# SIGN AND COSTING OF SMALL SCALE CHROME ELECTROPLATING PLANT.

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# CERTIFICATION PAGE

This thesis entitled "DESIGN AND COSTING OF A SMALL SCALE CHROME ELECTROPLATING PLANT", by BABALOLA RASHEED meets the regulation governing the award of degree of master of Engineering (M. Eng. Chem.) at Federal University of Technology, Minna and is approved for its contribution to knowledge and literary presentation.

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## DECLARATION

by declare that this work was carried out by me and it is a record of my research work.

not been presented in any previous application for higher degree. All the sources of ıation are duly acknowledged by means of references.

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**lola Rasheed**

14/04/08

**Date**

**DEDICATION**

ʼork is dedicated to the memory of my late mother Mrs. Sariyu Olalonpe Ayoka ʼla and to my daughter Maryam Omomayowa Babalola and my yet unborn children.

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## ABSTRACT

This project work was based on the designing of 2000kg/day of chrome electroplating plant for wrist watch chains. The design was carried out with the aid of an Engineering software and the various results of the equipment designed are shown in tables 4.1 to 4.4. A summary of the overall economic analysis has been presented in tables 4.6. The cost of equipment was $21,220 (Twenty One Thousand Two Hundred and Twenty Dollars). The profit after tax (PAT) was $61, 851 (Sixty One Thousand Eight Hundred and Fifty One Dollars); the pay back period (PBP) was 3 years and six months and the rate of return on investment was 27.28%.

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# CHAPTER ONE

# 1.0 INTRODUCTION

This project work tilled Design and Costing of small scale chrome electroplating plant is fully discussed accordingly.

Chrome electroplating is the covering of thin layer of chrome metal on a material usually a metal, plastic or other material in order to provide resistance to corrosion, wear, special appearance such as colour or luster or increase dimension, e.t.c. Thus, chrome electroplating is an electrolytic process whereby a chrome metal is cathodically deposited into another metal or a surface that has been made conductive. This process is done to import certain desirable properties while avoiding the prohibited cost of fabrications of the part entirely from chrome metal.

## 1.1 Background

Electroplating started as far back as 1800 when a chemist, Lugi Brugnatelli, carried out electroplating by making some metallic material surface to be coated with gold.

In 1805 a more refined electroplating process was conducted by a group of scientists in Britain and Russia when a printing press plate was electroplated with copper. By 1840 the process was refined and used for gold and silver plating.

In 1850 electroplating of bright nickel, brass, tin, and zinc on engineering material and other specific purposes was carried out by scientists in great Britain. The years 1870 to 1940 were a quiet period for electroplating as no new scientific discoveries were made until the year 1945 when heavy gold plating for electronic components was discovered. In 1956 the "User friendly" plating bath that is based on formulae was developed for large-scale commercial use. (htt://electrochem2002).

Nickel was the most widely used metal for corrosion resistance and shining property but the metal does not retain its luster for long.

Chrome metal thus quickly replaces nickel because it combined all other properties with the ability to retain luster for long.

Electroplating is the covering of a thin layer of metal on a material usually a metal plastic or other material in order to provide resistance to corrosion, special appearance such as colour or luster or increase dimension. Thus electroplating is an electrolytic process whereby a metal is cathodically deposited onto another metal or a surface that has been made conductive. This process is done to import certain desirable properties while avoiding the prohibitive cost of fabrications the part entirely from the metal used for coating other desirable characteristics of electroplating includes improved solder ability of the base metal (substrate), wear resistance, electrical conductivity, contact resistance and lubricity depending on their use. (Fowke et. al 1962).

Electroplated coating may be classified as either decorative or engineering but some fall into both.

Usually in electroplating a cheaper material is used as the basis material and plating technique is used to cover the surface of the material with an expensive material.

A typical example of the technique used to have expensive material is gold plating which is often found on religious articles.

Conventionally iron was and is still the most popular basis material for plating. We can therefore understand rust preventive technique easily when we concentrate on metal material, such as copper, brass, lead, zinc, as it's variations. Zinc plating is the most popular rust preventive plating method, followed by copper-nickel-chromium or nickel-chrome platting.

There are also alloys like brass, bronze plating as well as gold and silver plating.

Summarily, plating technique can be defined as applying thin coating and evenly deposited on the surface of base material. (Fowke et. al 1962).

## 1.2 Statement Of The Problems

Modern living conveniences such as wrist watches, spoons, openers, key holders, oven trays and transportation equipment such spare parts, car bumpers, bicycles and motorbikes parts are made up of iron and steel, which are liable to corrosion and this can be prevented by painting, or electroplating.

In the recent years, the output of chrome plated product is increasing tremendously as paints peel off, Nickel does not retain its luster for long from the base material yet, only few industries are into chrome electroplating. Out of these few, most are not servicing the public, thus the need to have more chrome electroplating plant in Nigeria; Most people are in doubt what chrome plating plant entails and its financial feasibility. This project work is therefore aimed at:

a. Carrying out a design of 2000kg/day of a small-scale chrome electroplating plant that is friendly to both human life and environment.
b. To chrome plate wrist watch chains and other related materials.
c. Prepare a financial feasibility profile for the plant operation.

## 1.3 Scope of Design work

**i. Material and Energy balance**

**ii. Equipment Design, Type and Specification.**

**iii. Equipment Cost and Economy Analysis.**

**iv. Cost Analysis**

## 1.4 Limitations

Findings of previous researchers were adopted

## 1.5 Approach

The approaches used in meeting these aims are as follows:

1. Source for local and international material on chrome electroplating.
2. Produce a flow diagram.
3. Carrying out material balance of the plant using MathCAD.
4. Carrying out energy balance on the plant using MathCAD.
5. Costing the plant using HYSYS/

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Brief History

The early history of electroplating may be traced back to around 1800. A University Professor, Luigi Brugnatelli, is considered as the first person to apply electrodeposition process to electroplate gold. Brugnatelli was a friend of Allisandro Volta (after whom the electric unit "volt" has been named) who discovered the chemical principles that would make possible the development of electrical cells.

Volta's first actual demonstration of that was called. As a consequence of his development, Brugnatelli's early work using voltanic electricity enable him to experiment with various plating solutions.

By 1805 he had refined his process enough to plate a fine layer of gold over large silver metal objects. He wrote in a letter to the Belgian Journal of Physics and Chemistry (later reprinted in Britain), which reads:

"I have lately gilt in a complete manner two large silver metals, by bringing them into communication by means of a steel wire, with a negative pole of a voltanic pile, and keeping them one after the other immersed in amount of gold newly made and well saturated".(http://eleectrochem,2002).

Unfortunately for Brugnatelli, a disagreement or falling out with the French Academy of Science, the leading scientific body of Europe at the time, prevented Brugnatelli's work from being published in the scientific journals of his day. His work remained largely unknown outside of his native Italy except for a small group of associates. By 1839, however, group of scientist in Britain and Russia had independently devised metal deposition processes similar to those of Brugnatelli's for copper electroplating of printing press plates. By 1840, this discovery was adapted and refined by Henry and George Elkington of Birmingham, England for gold and silver plating.

Collaborating with their partner John Wright and using formulae developed by the later potassium cyanide plating baths, the Elkingtons were able to have the first viable patents for gold and silver electroplating issued on their name. From Great Britain the electroplating process for gold and silver quickly spread throughout the rest of Europe and later to United States. By the 1850's electroplating method of bright nickel, brass, tin, and zinc were commercialized and were applied for engineering and specific commercial purposes. In time, the industrial age and financial capital had expanded from Great Britain to the rest of the world. As a result, electrodepositing process expanding in scope and found more and more usage in the production of a variety of goods and services.

While this expansion was taking place, no significant scientific discoveries were made until the emergency of the electronic industry in the mid forties of the last century. The years from 1870 to 1940 were a quiet period as far as electroplating was concerned, significant only in gradual improvement in larger scale manufacturing processes, and reaction principles and plating bath formulae. During the later years of the forties, rediscovery of heavy gold plating for electronic components took place. In comparison to that, during the mid to later fifties the usage of new and more "user friendly" plating baths based on formulae were developed and introduced for large scale commercial use.(htt// electrochem 2002).

## 2.2 An Over View Of Electroplating

Electroplating is electrodeposition of metals on metals alloys and non-metals. The objects of electroplating are as follows: -

i. To charge the surface properties of metals and non-metals.
ii. To get improved appearance on basic metals.
iii. To obtain improved resistance to corrosion, tarnish, chemical attack and wear.

Electroplating is performed in a liquid solution called the "plating bath". The bath is a specially designed chemical solution that contains the desired metals (such as gold, copper, or nickel) dissolved in a form of submicroscopic metallic particles introduce in the bath to obtain smooth and bright deposits. The object that is to be plated is submerged into the electrolyte (plating bath). Place usually at the center of the bath, the object that is to be plated acts as the Cathode, and the Anode placed at the opposite edges of the plating tank. It is then connected to the power supply (rectifier) thus causing film deposit on both sides of the cathode. In the bath, the electric current is carried largely by the positively charged ions from the anode(s) toward the negatively charged cathode. This movement makes the metals ions in the bath, to migrate toward extra electrons, that are located at or near the cathodes surface outer layer. (Adegoke R. 2001).

## 2.3 Theory Of Electroplating

If we have a solution of metallic salt and a potential difference is applied to this salt solution by means of two electrodes, it is ionized thus the metals ions migrate to cathode and are deposited there. If the anode is of the same metal of which the salt in solution is the anode metals passing into the solution in ionic form reform the salt. In this way there is a continuous deposition of metal on the cathode. (Fowke D. G. 1962).

For $ZnC1_2$ solution in water it is ionized as given below

$ZnC1_2 \longrightarrow Zn^{2+} + 2C1$..........................................2.1

Zinc will go to cathode and will get deposited there. Cathode ion will go to anode metals and will react with it to from zinc chloride.

### 2.3.1 Principles of chrome electroplating

The article to be electroplated is immersed in a solution containing dissolved chrome metal and made the cathode by connecting it to the negative lead of a low voltage D.C. supply(rectifier). The circuit is completed by immersing the Anodes e.g. wrist watch, into the solution and these are connected to the positive lead. Dissolved chrome ions are driven by a D.C. electrical current of low voltage and high amperage. The ions gain electrons at the cathode, causing the wrist watches to be plated. The potential difference applied between anode and cathode which is usually between 2 and 16 volts D.C. is the driving force for the transfer of charge ions across the metal solution interfaces.(Joe I. et al 1979).

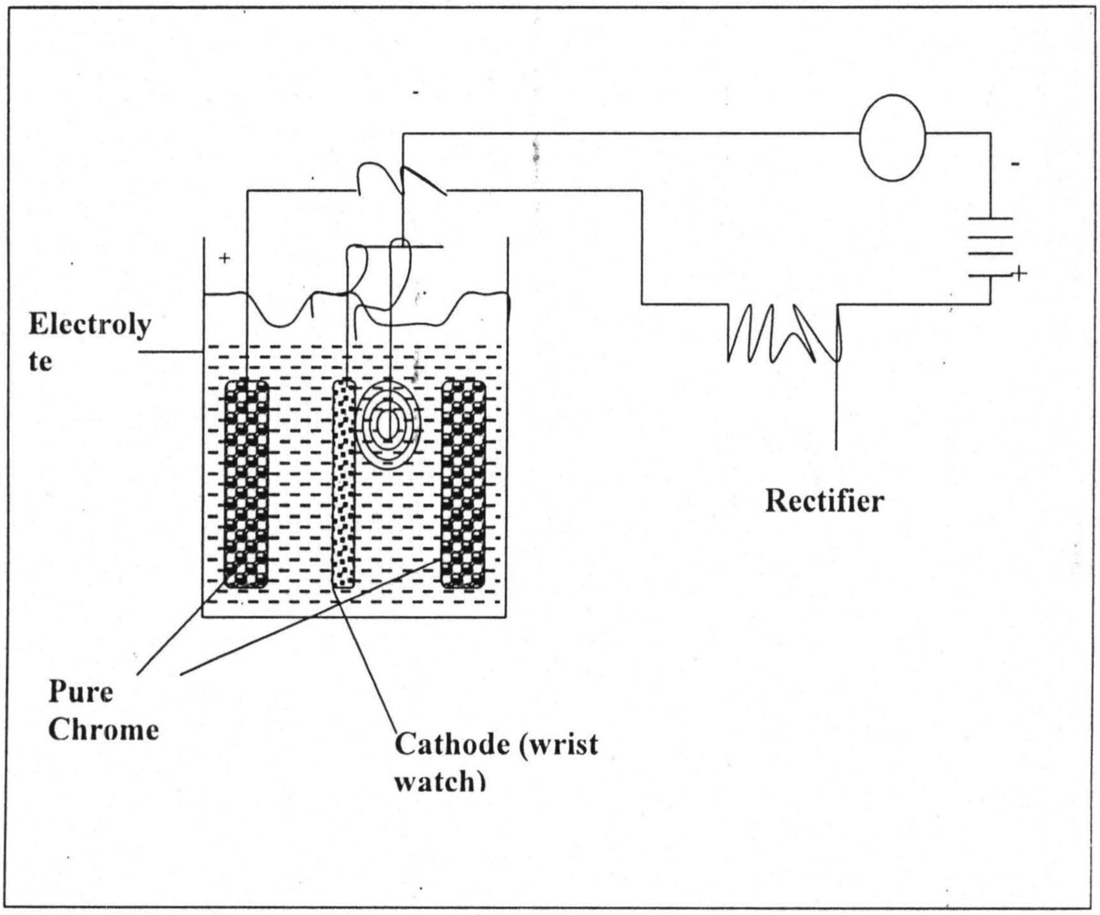


**Fig 2.1** **Schematic diagram of chrome electroplating of wrist watch chains**

### 2.3.2 Table 2.1 Electrochemical series

| | | |
|---|---|---|
| Manganese | -1.18 | ELECTRONEGATIVE METALS |
| Zinc | 0.76 | More cathodic potentials |
| Chromium | 0.56 | less noble potential |
| Iron (ferrous) | 0.44 | more noble potentials |
| Cadium | 0.40 | |
| Indium | 0.44 | ELETROPOSITIVE |

**METALS**

| | |
|---|---|
| Cobalt | 0.28 |
| Nickel | 0.25 |
| Tin (stannous) | 0.14 |
| Lead hydrogen | 0.12 |
| Copper (cupric) | +0.34 |
| Copper (cuprous) | +0.52 |
| Silver | +1.50 |
| Gold | +1.6 |

The electrochemical series lists the element in the order of their standard electrode potentials and to a degree, indicates the ease with which they ionize. As displacement series; usually a metals with a higher negative value will displace one lower in the series.

(M. M. Upper 1995). For example, if a piece of zinc is immersed in a solution of copper sulphate, copper is immediately deposited upon the zinc by chemical action without the assistance of applied current. Electropositive metals are deposited in preference to more electronegative metals.

### 2.3.3 Quantity of metal deposited

Faraday's laws of electrolysis guide quantity of metals deposited. According to these laws, the quantity deposited depends on the quantities of electricity passed per second and the chemical equivalent of these substances. (Joe L. et al 1979).

### 2.3.4 Rate of deposition

The minimum quantity 'of electricity require to deposit the equivalent weight in gramme of metals is 96500 coulombs. For instance, 96500 coulombs will discharge 1 mole of hydrogen; this quantity of electricity is called Faraday. One faraday is equal to one mole of electron since, the discharge of one mole of single charge ions involved the transfer of one mole of electron which contains Avogadro's number i.e. $6.02 \times 10^{23}$ of electrons

Thus: $W=ItA/ZF$..............................................................2.2

Where A is the atomic weight of metals deposited, ZF is a faraday constant. The relation between atomic weight and chemical equivalent is atomic weight=equivalent weight x valency.

The valency may be defined as being the number of atoms of hydrogen with which one atom of the element combines, or which it replaces. The figure is always a whole number, for example silver is monovalent and cadmium divalent, or in other words, have valencies of one and two respectively.

#### 2.3.4.1 electrolytes

The electrolyte is the medium that carries the current by means of ions. It is the ability of a solvent especially water to ionize substances, i.e. split them into two components which carries negative and positive charge that make electroplating possible.

### 2.3.5 Presence of ion and electrical conductance

When an electric field is applied to metals, according to the direction of applied field, electrons start moving from negatively charged end of metal to its positive end, this way current flows in metals. Thus, a substance conducts electricity when an electron or some other electrically charged particles like ion has to move through it. In all electrically conducting solution, the solute molecules give rise to two types of electrically charged particles or ions. The negatively charged types of ions are called anions and the positively charged ones are called cations.

### 2.3.6 Electrolysis

When a direct electric current is passed through an electrolyte (such as a molten salt or an aqueous solution of a salt, acid or base), chemical reactions take place at the contacts between the circuit and the solution. This process is called electrolysis. Electrolysis takes place in an electrolytic cell.

The components, which make contact with the electrolyte, are called electrodes. The electrode which is attached to the negative pole of the battery, and which supplies electrons to the electrolyte, is called cathode. Reduction takes place at the cathode.

The electrode which is attached to the positive pole of the battery, and which accepts electrons from the electrolyte is called the anode.

Various reactions take place at the electrodes during electrolysis. In general, reduction takes place at the cathode, and oxidation takes place at the anode. (Ollord et .al 1974).

### 2.3.7 Faraday's laws

In 1883, Michael Faraday explained the nature of electrolysis. Faraday's law is basic to the understanding of all electrolytic processes and may be summarized by the two following statements:

1. The amount of chemical change (metals deposited) that is produced by an electric current passing through solution in a cell is directly related to the quantity of electricity that flows.
2. The amount of substance liberated (i.e. metal deposited) by a given quantity of electricity is directly related to the gram equivalent weight of the substance. More specifically, 96,500-ampere seconds (or coulombs) reduce one gram equivalent of metals ions to metals atoms.

Faraday's law is used by the plater to determine the plating time and current required to deposit a specified weight (and considering the specific gravity and surface area, also a specified thickness) of a metal. Table 2.1 gives the electrochemical equivalents for some typically electroplated metals. The amount of time required to deposit a certain thickness at a specific current density can be calculated from this data. Q = IT ...................................2.3

where Q is the qty of electricity passed, I is current and T is time.(upper, 1995).

#### 2.3.7.1 Cathode efficiency

Faraday's law states that the total amount of chemical change at an electrode is directly related to the quantity of electricity (that is, the current flowing). In plating, however, the main concern is the quantity of metal deposited. Any other reactions, such as the liberation of hydrogen at the cathode, decrease the cathode efficiency. The average cathode efficiency percentage is determined by dividing the actual weight of metals deposited by the theoretical weight and then multiplying by 100. Change in solution composition and other external factors can improve cathode efficiencies to some degree; however the solution used is the major factor for determining efficiency.

#### 2.3.7.2 current distribution

Current density is the applied current divided by the total surface area of the work piece.

Table 2.2: Electrochemical Equivalent And Deposit Metal Weight

Calculated from Faraday's Law (Uppal, 1995)

| METAL | VALENCE | ATOMIC | SPECIFIC WEIGHT | | THICK COATING | WEIGHT IN 1 MIL (0z/ft$^2$) | WEIGHT GRAVITY |
|---|---|---|---|---|---|---|---|
| Cadmium (Cd) | 2 | 112.40 | 8.65 | | 0.074 (2.097) | 0.71 (8.659) | 9.73 (4.125) |
| Chromium (Cr) | 6 | 52.01 | 7.1 | | 0.011 (0.323) | 0.59 (7.146) | 51.8 (22.110) |
| Cobalt | 3 | | 7.1 | | 0.023 (0.646) | 059 (7.146) | 25.9 (11.060) |
| Copper (Cu) | 2 | 58.93 | 8.9 | | 0.039 (1.099) | 0.74 (8.719) | 19.0 (7.926) |
| Gold (Au) | | 1 | 63.54 | 8.96 | 0.084 (2.370) | 0.74 (8.935) | 8.84 (3.770) |
| Indium (In) | | 2 | 63.54 | 8.96 | 0.042 (1.186) | 0.74 (8.935) | 17.8 (7.540) |
| Iron (Fe) | 1 | 197.0 | 19.3 | 0.236 | (7.348)**1.47 (19.32)** | | 6.2 (2.631) |
| Lead (Pb) | | 3 | 197.0 | 19.3 | 0.079 (2.449)** | 1.47 (19.32)** | 18.6 (7.887) |
| Nicket (Ni) | | 3 | 114.82 | 7.31 | 0.045 (1.428)** | 0.56 (7.278)** | 12.0 (5.092) |
| Palladium (Pd) | 2 | 55.85 | 7.86 | 0.037 (1.042) | | 0.65 (7.868) | 17.9 (7.54) |
| Platinum (Pi) | 2 | 207.19 | 11.34 | 0.136 (3.865) | | 0.94 (11.350) | 6.9 (2.936) |
| Rhodium (Rh) | 2 | 58.71 | 8.90 | 0.039 (1.095) | | 0.74 (8.880) | 19.0 (8.044) |
| Silver (Ag) | | 2 | 106.4 | 12.0 | 0.064 (1.985)** | 0.86 (24.34)** | 13.5 (6.045) |
| Tin (Sn) | 4 | 195.09 | 21.41 | 0.058 (1.819)** | | 1.60** | 27.9 (11.77) |
| Zinc (Zn) | | 3 | 102.9 | 12.4 | 0.041 (1.280)** | 0.95 (8.29)** | 22.9 (9.73) |
| | 1 | 107.87 | 10.5 | 0.129 (4.042)** | | 0.79 (10.5)** | 62 (2.605) |
| | 2 | 118.69 | 7.30 | 0.078 (2.214) | | 0.61 (7.30) | 7.8 (3.30) |
| | 4 | 118.69 | 7.30 | 0.039 (1.106) | | 0.61 (7.30) | 15.6 (6.6040 |
| | 2 | 65.38 | 7.14 | 0.043 (1.219) | | 0.59 (7.15) | 14.3 (5.8630 |

*Assume 100% cathode efficiency for metal deposition

Current Density is usually measured in A/ft$^2$ or /dm$^2$. Depending on the system of units.

In Electroplating, current is concentrated at edges and points as well as in area closer to the opposite electrode (anode) and these latter areas consequently receive a greater deposit thickness (see fig 2.1). Normally, a part is plated to meet a minimum thickness specification. Since the excess metal thickness in high current density areas is usually not desired, the throwing power is defined as the electrolyte's ability to minimize the difference in deposit thickness between high and low current density areas.

Plating solution in which the cathode efficiency decreases with an increase in current density, generally displays better throwing power because less metal will be deposited in the less efficient high current density areas. Cyanide zinc is an example of such a bath. Chromium plating, on the other hand, becomes more efficient with an increase in current density and consequently has poor throwing power.

### 2.3.8 Introduction to basic electroplating process

In the simplest terms, plating transfers metals from positive Anode to the negative Cathode following Faraday's law.

Objects are immersed into chemical baths or vats to change their surface condition. Every plating is UNIQUE and the number of tanks and their chemical make up differ based on desired result. Metal slabs or balls (Anode) are placed in an electrolyte solution.

Dissolved metal ions are driven by a DC electrical current of low voltage and high amperage (Rectifier). During electroplating pure metal dissolving from the anode is deposited on the cathode by an electron gain – transfer method which can be represented thus: -

$$M^{+} + e^{-} \longrightarrow M \qquad 2.4$$

$$Cu^{+} + e^{-} \longrightarrow Cu \qquad 2.5$$

$$Ni^{2+} + 2e^{-} \longrightarrow Ni \qquad 2.6$$

$M^{+}$ represents metallic ion required $Cu^{+}$ and $Ni^{+}$ represent copper and nickel ions, and Cu and Ni represent deposit of copper and nickel.

Objects to be plated are placed on racks or perforated barrels and immersed in a series of chemical solutions to prepare them for plating. The objects to be plated must be "SURGICALLY" clean in order to be successfully plated.

## 2.4 Plating Process Line

Plating process can be divided into 3 basic units namely:-

i. Pre-treatment

ii. Plating

iii. Post-plating

### 2.4.1 Pre-treatment

Each material has its own treatment procedure. It is therefore necessary to know the nature of material or basis metal. Aluminum for example, cannot be cleaned in solutions formulated for cleaning steel. The nature of contamination and an incorrect identification may result in destruction or damage of the parts. Cleaning affects adhesion, appearance, composition and corrosion resistance of final deposit. The plater must therefore, be informed about pre-existing contamination. Such as inclusions in the base materials. Information supplied often help a customer – client relation resulting in successful metal finishing. The material is therefore, derusted or cleaned using necessary acid and depending on the base material. Acids used are sulfuric, hydrochloric, nitric or a combination of these. This removes rust, scale or smuts.

Depending on the material and configuration, it is polished or buffed/mopped. After proper rinsing, it is transferred to the degreaser tank where oils and greases are removed from the surface, then rinsed and ready for plating. Sandpapering is another manual method of polishing the surface of materials. These pre-treatment processes of pickling and degreasing can also be achieved by electrolysis called Electrolytic degreasing or pickling. The composition of materials or chemical used is based on the material being cleaned and it is unique for each base material. It is commonly accepted and often quoted by electroplaters that can make a poor coating performed with excellent pretreatment, but one cannot make an excellent coating perform with poor pre-treatment. Surface pretreatment by chemical and or mechanical means is important not only in the case of preparations for electroplating but is also required in preparation for painting. In either of these, methods are designed to ensure good adhesion of the coating the processes include solvent degreasing, alkali cleaning and acid dipping which are described below (Adegoke R. 2001)

#### 2.4.1.1 polishing

This is mechanical cleaning of the substrate to remove surface defects (scratches, etc) by polishing and buffing.

#### 2.4.1.2 swirling

This is a process of rinsing the pretreated articles in cold distilled water in order to avoid contamination of the electrolyte.

#### 2.4.1.3 solution heating

For many of the processes associated with electroplating it is necessary to heat the solution. The available methods of heating include steam, hot water, gas and electricity.

#### 2.4.1.4 solution cooling

A number of processes in which heavy current densities are employed or are operate at fairly low temperature may required cooling to prevent rise in solution. The cooling media employed are well water, recirculated water chilled water and brine.

### 2.4.2 Engineering application

Plating for appearance (decorative plating).For Decorative Plating Metals Used are gold, Nickel, brass/radius and copper. For special decorative effects tin, zinc, cadmium, lead, palladium and platinum, etc are also used.

#### 2.4.2.1 plating for protection

Steel must be protected from rusting chemical attack and so it is electroplated. Protective metals applied are zinc, cadmium and tin, etc. where both protection and good appearance are desired steel is given successive coating layers of copper, nickel and chromium. Copper and Nickel provide protection against rusting and chemical attack. The chromium plate above all plate, gives clean metal appearance. Nickel dulls by tarnish when exposed to atmosphere and chromium does not.

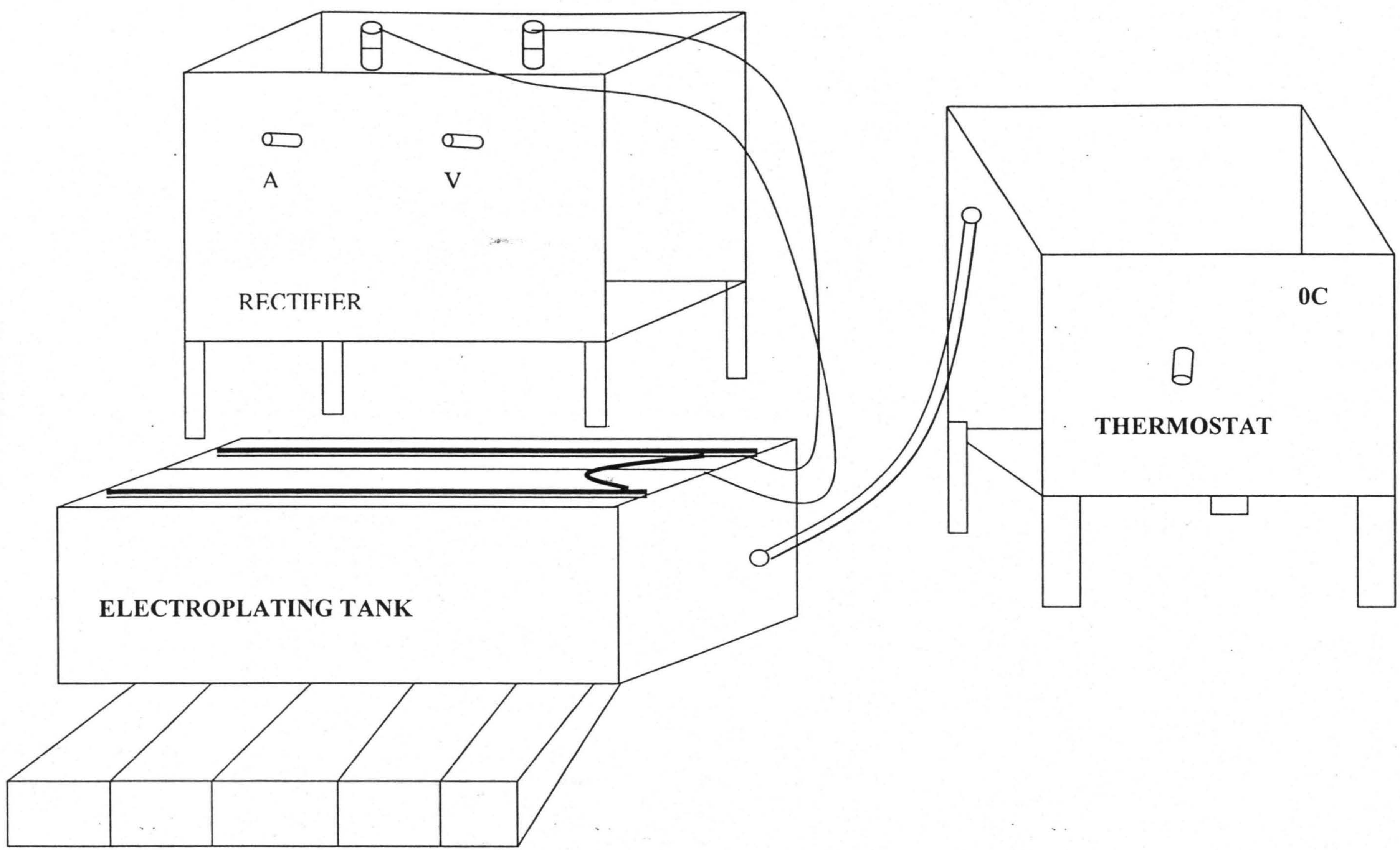


Fig. 2.2: Schematic Diagram of Electroplating Equipments.

### 2.4.2.2 plating bath constituent

Although it is often possible to electrodeposit metal from a simple solution of a metallic salt alone, it is rarely a practicable commercial process. Modern plating baths are somewhat complex and may contain as many as six or eight constituents, all which play an important part. Chlorides, for example, are added to nickel sulphate solutions to promote anode dissolution. Boric acid acts as 'buffer' and maintain $p^H$ equilibrium Colloids to refine the texture of the deposit, other metals and organic Brightnener to give luster, and anti-pitting agent to prevent 'pin-holing' due to hydrogen bubbles and Leveler allow even deposit on irregular object.

*Operating Condition*

For optimum plating some parameters such as pH, temperature, current etc. $P^H$ should be in range of 3-4, temperature from room temperature to $60^0$c depending on anode metal and a battery or rectifier to supply low voltage of 2-8v.

### 2.4.2.3 solution agitation

With many processes it is necessary to keep the solution well mixed in order to prevent local variation in concentration. Unless the solution is agitated there will be a reduction in the metal content of the solution surrounding the cathode, which will result in the production of a rough or "burnt" deposit.

### 2.4.2.4 electroforming

By electro-forming is meant formation of articles by electro-deposition of metal. In electroforming the layer of electrodeposited metal is quite thick. Automobile, aircraft, radio, adar and ammunition industries use parts made entirely by electroplating. Mandrels are used for depositing metals over it. The electro-form is removed without damage from its mandrel after obtaining the desired thickness

#### 2.4.2.5 electroless plating

Electroless plating is a process of plating by chemical reduction. For example, nickel can be plated by the addition of a reducing agent, such as sodium hypophosphate, a solution, to nickel salts. The nickel ion is reduced to the metals, which under proper conditions is deposited as a coherent and adhesive plate rather than simple as a powder throughout the solution. It is used, where electroplating is impossible, example plating the insides of pipes.

#### 2.4.2.6 displacement placing

Displacement plating occurs when the metal deposited is nobler than the substrate, and the substrate dissolves. The reaction ceases when the substrate is completely covered by a pore-free deposit.

### 2.4.3 Electroplating equipment

Electroplating may be divided into barrel, rack and strip continuous (reel-to-reel) plating. Barrel plating is used for plating smaller parts in some electrolytes. Rack plating is used for larger parts and for chromium plating. (Adegoke R. 2001).

#### 2.4.3.1 barrel plating

Barrel plating is usually performed in either horizontal or oblique barrels constructed of polypropylene or other suitable plastics. The walls of the barrels are perforated, and the barrel is plated during plating. Electrical contact is obtained via oxible conductor known as a dangler. Some barrels are not perforated, but contain the plating solution and an anode.

Mixed leads are not recommended in barrel plating unless the plater is not too concerned about plating thickness and distribution, or unless the parts require just a flash plate. Longer or larger parts in the mixture will usually receive the greater deposit and buildup on high current density areas will be increased. In addition, sorting the parts after plating is time consuming.

Larger pieces weighing more than 1 lb (0.5kg) and containing sharp edges should not be barrel plated because they will be damaged in the tumbling action of the barrel and the barrel itself may be damaged. Flat and lightweight parts should not be barrel plated because they tend to stick together and do not tumble properly. Wire forms are more easily rack plated than barrel plated.

#### 2.4.3.2 rack plating

Rack plating is usually employed in the processing of parts that are too heavy, too large or too complex in shape to be barrel plated. The parts can vary from a small knob that is to be nickel-chromium plated, to a large roller, weighing a ton or more for hard chromium plating. Rack plating is used with manual, semiautomatic and fully automatic machines.

One of the most important considerations in designing a plating rack is that the rack must have adequate current carrying capacity. Racks are usually constructed of copper because of its high current carrying capacity, ease of fabrication, and relatively high strength. After fabrication, the racks are covered with an inert insulating material to protect them and prevent metal plating on them, and to keep the plating solutions from becoming contaminated. Parts are hung or dipped to the insulated rack. The contract to the part should be made on a non critical area of the part such as the back, inside, or through a hole.

Another important factor in designing a plating rack is the position of the work on the rack. It must be positioned to obtain the most uniform current distribution possible and to prevent entrapment of air or gas in holes or pockets, which will restrict deposition of metal in these areas, resulting in non uniform thicknesses. The position of the plating rack in the processing track is also important for obtaining as uniform a plating deposit as possible. If the work is located too close to the anodes, excessive buildup of plating thicknesses, known as burning occurs in the high current density areas of the part. The parts are usually tracked so that they tend to shield the edges of adjoining parts, and are frequently racked back to back to increase the capacity of the rack and at the same time reduce the deposition of the metal in non critical areas. If a particular part has a deep recess, an auxiliary anode can be used to ensure the deposition of the required thickness in the recessed area.

#### 2.4.3.3 strip plating

Strip plating is a plating process whereby the work piece is a continuous strip being pulled through each process station (tank) by a take-up null. Wire and lead frames are commonly strip plated with tin,

tin lead, nickel, and precious metals. Steel sheet may be continuously zinc, tin, chromium, copper, brass, nickel iron or nickel zinc plated. The strip may be plated at specific points as it goes through the cycle, such selective plating is very common with precious metals.

