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Development of Solar Air Heater Using Compound Collector and Active Tracking

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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. In the solar-energy industry great emphasis has been place the development of "active" solar energy systems which involve the integration of several subsystems solar energy collectors, heat-storage containers, heat exchangers, fluid transport and distribution systems, and control systems. The major component unique to active systems is the solar collector.
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 warm air with constant heat input by varying the direction of the absorber plate and area of absorber plate. This device absorbs the incoming solar radiation, converting it into heat at the absorbing surface, and transfers this heat to a air flowing through the collector. From this experiment it is noticed that the maximum air temperature can be obtained at the collector outlet is 64°C. The warm air carries the heat, and it is utilized for drying applications, this is one of the low-cost warm air generation methods in the present scenario. Attempts have been made to improve the thermal performance of conventional solar air collectors by employing various design and flow arrangements. The pace of development of air heating collectors is slow compared to water heating collectors mainly due to lower thermal efficiency. Conventional solar air collectors have poor thermal efficiency due to high heat losses and low convective heat transfer coefficient between the absorber plate and flowing air stream.

Keyword:- Solar air heater, Active tracking, Compound effect, Flat plate collector

1. INTRODUCTION

1.1 Overview of Solar Energy

Solar power is the energy from the sun and without its presence, all the life on the earth would end. Solar energy has been looked upon as a serious source of energy for many years because of the vast amounts of energy that are made freely available. Harnessed by modern technology as shown in figure Simple example of the power of the sun can be seen by using a magnifying glass to focus the sun’s rays on a piece of paper. Before long the paper ignites to fames.

Figure: 1.1 solar energy

The simplest and the most efficient way to utilize solar energy is to convert it into thermal energy for heating application. The most important and basic components of the system required for conversion of solar energy into thermal energy are called solar collectors.

Advantages
- Solar energy does not cause pollution.
- Solar energy easily available without any cost.
- Solar energy available for 10 hour in day.
- Solar energy can be used in remote areas where it is too expensive to extend the electricity power grid.

- Many everyday items such as calculators and other low power consuming devices can be powered by solar energy effectively.

Nature has given us energy in many forms and this energy plays a key role in the industrial and economic growth of a country. The continuous growth of population and rising industrialization need large amounts of energy to quench their thirst for energy. Environmental degradation with use of fossil fuels is very dangerous to the life on earth. In view of world's depleting non-renewable reserves and environmental threats, development of technologies which make use of renewable energy sources is important. Among many renewable energy sources, solar energy is a huge energy source for meeting the demand and is everlasting. The freely available solar radiation provides an infinite and non-polluting reservoir of fuel. The Earth receives 174 pet watts (PW) of incoming solar radiation at the upper atmosphere. Approximately 30% is reflected to space while the rest is absorbed by clouds, oceans, and land masses.

The easiest way to utilize solar energy for heating applications is to convert it into thermal energy by using solar collectors. Flat-plate solar air collectors are extensively used as low temperature energy technologies which have attracted the attention of many scholars and scientists. Several designs of solar air heaters have been developed over the years in order to improve their performance. Generally, there are two types of flat-plate solar heating collectors: (a) Water heating collectors (b) Air heating collectors.

The pace of development of air heating collectors is slow compared to water heating collectors mainly due to lower thermal efficiency. Conventional solar air collectors have poor thermal efficiency due to high heat losses(because K low), low convective heat transfer coefficient(H) between the absorber plate and flowing air stream, however the low density and low specific heat of air requires high volume flow rates that may lead to high friction losses. Flat plate air collector is the key component of an active solar-heating system. It gathers the sun's energy and transforms its radiation into heat, then transfers that heat to the air. The heated air from the collector can be used for the application of space heating and crop drying and in chemical industries under forced mode of operation with air as a working fluid. There are generally two types of solar collectors: (1) Flat plate collector (2) Concentrator collectors.

The solar air heater occupies an important place among solar heating systems because of minimal use of materials. Furthermore, the direct use of air as the working substance reduces the number of required system components. The primary disadvantage of solar air heaters is the need for handling relatively large volumes of air with low thermal capacity as working fluid. The primary applications are space heating and drying.

