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# The Effect of Electrode Gap Distance on Brown's Gas

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ABSTRACT

The electrolysis of water is one of many methods to produce hydrogen by converting electrical and thermal energy into hydrogen and oxygen. In this study, a generator of the HHO dry cell type is used to produce brown gas. Brown's gas consists of two hydrogens and one oxygen or Oxyhydrogen (HHO). Observation will be conducted to obtain the effect of electrode gap distance to increase the productivity of Brown's Gas with a mixture of 2500 ml pure water and catalyst of NaHCO3. The results show that if the electrode gap is small, it will produce more brown gas than the long gap. However, research still needs to be done on how close the electrode gap distance is needed to produce maximum brown gas.

*Keywords: Raman Spectroscopy, PCU, Wear Scar, Pin on Disc*

## Introduction

Energy cannot be created and destroyed, but energy can change form from one form to another or what is called energy conversion. On the other hand, most of the energy needs are still supplied from fossil energy sources. At the same time, another problem caused is the availability of fossil energy which is depleting and causing air pollution effects. Human dependence on fossil fuels as a source of energy is quite significant in all sectors of life. This issue will cause people's demands for fossil fuels as an energy source to increase but are not comparable to the availability of energy sources available in nature. In addition, excessive use of fossil energy can cause environmental pollution, one of which is an increase in greenhouse gases (mainly $CO_2$) due to burning fossil fuels.

The above problems encourage the emergence of alternative energy that is environmentally friendly and sustainable. One alternative energy is water; almost 70% of the earth is covered by water. In addition, the result of the evaporation of water is harmless and very friendly to the environment. Water is a compound that is always available, and water ($H_2O$) consists of hydrogen ($H_2$) and oxygen ($O_2$), both of which can be burned and can also help the combustion process (Hidayatulloh, 2015). Water contains hydrogen, or an energy carrier because hydrogen cannot be obtained directly but from water electrolysis (U.S Department of Energy, 2014).

The electrolysis of water is an electrochemical process that converts electrical and thermal energy into a source of chemical energy in the form of fuel (hydrogen). The process that occurs is separating $H_2O$ compounds into hydrogen ($H_2$), and oxygen ($O_2$), electrolysis of water can also produce oxy-hydrogen (HHO) or Brown's gas. The electrolysis process is classified into two ways: using a separator and without using a separator (Kurniawan, et al., 2015). If the electrolysis process uses a separator, the resulting gas is hydrogen gas and oxygen gas, separated from each

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other. Meanwhile, if the electrolysis process does not use a separator, the gas produced is mixed hydrogen gas and oxygen gas, better known as Brown's Gas.

Brown's gas can be used to improve the performance of internal combustion engines (Ursua et al., 2012). The tool used to produce Brown's gas is an HHO generator. This study uses a dry cell type of HHO gas generator, generally in a plate (square cell). The electrodes are only partially immersed in water, namely through the holes and gaps in the plate. The advantages of this type lie in its cheaper and more straightforward design, faster production time, low current, and less water used because it only focuses on the plate gap. The reactions on each plate in the HHO gas generator are Eq. (1) (Mang et al., 2013).

$$\left.\begin{array}{ll} \text{Oxidation reaction at the anode (+)} & : 2H_2O_{(l)} \rightarrow O_{2(g)} + 4\,H^+{}_{(aq)} + 4e^- \\ \text{Reduction reaction at the cathode (-)} & : 2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + OH^-{}_{(aq)} \\ \text{Overall reaction} & : 2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)} \end{array}\right\} \quad (1)$$

Previous research on the productivity of Brown's gas has been widely carried out, among others, by studies examining the productivity of Brown's gas in dry cell electrolyzers using direct and indirect photovoltaic voltages. The research results obtained to state that using an indirect photovoltaic system will further increase the productivity of Brown's gas from time to time compared to a direct photovoltaic system (Imam et al., 2013). Another research is about the characteristics of Brown's gas production using solar power. This research found that the use of a direct solar system requires a more significant average power than the indirect system (Widhiyanuriyawan et al., 2013). The use of pure water without adding a catalyst will cause low electrical conductors and low Brown's gas production. Therefore, using an electrolyte solution, which is a mixture of water and a catalyst, will increase the conductivity so that the production of Brown's gas is high (Chakrapani et al., 2011).. The purpose of this study was to determine the effect of the configuration of the electrode gap distance used as an electrode plate and a neutral plate on the productivity level of Brown gas produced through the process of electrolysis of water with a dry cell type.

**Material and Methods**

This study uses experimental research methods. The object observed in the study is the effect of electrode gap configuration to optimize the productivity of Brown's gas in dry cell electrolysis. This study used a current of 10 Ampere obtained from an AC source converted into DC using an inverter. A DC of 10 Ampere is connected to an HHO gas generator consisting of two electrode plates and eight neutral plates. The electrode plate consists of an anode (positive) and a cathode (negative). At the anode, an oxidation reaction occurs, and a reduction reaction occurs at the cathode. The HHO generator used is a dry cell type using ten plates consisting of 8 neutral plates and two electrode plates. Each plate measures 70x70 mm with two 8 mm diameter holes.

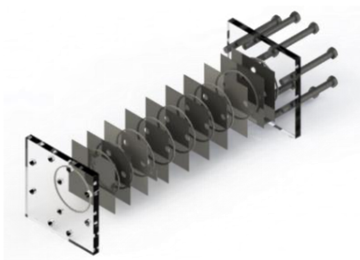


Figure 1. The HHO gas generator

This study used variations of the electrode gap distance of 1.5, 1.8, 2, and 3 mm. Meanwhile, the volume of water in the solution is 2.5 liters or 2500 ml, the thickness of plates is 1 mm, the percentage of the mass fraction of the NaHCO3 catalyst used is 1.77% (45 grams) and the current of amperes is 10 A. The ambient temperature is kept constant during the study. The dry cell electrolyzer used is O-Ring insulation with a diameter of 56 mm and an electrode plate and neutral plate with 304L Stainless Steel material. The dry cell electrolyzer construction used in this study is shown in Fig. 1.

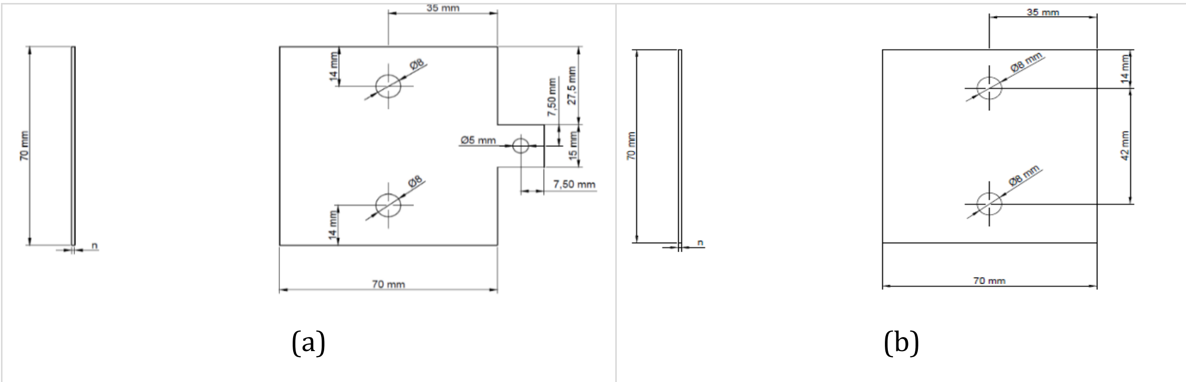
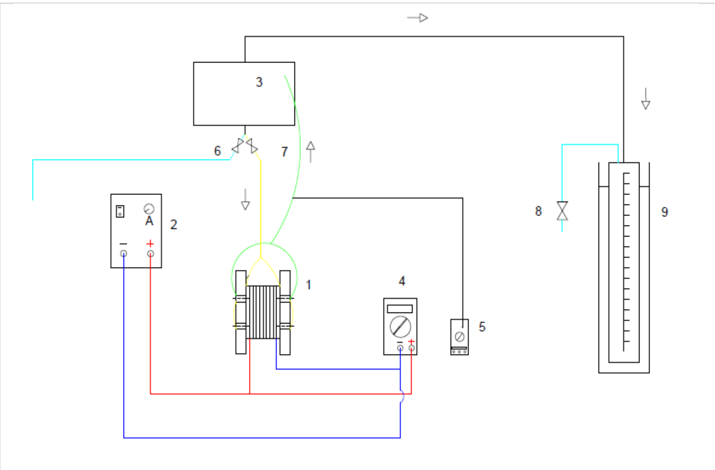


Figure 2. The dimension of plates, (a) electrode plates and (b) neutral plates

The dimensions of the electrode plates used in the study are shown in Fig. 2 below. The research installation used during the study is shown in Fig. 3. Data collection is done by looking at the measurement parameters that are read, namely voltage, temperature, and Brown gas volume. The Brown gas volume measurement method uses the manometer principle by looking at the change in height (Δt) of the air inside the tube and the air outside the tube at a pressure of 1 atm in a closed tube condition. The purpose of this study was to find the optimal performance of the HHO generator used by using easily obtained materials so that the electrode plate material was chosen and made of 304L stainless steel with variations in the electrode plate gap distance, namely 1.5, 1.8, 2, and 3 mm.




