# Study on various types of antirust to prevent corrosion on heat sink terminal

By

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Dissertation submitted in partial fulfillment of

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# CERTIFICATION OF APPROVAL

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Approved by,

____________________

Ms. Norlaili Bt Amir
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2008

# CERTIFICATION OF ORIGINALITY

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

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(AHMAD EXSAN BIN OTHMAN)

# ABSTRACT

Nowadays, electronics manufacturing industries are rapidly developing. Most of electronics used copper based board to mount small electronic components. Due to continuous current flow, copper board temperature increases. Heat transfer devices need to be mounted on that board to sink the excess heat from the board to improve the performance. This study is focusing on the corrosion prevention of heat sink terminal surface by using antirust coatings. Heat sink terminal which generally made of steel easily get corroded when exposed to environment. In this project, heat sink sample is made of Eco-Trio steel (or known as ZSNC steel), one of the Nippon Steel product. Heat sink manufacturer basically used steel terminal to reduce cost compare to other materials. However, using steel as terminal creates other problem to manufacturer which is corrosion or commonly called rust. This rusty terminal will resist any solder liquid, which means, heat sink terminal will not perfectly banded together to the copper board. Rust is critical problem in electronic manufacturing industries because it has potential to stop production line for substantial duration if no action taken to prevent this problem. The literature review has been divided into three parts which are study on corrosion, heat sink and antirust coatings. Several organic coatings have been selected for the study. The scope of study also includes the data weathering experiment which is important in simulating the similar condition for ageing process of coated samples. Besides, a few ISO Standards has been studied to guide the coating experiment to ensure the reliability of experiment conducted. Six methods has been suggested for this project include the research part, information gathering from journals and books, test procedure preparation and samples purchasing, coating process, manual and solder dip process and optimum antirust coating selection. Finally, this project should be a useful addition in order to understand the corrosion on heat sink terminal and its prevention by using antirust coatings. Hence, the outcome of this project should give benefits for all of the parties involved; particularly the student himself.

# ACKNOWLEDGEMENTS

First and foremost, all praise to Allah S.W.T for granting me the opportunity to complete this final year project, which has proven to be a very enriching experience.

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# CHAPTER 1
# INTRODUCTION

## 1.1 Background of study

The project has been proposed to prevent corrosion problem in manufacturing and electronic industries. This project focuses on corrosion of heat sink. Heat sink is the one of the most important components on complete board to improve performance by releasing excess heat. The terminal is made of steel, and therefore prone to corrosion. Other solution to prevent corrosion from occurring is by changing terminal material. However, it will increase production costs. In order to keep the cost as low as possible, other method of solution have been tried such as change packaging, add more Silica gel, change storage environment and so on but offer little improvement.

Three alternatives have been selected as the solution for corrosion problem, which are changing the packaging method, changing the materials used and application of antirust coating. All alternatives have been compared in three important terms that need to be considered in selection method. Economic factor need to be considered in selection method because it is the most critical and important part in engineering. Most of the companies preferred to use solutions with less manufacturing cost involved. Besides, administration and designer approvals are also vital in decision making process. As an example, before changes in material types or composition are made, manufacturers have to obtain permission from the administrator of customers companies. Another term that needs to be considered is the approval from the Material Conduct or Quality Control of customers' companies. Sometimes the decisions are made after consulting the Quality Control department to make sure the changes will not affect the parts that are used in production line.

From Table 1.1, Change Packaging and Antirust Coating are the most preferred alternatives. In economic consideration, Antirust Coating method is better because it will cost less than Change Packaging method. But Change Packaging if preferred alternative for Quality Control department because it is the faster temporary action in corrosion prevention. However, Antirust Coating method is selected based on total point of ranking in alternatives selection method.

Table 1-1: Alternative selection method

| Criteria | Method A<br>Change Packaging | Method B<br>Change Material | Method C<br>Antirust Coating |
|---|---|---|---|
| Economic consideration | 2 | 1 | 3 |
| Administration and Designer approval | 2 | 1 | 3 |
| Material conduct and Quality Control approval | 3 | 1 | 2 |
| Total | 7 | 3 | 8 |

| | |
|---|---|
| 1 | Not suitable or not approved |
| 2 | Moderate |
| 3 | Most preferred |

Heat sink terminal must be free form any corrosion on its surface to ensure no pin-hole problem occurs during dipping in solder liquid. Pin-hole problem which occurs continuously can be classified as most critical problem because can lead to board production line operation stop. Board having pin-hole problem must be repaired and this internal rework operation costs company much due to time, manpower and payment to repairer.

So to overcome this problem, researches have been planned; firstly about corrosion in general, then corrosion of heat sink terminal, heat sink production process, and antirust coatings. The research about heat sink terminal takes a few weeks because some conditions need to be considered such as material used, manufacturing process and storage condition. For the various types of antirust selection method, researches and experiment in laboratory have been done and it takes at least three months of work.

### 1.1.1 Confidence level of recurring problem

In order to continue the project, confidence level of recurring problem has been taken into account. All defect data has been analyzed since January 2007 until December 2007. Data source has been collected from Part Quality Department, SONY EMCS (M) Bangi. There were over 50 000 pieces of heat sink have been rejected due to corrosion problem in year 2007. Below are the table and graph to represent data collected:

Table 1-2: Data collection for rust heat sink for 2007

| Month | Quantity (pieces) |
|---|---|
| January | 1500 |
| February | 5150 |
| March | 3858 |
| April | 6554 |
| May | 3445 |
| June | 7750 |
| July | 3350 |
| August | 5500 |
| September | 2545 |
| October | 3210 |
| November | 4100 |
| December | 3250 |
| **Data was taken from Part Quality Assurance (PQA), SONY EMCS (M) Sdn. Bhd. Bangi.* | |

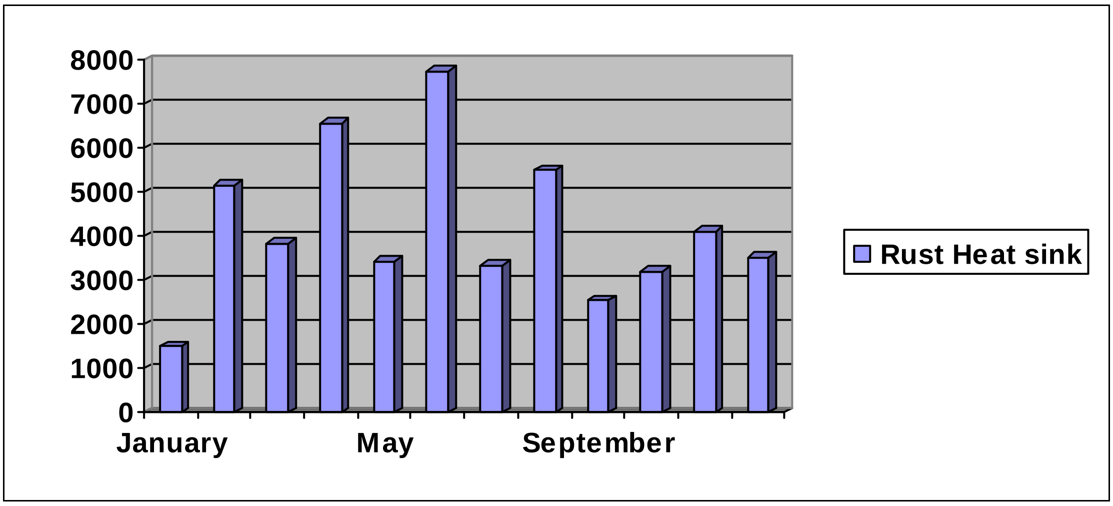


Figure 1-1: Data collection for rust heat sink from January to December 2007

## 1.2 Problem Statement

Heat sink is generally made of aluminum because it has great thermal conductivity. In order to reduce manufacturing cost, the terminal is made of other materials, which is steel. Metal, in this case is referred to steel, will corrode because of reaction with the environment. This reverse metallurgy extractive process of steel results in corrosion or rust. Rust at terminal affects soldering process, commonly creates pin-hole problem because it resists solder liquid (See Appendix A). Unsuitable antirust coatings types or coat thickness also affects soldering. In order to overcome these problems, this project has been proposed to find optimum antirust coatings. This will provide a prevention of corrosion problem on the heat sink terminal surface and also not resist the soldering process.

## 1.3 Objective of Study

The study and research are beneficial project because it is to select the best antirust to be used to coat heat sink terminal in order to reduce or if possible to eliminate corrosion problem on heat sink terminal surface**.** Expected outcome of this project is to solve rusty problem in Sony EMCS (M) and Hung Kee Hong Electronics & Metal (M) Sdn. Bhd. by applying optimum antirust instead of change material of terminal and packaging. Hopefully, the results of this study can help manufacturer to reduce rejected part.

## 1.4 Scope of Study

The scope of study is basically on corrosion, heat sink, heat sink manufacturing process, material used for hear sink terminal, various types of antirust coatings and also an optimization of antirust to be used in project. This project calls for co-operation from the heat sink manufacturer and antirust suppliers. For heat sink supplier, Hung Kee Hong Electronics & Metals (M) Sdn. Bhd. is selected as reference to study and research on production process. In addition, study of ISO Standards such as ISO 12944-6 (Paints and Varnishes – Corrosion protection of steel structure by protective paint system; Laboratory performance test method), ISO 6270-1 (Paints and Varnishes – Determination resistance to humidity; Continuous condensation) and ISO 4626 (Volatile Organic Liquid – Determination of boiling range of organic solvents used as raw materials) are important as a guideline to prepare Coating Experiment procedure. Ageing process for 20 days is required to visually check for rust, blister and crack on the surface. Coated specimens have been soldered for both manual solder and automatic solder dip process. Lastly, the best and optimum antirust coating has been selected based on the ageing and solder process results.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Corrosion

Destruction of metal by other mechanical means is defined as corrosive failure and is the result of a destructive attack by chemical or electrochemical reaction with its environment. Fretting corrosion, corrosive wear, and corrosion erosion are examples of chemical attacks that accompany physical deterioration (Schweitzer, 1987, p.11).

### 2.1.1 Definition of Corrosion

Corrosion is defined as the destruction or deterioration of a material's properties because of interaction with its environment. Some insist that the definition should be restricted to metals, but often the corrosion engineers must consider both metals and nonmetals for solutions of a given problem.

Corrosion of metals, which can be fast or slow, could be considered as extractive metallurgy in reverse as illustrated in Figure 2-1. Extractive metallurgy is concerned primarily with the winning of the metal from the ore and refining or alloying the metal for use. Iron or steel is intrinsically unstable in that it wants to return to its stable where it came from as an ore. Most iron ores contain oxides of iron, and rusting of steel by water and oxygen results in a hydrated iron oxide. To the great majority of people, corrosion means rust, an almost universal object of hatred. Rust has more referred specifically to the corrosion of iron or steel. But corrosion is a destructive phenomenon affects almost all metals.

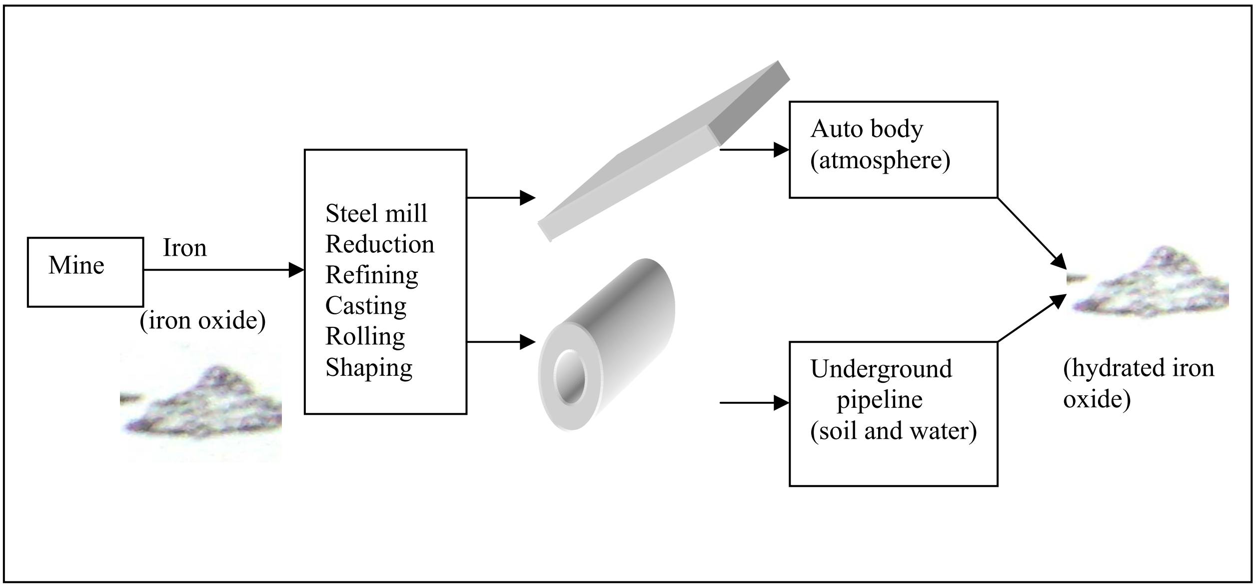


Figure 2-1: Metallurgy in reverse

### 2.1.2 Corrosion Principles

Fontana (1987) defined that "Corrosion resistance or chemical resistance depends on many factors." (p. 12). To have a complete and comprehensive study, it required several knowledge of scientific field as indicated in Figure 2-2. The most important to understand and control the corrosion is by understanding completely term of thermodynamics and electrochemistry.

Thermodynamic studies and calculations indicate the spontaneous direction of a reaction. In the case of corrosion, thermodynamic calculations can determine whether or not corrosion is theoretically possible.

According to Fontana (1987)

> Metallurgical factors frequently have a pronounced influence on corrosion resistance. In many case the metallurgical structure of alloys can be controlled to reduce corrosive attack. Physical chemistry and its various disciplines are most useful for studying the mechanisms of corrosion reactions, the surface conditions of metals, and other basic properties. (p. 13)

### 2.1.3 Mechanism Of Corrosion

The flows of electricity from one metal to another or from one part of the metal surface to another part of the same metal surface where conditions allow the flow of electricity cause corrosion in metals. A moist conductor or electrolyte must be present to ensure the flow of energy to take place.

Schweitzer (1987) points out that the energy passes from a negative area to a positive area through the electrolyte media. Therefore, if corrosion is to take place in a metal there must be an electrolyte, an area or region of the metallic surface with a negative charge in relation to a second area having a positive charge in opposition to the first area. This flow need not be within one piece of metal. It may flow between a metal and some kind of metal recipient, such as the soil, or between two dissimilar metals. If the soil is negative to the metal and an electrolyte such as water is present, corrosion of the metal will result (p.12).

