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Performance of Flat Plate Solar Collectors using Different Thickness of Glazing Material

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Abstract*: This paper throws light on the research of the outcome of breadth of glazing material such as glass on the flat plate solar saver presentation. There are 4 models of the solar saver comprised with varying thickness of glass which are investigated experimentally. The area of the collector fabricated is 0.72x0.15 meters. The thickness parameters considered in the study is low glass iron having the values of 2mm, 3mm, 4mm and 5mm. these materials are used as the glazing material in the present setup. The performance regarding the collector was evaluated and contrasted with the 5mm thickness glass. The result depicted that thickness material having 4mm value has the best results in the time duration considered in the study from morning 7:30 am to evening 6 pm. The effectiveness calibrated showed that 4mm glass gave 35.98% in comparison to the 5mm which incorporated 28.2%.

***Keywords* : Glazing Material, thickness, solar saver, glass, solar collectors.**

I. INTRODUCTION

Drying is a method which is used to eliminate the moisture from the food; this method is used to stop the activities of microorganism for effective storage and also to take out the volume weight which helps in the easy transportation. Sometimes it is step in the process of food preparation. Solar dryer helps to expose the substances to get dehydrated in a way that it transfers the solar radiations which strikes its upper part into the heat. The solar dryer is facilitated by the air movement which removes the inundated air away from the items which are dried (Saleh et al.). The original energy provider of our solar system is the Sun. A consistent nuclear fusion reaction inside the core of sun occurred huge amount of energy is dissipated; a lower portion of this energy touches the surface of earth and the impact of this energy causes the responsibility of all production of life cycle in earth. As same like the whole natural climatic conditions and weather cycles depends on solar energy and this occurrence are essential for life circle. (Tiwari). In present scenario of life drying fruits and agro based products making an attractive and gaining more popularity of researcher worldwide as it contains high nutrition value as it is a part of natural process. There are so many process of conservation of fruits and crops including drying, canning, cooling utilized all over the world. The removal of water is one of the most natural process to conserve the fruits and also agriculture. As it is consumed the waste materials from fruits and vegetables and their productivity too and maintain the quality and quantity of production. It could be categorized in many means like freeze drying, mechanical drying and vacuum drying. Drying (A removal of water content) has a vital role in this process as it would enhance the properties of products to leads a better marketability and storage capacity of this products too. The agricultural products need moisturizers too which is natural to prevent this products getting spoiled. The process of dehydrating is also known as energy concentration process use the conservative energy sources from solar energy. The material having the properties of absorbing moisture contents when opened in air it has a tendency to absorb and desorbs the moisture depends on the relative humidity of air (Snapyan)."

