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A REVIEW STUDY ON THE EFFECT OF GLASS ENVELOPE, WORKING FLUID AND GEOMETRY CONTRIBUTIONS FOR THE RECEIVER ON PERFORMANCE OF PARABOLIC TROUGH COLLECTOR (PTC)

Mohammed Saad Abbas[1,2], Azwan Bin Sapit[1], Hyder H. Balla[3], Ali Mohammed Haider[1,2] and Ali Najah Al-Shamani[3]
[1]Faculty of Mechanical and Manufacturing Engineering, University Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, Malaysia
[2]Technical Institute of Najaf, Al-Furat Al-Awsat Technical University, Iraq
[3]Engineering Technical College of Al Najaf, Al-Furat Al-Awsat Technical University, Iraq
E-Mail: timimimhamed@yahoo.com

ABSTRACT

Renewable energy resources play an essential role in the sustainable energy development as they are friendly energy resources. Solar energy is one of the renewable energy sources are used in many fields from domestic/industrial fluid heating, cooking and electricity production. The parabolic trough collector (PTC) is adopted to be the good choice for medium temperature (150–400 °C) heat necessities. The admiration of solar PTC has generated utility in maximum efficiency energy potential. The heat transfer element (HTE) receiver portion of PTC is the main part in PTC assembly manufactured as tubular shape either without glass envelope or covered with a glass envelope to reduce the radiative and convective heat losses. This article focused on the main parameters was considered in the HTE receiver design of parabolic trough solar collectors (PTC) which were enhanced the heat transfer process in deep details. Further, this work extended to discuss the primary results that came from a different design of PTC receiver based on previous studies in order to benefits researchers who are interested in solar energy collectors.

Keywords: solar energy, receiver, parabolic trough collectors, thermal losses.

1. INTRODUCTION

Solar thermal energy is one of the greatest prominent renewable sources that used the concentration of solar radiation [1]. Renewable energy that reaches the earth comes from the sun directly or indirectly. Therefore, solar power appears to be the energy of the future. The technology that allows us to use solar power is based on systems called solar collectors. The Parabolic Trough Collector (PTC) is an advanced solar thermal system. Many researchers have studied and designed the parabolic trough collector. At the end of 1977, Evans [2] had developed an integral relationship for evaluate the distribution of intensity falling on a flat absorbers used with cylindrical parabolic solar concentrators. In the same objective, Halil and Guven[3] determined the error tolerances for the optical design of PTC. They classified the errors into two sets: random and non-random. The parabolic trough solar systems (PTC) are a solar concentration technology that transforms solar direct beam radiation through the receiver into thermal energy. The design of parabolic trough builds depends on different parameters such as solar flux, reflectors material, aperture width, concentrator aperture area, the focal length of the PTC, the outer surface area of the receiver, receiver material, concentration ratio, rim angle and receiver diameter [1]. A trough collector receiver element is also referred to as a heat transfer element (HTE) or heat collector element (HCE). It consists of a metal tube surrounding with or without a glass cover in order to reduce the thermal losses to the surroundings and maintain the solar energy transfer to the working fluid [1, 3, 4, and 5]. Many working fluids are passing through the receiver of (PTC) depending on the thermal conductivity of the particular fluids that was selected in order to reach optimum heat transfer from the solar energy to the fluid [6-8]. The solar flux plays an important role to gain power from the sun [9]. Researchers contribute and modify the geometry of the receiver to increase the surface area which is subjected to the sun in order to gain more solar flux. This review paper will highlight several studies in different countries and numbers of parabolic trough collector designs in order to benefits researchers who are interested in solar energy collectors.

2. HEAT TRANSFER ELEMENT FOR PTC (RECEIVER)

In A trough collector receiver element manufacturing from different materials tube such as (copper, aluminum, stainless steel …etc.) surrounded by a glass envelope to reduce the heat losses to the surrounding. Dudley *et al.* [4] reported as part of a program to reduce operating and maintenance costs for SEGS plant, Sandia National Laboratories and the Kramer Junction operating company carried out a series of heat loss tests on the LS2 collector type. The tests show the dependence of heat loss on the working fluid temperature and the effect of the vacuum space between the absorber tube and the glass envelope as shown in Figure-1.

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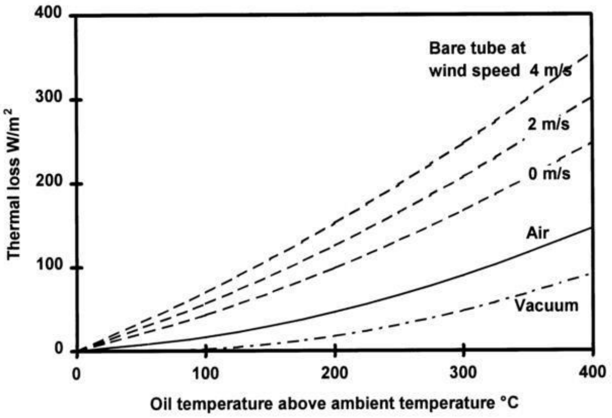

Figure-1. Thermal loss from shaded collector tests [4].

