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Elevating Solar Still Performance with Wick-Finned Absorber and Nano-Enhanced PCM Technology

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Abstract

The study aimed to enhance the heat transfer efficiency between saline water and the absorber in a Tubular Solar Still (TSS). This improvement was achieved by exploring various absorber designs, including flat and finned configurations. The research compared the performance of three systems: Conventional Solar Stills (CSS), the Tubular Solar Still (TSS), and a modified version with finned absorbers, known as Finned Tubular Solar Still (FTSS). To facilitate slow upward movement of feed water through the absorber, jute wick materials were employed as a covering for the finned absorbers. Furthermore, the internal sides of the TSS were equipped with reflective mirrors to evaluate their impact on performance. In a bid to further enhance the FTSS's capabilities, Phase Change Materials (PCMs) mixed with copper oxide nano particles were incorporated.

1. Introduction

Freshwater scarcity is a critical issue in both developed and developing countries. Various techniques have been employed to address this challenge and enhance freshwater productivity systems, including humidification dehumidification (HDH) [1], reverse osmosis (RO), multi-stage flash (MSF), vapor compression (VC), solar still (SS), and multi-effect boiling (MEB). The solar still, a compact water desalination unit, offers a viable solution for obtaining potable water in remote areas [2]. However, its low daily production has prompted extensive research to maximize freshwater output. Several investigations have focused on minimizing the saline water depth [3], increasing feed water temperature using solar water collectors, and employing mirrors to enhance solar energy absorption [4].

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2. Materials and methods

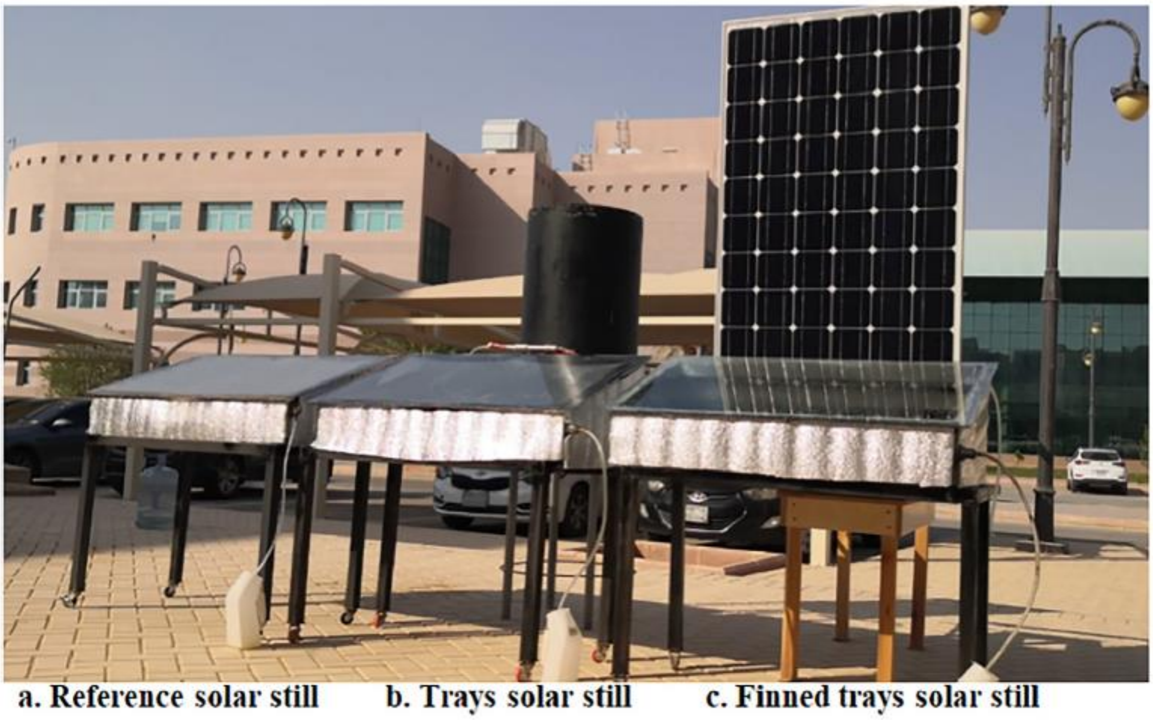

Fig. 1 Photograph of tested solar stills.

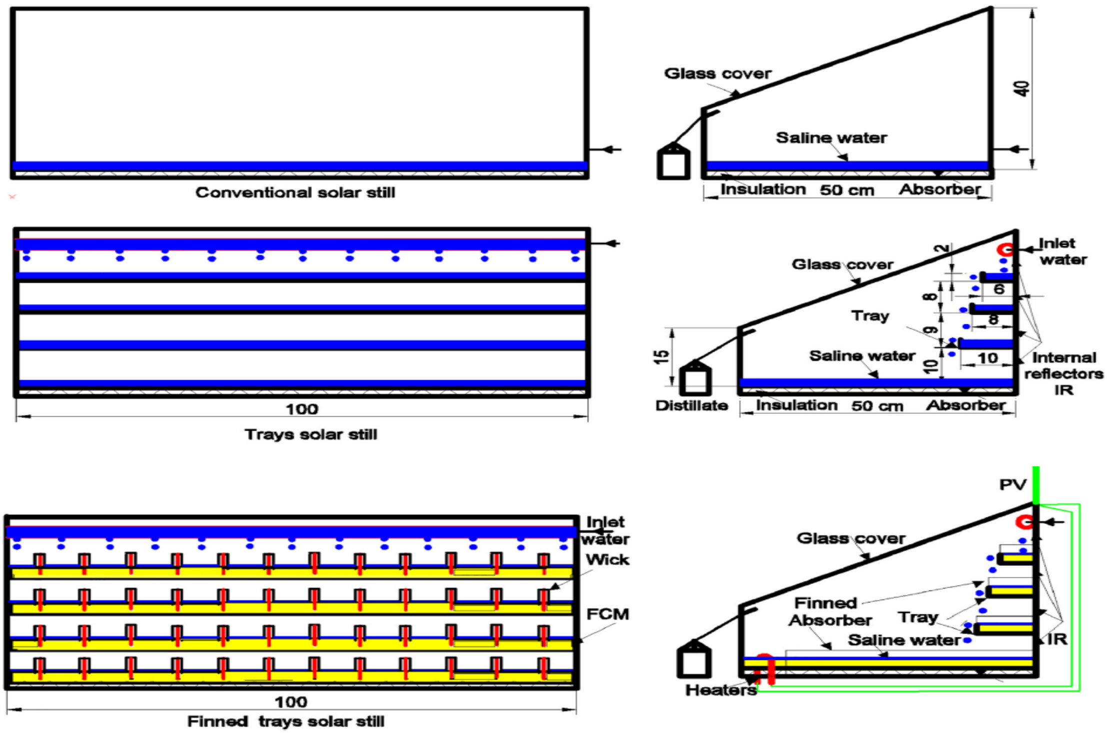

Fig. 2 Cross-sectional view of TSS, FTSS and conventional SS.

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Table 1 Properties of PCM and PCM with CuO nanoparticles.

Property	PCM with CuO nanoparticles	PCM (Paraffin wax)
Melting point, °C	53	54
Density, kg/m^3	941	876
Specific heat, kJ/kg °C	2.05	2.1
Thermal conductivity, W/m °C	0.28	0.21
Latent heat of fusion, kJ/kg °C	187	190

Table 2 Properties of nanoparticles.

Chemical composition	Density	Specific heat	Size,	Thermal conductivity
CuO	6320 kg/m^3	42.36 J/mol K	10–14 nm	76.5 W/m K

