Study of Various Insulation Materials on the performance of Non-Convecting Solar Pond in Malaysia

By

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1453

Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATE OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Program
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Approved by,

(Mr. Kamaruddin Shehabuden)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
JUNE 2004

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 concept as specified in the references and acknowledgement, and that the original work contained herein have not been taken or done by unspecified sources or persons.

MOHAMAD RIZAL BIN ISMAIL

ABSTRACT

The study will focus on the types of insulation that will be used in order to maintain the temperature of salty concentration. This can be detected from the calculation of heat loss (Q_{loss}). The less heat loss calculated, the better the insulator could be. However, in order to find the heat loss, one must determine the amount of solar radiation absorbed by the sun via radiation. To measure the total radiation that had been produced by the sunlight, photo radiometer or solarimeter had been used as the main device. Besides that, thermometer is used to measure the temperature of the surrounding and the temperature of the polystyrene.

The solar pond is using the salinity gradient solar technology. The purpose of solar pond is to collect and store solar energy. For this project, the writer has decided that the solar pond should have the depth of 2 inches of brine while the remaining 3 inches (5 inches total in depth) is the salinity gradient part **(Non Convective Zone and Upper Convective Zone).**

3 materials had been suggested for this project, which is polystyrene, polyurethane and cardboard paper. Whilst the first two has been regarded as the insulation materials, the final one is not. However, in order to test the hypothesis (theory) with the actual experiment, such condition is chosen before completing the project.

Finally, the project should be a useful addition in order to understand the concept of the salinity gradient solar pond and its insulator. This is because; it applied the heat transfer concept of conduction and convection. Hence, the outcome of this project should give benefits for all of the persons involved; particularly the student himself.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The project of the **"Study into the effectiveness of various insulation materials on the performance of non- convecting Solar Pond in Malaysia"** has been proposed to ensure that student will be able to differentiate the types of insulators; hence enabling them to identify the best insulators available. However, in order to proceed, further understanding on the solar pond concept must be done before continuing with the insulations part.

The purpose of solar pond is to utilize the energy produced from the sun (solar energy). This is because, it is stated in The First Law of Thermodynamic that energy neither cannot nor be created or destroyed, but can be transformed into another form. Using this concept; come the ideas of utilizing the solar energy using solar pond. The technology was introduced in United States; but remarkably progress had been seen in Israel where they developed the solar pond as there is not much space to develop hydroelectric dam.

For this project, the study is emphasizing on the various types of insulation used in the solar pond system. Three materials have been selected for analysis, where the calculation on the heat loss has been done. The three materials are the polystyrene, polyurethane and the cardboard paper. At the moment, the experiment involving polystyrene had been done via the analysis and graph plotted.

1.2 PROBLEM STATEMENT

1.2.1 Problem Identification

During literature review, it is understandable that one of the equipment that should be used is the solarimeter. This is because; the solarimeter has the ability to measure the intensity of sunlight radiation. However, the usage of solarimeter will leads to the difficulties of converting the units as it will give the readings of irradiance, which is in W/m^2. The main concern is about to relate the units produced by the solarimeter in order to fit into the calculation given, which is to convert it into the Watt unit, which is the heat loss (Q loss). As a result, the solution for this problem is to multiply the irradiance with the area of the solar pond (W/m^2 X m^2) to obtain the Watt unit.

Second and finally, the problem faced regarding material selection for the project. Initially, fiber was chosen as the one of the materials for this experiment. However, due to the cost and time constraint, the material selections has been revised and fiber was omitted from the list. Hence, polyurethane and asphalt came in as the replacement. However, the list has to be revised again after further studies and consultation with technicians shown that asphalt is very difficult to handle in order to paste it onto the walls of the solar pond. This is because, asphalt is often found in hard solid form. In order to paste it to the walls, a person has to boil it up to at least 135 °C inside the microwave. However, although it should have been transformed into the liquid form after the boiling process; it did harden in a very fast manner. Hence, it easily transform itself again back into the solid form after enduring such a short period. As a result, the experiment using asphalt as insulator was aborted due to the consequences. Consequently, as the final resolution, cardboard paper has been chosen to replace asphalt. Although it is totally not a good insulator, but practically, with the cheap cost and easy to be handled; it is obvious that such a package is difficult to resist. Furthermore, it is predictable that during the analysis; it will produce results which differ a little bit from the first two experiment using polystyrene and polyurethane.

1.2.2 Significant of the Project

The project focuses on the insulators; hence it will determine the decrease of the number of heat loss from the solar pond. This can be determined from the heat absorbed from the conduction and radiation process. The more the heat absorbed from the sunlight, the more the heat is stored under the solar pond. One of the factors to increase the heat absorption is by using the insulation materials. This will decrease the heat loss to the surroundings.

Since the data obtained is quite large (on daily basis), it can only be analyzed by plotting the graphs of heat loss vs. time taken and analyze the pattern. From there, it will reflect the overall pattern and the maximum, minimum obtained for the heat loss.

However, in engineering, theoretical is one thing, while practicality is the most important ones. The theory might be right or wrong, based on the calculations done. However, if this project works out as been suggested, it will be a major step towards the development of the solar pond.

1.3 OBJECTIVE AND SCOPE OF STUDY

1.3.1 Objective

The objective of this project is to write modules that can be used in the future references. Based on the project proposal written by the originator of the topic, the main objective for this project is **to use different types of insulation materials and observe their effectiveness in reducing heat loss through the solar pond.**

Meanwhile, the project scopes are:

a. **Undertake literature into basics of non-convecting solar pond**
b. **Understand the effect of insulation on the performance of the solar pond.**
c. **Develop strategies on the best insulation to be used within allocated budget**
d. **Test hypothesis using several types of insulation.**

1.3.2 Scope of study

The scope of project is divided into three stages. The **first stage** is the literature review of all elements that are related to the project which more towards the planning of the project. All of the findings will be discussed with supervisors. In the beginning, the study focuses on the types of solar pond and their mechanism. This includes the identification of the materials selected for the whole project. This is to enhance the understanding on solar pond mechanism. After understanding the mechanism of the solar pond, the focus had been changed on the device used, which are the thermometer and the solarimeter. It is important to understand that types of data that will be obtained from the solarimeter and the thermometer and how to process them. This is because, the data gathered is quite much with 3 times of data taking per day for each level in the solar pond. Hence, the task of gathering the data is quite a big task.

From there, the hypothesis or formula achieved must be in relevance of the data gathered. From there, the best insulators will be determined theoretically. The next step is to do the preparation of the manual of the control experimental and project. This is because, preparation of the control experimental manual is essential to ensure that there is no hesitation when going into further stages. Hence, the first experiment conducted is by using the plain water into the bath tub without the brine. The data will be gathered using thermometer and solarimeter. The manual of the solar pond and its insulation will also be done to ensure that the solar pond will be able to be built within the range of time.

Then, during the second stages only the original experiment will be initiated. The first material selected is the polystyrene, followed by polyurethane and finally cardboard paper as the final material. In the end, the second control experiment was initiated. The experiment uses solar pond with brine; however without insulating material pasted on the walls of the pond. All the methods of calculation learned during the first stage will be applied during the second stage of the project.

Finally, discussion about the outcome of the experiment conducted will be revealed plus the recommendation of the most suitable material. Mainly, the final stages will be done after all the findings have been found theoretically and beneficial for the project.

CHAPTER 2

LITERATURE REVIEW AND THEORY

The issues regarding the usage of solar energy have been highly debatable since the past few years. This is because; although it is beneficial to the community; the cost of producing such a technology has rise tremendously as it is not widely used. However, with the usage of solar pond technology, it has changed the perception about the method of utilizing the solar energy; which before this restricted to the usage of solar panels only. Hence, various aspects of studies and researches should be conducted and pertinent with the advancement of the technology.

2.1 LITERATURE REVIEW

2.1.1 Definition of Solar Pond

Solar pond is large, shallow bodies of salt water that are arranged so that the temperature gradients are reversed from the normal; producing the hottest layer at the bottom of the ponds. This allows their use to collect and storage of solar energy, which may under ideal conditions be delivered at temperatures of 40 to 50 °C above ambient temperature. [2]

2.1.2 Solar Pond

Salinity-gradient solar technologies are a generic name given to the application of a salinity gradient in a body of water for the purpose of collecting and storing solar energy. The technology is also known as salinity-gradient solar pond. Solar pond usually generates a one to two meter salinity gradient and operates at moderately high temperatures.

In a solar pond, there are 3 layers which separated all the main components from each other. All 3 layers are separated from each other by the characteristics of the layers. There are:

1. The bottom layer is called the **Lower Convective Zone (LCZ),** which is supersaturated solution with the most concentrated salinity. Usually, the solar energy was collected at the bottom of the solar pond with temperature varies in between 45 °C to 90 °C. The solar pond also will inhibit the convection to the surroundings.

2. The middle layer is called the **non Convective Zone (NCZ),** where it has the salinity gradient and density gradient. The middle layer can be salty and usually it should not be salty, depending on the salinity of the pond. The main function of the Non - Convective Zone is to isolate heat from the Lower Convective Zone from any form of loss; meaning it will enable as barrier. The heat transfer rate also will be lowered from LCZ to UCZ.

3. The upper layer is called the **Upper Convective Zone**, which explained why it was called. At this point, it has less salt concentration. The main function of upper convective zone is to enable solar heat penetration to go downwards and not upwards as it should be. It also acts as a buffer zone to the second layer, which is the non convective zone.

Most people know that fluids such as water and air rise when heated. The salinity gradient stops this process when large quantities of salt are dissolved in the hot bottom layer of the body of water, making it too dense to rise to the surface and cool.

Generally, there are three main layers. The top layer is cold and has relatively little salt content. The bottom layer is hot up to 100°C (212°F) -- and is very salty. Separating these two layers is the important gradient zone. Here salt content increases with depth.

Water in the salinity gradient cannot rise because the water above it has less salt content and is therefore lighter. The water below it has a higher salt content and is heavier. Thus, the stable gradient zone suppresses convection and acts as a transparent insulator, permitting sunlight to be trapped in the hot bottom layer from which useful heat may be withdrawn or stored for later use.

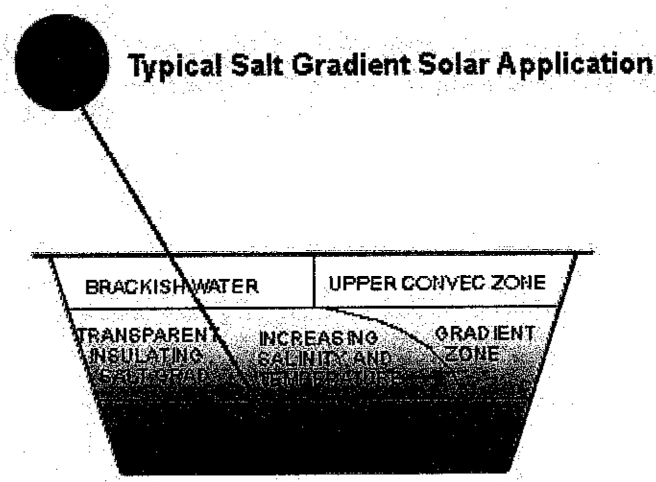

Figure 2.1: Solar Pond Diagram[9]

2.1.3 Solarimeter

The potential solar radiation (So) on a horizontal surface outside the earth atmosphere is calculated in Wm^{-2}. The solar radiation outside the earth is also known as solar constant. Although this varies slightly during the year, the accepted average value is 1373 Wm^{-2}. This value is constant for a surface normal to the sun's rays, as opposed to the horizontal exposure of the solarimeter. The potential solar radiation can be calculated using the formula:

$$So = 1373 \sin \phi$$

where ϕ is the elevation angle of the sun. Sin ϕ is computed from the formula:

$\sin \phi = \sin d + \sin l + \cos d \cos l \cos [15(t\text{-}to)]$

d = solar decimation angle

l = latitude of the site

t = clock time

to = time of solar hour

In order to measure the solar decimation angle of the device, it is advisable to approximate the sin d using a polynomial.

