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# Thermal Performance of a Flat Plate Solar Air Heater

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**ABSTRACT:** For the past few years ago, most machines had have powered by electricity produced remotely. But now there is a need to move towards alternative energy due to energy demand and technological advancement. Based on the existing technology, solar energy is more optimal and suitable because transmission loss and energy cost on it is very less. Solar energy is already being used in many industries, and many others are thinking of implementing in near future. This type of solar energy utilization can be divided into two types, one for power generation and the other for direct usage. Although there are many losses when converting energy for power generation. On the other hand, it can be effectively converted when solar energy is used for a direct application-based specific technology. Such technology is a solar Air Heater which is being used for drying applications for extending the lifespan of water-rich agricultural products by removing them through hot air. The aim of this work is to convert solar energy into thermal energy. For this solar flat plate collector is being used to get hot air the maximum outlet temperature obtained is 60°C.

**KEYWORDS:** solar energy, flat plat collector, hot air, food drying.

## I. INTRODUCTION

The amount of paddy production in Andhra Pradesh is about 139.73 lakh tones in 2019-20. The food drying is important to extend the life-span of the product. It consuming large quantities of energy when the electricity used. Many technology applied for drying the food products, but stable ambient condition drying is easy to handle. The main advantages of the drying is storage life can be extended by preserving the product. The drying operation is used either as a primary process for preservation, or a secondary process in certain product manufacturing operations. About 10 to 25 percent of energy is spent on food processing. The most important purpose of expending this energy is to reduce the amount of moisture in the grain products at a low cost. Nowadays it is considered very important to make the best use of energy in the current scenario. Of such energy solar energy is more likely to be used directly on flat plate solar air heaters are the most efficient ones.

Agricultural crops are important for the human diet, depending upon their nature, including vitamins, mineral and fibers. Some crops are highly seasonal and are usually available in plenty. In the peak seasons, the selling price of crops becomes too low, leading to heavy losses for the grower. Furthermore, this leads to an unnecessary stock in the market, resulting in the spoilage of large quantities. Due to its seasonal nature, a need was felt to preserve crops over a period of time for use during offseason. Preservation of crops can prevent the huge wastage and make them available in the off-season at remunerative prices. Additionally, the seasonal nature of availability has led to efforts to extend the shelf life of crops by dehydration. Various drying methods have been practiced for dehydrating crops. These technologies need sophisticated equipment and skill training, the adoption of which appears difficult at the field or rural level[1].

There are several changes taking place in quality parameters during drying and storage. The extent of changes depends on the care taken in preparing the material before dehydration and on the process used. Major quality parameters associated with dried food products include color, visual appeal, shape of product, flavour, microbial load, retention of nutrients, porosity-bulk density, texture, rehydration properties, water activity, freedom from pests, insects, and other contaminants, preservatives [2]. The state of the product (such as glassy, crystalline, or rubbery) is also important. Quality parameters of dried fruits and vegetable can be classified into four major groups: i. Physical qualities ii. Chemical qualities iii. Microbial qualities iv. Nutritional qualities.

## II. RELATED WORK

K R Arun, G Kanal et al conducted an experiment on flat plate solar air heater to attain uniform and flexible solar drying by using a multi tray indirect mode solar cabinet dryer. The work considers unripe untreated banana and bitter gourd with an average initial moisture content of 180% (db.) and 1328% (db.), respectively. It is found that for both banana and bitter gourd in all trays, moisture content reduces with drying time, the moisture diffusion from the samples to the air reduces as well[3]. Samir A.Dhatkar et al carried out the major heat losses from a normal solar air collector to increase the thermal efficiency. Many experiments have been carried out on the performance analysis of double pass solar air heater with porous media and solar air heater with extended surfaces. It is found that more increase in thermal efficiency in comparison with conventional solar air heater[4]. Kalogirou SA carried out the various types of collectors described include flat-plate, compound parabolic and Heliostat field collector (HFC). The optical, thermal and thermodynamic analysis of collectors is also presented as well as methods to evaluate their performance. These include water heating, space heating and cooling, refrigeration applications etc. The application areas described in this paper show that solar energy collectors can be used in a wide variety of systems, could provide significant environmental and financial benefits[5].

