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DESIGN OF A SOLAR WATER HEATER USING PARABOLIC REFLECTORS

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ABSTRACT
This research reflects on the modification of solar water heating system using parabolic reflectors. The system includes a parabolic dish, a cone-shaped absorber, and a water heater. In this arrangement, the conical absorber directly takes in sunlight, while the parabolic dish focuses sunlight from different angles onto the absorber. This combined approach makes the system more efficient at collecting heat. Water is stored at the base of the absorber tubes, which get heated by the sun. As the tubes heat up, the temperature of the water inside rises, causing some of it to turn into vapor. The vapor then moves upward due to buoyancy and enters a heat exchanger. When freshwater flows through the heat exchanger, it cools the vapor, causing it to condense back into liquid form. The condensed water then returns to the bottom of the absorber tube due to gravity. This cycle repeats continuously. The study shows that this new system improves heat collection, boosts heat transfer, and provides an efficient way to heat water.

INTRODUCTION
The development of domestic solar water heaters in Nigeria arose from challenges with electricity and fuel. This situation led to the adoption of solar water heaters with parabolic reflectors, which focus diffused solar thermal energy onto a single point.
According to the World Radiometric Centre in Davos, Switzerland, the sun is the oldest and most powerful energy source in the universe, with an average of 1367 W/m² reaching the outer edge of Earth's atmosphere [1]. Global solar radiation consists of both direct and diffuse components. Algeria receives some of the highest solar radiation in Africa, with most areas experiencing over 2,000 hours of sunshine per year, and up to 3,900 hours annually in the Highlands and Sahara regions [2-5]. Although solar water heating systems using flat plate and parabolic dish collectors are well-established, they have a low heat transfer rate due to their single-sided heat absorption. To address this problem, a new solar water heating system with a conical heat absorber will be developed. The conical absorber can capture heat from multiple directions, improving the heat transfer rate. It is anticipated that this new system will achieve a 20% higher heat exchange rate compared to the flat plate solar water heater.
The solar collector is the main component of any solar system. It is a specialized heat exchanger that converts solar radiation into heat and transfers this heat to a fluid (typically air, water, etc.) flowing through it. [6]. Various types of solar collectors, including concentrating and non-concentrating, are used worldwide for heating water in both domestic and industrial applications. [7,8]. The most common concentrating technologies include the parabolic trough collector (PTC), linear Fresnel reflector, solar dish, and solar tower, with the parabolic trough collector being one of the most well-known technologies [9,10]. This technology employs parabolic-shaped reflectors to focus incoming radiation onto a receiver tube located at the trough's focal line. The parabolic trough collector (PTC) offers several benefits, including its use in industrial steam generation and hot water production. Its advantages lie in providing a clean, cost-effective, and reliable source of thermal energy [11-23].
Sharma and Diaz [24] reviewed the use of parabolic reflectors in low-cost solar water heating systems. The researchers explored various reflector materials, including aluminum foil and polished metal sheets, to make solar heaters more affordable while maintaining efficiency. The study highlighted that even with inexpensive materials, a properly designed parabolic reflector could significantly increase the temperature of the water, making it suitable for domestic use. Yadav and

Bajpai [25] focused on optimizing the design parameters of solar dish water heaters. The study evaluated different parabolic dish geometries and reflector materials to maximize solar concentration and minimize heat loss. The researchers used simulation models to compare various designs, concluding that a larger dish aperture and higher focal length provided better performance in terms of heat collection efficiency. The study also recommended using composite materials for the reflector to reduce system weight and enhance durability.
Kalogirou [26] focused on enhancing the efficiency of solar water heaters by optimizing the design of parabolic reflectors. The study reviewed different reflector shapes and materials, finding that the use of reflective coatings like silver and aluminum could significantly improve the system's performance by increasing the concentration of solar energy on the absorber. The research concluded that properly designed parabolic reflectors could increase the overall thermal efficiency of solar water heating systems by up to 30% compared to traditional flat-plate collectors. Odeh et al [27] explored the use of parabolic trough collectors (PTCs) in domestic hot water systems. Their research showed that PTCs, with their ability to focus sunlight onto a receiver tube, provided higher thermal output compared to non-concentrating collectors. The study analyzed the temperature profiles of the fluid inside the receiver tube and concluded that incorporating selective coating materials on the absorber further enhanced heat absorption and retention, making the system more efficient for residential use. Kumar K V et al. [15] described a low-cost method for mass production of PTC with its automated sun tracking system. They analysed different types of absorbing materials to improve the performance of solar concentrator and the optical properties and degradation of the reflecting surfaces were assessed also.

MATERIALS AND METHODS

The following materials were chosen for the design of the parabolic reflector: lens, mirror, aluminium foil, mild steel, angle bar, and wood. These materials were evaluated based on efficiency, reliability, and availability, taking cost into account. While the lens was recognized for its efficiency, it was deemed too expensive for the project. Given that mirrors offered similar efficiency at a lower cost, we decided to use mirrors for the reflector. Additionally, we opted for angle bars for the base and mild steel to secure the mirrors for optimal support, instead of using wood.

METHODOLOGY

The main concept of this project involves using mirrors or other reflective materials, such as aluminized Mylar or foil, to focus sunlight from a large surface area onto a single focal point. At this focal point, an aluminum water container is placed to absorb the concentrated heat energy and get heated. This approach is like the method used in solar oven cookers. To accomplish this, a parabolic shape is used. The parabola is a unique curve that reflects incoming sunlight to a specific point known as the focal point. Apart from the glass that was cut to size to form the parabola shape, all other component parts of this design were fabricated using the common tools and equipment in the workshop as follows.

