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International Journal for Modern Trends in Science and Technology, 8(05):449-453, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0805066
Available online at: http://www.ijmtst.com/vol8issue05.html

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Experimental analysis of flat plate solar air heater

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To Cite this Article
Lenin V R, Nunna Sai Pavan, Karaggi Nikhil Chandra, Chilla Vishnu Vardhan, N Yuva Kishore and B Sri Hari. Experimental analysis of flat plate solar air heater. International Journal for Modern Trends in Science and Technology 2022, 8(05), pp. 449-453. https://doi.org/10.46501/IJMTST0805066

Article Info
Received: 18 April 2022; Accepted: 15 May 2022; Published: 21 May 2022.

ABSTRACT

One of the most renewable energy sources is Solar energy. In today's world, solar energy is regarded as one of the main important sources. It is more popular than other conventional fuels due to lower pollution and global warming, and its non-conventional nature. The work provides a brief overview of the thermal performance of flat plate solar air heaters. The main goal of this experiment is to produce the highest outlet air temperature with heat input of 1000 W/m² solar radiation by varying the height of the absorber plate, the outlet area, inlet area of the flat plate and angle of the absorber medium with horizontal. The flat plate solar air collector is a solar thermal energy receiving device that is widely used for space heating, food drying and many other applications. Finally, the results show that the flat plate solar air collector is a very simple solar thermal device which can be used for many applications for hot air generation.

KEYWORDS: *Flat plate solar air heater, absorber plate, solar radiation, air temperature, transient state*

1. INTRODUCTION

With recent developments in India's industrial sectors, energy demand is quickly approaching an each- time high. Conventional power generation methods based on fossil fuels aren't only ineffective, also poison the atmosphere. The use of fossil energies in Indian electric power generation accounts for 40% of total carbon emissions [1].

Flat- plate solar air heaters are intended for use in operations that demand energy delivery at low temperatures. They make use of both direct and diffused radiation from the sun and do not need sun chasing. Because of its low material necessities, the solar air heater is a main constituent of solar heating systems. Likewise, using air directly as working material decreases amount of system components required. The necessity for huge volumes of air with limited thermal capacity as the working substance is the fundamental disadvantage of Flat plate solar air heaters. The two most common applications are drying and heating of space.

Flat-plate solar air heaters are nonadiabatic radiative heat exchangers typically utilized in low-temperatures hot air-drying systems (T<373 K). In solar air heaters, using air instead of water as a heat transmission medium reduces the risk of erosion and freezing while also reducing collector weight and expense. Despite this, large volume inflow rates and lower density are required because to the low specific heat of air, which may result in high friction losses. Reduced thermal conductivity increases heat transfer resistance and the temperature difference between the fluid and the absorber, limiting thermal efficiency.

Transfer of heat inside the channel must be bettered while loss of heat is kept to a minimum to enhance thermal efficiency. Numerous heat transfer improvement styles use turbulators on the heat transfer surfaces to start or increase turbulence in the flow. Similar methodologies include ribs, artificially roughened surfaces, and grooves.[2].

Space heating, paint spraying, and drying operations are all common uses for flat plate solar air heaters. There have been numerous solar air heater technologies created and tested. Many of these devices, which are comprised of one or even more sheets of glass put over an absorbent material [3-5], have establish marketable success. Forced convection [6,7] enhanced heat-transfer area [8, 9] and airflow turbulence [10-12] have all been documented to play major part in enhancing solar air heater performance. Most recently there are some works with Cross flow heat exchanger work has done through by double pass [13].Reflectors and turbulators based work have done by single pass [14]. Curved and flat plate air heater performance has compared [15]. For food-processingother method-s are also there for example dehumidification [16]

The main aim of this work is to generate the hot air experimentally by considering various parameters such as inlet area, outlet area, height of the absorber plate and inclination angle in Flat plate solar air heater.

