SOLAR COLLECTOR STORAGE TANK

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ABSTRACT

Solar collector storage tank is water tank used to store hot water for space heating or domestic use. The main purpose of this project is to design and fabricate storage tank for evacuated tube solar collector and to determine the overall heat loss of the storage tank and the period of heat energy storage after sunset. Two types of insulator are used for testing the respectively such as polyurethane and woolen coat. This is due to low thermal conductivity of polyurethane and sheep wool of 0.03 W/m.K and 0.039 W/m.K compared to insulator which is many orders higher. The experiment consists to two types of fluid which are distilled water and nanofluid of silicon oxide (SiO_2). In this experiment, the systems are divided into two types which are without control system and with control system. The results obtained show that to the nanofluid using silicon oxide (SiO_2) with control system is the best result compared distilled water. It has shown the result of nanofluid achieved higher temperature of 86.7^oC and with different temperature of 47.52 %. The investigation for distilled water shows, the storage temperature with control system is higher than without control system with different 6.68 %.

ABSTRAK

Tangki simpanan pengumpul tenaga suria adalah tangki air yang digunakan untuk menyimpan air panas untuk pemanasan ruang atau penggunaan domestik. Matlamat utama projek ini adalah untuk mereka bentuk dan fabrikasi tangki simpanan untuk *evacuated tube solar collector* (ETSC) dan untuk menentukan kehilangan haba keseluruhan tangki simpanan dan tempoh penyimpanan tenaga haba selepas matahari terbenam. Dua jenis penebat digunakan untuk ujikaji seperti *polyurethane* dan *woolen coat*. Ini adalah kerana kekonduksian haba yang rendah daripada polyurethane dan bulu biri-biri 0.03 W /m.K dan 0.039 W/m.K berbanding penebat yang banyak yang lebih tinggi. Eksperimen ini terdiri kepada dua jenis cecair yang air suling dan nanofluid menggunakan silikon oksida (SiO_2). Dalam eksperimen ini, sistem terbahagi kepada dua jenis iaitu tanpa sistem kawalan dan dengan sistem kawalan. Keputusan yang diperolehi menunjukkan bahawa adalah nanofluid menggunakan silikon oksida (SiO_2) dengan sistem kawalan adalah hasil yang terbaik berbanding dengan air suling. Ia telah menunjukkan nanofluid mencapai suhu yang lebih tinggi sebanyak 86.7^{o}C dan dengan perbezaan suhu sebanyak 47.52 %. Hasil daripada ujikaji air suling menunjukkan, suhu tangki dengan sistem kawalan lebih tinggi daripada tanpa sistem kawalan dengan perbezaan 6.68 %.

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LIST OF SYMBOLS

^{o}C	Degree Celcius
^{o}F	Fahrenheit
δ	Declination angle
%	Percent
SiO_2	Silicon Oxide
W/m^2	Solar Radiation
$W/m.K$	Thermal Conductivity

LIST OF ABBREVIATIONS

CPC	Stationary Compound Parabolic Collectors
CRES	Corrosion resistant steel
DHW	Domestic hot water
ETSC	Evacuated Tube Solar Collector
FPC	Flat Plate Collector

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Since 1970^{-s} solar technology emerges or introduced due to the cost of electric energy increase from year to year. Solar energy consumption, which in most of case used for daily work at home like washing, bathes and so on. The features of each solar heating different but the basic component of heating was still same. The basic component include are a collector, heat storage and heat circulation system.

A solar collector is major component of any solar system. The function of solar collector is to capture the sun's energy falling on it in the form of heat to the fluid in the collector. There are many types of collector like flat plate collector, evacuated tube solar collector and compound parabolic collector. Every types of collector have different efficiency. The higher efficiency is better used in solar system.

Solar collector storage tank is water tank used to store hot water for space heating or domestic use. The design of storage tank must be considering pressure requirement and corrosion protection. The most important about solar collector storage tank is material used for tank and the material for insulation. The material for tank is such as steel, stainless steel and cooper. Percentage of corrosion that is lower better in material selection for storage tank. The corrosion aspects should be taken into consideration to ensure the tank well off under lock and key and could be utilized in long time period.

Insulation is the method used for every storage tank to reduce heat loss and consumption energy.

1.2 PROJECT BACKGROUND

A seido 2-16 evacuated tube solar collectors were installed at the solar house UMP Pekan campus is facing the problem of 200 degree centigrade stagnation temperature. At this temperature the PVC at the outlet for pressure monometer tends to be softened. A sufficient size of storage tank required to cater for the thermosyphon action of the stagnant working fluid. A device must be design to protect the tank from overheat or over pressure. The storage tank must be able to store the heat energy and it is cheap to fabricate. The storage tank will be installed above the header of the ETSC with inlet and outlet pipes.

