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Experimental investigation on the forced type evacuated tube solar collectors with and without absorber plate.

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Abstract: The objectives of the tentative were to examine the thermal concert on the force type evacuated tube solar collector (ETSC) with and without absorber plate (AP) by testing various air flow rates. The conduct test consists of four main parts such as evacuated tubes (ET), manifolds, blower, and absorber plate (AP). ETSC based heating air system has 30 numbers of modules having 3.6 m^2 apparatus area. The channel of manifold consists of two parts are Outer and inner circular tube. Air is passing through inside tube; the processed to heat, then by pressure difference the air flow through the outside manifold. The innovative proposed system i.e. ETSC to reduce the auxiliary power (Blower) requirement, since the air flow friction through ETSC is very high in magnitude, it draws high blower power requirement. The AP is made up of aluminium block coated sheet. The explicit effectiveness is increased by enhanced AP which is inserted at the bottom of the ET. Comparing with ETSC without AP, high outlet temperature and better proficiency is seen with the AP.

Keywords: ETSC, absorber plate, without absorber plate, channel manifold, blower

INTRODUCTION

Presently, India spends around 100 million tonnes of fossil fuels (FF) every year for various uses, where 40% is solely consumed by the industries. Approximately, 40-50% nearly 15 MT of fuel oil per year is used for heating appliance below 250°C catering to a huge annual energy requirement of approximately 150GW/hr in India. Solar energy (SE) which is abundantly available can be harnessed effectively to provide the heating requirements of various industries. One such important task is the use of heated air for drying application in automobiles, plastic packing, printing, food and beverage, drags and chemical industries. Presently available commercial technologies for air heating employ flat plate solar collectors (FPSC) where the maximum attained temperature is limited to 80°C and heat losses are higher. One of its best utilization of the SE is ETSC.The literature review is very useful for designing and developing SETAC. Umayal Sundari et al intended and fabricate the ETSC and its attainment was analyzed for drying ginger under the meteorological condition of Thanjavur District, Tamil Nadu. They concluded that when compared to natural sun drying, the

time of drying ginger has been reduced from 13 hrs to 6 hrs [1].

Lamnatou et.al refined a novel solar dryer(SD) with ETSC integrated with heat pipe and proved that the warm outlet air of the collector attains the temperature levels suitable for drying of vegetable products without the head of preheating. Thus, the collector as the source of heat made of the novel development, convective, indirect SD. The fact is that the articles show a few studies about these types of collectors in conjunction with SD relevance. They depicted that, for drying larger quantities of the products than those considered with the high collector effectiveness [2]. Pin-yang Wang et al fact-finded 10 linked ETSC connecting with each concentrator parabolic (CP) in a circular shape. In all ET was installed with a copper tube type U-shaped heat exchanger .The air in a tube gets heated gradually and passing through an exchange. The model analysis to calculate temperature of exchanger outer air resourcefulness and it results showed that the heated air temperature exceeding more than 200°C [3]. Kirk and Chakravertty inspect to find out the empirical relationship for overall heat loss coefficient of ETSC with the combination of series and parallel type. They made many analyses which are carried out at different variables and values. Finally, they bring down curtain that the adaptability is decreased in series type and constant for Parallel system [4]. Kumar et al expressed the thermal properties of a solar ETSC based pressure cooker [5]. Morrison et al. reviewed a number of heat transfer method that influenced into the ET. The heat transfer rate, low manufacturing cost is high where water is used as a medium [6]. Shah and Furbo performed tests on the vertical ETSC. The tubular absorber is made up the collector which absorbed solar radiations in all the direction. The thermal efficiency (TE) of the ETSC when compared with the FPSC yields an optimum tilt and orientation [7]. Morrison et al refined analysis of the fluid flow heat transfer in a one ended glass tube [8]. Kim et al research of the ETSC by tentative and numerical methods, different four type absorption patterns were taken to find the absorption medium. Among them, absorber by tube solar collector is considered to be the best. [9]. Shah et al exploration the ETSC inside the glass structure for operating different conditions by means of computational fluid dynamics. The design of the collector based on the ET connected in manifold channel either horizontal or vertical. The findings showed that only small variation in the capabilities by operating different conditions [10]. Budihardjo et al exploration ETSC estimates the FPSC. It showed that consummate of evacuated tube of 30- pipes had lower than 2-panel array plate, working medium used as water [11].

