Trends in Applied Sciences Research

ISSN 1819-3579

Academic
Journals Inc.

www.academicjournals.com

Trends in Applied Sciences Research 2 (3): 251-254, 2007
ISSN 1819-3579

Correlation Between Collector Performance and Tube Spacing for Various Absorber Plate Materials in a Natural-circulation Solar Water Heater

[1]S.N. Agbo and [2]C.E. Okeke
[1]National Centre for Energy Research and Development, University of Nigeria, Nsukka
[2]Department of Physics and Astronomy, University of Nigeria, Nsukka, Nigeria

Abstract: The effect of tube spacing as a design factor in the performance of a natural-circulation solar water heater is investigated for copper, zinc and galvanized steel absorber plates. The collector performance in terms of the collector efficiency and the collector fin efficiency are both obtained theoretically and by a computer-aided simulation based on the Hottel-Whiller model of the system. The result indicates that the tube spacing varies inversely with both the collector efficiency and the fin efficiency for the three absorber plates. Copper shows the best performance while galvanized steel shows the least. Performance is optimized with a tube spacing not exceeding 10 cm irrespective of the absorber plate used.

Key words: Tube spacing, absorber plate material, collector fin efficiency, collector efficiency, natural-circulation solar water heater

INTRODUCTION

In the light of the present deplorable state of the Nigeria's power sector, the ever-increasing cost of fossil fuel and the unquantifiable environmental degradation associated with every stage of its production and utilization, solar energy as a renewable energy is a better option as a supplement or even a substitute to our conventional energy sources (Agbo *et al*., 2005).

Solar water heaters are classified based on a number of designs, which are adopted to suit specific purposes and climatic conditions. Natural-circulation solar water heater is the simplest form of solar heaters given its simplicity of construction, design, utilization and maintenance. The design choice is based on a number of factors: Economic, climatic, availability of materials, among others. Design factors such as the area of the collector, nature of the absorber plate material, storage tank capacity, etc have been shown to affect the performance of a natural-circulation solar water heater in various forms (Garg, 1987; Agbo and Unachukwu, 2006). Eisenmann *et al*. (2004) has looked at the relationship between the collector efficiency factor and the material content of the collector.

The present study considers the variation of the collector fin efficiency and collector efficiency with tube spacing for copper, zinc and galvanized steel absorber plates.

MATERIALS AND METHODS

The collector fin efficiency and the overall collector efficiency are considered as performance parameters of a natural-circulation solar water heater (Agbo and Unachukwu, 2006). These were respectively evaluated theoretically and also by using a computer-aided simulation done in MATLAB™ software based on the Hottel-Whiller model of the system. Figure 1 shows the schematic diagram of the fin attached to each fluid tube. Thus, fin length per tube is given as W-D/2 as shown:

Corresponding Author: S.N. Agbo, National Centre for Energy Research and Development, University of Nigeria, Nsukka, Nigeria Tel: +2348030983646

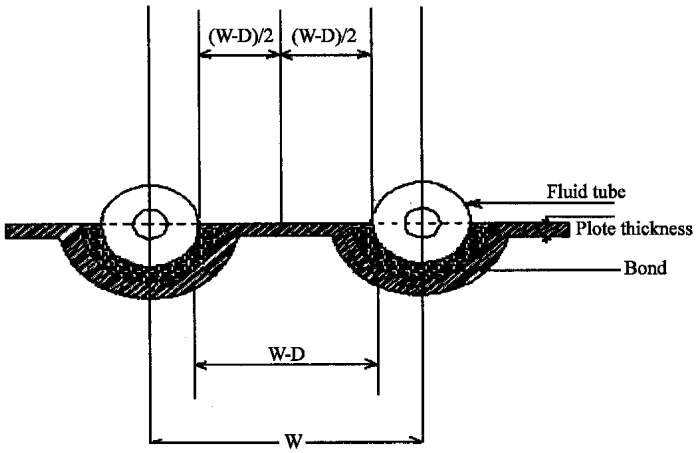

Fig. 1: Absorber plate and tube dimensions

The fin efficiency describes the fact that there is a decrease in the magnitude of the heat transferred by the fins when compared to the magnitude of the heat transferred if the fins were all at a constant temperature, T_K (Duffie and Beckman, 1974). Thus, fin efficiency F is given as:

$$F = \frac{\text{Heat transferd by fin}}{\text{Hett that would be transferd if fin were at } T_k}$$

In terms of the centre-to-centre tube spacing, the fin efficiency is given by:

$$F = \frac{\tanh\left[M\left(\frac{W-D}{2}\right)\right]}{M\left(\frac{W-D}{2}\right)} \quad (1)$$

where $M = \sqrt{\frac{U_L}{K_t \alpha_p}}$, α_p and, K_t are the absorber plate thickness and the thermal conductivity of the absorber plate respectively. W is the center-to–center tube spacing and D is the outside diameter of the tubes.

As presented by Close (1962), the collector fin efficiency and the tube spacing relate to the overall collector efficiency.

Based on the above models, the variation of the fin efficiency with tube spacing for the three absorber plate materials was investigated. Also, the overall collector efficiency and the mean system temperature as a function of the tube spacing were studied by means of a computer-simulation.