$\text{Sin d} = -0.37726 - 0.10564j + 1.2458\, j^2 - 0.757478\, j^3 + 0.13627\, j^4 - 0.0572\, j^5.$

j = Day of the year / 100.

As the data loggers, do not include the cosine function in the program. Hence, manipulating the cosine function into this function:

$\text{Cos}\, d = (1\text{-}\sin^2 d)^{1/2}$

The time of solar noon is given by:

To = 12 – Lc – Et (hr)

Lc = Longitude correction

Et = Equation of time

around 0.027 W/m.K, which can be considered as a good insulator in terms of groupings [1, 4 &5]. During the project, the polystyrene which has the thickness of 0.024 m is pasted around the solar pond as the insulator. The cost of buying the polystyrene is also cheap but to shape it according to the bath tub shape and size is a difficult task. In order to achieve that, the polystyrene has to be cut into small pieces before being pasted to the walls of the solar pond.

2.1.5 Polyurethane

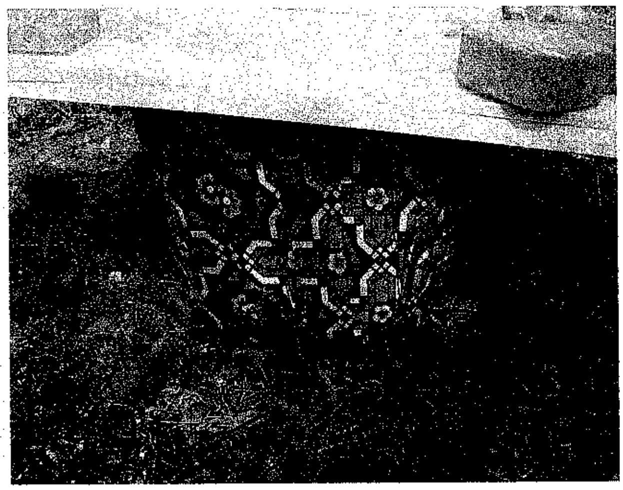

Figure 2.3: Polyurethane used for the second experiment

Polyurethane is formed when chemical compound composed of urea and ethanol was formed. Around 80% polyurethane used is in the form of foams; while the other 20% is used in the form of non-cellular products [3]. For this experiment, the polyurethane used is in the form of mats, which can be considered as **flexible** foam. There are few forms of polyurethane. These includes:

i. Flexible and Rigid Foams

It is the best known forms of Polyurethane. These types of foam are rarely seen except as a colourful stack of mats in department stores or Do It Yourself (DIY) centers. They are normally concealed by textile coverings, plasterboard, plastic panels and other outer layers.

ii. Non-Cellular Polyurethanes

It is usually visible, although not in the attractive manner. Users can actually see the non-cellular types in the form of leather goods; Polyurethane-coated parquet floors and last but not least in textiles containing Polyurethane fibres. This is based on its nature that enabling the materials to withstand the heat from the sun without conducting it.

It is normally known that this type of foam is concealed by textile coverings, plaster board and plastic panels. Polyurethane has a conductivity of 0.026 W/m.K, which is almost similar with polystyrene. Polyurethane is usually light, which is around 20 - 40 kg/m^3 in terms of density.

2.2 THEORY

2.2.1 Salt Concentration

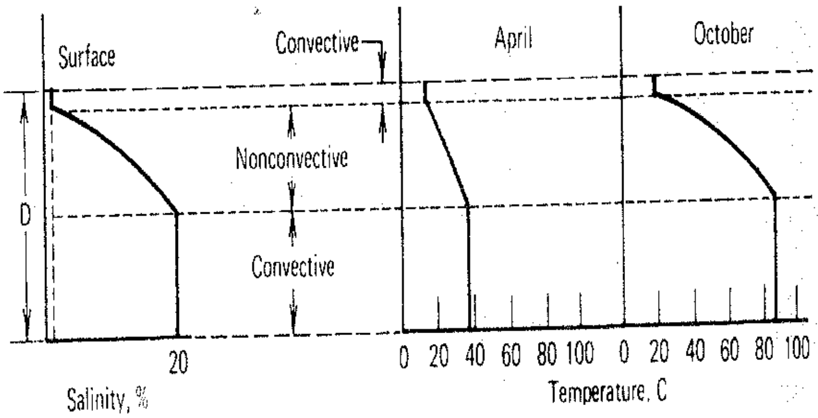

Figure 2.4: Salinity and temperature profiles for a salt gradient pond [2]

Figure 2.4 shows about the concentration and temperature distribution in the solar pond. From the diagram, we can see that the salinity of the pond is increasing from the top to the bottom of the pond. From figure 2.4 also, it is obvious that the salinity is divided into 3 zones, the upper convective zone, non-convective zone and lower convective zone. The concentration gradients that exist in the pond leads to the diffusion of salt from the top to the bottom of the pond; where the dilute layer should be [2]. In order to maintain the stability of the pond, at some stage of analysis, salt should be removed from the upper layer and added to the lower layer. The suggestion is that by injecting and removing process; enabling additional upward flow due to water addition and removal.

2.2.2 Heat Transfer Mechanism

Heat can be defined as the type of energy that can be transferred, hence increasing the kinetic energy of the molecular particles. There are two types of heat, the first one is called as the beneficial heat and the latter is called as heat loss. Beneficial heat is the heat that been produced; thus become useful for daily applications. Meanwhile, heat loss is the heat that had been produced but had been dissipated to the surrounding, thus becoming such a "waste". In order to become a good insulating material, it must be able to produce less heat loss as much as it could. [1 & 8]

2.2.2.1 Conduction

Conduction is a process where the transfer of the energy happens from the more energetic particle to the less energetic particles of a substance due to interactions between the particles [1]. The energy is related to the random translational motion, as well as the internal rotational and vibrational motions, of the molecules.

Usually, the higher temperatures are famously linked with higher molecular energies; hence when neighbouring molecules collided, a transfer of energy from the more energetic to the less energetic molecules must occur. This can be shown in the figure 2.5 below.

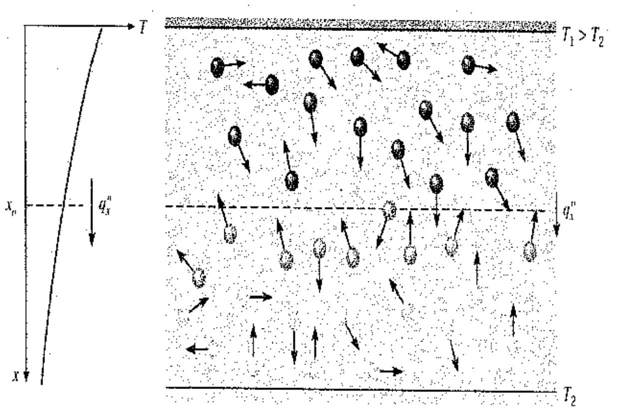

Figure 2.5: Association of Conduction Heat Transfer with Diffusion of Energy due to Molecular Activity [1]

From Figure 2.5, we can see that the hypothetical plane at x_o is constantly being crossed by molecules from above and below due to their random motion. However, the energy received by the upper half of the plane; tends to be more than their counterpart at the bottom half of the axis. This enabling the molecules to move faster with the extra energy received. The net transfer of energy by molecular motion can also be called as diffusion of energy.

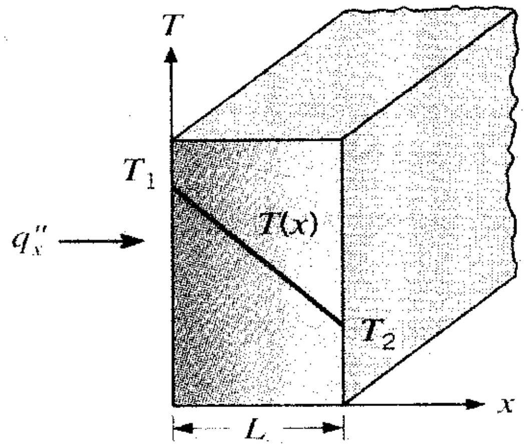

Figure 2.6: One dimensional conduction [1]

Using this concept, the related formula involved is the Fourier's Law. It has been stated that by using the formula, rate equation can be known.

$$q_x'' = -kdT/dx \qquad (2.1)$$

where:

q_x''	=	**The heat transfer rate in the x direction per unit area perpendicular to**
the		**direction of transfer, (W/m^2)**
k	=	**Thermal conductivity of the material, (W/m.K)**
dT	=	**Temperature differences (K)**
dx	=	**Path of the flux (m)**

2.2.2.2 Radiation

Thermal energy is usually emitted by matter which is at the finite temperature. Regardless of the form of the matter, radiation always occurs in the form of changes of electron configurations of the constituent atoms or molecules. Furthermore, radiation energy is always been supported by the electronic waves that occur. The most effective radiation transfer occurs in a vacuum condition. The condition of radiation is perfectly described by the Stefan-Boltzmann law which stated that:

$$\mathbf{E = \acute{\alpha} T_s^4} \qquad \mathbf{(2.2)}$$

Where,

E = **Emissive Power**

$\acute{\alpha}$ = **Stefan-Boltzmann Constant**

T_s = **Absolute Temperature (K) of the surface**

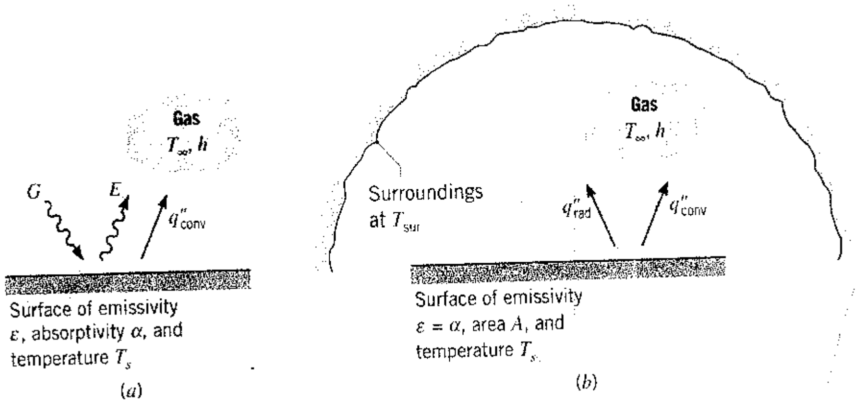

Figure 2.7: Radiation Exchange (a) At the surface;(b) Between a surface and large surroundings [1]

From figure 2.7, we can see that the radiation is emitted by the surface originates from the thermal energy of matter bounded by the surface.

