CHAPTER 1

INTRODUCTION

1.0 Introduction

Solar collectors are mechanical systems that collect solar energy from sun to heat water for daily usage. Some of the solar collector can convert the energy drawn from the sun to another source of energy like electric. Solar water heater can collect heat and store hot water for later use. Hot water are usually use for a lot of applications such as bathing, swimming pool and laundry, etc.

Heat can be transferred by three modes which are radiation, conduction and convection. These three modes would be studied to design a product that improved solar water heater. One of the purposes of the study is to design and develop an improved solar water heater that can be used to heat the water during the day time using solar energy and at the same time, the collector would be reducing the heat losses from the collector at off solar times.

1.1 Background

Solar energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar radiation, along with secondary solar-powered resources such as wind and wave power, hydroelectricity and biomass, account for most of the available renewable energy on earth. Only a minuscule fraction of the available solar energy is used. Earth received 175 petawatts amount of solar radiation each year. This great source of energy can be utilized for another work if it can be optimized. The application of sun energy utilization can be seen in the solar water heater.

Solar water heater is a device that absorbed and also reflects the sun radiation to the tank to convert it to heat and increase the water temperature. There are two type of solar water heating which is passive and active system. A passive system as shown in figure 1.1(A) also known as a compact system or monobloc has a tank for the heated water and a solar collector mounted on the same chassis. Typically these systems will function by natural convection to transfer the heat energy from the collector to the tank .Like their passive counterparts, active solar water heating systems come as two types: direct active systems circulate water directly to the collector and back to the storage tank, while indirect active systems circulate transfer fluid (HTF), the heat of which is transferred to the water in the storage tank. [1]

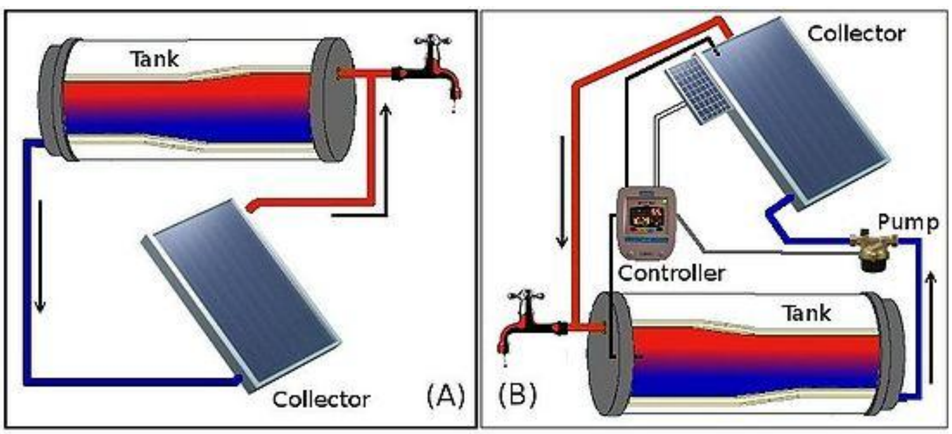

Figure 1.1 : (A) Passive Solar Water Heater (B) Active Solar Water Heater[1]

The tank that stored water in water heater system supposed to be insulated in order to reduce the heat loss to the surrounding. The design of water heater tank also needs to be considered. It is said that a vertical configurations of water tank is more effective to a horizontal one. This is due to the operation of thermosiphon system that depends on the stratification of the water in the storage tank. A good solar water heater system does not need a lot of maintenances. According to William H Kemp (2005) "Once a solar thermal system has been installed and commissioned, very little maintenance is required. For the majority of homeowners, sweeping snow from the collectors is the limit of day to day maintenance". [2]

1.2 Problem Statements

Solar water heaters have already been assigned and developed for the last few decades but the major problem with the existing designs is that they lose heat during off-solar hours resulting in temperature drop of the water. Fixed location of solar collector hinder the maximum temperature rise due to change of sun position .The main advantage of the new design would be not only high efficiency during sunshine hours but also a good insulator during off-sun hours.

1.3 Objectives

The objective of design and development of innovative solar water heater project is as stated below:

1. To design a new solar water heater for a good efficiency and insulating capabilities.
2. To fabricate the prototype using the available tools and resources.
3. To test the new solar water heater in a real surrounding to examine its working capability.

1.4 Scope of Study

This study is focusing on a standard family of a parent and two children. The usage of hot water by those 4 people will be calculated. The result will bring to a parameter of the design of the solar water heater. The size of the product will be based on the calculated parameter. The design cannot be used to cover the usage of all residential of an area. Study show that hot water mostly is used during the bath. In this project, a vertical cylindrical water storage tank is used to optimize the surface area for sun radiation to pass trough.

CHAPTER 2

LITERATURE REVIEW

2.0 Literature Review

Chapter 2 provides overview and information on solar water heater and the concept regarding that matter. In this chapter, the author also provides the review on the widely used solar collector and the mechanism behind its design. All of the relevant theories, facts and information related with the project objectives and finding of project research are includes in this chapter.

2.1Water Usage

The world's commercial low temperature heat consumption is estimated to be about 10 EJ per year for hot water production, equivalent to 6 trillion m^2 of collector area (Turkenburg, 2000). In about 2005, about 140 million m^2 of solar thermal collector area were in operation around the world, which is only 2.3 % of the potential (Philibert, 2005) [3]. A recommended temperature for how water consumption is about 120°F (49°C).[4]

The hot water demand can be calculated from equation 2.1:

$$\boldsymbol{V = N_{days} \times N_{person} \times V_{person}} \qquad (2.1)$$

The volumetric consumption varies considerably from person to person. Typical operations and consumption of water for residential usage are given in Table 2.2 .In the table, we can see most of the hot water are use for the purpose of bath. [3]

Table 2.1: Average hot water usage [3]

Use	Flow (L)
Food preparation	10-20
Manual dish washing	12-18
Shower	10-20
Bath	50-70
Face and hand washing	5-15

Table 2.2: Usage of water per capita[4]

Uses	Average gallons per capita per day	Average liters per capita per day	Indoor use percent	Total use percent
Toilet	18.5	70.0	30.9 %	10.8 %
Clothes washer	15	56.8	25.1 %	8.7 %
Shower	11.6	43.9	19.4 %	6.8 %
Faucet	10.9	41.3	18.2 %	6.3 %
Other domestic	1.6	6.1	2.7 %	0.9 %
Bath	1.2	4.5	2.0 %	0.7 %
Dishwasher	1	3.8	1.7 %	0.6 %
Indoor total	59.8	226.3	100.0 %	34.8 %
Leak	9.5	36.0	N/A	5.5 %
Unknown	1.7	6.4	N/A	1.0 %
Outdoor	100.8	381.5	N/A	58.7 %
TOTAL	171.8	650.3	N/A	100.0 %

2.2 Solar radiation to earth

Solar radiation is received at the earth surface in an attenuated form because it is subjected to the mechanism of absorption and scattering as it passes through the earth atmosphere. Absorption occurs primarily because of the presence of ozone and water vapor in the atmosphere and to a lesser extent due to other gases like CO2, NO2, CO, O2 and CH4 and particulate matter. It results in an increase in the internal energy of the atmosphere, on the other hand, scattering occurs due to all gaseous molecules as well as particulate matter in the atmosphere. The scattered radiation is redistributed in all directions, some going back into space and some reaching the earth atmosphere.

The atmosphere at any location on the earth surface is often classified into two broad types- an atmosphere without clouds and an atmosphere with clouds, in the former case, the sky is cloudless everywhere, while latter, the sky is partly or fully covered by clouds. The mechanism of absorption and scattering are similar with both types of atmosphere. However it is obvious that less attenuation takes place in a cloudless sky. Consequently maximum radiation is received on the earth's surface under the condition of a cloud less sky. Solar radiation received at the earth's surface without change of direction, i.e. in line with the sun is called beam or direct radiation. The radiation received at the earth's surface from all part of the sky's hemisphere (after being subjected to scattering in the atmosphere) is called diffuse radiation. The sum of the beam and diffuse radiation is referred to as total or global radiation.

According to S.P Sukhatme (2005), "In general the intensity of diffuse radiation coming from various directions in the sky is not uniform. The diffuse radiation is therefore to be anisotropic in nature. However in many situations, the intensity from all directions tends to be reasonably uniform. It is then modeled as being perfectly uniform and is said to be isotropic in nature". [6]

Figure 2.1 shows the schematic representation of the mechanism of absorption and scattering and beam and diffuse radiation received at the earth's surface.

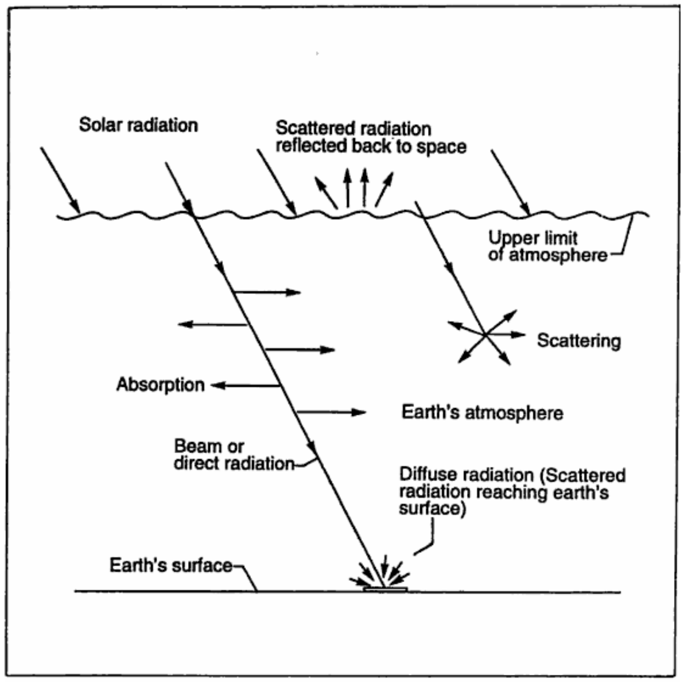

Figure 2.1: Schematic representation of the mechanism of absorption and scattering of radiation at earth's surface[6]

2.3 Solar Thermal system

Solar thermal systems are useful in many homes for several different options. There are many ways to get solar thermal systems to work in your home and it is important to look into available options that will help to lower the costs of energy consumption needed to heat water or a space. There are two main types of thermal systems that use solar power and those are the passive and active systems. Passive systems allow the heat to be absorbed and are naturally distributed amongst the system while active system will use different means to power the collected heat through the system by using pumps or other devices (which can also be powered by solar energy)

Solar thermal energy has been used for centuries by ancient people's harnessing solar energy for heating and drying. More recently, in a wide variety of thermal process solar energy has been developed for power generation, water heating, mechanical crop drying and water purification. Given the range of working temperature of solar thermal process, the most important applications are

- For less than 100°C, water heating for domestic use and swimming pools, heating of building and evaporative systems such as distillation and dryers.
- For less than 150°C, air conditioning , cooling and heating of water, oil or air for industrial use
- For temperature between 200°C and 2000°C generation of electrical and mechanical power
- For less than 5000°C, solar furnaces for the treatment of materials.

For process more than 100°C are required, solar energy flux is not enough to elevate the working fluid temperature to such a high level, instead, some type of concentration of the energy flux using mirror or lens must be used. Then the ration of the energy flux received for the energy absorber to that captured by the collector must be greater than one and design often easily achieve a concentration of hundred of suns. [7]

2.4 Solar Collector System

The need of hot water can be filled with the use of solar water heater system. Solar water heater is a combination of a solar collector array, an energy transfer system and a storage tank. The heat can either be stored or used directly. Solar energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The major part of solar system is solar collector. Solar collector is a device that absorbs the solar radiation and converts it to heat before transfer it to a fluid flowing through the collector. A large number of solar collectors can be found at market. Both type of solar collector given a various value of temperature output. A comprehensive list is shown at Table 2.3.

Table 2.3: Concentration ratio and indicative temperature range of solar collector [3]

Motion	Collector type	Absorber Type	Concentration ratio	Indicative temperature range (C)
Stationary	Flat plate collector (FPC)	Flat	1	30-80
	Evacuated tube collector (ETC)	Flat	1	50-200
	Compound parabolic collector (CPC)	Tubular	1-5	60-240
Single – axis tracking			5-15	60-300
	Linear Fresnel Collector (LFR)	Tubular	10-40	60-250
	Cylindrical trough collector (CTC)	Tubular	15-50	60-300
	Parabolic trough collector (PTC)	Tubular	10-85	60-400
Two- axis tracking	Parabolic dish reflector (PDR)	Point	600-2000	100-1500
	Heliostat field collector (HFC)	Point	300-1500	150-2000
Note : concentration ratio is defined as the aperture area divided by the receiver / absorber area of the collector				

2.4.1 Parabolic Trough Collector

System with light structure and low cost technology for process heat applications up to 400C could be obtained with parabolic trough collectors (PTC). Parabolic trough collectors are made by bending a sheet of reflective material into a parabolic shape. A black metal tube, covered with a glass tube to reduce heat losses is placed along the focal line of the receiver. The surface of the receiver is typically plated with a selective coating that has a high absorbance for solar radiation but a low remittance for thermal radiation loss. The concentrated radiation reaching the receiver tube heats the fluid that circulates through it thus transforming the solar radiation into useful heat. [8]

2.4.2 Pump

The pump is one of the most important parts of a solar heating system, it is the real heart of the systems. It transfers the heat content of the solar radiation from the collector to the heat store. A control unit starts the circulation in the solar loop as soon as the temperature in the collector exceeds the temperature at a reference point in the storage tank.

When sizing the pump, it is important to determine the flow rate is a solar heating system first, as the volume flow rate affects the pressure drop. The estimated pressure drop gives the capacity of the pump. It is complicated to increase the flow in an existing plant because the pressure drop increases more quickly than the flow rate. The supplier of the solar heating system should recommend both pipe dimensions and the capacity of the pump. When calculating the pressure drop, it is the heat transfer fluid that is the determining factor, not the temperature variations in the circuit. The example of the pumps is shown in figure 2.2.

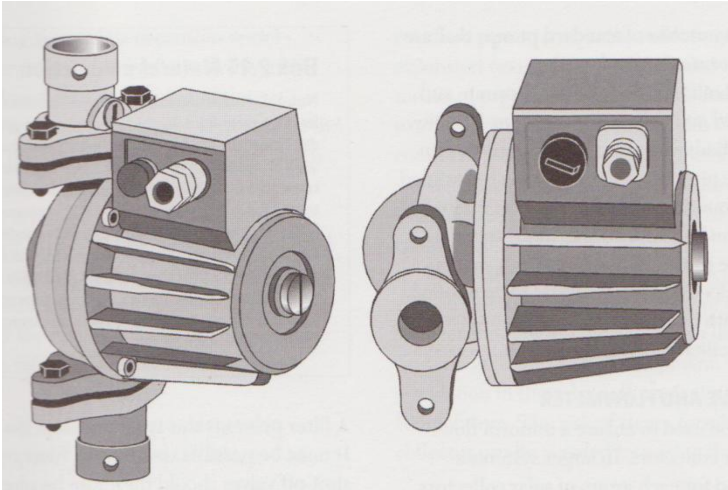

Figure 2.2: Pumps [8]

2.4.3 Heat transfer fluid

Glycol mixed with water is the heat transfer fluid that is normally used in solar heating plants, at least in the northern parts of the Europe. However, water on its own may be common as a heat transfer fluid in the future, with the development of drain back systems. In direct solar heating systems for outdoor pools chlorinated water is used as the heat transfer fluid.

In recent years a special brine solution has been tested as the heat transfer fluid in small – scale solar heating systems. This solution like glycols consists of organic carbon- hydrogen chains. It has good heat transfer properties and is biodegradable .One of its advantage is that it tends to leak.[14]

2.5 Angle of solar radiation

The angel of solar radiation is important in order to get a maximum amount of energy from sun. The angle and direction of installation is also of great importance as it will affect the efficiency of the solar collector. Naturally every individual want the collector to receive the maximum amount of sunlight each day and throughout the year.