A corrosion cell is formed on a metal surface when oxygen and water are present. Figure 2-2 shows a structure of corrosion cell. The electrochemical reactions taking place in the corrosion cell are:

Anodic reaction (M = metal):

$$M \longrightarrow M^{n+} + ne \qquad (2\text{-}1)$$

Cathodic reaction in acidic solution:

$$2H^{+} + 2e \longrightarrow H_2 \qquad (2\text{-}1)$$

Cathodic reaction in neutral and alkaline solutions:

$$O_2 + 2H_2O + 4e \longrightarrow 4OH^{-} \qquad (2\text{-}1)$$

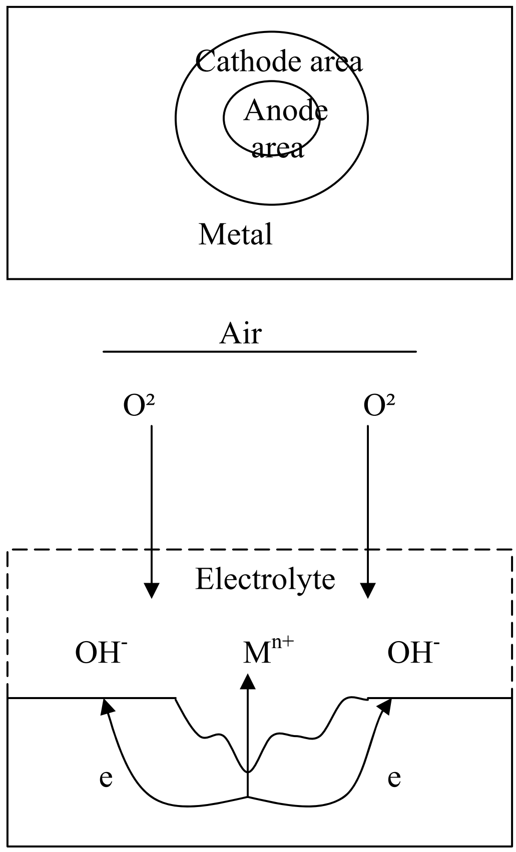


Figure 2-2: Structure of corrosion cell.

### 2.1.4 Types of Corrosion

There are many types of corrosion resulting from different conditions. The major forms are as following:

1. General corrosion
2. Galvanic corrosion
3. Cavitation corrosion
4. Pitting corrosion
5. Corrosion fatigue
6. Intergranular corrosion
7. Stress corrosion cracking
8. Impingement attack
9. Fretting corrosion
10. Hydrogen embrittlement

11. Graphitic corrosion
12. Dezincification and parting
13. Biological corrosion

Most metals form a natural protective film on their surface after being exposed to air for a period of time. In a sense this is corrosion, but once formed it prevents further corrosion as long as the film remains intact. Passivation is the name applied to the chemical treatment procedure used to form this film more rapidly.

Schweitzer (1987) says that metal is said to corrode when a chemical attacks this film. This attack will occur at a specific rate, which will differ between films and chemicals. The usual terminology for reporting this rate of attack is the United States is inches penetration per year (ipy), milligrams per square decimeter per day (mdd), or mil penetration per year (mpy). These are three groups or classifications for acceptable corrosion rates depending on the application. These groups are as follows:

1. <0.005 ipy (<5 mpy)

   This is indicative of a good corrosion resistance and metals in this category can be considered for crotical parts such as springs, valve seats, pump shaft, ect.

2. 0.005 to 0.05 ipy (5 to 50 mpy)

   If this degree of corrosion rate can be tolerated, metals in this group can be considered for piping, valve bodies, vessels, ect.

3. > 0.05 ipy (>50 mpy)

   Metals having this degree of corrosion rte are usually not considered for use in application.

### 2.1.5 Selecting Materials for Corrosion Resistance

Once a preliminary selection has been made based on the suitability of a specific material to resist the corrosion of the system, the following parameters of the materials must be considered, refer to Figure 2-3 and Figure 2-4.

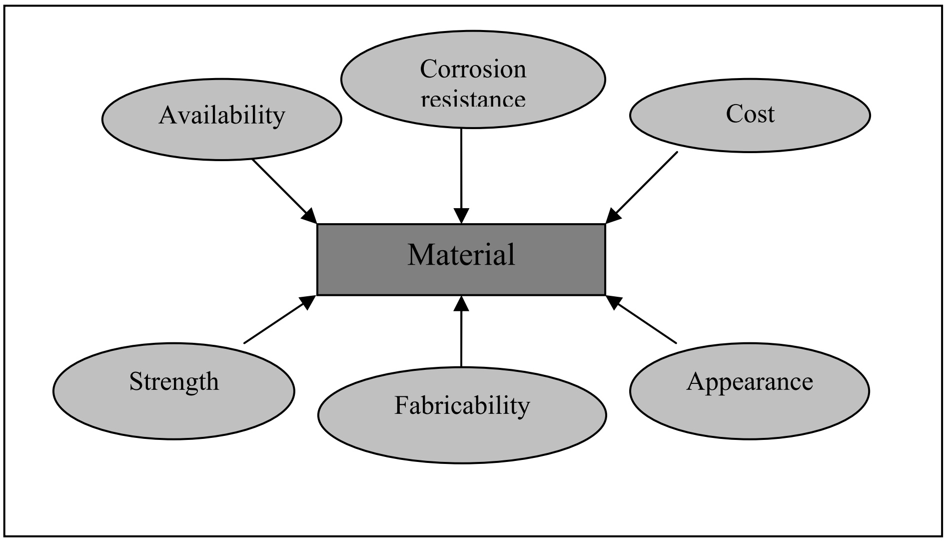


Figure 2-3: Factors affecting choice of an engineering material

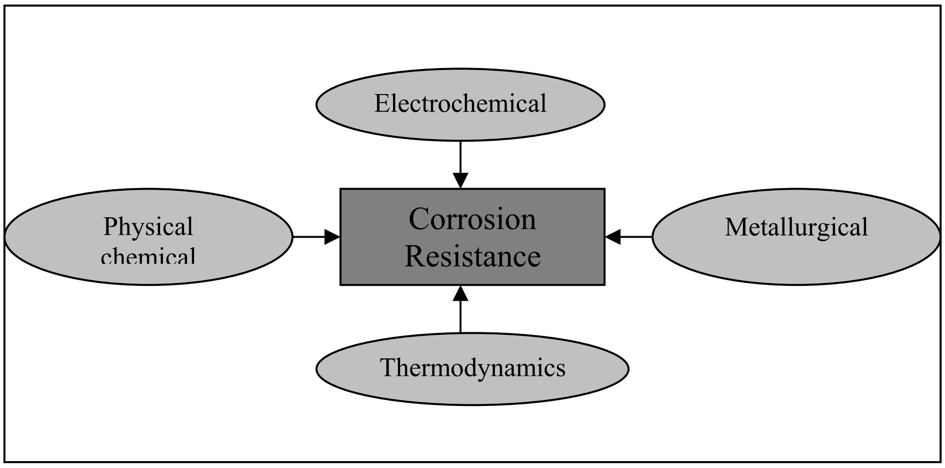


Figure 2-4: Factors affecting corrosion resistance of metals

### 2.1.6 Environment

Corrosion of iron or steel is normally decided by the environment and also the stability of the oxide layer on the surface. The environment is corrosive to some degree. Some examples are air and moisture; fresh, distilled, salt, and mine waters; rural, urban, and industrial atmosphere; steam and other gases such as chlorine, ammonia, hydrogen sulfide, sulfur dioxide, and fuel gases ; mineral acids such as hydrochloric, sulfuric, and nitric; organic acid such as naphthenic, acetic, and formic; alkalies; soils; solvents; vegetable and petroleum oils; and a variety of food products. In general, the "inorganic" materials are more corrosive than the "organics".

### 2.1.7 Corrosion Rate Expressions

Metals and nonmetals are compared based on of their corrosion resistance. Corrosion rates have been expressed in a different ways in the literature; such as percent weight loss, milligrams per square centimeter per day, and grams per square inch per hour. These do not express corrosion in terms of penetration. The rate of penetration, or the thinning of the structure piece, can be used to predict the life of a given component.

The expression *mils per year* is the most suitable way to express the corrosion rates. This expression is readily calculated form the weight loss of the metal specimen during the corrosion test by given formula below:

$$\text{mpy} = 534W / DAT \qquad (2\text{-}2)$$

where $W$ = weight loss, mg

$D$ = density of specimen, g/cm$^3$

$A$ = area of specimen, sq. in.

$T$ = exposure time, hr

*This corrosion rate calculation involves whole numbers, which are easily handled.

## 2.2 Heat Sink

Four main metals used for applications are carbon steel, zinc, aluminum, and copper. Of these, carbon steel is probably the most widely used because of it desirable physical and mechanical properties. It is readily available in many forms and shapes, and also can be easily fabricated and joined as well as it is economical.

Carbon steel does not have ability to form its own protective coating as do some other metals. Therefore unalloyed carbon steel must be provided with a surface protection. This usually in the form of an antirust paint or other type of paint protection formulated for resistance against a specific type of contaminant present in the area. At times a plastic coating may be applied.

When small amounts of copper, chromium, nickel, phosphorus, silicon, or manganese are added, a low-alloy carbon steel with improved corrosion resistance results. These steels are known as "weathering" steels. When exposed to the atmosphere a brown patina of protective film develops over a period of time. This film will not form in marine environments, nor will it provide adequate protection in heavily polluted industrial atmospheres.

### 2.2.1 Triple Coated Steel – Ecotrio

Ecotrio steel is the widely used especially in electronic industries such as vending machine, microwave oven, facsimile, audio and video equipments. This type of steel is one of the Nippon Steel products which is suitable for lead-free soldering. Ecotrio steel has 8 $g/m^2$ mass of coating with 4 $g/m^2$ to 15 $g/m^2$ coating range. This triple coated steel has three typical coating layer compositions which are special layer treatment, Zinc-Stanum layer and Zinc-Nickel layer in both side of surface, refer Figure 2-5 for better visual aid. (Source from Nippon Steel's : Coated Steel Sheets for Electrical Home Appliances)

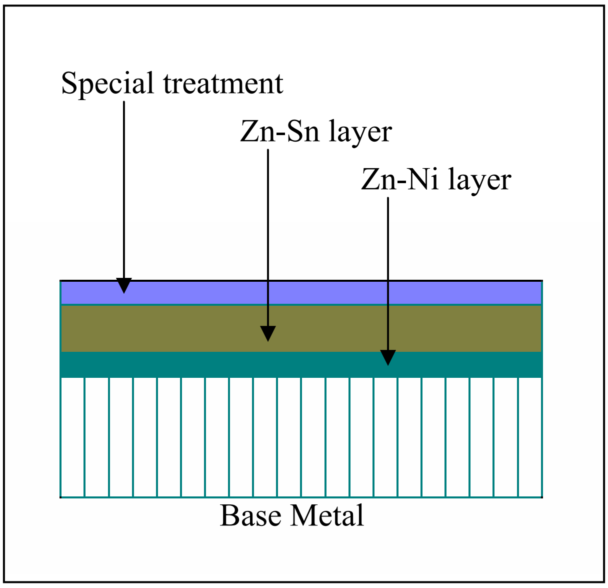


Figure 2-5: Ecotrio coating layer composition.

*(Source from Nippon Steel's : Coated Steel Sheets for Electrical Home Appliances)*

### 2.2.2 Heat Sink Principle and Performance

Heat sink is an object or system that absorbs and dissipates heat from another object using thermal contact (either direct or radiant) in order to protect heat-sensitive components. Heat sinks are used in a wide range of applications wherever efficient heat dissipation is required. The major examples include refrigeration, heat engines and cooling electronic devices. This component is been mounted on electric circuit board to dissipates heat from board. In this project, heat sink material used are Aluminium A6063 (hardness of T5) for body and Triple Coated Steel, ZSNC or generally known as Eco-Trio.

Heat sinks function by efficiently transferring thermal energy which is heat from one higher temperature object to a second object at a lower temperature with a much greater heat capacity. This rapid transfer of thermal energy quickly brings the first object into thermal equilibrium with the second, lowering the temperature of the first object, fulfilling the heat sink's role as a cooling device. Efficient function of a heat sink relies on rapid transfer of thermal energy from the first object to the heat sink, and the heat sink to the second object.

Tillmann Steinbrecher (1997-2005) points out that “the most common design of a heat sink is a metal device with many fins. The high thermal conductivity of the metal combined with its large surface area result in the rapid transfer of thermal energy to the surrounding, cooler or air” (p. 2).

This method of design cools the heat sink and whatever it is in direct thermal contact with. Use of fluids, for example coolants in refrigeration and thermal interface material in cooling electronic devices ensures good transfer of thermal energy to the heat sink. Similarly a fan may improve the transfer of thermal energy from the heat sink to the air.

### 2.2.3 Heat Sink Design

Below are the characteristics make a heat sink become good for the applications, according to Tillmann Steinbrecher (1997-2005).

a) High heat sink surface
The thermal transfer takes place at the surface of the heat sink. Therefore, heat sinks should be designed to have a large surface. This objective can be reached by using a large amount of fine fins, or by increasing the size of the heat sink itself.

b) Good aerodynamics
Heat sinks must be designed in a way that air can easily and quickly float through the cooler, and reach all cooling fins. Especially heat sinks having a very large amount of fine fins, with small distances between the fins may not allow good air flow. A compromise between high surface which is many fins with small gaps between them and good aerodynamics must be found. This also depends on the fan the heat sink is used with. A powerful fan can force air even through a heat sink with lots of fine fins with only small gaps for air flow whereas on a passive heat sink, there should be fewer cooling fins with more space between them. Therefore, simply adding a fan to a large heat sink designed for fanless usage doesn't necessarily result in a good cooler.

c) Good thermal transfer within the heat sink

Large cooling fins are pointless if the heat can not reach them, so the heat sink must be designed to allow good thermal transfer from the heat source to the fins. Thicker fins have better thermal conductivity; so again, a compromise between high surface, which many thin fins, and good thermal transfer which is thicker fins, must be found. Of course, the material used has a major influence on thermal transfer within the heat sink. Sometimes, heat pipes are used to lead the heat from the heat source to the parts of the fins that are further away from the heat source.

d) Perfect flatness of the contact area

The part of the heat sink that is in contact with the heat source must be perfectly flat. A flat contact area allows you to use a thinner layer of thermal compound, which will reduce the thermal resistance between heat sink and heat source.

e) Good mounting method.

For good thermal transfer, the pressure between heat sink and heat source must be high. Heat sink clips must be designed to provide a strong pressure, while still being reasonably easy to install. Heat sink mountings with screws or springs are often better than regular clips. Thermoconductive glue or sticky tape should only be used in situations where mounting with clips or screws is impossible.

### 2.2.4 Construction and Materials

A heat sink usually consists of a base with one or more flat surfaces and an array of comb or fin-like protrusions to increase the heat sink's surface area contacting the air, and thus increase the heat dissipation rate. While a heat sink is a static object, a fan often aids a heat sink by providing increased airflow over the heat sink. This will maintain a larger temperature gradient by replacing the warmed air more quickly than passive convection achieves alone. This method is known as a forced air system.

