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REVIEW ARTICLE

Comprehensive review on various parameters that influence the performance of parabolic trough collector

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Abstract

Among the different kinds of renewable energy sources, solar energy plays a major role because it is safe and inexpensive at all times. Several techniques are developed for steam and electricity generation by solar energy, in which the parabolic trough collector is an advantageous method for generating steam and electricity. Different types of collectors for various temperatures, in which PTCs are used to produce medium temperature ranges using the readily available solar energy, were developed, produced, and tests. Many theoretical and experimental studies have been carried out to improvise parabolic trough collectors' optical and thermal characteristics. The modifications are reviewed in this paper to enhance the design modification, optical and thermal properties utilized in the collector. This analysis paper also elucidates the use of PTC desalination, various integrated parabolic trough collector methods for power generation, and the economic aspects of parabolic trough collector.

Keywords Parabolic trough collector · Optical property · Thermal property · Heat transfer fluids · Solar energy

Introduction

Solar energy is the primary source of energy in all sorts of non-conventional power sources. The use of solar energy as an effective source for various purposes, such as the generation of direct steam, power, and desalination of parabolic trough collectors, is nowadays an important technique. The parabolic trough collector is a known technique among all kinds of solar energy techniques; therefore, any modifications to the PTC's output are essential. Solar-based technology started flourishing more than 70 years. The beginning of the oil crisis in the 1960s paved an effective way for an alternative energy source worldwide, and therefore, several parabolic trough systems have been developed. In the exemplary trough collector system, the absorber tube's temperature can be as high as 360–410 °C. And solar collector's thermal efficiency is primarily focused on the concentration ratio. The parabolic trough collector has diversified applications like heat generation, power generation and desalinisation. The process of converting saline water into potable water is termed as desalination process. In the present scenario, the water desalination is carried through a reverse osmosis method, which increases the energy consumption cost and depletes fossil fuel.

Various researchers conducted review in the recent developments of parabolic trough collector like alternative designs (Bellos et al. 2020). modelling and simulation tools (Sandá et al. 2019) thermal and optical properties could (Abdulhamed et al. 2018) applications of the solar-powered PTC (Ebrazeh and Sheikholeslami 2020) presents a concise preface for various types of solar panels. PTC with nanoparticles (Raj and Subudhi 2018) different factors and significant operating condition (Jamali 2019) silver reflective mirror (Akbarzadeh and Valipour 2018).

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The different nanofluids and various turbulators, essentially the internal fins and various inserts. (Jebasingh and Herbert 2016; Sathyamurthy et al. 2020) carried out review analysis in efficiency improvement. Also focused on the application of solar energy such as industrial heating, refrigeration, desalination, and air heating system. (Chauhan et al. 2021) reviewed various passive and active solar systems such as parabolic trough collector, flat plat collector, external and internal reflectors, water heater, nanoparticles. (Sathyamurthy et al. 2017) reviewed the integrated solar collectors with solar still to yield high productivity. Economic analysis and payback period were analyzed pertaining to integrated solar collectors. (Suman et al. 2015) carried review analysis in various types of solar based thermal methods for the efficiency enhancement. Hence, a novel review has been conducted in this review article focusing on the various modifications made in the parabolic trough collector, as it will provide new research with a way to achieve performance and optical property improvement in PTC.

A suitable method to increase heat transfer area of the receiver tube, proper focusing method of reflector, and increase in thermal conductivity of base fluid are the major research criteria and research gap in the PTC. Hence, the recent modifications used to attain an enhancement in the thermal performance of the PTC are elaborated in each section of the review article.

. The solar receiver is the primary component in parabolic trough collector. A PTC consists of a parabolic shaped reflective mirror which focuses the solar radiation to absorber tube. The focused solar energy rays are transformed into heat energy in the absorber part and it is grasped by the heat transfer fluid (HTF). The outer shell of the absorber tube is particularly coated to have a minimum reflection of thermal radiation and high absorbance of solar radiation. In receiver, the heat transfer is enhanced by adopting the following conditions like applying selective coatings in the absorber tube, utilizing turbulators, minimization of heat loss, and utilizing nanofluids as HTF (Kumaresan et al. 2017). The heat exchange in the receiver tube is enhanced by using particular coating on the exterior side. When the operating temperature of PTC increases, the heat loss enhances correspondingly. To reduce such high heat dissipation, particular coatings are used on the exterior of the absorber. The coatings stimulate minimum emissivity and high absorptivity in the absorber tube. The thermal performance increase is attained in the absorber tube by creating swirl flow, enhancing the actual heat transfer area and high rate of turbulence effect through minimising the expansion of boundary region. The temperature exchange is increased by including several turbulators, like porous discs, metal foams, baffles plate, dimples coil inserts, and twisted tapes (Too and Benito 2013). Minimization of heat dissipation in the solar absorber has immediate effect with the efficiency and thermal performance of PTC. One-dimensional analysis performed in the receiver of PTC reveals that convective heat dissipation in the absorber has major effect in the performance of PTC (Padilla et al. 2011). Maintaining vacuum around receiver tube has significant impact in the heat dissipation (Krishnavel et al. 2014; Manoj Kumar et al. 2020). Using nanofluid as HTF in the absorber increases the rate of heat transfer, efficiency and thermal performance of PTC. A simple economic analysis carried in solar thermal plant reveals an enhancement in the yearly revenue using nanofluid as HTF in the receiver.

The reflector has equal significance in the thermal performance of the PTC. High efficiency level and reflection rate of the receiver have direct impact on the thermal performance enhancement. Also, the addition of nanofluids has significant effect in the thermal performance of the PTC. The radiative property of the nanoparticles and increase in thermal conductivity of the base fluid due to addition of nanoparticles enhance the thermal performance of the PTC.

This article also explained the technique of desalination using the parabolic trough collector and its related improvements to increase the distillate water's efficiency. In this paper, the impact of wind load parameters, the angle of occurrence, modifications made to reflectors and receiver tubes, use of various traditional and modified heat transfer fluids, the use of various nano-fluids and their effect on thermal efficiency and improved optical property elucidated by different studies have been elaborated. The years and number of journals are distributed in the Fig. 1. This article also addressed the integrated techniques used to produce electricity, economic aspects, and desalination using parabolic trough collectors. The distribution of the percentage of the number of journals corresponding to different PTC parameters is shown in the Fig. 2. The parameter influencing the performance of the PTC is shown in the Fig. 3.

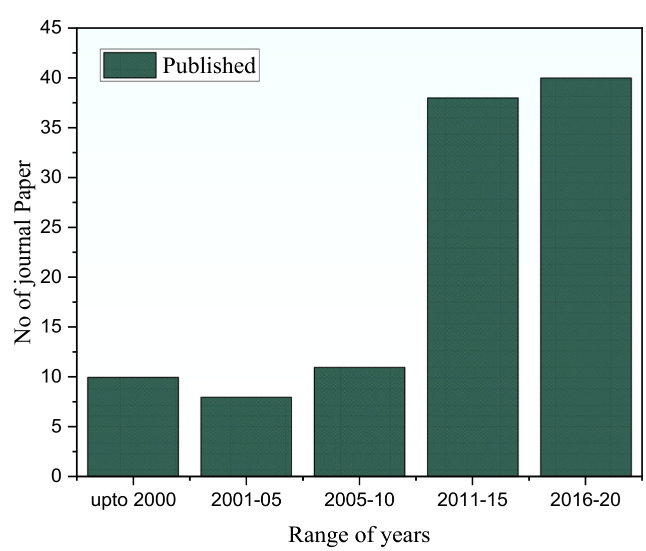


Fig. 1 Distribution of years and number of journal papers

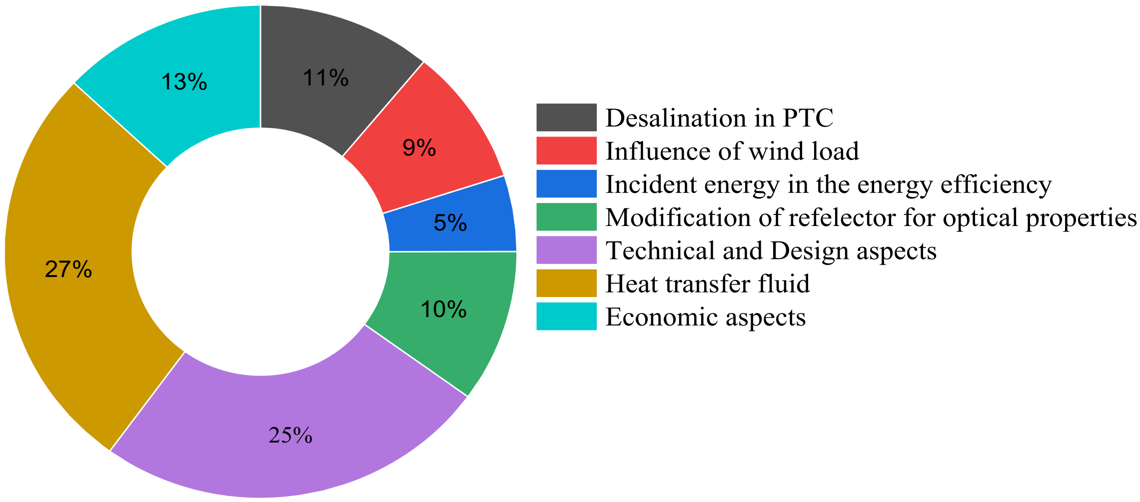


Fig. 2 Percentage distribution of the number of journal papers corresponding to various parameters of PTC

Design of the parabolic trough collector

The solar receiver tube is the primary component of solar thermal production systems using PTC. The PTC concept is the conversion of solar radiation to thermal energy. A significant technique for optimizing the performance and efficiency of the receiving tube will increase the thermal conversion to electricity. The receiver tube has a glass top tube and a metal tube inside. The concentrator is used to reflect the solar rays on the metal tube's external surface and capture the surface of the tube. A significant amount of energy was transferred to the metal tube's inner surface and absorbed by the combined heat transfer by working fluid in the metal pipe.

Porous medium in the receiver tube

The incorporation of various porous shapes within the receiving tube improved the heat transfer properties of the parabolic trough concentrator and its thermal efficiency. (Ravi Kumar and Reddy 2009) used the porous material in the solar PTC absorber for heat transmitting properties, and the results showed that the porous medium's inclusion increases the heat transfer properties, but the pressure fell significantly. The heat transfer field, thermal conductivity, and turbulence effect are improved significantly. The highest heat transfer coefficient with a sensitive drag is achieved in the parametric conditions of w = di, H = 0.5di at h = 30°. For a Reynolds number of 31.845 and a pressure loss of 0.0663 Psi, 64.2% is achieved as an improved tube-receiver number in Nusselt for the finest recipient. (Reddy et al. 2015) compared the PTC output based on the six recipient configurations with the collector and the improved disc-absorber of 15 m^2 solar parabolic troughs. The photograph of the collector system for solar parabolic troughs is shown in the Fig. 4. Two traditional and four porous SPTC disc absorbers are defined by taking time constant, peak efficiency, collector acceptance angle, and heat loss tests to measure their performance. If the thermal output of PTC is also equivalent to fluid intake and ambient temperature,

