DESIGN OF AN EFFICIENT ELECTROLYTIC CELL FOR HYDROGEN GENERATION

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Department
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CERTIFICATION OF APPROVAL

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Approved:

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June 2007

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Atikah Mohd Amin

ABSTRACT

The objective of this project is to generate the hydrogen gas from the water using electrolysis. The power supply circuit will be needed to supply the current to the cell containing water and it will go through some processes to break the bond of hydrogen and oxygen in order to get hydrogen gas. The scope of study is to do literature review on faraday's law regarding the breaking of hydrogen and oxygen molecule in water and type of converter involved in designing the power supply circuit. . The methodology also includes designing a power supply circuit and carry out some experiment regarding the hydrogen gas production from the electrolysis.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Hydrogen can be obtained by the separation process of some substances. The method of the separation process is thermochemical which uses heat with chemicals. Other than that is the electrolysis process where water can be charged with an electric current to isolate hydrogen and steam electrolysis where it combines heat and electricity tp produce hydrogen. Finally, hydrogen can also be produced by bacteria and algae as a waste product [8].

Electrolysis is the route of a direct electric current through an ion-containing solution that produces chemical changes at the electrodes. Electrical power is needed for the chemical reaction to occurred and it took place in the electrolytic cell. Electrolysis in water produces hydrogen and oxygen gas. The power supply unit is designed to supply the current to the electrolytic cell for the reaction to happen.

1.2 Problem Statement

It is believed that hydrogen will substitute the fossil fuel as the energy source for all the vehicles. The fossil fuel is bound to give a negative effect to the environment for a long time. Therefore, it is the suitable time for changing this situation before it gets worse. Furthermore, the increase of the fuel price due to some crisis involving the oil producing countries has resulted in more research on other sources of energy. An extensive research on hydrogen production has been made in the past few decades to improve the gas production in terms of cost and efficiency.

Hydrogen gas is abundantly available but it is not cheaper compared to other fuel due to the process of generation is quite expensive. This further increase if it includes the transportation of the gas to the user. Hydrogen gas generated through electrolysis requires large amount electrical energy while the gas produced is much less and could not cover the cost of its production. This project will contribute significantly in generating hydrogen at lower cost.

1.3 Objectives and Scope of Study

The objective of this project is to generate the hydrogen gas using the suitable electrolysis method and effective power supply unit to supply enough energy for the cell. Therefore, the project involved laboratory experiments and research.

The scope of study is focused on construction of cell geometry and suitable power supply circuit to improve the efficiency. The parameters that involved in this study include variation of types and number of electrodes, type and amount of electrolytes and configuration of electrodes.

CHAPTER 2

LITERATURE REVIEW

This literature review is done for further understanding concerning the design of the electrolytic cell by referring to the current discovery. The Joe Cell is one of the current innovations that relates to the hydrogen generation. This section will discuss more about the design characteristics of the cell including the insulation selection and the steel selection for the electrodes. Besides, this section also discussing about the calculation of power consumption.

2.1 Joe Cell

In this cell, Joe had discovered a new energy called Orgone energy which water is acting as medium that capture Orgone and allows it to be transported into the engine. This cell is neither water fuel cell nor the hydrogen fuel cell because it does not try to separate the water molecule into hydrogen and oxygen atom using the means of very high voltage. The energy produced is however greater than hydrogen gas. However, hydrogen can also be generated using this cell after certain modification. Figure 1 shows the picture of the Joe Cell prototype [1].

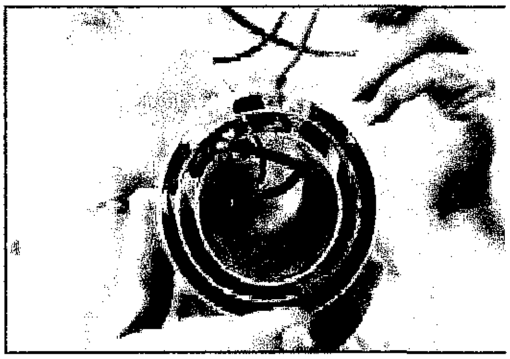

Figure 1: The prototype of Joe Cell [1]

2.1.1 Insulator selection

The cell is constructed using three concentric cylinders which are separated by insulators in between them.

In order to choose the suitable material for insulators, a test is usually carried out which is uses a spark lead in a car. The car is started, and the spark lead is held over insulators like radiator hoses, air intake hoses and vacuum hoses. As a result, those insulators responded as good insulators. [2]

2.1.2 Steel Selection for the Electrodes

The uniform pure non-shining steel is chosen in this type of cell. This type of steel will generate a maximum radiant frequency and owns a very consistent atomic structure.

In this case the most suitable type of steel chosen is high quality steel pipe which was not welded. This steel pipe has been shaped by forcing the metal through a die. Secondly, the pipe must be cold cut by using only pure water for lubricant/coolant during the cutting process. [3]

2.2 Calculation of Power Consumption in Electrolytic Cell

Based on the article written by Peter E.W. Lowrie on Electrolytic Cell, it is understood that one molecule of hydrogen used 870kJ energy to break the water molecule. Below is the equation for the breaking of the hydrogen bonding [4].

$$\mathbf{H_2O_{(l)} + 435kj \dashrightarrow HO + H + 435kj \dashrightarrow H + H + O_{(g)}\ [+870kj \dashrightarrow H_2O_{(l)}]}$$

The energy needed to break one hydrogen bonding from the water is 435kJ. After the breaking of the bond, there is still another bond to be broken. That is the reason of the existence of HO elements in the second phase of the equation. Then, another bond is breaking using the same amount of energy which is 435kJ produce two hydrogen atom and one oxygen atom. In order to convert the atoms to water again, another 870kJ of energy needed.

To electrolyze one mole of water 65.3 Wh of energy needed at 77 degree Fahrenheit and another 14Wh released to split the oxygen and hydrogen from water. At 77 degree Fahrenheit, the electrolysis reaction occurred between 1.23v and 1.47 V will absorb the heat while for over 1.47V it will release heat [4].

The overvoltage means the difference between the actual electrode potential when significant electrolysis begins and the reversible electrode potential [5].

The possibility of over voltage for the electrolysis cell voltage is 1.3 V. then, the voltage supplied is equal to;

1.47V + 1.3V = 2.77V

One mole of water weighs 18 grams and for 1liter of water, the total moles existed is equal to;

1000grams / 18grams = 55.55 moles

For 1 L of water;

55.55 moles of hydrogen existed and 27.775 moles of oxygen existed. The energy needed to break the bonding of hydrogen from water is equal to 48328.50kJ per liter water.

In terms of kWhr[4];

48328.50kJ / 3600 = 3.658 kWhr per liter of water.

1 mole of gas = 24.450 liters of gas at room temperature and at atmospheric pressure.

The volume of hydrogen gas = moles x 1mole of gas

from 1 liter of water = 55.55 x 24.450
= 1358.3 liters

The volume of oxygen gas = 27.775 x 24.450
from 1 liter of water = 679.15 liters

At room temperature, the hypothetical breakdown voltage for electrolysis is said to be 1.23 V at room temperature. On the other hand, due of overvoltage of H atom at cathode which occurred when chargers held in the cell acts as an inefficient battery. Other than that, it is also due to cell resistance itself, the normal requirement of voltages are between 2.00V to 2.50V [4].

Table 1: Effect on lowering the electrolyte (kOhms)

Voltage(Volt)	**Impedance (kOhms)**	**Current(A)**
4	1200	300
4	1000	250
4	100	25
4	10	2.5
4	1	0.25

This table shows that, the voltage of the cell is maintained while the electrolyte impedance is reduced. The results show that the current is also reduced with the decrement of electrolyte impedance.

When the voltage of cell is set to be between 6 to 40 V, the heat is generated and the cell's temperature increase. When voltage is decreased to that dictated by Faraday's law of Electrolysis, the cell temperature will decrease and starts to absorb energy [4].

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

This project is started by carrying out the literature review regarding the design of power supply unit and the principle of hydrogen production is carried out. Then, the design of electrolytic cell is carried out. The design is using different type of electrolyte which is tap water only, tap water with added salt and distilled water with added hydrofluoric acid. Different type of electrodes is used is this designing process which is shiny surface stainless steel, non-shiny stainless steel and galvanic pipe. Other than that, the experiment also uses different number of electrodes. The next process is to design and assemble the power supply unit. Then, the testing process which involve the electrolysis experiment using the different type of electrodes, electrolyte and electrodes' configuration. The cell is powered by the designed power supply circuit. The result obtained will be analyzed to choose the best method for the electrolysis. Finally, modification is done to the cell to ensure that it can produce a lot of gas. Figure 2 below summarize the process flow of this project.