2.2.3 Plane Walls Theory

The project has taken the plane wall approach, which is based on the plane wall of the insulators. This can be explained through the diagram below:

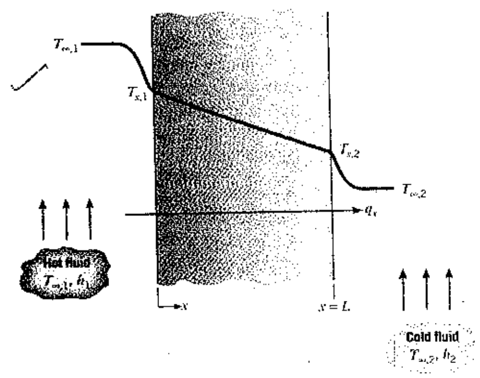

Figure 2.8: Diagram of plane walls and the temperature distribution [1]

Based on the conservation of energy formula, we will find out that

$$\mathbf{E_{in} + E_{out} = 0} \qquad \textbf{(2.3)}$$

From there, we will encounter that:

$$\textbf{q'' conduction} - \textbf{q'' convection} - \textbf{q'' radiation} = \mathbf{0} \qquad \textbf{(2.4)}$$

As this project is based on the non convecting solar pond, the effect of convection was neglected.

From there, equation 2.4 can be developed until it becomes:

$$(\acute{\alpha}\ G)sun - \frac{k\ (T_{s,3} - T_{\infty,3})}{L} - \acute{\alpha}\acute{\varepsilon}\ (T_{s,3}{}^{4} - T\infty^{4}) \qquad (2.5)$$

ά = **Percentage of heat absorbed**

G = **Radiation measured from the solarimeter**

T∞ = **Surrounding temperature**

k = **Conductivity of the materials selected**

$T_{s,3}$ = **The surrounding temperature at the bath tub.**

$T_{\infty,3}$ = **Temperature of the outer walls of the solar pond**

Based on this value, we will be able to find the percentages of heat absorbed to the upper layer of the solar pond. Meanwhile, the remaining percentages are the percentages of heat transmitted to the solar pond. Hence, the heat loss can be calculated from this formula:

$$Q\ loss = Q\ cond + Q\ rad$$

$$= \frac{k\ A(T_{s,3} - T_{\infty,3})}{L} + \acute{\alpha}\acute{\varepsilon}\ A(T_{s,3}{}^{4} - T\infty^{4}) \qquad (2.6)$$

The **less heat loss encountered**, the better the insulator it will be.

CHAPTER 3

METHODOLOGY

In order to proceed with the project, a clear and concise methodology is important to ensure that the flow of the project would be smooth and organized. There are few steps taken to ensure that the experiment will be handled successfully for the time period being. Below is the flow chart of the project methodology.

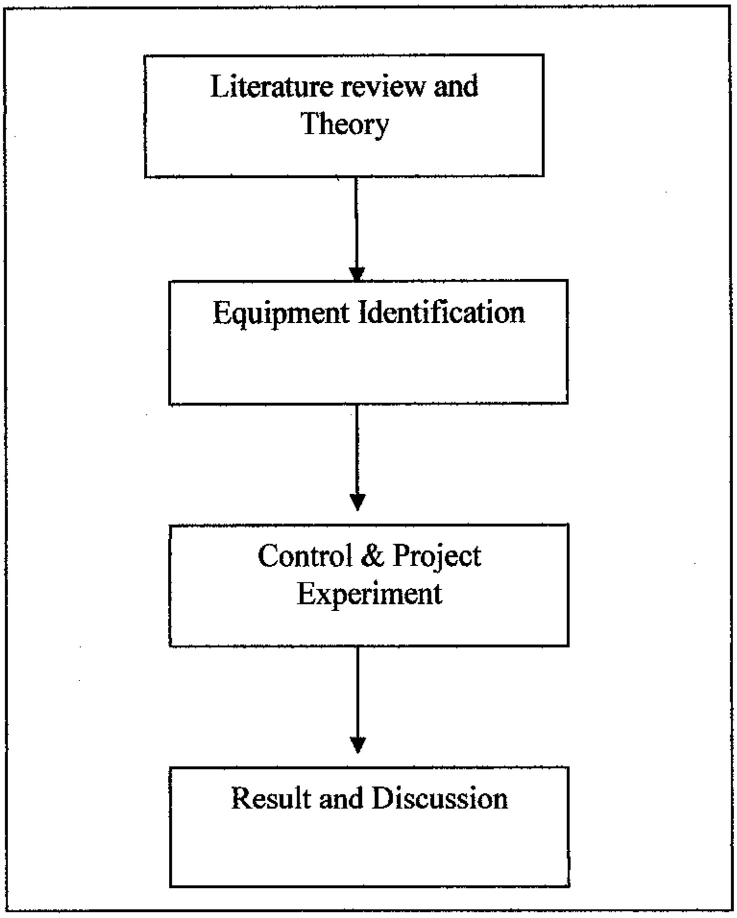

Figure 3.1: Flowchart of project methodology

3.1 LITERATURE REVIEW AND THEORY

In order to understand the project, literature review is vital in undermining the objectives of the project. This is because, from literature review, the whole concept of the project will be explained and thoroughly understood. Hence, from the reference guide such as books, journals and websites; lots of information can be gathered.

For the project, the most important factor that had been considered was selecting the most suitable insulating materials for the project. There are lots of insulating materials stated in the reference book; but to select it according to the budget and handling factor is quite difficult. Hence, the literature did help in doing the selection, besides consulting the experts.

Apart from that, for this project, the focuses of the literature review were on the making and maintaining the solar pond. This is to ensure that the solar pond made will not fail during the occasion. The salinity calculation was used to ensure that the solar pond will respond to the needs. Hence, the solar pond should have performed during the time period of the project.

Finally, the calculation method of heat loss is also founded from the literature review. This is because, from the heat transfer book, there are tons of heat transfer mechanism calculation methods written for the benefits of users. Since this project did not consider the convection effect, it only focuses on the calculation of conduction and radiation only.

3.2 EQUIPMENT IDENTIFICATION

Before proceeding with the experiment, it is important to know the equipment or apparatus used for this project. There are:

3.2.1 Solarimeter / Photo Radiometer

Solarimeter is used to measure the direct and diffuse solar radiations. For this project, one solarimeter will be place on the open ground to get the accurate reading from the solar radiation.

3.2.2 Thermometer

Thermometer is used for data gathering regarding the temperature of the slat solution with their insulators. The thermometer will measure the temperature of the inner wall, outer wall and the surrounding temperature. For this project, 2 types of thermometer will be used; the first is the digital thermometer to measure the temperature ambient of the surrounding while the other is the alcohol thermometer (manual) to measure the temperature of the solar pond.

3.2.3 Bath Tub

Bath tub is used to reflect the true condition of the solar pond system, only it is on the model scale, which is much smaller than the original size.

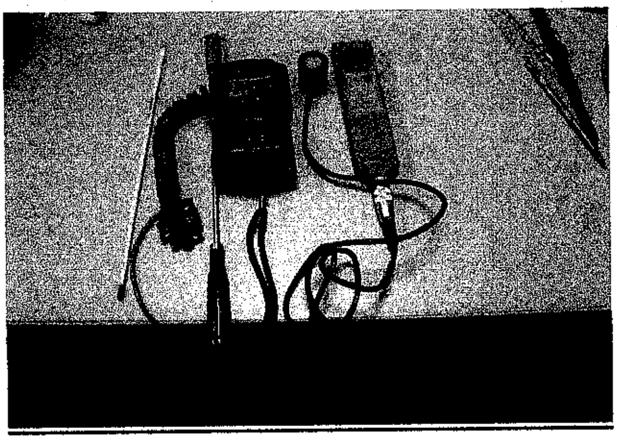

Figure 3.2: Equipment used for the experiment: From left: alcohol thermometer, digital thermometer and solarimeter

3.3 CONTROL AND PROJECT EXPERIMENT

In order to complete the experiment, a systematic procedure has been revised to ensure that there will be no difficulties while conducting the project. Below is the instruction of experimental procedure for this project:

3.4 EXPERIMENTAL PROCEDURE

3.4.1 Set up of Control Experiment Procedure

3.4.2 Objective

To find the temperature and heat loss of the insulating materials

3.4.3 Materials

1. 1 bath tub
2. 1 Perspex cover
3. Plain / tap water
4. Spray
5. Pail

6. Marker
7. Solarimeter
8. Thermometer
9. Measurement tape

3.4.4 Procedure

1. The bath tub was put on a free confined space as the main location. This is to ensure that the sunlight received will be the direct ones.
2. The bath tub was ensured to be clean from foreign matter and dust.
3. The base of the bath tub was sprayed by using black spray to ensure that when it was left on the sunlight, maximum amount of heat will be transferred.
4. The measurement tape was used to measure the level from the bottom of the pond to the upper parts of the pond. Each one inch was marked by using the marker until the top of the bath tub.
5. The markings was set at 0 at the bottom of the bath tub (the Lower Convective Zone)
6. The salt was put into the bath tub packets by packets. One packet usually consists of 2 kg of salt. Then, by using an empty and clean paint tin, the plain water was transferred into the bath tub by ratio needed before being left under the sunlight for a day.
7. The next day, the mixture of plain water and salt should have form the brine. Hence, plain water was poured into the bath tub until it reaches the markings at the top of the bath tub.
8. Then, the bath tub was closed at the top by using Perspex.
9. The bath tub was left for few hours to receive the sunlight
10. At the moment, the constant time of the data was set to take the readings, thrice a day (once in the afternoon, peak hours and later in the evening)
11. The ambient temperature, T_a and the solar radiation were measured simultaneously using digital thermometer and the solarimeter.

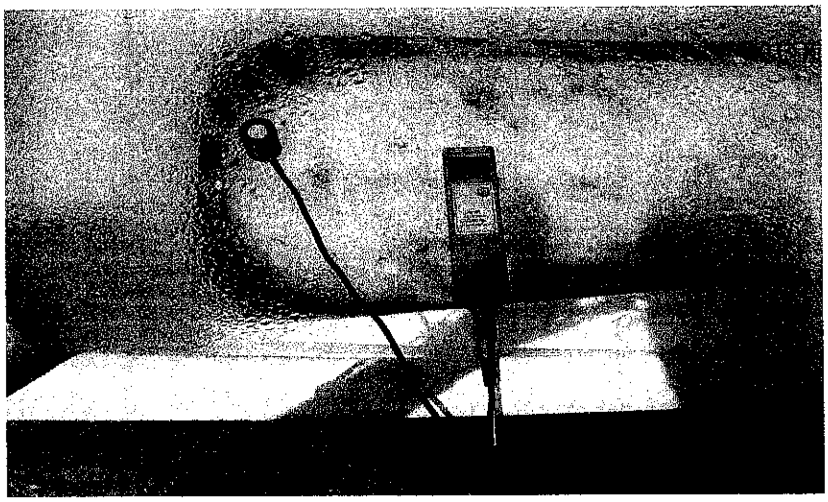

Figure 3.3: Solar Radiation readings taken from the Solarimeter

12. The temperature of each level in the solar pond will also be measured, starting from 0” until the top of the bath tub (5”).