2.1 Receiver of PTC with glass envelope

In this part of the study, an experimental and numerical studies collected from different researchers were addressed to help the investigators in future studies. The dimensions of the (HTE) and the materials have been considered in order to observe the influence of the glass envelope on the PTC performance. Arsasu *et al.* [5, 6] carried out experimentally investigations for the performance of PTC over two years on the same geometry with different objectives. The diameter of the copper receiver (d_o) was (0.0128) m, cover diameter (d_o) were (0.0226) m with length 1.25 m. The inlet temperature closed to ambient temperature (T_{in}) was 33°C. The experiment result showed thermal efficiency equal to 69.4%, while the heat loss coefficient was 7.73 W/m^2.k. Moreover, the parabola was tested under load by blowing wind and the destroyed of fiber reinforced parabola due to wind loading was acceptable. In addition to the Arsasu study, there was an experimental investigation by Hau *et al.* [7] to assess the efficiency of a PTC located in Yucatan, Mexico. The diameter of the copper receiver (d_o) was (3/4) inch cover diameter (d_o) was (0.05) m and the length 2.40 m. The investigation considered four different temperatures, the first three of on 21st June 2010, fourth on 22nd of June. The result showed that 5.43% was the efficiency of the collector. The reason for the deficiency due to the optical efficiency but the maximum outlet temperature was (T_{out}) was 55°C.

A number of investigators have shown that, enhancing the connective heat transfer in the absorber tube lead to improved performance of PTC. An experimental study established out by Zhang *et al.* [8] to determine the heat losses of a double glazing U-type solar receiver is fixed in a parabolic trough natural circulation system. The diameter of the receiver copper (d_o and d_i) was (0.07 and 0.045 m) respectively, cover diameter (d_o and d_i) was (0.125 and 0.1 m) respectively, with a length of 2.4 m. Researchers found that the efficiency of the known receiver was 79.1% and 47.2 % in calm and windy days, respectively, whereas the thermal efficiencies reached to 79.2% and 66.3%, respectively. The work extends to investigate the influence of wind, vacuum glass tube, radiation, and structural characteristics on heat losses. Moreover, an experimental work done by Sagade *et al.* [9] on the performance of PTC made of low-cost fiber reinforced reflector with mild steel receiver. The diameter of a mild steel receiver (d_o, d_i) were (0.025, 0.02 m), respectively, cover diameter (d_o, d_i) were (0.056, 0.05 m), respectively with length 1.21 m. The results showed the outlet temperature (T_{out}) was 67 °C, receiver temperature (T_r) was 75°C, heat flux absorbed was 562.1 W/m^2, useful heat energy was 704.6 W, overall heat loss ($U_{L)}$ was 8.9 W/m^2.°C, instantaneous efficiency was 54%. In another experimental study, by Basit *et al.* [10] to design and fabricate a Parabolic Trough Solar Energy System. The diameter of metallic receiver (d_o) were (0.9331 ft), cover diameter (d_o) were (0.145ft) with length 3 ft. Investigators showed that, the increases in the temperature in one pass achieved up to 11°C and in multi-pass arrangement reached to 86 °C temperature of the water reservoir. PTC took approximately 45-55 minutes to boil two liters of water within the receiver tube. The system shows convincingly that solar energy could be utilized for power production.

Wu *et al.* [11] did experimental study for the heat transfer characteristics of the low melting point of salt has investigated as working fluid. The diameter of steel receiver (d_o and d_i) were (0.07, and 0.066 m) respectively, cover diameter (do, and di) were (0.115 and 0.109 m), respectively with a six evacuated tubes (each one with a length equal to 2 m) joined together. The result noted that the heat loss from molten salt flow in the receiver tube could serve as a reference for applications in parabolic trough systems. The range of inlet and outlet temperature of molten salt was (200.6 - 286.9 °C), (195.9-273.8 °C), respectively. While Tayade *et al.* [12]did an experimental investigation to evaluate the performance of solar PTC. The diameter of the aluminum receiver (d_o and d_i) was (0.025 and 0.023 m) respectively, cover diameter (d_o and d_i) were (0.048 and 0.043 m) with length 1.5 m. The results were collected during November and December 2014 in Chandrapur city. The result showed that the outlet temperature was 65°C, the useful heat was 340 W, instantaneous efficiency up to 32%, overall heat losses 16.8 W/m^2. °C.

On another hand, an experiment done by Ramchandra and Bhosales.k. [13] carried out the CFD analysis of PTC with reflectors. The diameter of the copper receiver (d_o and d_i) was (0.032 and 0.030 m) respectively, cover diameter (d_o and d_i) were (0.043 and 0.040 m), respectively with 1.8166 m length. Two reflectors were taken: mirror and aluminum foil. Researchers pointed that for a mirror type has a maximum temperature is 59.6 °C, which is 14.22% more than Aluminum foil. Aluminum foil as a reflector, the outlet temperature is 53°C, efficiency is 18.98% more than mirror reflector. Moreover, at another place an experimental investigation of design and manufacturing of PTC system under Tunisian climate and performance was assed [14]. The diameter of stainless steel receiver (d_o and d_i) was (0.07 and 0.0685 m) respectively, cover diameter (d_o and d_i) was (0.12 and 0.117 m) respectively,

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with a length is 4 m. The result showed that the maximum outlet temperature at noon was 99 °C, the difference of heat transfer fluid (HTF) temperature was 7.8 °C, useful energy was 417.27 W/m^2, and thermal efficiency was 60.4%. For a cloudy day, the outlet temperature was 92.8 °C, useful energy was 40.30 W/m^2, and thermal efficiency was equal to 55.91%.