### 2.4.4 Process tank

Tanks may be fabricated of hot rolled low-carbon steel and protected with a rubber or other suitable liner rated to withstand the bath's corrosive action and to keep the steel tank from contaminating the solution. Polypropylene and other high-strength plastics may be used for smaller tanks. Alkaline-cleaner tanks and some plating solutions do not require liners. Rinse tanks may be equipped with spray nozzles and the water counter-flowed back into the previous rinse tank to reduce water usage.

### 2.4.5 Temperature control

Temperature control is important in most plating solutions. Some require cooling heating or both. For cooling, cold water piped through reeling coils of suitable construction may be sufficient or heaters dangers may be required. Heat may be provided by steam through heating coils or by electric immersion heaters. Instruments are commonly used to automatically control plating bath temperatures.

## 2.5 Power Supplies

Alternating current is converted to direct current by means of a rectifier or motor generator set, with rectifiers being preferred. Regulated and unregulated power supplies are available that provide filtered direct current with good reliability. A regulated power supply may be of the silicon-controlled or saturable reactor type. These power supplies maintain constant current or voltage under varied loads and are generally used in large operations. The more common unregulated types include the tap switch and manual powerstat Both air and liquid cooled rectifiers are available. The major advantage of the more expensive liquid-cooled type is that the unit is completely sealed so that rectifier components are not exposed to the atmosphere, which may be very corrosive in a plating shop. As a general rule, a rectifier should be operated at a minimum of 50% of its maximum rated output current to provide low-nipple direct current.

### 2.5.1 Anodes

The anode carries a positive charge and completes the electrolytic circuit. In most cases, the anode is fabricated of the metal being plated and serves to replenish the solution with metal ions. However, insoluble (metal) anodes are used in some applications, such as chromium plating and with precious metals. Anodes may be fabricated metal slabs or balls, or chips contained in an inert basket. The metallurgical structure and composition are important considerations for proper anode performance. Titanium is often used for the baskets because of its inert oxide film.

Most modern nickel plating installation use nickel chips in titanium backsets, shut, or cathode-deposited shapes. Zinc is usually plated from ball anodes, and copper from ball or bar anodes.

### 2.5.2 Automated control

Electroplating is subject to a wide variety of variables that frequently change. Automatic controllers add stability and consistency to the operation and should be used wherever possible. Automatic ampere hour feeders monitor the plating time and may be used to approximate thickness as well as automatically feed addition agents. Solutions pH may be controlled automatically with a relatively inexpensive piece of equipment, such control is especially useful in electrolytes where the pH tends to rise due to generation of the hydroxyl ion, such as in nickel and chloride zinc solutions. Rinse waters may be controlled by automatic conductivity meters connected to solenoid valves, these ensure good rinsing with reduced water consumption.

## 2.6 Substrate Preparation

In preparing the substrate for plating, it is important to properly select the correct pretreatment method. Pretreatment influences the adhesion, appearance, composition and corrosion resistance of the deposit.

Some of the factors that should be considered when selecting the pretreatment cycle are type of substrate, nature of the contamination, how the part is used, and part geometry. Each basis metal may require a different pretreatment. Aluminum, for example, cannot be properly processed in solutions formulated for steel. Even variations in alloy may cause the finisher to change pretreatment. (Adegoke R. 2001)

Typical Processing Cycles for Substrate Preparation for Electroplating.

I(a) Low-carbon steel-oily, not rusted

1. Soak clean, $180^0F$ ($82^oC$), 2-3 minutes.
2. Cold water rinse, 30 seconds.
3. Anodic electro clean, $180^oF$ ($82^oC$).
4. Rinse
5. Acid dip, 30 seconds
6. Cold water rinse, 30 seconds
7. Plate

I(b) Low-carbon steel - rusted

1. Soak clean, ($180^oC$), 2-3 minutes.
2. Cold water rinse
3. Periodic reverse electroclean, room temperature, 30-60 $A/H^2$ (3.2 & $4A/din^2$).
4. Plate.

II. Stainless steel and high-nickel alloys.

1. Soaked clean, 1-5 minutes
2. Cold water rinse, 30 seconds
3. Periodic reverse electroclean (10 seconds anodic, 7 seconds cathodic), room temperature, 30-60 $A/H^2$ (3.2-6.4 $A/dm^2$). 3-5 minutes
4. Cold water rinse, 30 seconds.
5. Hydrochloric acid dip. 30% by volume, room temperature, one minute.

6. Wood's nickel strike, 20-60 A/H$^2$ (2.2-6.4 A/dm$^2$). 1-3 minutes
7. Cold water rinse, 30 seconds
8. Plate.

III Cast Iron

1. Soak clean, 103 minutes
2. Cold water rinse.
3. Periodic reverse electro clean (7 seconds anodic, 5 seconds cathodic), 5 minutes
4. Warm water rinse.
5. Cold water rinse
6. Hydrochloric acid, 30% by volume, room temperature in seconds.
7. Cold water rinse
8. Plate

IV. Cast iron alternate method

1. Cathodic electro clean, 1-3 minutes
2. Warm water rinse
3. Cold water rinse
4. Hydrochloric acid dip. 10% by volume, 5-10 seconds
5. Cold water rinse
6. Plate.

V. Wrought aluminum alloys most alloys

1. Soak clean, nonetch cleaner, 1-1 minute
2. Cold water rinse
3. Alkaline etch clean

4. Cold water rinse

5. Desmut in a solution containing 50% by volume nitric acid, 25% by volume sulfuric acid, 25% by volume water, and 1 lb/gal (120 g/l) fluoride salt at room temperature for 20-45 seconds.

6. Cold water rinse.

7. Zancate, 5-30 seconds.

8. Rinse.

9. Plate, preferably first in a cyanide copper strike.

VI. Wrought aluminium alloys 5000 and 6000 series

1. Soak clean, nonetch cleaner, 1-3 minutes.

2. Cold water rinse.

3. Acid etch, 160°F (70°C) 1-3 minutes.

4. Cold water rinse.

5. Nitric acid, 50% by volume, room temperature, 30 seconds.

6. Cold water rinse.

7. Zincate, 5-30 seconds.

8. Cold water rinse.

9. Plate, preferably first in a cyanide copper strike.

VII. Sand or die-cast aluminium alloys

1. Nonetch soak clan, 1-2 minutes

2. Cold water rinse

3. Alkaline etch clean.

4. Cold water rinse

5. Desmut in a solution containing 50% by volume nitric acid, 25% by volume sulfuric acid, 25% by volume water, and 1 lb/gal (120 g/l) fluoride salt at room temperature for 20-45 seconds.

6. Cold water rinse

7. Zincate, 5-30 seconds

8. Rinse

10. Plate, preferably first in a cyanide copper strike.

VIII. Copper and Copper alloys

1. Soak clean, 3-5 minutes

2. Cold water rinse

3. Electro clean (cathodic or anodic depending on formulation), 30-90 seconds.

4. Cold water rinse.

5. Acid dip, 10% sulfuric acid or dry acid salt, 30 seconds.

6. Cold water rinse.

7. Plate.

IX Zinc-based die castings

1. Soak clean, 3-5 minutes.

2. Cold water rinse.

3. Spray alkaline clean, 30-60 seconds.

4. Cold water rinse.

5. Anodic electro clean, 10-25 $A/H^2$ ($1.1$-$2.7/dm^2$), 25-50 seconds.

6. Cold water rinse.

7. Acid dip. 30 seconds

8. Rinse

9. Plate, preferably first in a cyanide copper strike.

### 2.6.1 Product finishing

- The acid dip may be 10% sulfuric acid at 122.180°F (50 ox/gal (120 g/l) dry acid salt at 77-140°F (25-60°C).
- The two most widely used processes for the pretreatment of aluminium alloys before electroplating are the zincate process and the stannate process.
- On difficult to plate alloys, use double zincate with an intermediate nitric acid dip to improve deposit adhesion.
- Acid dip may be 1% hydrofluoric acid, 1% fluoboric acid or a dry acid salt.

Table 2.3: American Society for Testing and Materials Recommended Policies for Preparation of Substrates to be Electroplated.

(Fowke, 1962)

| Metal Substrate | Standard Number |
|---|---|
| Low-carbon steel | B.183 |
| High-carbon steel | B.242 |
| Zinc alloy disc castings | B.252 |
| Aluminium alloys | B.253 |
| Stainless steel | B.254 |
| Copper and copper-based alloys | B.281 |
| Lead and lead alloys | B.319 |
| Iron castings | B.320 |
| Nickel | B.343 |
| Magnesium and magnesium alloys | B.480 |
| Titanium and titanium alloys | B.481 |
| Tungsten and Tungsten alloys | B.482 |
| Nickel alloys | B.558 |

Several stages are generally required to provide adequate cleaning of the substrate and activation pre-cleaning, intermediate alkaline cleaning and electro cleaning. Pre-cleaning is designed to remove a large excess of soil, especially deposits of butting compound or grease. It is also useful in reducing the viscosity of waxes and heavy oils to enable later cleaning stages to be more effective, or to surround fingerprints and dry dust with an oily matrix to facilitate removal by alkaline cleaners.

Intermediate alkaline cleaning removes solvent residues and residual soil that has been softened or conditioned by precleaning. Spray or soak alkaline cleaning may also be used as a precleaning stage, followed by additional alkaline cleaning, if the soil and metal lend themselves to this treatment. Electro-cleaning is soak cleaning with agitation provided by the upward movement of bubbles of hydrogen or oxygen formed by the electrolytic decomposition of water in the solution.

Some parts cannot be etched because surface finish must be maintained, just as part used in structural applications should not be subjected to pretreatments that may cause hydrogen embrittlement. The design of the work may require special handling and surface treatment. For example, a large part may require external manual finishing or parts with deep recesses or blind holes may require special handling and drainage techniques to avoid excessive drag-out and cross-contamination.

### 2.6.2 Operating parameters

The four main concerns in electroplating are temperature, pH, and chemistry of the plating bath as well as current density. Most plating solutions have an optimum temperature range for producing best results, and close control of temperature is important for proper current control. As the temperature of the solution increases, conductivity increases, and therefore the current increase for a fixed applied voltage, the converse is also true. Over plating or under plating occurs if the temperature is not maintained properly.

The pH control of plating solutions is necessary to maintain the acidity or alkalinity that has been determined to produce the best results. Appearance, stress, leveling, electrode efficiency and coating hardness are influenced by the pH of the solution. Current density is a very important variable in all electroplating operations. The character of the deposit, its distribution, the current efficiency, and perhaps whether a deposit forms at all may depend on the current density employed.

## 2.7 Comparison of product with its competitors

The competitors of chrome are: Nickel, zinc, gold, tin, and copper. Amount all the competitors chrome stands Out as the most durable of all and that which give the best satisfaction on Metal because of its shinning and wear resistance properties any chrome Plated materials do not loose their appearance and never break, these make It has higher quality than its competitors e.g. Chrome plated jewelries, Automobile, motorcycle and bicycle part last longer and regains its shining ability.

## 2.8 Quality Control Aspect of Electroplating Technology

Since the main purpose of electroplating is to get a rust-free, lustrous finish on the object, apart from other engineering application of increasing surface thickness, a deviation from this target, is a deviation from excreted result.

Quality control therefore in planting starts from the beginning to the end to get customer fully satisfying and satisfied.

Material to be plated must be specified since some finishes cannot be applied to certain materials. Metals fabricators and spare parts manufactures must clearly understand the coating needed rather than what they just thought they wanted.

While designers are expected to know what the conditions the plated product will survive, engineers must also know and understand coating's limitation.

Since each of the coating; zinc, nickel, copper, chrome has unique properties with respect to use and environment, selection of a single coating or a combination for a given application is never a matter of chance, aesthetic nature or serious economic of financial consideration. Expected coating and selection require specialized knowledge as to use, application and shelf life.

To become a better customer and quality control conscious, the quotation that "the requirement of a supplier must be established long before he produces any material", by W Edwards Denning, out of the Crisis of quality control theorem must be followed.

Therefore, nickel plating is the best for food equipment/ material like oven trays, and the like, while chrome is acceptable for car bumpers.(Ollord, E.A. 1974)

In effect, quality specification and control is to make both plater and client a synergy of successful ventures. From the start therefore fabricators, engineers and benefactors of plating process will not choose high carbon steel, instead of low carbon steel, defective, pin-holed and scratched, pitted, scrapped metal, under the guise or disguise of "no-fund" will be a penny wise, pound foolish situation.

From quality assurance stand point, platers will use his science of materials knowledge to help client in the right choice of materials, dimensions, tolerance, and even in designing for improved palatability. Product starts receiving good control and specification from inception or conceptualization stage.

Plating quality is also controlled if the following salient point and actions are taken from the shop floor. Plating solutions are given preventive maintenance approach which makes plating to be cost effective, efficient, interesting and satisfying. Platers therefore tend towards zero control commandments to make plating profitable.

Tanks or Vats must be designed to specification with regard to lining. Most of the plating tanks are lined with polypropylene, rubber or fibre-glass materials with no outlet taps or valves.

There is need to periodically filter the solutions. Nickel solutions are regularly filtered or ultra filtered.

Air agitation and cathode rod movement are needed plating solutions like nickel to reduce hydrogen-oxygen embrittlement (covering) on the plated objects.

Some good plating will not take place unless at temperature above room temperature. Nickel plating and some cleaning (degreasing) processes are few examples.

During plating, operation conditions are religiously adhered to. The current voltage, current density. pH, temperature are closely monitored for good plating to take place.

Some shop floor problems reduced to the bearest minimum as a result of these quality control measures.

Constant addition (little) as the plating is done daily. Such daily addition of individual or formulated "propriety" salt are expected to keep platers out of trouble. Large addition of salt or additives like levelers, brighter, conducting salts are regarded in modern plating as poisonous additions.

Bus bars, anodes must be periodically wire brushed, cleaned and kept in a conducting state.

Plating time (duration) must be strictly adhered to, to avoid burning and uneconomical coating. (Lesile,1986)

Equipment must be given periodic servicing and on-line daily, weekly, and monthly maintenance.

To maintain uniform coating, chemical composition of the electrolyte's as well as electrochemistry of the bath must be maintained.

This is not least exhausted but proper adherence to these as well as good house keeping will lead to trouble-free plating.

## 2.9 Health and Safety Aspect

The very nature of Electroplating processes, products, and by products makes health and safety a primary consideration in setting up an electroplating plant of this nature. Most important fundamental principal is that the safe handling of chemicals, operation of plant and processes is a management responsibility.(Lesile,W.Flott 1986)

Proper facilities, and wares provided must be used judiciously, appropriately and correctly. General precautions must be adhered to properly.

In addition to the wok shop and laboratory design which must comply with health and safety regulation and requirements, a well organized medical service plays an important role in having efficient and effective workforce. A periodic medical examination is necessary in order to maintain the general good health of employees.(Adegoke R.,2002)

Enforcement of safety rules and regulations, mixing, and preparation technique of plating solutions, proper operating technique of machines and laboratory equipments and safe handling of chemical and waste are all necessary for a productive and profitable plating shop.

In addition, employees should be encouraged to be interested, alert and observing. Demonstration of respect for safety measures against fire, explosion and other hazards does much to endanger the same attitude amongst those who later carry out electroplating processes as operatives.

Chemical used in electroplating are toxic, carcinogenic and harmful. Cyanides must be stored away from acids and careful storage technique must be emphasized.

It is necessary that one of the supervisors should be trained in first aid or as a safety officer and there is a need to train all workers on matters of health and safety.

## 2.10 Important Uses and Application of Electroplating Technology

Modern living conveniences and transportation equipment are made up of coated iron since iron is corrosive to air, moisture and fumes. With the remarkable increase of iron products, in recent years, the output of plated products is also increasing tremendously. As electroplating technique has made great advances, the importance, uses and application of electroplating in industries has widely come to be recognized.

Although plating is applied commercially to copper, brass, nickel-brass, zinc, zinc-base die-casting the greatest proportion is applied to steel.

A small amount of plating is applied to non metals such as plastics, but these must first be coated with some electrically conductive materials. The plating materials are tin, zinc, silver. Nickel and chromium.

However, except in connection with production of tin plate for can industry most plating is done with nickel and chromium. Nickel plating is widely used for corrosion resistance, but since it does not retain its luster for long, it has been replaced to a great extent by chromium. However, chrome is seldom used alone and most chrome plating is a three layer process consisting first of a layer of copper, then one of nickel and finally, a thin layer of chrome 0.0001 inch or 0.00025cm.

The purpose of electroplating is to protect, beautify and also used to build up worn parts to larger dimension. It is also to coat the face of cutting tools to reduce friction and wear and to resist wear on the surface or gauges.

Generally, plating is used to save resources as new functions are added to base materials. This can enhance higher conductivity, improve resistance to corrosion economic and artistic losses. In printed and integrated circuit which is a semi conductor, the chip is surface treated and gold plated on its lead frame.

The terminal of lead frame is always tin plated or solder plated. Plating is basic industry that supports various other industries. It is not gainsaying or an exaggeration to say that modern industries cannot exist or thrive without plating techniques. The main uses and applications of plating with examples are shown in tables (A) and (B).

**Table 2.4A Main Uses Of Plating**

(Fowke D .G 1986)

| PURPOSE | AIM | EXAMPLE OF PLATING | EXAMPLES OF PLATED PRODUCT |
|---|---|---|---|
| DECORATION | Beautify the surface and prevent rust at the same time | Gold, silver, copper, nickel, chromium, zinc (chromate treated) | Bicycles, automobiles, motorbikes, sewing machines, clocks and watches, electric irons, tosters, personal accessories |
| Corrosion | Prevent rust and discoloration. To serve as undercoat plating for paints | Zinc, cadmium, lead (chromate treated) thodium | Electrical appliances, bolts, nuts, washers |
| Surface Hardening | Harden the surface to prevent abrasion and enhance duration | Chromium nickel | Chafing parts of energies, various types of rollers |
| Easing friction | Improve fitting between surface and prevent scratches and disfigurement | Tin | Pistons, piston rings, engine cylinders |
| Bonding | Ensure close adhesion to prevent exfoliation | Brass | Parts of engines |
| Preventing cementation and nitriding | Prevent hardening | Copper, tin | Various machine tools |
| Building up | Match measurements | Chromium nickel, copper | Same as above |
| Reproducing the surface | Reproduce the same surface (known as electroforming) | Copper, nickel | Matrices for gramophone records |
| Coloring | After plating, coloration in preferred colors is carried out (sometimes referred to as bronzing) | Copper, brass, zinc, silver, gold, (iron), (stainless steel), (aluminum) | Personal accessories, furniture. |

**Table 2.4B: Classification Of Main Electronic And Application Examples:**

| CLASSIFICATION | EXAMPLES | EXAMPLES OF APPLICATION |
|---|---|---|
| Super-Conductive Materials | Lead, niobium tantalum | General, motor, magnetic levitation train |
| Photoelectron material | Quartz, glass, silicon, germanium, indium-gallium arsenic | Fiber optic communications, light measurement video disc computer terminal |
| Conducive material | Copper, aluminum silver gold sodium | Wire print circuit terminal |
| Semiconductor material | Silicon, germanium selenium, gallium arsenic, cadmium sulfide | Transistor, diode, electronic copying machine, IC |
| Insulating material | Nitrogen, freon, mica, ceramics, glass, bakelite, silicon oil | Insulator, condenser, transformer, breaker |
| Resistance material | Nichrome, tantalum, manganin, constantan graphite | Resistor, potentiometer, electric furnace, electric heater, transducer |
| Magnetic core material | Pure iron, perm alloy, silicon steel | Transformer, motor, generator, relay. |
| Magnet material | KS steel, MK steel, fernate, alnico | Magnetic head, speaker, cartridge |
| Temperature measuring material | Platinum, nickel, platinium rhodium | Thermocouple, temperature regulator, temperature measurement |
| Joining material | Solder, silver solder, aluminum solder | Wining of parts, assembling of parts, joining of wires |
| Fuse material | Tin lead, silver , brass | Power fuse, temperature fuse |
| Contact material | Gold silver, platinum, tungsten | Switch, jack, relay, switchboard |
| Electron tube material | Tungsten, molybdenum, nickel | Vacuum tube, discharge .tube, X-ray tube. |

## 2.11 General Description Of Electrodepositing Process

**The main points of electrophoresis painting are:**

- **It is a process by dipping: It needs a container or bath of paint the volume of which being large enough to completely immerse the part to be coated: from few liters in a laboratory for painting small** panels, the volume may reach several tens of m3 for cap-parts (roof, bonnet) till several hundred m3 for cars.(PAN,1997)

Dipping into the paint tank is proceeded automatically either vertical and discontinuous dip, or continuously by the means of a conveyor which carries the car-bodies into the tank inlet, each one after the other and get it out after needed time at the outlet of the tank. That way the paint is progressively consumed during the dipping of parts; the consumption has to be compensated by addition of equivalent quantity and quality of fresh product to maintain constant paint quality all time along its exploitation.

- It is a process involving electricity: A direct current generator is necessary, the negative terminal of which is connected to the part to be painted (cathode) and positive one to anodes+.

### 2.11.1 Electrochemical Reactions

Electro deposition process may occur if:

- The paint to be coated is electrically conductive.
- Its viscosity is low enough to let the part to be printed completely submerged.
- The part itself is metallic.
- Another metallic contrary electrode is also submerged in the paint bath.
- The part to be painted and the contrary-electrode are connected to a direct current generator

The hereunder plan represents an electrodeposition installation:

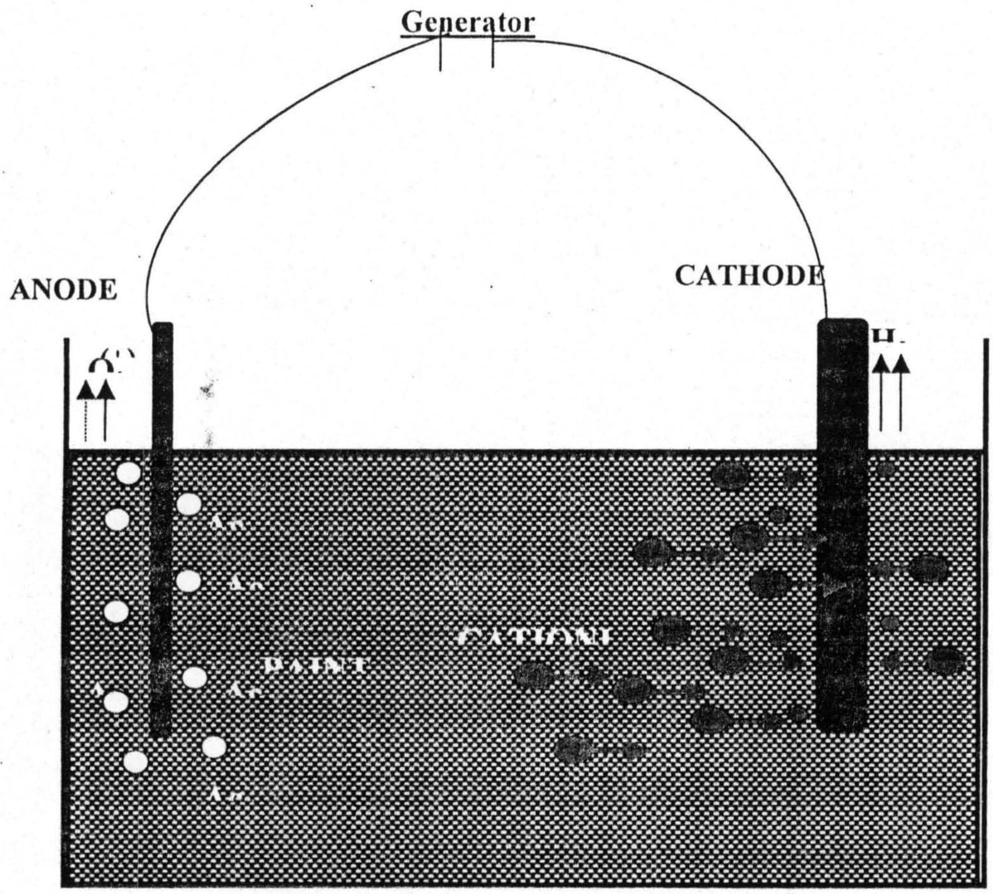


Fig. 2.3: **Electro deposition of Paints**

Paint is in fact polyelectrolyte in water and behaves, as it is when electrical current passes through. When a voltage input is applied between anode and cathode previously immerged in electrolytes aqueous solution (Paint), electrical field is created from electrons motion.(PAN, 1997)

The electrolyte milieu is here the ionized polymer previously described: Ac; water electrolysis takes place together with ions migration (it is the actual electrophoresis) towards the electrodes: anions Ac to the anode, cations H+ to the cathode.

Reactions at the electrodes occur as soon as a potential difference is applied on terminals of current generator; there are 3 types.

## 1. Water Electrolysis

At the anode: $2H_2O \xrightarrow{(1)} O2 + 4H^+ + 4e^-$

At the cathode: $4H_2O + \xrightarrow{4e^{-}(2)} 2H2 + 4OH^-$

Obviously Oxygen gassing is produced at the anode, Hydrogen gassing, twice the volume of previous one, at the cathode. Reaction (1) is an oxidation with acidification at the interface anode-paint: reaction (2) is a reduction with alkalinisation at the interface paint-cathode. Both are essential to realize the second type of reactions:

## 2. Electrodeposition

At the anode: $4Ac^- + \xrightarrow[4H^+]{(2)} 4AcH$

$+$ (3)

At the cathode $+ \; OH^- \qquad + \; H_2O$

The main side reaction is promoted by the acid created in the anode neigourgh; if this last is made of corrodable material; it is oxidized and constituent metal dissolves. Dissolution promotes metallic cations going to the cathode:

(2)

At the anode: Me(metal) $\longrightarrow$ $Me^{++} + 2e^-$

At the cathode: $Me^{++} + 2e^- \longrightarrow Me$

From all those reactions follows that:

a. At the same time the paint lays over the steel is produced hydrogen gas form. If this gassing becomes excessive, deposition is obstructed; then too powerful electrical field privileges water electrolysis to the detriment of paint electrodeposition, rupture is occurring.

b. If the resin is highly ionized, rupture becomes worse because NH+ groups on a given molecule need identical number of OH- groups.

To create OH-, same number of voltage electrons is consumed and proportional quantity of hydrogen escapes.

Moreover it is not necessary to neutralize all amine groups 'n' in NH+' to make the cationic polymer water soluble; minimum neutralization reaction is related to the polymer molecular weight.

Excess of electricity consumption (electron volt 'e' = 96.500 Coulombs) + risk of rupture even with low powerful electrical field + enough solubility in water are the 3 reasons why cationic binder is always under-neutralized: neutralization reaction (number of equivalents of Ac-/number of equivalent of N) is generally managed between 40 and 60%. Control of this ratio is mentioned.(PAN,1997)

There is a strong risk of anode corrosion, the reason why it is necessary to use non-corrodable material for anode, like graphite stainless steel.

Hence depositing of paint is the result of 4 connected events:

- Water Electrolysis
- Cations migration;is electrophoresis.
- Polymer coagulation on the cathode-liquid interface; is electrodeposition.
- Water shrinkage from that interface by osmotic pressure to let an homogeneous coat of coagulated polymer be deposited; is electrolysis.

## 2.12 Description Of The Product

Chrome is a blue white metal that takes on a high polish. It is hard, malleable, ductile, somewhat ferromagnetic and a fair conductor of electricity and heat.

The atomic mass of natural chrome is 24 and mass no of 51.996g, a member of the block and a group II of the periodic table of elements. It has melting point Of 187$^0$C and boiling point of 2672$^0$C. Chrome is of moderate strength and Hardness, when viewed as very small particles chrome appears black as do Metals in general.

Chrome has the following physical properties tensile strength of $600N/mm^2$, Proof stress of 132 $N/mm^2$, modulus of electricity of $220kn/mm^2$, hardness Between 80 – 150 and specific gravity of 8.80 chrome plating is applied over underplated layers of copper and nickel for decorative purposes and directly on the base metal for engineering purpose.

Chrome may be either shiny or dull and often tends to highlight imperfections In the base metal only very thin amount of chrome is coated on the metal. The usual thickness for bright chromium deposits is 0.25 to 0.8 microns (0.00001 to 0.00003 $In^2$). hardchrome is applied for wear resistance, or to restore an old warn out part to its original dimensions. It is general applied directly onto the base metal.

Chrome plated products are wrist watches chains, screw drivers, spanners, steel (car bombers), key Holders, keys, jewelry, padlocks, wheels, rim, bicycle part etc.(JOE L. et al 1981).

**Table 2.5 Trouble Shooting Grade for Chrome Electroplating**

| PROBLEM | POSSIBLE CAUSES | SUGGESTED SOLUTION |
|---|---|---|
| Poor chromium coverage | i. Decorative Chromium Rectifier failure. | Check rectifier meters for stable operation. AC ripple should not exceed 5%. Rectifier should operate at 38% traced amperage. |
| | ii. Poor electrical connection | Check electrical connections for lightness and contact. |
| | Inactive anodes | Check coating on anodes. A yellowish lead chromate coating indicates that the anode is inactive. A black-brown lead peroxide coating is on active anodes. Make sure proper current is used. When plating inside diameters. Use largest anode possible. |
| | Incorrect bath temperature. | Check bath temperature. Check bath agitation. |
| | Incorrect bath concentration. | Mix bath thoroughly and take bath sample. Analyze chromium and sulfate content. Adjust accordingly. |
| | iii. Improper racking | Check rack-to-fixture connection. |
| | Poor cleaning or rinsing. | Incorporate shields or rubbers in racking to direct current to specific areas. |
| | Copper or nickel roughness | Check temperature of raising water and maintain between 70 and 750F (21 and 240C). |
| | Passive nickel | Check copper or nickel plate for roughness. |
| | Chloride contamination | Dip nickel-plated part in 50% by volume solution of hydrochloric acid. If part brightness increases, correct nickel-plating bath. Dammy with high anode current density and agitation or treat with silver oxide. |
| | Improper current density. | Add sulfate acid to lower ratio and |

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| | | barium carbonate to increase ratio. |
| | Incorrect chronic acid to sulfate catalyst ratio. | Limit metallic impurities to less than 0.5 oz/gal (3.75 g/l). increase chronic acid concentration. |
| | Impurities. | Add sulfuric acid to lower ratio and barium carbonate to increase ratio. |
| | | Limit metallic impurities to less than 0.5 oz/gal (3.75g/l). increase chronic acid concentration. |
| Burned chromium deposits | iv. Passive nickel deposit | Current nickel brightener concentration increase density in nickel bath. |
| | Incorrect bath temperature | Correct bath temperature. |
| | Improper bath concentration. | Analyze chromium and sulfate content. Correct if necessary. |
| | Inactive anodes. | Check anode color. Inactive anodes are coated with a yellowish lead chromate. |
| | Incorrect anode length. | Anode should be 2-4$^0$ (50-100mm) shorter than cathode. Mask anodes that are too long with suitable insulator or cut to proper length. |
| | Current interruption. | Check racking of parts and electrical contacts. |
| | Improper Racking. | Check rack to fixture connection. Incorporate shields or rubbers in racking to direct current to specific areas. |
| | High current density. | Place work 3$^0$ (75mm) below surface of plating solution. |
| | Sulfate de-concentration or other catalyst too high. | Add barium carbonate to bath to lower sulfate concentration. Ratio should be 2.1. |
| | High or low concentration | Check ratio and adjust accordingly. |

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| | ration. | |
| Dull chromium deposit. | v. Dull or passive nickel. | Correct nickel brightener concentration. Increase current density in nickel bath. |
| | Excessive ripple in current. | Check rectifier operation. Ripple should not exceed 50%. |
| | Current interruption. | Check racking of parts and electrical contracts. |
| | Incorrect bath temperature. | Correct bath temperature. |
| | Low current density. | Adjust current density to bath temperature and concentration. Check rinsing procedures. |
| | Impurities. | Limit metallic impurities to less than 0.5 oz/gal (3.75 g/l). increase chronic acid concentration. |
| | Excess fluoride catalyst or fluoride contamination. | Add boric acid to reduce catalyst or use high anode current density dummy. |
| | High or low concentration ratio. | Check ratio and adjust accordingly. |
| White Motching | vi. Film of immersion nickel on work piece. | Rinse work piece thoroughly. |
| | Passive Nickel. | Check nickel plating bath or proper concentration. |
| | Excessive ripple in current. | Check rectifier operation. Ripple should not exceed 5%. |
| | Bipolarity caused by rapid work movement in automatic machines. | Reduce speed of work movement through machine. |
| | Bipolarity caused by dead entry into chromium. | Use live lead at reduce current. |
| | Bipolarity caused by dead entry into chromium. | Use live exit-lead from nickel. |

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| | Bipolarity caused by dead exit from nickel tanks.<br><br>Impurities especially chloride. | Check rinsing procedures. |
| Deposit roughness. | vii. Poor basis metal finish.<br><br>Copper or nickel roughness. | Reject parts with rough finish.<br><br>Check copper or nickel-plating for roughness. |
| Poor Chromium adhesion. | viii. Poor nickel adhesion. | Refers to solutions for bipolarity conditions under "white blotching". |
| No Chromium Plate. | ix. Rectifier failure.<br><br>Poor electrical connections.<br><br>Missing anodes.<br><br>Passive nickel.<br><br>Low current density.<br><br>Incorrect catalyst concentration. | Check operation of rectifier. Rectifier should operate at no less than 75% rated amperage.<br><br>Check connections for good contact.<br><br>Check for replacement of anodes after they have been removed.<br><br>Check nickel bath.<br><br>Adjust current density to bath temperature and concentration.<br><br>Analyze chromium-plating solution and adjust accordingly. |
| Poor Chromium brightness. | x. Hard Chromium. | |
| | xi. | |
| | xii. Poor basis metal finish. Excessive reverse etching.<br><br>Improper bath temperature.<br><br>Improper bath concentration.<br><br>Improper current density.<br><br>High concentration ratio. | Correct bath temperature. Check bath agitation.<br><br>Take Bauman reading of bath and correct.<br><br>Adjust current density to bath temperature and concentration.<br><br>Check ratio and adjust accordingly. |
| Chromium roughness. | xiii. High trivalent chromium. | Check color of chromium solution; a black color indicates trivalent chromium contamination. Electrolyze chromium-plating solution. |

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| | Magnetic particles.<br><br>Excessive reverse etching.<br><br>High current density.<br><br>Improper concentration ratio. | Attach a magnet to a piece of wood and then drag through solution to remove particles.<br><br>Adjust current density to bath temperature and concentration.<br><br>Check ratio and adjust accordingly. |
| Bauer Chromium deposit. | xiv. Improper concentration ratio.<br><br>xv. | Check ratio and adjust accordingly.<br><br>Check rack design and contacts. |
| | xvi. Poor fixturing.<br>xvii.<br>xviii.<br>xix.<br>xx. | Use shield to direct current to specific areas.<br><br>Anode should be shorter than cathode. Mask anodes that are too long with suitable insulator. |
| | xxi. Incorrect Anode length.<br>xxii.<br>xxiii.<br>xxiv.<br>xxv.<br>xxvi. Improper anode-cathode relationship.<br>xxvii. | For outside diameter plating. Anode cathode distance should be approximately 4" (100mm). For inside diameter plating. The distance should be from ½ or 1 (12-25mm). |
| Poor Chromium adhesion. | xxviii. Improper cleaning or rinsing.<br><br>Improper reverse etching.<br><br>Current interruption. | Follow recommended cleaning procedure.<br><br>Do not reverse etch in plating bath. Current used in reverse etching should be proportionated to work areas. Work should be at bath temperature before applying current.<br><br>Check racking of parts and electrical contacts. |
| Burned Chromium deposits. | xxiv. Etching in alkaline cleaner<br><br>Improper fixturing. | Check cleaner concentration.<br><br>Racks should be made from copper for best results. Check rack design and contact. |