2.5.1 Solar angles

The earth makes ones rotation about its axis every 24 hour and completes a revolution about the sun in a period of approximately 365.25 days. This revolution is not circular but follows an eclipse with the sun at one of the foci as shown in figure 2.3.

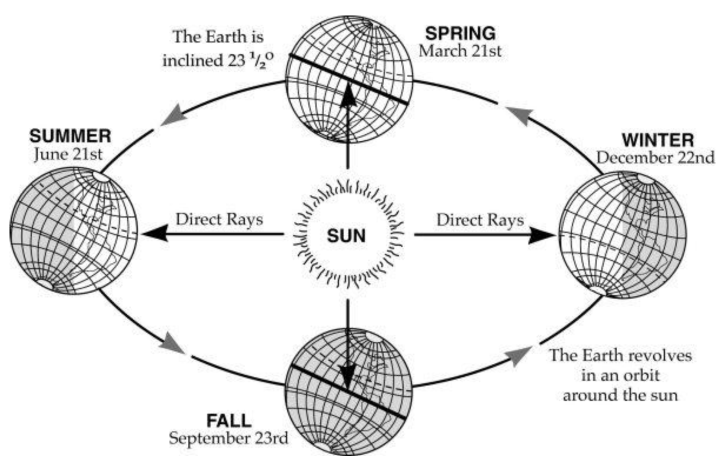

Figure 2.3: Annual motion of the earth about the sun

The sun's position in the sky changes from day to day and from hour to hour. It is common knowledge that the sun is higher in the sky in the summer than in the winter. Once a year, the earth moves around the sun in an orbit that is elliptical in shape. As the earth makes its yearly revolution around the sun, it rotates every 24 hour about its axis , which is tilted at an angle of 23.27 to the plane of the elliptic which contains the earth's orbital plane and the sun's equator as shown in figure 2.4.

To know the exact position of the sun at a given time of day and year is crucial in the solar energy applications. In the Ptolemaic sense, the sun is constrained to move with 2 degrees of freedom on the celestial sphere, therefore, its position with respect to an observer on earth can be described by means of two astronomical angles, the solar altitude (α) and the solar azimuth (z).[3]

2.5.2 Declination, δ

The ecliptic plane is the plane of orbit of the earth around the sun. As the earth rotates around the sun it is as if the polar axis is moving with respect to the sun. The solar declination is the angular distance of the sun's rays north or south of the equator. The declination is ranges from 0 at the spring equinox to + 23.45 at the summer solstices, 0 at fall equinox and -23.45 at the winter solstice.

2.5.3 Hour angle, h

The hour angle, h of a point on the earth surface's surface is defined as the angle trough which the earth would turn to bring the meridian of the point directly under the sun.

2.5.4 Solar altitude angle, α

The solar altitude angle is the angle between the sun's rays and a horizontal plane as shown in figure 2.4. It is related to the solar zenith angle, φ which is the angle between the sun's rays and the vertical.

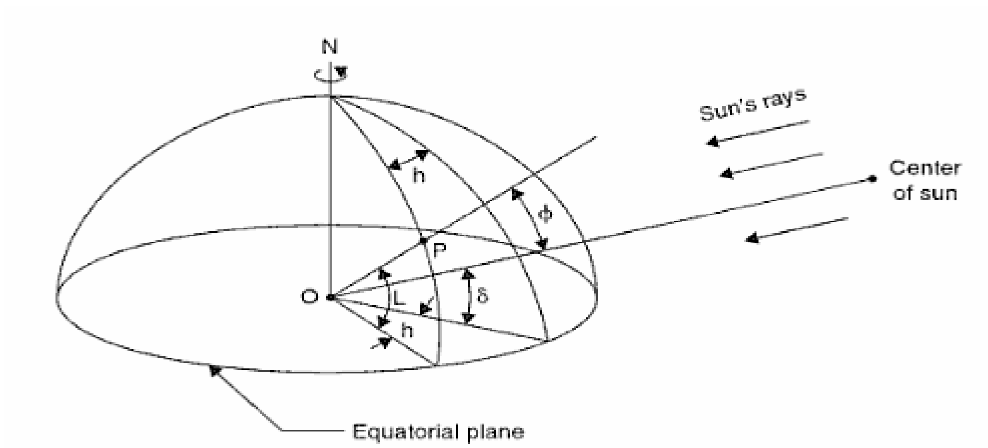

Figure 2.4: Definition of latitude, hour angle and solar declination

2.5.5 Solar azimuth angle, z

The solar azimuth angle, z is the angle of the sun's rays measured in the horizontal plane from due south for the northern hemisphere or due north for the southern hemisphere is designated as positive.

2.5.6 Sunrise and sunset times and day length

The sun is said to rise and set when the solar altitude angle is 0. The day length is twice the sunset hour, since the solar noon is at the middle of the sunrise and sunset hours. [3]

2.6 Orientation and output of solar collector

The incident angle of the sun ray's on a flat plate stationary solar collector varies with time. This variation as shown in figure 2.5 affects the amount of solar radiation that reaches the solar collector. Usable radiation decreases when the orientation deviates from the south and is also affected by the tilt.

An important detail in the design work is to find suitable places for solar collector that give the required heat output and are acceptable from the point view of cost. A basic question is what an angle and orientation should the solar collectors be placed to utilize as much as possible of the solar radiation.

The optimal position for a solar collector is facing south and is dependent on several factors such as the latitude, the load and whether the collector is over dimensioned for summer conditions. For a constant load that is met by the collector without significant overproduction during summer, the optimal tilt is 10-15 less than the latitude.

The solar collector's tilt can be reduces if heat production is intended mainly for summer use. One typical example is unglazed solar collectors for heating outdoor pools. It is important to avoid all forms of shading. Make a note of the risk of overshadowing from possible dormer windows, or if there is a risk that nearby vegetation might grow and overshadow the solar collector.[10]

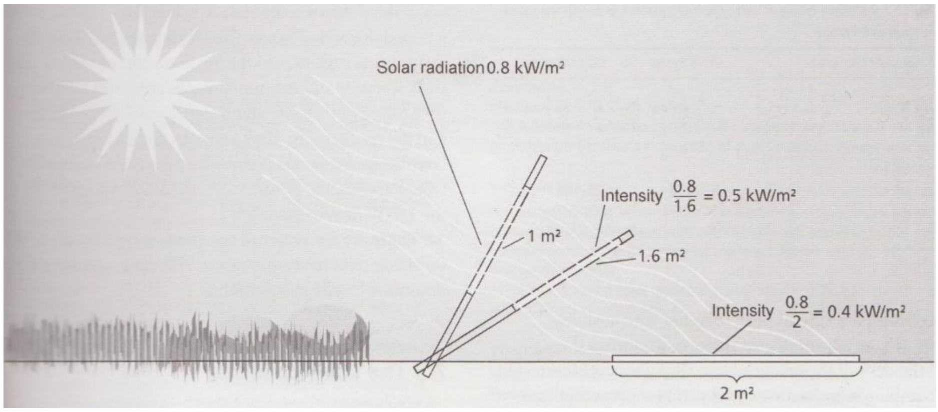

Figure 2.5: The variation of angle and intensity of solar radiation on a surface [10]

2.7 Cooper

Copper is an excellent conductor of electricity and heat so it is chosen to make the flexible cables used in wiring. Each copper atom has 29 negatively charged electrons. The number of electrons and protons is always the same, so copper has positively charged protons in the nucleus. The number of protons also stands for the atomic number of an atom which is 29. Copper is the second best heat conductor of all metals, being surpassed in this respect only by the silver. Comparatives values for thermal conductivity for different metals at room temperature are as follows in tables 2.4 and 2.5.

Table 2.4 : Heat conductivity of material at room temperature[13]

Heat conductivity (cal/cm3/cm/sec/C)	
Silver	1.006
Copper	0.918
Gold	0.705
Aluminium	0.480
Iron	0.161

Table 2.5: Thermal properties of Copper[13]

Thermal properties of copper	
Melting point	1083 0C (1981.4 F)
Boiling point	2325 C (4217 F)
Latent heat of fusion	5046 cal/gram (90.83 BTU/lb)
Specific heat (25 C)	0.0919 cal/gram/C
Linear coefficient of expansion (20C)	1642X10-6 / C
Thermal conductivity (20C)	0.923 cal/cm2/cm/sec/C

2.8 Fiberglass

Fiberglass is one of a group of glassy,non crystalline materials historically referred to as man-made mineral fibers (MMMFs) or manmade vitreous fibers (MMVFs). Glass fibers are made from molten sand, glass,other inorganic materials under tightly controlled conditions. Rock wool loose-fill insulation is similar to fiberglass except that it is spun from blast furnace slag. Rockwool fiberglass is inorganic and noncombustible. The fibers will not rot or absorb moisture and do not support the growth of microorganism. The R-value of fiberglass when settled naturally at as in attic at 0.7lb/ft3 is 2.2 per inch. One of the most significant criteria for achieving the desired R-value is meeting the designated minimum weight per square foot of material. It is also important that the minimum thickness is achieved since this along with the required weight is essential to obtain the desired R-value. The example of R-value is shown in table 2.6.

Table 2.6: R-value of insulation materials[12]

Material	**m²·k/(w·in)**	**ft²·°f·h/(btu·in)**
Vacuum insulated panel	5.28–8.8	R-30–R-50
Fiberglass batts	0.55–0.76	R-3.1–R-4.3
Fiberglass loose-fill	0.44–0.65	R-2.5–R-3.7
Rock and slag wool loose-fill	0.44–0.65	R-2.5–R-3.7
Silica aerogel	1.76	R-10
Rock and slag wool batts	0.52–0.68	R-3–R-3.85

CHAPTER 3

METHADOLOGHY

3.0 Methodology

During the project of design and development of innovative solar water heater, a lot of process involved. For starter, some information needs to be gathered regarding solar energy and the method of collection. Types of solar water heater is also been researched. Calculations to determine the parameter of the studies will be carried out to determine the size and dimension of the prototype. Flat plate collector and parabolic trough collector is the type of collector that would be studied for the study. Location for the study is focused at Ipoh, Malaysia at the date of 19^{th} April 2010.

3.1 Flow of process in the project

The project would be started with some research about the solar water heater and the types of solar collector itself. The research includes the solar radiation study to determine the best condition for the design of solar water heater. Then, some case study will be research to determine the parameter needed to construct the innovative solar water heater. Designing process will follows the parameter set before. After design stage is completed, an analysis would be done to know the result of the design made. If the result is not meeting the requirement for this project, an alternation to the design would be made. Fabrication will be done if the analysis result is satisfied. After the prototype is ready, it will be tested to meet the objective of the project. A modification to the design will be made if the test result is not meeting the requirement. If the test is successful, documentation about the project will be made.

3.2 Flow Chart

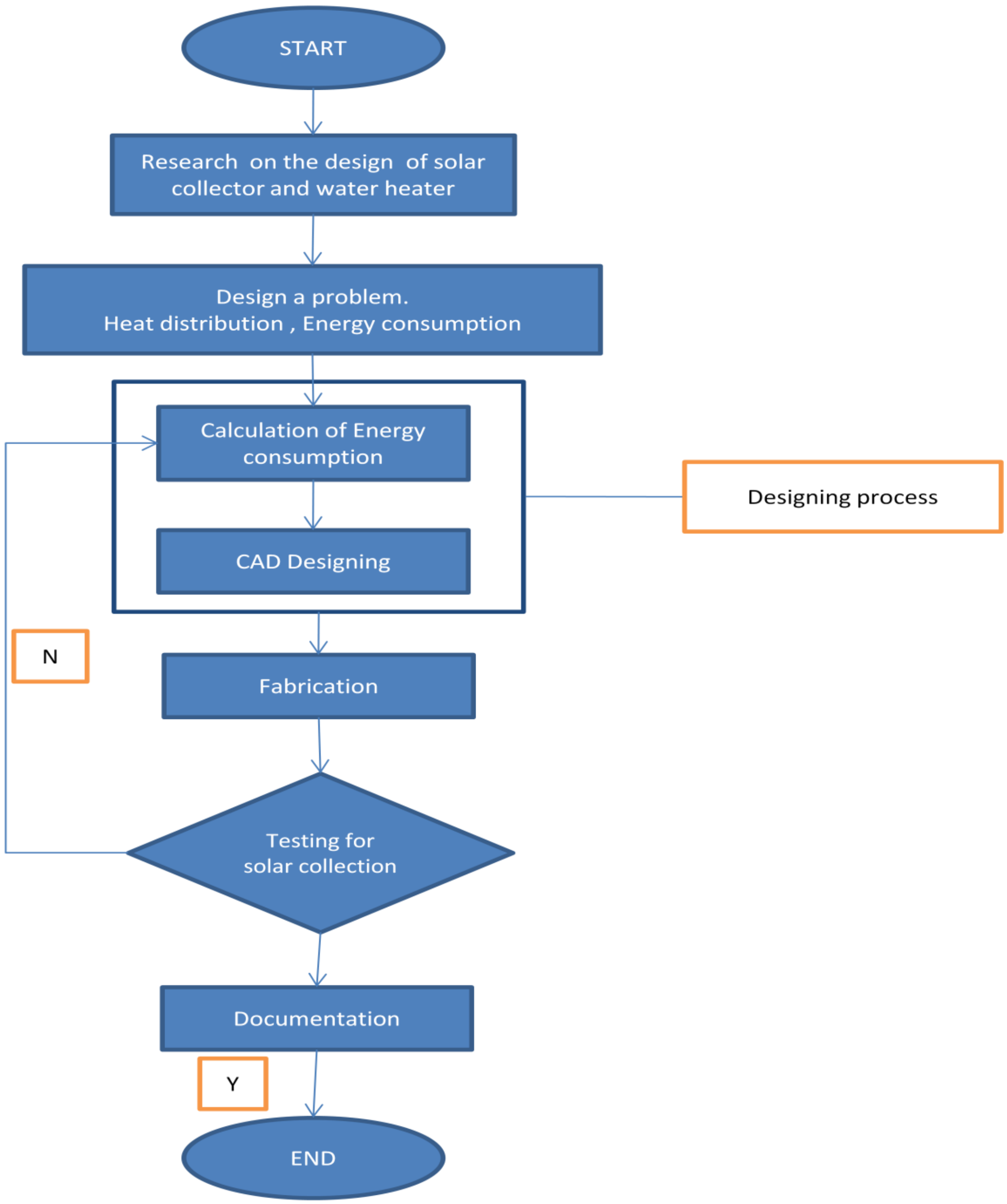

Figure 3.1: Flow Chart of FYP

3.3 Parameter Calculations

A good calculation is needed in order to scientifically prove the design that been made before fabricate it to a prototype. All parameter should be analyzed and justified before starting any fabrication of the prototype.

3.3.1 Solar Angle

There are some calculations needed to determine some parameter required for the study. From 2.5.2, we could see declination is important to verify the position of the sun according to the day of the year. The variation of the solar declination can be calculated for any day of the year (N) by equation 3.1[3]

$$\delta = 23.45\, sin[\frac{360}{365}\ (284 + N)] \tag{3.1}$$

For hour angle, h calculation, the equation below is used.

$$h = (AST - 12)15 \tag{3.2}$$

From 2.5.4, the solar altitude angle is required to determine the angle between sun's ray and horizontal plane on earth. The solar altitude angle can be calculated using equation 3.3

$$\sin \alpha = \cos \Phi = \sin(L)\sin(\delta) + \cos(L)\cos(\delta)\cos(h) \tag{3.3}$$

It is also important to know the solar azimuth angle (3.4) and the day length of certain date (3.5) to get the good parameter for the design.

$$\sin(z) = \frac{\cos(\delta)\sin(h)}{\cos(\alpha)} \tag{3.4}$$

$$DayLength = \frac{2}{15}\cos^{-1}[-\tan(L)\tan(\delta)] \quad (3.5)$$

3.3.2 Dimension of solar water heater

To decide the dimension of the tank used, we need to measure the volume of water usage and relate it to the cylindrical formula as equation 3.6:

$$V = \pi \times r \times h \quad (3.6)$$

3.3.3Parabolic trough collector

A method has been developed to construct the parabolic trough collector. The focal point of the structure is measured with a formula:

$$y = \frac{x^2}{4p} \quad (3.7)$$

With any value of p chosen as 30cm, the value of x and y can be identified thus create a parabolic shape of the collector as shown in figure 3.2

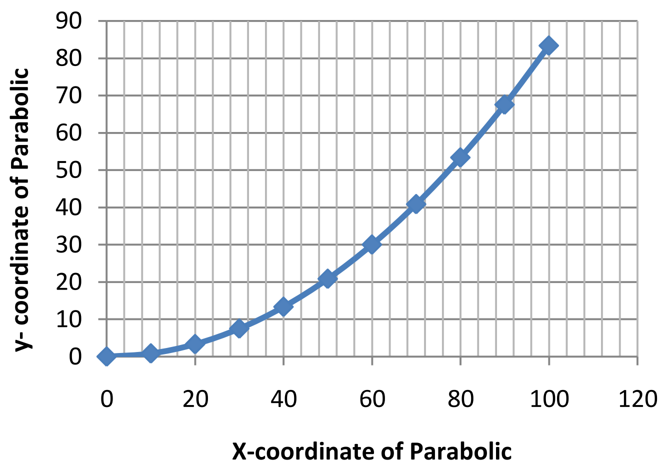

Figure 3.2: Parabolic design Graph

3.3.4 Solar water heater performance

The performance of the solar water heater needs to be calculated with the reference of energy balance. Energy in = Energy out. Incoming energy to solar water heater is equivalent to the energy stored and heat losses from the tank.

