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SHORT COMMUNICATION

Effect of flat plate collectors in series on performance of active solar still for Indian coastal climatic condition

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KEYWORDS

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Abstract Effect of flat plate collectors (FPCs) in series on the distillate output and performance of solar still have been studied in active mode. The solar still has an effective basin area of 1 m^2 and fixed cover inclination of 30°. Each FPC with an effective area of 2 m^2 is attached with solar still. For the present study, experiments have been conducted for 24 h during the summer months for active solar distillation system. An effective collector inclination of 5° is used. Outdoor experiments were conducted at Kakinada (16°.93′N/83°.33′E), A.P., India, which has coastal climatic conditions. The aim of the present work is to study the effect of FPCs connected in series on the yield and distillation efficiency of an active solar still for the selected location.

The results show that solar still, with two FPCs connected in series, provides 41% more distillate yield when compared to still with single FPC and the still efficiency is 0.47% more with two FPCs connected in series. The still with three FPCs connected in series has produced 89% more distillate yield when compared to still with single FPC. However, the still efficiency is 0.48% less with three collectors in series due to increase in area for radiation. The increase in distillate yield for the still with FPCs in series is due to the attainment of high water temperature.

1. Introduction

Supply of pure water is a big problem in underdeveloped as well as developing countries. Along with food and air, water is a basic necessity for humankind. Man has been dependent on non-purified water from rivers, lakes and underground water reservoirs. But the pollution of rivers and lakes by industrial effluent and sewage has caused scarcity of pure water in many towns and villages near lakes and rivers. Consumption of non-purified water causes various water related diseases to mankind. Pure and healthy water can be produced from

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Nomenclature

A_w	evaporative surface area (m^2)
A_g	area of glass cover (m^2)
A_c	area of collector (m^2)
C	unknown constant
Gr	Grashoff number
h_{cw}	convective heat transfer coefficient from water to condensing cover (W/m^2 °C)
h_{ew}	evaporative heat transfer coefficient from water to condensing cover (W/m^2 °C)
$I(t)$	hourly average of incident total radiation on still (W/m^2)
$I_c(t)$	hourly average of incident total radiation on collector(W/m^2)
K_v	thermal conductivity of the humid air (W/m °C)
L	latent heat of vaporization of water (J/kg)
L_V	characteristic dimension of condensing cover (m)
m_{ew}	yield (kgs)
n	unknown constant
P_{ci}	partial saturated vapor pressure at condensing cover temperature (Pa)
P_w	partial saturated vapor pressure at water temperature (Pa)
Pr	Prandtl number
q_{ew}	rate of evaporative Heat transfer (W/m^2)
t	time (s)
T_W	water temperature (°C)
T_{ci}	inner temperature of a condensing cover (°C)
T_{fpci}	temperature of flat plate collector inlet (°C)
T_{fpco}	temperature of flat plate collector outlet (°C)
Greek symbols	
ΔT	temperature difference between water and inner glass surface (°C)
η_D	distillation efficiency (%)

impure, brackish and saline water through solar distillation and desalination. Solar distillation and solar desalination are the best methods for purifying impure, brackish and saline water respectively in small scale. These systems will perfectly suit Indian coastal areas where we will find the shortage of pure water and availability of solar energy. The productivity of the solar stills is very low in passive mode (no forced circulation of water in still i.e. without FPC attachment). This is due to the low solar radiation catching areas of solar stills. In order to overcome this problem, many active solar stills were developed. In active mode the still could be coupled with FPCs either in series or in parallel and the basin water is circulated through FPCs by pump. The temperature difference between the evaporating and condensing surfaces is increased by feeding the additional thermal energy from the flat plate collector into the basin of the solar still. The water in the basin is circulated through FPC either in a natural circulation mode or a forced circulation mode depending upon the requirement.

2. Definition of the problem

The performance of the solar distillation unit can be predicted provided concerned basic relations of internal heat and mass transfer are estimated accurately. A semi-empirical relation for internal heat and mass transfer in solar distillation units was derived (Dunkle, 1961) based on which a number of solar stills with different geometries, different climatic conditions and different modes (passive and active) have been analyzed by various researchers.

This paper describes the comparative performances of solar still with a number of collectors connected in series to obtain maximum yield for the selected still design. The convective mass transfer relations are determined for the still connected with single, two and three collectors respectively. The still consists of an effective basin area of 1 m^2 and a fixed condensing cover inclination of 30°. The outdoor experimentation is conducted at JNTUK Kakinada, Andhra Pradesh, India in summer. The combined effect of evaporative and convective internal heat transfers is predicted by the relation Nu = $C \cdot (\mathrm{Gr} \cdot \mathrm{Pr})^n$. Fixed values of 0.075 and 1/3 are suggested for the constants C and n respectively by Dunkle (1961) whereas, Kumar and Tiwari (1996) has proposed regression analysis of experimental data for calculating the values for the constants. In this work the values of convective heat transfer coefficient (h_{cw}) and evaporative heat transfer coefficients (h_{ew}) for the still are compared using both Dunkle's and K&T models.

3. Literature review

For a solar still – collector system, Badran et al. (2005) experimentally proved that the yield substantially increases for both tap and saline water. For a single slope solar still, Badran et al. (2005) proved that productivity increases when the still is coupled with FPCs. Gaur and Tiwari (2010) optimized the number of FPCs for active solar stills. To enhance the yield Eltawila and Omarab (2014) integrated FPC, PV system and hot air. Rajaseenivasan et al. (2014) reported that higher evaporation rates for Flat Plate Collector Basin (FPCB) still compare to conventional still. Kumar et al. (2014) reported higher annual yield for solar still coupled with evacuated tube collector in forced mode compared to natural mode of operation. Feilizadeh et al. (2015) assessed the productivity of active solar still coupled with FPCs. Saeedi et al. (2015) investigated theoretically the effect of operating parameters on energy efficiency of the active solar still with PV/Thermal collectors. Taghvaei et al. (2015) indicated that the active solar still yield increases with increased collector area. Morad et al. (2015) observed maximum productivity for the active solar still compares to the passive solar still. Tiwari et al. (2003) conducted energy and economic analyses for PV/T and FPC active solar still. Prakash and Velmurugan (2015) reviewed the effect of factors like absorption area, water depth, heat storage, inlet water temperature etc. for improving the yield of solar stills using reflectors, FPCs etc. Viswanath Kumar et al. (2015) reviewed the performance of solar stills with passive and active mode of operation and described various design specifications of