INVESTIGATION OF EVACUATED DIRECT FLOW TUBE SOLAR COLLECTOR USING DIFFERENT TYPES OF SOLAR RELFECTOR WITH WATER-BASES NANOFLUID

MUHAMMAD IQBAL BIN GHAZALI

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UNIVERSITI MALAYSIA PAHANG

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ABSTRACT

This is a study on determination of the effect of applying rear reflector and using distilled water-bases nanofluid as the working fluid to the evacuated tube solar collector located at Solar House, UMP Pekan. The objective of this project is to fabricate the bracket for Evacuated Tube Solar Collector (ETSC) and the systems, to develop an efficient distilled water-based nanofluid solar collector by optimizing the flow rate and collector tilt angle applicable to Pekan, and to compare the efficiency of Evacuated Tube Solar Collector using solar reflector and without solar reflector with distilled water and distilled water-based nanofluid as working fluid. The experiment is conducted for the whole semester during Semester 2 2011/2012 and Semester 1 2012/2013 although only specific date of valid data were used on analysis. The data obtained were analysed using theoretical analysis and plotted in graph to be discuss. From the experiments and calculations, the tilt angle of the solar collector were set to 8º and the flow rate of the working fluid is 2.7L/min. The solar collector efficiency is 43.52% using distilled water and its efficiency increase to 48.48% using 1% TiO_2 nanofluid. For distilled water as the working fluid, the collector efficiency increase to 46.95% using aluminium reflector and increase to 44.28% using chrome reflector. For 1% TiO_2 nanofluid as the working fluid which the collector efficiency is 48.48%, the collector efficiency increase to 49.52% using aluminium reflector and increase to 48.95% using chrome reflector.

ABSTRAK

Ini adalah kajian untuk menentukan kesan apabila menggunakan pemantul suria dan bendalir bersaiz nano berasaskan air suling sebagai medium pada tiub vakum kolektor tenaga suria yang terletak di Rumah Solar, UMP Pekan. Objektif projek ini adalah untuk membuat asas untuk tiub vakum kolektor tenaga suria dan keseluruhan sistem, membina kolektor suria menggunakan bendalir nano berasaskan air suling yang efisien dengan mengoptimumkan kadar aliran dan sudut yang sesuai di Pekan, dan membandingkan kecekapan tiub vakum kolektor tenaga suria dengan menggunakan pemantul suria bersama bendalir bersaiz nano berasaskan air suling sebagai medium. Kajian dilakukan sepanjang Semester 2 2011/2012 dan Semester 1 2012/2013, namun hanya beberapa hari yang tertentu sahaja dipilih untuk analisa. Maklumat yang diperolehi telah dianalisa menggunakan teori analisis dan diplotkan dalam graf untuk dibincangkan. Berdasarkan kajian dan pengiraan, sudut kolektor suria telah ditetapkan kepada 8º, dan kadar aliran bendalir ditetapkan kepada 2.7L/min. Kecekapan kolektor suria ialah 43.52% dengan menggunakan air suling sebagai medium dan meningkat kepada 48.48% dengan menggunakan bendalir nano 1% TiO_2. Untuk air suling sebagai medium yang mempunyai kecekapan kolektor 43.52%, kecekapan kolektor meningkat kepada 46.95% dengan menggunakan pemantul aluminium dan meningkat kepada 44.28% dengan menggunakan pemantul krom. Untuk bendalir nano 1% TiO_2 sebagai medium yang mempunyai kecekapan kolektor 48.48%, kecekapan kolektor meningkat kepada 49.52% dengan menggunakan pemantul aluminium dan meningkat kepada 48.95% menggunakan pemantul krom.

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η_c	Solar collector efficiency
η	Overall system efficiency
ρ	Density of fluid (kg/m3)
t	Time (second)
β	Slope
I_{sc}	Solar Insolation
δ	Declination angle
ω_{st}	Hour angle
ϕ	Latitude

LIST OF ABBREVIATIONS

NASA	National Aeronautics and Space Administration
ETSC	Evacuated tube solar collector
Tin	Inlet collector temperature (ºC)
Tout	Outlet collector temperature (ºC)
Tamb	Ambient temperature (ºC)
I	Solar insolation (W/m²)
G	Global solar irradiance (W/m²)
Gb	Direct solar irradiance (W/m²)
Gd	Diffuse solar irradiance (W/m²)
V	Volume of the heat storage fluid tank (m³)
Cp	Specific heat of fluid(J/kg ºC)

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Solar water heater are one of the devices used to harness the energy of the sun. There are many methods that have been introduced to increase the efficiency of the solar water heater. The novel will focus on adding solar reflector on the system in order to increase efficiency. Overall, the adding of solar reflector will increase the solar water heater absorption area, increase the heat gain by the system thus increasing the efficiency. Nanofluids also will be introduced in solar water heater instead of conventional heat transfer fluids for example water. The poor heat transfer properties of conventional fluids compared to most solids are the primary obstacles to high compactness and effectiveness in the system. The essential initiative is to seek the solid particles having thermal conductivity of several hundred times higher than those of conventional fluids. An innovative idea is to suspend ultrafine solid particles in the fluid for improving the thermal conductivity of the fluid.

1.2 PROJECT BACKGROUND

Solar Energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The principle involve in collecting solar energy is rather simple depending on the receiving surfaces which are able to absorb as much as possible of the incoming solar flux. The ability to retain heat is a condition and transferred through tubes by working fluids.

The solar technologies have started their early development in the 1860s was driven by an expectation that coal would be soon become hard to obtain. However, the development of solar technologies stagnated in the early 20th century in the force of the increasing availability, economy and utility of coal and petroleum.

In the 1890s, a commercial solar water heater began appearing in the United States. The systems saw increasing use until the 1920s but were gradually replaced by cheaper and more reliable heating fuels. As with photovoltaic, solar water heater attracted renewed attention as a result of the oil crises in the 1970s but interest subsided in the 1980s due to falling petroleum prices. Development in the solar water heating sector progressed steadily throughout the 1990s and growth rates have averaged 20% per year since 1999. As of 2007, solar water heating and cooling is by far the most widely deployed solar technology with an estimated capacity of 154GW.

1.3 PROBLEM STATEMENT

The material cost for build solar technology is expensive. This will contribute to long payback period of building the solar system. Therefore, the implementation of water-based nanofluids and solar reflector is expected to reduce the payback period of building solar collector.

The available complete solar water heater at UMP Pekan didn't come with the reflecting system at the back of the tubes. To enhance the heat gain by the system, a simple design of reflector with variety types of reflector were fabricated to maximize the system performance.

Using water-based nanofluid as the system working fluid is expected to increase the system efficiency. There are two methods to prepare the nanofluids which is the one step method and two step method. However, many of researchers are still in research to find the best way of preparing the nanofluids.

1.4 PROJECT SCOPES

The scopes are:

1. The location of the experiment will be in UMP Pekan.
2. The design of the solar reflector will be based on the availability of material.
3. Characteristic of water-based nanofluids will be observed during testing like stability performance in turbulent flow, viscosity and thermal conductivity.
4. Calculation will based on instantaneous efficiency and average efficiency.
5. Efficiency of the solar collector will be compared using water and water-based nanofluids as the working fluid and running the system by using reflector and without reflector

1.5 OBJECTIVES

The objectives are:

1. Fabricate the bracket for Evacuated Tube Solar Collector (ETSC) and the systems.
2. To develop an efficient water-based nanofluids solar collector by optimizing the flow rate, collector tilt angle applicable to Pekan.
3. To compare the efficiency of Evacuated Tube Solar Collector using solar reflector and without solar reflector with distilled water and distilled water-based nanofluids as working fluid

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discusses about the previous researches that report on the related issues with this project. Five major scopes will be detailed in this report which are renewable energy, solar energy, evacuated tube solar collector, solar reflector and nanofluid. The literature review provides a background to the study being proposed. The background may consider previous findings, rational of the relevant study, methodology or research methods, and theoretical background. Most of the literature reviews have been extracted from journals, books and web site. The purpose of doing literature review is to provide information of previous research which is relevant to the scopes desired in this study and also for the project to run smoothly.

2.2 RENEWABLE ENERGY

Energy can divide into two major of energy which is renewable energy and alternative energy. Renewable energy were defined as energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which is naturally replenished. While alternative energy refers to any source of usable energy intended to replace fuel sources without the undesired consequences of the replaced fuels. The word energy is derived from the Greek en (in) and *ergon* (work). There are many forms of energy which are heat, work, chemical energy in forms of fuels or batteries, kinetic energy which in moving substances, electrical energy, gravitational energy and potential energy by virtue of its elevation.

2.2.1 World Energy Scenario

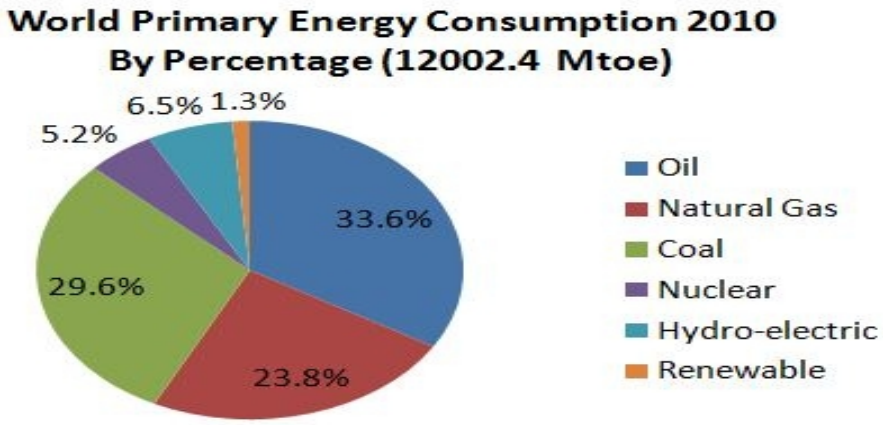

Figure 2.1: World's energy scenario at 2010

Source: BP Statistical Review of World Energy June 2011

Total energy consumption for 2010 have increased to 12002.4 Mtoe from 11363.2 Mtoe for 2009, which is increasing about 5.63% increase. The main world primary energy consumption is based on energy that can be depleted. Renewable energy only contributes 1.3% energy to the world energy consumption. Therefore, an increase of the number uses of renewable energy is necessary due to faster growth of energy demand which is mainly come from fossil fuels. The bad effects on environment caused by the production and consumption of energy have resulted in harsh environmental impacts across the globe. The supply of energy is expected to remain as much as necessary in coming years. However, imbalance of energy consumption is common around the world. Energy consumption is high in most developed countries. On the other hand, the developing countries need to consume more energy to ensure economic growth. The economic development of many countries is caught up due to "energy poverty" (Economy Watch 2010).

The major sources of energy in the world are oil, coal, natural gas, hydro energy, nuclear energy, renewable combustible wastes and other energy sources. Combustible wastes include animal products, biomass and industrial wastes. Renewable energy will be more concentrate in this project because to helps and decrease the usage of available energy.

