CHAPTER 5

EXPERIMENTAL SETUP AND PROCEDURE

According to the optimal parameter in Chapter 4, the solar water heater system consists of 8 evacuated tubes, themosyphon diameters in size of 15.88 mm (1/2 inch) for the evaporator diameter and 22.22 mm (3/4 inch) for the condenser diameter. These specific quantities of the evacuated tubes and diameters are considered to be the maximum net saving due to the mathematical model. As a result, in this chapter, there will be the procedure of the solar water heater system which is constructed and tested at Chiang Mai University, Thailand. The solar collector is tilted at 18^o (latitude of Chiang Mai province) from horizontal and facing to south. The experimental setup and schematic diagram are shown in Figure 5.1 to Figure 5.2.

5.1 Experimental setup

5.1.1 Evacuated tube with thermosyphon

Structure of evacuated tube consists of a coaxial double-layer tube with 58 mm outer tube diameter, 47 mm inner tube diameter, and 1800 mm length. The thermosyphon is made of a copper tube with 15.88 mm (1/2 inch) of evaporator and adiabatic outside diameter and 22.22 mm (3/4 inch) of condenser outside diameter. The lengths of evaporator, adiabatic, and condenser are 1700 mm, 150 mm and 80 mm, respectively. The thermosyphon and collector fin are inserted within the evacuated tube between inner tube walls of double-layer glass tube. Moreover, the working fluid within thermosyphon is R141 and its filling ratio is 70% of the evaporator volume, detailed as shown in Figure 5.3.

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Figure 5.1 Experimental setup of solar water heater

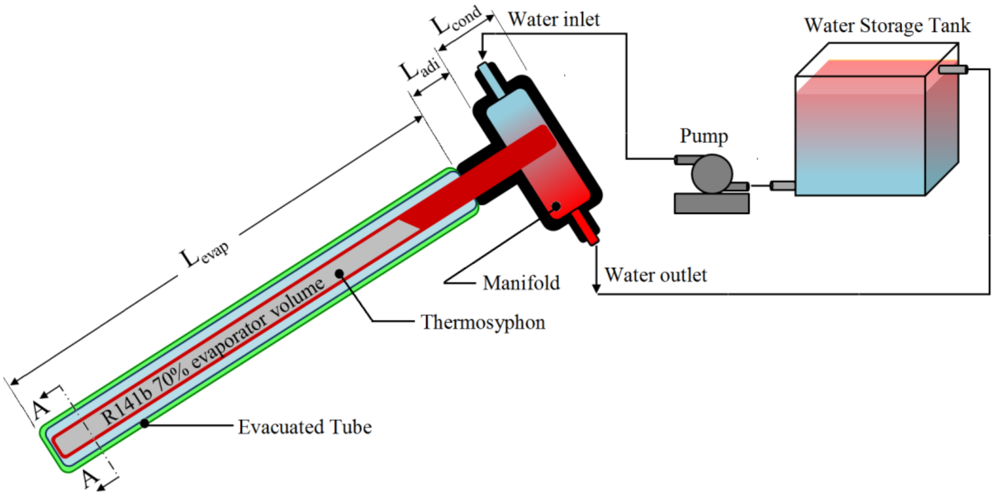

Figure 5.2 Schematic diagram of solar water heater

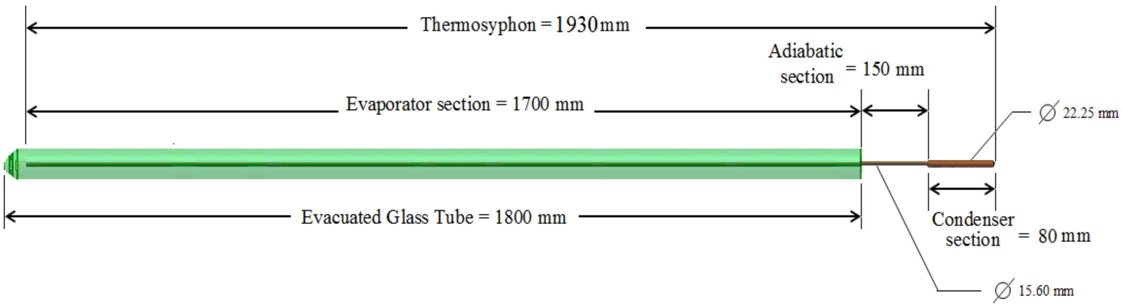

Figure 5.3 Evacuated tube with thermosyphon

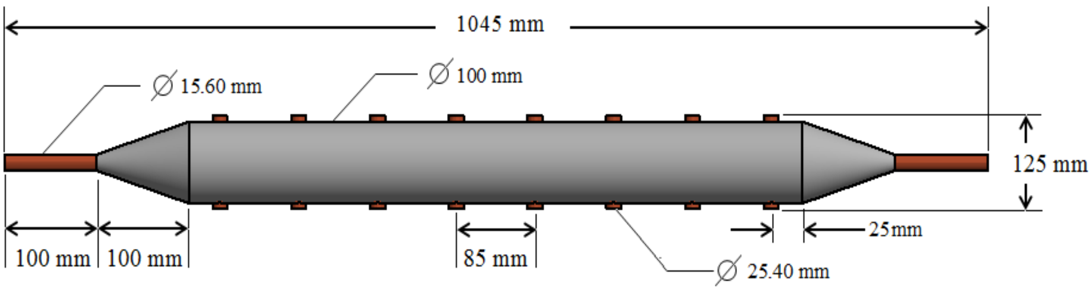

Figure 5.4 Explanation for manifold and hollow-jacket

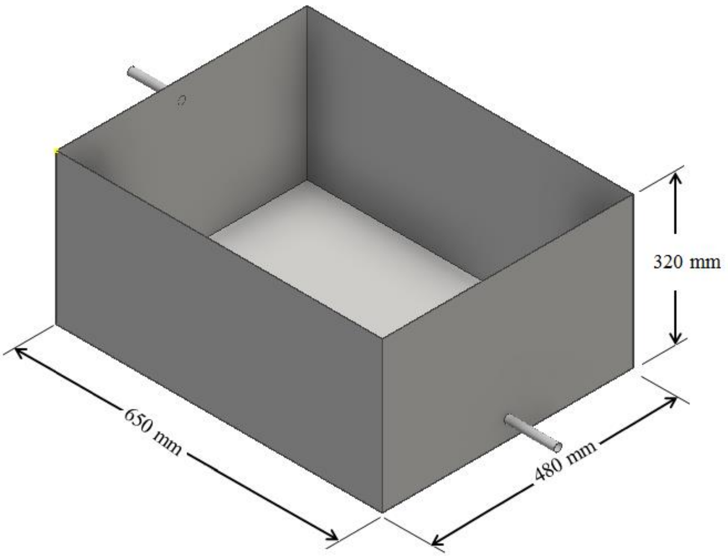

Figure 5.5 Dimensions of the water storage tank

5.1.2 Manifold and Jacket

For the manifold's diameter, it is in size of 100 mm and made of zinc alloy with 8 hollow-jacket inside. Hollow of the jackets is made of copper tube with diameter in size of 25.40 mm and 125 mm length, which it is welded together with the manifold. Condensers sections of the thermosyphon are inserted inside a hollow jacket. Heat energy of the thermosyphons is removed by water flowing through the manifold with hollow-jacket, which detailed as shown in Figure 5.4. It should be noted that the manifold with hollow-jacket is covered with insulator.

5.1.3 Water storage tank

Volume of the water storage tank is 100 liters. The tank is made of plastic and covered with thermal insulator, detailed as shown in Figure 5.5.

