18th Brazilian Congress of Thermal Sciences and Engineering
November 16-20, 2020, (Online)

ENC-2020-0476
EXPERIMENTAL ANALYSIS OF A LOW COST PARABOLIC SOLAR COLLECTOR FOR CLIMATE AND HEATING APPLICATIONS

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Abstract.
In view of the current energy scenario in Brazil, characterized by high tariffs, the challenge arises to develop solutions capable of enabling the introduction of appropriate means, which bring economy and sustainability intertwined in the production of energy on a national scale. Therefore, this study performs an experimental analysis based on the use of two low-cost parabolic solar collectors built from recyclable materials in conjunction with traditional materials, balancing cost and performance. The use of recyclable materials such as "pet bottle" brought in addition to the benefits attributed to the material, such as its easy access, the value of the most accessible product. The temperature data were collected using three thermocouples, positioned along the array. The results obtained by measuring the temperature attested to the purpose of the project and its advantages, highlighting among the results obtained, the temperature of 61ºC at the outlet of the collector when a flow rate of 15 L/h is used and the temperature of 63ºC at the outlet of the collector for the flow of 7.5 L/h, with the collectors were arranged in series, in addition to an efficiency of 68%. The results also showed the feasibility of using these collectors for the use of air conditioning and domestic heating.

Keywords: *solar collector, solar energy, sustainability, recycling.*

1. INTRODUCTION

Among the main forms of energy consumed in the world, electric energy stands out as one of the most consumed. Although electric energy can be produced through renewable sources such as solar, wind and hydroelectric, its production through the burning of fossil fuels represents a large portion in the generation of electric energy, however the burning of fossil fuels leads to the emission of greenhouse gases where according to Xu et al., (2020), these gases are responsible for great environmental pollution.

Among the ways of this electric energy is consumed it is the use for heating water, this water can be used for industrial or residential use. However, the use of electric energy as a way of heating water is leading to a destruction of exergy.

One way to achieve desired temperatures without the consumption of electricity is using solar collectors, which can be used to heat water through sensitive heat or to cause phase changes in materials (Mohamed et al., 2020). However, the commercial equipment available still has a high acquisition cost, making it impossible for a large part of the population to acquire it. Therefore, it is necessary to develop more accessible technologies that can deliver satisfactory temperatures in relation to the intended objective.

Therefore, this work aims to develop and analyze a parabolic solar collector built from recyclable and easily accessible materials, assessing its feasibility.

2. MATERIALS AND METHODS

The materials used in the preparation of the parabolic solar collector are listed in Tab. 1, where it is possible to observe the preference for low-cost materials, but that do not compromise the quality of the prototype and the collector's performance.

Table1: Materials adopted in the construction of the parabolic solar collector

ID	Name	Description	Unity	Quantity
1	Pet bottle	Colorless bottle	un	12
2	Glue	PVC glue	g	51
3	Sandpaper	Sandpaper P80, *blue metal*	un	1
4	Iron pipe	Iron pipe de 1/2 "	m	6
5	knee	knee 90° (Ø = 1/2")		4
6	Smoked film	Mirrored silver film	m²	2
7	Pipe PVC	Pipe PVC (Ø = 4")	m	0,5
8	Clapboard	Clapboard	m²	1,50
9	Screw, nut, washer	Slotted screw	un	16
10	Aluminum	Aluminum strip	-	-
11	Silicone	Pipe of silicone	g	50
12	Black ink	Matte black paint	ml	300
13	Sticker	Double-sided tape		1
14	Styrofoam	Styrofoam sheet (e = 15mm)	un	1
15	Thread Seal	Thread Seal	un	2
16	Thermal insulation	Foam insulating material	m	3

With the use of the materials described in Tab. 1, two collectors were created, one with the application of partial vacuum and the second without the application of vacuum. At the end of the assembly, the prepared collectors were positioned as shown in Fig. 1.

Figure 1: Disposal of solar collectors

The constructive difference between the two collectors is in the presence of a vacuum valve present in the equipment that was subjected to partial vacuum.