Ma et al. analysis to find the heat loss coefficient and productivity factor for the individual glass ETSC and also studied the influence the layer of air between copper tube and fin heat absorption capacity. The results stated that ETSC-glass tube with heat loss coefficient, the difference between the absorber coating surface and ambient air temperature was nonlinear [12]. Yadav et al inferred that the effectiveness of one ended ETSC at parallel and counter flow rate is based on the position of the blower. They said that the counter flow rate had more efficient and higher flow rate when compared to parallel flow rate

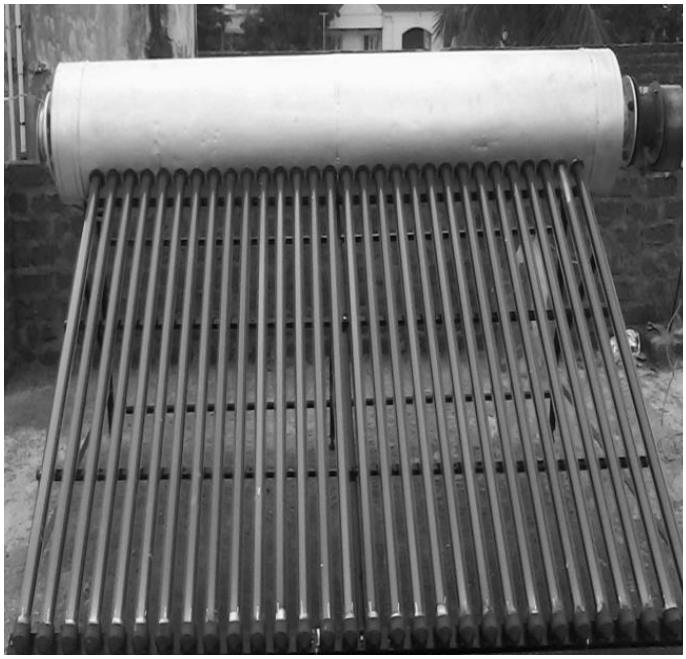
[13]. Hayek et al. practically inspected water-in-glass ETSC and heat pipe designs ETSC based on overall enforcement. Heated pipe SC had 15-20% higher efficiency than that of water-in-glass ETSC [14]. Lamnatou et al. trial surveyed the ETSC dryer for drying apples, carrots and apricots. This reveal was based on the generation of entropy is minimum for the mass flow rate, along with maximum collector and liquid exit temperature. From the results found that without preheating, the agricultural products are dried [15]. The designed and fabricated ETSC dryer for drying of large cardamom at Agricultural engineering, Post Harvest Technology ,University of central Agricultural, Ranipool (27° 20′ N, 88° 40′ E), Gangtok, Sikkim. The approval absorbed that solar dryer was obtained more temperature of 55.7% over the ambient temperature. The completions show that the net saving 50% of drying time for comparison to the open SD [16]. Balaet al searches the solar tunnel dryer pursuance for drying mushrooms. The dryer was made up of UV stabilized plastic covered FPSC and drying tunnel unit consists of 3 fans with 40 Watts solar module [17]. Zhijian Liu et al enforcement the heat transfer coefficient and heat loss coefficient for water-glass ET based on 915 measured samples of water-in-glass ETSC water heaters. The results analyzed by the personal computer and Android platforms [18]. Saravanakumar et al integrated with the different sensible heat storage material and tested the execution of SC under meteorological conditions for natural and forced convection (FC) [19]. Umayal Sundaria et al exploration ETSC with assisted solar dryer designed by drying Kinetics of Muscat grapes. The stated that the collector outlet and the chamber temperature varies from 74-130°C and 50-87 °C respectively, while the atmospheric temperature ranges from 29.5-33.2°C and the drier maximum adaptability for musket grapes is found to be 29.92% during the drying period [20]. Rajendra Patil et al inquisition alumina bricks as a TE system used for reduction in drying time and an improvement of the product quality. The reduction in drying time was between 30 - 50 % compared with natural drying thermal storage. Although the initial cost is relatively high, the running cost is low and the payback period is less than two years. From the empirical analysis, it is suggested that for best economy and potency, mass of commodities can be increased to utilize the TE developed [21].Satish Birbal Prajapati et al probe the drying of copra by natural and mode of FC. The analysis stated that without FC drying is more moisture content when compared with FC [22].Avadhesh Yadav et al pragmatic deal in upward direction of flow could not reaches the temperature more than 60°C because of some heat losses occurred where downward flow achieved maximum temperature [23].Gumus et al articulated calculate the content of moisture and drying rate at varying temperatures of 110°C, 120°C and 130°C. The temperature of drying at 110°C was the best in all favorable condition and yielding uniformly dried corn and ogbono [24].Chanchal Loha et al observation based on a FC cabinet dryer to study characteristics for sliced ginger. The study were carried out with different four drying temperatures of air are 45, 50, 55 and 60°C with fixed air velocity at 1.3m/s and also determined the thermal conductivity of ginger at moisture contents [25] .Pranav et al survey the various

kinetics studies, mathematical models and enhancement techniques on the indirect type SD to improve their effectiveness [26]. Pranav et al. exploration indirect forced and directs FC dryer and it showed that solar FC dryer is more suitable than sun drying for producing high quality copra for small holders [27]. Onkar B. Kadam et al inquiry SD by using thermal storage PCMs with different techniques such as infrared radiation, mechanical drying, and direct solar grapes dryer, grapes dryer with natural convection mixed mode type. This agreement showed that convection drying system was better when compared to other system [28]. Ezekoye et al are successfully advanced passive grain SD. Their accomplish test was carried out at different hotness and finally to found out moderate temperature of 67^{o}C [29]. Bala et al progress the channel SD which can be operated by an independent photovoltaic module of electric grid. The module drier must be optimized for efficient operation [30] .Mohan raj el reviews the temperature variations of air at outlet SC and drying of copra. It showed that in an average drying air inlets dryer is 50.4°C and maximum, minimum drying air inlet dryer is 68°C and 43°C [31].

From the above reviews, report was written by the present investigator based on the SD and ETSC. The objective of the assessment is to produce drying air which contains thirty number of ET horizontally connected with vertical circular manifolds and to evaluate the CE of producing hot air by hour base. The setup of the reveal is installed at Kotturpuram, Chennai district in Tamil Nadu, India. North (13°02’ in latitude) and South (80°53’in longitude).

EXPERIMENTAL SETUP

The intent of observation is to find out the TE of ETSC with FD by using with and without AP and to produce hot air. The endorsement setup consists of thirty tubes; Outer, inner diameter and length of the ET are 0.06 m, 0.03 mm and 1.5 m respectively. The surface area of the ETSC is 3.6 m^2. The one end of ET is connected to the circular channel of manifold and other end is supported by frame. The channel of manifold is made up of hollow circular tube with Outer, inner diameter and lengths of 0.40 m, 0.20 m and 3.6 m fold channels. The blower is fixed at the end of the manifold which rotates at constant speed is used for the blow of the air within the evacuated tube at varying air flow rates. The setup is consists of ET, Circular manifold channel, and Blower and AP. The ETSC mainly comprises of double glass –walled long ET in which the outer surface is transparent to absorb solar radiation easily and its inner tube is coated with a selective absorber coating for solar heat collection. In between these tubes aluminium fossil sheets are inserted for absorbing more solar radiation. The tube of evacuated absorbs SE and converting it into heat to use in air heating.



The schematic diagram of the ETSC is shown in Figure 1. In this operation, The atmospheric air enters the inner circular direction aluminium-coated ET, where it gain heat due to increase the solar radiation , and then exits the multi-channel outer circuit exhaust duct.

MEASURING DEVICES

To find out the TE of the ETSC by measuring devices are inlet and outlet air temperatures, solar intensity, velocity and mass flow rate of the air. Resistive temperature device PT100 that exhibit changes in resistance with change in temperature is measured at different point with a resolution of 0.1°C up to temperature range 450°C. It is made up of copper, nickel or nickel-iron metallic elements or alloys. Fluke 59 Max+ Infrared Pyrometer is used for measuring the flow rate of air and make a precise laser technology is used for more accurate and repeatable measurements. AcuRite 613 Indoor Humidity Monitor is easy-to-read display and also it monitored daily temperature and humidity. At the starting of the experiment, the flow rate of air is measured by using Testo 410-1 type air velocity vane anemometer. This measuring range of instrument is 0.4 to 20 m/s its revolution 0.1 m/s and accuracy of air velocity 0.2 m/s + 2% of MV. The operating ranges of temperature from 10°C to 50°C.