5.1.4 Anemometer

The wind velocity is important for calculating mathematical model since the wind velocity will affect the convection heat transfer. It can be said that an anemometer is a device used for measuring the velocity of wind. Figure 5.6 shows the Lutron AM-4203 anemometer with ± 2% accuracy and a measurement range from 0.4 to 25.0 m/s. Therefore, the Lutron anemometer is used for measuring the wind velocity in this experiment.

Figure 5.6 Lutron anemometer.

5.2 Experimental procedure

5.2.1 In the solar water heater system, there are 8 evacuated tubes, 58 mm outer tube diameter, 47 mm inner tube diameter, and 1800 mm length. The thermosyphons are made of copper tube in size of 15.88 mm (1/2 inch) of evaporator and adiabatic section diameter and 22.22 mm (3/4 inch) of condenser section diameter. The lengths of evaporator, adiabatic and condenser are 1700 mm, 150 mm, and 80 mm, respectively. The working fluid within thermosyphon is R141 and its filling ratio is 70% of evaporator volume. The evacuated tube collectors are built on the stand with tilted 18^{o} facing south. The volume of the water storage tank is 100 liters.

5.2.2 The 38 points of thermocouple on the evacuated tube solar water heater system and solar intensity are recorded by data logger as shown in Figure 5.7 and explained in details about thermocouple positions in Table 5.1. There are 8 thermocouples pasted inside the evacuated tube for measuring the air temperature inside the inner evacuated tube and collector fin temperature: 2 points are placed on the outer evacuated tube for recording outer temperature of evacuated tube; 6 points are placed on the evaporator section of thermosyphon; 8 points for adiabatic section, and 3 points for the condenser section. These thermocouples help recording temperature details of the heat transported from the evaporator to the condenser: 3 point are placed on the jacket for checking the interface between condenser section and jacket; 4 points are placed on the manifold for recording inlet and outlet water temperatures to compare with the mathematical model results; 2 points are placed on inside of the water storage tank for recording hot water temperature, and the other 1 point is placed under the collector stand for recording ambient temperature. Moreover, pyranometer integrated to a data logger and mounted on a surface is parallel with the tilt angle of the solar water heater.

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5.2.3 Water is pumped to the condenser. The water flow rate is controlled by a valve at the outlet of pump with water flow rate 0.03 kg/s (Nada et al., 2004). The water is discharged and filled in the water storage tank in the early morning for experiment

5.2.4 The solar shield of solar water heater system is removed at 08:00 a.m. while the data logger starts collecting. The temperature values and solar intensity are recorded in every 1 minute and the wind velocity is recorded in every 15 minute.

