THE EFFECT OF COPPER PIPE LENGTH AND DIAMETER TO SOLAR WATER HEATING SYSTEM

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THE EFFECT OF COPPER PIPE LENGTH AND DIAMETER TO SOLAR WATER HEATING SYSTEM

By

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This report is submitted in partial fulfilment of the requirement for the degree of Bachelor in Engineering (Hons) in Mechanical and Manufacturing System from the Faculty of Engineering

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Approval Sheet

This project report attached here to, entitled **"The Effect of Copper Pipe Length and Diameter to Solar Water Heating System"** prepared and submitted by Nor Aeshah binti Abdul Hamid as a partial fulfilment of the requirement for the degree of Bachelor of Engineering with Honours in Mechanical and Manufacturing system is hereby read and approved by:

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Introduction

1.1 Overview

Energy can be defined as capability to do work. Nowadays the demand for energy in developing country is increased as the population and the economic development growth. The major usage of energy is for transportation, heat, light and industrial power. The source of energy can be divided into three categories, which is exhaustible, renewable and inexhaustible. An exhaustible energy source means that energy that cannot be replaced once that is used. Currently this type of energy supply more than 90 percent of energy needs. While renewable energy source are those that can be used indefinitely if they are properly managed and maintained. The technologies of renewable energy can produce an energy that can be marketed by converting natural phenomenon into useful energy form. Wood and plants are the example of renewable energy. Inexhaustible energy is the energy, which is always available no matter how much it's been used. That energy includes wind energy, hydroelectric energy, energy from ocean and solar energy.

1.2 Solar Energy

Solar energy is the cleanest and most inexhaustible of all known energy sources. Solar energy is the energy that comes directly from the sun light while according to Lechner [1976], the term of solar

energy refers to the used of solar radiation in a number of different way. Solar radiation is the heat, light and other radioactive that are emitted from the sun. Solar radiation contains huge amount of energy and is responsible for almost all-natural process on earth.

The outer layer of sun known as ÷photosphere' emits a continuous spectrum of radiation. The temperature of this radiation is about 12,500° F while their radiation is 5762 K, [Janson, 1985]. The amount and composition of radiation reaching the earth surface however very widely with sun angle and the composition of the atmosphere. Ozone in the atmosphere absorbs radiation of short wave length (ultraviolet), carbon dioxide and water vapor absorb some of the longer wavelength (infrared) as shown by Figure 1.1. The wavelength or frequency of radiation emitted is a function of the temperature of the object. The shorter the wavelength of light, the more energy it contains. However it is still effected by natural properties of the material with which it interact and especially the surface of the material.

Another four possible interactions that affect the temperature of the material are transmitted, absorbed, reflectance and emittance. Transmitted refers to the situation in which radiation passed through material while absorbed refers to the situation in which the radiation is convert into sensible heat within the material. Reflectance refers to the situation in which the radiation is reflected off the surface and emittance refers to the situation in which radiation is given off by the surface. The balanced between absorptance and emittance will determined how hot the plate will get, the equilibrium temperature. (Lechner, 1976).

