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EFFECT OF LOCAL DAILY TIME ON THE STAGNATION TEMPERATURE AT THE FOCAL POINT OF A PARABOLIC CONCENTRATED SYSTEM

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ABSTRACT

Due to the depletion of fuel sources, as the petroleum and natural gas technologies are obsolete, the demand for alternative energy sources grows and increasing, includes the solar energy, wind energy, Hydrogen fuel cell, hydroelectric, geothermal and biomass. It is proved that the usage of petroleum and natural gases as our primary energy sources had brought many major pollution problems to our environment and human life although the price for such petroleum and natural gas products are much cheaper compared to this renewable energy. Solar energy can be categorized as clean technology and environmental friendly. Many research related to solar energy had been carried out. Photo-voltaic (PV), solar thermal and concentrating solar techniques are some example of the area of research. It cannot be denied that the installation, capital and maintenance of these renewable energy devices are quite high, but there are many studies and researches had been carried out on how to minimize the cost. For example, the installation of photo-voltaic set for home package reached thousands. But that is the disadvantage; we can manage it in right way, in term of advantages, such as introducing this solar concentrator. The main objective of this project is to examine the effect of parabolic concentrator as the collector of the radiation from the sun towards the stagnation temperature at the focal point of the parabolic concentrator. This is due to be done by use of a self-made concentrator which can reach temperature until 218^{o}C.

ABSTRAK

Kini, sumber asli seperti petroleum dan gas asli semakin berkurangan dari segi kuantiti dan penggunaannya pula semakin meluas. Atas faktor ini, permintaa terhadap sumber tenaga yang boleh diperbaharui semakin meningkat seperti tenaga solar, tenaga angin, Sel bahan api hidrogen, hidroelektrik, geoterma dan biomas. Penggunaan bahan api berasaskan petroleum dan gas asli jelas terbukti menimbulkan banyak masalah pencemaran terhadap manusia dan alam sekitar, walaupun harga pasaran untuk sumber ini jauh lebih murah jika dibandingkan dengan sumber tenaga yang boleh diperbaharui. Tenaga solar boleh dikategorikan sebagai teknologi bahan api yang bersih dan bebas daripada pencemaran. Telah banayk kajian yang telah dijalankan untuk mengurangkan kos-kos tersebut. Sebagai contoh, kos pemasangan untuk set photo-voltoic boleh mencecah ribuan ringgit. Ianya mungkin dianggap sebagai keburukan, namun uanya boleh diganti dengan alternative lain seperti penggunaan kaedah pengumpulan tenaga solar. Tujuan utama kajian ini dijalankan adalah untuk mengkaji kesan penggunaan parabola pengumpulan tenaga solar sebagai cara mengumpulkan cahaya matahari dalam bentuk haba yang dapat menghasilkan suhu maksima pada titik fokus parabola. Parabola tersebut dihasilkan sendiri dengan suhu maksima mencecah 218^{o}C semasa kajian dijalankan.

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The Sun, which emits electromagnetic radiation with approximately 1367W/m^2 of solar irradiance, is actually a potential great source of radiant energy ranging in wavelengths between 0.3 - 2µm. There are two types of Sun's radiation that is beam radiation and diffuse radiation (Christ Newton, 2003). By using flat surface collector, such as Photo Voltaic (PV) and solar cell, these beam and diffuse radiations can be obtained. On the other hand, by using concentric type, for example parabolic concentrator, focusing mirror, or semi-cylindrical (trough) concentrator, only beam radiation will be collected.

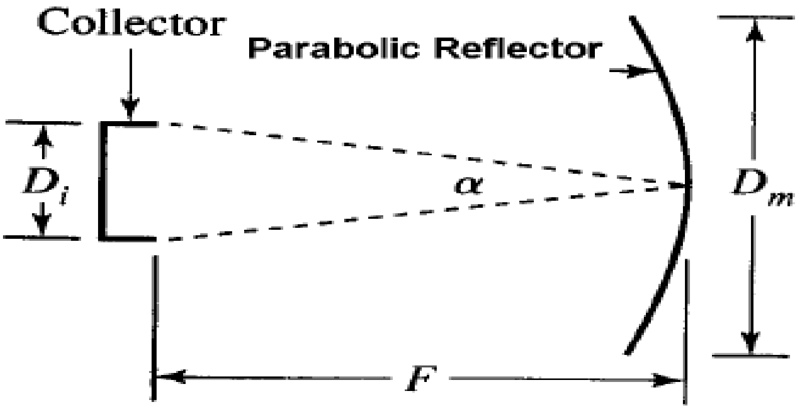

Figure 1.1: Parabolic concentrator theory (Christ Newton, 2003)

D_m represents dimension of the collector, while F refers to its focal length. The idea behind this study is basically, to collect the radiation of the Sun on the parabolic concentrator and focusing it towards a focal point that will produce sufficiently high temperature which is called stagnation temperature. Heat will be generated at the focal point and it can be transferred through a fluid and then converted either to electrical energy directly, or to the intermediate mechanical movement such as pistons that later produces electricity. This technology had been discovered 1000AD ago by Abu Ali Al-Hasan Al- Haitham, with the development of focusing mirror, followed by Father Athanasius Kircher, during 1640s in Rome, which had proved that sunlight could be concentrated to a point to ignite fire. This technique had been widely practiced and applied around 1700s, especially German burning mirror that used to set fire to a pile of wood from a distance (Newton Christ, 2003).

1.2 Problem Restatement

The demand for alternative source of energy that replacing the petroleum based energy increasing year by year in all around the world. This demand is forcing researchers and engineers to strive for higher quality in all aspects of energy sources.

However, instead of looking for other types of alternative sources of energy, there is a problem that we need to look at, which is how to decrease the costs of this renewable energy thus maintaining the increasing demands and overall cost of the alternative energy source. With the abundance of Sun's radiation in Malaysia, peoples should make use of it in right manner and not waste it. Thus, it is important need to study the effectiveness of the solar energy alternatives, especially this low cost parabolic concentrator and its output power generation and decrease the dependence on the petroleum source fuel from now on.

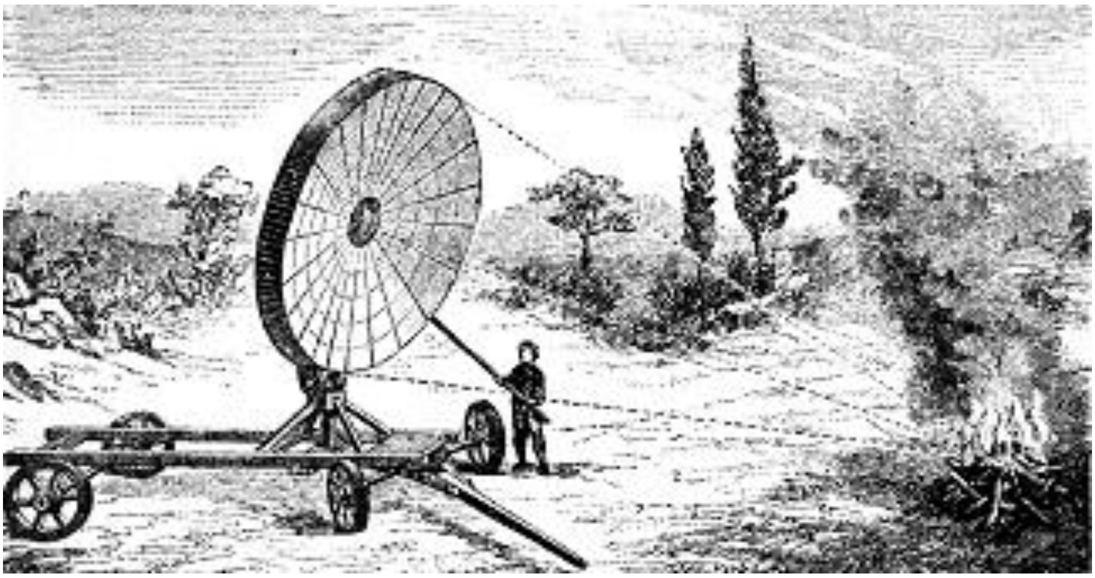

Figure 1.2: Picture of 'German burning mirror' around 1700s (Newton Christ, 2003)

1.3 Objective of the Study

The objectives of this study are:

i) To determine the stagnation temperature at the focal point of parabolic concentrator and collecting those stagnation temperature data for at least 30 days. Before all of these can be done, the parabolic concentrator must be constructed.

ii) To study the solar time, which is time for the Sun starts to rise until it is disappearing.

1.4 Scope of the Study

The scopes of this study are:

i) To design and develop the solar parabolic concentrator
ii) To collect the data stagnation temperature at the focal point of the parabolic concentrator
iii) To determine the temperature profile of the parabolic concentrated

1.5 Significance of the Study

The findings of this study are important to help researchers and perhaps Malaysian realizes that the source of light and heat from the Sun are abundance and it will be useless if the solar energy do not applied and make use of it in the right manner. This research needs to be carried out because Malaysia are still depends on petroleum-based fuel as the main source for generation of electricity and depletion phenomena of this kind of sources would be affect much in many sectors that depends and using a lot of petrol, diesel, kerosene and so on. With the results and some useful information at hand, many studies and experiments could be planned for the future. For example, application of the collected heat in industry or domestic building, conversion of the collected heat into another form of energy such as electricity, and cooking by using solar concentrator. Moreover, Malaysia receives abundance of solar irradiation throughout a year. Awareness among the Malaysian about the solar technologies and abundance of the solar irradiance in Malaysia must be increased and thus the optimum electrical costs and application can be optimized by using solar technologies.

CHAPTER 2

LITERATURE REVIEW

2.1 Solar Energy Alternatives

It is estimated that huge amount of energy, which is $3.47x10^{24}$ kJ per unit time produced by nuclear fusion reaction at the Sun and only small fraction of it irradiated to the Earth's surface, which is about $5x10^{-11}$ kJ (Zekai Sen, 2008). It cannot be denied that the solar energy is a clean technology, undepletable and harmless to all creatures in the Earth.

As Malaysia receives abundance sunshine all year long, solar energy has been identified as one of the most potential alternative energy resources, with monthly average daily solar radiation is 4000 - 5000 W.hr/m^2 and monthly average daily sunshine duration ranging from 4 hr to 8 hr (Sopian and Othman, 1992).

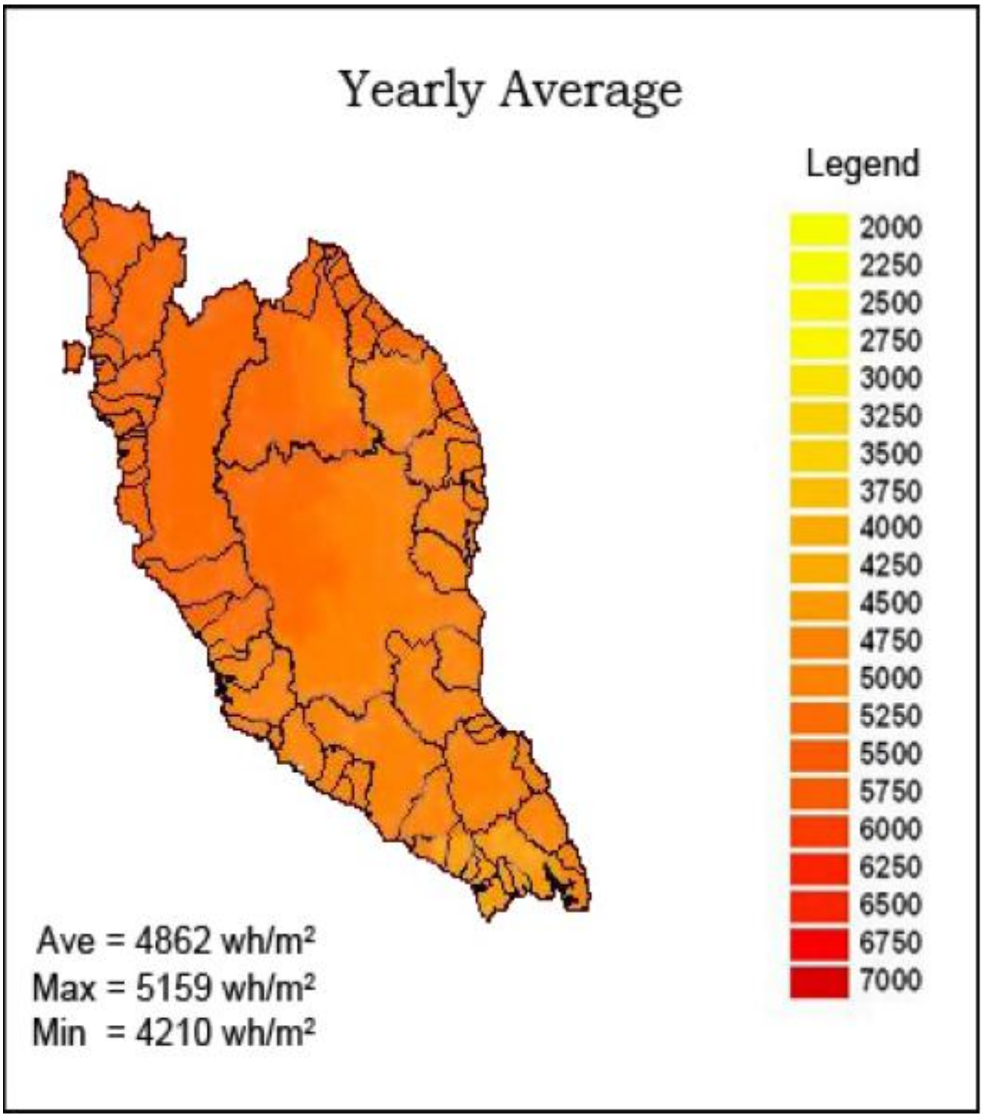

Figure 2.1: Yearly average daily solar radiation for Peninsular Malaysia (Sopian, 2006).