Description:

1. Dry cell electrolyzer
2. Inverter (Power supply)
3. Bubbler box
4. Voltmeter
5. Thermocouple
6. Exhaust valve (electrolyte solution)
7. Inlet valve (electrolyte solution)
8. Exhaust valve (Brown's gas)
9. Measuring tube

Figure 3. The installation of the experiment

**Result and Discussion**

The data generated is the voltage, the temperature, and the production rate, which is the volume of Brown's Gas in liters per second. Figure 4 shows that the closer the electrode distance, the greater the volume of Brown's gas compared to the longer electrode distance. In addition, the gradient value or line slope of each plate thickness indicates that the greater the gradient value, the larger the volume produced in the order of the largest to the smallest volume generator, namely the electrode distances of 1.5, 1.8, 2, and 3 mm.

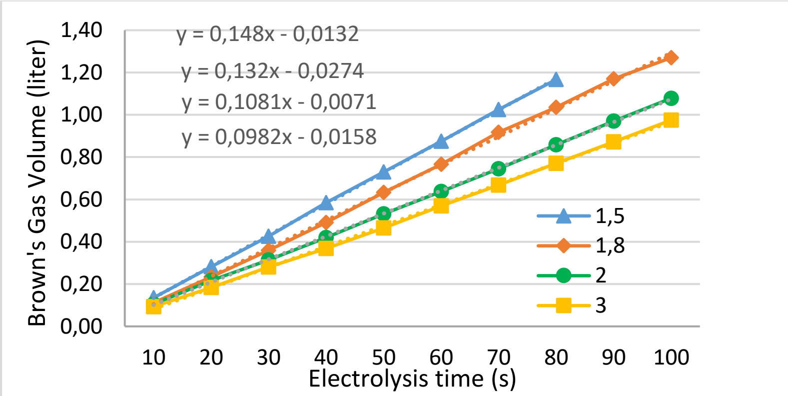



Figure 4. The comparison between the volume of Brown's gas and electrolysis time

Figure 5 shows that the longer the distance between the poles, the longer the electron transfer time from the cathode to the anode will waste much energy, which helps break down molecules. The farther the movement of electrons, which wastes much energy and results in the more time needed to break water molecules into hydrogen and oxygen, the more brown gas produced will decrease. The farther the distance between the electrode gaps used will cause the distance between the cathode and anode to be further apart. The more volume of electrolyte solution will fill the gaps between the plates so that Brown's gas production process will be hampered. The farther the distance between the electrode poles will also cause an increase in the resistance value that occurs in the system because the value is directly proportional to Eq. (2).

$$R = \frac{\alpha . l}{A} \tag{2}$$

where:
R = Resistance (Ohm)
α = Resistivity units (Ohm.mm)
l = The gap of electrode (mm)
A = Area (mm$^2$)

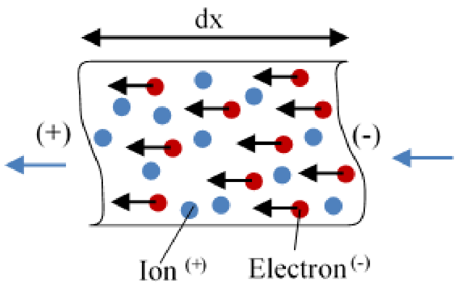



Figure 5. Movement of electrons when a potential occurs

Figure 6 shows that the farther the distance between the electrode gaps used in the dry cell electrolyzer, the more power consumption will increase. For the highest power consumption value, there is a 3 mm electrode gap configuration with a value of 445 Watt. This phenomenon shows that the farther the gap, the higher the electrolyzer's power consumption. The distance between the electrode gaps will cause the distance between the resulting electrodes to be further. The electrical resistance will increase when the electrode distance is further away, which causes the electrical energy to increase (Nagai et al., 2003). This statement is following Eq. (3). The greater the value of the potential difference will increase the power consumption used by the dry cell electrolyzer. This issue follows Eq. (4), which shows that if the value of the potential difference is enormous, the value of power will also be more significant because it is directly proportional to its value.