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II. LITERATURE SURVEY

Authors	Research Work	Result
(Li *et al.*, 2020)	"Experiment and simulation study on convection of heat transfer in covered glass evacuated tube solar collector"	"The straight row dual wall glass exiled tubes has been directly and indirectly inferred to the solar water heating system technology. It has been declared that the declination angle has greatly impact on energy conversion efficiency, flow patterns as well as straightness in the empty tubes. When θm > 0, as the declination angle increases, the immediate effectiveness increases, with the low clear temperature straightness and there was no major change in the coefficient of heat loss Declination angle was 6 degree allows to get the higher temperatures, shown with an inactive area of exile tubes appears at the bottom.."
(Deng *et al.*, 2015)	"An analysis of the solar air collector with a single pass flate plate on the dust deposit transparent glass cover"	"An analysis of the solar air collector with a single pass flat plate on the dust deposit transparent glass cover. The result reflects the projected thermal effectiveness in the case of dust deposition surface which is less by 10.7% to 21.0%, in the stable temperature difference ranges from 0 degree Celsius to 0.04 degree Celsius. Also the optical competence of the SAC with severe dust deposition surface is gradually decrease by 8.39% in distinction with the cover of clean surfaces."
(Gupta *et al.*, 2017)	"Water removal process of agriculture products from solar energy using solar dryer"	"It shows the drying parameters of the solar dryer for drying an agricultural product. The process was based upon the geographical location which is Nagpur and meteorological data were achieved for the requirement of proper design. Locally materials were used for the construction."
(Al-Busoul, 2017)	"Water removal process of fruits from sun energy using dryer under atmospheric condition of Jordan"	"In this process researcher concentrates on the new concept of a natural conduction dryer which is use to dry the fruits. It has been considered that these new concept having an ability to slow down the rate of water removal content from the products is up to 10% in two days.
(Colquitt *et al.*, 2015)	"Water removal process from fruits by sun energy using dryer under atmospheric condition of Shelek Kazakhstan"	Dissembled adjustment of the straight solar plate air heater having an uneven feature of impact on thermal effectiveness and ability to absorb the sun energy. It has been analysed that the inclined angle of 15 degree at a high temperature of 83.92 degree Celsius in afternoon. The hot air transfer required spraying dryer need 52.58 degree Celsius, comparatively consumption of electricity the solar heater consumption; it would be reduced of power of 30 kw/hrs. The measured of 8284.9 Baht/yr in the 34 days as the system operates at 5.35 baht/unit.
(Jongpluempiti *et al.*, 2017)	"An experimental study of structural assembly of the flat solar plate air spray heater"	"An experimental study of structural assembly on based on design of the solar flat plate air heater for spray. Disposed adjustment of the solar flat solar air heater has an uneven features affects thermal effectiveness as well as suitable in collecting the sun energy. It was analysed that, the inclined angle of 15 degree had a high temperature of 83.92 degree Celsius during 12:00-12:30 hours. At the same moment the hot air transfer to spray dryer was 52.58 degree Celsius, which was the finest temperature of all angles. When comparing the consumption of electricity before as well as after the solar air heater consumption, it can slow down the consumption of power of around 30 kW/hrs. Moreover when the system is in operation at 5.25 baht/unit, it generates profit of 8,284.9 Baht/yr also the payback period was measured around 34 days."
(Emetere, Osunlola and Otoko, 2019)	"Structural analysis of fruit solar drier"	"An experiment focuses of conserving fruits in rural area to stop waste. The temperatures in the concentrator and hanger cabins were stable. The structural geometry of solar fruit drier is raised by 13.57% to 20.14% respectively."
(Jambhulkar, 2017)	"Water removal techniques and their performance analysis"	Natural resources products have a wide used in present scenario. There is need to be more enhancement in this field effected the cost of dryer using sun energy. The products include agricultural and variety of fruits and edible should be profit-oriented. The case study focuses on various types of dryers and constraints of sun radiation, and its impact on temperature."

(Lingayat *et al.*, 2020)	"An impact of indirect solar driers to removal of water from agro based vegetables and fruits on its performace " .	"Insufficient techniques of preservation as well as poor storage provisions results in decline in vegetables and fruits and its quality. The payback duration and cost analysis of indirect solar drier have been discussed. Essential results found on indirect solar drier have been analysed, deliberated and arranged in a manner. The most leading constraints affect the water removal rate are the air temperature and its velocity which is followed by solar emission, type of product, initial water removal rate content too. Overall mass of the vegetables and fruits reactive sun dryers has been easily fabricated as comparison to active dryers. The amount of drying of pre-treated foods has very high and there is a improvement in quality keeps it drying
(Ananno *et al.*, 2020)	"Structural and numerical analysis of a fusion geothermal phase changing materaial uniform plate solar dryer in developing countries"	"Drying techniques low down the post-harvest food worsening. Numerical analysis provides the effectiveness of fusion geothermal PA-FPSC is 20.5% greater as compared to uniform solar plate collector as the rate of mass is at 0.02 kg/s. As per the analysis for specific research of technology in the fruits and vegetables i.e. in agro based industries in a developing countries it is step to move forwards step towards this technology of climatic changing condition."
(Papade and Boda, 2014)	"Structural analysis and development of indirect solar dryer in energy storage materials"	"In this study all the parameters of designs of indirect type of solar dryer are carried out like mass of water to be evaporate, energy essential to be evaporate water content, heat gain by air, drying time, needed velocity, average rate of drying, loss of heat along with insulator thickness. The investigation of 2D convergent along with divergent sections is completed by using CFD. The analysis is done to get the resultant data is the best to use in the indirect type solar dryer for flow of air."
(Djebli *et al.*, 2019)	"Drying tomatoes in a fusion dryer; An innovative study in the sector of Thermodynamics"	"An experimental thermodynamics analysis provides the results in the field of water removal content rate of specifically KAWA tomatoes, where the experiments taken out in a huge quantity dryer carried out by sun in thickness of 0.5, 1, 1.5, 2 cm."
(Jairaj, Singh and Srikant, 2009)	"An analysis of dryers using sun energy developed for removal of water from grapes"	"This experimental study re-evaluates the solar dryers entirely developed for grapes drying on typical unit. Comprehensive research work has been carried out in order to makes the dried grapes economically and. It has been a significant accomplishment in the specific process for grapes drying as the development is an advance technology. An analysis of solar dryers developed for grapes drying is very important"
(Montero *et al.*, 2010)	"An impact of a dryer using sun energy in agricutural crops and vegetables on performance and it's structural constraints"	"The structures of this model accessible and organised with the variation in the atmospheric parameters and its efficiency in all modes for e.g. Indirect mixed, passive and active modes. It includes study consumable kinetic energy and provides the better performance of fusion modes and reductions of the drying time are 50% in both cases.
(Mustayen, Mekhilef and Saidur, 2014)	"An impact analysis of solar dryer in agricultural applications"	"Removal of water content is important for the protection of agricultural applications. It has carried out using natural resources in a simulated mechanical drying process or by keeping the crops under direct sun light. The fusion modes dryers have the potential in drying the agricultural products in countries having Different climatic condition was studying and analysing in this experiment."
(Patel, Shah and Bhargav, 2017)	"Analysis of Dryer using sun energy for agro based products."	"The densely populated world have more than 6 billions peoples living below poverty and not get a proper nourishment. The experiment focused in the prevention of fruits vegetables and make it consumable. Solar dryers could make it of any size. Solar dryers are economical if the cash crops dried. The various designs of solar dryers have been taken in research."