An experimental and numerical analysis was carried by [15] on the thermal performances of a PTC under weather conditions of Errachidia city, India. A copper receiver was selected with a 2 m length, the focal length was 0.19 m, and the aperture area was 1.8 m^2. The results were collected for three days as follow: first day, the ranges of outlet temperature were (39, 70.3,82 °C), useful power was 640 W, second day, and the ranges outlet temperature were (81.2, 87.6 °C), useful power was 684 W, last day, outlet temperature ranges were (60, 77.3 °C), and the useful power equal to 752 W. The numerical result shows that the Errachidia location was suitable for installing the solar system. In another study, experimental and theoretical to study the non-evacuated tube done by [16]. It made of Copper receiver type with a diameter (d_o and d_i) were (0.051 and 0.028 m), cover diameter (d_o and d_i) was (0.053 and 0.051 m), respectively were selected. The result pointed that at 11.30 am, the efficiency reach to 77% with a glass cover reflector diameter was (1.8 x 1.6 m), the outlet temperature was 90 °C, and with different was 9% more than efficiency obtained from reflector without cover.

Due to the fact, that the experimental study needs time, effort and was too expensive, an alternative simulation with a powerful computer could be a solution to reduce the cost and effort. In connect with that, many authors [17, 18, 19, 20, 21] have performed a numerical analysis to assessment the effect of different factors on performance of the (PTC) and used a (PTC) in different applications. The researchers conclude that, when the inlet water temperature increased the receiver tube surface temperature increased lead to increased thermal losses by reason of re-radiation and convection to the surrounding result a reduction in thermal efficiency.

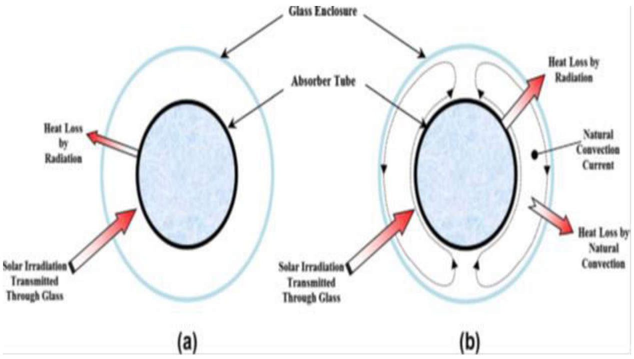

Figure-2. The receiver of a solar PTC filled with a half insulated air annulus[21].

Also, a numerical investigation has been done to simulate potential developments in optical and thermal efficiencies of PTC [22]. The diameter of the receiver (d_o and d_i) was (0.07 and 0.067 m) respectively, cover diameter (d_o and d_i) was (0.125 and 0.022 m) with length 4.06 m. A modification was done on the diameter of the receiver and rim angle to be (0.06 m, 70 degrees), respectively**.** The thermal efficiency of PTC was 83.2%, optical efficiency was 84.4% and outlet temperature was 390 °C.

Garcia *et al*. [23] simulated a PTC for cleaner industrial process heat. The diameter of carbon steel receiver (d_o and d_i) were (0.018 and 0.016 m) respectively, cover diameter (d_o and d_i) was (0.036 and 0.032 m) with 2 m length. Two designs were applied for the collector: flat glass aperture cover and flat glass aperture with glass cover tube. The results showed that the design of the collector with a flat glass aperture cover has the maximum thermal losses compared to another type.

Behar *et al*. [24] proposed a novel PTC mathematical model. The results that were collected from the model validated with experimental data and compared with the results obtained from another model design in a previous used Engineering Equation Solver (EES) code. The diameter of stainless steel receiver (d_o and d_i) was (0.070 and 0.066 m) respectively, cover diameter (d_o and d_i) were (0.115 and 0.109 m) with length 7.8 m were selected based on existing values, the receiver was coated with black chrome and cermet coat. The results showed that, the thermal efficiency in the case of cermet coating, predicts more accurately than those of EES with an average uncertainty of 64% compared to 1.11% for ESS.

Several works were studies the thermal system based on the climatic conditions. Analyses have taken for a year-round performance valuation of a solar PTC under a climatic condition in Bhiwani city, India [25]. The diameter of the receiver (d_o and d_i) was (0.0318 and 0.0284 m) respectively, cover diameter (d_o and d_i) were (0.0556 and 0.0506 m). Investigators reported that the water exit temperature increases to the maximum value up to 31.1 °C in April, and about 22.2 °C in December on a horizontal plane. For the inclined plane, the maximum temperature rose up to 32.2°C in April and nearly 25.5°C in December. The maximum optical efficiency was obtained as 72.26% and 72.4% on horizontal and an inclined plane respectively.

Guo. *et al*. [26] have been done a theoretical and experimental study to investigate the PTC solar receiver. The diameter of a metal receiver (do and di) was (0.07 and 0.066 m) respectively, cover diameter (do and di) were (0.146 and 0.14 m) respectively. (Dowtherm – A) was a HTF with mass flow rate 0.04 kg/s, the inlet temperature of working fluid 25.15°C. Theoretical study results showed that the thermal efficiency was 68% whereas, the experimental investigation showed the thermal efficiency was 71%, the outlet temperature was 102 °C.