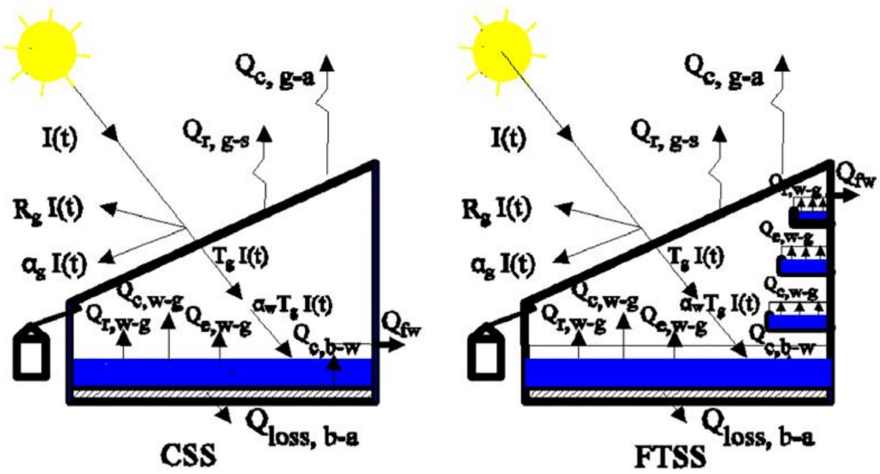

Fig. 3 Heat transfer rates to or from CSS and FTSS.

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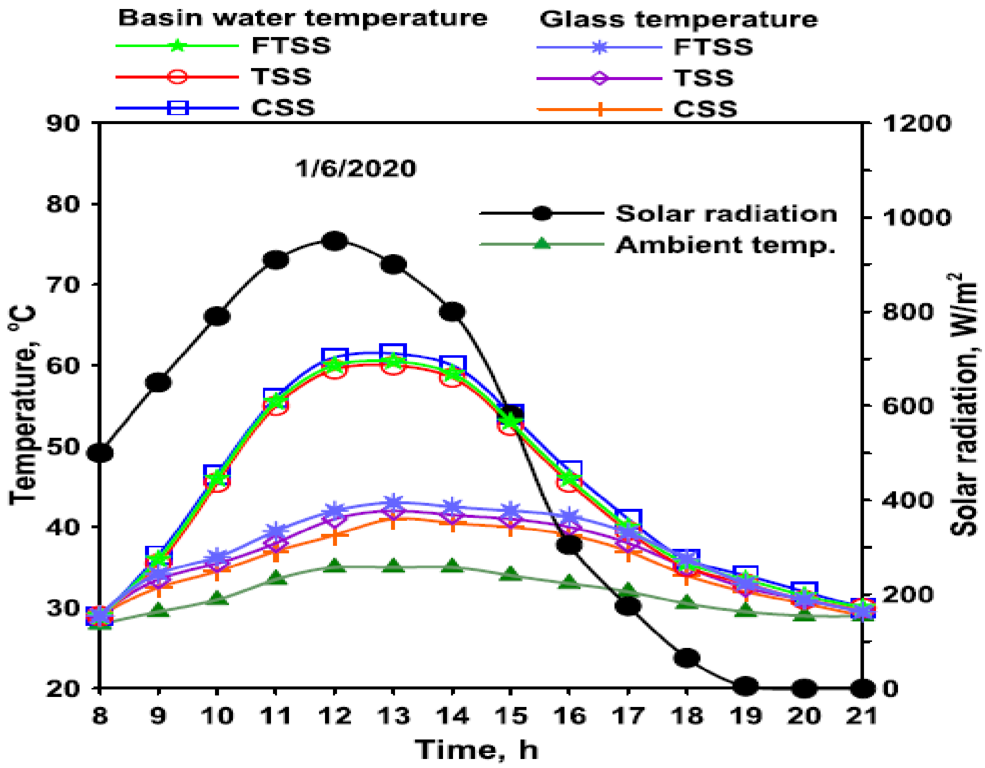

Fig. 5 Temperatures and solar radiation profiles for tested SSs.

