

**DESIGN OF ELECTROLYTIC RECOVERY TANK
WITH ROTATING ELECTRODES FOR THE REMOVAL
OF HEAVY METALS FROM INDUSTRIAL EFFLUENTS**

BY

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93/3537

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ENGINEERING AND ENGINEERING TECHNOLOGY,
FEDERAL UNIVERSITY OF TECHNOLOGY MINNA,
NIGERIA.**

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**A DESIGN PROJECT SUBMITTED IN PARTIAL FULFILMENT FOR
AWARD OF B. ENG DEGREE IN THE DEPARTMENT OF CHEMICAL
ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING
TECHNOLOGY. FEDERAL UNIVERSITY OF TECHNOLOGY. MINNA**

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CERTIFICATION

I hereby certify that this project was written by AWOYALE ADEOLU
ABIODUN of the Chemical Engineering Department of the Federal University of
Technology, Minna.

Mr. A. O. W. Akinbode
(supervisor)

Date

Dr. J.O. Odigure
(H.O.D)

Date

External Examiner.

Date

DEDICATION

To God Almighty

To my late parents, Engr. And Mrs Awoyale

To Dr. and Mrs T. O. Akande and family

To Mr, and Mrs Olubunmi Akande and family

To Susan, Adebola and Olurotimi

ACKNOWLEDGMENT

First and foremost, I thank God Almighty for his love and benevolence over me, for keeping me alive and helping me to carry out this work successfully. I am so much indebted to you my creator.

I will like to thank my supervisor Engr. A. O. W. Akinbode and all the lecturers in the department for their guidance and encouragement. May God bless them all.

The support received from some of my friends too, cannot also go unnoticed, friends like Jide Lawal, Lekan Lawal, Lanre Ajayi, Deji Aina, Ayo Akano, Wale Olasoju and a host of other too numerous to mention. I am indeed very grateful to you all.

My appreciation also goes to my siblings, Susan, Adebola and Olurotimi for their moral support and to Olohimai Ozolua for her moral and financial support.

My gratitude also goes to my uncle, Mr Olubunmi Akande for his care and support. I am really very grateful. I also wish to thank Dr. T. O. Akande and his family for the love shown towards me. I am so much indebted to him.

Finally, I will like to thank my parents posthumously, especially my dear mother who laboured so hard for my sake. Words cannot express how much I have missed you, continue to rest in the bosom of Christ..

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ABSTRACT

This work deals with the design of an electrolytic recovery tank with rotating electrodes for removal of heavy metals from industrial effluents. The electrolytic recovery tank is to remove lead and zinc from the waste water by the deposition of these metals on the cathode electrode in the tanks.

The area of the electrolytic tank designed was 18.51m^2 while the area of the electrodes was 0.047m^2 . The current density required for the electrolysis of Pb was $1.02 \times 10^{-3} \text{ A/m}^2$ while that of Zn was $5.4 \times 10^{-3} \text{ A/m}^2$ and the flow rate in and out of the tank was 3.05Kg/s . The rotating ring electrode was designed to provide a more efficient operation in the electrolytic recovery process. The advantage of this technique for the recovery of heavy metals is that the heavy metals recovered can be sold since they are obtained in their pure form and the amount realized from the sales used to augment the cost of maintenance of the plant.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

The term 'effluent' denotes the wastes coming out of a process. This effluents contains impurities which can be harmful to man, aquatic lives and the environment. The effluent can be in solid, liquid or gaseous forms.

Depending on the nature of the industry, various waste constituents of effluents include; soluble organics causing depletion of dissolved oxygen, suspended solids, trace organics which causes tastes and odours in water, heavy metals such as lead, zinc, chromium etc., cyanide and toxic organics, colour and turbidity.

Excessively high levels of various heavy metals in the environment arise from the dumping of toxic and hazardous wastes as well as indiscriminate discharge of untreated industrial effluents and sewage. The consequence is the degradation of the ecosystem. The need to constantly monitor the rate and routes of these toxic metals into the environment cannot therefore be over emphasised.

The united nations environment programs, following its conference, in 1972 instituted a Global Environment monitoring systems (GEMS) which has established a priority list of pollutants which includes heavy metals and chlorinated hydrocarbons amongst its key categories.

After carrying out analysis on soils around an industrial area and discovered that heavy metals have started building up in these soils, it is therefore very imperative to find a way of controlling these heavy metals from getting to the soil and this can be done by removing them from the effluents being discharged by the industry. This is to be achieved by designing an electrolytic recovery process to be integrated into the effluent treatment plant of the industry.

1.2 OBJECTIVE OF THE STUDY

The major aim of this study is to design an electrolytic recovery tank with a rotating electrode to remove lead and zinc metals from industrial effluents.

1.3 METHOD AND SCOPE OF THE STUDY

In this work, the whole effluent treatment plant which include mixing process, sedimentation process, filtration process and the electrolytic recovery process were highlighted and material balance was carried out on the whole plant. And then the electrolytic recovery process was designed in details.

1.4 PROBLEM STATEMENT

To design a waste water treatment plant to treat 250m³ of waste water per day. Assume 90% of the suspended solids are removed with the addition of 500mg of lime Ca(OH)₂. 8% of the suspended solids is lost to the filter and the remaining 2% which is the fraction of heavy metals is removed by the electrolytic recovery process.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Although most industries treat their effluents, there has not been much emphasis on the removal of heavy metals from effluents. There are many methods of heavy metals removal from effluents and it includes; ion exchange, reverse osmosis and electrolytic recovery techniques.

Electrolysis is the chemical conversion or breakup of a compound by passing an electric current through the compound, which must be in a fluid state, either dissolved as a solution or molten.

The electrically conducting fluid through which the current passes is known as the electrolyte and contains electrically charged particles called ions (from the Greek word for going). When an electric current is passed through the electrolyte by means of electrode which are immersed in it, the anions are attracted to the positively charged anode and the cations are attracted to the negative cathode, the opposite charges attracting one another. It is this movement of charged ions which produces a flow of electric current, but, it is at the electrodes where a transfer of current takes place, that the reaction of electrolysis take place. Thus, substances which do not release ions cannot conduct electricity in this manner and cannot be electrolyzed.

