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Bachelor of Mechanical Engineering (Thermal Fluids)’

Signature : .....
Name of Coordinator : PROF. DR. MD. RAZALI BIN AYOB
Date : 18 MAY 2009

# IMPROVEMENT ON THE DOMESTIC SOLAR WATER HEATING DESIGN

GAN KOK HENG

This report had been publish to
fulfill one of the parts of the requirement to obtain
Bachelor of Mechanical Engineering (Thermal Fluids)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

APRIL 2009

"I hereby declare that this report is my own works except for the abbreviations and parts which had been cited or show in the reference list."

Signature: .....

Writer's name: .....

Date: .....

**To my university (UTeM), father and mother, and friends who my beloved.**

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# ABSTRAK

Kajian ini adalah untuk mengaplikasi tenaga suria sebagai sumber tenaga alternatif kerana ia mempunyai potensi yang hebat untuk digunakan di pelbagai tempat termasuk dalam Malaysia. Matlamat projek ini adalah untuk merekabentuk pemanas air suria domestik yang sesuai digunakan di Malaysia. Sudut optimal papan pengumpul tenaga suria yang digunakan di Malaysia telah dicari. Pemanas air suria merupakan suatu projek yang menggunakan tenaga daripada matahari sebagai sumber tenaga. Sistem termosifon telah digunakan untuk mengkitar aliran air secara semulajadi dengan bantuan pergerakan air tabii dan daya graviti yang menarik air balik ke dalam pengumpul datar atau tangki penyimpan air. Prototap telah dibina untuk uji kaji tentang keberkesanan dan kebolehan untuk digunakan dalam kehidupan harian. Sudut optimal yang didapati di Malaysia ialah 15˚ menghadapi arah selatan atau 15˚ menghadapi utara dan keamatan suria tenaga per jam (S.H.O.T) ialah 4 hingga 5 kWjam/m²/hari. Uji kaji yang telah dijalankan menunjuk bahawa air boleh dipanaskan oleh tenaga suria dari 29.3˚C hingga 72.0˚C dan suhu air pade keesokan 8.00 pagi ialah 32˚C. Masa puncak untuk memanaskan air adalah sekitar jam 1300 hingga jam 1430. Pengiraan telah menunjukkan kuasa elektrik yang dijimatkan dengan menggunakan pemanas air suria ini adalah 7.75 kWjam untuk satu bulan. Kos pembinaan pemanas air suria ini adalah RM 330. Warna hitam dapat meningkatkan prestasi penyerapan haba sehingga 1.86˚C untuk 325 ml jika dibandingkan dengan warna putih. Pemanas air suria ini telah diperbaikkan dengan menambahkan 6 kepingan aluminium berwarna hitam di bawah tuib kuprum yang berwarna hitam.

## ABSTRACT

This study is to apply solar energy as an alternative energy source since it has the big potential to be utilized on various places include in Malaysia. The objectives of this project are to study and design a domestic solar water heater. Optimum tilt angle of solar collector panel which been used in Malaysia had been found. Solar water heating is a project which uses sun energy as the power source. The thermosiphon system is used to circulate the heated water naturally by convection and the gravitational force into the solar collector panel and water storage tank. A prototype of solar water heater had been build to test it performance and feasibility for the daily usage. The optimum tilt angle which had been found in Malaysia is 15˚ face south or 15˚ face north and the S.H.O.T (Sun Hours On Tilt) is 4 to 5 kWh/m²/day. The tests that were carried out had proved that the water can been heated by solar energy from 29.3˚C to 72˚C and the water temperature at the next day morning was 32˚C. The peak time for the solar water heater to heat up the water is around the time 1300 till 1430. The calculation show that the electricity been saved by using solar water heater is 7.75 kWh for a month. The cost of making this solar water heater is RM 330. The black colour surface can increase the performance of heat absorption till 1.86˚C higher in temperature rose (for 325 ml of water) compare to the white colour surface. The solar water panel had been improved by placing 6 black aluminum absorption plates under the black copper tubes.

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## SYMBOLS LIST

| | | |
|---|---|---|
| $C$ | = | Fraction of cloud cover in target area |
| $I_t$ | = | Solar intensity for time *t* |
| $I_{total}$ | = | Daily solar radiation (time is taken from 0700 until 1900) |
| $I$ | = | Monthly average daily global solar radiation |
| $U_f$ | = | Heat transfer coefficient of the front in the direction of the incident irradiance |
| $R_{a-g}$ | = | Thermal resistance of the standing air layer between the absorber and the glass cover |
| $R_{g-o}$ | = | Outside thermal resistance between the cover glass and the ambient air |
| WHAM | = | Water Heater Analysis Model |
| UA | = | Standby Heat Loss Coefficient |
| A | = | Area of the collector for supply hot water for 5 family members ($m^2$) |
| $A_1$ | = | Area for each solar collector panel ($m^2$) |
| S.H.O.T | = | Sun Hours On Tilt ($kWh/m^2/day$) |
| FS | = | Facing South |
| FN | = | Facing North |
| G | = | Irradiation |
| $\dot{E}_{acc}$ | = | Solar energy been received by the absorption plate |
| $\dot{E}_{in}$ | = | Energy in |
| $\dot{E}_{loss}$ | = | Energy loss |
| $m$ | = | Mass of the absorption plate (kg) |

| | | |
|---|---|---|
| $c_p$ | = | Specific heat (J/kg.˚C) |
| $\frac{dT_p}{dt}$ | = | Temperature change of the absorption plate over a period |
| $Q_u$ | = | Heat been absorbed by the water flow (W) |
| $A_c$ | = | Aperture area of the collector panel (m²) |
| $I_T$ | = | Solar radiant intensity (W/m²) |
| $\alpha$ | = | Coefficient of absorption for black plate (absorptivity) |
| $\tau$ | = | Coefficient of thermal radiation transmit through the glass (transmittivity) |
| $U_L$ | = | Coefficient of total heat loss (W/m².ºC) |
| $T_p$ | = | Temperature of absorption plate (black plate) (˚C) |
| $T_a$ | = | Ambient temperature (˚C) |
| $Ut$ | = | Coefficient of heat loss at the upper part |
| $Ub$ | = | Coefficient of heat loss at the bottom part |
| $v$ | = | Wind speed at the cover surface (m/s) |
| $N$ | = | Quantity of cover (glass cover) |
| $\varepsilon_c$ | = | Emissivity of the cover (glass cover) |
| $\varepsilon_p$ | = | Emissivity of the absorption plate (black plate) |
| $\sigma$ | = | Stefan-Boltzmann constant (5.669 X $10^{-8}$ W/m².$K^4$) |
| $Tp$ | = | Temperature of absorption plate (black plate) (K) |
| $Ta$ | = | Ambient temperature (K) |
| $k$ | = | Thermal conductivity of the insulator |
| $L$ | = | Thickness of the insulator (m) |
| $q$ | = | Heat gained (Joule, J) |
| $\Delta T$ | = | Change in temperature (ºC or K) |
| $Q_{trap}$ | = | Heat been trapped (J) |
| $E_{elec\_month}$ | = | Electricity been saved for one month (kWh) |

## APPENDIXES LIST

# CHAPTER I

# INTRODUCTION

## 1.1 Background

"THE world crude oil price may touch US$200 (RM654) soon. Never before has crude oil price reached such historic high in so short time."(Wed, July 30, 2008. New Straits Time)

"Oil is a cost in essentially all produces and services. The sudden jump in price has put the global economy at serious risk. Already inflation is commonplace. A hike in interest rates is now a matter of when, not if. Rising transportation, energy and heating costs are inevitable. The cost of living will go up."(Wed, July 30, 2008. New Straits Time)

"Indonesia, like China and India, a net importer of oil recently raised fuel prices by 30 per cent, slightly less than Malaysia's 40 per cent increase."(Wed, July 30, 2008. New Straits Time)

As can see from the above information, energy resources decaying is a serious issue and had been concern since few years before. Fossil fuel and natural gases will exhaust at one day just the matter of time. But till now, replacement energy sources still no been fully develop and still no common been use in the public. The replacement energy sources include nuclear energy, solar energy, wind energy, tide energy, geothermal energy and other. Nuclear energy can generate large amount of energy to meet the demand but it require high technology, create high

pollution, and is dangerous. Among the renewable energy, solar energy has it own benefit include no create pollution substance during the power generation, no mechanical moving parts like motor or dynamo for the power generation (so low maintenances required), and wide cover range for the usage. That mean as long as the earth receive the sun energy, solar energy can be use, unlike wind, tide, and geothermal energy have to mount the device at a specific place so it can function properly.

In the "Rancangan Malaysia Kelapan" (Eighth Malaysia Planning), the government had target to make the renewable energy as the fifth main energy to be use by the nation sequence after by petroleum, natural gasses, coke, and the hydraulic energy.