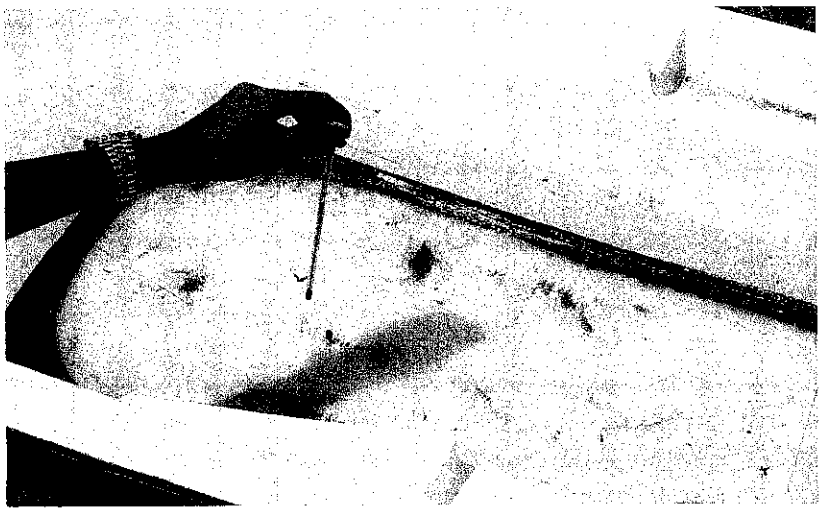

Figure 3.4: Solar Pond temperature readings was taken manually

13. The average temperature at solar pond is measured by:

$$T_{avg} = \frac{T0 + T1}{2}$$

(Note that the average temperature is based on the **lower convective zone,** which is the first 2 inches from the bottom of the bath tub. This is because, at solar pond condition, which is when the brine is added, the first three inches is the content of the bath tub).

14. The temperature on the inner and the outer walls of the bath tub will also be taken.

Figure 3.5 Data taking of Surface Temperature of outer walls of Solar Pond

15. The data collected will be tabulated on the graphs.
16. The solarimeter is used to measure the contents of radiation of the sunlight received on that time.

CHAPTER 4

RESULT AND DISCUSSION

4.1 FIRST EXPERIMENT

The first experiment was done for 2 weeks, from 5/10/2003 to 17/10/2003 using plain water. The main objective for this experiment is to see the pattern of water in a confined space without any outer factor or circumstances. Furthermore, it will encourage the study about equipment usage and applied the calculation method that has been analyzed before any corrections would have done based on the guidance of the experts. At this stage, the solar pond is called bath tub because there is no brine involved here; hence the terms of solar pond seem not appropriate.

The equipment used for this experiment is the solarimeter, digital thermometer and alcohol thermometer. For this experiment, the decision to use the alcohol thermometer is due to the advice of the technicians that the digital thermometer; which has probe attached to it might be rusty after frequent usage although during the testing conducted by him, proved that the results could be obtained.

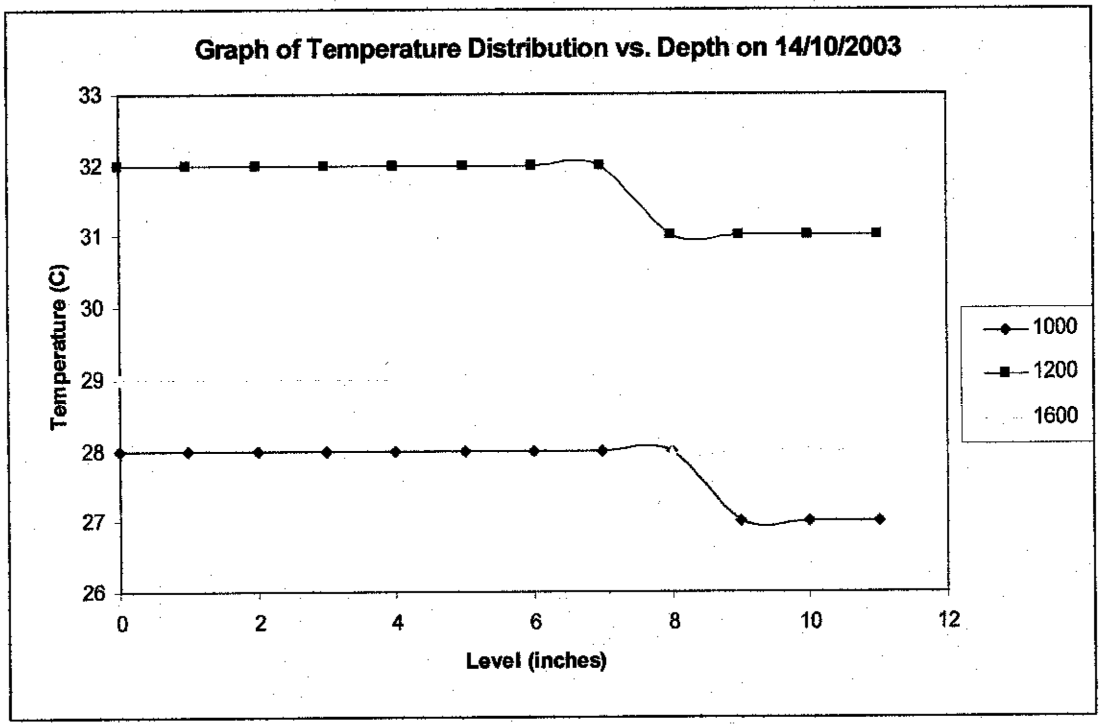

Figure 4.1: Graph of temperature distribution vs. Depth on 14/10/2003

During the control experiment, the results obtained were affected a bit by the frequency of raining that occurs during daytime. Luckily, most of the showers occur after 4 p.m., which is the optimum period for data checking. Hence, the results obtained did not affect too much with the weather changing.

The nighttime results were taken for the first few days, however after realizing that the solar radiation measured was too small for measurement (in the range of 0.002 to 0.012 W/m^2) hence it was neglected as for the calculation of **Q transmitted** only it did not reflect too much on the difference of values **(refer to table G1 in Appendix G)**. This trend will continue for all the experiment with no data taking on the night time.

Based on the control experiment done, it is found out that the temperature distribution at the bath tub without the brine shows that there is not much difference in temperature distribution from the bottom of the bath tub (0 inches) to the top of the bath tub (11 inches). The temperature distribution from the bottom to the top of the bath tub only varies in about 1°C to 2°C **(refer to Appendix H)**.

Meanwhile, from **figure 4.1**, the surface temperature of the bath tub is same with the ambient temperature. Normally, the maximum temperature occurs during the time period where the sunlight produces the most solar radiation; which is in between 1500 to 1600 hours (3.00p.m. to 4.00 p.m.). However, from figure 4.1, we can see the drop of temperature from the afternoon readings (1210 hours) to the evening reading (1547 hours). This is because the weather was changing from sunny to cloudy with a prospect of raining.

All the readings for the level temperature were taken at the inner walls of the bath tub to ensure that any changes on temperature based on the plane walls conduction process will be detected.

Finally, in order to complete the guidelines for calculations, the Q absorbed was calculated based on the solarimeter readings. From the readings, we can know the heat absorbed by the Perspex by calculating the surface area of the Perspex (only parts which include also the bath tub). This is because, the unit involve is W/m^2 when times with m^2 will result in W in unit. From there, the calculation of heat transmitted was done to find how much heat was transmitted. Hence, the control experiment was giving such a good idea in how to proceed with the next stage.

4.2 SECOND EXPERIMENT: POLYSTYRENE

The second experiment was done from **24/10/2003 to 26/10/2003 (first phase)** before continuing from **5/1/2004 to 4/2/2004 (second phase).** For this experiment, a cost of RM 15.00 is used to buy 3 stacks of polystyrene.

4.2.1 First Phase (24/10/2003 to 26/10/2003)

During the **first phase**, around 10 liters of tap water was added with 2.1 kg of salt; producing brine. The based of the measurement is by taking 2 full tin of water from paint tin; where the volume is 5 liters per tin. However, before using the pail as container; all the paint remnants from the container must be removed by using turpentine to ensure that the tin is fully clean.

The brine was exposed to the sunlight before pouring the tap water to ensure that salty concentration will precipitates on the time needed. The salinity was calculated based on the formula of:

ppt = 10^3 mg/L = g/L (Eq 4.1)

Hence in this case; the salinity is

Salinity = 2.1 X 10^3 g / 10 liters = 210.00 parts per trillion (ppt)

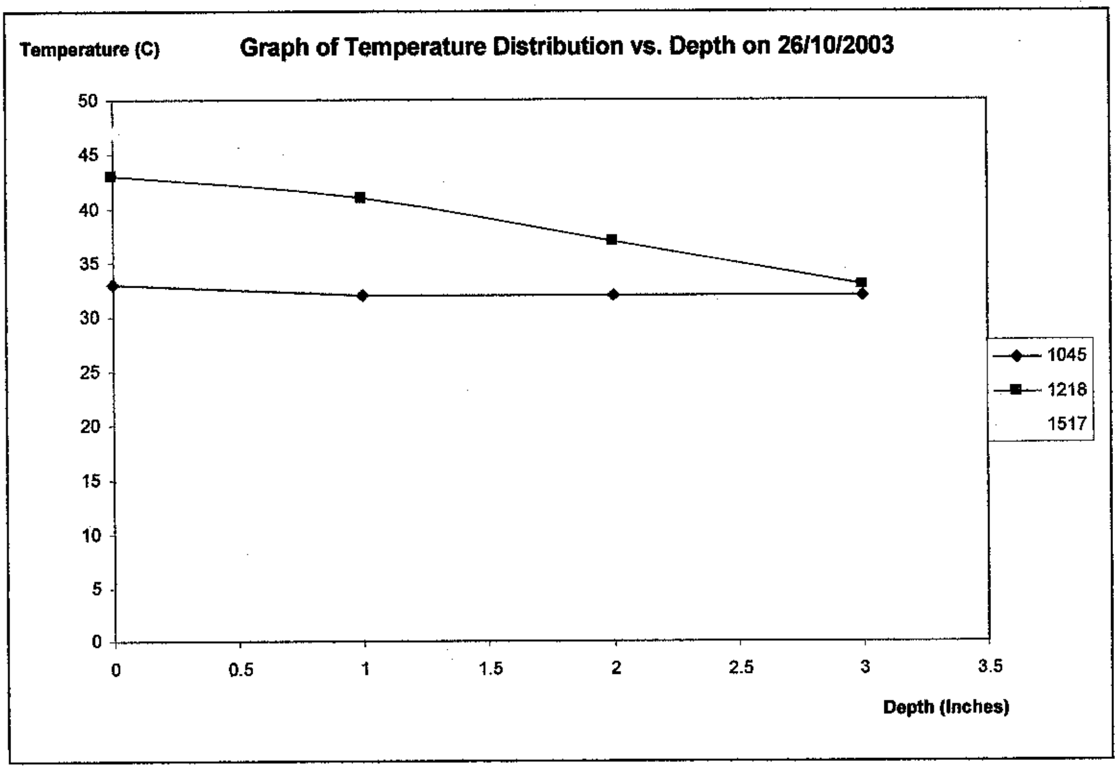

Figure 4.2: Graph of Temperature Distribution vs. Depth on 26/10/2003

Based on **figure 4.2**, we can see the temperature distribution of the solar pond is based on the salinity gradient; where it achieved its maximum during the final readings taken on 1517. It is also obvious that the temperature of the solar pond achieved its highest at the lowest part of the pond; which is at 0 inches.