(Hegde *et al.*, 2015)	"An impact on the performance evaluate in terms of fabricated structure of dryer using sun energy for banana."	"An eco-friendly and economically solar dryer designed to dry different agro products. In the end of this process the total difference in moisture contents rate found 3.1% which is important in the terms of cost of material which is significantly lower in cost and readily available and save the time. Concluded results get the data in which banana has been dry at the rate of 1m/s flow rate of air having a best quality of banana in terms of quality when compared to drying at 0.5 as well as 2 m/s air flow rate the climatic condition the same for all the cases with insignificant differences."
(Stiling *et al.*, 2012)	"Impact on analysis of fruit dryer using sun energy adding sun energy absorbed panels"	"Concentrating solar panels (CSP) gives the result with to increase the rate of water removal from specific product obtained when it was test in equally sunny and cloudy conditions. It was then further demonstrates and simulated in cloudy circumstances to dry and produce the satisfactory moisture content accurately with the motive of reducing post harvesting losses and preventing spoilage with a 27% decrease in total drying time in comparison to the normal dryer to reach the dimensionless target moisture content at the rate of 0.2.
(Karki, Haapala and Fronk, 2019)	"Feasibility of solar flate plate collector thermal energy system in terms of technically and economically for small and medium manufactureres unit"	"Manufacturing sectors requirements of heating for various manufacturing process and operations includes machining and sterlizing etc. A simple model is proposed to analyse the cost of solar flat plate dryer collector energy system and a sensitive analysis of savings to investment ratio is performed by varying the input constraints to ±30% performed from the base case. It was analysed that SIR is responsive to price of natural gas which is followed by collector area dependent cost, discount rate, cost of the auxiliary gas heater along with cost of the preheating system."
(Akhtar and Mullick, 2007)	"Calculation the temperatures and top heat loss coefficient of flat plate solar collectors with enclosed glass cover with double glazing"	Numerical based calculations are done to compute the correlation regarding the temperature of the glass with double glazing. The abosolute error in maximum within the evaluation of the projected method is merely 1%, hence numerical base calculations are required for U t

A. Glazing Material

Glazing material has some important features like reflection (r), absorption as well as transmission (τ). To achieve the highest effectiveness, reflection along with absorption must be as much lower as can, while the transmission should elevated as much possible. Therefore, regarding the factors which are considered in selecting the materials as glaze includes the strength, as well as the durability including the non-degradability when exposed to the rays of sun under ultraviolet involving cost effectiveness. Usually, the general materials such as polymers or glass utilized as glazing material (Adelaja and Babatope). The primary materials turns out be glass when it comes to material application for glaze. The material is capable of transmitting almost 90% of the radiations in short-wave, on the other hand long wave radiations released by the absorber cannot break in by the transmission. The basic advantages of plastics are, resistance to breaking, light in weight as well as economically available (Mujumdar). However, plastics degrade when prolonged exposure is encountered under UV rays. Also, plastics have difficulty at high temperatures experienced in the collector. (Sontakke and Salve).