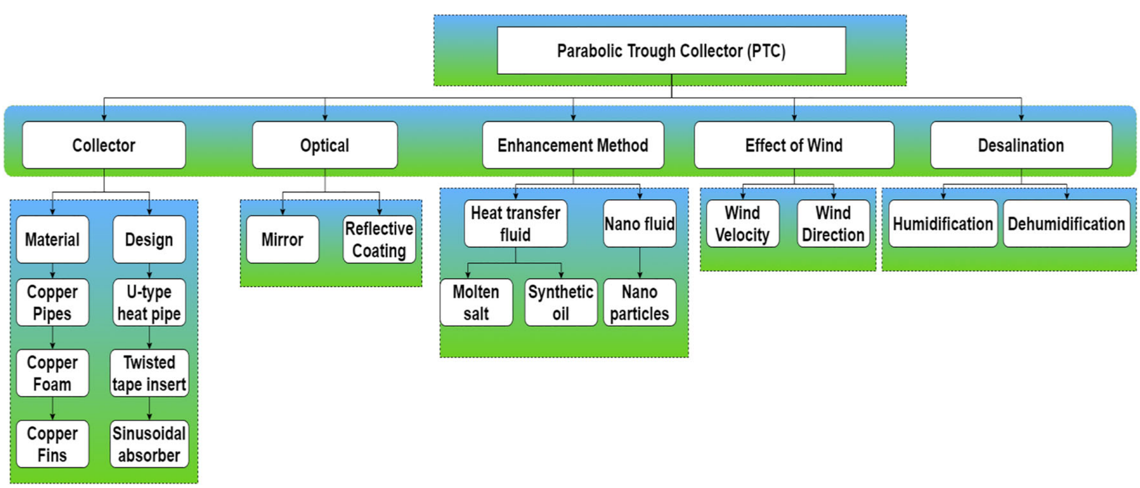


Fig. 3 Parameter influencing the performance of the PTC

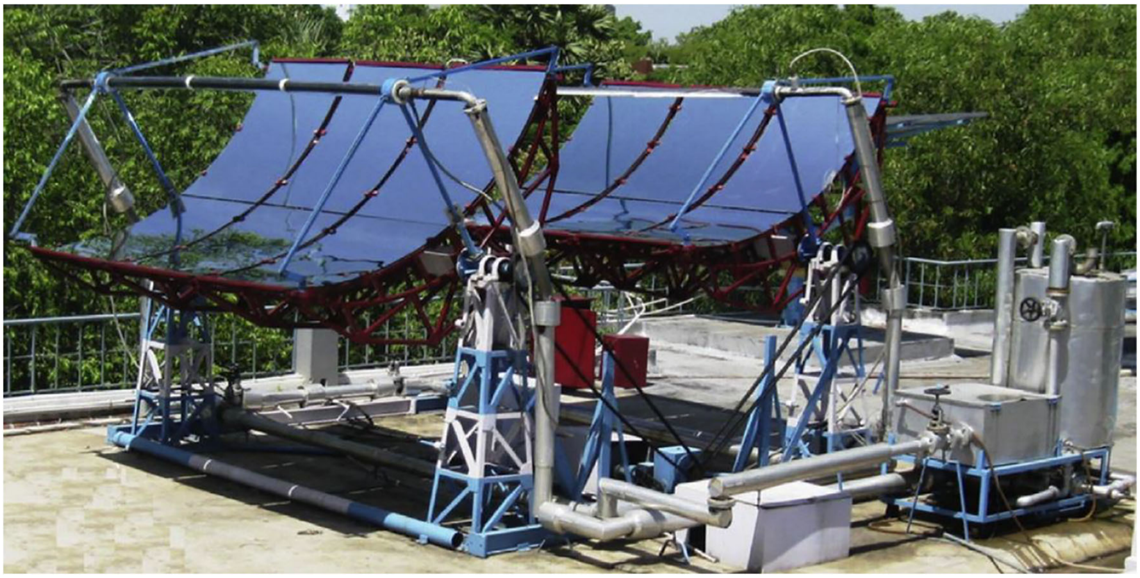


Fig. 4 Photographic view of solar parabolic trough collector system (Reddy et al. 2015)

measurement of 61%, 63.9%, 63.5%, 64.9%, 64%, and 66.66% for Shielded Tubular Receiver (STR), Un Shielded Tubular Receiver (USTR), Bottom Porous Disc Receiver (BPDR) and Inclined Bottom Porous Disc Receiver (IBPDR) will be measured in the calculation at 61.5% (Ebrahim Ghasemi and Akbar Ranjbar 2017). Numerical SPTC analysis with porous rings for their thermo-hydraulic properties was undertaken. The thermal efficiency of the collector is determined based on distance comparison and inner diameters of the rings. The insertion of porous rings in the solar tubular receiver increases heat transfer and its properties. The porous medium shall be used throughout the length of the receiver tube, as it decreases the thermal resistance and enhances turbulent intensity to attain better thermal property (A. (Karthick et al. 2018; Kumaresan et al. 2017)). Porous fin in the receiver tube provides a significant pressure drop and better heat transfer coefficient (Ravi Kumar and Reddy 2009; Sudalaiyandi et al. 2021). Numerical investigation carried in the porous disc receiver indicates that the upper portion possesses the high heat transfer rate and subsequently attain a significant enhancement in the Nusselt number and thermal performance (Ravi Kumar and Reddy 2009).

Copper pipes, foam, and internal fins

The modified copper metal tube receiver and the introduction of copper foam into the receiver tube decrease the total loss rate and improves thermal efficiency (Jamal-Abad et al. 2017). The pressure drop has been experimentally tested, and the PTC's thermal efficiency has been calculated to ensure that copper is used internally on the parabolic trough absorber. The total loss coefficient (UL) is decreased by 45% due to lower energy losses, and the thermal efficiency of the PTC is improved (Almanza and Lentz 1998). It is studied that when connected in series, 100 kg/h of steam is provided by four modules with a width of 250 cm and a length of 1450 cm. For the first, second, and third units, the black chrome-covered by the copper pipe absorber has a nominal diameter of 3.81 cm, and the fourth one chooses the black chrome-covered by the stainless-steel pipe absorber of approximately 2.54 cm respectively. The copper tube eradicates the bending due to heat stress in two-phase flows and generates a 3% efficiency.

(Muñoz and Abánades 2011) used the PTC measurement dynamic fluid method and examined the effect of using the internally finned tubes. The collector's energy and thermal efficiency increase, and the thermal loss and temperature gradient decrease. Due to the decrease of the tube substitution rate, maintenance, and operational costs are reduced, and the PTC's efficiency is 2% (Bellos et al. 2018). The PTC performance was evaluated by adding the internal fins to the PTC absorber. The finned metal tube inside the PTC is shown in Fig. 5. This paper focuses mainly on the required location and the optimal number of internal fins. When the optimum position (β=0°) of one fin is at lower sections and smooth conditions, thermal efficiency is 68.49% and 68.24%. The results showed that the thermal efficiency was 68.50 and 68.59% when two fins were perfectly combined with lower β=0° and β=45° and absorption was perfectly combined with three fins at lower β=0°, β=45°, and β=315° (Z. (Zhao et al. 2020)). Three separate receiver tubes were used to analyze the solar air concentrator's performance trough at median heat requirements. The two receiver tubes and smooth recipient tube with internal pin fins are checked on site. Pin finned rods are higher than smooth rods with a pressure drop and air temperature. The results show that energy efficiency and smooth tubes'

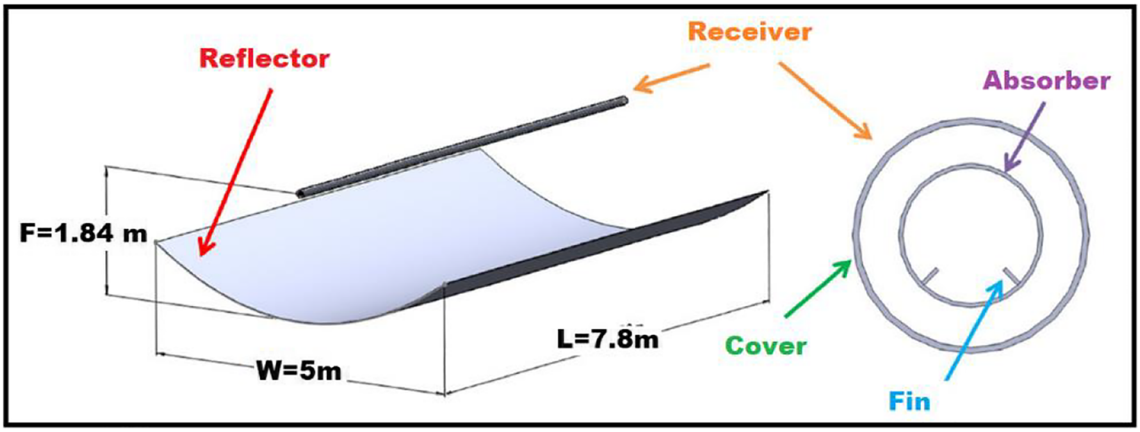
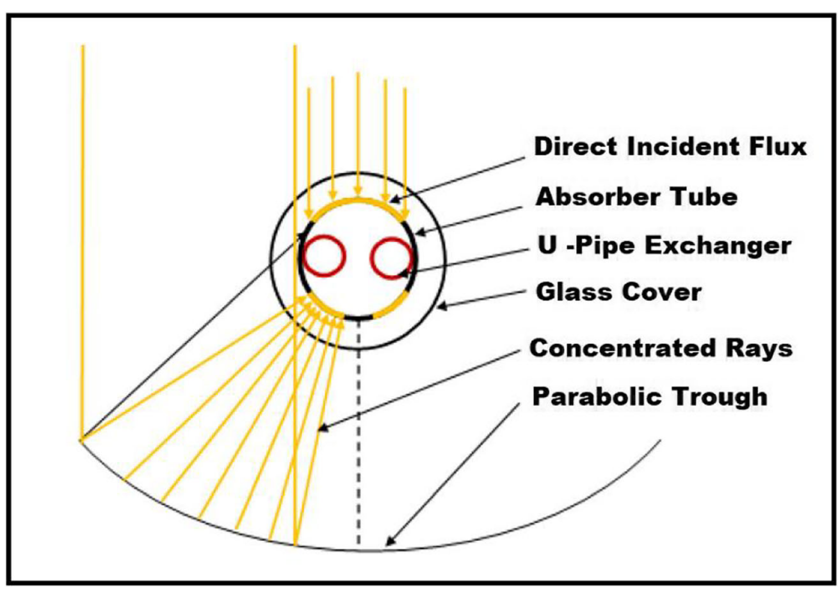


Fig. 5 Internally finned absorber metal tube in PTC (Bellos et al. 2018)

exergy are lower (2.55% and 4.29%) than internally finned tubes, with a value of 14.5% and 10.4%.

The adjustment considered in the absorber tube's geometric form and the inclusion of different inserts increase the thermal performance of the PTC. Several inventors have experimentally demonstrated that Liang (Zhang et al. 2012) have created a medium temperature steam generation with the natural circulation heat pipe (U type) parabolic solar collector trough. The performance of heat transfer and thermal behavior, especially the solar collector, was also evaluated experimentally. At 0.5 Mpa of dumping pressure, the thermal efficiency of 38.50% is achieved in the summer, and mid-temperature vapor is achieved at 0.75 Mpa. (Halimi et al. 2018) investigated the output of the parabolic trough concentrator shaped U exchanger for normal incidence radiation. The ray route in the form of a U-pipe exchanger fixed within the metal absorber pipe, and a view of the experimental configuration of a U-shaped pipe exchanger internally fixed in a PTC metal absorber tube is illustrated in Figs. 6 and 7. The study shows that in the PTC in which the exchanger is in parallel (Jaramillo et al. 2016), 40% thermal efficiency is obtained with a focal length of 0.19 m, the thermodynamic model calculates the parabolic concentrator's output and the twisted tape insert. The results show that the thermal efficiency, the friction factor, the removal factor, and the number of Nusselt increased because the twisted tap insert was included, and the number of Reynolds and twist ratio (y/h) decreased when twisted tapes were present (Demagh et al. 2015) based on the parabolic trough collector's absorber (S-curved/sinusoidal). Figure 8 shows the scheme & 3D view of the vacuumed absorber with an S-curved pipe at both ends in PTC. The test shows that the previous intercept factor with the normal straight vacuum receiver is not substantially better than the intercept factor of an SR unit fitted to the same condition with the vacuum receiver (S-curved). The asymmetric outer convex corrugated tube used in the parabola trough tube of metal has been studied by (Fuqiang et al. 2016). To optimize overall heat transfer reliability and efficiency.

