CONJUGATE HEAT TRANSFER IN A TWO STAGE TRAPEZOIDAL CAVITY STACK

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***Abstract*— The flow pattern and heat transfer in a pair of cavities stacked one over the other, with a separating solid plate in between, are numerically studied. The configuration idealizes two trays in a multiple effect desalinator. The work focuses on the computational modeling of the two conjugate recirculations in the cavities, conductively coupled through the thin separating plate. The effect of the plate physical parameters, thickness and conductivity, on the heat transfer are also analyzed. Plates made of glass, steel and aluminum of 2, 3, 4 and 6 mm are studied. Cavity flow and temperature patterns, depicted by streamlines, velocity fields, and isotherms are analyzed for steady state. Attention was paid to the temperature variation over, and heat flow through the separating plate. Global Nusselt numbers are calculated for the bottom side of the lower cavity. Data are obtained for air as the working fluid (Pr=0.7) in the range $10^3<Ra_H<10^7$.**

***Keywords*— cavity, natural convection, conjugate heat transfer.**

I. INTRODUCTION

The physics of basin type solar desalinators has attracted the interest of many researchers in the past, since the first one was built at Las Salinas, Chile, in 1872 (Duffie and Beckman., 1990). This type of desalinator consists of a closed cavity, of triangular or trapezoidal cross section; identified as the tray. In its bottom pan (the basin) is a small quantity of brine that is to be heated and evaporated in order to separate the water from the salts that may be present in it. Humid air in the interior of the tray is convected towards the cooler inclined cover of the cavity, where clean water is naturally removed by gravity, after condensation.

Natural convection in cavities related with the present and similar problems have been studied. Poulikakos and Bejan (1982), Asan and Namli (2000), Holtzman *et al.* (2000), Del Campo *et al.* (1988), numerically studied the convection in an attic space, a pitched roof, and other triangular cross sections respectively. Flack *et al.* (1979) and Flack (1980), experimentally addressed convection in triangular and trapezoidal cavities. Palacio and Fernández (1993) and Rheinländer (1982) studied the turbulent regime and mass transfer in solar still desalinators. Esteban *et al.* (2004) studied the heat and mass transfer in a trapezoidal cavity.

The two tray configuration posses a conjugate problem between the two recirculating flows coupled by heat conduction through the separating plates between trays. The recirculations are driven by the hot and cold plates of each cavity. The same problem was first addressed by Aramayo *et al.* (2004) in the case of a glass separating plate. Here we extend these results and we analyze the effect of the properties of the plate materials, considering glass, steel and aluminum. The materials cover a three order of magnitude range for the thermal diffusivity. We have also considered various commercial thicknesses, 2, 3, 4 and 6 mm.

Conjugate convection with conduction is an interesting problem in its own and it is receiving increasing attention since Anderson and Bejan (1980,1981) studied the problem of two fluid reservoirs separated by a vertical thin wall. Other conjugate natural convection problems have been addressed more recently. Polat and Bilgen (2003) studied the heat transfer from a wall to an open shallow cavity, Dong and Li (2004) studied the conjugate heat transfer between the top of a square cavity, a solid cylinder inside it, and the fluid in between. Aydin (2006) has studied double pane windows.

In this paper we address the conjugate heat transfer problem in a two stage trapezoidal cavity stack and the laminar convection of dry air inside both cavities.

In section II the mathematical description of the problem and the numerical method employed is presented. In section III the flow and temperature patterns, the effect of the Rayleigh number, the separating plate thickness and material are examined. Plate temperature and cavity temperature profiles are also presented. Global heat transfer data is discussed in section IV. Conclusions are presented in section V.

II. MATHEMATICAL MODEL

A. The fluid model

The physical system under consideration, as shown schematically in Fig. 1, is a two-dimensional enclosure. Flow and heat transport in the fluid obeys the continuity, the Navier Stokes, and the thermal energy equations. The Boussinesq approximation is applied as usual: constant properties apart from the density in the body force term. Incompressible flow results. Being u and v the velocity components in the x and y directions,