(Kalidasa Murugavel et al.) investigated and identified that primary losses of heat are from the front covers made of glass comprising the saver, the sides as well as the back end of the collector which are basically insulated. Therefore, the accurate considerations regarding the thermal based performance comprising the solar system firmly relies on the glass cover material. Analyses with 3mm glass in addition with glass with 6mm thickness were evaluated. Results showed that glass with 3mm thickness has the best results compared to one with 6mm.

B. Heat Transfer Through Glass

Energy engrossed glass cover is depends on temperature disparity among glasses along with fluid, glasses as well as plates, and glasses with relation:

$$I \cdot \alpha g = ha\,(Tg - Ta) + hfg\,(Tc - Tf) + hr,gp\,(Tg - Tp) + hr,ag\,(Tg - Ta) \qquad (1)$$

The radioactive transfers of heat coefficient of heat from the absorber in the direction towards the glazing along with the ambient conditions are, corresponding, given by":

$$h_{r,} = \frac{\sigma\,(Tg2 + Tp2)\,(Tg + Tp)}{((1/Eg) + (1/Ep) - 1)}, \qquad (2)$$

$$h_{r,} = \frac{\sigma\,(Tg2 + Ta2)\,(Tg + Ta)}{((1/Eg) - 1)} \qquad (3)$$

The universal thermal effectiveness of flat plate solar saver is the ratio comprising the energy from thermal sources which are useful with the entire incident regarding the solar rays aggregated around the similar period of time. Numerically it is defined as

$$\eta = \frac{\text{Useful Energy}}{\text{Solar energy available}} \qquad (4)$$

The energy that is useful regarding the thermal saver is the rate comprising thermal energy liberating from the saver, usually described in terminology of energy rate accumulated to the transfer of heat fluid going to the end of receiver or the absorber. Assume

$$Qu = m \cdot Cp \cdot (To - Ti) \qquad (5)$$

The collector region where the solar rays falls is known as the aperture area regarding the collector. Hence, complete energy received by the collector is explained as

$Q\text{in} = I \cdot A$ (6)

Similarly, the transmittances as well as absorptance are multiple effects comprising the capture of power visually, therefore the point factors out of the proportion regarding the solar radiations pass through the translucent coverings on the saver as well as proportion being absorbed.

$Q\text{in} = \alpha \cdot \tau \cdot I \cdot A$ (7)

The pace regarding the useful energy regarding the collector might be described by utilizing the entire loss of heat coefficient as well as the temperature of the collector,

$Q_{\text{useful}} = Q_{\text{in}} - Q_{\text{loss}} = \alpha \cdot \tau \cdot I \cdot A - UL \cdot AC \cdot (T_c - T_a)$ (8)

On the other hand, it is hard to explain aggregated saver temperature in (4). It becomes appropriate to explain the quantity which relates the definite utilization gain energy regarding any collector in accordance to gain over entire collector surface were at the inlet temperature of the fluid. This is referred to as the factor of removing heat from collector which is defined as

$$F_R = A \cdot \frac{m \cdot C\,p \cdot (To - Ti)}{[\alpha \cdot \tau \cdot I - UL \cdot (Ti - Ta)]} \quad (9)$$

Finally, equation for efficiency of flat plate solar collector can be given by "Hottel-Whillier-Bliss equation"

$$\eta = FR \cdot \alpha \cdot \tau - FR \cdot UL \cdot \left(\frac{Ti - Ta}{Ic} \right) \quad (10)$$

Considerations are made that τ and α are constants regarding a provided collector as well as the flow rate, the effectiveness of the saver is a function which is linear comprising three identities, i.e. irradiance (I), temperature at the inlet (Ti), temperature at the outlet (To). Hence, effectiveness of the flat plate collector might be evaluated using

$\eta = (m \cdot Cp/A) * [(To - Ti)/\ ]$ (11)

III. MATERIAL AND METHOD

In this paper four similar type of flat plate collectors operating using solar energy are utilized. The materials for glazing which were utilized for the experiments had the low glass iron comprising of the thickness of 2mm, 3mm, 4mm as well as 5mm. the structure of the collector was fabricated using the timber wood with a width of 2 inches and the inside was painted black. The ratio of the length of the saver with the thickness turns out to be 2 meters and depth of 0.15 meters. The collectors were positioned in the NS direction and place at 10 degree angle from the ground towards the north. The temperature at the outlet regarding the collector was evaluated by temperature sensor PT940 XR5 - SE data logger. The normal or the temperature of the ambience was evaluated by data of humidity logger. The concentration of the rays, flow of the air, etc were calculated. Extract fans with 1.27 m3 /min were utilized in the collector.

