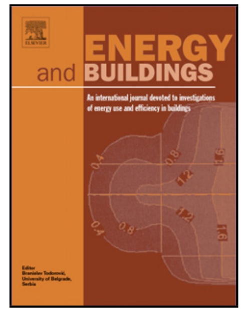
Accepted Manuscript



Title: The influence of radiation heat transfer on the prediction of air flows in rooms under natural ventilation

Author: M. Alejandra Menchaca-Brandan F. Alonso Dominguez Espinosa Leon R. Glicksman

PII: S0378-7788(16)31877-1
DOI: http://dx.doi.org/doi:10.1016/j.enbuild.2016.12.037
Reference: ENB 7216

To appear in: *ENB*

Received date: 15-6-2016
Revised date: 22-11-2016
Accepted date: 13-12-2016

Please cite this article as: M. Alejandra Menchaca-Brandan, F. Alonso Dominguez Espinosa, Leon R. Glicksman, The influence of radiation heat transfer on the prediction of air flows in rooms under natural ventilation, *<![CDATA[Energy & Buildings]]>* (2016), http://dx.doi.org/10.1016/j.enbuild.2016.12.037

The influence of radiation heat transfer on the prediction of air flows in rooms under natural ventilation

M. Alejandra Menchaca-Brandan*, F. Alonso Dominguez Espinosa, Leon R. Glicksman

Department of Mechanical Engineering, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA

Abstract

Scale experiments that use water of different salinities to represent air at different temperatures are a common tool used to investigate room air ventilation. However, it has been shown that these experiments cannot replicate the effects of radiation heat transfer in a room. This paper illustrates the importance of accounting for radiative effects when modeling airflow, especially regarding the air temperature profile. Computational Fluid Dynamics simulations were performed of flow in heated rooms with and without radiation. It was found that when radiation was ignored the temperature of the air surrounding the occupants was significantly lower, by 2 to 4 °C, than when including its effects. In addition, the surface temperature of the heat sources was consistently higher (up to 17 °C) when ignoring radiation. Finally, air velocity in the space was higher in simulations that included radiation. These differences have an important impact on the predicted thermal comfort of the occupants, since neglecting radiative heat transfer would result in an inaccurate estimation of operative temperature. We conclude that water scale models do not provide an accurate description of flow behavior in a space, so desired thermal and flow conditions might not be achieved in buildings designed or assessed using water scale models. For these reasons, theoretical models or computer simulations that omit radiation will also give misleading predictions of room temperature distribution.

Keywords: thermal stratification, radiation, CFD, airflow modeling, natural ventilation

Nomenclature

g	acceleration of gravity
h	height of temperature interface in displacement ventilation
k_λ	absoption coefficient for liquid water
L	characteristic thickness of fluid layer/characteristic length
T	temperature of air
T_{cold}	temperature of cooled vertical wall
T_{hot}	temperature of heated vertical wall
T_{inlet}	temperature of air at inlet of room
X	X axis/distance along X axis
Y	Y axis/distance along Y axis
y^+	nondimensional distance from wall
Z	Z axis/distance along Z axis

Greek symbols

α	thermal diffusivity
α_λ	absoptivity of fluid
β	coefficient of volumetric thermal expansion
θ	nondimensional temperature
ν	kinematic viscosity

1. Introduction

Modeling the airflow and thermal dynamics in a room is challenging. It requires understanding the effect that each element in the room has on the room physics, and then analyzing the interaction of all of these factors put together. Investigators of convective flows above heat sources commonly do not account for the effect of radiative heat transfer (e.g. [1, 2, 3]). Neglecting radiation allows the use of experimental methods such as filling boxes, small scale containers where the density difference between hot air and cold air can be replicated by using liquids (usually water) of different densities [4]. Because these liquids are opaque to infrared radiation, they allow us to understand the physics of individual buoyant elements, and lead to the development of closed analytical solutions describing room airflow and temperature. However, it is often overlooked

*Corresponding author.
Email address: alejandra@alum.mit.edu (M. Alejandra Menchaca-Brandan)