

## ***Enhancement of Heat Transfer in Solar Flat Plate Collector using Wind Shield – an Experimental Study***

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### **Abstract**

*The utilization of solar energy will be more relevant for developing countries whose energy requirements are increasing rapidly as a result of large-scale industrialization covers a large area of multiple applications. Installations of Solar Flat plate collector for tapping solar energy to some useful energy are the most frequently used in various solar thermal systems. From the present work the performances of the system both with and without wind shield were evaluated and compared. In a present solar system by adding the wooden windshields along perimeter of the flat plate solar energy collector creating the heat convective film that minimize the top loss coefficient by increasing the energy gained results enhancement in the heat flow rate from absorber plate to riser tubes. Hence, the efficiency of proposed system is more than the conventional system.*

**Keywords:** *Flat-plate solar collector, Heat transfer, Absorber plate, Thermal performance, Collector efficiency, Heat loss coefficient, Wind shield, Natural circulation*

### **INTRODUCTION**

Improvements in quality of life and rapid industrialization in many countries are increasing energy demand significantly, and the potential future gap between energy supply and demand is predicted to be large

[1,2]. As world-wide energy reserves have continued to diminish, the incentive to develop solar energy systems has increased. A solar collector helps to convert energy of solar radiation into thermal energy utilize in a large area of multiple applications [3]. In a

flat plate solar collector, the ability to absorb more energy is most important in its overall thermal performance is strongly influenced by the energy exchange, which takes place between the external environment and the uppermost surface of the collector.

The collector efficiency is an important parameter to measure the performance of the flat plate collector, defined as the ratio of the useful energy gain to the incident solar energy over a particular time period. The useful energy in term of efficiency depends strongly on the energy loss from the top surface of the collector both due to convective and radiative heat transfer processes. [3,4]. Thus, the wind can play a significant role in determining magnitude of  $U_t$  that induced convective heat transfer from the top surface of a flat plate collector & therefore overall efficiency of the collector [5].

Top heat loss coefficient  $U_t$  is a function of various parameters  $T_p$ ,  $T_a$ ,  $h_{wind}$ . Heat losses observed minimum at morning hours and maximum with  $T_p$ , and  $h_{wind}$  [6]. Top heat loss coefficient is decreases by using windshield enhancing the heat flow rate [3].  
Gomes Dalmo G. and Nide G. C. R. Fico,

Jr. observed that to restrict the natural circulation of wind flow by erecting the partition along the four sides of the collector. Author suggested the optimum height for the windshield from 140 mm to 220 mm for maximum heat loss reduction [7].

The main objective of the present work is to propose an alternative way for minimizing the energy loss through the addition of a windshield along the collector's perimeter. Addition of the windshields along the flat solar energy collector perimeter in order to modify the air flow pattern over it. The presence of this shield creates a region of re-circulating separated flow on top of the collector. The idea behind the windshield concept is to create a re-circulating zone behind it and thus minimize the convection film coefficient.

## EXPERIMENTAL WORK

The flat plate solar energy collectors facing due South, with two conditions in the experimental set-up, with windshield and without windshield as shown in figures 1 and 2 having copper absorber plate of 0.3 mm thick. Two thermocouples are mounted on the absorber plates for measuring the temperature of the plate from T1 and T2 of

the collector for without windshield and with windshield. The copper tubes (8 tubes of outside diameter 12.7 mm and 0.56 mm thick) are bonded by continuous TIG welding on the bottom side of the absorber plate.

The spacing between the adjacent tubes is 96 mm. All tubes are welded to the header

and footer pipe of copper material having outside diameter 25.4 mm and 0.71 mm thick. The flat plate solar energy collectors facing due south is mounted on separate M. S. stands maintaining the collector angle at 45° with the horizontal as shown in the figure 1 and 2.



**Fig 1: Liquid Flat Plate Collector**



**Fig 2: Liquid Flat Plate Collector**

**with Windshield**



**Fig. 3.A: Frame of Windshield**

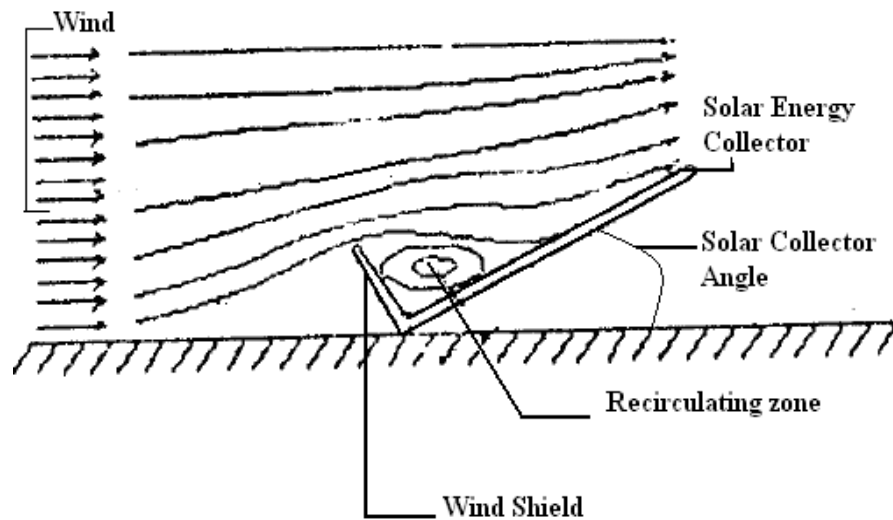


**Fig. 3.B: Frame of Windshield with Recirculation zone**

## EXPERIMENTATION

The natural circulation solar liquid flat plate collector experimentation was conducted between 23rd April to 30th in the month of April, 2016 at the intervals of one hour from 12 Noon to 5 P. M. The incident solar radiation intensity was measured using pyranometer. The insulated water tanks, headers and footers pipes and riser tubes are completely filled with liquid before starting the experimentation. The temperature of the absorber plate was measured by two different thermocouples mounted on the absorber plate. The liquid inlet (Tfi) and outlet (Tfo) temperatures of the collector

was measured by two thermometer immersed in inlet and outlet pipe. Glass plate temperatures are measured at six locations. Ambient temperature and glass plate temperatures are recorded by the multilevel temperature indicator instrument.

## RESULT AND DISCUSSION

Performance test and analysis to find out the effect of performance curve of the collector as per the Indian standard procedure for experimentation of solar flat plate collectors and reporting the performance was proposed by Bureau of Indian Standards (IS : 12933 : 2003, Part 1, 2, 3, 5, Second Revision). The standard sets limits for environmental conditions, specifies test procedures and

calls for the thermal performance to be reported in terms of efficiency of the collector.

Solar radiation energy received by the collector was low in the morning and late afternoon due to the low solar radiation, but it is high around mid-day during high. Therefore, the maximum temperature occurred after the peak solar radiation. Experimentation was conducted at the intervals of one hour from 12 A.M. to 5 P.

M. Wind shield caused creates a recirculation zone on top surface of the solar

collector as shown in figure 3. B, and thus observed to decrease the heat loss coefficient from top of the collector UL.

Therefore, the efficiency of the liquid flat plate solar collector with windshield is found to be about 44.27 % at 12 Noon which is more than without windshield collector which is found to be about 38.02 % for water, and comparative observation is shown in figure 4 between with and without wind shield.

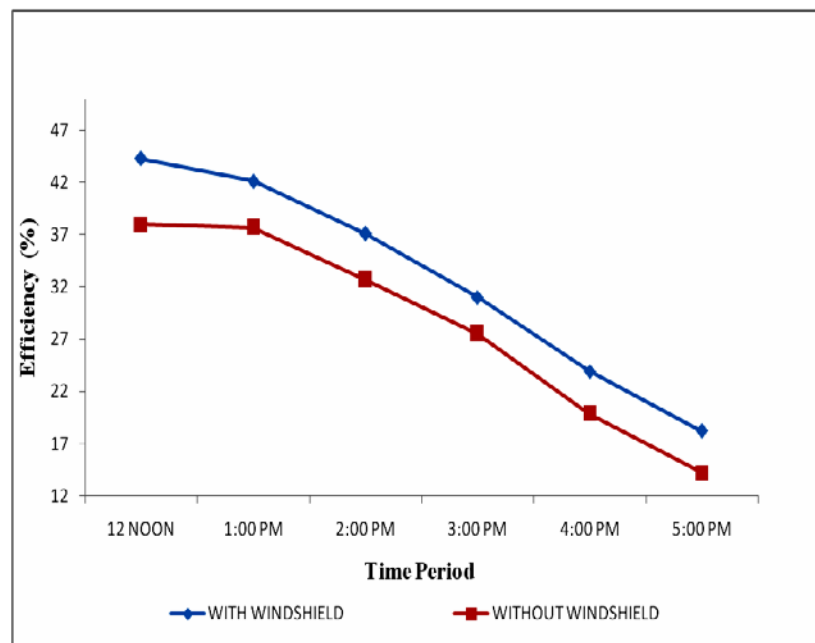


**Fig. 4: Variation of Collector Efficiency with Day Time period**

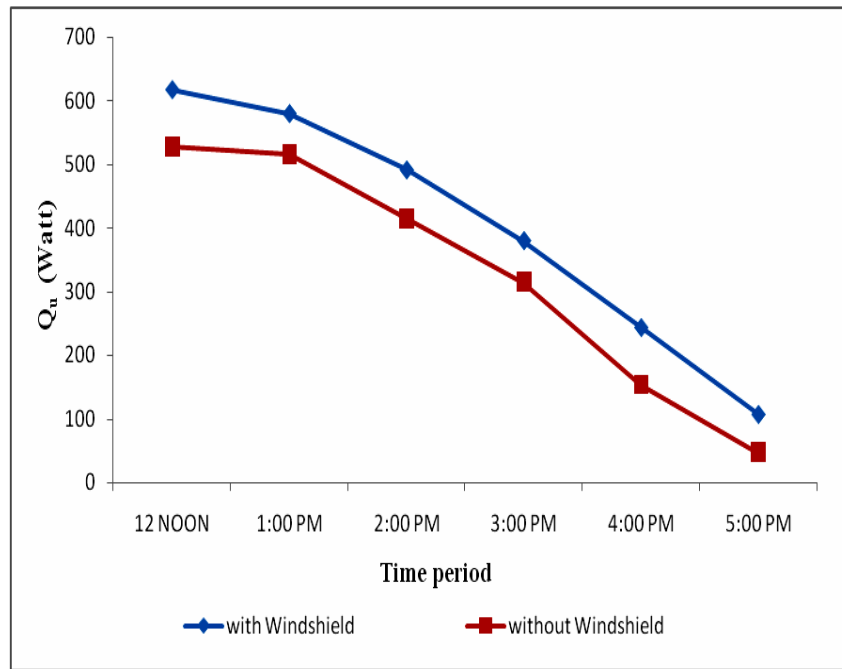


**Fig. 5: Variation of Heat Gain with Day Time period**

Solar radiation energy received by the collector was high around mid-day. Therefore, the maximum temperature was recorded at 12 Noon result of high solar radiation and decreases temperature for late afternoon due to the low solar radiation. Wind shield caused a separation of the boundary layer from the surface creates a recirculation zone on top surface of the solar collector and thus observed to decrease the heat loss coefficient from top of the collector UL and increases heat gained  $Q_u$ . The total heat gained by with windshield is about 617.53 W for water, and by without

windshield, is about 528.59 W for water, and comparative observation is shown in figure 5 between with and without wind shield.

The heat loss coefficient from top of the collector UL decreases and thus decreased in top heat loss  $Q_t$ , 335.02 w for water using windshield and 416.98 w in without windshield, is a effect of windshield caused a separation of the boundary layer from the surface creates a recirculation zone on top surface of the solar collector and result shown in figure 6.

