Solar Operated HDH Water Desalination System

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***Abstract*—This paper experimentally analyses the performance characteristics of a solar operated humidification and dehumidification (HDH) desalination unit. The main objective of the present work was to identify the most important parameter influencing the production of pure water. The analysis performed resulted in the correlation of different process parameters. It was found that the performance of the system primarily depends on the inlet saline water temperature. Also the mass flow rate of air, solar irradiance and ambient temperature were found to be having significant effects in deciding the output. The prototype made was capable of producing 700 ml per hour. The efficiency of the HDH desalination unit can be enhanced by using heat recovery system. This technology could be of great utility in arid conditions and isolated regions, similar to certain areas of the sultanate of Oman.**

Keywords—Desalination, Humidification, Dehumidification, heat exchanger, Solar heater

I. INTRODUCTION

The rapid growth of world population is posing tremendous scarcity on potable water resources on earth. Many parts of the world is facing severe drought and the need of exploring innovative methods of converting ocean water to drinkable water has increased. The desalination technologies currently employed are energy intensive and expensive. In this scenario, a promising technology which requires comparatively lesser energy has caught the attention of researchers around the world. This technique is called humidification and dehumidification (HDH) using solar energy, which has been found to be promising in countries such as Oman, where plenty of solar energy is available throughout the year.

II. PRINCIPLE OF OPERATION OF HDH DESALINATION SYSTEM

The humidification and dehumidification (HDH) desalination system operates based on the principle of vaporization and condensation of water. The sea water is a mixture of a number of chemicals. It is very difficult to separate pure water from this mixture. In HDH system the affinity of hot and dry air for water is utilized. Saline water is sprayed in to a stream of hot and dry air using a sprinkler. The water particles present in the saline water are absorbed by the air like a sponge. The air is made saturated by spraying water continuously and subsequently the pure water present in air is separated by dehumidifying it in the dehumidifier. The dehumidification involves cooling air below its dew point temperature and expelling water from air by condensing it.

III. LITERATURE SURVEY

Several researchers are currently involved in developing HDH desalination units and to make it a cost effective technology. E. Hassan et al [1] investigated the performance of a HDH unit comprising the following components; air heater, humidifier, dehumidifier, blower and for the entire energy requirement a photovoltaic solar energy unit and a solar thermal unit for providing hot saline water. This paper experimentally investigated the effects of various parameters like ambient conditions, unit design, and solar intensity on the productivity of the desalination system. This also consisted of the solar irradiance and wind velocity. The proposed design variables comprised of the solar air heater and an HDH system. Functional parameters consisted of flow rate of air and the temperature of saline water. The result showed that the productivity of the system is enhanced by optimizing the solar intensity, ambient temperature and wind velocity.

A review of research and developments in HDH desalination system by M. Adel et al [2] explicitly demonstrated the performance of a solar operated HDH desalination system of enhanced efficiency, based on the repeated evaporation - condensation cycles. This unit comprised of flat-plate collector, humidifier, and dehumidifier, where the air flow was by natural convection. The results pointed that very high inlet temperature has an adverse effect on the performance. There was no significant difference between the outlet temperatures of the heat exchanger and the collector.

In an attempt to develop a cost effective Solar HDH desalination system, Shaobo H, et al [3], worked on system by using pinch technology. The study aimed at determining the performance optimization of the HDH method by using pinch technology. The system developed for their study consisted of flat plate solar collector, humidifier and a dehumidifier column. The thermal energy recovery rate intensified while the temperature differences at a pinch point diminished.

A recent study by C. Yamal, and I. Solmus [4] proved to be of momentous contribution, where the HDH desalination unit was made up of of double- pass flat plate solar air heater with two glass covers, humidifying column, and condensation compartment and water tank. This system utilized recirculated water and open air cycle. The unit productivity was found to be influenced by is increasing the rate of inlet water flow and air flow rate in the humidifier.

Orfi.N,et al [5],analyzed a HDH desalination unit which also consisted of two solar collectors; for heating the air and water, humidifier and dehumidifier columns. This experiment was aimed at deriving a function for maximum production of potable water by taking into consideration the ratio of air flow rate and the saline water flow. The theoretical results reiterated the existence of a definite ratio of optimum air flow rate to an equivalent maximum potable water production.

IV. EXPERIMENTAL SETUP & PROCEDURE

A small experimental setup for the solar operated humidifying and dehumidifying (HDH) desalination system prototype was constructed (see figures 1 & 2).

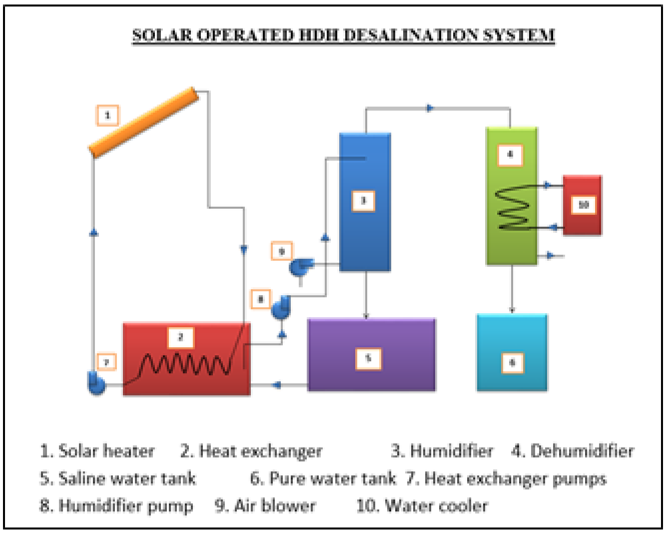

Figure 1: schematic of HDH desalination system

The main parts of the desalination system are solar water heater, heat exchanger, humidifier, dehumidifier, saline water tank, pure water tank, air blower and water cooler. The solar water heater is of flat plate type and is capable of heating saline water to around 60ºC. Pre-heating of saline water before humidification will have a positive effect on desalination process. The heat exchanger is a device where the saline water absorbs heat carried by the fluid from solar heater. The heat exchanger is made of copper pipe for maximum heat gain by the saline water. Humidifier is the most vital part of the desalination system. The performance of the system depends on the design of humidifier. The humidifier is fitted with a sprayer to spray saline water. Humidifier is packed with acrylic tiles to provide additional surface area, which will enhance humidification process. The blower passes air to the humidifier and the water vapor is absorbed by the air and becomes saturated. The dehumidifier is a device where pure water is separated from air. It is packed with a cooling coil which cools air to dew point temperature. The water vapor gets condenser to pure water, which is collected in the pure water tank.

The experiments on the HDH desalination system were carried out at the workshop of the Mechanical engineering department of Al Musanna college of Technology from 16th May to 19th May, 2016 from 9 AM to 6 PM. In order to optimize the power production from solar energy the solar collectors and solar photo-voltaic panels were set at 35º with ground level.

Figure 2: Experimental setup

V. RESULTS AND DISCUSSION

The experiments were conducted from 9 AM to 6 PM and the solar irradiance, ambient temperature, ambient relative humidity, inlet and outlet air and water temperature of the humidifier, inlet and outlet relative humidity of the humidifier and the production rate of pure water were measured for the air flow rates of 0.02 kg/s, 0.03 kg/s and 0.04 kg/s.

