Thermal Science and Engineering Progress 3 (2017) 24–30

Contents lists available at ScienceDirect

Thermal Science and Engineering Progress

journal homepage: www.elsevier.com/locate/tsep

Efficiency analysis of tank-type water distillation system integrated with hot water collector

Emin El [a], Gülşah Çakmak [b,*], Cengiz Yıldız [b]

[a] Vocational School of Technical Sciences, Bitlis Eren University, 13000 Bitlis, Turkey
[b] Department of Mechanical Engineering, Firat University, 23119 Elazig, Turkey

ARTICLE INFO

Article history:
Received 20 January 2017
Received in revised form 16 March 2017
Accepted 31 May 2017

Keywords:
Solar still
Energy efficiency
Drinking water
Tank type distiller

ABSTRACT

In this study, besides the hot water, it was also aimed to obtain distilled water from solar still water heating systems, which are widely used in obtaining hot water. For this purpose, a new type of distiller was obtained by making modifications, which enable us to obtain distilled water, on a solar still water heating system having flat-surface panel collector and vertical tank and operating as a closed system. The designed system was tested under both natural convection and forced convection at flow rates of 30 kg/h and 50 kg/h. As a result of performed experiments, the temperature, productivity, and distilled water production amounts were calculated for the designed system. It was determined that the temperature of hot water obtained was sufficient for daily use. According to the results, as the highest amount of water, 1.820 kg/day distilled water was obtained form also the natural convection system. In order to determine the drinkability of distilled water, the laboratory analyses were carried out, and it was found that the water meets EC standards. Thus, the clean and hot water was obtained at the same time from the designed system under real weather conditions.

1. Introduction

Population growth, industrialization and active agricultural activities lead to the depletion of limited underground and surface water resources of the world, and increase the environmental problems. The shortage of potable water is an important problem, and the actual underground water stock is brackish in general and cannot be used as potable water as is. Gradual depletion of energy and water resources of the world and non-usefulness of the existing resources bring the energy and water procurement into the forefront.

Renewable energy is the type of energy coming into the forefront with its characteristics such as, when appropriate technologies are used, having no pollutant effect and being local and environment-friendly. Even though the energy has an important role in development of human being, it is only a part of the whole. But, the water is a vital necessity that has to be met always. Water, which is our most vital requirement, has vital importance in terms of all our social activities.

For purifying the dirty water, many methods are used, but all of those methods require a significant amount of energy. The energy resources to be used in purification process such as oil, natural gas, and electricity have both high costs and lead to environmental pollution. The studies carried out in recent years aimed to increase the use of renewable energy resources as energy source.

Mamlook et al. [1] compared the performances of various solar energy implementations. They carried out a study, where they utilized fuzzy logic on solar water distillation, solar water heating, photovoltaic and solar electricity production methods. Those methods were compared from the aspects of efficiency and costs. They determined that the solar water distillation was the best method in terms of the costs.

Voropoulos et al. [2] experimentally examined the solar water distiller integrated with a storage tank under realistic conditions by keeping the water temperature stable at different water levels. The distillation system consisted of an asymmetrical pool-type distiller and the storage tanks under the distiller. The amount of water obtained from hot-water storage tank in 24-h was reported to be higher than that obtained from classical pool-type distillation system.

Al-Hayek and Badran [3] experimentally examined 2 different solar water distillation systems, and investigated the parameters affecting the production via water distillation. One of the systems they used was asymmetrical greenhouse-type distillation system with mirrors in inner walls, while another system was symmetrical greenhouse-type distillation system. As a result of their

* Corresponding author.
E-mail address: gulcak@gmail.com (G. Çakmak).

http://dx.doi.org/10.1016/j.tsep.2017.05.012
2451-9049/© 2017 Published by Elsevier Ltd.

experimental research, they reported that 20% more water was obtained from asymmetrical greenhouse-type water distillation system in proportion to symmetrical system. At the end of their study, they showed that the radiation was effective on the temperature at the surface of water in both of systems, and that the amount of water obtained from distillation system increased as the water depth decreased.

Ben-Amara et al. [4] designed a new-type solar collector for distilling process. They examined the parameters such as solar radiation, wind speed, temperature of the medium, mass flow, air intake moisture and temperature that are effective on collector efficiency. As a result, they optimized the collector for the new solar water distillation system.

Dayem [5] examined the numerical and experimental performance of classical solar water distilling systems based on very efficient condensation and vaporization cycle. Distillation room consisted of moistener and dehumidifier units. The air circulation in those 2 sections was provided via natural convection. The cold water was pre-heated inside, and then exposed to temperature change within the solar collector. It was determined that water can be produced 241 days a year in this system.

Tripathi and Tiwari [6] carried out experiments at different depths for active and passive solar pools. In active distillation process, in order to increase the temperature difference between glass and water surface, they pumped the hot water to the bottom of pool. In passive system, no pump was utilized. For those systems utilized, they made comparisons at various depths and modes in parameters such as water, inner glass, outer glass, vaporization, temperature, radiation, and amount of the water obtained.