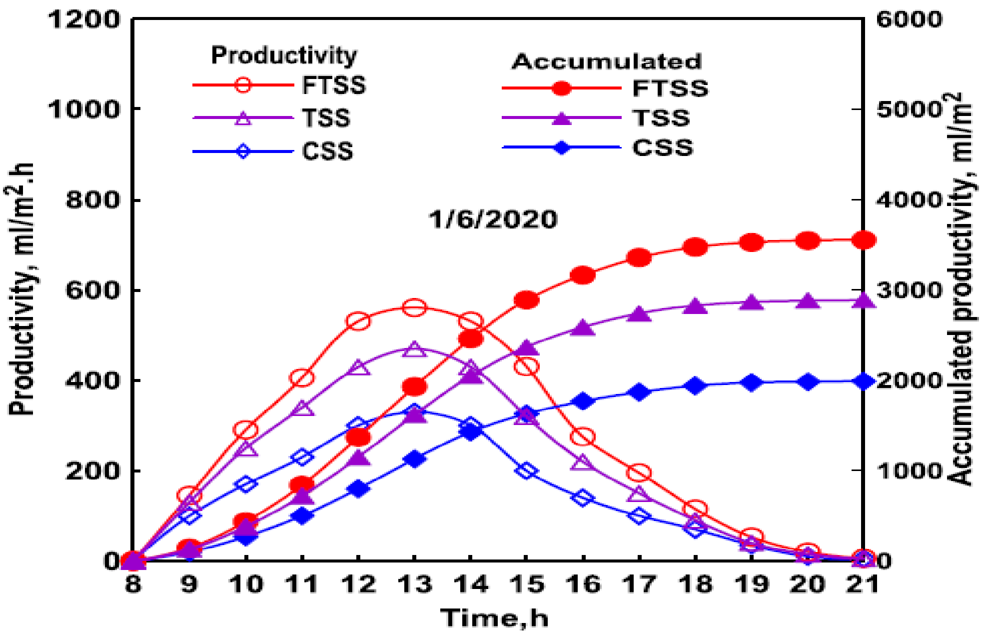

Fig. 6 The accumulated and hourly output yield for tested solar stills.

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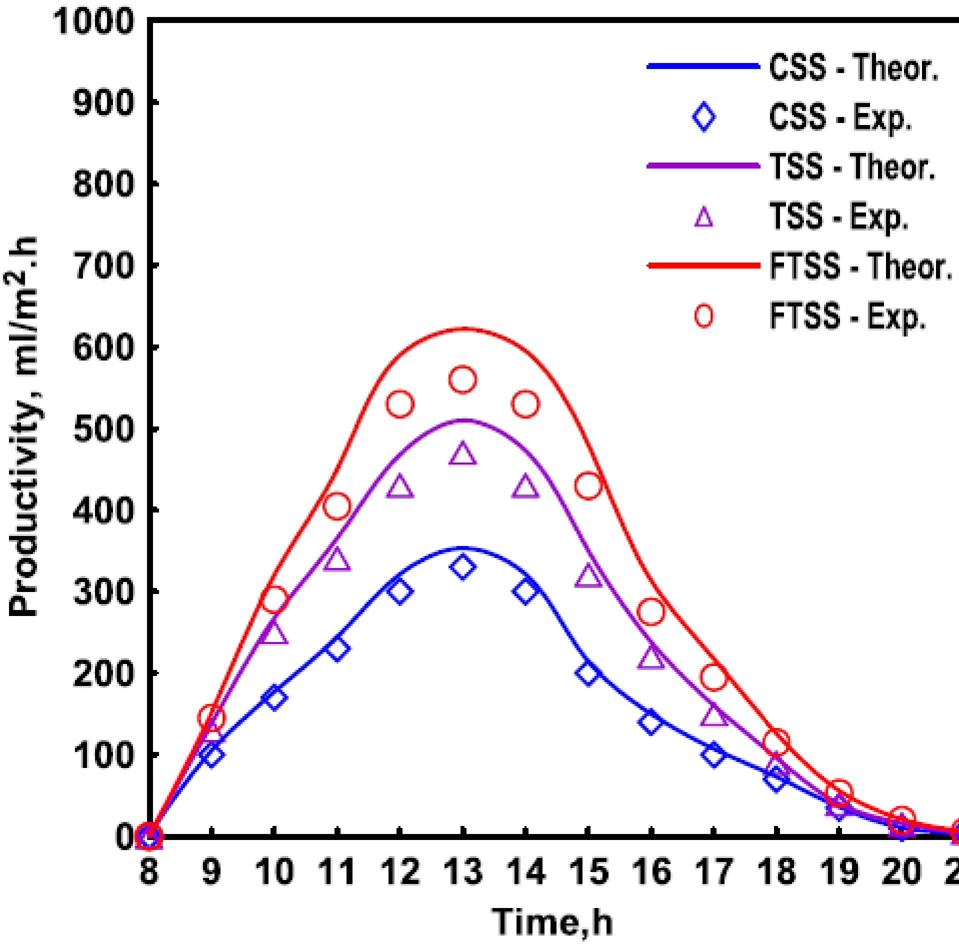

Fig. 4 A comparison between experimental and theoretical water productivity for tested solar stills.