Chapter 1 Introduction

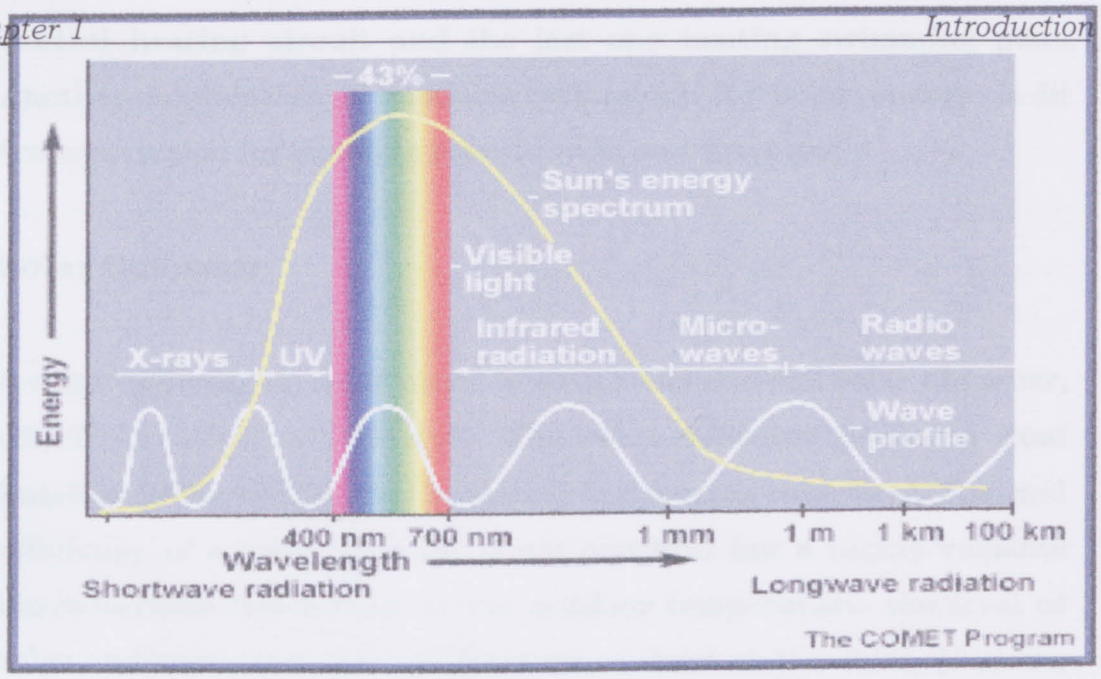

Figure 1.1: The sun radiates vast quantities of energy into space [University Corporation for Atmospheric Research, 1998]

Solar energy can be classified into two categories, Thermal and Light. Photovoltaic cells (PV) use semiconductor-based technology to convert light energy directly into an electric current. That can be used immediately, or stored, such as in a battery for a latter used. PV panels are now becoming widely used, as they are very versatile and can be easily mounted on building and other structures. They can provide a clean renewable energy source which can supplement and thus minimize the used of main electricity supply. Thermal energy can be used to passively heat the building through the used of certain building materials and architectural design or used directly to heat water for household used.

Solar energy can be easily converted into heat and the major usage of solar energy is for heating and electricity. There are three main application of solar radiation in domestic usage, which is domestic hot water for batch, shower, washing clothes and washing crockery, space heating either for ducted air system or for heated water

central heating circuit and the last one heating swimming pool. Another application of modern technology for solar energy is in transportation for example solar bicycle and solar car.

1.3 Solar Collector

A solar collector or solar panel is simply the thermal solar absorber, which is install on the roof. The solar collector performs dual function of absorbing solar radiation and storing solar heat. Thermal efficiency of a solar collector is not constant but a highly variable characteristic depending on the outdoor temperature, the level of solar radiation and the temperature of fluid at the inlet, [Jansen, 1985]. There are three types of collector, namely flat-plate collector, evacuated-tube collector and concentrating collector.

Flat plate collector forms the heart of any energy collection system designed for operation in low temperature range, from ambient to 60 ° C or the medium range, from ambient to 100° C. Essentially the majority of flat plate collectors consist of five basic element. The first one is a flat absorbing plate, normally metallic and with a black surface, upon which short wave solar radiation falls and is absorbed. The absorber plate material should have high thermal conductivity, adequate tensile and compressive strength and good corrosion resistance. Copper is generally preferred because of its extremely high conductivity and resistance to corrosion. The second one is tube, channels or passages attached to the absorber plated usually made of copper pipe to circulate the liquid to remove the thermal energy from the plate. The third element is thermal insulation that provided at the back and sides of the absorber plate to minimize the heat losses. The next element is a transparent cover (one or two sheet) of glass or transparent plastic to reduce the upward heat loss from the absorber plate and the last element a weather-tight

container to enclose the above component. The advantages of flat plate collector compare to another collector is that can absorb direct, diffuse and reflected components of solar radiation, are fixed in tilt and orientation and, thus, there is no need of tracking the sun, are easy to make and are low in cost, have comparatively low maintenance cost and long life and it can operated at comparatively high efficiency.