The thermal conductivity of the heat sink's material has a major impact on cooling performance. Thermal conductivity is measured in W/m·K; the higher values mean better conductivity. Heat sinks are made from a good thermal conductor such as copper or aluminum alloy. “Copper has thermal conductivity which is 401 W/(m·K) at 300 K, it significantly more expensive than aluminum (which its thermal conductivity is 237 W/(m·K) at 300 K) but is also roughly twice as efficient as a thermal conductor" (Wikipedia Encyclopedia, October 2007)

Aluminum has the significant advantage that it can be easily formed by extrusion, thus making complex cross-sections possible. The heat sink's contact surface must be flat and smooth to ensure the best thermal contact with the object needing cooling. Frequently a thermally conductive grease is used to ensure optimal thermal contact; such compounds often contain colloidal silver. Further, a clamping mechanism, screws, or thermal adhesive hold the heat sink tightly onto the component, but specifically without pressure that would crush the component.

As a rule of thumb, materials with a high electrical conductivity also have a high thermal conductivity. Alloys have lower thermal conductivity than pure metals, but may have better mechanical or chemical corrosion properties. The following materials are commonly used for heat sinks:

a) Aluminum

It has a thermal conductivity of 205W/m·K, which is better compare to steel which has about 50W/m·K. The production of aluminum heat sinks is inexpensive. The aluminum heat sink can be made using extrusion. Due to its softness, aluminum can also be milled quickly, for example die-casting and even cold forging are also the possible manufacturing process. Aluminum is also very light, thus an aluminum heat sink will put less stress on its mounting when the unit is moved around.

b) Copper

Copper's thermal conductivity is about twice as high as aluminum, which is almost 400W/m·K. This makes it an excellent material for heat sinks; but its disadvantages include high weight, high price, and less choice as far as production methods are concerned. Copper heat sinks can be milled, die-cast, or made of copper plates bonded together. Extrusion is not a possible process to manufacture the copper heat sink.

c) Silver

Silver has an even higher thermal conductivity than copper, but only by about 10%. This does not justify the much higher price for heat sink production. However, pulverized silver is a common ingredient in high-end thermal compounds.

### 2.2.5 Measuring Heat Sink Performance (Thermal Resistance, θ)

Heat sink performance is measured in °C/W or K/W. Since it is compared in term of temperature differences, there is no difference between Celsius and Kelvin scale. We refer to this as *thermal resistance (θ)*.

Here is an example of the thermal resistance value term; if a thermal load of 20W is applied to a heat sink, and this causes the temperature of the heat source to raise by 10°C, the heat sink has a rating of 10°C/20W = 0.5°C/W. A θ value is valid only for a certain power load and a certain temperature range. Heat sink can not be judged in performance by comparing θ specifications from different manufacturers. The θ values specified by manufacturers specialized in heat sinks for industrial applications are usually more accurate.

### 2.2.6 Use in Electronics

Commonly, heat sink is a metal object brought into contact with an electronic component's hot surface, and for the though most cases, a thin thermal interface material mediates between the two surfaces. Microprocessors and power handling semiconductors are examples of electronics that need a heat sink to reduce their temperature through increased thermal mass and heat dissipation, primarily by conduction and convection and to a lesser extent by radiation. Heat sinks are widely used in electronics, and have become almost essential to modern integrated circuits like microprocessors, DSPs, GPUs, printed wiring board and more.

### 2.2.7 In Soldering

Temporary heat sinks were sometimes used while soldering circuit boards, preventing excessive heat from damaging sensitive nearby electronics. In the simplest case, this means partially gripping a component using a heavy metal crocodile clip or similar clamp. Modern semiconductor devices, which are designed to be assembled by reflow soldering, can usually tolerate soldering temperatures without damage. On the other hand, electrical components such as magnetic reed switches can malfunction if exposed to higher powered soldering irons.

## 2.3 Antirust Coatings

Construction metals are selected because of their mechanical properties and machineability at a low price, although, they should also be corrosion resistant. Very often can these properties be met in one and the same material. This is where coatings come into play. By applying an appropriate coating, the base metal with the good mechanical properties can be utilized while the appropriate coating provides corrosion protection.

The majority of coatings are applied on external surfaces to protect the metal from natural atmospheric corrosion, and atmospheric pollution. On occasion, it may also be necessary to provide protection from accidental spills and splashes. In some instances, coatings are applied internally in vessels for corrosion resistance.

Schweitzer (2007) says there are basically four different classes of coatings such as organic, inorganic, metallic and conversion. Table 2-1 below show the coating classes and the examples of each types.

Table 2-1: Coating different classes

| Organic | Inorganic | Metallic | Conversion |
|---|---|---|---|
| Coal tars<br>Phenolics<br>Vinyls<br>Acrylics<br>Epoxy<br>Alkyds<br>Urethanes | Silicates<br>Ceramics<br>Glass | Galvanizing<br>Vacuum vapor deposition<br>Electroplating<br>Diffusion | Anodizing<br>Phosphating<br>Chromate<br>Molybdate |

### 2.3.1 Principle of Corrosion Protection

Most metals used for electronic purposes are unsuitable in atmosphere. These unstable metals are produced by reducing ores artificially; therefore, they will return to their original ores or to similar metallic compounds when exposed to the atmosphere. As example, oxidation of metallic iron to ferric oxyhydride in a thermodynamically stable state (iron in the higher level of free energy is changed to lepidocrocite, $\gamma$ – FeOOH, in the lower level):

$$4Fe + 3O_2 + 2H_2O \rightarrow 4FeOOH \qquad (2\text{-}3)$$

(Schweitzer, 2007, p.403-404)

This metal reaction in a natural environment is called corrosion. Coatings applied on the metal surface make a longer period of time is required for rust to form on the substrate, as shown in Figure 2-6 and Figure 2-7. Therefore, the most important part is to ensure the proper selection of coating material for application in the specific environment.

Effective coating is performed by isolating the base metal from the environment. The service life of a coating is dependent upon the thickness and the chemical properties of the coating layer. The latter determines the durability of a coating material in a specific environment that is the corrosion resistance of a metal coating or the stability of its organic and inorganic compounds. In order to be effective, the coating's durability must be greater than that of the base metal's, or it must be maintained by some means. In addition, a coating is often required to protect the base metal with its original pore and crack or with a defect that may have resulted from mechanical damage and pitting corrosion.

Schweitzer (2007) points out that corrosion are classified according to the electrochemical principle that they operate on to provide protection. These categories are:

1. EMF control
2. Cathodic control protection
3. Anodic control protection
4. Mixed control protection
5. Resistance control protection

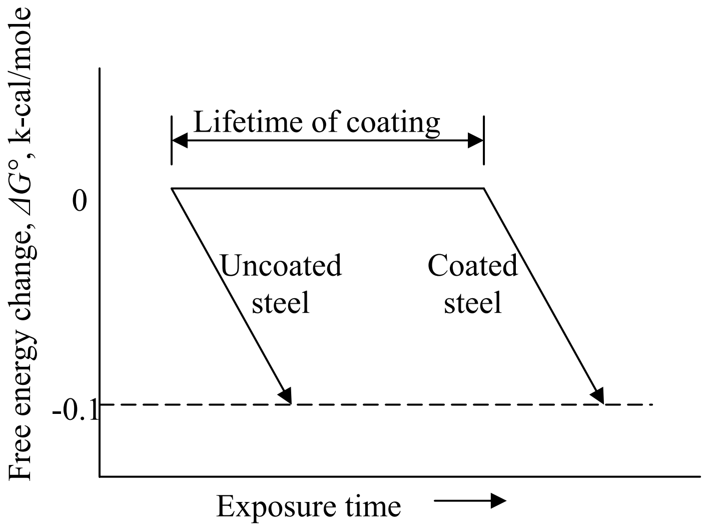


Figure 2-6: Role of corrosion resistant coating.

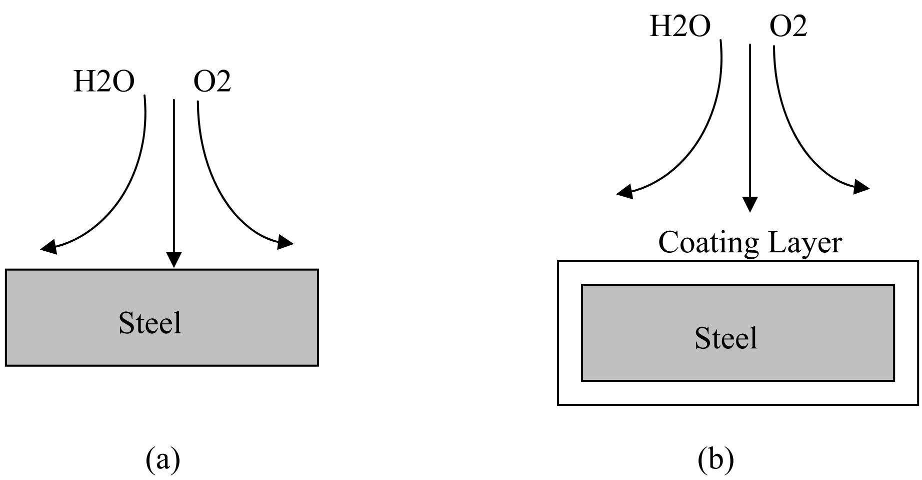


Figure 2-7: Differences between uncoated (a) and coated (b) metals.

### 2.3.2 Metallic Coatings

Metallic coatings are applied to metal substrates for several purposes. Typical purposes include improved corrosion resistance, wear resistance, and appearance. The primary concern is corrosion resistance.

By providing a barrier between the substrate and the environment or by cathodically protecting the substrate, metallic coatings protect the substrate from corrosion. Coatings of chromium, copper, and nickel provide increased wear resistance and good corrosion resistance. However, these noble metals make the combination of the substrate (mostly steel or an aluminum alloy) with the protective layer sensitive to galvanically include local corrosion. Nonnoble metallic layers such as zinc or cadmium provide good cathodic protection but show poor wear resistance.

A coating of a corrosion resistant metal on a corrosion prone substrate can be formed by various methods. The choice of coating material and selection of an application method are determined by the end use.

a) Nickel Coatings

Schweitzer (2007) defines there are three types of nickel coatings: bright, semibright, and dull bright. The difference between the coatings is in the quantity of sulfur contained in them as shown below (p. 423):

| | |
|---|---|
| Bright nickel deposits | > 0.04% Sulfur |
| Semibright nickel deposits | < 0.005% Sulfur |
| Dull bright nickel deposits | < 0.001% Sulfur |

The corrosion potentials of the nickel deposits are dependent on the sulfur content. Figure 2-21 shows the effect of sulfur content on the corrosion potential of a nickel deposit. A single layer nickel coating must be greater than 30 μm to ensure absence of defects.

As the sulfur content increase, the corrosion potential of a nickel deposit becomes more negative. A bright nickel coating is less protective than a semibright or dull nickel coating. The difference in the potential of bright nickel and semibright nickel deposits is more than 50 mV (Schweitzer, 2007, p. 423). Use is made of the differences in the potential in the application of multilayer coatings. The more negative bright nickel deposits are used as sacrificial intermediate layers. When bright nickel is used as an intermediate layer, the corrosion behavior is characterized by a sideways diversion. Pitting corrosion is laterally diverted when it reaches the nobler semibright nickel deposit. Thus, the corrosion behavior of bright nickel prolongs the time for pitting penetration to reach the base metal.

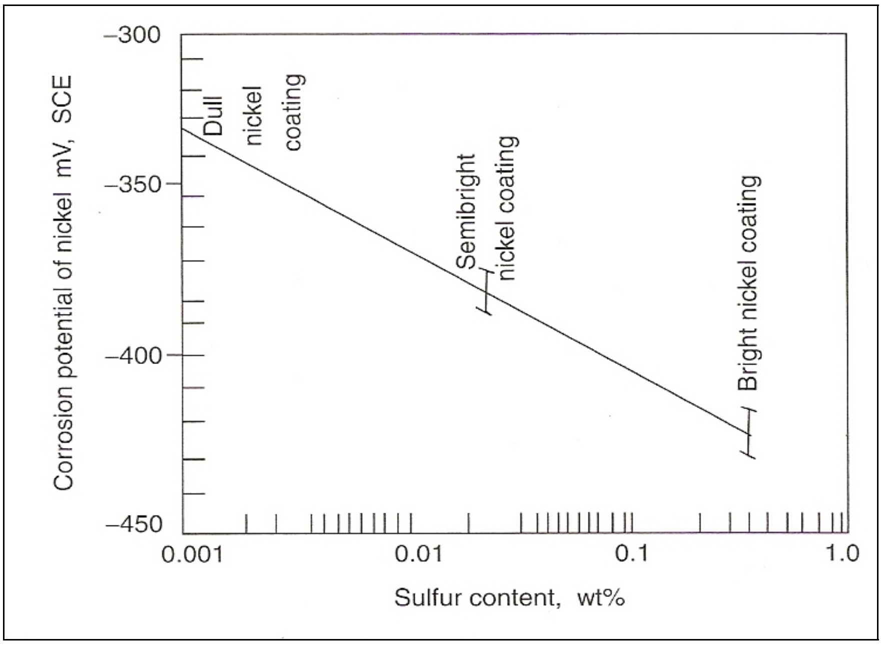


Figure 2-8: Effect of sulfur content on corrosion protection of nickel

*(Source from Schweitzer 2007, Corrosion Engineering Handbook 2nd Edition)*

Schweitzer (2007) says that in the duplex nickel coating system, the thickness ratio of semibright nickel deposit to bright nickel deposit is nominally 3:1, and the thickness of 20 – 25 μm is required to provide high corrosion resistance. The properties required for a semibright nickel deposit are as follows:

1. The deposit contains little sulfur.
2. Internal stress must be slight.
3. Surface appearance is semibright and extremely level.

Nickel coatings can be applied by electrodeposition or electrolessly from an aqueous solution without the use of an externally applied current. Depending on the production facilities and the electrolyte composition, electrodeposited nickel can be relatively hard (120 – 400 HV). Despite competition from hard chromium and electroless nickel, electrodeposited nickel is still being used as an engineering coating because of its relatively low price (Schweitzer, 2007, p. 425). Some of its properties are:

1. Good general corrosion resistance.
2. Good protection from fretting corrosion.
3. Good machineability.
4. The ability of layers of 50 – 75 μm to prevent scaling at high temperatures
5. Mechanical properties, including the internal stress and hardness, that are variable and that can be fixed by selecting the manufacturing parameters.
6. Excellent combination with chromium layers.
7. A certain porosity.
8. A tendency for layer thickness below 10 – 20 μm on steel to give corrosion spots because of porosity.

b) Zinc Coatings

Approximately half of the world's production of zinc is used to protect steel from rust. Zinc coatings are probably the most important type of metallic coating for corrosion protection of steel. The reasons for the wide application are:

1. Prices are relatively low.
2. Because of large reserves, an ample supply of zinc is available.
3. There is great flexibility in application procedures resulting in many different qualities with well-controlled layer thicknesses.
4. Steel provides good cathodic protection.
5. Many special alloy systems have been developed with improved corrosion protection properties.

