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EXPERIMENTAL STUDY OF A HYBRID SOLAR STILL SYSTEM USING PARABOLIC TROUGH CONCENTRATORS

M. Saad. Mustafa[1,2*], M. G. Mousa[3], Mohamed Mohamed Khairat Dawood[4], Tamer M. Mansour[2], Tamer Nabil[2]

[1] Higher Technological Institute, Tenth of Ramadan city, Egypt.

[2]Mechanical Engineering Department, Faculty of Engineering, Suez Canal University, Ismailia, 41522, Egypt.

[3]Mechanical Engineering, Faculty of Engineering, Damietta University, Damietta, Egypt.

[4]Mechanical Power Engineering, Faculty of Engineering, Damanhour University, Elbehira, Egypt.

***Correspondence:** mohamed.saad@hti.edu.eg

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ABSTRACT

The primary objective of this study was to conduct an experimental evaluation of the efficiency of a solar still integrated with parabolic trough concentrators (PTC). Two solar still systems have been fabricated, one being a conventional solar still (CSS) and the other a hybrid solar still (HSS) incorporating a phase change material (PCM) along with a parabolic trough concentrator (PTC).Investigations were carried out in the high-temperature environment of 10th of Ramadan city, Egypt. The performance of HSS systems, which included various masses of PCM with or without PTC, was analyzed in comparison to a conventional system. The focus was on assessing the operational temperature efficiency and freshwater output of the systems under study. The results suggest that the solar still combined with PTC exhibits elevated operational temperatures and enhanced productivity in contrast to the conventional solar still. The freshwater productivities of HSS setups with 2.5, 3, 3.5, and 4 kg of PCM showcase an escalation of 34.6%, 69.9%, 37%, and 9.6%, respectively, when juxtaposed with the conventional still. Conversely, in instances where solar stills incorporate identical PCM quantities without PTC, the improvements in freshwater productivity are 26.4%, 53.1%, 27.3%, and 6.9%, respectively, in comparison to the conventional still. Evidently, the solar still system enhanced with PCM and integrated with PTC (HSS) proves to be more effective and efficient than its counterpart.

KEYWORDS: Parabolic trough concentrator, hyprid solar still, freshwater productivity,phase change material.

دراسة تجريبية لنظام مقطر شمسي هجين باستخدام المكثفات ذات القطع المكافئ

محمد سعد مصطفى[1،2*]، محمد غصوب موسى[3]، محمد محمد خيرت داوود[4]، تامر محمد منصور[2]، تامر نبيل محمود[2]

[1] قسم الهندسة الميكانيكية، ، المعهد التكنولوجى العالى ، العاشر من رمضان، الشرقية، مصر.

[2] قسم الهندسة الميكانيكية، كلية الهندسة، جامعة قناة السويس، الإسماعيلية،41522 مصر

[3] قسم الهندسة الميكانيكية، كلية الهندسة،جامعة دمياط ،دمياط،مصر .

[4] قسم الهندسة الميكانيكية، كلية الهندسة، جامعة دمنهور، البحيرة،مصر.

***البريد الاليكتروني للباحث الرئيسي:** mohamed.saad@hti.edu.eg

الملخص

الهدف الأساسي من هذه الدراسة هو إجراء تقييم تجريبي لكفاءة جهاز التقطير الشمسي المدمج مع مركّزات الحوض المكافئ (PTC). تم تصنيع نظامين للتقطير الشمسي، أحدهما عبارة عن جهاز تقطير شمسي تقليدي (CSS) والآخر جهاز تقطير شمسي هجين (HSS) يشتمل على مادة متغيرة الطور (PCM) جنبًا إلى جنب مع مركّز حوض مكافئ (PTC). أجريت التحقيقات في بيئة ذات درجة حرارة عالية في

مدينة العاشر من رمضان، مصر. تم تحليل أداء أنظمة HSS، والتي تضمنت كتل مختلفه من PCM مع أو بدون PTC، بالمقارنة مع نظام تقليدي. كان التركيز على تقييم كفاءة درجة الحرارة التشغيلية وناتج المياه العذبة للأنظمة قيد الدراسة. تشير النتائج إلى أن جهاز التقطير الشمسي المدمج مع PTC يُظهر درجات حرارة تشغيلية مرتفعة وإنتاجية محسنة على النقيض من جهاز التقطير الشمسي التقليدي. تظهر إنتاجية المياه العذبة لأنظمة التقطير الهجينه مع 2.5 و3 و3.5 و4 كجم من PCM زيادة بنسبة 34.6٪ و69.9٪ و37٪ و9.6٪ على التوالي، عند مقارنتها بجهاز التقطير التقليدي. وعلى العكس من ذلك، في الحالات التي تتضمن فيها أجهزة التقطير الشمسية كميات متطابقة من PCM بدون PTC، فإن التحسينات في إنتاجية المياه العذبة هي 26.4٪ و53.1٪ و27.3٪ و6.9٪ على التوالي، مقارنة بجهاز التقطير التقليدي. ومن الواضح أن نظام التقطير الشمسي المعزز بـ PCM والمتكامل مع PTC (HSS) يثبت أنه أكثر فعالية وكفاءة من نظيره.
الكلمات المفتاحية : مكثف حوض مكافئ، مقطر شمسي هجين، إنتاجية المياه العذبة، مادة تغيير الطور.