E.Bellos *et al.* [27] has done a numerical study to simulate and optimize of a compound parabolic collector. The diameter of a copper receiver (d_o and d_i) was (0.034

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and 0.030 m) respectively, cover diameter (d_o and d_i) were (0.048 and 0.044 m), respectively with length 1 m. Researchers were use two types of fluids (pressurized water, thermal oil) as a working fluid. The numerical results showed that pressurized water performed better than thermal oil by giving greater efficiency in the whole operating range. The outlet temperature of the water was 109 °C**,** thermal efficiency for water was 79**%,** heat losses coefficient 1.4 W/m^2.k. In the terms of thermal oil, the thermal efficiency was 76%, higher heat loss than pressurized water.

Tagle *et al.* [28] numerically studied the applications of PTC technology. The diameter of (AISI 304) receiver with glass cover (Borosilicate type), (d_o) was 1 inch, the length was 3 m. Two cases studies were considered in Mexico. The workers showed that in case one, the outlet temperature was 85 °C, thermal efficiency was 58%, and in case two the outlet temperature was 90°C with thermal efficiency was 57%, with around 10% error in accuracy. While, Ghazzani *et al.* [29] did a numerical study to simulate thermal plant based on PTC heat generation in Morocco. The diameter of the receiver (d_o) was 0.028 m; cover diameter (d_o) was 0.045 m, with length 24 m. The simulation was performed under Moroccan city in order to inspire the use of this technology. The results mentioned that outlet temperature was 290 °C; the thermal efficiency was 56%. On the other hand, the environmental impact was analyzed and showed good results. Moreover, a numerical investigation has done the optimal thermal and thermodynamic performance of a PTC receiver with a different nanofluid at different concentration ratios [30]. The diameter of stainless steel receiver (d_o and d_i) was (0.08 and 0.076 m) respectively, cover diameter (d_o) was 0.12 m, with 5 m length. The results showed that when used the nanofluids enhanced the thermal efficiency and the thermodynamic performance of PTC system. The optimal efficiency was 76%, when the heat transfer fluid was copper-Therminol, the optimum concentrating ratio was.

Bellos *et al.* [31] evaluated the evacuated receiver tube for PTC with internally finned absorbers numerically. The diameter of stainless steel receiver (d_o and d_i) was (0.07 and 0.066 m) respectively, cover diameter (d_o and d_i) was (0.115 and 0.109 m), respectively with a 7.8 m length, the inlet temperature range from (27-327 °C, with step 50 °C). The results show optimum case was in the fin dimension length and thickness (10 x 2 mm) respectively, the thermal efficiency was 68.80%, and it present 82% enhancement compared to the smooth case, and the outlet temperature was 173.8 °C.

The enhancement in heat transfer for the various receivers of a solar PTC with glass cover from above studies is shown in Table-1. The techniques used to enhance the heat transfer by a different diameter of glass envelope covered the receiver performed by various researchers were addressed. According to the above discussion, and specified the current status of the technology. The ratio of the glass diameter to the tube diameter plays an essential role in enhancing the thermal efficiency and reduces the thermal losses. Thus, when the outer diameter of the glass cover increase the annulus gap between the tube and glass cover will be increased, therefore, the convection heat losses increase. Maximum thermal efficiency was up to 83% when the ratio of glass diameter to tube diameter was (1.7).

Table-1. The techniques used to enhance heat transfer by a different diameter of glass envelope.

Ref.	Year	Receiver material	$\frac{\text{do glass}}{\text{do cover}}$	η
[5]	2006	specified	1.76	69.4%
[6]	2007	specified	1.76	64%
[7]	2011	copper	2.63	less
[8]	2013	copper	1.78	79.2%
[9]	2013	mild steel	2.24	54%
[10]	2014	metallic	1.72	-
[11]	2015	steel	1.64	-
[12]	2015	Aluminum	1.92	32%
[13]	2016	copper	1.32	-
[14]	2016	stainless steel	1.71	60.4%
[15]	2017	copper	-	-
[16]	2017	copper	1.03	77%
[17]	1997	specified	2.17	-
[22]	2014	specified	1.78	83.%
[23]	2015	Carbon steel	2	-
[24]	2015	Stainless steel	1.64	-
[25]	2015	specified	1.74	72.4%
[26]	2016	metal	2.08	71%
[27]	2016	copper	1.41	79%
[28]	2016	AISI 304	-	58%
[29]	2017	specified	1.6	56%
[30]	2017	stainless steel	1.5	76%
[31]	2017	stainless steel	1.63	68.8%

2.2 Receiver of parabolic trough solar collector without glass cover

Numerous studies have treated the design performance issues of PTC without glass cover, in this section a study was reviewed based on the experiment and numerical results reported in previous studies. An experimental study by Singh *et al.* [32] designed and fabricated PTC for hot water generation without glass cover receiver. The diameter of (copper, aluminum) receiver (d_o, d_i) were (0.0325, 0.0315 m), with length 1.2 m. The result showed that the efficiency for two receivers (aluminum, copper) were (18.23 %, 20. 25%) respectively, and the heat loses for both were high.

Sagade *et al.* [9] have performed the experimental work to evaluate Performance of (PTC) made of mild steel receiver. The outer and inner diameter (d_o, d_i) was (0.025, 0.02 m), with length 1.21 m. The result was observed for a receiver without a cover, outlet temperature (T_{out}) was 41°C, receiver temperature (T_r) was 49°C, flux absorbed by receiver was 610.4 W/m^2, useful heat energy was 457.2 W, overall heat loss was (U_L) 44.1W/m^2 .°C, instantaneous efficiency was 41%.

