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Experimental determination of the effect of tube spacing on the performance of a flat plate solar collector

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ABSTRACT

The objective of the present work is to study the effect of tube spacing on the performance of a Flat Plate Collector (FPC). A comparative study of the performance of two FPC with average adjacent tube spacing of 20 cm and 11 cm was carried out for five days in July, 2011. Comparison shows that both the inlet and the outlet temperature of collector B with adjacent tube spacing of 20 cm are persistently higher than that of Collector A with adjacent tube spacing of 11 cm for most hours of the day. Efficiency 0f 10% and 21% was recorded for collector A and B respectively on day 1 while the values dropped to almost half on day 2 and to less than 5% on days 3, 4 and 5 for both collectors due to frequent cloud cover and rain. It can be inferred that adjacent tube spacing has significant effect on the performance of a flat plate collector.

Keywords: Flat Plate Collector (FPC), Solar Insolation, Collector efficiency, Tube spacing.

1. Introduction

About 65% of the energy consumed in the residential and commercial sector is for heating (46%), cooling (9%) and refrigeration (10%) (U.S. DOE, 2005), this energy requirement can be provided from a low temperature heat source. Also, recent development in low temperature differential Stirling engine technology has shown that Stirling engine coupled with low temperature heat source can be use to generate electricity and also to do mechanical work (Der Minassians et al, 2004). This energy can be provided by non-concentrating solar thermal system. Flat Plate Solar Collector is one of the known devices developed for harnessing solar energy and converting it to heat, particularly for applications requiring energy delivery at moderate temperature of up to 100^0C (Sukhatme and Nayak, 2008). A flat-plate solar collector consists of two main parts - a flat plate absorbing the heat and tubes or passages of the fluids. The plate absorbs most of the heat and transfer to the fluid flowing in passages or tubes (Ekadewi *et al*, 2009). System optimization is required for utmost performance of the Flat plate collector. Efficiency according depends on the temperature of the plate, ambient temperature, solar insolation, top loss coefficient, emissivity of plate, transmittance of cover sheet, number of glass cover (Sekhar *et al*, 2009). Study has also show that with constant collector area and the distance between tubes, the collector efficiency increases with increasing collector aspect ratio (i.e., either increasing tube length or decreasing number of glass cover, *n*) as well as with decreasing the inlet temperature for air or water flowing through the tubes(Ho-Mingyeh *et al*, 1999). This paper present study on the effect of tubular spacing on the performance of a flat plate solar collector and is aimed at providing useful information toward system optimization for better performance. Aside from providing heat energy for domestic and commercial sector, the use of flat plate collector coupled with low temperature differential Stirling engine for electricity generation is a promising solution to electricity problem especially in rural areas. This will help militate against the problem of climate change and deforestation/desert encroachments especially in rural areas where there is still total dependence on wood for energy supply.

2. Materials and method

2.1 Experimental Set-up

Two identical Flat Plate Solar Collectors were constructed with average tubular spacing of 11cm and 20 cm in each. Average of 11 cm spacing between adjacent lines yielded 15 turns while 20cm average line spacing yielded 9 turns of tubing per Flat plate. The assembly is made of 24SWG gauge copper tube of 0.0064m diameter. The effective area of absorber plate assembly is approximately 1.1 m^2. The whole assembly is enclosed inside a rectangular wooden frame with glass cover of transmittance of over 90% and refractive index of approximately 1.5. Styrofoam was used to insulate the sides and bottom of the absorber plate to minimize heat loss by conduction. Holes were drilled at suitable locations in the header tube to insert thermometer to measure the inlet and outlet temperatures of flowing water. The header tube was connected to a 10 liter capacity storage container. The whole assembly was inclined at 21^0 angles to the horizontal and is facing south.

Experimental setup for the above said task is as shown in figure 1. The water from the storage container enters through the inlet header to the collector and gets heated in the riser coiled tubes of the flat plate collector. The dynamics of the water is due to decreasing water density as the absorber plate gets heated and conduct the heat to the water. The lighter density water then moves up the tube and enters from the top of the water container. Higher density water from the bottom of the container then flows down and enters the lower part of the flat plate collector and gets heated to repeat the cycle.

