I admit that I have read this thesis fully and from my observation, it fulfills the scope and quality of honoring the Bachelor of Mechanical Engineering (Thermal Fluid)

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Date : 16/12/05

THE DEVELOPMENT OF A LABORATORY SCALE SOLAR WATER HEATER

A Thesis submitted to the
Kolej Universiti Teknikal Kebangsaan Malaysia
In partial fulfillment for Bachelor of Engineering
(Thermal Fluids)

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ACKNOWLEDGEMENT

To make the Final Year Project 1 a success, the author would like to acknowledge with appreciation the efforts of some people whose name may not appear in this report, but whose hard work, cooperation, friendship and understanding were crucial to make this report a great success.

Firstly the author would like to thank Mr. Ahmad Anas Bin Yusof the author's lecturer for accepting this project under his supervision. The author would like to thank him for all the support, encouragement and the knowledge he had passed to the author during the period of the semester whether formally or informally.

Finally, the author would like to thank his family and friends for all their support and care they have showed to him in the entire time of making this report a successful one.

ABSTRACT

A laboratory scale solar water heater rig is constructed to allow better understanding of the heating system of a solar water heater using thermosiphon system. Thermosiphon is a system that circulates water from the tank to the collector plate and back to the tank without the aid of any pumps. In this project, a flat plate black copper collector is used. The reason why black copper is used is because, black absorb heat better than any other. A well insulated stainless steel tank is used to minimize the heat transfer to the environment. Copper piping is used for the cold and hot water circulation for better efficiency. Finally the efficiency of the flat plate collector is calculate to evaluate the heat absorb by the flat plate to heat up the water.

ABSTRAK

Satu sistem pemanasan air yang berkonsepkan termosifon yang menggunakan tenaga solar sebagai ejen pemanasan telah dibina bagi membentuk kefahaman terhadap sistem solar dan termosifon. Termosifon merupakan suatu sistem yang mengitarkan air dari tangki ke plat pengumpul dan kembali ke tangki tanpa sebarang penggunaan pam. Di dalam projek ini, plat pengumbpul yang dibina dengan Kuprum hitam digunakan sebagai ejen pengumpul. Kumprum hitam digunakan kerana warna hitam dapat menyerap lebih banyak haba daripada yang lain. Tangki yang telah ditebat dengan sempurna digunakan bagi mengelakan pemindahan haba ke udara sekeliling. Paip Kumprum digunakan bagi pengaliaran air sejuk dan air panas untuk mendapatkan efficiency yang baik. Akhir sekali, efficiency plat pengumpul dikira untuk mengetahui haba yang diserap oleh plat tersebut untuk memmanaskan air.

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Standard

A	surface area (m^2)
C	concentration ($kg\ m^{-3}$)
c_p	specific heat ($J\ kg^{-1}\ K^{-1}$)
D	diameter (m)
f	friction factor (–)
h	heat transfer coefficient ($W\ m^{-2}\ K^{-1}$)
k	thermal conductivity ($W\ m^{-1}\ K^{-1}$)
L	length (m)
$\dot{q}$	Heat flux ($W\ m^{-2}$)
r	radial coordinate (m)
R	radius (m)
T	temperature (K)
R	*radiation*
I	solar radiation (W/m^2)
a	absorptivity of absorber plate
t	transmissivity of cover glass
T_s	Storage water temperature (C)
T_{amb}	Outdoor ambient temperature (C)

Dimensionless numbers

Gz	Graetz number
Nu	Nusselt number
Pr	Prandtl number
Re	Reynolds number

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CHAPTER I

INTRODUCTION

Solar energy to heat water has been in use for many years, and the design requirements of solar water heating equipment have been studied for more than 100 years. Solar water heaters were not widely used, not due to lack of understanding, but because the other sources of energy were more economical. Interest in solar water heating is the past was limited to those having the understanding and enthusiasm necessary to build their own equipment. A solar water industry in south Florida was started in 1900, it is estimated that about 30,000 to 50,000 units were installed by 1950, but around that time their popularity began to decline due to readily available cheap energy from fossil fuel.

Technical advance in solar water heating have been very rapid in the last 40 years. The obvious benefits to the house holder can not longer over look, where the climate is ideally suited for the application of solar energy for water heating, particularly, in the present situation of acute energy shortage. Solar water heaters find wide applications in large establishments like hostel, hotels, hospital, industries such as textile, paper and food processing, domestic uses and heating swimming pools.