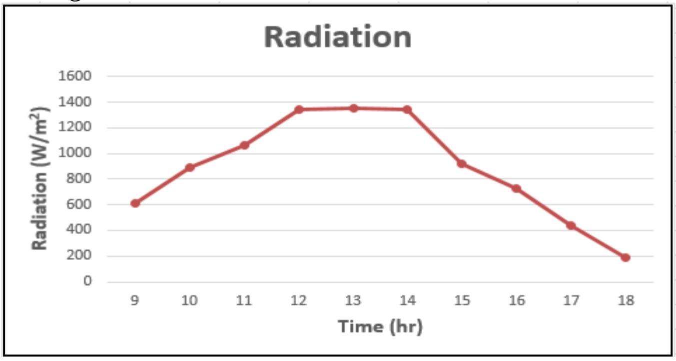

Figure 3: Variation of solar intensity with time at Al Musanna, Oman in May 2016

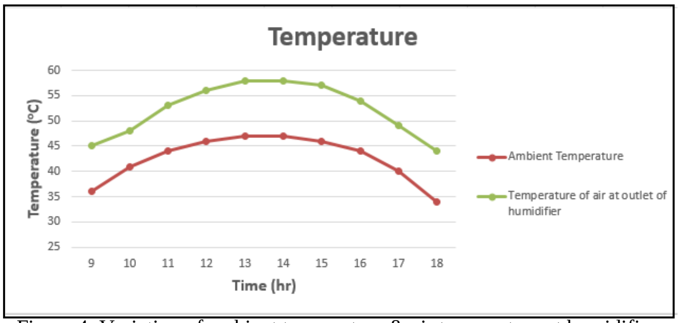

Figure 4: Variation of ambient temperature & air temperature at humidifier exit

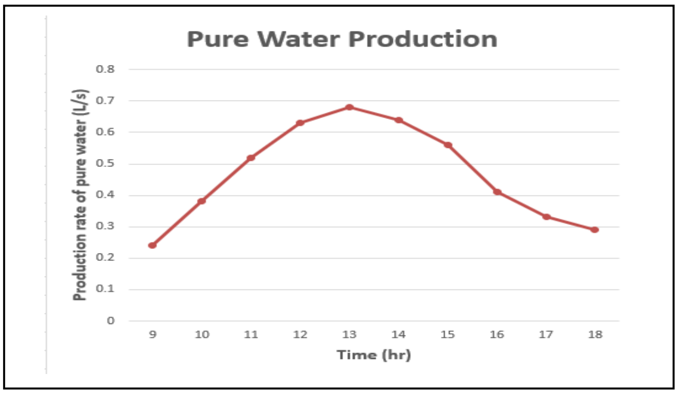

Figure 5: Variation of pure water production rate with time

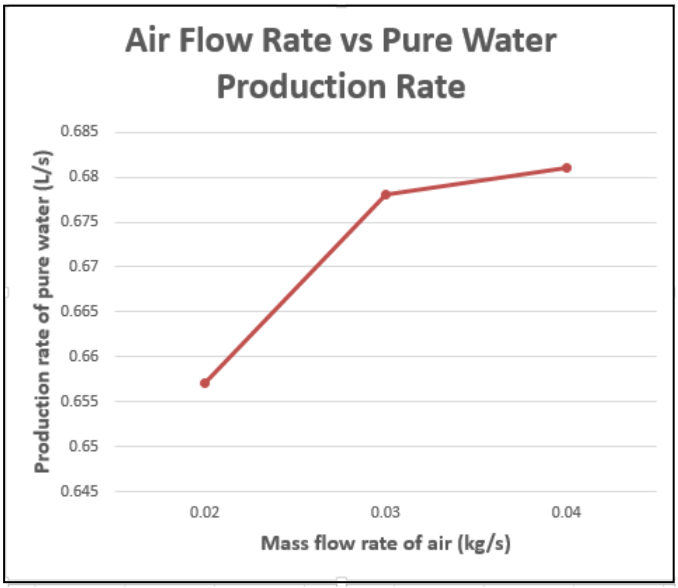

Figure 6: Variation of pure water production with air flow rate

Figure 3 shows the variation of solar radiation intensity with time. It steadily increases and reaches maximum at around 1 pm and then decreases. The ambient temperature is a function of solar radiation intensity (see figure 4). From figure 5 it is evident that the production of pure water depends on ambient temperature, which in turn depends on solar radiation intensity.

It is obvious from figure 6 that the air flow rate has a significant effect on pure water production to a certain level. Further increase in air flow rate does not increase the amount of pure water production considerably.

VI. CONCLUSION

The present work on desalination using humidification & Dehumidification principle was carried out at Al Musanna College of Technology, Oman in May 2016. The saline water temperature at the inlet of humidifier was found to be the most important parameter influencing the pure water production rate, which in turn depends on intensity of solar radiation. The air flow rate also influences the pure water generation to some extent.

The results obtained from the present work are in line with those given in standard literature. The findings of the present work are promising to countries like Oman, which depends on sea water for their potable water requirements.

VII. REFERENCES

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