1. INTRODUCTION

Water serves as the fundamental element for sustaining life on Earth for all living organisms. The vast majority of water on our planet, approximately 97%, is found in the oceans and seas, rendering it unsuitable for direct human consumption. The remaining 3% is distributed with 2% locked in icebergs in polar regions and 1% existing as fresh water in rivers, lakes, and groundwater sources [1]. The climate in Egypt is dominated by elevated temperatures year-round, leading to increased evaporation of water from the Nile River and its tributaries, further aggravating the issue of water scarcity in the region. Hence, the exploration of alternative sources to address the depletion of natural resources is imperative. Solar energy emerges as a viable alternative utilized in water desalination processes to overcome this issue. particularly in Egypt. Water desalination systems rely on evaporation and condensation techniques to extract fresh water from saline water. Additional systems like PTC and photo voltic PV can be integrated to enhance daily output beyond the typical capacity of desalination systems. Research efforts have been directed towards identifying optimal operational parameters and conditions for centralized water desalination facilities.Somwanshi and Tiwari [2] concluded that the annual productivity of fresh water can increase by approximately 56.5% when water passes from the air cooler over the cover of the solar basin. Zaki et al. [3] compared the performance of a SS equipped with an external trough concentrator with a traditional still, and it was found that the productivity of the still equipped with the external concentrator is 22% higher than the traditional one. Aburideh et al. [4] studied the performance of a SS and the effect of operating parameters on it. They found that the productivity of fresh water increases with increasing temperature differences between the water and the glass cover. Tanaka and Omara et al. [5,6] made an experimental design for an active SS containing reflectors. He concluded that the daily productivity of fresh water increases by a large percentage when using solar reflectors.Tiwari and Suneja [7] analyzed numerically inverted reflective SS. To improve the daily performance of SSs,. The innovative dome-shaped solar still design developed by Hamed et al.[8] incorporates a conical absorber basin and integrates a phase change material enriched with nanoparticles. The findings indicate that this novel solar still system, when combined with a phase change material containing nanoparticles, outperforms other systems in terms of energy and exergy efficiencies for freshwater production. Sheikh et al. [9] all developed a solar still in the shape of a wicked prism that included wick materials and feed spray nozzles to enhance the evaporation rates within the still basin, consequently leading to an increase in the production of fresh water. The findings from the experiments demonstrated that the daily freshwater output of the MSS reached 7.94 kg/m²/day, marking a significant improvement of 49.53% compared to alternative systems. Attia et al.[10] incorporated spherical rock salt balls into the saline water of a solar still as a means of enhancing absorption rates for efficient heat transfer. Their findings demonstrate a notable increase in freshwater productivity with the utilization of larger-sized rock salt balls.Hassan et al. [11,12] investigated a SS combined with a parabolic trough collector and a conventional one with three different saline water media in hot and cold climates. Amiri et al. [13] have analyzed theoretically and experimentally the energy and exergy of a novel SS system integrated with a parabolic trough collector. The average freshwater productivity of a SS system integrated with a tracking parabolic trough is higher than the productivity of a fixed system. Researchers are still looking for novel techniques to connect the parabolic collector to SS units for the purpose of optimum performance and freshwater production. Aqlan et al. [14] connected the parabolic trough collector with a novel SS directly without heat exchanger (H.X.). The field studies demonstrated that the modified SSs overall water productivity increased by 177% when compared to the conventional still. Ranjan et al. [15] evaluated the SS coupled with a parabolic trough collector experimentally. The results proved that increasing the temperature improves the production of combined solar condensers. Prabu et al. [16] investigated a SS system by designing and fabricating a parabolic trough collector integrated with a shell-tube receiver made of different metals. Despite the large number of studies on solar energy, it is still possible to provide work to improve its performance and productivity in terms of connection techniques and operating recommendations to reach the best times used for the intervention of devices coupled with the solar distillation unit.In this work, the impact of PTC combined with a single-slope solar still on SS temperature, productivity, and performance was investigated in comparison to a CSS with identical standard specifications. The saline water in the SS basin was heated using a H.X. positioned at the base of the basin and shielded from all sides. The H.X. obtained its thermal energy from an insulated plastic tank, where hot water from the PTC was stored at the minimum flow rate during the solar day and utilized at the most suitable time for the experimental conditions to maximize the benefits from the exchanged thermal energy. This optimization was reflected in the daily production of fresh water and the thermal efficiency of the system. It is anticipated that the heat capacity of the saline water will rise as a result of the increase in temperature of the working fluid in the H.X., the reduction of saline water in the still basin, and its retention of a heat capacity that is constrained by the solar energy received by the still.

2. Experimental work

The experiment setup was installed at the surface of the mechanical engineering department, the Higher Technological Institute in 10th of Ramadan City, Sharkia, Egypt, in the summer of 2023.

2.1. Experimental setup description

The test experiment consists of a single-slope SS coupled to a multi-solar parabolic collector via an insulated tank, as shown in the Fig. 1a and Fig.1b.

2.1.1 Solar Still Unit

The SS unit consists of a corrugated stainless-steel basin with dimensions of (58 * 50 * 5) cm and a thickness of 1 mm. The basin is painted black to absorb the largest amount of incident solar radiation. A tight wooden frame with a thickness of 1 cm and a height of 5 cm was placed around the basin. A sheet of blue thermal foam with dimensions of (90*55) cm and a thickness of 7 cm was also placed to reduce heat loss from the basin to the surroundings. The absorber basin used was covered with a cover made of acrylic with a thickness of 6 mm and inclined at an angle of 30 degrees to the horizontal axis, which is the latitude angle of 10th of Ramadan city, Egypt. Acrylic material was used instead of the glass used in many solar distillation units because it withstands shocks, is easy to move, and has a lower density than regular glass. The SS was directed in the NS direction of 10th of Ramadan City to make the maximum incident solar energy fall on the still. All the spaces between the basin and the acrylic casing were filled with silica to prevent any leakage. Three channels were created along the inclined wall with enough slope on each side of the glass wall, to collect the condensed fresh water in them, connected to bottles via plastic hoses. The PCM is placed in the lower corrugated area of the basin in the form of aluminum pouches. The weight of each pouch is 125 grams. **Fig. 2** illustrates the main parts of SS combined with the H.X., including a phase change material.