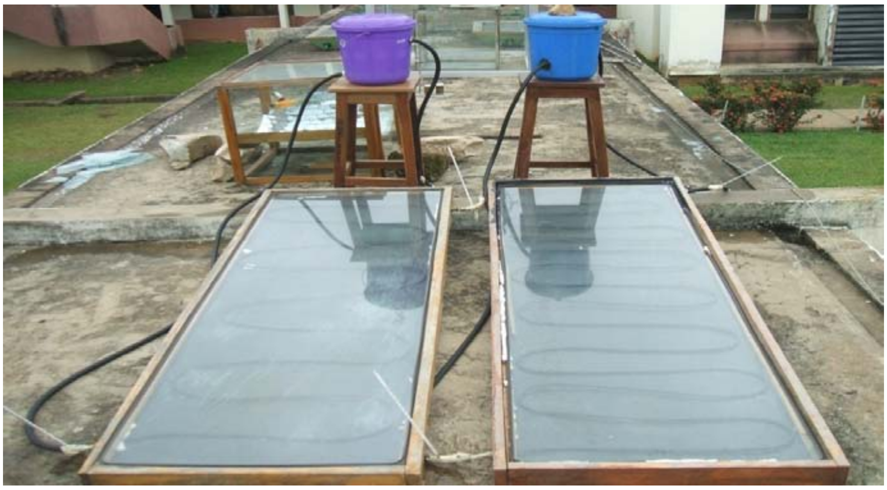

Figure 1: Experimental Set-up of two identical Flat-plate Collectors

2.2 Test Procedure

Inlet and outlet temperatures of the water in each Flat Plate Collector was measured every 30minutes for 5 days and tabulated. The experiment was carried out during raining season between 19th and 23rd July 2011 when the atmospheric condition was characterized with frequent cloud movement cover and rain. Graph of the Variation of the Inlet/ Outlet and Ambient Temperatures against Time for the Flat Plate absorbers A and B for the five days of study are presented in figure 2. Collector efficiency was also determined for both setups. Test result of five days is presented and discussed in the next section.

3. Result and discussion

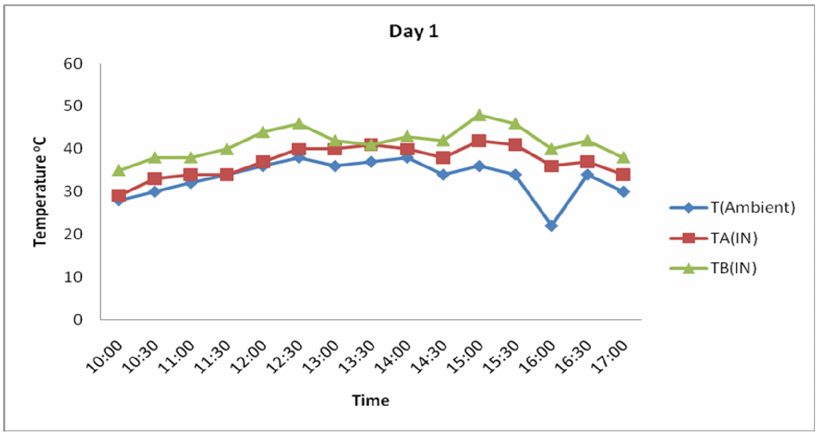

Figure 2a: Variation of inlet and ambient temperture with time of the day for flat-plate collector A and B

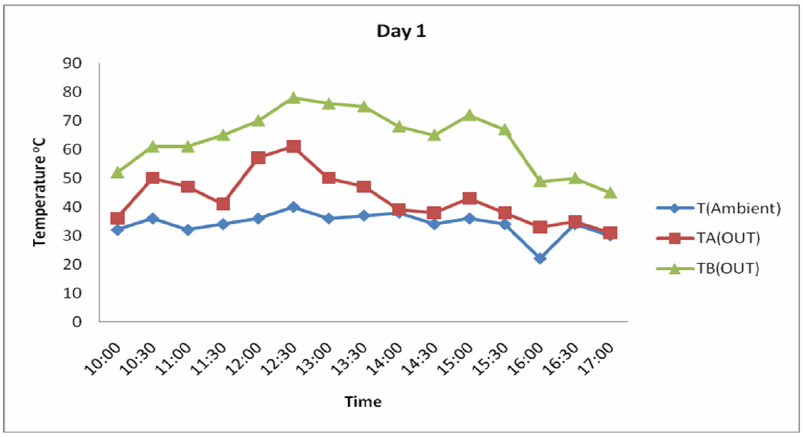

Figure 2b: Variation of outlet and ambient temperture with time of the day for flat-plate collector A and B