Valencia *et al* [33] have been experimentally studying an evaluated designed and constructed (PTC) as demonstrative prototype. The diameter of the copper receiver (do) was (1/2inch), with length was 0.95m. The result showed that on first day the maximum and minimum outlet water temperature was (47.3°C, 34.5°C) at 1.30 p.m., 12.40 p.m. respectively. Thermal efficiency was 50.57% and useful energy was 152 J/s. On the second day of evaluation meteorological conditions were partially cloudy. The maximum and minimum outlet water temperature was (42.2°C, 30°C) at 12.20 p.m, 12.50 p.m respectively. Thermal efficiency was 36.49 % and useful energy was 136 J/s. Also, The experimental analysis was done by Iqbal *et al*. [34] to design, fabricate the solar (PTC) for a steam engine. The diameter of metallic receiver (d_o) was (0.04 m), with length 1.27 m. No fluid was used just measurement the receiver wall temperature experimentally. Two types of reflector material were taken for experimental results (hard stainless steel, soft stainless steel). The researchers reported that, the efficiency of stainless steel is less than mirrors due to scattering and heat absorption. When, an experimentally study done by Hrushikesh [35] to investigated, design and development of prototype cylindrical (PTC) for water heating application. The diameter of mild steel receiver (d_o and d_i) were (0.019 and 0.017 m) respectively, length of the receiver 1.82 m. The result showed that thermal efficiency was 51% while, the outlet temperature was 55 ºC. Useful heat was 900 W, heat loss was 150 W. This system generates hot water at average temperature was 50 ºC with an average efficiency of was 49%.

Murtuza *et al*.[36]performed the experimental work and simulation study for the smooth receiver of a PTC. The diameter of stainless steel receiver (D) were (0.0508 m), with length 5m. The experimental result showed that outlet temperature was high in the month of (March, April, and May) carried ranges [(31-93), (40-103), and (41-99)] °C respectively. The maximum thermal efficiency was in May. In connecting with that authors were analyzed the structure of the receiver numerically under static loading conditions to ensure the robustness of the design. The results obtained were quite satisfactory. While, a numerical simulation by Bharti *et al.* [37] simulated and design of solar (PTC). The diameter of the copper receiver (D) was (0.0214 m), with length 2.5 m, the aperture area was 3.75 m^2. The result reported that 80° rim angle is sufficient to concentrate all the direct solar radiation on the bottom of the receiver tube. This design was useful in manufacturing of solar parabolic trough collector.

A brief review of thermal analysis on PTC contains the receiver without glass cover at different dimensional collected from various studies published in different journals are listed in Table-2.

Table-2. Brief review of thermal analysis on PTC without glass cover.

Ref.	year	Receiver material	Dm	Outlet Temperature ◦C	η
[32]	2012	copper Aluminum	0.033	75	20. 25
[9]	2013	mild steel	0.025	41	41
[33]	2014	copper	0.013	47.3	50.57
[34]	2014	metallic	0.04	95	accepted
[35]	2016	mild steel	0.019	51	55
[36]	2017	stainless steel	0.051	103	Maximum in may
[37]	2017	copper	0.022	accepted	accepted

3. NANOFLUID AS WORKING FLUID

Nanofluids or oil showed improved thermophysical heat transfer properties. The application of nanofluids or oil as heat transfer fluid (HTF) increases the heat transfer coefficient of the fluid. Therefore the heat transfer fluid absorbs the most solar radiation which is concentrated on the receiver, resulting in improved the overall efficiency of the system. Many experimental and numerical studies have been presented to enhancement of heat transfer by using oil or nanofluids. However, the concept of using working fluids in solar collector's thermal oil was old aged, but nanofluid is a recent one and has a limited history of published results with little research work attempted thus far. An experimental study was worked on by Kasaeian *et al*. [38] having done the experimental investigation by using multi-walled carbon nanotube/oil based nanofluid. The result carried that the optimum optical and thermal efficiencies when applied to the vacuumed copper absorber tube, that reached as 61% and 68%, respectively. The overall efficiency of the trough collector was improved by about 4–5% and 5–7%, when 0.2% and 0.3% of nanofluid was used, instead of pure oil. Moreover, Bajestan *et al.* [39] performed an experimental analysis using TiO_2/water as HTF in a straight tube to study the development of heat transfer considering its usage in solar PTC and flat plate collector.

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Arthurs indicated that the convective film heat transfer coefficient enhances with an increase in nanoparticle concentration and flow Reynolds number.

On other hands, numerous of numerical studies were presented and reviewed their result in this paper in order to study the factors effecting the performance of PTC. A numerical analyzation done by Kasaeian *et al.* [40] for heat transfer augment in a PTC when using Al_2O_3/synthetic oil nanofluid with mass flow rate 0.9 kg/s. The result indicated that the heat transfer coefficient increases with an increase in the concentration of nanofluid but reduces with an increase in the operating temperature. The average heat transfer coefficient increases more than the other temperatures. While, a numerous study by Sokhansefat *et al.* [41] reported the heat transfer enhancement of solar PTC with Al_2O_3/synthetic oil nanofluid. Researchers observed that an increase in the concentration of nanoparticles in the HTF increases its heat transfer coefficient but reduces the same when the operating temperature increases.