RESULTS AND DISCUSSION

Figure 2 and 3 represent the effects of collector tube spacing on the collector efficiency and the mean system temperature, respectively. The results indicate that both of these parameters decrease with increasing tube spacing. For tube spacing not exceeding 10 cm, these performance parameters are optimized. The result also shows that a collector efficiency of up to 80% is possible in a natural-circulation solar water heater. This agrees with the report of an earlier work done by another author. (Danshehu *et al*., 1996).

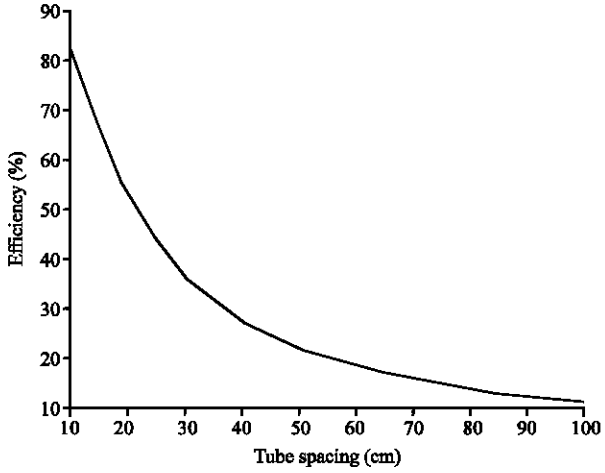

Fig. 2: Effect of collector tube spacing on collector efficiency

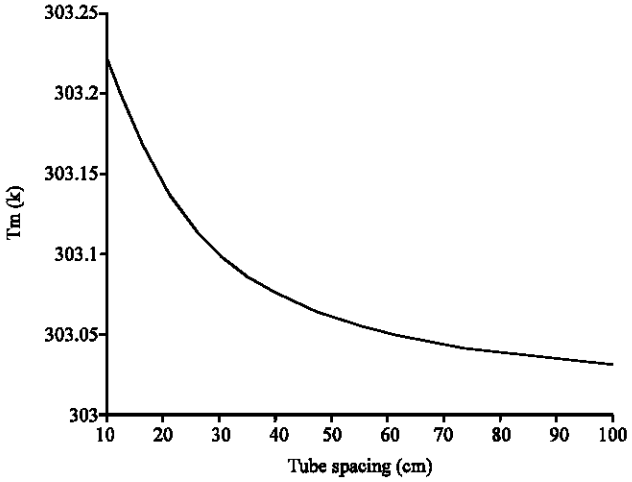

Fig. 3: Tube spacing and the mean system temperature

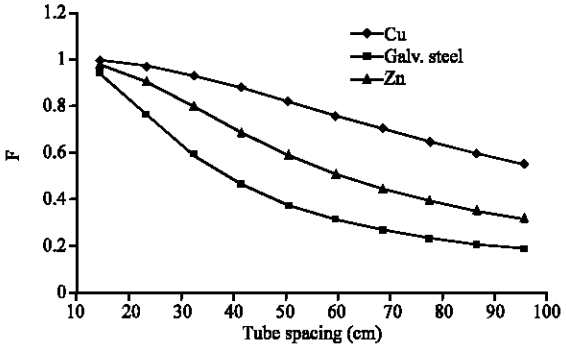

Fig. 4: Fin efficiency against tube spacing for various absorber plate materials

Figure 4 presents the tube spacing effect on the fin efficiency of the collector for the three absorber plates. Generally for all the absorber plates, collector fin efficiency decreases with increasing collector tube spacing. The result shows that copper plate performs best among the three absorber materials. Zinc performs better than galvanized steel. However, at a certain tube spacing (<10 cm), the fin efficiencies for the three plates are optimized and almost equal. Thus, with this tube spacing the performance of the collector is independent of the nature of absorber plate material in use.

CONCLUSIONS

The collector fin efficiency and the overall collector efficiency, as performance parameters of a natural-circulation solar water heater are dependent on the tube spacing and the nature of the absorber plate material. For the three absorber plate materials considered, the fin efficiency decreases with increasing collector tube spacing. With a tube spacing not exceeding 10 cm, the performance of the system is optimized independent of the nature of the absorber plate. However, for higher values of tube spacing, the type of absorber plate becomes significant. This way, the cost implication of using very highly conductive and expensive absorber plate like copper can be avoided or reduced by using other cheaper and readily available plate instead.

REFERENCES

Agbo, S.N., G.O. Unachukwu, S.O. Enibe and C.E. Okeke, 2005. Solar water heating for resident university students. Nig. J. Solar Energy, 15: 85-92.

Agbo, S.N. and G.O. Unachukwu, 2006. Performance evaluation and optimization of the NCERD thermosyphon solar water heater. Proc. World Renewable Energy Congress, Aug., 19-25, 2006, Florence, Italy.

Close, D.J., 1962. The performance of solar water heaters with natural circulation. Solar Energy, 6: 33-40.

Danshehu, B.G., A.T. Atiku and A.S. Sambo, 1996. Some Design and fabrication features of solar water heaters for low and higher temperature requirements. Nig. J. Renewable Energy, 4: 51-55.

Duffie, J.A. and W.A. Beckman, 1974. Solar Energy Thermal Processes; John Wiley Inc., New York.

Eisenmann, W., K.Vajen and H. Ackermann, 2004. On the correlations between collector efficiency factor and materials content of parallel flow flat-plate solar collectors. Solar Energy, 76: 381-387.

Garg, H.P., 1987. Advances in Solar Energy Technology; Vol. 1, D. Reidel Pub. Co., Holland.