"The sun heats the planet most at the equator, although solar energy provides at least 2 kilowatt-hours of energy per square meter per day at any given spot on land, sea or iceberg."(Retrieved from Discover Magazine, August 2008, pg. 56)

"Seven square meters of the earth's surface gets, on average, about 29 kilowatt-hours of the sun's energy daily, enough to power a typical U.S. household."(Retrieved from Discover Magazine, August 2008, pg. 56)

"The sun's core is a mass of fusion reactions that create radiation. It shoots out into space, traveling some 93 million miles before it reaches us."(Retrieved form Discover Magazine, August 2008, pg. 56)

The sun's energy had high constancy and it is enough to generate required power for the household's usage. Malaysia located near the equator has advantage on receiving the solar energy. Generally, Malaysia received five pattern of sun's radiation. Research done by "Kumpulan Penyelidik Tenaga Suria, Universiti Kebangsaan Malaysia"(Solar Energy Research Institute, Universiti Kebangsaan Malaysia)(Mohd. Yusof Othman *et al*, 1993a) found that the solar radiation in Malaysia can be dividing into 5 categories:

(a) sunny along the day

(b) whole day cover with cloud (rain)
(c) day with the pattern of cloud keep changing (cloudy)
(d) evening raining day
(e) sunny day with the sun's radiation higher than the solar constant (solar constant= 1.367 kW/m²)

The daily solar radiation is taken from time 0700 until 1900. On average, Malaysia receives about 4.862 kWh/m² of solar radiation in a year. The maximum solar radiation receive is 5.159 kWh/m² mostly in Northern region of Peninsular Malaysia. The Southern and Northeast region of Peninsular Malaysia receives the lowest average solar radiation. A study by Kamaruzzaman and Mohd Yusof (1992) indicate almost the same results but there is a slight increase in the minimum value from 3.375 kWh/m² in 1992 to 4.210 kWh/m² in 2006. (Retrieved from "Application of GIS in solar radiation mapping for Malaysia", September 2008)

Figure 1.1 shows the monthly average daily solar radiation of Malaysia for the month of January until December.

From all of the information been stated above, solar energy is applicable and can be fully utilize for heating the water. The water been heated suitable for domestic usage and will help to save the cost in long term consideration.