2. METHODOLOGY

A. Construction

The things that are required to make the flat plate collector are glass plates,wooden sheets, absorber plate. The glass plate is 7mm thickness and150cmlength. Absorber flat plate is paintedwithblackcolorbecauseblack is a good absorberofheat. Painted absorber flat plate is arrangedinsidethecollector setup. The length of the flat plate collector is 150cm whereas its width is64 cm,anditsheightis25cm.There are 3 PVC pipes for holding thehalogen lamps which will produce the solar radiation. The length of pipe is 8 feet. Those pipes are arranged in such a way that one isvertical, another one is horizontal, and the other is inclined. Halogen lamps areplaced on the inclined pipe with equal distance between them. These pipesare joined with the help of Scaffolding Clamp. Scaffolding clamps are usedfortheadjustmentforthepipesi.e.,usedtoincrease/decreasetheheightof the pipes. Stand is made to insert the pipes into it such that it will erect.Twohalogenlampsarerequiredtoproduce1000 W/m^{2}solarradiation.The specification of each halogen lamp is 1000 W. The halogenlampsareplacedparalleltotheflatplatecollector.

B. Components

1. Halogen lamps: - Halogen lamps are used for producing the solar radiation, light on the flat plate.
2. Scaffoldingclamps: -Scaffoldingclamps are used to hold, increase, and decrease the length of the pipe.
3. PVC pipes: - PVC pipes are used to hold the halogen lamps in the desired position.
4. Stand: - Stand is used to erect the PVC pipes.
5. Flat Plate solar air collector: - its main application is to absorb the solar radiation and turn this radiation into the outlet heat.

C. Instrumentation

1. Solar power meter: - Solar power meter is a device which is used to measure the radiation emitted by sun. The unit of solar radiation is W/m2.
2. Digital Thermocouple: - Digital Thermocouple is used to measure the inlet, outlet, and room temperature.
3. Infrared Thermometer: - Infrared Thermometer is used to measure the temperature of the flat plate air heater.

D. Experimentation

First, switch off all the lights and fans that are in the room. Now note down the initial readings of T_1, T_2, T_3, T_4, in the atmosphere temperature conditions. Where T_1 is room temperature, T_2 is the absorber plate temperature, T_3 is the outlet air temperature at 5cm distance from the glass plate of Flat plate solar air collector, T_4 is the temperature of air at outlet at 10cm distance from the glass plate of FPSAH. Arrange the flat plate collector with inclination(Ø) to horizontal. Arrange the halogen lamp setup parallel to the flat plate collector. Switch on the lights such that halogen lamp will glows. Make sure that the solar radiation on the flat plate should be 1000 W/m^2. If the halogen lamps are unable to produce the solar radiation 1000 W/m^2 arrange the halogen lamps setup in a way that it will produce desired solar radiation.

After this arrangement for every 5 minutes note down the readings of T_1, T_2, T_3, T_4. This process should be continued until and unless T_3 and T_4reach a steady state. Once it attains the steady state switch off the lights of the halogen lamps and switch on the fans and lights available in the room. After that wait for 30 minutes until T_3 and T_4 will come to room temperature. Once T_3 and T_4 attain the room temperature readings then continue the experiment with varying factors.

