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Assessment of Stagnation Temperature and Thermal Efficiency in Conventional and Evacuated Tube Integrated Solar Stills

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Abstract

The present study conducts a comprehensive investigation into the thermal characteristics of a solar device by examining evacuated tubes, determining their stagnation temperature, and evaluating the thermal performance of both conventional and evacuated tube–integrated solar desalination systems. The measurements carried out on the evacuated tube confirmed that its physical parameters complied with standard specifications. The stagnation temperature analysis indicated that the evacuated tube could achieve temperatures adequate for effective heating of the working fluid under operating conditions. The Stagnation temperature of triple layer absorptive coating evacuated tube and nano triple layer absorptive coating evacuated tube were found to be 40.0% and 45.5% respectively. Experimental evaluation of the desalination systems showed thermal performance values of 14.0% for the conventional system and 16.6% for the evacuated tube with nano absorptive triple layer coating integrated system. It could be concluded that the evacuated tube integrated solar desalination system would be utilized to match the demand and supply of fresh water in application sectors due to its improved thermal gain, elevated yield of distillate and enhanced thermal performance.

***Keywords** – Solar desalination system – Integration of evacuated tube – Improved thermal gain - Elevated yield of distillate - Enhanced thermal performance.*

Introduction

The design, fabrication and thermal performance evaluation of novel solar still is the need of the hour, as it can provide the benefits like enhanced thermal efficiency and reduced heat losses. It can also provide the benefits like effective renewable energy utilization, effectual environmental protection and hence the sustainable development. All these significances have high social relevance and hence the proposed investigation. The Twin-glass evacuated tubes are widely used in solar applications because of their high thermal durability, thermal gain, and overall thermal performance [1]. These tubes can be coupled with conventional systems to achieve improved thermal output and efficiency in integrated solar devices [2]. Accordingly, the present study focused on three key objectives: (i) measuring the physical parameters of the evacuated tubes, (ii) determining their stagnation temperature of the evacuated tubes, and (iii) evaluating the thermal performance of both conventional and evacuated-tube-integrated solar desalination systems. The findings from this applied research are documented in this research paper.

Materials and Methods

The physical parameters of the evacuated tube were measured using calibrated instruments. For evaluating the stagnation temperature, the experimentation was carried out on test, accompanying evacuated tubes. These tubes were mounted on the supporting frame, and their openings were sealed using airtight corks fitted with thermometers. The air temperature inside the evacuated tubes, under quasi–steady-state conditions, was periodically recorded along with the relevant outdoor atmospheric factors influencing it. The monitoring was continued until the attainment of stable temperature of the working fluid within the evacuated tubes over an extended period of time. For estimating the thermal performance, the solar desalination system containing an appropriate volume of water was placed in an open-air environment. It was tested during sunshine hours with periodic measurements of solar radiation, ambient temperature, wind speed, and other influencing parameters. The thermal efficiency of the system was then calculated using the standard formula.

$$\eta = (M_e \times L) / (A_c \times I \times t) \quad (1)$$

Where, η = Thermal efficiency, M_e = Quantity of output of distillate, L = Latent heat of vaporization, A_c = Area of the collector, I = Incident solar radiation and t = time taken to collect the distillate [3].

Results and Discussion

As the present research pertains to the assessment of performance characteristics, the measurement on evacuated tube, evaluation of stagnation temperature of evacuated tube and estimation of thermal performances of conventional and evacuated tube integrated solar desalination systems were carried out. While the physical parameters along with dimensions and specifications have been presented in Table 1. The Stagnation temperature of triple layer absorptive coating evacuated tube have been presented in Table 2, the stagnation temperature of nano triple layer absorptive coating evacuated tube have been presented in Table 3, and the thermal performances have been presented in Table 4 and Table 5 respectively.

Table 1 Dimensions and specifications of evacuated tubes

Parameters	Dimensions / Specifications	
	Evacuated Tube - I	**Evacuated Tube - II**
Material	Borosilicate	Borosilicate
Glass thickness	1.6 mm	1.6 mm
Inner tube diameter	38 mm	38 mm
Outer tube diameter	58 mm	58 mm
Length (nominal)	1500 mm	1500 mm
Absorptive Coating	Triple layer coating	Nano triple layer coating
Vacuum Pressure	$5x10^3$ Pascal	$5x10^3$ Pascal
Stagnation Temperature	212.4	243.9
Stagnation Percentage	40.0 %	45.5%

Table 2: Stagnation temperature of triple layer absorptive coating evacuated tube

Time	Solar Radiation (W/m^2)	Wind Speed (m/s)	Ambient Temperature (°C)	Tube Temperature (°C)
10:00 a.m.	480. 1	0.1	33 .0	135 .1
10:30 a.m.	548.7	0.4	34.4	149.3
11:00 a.m.	590.3	0.2	34.7	168.4
11:30 a.m.	634.8	0.1	34.9	198.6
12:00 noon	663.5	0.3	35.2	201.6
12:30 p.m.	781.4	0.2	35.6	208.2
13:00 p.m.	726.6	0.7	33.8	210.1
13:30 p.m.	680.1	0.3	31.3	211.9
14:00 p.m.	587.2	0.4	30.8	**212.4**
14:30 p.m.	472.4	0.2	29.0	**212.4**
15:00 p.m.	471.9	0.9	29.3	**212.4**