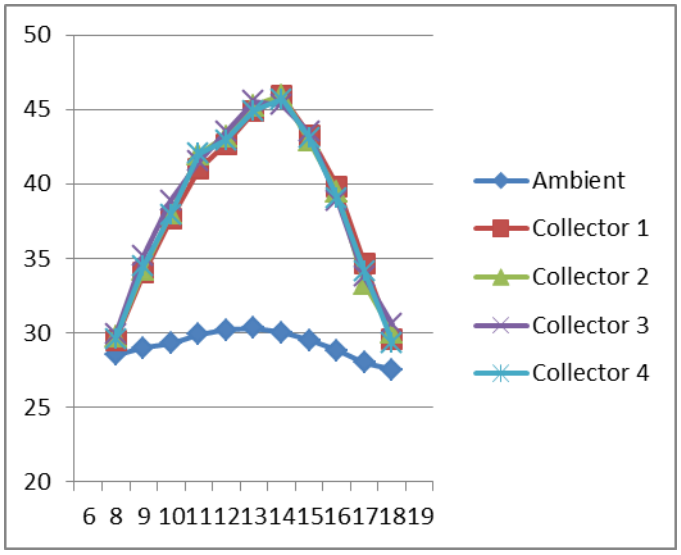

Fig. 1.Temperature profile of collector with similar glazing thickness.

Each of collectors were tested keeping the thickness of the glass same as 5mm in order to identify the efficiency. The time duration was calibrated from morning 7:30 am to evening 6 pm. The models were positioned on the top of the building

Table I: ANOVA comprising similar glass thicknesses.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.3648	3	0.467	1.346	0.375
Within Groups	4.576	12	0.384		
Total	5.9408	15			

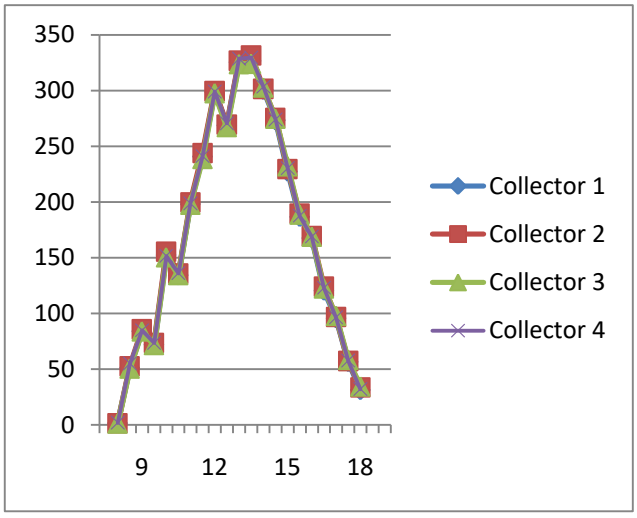

Fig. 2.Energy curve comprising similar glazing thickness.

IV. RESULT AND DISCUSSION

The main motive of the experimentation was to discover whether there are important performance differences in between the designed collectors models with same features for which collector with similar glass thickness are used. Every saver model was experienced for its presentation by means of 5 mm glass thickness."

From figure 1, it can be clearly seen that, there are no alterations in the temperature among the collectors, further; there might be fluctuation in the temperature as per the intensity of the rays. The alteration in temperature as the morning temperature slowly tends to rise up is contradicted to the afternoon temperature with cloudy sky which might result in degraded power from sun. similar characteristics are depicted in the figure 2. The effectiveness regarding the solar collector was calibrated by obtaining the region under the energy curve. The numerical based calculations regarding the thermal activities comprising same glazing was carried out using the SPSS tool having a confidence level of 95%. The saver model effectiveness depicted as 1, 2, 3 and 4 were 29.4%, 29.6%, 30.1%, and 30.1%, respectively for all the models in the study. ANOVA method is used and the details are described in table 1. The primary objective was to evaluate whether is there any significant difference exists among the effectiveness from the collector when exposed under similar material of glaze. From table 1 the import value is 0.375 ($P < 0.05$). Hence, it has been summarised that there were no numerically significant differences between the source of collector effectiveness with the same glass thickness as well as that their minor variations were because of changes in environment and not because if design variations.

A. Collectors with the Different Glass Thicknesses

The Graphical representation depicts that the profile trends of context also outlet temperature for 4 saver models are noted down from the morning 7:30 am till the evening 6pm. It is observed that, from the morning these is a rise in the temperature due to the change or rising intensity of the sun rays.

