ISSN No:-2456-2165

Studying the Effect of Absorber Plate Material of the Evacuated Tube Solar Heaters in Heater Performance and Heating Duty

MSc Hassan Albusairi [1], Eng Husain Qumber. [2]
Specialist Trainer (B), the Public Authority for Applied Education and Training, Al-Azhar University, Egypt

Abstract:- The Evacuated tube solar heater (EVH) consists of parallel tubes made of reinforced glass (transparent) which are installed inside steel frame and connected to a collector(manifold). These tubes are two concentric tubes with vacuum clearance between each other to avoid the heat loss.The absorber plate is connected to the inner heater tube in order toincrease and concentrate the sun radiation on the inner tube to increase the heat transfer. The absorber plate can be made of aluminum, copper, silver, or nickel. The experimental setup consisted of 20 parallel evacuated tubes, connected to horizontal tank. It is required to heat the domestic water. The tests were carried out from February to September and the water outlet temperature was measured at different days and times and comparisons were applied for each absorber plate material. Finally, it was concluded that the copper absorber plate has higher efficiency, satisfied water outlet temperature, and reasonable cost.

***Keywords**: Evacuated tube, solar heater, absorber plate, solar heater efficiency, domestic water heating.*

I. INTRODUCTION

The Evacuated tube solar heater (EVH) consists of parallel tubes made of reinforced glass (transparent) which are installed inside steel frame and connected to a collector or tank(manifold) as shown in figure 1. The tubes are two concentric pipes. The outer tube has a transparent thick glass and the inner tube are connected to high thermally conductive metal rod to allowhigher heat transfer and high heater efficiency as shown in figure 2.

The outer tubes are commonly made of borosilicate material, which has higher strength, resistant to high temperatures and has a high transmittance for solar irradiation. The EVHdo not heat the water through the pipes directly. There is vacuum space between two concentric tubes which decrease the heat loss and increase solar efficiency. The absorber plate that connected to the inner heater tube is used to increase and concentrate the sun radiation on the inner tube to increase the heat transfer. Moreover, it is storing the energy inside during the night time. The absorber plate can made of aluminum, copper, silver, or nickel. It isdepend on the required heat duty, collector area, and tank volume.

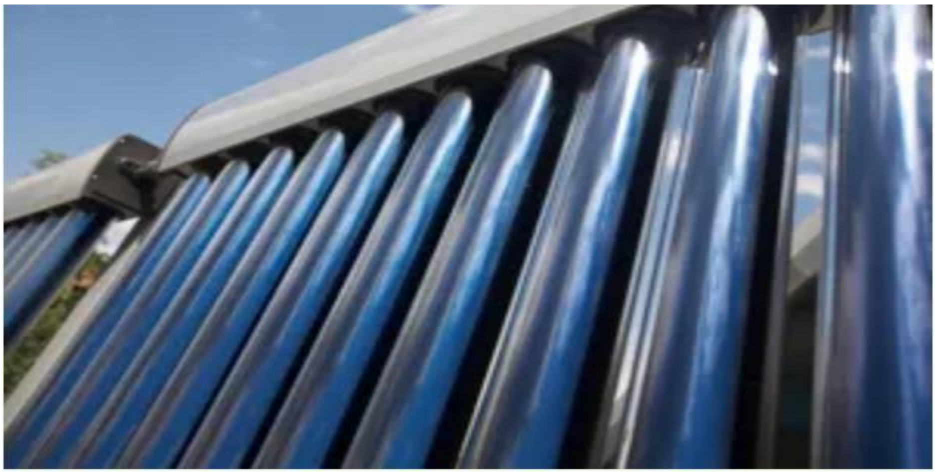

Fig. 1: Evacuated tube solar heater

There are several advantages of the evacuated tube solar heaters. These glass tubes have cylindrical shape. So, the angle of the sun ray is always normal to the tubes which make the solar heaterreliable during cloudy weather or evening. ETHare very useful in cold or cloudy weathers.