On average, Malaysia receives about 4.862kWh/m^2 of solar radiation in a year, the maximum solar radiation receive is 5.159kWh/m^2 mostly in Northern region of peninsular Malaysia, meanwhile the Southern and Northeast region of Peninsular Malaysia receives the lowest average solar radiation (Sopian, 2006).

2.2 Theory of Heat Transfer Principle

Generally, heat is transferred from high temperature body to the low temperature body, which not all the heat are perfectly transmitted. Although the bodies are well insulated, there are still chances for the heat to be not just absorbed, but either reflected or transmitted to somewhere else. The following energy conservation equation explains how the total amount of radiated energy must be considered through absorption, transmission and reflection processes.

$$G_{abs} + G_{tr} + G_{ref} = G, \quad \alpha + \tau + \rho = 1$$

G is the incident radiation, α is the absorptivity, τ is transmissivity and ρ is reflectivity (Christ Newton, 2003). Each mode of radiation takes a fraction of the incident radiation and combination of these modes would yield unity. These three dimensionless constants are properties of any materials.

For an opaque body the transmissivity, τ value is equals to zero and the remaining coefficient transfer all radiation (Geankoplis, 2003). In order to search the material that would be used as reflector of the parabolic concentrator, bear in mind that the reflectivity of the material must high and can adhere to the parabolic shape, on the other hand, the heat absorber must have lower reflectivity value.

Generally, metals have high conductivities, which metals can transmit large amount of radiation under small temperature gradient (Zekai Sen, 2008). On the other hand, there are conditions where small amount of radiation is conducted under large temperature gradient, such solids known as insulator, for example plastic, sponge and cotton. Some of materials and its conductivity value are shown in Table

2.1 below. Currently, there are two options to achieve the goals. First is reducing the heat loss to surrounding, second is more adaptive option that is increase the incident solar radiation, hence increase the heat absorbed per unit area (Christ Newton, 2003).

Table 2.1: Selected materials and its conductivity value, k (Zekai Sen, 2008)

Material		**k (W/m^{0}C)**
Metals	Copper	385
	Aluminium	205
	Steel	50
Non-metals	Glass	0.8
	Concrete	0.8
	Wood	0.14
	Saw-dust	0.06
	Rock wool	0.04
	Polystyrene (expanded)	0.03
	Glass fiber	0.03
Liquids	Water	0.61
Gases	Hydrogen	0.142
	Helium	0.142
	Air	0.0239

2.3 Radiation Mechanism

Generally there are three basic mechanisms of heat transfer and may occur by any of these three of perhaps more, which is conduction, convection and radiation. Conduction occurs when heat is transferred from one part of a body to another, and involved material is heated. In convection, heat is transferred by the actual mixing of materials and by conduction. Both conduction and convection needs medium in order to transfer the heat, meanwhile radiation does not depend on medium to propagate but involving energy transfer through space by means of electromagnetic waves (EM) (Geankoplis, 2003). Basic equation for heat transfer through radiation from a perfect black body with an emissivity ε=1.0 is given by;

$$Q = A\sigma T^4$$

Q is the heat flow, A is the surface area, σ is Stefan's constant $5.676\text{x}10^{-8}$ $W/m^2.K^4$ and T is temperature. Emissivity can be defined as ratio or fraction of emissive power of a surface to the black body, while absorptivity refers to the fraction absorbed (Geankoplis, 2003). When heat is transferred by mean of radiation mechanism from surroundings to an object, Stefan-Boltzmann equation are predominant, which is;

$$Q = A_1\,\varepsilon_1\sigma T_1^{\,4} - A_1\alpha_{12}\sigma T_2^{\,4}$$
$$= A_1\sigma\,(\varepsilon_1 T_1^{\,4} - \alpha_{12}T_2^{\,4})$$

The α_{12} is absorptivity of body 1 for radiation from the enclosure at T_2, and its value is approximately the same as the emissivity of this body T_2 (Geankoplis, 2003).

One of the most common and important radiation mechanisms can be referred to heat transferred from the Sun to the Earth. Heating of fluids in coils of tubing inside a combustion furnace, cooking of food when passed below red-hot electric heaters, loaf of breads in an oven absorbs radiation from the wall around it, packages of meat or food that radiating heat to the surrounding walls of freezing enclosure and hot ingots of solid iron cooling and heat also radiates to the surrounding wall of a large room are some of applications of radiation mechanism in our daily life (Geankoplis, 2003). The polished metal surfaces having low value of emissivity ε, which is similar to absorptivity, meanwhile high value of ε for oxidized metal surfaces since value of emissivity ε and absorptivity α of an object, are the same at the same temperature (Geankoplis, 2003).

It is necessary to know how the power density will change during day at the site concerned, in order to design solar energy powered device. It is also important to take into account the tilting of the collector surface with the horizontal axis. Most often, amount of direct radiation are significant in solar engineering device designs. The relative proportion of direct radiation to diffuse radiation depends on meteorological conditions, surroundings and day of the year (Zekai Sen, 2008).

Most materials used in building construction radiate about 90% of the theoretical maximum for a given temperature, which is referred as having high value of emissivity, 0.9. It shows that amount of radiation is depend on the emissivity of a body, and strongly dependent on temperature of the radiating body, then on the destination of the radiation (Zekai Sen, 2008).

2.4 Stagnation Temperature, T_{st}

One of an inexpensive method for determining the changes in collector performance resulting from the material properties is the investigation of the performance of the parabolic concentrator at its stagnation temperature. At certain temperature of the parabolic concentrator where, the system achieves its maximum temperature and no useful energy is being collected for constant solar intensity is called stagnation temperature. The thermal performance of the parabolic concentrator is strongly influenced by stagnation temperature of the receiver or absorber surface, and this is one of important fundamental characteristic of the parabolic concentrator (Palavras, 2006).

The energy balance for the receiver or absorber is given by;

$$Q_u = A_p I(\rho\alpha)_{eff} - U_L(T_{st}-T_a)A_r$$

At stagnation temperature, where is no useful heat collected, $Q_u = 0$,

$$U_L = \frac{CR\ I\ (\rho\alpha)_{eff}}{T_{ST} - T_U}$$

Q_u is useful energy colected, A_p aperture area of the parabolic concentrator, I is the solar intensity, $(\rho\alpha)_{eff}$ is effective absorbance-reflectance product, U_L is overall heat loss coefficient, T_{st} is the stagnation temperature, T_a is ambient temperature, A_r is receiver or focal image area and CR is the concentration ratio (Palavras, 2006).

2.5 Concentration Ratio, CR

Another parameter which plays an important role in effectiveness of a solar parabolic concentrator is Concentration Ratio, CR. The Concentration Ratio CR is defined as the ratio of the collector area to the focal area (Christ Newton, 2003). The maximum concentration ratio for a circular collector is given by the following equation:

$$C_{max} = \frac{A_{Collector}}{A_{Focal\ Point}}$$

The maximum concentration ratio C_{max} for a circular parabolic collector is 45,000 (Christ Newton 2003). The purpose of calculating this parameter is to match with the following graph, which relates the calculated concentration ratio to receiver temperature. This step is a critical, in fact, to find out the limit of highest stagnation temperature that can be obtained by certain value of receiver and collector areas.

From the graph actually, if higher stagnation temperature is required, thus the collector must be designed to have large surface area and/or reducing the size of focal point, which referred to the heat absorber.

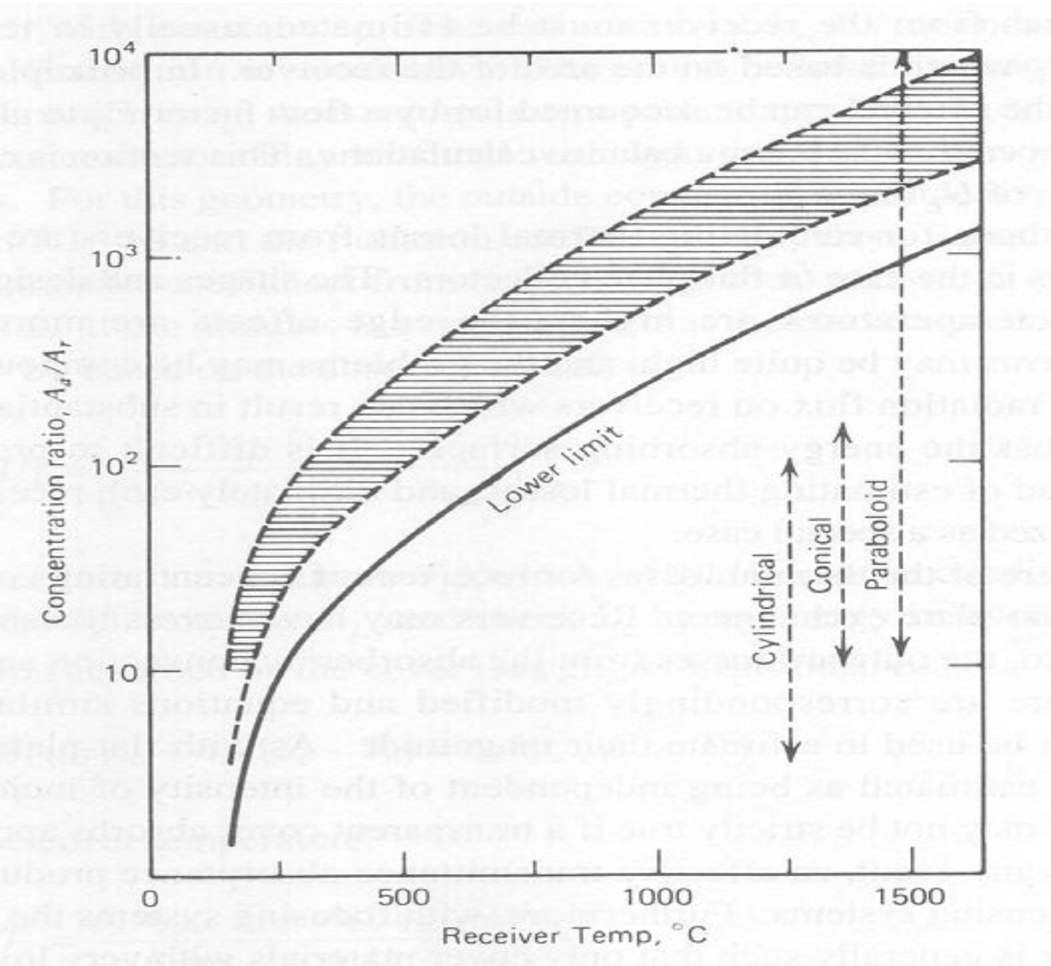

Figure 2.2: Concentration Ratio versus Receiver Temperature

2.6 Parabolic Concentrator description

2.6.1 Parabolic shape

Parabola is defined mathematically as a conical section with intersection of a right circular conical surface and a plane parallel to a generating straight line of the conical surface. There are several parameters that describing the shape and equation of the parabola is the focal point F, vertex V and a directrix line L (http://en.wikipedia.org/wiki/Parabola).

