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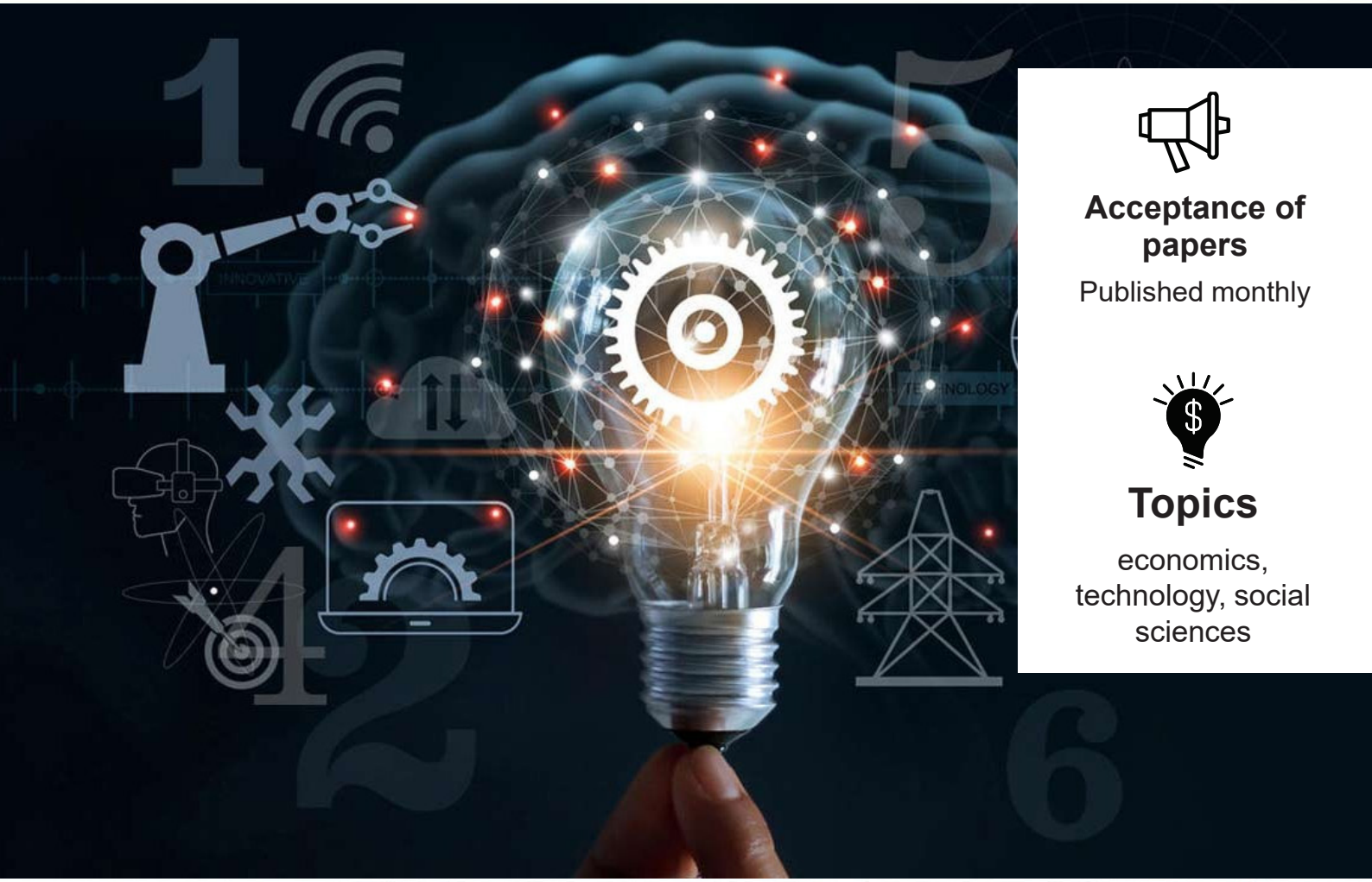

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MODERNIZED HEAT RECEIVER TO IMPROVE THERMAL EFFICIENCY OF PARABOLIC TROUGH COLLECTOR

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Abstract: This article considers the design of a modernized heat receiver for a parabolic trough solar collector, aimed at improving the thermal efficiency of the installation. A comparative analysis of the thermal performance and calculation of the efficiency of the traditional and improved heat collectors is carried out. As a result of modernization it was possible to achieve an increase in heat transfer due to optimization of the shape of the receiving tube and application of selective coating.

