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Evaporative heat loss and heat transfer for open- and closed-cycle systems of a floating tilted wick solar still

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Abstract

An analytical expression for the thermal efficiency of evaporative heat loss and heat transfer for a open- and closed-cycle systems of floating tilted wick solar stills in terms of system design and climatic parameters has been derived. The expression for open- and closed-cycle systems was validated by performing experiments for both systems. Optimization of the design of the still for evaporative cooling (open cycle) and the distillation unit (closed cycle) was obtained using the derived analytical expression for large-scale installation. Numerical calculations were also carried out for a typical summer day at the Sri Ramakrishna Mission Vidyalaya College of Arts and Science, Coimbatore, India, to predict the performance of the still.

Keywords: Solar distillation; Transient theory; Thermal efficiency

1. Introduction

Tiwari et al. [1] derived analytical expressions for evaporative heat loss (open-cycle mode) based on the mass transfer rate from a wetted surface to the atmosphere as a function of relative humidity. The same expressions were used by Tiwari et al. [1] and Lawrence and Tiwari [2] to study the effect of evaporative heat loss on the open-cycle mode of operation. Malik et al. [3] examined the same expression for closed cycle system (for $g = 1$), which is similar to Dunkle's relation for evaporative heat loss for a different design of the unit for distillation of saline water. Tiwari and Salim [4] used the same expression to investigate the performance of a double-sloped, fibre-reinforced, plastic, multiwick solar still without considering the flow rate of water flowing over the jute cloth. The effects of climate, design and operational parameters on the per-

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formance of wick-type solar distillers have been studied by Yeh and Chen [5] using artificial simulation. In this common tilted-wick-type solar still with an inside water reservoir, the following problems were identified.

- The wick becomes dry during peak sunny hours.
- Heat loss occurs through excess of wasted hot water during late and early working hours.
- Salt scale formation is greater in the basin.

In order to solve the problems, a new floating tilted wick solar still was designed to overcome the inconvenience/uncertainties of the common tilted wick solar still.

Based on the energy balance for different components of the proposed still, an expression for tilted-wick, floating-wick temperatures and thermal efficiency was derived by incorporating the design and climatic parameters. Numerical calculations were carried out for a typical summer day (June 12, 2004) in Coimbatore to predict the performance of the system. Results were validated by performing an experiments for both open- and closed-cycle systems.

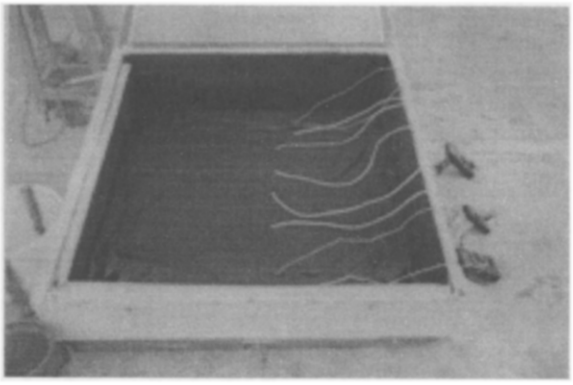

Fig. 1a. Photograph of the experimental still for the open-cycle system.

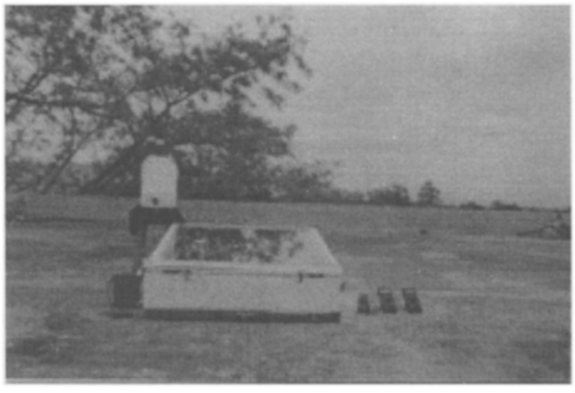

Fig. 1b. Photograph of the experimental still for the closed-cycle system.

2. Illustration of the design

Schematic photographs of the floating tilted wick solar still for open- and closed-cycle systems are depicted in Figs. 1a and 1b. In the proposed still the blackened jute wick is spread along with a 15° tilted portion, and the remaining part of the wick was prepared in a corrugated shape and floated in the inside water reservoir of the still with a thermocole sheet 2½ cm thick.

The water level in the reservoir was maintained so as not to overflow into the tilted portion and always to be 0.25 cm below the tilted portion through an inlet controlled by a valve. Due to the raised water level in the reservoir, the tilted wick is always wet, and the floating-wick water surface facing upwards towards the glass cover also serves as an evaporative area, thereby solving the first problem. The second problem was solved by feeding the excess wasted hot water into the reservoir during early and late working hours of the still for the closed-cycle system. The third problem, that is the salt scale formation in the tilted-wick portion, was solved due to the deposition of salt in the lower part of the floating wick, and hence the salt diminished saline water flow towards the tilted wick due to capillary action of the jute wick.

The sectional view and energy flow diagrams for the closed- and open-cycle systems of a floating tilted wick solar still are shown in Figs. 1c and 1d.