Efficiency and Performance Improvement by New Development in Solar Liquid Flat Plate Collector

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Abstract— Solar energy is the better alternative source due to its availability all over the world. There are many devices are developed which replaces the use of conventional energy sources by the solar energy. There are various types of solar collectors which converts solar energy into useful heat energy. The main criterion for the selection of collector is the temperature of working medium required for the application. The paper reviews the effect of various parameters which influence the performance of solar flat plate collector. Various researchers have carried out numbers of experiments and studied the performance of solar flat plat collector by changing the various criteria like material of absorber plate, size and material of fluid tubes, use of glass covers, insulation material, spacing between absorber plate and cover, use of Nano-fluid etc. and concluded that increase in the thermal efficiency of solar flat plate collector in comparison to conventional solar flat plate collector. The paper gives the idea regarding selection criteria to create the best design and operational conditions with the best economic characteristics for solar flat plate collectors.

Key words: Solar Energy, Solar Liquid Flat Plate Collector

I. INTRODUCTION

The flat plate collectors are the commonly used device for residential water and space-heating applications. Solar collectors have potential to fulfill the industrial process heating demands which helps in the saving of electric energy. Basically, solar collectors are used for the low temperature application due to its operating simplicity. From the non-concentrating collectors liquid flat plate solar collector (LFPSC) is much preferable because of its design simplicity and more reliability. The main purpose of this paper is to give the selection criteria to create the best design and operational conditions with the best economic characteristics for solar flat plate collectors.

II. EFFECTS OF VARIOUS PARAMETERS ON THE PERFORMANCE OF FPC

There are number of various parameters influence the performance of a liquid flat Plate collector. These parameters could be classified as Design parameters, operational parameters, meteorological parameters, Environmental parameters.

From this point of view following parameters are more effective to affecting the performance of LFPC.

A. Selective Surface

Absorber plate surface which exhibit the characteristics of high value of absorptivity for incoming solar radiation and a low value of emissivity for outgoing re-radiation are called selective surfaces. Such surfaces are desirable because they maximize the absorption of solar energy and minimize the emission of the radiative losses. The CuO layer was formed by chemical conversion, by treating a cleaned and polished copper plate in a hot solution of sodium hydroxide and sodium chloride for a specified time. The nickel black coating-value of α is 0.81 and emissivity is 0.16 to 0.18.Black crome-Cr_2O_3 Value of absorptivity (α) and emissivity (ϵ) for this surface are 0.95 to 0.97 and 0.09 to 0.15 respectively and also the value of absorptivity and emissivity for CuO are 0.08 to 0.93 and 0.09 to 0.21respectively.

B. Number of Glass Covers

For selective surfaces of absorber plate, the highest value of efficiency is obtained with one glass cover and with the addition of more covers, the efficiency decreases. For non-selective surfaces of absorber plate the efficiency increases when the number of glass covers is increased from one to two. Thereafter the efficiency decreases with the addition of more covers for non-selective surfaces. It is optimum to use only one glass cover if the absorber plate surface is selective and two glass covers if the surfaces are non-selective.

C. Spacing

The proper spacing to be kept between the absorber plate and first cover, or between two Covers at from the point of view of heat loss from the top, spacing must be such that the values of convective heat transfer coefficient are minimized. Spacing from 4 to 8 cm has been suggested by Buchberg *et al*.

D. Collector Tilt

The collector is tilted at some angle to absorb the maximum radiation. Optimum tilt would be different if the nature of the energy demand is different. Generally To use a tilt angle greater than the latitude for winter application and reverse for summer Application. The usual practice is to recommend values of (ϕ+ 10^0 to15^0) for the former and (ϕ- 10^0 to 15^0) for the latter.

E. Fluid Inlet Temperature

The efficiency of the collector decreases more with increasing the value of T_{fi}, the value varies from 56.4 to 29.9 % as T_{fi} increases from 30^0 to 90^0 C. As inlet temperature increases, the top loss coefficient as well as the temperature difference with the surrounding increases, heal loss increases and useful heat gain is decreases.