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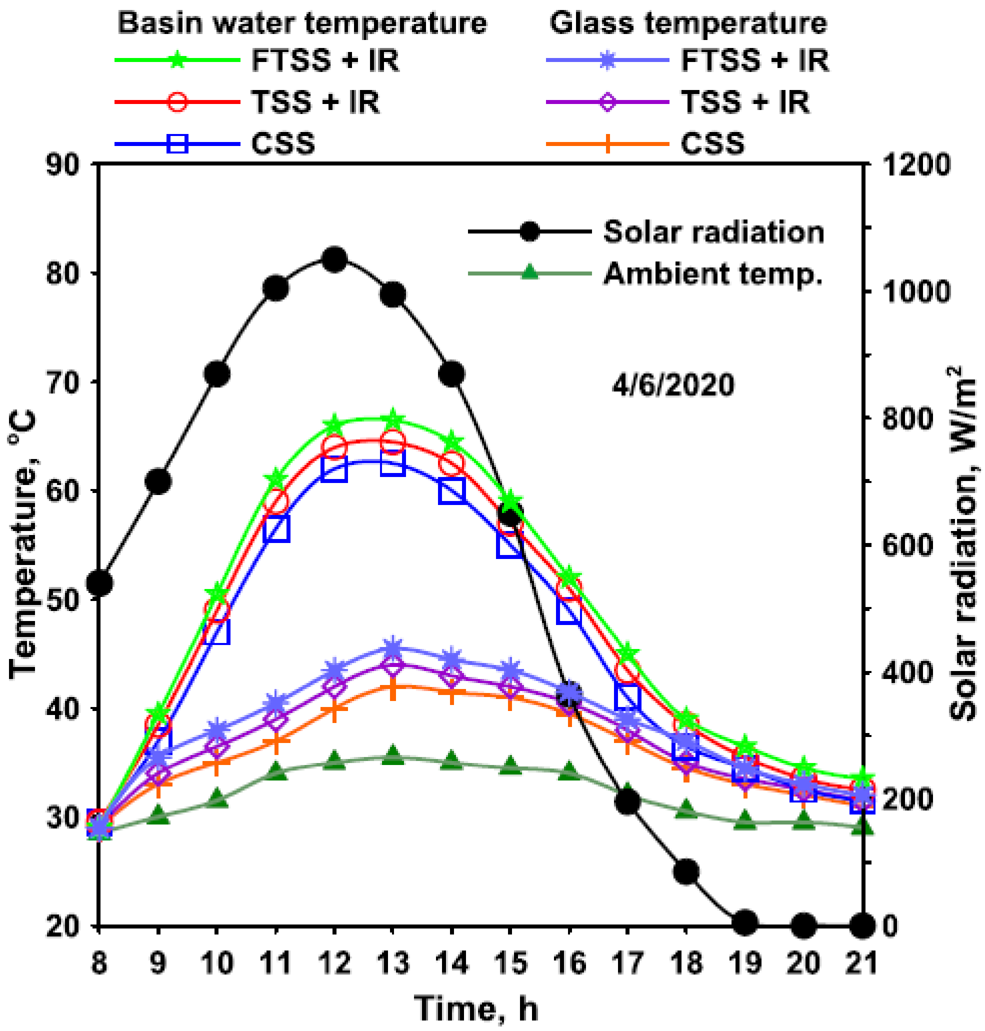

Fig. 7 Temperatures and solar radiation profiles for tested SSs with IR.