Incoming solar energy :

$$\boldsymbol{\alpha} \times \mathrm{I} \times \text{Area of absorber} \tag{3.8}$$

Heat losses(Convenction):

$$\mathrm{K} \times \Delta\ \mathrm{T} \times \text{Area of Tank} \tag{3.9}$$

Heat losses (Radiation):

$$\sigma \times \varepsilon \times \left(T_W{}^4 - T_S{}^4\right) \times Areaoftank \tag{3.10}$$

Efficiency of solar water heater:

$$\frac{Useful\ energy\ stored}{Incoming\ solar\ energy} \tag{3.11}$$

3.3.5Solar Collector Design Parameters

An engineer needs to have some knowledge and reason about their choice during their work. In the project, a dimension of copper tube need to be calculated and from there, an approximate value of parameter of material needed can be acquired.

The convection heat transfer coefficient between glass cover and ambient air which due to wind[15]:

$$h_w = \frac{8.6V^{0.6}}{L^{0.4}} \tag{3.12}$$

Radiation heat transfer coefficient between glass cover and the ambient:

$$h_{r,c-a} = \varepsilon_g \sigma \left(T_g + T_a\right)(T_g^2 + T_a^2) \tag{3.13}$$

Radiation heat transfer coefficient between absorber tube and cover tube:

$$h_{r,r-c} = \frac{\sigma\left(T_{abs} + T_g\right)(T_{abs}{}^2 + T_g{}^2)}{\frac{1}{\varepsilon_{abs}} + \frac{A_r}{A_a}\left(\frac{1}{\varepsilon_{abs}} - 1\right)} \tag{3.14}$$

Overall heat loss coefficient:

$$U_L = \left[\frac{A_r}{A_c(h_{c,c-a} + h_{r,c-a})} + \frac{1}{h_{r,r-c}}\right]^{-1} \tag{3.15}$$

Reynold number for the flow can be determined to classify whether the flow is turbulent or laminar:

$$Re = \frac{4\dot{m}}{\pi D_i \mu} \tag{3.16}$$

Nusselt number:

$$Nu = 0.023 Re_D{}^{0.8} . Pr^{1/3} \tag{3.17}$$

Convective heat transfer between absorber and fluid:

$$h_{c,i} = \frac{N_u K}{D_i} \tag{3.18}$$

The collective efficiency factor:

$$F' = \frac{1/U_L}{\frac{1}{U_L} + \frac{D_{abs,o}}{h_{c,i} D_{abs,i}} + \frac{D_{abs,o} \ln(\frac{D_{abs,0}}{D_{abs,i}})}{2k}} \quad (3.19)$$

Heat removal efficiency factor:

$$F_R = \frac{\dot{m} C_f}{A_{abs} U_L} \left[1 - \exp\left(- \frac{A_{abs} U_L F'}{\dot{m} C_f} \right) \right] \quad (3.20)$$

To calculate the useful energy that the collector received from the solar energy, Q_u need to be determined. :

$$Q_u = F_R A_a \left[S - \frac{A_r}{A_a} U_L \ (T_i - T_a) \right] \quad (3.21)$$

The useful energy can also be found with equation below:

$$Q_u = \dot{m} C_f (T_{f,o} - T_{f,i}) \quad (3.22)$$

$$\dot{Q}_{out} = \dot{Q}_{opt} - \dot{Q}_{loss} \quad (3.23)$$

$$\dot{Q}_{out} = A_a \rho_{s.m} \tau_g \alpha_r R S I_a - A_r U_l (T_r - T_a) \quad (3.24)$$

The parabolic collector efficiency can be found with the equation stated below:

$$\eta_{col} = \frac{\dot{Q}_{out}}{A_a I_a} \quad (3.25)$$

Lastly, an energy required for a volume of water in tank can be calculated as:

$$E_h = \rho V c \ (T_h - T_i) \quad (3.26)$$

3.3.6 Heat loss from tank

Heat is transferred by three methods such as convention, conduction and radiation. The amount of heat escaped from the storage tank can be determined using formula such as:

Heat loss trough radiation from the tank[16]:

$$Q = \sigma \varepsilon A_c ({T_h}^4 - {T_c}^4) \tag{3.27}$$

Heat loss trough convection from the tank:

$$Q = -hA(T_h - T_c) \tag{3.28}$$

Heat loss from the tank can be calculated using equation 3.29 and thickness of insulation material is shown in equation 3.30:

$$H = \frac{A(T_h - T_c)}{R} \tag{3.29}$$

$$R = {}^{L}/_{K} \tag{3.30}$$

3.4 Tools and Equipment Required

During the progress of the project, some equipment and tools are needed in the design and fabrication of the prototype of innovative solar water heater. The tools and equipment uses are:

3.4.1 Software

- CATIA
- Microsoft Office

3.4.2 Fabrication tools

Some fabrication tools are needed in order to materialize the prototype so the testing stage can be done. Several tools is used in fabricating the design using a limited resources. The fabrication tools used is shown in figure 3.3:

Figure 3.3: Fabrication tools

3.4.3 Testing equipment

Testing need to be done after finish with prototype fabrication to make sure it's working according to the design. Some equipment is acquired from the lab for testing purpose. The testing setup is shown in figure 3.4. the experiment is conducted using the tools list in table 3.1 and shown in figure 3.5.

Figure 3.4: Testing of the prototype

Table 3.1: Equipments and tools for prototype testing

No	Tool/Equipment	Purpose
1	Digital thermocouple	To measure the water, surface and surrounding temperature in the solar water heater.
2	Flow meter	To measure the water flow in the retractable pipe
3	Pyranometers	Measure the intensity of solar radiation

Figure 3.5: Digital thermocouple, pyranometer, flowmeter

CHAPTER 4

INITIAL RESULT AND DISCUSSION

4.0 Result and Discussion

Some research has been made in determining the design of the innovative water heater. The information below is still can be subject to change.

4.1 Water Tank design

In order to determine the tank size needed for the project, the maximum volume of water usage must be calculated. Table above shows the usage of water for a person per day. Hot water consumption mostly only applied to the use of shower, clothes washer and some other domestic. In my project, it is focus on a regular family which is consisting of father, mother and two children. The water usage for a day for one family is:

Shower: 43.9 liter x 4 person = 175.6 liter

Clothes washer: 56.8 liter

Other domestic: 6.1 liter

Total of water usage: 175.6 + 56.8 + 6.1 = 238.5 liter per day

A safety factor needs to be considered for the total volume of the water. In this case, the value for safety factor is 1.3. Safety factor need to be added into consideration because someone would eventually use extra amount of water for daily uses.

Total volume with 1.3 safety factor:

238.5 liter x 1.3 = 310.05 liter

4.2 Size of Water Tank

There a lot of option in choosing the shape of water tank. The vertical cylindrical water tank is chosen due to the effect of thermosiphon system that depends on the stratification of the water in the storage tank.

Cylindrical Volume equation:

$$V = \pi \times r \times h \tag{3.6}$$

The volume of the water need to be converted from liter to meter cubic. 1 liter of volume is equal to 1000 $m^{3.}$ Thus, 310.05 liter = 0.3101 m^3. By the volume of water usage per day that has been calculated, we can list out the possible size of water tank to be used in the solar water heater project.

h = 1.5 meter V = 0.3101 m^3

($\pi \times r^2 \times 1.5$

$r^2 = 0.0658$

$r = \sqrt{0.0658}$

$r = 0.256$ m

Due to budget constraint, the prototype will be scaled down to 3 times its actual dimension.

4.3 Solar angle

Solar collector need to be positioned differently based on the location. This section shows the calculations needed to determine the value of angle needed for solar water heater location. The solar angle calculation is based on the date 19th April 2010 and focused on Ipoh, Malaysia.

Malaysia latitude: 4°0´0´´ N

Date: 19/4/2010

Day: 109 days

Longitude: 102° 0´ 0´´ E

Ipoh latitude: 4° 35´ 0´´ N

Height above sea level 40.1 m

Longitude: 101° 05´ 0´´

LST = 12 - ET ± 4 (SL – LL)

ET = 9.87 sin (2B) – 7.53 cos(B) – 1.5 sin(B) (4.1)

$$B = (n - 81)\frac{360}{364}$$

$$B = (109 - 81)\frac{360}{364}$$

$$= 27.692$$

ET = 9.87sin (2 (27.692)) – 7.53 cos (27.692) – 1.5 sin (27.692)

= 0.488

LST = 12 – 0.488 + 4(102 – 101)

AST = LST + ET + 4 (SL- LL)

= 15.512 + 0.488 + 4(102 – 101)

=20

Declination, δ $= 23.45\ sin\ [\frac{360}{365}(284 + N)]$ (3.1)

$= 23.45 \sin\left[\frac{360}{365}(284 + 109)\right]$

= 10.87°

Hour angle, h = (AST – 12) 15 (3.2)

= (20 – 12) 15

= 120

Noon altitude = 90 – L + δ (4.2)

= 90 – 4.583 + 10.87

= 96.287°

Day length $= \frac{2}{15}\cos^{-1}[-\tan L \tan \delta]$ (3.5)

$= \frac{2}{15}\cos^{-1}[-\tan 4.583\ \ \tan 10.87\ ]$

= 12.118 hours

Solar altitude angle, α:

Sin (α) = cos (Φ) = sin (L) sin (δ) + cos (L)cos(δ)cos (h) (3.3)

= sin (4.583) sin (10.87) + cos(4.583) cos (10.87) cos (120)

$= -0.471$

$\alpha = -28.099$

$z + \alpha = 90$

$z = 90 + 28.099 = 118.09$

In these calculations, it shows the declination of the sun in Ipoh on 19th April 2010 is at 10.87°. The solar altitude angle shows the position of solar collector should be to get the maximum solar energy. That means the solar collector panel will be positioned at 28.1° angle from horizontal plane to get a maximum solar radiation.

4.4 Prototype design parameter calculations

The resulting calculations below are based on the surrounding parameter on 16th July 2006. These calculations are needed to determine the parameter of prototype of solar water heater. The parameter of the surrounding is shown in table 4.1:

Table 4.1: Parameter condition for testing stage

Parameter	Dimension
Ambient temperature	320 K
Copper tube temperature	324 K
Wind Speed (Assumption)	5 km/h

Energy required for 0.1 m^3 of water in tank:

$$E_h = \rho V c \ (T_h - T_i) \quad (4.3)$$

= (1000 kg/ m³) (0.100 m³) (4190 J/ kg.K) ((50 – 27)K)

= 9.637 MJ @ 2676 W

The convection heat transfer coefficient between glass cover and ambient air which due to wind

$$h_w = \frac{8.6V^{0.6}}{L^{0.4}} \quad (3.12)$$

$$h_w = \frac{8.6(5)^{0.6}}{(13.17)^{0.4}}$$

$$h_w = 8\text{W}/m^2.\text{K}$$

Radiation heat transfer coefficient between glass cover and the ambient:

$$h_{r,c-a} = \varepsilon_g \sigma \left(T_g + T_a\right)(T_g^2 + T_a^2) \quad (3.13)$$

$$h_{r,c-a} = (5.67 \times 10^{-8})(0.94)(331 + 320)(331^2 + 320^2)$$

$$h_{r,c-a} = 7.375\text{W}/m^2.\text{K}$$

Radiation heat transfer coefficient between absorber tube and cover tube:

$$h_{r,r-c} = \frac{\sigma\left(T_{abs} + T_g\right)(T_{abs}{}^2 + T_g{}^2)}{\frac{1}{\varepsilon_{abs}} + \frac{A_r}{A_a}\left(\frac{1}{\varepsilon_{abs}} - 1\right)} \quad (3.14)$$

$$h_{r,r-c} = \frac{(5.67 \times 10^{-8})(324.6 + 331)(324.6^2 + 331^2)}{\frac{1}{0.05} + \frac{0.5}{1.5}\left(\frac{1}{0.05} - 1\right)}$$

$$h_{r,r-c} = 7.285\text{W}/m^2.\text{K}$$

Overall heat loss coefficient:

$$U_L = \left[\frac{A_r}{A_c(h_{c,c-a} + h_{r,c-a})} + \frac{1}{h_{r,r-c}}\right]^{-1} \quad (3.15)$$

$$U_L = \left[\frac{0.5}{0.6(7.375 + 8)} + \frac{1}{7.2847}\right]^{-1}$$

U_L =5.223 W/m^2.K

Reynold number:

$$Re = \frac{4\dot{m}}{\pi D_i \mu} \quad (3.16)$$

$$Re = \frac{4(0.04)}{\pi(0.01)(5.716 \times 10^{-4})}$$

Re =8900

From the Reynold number that obtained, it showed that the flow inside the tube is turbulent. Thus, the theNusselt Number become:

Nusselt number:

$$Nu = 0.023 {Re_D}^{0.8}. Pr^{1/3} \quad (3.17)$$

$$Nu = 0.023(8900)^{0.8}. (4.002)^{1/3}$$

Nu =526.98

Convective heat transfer between absorber and fluid:

$$h_{c,i} = \frac{N_u K}{D_i} \quad (3.18)$$

$$h_{c,i} = \frac{(526.98)(0.6331)}{(0.01)}$$

$$h_{c,i} = 33363 W/m^2.K$$

The collective efficiency factor:

$$F' = \frac{1/U_L}{\frac{1}{U_L} + \frac{D_{abs,o}}{h_{c,i} D_{abs,i}} + \frac{D_{abs,o} \ln(\frac{D_{abs,0}}{D_{abs,i}})}{2k}} \quad (3.19)$$

$$F' = \frac{1/5.223}{\frac{1}{5.223} + \frac{0.012}{(33363)(0.010)} + \frac{(0.012)\ln(\frac{0.012}{0.010})}{2(401)}}$$

$$F' = 1.00261$$

Heat removal efficiency factor:

$$F_R = \frac{\dot{m} C_f}{A_{abs} U_L}\left[1 - \exp\left(-\frac{A_{abs} U_L F'}{\dot{m} C_f}\right)\right] \quad (3.20)$$

$$F_R = \frac{(0.04)(4.179)}{(0.5)(5.223)}\left[1 - \exp\left(-\frac{(0.5)(5.223)(1.00261)}{(0.04)(4.179)}\right)\right]$$

$$F_R = 0.06$$

Useful energy collected:

$$Q_u = F_R A_a \left[S - \frac{A_r}{A_a} U_L \,(T_i - T_a)\right] \quad (3.21)$$

$$Q_u = (0.06)(1.5)\ \left[\,960 - \frac{0.5}{1.5}\ 5.223\ (-7.2)\right]$$

$$Q_u = 87.528 \text{W}$$

$$Q_u = \dot{m} C_f (T_{f,o} - T_{f,i}) \quad (3.22)$$

$$\dot{Q}_{out} = \dot{Q}_{opt} - \dot{Q}_{loss}$$

$$Q = A_a \rho_{s.m} \tau_g \alpha_r RSI_a - A_r U_l (T_r - T_a) \tag{3.24}$$

$$Q = (1.5)\eta_{opt}(960) - (0.5)(5.223)(-6.7)$$

$$Q = 1440\eta_{opt} + 17.497$$

$$87.528 = 1440\eta_{opt} + 17.497$$

$$\eta_{opt} = 0.0486$$

Collector efficiency:

$$\eta_{col} = \frac{\dot{Q}_{out}}{A_a I_a} \tag{3.25}$$

$$\eta_{col} = \frac{87.56}{1.5(960)}$$

$$\eta_{col} = 0.067$$

With assume that

U_L =5.223 W/m^2.K

$\dot{Q}_{out}$ required to produce 50 ^oC output temperature from room temperature at flow rate of 0.5 kg/s for water is

$$\dot{Q}_{out} = \dot{Q}_{opt} - \dot{Q}_{loss} \tag{3.23}$$

$$Q = A_a \rho_{s.m} \tau_g \alpha_r RSI_a - A_r U_l (T_r - T_a) \tag{3.24}$$

$$Q = (4.255L)(0.1598)(960) - (2\pi \times 0.012L)(5.223)(23)$$

$$Q = (198.52L) - (9.0575L)$$

$$2676\ W = 189.46L$$

$$L = 14.08m$$

4.5 Heat transfer calculations

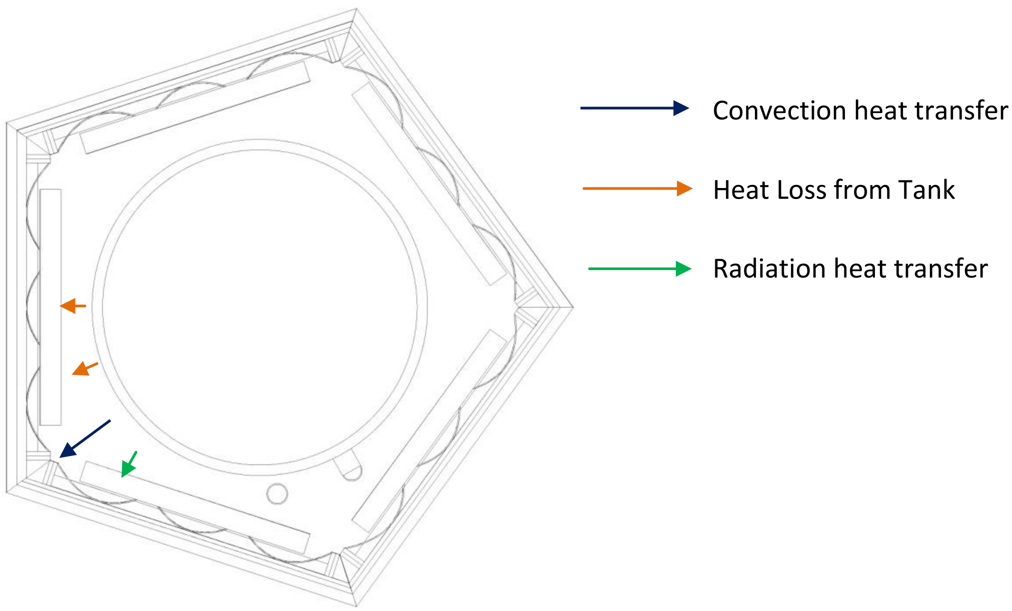

Figure 4.1: Schematic Diagram of Heat Transfer from Tank

Figure 4.1 shows the heat transfer occurs from the water tank. To create a perfect insulated water tank is almost impossible. Some heat loss is occurring during day and night from exposed surface to the surrounding. We need to determine the heat loss from the tank so that a proper insulation material and dimension can be prepared.

4.5.1 Heat loss trough radiation from the tank:

$$Q = \sigma\varepsilon A_c({T_h}^4 - {T_c}^4) \quad (3.27)$$

$$Q = (5.67 \times 10^{-8})(0.05)(0.34)(323^4 - 300^4)$$

$$Q = 4.83W/m^2.K$$

4.5.2 Heat loss trough convection from the tank:

$$Q = -hA(T_h - T_c) \tag{3.28}$$

$$Q = -(40)(0.34)(323 - 300)$$

$$Q = 312W/m^2.K$$

4.5.3 Heat loss from the tank:

$$H = \frac{A(T_h - T_c)}{R} \tag{3.29}$$

$$R = {}^{L}/_{K} \tag{3.30}$$

$$R = {}^{0.3934}/_{0.250}$$

$$R = 1.572$$

$$H = \frac{1.162(122 - 73.4)}{1.572}$$

$$H = 35.93\text{Btu/Hr}$$

$$35.93 \div 3412 = 10.6\,W$$

4.6 Parabolic Trough Collector

To fit the dimension of the improved solar water heater, a parameter of the solar collector need to be determined. Using equation for determining the dimension of the reflector, we calculated the parameter. The parameters are shown in table 4.2 and the result illustrated in figure 4.2.

Table 4.2: Cylindrical Parabolic trough collector dimension

Cylindrical Parabolic Trough Collector	
Input	
Width, w	100 mm
Depth, d	23.148 mm
Output	
Focus Length, f	27 mm
Arc Length, L_{arc}	130.256 mm

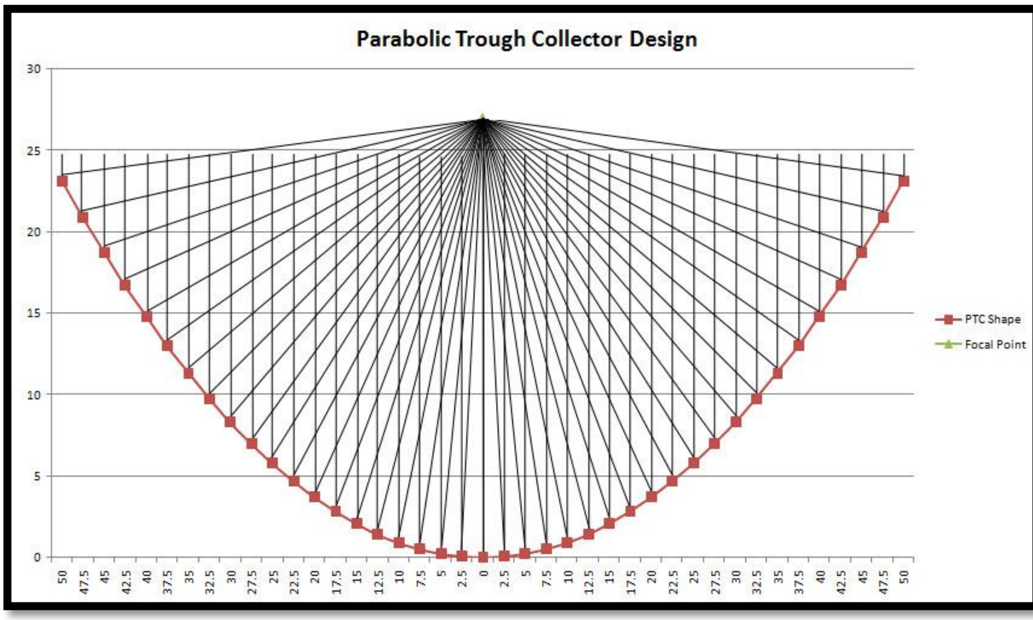

Figure 4.2: Cylindrical Parabolic Trough Collector Design

4.7 Prototype of solar water heater

The improved solar water heater is consisting of several parts that combine a solar collector and then hot water storage in a same unit. This prototype is a scaled down model from the actual design. Only one layer of the solar collector is fabricated just to show the working concept and the design workability of the prototype.

4.7.1 Full assembly

The improved solar water heater is designed for a family of 4 members that consists of a parent and two children. 5 panels per layer are assigned to the solar water heater for optimization of space. The prototype is separated into 4 major parts which is solar collector, insulation material, water tank and base of the tank. The prototype is shown in figure 4.3.

Figure 4.3: Fabricated Prototype

4.7.2 Water tank

The water tank as shown in figure 4.4 is used to store the hot water that been heated using solar energy. The tank is made from an aluminum sheet. A rock wools fiberglass is used as insulation material to insulate the tank. The insulation material is used to reduce the heat loss from the water tank itself. The reflective foil on the tank is used to reduce the heat by convection and radiation heat transfer.

Figure 4.4: Hot Water Storage Tank

4.7.3 Solar collector

The solar collector is used to harvest solar energy at the surrounding. The plate has solar reflector, copper tube absorber, fiberglass insulation and piping system installed on it. The solar reflector will reflect the solar radiation and concentrate it to the copper tube and it will heated up the heat transfer fluid in it.The parabolic solar collector is shown in figure 4.5.

Figure 4.5: Solar Collector

4.7.4 Fluid flow system

A pump is like a heart to all the solar water heater system. A small pump is installed to circulate the water and make sure the heat is uniformly distributed among the fluid in the copper tube. A rubber tube connects all the copper tube to make it one continuous line of fluid flow for heat collection. The fluid is flow using a pump that located inside the water tank. The piping system can be seen in figure 4.6.

Figure 4.6: Piping System

4.8 Material selection

A detail research have been made to identify a suitable material used for prototype of this project. Selection of materials need to be carefully done in order for a good final result during the testing stage. Figure 4.7 shows the material selection for the solar collecctor

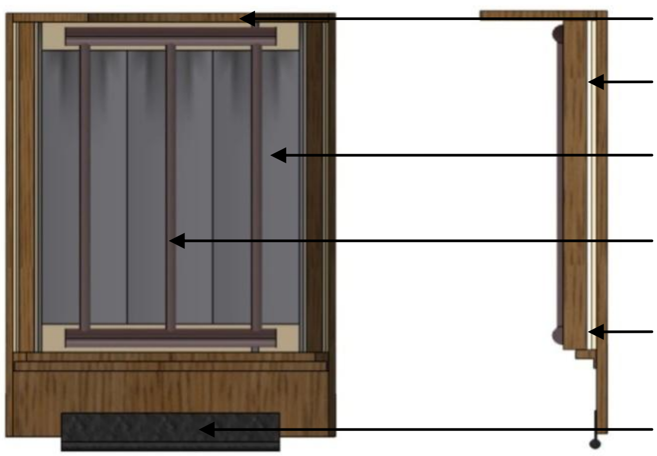

Figure 4.7: Layer of Solar Collector

In figure 4.8, open position solar water heater is shown with some material labeling.

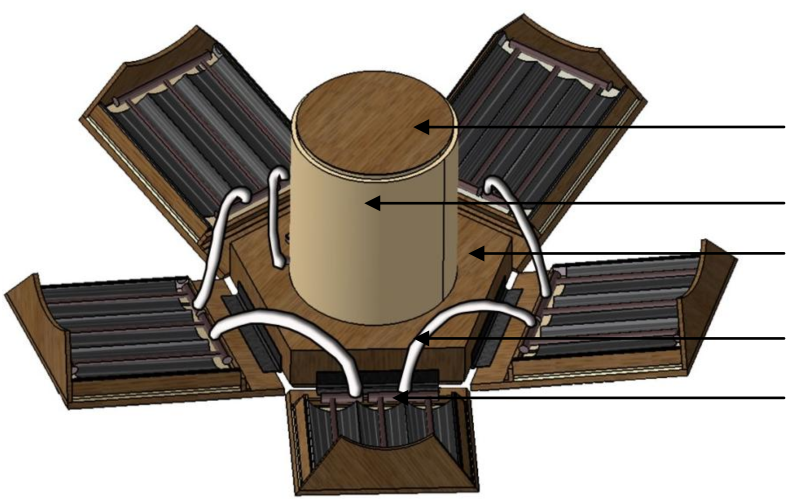

Figure 4.8: Open positioned of solar collector

Figure 4.9 shows the closed position of solar water heater in closed position and the material used for the layout is wood.

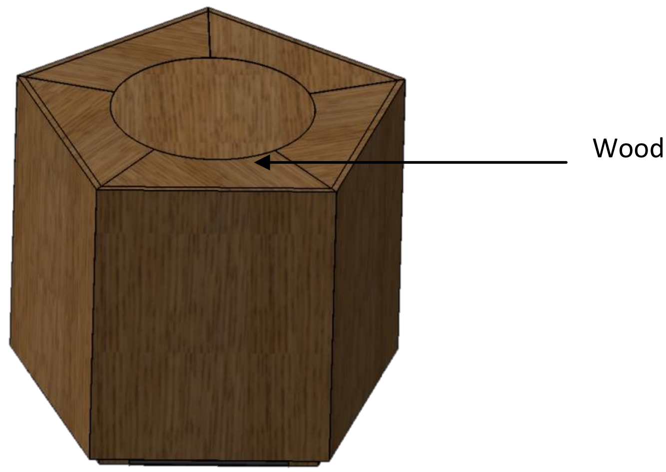

Figure 4.9: Closed position of solar water heater

4.9 Prototype testing

From the data gathering done during testing the prototype, an analysis has been made and the graph below shows the result of the experiment. The data gather at 5th October 2010 from local time 0800 to 1700. The main objective of the testing is to gain understanding on the relationship between the variables. The following graphs will display the relationships between several variables (Solar radiation, ambient temperature, outlet temperature, copper tube surface temperature, and storage water temperature) with a constant water flow of 0.09 L/s. Figure 4.10 and 4.11 shows the relations between solar radiation and water tank temperature versus time in hours. In figure 4.12 and 4.13, it shows the temperature variations at day and temperature of water tank during off solar hour.