Our design of a solar air heater has an extended heat-transfer area, arrangements for producing free convection and creation of air turbulence behind the heating surface as well as inclusion of strong forced convection. It is well known that the collector configuration influenced the fluid velocity and also the strength of forced convection. A simple procedure for changing the fluid velocity and the strength of forced convection involves adjusting the aspect ratio of a rectangular, flat-plate collector with constant flow rate the strength of forced convection may also be enhanced by placing parallel barriers on the flat-plate collector, thereby dividing the collector into several sub collectors. Flat-plate solar air heaters are no adiabatic radioactive heat exchangers; they are essentially used on low temperature levels in air heating and drying systems. The use of air as a heat transfer medium instead of water in solar collectors reduces the risks of corrosion and freezing and helps to reduce weight and costs of collectors.

1.2 Solar Air Heating

Solar Air Heating is the conversion of solar radiation to thermal heat. The thermal heat is absorbed and calmed by air which is delivered to a living or working space. The transparent property of air means that it does not directly absorb effective amounts of solar radiation, so an intermediate process is required to make this energy transfer possible and deliver the heated air into a living space. The technologies designed to facilitate this process are known as solar air heaters.

Solar air heaters operate on some of the most fundamental and simple thermodynamic principles: Absorption of the solar radiation by a solid body results in the body heating up. In broad terms this solid body is known as the collector. Some bodies are better at absorption than others, such as those with black non-reflective surfaces. Convection of heat from the heated solid body to the air as it passes over the surface.

Typically, a fan is used to force the air across the heated body, the fan can be solar powered, or mains powered. Different types of solar air heater Technology achieve this process using the same basic principles but using different solid bodies acting as the collector. The fan that transfers the air across the heated surface is also used as part of a ducting system to direct the heated air into the dwelling space. In addition to heating the air within that space, the heat can further be absorbed by thermal mass such as walls boring, furniture and other contents. Such heat is effectively stored and slowly dissipates beyond sunlight hours.

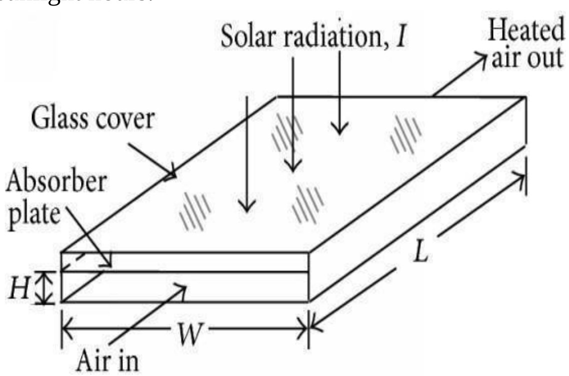

Figure 1.2 flat plate collectors

1.2.1 Solar Air Heater Advantages

- The need to transfer heat from working fluids to another fluid is eliminated as air is being used directly as the working substance.
- The system is compact and less complicated.
- Corrosion is a great problem in solar water heater. This problem is not experienced in solar air heaters.
- Freezing of working fluid virtually does not exist.

Thus, air heater can be designed using cheaper as well as lesser amount of material and it is simpler to use than the solar water heaters.

1.2.2 Solar Air Heater Disadvantages

- Thermal efficiency is less as compare to solar water heater.
- Efficiency less due high heat loss and high heat loss due low thermal conductivity of air.
- Efficiency less due to heat transfer coefficient of air low between absorber and air.
- Efficiency less due to high friction loss and high friction loss due to high volume flow rate and high volume flow rate due to low density and low specific heat.
- Solar air heaters can only be utilized efficiently on sunny days.
- It also depends upon the geographic location.
- Need to have large volumes of air for efficient use of solar air heaters.
- Thermal losses like convection and radiation take place.

1.2.3 Applications

The benefits of solar thermal air are often more than just heating. These are given below in diagram.