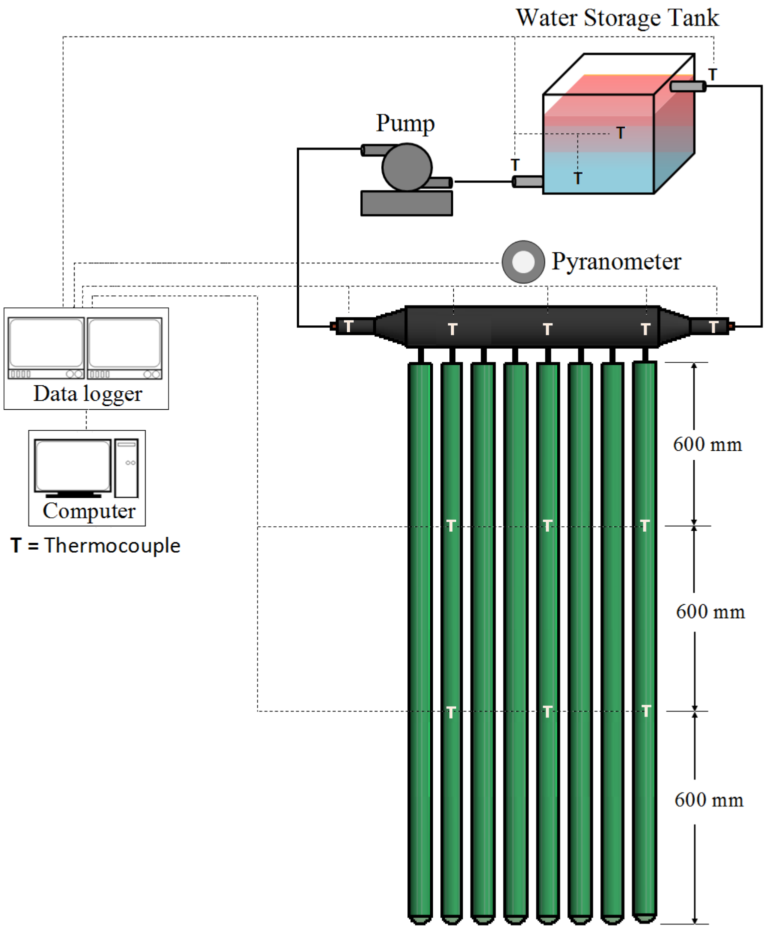

Figure 5.7 Schematic measurements of evacuated tube in the solar water heater system

Table 5.1 Position measurements of evacuated tube in the solar water heater system

Position	Details
Evaporator section	$T_{evap\_2.1}$, $T_{evap\_2.2}$, $T_{evap\_5.1}$, $T_{evap\_5.2}$, $T_{evap\_8.1}$, $T_{evap\_8.2}$
Collector fin	$T_{fin\_2.1}$, $T_{fin\_2.2}$, T_{fin_4}, $T_{fin\_5.1}$, $T_{fin\_5.2}$, T_{fin_7}, $T_{fin\_8.1}$, $T_{fin\_8.2}$
Condenser section	T_{cond_2}, T_{cond_5}, T_{cond_8}
Jacket	T_{jacket_2}, T_{jacket_5}, T_{jacket_8}
Adiabatic section	T_{adi_1}, T_{adi_2}, T_{adi_3}, T_{adi_4}, T_{adi_5}, T_{adi_6}, T_{adi_7}, T_{adi_8}
Evacuated tube	$T_{o\_evac\_3}$, $T_{o\_evac\_8}$
Clearance evacuated tube	$T_{air\_i\_evac\_1}$, $T_{air\_i\_evac\_6}$
Manifold	$T_{wi\_m\_1}$, $T_{wi\_m\_2}$, $T_{wo\_m\_1}$, $T_{wo\_m\_2}$
Water storage tank	$T_{w\_tank\_1}$, Tw_tank_2

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5.2.5 The experiments are carried out from 8:00 a.m. to 4:00 p.m.

5.2.6 The temperature of hot water and solar intensity of the experiment results are used for calculating heat rate of water and thermal efficiency of the experiment. These values are used to compare with the mathematical model results for.

5.3 Data analysis method

5.3.1 The temperatures are obtained from the experiment. There are ambient air temperature, evaporator temperatures, condenser temperatures, water inlet and water outlet temperatures, and hot water temperatures according to time. The temperatures are presented in average temperature form of each position in each day.

5.3.2 The solar intensity, ambient air temperature, and wind velocity are plotted according to time and inputted to mathematical models for predicting temperatures of each position in the solar water heater system. Then, heat rate of water and thermal efficiency of the mathematical models are calculated.

5.3.3 Regarding to the accuracy of mathematical models towards the prediction, the temperatures, heat rate of water, and thermal efficiency from the mathematical models are validated by the experiment results under the identical climatic condition of the experiment.

5.3.4 The thermal efficiency with respect to the function of environmental and functional conditions of $(T_{wo\_tank} - T_{am})/I_G$ system presents the instantaneous thermal efficiency and overall heat transfer coefficient of the solar water heater system of both mathematical models as well as the experiment are compared to the other researcher.

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5.3.6 The heat rate of water in the experiment is converted to electric price in order to calculate power consumption compared to the electric water heater capacity with 100 liters. After that, the heat rate will be used for economics analysis such as Simple Payback Period (SPP), Net Present Value (NPV), and Internal Rate of Return (IRR).