

ZINC PLATING OF METALS

**A RESEARCH PROJECT PRESENTED TO THE CHEMICAL
ENGINEERING DEPARTMENT**

BY

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DECLARATION

I **LAWAL ADEKUNLE ABDULLAHI** declare that the project presented for the award of bachelor of Engineering in chemical. Engineering Department has not been presented either wholly or partially for any other degree elsewhere.

~~Lawal~~ _____

30/10/2003 _____

Student

Date

DEDICATION

This work is dedicated to my parent **Alhaji and Hajiya Abass Lawal** and my brothers and sisters, **Kamaldeen, Asimiyu, Sekinat, Barakat and Mariyam.**

A C K N O W L E D G E M E N T

Foremost glory to the Almighty Allah, the most beneficent, the most merciful, who commands man to read and teach the use of pen and taught man that which he knew not Q.96:3-6. My profound gratitude really goes to him for the health, strength and wisdom which it has pleased him to endow me with during my sojourn at F.U.T. MINNA.

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ABSTRACT

This research project gives a clear view of the fundamental aspect of electroplating process. It shows how zinc plating serves as a corrosion resistance and decorative plating metal which was carried out using pure zinc anodes.

To achieve this experiment was carried out at room temperature with proper agitation of the electrolyte. The variation of voltage and plating time brings about an increase in weight (g) of the metal and the thickness (Y). the value of these parameters were observed. A regression equation was obtained to establish the highest voltage and time required for the appearance of the electroplated metals which is

$$Y = -1.115E-05 - 1.009E-06X_1 + 2.02E-06X_2$$

The confidence of this equation is 95%, and the coefficient of regression R^2 was calculated to be 0.9906395, close to 1.0, thus means that the regression equation model best represent the experimental data.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 HISTORICAL BACKGROUND:

The postulates that chemical and electrical phenomena were mutually related were put forward by M. Lomonov as early as in the middle of 18th century. Much progress was made in the study of electrolyte solution. In 1853, I. Hittorf established that solution ions in an electric field move at different velocities determined by the nature of ion. In 1874, F. Kohlrausch established the law of independence of electric conductivities of ions. In 1887, the Swedish scientist, S. Arrhenius formulated the theory of electrolytic dissociation which remains applicable at the present time. In 1891,

1. Kablukov noted that Arrhenius theory must be used in combination with Medeleev's hydrate theory and pointed out that ions formed in molecular dissociation become hydrated. In 1923, Strong electrolytes. The works of the soviet scientists; P. Antipin, Yn. Baimakov, Yu. Delimarstky, Ya. Frenkel, V. Mashovets, V. Alabysheu, O. Esin, E. Ukshe and their fellow workers advanced to a considerable extent modern concepts of (the theory of eletrolysis of melted substances. The development of theoretical concept of electrochemistry was accompanied by practical electrochemical phenomena.

In 1830s, Micheal Faraday discovered the quantitative laws according to which the amount of substances formed at the electrodes depends on the quantity of electricity passed through the system. In 1838, Russian academician, B Yakobi used an electric current and metal deposition on different shaped electrodes to obtain metal articles of the shapes. Yakobi's discovery subsequently gave birth to a new field of applied electrochemistry. The electroplating, that is the technique by which solid metal is deposited on different articles to render their surface specific properties.

Electroplating is a process whereby an object usually metallic is coated with one or more relatively thin, tightly adherent layers of some other metal. Electroplating is specified when there is a need for surface characteristics that the basis metal, selected for cost or structural reasons does not possess. What the purpose be it improvement of appearance, corrosion protection and the like.

Originally electroplating process was introduced as a means of applying a deposit of nickel, gold or silver as a decorative finish to jewelry, cutlery and bicycle parts. It was the mastery of the science by British, German and American manufacturers and the consequent superiority of their products that brought this electroplating industry into limelight. Now this

has been developed to such an extent that there is hardly a branch of industry which does not make use of the process, not only as a means of adding a finish to goods, but also for adding a protective coating such as cadmium plating and anodizing. Common examples of electroplated materials are chromium-plated steel for automobile accessories, tin-plated steel for food containers, and silver-plated table ware (spoon, forks, knives), gold plated jewelry and chromium plated automobile bumpers. The object to be plated, as well as the plating materials is usually metal. The plating operation is an important and necessary part of the manufacturing process and should be planned for with the same care accorded to fabrication operations.

Electroplating could be well understood with the knowledge of electrolysis and its mechanisms. The mechanisms of electrolysis involve electrolytic reaction i.e. the reactions at the anode (anodic half reaction) and at the cathode (cathodic half reaction), which are oxidation and reduction (redox) reactions. It also involves preferential or selective discharge of ion in an electrolyte, which is dependent on the position of the ion in the electrochemical series, concentration of the ions in the electrolyte and nature of electrode.

Electrolysis; in chemistry, the chemical decomposition of a substance into its components by means of electricity. The substance that decomposes is called an electrolyte and is usually an acid, base or salt that conducts electricity when in solution or in molten form. Science of electroplating has been developed from this principle- if a direct current passed through an electrolyte, metal will be eaten away from the anode; the composition of the electrolyte remains unchanged.

Electroplating has been employed for giving decorative finishes and protective coating for a variety of articles. Cheaper material is usually used as the basis material and plating techniques is used to cover the surface of the material with expensive material. Electroplating includes 'cold casting' or building up of one metal on the surface of the same or another metal for removing worn out or undersize machine parts. It is also used for imparting new characteristics e.g. water resistance to machine parts. In electroplating or electroforming, a metal coating is deposited upon a mould to produce complicated contours, high re-entrant angles and precise diameter configurations, or surface designs e.g. printing plates and gramophone matrices.

Electrolytic processes have been employed on a large scale for the extraction and refining of metals. About three quarters of the world's copper and about one quarter of its lead are refined by electrolysis. The technique of electro-deposition has been extended to obtain rubber deposits from latex solutions for covering metal sheets and frame required for

chemical plants. Inner tubes for popular basis material for plating. Rust preventative technique can therefore be understand easily when we concentrate on plating on iron and regard plating on all other materials such as copper, brass, lead, zinc, as its variation.

1.2 AIMS AND OBJECTIVES

The major objectives of this project (zinc plating) are: -

1. To change the surface properties of metal.
2. To obtain improve resistance to the corrosion, tarnish, chemical and wears.
3. To get improve surface appearance on the basis metal.
4. To increase hardness of the metal.
5. To improve electrical conductivity.