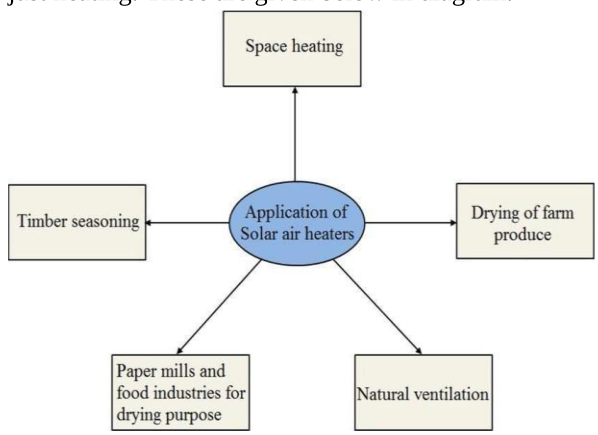

Figure 1.3 Application solar air heater

1.3 Motivation

The motivation for doing this project was primarily an interest in undertaking a challenging project in an interesting area of research i.e., how to use solar energy more efficiently. The fact is that the sun is the source of life and energy to all living creatures on the earth for millions of years. Energy is a vital need in all aspects and due to the increasing demand for energy coupled with its inefficient consumption, the environment has been polluted either directly or indirectly. To prevent this from becoming a global disaster, it is inevitable to strengthen efforts of energy generation and utilization using sustainable means and progressively substituting fossil fuels for renewable sources of energy. Solar energy has experienced a remarkable development in recent years because of cost reduction due to technological development and this is what has led us to make flat plate air collectors. Although we are doing this project with just waste cardboard, coke tins, PVC pipes. By using this waste, we are producing some amount of heat and power.

2. CONSTRUCTION AND WORKING

2.1 Stand
Base with two legs of different height are use to support the flat plate solar air heater collector. Base made with plywood with length = (120 cm) and width = (60 cm)
Two legs made with iron rod with different height.
Long leg height = (70 cm)
Short leg height = (30 cm)
Due to above arrangement, flat plate collector makes a (30) degree with horizontal

Figure 2.1 Stand

2.2 Battery
Battery is use as power source to run the electrical and electronics component of experimental arrangement. Here use battery with = (6) volt

Figure 2.2 Battery

2.3 Electronics control unit:
Electronics control unit contains many components like sensor, resistor, microcontroller, button, and wiring. Basically, it is the electronics part of tracking system which is useful for the absorb the more solar energy incident on earth by making source and absorber perpendicular to each other.
Sensor is of photovoltaic type are use here which sense the solar rays which is incident on flat plate solar air heater collector. After sensing solar energy, sensor transfer signal to the microcontroller. Microcontroller manipulates this signal and operates motor motion according to intensity of solar energy require for solar sir heater.

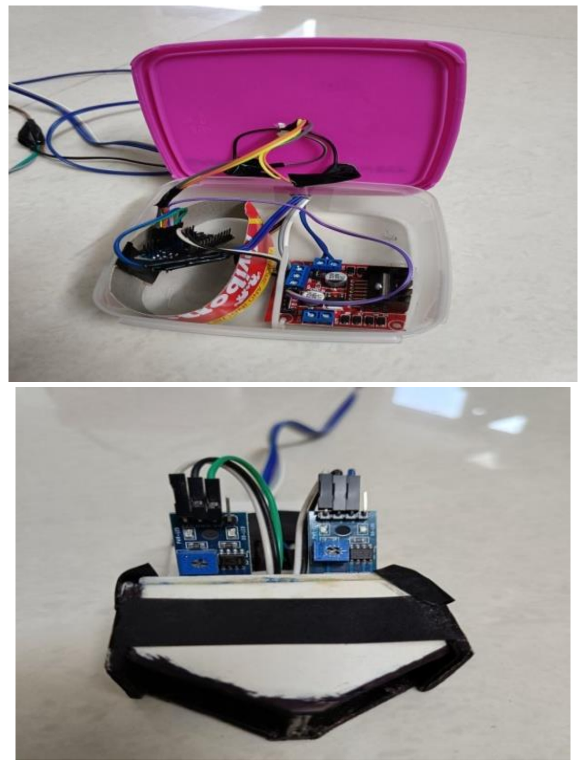

Figure 2.3 Electronics control unit

2.4 Motoring unit:
Motoring unit contain motor, reduction gear, pulley and v-belt. Basically, it is the mechanical part of tracking system which is useful for the absorb the more solar energy incident on earth by making source and absorber perpendicular to each other.
Motor motion control by microcontroller. Once the motor operate this motion transfer to reduction gear which reduce the motion further. Small pulley attach with reduction gear system. Bigger pulley attach with flat plate collector. This two pulley join with v-belt. This pulley arrangement tilts the flat plate collector towards the solar energy to absorb more energy. Pulley

diameter and gear teeth decide the reduction obtain the system.

