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MEASURING AND OPTIMISATION OF HHO DRY CELL FOR ENERGY EFFICIENCY

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Abstract: A series of experiments was carried out on a HHO gas producing dry cell, whether we can optimize it by finding an electrolyte concentration, current value, etc. or changing the setup by alternating the distance between the plates. KOH solution was used, and the unit was monitored in several regards, for example cell voltage, gas production, ml/min/W value. Peaks in efficiency were between 5 and 8 g/l concentration and the more current went through the electrolyte, the gas was produced.
Keywords: HHO gas, electrolyte concentration, dry cell

1. INTRODUCTION

Nowadays, with the growing need for energy and revulsion toward fossil and nuclear fuels puts sustainable and green energy in the foreground, e.g. energy from the Sun, the wind, tides, waves, and so on. Several disadvantages stop renewable energy from replacing traditional, oil or natural gas-based and nuclear energy sources, cost of installation, the continuity of the sources, combined with the unbalanced need for energy (both on the residential and industrial level), but the main problem is regulations stopping the energy being fed it into the main grids. So the solution could lie in storing energy. There are numerous methods to store energy, for example electro-chemical (HHO dry cell), chemical, [1] mechanical ways, or simply storing it as heat by crystallizing $CaCl_2$ hydrates. Most of these methods have their disadvantages and limited efficiency. We carried out experiments on a HHO gas producing dry cell, to see if we can optimize it, choosing a certain value of current, concentration of the solution, at which it produces the most gas. We can store hydrogen (or the oxygen-hydrogen mixture), thus we can store energy.

In the cell, electric current splits distilled water to its components, hydrogen and oxygen. Making hydrogen and oxygen from water with electricity is a very simple electrochemical process that can be carried out easily and in a very demonstrative way. The electrolyte in the cell is made up of the distilled water and a strong but diluted base, KOH in our case. Producing hydrogen in large or industrial quantities calls for an optimized or a near-optimized cell model. In a process with a big demand for energy only a few percent of variance in the efficiency could mean a significant energy surplus or shortage. [2]

We used a so-called dry cell to make hydrogen and oxygen gas and henceforward we discuss the electrochemical parameters of this dry cell.

What is this dry cell? Why dry cell?

The name could be misleading as this electrolyzing cell uses water just like any other electrolyzing unit. There are, though, some attributes of this cell that makes it easier to design and handle. With wet HHO cells, the whole unit is underwater, while in the case of dry cells, the plates are separated with rubber seals. These seailings stop the water from leaking from the cell, the electrical connections and the edges of the plates are not touching the electrolyte. These parts of the unit are staying dry, thus the name dry cell.

To make sure the gas made from the electrolyte gets out of the cell and the solution to flow between the plates, there are holes on the top (for the gas) and bottom (for the electrolyte) on the metal slats. (Figure 1)

What are the benefits of these cells? There are two main advantages to the application of the HHO units.

1. With the dry cell generator, considering the surface of the plates in the unit, we can use much less electrolytes compared to wet cells. Therefore, the volume and weight of the cell is smaller.
2. As the electronic connections are underwater in the wet cell model, their surface will slowly be corroded by the electrolyte. In the HHO cells, the connections are situated on the outside, thus not corroding. [3]

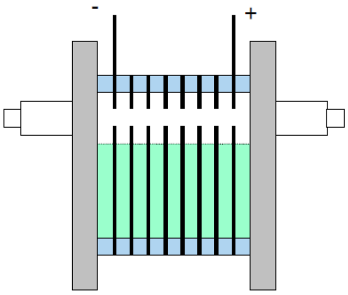

Figure 1. The theoretical setup of HHO block

2. ELECTROCHEMICAL BASIS OF CALCULATIONS

Electrochemical cells could be galvanic battery or an electrolyzing cell. Cells are called electrolytic cells are when they are using external current supply to create chemical reactions. The electrochemical cell is made up of two electrodes and a fluid, current-carrying electrolyte. The electrolyte can be a watery solution or molten salts (solvation). The chemical reaction happening on the surface of the electrodes (reduction or oxidation) is called an electrode reaction.
If the electrode's material is not participating directly in the electrode reaction, it is called an indifferent electrode (e.g. graphite electrode). The oxidation happens on the anode, the other electrode is the cathode, on which the reduction happens. In the process of electrolysis, if there is more than one possible type of electrical reaction, then a simple anion will detach form the positive anode (e.g. chloride), lacking this anion, OH^- will be created by water splitting. [4]
Water's dissolution voltage at 25°C (room temperature) is 1,23 V (E_{MF}), the temperature coefficient is -0,85 mV/K, meaning that at 100°C this voltage goes down to 1,17V. [5,6] Therefore, in the light of these data, the specific energy demand to make hydrogen through electrolysis at 25°C can be calculated in the following way [7]:
The amount of charge needed to detach 1 kg hydrogen gas:

$$q = z \cdot F \cdot M = 2 \cdot 96487 \cdot 0{,}5 = 96487 As/mol = 26801 Ah/kg$$

$$w_{H2} = q \cdot E_{MF} = 26801 \cdot 1{,}23 = 32966 Wh/kg$$

Since the volume of 1 kg standard state H2 is 12474 l, the amount of energy required to produce 1 liter hydrogen is:

$$w_{H2} = \frac{32966}{12474} = 2{,}64 Wh/l$$

To have 1 liter of hydrogen, we need 1.5 liter HHO gas. To produce 1 liter HHO gas(0.667 l hydrogen) this much energy is necessary: [3]

$$w_{H2(HHO)} = 0{,}667 \cdot 2{,}64 = 1{,}76 Wh/l$$

We measured the unit at 10 different concentration of electrolyte, at different currents. We examined the voltage on the plates and the amount of gas produced through electrolysis.

3. THE MEASUREMENT UNIT

You can see the setup of one block of the unit on Figure 2.

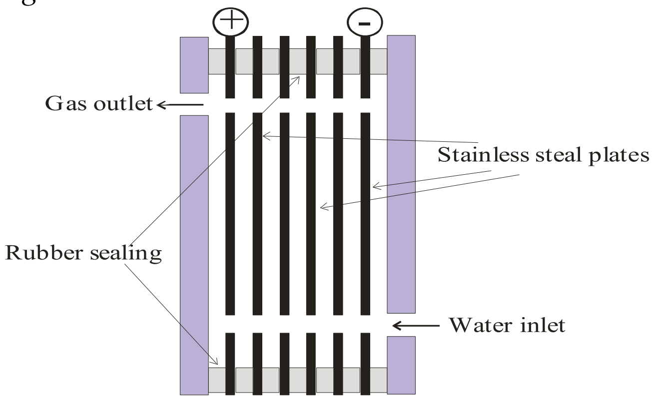

Figure 2: Gas generator block setup

In our setup, 5 cells make up one block, so 5 cells connected in series gives one gas-producing block. The block's electrical connections are on the two plates on the ends (see Fig. 1). Out of the six electrode plates, four are neutral electrodes, as they don't have electrical connection on them. The potential is divided between the neutral plates according to voltage division in series connections. That means that voltage between two electrodes is the fifth of the voltage on one whole block. In our experiment, we had a unit that had 3 blocks connected in parallel connection that made up the unit. (Fig. 2)
Other than the HHO cell, we needed a water tank to infuse the electrolyte into the cell. We also installed a tube between the gas outlet and the tank, because the produced gas is not pure gas, it comes out as bubbles, so there is electrolyte coming out in the tube that needs to be recycled into the

system. Then, as the electrolyte drips back in the tank, the gas can escape through another hose, into the bottle, which we use to measure the volume and speed of the production of hydrogen.

We connected a power supply (Manson SPS9600) to the electrical connections of the HHO unit, and we could adjust the voltage input during the experiment. We also needed a PWM modulator to adjust the current and frequency.

4. EXPERIMENTS AND RESULTS

According to the principle of electrolytic dissociation, due to added energy or dilution, a chemical compound's molecules can break up into ions. This causes the ions to have a weak electrical conductivity. But you can dilute an electrolyte and increase this electricity to a certain limit, and beyond that it stagnates. This explains why there's only a small window for the optimum, when it comes to finding the right concentration of the solution. We monitored current, voltage, cell voltage, MMW (milliliter/minute/watt) and liter/minutes (we didn't experiment with the temperature, but we noticed some changes in the performance of the unit). The voltage, frequency and current was controlled by us, we also experimented with the distance between the plates. We can judge the effectiveness of the unit at certain concentrates by MMW value, liter/minute, current/gas production and power. (Table 1)

Table 1. Obtained results of experiment

Electrolyte concentration (g/l)	MMW (ml/min/W)	Gas production (l/min)	Power of unit (W)
1	2.13	0.2	10.8
2	2.66	0.75	34.44
3	2.66	1.37	55.83
4	2.59	1.51	82.15
5	2.72	1.9	90.6
6	2.63	2.52	119.5
7	2.67	2.96	140
8	2.65	2.76	125
9	2.46	2.28	105.6
10	1.82	2.15	103.2

We expected that 3-5 grams of KOH/liter is where the electrolytic dissociation is allowing the most electrical conductivity, thus at higher current (15-40 A) the unit would produce the most hydrogen. The first series of experiments were done according to voltage. We measured the productivity of the cell at six different values of voltage (2,5 – 15 V) and 10 different solution concentration (1-10 grams KOH per liter). We used software called Statsoft Statistica to make graphs of our findings (Figure 3).

