STUDY ON A FLAT PLATE SOLAR COLLECTOR: APPLICATION, PERFORMANCE & EFFICIENCY AT DIFFERENT FLOW RATES

Prakash Kumar Sen[1], Gayatri Choudhary[2], Shailendra Kumar Bohidar[3]

[1]*Student, M.Tech. Manufacturing Management, BITS Pilani (India)*

[2]*Student, Mechanical Engineering, Kirodamal Institute of Technology, Raigarh, Chhattisgarh, (India)*

[3]*Ph.D. Research Scholar, Kalinga University, Raipur (India)*

ABSTRACT

Solar energy is become an alternative for the limited fossil fuel resources. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat, which can be used in water heating systems. A commonly used solar collector is the flat-plate. Flat Plate Collector (FPC) is widely used for domestic hot-water, space heating/drying and for applications requiring fluid temperature less than 100oC. Three main components associated with FPC namely, absorber plate, top covers and heating pipes. The absorber plate is selective coated to have high absorptive. It receive heat by solar radiation and by conduction. Low emissivity coatings can significantly reduce radioactive heat losses of glass panes for solar energy use. Their effectiveness is strongly dependent on their optical properties, which need to meet the requirements for the specific application. The paper analyses the performance of newly developed. Two flat plate solar collectors for solar heating plants from Arson Solver A/S are tested in a laboratory test facility for solar collectors at Technical University of Denmark (DTU). The collectors are designed in the same way. However, one collector is equipped with an ETFE foil between the absorber and the cover glass and the other is without ETFE foil. The efficiencies for the collectors are tested at different flow rates. On the basis of the measured efficiencies, the efficiencies for the collectors as functions of flow rate are obtained. The calculated efficiencies are in good agreement with the measured efficiencies

Keywords: Flat Plate Collector, Efficiency of Collector, Solar Water Heating, Solar Energy.

I. INTRODUCTION

1.1 Solar Collectors

Solar collectors are the major component of active solar-heating system. They collect and store 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.[1] Solar energy is the most essential and economical of all energy forms. Renewable sources of energy from sun are fairly non-polluting and considered clean. Solar energy as the green and environmental friendly energy has produced energy for billions of years. Solar energy that reaches the earth is around 4x1015 MW and it is 200 times as large as the global utilization. [2] There are a large number of solar collector designs that have are functional.

These designs are classified in two general types of solar collectors:-

1) Flat-plate collectors – The absorbing surface is approximately as large as the overall collector area that intercepts the sun's rays.

2) Concentrating collectors – Large areas of mirrors or lenses focus the sunlight onto a smaller absorber.[3]

1.2 Heat Collectors

Solar collectors are either non-concentrating or concentrating. In the non-concentrating type, the collector area (i.e., the area that intercepts the solar radiation) is the same as the absorber area (i.e., the area absorbing the radiation). In these types the whole solar panel absorbs light. Concentrating collectors have a bigger interceptor than absorber. Flat-plate and evacuated-tube solar collectors are used to collect heat for space heating, domestic hot water or cooling with an absorption .[4]