2.1 Geometry characteristics of sollar collectors

The collector developed presents in its cross section the shape of a parabola described by Eq. 1 so that all radiation from the sun is reflected by the channel, passing through a point known as focal point f.

$$y = \frac{1}{4f}\, x^2 \tag{1}$$

The angle ψ shown in Eq. 2 is formed between the optical axis and the line located between the focal point and the mirror edge and is responsible for defining the shape of the edge of the parabolic trough.

$$\psi = tan^{-1}\left(\frac{8\frac{f}{a}}{16\,(\frac{f}{a})^2 - 1}\right) \tag{2}$$

Another important parameter is the opening width obtained through Eq. 3 and the irradiation opening area, which consists of the product between the length and the opening width, presented in Eq. 4.

$$a = \left(\frac{a}{2}\sqrt{1 + \frac{a^2}{16f^2}} + 2f.\ln\left(\frac{a}{4f} + \sqrt{1 + \frac{a^2}{16f^2}}\right)\right) \tag{3}$$

$$A_{ap} = \left(\frac{a}{2}\sqrt{1 + \frac{a^2}{16f^2}} + 2f.\ln\left(\frac{a}{4f} + \sqrt{1 + \frac{a^2}{16f^2}}\right)\right).l \tag{4}$$

Finally, the concentration rate that relates the opening area of the solar collector and the absorption area of the receiver can be highlighted, as shown in Eq. 5.

$$C = \frac{A_{ap,c}}{A_{ap,r}} \tag{5}$$

Table 2 describes the specifications of the solar collectors after assembly.

Table 2: Construction characteristics of the thermal collector

Mirror diameter	0,1 m
Collector length	0,96 m
Tube absorptivity	0,9
Bottle transmissivity	0,9
Specific heat of water	4180 J/kg C°
Inner tube diameter	0,0127 m
Tube outer diameter	0,0215 m
Tube thickness	0,0088 m
External tube area	0,1296192 m²
Inner tube area	0,07656576 m²
Mirror area	0,60288 m²

3. RESULTS

The experimental data collect was performed using thermocouples that were installed at three different points in the system. The first thermocouple was positioned inside the reservoir, the second was installed between the collectors A and B (when the system was positioned in series), while the third was placed at the outlet of the collector B as shown in Fig. 2.

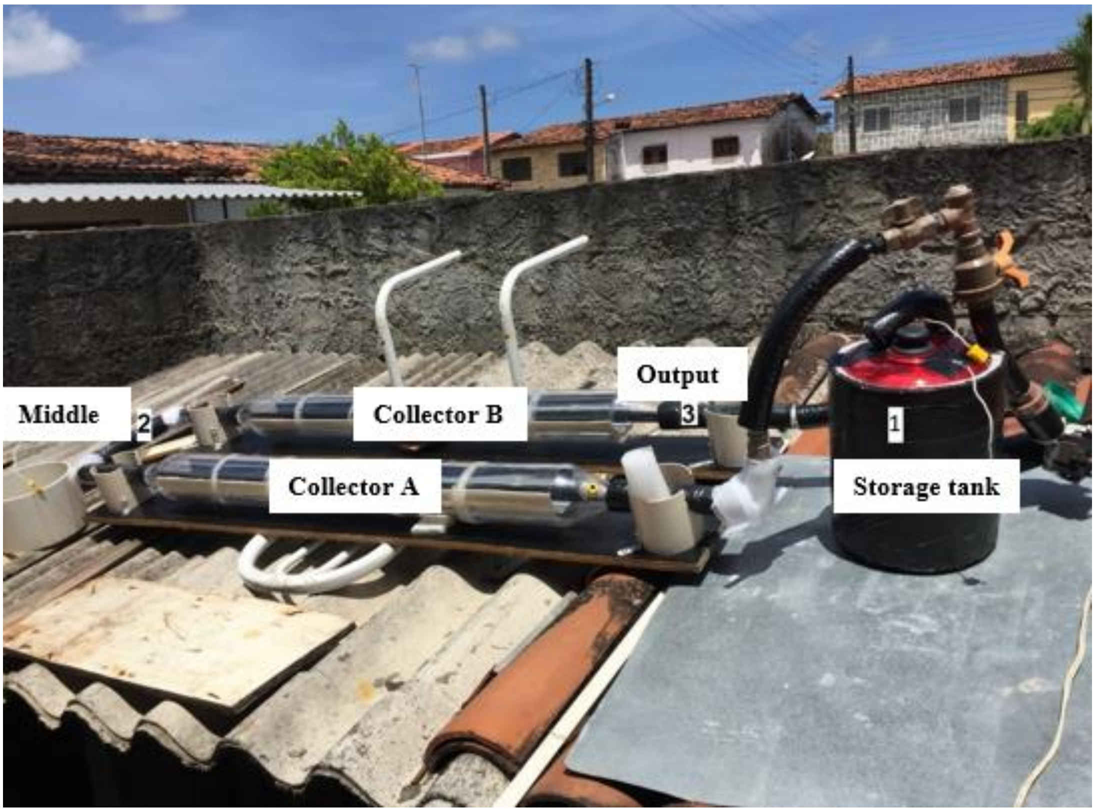

Figure 2: Installed system

The first analysis was performed by placing the two collectors in series as shown in Fig. 2 and two flows were evaluated, the first at 15 L/h and the second at 7.5 L/h. The temperature distribution on the thermocouples throughout the day is shown in Tab. 3 and Tab. 4, which deals with the flow rates of 15 L/h and 7.5 L/h respectively.