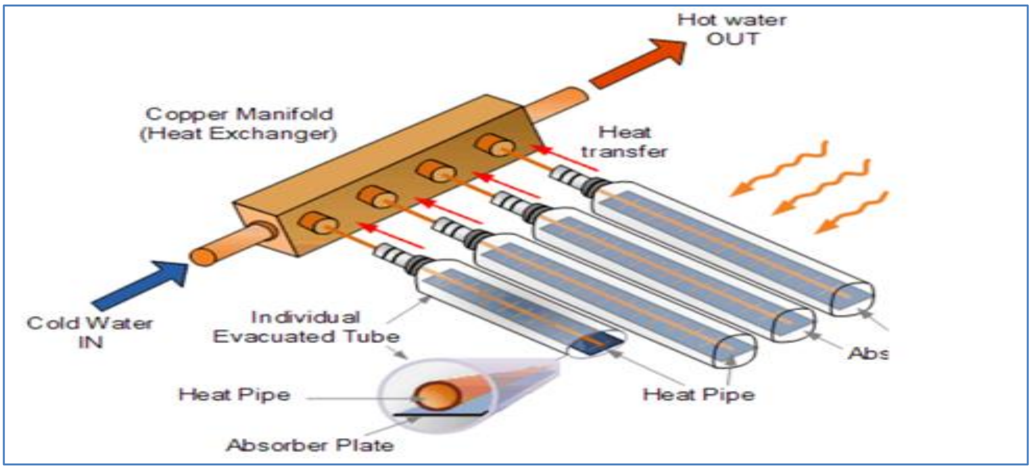

Fig. 2: Evacuated tube solar heater parts

In this research, an experimental investigation was carried out to study the effect of different absorber plate materials on the solar heater performance and heat transfer represented in the medium outlet temperature.

II. MATERIALS PREPARATION AND METHODOLOGY

In order to investigate the effect of absorber plate material on the solar heater performance; evacuated solar heater was fabricated with different absorber plate materials; silver, copper, nickel, or aluminum. It was required to heat the domestic water.Generally, the measured data were recorded from February to September to check the absorber material effect in winter, spring, and summer. The average daily water consumption is ~ 65 Liter / hr.

The performance will be measured in respect of the following parameters for four selected materials mentioned above:

- Water temperatures difference between inlet and outlet at random selected days in summer and winter.
- Water temperatures difference between inlet and outletstarting from sunrise to sunsetin certain day with the same ambient temperature.
- Performance evaluation of the solar heater represented in efficiency calculations.

A. *Experimental setup*

The evacuated solar heater was fabricated with the following specifications as shown in figure 3:

- No of tubes: 20
- Tube length: 1.7m (end to end)
- Outer tube diameter: 1.5" (38 mm)
- Inner tube diameter: 1" (25 mm)
- Tank volume: 140 Liter
- Medium: domestic water
- Inclination angle: 42°
- Tracking mechanism: No

B. *Instruments used*

Several instruments were used to record the parameters as below:

- Temperature indicators: used to measure the ambient, inlet, and outlet temperatures. Its range is from 0° to 100° C with 2° step increment (brand: Rototherm)
- Solar power meter: used to measure the solar radiation flux (W/m^2). Its range is up to 2000 W/m^2 (brand: Subitek SM-206)
- Floating flow meter: used to measure the water flow rate. Its range is from 0 to 10 L/m with 0.2 L/m accuracy (brand: Apure)


Fig. 3: Fabricated evacuated solar heater

C. *Efficiency calculations for solar heater*

To calculate the solar heater efficiency; the following parameters have to be calculated in respect of the following equations:

First, the transmitted solar power must be calculated. It was calculated from equation (1) as below:

$$Q = R \ Ac \quad \text{--} \ (1)$$

Where:
Q: Transmitted solar energy (Q)
R: Solar radiation flux incident (R)
Ac: Solar heater surface area (Ac)

Secondly, the useful heat gain to storage (Qc) has to be calculated from equation (2) as below:

$$Q_c = m \ Cp \ (T_o - T_{in}) \quad \text{-----------------------------} \ (2)$$

Where:
m: Mass flow rate (Kg/sec)
Cp: Water specific heat (4150 J/g°C for water)
To: Outlet temperature (°C)
Ti: Inlet temperature (°C)

Thus, the heater efficiency (η) could be determined from equation (3) as follows:

$$\eta = (Qc/Q) \times 100\% \quad \text{------------------------------} \ (3)$$

III. RESULTS AND DISCUSSION

A. *Monthly water temperatures differencefor 4 absorber materials*

Both inlet and outlet temperatures were recorded at the first days of each month starting from February 2023 to September 2023 for 4 absorber materials. The temperatures difference were calculated to avoid misleading of ambient temperature changes between summer and winter.

Comparison were carried out between four absorber materials as shown in figure 4 and 5.

It is shown that the silver absorber material have the highest temperature difference between water inlet and outlet. Meaning that, it has the highest heat transfer. The second one was found the copper material, the third one is Aluminum. Finally, the least outlet temperature is Nickel absorber plat.

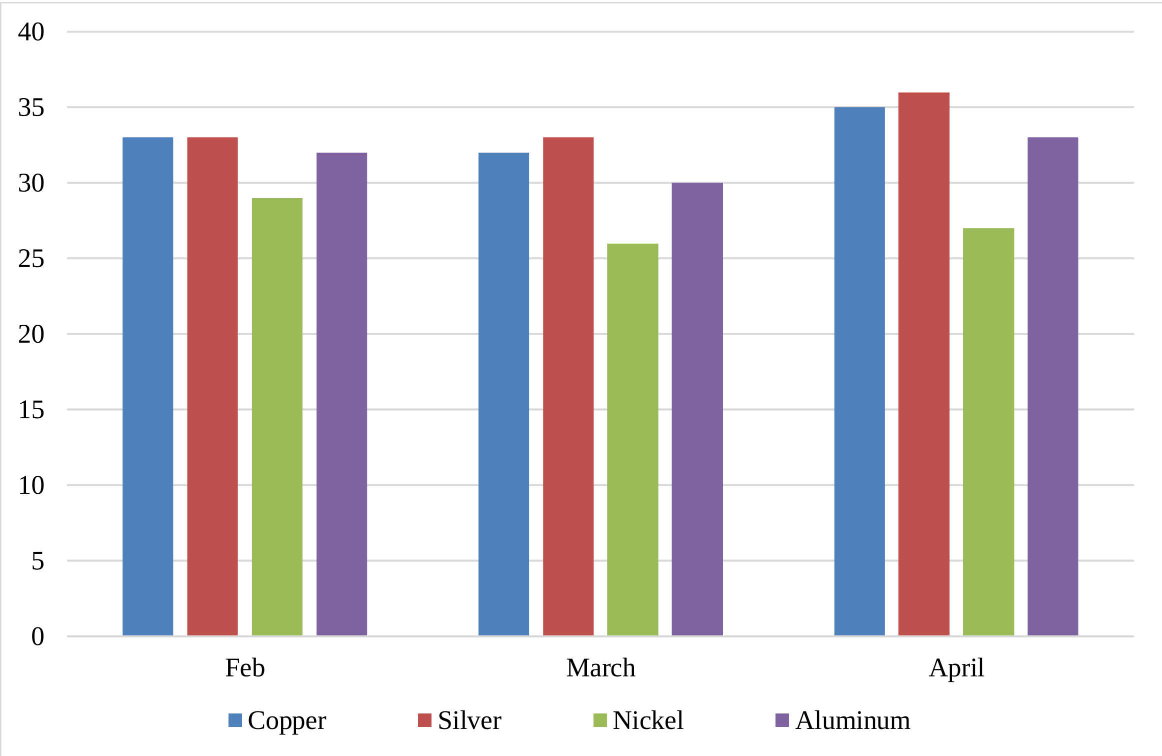

Fig. 4: Temperature Difference comparison in Feb, March, and April months for 4 absorber material

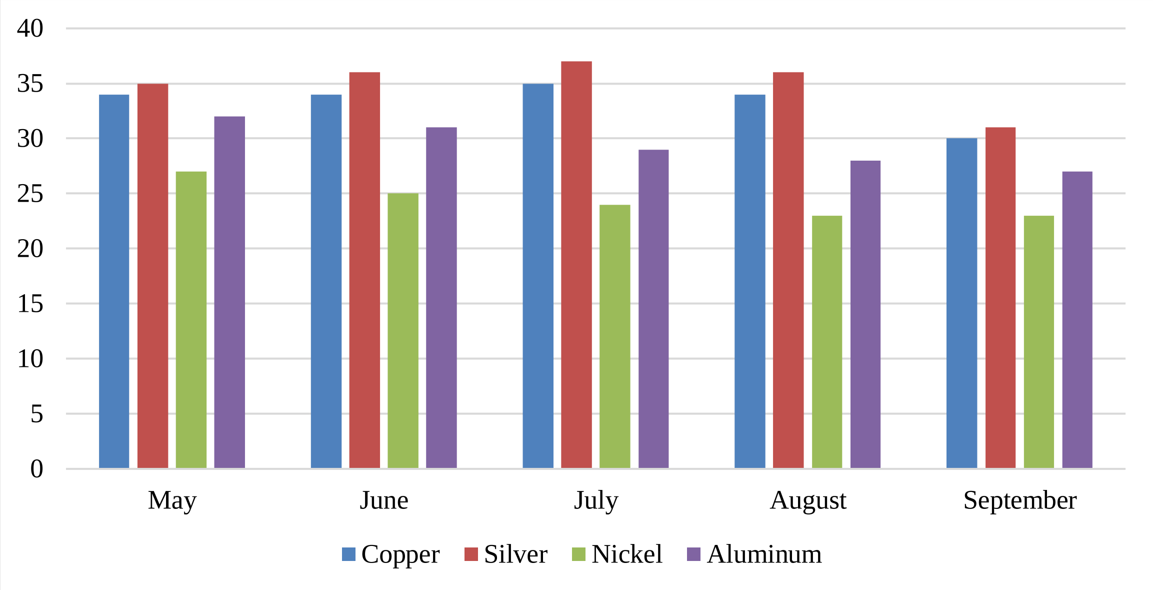

Fig. 5: Temperature Difference comparison in May, June, July and Sept. months for 4 absorber material

This is expected because silver material has higher conductivity coefficient than othermaterials. Generally, the material that has higher thermal conductivity coefficient, will produce much heat transferred to water through the inner tube.

B. Water temperatures difference between inlet and outlet starting from sunrise to sunset.

Both of inlet and outlet temperatures were recorded from 20th May to 23rd May 2023 with the constant ambient temperature, starting from 8:00 am to 11:00 pm. The temperature difference were calculated. Comparison were carried out between four absorber materials as shown in figure 6.

It is shown that the highest stable heat transfer; especially in evening, is the copper absorber plate. However, the silver absorber plate has lower stability compared with copper.So, the silver absorber plate gain much heat but it lose it in short time, while copper has more stability in its heat transferring behavior.Still, the nickel absorber plate has the worst heat transfer and hear storage relatively.

