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ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ УЛУЧШЕНИЯ ПРОЦЕССА ИСПАРЕНИЯ И КОНДЕНСАЦИИ ВНУТРИ СОЛНЕЧНОГО ДИСТИЛЛЯТОРА

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Аннотация. В данной работе было проведено экспериментальное исследование, чтобы показать эффект улучшения процессов испарения и конденсации внутри модифицированного одиночного солнечного дистиллятора с помощью комбинированных ультразвуковых увлажнителей в воде бассейна, внутри палатки из хлопковой сетки, в дополнение к установленному в верхней части солнечному дистиллятору — холодильная камера с термоэлектрическими элементами. Результаты показали, что производительность модифицированного солнечного дистиллятора увеличилась на 124 % по сравнению с традиционным солнечным дистиллятором

Ключевые слова: процесс испарения и конденсации, ультразвуковая хлопковая палатка

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Original article

EXPERIMENTAL INVESTIGATION OF ENHANCEMENT OF EVAPORATION AND CONDENSATION PROCESS INSIDE SOLAR STILL

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Abstract. In the current work, an experimental investigation study was conducted to show the effect of enhancing the evaporation and condensation processes inside a modified single solar still by combined ultrasonic humidifiers in the basin water inside a cotton mesh tent, in addition installing at the top of the solar still a cooling chamber with thermoelectric elements. The results showed that the productivity of the modified solar still increased by 124 % than the traditional solar still.

Keywords: evaporation and condensation process, ultrasound cotton tent

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Introduction. Researchers have used various techniques to solve the problem of drinking water shortage, such as reverse osmosis, vapor pressure, and electrolysis. The most recently applied methods are considered the most economical and don't have side effects on the environment [1]. Renewable energies are one of the easiest and most cost-effective sources of drinking water production, and among these most abundant energies is solar energy, which is a free, renewable, and clean source used in many thermal applications such as water heating, heating, and cooling, and drying applications. Solar distillation systems for saline and untreated water are considered an essential solution to reduce energy consumption [2]. However, the main disadvantage of solar water still is low productivity. Therefore,

researchers tried to use different methods and designs to increase the productivity and thermal efficiency of solar water stills [3]. The current work is an extension of the previous studies as a pioneering attempt to enhance the evaporation and condensation processes inside the single slope solar still in Ekaterinburg, Russia, and thus improve its performance by using ultrasonic humidifiers in the basin water inside a cotton mesh cloth (wick), and by installing a cooling chamber with thermoelectric coolers.

Experimental part. Figure 1 shows a schematic diagram of the experimental station. The traditional and modified solar distillers were manufactured of 1.8-cm MDF wooden. Both distillers have the same dimensions (103.6-cm in length, 53.6-cm in width, big side 61.8 cm, and small side 26.6 cm). The dimension of the black galvanizes water basin (100-cm length, 50-cm width, 10-cm depth, and 0.1-cm thickness). The solar distillers under study are covered with inclined Plexiglass 35 degrees with dimensions of (103.6-cm length, 53.6-cm length width, 50-cm big side, small side 14.8 cm, and thickness of 0.3 cm). Aluminum channels have been used to instill the plexiglass cover on the solar still body. After the water vapor condenses on the inner surface of the plexiglass cover and the aluminum plate of the cooling chamber, the distilled water flows through the collection aluminum channels to the graduated vessel below the solar still. Silicone glue was used to fix all the parts. For the modified solar distiller, three ultrasonic humidifiers were immersed in basin water, inside a polycarbonate shell, and covered with a black cotton mesh, to improve the rate of basin water evaporation. A cooling chamber was installed at the top of the solar still made of a 0.1 cm thick aluminum plate, and four thermoelectric cooling elements (Peltier elements) were installed on it to improve the condensation process.

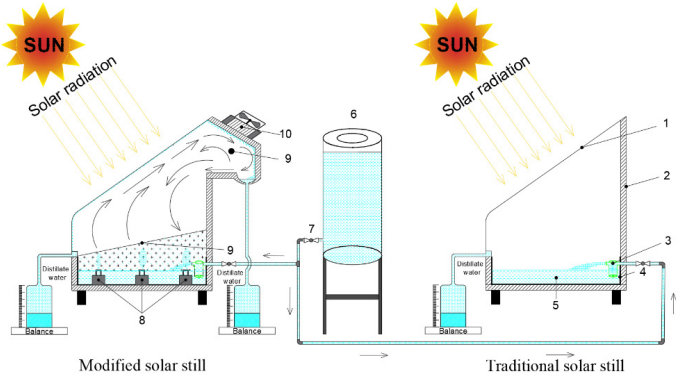

Figure 1. Schematic diagram of the modified solar still and the traditional solar still

The discussion of the results. Figure 2 shows the hourly temperature differences of the basin liner (T_{bp}), basin water (T_{bw}), plexiglass cover (T_g), the mesh cloth (T_{cloth}), and the inner surface of the cooling chamber (T_{cooler}) of the modified and traditional solar stills for a typical sunny day 29.07.2021.