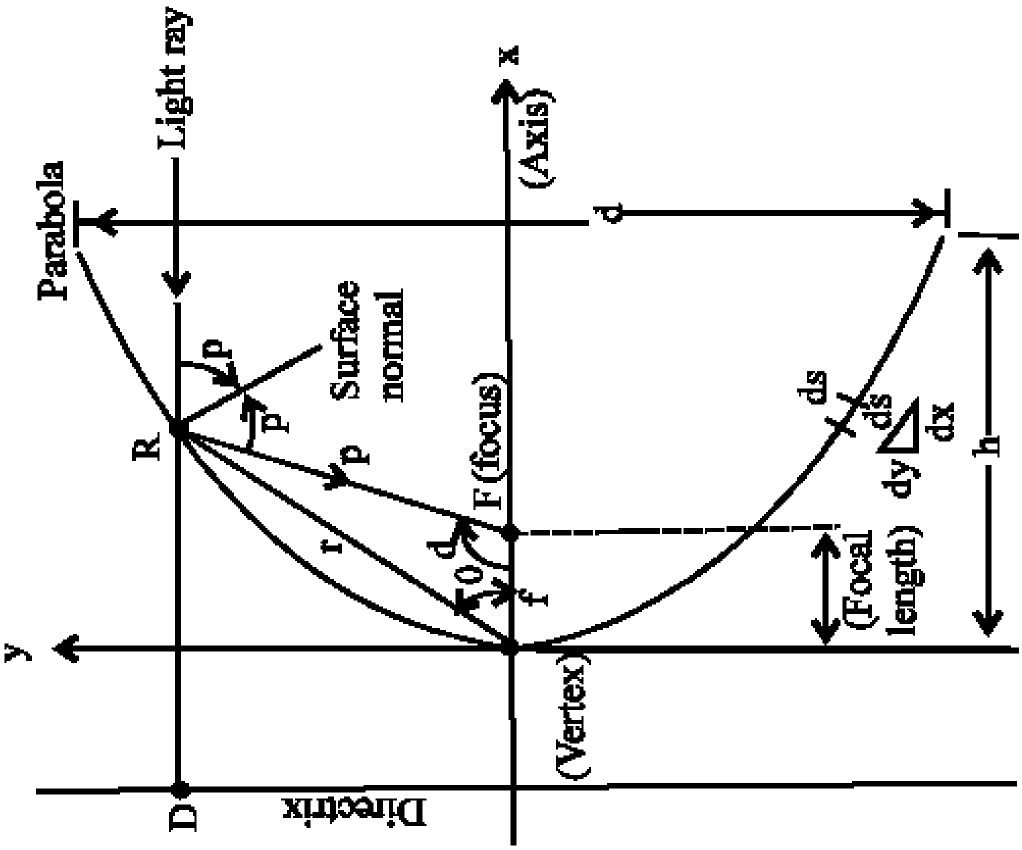

Figure 2.3: Paraboloid of revolutions (http://en.wikipedia.org/wiki/Parabola)

A parabola with an axis parallel to the y-axis with vertex (*h*,*k*), focus (*h*,*k* + *p*) and directrix $y = k - p$, with *p* being the distance from the vertex to the focus, has the equation with axis parallel to the *y*-axis;

$$(x-h)^2 = 4p(y-k)$$

Or, alternatively with axis parallel to the x-axis;

$$(y-k)^2 = 4p(x-h)$$

More generally, a parabola is a curve in the Cartesian plane defined by an irreducible equation of the form;

$$Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0, \quad B^2 = 4AC$$

All of the coefficients are real, where A≠0 or C≠0, and where more than one solution exist, which defining a pair of points (x, y) on the parabola. Irreducible can be defined as it does not factor as a product of two not necessarily distinct linear equations. A parabola has a single axis of reflective symmetry, which passes through its focus and is perpendicular to its directrix. The point of intersection of this axis and the parabola is called the vertex. A parabola spun about this axis in three dimensions traces out a shape is theoretically known as a parabolic of revolution (http://en.wikipedia.org/wiki/Parabola).

2.6.2 The Collectors

In order to make use of the Sun's radiation efficiently, especially solar radiation is the main source of energy; manufacturers strive to produce glass as transparent as possible by keeping low content of iron (Zekai Sen, 2008). The optical properties of commonly used glazing materials can be referred in the following table:

Table 2.2: Optical properties of commonly used glazing materials (Zekai Sen, 2008)

Material	**Thickness (mm)**	**Solar Transmittance**	**Long-Wave Infrared Transmittance**
Float Glass (normally window glass)	3.9	0.83	0.02
Low iron glass	3.2	0.90	0.02
Perspex	3.1	0.82	0.02
Polyvinyl Fluoride	0.1	0.92	0.02
Polyester	0.1	0.89	0.18

Several uses of collectors can be divided into four different categories depending on its purpose, which are:

1) Direct conversion from heat to electrical energy by Photo Voltaic panels
2) Domestic water heating or drying crops by using low-temperature heat source
3) Generate heat engines by using high heat collectors
4) Power refrigerators and air-conditioners depending on the climate.

2.6.2.1 Flat Plate Collectors

The flat plate collector designed based on two important principles, which is black body will absorbs the heat radiated better than other colors and a glass lid that is needed to keep the energy in. In order to absorb radiated energy as maximum as possible, the surface should be located perpendicularly with the radiation direction (Zekai Sen, 2008). Usually this flat plate collector used for water heating and cooking in houses, for heating or drying process in small and medium scale industries. It is mounted or installed at top of house, on the roof and consist of solar tracking device to obtain maximum gain of energy. It is exposed to weather conditions such as frost, wind, sea spray, acid rains, hail stones, corrosions, significant temperature change that possibly would damage the plate and flat plate are designed such that resist to these conditions (Zekai Sen, 2008).

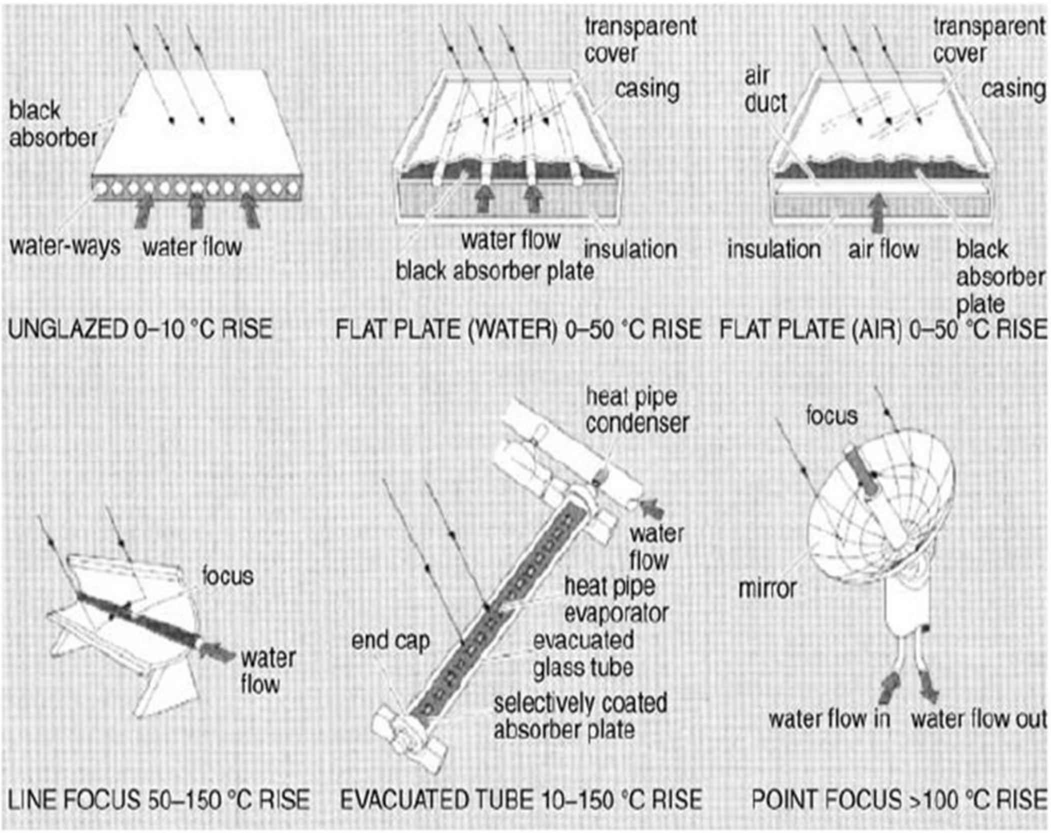

Figure 2.4: Patterns and types of flat plate collector (Zekai Sen, 2008)

2.6.2.2 Concentrating Collectors

Concentrating collectors are used when stagnation temperature are needed. The solar radiation focused at known focal point by a mirror or lens and resulting sufficient heat compared to the flat plate collector. The concentration ratio (CR) for this parabolic collectors are approximately 40,000 differs from ordinary one dimensional linear device of a linear parabolic system which is about 200, since the solar radiation is more focused into one focal point. It would be a surprise that the stagnation temperature at the focal point can reach 300-6000^{0}C with good accuracy and precision of developing and installation the concentrator (Zekai Sen, 2008). However, one disadvantage of concentrating collector is that the probability or tendency for radiation diffusion is high, where somehow the radiations are not reflected back to the focal point. Greater degree of concentration requires more accuracy in the alignment.

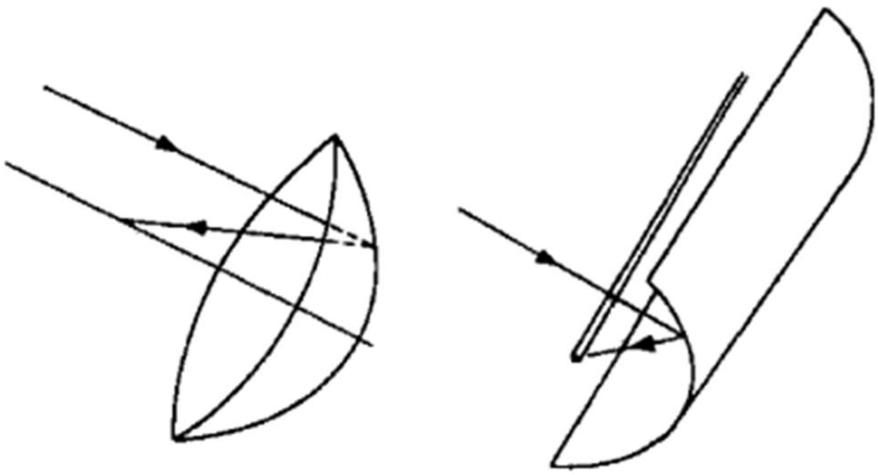

Figure 2.5: Spherical (left) and linear parabolic collector (Zekai Sen, 2008)

2.7 Application of the collected heat

The incident of the Sun's radiation distributed and applied in several ways as shown in Figure 2.6. It is necessary to plan smartly on utilizing the solar radiation that can produce such high temperature thus generate the electricity either for domestic or industrial uses. From the figure itself, heat obtained from the Sun's radiation mainly used in solar furnace application, drying agricultural products, refrigeration, distillation, heat engines and many more for industrial purposes, also cooking and water heating for domestic application.

In Malaysia, solar radiation is generally and mostly used for drying agricultural products and salted fish purposes. Not all Malaysian install solar panels and solar water heaters (SWH) system because of high initial, installation and maintenance costs. Lack of public understanding and awareness on the abundance of solar radiation and its application in conjunction for optimizing the falling sunlight is another factor which contributing to this scenario. Easy to purchase and install electrical appliances rather than solar technologies also contributing to the question on why Malaysian does not really appreciating and using solar technologies (K. Sopian, 2000).

In most African country, solar radiation is used for cooking instead of using Liquefied Petroleum Gas or LPG as fuel. The parabolic concentrator built in bulk and used for cooking purposes for their family. Meanwhile in American and European countries, some researches and companies tend to build solar tower and other advanced technologies in order to optimizing and replacing the use of depleting petroleum fuel sources. It can be seen that Malaysia is actually left behind in solar engineering technologies and its application, far away from the developing countries (AMSI).

