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# Characterization of the Generation through Electrolysis of HHO and its Combustion Process

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## Abstract

**Background/Objectives:** Implement a cell's bench hydrogen producers for partial replacement fuel in a diesel burner, so that the generation and combustion of HHO it can be quantified and in this way make theoretical models that predict the rate of generation of this gas. **Methods:** With the simulations, volume data produced gas, produced by the water electrolysis and the set of variables formed such as they are, mixed temperature of the liquid form, the operating pressure, the intensity of the consumed current by the electrolyzer, the length and duration of the flame and the electrical power required. With these data characterizing the process is done. **Findings:** The results allow to determine the concentration of KOH is the fundamental factor that directly influences the production and all its variables, the best working concentration is 300 gr because it produces more HHO in less time compared to the others, but brings adverse effect a high current and temperature intensity, which makes an increasein the energy consumption. **Application:** This methodology can be used for the process of optimization and redesign of thermal engines, to maximize the output power for the same fuel and operational conditions.

**Keywords:** Cell, Concentration, Electrolysis, Flame, HHO

## 1. Introduction

Alternative fuels and additives conventional oil derivatives represent an important field of exploration for many types of research to reduce demand for hydrocarbons and pollutant emissions produced by combustion engines interna1. Hydrogen has a remarkable advantage compared to other alternatives fuels, because of this gas does not contain carbon, in appearance resulting in the almost total elimination of CO and $CO_2$ and Hydrocarbons (HC) sunburned[1]. It was discovered by Cavendish in 1766. Later in 1781, he noted that it was a combustible gas when it burned formed water. This discovery was it named hydrogen, which means "water generator"[2].

The earliest work for substitution with hydrogen in diesel engines were carried out in 1984 which measured 50% reductions of fuel gases with $CO_2$ and CO, with slight increases in $NO_X$ emissions[3]. In addition, it was observed that larger quantities of hydrogen higher than 15% it produced an increase of 30% in $NO_X$ emissions, for this reason, the best option is to use diesel oil as a main fuel and inject a small amount of this gas (up to 15% of the total energy of the main fuel) in the combustion chamber[4,5].

Electrolysis of water is one of the cleanest procedures, as well as the simplest and intuitive toobtain hydrogen. This process, discovered in 1820, consists to decompose the water ($H_2O$) into its constituent elements[6], hydrogen and oxygen through an energetic contribution (electricity)[7]. Other studies on alternative fuels are focused on the thermodynamic study and the study of specific phenomena such as auto-ignition[8,9].

This article is aimed at building an oxyhydrogen generating cell, which is compact and it can be installed anywhere required; it's a cell of high performance, which

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was designed to obtain highly flammable gas, which may partially replace the consumption of polluting waste products of fossil fuels and petroleum products, thereby reducing waste highly toxic manner released into the atmosphere.

## 2. Methodology

The first step is to propose a mathematical-chemical model, to calculate the theoretical HHO production, taking into account factors that affect the variables obtained, like the chemical composition of H and O elements, pressure and temperature, etc. These calculations and models help us to estimate the actual gas production Brown cell during the electrolysis process.

Described the above mathematical model, this validation is required; thus a design generating cell HHO and considerations in the simulation process in the ANSYS packet by observing the profiles of dissociation of gas in the gas producer cell thereof. Subsequently, the results obtained in the testing and characterization of the flame arises.

### 2.1 Thermodynamics considerations in Model

The following considerations are fundamental to the development of model theoretical gas production:

- The HHO gas has an implosive nature; when it's burned in its purest mixture forms a high purity vacuum. Of course, a diatomic mixture also produces a vacuum, but there will be an explosion and then implode.
- When diatomic oxygen ($O_2$) and hydrogen ($H_2$) light, the bonds between the atoms of gas must first be broken, it consumes energy. Energy is released when the hydrogen and oxygen atoms are recombined in $H_2O$. The total amount of energy released is the sum of these two energies; these have opposite signs.
- Assuming standard conditions, gas volume is scaled with a ratio of temperatures (higher temperature = greater volume) and inversely with the pressure ratio (lower pressure higher volume).
- Faraday's laws are independent of the voltage used to produce electrolysis, although the voltage should be considered for calculating energy consumed in the process.
- The working pressure is set at 0.6 bar given working conditions required

### 2.2 Fundamental Equations

The diagnostic base production is the calculation of the energy consumed during the process and the rate of generation of theoretical HHO. It is necessary to have a balance in the reactions associated with the process[10].

Combustion of diatomic $H_2$ and $O_2$ to form water as steam (releases energy):

$$H_2\,(g) + ½O_2\,(g) \rightarrow H_2O\,(g) \tag{1}$$

The value for the monoatomic 2H + O, reaction is calculated in the following:

$$H_2\,(g) + ½O_2\,(g) \rightarrow 2H\,(g) + O\,(g) \tag{2}$$

### 2.3 Experimental Equipment

To obtain the experimental data, it was used a tested generating HHO cell illustrated in Figure 1. This bench is equipped with an electrolyzer 7 plates 316 L stainless steel, insulating neoprene, compacted with screws between two acrylic sheets and whose actions are seen in Table 1, this cell is connected to a control system composed by a

**Table 1.** Dimensions of the cell HHO

| CELL DATA | | | | |
|---|---|---|---|---|
| | **Positive plate** | **Negative plate** | **Neutral plate** | **Plate seal** |
| # of plates | 1 | 1 | 5 | 9 |
| Width [cm] | 12.5 | 12.5 | 12.5 | 12.5 |
| High [cm] | 21.5 | 21.5 | 21.5 | 21.5 |
| Area | 53.75 | 53.75 | 268.75 | 47.61 |

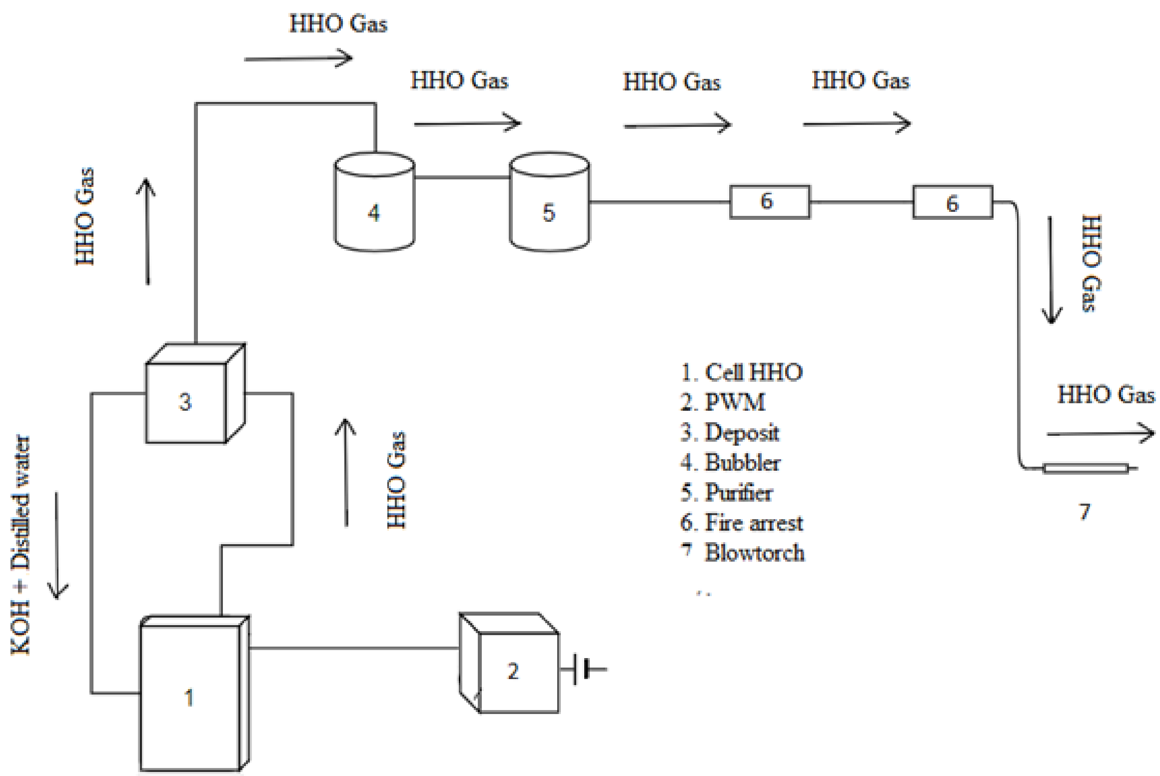


**Figure 1.** Experimental scheme.

PWM and a power source. The bench is equipped with three components where the mixture is stored, cleaned and then removes water vapor and moisture content, is a water tank and purifying bubbler. The gas path ends with two arresters to prevent flashback and a burner for combustion observed.

