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Development of Hydrogen Generator for Hydrogen Gas Production

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ABSTRACT

This paper presents the development of hydrogen generator to produce hydrogen gas from electrolysis of water. The generator housing is made of cylindrical shaped Perspex with screwed cover made of the same material. The electrodes were made from scrapped lead from old battery lead terminals. The electrolyte is distilled water containing sodium hydroxide. The hydrogen gas produced is 27 liters when an electric current of 60 amps was passed through the electrolyte for 30 minutes. This is generator can be easily replicated with materials readily available.

Keywords : *Hydrogen gas, water electrolysis, hydrogen gas production, Energy carrier.*

I. INTRODUCTION

The potential of hydrogen gas as an energy carrier is immense, though it carries less energy than fossil fuel by volume. Its overall effect on the environment is minimal. Hydrogen is the smallest and the most abundant element in the universe [1]. It rarely exists in pure nature as hydrogen gas (H_2) but in compounds such as hydrides and hydrocarbons. Hydrogen gas was first artificially produced and formally described by T. Von Hohenheim (1493 – 1541) via the mixing of metals with strong acids. In 1671, Robert Boyle rediscovered and described the reaction between iron fillings and diluted acids which results in the production of hydrogen gas. In 1766, Henry Cavendish [2] was the first to recognize hydrogen gas as a discrete substance, by identifying the gas from a metal-acid reaction as "inflammable air" and further finding that the gas produced water when burned in the air. In 1783, Antoine Lavoisier, considered widely as the "Father of Modern Chemistry", gave the element the name of hydrogen when (with Laplace) reproduced the Cavendish experiment [3]. One of the famous early uses of hydrogen gas was for lifting in balloons, and later in airships. The hydrogen was obtained by reacting sulfur acid and metallic iron. The famous "Hindenburg" air disaster was attributed to hydrogen gas [4] but investigation carried out by NASA investigator proved otherwise [5]. Hydrogen can be produced industrially by steam reforming of natural gas. Hydrogen is mostly produced close to where needed [6].

The energy density per unit volume of hydrogen either in compressed gas or as a liquid hydrogen is less than that of traditional fuel sources but energy density per unit fuel mass is higher [7] but it is widely believed that Hydrogen will be the energy carrier of the future economy. Many laboratory and small-scale production of hydrogen gas has been attempted. Erickson [8] established pathway for reforming coal derived methanol to produce hydrogen. Researchers at National renewable Energy Laboratory [9] are experimenting several methods of producing hydrogen such as by fermentation, biological water splitting, photo-electrochemical water splitting, conversion of biomass and wastes, solar thermal water splitting and renewable electrolysis. Fermentation is a technology by converting lignocellulosic biomass into sugar rich feed stocks including hemicelluloses and cellulose that can be fermented directly to produce hydrogen, ethanol, and other chemicals [10, 11]. Biological water splitting by photosynthetic microbes which produces hydrogen from water during their metabolic activities, the limitation identified is the limitation of oxygen sensitivity of the hydrogen evolving enzyme systems [12, 13]. Another method being researched by NREL is Photo-electrochemical water splitting to produce hydrogen by using sunlight to directly split water into hydrogen and oxygen, this is believed to be the cleanest way to produce hydrogen but it is still an on going research [14].

Research is still on going to produce hydrogen through pyrolysis or gasification of biomass resources such as agricultural residues, consumer wastes or biomass specifically grown for energy purposes [15]. Solar thermal water splitting [16] is also being researched into in which highly concentrated sunlight is used to generate the high temperature needed to split methane into hydrogen and carbon. Renewable energy sources is suggested by NREL as one solution to produce hydrogen through the electrolysis of water and to use that hydrogen to produce electricity during times of low power production or peak demand, to use the hydrogen directly in fuel cell vehicles [9]. This paper outlines the design and development of hydrogen production through electrolysis by splitting water into hydrogen and oxygen.