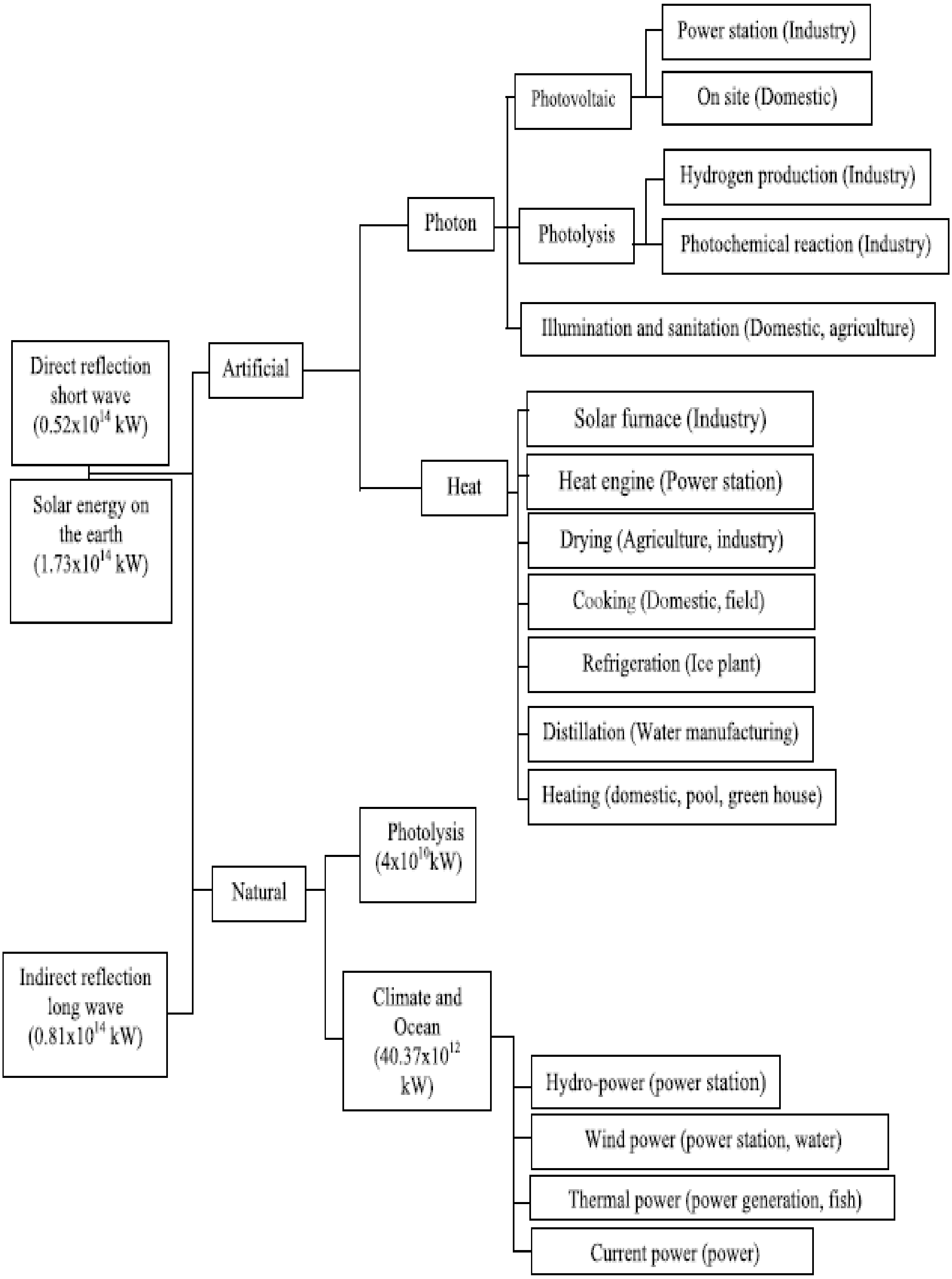

Figure 2.6: Solar energy distribution and utilization (Ohta, 1979)

2.8 Solar tracking technology

In order to obtain maximum intensity of the Sun's radiation, a solar tracker system must be used that will follows the movement of the Sun from East to West. Basically, it consists of electronic components that connected either through tighten them into a connecting block, solder it to a veroboard or printed circuit board (PCB). The main electronic components that usually used are resistors, transistors, Light Emitting Diode (LED), Light Dependent Resistor (LDR), Integrated Circuit (IC), diodes, DC motor and relays.

The solar tracking system also must independent from the external disturbances such as transient shadows and lights from fast moving sources. It can be clouds, shrubby, birds and insects. Also, the system must be stable and resist to oscillation of the parabolic concentrator that caused by wind. It will be nice if the system has self-reset, which mean after finished sensing the solar radiation, it is capable to return to its original position and ready for sensing at the next day (Christ Newton, 2003). The safety of the system is quite important, especially grounding element. Metal wire that connected from parabolic concentrator to the ground will protect it from destroyed by high voltage of lightning and thunder.

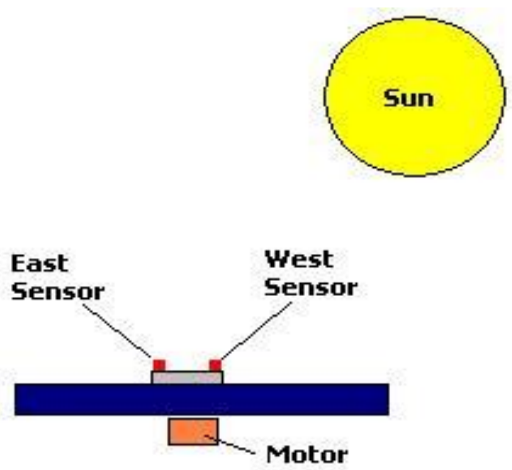

Figure 2.7: Example of Solar Tracker Mechanism: East-West Tracker

2.8.1 Basic circuits of the solar tracker

The following figure shows how the electronic components are arranged in a schematic diagram. This is the simplest form of dark activated switch circuit.

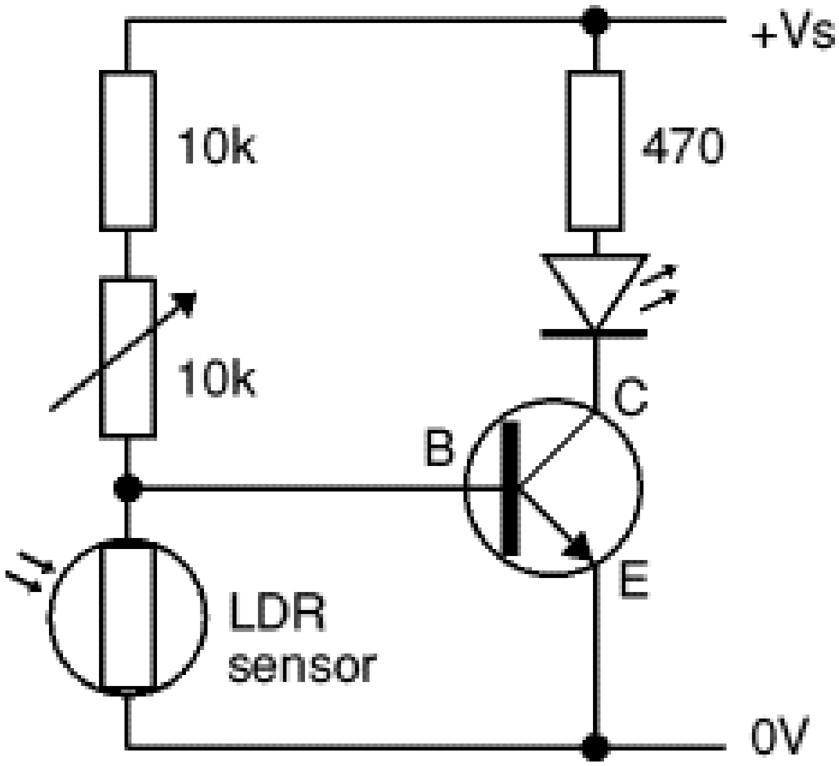

Figure 2.8: Dark activated switch circuit (www.kpsec.freeuk.com/trancirc.htm)

When light falls on the LDR surface, its resistance decreased and current will flow through it, thus completing the circuit which results the LED turned off. At this moment, no current, or perhaps, small quantity of current will flow through the base terminal of the transistor (B), which turns the transistor off, thus no current flowing through LED.

Meanwhile, if the LDR is covered, its resistance builds up, thus no current flowing through it. In the other way, current will flow through the base of the transistor, completing the circuit and LED will switch on. Function of the variable resistor, VR is controlling the amount of current flowing to the LDR, which making the sensor more sensitive to lights.

This circuit is the simplest form of light activating circuit by using LDR and can be modified to make it in reverse operation by combining two LDR's in series, which means, when the LDR is covered, the LED or DC Motor will not functioning and vice versa. This operation can be applied for detecting sunlight by its shadow.

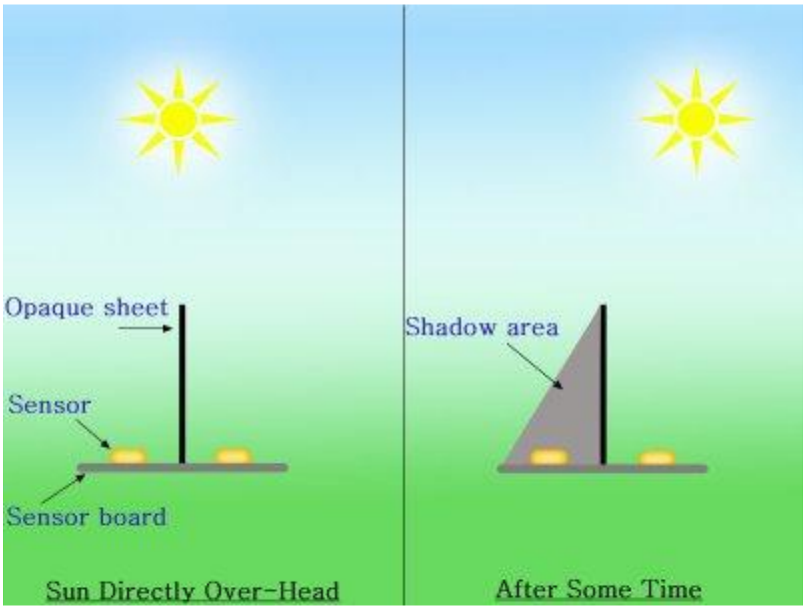

Figure 2.9: Mechanism of solar tracker based on shadowed area

If the sunlight falls on both LDR, the motor will stop rotating and let the radiation falls onto the surface of reflector for a period of time. The Sun continuously move, and letting the sensor behind. When one LDR is no longer exposed to the sunlight, it becomes dark and activates the motor, so that it will track the path of the maximum radiation of the Sun continuously.

Another circuit that usually installed with the parabolic concentrator is the Phresh Phontonics' SiQu50-M module, shown in figure below. The circuit is completed with some amplifiers and main sensor, which is Silicon Quadrant

Photodiode. The Silicon Photodiode produce a current, which is proportional to the amount of light falls on it.

The produced currents compared by a voltage comparator and location of the light source can be easily determined by rotational of DC motor. When the currents are equivalent, source of light will be centered and motor stops (Christ Newton, 2003).

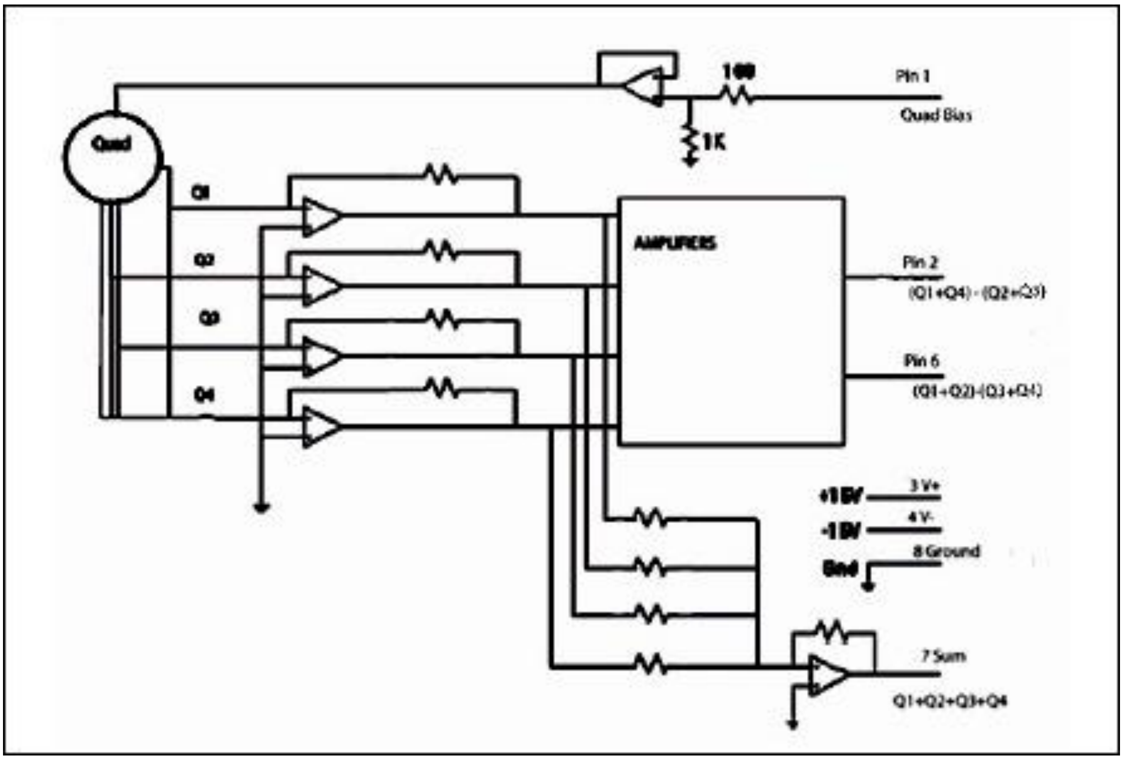

Figure 2.10: Schematic diagram of SiQu50-M module (Christ Newton, 2003)

2.9 Material science and engineering

The important aspect that needs to be considered most is, since solar concentrators often are large, the reflector must be aesthetical and placed fully visible on open space so that the concentrator aperture is not shaded by objects in the surroundings. The surface of the concentrator should have high degree of reflectivity in order to obtain as higher stagnation temperature as possible to generate more power for the Sterling engine. The metal that seems suitable are silver and aluminium with a solar hemispherical reflectance of approximately 97% and 92% respectively (Maria Brogren, et.al, 2004). However, its optical performance will degrade in only a couple of months if the metals are not protected, for example by glazing, cover with plastic foil or a lacquer.

Some of researcher uses back surface mirrors, evaporated on the back of a glass or polymer substrate that protects the metal from oxidation. Other options are using aluminized Mylar instead of ordinary aluminium sheets, which improves the reflectivity of aluminium up to 0.83 or applying Polymethylmethacrylate (PMMA) or back-surface-silvered low iron glass. However, the disadvantages on using such glass are that glass having high tendency to brittle and it is heavy (Zekai Sen, 2008). High reflectance should be performed during entire life span of the concentrator, which is often longer than 20 years (Maria Brogren, et.al, 2004). Therefore, cleaning process will be useful and it enhances the reflectivity of the concentrator. Cleaning the aluminium reflector can be done by applying aluminium polish, and not water. Bear in mind that structure of the concentrator must be designed correctly in order to ease the cleaning process, which screwing the aluminium sheets or perhaps joining it with aluminium wires are more preferable than rivet or brazing.

Inexpensive reflector material and its support structure should be used. This is due to the minimization of the capital and maintenance cost. Thus, aluminium sheet will be used as the reflector material and reused wood panels or reused reinforcement steel bar will be used in constructing the supporter.

A solar concentrator is not subject to the same high temperatures and thermal cycling as a solar absorber. Also, environmental conditions impose stringent on the material, whose surface will deteriorate more or less upon exposure to the environment. Another thing is, erosion and oxidation, dirt accumulation and action of cleaning agent on the reflector surface will contribute to the loss of solar reflectivity while the degradation of the metal is essentially reversible, which will occur when dust starts to accumulate on the reflecting surface (Zekai Sen, 2008). The optical performance of solar reflectors depends on the mechanical and chemical properties of the surface and the protective coatings. A support of sheet metal may be necessary for flexible reflective foils, while simple frame construction would be the best for self-supporting reflector, which is case for corrugated sheets.

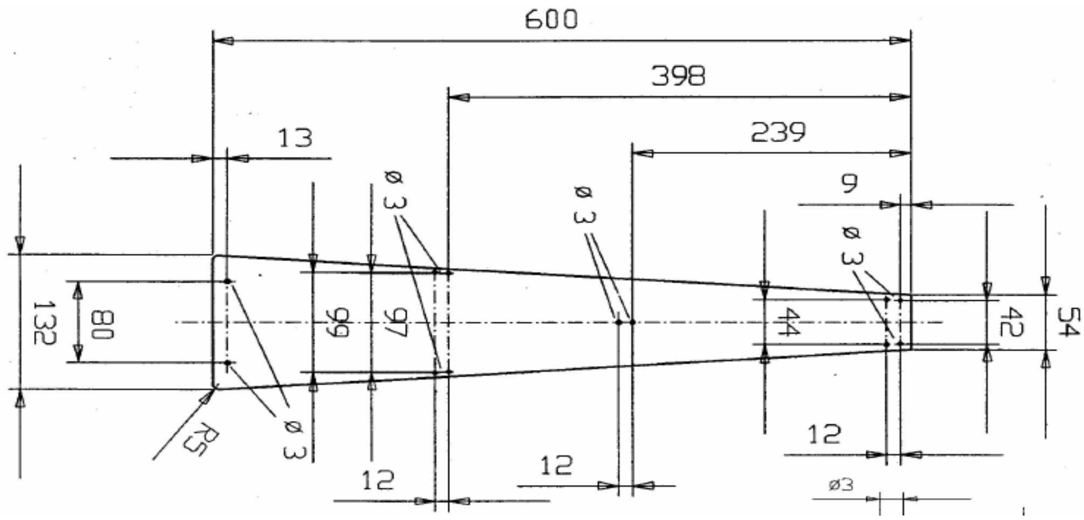

Figure 2.11: Example of aluminium cutaway dimensions (AMSI)

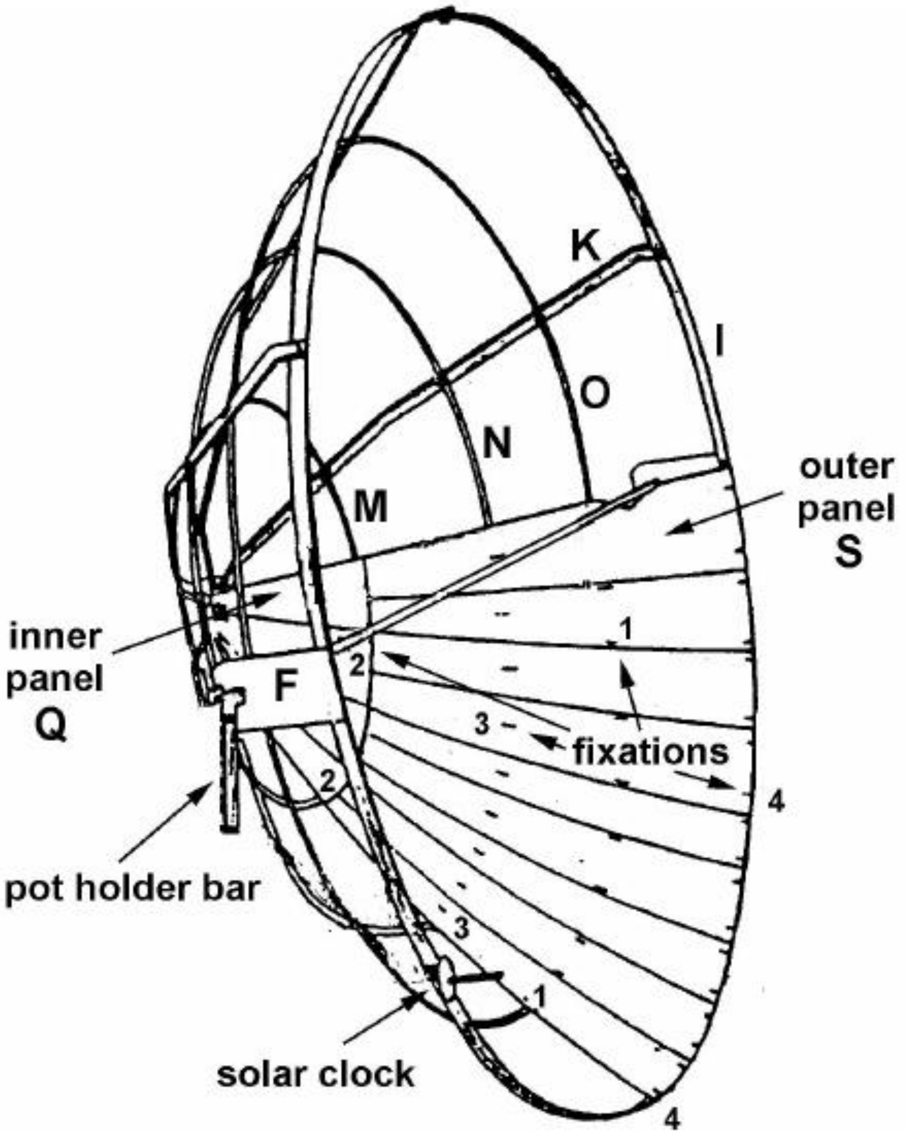

Figure 2.12: Idea on the construction of parabolic concentrator (AMSI)

2.10 Conceptual designs

There are three conceptual designs, so far, that needs to be considered and detailed through many aspects. First is the design with all equipments such as the Sterling engine and the generator are mounted at top of the parabolic concentrator. The second design is much depends on the working fluid, such as salts, steam or any suitable gases such as Helium or compressed air. Meanwhile, the third design introduces the application of a concave mirror, which reflects back the collected solar radiation.

All of these designs is just recommendation or in preliminary experiment. The most simple design and not cost too much will be selected. The criteria that will be considered in order to select and construct the complete set of parabolic concentrator along with the solar tracker is the reflectivity of the reflector material, weight of the design, total cost, maintenance and installation work and effectiveness of the design.

The stagnation temperature at the focal point will be fully depends on the solar time, which is time of sunlight radiation started until it disappeared, the intensity of sunlight falls on the reflector and also the effectiveness of the solar tracker, which tracks the maximum point of the solar radiation.

2.10.1 First Design

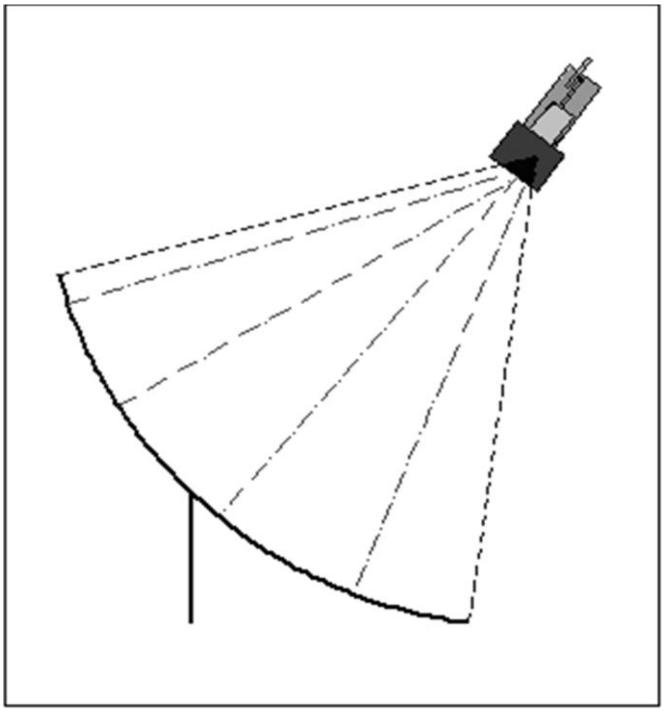

Figure 2.13: Design Concept 1. All equipments mounted at top of the concentrator (Christ Newton, 2003)

The theory behind of this design is quite simple. Heat received and reflected will be collected by solar absorber or heat containment system that mounted exactly at the focal point. The Sterling engine and probably a generator have to be installed at that particular point. The problem occur when the weight of these equipments considered, and it also certain area of the reflector will be blocked by the shadows of huge engine and generator. Large amount of weight need to be balanced since the parabolic dish is moving and rotating.

2.10.2 Second Design

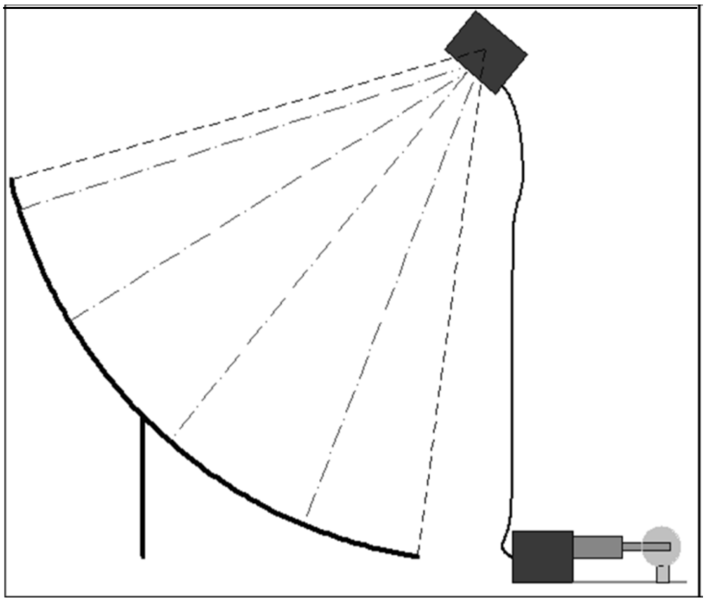

Figure 2.14: Design Concept 2. Working fluid as heat transfer (Christ Newton, 2003)

In this second design, heat containment unit will be introduced. This unit then filled up with working fluid, which is a medium that will be used to transfer the collected heat from the parabolic to the Sterling engine. The proposed working fluids are molten salt or gas, such as Helium that are non-reactive towards the environment rather than Hydrogen gas. Usually, steam is used because of abundance, cheap and need less maintenance. The Sterling engine is located on ground level to prevent excessive mass at top of the concentrator which will cause instability during storm. This design can be considered as enhancement of the first design. There will be heat loss that will contribute to the ineffectiveness and cost much in term of maintenance for replacing the fluid, if the fluid is expensive also needs proper insulation.