2.2.2 Malaysia Energy Resources

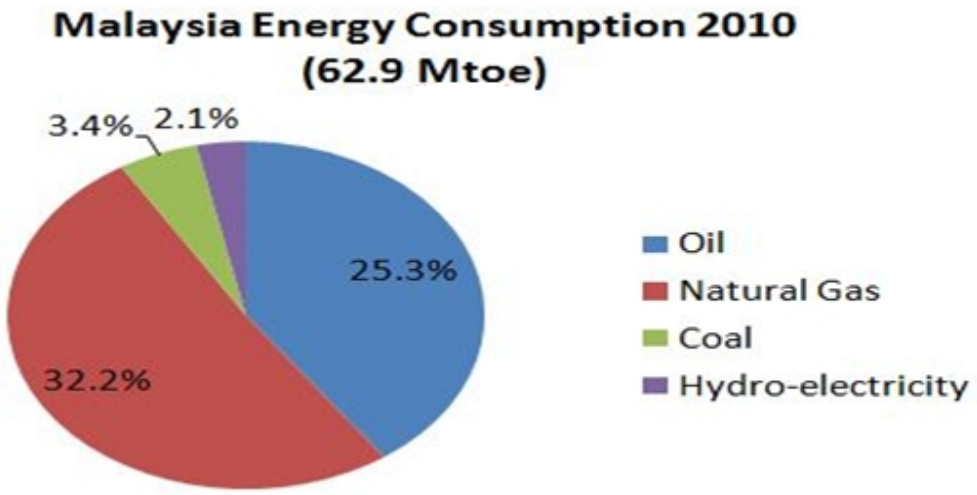

Figure 2.2: Malaysia energy consumption for 2010

Source: BP Statistical Review of World Energy June 2011

2.2.2.1 Generation Fuel Options

The New Five-Fuel Diversification Strategy replaces the Four-Fuel Diversification Strategy, in which the fifth fuel under the New Strategy is non-hydro renewable energy (RE) alongside the existing four fuels utilised for power generation, namely, oil, gas, coal and hydro. The Four-Fuel Strategy and subsequently the New Five-Fuel Strategy has been successful in bringing down oil consumption for power generation from more than 80% in the 1980's to about 32% in FY1998 and further down to about 4% in FY2000. The Government is also looking into efficient energy utilisation and consumption through the National Energy Efficiency Strategy. There are therefore no firm plans at present for the introduction of nuclear power generation, although TNB maintains an interest in nuclear power technology through a continuing programme of technical and manpower training. TNB has the largest generation capacity of over 7,500 MW that accounts for over 62% of the total power generation of Peninsular Malaysia.

2.2.2.2 Renewable Energy

Renewable energy (RE) has been identified and finalised by the Government as the fifth fuel under the New Five-Fuel Diversification Strategy. The RE focus would be on biomass, especially from palm oil and wood wastes. The target of contribution towards the total electricity generation mix from RE is 5% by 2005 and 10% by 2010, after which this ratio could be maintained thereafter.

2.2.2.3 Natural Gas

The highest contributor of Malaysia energy consumption, natural gas occupy 32.2% or 25.3 Mtoe of energy consumption until 2010. The value has increase about 3.26% since 2009 which is 24.5 Mtoe. Natural gas has become an important fuel for gas turbines and combined-cycle plant developments, both for TNB and IPPs. The Phase II of the Peninsular Gas Utilisation Pipeline Project has made available natural gas to the West Coast and South of Peninsular Malaysia in the late 1991.

With the completion of the gas pipeline project and the advent of Independent Power Producers (IPP) in 1994, gas utilisation in power generation has increased tremendously. To-date, gas contributed to about 76% of the total generation capacity mix.

2.2.2.4 Oil

Oil contribute 25.3% of energy consumption at 2010 which is 25.3 Mtoe. The total oil energy consumption at 2009 is 24.5, which indicate an increase of 3.26% of demand. Oil-fired generation contributes to a substantial proportion of TNB's output and operating costs were significantly affected by excursions in oil prices since late 1973. Despite current low prices of fuel oil, oil-fired generating plants are not considered to be strongly competitive options for long term planning purposes, in view of the uncertainties of future prices, and other available alternatives.

2.2.2.5 Coal

Since Malaysia sources of coal have long depleted, mainly at Batu Arang which used to have a coal mines, current demand of coal is available from foreign sources and this fuel is an option for our power generation development studies. Current indications are that imported coal will be a competitive fuel source for electric power generation in Malaysia. Coal contribute 3.4% of energy consumption until 2010, which is about 3.4 Mtoe. Unlike other energy resources, coal demand have decreased for 15% compare to 2009 coal consumption which is 4.0 Mtoe. The third phase Port Klang Power Station, comprises two 500 MW coal-fired units capable of burning coal, and can also burn gas and oil. In addition, the Janamanjung Power Station which is a 2,100 MW coal-fired plant have been running since the year of 2003.

More coal-fired plants (including IPPs) have been proposed in the years beyond 2000 for security of power supply and to conform to the diversification of fuel usage in power sector as required by the national fuel policy. Currently coal-fired generation constitutes about 5% of the total generation capacity mix.

2.2.2.6 Hydroelectricity

During 2009, hydroelectricity energy consumption is 2.0 Mtoe. Until 2010, there number increase for 5%, which is 2.1 Mtoe. This contribute 2.1% from total Malaysia energy consumption until 2010. It is estimated that the indicative hydro potential in Peninsular Malaysia totals some 16 TWh/year. Nine major hydro stations with a capacity of 1,874 MW are currently in service. This total capacity includes the recently commissioned Pergau Hydroelectric Station (in 1997) which contributes a total peaking capacity of 600MW. Three other hydroelectric projects have been identified and under planning stage namely, Ulu Terengganu (300MW), upgrading of Kenyir Hydro station (300MW) and Ulu Jelai's mixed pumped storage (1,000MW-1,200MW) with 300MW conventional hydro scheme.

2.3 SOLAR ENERGY

Solar Energy is one of the renewable energy commonly been practiced. Solar radiation we receive on the Earth's surface comes directly or indirectly, and the sum of both components is measured as the global radiation. Solar radiation is received on the Earth's surface after being subjected to attenuation, reflection and scattering in the Earth's atmosphere. The radiation received without change in direction is called direct radiation; while that received after its direction has been changed by scattering is called diffuse radiation. The sum of both components is called the global radiation. Most radiation data are measured for horizontal surfaces.

In this context, “solar energy” refers to energy that is collected from sunlight. Solar energy can be applied in many ways, including to:

a) Generate electricity using photovoltaic solar cells.
b) Generate electricity using concentrating solar power.
c) Generate electricity by heating trapped air which rotates turbines in a solar updraft tower.
d) Generate hydrogen using photo electrochemical cells.
e) Heat water or air for domestic hot water and space heating needs using solar-thermal panels.
f) Heat buildings, directly, through passive solar building design.
g) Heat foodstuffs, through solar ovens.
h) Solar air conditioning

The sun is a fusion reactor that has been burning over 4 billion years. In fact, “The amount of solar radiation striking the earth over a three-day period is equivalent to the energy stored in all fossil energy sources.” Sun provides energy in one minute to supply the world’s energy needs for one year. In one day, sun can provides more energy than our current population would consume in 27 years. It means, the sun can deliver 7000 times more energy to the Earth’s surface. Earth receives approximately 170 million GW of power from the sun, which is a relatively tiny fraction of the sun’s total output, but is millions of times greater than the maximum power demand of Earth’s entire population. The Earth distance from the sun is 149,596,000 km, therefore, the solar flux relatively small. About 1367 watts per square meter (W/m^2)

is the intensity of the solar radiation that reaches us and this values also known as Solar Constant. To put it another way, solar energy captured by the Earth over a period of 1000 years is equal to the energy produced by the Sun in just only 14 seconds.

