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Thermal and Hydraulic Evaluation of a Parabolic Trough Collector Using Different Types of Porous Filling in an Absorber Receiver: A Review

Renas Burhan Muhammed[1,2*], Musa Mustafa Wais[3], Ehsan Fadhil Abbas[3]

[1] Kirkuk Technical Engineering College, Renewable Energy, Northern Technical University, Kirkuk 36001, Iraq
[2] Research Center Kirkuk, Northern Technical University, Kirkuk 36001, Iraq
[3] Kirkuk Technical Engineering College, Northern Technical University, Kirkuk 36001, Iraq

Corresponding Author Email: renasburhan8889@ntu.edu.iq

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ABSTRACT

The large amount of energy consumed is produced as a result of the combustion of fossil fuels. This is due to the obvious pollution of the environment, the high cost and the possibility of running out of these sources that make alternative energy sources more important. Sunlight is a popular renewable energy source. Among the various alternatives, harnessing solar energy has become a promising option in all over the world being less expensive, environmentally friendly and impermeable. Parabolic collectors are an effective way to produce steam in thermoelectric power plants to convert radiant energy into thermal energy. However, these complexes can be improved by improving their design and modifying parameters related to thermal behavior. Heated receiver tubes are key components of a PTC device. These types of improvements can be achieved through use of Nano fluids and insert fins, or porous materials with in receiver tube to enhance the PTC performance. The current review papers seek to increase heat transfer in the receiver tube and reduce heat loss to improve convection fluid heat transfer.

1. INTRODUCTION

Energy use is expanding faster than population growth, and the need for electricity will double in 15-20 years+ [1]. By 2025, oil demand might exceed 123 million barrels per day [2]. and the rising demand for conventional energy and its negative impact on the environment have driven search for alternative energy sources. Sunlight is a permanent energy source. The earth's hourly solar flux can supply all human energy needs year-round with minimum environmental effect [3]. In 1912, Frank Schumann built the largest pumping station to date powered by solar energy. The system was in Maadi, Egypt. Because of the fall in oil prices as a result of the First World War, the factory was closed in 1915 [4]. Solar power generation includes water heating, electricity generation, and air conditioning for household and industrial units. Depending on the operation, the right technology is applied [5]. Despite this, clean energy provided 11% of the total global energy need in 2019, i.e. 81% of global demand. It is still produced as a result of burning fossil fuels (gas, coal, and oil), which releases carbon dioxide into the atmosphere and pollutes the environment [6]. Among the four established CSP systems, the central tower, PTC, parabolic dish, and linear Fresnel collector stand out. A point focus system is the parabolic dish and central tower, while linear Fresnel collectors and the parabolic trough constitute a line focus system [7]. PTC is the most widely used type, as it is the best solar thermal energy system [8]. PTC is chosen when it comes to thermal systems, such as heating, steam turbines, etc., as it is the most popular because it requires less space and costs less. Parabolic reflectors reflect parallel sunlight from all parts of the basin to the focus line, as shown in Figure 1. The PTC is set during the day to track the path of the sun using the tracking system [8-10]. Standard PTC thermal power plants have a solar field and a power conversion mechanism [11]. A SPTC uses a parabolic mirror to focus direct solar radiation on a linear receiver system, which converts it into thermal energy and absorbed it. To reduce receiver heat loss by convection and radiation, a glass cover tube is concentrically put around the ERT [12]. all facing north-south or east-west. Summer and winter energy is concentrated on the north-south and east-west axes. Each day, the tracking mechanism rotates the collector on its single axis to track solar radiation's (DNI) into the receiving tube, which stores pressurized water, processed thermal oil, or molten salt [13]. And the absorption tube has a major influencing role on the efficiency. The collector absorbs the reflected sunlight and transfers it to the HTF [14]. The filler material is used in the absorbing receiver to improve the performance of the accumulator because it affects its thermal and hydraulic properties [15]. The increased surface area and heat transfer capabilities of porous fillers like metal foams and porous ceramics are attracting interest [16]. Because solar radiation may be transported into a fluid medium, surface heat is reduced [17]. In this paper, different approaches to improving PTC performance are discussed, including a variety of porous materials with in the absorption tube at variable flow rates. Find the optimal fill type and flow range of the collector, as well as calculate the theoretical and practical efficiency of the collector, to optimize performance (PTC) for real-world renewable energy applications.

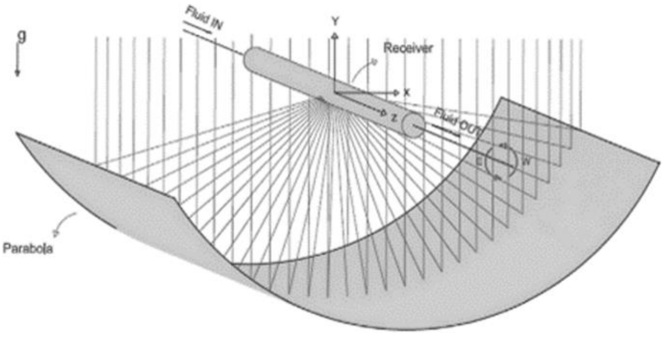


Figure 1. Schematic diagram of SPTC [10]

2. METHODOLOGY

The research includes a review of previous studies and research on PTC, including information on their applications and performance, various techniques for raising the collectors' efficiency, and the application of various porous materials for enhancing heat transfer.