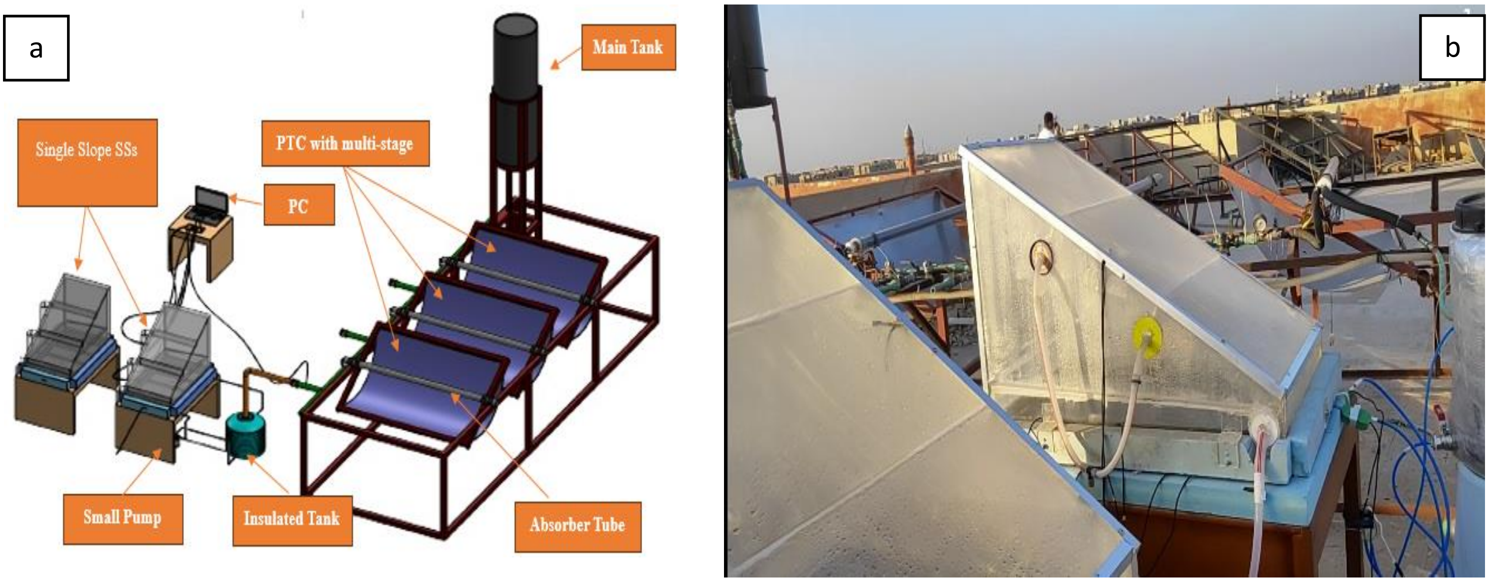

Fig.1.(a)The Schematic Diagram of The SS Coupled With PTC and (b) The Typical Photo of The Test Rig.

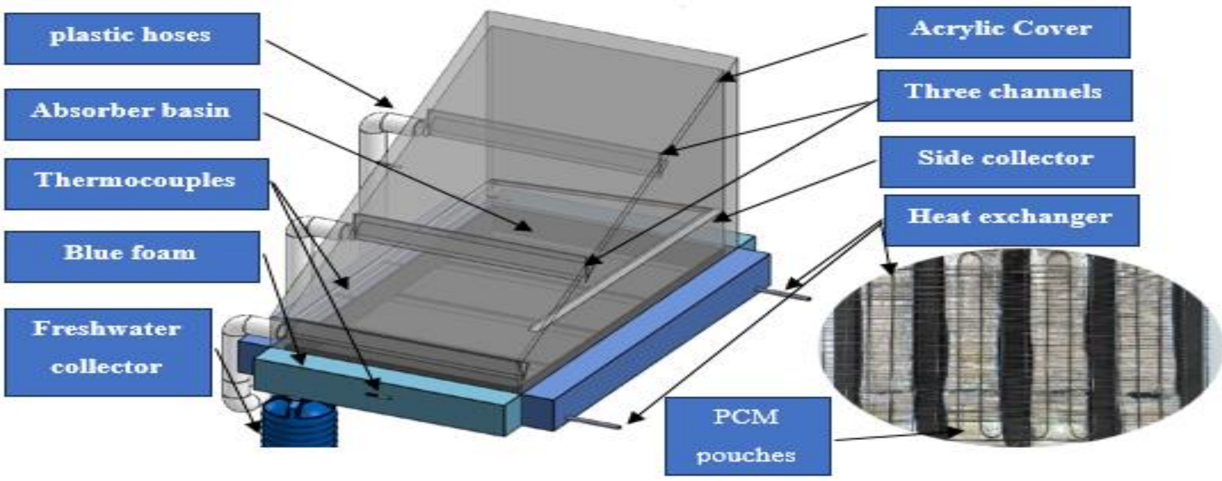

Fig. 2. The Schematic Diagram of SS Unit with H.X.