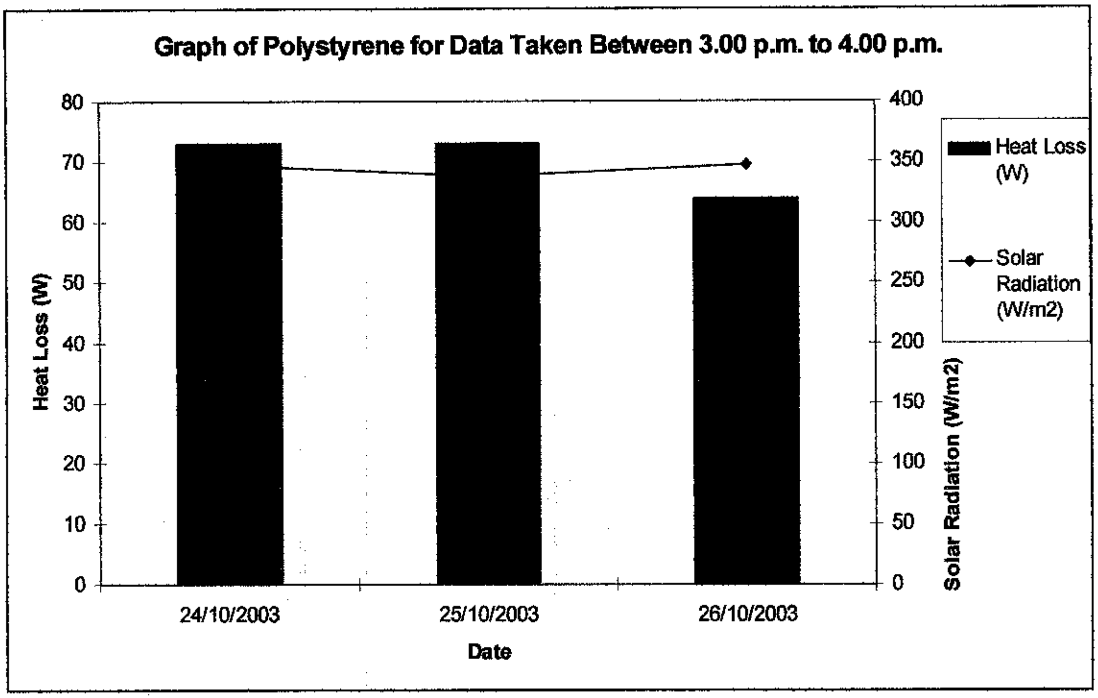

Figure 4.3: Graph of Polystyrene for Data Taken Between 3.00 p.m. to 4.00 p.m.

From **figure 4.3**, the heat loss of the solar pond can be determined. From the measurement, the polystyrene has thickness of 0.024 m. The value of heat loss can be determined from calculations of heat conduction and radiation. The sample of calculations is shown in **Appendix B.** From the experiment, it is obvious that the more the difference in temperature occurs, the more heat loss detected **(Please refer to Appendix I)**. From the calculation, the most heat losses are on the 24/10/2003 and 26/10/2003 (the range after 1500 hours or 3.00 p.m.); after calculated, the heat loss is around 73.00 W in figure 4.3. The depth of the solar pond at the moment was only 3 inches; with markings from 0 to 3 inches. So, the experiment was done successfully during this period alas less interference from the weather changing especially rains. For this experiment also, the assumption that only the 0 inches can be considered as the lower convective zone as the value of temperature gradient rise so rapidly.

Meanwhile, the pattern of the solar radiation reading is shown in by the line graph. Usually, when taking the readings, one has to ensure that there will be no deflection in transmitting from the sunlight to the solarimeter. This will ensure the accuracy of the readings taken. In other words, the readings should be taken on the open grounds as there will be no obstructing object such as tree or building roof to hinder the direct sunlight radiation. Such a place where the appropriate readings should be taken is on the project site itself. This is because; the project site is situated on the open grounds; where also the solar ponds should be situated.

In order to get the true picture of the real solar radiation readings, it is advisable to wait for a while to get the thorough sunlight radiation. This is because, on a few occasions, when the time the readings were taken, suddenly the sunlight radiation readings was not as expected due to the obstruction of the cloud; making it cloudy temporarily. Hence, at that time, it is better for the readings to be postponed until the sunlight radiation become fully again. Unless the forecast weather shows cloudy with signs of rain, it is better to wait until the true conditions were revealed.

The readings were taken on the Perspex to resemble on the conditions direct sunlight condition emitted through the Perspex. The first step to do during reading takings is press the **on** button on the digital analyzer. Then, the probe must be placed with the surface of white facing on the probe must be directly face the sunlight radiation. This to ensure that direct sunlight radiation will be emitted on the surface of the probe. After certain period the readings should be stabilized. Then only the readings should be taken. On the surface of the perspex; there are lots of water droplets due to the evaporation process of the water from solar pond to the surroundings. It is obvious that due to the higher temperature inside the solar pond, it tends to attract the molecules of water to become evaporate from the effect of the solar radiation. All the readings were taken and graphs are plotted.

From experiment, the pattern of the solar radiation readings is usually increasing during the peak hours time (from 1500 to 1600 hours).Usually, the rise of temperature has been detected from 1200 hours until the peak hours time is about to be constant; unless there are extreme cases such as cloudy or the temperature is getting hotter. The reasoning is because, during that period, the sun shine directly on the top of solar pond; unlike early morning, where the sun still have time to rise up. The maximum reading was taken on 24/10/2003 with readings of 347.94 W/m^2.

4.2.2 Second Phase (5/1/2004 to 4/2/2004)

For this experiment, the data was taken approximately a month from 5/1/2004 to 4/2/2004. The temperature was taken 3 times a day, but different from the first phase. Unlike the first phase, the second phase readings were taken beginning from the afternoon, followed by during the peak hours (from 1500 to 1600 hours) and finally in the evening; around 1615 hours to 1800 hours (4.15 p.m. to 6.00 p.m.).

In order to ensure that all the surface of the polystyrene make contact with the walls of the solar pond, the polystyrene has been cut into many small parts. This is to ensure that the continuity and accuracy of the pond will be without doubt.

During the first week (1/1/2004), around 10 liters of water was added with 12 kg of salt, giving a salinity of **1200 ppt.** The brine was added to the pond and left it for a day before adding water on the next day to complete 5 inches of solar pond. Then, the readings were taken starting on the following week; which is from 5/1/2004 to 9/1/2004. During the holidays, additional of 12 kg of salt was added; making the total salt added into the pond was 24 kg assuming the mass of the salt will not evaporate. At the same time, additional 50 liters of water was added to make the total volume of the pond now is 60 liters of water; hence the salinity should be around 400 ppt. The brine was left for one day before being measured, before adding the level of water to fulfill 11 inches of depth of the solar pond. Unfortunately, the solar pond did not respond as expected. The temperature did not increase as expected; hence no salinity gradient. Initially, it was suggested that the pond needed more time to stabilize itself before performing its natural ability to store some heat and energy. However, after 3 days, the situation remains the same. As a resolution, all the brine and water were removed and the original configuration was restored with a pond with 5 inches depth. The data taking were continued on 19/1/2004 until 4/2/2004.

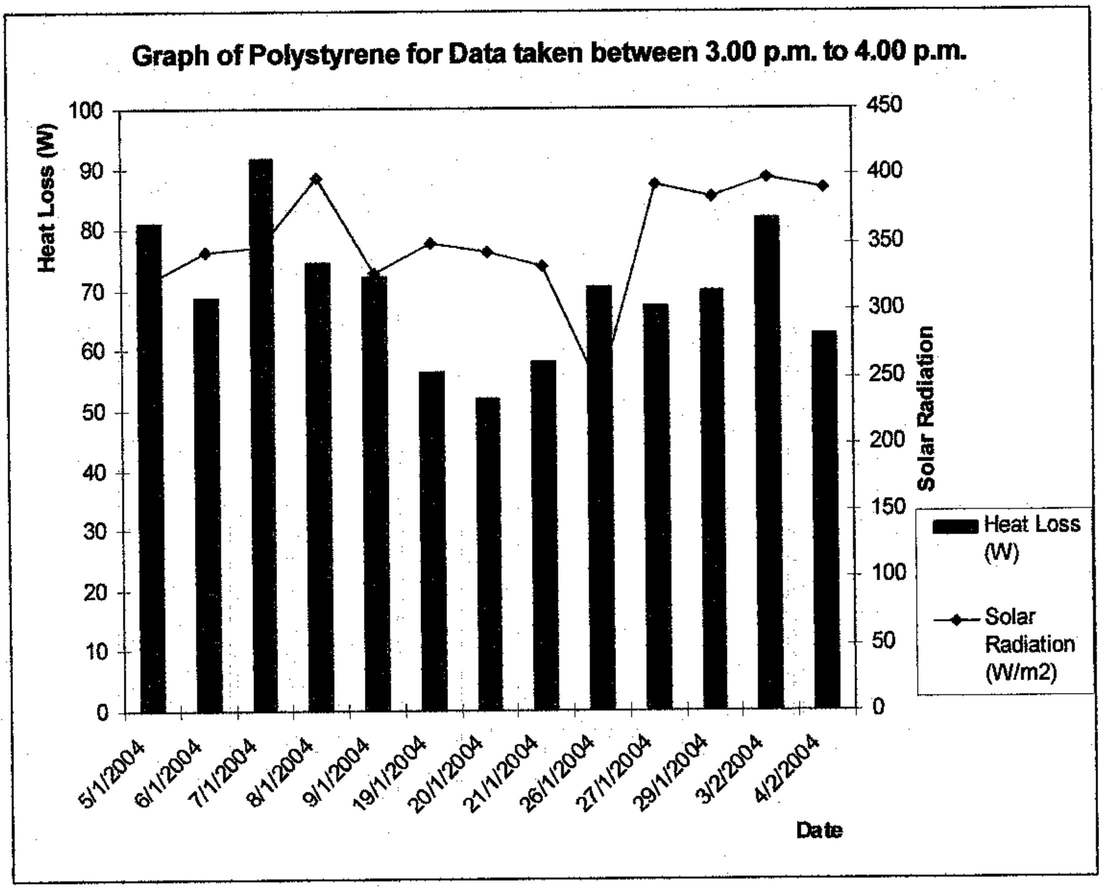

Figure 4.4: Graph of Polystyrene for Data Taken Between 3.00 p.m. to 4.00 p.m.

As predicted, the temperature tends to decrease when it is measured from the bottom to the top of the solar pond. This is because, it complies with the rules of salinity gradient, and where at the bottom (LCZ) has the most saturated salty concentration. At the top, it has only small portion of salty concentration due to the evaporation process of the water, which brings along the bottom salty concentrations to the top to stabilize the pond.

From the graph and data plotted, the temperature distribution of the pond always at it's lowest in the morning (around 11.00 a.m. to 12.00 p.m.). However, it reaches its maximum always peak around 3.00 p.m. to 4.00 p.m. This is because, at the morning, the heat transmitted from the sun is not yet been fully absorbed by the solar pond, thus the solar pond is not fully utilized. However, during the peak time (3.00 p.m. to 4.00 p.m.), the pond reaches its maximum reading as it utilizes the sun weather constantly due to the heat transmitted by the sun is much higher from the afternoon until around 3.00 p.m. to 4 p.m. This factor is added more by the maximum capability of the sun to produce the largest solar radiation at that part of the day (3.00 p.m. to 4 p.m.).

