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The Contact Surface Model between Fin and Tube of Solar Collector in Solar Water Heater

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Abstract

In this study was the solar collector testing for bond conductance (C_b) and the thermal efficiency of solar collector including types of materials and contact surface model of fin and tube of thermal collector. The experiment of solar collector was tested by the single tube on the collector and there were three types of fins consist of small zinc fin, large zinc fin and aluminum fin. The experimental conditions were tested and calculated the average C_b between fin and tube of each type collector (small zinc fin, large zinc fin and aluminum fin) that were performed 8.40, 5.31 and 9.60 W/m.°C, respectively. The average thermal efficiency of solar collector was shown that the small zinc fin of solar collector was highest as 0.93, the aluminum fin of 0.77 and the large zinc fin of 0.76. On the reverse side of the solar collector, the thermal efficiency was slightly changed based on the original solar collector. The small zinc fin of solar collector was an easy to find on local material, cheap and do it yourself (DIY). Also, the small zinc fin of solar collector had the potential to be a part of component in a solar water heater.

Keywords: Bond conductance; Solar collector; Thermal efficiency; Solar water heater

INTRODUCTION

Solar energy was a renewable energy that was natural source, clean pollution-free and highly energy efficient [1-2]. In Thailand, the annual average daily solar radiation of the country was 18-19 MJ/m2-day, indicating that Thailand had the potential to utilize solar energy in various ways [3]. In general, solar energy was used in a variety of ways that could be classified into two main forms: the solar energy to generate electricity and the solar energy to produce heat. In the present, solar energy was used to instead of other forms of energy by using solar radiation to produce heat. The use of solar heat to produce hot water was very popular in household consumption. Also, in the industry used very high quantities of hot water consumption [4].

Solar Water Heater (SWH) could be divided by working classification as follows active solar heater and passive solar heater. The active system used an electric pump to regulate the flow of liquid in the heat transfer. The passive system was not had pump, that was the natural motion of the liquid to transfer heat. For hot water producing depend on the type and size of the system. In addition, the various solar radiations, the angle and the direction of installation of the collector also affected the amount of hot water producing, too [5]. The considerations in characteristics of solar water heater might be split into open systems or sometimes referred to as open loop or direct and closed systems sometimes referred to as closed loop or indirect. For the open system, water was passed through the heat trap to be used. In the other side, the closed system, the liquid was used to transfer heat that might be the treated water to prevent slag and low freezing point of liquid that was suitable for cold weather locations. The heat of transfer fluid transferred to the heat exchanger, which was transferred to the water for usable hot water [6-7].

At present, there were more solar water heater manufacturers, distributors growing up and a relatively high price [8]. The production of some equipment in different systems of solar water heater affected to change the overall system performance. One of the issues was the bond conductance (Cb) estimation of the solar collector joints. In general, it was not possible to immediately determine the Cb values. The Cb value estimation was 30 W/m.°C or more that indicated the Cb of the joints was too great [9].

2. Objectives:

The researchers interested to study the bond conductance between fin and tube of the various solar collectors and the thermal efficiency of the solar collector in the solar water heater system. In order to apply for local solar water heater producer, that had system efficiency, local materials as well as able manually producer.

MATERIALS AND METHODS

3.1. Materials and Equipment Preparation:

The preparation of materials and equipment testing of the thermal collector between fin and tube in solar water heater with black metal plate on the surface operated as the thermal absorber plate. The copper tube was a 0.5 inch diameter and the fin and tube hold together by using a copper wire every 30 mm. The tested collector used a clear glass 0.5 mm thick to prevent heat loss from air convection on top. The 25 mm thick polyethylene jacket was used to prevent heat loss in the bottom and sides of the solar collector. The experiments used a solar collector size of 2.00 x 0.18 m^2. For this research tested 4 types of solar collector for water heater: 1.) a small zinc fin 1.86 m long, 0.035 m wide 2.) a large zinc fin 1.86 m long, 0.07 m wide 3.) an aluminum fin 0.8 mm thick, 1.86 m long, 0.115 m wide, the aluminum was applied to the groove with 8.0 mm depth for placing of copper tube 4.) a single copper tube without fin 1.86 m long in the tested collector to compare with other conditions of solar collector.