**Figure 2.** Test bench HHO.

## 3. Result and Discussion

To get an idea of the internal behavior of the cell graphically, it resorted to the use of ANSYS software to perform a simulation, where the gas dissociation profile tends to be higher in areas where the temperature is higher. To obtain accurate results the information literature about the fundamental factor is the amount of electrolyte that must be diluted in water to characterize the production of HHO as shown in Figure 2 taking into account the previous can be concluded that concentrations of electrolyte in 1.5 L distilled $H_2O$ should be as follows:

- 180 g
- 240 g
- 300 g

### 3.1 Behavior of the Flame Varying the Electrolyte Concentrations

The Gas Brown production was the most important factor in this project, but analyze the behavior of the flame generated at making the combustion of HHO is the tangible form of observation of this researching as it was explained previously the electrolyte concentration is the factor fundamental to the production variation and behavior of the measured variables. Therefore, it is described all the study of the flame described below:

- The color of the flame has notable changes in tone as the electrolyte concentration.
- The output of the burner used 0.5 mm had an excellent performance as this gas handled very low pressures so that the less contact with the gas has the best outside for a constant flame.
- The length and duration of the flame are directly proportional to the amount of electrolyte used.
- Visualization of the flame due to the preceding paragraph under high sunlight conditions which is a little observable, so the tests were conducted at night hours and with a thermographic camera. See Figures 3 and 4.