THE FORMULA USED

Hematianet al., 2012 and Kurt bash & Durmush 2004 stated that the TE of the ETSC is the ratio useful heat gain by the air to incident solar radiation on the AP.

$$\eta_{collect} = \frac{P_{useful}}{P} \times 100 \text{ in } \% \quad (1)$$

$$P_{useful} = mc_p (T_2 - T_1) \text{ in W} \quad (2)$$

$$P = I_\beta \times A_c \text{ in W} \quad (3)$$

$$m = \rho \, s \, V \text{ in Kg/sec} \quad (4)$$

$$A_c = 2NDL \quad (5)$$

Where P_{useful} is the useful heat gained by the ETSC (W) and P is the solar incident radiation absorbed by absorber plate (W). m is the mass rate of air flow through the collector (Kg/s), C_P is at constant pressure specific heat in (J/Kg°K).T_1 ,T_2 are inlet temperature of inside absorber collector and outlet temperature of collector tray. I_β is the solar intensity Radiation which was measured by solar meter with accuracy ± 10 W/m^2 and resolution 0.1 W/m^2. A_C is the solar collector area and V is the air velocity at outlet of collector tray is measured by a speed meter type within precision of 0.1 m/s. ρ

is the air density in Kg/m^3 and S is drying chamber area in m^2 ,N is the number of tubes ,D is the outer diameter and L is the length of the tube.

RESULT AND DISCUSSION

The objective of the empirical setup was to monitor the average value (AV) of calculation and measuring parameters in ETSC with and without AP. The CSA is 3.6 m^2. The research were carried out during the month of March 2nd week of 2017 that is, summer-like conditions, taken the readings for 7days and which during the period the temperature varied from 30.2°C to 39.9°C. The progress was carried out from 8:00 am to 6:00 pm for 7 days.

Two cases have been taken for discussing the results.

- The AV of calculation and measuring parameters in ETSC without AP.
- The AV of calculation and measuring parameters in ETSC with AP.

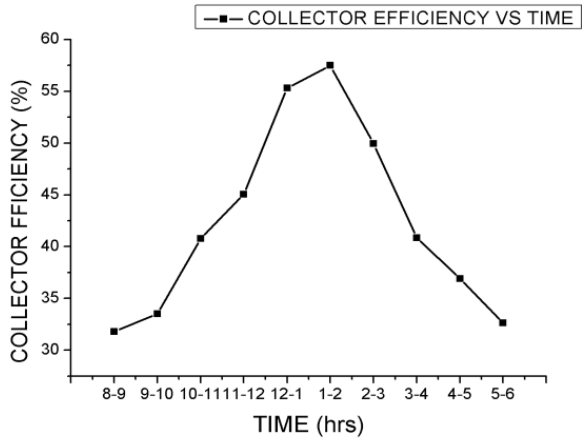


Figure 1: The AV of CE verses Time for the ETSC without absorber plate. The CSA= 3.6 m^2

Figure 1, the AV of the change in CE with respect to time (WT) of ETSC without AP. The expose demonstrate that the utmost temperature air is 57.5% at 1.00 to 2.00 P.M without AP.

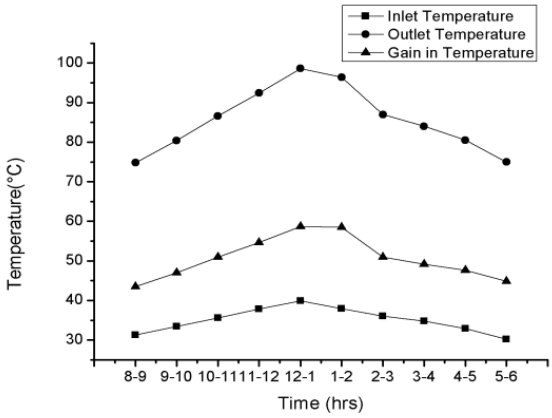


Figure 2: The AV of Temperature verses Time for the ETSC without AP. The CSA= 3.6 m^2

Figure 2, the AV of the modify in temperature WT of ESTC without AP. The major outlet temperature and the gain in temperature (GT) of air are 98.6°C and 58.7°C at 12.00 to 1.00 P.M without AP.

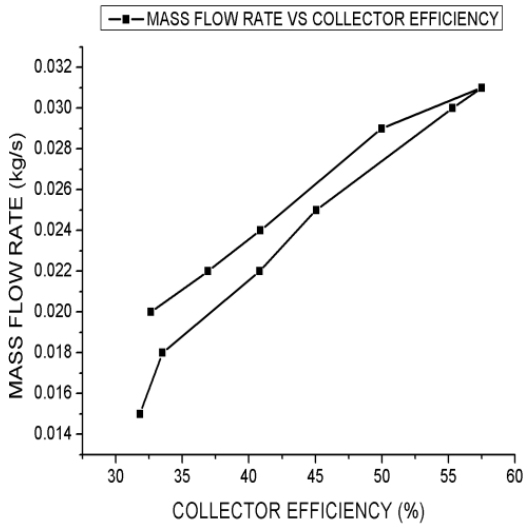


Figure 3: The AV of mass flow rate verses CE for the ETSC without AP. The CSA= 3.6 m^2

The AV of the mass flow rate of air with effect of altering CE is presented in Fig.3. The upshot

arrive that the most CC is achieved at 57.5 % in the flow rate of 0.030 kg/sec at 12.00 to 1.00 P.M without AP.