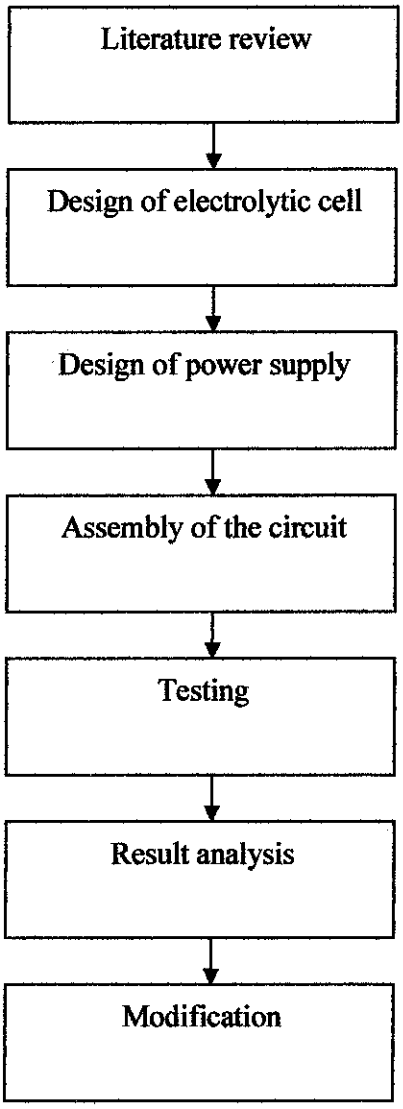

Figure 2: The process flow of the project

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Electrolytic Cell

The design of the electrolytic cell is based on a few parameters which are:

- The material of electrode
- The configuration of the electrode
- The electrolyte used
- The container

Based on these parameters, the writer has designed a few electrolytic cell in order to get the most efficient configuration.

4.1.1 Design of the Electrolytic Cell Using Soft Drink Tin

The cell is designed by using the 400ml beaker as the container of the cell. By referring to the Figure 3, a piece of 4mm thick perspex is used as the cap for the beaker. Perspex is chosen because it is one type of acrylic which been proposed in the draft report as the suitable material for the container. The Perspex is cut into a round shape using the equipment at the workshop. On the perspex three holes are made using the drilling machine. Two for the banana plug that will be soldered to the crocodile clip which will hold the electrode. Another one hole is for the tube that channels the gas to the flowmeter. In order to ensure that the gas will not escape from the beaker, it is sealed using the tack sticker. This also involves the three holes that have been made. Refer Figure 4 for the overall cell structure.

Figure 3: The cap of the cell

Figure 4: the overall cell structure

4.1.1.1 Electrolysis experiment of the cell

The experiment regarding the electrolytic cell had been carried out by using the concentric structure of cell. The anode and cathode electrode that been used in this experiment is the tin while 100ml of tap water was used as the electrolyte. Insulators consist of the masking tape are placed in between the electrode. They will prevent the electrodes from touching each other. The voltage used in this experiment is 15V and 25V DC. A flowmeter also used to measure the flow rate of the gas releases from the electrolysis. Refer Figure 5 for the electrolysis experiment using the tin as the electrodes and tap water as the electrolyte.

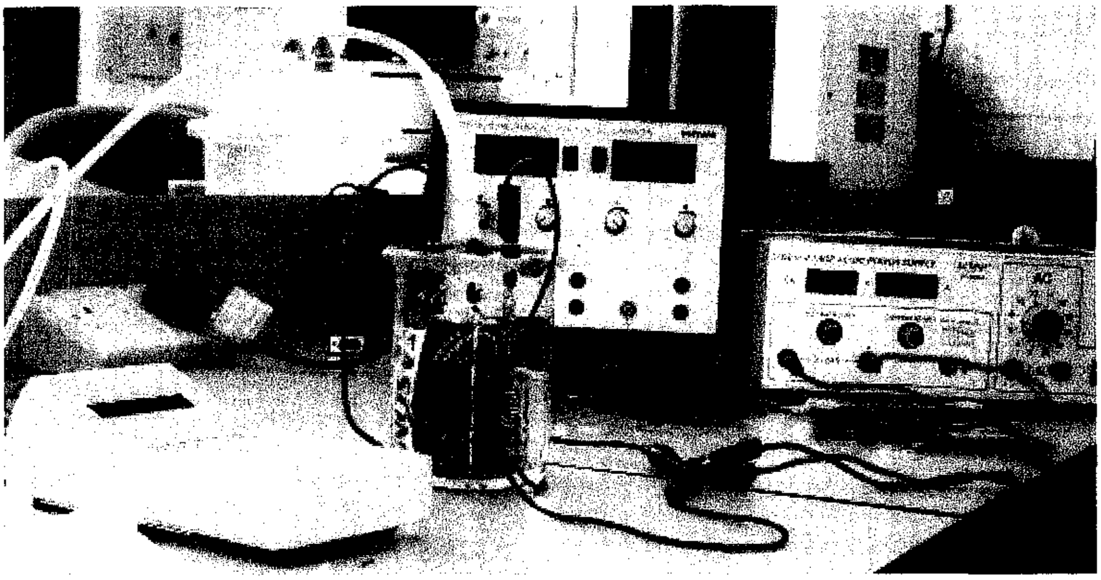

Figure 5: The experiment of electrolysis of tin using tap water as electrolyte

The experiment is carried out by connecting the wire to the banana plugs and to the power supply. Then, connect the tube of the flowmeter to the designated hole. Lastly, switch on the power supply and observe the cell.

4.1.1.2 Results

Firstly, the experiment conducted by using 15V DC power supply. By referring to Figure 6, some tiny bubbles are seen coming out from the wall of the electrode after 2 minutes. The total of bubbles keeps increasing by time but the bubbles increase slowly. The flowmeter did not show any reading.

Then, the power supply is changed to the 25V DC. The same thing happened where tiny bubbles produced but it did not take a lot of time for the bubble to be produced.

In about 30 seconds the bubble started to appear. The total of bubbles produced also increasing fast with time. The flowmeter also did not show any reading as a result of very small amount of gas produced. For both power supply used, there were some white material floating on the surface of the water.

Figure 6: The observation of the experiment

4.1.1.3 Discussion

The reactions of the electrolysis were very slow this due to the low power supply. The reaction can be fastened if higher power supply is used. The low power supply can also be one of the reason why there is no gas measured by the flowmeter. There will be possibility that the gas released through the experiment was too little to be detected by the flowmeter. Other reason would be a bigger unit used in the flowmeter and it cannot detect very small amount gas produced

The flowmeter did not show any readings maybe because of the cell structures. Maybe the cell is not sealed tight enough that the gases escape to the air. Other things like the type and size of the electrodes may also affect the reaction during the electrolysis and production of the gas. The type of electrodes used was not very suitable for electrolysis. The area of the electrodes was also too big and not proportionate to the electrolyte used.

As for the material that floating on the surface of the water, it would the aluminium that was produced during the reaction of the electrolysis.

The cell structure used in this experiment did not allow the gases produced to be measured individually. The measurement obtained from the flowmeter is the mixture of oxygen and hydrogen. The exact amount of the gas produced cannot be measured.

4.1.2 Design of the Electrolytic Cell Using Shiny Surface Stainless Steel

A new cell has been designed using two cylindrical steels with different diameter and a drink container as the cell's container. By referring to Figure 7a and 7b, the steels used have a shiny surface in the outer layer and normal steel surface in the inner layer. The diameter for the inner cylinder is 2 inch while for the outer cylinder is 2.5 inch. Both of the cylinders share the same height which is 6 inch. The cylinder conductivity is about 1.7ohm.

Figure 7a: outer layer surface

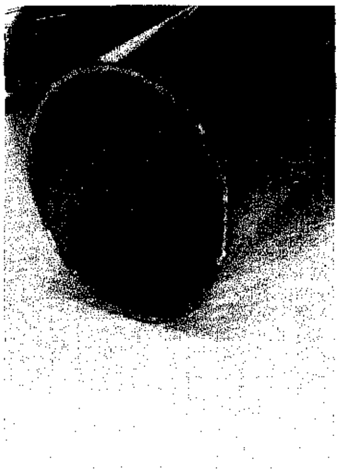

Figure 7b: inner surface

The container is made of plastic which can withstand heat and durable. The cap is tight enough to ensure that the container is vacuum. The height of this container is 11 inch with base of 3 inch and the opening is about 3.5 inch in diameter. The container can be filled with 1.2L of liquid. Three holes are made on the cap for electrical connection to the cylinders and one hole for a gas channel to the flowmeter. Two banana plugs are to be fitted in the holes for the electrical connection. By referring to Figure 8a, wires with crocodile clip attached to them are soldered to the banana plugs. Figure 8b shows the overall picture of the cell container.

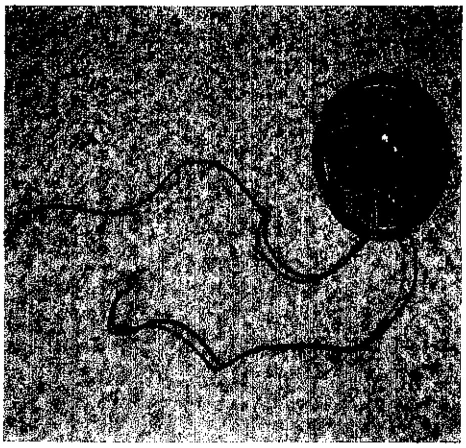

Figure 8a: Cap of the container

Figure 8b: the cell container

To ensure that the cylinders did not touch each other during experiment, two insulators made of plastic are placed at the bottom and in the middle of inner cylinder. Refer figure 9 for the location of the insulator.

Figure 9: The location insulators

4.1.2.1 Electrolysis experiment of the cell

An experiment is carried out to see the reaction of the steel with water using the concentric structure of cell. The anode and cathode electrode that been used in this experiment is the steel while 500ml of tap water was used as the electrolyte. The voltage used in this experiment is 25V DC. Refer Figure 10 for the whole picture of the experiment is carried out.