1.3 SCOPE OF WORK

In theory at least to every metal, electroplating can occur and their electro-deposition can theoretically be carried out. In practice however, there are chemical, electrochemical and metallurgical consideration, which considerably limit the number of metals with which the present state of knowledge can be difficult to electroplate even impossible to plate.

This project examine the case with which metal can be zinc plated as well as its suitability for electro-deposition.

This process based on the fact that when a direct current of electricity is passed between electrodes immersed in solution containing metallic salt, electrolysis will occurs. This will results in all metals, as ions migrating to the negatives or cathodic electrode. But in this case zinc dissolution is the main anode process. Water is involved, as it is the solvent used for metallic salt.

CHAPTER TWO

2.0 LITERATURE REVIEW:

2.1 AN OVERVIEW OF ELECTROPLATING

Electroplating is a process of electro deposition by which a thin smooth sound metallic deposit is produced over a basis metal. The arrangement of electrolytic cell in electroplating is the same as that for verification of electrolysis by faraday, the cathode is the metallic object which is to be coated or plated, the anode is a strip of the plating metal and the electrolyte is a salt of the plating metal. Metals usually used in plating are copper, zinc, chromium, gold, nickel, and silver e.t.c.

Electroplating is carried out in a vessel called the plating bath that contains the electrolyte. The electrolyte is usually a solution containing a salt of the metal that is to form the coating. The object to be plated and a rod of the plating metal are immersed in the electrolyte. Using the object and the rod as electrodes, a direct current from a generator (rectifier) or battery is passed through the electrolyte. The object is connected to the negative terminal of the current source and is therefore cathode. The metal rod is connected to the positive terminal and is therefore the anode.

The positively charged metal ions from the electrolyte are then deposited on the object (the negative electrode) and are reduced to metal atoms. The metal from electrolyte is replaced by metal dissolved from the rod (anode). In theory the amount of metal deposited on the cathode equals the amount dissolved from the anode. In practice, metal may in some cases be removed from anode at a faster rate than it is deposited on the cathode; in others the reverse situation may occur. The composition of the plating bath may also be altered by contamination from the air or from impurities present in the anode. For these reasons it is usually necessary to adjust the concentration of the plating bath from time to time by adding more of the metallic salt or more water. In this chapter basic principles dealing with electroplating is discussed.

2.2 PRINCIPLES OF ELECTROPLATING

2.2.1. QUANTITY

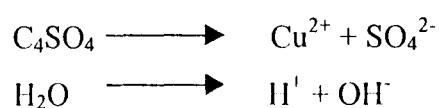
The quantity of products liberated at the electrode during electrolysis or electroplating depends on three factors, which are the magnitude of the steady current, the time of flow of the steady current and the ionic charge of the liberated element. These quantitative aspects of electrolysis or electroplating were first investigated by faraday that later put forward two laws

in 1833 to describe these quantitative relationships, these laws are called faraday laws of electrolysis.

Electroplating which involves electrolysis is guided by theories and laws. These are ionic theory, which was first presented by Arrhenius in 1887. Another law guiding electrolysis is the faraday's law of electrolysis as earlier stated.

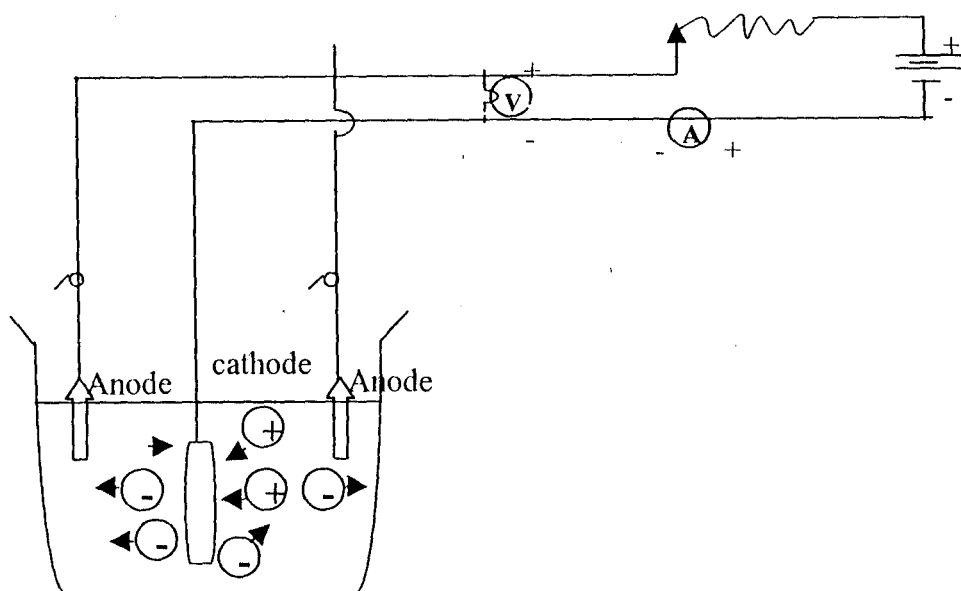
2.2.2 THE IONIC THEORY:

The ionic theory was first presented by Arrhenius in 1887 to explain electrolysis. The theory stated that when an electrolyte is molten or dissolved in water, some, if not all, of the molecules of the substance dissociate (breaks up) into freely moving charged particles called ions. The process of dissociation into ions is known as ionization. e.g.



The metallic ions, like hydrogen ion and copper ion are positively charged while the non-metallic ion, hydroxide ion and sulphide ion are negatively charged. The number of electrical charges carried by an ion is equal to the valency of the corresponding atom or group. Due to the electronic charges carried by these ions, their properties are quite different from those of their corresponding atoms, which are electrically neutral. A metallic ion for instance is formed from the corresponding atom by the gain of a number of electrons equal to the valency of the atom.

When an electrolyte is dissolved in water or is melted, its molecules dissociate, or separate into freely moving ions. These free ions can exist independently of one another in solution, but must of course always balance out electrically, in other words, the numbers of positives and negatives charges must always be equal. Under the influence of a potential applied between two electrodes immersed in the solution (cell voltage or cell potential) the ions will migrate, the positively charged ions towards the cathode or negative electrode. The positive ions are specifically known as cations i.e. cathode ions, at the cathode the cations gain electrons and become uncharged atoms. Simultaneously, the negatively charged ions, called anions, travel to anode. Where they give up electrons and also become uncharged atoms.