1.3 PROBLEM STATEMENT

The design of storage tank have many factor must to be considered. People are spending a lot of time and money to study and investigate about material, insulation and capacity of storage tank. The best idea must be decided before the process fabrication being conducted. To achieve the best storage tank, the heat lose must be zero. The lowest of heat lose is best storage tank.

1.4 PROJECT OBJECTIVE

The main objectives of this project are:

i) Design and fabricate storage tank for ESTC.

ii) Determine the overall heat loss of the storage tank and the period of heat energy storage after sunset.

iii) Simulation in software to determine suitable heat insulator for the storage tank.

1.5 SCOPE AND LIMITATION OF PROJECT

In order to achieve the objectives this project, the scope are list as below:

i) Design a cost effective 80 liter capacity storage tank with weather proof material

ii) Use the available temperature transducer for taking the temperature.

iii) Simulation in Algor on the heat storage by varying the insulation material for storage tank.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

There are some previous studies on domestic solar system. Through this paper, the detail description of the solar positioning, types of solar collector and storage tank was discussed generally at the early part of this chapter. Then, the sizing, insulator and material of tank were discussed in this chapter.

2.2 SOLAR ENERGY

The solar positioning will bring negative impact and positive in solar radiation. The relationship between sunlight and position solar is very associated closely. According to studies, sunlight are available for more than ten hours per day and the irradiation of direct sunlight is between 800 W/m^2 and 1000 W/m^2 with approximate six hour. The weather condition on Malaysia is very suitable to implement solar energy as the alternative energy to replace the existing fossil fuel energy (Azhar Ghazali M et al., 2012).

Reflection of sunlight by solar panel is one of the main losses during operation. To reduce these losses, solar panel must be perpendicular to the irradiation of sunlight. The optimum tilt angle of solar panel is depending on seasons, location, month by month basic throughout the year. However, the best position to receive irradiation of direct sunlight for the Northern Hemisphere countries this is south, for countries on the Southern Hemisphere this is north (refer to Figure 2.1).

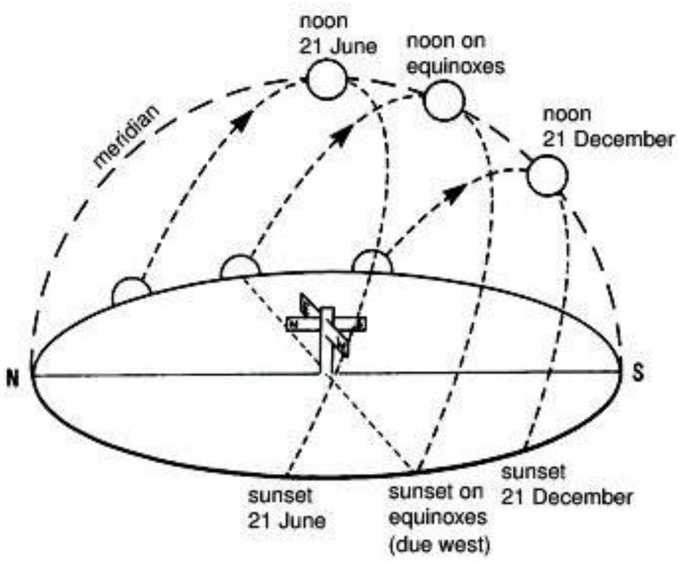


Figure 2.1: Sun in the northern hemisphere countries, solar panel have to tilt to south.

Source: H P Garg et al. (2000)

2.2.1 Declination angle

Our earth revolves around the sun as much as 360^o per day. Every rotation has different degree of declination on sunlight. Declination angle (δ) is the angle subtended by a line joining the centers of the earth and the sun with its projection on the earth's equatorial plane. Figure 2.2 shows the rotation of earth to sun for tropics and northern hemisphere.