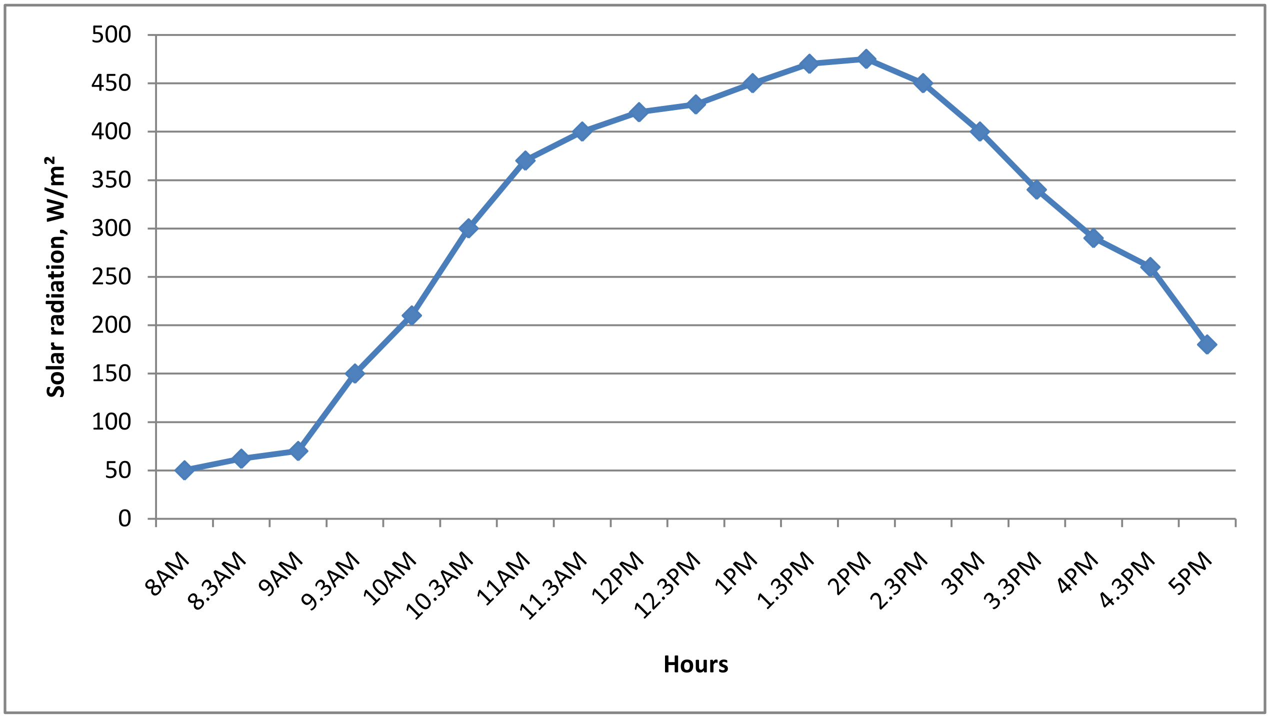

Figure 4.10: Graph of solar radiation distribution

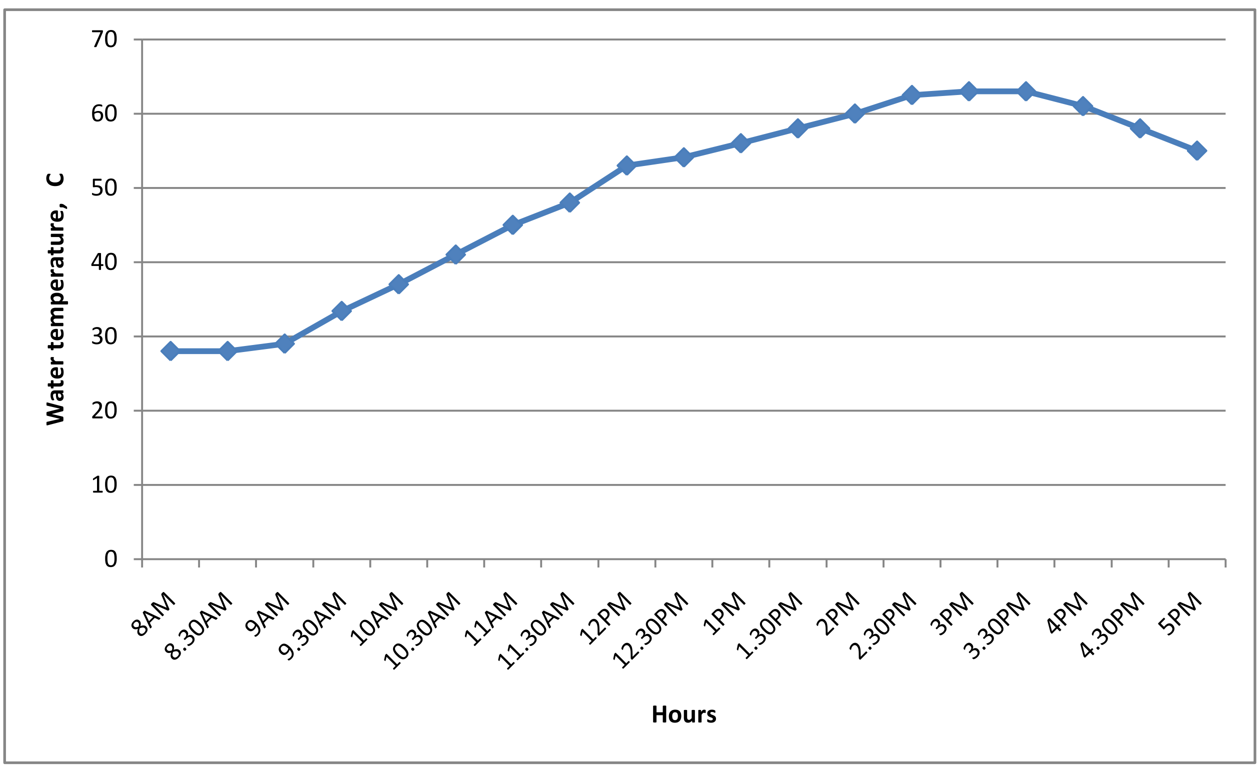

Figure 4.11: Graph of water tank temperature variation

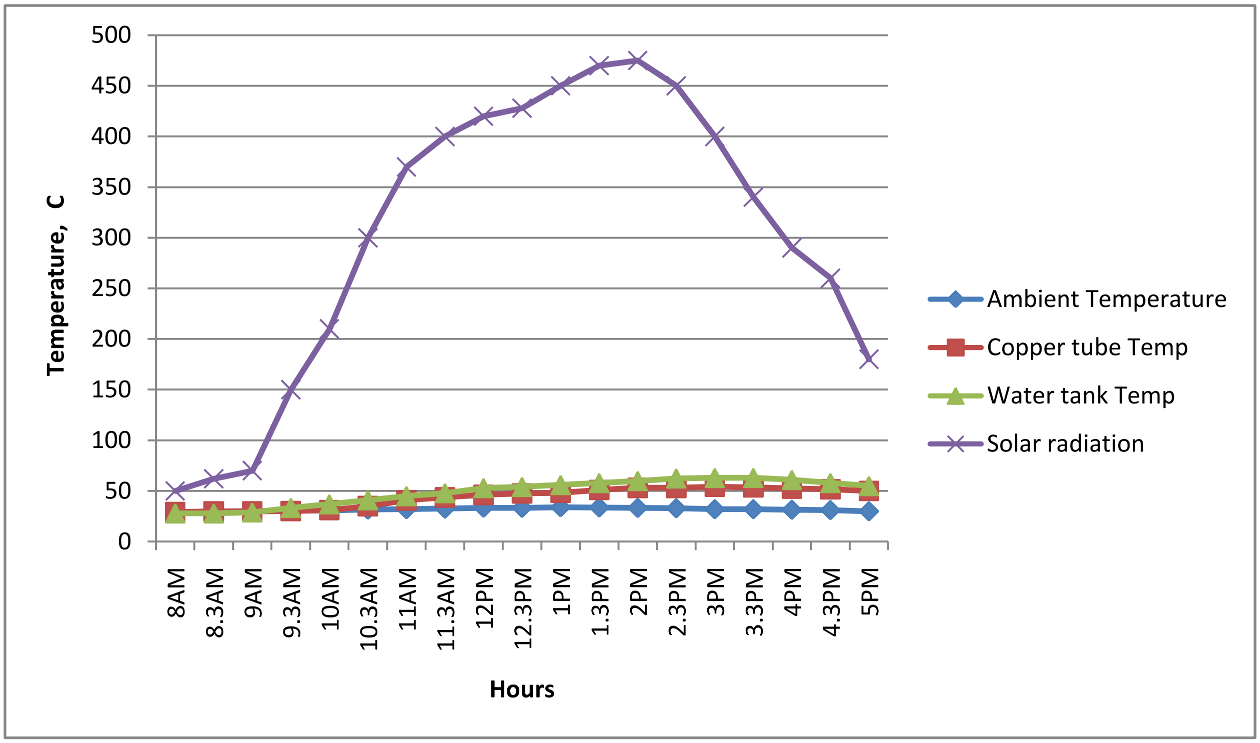

Figure 4.12: Graph of overall temperature distribution

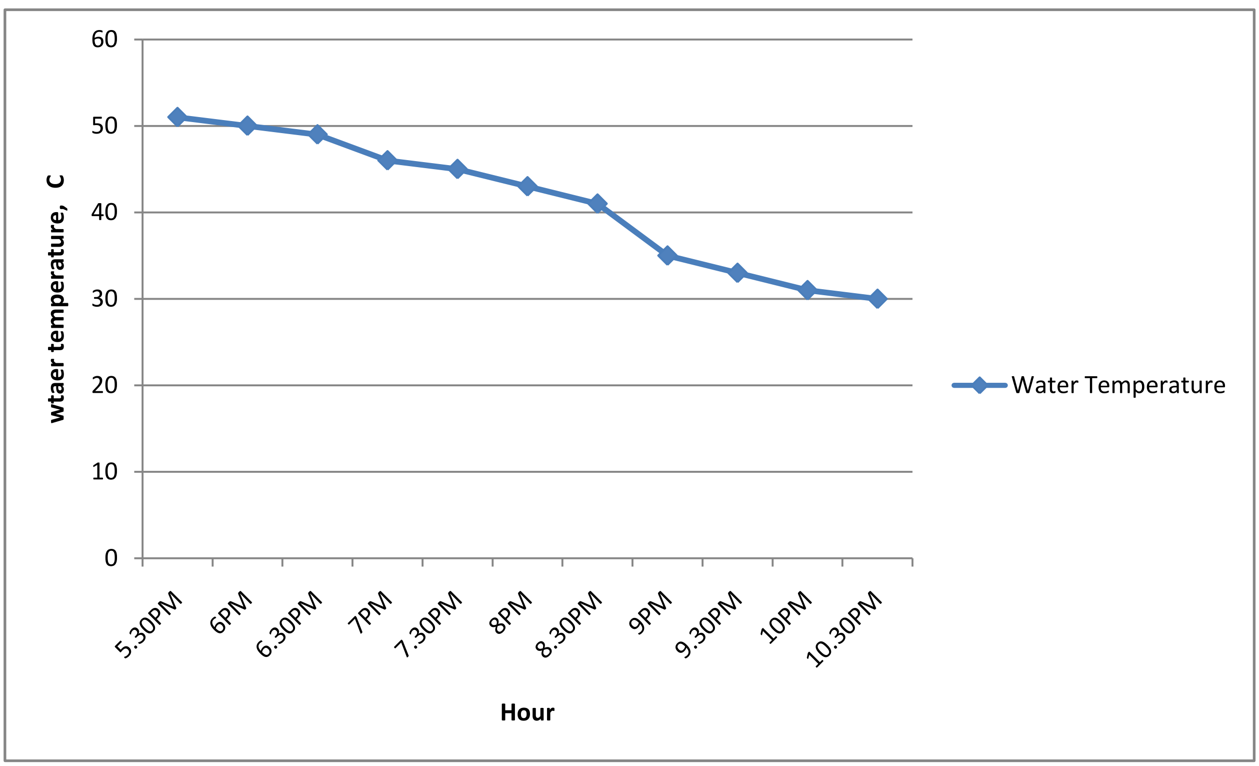

Figure 4.13: Graph of water temperature during off solar hour

4.10 Discussions

The graph shows that the maximum water temperature gained from sun is at 1430 hours when the solar radiation is at its peak. The average water temperature rise is about 5°C per hour. This prototype is able to contain the heat of water for about 3.5 hours before returning to room temperature.From the experimental result that collected, it can be observed that constant value of solar radiation give result in the increasing of the temperature in the water storage tank. From the experiment, we can see that the temperature of water is dependent with the solar radiation to the solar water heater. It can be said from the calculation, the intensity of wind also play an important part in the increase of the temperature of water. The temperature in the water tank can be stored for about 3.5 hours before reaching room temperature. A good insulated tank can increase the time for better heat storage.A glass cover is supposedly used in order to prevent the effect of wind to the copper tube. These two features can be used for better efficiency and performance of the solar water heater.

4.10.1 Efficiency of solar collector

A good solar water heater has average efficiency of 40%. To calculate the efficiency of solar water heater, a formula below is used[11]:

$$solarheatgainperhour = temperatureincperhour \times volume \times area$$

$$solarheatgainperhour = 12 \times 25 \times 0.51$$

$$solarheatgainperhour = 153$$

$$solarenergyavailableperhour$$
$$= area \times solarradiation \times fluxdensityfactor$$

$$solarenergyavailableperhour = 0.51 \ \times 2700 \ \times 0.65$$

$$solarenergyavailableperhour = 890$$

$$efficiency = \frac{153}{890}$$

$$efficiency = 0.18 \ @ \ 18\%$$

CHAPTER 5

CONCLUSION AND DISCUSSION

5.0 Conclusion

The design of innovative solar water heater is successfully done. The working parts are inspired from the mechanism of the flower's petal. CATIA software is used to develop the design and a modeling is done to make sure no interference between all the parts. The project is done according to the timeline prepared at the beginning of the project. Some calculations been made to determine the dimension of the product and also to set the surrounding parameter for the solar water heater. The objective for Final Year Project is to design an innovative solar water heater that can be used to reduce heat loss during off solar hour. The design shown in this project proves that the objective of this project is accomplished. The design is combining parabolic trough collector with a satellite shape open position. This makes the solar energy received is more compared to normal fixed solar water heater. The efficiency of the prototype is 18% which is less compared to the average of 40% efficiency of conventional solar water heater. This may result in the completeness of the fabricated design which can be improved with a right materials and suitable fabrication tools. The final objective of the project is completed by showing it succeeds in achieving a target temperature of 50°C. The maximum temperature that achieved by the prototype is 62°C which is 12°C more than the target temperature.

5.1 Recommendations

Throughout the project, a lot of difficulties is faced and some problem cannot be solved. An improvement can be added to the prototype in order to have a better efficiency and performance. The project right now focuses on static design of the prototype. A tracking device can be installed at the prototype for some improvement. This will give maximum exposure to the solar collector while tracking the position of the sun. An improvement also can be done by replacement to better materials. The reflector is better used as mirror for a higher reflectivity and also includes some glass cover for the solar collectors.

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APPENDICES

APPENDIX A

MOHD NORHAFIZ BIN OTHMAN

Milestone for the First Semester of the Final Year Project (January 2010)

No	Description / Weeks	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of project topic • Choose topic • Topic assigned to student															
2	Research for the subject								Mid semester break							
3	Preliminary research work • Solar water heater research															
4	Submission of preliminary report															
5	Analysis of design parameter															
6	Designing the prototype • CATIA 3D Modelling															
7	Submission of progress report															
8	Seminar															
9	Research of material and specifications • Copper tube and Rockwool															
10	Modeling data in design software • Finalizing the design															
11	Submission of interim report final draft															
12	Oral presentation									During study week						

UNIVERSITI TEKNOLOGI PETRONAS

Milestone for the Second Semester of the Final Year Project (July 2010)

No	Description / Weeks	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project work continues • Building the prototype's body • Welding the copper tube	■	■	■	■				Mid semester break							
2	Submission of Progress Report 1				●											
3	Project work continues • Assembling the parts					■	■	■								
4	Submission of Progress Report 2									●						
5	Seminar									●						
6	Project work continues • Assembling the solar collectors • Prototype testing									■	■	■	■	■	■	■
7	Poster exhibition												●			
8	Submission of dissertation final draft															●
9	Oral presentation									During study week						
10	Submission of Dissertation Hard bound)									7 days after oral presentation						

APPENDIX B

Data Collection

5.10.2010							
Local time (hr)	Flow rate (l/s)	Volume of water (l)	Solar radiation (W/m2)	Ambient temperature (°C)	Copper tube temperature (°C)	Tank Water temperature	Temperature different (°C)
0800	0.09	0.1	50	29	29.2	28	0
0830	0.09	0.1	62	29.8	29.7	28	0
0900	0.09	0.1	70	30.2	29.8	29	1
0930	0.09	0.1	150	30.6	30	33.4	5.4
1000	0.09	0.1	210	31	31	37	9
1030	0.09	0.1	300	32	35	41	13
1100	0.09	0.1	370	32.6	40.7	45	17
1130	0.09	0.1	400	33.5	43.5	48	20
1200	0.09	0.1	420	33.4	46	53	25
1230	0.09	0.1	428	34	47.5	54.1	26.1
1300	0.09	0.1	450	33.8	48	56	28
1330	0.09	0.1	470	33.3	51	58	30
1400	0.09	0.1	475	33	53	60	32
1430	0.09	0.1	450	32	53	62.5	34.5
1500	0.09	0.1	400	32	54	63	35
1530	0.09	0.1	340	31.9	53.5	63	35
1600	0.09	0.1	290	31.5	52.3	61	33
1630	0.09	0.1	260	31.1	51.6	58	30
1700	0.09	0.1	180	30	50	55	27

Closing of the Solar panel							
1730	-	0.1	-	31	50	53	25
1800	-	0.1	-	31.5	48	52	24
1830	-	0.1	-	29.4	47	50	22
1900	-	0.1	-	28.5	45	48	20
1930	-	0.1	-	28	41	46	18
2000	-	0.1	-	28	39	44	16
2030	-	0.1	-	27.1	38	42	14
2100	-	0.1	-	26	36	39	11
2130	-	0.1	-	26	30	34	6
2200	-	0.1	-	25.6	29	31	3
2230	-	0.1	-	25	27	30	2