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Table 3 Temperature of saline water of the basin and trays of TSS with IR.

hour	Trays temperature, ℃			Basin, °C	Average, °C
	Upper	intermediate	lower		
8	29.5	29.3	29	28	29
9	44	42.5	41	38	39
10	54	52.5	50	47	48.5
11	65.5	63.5	61	57	58.5
12	72	70.8	68	63	64
13	73	72	68.7	64	64.5
14	70.6	68.5	65	61	63
15	66	64	61	57	57
16	59	57.5	54	50.5	52
17	51	49.5	47	44	44
18	44	43.5	42	40	40
19	38	37	36	35	35.5
20	34	33.5	33	32	32.5
21	31	30.8	30.5	30	30.5

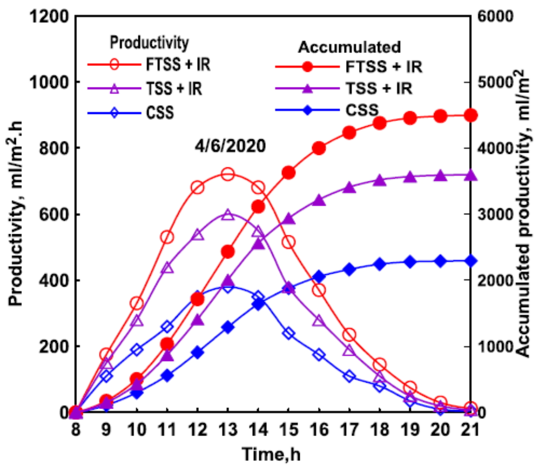

Fig. 8 The accumulated and hourly output yield for tested solar stills with IR.

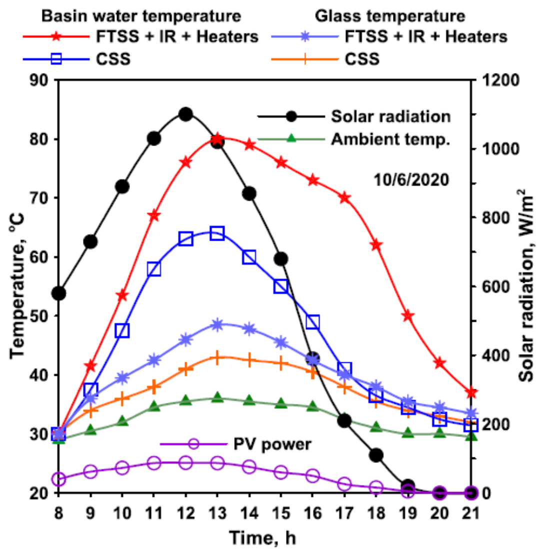

Fig. 9 Hourly distribution of temperatures, PV power and solar

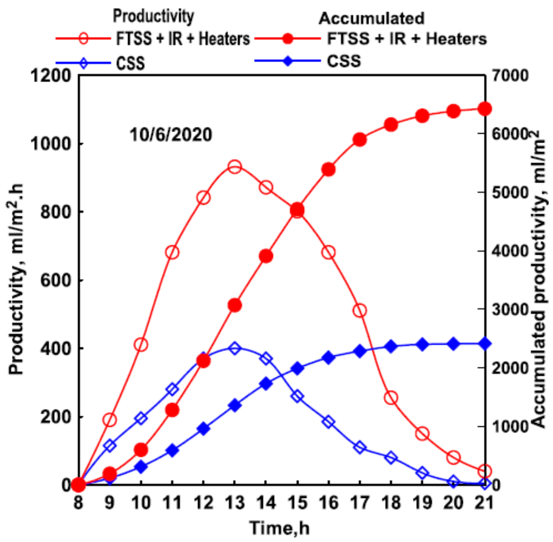

Fig. 10 Productions of conventional SS and FTSSs with EHs.

