Experimental Research of Solar Collector with Copper Tube over Steel Plate of U Shape and Solar Boosted Heat Pump

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Keyword; Solar collector, Solar energy, Copper pipe, Heat pump

1. Introduction

Using solar energy is very important to prevent grovel warming and to save energy from fossil fuel. Solar energy is also renewable one so that a number of researches on solar energy have been conducted up to now[1),2)]. A solar collector is one of the systems of to use solar energy. In general the solar collector almost is put copper tube to collect heat on flat steel plate. In this research new solar collector that has copper tube is put over the steel plate with U shape and combination of solar boosted heat pump was proposed. Characteristic and performance of the solar collector were examined experimentally.

2. Experimental apparatus and experimental procedure

2.1 Experimental apparatus

Figure 1 and Fig.2 show experimental apparatus used in this research. Area of solar collector is 1.56 m^2 with 8 copper tubes. The cupper tubes are placed over galvanized steel. Solar radiation can be reflected from U shape galvanized steel or the flat plate to the copper tube. Diameter and length of copper tube are 15.8 mm and 1.88 m respectively. Left, right and bottom side of solar collector are insulated as shown in Fig.3. The solar collector is placed with inclined angle of 18° toward horizon and oriented to the south. Fig.4 shows a water tank which is made of stainless steel. Its diameter is 0.58 m and height 0.8 m with capacity of 125 L. The storage tank is covered by thermal insulator of which thickness is 50 mm with thermal conductivity of 0.036 W/mK. The solar boosted heat pump consists of condenser coil, hermetic reciprocating compressor and capillary tube. The condenser Coil is made of copper tube of L type with inside diameter 9 mm (3/8 inch) and length 3.8 m. Heat rejected from the condenser is 1.75 kW. Heat absorbed by evaporator is 1.4 kW. Power of hermetic reciprocating compressor is 0.3 kW and capillary tube diameter is 1.3 mm with length of 2 m.

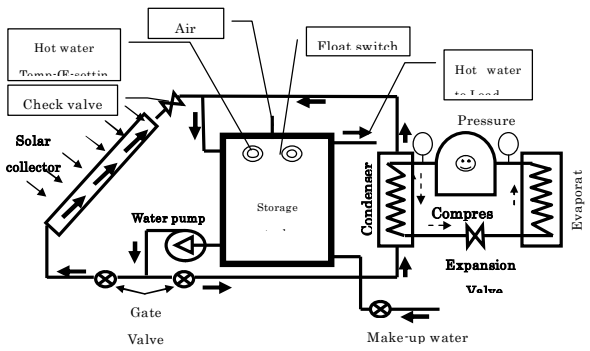


Fig.1 Schematic diagram of experimental apparatus

Fig.2 Photo of experimental apparatus

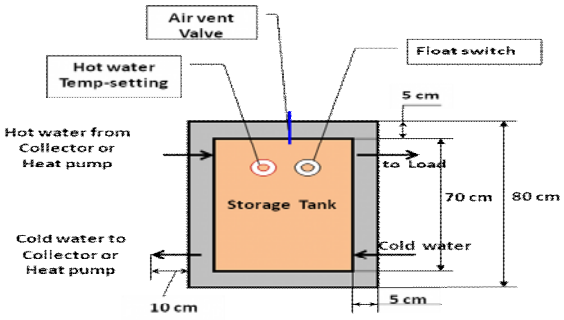
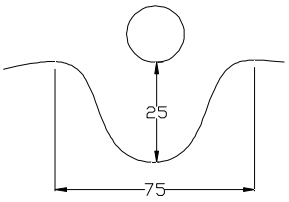


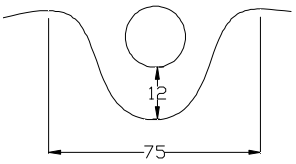
Fig.4 Storage tank

2.2 Experimental method

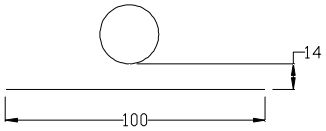
Arrangement of copper tubes on the galvanized steel plate is shown in Fig.5. The cupper tubes are placed at 25 mm, 12 mm, 10 mm, 5 mm over U shape galvanized steel plate, and 14 mm and -6 mm over the flat galvanized steel plate that are adhesive with aluminum foil. In the experiment, first water is filled by the same volume in the copper tubes and close at the end edges of pipes. On the bottom of each pipe has small hole that can put thermocouple for measuring the water temperature and then all copper tubes are placed at the same condition. Temperature of water and heat flux of solar are measured by using thermocouple connected wit data logger and heat flux meter, respectively as shown in Fig.6 and Fig.7 at interval of 30 minutes. This experiment was started from 9:30 am to 17:00 pm.



