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Experimental Analysis of Solar Parabolic Trough Heat Collector

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ABSTRACT

This study outlines the development, construction, and empirical examination of a solar parabolic trough heat collector aimed at concentrating solar energy to generate high temperatures. The collector was designed to track the sun's movement and constructed using stainless steel piping with a diameter of 21mm to regulate water flow and enhance water temperature output. Experimental testing was conducted using a prototype test rig over specific days. Performance metrics, including thermal collector efficiency and energy gain by the fluid, were determined through outdoor experimentation. The fluid temperature rose from 30°C to 135°C between 09:30 am and 01:30 pm, with an average thermal efficiency of approximately 80%. The performance characteristics of the collector increased significantly throughout the day until 01:50 pm, after which they declined steadily with a constant flow rate of 1ml/sec. The fabricated compound parabolic concentrator (CPC) model, with a half acceptance angle (θ) of 68.38°, demonstrated enhanced concentration capabilities. Additionally, an optimal mass flow rate for maximum efficiency was empirically determined. The CPC model achieved a maximum temperature of 140°C under solar irradiance ranging from 900-1050W/m^2.

Keywords: Stainless Steel Piping, Reflective Stainless Steel Surface, Glass Enclosure Tube, Wooden Framework

INTRODUCTION

Currently, energy stands as a fundamental necessity in human civilization. Nations with higher energy production typically exhibit greater development compared to others. Energy serves as a crucial enabler for various tasks. Our modern energy sources can be broadly categorized into renewable and non-renewable types. Renewable energy stems from natural processes that replenish regularly, predominantly originating from the sun. Solar, wind, ocean, tidal, hydropower, biomass, geothermal, biofuels, and hydrogen are among the renewable resources. Non-renewable energy, on the other hand, comprises sources that cannot be replenished in the foreseeable future, such as coal, oil, and natural gas. Both renewable and non-renewable sources contribute to generating secondary energy forms like electricity.

The consumption rate of energy by a nation typically reflects its level of prosperity. As economies and populations grow, energy consumption rises, often accompanied by escalating environmental concerns. The increasing costs of fuel resources pose significant challenges to economic and social development globally. Less developed countries, in particular, feel the brunt of energy crises, as a substantial portion of their national budgets must be allocated to fuel imports. To address these challenges and reduce reliance on costly foreign fuels, many countries have initiated programs to develop energy sources based on domestic renewable resources. Sustainable development goals necessitate minimizing the consumption of finite natural resources and mitigating environmental impacts within nature's restorative capacity.

There is a global consensus that future energy sources must predominantly be renewable to meet long-term global energy demands. Solar thermal power plants emerge as promising options for renewable electricity production. Unlike conventional power plants, concentrating solar energy systems offer environmentally friendly energy sources, emitting minimal pollutants and relying solely on sunlight as fuel. The objective of this project is to explore general strategies and specific design concepts aimed at enhancing collector efficiency.

EXPERIMENTAL SETUP AND TESTING

Literature Review: Extensive research encompassing books, journals, and articles has been undertaken concerning solar technology, with a focus on performance enhancement and the current practices in various countries.Prototype Development: A parabolic trough model has been meticulously designed with specific dimensions. To streamline the design process, appropriate software tools have been utilized, aiding in visualizing the model before fabrication. Manufacturing Process: Following the completion of the design phase, the parabolic trough model is manufactured according to designated parameters and materials. The manufacturing process is carried out within the Mechanical Engineering Department workshop. Installation: The fabricated parabolic trough model is then installed at a site in close proximity to the Mechanical Engineering Department. Experimental Investigation: Subsequent to installation, an experimental investigation is conducted, during which data is systematically recorded. Analysis and Interpretation of Results: The obtained test results are meticulously compiled and juxtaposed with those derived from mathematical models to assess their validity and facilitate comprehensive comparison. Solar Radiation Measurement: To gauge global shortwave radiation from both solar and atmospheric sources, a pyranometer (Radiometers) is employed. Additionally, a solar-tracking pyrheliometer is utilized to measure the direct normal component of solar irradiance. Temperature Measurement: Instruments calibrated for measuring temperature differentials within the test range have been employed. Thermocouples within the range of -50℃ to +300℃ (-58℉ to +572℉) are utilized, adequately covering the testing parameters. These instruments are of digital type, facilitating precise temperature measurements