The ability to select a particular alloy or to specify a particular thickness of coating depends on the type of coating process used. Zinc coatings can be applied in many ways. The six most commonly used procedures as follows:

1. Hot dipping.
2. Zinc electroplating.
3. Mechanical coating.
4. Sherardizing.
5. Thermally sprayed coatings.
6. Zinc dust painting.

### 2.3.3 Organic Coatings

Organic coatings are widely used to protect metal surfaces from corrosion. The effectiveness of such coatings is dependent not only on the properties of the coatings that are related to the polymeric network and possible flaws in this network, but also on the character of the metal substrate, the surface pretreatment and the application procedures. Thus, when considering the application of a coating, it is necessary to take into account the properties of entire system.

There are three broad classes of polymeric coatings: lacquers, varnishes and paint. Vanishes are materials that are solutions of either a resin alone in a solvent (spirit vanishes) or an oil and resin together in a solvent (oleo resinous vanishes). A lacquer is generally considered to be a material whose basic film former is nitrocellulose, cellulose acetate-butyrate, ethyl cellulose, acrylic resin, or another resin that dries by solvent evaporation. The term paints is applied to more complex formulations of a liquid mixture that dries or hardens to form a protective coating (Schweitzer, 2007, p. 459).

Organic coatings provide protection either by the formation of a barrier action from the layer or from active corrosion inhibition provided by pigments in the coating. In actual practice, the barrier properties are limited because all organic coatings are permeable to water and oxygen to some extent. The average transmission rate of water through a coating is about 10 – 100 times larger than the water consumption rate of a freely flowing surface, and in normal outdoor conditions, an organic coating is saturated with water at least half of its service life. Table 2-2 shows the diffusion data for water through organic films.

Table 2-2: Diffusion Data for Water through Organic Films

| Polymer | Temperature °C | $p \times 10^9$ ($cm^3$ (STP)cm) | Dx 109 $cm^2/s$ |
|---|---|---|---|
| Epoxy | 25 | 10 – 44 | 2 – 8 |
| | 40 | – | 5 |
| Phenolic | 25 | 166 | 0.2 – 10 |
| Polyethylene (low density) | 25 | 9 | 230 |
| Polymethyl methacrylate | 50 | 250 | 130 |
| Polyisobutylene | 30 | 7 – 22 | – |
| Polystyrene | 25 | 97 | – |
| Polyvinyl acetate | 40 | 600 | 150 |
| Polyvinyl chloride | 30 | 13 | 16 |
| Vinylidene chloride / Acrylonitrile compolymer | 25 | 1.7 | 0.32 |

Additional protection may be supplied by resistance inhibition that is also a part of the barrier mechanism. Retardation of the corrosion action is accomplished by inhibiting the charge transport between cathodic and anodic sites. The reaction rate may be reduced by an increase in the electrical resistance and the ionic resistance in the corrosion cycle. Applying an organic coating on a metal surface increases the ionic resistance. The electronic resistance may be increase by the formation of an oxide film on the metal.

a) Poly Urethane

Poly Urethanes were among the first coatings to be used for printed wiring board electrical insulation and protection from moisture, salt spray, and handling. Poly Urethanes are also used as potting compounds for connectors and as vibration-damping fillets for large components. Poly Urethanes can be softened and penetrated with a hot solder iron and residues may even act as flux in resoldering a new component. The urethane technology was based on a series of addition polymers formed from polyisocyanates called desmodurs and polyesters called desmophens (Licari, 2003, p. 104). These polymers became popular and widely used as coatings because of their flexibility, toughness, excellent electrical insulation properties and excellent moisture, abrasion, chemical, and corrosion resistance.

b) Acrylic

Acrylics are the most widely used coatings for the protection of printed wiring boards due to a combination of low cost, excellent electrical insulation properties, moisture protection and ease of repair. Schweitzer (2001) define that acrylic can be formulated as thermoplastic resins, thermosetting resins and as a water emulsion latex. The resins are formed from polymer of acrylate esters, primarily polymethyl methacrylate and polyethyl acrylate (p. 304). Acrylics limitations are that some formulations discolor and degrade on prolonged humidity/temperature exposure. Acrylics are susceptible to attack by organic solvent such as ketones, esters, chlorinated and fluorinated solvents, and aromatic hydrocarbons. This poor solvent resistance becomes a benefit for rework and repair since the coatings ban be selectively or completely dissolved and removed.

c) Alkyd

Alkyd paints are most widely used synthetic resins. Schweitzer (2007) define that alkyd is produced by reaction of phthalic acid with polyhydric alcohols such as glycerol and vegetable oil (or fatty acid). Classification is by oil content into drying types and baking types. Drying types provide good weathering resistance and good adhesion to a wide variety of substrate, but relatively poor resistance to chemical attack. It has a maximum temperatures resistance of 225°F / 108°C dry; 150°F / 66°C wet (p. 493). These paints are used on exterior surfaces for primers requiring penetrability and in less severe chemical environments.

d) Aliphatic Hydrocarbon

In organic chemistry, compounds composed of carbon and hydrogen are divided into two classes: aromatic compounds, which contain benzene and other similar compounds, and aliphatic compounds, which do not. In aliphatic compounds, carbon atoms can be joined together in straight chains, branched chains, or rings (in which case they are called alicyclic). They can be joined by single bonds known as alkanes, double bonds known as alkenes, or triple bonds known as alkynes. Besides hydrogen, other elements can be bound to the carbon chain, the most common being oxygen, nitrogen, sulfur, and chlorine. The simplest aliphatic compound is methane ($CH_4$). Aliphatic include alkanes such as fatty acids and paraffin hydrocarbons, alkenes such as ethylene and alkynes such as acetylene. Most aliphatic compounds are flammable.

# CHAPTER 3
# METHODOLOGY / PROJECT WORK

## 3.1 Procedure Identification

In order to achieve the objectives of the project, the procedures are identified and planned accordingly. Figure 3-1 shows the project work flow involves for overall project. Thus, one of the important steps has been taken was debugging at every step in this procedures. This involves correction, which is done to meet the specification of each step. Besides that, all procedures have been well-planned in details and systematic to avoid problem in the following procedures. Each procedure followed step by step in order to make the process flow become smooth and well planned.

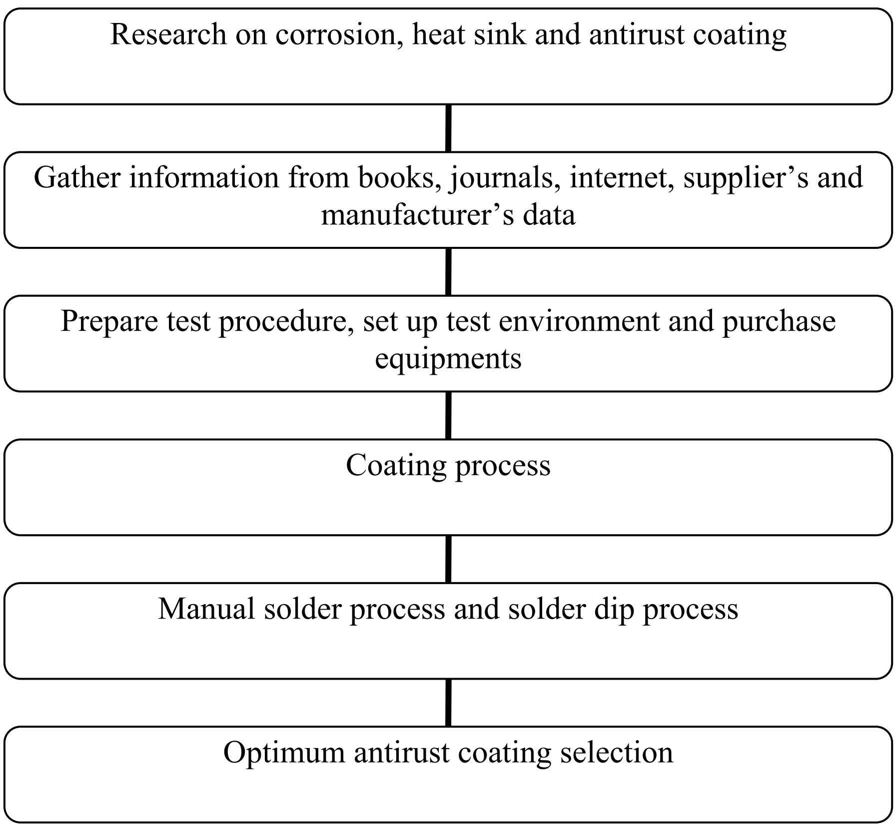


Figure 3-1: Project work flow for FYP 1 & 2

## 3.2 Methodology

Research methodology for this project mostly involve on the background study, test procedure preparation and experimental work. This project is about the study of corrosion, heat sink and antirust coating that need to be applied to steel surface to prevent corrosion. There are six main steps involved in procedure which are researches, information gathering, test procedure preparation, coating process, solder process and antirust coating selection.

First task of this project was study on corrosion, heat sink and antirust coating. The most important thing here is to fully understand the concept of corrosion on a metal surface. Books of corrosion has been referred in order to has better understand on principle of corrosion, corrosion mechanism, factor affecting corrosion, classification of corrosion and material selection for corrosion resistance. The research also focused on heat sink, since heat sink is also the main subject in this study. Generally, heat sink is used in electronic application to reduce excess heat to maintain the electronic device performance. Research on heat sink was mainly on construction material used for heat sink body as well as the terminal. Besides, the principle, performance, design and soldering process also has been studied. Other part of research was on antirust coating, which is a process to protect a metal surfaces from reaction with the environment that result rust. Factor affecting the life of coating film and causes of the coating failure are the core matter in this part of research.

All the data and information needed were collected and analyzed in this study. Data and all the particular information were gathered from books, journals, internet sources, handbooks and also manufacturer's sources. The references are very important to guide an experiment procedure according to ISO Standards.

Next step was preparing a test procedure which ensures the environment and room condition is absolutely similar with the original storage room. For this purpose, data weathering experiment has been conducted in Material Control Department (Metacon) storage room of SONY EMCS (M) Bangi. The experiment procedure has been prepared according to International Standardization Organization (ISO) Standards such as ISO Standard 12944-6 (Paints and Varnishes – Corrosion protection of steel structure by protective paint system; Part 6 – Laboratory performance test method), ISO Standard 6270-1 (Paints and Varnishes – Determination resistance to humidity; Part 1 – Continuous condensation) and ISO Standard 4626 (Volatile Organic Liquid – Determination of boiling range of organic solvents used as raw materials). The details of experiment procedure have been fully explained in next experiment procedure part. All the data gathered has been analyzed and the average reading has been taken to carry out the experiment.

After analyzing the data, a coating process experiment has been set up. The experiment was strictly followed the specific data such as relative humidity and temperature. Coating process was conducted in a laboratory. The specimens have been immersed in the water based antirust coating for 24 hours. After the coating process, the specimens have been visually checked for rusting, blistering, cracking or chipping according to ISO Standard 4624 after 24 hours of exposal. All the specimens have been going through aging process, which required all the specimens exposed to environment for 20 days. Sticking test also has been carried out 24 hours after ending the test.

Before going through solder dip process, the specimens have been soldered manually to a copper board using iron solder and solder coil. This is to ensure only the non-solder resist coated specimens are used to mount on a board for solder dip process in order to avoid wasting of time.

Based on solder dip process, the specimen which perfectly bonded on the copper board has been selected as the best or optimum coating. This visual inspection is important to avoid any interference of antirust coating to the solder process.

## 3.3 Data Weathering Experiment

Data weathering is a process to collect environment data such as relative humidity, wind velocity and ambient temperature. This process is very important in simulating a similar room condition for experimental purposes. Thus, the experiment is more reliable and based on original storage condition, not the accelerated condition. Below are the details of the data weathering process:

1. Date: 29 February 2008
2. Location: Material Control Department (Matecon) storage, SONY EMCS (M) KL Tech. Bangi, Selangor
3. Test parameter: Relative Humidity, Temperature and Wind Velocity.
4. Apparatus/Instrument: Relative Humidity Meter and Anemometer.
5. Procedures:
    a. Starting at 1600 until 1800, the readings of relative humidity, temperature and wind velocity were taken every 10 minutes interval.
    b. The data measured was represented in table and graphs.

Figure 3-2: Data weathering instruments - Anemometer and Relative Humidity meter

Figure 3-3: Material Control Storage room for heat sink

## 3.4 Coating Experiment Procedure

Coating experiment was the main test in this project. The objective to carry out this experiment is to coat the specimens with antirust coatings with the standard room condition (temperature and relative humidity) to test the effects of antirust on heat sink terminals.

Description of Testing Method

1. The specimens have been immersed into antirust coating solution for 24 hours with different types of antirust which are Poly Urethane (plus thinner and hardener in mixture ratio of 4:1:1), Acrylic (plus 10% thiner), Nitro Cellous (also known as Nitro Cellulose), Black Oxide, Synthetic Clear (Alkyd topcoat with Xylene, Naphta and Talcum), WD-40 (Aliphatic Hydrocarbon), LPS Rust Inhibitor (Aliphatic Hydrocarbon), high viscosity Poly Urethane and Acrylic Lacquer solutions (high viscosity Poly Urethane and Acrylic Lacquer are applied by brush and spray).

2. Coated specimen has been placed into two (2) different environment of testing room: (Constant Humidity and temperature during the test).

i) 71.5 % Relative Humidity, 26.6°C
ii) 100 % Relative Humidity, 23.0°C

3. The specimens have been monitored in every 24 hours until 20 days.

4. Sticking test has been conducted 24 hours after ending the test.

5. The specimens have been visually checked for rusting, blistering, cracking or chipping according to ISO Standard 4624 after 24 hours of exposal.

6. Every specimen has been manually soldered to a copper board using manual iron solder and solder coil.

7. Specimens which not resisting solder in manual process will be go through solder dip process.

8. Data will be recorded and gathered. All data will be representing in table.

Table 3-1 below shows the condition of testing room which the ageing process has been carried out. There were two different conditions of storages; one of them was set up as actual storage condition (Sony EMCS storage room) and the other one was the accelerated condition.

Table 3-1: Condition description for coating tests

| |
|---|
| Actual condition storage room |
| Location : SONY EMCS (M) Bangi<br>Relative Humidity: 71.5%<br>Temperature: 26.6°C |
| Simulated condition storage room |
| Location: Village 5E common room.<br>Relative Humidity: 71.5 %<br>Temperature: 26.6°C |
| Accelerated condition storage room |
| Location: Block 15 (15-00-02)<br>Relative Humidity: 100%<br>Temperature: 23.0°C |

Table 3-2 below describes types of coating, application method and solutions appearance.