F. Cover Transmissivity

The higher the transmissivity, the better is the performance of the LFPC Collector. The efficiency increases as the extinction coefficient deceases from 19.0 m^{-1} to 4 m^{-1}.

G. Dust on the Top Cover

Generally, cleaning is done once in every few days. It is recommended that the incident flux be multiplied by a correction factor which accounts for the reduction in intensity because of the accumulation of dust. Correction factor is the ratio of the normal transmissivity of a dust –laden cover to the normal transmissivity of a clean cover. Also recommend that for India a value ranging from 0.92 to 0.96 to be adopted. The actual value would depend upon the location in India and time of the year.

III. LIMITATIONS OF CONVENTIONAL FLAT PLATE COLLECTOR

The conventional flat plate collectors installed since last 40-50 years are stationary devices with limited solar radiation absorption area. Observed practical limitations of conventional flat plate collector are:-

1) It requires large installation space hence difficult to install on small roof area.
2) As LFPC are at constant angular inclination with surface, it is difficult to utilize effective solar radiations for long day hours.
3) Top front surface exposed to solar radiation hence only some part of solar heat is absorbed. Surface heating require more time to heat water.
4) Operating temperature limits are inefficient.
5) Very low efficiency due to heat loss.
6) Installation cost is more as compared to performance

Hence unwillingness of costumers to handle such bulky and costly device.

IV. RECENT DEVELOPMENT IN FPC COLLECTOR TO IMPROVE THE PERFORMANCE AND EFFICIENCY

In order to increase the efficiency and performance of flat plate collector various researcher proposed technical advancements. The developments are carried out in the field of cover materials, absorber plate materials, absorber and glazing coating etc. along with the changes in the design, fluid used for heat transfer.

R. Sivakumar, V. Sivaramkrishnan, M. Vivekanandan [1] has developed the batch type solar water heater by CFD model with different size of fins and dimples; V-grooves type absorber surface was utilized. They observed that the temperature of water 'T' in various absorber surface models is: $T_{Dimple} < T_{Without\ fin} < T_{20mm\ fin} < T_{40mm\ fin} < T_{60mm\ fin} < T_{V\text{-}groove}$. The temperature of water with that of V-groove absorber surface is maximum when compared to other models and minimum for dimpled surface. Among all these models, the model with V-groove is advantageous for hot water usage in the evening, because it gains maximum heat and hence temperature when compared with other fins.

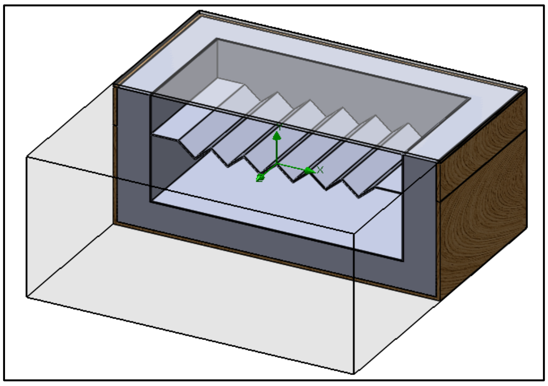

Fig. 1: ICSMFPSWH with V-grooves

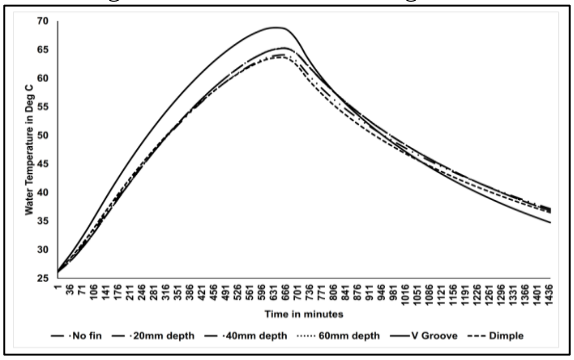

Fig. 2: Variation of mean water temperature with time in ICSMFPSWH for different absorber surface configuration

Deepak.P, Adhichelvan.B[2] was carried out an Experimental work using pebble stone as a porous medium for packing of absorber surface and agitator used in the riser tube. They found that the temperature is increasing using combination of agitator and porous medium. A pebble stone is used as a porous medium as it has high heat energy absorbing properties, so it has highest temperature in comparison with agitator and ordinary solar water heater.