Fig. 6 Ray path in U-shaped pipe exchanger fixed internally in metal absorber tube of PTC (Halimi et al. 2018)



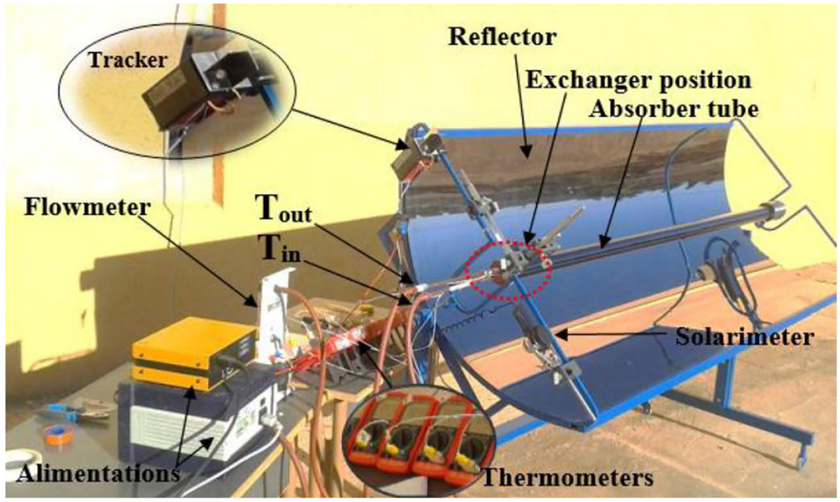


Fig. 7 Photographic view of experimental arrangement of U-shaped pipe exchanger fixed internally in metal absorber tube of PTC (Halimi et al. 2018)

The limit value of the thermal stress and total heat transfer efficiency are 27% and 148%, while the receiver tube is adapted to an asymmetrical external convex corrugated tube.

The parabolic curve concentration's thermal efficiency can be improved by experimental investigations involved by various adjustments in the absorber tube, such as movable cover, bellow caps, isolated annulus, cubic cavity, evacuated tube, and several researchers. [38] examined cavity receiver overheating safety in parabolic trough concentrator and the effect of novel mobile covers on thermal drop reduction. A heat loss test was conducted at various mass flow rates (59.83~92.32 g/s) and inlet temperatures (140.8 ~160.2 °C) based on the 3D thermal transfer test data model. The result indicates that the range of heat drops between 6.36% and 13.55% is higher than turning the smartphone cover off. (Valenzuela et al. 2020) studied the solar radiation concentration impingement on the northern bellow caps of the recipient for understanding the installation failure of the North-South Parabolic Trough Solar Power Plant Recipient. As the angle of incidence increases, the solar flow is increased in the caps. The solar flux is below 1.75° and 2.5° for the defocusing angle relative to the zero defocusing angles during sun monitoring. The successful defocusing angle, therefore, varies from 0.75° to 1.5°. (Al-Ansary and Zeitoun 2011) conducted the heat loss studies numerically from the half-insulated annulus between two horizontal concentric cylinders. The heat recovery and loss mechanism scheme: (a) evacuated receiver and (b) gas-filled annulus receiver is shown in Fig. 9. The simulation of conduction and convection is calculated from the new PTC architecture. The heat loss, coupled with the conduction and convection, was decreased by a maximum of 25% using this technique (Loni et al. 2020). PTC's output, whose receiver is enriched with linear cubic cavity and the thermal oil is the working fluid. Figure 10 displays the schematic of the rectangular tube cavity receiver in PTC. At the lower traceability and optical defects, a high optical output rate is achieved. The

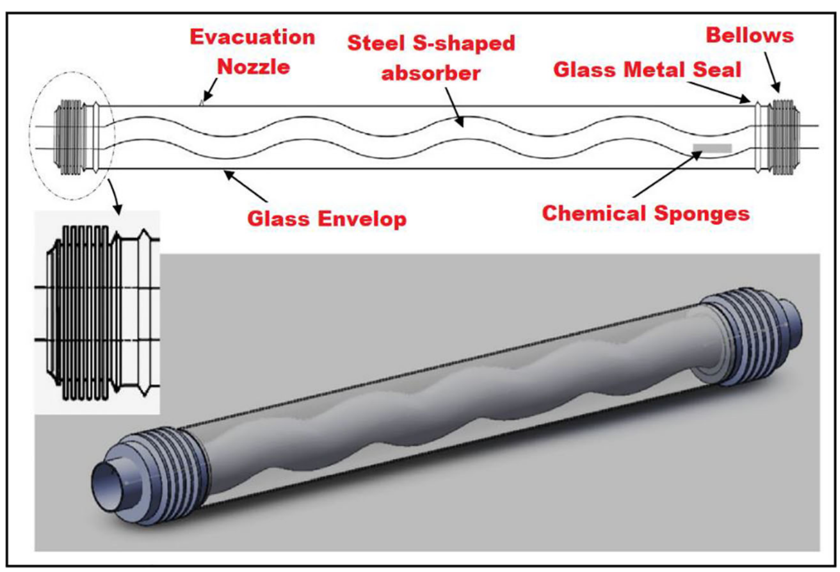


Fig. 8 Schematic diagram and 3D view of the vacuumed absorber with an S-curved pipe and bellows at both ends in PTC (Demagh et al. 2015)

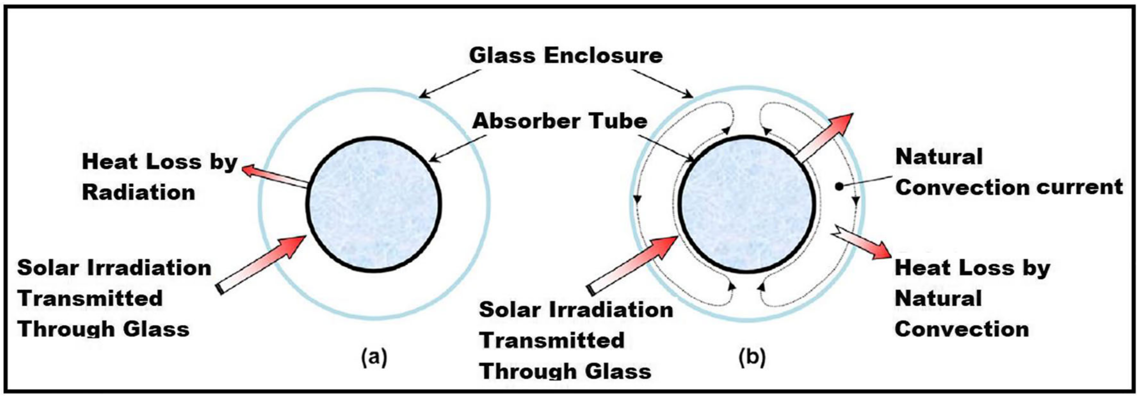


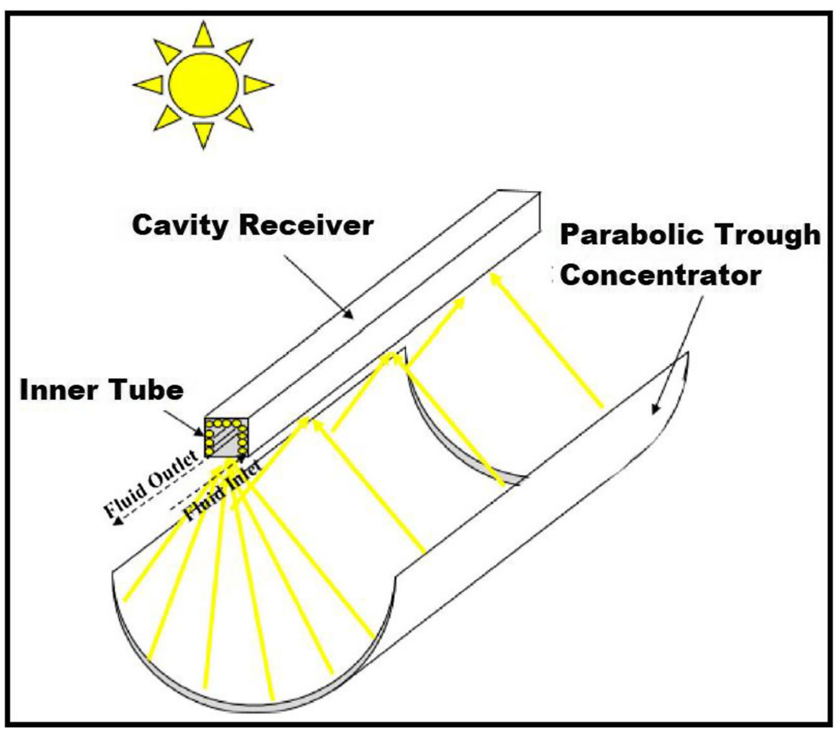
Fig. 9 Schematic of heat gain and loss mechanisms: (a) evacuated receiver and (b) receiver with gas-filled annulus (Al-Ansary and Zeitoun 2011)

absorbed energy increases with the focusing aperture increased. The results show that the parabolic focal axis has a cavity and a cavity tube diameter of 0.5 cm, the solar system's thermal efficiency, and solar heat absorption is 618 W and 77%.

(Daniel et al. 2011) compared the non-evacuated tube to the vacuum shell output and the evacuated configuration. Relevant coating of the evacuated tube guarantees the highest of all configurations. The result shows that the vacuum shell has a 10% higher yield than the unevacuated selective coated receiver tube. (Rolim et al. 2009) calculated efficiency of PTC with three separate absorber fields for the electricity generation by model analysis: evacuated, non-evacuated, and bare absorber. The maximum overall efficiency is 940 W/m^2, depending on the form of the absorber. The outcome has been shown to have 26.2% and 320 °C, 24.3%, and 310°C, as well as 21.9% and 300°C, for evacuated non-evacuated absorber and bare absorber.

Many researchers explained that receiver tube diameter, selective surface cover, heat flux, and various adoptions of heat exchangers in PTC have a major impact on the parabolic trough concentrator's thermal efficiency (Thappa et al. 2020). The receiver tube was analyzed with various diameters. The box I and II have a receiver tube diameter of 6.5 cm, 1.1 cm, and 7 cm, 1.6 cm, inside and outside. The study shows that almost 77 to 78% and 79 to 81% efficiency was achieved in case I and II. (Tao and He 2010) studied the unified 2-D PTC model of heat transfer coupling. The tube diameter ratio increases, the NU2 is decreased, and the amount NU2 in the internal tube increases, while the tube wall's thermal conductivity increases Nu1 and the NU2 decreases.

Fig. 10 Schematic of tubular rectangular cavity receiver in PTC (Loni et al. 2020)



(Barriga et al. 2014) investigated the PTC configuration which an absorber collector at a maximum operating temperature of about 400°C has been based. When the selective coating is done on the receiver tube, the working temperature and the output are increased to 600°C and 5–10%. The absorption will achieve a higher value if two are used with different quantities of metal substances than with the single cermet. To optimize the absorption rate, a low metal cermet (Cermet L), high-metal cermet (Cermet H), silicone oxide reflectance (SiO_2) layer is added to the bottom, and the silver is emitting mirror applies to the top. (Cheng et al. 2010; Karthick et al. 2020a)measured PTC's efficiency concerning the tube's absorber. The result shows that the glass cover tube's internal surface and the external wall of the absorber tube have high heat transfer radiation when the performance of the collector is improved by the application of a suitable solar-absorbent specific coating.

Z. (Wang et al. 2017) carried out the NUHF estimation and scanning methods of PTC. NUHF can maximize overall convective heat transfer in the receiver tube. Variant methods for optimization and replication of non-uniform PTR heat flow were performed. The result shows that the NUHF outside the receiver tube is entirely different from the relative uniform heat transfer convection. (Zaversky et al. 2013) studied a lab-scale experiment with cylindrical storage containers for high heat temperatures. The two heat exchanger pipes are helically coiled and vertically straight. A mathematical model of NSSHE is developed for the experimental effects. The heat transfer rate and storage efficiency of the helically coiled pipe exchanger are approximately 0.1 kg/s and 63.1%, respectively, and can be adjusted and used properly in the PTC receiver tube.

