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Experimental Investigations on the Performance Evaluation of Zig-Zag Flow in a Solar Air Heater

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Abstract: Solar energy has great potential for low temperature applications, Particularly for agricultural products. This study focuses on the performance of zig-zag flow solar air heater. The fabrication of solar air heater with zig-zag flow was completed with conventional solar air heater. A uniform flow rate was maintained. Heat transfer rate and thermal efficiency of zig-zag flow solar air heater was higher than conventional solar air heater. Further ,when mass flow rate is changed, Heat transfer rate and thermal efficiency increases on experimental condition.
Keywords: Air heater, Radiation, Solar intensity, Efficiency, Zig-Zag flow.

I. INTRODUCTION

The combustion of fossil has caused serious air pollution problems in many areas because of the localized released of more amounts of released of more amount of harmful gases in the atmosphere. It has also resulted in the phenomenon of global warming which is now a matter of greater concern. The release of large amounts of waste heat from power plants has caused thermal pollution it takes and rivers leading to the destruction of many forms of plant and animal life. In the case of nuclear power plant is also concern over the possibility of radioactivity being released in to the atmosphere in the event of accident and over long terms of problems of disposal of radioactive waste from these plants. The environmental problems had not really been seen now, however as man on the earth on search for alternative sources of energy it is clear that he would do well to keep the environment in mind.

The solar option has been identified as one of the promising alternative energy source of the future. The nature of this source its magnitude and its characteristics have been described, and a classification of the various methods has been given.

II. SOLAR RADIATION

This chapter is concerned with the availability of solar radiation as an energy source. Extra -terrestrial radiation its spectral distribution and the radiation at the earth's surface is discussed. Instruments used for measuring solar radiation and methods used for presenting data are then described.

A. *Solar Radiation Of Outside The Earth's Atmosphere*

The sun is large sphere of very hot gases, the heat being generated by various kinds of fusion reactions. Its diameter is $1.39x10^6$ km, while that of the earth is $1.27x10^4$ km. The mean distance between two is $1.496x10^8$.Although the sun is larger , its subtends an angle of only 32 minutes at the earth's surface. This is because it is also at a very large distance .Thus radiation received from the sun on the earth is almost parallel. The brightness of the sun varies from its rate to this edge.

B. *Solar Radiation At Earth's Surface*

Solar radiation is received at the earth's surface in an attenuated from because it is subjected to the mechanism of scattering and it passes through the earth's atmosphere. Absorption occurs primarily because of the presence of ozone and water-vapor in the atmosphere, and to lesser extend other gases like co_2,co,o_2 and particulate matter. It results in an increase in the internal energy of the atmosphere.

C. *Pyranometer*

Solar radiation is usually measured with the help of pyranometer. A pyranometer is an instrument which either global or diffuse radiation over hemispherical field of view. The pyranometer is used commonly in India. It has its hot junction arranged in the form of a circular disc of diameter 25 mm and is coated with a special black lacquerer having a very high absorptive in the solar wave length of region. Two concentric hemisphere 30 and 50 mm in an diameter respectively made of optical glass having excellent transmission characteristics are used to protect the surface from the weather the accuracy of about (+)or(-) 2% can be obtained with instrument.

The pyranometer can also be used for measurement of diffuse radiation. This is done by mounting it at centre of a semicircular. The shading ring is fixed in such away that its plane is parallel to the path of the suns daily movement across domes of the pyranometer at all times for direct sunshine. Consequently the pyranometer measures only the diffuse radiation received from the sky. The pyronometer is mounted at the centre of the shading ring.

