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A Comprehensive Literature Review On The Heat Transfer Properities Of Flat Plate Solar Air Heater

1. Junaid Bashar, 2. Dr. Ajay Singh, 3. Prof. Parag Mishra,

1 PG Scholar, Department of Mechanical Engineering, RITS Bhopal, MP, India.
2 Professor & Head, Department of Mechanical Engineering, RITS Bhopal, MP, India.
3 Asst. Professor, Department of Mechanical Engineering, RITS Bhopal, MP, India.

Abstract : In the pursuit of sustainable and clean energy solutions, solar power has emerged as a beacon of hope globally, and India is no exception. As one of the world's fastest-growing economies, India has made significant strides in harnessing solar energy to meet its growing power demands while addressing environmental concerns. The literature survey on solar air heaters reveals a rich landscape of research exploring heat transfer dynamics. Investigations into rib height variations emphasize their significant impact on thermal performance. Computational Fluid Dynamics (CFD) simulations, particularly using ANSYS software, play a pivotal role in visualizing fluid flow and heat transfer characteristics. The study underscores the importance of rib shape considerations and validates results against base papers. The findings advance understanding of fluid dynamics within solar collectors, providing valuable insights for optimizing solar air heater designs in the quest for enhanced efficiency and sustainable energy solutions.

***IndexTerms* - Computational Fluid Dynamics, solar air heaters, sustainable energy solutions.**

1. INTRODUCTION

Harnessing the sun's energy through solar air heating systems offers a sustainable solution to counter the escalating costs of conventional energy sources. These systems exclusively leverage renewable and clean solar energy, providing a cost-effective means of heating air for diverse applications. Solar air heaters function by capturing thermal energy from direct sunlight and utilizing it to heat air, creating a warmth distribution mechanism within a structure. The heated air can be directly introduced into interior spaces or directed to a storage medium, such as a rock bin, for later use.

Comprising essential components like solar collection panels, a duct system, and diffusers, solar air heaters play a pivotal role in heating spaces. Some systems operate without the need for a fan, relying on natural ventilation to distribute air effectively. Beyond their basic function, solar air heaters contribute to indoor warmth without the associated costs of traditional temperature control systems. While solar heaters' efficiency may be influenced by fluctuations in sunlight due to factors like cloud cover, they prove particularly beneficial for smaller spaces. Placing collector panels on a suitable, unshaded south-facing (in the northern hemisphere) roof or wall enables the utilization of solar air heating in various structures requiring heating.

Solar energy may be classified into two types depending on the methods utilised to convert and use the sun's energy. There are a few key differences between the two varieties, which we've outlined here. Mechanical and electrical equipment is used in the production of the active solar energy. Passive solar energy, on the other hand, utilises the sun's energy without the need of additional sources of electricity or machinery. The direct ongoing live use of the sunlight to create energy or heat may be referred to as solar power generation. Solar collectors are used to gather sunlight and turn it into heat in an active solar, whereas passive solar utilises the architecture of a building to catch sunlight. Additionally, we might refer to it as "natural" solar energy and "tweaked" solar energy. It is more advantageous to utilise active solar energy since it does not need you to modify the orientation of the home, but passive solar energy requires you to have your house in a certain orientation. Active solar heating applications include the active solar water heating, active solar space heating, as well as active solar pool heating; passive solar energy applications include passive cooling, passive heating, as well as day lighting

2. LITERATURE SURVEY

(Henein & Abdel-Rehim, 2022) [1] in order to improve the "thermal performance of the solar collector", used a hybrid nanofluid. In this study, the thermal performance of an "evacuated tube solar collector" is evaluated using a hybrid nanofluid of magnesium oxide and "multi-walled carbon nanotubes" (MgO/MWCNT). An MgO/MWCNT water base hybrid has four possible weight ratios, each with a different percentage of MWCNTs: (80:20), (70:30), (60:40) & (50:50). At a 0.02% particle concentration and flow speeds ranging from 1 to 3 L/min, the tests are carried out. With an increase in the MWCNTs nanoparticle weight ratio as well as volume flow rate, energy & exergy efficiency rise. MgO/MWCNT (50:50) hybrid nanofluid improves collector energy & exergy efficiency by 55.83% and 77.14%, respectively. When compared to other hybrid nanofluids, raising the weight ratio of the MWCNTs nanoparticles from 20% to 30% increases collector efficiency significantly. There are no other hybrid nanofluids that perform better than MgO/MWCNT (50:50) at any volume flow rate, according to the data.

(Sethi et al., 2021) [2] satisfied the thermal needs of the facility by the employment of evacuated tube solar collectors. As a result of a variety of design advancements, new solutions for capturing maximum solar energy as useful heat have been developed. A few approaches have been sold, while others have been used as teaching aids. Significant improvements have come from recent technical advances, such as the combination of the "evacuated-tube solar collectors" with phase-change materials. This led to prior investigations looking into different ways to include PCM into the collector cavity. "Thermal energy storage" (TES) has been improved by using several PCMs. Maximizing the contact surface area between the PCM as well as absorber plate improved the outflow temperatures significantly. The current study reviews existing experiments that use air or water as a fluid to include PCM into ETSC and suggests a setup for optimal performance.