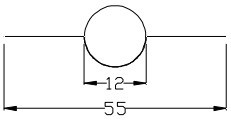
A) H=25mm



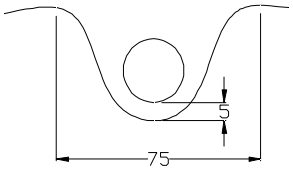
B) H=12mm



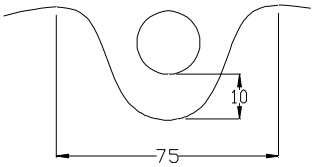
C) H=14mm



D) H= -6mm.



AA) H=5mm



BB) H=10mm

Fig.5 Arrangements of copper tube and galvenized

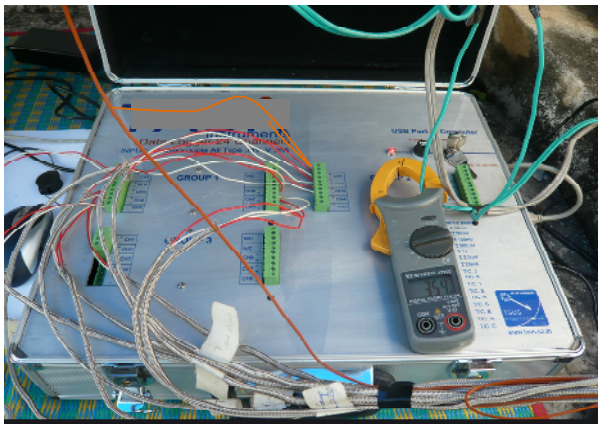


Fig.6 Temperature measurement system with data logger

Fig.7 Heat flux meter

3. Experimental results

3.1 Effect of copper tube location on solar collector

Fig.8 shows temperature variation in cases of copper tube location over the galvanized steel plate shown in case of A, B, C and D of Fig.5. Case of D has the best temperature rise than other cases that copper tube is put 12mm, 14mm and 25mm over the bottom of galvanized steel plate of U shape. Fig.9 shows temperature variation in cases of copper tube location of 5mm and 10 mm over the galvanized steel plate of U shape as shown in cases of AA and BB in Fig.5. Case of BB, namely copper tube location 10 mm over the galvanized steel plate of U shape has better temperature rise than previous the best case D. Therefore this kind of arrangement of copper tube over galvanized steel of U shape is selected to design solar collector.

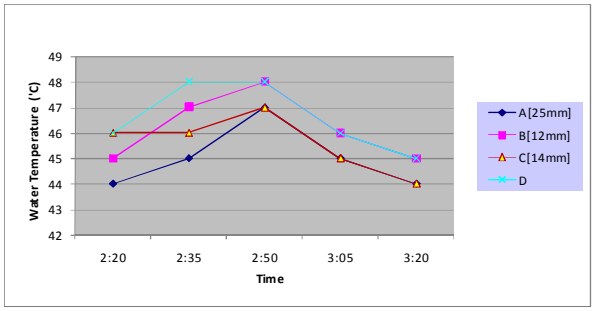


Fig. 8 Temperature versus copper tube location from galvanized steel plate

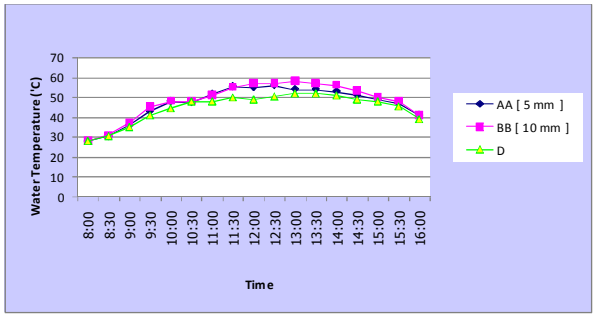


Fig. 9 Temperature versus copper tube location from galvanized steel plate

3.2 Effect of combination of boosted heat pump on performance

Experiment is divided by three steps. In first step, heating water is conducted by solar collector alone to know the efficiency of solar collector and what parameters has influence on the efficiency of solar collector or on hot water produced. First, water is filled in the tank with capacity 125 L and switch on pump to circulate 1 L/min of water from the tank pass through solar collector. Initial temperature of water in the tank is 33°C and for 4 hours experiment the temperature in the