APPENDIX C

Weather Tabulation on 5th August 2010

Time (hours)	Condition	Ambient Temperature	Dew Point	Humidity	Visibility	Pressure	Wind
0100	Mostly cloudy	28°C	25°C	29%	9.0km	1008.1 → millibars	CALM
0200	Mostly cloudy	28°C	25°C	29%	9.0km	1007.1 → millibars	From E 3km/h
0300	Mostly cloudy	27°C	24°C	32%	9.0km	1006.1 ↓ millibars	From ESE 3km/h
0400	Mostly cloudy	27°C	24°C	29%	9.0km	1006.1 ↓ millibars	From ESE 3km/h
0500	Mostly cloudy	27°C	24°C	29%	9.0km	1006.1 → millibars	From E 2km/h
0600	Mostly cloudy	27°C	24°C	29%	9.0km	1006.1 → millibars	CALM
0700	Mostly cloudy	27°C	24°C	29%	9.0km	1008.1 ↑ millibars	From SE 8km/h
0800	Mostly cloudy	28°C	24°C	26%	10.0km	1008.1 → millibars	From ESE 5km/h
0900	Mostly cloudy	30°C	24°C	21%	10.0km	1009.1 ↑ millibars	From E 11km/h
1000	Mostly cloudy	31°C	24°C	19%	10.0km	1009.1 → millibars	From ESE 10km/h
1100	Mostly cloudy	32°C	25°C	19%	10.0km	1009.1 → millibars	From ESE 10km/h
1200	Mostly cloudy	32°C	25°C	19%	10.0km	1009.1 → millibars	From SSE 10km/h
1300	Mostly cloudy	34°C	25°C	15%	10.0km	1008.1 ↓ millibars	From SSE 10km/h
1400	Mostly cloudy	34°C	25°C	15%	10.0km	1007.1 ↓ millibars	From S 10km/h
1500	Mostly cloudy	35°C	24°C	12%	10.0km	1005.1 ↓ millibars	From S 10km/h
1600	Mostly cloudy	34°C	24°C	13%	10.0km	1005.1 → millibars	From S 10km/h
1700	Mostly cloudy	33°C	24°C	15%	10.0km	1005.1 → millibars	From SSE 14km/h
1800	Mostly cloudy	32°C	24°C	17%	10.0km	1005.1 → millibars	From S 10km/h
1900	Mostly cloudy	31°C	23°C	17%	10.0km	1006.1 ↑ millibars	From SSE 10km/h

2000	Mostly cloudy	30°C	23°C	19%	10.0km	1007.1 ↑ millibars	From SSE 5km/h
2100	Mostly cloudy	29°C	24°C	23%	10.0km	1008.1 ↑ millibars	From ENE 3km/h
2200	Mostly cloudy	29°C	23°C	21%	10.0km	1009.1 ↑ millibars	From NE 2km/h
2300	Mostly cloudy	29°C	25°C	26%	10.0km	1009.1 → millibars	From ENE 2km/h
2400	Mostly cloudy	28°C	25°C	29%	9.0km	1008.1 → millibars	From E 2km/h

APPENDIX D

Relevant Codes and Standards

The use of solar water heating is consistent with administration directives:

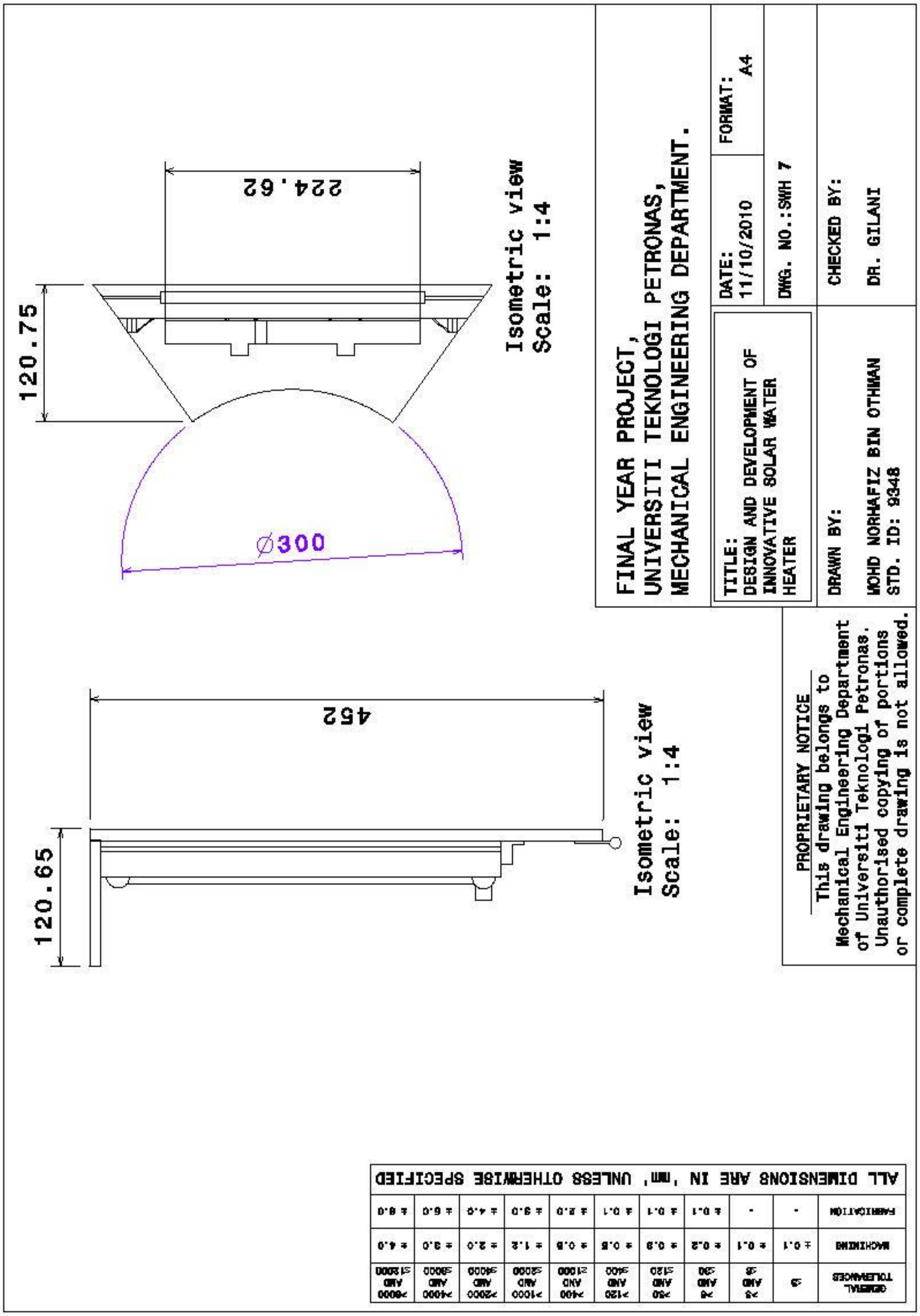
- Executive Order 13423, "Strengthening Federal Environmental, Energy, and Transportation Management"
- Energy Policy Act of 1992 (EPAct) directs agencies to:
    - "include renewable energy [such as solar water heating] along with energy efficiency measures" (Section 542 of the National Energy Conservation Policy Act),
    - "demonstrate new technologies, and include environmental benefits such as reduced greenhouse gas emissions in the criteria by which demonstration technologies are selected" (Section 549),
    - "include recommendations for cost-effective renewable energy projects" (Section 550).
- Energy Policy Act of 2005 (PDF 1.9 MB, 550 pgs)
- The President's Million Solar Roofs Initiative asks agencies to commit to implementing 20,000 solar systems (including solar water heating systems) on Federal Buildings by the year 2010. The Department of Defense has committed to 4085 projects by the year 2000, many of which will be on buildings.

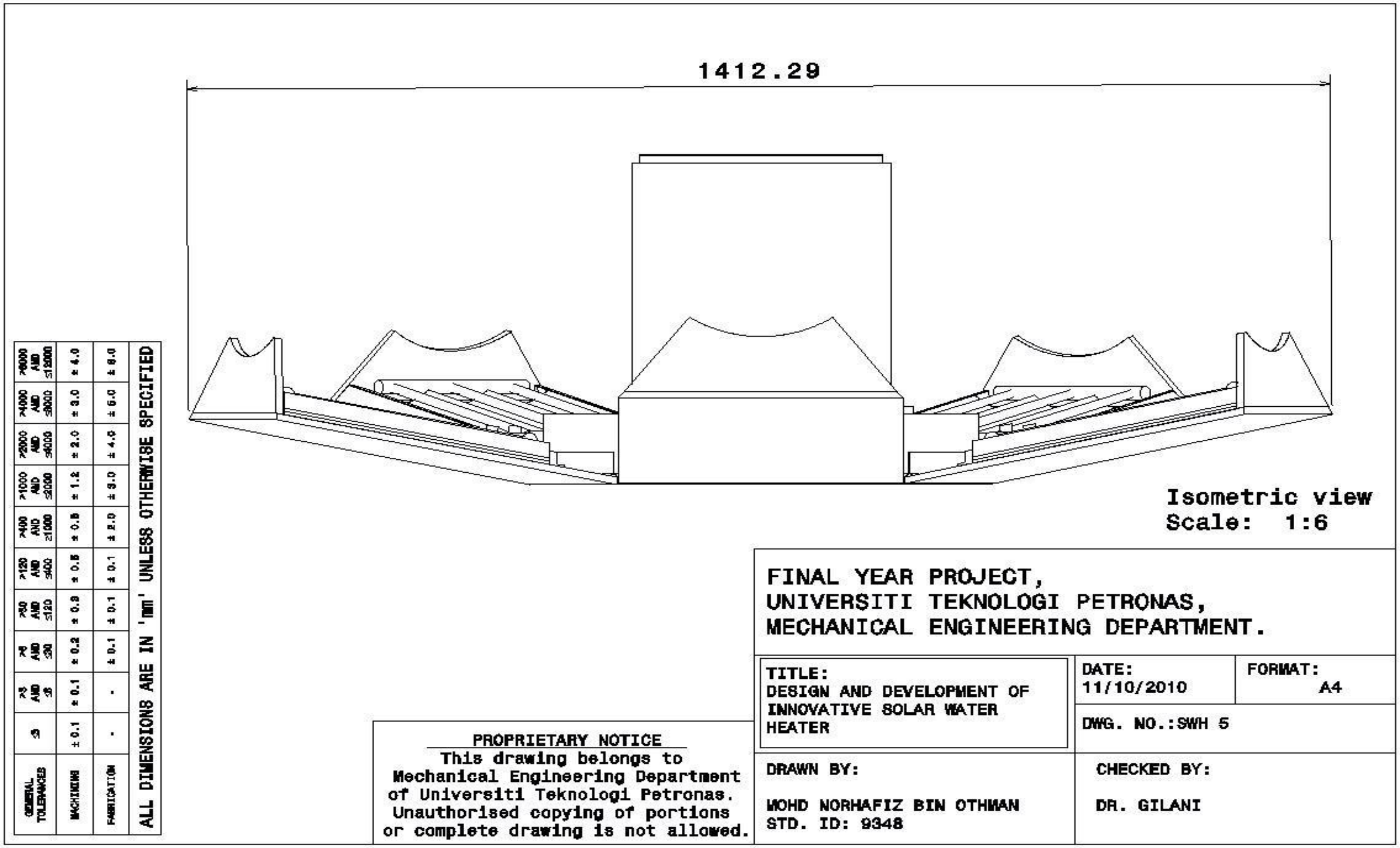
Installation of all solar water heating equipment in conformance with industry standards, including:

- American Water Works Association (AWWA)
    - *AWWA C651 Disinfecting Water Mains*
- ASHRAE
    - *ASHRAE 90003 Active Solar Heating Design Manual*
    - *ASHRAE 90336 Guidance for Preparing Active Solar Heating Systems Operation and Maintenance Manuals*
    - *ASHRAE 90342 Active Solar Heating Systems Installation Manual*
    - *ASHRAE 93 Methods of Testing to Determine the Thermal Performance of Solar Collectors*
- Department of Defense
    - *UFC 3-440-04N Solar Heating of Buildings and Domestic Hot Water*
- Factory Mutual Engineering and Research Corp. (FM Global)
    - *FM P7825 Approval Guide*
- National Fire Protection Association (NFPA)
    - *NFPA 70 National Electrical Code*
- Solar Rating and Certification Corporation (SRCC)
    - *SRCC OG-300-91 Operating Guidelines and Minimum Standards for Certifying Solar Water Heating Systems*

APPENDIX E

Detail Drawings




1412.29
Isometric view
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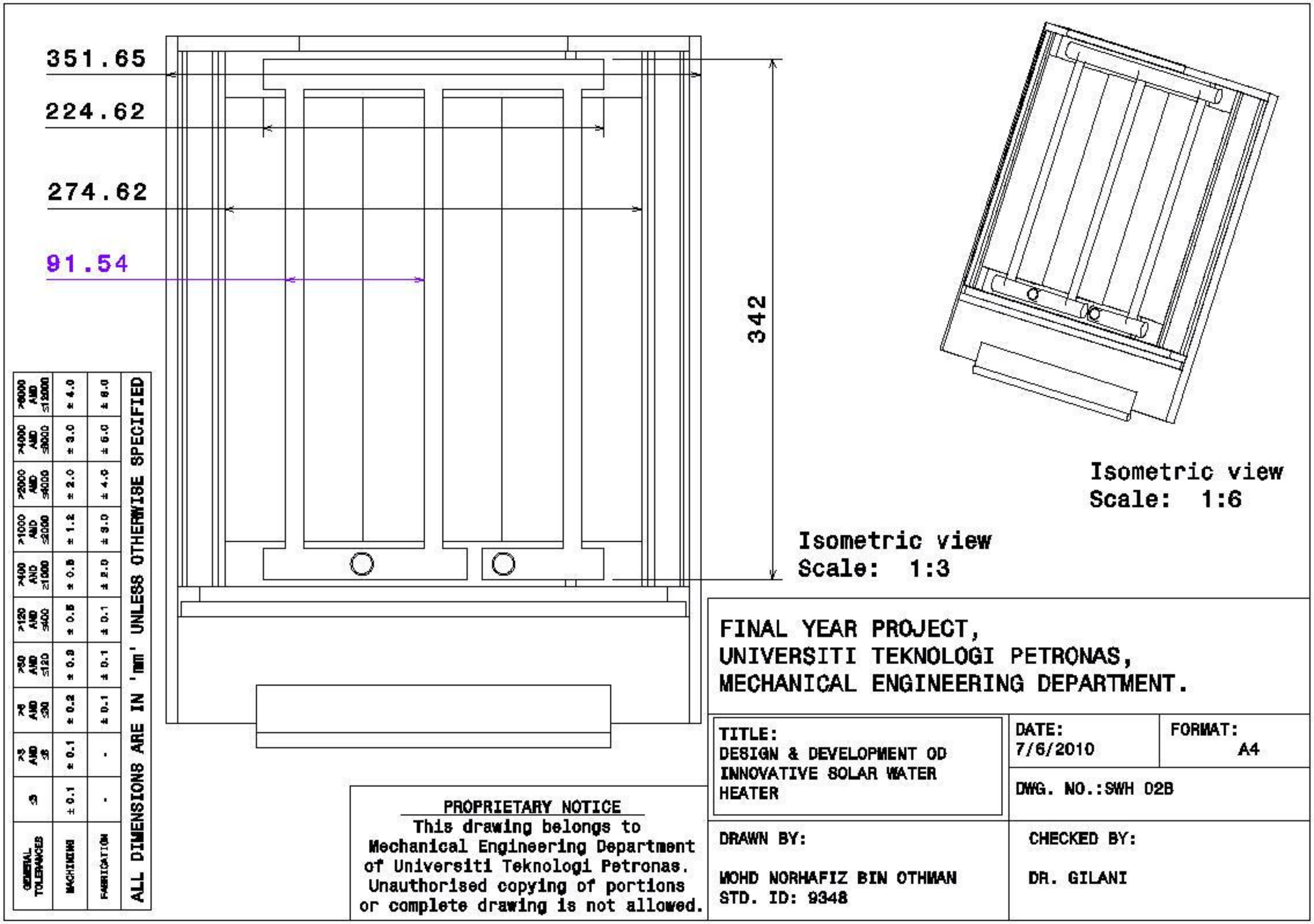
FINAL YEAR PROJECT,
UNIVERSITI TEKNOLOGI PETRONAS,
MECHANICAL ENGINEERING DEPARTMENT.
TITLE:
DESIGN AND DEVELOPMENT OF INNOVATIVE SOLAR WATER HEATER
DATE:
11/10/2010
FORMAT:
A4
DWG. NO.:SWH 5
DRAWN BY:
MOHD NORHAFIZ BIN OTHMAN
STD. ID: 9348
CHECKED BY:
DR. GILANI
PROPRIETARY NOTICE
This drawing belongs to Mechanical Engineering Department of Universiti Teknologi Petronas. Unauthorised copying of portions or complete drawing is not allowed.
GENERAL TOLERANCES
MACHINING
FABRICATION
ALL DIMENSIONS ARE IN 'mm' UNLESS OTHERWISE SPECIFIED