(Gholipour, Afrand, and Kalbasi, 2021) [3] examined how three different absorber tube types increased the vacuum tube solar collector thermal efficiency. The absorber tubes were coated with a nanofluid of water/silica/ethylene glycol. Temperatures at the entrance and outflow, as well as the surrounding air and sun radiation, were all recorded over the course of the experiment. The thermal performance of the spiral-tube, helical-coil, and U-tube were compared. Spiral as well as helical-coil tubes were both shown to boost efficiency, but the helical-coil tubes fared substantially better in the experiments. In addition, without nano-additives, economic studies showed that spiral & helical-coil tubes raised the cost by 60 percent and 72 percent. By using nanofluid in the helical coil, the cost was 3.4 times more than it would have been without it.

(Kumar, Tiwari and Said, 2021) [4] found that there are several industrial and home uses for solar thermal energy including drying, heating and desalination. It is used to convert the solar radiation into thermal energy by use of a solar collector. By far, the most widely used the solar thermal collector in market is the "evacuated tube collector" because of its lower convective losses. Researchers tried a variety of methods, including heat pipes, thermosiphons, and U-tubes. The thermal performance of the "Evacuated tube solar collector" was much improved when nanofluids and "Phase Change Materials" (PCMs) were employed in conjunction with the different geometrical modification approaches, such as integrated reflectors as well as fins integrated heat pipes. Evacuated tube solar collector's energy as well as exergy performance but also economic and environmental consequences are described in this study using several numerical models. Research on the evacuated tube solar collector's trigeneration, cogeneration, as well as polygeneration applications will inspire researchers to concurrently create various sources of energy. The recommendations and future scope of this study will be beneficial to researchers and practising engineers who want to improve the thermal performance of the "evacuated tube solar collector".

(Olfian, Ajarostaghi and Ebrahimnataj, 2020) [5] studied the impact of nanofluids in “solar evacuated tube solar collectors” (ETSCs). Work on this sort of collector has just been summarised. Choosing ETSCs for the solar domestic hot water is critical, and this section explains how these collectors are classified and used in each category. Some topics, such as different types and sizes of nanofluids, their volume fraction (volume of nanofluids divided by total volume of fluid), and the effect of nanofluids on the heat transfer in all types of ETSCs, have been examined in this comprehensive study. The most common nanofluids in ETSCs, according to an up-to-date study, are water-based and include nanoparticles of CuO, TiO2, & Al2O3. Nanoparticles such as WO3, CeO2, Ag, GNP, CeO2 & Cu have previously been less often explored. Nanofluids having a diameter of between 1–25 nm & 25–50 nm were employed by 40%, 34% & 26% of all nanofluids, respectively. Additionally, the "heat pipe type solar collector" using SWCNT-based nanofluids has the best thermal improvement of 93.43 % at $\dot{m}$ = 0.025 kg/s. Nanofluid use in ETSCs is complicated by the high concentration of the nanoparticles in the fluid. ETSCs' performance has been somewhat hampered by this setting. To help with future research, the ideal quantity of this parameter will be determined for each form of the nanofluid.

(Pawar and Sobhanbandi, 2020) [6] investigated whether or not "phase change materials" (PCMs) could be included into a "computational fluid dynamics" (CFD) model of a heat pipe ETC (HPETC). The boundary conditions for CFD and current experimental analysis are established as the data from field testing in order to cross-validate the findings. A 3D model of commercially available HPETC is simulated in phase I, while the HPETC integrated with the PCM is built in phase II. In this case, PCM is made of the compound Tritriacontane paraffin (C33H68) having a melting point of 72 degrees Celsius. According to the simulation findings, the experimental data shows a satisfactory agreement with the simulation results, with an average variation of 4.80% & 2.04%, respectively. A benchmark for HPETCs in the "thermal energy storage systems" may be set by the findings of this research.

(Aramesh and Shabani, 2020) [7] observed the market for solar thermal collectors (STCs) has seen a considerable increase in the use of "evacuated tube solar collectors" (ETSCs). ETSCs have a wider temperature range, greater thermal efficiency, and lower cost than other kinds of collectors. ETSCs are readily accessible. Intermittency of the solar radiation is one of the key downsides of ETSCs, much like other solar energy sources. To get around this problem, a lot of "phase change materials" (PCMs) have been developed. While solar thermal energy may be stored in PCMs during daylight hours, it can also be released when there is no sunshine. PCMs and ETSCs have been merged in several research, but a complete systematic evaluation of such "integrated energy systems" is missing from the record. The current review research fills up this knowledge hole. PCM-aided ETSC systems are examined from a variety of viewpoints, including design parameters, integration types and performance, as well as theoretical and experimental findings. The pros and drawbacks of each of the four basic forms of integration between the PCMs as well as ETSCs are examined. In addition, the state of the art is explained, knowledge gaps are highlighted, and a research plan for these energy systems is supplied in accordance.