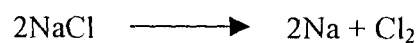


MIGRATION OF IONS TO THE OPPOSITE POLES UNDER THE INFLUENCES OF CELL VOLTAGE

As a result of this transfer electrons, uncharged atoms of the elements of which electrolyte is composed gather at the electrodes. Elements processing positive oxidation number (metals) accumulate at the cathode, while elements with negative oxidation numbers (non-metals) gather at the anode.

When these elements are gases, such as hydrogen or chlorine, the atoms of each join and form bubbles that escape from the electrode at which they accumulate.

The commercial preparation of sodium provides a good example of electrolytic process. In this process an electric current is introduced, sodium ions, Na^+ , travel toward the negatively charged iron cathode, where each one gains an electron and becomes a sodium atom, Na. At the same time, chloride ions, Cl^- , move toward the positively charged graphite anode, where each one loses an electron to the anode and becomes a neutron chlorine atom, Cl. the chlorine atoms then join together in pairs to form molecules of chlorine gas, Cl_2 . The equation for this electrolytic reaction is: -



In a deposition, although metal is continuously removed from the layer of electrolyte next to the cathode, the concentration of metal ions at the interface does not continuously

decrease. A steady or equilibrium state is quickly reached because a number of natural agencies transport metal ions from the body of the bath to the cathode, to replace the ions from the body of the bath to the cathode, to replace the ions deposited. These agencies are diffusion, convection and electrical migration. Electrical migration, the transport of ions under an applied electric field (positive ions being attracted to the negative electrode and vice versa), contributes little to the total transport of ions, as the speed of the ions is very small. The other two agencies, convection and diffusion transport most ions. These agencies do not rely upon an electric field in order to operate. Convection is due to density gradients with the solution temperature.

Diffusion is the natural movement of ions from concentrated to less concentrated regions of the electrolyte. Its effect is most pronounced in the regions of the electrolyte next to cathode (called the cathode diffusion layer) from which ions are continuously removed by deposition, and replaced by transport from bulk of the bath. Both diffusion and convection play a major role in the transport of complex ions from body of bath to the cathode.

2.2.3 ELECTROFORMING:

Electroforming is a variety of electro-deposition (deposition by electrolysis) in which an article to be reproduced is made conductive by spraying it with metallic coating, then electroplated with a metallic deposit in the normal way. The metallic deposit forms a mold, which is removed from its base and filled into reproduce the original article.

2.2.4. PREPARATION OF THE OBJECT:

The object to be plated must be thoroughly or surgically cleaned and rinsed before being placed in the plating bath. The surface must be free of dirt, rust, grease, oil and any oxides or other chemical impurities. If such substances are not removed, the coating may not adhere well to the surface. Grease and dirt are removed by organic solvents or alkaline solutions. Oxides are removed by organic solvents or alkaline solutions. Oxides are removed by immersing the object in acid in a process called pickling. In some cases the object is cleaned by making it the anode in an electrolytic process. This process is called **electro polishing**.

2.2.5 ELECTRICAL CONDUCTANCE OF A SOLUTION

Solution of sodium chloride, lime in water is good conductor of electricity, while solutions of sugar, urea are bad conductor. To understand this difference in electrical conductance capacities of solutions, it is essential to know what was difference in conducting solutions as compared to a non-conducting one.

2.2.6. PRESENCE OF ION AND ELECTRICAL CONDUCTANCE

Ordinarily metal wires are good conductors of electricity. This is due to easy availability of electrons in a metal and they have freedom of movement. When an electric field is applied to a metal, according to the direction of applied field electrons start moving from negatively charged end of metal to its positive one, this way current flow in metal. In actual practise, it happens that only electrons can move in a metal, larger particles (i.e. atomic nuclei or metallic ions) cannot move through a metal. Thus, a substance conducts electricity when an electron or some other electrically charged particles like ion have to move through to two types of electrically charged particles or ions. One type of ions negatively charged and is called anions and other is positively charged and is called cations.

2.2.7. CATHODE AND ANODE

The metal plates dipped in a solution through which the electrons are liberated or absorbed, are called electrodes. The electrode, which liberates electrons from the solution after acquiring them from negatively, charged ions in the solution is positively charged and called the **ANODE** but the electrode which gives electrons to the solution (negatively charged) is called **CATHODE**.

2.2.8. ELECTRIC CURRENT:

The electric current that is used in electroplating must be very carefully controlled in order to produce a smooth, even, non-porous coating of metal. The weight of metal deposited on the object and its average thickness deposited depend on the amount of electricity used and the time for which it flows.

2.2.9. ELECTRICAL CONDUCTANCE OF A SOLUTION AND CONCENTRATION OF IONS IN IT.

When an electric current is passed through a metallic conductor, according to the direction of the applied electrons flow as a stream in a single direction. Thus flow of current in an electrolyte (solution), have two streams of cations and anions flowing in mutually opposite directions, but the total current strength is the sum of current strength due to the stream of cations and anions.

2.2.10. ELECTROLYTES:

The kind of electrolyte that is used for electroplating and its concentration has an important effect on the quality of the coating. The electrolyte solution must be a good conductor of electricity and should not oxidize when exposed to air. It should also have a good throwing power, the measure of its ability to coat all parts of the object close to the anode. Even when the throwing power of electrolyte is good, the object is sometimes rotated during electroplating to make the coating more uniform. In many cases certain chemicals, called brighteners, are added to the electrolyte to help make the coating brighter.

2.2.11 METALS USED IN ELECTROPLATING:

Nearly all metals can be used for electroplating. The most important are gold, silver, chromium, nickel, tin, copper, cadmium, lead and zinc (which this project really based on). Certain alloy, such as brass, nickel, cobalt and speculum, an alloy of tin and copper are also used for plating. The most commonly used plating metal is nickel, because it is more resistant to corrosion than most of the other metals. Chromium plating, which is also very common, is usually applied on top of a layer of nickel plating. This double plating gives better production and the chromium adheres more strongly to the nickel than it does to most base metals. Zinc is the most reactive of all common metals it may however, be attacked or dissolved by ordinary liquids such as soft drinks and vinegar. Therefore, materials that are plated with zinc are usually passivated with blue or yellow solution, that is the surface is finally covered with a solution that makes the surface passive to attack like oxidation, which can bring about tarnishing. In this project zinc (metal) was used for electroplating of basis metal.