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| | Improper anode cathode relationship.<br><br>Improper solution level.<br><br>Improper anode length.<br><br>Inadequate stop-off anodes.<br><br>Improper bath temperature.<br><br>Low bath concentration.<br><br>High current density.<br><br>Impurities.<br><br>Excess catalyst or chloride contamination. | See "uneven chromium deposit".<br><br>Work should be 3" (75mm) below surface of plating solution.<br><br>Anode should be shorter than cathode.<br><br>Correct bath temperature.<br><br>Mix bath thoroughly and take sample to obtain baume reading. Adjust accordingly.<br><br>Adjust current density to bath temperature and concentration.<br><br>Adjust current density to bath temperature and concentration. |
| Lack of chromium hardness. | xxx. Incorrect bath temperature.<br><br>Improper bath concentration.<br><br>High ratio.<br><br>Insufficient deposit thickness. | Check bath temperature and agitation.<br><br>Take Baume reading of bath and correct.<br><br>Check ratio and adjust.<br><br>Check deposit thickness. |
| Fitting | xxxi. Poor basis metal and rework.<br><br>Improper cleaning.<br><br>Incorrect catalyst suppressant.<br><br>Incorrect fume suppressant. | Check metal prior to plating.<br><br>Check cleaning procedures.<br><br>Analyze chromium plating solution and adjust accordingly.<br><br>Eliminate use of fume suppressant that lower surface tension. |
| No Chromium plate. | xxxii. Rectifier failure. | Check operation of rectifier. |

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| | Poor electrical connection.<br><br>Missing anodes.<br><br>Inactive anodes.<br><br>Incorrect catalyst concentration. | Check connections for good contact.<br><br>Check if anodes are properly placed.<br><br>Check anode colour reactive anodes and coated with a yellowish lead chromate.<br><br>Analyze chromium plating solution and adjust accordingly. |
| **PROBLEM** | **POSSIBLE CAUSES** | **SUGGESTED SOLUTION** |
| Poor chromium coverage | i. Decorative Chromium Rectifier failure. | Check rectifier meters for stable operation. AC ripple should not exceed 5%. Rectifier should operate at 38% traced amperage. |
| | ii. Poor electrical connection<br><br>Inactive anodes<br><br>Incorrect bath temperature.<br><br>Incorrect bath concentration. | Check electrical connections for lightness and contact.<br><br>Check coating on anodes. A yellowish lead chromate coating indicates that the anode is inactive. A black-brown lead peroxide coating is on active anodes. Make sure proper current is used. When plating inside diameters. Use largest anode possible.<br><br>Check bath temperature. Check bath agitation.<br><br>Mix bath thoroughly and take bath sample. Analyze chromium and sulfate content. Adjust accordingly. |
| | iii. Improper racking<br><br>Poor cleaning or rinsing.<br><br>Copper or nickel roughness<br><br>Passive nickel | Check rack-to-fixture connection. Incorporate shields or rubbers in racking to direct current to specific areas.<br><br>Check temperature of raising water and maintain between 70 and 750F (21 and 240C).<br><br>Check copper or nickel plate for roughness.<br><br>Dip nickel-plated part in 50% by volume solution of hydrochloric acid. |

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| | | If part brightness increases, correct nickel-plating bath. Dammy with high anode current density and agitation or treat with silver oxide. |
| | Chloride contamination | Add sulfate acid to lower ratio and barium carbonate to increase ratio. |
| | Improper current density. | Limit metallic impurities to less than 0.5 oz/gal (3.75 g/l). increase chronic acid concentration. |
| | Incorrect chronic acid to sulfate catalyst ratio. | Add sulfuric acid to lower ratio and barium carbonate to increase ratio. |
| | Impurities. | Limit metallic impurities to less than 0.5 oz/gal (3.75g/l). increase chronic acid concentration. |
| Burned chromium deposits | iv. Passive nickel deposit | Current nickel brightener concentration increase density in nickel bath. |
| | Incorrect bath temperature | Correct bath temperature. |
| | Improper bath concentration. | Analyze chromium and sulfate content. Correct if necessary. |
| | Inactive anodes. | Check anode color. Inactive anodes are coated with a yellowish lead chromate. |
| | Incorrect anode length. | Anode should be $2\text{-}4^0$ (50-100mm) shorter than cathode. Mask anodes that are too long with suitable insulator or cut to proper length. |
| | Current interruption. | Check racking of parts and electrical contacts. |
| | Improper Racking. | Check rack to fixture connection. Incorporate shields or rubbers in racking to direct current to specific areas. |
| | High current density. | Place work $3^0$ (75mm) below surface |

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| | | of plating solution. |
| | Sulfate de-concentration or other catalyst too high. | Add barium carbonate to bath to lower sulfate concentration. Ratio should be 2.1. |
| | High or low concentration ration. | Check ratio and adjust accordingly. |
| Dull chromium deposit. | v. Dull or passive nickel. | Correct nickel brightener concentration. Increase current density in nickel bath. |
| | Excessive ripple in current. | Check rectifier operation. Ripple should not exceed 50%. |
| | Current interruption. | Check racking of parts and electrical contracts. |
| | Incorrect bath temperature. | Correct bath temperature. |
| | Low current density. | Adjust current density to bath temperature and concentration. Check rinsing procedures. |
| | Impurities. | Limit metallic impurities to less than 0.5 oz/gal (3.75 g/l). increase chronic acid concentration. |
| | Excess fluoride catalyst or fluoride contamination. | Add boric acid to reduce catalyst or use high anode current density dummy. |
| | High or low concentration ratio. | Check ratio and adjust accordingly. |
| White Motching | vi. Film of immersion nickel on work piece. | Rinse work piece thoroughly. |
| | Passive Nickel. | Check nickel plating bath or proper concentration. |
| | Excessive ripple in current. | Check rectifier operation. Ripple should not exceed 5%. |
| | Bipolarity caused by rapid work movement in automatic machines. | Reduce speed of work movement through machine. |

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| | Bipolarity caused by dead entry into chromium.<br><br>Bipolarity caused by dead entry into chromium.<br><br>Bipolarity caused by dead exit from nickel tanks.<br><br>Impurities especially chloride. | Use live lead at reduce current.<br><br>Use live exit-lead from nickel.<br><br>Check rinsing procedures. |
| Deposit roughness. | vii. Poor basis metal finish.<br><br>Copper or nickel roughness. | Reject parts with rough finish.<br><br>Check copper or nickel-plating for roughness. |
| Poor Chromium adhesion. | viii. Poor nickel adhesion. | Refers to solutions for bipolarity conditions under "white blotching". |
| No Chromium Plate. | ix. Rectifier failure.<br><br>Poor electrical connections.<br><br>Missing anodes.<br><br>Passive nickel.<br><br>Low current density.<br><br>Incorrect catalyst concentration. | Check operation of rectifier. Rectifier should operate at no less than 75% rated amperage.<br><br>Check connections for good contact.<br><br>Check for replacement of anodes after they have been removed.<br><br>Check nickel bath.<br><br>Adjust current density to bath temperature and concentration.<br><br>Analyze chromium-plating solution and adjust accordingly. |
| Poor Chromium brightness. | x. Hard Chromium. | |
| | xi. | |
| | xii. Poor basis metal finish. Excessive reverse etching.<br><br>Improper bath temperature.<br><br>Improper bath concentration.<br><br>Improper current density. High concentration ratio. | Correct bath temperature. Check bath agitation.<br><br>Take Bauman reading of bath and correct.<br><br>Adjust current density to bath temperature and concentration.<br><br>Check ratio and adjust accordingly. |

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|---|---|---|
| Chromium roughness. | xiii. High trivalent chromium.<br><br>Magnetic particles.<br><br>Excessive reverse etching.<br><br>High current density.<br><br>Improper concentration ratio. | Check color of chromium solution; a black color indicates trivalent chromium contamination. Electrolyze chromium-plating solution.<br><br>Attach a magnet to a piece of wood and then drag through solution to remove particles.<br><br>Adjust current density to bath temperature and concentration.<br><br>Check ratio and adjust accordingly. |
| Bauer Chromium deposit. | xiv. Improper concentration ratio.<br><br>xv. | Check ratio and adjust accordingly.<br><br>Check rack design and contacts. |
| | xvi. Poor fixturing.<br>xvii.<br>xviii.<br>xix.<br>xx. | Use shield to direct current to specific areas.<br><br>Anode should be shorter than cathode. Mask anodes that are too long with suitable insulator. |
| | xxi. Incorrect Anode length.<br>xxii.<br>xxiii.<br>xxiv.<br>xxv.<br>xxvi. Improper anode-cathode relationship.<br>xxvii. | For outside diameter plating. Anode cathode distance should be approximately 4" (100mm). For inside diameter plating. The distance should be from ½ or 1 (12-25mm). |
| Poor Chromium adhesion. | xxviii. Improper cleaning or rinsing.<br><br>Improper reverse etching.<br><br>Current interruption. | Follow recommended cleaning procedure.<br><br>Do not reverse etch in plating bath. Current used in reverse etching should be proportionated to work areas. Work should be at bath temperature before applying current.<br><br>Check racking of parts and electrical contacts. |

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| Burned Chromium deposits. | xxiv. Etching in alkaline cleaner<br><br>Improper fixturing.<br><br>Improper anode cathode relationship.<br><br>Improper solution level.<br><br>Improper anode length.<br><br>Inadequate stop-off anodes.<br><br>Improper bath temperature.<br><br>Low bath concentration.<br><br>High current density.<br><br>Impurities.<br><br>Excess catalyst or chloride contamination. | Check cleaner concentration.<br><br>Racks should be made from copper for best results. Check rack design and contact.<br><br>See "uneven chromium deposit".<br><br>Work should be 3" (75mm) below surface of plating solution.<br><br>Anode should be shorter than cathode.<br><br>Correct bath temperature.<br><br>Mix bath thoroughly and take sample to obtain baume reading. Adjust accordingly.<br><br>Adjust current density to bath temperature and concentration.<br><br>Adjust current density to bath temperature and concentration. |
| Lack of chromium hardness. | xxx. Incorrect bath temperature.<br><br>Improper bath concentration.<br><br>High ratio.<br><br>Insufficient deposit thickness. | Check bath temperature and agitation.<br><br>Take Baume reading of bath and correct.<br><br>Check ratio and adjust.<br><br>Check deposit thickness. |
| Fitting | xxxi. Poor basis metal and rework.<br><br>Improper cleaning.<br><br>Incorrect catalyst suppressant. | Check metal prior to plating.<br><br>Check cleaning procedures.<br><br>Analyze chromium plating solution and adjust accordingly. |

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| | Incorrect fume suppressant. | Eliminate use of fume suppressant that lower surface tension. |
| No Chromium plate. | xxxii. Rectifier failure.<br><br>Poor electrical connection.<br><br>Missing anodes.<br><br>Inactive anodes.<br><br>Incorrect catalyst concentration. | Check operation of rectifier.<br><br>Check connections for good contact.<br><br>Check if anodes are properly placed.<br><br>Check anode colour reactive anodes and coated with a yellowish lead chromate.<br><br>Analyze chromium plating solution and adjust accordingly. |

## 2.13 Small Scale Industries

### 2.13.1 Definitions

It will be vague to offer a precise definition of the terms "small scale" business because the expression covers a wide range of activities that are related to social and economic development of a given nation, even among researchers and practitioners, There has been no consensus as regards what constitutes a small scale business. The multiplicity of definition relates to the culture and peculiar circumstances of the person(s) attempting the definition. (Adama et al, 2003).

Hence, there is no single yardstick for classifying a business unit as small scale. The classification essentially varied according to time and setting. Since attempts in the past to produce a universally accepted definition of what business unit can rightly be referred to a small scale, industry had caused some confusion and protracted debate among discussant. So the solution to this multiplicity of definition or criteria employed would seem to be in the revision of whatever definition is used from time to time based on specific objective as to what these micro economic unit are meant to achieve (Blunt et at, 1990).

The central Bank of Nigeria in its 1998 operational guidelines defined small-scale business with reference to two Financial Institutions; the Merchant Bank, a small scale business is the "one with a capital investment of more than N200,000 excluding the cost of land and annual turnover of N500,000". But for Commercial Banks, a small scale business is "one with maximum annual turnover not exceeding

N500,000(Koh,1988).

The center for management science development at the University of Netherlands, defines a small-scale business as a business in which manager personally perform at the function of management. These centers classifies small scale business as an establishment employing not more than 99 persons, while the employment of 1-9 persons is regarded as cottage industry (Blunt et al, 190).

The United Nations industrial development organization (UNIDO) classified small scale enterprises as those with less than 150 employees on its pay roll. Such enterprises can be classified into two:

i. The traditional craftsmen and artisan and
ii. The small manufacturing enterprises which produce a variety of consumer and simple producer goods.

The Nigeria Bank for commerce and industry (NBCI) in 1987, defined small enterprises as those with total cost of not more than 750,000.

This definition which is expected to be valid until 1990 before it is reviewed has been accepted by the government (Central Bank of Nigeria, 1995).

However, the definitions of small scale enterprises as those whose total cost, excluding cost of land but including working capital is above N1,000,000 but does not exceed N10,000,000 has irraddvertently left out credit-worthy cottage industries. This has created problems for the category of enterprises and banks that are other-wise disposed to granting credit to them. For this purpose therefore, small scale enterprises shall include cottage industries and defined as enterprises whose total cost, excluding cost of land but including working capital does not exceed N10,000,000 (Oladeepo, 1998).

Finally, according to National Council of Industrial/Federal Ministry of Industry, 2002 gives the following definition as regards various sectors of industries.

i. Cottage Industry: This is any firm with total cost including working capital but excluding cost of land below N1.5 million and labour size below 11 workers.

ii. Small Scale Industry: This is any firm with total cost including working capital but excluding cost of land above N1.5million but not exceeding N50 million and labour size between 11 and 35 workers.

iii. Medium Scale Industry: This is any firm with total cost including working capital but excluding cost of land above N50,000,000 but not exceeding N200,000,000 and labour size of between 36 and 100 workers.

iv. Large Scale Industry: This refers to any firm with total cost including working capital but excluding cost of land above N200 million and labour size above 100 workers (Onyeneke, 2002).

Furthermore, the revision of these definitions are done from time to time to enable many more unit of small scale industry to modernize their operation and following the trend of change within the sector.

### 2.13.2 Cost indices

A cost index is merely an index value for a given point in time, showing the cost at that time relative to a certain base time. If the cost at some time in the past is known, the equivalent cost at the present time can be determined by multiply the original cost by the ratio of the present index value to the index value applicable when the original cost was obtained (Peters and Timmerhaus, 1991).

Present Cost = (Original Cost) x (Index value at preset time) / (Index value at time Original cost was obtained).

Statements of cost are based on the value of the dollar at a given year, and a cost index is needed to compare cost, which are presented on different bases. The uses of cost index to express the changing purchasing power of the dollar dates back to 1913 with the ENR cost index which is a weighted average of the cost of steel, lumber, cement and common labour (Rudd and Watson, 1968).

Cost Indices can be used to give a general estimate, although, no index can take into account all factors, such as special technological advancement, or local conditions.

The common index permits fairly accurate estimates if the time period involved is less than 10 years.

Many different types of cost Indices are published regularly. The most common of these Indices which can be used for estimating equipment cost are the Marshall and Smith Equipment Cost Index, and the Chemical Engineering Plant Cost Index. For the purpose of this work, the latter shall be used.

### 2.13.3 Chemical engineering plant cost index

Construction cost for chemical engineering plants form the basis of the Chemical Engineering Plant Cost Index. The four major components of this index are weighted by percentage in the following manner: equipment, machinery and supports, 61; erection and installation labour, 22; building materials and labour, 7' and engineering and supervision, 10. The major component, equipment, is further subdivided and weighted as follows:

Fabricated equipment, 37; process machinery, 14; pipes , valves and fillings, 20; process instruments and control, 7; pumps and compressors, 7; electrical equipment and materials, 5; structural supports, paints and instrumentation, 10. All index components are based on 1957-1959 = (Peter and Timmerhaus).

## 2.14 Process Simulation

This is an act of representing some aspects of the real world by symbols that may be easily manipulated to facilitate their study. The important steps of process simulation are therefore, description of the part of the "real world" that needs to be simulated, representation of this part of the 'real world' in terms of a model (mathematical or symbolic), and finally, solution of the mathematical model to obtain numbers or symbols. With respect to chemical engineering, the real world is a chemical process described by a process flow sheet. Typically, process simulation is needed to solve problems related to process design, process analysis, process control and many more. Depending on the type of the problem, different types of process simulation problems are formulated. For example, verification of design or for inventory control (mass and energy balance) requires the solution of steady state simulation problems while verification of the control system or analysis of the effect of disturbances requires the solution of dynamic simulation problems.

Obviously, each simulation problem is associated to a corresponding mathematical model. In steady state simulation, the mathematical model is usually represented by a mixed set of algebraic equations and ordinary differential equation. For complex or rigorous simulation problems, the mathematical model may even be represented by a mixed set of algebraic equations. Each mathematical model, therefore, is associated to a corresponding method of solution.

Since there can be many way to solve a set of equat6ions representing a mathematical model, it is necessary to have a simulation strategy which ensures that the simulation problem is solves efficiently and that the simulation results are reliable. Reliability also depends on the model accuracy. Use of inappropriate models or modes parameters may result in erroneous simulation results. (floudas, 1995).

As described above, process simulation requires a number of important steps that are linked to each other. Each step, however, can be large enough to justify the use of a computer to solve the problem. A computer problem that combines the important steps into a single program package is called a process simulator. The process simulator is designed to help the user in performing the important steps without the need to develop new computer programs for solving new problems.

In the solution of problems related to process synthesis or design, control or operation, analysis etc., the user needs to provide sufficient information to properly specify the simulation problem. Typically, a simple steady state simulation of a process flow sheet requires a description of the process flow sheet (including an identification of the compounds present in the system and unit operations present in the flow sheet), choice of method of solution, specification of equipment parameters and input streams and many more. Solution of a process design problem may require many solution of the process simulation problem (for each trial, a different simulation problem may need to be solved). User does not have all the information necessary to specify the simulation problems, in order to assist the user; the concept of an integrated simulation system has been introduced.

The objective of integrated system is to help the user to generate the necessary information so that a simulation problem can be properly defined and solved. Usually, the time spent on collecting the information necessary to defined a simulation problem is much greater than the time spent by the process simulator in finding the solution. By reducing the time spent by the user in defining the simulation problem, the integrated system helps to improve the work efficiency or user. In the integrated system helps to improve the efficiency of the user. In the integrated system, the user has available, computational tools that can be used to generate the missing information.

### 2.14.1 Structure of a process simulator

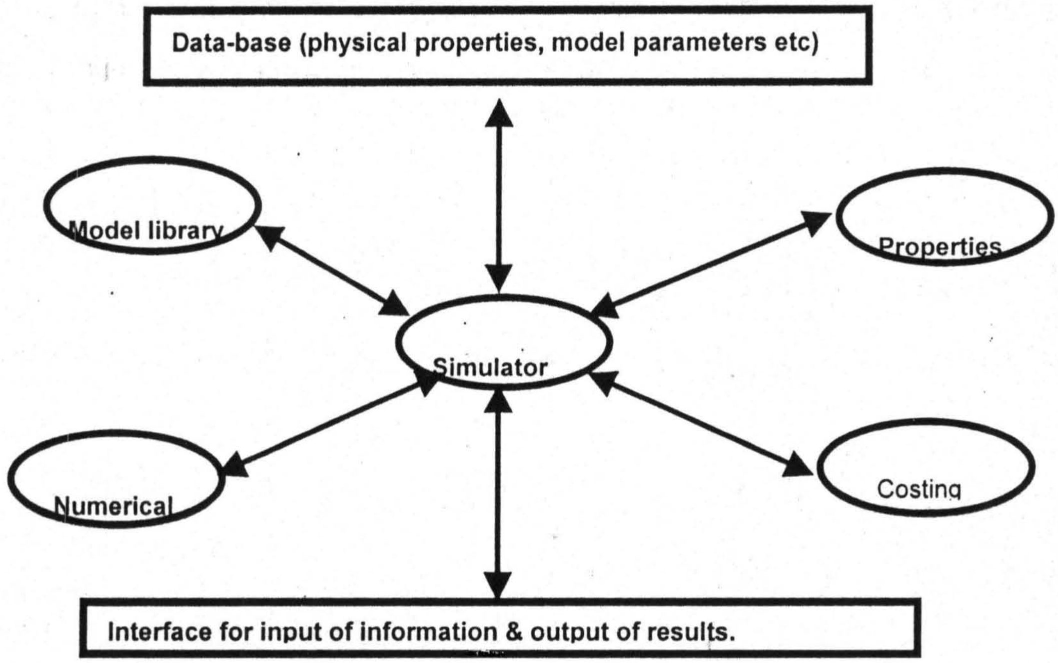



**Figure 2.4 Main features of a process simulation**

### 2.14.2 Commercial process simulators

The three common commercial process simulator are;

ASPEN Plus - Aspen Technology, USA.

Pro-II/Provision – Simulation Sciences, USA (Seibe, UK)

HYSIS-Hypro tech, Canada (AEA Technologies, UK).

ASPEN and Pro-II are steady state process simulators with process optimization feature. Both of them employ a sequential modular approach. HYSIS provides both steady and unsteady simulation features. It employs a mixed simulation strategy. ASPEN has the largest number of users followed by pro-II and then HYSIS. All the three simulators have windows-based PC-versions. All have extensive data for compound and physical properties, it has a large collection of unit operation models and thermodynamic models.

### 2.14.3 Computer application to chemical engineering

Computer can be applicable to the following chemical engineering subject: Heat transfer, process dynamic and control, introduction to Chemical Engineering, , chemical reaction engineering, fluid mechanics, mathematical methods, thermodynamics, separation process, process design and electrochemical processes.

### 2.14.4 Hysys

This simulator provides you with an intuitive and interactive approach toward process modeling, simulation and optimization.

This software lets you to create detailed high-fidelity plant simulations for analyzing and optimizing your plant's operation. Through the completely interactive HYSYS interface, you have access to a fine level of equipment geometry, performance detail as well as the ability to completely customize your simulation using its extensibility capability.

This program is used by industry to design and simulate process plants such as oil and gas refineries, chemical and pharmaceuticals production and electrochemical facilities. (HYSIS Simulation Manual, 2004).

### 2.14.5 MathCAD

MathCAD provides a rich problem-solving environment that gives you a wide choice of tools and supports a variety of analysis and visualization techniques. MathCAD is used by hundreds of thousands of engineers, scientists, and students across a broad range of technical disciplines to perform calculations, to interface with other engineering, drawing and business applications and to publish their "live" documents on the web.

In the most general sense, you can think of MathCAD as a combination of;

(i) A powerful technical computing environment centered on real math notation.

And

(ii) A flexible, full-featured technical word processor.

This means that with MathCAD the tasks of performing computations and documenting them are integrated into one seamless process, resulting in substantial increases in productivity.

#### 2.14.5.1 features of the mathCAD window

Before you move on to learning more about MathCAD's features and especially about building math and text in your own MathCAD worksheets, take a moment to look at the MathCAD application window in front of you.

(a) The Main Menu

| | | | | |
|---|---|---|---|---|
| File | Edit | View | Insert | Format |
| Math | Symbolic | Window | Help | |

This gateway to math, graphics, and functions provides the commands that handle the details of editing and managing your worksheets. Click on the menu to see the array of computational and formatting functionally available to you.

#### 2.14.5.2 the math toolbar

Choose Toolbars Math from the View menu to see a tear-away bar whose buttons bring up toolbars of math operators. You can click the bar under the main menu. If you let your mouse however each of the buttons on the bar in turn, you will see a tool tip telling you what menu each button brings up:

Calculator toolbar

Boolean toolbar

Matrix toolbar

Calculus toolbar

Graph toolbar

Programming toolbar

Greek toolbar

Click on one of these buttons in the bar to bring up the associated operator toolbar. You can then use the operator toolbar to insert math symbols right into your MathCAD worksheet.

## 2.15 Costing

It is an economic fact that the purchasing power of the monetary unit, no matter what the currency is, erodes and depreciates with time, and there is little if any reason, to suggest that this trend will change in the future. This depreciation in the value of money is termed inflation. Inflation is the rise in price level or fall in the purchasing power, or the rate of increase in some national price level . The official rate of inflation is based on a specified mixture of goods required in cash outlay required to purchase this basket of goods is the official rate of inflation.

Due to inflation and other factors, the economic environment in which a chemical plant (Chrome Electroplating Plant) operates is a dynamic and not static one, and it undergoes continuous change, as will the factors that determine its profitability, e.g. labour, raw materials and utilities. The overall cost of establishing such a plant will equally change upwards, as the years slowly go by. One of the most important factors contributing to the changes above is inflation, which will also seriously affect the cost of equipment.

### 2.15.1 Equipment cost estimation

There are methods of estimation of equipment costs of the Chrome Electroplating Plant amongst are the method of Cost Index, the Six-Tenth-Factor Rule Method, and method of Cost Index and scaling.

### 2.15.2 The method of cost index

If the cost of each piece of equipment at sometime in the past is known, then the equivalent cost at the present time can be determined by multiplying the original or historical cost by the ratio of the present index value to the historical index value applicable when the historical cost was obtained (See Table 3.1 for cost data).

Let historical cost (Original) cost of each equipment be HC, say; the historical cost index be HI; the current cost index be CI, and the current cost of the current cost of the equipment be CC.

Therefore, the current cost of any equipment was given by the following equation:

$$CC = HC\,(CI/HI) \quad \text{.........} 2.7$$

### 2.15.3 Six-tenths factor rule method

It is often necessary to estimate the cost of a piece of equipment when no cost data are available for the particular size of operational capacity in question. Good results can be obtained by using the logarithmic relation known as the six-tenth-factor the cost data are available. According to this rule, if the cost of a given equipment at one capacity is known, the cost of a desired similar unit with X times the capacity of the first equipment is approximately $(X)^{0.6}$ times the cost of the original equipment.

Let HCB – historical cost of equipment B (desired).

HCA – historical cost of equipment A.

QA – known capacity of equipment A.

QB – capacity of equipment B.

Therefore, the historical cost of equipment B that is not available in literature is given by:

$HCB = HCA\,(QB/QA)^{0.6}$ ............................................2.8

The current cost of equipment A is given by the following cost index equation:

CCA – HCA (CIA/HIA)................................................2.9

From equation 3.2, it follows that the current cost of the desired equipment B is given by:

$CCB = HCA\,(CIA/HIA)(QB/QA)^{0.6}$ .................................2.10

Combining equation 3.1 and equation 3.4 obtain.

$CCB = HCA\,(CIA/HIA)(QB/QA)^{0.6}$ .................................2.11

### 2.15.4 Method of cost index and scaling.

This method is similar to the Six-Tenth-Factor Rule method, but different in the fact that whereas the index to which the equipment capacities are raised was constant (0.6) for the former method, it varied for this method depending on the equipment. Secondly this method is used when cost data for a particular size of operational capacity of the same equipment is available, but lack for the desired size.

The current cost of a piece of equipment of desired size B was given by the following equation:

$$CCB = HCA\ (CIA/HIA)\ (QB/QA)^{EI} \qquad \text{.......... 2.12}$$

Cost data for this equation is given in Table 3.1.

### 2.15.5 Estimation of the delivered purchased equipment cost

The cost of delivered purchased equipment is the basis for estimating Capital Investment. This was computed here as a summation of the individual equipment costs determined by any of the three equipment cost estimation methods discussed in 3.2.1.

Therefore,

$$PECT = \sum_{i=1}^{n} CC_1 \qquad \text{.......... 2.13}$$

Cost data for this equation is given in Table 3.1.

### 2.15.6 Estimation of the fixed capital investment

This consists of manufacturing fixed-capital investment, which represents the capital necessary for the installed process equipment with all auxiliaries that are needed for complete process operation are typical examples of costs included in the manufacturing fixed-capital investment.

Fixed capital required for construction of overheads and for all plant components that are not directly related to the process operation is designated as the non-manufacturing fixed-capital investment. These plant components included the land, processing buildings, administrative and other offices, warehouses, laboratories, transportation, shipping and receiving facilities, utility and waste disposal facilities, shops and other permanent parts of the plant. The construction overhead costs consist of field-office and supervision expenses, home-office expenses, engineering expenses, miscellaneous construction cost, contractor's fees, and contingencies (Peters and Timmerhaus 1991).

The fixed-capital investment shall be determined by means of the factored estimate method, which is a method by which the investment cost in a completed system can be extrapolated from the delivered cost of the major items of processing equipment (Rudd and Watson, 1968).

It has been observed that the cost of the other essential items needed to complete the process system can be correlated with the investment cost in major items of equipments, and the capital investment can be estimated by the application of experience factors to the base investment of delivered purchased equipment cost (Rudd and Watson 1968).

Thus, the factored estimate equation below results. The experience factors $f$ are obtained from a study of many similar processing systems. Values for the directs and indirect factors are given in Table 3.2.

$$FCAPN = [PECT + (\Sigma f_i \, PEECT)] \, f_1 \quad \text{.......} 2.14$$

Where $f_1 = (1 + \Sigma f_1)$.

### 2.15.7 Computation of the total and working capital investments.

Total capital investment consists of fixed capital and working capital investment.

The fixed-capital investment was taken as eighty five percent of the total capital investment, while the remaining fifteen percent became the working capital investment.

Thus, the total capital investment given by;

TCAPN = FCAPN/0.85.....................................................2.15

And, the working capital investment was given by:

WCAPN = 0.15 * TCAPN..................................................2.16

Cost estimation of equipment and economic acceptable plant design must present a process that is capable of operating under conditions which will yield profit when the cost for any type of commercial process is to be determined, sufficient accuracy has to be provided for reliable decision.

There are many factors affecting investment and production cost. These are:

i. Company Policies

   Source of equipment

ii. Price fluctuation

iii. Operating and rate of production

iv. Government Policies

(Peters et al, 1991)

Before an industrial plant can be put into operation, a large sum of money must be supplied to purchase and install the necessary machinery and equipment. (Gaeul, 1977).

Hysis cost estimation and Marshal and Smith cost estimation index were used and the summary of result for the cost can be seen in chapter four.

Cost of equipment from hysis online cost.

Simulator and cost are in Dollar.

Exchange rate ER is 150 Naira = 1 Dollar

This cost estimation is based on cost data of 2006 and is available in dollar.

Exchange rate (ER) 130 Naira = 1 Dollar

Data for cost of Acid pickling tank' Degreasing Tank, Electroplating tank and washing tanks are estimated using Marshall and Smith cost index. However this cost estimation method cannot be used for some equipment e.g. cooler, rectifier, tank mixers, heaters, and air dryer. direct online costs were used.

Pc = M.S (101.9) 1.066

Where D = Diameter of the tank/column in ft.

H = Height of the tank/column in ft.

M.S = Marshall and Smith index = 110

Fc = 1.00 + Fm + Fp

(Gealu, etal, 2006)

The material of construction selected for most equipment is carbon steel because of its corrosive resistance.

Hence, Fm = 1.00 Fp = 1/00

Fc = 1 + Fm + Fp

Fc = 3 Diameter = D Volume = V

Height = H

## CHAPTER THREE

### 3.0 METHODOLOGY

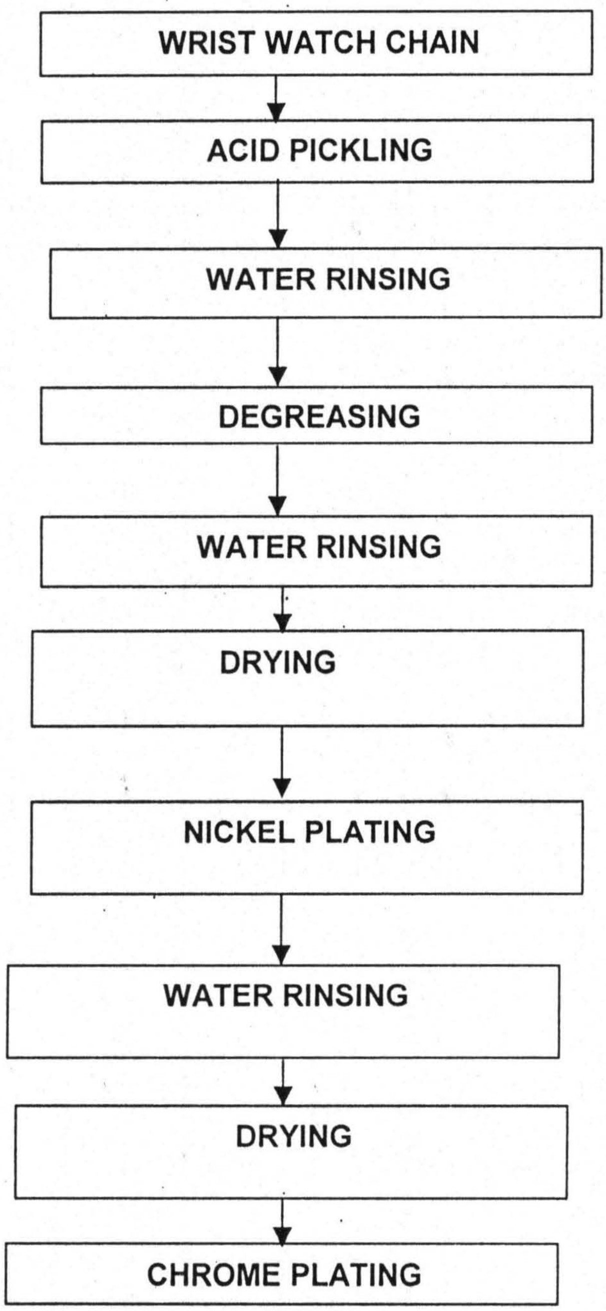
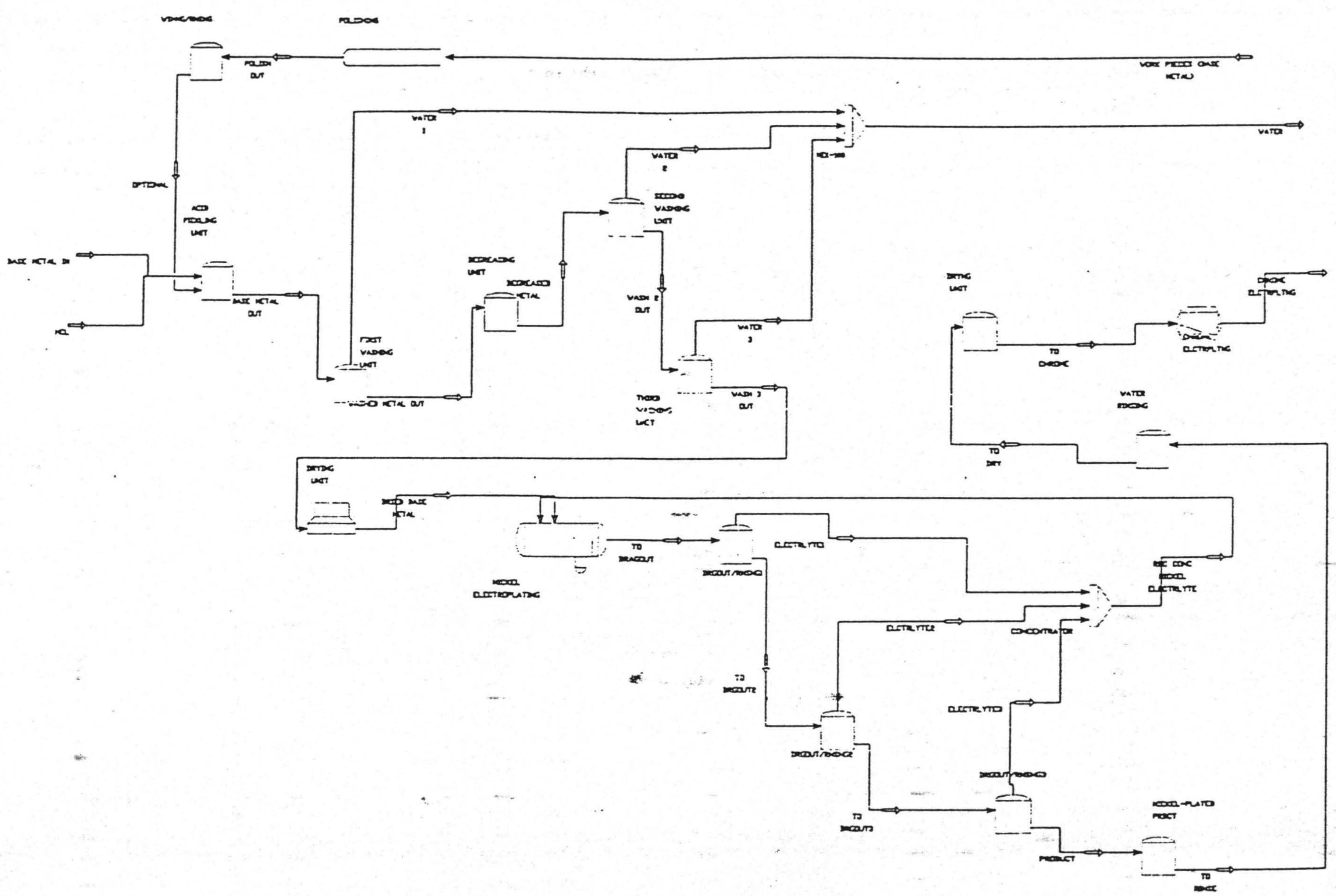



**Fig. 3.0 Block Diagram Of Chrome Electroplating.**

# FLOW DIAGRAM OF CHRO



## 3.1 Process description

### 3.1.1 Acid pickling

In this process, oxides are removed from surface of the basis metal for steel, warm, dilute sulfuric acid is used in large-scale operations because it is inexpensive; but room temperature, dilute hydrochloric acid is also used for pickling of steel, attack of the metal is retarded while the oxide is being dissolved. In addition to rough pickling acid treatment to activate the surface just prior to plating are often used. When an inhibitor is added to acids, it covers the exposed iron material and thus inhibits excessive corrosion by acids.

