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Mathematical model of the thermal utilization coefficient of salt gradient solar ponds

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Abstract

The performance of the heat collection and storage of three zone solar ponds is studied in this paper, based on similar methods to analyze and calculate flat plate solar collector performance. A mathematical model of the thermal utilization coefficient of the solar ponds is proposed, and several factors influencing it are discussed in detail.

Keywords: Salt gradient solar pond; Thermal utilization coefficient; Mathematical model

1. Introduction

A lot of theoretical and experimental studies on salt gradient solar ponds have been made because of their excellent heat collection and storage performances. Many novel solar ponds have been designed [1,2]. Recently, the research works have been pushed into the practical utilization stage [3,4].

As is known to all, solar ponds can provide huge amounts of thermal energy for our industry, agriculture or domestic lives. However, how much are their thermal utilization coefficients? Up to now, there is no suitable mathematical model to calculate it. It is necessary for the convenience of practical works to establish a universal mathematical model of the solar pond thermal utilization coefficient. It can be used to optimize the size and operational parameters of the ponds and to find the optimal relations between the ponds and the loads. In fact, a solar pond is a horizontally placed solar collector. Many publications have reported that there are similar performances between the solar pond and the flat plate solar collector [5–7]. Ref. [5] even considered that the

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Nomenclature

A_c	area of pond
C_p	specific heat of solution
D_i	thickness of insulation layer of bottom
D_g	thickness of dry soil between bottom and underground water
F_R	heat removal factor
G_p	fluid flow rate per unit pond area
$H(x,t)$	solar insolation
K	thermal conductivity of solution
K_i	thermal conductivity of insulation layer
K_g	thermal conductivity of dry soil
N	day numbers of month
$\overline{p}$	weighted average coefficient of diffusion and beam fraction of solar radiation on surface of pond
Q_{up}	useful heat collected from pond
x	downward coordinate of depth
t	operational time
T	temperature of solution
T_3	temperature of underground water
T_2	temperature of solution of nonconvective zone (NCZ)
T_1	temperature of water of upper convective zone (UCZ) soil
U_{Lp}	total heat loss factor of solar pond
χ_0, b	two constants connected with sun light absorbed by salt water
γ	average reflection angle of sun light in pond
$(\tau\alpha)_p$	equivalent absorptivity–transmissivity product
φ	thermal utilization coefficient of solar pond
ρ	density of solution
$\tau(x_2)$	transmissivity of water and solution in point x_2

gradient zone of the solar pond acts as the glazed cover of the flat plate solar collector. Thus, it is suitable to research the contrast of the solar pond with the flat plate solar collector.

Through the comparative researches between the solar pond and the flat plate solar collector, a mathematical model of the thermal utilization coefficient of the ideal solar pond is proposed in this paper, which will provide the convenience for the optimal design and management of the solar pond.

2. The performance analysis of the ideal solar pond

In a practical solar pond project, the operating state of the solar pond is usually complicated due to the differences of its inner or outer conditions. For simplifying the analysis, some conditions are assumed as follows: