Journal of Engineering Research

ISSN 2764-1317 vol. 6, n. 1, 2026

ARTICLE 2
Acceptance date: 21/01/2026

EFFECT OF COPPER COATING ON SPHERICAL DISTILLERS

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Abstract: This study evaluates the thermal performance and productivity of an improved spherical solar distiller by incorporating a laminated copper coating on the absorber plate, which is also coated with black automotive paint. The prototype, constructed of transparent acrylic with a hemisphere radius of 100 mm and an absorber plate of 90 mm, includes an upper perimeter ring that increases water retention capacity to 550 ml. The research combines experimental tests under real conditions in Dolores Hidalgo, Guanajuato (lat. 21.1687°; long. −100.9339°) with measurements of temperature, relative humidity, and thermal analysis by infrared camera to evaluate heat distribution and evaporation rate. Preliminary results show a more homogeneous heat distribution on the coated plate and a significant increase in volumetric productivity, reaching 150 $ml{\cdot}h^{-1}$ with an initial 550 ml in the tray. Likewise, it is identified that the maximum percentage of evaporation occurs with an initial 100 ml. Empirical models are proposed that relate productivity (R, $mL{\cdot}h^{-1}$) and the percentage of evaporation (%) to the initial volume V (ml). Preliminary findings indicate that copper coating promotes thermal conductivity and homogeneity, which increases heat transfer efficiency and evaporation rate. Experimental limitations and recommendations for the next stage are discussed: quantitative comparative tests, geometric optimization, and verification under different solar radiation conditions.

Keywords: Solar distiller, Thermal efficiency, Copper coating.

Introduction

Water purification using passive solar distillers represents a sustainable alternative for water supply in regions with high solar radiation. The optimization of materials and geometries is essential to improve the thermal efficiency of these devices and, therefore, their practical productivity. Previous studies suggest that the selection of high-conductivity materials can increase the thermal performance of solar distillers (Aybar et al., 2015; Kalogirou, 2005).

This study examines the effect of modifying the absorbent plate of a spherical distiller. The related variables are: *Independent Variable* (Study Factor): The application of a laminated copper sheet and black automotive paint on the absorbent plate. *Dependent Variable* (Result to be Measured): The thermal performance and practical productivity of the distiller (liters/day). *Related Factors* (Operating Conditions): The thermal conductivity of the absorbent material, the geometry of the collector, and the actual environmental operating conditions in Dolores Hidalgo, Guanajuato (solar radiation, ambient temperature).

Development

The impact of this research lies in the active optimization of the absorbing element of the passive spherical distiller, a geometry that has been little explored in the literature with this combination of materials. The central novelty is the incorporation of a copper sheet (0.4 mm) as a heat transfer interface. This modification seeks to exploit the high thermal conductivity of copper to maximize solar absorption and accelerate heat transfer to water, overcoming the limitations of standard polymeric materials (acrylic). This approach not only increases the internal thermal gradient for evaporation but also, together with the increase in container capacity (from 10 ml to 550 ml), ensures greater practical representativeness of the distiller's productivity under real operating conditions. Preliminary evaluation with calibrated instrumentation confirms the viability of the new configuration (see Figs. 1–4 and Table 1).

General Objective and Specific Objectives

General Objective.

To evaluate the effect of copper coating on the absorbent plate on the thermal efficiency and productivity of a spherical solar distiller under field conditions in Dolores Hidalgo, Guanajuato.

Specific Objectives.

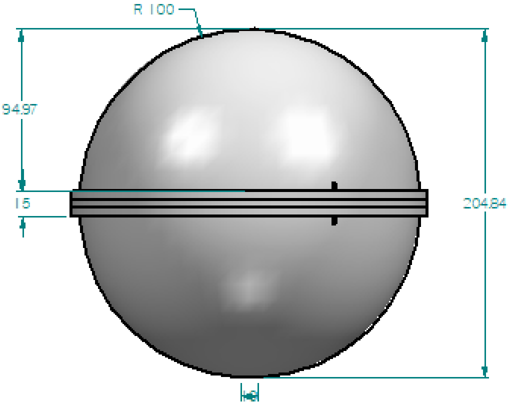
- Determine and compare the surface temperature distribution and internal thermal gradients of the copper-coated absorber plate using thermal camera measurements.
- To quantify volumetric productivity ( ) and daily thermal efficiency by adjusting empirical models based on the initial volume of water.
- Propose a set of operational and design recommendations for optimizing the spherical distiller, based on the results of the thermal efficiency obtained.