The conducting wires leading to the electrodes will be metallic and they conduct electricity by the movement of electrons along them. Each electron bears a single unit negative charge and the current in amperes is really a measure of how many electron pass any point in the circuit in a given time. At the cathode, electrons flow down into the electrode and they react with cations, causing a chemical change to them. Hydrogen ions H^+ , for example, are converted into hydrogen atoms, H,

after taking up one electron. Subsequently, the atoms form molecules of hydrogen gas (H_2) which bubbles off.

Since the ions each have a fixed weight and electrical charge and therefore react with a fixed number of electrons, it is easy to see the basis of Faraday's laws of electrolysis, which states that the weight of a substance changed by electrolysis is proportional to its equivalent weight (the weight of a fixed number of ions divided by the electrical charge of each one) and also to the current that has passed and the duration of the electrolysis

2.2 ELECTROLYTIC RECOVERY TECHNIQUES

Electrolytic recovery techniques are used primarily for the recovery of metals from process streams or rinse waters. These metals must be removed or recovered from the effluent streams prior to discharge either to meet the effluent discharge limits imposed by the environmental regulations, or to recover the metals for their economic values. (Benirati 1983).

The major process equipment consists of (1) The electrochemical reactor containing electrodes (2) a gas - venting system (3) recirculating pumps and (4) a power supply. After the metal coating or deposition at the cathode reaches the desired thickness, the metal can be removed and generally reused or sold. In electroplating, for example, either the recovered metal, which is essentially pure, is returned to the plating tank or the metal - plated cathode can now be used as an anode in the plating bath (Hradil, 1984).

Electrolytic recovery techniques have been used to recover copper, nickel, zinc, silver, cadmium, gold and other heavy metals. The capital cost and operation and maintenance costs are generally low, especially when compared with those for other processes. The process can generally pay for itself in about a year, or in a matter of weeks when precious materials such as gold are being recovered (Campbell, 1982)

2.2.1 DESCRIPTION

The conventional electrochemical reactor consists of the electrode, associated appliances such as recirculation pumps and a power supply. The cathodes are made of stainless steel of approximately 150mm width upon which the recovered metal is deposited.

After coating or deposition of metals reaches sufficient thickness (6mm), the metal deposited can be removed and is generally re-used or sold. The electrolytic recovery tank is usually designed to produce high flow rates in a narrow channel.

The conventional recovery tank is very efficient at high concentration but not at low concentration due to mass transfer limiting conditions.

As a result, advanced electrolytic recovery devices have been fully developed and are commercially available.

These electrochemical devices or cells may be in the form of a packed bed or fluidized bed, cells with spiral wound electrodes, or cell with rotating cylindrical electrodes. One such advanced electrolytic recovery device is the extended - surface electrolysis (ESE) recovery system. This system unlike conventional recovery devices, recovers metals better at low concentrations than at high concentrations. However, the mechanism of metal removed is essentially the same as the conventional types.

A number of cells can be stacked as modules, so that a large fraction of contaminants metal can be recovered from an effluent. The solution to be treated is pumped in at the top of the module and flows down through the cells where the metals are plated out on the cathode.

Another advanced electrolytic recovery device is the high surface area (HSA) reactor. This reactor can be used to treat effluent from plating streams or other streams containing metals. The cathode achieves a high surface area by incorporating a large number of carbon filament mats. These mats collect the materials from the still rinse bath during plant operations. When plating operation ceases, vat solutions are drawn from the bath into a separate compartment of the

reactor where they remove the metal from the cathode by an electrochemical or sometimes chemical process.

Other advanced electrolytic recovery devices, such as fluidized - bed electrochemical reactors, are commercially available for the removal and recovery of metal from dilute solutions. This process makes recovery from dilute streams economically attractive.

2.2.2 ADVANTAGES

- i. Valuable metals are recovered, reused or sold.
- ii. Discharge of toxic heavy metals is reduced or eliminated
- iii. Initial investment for the process is low
- iv. production of toxic sludges is eliminated
- v. Operating expenses are low
- vi. Equipment maintenance is minimal (Freeman, 1989)

2.3 RESULTS OF CASE STUDIES

Tin and silver have been electrolytically recovered from their respective rinse water using conventional methods. Using a cathode area of 4.1m^2 , (current density of 5 to 10 A/ft², and flow rate of $0.005\text{m}^3/\text{h}$ (1.2gal/h), the recovery efficiency for tin was reported to be 97 to 99%, but the current efficiency for tin was 70% (USEPA, 1979). A 99.8% recovery was reported for silver. In this case, the flow rate was $0.003\text{m}^3/\text{h}$, with a cathode area of 3.1m^2 and a current density of 3 to 5A/ft². A current efficiency of 25 to 50% was reported.

A high - surface area (HSA) reactor was constructed at allied metal finishing in Baltimore, Maryland in 1980 for the recovery of cadmium and destruction of cyanide (Horeclick, 1982).

The cathode is made of carbon fiber which has an enormous surface area/volume ratio. It is claimed that this reactor is capable of recovering 99.9% of the metals contained in the feed stream. The reactor can reportedly electro-oxidize and destroy cyanide to below detection limits at a cost much lower than the conventional

alkali chlorination process.

Since the installation, Allied metal finishing has saved money on water use as a result of recycling (\$17,000 in the first year), reduced purchase of cadmium as metal was made available for reuse and reduced cost associated with sludge disposal.

The GTE/Automatic Electric facility uses an electrochemical reactor to recover copper from sulfuric acid solutions (Benirati, 1983). It was reported that over a five-week period, 241 kg of copper were recovered. The average copper concentration was approximately 5 g/l and the cathode efficiency was reported to be 90%.

A HSA system designed to recover cadmium and destroy cyanide was instituted at the expert metal finishing plant in Ontario, Canada in 1981. It has been reported that 99.9% of cadmium was recovered and that most of the cyanide was destroyed (Campbell, 1982)

These and many other case studies point to the fact that many metals can be recovered using electrolytic recovery techniques.