PARABOLA FOR WATER HEATER

To construct the parabola, the process begins with using an 81x41 mm mild steel plate. First, two perpendicular lines are drawn through the centre of the plate, each measuring 1950 mm—one vertical and one horizontal. Next, a circle with a radius of 975 mm is drawn from the midpoint of these lines, representing the diameter. From the same centre point, a smaller circle is drawn with a radius of 60 mm. The circumference of the larger circle is then calculated using the formula: Circumference = 3.14 × Diameter, resulting in a circumference of 6120 mm. This value represents the total length of the sheet material required for the construction. The circumference is then divided into the desired number of segments—in this case, 68 segments—giving each segment a width of 90 mm.

Similarly, the circumference of the smaller circle is calculated as 680 mm using the same formula (3.14 × Diameter). This circumference is also divided into 68 segments, resulting in each segment being 10 mm wide. Using a compass, the larger circle is marked at 90 mm intervals along the circumference, dividing it into 68 equal segments (Fig. 1). The same process is repeated for the smaller circle, with 10 mm intervals. To ensure easy identification during construction, the points where each segment intersects are clearly numbered. A cutting machine was used to cut out the odd numbers leaving only the even segments in a triangular form (Fig. 2). A conical parabola is formed by raising up each segment and joining same to the next segment. These joints are then tacked and welded together to achieve the predesigned conical parabola (Fig. 3).

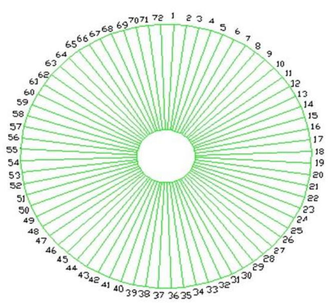

Fig. 1. Marking out

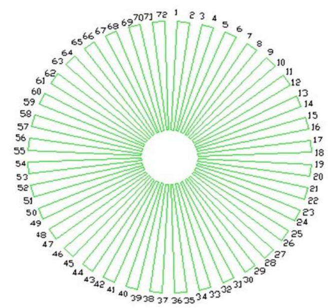

Fig. 2. Marking out

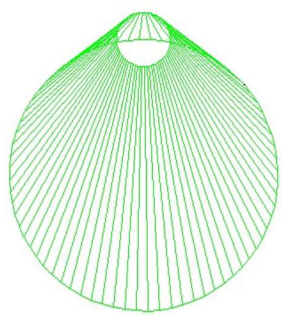

Fig. 3. Parabolic sheet

THE REFLECTOR
In this research, a plane mirror was used as the reflective device. A template of one segment of the parabola was produced by using the diamond cutter to cut the mirror according to the parabolic segments.

THE WATER TANK AND BASE
Aluminium sheets were used for the water tank. The sheet was measured, folded and welded to specification (Fig.). The base is fabricated in the same way but with thick angular bars. The aluminum tank is painted with a dull black, and when the paint is dry, it was filled with water and place it at focal point of the parabolic reflector.

WATER HEATING EXPERIMENT
After assembly, the concentrator's performance was evaluated by measuring its ability to heat or boil water. An aluminum tank, coated with black paint to enhance heat absorption, was filled with 4.0 liters of water and positioned at the focal point of the concentrator. The water was heated to 85°C within one hour, indicating an absorption of approximately 300W of solar power. This resulted in an efficiency of around 60% or higher, based on an incident solar radiation of 1kW/m². The efficiency was found to vary depending on factors such as the properties of the absorbing vessel, including its shape, size, and the extent of its black coating. The table below presents the experimental values recorded at different time intervals (Table 1).

		Temperature of H_2O in 0^oC	
S/N	Time	Day 1	Day 2
1	11:30	27	25
2	11:45	42	37
3	12:00	59	41
4	12:15	75	52
5	12:30	88	61

Table 1. Observed Experimental Details

Based on the experimental result, it can be concluded that the project is based on luminal intensity. This is because in the first day, at a higher sun intensity, we obtained a temperature of 88ºC within one hour (from 11:30am to 12:30Pm), but due to low intensity in the next day, we obtained a temperature of 61ºC. at about one hour (from 11:30 to 1:30).

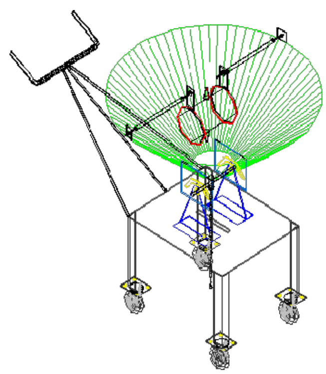

Fig. 4. Illustrative Diagram of the Assembly Drawing

CONCLUSION

This research work presents an alternative approach to water heating using renewable energy by employing a parabolic reflector. The heat transfer analysis carried out aims to determine the useful heat gain, which influences the temperature distribution of the fluid along the tube. The findings indicate that the performance and feasibility of the solar collector are largely affected by various factors, including the collector's surface area, the arrangement of the absorber tubes, solar heat flux, mass flow rate, and overall heat loss. The system achieved a maximum efficiency of 77% when using a parabolic dish collector, compared to 48% efficiency without it, resulting in a difference of about 29%. This offers a significant advantage for solar water heating, providing better heat gain, thereby making the use of a parabolic reflector an attractive solution for producing large quantities of hot water from a renewable heat energy source.

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