EXPERIMENTAL STUDY ON PERFORMANCE OF SINGLE BASIN SOLAR STILL WITH EXTERNAL REFLECTOR AND EVACUATED TUBE COLLECTOR

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ABSTRACT

In this research work, comparison of single slope conventional solar still and a solar still coupled with evacuated tube collector (ETC) and external reflector mounted over solar still have been made. Two solar water desalination units of same dimensions were fabricated and their performances have been evaluated. The productivity of modified solar still was observed to be 2090 ml/day, which was nearly 111.75% more than conventional solar still. Economical cost also confirms the feasibility of both the solar stills.

Keywords: Solar desalination, external reflector, efficiency factor, daily yield.

I. INTRODUCTION

Utilization of fresh water and renewable energy is a future need. Use of the available renewable energy to make the water portable is a serious issue in many countries. About 97% of the earth's water is in the form of salty (brackish) water in the oceans or is in the form of ice glacier, and a negligible fraction of 2.6% is the fresh water which is available for human being [1]. According to the report on water scarcity by United Nations Department of Economic and Social Affairs (UNDESA) nearly 1.2 billion population (one-fifth of world population), is in area of water scarcity. Whereas 1.6 billion person (almost one fourth of world population), facing economic shortage (where countries lack the necessary infrastructure) to utilize the fresh water [2]. We need to think the methods to solve the necessity of portable water for our daily need using renewable energy resources. Solar energy is one of the renewable energy resources which are available in abundant amount [3].10^{17}watt of solar power hits to the atmosphere, whereas 10^{16}watt of solar power reaches to the earth's surface. Total demands of power for world to do all need are nearly 10^{13} watt. Therefore, solar power is nearly 10^{3}times than our needs. If we utilize 5%of solar power, then it is still 50 times more than our world's requirement [4]. Solar still is an important device which uses solar energy to desalinate water [5]. It is an ideal device which converts brackish or saline water using solar energy. A conventional solar still have low productivity and thus need to be improved for high performance characteristics [6]. A lot of research work has been done in enhancing the condensation using heat storage, solar collector and increasing free surface area [7-8].A few research papers [9-10] deals with performance modification in basin type solar still by coupling or usage of solar collectors, condenser, phase changing material, sponge cubes, sun tracking technique and using evacuated tube collectors [9-10]. There is an ample scope in redesigning of conventional solar still by implementing enhancing techniques in order to improve its performance characteristics. In the paper, two solar stills have been tested, one is conventional solar still and other solar still coupled with evacuated tube collector and external reflector. The daily yield and efficiency have been calculated and compared.

II. MATERIALS AND COMPONENTS

Experimental work has been done on two separate solar still units: (i) Single slope single basin solar still or conventional solar still unit (ii) Single slope single basin solar still with external reflector and evacuated tubes with a basin size of $0.49m^2$ made of galvanized iron and painted black from inside, having nine evacuated tube of borosilicate glass aperture area of $0.94m^2$ and reflector of same area as that of still and mounted vertical on solar still.Float valve and inlet storage tank were used to maintain a water level in the basin of solar still to a height of 0.03m. Thermocouples with temperature indicators are used to monitor the temperature variation and solar power meter were used to measure the solar intensity.

III. ANALYSIS OF EXPERIMENTAL DATA

For analytical work Dunkle's relation of heat transfer [16] is used which are as following:

$$P(T_{sw}) = e^{\left[25.327 - \frac{5144}{273+T_{sw}}\right]},$$

$$P(T_{gi}) = e^{\left[25.327 - \frac{5144}{273+T_{gi}}\right]},$$

$$(\Delta T)' = (T_{sw} - T_{gi}) + \frac{(P_{sw} - P_{gi})(T_{sw} + 273)}{(268.9 \times 10^3 - P_w)},$$

$$h_{cw} = 0.884 \times \sqrt[3]{(\Delta T)'},$$

$$h_{ew} = 16.273 \times 10^{-3} \times h_{cw} \times \frac{(P_{sw} - P_{gi})}{(T_{sw} - T_{gi})},$$

$$\eta_{REF.ETC} = \frac{h_{ew} \cdot A_{sw} \cdot (T_{sw} - T_{gi})}{I(t)_s \cdot A_{sw} + I(t)_{REF.ETC} \cdot A_{ETC}} \times 100$$

For annual cost of desalinate water per litre for desalination unit [17]

$$\text{Annual cost of desalinate water per litre} = \frac{\text{principle cost of solar still} \times i \times (1+i)^n}{\text{days of working} \times \text{Daily yield} \times [(1+i)^n - 1]}$$