3. USES OF PARABOLIC SOLAR COLLECTOR

Many systems, including those for residential heating, water desalination, cooling systems, industrial heating, power plants, irrigation water pumps, and PV systems, can be equipped with PTC. It needs to operate continuously without halting when desalinating water, which calls for the usage of thermal energy storage device. Alamr and Gomaa [18] suggest that the most effective and affordable solar heating system (SHS) mediation can be achieved using a water tank, with the tank size depending on the operational temperature and production capacity. Chaudhary et al. [19] analyzed the efficiency of the parabolic trough collector (PTC) system for solar-powered air conditioning using both numerical and real-time techniques, utilizing receivers equipped with evacuated tubes. An EES with a 3 kW capability is utilized to analyze the impact of various operational parameters on the dehumidification ratio. The parameters consist of direct solar radiation, intake fluid temperature, and the integration of the PTC system with the SDD. the peak efficiency is 62%, and the highest recorded temperature increase is approximately 5.2°C. The maximum thermal energy gain is 2.33 kW on gloomy days and 3.07 kW on bright days. for an annual transient study in TRNSYS over five different climates in Pakistan. Quetta achieved a peak solar insolation of 656 W/m^2 and a peak thermal energy of 1139 MJ with an efficiency of 46%. The root mean square error is approximately 9%, suggesting a high level of agreement between the experimental and simulation results. Kumar et al. [20]. analyses PTC in conjunction with a solar distiller, which is a cheap, efficient, and environmentally friendly method of water purification in rural areas. Reducing the water level from 15 to 5 cm enhances energy output by the same amounts, shortens the payback period, and boosts daily energy generation by 22% [21]. Using saltwater as a medium in a modified solar distiller with a (TPTC) might explain why daily freshwater production increases in winter and summer [22]. Because of their efficiency in converting solar radiation into thermal energy, CPCs are an important part of the water desalination process. They are also helpful for applications involving lower and medium temperatures, yet they are costly.

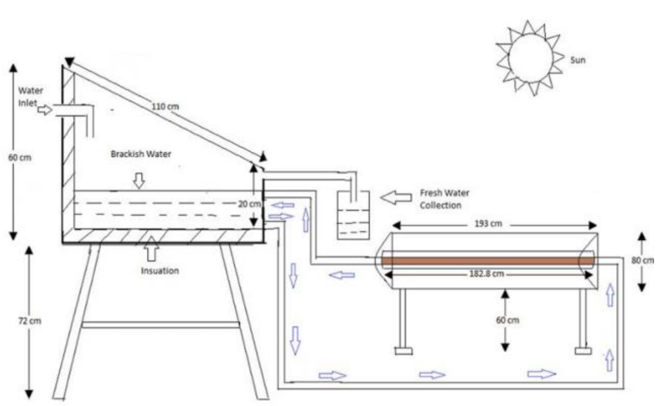


Figure 2. Schematic diagram of single slope SS coupled with PTC [20]

4. PERFORMANCE EVALUATION OF PTC

Wang et al. [23] conducted a numerical analysis of the thermal and optical performance of PTCs. They found that the uneven distribution of temperatures across the absorption tube is due to variations in heat flow in the circumferential direction. Near the tube's fixed end, the pressure concentration zone manifests at an edge angle of 75 degrees, and the stress reaches its peak at around 100 MPa. The location of the limit shifts as the geometric concentration ratio grows. When the temperature distribution becomes uneven, the highest flow to the bottom of the tube causes the heat transfer fluid to get hotter, and the pressure on the tube increases. The pressure drops as the edge angle rises because the temperature distribution becomes more uniform, and the maximum heat flow position shifts to both ends of the tube. The findings shown that adjusting the geometric focus and edge angle can enhance the performance of PTC [24]. Solar parabolic trough collectors use a (CPC) as a secondary reflector to improve optical performance at divergent sun angles. Based on local environmental variables, SPTC with CPC creates a single-axis-tracking concentrating collector. This study models tracking faults and evaluates the optical efficiency of the revolutionary SPTC system with and without a secondary reflector using MATLAB and TRACEPRO. At 2 degrees of sun incidence, the SPTC with a secondary reflector has 20% higher optical efficiency than the standard collector.

5. MAKING IMPROVEMENTS TO THE SOLAR COLLECTOR

The improvement approaches of many experimental and theoretical investigations on PTC performance worldwide may be categorized.

5.1 Improvements to the tracking system

Bakos et al. [25] reported that solar parabolic trough collectors (SPTCs) utilize a compound parabolic concentrator (CPC) as a secondary reflector to enhance optical performance at divergent sun angles. They noted that, depending on local environmental variables, an SPTC equipped with a CPC function as a single-axis-tracking concentrating collector. This study models tracking faults and evaluates the optical efficiency of the revolutionary SPTC system with and without a secondary reflector using MATLAB and TRACEPRO. At 2 degrees of sun incidence, the SPTC with a secondary reflector has 20% higher optical efficiency than the standard collector. Bakos et al. [25]. This study aimed to compare the solar energy levels measured on a flat surface tilted at 40 degrees south with those obtained using a continuously operating two-axis tracking system. The moving surface produced 46.46 percent more solar energy than the fixed surface, as shown in Figure 3.

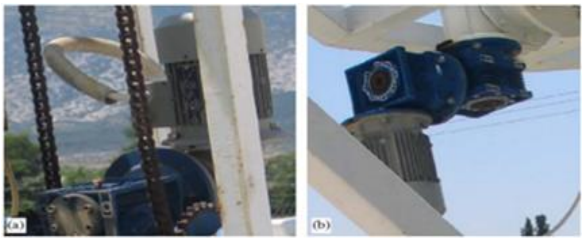


Figure 3. (a) Motor for vertical movement and (b) Motor for horizontal movement [25]

5.2 Research on improvements to the absorber tube

5.2.1 Increased heat transfer area

(1) Add fins

By applying fins to increase the contact area between the absorber wall and the working fluid, you can accelerate the rate of heat transfer. Peng et al. [26] analyzed the effect of including semi-annular fins and various fin shapes (triangle, rectangle, and trapezoid) on the absorber tube within a metal foam hybrid structure, as shown in Figure 4. The absorber tube showed enhanced thermodynamic and hydrodynamic performance compared to the smooth tube.

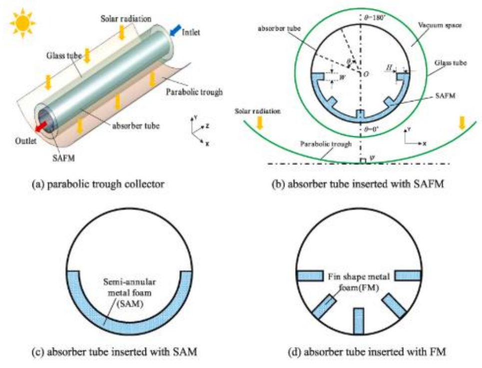
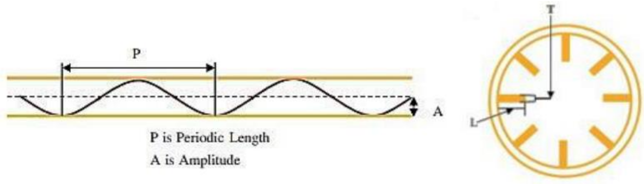


Figure 4. Schematic diagram of physical model [26]

Kurşun [27] used the finite volume approach and realizable k at turbulent flow to analyze the effect of the absorber tube's sinusoidal surface and internal longitudinal fins (as shown in Figure 5). Findings demonstrated that longitudinal fins increased the Nu value by 25% and sinusoidal fins by 78%.

An experimental investigation was conducted on the impact of introducing pin fins into an absorption tube that utilized air as the working fluid [28]. Two receiving tubes with internal pin fins and one smooth receiving tube were tested in order to assess the overall performance of a parabolic solar air collector with various receiving tubes. Under approximately 900 W/m^2 of solar radiation, the air temperature reached 266 °C at a flow rate of 93 Nm^3/h. According to the experimental findings, the inner pin-finned tube's air temperature rise and pressure decrease were significantly greater than those of the smooth tube. The inner finned tube was found to have an exergy and exergy efficiency that were, respectively, 10.4-14.5% and 2.55-4.29% greater than those of the smooth tube over the tested air flow rate range, as shown in Figure 6.



(a) (b)

Figure 5. (a) Sinusoidal fin and (b) Longitudinal fin [27]

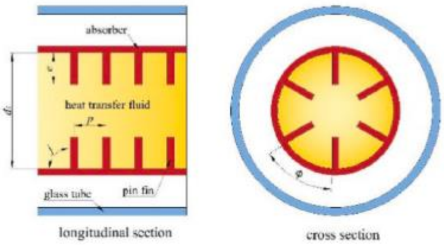


Figure 6. Schematic profiles of IPF-tube [28]

Hameed et al. [29] studied the enhanced thermal performance of an absorber tube after attaching triangular fins to its exterior. The PTC which had the following measurements: 1 m in length, 0.2 m in width, 100 1 cm fins, and 1 cm base, was used for the experiments. (0.5, 3, 7, 9) liters per minute have thermal efficiencies of 87.12%, 81.78%, 75.72%, and 58.53%, correspondingly. Zaboli et al. [30] conducted a numerical study focused on a parabolic trough collector (PTC) that generates or tabulates swirls using inner helical axial fins. The study investigated variations in fin pitch, ranging from 250 mm to 1000 mm. The FVM is employed to derive the numerical outcomes. According to the results, compared to a typical solar collector, one of the new SPTC can improve thermal performance by 23.1%. The thermal performance gains ranges from 14.1 to 21.53% for P = 250 mm when comparing the casings with and without of fins as shown in Figure 7.

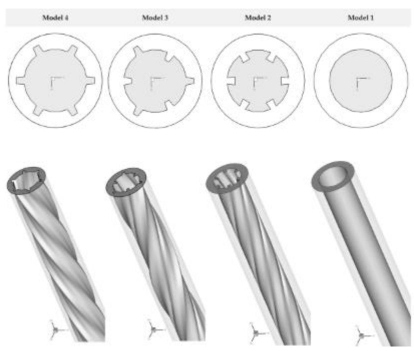


Figure 7. Schematics of inner helical axial fins [30]

Al-Aloosi et al. [31] introduced a new design that incorporates fins into the absorption tube of a CPS in multiple groups, with each group featuring fins of increasing height. The goal of this research is to enhance the efficiency of the heat transfer process. ANSYS FLUENT software was used to conduct 3D simulations based on the Finite Volume Method (FVM). The findings demonstrate that all modified models outperform the reference model in terms of thermal performance within the measured Reynolds number range. Furthermore, the maximum thermal performance of the six-fin assembly is 1.4. Akbarzadeh et al. [32] examined the effects of altering the pitch-to-diameter ratio on the exergy and efficiency of a parabolic trough collector to improve heat transmission. The surface of the tube in question was spirally corrugated. pH and the ASHRAE 93 standard's roughness-to-diameter ratio (v/DH). The results show that increasing step ratios decreases thermal efficiency. PTC efficiency can be increased to 65.8% with an absorber tube if P (D*H¼0.12) and e (D*H¼0.06) have certain values as shown in Figure 8.

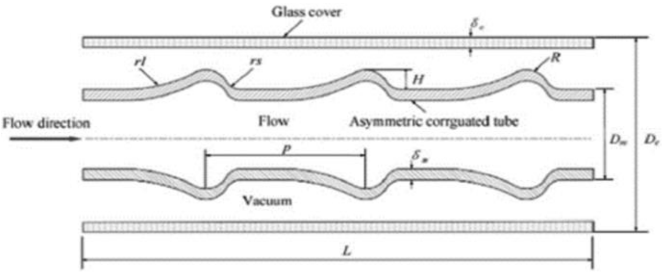


Figure 8. The absorber tube with asymmetrical outward convex [32]

Limboonruang et al. [33] examined the effects of altering the pitch-to-diameter ratio on a PTC exergy and efficiency in order to improve heat transmission. The surface of the tube in question was spirally corrugated. pH and the ASHRAE 93 standard's roughness-to-diameter ratio (v/DH). The results show that increasing step ratios decreases thermal efficiency. PTC efficiency can be increased to 65.8% with an absorber tube if P (D*H¼0.12) and e (D*H¼0.06) have certain values as shown in Figure 9.

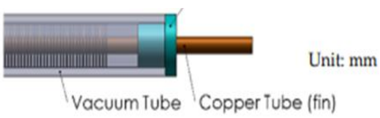
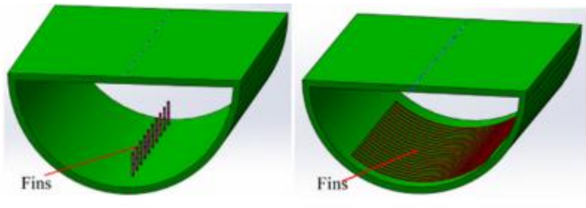


Figure 9. Solar receiver tube finned copper tube geometry [33]

Gong et al. [34] found that semi-circular evacuated absorber tubes are the most effective design for large-aperture parabolic trough collectors (PTC). The glass cover of the absorber tube encloses the flat-plate radiation barrier and vacuum section. The tube's thermal efficiency can increase from 75.7% to 76.9% with a short, thick fin to 77.3% with a long, thin fin at flow speeds between 0.4 and 1.5 m/s. Heat transfer via the air tube is improved by both fins. Compared to the short, thick fins, the long, thin fins of the AT facilitate heat transmission significantly as shown in Figure 10.

(2) Porous mate inserts

Improving the rate of heat transmission between the receiver wall and HTF is possible with the use of inexpensive, traceable, porous inserts placed within the receiver tube. The heat transfer surface may be improved using various kinds of porous media, such as uniformly sized metal meshes that are welded onto a thin metal rod to establish the porosity as shown in Figure 11.



(a) (b)

Figure 10. (a) Long and thin fins and (b) Short and thick fins [34]

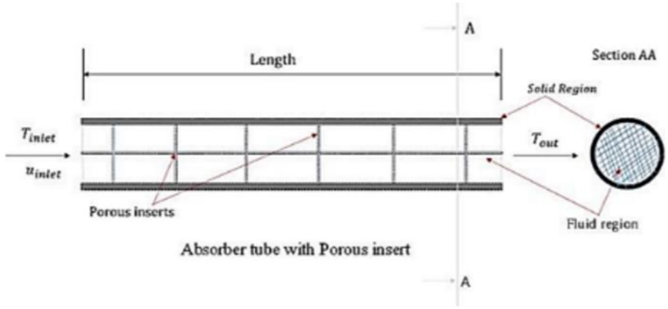


Figure 11. Absorber tube with porous insert [35]

Jamal-Abad [36] demonstrated that the effectiveness of parabolic trough collectors (PTC) increases when the total loss coefficient (u) is reduced by 45% by filling the absorber tube with copper foam as a porous medium, as illustrated in Figure 12.