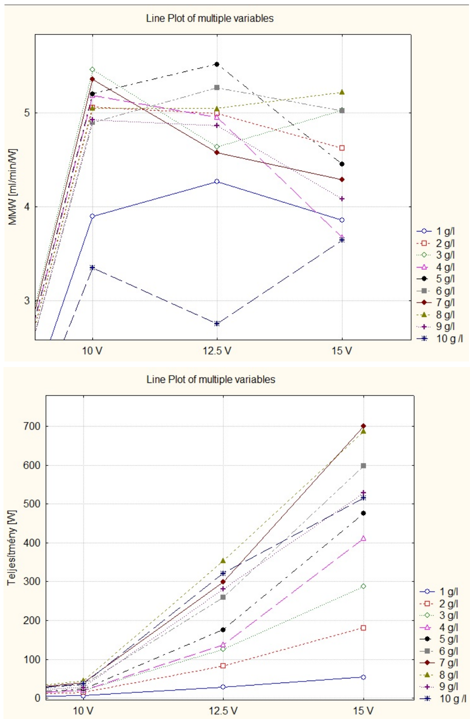

Figure 3. MMW and power of dry cell – voltage-based experiments

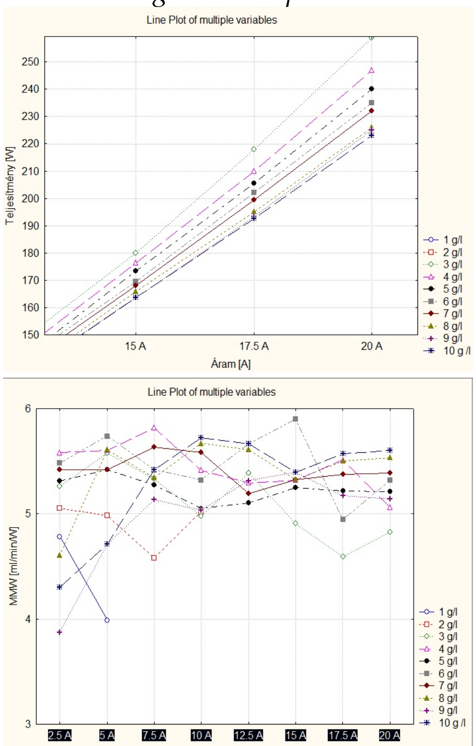

Figure 4. MMW and power – current-based experiments

While, we had the highest MMW value at 5 g/l, we can say that the concentration that has very high values at all of the monitored values is the 7g/l concentration. The cell produced 3 liters of HHO *gas per minute, has a 5,35 MMW value, worked with 50 A and 700 W at 7 g/l.*

The second batch of experiments was done in a similar fashion, but by current values. (Figure 4)

We went on to see whether or no frequency has any significance in the operation of the cell. At 6 g/l concentration and 14 A, we found that frequency doesn't play a significant role in electrolysis (Figure 5).

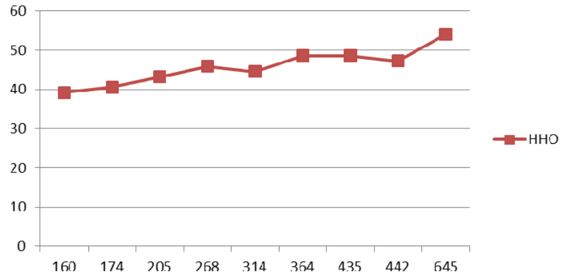

Figure 5. The relation between frequency and gas output

Lastly, we changed the distance between the plates, 1mm to 5 mm. We found that the closer the plates are the better efficiency the cell worked with. (Figure 6)

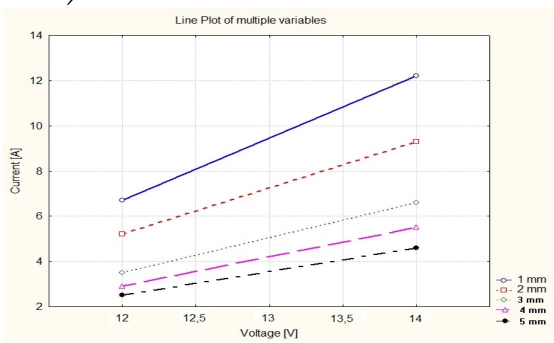

Figure 6. Realtion between distance of the plates and current

While we couldn't pinpoint an optimal concentration or current value, we should change the range of 3-5 g/l to 5-8 g/l, because we found that our dry cell worked with the best efficiency in that domain. The theoretical efficiency of an HHO cell is 60-70 %, ours was working at approximately 55 %. We also proved the Faraday laws, by observing that the more current we let through the electrolyte, the more gas we could produce. Temperature also alter gas production, as the hotter the solution (the more mobile are the ions), the more HHO gas is put out.

Acknowledgement

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