$$V = I.R \tag{3}$$

$$P = V.I \tag{4}$$

where:
V= Electric Potential (Volts)
I = Electric Current (Amperes)
R = Resistance (Ohms)
P= The power of dry cell electrolyzer (Watt)

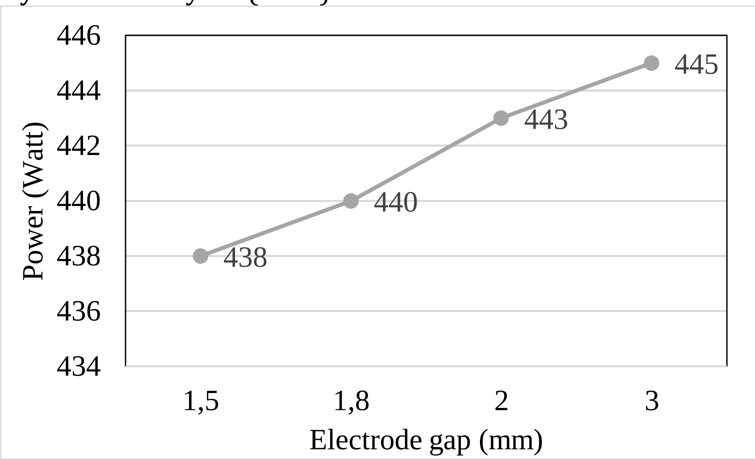



Figure 6. The relationship between power and electrode gap distance

Figure 7 shows that the electrolyzer configuration with the highest efficiency value is the configuration of the 1.5 mm gap distance with an efficiency of 22.6501%. In comparison, the electrolyzer configuration with the lowest efficiency value is the configuration of the 3 mm gap distance with an efficiency of 13.1882%. These results explain that the farther the gap distance used, the lower the efficiency of the electrolyzer. To determine the efficiency of the electrolyzer can be calculated by Eq. (5) as follows:

$$\eta = \frac{Q_{HHO}\rho_{HHO}LHV_{HHO}}{P} \tag{4}$$

where:
$Q_{HHO}$ = Brown’s gas productivity (l/s)
$\rho_{HHO}$ = Density of brown’s gas (gr/l)
LHV = Lower Heating Value (J/gr)
P = Electrolyzer power consumption (Watts)

The value of LHV and the density of Brown's internal gas does not affect the cause of the decrease in efficiency on the graph because hydrogen and oxygen gas has a constant ratio value for each variation used in the study. The influencing factors are Brown's gas flow volume and power consumption, which depend on the electrode gap distance and the thickness of the plate. The farther the distance between the electrode gaps and the thicker the plate, the lower the flow volume of Brown's gas produced and will increase power consumption so that the efficiency value will decrease.

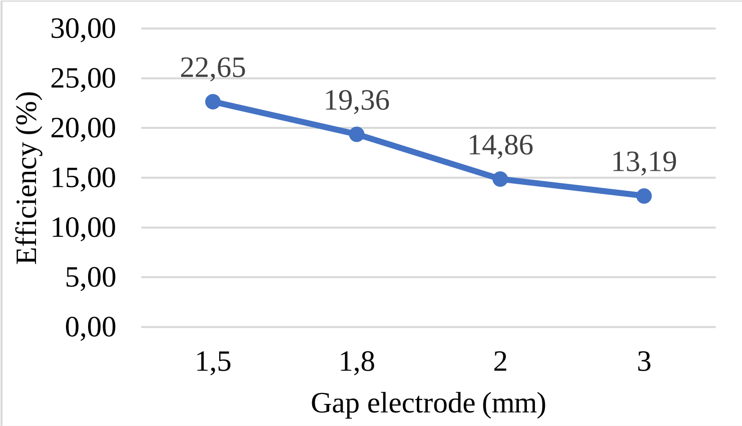



Figure 7. The relationship between efficiency and electrode gap distance

## Conclusion

The highest productivity of Brown's gas at the 80th-second data collection was found in the use of an electrode gap of 1.5 mm with a productivity value of 0.18958 l/s. The lowest productivity value is found in using a 3 mm electrode gap with an average productivity value of 0.7875 l/s. The closer the electrode gap distance used in the dry cell type electrolyzer construction will result in higher Brown's gas productivity because it has a smaller resistance value which will cause the electron transfer to take place more intensely and faster.

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