Fig. 3: solar water heater with agitator,porous medium and transperent cover

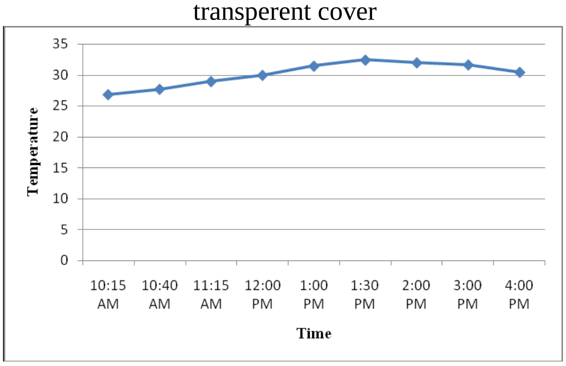

Fig. 4: Temp Vs. time with agitator, porous medium

Sethuraman Ramasamy, Pakkirisamy Balashanmugam [3] presented the analysis of solar water heater carried out with circular and rectangular fins used in the riser tube. They have used consist of 9 tubes, having 4 tubes with circular fins and 4 tubes with rectangular fins and remain one tube is without fin. They obtained that the efficiency of circular finned tubes is higher than that of rectangular finned tubes and without tubes. They have concluded that the radiation, energy gain and the efficiency are high when the fin is used. They have also found that the temperature difference between with fins and without fins of solar flat plate collector is 7^0C - 8^0C in normal condition.

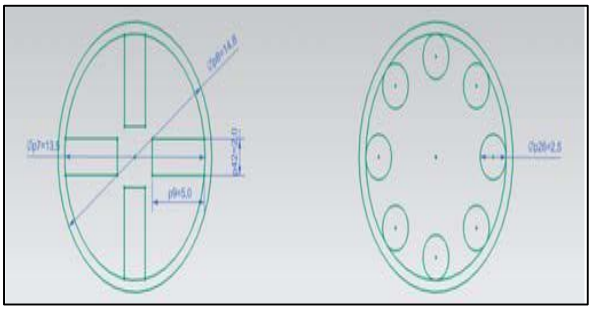

Fig. 5: two dimensional diagram of circular and ractangular fins

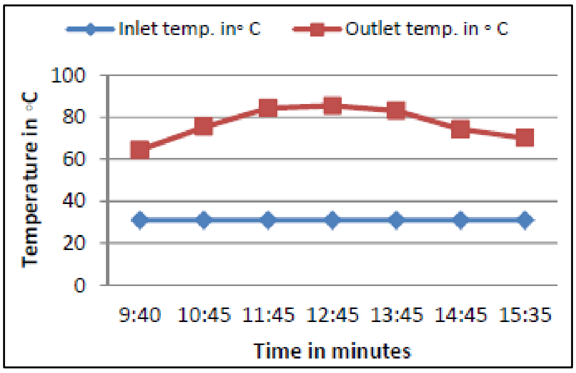

Fig. 6: comparison of inlet and outlet temperature with fins

S.Rajasekaran, M.Chandrasekar, T.Senthil Kumar [4] presented the experimental performance using three different coating tubes to obtain good efficiency of the collector. They used stainless steel tube coated with epoxy polyether, aluminum with copper oxide used as a header and riser tube. The result shows that maximum water temperature of 70^{0}C for copper, 66^{0}C for aluminum coated with copper oxide and 62.5^{0}C in stainless steel coated with epoxy-polyether are obtained. They have also observed the maximum efficiency at the time of 13:00 hour in three case are 45.31% in copper tubes, 42.66% in aluminum tubes and 40.65% in stainless steel tubes and then efficiency decreases. So they concluded that the cost of FPC was reduced 30% by using epoxy-polyether stainless steel riser tubes and aluminum with copper oxide tubes instead of copper tube.