351.65
224.62
274.62
91.54
342
Isometric view
Scale: 1:3
Isometric view
Scale: 1:6
GENERAL TOLERANCES | ≤3 | >3 AND ≤6 | >6 AND ≤30 | >30 AND ≤120 | >120 AND ≤400 | >400 AND ≤1000 | >1000 AND ≤2000 | >2000 AND ≤4000 | >4000 AND ≤8000 | >8000 AND ≤12000
MACHINING | ± 0.1 | ± 0.1 | ± 0.2 | ± 0.3 | ± 0.5 | ± 0.8 | ± 1.2 | ± 2.0 | ± 3.0 | ± 4.0
FABRICATION | - | - | ± 0.1 | ± 0.1 | ± 0.1 | ± 2.0 | ± 3.0 | ± 4.0 | ± 6.0 | ± 8.0
ALL DIMENSIONS ARE IN 'mm' UNLESS OTHERWISE SPECIFIED
PROPRIETARY NOTICE
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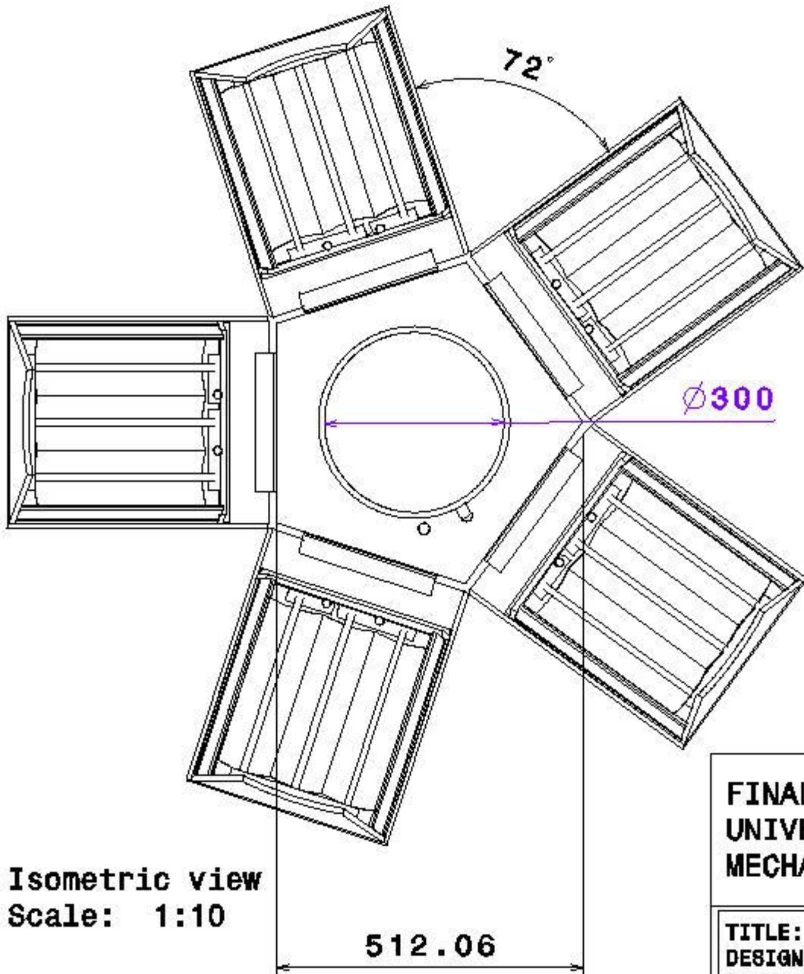
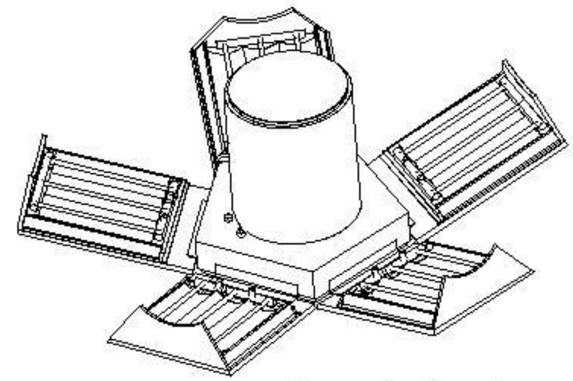
FINAL YEAR PROJECT,
UNIVERSITI TEKNOLOGI PETRONAS,
MECHANICAL ENGINEERING DEPARTMENT.
TITLE:
DESIGN & DEVELOPMENT OD INNOVATIVE SOLAR WATER HEATER
DATE:
7/6/2010
FORMAT:
A4
DWG. NO.:SWH 02B
DRAWN BY:
MOHD NORHAFIZ BIN OTHMAN
STD. ID: 9348
CHECKED BY:
DR. GILANI



Isometric view
Scale: 1:10



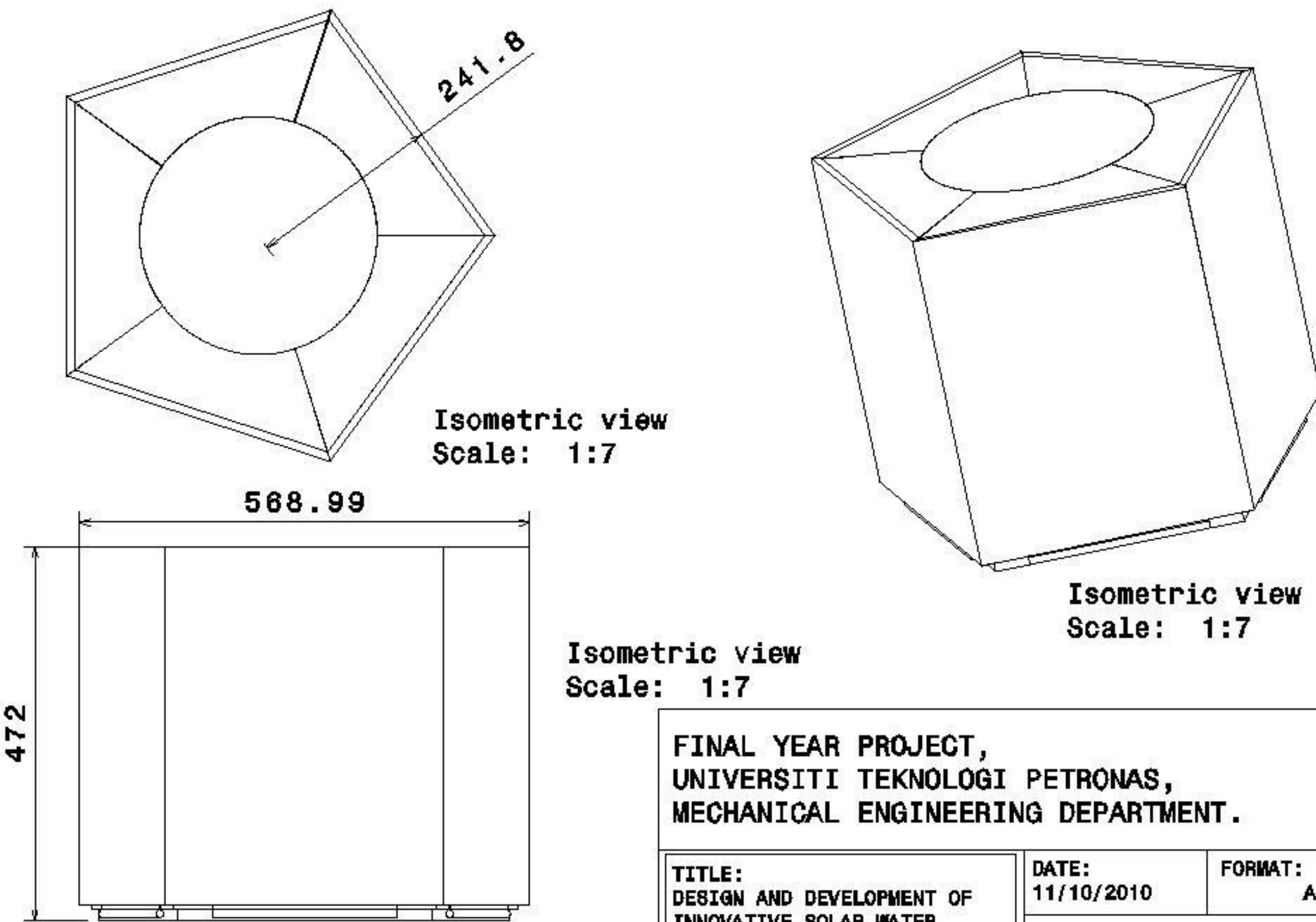
Isometric view
Scale: 1:15

GENERAL TOLERANCES	≤3	>3 AND ≤6	>6 AND ≤30	>30 AND ≤120	>120 AND ≤400	>400 AND ≤1000	>1000 AND ≤2000	>2000 AND ≤4000	>4000 AND ≤8000	>8000 AND ≤12000
MACHINING	± 0.1	± 0.1	± 0.2	± 0.3	± 0.5	± 0.8	± 1.2	± 2.0	± 3.0	± 4.0
FABRICATION	-	-	± 0.1	± 0.1	± 0.1	± 2.0	± 3.0	± 4.0	± 6.0	± 8.0

ALL DIMENSIONS ARE IN 'mm' UNLESS OTHERWISE SPECIFIED

FINAL YEAR PROJECT,
UNIVERSITI TEKNOLOGI PETRONAS,
MECHANICAL ENGINEERING DEPARTMENT.

TITLE: DESIGN & DEVELOPMENT OF INNOVATIVE SOLAR WATER HEATER	DATE: 7/6/2010	FORMAT: A4
	DWG. NO.: SWH 01A	
DRAWN BY: MOHD NORHAFIZ BIN OTHMAN STD. ID: 9348	CHECKED BY: DR. GILANI	

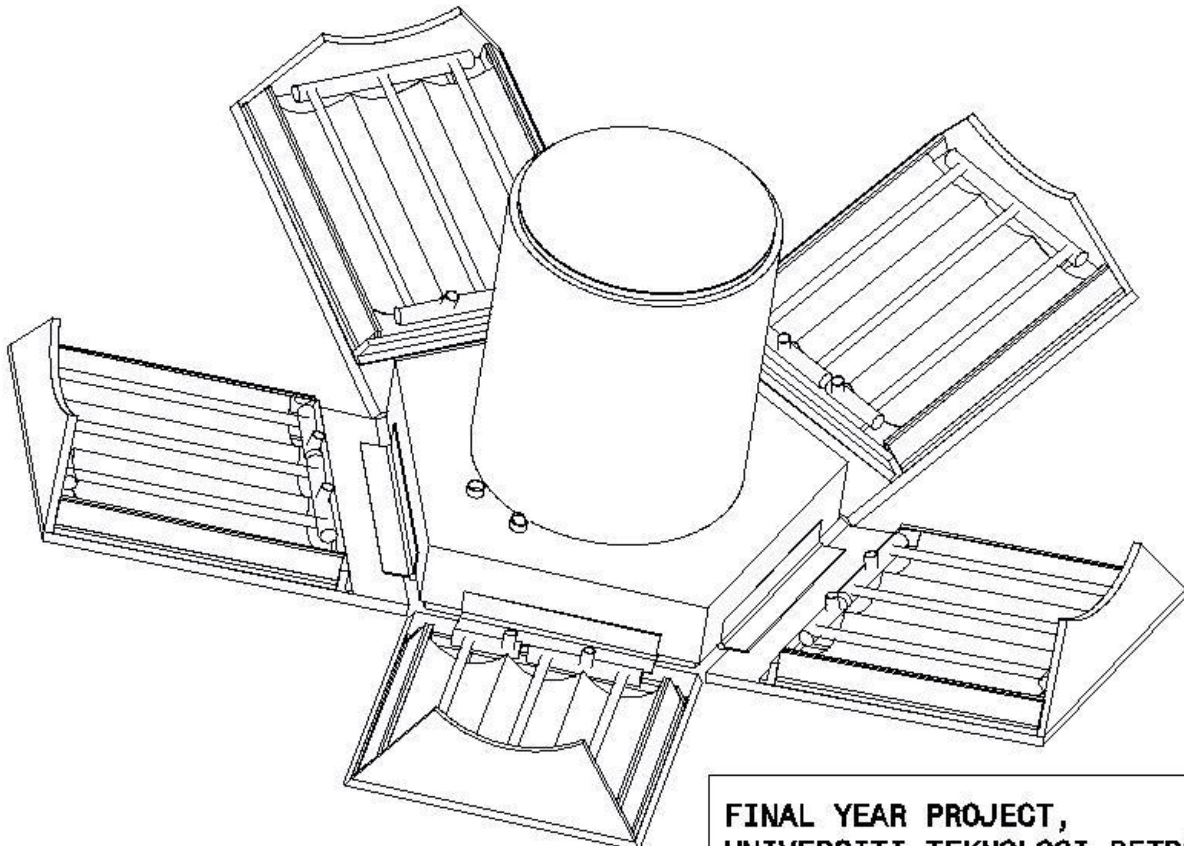


GENERAL TOLERANCES	≤3	>3 AND ≤6	>6 AND ≤30	>30 AND ≤120	>120 AND ≤400	>400 AND ≤1000	>1000 AND ≤2000	>2000 AND ≤4000	>4000 AND ≤8000	>8000 AND ≤12000
MACHINING	± 0.1	± 0.1	± 0.2	± 0.3	± 0.5	± 0.8	± 1.2	± 2.0	± 3.0	± 4.0
FABRICATION	-	-	± 0.1	± 0.1	± 0.1	± 2.0	± 3.0	± 4.0	± 6.0	± 8.0

ALL DIMENSIONS ARE IN 'mm' UNLESS SPECIFIED

FINAL YEAR PROJECT,
UNIVERSITI TEKNOLOGI PETRONAS,
MECHANICAL ENGINEERING DEPARTMENT.

TITLE: DESIGN AND DEVELOPMENT OF INNOVATIVE SOLAR WATER HEATER	DATE: 11/10/2010
	FORMAT: A4
	DWG. NO.:SWH 6
DRAWN BY: MOHD NORHAFIZ BIN OTHMAN STD. ID: 9348	CHECKED BY: DR. GILANI



Isometric view
Scale: 1:7

FINAL YEAR PROJECT,
UNIVERSITI TEKNOLOGI PETRONAS,
MECHANICAL ENGINEERING DEPARTMENT.