Neeraj Kumar et al carried out an experiment on Absorber plates which are covered with a high absorbent coating. The top cover should be made of a maximum transmittance. Based on the experiments it has been found that most of the studies on the solar collector are done to increase its thermal efficiency by enhancing the rate heat transfer between air and the absorber plate by using rough surface on the absorber plate[6]. Jagadeesh D carried out experimented the thermal performance of a single pass solar air dryer is compared with a transient computational fluid dynamics studies for flat plate without fins, flat plate with fins and overlay composite absorber plate for two flow rates. Conducting Experiment providing the fins on the absorber plate there is an improvement in outlet temperature. With fin configuration is 25% more efficient than the without fin configuration, and there is a 10% enhancement in outlet temperature is achieved by varying the flow rate from 0.012 to 0.016 kg/s and Thermal efficiency increased from 40% to 51% for mass flow rates of 0.012 and 0.016 kg/s respectively[7].

RajendraKarwa et al carried out an experiment to investigate on thermal efficiency of a solar air heater and the pumping power required to propel the air through the air heater duct are strong functions of the duct geometry and roughness etc. It has been found that the iteration time is short even when the iteration is terminated for very close successive values of various temperatures and top loss[8]. Fatah. O. Al Ghuol et al carried out experiment on solar collectors of Flat Plate type is a thermal transfer device that absorbs solar radiation and converts it into heat. The effectiveness of the flat plate air collector is highly affected by the losses through the top covering material and also due to the low heat transfer coefficient between the absorber plate and the air flowing through it[9]. Velmurugna P, et al carried out experiment on a solar air heater that is used by using solar collector. The efficiency of this is determined by using with and without using fins which are attached under the absorbing plate. Therefore the efficiency of the solar air heater is higher while the fins are used[10]. Foudedchabana et al carried out an experiment on solar air heater that is used by using solar collector. The efficiency of this is determined by using with and without using fins which are attached under the absorbing plate. Therefore the efficiency of the solar air heater is higher while the fins are used[11]. Velmurugan P et al carried out experiment on the energy performance of solar air heaters improved by using or employing double pass with different absorber surface. There is effect on various mass flow rate and solar intensity on temperature and pressure drop. Here the efficiency of energy increases while the temperature rise decreases. So the surface geometries are influential in enhancing the performance of solar air heater[12].

G.Kalaiarasi et al carried out an experiment on flat plate solar air heater (SAH) has been designed to yield a good outlet air temperature irrespective of fluctuations in solar radiation. It was achieved with the help of a specially designed, integrated absorber plate cum storage unit, together acted as a single component. It also concluded that sensible heat storage at the absorber plate improves the thermal output, therefore leads to a consistent performance[13]. Mohammad Ansari et al carried out investigation on the effect of repeated ribs on the thermal performance of a flat plate solar air heater. It was found that employing ribs in a flat plate solar air heater improves the thermal efficiency by more than 9% under the low air mass flow conditions[14]. Hatami N et al carried out an experiment on natural convection heat transfer in a vertical flat-plate solar air heater of 2.5 m height and 1 m width, with one- and two-glass covers. Totally six cases of airflow (two for air heater with one glass cover and four for air heater with two-glass covers) were considered[15].



Ho-mingyeh et al carried out investigation theoretically and experimentally on the effect of parallel barriers on the collector efficiency of flat-plate solar air heaters. The theoretical predictions agree reasonably well with experimental results. The optimal barrier location for maximum collector efficiency is the centre line of the collector. The collector efficiency increases theoretically as the number of barriers increases[16]. C.D. Ho et al carried out investigation on a device for inserting an absorbing plate into the double-pass channel in a flat-plate solar air heater with recycle. This method substantially improves the collector efficiency by increasing the fluid velocity. Considerable improvement in heat transfer that is obtainable by employing recycle-type double-pass devices instead of single-pass device[17]. The objective of this work is to produce hot air from solar energy with the help of a flat plate collector.