Figure 12. Copper foam as a porous media [36]

Kumar et al. [37] analyzed mathematically how inserting a metal foam circumferential porous into the lower half of the absorber tube (as shown in Figure 13) affected the heat transfer performance. This porous material improved heat transfer efficiency and decreased temperature gradient, according to their findings. In contrast, when contrasted with a smooth tube, it exhibits a maximum temperature differential ranging from 47 to 72% as well as a maximum net energy of 3.71 and exergy of 2.32%.

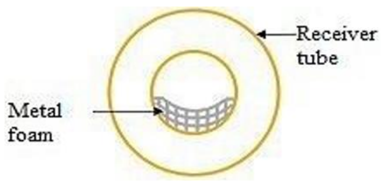


Figure 13. Circumferential metal foam [37]

Yang et al. [16] examined A shell-and-tube thermal energy storage device with the natural convection was modeled asymmetrically. Employed Open-cell metal foam with 0.94 porosity and 15 pore density was studied. The experimental results showed that metal foam location and porosity affected heat storage. By decreasing heat transfer fluid thermal resistance, foam improved heat conduction. Heat flow, j-factor, and temperature response rate rose by 834.27%, 5186.91%, and 774.90%, respectively, while melting time decreased by 88.548%. Valizade et al. [38] used Copper foams with a lower density (pores per inch) of 10 and 0.95 porosity were studied utilizing the direct absorption method. The outside test was carried out according to ASHRAE 93 guidelines and used a glass absorber tube. Three absorption tubes were employed (full porous, partly porous, and nonporous), with flow rates ranging from 0.3 to 1.6 L/min and intake temperatures ranging from 20 to 40°C. The end outcome appeared to be better. Thermal efficiency increases with a lower input temperature and a higher flow rate, while semi-inset and full-inset tubes have the highest efficiency, 119.6% and 171.2%, respectively, compared to smooth tubes. For full foam, partly foam, and without foam, respectively, the maximum temperature difference is 12.20, 8.80, and 3.30°C, as shown in Figure 14.

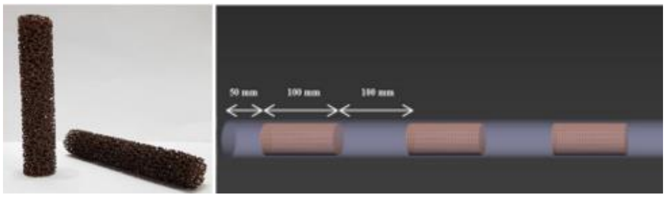


Figure 14. Metal foam with glass tube schematic [38]

Ebadi et al. [39] created a three-dimensional model of pore inserts with random packing of mineral Raschig rings (RR) at the pore scale. This came after a numerical study of the gas tubular absorbers used in the solar furnace. The smooth tube and two improved pipes (20RR and 40RR) with 20mm and 40mm RR inserts, respectively, were among the three samples that underwent evaluations. Analyses demonstrated a notable improvement in heat transmission. It was found that heat transmission was much better, with a maximum reinforcement factor of 10–15 for smooth tubes. A more in-depth thermo-hydraulic study also showed that flow was uneven in the porous area. The improved absorbers also show performance evaluation values of up to 2 in the thermal hydraulic performance assessment when comparing the tube with and without RR inserts, as shown in Figure 15.

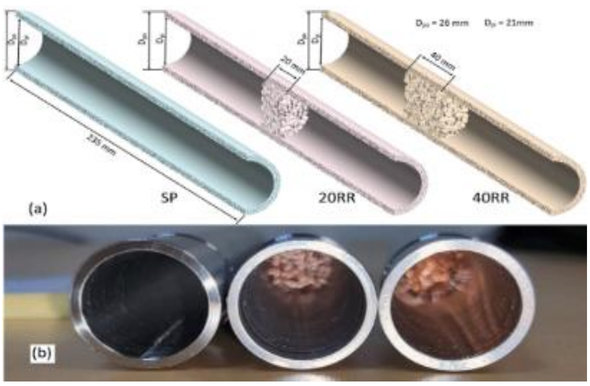


Figure 15. (a) Section cut view for (SP, 20RR, and 40RR) and (b) example photo after manufacturing [39]

Abdel-Hady et al. [40] utilized structural Finite Element Analysis (FEA) simulations and 3D modeling for the design. The simulations applied the upper limits of wind pressure and temperature increase loads, which represent actual operating conditions, to the ITPVCPC structure throughout the simulation process. The impact of structural deformation on solar radiation collection was investigated through an optical examination of the basin. Glass-covered ITPVCPCs exhibited more structural distortion than those without. ITPVCPC is made of fiberglass with polyester resin because it is less expensive than other composite materials. The study demonstrated that because of its high stiffness, low cost, and ease of production, fiberglass (with a polyester matrix) is the perfect composite material for ITPVCPC. This design is the source and has been applied successfully.