Table 3: Temperature distribution in the series system and flow rate of 15L / h

Hour	Tank	Middle	Output
8 h	25ºC	25ºC	25ºC
9 h	36ºC	39ºC	40ºC
10 h	41ºC	42ºC	44ºC
11 h	53ºC	44ºC	50ºC
12 h	56ºC	50ºC	52ºC
13 h	61ºC	60ºC	61ºC
14 h	57ºC	58ºC	54ºC
Average	47ºC	45ºC	47ºC

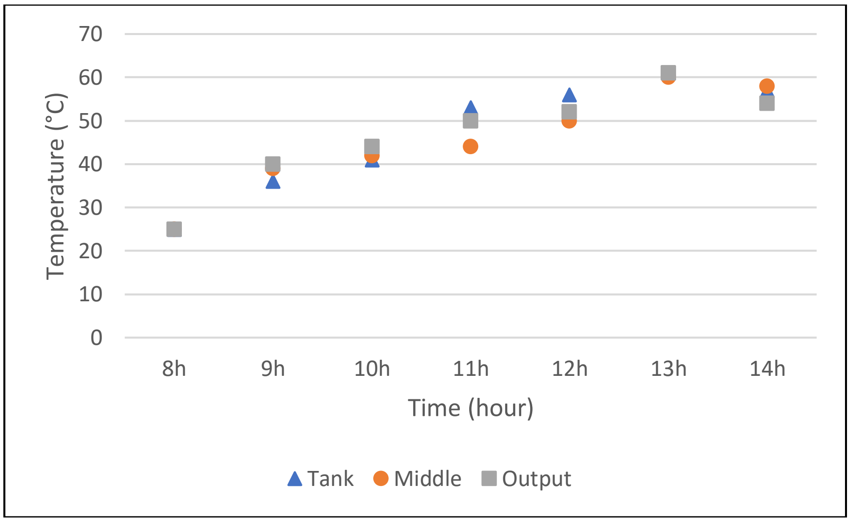

Figure 3: Temperature distribution in the series system and flow rate of 15L / h

Table 3 and Fig. 3 shows the increase in temperature throughout the day together with a reduction in the temperature difference between the tank and the outlet of the collector set. It can also be observed that at 2 pm the thermocouple located between the two collectors has a temperature higher than the outlet of the system. This occurred due to the presence of clouds during this measurement, but as the first collector was built with a partial vacuum applied, it presents a lower heat loss than the second collector, thus providing a higher temperature.

It is also possible to highlight the temperature gain of the thermal tank, which went from 25ºC to 61ºC, between 8 am and 1 pm, with a gain of 36 °C throughout the day.

When the flow is reduced by 50% it is possible to observe the temperature distribution in the thermocouples throughout the system installed in series, as described in Tab. 4 and Fig.4.

Table 4: Temperature distribution in the system in series and with a flow rate of 7.5L/h

Hour	Tank	Middle	Output
8 h	25ºC	25ºC	25ºC
9 h	39ºC	40ºC	43ºC
10 h	47ºC	48ºC	52ºC
11 h	55ºC	56ºC	58ºC
12 h	56ºC	62ºC	60ºC
13 h	57ºC	61ºC	60ºC
14 h	58ºC	63ºC	61ºC
Average	48ºC	51ºC	51ºC