### III. METHODOLOGY

Solar heaters are the collection devices which are usually accompanied to expose a dark surface to solar radiation so that the radiation is absorbed. The transparent cover used to allow the radiation to pass and prevents them from exiting, insulation used to resist back and rare side heat losses, a portion of the absorbed radiation is then transferred to a fluid, the system in which the series is achieved is called flat plate solar collector. This Flat plate solar Air heater collector having dimensions 1.5mts, 0.67mts and 0.25mts length, width and height respectively. The collector volume is 0.25 m<sup>3</sup>. 9mm plywood we have used to construct the main body of the collector. 0.5-inch thermocol is used as insulation to avoid the escape of hot air. GI sheet of dimensions 1.5mts length and 0.64mts breadth is placed over the bottom over thermocol. A transparent glass cover with 5mm thickness is placed over the top portion of the collector and we have used Solar power meter to measure the solar radiation and we have used 7 thermocouples as follows 1. The first on air inlet. 2. The second on 50cm from air inlet. 3. The third on Glass surface. 4. The fourth on 100cm from air inlet. 5. The fifth on GI sheet surface. 6. The sixth for atmospheric temperature. 7. The seventh on air outlet. The experiment has conducted at vizag location. It's having latitude and longitude 17.6868°N and 83.2185°E respectively.

### IV. EXPERIMENTAL RESULTS

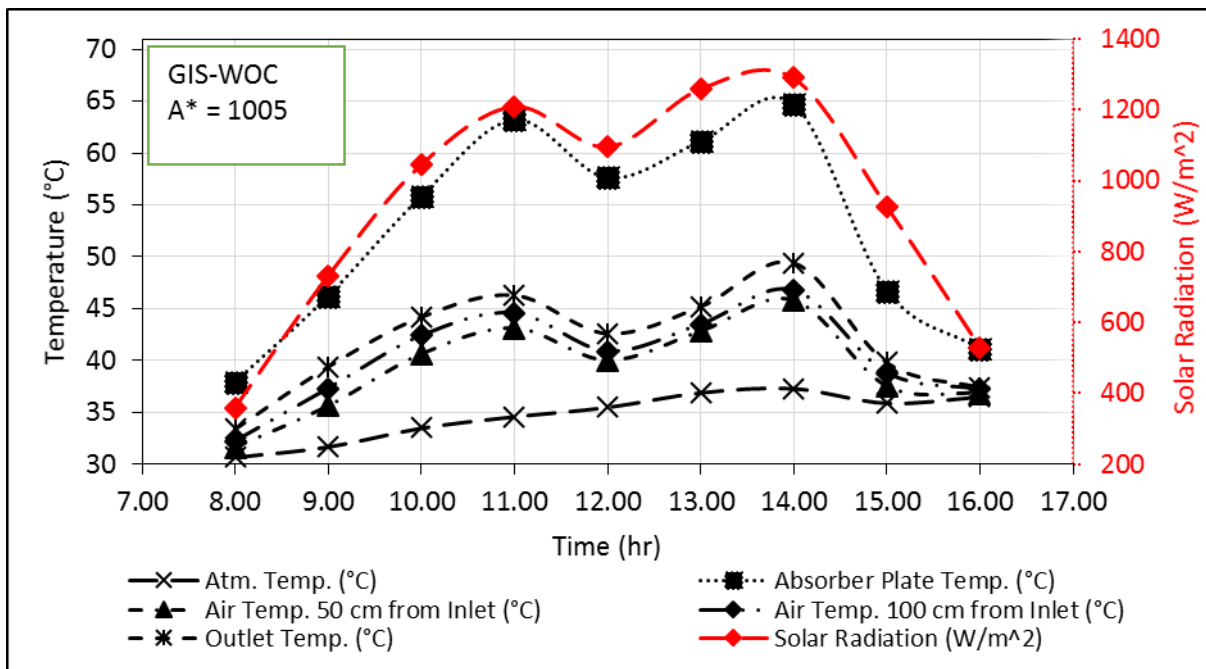


Fig. 1. Graph for Experiment conducted using plane GI sheet which is not coated with black paint.