(3) Surface modified

Loni et al. [41] Using a rectangular absorption tube with an internal chamber, the researcher examined its effects. The inside of a cube has little tubes connecting to it. Factors such as cavity placement, bore opening, bore height, and bore tube diameter were incorporated into the sensitivity analysis plans. In this case, the optimal cavity depth was found to be the slot width. In order to maximize energy absorption, the focusing aperture must be set higher; with this aperture, the bore must be in the focal line. The reason being, its thermal efficiency was 77.26%, as shown in Figure 16.

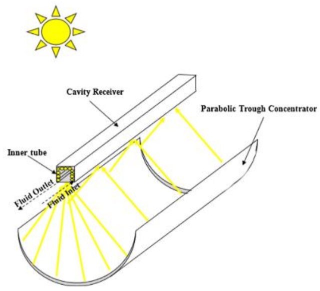


Figure 16. Experimental PTC system schematic with tubular rectangular cavity receiver [41]

5.2.3 Increased heat transfer coefficient

(1) Turbulent flow

Norouzi et al. [42] studied the process of using a rotating absorption tube to avoid concentration The radiation is reflected on the bottom of the tube only, which leads significant increase in the surface temperature reducing thermal stress as well. The results showed a control and reduction in the temperature difference by 60% and an increase by 17% in thermal efficiency of the equivalent basic collector, as shown in Figure 17.

Figure 17. Left: the absorber tube's rotary joint and Right: the DC motor that turns the absorber tube [42]

Akroot and Namlı [43] studied the thermal performance of a parabolic trough collector (PTC) utilizing an absorption tube with a convergent-divergent internal surface (PTC-CD). They found that this design regularly achieves better heat dispersion and efficiency within the suction tube. MCRT and the technique FVM were also employed. In order to mimic the processes of heat transmission with in an absorption tube. The number of sections in the pipe was also investigated, and the results showed the PTC entrance speed (s/m) ranged from 0.05 to 0.75 when compared to the convergence-divergence flow and flow characteristics. There was a 66% improvement in the Nussle number and an improvement in heat transfer ability when Re=86400 and N=25, according to the data. The percentage of mistakes is practical results compared to theoretical ones are 1.103 times higher.

(2) Using Nano fluid

The PTC can absorb both the beam and the scattered radiation due to their high acceptance angle. The Nano fluid is used as an absorbing fluid that passes through the collectors, absorbing the heat of the solar energy [44].

Nano fluids are classified as used in PTC to enhance the thermal performance of the collector. The main classes of Nano particles are:

1. Metal nanoparticles composed of iron, copper, zinc and aluminum.

2. Non-metallic Nano particles such as SiO_2, TiO_2, Fe_2O_3, ZnO, CeO_2, multi-walled carbon Nano tubes) [18]. Bellos and Tzivanidis [45]. Nano fluid outperforms basic fluids in convective heat transfer and thermal efficiency. Nano fluids have better thermal conductivity, density, and specific heat capacity than ordinary fluids, but their higher viscosity increases friction and pumping force. Alsaady et al. [46] performed experimental studies on ferro Nano fluid in a non-magnetic field with a magnetic volume fraction of 0.05%. The results of the experiment show that, as compared to when a magnetic field is used, the thermal efficiency of non-magnetic materials applied to the PTC collector is 25% higher, Sekhar et al. [47] studied experimentally how Nano particles affected the PTC's thermal efficiency. Copper oxide, aluminum oxide, and water (volume fractions ranging from 0.5 to 3%) were used as base fluids in this investigation. The best thermal efficiency was determined to be 27.25% for Copper oxide, 23.25% for aluminum oxide, and 23% for TiO_2 when the volume percentage of water was 3% (CuO_2-H_2O). Ghaderian and Sidik [48] experimented with a 2 L/min flow rate in an exposed PTC system to determine the impact of a 0.1% mass concentration of aluminum oxide –water, 32% increase in efficiency and a 7% increase in thermal conductivity were shown in the results. Shirole et al. [49] Comparing PTC performance in different ways to make a new model that works well under high pressure, thermodynamic properties and equations were used to figure out how well Nano fluids with CuO, SWCNH, magnetite, graphite, Al_2O_3, ZnO, Fe_2O_3, TiO, MWCNT, and SiO would work in theory. Adding Nano particles to the base fluid increases heat conductivity. Following magnetite in thermal efficiency were graphite, SiO_3, O_2Al, etc. Thermal efficiency is high in most Nano fluids. At 0.4% concentration, thermal efficiency rose from 10% to 20% as the mass flow rateincreased from 70 to 90 kg/s. Figure 18 shows the relationship between coefficient of convective heat of nano fluids [50].

In the PTC receiver, aluminum oxide and water produced a 28% increase in heat transfer, which can all be mathematically calculated for forced convection heat transfer. eddy cutting-edge glide is employed in conjunction with Nano fluid. Additionally, a 35% improvement in heat transmission was seen upon adding 3% of aluminum oxide Nano particles to water. Figure 19 shows the effectiveness of this addition of Nano particles [51].