Optical properties in PTC

Sun radiation is used to create energy and is a direct operation. The receiver tube will not be redirected from the focus line. When the sun's rays are focused on a tip or a stripe, thermal energy is transferred to the heat transfer fluid, so it is not very thicker in electricity generation. The concentration factor is used to assess concentration intensity, and the increase in concentration factor has increased concentration intensity. The reflector plays a predominant part in achieving such a high concentration ratio and high electricity generation temperature. The reflectors' purity also has a big impact on the transfer of thermal energy to the heat transfer fluid available in the receiver tube.

(Mart et al. 2000) investigated the solar mirror and soda-climatic parabolic trough concentrator with a focal concentration of 78.1% at 0.0024 m and a commercial solar mirror at an efficiency level of 74.4% at the same constraint. (El Gharbi et al. 2011) tested the LFR output and found it to be optically identical to PTC. The series of linear mirror strips that travel autonomously and collectively concentrate on receiver lines hang from prominent towers and are used to achieve the parabola reflecting surface. It is the form of a linear reflector. The study shows that LFR is cost-efficient, thus replicating PTC efficiency at lower costs (Meiser et al. 2015). The impact of the deviation values resulting in slope, load gravity, and focus mirror form of the parabolic trough was studied. The average value of the focus difference and the RMS slope for the optimizing and undeformed mirror shape is smaller at 0° (zenith) of the collector-angle and is thus more beneficial. Based on the manufacturing and design of parabolic dish mirror, the optimal shaped flat metal petals are used to form a highly reflective surface plate mirror. The ends are pulled to each other through rods or cables to produce parabola-shaped reflective petals where the back is thinner in metal. Of the 40 image points, only 16 were single-layer mirrors that were not calibrated, with the energy efficiency of 40% being dependent on the receiver diameter. Thirty-seven points of reflected laser in the respective focus area should be ensured to generate 92.5% of energy efficiency.

The hand layout technique for producing hot water, with the fiber, strengthened PTC with the thickness of the parabolic trough and the rim's angle being 70 cm and 90^o, respectively (Valan Arasu and Sornakumar 2007). During processing, a high level of surface finish is performed on the reflector attached to the concave surface of PTC. The fiber-reinforced parabolic trough concentrator is checked in a wind tunnel with a speed of 34 m/s. The results show that the thermal power of the fiberglass-reinforced PTC is 70%. (Reddy et al. 2019) used the various composites as reflectors for the 23.08m^2 solar PTC optical and structural inspections in a custom-made modelling approach. It shows that facets of PTC made by woven jute/glass fiber-reinforced polyester hybrid composite material will possess γmax = 0.955 for avg, SD = 1.349 mrad in elastic case under gravity load, γmax = 0.866 for avg, SD = 3.78 mrad in stiff case, γmax = 0.863 for avg and γmax= 0.957 for avg, SD = 1.34 mrad in stiff case. When taking into account wind elasticity and gravity, the optimal results were achieved by SD= 3.81 mrad. The research has shown that the elastic case and the stiff case of maximum weight are reduced to 4.5% and 30%. Production costs are efficient, and tracking power is reduced in comparison with the traditional hybrid composite glass concentrator

Reflector adjustment in a parabolic trough concentrator was studied. Zinc-coated reflective sheet possesses high reflective nature. The increase in reflectivity subsequently enhances the temperature in the receiver tube and thermal performance of the PTC (Singh et al. 2020). This paper shows the efficiency of zinc-plated galvanized plate with reflective silvery RS-20 film when the general reflector is replaced. The result shows that the latest modification of reflectors absorbs 4070 J, suggesting that a high heat rate is absorbed within the small collector and can be used for many applications. PTC measured the energy efficiency about the surface of a variant absorber, such as aluminium foil absorber, mirror sticker, and aluminium plate absorber. The research demonstrates that the aluminium sheet absorbs high heat rates. Also, the aluminium plate as reflector possesses high reflective ability to transfer the maximum amount of incident solar radiation in to useful heat energy in the parabolic trough collector to attain better thermal performance ((Ibrahim et al. 2014); A. (Karthick et al. 2020b)). Aluminium module as reflector will enhance the efficiency of parabolic trough collector, as the reflection rate of aluminium module is 89% (Ortega-Delgado et al. 2016). (Spirkl et al. 1997) used secondary reflectors to improve their PTC performance and increase the solar irradiance concentration of an absorber channel. Although the efficiency is ideal for its unity, the wider shape class is optimal, and the result shows that the concentration rise comes from the secondary reflectors. (Zaversky et al. 2012) concluded that the cleanliness of the parabolic mirror collector improves annual power plant efficiency. Mirror cleanliness rises by 1% in the Spiegel-water cycle research series and by 0.72% in the yearly net energy production.

Various heat transfer fluids

Conventional HTF in parabolic trough collectors

The optics were used to converge solar radiation on the thermal absorber's surface in focused solar power systems. The absorbed solar intensity was transformed into electrical power by HTF, and solar radiation was collected at higher temperatures. In recent years, the integrated PTC has been installed at solar thermal plants with a total capacity of 5000 MW worldwide. Solar Thermal Power Plants (STTPs) have been constructed around the world with about 5000 MW. The synthetic oil is used as HTF by most parabolic trough collectors. Besides synthetic oil-equivalent fluids such as water, molten salt, and pressurized gases were also used and evaluated to increase PTC performance and avoid environmental problems related to synthetic oil.

Molten salt, synthetic oil, and various influenced parameters of HTF

Many researchers have used molten salt as a standard HTF and have studied the parabolic trough collectors' heat transfer capability on an experimental basis. The molten salt has many desirable properties at high temperature; hence, it has been used as a heat transfer fluid in solar applications (Ramanan et al. 2020). The standard thermal oil HTF has been replaced by 60% $NaNO_3$ and 40% KNO_3 (molten salt) in transient PTC by (Zaversky et al. 2013). The use of molten salt as the HTF greatly improves the parabolic trough collector thermal efficiency parameters. (Ruegamer et al. 2014) improved parabolic trough technology's competitiveness by raising the efficiency of the power bundle, which is considered the largest indicator, and by reducing the level of electricity consumption by 20% and increasing heat collection elements that allow higher working temperatures by using molten salts like HTF. The thermal performance of (Hoste and Schuknecht 2015) was about 70.5%, and the optical performance was 76%, with molten salt being an HTF range of between 300°C and C. The findings also confirm the freezing recovery and activity with molten salt experiments as HTF. The molten salts as a secondary HTF and supercritical CO_2 were used as the primary operating fluid in a new design of solar thermal power plants with wide openings parabolic-trough collectors, which results in a net efficiency of 12.5% per year at 503°C of collector outlet temperature and a rating of 12.4% for the same preplanned collection surface for solar fibers. The study shows that the plant output characteristics will grow to 12.9% by extending the field to a net area of 625587m^2. Experimentally, (Muñoz-Anton et al. 2014) tested a new technology by gas-cooling at a maximum high temperature (up to 525°C) and pressure (up to 100 bar) in PTCs. At the first step, the limited temperature of a gas is 400 °C. To assess the commercial plants' operating conditions, the molten salt storage device has been incorporated, and the loop design has been changed, employing this new technology in the respective second step to achieve high temperatures. Figure 11 displays the schematic map of two-tank molten salt storage used by the parabolic power plant.

The performance analysis of PTC was carried out by (Marif et al. 2014), considering Therminol VP-1 synthetic oil and fluid water as the HTF required. Synthetic oil is thermally stable at high temperature as above 400 °C. Hence, synthetic oil is commonly used as conventional heat transfer fluid in PTC (Senthilkumar et al. 2021). Thermal performance improved by 2% in the summer with a mean of 72.3% in all seasons when liquid water is used as an HTF. The absorber tube, the glass envelope, and the output fluid temperatures have a higher rate when synthetic oils are used as an HTF compared to liquid water cases. The study shows that synthetic oil is only suitable for application at high temperatures. C.S. (Dhanalakshmi et al. 2020); C Sowmya (Dhanalakshmi et al. 2021) studied that PTC with Synthetic Oil is an efficient tool for supply and maintenance costs as a heat transfer fluid and a solidified medium sensitive retention method. Two retaining systems are built with a maximum temperature of 390°C and a capacity of 350 kWh. Both the rubber and concrete high-temperature ceramics are chosen as suitable heat storage sensitive systems for solid media. The findings show that high-

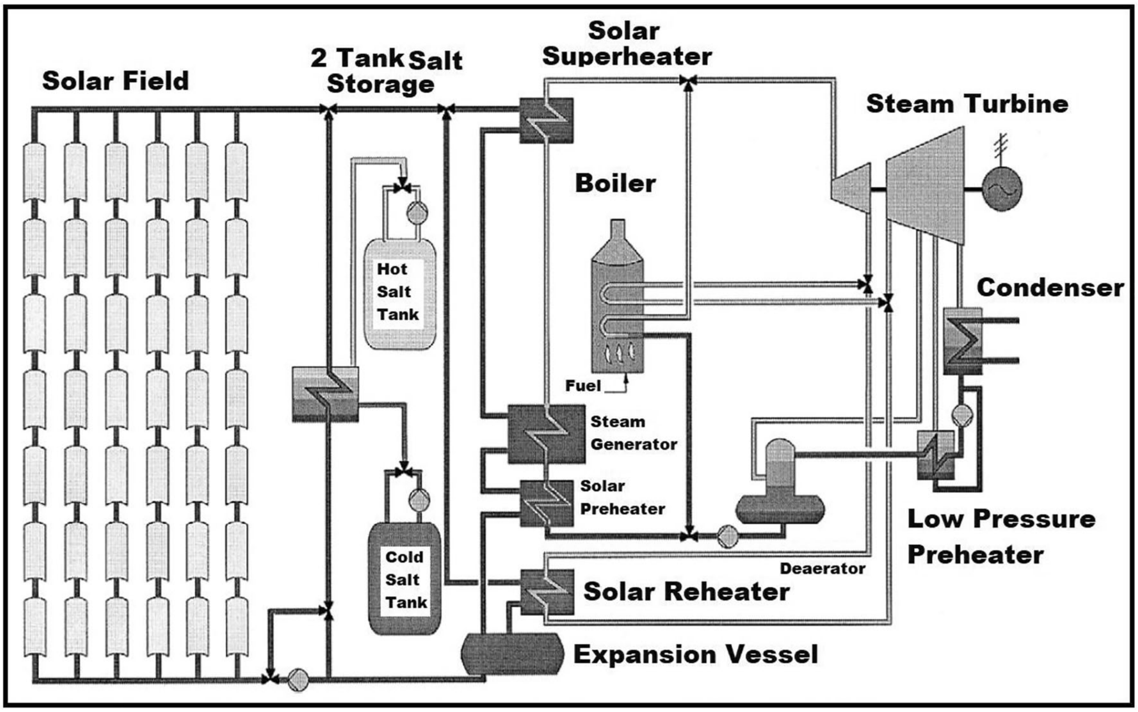


Fig. 11 Schematic diagram of two-tank molten salt storage utilized parabolic trough power plant (Herrmann et al. 2004)

temperature concrete, due to easy handling, dense mechanical strength, and economically healthy, is considered the most effective material.

Different researchers studied the other parametric conditions involved in selecting the HTF and assessment system, and the findings suggest a successful outcome. (Valenzuela et al. 2014) conducted a test to show the optical efficiency and thermal performance of the STPP parabolize solar concentrator. The study has shown that the parabolic trough concentrator's thermal efficiency is calculated based on the atmospheric conditions and the temperature of the heat transfer fluid. (Almasabi et al. 2015) have calculated a distributed transient PTC thermal-optical-fluid model using field data from a 100-MW concentrated solar-power station. The corresponding loop bay valve and overall pump control were implemented at a stable multiple solar collector loop at high temperature to optimize a large concentrated solar power plant's power output. PTC's output was assessed by (Widyolar et al. 2019), which allowed a concentration of two-stage (50 pounds) to operate at 650°C from a linear solar thermal system of suspended particles as a heat-transfer medium. The test shows that the heat and optical outputs are 40% and 63% at 650°C, respectively. (Liu et al. 2012) optimized the LSSVM method for the SPTC scheme. The result shows that the solar collector's performance increases by increasing the flow rate of HTF and solar flux and decreases the temperature for the inlet of heat transfer fluid, which shows that the LSSVM approach is capable of optimizing the solar collector systems.

Nanofluids in parabolic trough collectors

In PTC, several improvisations have been made, and its part and improvements in heat transfer fluids have also been made. One of the most capable techniques is the use of nano-fluids as heat transfer fluid. Nanoparticles such as deionized water or thermal oil can be fitted into the base fluid by inserting nanoparticles. The nanofluids boost the thermal properties of the base fluid by an improved volume-to-surface ratio and radiative properties. It is, therefore, an acceptable alternative for heat transfer applications. The most widely used nanoparticles in nano-fluid preparation are Al, $Al2O_3$, Cu, SiO_2, TiO_2, Au, ZnO, Ni, Fe, and Fe_2O_3.

The CuO nanoparticle is primarily nano-metal oxide and can be used in conjunction with deionized water as an efficient HTF. Several researchers used this CuO nano-fluid and achieved a remarkable improvement in the thermal efficiency of the PTC. (Liang et al. 2018) developed a 1-D heat transfer model of nano-fluid based on direct absorption of PTC. The diagram of nano-fluid about direct absorption is shown in Fig. 12. The performance of the collector of NDAPTC is 10.3% higher than that of the collector of CIAPTC. The examination shows that the collector efficiency of CuO/synthetic oil nanofluid NDAPTC is 52%. (Potenza et al. 2017) have examined PTC with high-temperature and transparent nano-fluid absorber tubes. The working fluid is CuO nano powder, and the receiver pipe consists of a pair of quartz coaxial tubes with an internal vacuum. The results show that the mean efficiency is 65% if a temperature is above 145 °C for 10 h, and the

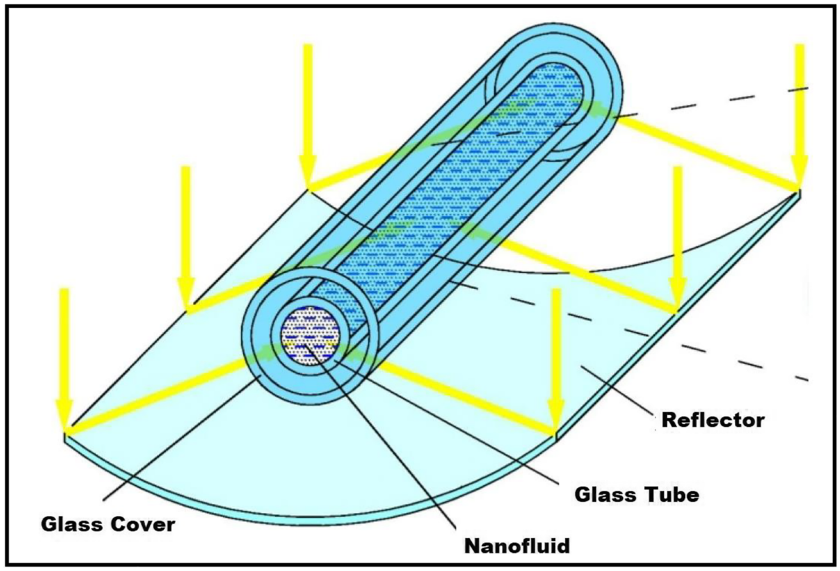


Fig. 12 Schematic of nanofluid-based direct absorption PTC (Liang et al. 2018)

maximum temperature in the nano-fluid circuit is 180 °C. (Bellos et al. 2020) investigated syltherm 800/Cu nano-fluid parabolic trough collectors in a successful way that improves the parabolic trough concentrator's thermal efficiency.

The evacuated tube receiver, the unevaluated tube absorber, and the exposed bare tube were examined. The test shows that the bare tube improves the most in cases with maximum thermal drops and that the use of nano-fluids also improves most of the results. There is a bigger change when the flow rate is lower and with higher emissions. Improvements of the un-evacuated receiver, evacuated receiver, and bare tube are 4.9%, 4.1%, and 7.2%, respectively, when flow rates are 25 l/min and cermet coating is present. (Malekan et al. 2019) carried out an investigation with the PTC in the external region of magnetic CuO/Therminol 66 and Fe3O4/Therminol 66. The convective transfer of heat coefficient, PEC, Nusselt number, and collector efficiency was improved by reducing particle size and improving volume. (de Risi et al. 2013) studied the solar TPTC for solar energy absorption and invented it. The mixture of CuO and Ni nanoparticles was used in an absorber tube for inclusive solar energy absorption. The thermal efficiency is 62.5% at 650 ° C, and the nanoparticles' volume is 0.3%. (Pasupathi et al. 2020) conducted numerical investigation of CuO-water and Al_2O_3-water nano-fluids on a solar PTC inside the receiver tubes for convectional heat transfer. The average friction factor and Nusselt number increased by increasing the nanoparticle volume and adding Al2O_3 and CuO nanoparticles at ϕ=3%. The result also indicates that the transfer of heat rate enlarges by 28% and 35% by utilizing CuO-water nanofluids and Al_2O_3-water.

Many researchers utilized this Al_2O_3 nanofluid and attained an incredible enhancement in the parabolic trough concentrator's thermal efficiency. Y. (Wang et al. 2016) evaluated the application of synthetic/Al_2O_3 oil nanofluid on a PTC. Using the synthetic/Al_2O_3 oil nanofluid as an HTF with NUHF distribution, there is a fall of temperature gradient and maximal heat gradient. PTC's efficiency is observed to be higher when synthetic/Al_2O_3 oil nano-fluid is used compared with synthetic oil. (Ghasemi and Ranjbar 2017) numerically conducted simulation to estimate the efficiency of the solar system with Therminol 66/Al_2O_3 nanofluid. The improvised heat transfer rate is obtained by using nano-fluid rather than using base fluid as an HTF. (Norouzi et al. 2020) stated that solar radiation is mainly concentrated on the underneath part of the receiver tube, which exaggerates high temperatures, thermal stress, and tube deformation. The author suggested a method to overcome the problems to minimize the higher surface temperature and improves energy absorption is to turn around the absorber tube at a precise frequency, and the nano-fluids (Al_2O_3-Therminol) act as the heat-carrying fluid. The study enumerates the aluminium receiver tube's performance as 25% greater than the steel tube with a rotational velocity of 0.25 rad/s and molecular concentration of 0.03%. (Tagle-Salazar et al. 2018) theoretically stated the heating uses of Al_2O_3 nano-fluid as HTF for the PTC. An experimental study was also conducted to detect the energizing parameter and measure thermal enumeration using nano-fluids. The small improvisation in 0.3 W/m of heat gain and a thermal efficiency rate of 0.03% was obtained for a single collector. (Bellos and Tzivanidis 2018) made an investigational approach to study the use of hybrid and mono nano-fluids. The experiment was conducted at a different temperature ranging from 300 to 650K and a considerable flow rate of 150 L/min. The composition study was made on TiO_2/Syltherm 800, Al_2O_3/Syltherm 800, pure Syltherm 800, and Al_2O_3 and TiO_2/Syltherm 800 under similar conditions. The transfer of heat coefficient for hybrid nano-fluid was 142%, 35% for the Al_2O_3 nano-fluid, and 35.2% for the TiO_2 nano-fluid. The mean thermal performance improvisation for TiO_2 HTNF is 0.341%, and the Al_2O_3 HTNF is 0.340%, whereas, for hybrid nano-fluid, it is found to be 0.74%. (Razmmand et al. 2019) conducted numerical investigation by adding silver, gold, nickel, aluminium, and titanium dioxide nanoparticles in pure water. The improvisation in critical heat flux occurrence is studied by the addition of various amounts of the chosen nanoparticles. A special study was made using the Al-H_2O & Au-H_2O nanofluids in a 2% volume concentration; the obtained results are approximately three times greater than the critical heat flux of pure water. (Manoram et al. 2020) carried economic analysis of parabolic trough collector with different volume concentrations of Al_2O_3 and CuO nanofluid and concluded that the addition of nanofluid has no major cost effect. However, the addition of the high-cost nanofluid in PTC will have significant economic impact.

Besides the nanofluids described above, the other nanofluids also have an equal effect on the concentrated dry parabola's thermal efficiency increase. (Okonkwo et al. 2018) studied an ingenious thermal output assessment using water/OLE-TiO_2 and water/BH-SiO_2 in PTC (green-synthesized nano-fluids). The morphological and analytical techniques were used to research the characteristics of nanoparticles amalgamated. The test results show that the BH-SiO2/water nano-fluids yield 0.073% mean thermal efficiency improvement and 0.077% mean improvements with the use of OLE-TiO_2/water/nano-fluids. For water/OLE-TiO2, water/BH-SiO_2, and nano-fluids, the mean improvisation of 128% and 138% was achieved. (Subramani et al. 2018) proved experimentally that the efficiency of the PTSC was efficiently improved by using TiO_2/DI-H_2O nano-fluid. The use of TiO_2 nano-fluids achieves a convective thermal transfer rate of 22.8%. TiO_2 nano-fluid with a molecular concentration of 0.2% achieves the maximum efficiency of 8.7%. (Gowda et al. 2020) investigated the solar PTC replica thermal conduction rate using a 10% volume proportion of simple nanofluid (graphene oxide(rGO)). The thermal efficiency improved, and friction factor decreased during rGO/water use in the evacuated receiver model rather than pure water. A DAPTSC system for the use of plasmonic nano-fluid was guided by (Qin et al. 2019). Moreover, its thermal efficiency was found to be 5–10% higher than the conventional SBPTSC. A. (Karthick et al. 2020c) investigated the parabolic trough collector using carbon-based nanofluid and found that the utilization of carbon-based nanofluid in PTC is more economical, as compared to other high cost nanofluids.

Several experiments, such as the effects of the incident angle and real sun shape, have been carried out to determine the optical efficiency of PTC. The angle of incident plays an important role in the thermal output and energy efficiency of the PTC. Installation direction of incident angle will be defined based on external conditions such as location, time and atmospheric quality. The specific collector angle also depends on the end loss in the receiver tube. The increase in end loss will decrease the optical efficiency significantly (Zou et al. 2017). (Karthick et al. 2020d) improvised the OPTIC method for measuring non-zero incidence angle interceptors that account for the 3-D PTC impact. Optical output at varying PTC incident angle is rapidly estimated by the analytical type of method developed. The first optical treatment of errors concerning this approach achieves optimum precision. The analysis shows that the longitudinal incline error is more prevalent at high incident angles and that the transversal error is more prominent at a low incident angle. (Khanna et al. 2014) showed that the solar fluid assignment is not uniform on the receiver tube surface, resulting in circumferential temperature, which causes the bending moment that results in the parabolic drill concentrator's focal line deflecting the receiver tube. The analysis shows that the receiver tube is not diverted from the focus line at an angle of the incidence of sunlight, and the receiver tube is not redirected from the focal length at an angle of not zero incidences. The absorber tube has no concentrated flux during the non-zero angle of incidence at the sun's end. D. (Zhao et al. 2016) analyzed the effects of flow allocation based on the geometric variant concentration, errors, and incident angles due to errors in monitoring and implementation. 4 m rad are the maximum tracking error limit, X direction of the error is implementation errors of −0.2~0.2%, and of −1.0–0.5% is errors in the Y direction when Rim angle and GC are 90o and 20, respectively. In Fig. 13, the solar radiation paths in the PTC are specified. The analysis shows that the mistakes are directly proportional to the incident angle and inverse to the concentration ratio (Zou et al. 2017). PTC efficiency analysis for incident angles reduces optical efficiency due to the loss of end angles in the incident. The final loss increases for the incident's constant angle as the absorber diameter is small and wider. The effect of the angle of incident is negligible if the duration of the absorber is much greater. The study demonstrates that the focal length increase improves the optical performance for short focal length and continuously reduces efficiency when the focal length is beyond range (Hoseinzadeh et al. 2018). PTC's output was measured based upon rim angle, receiver diameter, and collector aperture for variant sizes. The study reveals that the output of collector components with a recipient diameter of 25 mm, the collector's aperture width 600 mm, the 100° rim angle is 65%, with a 25 mm diameter, a 700 mm aperture width, and a 90° rim angle is 61%.