Figure 10: The experiment of electrolysis of tin using tap water as electrolyte

The experiment is carried out by connecting the wire to the banana plugs and to the power supply. Then, connect the tube of the flowmeter to the designated hole. Switch on the power supply and observe the cell. .Then, the electrode configuration is changed by placing the inner and outer electrodes side by side. Repeat the experiment by the negative and positive electrode.

4.1.2.2 Results

Firstly, the experiment conducted by using 25V DC power supply. By referring to Figure 11, tiny bubbles are seen coming out between the gap of inner and outer cylinder. After a while, the current which starts at 0.45A, increase slowly.

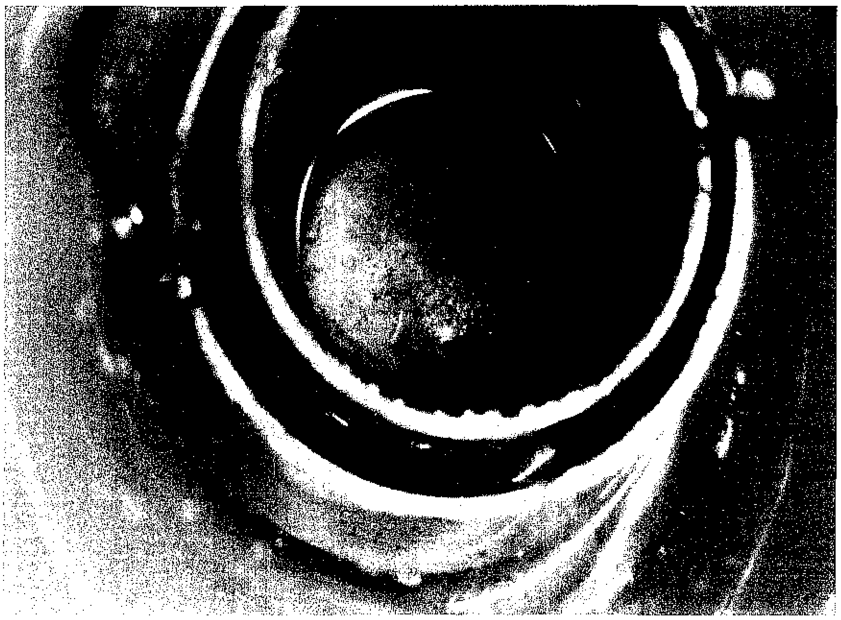

Figure 11: The bubbles between the gaps

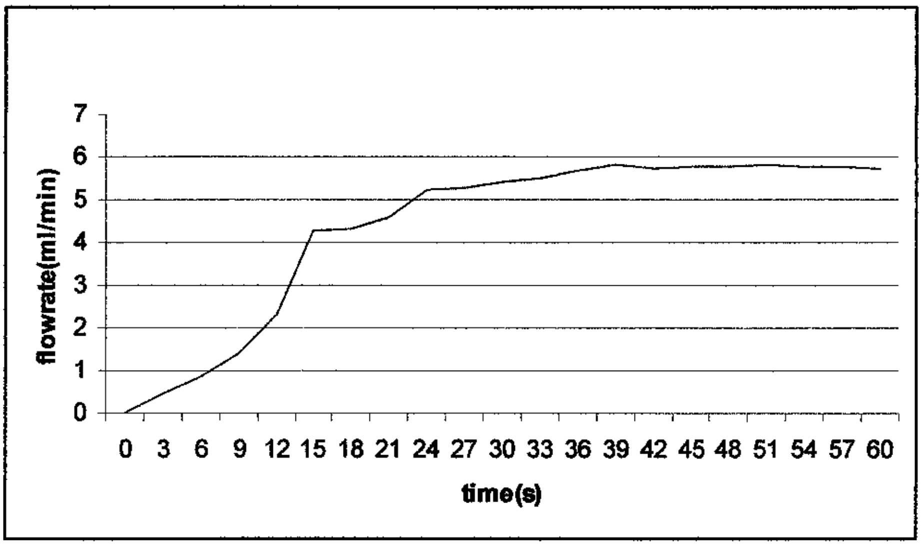

Figure 12: Graph of flow rate vs time for the shiny surface stainless steel electrode and tap water as the electrolyte

By referring to Figure 12, the reaction is quite slow, so 7 grams of table salt is added to the electrolyte to fasten the reaction. When, the experiment carried out with the salt, more tiny bubbles were seen coming out between the gap and current increase to 6.49A. By referring to Figure 13, a brown precipitate was found in the electrolyte.

Figure 13: The brown precipitate

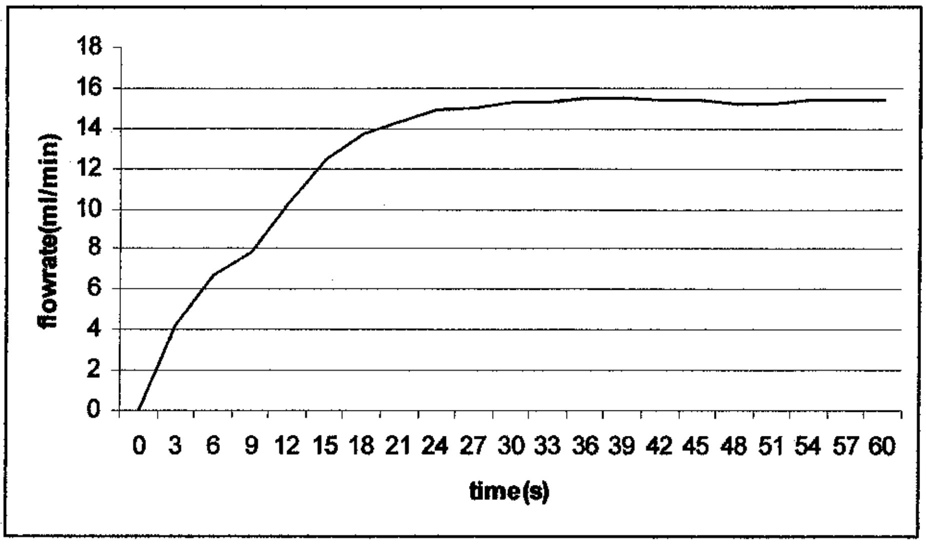

Figure 14: Graph of flow rate vs time for the shiny surface stainless steel electrode and tap water with added as the electrolyte

When, both electrodes is being put side by side, the reaction happen but it only happened between the nearest surface of the steel. There were bubbles coming out of the steel surface. Due to the cylindrical shape of the electrode, some surface which was far from the other electrodes would not have any reaction. This can bee seen by small amount of bubbles coming out of the surface.

4.1.2.3 Discussion

By referring to Figure 12, the amount of gas produced is small. The reactions of the electrolysis were very slow this due to the low power supply. By referring to the Figure 14, the amount of gas produced is larger to compare to the Figure 12. The reaction process is also faster as a result of adding the salt is the electrolyte. The salt increases the conductivity of the electrode and as a result the current and reaction rate increases.

The brown precipitate is the material produced from the reaction between the steel and water. When, the surface of the electrode is observed, the surface had gone through some changes due to the reaction.

Referring to Figure 15a below, the brown precipitate is seen in the inner cylinder surface which acts as the negative electrode. For Figure 15b, it shows that the surface of the outer cylinder that acts as negative electrode corroded the reaction.

Metals in contact with liquids that conduct electricity like water will have tendency to give up electrons by oxidation process. The steel has losses electrons at the anode and this electron travel through water to cathode where the reduction process occurs. The brown precipitate is the product of the oxidation process from the steel. The corroded surface is due to reduction process.

Figure 15a: Surface of inner electrode

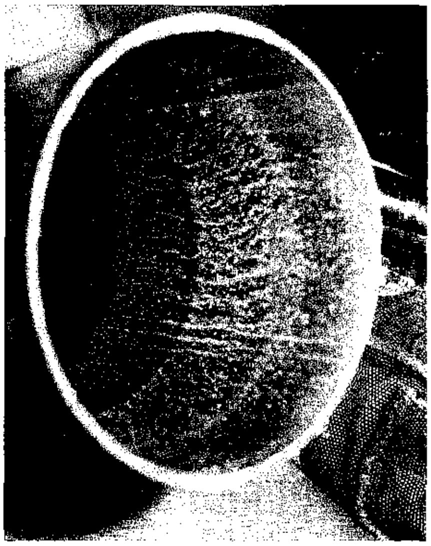

Figure 15b: Surface of outer electrode

When the electrode is changed, where outer cylinder will be negative electrode and outer cylinder will be positive electrode, the shiny surface of the inner cylinder also going through corrosion. The brown precipitate can also be seen on the surface of the outer electrode. Figure 16 below shows comparison between the real shiny surface and the corroded. The surface of outer and inner electrodes where reaction happens is not similar. So this design is not really good because the reaction happens on the different material. This does not fill the criteria of the actual design where the reaction should happen between the same materials.

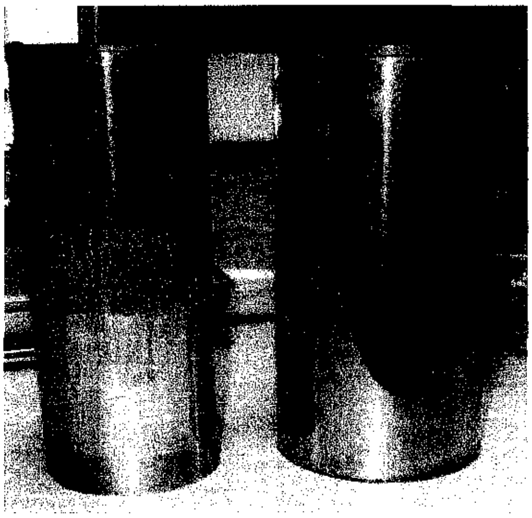

Figure 16: Comparison between two cylinders

When electrode is put side by side, the reaction is low therefore for the cylindrical shape electrode; this configuration is not suitable because only small amount of surface area reacted to the electrolysis process. If the concentric configuration used, the whole surface area would react with another electrodes.