Figure 2.4 Motoring unit

2.5 Solar air heater

Solar air heater is use to heat up the air by absorbing heat first by solid body and then transfer this heat to air which flowing over it. Solar air heater has rectangular shape has length = (90 cm) and width = (50 cm). Solar air heater has one inlet and one outlet which is made with pipe duct. Baffles of c shape use to increase the surface area of solar air heater for increase the compounding effect of heating.

(a) Surface area without baffle = (length * width) = 90*50 = 4500

(b) Baffle area = (2 * length * height) = 2*30*10 = 600

(c) Total baffle area = (b) * no. of baffle = 600*6 = 3600

(d) Surface area with baffle = (a) + (c) = 4500+3600 = 8100

Solar air heater consists of a black flat-plate absorber which has high absorptive power, a transparent glass cover that reduces heat losses and allows the transmittance of solar radiations. The fluid should have high heat transfer coefficient and a heat insulating backing. The absorber consists of a thin absorber sheet often backed by a grid or coil of fluid tubing placed in an insulated casing with a glass or polycarbonate cover which allows the radiation to fall upon the absorber plate.

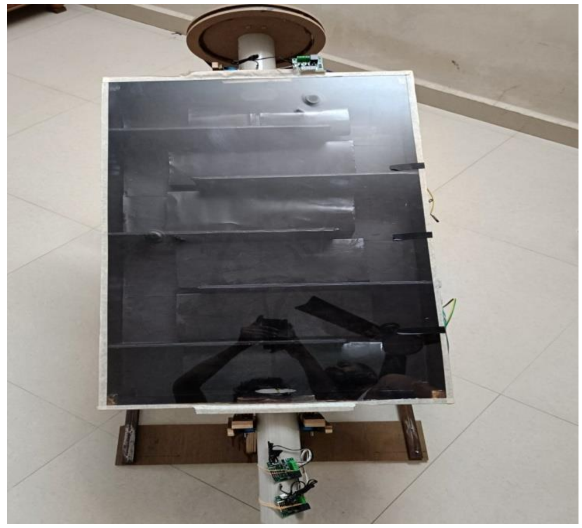

Figure 2.5 Solar air heater

2.6 Solar power meter

A solar power meter is a device that can measure solar power or sunlight in units of W/m2, either through windows to verify their efficiency or when installing solar power devices. Solar meters accumulate PV yield production and local energy consumption to monitor and analyze PV plant performance. Solar energy is measured in kilowatt hours - or with large solar energy systems, in megawatt hours

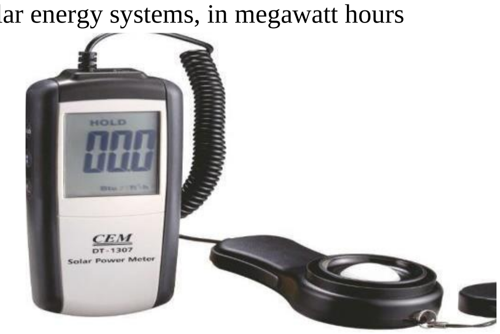

Figure 2.6 Solar power meter

2.7 Digital thermocouple

A digital thermocouple thermometer needs two measurements to determine temperature. First, it has a sensor to measure the temperature where the thermocouple connects to it, this is known as cold-junction compensation (CJC). Secondly, it measures the mV signal from the thermocouple. In order to determine the temperature at the end away from the thermometer, it subtracts the CJC temperature from the hot end signal and then converts that voltage to temperature.

Figure 2.7 Digital thermocouple

2.8 Final assembly

Figure 2.8 Final assembly

3. METHODOLOGY

3.1 Theoretical Formulae

Flat plate collector efficiency → $\eta = m*Cp*(to - ti) / A*G$

A = collector area (m2)

Cp = specific heat capacity of air at constant pressure (J/kg0C)

G = solar radiation incident on the collector (W/m2)

m = air flow rate (kg/sec)

ti = temperature of the inlet air(0C)

to = temperature of the outlet air (0C)