2.2.12. ELECTROLYSIS

A solution, which is a good conductor of electricity, cations and anions in it. These ions are normally produced from solute and are sometime produced by a reaction between the solute and solvent. When an electric current is flown in solution by dipping electrodes in electrolyte, positively charged ions (cations) move to the positively charged electrode. Thus in electro chemical reaction the electro-chemical changed involving combination with release of electrons takes place and ions are normally converted to the electrically neutral product which are total different from solution. This phenomenon is called **electrolysis**.

In other words, electrolysis is a process in which the anions and cations present in dissolved state of a substance, are applying an electric field, these are transferred to their respective electrode (i.e. cathode and anode) and these loses there charges and are converted to new substances.

2.2.13 FUNDAMENTAL LAWS OF ELECTROLYSIS:

Product of electrolysis only appear on the surface of electrode and no where else in the solution, because the electrolysis is the result of electron acceptance and electron shedding phenomena, and this can occur only at electrode surfaces.

The fundamental of electrolysis were investigated by Michael Faraday, the English physicist and chemist, discovered the two law that bear his name, who laid down two important principles, which adapted to electrode position or electroplating, these are: -

1. The amount of chemical substances (W) deposited at or dissolved from an electrode during electrolysis is directly proportional to the quantity of electricity (Q) that passes through the solution.

$$\text{i.e. } M \propto Q$$

$$\text{But } Q = It$$

If the quantity electricity (Q) is measured in coulomb and current flown (I) is measured in ampere and time (t) in seconds.

$$\text{Weight of deposit on electrode (W) = } Z \cdot I \cdot t$$

Where Z is constant of proportionality and depends upon the characteristic of the ionic species discharges at electrode. The constant is called electrochemical equivalent of the ionic species and its unit is gram per coulomb.

The electrochemical equivalent of an ionic species is its quality in grammes, which is liberated from an electrode – passing one coulomb of electricity through the electrolyte.

2. That when equal quantities of electricity (Q) pass through solutions of different electrolytes, the amount of the substance (W) deposited or dissolved at the electrodes is directly proportional to the equivalent weight of the substance. (Assuming current efficiency of 100 percent).

The equivalent weight of a substance is its atomic weight divided by its oxidation number or valency.

Chemical equivalent = atomic weight/valency

By second law of faraday; when a current is passed through two electrolyte, if the deposits in two different electrolytes, electrode is W_1 and W_2 gm, and their equivalent weight is M_1 and M_2 , then

$$W_1/W_2 = M_1/M_2$$

2.2.14 RATE OF DEPOSITION

The minimum quantity of electricity required to deposit the equivalent weight in gramme of metal is 96500coulombs. For instance, 96500 will discharge 1mole 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 charged ions involves the transfer of one mole of electron which contains Avogadro's number i.e. 6.02×10^{23} of electrons.

Thus: $W = ItA/ZF$

Where A is the atomic weight of metal deposited of valency, Z, F is a constant called the faraday. 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.

The faraday's law of electrolysis can also be explained in terms of discharge of ion at the electrodes in electroplating, since electrons are involved in the discharge of an element from electrolysis.

2.3 GENERAL APPLICATION OF ELECTROPLATING

PLATING FOR PROTECTION:

Steel must be protected from rusting and chemical attack and so it is electroplated. Protective metals applied are zinc, cadmium and tin e.t.c. Where both protection and good appearance. Nickel dulls by tarnish when exposed to atmosphere and chromium does not.

2.3.1 PLATING FOR APPEARANCE (DECORATIVE PLATING)

For decorative plating metals used are Gold, Nickel, Chromium, Brass, Rhodium and Copper. For special decorative effect Tin, Zinc, Lead, Cadmium, Palladium and Platinum e.t.c. Are also used. One metal may be plated over the basis metal or an alloy may be plated over the basis metal or several metals may be plated one over the other on the basis metal. Metal which forms basis metals are steel, Brass, Copper, Nickel, Silver, white metals alloys of Lead, Zinc or Tin base and aluminum alloys.

2.3.2 PLATING FOR SPECIAL SURFACE AND ENGINEERING EFFECTS:

A part of a plant can be fabricated of an alloy which is easy to fabricate and has got the require mechanical properties but is readily corroded when subjected to atmosphere of working. In such a case electroplating of the part with corrosion resisting metal serves the purpose very well.

Electroplating in engineering is employed for temporary use in metal treatment. For examples steel are parts before carbonizing are copper plated to prevent carbonization of undesired portions.

In hardening process, portions of steel are protected from nitriding by electroplating tin or copper-tin alloys on such portions.

2.4 PROPERTIES OF ZINC

Zinc is a bluish – white lustrous metal, which is hard, crystalline and brittle. The metal is electronegative to iron and gives excellent corrosion resistance, particularly in industrial and urban environments. Zinc readily alloys with many other metals and one of its primary uses is in an alloy form for ‘**Zinc base die castings**’, which are of importance in the metal finishing trade. The ‘**super plastic**’ alloys are also zinc based and can be blow-moulded.

Zinc is almost always deposited in the fully bright condition where an attractive and corrosion resistant finish is required: this can be subsequently passivated or dye.

Zinc dissolves readily in dilute acids and alkalis; therefore it is an unsuitable material for electroplating onto articles that are liable to come into contact with foodstuffs. Lacquered bright zinc plated components are, however, widely used for applications such as refrigerators.

2.5 ZINC PLATING

Zinc plating is a soft ductile, decorative, marginally solderable, corrosion-resistant finish. Unlike most other commonly plated metals, zinc protects the substrate by sacrificing itself and thus corrodes before the base metal. This means that zinc will protect even if the zinc coating sustains minor damage. Such as small scratches or punctures: this is the most reactive of all common metals. It may however, be attacked or dissolved by ordinary liquids such as soft drinks and vinegar. The ultimate corrosion resistance of zinc is a function of the plating thickness. To increase the corrosion resistance of zinc, a conversion coating is usually added.

Chloride zinc plating was introduced about 1980, when environmental pressures began to demand the replacement of cyanide plating baths. By far, the majority of these are chloride baths using potassium or sodium chloride. The baths have high cathode efficiency and excellent throwing power because of the high cathode efficiency over the entire current density range.

The purpose of passivation processes is to protect zinc-plated surfaces, and in some cases zinc base 'die castings' from corrosion, so that their main task of sacrificial protection to steel is not reduced.