Table 3-2: Coating type description

| No. | Coating Type | Description |
|---|---|---|
| 1. | Steel terminal as basic comparative test sample. | Non-coating terminal. Control sample. |
| 2. | Steel terminal coated with Poly Urethane + thinner + hardener (clear metallic). | Clear metallic solution, mixture of Poly Urethane, thinner and hardener in ratio of 4:1:1. Applied by immersing sample into solution. |
| 3. | Steel terminal coated with Acrylic + thinner. | Clear coating solution, mixture of acrylic and 10% thinner. Applied by immersing sample into solution. |
| 4. | Steel terminal coated with Nitro Cellous. | Clear coating solution with thinner. Applied by immersing sample into solution. |
| 5. | Steel terminal coated with Black Oxide. | Black coating solution. Applied by immersing sample into solution. |
| 6. | Steel terminal coated with Synthetic Clear (Xylene + Naphta + Talcum) – Alkyd topcoat. | Clear coating solution. Applied by immersing sample into solution. |
| 7. | Steel terminal coated with high viscosity Poly Urethane. | White coating liquid. Applied by brushing. |
| 8. | Steel terminal coated with WD40 (Aliphatic Hydrocarbon). | Yellow colour solution. Applied by spray. |
| 9. | Steel terminal coated with LPS Rust Inhibitor (Aliphatic Hydrocarbon). | Yellow colour solution. Applied by spray. |
| 10. | Steel terminal coated with Acrylic Lacquer. | Clear coating solution. Applied by spray. |

## 3.5 Solder Process

Solder test is important to be carried out in this study. This test basically shows the affects of antirust coatings on the heat sink terminal surface, whether or not the coating interface the solder process. The good antirust coating will not interfering solder process which means, the presence of coating on the terminal surface will not contribute any side effect in term of soldering. There were two types of solder process used in this project which are manual solder and machine solder dip process.

### 3.5.1 Manual Solder

The main purpose of manual solder test is to figure out the effect of coating layer on the terminal surface. Unsuitable coating will resist the solder from sticking at the terminal surface. The test was carried out in normal room temperature and humidity which are approximately about 27°C and 70% accordingly. The coated specimens have been mounted on the circuit board and the terminal has been soldered to the copper area of the board. Solder condition has been visually inspected.

### 3.5.2 Machine Solder Dip

The objective of machine solder dip process is the same as manual solder. It is to monitor the perfection of solder condition of coated terminal on the copper board by visual inspection. For this purpose, an experiment has been done at Board Business Department Sony EMCS (M) Bangi with help of the technicians and engineers. The coated heat sink terminal has been mounted on circuit board and goes through machine solder dip process. The solder condition has been checked and all the result has been gathered.

## 3.6 Tools and Equipment Required

There were a few tools and equipment required to carry out the experiment of data weathering such as Relative Humidity Tester and Anemometer. In addition, some other tools were also required during this project such as heat sinks, various types of antirust, Silica gel, Printed Wiring Board (PWB), tanks, solder iron and solder. Below are the lists of purchased items for coating experiment:

1. Poly Urethane solution.
2. Acrylic solution.
3. Nitro Cellous solution (also known as Nitro Cellulose).
4. Black Oxide solution.
5. Alkyd topcoat synthetic clear solution.
6. High viscosity Poly Urethane.
7. Aliphatic Hydrocarbon spray.
8. Acrylic Lacquer.
9. Thinner.
10. Hardener.
11. Heat sink.
12. Tupperware.

# CHAPTER 4
# RESULT AND DISCUSSION

The main objective of this project is to select the best antirust to be used to coat heat sink terminal. Based on experiments and tests conducted, the optimum antirust coating is Acrylic lacquer. Acrylic was selected as the optimum antirust coating based on the result of coating experiment, monitoring activity, manual solder as well as machine solder dip process. Acrylic lacquer is the only one out of eleven coatings which passed the solder dip process without having solder resist problem.

The results of every test are important to take into account before the final selection of antirust coating. There are two types of results from this project. First result is from monitoring activity and the second result is from solder tests. The purpose of monitoring activity is to select the coating which can prevent corrosion on terminal surface for at least 20 days while the purpose of solder test is to select coating type which not interfering solder process.

After conducted the tests, all results have been gathered and data has been presented in form of tables and graphs in the following pages according to its respective section.

## 4.1 Data Weathering Experiment Result

Below are the detail results of weathering experiment. This result is important to obtain the real storage condition and simulate a similar room condition. Table 4-1 show the data of relative humidity in percent (%), temperature in degree Celcius and wind velocity in m/s. The average value of data was taken for next step of test, which is coating experiment ageing process. Reading was taken every 10 minutes for two hours. Due to effect of surrounding, the readings measured are not consistent. Thus, the average value was calculated to represent the readings measured. The average relative humidity, temperature and wind velocity are 71.5%, 26.6°C and 0.2m/s respectively.

Table 4-1: Data of Relative humidity, Temperature and Wind velocity

| No. | Time | Relative Humidity, (%) | Temperature, (°C) | Wind Velocity, (m/s) |
|---|---|---|---|---|
| 1 | 1600 | 69.4 | 26.5 | 0.1 |
| 2 | 1610 | 69.5 | 26.5 | 0.1 |
| 3 | 1620 | 69.9 | 26.7 | 0.1 |
| 4 | 1630 | 69.7 | 26.9 | 0.2 |
| 5 | 1640 | 70.5 | 26.5 | 0.2 |
| 6 | 1650 | 69.1 | 26.3 | 0.3 |
| 7 | 1700 | 71.3 | 26.6 | 0.1 |
| 8 | 1710 | 73.5 | 26.5 | 0.3 |
| 9 | 1720 | 75.0 | 26.5 | 0.3 |
| 10 | 1730 | 74.6 | 26.5 | 0.1 |
| 11 | 1740 | 69.5 | 26.6 | 0.1 |
| 12 | 1750 | 72.2 | 26.5 | 0.2 |
| 13 | 1800 | 75.0 | 26.6 | 0.3 |
| Average | | 71.5 % | 26.6 °C | 0.2 m/s |

Graph of Relative humidity, Temperature and Wind velocity versus time has been plotted and the following graphs show the result.

Relative humidity of the storage room is 69.4% in the beginning of the test and at the end of two hours test, it increased to 75.0% as shown in Figure 4-1. This is because the room condition was affected by surrounding humidity since the operator entered the room every two hours to take the heat sinks and brought to the operation line.

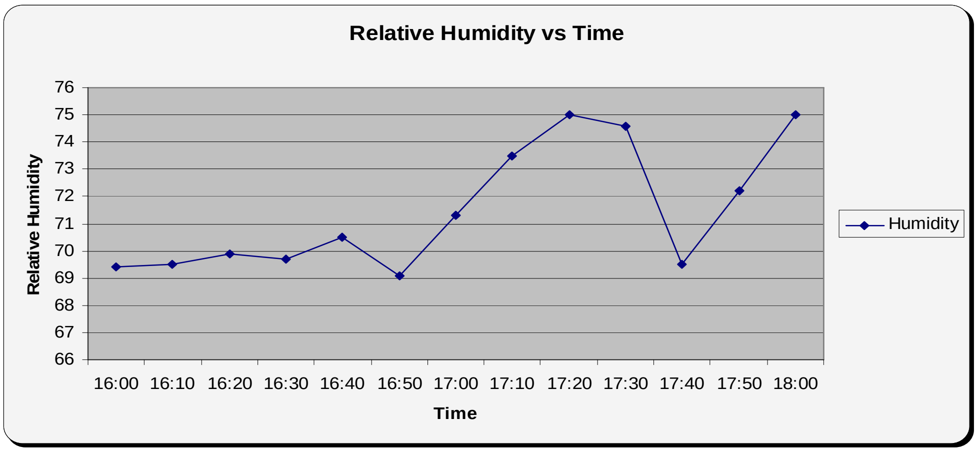


Figure 4-1: Graph Relative humidity versus time

The graph temperature versus time below (Figure 4-2) shows that the temperature starts at 26.5°C and increases to 26.9°C in 30 minutes and drop to 26.3°C after 50 minutes. However the differences of temperature are still in the tolerance range which is ± 0.5°C. The differences of room temperature are also affected by surrounding condition.

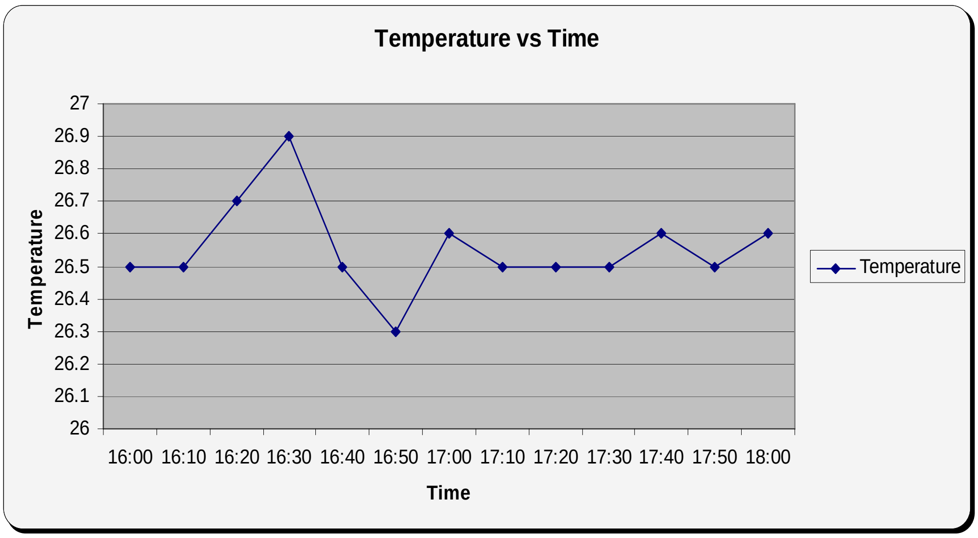


Figure 4-2: Graph Temperature versus time

The following graph shows the wind velocity versus time in two hours. The minimum wind velocity was 0.1m/s and the maximum value was 0.3m/s. This shows the room was not really affected by wind flow. The wind velocity readings are too small compared to the normal room that has a good air flow (approximately 10 -20 m/s).

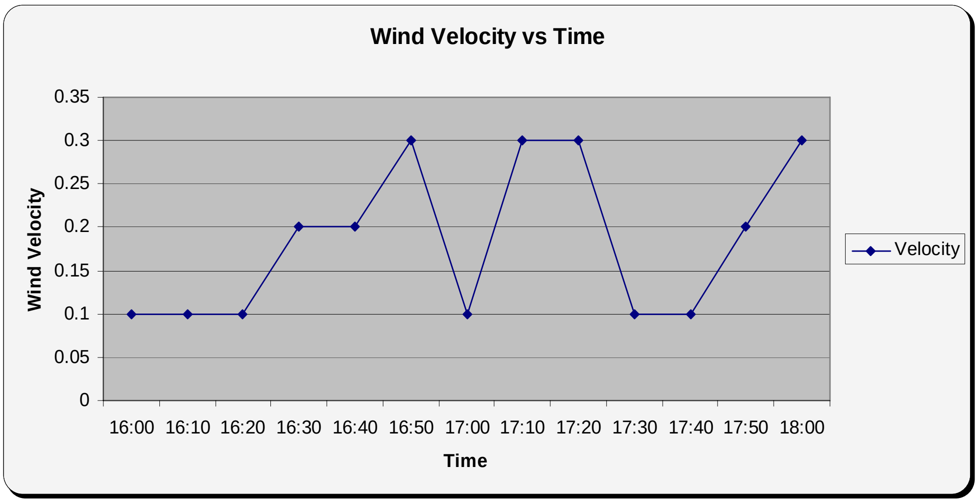


Figure 4-3: Graph Wind velocity versus time

## 4.2 Coating Visual Inspection Result

After 24 hours heat sink specimen has been immersed or sprayed, a visual inspection has been carried out. This inspection is to monitor the coatings appearance on the terminal. The following table describes the terminal surface appearance after coating process.

Table 4-2: Result of coating description in term of surface appearance

| No. | Coating Type | Description |
|---|---|---|
| 1. | Steel terminal as basic comparative test sample (Control sample) | Non-coated terminal surface. |
| 2. | Steel terminal coated with Poly Urethane + thinner + hardener (clear metallic) | Clear layer on the surface. |
| 3. | Steel terminal coated with Acrylic + 10% thinner | Thick clear layer on the surface. |
| 4. | Steel terminal coated with Nitro Cellous | Clear layer on the surface. |
| 5. | Steel terminal coated with Black Oxide | Black layer on the surface. |
| 6. | Steel terminal coated with Synthetic Clear (Xylene + Naphta + Talcum) – Alkyd topcoat | Clear layer on the surface. |

| | | |
|---|---|---|
| 7. | Steel terminal coated with high viscosity Poly Urethane | White layer on the surface. |
| 8. | Steel terminal coated with WD40 (Aliphatic Hydrocarbon) | Yellow layer on the surface (oily surface). |
| 9. | Steel terminal coated with LPS Rust Inhibitor (Aliphatic Hydrocarbon) | Yellow layer on the surface (oily surface). |
| 10. | Steel terminal coated with Acrylic Lacquer | Clear layer on the surface. |

(Refer Appendix H for visual aid)

## 4.3 Monitoring Activity Result

This section shows the results of daily monitoring activity which has been done in 20 days. There are two types of condition of storage room. The first one is a simulated condition which has similar humidity and temperature and the second one is known as accelerated condition which used to compare the corrosion rate between simulated and accelerated humidity. Corrosion rate scale 0 till 5 used is based on ISO Standard 4626 interpretation. The word 'Ri', refer to rust condition. Number 0 describe the rust condition is at most and 4 is the least. Number 5 was used if the corrosion is not occurring. Table 4-3(a) shows the scale that has been used in this project to interpret the corrosion.

Table 4-3: Corrosion Scale

| Scale for ISO Standard 4626 interpretation | | | | | | |
|---|---|---|---|---|---|---|
| Ri (Rusting) | Very good | Good | Medium | Bad | Very Bad | Zero |
| | 0 | 1 | 2 | 3 | 4 | 5 |

Monitoring results have been recorded in four (4) tables that attached in Appendix D and Appendix E. Daily monitoring activity that has been carried out for simulated and accelerated condition room in 20 days. Both storage conditions have 10 different types of coating and coating 1 refers to non coated or known as control sample. Control sample for simulated condition get corrode in 13 days and all the coated samples do not corrode until the 20th day. Control sample corrodes after 13 days because it reacts with environment.

For accelerated condition, the control sample corrodes within 12 days. It is faster than simulated control sample. This is because 100% humidity accelerates the corrosion rate growth faster compared with the lower humidity. The table in Appendix D and Appendix E show the corrosion scale according to ISO Standards 4626 interpretation.

## 4.4 Manual Solder Result

Manual solder experiment has been carried out at laboratory to figure out the effect of coating layer on the terminal surface. Solder is perfectly bonded with terminal if the coating is suitable for electronic application. Solder resist problem occur when the coating used is not suitable. Table 4-5 below shows the result of manual solder condition and Appendix B shows the picture of OK and REJECT solder condition.