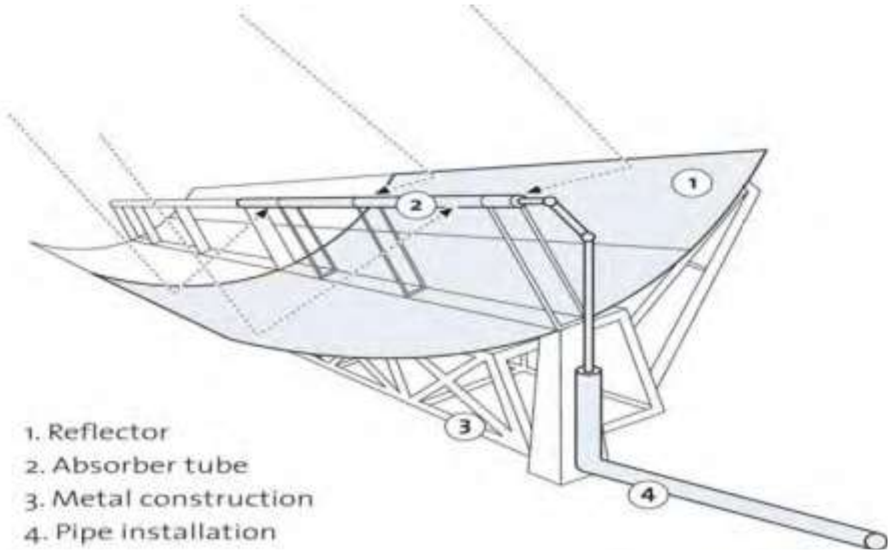

Figure 1.: Schematic of a Concentrating Solar Collector[5]

II. FLAT PLATE COLLECTOR

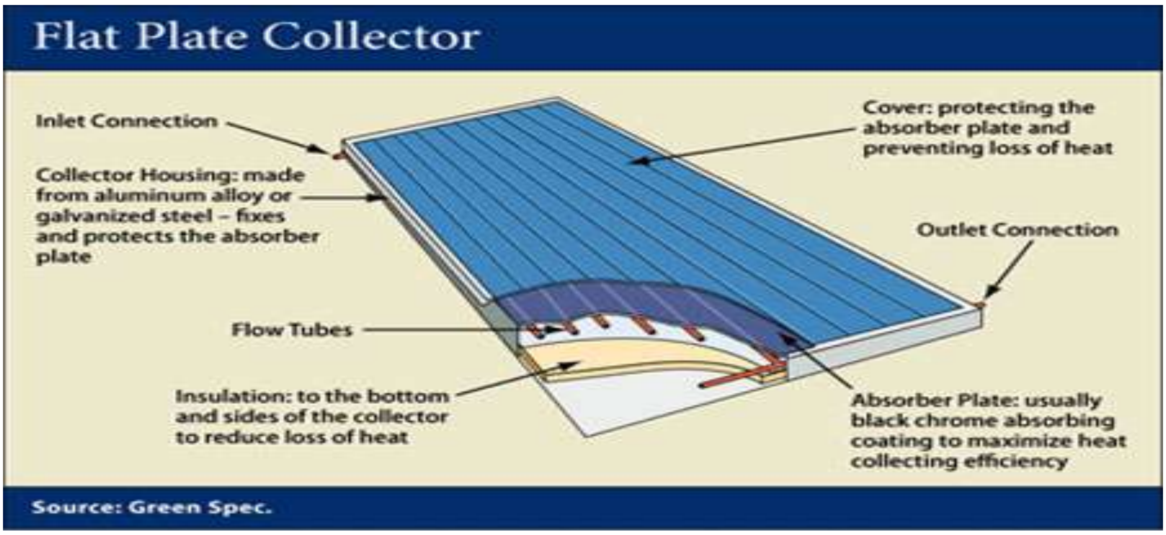

Fig2. Flat Plate Thermal System For Water Heating Deployed on a Flat Roof.

A typical flat-plate collector made up of an absorber which is in an insulated box together with transparent cover sheets (Glazing). The absorber is usually made up of a metal sheet of high thermal conductivity such as copper or aluminium, with integrated or attached tubes. Its surface is coated with a special selective material to maximize radiant energy absorption while minimizing radiant energy emission. The insulated box reduces heat losses from the back and sides of the collector. These collectors are used to heat a liquid or air to temperatures less than 680°C.[6] Flat plate collectors: in which absorbing surface is approximately as large as the overall collector are that intercepts the sun's rays. Concentrating collectors in which large areas of mirrors or lenses focus the Sun light onto a smaller absorber.[7]

Flat-plate collectors consist of

(1) a dark flat-plate absorber,

(2) a transparent cover that reduces heat losses,

(3) a heat-transport fluid (air, antifreeze or water) to remove heat from the absorber, and

(4) a heat insulating backing.[8]

Flat-plate collectors are in wide use for domestic household hot-water heating and for space heating, where the demand temperature is low. Many excellent models of flat-plate collectors are available commercially to the solar designer.[9] Solar flat plate collectors are used for water heating applications and the efficiency of these systems are around 70% which is very high as compared to solar direct energy conversion systems having efficiency around 17% [10].