(Nidhul et al., 2020) [8] investigated the effect of secondary flow created by V-ribs on the overall performance of a "triangular solar air heater" (SAH) duct using "computational fluid dynamics" (CFD) and exergy analysis. Using CFD, the influence of rib inclination (α) on Reynolds number ($5000 \leq Re \leq 20000$) is investigated for a "fixed relative rib pitch (Rp = 10) and relative rib height (Rh = 0.05)". Nu & f are predicted with an absolute variance of 8.7% & 4.7%, respectively, using empirical correlations generated from the CFD simulation data. "Exergetic performance analysis" is performed using these relationships. When α = 45° is used with Re = 7500, the maximum efficacy parameter (ε) is 2.01. With respect to the exergy analysis, it is shown to be lower for the ribbed triangle tubing than the smooth duct with "maximum enhancement in exergetic efficiency (ηex) as 23% for α = 45°". This is because entropy is created at a lower rate for the ribbed tubing. SAH with ribbed triangle ducts (α = 45°) are being tested against the results of the rectangular duct. At greater mass flow rates, the ribbed triangular duct SAH (α = 45°) outperforms other ribbed rectangular duct SAH arrangements.

(Sharafeldin and Gróf, 2019) [9] assessed the "evacuated tube solar collector" thermal performance using WO3/Water Nanofluid. The WO3 nanoparticles had a 90 nm diameter and were round. All three nanoparticle volumes were tested at three distinct mass flux rates: 1.13 kg/s.m2, 1.15 kg/s.m2 and 1.17 kg/cm2 for 0.014 %, 0.028% & 0.042% of volume, respectively. The nanofluid stability was tested. In Budapest, Hungary, in the latitude 47°28′N as well as longitude 19°03′E, experiments were carried out. Adding WO3 nanoparticles raised the temperature differential of the fluid by up to 21%. A 23 percent increase in maximum heat gain under a solar irradiation of 900 W/m^2 was achieved by using nanoparticles of WO3. At the same mass flow rate as water, the heat-removal factor of nanofluids grows between 1.05 and 1.16. The findings showed that adding more nanoparticles improved the "evacuated tube solar collector" efficiency. The evacuated tube solar collector "thermal-optical efficiency" was 72.8%.

(Mercan and Yurddaş, 2019) [10] investigated the numerical analysis of water and water-based nanofluids in ETSCs using Computer-aided fluid dynamics (CFD). By comparing the experimental result to two numerical outcomes, the study's validity was established. Analyses helped to determine the impacts of water-based Al2O3–H2O as well as CuO–H2O nanofluids on the heat transfer for varied volume percentages of nanoparticle, varying collector angles, varying mass flow rates, as well as varying numbers of the evacuated tubes. The Boussinesq approximation was used to assess the collector's thermal as well as hydraulic state, and the tank output temperatures were calculated based on these characteristics. The use of nanofluids in ETSC systems has increased heat transmission, and the greatest results were achieved using CuO–H2O nanofluids.

(Naik, Bhowmik and Muthukumar, 2019) [11] evaluated an experimental research to forecast the performance of an evacuated U-tube solar collector. The outlet temperature of the working fluid of a single evacuated U-tube solar collector as well as the whole "solar collector system" may be predicted using a basic numerical model. When the model's predictions are compared to the actual results, it's clear that the two accord rather well. Experiments and numerical simulations show that series-connected evacuated U-tube solar collector manifolds produce a larger temperature increase of the working fluid at the higher solar intensities as well as lower temperatures but also flow rates of working fluid at their inlets. In an evacuated U-tube solar collector, the time it takes for a working fluid to reach a steady state is measured in terms of the working fluid transition time. It has been determined that the energy efficiency, transition time as well as the exergy efficiency of the working fluids may be predicted using three empirical correlations. Predicted values from these correlations match actual data with maximum errors of 12.7%, 6.9%, & 7.8% for the working fluid energy efficiency, transition time, and exergy efficiency of an "evacuated U – tube solar collector".

(Xu et al., 2019) [12] devised a novel saltwater desalination system with the multi-stage evaporation as well as recovery procedures and tested using a "solar mid-temperature evacuated tube collector". As a mid-temperature steam generator, this collector is capable of producing steam with a temperature of more than 130°C. No need for the solar concentrator that is often used in most mid-temperature collectors, since this collector uses superior "all-glass evacuated tubes" with low emissivity. A lot of money may be saved as well as the system is very inexpensive as a result. A number of tests were conducted to determine the impact of various operating factors on the solar collector's performance, including the steam temperature, solar irradiation, meteorological conditions, as well as the volume of steam drums. The results of the tests showed that solar collector has a high collection efficiency and can provide enough mid-temperature steam for an extended period of time. To provide the groundwork for subsequent research into the full seawater desalination system, this study presented a low-cost solar collector for a steam generator.