Table 4-4: Manual Solder Result

| No. | Coating Type | Result Description |
|---|---|---|
| **1.** | Control sample | Solder perfectly bonded. |
| **2.** | Poly Urethane | Solder perfectly bonded. |
| **3.** | Acrylic + Thinner | Solder resist. |
| **4.** | Nitro Cellous | Solder perfectly bonded. |
| **5.** | Black Oxide | Solder resist (coating layer melt). |
| **6.** | Alkyd | Solder resist (coating layer melt). |
| **7.** | High viscosity Poly Urethane | Solder resist (coating layer melt). |
| **8.** | Aliphatic Hydrocarbon | Solder resist. |
| **9.** | Aliphatic Hydrocarbon | Solder resist. |
| **10.** | Acrylic lacquer | Solder perfectly banded. |

### 4.5 Machine Solder Dip Result

Machine solder dip process has been done at Sony EMCS Bangi. The result is essentials to choose the best antirust coating for electronic application. Result of manual solder was taken into account. Coatings that resist solder in manual test were not proceeding to machine solder dip test to avoid any problem to Board Production line due to time constraint. From manual solder test, only three types of coated specimens that result perfect solder which are Poly Urethane, Nitro Cellous and Acrylic lacquer. Symbol '-' is used in Table 4-6 to notify that the particular coating type was not go through machine solder dip test.

Table 4-5: Machine Solder Dip Result

| No. | Coating Type | Result Description |
|---|---|---|
| **1.** | Control sample | Solder perfectly bonded. |
| **2.** | Poly Urethane | Solder resist. |
| **3.** | Acrylic + Thinner | - |
| **4.** | Nitro Cellous | Solder resist. |
| **5.** | Black Oxide | - |
| **6.** | Alkyd | - |
| **7.** | High viscosity Poly Urethane | - |
| **8.** | Aliphatic Hydrocarbon | - |
| **9.** | Aliphatic Hydrocarbon | Solder perfectly bonded. |
| **10.** | Acrylic lacquer | Solder resist. |

Table 4-6 above shows only one type of coating results perfect solder condition. Appendix B shows the picture of OK and REJECT solder condition. Acrylic lacquer is selected as the optimum antirust coating based on both manual solder and machine solder dip test.

During coatings and solder test, some improvements on coating procedure were recognized necessary to make the result more precise and accurate. Solder probably not stick on the coated heat sink surface because the coating layer is too thick. The perfect layer thickness can be obtained by using another method of coating such as air spray. The layer thickness also can be measure using film thickness gauge (for example Erichsen Model 455).

### 4.6 Discussion of Rust Occurrences on Coated Steel

Steel is said coated when it is provided with a barrier layer on the surface. Thus, it has better performance in term of life time due to exposure. Somehow, secondary processes such as cutting, stamping, forging and others can make coating layer damage. Corrosion occurs at the exposed side of surface, which has no barrier to prevent the steel surface react with environment. Figures 4-4 below provide better visual aid on how coated steel rust.

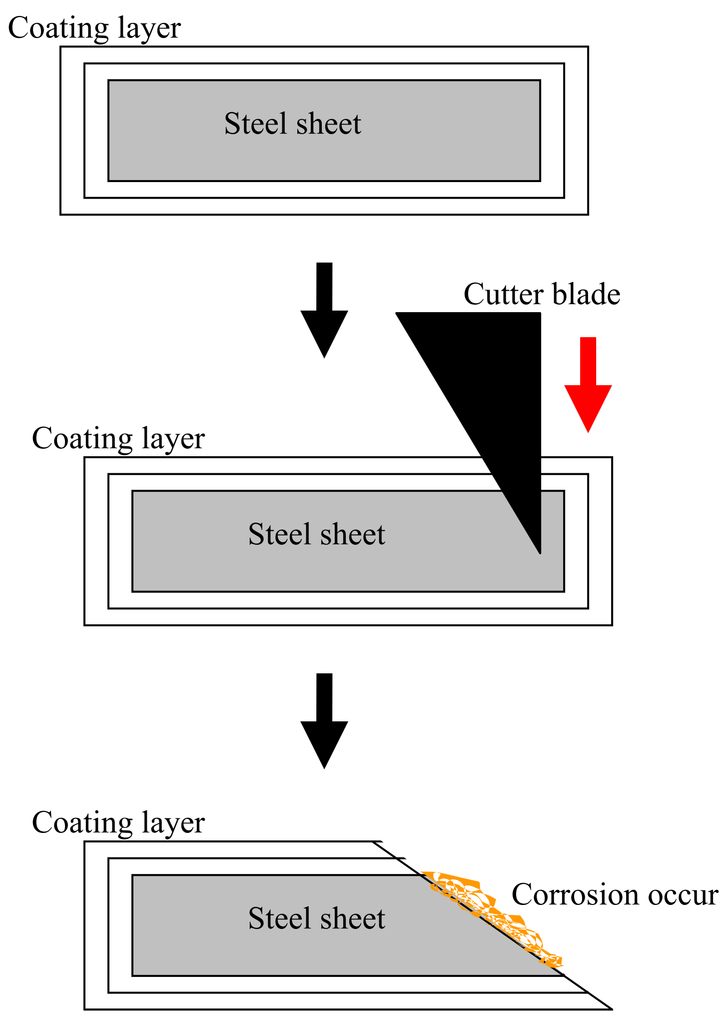


Figure 4-4: Illustration of corrosion occurs on the coated steel surface

# CHAPTER 5
# CONCLUSION AND RECOMMENDATION

This section will discuss more about conclusion and recommendations. The conclusion part focuses on project conclusion after two semesters work while recommendation part is to describe some recommended steps to prevent corrosion on heat sink terminal.

## 5.1 Conclusion

All of the work is successfully done within the timeframe. The theory and concept of corrosion and antirust coatings has been studied. The coating, monitoring and soldering experiment has been carried out. Optimum antirust coating has been selected based on the coating, monitoring as well as soldering process. The selected antirust can protect heat sink terminal surface by providing a clear layer of barrier on the surface. The most important characteristic of the selected coating is not interfere solder process. Some of coatings applied offer less suitable surface condition for soldering.

Generally this project has been completed in two semesters. In the first semester, the project was more on gaining the ideas by studying the concept and principle of corrosion, heat sink and coatings. Researches and experiment have been done for data weathering test, laboratory coating test, visual check and solder process. After all the data has been obtained and gathered, some ISO standards has been referred to make sure the test procedures are according the standards.

As for second semester, the project was more focused on purchasing various types of coating, heat sink sample, equipments and tools as preparation for laboratory tests. After all samples have been purchased, the tests have been conducted started with data weathering test. This test is to ensure environment for ageing process is simulated from the real storage condition in term of humidity and temperature. After data of weathering test was obtained, coating experiment has been conducted and placed in a simulated room. Monitoring process has been done for 20 days to visually check the specimens. Manual solder and machine solder dip process has been conducted to measure the solder suitability of coating applied on the terminal surface. Lastly, after all tests have been conducted, optimum coating selection based on all the tests has been done.

Hopefully this study and project could give a big contribution for manufacturing industries. This project will also lift up UTP credibility in education and engineering environment suit with the motto, UTP; Engineering Futures.

## 5.2 Recommendation

During this project, some findings on corrosion have been discovered. Corrosion on the terminal surface occurs because of improper design control. Metal sheet used in the electronic manufacturing industries is already coated with some coatings such as Zinc layer, Nickel layer and some other metallic coatings. However, the coating layer has been damaged by mechanical process such as stamping for metal shaping purposes. The side part which has been cut is exposed to the environment without any corrosion protection, lead to corrosion.

In order to prevent corrosion because of this kind of process, the stamped metal sheet should be recoated by another organic layer. This layer prevents exposed side or parts of metal surface from corrode. The example of the organic layer which is generally used in electrical and electronic industries are Acrylic, Epoxy, Furans, Phenolics, Polysters, Vynil ester and Vynil Ester Novolac. The organic composition in the coating solvent such as resin component, pigment, fillers and additives make the coatings efficient.

Maintenance is the most important part in coating technology. Any coating or paint job, even if properly done, dies not last forever. Thus, an inspection or repair process should be done to detect any failure of coating layer.

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# APPENDICES

# APPENDIX A

**Pin Hole Problem Picture**

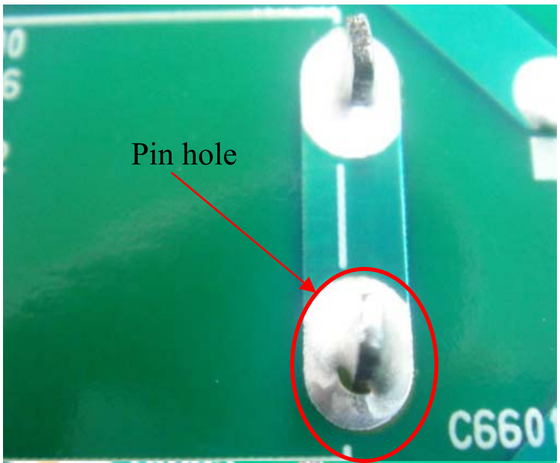



Figure A-1: Pin hole problem occurs on PWB complete board (gap between terminal and copper area of PWB).

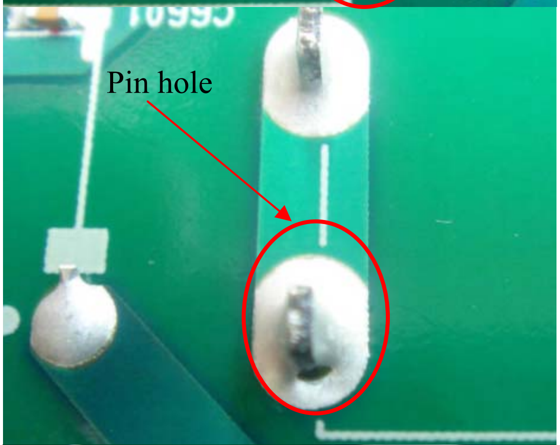



Figure A-2: Other example pin hole problem occurs on PWB complete board (different location).

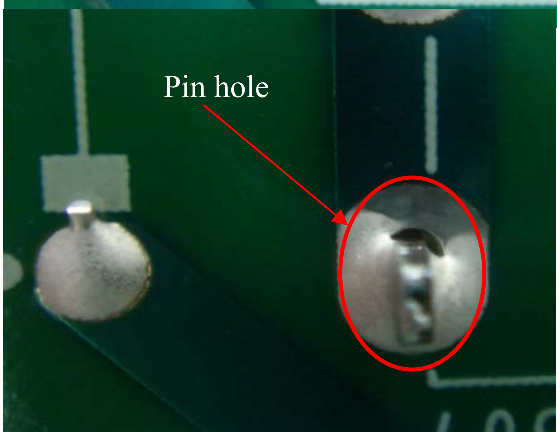



Figure A-3: Other location of pin hole problem occurs on PWB complete board.

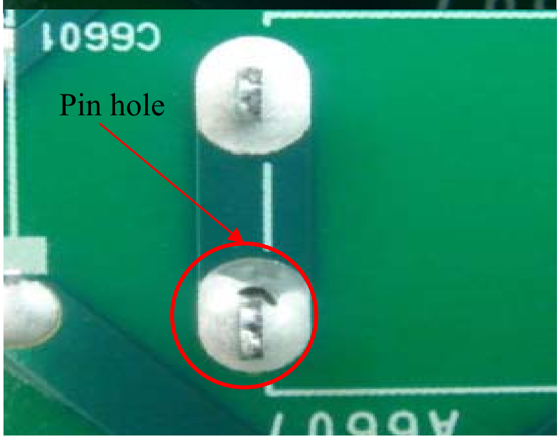



Figure A-4: Other location of pin hole problem occurs on PWB complete board.

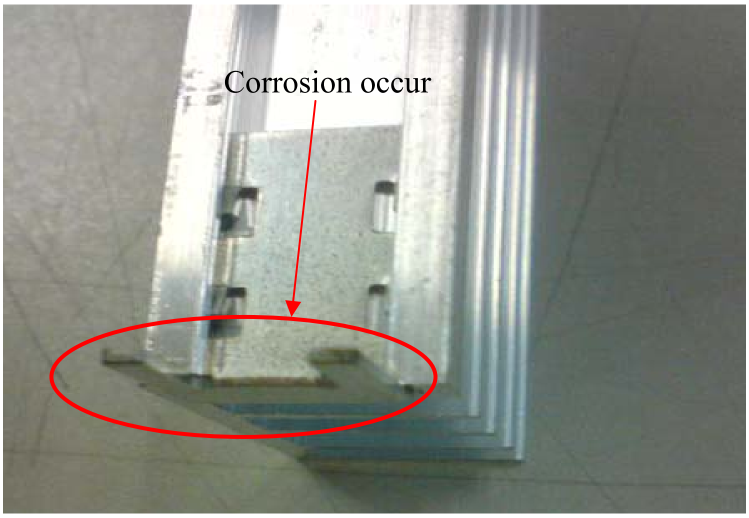



Figure A-5: Corrosion occurs on the terminal surface.

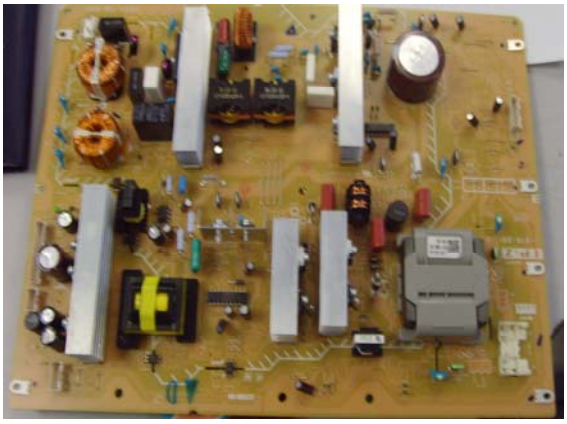


Figure A-6: Complete circuit board with heat sink mounted.

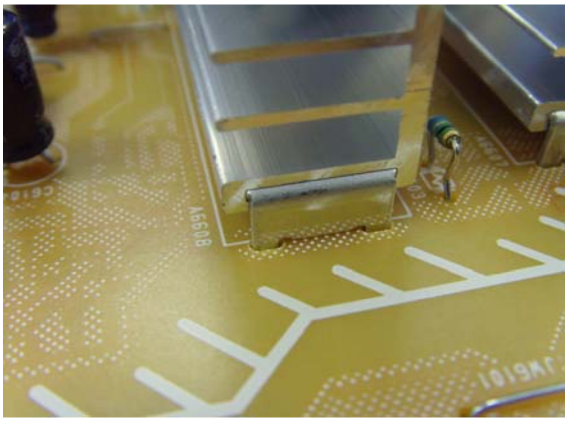


Figure A-7: Close up of heat sink which mounted on PWB.

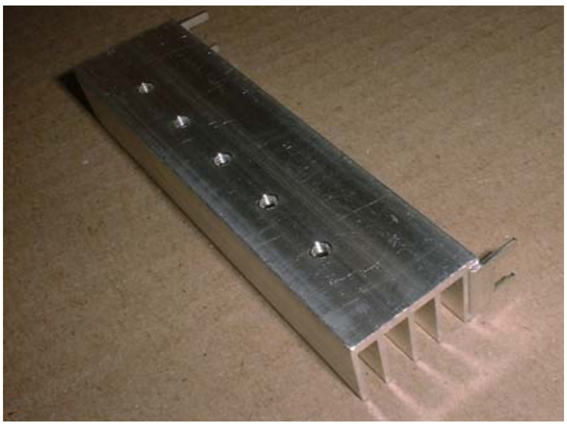


Figure A-8: Sample heat sink that used in this project.