2.6 APPLICATIONS AND CORROSION RESISTANCE

The value of zinc as a rust-proof finish for iron and steel has long been appreciated and galvanizing by means of the molten metal practiced for at least two centuries. In recent years electro deposition of zinc has made rapid strides and is now used extensively for finishing all manner of iron and steel products including castings, forgings and sheets steel pressings.

Zinc plating is being used on an increasing scale, particularly in the electrical industry for components which would formerly have been cadmium plated.

Electro deposited zinc coating is of a more uniform thickness than that produced by hot galvanizing and does not tend to fill up slots and screw holes or obliterate threads and other fine details of the work.

The protection afforded to iron and steel is not due to an envelope effect alone i.e. by reason of the zinc forming a continuous coating over the whole article, but is largely due to its behaviour as the anode in any corrodes preferentially to the underlying metal. From this it might appear that the protection would be of short duration and that the deposit would soon be entirely corroded, but in practice rapid corrosion does not occur, as the zinc (unless exposed to exceptionally humid atmospheric conditions) develops upon its surface a tenacious film of oxide, which resists further attack. Passivated coatings increase the resistance of zinc and thus extend considerably the basis metal. Passivated coatings also form a perfect bonding layer for subsequently applied paint schemes.

2.7 IMPORTANT FORMULARS

1. Electrochemical equivalent

$$Z = m/I, t$$

2. E.C.E of metal A/E.C.E of metal B = equivalent weight of metal A/equivalent weight of metal B

3. Volume of metal deposit $V = m/D$

Where D = density of metal.

Thickness of deposit = V/A

Where A = area.

4. Mass of metal deposited

$M = \text{surface area} \times \text{thickness of coating} \times \text{density of metal.}$

5. Time required

$$t = m/ Z.I$$

6. Equivalent weight of metal A/equivalent weight of metal B = electro deposited weight of metal A/ electro deposited weight of metal B.

CHAPTER THREE

3.0- METHODOLOGY

3.1 EQUIPMENT USED

- Rectifier consisting of both voltmeter and the ammeter.
- Beaker
- Stirrer
- Oven (dryer)
- Digital weighing balance.
- Copper wires (electrodes).

3.2 MATERIAL USED

- Acid solution
- HCl –for pickling
- Zinc sulphate
- Potassium chloride
- Boric acid
- Aluminium sulphate
- Dextrin
- Water (distilled)
- Metal to be plated (steel) – cathode
- Zinc anode
- Sodium chromate or potassium chromate
- H_2SO_4

3.3 PREPARATION OF A BATH

The solutions (electrolyte) are made in the appropriate concentration as stated above (3.2) and are mixed to gather. That is zinc sulphate, potassium chloride, boric acid, aluminum sulphate and the likes. After the solutions are made, the first step is to do selective cleaning of the bath to remove all inorganic compounds present. Process of removing them is selective cleaning, by leaving the current in the bath to run at low rate.

The second step is the activation carbon, which is for removing organic compound in the baths. The bath is allowed to stay for 24 to 72 hours before it is free from organic materials hence the bath is ready for use.

3.4 PLATING PROCEDURE

Plating procedure can be divided into three basic units.

1. Pretreatment
2. Plating
3. Post plating

3.4.1 CLEANING OF BASIS METAL (PRE-TREATMENT)

Each material has its own treatment procedure, which depends on the nature of the material. It is therefore necessary to know the nature of basis metal. For example, aluminum cannot be cleaned in a solution formulated for cleaning steel. The nature of contamination and in incorrect identification may result in destruction or damage of the part. Cleaning affects adhesion appearance, corrosion, and resistance of final deposit of metals. These are the following types of cleanliness;

- (a) **Physical Cleanliness:** since the surface of the material (basis metals) is oily, greasy and rusty, it was degreased at first. Impurities or grease greatly affects efficiency in mechanical or chemical cleanliness; therefore, metals were freed from oil, grease and superficial dirt. This is done by using aqueous cleaner like alkaline sodium phosphate. Organic solvent such as tetrachloride ethylene can also be use.
- (b) **Chemical cleanliness:** The metal should be free from oxides or other compounds formed on the surface of the basis metal. For chemical cleanliness, tarnish and oxide film are removed by dipping in acid solution of 10-30% by volume, this is also known as "*Acid pickling*". The acid used is Hydrochloric acid (HCl). Dilute tetraoxosulphate (vi) acid could also be used as well.
- (c) **Mechanical cleanliness:** The metal surface defects such as scratches, and scans are removed by polishing with the aid of floor -type-balancing tool (belt polishing). The metal should have no damaged surface skin, which is caused by mechanical operation. Sometime sand paper was also used so as to achieve better surface and later buffed as well. Polishing improves the adhesion on the basis of metal.

3.4.2 PLATING

After pretreatment and testing for "water break" on the basis metal, it was transferred to the racks or jigs of the plating solution. The cathode is the metallic object, which is to be plated or coated, the zinc anode is a strip of the plating metal and the electrolyte is a salt of the zinc. Electroplating was carried out in a vessel, called the plating bath that contains the electrolyte.

The electrolyte is a solution containing zinc salt of the metal that is to form the coating. The object to be plated (metal) and a rod of the plating metal (zinc) are immersed in the electrolyte. Using the object and the rod as electrodes, a direct current from a "rectifier" was passed through the electrolyte. The object (basis metals that was surgically cleaned) was connected to the current source (rectifier) and is therefore "cathode". The metal rod is connected to the positive terminal and is therefore "zinc anode".

The positively charged metal ions, that is zinc ions from the zinc electrolyte are then moved and deposited on the basis metal (negative cathode) and are reduced to metal atoms. The metal from electrolyte is replaced by metal dissolved from the rod (zinc anode). In theory the amount deposited on the basis metal (cathode) equals the amount dissolved from the zinc anode. After the required plating, the work piece (metals) was removed from the electrolyte and rinsed, and transferred to the next stage, which is "passivation".

3.4.2.1. COMPOSITION OF THE ELETROLYTE

The composition of the electrolyte in the bath is based on the following concentration.