Zadeh *et al.* [42] proposed a numerical analysis optimization for thermal efficiency in a solar PTC authors have tried two main stages and three states for the test with Al_2O_3/synthetic oil nanofluid as heat transfer fluid. In state 1 mass flow rate was 0.66 kg/s, the ambient temperature was 21.2°C, inlet temperature was 102.2°C. Studies have found that thermal efficiency 72.27 %, outlet temperature was 126.1°C, and heat transfer enhancement has a direct relationship with the nanoparticle concentration.

Mwesigye and Huan [43] have done a numerical investigation by demonstrating the heat transfer enhancement in a parabolic trough receiver tube with Syltherm800/Al_2O_3nanofluid. The authors concluded that the heat transfer performance increased up to 76% and the collector thermal efficiency increased up to 8% for flow rates lower than 24.6 m^3/h, where the maximum efficiency accrued at the particular mass flow rate was 4.93 m^3/h. Also, the numerical study by Wang *et al.* [44] reported synthetic oil/Al_2O_3nanofluid as a working fluid in a solar PTC receiver tube with non-uniform heat flux distributions. The collector efficiency was 1.2% higher for the solar PTC system using the use of nanofluid. Finally in this section, numerically studied by Kaloudis *et al*. [45] reported the parabolic trough collector with Syltherm800/Al_2O_3 as nanofluid. They pointed that the presence of nanoparticles enhanced heat transfer and increased the collector efficiency there was an increase in the overall efficiency of 10% collector efficiency 79%.

In Table-3 below highlight on different techniques were used oil, nanofluid as working fluid.

Table-3. Different techniques were used oil, nanofluid as working fluid.

Ref.	year	Working fluid	Results
[38]	2015	multi walled carbon nanotube /oil	The optimum optical and thermal efficiencies are reached as 0.61 and 0.68, respectively. the overall efficiency improved by about 4–5% and 5–7%, when 0.2% and 0.3% of nanofluid was used, instead of pure oil.
[39]	2016	TiO_2/water	The convective film heat transfer coefficient enhances with an increase in nanoparticle concentration and flow Reynolds number.
[40]	2012	Al_2O_3/synthetic oil	The heat transfer coefficient increases with increase in the concentration of nanofluid but reduce with an increase in the operating temperature.
[41]	2014	Al_2O_3/synthetic oil	The increase in the concentration of nanoparticles in the HTF increases its heat transfer coefficient.
[42]	2015	Al_2O_3/synthetic oil	Thermal efficiency 72.27%, outlet temperature was 126.1°C.
[43]	2015	Syltherm800/Al_2O_3	The heat transfer performance increased up to 76% and the collector thermal efficiency increased up to 8%.
[44]	2016	synthetic oil/Al_2O_3	The collector efficiency is was 1.2% higher for the solar PTC system using the use of nanofluid.
[45]	2016	Syltherm800/Al_2O3	There was an increase in the overall efficiency of 10% collector efficiency 79%.

4. HEAT TRANSFER ELEMENT GEOMETRY (RECEIVER GEOMETRY)

There is a significant interest in the development of the heat transfer regime in the PTC system. This section will focuses on various techniques followed for improvement of heat transfer in the (HTE) heat transfer element (receiver) of the solar PTC. The HTF has to absorb the maximum heat from solar flux comes from the sun and collect by the collector. Therefore, there should be a way for the HTF to gain all the power provided by the sun to the unit. An experimentally investigated by Waghole *et al.* [46] on the heat transfer and the friction factor of silver nanofluid in the receiver of a solar PTC with twisted tape inserts. The experimental analyzation showed that a Nusselt number, friction factor and enhancement efficiency for the receiver with twisted tapes were 1.25-2.10 times, 1.0-1.75 times and 135-205% respectively more than that of the plain receiver tube. In recent years, the porous media for enhancing heat transfer was applied. The use of porous media in the flow stream supports the increase of physical properties of fluids such as thermal conductivity. Another experimental study was

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done by Reddy *et al*. [47] it carried on the heat transfer improvement in the absorber of a solar PTC with porous discs. Several types of absorber tubes (receiver) configurations were tested in the solar PTC, called shielded tubular receiver (STR), unshielded tubular receiver (USTR), bottom porous disc receiver (BPDR), U-shaped bottom porous disc receiver (UBPDR), inclined bottom porous disc receiver (IBPDR) and alternate porous disc receiver (APDR). The maximum thermal efficiency of the PTC with STR, USTR, BPDR, UBPDR, IBPDR and APDR were found out to be 66.96%, 64.78%, 67.59%, 67.78%, 67.43% and 69.03% respectively.