Figure 1: Thermocouple

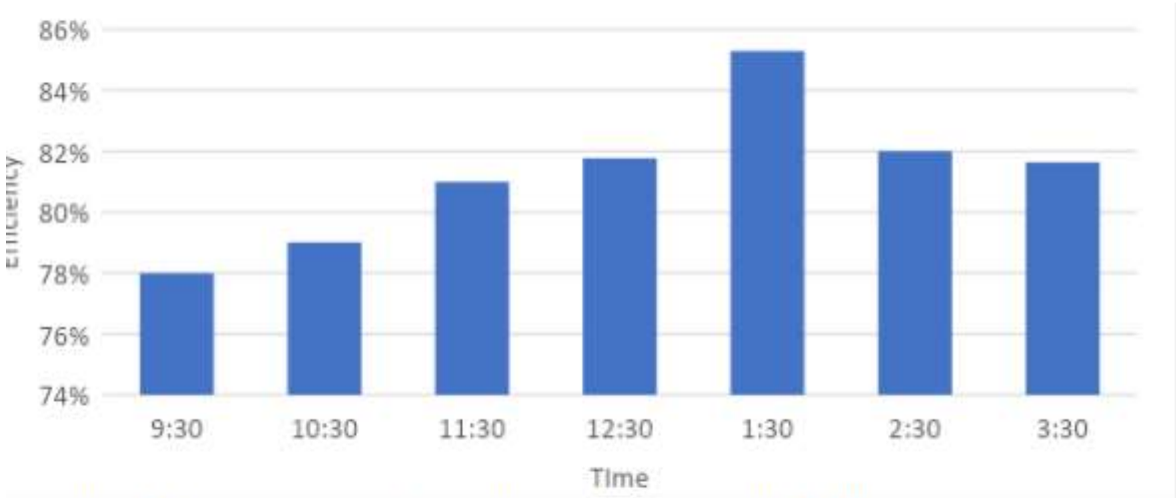
Figure 2: Flow measuring tube

Figure 3: Wind velocity measurement

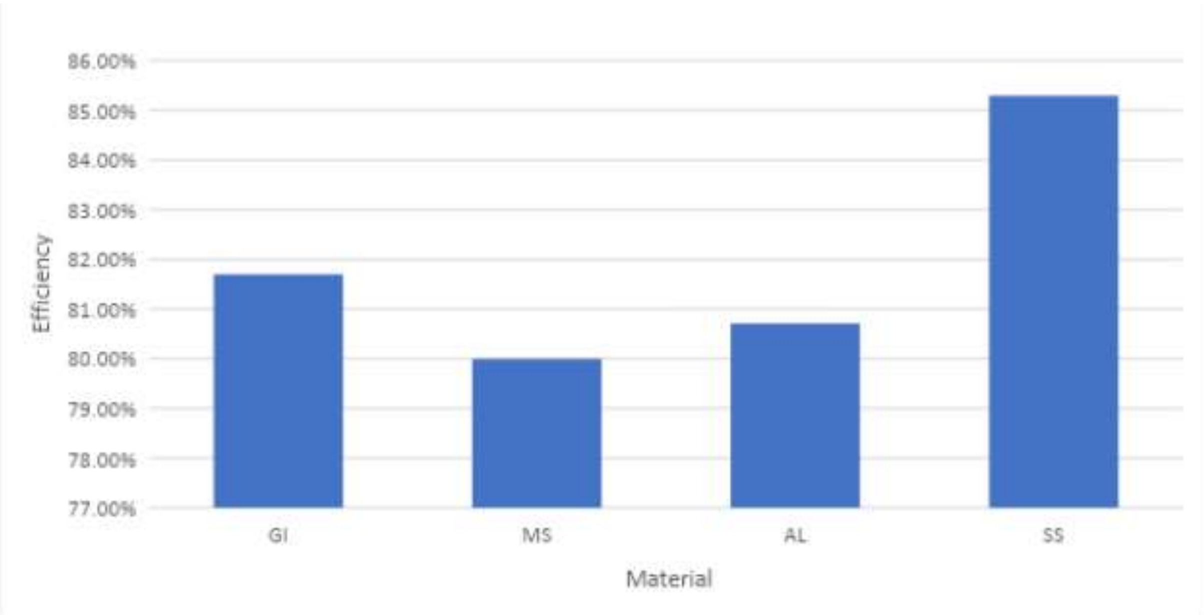
Table 1: Dimension of modal

Component	Typical dimension
Diameter of tube (OD)	25 cm
Width	100 cm
Focal Length	30 cm
Length	300 cm
Aperture Area	30000cm²