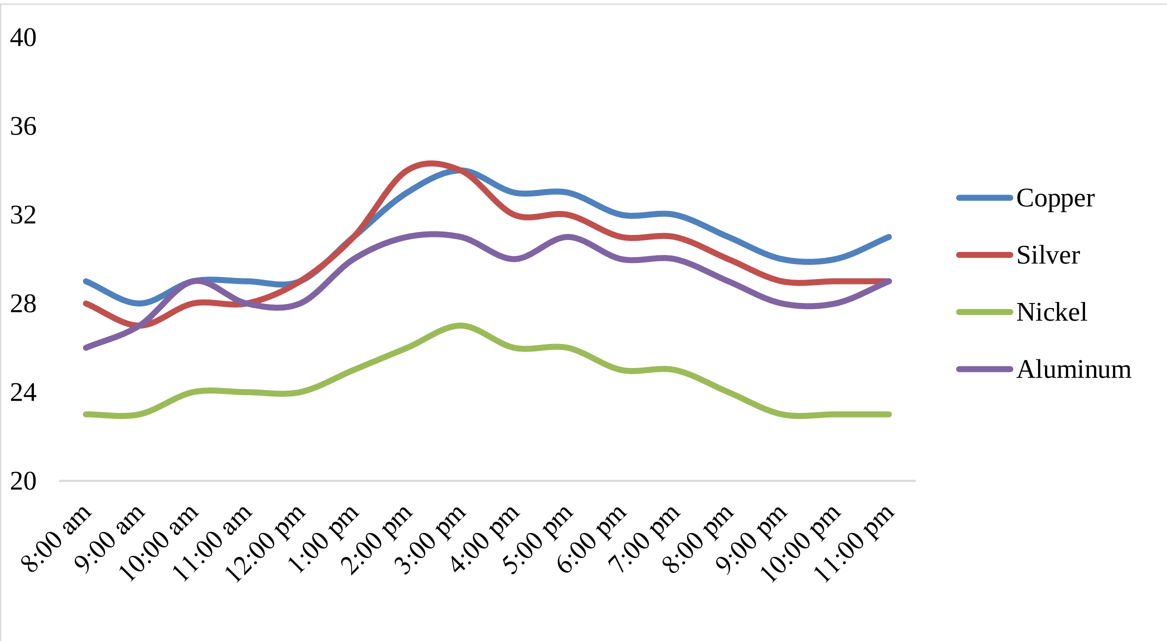

Fig. 6: Temperature Difference along one day for 4 absorber material

C. Performance evaluation of the solar heater represented in efficiency calculations.

Both of inlet and outlet temperatures were recorded in June, July and August. The test was implemented four times for four absorber material in each month. The temperature difference were calculated in each case. The efficiency was calculated in respect of equations 1, 2, and 3 each month for each material.

The following parameters were substituted in equations 1, 2, and 3:

- Water volume flow rate was 65 Lit/hr
- Measured solar flux was 1400, 1440, 1490 W/m2 for June, July and August respectively
- Water density was estimated 1000 Kg/m3,
- Heater Area was calculated by timing solar heater length and width as in paragraph 2.1.

Thus comparison was implemented as shown in figure 7. It is shown that the higher solar heater efficiency was in silver absorber plate for June and July but both of silver and copper absorber plates were equal in August. This is back to the same reasons mentioned in 3.1 paragraph. On the other hand, aluminum and nickel were not efficient compared with copper or silver.

So, copper was considered the best suitable material for absorber plate due to its reasonable cost and satisfied heat transfer behavior.