In the Fig (1) represents each and every temperature and solar radiation with respect to time from the primary experiment conducted on flat plate collector with plane GI Sheet which acts as an absorber plate. The temperature of air at outlet is 49°C at 14.00 and solar radiation is approximately under 1300 W/m<sup>2</sup>, the reason behind this outlet

temperature is because of natural convective heat transfer from GI Sheet to Low dense air molecules. The high density cold air enters into the system (flat plate collector) through the inlet portion and because of the temperature difference there is a transfer of heat from absorber plate and air molecules throughout the system heat in the mode of natural convection process. The air heated up by absorbing the heat from the absorber plate throughout the system and escape from the outlet portion. Because of this outlet temp reached to 49°C at 14.00 and solar radiation is under 1300 W/m<sup>2</sup>.

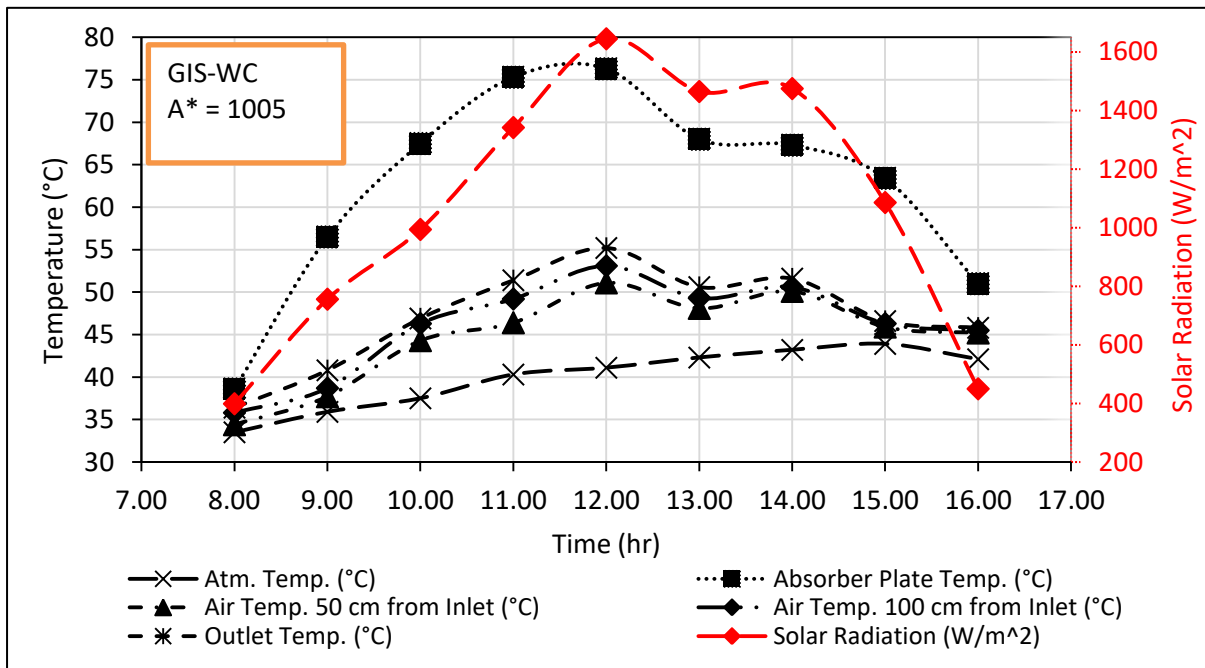


Fig. 2. Graph for Experiment conducted by using GI sheet which is double coated with black paint.

In the Fig (2) obtained from the experiment conducted on the flat plate solar air heater by using GI sheet which is double coated with the black paint. In this outlet and GI sheet temperature are more than previous plane GI sheet temperature. The distance between the top surfaces of the GI Sheet to bottom surface of the glass is 23cm. In the Fig (2) represents each and every temperature and solar radiation with respect to time from the second experiment what we have conducted on flat plate collector with the GI Sheet which is double coated with black paint acts as an absorber plate. The temperature of air at outlet is 56°C at 12.00 and solar radiation is approximately under 1650 W/m<sup>2</sup>, the reason behind this is in this experiment we have coated the GI sheet with black paint which absorbs the maximum solar radiation when compared to the plain GI sheet due to there is a high temperature difference between GI sheet and air molecules. So, there is an increase in air outlet temperature (i.e. 56°C) when we compared with the previous experiment.