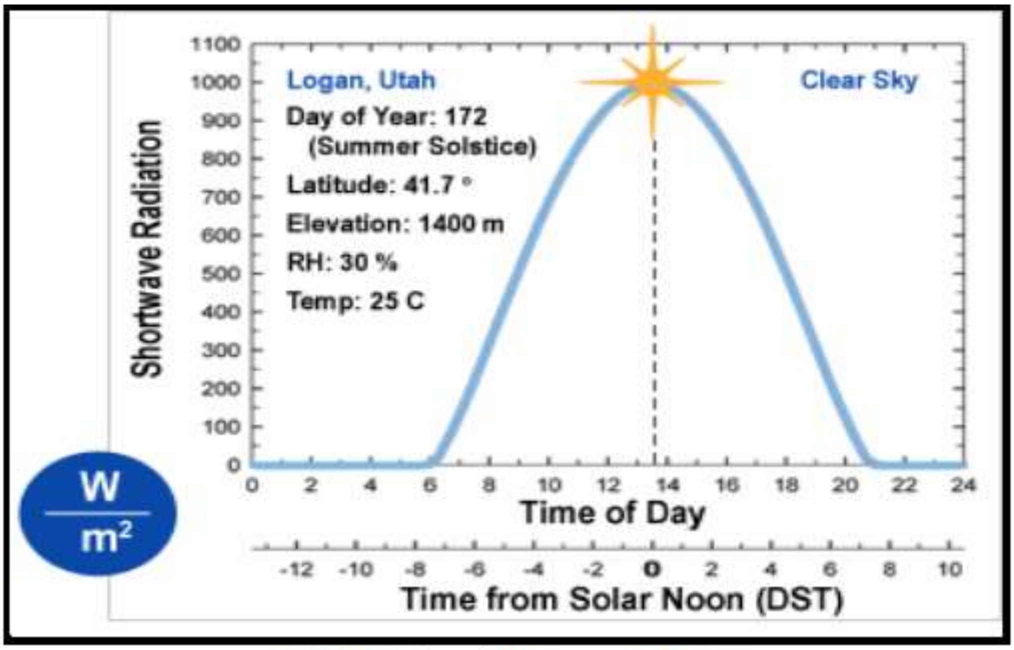
RESULT & DISCUSSION:



Graph 1: Mass flow rate, 1.ml/sec, ambient temperature; Tin, inlet fluid temperature; Tout, outlet fluid temperature; ΔT, temperature gradient.



Graph 2: Comparison between Stainless steel pipe, Iron pipe, Aluminium pipe, & Mild steel pipe with glass cover



