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Experimental Study and Economic Evaluation of a Cascade Solar Water Desalination Unit in Various Conditions

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ABSTRACT: Lack of freshwater as a major crisis in the world and an attempt to find a solution is one of the most important debates in the world that has attracted many researchers. In this paper, a cascade solar desalination unit with external reflector has built and experimented in eight days. In order to increase the production of fresh water, various techniques were applied such as 1) installing a number of fins on the stairs and on the waterway to create hot spots, 2) use of internal reflectors at the base of the stairs and 3) use of an external condenser for increasing condensation rate of produced vapor. Then, the system was experimented in eight configuration using combination of above techniques that the experimental results were presented as well as the results of economic analysis. The results showed use of the fins led to the most amount of fresh water although the rest of techniques significantly increased the product. It is worth mentioning that use of the fins led to fresh water with the lowest cost of product in value of 1341.5 Rials/lit. On the other hand, the system with an external condenser had the maximum efficiency and the system with the fins has the third place among the eight study configuration.

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1- Introduction

Water is one of the most abundant resources on earth, covering about 75% of the earth's surface. However, the shortage of drinking water in many countries is a crisis. In order to deal with fresh water leakage, the best and most economical way should be chosen for desalting water. Solar energy is one of the important sources of energy which can be used to desalinate sea water and brackish water due to low cost and simple technologies. Up to the present time several research have been conducted on fresh water and increase the product [1-5].

In this study, a model of a cascade solar water desalination unit has been designed and built. In this system, some weirs are embedded in front of any stairs of desalination in order to force the flowing water to go through the absorber plate to increase the production of fresh water, Moreover, the residence time of water flow is increased in the system. In addition, some metallic fins are inserted to the stairs to create hot spots on the stairs and consequently increase the evaporation rate. Other techniques such as the use of the internal reflectors in the base of the stairs for reflecting the Sun's rays to the floor stairs and increasing water temperature as well as the use of external condenser to rise rate of vapor condensation have been also studied. Finally, the combination of these techniques has been tested binary and ternary and economical results have been presented.

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2- Experimental Setup

Fig. 1 shows a schematic diagram of the experimental setup. According to this figure, the flow of saline water from the saline water tank enters to the first stair of the desalination and, due to the weirs embedded in front of each stair, the water tracks the spiral path along the desalination stairs. A portion of the vapor formed is condense on the internal wall of glass cover of the desalination and fresh water droplets are collected at the bottom of the glass cover. The other part of the vapor formed into the external condenser and distilled there and transmitted from the condensing floor into a fresh water container. The increase in evaporation rate is one of the important issues in the operation of evaporation desalination, which can be done by increasing the temperature of the interior space and the water pond. In order to achieve this goal, in the different parts of the stairs, number of galvanized fins and internal reflectors were embedded in stainless steel at the base of the stairs to create hot spots on the stairs and rise the floor temperature of the stairs, resulting evaporation will increase. The external reflector is also used to reflect the rays of the sun to the floor of the stairs. In order to comprehensive assessment, the cascade desalination system, seven different configuration along with the basic configuration were investigated in different days. Various configuration have been tested are:

1.Basic desalination
2.The desalination plant with a number of fins on the stairs of desalination
3.The desalination plant with internal reflectors
4.The desalination plant with fins and internal reflectors
5.The desalination plant with external condenser
6.The desalination plant with external condenser and fins

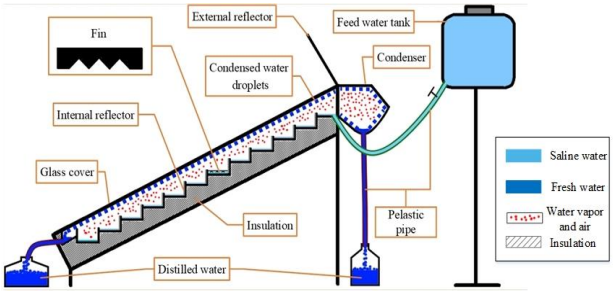

Fig. 1. Total schematic of cascade solar water desalination with fin, condenser, internal and external reflector