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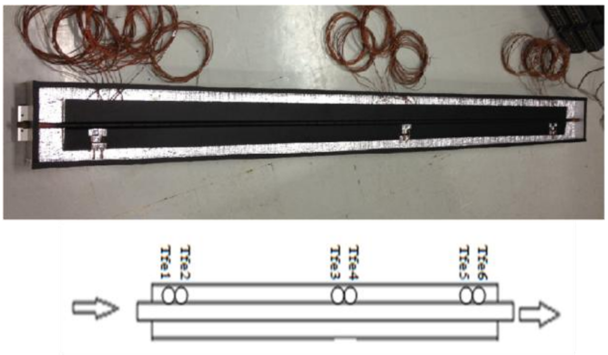

Fig. 1: The tested solar collector and temperature recorder.

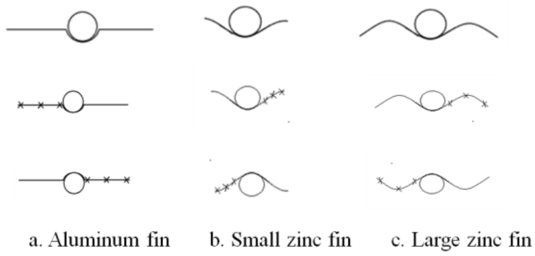

Fig. 2: The types of solar collector in the solar water heater.

3.2. Methods:

For solar collector testing considered the temperature distribution around the tube on the absorber plate. The collector testing of bond conductance between fin and tube as well as the thermal efficiency of solar collector in solar water heater were as follows.

The installation of the equipments and measuring instruments i.e. Thermocouple Type T, accuracy$\pm$0.1°C of various positions on the fin were tested in both parallel and perpendicular directions at least 3 points of the inlet, middle and outlet tube of the fluid. The Pyranometer, KIPPA & ZONEN, Model CM11 was installed in the same plane of solar collector for radiation intensity measurement. All signals were connected to Data Logger, Yogogawa, Model DX2000 for data collecting. The front of the solar collector was turned to the south-west, tilted at 14 degrees to ensure uniform radiation from 11.00 a.m. to 4.00 p.m. testing duration.

The tested collectors were measured the temperature of hot water tank in 15-liter size at the lower, middle and top positions of the tank. The temperature was monitored to close the ambient temperature before starting next step.

The inlet water of solar collector was controlled the water flow rate 0.02±10% kg/s-m2, which was the optimum flow rate for the solar collector testing [13]. The slowly water flow rate adjustment was determined in mass flow rate per square meter. The water in the tank was closely controlled the stability of water feeding rate entered the test collector to maintain an all time constant state of testing system.

The testing system was held to steady state that came into the same temperature at each position.

The data was collected from every point of measurement set up.

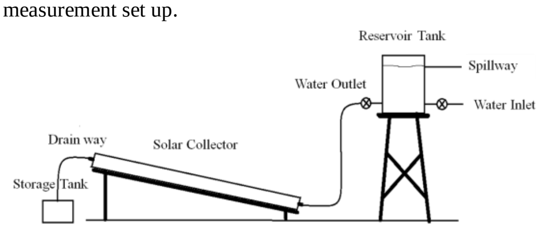

Fig. 3: The installation and testing equipment.

3.3. Bond conductance (C_b) [9,12]:

The bond conductance (C_b) varied according to the contact area of the joints between fin and tube and depending on the exposure such as welding, soldering, wire or clamp. The all heat utilization was considered that transferred thought the joint between the surface of tube and the base of fin. It was equal the product of the temperature difference per the thickness of the joint and the thermal conductivity between the joints and the heat transfer area (Q = -kA dT/dx) as follows.

$Q_u = kBL/S\ (t'_p - t_b)$

Or $Q_u = C_b L\ (t'_p - t_b)$

While, $C_b = kB/S$

Q_u = The amount of heat that flows through the joints, W (The amount of heat that can be utilized when there was no heat loss below)

t'_p = Temperature on the surface of the tube contacted with the fin base, °C

t_b = Base temperature

In experimental testing of t'_p position was a difficult measurement of the temperature-sensitive position. Therefore, in case of no temperature difference around the tube, it was possible to select the temperature position on the surface of the tube at t_p. Therefore, the steady state of the bond conductance between fin and tube could be obtained equation.

$$C_b = \frac{Q_u}{L(t_p - t_b)} \tag{1}$$

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From equation (1), it could be shown that if the heat utilization of system was high or the difference temperature on the surface of the tube and the fin base was low, it indicated that the thermal resistance of the joint was low.