Subject of Study

The main object of this study is the modified spherical solar distiller, a device designed for water purification through passive solar distillation. The research focuses specifically on evaluating its thermal performance after the implementation of a copper coating on the absorbent plate.

The importance of addressing this modified system lies in the search for more efficient and sustainable passive solar technologies for the supply of drinking water in rural areas with high solar radiation. The copper coating was selected due to its high thermal conductivity, which, together with a black automotive paint coating, seeks to significantly increase solar energy capture and transfer. This optimization is essential to improve the distiller's thermal efficiency and, therefore, its productivity under the climatic conditions of Dolores Hidalgo, Guanajuato.

The basic configuration of the system consists of two transparent acrylic hemispheres (radius 100 mm) that form an internal cavity where the absorbent plate is housed. As shown in Figure 1, the prototype retains its spherical design, which favors the formation of internal thermal gradients.



Note: The tray containing the water to be distilled, located in the center of the prototype, has been redesigned with an upper perimeter ring that gives it a maximum capacity of 550 ml, improving the practical representativeness of the performance tests .

Figure 1. DIAGRAM OF THE SPHERICAL PROTOTYPE

Component	Material	Relevant Properties
Sphere	Acrylic	Transparent, thickness 3 mm, radiation transmission.
Absorbent plate	Copper (painted black)	High absorption capacity, good conductivity.

Note. Copper was selected for the absorbent plate due to its high thermal conductivity, a key property for improving heat capture and transfer to water, while acrylic was chosen for the sphere due to its transparency and low conductivity, which promotes heat retention and the greenhouse effect in the system.

Table 1 *MATERIALS USED IN THE PROTOTYPE.*

The modified absorbent plate has a diameter of 90 mm and a thickness of 3 mm. Table 1 describes the main materials used in its construction:

Methodology

This research used an experimental approach, structured in sequential stages of design, calibration, and testing under field conditions. This methodology was chosen because of its ability to validate, in a controlled and measurable way, the impact of design modifications on a technological device, as well as to quantify the effect of operational variables on the final performance of the system.

The experimental methodology allows us to establish the causal relationship between the copper coating (independent variable) and the thermal efficiency (dependent variable) of the distiller.

Development Phases

A. Prototype Design and Construction

In this phase, the base structure was manufactured and the absorbent element of the solar distiller was modified. The main body was manufactured with two acrylic hemispheres with a radius of 100 mm, ensuring transparency and heat retention. The internal absorbent plate, with a diameter of 90 mm, was the key piece of the innovation. The plate was coated with a 0.4 mm thick copper sheet, attached with a thermal adhesive and covered with black automotive paint to maximize solar absorption. In addition, we incorporated an upper perimeter ring that increased the capacity of the water container, improving the practical representativeness of the tests. The composition of materials is detailed in Table 1 in the Study Object section.

B. Calibration and Verification

Before field testing, exhaustive tests were carried out to ensure the integrity and accuracy of the system. The distiller was checked for leaks to prevent vapor leakage, and the adhesion of the copper coating was measured under heating to ensure its operational stability. The structural verification of the perimeter ring was also confirmed. Preliminary calibration of the temperature and humidity sensors indicated correct operation and consistency, which is essential for data recording during experimental testing.

C. Experimental Field Tests

The tests were carried out under field environmental conditions between 9:30 a.m. and 3:30 p.m., a period selected because it represents the time of greatest energy use according to the local solar path. Environmental variables (incident radiation, am-

DOI https://doi.org/10.22533/at.ed.8208162614012

bient temperature, and relative humidity) were recorded, and the surface temperature of the absorber plate was measured using a thermal camera. Simultaneously, the distilled volume was quantified at hourly intervals. This phase allowed the necessary data to be obtained to quantify the efficiency of the modified system.

D. Data Analysis and Empirical Modeling

Data analysis focused on relating the productivity of the system to the initial volume of water. An empirical model was adjusted to predict the percentage of evaporation yield as a function of the initial volume of water in tray V (ml). Preliminary results showed that, with an initial 100 ml in the tray, the maximum percentage of evaporation is achieved within the prototype, as shown in Figure 2.