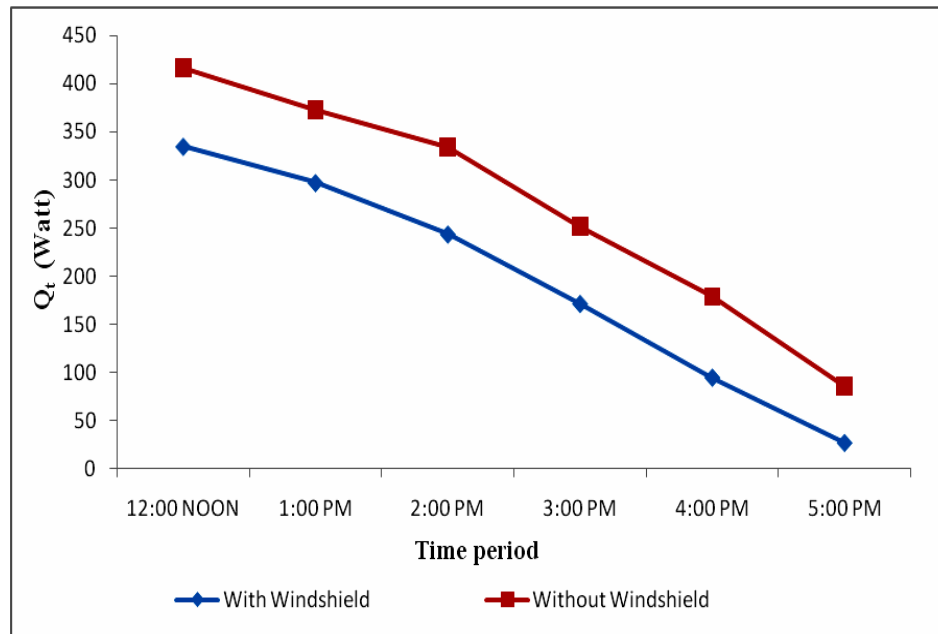


**Fig. 6: Variation of Heat Loss from Top of the Collector with Day Time period**

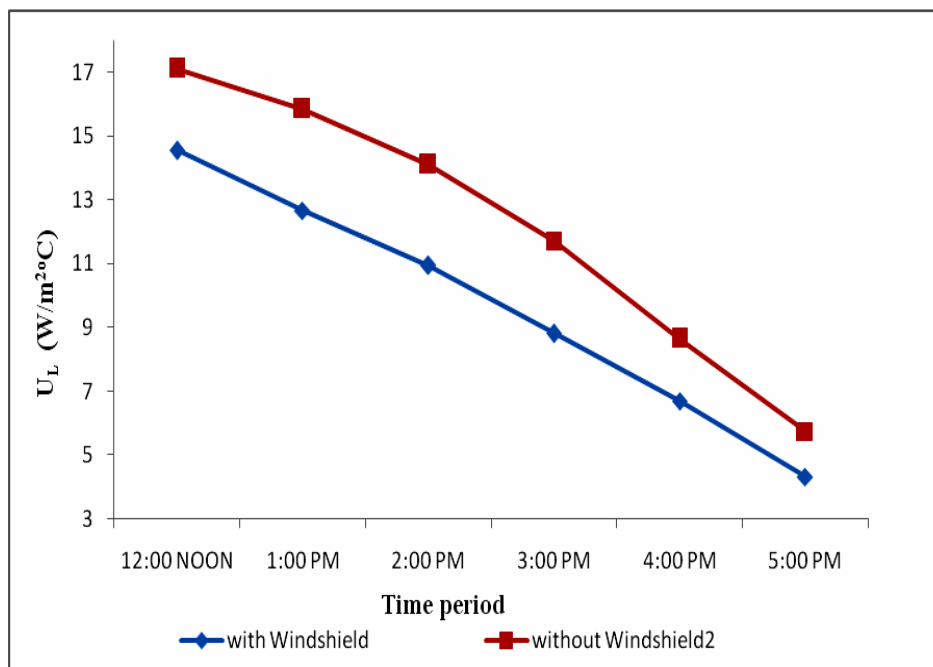


**Fig. 7: Variation of Heat Loss Coefficient from Top of the Collector with Day Time period**

The heat loss coefficient from top of the collector  $U_L$  decreases is a effect of windshield caused a separation of the boundary layer from the surface creates a recirculation zone on top surface of the solar collector and result 14.55 W/m<sup>2</sup>oC for water using windshield and 17.11 W/m<sup>2</sup>oC in without windshield, shown in figure 7.