- Zinc sulphate ----- 300gm
- Potassium chloride -----15gm
- Boric acid----- 20gm
- Aluminum sulphate -----30gm
- Dextrin ----- 15gm
- Water (distilled) ----- 1litre

3.4.2.2 PASSIVATION CONCENTRATION

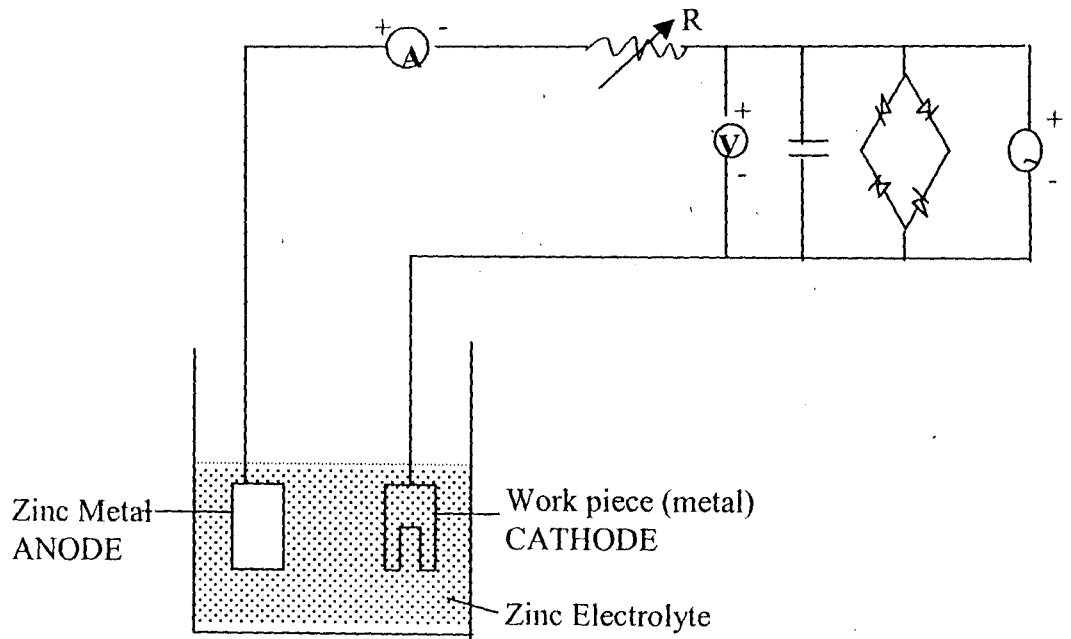
For yellow passivation, the concentrations are:

- Potassium chromate ----- 200gms
- H₂SO₄ -----6.5m.l (made up to 1 litre

For blue passivation:

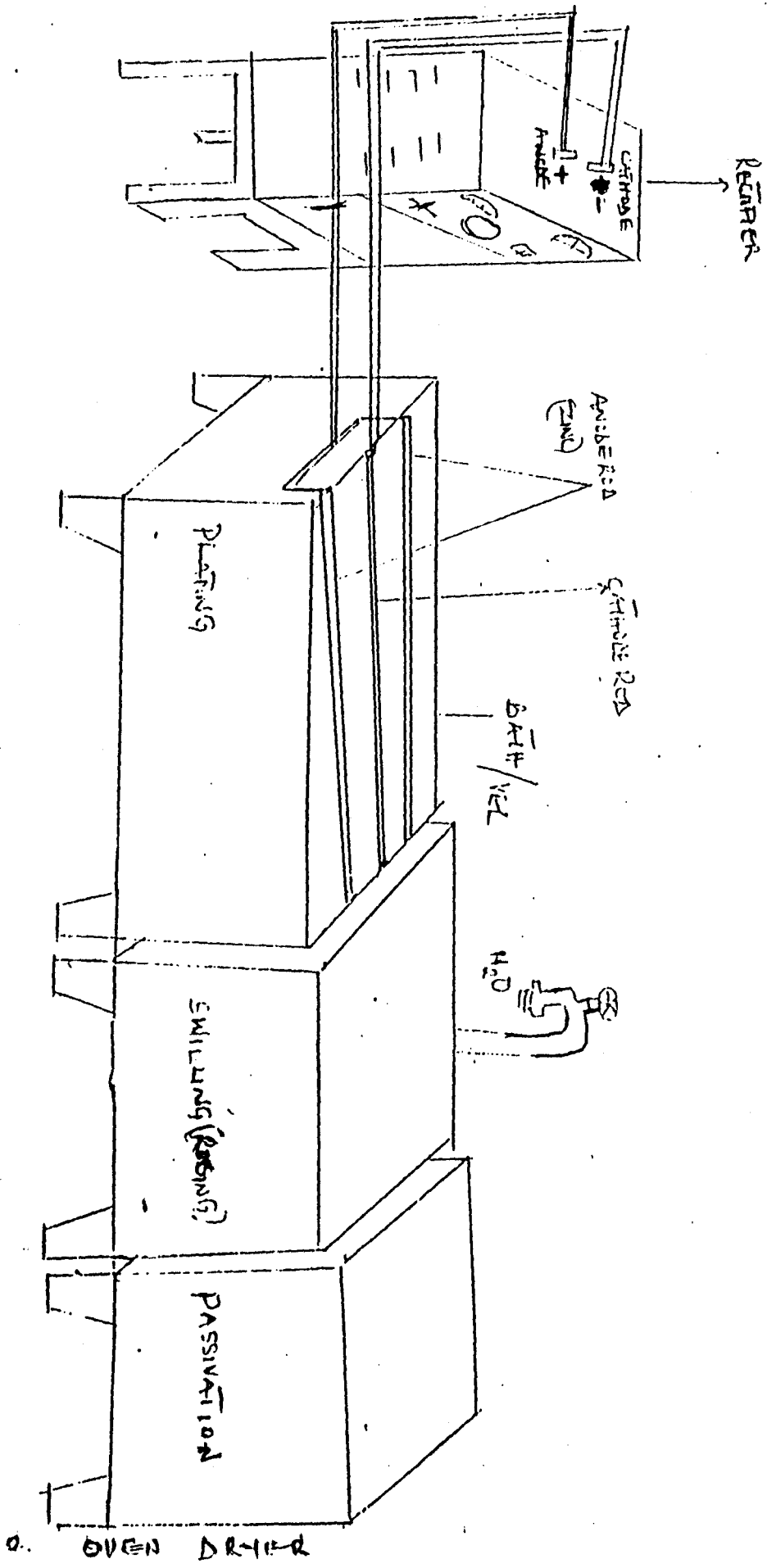
-Proprietary salt ----- $4\text{g}^{\text{l}}/15\text{cc/L HNO}_3$

- H_2O ----- 1 litre.