D. Solar Geometry

The amount of solar energy reaching the earth's surface was measured and that is thousand times greater than the present rate of fossil fuels. The energy is free, non-polluting and virtually inexhaustible. The above fact is true since the sun being nearest star to earth which is at an average distance of $1.5x10^8$ km from it with a solar interior constituting the main mass of the sun and gases at a pressure of one billion atmosphere and temperature ranging from $8x10^6$ to $40x10^6$k.The density is 80 to 100 times of the water. Most of the solar energy is generated because of the conversion of hydrogen ion into helium ion. The mass of helium necleus is less than that of four protons, mass have been lost in the reaction and converted into energy. The energy produced in the interior of the solar sphere is transferred to the surfaces and radiated in to space. The angle at which a beam or direct solar radiation strikes the earth surface is influenced by several factors pricipally, declination, latitude and the hour angle. Declination is defined as the sun's angular position at solar noon relative to the plane of equator and is caused by the earth's axis being tilted at $23^1/_2$ degree from the vertical to the earth orbital plane. The earth's annual orbit around the sun declination varies from $23^1/_2$ degree N of equator on june 21 to $23^1/_2$ degree S of the equator on december 21.

E. Solar Effects

The sun's great release energy is the result of an elaborate chemical process in the sun's core ,a process of thermo nuclear fusion like reaction in a hydrogen bomb. At tremendous heat of more than 45 million degrees Fahrenheit in the sun's interior ,hydrogen atoms fuels with helium atoms to produce the energy .So the energy can only be released in the form of radiation rays of heat energy.

F. Sun Earth Relationship

The eccentricity of the earth's orbit such that the distance between the sun and earth varies by 34%.The sun subtends at angles of 32^o E. The characteristics of the sun and spatial relationship to earth result in a nearly fixed intensity of solar radiation of the earth's atmosphere.

G. Solar Constants And Components

Ninety nine percent of the sun’s energy is contained within the wavelength 0.28 to 4.96m. the solar spectrum normally considered is terrestrial applications is 0.3 to 5m.

The solar constant is defined as the intensity of solar radiation essentially in this wave length range on the surface normal to the sun’s rays beyond the earth’s atmosphere at average earth-sun distances. Although atmosphere transmittance is a major uncertainty emission of energy by sun can be considered constant. However, because the earth’s orbit is slightly elliptical, the normal incidence intensity on extra terrestrial surfaces of irradiated area.

H. Solar Angles

Solar angles must be calculated to determine the intensity of direct solar radiation incident on a collector at as given instant or to complete the shading of a surface collector. The geometric relationship between planes oriented arbitrary relative to the earth such as a solar collector and the incoming beam of solar radiation. That is the position of the sun relative to the plane can be considered in terms of several angles.

I. Solar Air Heater

A conventional solar air heater generally consists of an absorber plate with a parallel plate below forming a passage of high aspect ratio through which the air to be heated flows. The use of air as a working fluid in a flat plate collector eliminates the need for a heat exchanger which is generally employed for transferring heat from liquid to air in a liquid flat plate collector.

The main difference between liquid flat plate collector and air collectors the mode of heat transfers between the absorber plate and the heated fluid. In liquid flat plate collector heat absorbed in the absorber plate is transferred to liquid tubes by conduction. So the liquid flat plate is constructed with the help of fin type arrangement, therefore a sheet of high thermal conductivity is required to work as an absorber plate in the case of liquid flat plate collector. In air collectors where the air stream can be in contact with the complete absorbing surface, So the plate conductivity is of small importance. This principle of solar air collector is virtually the same that of the liquid flat plate collector, air is circulated in contact with a black radiation absorbing surface which is usually overlaid by one or more transparent covers for heat loss reduction for practical and technical reasons heat is generally stored by transfer to a pebble bed when not needed, night air heating is than accomplished by circulating cool air through the warm pebble beds.

J. Types Of Air Heating Collectors

In the non porous type air stream does not flows through the absorber plate. The air may flow either above or below or both above and below the absorber plate in porous type the air passes through the absorbing material which includes slit and expanded metal.