(Jowzi, Veysi and Sadeghi, 2019) [13] removed stagnant water from the bottom of the evacuated tube in this investigation by employing a bypass tube to link the storage tank to its bottom end. In order to better understand the thermal performance of a METSC, both experimental as well as numerical research has been conducted. There were no differences in temperature between the commercial sample and the METSC under the same settings. Numerical studies have also looked at the effect of bypass pipe diameter on the fluid velocity profile as well as temperature distribution inside the redesigned collector in order to find the optimal diameter. By eliminating a stagnant area at the bottom of an evacuated tube and a holding tank, this construction alteration increases collector performance. This change improved the temperature distribution between the pipe and tank, resulting in an efficiency boost of up to 11%. Over a one-hour period, the improved solar collector's useable gain was 25% more than that of the standard type. According to METSC's data, in compared to the conventional model, the average temperature of the water in the tank increased by 1.5 °C for the same time.

(Kotb, Elsheniti and Elsamni, 2019) [14] made an attempt to optimise the overall number of tubes as well as their arrangement in vast arrays of "evacuated-tube collectors" used to feed a heat-driven cycle running at a relatively high input temperature, such as desalination and the absorption chillers. For a variety of series and parallel configurations, an a priori-derived equation for the "evacuated-tube collector" thermal efficiency was empirically confirmed. With a maximum relative error of about 2%, experimental validation shows that the expression can accurately forecast the exit water temperature. Under various climatic and operational situations, optimization charts for the optimal number as well as arrangement of tubes are generated. The minimal number of tubes as well as the appropriate layout are researched and addressed in relation to the effects of sun irradiation, mass flow rate, as well as temperature increase. Up to a 41% decrease in total tubes may be obtained by the optimization strategy utilised in the current work, resulting in a substantial reduction in the initial cost.

(Elbahjaoui, El Qarnia and Naimi, 2018) [15] investigated the thermal performance of "triple concentric-tube latent heat storage" devices using a commercial phase change material (PCM: RT50). A "flat-plate solar collector" is coupled to the PCM-enabled "triple concentric-tube storage" devices. The solar collector collects solar thermal energy and transfers it to water functioning as a heat transfer fluid (HTF). Forced convection is used to get the latter to the PCM, where it is stored as latent heat. The melting as well as heat transmission processes are mathematically modelled and investigated using the finite volume approach. "Effective thermal conductivity" of the liquid phase of PCM is used to account for the effects of natural convection on melting heat transfer. Using the weather circumstances of a typical July day in Marrakesh, Morocco, we compare the thermal performance of the "triple concentric-tube latent heat storage" unit to that of the double concentric-tube storage unit. the "triple concentric-tube storage unit" is more efficient at storing and collecting solar energy than the "double concentric-tube unit" is.

(Ramirez Minguela et al. , 2018) [16] investigated the thermo-hydraulic performance and the rate of entropy formation for two distinct low temperature solar collectors: the flat plate (FPC) and "water-in-glass evacuated tube solar collector" (ETC), and the findings were compared. For a valid comparison, the absorber area of both solar collectors was presumed to be equal. For the Mexican state of Guanajuato, the functioning of the solar collectors was simulated under various flow rates and solar radiation levels. Both collectors had volumetric flow rates ranging from 1 to 9 L/min. A change in the amount of solar radiation: (1) the sun radiation gathered from a number of experiments that have been published elsewhere. (2) two months in a year that have the lowest average sun radiation, (3) a year's worth of annual average solar radiation and (4) the hottest month of the year, as measured by annual average sun radiation. A model called the "Boussinesq approximation" (BA) was used in CFD simulations to account for buoyancy effects. An in-depth look at the local entropy production rates owing to heat transfer and fluid viscosity is displayed together with pressure, temperature, and velocity profiles within the solar collector tubes. At low flow rates (under 3.0 L/min), the findings demonstrate that the solar "water-in-glass evacuated tube collector" (ETC) performs better thermally than the "flat plate solar collector" (FPC). For the volumetric flow rates greater than 3.0 L/min, the output temperature in both collectors is identical. Entropy generation due to the heat transfer is up to 10% more in an ETC system than in an FPC system at high volumetric flow rates (above 3.5 L/s), although this contribution is negligible. Entropy generation in the FPC system is higher than in an ETC system at high volumetric flow rates (above 3.5 L/s). When volumetric flow rates are low (below 3.0 L/s), the total entropy production rate for the FPC is greater than that of the ETC, and this is amplified as solar radiation rises.