Fig (3) has obtained from the experiment conducted on the flat plate solar air heater by using GI sheet which is double coated with the black paint. In this experiment outlet area got reduced to 670cm<sup>2</sup>. Because of reducing outlet area, outlet temperature is increased. The distance between the top surfaces of the GI Sheet to bottom surface of the glass is 23cm. In the Fig (3) represents each and every temperature and solar radiation with respect to time from the third experiment what we have conducted on flat plate collector with the GI Sheet which is double coated with black paint acts as an absorber plate and reduces the outlet area to 670 cm<sup>2</sup>. Because of this restriction in outlet area, the air retains in the space in system and it has the time to absorb the maximum amount of heat energy. So, the temperature of air at outlet is 53°C at 14.00 and solar radiation is approximately under 1000 w/m<sup>2</sup>. When compared to previous experiment there is a decrease in air outlet temperature. The reason for this is because of the low solar radiation (i.e. 1000 W/m<sup>2</sup> solar radiation.). Though there is decrease in solar radiation up to 60% from the previous experiment there is a less decrease in air outlet temperature (i.e. 3°C). The reason behind this is due to reduction of air outlet area the air molecules retains within the system and absorbs maximum heat from absorber plate.

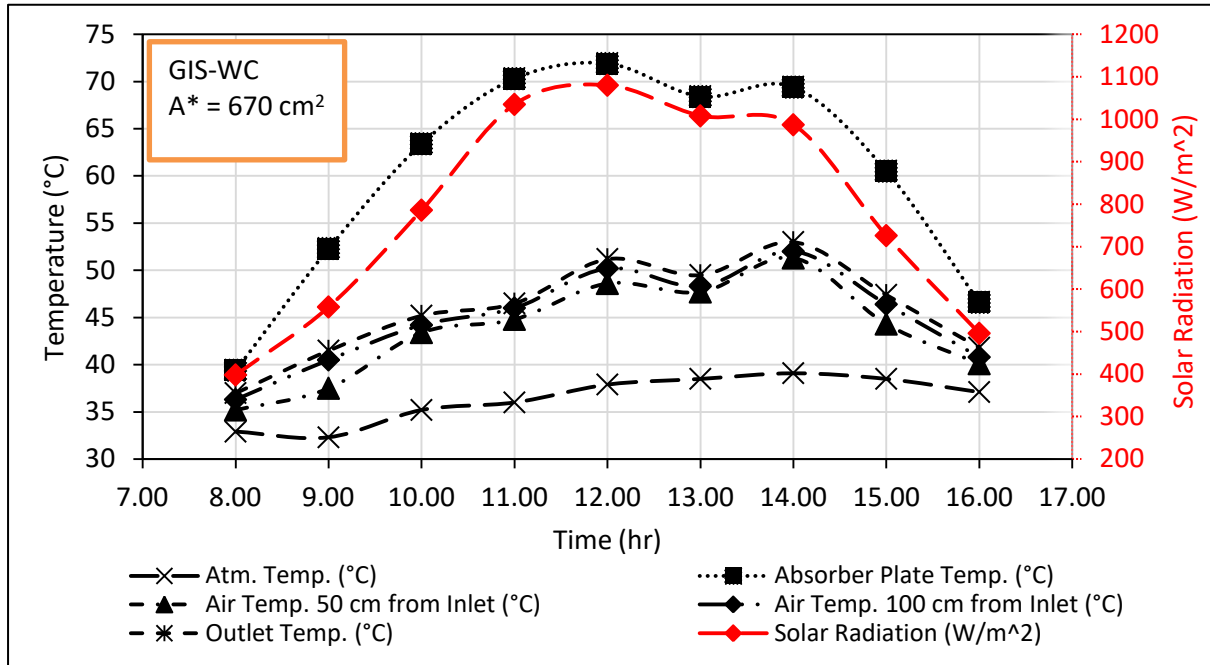


Fig (3): Graph for Experiment conducted by reducing outlet area to 670cm<sup>2</sup> using GI sheet which is double coated with the black paint.