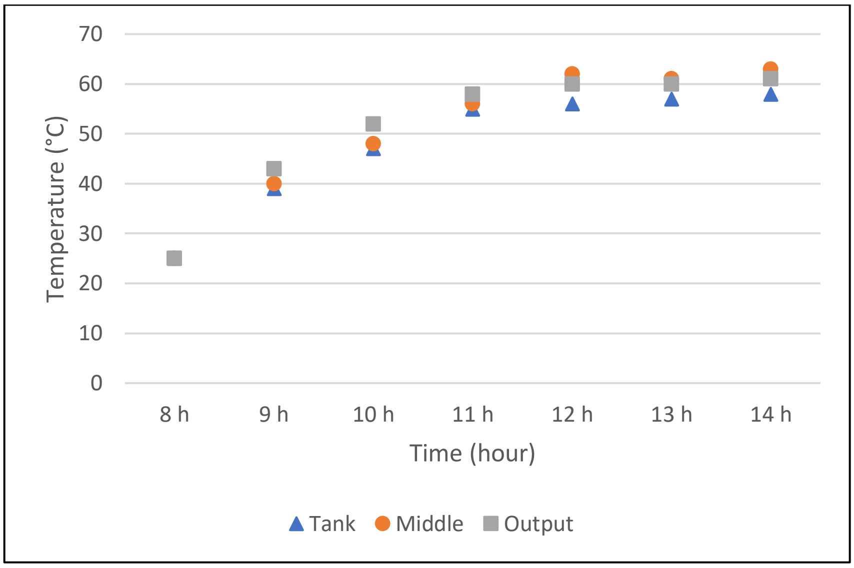

Figure 4: Temperature distribution in the system in series and with a flow rate of 7.5L/h

As shown in Fig.3, Fig.4 presents an increasing temperature throughout the day and a thermal gain in the reservoir of 28ºC between 8 am and 2 pm, however it can be seen in the thermocouples installed in the center and at the exit of the system that the system has not yet stabilized its temperature, being able to reach higher temperatures in the reservoir with longer operating time.

When the analysis was performed with the collectors in parallel as shown in Fig. 5, the thermocouple installation points were 1) in the tank and 2) in the union of the two collectors before coupling to the thermal tank.

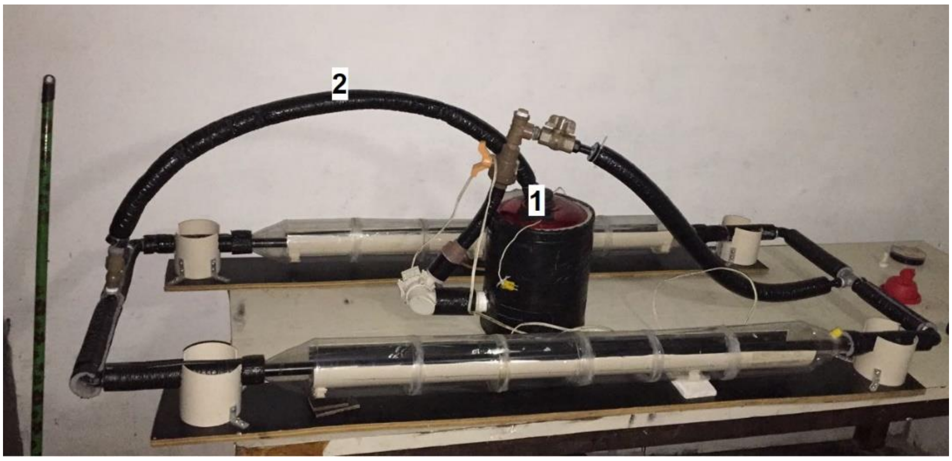

Figure 5: Collectors positioned in parallel

The data presented by the thermocouples are shown in Tab. 5 and Tab. 6 for flows of 15 L/h and 7.5 L/h respectively.

As shown in the previous results, the parallel system presented in Tab.5 and Fig. 6 presents a consistent operation for the system, obtaining increasing temperatures throughout the day. However, parallel systems have a temperature gain of 20ºC between 8 am and 2 pm, which is on average less than 44.4% when compared to the series system with the same flow.

Table 5: Temperature distribution in the system in parallel for 15L/h flow

Hour	Tank	Output	ΔT
8 h	26ºC	26ºC	00ºC
9 h	39ºC	39ºC	00ºC
10 h	43ºC	43ºC	00ºC
11 h	46ºC	48ºC	02ºC
12 h	48ºC	50ºC	02ºC
13 h	48ºC	49ºC	01ºC
14 h	46ºC	47ºC	01ºC
Average	42ºC	43ºC	01ºC