II. THE DESIGN

The Housing: The generator housing holds the electrolyte and the electrode. It is made from a low density polyethylene material with 2mm thickness, Figure 1(a). It has a height of 180mm and a radius of 170mm. The cover of the housing is made from 170mm diameter low density polyethylene, 2mm thick. The cover, Figure 1(b) is reinforced with three 30mm by 30mm and 5mm thick Perspex. The Perspex is placed on the outer part of the cover directly above each of the three holes of 15mm diameter drilled into the cover of the housing. Adhesive is used to hold the Perspex in position. Battery lead terminals were moulded into two out of the three Perspex. A pre-fabricated exit valve of 10mm diameter for its outlet and 15mm diameter inlet was used; it is screwed between the two terminals and secured with an adhesive to avoid leakages. A hose is then connected to the outlet part of the open valve to direct hydroxyl gas into a container of water. The outlet serves the double purpose of inlet for water refill and outlet for gas.

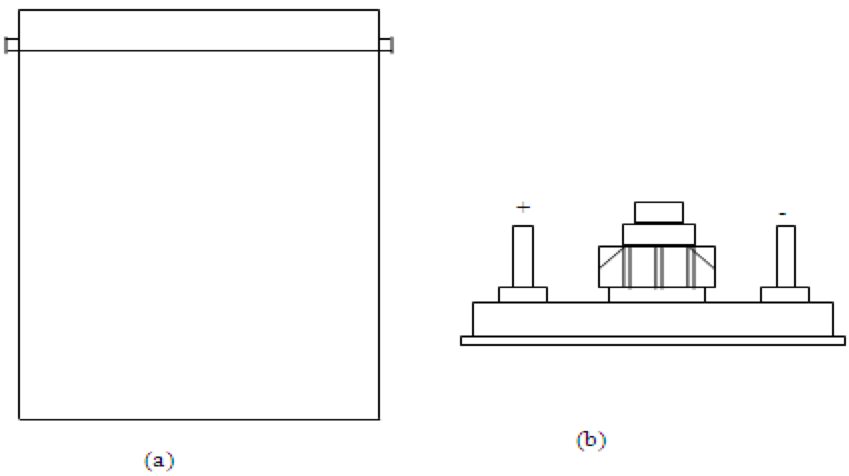

Figure 1: The generator housing, (a) electrolyte container and (b) the container cover

The Electrodes: The electrodes, Fig. 2, are the go between the electrolyte and the battery terminals. They conduct current from the battery to the electrolyte. Oxidation and reduction reactions take place at the electrodes. The dimensions and the number of the electrodes were chosen with the consideration of the housing dimensions. The electrodes were fabricated from lead. A mould was made and liquid lead was poured into it to form the cylindrical shape required.

Figure 2: Lead electrode

Electrode Stands: The electrode stands were used to stack the electrodes in the electrolyte. Two electrodes stand were fabricated from Perspex. The Perspex has an area of 70mm x 50mm and 5mm thick. Six holes of 10mm diameter were drilled into it in the 2 x 3 formation with a distance of 10mm between each hole and from the edges of the material. In the assembly, each stand is placed 10mm from the tip of the electrodes thereby forming a stack of electrodes. The electrode stand is shown in Fig. 3.

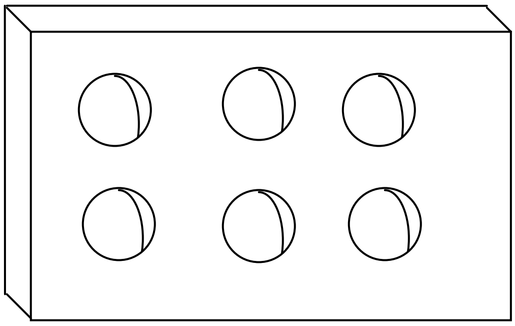

Figure 3: The electrode stand

The Electrolyte: The electrolyte is formed from two liters of distilled water and 10grammes of sodium hydroxide mixed together. The solution is stirred properly allowed to cool. The electrolyte is poured into the housing after the electrode stack has been lowered into the housing.

The Battery: The battery produces the electromotive force to drive the free charged electrons (ions) towards their respective electrodes for oxidation – reduction reactions. The battery is a 12V 100A deep cycle gel cell. The battery can be charged through solar PV panels or wind generator.