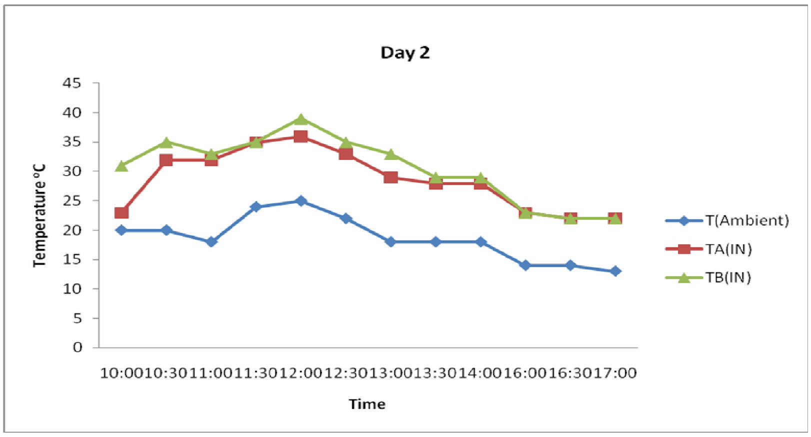

Figure 3a: Variation of inlet and ambient temperture with time of the day for flat-plate collector A and B

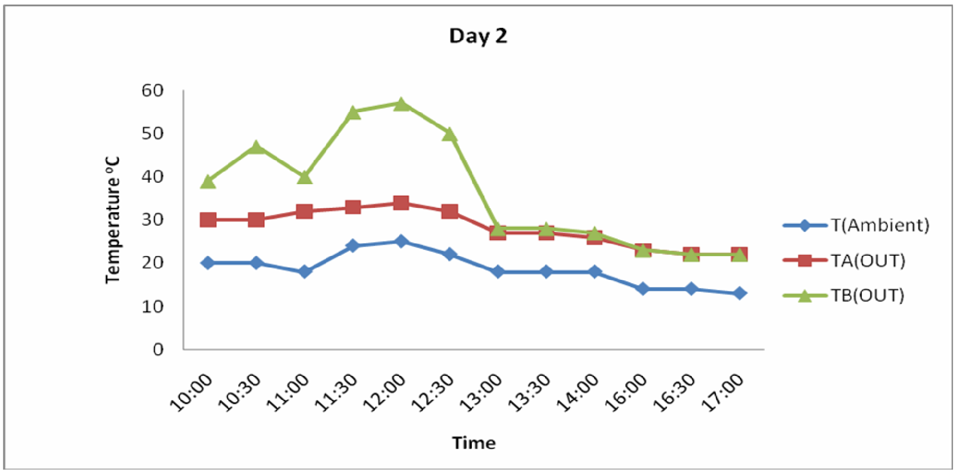

Figure 3b: Variation of inlet and ambient temperture with time of the day for flat-plate collector A and B