Table 3: Stagnation temperature of nano absorptive triple layer coating evacuated tube

Time	Solar Radiation (W/m^2)	Wind Speed (m/s)	Ambient Temperature (°C)	Tube Temperature (°C)
10:00 a.m.	453. 1	0.3	34 .2	167 .1
10:30 a.m.	548.7	0.6	34.5	179.3
11:00 a.m.	590.3	0.7	34.7	198.4
11:30 a.m.	634.8	0.1	34.9	208.6
12:00 noon	663.5	0.3	35.2	226.6
12:30 p.m.	681.4	0.2	35.6	238.2
13:00 p.m.	726.6	0.6	33.8	240.1
13:30 p.m.	680.1	0.1	31.3	242.4
14:00 p.m.	587.2	0.4	30.8	**243.9**
14:30 p.m.	474.4	0.8	29.0	**243.9**
15:00 p.m.	472.9	0.9	29.3	**243.9**

Table 4: Performance of conventional solar desalination system

Time	Solar Radiation (W/m^2)	Wind Speed (m/s)	Ambient Temperature (°C)	Thermal Performance (%)
9.00 am	624.7	0.1	29.3	14.0%
10:00 am	681.6	0.3	30.4	
11:00 am	751.4	0.2	32.2	
12:00 pm	887.3	0.3	33.6	
13:00 pm	823.8	0.2	33.3	
14:00 pm	758.7	0.4	32.4	
15:00 pm	654.5	0.3	31.6	

Table: 5 Performance of evacuated tube integrated solar desalination system

Time	Solar Radiation (W/m^2)	Wind Speed (m/s)	Ambient Temperature (°C)	Thermal Performance (%)
9.00 am	602.5	0.1	29.2	16.6%
10:00 am	676.8	0.1	30.6	
11:00 am	780.6	0.2	31.8	
12:00 pm	900.6	0.3	32.7	
13:00 pm	908.5	0.1	31.9	
14:00 pm	863.7	0.3	31.8	
15:00 pm	783.8	0.1	31.2	

In the present research, the stagnation temperature was experimentally estimated. The estimated level of stagnation temperature could be correlated with the level of incident solar radiation [4]. The estimated level of stagnation temperature could also be correlated with the dimensions of evacuated tube, the level of vacuum in evacuated tube and nature of coating on the outer side of the inner tube of evacuated tubular collector [5]. The Stagnation temperature of triple layer absorptive coating evacuated tube and nano triple layer absorptive coating evacuated tube were found to be 212.4℃ and 243.9℃ respectively. As the evacuated tubular collector had the enhanced steady state temperature over an extended period of time, it could be used in solar desalination applications.

In the present research, the solar desalination system was tested during sunshine hours in outdoor conditions. While the volume of inlet water was kept constant, the outlet volume of distillate was measured as soon as the experiment was over. It was found that the thermal performance of conventional solar desalination system was 14.0%. It was also found that the thermal performance of evacuated tube integrated solar desalination system was 16.6%. The enhancement of thermal performance of evacuated tube integrated solar desalination system could be attributed to improved absorption of radiation, elevated heating of working fluid and enhanced evaporation of working fluid due to the usage of evacuated tubes [6&7].

It is to be noted here that the thermal efficiency of the evacuated tube integrated solar desalination system would be further improved by integrating more number of evacuated tubes with the conventional desalination system. It is also to be noted here that thermal losses in the evacuated tube integrated solar desalination system would be further reduced by integrating heat proof gaskets at the points of integration of evacuated tubes with the conventional desalination system [7].

Conclusion

It could be concluded that the evacuated tube integrated solar desalination system would be utilized to match the demand and supply of fresh water in application sectors due to its improved thermal gain, elevated yield of distillate and enhanced thermal performance.

REFERENCES

1. Soteris A. Kalogirou, “Solar Thermal Collectors and Applications”, Progress in Energy and Combustion Science, 30:231–295, 2004.

2. Syed Firozuddin, Walke, P.V., 2013, “Thermal Performance on Single Basin Solar Still with Evacuated Tubes Solar Collector- A Review”, International Journal of Modern Engineering Research, 3(2):1022-1025.
3. John A. Duffe and William A. Beckman, “Solar Engineering of Thermal Processes”, A Wiley Interscience Publications, New York, U.S.A. 1980.
4. Jeyasankar, P., Jeba Rajasekhar, R.V., “Preparation, Characterization and Evaluation of Thermal Efficacy of Nano Carbon-MnO2 Coated Solar Absorber”, International Journal of Scientific Research in Physics and Applied Sciences, 6(2):52-54, 2018.
5. Pramod, B. V. N., Prudhvi Raj, J., Hari Krishnan,S. S., Vinod Kotebavi, 2017, “Performance Analysis of a Solar Sill Coupled with Evacuated Heat Pipes”, Proceedings of Materials Science Engineering, IOP Conference Series, 300(1) : 1-7.
6. Sampathkumar, K., Arjunan, T.V., Senthilkumar, P., 2013, “Experimental Investigation of a Solar Still Coupled with an Evacuated Tube Collector”, Energy Sources, 35(3):261-2.
7. Shiv Kumar, Aseem Dubey, Tiwari, G.N., 2014, “A Solar Still Augmented with an Evacuated Tube Collector in Forced Mode”, Desalination, 347:15-24.