(Martínez-Rodríguez, Fuentes-Silva and Picón-Núñez, 2018) [17] addresses the design and specification of solar collector networks. To catch sunlight and transfer it into the thermal energy for use in low-energy intensity processes. This research is focused on the use of all the "glass evacuated tube solar collectors". Design goals for the solar collector networks include determining the number of the collectors in series in a row as well as the number of rows in parallel, which are accomplished by specifying two design variables. The definition of the network's critical point conditions takes into consideration the unpredictability of the environment. The design's specified ambient circumstances determine the quantity of the solar collectors or the heat transfer surface area needed to meet the goals from a thermal perspective. A thermal model is used to determine the network structure's goal parameters. As a function of mass flow, intake temperature, solar radiation intensity, and goal temperature, the different design possibilities for specifying the number of the solar collectors in a row are shown graphically.

(Mahbubul et al., 2018) [18] found that nanofluids might increase the heating performance of an "evacuated tube solar collector system" that was originally operated with water. The absorption cooling system includes the collector (which has a heating capability of roughly 20 kW). Research in this area is focused on the influence of "Single Walled Carbon Nanotube–Water Nanofluid" on the performance of the collectors comparative examinations of collectors using conventional water and those using nanofluid are used to see if there is an increase in thermal efficiency. The findings show that when the collector is operated with water and 0.2 vol percent nanofluid, up to 56,7% & 66% of efficiencies are recorded, respectively. As a result, nanofluids have great promise for improving solar collector efficiency.

(Sobhansarbandi et al., 2017) [19] With a melting point of 28 degrees Celsius, Octadecane paraffin is classified as a non-toxic PCM with long-term chemical stability, making it an ideal material for the solar collector. CNT layers with high thermal diffusivity as well as thermal conductivity compared to phase change materials (PCMs) may overcome the disadvantages of PCMs and create a new and efficient solar water heater, since PCMs alone may not be sufficient.. Near optimal black body surfaces can be achieved with present technology, absorbing up to 98% of solar light between 600 and 1100nm and giving extra absorption that enhances the efficacy of the solar heater. A more consistent output, even on a cloudy day, is made possible by the combination of CNT sheets with PCM, and thus allows for a longer nighttime production of heat.

(Essa & Mostafa, 2017) [20] looked at a numerical simulation of the water flow in an "evacuated tube solar collector" coupled to a storage tank in three dimensions under transient conditions. It confirms the temperature distribution in the evacuated tube by comparing it to experimental data from previous investigations. We spoke about how the intensity and incidence angle of solar radiation may vary. Temperature excursions as well as flow circulation inside the tube were also studied as a result of radiation variations At the verified temperature measurement locations, the simulated findings agreed with the experimental data with an average relative error range from 4.2 to 7.8 percent. When the intensity and angle of the solar radiation change, the flow structure within the tube changes as well. The streamlines within the tube take on two distinct forms as a result of this variance. The first form has a linear profile that extends from the tube's top surface toward the tube's inclination. Using a vision experiment, we were able to corroborate the helical structure within the tube announced at the conclusion of the simulation duration. As the sun's rays move over the tube's outside and the flow moves upward, a helical structure is created. During the peak of solar noon, when buoyant velocity rises, this becomes abundantly obvious.

(Siva Kumar et al., 2017) [21] observed that the future energy source which will fulfil our energy needs is renewable. Solar power is one of the most important sources of energy in this case. both Solar (PV) and Solar Thermal may be used to capture the sun's energy. Heating, cooling, hot water systems, drying, and space heating are all examples of household uses for solar thermal. As a result, it is critical to generate thermal energy using collectors. The ETSC (evacuated tube solar collector) is the most efficient of all thermal collectors when exposed to low sun insolation. Heat pipe is used in this research to improve the heat produced by the collector in an evacuated tube. The goal of this study is to develop and explore the heat transfer analysis of a Borosilicate glass Heat Pipe Evacuated Tube solar collector for the Coimbatore site, which has an outer tube diameter of 0.058 metres and an inner tube diameter of 0.049 metres.

(Ghaderian et al., 2017) [22] employed a "thermosyphon circulation system" in this study to test the efficiency of a "evacuated tube solar collector" (ETSC) water heater. It was found that the nanoparticle volume fraction ranged from 0.03 percent to 0.06 percent. Coils were able to draw up to 60 litres per hour of water. ASHRAE standard 86-93 was used to calculate collector efficiency. ETSC's efficiency was increased when we used nanofluid as an absorption medium. By comparison to water, CuO nanofluids in ETSC at a volume fraction of 0.03 percent improved performance by as much as 14%.

