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ANALYSIS OF FLAT PLATE SOLAR COLLECTOR

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ABSTRACT: Flat-plate collectors are the most common for residential water-heating and space heating installations. A typical flat-plate collector consists of an absorber, transparent cover sheets and an insulated box. The absorber is usually a sheet of high-thermal conductivity metal with tubes or ducts either integral or attached. Its surface is painted or coated to maximize radiant energy absorption and in some cases to minimize radiant emission. The insulated box provides structure and sealing and reduces heat loss from the back or sides of the collector. The cover sheets, called glazing, allow sunlight to pass through to the absorber but insulate the space above the absorber to prevent cool air from flowing into this space. However, the glass also reflects a small part of the sunlight, which does not reach the absorber.

KEYWORDS: Solar Collector, Solar Air Collectors, Flat-plate

INTRODUCTION

1.1 General

Humans have always used the rays of the sun to gather their energy needs. In the energy needs today with increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such possibility is solar energy, which has become increasingly popular in recent year.

Solar energy is the radiation produced by nuclear fusion reactions in the core of the sun. This radiation travels to Earth through space in the form of energy called photons. Even though only 30% of the solar power actually reaches the Earth, every 20 minutes the sun produces enough power to supply the Earth with its needs for an entire year.

Unfortunately the atmosphere and clouds absorb a large amount of this sunlight. So the amount of light that reaches any point on the ground depends on the time of day, the day of the year, the amount of cloud cover, and the latitude at that point, with the solar focus directly dependent on three of these factors.

SOLAR COLLECTORS

Solar collectors are the key component of active solar-heating systems. They gather the sun's energy, transform its radiation into heat, and then transfer that heat to a fluid (usually water or air). The solar thermal energy can be used in solar water-heating systems, solar pool heaters, and solar space-heating systems.

There are a large number of solar collector designs that have shown to be functional. These designs are classified in two general types of solar collectors:

i. **Flat-plate Collectors** – the absorbing surface is approximately as large as the overall collector area that intercepts the sun's rays.
ii. **Concentrating Collectors** – large areas of mirrors or lenses focus the sunlight onto a smaller absorber.

LITERATURE REVIEW

Fabio. S [1] In the solar-energy industry great emphasis has been placed on 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.

Sunil.K.Amrutkar, et al[2]There are efficiency variation in given collectors with their given parameter, and also in cost, area, and its storage outlet temperature. But there is huge scope to reducing the collector area and minimizing the number of tubes which required for water circulation in collector assembly and its result at same outlet temperature reduce area and cost of collector by changing its geometric shape of flat plat collector.

1.3.1 Flat plate Solar Collectors

Flat-plate collectors are the most common for residential water-heating and space heating installations. A typical flat-plate collector consists of an absorber, transparent cover sheets and an insulated box. The absorber is usually a sheet of high-thermal conductivity metal with tubes or ducts either integral or attached. Its surface is painted or coated to maximize radiant energy absorption and in some cases to minimize radiant emission. The insulated box provides structure and sealing and reduces heat loss from the back or sides of the collector. The cover sheets, called glazing, allow sunlight to pass through to the absorber but insulate the space above the absorber to prevent cool air from flowing into this space.

FLAT PLATE SOLAR COLLECTOR

The absorber plate which covers the full aperture area of the collector must perform three functions: absorb the maximum possible amount of solar irradiance, transfer this heat into the working fluid at a minimum temperature difference and lose a minimum amount of heat back to the surroundings.
Solar irradiance passing through the glazing is absorbed directly onto the absorber plate. Surface coatings that have a high absorptive value for short-wavelength light are used on the absorber. Paint or plating is used and the resulting black surface will absorb almost over 95% of the incident radiation. The second function of the absorber plate is to transfer the absorbed energy into a heat-transfer fluid at a minimum temperature difference. This is achieved by conducting the absorbed heat to tubes that contain the heat-transfer fluid.