The evaporation percentage is defined by the following expression:

$$\%\ de\ evaporación = \frac{V_{evaporado}}{V_{inicial}} X\,100 \quad (1)$$

Where $V_{evaporado}$ represents the volume of evaporated water and $V_{inicial}$ is the initial volume of water. The volumetric productivity $(ml \cdot h^{-1})$ and the evaporation percentage were calculated for the thermal distribution analysis and the final discussion of the results.

Measurement Considerations

The International System of Units (SI) was used. Data recording was limited to the local solar domain. We verified the dimensional consistency of the prototype, which was 0.2 m in diameter, and used the equation editor for all mathematical notation.

Results and Discussion

A) Thermal Distribution and Solar Behavior

The analysis of the local solar path, performed for the conditions in Dolores Hidalgo, Guanajuato (specifically on February 28, 2025, at 10:20 a.m.), allowed us to identify the optimal azimuth and elevation angles required for the correct orientation of the prototype during the experiment. It was determined that the period of greatest energy utilization is between 9:30 a.m. and 3:30 p.m. The thermal camera used in the tests recorded a more homogeneous heat distribution on the surface of the copper-coated absorber plate. This finding suggests a significant reduction in local thermal gradients, which translates into a more uniform and effective heat transfer to the working fluid.

B) Volumetric Productivity and Modeling

The maximum productivity of the distiller was observed to be 150 ml/h when the initial volume in the tray was set at 550 ml. To describe this behavior, an empirical model was obtained that relates productivity R in ml/h to the initial volume of water (V in ml). The mathematical expression adjusted by regression is as follows:

$$R\left[\frac{ml}{h}\right] = e^{2.63 - \frac{49.71}{V[ml]} + 0.39\,lnV[ml]} \qquad (2)$$

This model (2) indicates a complex dependence between the initial water volume and productivity. The behavior suggests $\left[\frac{ml}{h}\right]$ to maximize absolute productivity in, the operation should focus on ranges above 550 ml. The experimental results used to adjust this model, as well as the resulting yield curve, are presented in Figure 3.