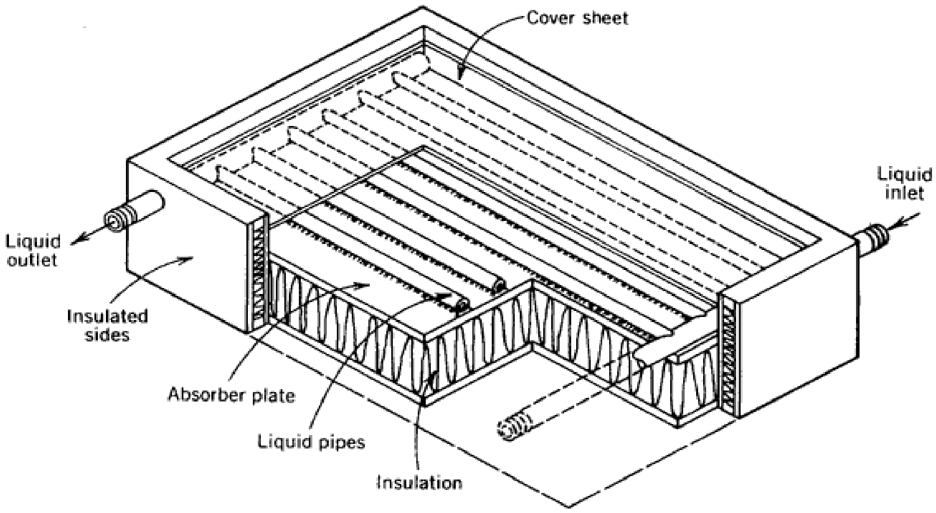

Figure 3: Cross-Section of a Typical Liquid Flat Plate Collector [11]

III. APPLICATION IN FLAT PLATE COLLECTOR

Based on the optical characteristics of the newly developed low-e glass its potential for the use in solar thermal flat plate collectors is investigated by means of calculation of the efficiency and the annual yield. The theoretical calculations are supported by experimental results for exemplary constructions. The basic data of the glass used for the comparative study are listed the selected values of solar transmittance and emissivity for the coated panes correspond to the optimum range, which is accessible by variation of the coating structure and the manufacturing parameters, according to the current state of development.

IV. PERFORMANCE

The performance of the solar thermal flat plate collector depends on the amount of solar insulations absorbed by the plate. The emissivity of the selective coated plate is Usually around 0.1 and that of glass cover lies between 0.85 - 0.88.[13] The major heat loss in the collector is from the top through the glass cover compared to bottom and side losses. The top loss coefficient from the collector is evaluated by considering both convection and radiation from the absorber plate to ambient. the collector efficiency under different conditions such as the absence of cover, with single and double glazing under different ambient conditions, tilt angles, wind speeds, emissivity of both glass cover and absorber plate.[14]

4.1 Collector concept

The aim of our research project is to develop a new high efficiency flat plate collector up to a prototype status. The general concept of this collector, as shown in Figure 1, is the combination of a standard flat plate collector and a low-e1 double-glazing. As these two components are standard industrial products, the fabrication of this collector can be highly automated, which provides benefits for the expected production costs.[15]

4.2 Design parameters and collector performance

We built a prototype collector with an indium tin oxide (ITO) low-e coating applied in the argon-filled glazing. The lower glass pane with a low iron content and coated on one side with the ITO coating system provides a solar transmittance (λ = 300 – 2500 nm) of 86.5 %. If an additional antireflective coating on the opposite side of the glass pane is applied, the solar transmittance is increased to 89 %. The low-e coating reduces the thermal emissivity from 83 % (uncoated glass) to 30 %. The gap sizes between the absorber and the glass panes are dimensioned to minimize convective heat losses depending on the used gas filling according to previous theoretical and experimental investigations [15].