1.3 Further features of solar water collectors

The collector performance test data are associated with the collector temperature rises above correlation is normally the temperature of the heat transfer fluid entering the collector, not the average fluid temperature.
The use of fluid inlet temperature makes the application of the performance correlation easier in design studies; it also makes the correlation considerably more dependent on the flow rate of the heat-transfer fluid. Every correlation using fluid inlet temperature must specify the fluid flow rate at which the measurements were made. The recommended test flow rate for a liquid collector is 0.02 kg/hr.
Flat-plate collectors cost less than other types of collectors (i.e. concentrating, evacuated tube collectors), as they do not operate using a tracking system. In addition, today there are much more flat-plate than other types of collectors being produced. Due to their potential to produce more low-temperature energy for a given cost, flat plate collectors have been considered for use as pre-heaters for concentrating collectors in high-temperature industrial process heat systems.
Ambient divided by the solar irradiance. The collector temperature used for flat plate collector performance

1.4 Solar Air Collectors

Solar air collectors operate similarly to liquid collectors at the difference that air is circulated through the collector to cause of heat transfer. Air collectors are simple flat plate collectors used primarily for space heating.

The absorber plates in air collectors can be metal sheets, layers of screen, or non-metallic materials. Air collector absorber plates can be unfilled or wavy to create air turbulence that helps the heat to pass from the plate. The air flows through the absorber by natural convection or it is forced by a fan.

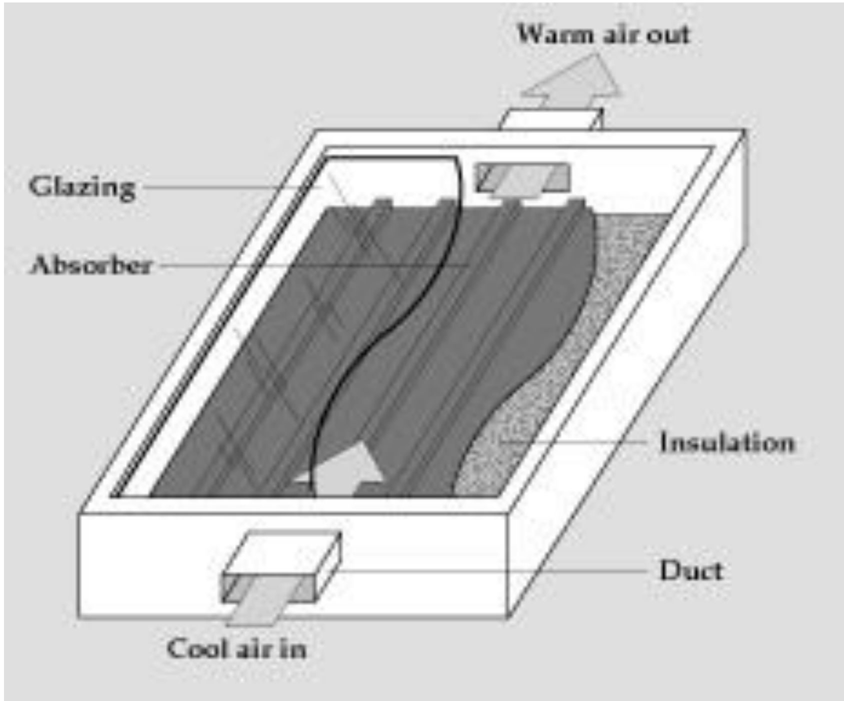

Fig. 1.3 Flat Plate Air Collector

As air conducts heat slower than liquid does, less heat is transferred between the air and the absorber than in a liquid collector. The disadvantage of this design is that it can also increase the amount of power needed for fans and hence increase the costs of operating the system

1.6 Concentrating Solar Collectors

Concentrating solar collectors are used when higher temperatures are required. Solar energy which is falling onto a large reflective surface is reflected onto a much smaller area before it is converted into heat. Most concentrating collectors can only concentrate the parallel isolation coming directly from the sun's beam and hence must follow (track) the sun’s direction across the sky. Three types of solar concentrators are in common use; central receivers, parabolic dishes and parabolic troughs.

1.6.1 Central Receiver System

A central receiver system illustrated consists of a large field of independently movable flat mirrors (heliostats) and a receiver located at the top of a tower.

Each heliostat moves about two axes throughout the day to keep the sun's rays reflected onto the receiver at the top of the tower. The amount of energy coming out of the sun rays when concentrated at one point (the tower in the middle) produces a range of temperatures between 550°C to 1500°C. This thermal energy can be used for heating water or molten salt, which saves the energy for a later use. The water changes to steam which is used to move the turbine-generator; hence thermal energy is converted into electricity.