Solar water offers a number of advantages such as:

a) Simple to construct and install
b) Almost no maintenance and running cost
c) Save time and energy
d) Retrofit table to existing houses
e) Required temperature easily achieved with electric water heater

For the water heating it is not economical to concentrate the radiation because tracking the sun throughout the years is both costly and complex. Development work on solar water heating has, therefore, mainly been done on flat-plate solar collector. Almost all solar water heaters are based on the principle of flat plate collectors. Over the past 60 years pioneering work has been done mainly in USA, the UK, Australia, South Africa and India and many different types of solar water heater have been designed and build. The main objective of these studies is, to convert as much solar radiation as possible into heat and the highest attainable temperature and for the lowest possible investment in materials and labor.

Solar water heater employing flat plate collectors can be divided into the following four types according to their application, temperature of operation and capacities:

a) *Swimming pool* water heater in which a cheap plastic collector can be used without any cover and insulation. A high flow rate is maintained to limit the temperature rise to less than 2 °C.

b) *Built in storage* type solar water heater in which all the three function/component i.e collections, storage, and control are combine into a single unit. Hot water (up

to 60 °C only) from such water heater has to be use during the day; otherwise the heat stored would be lost during the night.

c) *Domestic* solar water heaters are used where the maximum temperature is not more than 70 °C. The collector and storage function in this devise are separate. The control function is still accomplished through the use of natural principle and this technology is frequently employed for domestic system in the form of rather well known *'thermosyphon system'*

d) *Large size* solar water heater design for community and industrial use. Since, here the requirement of hot water is large, a large number of collector are employed with a storage tank along with a control system which to be build required.

1.1 PROBLEM STATEMENT

Currently, there are a very few system or types that are available in the market. Furthermore, a laboratories solar water heater can rarely been seen. Most of the solar system are in huge size and can't be moved once it has been installed. A laboratory solar water heater will not only serve the purpose of heating or generating hot water from the sun but it can be also use as a experiment device and indirectly lead to new invention with better efficiency. Student can use this rig to find the efficiency of the collector plate. By developing a solar water heater rig, it can be used as a research device where, different kind collector plates can be tested using the same rig and different kind of glazing material also can be tested using the same rig. The insulated material also can be tested for its efficiency.

1.2 OBJECTIVE OF THE STUDY

a) To develop a laboratory scale solar water heater rig for educational and research purpose.

b) To study the features of a solar water heater.

c) To calculate the efficiency of the flat plat collector.

d) To create the awareness, of the benefits and the efficiency of a solar water system.

1.3 THE SOLAR ENERGY

Renewable energy resources come from the sun, wind, oceans, rivers and plants. They are the oldest, cleanest and in most cases the most efficient forms of energy humans have at their disposal. Unlike fossil fuels, such as oil and coal, it will never run out and will not pollute the environment. Right now, only 8 percent of the total energy use comes from renewable energy resources. The other 92 percent are primarily made up of fossil and nuclear fuel sources. Fossil fuels have had damaging effects on the quality of air, water and soil. In order for people to continue to live healthy lives, there must be increase in the use of renewable energy sources. The three most common natural renewable energy resources are sun, wind and water. The first and most important renewable energy is solar energy.

Solar energy is the energy that is produced by Sun. It is the oldest and most efficient form of renewable energy. Solar Energy is nothing but electro-magnetic radiation given off by the sun and received by the Earth. It is the world's most abundant, permanent source of energy. The amount of solar energy received by earth is 170 trillion kilowatts, an amount five thousand times greater than the sum of all other energy sources combined.

Solar energy device is designed to perform certain function by using the free and natural Light Energy from the Sun is called a "Solar Energy Device". The function could be heating water from sunlight, heating air from Sunlight, Producing Electricity from sunlight and also cooking food using Sunlight.

A solar Water Heater is a device that helps us in heating the water by using the free and Natural Light energy from the Sun. The water can be heated to any desired

temperature above normal temperature but cannot exceed the boiling point temperature (100° C). "Every 15 minutes sufficient amount of energy from the sun strikes the earth which is enough to supply the energy requirements of the whole world for one year"

Solar Thermal Technology works when the sun's rays hit certain types of materials such as copper and aluminum, they become very hot. Lining containers with copper and aluminum can produce very high temperatures. As water flows through these containers it is heated. This heated water can be used for pool water, shower water or to heat homes. Today, Solar heating is becoming more important than ever before. Natural gas and oil, which is burned to heat homes and water, is limited. As reserves of gas and oil shrink, these fuels become more expensive. If more people began using solar heating systems, fossil fuels such as oils and gas would become less expensive and last longer. Burning natural gas and oil in our heating systems also causes air pollution. Even electric water and space heaters cause air pollution indirectly, because coal and natural gas in burned to produce electricity in large power plants. So if the usage solar energy to heat the air and water in homes increase, the environment would be cleaner. *(HP Garg and J Prakash, 1997.)*

Solar Water Heater is increasing rapidly during the years. Consider any place like House, Hotels, Lodges, Hostels, Industries, and Colleges etc., most (80%) of the energy consumed by these organizations is used for heating water whether it is in the form of Electricity, Gas or Oil. Since major part of the energy consumed is for heating water, the need is to use an alternative way in which water could be heated by using the free and naturally available energy from the sun. This led to the introduction of Solar Water Heaters. Since the Solar Energy is inexhaustible and is continuously available, importance should be given for designing. Since, Solar Energy is an inexhaustible source of energy and hence increase in the life of the system meant increase in energy saving.