Key words: parabolic trough collector, solar energy, heat receiver, thermal efficiency, selective coating.

INTRODUCTION

The growing interest in renewable energy sources is driven by the need to improve the energy efficiency and environmental sustainability of energy systems. Among the various solar plant technologies, parabolic trough collectors (PTCs) occupy an important place due to their ability to focus solar energy on a linear heat receiver. However, thermal losses and design limitations of the receiving tubes reduce the overall efficiency of such systems. The objective of this study is to develop and experimentally verify a modernized heat receiver design to improve the efficiency of PTCs.

LITERATURE REVIEW

A number of studies are devoted to the issues of heat transfer enhancement in the PCC intake tube, including the use of turbulators, nanofluids and selective coatings [2-6]. For example, [4] demonstrated an increase in thermal efficiency of up to 12% by using copper oxide absorbing coatings. In [5], the use of a double-wall pipe with a thermal insulation gap is discussed, which reduced losses by up to 15%. Nevertheless, most of the works focus on theoretical modeling, while the practical implementation of modernized receivers requires further study.

RESEARCH METHODOLOGY

The experimental study consists of the process of hot water treatment with temperature 80℃ on the PTC (Fig.1.) with geometrical characteristics: width D=1640 mm, length L=5000 mm, focal length f=680 mm and angle of coverage α=60°. The reflective surface is formed by sheets of mirror aluminum produced in Germany with integral reflection of solar rays R_z=0,79÷0,80. The PTC is installed on the polygon of Fergana State Technical University in the west-east direction. The concentrator is fixed on two welded trusses, providing its installation at a specific angle relative to the horizon calculated for the latitude of the terrain. In the focal plane of the collector on adjustable fasteners installed receiver of the calculated dimension in the form of a tube. The receiver is a blackened stainless-steel pipe with an outside diameter of d=42 mm, the length of which is l=5000 mm. The heat carrier is water.

Fig.1. General view of the experimental PTC.

A parabolic trough collector with two variants of the receiving tube was investigated as part of the experiment:
Basic sample: a blackened steel tube with a diameter of 42 mm
Modernized sample [1] (Fig.2.): an aluminum tube hermetically sealed from both sides with length l=5000 mm and outer diameter d=25 mm (displacement tube) was placed in the initial heat receiver. The displacement tube is wrapped with a 15 m long and 3 mm thick aluminum wire in the form of a spiral, by means of which the displacement tube was fixed to the steel tube from inside.

Fig.2. Modernized receiver [1].

DS 1820b temperature sensors are installed at four points along the pipe:
t1 - at the inlet
t2 and t3 in the middle section
t4 - at the outlet.
Measurements were taken over several sunny days under similar weather conditions. The results were recorded in real time in DATA BASE.