K. Experimental Setup And Procedure

The experimental duct of mild steel, channel that includes three sections, namely entrance, test and exit sections. An aluminium zig-zag shape sheet of 1.2x0.7m size was used as absorber plate. Two glass plate were used as protection for heat loss from absorber plate to atmosphere. Air is sucked through, a rectangular duct by means of centrifugal blower. A gate valve is used to control the amount of air passing through the duct. The duct was covered with heat resistant material to minimize the heat loss to the surroundings. Air flow rate in the duct was measured by means if vane type anemometer. T type copper constant thermocouple were used for measurement of absorber plate temperature ,inlet, outlet glass plate temperatures. Pyranometer is used to measure solar intensity.
The performance test on zig-zag solar air heater was conducted by taking the observation on air velocity, absorber plate temperature, air outlet temperature, atmospheric temperature and pyranometer reading throughout the day and the observation for different ways with zig-zag solar air heater were tabulated.

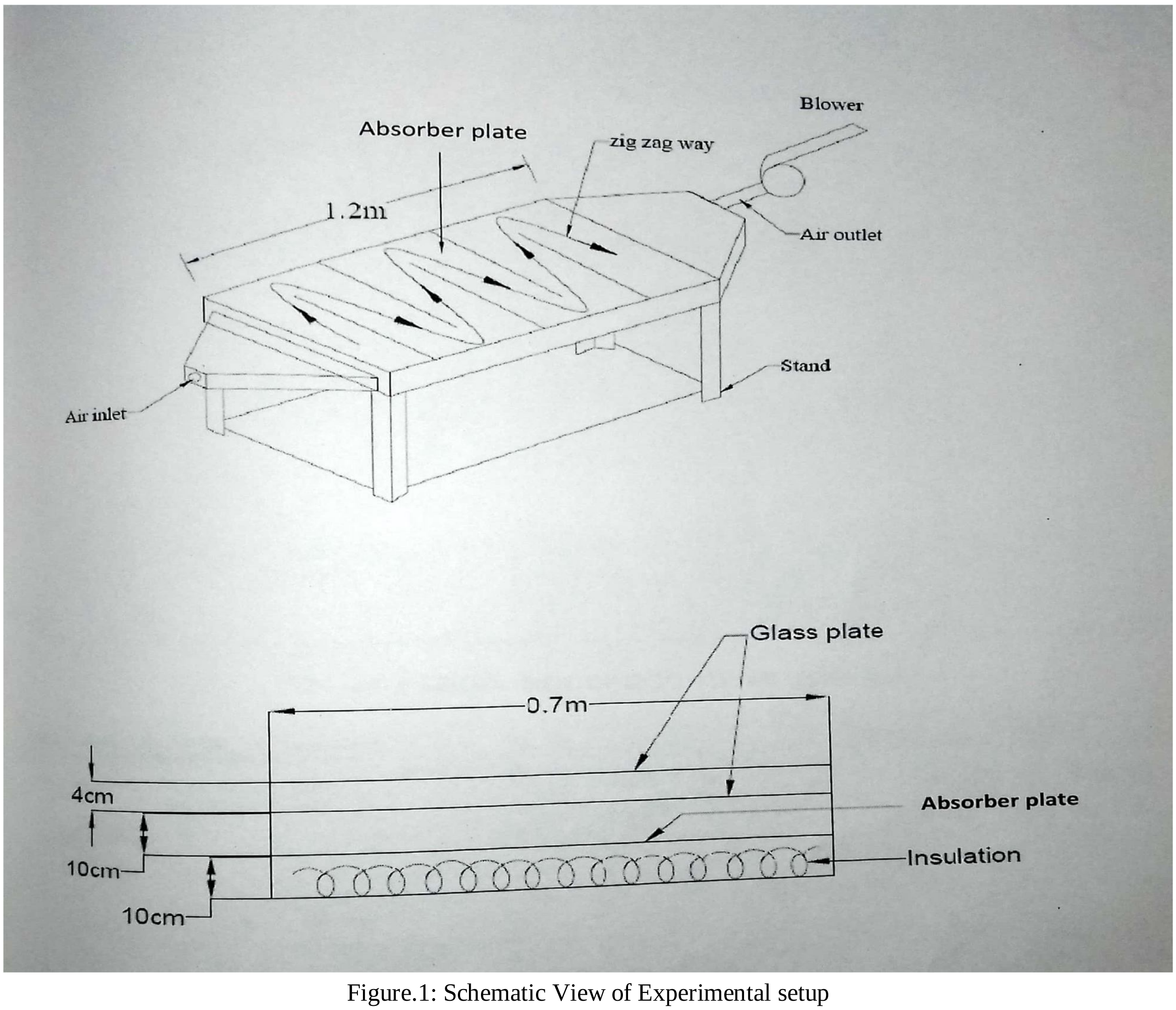

Figure.1: Schematic View of Experimental setup

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Figure.2: Photographic view of Zig-Zag Flow type experimental setup