Zamen et al. [7] optimized the solar energy system for desalinating the water. The aim of this optimization was to decrease the cost of obtaining clean water. The results obtained according to the solutions obtained from cost objective function were reported to be lower than those obtained from other objective functions.

Esfahani et al. [8] attempted to produce a portable solar water distiller. By comparing the summer and winter results, they determined that the efficiency in summer was higher than winter efficiency.

Tsilingiris [9] developed a new theoretical model for estimating the mass transportation in solar water distillation systems. The model he used was based on the Chilton-Colburn simulation that can be applied for wide range of Prandtl and Schmidt pure numbers. In order to perform comparative verification, he utilized a series of experimental results, which were obtained from passive solar water distillation system under summer conditions at higher process temperatures, for examining the higher process temperature conditions.

Ahsan et al. [10] made a comparison by designing two Tubular Solar Still (TSS) obtained using a vinyl chloride layer and a polyethylene film cover as a transparent tube cover. According to the results obtained, the hourly evaporation, condensation and production flows are explained by the proportions of moist air temperature and relative humidity fraction. In order to estimate the hourly production flow at the end of their work, they proposed an empirical equation based on this relationship.

Al-Sulttani et al. [11] designed, produced and tested a new double-slope solar still hybrid with rubber scrapers (DSSSHS) and a double-slope solar still (DSSS). The proposed DSSSHS design utilizes the advantages of using a small slope of the backing cover, which allows for higher solar radiation to penetrate. The maximum recorded value of the total internal heat transfer coefficient for the DSSSHS was found to be 38.754 W/m^2 °C and the daily yield to be 4.24 L/m^2 day with productivity improvement of 63%.

Feilizadeh et al. [12] investigated separately, the effects of water depth and the water surface-cover distance (WCD) and examined effects of water depth on the performance of solar stills with the same WCD. It was found that WCD can affect the amount of distillate yield up to 26%. In addition, the solar stills with various water depths were mathematically modelled and the rates of their productivity were predicted. The theoretical results were compared with the current experimental data and it was found that there is a good agreement between the present theoretical predictions and experimental observations.

Rahbar and Esfahani [13] obtained the optimum geometric condition for increasing the productivity in a single-slope solar still by using theoretical and numerical methods. Their results indicate that for a fixed length of a solar still, the productivity increases with decrease in the specific height. In addition, they observed identical trends for both water productivity and convective heat transfer coefficient.

In this study, besides the hot water, it was also aimed to obtain distilled water from solar still water heating systems, which are widely used in obtaining hot water. For this purpose, a new type of distiller was obtained by making modifications, which enabled us to obtain distilled water, on a solar water heating system having flat-surface panel collector and vertical tank and operating as a closed system. The designed system was tested under both natural convection and forced convection at flow rates of 30 kg/h and 50 kg/h, and the results were presented.

2. Materials and method

2.1. Experimental set-up

In this study, a tank-type solar water distillation system integrated with hot water collector was designed and manufactured. The designed experimental setting was assembled at terrace of Heat Engineering Lab of Machinery Engineering Department of Engineering Faculty of Fırat University in the way preventing the shadowing. The experiments were carried out between July and October months under climate conditions of Elazığ. This system was designed as natural convection and forced convection, and then tested.

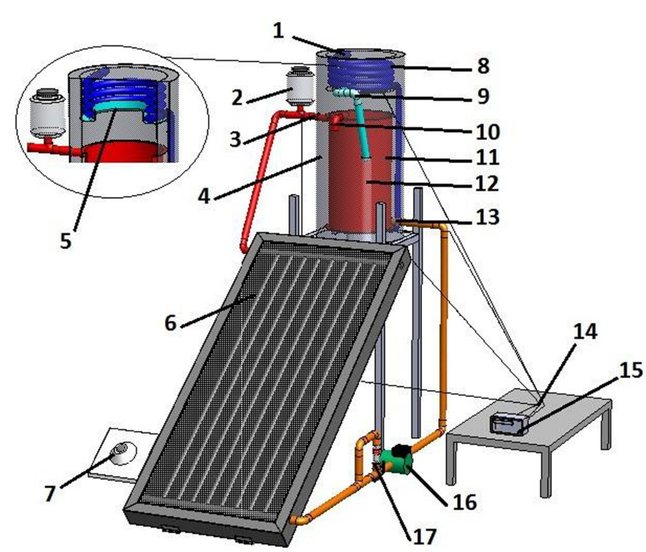

Fig. 1. Tank-type water distiller integrated with hot water collector. 1. City water inlet, 2. Hot liquid glass jar, 3. Hot liquid inlet, 4. Insulation, 5. Distilled water collection channel, 6. Collector, 7. Pyranometer, 8. Top serpentine (Cold), 9. Distilled water outlet, 10. Hot water outlet, 11. Bottom serpentine (Hot), 12. Measure, 13. Hot liquid outlet, 14. Thermocouple, 15. Digital thermometer, 16. Circulation, 17. Rotameter.