Power generation in parabolic trough collectors

The worldwide generation of power in concentrating solar power (CSP) plants is performed through a fascinating technology so called parabolic-trough collector. The primary

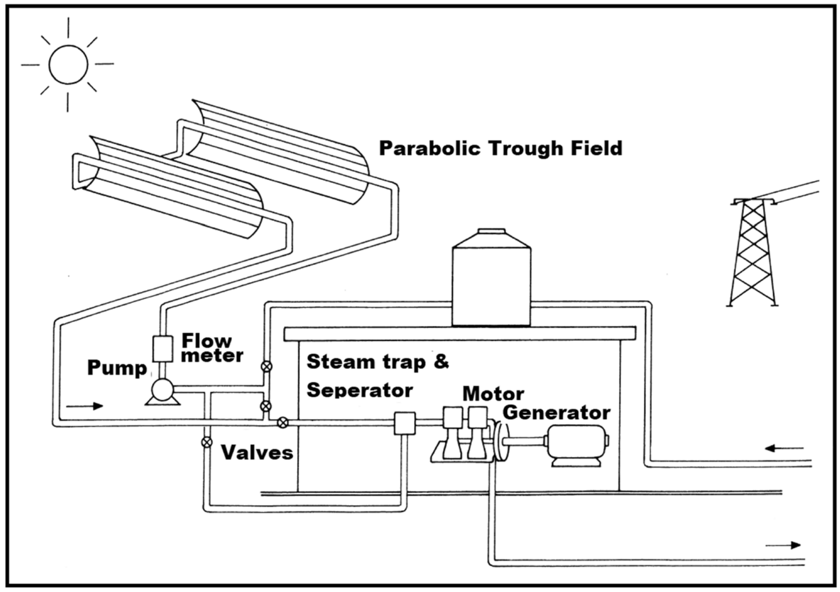


Fig. 13 Schematic diagram of solar power plant with integrated PTC [29]

energy sources worn for power generation in parabolic trough solar power plants prevail by fetching a strenuous amount of photosynthetic beam in a PTC. The heat energy source for the power cycle is, on the whole, dependent on the solar field setup. The power-generating parabolic trough collectors is integrated with various methods to attain enhanced efficiency and produce a combined effect. To attain an efficient parabolic trough collector with economically enhanced existence is essential.

The parabolic trough collector is installed into a combined heat cycle process, gas turbine plant, heating, cooling and power generating combined, electric generator Stirling and biomass catalytic hydrothermal reforming process to increase the thermal, electrical and total performance of both the parabolic trough system and of the integrated system. Another way to improve the performance of an SHCFPP is a rotating axis tracking device in PTC. (Coventry 2005) has conceptually indicated that monocrystalline solar silicon cells specified in combined-heat-and-power solar (CHAPS) collectors are supported by the use of specialist glass-on-metal mirror setups that can efficiently concentrate high numbers of photovoltaic ions to the mono-si solar cells. (Montes et al. 2011) examined the maximum effort to provide solar thermal power in a hot and withered environment to boost the gas-fired combined cycle efficiency. The scheme of the traditional ISCC with a parabolic heat transfer fluid trough is shown in Fig. 14. The results obtained will provide an ideal evaluation of its capacity and represent the correct route for Direct Steam Generation (DSG) to achieve significant results. The updated architecture consists of a parabolic field for direct steam generation coupled with the underlying gaseous steam cycle of a combined cycle gas turbine (CCGT) in an integrated combined solar cycle (ISCC) power plant. The archetypal plot is considered cost-effective for using solar energy in combined cycle power for a minimum fraction. The study ensures that solar power has a marginal tax value by integrated plot design.

(Al-Sulaiman et al. 2012) carried out a performance assessment on a new device with integrated freezing, heating, and power for PTC solar and organic Rankine cycles. The researcher proposed a triangle of behavioural modes—a solar mode (minimum solar radiation density), a solar and a storage mode (high solar radiation density), and a storage mode (in the dusky night, the device could effectively be enabled by the thermal storage tank in the process of design). The results show that the standard process has the highest solar energy output of 15%, while solar and storage have a 7% efficiency and storage efficiency of 6.5%. The efficiency of CCHP for storage, solar and stock, and solar mode is 42%, 47%, and 94%. First travelled via a free-piston Stirling electric generator coupled with a PTC and inspected the combined device's power characteristics using Therminol VP-1 as circulating heat carrier fluid (Zhu et al. 2019). The experimentation has shown that the device has the highest overall efficiency of 3% with a heater head temperature of 573 K and a maximum electrical power output of 2.008 kW, and thermal efficiency of 15%. (Azadi 2012) clarified the combination of the parabolic solar thermal system and the catalytic biomass mechanism of hydrothermal reformation. The concept proposed has an economical advantage because reliance on the natural energy supply has been regulated. It results in efficient electricity generation technologies by absorbing photosynthetic energy rays from molten salts and reducing greenhouse gas emissions. (Peng et al. 2013) performed a comparative analysis of the rotative and single-axis tracking systems and found that the rotative tracking system performs better than the one-axis tracking system. The experimental research was carried out so that the recipient's declining energy and concentrate were inspected over four representative days. The regular loss

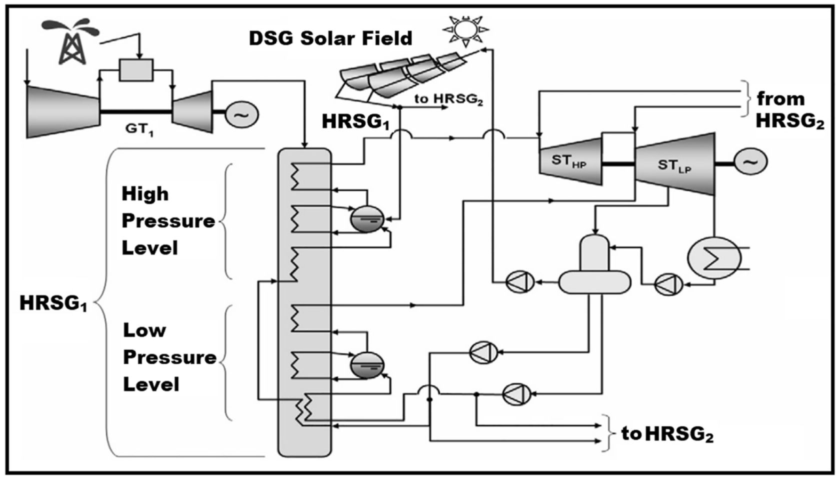


Fig. 14 Schematic diagram of conventional ISCC with a HTF parabolic trough field (Montes et al. 2011)

factors of cosine are measured and studied every day. The experimental study shows that in winter, cosine loss de facto is decreased up to 15% in the rotatable axis tracking system compared with the one-axis tracking system; the rotatable axis system could provide 4% greater energy tracking fields than the single-axis tracking system each year. The experimental study was conducted to reduce the required compartment of SHCFPP and refine the solar generator's efficiency. The schematic diagram of an integrated PTC solar power plant can be seen in Fig. 15. (Ghosh 2020) designed a 100-MW PTC-based solar thermal power plant and carried simulation using system advisor model (SAM) software. The results indicate that the designed solar thermal power plant generates electricity with 21% efficiency.

The stability and heat exchange between the ambient air and solar receiver and PTC's optical output depends on the wind load since the PTC is exposed to atmospheric conditions with high wind load impacts. The wind cools the receiver tubes moves through the receiver tubes, which affects the PTC's performance. The collector's angles also have a crucial influence on the parabolic trough concentrator's performance, given the airflow.

The wind speed has an important influence on the amount of Nusselt. (Naeeni and Yaghoubi 2007) studied the impact of the collector angle deviation, floor height allocation, and the 250-kW wind speed solar power plant versus the Nusselt number. The wind-flow configuration of a tube on each side is discrete to the cross-flow of a horizontal cylinder on each side, which defines the thermal field and wind flow of a large parabolic thermal power plant tube that uses solar radiation as a heat source. The contour of the wind limit layer and the collector distance is used to assess the flow area. The study shows that the mean number of Nusselt is less exaggerated when the recipient tube is on the reverse side due to rising wind speed but rises brusquely when the wind blows to the recipient tube. (Hachicha et al. 2014b) analyze the PTC wind flow in practical circumstances. The wind load has direct correlation with the optical efficiency of PTC. For a wind velocity of 14 m/s, the loss in optical efficiency of PTC is 20% (Z. (Zhao et al. 2020)).

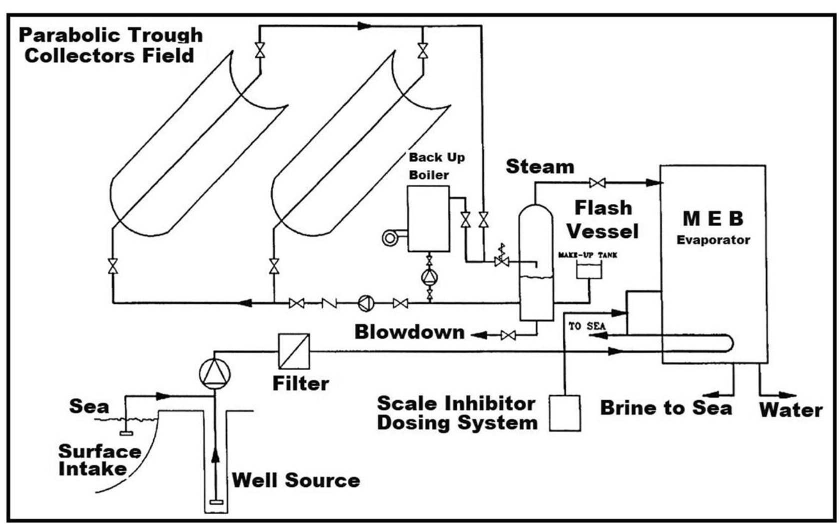


Fig. 15 Schematic diagram of multieffect desalination system arrangement (Kalogirou 1998)

The study shows that the number of Nusselt varies by pitch angle and wind speed, and the results also demonstrate that the elevator and drag forces depend on the number of Reynolds. (Hachicha et al. 2014a) performance analysis in pitch angles in various instances, under practical conditions, through wind flow analysis around a PTC. The study shows that the huge wind flow of the mean Nusselt number is reduced based on the cross-flow condition. Moreover, the PTC's thermal efficiency increases as the mean Nusselt number decreases, and the heat collector portion's thermal losses are minimized.