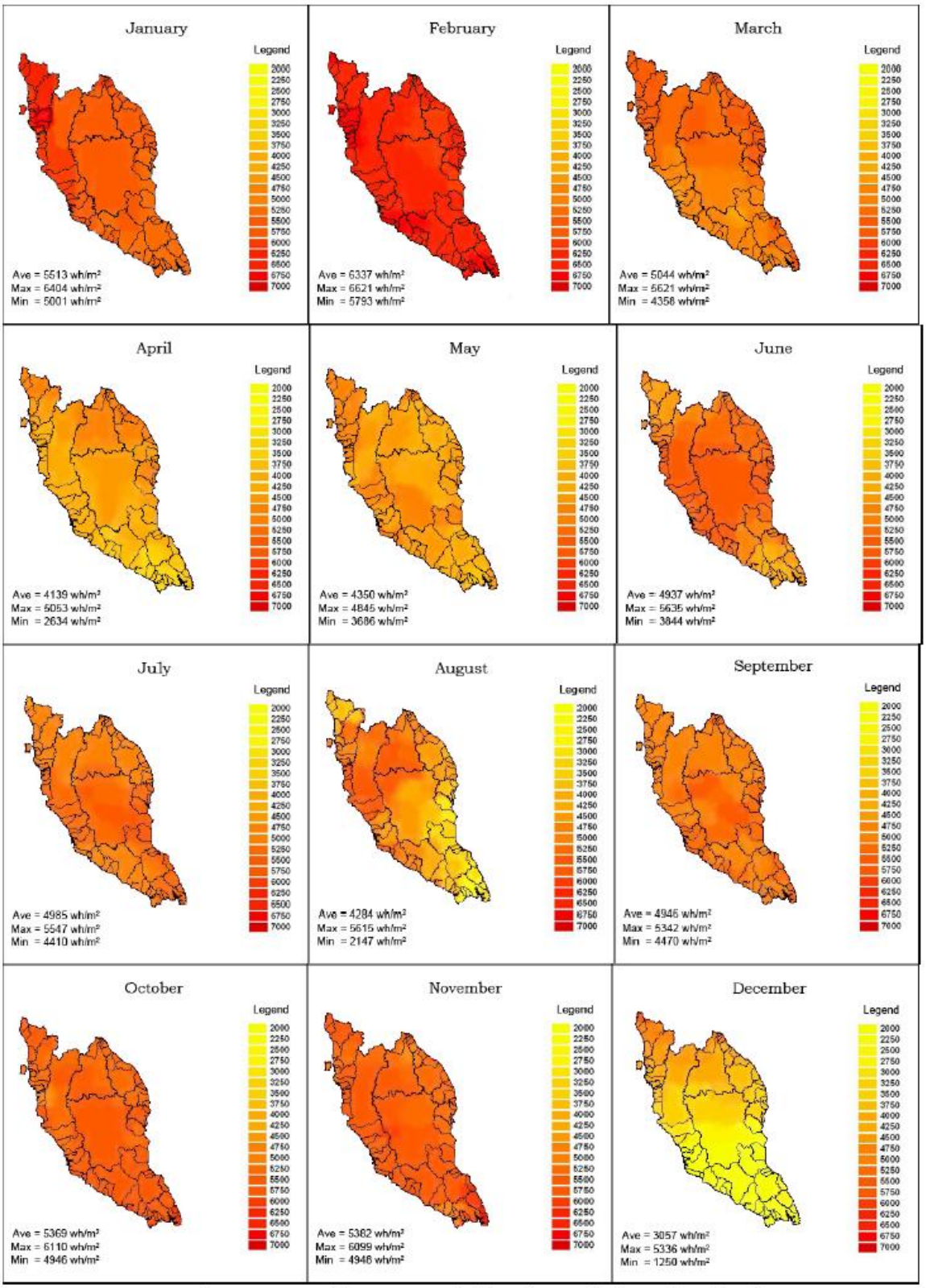


Figure 1.1 Monthly average daily solar radiation of Malaysia
for the month of January until December
(Retrieved from: www.**aars-acrs.org**/acrs/proceeding/ACRS2007/Papers/PS2.G3.13.pdf)

## 1.2 Objectives

Some objectives had been set for the designation and produce a solar water heater, the objectives include:

(a) To design a domestic solar water heater that is suitable for domestic usage.

(b) To find the tilt angle of the solar collector panel that can receive maximum amount of solar radiation in Malaysia.

(c) To collect the solar information, doing testing, collect data, record performance, and do the improvement.

## 1.3 Scope

The scope include study the existing solar water heating device and it's design, design a solar water heater that suitable to use in tropical country, not include anti-freezing system, design a solar water heater only for domestic usage. The solar water heater will use the principle of thermo siphon to heat and circulate the water. Photovoltaic cell will not be use in the design.

## 1.4 Problem Statement

Hot water supply is essential for the domestic application. 'Free' energy should be utilized fully is this case. A domestic solar water heating design has been presented. However the effectiveness of such design is still far from the intended purposes. This problem can be studied again so that a proper design and construction of the industry standard could be achieved.

The solar water heater that been sell in the market is expensive. Some of the solar water heater uses the photovoltaic cell to generate the electric and heat the water. Photovoltaic cell is still expensive now because it manufactured by using the

same principle as manufacture the microchip (semiconductor). The previous works on the design and produce of thermo siphon water heater show that the temperature of the water can be heat up to 55˚C - 70˚C. Since the thermo siphon need a water circuit for doing the circulation of the water, it is heavy and had some limitations like heat losses when low ambient temperature and water leakage.

## 1.5 Hypothesis

The results be expected is to heat the water and store it at the temperature between 55˚C - 60˚C. The quantity of the water be expected to store is 300 liters, that is enough for a typical household's usage. The weight of the heater and tank will be distributed separately at different area of the roof so that the roof didn't withstand with heavy weight. The peak time for the heater to heat up the water is expected to be at afternoon (around 1.00 p.m.).

## 1.6 Briefing of the report

This report divided into 6 chapters. Chapter I is the Introduction, Chapter II Literature Review, Chapter III Methodology, Chapter IV Results, Chapter V Discussion, and lastly Chapter VI Conclusion. Chapter I give an overview about the project and studies. It included objectives, scope, problem statement, hypothesis, and briefing of the report. Chapter II Literature Review will show the previous work on the solar energy and solar water heater in Malaysia and other country. Chapter III described the methodology of this project, here will show the ways design, finding the tilt angle, maximum temperature of the heated water by the solar that can be achieve, fabrication process, and testing method. Chapter IV shows the data been collected and data analysis, material selection, and the final design of the solar water heater. Chapter V discussed the results and some factors that must be take into consideration when doing the experiments or testing. Finally in Chapter VI conclusion and further study's suggestion had been done.

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Introduction

Hot water is an important demand for human daily life. A typical solar hot water system will reduce the need for conventional water heating by about two-thirds. Medium-temperature solar water heaters can provide energy-efficient hot water and hot water heat for large commercial and industrial facilities. There are huge potential for the use solar hot water heating in hotels where almost of quarter of the total energy consumption is for water heating. Other promising applications include the use of solar industrial process heat in textile factories large commercial, industrial facilities and other manufacturing facilities (Sopian, K. *el al*, 2005)

The demand of hot water will continue to increase when a country is continued to grow. Recently, effort had been put to generate electrical power supply by using concentrating solar hot water system which could produce high temperature hot water, over 200˚C, has greatly been develop (Sulaiman, M.Y. 1996).

From the news at July 28, 2008, reported by COIL Bureau, First Solar Inc. announced that the first of its four solar module manufacturing plants being constructed at the Kulim Hi Tech Park in Kedah, Malaysia was formally inaugurated by YAB Dato' Seri Ustaz Azizan Bin Abdul Razak, Chief Minister of Kedah Darul Aman and Bruce Sohn, President of First Solar. First Solar's investment of $680 million (RM 2.2 billon) will bring more than 2,000 jobs in management, engineering, accounting, human resources and factory operations when all four plants are fully