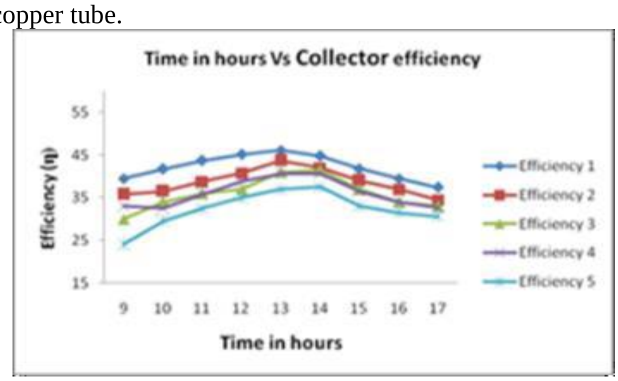

Fig. 7: The curve of collector efficiency against Time

Mahesh. Kulkarni, Dr.D.S.Deshmukh[5] developed a flat plate collector using aluminum material as an absorbing surface. The absorbing surface made of rectangular aluminum pocket with aluminum pipes. They found that the temperature of water obtained at outlet of a new collector is about 69^{0}C and efficiency of the collector is 35.47% as compared to that of conventional collector efficiency is around 40.05%.they also detected that the solar collector with aluminum pocket, the cost is reduced to that of solar collector with copper.

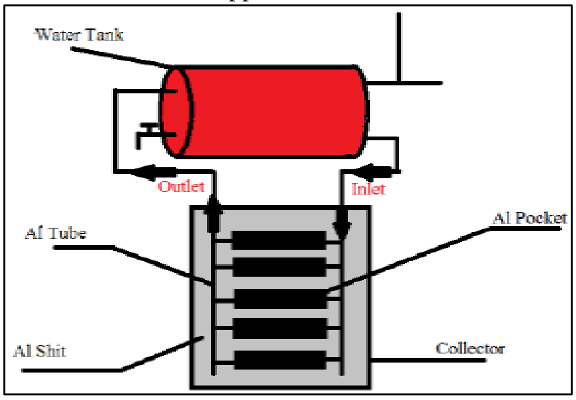

Fig. 8: SWH with Aluminum pocket flat plat collector

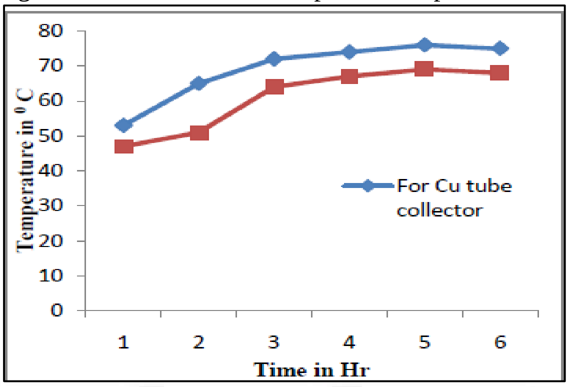

Fig. 9: water outlet temperature vs. time

Kawther.K.Mankhi, H.N.Noori, AL-Hashimi [6] carried out an experimental work with two different collector design based on surface area of the green house. The dimension of the green house of first collector is (112 cm, 62 cm, 12 cm), whereas the dimension of the second green house of second collector is (112 cm, 27 cm, 12 cm). All data was recorded, during clear day and cloudy day hours from 8:00 am to 13:00 pm. The highest temperatures were recorded at 13:00 pm for collector 1 is 89.5^{0}C and for collector 2 is 80^{0}C. During cloudy day, the highest temperature recorded is 29^{0}C for the collector 1 at 13:00 pm, and the highest temperature recorded for collector 2 was 26^0 C. the model no. 2 is suitable for domestic purpose although model no 1 is more efficient than 2.