4.1.3 Design of Electrolytic Cell Using Galvanic Pipe

The next design is using eight galvanic pipe (refer Figure 17) as the electrodes. Four of the pipes have diameter of 2 inches and another four have diameter of 2.5 inches and both of them are 6 inches long. A bigger diameter pipes will be paired with smaller diameter pipes to make a concentric cell. So right now, the will be 4 pair of electrodes used in the design. Then, the electrodes will be arranged so that the gap between each pair of electrodes is small.

Figure 17: Galvanic pipe

The electrolyte used in this experiment was tap water with added salt. In order to fit 4 pair of electrodes, a bigger container was used. Amount of electrolyte used will be bigger compared to previous design. The PTFE holder is used as the insulator to prevent the inner electrode from touching the outer electrode. The holder is fitted in at the bottom of the inner electrode.

4.1.3.1 Electrolysis of the experiment

The experiment is carried out to see the reaction of the galvanic pipe with water using the concentric structure of cell with one and four pairs of electrodes. The electrolyte which is water must be filled into the container until the electrodes submerged. The voltage used in this experiment is 25V DC.

Firstly, the crocodile clip is connected directly to the electrode and the other end of the crocodile clip is connected to the power supply. Then, switch on the power supply and observe the reaction.

4.1.3.2 Results

When one pair of electrode is used, the reaction is quite slow. By referring to the Figure 18, the amount of gas is about 12.7 ml/min after the electrolysis is carried out for 1 minute. At the end of the experiment, the amount of gas produced is almost maintained.

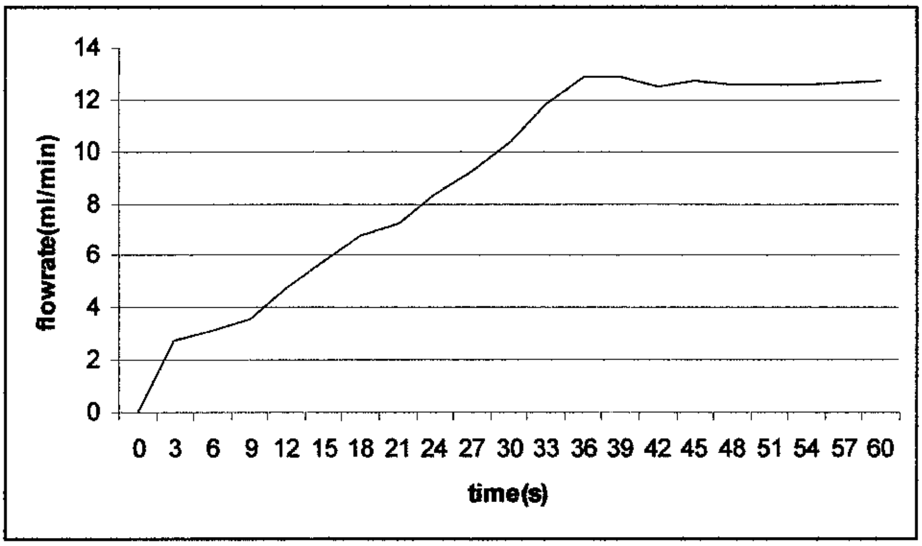

Figure 18: Graph of flow rate vs time for 1 pair of galvanic pipe electrode and tap water with added as the electrolyte

By referring to Figure 19, when 4 pair of electrodes is used reaction during the experiment is quite vigorous; a lot of small bubbles can be seen come out from the gap between the inner and outer electrodes. This can be seen clearly because the electrodes are submerged in the water and help the bubbles to move smoothly to the surface of the water. There are also white precipitate produced and they are floating at the surface of the water as showed in Figure 20. Other than that, this experiment produces brown residue that can be seen at water surface. The electrodes surface also becomes corroded.

Figure 19: The bubbles produced from the reaction

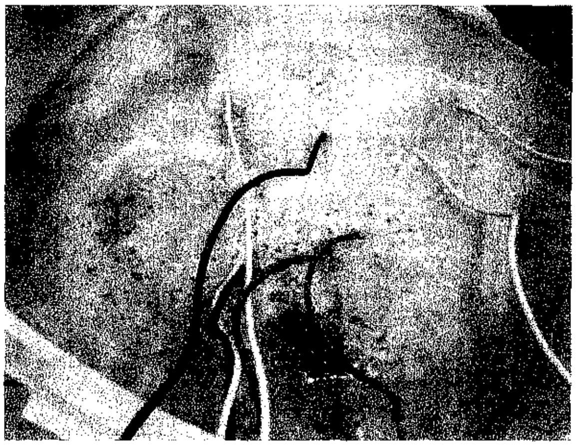

Figure 20: The residue produced

By referring to Figure 21, the amount of gas is increasing compared to when using 1 pair of electrodes only. When the time approaching 60seconds, the amount of gas produced is almost stable.

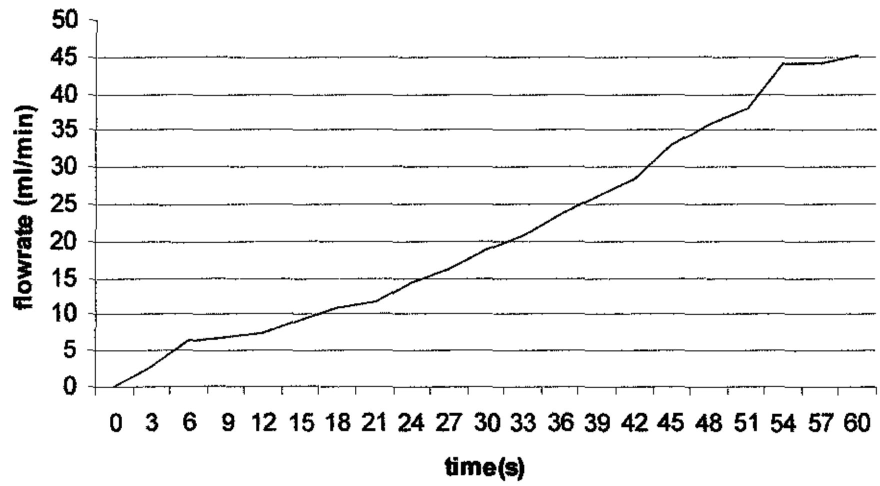

Figure 21: Graph of flow rate vs time for four pairs of galvanic pipe electrode and tap water with added as the electrolyte

4.1.3.2.1 Discussion

From this design, it can be seen that more gas can produce by using four pairs of electrodes by observing the amount of bubbles coming out of the electrodes. The material for this design is more suitable because the surface where the reaction happens used the same material. The reaction also more vigorous compared to the previous design.

Although the gas gas produced is quite big which is about 45ml/min, this cell configuration problem is the white precipitate produced. It is a type of salts that produced during the reaction between water and steel. The residue produced should be some impurities existed in the steel. They will come out during the electrolysis when current passes through them.

4.1.4 Electrolytic design Using Stainless Steel Grade 304

The 304 type of stainless steel has a minimum of 18% chromium and 8% nickel, combined with a maximum of 0.08% carbon [6]. It has good heat and corrosive resistance which is suitable for this design. Refer Appendix A for the properties of stainless steel 304.

In this design, a smaller diameter electrodes are used which are 2.5cm diameter for the outer electrode and 2cm diameter for the inner electrode. Both electrodes are 15cm long and 4 pairs electrodes are used which is same as previous design.

The electrolyte is used is the tap water. The inner electrode will be fit in slightly lower than the outer electrode so that the inner electrodes bottom part will be exposed in order to make it easy to put a screw for connection wires. Both outer and inner electrodes will be connected using the wires.

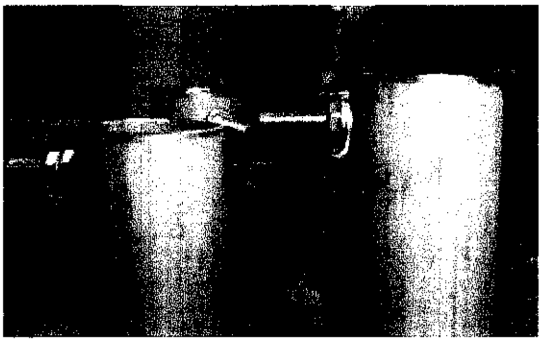

Figure 22a: Wire connection for the outer electrode

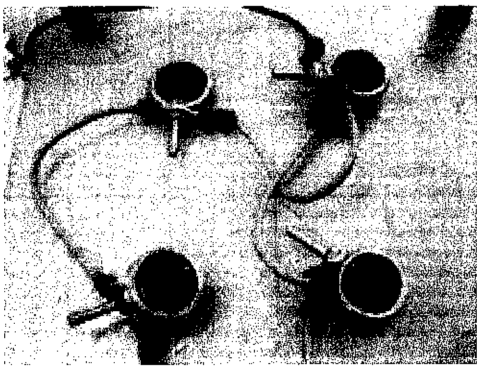

Figure 22b: Wire connection for inner electrode

Figure 22a and 22b shows the connection of the outer and inner electrode of the cell. All the electrodes will be mounted on the Perspex. Four holes with size of inner electrode diameter are made. Then, the inner electrodes will be fitted in the holes while the outer electrodes just stay on the surface of the Perspex.