CHAPTER THREE

MATERIAL BALANCE OVER THE PLANT

3.1 DESIGN DATA

250m³ of waste water to be treated per day Influent composition

Suspended solids = 450mg/l

Po₄³⁻ as p = 20mg/l

Ca²⁺ = 100mg/l

Mg²⁺ = 20mg/l

Pb²⁺ = 0.41mg/l

Zn²⁺ = 0.52mg/l

Treated Effluent

phosphorus P = 0.60mg/l

Calcium Ca = 74mg/s

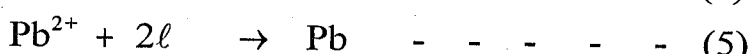
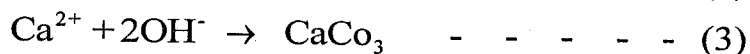
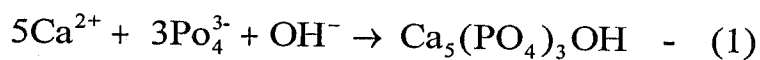
Magnesium Mg = 0 mg/l

Lead Pb = 0.5mg/l*

Zinc Zn = 0.5mg/l*

* Maximum discharge limit

Equation of the reaction



Molar Masses

P = 30.97g/mol

Ca₅(PO₄)₃OH = 502g/mol

Mg = 24.31g/mol

Mg(OH)₂ = 58.3g/mol

CaCO₃ = 100g/mol

Ca = 40g/mol

Ca(OH)₂ = 74g/mol

Pb = 208g/mol

Zn = 65.38g/mol

Assumed specific gravity of the sludge = 1.38

Assumed specific gravity of the waste water = 1.06

Assume the sludge contain 80% of water .

Assume that 2% of the stream from the holding tank is used to backwash the filter and that 8% of the saids is lost as filter residue.

3.2 CALCULATIONS

OVERALL MATERIAL BALANCE

$$A + B = C + D + E + F$$

where,

A = waste water to be treated

B = Chemical Addition

C = Sludge

D = Filter loss

E = Pb and Cr metals deposited

F = Effluent

To determine the mass of $\text{Ca}_5(\text{PO}_4)_3 \text{OH}$ in the sludge

i. Mole of P removed = $\frac{\text{Amount in influent} - \text{Amount in effluent}}{\text{molar mass}}$

$$= \frac{20\text{mg/l} - 0.6\text{mg/l}}{30.97\text{g/mol} \times 10^3\text{mg/g}}$$

$$= 6.26 \times 10^{-4} \text{ mole/l}$$

$$\begin{aligned} \therefore \text{Mass of } \text{Ca}_5(\text{PO}_4)_3 \text{OH formed} &= \text{concentration} \times \text{molar mass} \\ &= 2.08 \times 10^{-4} \text{ mol/l} \times 502 \times 10^3 \text{ mg/mol} \\ &= 104.41 \text{ mg/l} \end{aligned}$$

ii To determine the mass of $\text{Mg}(\text{OH})_2$ formed

$$\text{mole of Mg removed} = \frac{20\text{mg/l}}{24.31\text{mol/l} \times 10^3\text{mg/g}}$$

$$= 8.23 \times 10^{-4} \text{ mol/l}$$

From equation 2 above, 1 mole of Mg formed 1 mole of $\text{Mg}(\text{OH})_2$

$$\therefore \text{mole of } \text{Mg}(\text{OH})_2 \text{ formed} = 8.23 \times 10^{-4} \text{ mol/l}$$

$$\begin{aligned} \text{mass of Mg(OH)}_2 \text{ formed} &= 8.23 \times 10^{-4} \text{ mol/l} \times 58.3 \times 10^3 \text{ mg/mol} \\ &= 47.98 \text{ mg/l} \end{aligned}$$

ii) To determine the mass of CaCO_3 formed

$$\begin{aligned} \text{moles of Ca}^{2+} \text{ in Ca}_5(\text{PO}_4)_3\text{OH} \\ &= 2.08 \times 10^{-4} \times 5 = 1.04 \times 10^{-3} \text{ mole/l} \end{aligned}$$

$$\begin{aligned} \text{mass of Ca}^{2+} \text{ in Ca}_5(\text{PO}_4)_3\text{OH} &= 1.04 \times 10^{-3} \text{ mol/l} \times 40 \times 10^3 \text{ mg/mol} \\ &= 41.6 \text{ mg/l} \end{aligned}$$

The mass of Ca added in the original dose

$$\begin{aligned} \text{i.e mass of Ca in Ca(OH)}_2 &= \frac{40 \text{ g/mol} \times 500 \text{ mg/l}}{74 \text{ g/mol}} \\ &= 270.3 \text{ mg/l} \end{aligned}$$

mass of Ca present in CaCO_3

$$\begin{aligned} \text{Ca in CaCO}_3 &= \text{Ca in Ca(OH)}_2 + \text{Ca in influent waste water} - \\ &\quad \text{Ca in Ca}_5(\text{PO}_4)_3\text{OH} - \text{Ca in effluent waste water.} \\ &= 270.3 + 100 - 41.6 - 74 \\ &= 254.7 \text{ mg/l} \end{aligned}$$

$$\begin{aligned} \text{mass of CaCO}_3 &= \frac{254.7 \text{ mg/l} \times 100 \text{ g/mol}}{40 \text{ g/mol}} \\ &= 636.75 \text{ mg/l} \end{aligned}$$

$$\begin{aligned} \therefore \text{mass of suspended solids removed} &= \frac{0.9 \times 450 \text{ g/m}^3 \times 250 \text{ m}^3 \text{ / day}}{1000 \text{ g/kg}} \\ &= 101.25 \text{ kg/day.} \end{aligned}$$