3.4. The Efficiency of Solar Water Heater (Whillier, A. and G. Saluja, 1965; Ariyawiriyanan, W., 2013):

$$n_c = Q_u/A_c I = \dot{m}' C_p\left(\frac{T_{fo} - T_{fi}}{A_c I}\right) \quad (2)$$

While, A_c = Area of the solar collector, m^2

C_p = Specific heat capacity of water, J/kg °C

I = Incident radiation intensity, J/m^2-hr

Q_u = Energy utilization per time, W

$\dot{m}'$ = Mass flow rate, kg/s

T_{fo} = Temperature of outlet water of solar collector, °C

T_{fi} = Temperature of inlet water of solar collector, °C

n_c = Efficiency of solar collector

The energy utilization during the daily testing in solar water heater system was divided into two types: the energy utilization and the energy accumulation in the tank at the end of testing.

The energy utilization of each time could be as the following.

$$q_u = MC_p\left(T_{st} - T_{sf}\right) + \dot{m}' C_p\left(T_{so} - T_{si}\right) \quad (3)$$

While, $\dot{m}'$ = Hot water transfer rate for utilization, kg/hr

The water was used n times as the following.

$$q_u = MC_p\left(T_{st} - T_{sf}\right) + \sum_1^n \dot{m}' C_p\left(T_{so} - T_{si}\right) \quad (4)$$

While, q_u = The amount of energy utilization of solar water heater, kg/hr

T_{sf} = The average temperature of the hot water in the storage tank in the last hour of the testing, °C

n = Number of hours tested each day, hr

The daily average of system efficiency = [(The amount of energy utilization + The amount of energy storage) / The amount of incident energy of solar collector]

$$n_s = \frac{\sum_1^n \dot{m}' C_p\left(T_{so} - T_{si}\right) + MC_p\left(T_{st} - T_{sf}\right)}{I_t A_c} \quad (5)$$

$$n_s = \frac{q_u}{I_t A_c} \quad (6)$$

While, A_c = Area of the collector, m^2

C_p = Specific heat capacity of water, J/kg °C

T_{st} = The inlet temperature of the cold water in the storage tank at the last hour of the testing, °C

T_{si} = The inlet temperature of the cold water in the storage tank, °C

T_{so} = The outlet temperature of the cold water in the storage tank, °C

I_t = Incident radiation intensity of solar collector on the day of the testing, MJ/m^2-day

M = The remaining hot water in the storage tank at the end of the testing, kg

$\dot{m}'$ = Rate of hot water utilization in hot water storage tank per hour, kg/hr

n_s = Thermal efficiency of solar water heater system

RESULTS AND DISCUSSION

The temperature profile of fin in solar collector:

The various temperatures any points were in this case parallel with flow direction of fluids to study the heat transfer on fin at different points. The temperature measurements were installed at end of the fin from the inlet to outlet of the fluid. And the various temperatures any points were in this case perpendicular with flow direction of fluids on the fin from the end to the base of fin.

The results were shown as Figure 4 that the temperature of the fin at various positions. The parallel with flow direction of fluid changed the temperature of the fin at the closest point of the outlet water from solar collector that was the maximum temperature. The temperature of the fin was gradually reduced in a