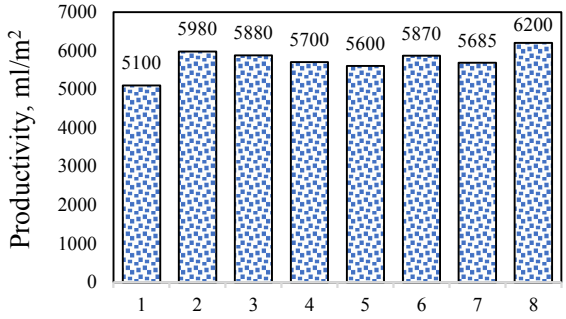

Fig. 2. Comparison of the fresh water produced in each experiment with basic desalination

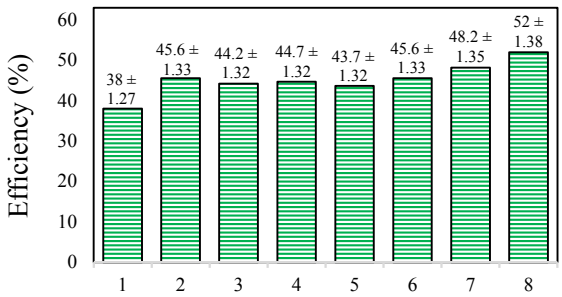

Fig. 3. Daily efficiency of desalination in any configuration with uncertainty

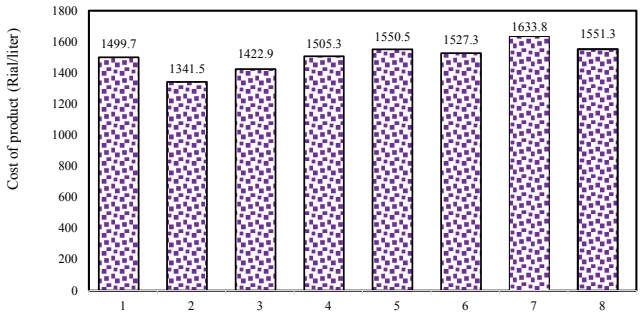

Fig. 4. The cost of fresh water produced (Rials / lit)

7.The desalination plant with external condenser and internal reflectors

8.The desalination plant with external condenser, fins and internal reflectors in desalination

All experiments are carried out in Qaen with a latitude of 32-33 degrees in Southern Khorasan and the angle of inclination of the desalination relative to the horizon was equal to the latitude of the region. Experiments have been conducted 24-hour in 8 consecutive days from 16/8/2015 to 24/8/2015.

3- Results and Discussion

Fig. 2 shows the amount of fresh water produced for different configuration. In this figure, the numbers on the horizontal axis represent the test configuration for example the number 1 corresponding to the Basic desalination. The highest amount of product is related to configuration 8 and the lowest amount of the product in the basic desalination.

Fig. 3 shows the efficiency of desalination for different configuration. As seen the use of external condenser (configuration 8) leads to gain efficiency of $52 \pm 1.38\%$, which can be related to an increase in the production of the fresh water comparing with other configurations.

Fig. 4 shows the results of economic evaluation for different configuration. The cost of fresh water produced with the fins (configuration 2) is the lowest and with the external condenser and the internal reflectors (configuration 7) has the highest value. Configuration 2, in term of initial investment cost, has the lowest value after the basic desalination and has the second highest grade of freshwater production among different configurations, which has led to the lowest cost of fresh water.

It is worth mentioning that the amount of fresh water produced and the average daily amount of radiation are effective in the efficiency of desalination, it is observed that configurations 7 and 8 have the highest fresh water cost, however according to Fig. 3, have the highest efficiency among different configuration.

4- Conclusions

In this paper, an experimental study and economic analysis a cascade solar desalination was investigated. The object of the present work was applying some techniques for increasing the production of fresh water. Some of the most important results are given below.

- The use of fins on the stairs increased 17.25% the product and reduced the cost of fresh water production by rate of 10.5% compared to the basic desalination.
- The combination of condensers, fins and reflectors increased 21.57% fresh water production and 3.44% cost of fresh water compared to the basic desalination and also gave the highest efficiency.

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