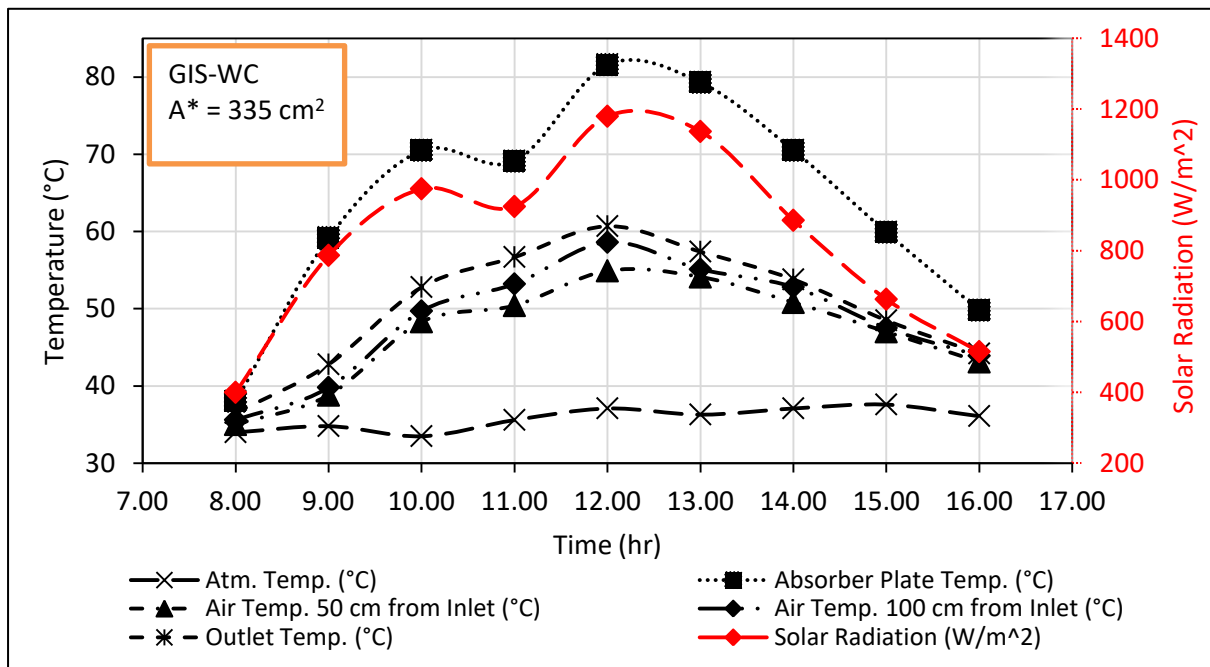


Fig (4): Graph for Experiment conducted by reducing outlet area to 335cm<sup>2</sup> using GI sheet which is double coated with the black paint.

This was the graph obtained from the experiment conducted on the flat plate solar air heater by using GI sheet which is double coated with the black paint. In this experiment outlet area got reduced to 335cm<sup>2</sup>. This was giving the best results. That's why we taken this as reference. The distance between the top surfaces of the GI Sheet to bottom surface of the glass is 23cm. In the Fig (4) represents each and every temperature and solar radiation with respect to time from

the fourth experiment what we have conducted on flat plate collector with the GI Sheet which is double coated with black paint acts as an absorber plate and reduces the outlet area to  $335\text{cm}^2$ .

The air outlet temperature is  $61^\circ\text{C}$  at 12.00 and solar radiation is approximately under  $1200\text{W/m}^2$ , the reason behind this outlet temperature is because of natural convective heat transfer from GI Sheet to high density air molecules and restriction in outlet area, the air retains within the system and it has maximum time to absorb the maximum amount of heat energy. So, in this experiment there is a maximum air outlet temperature and good thermal performance when compared with the other experiments.

## V. CONCLUSION

The significant conclusions drawn from the results analysed are:

1. The temperature of air at outlet is  $56^\circ\text{C}$  at 12.00 and solar radiation is approximately under  $1650\text{W/m}^2$  for the experiment conducted on flat plate solar air heater by using a GI Sheet which is coated with black paint acts as an absorber plate.

2. The temperature of air at outlet is  $61^\circ\text{C}$  at 12.00 and solar radiation is approximately under  $1200\text{W/m}^2$  for the experiment conducted on flat plate solar air heater by using a GI Sheet which is coated with black paint acts as absorber plate and outlet area reduced to  $335\text{cm}^2$ .

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