4.3 Reliability of the collector

The significantly reduced heat losses through the insulated transparent cover lead to increased stagnation temperatures compared to a basic flat plate collector. Temperatures up to 264 °C were measured on the absorber plate at standard conditions (G = 1000 W/m², T_{amb} = 30 °C). Standard single glazed collectors with antireflective coated glass can reach a maximum temperature of only 210 °C. The collector components have to withstand the increased temperature loads. Investigations with different solar absorbers, varying the materials (copper, aluminum) and the piping geometry (harp, serpentine), were performed, with focus on the thermo-mechanical loads and esulting deformation at high temperatures. For details on these investigations, we refer to Ref. [16]

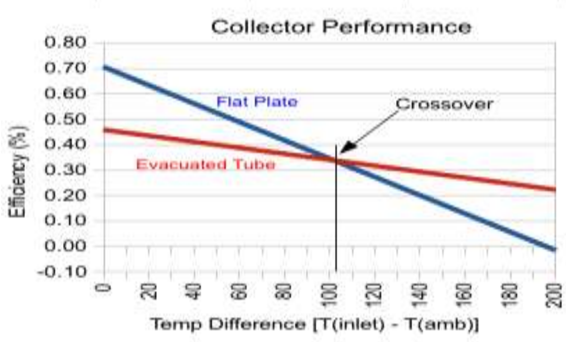

Fig.4:- Graph Between Efficiency & Temp Diff Of Collector Performance

V. EFFICIENCY

1. Theoretical Efficiencies of Flat Plate Solar Collectors

Based on the measured data of total solar irradiance, diffuse solar irradiance, volume flow rate of collector fluid, ambient temperature, mean temperature of collector fluid, wind speed as well as the geometric and physical parameters of the flat plate solar collectors, the efficiencies are calculated with SOLEFF. The measured and calculated efficiency points for the collector without ETFE foil and for the collector with ETFE foil under the same conditions

2. Efficiency of a Flat Plate Solar Collector as a Function of Flow Rates

As seen above there is a good agreement between measurements and calculations. Therefore the efficiencies both for the collector without ETFE foil and the collector with ETFE foil as a function of the volume flow rate and the reduced temperature difference T^{*}_{m} can be developed with SOLEFF. Assuming a 40% concentration of propylene glycol/water mixture, 1000 W/m2 of total solar irradiance, ambient temperature of 20 °C, wind speed of 2 m/s and a diffuse irradiance of 110 W/m2, mean temperature of collector fluid lower than 100 °C and a volume flow rate between 5 l/min and 25 l/min,