3.2 Experimentation

- Arrange the setup as shown in the above assembly figure.
- Arrange the flat plate collector in such a way that inclination of 30.
- Clean the flat plate collector before start experiment.
- Experiment should perform in clean weather for accurate reading.
- Experiment should perform in day time.
- Experiment should perform on place where shadow not disturbs the performance.
- Start reading from 8.00 mornings to 17.00 evening.
- Take reading in time gap of one hour.
- Check inlet and outlet temperature of air in flat plate collector.
- Take all reading after steady state condition attain.
- Assume mass flow rate of air 1 (kg/sec).
- Assume specific heat of air 1000 (J/kg0C).
- Calculate surface area of flat plate collector.
- Now check the solar radiation at each and every corner of the flat plate collector produced by the sun with the help of a solar power meter.
- Make observation table with four conditions.
- i.e. flat plate collector without compounding with tracking
- i.e. flat plate collector without compounding without tracking
- i.e. flat plate collector with compounding with tracking
- i.e. flat plate collector with compounding without tracking
- Compare all observation tables for find the best.

4. RESULT AND DISCUSSION

A flat plate solar air heater was experimentally analyzed for its thermal performance by varying surface areas and direction of tracking of the absorber plate. The test was performed between 26/03/2023 and 01/04/2023 in the summer months of Amravati (Maharashtra). The solar air heater was installed at an inclination of 30° horizontally. The incident radiation was applied in two ways one with tracking system and second with not tracking system. The surface area of collector varies by providing the attachable baffle of c section with increase the surface area of collector. Temperature readings were observed for every one hour between 8.00 mornings to 17.00 evening until the steady state of temperature.

In this experiment, I take four conditions for analysis of solar air heater with varying surface area and direction of tracking of the absorber plate. These conditions are as follows:-

- Flat plate collector without compound effect and without tracking
- Flat plate collector without compound effect and tracking
- Flat plate collector compound effect and without tracking
- Flat plate collector compound effect and with tracking

4.1 Flat plate collector without compound effect and without tracking

Timing	Inlet temp.(t1) In degree	Outlet temp.(t2) In degree	Change temp.(t2-t1) In degree	Surface area of collector In m2	Solar energy In w/m2	Efficiency
8.00 a.m.	30.5	31.4	0.9	0.45	325	6.15
9.00 a.m.	32.2	33.9	1.7	0.45	410	9.21
10.00 a.m.	34.6	36	1.4	0.45	530	5.87
11.00 a.m.	37.8	40	2.2	0.45	765	6.39
12.00 a.m.	41.4	45.8	4.4	0.45	982	9.95
13.00 p.m.	40.3	45.6	5.3	0.45	862	13.66
14.00 p.m.	39.7	42.2	2.5	0.45	784	7.08
15.00 p.m.	39.5	42.7	3.2	0.45	657	10.82
16.00 p.m.	38	40.7	2.7	0.45	598	10.03
17.00 p.m.	35	37	2	0.45	486	9.14

Table 4.1 Flat plate collector without compound effect and without tracking

4.2 Flat plate collector without compound effect and tracking

Timing	Inlet temp.(t1) In degree	Outlet temp.(t2) In degree	Change temp.(t2-t1) In degree	Surface area of collector In m2	Solar energy In w/m2	Efficiency
8.00 a.m.	30.5	32.4	1.9	0.45	425	9.93
9.00 a.m.	32.2	34.9	2.7	0.45	510	11.76
10.00 a.m.	34.6	37	2.4	0.45	630	8.46
11.00 a.m.	37.8	41	3.2	0.45	765	9.29
12.00 a.m.	41.4	46.8	5.4	0.45	982	12.21
13.00 p.m.	40.3	45.6	5.3	0.45	862	13.66
14.00 p.m.	39.7	43.2	3.5	0.45	784	9.92
15.00 p.m.	39.5	43.7	4.2	0.45	657	14.20
16.00 p.m.	38	41.7	3.7	0.45	598	13.74
17.00 p.m.	35	38	3	0.45	486	13.71

Table 4.2 Flat plate collector without compound effect and tracking

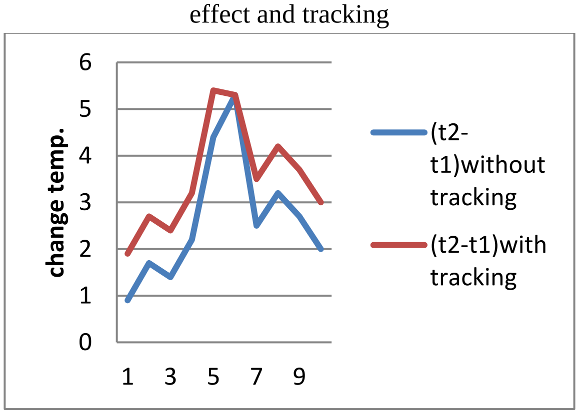

Figure 4.1 comparison of temperature change

The above graph shows comparison between tracking and without tracking conditions of temperature change. This graph shows clear indication that with tracking conditions contains more temperature change as compare to without racking conditions.

