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NO LOAD TESTING OF SINGLE SLOPE SOLAR DISTILLATION-CUM-DRYING UNIT: AN EXPERIMENTAL STUDY

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Abstract

A new design of solar distillation-cum drying system has been developed to solve the fresh water shortage and drying of various food and agricultural commodities in an eco-friendly way. The developed unit has been tested under no load conditions at Guru Jambheshwar University of Science and Technology Hisar (India). A drying unit is attached to the bottom of the distillation system that receives energy transmitted through the bottom of the basin of distillation unit along with the concentrated solar radiation from parabolic reflector. Rise in temperature plays significant role in the removal of water in the form of vapors from the impure water column stored in the basin of distillation unit and from the commodity placed in the drying unit. In this manuscript, temperatures attained at various locations of distillation-cum-drying unit and difference in temperatures between the condensing cover and basin surface have been presented. An average temperature of 81.2 oC and 60.78 oC has been observed in the distillation and drying units respectively. Productivity of solar distillation system depends on the temperature difference between condensing cover and basin of the distillation unit. The temperature difference of 2.1oC to 23.1oC between condensing cover and basin of the distillation unit has been registered. This novel design of solar distillation-cum-drying unit would be highly beneficial in the energy saving by Indian rural population.

Keywords- *energy; pure water; solar distillation; solar drying; distillation-cum-drying unit*

Introduction

One of the main reasons for life on our earth planet is availability of water. It is the only substance on earth that exists in all three state of matter i.e. solid, liquid and gases. Solid water found in the Polar Regions and covered nearly 1.74% of earth's surface. Most of the water nearly 98% is in liquid state and a very little amount is available in its vapor form. Among the liquid state water, major portion is saline water which is not suitable for agriculture and drinking purposes. Resources of fresh water are very little and are squeezing at a faster rate. Nearly one billion people lack access to fresh water globally (Brezonik and William, 2011). Desalination/distillation of saline water/brine water is the solution of fresh water scarcity but requires high amount of energy.

Solar distillation is the simplest solution of water problem for rural and arid areas. It is clean, less costly and environmental friendly process. In the process of solar distillation, energy from the sun is absorbed by brackish/contaminated water to make some of it to evaporate. These evaporated water vapors gets condensed and collected as fresh water. Solar drying is also one of the solar energy based application widely used for long preservation of food stuff (Kumar et al., 2016; Manchanda and Kumar 2016).

Solar energy used as an energy source for the various solar applications is available in scattered form. Parabolic concentrators/reflectors are designed to focus the vastly available solar radiations on different solar energy operated system. They have been mostly used in solar cooking, solar water heating, solar power generation and solar distillation system to increase their performance.

Many researcher works on the geometrical parameters of parabolic solar dish concentrator along with their application. Rafeeu and Kadir (2012) experimentally investigated the performance of different geometrical solar parabolic concentrators under Malaysian environment condition. Small aperture area of the concentrator resulted higher efficiency than others. Thermo-economic analysis of solar parabolic dish collector power plant was investigated by Reddy and Veershetty (2012). It was concluded from their study that from the financial view most of the northern region location of India are suitable for power generation by the solar parabolic dish power collector. Mahdi and Bellel (2014) designed and developed a spherical solar collector with a cylindrical receiver. Developed system was observed to be suitable for the systems requiring high heat for their operations. Bijarniya et al. (2016) reviewed various concentrated solar power (CSP) technologies and their status in power generation in India.

Chaouchi et al. (2007) designed and tested a solar desalination system equipped with a parabolic solar concentrator. From the experimental results it has been observed that efficiency of the system increases in the beginning and nearly constant afterwards. Maximum distillate and maximum efficiency were observed in afternoon hours. Arunkumar et al. (2013a) experimentally investigated the performance of a conical concentrator coupled hemispherical basin solar still integrated with PCM-filled metallic balls in the basin. Maximum distillate output of nearly 4.5 and 3.5 l/m2/day was observed using with and without PCM to the system. Arunkumar et al. (2013b) studied compound parabolic concentrator concentric tubular solar still with water and air condensing cover cooling. It has been reported that use of concentrator and condensing cover cooling significantly increase the distillate output.
A concentrating conical solar distillation system carried phase change material in its base was studied by Chaichan et al. (2015). The designed system heating efficiency and productivity was observed to be increase by 157.8% and 428.5% respectively using a concentrating unit and PCM with the distiller.