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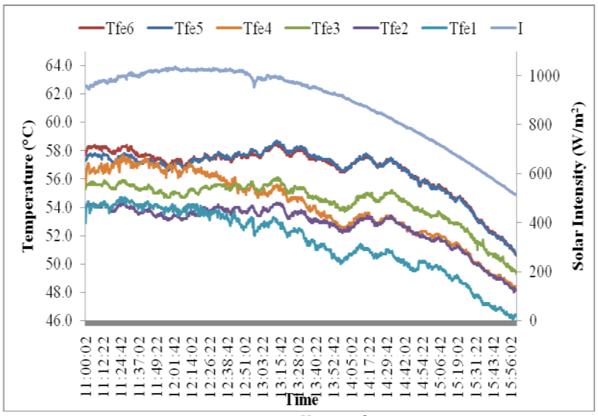
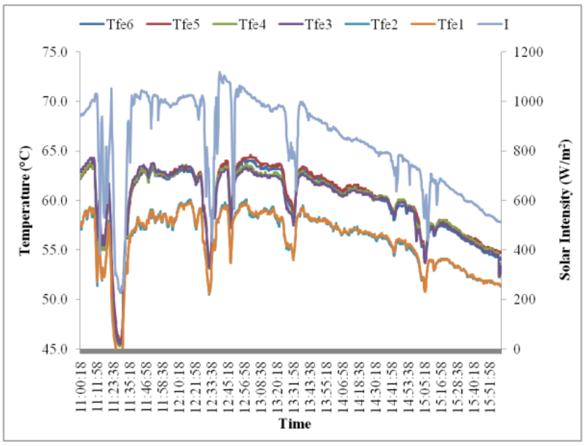
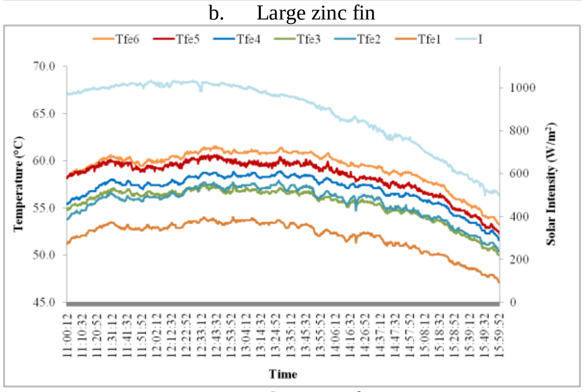
position away from the outlet to inlet of flow of the solar collector. The lowest temperature was at the closest point of the inlet water in the solar collector. As Shown in Figure 5 the temperature of the fin in the perpendicular with flow direction of fluid had different temperatures at various positions. The highest temperature was at the end of the fin and the temperature at the next point was slow down until the lowest temperature at the base of the fin. Due to the increased temperature on the fin of the solar collector, it was sensitively caused the absorption of heat from the solar radiation and the heat transferred to the tube as well as fluid. The change of solar intensity was shown in Figure 6 and it was found that the change of solar intensity immediately affected to the temperature of the fin and fluid.



a. Small zinc fin



b. Large zinc fin



c. Aluminum fin

Fig. 4: The variation of temperature and time in parallel with flow direction.

The bond conductance (C_b):

The testing and evaluation of bond conductance (C_b) between fin and tube had measured the temperature at the base of fin, which was closely point at the tube of fluid. And the tube temperature of fluid at the position was closely measured the surface contact of fin to calculate the bond conductance between fin and tube. It was measured three main points of the tested collector i.e. the entrance, central and the end of collector at the repetition three each point. The average values were obtained for the bond conductance between fin and tube in the solar collector that were shown in Table 1. The bond conductance of surface contact of fin and tube in the solar collector was shown that the highest bond conductance value of aluminum fin was 9.60 W/m.°C. The next order of bond conductance value in small zinc fin was 8.40 W/m.°C and then minimum bond conductance value of large zinc fin was 5.31 W/m.°C. The consideration of surface contact between fin and tube of aluminum and small zinc fin were more than large zinc fin and bond conductance value, too.

The efficiency of solar water heater:

The average thermal efficiency of the tested collector was assessed by the temperature measurement in the solar collector i.e. inlet and outlet of water as well as the solar intensity at the tested time in each type of solar collector. The highest thermal efficiency of the solar collector of small zinc fin was 0.93. The next order of thermal efficiency of the solar collector of aluminum fin was 0.76 and then lowest thermal efficiency of the solar collector of large zinc fin was 0.77 as shown in Table 2. In the other hand of these experimental results of solar collector were turned upside down as shown that the thermal efficiency of solar collector in both small and large zinc fin slightly changed to 0.83 and 0.61, respectively. The thermal efficiency of solar collector of aluminum fin slightly increased to 0.77.