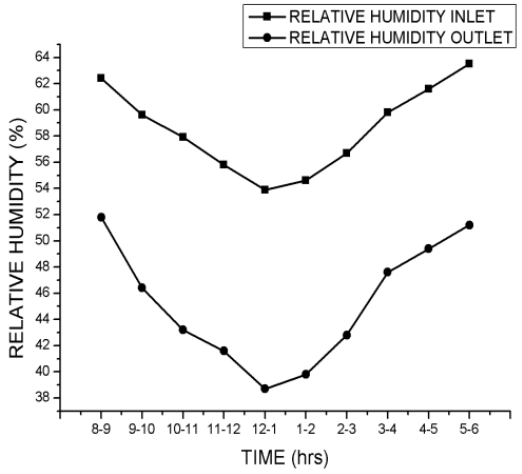


Figure 4: The AV of Relative humidity verses for the ETSC without AP. The CSA = 3.6 m^2

The AV of relative humidity of inlet and outlet of air WT is presented in Fig.4. The proceed attend that the maximum relative humidity decrease at 12.00 to 1.00 P.M without AP was calculated the inlet and outlet is 39%, 55% respectively.

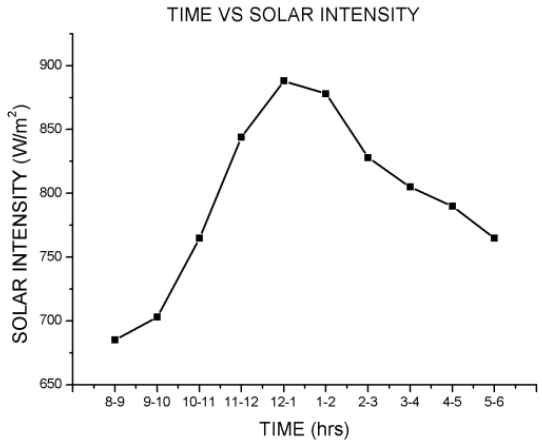


Figure 5: The AV of solar intensity VS Time for the ETSC without AP. The CSA = 3.6 m^2

The AV of the solar intensity of air WT is presented in Fig.5. The outcome arrive that the maximum solar intensity at 12.00 to 1.00 P.M without AP was measured 880 W/m^2 respectively.

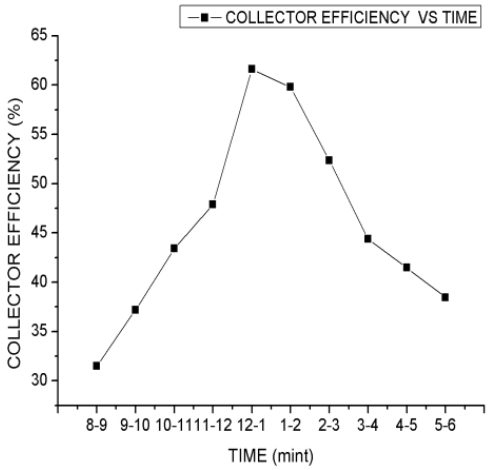


Figure 6: The AV of CE verses Time for the ETSC with AP. The CSA = 3.6 m^2

Figure 6, the AP of the modernize in CE through temperature of ETSC with AP. The consequence illustrated that the greatest potency air is achieved at flow rate of 0.027 kg/sec is 61.6 % at 12.00 to 1.00p.m with AP

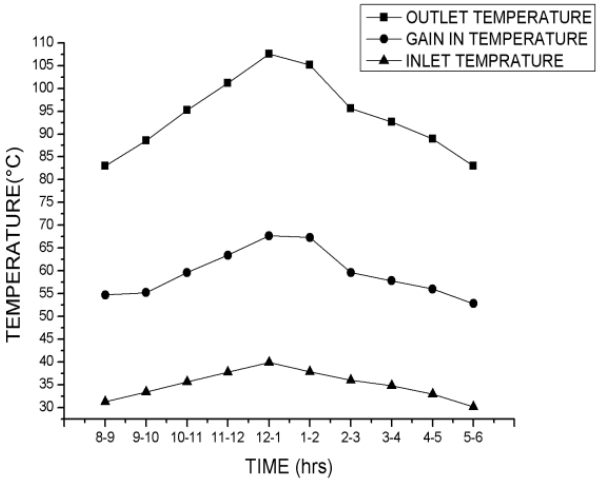


Figure 7: The AV of Temperature verses Time for the ETSC with AP. The CSA = 3.6 m^2

Figure 7, the AP of the make changes in temperature WT of ESTC with AP. The greatest passage and GT variation of air is attributed at flow rate of 0.027kg/sec are 107.6°C and 67.7°C at 12.00 to 1.00P.M with AP.

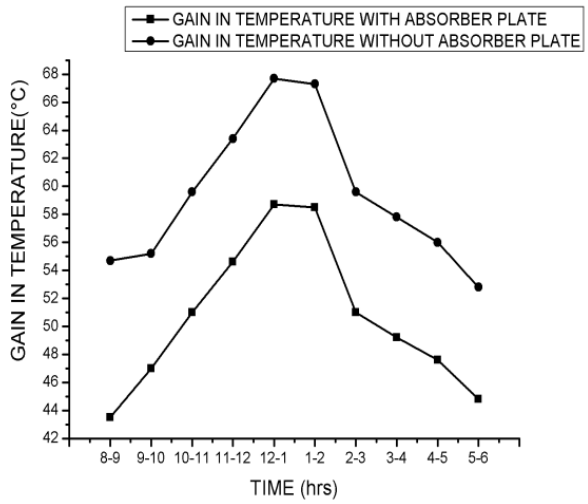


Figure 8: The AV of Gain in temperature verses Time for the ETSC with and without AP. The CSA = 3.6 m^2

The AV of GT among temperature for the ETSC with and without AP is presented in Figure 8, the aftermath display that GT of ETSC with AP is 13.6 % more than without AP.

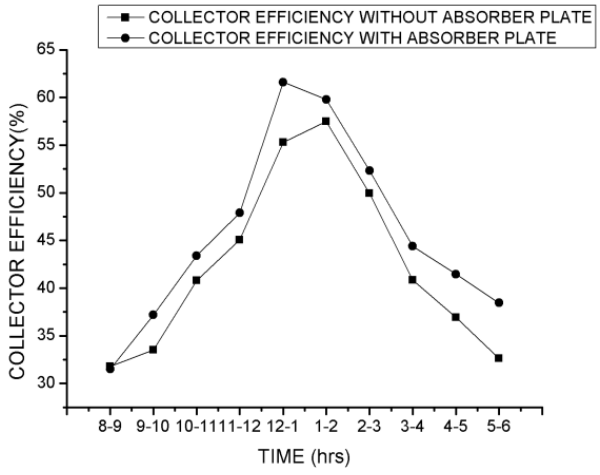


Figure 9: The AV of CE verses Time for the ETSC with and without AP. The CSA = 3.6 m^2.

The AV of CE of the ETSC with and without AP is presented in Figure 9. The completion offers that the CE of ETSC with AP is 7.1 % more than without AP.

CONCLUSION

Solar air heat is a technology based on solar TE that captured SE from the sun, which is used to heat the circulating fluid i.e. air. It is a renewable energy heating technology to heat air using thermal applications at 40 ° C -130 ° C temperature range. The following conclusions have been made from the experiment by the investigator.

(i) The top limit exit temperature and temperature distinction of air is attributed at flow rate of 0.030 kg/sec are 98.6°C and 39.9°C at 12.00 to 1.00 P.M without AP.

(ii) The maximum capability in air is attained at the flow rate of 0.031kg/sec is 0.575 at 1.00 to 2.00 P.M without AP.

(iii) The utmost outlet hotness and heat difference of air is attributed at flow rate of 0.027kg/sec are 107.6°C and 67.7°C at 12.00 to 1.00P.M with AP.

(iv) The most competence air is attributed at flow rate of 0.027 kg/sec is 0.616 at 12.00 to 1.00p.m with AP.

(v) The GT of ETSC with AP is 13.6 % more than without AP.

(vi) The CE of ETSC with AP is 7.1 % more than without AP.

The experiment concluded that the productivity of the ETSC can be significantly increased with the use of AP. In future, with increased number of ET with AP will be more evident to use as an effective method of solar collectors.

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