IV. RESULTS AND DISCUSSION

The experimentation was carried out at Department of Mechanical Engineering, Guru Jambheshwar University of Science and Technology, Hisar for the period of January 2016 to July 2016.Out of the two fabricated units; one was simple conventional unit while the other one was coupled with evacuated tube collector mounted with external reflector over solar still. These units lie in the latitude position of the working location, so that sun rays strike nearly normal to them. The insulation of solar still unit was carried out by wrapping glass wool around it. Different parameters like temperature, solar still were measured and hourly from 7:00AM to 7:00 PM.

In order to compare the performance characteristics of two solar still units under different operating conditions different cases were considered as discussed in the present section.

CASE I: Temperature variations with time in conventional solar still and modified solar still (solar still coupled with ETC and external reflector).

In order to know the behaviour of conventional solar still and solar still coupled with ETC and external reflector experimentation have been performed at same water depth of 0.03 m. Variation in temperature at different locations in solar still and solar intensity were measured from 7:00AM to 7:00PM on hourly basis. During this time interval, solar radiations were considerably falling on the solar still surface. Solar still was firstly filled with the saline water to preset water depth of 0.03 m using float valve. Temperature at different locations namely solar still basin, inner and outer glass surface, ambient temperature, water at inlet of basin, water in evacuated tube collector were measured by using thermocouples placed at different position. Solar intensity was also observed at evacuated tube collector; solar intensity on solar still glass (30^0 inclined) using the Figure 1, shows the variation in solar intensity and variation of temperature at different location with time for conventional solar still.

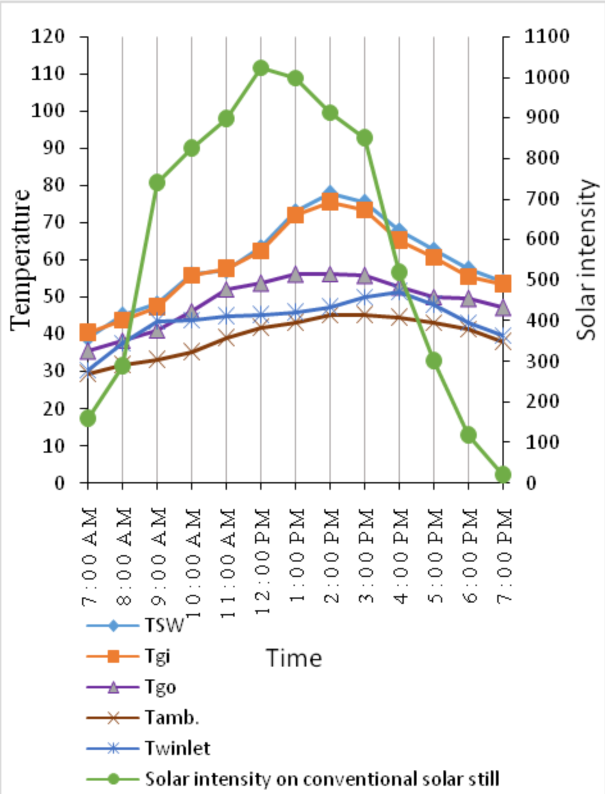

Figure1: Variation in solar intensity and temperature at different location with time for conventional solar still.

From the figure 1, the maximum solar intensity was observed as 1023 w/m^2 at 12:00 PM. Temperature of water inside the basin reaches maximum value of 77.8^0C at 2:00 PM and solar still gives maximum distillate during this period. Temperatures at the inner and outer glass surfaces were recorded to be 75.4^0C and 56.3^0C at 2:00

PM respectively. Ambient temperature had observed to be 45.3^{0}C at 2:00 PM. Figure 2 shows the variation in solar intensity and temperature at different locations with time for modified solar still.