Solar Dishes use a parabolic mirror to concentrate solar energy at its focal point. Then a receiver, mounted at the focal point, converts the energy of the sun’s rays into heat. The heat gained produces a temperature of between 650 ºC to 800 ºC and this is used to drive a Stirling Engine that generates electricity.

1.6.2 Parabolic Trough Collectors

A parabolic trough collector shown in Figure 1.6 has a linear parabolic-shaped reflector that focuses the sun's radiation onto a linear receiver tube located along the trough's focal line. The collector tracks the sun along one axis from east to west during the day to ensure that the sun is continuously focused on the receiver.

Mechanical drives slowly rotate the troughs during the day to keep the reflected sunlight focused onto the pipe receivers. The fluid flowing in the tube is heated in the range of 300 °C to 400 °C. The working fluid is heated as it circulates through the receivers and returns to a series of heat exchangers at a central location where the fluid is used to generate high-pressure superheated steam. The steam is then fed to a conventional steam turbine/generator to produce electricity. The solar trough generators operating today have gas-fired backup heaters so electricity can be generated during cloudy periods or at night.

1.7 Glazing

Glass is a good material for glazing flat plate solar collectors as it transmits almost 90% of the received shortwave solar radiation. Types of plastics can also be used as covers as few of them can endure ultraviolet radiation for a long time.

A design of the solar window was developed with the expectation to improve the performance of the solar energy collectors at high solar radiation incidences. The solar window was composed of two transparent plastic sheets of acrylic ribbed together. One of the inner surfaces of the solar window has triangular projection pairs separated from the adjacent projection pair by a distance equal to the width of the triangular projection pair at the top.

METHODOLOY

The absorber plates radiates back small amount of heat because of its higher temperature. This loss mechanism is a function of the emittance of the surface for low-temperature, long wavelength radiation. Many coatings that enhance the absorption of sunlight (short-wavelength radiation) also enhance the long wavelength radiation loss from the surface. An ideal coating will be a good absorber of short-wavelength solar irradiance and a poor emitter of long-wavelength radiant energy.

EXPERIMENTAL SETUP

All the experiments took place in the mechanical workshop in the Engineering Department at Sharda University, over a period of 6 months. The experimental work involved tests conducted with solar collector panel.

In solar water collectors, incident solar radiation is converted to heat and passed on to a working fluid such as water. Therefore effective heat transfer is important with the aim to assist energy conversion process.

OBSERVATION AND CALCULATION

Table 5.1: Observation and calculation of different parameters for 7th may 2016

S.NO.	Time	I (W/m^2)	T_{wi} (°C)	T_{wo} (°C)	T_G (°C)	T_C (°C)	T_a (°C)	η_{th}
1.	11:00 am	460	29.7	30.3	37.2	50.2	35	9.90
2.	11:15am	480	30.1	31	40	54	35.1	14.23
3.	11:30 am	500	30.5	31.5	41	55.1	35	15.18
4.	11:45am	550	30.5	33.3	41.5	55.2	35	38.65
5.	12:00 pm	650	32.8	36.1	39	55.3	35.1	38.54
6.	12:15 pm	670	32.8	37	43.5	60.5	36	47.59

7.	12:30 pm	680	32.8	37.8	44.1	58.9	36.1	55.82
8.	12:45 pm	690	33	38.1	43.8	60.6	36.1	56.11
9.	1:00 pm	710	33.1	38.1	43.7	58.9	36.1	53.46
10.	1:15 pm	715	33	37.9	40.8	57.9	36.8	52.02
11.	1:30 pm	725	33.1	38.2	43.7	60.1	37	53.40
12.	1:45 pm	730	33	38.1	43.2	55.6	37	53.03
13.	2:00 pm	745	33.1	38.2	41.7	52.8	36.9	51.97

RESULT & DISCUSSION

In this section graph has been plotted to show water inlet temperature, water outlet temperature, glass temperature and collector temperature at different time of the day. The graphs show that as the time of the day increases the mean temperature difference increases vice versa. The heat absorbed by the collector was observed to be higher at the beginning of the experiment and decreases steadily as the experiment progresses with time. This is because the temperature difference between the fluids collected at the outlet of the collector and the inlet of the collector decreases. Thereby, decreasing the heat absorbed by the collector.