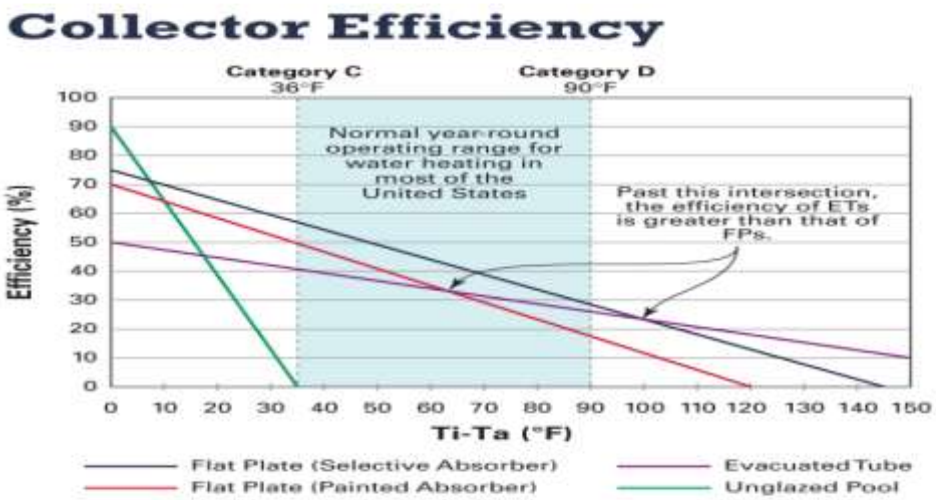

Fig.5:- Graphical Representation of Collector Efficiency

VI. CONCLUSION

Theoretical and experimental analysis is performed on a flat plate collector with a single glass cover. It can be concluded that the emissivity of the absorber plate has a significant impact on the top loss coefficient and consequently on the efficiency of the Flat plate collector. The efficiency of FPC is found to increase with increasing ambient temperature. Using the solar fuel with in solar collector application have enormous potential in the future and is under global focus to attain clean and green energy. A detailed mathematical derivation for the flat-plate solar collector cross sections (cover, air gap, absorber, working fluid, and insulation) was presented. A way to describe the thermal performance of a Flat Plate Solar collector has been shown. The most important measure is the collector efficiency. A more precise and detailed analysis should include the fact, that the overall heat loss coefficient

REFERENCE

[1]. Cooper, P.I.; Dunkle, R.V., 1981, "A non-linear flat-plate collector model", Solar Energy Vol. 26, Issue 2 pp. 133-140.

[2]. Wen D, Ding Y. Experimental investigation into convective heat transfer of nanofluids at the entrance region under laminar flow conditions. International Journal of Heat and Mass Transfer.2004a; 47: 5181-5188

[3]. Anderson T., Duke M., and Carson J., 2010, The effect of color on the thermal performance of building integrated solar collectors, Solar Energy Materials & solar cells, 94, 350-354

[4]. Norton, Brian (2013). Harnessing Solar Energy. Springer. ISBN 978-94-007-7275-5.

[5]. http://asolarheater.net/1198-solar-trough-collectors.html]

[6]. Augustus M. and Kumar S., 2007, Mathematical modeling and thermal performance analysis of unglazed transpired solar collectors, Solar Energy, 81,62-75.

[7]. B. Kundu, Performance analysis and optimization of absorber plates of different geometry for a flat-plate solar collector: A comparative study, Applied Thermal Engineering 22 (2002) 999–1012

[8]. rise.org.au. "Domestic Hot Water Systems". Retrieved 2008-10-29.[dead link]

[9]. ASHRAE (1977), "Methods of Testing to Determine the thermal Performance of Solar Collectors," ASHRAE Standard 93-77, American Society for Heating, Refrigeration, and Air -Conditioning Engineering, New York

[10]. Jaisankar S, Ananth J, Thulasi S, Jayasuthakar ST, Sheeba KN. A comprehensive review on solar water heaters. Renewable and Sustainable Energy Reviews.2011; 15-6: 3045-3050

[11]. Close D., 1967, A design approach for solar processes, Solar Energy, 11, 112

[13]. H. Tabor, Radiation. 1985. Convection and conduction coefficients in solar collectors, Bull. Res. Council of Israel. 6C. pp. 155-176.

[14]. K. G. T. Hollands, T. E. Unney, G. D. Raithby and L. Konicek. 1976. Free convective heat transfer across inclined air layers, J. Heat Transfer,Trans.ASME. 98(2): 189-193

[15]. Föste S. Flachkollektor mit selektiv beschichteter Zweischeibenverglasung (in German). PhD Thesis, Leibniz University Hanover, April 2013.

[16]. Föste S; Müller S, Giovannetti F, Rockendorf G. Temperaturbedingte Verformung von Absorbern in hocheffizienten Flachkollektoren (in German). Tagungsband 23. Symposium Thermische Solarenergie, Bad Staffelstein, May 2013.