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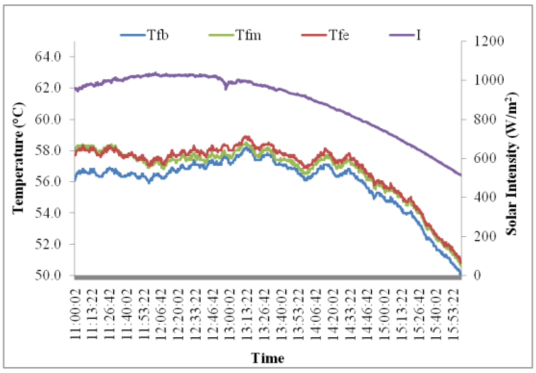
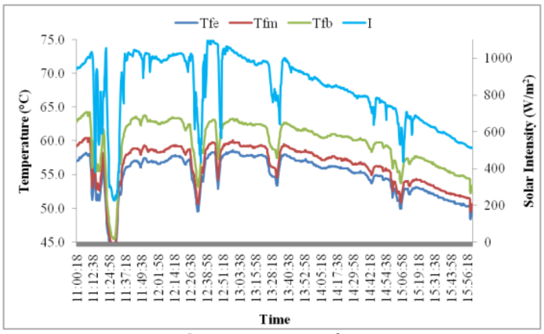
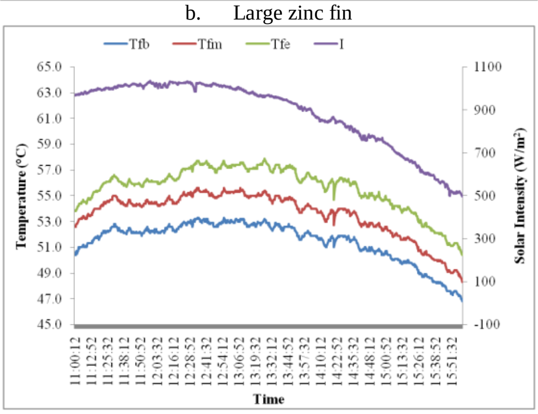
The solar collector of small zinc fin had a high performance of thermal absorber from solar intensity. The heat of solar was transferred to the fluid as well and a high thermal efficiency. In terms of the thermal performance of other solar collector slightly changed due to the good surface contact between the fin and tube as well as the different thermal conductivity of materials utilization in the tested collector.



a. Small zinc fin



b. Large zinc fin



c. Aluminum fin

Fig. 5: The variation of temperature and time in perpendicular with flow direction.

Table 1: The description of bond conductance (C_b) between fin and tube of various types of solar collector.

Types of Solar Collector	C_b (W/m.°C)			
	Inlet	Mid	Outlet	Avg.
Small Zinc Fin	8.50	6.84	9.84	8.40
Large Zinc Fin	5.03	4.51	6.39	5.31
Aluminum Fin	11.17	7.98	9.64	9.60

Conclusions:

The bond conductance between fin and tube of the various solar collectors and the thermal efficiency of the solar collector in the solar water heater system was investigated. The various temperatures of fin and tube at any points was studied the parallel and perpendicular with flow direction of fluid. According to the parallel fluid flow direction, the temperature at the inlet water was the lowest temperature and then higher following with a length of solar collector until the outlet of solar collector was highest. Also, the perpendicular fluid flow direction, the temperature of final fin was highest and down to the lowest temperature at the base of fin. The bond conductance (C_b) between fin and tube was found that the solar collector of aluminum fin had the highest C_b of 9.60 W/m.°C, next the solar collector of small zinc fin of 8.40 W/m.°C and lowest the solar collector of large zinc fin of 5.31 W/m.°C. In terms of the thermal efficiency of the solar collector, it was found that the highest thermal efficiency of the solar collector of small zinc fin of 0.93, next the solar collector of aluminum fin of 0.77 and the solar collector lowest the solar collector of large zinc fin of 0.76. The use of local materials in small zinc fin was cheap, affordable price and own producer. It had a potential to be used a solar collector as well.

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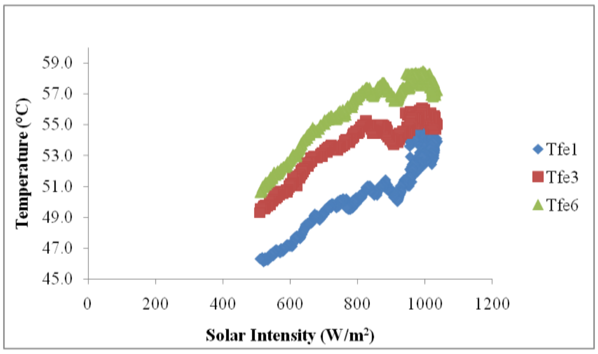
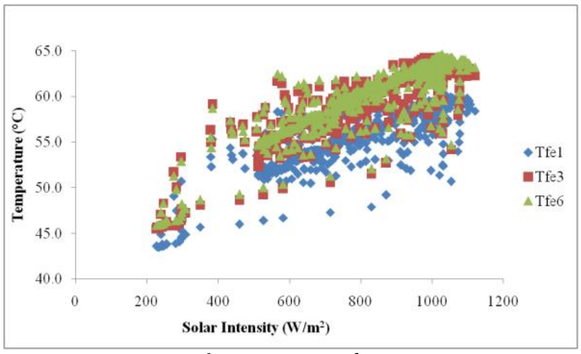
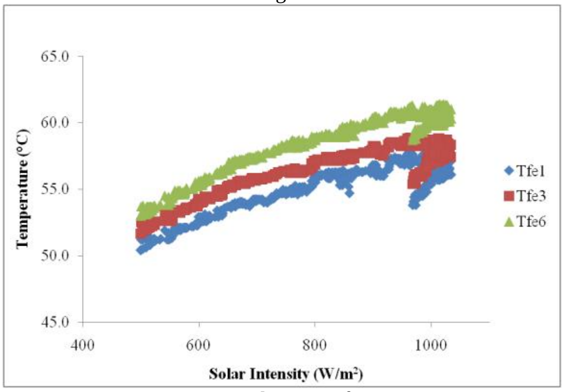