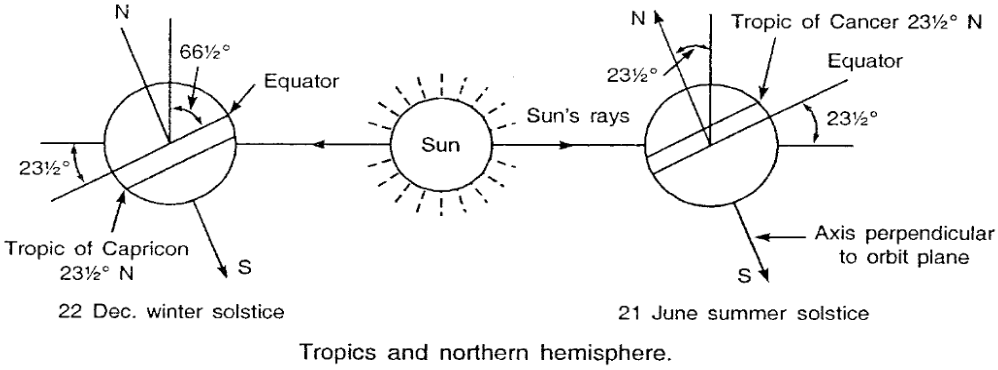


Figure 2.2: The rotation of earth to sun for tropics and northern hemisphere

Source: H P Garg et al. (2000)

The declination angle for an nth day may be calculated from the following simple relationship given by Cooper *(*1969*)* in Eq. (2.1)

$$\delta(\text{in degrees}) = 23.45^\circ \sin\left[\frac{284+n}{365} \times 360^\circ\right] \tag{2.1}$$

Where n is the total number of days counted from first January till the date of calculation. The figure 2.3 below shows that the declination angle δ is a sine graph. The zero declination angles δ on March 22 (fall) and September 22 (spring). Besides that, the minimum declination angle δ change from value –23.5° December 22 to +23.5° on Jun 22.

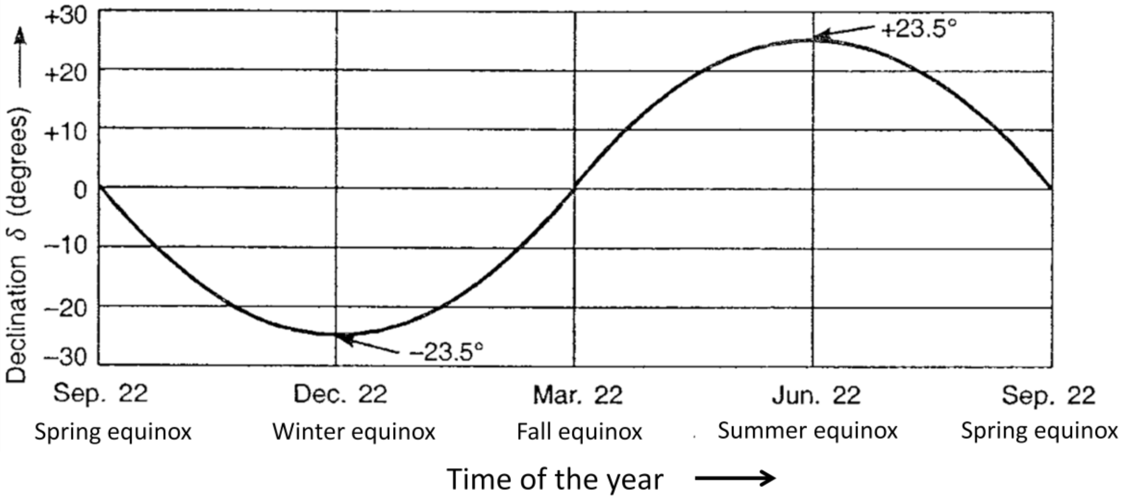


Figure 2.3: Variation of declination angle δ with the *nth* day of the year

Source: H P Garg et al. (2000)

Earth has various seasons. Every season have declination difference of rate to get maximum irradiation solution. During winter season, inclination angle solar panel must be bigger whereas in spring and fall the angle inclination is smaller or zero.

2.3 SOLAR COLLECTOR

Solar collector is main component that working as solar radiation absorber. Solar radiation will be transformed into heat and transfer the heat to the working fluid which flow through the collector. There are two types of collector, stationary or non-concentrating solar collector and concentrating solar collector. The stationary collectors are permanently fix in position and has same area for intercepting and for absorbing the solar radiation. However the concentrating collector usually has concave reflecting surface to intercept and focus the solar radiation beam to a specific area, which increases the radiation flux.

Flat Plate Collectors (FPC), Stationary Compound Parabolic Collectors (CPC) and Evacuated Tube Collectors (ETC) were types of solar collector. This solar collector included in stationary or non-concentrating type. Every types of collector have different the efficiency.