Table.1: Observed Tabulation of Conventional Solar Air Heater

Sl. No.	Time of the Day	Absorber Plate Temp ^{O}C	Air Velocity m/s	Air Temp (inlet) ^{O}C	Air Temp. (Outlet) ^{O}C	Pyranometer reading (mv)	Solar Intensity (kJ/hr-m ^{2})	Glass Plate Temp. ^{O}C	
								Upper Glass Plate	Lower Glass Plate
1	11:00	71.6	3	33.4	52.3	6.6	2982.10	51.8	63.2
2	11:15	69.1	3	33.5	49.5	6.8	3072.46	49.3	56.4
3	11:30	54.6	3	33.6	45.2	6.1	2711.00	45.6	53.7
4	11:45	68.7	3	33.2	48.5	7.0	3162.84	47.8	53.7
5	12:00	50.2	3	33.8	43.4	6.8	3072.46	44.3	51.8
6	12:15	71.5	3	34.4	49.6	7.2	3253.20	50.1	54.2
7	12:30	75.9	3	34.2	53.1	7.2	3253.20	52.4	64.3
8	12.45	75.7	3	34.8	53.4	7.2	3523.20	53.7	60.8
9	01:00	76.2	3	36.4	54.2	7.2	3523.20	54.3	61.1
10	01.15	76.1	3	37.3	54.7	7.2	3523.20	55.2	61.3
11	01:30	77.0	3	38.1	56.3	7	3162.83	55.8	61.8
12	01:45	75.6	3	37.3	56.4	6.5	2936.92	55.6	62.1
13	02:00	76.5	3	38.5	54.2	6.6	2982.11	57.6	62.6

Table.2: Observed Tabulation of Zig-Zag Flow Solar Air Heater

Sl. No.	Time of the Day	Absorber Plate Temp ^{O}C	Air Velocity m/s	Air Temp (inlet) ^{O}C	Air Temp. (Outlet) ^{O}C	Pyranometer reading (mv)	Solar Intensity (kJ/hr-m ^{2})	Glass Plate Temp. ^{O}C	
								Upper Glass Plate	Lower Glass Plate
1	11:00	68.2	3	32..5	53.5	6.6	2982.10	48.2	56.2
2	11:15	64.5	3	32.8	50.2	6.8	3072.47	43.6	50.4
3	11:30	53.6	3	32.9	46.2	6.0	2711.00	42.8	50.2
4	11:45	63.6	3	33.3	49.6	7.0	3162.84	44.4	48.5
5	12:00	48.4	3	33.4	44.4	6.9	3117.65	41.4	48.8
6	12:15	65.5	3	33.5	51.2	7.2	3253.20	46.3	49.3
7	12:30	73.6	3	33.5	56.3	7.2	3253.20	49.0	59.4
8	12:45	70.4	3	34.6	56.7	7.2	3253.20	51.2	56.7
9	01:00	70.6	3	35.6	56.8	7.2	3253.20	50.6	56.7
10	01:15	70.6	3	35.8	56.8	7.2	3253.20	50.6	57.0
11	01:30	70.6	3	35.7	57.5	7.0	3162.84	51.8	57.7
12	01:45	69.1	3	34.8	56.4	6.5	2936.92	51.3	57.5
13	02:00	69.2	3	36.5	57.2	6.6	2982.10	52.7	57.8