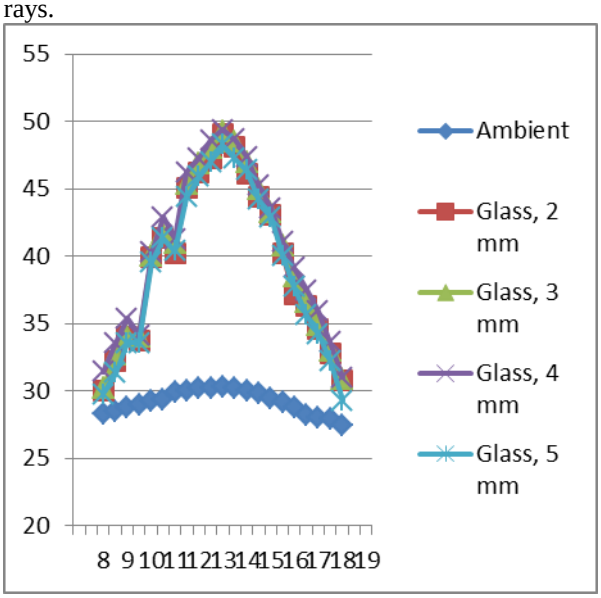

Fig. 3.Temperature curves comprising different glass thicknesses.

Table- IV: Material property of blade

Material type	Young's modulus, E, (Mpa)	Poisson's ratio	Tensile strength , (Mpa)	Density, (kg/m^3)
E-Glass fibre reinforced plastic	38000	0.2	1800	1870
Carbon fibre reinforced plastic	176000	0.27	2050	1490

a.

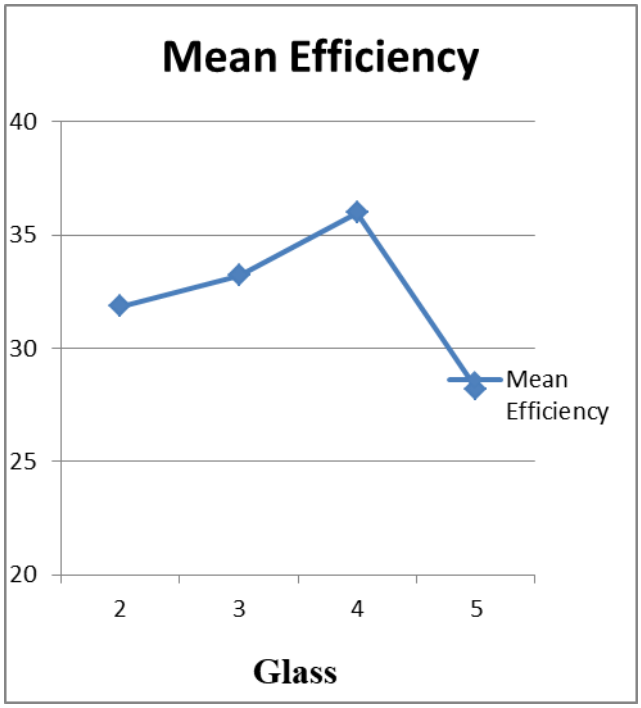

Fig. 4.Mean plot of performances of solar collectors with varying glass thicknesses

The features resembling thermal characteristics regarding the captured cover of glass such as transmittance, as well as reflectance and the absorptance regarding the collector presentation are enclosed. Therefore, the selection on the glazing material ought to be aimed at the elevating transmittance as well as declination of the convective losses, on the other hand increase in the reflectance and vice-versa. From the research it is clear that 2mm glass provided high transmittance and losses of convective form hence lowered the performance in contradiction to 3mm thickness which turns out to be even bad compared to 4mm thickness. The thickness comprising 5 mm glass provides degraded transmittance as well as lower connective losses and therefore it incorporates poor performance compared to 4mm thickness. So, the thicknesses with 4mm turn out to be the best among all the cases considered in the study.

V. CONCLUSION

The experiment is successfully carried out and the result is calibrated. In conclusion it can be said that varying thickness of the glazing material in the solar collector varies the performance of the setup. The 4mm thickness has the best result as it saved the efficiency of about 7.6% compared to cases with 2mm, 3mm, 5mm thickness.

The structure and construction of the collector with 4mm glass is robust which further reduces the risk of breakage and failures. The hourly based study showed that in the afternoon the temperature value is maximum, probably due to the increase in the concentration of the radiations of the sun and then slowly degrades as the evening arises.

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