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The performance simulation of all-glass vacuum tubes with coaxial fluid conduit☆

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Abstract

A numerical investigation has been carried out for a solar system, which consists of all-glass (double skin) solar vacuum tubes. Water is heated as it flows through the coaxial fluid conduit inserted in each tube. The space between the exterior of the fluid conduit and the glass tube is filled with antifreeze solution. This is to facilitate heat transfer from the solar heated absorber surface to water and to prevent the functional problems due to freezing in frigid weather conditions. Results show good agreement when compared with other experimental data demonstrating the reliability of the present model. The one-dimensional numerical model could be used efficiently in designing all-glass solar collector tubes with different geometrical parameters other than those considered in the present analysis.

Keywords: Analytical approach; One-dimensional; Solar tubular collectors; Coaxial conduit

1. Introduction

Although today's powerful CFD (Computational Fluid Dynamics) codes and computers are capable of simulating convection heat transfer processes under almost any operating conditions, a one-dimensional analytical solution often yields satisfactory accuracy for steady-flow convection heat transfer processes. Analytical solutions also provide more physical insights about the flow and energy transfer processes involved. In addition, normalization and dimensional analysis generally become much easier if the flow can be approximated as one-dimensional. For these reasons, one-dimensional analytical solutions have been widely applied to solar collector designs and analyses, and to obtain the pertinent dimensionless parameters.

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Nomenclature

P	cross-section area, m^2
C_p	specific heat, J/kg K
$\dot{m}$	mass flow rate, kg/s
T	temperature, °C
U_L	heat loss coefficient, W/m^2 K
V	velocity, m/s
S_{eff}	effective solar radiation, W/m^2 K (per tube)
h	heat transfer coefficient, W/m^2 K
x	one-dimensional coordinate

Greek

α	absorptivity
θ	tilt angle, °
ϵ	emissivity
τ	transmissivity

Subscripts

1,2,3	regional parameters
r	radiation
i, in	interior, inner
o, out	exterior, outer

A closed-form solution was obtained in Eberlein's analytical study [1] of convective heat transfer in a glass tubular collector employing air as the heat transfer medium. Despite the simplifications and approximations made in this one-dimensional, steady-flow analysis, results and conclusions of Eberlein's study shed much light on the design and operation of solar tubular collectors, and can be applied to other designs such as the one considered in the present study. Adopting Eberlein's approach, a one-dimensional model has been developed for a double skin solar tubular collector

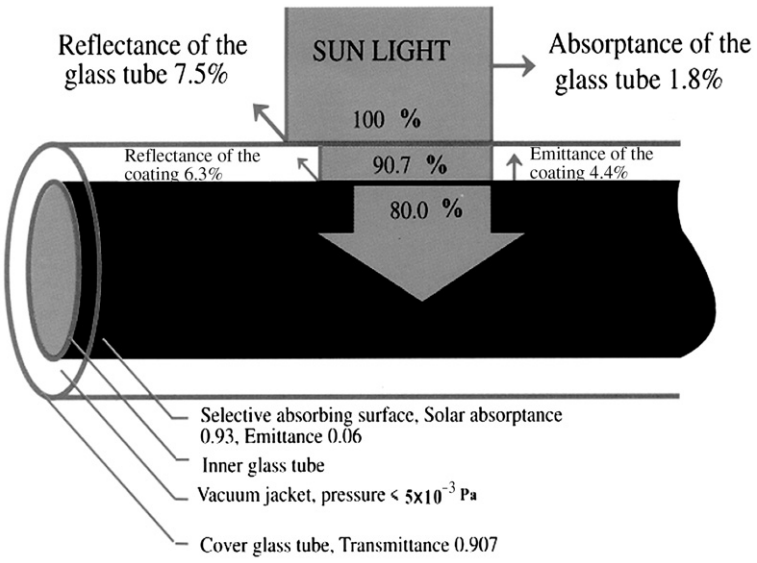

Fig. 1. A typical double skin solar tubular collector.