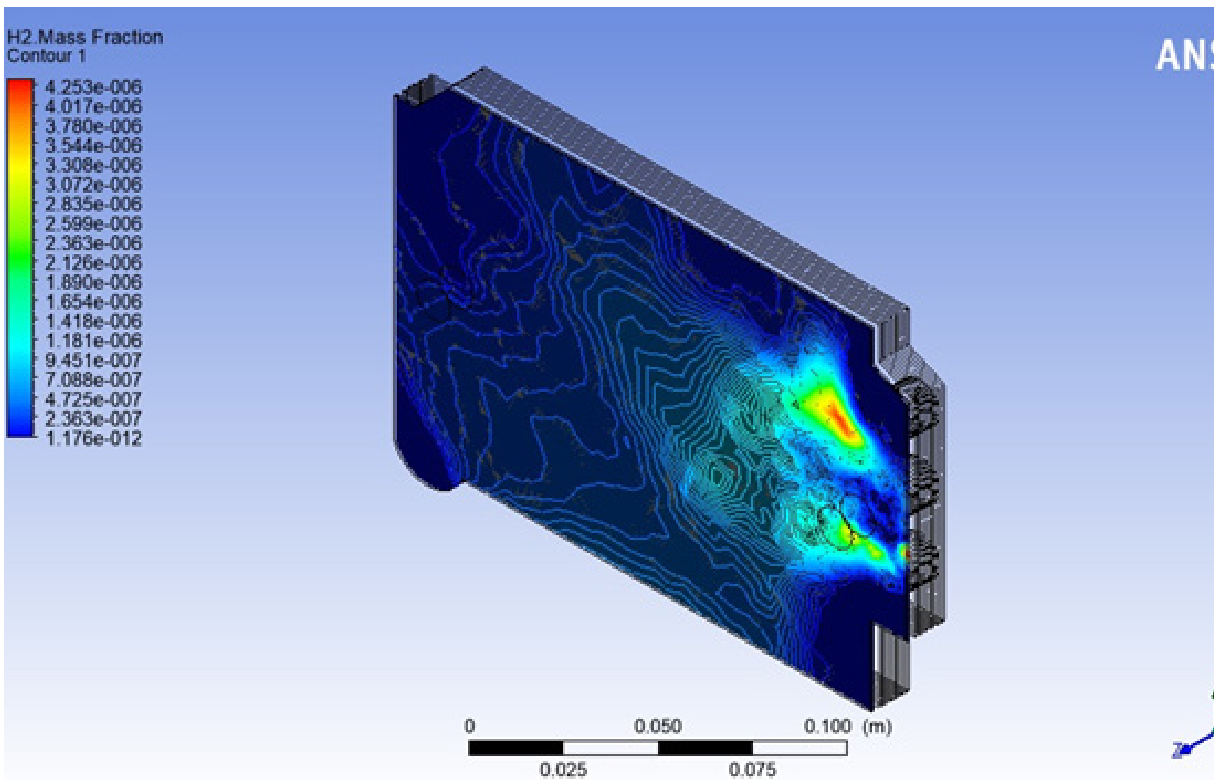


**Figure 3.** Profile of dissociation of gas in ANSYS.

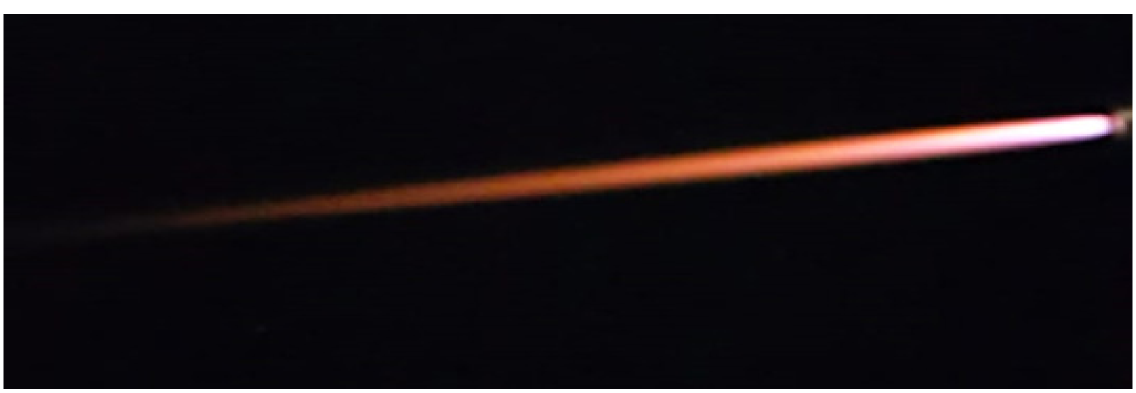

**Figure 4.** Generated flame.

## 3.2 Experimental Gas Volume Generated

Summarizing the process gas generation in an easy way, the experimental production volume HHO is determined. These results are evident in Figures 5 and 6. The concentration of 300 g KOH gave the best results with a volume of 0.781969 $\frac{L}{min}$.

In making this series of tests some variables that depend directly on the electrolyte concentration as they are obtained; mixture temperature and electric current supplied voltage are illustrated in Figure 7. Figures 8 and 9 shows the behavior of the voltage and the amperage respectively.