2.1.2. Parabolic Trough Concentrators

The parabolic trough concentrators in use consist of three cylindrical troughs placed in succession. Each trough is strategically positioned to avoid casting shadows from neighboring troughs. These cylindrical parabolic concentrators are made of polished zinc-coated steel to prevent corrosion, with dimensions measuring 155 * 91.5 * 0.3 cm^3 and a rim angle of 62 degrees. The receiver tube, located at the focal point of the parabolic trough, is made up of an evacuated tube to reduce heat loss through convection to the surroundings. It is constructed from borosilicate glass, 180 cm in length, with an outer diameter of 5.7 cm and a wall thickness of 1 cm. Inside the glass tube, there is a U-shaped copper tube measuring 400 cm in length and 1.5 cm in diameter. Furthermore, the PTCs were positioned facing south at an inclination angle on the horizontal axis equal to the latitude of the 10th of Ramadan City, which is approximately 30 degrees.

The parabolic troughs extract heat transfer fluid (tap water) from a 100-liter primary water tank linked to the steel structure, allowing the water to move in sequence through the copper tubes utilizing its gravitational potential energy. The heated water is then stored in an insulated tank, where it is pumped using a 12V mini pump to the H.X. positioned beneath the SS at the minimum flow rate. This flow configuration enables the attainment of the maximum heat transfer rate through conduction between the H.X. and the PCM, as illustrated in Figure 2. To enhance their heat absorption capacity, all H.X. tubes and fins are coated with black paint material.

2.2 Experimental measurements

The experiment was conducted in August 2023 from 8:00 to 22:00. During the experiment's operation, waterproof DALLAS 18B20 temperature sensors were used to measure the temperature at the bottom of the absorber basin, the temperature of the saline water, the temperature of the inner glass cover, the temperature of evaporation, and the temperature of atmospheric air. On the other hand, the temperature of the hot water flowing from the PTC to the insulated tank was measured, and the temperature of the water entering the H.X. and the temperature of its exit from it were measured. The specifications of the temperature sensor were shown in **Table 1.**

Table 1. The Specifications of 18B20 DALLAS Temperature Sensor.

Main specifications	The Range
The operating voltage	3.0V to 5.5V
Accuracy	±5°C from -10°C to +85°C.
The operating temperature range	-55°C to +125°C
The selectable resolution	9 to 12 bits.

The freshwater weighing device with accuracy of 0.1 g was used for weighing the amount of fresh water produced from the evaporation process of saline water. This device is also used to weigh the PCM amounts in pouches. Solar power meter is a precision instrument for measuring light intensity. It is used in solar radiation measurement, solar research which contained a several specifications and features shown in **Table 2.**

Table 2. The Specifications of Solar Power Meter

	The specifications
Resolution	0.1W/m², 0.1 Btu/（ft²-h）
Error range	± (10%R+2dgts) R: readings
Measuring range	0.1-1999.9 W/m², 0.1-1999.9 Btu/（ft²-h）
Wavelength range	340nm--1100nm, Incidence Angle normal direction less than ±45-degree， peak wavelength 900nm
Battery needed	9V battery

3. Test procedure

The experimental set up are tested and conducted under the summer climatic condition on the campus of the Higher Technological Institute, 10^{th} of Ramadan city, El-Sharqia, Egypt (Latitude 30.3◦, longitude 31.7◦ and height 112 m). All tests were carried out from 08:00 until 22:00. Four trials were conducted, the constructed single slope SS with PTC was investigated at an angle of inclination 30°.The saline water depth of both solar stills remained constant at 2 cm during all tests. This is based on previous studies, where it was found that reducing the saline water depth increases the productivity of the solar still [17], so it is important to reduce the brine depth but at the same time have enough water depth in the basin to cover the corrugated surfaces. This test's measured values were used as a benchmark to evaluate the effect of PTC in all tests. Finally, the effect of the PTC on thermal performance was evaluated, and the desalination process was monitored accordingly.

4. Results and discussion

The measured temperatures included the basin temperature (T_b), the saline water temperature (T_w), the vapor temperature (T_{ev}), the inner surface temperature of the glass cover (T_g), the ambient temperature (T_a), the PCM temperature (T_p) During each test process, with various masses of PCM (2.5, 3, 3.5, and 4 kg), the operation temperatures, hourly and cumulative freshwater productivity were measured during the test days for the two SSs (CSS and MSS with fixed PTC) from 8:00 to 22:00 during the summer season at 25, 26, 27, and 28 August 2023. Production was weighed on a digital scale, and the measured values were recorded. The present work aims to increase the productivity rate of fresh water due to the increased evaporation rates of saline water over the conventional state by adding extra heat supplied by PTC coupled with the MSS. **Fig.3** illustrated the operating temperatures during test days with solar intensity.

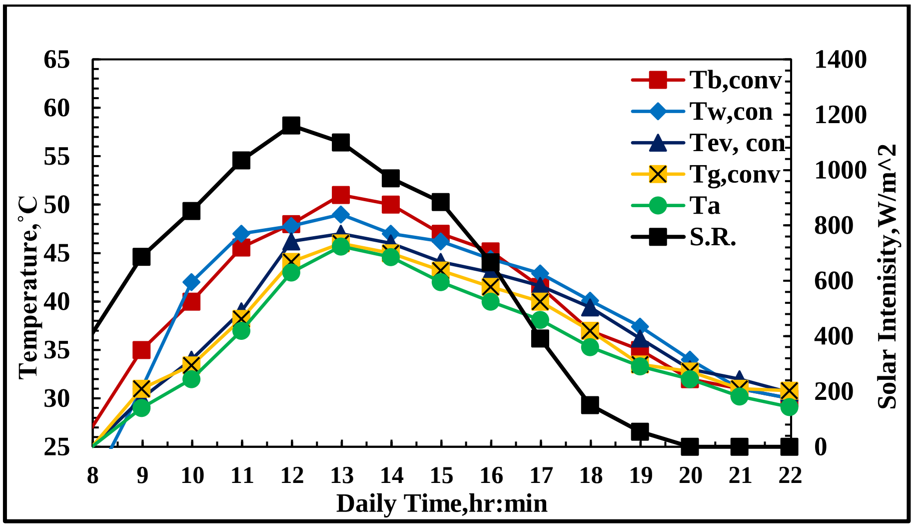

Fig. 3. Temperatures Evaluations with Time for the CSS in Summer Season.