tank reaches to 55°C. The data of experiment is shown in Fig. 10. The experiment was carried out on 16th June 2010. Where Ta; Ambient air temperature, Tfi; water, temperature at the inlet of solar collector, Tfo; water temperature at the outlet of solar collector, Tst; water temperature in the tank. Each temperature is measured in °C and solar radiation flux W/m^2.

In second step, to known how the coefficient of performance (COP) varies during hot water production and also how the condenser and compressor performance, experiment using only heat pump to heat water was conducted. The experiment is same as we do with solar collector alone, but only water circulate water through heat pump unit. Experimental results show in Fig.12 and Fig.13. This experiment was 3 June 2010. Where, Wcomp; compressor power (kW), COP; coefficient of performance, heat rejected rate from condenser coli (kW). From this experiment it is found that water temperature increases at the same range compare with used solar energy. Heating time is only 40 min to increase water temperature rise for 20°C.

In third step, performance of combination between solar collector and heat pump was examined. This experiment was done on 14th of June, 2010. From this experiment it is found that as the sky is very sunshine from 9:00 am to 11:30am, there is good solar radiation and the temperature of water increases from 30°C to 40°C. After that the sky is clouded and the ambient temperature and solar radiation decrease. And then we start heat pump to boost temperature of water to reach to 50°C. The pump was used it only 25 min and this temperature was achieved. At the same time when heat pump started working, some parameters concern to the heat pump performance was measured as shown in Fig 14 - Fig.18. Combination of the solar collector and heat pump is more effective to increase coefficient of the solar collector system

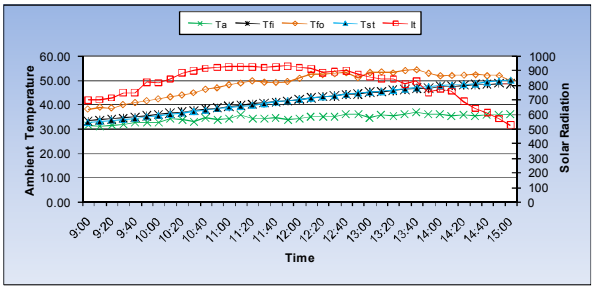


Fig. 10 Temperature and time

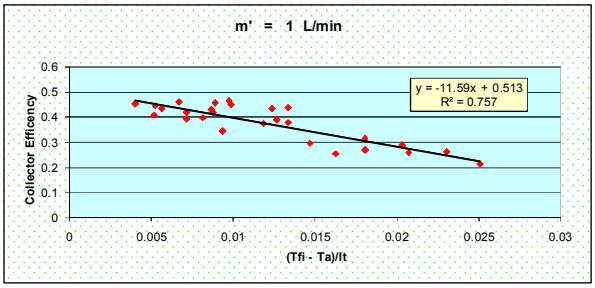


Fig.11 Efficiency of solar collector

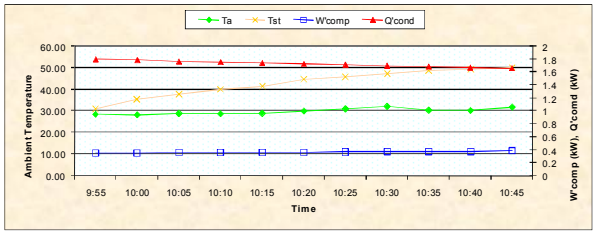


Fig.12 Variation of each part of temperature, power of compressor and heat flux of condenser versus time

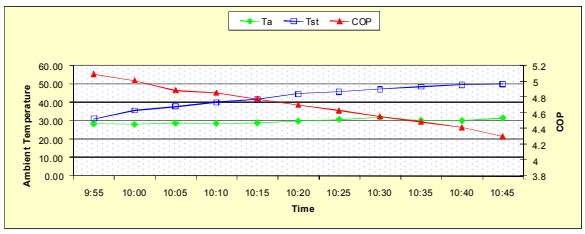


Fig.13 Variation of ambient and storage tank temperature, and coefficient of performance versus time