(Daghigh and Shafieian, 2016) [23] carried out a theoretical and practical evaluation of the performance of a solar water heating system with an evacuated tube heat pipe collector. The thermal and exergy study of the collector's performance was first provided in a mathematical model, and then the collector was built and tested in accordance with a real consumption pattern. The best number of collection pipes was found to be 15, according to the findings. Hot water use and system performance were also shown to be linked. As time goes on, we're seeing an increase in exergetic efficiency changes. Finally, its efficiency reaches a high of roughly 5.4% towards its conclusion. It was between 15:00 & 16:00 pm when the collector's output temperature reached 64 °C. At first, an additional system was needed, however this support system was turned off at 14:00 pm as well as the solar cycle alone provided the necessary energy.. Based on this model's capacity to forecast heat pipe solar water heater performance with an absolute error rate of 8.4% and an absolute standard deviation of 1.91 percent, data from both theoretical as well as experimental testing have been compared.

(Ren et al., 2016) [24] models the energy transfer process in a collector tube using heat transfer and exergy transfer techniques. In contrast to conventional techniques of analysis, an objective function is presented to transform the job into a restricted optimization problem in order to guarantee that the molten salt obtains the greatest amount of accessible energy. Gravitational search (GS) is used to find the best possible answer to the suggested goal function. Under a variety of situations, the suggested optimization approach is able to identify the best operating parameters. During ideal working conditions, the collector tube's heat transfer but also exergy transfer characteristics are disclosed, which quantifies the available energy as well as exposes the site of energy degradation in the collecting tube. The study's results will serve as a useful guide for maximising the benefits of solar energy.

(Kabeel et al., 2015) [25] aimed to introduce a procedure for simulating the absorbed solar radiation and heat transfer process in water-in-glass evacuated tube solar collectors. No experimental factors are required to compute the daily used solar energy and outflow temperatures of collectors with varying tilt angles, azimuth angles and other geometric characteristics. Integration of solar collector performance equations across the tube circumference is used to calculate the "total absorbed solar radiation", taking into consideration shadowing from nearby tubes and the variation in transmissivity and absorptivity product with incidence angle. Subtracting the heat loss from the total solar energy absorbed yields an estimate of the heat transfer into the collector fluid. Comparing estimated and observed tank temperatures under various heating loads demonstrates a high agreement between the two. Different tilt angles, tube spacing, collector Azimuth angles, and the collector mass flow rate are studied theoretically to determine the performance of a solar collection.

(Wang et al., 2015) [26] used "All-glass solar evacuated tubes" to create medium-temperature solar collectors. Sol-gel deposition of a porous SiO_2 antireflection layer raised the solar transmittance of the envelop tubes to 0.94. " Dual-cathode co-sputtering" was used to create a solar selective coating with a solar absorbance of 0.95 and a thermal emittance of 0.05 (at 180?C). Outgassing at 450ºC was used to create vacuum in the evacuated tubes, and evaporable as well as non-evaporable getters were used in tandem to keep the vacuum constant. Solar selective coating heat was transferred to working fluid by welding copper U-tubes to aluminium fins with anti-oxidation treatment. A smooth aluminium sheet compound parabolic concentrator (CPC) was used to concentrate the solar radiation, with a solar reflectance of 0.91.

(Naghavi et al., 2015) [27] used ETHPSC ("evacuated tube heat pipe collectors") and a common manifold loaded with phase change material in this article to develop a theoretical solar hot water system. The LHTES tank collects and stores solar energy from the ETHPSC. A "finned heat exchanger pipe" installed within the tank transfers the stored heat to the residential hot water supply. The suggested system's heat absorption, storage, and release modes are all modelled using a variety of mathematical techniques. Latent heat storage improves the thermal performance of the ETHPSC-LHTES system across a wide range of flow rates, according to the data. Another study showed a lower dependence on water flow rate for the introduced system than for a typical system. According to the results of the study, this system might be used as an additional component to standard ETHPSC systems in order to provide hot water for use at night or during periods of low radiation.

(Alfaro-Ayala et al., 2015) [28] used "Computational Fluid Dynamics" (CFD) to conduct a computational research on a low temperature "water-in-glass evacuated tube solar collector". two separate models were used to simulate buoyancy effects to forecast water temperature at the solar collector manifold output. The first model consisted of usage of the BA approximation and the second model is to accommodate for temperature-dependent changes in the proprieties (VPT). The experimental temperature at solar collector manifold was determined by conducting four experiments under genuine working settings, based on an official Mexican standard. According to the findings, the solar collector's output temperature as well as thermal efficiency are more closely correlated with data from the experiment than with data from the VPT model.

(Ataee & Ameri, 2015) [29] developed models for forced convection flow in T- & H-type solar collector tubes with evacuated all-glass tubes with the coaxial fluid conduit. Analytical solutions of "energy balance equations" for different collector tube components underlie these models. The findings of this study are in excellent accord with those of prior studies. Working fluid temperature distribution in the collector tube has been studied by modifying the working fluid and the parameters of the delivery tube and absorber tube. As well as mass flow rate and concentration on fluid temperature and energy efficiency and exergy efficiency have been investigated in both models. In addition, solar radiation intensity as well as inlet and ambient temperature have also been examined in both models. When a selective coating absorber tube is used, both models exhibit an increase in collection tube outlet temperature, regardless of changes in the thermal conductivity as well as emission coefficients of the delivery tubes. Air as well as carbon dioxide as working fluids have higher outlet flow temperatures and exergy efficiency in the H-type model than in the T-type model, according to the findings.