Collector angles, pitch angles, and lay angles are directly related to the wind direction and are chosen to ignore the PTC wind speed impacts. (Naeeni and Yaghoubi 2007) centered on the collector, the pressure field on all sides of the collector, and the variant provinces on the west and the forward sides of the concentrators based on the wind speed of 2.5, 5, 10, and 15 m/s and wind speed angles of 90°, 60°, 30°, 0°, −30°, −60°, and −90°. The study shows that the gap between the collector and and ground, the gap between the two parabolic segments in the centres, and the absorber tube's impact as a negligible flow field are considerable. The effects of wind were explored by altering the parabola's focal length, based on three separate geometries of yaw and the pitch angles. The positive angle is greater than 15 degrees, and the lagoon angle is 0 degrees, the strongest forces have been observed, and the curved side of the concentrator experiences wind load. High forces were achieved at broad negative angles (less than − 60°), with a positive pitch angle of about 75–85%. The study shows that an improvement in the yaw angle greatly decreases aerodynamic forces, and the maximum total force increases by decreasing the focal length, leading to deeper geometry. Based on this analysis, aerodynamic forces have suggested an improved performance of shallow troughs, and the deep trough shows the benefits of thermal performance (Winkelmann et al. 2020). The 0°/45°/60° pitch angles and wind directions at 0°/30°/ 150°/180 ° are most remarkable and have been calculated by performing the 3-dimensional, printed shell-like PTC wind tunnel tests with an aperture width of 10 m and module length of 30 m. There are four trait sectors, which, based on shadowing effects and the numerically assessed internal forces, are listed from solar fields, in which parabolic troughs were stressed uniformly. These four sectors are high suction and pressure (first and second-row modules), reduced stress (internal field modules), similarly stressed (edge modules), and full stress (corner modules). (Gong et al. 2012) focused on full-scale field measurements for solar concentrate wind pressure and wind loads. Simultaneously, the solar collector monitors field data such as wind pressure, wind direction, and wind speed. The upper edge of the mirror, including the wind pressure points net-1, net-4, net-7, net-10, and net-13, would have reduced pressure in the peak zone at pitch angles 120–180°. The value ranges between −5 and −3. At 90–120° pitch angles, the mirror's lower edge with net-6 and net-9 wind pressure points are at full pressure.

The axial and radial loops, wind load distribution in the reflective PTC mirrors have a major impact on PTC efficiency and performance. L. (Zhang et al. 2015) calculated wind load between reflective mirrors of the PTC using CFD on different radial and axial gap sizes. The study shows that the wind load on concentrators is reduced by approximately 13% as the axial space from 0 to 6 cm increases and that the radial spacing has a slight effect on wind load. The results showed an optimum radial divide, and axial divide between 2 cm and 6 cm. (Fu et al. 2015) studied the simulation of wind load delivery with CFX ANSYS software reflecting mirrors. The difference between maximum deformation under medium pressure and maximum mirror deformation is approximately 30.3%. The study shows that the simulation of mean wind pressure is less accurate than the program ANSYS CFX. The beam and torque box's cross-section sizes were optimized by using the variable cross-sectional beam mechanical characteristics. The analysis shows that the concentrators' efficiency has improved, maximum tension, maximum distortion of the mirror, and the collector weight reduced to 15.4%, 4.6%, and 5.8%. The wind load and gravity deformation contour are shown in Fig. 16.

Desalination in parabolic trough collector

During selecting different desalination methods, energy use, water treatment demand for salt, and equipment are the key factors to be considered. The study shows that the most satisfactory approach for stimulating solar energy is to evaporate boiling multiple results. The ability to work at high temperatures with high efficiency rendered the solar PTC more desalination-capable as compared to conventional solar still (Attia et al. 2021; Ramalingam et al. 2021; Sebastin et al. 2020).

Multi-effect desalination

The Multi-Effect Distillation has an important influence on potable water productivity and is considered an efficient process for processing distillates using PTC (Kalogirou 1998). Specifically, the capacity to work under extreme heat with high efficiency could reduce the desalination of solar PTCs and the unit water price by 4.3%. The multi-effect desalination system schematic diagram is presented in Fig. 17. Lourdes (García-Rodríguez et al. 1999) explored the use, both in technical and economic terms, of direct steam generation in the PTC for multi efficiency distillation. The pure water is seen in a solar field as a thermal fluid when it moves through solar collector tubing. A comparison of the solar desalination system with multi-effect plants integrated with the conventional

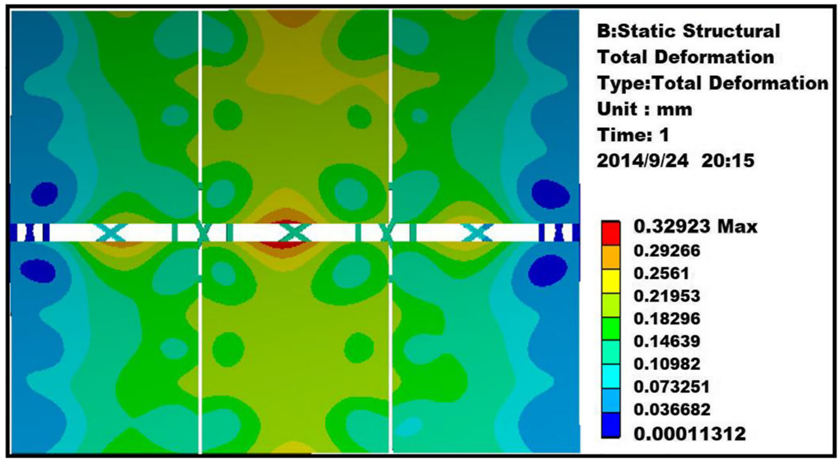


Fig. 16 Deformation contour of wind load and gravity (Fu et al. 2015)

PTC field and fossil-fuel distillery plants is carried out. The following research led to economic viability and high performance combined with the parabolic trough collector for multiple effects distillation. The researchers have carried out a thermo-economic analysis, which is also carried out on a multi-stage flash plant and a multi-effect distillation connected to a solar PTC"S." The thermal economic solar multi-effect distillation study suggested the prerequisites for direct steam production using suitable collectors.

Freshwater or salty water is known to be the appropriate thermal fluid. L. (García-Rodríguez and Gómez-Camacho 1999) have examined the combined characteristics of a multi-stage flash multi-effects distillation system and seawater for a PTC field combination. The study's primary results suggested that higher productivity in a combined PTC is only met with higher thermodynamic efficiency by the provision of high-temperature steam to the desalination system and the global system. (ElHelw et al. 2020) researched the design of a solar distillery with an inclusive MED unit to minimize the operation of standard plants rather than conventional parabolic solar collectors. Various thermal oils such as THERMINOL VP1, THERMINOL 66, THERMINOL 59, THERMINOL SP, THERMINOL 55, DOWTERM A, and steam generation water are included in the test. THERMINOL VP1 with 1.025% filtered water recorded a good test.

PTC's key application is desalination, and it was adjusted using DSG, one-axis solar & monitoring combination, dehumidify-moisture moisture, and twin-glass tube technology. Lourdes (García-Rodríguez et al. 2001) emulated that a thermo-economic analysis could substantially increase the potential to boost distillate by using DSG parabolic troughs. Conceptual thermodynamic research demonstrates that substituting oil-based technology with direct steam generation increases environmental risks, land use, and natural source use. It stabilizes the life of collectors economically. Lourdes (García-Rodríguez et al. 2002) expressed that the capacity for saltwater desalination in traditional hybrid one-axis solar systems is exotically exploited with the aid of parabolic troughs along with the direct steam generation system under Spanish climatic conditions. The schematic diagram of desalination in traditional hybrid solar PTC with one axis is shown in Fig. 18. This system steadily increased the quality of freshwater by conventional parabolic trough collectors between 18 and 32%. (Arun and Sreekumar 2018) outlined the solar PTC desalination plot analysis with a tracking device to focus, regardless of location, high concentrations of sun rays. The machine enables a 2-l/m^2 distillate. (Mohamed and Elminshawy 2011) worked on the analysis to test the efficiency characteristics of solar energy desalination

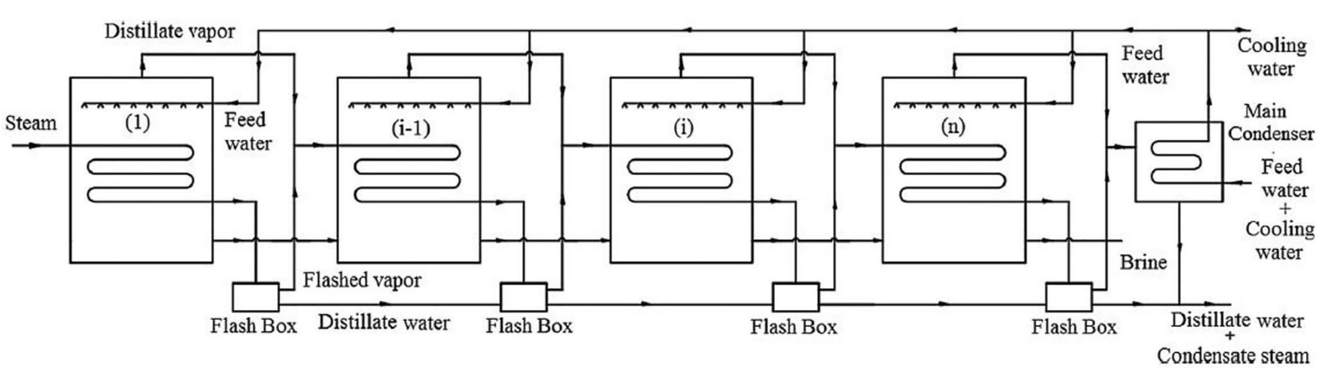


Fig. 17 Schematic diagram of multi-effect desalination system ((ElHelw et al. 2020))

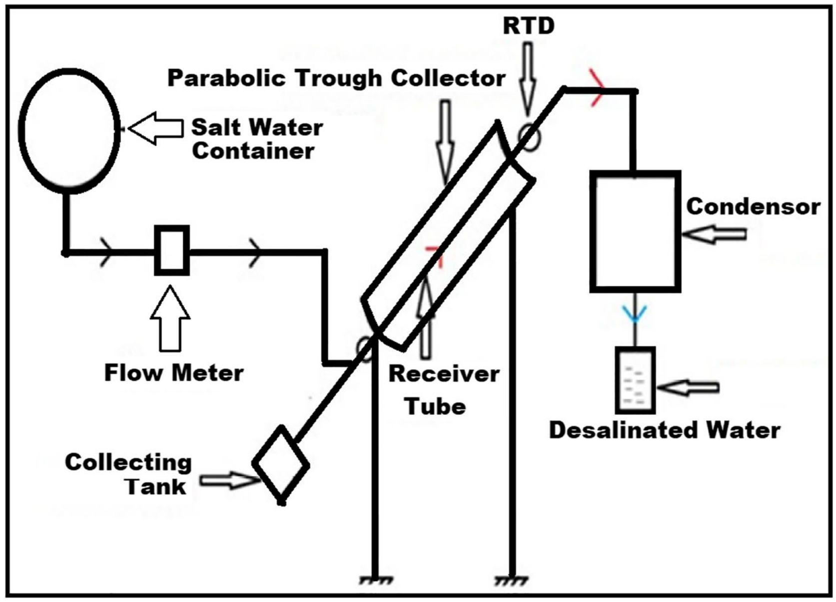


Fig. 18 Schematic diagram of desalination in hybrid one-axis solar conventional PTC(Lourdes (García-Rodríguez et al. 2002))

humidification-dehumidification device. The scheme of the open-water humidifying desalination system with PTC is shown in Fig. 19.

Solar PTC performed the analysis under an outlet temperature of less than 100°C to cope with the desalination method for seawater humidification. There was an optimum rise in the daytime output rate and a night decline in freshwater efficiency. The high concentration of solar rays and long solar time contributes to the high productivity of fresh water in summer. The overall output of 42% is only achieved during the hot summer. (Al-Sulaiman et al. 2015) assessed the HDH device's efficiency through a comprehensive thermodynamic screening using an integrated parabolic solar trough collector. The solar focus parabolic trough is used as an air heater in the HDH system. There were two variant considerations on the design of the HDH system. The result is that the generation ratio of 1.5 for the solar air heater before the humidifier and the recovery ratio of 4.7 for the solar heater between the humidifier and the dehumidifier is located. (Jafari Mosleh et al. 2015) worked on PTC along with the integration of the heat pipe and the evacuated tube collector. The performance and output rate could be increased profitably to 270 g/m^{2}hr and 22.1% using aluminium conducting foils to effectively transmit heat from the collector to the pipes. For the heat exchange process, oil as an HTF will increase the output rate and the efficiency to 939 g/m2hr and 65.2%.