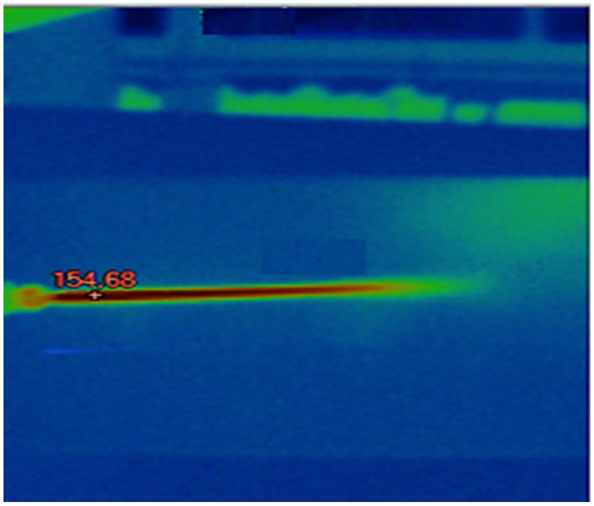


**Figure 5.** Thermographic image of flame generated.

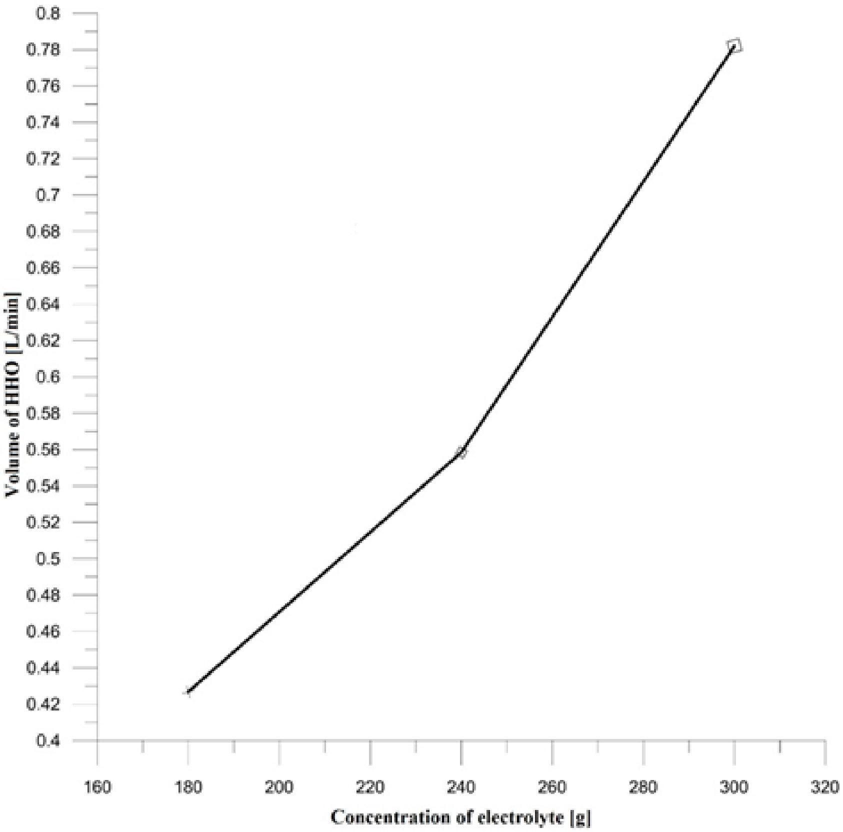


**Figure 6.** Volume generated at different concentrations of KOH.

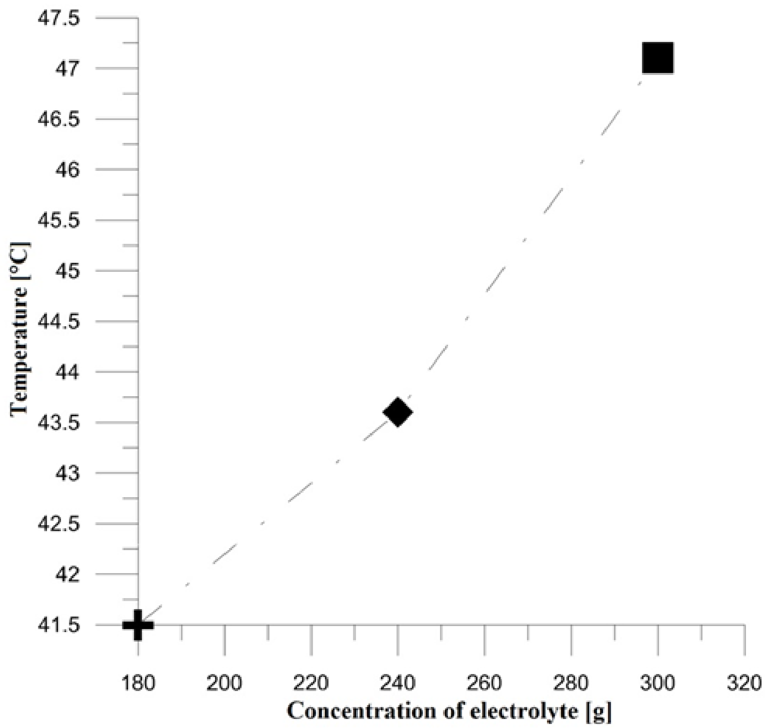


**Figure 7.** Temperature of the mixture at different concentrations of KOH.

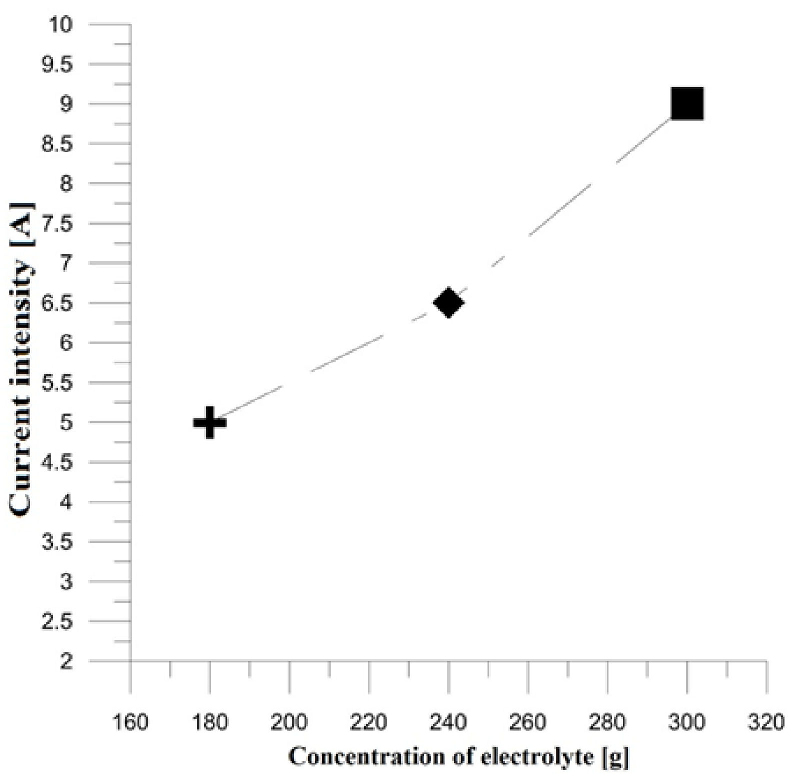


**Figure 8.** Current at different concentrations of KOH.

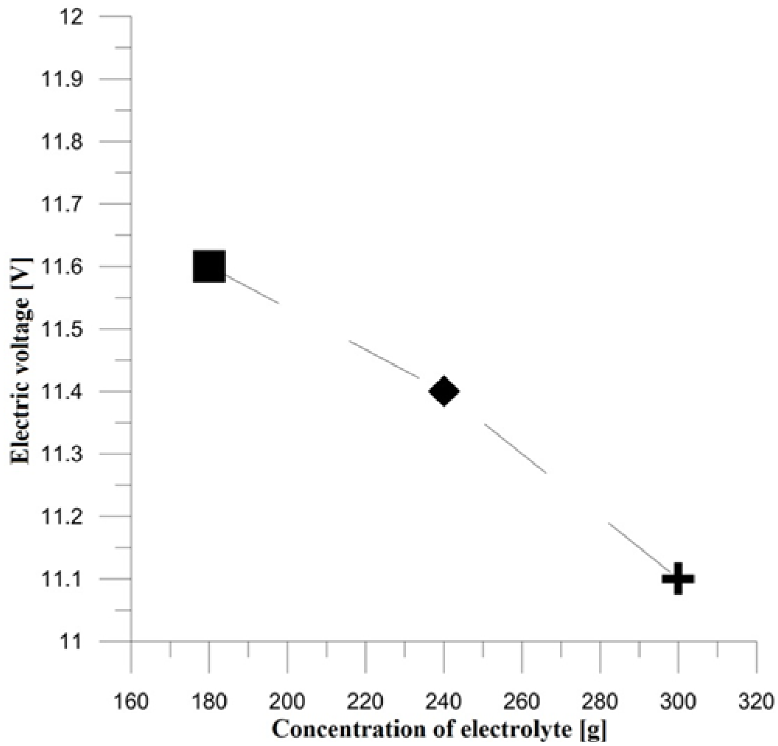


**Figure 9.** Voltage at different concentrations of KOH.

## 4. Conclusions

The best working concentration is 300 g since it produces more HHO in less time compared to the others, but brings adverse effect of high current and temperature of the mixture, causing an increase in power consumption. For best results in the generation of gas preheat the electrolyte, before performing the required application for a slight increase in the temperature of the mixture increases production.

- The HHO is an efficient solution as it is safe, clean and involves less operating cost. When burned, it produces water and that will reduce pollutants from exhaust gases.
- One of the best chemicals added to the water is potassium hydroxide, which acts as a catalyst in the process of electrolysis, as it promotes the production of gas but not consumed in the process. It is a strong and pure electrolyte. HHO gas production generates pure along with a proper design generator. But it is dangerous to work with and need more care when used.