III. RESULT AND DISCUSSION

Table. 3: Result Tabulation of Conventional Solar Air Heater

Sl.No.	Time of the day	Mass Flow Rate of Air (kg/hr)	Heat Gained by the air (kJ/hr)	Heat Available in the heater (kJ/hr)	Efficiency %
1	11:00	47.69	910.64	2504.96	36.35
2	11:15		762.06	2580.87	29.51
3	11:30		555.97	2277.23	24.42
4	11:45		685.36	2656.77	25.79
5	12:00		460.10	2618.82	17.56
6	12:15		728.51	2732.68	26.65
7	12:30		905.83	2732.68	33.15
8	12:45		891.45	2732.68	32.62
9	01:00		853.11	2732.68	31.22
10	01:15		833.95	2732.68	30.52
11	01:30		872.30	2656.78	32.84
12	01:45		915.42	2467.01	37.12
13	02:00		886.66	2504.95	35.39

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Table.4 : Result Tabulation of Zig-Zag Flow Solar Air Heater

Sl.No.	Time of the day	Mass Flow Rate of Air (kg/hr)	Heat Gained by the air (kJ/hr)	Heat Available in the heater (kJ/hr)	Efficiency %
1	11:00	47.50	1007.68	2504.96	40.22
2	11:15		830.98	2580.87	32.18
3	11:30		639.95	2277.24	28.11
4	11:45		773.67	2656.78	29.12
5	12:00		525.33	2618.83	20.06
6	12:15		845.30	2732.68	30.93
7	12:30		1088.86	2732.68	39.84
8	12:45		1060.21	2732.68	38.79
9	01:00		1012.46	2732.68	37.05
10	01:15		1002.90	2732.68	36.71
11	01:30		1031.55	2656.78	38.81
12	01:45		1031.55	2467.01	41.81
13	02:00		988.57	2504.96	39.46