Result of variation of Heat Loss Coefficient from Top of the Collector as a function of Temperature Difference between Collector Outlet Water Temperature an Air Temperature,  $(T_{fo} - T_a)$  oC as shown in figure 8.

In this experiment, effect of wind velocity was studied on top loss coefficient by

varying the velocity from 0 to 5 m/s. The pedestal fans were used to get desired velocities. Observations were taken for heat inputs at fixed,  $(T_p - T_a)$  oC, after attaining the steady state condition all temperature and power inputs were recorded as shown in figure 9. Result shows in without using windshield as wind velocity increase,  $U_L$  increases due to increase in convection losses at fixed,  $(T_p - T_a)$  oC and wind shield caused a separation of the boundary layer from the surface creates a recirculation zone on top surface of the solar collector and thus observed to decrease the heat loss coefficient from top of the collector  $U_L$  and increases heat gained  $Q_u$ .

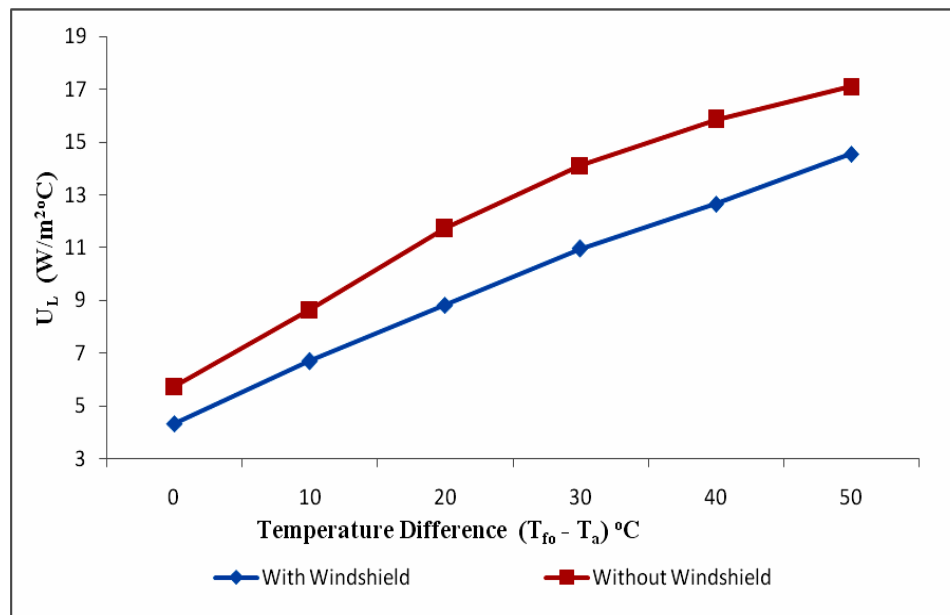


**Fig. 8: Variation of  $U_L$  as a function of  $(T_{fo} - T_a)$  oC**

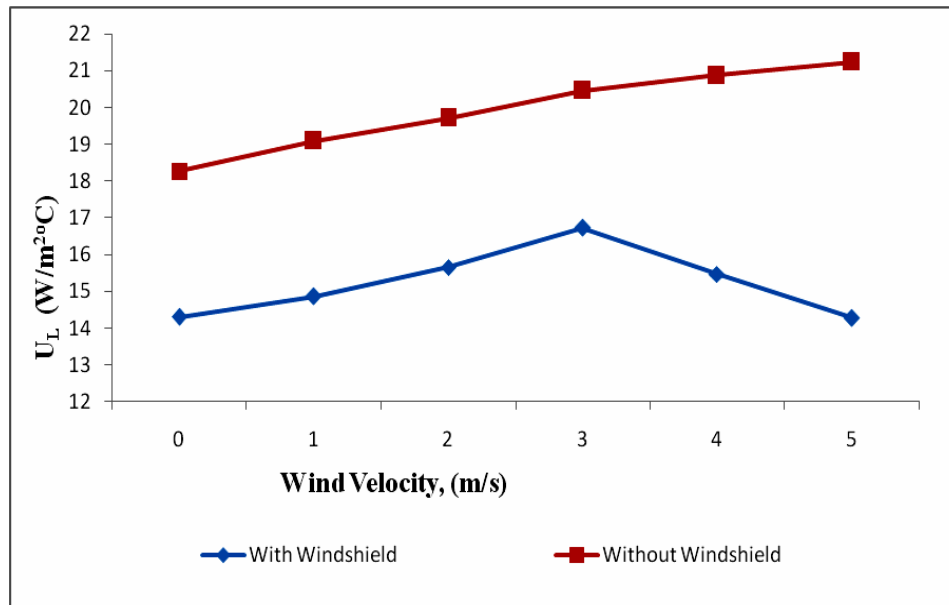


**Fig. 9: Variation of  $U_L$  as a function of  $V_w$ , (m/s), at fixed  $(T_p - T_a)$  °C.**

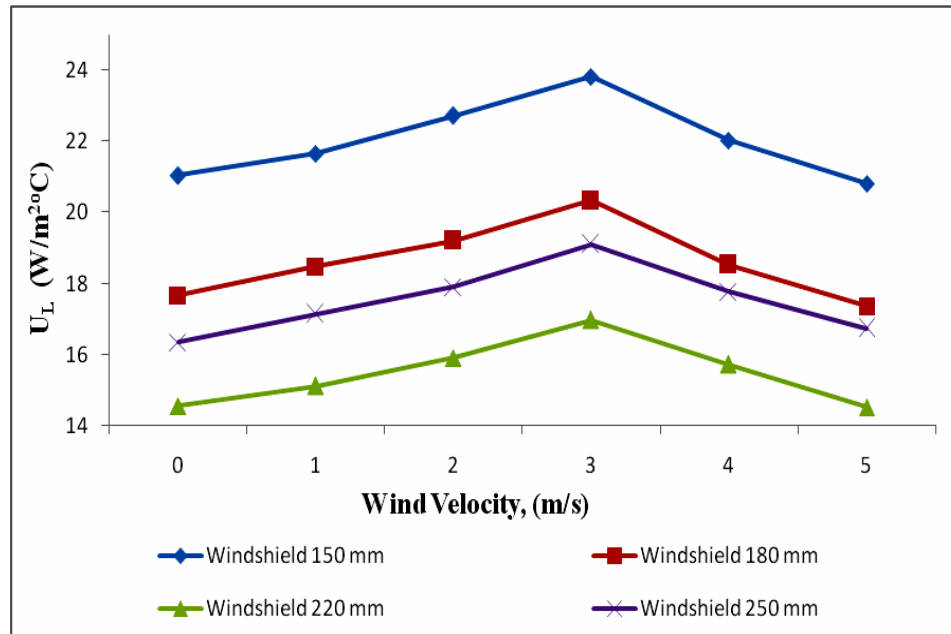


**Fig. 10: Variation of Heat Loss Coefficient from Top of the Collector for different windshield size as a function of Average Wind.**

The value of UL increases linearly with wind velocity for each wind shield height as shown in figure 10. A change in wind shield height from 150 mm to 250 mm produces increase in UL, but UL decreases as the wind shield height is increased further from 220 to 250 mm. The study of variations in the heat loss coefficient from top of the Collector UL due to wind shields of different heights are caused by variations in the airflow patterns.

Airflow patterns creates a separation of the boundary layer from the surface caused by the wind shield there was a subsequent reattachment of the boundary layer downstream. There is a recirculation zone where the lower part of the boundary layer is reattached, found that the heat loss coefficient from top of the collector UL decreases and heat gained  $Q_u$  increases in the neighborhood of the attachment point.

**See Figure 10.**

## CONCLUSION

Maximum solar radiation energy received by the collector around mid-day. Therefore, the maximum temperature occurred after the peak solar radiation. Wind shield caused creates a recirculation zone on top surface of the solar collector, and thus observed to

decrease the heat loss coefficient from top of the collector UL. Therefore, the efficiency of the liquid flat plate solar collector with windshield is found to be about 44.27 % at 12 Noon which is more than without windshield collector which is found to be about 38.02 % for water.