TITLE: DESIGN AND DEVELOPMENT OF INNOVATIVE SOLAR WATER HEATER	DATE: 11/10/2010	FORMAT: A4
	DWG. NO.:SWH 1	
DRAWN BY: MOHD NORHAFIZ BIN OTHMAN STD. ID: 9348	CHECKED BY: DR. GILANI	

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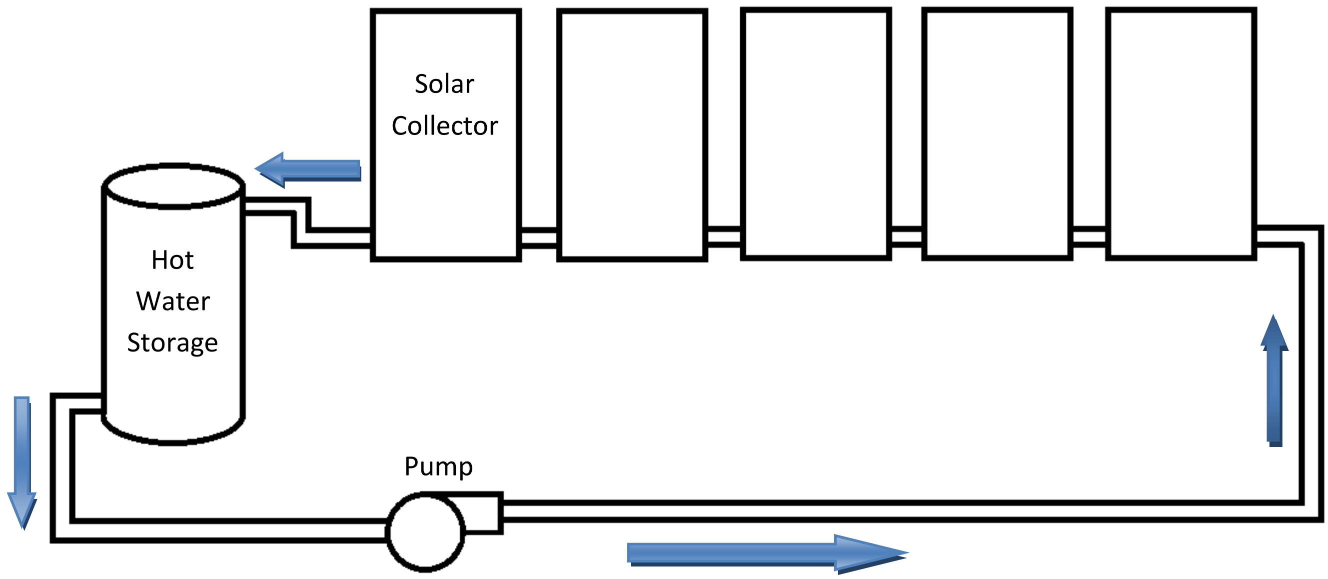
GENERAL TOLERANCES	≤3	>3 AND ≤6	>6 AND ≤30	>30 AND ≤120	>120 AND ≤400	>400 AND ≤1000	>1000 AND ≤2000	>2000 AND ≤4000	>4000 AND ≤8000	>8000 AND ≤12000
MACHINING	± 0.1	± 0.1	± 0.2	± 0.3	± 0.5	± 0.8	± 1.2	± 2.0	± 3.0	± 4.0
FABRICATION	-	-	± 0.1	± 0.1	± 0.1	± 2.0	± 3.0	± 4.0	± 6.0	± 8.0

ALL DIMENSIONS ARE IN 'mm' UNLESS OTHERWISE SPECIFIED

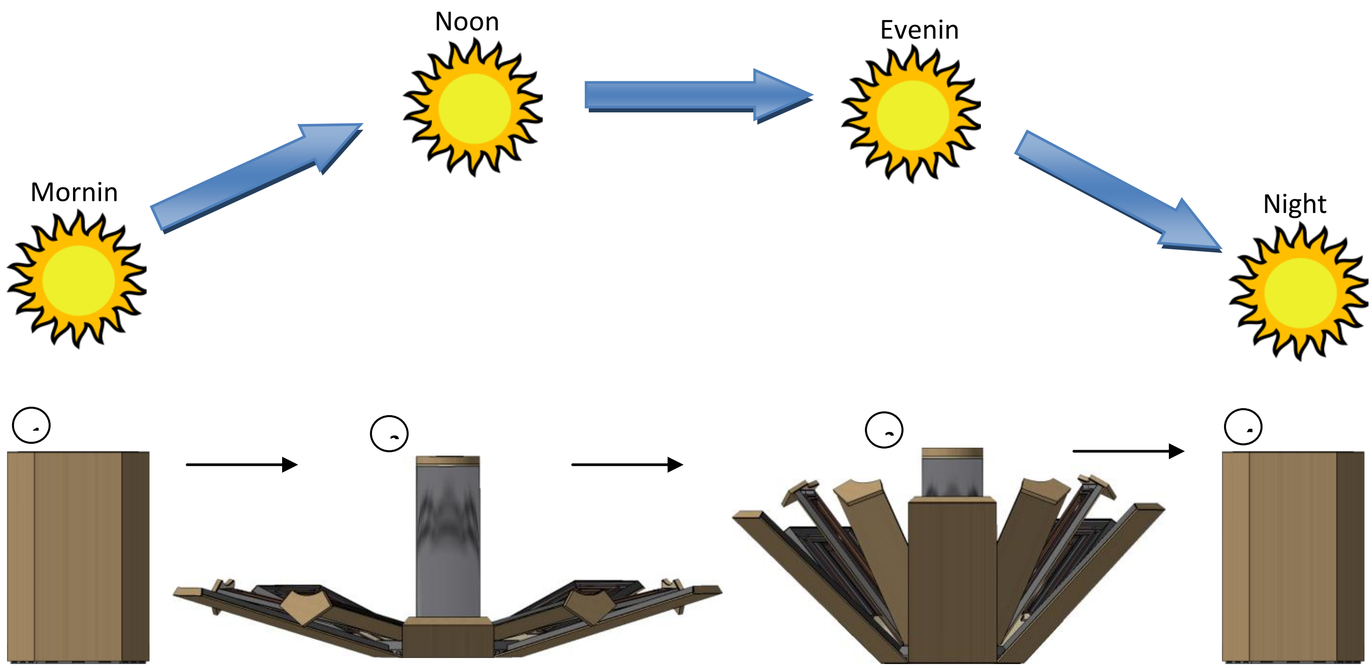
APPENDIX F

Schematic Diagram of The Innovative Solar Water Heater



APPENDIX G

Solar Water Heater Orientation



APPENDIX H

Advantage of Solar Water Heater

- **Conventional Water Heaters Use Energy**

  According to mechanical engineers at the University of Wisconsin's Solar Energy Laboratory, an average four-person household with an electric water heater needs about 6,400 kilowatt hours of electricity per year to heat their water. Assuming the electricity is generated by a typical power plant with an efficiency of around 30 percent, it means that the average electric water heater is responsible for about eight tons of carbon dioxide (CO2) annually, which is almost double that emitted by a typical modern automobile. The same family of four using either a natural gas or oil-fired water heater will contribute about two tons of CO2 emissions annually in heating their water.

- **Conventional Water Heaters Pollute**

  Surprising as it may seem, analysts believe that the annual total CO2 produced by residential water heaters throughout North America is roughly equal to that produced by all of the cars and light trucks driving around the continent. Another way of looking at it is: If half of all households used solar water heaters, the reduction in CO2 emissions would be the same as doubling the fuel-efficiency of all cars.

- **Solar Water Heaters Gaining Popularity**

  Having half of all households use solar water heaters might not be such a tall order. According to the Environmental and Energy Study Institute (EESI), there are 1.5 million solar water heaters already in use in U.S. homes and businesses. Solar water heater systems can work in any climate and EESI estimates that 40 percent of all U.S. homes have sufficient access to sunlight such that 29 million additional solar water heaters could be installed right now.

- **Solar Water Heaters: The Economical Choice**

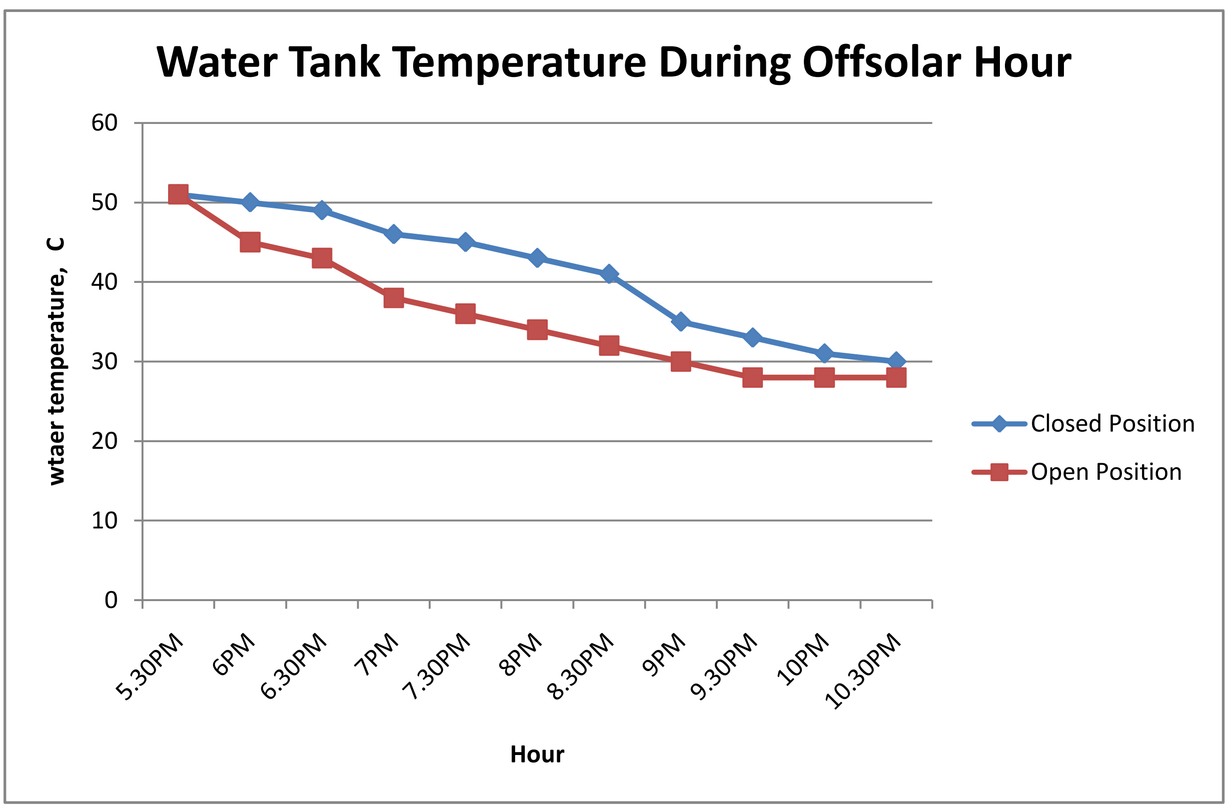
  Another great reason to switch to a solar water heater is financial. According to the EESI, residential solar water heater systems cost between $1,500 and $3,500, compared to $150 to $450 for electric and gas heaters. With savings in electricity or natural gas, solar water heaters pay for themselves within four to eight years. And solar water heaters last between 15 and 40 years--the same as conventional systems--so after that initial payback period is up, zero energy cost essentially means having free hot water for years to come.

What's more, in 2005 the U.S. began offering homeowners tax credits of up to 30 percent (capped at $2,000) of the cost of installing a solar water heater. The credit is not available for swimming pool or hot tub heaters, and the system must be certified by the Solar Rating and Certification Corporation.

APPENDIX I

Data for Open and Closed Position

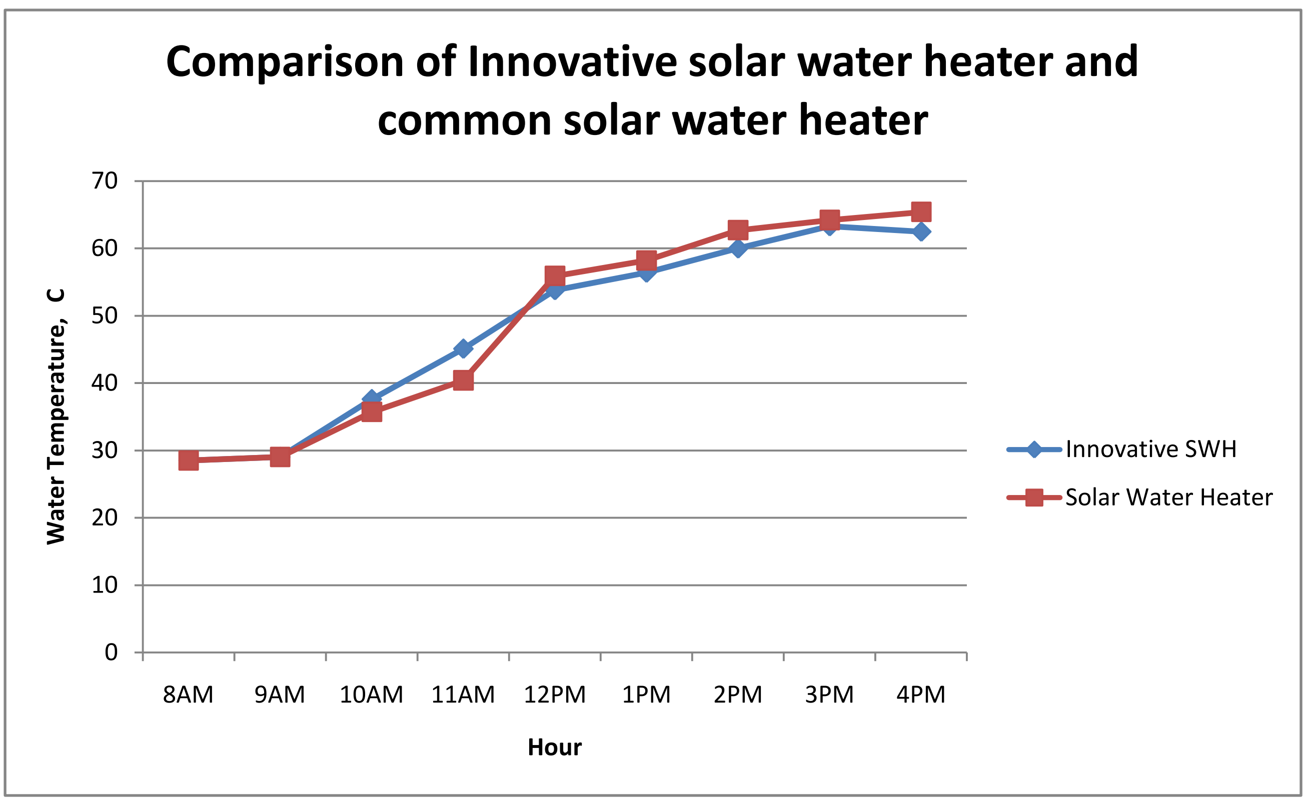
Time (Hour)	Closed Position	Open position
1730	51°C	51°C
1800	50°C	45°C
1830	49°C	43°C
1900	46°C	38°C
1930	45°C	36°C
2000	43°C	34°C
2030	41°C	32°C
2100	35°C	30°C
2130	33°C	28°C
2200	31°C	28°C
2230	30°C	28°C



APPENDIX J

Data for Innovative SWH and common Solar Water Heater

Time (Hour)	Innovative Solar Water Heater	Solar Water Heater
0800	28.5°C	23.5°C
0900	29.0°C	26.1°C
1000	37.6°C	35.7°C
1100	45.1°C	40.4°C
1200	53.8°C	55.9°C
1300	56.4°C	58.2°C
1400	60.0°C	62.7°C
1500	63.3°C	64.2°C
1600	62.5°C	65.4°C



The comparison is made with another solar collector which has a similar solar collector area which is 0.5 m^{2}. Common solar water heater shows a higher maximum temperature because of the fabrication feature of the product. Perspex is installed on the solar collector which caused reduction in heat loss at the copper tube. Compared to the innovative solar water heater, the absence of glass cover caused some heat loss from the copper tube. The reflector that made from steel which have lower reflectivity value compared to mirror also caused the prototype to not be able to achieve higher temperature. Some improvement can be made to give the innovative solar water heater its true potential.

APPENDIX K

Engineering Design Exhibition 26 (EDX 26) Gold Medal Award

Certificate of Appreciation

This certificate is awarded to

MOHD NORHAFIZ BIN OTHMAN

881108-01-5291

for his/her participation as

FINAL YEAR PROJECT

'GOLD'

in recognition of your contribution in the twenty-sixth edition of

UNIVERSITI TEKNOLOGI PETRONAS

Engineering Design Exhibition

held from

25 - 26 October 2010

Dr. Rosdiazli bin Ibrahim
Chairman
26th Engineering Design Exhibition

Assoc. Prof. Dr. Hilmi Mukhtar
Director of Undergraduate Studies
Universiti Teknologi PETRONAS

ENGINEERING DESIGN XHIBITION

EDX
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