The insulator used is the rubber pipe which is fit in the bottom of the inner electrode. Figure 23 shows the location of the insulator.

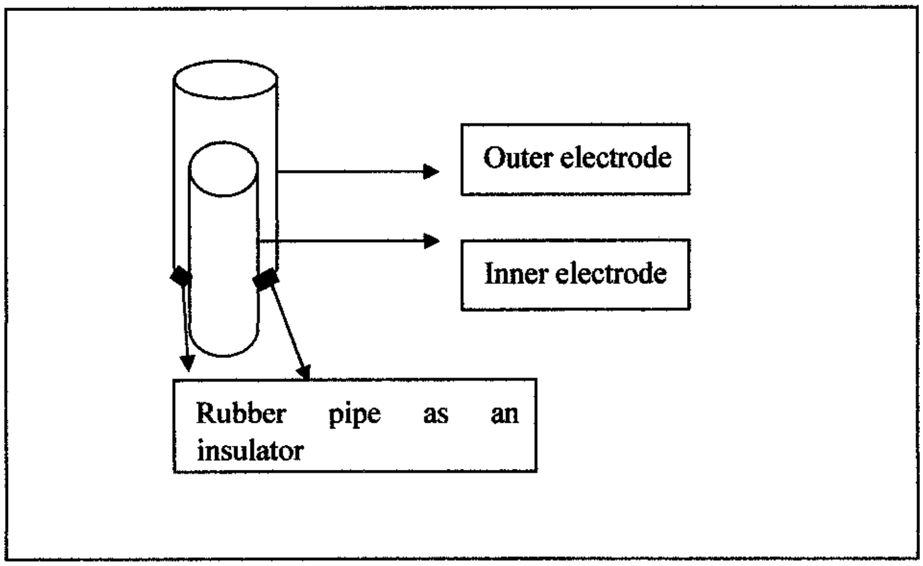

Figure 23: The insulator location

4.1.4.1 Results

The procedure of experiment is same as the previous design. By referring to Figure 24, a lot of bubbles are coming out between the gaps of inner and outer electrode. But the reaction is not really vigorous compared to previous design. There is no residue or precipitate produced using this material.

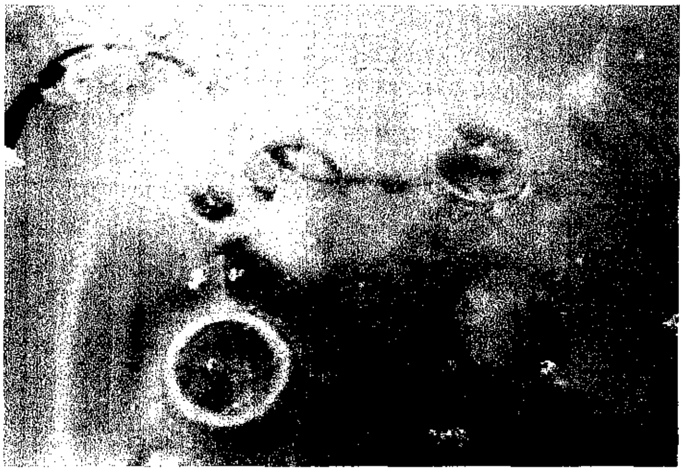

Figure 24: Reaction that happens between the stainless steel 304 and tap water

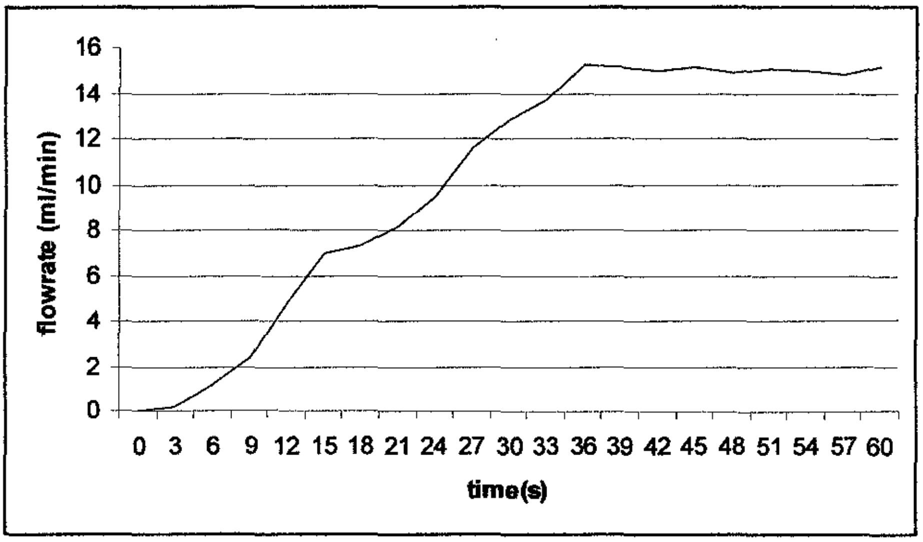

Figure 25: Graph of flow rate vs time for stainless steel grade 304 electrode and tap water as the electrolyte

By referring to Figure 25, the amount of gas produced is not large although using 4 pairs of electrodes. The gas produced is maintained at the end of the experiment.

4.1.4.2 Discussion

This design has reduced the residue to the cell but the output of gas is lower compared to previous design. The experiment is still conducted in the same big container and the amount of electrolyte used is not proportionate to the size of the electrodes. in order to submerged the electrode, a lot of electrolyte is needed, that is the reason why the big container is still being used.

The gap between the outer electrodes also too big compared to previous design. The electrodes are being mounted too far from each other on the perspex. This would also be one of the factors why the reaction is lower than before.

4.1.5 Modified Electrolytic Cell Design Using Stainless Steel Grade 304

The modified version of the electrolytic cell will not use the prespex as the platform to hold the electrodes all together. This design will be simplified by just tying them all together using cable.

The container used in this design is same as in design 4.1.2. The container is long enough to fit in four pairs of electrodes and submerged them. Figure 26 shows how the electrode is configured, Figure 27 show the whole cell configuration and Figure 28 shows the view inside the container.

Figure 26: The electrodes configuration

Figure 27: The whole cell configuration

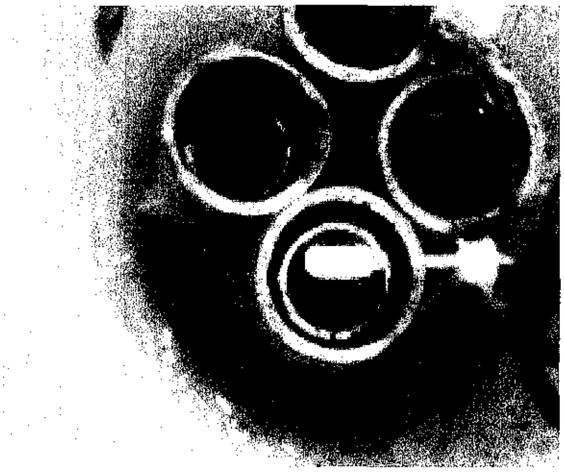

Figure 28: The view inside the container

This design used hydrofluoric (HF) acid as the electrolyte because the reaction between the acid and the steel also produce hydrogen. Refer Appendix B for the full the properties of HF acid. This acid is quite hazardous, so it needs to be diluted to decrease the concentration.

C_1=Normal concentration=49%

V_1=Volume used=1ml

C_2=Expected concentration=0.5%

V_2=Volume of water to dilute the acid

$$\frac{(C_1)(V_1)}{(C_2)(V_2)} = \text{Dilution}$$

$$V2 = \frac{(C_1)(V_1)}{(C_2)}$$

$$= \frac{(49\%)(1\text{ml})}{(0.5\%)}$$

$$= 98\text{ml}$$

From the calculation, to dilute 49% HF acid to 0.5% concentration, 98ml distill should be added to the acid. 25ml of diluted HF acid then added to 1.2L distilled water in the container. The concentration of decrease again when added to the distilled water and this to ensure the safety of the design.

4.1.5.1 Results

The result of this design is a lot of bubble comes out and it can be seen that the reaction is a lot faster. By referring to Figure 29, the bubbles produced are coarser compared to small bubbles produced during the previous design. There are also small amount of smokes that can be seen coming out of the opening of the container. When the smoke tested with a light up matches, a massive combustion occurs.

There is also brown colored precipitate produced from the experiment. It looks like some kind of oil.