The following reaction took place

$$Fe_2O_{3(s)} + 6\ HCL\ (aq) \longrightarrow FeCl_{3(aq)} + 3\ H_2O \ldots\ldots\ldots\ldots\ldots 3.1$$

### 3.1.2 Water rinsing

Cold distilled water is used for rinsing of the product from Acid pickling to avoid contamination of the electrolyte, by removing the iron III chloride formed and at the same time reduces the traces of acid on the work pieces before degreasing.

### 3.1.3 Degreasing (alkaline soak cleaning)

This process generally involves the use of chlo rinated hydrocarbons in either the heated or vapour form. The solvents commonly used are Trichloroethylene, perchloroethyene and 1,1,1-trichloroethyene. This process is basic, and therefore a very important process in the plating process The degreasing salt is dissolved in water and the solution is heated to a temperature of between $50^0c$ to $80^0c$.

After ward the object is suspended in the solution and left for about 15 minutes by which time all the dirt and grease would have been completely removed. The degreasing speed tend to become faster when the product to be plated is stained by an highly viscous oil, since the oil will soften faster under a higher temperature.Saponification process is the basic reaction here

Fat or oil or greese + Caustic (alkali) Soaps + Propane 1,2,3 triol

$$R^{I}COOCH \quad + \quad 3NaoH \longrightarrow R^{II}Coo^{-}Na^{+} \qquad .....3.2$$

### 3.1.4 Water rinsing

Similarly cold distilled water is used to rinse off the soaps, emulsified products and left over sodium hydroxide on the product.

### 3.1.5 Drying

The water on the base metal is dried to avoid further dilution of content of the electroplating bath .

### 3.1.6 Nickel electroplating

Nickel plating solutions, nickel anodes are used to provide the necessary anode surface to secure as possible distribution of the electro deposit on the work and to maintain the nickel content for the plating solution. A typical electrolyte for Nickel plating can be made by dissolving the following salts

| | | |
|---|---|---|
| Nickel Sulphate | 225 – 357g/L, | Mean 291g/L |
| Nickel Chloride | 30 – 75g/L, | Mean 52.5g/L |
| Boric acid | 30 – 55g/L, | Mean 42.5g/L |

2-3 droplets of $H_2So_4$ at a $P^H$ 0f 3.6.

The nickel anodes are enclosed in cotton polypropylene or terylene bags.

### 3.1.7 Operating condition for Nickel plating solutions.

| | |
|---|---|
| Cathode Current density | 4.0 to 6.5amp/dm2 (40 to 60 amp/ft$^2$) |
| P$^H$ Value | 4.0 to 4.8 |
| Voltage | 3 to 4 volts |
| Temperature | 55 to 65$^0$c |
| Anode | nickel |

### 3.1.8 Chrome electroplating

In Chrome Electroplating, chrome anodes are used to provide the necessary anode surface to secure distribution of the electro deposit on the work and to maintain the nickel content for the plating solution. A typical electrolyte for chromium decorative plating can be made by dissolving the following salts

| | | |
|---|---|---|
| Chrome Sulphate | 200 – 300g/L, | Mean 250g/L |
| Ratio of chromic acid to sulfate | | 100:1 to 125:1 |
| chrome Chloride | 30 – 75g/L, | Mean 52.5g/L |

### 3.1.9 Operating condition for chromium plating solutions.

| | |
|---|---|
| Cathode Current density | 8.0 to 12amp/dm2 (75 to 110 amp/ft$^2$) |
| Voltage | 4 to 5 volts |
| Temperature | 35 to 40$^0$c |
| Anode: | lead/antimony. |

### 3.1.10 Dragout/Water rinsing tanks

The dragout/water rinsing tank does two things;

To capture the dragout volume and also rinse the works pieces(wristwatches) from concentrated Nickel solution and subsequently from concentrated chrome solution. The tanks are connected to each other and Nickel and chromium plating tank by drop board.

### 3.1.11 Concentrator

Concentrator helps to recover Nickel and chrome metal from plating rinse waters (Dragout tanks). However, chemical precipitation, solvent extraction, ion exchange of reverse Osmosis will recovered metal as concentrated solutions or sludges, which can be recycle back for reused. Also, where the metal form plating rinse water is required as pure metal then an electrolytic. Extraction may be used for this design ion exchange with reverse Osmosis concentrator is used.

### 3.1.12 Air drying

The work piece (base metal) after electroplating was spread to dry under atmospheric air before packaging.

## 3.2 Equation of The Reactions

The equation of the reaction is obtained based on the anodic and cathodic half reactions. Electrochemical deposition of nickel and chrome from typical electrolyte is a relatively slow process compared to the speed at which their ions moved in the bath. This fact is possible to use very high current densities at direct current conditions, and even higher current densities using pulse plating.

The deposition of nickel takes place through a number of intermediate steps, as indicated below,

$$Ni^{2+} + H_2O \longleftrightarrow Ni\,OH^+ + H^+ \quad ..................3.3$$

$$Ni\,OH^+ + e^- \longleftrightarrow Ni\,OH_{ad} \quad ...................3.4$$

$$Ni\,OH_{ad} + H^+ + e^- \longleftrightarrow Ni + H_2O \quad ...................3.5$$

Similarly the deposition of chrome takes place as follows:

$$Cr^{3+} + H_2O \longrightarrow Cr^{3+}OH + H^+ \quad .....................3.6$$

$$Cr\,OH + e- \longrightarrow Cr\,OH_{aq} \quad ........................3.7$$

$$Cr\,OH_{aq} + H^+ + e- \longrightarrow Cr + H_2O \quad ........................3.8$$

From the reaction above, it can be seen that that pH value in the bath is of great importance. Since free hydrogen ions play an important role in the deposition mechanism. The bath temperature is also an important parameter, since the speed of the reaction is all dependence on temperature (but some more than others).

Also the concentration of nickel and chrome ions at the cathode, and the current density (available electrons) has influence on the deposition process .

Also, noted is the equation of reaction at the positive and negative poles respectively.

$$4Ni \longrightarrow 4Ni^{2+} + 2e- \quad .....................3.9$$

In the electrolyte, the dissociation is

$$Ni\,SO_4 + 6H_2O \longrightarrow Ni^{2+} + SO_4^{2-} + 6H+ + 6OH- \quad .............3.10$$

$$Ni\,Cl_2 + 6H2O \longrightarrow Ni^{2+} + 2Cl- + 6OH- \quad .............3.11$$

$$Ni_3\,Bo_3 \longrightarrow 3H+ + BO3^{3-} \quad .............3.12$$

$$H_2\,SO_4 \longrightarrow 2H+ + SO_4^{2-} \quad ..........3.13$$

The net reaction is given as (overall equation), this involve the combination of equation 3.6 – 3.10

$Cr^{3+}$ + 4Ni + Ni $SO_4$ + 6 $H_2O$ + Ni $CL_2$ + $6H_2O$ + $H_3BO_3$ + $H_2$ $SO_4$ $6Ni^{2+}$ +

$2SO_4^{2-}$ + $2CL^-$ + $BO_3^{3-}$ + $18H^+$ 11 $OH^-$ ......................3.14

### 3.2.1 Anodic reaction

2Ni + $SO4^{2-}$ + $2CL^-12H^+$ + $12OH^-$ $NiSO_4.6H_2O+NiCL_2.6H_2O$

2Cr + $SO4^{2-}$ + $2CL^-12H^+$ + $12OH^-$ $Cr_2SO_4.6H_2O+NiCL_2.6H_2O$

### 3.2.2 Cathodic reaction

$6Ni^{2+} + 6\ H_2O \longrightarrow 6\ Ni\ OH^+ + 6H^-$ ...3.15

$6Ni\ OH^+\ 6e^- \longrightarrow 6\ Ni\ Oh_{ad}$ ....3.16

$6\ Ni\ Oh_{ad} + 6H^+ + 6e^- \longrightarrow 6Ni + 6H_2O$ ......3.17

Similarly, for chrome:

$Cr \longrightarrow Cr^{3+}$ + 3e- ..................3.18

In the electrolyte, the dissociation is

$CrSO_4+6H_2O \longrightarrow Cr^{3+} + SO_4^{2-} + 6H+ + 6OH-$ .............3.19

$Cr\ Cl_2+6H2O \longrightarrow Cr^{3+} + 2CL- + 6OH-$ .............3.20

$H_2\ SO_4 \longrightarrow 2H+ + SO_4^{2-}$ .............3.21

The net reaction is given as (overall equation), this involve the combination of equation 3.18 – 3.21

$Cr3+ + Cr\ SO_4 + 6\ H_2O + Cr\ Cl_2 + 6H_2O + H_2\ SO_4 \longrightarrow Cr3^+ + 2SO_4^{2-} + 2CL^- +$

$18H^+$ 11 $OH^-$ .....................3.22

### 3.3 Material Balance

A computer aided design was used for this plant, MathCAD was chosen to carry out the material balance . The basis chosen was 2000kg/day of wrist watches, Rust of 0.05% and grease of 0.02% were used. The mass flow rates of the materials were calculated: rust ($Fe_2O_{3)}$ was 1.0kg/day and grease was 0.4kg/day and reacting mass of rust was 6.25 x $10^{-3}$kg.

The volume of the metal base was 254.0L and for the acid pickling vessel was 304.8L and acid concentration was 0.148mol/m3. These were followed with the evaluation of material balances for the various pre plating and plating units starting from acid pickling vessel to dragout tanks where the input stream of previous unit is made to serve as an input stream to the next unit finally, 1998.6kg/day of wrist watches goes for electroplating and 351.62kg of nickel metal was required and 187.888kg of chrome metal was required for this task.

## Overall Material balance

$$Basis = 2000\frac{kg}{day}$$

$$1day = 8hours$$

$$Rust := 0.05\% \cdot Basis \qquad Mass\_flowrate\_of\_Rust = 1\ kg\ /day$$

$$Grease := 0.02\% \cdot Basis$$

$$Iron := Basis - (Rust + Grease)$$

$$Mass\_flowrate\_of\_Rust := Rust$$

$$Mass\_flowrate\_of\_Grease := Grease$$

$$Mass\_flowrate\_of\_Grease = 0.4\ kg$$

### 3.4.2 Material balance around the acid pickling unit

#### 3.4.2.1 input streams

$SPECIES_I :=$ $Mwt_I =$

| $SPECIES_I$ | $Mwt_I$ ($kg \cdot mol^{-1}$) |
|---|---|
| $Fe_2O_3$ | 160 |
| HCl | 36.5 |
| Fe | 56 |
| $FeCl_3$ | 162.2 |
| Grease | 287.27 |
| Water | 18 |

$$Mole\_of\_Rust := \frac{Rust}{160\frac{kg}{mol}}$$

$$Mole\_of\_Rust = 6.25\times 10^{-3}\ mol$$

$$Mole\_of\_HCl := 6\cdot Mole\_of\_Rust$$

$$Mole\_of\_HCl = 0.038\,mol$$

$$HCl := Mole\_of\_HCl\cdot 36.5\frac{kg}{mol}$$

$SPECIES_I :=$

| |
|---|
| $Fe_2O_3$ |
| HCl |
| Fe |
| $FeCl_3$ |
| Grease |
| Water |

$Inlet\_Mass\_1_I :=$

| |
|---|
| Rust |
| HCl |
| Iron |
| 0 |
| Grease |
| 0 |

$$Unit\_one\_input := \sum_{I=1}^{6} Inlet\_Mass\_1_I$$

$$Unit\_one\_input = 2\times 10^{3}\ kg$$

#### 3.4.2.2 evaluation of HCl concentration

$$Mass\_of\_metal\_base := Basis$$

$$Density\_of\_metal\_base := 7874\frac{kg}{m^3}$$

$$Volume\_of\_metal\_base := \frac{Mass\_of\_metal\_base}{Density\_of\_metal\_base}$$

$$Volume\_of\_metal\_base = 254.001\,L$$

$$Tank\_Volume := 1.2\cdot Volume\_of\_metal\_base$$

$$Tank\_Volume = 304.801\,L$$

$$Conc_{HCl} := \frac{Mole\_of\_HCl}{Volume\_of\_metal\_base}$$

$$Conc_{HCl} = 0.148\frac{mol}{m^3}$$

### 3.4.2.3 output stream

$Mole\_of\_Water := 3 \cdot Mole\_of\_Rust$

$Mole\_of\_FeCl3 = 0.013\,mol$

$$Mole\_of\_Iron := \frac{Iron}{56\frac{kg}{mol}}$$

$Mole\_of\_Water = 0.019\,mol$

$Outlet\_Mass\_1_I := Outlet\_Mole_I \cdot Mwt_I$

$$Mole\_of\_Grease := \frac{Grease}{287.27\frac{kg}{mol}}$$

$Mole\_of\_Grease = 1.392 \times 10^{-3}\,mol$

$Mole\_of\_Iron = 35.689\,mol$

$SPECIES_I :=$

| $SPECIES_I$ | $Outlet\_Mole_I$ |
|---|---|
| $Fe_2O_3$ | 0.0 |
| HCl | 0.0 |
| Fe | Mole_of_Iron |
| $FeCl_3$ | Mole_of_FeCl3 |
| Grease | Mole_of_Grease |
| Water | Mole_of_Water |

$SPECIES_I :=$

| $SPECIES_I$ | $Outlet\_Mass\_1_I =$ (kg) |
|---|---|
| $Fe_2O_3$ | 0 |
| HCl | 0 |
| Fe | 1.9986?10³ |
| $FeCl_3$ | 2.0275 |
| Grease | 0.4 |
| Water | 0.3375 |

$$Unit\_one\_output := \sum_{I=1}^{6} Outlet\_Mass\_1_I$$

$Unit\_one\_output = 2 \times 10^{3}\,kg$

## 3.4.3 Unit two

**Estimation of the amount of washing Water**

From solubility curve; solubility of $FeCl_3$ at 25°C

$$Solubility := 4.3 \cdot 10^{-3}\frac{mol}{m^3}$$

$$\text{Volume\_of\_Water\_Required} := \frac{\text{Mole\_of\_FeCl3}}{\text{Solubility}}$$

$\text{Volume\_of\_Water\_Required} = 2.907 \times 10^{3}\ \text{L}$

$\rho_{water} = \text{Density\_of\_water}$

$$\rho_{water} := 997.99 \frac{\text{kg}}{\text{m}^3}$$

$\text{Mass\_of\_water} := \rho_{water} \cdot \text{Volume\_of\_Water\_Requirec}$

$\text{Mass\_of\_water} = 2.901 \times 10^{3}\ \text{kg}$

### 3.4.3.1 unit two inlet

$\text{Unit\_Two\_inlet}_I := \text{Outlet\_Mass\_1}_I$

$\text{SPECIES}_I :=$ $\quad$ $\text{Unit\_Two\_inlet}_I =$

| $\text{SPECIES}_I$ | $\text{Unit\_Two\_inlet}_I$ (kg) |
|---|---|
| $Fe_2O_3$ | 0 |
| HCl | 0 |
| Fe | 1.9986?10^3 |
| $FeCl_3$ | 2.0275 |
| Grease | 0.4 |
| Water | 0.3375 |
| | |

$$\text{Total\_mass\_inlet} := \left( \sum_{I=1}^{6} \text{Unit\_Two\_inlet}_I \right) + \text{Mass\_of\_water}$$

$\text{Total\_mass\_inlet} = 4.9 \times 10^{3}\ \text{kg}$

### 3.4.3.2 unit two output

$\text{SPECIES}_I :=$ $\quad$ $\text{Outlet\_Mass\_2a}_I :=$ $\quad$ $\text{Outlet\_Mass\_2b}_I :=$

| $\text{SPECIES}_I$ | $\text{Outlet\_Mass\_2a}_I$ | $\text{Outlet\_Mass\_2b}_I$ |
|---|---|---|
| $Fe_2O_3$ | 0.0 | 0.0 |
| HCl | 0.0 | 0.0 |
| Fe | 1998.6 | 0.0 |
| $FeCl_3$ | 0.0 | 2.027 |
| Grease | 0.4 | 0.0 |
| Water | 0.0 | $2.901 \cdot 10^3$ |
| | | |

$$\text{Total\_mass\_outlet} := \sum_{I=1}^{6} \left[ \left( \text{Outlet\_Mass\_2a}_I + \text{Outlet\_Mass\_2b}_I \right) \cdot \text{kg} \right]$$

$$\text{Total\_mass\_outlet} = 4.9 \times 10^{3}\ \text{kg}$$

### 3.4.4 Unit three

**Degreasing unit**

Stearic Acid + NaOH ⟶ Soap + Water

$$\text{Mass\_of\_Grease} := \text{Grease}$$

$$\text{Mwt}_{\text{Grease}} := 287.27 \frac{\text{kg}}{\text{mol}}$$

$$\text{Grease\_Reacting\_Mole} := \frac{\text{Mass\_of\_Grease}}{\text{Mwt}_{\text{Grease}}}$$

$$\text{Grease\_Reacting\_Mole} = 1.392 \times 10^{-3}\ \text{mol}$$

$$\text{Mass\_of\_NaOH} := \text{Grease\_Reacting\_Mole} \cdot 40 \frac{\text{kg}}{\text{mol}}$$

$$\text{Mass\_of\_NaOH} = 0.056\ \text{kg}$$

#### 3.4.4.1 inlet stream

$\text{Species}_{\kappa}$ := 

$\text{Unit\_3\_Inlet}_{\kappa}$ =

| $\text{Species}_{\kappa}$ | $\text{Unit\_3\_Inlet}_{\kappa}$ (kg) |
|---|---|
| Fe | 1.9986?10³ |
| NaOH | 0.056 |
| Grease | 0.4 |
| Water | 0 |

$$\text{Unit\_3\_inlet} := \sum_{\kappa=1}^{4} \text{Unit\_3\_Inlet}_{\kappa}$$

$$\text{Unit\_3\_inlet} = 1.9991 \times 10^{3}\ \text{kg}$$

#### 3.4.4.2 outlet stream

$$\text{Mass\_of\_Soap\_formed} := \text{Grease\_Reacting\_Mole} \cdot \text{Mwt}_{\text{soap}}$$
$$\text{Mass\_of\_Soap\_formed} = 0.427\ \text{kg}$$

$\text{Mwt}_{\text{soap}}$ := [illegible] mol

$$\text{Mass\_of\_Water\_formed} := \text{Grease\_Reacting\_Mole} \cdot \text{Mwt}_{\text{water}}$$

$$Mwt_{water} \equiv 18 \frac{kg}{mol}$$

Mass_of_Water_formed = 0.0251 kg

### 3.4.4.3 unit three outlet

$Species_{\omega}$ :=

| |
|---|
| Fe |
| NaOH |
| Grease |
| Water |
| Soap |

$Unit\_3\_Outlet_{\omega}$ =

| | |
|---|---|
| 1.9986?10³ | kg |
| 0 | |
| 0 | |
| 0.02506 | |
| 0.42672 | |

$$Unit\_3\_outlet := \sum_{\omega = 1}^{5} Unit\_3\_Outlet_{\omega}$$

$Unit\_3\_outlet = 1.9991 \times 10^{3}$ kg

## 3.4.5 Unit four

### Water rinsing ( Soap Removal )

**Calculation of Amount of Water Required for Rinsing**

Solubility of Sodium Stearate at 25° C

$$Solubility_{soap} = \frac{0.1 g_{soap}}{100 g_{water}}$$ ( Shreves et.al )

$$Mass\_of\_water\_required := \frac{Mass\_of\_Soap\_formed}{Solubility_{soap}}$$

**Using 35% Excess Water for Rinsing**

Mass_of_water_required = 426.721 kg

Actual_water := Mass_of_water_required + 35%·Mass_of_water_required

Actual_water = 576.073 kg

#### 3.4.5.1 input summary

Species$_\omega$ :=

| |
|---|
| Fe |
| NaOH |
| Grease |
| Water |
| Soap |

Mass_Input_4$_\omega$ =

| | |
|---|---|
| 1.9986?10³ | kg |
| 0 | |
| 0 | |
| 576.0977 | |
| 0.4267 | |

$$UNIT\_4\_Input := \sum_{\omega=1}^{5} Mass\_Input\_4_{\omega}$$

$UNIT\_4\_Input = 2.5751\times 10^{3}$ kg

#### 3.4.5.2 out summary

Species$_\omega$ :=

| |
|---|
| Fe |
| NaOH |
| Grease |
| Water |
| Soap |

Mass_Output_4a$_\omega$

| | |
|---|---|
| 1.999?10³ | kg |
| 0 | |
| 0 | |
| 3.5 | |
| 0 | |

Mass_Output_4b$_\omega$

| | |
|---|---|
| 0 | kg |
| 0 | |
| 0 | |
| 572.598 | |
| 0.427 | |

$$UNIT\_4\_OUTPUT := \sum_{\omega} \left(Mass\_Output\_4b_{\omega} + Mass\_Output\_4a_{\omega}\right)$$

$UNIT\_4\_OUTPUT = 2.575\times 10^{3}$ kg

### 3.4.6 Unit five

**drying of base metal**

#### 3.4.6.1 inlet stream

**( water removal )**

$Mass\_Inlet\_5_{\omega} := Mass\_Output\_4a_{\omega}$

Species$_\omega$ :=

| |
|---|
| Fe |
| NaOH |
| Grease |
| Water |
| Soap |

Mass_Inlet_5$_\omega$ =

| | |
|---|---|
| 1.9986?10³ | kg |
| 0 | |
| 0 | |
| 3.5 | |
| 0 | |

#### 3.4.6.2 output stream

$Species_{\omega} :=$

| |
|---|
| Fe |
| NaOH |
| Grease |
| Water |
| Soap |

$Mass\_Output\_5a_{\omega} :=$

| | |
|---|---|
| 1.9986?10³ | kg |
| 0 | |
| 0 | |
| 0 | |
| 0 | |

$Mass\_Output\_5b_{\omega}$

| | |
|---|---|
| 0 | kg |
| 0 | |
| 0 | |
| 3.5 | |
| 0 | |

### *3.4.7 Calculation of the mass of nickel required per metal base*

density of nickel

$$\rho_{nickel} := 8908\frac{kg}{m^3}$$

mass of nickel per metal base

$$M_{nickel} := \rho_{nickel} \cdot VOLUME\_OF\_NICKE$$

$$M_{nickel} = 0.021\,kg$$

$Chain\_Unit\_Mass := 0.1200kg$

$$Chain\_Total\_Number := \frac{METAL\_BASE}{Chain\_Unit\_Mass}$$

$Chain\_Total\_Number = 1.665\times 10^{4}$

$TOTAL\_NICKEL\_REQUIRED := Chain\_Total\_Number \cdot M_{nickel}$

$TOTAL\_NICKEL\_REQUIRED = 351.62kg$

#### 3.4.7.1 input summary

$Species_q :=$

| |
|---|
| Base_Meta |
| Nickel |

$Unit\_6\_Input_q =$

| | |
|---|---|
| 1.999?10³ | kg |
| 351.62 | |

$$UNIT\_6\_INPUT := \sum_{q} Unit\_6\_Input_q$$

$UNIT\_6\_INPUT = 2.35\times 10^{3}\ kg$

$Amount\_of\_solution := 1.2 \cdot METAL\_BASE$

$Amount\_of\_solution = 2.398\times 10^{3}\ kg$

### 3.4.7.2 output stream

$\text{Associated\_Solution} := 0.95\% \cdot \text{Amount\_of\_solution}$

$\text{Associated\_Solution} = 22.784\text{kg}$

$\text{Species}_{\phi} :=$

| |
|---|
| Base_Metal |
| Nickel |
| Solution |

$\text{Unit\_6\_Output}_{\phi} =$

| | |
|---|---|
| 1.999?10^3 | kg |
| 351.62 | |
| 22.784 | |

$$\text{UNIT\_6\_OUTPUT} := \sum_{\phi = 1}^{3} \text{Unit\_6\_Output}_{\phi}$$

$\text{UNIT\_6\_OUTPUT} = 2.373 \times 10^{3}\ \text{kg}$

## 3.4.8 Unit seven

**DRAG OUT (WATER RINSING USING FOUR CASCADE TANK)**

$\text{Unit\_7\_Input}_{\phi} := \text{Unit\_6\_Output}_{\phi}$

$\text{Species}_{\phi} :=$

| |
|---|
| Base_Metal |
| Nickel |
| Solution |

$\text{Unit\_7\_Input}_{\phi} =$

| | |
|---|---|
| 1.9986?10^3 | kg |
| 351.6197 | |
| 22.784 | |

$$\text{Solution\_Solubility} = \frac{1.25\text{g}}{100\text{g}_{\text{water}}}$$

$$\text{Amount\_of\_Water\_Required} := \frac{\text{Associated\_Solution}}{\text{Solution\_Solubility}}$$

$\text{Amount\_of\_Water\_Required} = 1.823 \times 10^{3}\ \text{kg}$

$$\text{UNIT\_7\_INPUT} := \text{Amount\_of\_Water\_Required} + \sum_{\phi} \text{Unit\_7\_Input}_{\phi}$$

$\text{UNIT\_7\_INPUT} = 4.196 \times 10^{3}\ \text{kg}$

### 3.4.8 Output streams

$\text{Associated\_Water} := 0.50\% \cdot \text{Amount\_of\_Water\_Required}$

$\text{Associated\_Water} = 9.114\text{kg}$

$Species_{\phi} :=$

| |
|---|
| Base_Metal |
| Nickel |
| Water |
| Solution |

$EXIT\_7A_{\tau} =$

| | |
|---|---|
| 1.999?10^3 | kg |
| 351.62 | |
| 9.114 | |
| 0 | |

$EXIT\_7B_{\tau} =$

| | |
|---|---|
| 0 | kg |
| 0 | |
| 1.814?10^3 | |
| 22.784 | |

$$UNIT\_7\_OUTPUT := \sum_{\tau} \left( EXIT\_7A_{\tau} + EXIT\_7B_{\tau} \right)$$

$UNIT\_7\_OUTPUT = 4.196 \times 10^{3}$ kg

**Air dryer**

### 3.4.9 Unit 8

#### 3.4.9.1 input

$Species_{\phi} :=$

| |
|---|
| Base_Metal |
| Nickel |
| Water |
| Solution |

$Unit\_8\_Input_{\tau} =$

| | |
|---|---|
| 1.9986?10^3 | kg |
| 351.6197 | |
| 9.1136 | |
| 0 | |

#### 3.4.9.2 output

### 3.4.10 Chrome plating unit

#### *3.4.10.1 determination of the amount of chrome needed for plating using the classical exide method.*

$Species_{\phi} :=$

| |
|---|
| Base_Metal |
| Nickel |
| Water |
| Solution |

$Unit\_8a\_Output_{\tau} =$

| | |
|---|---|
| 1.9986?10^3 | kg |
| 351.6197 | |
| 0 | |
| 0 | |

$Unit\_8b\_Output_{\tau}$

| | |
|---|---|
| 0 | kg |
| 0 | |
| 9.114 | |
| 0 | |

$Total\_Surface\_Area = 7.9 \times 10^{-3}\ m^{2}$

$CHROME\_THICKNESS := 0.02cm$

$VOLUME\_OF\_CHROME := Total\_Surface\_Area \cdot CHROME\_THICKNES!$

( Steven S. Zumdahl, 1998. )

### 3.4..10.2 calculations of the volume of chrome required per metal base

VOLUME_OF_CHROME= $1.58 \times 10^{-3}$ L

### 3.4..10.3 calculation of the mass of chrome required per metal base

density of chrome

$$\rho_{chrome} := 7140 \frac{kg}{m^3}$$

mass of chrome per metal base

$$M_{chrome} := \rho_{chrome} \cdot VOLUME\_OF\_CHROM]$$

$$M_{chrome} = 0.011\, kg$$

Chain_Unit_Mass= 0.12 kg

Chain_Total_Number = $1.665 \times 10^4$

TOTAL_CHROME_REQUIRED= 187.888kg

TOTAL_CHROME_REQUIRED= Chain_Total_Number·$M_{chrome}$

### 3.4.10.4 input summary

Species$_\phi$ :=

| |
|---|
| Base_Metal |
| Nickel |
| Water |
| Chrome |

Unit_9a_Input$_\tau$ =

| | |
|---|---|
| 1.9986?10³ | kg |
| 351.6197 | |
| 0 | |
| 0 | |

Unit_9b_Input$_\tau$ =

| | |
|---|---|
| 0 | kg |
| 0 | |
| 0 | |
| 187.888 | |

$$Unit\_9\_Output\_ := \sum_{\tau} \left( Unit\_9a\_Input_{\tau} + Unit\_9b\_Input_{\tau} \right)$$

Unit_9_Output_ = $2.5381 \times 10^3$ kg

### 3.4.10.5 output summary

$$Unit\_9\_Output_{\tau} := \left( Unit\_9a\_Input_{\tau} + Unit\_9b\_Input_{\tau} \right)$$

Species$_\phi$ :=

| |
|---|
| Base_Metal |
| Nickel |
| Water |
| Chrome |

Unit_9_Output$_\tau$ =

| | |
|---|---|
| 1.9986?10³ | kg |
| 351.6197 | |
| 0 | |
| 187.8884 | |

$$Unit\_9\_Input := \sum_{\tau} \left( Unit\_9a\_Input_{\tau} + Unit\_9b\_Input_{\tau} \right)$$

## 3.5 Energy Balance

MathCAD was Similarly used to carry out the energy balance, knowing the temperature of each of the unit; from program tool bar and thermodynamic package the different change in enthalpy of formation of chemical species involved were selected and consequently, for each species the product of mass and enthalpy($\Delta H$) multiplied by 1000J/kg gives energy balance for each component and the MathCAD automatically calculate. This is done for each unit starting from acid pickling tank to drying unit. Finally, the time for nickel plating was 3.56hrs energy spent was 20.89 x $10^5$j and power was 22.5 watts while time for chrome plating was 1.42hrs energy spent was 2.557 x $10^7$ j and the power was 20.5 watts.