Graph below shows the efficiency of the flat plate collector for increasing the temperature of inlet water at different time of the day. The efficiency of the collector was observed to be increasing at the beginning of the experiment and decreases steadily as the experiment progresses with time. This is because the temperature difference between the fluids collected at the outlet of the collector and the inlet of the collector decreases, thereby decreasing the heat absorbed by the collector and invariably causing a decrease in the efficiency of the flat plate collector.

The maximum efficiency of the flat plate collector was gotten as 4:00pm as 99.63 while the lowest is obtained at 11:00am as 9.90.

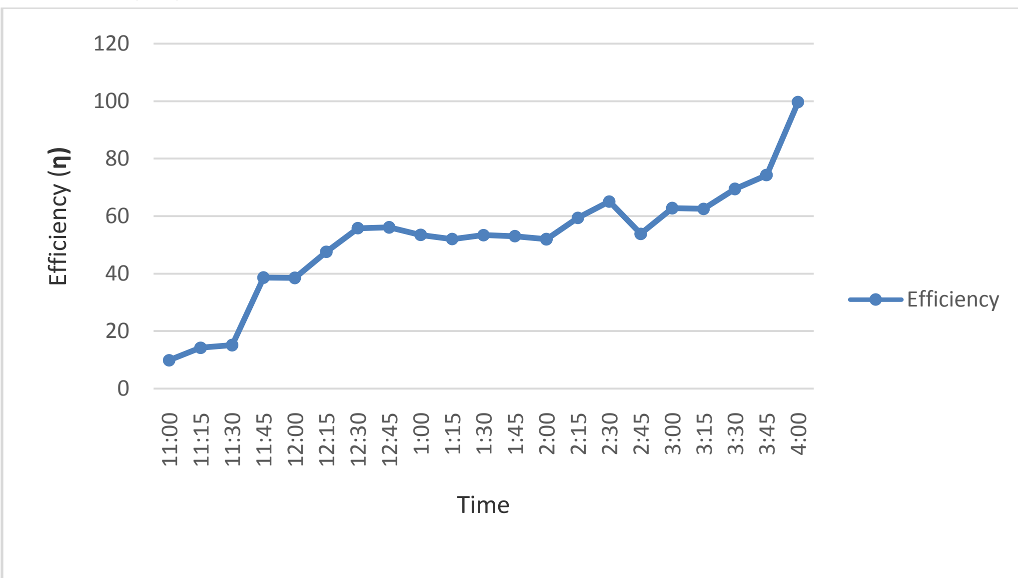

Fig. 6.3: Efficiency Vs Time on 7th may 2016

7 Graph obtained between efficiency and time on 8th may 2016 as given in table 5.2

Graph below shows the efficiency of the flat plate collector for increasing the temperature of inlet water at different time of the day. The efficiency of the collector was observed to be increasing at the beginning of the experiment and decreases steadily as the experiment progresses with time. This is because the temperature difference between the fluids collected at the outlet of the collector and the inlet of the collector decreases, thereby decreasing the heat absorbed by the collector and invariably causing a decrease in the efficiency of the flat plate collector.

The maximum efficiency of the flat plate collector was gotten as 4:00pm as 68.79 while the lowest is obtained at 11:00am as 40.48.