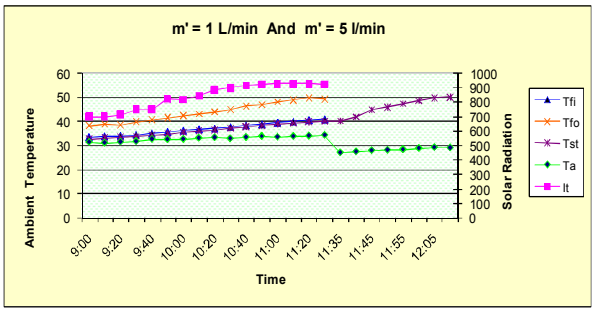


Fig 14 Variation of each part of temperature versus

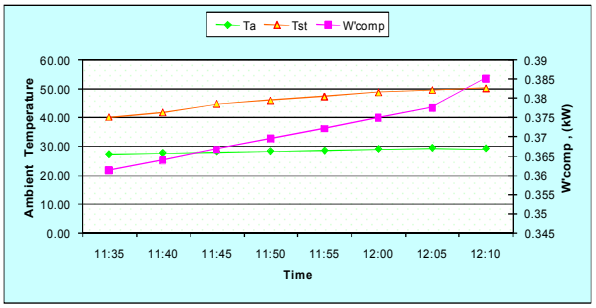


Fig.15 Variation of ambient and storage tank temperature and power of compressor versus time

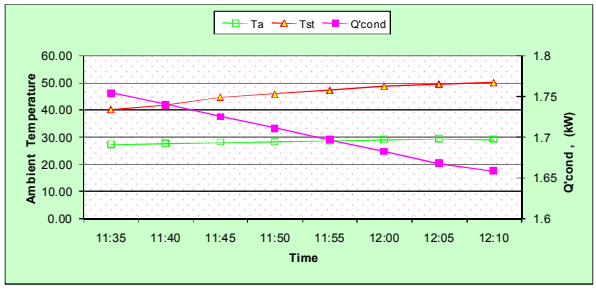


Fig.16 Temperature and heat release rate of condenser

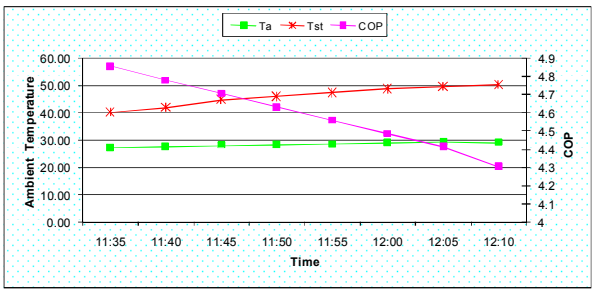


Fig.17 Temperature and coefficient of solar collector

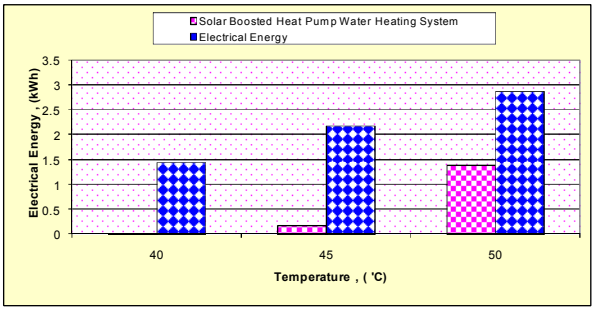


Fig. 18 Electric energy for solar collector with and without water heating system by boosted heat pump

4. Conclusion

New solar collector that copper tube is put over the steel plate with U shape was proposed and its characteristic and performance of the solar collector were examined experimentally. From the experiment it is found that copper tube arrange over galvanized steel plate about 5mm receives more radiation heat from solar than other arrangement. Combination of the solar collector and heat pump is more effective to increase coefficient of the solar collector system.

References

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2) Artur V. Killian, Solar Collectors: Energy Conservation, Design and Applications (Renewable Energy: Research, Development and Policies), Nova Science Pub Inc., 2009.