Chemical solids removed

$$\begin{aligned} \text{mass of Ca}_5(\text{PO}_4)_3\text{OH} &= \frac{104.41 \text{ g/m}^3 \times 250 \text{ m}^3 \text{ / day}}{10^3 \text{ g/kg}} \\ &= 26.10 \text{ kg/day} \end{aligned}$$

$$\begin{aligned} \text{mass of Mg(OH)}_2 &= \frac{47.98 \text{ g/m}^3 \times 250 \text{ m}^3 \text{ / day}}{10^3 \text{ g/kg}} \\ &= 11.99 \text{ kg/day} \end{aligned}$$

$$\begin{aligned} \text{mass of CaCO}_3 &= \frac{636.75 \text{ g/m}^3 \times 250 \text{ m}^3 \text{ / day}}{10^3 \text{ g/kg}} \\ &= 159.19 \text{ kg/day} \end{aligned}$$

Total mass of solids removed

$$= 101.25 + 26.10 + 11.99 + 159.19 = 298.53 \text{ kg/day}$$

Total volume of sludge resulting from chemical precipitation is given

$$\begin{aligned} \text{by: } \frac{298.53 \text{ kg/day}}{1.38 \times 1000 \text{ kg/m}^3 \times (1-0.8)} &= \frac{298.53}{1380 \times 0.2} \\ &= 1.082 \text{ m}^3 \text{ / day.} \end{aligned}$$

To calculate the mass of sludge,

$$\text{Density} = \frac{\text{mass}}{\text{volume}}, \text{ Density} = \text{specific gravity} \times 1000$$

$$\begin{aligned} \text{mass of waste water entering A} &= 250 \text{ m}^3 \text{ / day} \times 1.06 \times 1000 \text{ kg/m}^3 \\ &= 2.65 \times 10^5 \text{ kg/day} \end{aligned}$$

$$\begin{aligned} \text{mass of sludge C} &= 1.082 \times 1.38 \times 1000 \\ &= 1493.16 \text{ kg/day} \end{aligned}$$

$$\begin{aligned} \text{mass of Ca(OH)}_2 \text{ added} &= \frac{500 \text{ g/m}^3 \times 250 \text{ m}^3 \text{ / day}}{1000 \text{ g/kg}} \\ &= 125 \text{ kg/day} \end{aligned}$$

To determine the masses of Pb and Zn deposited on the cathode,

$$\begin{aligned}\text{mole of pb removed} &= \frac{\text{Amount in influent} - \text{Amount in effluent}}{\text{molar mass}} \\ &= \frac{0.41\text{mg/l} - 0.05\text{mg/l}}{208\text{g/mol} \times 10^3\text{mg/g}} \\ &= 1.73 \times 10^{-6} \text{mol/l}\end{aligned}$$

From Faraday's law of electrolysis

$$n = \frac{Q}{z_t F}$$

where n is the number of moles of metal deposited

Q is the quantity of electricity

Z_t is the number of electrons

F is the Faraday's constant which is equal to 96,485

$$\therefore 1.73 \times 10^{-6} = \frac{Q}{2 \times 96,485}$$

$$Q = 0.33\text{c}$$

The mass of metal (Pb) deposited is then given by

$$m = \frac{QM}{Z_t F}$$

where M is the molar mass of the metal and

m is the mass of metal deposited

$$\begin{aligned}\therefore m &= \frac{0.33 \text{ molC/l} \times 208 \times 10^3 \text{ mg/mol}}{2 \times 96,485\text{c}} \\ &= 0.35 \text{ mg/l}\end{aligned}$$

converting to kg/day,

$$\begin{aligned}&\frac{0.35\text{g/m}^3 \times 250\text{m}^3/\text{day}}{1000\text{g/kg}} \\ &= 0.085\text{kg/day}\end{aligned}$$

For Zn

$$\begin{aligned}\text{number of moles of Zn removed} &= \frac{0.52\text{mg/l} - 0.05\text{mg/l}}{51.9\text{g/mol} \times 10^3\text{mg/g}} \\ &= 9.06 \times 10^{-6} \text{mol/l}\end{aligned}$$

$$\begin{aligned}9.06 \times 10^{-6} &= \frac{Q}{2 \times 96,485\text{c}} \\ &= 1.75\text{c}\end{aligned}$$

$$\begin{aligned}m &= \frac{QM}{Z_t F} \\ &= \frac{1.75\text{molc/l} \times 65.38 \times 1000 \text{ mg/mol}}{2 \times 96,485\text{c}} \\ &= 0.59 \text{ mg/l}\end{aligned}$$

converting to kg/day

$$\begin{aligned}&\frac{0.59\text{g/m}^3 \times 250\text{m}^3/\text{day}}{10^3\text{g/kg}} \\ &= 0.15\text{kg/day}\end{aligned}$$

mass of solid loss to the filter

$$\begin{aligned} &= \frac{0.08 \times 450 \text{ g/m}^3 \times 250 \text{ m}^3/\text{day}}{10^3 \text{ g/kg}} \\ &= 9.0 \text{ kg/day} \end{aligned}$$

mass of waste water entering the system A = 2.65×10^5 kg/day

mass of $\text{Ca}(\text{OH})_2$ added B = 125 kg/day

mass of sludge C = 1493.16 kg/day

filter loss D = 9.0 kg/day

mass of Pb and Zn deposited E = 0.085 kg/day pb and
0.15kg/day Zn

final effluent F = 98% of stream K

backwash to drain Bw = 2% of stream k

overall material balance

$$A + B = C + D + E + F + \text{BW} - *$$

Substituting the above values into equation *,

$$2.65 \times 10^5 + 125 = C + D + E + F + \text{BW}$$

$$= 2.65 \times 10^5 + 125 - 1493.16 - 0.085 - 0.15 - 9.0 = F + \text{BW}$$

$$= 263622.60 = F + \text{BW}$$

$$\text{Let } 263622.60 = K$$

$$\therefore k = F + \text{BW}$$

$$\therefore 263622.60 = F + \text{BW}$$

$$F = 0.98 \times 263622.60 = 258350.15$$

$$\text{BW} = 0.02 \times 263622.60 = 5272.45$$

$$\therefore 263622.60 = 258350.15 + 5272.41$$

material in = material out.