(Yang et al., 2015) [30] used Sol-gel and dip-coating techniques to create antireflective nanoporous SiO_2 films. Solar transmittance (96 percent in the extended spectrum range of 250 nm-2500 nm) is at its greatest level ever. To improve the "static contact angle values", the ethylchlorosilane and examine solutions were used. The antireflective films must be able to withstand a wide range of operating circumstances, including low temperatures, hot temperatures, as well as humid environments, all of which may damage its optical qualities over time.

3. SOLAR COLLECTORS

It is a solar collector which gathers and/or focuses the sun's incoming solar energy. Active solar heating is the primary purpose for these devices. They also heat water for personal use. Due of the diversity of the weather conditions they are exposed to, these collectors are typically positioned on the roof. With the use of such solar collectors, a water heater may be replaced with a more energy-efficient option for heating household water. Solar thermal power plants may create energy using an array of these collectors, which can be used both for household and commercial purposes.

Despite the fact that there are a wide variety of solar collectors, they are all built with the same fundamental principle in mind. In principle, there is a substance that can be used to gather and concentrate the sun's rays and utilise them to warm water. In the simplest of such systems, water runs via pipes that are encased in a black substance. Thermal energy is transferred from the water to the black substance by the sun light it absorbs. Collectors, on the other hand, might go to great lengths to complicate something as basic as this. If a large increase in the temperature is not required, absorber plates may be utilised; nevertheless, most solar concentrators that employ reflective materials to concentrate sunlight cause a larger rise in temperature.

a. Flat Plate Collectors

There is nothing fancy about these collectors. They are basically metal boxes with glass glazing on the top of a dark-colored absorber plate. In order to reduce heat loss to the collector's other sections, the sides as well as bottom are normally insulated. The absorber plate is struck by solar radiation that has passed through the transparent glazing material.

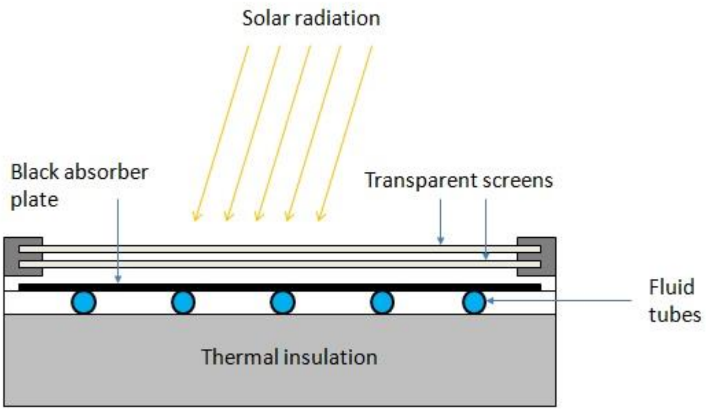


Figure-1 A Flat Plate Solar Collector

As the absorber plate warms up, the heat is transferred to the water or the air contained between absorber plate as well as the glazing. They may be coated with specific coatings meant to improve heat absorption and retention, as opposed to ordinary black paint. Copper or aluminium are the most common metals used to make these plates.

b. Evacuated Tube Collectors

The water is heated by a series of evacuated tubes in this sort of solar collector. It is possible to catch the sun's rays while limiting heat loss with the use of vacuum tubes. Their absorber plate is an inner metal tube, which is attached to a heat pipe that transfers the sun's heat to water. The fluid in this heat pipe is under a very high pressure in a conduit of this kin.