Creation of a recirculation zone on top surface of the solar collector using windshield, decreases the heat loss coefficient from top of the collector UL and increases heat gained  $Q_u$ , the total heat gained by with windshield is about 617.53 W for water, and by without windshield, is about 528.59 W for water, and thus, decreased in top heat loss  $Q_t$ , 335.02 w for water using windshield and 416.98 w in without windshield.

The value of UL increases linearly with wind velocity at fixed,  $(T_p - T_a)$  °C for each wind shield height. A change in wind shield height from 150 mm to 250 mm produces increase in UL, but UL decreases as the wind shield height is increased further from 220 to 250 mm. The study of variations in the heat loss coefficient from top of the Collector UL due to wind shields of different heights are caused by variations in the airflow patterns. Airflow patterns creates a separation of the boundary layer from the

surface caused by the wind shield there was a subsequent reattachment of the boundary layer downstream. There is a recirculation zone where the lower part of the boundary layer is reattached, found that the heat loss coefficient from top of the collector UL decreases and heat gained  $Q_u$  increases in the neighborhood of the attachment point.

## NOMENCLATURE

|           |                                                                                      |
|-----------|--------------------------------------------------------------------------------------|
| Aa        | collector aperture area, m <sup>2</sup>                                              |
| Ac        | collector gross area, m <sup>2</sup>                                                 |
| Ap        | absorber plate area, m <sup>2</sup>                                                  |
| Cp        | specific heat, kJ/kg-k                                                               |
| Di        | inner diameter of tube, m                                                            |
| Do        | outer diameter of tube, m                                                            |
| f         | friction factor                                                                      |
| F'        | collector efficiency factor                                                          |
| FR factor | collector heat – removal factor                                                      |
| h         | heat transfer coefficient, W/m <sup>2</sup> - k                                      |
| hp-c      | heat transfer coefficient between absorber tube and glass cover, W/m <sup>2</sup> -k |
| hw        | wind heat transfer coefficient, W/m <sup>2</sup> -k                                  |
| Ib        | beam radiation, W/m <sup>2</sup>                                                     |
| Id        | diffused radiation, W/m <sup>2</sup>                                                 |

|            |                                                                                              |
|------------|----------------------------------------------------------------------------------------------|
| I'sc       | extra- terrestrial flux on any day of the year, W/m <sup>2</sup>                             |
| $\kappa$   | thermal conductivity, W/m-k                                                                  |
| LAT        | local apparent time, h                                                                       |
| mf         | mass flow rate, kg/m <sup>3</sup>                                                            |
| M          | number of transparent covers                                                                 |
| n          | number of days of the year.                                                                  |
| Qu         | total heat gain, W                                                                           |
| Ql         | top heat loss, W                                                                             |
| Qs         | side heat loss, W                                                                            |
| Qb         | bottom heat loss, W                                                                          |
| UL         | top heat loss coefficient, W/m <sup>2</sup> -k                                               |
| $\alpha$   | absorptivity of absorber surface for solar radiation; thermal diffusivity, m <sup>2</sup> /s |
| $\beta$    | slop or tilt angle                                                                           |
| $\delta_b$ | thickness of bottom insulation, m                                                            |
| $\delta_s$ | thickness of side insulation, m                                                              |
| $\phi$     | latitude angle                                                                               |
| $\theta$   | incidence angle                                                                              |
| $\omega_s$ | hour angle corresponding to Sunrise and Sunset                                               |
| $\rho$     | reflectivity; density, kg/m <sup>3</sup>                                                     |
| $\mu$      | dynamic viscosity, N-s/m <sup>2</sup>                                                        |

|                       |                                                           |
|-----------------------|-----------------------------------------------------------|
| $\nu$                 | kinematic viscosity, m <sup>2</sup> /s                    |
| $\rho_b$              | reflectivity of beam radiation                            |
| $\rho_d$<br>radiation | reflectivity of diffused radiation                        |
| $\tau$                | transmissivity of cover plate                             |
| $(\tau\alpha)_b$      | transmissivity-absorptivity product of beam radiation     |
| $(\tau\alpha)_d$      | transmissivity-absorptivity product of diffused radiation |
| $V_w$                 | wind velocity, m/s                                        |
| $\eta$                | collector efficiency                                      |

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