- The way the plates are connected has a positive influence on the efficiency.
- Nowadays it is not very viable storage at low hydrogen scale; this is due to low efficiencies which are used in current systems, for this reason, they are working on the development of a more efficient system to achieve a reduction in the cost of the value of hydrogen, which makes it more competitive with fossil fuels.

## 5. Acknowledgment

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## 6. References

1. Barreto L, Makihira A, Riahi K. The hydrogen economy in the 21st century: A sustainable development scenario. International Journal of Hydrogen Energy. 2003; 1(28): 267–84. https://doi.org/10.1016/S0360-3199(02)00074-5.
2. Musmar SA, Al-Rousan AA. Effect of HHO gas on combustion emissions in gasoline engines. Fuel. 2010; 2(90):3066–70.

3. Santilli RM. A new gaseous and combustible form of water. International Journal of Hydrogen Energy. 2006; 2(27): 1113–28. https://doi.org/10.1016/j.ijhydene.2005.11.006.
4. Appleby AJ. Fuel cell electrolytes: Evolution properties and future prospects. Journal of Power Sources.1994; 1(90): 15–34. https://doi.org/10.1016/0378-7753(93)01790-O.
5. Rajaram PS, Kandasamy A, Arokiasamy P. Effectiveness of oxygen enriched hydrogen-HHO gas addition on direct injection diesel engine performance, emission and combustion characteristics. Thermal Science. 2014; 1(35):259–68.