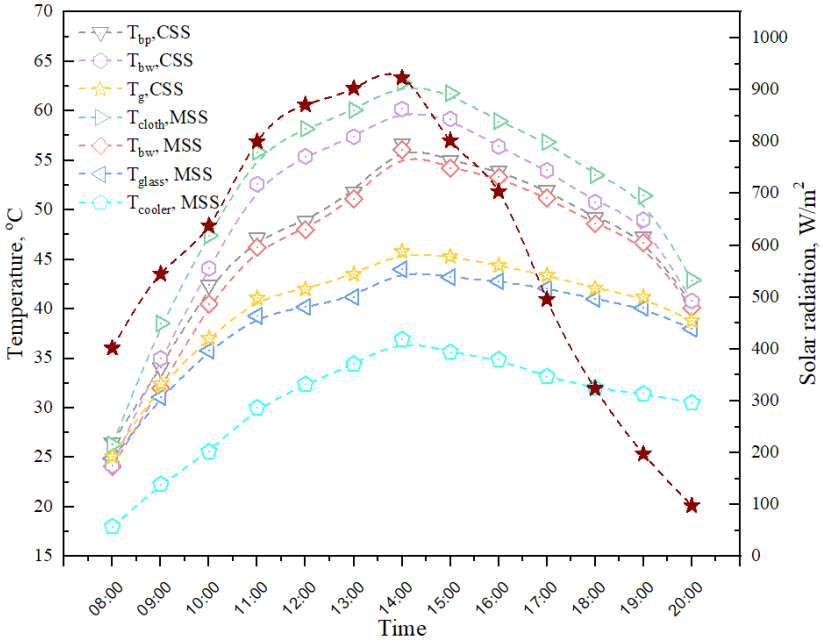

Figure 2. Hourly change of temperatures of different points of modified and traditional solar stills for a typical day 29.07.2021

From this figure, noted that the temperature of the Plexiglas cover and the basin water of the traditional solar still in the early hours was close. Over time, the difference between the temperatures of the basin water and the plexiglass cover increases, due to the heat capacity of the water is higher than that of the plexiglass, and the highest basin water temperature was at 2:00 pm at the highest value of solar radiation intensity. For the modified solar still, the temperature of mesh cloth (wick) that is moistened by a water film (aerosol) of flowing water from the ultrasonic humidifiers was recorded, which was always higher than that of the basin water of the traditional solar still, due to the thinness of the water layer of the wick, which needs little time to raise its temperature compared to the thickness of basin water (5 cm) in the traditional solar still. Also, from this figure, found that the temperature of the inner surface of the cooling chamber was lower than that of the plexiglass in the modified and tradition-

al solar stills, due to the effective effect of the thermoelectric elements to decrease the temperature condensed surface of the cooling chamber. From figure 3, it is clear that the cumulative production of distillate water from 08:00 am to 8:00 pm, for the modified solar distiller, was more than the traditional solar distiller by about 124% (4.7 lit/m^2.day, and 2.095 lit/m^2.day from modified and traditional solar stills, respectively), due to the high condensation rate (effect of ultrasonic humidifiers inside the wick tent), and the high ability of the cooling chamber to condense more water vapor on its inner walls.

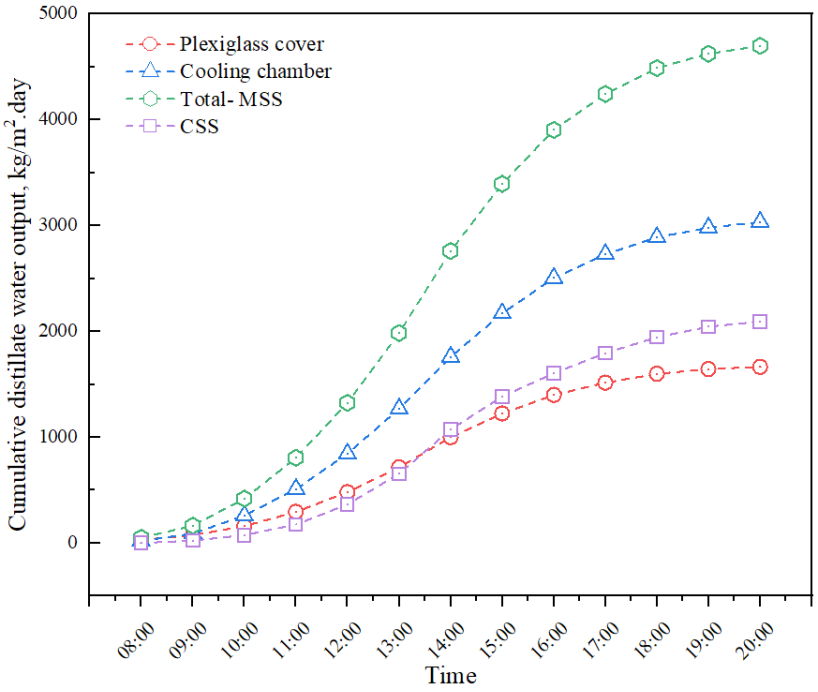

Figure 3. Cumulative daily distillate water of modified and traditional solar stills for a typical day 29.07.2021

Conclusion. The productivity of distilled water in the cooling chamber is enhanced by installing thermoelectric Peltier cooling elements on its walls, thus increasing the condensation of water vapor in the channel of the cooling chamber, and by added ultrasonic humidifiers in the basin water inside the cotton mesh tent. The thermal efficiency of the modified solar still was always higher than of the traditional solar still during 12 hr, due to the increase in productivity because of improvement of the evaporation and condensation processes. The results of the economic analysis showed that the proposed

modification in the current study showed good agreement in terms of the cost of producing distilled water with previous studies under the same environmental conditions of Ekaterinburg, Russia.

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