Evacuated-tube collectors are made up of rows of parallel transparent glass tubes. There are two types of evacuated tube that is glass-glass tube and glass-metal tubes. Glass-glass tube consists of a glass inner and glass outer. While glass-metal tube consist of a single glass tube. Inside the tube is a flat or curved copper plated which is attached to a copper heat pipe. Glass-glass tube although not quite as efficient as glass-metal tube are generally more reliable and much cheaper.

Concentrating collectors for residential applications are usually parabolic troughs that use-mirrored surface to concentrated the sun energy on an absorber tube (called a receiver) containing a heat transfer fluid, or the water itself. This type of solar collector is virtually antiquated as it compares poorly with evacuated tube solar collectors in term of reliability and efficiency.

1.4 Solar water heating system

Solar water heater also called as domestic hot water system. These systems use the sun to heat up either water or a heat-transfer fluid, such as a water-glycol antifreeze mixture, in collectors generally mounted on a roof. The heated water is then stored in a tank similar to a conventional gas or electric water tank. Some systems use an electric pump to circulate the fluid through the collector. Solar

water heating system can be either active or passive system. Solar water heating system is also characterized as open loop (also called ÷direct') or closed loop (also called ÷indirect'). An open loop system circulates household (potable) water through collector. A closed-loop system uses a heat transfer fluid (water or diluted antifreeze) to collect heat and a heat exchanger to transfer the heat to the household water.

1.4.1 Active system

Active system uses valve, pump and controller to circulate the heat transfer of water or other fluid through collector. They are usually more expensive than passive systems but generally more efficient and generally easier to retrofit because their storage tank does not need to be installed above or closed to the collector. If it installed using PV panel to operate the pump, they can operate better during a power outage. There are three types of solar water heating system as followed

i ***Direct system or open loop Active system***

Direct system used pump to circulated household water through collector. This design is very suitable for the area that does not freeze for long period and do not have acidic water because scale and corrosion will quickly disable the system. The example of direct system as in Figure 1.2

ii ***Indirect system or close-loop active system.***

Indirect system consists heat transfer fluid such as a mixture of glycol and water anti-freeze, which will be pumped through collector. Heat will be transfer from the fluid to the water. The glycol antifreeze is more expensive in purchase and install and glycol must be checked each year and changed every 3 to 10

years, depending on glycol quality and system temperature. Figure 1.3 shows the example of indirect system.

iii. The Drain back System

Drain back system uses water as the heat transfer fluid in the collector loop. A pump circulates water through the collectors. The water drain by gravity to the storage tank and heat exchanger. Therefore there are no valves to fail. When the pump turn off, the collector is empty, which assures freezes protection and also allows the system to be turned off if the water in storage tank becomes too hot. Figure 1.4 shows the example of drain back system.

1.4.2. Passive System

For passive system, there are no pumps involved during movement of household water or a heat transfer fluid. Passive systems also have no electric component to break, therefore, this makes them more reliable, easier to maintain and possible long lasting compare to active system. Passive system are often less expensive than active system, but are also less efficient due to slower water flow rates through the system. The amount of hot water a solar water heater produced depends on the type and size of the system, the amount of sun available at the site, proper installation, and the flit angle and orientation of the collectors. There are two types of passive system as shown below; -

i Thermosiphon system

A thermosiphon system relies on warm water rising, a phenomenon known as natural convection, to circulate water through the collector and to the tank. In these types of installation, the tank must be located above the collector. As

the water in the collector heat, it become lighter and naturally rises into tank above. Meanwhile cooler water in the tank flows downward into the collector, thus causing circulation throughout the system. For small system, the tank is actually incorporated into collector. Large tank must be located next to collector.

ii ***Batch Heater or integral collector system.***

Batch heater has one or more storage pump placed in insulated box with the glazed side facing the sun. This system is very useful during winter where it can protect the system from freezing or drains.

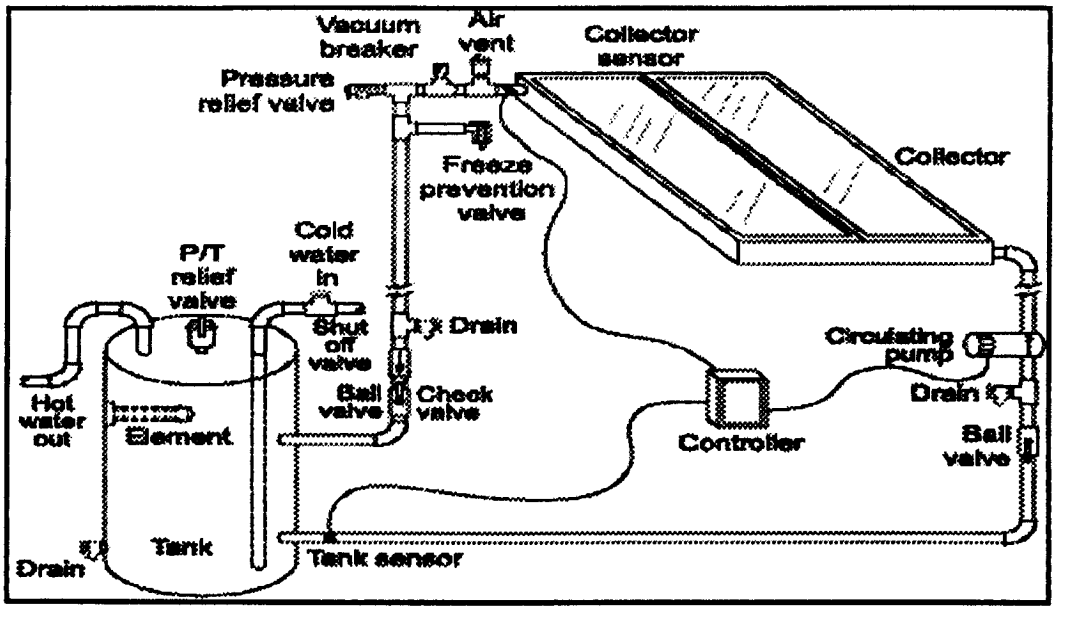

Figure 1.2; Example of direct system [Harrison, Teideman, 1997]

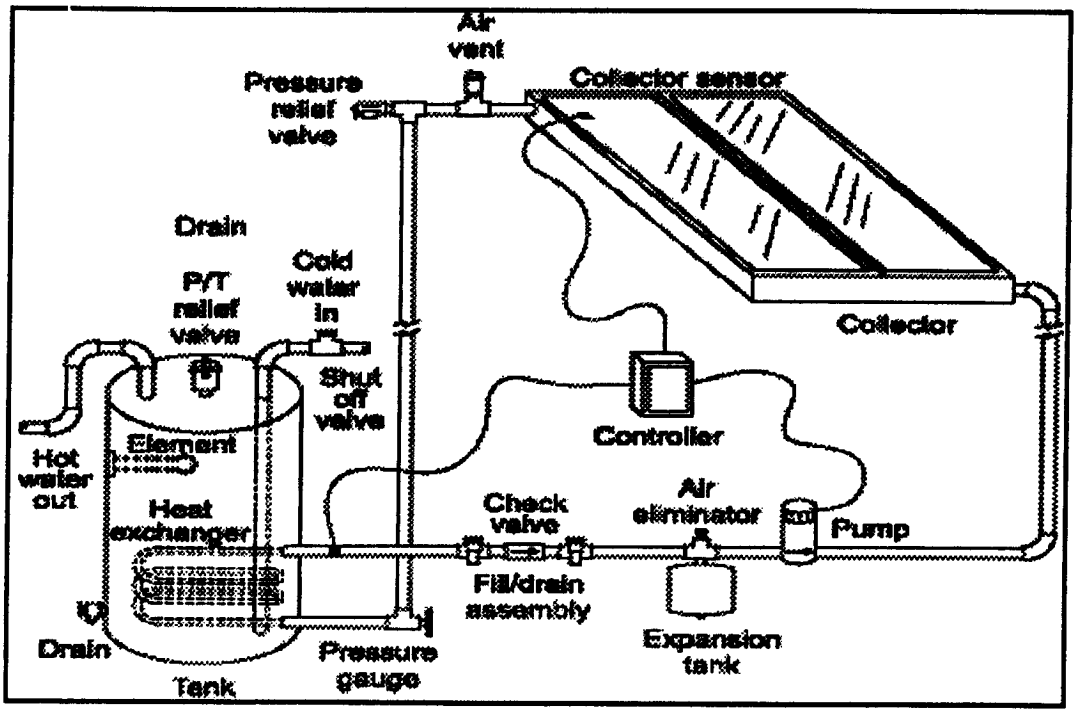

Figure 1.3: Indirect system of solar water heating system [Harrison, Tiedeman, 1997]

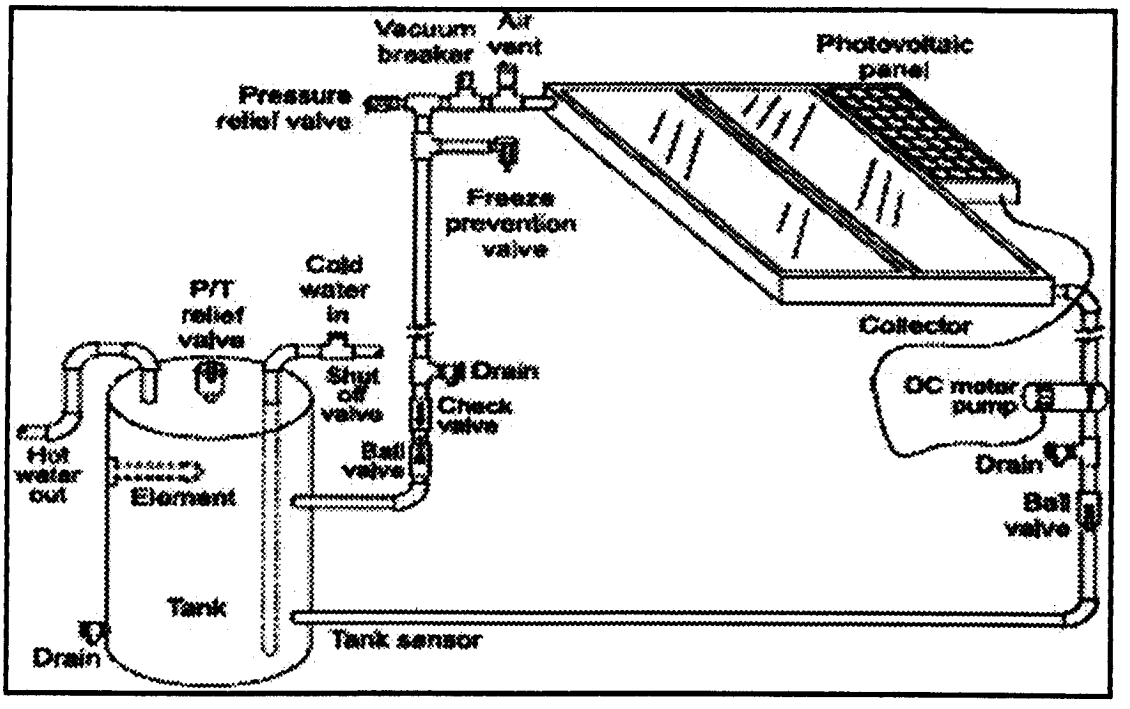

Figure 1.4; Drain back system [Harrison, Tiedeman, 1997)]