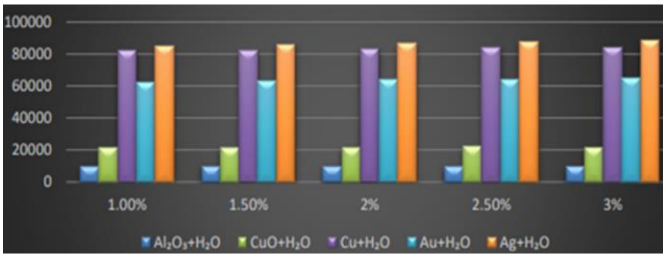


Figure 18. Comparison in coefficient of convective heat [50]

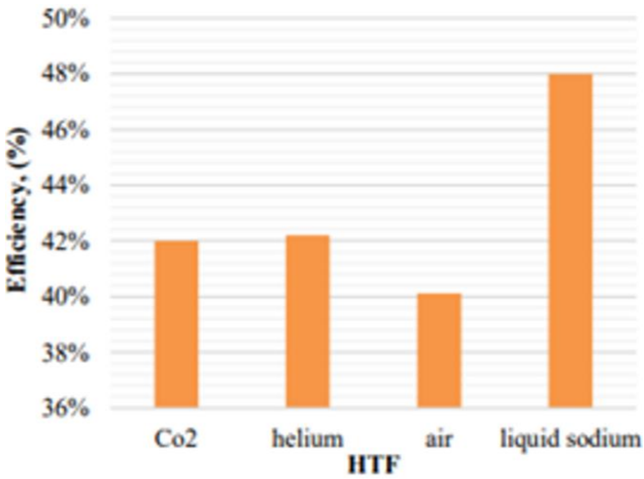


Figure 19. The efficiency of different HTF (Co2, helium,air, and liquid sodium) [18]

5.2.3 Heat loss reduction

(1) Use an evacuated tube

Kumar et al. [52] reported on a survey of recent numerical and experimental designs for evacuated solar collectors. They looked at how various design characteristics, including optical design, mass flow rate, and working fluid types, affected the outcome. Thappa et al. [53] experimented with the thermodynamic and geometrical properties of a double-evacuated receiver tube. A set of six receiver tubes is tested with rim angles of (400o, 800o, and 1200o), a flow rate of (16 to 216) L/h, and a fluid inlet temperature of (323, 423, 523, 623, and 723) K. They obtained that the receiver tube of 27 mm covered with a double-evacuated glass tube gives the highest energy and energy efficiency. It is around 79% and 47%, respectively, at 800 optimum rim angles at a broad parabolic aperture of 5.7 m, as shown in Figure 20.

Table 1. PTC systems simulation result

Parameters	New Design	Mono and Bi-Axial
Maximum temperature	$179C^0$	$134C^0$-$120C^0$
Increased in useful daily energy	33%	15%
Thermal efficiency	8.9%	5.8%
Maximum useful energy	22.6(73%)	17.93(67.41%)

Table 2. Optical and thermal properties of black chrome and graphene

Selective Coating	Emissivity (C)	Absorptivity	Heat Resistance Temperature (K)
Deposited black chrome	0.15	0.92	873
Deposited graphene nanostructure	0.99	0.99	1600

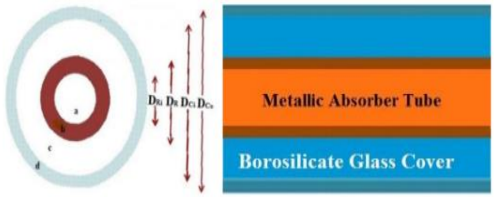


Figure 20. One-evacuated receiver tube with sectional view

Chargui et al. [54] evaluated the novel PTC design using a glass-covered biaxial absorber in comparison to momo / biaxially oriented absorbers that did not have a glass cover. To evaluate these systems, a transient simulation was employed. They arrived at the conclusion that a novel design provides the greatest thermal performance (see Table 1).

(2) Selective absorption tube coating

Jamali [55] examined the radiative characteristics displayed in Table 2 to compare the utilization of graphene Nano structure and black chrome as selective coating absorber tubes. Graphene Nano structures, they say, are prefer able to black chrome due to their superior physical radiative qualities.

(3) Cover material

Khalaf et al. [35] measured the dimensions of the glass cover to minimize heat loss by convection and radiation. An important factor influencing the efficiency and cost of PTCs is the glass's mechanical and optical properties. Here are some characteristics of the perfect glass cover:

•Quite inexpensive.

•Easy to carry and operate.

•The transmittance is very high.

•When exposed to UV light, it reaches a high temperature and maintains that temperature for a long time.

•Its emissivity is poor.

•Cuts down on heat loss by blocking out long-wave infrared light.

6. MATHEMATICAL MODELING

The absorbers tubes energy components as shown in Figure 21. The red arrows mean the solar energy absorbed by the glass tube and absorber tube.