2.10.3 Third Design

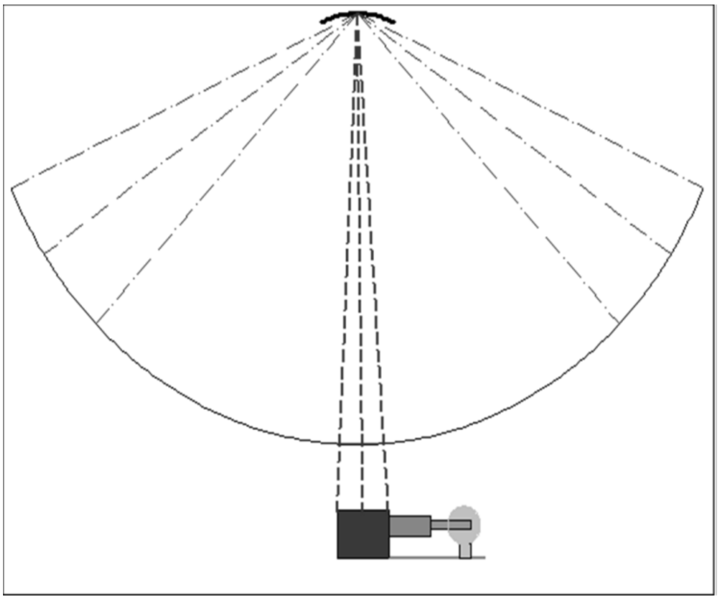

Figure 2.15: Design Concept 3. Introduction to the concave mirror (Christ Newton, 2003)

The concave mirror mounted at the focal point, thus increases the efficiency of the concentrator, lowering the heat loss. This third design is quite reliable and interesting. Furthermore, there are no worries about the external weight at top of the concentrator because the Sterling engine is located at center, under the concentrator. There is no working fluid and totally simple design. But, the disadvantages is, by fact, it is difficult to design a concave mirror and it need to be purchased somewhere from other country that would consume higher installation cost.

2.11 Whole set of parabolic concentrator

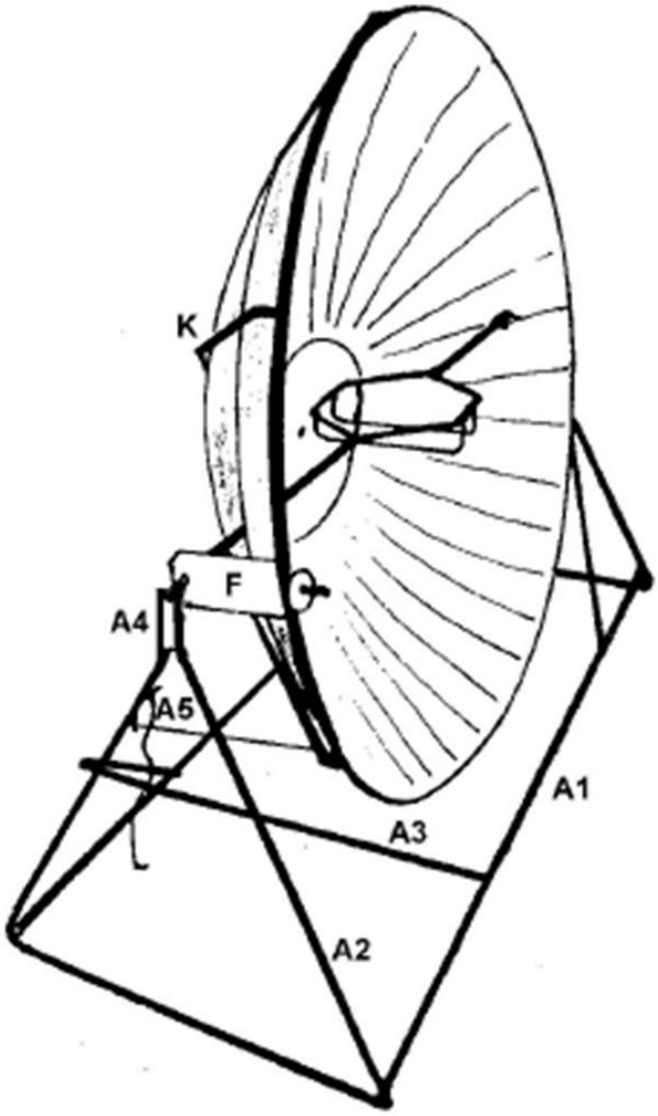

Figure 2.16: A complete set of parabolic concentrator (AMSI)

The physical look of final product should be look like in the figure above, the complete parabolic concentrator, one of the objectives that highlighted before.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, materials used during the study will be explained and some of the parabolic concentrator designs will be discussed. Generally this study will concern basically on three main areas in conjunction for developing the whole set of parabolic concentrator. Firstly, the construction of parabolic reflector, the second one is the solar absorber system and the last one is construction of the bench to support the solar parabolic concentrator system.

In order to construct the concentrator, several basic conceptual ideas need to be considered. There are three patterns for this instant and between this three patterns, the most feasible and simple construct will be selected. Complete dimensions of the parabolic concentrator and the solar absorber will be detailed.

3.2 Selection of design

After several aspects and factors, such as add-ons equipments, weight and stability, reliability of working fluid and total cost has been considered, among three conceptual designs the first design is most suitable. In the first design, there are no add-ons equipments such as the massive Sterling engine, no power generator and no complex solar tracking circuit at top of the parabolic concentrator. Only absorber or heat containment system is mounted at that particular point. There are no problems regarding to massive structure and stability. The overall costs are considerable, since there are no concave mirrors. The construction of parabolic concentrator has begun since July 2009 and completed on August 2009.

Figure 3.1: N12 Building. Parabolic concentrator is located at top of the building.

3.3 Selection of materials

Aluminium is chosen as the reflective surface material based on its high reflectivity and cheaper than silver plate or mirrors. The polishing activity will be done after combining all those aluminium panels into the parabolic concentrator and continuously during the experiment was conducted. The polishing agent can be purchased at hardware store. Support structure and cage of the parabolic concentrator will be constructed by using reinforcement steel bar because it is easily welded and abundance at Workshop N08, rather than PVC which requires molding equipment and it is time consuming.

Figure 3.2 Aluminium Panels

Figure 3.3 The parabolic cage after finishing process.

The involved equation in conjunction for constructing the parabolic concentrator is based on the following data:

Diameter of the parabola: 1.00m

Depth of the parabola: 0.30m

The focal length:

$$f = \frac{D^2}{16d} = \frac{1.00^2}{16(0.30)} = 0.2083m$$

Thus, the equation of parabolic involved:

$$y = \frac{x^2}{4f} = \frac{x^2}{4(0.2083)} = \frac{x^2}{0.8333}$$

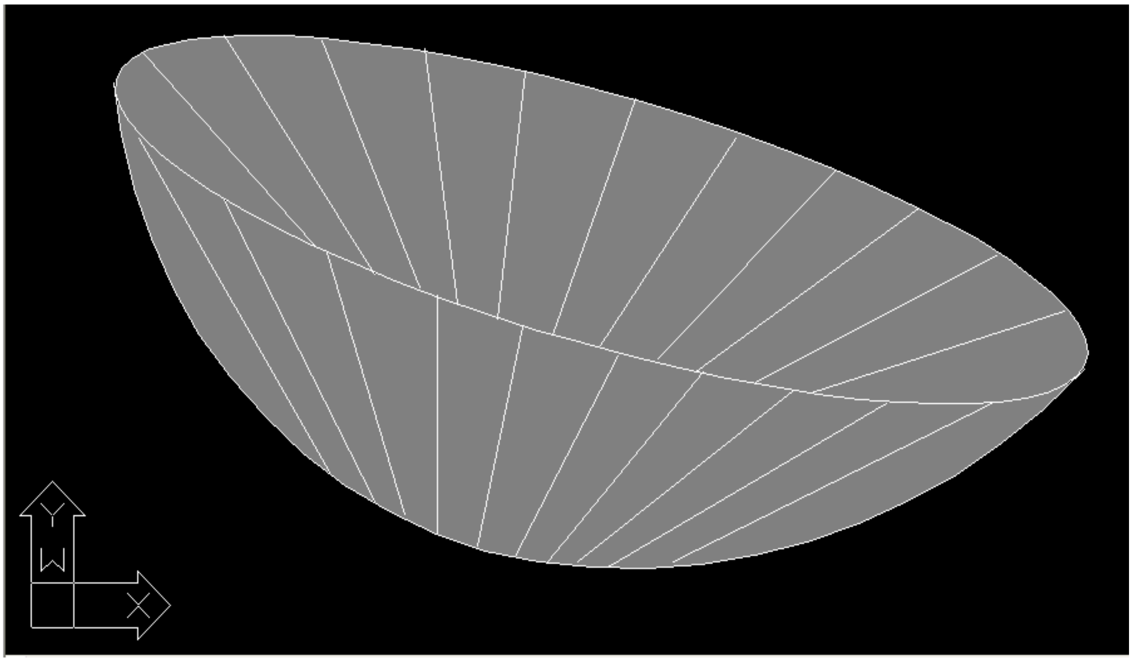

Figure 3.4: AutoCAD drawing on the panels of the parabolic concentrator

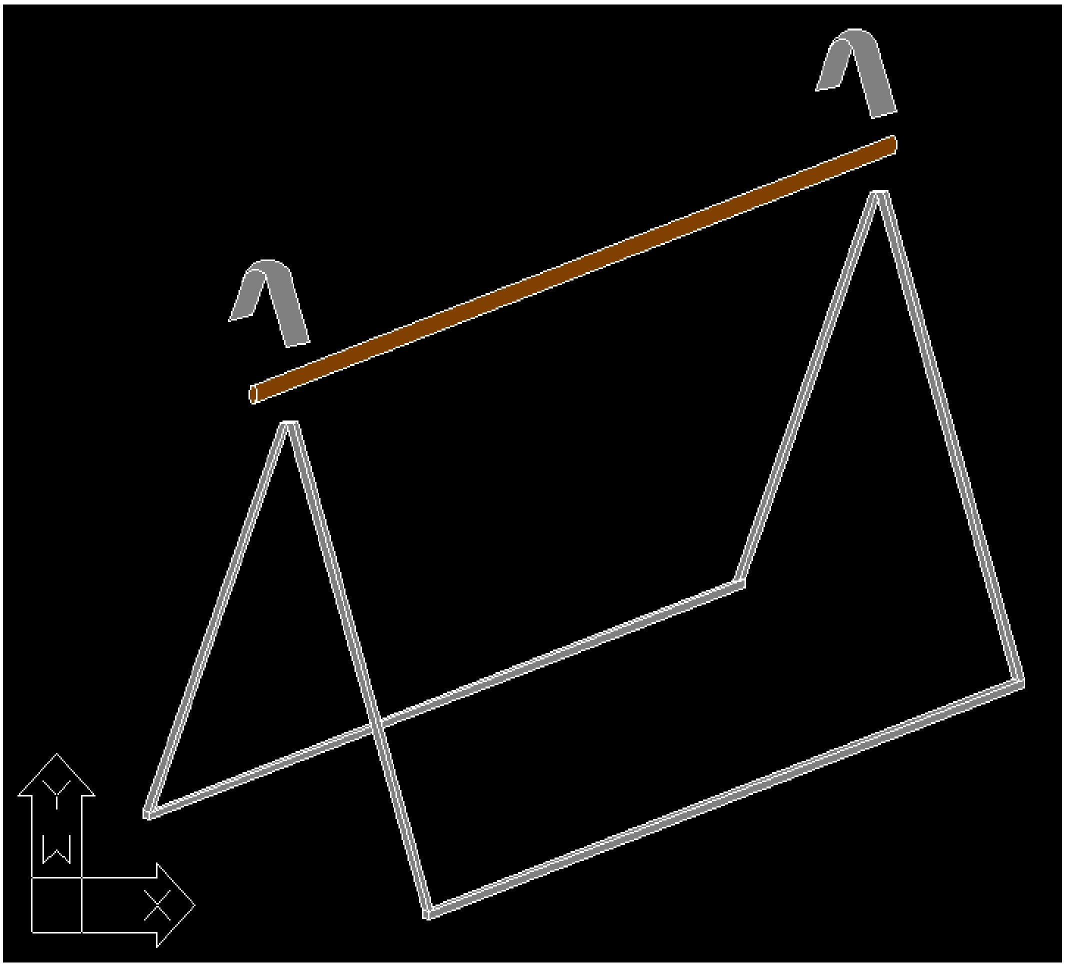

Figure 3.5: Drawing of the parabolic stand

Meanwhile the heat containment or the absorber system will be designed by using tin. Tin has several enhanced properties rather than ordinary pure metal or element. It is extra strong, more resist to weather conditions and most chemicals and perhaps it saves a lot of money than ordinary pure metal. In this research, tin are cheaper than pure metal cylinder. It is also lighter than pure copper, which is massive. To obtain nearly perfect absorption, the heat absorber was painted in black at outside and inside, thus making the absorber as black body, which absorb all energy and transmit none. As the result, the stagnation temperature will be higher than the result for unpainted absorber.