Graph 3: Solar radiation energy Vs time

Conclusion-

Based on the current status of the country, a novel approach to solar energy application has been tested, focusing on new technical and technological opportunities for water heating and steam generation. The parabolic trough is constructed using easily bendable stainless steel sheet material. Black-painted steel pipes serve as absorber tubes, while temperature-sensing thermocouples monitor water temperature variations at the inlet and outlet of the central receiver. Daily data collection is conducted for each absorber material to assess its effectiveness in raising water temperature. On clear days, a peak water temperature of 100℃ is attained using stainless steel pipe absorber tubes. The results indicate that the parabolic trough efficiently generates high water temperatures, reaching up to 100℃ for approximately 512 working hours (from 10:00 to 15:30). Environmental factors significantly impact the performance of the solar collector. Variables such as wind and scattered clouds can diminish the antenna's efficiency. Various materials are tested as absorber pipes, including iron, mild steel, and aluminum, each yielding different efficiency levels compared to stainless steel. Among these materials, stainless steel exhibits the highest efficiency, reaching 85.29%. The results highlight the effectiveness of the parabolic trough in generating high-temperature water, particularly when employing stainless steel absorber pipes.

REFERENCES

[1] Garud S.Making solar thermal power generation in india reality overview of technologies, opportunities and challenges, The energy and resources institute(TERI)India,http://www.aprekh.org/files/SolarThermalPowergeneration_Final.pdf.

[2] Laing, D., Steinmann W.D., Tamme R. and Richter C. (2006) examination of Solid media thermal storage for parabolic trough power plants. Vol- 80, page 1283–1289, Germany

[3] Qu.M., Archer D.H. and Masson S.V. (2006) A linear Parabolic Trough Solar Collector Performance Model. Renewable Energy Resources and a Greener Future, Vol.VIII-3-3, USA

[4] Arancibia-Bulnes C.A., and Cuevas S.A. (2004) Modeling of the radiation field in a parabolic trough solar photocatalytic reactor. Mexico

[5] E. Zarza, L. Valenzuela, J. Leon, K. Hennecke, M. Eck, H.D. Weyers, & M. Eickhoff, "Direct Steam Generation in Parabolic Troughs: Final Results and Conclusions of the DISS Project," Energy, vol. 29, pp. 635-644, 2004.

[6] Y. Shuai, X. Xia, H. Tan, "Radiation performance of dish solar concentrator cavity receiver systems," Solar Energy, vol. 82, Issue 1, pp.13-21, 2008.

[7] C.A. Estrada, O.A. Jaramillo, R. Acosta, C. Arancibia-Bulnes, "A Heat transfer analysis in a calorimeter for concentrated solar radiation measurements," Solar Energy, vol. 81, Issue 10, pp. 1306-1313, 2007.

[8] A Primer on CPV Technology, SolFocus, available online at <http://www.solfocus.com/>, (accessed May 2008)

[9] Bakos, G. C., Adamopoulos, D., Soursos, M. and Tsagas, N. F. 1999. Design and construction of a linefocus parabolic trough solar concentrator for electricity generation. In Proceedings of ISES Solar World Congress, Jerusalem.

[10] Bakos G.C., Ioannidis I., Tsagas N.F. and Seftelis I. (2001) examination of Design, optimisation and conversion efficiency determination of a line-focus parabolic-trough solar collector. Vol-68, page 43-50, Greece

[11] Price H. and Kearney D. (2003) examination of Reducing the Cost of Energy from Parabolic Trough Solar Power Plants. Page 1-9. Hawaii.

[12] A Primer on CPV Technology, SolFocus, available online at<http://www.solfocus.com/>, (accessed May 2008)

[13] Bakos, G. C., Adamopoulos, D., Soursos, M. and Tsagas, N. F. 1999. Design and construction of a linefocus parabolic trough solar concentrator for electricity generation. In Proceedings of ISES Solar World Congress, Jerusalem.

[14] Garud S.Making solar thermal power generation in india reality overview of technologies, opportunities and challenges, The energy and resources institute(TERI)India,http://www.aprekh.org/files/SolarThermalPowergeneration_Final.pdf.

[15] Laing, D., Steinmann W.D., Tamme R. and Richter C. (2006) examination of Solid media thermal storage for parabolic trough power plants. Vol-80, page 1283–1289, Germany

[16] Qu.M., Archer D.H. and Masson S.V. (2006) A linear Parabolic Trough Solar Collector Performance Model. Renewable Energy Resources and a Greener Future, Vol.VIII-3-3, USA