Srithar et al. (2016) investigated the performance of a triple basin solar still (TBSS) with condensing cover cooling arrangement and a parabolic dish concentrator. Designed system is also tested by attaching triangular hollow fins at the bottom of basin using different phase change material (PCM) in it. The output of the designed system was observed 16.94 kg/m2 day with concentrator, cover cooling and using charcoal as PCM in hollow fins. Singh and Tiwari (2017) investigate the performance of single and double slope basin type solar distillation system integrated with photovoltaic thermal compound parabolic concentrator collector (PVT-CPC). Single slope PVT-CPC distillation system concluded better efficiency and output at a water depth of more than 0.31 m.

Several others improvement techniques like use of reflectors, Photovoltaic thermal module (PV/T), solar collector system, heat pipe etc. are tested by various researchers to transfer/store the solar energy to the distillation system for improvement in productivity and efficiency. Detailed review of different designs of solar distillation system along with improvement techniques have been discussed in several studies (Arjunan et al., 2009; Muftah et al., 2014; Manchanda and Kumar 2015; Velmurugan and Srithar 2011; Yadav and Sudhakar 2015; Manikandan et al. 2013; Sivakumar and Sundaram 2013; Sharon and Reddy 2015; Kabeel et al. 2015; El-Sebaii and El-Bialy 2015).

Solar drying is a solar energy operated process for preservation of food, vegetables, herbs, fruits, medicinal commodities etc. for a long time by removing moisture from them under controlled conditions. This technique is highly beneficial for the developing countries to save their crops from post-harvest losses. Different designs of solar dryer for drying different commodities/products have been reviewed by various researchers(Sharon and Reddy 2015; Kabeel et al., 2015;El-Sebaii, and El-Bialy 2015;Sharma et al., 2009;Fudholi et al., 2010;Bal et al., 2011).

In the present study, solar distillation cum drying unit have been design, fabricated and tested under no load conditions. Temperature at different locations, solar intensity, ambient temperature, wind speed have been recorded which plays an important role in heat and mass transfer processes.

Experimental setup detail

Experimental unit consists of an integrated distillation and drying unit and a parabolic reflector. Sides of distillation and drying unit were fabricated using 6 mm wooden plywood and were insulated from inside using 5 mm thermocol sheet. Basin of the distillation unit was of 6 mm acrylic sheet while bottom of the drying unit was of 5 mm glass sheet of size 50 cm×50cm. The distillation unit had an area of 0.25 m^2 and it was covered with a transparent glass sheet of thickness 3 mm. The glass cover is inclined at 30° which is the latitude angle of the location. Below the distillation unit drying unit of size 0.5m×0.5m×0.15m was attached. Distillation cum drying unit was placed above a mirror polished stainless steel parabolic reflector. Figure 1 represents the schematic view of the designed experimental setup.

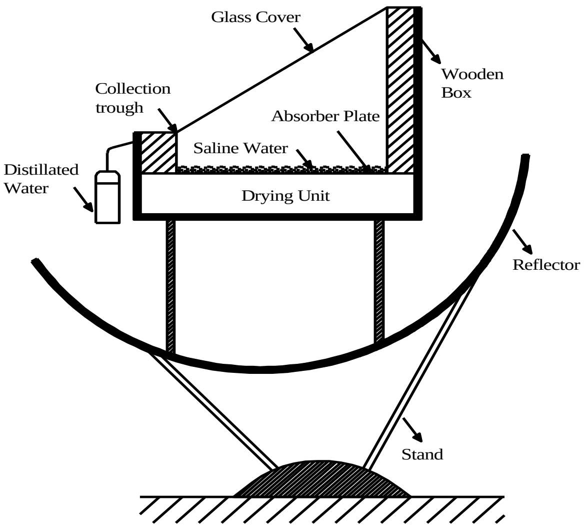

Figure 1. Schematic view of the designed experimental setup

Observation and observation Table

Whole assembly of distillation cum drying unit is placed towards north direction. Distillation unit directly using solar energy for their operation. Sun radiation passing through the glass cover enters into the distillation unit and transfers their energy to the contaminated water. Drying unit gets energy from the reflected sun radiation from parabolic reflector along with heat losses from the basin of distillation unit.