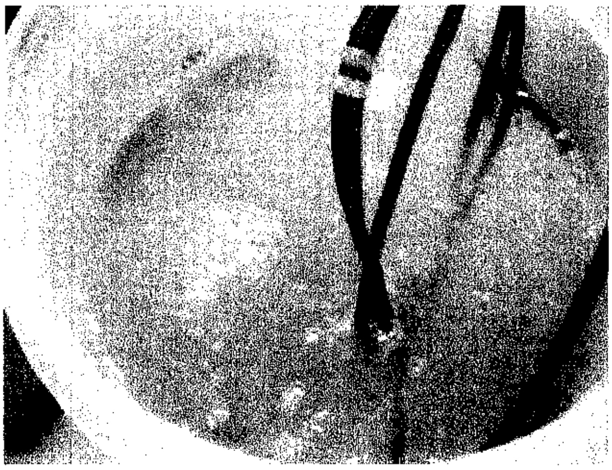

Figure 29: the coarse bubbles produced and the brown precipitate

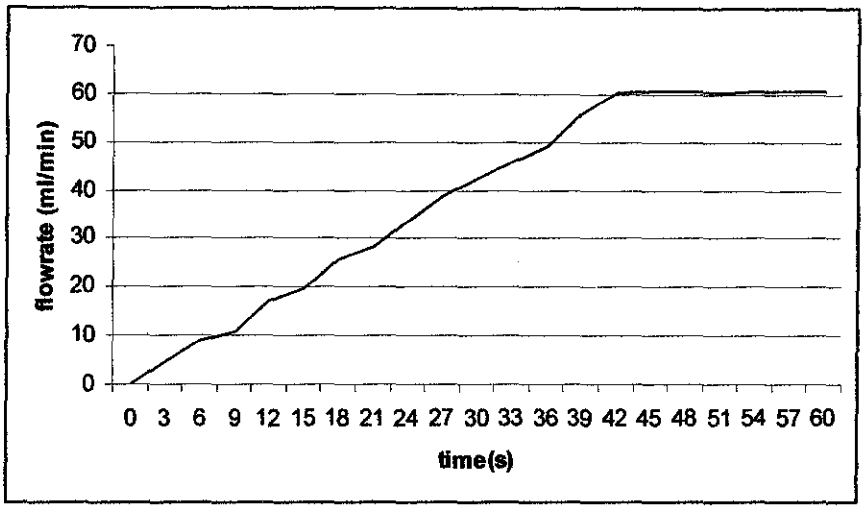

Figure 30: Graph of flow rate vs time for stainless steel 304 electrode and distilled water with added HF acid as the electrolyte

By referring to the Figure 30, the amount of gas is the biggest compared to other cell configuration. The reaction of the process is also very fast.

4.1.5.2 Discussion

From the observation, it can be seen that this design produces the most hydrogen compared to other designs. A smaller container used gives a good effect to the design. The HF acid used as an electrolyte has affected the reaction in the electrolysis process. It has increase the amount of gas produced.

The brown precipitate produced is the effect of using the HF acid. It is actually the impurities that become part of the steel during the process of the steel production. When the steel reacted with the HF acid, the impurities will be removed from the steel because one of the functions of HF acid is to aloof the impurities out of the steel. So, this design is the most efficient to produce more hydrogen.

4.2 Power Supply Design

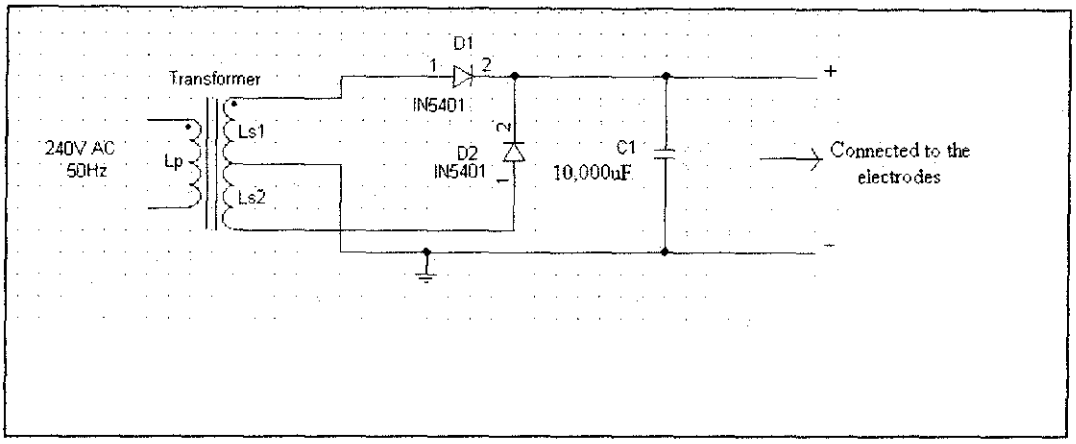

Figure 31: The power supply circuit

By referring to Figure 31, the circuit consists of the transformer, a capacitor and two diodes. The transformer used to supply the AC power direct from the power source. The input of the transformer is connected to a power chord then it will be used to channel the power from the source. While for the diodes, it function as a full wave rectifier where it only uses half windings at a time. The full wave rectifier used to convert AC supply to DC supply. The capacitor is used to filter the ripple caused by converting the AC to DC. Then, the circuit is connected to both of the electrodes.

The transformer is 240VAC is a center tapped type with a 12V or 12-0-12 for the full wave and 15A supply AC current [7]. The transformer secondary winding rated current should be 1.2 times higher than the current supply of the transformer.

Output current = 12 x 15A

=18A

The output current of this circuit is 18A which enough to supply the power to the electrolytic cell.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The water can be separated into oxygen and hydrogen molecule by using this modified electrolysis process. The electrolytic cell that has been designed can break the water molecule and produce hydrogen in an efficient way. The power supply is designed so that it can supply power for the cell. The design which used four pairs of stainless steel 304 and distilled water with added HF acid produced the largest amount of gas as a result of the modification of the previous design.

5.2 Recommendations

For future design, it is recommended to add more electrodes to the cell to increase the amount of gas produced. Other than that, electrodes with larger surface area should be used to improve this project. Finally, a more proper electrolyte should be investigated to increase the performance of the electrolytic cell.

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APPENDICES

APPENDIX A

STAINLESS STEEL 304 PROPERTIES

Material Notes

Type 304 stainless steel is a T 300 Series Stainless Steel austenitic. It has a minimum of 18% chromium and 8% nickel, combined with a maximum of 0.08% carbon. It is defined as a Chromium-Nickel austenitic alloy.

Grade 304 is the standard "18/8" stainless that you will probably see in your pans and cookery tools.

These are some of its characteristics:

- Forming and welding properties

- Corrosion/ oxidation resistance thanks to the chromium content

- Deep drawing quality

- Excellent toughness, even down to cryonegic temperatures which are defined as very low temperatures

- Low temperature properties responding well to hardening by cold working
- Ease of cleaning, ease of fabrication, beauty of appearance

Grade 304L is the low carbon version of 304. It does not require post-weld annealing and so is extensively used in heavy gauge components (over about 6mm).

Grade 304H with its higher carbon content finds application at elevated temperatures.

Applications

It is used for a wide variety of home and commercial applications, this is one of the most familiar and most frequently used alloys in the stainless steel family.

Typical applications include tanks and containers for a large variety of liquids and solids:

- Food industry

Food processing equipment, particularly in beer brewing, milk processing & wine making.

For example it is highly suitable and applied in dairy equipment such as milking machines, containers, homogenizers, sterilizers, and storage and hauling tanks, including piping, valves, milk trucks and railroad cars.

Very common in the brewing industry where it is used in pipelines, yeast pans, fermentation vats, storage and railway cars, etc.

The citrus and fruit juice industry also uses Type 304 for all their handling, crushing, preparation, storage and hauling equipment.

- Domestic tools industry

Because of its ability to withstand the corrosive action of various acids found in fruits, meats, milk, and vegetables, Type 304 is used for sinks, tabletops, coffee urns, stoves, refrigerators, milk and cream dispensers, and steam tables. It is also used in numerous other utensils such as cooking appliances, pots, pans, and flatware.

-Architectural panelling, railings & trim

- Chemical containers, including for transport

-HeatExchangers

- Woven or welded screens for mining, quarrying & water filtration

- Dyeing industry

- In the marine environment, because of it slightly higher strength and wear resistance than type 316 it is also used for nuts, bolts, screws, and other fasteners.

Chemistry % by Weight

Element	Type 302	Type 304	Type 304L	Type 305
Fe	64.99-74%			
Cr	17%	18%	18%	17%
Ni	8%	8%	8%	10.50%

Mn	2%	2%	2%	2%
N	0.10%	0.10%	0.10%	-
S	0.03%	0.03%	0.03%	0.03%
C	0.15%	0.08%	0.03%	0.12%
Si	0.75%	0.75%	0.75%	0.75%
P	0.045%	0.045%	0.045%	0.045%

Possible Alternative Grades

Possible alternative grades to 304 grade stainless steel:

- Grade 301L: It is applicable for higher work hardening rate grade.
It could be required for certain roll formed or stretch formed components.

- Grade 302HQ: Lower work hardening rate grade. It could be needed for cold forging of screws, bolts and rivets.

- Grade 303: Higher machinability needed; lower corrosion resistance; acceptable formability and weldability.

- Grade 316: Used when higher resistance to pitting and crevice corrosion is required, also in chloride environments

- Grade 321: Better resistance to temperatures of around 600-900°C. It has higher hot strength.

- Grade 3CR12: It has lower cost; reduced corrosion resistance and resulting discoloration are acceptable.

- Grade 430: It has lower cost; reduced corrosion resistance and fabrication characteristics are acceptable.