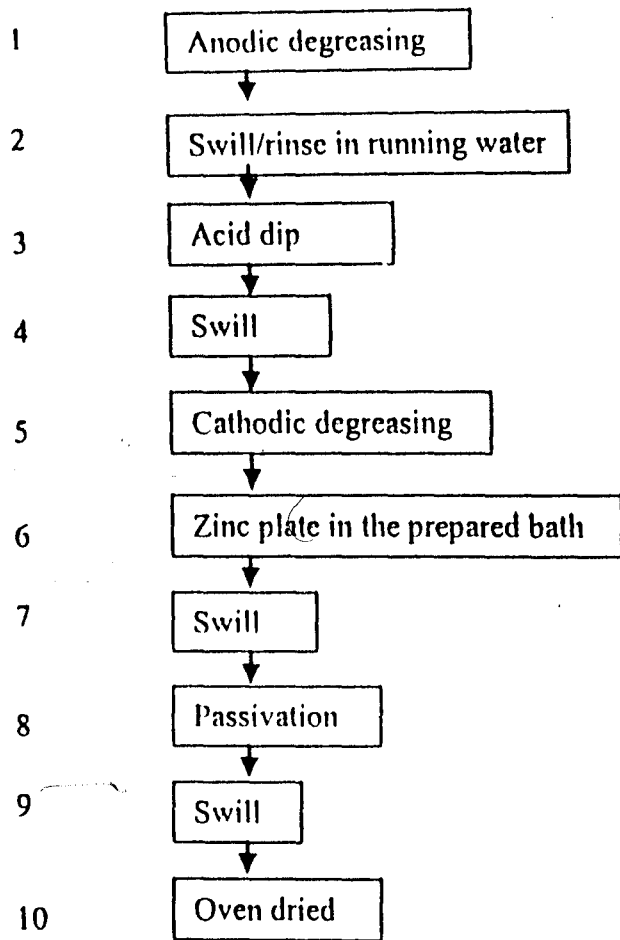
ELECTROPLATING CIRCUIT

ZINC PLATING PROCESS LINE



3.4.3. POST PLATING

This is the final stage of plating. After the required plating, the Zinc-plated items (metals) was swilled and transferred to the next stage, which is '*passivation*' of the work piece. The already zinc plated metals was passivated with yellow or blue solution, that is the surfaces is finally converted with solution that makes the surface passive to attacks like oxidation which can bring about tarnishing. After been passivated the items was rinsed and they are all oven dried or air-dried for some minutes before it was considered a successful plating.



ELECTROPLATING PROCESS FLOW CHART

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The results obtained are tabulated and the voltage, times of plating are recorded and the physical appearances were observed. Different in weight of the metals were also measured and recorded as well as the thickness. Effect of voltage and time were discussed as well.

4.1 EXPERIMENTAL RESULT

Independent variable				Dependent variable			
S/no	Voltage(v) X ₁	Time (min) X ₂	Initial Y ₁	Final wt (g) Y ₂	Different in wt (g) Y ₂ - Y ₁ (10 ⁻³)	Thickness (cm) Y (cm) X10 ⁻⁶	Observation
1	2	8	90.00	90.0015	1.5	2.998	Bright yellow
2	4	10	83.60	83.6025	2.5	4.713	Brighter yellow
3	6	13	91.20	91.2055	5.5	9.691	Bright blue Brighter
4	8	16	86.10	86.1088	8.8	12.8	blue.

Temperature is at room temperature

pH of electrolyte is 3.9

4.2 SIMULATED RESULT

S/no	Voltage (v) X ₁	Time (min) X ₂	Different In weight (10 ⁻³)	Simulated value of Y (10 ⁻⁶)	Observation
1	2	8	1.5	2.998	Bright yellow
2	4	10	2.5	5.0212	Brighter yellow
3	6	13	5.5	9.06474	Bright blue
4	8	16	8.8	13.11	Brighter blue

4.3 DISCUSSION OF EXPERIMENTAL RESULT

In the process of coating the metals, different voltage and time were varied and the surface appearance after passivation were noted as well as different in weight and thickness (Y). In this experiment two types of passivation solution were used for the plating of the metals so as to have an improved surface appearance. Passivation of the surface means covering of the Zinc-plated items with solution that make the surface passive to attacks like oxidation, which can bring about surface tarnishing.

It was observed that at the voltage of 2V with time of 8mins there is 1.5×10^{-3} g in different in weight with 2.998 E^{-06} thicknesses and a bright yellow colour were noted. When the voltage was increased to 4V with corresponding increase in time to 10min it brings about increase in weight difference to 2.5×10^{-3} g with thickness of 4.713×10^{-6} and a brighter yellow colour was observed.

Also at time 13mins with voltage of 6V a bright blue surface and a thickness of 9.691×10^{-6} was recorded while an increase in the time and voltage to 16mins and 8V respectively yielded and increase in weight difference to be 8.8×10^{-3} g and a thickness of 12.8 E^{-05} with a brighter blue surface appearance were noted.

From the experimental result it was observed that as plating time and voltage increases there is an increase in weight difference and thickness of the metals.

4.6 OTHER EFFECTS ON ZINC PLATING

4.6.1. EFFECT OF ANODE

Zinc anode must be kept in polypropylene bag or in cotton; anode that is not been kept properly might bring about direct corrosion into the surface of the cathode. This might result to a rough physical appearance.

4.6.2. EFFECT OF PROPER AGITATION

The agitation of the plating solution (zinc electrolyte) is very essential that is the solution must be well stirred to avoid ions settlement, which will affect the surface of the substrates.

4.6.3 EFFECT OF IMPURITIES

It could be inform of organic constituents, whenever zinc solution comes in contact with these contaminants it causes roughness of the surface of the material. Roughness also arises when anode bag is punctured or the surface of the material appears rough.

Pitting is caused by gas bubble adhering to the cathode surface and electro deposition grows around the attained gas bubble and hence a hole is produced in the coating.