The Lower Convective Zone (LCZ) is detected from the data obtained. From the data, it is obvious that the temperature decreases when it is measured at each level (one inch for every level). However, for the first 2 inches (level 0 and 1) measured from the bottom of the pond, the difference is not too much as from the other remaining levels of the pond. Thus, the temperature of these two levels can be considered as the temperature of the Lower Convective Zone and their average is calculated.

From **figure 4.4**, the heat loss and solar radiation graphs were plotted during peak hours. From the graphs, the pattern of the heat losses can be obtained. The heat losses are calculated based on the temperature difference. The more temperature difference between the solar pond (LCZ average temperature only), polystyrene and ambient temperature, and the more heat losses will be obtained. From the heat loss, it will indicate on how efficient the insulator is. This is because; the less heat loss produced by the insulator especially during the peak hours (3.00 p.m. to 4.00 p.m.) the more efficient is the insulator should be.

Based on the data taken, the average heat loss calculated (for peak hours) is around 70.00 W; assuming all the peak hours is around 1500 to 1600 hours. Meanwhile, the highest reading was taken on 7/1/2004 with a reading of 91.00 W.

4.3 THIRD EXPERIMENT: POLYURETHANE

In order to proceed for the third experiment, the first step is to removed all the polystyrene on the solar pond and replace it with the polyurethane. The approach of cutting the polyurethane into small pieces; like during the polystyrene experiment indicates that it is much easier to do parts by parts pasting due to the unsymmetrical and unconventional shape of the solar pond. A small sample was taken to the lab, and its thickness was measured, which is around 5×10^{-3}m. The cost for this experiment is estimated around RM 35.00, where it is the most expensive insulating materials used for this project.

After that, the old brine was removed and new brine, consisting of 12 kg of salt and 10 liters of water was added to the solar pond. The salinity of the solar pond is 1200 ppt after manipulating the salinity calculation.

From the data gathered, it is found that the temperature of the polyurethane at the outer walls of the solar pond, is usually 3°C to 7°C higher than the ambient temperature. However, it is no surprise that the surface temperature of the polyurethane become higher due to the effectiveness of the solar pond itself; even after the insulation process.

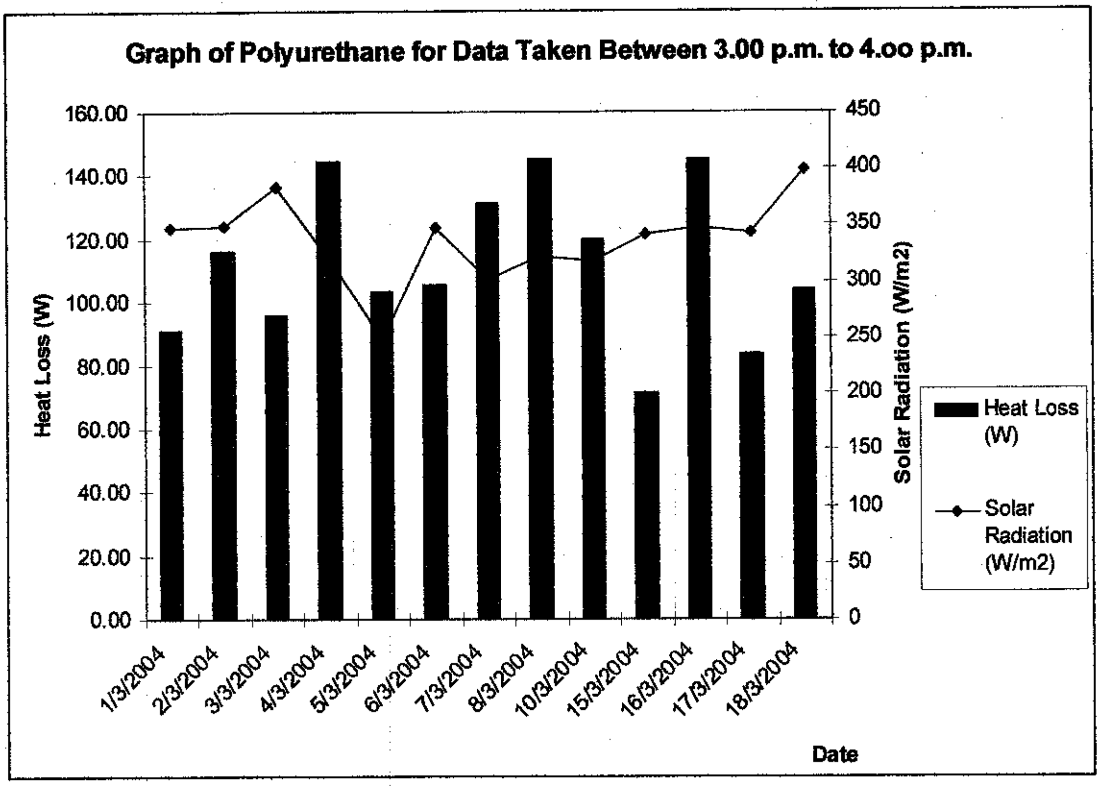

Figure 4.5: Graph of Polyurethane Data Taken Between 3.00 p.m. to 4.00 p.m.

The highest average temperature taken based on the Lower Convective Zone was on 4/3/2004 with the average temperature of 50°C. This might be due to the rise of temperature when the readings was taken on that day, where during the first reading; which was on 1211 Hours (12.11 p.m.), the temperature was 35°C with solar radiation readings was 398.64 W/m^2. Hence, most of the solar energy was transferred into the solar pond and its effect can be seen during the second reading; which is on 1538 Hours (3.38 p.m.); although the readings of the solar radiation at that moment was as not as high as the previous readings. The reading at that moment was around 318.38 W/m^2. The graph of the solarimeter readings can be seen in **figure 4.5.**

The heat loss data was calculated and the graphs were tabulated. The pattern of the heat loss is similar from one experiment to the other. However, the range of the heat loss this time is much higher, exceeding 100W during the peak hours. The highest reading taken was on 8/3/2004; 1510 hours with a heat loss of 145.11 W.

This higher value of heat loss was due to the thickness of the polyurethane itself, as the polyurethane thermal conductivity is lower to the thermal conductivity of the polystyrene. The thermal conductivity of polyurethane is 0.026 W/m.K, while the thermal conductivity of polystyrene is 0.027 W/m.K. However, their thickness was a lot in difference with polystyrene is having a thickness of 0.24m while polyurethane is having a thickness of 5×10^{-3} m.

All the readings were taken 3 times per day with the exception on 11/3/2004 and 12/4/2004, the data was taken only once due to the rain in the evening. Hence the graph plotted on that dates looks like a simple dot.

4.4 FOURTH EXPERIMENT: CARDBOARD PAPER

The experiment was conducted from 12/4/2004 to 17/4/2004, using card board paper as a material. Although the cardboard paper is not a really good insulator with a thermal conductivity of 0.159 W/m.K, it is a good try in order to see the pattern of the heat loss graph being initiated during the calculation.

Like the previous experiment, all the previous steps were taken into the account. In order not to risk during the experiment, the brine was removed and the new brines were added according to the previous measurement (12 kg of salt and 10 liters of water to produce brine). Then, the cardboard paper was cut into small pieces before being pasted on the walls of the solar pond. The thickness of the cardboard paper is around 1×10^{-3}m. Meanwhile, the cost for each cardboard paper is a mere of RM 2.50 per paper. 2 cardboard papers are used for this experiment.

Like the previous experiment, the readings of the solar radiation and temperature were measured to determine the peak hours and readings. It is obvious that the readings of the solar radiation and the temperature were highest during the peak hours; which is around

1500 hours to 1600 hours (3.00 p.m. to 4.00 p.m.). The highest reading for the average temperature of the solar pond was recorded on 17/4/2004; 1534 Hours, around 47.0°C.

During that week, the weather forecast seems unpredictable; with weather changed from sunny to cloudy. In the evening, especially after 1630 hours (4.30 p.m.), rain always occurs heavily. Hence, in order not to conflict or lack of data, the final readings for each day were taken between 1600 Hours and 1630 Hours.

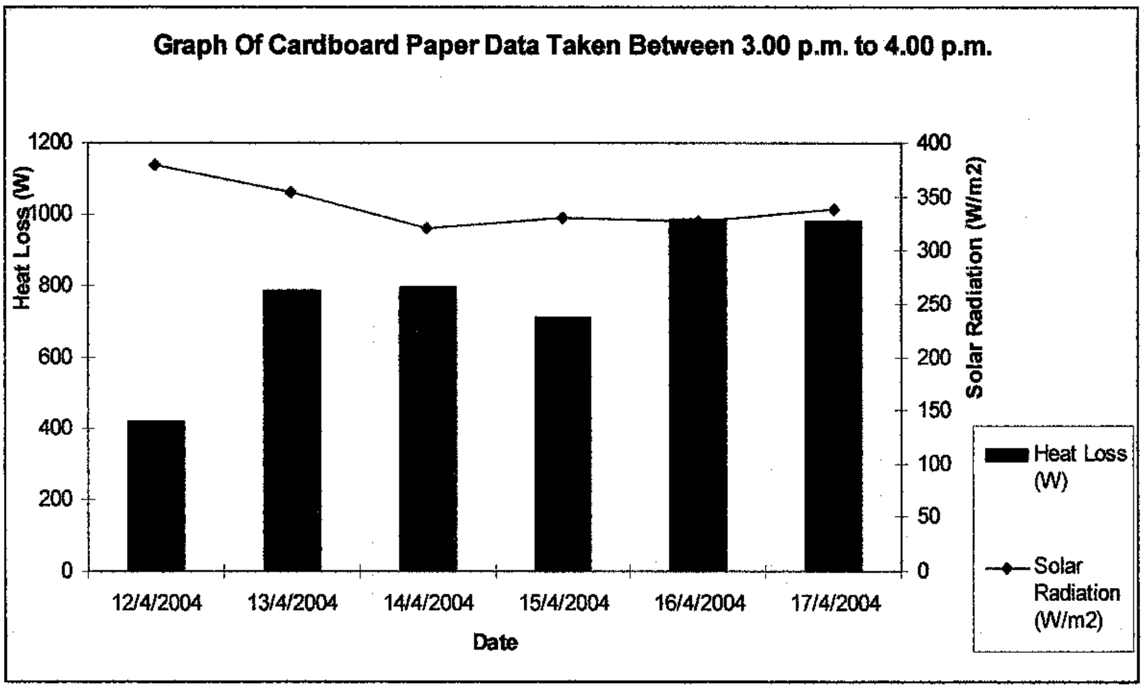

Figure 4.6: Graph of Cardboard Paper Data Taken Between 3.00 p.m. to 4.00 p.m.

From **figure 4.6**, the heat loss graph plotted was extreme. The peak of heat loss was calculated on 16/4/2004, the data taken on 1537 hours, which is around 986.17 W. From the graph, there are two assumptions that can be made. The first assumption, the heat loss was extreme as cardboard paper is not a good insulator; hence; producing the worst result of heat loss when compared with polystyrene and polyurethane. This is because; the thermal conductivity of the cardboard paper is around 0.190 W/m.K; whilst polystyrene and polyurethane has the thermal conductivity of 0.027 W/m.K and 0.026 W/m.K. The second assumption is that there might be some deviations in the heat loss calculation, or in other words errors. Although the formula used is correct, it might only suit on certain conditions such as the material used should be a good insulator and the calculation of the heat loss should depends on the thickness of the material itself.