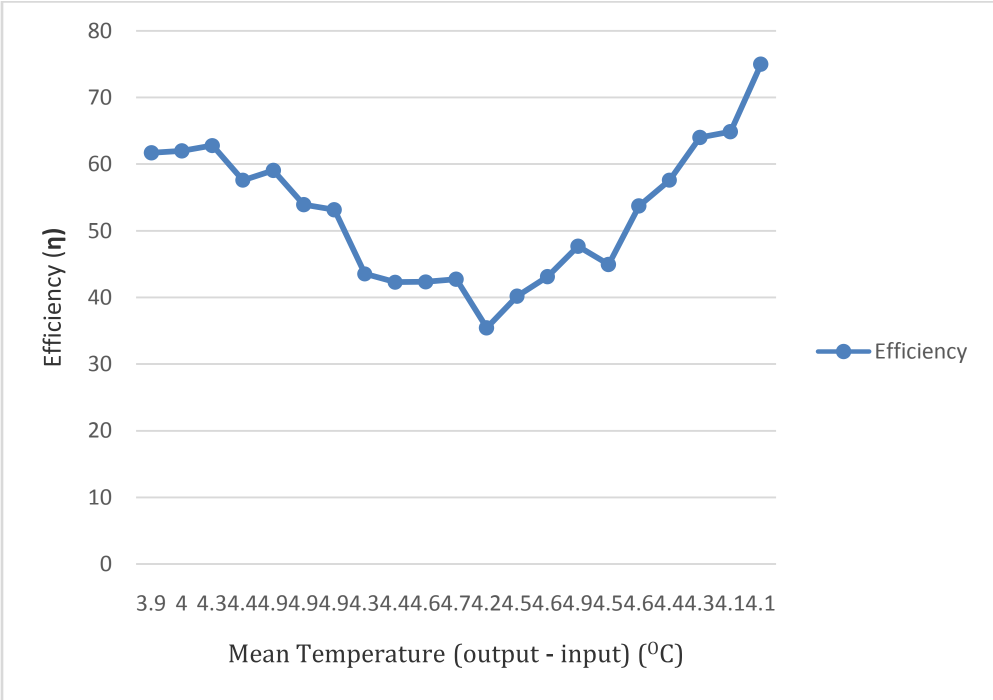

Fig. 6.12: Efficiency Vs Heat absorbed on 9th may 2016

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CONCLUSION

The following conclusion summarized for the work presented in this thesis:-

i. The efficiency of the collector was observed to be increasing at the beginning of the experiment and decreases steadily as the experiment progresses with time.
ii. The intensity of solar radiation is maximum at afternoon and decreases afterwards.
iii. The practical conclusion to be drawn from this is that, the higher the difference between the fluid at the outlet and the inlet the higher the efficiency of the collector.

REFERENCES

1. Fabio Struckmann , Analysis of a Flat Plate Collector ,2008 MVK 160 Heat and Mass Transport.
2. Sunil.K.Amrutkar, Saty Shree Ghodhe, Dr.K.N.Patil,Solar Flat Plate Collector Analysis, Vol.2 Issue 2, Feb.2012,pp.207-213.

3. Musallam Ahmed Tabook , Mohad Yusof Othman , Kamaruzzaman Sopian , MohdHafidz Ruslan, A Review Paper on PV/T Combination Flat Plate Collector System and Design , 2014©Available online at www. Worldessaysj.com
4. Sunil Chamoli ,Exergy analysis of a flat plate solar collector, GRDIMT Dehradun,Uttarakhand, India .
5. Zhong Ge , Huitao ,Hua Wang , Songyuan Zhang and Xin Guan, Exergy Analysis of Flat Plate Collectors , www.mdpi.com/journal/entropy.
6. Pravin N. Gajbhiye ,Rupesh S. Shelke . "Solar Energy Concentration Techniques In Flat plate Collector" . International Journal Of Mechanical Enginering And Technology (IJMET),Volume 3. September-December (2012),pp.450-158.
7. J.V. Bute, R.W. Pimpalshende , Dr. S.C.Kongre, Volume-3, Issuse 05,2015, "Developments in the Field of Solar Heater using Flat Plate Collector – A Review" , International Journal for Scientific Research and Development, ISSN : 2321-0613 .
8. Gambo Buhari Abubakar, Gerry Egbo , Volume-3, Issue-10, pp-34-40. "Performance Evaluation of Flat Plate Solar Collector (Model Te39) In Bauchi". American Journal of Engineering Research (AJER), e-ISSN : 2320-0847, p-ISSN : 2320-0936,
9. R. Herrero Martin, A. Garcia Pinar, J. Perez Garcia. "Experimental heat transfer research in enhanced flat- plate solar collectors". World Renewable Energy Congress 2011 – Sweden 8-13 May 2011 , Linkoping , Sweden.
10. Alvarez, M. Baz , O. Cabeza , J. L. Ferrin , L. M. Varela . "Experimental and numerical simulation of a storage tank connected to a flat – plate solar collector". International Conference on Renewable and Power Quality (ICREPQ 13) , ISSN 2172-038 X, No.11, March 2013.
11. Raj Thundil Karuppa R. , Pavan P. , Reddy Rajeev D. "Experimental Investigation of a New Solar Flat Plate Collector ". Research Journal of Engineering Sciences, ISSN 2278-9472, Vol. 1(4), 1-8. October (2012).
12. G.N TIWARI, SOLAR ENERGY" Fundamentals, Design, modelling and applications, handbook narosa publishing New Delhi 2013.