Fig. 3 also shows the average solar radiation and the ambient temperature for the tested days. The variations in solar radiation and ambient temperature displayed a uniform trend throughout the duration of the four successive days of experimentation.The mean solar radiation and ambient temperature averaged 703 W/m^2 and 37.1 °C, respectively, over a 12-hour period of data collection on a test day. The maximum temperatures for the basin, saline water, water vapor, and inner glass surface were 51.2, 49, 47.3, and 46°C, respectively. The maximum temperature difference between the inner glass surface and basin water was 7°C, indicating heat transfer and rapid condensation due to the increasing temperature difference between the inner glass plate and basin water. The current figure indicated that the intensity of solar radiation increases with time from the beginning of the experiment at 8:00 until it reaches a peak at approximately 12:00 by 1161 w/m^2 and then decreases after that until it disappears at the end of the solar day at 22:00. In this context, the operating temperatures of the SSs rise with the increase in the intensity of solar radiation until they reach their maximum value at 13:00 and then decrease after that with a decrease in the intensity of solar radiation until the end of the experiment and become at their minimum rates. It is also noted that there is an hour difference between the peak solar radiation and the maximum value for the various operating temperatures of the solar system, due to the time spent converting the solar energy falling on the SS into thermal energy gained by the system and its effect on the temperatures. Moreover, in all tested cases, the evaporation temperature is lower than the temperature of saline water, which is consistent with the evaporation process. This is due to the penetration of solar rays through the high-permeability glass cover into the black basin, which absorbs solar radiation to a very large extent. By comparing the different operating temperatures of the solar system (T_p, T_b, T_w, and T_{ev}), it was found that the still combined with PTC has higher temperatures than the conventional still, which contains the same amount of PCM placed at the bottom of the basin in the same configuration. it was found that the masses of 3 and 4 kg of PCM are more contrasted than the other masses, so a comparison was made between them to clarify the effect of a SS combined with PCM masses with or without PTC. **Fig. 4** shows the relationship between 3 and 4 kg of PCM masses and their effect on PCM temperatures with and without the heat exchanger.

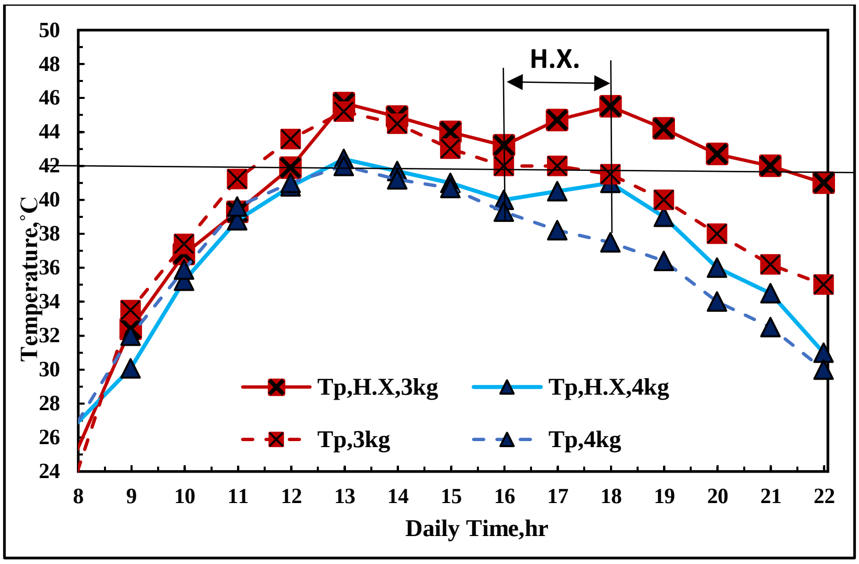

Fig. 4. The Effect of PTC on 3 and 4 kg Masses of the PCM Temperatures.

Fig. 4 shows the positive effect of both SSs coupled with PTC and equipped with PCM masses over conventional stills equipped only with the same PCM masses. When using PCM reached the melting point in all cases (42°C), but in the two cases of the system coupled with PTC. There was a long period during the liquefaction stage, which indicates an increase in the period of time affecting the basin water of the SS due to the thermal energy gained from solar energy in the morning period, in addition to the thermal energy gained from the H.X. through coupling with the PTC water collected in the isolated tank during the time period of From 11:00 to 16:00, this is the period during which solar radiation has a significant impact on the heat transfer fluid flowing in the pipes.