4.5 FIFTH EXPERIMENT: CONTROL EXPERIMENT WITH BRINE

This is the final experiment of the project. It was done in 3 days, from 20/4/2004 to 22/4/2004. The purpose of this experiment is to study the effect of the temperature on the walls of the normal solar pond without insulator. However, the heat loss was not calculated in this experiment. This is because, the unsymmetrical shape of the bath tub made it very difficult to measure its thickness. Furthermore, all the calculation of heat loss of the previous experiment was conducted based on the materials thickness, excluding the bath tub thickness.

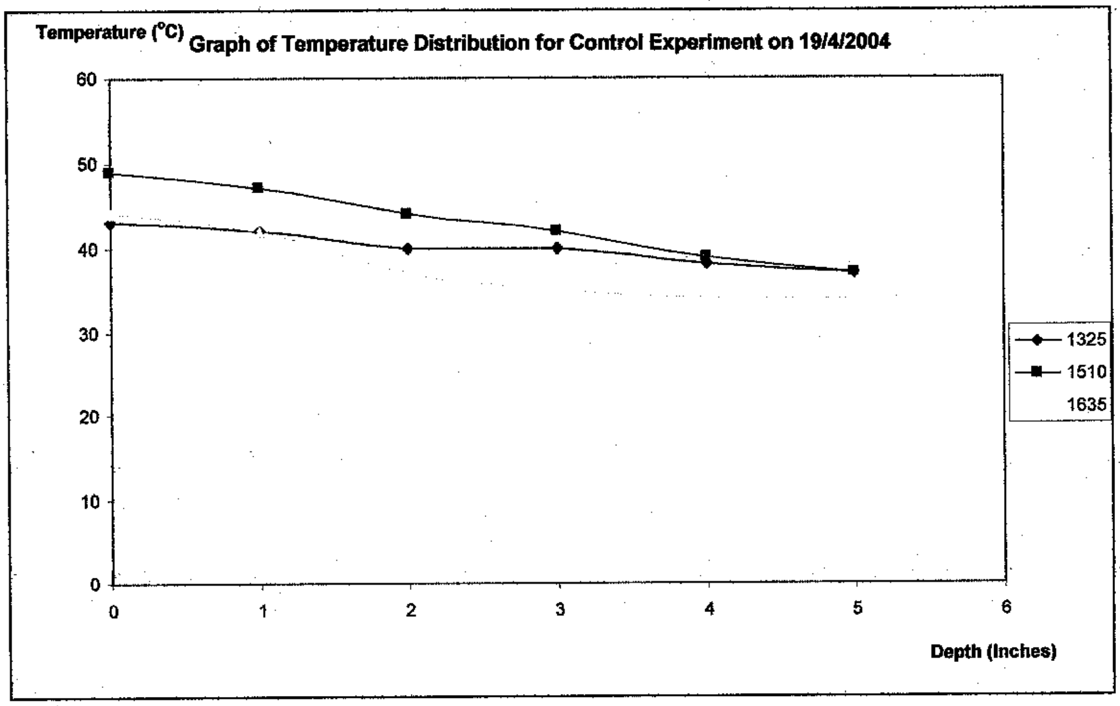

Figure 4.7: Graph of Temperature Distribution for Control Experiment on 19/4/2004

From **figure 4.7**, the temperature of the solar pond did obey the pattern of the 3 zones involve which is the Upper Convective Zone (UCZ), Non Convective Zone (NCZ) and Lower Convective Zone (LCZ). Hence, it is still believe that the salinity of the solar pond still maintain to be almost same when fourth experiment was conducted, since there was no changes made at all, apart from removing the cardboard paper from the walls of the solar pond. The peak temperature measured during the peak hours, which is between 1500 to 1600 hours. Hence, based on the graph, it really reflected the situation. From the data gathering also, it is also obvious that the temperature at the walls of the solar pond, where the heat loss calculation started, is almost similar with the result produced when conducting the fourth experiment. This is due to the lack of insulation, thus the temperature at the walls rise higher than during conducting the polystyrene and polyurethane experiment.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This project is still an experiment in developing the solar pond, based on the model concept. By taking bath tub and reserved it to become the control experiment is a good example to ensure that the pattern of the actual solar pond can be achieved without risking too much. However, based on the outcome of any of the project including this project, it is a must that the organizing panel makes one step closer by initiating the actual solar pond.

There are several parameters that should be taken into consideration during this project. The first criterion is to maintain the salinity of this experiment. Since this experiment is not totally about solar pond; but more towards the insulating materials, it is better not to risk with the level of salinity as it will cost time. This is because; any mixture of water and brine must be left for at least 1 day to ensure that it will mix better before adding any tap water. Any delay caused by adding the mixture by mistake will only postpone the project flow.

All the insulating materials are pasted on the walls of the solar pond before any data gathering could be done. Due to the unsymmetrical shape of the bath tub, all the insulating materials has been cut into small pieces before being pasted to ensure that it will have maximum contact with the solar pond.

The solarimeter is used to measure the sunlight radiation or intensity. The units for this the sunlight radiation is Watt per meter square (W/m^2). Hence, the calculation of heat loss has been adapted to suit the final unit which is in Watt (W). The pattern of the solar radiation is usually similar, where it will reaches its maximum during its peak hours

(1500 hours to 1600 hours). However, in some cases, where the current weather is cloudy, the solar radiation will not reach its maximum during the peak hours.

From the heat loss data and graph drawn, it is apparent that the heat loss is also reaches its maximum during the peak hours. This determine that during the data gathering, in the afternoon the solar pond started to store heat from the sunlight and reaches its maximum capabilities during the peak hours. After that, when the peak hours has passed, the temperature of the solar pond begin to falls down and as a result, lower heat losses were calculated at that time.

From the three experiments that involve the insulating materials, there are some characteristics that have been taken into consideration. The characteristics are the heat loss produced, the cost involved and the handling of each material.

From the first characteristic, it is obvious that the polystyrene has the best insulation package rather than polyurethane and cardboard paper. This may be due to the thickness of the polystyrene, which is obviously thicker than polyurethane and cardboard paper. Hence, although the polyurethane has a slightly better thermal conductivity value than polystyrene, it could not contain heat from the pond and avoid it from becoming the heat loss. For the cardboard paper case, it is obvious from the theoretical value of thermal conductivity; it could not contain more heat from the solar pond. Even the high number of heat loses also raised the possibility that there might be some errors during calculation.

From the cost spent for buying the insulator, it is obvious that the polyurethane cost the most as it is actually taken from the mat bought from the departmental store. Then, polystyrene and cardboard paper followed the trend of cost by sequence.

The third characteristic shows that polystyrene is the hardest to handle, where it is quite messy and easily brittle if much force exerted on it. Moreover, during the pasting process on the walls, the polystyrene is the hardest to stick in. It must be hold for a while before sticking in to the walls of the solar pond. Meanwhile, the cardboard paper and the polyurethane are the much easier to handle, with both materials did not have any characteristics showing brittle when being handle. Both materials are also easy to use during the pasting process.

From all the three characteristics taken into consideration, it is obvious that polystyrene is the best insulator when compared with polyurethane and cardboard paper; after topping two of the three categories involved.

As a result, this project has been done successfully, due to the tropical weather in Malaysia. Hence, it should be a stepping stone for more solar pond implementation and perhaps, advancement to the real scale solar pond projects.

5.2 RECOMMENDATIONS

The first recommendation is the organizer involved, should have installed a tap to supply tap water. This is because, during the experiment, the only way to fill the bath tub is to link the hose bought, which is approximately 20 m long with the hose at the nearest tap; which is 40 m away. Hence, the distance is too far for the student to do his water fillling process

During the experiment, there might be some errors in the data gathering process, especially when taking the temperature of each level of the solar pond. There might be slight deviations in data readings as reader is prone making the parallax error. It is understandable that the digital thermometer cannot be used because of its limited quantity and the effect of corrosion on the probe when it is put under the saline water. Hence, as a recommendation, it is better to purchase a special digital thermometer to ensure that the next experiment involving solar pond uses the digital thermometer.

The solarimeter used for this project also produces readings of sunlight intensity that are lower than its actual value. This might be caused of the less diffuse of radiation occur between the earth surfaces the facings of the readings. One suggestion is to use or purchase a more accurate solarimeter especially the ones with integrator to enhance the stability of the readings. Collaboration with other universities regarding equipment purchasing and lending could be a good suggestion.

The final suggestion is for the organizer to start produce the actual solar pond. This is because, for the past two years, the research on this particular subject has been done by the university. Hence, much experience has been gathered and recorded for the past two years. It is believed that the time has come for the actual project to be conducted. In order not to be risky, small solar pond should be built, however producing electricity just to fill a small area as the main target. Furthermore, collaboration can be done with the Electrical Engineering Department in order to consult on the electrical side of the project.

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APPENDICES

APPENDIX A (i)	:	Suggested milestone for the first semester of 2 semester Final year project
APPENDIX A (ii)	:	Suggested milestone for the second semester of 2 semester final year project
APPENDIX B	:	Sample of Calculations
APPENDIX C	:	Physical Properties
APPENDIX D	:	Solar Pond Drawings and Dimension
APPENDIX E	:	Photographs

APPENDIX A (i)

SUGGESTED MILESTONE FOR THE FIRST SEMESTER OF 2 SEMESTER FINAL YEAR PROJECT

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	SW	EW	
1	Selection of topics	■	■															
2	Scheduling and preparing Gantt Chart	■	■															
3	Literature Review on the Solar pond		■	■	■	■	■	■	■									
4	Literature Review on the Insulator					■	■	■	■	■	■	■	■	■				
5	Submission of Preliminary Report (15/8/2003)				●													
6	Equipment Identification					■	■	■	■									
7	Equipment handling Consulting Supervisor and Technicians					■	■											
8	Submission of Progress Report (22/9/2003)									●								
9	First Experiment - Bath tub filled with plain water								■	■								
10	Second Experiment - Solar pond with polystyrene as insulator											■						
11	Submission of interim report final draft (20/10/2003)													●				
12	Oral Presentation												■					
13	Submission of interim report (21/11/2003)																●	

Table A1. First Semester Gantt chart

●	Suggested milestone
■	Process

APPENDIX A (ii)

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	SW	EW	
1	First Experiment Polystyrene	■	■	■	■													
2	Submission of Progress Report 1				●													
3	Preparation of 2nd Experiment					■	■											
4	Progress of 2nd Experiment (Polyurethane)							■	■	■	■							
5	Submission of Progress Report 2										●							
6	Final Experiment (Cardboard Paper)												■	■	■			
7	Submission of Dissertation Final Draft													●				
8	Oral Presentation															●		
9	Submission of Project Dissertation																	●

Table A2: Second semester Gantt Chart

●	Suggested milestone
■	Process

APPENDIX B
SAMPLE OF DATA CALCULATION
(DATA TAKEN ON 1/3/04; 1235 HOURS)

$$(\acute{\alpha}\ G)sun - \frac{k\ (T_{s,3} - T_{\infty,3})}{L} - \acute{\alpha}\acute{\varepsilon}\ (T_{s,3}{}^4 - T\infty^4) = 0 \qquad \textbf{(B.1)}$$

$\acute{\alpha}$ = Percentage of heat absorbed

G = Radiation measured from the solarimeter = 297.68

$T\infty$ = Surrounding temperature = $32^{O}C$ = 305 K

k = Conductivity of the materials selected = 0.026 for polystyrene

$T_{s,3}$ = The surrounding temperature at the bath tub = $38^{O}C$ = 311K

$T_{\infty,3}$ =. Temperature of the outer walls of the solar pond (polyurethane) = 35 ^{O}C = 308 K