# APPENDIX B

**i) Pictures of Coating Experiment storage**

Figure A-9: Coated heat sink in accelerated condition storage (Block 15-00-02)

Figure A-10: Coated heat sink in simulated condition storage (Common room V5E)

**ii) Pictures of Solder Experiment**

1. Manual Solder Result

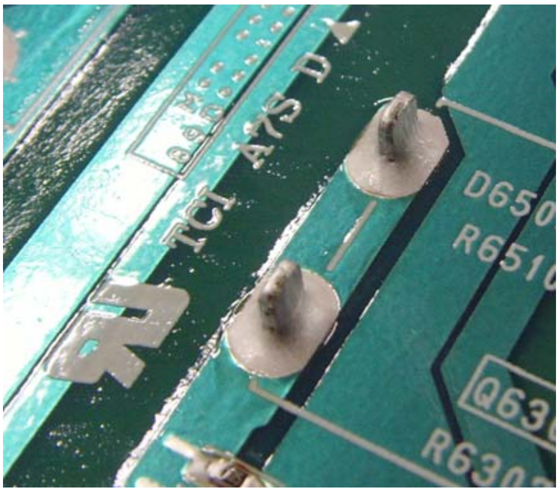
(a)

(b)

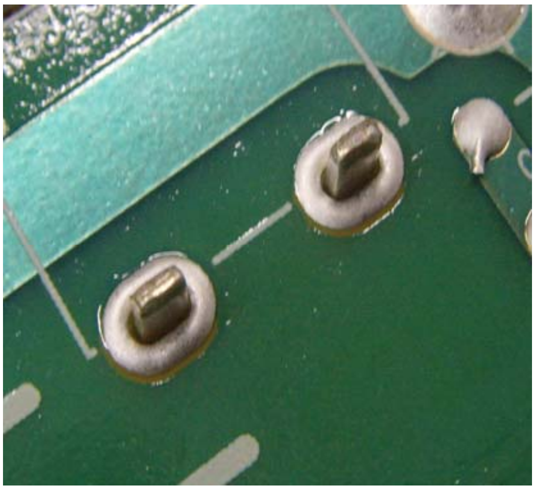
Figure A-11(a): Picture of OK solder condition

Figure A-11(b): Picture of REJECT solder condition (resist solder)

2. Machine Solder Dip Result



(a)



(b)

Figure A-12(a): Picture of OK solder condition

Figure A-12(b): Picture of REJECT solder condition (solder resist)

**iii) Two Different Solder Process**

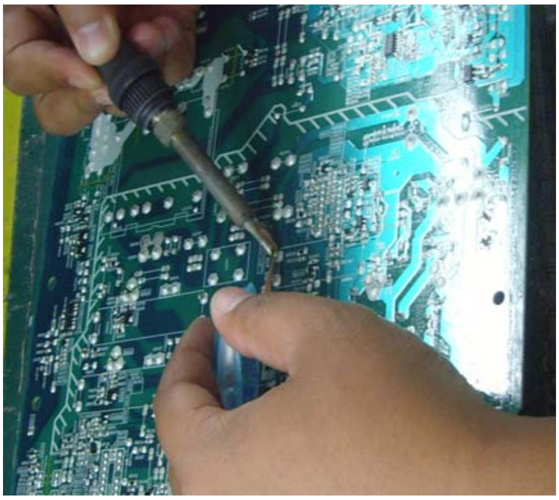


Figure A-13: Manual solder process

Figure A-14: Machine solder dip process

# APPENDIX C

## Heat Sink Process Descriptions

Incoming raw material for heat sink body is in aluminum bars form. It is stored in closed area to prevent corrosion. The extrude bar metal then went through cutting process and also clear sawing using cutting blade (Figure A-16(a) & A-16(b)). After sawing process, the part has been blew using the air gun. The main function of air blow process is to remove the cutting burr and as a pre cleaning for sawing process.

(a)

(b)

Figure A-15(a) & A-15(b): Raw material storage room

The parts has been immerse in a chemical solution after blew by air gun. The chemical reacts as a coolant for materials and this coolant helps increasing cutting rates, improve the cut finishing and extend blade life. The green color liquid which has been referred to coolant chemical is known as COOL SM 800 (Figure A-17).

After being sawed and immersed in coolant for a minute, the part has been collected back to the temporary storage basket, and then it has been placed inside the bin to be transfer to the next process.

(a)

(b)

Figure A-16(a) & A-16(b): Sawing process

Figure A-17: Green chemical used as coolant – COOL SM 800

The next process was stamping. This process punched hole to the part. The hole puncher for the part is located on the upper tooling which is replaceable. Below is the tooling diagram for punching hole on heat sink process.

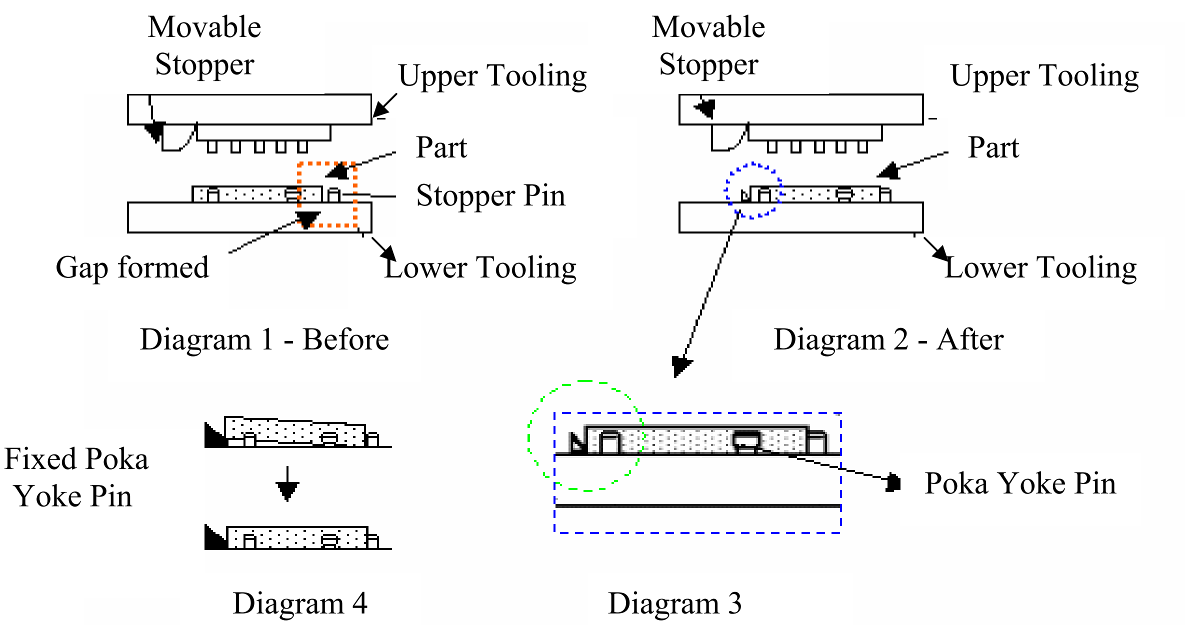
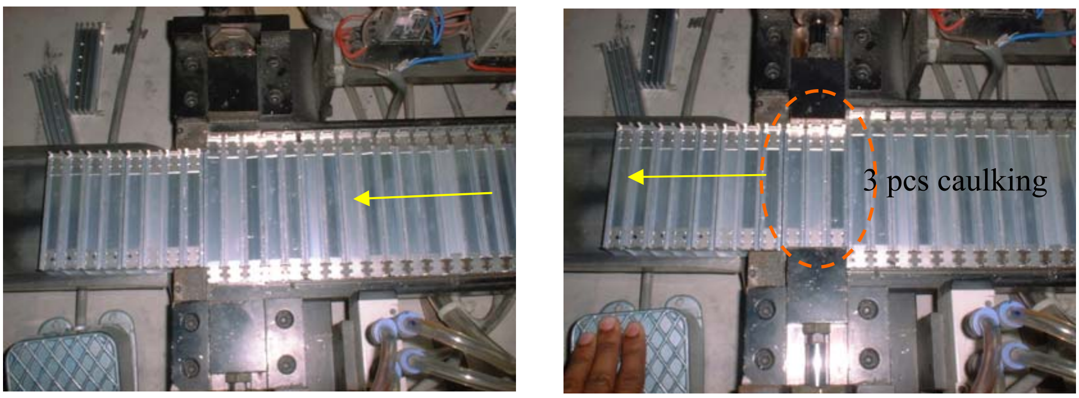



Figure A-18: Schematic diagram for punching tool

*Source:* From Kunju Raman, Hung Kee Hong Electronics & Metal ISO Coordinator, 2007.

Once this process has been completed the part has been sent to caulking process. After the part was manually joined with the terminal, it was placed on a caulking jig. The caulking jig is used to tighten the terminal with heat sink. With one press, it was able to caulk 3 pieces of parts. Refer to the figure A-19(a) and A-19(b) below for more visual aid.




(a) (b)

Figure A-19(a) & A-19(b): Caulking process after insert the terminal

Some other part which have special terminal called terminal pin, go through other process instead insert and caulking process. The tools used are absolutely different. Below is the process flow of the pin terminal process.

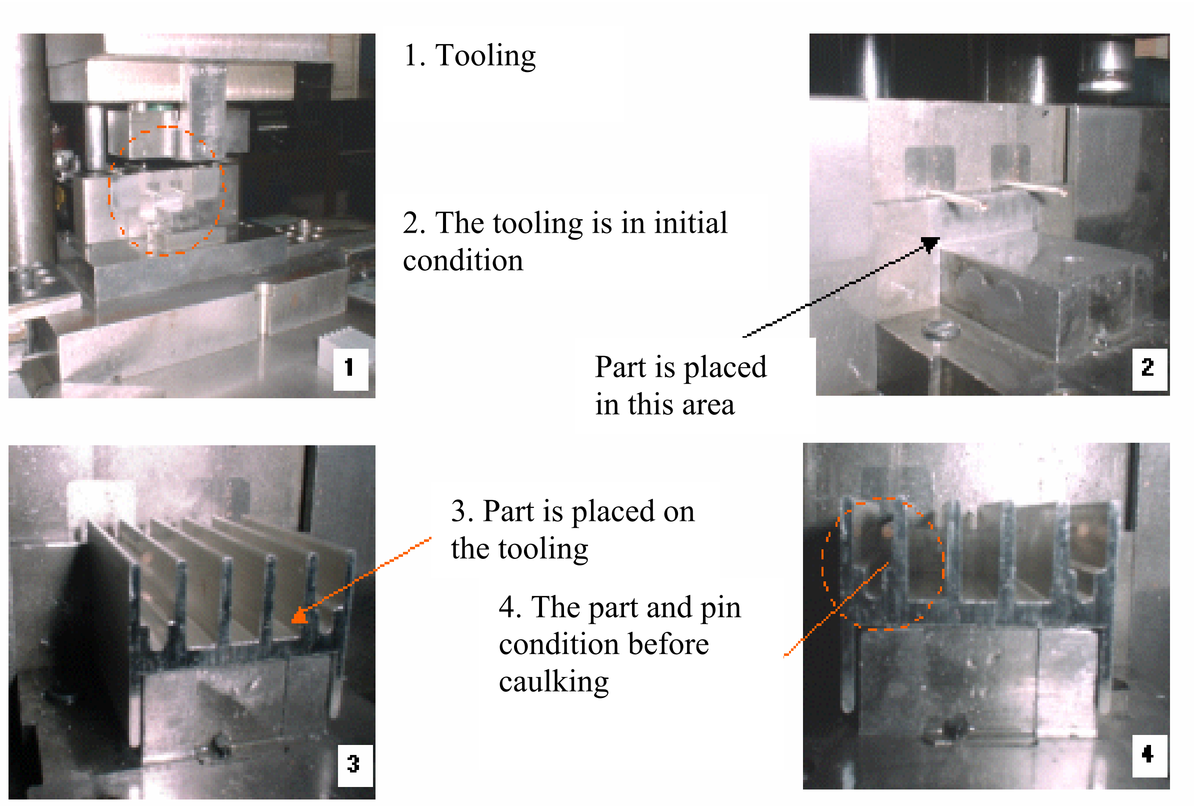



Figure A-20: Flow diagram for terminal pin inserts process

*Source:* From Kunju Raman, Hung Kee Hong Electronics & Metal ISO Coordinator, 2007.

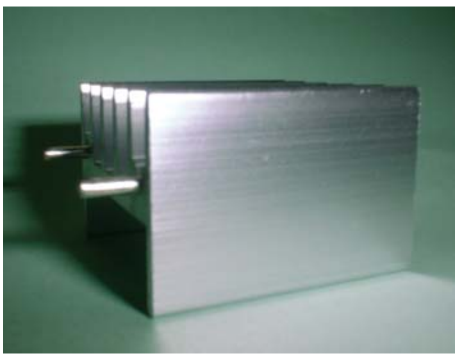


Figure A-21: Complete part for pin terminal

After went through insert process, the part has been sent to another process which generally known as taping. This process made a thread to the part which diameter is referred to drawing specified by customer. Then, to remove coolant oil from surface, the part has been through the Decreasing process. This is to ensure the chemical is 100% removed from the surface to avoid oily surface problem. The decreasing process also functioned as antirust coating to the heat sink terminal.

For the Decreasing Process, there should be a specified ambient setting, which is tank temperature and also air conditioning temperature. Below is the specified list of the common temperature setting for this process.

1. Tank temperature Set to:
   Tank 1 : 60° ± 10°C
   Tank 2 : 90° ± 10°C
2. Air-con Temperature Set to 40°C
3. Ensure both of Tank 1 & Tank 2 full filled with degreasing chemical.
   Chemical used: ULTRACLEAN NE
   Tank 1 - Tank 2 - Duration about 10-12 minutes.

After went through decreasing process, the part has been placed at the Work In Progress (WIP) area. Lastly, the part has been packed and the specific label was pasted on the carton. The carton then was stored if it passed OQC inspection. Usually supplier plan to run is about advance three to five days before the delivery date.

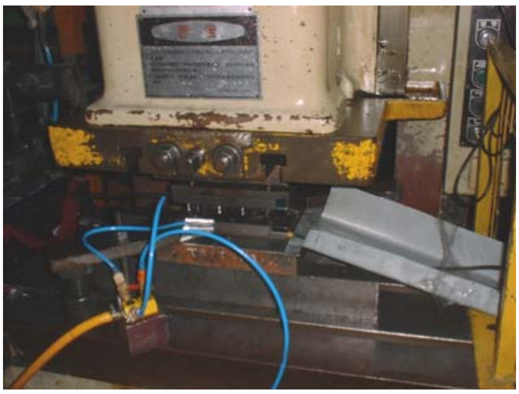


Figure A-22: Terminal stamping machine

Figure A-23: Terminal immersed in stamping oil

Figure A-24: Temporary storage at caulking area

Figure A-25: Sample of heat sink

Figure A-26: Current packaging to prevent corrosion

Figure A-27: External packaging (carton)

*Source:* From Kunju Raman, Hung Kee Hong Electronics & Metal ISO Coordinator, 2007.