4.1 Solar Still Temperatures

One of the most important factors that helps in interpreting and analyzing the experiment results of the SS is measuring the operating temperatures at different points, which indicates a good performance evaluation of the SS. **Fig. 5a, 5b and 5c** indicate the effect of PTC on 3 and 4 kg masses of PCM on operating temperatures, where **Fig.5a** shows the effect of PTC on the basin temperature, **Fig. 5b** indicates the effect of saline water temperature with PTC, and **Fig. 5c** mentions the effect of PTC on the evaporation. The following figures indicate that operating temperatures increase with increasing intensity of solar radiation until temperatures reach their peak at 13.00 and then decrease again until they decline with the disappearance of solar radiation. **Fig. 5a** shows the variation between the basin temperature of the improved still with 3 and 4 kg masses of PCM coupled with PTC compared to the conventional still. This figure indicates the same trend as the previous figures, where basins temperatures rise to their maximum value at approximately 13:00 according to the solar energy density, where the advanced system with 3 kg of PCM + PTC recorded the highest basin temperature, which is 57^0, compared to other systems (SS with 3 kg, SS with 4 kg +PTC, SS with 4 kg, CSS). While the temperatures of the basins gradually decrease with the disappearance of the sun. On the other hand, water (the heat transfer fluid) previously stored in the insulated tank is used by flowing water into it at the lowest rate that allows the flow to continue according to the pressure differences between the water entering and exiting to/from the PTC. At 16:00, that is, at a radiation intensity of 667 w/m^2, which is the time during which the benefit from solar radiation is at its lowest stage, the tank valve is opened so that hot water with an average temperature of 52^0 flows into the heat exchanger at a flow rate of 75.5 ml/ min. This results in an increase in the temperature of the basin, rising again reach to 53^0 of 3 kg of PCM + PTC, with an increase of 12.8%, 6%, 38%, and 43.2% compared to (SS with 3 kg, SS with 4 kg +PTC, SS with 4 kg, CSS) systems. **Fig. 5b** shows the effect of PTC associated with different systems on the saline water temperature. It was found that the still combined with 3 kg of PCM + PTC has the highest temperatures compared to other systems for the same amount of saline water, due to the heat added by the PTC at the bottom of the basin through the heat exchanger, which enhances the productivity of the system. The results indicate the same trend for the figure of the basin temperature, except that the temperature of the saline water is lower than the temperature of the basin for the same system at the peak of solar radiation (at 13.00) by 3.3 degrees. These differences in temperatures indicate the heat transferred by conduction between the basin and the static saline water. the temperature of the basin must exceed the temperature of the saline water to achieve the theory of heat transfer between them. **Fig. 5b** also shows the percentage increase in temperature of the saline water when allowing hot water to pass through the heat exchanger (heat transfer fluid) at 16:00, where the record of the still combined with (3 kg of PCM + PTC) is 24.6%, 8.7%, 27%, and 31.4% compared with (SS with 3 kg, SS with 4 kg +PTC, SS with 4 kg, PTC) systems. Furthermore, **Fig. 5c** shows the water vapor temperatures for the different cases studied.. The results of the analysis indicate that the evaporation temperatures of the SS combined with 3 kg of PCM + PTC are better than the other studied systems, as the maximum evaporation temperature was recorded at the peak of the solar day at 51.7 degrees, which is lower than the basin temperature at the same point by approximately 10%.