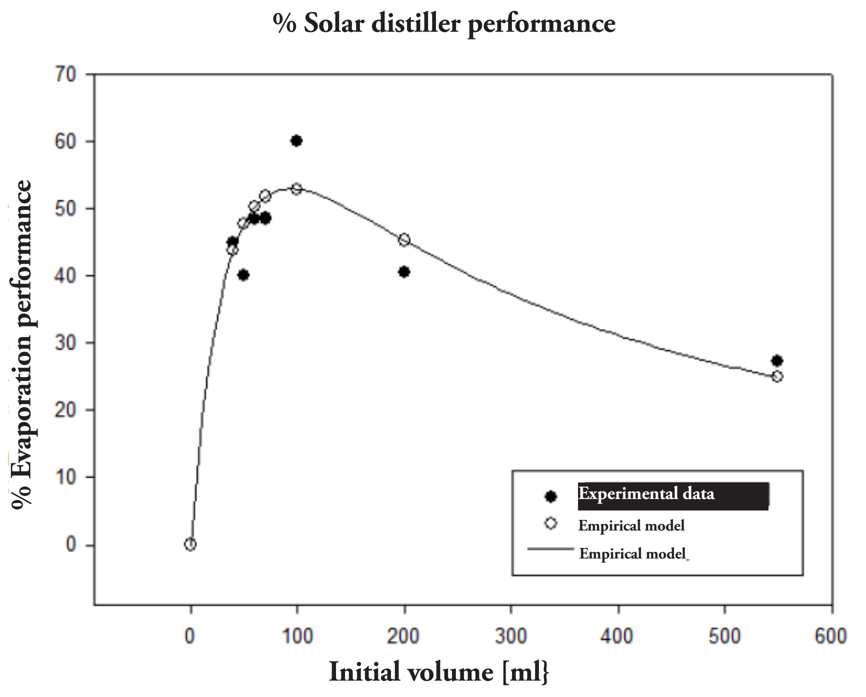


Figure 2. *SYSTEM PERFORMANCE PERCENTAGE*

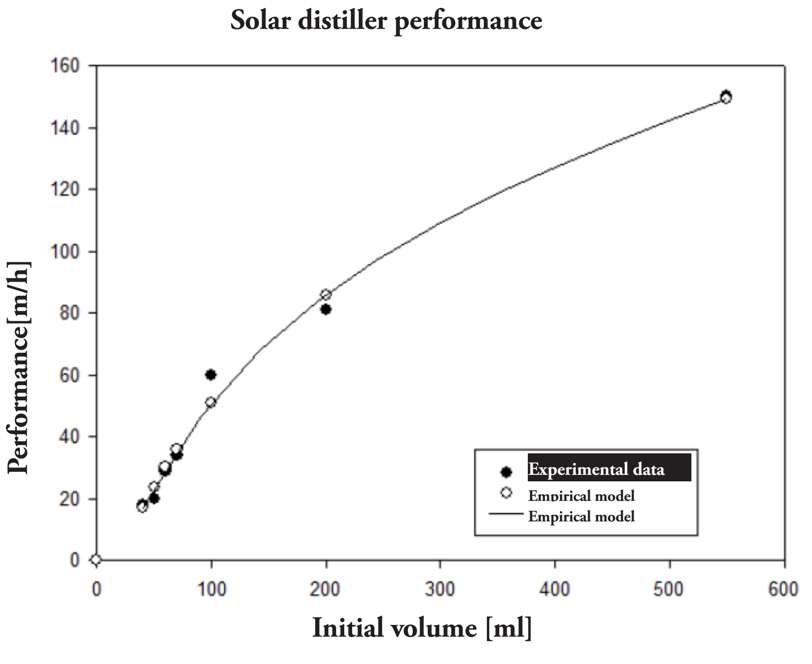


Figure 3 SYSTEM PRODUCTIVITY

C) Percentage of Evaporation

The evaporation percentage parameter was calculated according to Equation (1), which evaluates the fraction of initial water that is evaporated during the experiment. It was found that the maximum evaporation percentage was achieved with an initial volume of 100 ml in the tray. This result, shown in Figure 2, is crucial for evaluating the relative efficiency and kinetics of the process within the closed system.

The empirical model proposed for the percentage yield (%Y) as a function of the initial volume V was adjusted using nonlinear regression and is described as:

$$\%R = \frac{V[ml]}{0.48 + 0.0084\,V[ml] + 0.000055\,V[ml]^2} \quad (3)$$

This behavior exposes the operational tension inherent in the system: small volumes of water favor a high evaporated fraction (being more useful for relative efficiency studies), while large volumes allow for greater total production in $\left[\frac{ml}{h}\right]$.

D) Interpretation and Limitations

The improvement in thermal performance is directly attributed to the higher thermal conductivity of copper and the black coating that increases spectral absorption. The thermal homogeneity provided by copper contributes to more effective heat transfer to the fluid, eliminating cold spots that could limit evaporation. However, it is recognized that the measurements presented are preliminary: the sensors are in the final calibration stage, so the tests must be replicated to ensure statistical robustness and control of incident radiation. It is necessary to quantify the long-term durability of the adhesive and coating, as well as to evaluate the influence of the shading effect and orientation through seasonal testing.

Conclusion

It is concluded that the copper coating on the absorbing plate of the spherical solar distiller has produced a more homogeneous thermal distribution on the surface and a demonstrable improvement in the volumetric productivity of the system under field conditions in Dolores Hidalgo. The integration of copper's high thermal conductivity and high- , together with the spherical geometry, accelerated heat transfer to the fluid, achieving the goal of optimizing the device.

$\left[\frac{ml}{h}\right]$The experimental results validate the trade-off between absolute production and relative efficiency. A maximum production of 150 liters was found, operating with an initial volume of 550 ml. However, the maximum evaporation percentage (relative efficiency) was achieved when the initial volume was 100 ml. This duality must be considered in the selection of the operating strategy, depending on whether the total volume of distilled water or the thermal process yield is prioritized.

The development of empirical models provides a predictive tool for estimating productivity and relative yield based on the initial volume of water. However, additional statistical validation including replicated data is required to strengthen its predictive capacity.

As complementary work and to consolidate the research, it is recommended to proceed with the following experimental stage. This should include:

DOI https://doi.org/10.22533/at.ed.8208162614012

✓ Direct comparative tests between the original prototype (without copper) and the coated prototype.

✓ A rigorous evaluation of the long-term durability of the adhesive and copper coating.

✓ The performance of a complete heat balance and the estimation of energy efficiency (η) to fully characterize the performance of the system.

✓ Sensitivity analysis to orientation and the effect of shading through seasonal testing.

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