1.5 Advantages of solar water heating system

Nowadays, the solar energy has been utilized with modern technology for daily life. An application of this solar technology is very useful in a way to replace the usage of another energy source especially exhaustible energy, which is the most-used energy source in the world. For solar water heating and air heating application solar energy could provide a significant proportion of the domestic hot water and space heating demand in many country. The advantages of solar water heating system for domestic usage are as followed;-

i *Economic benefit*

Solar water heating heater is economical compare to the electric water heater. It makes economic sense to think beyond initial purchase price and consider lifetime energy cost. From research of the ÷Florida Solar Energy Center (FSEC)' found that solar water heater offer the largest potential of saving which is around 50% to 85% if compare to electric water heater.

ii *Environment benefit.*

Solar water heater is user friendly, means that solar water heater do not pollute. By investing one, it will be avoiding carbon dioxide (CO2), sulfur dioxide, nitrogen oxide and waste the fuel. When solar water heater replace an electric water heater, the electricity displace over 20 years represent more than 20 ton of carbon dioxide (CO2) emission alone. Carbon dioxide traps heat in the upper atmosphere, thus contributing to the ÷greenhouse effect'.

iii *Long-term benefit*

Solar water heater also offers long-term benefit for the user the go beyond simple economic. By using the solar water heater, user will be cushioned from future fuel shortage and price increase through their having free hot water heater after the system has paid for itself to reduce utility bills. It can also, reduce the country dependent on foreign oil.

1.6 The limitation of solar water heating system

Solar water heating is a long-term investment that save money and energy for many years. Like other renewable energy system, solar water heaters minimize environment effect without sacrificing comfortable and modern lifestyles. In addition, they provide insurance against energy price increase; reduce dependency on foreign oil and an investment for future. Currently the development technology of solar water heating system has improved, however its usage in some country includes Malaysia is still limited. These is mainly due to of the following factor;-

i *High cost*

The user should pay more money to purchase and install the solar system. As happened in Malaysia, the price of solar water heating system is expensive compare to electricity water heater system. From Appendix 1.1, known that the price of solar water heating system is around RM 4190 to RM 13190 per unit.

ii *Complex maintenance*

The maintenance is complex attribute to complexity of the system and the installation of solar water heater required a large space.

iii ***Efficiency***

The efficiency of solar water heating system deter according to the types and most have lower efficiency

1.7 Objective of Study

This project study is focus on the available solar water heating system. The information on solar water heating system is collected for future and improvement design. Thus, the objective of this study are as followed:-

I. **To determine the effect of copper pipe to solar water heating system based on the diameter and length. Most of solar hot water system used copper as basic material for collector where the copper plate is used as absorber and copper as flow tube. Therefor, this project is studying the effect of copper diameter and length on the solar water heating system.**
II. **There are the numerous types of solar water heating system available on the market. The efficiency of each type varies and so does the purchasing, installation and maintenance cost. Thus, some comparison on this matter could provide better understanding on the commercially available design of solar water heating system.**

Chapter 2

Literature Review

2.1. Application of solar energy.

Several studies have been done to improve the solar technology in a way to increase their efficiency for daily usage. The Department of Energy, USA, has funded the design and construction of several industrial process heat systems for various industrial applications ranging from drying of fruit to curing of building materials. In some system hot water is produced while in few others steam is produced using solar energy for different industrial application [Garg and Prakash, 1997]

The application of solar energy started in hundred years ago, According to Garg, (1997). In 1747 which shown by Frenchman, M. Buffon used more than 150 mirrors at a focus point of over 250 ft. (75m) to set fire to wood and charcoal. Between the early seventeenth and late eighteenth centuries, various attempts were made to invent solar power pump and studies will also made on concentrating power on curve surface. In 1774, Joseph Priestly focused the sun's rays through a large lens onto mercuric oxide and discovered that it released a gas. In 1883, first solar Power Company was founded in California, which developed various forms of solar cookers, and solar furnace, solar operated refrigerator and solar heat reservoir.[Garg and Prakash, 1997]

More recent applications have included factories and offices complex, built in 1978, in Zurich, Switzerland, the largest solar

buildings in the world, providing not only all the hot water but also some of the space heating for the four-storey building.