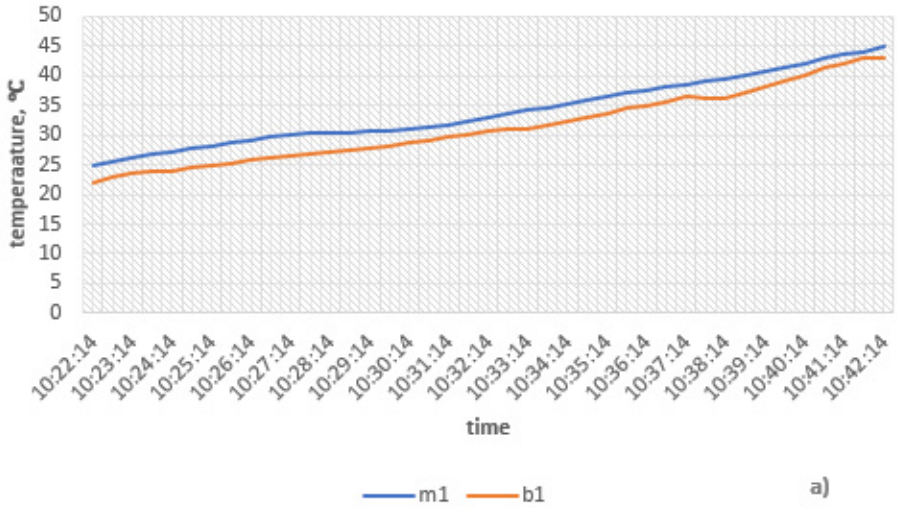
ANALYSIS AND RESULTS

The experiment showed a stable increase in the output temperature of water in the modernized heat receiver by an average of 32-37% compared to the basic one. The temperature distribution graph is shown in Fig. 3. a) – d).

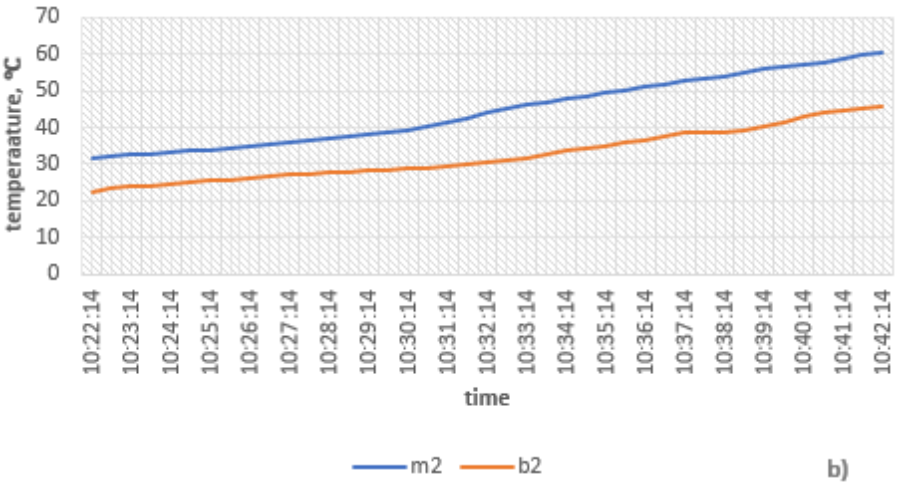
Fig. 3-a) shows the variation of the inlet temperature of the upgraded (m1) and base (b1) heat receivers as a function of time. Throughout the observed interval, the temperature of m1 is consistently higher than that of b1, indicating more efficient heating of the retrofitted heat receiver. The difference between the curves is maintained throughout the experiment, confirming a steady improvement in the thermal efficiency of the retrofitted design. The maximum excess of m1 temperature over b1 is observed closer to the end of the measurements, reaching about 2-3 °C.

Figs. 3-b) and c) show the temperature variation in the middle part of the receivers. Similar to the previous case, the m2 temperature is consistently higher than the b2 temperature throughout the experiment. The temperature difference averages 10-15 °C, which demonstrates the improved heat transfer properties of the upgraded receiver in the zone of maximum heat flux. By the end of the measurements, m2 reaches about 63 °C, while b2 reaches about 47 °C. The temperature values of m3 are significantly higher than those of b3 throughout the experiment, with the difference increasing over time. The temperature of m3 increases to ~76 °C, while b3 only reaches ~49 °C.

The 3-d plot shows that the output temperature of the upgraded receiver is consistently higher than that of the basic receiver throughout the measurements. In addition, the temperature rise of the upgraded receiver is faster and more uniform. This confirms more efficient heat absorption and retention, stable and high thermal efficiency of the modernized design, especially in the central part, where the main energy of solar radiation is concentrated, which indicates the increased efficiency of heat transfer in the design of the modernized receiver compared to the basic one.



a)