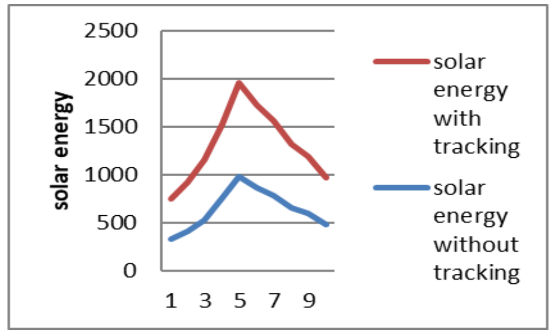

Figure 4.2 comparison of solar energy

The above graph shows comparison between tracking and without tracking conditions of solar energy incident on collector. This graph shows clear indication that with tracking conditions contains more solar energy incident on collector as compare to without racking conditions.

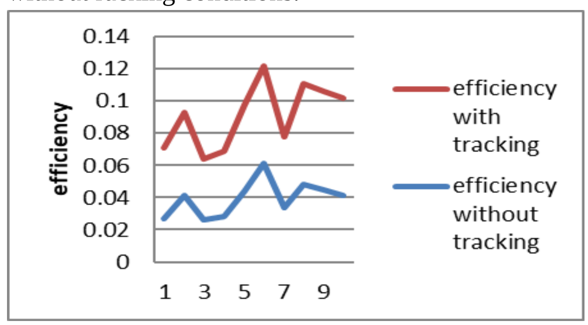

Figure 4.3 comparison of thermal efficiency

The above graph shows comparison between tracking and without tracking conditions of thermal efficiency of solar air heater. This graph shows clear indication that with tracking conditions contains more thermal efficiency solar air heater as compare to without racking conditions.

From that, I can say that tracking condition is more efficient than non tracking conditions.

4.3 Flat plate collector compound effect and without tracking

Timing	Inlet temp.(t1) In degree	Outlet temp.(t2) In degree	Change temp.(t2-t1) In degree	Surface area of collector In m2	Solar energy In w/m2	Efficiency
8.00 a.m.	30.5	33.4	2.9	0.81	325	11.01
9.00 a.m.	32.2	36.9	4.7	0.81	410	14.15
10.00 a.m.	34.6	38	3.4	0.81	530	7.91
11.00 a.m.	37.8	42	4.2	0.81	765	6.77
12.00 a.m.	41.4	49.8	8.4	0.81	982	10.56
13.00 p.m.	40.3	49.6	9.3	0.81	862	13.31
14.00 p.m.	39.7	48.2	8.5	0.81	784	13.38
15.00 p.m.	39.5	47.7	8.2	0.81	657	15.40
16.00 p.m.	38	45.7	7.7	0.81	598	19.89
17.00 p.m.	35	42	7	0.81	486	17.78

Table 4.3 Flat plate collector compound effect and without tracking

4.4 Flat plate collector compound effect and with tracking

Timing	Inlet temp.(t1) In degree	Outlet temp.(t2) In degree	Change temp.(t2-t1) In degree	Surface area of collector In m2	Solar energy In w/m2	Efficiency
8.00 a.m.	30.5	34	3.5	0.81	425	10.16
9.00 a.m.	32.2	37.2	5	0.81	510	12.10
10.00 a.m.	34.6	39.4	4.8	0.81	630	9.40
11.00 a.m.	37.8	43.2	5.4	0.81	765	8.71
12.00 a.m.	41.4	50.4	9	0.81	982	11.31
13.00 p.m.	40.3	50.1	9.8	0.81	862	14.03
14.00 p.m.	39.7	48.8	9.1	0.81	784	14.32
15.00 p.m.	39.5	48.2	8.7	0.81	657	16.34
16.00 p.m.	38	46.1	8.1	0.81	598	16.72
17.00 p.m.	35	42.8	7.8	0.81	486	19.81