Hydrogen generator: The hydrogen generator, Fig. 4, is a device that is designed to produce hydrogen gas from electrolysis of water. It is a closed container containing six lead electrode rods and an aqueous electrolyte with the electrodes being connected to two terminals of the battery. The generator housing is made from low density plastic, with a cover made from the same material and reinforced with Perspex for rigid and support. A pair of terminals was fabricated from lead into the cover. The exit valve for the gas is situated at the middle of the cover connected to hose. The electrodes are three pairs placed on their sides on the floor of the container. They are stacked into two stands, one each on the opposite ends of the electrodes. Insulated copper wires were connected from the terminals to the electrodes to deliver necessary electric current to the electrodes. The generator is designed to use electricity to produce hydrogen and oxygen gases by electrolysis of aqueous solution of sodium hydroxide and water. Electric current is passed through the water to break down the molecules of water to produce hydrogen and oxygen gases. If there is partition in the generator chamber, the pure hydrogen and oxygen gases can be collected separately but in this case, they are collected together as a mixture of hydrogen and oxygen gases called ‘hydroxyl’ gas. The hydroxyl gas is eventually passed through water to dissolve oxygen and liberate hydrogen gas.

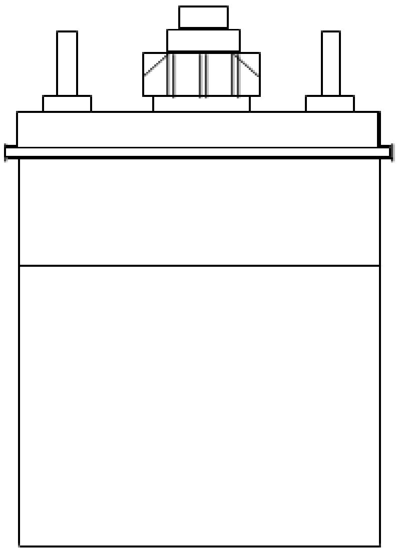

Figure 4: The hydrogen generator for hydrogen gas production.

III. RESULTS

The rate of gas produced during the electrolysis of water is dependent on the electrolyte, the spacing between the electrodes, the area and the preparation of the electrodes, the current flowing in the cell, and the concentration and the temperature of the electrolyte.

Gas Volume

The volume produced during the electrolysis of water is calculated by using Faraday's Law of Electrolysis
In water, the weight of one mole is

$$H = 2 \times 1.008\ g/mol \quad (1)$$

$$O = 15.999\ g/mol \quad (2)$$

Thus, 1 mol of $H_2O = 18.015\ g/mol$

The current supplied is 60 amps for 30 minutes (1800 seconds),

Redox Reactions:
At the cathode

$$2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)} \quad (3)$$

At the Anode

$$OH^-_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)} + \tfrac{1}{2} O_{2(g)} + 2e^- \quad (4)$$

Number of moles of electrons:

$$60\ A \times 1800s = 1.08 \times 10^5\ \text{coulombs} \quad (5)$$

1. 08 x 105 C x 1F/96,485 C = 1.1193 F = 1.1193 moles of electrons.

In water electrolysis, 2 electrons are involved, 1 volume of oxygen gas is liberated whenever 2 volumes of hydrogen gas is produced.

Using the ideal gas law, the volume of hydrogen gas produced at standard temperature and pressure is:

$$pV = nRT \quad (6)$$

Where p = pressure = 1.013×10^5 Pa
V = volume = to be determined!
n = number of moles = 1.1193
R = gas constant = 8.3141
T = Temperature = 298 K

$$V = \frac{nRT}{P} \quad (7)$$

$$= \frac{1.1193 \times 8.3141 \times 298}{1.013 \times 10^5}$$

= 27.379 liters in 30 minutes at 60 amps of electric current
In one minute, hydrogen gas produced is 0.9126 liters.

IV. CONCLUSION

The hydrogen gas producing generator has been developed. Hydrogen gas can replace gasoline in small domestic electric power generators especially in Nigeria where the demand for utility power is far more than what is being produced. This hydrogen gas generator can easily be replicated, thus making the shift from fossil fuel to sustainable fuel is easy. The next phase of this project is to convert small gasoline engines to run purely on hydrogen gas.

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