Properties

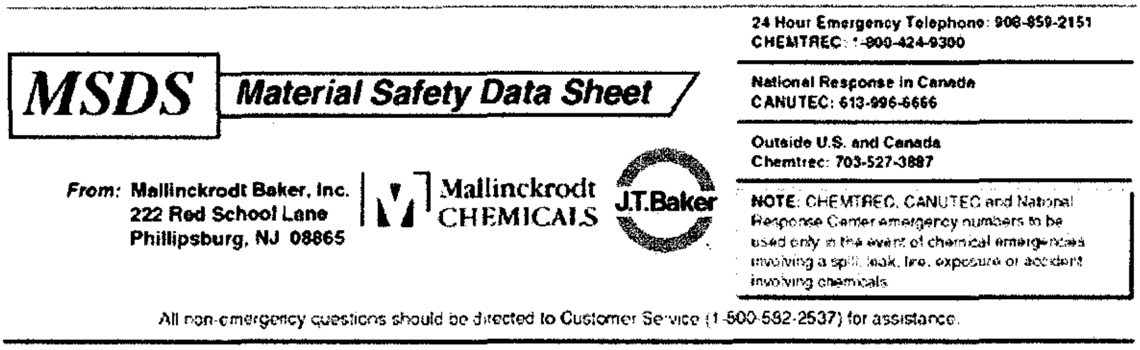
Properties	**Value**	**Comment**
Physical Properties		
Density	8.03 g/cc	
Mechanical properties		
Hardness, Rockwell B	82	
Tensile Strength, Ultimate	621 Mpa (=90100psi)	
Tensile Strength, Yield	290 Mpa (=42100psi)	0.2% YS
Elongation at Break	55%	in 2 inches

Modulus of Elasticity	193 Gpa	tension
Modulus of Elasticity	78 Gpa	torsion
Electrical properties		
Electrical Resistivity	0.000116 ohm-cm	659 °C
Electrical Resistivity	7.2e-005 ohm-cm	
Magenetic permeability	Max 1.02	H = 200 Oersteds, Annealed
Thermal properties		
CTE, linear 20°C	16.9 µm/m-°C	0 to 100°C
CTE, linear 20°C	18.7 µm/m-°C	to 649°C
Heat Capacity	0.5 J/g-°C	0°C to 100°
Thermal Conductivity	16.2 W/m-K	100°C
Thermal Conductivity	21.4 W/m-K	500°C
Processing properties		
Melt temperature	1371- 1399 °C	

APPENDIX B

HCL PROPERTIES

MSDS Number: **H3994** * * * * * *Effective Date:* ***08/18/05*** * * * * * *Supercedes:* ***07/07/04***



MSDS *Material Safety Data Sheet*

From: **Mallinckrodt Baker, Inc.**
222 Red School Lane
Phillipsburg, NJ 08865

Mallinckrodt CHEMICALS

J.T.Baker

24 Hour Emergency Telephone: 908-859-2151
CHEMTREC: 1-800-424-9300

National Response in Canada
CANUTEC: 613-996-6666

Outside U.S. and Canada
Chemtrec: 703-527-3887

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

All non-emergency questions should be directed to Customer Service (1-800-582-2537) for assistance.

1.1 1. Product Identification

Synonyms: Fluorohydric acid; fluoric acid; Hydrogen fluoride solution
CAS No.: 7664-39-3
Molecular Weight: 20.01
Chemical Formula: HF in Aqueous Solution.
Product Codes:
J.T. Baker: 5368, 5659, 5818, 5823, 5824, 5840, 5865, 5900, 6904, 9559, 9560, 9563, 9564, 9567, 9572, 9573, 9574
Mallinckrodt: 2640, 2648, V141, V580

1.2 2. Composition/Information on Ingredients

```
  Ingredient                                CAS No          Percent
Hazardous
  ---------------------------------------   ------------    ---------
---    ---------
```

Hydrogen Fluoride	7664-39-3	48 - 52%	Yes
Water	7732-18-5	48 - 52%	No

1.3 3. Hazards Identification

Emergency Overview

POISON! DANGER! CORROSIVE. EXTREMELY HAZARDOUS LIQUID AND VAPOR. CAUSES SEVERE BURNS WHICH MAY NOT BE IMMEDIATELY PAINFUL OR VISIBLE. MAY BE FATAL IF SWALLOWED OR INHALED. LIQUID AND VAPOR CAN BURN SKIN, EYES AND RESPIRATORY TRACT. CAUSES BONE DAMAGE. REACTION WITH CERTAIN METALS GENERATES FLAMMABLE AND POTENTIALLY EXPLOSIVE HYDROGEN GAS.

SAF-T-DATA$^{(tm)}$ Ratings (Provided here for your convenience)

Health Rating: 4 - Extreme (Poison)
Flammability Rating: 0 - None
Reactivity Rating: 2 - Moderate
Contact Rating: 4 - Extreme (Corrosive)
Lab Protective Equip: GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES
Storage Color Code: White (Corrosive)

Potential Health Effects

Exposure to hydrofluoric acid can produce harmful health effects that may not be immediately apparent.

Inhalation:
Severely corrosive to the respiratory tract. May cause sore throat, coughing, labored breathing and lung congestion/inflammation.
Ingestion:
Corrosive. May cause sore throat, abdominal pain, diarrhea, vomiting, severe burns of the digestive tract, and kidney dysfunction.
Skin Contact:
Corrosive to the skin. Skin contact causes serious skin burns which may not be immediately apparent or painful. Symptoms may be delayed 8 hours or longer. The

fluoride ion readily penetrates the skin causing destruction of deep tissue layers and even bone.

Eye Contact:
Corrosive to the eyes. Symptoms of redness, pain, blurred vision, and permanent eye damage may occur.

Chronic Exposure:
Intake of more than 6 mg of fluorine per day may result in fluorosis, bone and joint damage. Hypocalcemia and hypomagnesemia can occur from absorption of fluoride ion into blood stream.

Aggravation of Pre-existing Conditions:
Persons with pre-existing skin disorders, eye problems, or impaired kidney or respiratory function may be more susceptible to the effects of this substance.

1.4 4. First Aid Measures

For any route of contact: Detailed First Aid procedure should be planned before beginning work with HF.

Inhalation:
Get medical help immediately. If patient is unconscious, give artificial respiration or use inhalator. Keep patient warm and resting, and send to hospital after first aid is complete.

Ingestion:
If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Get medical attention immediately.

Skin Contact:
1) Remove the victim from the contaminated area and immediately place him under a safety shower or wash him with a water hose, whichever is available. 2) Remove all contaminated clothing. Handle all HF-contaminated material with gloves made of appropriate material, such as PVC or neoprene. 3) Keep washing with large amounts of water for a minimum of 15 minutes. 4) Have someone make arrangements for medical attention while you continue flushing the affected area with water. 5) If the following materials are available, limit the washing to five minutes and immerse the burned area in a solution of 0.2% iced aqueous Hyamine 1622 or 0.13% iced aqueous Zephiran Chloride. If immersion is not practical, towels should be soaked with one of the above solutions and used as compresses for the burn area. Ideally compresses should be changed every 2 minutes. Alternately, 2.5% calcium gluconate gel should be massaged into the affected area. 6) Seek medical attention as soon as possible for all burns regardless of how minor they may appear initially. Hyamine 1622 is a trade name for tetracaine benzethonium chloride, Merck Index Monograph 1078, a quaternary ammonium compound sold by Rohm & Haas, Philadelphia. Zephiran Chloride is a trade name for benzalkonium chloride, Merck Index Monograph 1059, also a quaternary ammonium compound, sold by Sanofi-Synthelabo Inc., New York, NY.

Eye Contact:

1) Irrigate eyes for at least 30 minutes with copious quantities of water, keeping the eyelids apart and away from eyeballs during irrigation. 2) Get competent medical attention immediately, preferably an eye specialist. 3) If a physician is not immediately available, apply one or two drops of ophthalmic anesthetic, (e.g., 0.5% Pontocaine Hydrochloride solution). 4) Do not use oily drops, ointment or HF skin burn treatments. Place ice pack on eyes until reaching emergency room.

Note to Physician:
General: For burns of moderate areas, (greater than 8 square inches), ingestion and significant inhalation exposure, severe systemic effects may occur, and admission to a critical care unit should be considered. Monitor and correct for hypocalcemia, cardiac arrhythmias, hypomagnesemia and hyperkalemia. In some cases renal dialysis may be indicated.

Inhalation: Treat as chemical pneumonia. Monitor for hypocalcemia, 2.5% calcium gluconate in normal saline by nebulizer or by IPPB with 100% oxygen may decrease pulmonary damage. Bronchodilators may also be administered.

Skin: For deep skin burns or contact with concentrated HF (over 50%) solution, consider infiltration about the affected area with 5% calcium gluconate [equal parts of 10% calcium gluconate and sterile saline for injection]. Burns beneath the nail may require splitting the nail and application of calcium gluconate to the exposed nail bed. For certain burns, especially of the digits, use of intra-arterial calcium gluconate may be indicated.

Eyes: Irrigation may be facilitated by use of Morgan lens or similar ocular irrigator, using 1% aqueous calcium gluconate solution [50ml of calcium gluconate 10% in 500 ml normal saline].