Table 4.4 Flat plate collector compound effect and with tracking

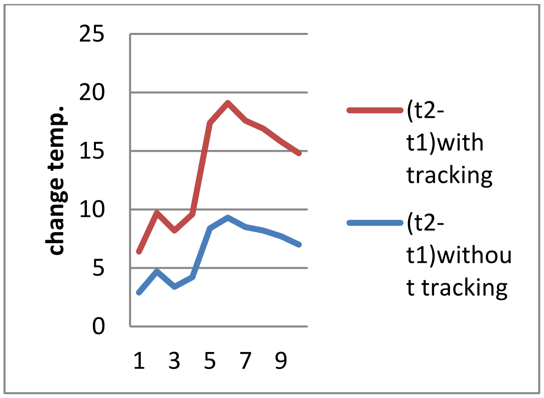

Figure 4.4 comparison of temperature change

The above graph shows comparison between tracking and without tracking conditions of temperature change. This graph shows clear indication that with tracking conditions contains more temperature change as compare to without racking conditions.

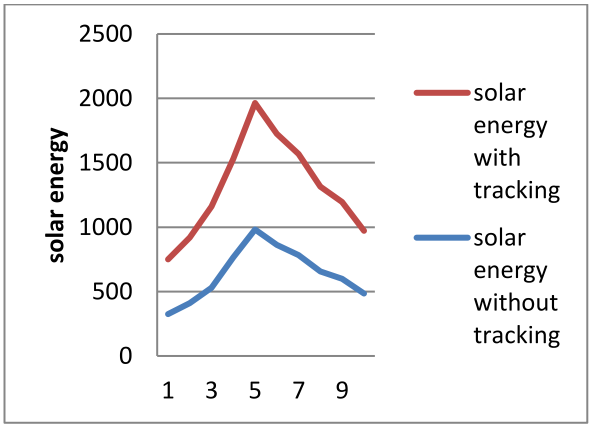

Figure 4.5 comparison of solar energy

The above graph shows comparison between tracking and without tracking conditions of solar energy incident on collector. This graph shows clear indication that with tracking conditions contains more solar energy incident on collector as compare to without racking conditions.

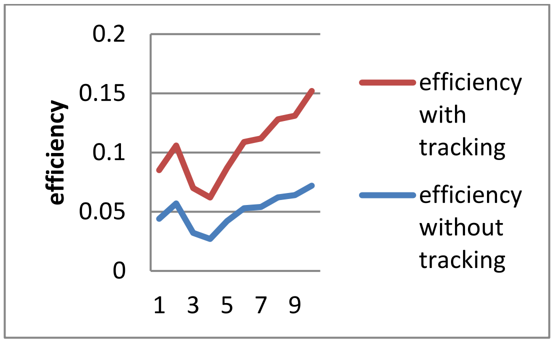

Figure 4.6 comparison of efficiency

The above graph shows comparison between tracking and without tracking conditions of thermal efficiency of solar air heater. This graph shows clear indication that with tracking conditions contains more thermal efficiency solar air heater as compare to without racking conditions.

From that, I can say that tracking condition is more efficient than non tracking conditions.

4.5 Flat plate collector without compound effect and tracking

Timing	Inlet temp.(t1) In degree	Outlet temp.(t2) In degree	Change temp.(t2-t1) In degree	Surface area of collector In m2	Solar energy In w/m2	Efficiency
8.00 a.m.	30.5	32.4	1.9	0.45	425	9.93
9.00 a.m.	32.2	34.9	2.7	0.45	510	11.76
10.00 a.m.	34.6	37	2.4	0.45	630	8.46
11.00 a.m.	37.8	41	3.2	0.45	765	9.29
12.00 a.m.	41.4	46.8	5.4	0.45	982	12.21
13.00 p.m.	40.3	45.6	5.3	0.45	862	13.66
14.00 p.m.	39.7	43.2	3.5	0.45	784	9.92
15.00 p.m.	39.5	43.7	4.2	0.45	657	14.20
16.00 p.m.	38	41.7	3.7	0.45	598	13.74
17.00 p.m.	35	38	3	0.45	486	13.71