Fig. 10: Collector no.2

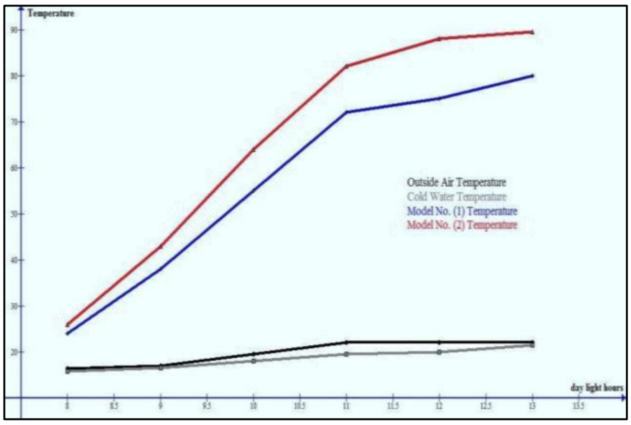

Fig. 11: Temperatures of the totally clear day

Dr.K.Sridhar, G.Vinodkumar, S.Anilkumar [7] is carried out an experimental work to study the performance of a solar flat plate collector-packed bed system by using various secondary working fluids such as water and air. They used packed beds to store the thermal energy in the form of sensible heat over a period of time and utilize whenever it is required. Basically packed bed consists of materials like gravels, possessing high thermal conductivity. Air is used as the secondary working fluid in the system. They define two cycles, Primary cycle consists of solar flat plate through which primary working fluid (water) flows, Secondary cycle consists of packed bed (placed beneath the solar flat plate collector) through which secondary working fluid flows. For a continuous input of solar radiation, performance of system is determined and a comparison is carried out. From the calculations it is observed that the efficiency of packed bed Solar Flat Plate Collector is higher than the simple flat plate water heater.

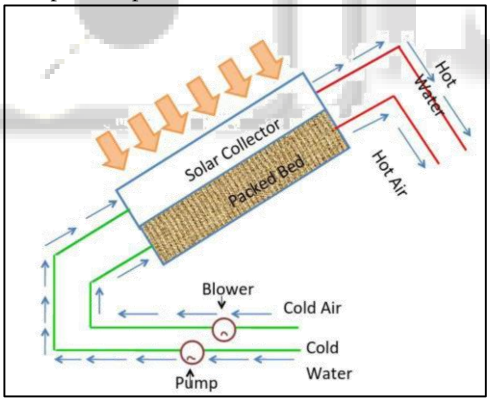

Fig. 12: Simple flat plate collector with packed bed

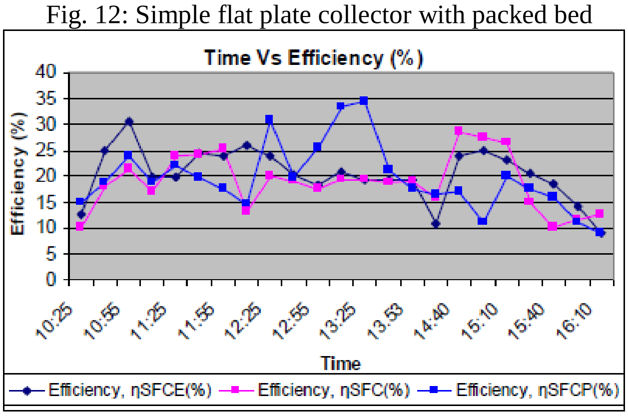

Fig. 13: Variation of time with efficiency of (1) With SFC (2) SFC with empty box (Air inside) (3) SFC with packed bed (material: gravels)

Alok Kumar [8] presented the performance of flat plate collector using semi-circular tube, so that the area of intimate contact is increases between fluid and absorber plate and hence resistance due to adhesive is decreases. Due to this reason performance of solar flat plate collector is increased.