2.3.1 Flat plate collector

Flat plate collector is one of solar collector. FPC is usually permanently fixed in position and requires no tracking of the sun. The collectors should be oriented directly towards the equator, facing south in the northern hemisphere and north in the southern. As cited in The Potential of Solar Industrial Process Heat Applications (S.A. Kalogirou , 2004) the optimum tilt angle of the collector is equal to the latitude of the location with angle variations of 10º–15º more or less depending on the application. A typical FPC is shown in figure 2.4.

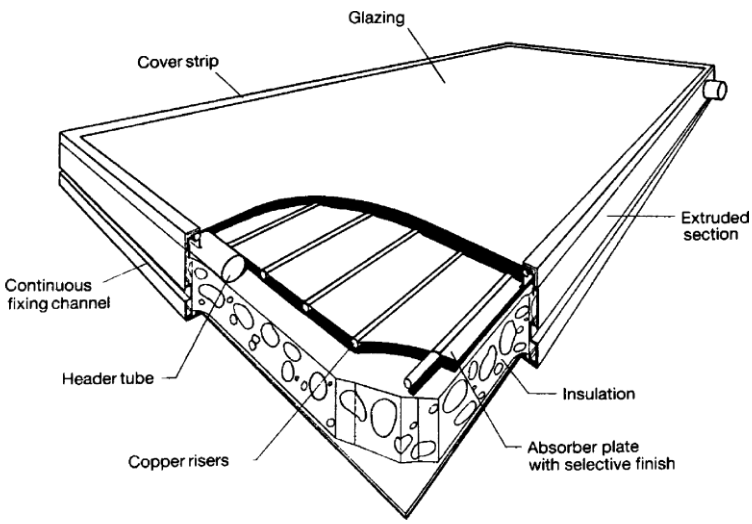


Figure 2.4: Pictorial view of a flat plate collector

Source: S.A.Kalogirou (2004)

Figure 2.5 is shown the following component of flat plate collector. Glazing is one of component in FPC. The material used for glazing is glass because it can transmit as much as 90% of the incoming shortwave solar irradiation while transmitting virtually none of the long wave radiation emitted outward by the absorber plate. Glass with low iron content has a relatively high transmittance for solar radiation (approximately 0.85–0.90 at normal incidence), but its transmittance is essentially zero for the long wave thermal radiation (5.0–50 mm) emitted by sun-heated surfaces (S.A. Kalogirou, 2004). The second component is riser tube. The function of riser tube is to conduct or direct the heat transfer fluid from the inlet to the outlet.

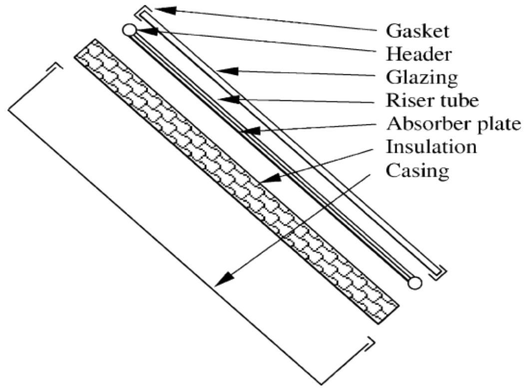


Figure 2.5: Exploded view of a flat plate collector

Source: S.A. Kalogirou (2004)

The next component is absorber plate. According in experiment analysis of flat plate collector and comparison performance with tracking collector (Prasad P.R. et al., 2010) the function of absorber plate are to absorb as much as possible radiation that until through the glazing , releasing a little heat to the atmosphere and downward through the back of container, and to transfer heat to trafficking fluid. The absorptance of the collector surface for shortwave solar radiation depends on the nature and color of the coating and on the incident angle. Usually black color is used, however various color coatings have been proposed in mainly for aesthetic reasons. A major problem is obtaining a good thermal bond between tubes and absorber plates without incurring excessive costs for labour or materials. Material most frequently used for collector plates are copper, aluminum, and stainless steel. UV-resistant plastic extrusions are used for low temperature applications. If the entire collector area is in contact with the heat transfer fluid, the thermal conductance of the material is not important.

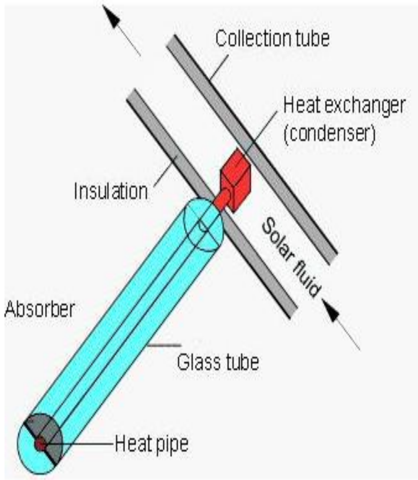
Header is one of component in FPC to admit and discharge the fluid (S.A. Kalogirou, 2004). The other component is insulation. The function of insulation is to minimize the heat loss from the back and sides of the collector. The low thermal conductivity, stability at high temperature (up to 200^oC, no degassing up to around 200^oC, self supporting feature without tendency to settle, ease of application and no contribution in corrosion are features should have in insulator selection. (Solar energy: Fundamental and application, 2000 by H P Garg et al., pages 50). The last component is casing. Casing is to surround the aforementioned component and keep them free from dust, moisture, etc (S.A. Kalogirou, 2004).

2.3.2 Evacuated tube solar collector

In particular for high temperature operation, evacuated tube solar collector is better performance than flat plate collector (G.L. Morisson, 2003). Since the past 20 years more commercially has been found, however until today they are not provided any real competition for evacuated tube solar collector. In Europe, the single envelope vacuum tube with heat pipe energy removal for ETSC has been commercialized and a U-tube heat removal system for all glass evacuated tube has been successfully in Japan. As a result development in China already has been a major expansion of evacuated tube solar water heater market (Yin et.al., 1997).

There are two types of evacuated tube solar collector (ETSC) namely the direct flow and heat pipes (E.Zambolin et al., 2010). The run down and back are pipes that occur inside pipe type direct flow ETSC. One pipe is for outlet fluid and the other pipe for inlet fluid. The tube not easily replaced when the fluid flow into and out of each tube. Whereas for heat pipe ETSC contain heat pipe cooper where it enclosed on absorber plate within a vacuum sealed solar tube. The heat pipe must be hollow and space inside also must evacuated. There is small quantity such as alcohol pure water with special well off additives in heat pipes ETSC. The liquid in heat tube quickly turn to hot vapor and rises to the top of the pipe when collapsed at absorber surface. Water or glycol, flow through one various and detect heat. Then, fluid in heat pipe condenses and flow back down the tube.

(a)



(b)

Figure 2.6: The types of evacuated tube solar collector. a) Direct flow of ETSC. b) Heat pipes of ETSC

Source: Greenterrafirma (2012)

ETSC consists of two glass tube which made of extremely strong glass. The outer tube has very high transitivity and low reflectivity which enable the radiation to pass through. The inner tube has a selective coating layer which can maximizes absorption of solar energy while minimizes the refection, thereby it locking the heat. The both of tube have cooper coating in it, the cooper is absorber medium which collected energy and exchanged to heat. The absorber plate on the internal surface of the inner glass tube collects all the solar radiations passes through the glass layer. This effect tends to give advantages to ETSC over FPC in day long performance and be efficient at season climate area.

The most effective absorbers are aluminum and copper which has high heat reflectivity and transitivity quotient. The surface of the absorber tube has been blackened to make it act as black body and ideally has α = Ɛ ~ 1 (Holman, 2009). The area of absorber has to be maximizing to make sure the absorber plate is placed in direct contact with the inner glass tube.

2.3.3 Thermal efficiency

The collector efficiency factor can be calculated by considering the temperature distribution between two pipes of the collector absorber and by assuming that the temperature gradient in the flow direction is negligible. For FPC, the efficiency can be written in Eq. (2.2) (H P Garg et al., 2000).

$$\eta_c = \frac{q_{col}}{A_c I_c} \tag{2.2}$$

According to research, the usage evacuated tube solar collector in Hong Kong increasingly widespread because the thermal efficiency and high water temperature achievable compared to flat plate collector. There is thermosyphon flow in vacuum-sealed tube of evacuated tube solar collector that aim to minimize the heat transfer through thermal conductivity and convention (T.-T.Chow et al., 2011).

There are two types of thermosyphon flow of evacuated tube such as single-phase or two-phase. The concept for the both thermosyphon flow is can work either forced or natural flow in domestic water storage and distribution. There is two concentric borosilicate glass tube sealed at the lower end that designed for single phase open thermosyphon. At the outside of the inner glass there was selective coating to increase solar absorption and reduce heat radiation losses. A buoyant flow of water up the tube are developed by heat absorption and replaced by a cold water flow from tank. The second type of thermosyphon flow has a sealed borosilicate glass tube and a metallic (mostly aluminum) fin and a sealed metallic (mostly cooper) tube with a working fluid in it. The lower evaporator section and the upper