Calculation of the flow rates

Taking a basis of kg/s

For the influent A

$$A = 2.65 \times 10^5 \text{ kg/day}$$

$$\therefore \frac{2.65 \times 10^5}{24 \times 3600} = 3.067 \text{ kg/s}$$

For B going in

$$B = \frac{125}{24 \times 3600} = 1.45 \times 10^{-3} \text{ kg/s}$$

$$\text{For (A + B) out} = \frac{265125}{24 \times 3600} = 3.068 \text{ kg/s}$$

For the sludge going out of sedimentation tank

$$C = \frac{1493.16}{24 \times 3600} = 0.017 \text{ kg/s}$$

For the influent into filtration tank h,

$$h = \frac{263631.84}{24 \times 3600} = 3.05 \text{ kg/s}$$

For the backwash to drain BW

$$BW = \frac{5272.45}{24 \times 3600} = 0.06 \text{ kg/s}$$

For the solid loss to filter,

$$D = \frac{5272.45}{24 \times 3600} = 0.06 \text{ kg/s}$$

For stream k going out of the filter

$$k = \frac{258359.39}{24 \times 3600} = 2.9 \text{ kg/s}$$

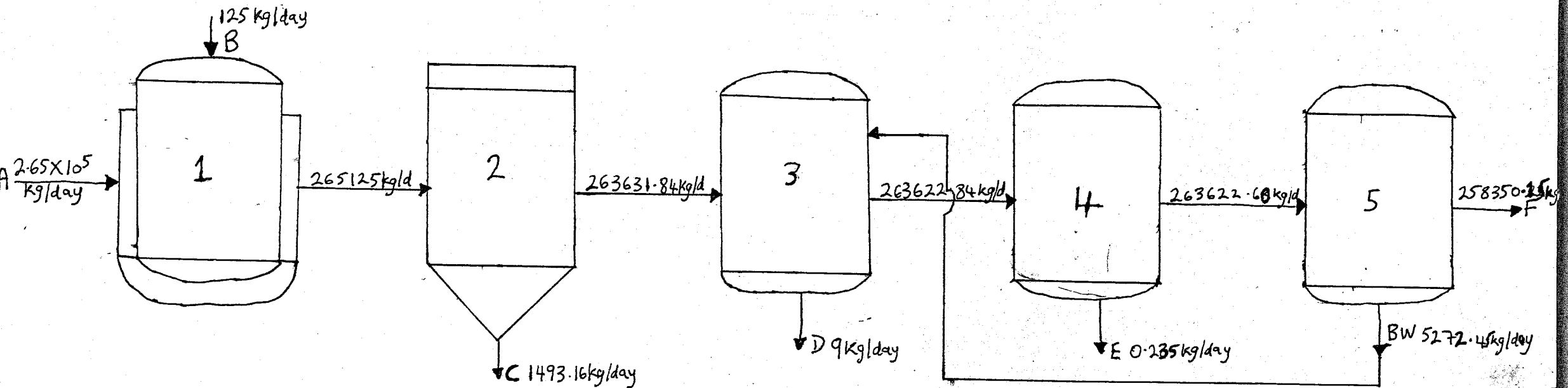
For k going out of the electrolytic recovery tank

$$k = \frac{258359.15}{24 \times 3600} = 2.9 \text{ kg/s}$$

For F going out of the tank

$$F = \frac{258359.15}{24 \times 3600} = 2.9 \text{ kg/s}$$

SIMPLIFIED FLOW SHEET OF A WASTE WATER PLANT



A = WASTE WATER

B = LIME

C = SLUDGE

D = FILTER LOSS

E = Pb AND Zn METALS DEPOSITED

F = EFFLUENT

1 MIXING TANK

2 SEDIMENTATION TANK

3 FILTRATION TANK

4 ELECTROLYTIC RECOVERY TANK

5 WATER TANK

SUMMARY OF RESULT

MATERIAL BALANCE TABLE FOR WASTE WATER TREATMENT PLANT. BASIS Kg/day

Material	Mixing tank		Sedimentation tank		Filtration tank		Electrolytic recovery tank		Water tank	
	in	out	in	out	in	out	in	out	in	out
influent waste water	2.65x10 ⁵									
Ca(OH) ₂	125	265125	265125	263631.84						
sludge				1493.16						
influent from sedimentation tank					263631.84	263622.84				
filter loss						9.0	263622.84	263622.60		
Pb and Zn deposited								0.235	263622.60	258350.15
Back wash to filter										5272.45
TOTAL	265125	265125	265125	265125	263631.84	263631.84	263631.84	263631.84	263622.60	263622.60
Flow rates kg/s										
	3.067	3.068	3.068	3.05	3.05	3.05	3.05	3.05	3.05	2.99
	1.45x10 ⁻³	-	-	0.017	-	1.04x10 ⁻⁴	-	-	-	0.06

CHAPTER FOUR

EQUIPMENT DESIGN

- 4.1 The equipment to be designed in detail is electrolytic recovery tank with a rotating electrode

4.1.1 CAPACITY OF THE TANK

The capacity of the tank depends on the rate of electrolysis and also on the volume of waste water to be treated.

Assuming that the time taken for electrolysis is 30 minutes and the mass of the influent waste water into the electrolytic recovery tank is 263622.84kg/day.

$$\begin{aligned}\text{The tank's capacity} &= \frac{263622.84\text{kg / day} \times 0.5 \text{ hours}}{24\text{hours / day} \times 1000 \text{ m}^3 / \text{kg}} \\ &= 5.49\text{m}^3\end{aligned}$$

Given a safety factor of 10%.

$$\begin{aligned}\text{capacity} &= 5.49(1+0.1) \\ &= 6.03\text{m}^3\end{aligned}$$