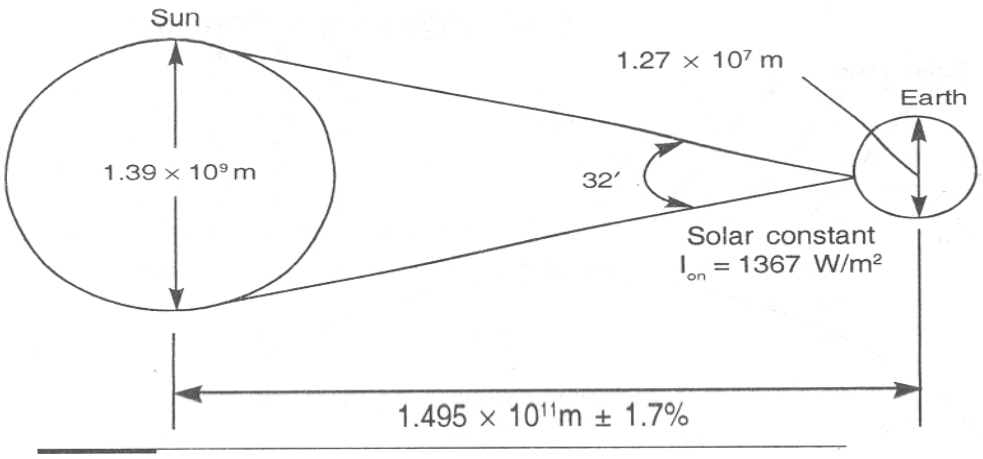

Figure 2.3: The sun-earth relationship

Source: Tiwari, 2004

The information on sunshine hour, solar radiation intensity and daily variation of global solar radiation are one of the important aspects to design a suitable solar system for a particular application such as photovoltaic water pumping system, solar thermal and drying system. In tropical countries like Malaysia, the cloud pattern can be highly variable due to high humidity and unpredictable weather, especially during the monsoon seasons. Mainland Malaysia is a peninsula lying between latitudes 1.30 and 6.60^0N, and longitudes 99.50 and 103.30^0E. As in many places at Malaysia is mainly influenced by the system of the Asian monsoons (Yusof 1992).

Some observations has observed at Malaysia that instantaneous solar radiation intensity sometimes rises higher than solar constant, even reaching 1.4 kW/m^2 which is the saturation point of the recording system. For such a clear day, the maximum instantaneous solar intensity was 971 W/m^2 and the amount of solar energy received during the whole day was 6.957kWhr/m^2. For the whole day, about

12hours Malaysia will receive the amount of solar energy which is from 7 a.m. until 7 p.m. The comparison of lower value than desert area is because the atmosphere in Malaysia is denser than desert due to the higher humidity. Besides that, for fully cloudy day, the maximum solar intensity received was 121.4 W/m^2 and for the whole day was 0.5$kWhr/m^2$.

Furthermore, the global solar radiation pattern with instantaneous intensity higher than solar constant was record 1400 W/m^2 which the maximum intensity that recorded and the total amount solar radiation on that day can achieve 4.16$kWhr/m^2$. The difference in units by using W/m^2 and $kWhr/m^2$ are for W/m^2, are taking from the reading. However, for $kWhr/m^2$ is because the total of solar radiation times the sun received for the whole day. Other than that, when it's rainy in the afternoon, the maximum instantaneous solar intensity was 957 W/m^2 and total solar radiation received for the day was 3.00$kWhr/m^2$ (Yusof 1992). Due to this consideration, the specifications and components solar system can be determine for installation in Malaysia and similar locations.

For thousand of year, solar energy has been used. Solar energy provides heating and cooling for buildings and to heat water. All the living things on Earth could not exist without sun. Sun is responsible as energy sources for produced primary fossil fuels used today by decaying plants millions of years ago. Other than that, the sun that produced heat will make renewable source energy such as wind. At the atmosphere of Earth, that heated by the sun will arises the wind. The other source but produced heat that did not come from sun is radioactive decay, ocean tides that influence by moon's gravitational force and nuclear fusion and fission.

Solar energy can be used direct and indirectly to make more extensive use of renewable sources of energy derived from the sun. For directly used, it can be in a variety of thermal applications like heating water or air, drying, distillation and cooking. For applications like power generation or refrigeration, the heated fluids can turn to be used. In other ways for directly using solar energy is through photovoltaic effect in which it is converted to electrical energy. However, for indirect usage of solar energy is like the sun causes winds to blow, plants to grow, rain to fall and temperatures differences to occur from the surface to the bottom of the oceans.

For commercial and non-commercial purposes through all these renewable sources, the useful energy can be obtained. Renewable energy sources are sun, wind,