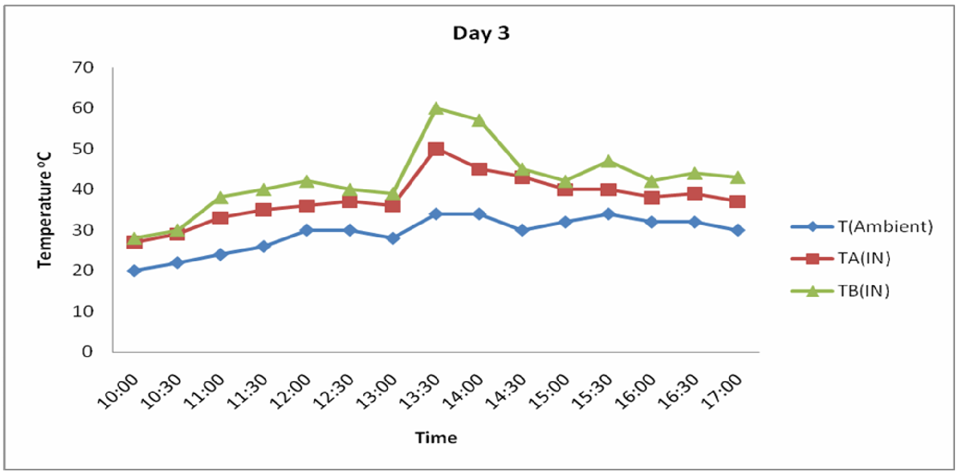

Figure 4a: Variation of inlet and ambient temperture with time of the day for flat-plate collector A and B

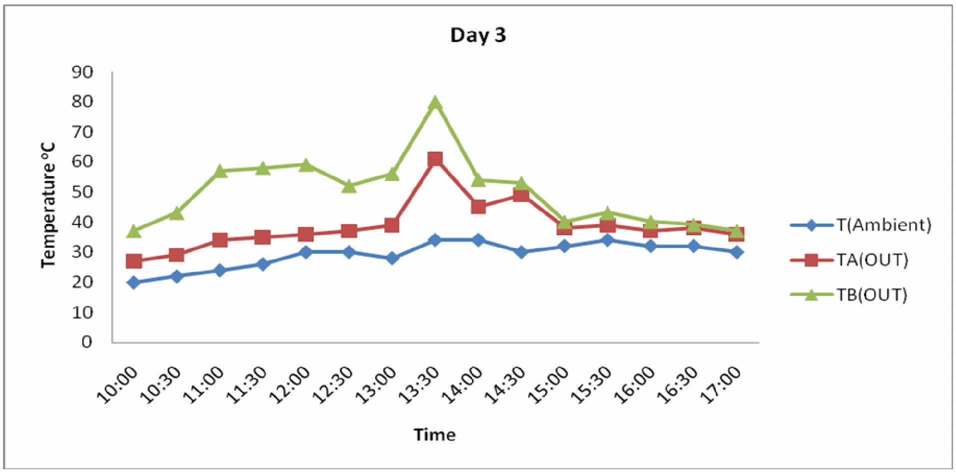

Figure 4b: Variation of outlet and ambient temperture with time of the day for flat-plate collector A and B

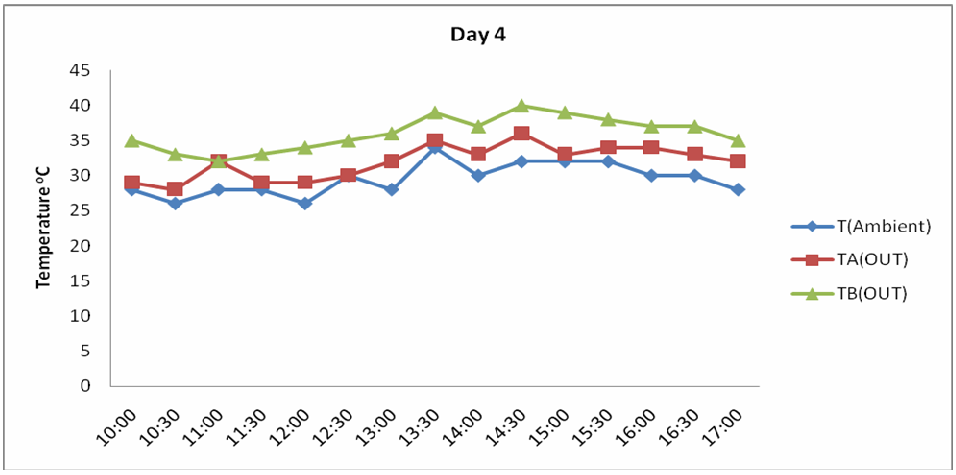

Figure 5a: Variation of outlet and ambient temperture with time of the day for flat-plate collector A and B