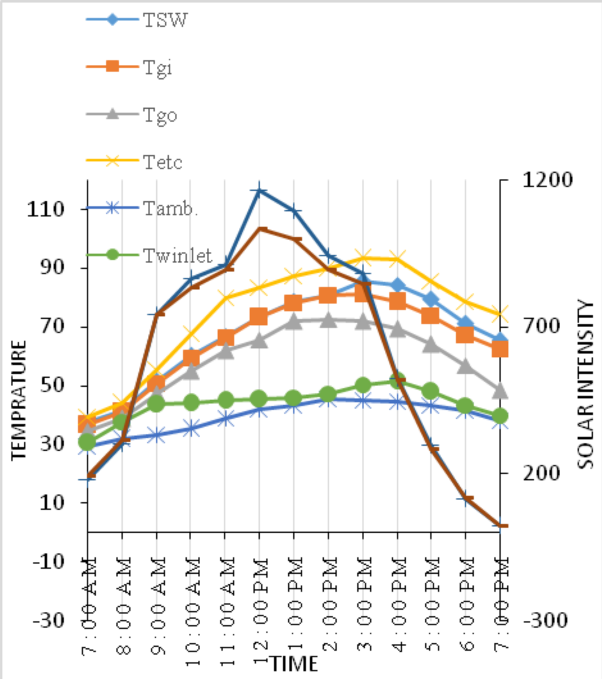

Figure2: Variation in solar intensity and temperature at different location with time for modified solar still.

In the modified solar still, the external reflector and evacuated tube collector have been coupled with conventional solar still to increase the water temperature and hence the distillate. The working conditions of the modified solar still were same as that of conventional still. From the figure 2, it has been observed that basin water temperature reached was 85.3^{0}C at 3:00PM whereas maximum temperature in inner and outer glass were 80.9^{0}C at 3:00PM and 72.4^{0}C at 2:00PM. Maximum temperature was observed in ETC was 93.2^{0}C at 3:00PM with maximum ambient temperature of 45.3^{0}C at 2:00PM.

CASE II: Productivity and efficiency of conventional and modified solar still:

From the experimentation data daily distillate productivity and efficiency of conventional and modified solar still were calculated. Figure 3 represents the daily distillate productivity of conventional solar still and modified solar still.

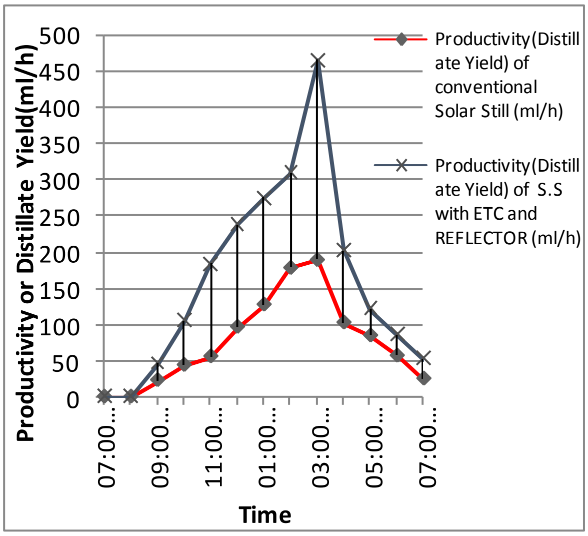

Figure3: Productivity (distillate yield)-time variation of conventional and modified solar still.

It was observed that during first two hours of experimentation, the productivity of both the solar stills was negligible but with passage of time and increase of solar radiation, the distillate output was increased. Maximum productivity in case of conventional solar still was observed to be 190 ml/hr at 3:00PM. Average daily productivity of conventional solar still was 987 ml/day whereas for the case of modified solar still having external reflector along with evacuated tube collector has given average daily yield of 2090 ml/day. Increase in daily productivity of modified solar still was increased due to use of external reflector and evacuated tube collector, which increased the basin water temperature. The productivity for the modified solar still was observed to be nearly 111.7527% higher than conventional solar still.

CASE III: Economic analysis and costing of system:

Principle cost of conventional solar still unit= Rs. 7990

Principle cost of solar still unit with ETC and external reflector= Rs. 11890

Daily working days =280 per year

Rate of interest (i) =10%

Annual cost per litre distillate for various working period of solar still has been represented in Table1.

Table1. Cost analysis of conventional and modified solar still

Years(n)	10 (years)	15 (years)	20 (years)
Annual cost of desalinate water per litre for conventional solar still	Rs.4.70	Rs.3.80	Rs.3.39
Annual cost of desalinate water per litre for solar still with ETC and reflector	Rs.3.30	Rs.2.67	Rs.2.38

V. CONCLUSION

Following conclusions have been made from the study.

- External reflector enhances the temperature of outer glass and temperature inside the solar basin.
- Annual daily yield for conventional solar still and modified solar still were observed to be 987ml/day and 2090 ml/day respectively.
- Percentage increase in daily yield with modified solar still was 111.75% than conventional solar still.
- From the experimentation, we have concluded that modified solar still gives better performance than that of conventional solar still.