4.1.2 DIAMETER OF THE TANK (D_T)

For a cylindrical tank,

$$V = \frac{\pi d^2 h}{4} \text{ where } h = 1.3d \text{ (for design specifications)}$$

$$V = \frac{1.3\pi d^3}{4}$$

$$6.03 = \frac{1.3\pi d^3}{4}$$

$$d^3 = \frac{6.03 \times 4}{1.3\pi}$$

$$d^3 = 5.91$$

$$d = \sqrt[3]{5.91}$$

$$= 1.807\text{m}$$

$$D_T = 1.81\text{m}$$

4.1.3 HEIGHT OF THE TANK (H_T)

For standard, we have $h = 1.3d$

$$H = 1.3 \times 1.81$$

$$= 2.35\text{m}$$

$$H_T = 2.35\text{m}$$

4.1.4 AREA OF TANK

$$\begin{aligned} A &= 2\pi rh + 2\pi r^2 \\ &= 2\pi r (h + r) \\ &= 2\pi \frac{d}{2} (h + \frac{d}{2}) \\ &= 2\pi \times \frac{1.81}{2} (2.35 + \frac{1.81}{2}) \\ A &= 18.51\text{m}^2 \end{aligned}$$

4.1.5 DETERMINATION OF PIPE DIAMETER

using the formula

$$d_{\text{optimum}} = 260G^{0.52} \rho^{-0.37}$$

where G = mass flow rate in kg/s

ρ = density of fluid in kg/s

i) For pipe carrying waste water into the tank, $G = 3.05$ kg/s

$$\begin{aligned} \therefore d_{\text{opt}} &= 260 \times 3.05^{0.52} \times 1050^{-0.37} \\ &= 35.39 \text{ mm} \end{aligned}$$

ii) For the pipe carrying waste water out of the tank, $G = 3.05$ kg/s

$$\begin{aligned} d_{\text{opt}} &= 260 \times 3.05^{0.52} \times 1050^{-0.37} \\ &= 35.39\text{mm} \end{aligned}$$

4.2 DESIGN OF THE ELECTRODE]

The rotating ring electrode is to be used to produce a higher efficiency of metal depos

4.2.1 LENGTH OF THE ELECTRODE (L_e)

$$\begin{aligned} L_e &= \frac{1}{2} H r \\ &= \frac{1}{2} \times 2.35 \\ &= 1.18\text{m} \end{aligned}$$

4.2.2 INNER DIAMETER OF THE ELECTRODE (D_i)

$$\begin{aligned} D_i &= \frac{1}{16} D_T \\ &= \frac{1}{16} \times 1.81 \\ &= 0.1\text{m} \end{aligned}$$

4.2.3 OUTER DIAMETER OF THE ELECTRODE (D_o)

$$\begin{aligned} D_o &= \frac{1}{8} D_T \\ &= \frac{1}{8} \times 1.81 \\ &= 0.22\text{m} \end{aligned}$$

4.2.4 AREA OF THE ELECTRODE

$$A_e = \pi(r_o^2 - r_i^2)$$

where r_o is the outer radius and r_i is the inner radius

$$\text{but } r_o = \frac{D_o}{2} \text{ and } r_i = \frac{D_i}{2}$$

$$A_e = \pi \left(\frac{0.22^2}{2} - \frac{0.1^2}{2} \right)$$

$$= \pi(0.02 - 0.005)$$

$$A_e = 0.047\text{m}^2$$

4.2.5 DETERMINATION OF THE MASS TRANSFER COEFFICIENT OF THE ELECTRODE (M_o)

$$M_o = \frac{V}{TA}$$

Where M_o = mass transfer coefficient

V = volume flow of waste water

A = area

T = time

$$m_o = \frac{263.63\text{m}^3}{1800 \times 0.18}$$

$$= 0.81\text{m/s}$$

4.2.6 DETERMINATION OF THE ELECTRODE POTENTIAL (E)

$$E = E^\circ + \frac{RT}{nF} \ln C_o$$

where E is the electrode potential

E° is the standard electrode potential

$\frac{RT}{F}$ is a constant

n is the number of electrons

C_o is the concentration of the metal

i) For lead (Pb)

$$E = -0.1263 + \frac{0.02569}{2} \ln 1.73 \times 10^{-6}$$

$$= -0.1263 + 0.012845 (-13.27)$$

$$E = -0.1263 - 0.17$$

$$E = -0.29\text{v}$$

ii) For Zinc (Zn)

$$E = -0.7628 + \frac{0.02569}{2} \ln 9.06 \times 10^{-6}$$

$$\begin{aligned}
 &= -0.7628 + 0.012845(-11.61) \\
 &= -0.7628 - 0.15 \\
 &= -0.91\text{v}
 \end{aligned}$$

4.3 DETERMINATION OF THE CURRENT DENSITY REQUIRED FOR THE ELECTROLYSIS

$$Q = it$$

where Q is the quantity of electrocity required

i is the current

t is time for electrolysis

i) For lead (Pb)

$$0.33 = i \times 1800$$

$$\begin{aligned}
 i &= \frac{0.33}{1800} \\
 &= 1.83 \times 10^{-4} \text{ A}
 \end{aligned}$$

The current desity is given by

$$\begin{aligned}
 j &= \frac{i}{A} \\
 j &= \frac{1.83 \times 10^{-3} \text{ A}}{0.18\text{m}^2} \\
 &= 1.02 \times 10^{-3} \text{ A/m}^2
 \end{aligned}$$

ii) For Zinc (Zn)