The temperature at reflector surface (T_1), drying unit (T_2), outer glass cover (T_3), inner glass cover (T_4), ambient (T_5), above basin (T_6), and at the bottom of basin (T_7) were measured by calibrated Pt-100 thermocouples. The relative humidity (RH) inside the drying unit was measured by a digital humidity meter (least count of 0.1%). Solar intensity was measured with solar power meter (least count of 0.1 W/m^2 upto 999.9 W/m^2 and 1 W/m^2 between 1000-2000 W/m^2). A digital anemometer having a least count of 0.1 m/s was used to measure the wind speed. Experimental unit was tested at no load in the month of September from 9:00 am - 5:00 pm. for the climatic conditions of Hisar, India. Table-1 shows the experimental data for the developed unit.

Results and discussions

From the experimental data it has been observed that maximum temperature in the distillation and drying unit is in between afternoon hours. Figure 2 and Figure 3 shows the variation of solar intensity (I) and wind speed during working hours of the experimentation.

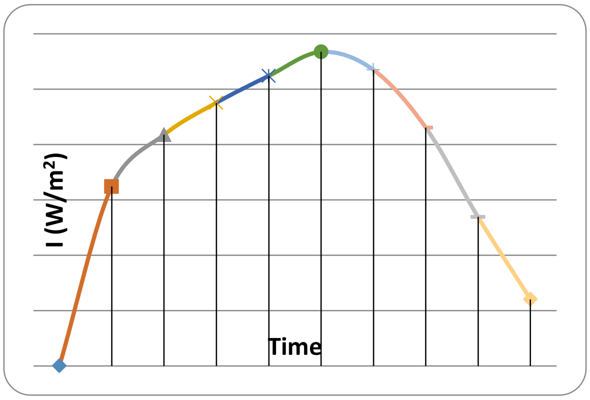

Figure- 2 Variation of solar intensity (I) with time

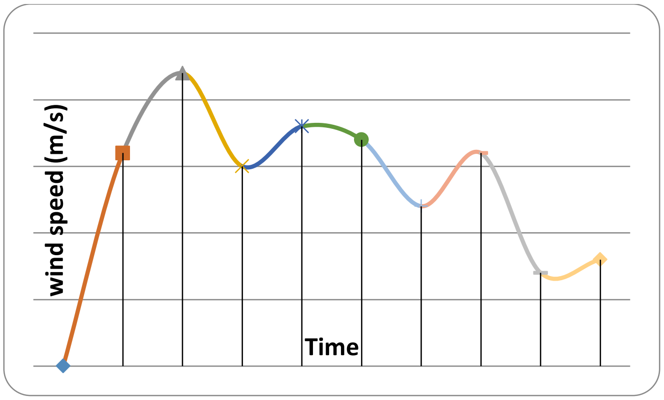

Figure- 3 Variation of wind speed with time

Time	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)	T_7 (°C)	RH (%age)
9:00	41.2	44.1	36.1	51.8	35.2	61.5	69.1	11.20
10:00	46.1	55.9	39.3	63.8	36.6	78.7	88.8	2.82
11:00	48.4	69.5	42.5	76.3	40.1	89.1	101.8	2.59
12:00	51.9	70.7	45.6	83.1	42.7	91.2	102.7	0.96
01:00	47.5	68.7	46.8	84.7	42.2	87.8	99.1	1.75
02:00	46.1	65.6	45.7	81.3	42	82.1	89.7	3.93
03:00	44.4	64.0	45.5	78.2	41.8	71.8	73.5	6.50
04:00	43.1	57.1	44.2	71.3	41.4	68.0	69.8	9.67
05:00	41.9	53.0	41.0	65.8	39.9	60.9	62.6	14.16

Table-1 Experimental data for solar distillation cum drying unit

Figure 4 represent the variation of temperature in distillation and drying unit with respect to time. As the solar intensity and ambient temperature increases, temperature inside the distillation and drying unit also increases and reduces in the evening hours. Maximum temperature of 102.7 °C and 70.7 °C has been recorded for distillation and drying unit at 12:00 noon.

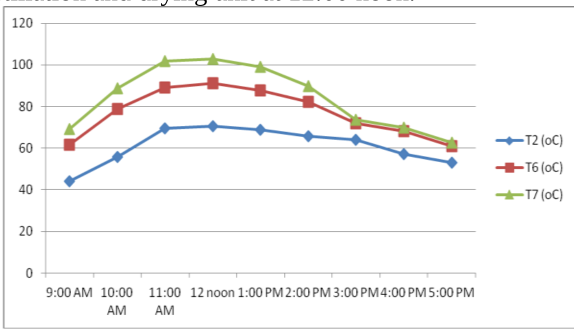

Figure 4. Distillation and drying unit temperature Vs Time

Temperature difference between basin of distillation unit and inner condensing cover is shown in Figure 5. Large deviation between temperatures was observed during day hours where as in the late hours temperature of both locations was nearly same.

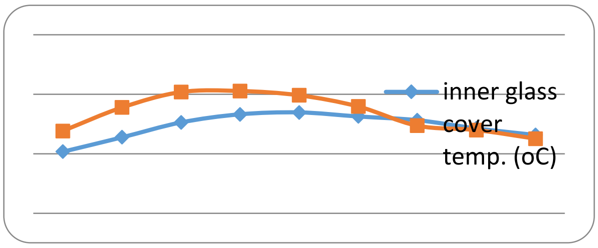

Figure 5. Temperature difference between condensing cover and basin temperature

Conclusion

Solar energy has a great potential to solve the most of the energy related problems in a clean, free, and environment friendly way. From the last few years water related problems arises at a faster rate. In this study an attempt has been made to design and develop a solar distillation-cum-drying unit for water purification and solar drying. This new design of distillation cum drying unit operated at no load conditions is presented in this communication. A very high temperature of 102.7 °C and 70.7 °C has been observed inside the distillation and drying unit respectively at 12:00 noon which is sufficient to evaporate the water and can dry the commodities at a faster rate. From the observed data it has been concluded that the proposed design of distillation-cum-drying unit is highly beneficial for the growth of underdeveloped, arid and rural area population.

References

Arjunan, T. V., Aybar, H. S., Nedunchezhian, N., (2009), Status of solar desalination in India. *Renewable and Sustainable Energy Reviews* 13, 2408-2418.

Arunkumar, T., Denkenberger, D., Ahsan, A., Jayaprakash, R. (2013a), The augmentation of distillate yield by using concentrator coupled solar still with phase change material. Desalination, 314, 189–192.

Arunkumar, T., Jayaprakash, R., Ahsan, A., Denkenberger, D., Okundamiya, M. S. (2013b), Effect of water and air flow on concentric tubular solar water desalting system. Applied Energy, 103, 109–115.

Bal, L., Satya, S., Naik, S., Meda, V., (2011), Review of solar dryers with latent heat storage systems for agricultural products. Renewable and Sustainable Energy Reviews 15:876-880.

Bijarniya, J.P., Sudhakar, K., Baredar, P. (2016), Concentrated solar power technology in India: A review, Renewable and Sustainable Energy Reviews 63, 593-603

Brezonik, P.L. and William A. A., (2011), Water chemistry- An Introduction to the Chemistry of Natural and Engineered Aquatic Systems, Oxford University Press.

Chaichan, M.T., Abbas, K.L., Kazem, H.A. (2015), Design and assessment of solar concentrator distillating system using phase change materials (PCM) suitable for desertic weathers. *Desalination and water treatment*: 1-11

Chaouchi, B., Zrelli, A., Gabsi, S. (2007), Desalination of brackish water by means of a parabolic solar concentrator, Desalination 217, 118–126

El-Sebaii, A. A., and El-Bialy, E. (2015), Advanced designs of solar desalination systems: A review. Renewable and Sustainable Energy Reviews, 49, 1198–1212.