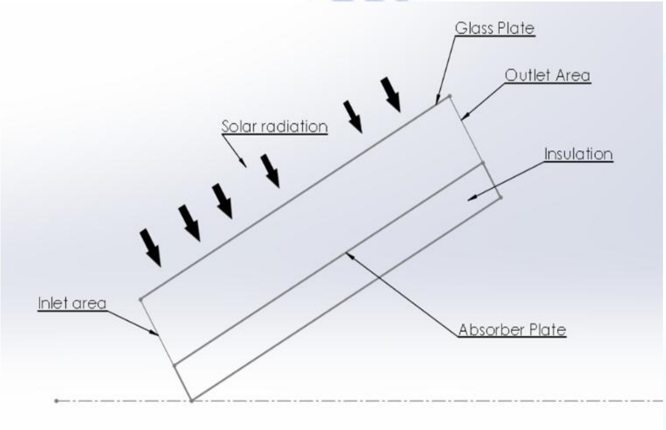


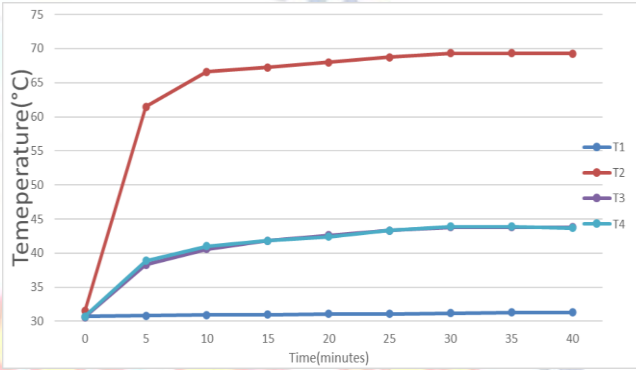
Fig 1: Flat plate solar heater

3. Results And Discussions

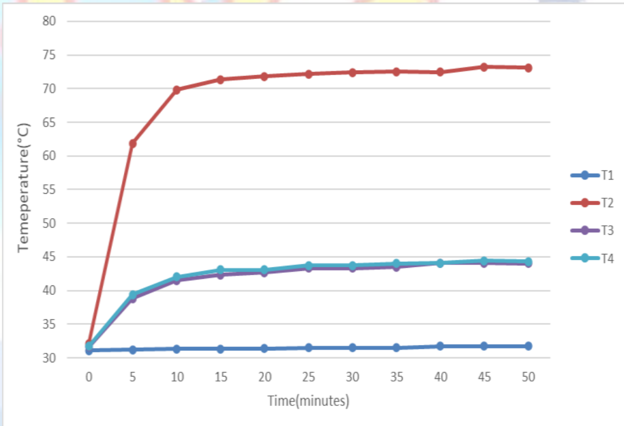
A Flat Plate Solar Heater was experimentally analyzed for its Thermal performance by varying outlet areas and Height of the absorber plate. The test was performed between 16/03/2022 and 21/04/2022 in Spring months of Visakhapatnam. The SAH was installed at an inclination of 30°and 60° with horizontal. The Incident radiation of 1000 W/m2 was applied constantly, and temperature readings were observed at different places for every 5 minutes until the steady state of temperature. With maximum temperature reached for experimental setup where the outlet area is least and height of the absorber plate at maximum and absorber plate is at 60° with horizontal.

For every setup of experiment, the inlet area (A_i) of 64 cm X 15 cm is fixed, and outlet area (A_o) varied. For the first setup of experiment, outlet area is constant i.e., 64 cm X 15 cm and varied angle of absorber plate and distance between absorber plate and source of radiation. experiment was performed until steady state of outlet air temperatures are achieved. Graphs are drawn between temperatures and time taken for attaining steady state.

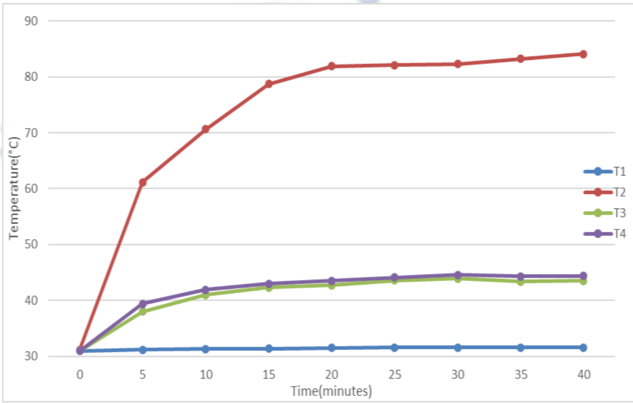
The graphs 1,2, 3 are drawn with constant outlet area 64 cm X 15 cm. when compared these 3 arrangements the third setup has highest outlet air temperature of T_4 = 44.4°C and T_3 = 43.5°C where the absorber plate is at 60° with horizontal and height of absorber plate in Solar air heater setup is 55 cm. The values are drawn in Graph 03. The other setup with 30° angle and height of absorber plate 55 cm had 44.3°C and 44°C as T_4 and T_3 respectively these values are plotted in graph 2.For the remaining setup the temperatures are least when compared to other setups i.e., 43.7 and 43.8 for T_3 and T_4 respectively. These observations were considered from graph 1.