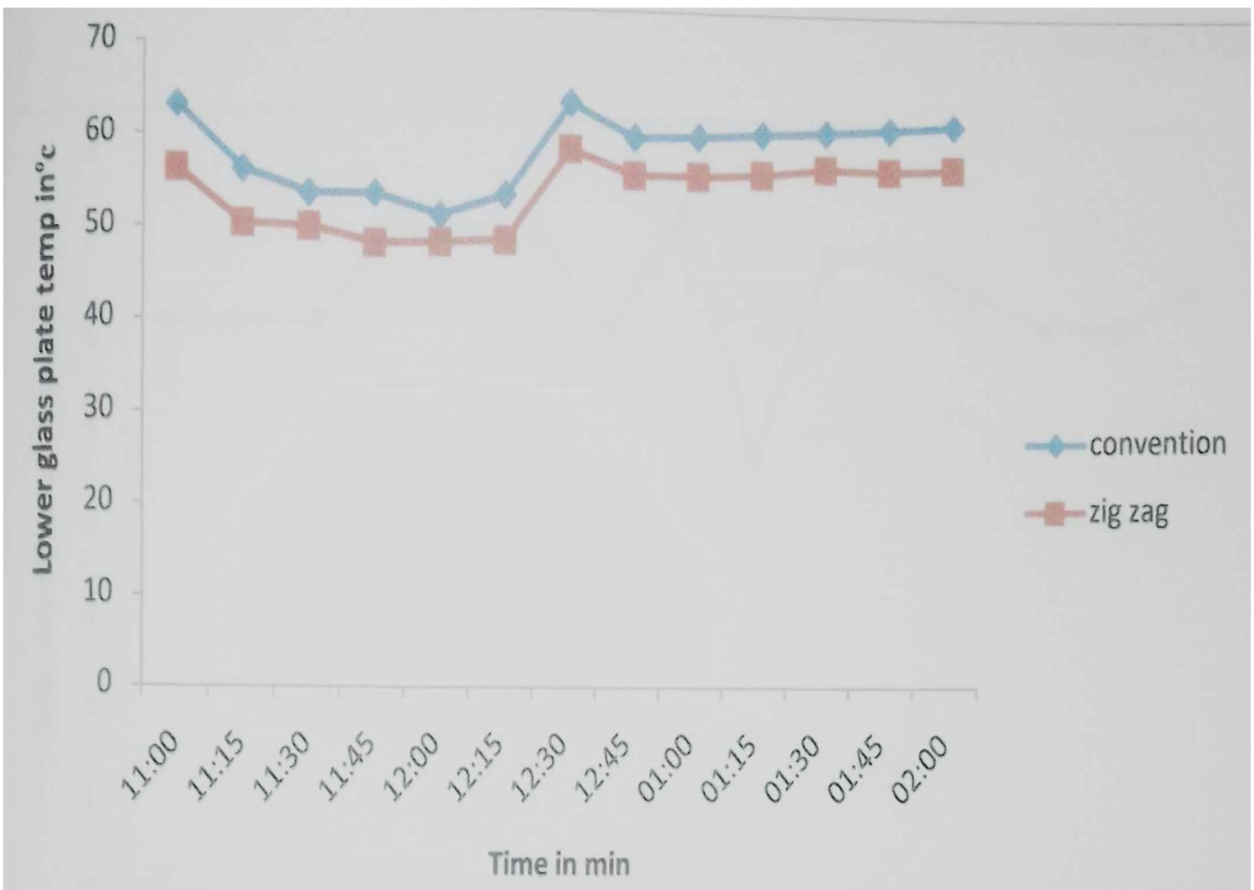

Figure.3: Time Vs Lower glass plate temperature

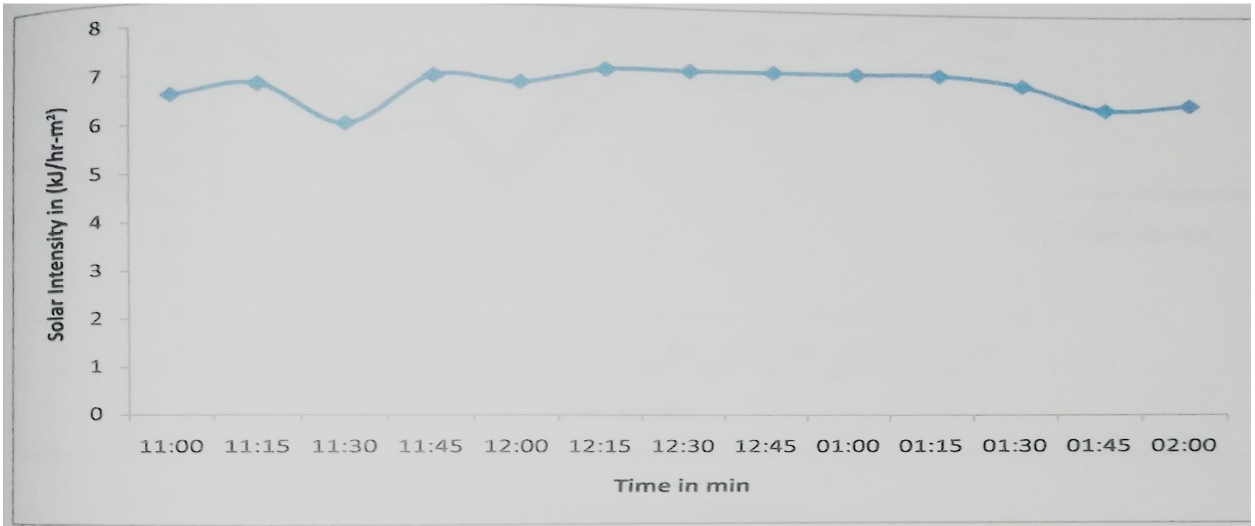

Figure.4 : Time Vs Solar Intensity

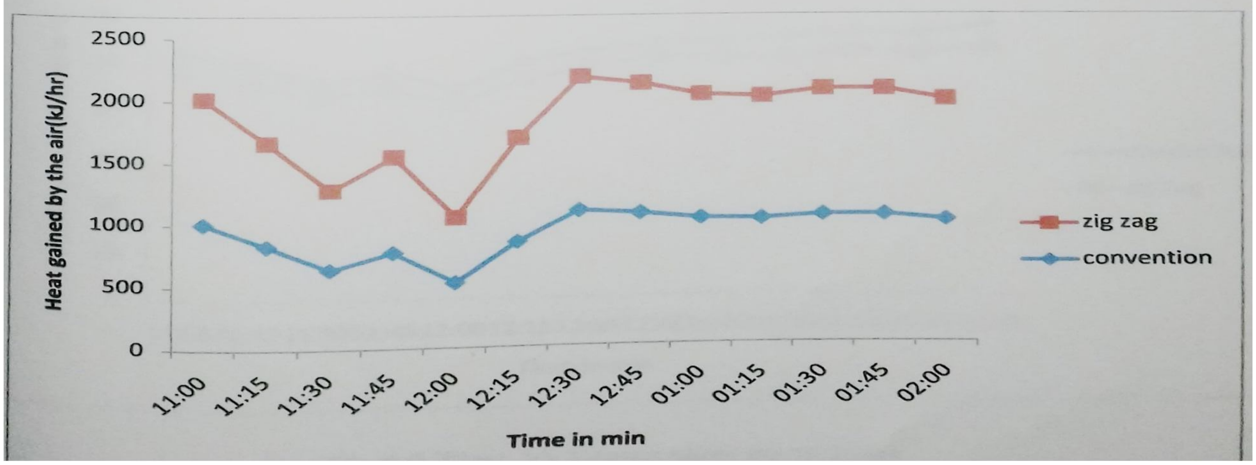

Figure.5: Time Vs Heat Gained by the Air

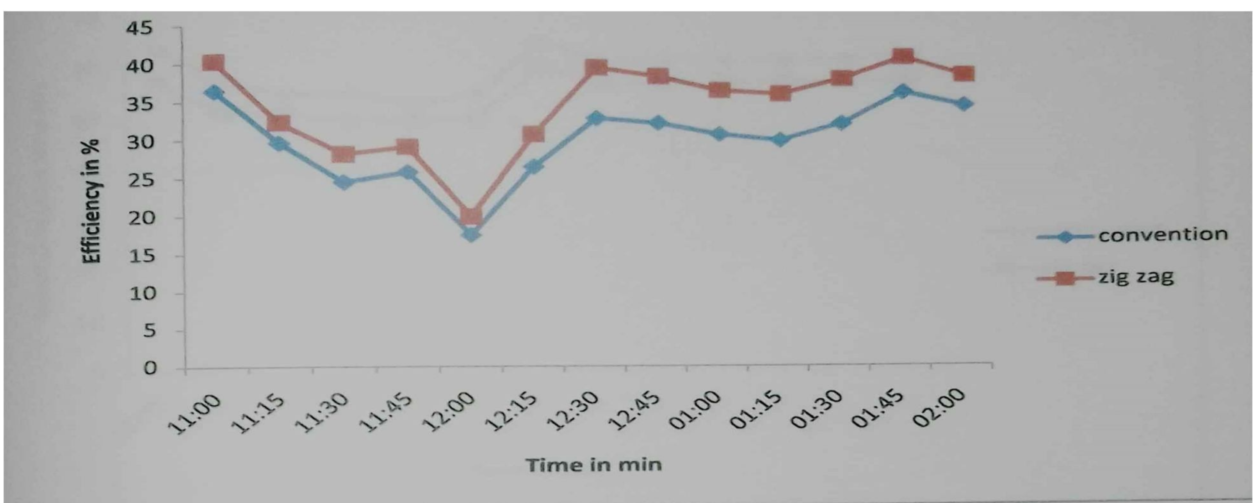

Figure.6: Time Vs Efficiency

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IV. CONCLUSION

Solar air heater with zig-zag flow was fabricated and the performance characteristics were studied at uniform mass flow rate and solar intensity.

Thermal efficiency is higher, when zig-zag flow absorber plate was employed.

When zig-zag absorber plate is used, a significant increase in heat transfer rate was achieved .

When mass flow rate is increased, heat transfer rate and the efficiency increases for both conventional and zig-zag way.