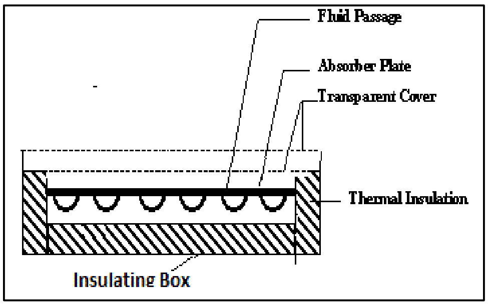

Fig. 14: Flat Plate Collector with semi-circular cross-sectional tube

Hussein Chaji, Yahya Ajabshirchi [9] had performed experimental work to find thermal efficiency using tio_2 as a Nano-fluid. They studied the effect of different Nano particle concentrations of TiO_2 in water as base fluid. Three flow rates (i.e. 36, 72 and 108lit/m^{2}hr) and four particles concentration ratios (i.e. 0, 0.1, 0.2 and 0.3 % wt.) were investigated. Experimental testing method was selected based on EUROPEAN STANDARD EN 12975-2 as a quasi-dynamic test method (QDT). Adding Nano particles to water brought about an improvement of initial efficiency of flat plate collector between 3.5 and 10.5% and the index of collector total efficiency between 2.6 and 7% relative to base fluid. Also the results indicate that the initial efficiency (η_i) for 36, 72 and 108 lit/m2.hr flow rates of water as base fluid were 0.4712,0.4998 and 0.5457, respectively which reveals the increase of 6.1 and 15.8% of it in the two latter cases in comparison with the first case, 36 lit/m^{2}hr flow rate.

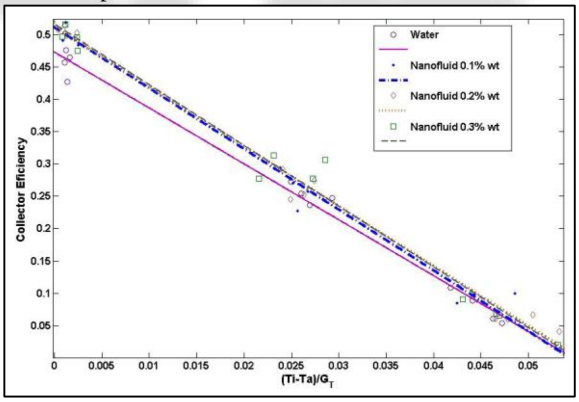

Fig. 15: Collector efficiency for mass flow rate 36 lit/m^{2}hr

Siddhartha Roy, Enoch Cephas [10] has worked on experimental study to investigate the heat transfer characteristic using silver/water Nano fluid in a solar flat plate Collector. They studied that the particle concentration varies between 0.01%, 0.03%, and 0.04%. The fluid Reynolds number varies from 5000 to 25000. Both parameters increase with increase in the particle volume concentration and flow rate. The maximum percentage increase in the convective heat transfer coefficient is 18.4% for the 0.04% volume concentration at a Reynolds number of 25000. So that the efficiency increased by using Nano fluid when compared to the base fluid, which has a strong dependency on volume concentration and mass flow rate.

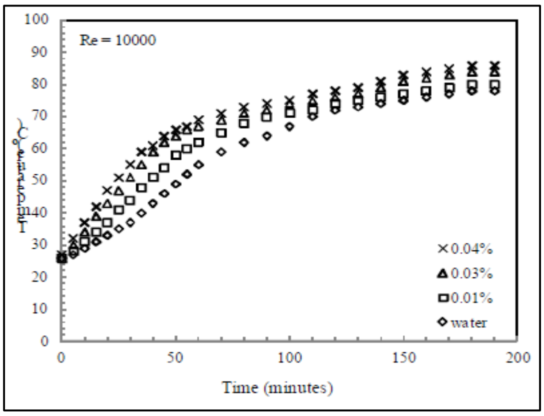

Fig. 16: evolution of fluid inlet temperature profile with respect to time

Raj Thundil Karuppa R [11] investigated a sandwich type solar flat plate collector which is made by bracing two corrugated metal sheets one on another. The absorber plate is made of 2 sheets of GI (1 mm) with integrated channels, painted with silica based black paint. The outer casing which provides mechanical strength to the equipment is insulated to reduce the heat losses from back and sides of the collector. The collector is differ from conventional collector is that the absence of fluid carrying metallic tubes. The working fluid is made to pass through the channels. Efficiency of the flat plate conventional is 24.17 and efficiency of the new collector is 20.19%.