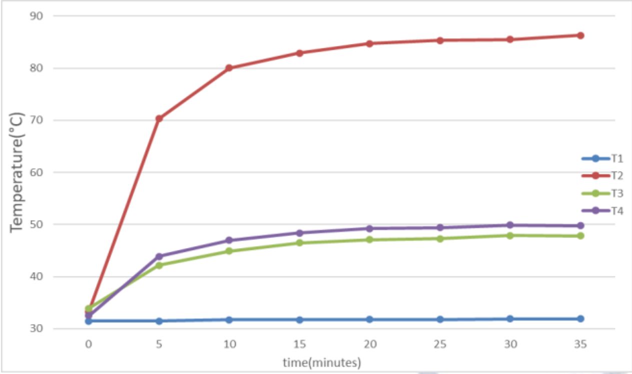
Graph 1: Temperature vs Time(A_i = 64cm X 15cm, A_o = 64cm X 15 cm, H = 15 cm, Ø = 30°)



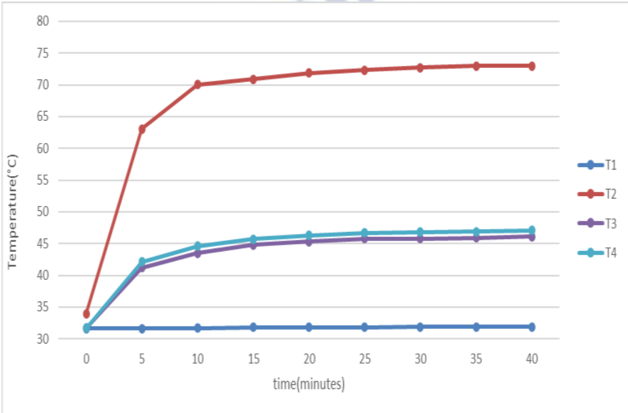
Graph 2: Temperature vs Time(A_i = 64 cm X 15 cm, A_o= 64 cm X 15 cm, H = 55 cm, Ø = 30°)



Graph 3: Temperature vs Time(A_i = 64 cm X 15 cm, A_o = 64 cm X 15 cm, H = 55 cm, Ø = 60°)



Graph 4: Temperature vs Time (A_i = 64 cm X 15 cm, A_o = 64 cm X 10 cm, H = 55 cm, Ø = 30°)



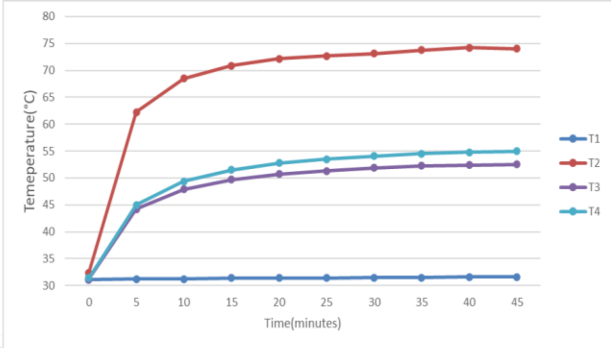
Graph 5: Temperature vs Time(A_i = 64 cm X 15 cm, A_o = 64 cm X 10 cm, H = 55 cm, Ø = 60°)

The values of graph 4 and graph 5 were taken from the experimental setups with constant outlet area of 64 cm X 10 cm and height 55 cm. The angle of absorber plate varied from 30° to 60°.