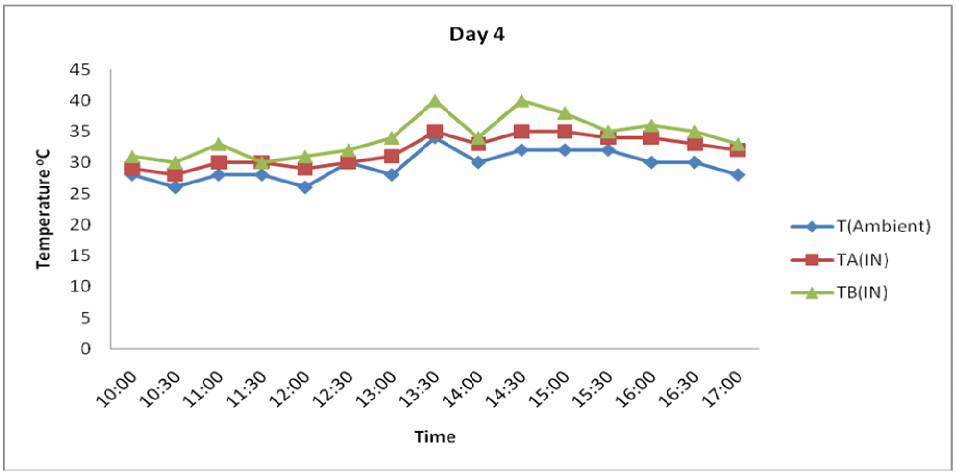

Figure 5b: Variation of inlet and ambient temperture with time of the day for flat-plate collector A and B

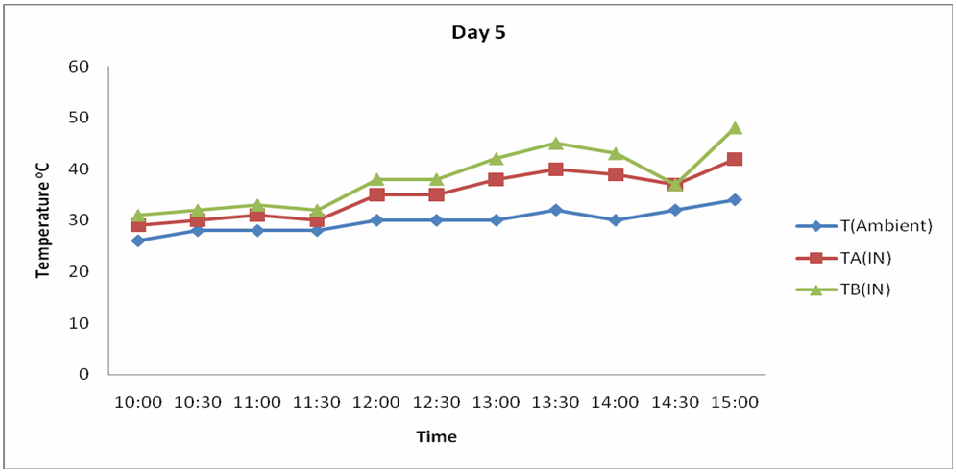

Figure 6a: Variation of inlet and ambient temperture with time of the day for flat-plate collector A and B

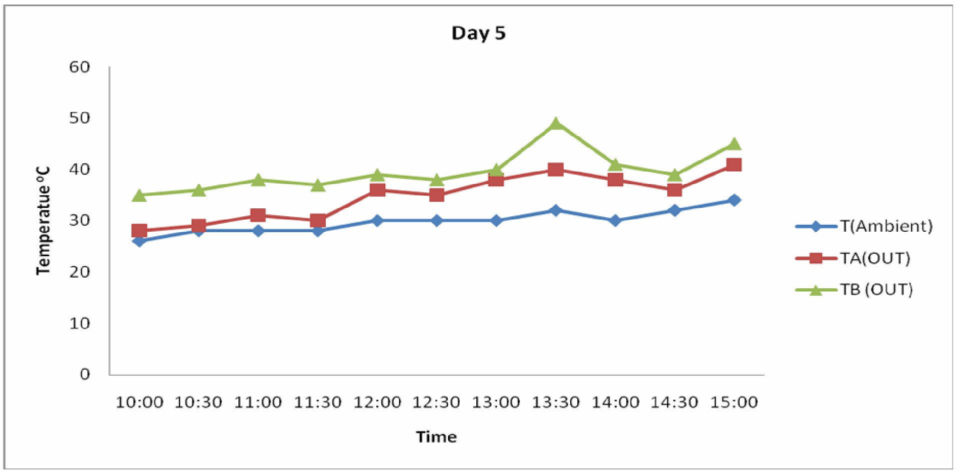

Figure 6b: Variation of outlet and ambient temperture with time of the day for flat-plate collector A and B