APPENDIX A

DETERMINATION OF THICKNESS OF ZINC DEPOSIT

Average thickness of zinc (inch) = weight of deposit (g)/ area x 113

For material 1

Section 1: B = 2.4cm

L = 5.0cm

Area = A x B

$$= 5 \times 2.4$$

$$A_1 = 12\text{cm}^2$$

Section 2:

B = 1.8cm

L = 4.6cm

Area = 4.6 x 1.8

$$A_2 = 8.28\text{cm}^2$$

But $A_2 = A_3$

$$\therefore A_T = A_1 + A_2 + A_3$$

$$= 12 + 8.28 + 8.28$$

$$= 28.56\text{cm}^2$$

$$= 11.24\text{in}^2$$

Average thickness = weight of deposit (g)/ area (in)² x 113 = 0.0015/11.24 x 113

$$= 1.18 \times 10^{-6}\text{in}$$

$$Y_1 = 2.998 \times 10^{-6}\text{cm}$$

Material 2

Section 1

L₁ = 5.3cm

B₁ = 2.2cm

Area = 5.3 x 2.2

$$A_1 = 11.66\text{cm}^2$$

Section 2

L₂ = 4.9cm

B₂ = 1.9cm

A₂ = 4.9 x 1.9

$$A_2 = 9.31\text{cm}^2$$

But $A_2 = A_3$

$$\therefore A_T = A_1 + A_2 + A_3$$

$$= 11.66 + 9.31 + 9.31$$

$$= 30.28\text{cm}^2$$

$$= 11.92\text{in}^2$$

Average thickness (Y) = 0.0025/11.92 x 113 = 1.855 x 10⁻⁶in

$$Y_2 = 4.713 \times 10^{-6}\text{cm}$$

For Material 3

Section (1)

$$B_1 = 3\text{cm}$$

$$L_1 = 5.2\text{cm}$$

$$A_1 = 15.6\text{cm}^2$$

Section (2)

$$B_2 = 2\text{cm}$$

$$L_2 = 4.2\text{cm}$$

$$A_2 = 8.4\text{cm}^2$$

But $A_2 = A_3$

$$\begin{aligned} A_T &= A_1 + A_2 + A_3 \\ &= 15.6 + 8.4 + 8.4 \\ &= 32.4\text{cm}^2 \\ &= 12.755\text{in}^2 \end{aligned}$$

$$\begin{aligned} \text{Average thickness} &= 0.0055/12.755 \times 113 \\ &= 3.815 \times 10^{-6}\text{in} \end{aligned}$$

$$Y_3 = 9.691 \times 10^{-6}\text{cm}$$

Material 4

Section (1)

$$B_1 = 4.2\text{cm}$$

$$L_1 = 5.0\text{cm}$$

$$A_1 = 21\text{cm}^2$$

Section (2)

$$B_2 = 1.9\text{cm}$$

$$L_2 = 4.8\text{cm}$$

$$A_2 = 9.12\text{cm}^2$$

But $A_2 = A_3$

$$\begin{aligned} A_T &= A_1 + A_2 + A_3 \\ &= 21 + 9.12 + 9.12 \\ &= 39.24\text{cm}^2 \\ &= 15.448\text{in}^2 \end{aligned}$$

$$\begin{aligned} \text{Average thickness} &= 0.0088/15.448 \times 113 \\ &= 5.04 \times 10^{-6}\text{in} \end{aligned}$$

$$Y_4 = 1.28 \times 10^{-5}\text{cm}$$

Electro deposition: The process of depositing a substance upon an electrode by electrolysis. Includes electroplating, electro-finishing and electro-winning.

Electrode potential: The difference in potential between an electrode and the immediately adjacent electrolyte, referred to some standard electrode potential difference as zero.

Electroforming: The production or reproduction of articles by electro-deposition upon a mandrel or mould that is subsequently separated wholly or partly from the deposit.

Electrolyte: (1) A conducting medium in which the flow of current is accompanied by movement of matter. Most often an aqueous solution of acids, bases or salts but includes many other media as fused salts some solids, e.t.c.

(2) A substance which when dissolved in a solvent (usually water) produces a conduction medium. Thus, a solution of an electrolyte

Electrolysis: Production of chemical changes by the passage of current through an electrolyte(1)

Electrolytic cell: A unit apparatus designed for carrying out an electrochemical reaction; includes a vessel, two or more electrodes and one or more electrode for the purpose of securing a surface with properties or dimensions different from those of the basic metal.

Electro-polishing: The improvement in surface finish of a metal affected by making it anodic in an appropriate solution.

Element: A collection of atoms of one type, which cannot be decomposed into any simpler units by chemical means.

pH: (1) The cologarithm (negative logarithm) of the hydrogen ions activity (less precisely, concentration) of a medium.

$$\text{pH} = \log (H) = \log 1/(H^*)$$

(2) Colorimetric pH. The pH as measured by a colorimeter, using indicators or by pH papers.

(3) Electrometric pH. The pH as determined by half-cell methods.

Polishing: The smoothing of a metal surface by means of abrasive particles attached by adhesive to the surface of wheels or belts.

Tarnish: Dulling, staining or discoloration of metals due to superficial corrosion. The film so formed.

APPENDIX B

GLOSSARY OF ELECTROPLATING

Activation: Elimination of a passive condition on a surface.

Adhesion: (1) the attractive force that exists between an electrodeposits and its substrate.
(2) The force required separating an electrodeposit from its substrate.

Alloy: A substance having metallic properties composed of two or more elements of which at least one is a metal.

Anion: Anion, which is negatively charged.

Anode: The electrode at which current enters or electrons leaves the solution; the positive electrode in electrolysis, the electrode at which negative ions are discharged, positive ions are formed, or at which other oxidizing reactions occur.

Anodizing: Anodic treatment of metals, particularly aluminum to form an oxide film of controlled properties.

Brightener: An addition agent, which leads to the formation of a bright plate; or which improves the brightness of the deposit over that which is obtained without its use.

Cathode: The electrode through which current leaves, or electrode in electrolysis. The electrodes at which positive ions are discharged, negative ions are formed, or other reducing reactions occur. In electroplating, the electrode which receives the deposit.

Chemical pickling: The surface layer is removed from metal by chemical pickling.

Cleaning: The removal of grease in which a current is passed through the solution, the work being one of the electrodes.

Solvent: Cleaning by means of organic solvents.

Coating: A protective layers.

Corrosion: (1) Gradual destruction of a material usually by solution. Oxidation or other means attributable to a chemical process.

(2) (Of anodes in plating) solution of anode metal by the electrochemical action in the plating cell.

Degreasing: The removal of grease and oils from a surface by using solvent.

Drag-in: The water of solution that adheres to the objects introduced into a bath.

Drag-out: The solution that adheres to the objects removed from a bath.

Electrode: A conductor of the metallic class through which a current enters or leaves an electrolytic cell; at which there is a change from conduction by electrons to conduction by particles of matter, or vice versa.