Figure 3.6: Black body solar heat absorber

Figure 3.7: The completed set of parabolic concentrator

3.4 The stagnation temperature measurement

There are many devices used to measure temperature, for example thermometer, thermocouple, Resistive Temperature Detector (RTD), Thermistor, Thermostat, Radiation Pyrometer, Bimetallic Sensors, Integrated Circuit Sensors (ICS) and many more. For this study, thermocouple is used to measure the temperature on the focal point. The reason of using thermocouple instead other temperature instrument/sensor is because it is small size, cheap price, large range of temperature, durable, satisfactory accuracy and large range of signal transmission

In order to record the data, Picolog data logger and computer will be use along with thermocouple. Just insert the thermocouple inside a small hole drilled on top of the heat absorber, and record the temperature reading. Signal from thermocouple will be send to Picolog data logger and into the computer. Temperature data will be record every 30 minutes.

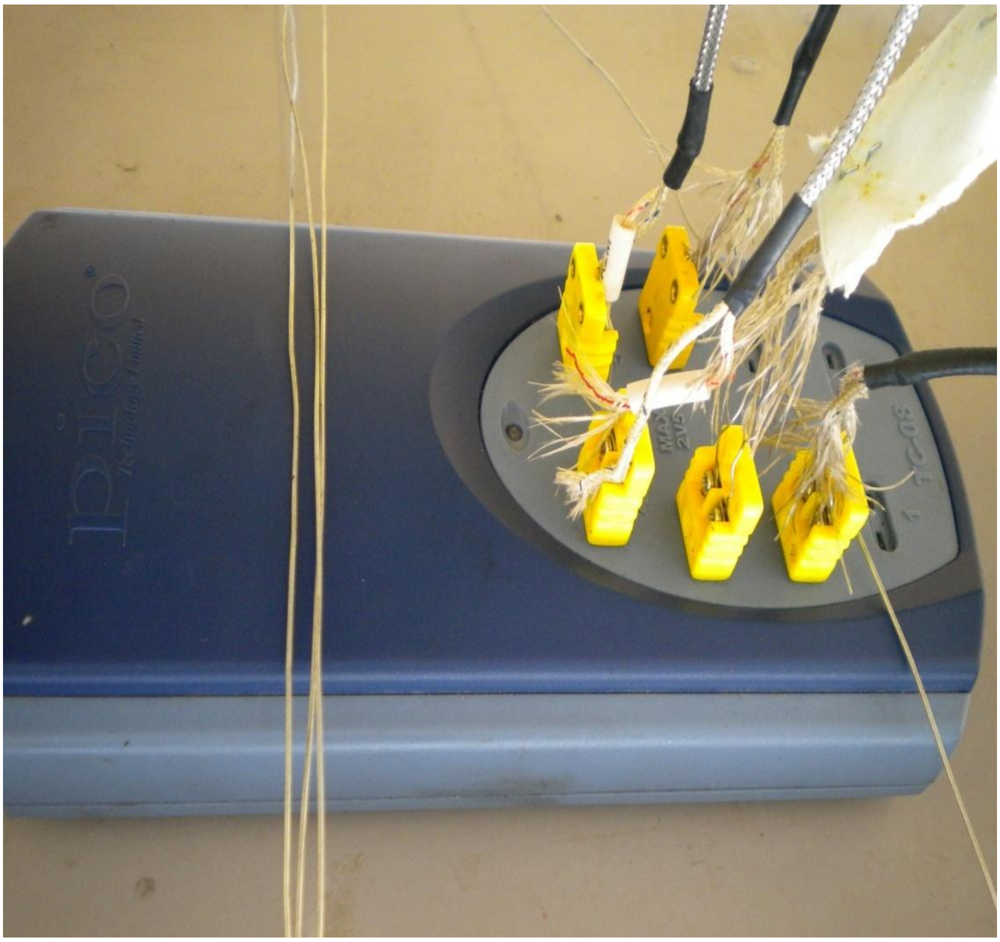

Figure 3.8 PicoLog data logger

Figure 3.9 Data recording

3.5 The distribution of tasks

The project will be divided into several tasks and actions so that it will not be too messy.

Table 3.1: Tasks and actions

Task	Action
Getting Started	- Perform a check list to gather all equipments, materials with complete dimension and perform a check list.
Wood panels	- Measure the wood panel with accurate dimensions. - Cutting and shaping process. - Finishing and fit the panels perpendicularly.
Parabolic body	- Measure the steel bar with accurate dimensions. - Cutting and grinding process.

	- Forming two circles; different in diameter and two arcs; also different in diameter, by using bending machine. - Welding process, to get steel cage of parabolic concentrator. - Removing stains and dusts. - Finishing process.
Support / stand	- Measure the steel rod with accurate dimensions. - Cutting and grinding process. - Welding the steel rods, step-by-step procedures. - Remove stains and dusts. - Finishing process.
Aluminium panels	- Measure the aluminium panel according to the dimension. - Cutting the panels by using shear cutting machine. - Polishing the panels, in order to make it shinier.
Structuring	- The aluminium panels fitted and wired on the parabolic cage. - Another polishing step applied. - Testing the parabolic concentrator.
Solar absorber	- Purchasing the copper-aluminium-stannum cylindrical alloy. - Paint inner section with black color. - Aluminium cap fitted at top and bottom of the cylinder, with a hole drilled on top section of aluminium cap for thermocouple. - Three rods used to interconnect the cylinder and the parabolic cage screwed.
Finish	- Now, the thermocouple and data logger are connected together and the experiment can be run immediately.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The objective of this chapter is mainly to present and show the experimental results, which is corresponding on stagnation temperature at the focal point of the parabolic concentrator investigation. More discussions will be focused on factors which errors can occur, several mistake explanations, lot of advantages and disadvantages, and also the way to overcome the possible errors.

4.2 Stagnation Temperature Data

The following graphs were several graphs that represent the stagnation temperature result which had been measured from 8.30 a.m until 6.30 p.m everyday.