# APPENDIX D

**Result of Monitoring Activity for Simulated Condition**

Table A-1(a): Monitoring Result for Simulated Condition (Coating type 1-5)

| Day | Coating 1 (Control) | Coating 2 (Poly Urethane) | Coating 3 (Acrylic + thinner) | Coating 4 (Nitro Cellous) | Coating 5 (Black Oxide) |
|---|---|---|---|---|---|
| **1** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **2** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **3** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **4** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **5** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **6** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **7** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **8** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **9** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **10** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **11** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **12** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **13** | Ri = 4 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **14** | Ri = 3 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **15** | Ri = 3 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **16** | Ri = 3 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **17** | Ri = 3 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **18** | Ri = 2 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **19** | Ri = 2 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **20** | Ri = 2 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |

Table A-1(B): Monitoring Result for Simulated Condition (Coating type 6-10)

| Day | Coating 6 (Alkyd) | Coating 7 (High viscosity Poly Urethane ) | Coating 8 (Aliphatic Hydrocarbon) | Coating 9 (Aliphatic Hydrocarbon) | Coating 10 (Acrylic lacquer) |
|---|---|---|---|---|---|
| **1** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **2** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **3** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **4** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **5** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **6** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **7** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **8** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **9** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **10** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **11** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **12** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **13** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **14** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **15** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **16** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **17** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **18** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **19** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| **20** | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |

# APPENDIX E

## Result of Monitoring Activity for Accelerated Condition

Table A-2(a): Monitoring Result for Accelerated Condition (Coating type 1-5)

| Day | Coating 1 (Control) | Coating 2 (Poly Urethane) | Coating 3 (Acrylic + thinner) | Coating 4 (Nitro Cellous) | Coating 5 (Black Oxide) |
|---|---|---|---|---|---|
| 1 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 2 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 3 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 4 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 6 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 7 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 8 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 9 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 10 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 11 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 12 | Ri = 3 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 13 | Ri = 3 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 14 | Ri = 2 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 15 | Ri = 2 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 16 | Ri = 2 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 17 | Ri = 2 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 18 | Ri = 1 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 19 | Ri = 1 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 20 | Ri = 1 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |

Table A-2(b): Monitoring Result for Accelerated Condition (Coating type 6-10)

| Day | Coating 6 (Alkyd) | Coating 7 (High viscosity Poly Urethane ) | Coating 8 (Aliphatic Hydrocarbon) | Coating 9 (Aliphatic Hydrocarbon) | Coating 10 (Acrylic lacquer) |
|---|---|---|---|---|---|
| 1 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 2 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 3 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 4 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 6 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 7 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 8 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 9 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 10 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 11 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 12 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 13 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 14 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 15 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 16 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 17 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 18 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 19 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |
| 20 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 | Ri = 5 |

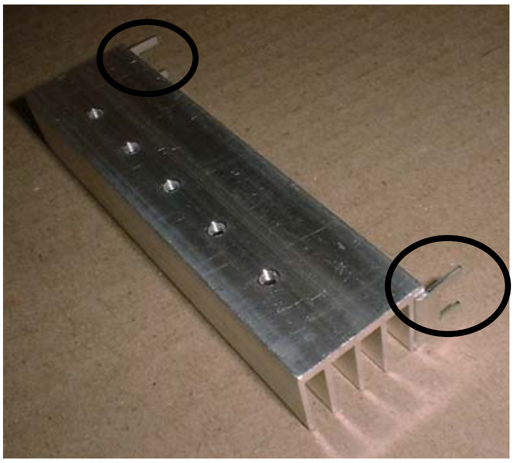
# APPENDIX F

**Pictures of Heat Sink and Heat Sink Terminal**

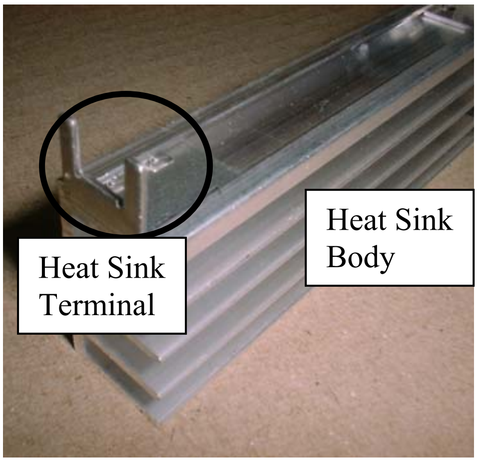

Figure A-28: Sample Produce Part For Sony EMCS (M)


Figure A-29: Sample Heat Sink Produce


Figure A-30: Sample Of Heat Sink with different terminal



A-31




A-32

Figure A-31 & A-32 : Sample Heat Sink and Terminal which get rust area

Figure A-33: Storage at caulking area

Figure A-34: Current Internal Packaging

Figure A-35: Current External Packaging (Carton box)

*Source:* From Kunju Raman, Hung Kee Hong Electronics & Metal ISO Coordinator, 2007.

# APPENDIX G

**Pictures for Machine Solder Dip Flow**

(a)

Figure A-36(a): Heat sink is mounted on the board

(b)

Figure A-36(b): Weight and jigs is attached on the board

(c)

Figure A-36(c): Board goes through hot liquid solder

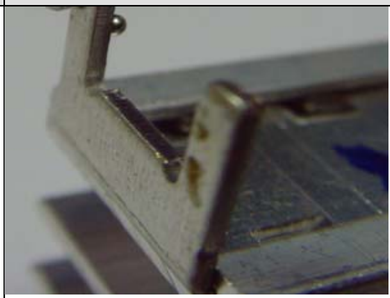
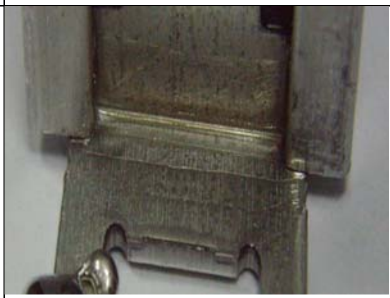
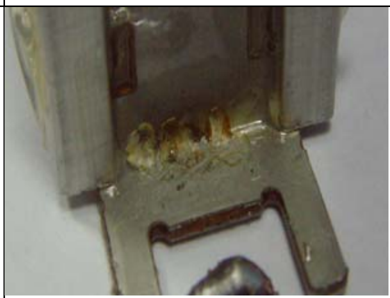
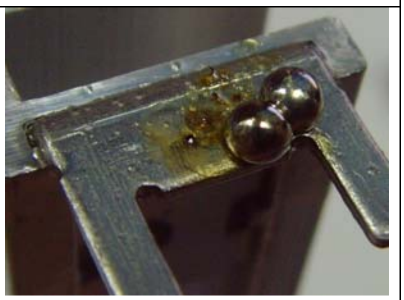
(d)

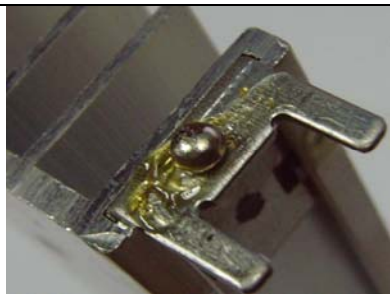
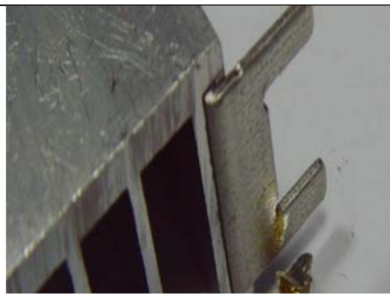
Figure A-36(d): Soldered board is been cooled by fans below

# APPENDIX H

**Picture of Coating Visual Inspection Result**

Table A-3: Result of coating description in term of surface appearance

| No. | Coating Type | Description | Picture |
|---|---|---|---|
| 1. | Steel terminal as basic comparative test sample (Control sample) | Non-coated terminal surface. |  |
| 2. | Steel terminal coated with Poly Urethane + thinner + hardener (clear metallic) | Clear layer on the surface. |  |
| 3. | Steel terminal coated with Acrylic + 10% thinner | Thick clear layer on the surface. |  |
| 4. | Steel terminal coated with Nitro Cellous | Clear layer on the surface. |  |

| | | | |
|---|---|---|---|
| 5. | Steel terminal coated with Black Oxide | Black layer on the surface. |  |
| 6. | Steel terminal coated with Synthetic Clear (Xylene + Naphta + Talcum) – Alkyd topcoat | Clear layer on the surface. |  |
| 7. | Steel terminal coated with high viscosity Poly Urethane | White layer on the surface. |  |
| 8. | Steel terminal coated with WD40 (Aliphatic Hydrocarbon) | Yellow layer on the surface (oily surface). |  |
| 9. | Steel terminal coated with LPS Rust Inhibitor (Aliphatic Hydrocarbon) | Yellow layer on the surface (oily surface). |  |

| | | | |
|---|---|---|---|
| 10. | Steel terminal coated with Acrylic Lacquer | Clear layer on the surface. |  |

**Table A-4: Suggested Milestone for the First Semester of 2-Semester Final Year Project**

| No. | Detail/ Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mid-semester break | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Selection of Project Topic | ■ | ■ | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 2 | Preliminary Research Work | | ■ | ■ | ■ | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 3 | Submission of Preliminary Report | | | | ● | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 4 | Seminar 1 (optional) | | | | | ■ | ■ | ■ | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 5 | Project Work | | | | | ■ | ■ | ■ | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 6 | Submission of Progress Report | | | | | | | | | ● | | | | | | |
| | | | | | | | | | | | | | | | | |
| 7 | Seminar 2 (compulsory) | | | | | | | | | | ■ | ■ | ■ | ■ | | |
| | | | | | | | | | | | | | | | | |
| 8 | Project work continues | | | | | | | | | ■ | ■ | ■ | ■ | ■ | | |
| | | | | | | | | | | | | | | | | |
| 9 | Submission of Interim Report Final Draft | | | | | | | | | | | | | | ● | |
| | | | | | | | | | | | | | | | | |
| 10 | Oral Presentation | | | | | | | | | | | | | | | ● |
| | | | | | | | | | | | | | | | | |

● Suggested milestone
■ Process

**Table A-5: Suggested Milestone for the Second Semester of 2-Semester Final Year Project**

| No. | Detail/ Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Project Work Continue | ■ | ■ | ■ | | | | | Mid-Semester Break | | | | | | | |
| 2 | Submission of Progress Report 1 | | | | ● | | | | | | | | | | | |
| 3 | Project Work Continue | | | | ■ | ■ | ■ | ■ | | | | | | | | |
| 4 | Submission of Progress Report 2 | | | | | | | | | ● | | | | | | |
| 5 | Seminar (compulsory) | | | | | | | | | | ■ | ■ | ■ | | | |
| 5 | Project work continue | | | | | | | | | ■ | ■ | ■ | ■ | | | |
| 6 | Poster Exhibition | | | | | | | | | | | ● | | | | |
| 7 | Submission of Dissertation (soft bound) | | | | | | | | | | | | | ● | | |
| 8 | Oral Presentation | | | | | | | | | | | | | | ● | |
| 9 | Submission of Project Dissertation (Hard | | | | | | | | | | | | | | | ● |

● Suggested milestone

■ Process

**Table A-6: Final Year Project Workflow for the First Semester of 2-Semester Final Year Project**

| No. | Details / Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Project topic awarded | ● | ● | | | | | | Mid-semester break | | | | | | | |
| 2. | Research from books, journals, internet and encyclopedias on: | | | ● | | | | | | | | | | | | |
| | Corrosion<br>Definition of Corrosion<br>Corrosion Principle<br>Mechanism of Corrosion<br>Types of Corrosion<br>Selecting Materials for Corrosion Resistance | | | ● | ● | ● | ● | ● | | ● | ● | ● | | | | |
| | Heat Sink<br>Triple Coated Steel – Ecotrio<br>Heat Sink Principle and Performance<br>Heat Sink Design (Personal Interview)<br>Use in Electronics<br>In Soldering | | | ● | ● | ● | ● | ● | | | | | | | | |
| | Antirust Coatings<br>Principle of Corrosion Protection<br>Metallic Coatings<br>Organic Coatings | | | | | ● | ● | ● | | ● | ● | ● | | | | |
| 3. | Prepare Test Procedure | | | | | | | | | | | | | | | |
| | Data Weathering Measurement | | | | | | | | | | | | ● | | | |
| | Coating Experiment Procedure (according to ISO Standards) | | | | | | | | | | | | | ● | | |
| | Solder Process<br>Manual Solder<br>Machine Solder Dip | | | | | | | | | | | | | | ● | |
| 4. | Gather information in a report | | | | | | | | | | | | | | | ● |

● Process Implementation

**Table A-7: Final Year Project Workflow for the Second Semester of 2-Semester Final Year Project**

| No. | Details / Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Deal with suppliers | ● | ● | ● | ● | ● | ● | | Mid-semester break | | | | | | | |
| 2. | Prepare Test Procedure | | | | | ● | ● | ● | | | | | | | | |
| 3. | Set up experiment environment<br>Simulated condition<br>Accelerated condition | | | | | ● | ● | ● | | ● | ● | ● | | | | |
| 4. | Data Weathering Test at Sony EMCS (M) Bangi | | | | | | ● | | | | | | | | | |
| 5. | Purchase equipment and sample for coating experiment | | | | | | | | | | | | | | | |
| | Equipment<br>Tupperware (container)<br>Heat Sink<br>Antirust Coatings<br>Poly Urethane solution<br>Acrylic solution<br>Nitro Cellous solution (also known as Nitro Cellulose).<br>Black Oxide solution<br>Alkyd topcoat synthetic clear solution.<br>High viscosity Poly Urethane (commonly used for glass)<br>Aliphatic Hydrocarbon spray.<br>Acrylic Lacquer.<br>Thinner<br>Hardener | | | | ● | ● | ● | ● | | ● | ● | ● | ● | | | |
| 6. | Coating Experiment | | | | | | | | | | | | | ● | | |
| 7. | Monitoring Activity | | | | | | | | | | | | | ● | ● | ● |
| 8. | Solder Test | | | | | | | | | | | | | | | |
| | Manual Solder (Block 22 UTP) | | | | | | | | | | | | | | ● | |
| | Machine Solder Dip (Sony EMCS Bangi) | | | | | | | | | | | | | | | ● |
| 9. | Optimum Coating selection | | | | | | | | | | | | | | | |
| 10. | Prepare final report | | | | | | | | | | | | | ● | ● | ● |
| | ● Process Implementation | | | | | | | | | | | | | | | |