## 3.5.1 Energy balance

### 3.5.1.1 energy balance around unit one at 25$^{O}$C

$$Q_{one.IN} = mass\_in\_1_1 \Delta H_1$$

$$Q_{IN} = Q_{OUT}$$

$SPECIES_{\omega} :=$ , $Mass\_Out\_1_{\omega} :=$ , $\Delta H_{1_{\omega}} :=$

| SPECIES | Mass_Out_1 | ΔH1 |
|---|---|---|
| $Fe_2O_3$ | 0 | 7950.63 |
| HCl | 0 | 2534.2 |
| $FeCl_3$ | 2.0275 | 2999.5 |
| Grease | 0.4 | 3150.1 |
| Water | 2.025 | 15808 |

( Steven S. Zumdahl, 1998. )

$$Q_{one.IN} := \sum_{\omega} \left[ \left( mass\_in\_1_{\omega} \cdot \Delta H_{1_{\omega}} \right) \frac{1000J}{kg} \right]$$

$$Q_{one.IN} = 1.268 \times 10^{7}\ J$$

$Q_{one.OUT} = Mass\_out\_1_1 \cdot \Delta H_2$

$SPECIES_{\omega} :=$

| |
|---|
| $Fe_2O_3$ |
| HCl |
| $FeCl_3$ |
| Grease |
| Water |

$mass\_in\_1_{\omega} :=$

| |
|---|
| Rust |
| HCl |
| 0 |
| Grease |
| 0 |

$\Delta H_{2_{\omega}} :=$

| |
|---|
| 7950.63 |
| 2534.2 |
| 2999.5 |
| 3150.1 |
| 15808 |

$$Q_{one.OUT} := \sum_{\omega} \left[ \left( Mass\_Out\_1_{\omega} \cdot \Delta H_{2_{\omega}} \right) \cdot 1000 \right]$$

$Q_{one.OUT} = 3.935 \times 10^{7}$ J

### 3.5.1.2 calculation of energy required

$Q_{RQD} = Quantity\_of\_Energy\_Require($

$Q_{RQD} := Q_{one.OUT} - Q_{one.IN}$

$Q_{RQD} = 2.667 \times 10^{7}$ J

## 3.5.2 Energy balance around unit two at 25°c

### 3.5.2.1 Input energy

$Q_{two.IN} = Mass\_Out\_1_{\omega} \cdot \Delta H_{2_{\omega}}$

$Q_{two.IN} = Q_{two.OUT}$

$SPECIES_{\omega} :=$

| |
|---|
| $Fe_2O_3$ |
| HCl |
| $FeCl_3$ |
| Grease |
| Water |

$Mass\_Out\_1_{\omega} :=$

| |
|---|
| 0 |
| 0 |
| 2.0275 |
| 0.4 |
| 2.025 |

$\Delta H_{.2_{\omega}} :=$

| |
|---|
| 7950.63 |
| 2534.2 |
| 2999.5 |
| 3150.1 |
| 15808 |

$$Q_{two.IN} := \sum_{\omega} \left[ \left( Mass\_Out\_1_{\omega} \cdot \Delta H_{.2_{\omega}} \right) \cdot 1000J \right]$$

$$Q_{two.IN} = 3.935\times 10^{7}\ J$$

$$Q_{two.OUT} := Q_{two.IN}$$

$$Q_{two.OUT} = 3.935\times 10^{7}\ J$$

## 3.5.3 Energy balance around unit three

**Input Energy** **At 25$^{O}$C**

$Species_{\kappa}$ :=

| |
|---|
| Fe |
| NaOH |
| Grease |
| Water |

$Unit\_3\_Inlet_{\kappa}$ =

| | |
|---|---|
| 1.9986?10$^{3}$ | kg |
| 0.056 | |
| 0.4 | |
| 0 | |

$\Delta H\_3_{\kappa}$ :=

| |
|---|
| 0 |
| -4555.1 |
| -3150.1 |
| -15808 |

$$Q_{three.IN} := \sum_{\kappa} \left[ \left( Unit\_3\_Inlet_{\kappa} \cdot \Delta H\_3_{\kappa} \right) \cdot 1000 \frac{J}{kg} \right]$$

**Output Energy** **At 50$^{O}$C**

$Species_{\omega}$ :=

| |
|---|
| Fe |
| NaOH |
| Grease |
| Water |
| Soap |

$Unit\_3\_Outlet_{\omega}$ =

| | |
|---|---|
| 1.9986?10$^{3}$ | kg |
| 0 | |
| 0 | |
| 0.0251 | |
| 0.4267 | |

$\Delta H_{\_3_{\omega}}$ :=

| |
|---|
| 0 |
| -4327.8 |
| -3098.4 |
| -15707 |
| -2513.9 |

$$Q_{three.OUT} := \sum_{\omega} \left[ \left( Unit\_3\_Outlet_{\omega} \cdot \Delta H_{\_3_{\omega}} \right) \cdot 1000 \frac{J}{kg} \right]$$

### 3.5.3.1 Energy balance equation

$$Q_{three.IN} + Q_{\chi} = Q_{three.OUT}$$

$$Q_{\chi} = ENERGY\_REQUIREI$$

$$Q_{\chi} := Q_{three.OUT} - Q_{three.IN}$$

$$Q_{\chi} = 4.872\times 10^{4}\ J$$

### 3.5.4 Energy balance around unit four

**Energy Input** **At 50°C**

$Species_{\omega} :=$

| |
|---|
| Fe |
| NaOH |
| Grease |
| Water |
| Soap |

$Unit\_3\_Outlet_{\omega} =$

| | |
|---|---|
| 1.9986?10³ | kg |
| 0 | |
| 0 | |
| 0.0251 | |
| 0.4267 | |

$\Delta H\_4_{\omega} :=$

| |
|---|
| 0 |
| -4327.8 |
| -3098.4 |
| -15707 |
| -2513.9 |

$$Q_{four.IN} := \sum_{\omega} \left[ \left( Mass\_Output\_4a_{\omega} \cdot \Delta H\_4_{\omega} \right) \cdot 1000 \frac{J}{kg} \right]$$

**Energy Output** **At 25°C**

$Species_{\omega} :=$

| |
|---|
| Fe |
| NaOH |
| Grease |
| Water |
| Soap |

$Mass\_Output\_4a_{\omega} =$

| | |
|---|---|
| 1.9986?10³ | kg |
| 0 | |
| 0 | |
| 3.5 | |
| 0 | |

$\Delta H\_\_4A_{\omega} :=$

| |
|---|
| 0 |
| -4555.1 |
| -3150.1 |
| -15808 |
| -2534.2 |

$$Q\_4A_{out} := \sum_{\omega} \left( Mass\_Output\_4a_{\omega} \cdot \Delta H\_\_4A_{\omega} \cdot 1000 \frac{J}{kg} \right)$$

$Species_{\omega} :=$

| |
|---|
| Fe |
| NaOH |
| Grease |
| Water |
| Soap |

$Mass\_Output\_4b_{\omega}$

| | |
|---|---|
| 0 | kg |
| 0 | |
| 0 | |
| 572.598 | |
| 0.427 | |

$\Delta H\_\_4B_{\omega} :=$

| |
|---|
| 0 |
| -4555.1 |
| -3150.1 |
| -15808 |
| -1024.2 |

$$Q_{4B.out} := \sum_{\omega} \left[ \left( Mass\_Output\_4b_{\omega} \cdot \Delta H\_\_4B_{\omega} \right) \cdot 1000 \frac{J}{kg} \right]$$

$$Q_{four.OUT} := Q\_4A_{out} + Q_{4B.out}$$

$$Q_{\Psi} := Q_{four.IN} - Q_{four.OUT}$$

$Q_{\Psi} = 9.052\times 10^{9}$ J

$Q_{\Psi}$ = Amount_of_Energy_Removec

### 3.5.5 Energy balance around unit five

ENERGY_IN= ENERGY_OU1

**Input Energy At 25$^{O}$C**

$Species_{\omega}$ :=

| |
|---|
| Fe |
| NaOH |
| Grease |
| Water |
| Soap |

$Mass\_Inlet\_5_{\omega}$ =

| | |
|---|---|
| 1.999?10$^{3}$ | kg |
| 0 | |
| 0 | |
| 3.5 | |
| 0 | |

$\Delta H\_5_{\omega}$ :=

| |
|---|
| 0 |
| -4555.1 |
| -3150.1 |
| -15808 |
| -2534.2 |

$$Q_{five.IN} := \sum_{\omega}\left[\left(Mass\_Inlet\_5_{\omega}\cdot\Delta H\_5_{\omega}\right)\cdot 1000\frac{J}{kg}\right]$$

$Q_{R}$ = ENERGY_REQUIRED_TO_DRIVE_AWAY_WATER_MOLECUL

$Q_{R} = M\cdot C_{P}\cdot\Delta T$

$M := 3.5kg$

$C_{P} := 4185\frac{J}{kg\cdot K}$

$\Delta T := (303 - 298)K$

$Q_{R} = 7.324\times 10^{4}$ J

$UNIT\_5\_EXIT\_ENERGY := Q_{R} - Q_{five.IN}$

$UNIT\_5\_EXIT\_ENERGY = 5.54\times 10^{7}$ J

## 3.5.6 Energy balance around unit six

$Species_q :=$

| |
|---|
| Base_Metal |
| Nickel |

$Unit\_6\_Input_q =$

| | |
|---|---|
| 1.9986?10$^3$ | kg |
| 351.6197 | |

$$Ni \longrightarrow Ni^{2+} + 2e^-$$

**Applying Faraday's Law**

$W_{Ni} =$ MOLECULAR_WEIGHT_OF_NICKE

$$W_{Ni} := 58.69 \frac{kg}{mol}$$

$M_{Ni} =$ MASS_OF_NICKEL_DEPOSITEI

$M_{Ni} :=$ TOTAL_NICKEL_REQUIRE

$n_{Ni} =$ MOLE_OF_NICKEL_DEPOSITEI

$$n_{Ni} := \frac{M_{Ni}}{W_{Ni}}$$

$$n_{Ni} = 5.991\, mol$$

$2 mol \cdot e^- = 96486 columb$ ( Faraday's Law )

$M_{Ni} = E \cdot I \cdot T$ .....eqn_1

E is the Electrochemical Equivalence

I is the Current Density
T is the time required for Plating

Calculation of Amount of Columb Required

$A_{columb} =$ Amount_of_Columb

$$A_{columb} := n_{Ni} \cdot \frac{96486C}{2mol}$$

$$A_{columb} = 2.89 \times 10^5\, C$$

From Literature, $I := 22.5 \frac{C}{s}$

From eqn_1, $\frac{M_{Ni}}{E} = I \cdot T$

$$\frac{M_{Ni}}{E} = A_{columb}$$

Then,

$$A_{columb} = I \cdot T$$

$$Time\_Required := \frac{A_{columb}}{I}$$

$$Time\_Required = 1.285 \times 10^{4}\ s$$

$$Time\_Required = 3.569\ hr$$

$$Q_{Plating} = Energy\_Required\_for\_Platinc$$

$$Q_{Plating} = I \cdot V \cdot Time\_Requirec$$

$$V = Voltage\_Require$$

$$V := 220volt$$

$$Q_{Plating} = 2.89 \times 10^{5}\ J$$

$$Power := \frac{Q_{Plating}}{Time\_Required}$$

$$Power = 22.5\ W$$

## 3.5.7 Chrome plating unit

$$Cr \longrightarrow Cr^{3+} + 3e^{-}$$

### 3.5.7.1 Applying Faraday's Law

$$W_{Cr} = MOLECULAR\_WEIGHT\_OF\_CHROMIU$$

$$M_{Cr} = MASS\_OF\_CHROME\_DEPOSITEI$$

$$W_{Cr} := 51.9961 \frac{kg}{mol}$$

$$M_{Cr} := TOTAL\_CHROME\_REQUIREI$$

$n_{Ni}$ = MOLE_OF_CHROME_DEPOSITED

$$n_{Cr} := \frac{M_{Cr}}{W_{Cr}}$$

$n_{Cr} = 3.614\,mol$

$3mol \cdot e^{-} = 96486 columb$

$M_{Ni} = E \cdot I \cdot T$

$A_{columb}$ = Amount_of_Columb

<u>Calculation of Amount of Columb Required</u>

$$A1_{columb} := n_{Cr} \cdot \frac{96486C}{3mol}$$

$A1_{columb} = 1.162 \times 10^{5}\ C$

$$Time\_\_Required := \frac{A1_{columb}}{I}$$

$Time\_\_Required = 5.165 \times 10^{3}\ s$

$Time\_\_Required = 1.243 hr$

$Q_{Plating}$ = Energy_Required_for_Plating

$Q_{Plating\_} = 2.557 \times 10^{7}\ J$

$$Power = \frac{Q\ Plating}{Time\ Required}$$

Power = 20.5

# CHAPTER FOUR

## 4.0 EQUIPMENT DESIGN

The result of the equipment that were designed are given in Table 4.1 to 4.3 and the result of the cost can be seen in Table 4.4. Detail calculation shown in Appendix i.

Table 4.1:Design Summary Vessel Parameter and Sizing for Electroplating Equipment

| Design Parameters | Acid Pickling | Washing Tank 1 | Degreasing Unit | Washing Tank 2 | Washing Tank 3 | Nickel Plating Unit | Drag Out Tank 1 |
|---|---|---|---|---|---|---|---|
| M/TYPE | Carbon Steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel |
| Diameter (m) | 1.200 | 1.198 | 0.3048 | 1.203 | 1.200 | - | 0.9405 |
| Height (m) | 1.799 | 1.797 | 1.804 | 1.799 | 1.799 | - | 1.411 |
| Length (m) | 4.801 | 3.535 | 1.676 | 1.804 | 2.515 | 3.353 | 0.9800 |
| Volume (m3) | 2.024 | 2.024 | 2.583 | 2.050 | 2.034 | 2.583 | 1.676 |
| Shell thickness | 6.350 | 6.350 | 6.350 | 6.350 | 6.350 | 6.350 | 6.350 |
| Corrosion thickness (mm) | 3.175 | 3.175 | 3.175 | 3.175 | 3.175 | 3.175 | 3.175 |
| Vessel Pressure (Kpa) | 100 | 100 | 100 | 100 | 100 | 90.00 | 90.00 |
| Joint efficiency | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| L/D Ratio | 3.000 | 5.000 | 5.000 | 5.000 | 5.000 | | |
| Allowance stress (Kpa) | 9.446 e + 004 | 9.446 e + 004 | 9.446 e + 004 | 9.446 e + 004 | 9.446 e + 004 | 9.446 e + 004 | 9.446 e + 004 |

| Design Parameter | Dragout Tank 2 | Dragout Tank 3 | Concentrator | Chrome Plating Tank |
|---|---|---|---|---|
| M/TYPE | Carbon Steel | Carbon steel | Carbon steel | Carbon steel |
| Diameter (m) | 0.9405 | 0.9405 | 0.9405 | - |
| Height (m) | 1.411 | 1.411 | 1.411 | 3.535 |
| Length (m) | 1.676 | 1.676 | 1.676 | 2.583 |
| Volume (m3) | 0.9800 | 0.9800 | 0.1223 | - |
| Shell thickness | 6.350 | 6.350 | - | 6.350 |
| Corrosion thickness (mm) | 3.175 | 3.175 | 3.175 | 3.175 |
| Vessel Pressure (Kpa) | 90 | 90 | 90 | 90.00 |
| Joint efficiency | 1.000 | 1.000 | - | 1.000 |
| L/D ratio | - | 5.000 | - | |
| Allowance stress (Kpa) | 9.446 e + 004 | 9.446 e + 004 | 9.446 e + 004 | 9.446 e + 004 |

**Table 4.2 Design Summary of Pumps Parameters and Sizing for The Entire Electroplating Process.**

| I. Design Parameter | Pump 1 | Pump 2 | Pump 3 | Pump 4 | Recycling Pump |
|---|---|---|---|---|---|
| Power | 1.978 kJ/h | 1.045 kJ/h | 2.090 kJ/h | 16.09 kJ/h | 53.71 kJ/h |
| Pressure Heat | 0.6897m | 1.012m | 1.012m | 1.012m | 1.016m |
| Duty | 5.498e' 088kw | 2.903e' 004kw | 5.305e'004 kw | 4.470e'003 kw | 1.480e'002 kw |
| Capacity | $1.560m^3$ | 0.1002 $m^3/h$ | 0.2004 $m^3/h$ | 1.543 $m^3/h$ | 5.131 $m^3/h$ |
| Heat Velocity | 017m | 001m | 90m | 009m | 007m |
| Head | -1.48e'017 | -5.557e' | -2.223e' | -1.318e' | -1.457e'007 |
| DP | 10kpa | 10kpa | 10kpa | 10.00kpa | 10.00kpa |
| Radius of Gyration | 0.1000 0.1000 | 0.1000 0,1000 | 0.1000 | | |

**Table 4.3 Design Summary of Parameter for Heater, Pre Heater Cooler.**

| Design parameter | Pre heater | Heater | Cooler |
|---|---|---|---|
| Duty | 5.466e+005kJ/h | 6.319kJ/h | -5.251e+005kJ/h |
| Pressure drops | 0.0000k/a | 0.0000k/a | 2.000k/a |
| Area (cm) | $4.320m^2$ | $4.650m^2$ | |
| Overall heat | | | |
| Loose (kJ/h) | | | |

**Table 4.4 Design Summary of Parameter for Air Dryer**

| Design parameter | Sizing |
|---|---|
| Volumetric Air flow | 7.200e+005 (ACT $m^3/h$) |
| UA | -1625Kj/c-h |
| Working fluid duty | 1.225kJ/h |
| Mass Air Flow | 8.491e+005kg/h |
| LMTD | 1.865 C |

## 4.1 Result of Equipment Costing

Exchange rate ER as at 2006 is 130 Naira for 1 Dollar as at 2006.

**Table 4.5 Costing of Equipment Using Marshall and Smith Cost Estimation Index**

| FM | | FP | |
|---|---|---|---|
| Carbon steel CS | 1.00 | < 50 P SIG | 1.00 |
| Stainless Steel SS | 3.67 | 200 | 1.15 |
| Moniel Steel | 6.34 | 400 | 1.35 |
| Titanium | 7.89 | 600 | 1.60 |

**Table4.6 Cost of Raw Material Using Direct Cost Estimation**

| Raw Material<br>$Cr (So^4)_3$ | Quantity | COST IN DOLLAR | Equivalent Cost in Naira |
|---|---|---|---|
| $Ni SiO_{4}. 6 H_2O$ | 3295 kg | 234 | 30,500 |
| $NiCl_{2}. 6H_2O$ | 10.71kg | 230 | 21,800 |
| $H_2BO4$ | 7.03 kg | 167 | 1.200 |
| $H_2SO_4$ | 1.0 x 10-2L | 19.2 | 2,500 |
| Dissolvable Nickel Anode | 40.679Kg | 98.5 | 12,800 |
| HCL | 8.4635 X 10-2 Kg | 13.8 | 1800 |
| NaOH | 3.402 x 10-2 Kg | 6.9 | 900 |
| Water required for entire process | 6.5874 x 10 3L | 65.4 | 8,500 |
| Wrist watches | 1999.0kg | 153.8 | 19,900 |

## 4.2 Summary OF Result

**Table 4.7 Result of Cost Estimation and Economic Analysis Using Marshal and Smith Cost Index Data**

| Items | Economic Analysis Marshal and Smith Cost Index ) | |
|---|---|---|
| | DOLLARS | (Naira |
| Purchase cost of equipment | 21,220.6 | 2,758,677 |
| Total fixed capital cost (TFC) | 212,205.9 | 27,586,770 |
| Working capital (WC) | 106,103 | 13,793,385 |
| Total land cost (TLC) | 21,220.6 | 2,768,677 |
| Total fixed cost invested (Tinv) | 339,529.5 | 44,138.832 |
| Labour cost | 12,732.4 | 1,655,206 |
| Plant maintenance and repairs (MC) | 16,976.5 | 2,206,941 |
| Insurance InSc | 2,122.1 | 275,867 |
| Local Taxes (Ltxc) | 4,244.1 | 551.735.4 |
| Royalties (Royc) | 2,122.1 | 275.867 |
| Laboratory cost (Labc) | 848.8 | 110,347.08 |
| Supervision (Sc) | 169.8 | 22,069.4 |
| Plant overhead cost (POHc) | 2,122.1 | 275,867 |
| Administrative cost (ADMc) | 1,061 | 137,933.85 |
| Reaserch and development cost (RADc) | 3,183.1 | 413,801.55 |
| Total fixed operating cost (TFOc) | 45,412 | 5,903,567 |
| Total annual fixed operating cost TFO | 2,270.6 | 295,178 |
| Cost of raw material (CRMc) | 1,134.9 | 147,540 |
| Annual cost of raw material (ACRMc) | 340,476.9 | 44,262,000 |
| Miscellaneous (Msc) | 212.2 | 27,586.77 |
| Utilities Cost (utc) | 84.8 | 11,034.7 |
| Packaging Pac | 4.2 | 551.7 |
| Total variable operating cost (Tvoc) | 340,778.3 | 44,301,173 |
| Annual variable cost (Tvo) annual | 17,038.9 | 2,215.058 |
| Total annual operating cost (AOCc) | 19,309.5 | 2,510,236 |
| Annual production rate (APR) | - | 181440000kg/yr. |
| Production cost per kg (PC) | 0.015 | 2.0 |
| Annual product sales (APS) | 167,483 | 21,772,800 |
| Selling price (SP) | 0.09 | 12 |
| Profit before tax (PBT) | 148,174 | 19,262,563 |
| Depreciation annual (Dep) | 15,385 | 2,000,040 |
| Tax payable (TP) | 86,312.6 | 11,220,639 |
| Profit after tax (PAT) | 61,851 | 8,041,923 |
| Net Income (NIN) | 77,245.8 | 10,041,964 |
| Pay Back Period (PBP) | - | 3.5 years |
| Rate of return on investment ROR | - | 27.28% |

## 4.3 Discussion Of Results

The small scale chrome electroplating plant was designed with the aid of computer program and process simulator. MathCAD was used to carry out the material and energy balance, Hysys was used to obtain the equipment design and process flow sheet .

The results of the equipment designed shows that the Acid Pickling unit, washing tanks, degreasing unit, Nickel plating unit, dragout unit concentrator and chrome plating unit are all rectangular shape tanks as shown in Table 4.1 to 4.13 and the corresponding result of the costing were shown in Tale 4.14 to 4.26. Marshall and Smith Cost Estimation Index approach was used for the cost estimation and economic analysis for the plant and are has shown in table 4.28. Details are shown in Appendix III.

The purchase cost of equipment was $21,220 (Twenty One Thousand Two Hundred and Twenty Dollars) and the total fixed cost to be invested on the plant was $339,529 (Three hundred and Thirty Nine Thousand Five Hundred and Twenty Nine Dollars).

Also the annual cost of raw materials was $340,476 (Three Hundred and Fourty Thousand Four Hundred and Seventy Six Dollars), the annual production rate was estimated as 181440000kg/yr and was as shown in table 4.28. The cost of chrome electroplating of 0.12kg of iron wrist watch chain was N2 and the selling price was N12 each respectively.

The plant has an annual operating cost of $2,270 (Two Thousand Two Hundred and Seventy Dollars) and the profit after tax (PAT) was

$61,851 (Six One Thousand Eight Hundred and Fifty One Dollars) while the profit before tax (PBT)) was $148,174 (One Hundred and Forty Eight Thousand One Hundred and Seventy Four Dollars. The pay back period of the capital invested on the plant was 3 ½ years and the rate of return on investment (ROR) was 27.28% . However, in this design work attention was given to the process aspect while datas are provided in Appendix I for Mechanical Technicians and Fabricators. The general observation of table 4.28 shows that electroplating is a very lucrative business the any intending business man can venture into and make handsome profit.

# CHAPTER FIVE

## 5.0 CONCLUSION

A powerful technical computer environment (MATHCAD) was used to carry out the material and energy balance of this design work while process simulator (HYSYS) was used for the equipment design and flow sheet construction. The Marshal & Smith cost index estimation approach was used. This design of 2000kg/day of chrome electroplating of a wrist watch chain plant, was made to develop a cost effective, user and environmental friendly plant, that takes into consideration the technological development of a viable economy and market structure for an electroplating plant .

The economic analysis as shown in table 4.28 shows that the cost of equipment was $21,220 (Twenty One Thousand Two and Twenty Dollar). the profit after tax of $61,851 (Sixty One Thousand Eight Hundred and Fifty One Dollars) with pay back period of 3 ½ years and rate of return (R)OR) of 27.28%. In view of all these it can be concluded that this project is economically viable.

## 5.1 Recommendation

The under listed recommendation are of paramount importance for any potential businesspersons or government bodies. Interested in electroplating business.

1. The design of the plant should be supervised by a technical personnel.
2. An adequate safety measure should be put into consideration.
3. A good electroplating bath maintenance culture ensured.
4. A Proper statistic of bath technological parameters should be kept to ensure quality product.
5. Further work remains to be done on optimization of electroplating plant.

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# APPENDIX I
# EQUIPMENT DESIGN DETAILS



## Tank: ACID PICKLING UNIT

### CONNECTIONS

#### Inlet Stream

| Stream Name | From Unit Operation |
|---|---|
| METAL | |

#### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| R | | |
| METAL | Tank: | WASHING UNIT 1 |

#### Energy Stream

| Stream Name | From Unit Operation |
|---|---|

### PARAMETERS

| | | | | | |
|---|---|---|---|---|---|
| Volume: | 2.034 m3 | Level SP: | 50.00 % | Liquid Volume | 1.017 m3 |
| Pressure: | 100.0 kPa | Pressure Drop: | 0.0000 kPa | Duty: | 0.0000 kJ/h |
| Heat Transfer Mode | Heating | | | | |

#### User Variables

### RATING

#### Sizing

| Cylinder | | Vertical | | Separator has a Boot: No | |
|---|---|---|---|---|---|
| | 2.034 m3 | Diameter | 1.200 m | Height | 1.799 |

#### Nozzles

| | | | | | |
|---|---|---|---|---|---|
| evation Relative to Ground Level | 0.0000 m | Diameter | 1.200 m | Height | 1.799 |

| | | BASE METAL | HCl | WATER |
|---|---|---|---|---|
| er | (m) | 8.997e-002 | 8.997e-002 | 8.997e-002 |
| n (Base) | (m) | 0.8997 | 0.8997 | 1.799 |
| n (Ground) | (m) | 0.8997 | 0.8997 | 1.799 |
| n (% of Height) | (%) | 50.00 | 50.00 | 100.00 |
| | | BASE METAL | | |
| er | (m) | 8.997e-002 | | |
| n (Base) | (m) | 0.0000 | | |
| n (Ground) | (m) | 0.0000 | | |
| n (% of Height) | (%) | 0.00 | | |

#### Detailed Heat Loss Parameters

| | | | |
|---|---|---|---|
| Heat Loss (kJ/h) | 0.0000 | Area (m2) | 6.782 |

#### Temperature Profile

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0.0000 | Inner Wall (C) | 25.00 | Outer Vessel (C) | 25.00 | Outer Insulation (C) | 25.00 | Ambient (C) | 25.00 |

#### Conduction

| | | Metal | Insulation |
|---|---|---|---|
| ss | (m) | 1.000e-002 | 3.000e-002 |
| | (kJ/kg-C) | 0.4730 | 0.8200 |
| | (kg/m3) | 7801 | 520.0 |
| ivity | (W/m-K) | 45.00 | 0.1500 |

#### Convection

| | | | | | |
|---|---|---|---|---|---|
| ap Phase U (kJ/h-m2-C) | 7200 | Inside Liq Phase U (kJ/h-m2-C) | --- | Outside U (kJ/h-m2-C) | 54.00 |

#### Level Taps: Level Tap Specification

| ap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

#### Level Taps: Calculated Level Tap Values

| ap | Liquid Level | Aqueous Level |
|---|---|---|

175 175

#### Options

# Tank: ACID PICKLING UNIT (continued)

| | | | |
|---|---|---|---|
| PV Work Term Contribution | (%) | 100.00 * | |

## DYNAMICS

### Vessel Parameters: Initialize from Product

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume | (m3) | 2.034 * | Level Calculator | | Vertical cylinder |
| Vessel Diameter | (m) | 1.200 | Fraction Calculator | | Use levels and nozzles |
| Vessel Height | (m) | 1.799 | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 100.0 |

### Holdup: Vessel Levels

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | --- | --- | 0.0000 |
| Liquid | --- | --- | 0.0000 |
| Aqueous | --- | --- | 0.0000 |

### Holdup: Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 | 0.0000 |
| Liquid | 0.0000 | 0.0000 | 0.0000 |
| Aqueous | 0.0000 | 0.0000 | 0.0000 |
| **Total** | **0.0000** | **0.0000** | **0.0000** |

# Vessel Sizing: Vessel Sizing-8

## Vertical Seperator Properties: CHROMEPLATING TANK

| | | | | |
|---|---|---|---|---|
| L/D Ratio | 5.000 * | Demister to Top | (m) | 0.3048 * |
| Liq. Res. Time (seconds) | 300.0 * | | | |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.7068 * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 7476 | Associated Cost ($US) | 1658 | Total Cost (FOB $US) | 9134 |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 0.6096 | Liquid Residence Time | (seconds) | 300.0 |
| Total Length | (m) | 3.353 | Liquid Surge Height | (m) | 1.521 |
| L/D Ratio | | 5.000 | LLSD | (m) | 0.4572 |
| Max. Allowable Vapour Velocity | (m/s) | 0.6644 | Liquid Res. Time at LLSD | (seconds) | 82.94 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | 0.3048 |
| Inlet Nozzle to Demister | (m) | 1.070 | Ellipsoidal Head | (m) | 0.1524 |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | 1.832 |

# Tank: TEMPORARY STORAGE TANK

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| HROME_SOLUTION | Separator | CHROME SOLUTION CONCENTRATOR |

### Outlet Stream

| Stream Name | To Unit Operation |
|---|---|
| | |
| | |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| | |

## PARAMETERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ssel Volume: | -- | Level SP: | 50.00 % | Liquid Volume: | -- | | |
| ssel Pressure: | 90.00 kPa | Pressure Drop: | 0.0000 kPa * | Duty: | 0.0000 kJ/h | Heat Transfer Mode: | Heating |

### User Variables

## RATING

### Sizing

| Cylinder | | Vertical | | Separator has a Boot: No | |
|---|---|---|---|---|---|
| ume | -- | Diameter | -- | Height | -- |

### Nozzles

| | | | | | |
|---|---|---|---|---|---|
| se Elevation Relative to Ground Level | 0.0000 m * | Diameter | -- | Height | -- |

| | | CHROME_SOLUTION | ... | ... |
|---|---|---|---|---|
| meter | (m) | 5.000e-002 | 5.000e-002 | 5.000e-002 |
| vation (Base) | (m) | 0.0000 | 0.0000 | 0.0000 |
| vation (Ground) | (m) | 0.0000 | 0.0000 | 0.0000 |
| vation (% of Height) | (%) | -- | -- | -- |

### Level Taps: Level Tap Specification

| vel Tap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

### Level Taps: Calculated Level Tap Values

| vel Tap | Liquid Level | Aqueous Level |
|---|---|---|

### Options

| | | | | |
|---|---|---|---|---|
| Work Term Contribution | (%) | 100.00 * | | |

## DYNAMICS

### Vessel Parameters: Initialize from Product

| | | | | | |
|---|---|---|---|---|---|
| ssel Volume | (m3) | -- | Level Calculator | | Vertical cylinder |
| ssel Diameter | (m) | -- | Fraction Calculator | | Use levels and nozzles |
| ssel Height | (m) | -- | Feed Delta P | (kPa) | 0.0000 * |
| uid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 90.00 |

### Holdup: Vessel Levels

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | -- | -- | 0.0000 |
| Liquid | -- | -- | 0.0000 |
| Aqueous | -- | -- | 0.0000 |

### Holdup: Details

# Tank: TEMPORARY STORAGE TANK (continued)

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| **Total** | 0.0000 | 0.0000 | 0.0000 |


* Specified by user.

| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: | C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.3.hsc |
|---|---|---|---|
| | | Unit Set: | SI |
| | | Date/Time: | Wed Feb 07 12:21:17 2007 |

# Conversion Reactor: CHROME PLATING TANK

## CONNECTIONS

### Inlet Stream Connections

| Stream Name | From Unit Operation | |
|---|---|---|
| SOLUTION | | |
| PLATED METAL | Tank | DRAGOUT TANK.3 |

### Outlet Stream Connections

| Stream Name | To Unit Operation | |
|---|---|---|
| CHROMED METAL | Tank: | DRAGOUT TANK.4 |
| L.SOLN | Mixer: | CHROME SOLUTION MIXER |

### Energy Stream Connections

| Stream Name | From Unit Operation |
|---|---|
| Q.TH | |

## PARAMETERS

| Physical Parameters | | Optional Heat Transfer: | Heating |
|---|---|---|---|
| Delta P | Vessel Volume | Duty | Energy Stream |
| 0.0000 kPa * | -- | 6.641e+006 kJ/h | Q.TH |

### User Variables

## RATING

### Sizing

| Cylinder | | Vertical | | Reactor has a Boot: | No |
|---|---|---|---|---|---|
| Volume | -- | Diameter | -- | Height | -- |

### Nozzles

| Base Elevation Relative to Ground Level | 0.0000 m * | Diameter | -- | Height | -- |
|---|---|---|---|---|---|

| | | SOLUTION | PLATED METAL | CHROMED METAL |
|---|---|---|---|---|
| Diameter | (m) | 5.000e-002 | 5.000e-002 | 5.000e-002 |
| Elevation (Base) | (m) | 0.0000 | 0.0000 | 0.0000 |
| Elevation (Ground) | (m) | 0.0000 | 0.0000 | 0.0000 |
| Elevation (% of Height) | (%) | -- | -- | -- |
| | | L.SOLN | | |
| Diameter | (m) | 5.000e-002 | | |
| Elevation (Base) | (m) | 0.0000 | | |
| Elevation (Ground) | (m) | 0.0000 | | |
| Elevation (% of Height) | (%) | -- | | |

## DYNAMICS

### Vessel Parameters: Initialize from Product

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume | (m3) | -- | Level Calculator | | Vertical cylinder |
| Vessel Diameter | (m) | -- | Fraction Calculator | | Use levels and nozzles |
| Vessel Height | (m) | -- | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 90.00 |

### Holdup: Vessel Levels

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | -- | -- | 0.0000 |
| Liquid | -- | -- | 0.0000 |
| Aqueous | -- | -- | 0.0000 |

### Holdup: Details

# Conversion Reactor: CHROME PLATING TANK (continued)

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| Total | 0.0000 | 0.0000 | 0.0000 |

Duty Valve Source : Direct_Q

| SP (kJ/h) | Min. Available (kJ/h) | Max. Available (kJ/h) |
|---|---|---|
| 6.641e+006 * | -- | -- |

Liquid Heater Height as % of Vessel Volume

| | |
|---|---|
| Top of Heater : 5.00 % * | Bottom of Heater : 0.00 % * |

Heat Flow into the PFR: Heating

| | | |
|---|---|---|
| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.2.hsc<br>Unit Set: SI<br>Date/Time: Wed Feb 07 12:28:27 2007 |

# Separator: CHROME SOLUTION CONCENTRATOR

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| .L | Heater | PRE_HEATER |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| WATER_VAPOUR | | |
| CHROME_SOLUTION | Tank: | TEMPORARY STORAGE TANK |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| | |

## PARAMETERS

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume: | 0.9966 m3 | Level SP: | 50.00 % | Liquid Volume: | 0.4983 m3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vessel Pressure: | 90.00 kPa | Pressure Drop: | 0.0000 kPa * | Duty: | 0.0000 kJ/h | Heat Transfer Mode: | Heating |

### User Variables

## RATING

### Sizing

| | | | | | |
|---|---|---|---|---|---|
| Cylinder | | Vertical | | Separator has a Boot: No | |
| Volume | 0.9966 m3 | Diameter | 0.8700 m * | Height | 1.676 * |

### Nozzles

| | | | | | |
|---|---|---|---|---|---|
| Base Elevation Relative to Ground Level | 0.0000 m * | Diameter | 0.8700 m * | Height | 1.676 * |

| | | .L | WATER_VAPOUR | CHROME_SOLUTION |
|---|---|---|---|---|
| Diameter | (m) | 8.382e-002 | 8.382e-002 | 8.382e-002 |
| Elevation (Base) | (m) | 0.8382 | 1.676 | 0.0000 |
| Elevation (Ground) | (m) | 0.8382 | 1.676 | 0.0000 |
| Elevation (% of Height) | (%) | 50.00 | 100.00 | 0.00 |

### Detailed Heat Loss Parameters

| | | | |
|---|---|---|---|
| Overall Heat Loss (kJ/h) | 0.0000 | Area (m2) | 4.582 |

### Temperature Profile

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fluid (C) | 0.0000 * | Inner Wall (C) | 25.00 | Outer Vessel (C) | 25.00 | Outer Insulation (C) | 25.00 | Ambient (C) | 25.00 |

### Conduction

| | | Metal | Insulation |
|---|---|---|---|
| Thickness | (m) | 1.000e-002 | 3.000e-002 |
| Cp | (kJ/kg-C) | 0.4730 | 0.8200 |
| Density | (kg/m3) | 7801 | 520.0 |
| Conductivity | (W/m-K) | 45.00 | 0.1500 |

