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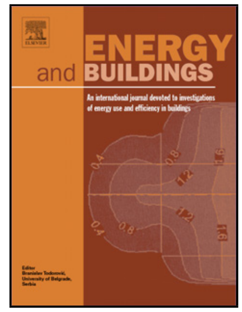

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Author: D. Frank P.F. Linden

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The effects of an opposing buoyancy force on the performance of an air curtain in the doorway of a building

D. Frank, P. F. Linden

Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Wilberforce Road, CB3 0WA Cambridge, United Kingdom

Abstract

We investigate the effects of an opposing buoyancy force on the performance of an air curtain in the doorway which separates a warm indoor environment from the cold exterior. Such an opposing buoyancy force arises for example if a downwards blowing air curtain is heated. We conducted small-scale experiments using water, salt and sugar solutions as the working fluids. The effectiveness curve of a downwards blowing air curtain as a function of the deflection modulus was measured for situations in which the initial density of the air curtain was less than both the indoor and the outdoor fluid density, which corresponds to the case of a heated curtain. It was found that the effectiveness of the air curtain starts to decrease if it is heated beyond a critical temperature. We also discuss the question whether it is more energy efficient to use a heated air curtain or an air curtain operating at room temperature. Based on our experimental results we conclude that a heated air curtain is likely to be less energy-efficient. Further, we propose a theoretical model to describe the dynamics of the buoyant air curtain. Numerical results obtained from solving this model corroborate our experimental findings.

Keywords:
air curtains, planar fountains, heat transfer

1. Introduction

Air curtains are commonly used as virtual barriers in doorways separating two different environments. Examples include public buildings with high human traffic such as shops or hotels, cold stores, industrial premises and hospitals. An air curtain can considerably reduce the mass, heat, moisture or particle exchange between two adjacent spaces without impeding the traffic through the doorway.

The design of air curtains is as versatile as the installation sites at which they are deployed [1]. An air curtain can be directed either vertically or horizontally, it can consist of one or multiple jets, the primary air supply may be drawn from inside or outside or even additionally heated or cooled, and the air curtain may be inclined or designed as a recirculatory system with a return grill at the opposite side of the door frame. However, regardless of the specific details, the basic operating principle of air curtains is always the same. A high-velocity plane jet is discharged from a thin nozzle located on one side of the door frame. The planar jet is usually subjected to transversal forces which are most commonly due to either the stack effect resulting from a temperature difference across the doorway or the wind pressure. As the jet travels across the opening, it entrains fluid from both sides of the doorway, mixes it to a certain degree and then spills the fluid back again when it impinges on the opposite site of the doorframe. This process is commonly known as the entrainment-spill mechanism of the air curtain [2, 3].

The basic idea of the aerodynamical sealing dates back to the beginning of the 20th century [2, 4]. However, air curtains grew in popularity only in the last 50 years with the raising awareness for thermal comfort, energy saving and, more recently, climate change. The first systematic studies on the sealing ability of air curtains were carried out in 1960s. Based on full-scale experimental results, Hayes and Stoecker [2, 5] presented a fundamental discussion of the air curtain stability. An air curtain is called stable if it reaches the opposite side of the doorway and impinges on it. In contrast, the air curtain is said to be unstable and to break through if it is deflected too much out of the plane of the door frame by the lateral pressure difference until it discharges hor-

Email address: D.Frank@damtp.cam.ac.uk (D. Frank)