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An Improved Parabolic Trough for Industrial Water Heating

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***Abstract**: Currently, Ugandan industries depend to a very large degree on fossil fuels for water heating. More specifically, they use furnace oil to heat water and generate steam. This leads to the release of greenhouse gases, which pollute the atmosphere. In this paper, a hybrid solar heater was designed using locally available resources. During the testing of the system, the ambient temperature, initial water temperature, and final water temperature were monitored throughout the day at different work hours and the system efficiency was calculated.*

Keywords—Collector, solar, greenhouse gases, efficiency, parabolic trough, energy

1. Introduction

The challenge of industrial use of solar water heaters has not yet been fully addressed for all climates and regions of the globe. This has been due to the limited amount of heat that can be produced using solar water heaters and the temperature-efficiency trade-offs associated with the technology [1]. This challenge therefore calls for a thorough analysis of the possible designs of solar systems and collectors. Currently, most industries in Uganda depend on fossil fuel to boil water for industrial purposes, and the furnace use is bought with hard currency, which has a huge negative impact on the export-import balance. While Uganda is only marginally industrialized and the environmental effects of fossil fuel burning are relatively low, one needs to bear in mind that Uganda does not have environmental emission standards compared to those of the industrialized world [2]. On the Ugandan scale, industrial oil burning for water heating alone does have a significant impact on the overall emission levels of the region. In this research, a suitable solar system with a concentrator and collector combination has been designed as an eventual option for industrial usage. The project prototype is a hybrid parabolic collector which is used to obtain the high temperature requirements of industrial processes [3]. The overall long-term objective of this project is to provide opportunities for middle-sized industries in Uganda to increase their competitiveness in the national and international markets while at the same time reducing the cost of furnace oil usage and emission of carbon dioxide, as well as other gases contributing to global warming, and securing more jobs under better working conditions for unskilled laborers.

2. Design of the project

A parabolic trough was made from aluminum sheets with dimensions of 10m long by 2.7m apart, meaning the collecting surface area is 30m.The trough had a nickel-coated pipe which acts as an absorber through which water is heated as it passes from one end to another. It is mounted on strong stands made of cast iron, completely bolted to the ground by nuts of 14 inches in order to avoid external disturbance. The design incorporated a solar tracker, which helped to follow the sunlight intensity, optimizing its operation by improving the boiling and heat concentration. The tracker sensor also operated a single Danfoss induction motor of 20Kw, 230V, 0.967 lagging, which helped to rotate the trough.

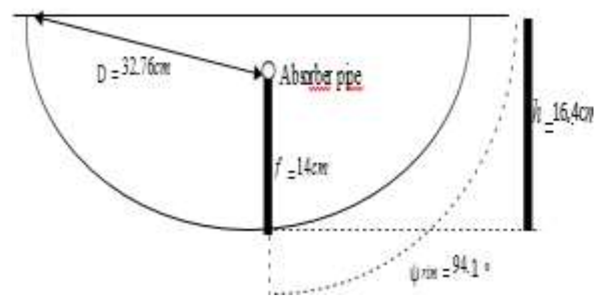

Figure 1: Curvature measurement of the parabolic trough

Figure 2: Complete assembly of the parabolic trough

3. Operation

When the solar tracker circuit is powered, the sensor activates the motor to rotate according to the intensity of the radiation hitting the sensor. The trough concentrates the radiation intensity onto the 2.5m long pipe, which is positioned at the focal point of the concentrator trough. Water is then passed through the 2.5-meter long pipe at a speed of 0.23 m/s. The heated water is then directed to the bottle washer, packer, and other areas where it is needed.

Table 1: Data analysis and results for system efficiency

No of Measurements	Time of the day	Ambient Temperature	Initial water temperature	Final water temperature
1	10:00-10:10	31	25	60
2	10:30-10:45	31	25	65
3	10:45-11:45	32	25	70
4	11:45-12:45	32	25	70
5	12:45-01:45	32	25	70
6	01:45-02:45	32	25	70
7	02:45-03:45	35	25	73
8	03:45-04-45	35	25	73
9	04:45-05:45	34	25	71
10	05:45-06:45	33	25	70
11	06:45-07:45	28	25	67
12			25	

Efficiency of this system was calculated using the ratio of thermal energy gained by the water and absorber pipe Q_h to the radiant solar energy supplied Q_s. For a rise in temperature from T_o to T_1 [4].
Thermal energy gained Q_h =Heat gained by the absorber +Heat gained by water
$Q_h = M_p C_P (T_1 - T_o) + M_w C_w (T_1 - T_o)$
Where M_p, M_w weights of container and water in(KG) respectively, C_P, C_w are specific heats of the container and water(KJ/kg⁰K) respectively. T_1, T_o are final and initial temperature of water respectively. This implies that
The radiant solar energy $Q_s = HA$ and $H = ŋI$
Where H is the amount of accumulated solar radiation per unit area(KJ/M2), A is the aperture of the focal sport area in (M^2), ŋ is optical efficiency of the collector and I is the amount of solar radiation/unit area(KJ/M^2).
Thus the thermal efficiency of this solar water heater system is given as
$ŋ = Q_h / Q_s$

Table 2: Hourly thermal energy gained, hourly direct solar radiation and the thermal efficiency of the solar water heater

TIME OF THE DAY	HOURLY THERMAL ENERGY GAINED Qh(KJ)	HOURLY DIRECT SOLAR RADIATIONQs(Kj)	Thermal efficiency ŋwh(%)
10:00-11:00	200	344	58.2
11:-12:00	450	552	81.45
12:00-1:00	550	670	82.05

Average thermal efficiency of the designed concentrator is (58.2+81.45+82.05)/3=74%

4. Conclusion

The average thermal efficiency of this designed system is 74%, which is considered effective compared to the thermal efficiency 60% of the fossil fuel heater which was currently used by the factory at the time of testing this prototype.

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