Table 4.5 Flat plate collector without compound effect and trackin

4.6 Flat plate collector compound effect and with tracking

Timing	Inlet temp.(t1) In degree	Outlet temp.(t2) In degree	Change temp.(t2-t1) In degree	Surface area of collector In m2	Solar energy In w/m2	Efficiency
8.00 a.m.	30.5	34	3.5	0.81	425	10.16
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12.00 a.m.	41.4	50.4	9	0.81	982	11.31
13.00 p.m.	40.3	50.1	9.8	0.81	862	14.03
14.00 p.m.	39.7	48.8	9.1	0.81	784	14.32
15.00 p.m.	39.5	48.2	8.7	0.81	657	16.34
16.00 p.m.	38	46.1	8.1	0.81	598	16.72
17.00 p.m.	35	42.8	7.8	0.81	486	19.81

Table 4.6 Flat plate collector compound effect and with tracking

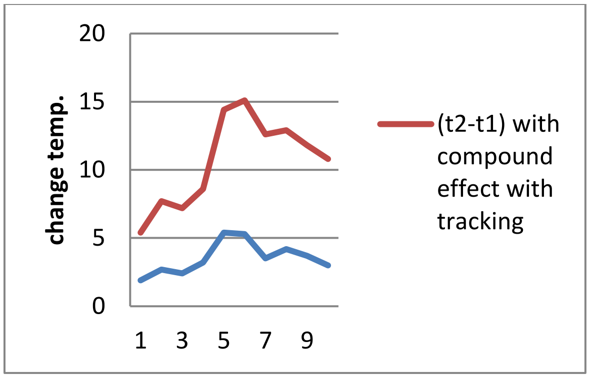

Figure 4.7 comparison of temperature change

The above graph shows comparison between with compound effect and without compound effect with tracking conditions of temperature change. This graph shows clear indication that with compound effect with tracking conditions contains more temperature change as compare to without compound effect with tracking conditions.

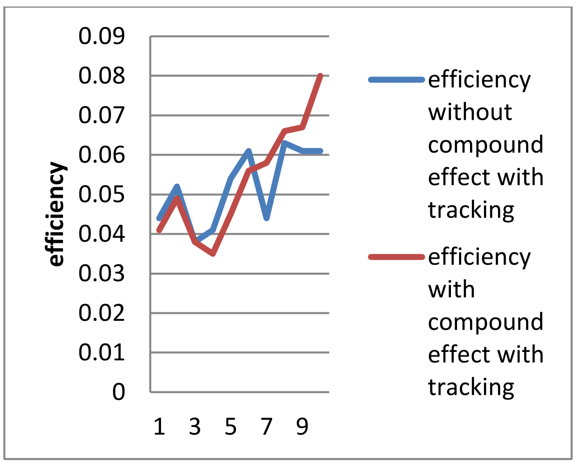

Figure 4.8 comparison of efficiency

The above graph shows comparison between with compound effect and without compound effect with tracking conditions of thermal efficiency of solar air heater. This graph shows clear indication that with compound effect with tracking conditions contains more thermal efficiency of solar heater as compare to without compound effect with tracking conditions.

All of form above graph, I can say that performance of solar air heater can we increase by increasing the surface area of collector means increasing the compounding effect of heating in collector and by increasing the solar energy which is incident on collector by continuous tracking of solar rays which should be perpendicular to the collector surface. So that I can able to absorb the more energy from sun for air heating.

5. CONCLUSION

This experimental study conducted on these different setups and evaluated and tabulated their values. The tests were conducted for different surface areas and tracking of absorber media. It was found that the outlet temperatures depend upon the surface area means compounding effect and angle between the source and absorber means tracking of solar energy with respect to absorber. As the surface area increases the outlet temperature increases and as the source and absorber perpendicular to each other the absorber media absorbs more radiation which results in more outlet temperature.

From these results the black absorber media absorbs more radiation resulting in an increase of heat absorption which increases air temperature at the outlet of the Solar Air Heater. The maximum outlet air temperature is observed for the setup which has compounding effect of heating and tracking system.

From the findings, the study concludes that flat plate solar air heater are useful for producing hot air which can be used for various purposes such as in process of removal of moisture, energy production etc.

FUTURE SCOPE:

Highly efficient and innovative solar thermal energy systems providing hot water, space heating and cooling can be developed. For a widespread market deployment of solar thermal systems, it is necessary to store heat (or cold) efficiently for longer periods of time to reach high solar fractions, and therefore efficient and cost-effective compact storage technologies have to be developed.

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