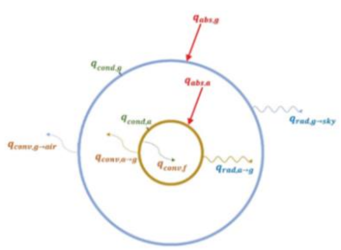


Figure 21. Flow of energy in the PTC absorber tube [56]

By the equations shown below can be calculate the losses from the system by using the thermal resistance network as shown in Figure 22.

The following equations relate to the energy balances on the absorber tube and the glass envelope. The heat flow values ($\dot{q}'$) can be found by solving for the temperatures at each section, as shown in Figure 22. These values are functions of the temperatures at the corresponding boundaries [56].

$$q\,'\,ThermalLoss = \dot{q}'\,rad,\,g \to sky + \dot{q}'\,conv,\,g \to air$$
$$q\,'\,u = \dot{q}'\,Abs - \dot{q}'\,ThermalLoss$$
$$q\,'\,abs{,}g = \dot{q}'\,focus.\,\alpha g$$
$$q\,'focus = (Idn.\rho.\gamma.IAM.Aa)/L$$

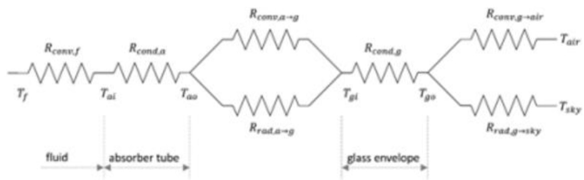


Figure 22. Thermal resistance network showing the heat losses in the PTC

7. ECONOMIC ANALYSIS

Economic costs, such as the initial investment, maintenance, operating, replacement, and equipment expenditures, have been planned for in the economic modeling. The solar thermal systems' cost could be obtained by Eq. (1):

$$CS=Ca\ Aa + CH\&H\ Aa + Cst + CM\&O \tag{1}$$

where,

CS: The cost of the solar thermal system

Aa: The collector's area

Ca: The hydraulic circuit a

HTF (CH&H), the energy stored in the tank (Qst) (Cst), and the maintenance and operations (CM&O) costs are all equal to 2% of the initial investment cost 1.

An annuity is a series of equal annual payment flows. Its present value is calculated using a ratio called the capital recovery factor (CRF). What the formula for the CRF is:

$$CRF = \frac{r(1+r)n}{(1+r)n-1}$$

where, n is the system's performance years, or 20 years, and r is the interest rate, or 15%. The definition of the total annual system cost is:

TCA = CRF CS + CAUX -+ +˙CAUX Q AUX

Fuel cost, represented by ˙CAUX in the previous equation, is 0 because there is no fuel usage [57].

8. SUMMARY OF PREVIOUS RESEARCH

Table 3 describes data from previous analyses of parabolic trough collector performance, along with suggestions for improving it in countries around the globe, and their effects on productivity.

Table 3. Review of some various developments in PTC

Reference	Year	Method of Improving	Type of Absorber Tube	Implementation	Finding
[17]	2019	Porous mate inserts	Copper metal foam.	Studied used three glass absorber tube with different porosity (full porous, partly porous, and nonporous)	Increase thermal efficiency (semi-inset and full-inset tubes) 119.6% and 171.2% respectively.
[41]	2020	Surface modified	Rectangular cavity absorber	Performed a numerical analysis on a novel PTC collector design including a rectangular cavity absorber.	The highest thermal efficiency achieved was around 77.26%, with an absorbed heat energy of 618.09W
[46]	2019	Nano-fluids	Normal	Completed an experimental study on the impact of Ferro fluid in a nonmagnetic field.	Thermal efficiency is increased by 25% compared to using a magnetic field.

9. CONCLUSION

According to the data shown in Table 3, which is based on a literature analysis that addressed various methods for enhancing heat transmission in concentrated solar collectors. The most effective improvement strategy was found to be employing copper foam as a porous mate insert. This was demonstrated by Norouzi et al. [42], which achieved an energy efficiency of 119.6% for semi-inset tubes and 171.2% for full-inset tubes. In contrast, research has demonstrated that enhancement methods including an evacuated tube and a finned tube may achieve energy efficiency of more than 65% [30, 49, 54]. As seen in Table 3, the alternative way of improvement stated in the literature study also resulted in improvements in thermal energy transfer, albeit to a lesser extent. In order to achieve the maximum thermal efficiency of the PTC. it is suggested that future research should focus on finding a suitable porous material that is readily available at low cost to enhance heat transfer into the absorber receiver and thus improve the performance of the entire PTC.

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NOMENCLATURE

PTC	parabolic-trough-collector
SS	solar-still
PV	photovoltaic
ETC	evacuated-tube-collector
FVM	finite volume measurement
MCRT	monte carlo ray tracing
SP	solar power
RR	raschig ring
SHS	solar heat system
EES	engineering equation system
SDD	solar during day
DNI	direct typical reflection
CSP	collector solar power
CPCs	compound parabolic collectors
ETC	evacuated-tube-collector