Several investigations on use of nanofluids in PTC were conducted. An analayzazion of numerical was performed by Reddy and Satyanarayana *et al.* [48] a porous inserted receiver for a solar PTC, where circular, square and trapezoidal fins were used. Among three configurations referred in above, trapezoidal fin with a tip to base length ratio of $\lambda= 0.25$ gain best thermal performance. The heat transfer increased up to 13.8% with a pressure difference of 1.7 kPa for a tubular receiver with trapezoidal fin. Also, a numerically investigated was performed by Reddy *et al.* [49] to an energy efficient receiver for a solar PTC. The porous fin receiver considered in their analysis had preferable heat transfer coefficient and higher pressure drop when compared to solid fin receiver; authors concluded that the application of porous fin receiver effected an increase in heat transfer of about 17.5% with a pressure drop of 2 kPa. Moreover, a numerically analyzed by Kumar and Reddy *et al.* [50] on the thermal analysis of the solar parabolic trough with various configurations of porous disc receiver. The author reported that the heat transfer augmented for various configurations of the porous disc; particularly, the top half porous disc receiver showed maximum heat transfer coefficient. This configuration enhanced 64.2% of Nusselt number compared to the tubular receiver.

Munoz and Abanades have *et al*. done analyses [51, 52] to the effect of utilizing internal finned receiver tubes for the design of solar PTCs using CFD tools. The results presented CFD analysis observed that with the introduction of internal fin in trough receiver tubes, the solar parabolic trough plant's efficiency can be improved. In the same objective a numerical study was done by Kumar and Reddy *et al*. [53] to study the heat transfer enhancement of a solar parabolic trough receiver with a porous disc. This study indicates that the receiver with half vertical porous disc and bottom inclined porous disc gave the highest heat transfer enhancement efficiency of 13.5% and 31.4%.

A numerical investigation by Cheng *et al*. [54] studied the heat transfer enhancement in a parabolic trough receiver with unilateral longitudinal vortex generators (LVG) . Finite volume method and Monte Carlo ray analysis were used to model the receiver physically. The presented analyzed findings showed that, the application of LVG in the receiver, leads to low wall temperature and low heat loss with further enhancement in heat transfer. Also, A numerically study by Song *et al*. [55] investigated a parabolic trough receiver with helical screw tape inserts. Result shows that the transverse angle (β) largely affects the incident flux distribution, heat loss, maximum temperature and temperature difference in the receiver. The author found that increase in Reynolds number gradually reduces the effect of β on the above parameters. On another side, The numerically studied by Huang *et al.* [56] study the heat transfer enhancement of a parabolic trough receiver with dimples, protrusions and helical fins. The result shows that the dimpled tube with deeper depth and narrow pitch provided better heat transfer enhancement in the receiver tube than protrusions and helical fins. The performance enhancement factor for dimple tube is in the range of 1.23-1.37.

Chen *et al.* has done the design [57] then theoretically investigation to the linear cavity receiver for a PTC performed. Values of the theoretical studies were more than the experimental values and the maximum theoretical and experimental efficiencies were observed to be 56.20% and 51.20% respectively at 345 K inlet HTF temperature. The researchers found that the use of fins and glass cover reduce the temperature difference in the absorbers tube and achieve better thermal performance PTC at medium temperature.

All the researchers of literature above section are classified under different techniques briefly. Table-4 below is highlights the studies have done by various Authors.

Table-4. Receiver geometry design techniques.

Ref.	year	Geometry configuration (modification)	Results
[46]	2014	The receiver of a solar PTC with twisted tape inserts	A Nusselt number, friction factor and enhancement efficiency for the receiver with twisted tapes were 1.25–2.10 times, 1.0–1.75 times and 135–205%.
[47]	2015	Several types of the absorber tubes (receiver) configurations were tested with porous discs	The maximum thermal efficiency of the PTC with STR, USTR, BPDR, UBPDR, IBPDR and APDR were found out to be 66.96%, 64.78%, 67.59%, 67.78%, 67.43% and 69.03% respectively.
[48]	2008	The porous inserted receiver for a solar PTC. Where circular, square and trapezoidal fins were used.	Trapezoidal fin with a tip to base length ratio of λ= 0.25 gain best thermal performance.
[49]	2008	The porous fin receiver.	Effected an increase in heat transfer of about 17.5% with a pressure drop of 2 kPa.
[50]	2009	Utilizing various configurations of porous disc receiver.	The top half porous disc receiver. This configuration enhanced 64.2% of Nusselt number compared to the tubular receiver.
[51,52]	2011	Utilizing internal finned receiver tubes for the design of solar PTC	The internal fin in trough receiver tubes, the efficiency can be improved.
[53]	2012	A solar parabolic trough receiver with a porous disc	This study indicates that the receiver with half vertical porous disc and bottom inclined porous disc gave the highest heat transfer enhancement efficiency of 13.5% and 31.4%.
[54]	2012	A parabolic trough receiver with unilateral longitudinal vortex generators (LVG)	The application of LVG in the receiver, lead to low wall temperature and low heat loss with further enhancement in heat transfer.
[55]	2014	A parabolic trough receiver with helical screw tape inserts	Increase in Reynolds number gradually reduces the effect of β on the above parameters
[56]	2015	Used a parabolic trough receiver with dimples, protrusions and helical fins	The dimpled tube with deeper depth and narrow pitch provided better heat transfer enhancement in the receiver tube than protrusions and helical fins
[57]	2015	Used linear cavity receiver for a PTC	The use of fins and glass cover reduce the temperature difference in the absorbers tube and achieve better thermal performance PTC at medium temperature.