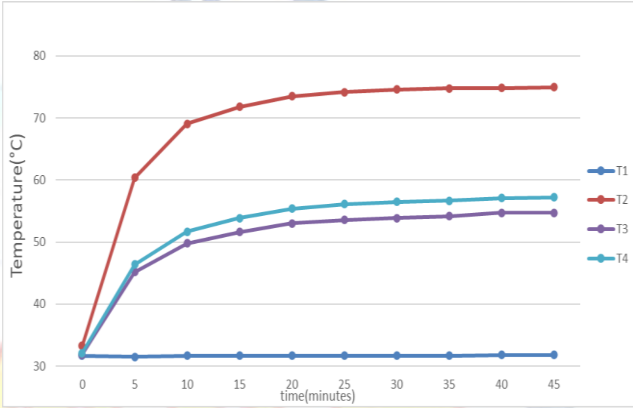
The highest temperatures of arrangement 5 had 49.8°C and 47.8°C of T_4 and T_3 respectively whereas arrangement 4 had 47.1°C and 46.1°C of T_4 and T_3 respectively. It is observed that arrangement 5 had higher temperatures which had 60° angle with horizontal.

Experimentation was done with other setups which had reduced outlet area to 64 cm X 05 cm. Keeping outlet area constant height of absorber plate and angle of absorber plate were varied.

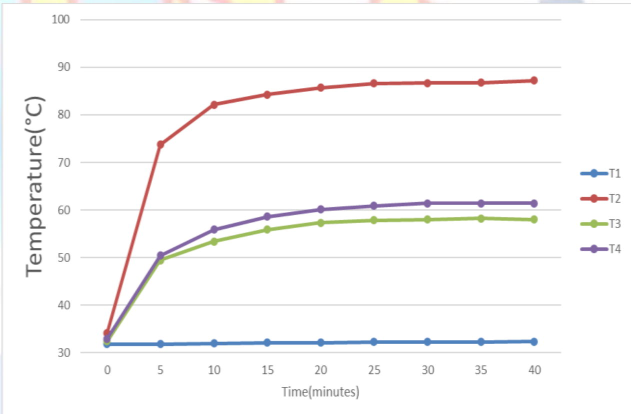
Arrangement 6 which had 30° and unraised absorber plate i.e., height(H) = 0 is experimented and values were taken and plotted graph between temperatures and time and plotted in graph 6. We got values of T_4 = 55°C and T_3 = 52.5°C



Graph 6: Temperature vs Time(A_i = 64 cm X 15 cm, A_o = 64 cm X 05 cm, H = 0 cm, Ø = 30°)



Graph 7: Temperature vs Time(A_i = 64 cm X 15 cm, A_o = 64 cm X 05 cm, H = 55 cm, Ø = 30°)



Graph 8: Temperature vs Time (A_i = 64 cm X 15 cm, A_o = 64 cm X 05 cm, H = 55 cm, Ø = 60°)

For the arrangements 7 and 8 constant height of absorber plate of 55 cm was applied, but the angle of absorber plate was varied from 30° to 60°and plotted the graphs 7(arrangement 7) and graphs 8(arrangement 8). arrangement 8 has highest outlet air temperatures i.e., T_4 = 61.4°C and T_3 = 58°C whereas arrangement 7 had T_4 = 57.2°C and T_3 = 54.2°C.

4. Conclusion

This experiment had been conducted on various parameters (different outlet areas, heights of absorber media and angle of absorber media) experimentally. These values of different experimental setups have evaluated. It was found that the outlet air temperatures depend on various factors such as outlet area, distance between the source and absorber and angle of absorber media with the horizontal. As the outlet area decreases the outlet area temperature increases and as distance between the sources and observer decreases the absorber media absorbs more radiation which results in more outlet temperature.The temperatures are dropping as outlet area increases, and it takes more time to attain steady state. When angle of absorber plate increases the temperatures are higher. When the outlet areas are 64 cm X 10 cm, 64 cm X 15 cm and 64 cm X 05 cm the maximum air temperatures at outlet are 49.8°C, 44.4°C and 61.4 °C which are at 10 cm distance from glass plate.The maximum outlet air temperature is observed for the setup which had outlet area of 64 cm X 05 cm and when absorber is raised by 55 cm with angle of 60° with horizontal.

From the findings, the study concludes that Flat Plate Solar Air Heater is useful for producing hot air which can be used for varies purposes such as in process of removal of moisture, energy production.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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