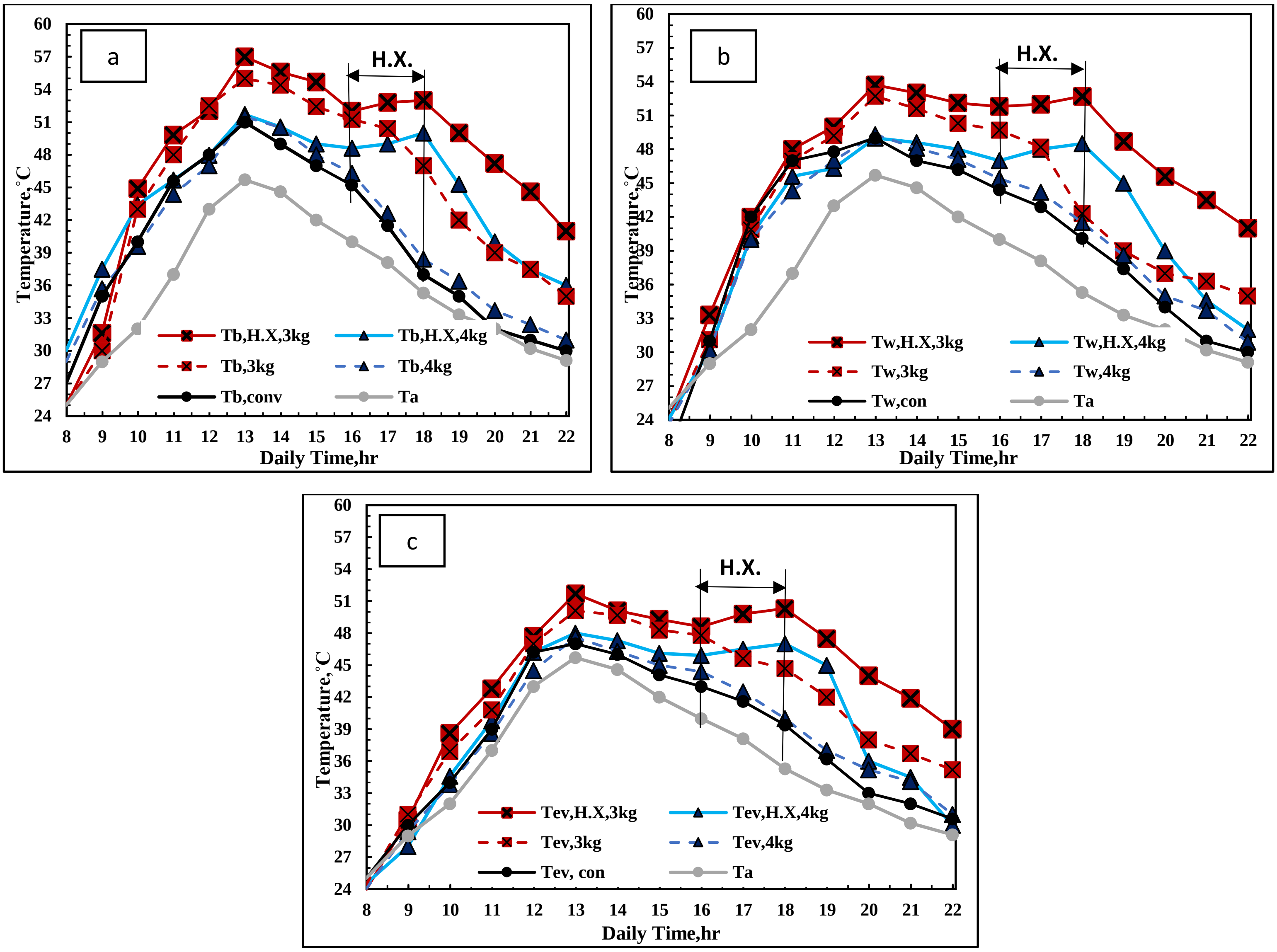

Fig. 5. The Effect of PTC System on HSS system with 3&4 kg PCM According to (a) Basine Temperature,(b) Saline Water Temperature, and (c) Evaporation Temperature.

This leads to enhanced heat transfer through the evaporation process, specially during times of solar decay. On the other hand, the evaporation temperature during the coupling process with hot water through PTC recorded an increase of 5.6 degrees, a 12.5% increase over the improved SS with the same amount of PCM only. It is found that the percentages of increase between the SS system combined with 3 kg of PCM + PTC and the other systems (SS with 4 kg +PTC, SS with 4 kg, CSS) are 7%, 25.75%, and 27.7%, respectively, during the period of thermal energy supply through hot water stored in the insulated tank.

4.2 Fresh Water Productivity

Figs. 6a and 6b show the variation in the production of potable water (fresh water) accumulated during the solar day for the two solar distillation systems improved with 3 and 4 kg of PCM and coupled with PTC compared to the conventional system, respectively. These figures indicate an increase in freshwater productivity with increasing time from 8:00 until the end of the test day. In **Fig. 6a**, it is observed that there is no change between the two systems (coupled with PTC and without PTC) in the productivity of fresh water until 16:00. While the experiment exceeds 16:00, the productivity of the fresh water of the system coupled with PTC increases significantly compared to other systems (without PTC, conventional). Analysis of these results indicates that the productivity of fresh water increases significantly when the SS is coupled to PTC through hot water (heat transfer fluid) previously stored in the insulated tank. The water flows at the lowest flow rate, which is 75.5 ml/min, through the heat exchanger network under the PCM pouches located at the bottom of the still. The freshwater productivity of the hybrid still was recorded at 3 and 4 kg, with an increase of about 10.5% and 69.2% compared to the systems (SS with 3 kg, PTC). This indicates an increase in the amount of heat added to the system coupled to the PTC, as the SS was supplied with hot water (the heat transfer fluid) when it was confirmed that the intensity of solar radiation had decreased at 16:00, meaning that the intensity of solar radiation at this time is unable to complete the evaporation process for static saline water. In addition, the PCM works at this time as an energy-discharging material, as the temperature differences at this time favor the phase-changing material, which allows heat to be transferred from the heat exchanger network to the PCM pouches and then to the saline water through the basin, which leads to an increase in productivity over the other systems studied. On the other hand, the rate of condensation at this time increases with an increase in the temperature differences between the evaporation temperature and the temperature of the inner glass of the still's cover. Hence, productivity increases more than is usual in the case of PCM only.

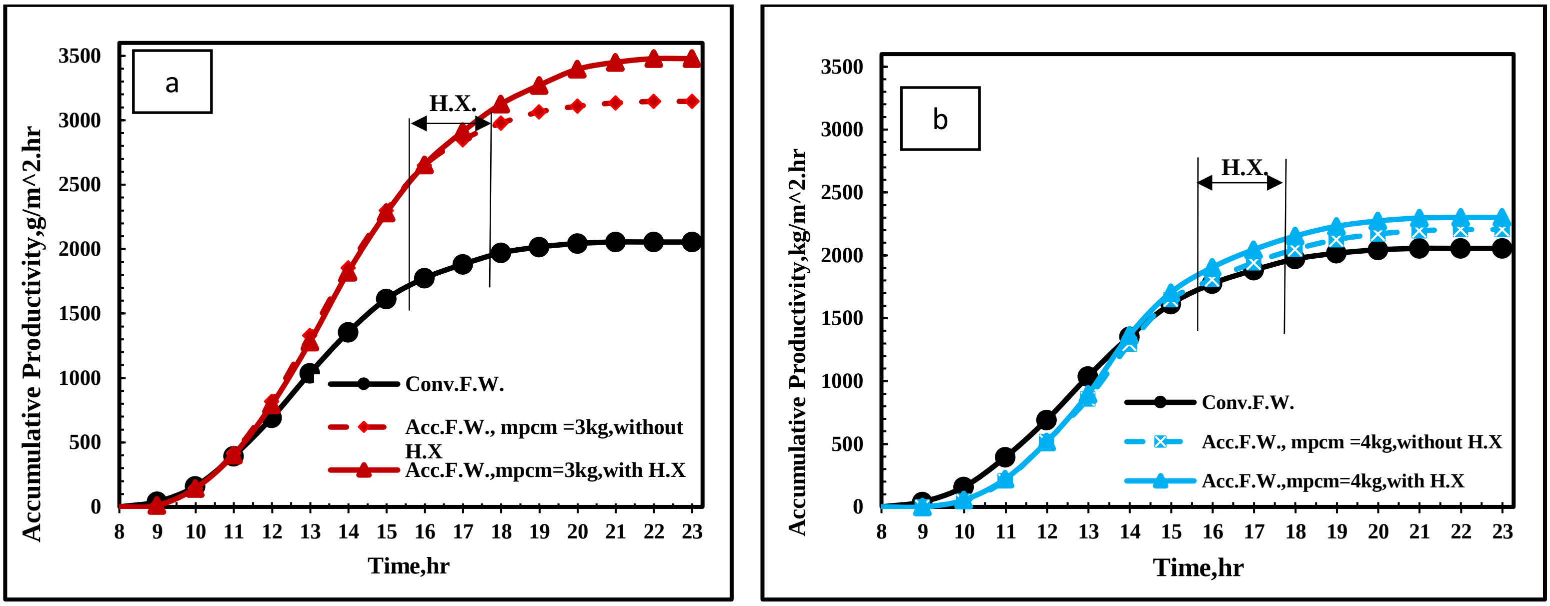

Fig. 6. Accumulative Fresh Water Productivity of HSS.(a) 3kg PCM with/without H.X and (b) 4kg PCM with/without H.X.

Fig. 6b shows the variation between the productivity of the two hybrid systems (4 kg PCM with or without PTC), the results of the analysis show that the figure has the same variation as in **Fig. 6a**, where the advanced system combined with PTC achieved an increase in productivity of about 100 g, which is equivalent to 4.5% compared with the advanced system that is not coupled with PTC. This increase is very slight because the amount of PCM is larger than it should be in order to complete the melting process (partial melting), as shown in **Fig. 4**, where it is noted that the mass of 4 kg of PCM did not reach the melting temperature over the duration of the experiment. Therefore, the PCM is in a state of permanent charge to reach a steady state. On the other hand, the productivity of the hybrid system coupled with the PTC increased by 246 g, i.e., by 12% over the conventional system. While it was noted that the productivity of the hybrid system (3 kg of PCM+PTC) is greater than the hybrid system (4 kg of PCM+PTC) by 51% due to the additional energy through the PTC and PCM during the solar decay period.**Fig. 7** shows the percentages of increase in freshwater productivity between the systems that were studied during the days of the experiment combined with PTC and with different masses of PCM compared with the conventional system. It is noted from the results of the figure that the highest percentage of freshwater productivity for the hybrid system (3 kg PCM + PTC) is 69.2%. As the mass of the PCM increases or decreases, productivity decreases. This indicates that the mass of 3 kg of PCM is the best mass in this case, according to the configuration of the PCM within the experiment.

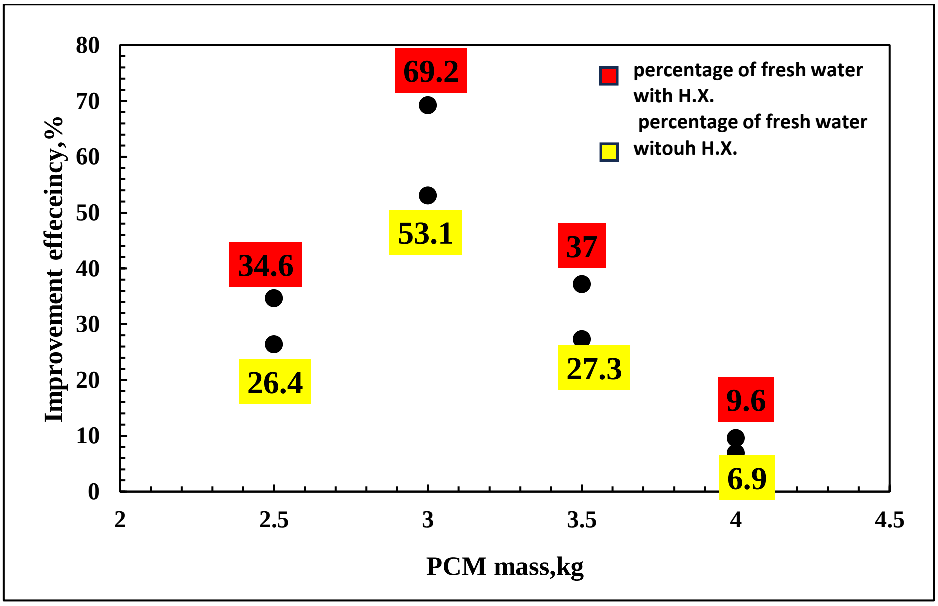

Fig. 7. Efficiency Improvement of HSS System by Using Heat Exchanger

Conclusion

In the current work, HSS systems containing PCM masses with or without PTC were analyzed compared to the conventional system in terms of evaluating the operating temperature performance of the studied systems and freshwater production. The main conclusions can be written as follows:

- The 3 kg and 4 kg PCM masses show a more pronounced difference when compared to the other masses. Hence, a study was carried out to analyze the effects of a SS in combination with PCM masses, with or without PTC.
- The basin temperature of the hybrid still (3 kg PCM+PTC) increased by 12.8%, 6%, 38%, and 43.2 compared to the (SS 3 kg, 4 kg PCM+PTC, SS 4kg, CSS) systems.
- The hybrid still (3 kg PCM+PTC) experienced a rise in saline temperature by 24.6%, 8.7%, 27%, and 31.4% in comparison to the (SS 3 kg, 4 kg PCM+PTC, SS 4kg, CSS) systems.
- The evaporation temperature of the hybrid still (3 kg PCM+PTC) increased by 12.5%, 7%, 25.75%, and 27.7% compared to (SS 3 kg, 4 kg PCM+PTC, SS 4kg CSS systems.
- The overall daily cumulative productivity of the hybrid system (MSS with 3kg PCM+PTC) saw a 69.2% increase, while the MSS with 4kg PCM+PTC system experienced a 10.5% rise compared to CSS.

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