Specifications of terms used in equations are given below.

A_{SW}	Basin area of solar still, m^2
h_{cw}	Coefficient of convective heat transfer from basin water to glass surface, $W/m^{2\circ}C$
h_{ew}	Coefficient of evaporative heat transfer from basin water to glass surface, $W/m^{2\circ}C$
$I(t)_{REF.ETC}$	Intensity of solar radiation at solar collector, W/m^2
$I(t)_{SW}$	Intensity of solar radiation at solar still, W/m^2
P_{gi}	Partial vapour pressure at inner glass surface temperature, N/m^2
P_{sw}	Partial vapour pressure at basin water temperature, N/m^2
P(T)	Partial vapour pressure at T temperature, N/m^2
T_{go}	Temperature of outer surface glass cover, $^\circ C$
T_{gi}	Temperature of inner surface glass cover, $^\circ C$
T_{sw}	Temperature of basin water, $^\circ C$
Σ	Stefan boltzman constant, $5.67{*}10^{-8}$ W/m^2K^4
$\eta_{conv.}$	Efficiency of simple/conventional solar still (without painted black)
$\eta_{REF.ETC}$	Efficiency of basin of solar still coupled with ETC, reflector.
N	Working life of solar still unit.
I	Rate of interest per annum.

REFERANCE

[1] Tiwari, G. N., Singh, H. N., &Tripathi, R. (2003). Present status of solar distillation. *Solar energy*, *75*(5), 367-373.

[2] Tiwari, G. N., H. N. Singh, and Rajesh Tripathi. "Present status of solar distillation." *Solar energy* 75.5 (2003): 367-373.

[3] Sharshir, S. W., Yang, N., Peng, G., &Kabeel, A. E. (2016). Factors affecting solar stills productivity and improvement techniques: A detailed review. *Applied Thermal Engineering*, *100*, 267-284.

[4] Chaturvedi, Aravind Kumar. "A Review of Solar Flat Plate Liquid Collector‟ s Components." International Journal 3.1 (2015): 138-141.

[5] Velmurugan, V., &Srithar, K. (2011). Performance analysis of solar stills based on various factors affecting the productivity—a review. *Renewable and Sustainable Energy Reviews*, *15*(2), 1294-1304.

[6] Esfahani, J. A., Rahbar, N., &Lavvaf, M. (2011). Utilization of thermoelectric cooling in a portable active solar still—an experimental study on winter days.*Desalination*, *269*(1), 198-205.

[7] Tiwari, G. N., H. N. Singh, and Rajesh Tripathi. "Present status of solar distillation." *Solar energy* 75.5 (2003): 367-373.

[8] Xiao, G., Wang, X., Ni, M., Wang, F., Zhu, W., Luo, Z., & Cen, K. (2013). A review on solar stills for brine desalination. *Applied energy*, *103*, 642-652.

[9] Ibrahim, A. G., &Elshamarka, S. E. (2015). Performance study of a modified basin type solar still. *Solar Energy*, *118*, 397-409.

[10] Kabeel, A. E., & El-Agouz, S. A. (2011). Review of researches and developments on solar stills. *Desalination*, *276*(1), 1-12.

[11] Kaviti, A. K., Yadav, A., & Shukla, A. (2016). Inclined solar still designs: A review. *Renewable and Sustainable Energy Reviews*, *54*, 429-451.

[12] Sivakumar, V., &Sundaram, E. G. (2013). Improvement techniques of solar still efficiency: A review. *Renewable and Sustainable Energy Reviews*, *28*, 246-264.

[13] Prakash, P., &Velmurugan, V. (2015). Parameters influencing the productivity of solar stills–A review. *Renewable and Sustainable Energy Reviews*, *49*, 585-609.

[14] Tanaka, H., &Nakatake, Y. (2006). Theoretical analysis of a basin type solar still with internal and external reflectors. *Desalination*, *197*(1), 205-216.

[15] Tanaka, H. (2009). Experimental study of a basin type solar still with internal and external reflectors in winter. *Desalination*, *249*(1), 130-134.

[16] Dev, R., & Tiwari, G. N. (2009). Characteristic equation of a passive solar still. *Desalination*, *245*(1), 246-265.

[17] Rahul Dev, Sabah A. Abdul-Wahab, G.N. Tiwari, Performance study of the inverted absorber solar still with water depth and total dissolved solid, *Applied Science*, 88, 2011, 252-264.