Solar energy to heat water has been in used for many years, and the design requirement of solar water heating equipment have been studied for more than 100 years. According to Garg and Prakash, 1997, solar water heater 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 fuels.

2.2. Existing solar water heating system.

Solar water heater becoming popular in China. There are over 1000 solar water heater manufacturer in China prior to the end of 1998 and had produced about 2.5 million square meters worth of water heaters. Today over 12 million homes in China use solar water heater and it is becoming a major force in ÷energy saving' market. In China, the majority of water heaters are evacuated tube, as this type is most reliable, efficient and cost effective. Evacuated tube solar water heater can be used in cold region where flat-plate style solar water heaters are prone to freezing. [Harrison and Teideman, 1997]

In Southern Florida, USA, during the late 1930s, solar energy was the main method used for providing hot water service to single family residences, block of flat and other small commercial building. Several studies concerned with a comparison of thermosiphon solar water heating system with as described by Northon and Probert (1983). In United State, National Bureau of Standards Program (Fanny and Liu, 1979,1980) stated that five types of pump solar energy water heating system were monitored along with thermosyphon water heating system.

Simple types of solar domestic water heaters using glass-topped boxes lined with black plastic were developed in Japan in 1948. By early 1970s they had been fitted to 30 per cent of the homes in that country. With a normal cold-water inlet they are capable of providing hot water at 55 ° C (131 ° F) in summer and 30 ° C (86 ° F) in winter.

Solar research Sdn. Bhd who becomes a dealer of solar water heater system in Malaysia provides several types of solar water heater system. The latest designs are microsolar multivave, which work by thermosiphon' natural convection circulating the hot water. This type of solar water heater consist 32 number of valve that is 16 inlets and 16 outlets from panel to tank. The operating temperatures is around 65 ° C to 75 ° C and the maximum temperatures is 90 ° C.

The Public Housing Corporation of Japan monitored, from November 1976 to August 1980, two town houses installed with equipment to harness solar energy (Udagawa and Tanaka, 1979; Udagawa et al;,1980) one house incorporated a direct thermosiphon domestic hot water system; in the other an indirect pumped system provided domestic hot water and space heating.

The largest reported thermosiphon solar water heating systems are in Honolulu, Hawaii USA (Kelly, 1981). Three systems, each of 75 m^2 collector area and connected to a tank of capacity 4.66 m^3 were installed. The systems were found to be reliable and provided 98 percent of the hot water requirement.

One of the largest installations in Great Britain was at Mountain Hotel a few miles south of Brecon, Powys. There are three rows of solar panel covering an area of 52 m^2 (560ft^2) used to provide hot

water, mainly for bedroom in the hotel. The average daily hours of sunshine vary from 0.92 in December to 6.14 in April. With this additional contribution due to diffuse radiation, more hot water is obtained than is required for much of the year.

2.3. The experimental of solar water heating system and it's performances.

Various studies have been performed on thermosiphon system. For specific thermosiphon configuration, Close (1962) experimentally observed that the average collector temperature was only slightly higher than the average tank temperature. Thus considering the system to be at some mean temperature, he developed a simple mathematical model to predict the daytime performance of a thermosiphon water heating system.

Desa (1964) used a lumped parameter heat balance equation which he solved numerically using actual solar radiation data and a half-hour time step. This model was used to predict the tank temperature as a function of time for a particular day with no withdrawal water. Experimental measurements agreed with the actual predictions within about 1 ° C.

Iqbal (1996) performed experimental and theoretical studies of effect of free convection superimposed on forced flow in uniformly heated inclined tubes. The studies identified the tube tilt angle for transferring heat from the absorber plate to the circulating fluid, but the system's performance was not optimized for the tilt angle.

Gupta and Garg (1968) improved analysis of Close (1962) by incorporating a collector plate efficiency factor and approximating a variable ambient condition by using Fourier series expansion for the