L = $5X10^{-3}$m (thickness of polyurethane)

Insert all the values into the calculation

$\boldsymbol{\acute{\alpha}}$ **(297.68) - (0.026 (311 - 308))/ (5X10-^{3}) - (5.67 X 10 $^{-8}$X1.0 X(311^{4} - 305^{4}) = 0**

$\boldsymbol{\acute{\alpha}}$ **= 0.186**

Hence, from the heat transfer method = 297.68 X 0.4864 (area of perspex)

We get heat transfer = 144.79

However to get heat transmitted; we use; 144.79 (1-0.186) = 117.86 W

Q loss = Q cond + Q rad

$$= \frac{k\ (T_{s,3} - T_{\infty,3})A_1}{L} + \acute{\alpha}\acute{\varepsilon}\ A_2(T_{s,3}{}^4 - T\infty^4) \qquad \textbf{(B.2)}$$

For this part A_1 = 1.53 X 0.30 X 2 + 0.44 X 0.30 X 2 = 1.182

Where 1.53 = the length of the solar pond

0.44 = the width of the solar pond

0.30 = the height of the solar pond

2 = number of surfaces in solar pond

by inserting the values we will get

= (0.026 (311 - 308)1.182)/ (5X10^{-3}) + (5.67 X 10 $^{-8}$X1.0 X (311^{4}-305^{4}) (0.4864)

= 38.49

APPENDIX C

PHYSICAL PROPERTIES

1. Physical Properties of the Solar Pond

1.1 Dimension

i. Height = 30 cm = 0.3m

ii. Length = 153 cm = 1.53 m

iii. Width (inner) = 38 cm = 0.38 m

iv. Width (outer) = 44 cm = 0.44m

v. Width of walls (from Top) = (44 - 38)/2 = 3 cm = 0.03 m

vii. Area of the solar radiation to enter the solar pond = 1.28m X 0.38 m = 0.4864 m^2

2. Insulating Materials Physical Properties

i. Polystyrene

a. Thickness: 0.024 m

b. Thermal Conductivity, k : 0.027 W/m.K

ii. Polyurethane

a. Thickness: 5 $X10^{-3}$ m

b. Thermal Conductivity, k : 0.026 W/m.K

iii. Cardboard paper

a. Thickness : $1X10^{-3}$ m

b. Thermal Conductivity, k : 0.159 W/m

APPENDIX D

SOLAR POND DRAWING AND DIMENSION

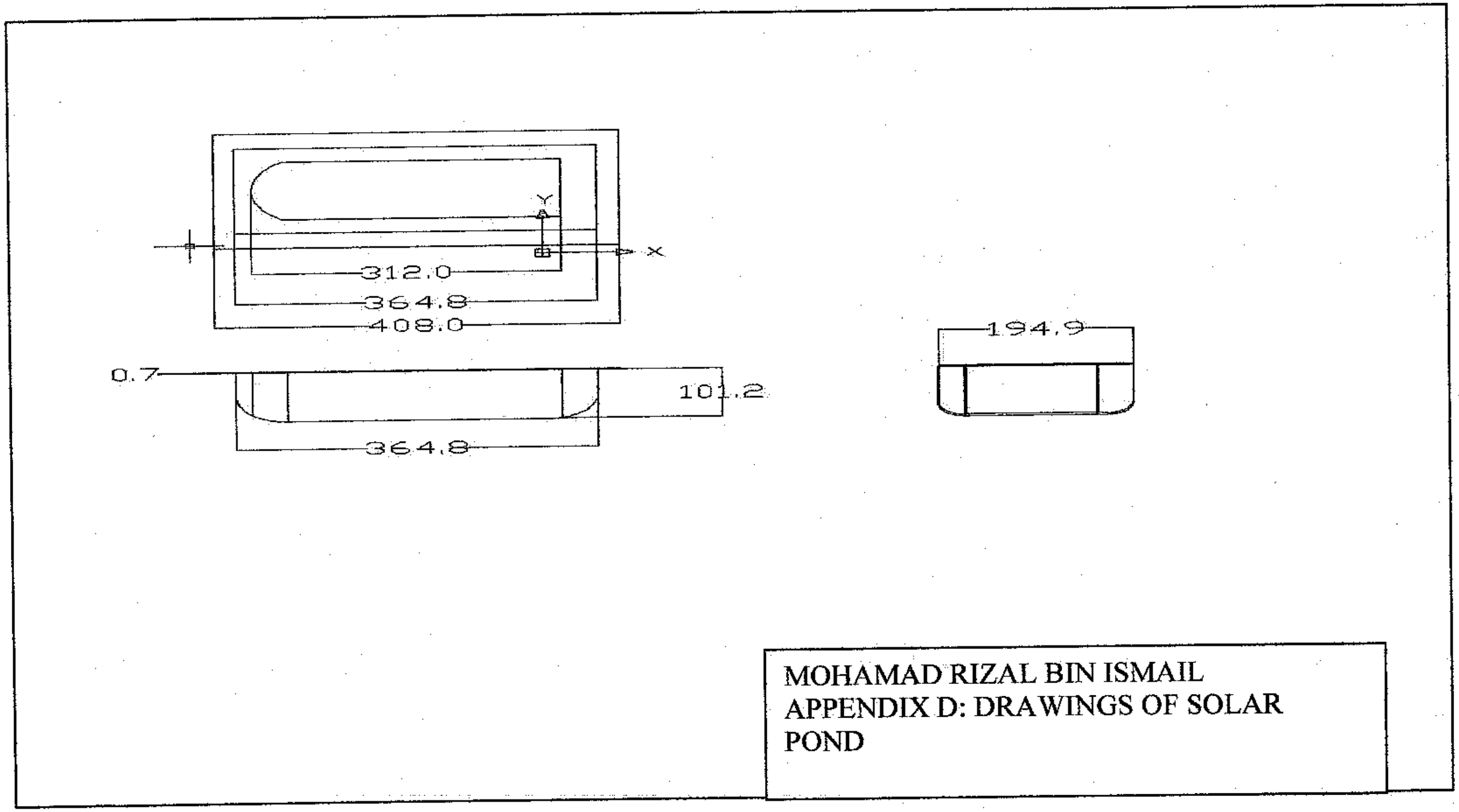

Figure D.1: Solar Pond Drawings and Dimension

APPENDIX E

PHOTOGRAPHS

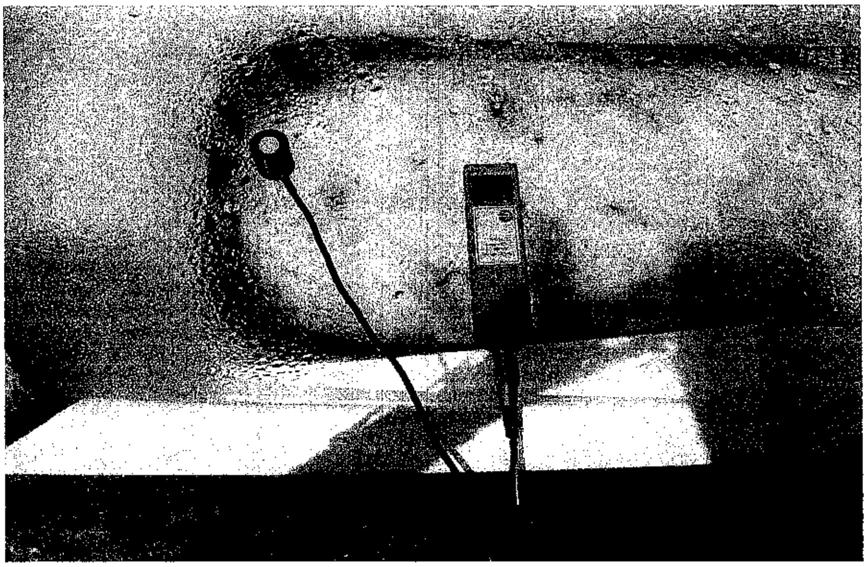

Figure E.1: Readings taken from the Solarimeter

Figure E.2: Readings of Surface Temperature of Solar Pond was taken

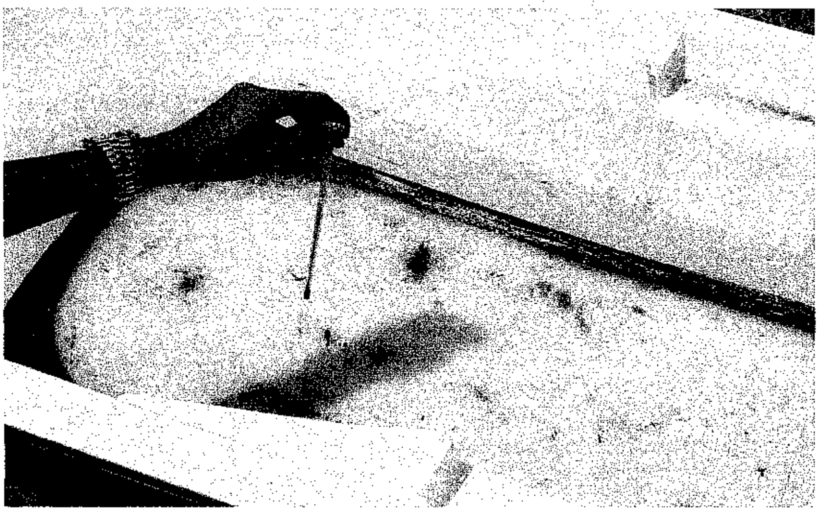

Figure E.3: Readings of Solar Pond Temperature was taken manually

Figure E.4: Solar Pond Using Polystyrene as Insulator

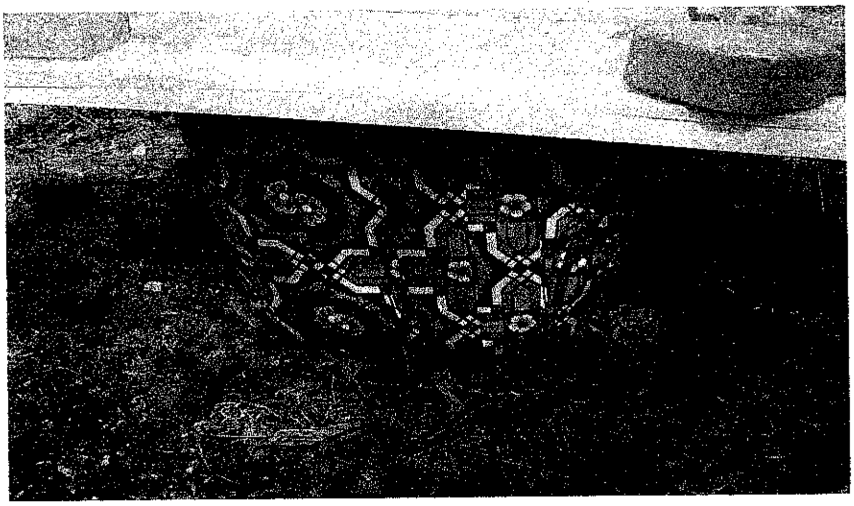

Figure E.5: Solar Pond Using Polyurethane as Insulator

Figure E.6: Solar Pond Using Cardboard Paper as Insulator