6. Manu PV, Sunil A, Jayaraj P. Experimental investigation using an on-board dry cell electrolyzer in a CI engine working on dual fuel mode. Energy Procedia. 2016; 1(24):209–24. https://doi.org/10.1016/j.egypro.2016.11.187.
7. Uludumar E, Tosun E, Tuccar G, Yildizhan S, Calik A,Yildirin S, Serin H, Ozcanli M. Evaluation of vibration characteristics of a hydroxyl (HHO) gas generator installed diesel engine fuelled with different diesel–biodiesel blends. International Journal of Hydrogen Energy. 2017; 2(12): 525–65. https://doi.org/10.1016/j.ijhydene.2017.01.192.
8. Amador G, Forero JD, Rincon A, Fontalvo A, Bula A, Padilla RV, Orozco W. Characteristics of auto-ignition in internal combustion engines operated with gaseous fuels of variable methane number. Journal of Energy Resources Technology. 2017; 139(4):1–14. https://doi.org/10.1115/1.4036044.
9. Duarte J, Garcia J, Jimenez J, Sanjuan ME, Bula A, Gonzalez J. Auto-ignition control in spark-ignition engines using internal model control structure. Journal of Energy Resources Technology. 2017; 139(2):1–12.
10. Baltacioglu MK, Arat HT, Ozcanli M, Aydin K. Experimental comparison of pure hydrogen and HHO (hydroxy) enriched biodiesel (B10) fuel in a commercial diesel engine. International Journal of Hydrogen Energy. 2016; 41(19):8347–53. https://doi.org/10.1016/j.ijhydene.2015.11.185.