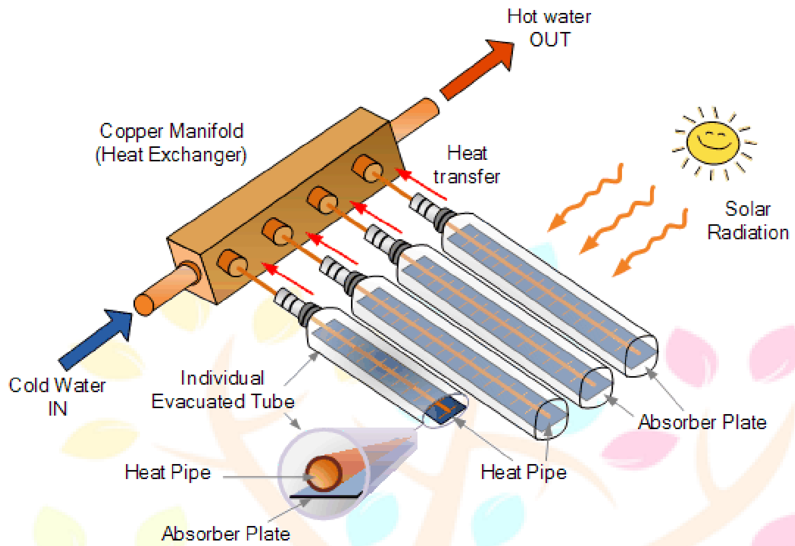


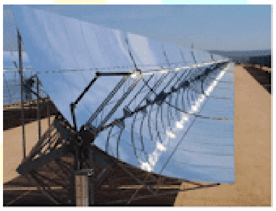
Figure -2 Evacuated Tube Collectors

Boiling liquid may be found at the "hot" end of the pipe, whilst condensing the vapour can be found at the "cold" end of pipe. A more efficient transfer of heat between the pipe's two ends is made possible. It's only when the Sun's heat flows from one end of heat pipe to the other that the water may be heated for the use.

c. Line Focus Collectors

Reflective materials are used to capture and concentrate the heat energy from the solar radiation in these collectors. A lengthy trough connects a series of parabolically curved reflecting portions that make up these collectors. Reflective material is put in the middle of this trough to direct sunlight toward a water pipe, causing the water to heat up.

"Solar thermal power plants" employ these collectors to create steam, which is why they aren't suitable for household usage because of their high power. These troughs, especially those that can swivel to follow the Sun's path in the sky, may be incredibly successful at producing heat from the Sun.



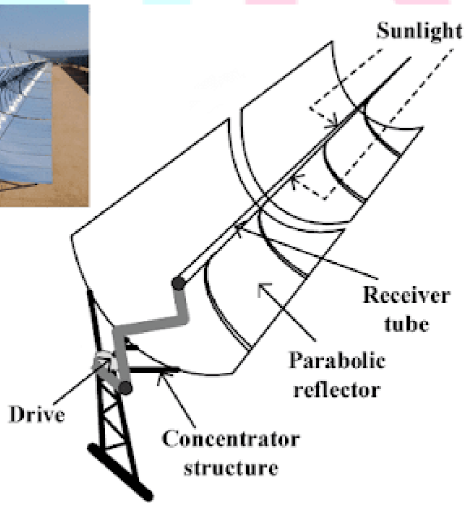


Figure -3 Line Focus Collectors

d. Point Focus Collectors

Large parabolic dishes made of reflecting material concentrate the energy of the Sun into a single point in these collectors. It is most often utilised to power Stirling engines using the heat from such collectors. Even though they are very efficient at capturing sunlight, they should be constantly monitored to be of any use. Each of these dishes may be used on its own, but they can also be connected into a larger array to capture even more solar power.

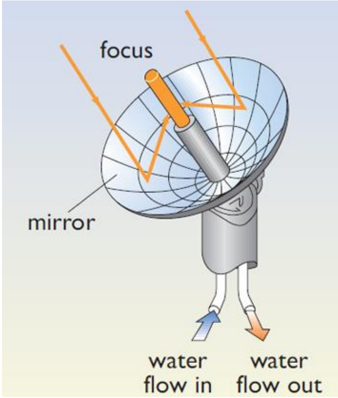


Figure -4 Point Focus Collectors

Concentrated photovoltaics may make use of point focus collectors as well as other similar devices to concentrate the solar energy. High-efficiency photovoltaic cells, particularly developed to capture the concentrated solar energy, convert the solar energy directly into electricity rather than heat in this application.

4. CONCLUSION

The literature review encompasses a variety of studies conducted on different aspects of solar collectors, with a particular focus on evacuated tube solar collectors (ETSCs) and their performance enhancements through the utilization of nanofluids, phase-change materials (PCMs), and innovative design modifications. Nevertheless, we can infer some potential gaps and areas that require further investigation:

- **Limited Focus on Ribbed Solar Air Heaters:** While the literature discusses solar collectors and their enhancements using nanofluids, PCM, and various geometrical modifications, there seems to be a gap specifically related to the effects of rib height in solar air heaters. The studies mentioned mostly focus on evacuated tube solar collectors or other types, but there is a lack of detailed exploration into the impact of rib height on the heat transfer properties in solar air heaters.
- **Need for Specific Information on Rib Height Variation:** The literature provides insights into the thermal performance improvement using different materials, nanofluids, and geometrical modifications, but there is no direct mention of the effects of varying rib height in solar air heaters.
- **Focus on Computational Fluid Dynamics (CFD):** Many studies use CFD simulations to predict and analyze the performance of solar collectors. However, there is a gap in the literature regarding the application of CFD simulations specifically to assess the impact of rib height variations in solar air heaters. Incorporating CFD analysis into our research could be a valuable contribution to understanding the fluid dynamics and heat transfer within ribbed solar air heaters.

In summary, the literature review highlights a lack of direct exploration into the effects of rib height on heat transfer properties in solar air heaters. Our research will contribute significantly by delving into this specific aspect and potentially employing computational fluid dynamics to enhance the understanding of fluid flow and heat transfer mechanisms in ribbed solar air heaters.

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