Fudholi, A., Sopian, K., Ruslan, M., Alghoul M., Sulaiman, M., (2010), Review of solar dryers for agricultural and marine products. Renewable and Sustainable Energy Reviews 14:1-30.

Kabeel, A. E., Omara, Z. M., Younes, M. M. (2015), Techniques used to improve the performance of the stepped solar still-A review. Renewable andSustainable Energy Reviews, 46, 178–188.

Kumar, M. Yadav, C., Manchanda, H. (2016), Thermal performance of a weir-type cascade solar still: An experimental study, International Journal of Advance Research and Innovation 4 (1), 339-344.

Kumar, M., Sansaniwal, S.K., Khatak, P., (2015), Progress in solar dryers for drying various commodities. Renewable and sustainable energy reviews 55: 346-360.

Mahdi, K., and Bellel, N., (2014), Development of a Spherical Solar Collector with a cylindrical receiver, Energy Procedia 52, 438-448.

Manchanda, H. and Kumar, M. (2016), Experimental Investigation of a Solar Water Distillation cum Drying Unit, International Journal of green energy, 10.1080/15435075.2016.1261706.

Manchanda, H., and Kumar, M. (2015), A comprehensive decade review and analysis on designs and performance parameters of passive solar still, Renewables: Wind, Water and Solar 2:17, 1-24.

Manikandan, V., Shanmugasundaram, K., Shanmugan, S., Janarthanan, B., Chandrasekaran, J. (2013), Wick type solar stills: A review. Renewable andSustainable Energy Reviews, 20, 322–335.

Muftah, A. F., Alghoul, M. A., Fudholi, A., Abdul-Majeed, M. M., Sopian, K. (2014), Factors affecting basin type solar still productivity: A detailed review, Renewable and Sustainable Energy Reviews 32, 430–447.

Pirasteh, G., Saidur, R., Rahman, S., Rahim, N., (2014), A review on development of solar drying applications. Renewable and Sustainable Energy Reviews 31:133–48.

Prakash, O. and Kumar A., (2013), Historical review and recent trends in solar drying systems. International Journal of Green Energy, 10: 690–738.

Rafeeu, Y. and Kadir, M.Z.A.A. (2012), Thermal performance of parabolic concentrators under Malaysian environment: A case study, Renewable and Sustainable Energy Reviews 16 (6), 3826- 3835.

Reddy, K.S. and Veershetty, G. (2012), Viability analysis of solar parabolic dish stand-alone power plant for Indian conditions, Applied Energy 102, 908-922.

Sharma, A., Chen, C.R. Vu Lan, N., (2009), Solar energy drying system: A review. Renewable and Sustainable Energy Reviews 13:1185–1210.

Sharon, H., and Reddy, K. S. (2015), A review of solar energy driven desalination technologies. Renewable and Sustainable Energy Reviews, 41, 1080–1118.

Singh, D.B. and Tiwari, G.N. (2017), Performance analysis of basin type solar stills integrated with N identical photovoltaic thermal (PVT) compound parabolic concentrator (CPC) collectors: A comparative study, Solar Energy 142, 144-158.

Sivakumar, V., and Sundaram, E. G. (2013), Improvement techniques of solar still efficiency: A review. Renewable and Sustainable Energy Reviews, 28, 246–264.

Srithar, K., Rajaseenivasan, T., Karthik, N., Periyannan, M., Gowtham, M. (2016), Stand alone triple basin solar desalination system with cover cooling and parabolic dish concentrator, Renewable Energy 90, 157-165.

Velmurugan, V., and Srithar, K. (2011). Performance analysis of solar stills based on various factors affecting the productivity-A review. Renewable andSustainable Energy Reviews, 15, 1294–1304.

VijayaVenkataRamana, S., Iniyanb, S., and Goic, R., (2012), A review of solar drying technologies. Renewable and Sustainable Energy Reviews 16: 2652-2670.

Yadav, S., and Sudhakar, K. (2015). Different domestic designs of solar stills: A review. Renewable and Sustainable Energy Reviews, 47, 718–731.

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