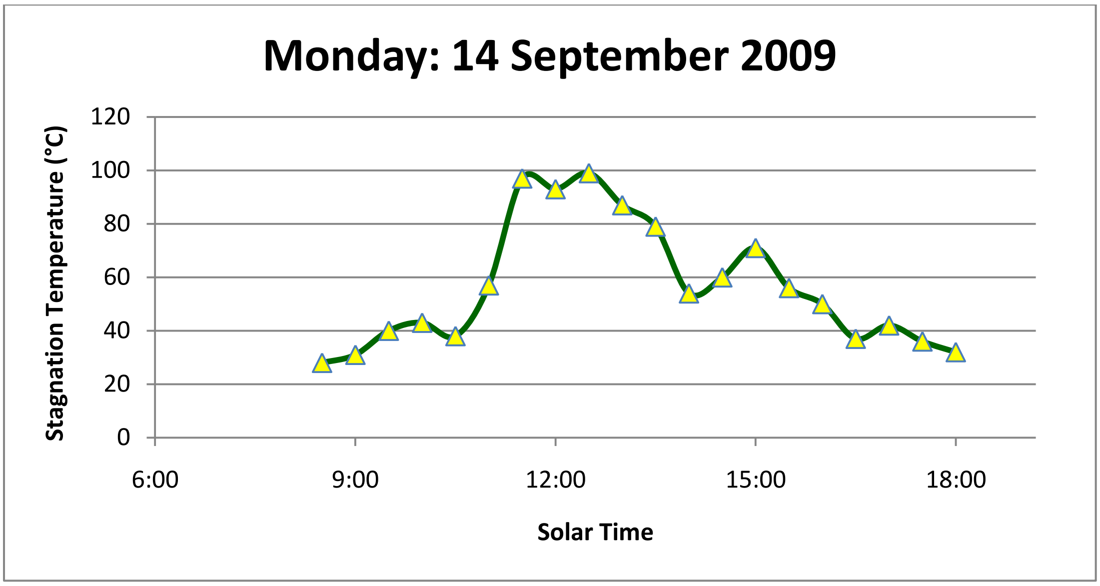

Figure 4.1: Graph of temperature profile for 14 September 2009

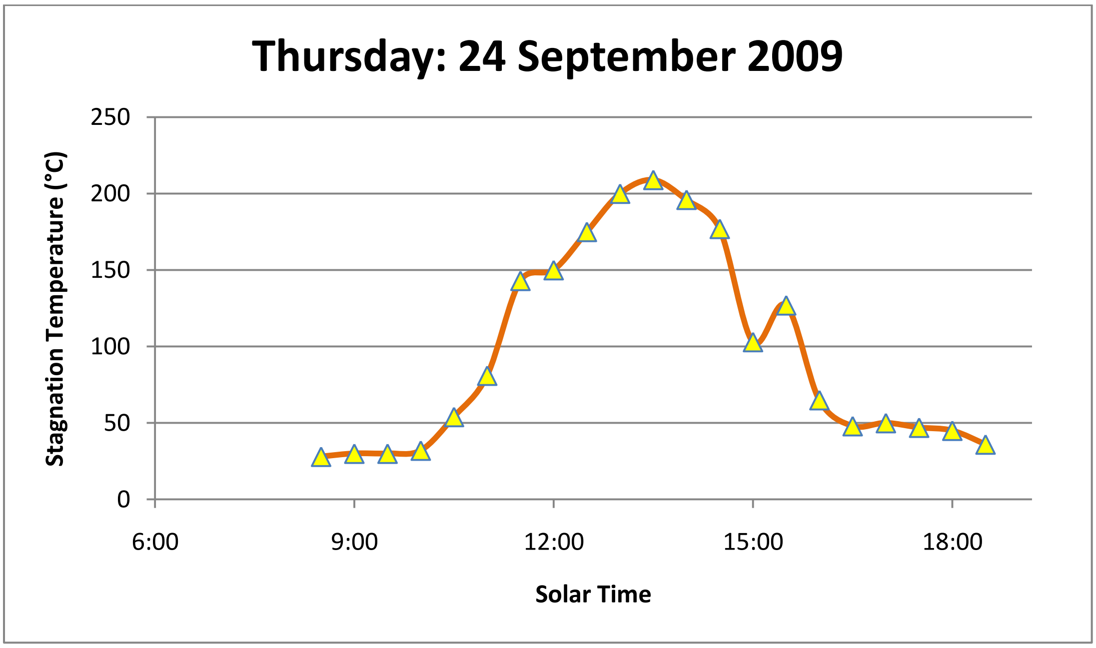

Figure 4.2: Graph of temperature profile for 24 September 2009

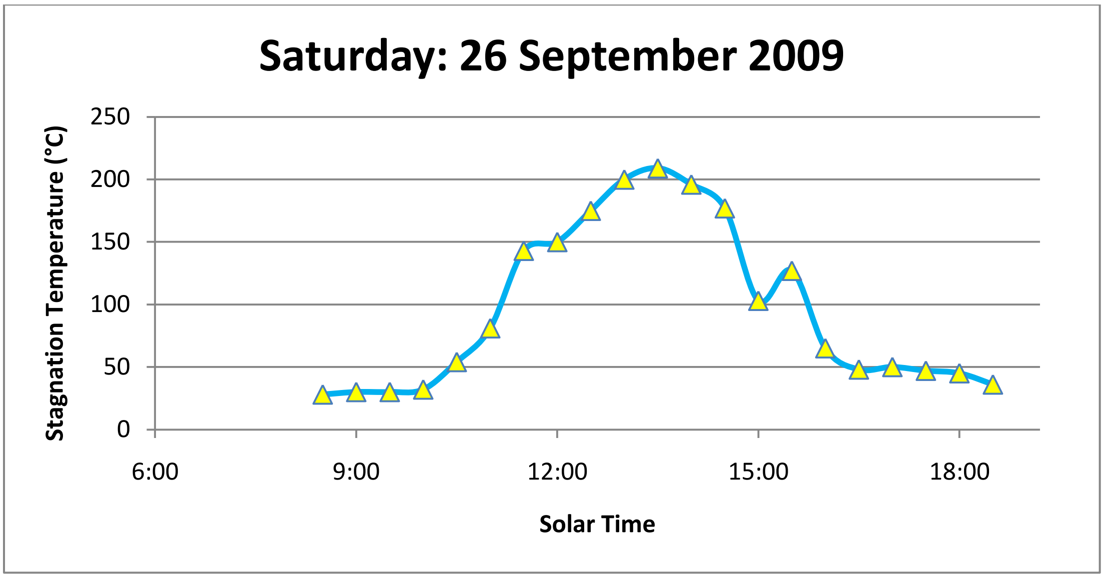

Figure 4.3: Graph of temperature profile for 26 September 2009

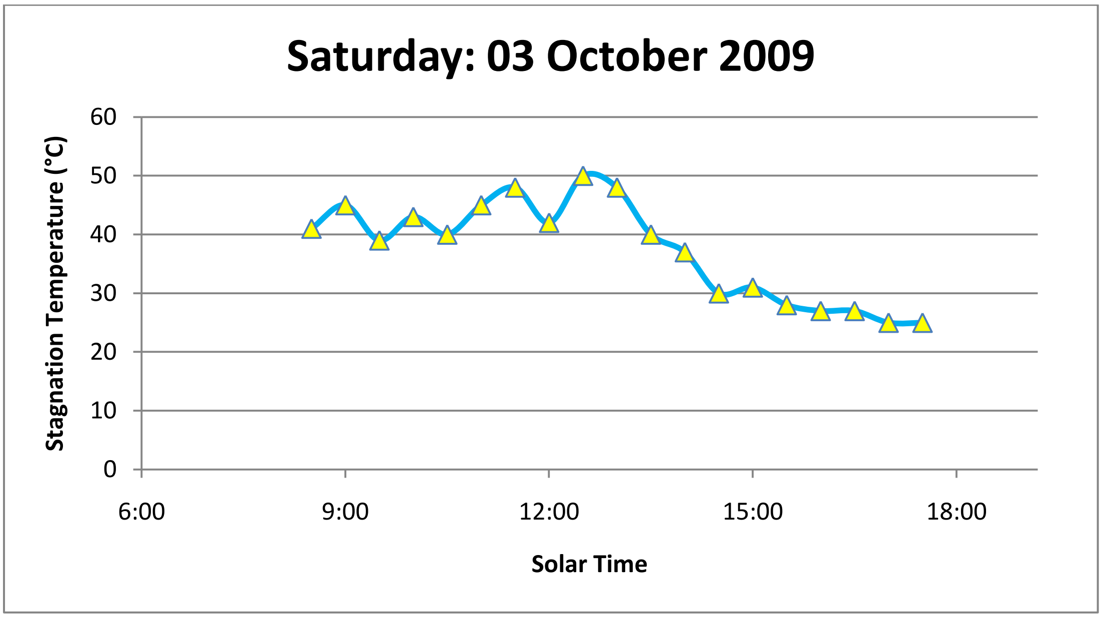

Figure 4.4: Graph of temperature profile for 3 October 2009

Based on results obtained, the highest temperature recorded was 209°C and the lowest temperature was 25°C. Basically, every day's highest temperature was recorded at noon because during this time it was the peak temperature for surrounding. So the heat from the sun is at maximum. The heat radiation from the sun will reflect by parabolic shape into absorber. The absorber will absorb all the heat and thermocouple inside it will measure the temperature.

Based on Figure 4.2 and Figure 4.3, the highest temperature was recorded during the experiment occurred. During this day, heat from the sun was efficiently absorbed by solar parabolic concentrator and the surrounding temperature also very high. But based on result from Figure 4.4, actually it was a rainy day and the surrounding temperature also very low. Wind and cloud also can influence the heat from the sun. For example based on Figure 4.1, some heavy wind occurred during this day.

During the experiment, not all reflection of solar radiation is focus to the absorber. From that, the collector cannot reflect the optimum solar radiation get from the sun to the absorber and that mean have the energy loss during collector reflect the solar radiation focus to the absorber. This is because the temperature can affect the value of energy loss. For example, at the temperature high, the radiation of solar is become high and the collector cannot reflect all of the radiation and it is increase the energy loss to the surrounding.

4.3 Average Of Stagnation Temperature Data

After the analyses of daily stagnation temperature were made, the final step is analysis about average of stagnation temperature data for each day the experiment was held. From this, the performance of solar parabolic concentrator can be known whether the performance was good or not. The Figure 4.5 shows the average of stagnation temperature versus time from day one to days thirty.

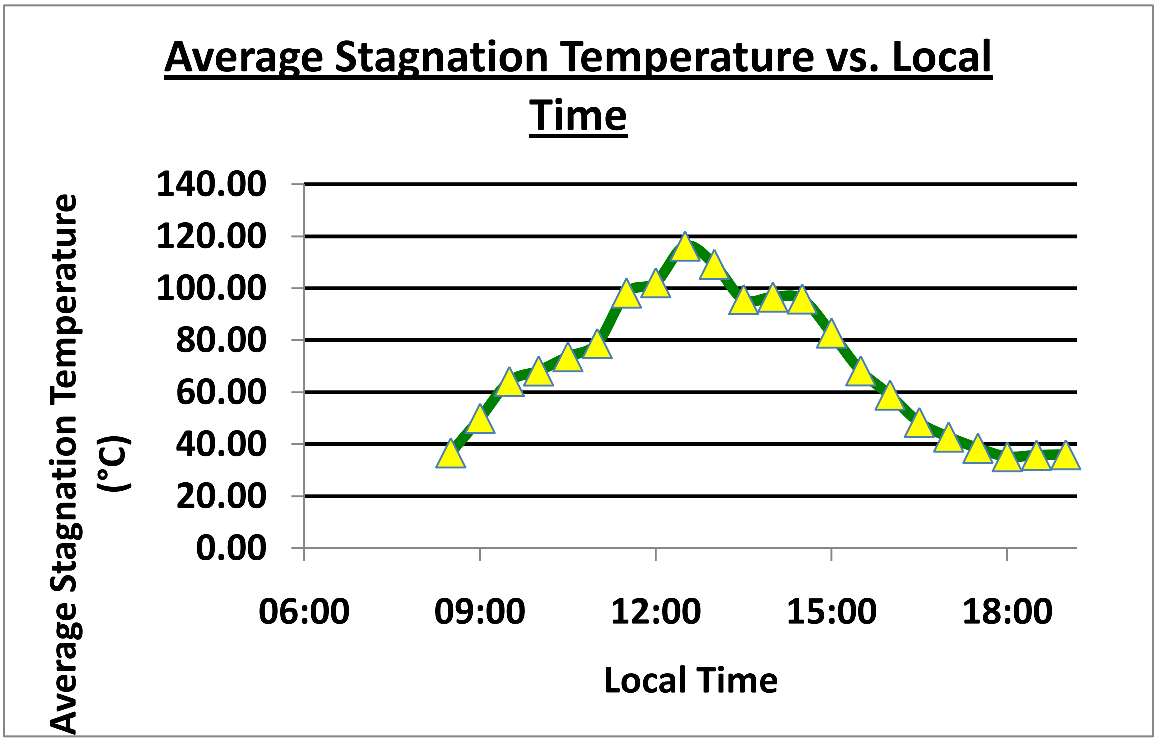

Figure 4.5 Graph of average stagnation temperature vs. local time

Solar energy technologies are strongly dependant on weather. Luckily Malaysia receives high intensity of radiation. Unfortunately, the Equatorial condition which contributes to cloudy, windy and rainy days making solar energy applications are not too effective. Based on Figure 4.5, the average temperature along the experiment was held does not very high because of some obstacle occurred to prevent the absorption the heat from the sun by solar parabolic concentrator.

During 30-days experiment conducted, almost every day are cloudy and windy. The clouds tend to prevent the solar radiation from reaching the Earth. Moreover, the experiment is conducted at high altitude building, so the possibility of the stagnation temperature being affected by blowing wind is high enough. The blowing wind contributes a condition which known as natural convection. This natural convection is one of heat transfer mechanism which occurs when a solid surface is in contact with a gas or liquid which is at a different temperature from the surface. Density differences in the fluid arising from the heating process provide the buoyancy force required to move the fluid. Free or natural convection is observed as a result of the motion of the fluid.

From the explanation, it is clearly that the stagnation temperature are actually strongly affected by weather condition such as clouds and wind, which possibly reducing the collected heat at the focal point, thus lowering the stagnation temperature recorded. In the other words, the weather condition cannot be avoided when dealing with solar energy technology.

The performance of solar parabolic concentrator was very good as it gave higher stagnation temperature at the focal point. From figure 4.5, it showed the higher average temperature achieved is only around 110 to 120^{o}C which is lower compare to the result achieved by other researcher for this type of solar system. It is due to several error or factor that occurred during the experiment conducted such as the material of the absorber and also the reflectivity of the aluminum.

The surface of the aluminum was not polished well and the roughness and scratches around the surface reduce the reflectivity of the solar radiation to the absorber. It can be improved by changing the reflector to other material or frequently polished the surface of aluminum to remove the scratches and reduce roughness to get a good reflectivity surface of the reflector.

The black coating of the absorber is not assuring that it absorbs all the heat radiate on it. This absorber cannot be assumed as black body because the material and the coating used still reflect some heat. So, absorptivity of this material cannot be assumed as one. Besides, the exposure of the material to the surrounding condition causes the corrosion on the absorber. The effectiveness of the absorber was decreased with the corrosion on that material.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the result obtained for 30 days, the highest stagnation temperature recorded is 218^0C and distribution of the stagnation temperatures are shown in the Result and Discussion section. Solar energy is truly one of important alternatives to replace the usage of petroleum as primary sources. Instead of developing and studying the properties and advantages of Photo-Voltaic (PV), research about other alternatives such as parabolic concentrator and other solar thermal system should be considered. Instead of collecting the data on the stagnation temperature, this study is actually also focused on the development of the parabolic concentrator also searching and build the solar tracker, which is quite important. With this research, hopefully there are awareness about this interesting and costless parabolic concentrator and applied either for domestic houses or industrial areas. Solar technologies should be applied and enhanced by now, because solar energy and its applications are among the highest potential of renewable and sustainable energy in Malaysia.

5.2 Recommendation

Several recommendations on this research can be highlighted as follow

1. Widen the area of this solar energy research in Malaysia generally, and Universiti Teknologi Malaysia (UTM) especially. Not only focused on development of Photo Voltaic (PV), but instead of that it can be broaden and widen to other branches such as Solar Thermal system, solar heat storage system, optimization of solar energy in chemical industries, for example in distillation columns, crystallizers, dryers, evaporators and so fourth.
2. Introducing the solar energy or perhaps renewable energy subject to new students. Students will be more appreciating on what are they have learned and apply it in daily life. Malaysia has so many opportunities regarding with renewable and sustainable energy such as solar, biomass, wind and so on. It is quite important and critical since the public awareness among students, and perhaps Malaysian is at low level.
3. Construct parabolic concentrator with larger in diameter and minimize the focal point area as small as possible, to get higher stagnation temperature, thus increase the effectiveness of the parabolic concentrator.
4. Develop solar tracker with more effective and consume less cost. Solar tracker circuits are available but quite expansive. Solar tracker is an important key to obtain higher stagnation temperature because it tracks maximum point of the Sun's radiation. The container should be designed properly so that rain drops cannot penetrate thus leading a serious short circuit.
5. More funds should be provided in order to enhance the solar parabolic concentrator, especially in solar tracking system and heat containment system or heat absorption system. The modification on the solar tracking mechanism should be worked on and development of more enhanced technology of

parabolic concentrator must be applied to obtain the best result of stagnation temperature, thus solar energy can be harnessed.

6. Find more wide space or place for conducting the experiment and prevent or minimize the wind blowing through the parabolic concentrator. As stated in Discussion section, the blowing wind would bring the stagnation temperature down and deviate from what had been targeted.

7. Also, enhancement on the reflector material should be made. For example, application of Aluminized Mylar, this has been by Christ Newton, et. al. (2003) or attaching Polymer laminated steel reflector developed by Maria Brogen, et. al. (2004). These materials developed in order to enhance the reflectivity of the surface and minimizing the heat absorbed by the material.

8. Collaboration between faculties has to be made to promote the solar energy techniques and application among the staff and students in UTM, especially. For example, collaboration between Mechanical Engineering Faculty in order to design the optimal performance of the parabolic concentrator and deals with Sterling engine for electric generation purpose, Electrical Engineering Faculty, to enhance and develop more reliable solar tracking circuit and maximum power point tracking devices, Chemical and Natural Resources Engineering Faculty, for undergoing researches on heat storage materials, suitable working fluid that can work well on high temperature and optimizing the collected heat by applying the collected heat to heat up equipments such as crystallizers, distillation columns, dryers, evaporators and so on, also Geo-information Science and Engineering Faculty in conjunction for predicting the weather because weather is one of the significant obstacle that affecting much on solar technologies.

Human Capital Development

6.1 Details of Human Capital Development

1. Nor Aizat Kamaruzaman
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5. Mohd Zulfadli Bin Zulkifli
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6. Saifaralina Binti A. Jalil
   880804-23-6130
   Graduate in Bachelor of Engineering (Chemical) 2011

Research Output

7.1 Details of Conference Papers

Project leader had attended two international conferences to present the project paper at Putra World Trade Centre, Kuala Lumpur on 26 to 29th July 2010.

Conference: 1. 2nd International Conference and Exhibition on Waste to Wealth
2. 6th International Conference on Combustion, Incineration/Pyrolysis and Emission Control

Title of Project Paper:

1. Characteristics of Medical Waste in Malaysia
2. Effect of Fluidization Number on the Combustion of Simulated Municipal Solid Waste in a Fluidized Bed

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