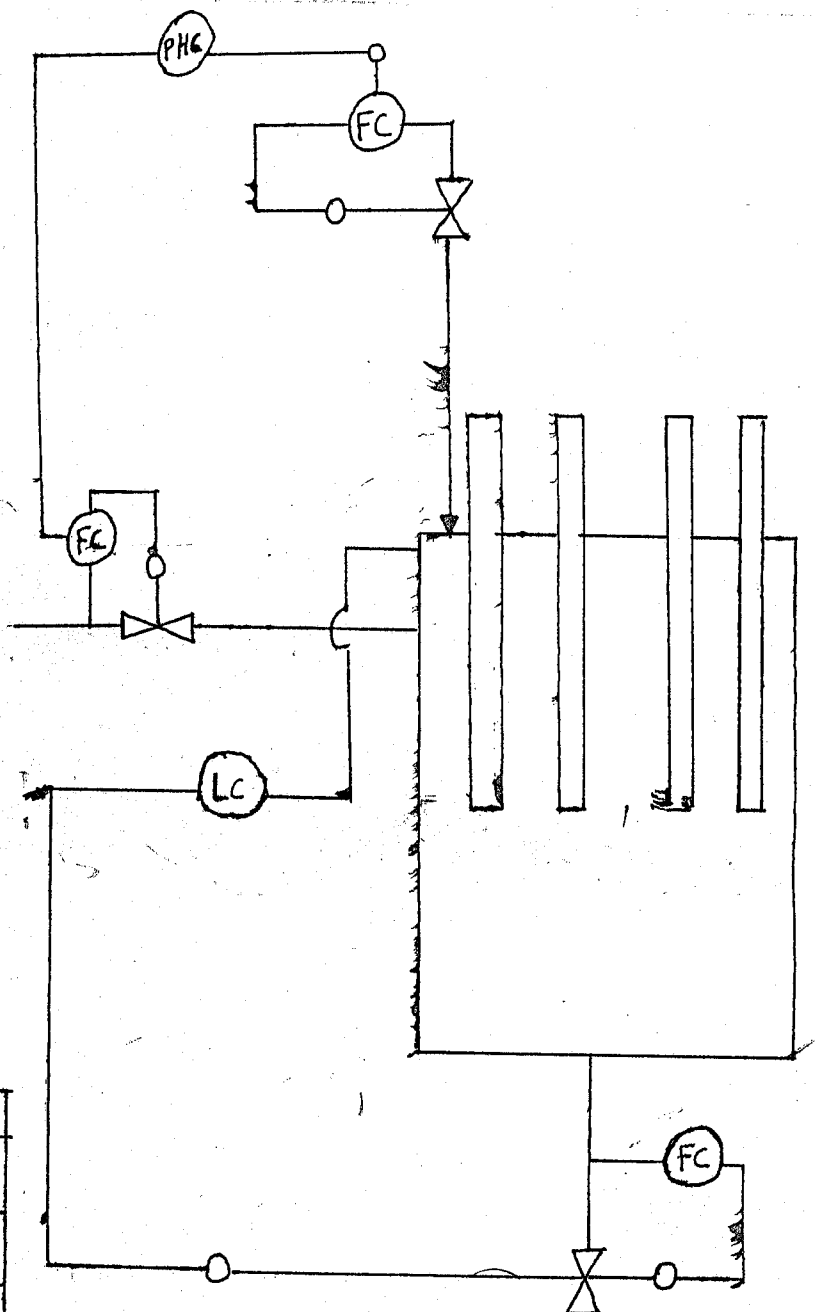
$$1.75 = i \times 1800$$

$$\begin{aligned}
 i &= \frac{1.75}{1800} \\
 &= 9.72 \times 10^{-4} \text{ A}
 \end{aligned}$$

The current density is therefore

$$\begin{aligned}
 j &= \frac{i}{A} \\
 j &= \frac{9.72 \times 10^{-4} \text{ A}}{0.18\text{m}^2} \\
 &= 5.4 \times 10^{-3} \text{ A/m}^2
 \end{aligned}$$

4.4 CONTROL OF OPERATION



KEYS
LOW CONTROL
LEVEL CONTROL
CONTROL

4.5 MATERIALS OF CONSTRUCTION

The material to be used for the construction of the electrolytic recovery tank is stainless steel. Stainless steel is chosen because of its high resistance to corrosion as the waste water can cause corrosion to the tank if the tank is not fortified against it. Also, the use of stainless steel for the construction of the tank will prevent undesirable side reactions between the tank and the chemical constituents of the waste water.

Type 316 of the stainless steel is to be used. The electrode is also to be made of stainless steel to prevent corrosion.

4.6 PLANT LAYOUT AND SAFETY OF OPERATION

The effluent treatment plants is an ancillary unit of the main production plant of the factory.

The plant is designed to treat the effluent from production process and hence is located at a safe distance from the production unit and also proximal to the point of disposal.

It should have the shortest possible run of connecting pipe between it and the main plant for economic and safety purposes.

Also, in laying out the plant, full consideration must be given to safety so that the plant does not impose additional risk to the local community.

Other aspect of the plant layout to be considered are the availability of sufficient land, so that it can be conveniently expanded incase of any future expansion process.

For the safety of operation, the aspect of the plant that needed consideration are the control valves which regulate the flow of liquid into and out of the tanks to prevent overflow in case of unexpected fluctuation in the flow rate of waste water caused by faults in the operating system.

4.7 ECONOMIC ANALYSIS OF EQUIPMENT

	Fixed cost	Amount (₦)
i	Tank	1,239,864.36
ii	Electrodes	97,200.00
iii	Maintenance	66,853.21

variable cost

Electricity	1,200
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Total cost	1,405,117.58
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- Note that the amount realized from the sale of Pb and Zn metals deposited could be used to augment the maintenance cost.

4.8 PROCESS OPTIMIZATION

Optimization of the process is carried out by conserving space and eliminating unnecessary steps as well as reducing yard piping and valving to a minimum. For instance, a rotating electrode was used to provide a faster rate of reaction instead of having a recirculation pump. And the cathodes for both Zn and Pb are contained in one tank instead of having them in separate tanks this could also be used if many metals are to be electrolytically recovered, A number of electrodes can be stacked as module to save space and unnecessary steps.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

5.1 CONCLUSIONS

In view of the fact that most factories do not treat their effluents for heavy metals before discharging such waste waters, these heavy metals like lead, zinc and so on have started building up in the soils in the immediate vicinity of these industries and it is gradually spreading to other part of the environment, an electrolytic recovery tanks was therefore designed to check the rate at which these heavy find their way into the environment. The electrolytic recovery tank is to be integrated into the conventional effluent treatment plant of the factories.

The area of the electrolytic recovery tank designed was 18.51m^2 while the area of the electrode was 0.18m^2 . The advantage of his technique for the recovery of heavy metals from waste water streams is that the heavy metals recovered can be sold and the amount realized form the sales can be used to augment the cost of maintenance of the plant.

5.2 RECOMMENDATION

I wish to recommend a more intensive research work on this technique of heavy metal removal from waste water as it is quite inexpensive to maintain and if properly managed, it can pay for itself in a good time.

The Government should pump money into research work that involves the construction of pilot plants for this process of recovery of heavy metals from effluents.

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APPENDIX

1. CALCULATIONS OF THE COST OF THE EQUIPMENT

i) For the tank,

$$C_e = CS^n$$

where $c = 1250$

$$S = 6.03\text{m}^3$$

$$n = 0.6$$

$$C_e = 1250 \times 6.03^{0.6}$$

$$3673.67 \text{ pounds}$$

for stainless steel,

$$3673.67 \times 2.5$$

$$= 9184.18 \text{ pounds}$$

converting to Naira

$$9184.18 \times 135$$

$$= \text{N}1,239,864.36$$

ii) For electrode,

$$C_e = CS$$

$$C = 1000$$

$$S = 0.18$$

$$n = 0.5$$

$$C_e = 1000 \times 0.18$$

$$= 180 \text{ pounds}$$

converting to N; 180×135

$$= \text{N} 24,300$$

The number of electrodes (anode and cathode) to be use will be 4 since two metals are to be removed

$$\text{Hence } \text{N}24,300 \times 4$$

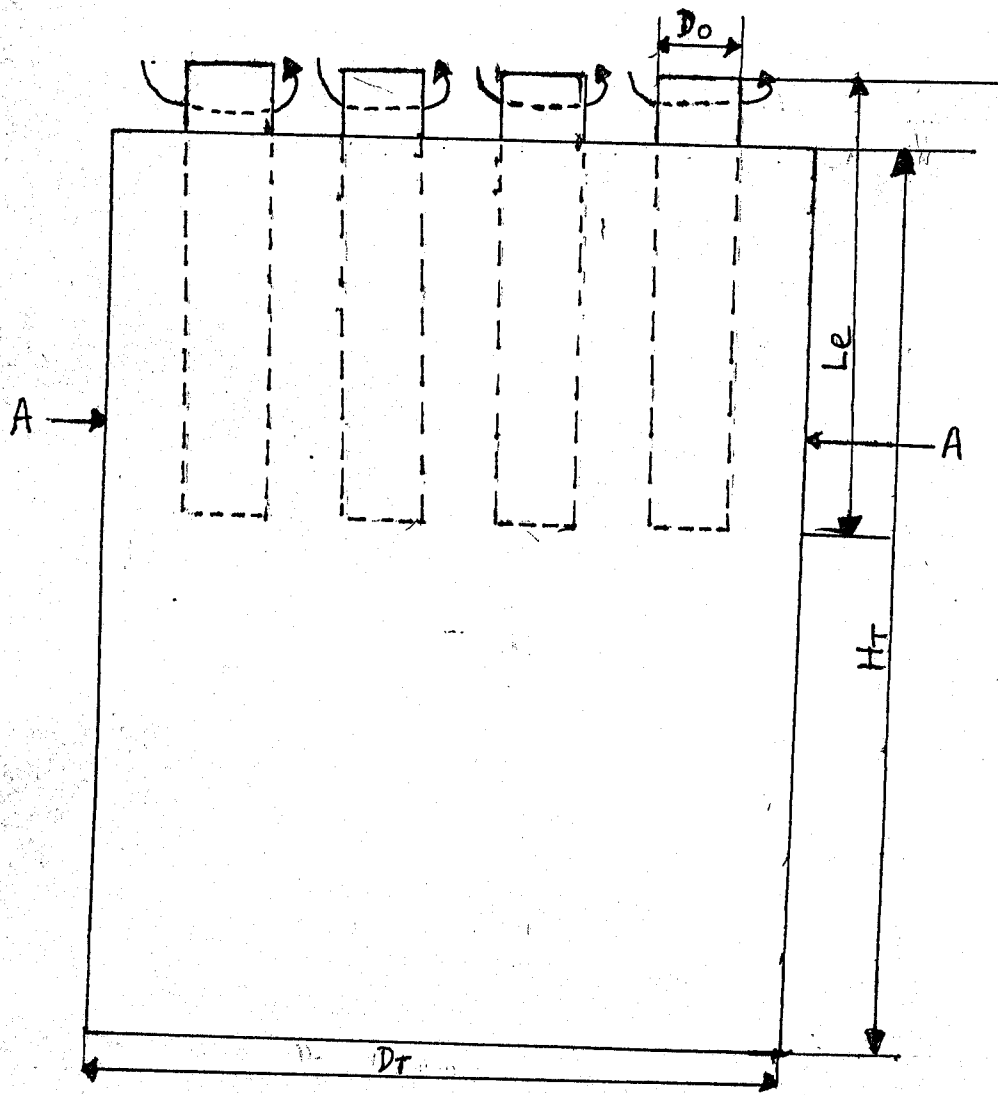
$$= \text{N}97,200$$

iii) Cost of maintenance

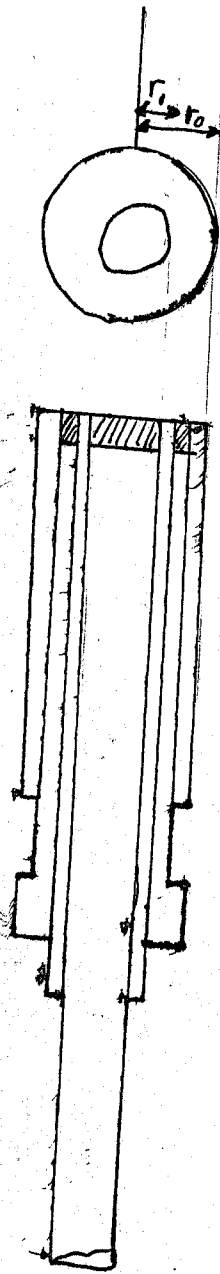
$$5\% \text{ of } \text{N} (1,239,864.36 + 97,200)$$

$$= \text{N} 66,853,21$$

SIZING OF THE ELECTROLYTIC RECOVERY TANK



SECTION A-A



THE ROTATING RING ELECTRODE