1.4 THE BENEFITS OF SOLAR WATER HEATER

There are many benefits of owning a solar water heater, and number one is, economics. Solar water heaters are economic compare quite favorably with those of electric water heaters, while the economics aren't quite attractive when compared with those of gas water heaters. Heating water with the sun also means long-term benefits, such as being cushioned form future fuel shortages and price increases, and environmental benefits. In large factory canteens employing steam cooking & feeding of hot water at 90° C from Solar Water Heater to the boilers can save 70-80% on electricity or fuel bills.

Many homebuilders choose electric water heaters because it is easy to install and relatively inexpensive to purchase. However, research shows that an average household with an electric water heater spends about 75% of its home energy costs on heating water.

It makes economic sense to think beyond the initial purchase price and consider lifetime energy costs, or how much to spend on energy to use the appliance over its lifetime. It is found that solar water heaters offered the largest potential savings, with solar water-heater owners saving as much as 50% to 85% annually on their utility bills over the cost of electric water heating. *(Home Mechanix)*

Depending on the price of fuel sources, the solar water heater can be more economical over the lifetime of the system than heating water with electricity, fuel, oil, propane, or even natural gas because the fuel (sunshine) is free. Payback varies widely, but the payback can expect fast on a well-designed and properly installed solar water heater. (Simple payback is the length of time required to recover the investment through

reduced or avoided energy costs). Shorter can be expected in areas with higher energy costs. After the payback period, savings is accrued over the life of the system, which ranges from 15 to 25 years, depending on the system and how well it is maintained.

The simple payback of a solar water heater can be determined by first determining the net cost of the system. Net costs include the total installed cost less any tax incentives or utility rebates. After that, calculate the net cost of the system, calculate the annual fuel saving and divide the net investment by this number to determine the simple payback. If a new home is build or refinancing a present home to do a major renovation, the economics are even more attractive. A Hospital can save 70-80% on electric or fuel bills by replacing its conventional water heater with a solar water heating system for bathing, cleaning, washing & sterilization.

It also offers long-term benefits that go beyond simple economics. In addition to having free hot water after the system has paid for itself in reduced utility bills, it also help from future fuel shortages and price increases and at the same time reduces country's dependence on foreign oil. When a solar water heater replaces an electric water heater, the electricity displaced over 20 years represents more than 50 tons of avoided carbon dioxide emissions alone. Carbon dioxide traps heat in the upper atmosphere, thus contributing to the greenhouse effect.

Solar water heaters do not pollute. By investing in one, carbon dioxide, nitrogen oxides, sulfur dioxide, and the other air pollution and wastes created when a utility generates power or the fuel burn to heat household water can be avoided.

A solar water heater is a long-term investment that will save money and energy for many years. Like other renewable energy systems, solar water heaters minimize the

environmental effects of enjoying a comfortable, modern lifestyle. In addition, it provides insurance against energy price increases, helps to reduce dependence on foreign oil, and are investments in future. Water heating accounts for approximately half of the total energy used in a typical single - family home.

CHAPTER II

LITERATURE REVIEW

2.1 SOLAR WATER HEATER

Today's solar water-heating systems are well proven and reliable when correctly matched to climate and load. The current market consists of a relatively small number of manufacturers and installers that provide reliable equipment and quality system design. A quality assurance and performance-rating program for solar water-heating systems, instituted by a voluntary association of the solar industry and various consumer groups, makes it easier to select reliable equipment with confidence. Building owners should investigate installing solar hot water-heating systems to reduce energy use. Before sizing a solar system, water-use reduction strategies should be put into practice.

2.2 TYPES OF SOLAR HOT WATER SYSTEMS

There are five types of solar hot water systems:

a) Thermosiphon Systems
b) Direct-Circulation Systems
c) Drain-Down Systems
d) Indirect Water-Heating Systems
e) Air Systems

2.2.1 THERMOSIPHON SYSTEMS

These systems heat water or an antifreeze fluid, such as glycol. The fluid rises by natural convection from collectors to the storage tank, which is placed at a higher level. No pumps are required. In thermosiphon systems fluid movement, and therefore heat transfer, increases with temperature, so these systems are most efficient in areas with high levels of solar radiation. Figure 2.1 shows a common solar water heater and figure 2.2 shows the basic operation of a thermosiphon system. *(BALAJ)*