AN ALTERNATIVE FIRST AID PROCEDURE: The effect of HF, i.e. onset of pain, particularly in dilute solutions, may not be felt for up to 24 hours. It is important, therefore, that persons using HF have immediate access to an effective antidote even when they are away from their work place in order that first aid treatment can be commenced immediately.
We recommend that any person in contact with HF should carry, or have access to a tube of HF Antidote Gel at all times; ideally with one tube at the work place, one on the person and one at home.
It is imperative that any person who has been contaminated by HF should seek medical advice when the treatment by HF Antidote Gel has been applied.
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HF ANTIDOTE GEL:
Distributed by Pharmascience Inc.
8400 Darnley Rd. Montreal, Canada. H4T 1M4
Phone: (514) 340 - 1114
Fax: (514) 342 - 7764
U.S. (Buffalo, NY) distributor: 1-800-207-4477

1.5 5. Fire Fighting Measures

Fire:
Not considered to be a fire hazard. Fire may produce poisonous or irritating gases.
Explosion:
Violent exothermic reaction occurs with water. Sufficient heat may be produced to ignite combustible materials. Reacts with metals forming flammable Hydrogen gas.
Fire Extinguishing Media:
Keep upwind of fire. Use water or carbon dioxide on fires in which Hydrofluoric Acid is involved. Halon or foam may also be used. In case of fire, the sealed containers can be kept cool by spraying with water.
Special Information:
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode. Avoid getting water in tanks or drums; water can cause generation of heat and spattering. In contact with air, the acid gives off corrosive fumes which are heavier than air.

1.6 6. Accidental Release Measures

Notify safety personnel, provide adequate ventilation, and remove ignition sources since hydrogen may be generated by reactions with metals. Wear appropriate personal protective equipment as specified in Section 8. Do not flush to sewers or waterways. Spills: Evacuate the danger area. Apply magnesium sulfate (dry) to the spill area. Follow up with inert absorbent and add soda ash or magnesium oxide and slaked lime. Collect in appropriate plastic containers and save for disposal. Wash spill site with soda ash solution. NOTE: Porous materials (concrete, wood, plastic, etc.) will absorb HF and become a hazard for an indefinite time. Such spills should be cleaned and neutralized immediately. US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National Response Center is (800) 424-8802.

J. T. Baker NEUTRASORB® acid neutralizers are recommended for spills of this product.

1.7 7. Handling and Storage

Keep in tightly closed polyethylene containers. Store in a cool, dry place with adequate ventilation separated from other chemicals. Protect from physical damage. Storage facilities should be constructed for containment and neutralization of spills. Handling and storage of HF requires special materials and technology for containers, pipes, valves, etc., which is available from suppliers. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.

1.8 8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
Hydrogen fluoride:
-OSHA Permissible Exposure Limit (PEL):
3 ppm (TWA)
ACGIH Threshold Limit Value (TLV):
3 ppm Ceiling as F

Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures as low as possible. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, *Industrial Ventilation, A Manual of Recommended Practices*, most recent edition, for details.

Personal Respirators (NIOSH Approved):
If the exposure limit is exceeded, a full facepiece respirator with an acid gas cartridge may be worn up to 50 times the exposure limit or the maximum use concentration specified by the appropriate regulatory agency or respirator supplier, whichever is lowest. For emergencies or instances where the exposure levels are not known, use a full-facepiece positive-pressure, air-supplied respirator. WARNING: Air purifying respirators do not protect workers in oxygen-deficient atmospheres. Since the IDLH is low (30 ppm), the above cartridge system is not specifically approved for HF. (3M Respirator Selection Guide)

Skin Protection:
Wear protective clothing, including boots or safety shoes with polyvinyl chloride (PVC) or neoprene. Use chemical goggles and/or a full face shield. Wear coveralls with long sleeves, gauntlets and gloves of PVC or neoprene. A high degree of protection is obtained with an air-inflated suit with mask and safety belt. Use protection suitable for conditions.

Eye Protection:
Use chemical safety goggles and/or full face shield where splashing is possible. Maintain eye wash fountain and quick drench facilities in work area.

1.9 9. Physical and Chemical Properties

Appearance:
Colorless, fuming liquid.
Odor:
Acrid odor. Do not breathe fumes.
Solubility:
Infinitely soluble.
Specific Gravity:
1.15 -1.18
pH:
1.0 (0.1M solution)
% Volatiles by volume @ 21C (70F):
100 (as water and acid)
Boiling Point:
108C (226F)
Melting Point:
< -36C (< -33F)
Vapor Density (Air=1):
1.97
Vapor Pressure (mm Hg):
25 @ 20C (68F)
Evaporation Rate (BuAc=1):
No information found.

1.10 10. Stability and Reactivity

Stability:
Stable at room temperature (68F) when stored and used under proper conditions.
Hazardous Decomposition Products:
On contact with metals, liberates hydrogen gas. On heating to decomposition, could yield toxic fumes of fluorides. Attacks glass and other silicon containing compounds. Reacts with silica to produce silicon tetrafluoride, a hazardous colorless gas.
Hazardous Polymerization:
Will not occur.
Incompatibilities:
Hydrofluoric acid is incompatible with arsenic trioxide, phosphorus pentoxide, ammonia, calcium oxide, sodium hydroxide, sulfuric acid, vinyl acetate, ethylenediamine, acetic anhydride, alkalis, organic materials, most common metals, rubber, leather, water, strong bases, carbonates, sulfides, cyanides, oxides of silicon, especially glass, concrete, silica, fluorine. Will also react with steam or water to produce toxic fumes.

Conditions to Avoid:
Moisture and incompatibles.

1.11 11. Toxicological Information

Hydrofluoric acid: Inhalation rat LC50: 1276 ppm/1H; Investigated as a mutagen, reproductive effector.

--------\Cancer Lists\--

	---NTP Carcinogen---		
Ingredient	Known	Anticipated	IARC Category
Hydrogen Fluoride (7664-39-3)	No	No	None
Water (7732-18-5)	No	No	None

1.12 12. Ecological Information

Environmental Fate:
If the pH is > 6.5, soil can bind fluorides tightly. High calcium content will immobilize fluorides, which can be damaging to plants when present in acid soils.
Environmental Toxicity:
This material is expected to be slightly toxic to aquatic life. 60 ppm/*/Fish/Lethal/Fresh Water *=time period not specified. > 300ppm/48hr./Shrimp/LC50/Aerated Saltwater

1.13 13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved incinerator or disposed in a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

1.14 14. Transport Information

Domestic (Land, D.O.T.)

Proper Shipping Name: RQ, HYDROFLUORIC ACID (WITH NOT MORE THAN 60% STRENGTH)
Hazard Class: 8, 6.1
UN/NA: UN1790
Packing Group: II
Information reported for product/size: 500LB

International (Water, I.M.O.)

Proper Shipping Name: HYDROFLUORIC ACID (WITH NOT MORE THAN 60% STRENGTH)
Hazard Class: 8, 6.1
UN/NA: UN1790
Packing Group: II
Information reported for product/size: 500LB

1.15 15. Regulatory Information

--------\Chemical Inventory Status - Part 1\---------------------------------

Ingredient	TSCA	EC	Japan	Australia
Hydrogen Fluoride (7664-39-3)	Yes	Yes	Yes	Yes
Water (7732-18-5)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\---------------------------------

		--Canada--		
Ingredient	Korea	DSL	NDSL	Phil.
Hydrogen Fluoride (7664-39-3)	Yes	Yes	No	Yes
Water (7732-18-5)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\----------------

	-SARA 302-		------SARA 313------	
Ingredient	RQ	TPQ	List	Chemical Catg.

Hydrogen Fluoride (7664-39-3)	100	100	Yes	No
Water (7732-18-5)	No	No	No	No

--------\Federal, State & International Regulations - Part 2\-----------------

Ingredient	CERCLA	-RCRA- 261.33	-TSCA- 8(d)
Hydrogen Fluoride (7664-39-3)	100	U134	No
Water (7732-18-5)	No	No	No

Chemical Weapons Convention: Yes TSCA 12(b): No CDTA: No
SARA 311/312: Acute: Yes Chronic: Yes Fire: No Pressure: No
Reactivity: Yes (Mixture / Liquid)

Australian Hazchem Code: 2R
Poison Schedule: S7
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

1.16 16. Other Information

NFPA Ratings: Health: 4 Flammability: 0 Reactivity: 1
Label Hazard Warning:
POISON! DANGER! CORROSIVE. EXTREMELY HAZARDOUS LIQUID AND VAPOR. CAUSES SEVERE BURNS WHICH MAY NOT BE IMMEDIATELY PAINFUL OR VISIBLE. MAY BE FATAL IF SWALLOWED OR INHALED. LIQUID AND VAPOR CAN BURN SKIN, EYES AND RESPIRATORY TRACT. CAUSES BONE DAMAGE. REACTION WITH CERTAIN METALS GENERATES FLAMMABLE AND POTENTIALLY EXPLOSIVE HYDROGEN GAS.
Label Precautions:
Do not get in eyes, on skin, or on clothing.
Do not breathe vapor.
Cool before opening.
Use only with adequate ventilation.
Wash thoroughly after handling.

Store in a tightly closed container.

Label First Aid:

IN ALL CASES, CALL PHYSICIAN IMMEDIATELY. First Aid procedures should be pre-planned for HF emergencies. A supply of 50:50 water/magnesium sulfate paste or 2 1/2% Calcium Gluconate paste should be available where first aid medications are administered. If ingested, DO NOT INDUCE VOMITING. If patient is conscious, give large quantities of milk or water and send to hospital. If inhaled and patient is unconscious, give artificial respiration or use inhalator and send to hospital. In case of eye contact, wash open eyes with large but gentle stream of water for 15 minutes. Place ice pack on eyes until reaching emergency room. In case of skin contact, remove contaminated clothing and wash burn area with plenty of water to remove acid. Cover burn area with a poultice of 50:50 water/magnesium sulfate paste or 2 1/2% calcium gluconate paste. Leave in place until medical help arrives or patient is transferred to hospital.

Product Use:

Laboratory Reagent.

Revision Information:

MSDS Section(s) changed since last revision of document include: 3.

Disclaimer:

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