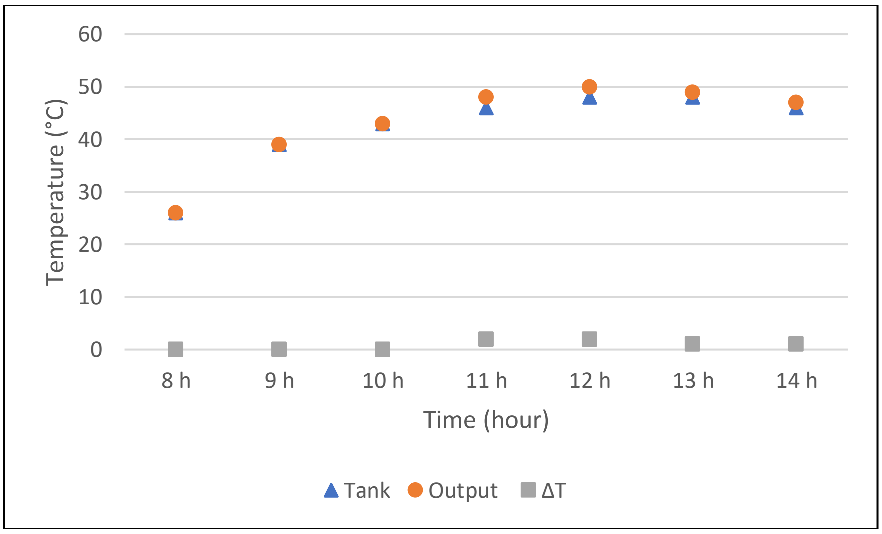

Figure 6: Temperature distribution in the system in parallel for 15L/h flow

When the flow is reduced by 50%, the temperature distribution described in Tab. 6 and Fig. 7 are obtained. It is possible to observe a 23ºC gain in the reservoir temperature between 8 am and 2 pm. The gain is higher than that obtained for the flow rate of 15L/h, however it is lower when compared with the series system.

Table 6: Temperature distribution in the system in parallel for a flow rate of 7.5L/h

Hour	Tank	Output	ΔT
8 h	26ºC	26ºC	00ºC
9 h	30ºC	36ºC	06ºC
10 h	38ºC	39ºC	01ºC
11 h	43ºC	44ºC	01ºC
12 h	46ºC	48ºC	02ºC
13 h	51ºC	53ºC	02ºC
14 h	49ºC	48ºC	-01ºC
Average	40ºC	42ºC	02ºC

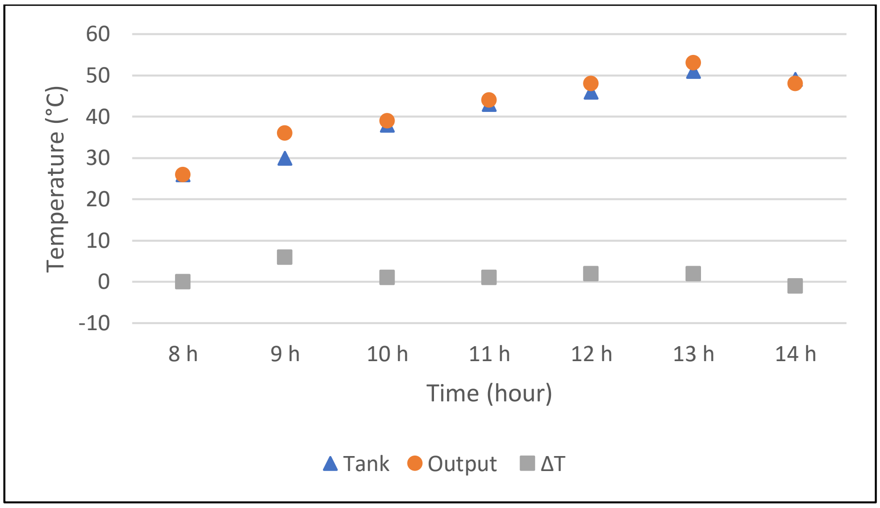

Figure 7: Temperature distribution in the system in parallel for a flow rate of 7.5L/h

4. CONCLUSIONS

It can be concluded that the designed and constructed system is viable from the point of view of the adopted temperatures and flows as well as from the financial point of view.

It is possible to observe a temperature gain of up to 36ºC throughout the day of operation.

Finally, a temperature of 61ºC was reached at the outlet of the collector when a flow of 15 L/h was used and a temperature of 63ºC at the outlet of the collector for a flow of 7.5 L/h. the temperature reached can be used for heating purposes as well as for activating the absorption chiller

5. ACKNOWLEDGEMENTS

The second author thanks the Capes for the doctorate's and master's degree scholarship and also the Post-Graduate Program in Mechanical Engineering at UFPE/UFPB for the opportunity to develop his project.

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7. RESPONSIBILITY NOTICE

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