy concerning HHO mileage boosting. Mileage booster scammers gave HHO a bad rep. However, running generators on HHO proves this technology. HHO is very real fuel.

Gasoline Generator Modes

The other shoe is about to fall- ready? Who would have thought that gasoline generators could run completely on HHO without engine modification? We were expecting serious engine modification just to get them to idle on HHO. I know this aspect was not grasped by most viewers on the debut. This is a testament of the versatility and viability of HHO fuel.

Advanced Electrolysis Theory

D3 deserves credit for his work on the advanced electrolysis theory. His efforts detail & explain the new .5 MMW milestone gain. D3's secret sause is trade information and will likely find application only in a closed loop HHO engine. This may be disclosed when we have substantial working prototypes.

HHO Cell Builds

When we learn that water can become fuel, and that we can do it at home, we get excited about HHO devices.

A first build might look like this:

'Bazooka' Cell

Freedom Cell

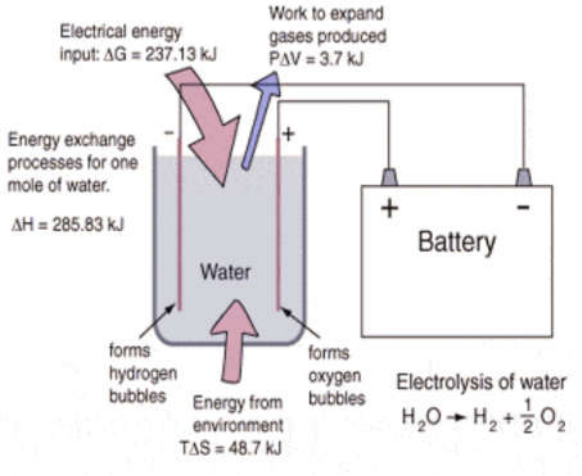
HHO Welder

The HHO welder project started with a concept of: (single, twin, or quad) cells for (Jeweler, Home, or Commercial) welding respectively. The Jewelers single cell to be powered by a 12 volt battery and charger. The Home HHO Welder twin cell to be powered by line voltage. The Commercial quad welder to be powered by 220 services. When Brain storming for a cart or some type of enclosure, I came across the idea of mounting into the bottom of a roll around tool chest. Mobility plus drawer storage in a cost effective and very available form factor. This photo was taken near the beginning of the project.

Advantages and disadvantages

HHO advantages

Producing hydrogen from water may be achieved in several different ways such as electrolysis, direct solar, thermo-nuclear high temperature cracking, using catalysts, using biomaterials or using some form of chemicals to split water (H2O) into H2 (hydrogen) and O (oxygen).



Hydrogen from Water

HHO advantages

Advantages:

• HHO, Hydroxyl gas, is an environmentally friendly fuel, nonpolluting, with a low temperature ignition point, and returns to water when combusted.

• HHO gas by weight has 3 times the explosive power than gasoline. For this reason it is unstable and not safe to store (when mixed with oxygen), for this reason we produce it on demand. But HHO is MUCH safer than gasoline; gas when spilled is heavier than air and will

collect at lower areas. HHO gas is lighter than air, and when "spilled" will dissipate very rapidly in the atmosphere, without polluting, chemicals or toxins.

• When installed in an automobile, the HHO gas mixes with the gasoline "injected" and gives a more complete and efficient combustion in the cylinder, while lowering the amount of CO2 and other toxic gases produced. Each different type of engine will give varied results, depending on the shape of the piston and head, and 4 to 8 cylinder.

• Round gasket design - no corners for the electrolyte to collect, overheat, and solids to build up. The gas naturally flows around and up to the top opening and flows out.

• Extended plate design for additional cooling, just in case one decides to power this to the maximum.

• EPDM 3/8" round gaskets, to withstand the most nasty caustic if necessary.

• 5/16" brass electrical connections, brass conducts electricity best, and stays cool, (stainless steel is actually a resistor).

More than a year in purchasing, fabricating, and testing the best and most efficient designs in out shop, each of us with mechanical and engineering backgrounds.

Disadvantages

One of the disadvantages of creating hydrogen from water is how much energy is used in the process and whether the process is clean beginning to end. For instance, simple brute force electrolysis of water takes a lot of energy and that energy will most likely for now be coal-powered.

HHO technology safe to use

Since HHO Generators produce highly explosive gas, you might be thinking "Is it safe to have this under the hood of my car. HHO Technology is totally safe, for a number of reasons. HHO Generators employ two different types of safety measures; a Safety Bubbler and another device called a "Flashback Arrestor". Also, with HHO Technology your creating Hydrogen ON DEMAND, so nothing is stored under pressure in tanks. Turn the key ON, and your HHO Generator starts making hydrogen and oxygen.

Turn the key OFF, and it stops making HHO Gas instantly

Need of HHO technology

- Double or even TRIPLE your fuel mileage: Although mileage scores may depend on other things such as overall vehicle condition, driving habits and whether or not you employ HHO Enhancers like the EFIE device described below. Some vehicles have been known to increase mileage as much as 185% with HHO Gas. Some users are saving over $300 per month on fuel costs!
- Increase the Performance of your vehicle! With HHO Technology you will notice significant improvements in torque, faster acceleration, better throttle response, smoother gear shifts and reduced vibration. HHO Gas also eliminates "knocking" and "pinging" inside your engine.
- Lower harmful exhaust gas emissions and help protect the environment. When HHO gas is burned inside your engine it converts back into oxygen and water vapor. You can drive around knowing that your vehicle is releasing oxygen into the atmosphere!
- Remove carbon deposits and sludge from inside your vehicle's engine and exhaust system. HHO causes gasoline and diesel fuel to ignite faster and more completely inside your engine, which will increase the overall lifespan of your engine by reducing wear and excessive vibration.
- You can start a part-time business with HHO Technology and help your community, while making an extra $300-$600 per week. Not only that, you can make the IRS pay for everything! We provide you with IRS Tax Rebate forms so you can write off the

cost of building and installing your HHO system. And should you decide to start a business selling HHO Kits in your community, you can also receive tax benefits for providing "Alternative Energy" to your customers as well!

Conclusion:

This sort of analysis highlight's the state of uncertainty regard laboratory evaluation of the idea of HHO. An investigation should be a diligent attempt to represented the best results that have been obtained. There it n wide variety of configurations of reactors that are purported to produce HHO. If the effect of HHO on engine efficiency is the mull of some product of the combustion of HHO, it is possible. Then all of the variability; associated with reactor op-emotion can be reduced down to a few variable or Perham one variable. It would also be important that this factor remains constant for each scrim of tests. Mass flow rate of HHO should be measured. Average molecular weight is n relevant variable. Effective compression ratio should also be included among tut conditions. Most Diesels for vehicles are turbo champs. By carefully offsetting the turbocharger mule rte. actuator, effective compression ratio can be adjusted. By means of combustion pressure analysis, mg-mars can essentially see what is going on inside the cylinder through the course of the compression/power stroke.. This amid be helpful in improving wince and flexibility of HHO technology. A Europe-wide education and training programme, spanning primary schooling to world-class research;

References

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