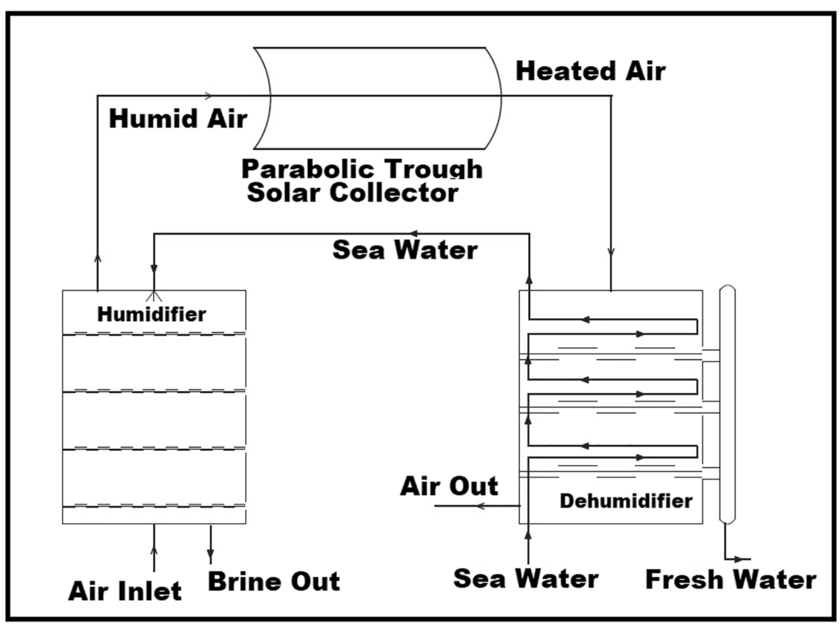


Fig. 19 Schematic diagram of open-water open-air humidification dehumidification desalination system using PTC (Mohamed and Elminshawy 2011)

Among different types of solar collectors, PTC has significant attention by various investigators due to its wide range of operating temperature. Conventional heat transfer fluids used in PTC have poor heat transfer characteristics; hence, nanofluids can be used as an alternative heat transfer fluid in PTC. Since nanofluids have high radiative properties and enhance the thermal conductivity of base fluid, the heat transfer ability increases significantly. It will directly enhance the overall efficiency and distillate yield in desalination using PTC. Hence, several researchers used nanofluids in desalination techniques using PTC. (Krishna et al. 2020) conducted review in desalination using PTC with nanofluids and concluded that the addition of nanoparticles in base fluid enhance the thermal stability at high temperature. (Potenza et al. 2017) conducted a numerical analysis in PTC with different nanofluids Fe_2O_3, SiO_2, TiO_2, ZnO, Al_2O_3 and Au and found that the utilization of nanofluids in PTC has significant increase in productivity. (Rolim et al. 2009) investigated the thermal performance of a parabolic trough system using CuO nanofluid in Syltherm 800 base fluid. Using CuO nanofluid in the PTC for desalination enhances the thermal efficiency and thermal performance by 15% and 38%. (Hoseinzadeh et al. 2018) conducted a pilot study in a steel mirror reflector PTC enriched with multi walled carbon nanotube. The results reveal that maximum efficiency enhancement in PTC is 7% and 5%, when 0.3% and 0.2% multi-walled carbon nanotube nanofluid is used, instead of conventional oil. The results found by various investigators state that utilizing different nanofluids in desalination of PTC enhances the heat transfer coefficient, thermal performance, and efficiency significantly.

Economic aspects associated with parabolic trough collector

The critical parameter for selecting an acceptable modification is evident from the economic conditions. Different researchers established the economic conditions of the modified PTC. Provided a theoretical plot that explains how a solar thermal device could comfortably fulfil a mid-life address (Bakos and Tsagas 2002). The thermal device pays for the annual heat water demand and can supply electricity for electrical equipment on an inexpensive basis. Considering the initial capital, which is marginally higher than an ordinary flat plate collector and the device, the payback period is likely to be 12 years. (Herrmann et al. 2004) have reported that thermal storage systems can enhance the enchantment of solar thermal plants. Recent studies have found the scientific and economic basis for two-tank molten storage. The economies of parabolic plants are only improvised when the depot's capacity is significantly high, and the cost of energy is Levelized. The Levelized energy costs could be minimized by an average load measurement of up to 10% for 12 h. The heat transfer floor used in the integrated solar combined cycle system means that economic and technological aspects are better than ISCCS is the news for (Horn et al. 2004). Both systems are cost-effective and levelled energy. The Levelized solar electricity cost is comparatively higher than the solar part of the solar combined cycle system ranges up to \$10/kWh). (Reddy and Kumar 2012) provided an electricity extraction solar PTC field report by using different work fluids. The low cost of producing electricity from free-standing solar parabolic power plants has experimented with lubricant (oil and water and is found as Rs11 and Rs.12). (Montes et al. 2009) briefly explained in a standard strategy the economic increase of the solar multiple in PTP. The key material is solely influenced by the conventional, unnatural oil parabolic drilling plant with inadequate storage capacity or fusion. The inference is that this could be done for several complex systemic network plots. (Morin et al. 2012) performed a comparative analysis to study LFC and PTC electric energy production costs. The result shows that LFC is economically feasible, but PTC efficiency should be met by LFC efficiency. (Sallaberry et al. 2017) justified a large-scale parable collector research strategy focused on new IEC standards and considered driving factors such as economics and cleaning. The resulting Fc cleanliness variable has a significant impact on the refining of plant economy and efficiency. (Sakhaei and Valipour 2020) conducted experimental analysis in PTC for desalination using membrane techniques and found that cost of distillate yield and exergy efficiency as 3.075 US\$/m^3 and 26.15%. (Jebasingh and Herbert 2016) conducted review analysis in parabolic trough desalinating systems, which shows that the multi-effect distillation-thermal vapour compression system powered by PTC is more economic than a reverse osmosis method. (Devanarayanan and Kalidasa Murugavel 2014) concluded that the application of solar parabolic trough collector in multi-effect distillation high distillate generation cost. A suitable improvisation in both convention PTC and distillation leads to provide a significant reduction in distillate yield generation cost.

Future work

There is an important scope for future work to develop the most successful strategies in collecting parabolic troughs. The experimental studies are important for the performance assessment and stability of the alternative design. The experimental studies are also important for evaluating the actual significant change in large-scale systems in the scale of non-conventional real energy sources. The findings derived from experimental studies provide researchers and investors with an accessible and important method of investing money in alternative design principles. Furthermore, subsequent relative methods are required to determine different design aspects with similar operating conditions and considerable technology. This form of study suffices for researchers to properly connect the different design concepts and achieve an essential conclusion. Various analyses in the literature focus on methods to improve heat properties and increase flow characteristics. However, several effective and relative techniques are needed. Another fundamental prerequisite in this field is developing a typical system for performing relative experimental or simulation studies. It offers a solution for understanding and comparing the recent changes and adjusting the parabolic trough collector. An additional observation for future work is combined with the combination of thermal and optical adjustment techniques. From previous research, the incorporation of efficient approaches can achieve substantially higher performance and portable arrangements. In particular, the integration of thermal and optical adjustments is particularly important in works aligned with the maximum temperature values in progress systems capable of promoting the traditional method and technically proven performance.

Other parameters can be measured, and design adjustments can be evaluated and applied, as well as various design and environmental factors, such as wind pressure parameters, incident angle changes, reflector and receiver tube modifications, various inserts, traditional and nano-fluid use, incorporation of methods and dermal techniques associated with parabolic trough selection. Economic analysis may also be carried out in different alternative designs with the required method to achieve the appropriateness of these principles, which are not only economic but also technological. There is also an urge to emphasize the probable production complications in realistic designs, as in many methods, the improvement of performance is restricted with various production problems. The selection of suitable coating, inclusion of effective porous medium, internal fins and different inserts in the receiver tube will enhance the thermal efficiency of PTC. Inclusion of secondary reflectors modified mirrors and various plated material will significantly enhance the optical property of the parabolic trough collector. Using nanofluids as an alternative for conventional heat transfer fluids will remarkably increase the thermal performance of the PTC. Selecting suitable angle of incidence for the various locations of experimental study has major impact in the optical properties of the PTC. A combined technique to enhance the thermal and optical efficiency of the PTC will suffice a considerable scope for future developments.

Conclusion

PTC is a high and medium temperature, technically proven solar focusing process. This review paper's key concept is to create a stable configuration by providing various designs and impacts of different parameters in PTC. Various parameters and improvements have been studied, including wind load parameters, incident angle changes, changes in reflector and receiving tube, different inserts, traditional and nano-fluids as an HTF, incorporation in PTC methods, and desalination techniques. The main aim of these ideas is to enhance the economically viable efficiency of PTC. The following are the most important findings of this review article:

- The numbers Nusselt and Reynolds are outstanding parameters for PTC efficiency. The Nusselt number is greatly connected to the speed of the wind and pitch angle, and the Reynolds number is independent of the drag and elevation powers.
- The solar mirror on the first surface and the soda-lime glasses have a focal point mean of 78.1%. The average value of the focal point deviation and the RMS slope is smaller in the 0° (zenith) collector angle to establish mirror form. The thermal efficiency of the modified fiberglass-reinforced PTC was found to be 70%.
- The aluminium sheet generates high heat. Furthermore, the findings show that, by adding secondary reflectors, the concentration of solar radiation increases. The findings concerning the receiver tube modifications suggest that insertion, heat transfer, and its characteristics of porous rings in tubular solar absorbers are improved. The cumulative loss coefficient (UL) of metal foam absorbers decreases by 45%, and the performance increases dramatically.
- The use/insertion of porous materials, internal good, copper foam, U-type heat pipe, twisted tape inserts, sinusoidal absorber, asymmetric external corrugated pipe, new moving cover, bellow caps, isolated annulus, linear cubic cavity, the non-evacuated and evacuated tube has greatly improved the heat output of PTC in the receiving tube.
- Optical efficiency is 76% and thermal efficiency 70.5% with HTF melted salt between 300°C and C. NDAPTC collector performance is 10.3% higher than CIAPTC collector efficiency. The use of Cu nano-fluid increases the receiver's efficiency, evacuated receiver, and bare tube by 4.9%, 4.1%, and 7.2%. The performance of PTC is also shown to be higher when nano-fluid Al_2O_3/synthetic oil is used compared with synthetic oil.
- The aluminium tube performance is 25% higher than the steel tube with a rotation speed of 0.25 rd/s and a molecular concentration of 0.03% with Al_2O_3 nano-fluid as HTF. The mean improvisation in thermal efficiency for nano-fluid Al_2O_3 is 0.340% and nano-fluid TiO_2 0.341%, whereas nano-fluid hybrid is 0.74%. Moreover, for water/BH-SiO2 and water/OLE-TiO2 nano-fluids, the mean improvisation was 138% and 128% in the heat transfer coefficient.

- Desalination in hybrid one-axis solar, conventional systems is comparatively studied with parabolic troughs and the direct steam generation system. This system gradually enhanced the freshwater production of traditional parabolic trough collectors between 18–32%.

The significant conclusions can be used as a guiding principle for further investigation in the future and to conduct experimental work in the field of modified parabolic trough collector designs. Additionally, there is a requirement for conducting effective economic analysis to attain a better thermal efficiency enhancement to compensate for the investment cost enhancement.

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Consent for publication Not applicable

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