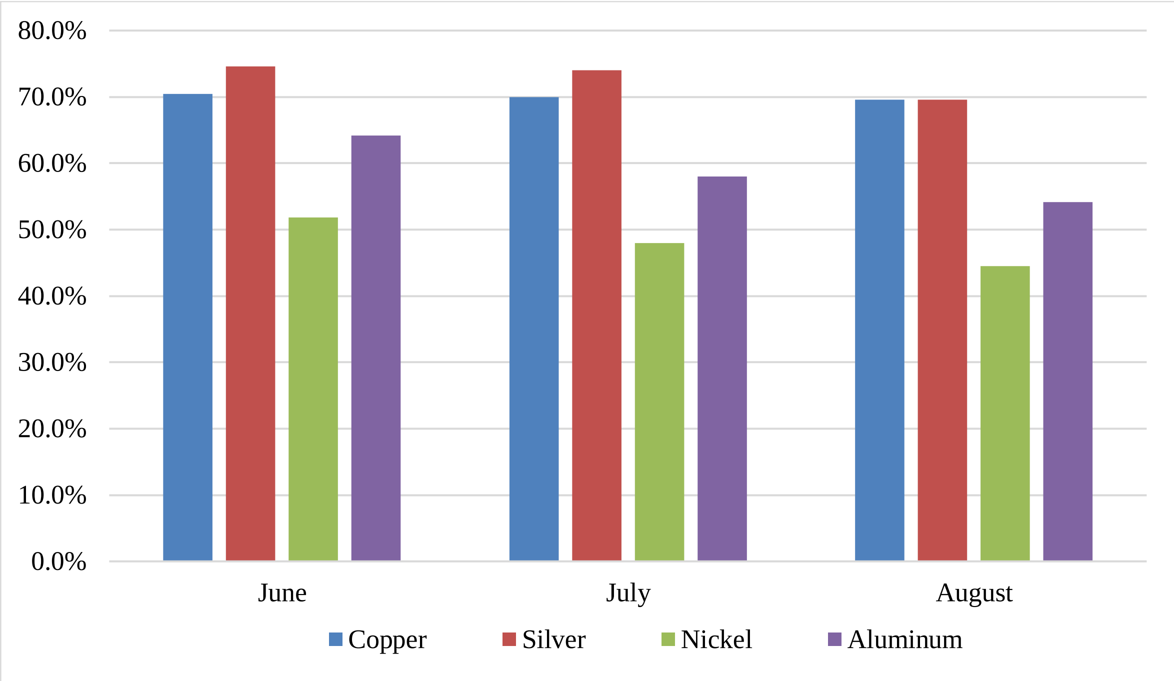

Fig. 7: Efficiency Comparison for 4 absorber materials at summer months

IV. CONCLUSION

Finally and after completion the experimental setup and testing for 8 months; it was concluded that generally, the highest absorber plate material is silver followed by the copper in respect of the outlet temperature and calculated solar heater efficiency. However, the copper plate material have the advantage of storing energy from day to night more than silver and aluminum. Moreover and respect of cost wise, copper is more favorable compared with the silver material.

REFERENCES

[1]. Ayompe, L.M.; A. Duffy; M. McKeever; M. Conlon and S. J. McCormack; Comparative field performance study of flat plate and heat pipe evacuated tube collectors (ETCs) for domestic water heating systems in a temperate climate; Energy, 36: 3370-3378; 2007.

[2]. Darwesh. M.* , Thermal performance test of evacuated tube and flat plate solar collectors under climatic conditions of Egypt; Biological Engineering

[3]. Duffie, J. A and W. Beckman, Solar engineering of thermal processes, J. Wiely and Sons, 2006

[4]. Budiharjo, I. G and G. L. Morrison; Performance of water – in-glass evacuated tube solar water haters; Solar Energy, 83:49-56; 2009.

[5]. Dabra, V.; L. Yadav and A. Yadav, The effect of tilt angle on the performance of evacuated tube solar air collector: experimental analysis, International Journal of Engineering, Science and Technology, 5(4): 100-110; 2013.

[6]. Gunerhan, H. and A. Hepbasli; Exergetic modeling and performance evaluation of solar water heating systems for building applications; Energy and Buildings, 39(5): 509-516; 2007.
[7]. Kalogirou, S. A.; Environmental benefits of domestic solar energy systems" Energy Conversion and Management, 45 (18-19): 3075 – 309; 2004.
[8]. Zhang X.R .and H. Yamaguchi, An experimental study on evacuated tube solar collector using supercritical CO2, Applied Thermal Engineering, 28:1225-1233, 2008.
[9]. Ahmad Syuhada 1 and Muhammad Ilham Maulana, Absorber Thickness Effect on The Effectiveness of Solar Collectors to Production Hot Air For Drying, Mechanical Engineering of Syiah Kuala University, Darussalam–Banda, Indonesia
[10]. A.M. Shariah a, *, A. Rousana, Kh.K. Rousanb, A.A. Ahmada, Effect of thermal conductivity of absorber plate on the performance of a solar water heater, Physics Department, Jordan University of Science and Technology, 1997.
[11]. Tiwari, Anupam., A review on solar drying of agricultural produce, journal of food (2016).
[12]. Teja, Ravi, F. Z. Pathan, and Mandar Vahadne, Optimization of Heat Transfer through Rectangular Duct, International Research Journal of Engineering and Technology (IRJET) 2, no. 4 (2015): 1906-1910.
[13]. Mohammad karim, Ahmadreza, AlibakhshKasaeian, and AbdolrazaghKaabinejadian, Performance investigation of solar evacuated tube collector using TRNSYS in Tehran, International Journal of Renewable Energy Research (IJRER)4, no. 2 (2014): 497-503.