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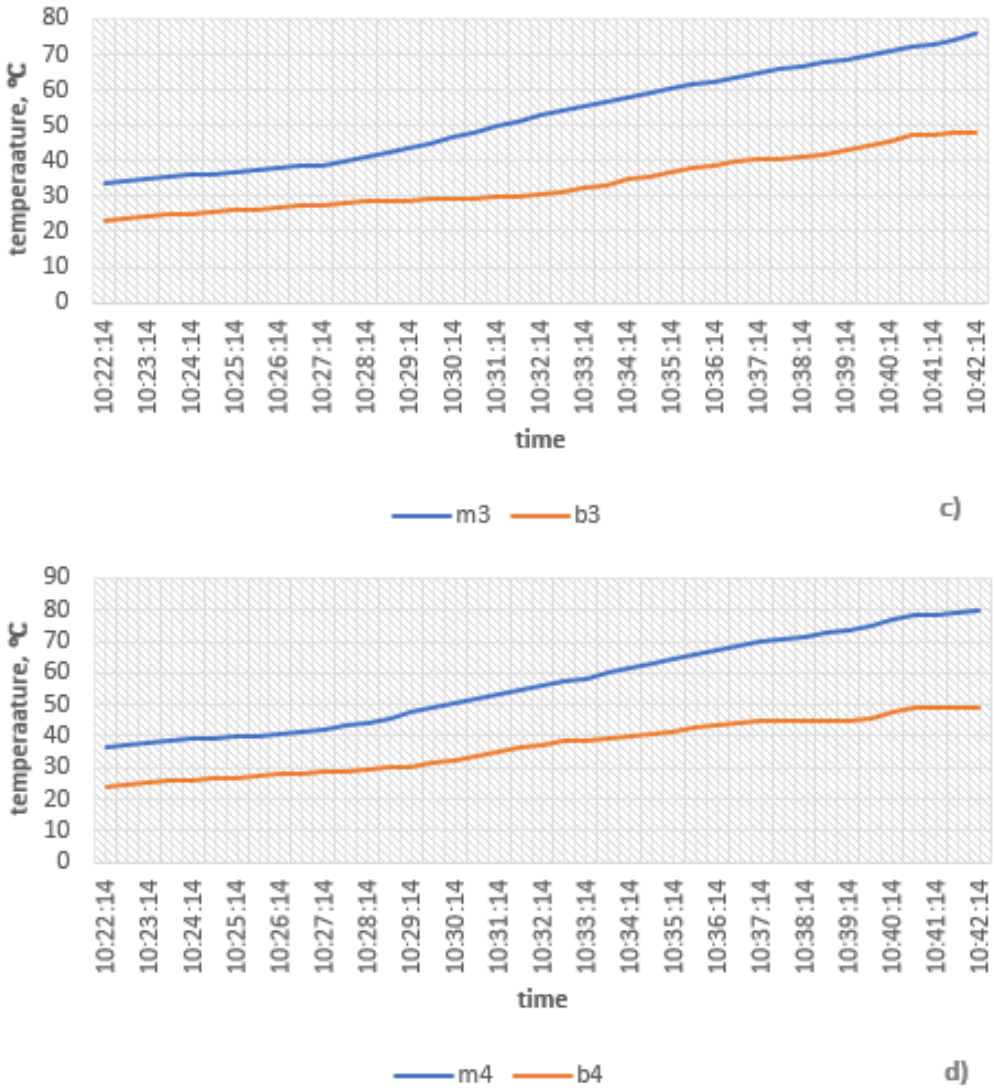

Fig. 3. Temperature trends in the modernized [1] and baseline receivers (a-d).

Therefore, the use of the displacement tube has significantly improved the heat transfer efficiency, as the modernized receiver shows better thermal performance compared to the base receiver.

CONCLUSIONS

As a result of experimental works we have made sure that the thermal performance of the modernized heat receiver has improved due to:

application of the displacement pipe, providing the directional movement of the coolant and more uniform heat distribution along the entire length of the receiver;

optimized geometry of the heat exchanger part, which increases the heat transfer coefficient;

increased heat exchange area and increased flow turbulence, which contributes to more efficient heat transfer from the tube walls to the heat transfer medium;

more effective contact between the absorber element and the heat transfer medium, ensuring a rapid and stable temperature rise.

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