a. Small zinc fin



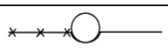
b. Large zinc fin



c. Aluminum fin

Fig. 6: The variation of temperature and solar intensity.

Table 2: The description of thermal efficiency of various types of solar collector.

Types of Solar Collector	Shape	Thermal Efficiency
Small Zinc Fin		0.93
Large Zinc Fin		0.76
Aluminum Fin		0.76
Solar Collector (Turn Upside Down)	Shape	Thermal Efficiency
Small Zinc Fin		0.83
Large Zinc Fin		0.61
Aluminum Fin		0.77

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REFERENCES

[1] ASHRAE., "Methods of testing to determine the thermal performance of solar collectors", American Society of Heating, Refrigeration and Air Conditioning Engineers, New York (USA).
[2] Ariyawiriyanan, W., T. Meekaew, M. Yamphang, P. Tuenpusa, J. Boonwan, N. Euaphantasate, P. Muangchareon and S. Chungpaibulpatana, 2013."Thermal Efficiency of Solar Collector Made from Thermoplastics", Energy Procedia 2013; 34: 500-505.
[3] Badran, A.A., M.F. Mustafa, W.K. Dawood, Z.K. Ghazzawi, 2008. "On the measurement of bond conductance in solar collector absorber plate", Energy Conversion and Management, 49: 3305-3310.
[4] Duffie, J.A. and W.A. Beckman, 1977. "Solar engineering of thermal processes", 2nd ed., Wiley-Interscience, New York, 1991.
[5] Herzog, A.V., T.E. Lipman, D.M. Kammen, 2001. "Encyclo- pedia of life support systems (EOLSS) forerunner volume-perspectives and overview of life support systems and sustainable development", Renewable Energy Sources.
[6] Khan, E.U., 1967. "Evaluation of Bond Conductance in Various Tube-in-Strip Type of Solar Collector",Solar Energy, 11(2): 95-97.
[7] Nieuwenhout, F., 2001. "Experience with solar home systems in developing countries", a Review. Progress in Photovoltaic: Research and Applications, 9(6): 455-74.
[8] Panwar, N., S. Kaushik, S. Kothari, 2011. "Role of renewable energy sources in environmental protection", Renewable and Sustainable Energy Reviews, 15(3): 1513-24.
[9] Patel, K., P. Patel, J. Patel, 2012. "Review of solar water heating systems", International Journal Advance Engineering Technology, 3(4): 4.
[10] Soo Too Y.C., G.L. Morrison, 2009. "Behnia, Performance of solar water heaters with narrow mantle heat exchangers", Solar Energy, 83(3): 350-362.
[11] Samo, S.R., A.A. Siyal, Z.A. Siyal, 2012. "Rahman, Analysis of an active and passive solar water heating system", Sixteenth International Water Technology Conference, Is- 878 tanbul, Turkey.
[12] Thailand Ministry of Energy,2015. "Areas with Solar Power Potential", Department of Alternative Energy Development and Efficiency.
[13] Tian, Y., C.Y. Zhao, 2013. "A review of solar collectors and thermal energy storage in solar thermal applications", Applied Energy, 104: 538-553.
[14] Whillier, A. and G. Saluja, 1965. "Effect of Materials and Costruction Details on the Thermal Performance of Solar Heaters", Solar Energy, 9(1): 21-26.