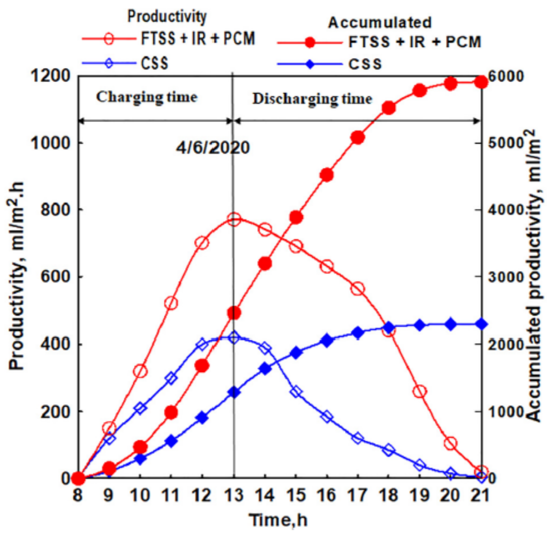

Fig. 12 The productivity of CSS and FTSS with PCM and nanoparticles.

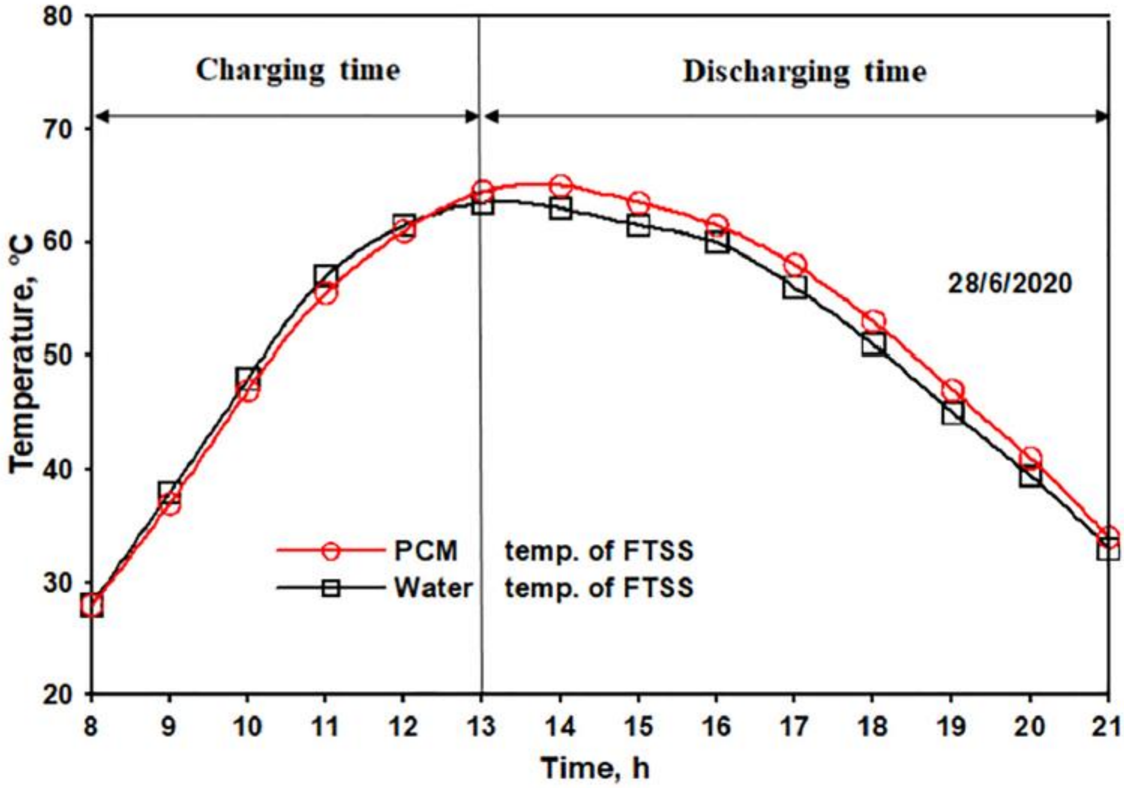

Fig.11 Temperatures of PCM and saline water of FTSS.

Table 4 Daily thermal efficiency of CSS and FTSS with IR under different investigated conditions.

Tested case	CSS	TSS	FTSS	FTSS + Heaters	FTSS + FCM	FTSS + FCM + Heaters
Thermal Efficiency, %	34	43	49	59	54	63

6. Conclusion

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In the present study, increasing the surface area of absorber of TSS was targeted for better performance of the distiller. As a result, the TSSs with finned and flat absorbers shapes have been studied.

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