Low plate temperature is higher than upper plate as a result of lower convective heat loss from absorber plate to ambience.

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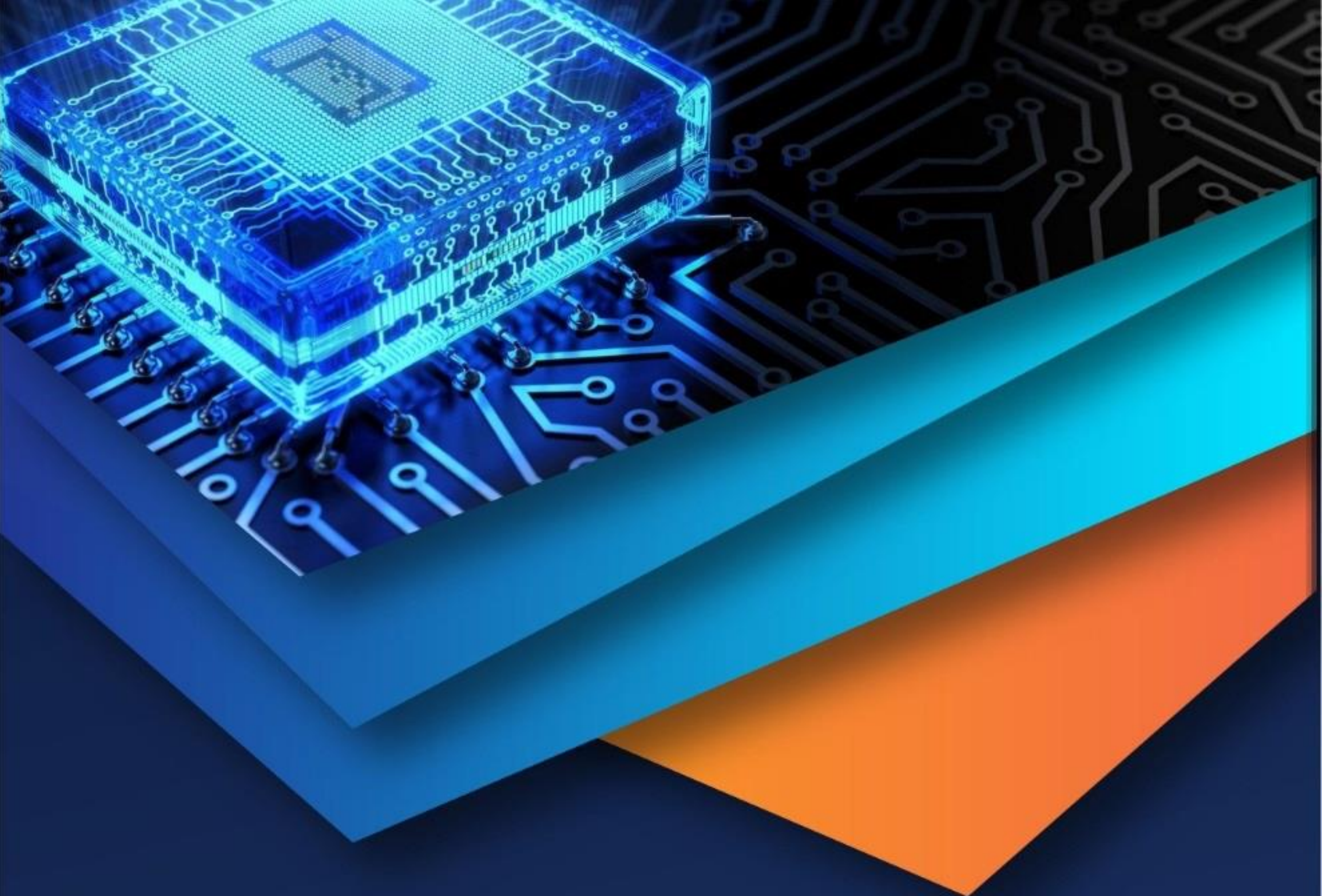

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