Fig. 17: sandwich type absorber plate

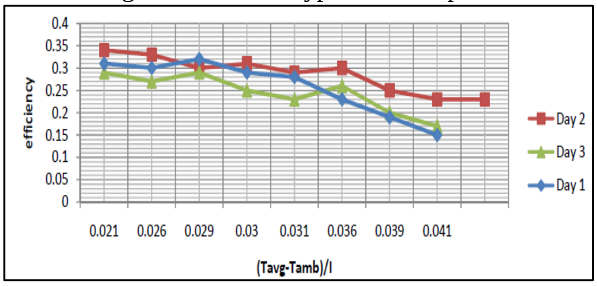

Fig. 18: Efficiency curves for sandwich type collector

J.S.Khatik, S.V.Yeole[12] presented an experimental study of absorber plate having concavities and compare with the simple absorber plate. The results show that an improvement in the heat transfer rate. The heat transfer rate is increased by 5.12%. It shows that the increase in outlet temperature due to the provision of concavities which increase the diffusion area for radiation reducing the reflection losses.

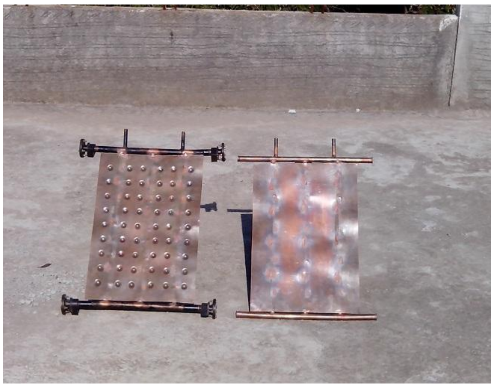

Fig. 19: concavities and simple FPC

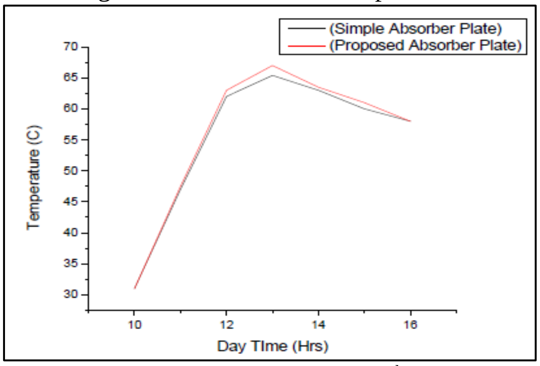

Fig. 20: Temperature Vs. time on 17th march 2014

V. Conclusion

From extensive review on research literature, it has been observed that influence the performance of a flat plate collector such as changing the absorber tube, selective coatings, numbers of covers, spacing between covers and absorber plate, working fluid etc. This report highlights the advancements in design configurations and component material investigation to enhance efficiency and performance of flat plate collector. It has been found that flat plate collector enhancement widely investigated both analytically and experimentally. Advancement like modify V-groove, dimples type absorber surface, circular and rectangular absorber fins in a tube, pocket type absorber plate, absorber with fins, absorber plate having concavities, sandwich type absorber plate, semi-circular absorber tube, double glazing polymer films, selective coatings, use of Nano-material, packed bed material and fluids provide improvement in flat plate collector performance lead to increase the solar flat plate collector application worldwide. The basic idea of all the research is to increase the efficiency of the Flat-Plate Solar Collector and also reducing the heat losses occurring in the particular device. Analysis given in this paper will help to create the best design and operational conditions with the best economic characteristics for solar flat plate collectors.

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