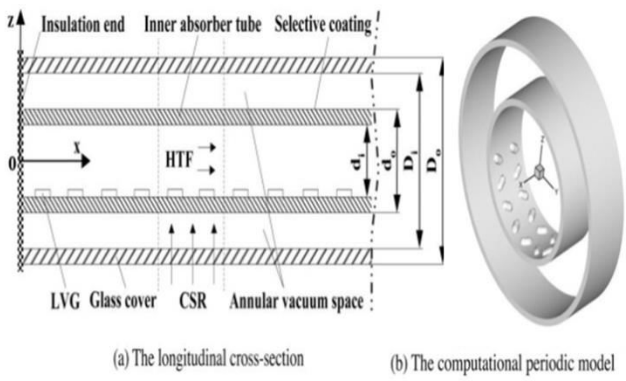

Figure-3. The diagram of the UMLVE-PTR [54].

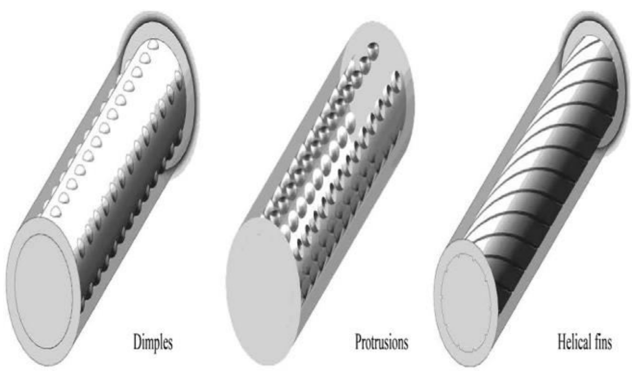

Figure-4. Diagram of parabolic trough receiver with dimples, protrusions and helical fins [56].

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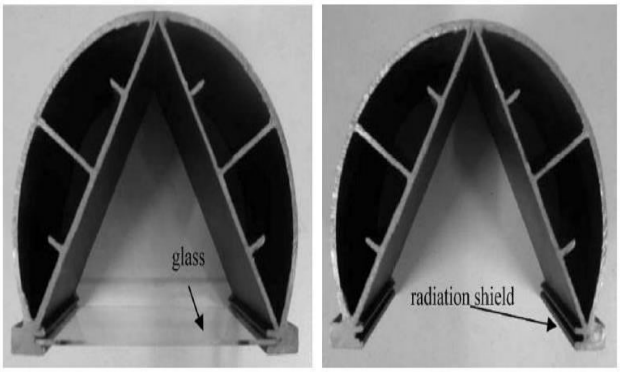

Figure-5. The linear cavity absorber [57].

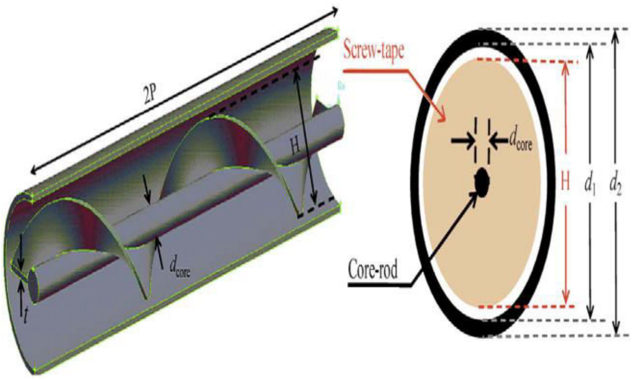

Figure-6. Schematics of parabolic trough receiver with helical screw tape inserts [55].

5. CONCLUSIONS

This review collects and analyzes published papers concerning the usage of solar energy as an alternative fuel in most daily applications. It covers parabolic trough collector at different operating conditions. Moreover, this study extended to cover used PTC in the industries or plants at different countries in order to known the effect of the weather condition on PTC performance. The key findings of this article, resulting from the comparison of the receiver with glass cover and without glass cover, working fluid, receiver design, are as follows:

a) The PTC was commonly utilized in the industries by used different working fluids for different purposes.
b) The receiver glass cover reduced the thermal losses to the surrounding.
c) The annulus gap between the receiver tube and glass cover increase, the thermal efficiency decrease due to increase the outside receiver tube convection heat transfer coefficient.
d) The vacuum conditions and coating's emittance in the receiver tube were the major criteria for heat loss.
e) There were conduction heat losses in bellows and support flange of the receiver
f) The thermal efficiency increased when the receiver diameter increased as the outer surface of the absorber tube increased. While the thermal efficiency decreased when the working fluid mass flow rate increased. As the mass flow rate increases, the inside heat transfer coefficient increases resulting in the tube overall heat loss coefficient increases.
g) Few of these studies used nanofluid passing through the receiver enhancing the PTC performance.
h) The thermal efficiency, PTC performance, inlet and outlet temperature was improved when using different receiver design techniques.
i) The investment of the alternative energy in the world recently. Many of the industries and electricity plants were used fuel oil (its one product of the crude oil) to generate heat. The Fuel oil viscosity and density are high, the discharge fuel oil from the main storage to pumps very slow and default, which needs a huge load to pumps. Hence, there is a needing to use an alternative clean method such as solar energy to preheating the fuel oil. It's suggested to use parabolic trough collector.

Nomenclature

HTE	Heat transfer element	
HCE	Heat collect element	
PTC	Parabolic trough collector	
η	Thermal efficiency	%
U_l	Overall heat losses	$w/m^2.°c$
T_{out}	Outlet temperature	°c
D_{or}	Receiver outer diameter	m
D_{og}	Glass outer diameter	m

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