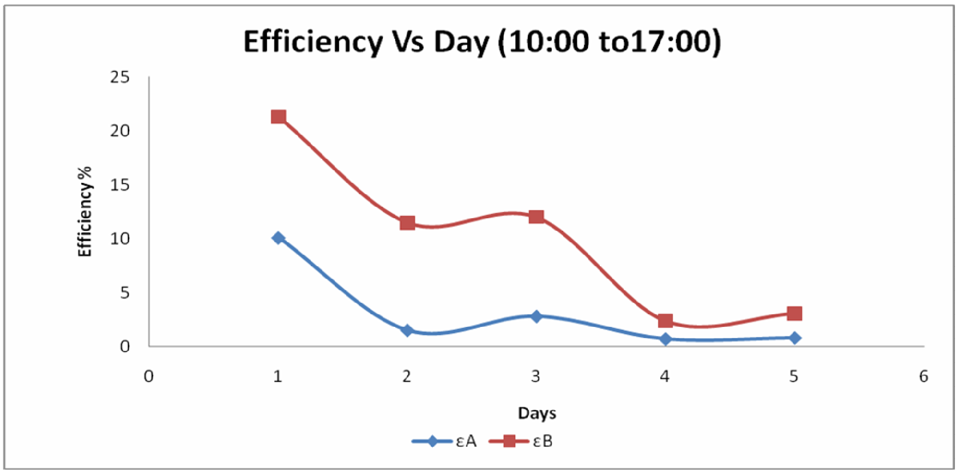

Figure 7: Daily variation of Collector Efficiency with Days for Flat-plate A and B

The daily average solar insolation for 5 days of experimental set-up in the month of July was estimated to be 3231Whr/m^2/day based on data provided by Magda Moner [7] and this value was used in the computation of results. Solar radiation received at Ilorin between 10:00hour and 17:00hour is estimated to be 3392568Wsec/m^2. The Collector surface area of 1.1m^2, received approximately 3731824.8Ws(or Joules) of solar energy between 10:00 hour and 17:00 hour on the average. The energy output of the collector Q = mcΔT, was estimated using daily average temperature increase ΔT above ambient temperature for five days. The collector efficiency was calculated using the ratio of energy output to energy input.

The variation of inlet, outlet and ambient temperatures against time of the day for Collectors A and B are shown in figures 2,3,4,5 and 6. The figures shows that temperature increases gradually with time in both Collector A and Collector B from 10:00 hour and gets to the maximum around 14:00 hour then it starts decreasing gradually within the 5 days of observation. It was observed that the average temperature increased above ambient temperature is higher for Collector B than Collector A which has shorter tubular spacing. The difference is higher within the optimum operating hour of 11:00 hour and 14:00 hour. Lower ambient temperatures recorded on days 2, 3, 4 and 5 due to frequent cloud cover and rain resulted into lower efficiency obtained for those days when compare to day 1. This observation further confirms the effect of ambient temperature on collector efficiency as presented by Sekhar *et al* (2009).

Figure 7 shows the daily variation of Collector efficiency for the five days. The efficiency of Collector B was found to be significantly higher than that of Collector A for the five days of the experiment. Efficiency of 10% and 21% was obtained for collectors A and B respectively on day 1 while the value dropped to almost half on day 2 and to less than 5% on days 3, 4 and 5 for both collectors. The efficiency of collector B with average spacing of 20 cm between adjacent tubes was about twice the efficiency of collector A with average spacing of 11cm between adjacent tubes. This observation shows that distance between adjacent tubes has a significant effect on the Collector efficiency. When the spacing is about twice between similar collectors, the efficiency was also about twice.

4. Conclusion

Experimental analysis was performed on two identical flat plate Collectors with different tube spacing. Collector B with wider spacing performed better than Collector A with a difference of 11% efficiency. Therefore, it can be inferred that tube spacing has a significant effect on the Collector efficiency.

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