### Convection

| | | | | | |
|---|---|---|---|---|---|
| Inside Vap Phase U (kJ/h-m2-C) | 7200 | Inside Liq Phase U (kJ/h-m2-C) | -- | Outside U (kJ/h-m2-C) | 54.00 |

### Level Taps: Level Tap Specification

| Level Tap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

### Level Taps: Calculated Level Tap Values

| Level Tap | Liquid Level | Aqueous Level |
|---|---|---|

### Options

| | | | | |
|---|---|---|---|---|
| PV Work Term Contribution | (%) | 100.00 * | | |

## DYNAMICS

### Vessel Parameters: Initialize from Product

# Separator: CHROME SOLUTION CONCENTRATOR (continued)

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume | (m3) | 0.9966 | Level Calculator | | Vertical cylinder |
| Vessel Diameter | (m) | 0.8700 * | Fraction Calculator | | Use levels and nozzles |
| Vessel Height | (m) | 1.676 * | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 90.00 |

## Holdup: Vessel Levels

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | -- | -- | 0.0000 |
| Liquid | -- | -- | 0.0000 |
| Aqueous | -- | -- | 0.0000 |

## Holdup: Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| Total | 0.0000 | 0.0000 | 0.0000 |

# Mixer: CHROME SOLUTION MIXER

## CONNECTIONS

### Inlet Stream

| STREAM NAME | FROM UNIT OPERATION | |
|---|---|---|
| ;OLN | Conversion Reactor | CHROME PLATING TANK |
| ;OLN.2 | Tank | DRAGOUT TANK.4 |
| ;OLN.3 | Tank | DRAGOUT TANK.5 |
| ;OLN.4 | Tank | DRAGOUT TANK 6 |

### Outlet Stream

| STREAM NAME | TO UNIT OPERATION | |
|---|---|---|
| IROME SOLUTION | Heater | PRE_HEATER |

## PARAMETERS

### User Variables

## NOZZLE PARAMETERS

se Elevation Relative to Ground Level 0.0000 m *

| | | L.SOLN | L.SOLN.2 | L.SOLN.3 |
|---|---|---|---|---|
| ımeter | (m) | 5.000e-002 | 5.000e-002 | 5.000e-002 |
| ·vation (Base) | (m) | 0.0000 | 0.0000 | 0.0000 |
| ·vation (Ground) | (m) | 0.0000 | 0.0000 | 0.0000 |
| | | L.SOLN.4 | CHROME SOLUTION | |
| ımeter | (m) | 5.000e-002 | 5.000e-002 | |
| ·vation (Base) | (m) | 0.0000 | 0.0000 | |
| ·vation (Ground) | (m) | 0.0000 | 0.0000 | |

## DYNAMICS

Pressure Specification: Set Outlet to Lowest Inlet

### Holdup Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| **Total** | 0.0000 | 0.0000 | 0.0000 |

| | | |
|---|---|---|
| PROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.2.hsc<br>Unit Set: SI<br>Date/Time: Wed Feb 07 12:25:42 2007 |

# Cooler: COOLER 1

## CONNECTIONS

### Inlet Stream

| STREAM NAME | FROM UNIT OPERATION | |
|---|---|---|
| CENTRATED NICKEL SOLUTION | Separator | CONCENTRATOR |

### Outlet Stream

| STREAM NAME | TO UNIT OPERATION | |
|---|---|---|
| | Pump | P-100 |

### Energy Stream

| STREAM NAME | TO UNIT OPERATION |
|---|---|
| R | |

## PARAMETERS

| | | | | | |
|---|---|---|---|---|---|
| ure Drop: | 2.000 kPa * | Duty: | 1.235e+006 kJ/h | Volume: | 0.1000 m3 |
| ion: | Not Selected | Zones: | 1 | | |

## User Variables

## NOZZLE PARAMETERS

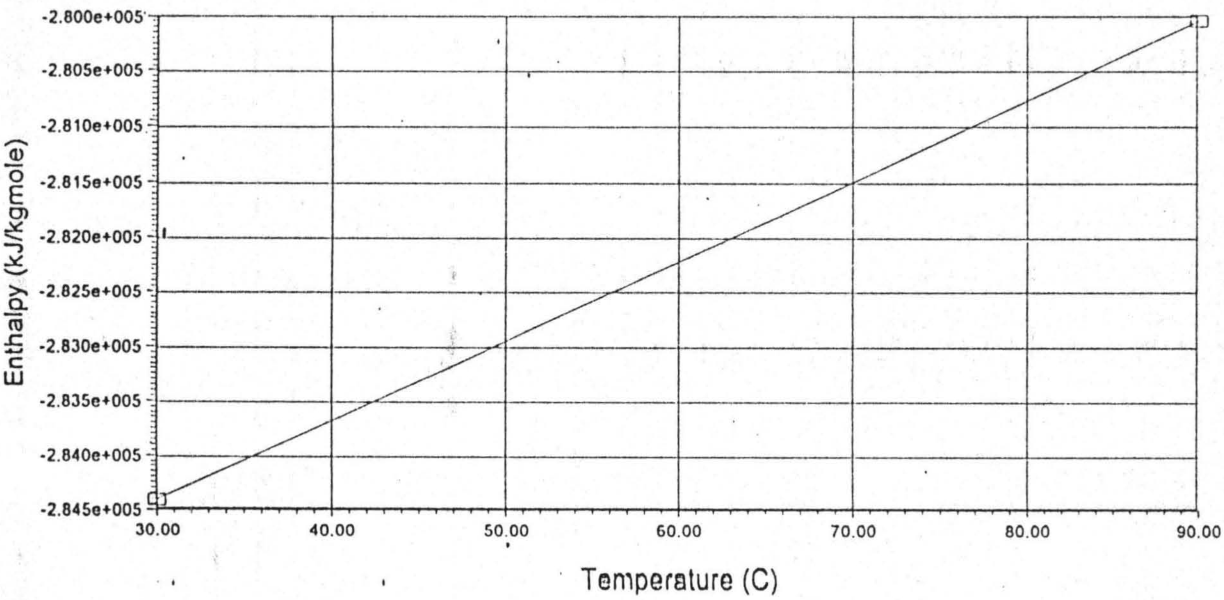
Elevation Relative to Ground Level 0.0000 m *

| | | ONCENTRATED NICKEL SOLUTIO | CNS | |
|---|---|---|---|---|
| eter | (m) | 5.000e-002 | 5.000e-002 | |
| tion (Base) | (m) | 0.0000 | 0.0000 | |
| tion (Ground) | (m) | 0.0000 | 0.0000 | |

## PERFORMANCE PROFILES

| Zone | Pressure (kPa) | Temperature (C) | Vapour Fraction | Enthalpy (kJ/kgmole) |
|---|---|---|---|---|
| Inlet | 90.00 | 90.00 | 0.0000 | -280029.47 |
| 0 | 88.00 | 30.00 | 0.0000 | -284409.78 |

## PERFORMANCE PLOT



# Cooler: COOLER 1 (continued)

## PERFORMANCE TABLE

| Temperature (C) | Pressure (kPa) | Heat Flow (kJ/h) | Enthalpy (kJ/kgmole) | Vapour Fraction |
|---|---|---|---|---|
| 90.00 | 90.00 | 0.00 | -280029.47 | 0.0000 |
| 30.00 | 88.00 | -1234767.49 | -284409.78 | 0.0000 |

## DYNAMICS

### Model Details: Supplied Duty

| | | | | | |
|---|---|---|---|---|---|
| Zone | | 1 * | Delta P | (kPa) | 2.000 * |
| Volume | (m3) | 0.1000 * | Overall K | (kg/hr/sqrt(kPa-kg/m3)) | 117.4 * |
| Duty | (kJ/h) | 1.235e+006 | | | |

### Holdup Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 | 0.0000 |
| Liquid | 0.0000 | 0.0000 | 0.0000 |
| Aqueous | 0.0000 | 0.0000 | 0.0000 |
| **Total** | **0.0000** | **0.0000** | **0.0000** |

### Individual Zone Holdups: Zone 0

### Delta P Specs and Duties

| Zone | dP Value (kPa) | dP Option | Duty (kJ/h) |
|---|---|---|---|
| 0 * | 2.000 * | not specified | -6084 * |

### Zone Conductance Specifications

| Zone | k (kg/hr/sqrt(kPa-kg/m3)) | Specification |
|---|---|---|
| 0 * | 117.4 | Disabled |

| | | |
|---|---|---|
| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.3.hsc<br>Unit Set: SI<br>Date/Time: Thu Dec 21 17:08:03 2006 |

# Air cooler: AIR DRIER

## CONNECTIONS

### Inlet Stream

| STREAM NAME | FROM UNIT OPERATION | |
|---|---|---|
| W.B.M | Tank | WASHING UNIT 3 |

### Outlet Stream

| STREAM NAME | TO UNIT OPERATION | |
|---|---|---|
| DRIED BASE METAL | Conversion Reactor | ELECTROPLATING TANK |

## DESIGN PARAMETERS

| | | | |
|---|---|---|---|
| Pressure Drop: | 10.00 kPa * | UA: | -97.27 kJ/C-h |
| Inlet Air Temp: | 25.00 C | Outlet Air Temp: | 25.00 C |
| Configuration: | | | one tube row, one pass |

## PERFORMANCE

| | | | |
|---|---|---|---|
| Working Fluid Duty: | 147.2 kJ/h | Correction Factor: | 0.8111 |
| UA: | -97.27 kJ/C-h | LMTD: | 1.865 C * |
| Feed Temp: | 25.43 C | Prod Temp: | 30.00 C * |
| Air Feed Temp: | 25.00 C | Air Prod Temp: | 25.00 C |
| Volumetric Air Flow: | 7.200e+005 ACT_m3/h * | Mass Air Flow: | 8.491e+005 kg/h * |

## User Variables

## SIZING

Number of Fans 2 *

| Fan | | Fan 0 | Fan 1 | |
|---|---|---|---|---|
| Speed | (rpm) | 60.00 | 60.00 | |
| Speed | (rpm) | 60.00 | 60.00 | |
| Max Acceleration | (rpm) | --- | --- | |
| Design Speed | (rpm) | 60.00 | 60.00 | |
| Design airflow | (ACT_m3/h) | 3.600e+005 | 3.600e+005 | |
| Current airflow | (ACT_m3/h) | 3.600e+005 | 3.600e+005 | |

## NOZZLE PARAMETERS

Base Elevation Relative to Ground Level 0.4500 m *

| | | W.B.M | DRIED BASE METAL | |
|---|---|---|---|---|
| Diameter | (m) | 5.000e-002 | 5.000e-002 | |
| Elevation (Base) | (m) | 0.0000 | 0.0000 | |
| Elevation (Ground) | (m) | 0.4500 | 0.4500 | |

## NOTES

| | | |
|---|---|---|
| HYPROTECH Lifecycle Innovation | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.2.hsc<br>Unit Set: SI<br>Date/Time: Thu Dec 21 16:52:36 2006 |

# Pump: PUMP.1

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation |
|---|---|
| NaOH | |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| NaOH. | Heater | HEATER |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| QP.1 | |

## PARAMETERS

| | | | | | |
|---|---|---|---|---|---|
| Adiabatic Efficiency (%): | 75.00 * | Delta P: | 10.00 kPa * | Duty: | 6.964e-008 kW |

## CURVES

| | | | | | |
|---|---|---|---|---|---|
| Delta P: | 10.00 kPa * | Duty: | | | 6.964e-00 |
| Coefficient A: | 0.0000 * | Coefficient B: | 0.0000 * | Coefficient C: | 0.00 |
| **Parameter Preferences** | Units for Delta P: m | Flow Basis | ActVolFlow | Units for Flow: | m3/h |

### User Variables

## RATING

### Characteristic Curves

| | Speed: | |
|---|---|---|
| Flow | Head | Efficiency (%) |

### NPSH

| | | | | | |
|---|---|---|---|---|---|
| NPSH Required | -- | NPSH Available | -- | Enable NPSH Curves: | No |

NPSH Curves

### Nozzle Paramaters

Base Elevation Relative to Ground Level 0.0000 m *

| | | NaOH | NaOH. | |
|---|---|---|---|---|
| Diameter | (m) | 5.000e-002 | 5.000e-002 | |
| Elevation (Base) | (m) | 0.0000 | 0.0000 | |
| Elevation (Ground) | (m) | 0.0000 | 0.0000 | |

### Inertia

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Rotational inertia (kg-m2) | 0.5000 | Radius of gyration (m) | 0.1000 * | Mass (kg) | 50.00 * | Friction loss factor (rpm) | 6.000 * |

### Start Up

Design Flow Typical Operating Capacity 10.00 m3/h

## PERFORMANCE

### Results

| | | | |
|---|---|---|---|
| Total Head | -- | Velocity Head | -1.548e-017 m |
| Pressure Head | 0.6897 m | Delta P excluding Static Head Results | -- |

## DYNAMICS

### Dynamic Specifications

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Duty | (m) | -- | Not Active | Power | (kJ/h) | 2.507e-004 | Not Active |
| Adiabatic Efficiency | (rpm) | -- | Not Active | Capacity | (m3/h) | 1.560e-005 | |
| Polytropic Efficiency | (%) | 75.00 * | Active | Use Characteristic Curves | | | Not Active |
| Pressure Increase | (kPa) | 10.00 * | Active | Pump is Acting as a Turbine | | | Not Active |

# Pump: PUMP.1 (continued)

## Holdup Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| **Total** | **0.0000** | **0.0000** | **0.0000** |

# Heater: HEATER

## CONNECTIONS

### Inlet Stream

| STREAM NAME | FROM UNIT OPERATION | |
|---|---|---|
| NaOH. | Pump | PUMP 1 |

### Outlet Stream

| STREAM NAME | TO UNIT OPERATION | |
|---|---|---|
| SODIUM HYDROXIDE | Tank | DEGREASING UNIT |

### Energy Stream

| STREAM NAME | FROM UNIT OPERATION |
|---|---|
| Q.HEATER1 | |

## PARAMETERS

| | | | | | |
|---|---|---|---|---|---|
| Pressure Drop: | 0.0000 kPa * | Duty: | 6.319 kJ/h | Volume: | 0.8000 m3 * |
| Function: | Not Selected | Zones: | 1 | | |

### User Variables

## RATING

## NOZZLE PARAMETERS

| | | | | |
|---|---|---|---|---|
| Base Elevation Relative to Ground Level | | | | 0.7620 m * |
| | | NaOH. | SODIUM HYDROXIDE | |
| Diameter | (m) | 5.000e-002 | 5.000e-002 | |
| Elevation (Base) | (m) | 0.0000 | 0.0000 | |
| Elevation (Ground) | (m) | 0.7620 | 0.7620 | |

## DETAILED HEAT LOSS PARAMETERS

| | | | |
|---|---|---|---|
| Overall Heat Loss (kJ/h) | -- | Area (m2) | |

### Temperature Profile

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fluid (C) | -- | Inner Wall (C) | 25.00 | Middle Wall (C) | 25.00 | Outer Wall (C) | 25.00 | External (C) | 25.00 |

### Conduction

| | | Metal | Insulation |
|---|---|---|---|
| Thickness | (m) | * 1.000e-002 | 3.000e-002 |
| Cp | (kJ/kg-C) | 0.4730 | 0.8200 |
| Density | (kg/m3) | 7801 | 520.0 |
| Conductivity | (W/m-K) | 45.00 | 0.1500 |

### Convection

| | | | |
|---|---|---|---|
| Outside U (kJ/h-m2-C) | 54.00 | Inside U (kJ/h-m2-C) | 7200 |

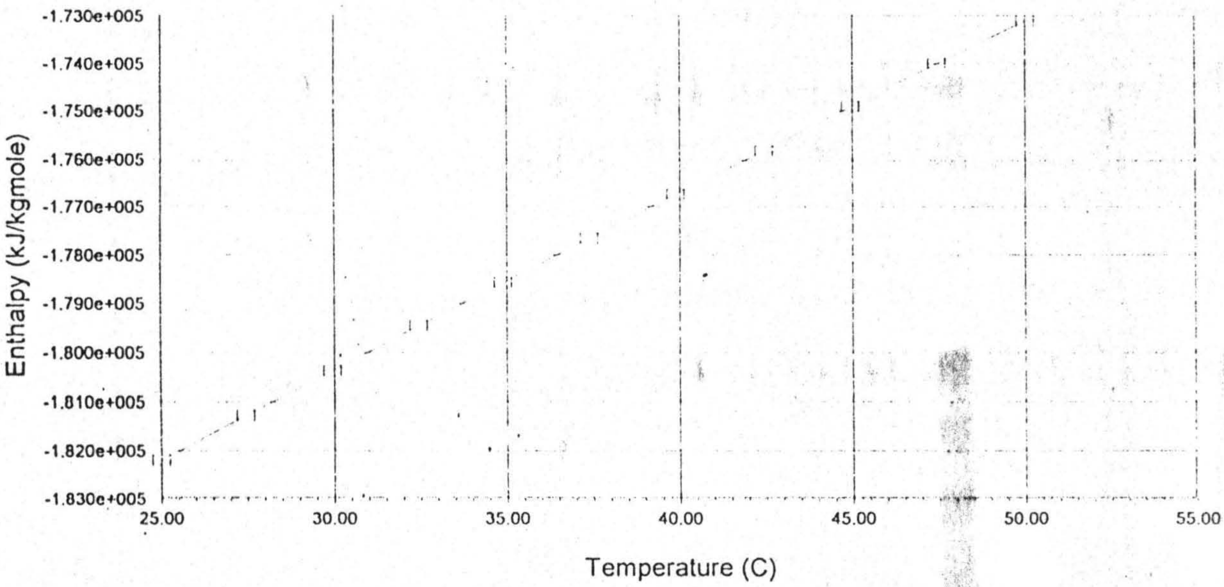
## PERFORMANCE PROFILES

| Zone | Pressure (kPa) | Temperature (C) | Vapour Fraction | Enthalpy (kJ/kgmole) |
|---|---|---|---|---|
| Inlet | 120.00 | 25.00 | 0.0000 | -182180.76 |
| 0 | 120.00 | 50.00 | 0.0000 | -173089.36 |

## PERFORMANCE PLOT

| | | |
|---|---|---|
| TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: | C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.2.hsc |
| | Unit Set: | SI |
| | Date/Time: | Thu Dec 21 16:56:32 2006 |

# Heater: HEATER (continued)




**PERFORMANCE TABLE**

| Temperature (C) | Pressure (kPa) | Heat Flow (kJ/h) | Enthalpy (kJ/kgmole) | Vapour Fraction |
|---|---|---|---|---|
| 25.00 | 120.00 | 0.00 | -182180.76 | 0.0000 |
| 27.47 | 120.00 | 0.63 | -181271.62 | 0.0000 |
| 29.96 | 120.00 | 1.26 | -180362.48 | 0.0000 |
| 32.44 | 120.00 | 1.90 | -179453.34 | 0.0000 |
| 34.93 | 120.00 | 2.53 | -178544.20 | 0.0000 |
| 37.43 | 120.00 | 3.16 | -177635.06 | 0.0000 |
| 39.93 | 120.00 | 3.79 | -176725.92 | 0.0000 |
| 42.44 | 120.00 | 4.42 | -175816.78 | 0.0000 |
| 44.96 | 120.00 | 5.06 | -174907.64 | 0.0000 |
| 47.48 | 120.00 | 5.69 | -173998.50 | 0.0000 |
| 50.00 | 120.00 | 6.32 | -173089.36 | 0.0000 |

# Pump: P-100

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| CNS | Cooler | COOLER 1 |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| P.CNS | Recycle | RCY-1 |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| Q.P | |

## PARAMETERS

| | | | | | |
|---|---|---|---|---|---|
| Adiabatic Efficiency (%): | 95.00 * | Delta P: | 10.00 kPa * | Duty: | 1.480e-002 [illegible] |

## CURVES

| | | | |
|---|---|---|---|
| Delta P: | 10.00 kPa * | Duty: | 1.480e-002 [illegible] |

| | | | | | |
|---|---|---|---|---|---|
| Coefficient A: | 0.0000 * | Coefficient B: | 0.0000 * | Coefficient C: | [illegible] |

| | | | | | | |
|---|---|---|---|---|---|---|
| Parameter Preferences | Units for Delta P: | m | Flow Basis | ActVolFlow | Units for Flow: | [illegible] |

### User Variables

## RATING

### Characteristic Curves

| Speed: | | |
|---|---|---|
| Flow | Head | Efficiency (%) |

### NPSH

| | | | | | |
|---|---|---|---|---|---|
| NPSH Required | -- | NPSH Available | -- | Enable NPSH Curves: | No |

| NPSH Curves | | |
|---|---|---|
| | | |

### Nozzle Paramaters

| | |
|---|---|
| Base Elevation Relative to Ground Level | 0.0000 m * |

| | | CNS | P.CNS | |
|---|---|---|---|---|
| Diameter | (m) | 5.000e-002 | 5.000e-002 | |
| Elevation (Base) | (m) | 0.0000 | 0.0000 | |
| Elevation (Ground) | (m) | 0.0000 | 0.0000 | |

### Inertia

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Rotational inertia (kg-m2) | 0.5000 | Radius of gyration (m) | 0.1000 * | Mass (kg) | 50.00 * | Friction loss factor (rpm) | 6.000 * |

### Start Up

| | |
|---|---|
| Design Flow Typical Operating Capacity | 10.00 m3/h |

## PERFORMANCE

### Results

| | | | |
|---|---|---|---|
| Total Head | 1.016 m * | Velocity Head | -1.457e-007 m |
| Pressure Head | 1.016 m | Delta P excluding Static Head Results | -- |

## DYNAMICS

### Dynamic Specifications

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Duty | (m) | 1.016 * | Not Active | Power | (kJ/h) | 53.27 | Not Active |
| Adiabatic Efficiency | (rpm) | -- | Not Active | Capacity | (m3/h) | 5.089 | |
| Polytropic Efficiency | (%) | 95.00 * | Active | Use Characteristic Curves | | | Not Active |

# Pump: P-100 (continued)

| | | | | | | |
|---|---|---|---|---|---|---|
| Pressure Increase | (kPa) | 10.00 * | Active | Pump is Acting as a Turbine | | Not Active |

## Holdup Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| Total | 0.0000 | 0.0000 | 0.0000 |

| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: | C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.hsc |
|---|---|---|---|
| | | Unit Set: | SI |
| | | Date/Time: | Fri Feb 09 09:10:03 2007 |

# Vessel Sizing: DEGREASING UNIT

## Vertical Seperator Properties: CONCENTRATOR

| | | | |
|---|---|---|---|
| L/D Ratio | 5.000 * | Demister to Top (m) | 0.3048 * |
| Liq. Res. Time (seconds) | 300.0 * | | |

## Construction Information

| | | | |
|---|---|---|---|
| Chem Eng Fab Index | 252.5 | Allowable Stress (kPa) | 9.446e+004 |
| Material Type | Carbon Steel | Shell Thickness (mm) | 6.350 |
| Mass Density (kg/m3) | 7861 | Corrosion Thickness (mm) | 3.175 |
| FMC | 1.000 | Joint Efficiency | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.7068 * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 7476 | Associated Cost ($US) | 1658 | Total Cost (FOB $US) | 9134 |

## Sizing Results

| | | | |
|---|---|---|---|
| Diameter (m) | 0.6096 | Liquid Residence Time (seconds) | 300.0 |
| Total Length (m) | 3.353 | Liquid Surge Height (m) | 1.567 |
| L/D Ratio | 5.000 | LLSD (m) | 0.4572 |
| Max. Allowable Vapour Velocity (m/s) | 1.000 | Liquid Res. Time at LLSD (seconds) | 80.44 |
| Demister Thickness (mm) | 0.0000 | | |

## Vapour Space

| | | | |
|---|---|---|---|
| Sump To Inlet Nozzle (m) | 0.3048 | Demister To Head (m) | 0.3048 |
| Inlet Nozzle to Demister (m) | 1.024 | Ellipsoidal Head (m) | 0.1524 |
| Demister Thickness (mm) | 0.0000 | Total Vapour Height (m) | 1.786 |



* Specified by user.

| | | | |
|---|---|---|---|
| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: | C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.2.hsc |
| | | Unit Set: | SI |
| | | Date/Time: | Wed Feb 07 12:26:38 2007 |

# Separator: CONCENTRATOR

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| P | Heater | PRE-HEATER |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| WATER VAPOUR | | |
| CONCENTRATED NICKEL SOLUTION | Cooler: | COOLER 1 |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| | |

## PARAMETERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vessel Volume: | 0.1223 m3 | Level SP: | 50.00 % | Liquid Volume: | 6.116e-002 m3 | | |
| Vessel Pressure: | 90.00 kPa | Pressure Drop: | 0.0000 kPa * | Duty: | 0.0000 kJ/h | Heat Transfer Mode: | Heating |

### User Variables

## RATING

### Sizing

| Cylinder | | Vertical | | Separator has a Boot: No | |
|---|---|---|---|---|---|
| Volume | 0.1223 m3 | Diameter | 0.3048 m * | Height | 1.676 * |

### Nozzles

| Base Elevation Relative to Ground Level | | 0.0000 m * | Diameter 0.3048 m * | Height 1.676 * |
|---|---|---|---|---|
| | | P | WATER VAPOUR | ONCENTRATED NICKEL SOLUTIC |
| Diameter | (m) | 8.382e-002 | 8.382e-002 | 8.382e-002 |
| Elevation (Base) | (m) | 0.8382 | 1.676 | 0.0000 |
| Elevation (Ground) | (m) | 0.8382 | 1.676 | 0.0000 |
| Elevation (% of Height) | (%) | 50.00 | 100.00 | 0.00 |

### Level Taps: Level Tap Specification

| Level Tap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

### Level Taps: Calculated Level Tap Values

| Level Tap | Liquid Level | Aqueous Level |
|---|---|---|

### Options

| | | | |
|---|---|---|---|
| PV Work Term Contribution | (%) | 100.00 * | |

## DYNAMICS

### Vessel Parameters: Initialize from Product

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume | (m3) | 0.1223 | Level Calculator | | Vertical cylinder |
| Vessel Diameter | (m) | 0.3048 * | Fraction Calculator | | Use levels and nozzles |
| Vessel Height | (m) | 1.676 * | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 90.00 |

### Holdup: Vessel Levels

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | -- | -- | 0.0000 |
| Liquid | -- | -- | 0.0000 |
| Aqueous | -- | -- | 0.0000 |

### Holdup: Details

# Separator: CONCENTRATOR (continued)

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| Total | 0.0000 | 0.0000 | 0.0000 |

# Vessel Sizing: Vessel Sizing-11

## Vertical Seperator Properties: DRAGOUT TANK.6

| | | | | |
|---|---|---|---|---|
| L/D Ratio | 5.000 * | Demister to Top | (m) | 0.3048 * |
| Liq. Res. Time (seconds) | 3537 * | | | |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.7068 * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 5205 | Associated Cost ($US) | 608.5 | Total Cost (FOB $US) | 5814 |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 0.3048 | Liquid Residence Time | (seconds) | 3537 |
| Total Length | (m) | 1.676 | Liquid Surge Height | (m) | 0.4572 |
| L/D Ratio | | 5.000 | LLSD | (m) | 0.4572 |
| Max. Allowable Vapour Velocity | (m/s) | 1.000 | Liquid Res. Time at LLSD | (seconds) | 3537 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | 0.3048 |
| Inlet Nozzle to Demister | (m) | 0.5334 | Ellipsoidal Head | (m) | 7.620e-002 |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | 1.219 |


* Specified by user.

# Tank: DRAGOUT TANK 6

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| WCM.2 | Tank | DRAGOUT TANK.5 |
| WATER.10 | Tee | TEE-100 |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| WCM,3 | | |
| L.SOLN.4 | Mixer: | CHROME SOLUTION MIXER |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| | |

## PARAMETERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vessel Volume: | -- | Level SP: | 50.00 % | Liquid Volume: | | | |
| Vessel Pressure: | 90.00 kPa | Pressure Drop: | 0.0000 kPa * | Duty: | 0.0000 kJ/h | Heat Transfer Mode: | |

### User Variables

## RATING

### Sizing

| Cylinder | | Vertical | | Separator has a Boot: No |
|---|---|---|---|---|
| Volume | -- | Diameter | -- | Height |

### Nozzles

| | | | | |
|---|---|---|---|---|
| Base Elevation Relative to Ground Level | 0.0000 m * | Diameter | -- | Height |

| | | WCM.2 | WATER.10 | WCM,3 |
|---|---|---|---|---|
| Diameter | (m) | 5.000e-002 | 5.000e-002 | 5.000e-002 |
| Elevation (Base) | (m) | 0.0000 | 0.0000 | 0.0000 |
| Elevation (Ground) | (m) | 0.0000 | 0.0000 | 0.0000 |
| Elevation (% of Height) | (%) | -- | -- | -- |
| | | L.SOLN.4 | | |
| Diameter | (m) | 5.000e-002 | | |
| Elevation (Base) | (m) | 0.0000 | | |
| Elevation (Ground) | (m) | 0.0000 | | |
| Elevation (% of Height) | (%) | -- | | |

### Level Taps: Level Tap Specification

| Level Tap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

### Level Taps: Calculated Level Tap Values

| Level Tap | Liquid Level | Aqueous Level |
|---|---|---|

### Options

| | | | | |
|---|---|---|---|---|
| PV Work Term Contribution | (%) | 100.00 * | | |

## DYNAMICS

### Vessel Parameters: Initialize from Product

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume | (m3) | -- | Level Calculator | | Vertical cylinder |
| Vessel Diameter | (m) | -- | Fraction Calculator | | Use levels and nozzles |
| Vessel Height | (m) | -- | Feed Delta P | (kPa) | 0.000 |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 90.0 |

### Holdup: Vessel Levels

# Tank: DRAGOUT TANK 6 (continued)

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | -- | -- | 0.0000 |
| Liquid | -- | -- | 0.0000 |
| Aqueous | -- | -- | 0.0000 |

## Holdup: Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| **Total** | **0.0000** | **0.0000** | **0.0000** |

| | | | |
|---|---|---|---|
| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: | C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.hsc |
| | | Unit Set: | SI |
| | | Date/Time: | Fri Feb 09 09:21:23 2007 |

# Vessel Sizing: Vessel Sizing-10

## Vertical Seperator Properties: DRAGOUT TANK.5

| | | | | |
|---|---|---|---|---|
| L/D Ratio | | 5.000 * | Demister to Top (m) | 0.3048 * |
| Liq. Res. Time | (seconds) | 1.047e+004 * | | |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.7068 * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 5205 | Associated Cost ($US) | 608.5 | Total Cost (FOB $US) | 581[illegible] |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 0.3048 | Liquid Residence Time | (seconds) | 1.047e+00[illegible] |
| Total Length | (m) | 1.676 | Liquid Surge Height | (m) | 0.4572 |
| L/D Ratio | | 5.000 | LLSD | (m) | 0.4572 |
| Max. Allowable Vapour Velocity | (m/s) | 1.000 | Liquid Res. Time at LLSD | (seconds) | 1.047e+004 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | 0.3048 |
| Inlet Nozzle to Demister | (m) | 0.5334 | Ellipsoidal Head | (m) | 7.620e-002 |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | 1.21[illegible] |

# Vessel Sizing: Vessel Sizing-9

## Vertical Seperator Properties: DRAGOUT TANK.4

| | | | | | |
|---|---|---|---|---|---|
| L/D Ratio | | 5.000 * | Demister to Top | (m) | 0.3048 * |
| Liq. Res. Time | (seconds) | 1.042e+004 * | | | |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.7068 * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 5205 | Associated Cost ($US) | 608.5 | Total Cost (FOB $US) | 5814 |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 0.3048 | Liquid Residence Time | (seconds) | 1.042e+004 |
| Total Length | (m) | 1.676 | Liquid Surge Height | (m) | 0.4572 |
| L/D Ratio | | 5.000 | LLSD | (m) | 0.4572 |
| Max. Allowable Vapour Velocity | (m/s) | 1.000 | Liquid Res. Time at LLSD | (seconds) | 1.042e+004 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | 0.3048 |
| Inlet Nozzle to Demister | (m) | 0.5334 | Ellipsoidal Head | (m) | 7.620e-002 |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | 1.219 |

| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.3.hsc<br>Unit Set: SI<br>Date/Time: Wed Feb 07 12:21:49 2007 |
|---|---|---|

# Tank: DRAGOUT TANK.4

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| CHROMED METAL | Conversion Reactor | CHROME PLATING TANK |
| WATER.8 | Tee | TEE-100 |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| WCM.1 | Tank: | DRAGOUT TANK.5 |
| L.SOLN.2 | Mixer: | CHROME SOLUTION MIXER |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| | |

## PARAMETERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vessel Volume: | 1.216 m3 | Level SP: | | 50.00 % | Liquid Volume: | | 0.6081 m3 |
| Vessel Pressure: | 90.00 kPa | Pressure Drop: | 0.0000 kPa * | Duty: | 0.0000 kJ/h | Heat Transfer Mode: | Heating |

### User Variables

## RATING

### Sizing

| Cylinder | | Vertical | | Separator has a Boot: No | |
|---|---|---|---|---|---|
| Volume | 1.216 m3 | Diameter | 0.7620 m * | Height | 2.667 * |

### Nozzles

| Base Elevation Relative to Ground Level | | 0.0000 m * | Diameter 0.7620 m * | Height 2.667 * |
|---|---|---|---|---|
| | | CHROMED METAL | WATER.8 | WCM.1 |
| Diameter | (m) | 0.1334 | 0.1334 | 0.1334 |
| Elevation (Base) | (m) | 1.333 | 1.333 | 2.667 |
| Elevation (Ground) | (m) | 1.333 | 1.333 | 2.667 |
| Elevation (% of Height) | (%) | 50.00 | 50.00 | 100.00 |
| | | L.SOLN.2 | | |
| Diameter | (m) | 0.1334 | | |
| Elevation (Base) | (m) | 0.0000 | | |
| Elevation (Ground) | (m) | 0.0000 | | |
| Elevation (% of Height) | (%) | 0.00 | | |

### Level Taps: Level Tap Specification

| Level Tap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

### Level Taps: Calculated Level Tap Values

| Level Tap | Liquid Level | Aqueous Level |
|---|---|---|

### Options

| PV Work Term Contribution | (%) | 100.00 * |
|---|---|---|

## DYNAMICS

### Vessel Parameters: Initialize from Product

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume | (m3) | 1.216 | Level Calculator | | Vertical cylinder |
| Vessel Diameter | (m) | 0.7620 * | Fraction Calculator | | Use levels and nozzles |
| Vessel Height | (m) | 2.667 * | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 90.00 |

### Holdup: Vessel Levels

# Tank: DRAGOUT TANK.4 (continued)

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | -- | -- | 0.0000 |
| Liquid | -- | -- | 0.0000 |
| Aqueous | -- | -- | 0.0000 |

## Holdup: Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| Total | 0.0000 | 0.0000 | 0.0000 |

| | | |
|---|---|---|
| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.hsc<br>Unit Set: SI<br>Date/Time: Fri Feb 09 09:13:17 2007 |

# Vessel Sizing: Vessel Sizing-3

## Vertical Seperator Properties: DRAGOUT TANK.3

| | | | | | |
|---|---|---|---|---|---|
| L/D Ratio | | 5.000 * | Demister to Top | (m) | 0.3048 * |
| Liq. Res. Time | (seconds) | 3537 * | | | |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.706[illegible] * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 5205 | Associated Cost ($US) | 608.5 | Total Cost (FOB $US) | [illegible] |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 0.3048 | Liquid Residence Time | (seconds) | [illegible] |
| Total Length | (m) | 1.676 | Liquid Surge Height | (m) | 0.4572 |
| L/D Ratio | | 5.000 | LLSD | (m) | 0.4572 |
| Max. Allowable Vapour Velocity | (m/s) | 1.000 | Liquid Res. Time at LLSD | (seconds) | 3537 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | 0.3048 |
| Inlet Nozzle to Demister | (m) | 0.5334 | Ellipsoidal Head | (m) | 7.620e-002 |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | 1.2[illegible] |

| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: | C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.3.hsc |
|---|---|---|---|
| | | Unit Set: | SI |
| | | Date/Time: | Wed Feb 07 12:19:29 2007 |

# Tank: DRAGOUT TANK.3

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| P.IRON. | Tank | DRAGOUT TANK.2 |
| WATER.7 | Tee | WATER SPLITTER |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| PLATED METAL | Conversion Reactor: | CHROME PLATING TANK |
| WASH WATER.3 | Mixer: | MIXER.2 |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| | |

## PARAMETERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vessel Volume: | 0.9800 m3 * | Level SP: | 50.00 % | Liquid Volume: | 0.4900 m3 | | |
| Vessel Pressure: | 90.00 kPa | Pressure Drop: | 0.0000 kPa * | Duty: | 0.0000 kJ/h | Heat Transfer Mode: | Heating |

### User Variables

## RATING

### Sizing

| Cylinder | | Vertical | | Separator has a Boot: No | |
|---|---|---|---|---|---|
| Volume | 0.9800 m3 * | Diameter | 0.9405 m | Height | 1.411 |

### Nozzles

| | | | | | |
|---|---|---|---|---|---|
| Base Elevation Relative to Ground Level | | 0.0000 m * | Diameter 0.9405 m | Height 1.411 | |
| | | P.IRON. | WATER.7 | PLATED METAL | |
| Diameter | (m) | 7.054e-002 | 7.054e-002 | 7.054e-002 | |
| Elevation (Base) | (m) | 0.7054 | 0.7054 | 1.411 | |
| Elevation (Ground) | (m) | 0.7054 | 0.7054 | 1.411 | |
| Elevation (% of Height) | (%) | 50.00 | 50.00 | 100.00 | |
| | | WASH WATER.3 | | | |
| Diameter | (m) | 7.054e-002 | | | |
| Elevation (Base) | (m) | 0.0000 | | | |
| Elevation (Ground) | (m) | 0.0000 | | | |
| Elevation (% of Height) | (%) | 0.00 | | | |

### Detailed Heat Loss Parameters

| | | | |
|---|---|---|---|
| Overall Heat Loss (kJ/h) | 0.0000 | Area (m2) | 4.168 |

### Temperature Profile

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fluid (C) | 0.0000 * | Inner Wall (C) | 25.00 | Outer Vessel (C) | 25.00 | Outer Insulation (C) | 25.00 | Ambient (C) | 25.00 |

### Conduction

| | | Metal | Insulation |
|---|---|---|---|
| Thickness | (m) | 1.000e-002 | 3.000e-002 |
| Cp | (kJ/kg-C) | 0.4730 | 0.8200 |
| Density | (kg/m3) | 7801 | 520.0 |
| Conductivity | (W/m-K) | 45.00 | 0.1500 |

### Convection

| | | | | | |
|---|---|---|---|---|---|
| Inside Vap Phase U (kJ/h-m2-C) | 7200 | Inside Liq Phase U (kJ/h-m2-C) | -- | Outside U (kJ/h-m2-C) | 54.00 |

### Level Taps: Level Tap Specification

| Level Tap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

### Level Taps: Calculated Level Tap Values

| Level Tap | Liquid Level | Aqueous Level |
|---|---|---|

### Options

# Tank: DRAGOUT TANK.3 (continued)

## Options

| | | | |
|---|---|---|---|
| PV Work Term Contribution | (%) | 100.00 * | |

## DYNAMICS

### Vessel Parameters: Initialize from Product

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume | (m3) | 0.9800 * | Level Calculator | | Vertical cylinder |
| Vessel Diameter | (m) | 0.9405 | Fraction Calculator | | Use levels and nozzles |
| Vessel Height | (m) | 1.411 | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 90.00 |

### Holdup: Vessel Levels

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | -- | -- | 0.0000 |
| Liquid | -- | -- | 0.0000 |
| Aqueous | -- | -- | 0.0000 |

### Holdup: Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| **Total** | **0.0000** | **0.0000** | **0.0000** |



* Specified by user.

| | |
|---|---|
| HYPROTECH LIFECYCLE INNOVATION — TEAM LND, Calgary, Alberta, CANADA | Case Name: C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.hsc |
| | Unit Set: SI |
| | Date/Time: Fri Feb 09 09:12:35 2007 |

# Vessel Sizing: Vessel Sizing-2

## Vertical Seperator Properties: DRAGOUT TANK.2

| | | | | | |
|---|---|---|---|---|---|
| L/D Ratio | | 5.000 * | Demister to Top | (m) | 0.3048 * |
| Liq. Res. Time | (seconds) | 1.047e+004 * | | | |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.7068 * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 5205 | Associated Cost ($US) | 608.5 | Total Cost (FOB $US) | 5814 |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 0.3048 | Liquid Residence Time | (seconds) | 1.047e+004 |
| Total Length | (m) | 1.676 | Liquid Surge Height | (m) | 0.4572 |
| L/D Ratio | | 5.000 | LLSD | (m) | 0.4572 |
| Max. Allowable Vapour Velocity | (m/s) | 1.000 | Liquid Res. Time at LLSD | (seconds) | 1.047e+004 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | 0.3048 |
| Inlet Nozzle to Demister | (m) | 0.5334 | Ellipsoidal Head | (m) | 7.620e-002 |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | 1.219 |

# Tank: DRAGOUT TANK.2

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| P.IRON | Tank | DRAGOUT TANK.1 |
| WATER.6 | Tee | WATER SPLITTER |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| P.IRON. | Tank: | DRAGOUT TANK.3 |
| WASH WATER.2 | Mixer: | MIXER.2 |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| | |

## PARAMETERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vessel Volume: | 0.9800 m3 * | Level SP: | 50.00 % | Liquid Volume: | 0.4900 m3 | | |
| Vessel Pressure: | * 90.00 kPa | Pressure Drop: | 0.0000 kPa * | Duty: | 0.0000 kJ/h | Heat Transfer Mode: | Heat[illegible] |

### User Variables

## RATING

### Sizing

| Cylinder | | Vertical | | Separator has a Boot: | No |
|---|---|---|---|---|---|
| Volume | 0.9800 m3 * | Diameter | 0.9405 m | Height | 1.411 |

### Nozzles

| | | | | | |
|---|---|---|---|---|---|
| Base Elevation Relative to Ground Level | 0.0000 m * | Diameter | 0.9405 m | Height | 1.411 |

| | | P.IRON | WATER.6 | P.IRON. |
|---|---|---|---|---|
| Diameter | (m) | 7.054e-002 | 7.054e-002 | 7.054e-002 |
| Elevation (Base) | (m) | 0.7054 | 0.7054 | 1.411 |
| Elevation (Ground) | (m) | 0.7054 | 0.7054 | 1.411 |
| Elevation (% of Height) | (%) | 50.00 | 50.00 | 100.00 |
| | | WASH WATER.2 | | |
| Diameter | (m) | 7.054e-002 | | |
| Elevation (Base) | (m) | 0.0000 | | |
| Elevation (Ground) | (m) | 0.0000 | | |
| Elevation (% of Height) | (%) | 0.00 | | |

### Level Taps: Level Tap Specification

| Level Tap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

### Level Taps: Calculated Level Tap Values

| Level Tap | Liquid Level | Aqueous Level |
|---|---|---|

### Options

| | | | | |
|---|---|---|---|---|
| PV Work Term Contribution | (%) | 100.00 * | | |

## DYNAMICS

### Vessel Parameters: Initialize from Product

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume | (m3) | 0.9800 * | Level Calculator | | Vertical cylinder |
| Vessel Diameter | (m) | 0.9405 | Fraction Calculator | | Use levels and nozzles |
| Vessel Height | (m) | 1.411 | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 90.00 |

### Holdup: Vessel Levels

# Tank: DRAGOUT TANK.2 (continued)

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | -- | -- | 0.0000 |
| Liquid | -- | -- | 0.0000 |
| Aqueous | -- | -- | 0.0000 |

## Holdup: Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| **Total** | **0.0000** | **0.0000** | **0.0000** |

| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: | C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.hsc |
|---|---|---|---|
| | | Unit Set: | SI |
| | | Date/Time: | Fri Feb 09 09:11:46 2007 |

# Vessel Sizing: Vessel Sizing-1

## Vertical Seperator Properties: DRAGOUT TANK.1

| | | | | | |
|---|---|---|---|---|---|
| L/D Ratio | | 5.000 * | Demister to Top | (m) | 0.3048 * |
| Liq. Res. Time | (seconds) | 1.042e+004 * | | | |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.7068 * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 5205 | Associated Cost ($US) | 608.5 | Total Cost (FOB $US) | 5814 |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 0.3048 | Liquid Residence Time | (seconds) | 1.042e+004 |
| Total Length | (m) | 1.676 | Liquid Surge Height | (m) | 0.4572 |
| L/D Ratio | | 5.000 | LLSD | (m) | 0.4572 |
| Max. Allowable Vapour Velocity | (m/s) | 1.000 | Liquid Res. Time at LLSD | (seconds) | 1.042e+004 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | 0.3048 |
| Inlet Nozzle to Demister | (m) | 0.5334 | Ellipsoidal Head | (m) | 7.620e-002 |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | 1.219 |

# Tank: DRAGOUT TANK.1

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| PLATED IRON | Conversion Reactor | ELECTROPLATING TANK |
| WATER.5 | Tee | WATER SPLITTER |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| P.IRON | Tank: | DRAGOUT TANK.2 |
| WASH WATER.1 | Mixer: | MIXER.2 |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| | |

## PARAMETERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vessel Volume: | 0.9800 m3 * | Level SP: | 50.00 % | Liquid Volume: | 0.4900 m3 | | |
| Vessel Pressure: | 90.00 kPa | Pressure Drop: | 0.0000 kPa * | Duty: | 0.0000 kJ/h | Heat Transfer Mode: | Heating |

### User Variables

## RATING

### Sizing

| Cylinder | | Vertical | | Separator has a Boot: No | |
|---|---|---|---|---|---|
| Volume | 0.9800 m3 * | Diameter | 0.9405 m | Height | 1.411 |

### Nozzles

| | | | | | |
|---|---|---|---|---|---|
| Base Elevation Relative to Ground Level | 0.0000 m * | Diameter | 0.9405 m | Height | 1.411 |

| | | PLATED IRON | WATER.5 | P.IRON |
|---|---|---|---|---|
| Diameter | (m) | 7.054e-002 | 7.054e-002 | 7.054e-002 |
| Elevation (Base) | (m) | 0.7054 | 0.7054 | 1.411 |
| Elevation (Ground) | (m) | 0.7054 | 0.7054 | 1.411 |
| Elevation (% of Height) | (%) | 50.00 | 50.00 | 100.00 |
| | | WASH WATER.1 | | |
| Diameter | (m) | 7.054e-002 | | |
| Elevation (Base) | (m) | 0.0000 | | |
| Elevation (Ground) | (m) | 0.0000 | | |
| Elevation (% of Height) | (%) | 0.00 | | |

### Detailed Heat Loss Parameters

| | | | |
|---|---|---|---|
| Overall Heat Loss (kJ/h) | 0.0000 | Area (m2) | 4.168 |

### Temperature Profile

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Liquid (C) | 0.0000 * | Inner Wall (C) | 25.00 | Outer Vessel (C) | 25.00 | Outer Insulation (C) | 25.00 | Ambient (C) | 25.00 |

### Conduction

| | | Metal | Insulation |
|---|---|---|---|
| Thickness | (m) | 1.000e-002 | 3.000e-002 |
| Cp | (kJ/kg-C) | 0.4730 | 0.8200 |
| Density | (kg/m3) | 7801 | 520.0 |
| Conductivity | (W/m-K) | 45.00 | 0.1500 |

### Convection

| | | | | | |
|---|---|---|---|---|---|
| Inside Vap Phase U (kJ/h-m2-C) | 7200 | Inside Liq Phase U (kJ/h-m2-C) | -- | Outside U (kJ/h-m2-C) | 54.00 |

### Level Taps: Level Tap Specification

| Level Tap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

### Level Taps: Calculated Level Tap Values

| Level Tap | Liquid Level | Aqueous Level |
|---|---|---|

### Options

# Tank: DRAGOUT TANK.1 (continued)

## Options

| | | | | |
|---|---|---|---|---|
| PV Work Term Contribution | (%) | 100.00 * | | |

## DYNAMICS

### Vessel Parameters: Initialize from Product

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume | (m3) | 0.9800 * | Level Calculator | | Vertical cylinder |
| Vessel Diameter | (m) | 0.9405 | Fraction Calculator | | Use levels and nozzles |
| Vessel Height | (m) | 1.411 | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 90.00 |

### Holdup: Vessel Levels

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | -- | -- | 0.0000 |
| Liquid | -- | -- | 0.0000 |
| Aqueous | -- | -- | 0.0000 |

### Holdup: Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| **Total** | **0.0000** | **0.0000** | **0.0000** |

| | | |
|---|---|---|
| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.hsc<br>Unit Set: SI<br>Date/Time: Fri Feb 09 09:14:00 2007 |

# Vessel Sizing: Vessel Sizing-4

## Vertical Seperator Properties: ELECTROPLATING TANK

| | | | | | |
|---|---|---|---|---|---|
| L/D Ratio | | 5.000 * | Demister to Top | (m) | 0.3048 * |
| Liq. Res. Time | (seconds) | 300.0 * | | | |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.7068 * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 7476 | Associated Cost ($US) | 1658 | Total Cost (FOB $US) | 9134 |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 0.6096 | Liquid Residence Time | (seconds) | 300.0 |
| Total Length | (m) | 3.353 | Liquid Surge Height | (m) | 1.521 |
| L/D Ratio | | 5.000 | LLSD | (m) | 0.4572 |
| Max. Allowable Vapour Velocity | (m/s) | 0.6644 | Liquid Res. Time at LLSD | (seconds) | 82.94 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | 0.3048 |
| Inlet Nozzle to Demister | (m) | 1.070 | Ellipsoidal Head | (m) | 0.1524 |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | 1.832 |

# Conversion Reactor: ELECTROPLATING TANK

## CONNECTIONS

### Inlet Stream Connections

| Stream Name | From Unit Operation | |
|---|---|---|
| RCY | Recycle | RCY-1 |
| DRIED BASE METAL | Air cooler | AIR DRIER |

### Outlet Stream Connections

| Stream Name | To Unit Operation | |
|---|---|---|
| PLATED IRON | Tank: | DRAGOUT TANK.1 |
| NICKEL SOLUTION | Mixer: | MIXER.2 |

### Energy Stream Connections

| Stream Name | From Unit Operation |
|---|---|
| | |

## PARAMETERS

| Physical Parameters | | Optional Heat Transfer: | Heating |
|---|---|---|---|
| Delta P | Vessel Volume | Duty | Energy Stream |
| 0.0000 kPa * | 2.583 m3 * | 0.0000 kJ/h | |

### User Variables

## RATING

### Sizing

| Cylinder | | Vertical | | Reactor has a Boot: No | |
|---|---|---|---|---|---|
| Volume | 2.583 m3 * | Diameter | 1.299 m | Height | 1.949 |

### Nozzles

| Base Elevation Relative to Ground Level | 0.0000 m * | Diameter | 1.299 m | Height | 1.949 |
|---|---|---|---|---|---|

| | | RCY | DRIED BASE METAL | PLATED IRON |
|---|---|---|---|---|
| Diameter | (m) | 9.743e-002 | 9.743e-002 | 9.743e-002 |
| Elevation (Base) | (m) | 0.9743 | 0.9743 | 1.949 |
| Elevation (Ground) | (m) | 0.9743 | 0.9743 | 1.949 |
| Elevation (% of Height) | (%) | 50.00 | 50.00 | 100.00 |
| | | NICKEL SOLUTION | | |
| Diameter | (m) | 9.743e-002 | | |
| Elevation (Base) | (m) | 0.0000 | | |
| Elevation (Ground) | (m) | 0.0000 | | |
| Elevation (% of Height) | (%) | 0.00 | | |

### Detailed Heat Loss Parameters

| Overall Heat Loss (kJ/h) | 0.0000 | Area (m2) | 7.953 |
|---|---|---|---|

### Temperature Profile

| Fluid (C) | 0.0000 * | Inner Wall (C) | 25.00 | Outer Vessel (C) | 25.00 | Outer Insulation (C) | 25.00 | Ambient (C) | 25.00 |
|---|---|---|---|---|---|---|---|---|---|

### Conduction

| | | Metal | Insulation |
|---|---|---|---|
| Thickness | (m) | 1.000e-002 | 3.000e-002 |
| Cp | (kJ/kg-C) | 0.4730 | 0.8200 |
| Density | (kg/m3) | 7801 | 520.0 |
| Conductivity | (W/m-K) | 45.00 | 0.1500 |

### Convection

| Outside U (kJ/h-m2-C) | 54.00 | Inside U (kJ/h-m2-C) | 7200 |
|---|---|---|---|

## DYNAMICS

### Vessel Parameters: Initialize from Product

| Vessel Volume | (m3) | 2.583 * | Level Calculator | Vertical cylinder |
|---|---|---|---|---|
| Vessel Diameter | (m) | 1.299 | Fraction Calculator | Use levels and nozzles |

# Conversion Reactor: ELECTROPLATING TANK (continued)

| | | | | | |
|---|---|---|---|---|---|
| Vessel Height | (m) | 1.949 | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 90.00 |

## Holdup: Vessel Levels

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | -- | -- | 0.0000 |
| Liquid | -- | -- | 0.0000 |
| Aqueous | -- | -- | 0.0000 |

## Holdup: Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| **Total** | **0.0000** | **0.0000** | **0.0000** |

# Vessel Sizing: DEGREASING UNIT

## Vertical Seperator Properties: DEGREASING UNIT

| | | | | | |
|---|---|---|---|---|---|
| L/D Ratio | | 5.000 * | Demister to Top | (m) | 0.3048 * |
| Liq. Res. Time | (seconds) | 1.360e+006 * | | | |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.7068 * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 5205 | Associated Cost ($US) | 608.5 | Total Cost (FOB $US) | 581[illegible] |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 0.3048 | Liquid Residence Time | (seconds) | 1.360e+006 |
| Total Length | (m) | 1.676 | Liquid Surge Height | (m) | 0.4572 |
| L/D Ratio | | 5.000 | LLSD | (m) | 0.4572 |
| Max. Allowable Vapour Velocity | (m/s) | 0.8129 | Liquid Res. Time at LLSD | (seconds) | 1.360e+006 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | 0.3048 |
| Inlet Nozzle to Demister | (m) | 0.5334 | Ellipsoidal Head | (m) | 7.620e-002 |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | 1.219 |

# Tank: DEGREASING UNIT

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| WASHED.B.M. | Tank | WASHING UNIT 1 |
| SODIUM HYDROXIDE | Heater | HEATER |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| DEGREASED B.M | Tank: | WASHING UNIT2 |
| SOAP + WATER | Mixer: | MIXER |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| | |

## PARAMETERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vessel Volume: | -- | Level SP: | 50.00 % | Liquid Volume: | -- | | |
| Vessel Pressure: | 100.0 kPa | Pressure Drop: | 0.0000 kPa * | Duty: | 0.0000 kJ/h | Heat Transfer Mode: | Heating |

### User Variables

## RATING

### Sizing

| Cylinder | | Vertical | | Separator has a Boot: | No |
|---|---|---|---|---|---|
| Volume | -- | Diameter | -- | Height | -- |

### Nozzles

| | | | | | |
|---|---|---|---|---|---|
| Base Elevation Relative to Ground Level | 0.0000 m * | Diameter | -- | Height | -- |

| | | WASHED.B.M. | SODIUM HYDROXIDE | DEGREASED B.M |
|---|---|---|---|---|
| Diameter | (m) | 5.000e-002 | 5.000e-002 | 5.000e-002 |
| Elevation (Base) | (m) | 0.0000 | 0.0000 | 0.0000 |
| Elevation (Ground) | (m) | 0.0000 | 0.0000 | 0.0000 |
| Elevation (% of Height) | (%) | -- | -- | -- |
| | | SOAP + WATER | | |
| Diameter | (m) | 5.000e-002 | | |
| Elevation (Base) | (m) | 0.0000 | | |
| Elevation (Ground) | (m) | 0.0000 | | |
| Elevation (% of Height) | (%) | -- | | |

### Level Taps: Level Tap Specification

| Level Tap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

### Level Taps: Calculated Level Tap Values

| Level Tap | Liquid Level | Aqueous Level |
|---|---|---|

### Options

| | | | |
|---|---|---|---|
| PV Work Term Contribution | (%) | 100.00 * | |

## DYNAMICS

### Vessel Parameters: Initialize from Product

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume | (m3) | -- | Level Calculator | | Vertical cylinder |
| Vessel Diameter | (m) | -- | Fraction Calculator | | Use levels and nozzles |
| Vessel Height | (m) | -- | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 100.0 |

### Holdup: Vessel Levels

# Tank: DEGREASING UNIT (continued)

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | --- | --- | 0.0000 |
| Liquid | --- | --- | 0.0000 |
| Aqueous | --- | --- | 0.0000 |

## Holdup: Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| **Total** | **0.0000** | **0.0000** | **0.0000** |

| | | |
|---|---|---|
| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.hsc<br>Unit Set: SI<br>Date/Time: Fri Feb 09 09:15:38 2007 |

# Vessel Sizing: Vessel Sizing-7

## Vertical Seperator Properties: WASHING UNIT.3

| | | | | |
|---|---|---|---|---|
| L/D Ratio | | 5.000 * | Demister to Top (m) | 0.3048 * |
| Liq. Res. Time | (seconds) | 300.0 * | | |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.7068 * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 6297 | Associated Cost ($US) | 1094 | Total Cost (FOB $US) | 739[illegible] |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 0.4572 | Liquid Residence Time | (seconds) | 300.0 |
| Total Length | (m) | 2.515 | Liquid Surge Height | (m) | 0.8147 |
| L/D Ratio | | 5.000 | LLSD | (m) | 0.4572 |
| Max. Allowable Vapour Velocity | (m/s) | 0.5607 | Liquid Res. Time at LLSD | (seconds) | 161.9 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | 0.3048 |
| Inlet Nozzle to Demister | (m) | 0.9760 | Ellipsoidal Head | (m) | 0.1143 |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | 1.700 |

| | | | |
|---|---|---|---|
| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: | C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.3.hsc |
| | | Unit Set: | SI |
| | | Date/Time: | Thu Dec 21 17:04:59 2006 |

# Tank: WASHING UNIT.3

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| WASHED.BM | Tank | WASHING UNIT2 |
| P.WATER.4 | Pump | PUMP.4 |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| W.B.M | Air cooler: | AIR DRIER |
| WATER+LIGTH SOAP | Miker: | MIXER |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| | |

## PARAMETERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vessel Volume: | 2.034 m3 * | Level SP: | 50.00 % | Liquid Volume: | 1.017 m3 | | |
| Vessel Pressure: | 100.0 kPa | Pressure Drop: | 0.0000 kPa * | Duty: | 0.0000 kJ/h | Heat Transfer Mode: | Heat[illegible] |

### User Variables

## RATING

### Sizing

| Cylinder | | Vertical | | Separator has a Boot: | No |
|---|---|---|---|---|---|
| Volume | 2.034 m3 * | Diameter | 1.200 m | Height | 1.799 |

### Nozzles

| Base Elevation Relative to Ground Level | | 0.0000 m * | Diameter | 1.200 m | Height 1.799 |
|---|---|---|---|---|---|
| | | WASHED.BM | P.WATER.4 | W.B.M | |
| Diameter | (m) | 8.997e-002 | 8.997e-002 | 8.997e-002 | |
| Elevation (Base) | (m) | 0.8997 | 0.8997 | 1.799 | |
| Elevation (Ground) | (m) | 0.8997 | 0.8997 | 1.799 | |
| Elevation (% of Height) | (%) | 50.00 | 50.00 | 100.00 | |
| | | WATER+LIGTH SOAP | | | |
| Diameter | (m) | 8.997e-002 | | | |
| Elevation (Base) | (m) | 0.0000 | | | |
| Elevation (Ground) | (m) | 0.0000 | | | |
| Elevation (% of Height) | (%) | 0.00 | | | |

### Detailed Heat Loss Parameters

| | | | |
|---|---|---|---|
| Overall Heat Loss (kJ/h) | 0.0000 | Area (m2) | 6.782 |

#### Temperature Profile

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fluid (C) | 0.0000 * | Inner Wall (C) | 25.00 | Outer Vessel (C) | 25.00 | Outer Insulation (C) | 25.00 | Ambient (C) | 25.00 |

#### Conduction

| | | Metal | Insulation |
|---|---|---|---|
| Thickness | (m) | 1.000e-002 | 3.000e-002 |
| Cp | (kJ/kg-C) | 0.4730 | 0.8200 |
| Density | (kg/m3) | 7801 | 520.0 |
| Conductivity | (W/m-K) | 45.00 | 0.1500 |

#### Convection

| | | | | | |
|---|---|---|---|---|---|
| Inside Vap Phase U (kJ/h-m2-C) | 7200 | Inside Liq Phase U (kJ/h-m2-C) | --- | Outside U (kJ/h-m2-C) | 54.00 |

### Level Taps: Level Tap Specification

| Level Tap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

### Level Taps: Calculated Level Tap Values

| Level Tap | Liquid Level | Aqueous Level |
|---|---|---|

### Options

# Tank: WASHING UNIT.3 (continued)

| | | | |
|---|---|---|---|
| PV Work Term Contribution | (%) | 100.00 * | |

## DYNAMICS

### Vessel Parameters: Initialize from Product

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume | (m3) | 2.034 * | Level Calculator | | Vertical cylinder |
| Vessel Diameter | (m) | 1.200 | Fraction Calculator | | Use levels and nozzles |
| Vessel Height | (m) | 1.799 | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 100.0 |

### Holdup: Vessel Levels

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | --- | --- | 0.0000 |
| Liquid | --- | --- | 0.0000 |
| Aqueous | --- | --- | 0.0000 |

### Holdup: Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 | 0.0000 |
| Liquid | 0.0000 | 0.0000 | 0.0000 |
| Aqueous | 0.0000 | 0.0000 | 0.0000 |
| **Total** | **0.0000** | **0.0000** | **0.0000** |

| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: | C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.hsc |
|---|---|---|---|
| | | Unit Set: | SI |
| | | Date/Time: | Fri Feb 09 09:14:39 2007 |

# Vessel Sizing: Vessel Sizing-5

## Vertical Seperator Properties: WASHING UNIT2

| | | | | |
|---|---|---|---|---|
| L/D Ratio | | 5.000 * | Demister to Top (m) | 0.3048 * |
| Liq. Res. Time | (seconds) | 564.7 * | | |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.7068 * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 5205 | Associated Cost ($US) | 608.5 | Total Cost (FOB $US) | 5814 |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 0.3048 | Liquid Residence Time | (seconds) | 564.7 |
| Total Length | (m) | 1.676 | Liquid Surge Height | (m) | 0.4572 |
| L/D Ratio | | 5.000 | LLSD | (m) | 0.4572 |
| Max. Allowable Vapour Velocity | (m/s) | 1.000 | Liquid Res. Time at LLSD | (seconds) | 564.7 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | 0.3048 |
| Inlet Nozzle to Demister | (m) | 0.5334 | Ellipsoidal Head | (m) | 7.620e-002 |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | 1.219 |


* Specified by user.

| | | | |
|---|---|---|---|
| HYPROTECH LIFECYCLE INNOVATION | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: | C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.2.hsc |
| | | Unit Set: | SI |
| | | Date/Time: | Thu Dec 21 17:01:19 2006 |

# Tank: WASHING UNIT2

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| DEGREASED B.M | Tank | DEGREASING UNIT |
| P.WATER.3 | Pump | PUMP.3 |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| WASHED.BM | Tank: | WASHING UNIT.3 |
| WATER+SOAP | Mixer: | MIXER |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| | |

## PARAMETERS

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume: | 2.050 m3 * | Level SP: | 85.00 % * | Liquid Volume: | 1.742 m3 |
| Vessel Pressure: | 100.0 kPa | Pressure Drop: | 0.0000 kPa * | Duty: | 0.0000 kJ/h |
| Heat Transfer Mode: | Heatin | | | | |

### User Variables

## RATING

### Sizing

| Cylinder | | Horizontal | | Separator has a Boot: No | |
|---|---|---|---|---|---|
| Volume | 2.050 m3 * | Diameter | 1.203 m | Length | 1.804 |

### Nozzles

| Base Elevation Relative to Ground Level | 0.0000 m * | Diameter | 1.203 m | Length | 1.804 |
|---|---|---|---|---|---|

| | | DEGREASED B.M | P WATER.3 | WASHED.BM |
|---|---|---|---|---|
| Diameter | (m) | 6.014e-002 | 6.014e-002 | 6.014e-002 |
| Elevation (Base) | (m) | 0.6014 | 0.6014 | 1.203 |
| Elevation (Ground) | (m) | 0.6014 | 0.6014 | 1.203 |
| Elevation (% of Height) | (%) | 50.00 | 50.00 | 100.00 |
| | | WATER+SOAP | | |
| Diameter | (m) | 6.014e-002 | | |
| Elevation (Base) | (m) | 0.0000 | | |
| Elevation (Ground) | (m) | 0.0000 | | |
| Elevation (% of Height) | (%) | 0.00 | | |

### Detailed Heat Loss Parameters

| Overall Heat Loss (kJ/h) | 0.0000 | Area (m2) * | 6.817 |
|---|---|---|---|

#### Temperature Profile

| Fluid (C) | 0.0000 * | Inner Wall (C) | 25.00 | Outer Vessel (C) | 25.00 | Outer Insulation (C) | 25.00 | Ambient (C) | 25.00 |
|---|---|---|---|---|---|---|---|---|---|

#### Conduction

| | | Metal | Insulation |
|---|---|---|---|
| Thickness | (m) | 1.000e-002 | 3.000e-002 |
| Cp | (kJ/kg-C) | 0.4730 | 0.8200 |
| Density | (kg/m3) | 7801 | 520.0 |
| Conductivity | (W/m-K) | 45.00 | 0.1500 |

#### Convection

| Inside Vap Phase U (kJ/h-m2-C) | 7200 | Inside Liq Phase U (kJ/h-m2-C) | -- | Outside U (kJ/h-m2-C) | 54.00 |
|---|---|---|---|---|---|

### Level Taps: Level Tap Specification

| Level Tap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

### Level Taps: Calculated Level Tap Values

| Level Tap | Liquid Level | Aqueous Level |
|---|---|---|

### Options

# Tank: WASHING UNIT2 (continued)

| PV Work Term Contribution | (%) | 100.00 * |
|---|---|---|

## DYNAMICS

### Vessel Parameters: Initialize from Product

| Vessel Volume | (m3) | 2.050 * | Level Calculator | | Horizontal cylinder |
|---|---|---|---|---|---|
| Vessel Diameter | (m) | 1.203 | Fraction Calculator | | Use levels and nozzles |
| Vessel Length | (m) | 1.804 | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 85.00 * | Vessel Pressure | (kPa) | 100.0 |

### Holdup: Vessel Levels

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | --- | --- | 0.0000 |
| Liquid | --- | --- | 0.0000 |
| Aqueous | --- | --- | 0.0000 |

### Holdup: Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| **Total** | **0.0000** | **0.0000** | **0.0000** |

# Vessel Sizing: Vessel Sizing-6

## Vertical Seperator Properties: WASHING UNIT.1

| | | | | | |
|---|---|---|---|---|---|
| L/D Ratio | | 5.000 * | Demister to Top | (m) | 0.3048 * |
| Liq. Res. Time | (seconds) | 300.0 * | | | |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10. | 0.7068 |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 7476 | Associated Cost ($US) | 1658 | Total Cost (FOB $US) | 9134 |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 0.6096 | Liquid Residence Time | (seconds) | 300.0 |
| Total Length | (m) | 3.353 | Liquid Surge Height | (m) | 1.719 |
| L/D Ratio | | 5.000 | LLSD | (m) | 0.4572 |
| Max. Allowable Vapour Velocity | (m/s) | 0.8989 | Liquid Res. Time at LLSD | (seconds) | 73.10 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | 0.3048 |
| Inlet Nozzle to Demister | (m) | 0.8721 | Ellipsoidal Head | (m) | 0.15[illegible] |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | 1.634 |

# Tank: WASHING UNIT.1

## CONNECTIONS

### Inlet Stream

| Stream Name | From Unit Operation | |
|---|---|---|
| BASE.METAL | Tank | ACID PICKLING UNIT |
| P.WATER.2 | Pump | PUMP.2 |

### Outlet Stream

| Stream Name | To Unit Operation | |
|---|---|---|
| WASHED.B.M. | Tank: | DEGREASING UNIT |
| FeCl3 +WATER | | |

### Energy Stream

| Stream Name | From Unit Operation |
|---|---|
| QEEE | |

## PARAMETERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vessel Volume: | 2.024 m3 * | Level SP: | 50.00 % | Liquid Volume: | 1.012 | | |
| Vessel Pressure: | 100.0 kPa | Pressure Drop: | 0.0000 kPa * | Duty: | 4.962e+005 kJ/h | Heat Transfer Mode: | Heating |

### User Variables

## RATING

### Sizing

| Cylinder | | Vertical | | Separator has a Boot: | No |
|---|---|---|---|---|---|
| Volume | 2.024 m3 * | Diameter | 1.198 m | Height | 1.797 |

### Nozzles

| | | | | | |
|---|---|---|---|---|---|
| Base Elevation Relative to Ground Level | 0.0000 m * | Diameter | 1.198 m | Height | 1.797 |

| | | BASE.METAL | P.WATER.2 | WASHED.B.M. |
|---|---|---|---|---|
| Diameter | (m) | 8.983e-002 | 8.983e-002 | 8.983e-002 |
| Elevation (Base) | (m) | 0.8983 | 0.8983 | 1.797 |
| Elevation (Ground) | (m) | 0.8983 | 0.8983 | 1.797 |
| Elevation (% of Height) | (%) | 50.00 | 50.00 | 100.00 |
| | | FeCl3 +WATER | | |
| Diameter | (m) | 8.983e-002 | | |
| Elevation (Base) | (m) | 0.0000 | | |
| Elevation (Ground) | (m) | 0.0000 | | |
| Elevation (% of Height) | (%) | 0.00 | | |

### Detailed Heat Loss Parameters

| | | | |
|---|---|---|---|
| Overall Heat Loss (kJ/h) | 0.0000 | Area (m2) | 6.759 |

#### Temperature Profile

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fluid (C) | 0.0000 * | Inner Wall (C) | 25.00 | Outer Vessel (C) | 25.00 | Outer Insulation (C) | 25.00 | Ambient (C) | 25.00 |

#### Conduction

| | | Metal | Insulation |
|---|---|---|---|
| Thickness | (m) | 1.000e-002 | 3.000e-002 |
| Cp | (kJ/kg-C) | 0.4730 | 0.8200 |
| Density | (kg/m3) | 7801 | 520.0 |
| Conductivity | (W/m-K) | 45.00 | 0.1500 |

#### Convection

| | | | | | |
|---|---|---|---|---|---|
| Inside Vap Phase U (kJ/h-m2-C) | 7200 | Inside Liq Phase U (kJ/h-m2-C) | --- | Outside U (kJ/h-m2-C) | 54.00 |

### Level Taps: Level Tap Specification

| Level Tap | PV High | PV Low | OP High | OP Low |
|---|---|---|---|---|

### Level Taps: Calculated Level Tap Values

| Level Tap | Liquid Level | Aqueous Level |
|---|---|---|

### Options




* Specified by user.

# Tank: WASHING UNIT.1 (continued)

| | | | |
|---|---|---|---|
| PV Work Term Contribution | (%) | 100.00 * | |

## DYNAMICS

### Vessel Parameters: Initialize from Product

| | | | | | |
|---|---|---|---|---|---|
| Vessel Volume | (m3) | 2.024 * | Level Calculator | | Vertical cylinder |
| Vessel Diameter | (m) | 1.198 | Fraction Calculator | | Use levels and nozzles |
| Vessel Height | (m) | 1.797 | Feed Delta P | (kPa) | 0.0000 * |
| Liquid Level Percent | (%) | 50.00 | Vessel Pressure | (kPa) | 100.0 |

### Holdup: Vessel Levels

| Phase | Level (m) | Percent (%) | Volume (m3) |
|---|---|---|---|
| Vapour | --- | --- | 0.0000 |
| Liquid | --- | --- | 0.0000 |
| Aqueous | --- | --- | 0.0000 |

### Holdup: Details

| Phase | Accumulation (kgmole/h) | Moles (kgmole) | Volume (m3) |
|---|---|---|---|
| Vapour | 0.0000 | 0.0000 * | 0.0000 |
| Liquid | 0.0000 | 0.0000 * | 0.0000 |
| Aqueous | 0.0000 | 0.0000 * | 0.0000 |
| **Total** | **0.0000** | **0.0000** | **0.0000** |

### Duty Valve Source : Direct_Q

| SP (kJ/h) | Min. Available (kJ/h) | Max. Available (kJ/h) |
|---|---|---|
| 4.962e+005 | --- | --- |

### Liquid Heater Height as % of Vessel Volume

| | |
|---|---|
| Top of Heater : 5.00 % * | Bottom of Heater : 0.00 % * |

### Heat Flow into the PFR: Heating

| HYPROTECH | TEAM LND<br>Calgary, Alberta<br>CANADA | Case Name: | C:\Program Files\Hyprotech\HYSYS 3.1\Cases\MR. BABALOLA.hsc |
|---|---|---|---|
| | | Unit Set: | SI |
| | | Date/Time: | Fri Feb 09 09:09:22 2007 |

# Vessel Sizing: DEGREASING UNIT

## Vertical Seperator Properties: ACID PICKLING UNIT

| | | | | | |
|---|---|---|---|---|---|
| Max. Vap. Velocity | (m/s) | 0.5343 * | Liq. Res. Time | (seconds) | 300.0 * |
| L/D Ratio | | 3.000 * | Demister to Top | (m) | 0.3048 * |

## Construction Information

| | | | | | |
|---|---|---|---|---|---|
| Chem Eng Fab Index | | 252.5 | Allowable Stress | (kPa) | 9.446e+004 |
| Material Type | | Carbon Steel | Shell Thickness | (mm) | 6.350 |
| Mass Density | (kg/m3) | 7861 | Corrosion Thickness | (mm) | 3.175 |
| FMC | | 1.000 | Joint Efficiency | | 1.000 |

## Costing Coefficients

| Shell Thick | | Shell Mass | | Base Cost | | Accessories | |
|---|---|---|---|---|---|---|---|
| A1: | 0.4000 * | A4: | 0.8116 * | A5: | 8.600 * | A8: | 1017 * |
| A2: | 2.000 * | | | A6: | -0.2165 * | A9: | 0.7396 * |
| A3: | 0.2000 * | | | A7: | 4.580e-002 * | A10: | 0.7068 * |

## Costing Results

| | | | | | |
|---|---|---|---|---|---|
| Base Cost ($US) | 1.200e+004 | Associated Cost ($US) | 3894 | Total Cost (FOB $US) | 1.589e[illegible] |

## Sizing Results

| | | | | | |
|---|---|---|---|---|---|
| Diameter | (m) | 1.372 | Liquid Residence Time | (seconds) | 300.0 |
| Total Length | (m) | 4.801 | Liquid Surge Height | (m) | 0.4300 |
| L/D Ratio | | 3.000 | LLSD | (m) | 0.7620 |
| Max. Allowable Vapour Velocity | (m/s) | 0.5343 | Liquid Res. Time at LLSD | (seconds) | 615.5 |
| Demister Thickness | (mm) | 0.0000 | | | |

## Vapour Space

| | | | | | |
|---|---|---|---|---|---|
| Sump To Inlet Nozzle | (m) | 0.3048 | Demister To Head | (m) | [illegible] |
| Inlet Nozzle to Demister | (m) | 3.418 | Ellipsoidal Head | (m) | [illegible] |
| Demister Thickness | (mm) | 0.0000 | Total Vapour Height | (m) | |

# APPENDIX II

## Cathodic balance

Nickel deposited is 40.679kg.

Chrome deposited is 351.62kg.

### Anodic Balance

Since it is assumed that what is removed from Anode is deposited on the cathode. It implies that 351.62kg and 187.89kg of nickel and chrome were what is removed from Anode and consequently deposited at the cathode.

Electrolyte balance

Volume of Electroplating tank is $2.583m^3$

Volume of Bath = 0.6 x volume of the Electroplating Tank.

= 0.6 x 2.583

= $1.550m^3$

It implies total quantity of water required to make the Electrolyte is $1.550m^3$ and quantity of salt to dissolve can be calculated thus.

| $NiSO_46H_20$ 291g | 1000L | 1kg |
|---|---|---|
| L | Im3 | 1000g |

= $291kg/m^3$

| $NiCl_26H_2O$ 52.5g | 1000L | 1kg | |
|---|---|---|---|
| L | Im3 | 1000g | |

= $52.5kg/m^3$

| | | |
|---|---|---|
| $H_3BO_3$ (Boric Acid) 42.5g | 1000L | 1kg |
| L | $Im^3$ | 1000g |

| | | |
|---|---|---|
| $Cr_2(SO_4)_36H_2O$ 300g | 1000L | 1Kg |
| L | $Im^3$ | 1000g |

= 300kg/m$^3$

Sulphuric Acid tetraoxosulphate (vi) Acid

10ml is required it implies

0.01L is required

$1000L \longrightarrow 1M^3$

$$1L = \frac{1}{1000m^3}$$

$$0.01L = \frac{1 \times 0.01m^3}{1000}$$

$0.01L = 1.0 \times 10^{-5}\ m^3$

Density of $H_2SO_4$ is 1184kg/m$^3$

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{Mass} = \text{Density} \times \text{Volume}$$

$$= \frac{1184kg \times 1.0 \times 10^{-5}m^3}{m^3}$$

$$= 0.01184kg$$

Volume Equivalent of constituent of the electrolyte

$NiSO_4.6H_2O$ $\frac{291}{386.01} \times 1.550 = 1.168m^3$

NiCl2.6H2O $\frac{52.5}{386.01} \times 1.550m^3 = 0.211m^3$

$Cr_2(SO_4)_36H_2O$ $\frac{300}{386.01} \times 1.550 = 1.205$

Boric Acid H3B2 $\frac{42.5}{386.01} \times 1.550 = 0.171m^3$

Sulphuric Acid $H_3SO_4$ $= \frac{0.01184 \times 1.550}{386.01} = 4.754 \times 10^{-5}m^3$

Quantity of each constituent that will be require to make 1.502 titles are

$NiSO_4.6H_2O$ $\frac{291kg}{m^3} \times 1.168^3m^3 = 339.89kg$

$NiCl_2.6H_2O = \frac{52.5KG}{M^3} \times 0.211m^3 = 11.08kg$

$H_3B_2 = \frac{42.5kg}{M^3} \times 0.171m^3 = 7.27kg$

$H_2SO_4 = 0.01184kg$

Direct evaluation of cost of material

$NiSO_4.6H_2O$ 1kg ⟶ ₦400.00

339.89kg ⟶ ₦400 x 339.89 = ₦ 135,956

NiCl2.6H2O 1kg ⟶ ₦340.00

11.08Kg ⟶ ₦340 x 11.08

= ₦3,767

Boric Acid 1 kg ⟶ ₦630.00

7.27kg ⟶ ₦620 x 7.27

= ₦4.580

10ml $H_2SO_4$ I is needed

10ml = 0.01L

1L = ₦500

$Cr_2(SO_4)_3 6H_2O$ 1Kg ⟶ ₦380

189.89Kg ⟶ ₦380 x 189.89 = N72,158

0.01L = 0.01 x ₦500 = ₦5

Anode 1kg ⟶ ₦720

351.62kg ⟶ ₦720 x 351.62 = ₦253.159

Water required in dissolution of salts.

25 litres ⟶ ₦5.00

$1.550m^3$ ⟶ 1550 litres

Cost of water required in dissolution $\frac{5 \times 1550}{25}$ = ₦310.00

Total water required for washing

Post acid pickling washing 2901kg

Post decreasing unit washing 576.073kg

Post electroplating washing (Dragout) 1823kg

Total water required is (2901 + 576.07 + 1823 ) kg = 5,300.07kg

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}}$$

$$\text{Volume } \frac{5300.07}{1000} \; \frac{Kg}{Kg/m^3} = 5.3m^3$$

$5.3m^3 \longrightarrow$ 5,300Litres

Total water required for the entire process =

Water required for dissolution + water required for post (Acid pickling, Decreasing and Electroplating) + water required in Acid pickling tank + water required in dragout tank =

(1550 + 5300 + 1220 + 1215) litres.

= 9,285 litres

$$\text{cost of this Water} = \frac{N5 \times 9,285 \times 10^3}{20}$$

= ₦46,425

Actual mass of HCL required = $0.6935kg/m^3 \times 1.2204m^3$ = 0.846kg

Actual mass of NaOH require = $0.028kg/m^3 \times 1.215m^3$ = 0.034kg

Volume of Acid = $0.6 \times 1.550m^3$

Pickling unit = 0.6 x 1.550 x 1000L = 930L

Volume of Degreasing = 0.6 x 2.583

Unit = 0.6 x 2.583 x 100L

= 154.98L

Costing of NaOH and HCl required

NaOH

1kg $\longrightarrow$ ₦5,00

0.034 $\longrightarrow$ 0.039 = ₦17.00

HCl

2.795kg $\longrightarrow$ ₦300

$1kg \longrightarrow \frac{₦300}{2.795} = ₦107.33$

$0.8464kg = \frac{300 \times 0.8464}{2.795}$

$= ₦90.85$

Cost of wrist watch1kg of raw wrist watch chain ⟶ ₦10

Each wrist watch weight of 0.25kg

$0.25kg \longrightarrow 0.25 \times 10 = ₦2.50$

$1999.0kg \longrightarrow 1999.0 \times 10 = 19,990$

$= ₦1.2 \times 10^4$

## APPENDIX III

## COST ESTIMATION OF EQUIPMENT AND ECONOMIC ANALYSIS USING COST INDEX ESTIMATION (Marshall and Smith Cost Index)

**Cost equipment**

The cost are based on cost data of 2006 which are available in dollars.

Exchange rate ER as at 2006: 130 naira = 1 dollar

Therefore ER: 130 naira

**Purchased Cost Data**

The purchased cost data for process equipment is given below as: Purchase Cost Data for Reactors, Degreasing Tank, Acid Pickling, tank electroplating tank and washing tanks.

$$PC = \frac{M.S}{280}\left(101 . D^{1.066} H^{0.802}\right) ER$$

Where D = Diameter of the column (ft)

H = Height of the column (ft)

M.S = Marshall and Smith index

Fc = 1.00 + Fm + Fp

| Fm | | Fp | |
|---|---|---|---|
| CS | 1.00 | <50Psia | 1.00 |
| SS | 3.67 | 200 | 1.15 |
| Monel Steal | 6.34 | 400 | 1.35 |
| Titanium | 7.89 | 600 | 1.60 |

Note: CS = Carbon Steel

SS = Stainless Steel

Monel Steal

**Purchase cost of the acid pickling unit**

Purchase cost PC is given by the relation below:

Marshall and Smith index is Ms: = 110

The material of construction selected is

Carbon Steel:

Fm = 1.00 Fp = 1.00

Fc = 1 + fm + fp

Fc = 1 + 1 + 1

Fc = 3 Note: 1m□ 3.281

Diameter of the tank D:1.200m or 3.937 ft

Height H: 1.799m or 5.903ft

$$PC_{\text{Acidpickling tank}} = \frac{M/s}{280}\left[101.9(D)^{1.066}_{\text{Acid pickling tank}}(H_{\text{Acidpickling tank}})\ 0.802\ Fc\ ER\right]$$

$$= \frac{11.0}{280}\left[101\ X\ 9(3.907)1.066\ X\ (5.903)0.802\ x\ 3\right]\ 130$$

= ₦277,191

**Purchased cost of the Washing Tank 1**

Purchase cost Pc is given by the relation below:

Marshall and Smith index is Ms: = 110

The material of construction is carbon steel

For carbon steel

Fm = 1.00 fp = 1.00

Fc = 1+fm+fp

Fc = 1+1+1

Fc = 3

Diameter of the tank 1.198m $\longrightarrow$ 2.9306ft

Height of the tank 1.979m $\longrightarrow$ 5.896ft

$$Pc_{washing\ tank} = \frac{Ms}{280}\left[101.9(D_{washing\ tank})^{1.066}(H_{washing\ tank})^{0.802}Fc\right]ER$$

$$= \frac{110}{280}\ 101.9(3.9306)1.066 \times (5.896)0.802 \times 3 \times 130$$

= ₦278,711

**Degreasing Unit**

**Purchasing cost of the degreasing tank**

Purchase cost Pc is given by the relation below:

Marshall and Smith index is Ms: 110

The material of consturciton selected is carbon steel

Fm = 1.00 Fp = 1.00

Fc = 1 + fm + fp

Fc = 1+1+1

Fc = 3

Diameter of the tank D = 1.198m or 3.931 ft

H = 1.797m or 5.896 ft

$$PC_{\text{Degreasing tank}} = \frac{Ms}{280}\left[101.9\,(D_{\text{Degreasing tank}})^{1.066}\,(H_{\text{Degreasing tank}})^{0.802}\,Fc\right] ER$$

$$= \frac{110}{280}\left[101.9\,(3.931)^{1.066} \times (5.896)^{0.802} \times 3\right] 130$$

= ₦278,741

**Purchasing Cost of Washing Tank 2**

Purchasing cost Pc is given by the relation below

Marshall and Smith index is Ms = 110

The material of construction selected is carbon steel

Fm = 1.00 Fp = 1.00

Fc = 1 + Fm + Fp

Fc = 1+1+1

Fc = 3

Diameter of the tank D = 1.203m or 3.947 ft

H = 1.804m or 5.919 ft

$$PC_{\text{washing tank 2}} = \frac{Ms}{280}\left[101.9\,(D_{\text{washing tank 2}})^{1.066}\,(H_{\text{washing tank}}\ 2)^{0.802}\ Fc\right] ER$$

= ₦297,500

$$= \frac{110}{280}\ [\ 101.9\ (3.947)1.066 \times (3.919)0.802 \times 3]\ 130$$

= ₦201,753

**Purchasing cost of the washing tank 3**

Purchase cost Pc is given by the relation below

Marshal and Smith index is Ms = 110

The material of construction selected is carbon steel.

Fm = 1.00 Fp = 1.00

Fc = 1 + Fm + Fp

Fc = 1+1+1

Fc = 3

Diameter of the tank D = 1.299 or 4.262

H = 1.949 or 6.395

$$Pc_{\text{washing tank 3}} \frac{Ms}{280} \left[ 101.9\ (D_{\text{washing tank 3}})^{1.066}\ (H_{\text{washing tank 3}})^{0.802}\ Fc \right] ER$$

$$= \frac{110}{280} \left[ 101.9\ (4.262)^{1.066} \times (6.395)^{0.802} \times 3 \right] 130$$

= ₦324,284

Purchasing Cost of the Electroplating Tank

Purchase Cost Pc is given by the relation below:

Marshal and Smith Index is Ms = 110

The material of construction selected is carbon steel

Fm = 1.00 Fp = 1.00

Fc = 1 + Fm + Fp

Fc = 1 +1 + 1

Fc = 3

Diameter of the tank

$D = 1.299m \text{ or } 4.262$

$H = 1.949m \text{ or } 6.395$

$$Pc_{Electroplating\ tank} = \frac{Ms}{280}\left[101.9\,(D_{electroplating\ tank})^{1.066}\,(H_{electroplating\ tank})^{0.802}\,Fc\right] ER$$

$$= \frac{110}{280}\left[101.9\,(4.262)^{1.066} \times (6.395)^{0.802} \times 3\right] 130$$

$= ₦324,284$

**Purchasing cost of the Dragout tank 1**

Purchase cost Pc is given by the relation below

Marshal and Smith index is : $Ms = 110$

the material of construction selected is carbon steel

$Fm = 1.00 \quad Fp = 1.00$

$Fc = 1 + Fm + Fp$

$Fc = 1 + 1 + 1$

$Fc = 3$

Diameter of the tank $D = 0.9405m \text{ or } 3.08616ft$

$H = 1.411 \text{ or } 4.629ft$

$$Pc_{Dragout\ tank\ 1}\ \frac{Ms}{280}\,[101.9\,(D_{dragout\ tank\ 1})^{1.066}\,(H_{dragout\ tank\ 1})^{0.802}\,Fc\,]ER$$

$$= \frac{110\,[101.9(3.086)^{1.066} \times (4.629)^{0.802} \times 3\,]\,130}{280}$$

$= ₦177,374$

**Purchasing cost of the Dragout Tank 2**

Purchase Cost Pc is given by the relation below:

Marshall and Smith index is : Ms = 110

The material of construction selected is carbon steel

Fm = 1.00 Fp = 1.00

Fc = 1+Fm+Fp

Fc = 1 + 1 + 1

Fc = 3

Diameter of the tank D = 0.9405m or 3.086ft

H = 1.411m or 4.629ft

$$Pc_{Dragout\ tank\ 2} = \frac{Ms}{280}\left[101.9\,(D_{dragout\ tank\ 2})^{1.066}\,(H_{Dragout\ tank\ 2}{}^{0.802})Fc\right]ER$$

$$= \frac{110}{280}\left[101.9\,(3.086)^{1.066} \times (4.629)^{0.802} \times 3\right] 130$$

= ₦177,374

**Purchasing cost of the Dragout Tank 3**

Purchase Cost is given by the relation below:

Marshall and Smith index is Ms = 110

The material of construction selected is carbon steel

Fm = 1.00 Fp 1.00

Fc = 1 + Fm + Fp

Fc = 1 + 1 + 1

Fc = 3

Diameter of the tank D = 0.9405m or 3.086ft

H = 1.411m or 4.629ft

$$Pc_{Dragout\ tank\ 3} = \frac{Ms}{280} [\ 101.9\ (\ D_{Dragout\ tank\ 3})^{1.066}\ (H_{\ Dragout\ tank\ 3})^{\ 0.802}\ Fc]\ ER$$

$$= \frac{110}{280} [\ 101.9\ (3.086)^{1.066} \times (4.629)^{0.802} \times 3]\ \ 130$$

= ₦177,374

**Purchasing cost of the Dragout Tank 4**

Purchase Cost is given by the relation below:

Marshall and Smith index is Ms = 110

The material of construction selected is carbon steel

Fm = 1.00 Fp 1.00

Fc = 1 + Fm + Fp

Fc = 1 + 1 + 1

Fc = 3

Diameter of the tank D = 0.762m or 2.500ft

H = 2.667m or 8.750ft

$$Pc_{Dragout\ tank\ 3} = \frac{Ms}{280} [\ 101.9\ (\ D_{Dragout\ tank\ 3})^{1.066}\ (H_{\ Dragout\ tank\ 3})^{\ 0.802}\ Fc]\ ER$$

$$= \frac{110}{280} [\ 101.9\ (2.500)^{1.066} \times (8.750)^{0.802} \times 3]\ \ 130$$

= ₦236,139

**Purchasing cost of the Dragout Tank 5**

Purchase Cost is given by the relation below:

Marshall and Smith index is Ms = 110

The material of construction selected is carbon steel

Fm = 1.00 Fp 1.00

Fc = 1 + Fm + Fp

Fc = 1 + 1 + 1

Fc = 3

Diameter of the tank D = 0.762m or 2.500ft

H = 2.667m or 8.750ft

$Pc_{Dragout\ tank\ 3}$ Ms [ 101.9 ( $D_{Dragout\ tank\ 3})^{1.066}$ ($H_{Dragout\ tank\ 3})^{0.802}$ Fc] ER

$= \frac{110}{280}$ [ 101.9 $(2.500)^{1.066}$ x $(8.750)^{0.802}$ x 3] 130

= ₦236,139

**Purchasing cost of the Dragout Tank 6**

Purchase Cost is given by the relation below:

Marshall and Smith index is Ms = 110

The material of construction selected is carbon steel

Fm = 1.00 Fp 1.00

Fc = 1 + Fm + Fp

Fc = 1 + 1 + 1

Fc = 3

Diameter of the tank D = 0.762m or 2.500ft

H = 2.667m or 8.750ft

$Pc_{Dragout\ tank\ 3}$ Ms [ 101.9 ( $D_{Dragout\ tank\ 3})^{1.066}$ ($H_{Dragout\ tank\ 3})^{0.802}$ Fc] ER

$= \frac{110}{280}$ [ 101.9 (2.500)1.066 x (8.750)0.802 x 3] 130

= N236,139

**Purchasing cost of the Concentrator**

Purchase Cost Pc is given by the relation below:

Marshal and Smith index is : Ms = 110

The material of construction selected is carbon steel

Fm = 1.00 Fp 1.00

Fc = 1 + Fm + Fp

Fc = 1 + 1 + 1

Fc = 3

Diameter of the tank D = 0.3048m or 1.000ft

H = 1.676m or 5.499ft

$$Pc_{concentrator} \frac{Ms}{280} [\, 101.9\, ( D_{concentrator})^{1.066} (H_{Dragout\ tank\ 3})^{0.802}\ Fc]\ ER$$

$$= \frac{110}{280} [\, 101.9\, (1.000)^{1.066} \times (5.499)^{0.802} \times 3]\ 130$$

= ₦61,260

Purchasing cost of Pump

$$\text{Cost Pump} = C2 \left( \left( C1 \frac{Q2}{Q1} \right)^{n} \right) \left( \frac{M-s\ 2006}{M-s\ 1979} \right) \text{ER Naira}$$

Where Q = Volumetric Flow rate gal/min

C = Cost of pump and

M-s = Marshal and Smith index

n = Exponent

Note that all flow rates are converted into gallon/minutes

From Timmerhaus, Cost of pump of 10gpm is $1 \times 10^3$

Q1 = 10 gal/min C1 = 1000

Flow rate of the pump 1 designed is:

$$Q_2 = \frac{1.560\text{m3}}{\text{h}} \left| \frac{1000\text{L}}{1\text{m}^3} \right| \frac{4 \text{ gallon}}{4\text{L}} \left| \frac{1\text{h}}{60 \text{ min}} \right.$$

$Q_2$ = 6.5 gal/min

Marshal and Smith index

M . s 1979 645 n = 0.34

Accordingly Chebrony, Marshall and Smith index obtained by extrapolating equation for year 2006 is:

M .s_2006 is :

M . s – 2006 = 1098

Cost of pump 1 in year 2006 is:

$$C_2 = \left(\left(C_1 \frac{Q_2}{Q_1}\right)^n\right) \frac{M - s\ 2006}{M - s\ 1979} \text{ ER Naira } C^2\ 1000\left(\left(\frac{6.5}{10}\right)^{0.34}\right) \frac{1098}{645}\ 130$$

$$C_2 = \left(\left(C_1 \frac{Q_2}{Q_1}\right)^n\right) \frac{1098}{645}\ 130$$

= ₦2,002

Cost of pump 2 in year 2006 is

$Q_1$ = 10 gal/min. $C_1$ = 1000

M – s – 1979 = 645

M – s 2006 = 1098 n = 0.34

$$Q^2 = \frac{0.1002\text{m}^3}{\text{h}} \left| \frac{1000\text{L}}{1\text{m}^3} \right| \frac{1 \text{ gallon}}{4 \text{ litres}} \left| \frac{1\text{h}}{60 \text{ min}} \right.$$

$Q_2 \quad = \quad 0.4175$ gallon/min

$$C_2 = \left(\left(C_1 \frac{Q_2}{Q_1}\right)^{n}\right) \frac{M-s\ 2006}{M-s\ 1979} \text{ ER naira}$$

$$C_2 = \left(\left(1000 \left(\frac{0.4175}{10}\right)^{0.34}\right) \frac{1098}{645}\right) 130$$

$= \quad$ ₦787

Cost of pump 3 in year 2006 is

$Q^1 \quad = \quad 10$ gal/min. $\qquad C_1 \quad = \quad 1000$

M – s – 1979 $\qquad$ 645

M – s – 2006 $\qquad$ 1098 $\qquad n = 0.34$

$$Q_2 = \frac{0.2\ 044}{H} \left| \frac{1000L}{1m^3} \right| \frac{1 \text{ gallon}}{4 \text{ litres}} \left| \frac{1h}{60 \text{ min}} \right.$$

$Q_2: \quad = \quad 0.852$ gallon/min

$$C_2 = \left(\left(C_1 \frac{Q_2}{Q_1}\right)^{n}\right) \left(\frac{M-s\ 2006}{M-s\ 1979}\right) \text{ER naira}$$

$$C_2 = \left(1000 \left(\frac{0.852}{10}\right)^{0.34}\right) \frac{1098}{645}\ 130$$

$= \quad$ ₦1,003

Cost of pump in year 2006 is

$Q^1$ = 10 gal/min. $C_1$ = 1000

M – s – 1979 645

M – s – 2006 1098 n = 0.34

$$Q_2 = \frac{1.543m^3}{H}\left|\frac{1000L}{1m^3}\right|\frac{1 \text{ gallon}}{4 \text{ litres}}\left|\frac{1h}{60 \text{ min}}\right.$$

$Q_2$: = 6.43 gallon/min

Cost of pump 4 in year 2006 is

$Q_2$: = 0.835 gallon/min

$$C_2 = \left(C_1\left(\frac{Q}{Q_1}\right)^n\right)\left(\frac{M - s\ 2006}{M - s\ 1979}\right) ER \text{ naira}$$

$$C_2 = \left(1000\left(\frac{6.43}{10}\right)^{0.34}\right)\left(\frac{1098}{645}\right)130$$

= ₦4,261

Cost of recycling pump in year 2006 is

$Q_1$ = 10 gal/min. $C_1$ = 1000

M – s – 1979 645

M – s – 2006 1098 n = 0.34

$$Q_2 = \frac{5.131m^3}{H}\left|\frac{1000L}{1m^3}\right|\frac{1 \text{ gallon}}{4 \text{ litres}}\left|\frac{1h}{60 \text{ min}}\right.$$

$Q_2$: = 21.38 gallon/min

$$C_2 = \left( \left( C_1 \frac{Q_2}{Q_1} \right)^n \right) \left( \frac{M - s\ 2006}{M - s\ 1979} \right) \text{ER naira}$$

$$C_2 = \left( 1000 \left( \frac{21.38}{10} \right)^{0.34} \left( \frac{1098}{645} \right) \right) 130$$

= ₦3000

Total cost of pump= cost of pump 1 + cost of pump 2 + cost of pump 3 +

Cost of pump 4 + cost of recycling pump

N(2,002 + 787 + 1003 + 4,261 + 3000)

Tc pumps ₦11,053

**Operating Cost**

**Total purchased cost of equipment**

$$Pc_{\text{Equip}} = Pc_{\text{Acid pickling Tank}} + Pc_{\text{washing tank1}} + Pc_{\text{Degreasing tank}} + Pc_{\text{washing tank 2}} + Pc_{\text{washing tank 3}} + Pc_{\text{Electroplating tank}} +$$

$$Pc_{\text{Dragout tank 1}} + Pc_{\text{dragout tank 2}} + Pc_{\text{dragout tank 3}} + Pc_{\text{dragout tank 4}} + Pc_{\text{dragout tank 5}} + Pc_{\text{dragout tank 5}} + Pc_{\text{Concentrator}} + Tc_{\text{pumps}}$$

$$+ Pc_{\text{heater}} + Pc_{\text{air dryer}} + Pc_{\text{preheater}} + Pc_{\text{cooler}} + Pc_{\text{Mixer}}$$

$Pc_{\text{Equip}}$ = ₦(277,191 + 278,711 + 278,741 + 201,753 + 324,284 + 324,284 + 177,374 + 177,374 + 177,374 + 236,139 + 236,139 +236,139 + 61,260 + 2002 + 787 + 1003 + 4261

Pc = ₦2,758,677

## ECONOMIC ESTIMATION OF TOTAL CAPITAL INVESTMENT

The total capital investment can be given by

Tin = TFC + Wc + TLC

Where TFC = Total fixed cost

Wc = Working capital

TLC = Total Land cost.

**Total Fixed Cost**

The factorial method can be used with the relationship below: (Direct Cost)

TFC: = 10Pc equip

= 758,677

= ₦27,586,770

**Working Capital**

WC = 0.5 TFC

= 0.5 ₦27,586,770

= ₦13.793,385

**Total land cost**

TLC = 0.1 TFC

= 0.1 x N27,586,770

= ₦2,758,677

Tinv = TLC + WC + TFC

= ₦(2,758,677 + 13,793,385 + 27,586,770)

= ₦44,138,832

**Operating Cost**

This is divided into fixed and variable operating cost.

Let the plant life be 20 years n = 20 years

**Fixed Operating Cost**

Direct Labour Cost

Lbc = 0.06 TFC

= 0.06 x ₦27,586,770

= ₦1,655,206.2

Plant Maintenance and Repair

Mc = 0.08 TFC

Mc = 0.08 x ₦27,586,770

Mc = ₦2,206,941.6

**Insurance**

Insc = 0.01 TFC

= 0.01 X ₦27,586,770

= ₦275,867.7

**Local Taxes**

Lbc = 0.02 TFC

= ₦0.02 x 27,586,770

= ₦551,735.4

**Royalties and licensed fee**

Royc = 0.01 TFC

= 0.01 x ₦27,586,770

= ₦275,867.7

**Laboratory Cost**

Labc = 0.21bc

= 0.2 x ₦551,735.4

= ₦110,347.08

**Plant overhead cost**

POHc = 0.5 Lbc

## GENERAL EXPENSES

i. Administrative

ADMc = 0.25 Lbc

= 0.25 x ₦551,735.4

= ₦137,933.85

ii. Research and Development

RADc = 0.015 TFC

= 0.015 x ₦27,586,770

= ₦413,801.55

**Total Fixed Operating Cost**

TFOc: = RADc +ADMc +POHc +Labc + Royc + Labc + Insc + Mc + Lbc + Sc

TFOc = ₦[413,801.55 + 137,933.85 + 275,867.7 + 110,347.08 + 275,867.7 + 551,735.4 + 275,867.7 + 2,206,941.6 + 655,206]

TFOc = ₦5,903,567.98

Annual fixed operating Cost

$$\text{TFO annum} = \frac{\text{TFOc}}{\text{N}}$$

$$\text{TFO annum} = \frac{₦5,903,567.98}{20}$$

= ₦295,178.4/Annum

**Variable Operating Cost**

Cost of raw materials CRMC

Cost of Raw Material = Chrome sulphate+Nickel Sulphate Cost + Nickel Chloride Cost + Boric Acid Cost + Sulphoric Acid + Aniode Cost + Total cost of water for the electroplating system + Cost of Hydrochloric acid + Cost of Sodium Hydroxide + Cost of Base Metal

CRMc = (30,500 + 52,300 + 1,200 + 2,500 + 50 + 18,000 + 14,000 + 9,000 + 19,990)
₦147,540

**Annual cost of raw material**

| 536,148 | 300 days |
| --- | --- |
| Day | 1 year |

ACRM = ₦44,262,000/Annum

Miscelleneous

Msc = 0.05 Lbc

= 0.05 x ₦551,735.4

= ₦27,586.77

**Utilities cost**

Utc = 0.02 Lbc

= 0.02 x N551,735.4

= N11,034.7

**Packaging**

PAC = 0.001 Lbc

= 0.001 x ₦551,735.4

= ₦551.7

**Total Variable Operating Cost**

TVOc = Pac + Msc ACRM + Utc

= ₦(551.7 + 27,586.77 + 11,034.7 + 147,540)

= ₦44,301,173

**Annual Variable Operating Cost**

$$\text{TVO annum} = \frac{\text{TVOc}}{n}$$

$$\text{TVO annum} = \frac{44{,}301{,}173}{20}$$

TVO annum = ₦2,215,058

**Total Annual Operating Cost**

AOCc = TFO annual + TVO annual

= ₦295,178 + 2,215,058

= ₦2,510,236.7

Profit Analysis

**Annual Production Rate (APR)**

= 7x 3600 x 20 x 300 = 1814400kg

Production Cost (PC) per kg = AOCc/APR

= ₦2,501,236.7/181,4400kg

= N2.0

Selling Price

This is a function of total production cost demanded and market forces.

Distribution price of N12.00 per kg is assumed

= 12 x 181440000

APS (Annual Product Sales)

= ₦21,772,800

**Profit before tax (PBT)**

PBT = APS – AOCc

= ₦[21,772,800 – 2,510,236.7

PBT = ₦19,262,563.3

**Annual Depreciation (Depr)**

Let S = Salvage value after n years of the plant

Assume plant life of 20 years

Then S:=

Let Vs after 20 years be taken as 15% of TFC in

$$\frac{15}{100} \times ₦27,586,770$$

S = ₦4,138,015.5

$$Dep = \frac{Tin - s}{n} = \frac{₦[44,138.832 - 4,138,015.5]}{20}$$

= ₦2,000,040.8

**Tax Payable (TP)**

Assume tax ratio of 65% and depreciation is tax allowable, hence tax ratio = 0.65

TP = (PBT – Depr) Tax ratio

= N[19,262,563.3 - 2,000,040.8

TP = 17,262,522.5 x 0.65

TP = N11,220,639.6

**Profit after tax (PAT)**

PAT = PBT - TP

= N[19,262,563.3 – 11,220,639.6

= N8,041,923.7

Net Income (NIN)
NIN = N8,041,923.7 + 2,000,040.8/year

= N10,041,964.5

**Pay back period (PBP)**

$$PBP: = \frac{Tinv}{NIN}$$

$$= \frac{N44,138.832}{N10,041,964.5}$$

PBP = 4.39 year

| 4.39 year | 300 days |
| --- | --- |
| | 1year |

PBP = 1317 days

Rate of return on investment

$$RORI = \frac{Nin + Dep}{Tinv} = 100$$

$$\frac{N10{,}041{,}964.5 + 2{,}000{,}040.8}{N44{,}138{,}832} = 0.273 = 108.5\%$$

$$= 0.273 \times 100 = 27.28\%$$