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Thermal modeling of passive and active solar stills for different depths of water by using the concept of solar fraction

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Abstract

This communication presents the thermal analysis of passive and active solar distillation system by using the concept of solar fraction inside the solar still with the help of AUTOCAD 2000 for given solar azimuth and altitude angle and latitude, longitude of the place. Experiments have been conducted for 24 h (9 am to 8 am) for New Delhi climatic conditions (latitude 28°35′N, longitude 77°12′E) during the months of November and December for different water depths in the basin (0.05, 0.1 and 0.15 m) for passive as well as active solar distillation system. Analytical expressions for water and glass cover temperatures and yield have been derived in terms of design and climatic parameters. It is observed that

(i) the solar fraction plays a very important role at lower values of solar altitude angle;
(ii) the internal convective heat transfer coefficient decreases with the increase of water depth in the basin due to decrease in water temperature;
(iii) there is a fair agreement between the experimental observation and theoretical prediction during daytime as compared to that during the night.

Keywords: Solar fraction; Solar distillation

1. Introduction

As early as from the fourth century B.C., different methods have been developed for getting potable water from impure water. The process of getting potable water from saline/brackish water with the help of solar energy is known as solar distillation. Talbert et al. (1970) gave an excellent historical review of solar distillation. Delyannis and Delyannis (1983) gave an overview of the existing solar distillation plants in the world, as well as the design geometry of various commercial solar stills

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Nomenclature

A_c	area of collector (m^2)
A_E	area of east wall (m^2)
A_h	area of water directly receiving rays (m^2)
A_N	area of north wall (m^2)
$A_{N'}$	area of projection of north wall (m^2)
A_W	area of west wall (m^2)
A_S	area of south wall (m^2)
A_{water}	area of water surface (m^2)
C_w	specific heat of water in solar still (J/kg °C)
F_b	solar fraction for the basin of the still
F_n	solar fraction for the north wall of the still
F_R	heat removal factor
h_b	overall heat transfer coefficient from basin liner to ambient air through bottom and side insulation (W/m^2 °C)
h_{1g}	convective heat transfer coefficient from glass cover to ambient (W/m^2 °C)
h_{1w}	total heat transfer coefficient from water surface to glass cover (W/m^2 °C)
h_w	convective heat transfer coefficient from basin liner to water (W/m^2 °C)
h_{cw}	convective heat transfer coefficient from water surface to glass (W/m^2 °C)
h_{ew}	evaporative heat transfer coefficient from water surface to glass (W/m^2 °C)
I	solar intensity on the glass cover of the solar still (W/m^2)
I_c	solar intensity on the glass cover of the solar collector panel (W/m^2)
I_h	solar radiation incident on the horizontal surface of solar still (W/m^2)
I_E	solar radiation incident on the east wall of solar still (W/m^2)
I_W	solar radiation incident on the west wall of solar still (W/m^2)
I_N	solar radiation incident on the north wall of solar still (W/m^2)
I_S	solar radiation incident on the south wall of solar still (W/m^2)
I_{eff}	effective solar radiation intensity (W/m^2)
L	latent heat of vaporization (J/kg)
M_w	mass of water in basin (kg)
$\dot{m}_{ew}$	hourly output of still (kg/m^2 h)
$\dot{m}_{ew}(E)$	experimental hourly output of still (kg/m^2 h)
$\dot{m}_{ew}(T)$	theoretical hourly output of still (kg/m^2 h)
N	number of observations
$\dot{Q}_u$	rate of useful energy from collector (W)
T_a	ambient air temperature (°C)
T_b	basin temperature (°C)
T_{ci}	inner temperature of condensing cover (°C)
T_w	average water temperature (°C)
T_g	average glass temperature (°C)
U_L	overall heat transfer coefficient (W/m^2 °C)
X_i	theoretical or predicted value
Y_I	experimental value

Greek symbols

α	absorptivity
α'_b	solar flux absorbed by the basin liner
α'_w	solar flux absorbed by water mass
α'_g	solar flux absorbed by glass cover
ρ	reflectivity
τ	transmittance

Subscripts

b	basin liner
c	collector
g	glass cover
w	water

at that time. The process of solar distillation operates under two modes: namely, passive and active. The simplest unit of solar distillation is known as the conventional single slope solar still. But the yield of this still is about 2 l/day/m^2 of still area, which is very low. There are, however, several methods to increase this yield, which generally fall into two categories: concentrators and flat-plate collectors. Zaki et al. (1983) studied an active system of conventional single-slope solar still integrated with a flat plate collector under thermosyphon mode of operation and found that the maximum increase in the yield was up to 33% when the water in the still was preheated in the collector. Delyannis (1987) presented the status of the solar assisted desalination and the installed plants in commercial or