Air Curtains as Alternatives to Vestibules

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This article describes the function and benefits of air curtains. It presents results from a recent study on the energy performance of air curtains relative to vestibules and provides useful information for engineers and code officials.

HOW AIR CURTAINS WORK

An air curtain installed on the interior of a building creates a coherent sheet of air composed of the air curtain discharge and the surrounding entrained air. This sheet of air stabilizes when it meets a return grill or splits at a surface, such as a floor or another opposing air stream. When this stability combines with the building's interior pressure, it resists and reduces thermal exchange over an opening in the building envelope.

The air curtain is not intended to replace a physical door, but may be used as a low-cost, low-maintenance alternative to a vestibule, when appropriate. This would save valuable floor space and create an invisible, energy-saving barrier that reduces infiltration when the door is open.

The most common types of controls are switches triggered by the door, or motion sensors that are triggered by people approaching the door.

BENEFITS OF AIR CURTAINS

Approved as an alternative to vestibules in the 2015 *International Energy Conservation Code* (IECC) and the 2015 *International Green Construction Code*® (IgCC), air curtains make egress in an emergency exit situation safer and faster by providing clear, uninhibited flow to the traffic passing through it, while still saving energy during heating and cooling seasons. This is in contrast to a vestibule where the user would need to pass through two sets of doors instead of one with an air curtain.

An additional benefit of using an air curtain is a cleaner indoor air environment. It can limit infiltration of dirt, fumes and debris and repel flying insects. As recognized by ANSI/NSF Standard 37: *Air Curtains for Entranceways in Food and Food Service Establishments*, they are approved for the food service industry to control flying insects at customer entry doors, service windows and delivery doors.

Numerous studies have validated the effectiveness of air curtains with regard to energy savings at building entrances, among other areas. When these studies were compared to vestibules, air curtains consistently matched or outperformed them in energy savings. Recent studies take advantage of modern technology to evaluate the air curtains' efficiencies and effectiveness, while considering installation, operating and maintenance costs.

Labeling programs, such as the AMCA Certification Seal, can provide assurance of product performance and a simple way to visibly enforce compliance to the codes.

HOW THE AIR CURTAIN WAS MODELED

Because laboratory testing methods for an entire building are impractical, modeling approaches are regularly used instead. For example, computational fluid dynamics (CFD) software and building simulation models can examine whole building energy usage at hourly intervals during an entire year for multiple climate zones.

The most recent air curtain study, *Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use*[1], was conducted by Liangzhu Wang, Ph.D., assistant professor at the Department of Building, Civil and Environmental Engineering of Concordia University, Montreal, Canada. Dr. Wang compared the energy performance of an air curtain mounted over a single-entry door versus a vestibule using an integration of three types of modeling software.

Using ANSYS Fluent CFD software, Dr. Wang found an air curtain reduced air infiltration significantly across a building entrance door under various pressure conditions. The entire building annual energy usage then was determined using TRNSYS energy modeling software and CONTAM software for modeling building air pressure and infiltration. The results verified the air curtain allowed less infiltration than a vestibule for a given building. The study found that in all of the climate zones where the IECC currently requires vestibules, an air curtain was equally effective or better at energy savings.

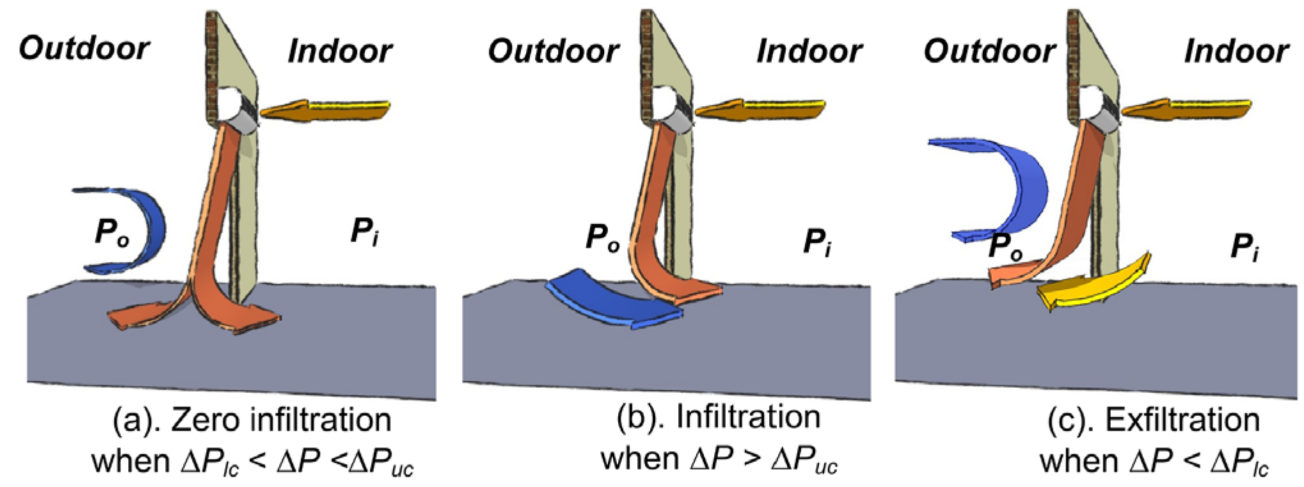

Figure 1: Infiltration/exfiltration characteristics of an air curtain jet under different pressure differences, $\Delta P = P_o - P_i$ (Note the zero infiltration does not apply to the air recirculating through the air curtain).

Two steps were necessary to model the air curtain in a whole-building simulation. First, three door setups were used to determine the amount of air infiltration through building entrance:

1. Single door without vestibule or air curtain (hereafter, a single door)
2. Single door equipped with air curtain (hereafter, an air curtain door)
3. A vestibule with two sets of doors (hereafter, a vestibule door)

Second, determine the impact of air infiltrations on the whole building and annual energy use for the three different door setups.

Infiltration through the single door and vestibule door setups were calculated by a commonly used orifice equation model, which considers the amount of infiltration to depend linearly on a power law function of the pressure difference across the door. Yuill (1996)[2] conducted extensive experimental studies to provide the orifice equation models for both single and vestibule doors based on door usage frequency, geometry and pressure difference across a door. The infiltration model for the air curtain door was determined using the similar method as Yuill's study, in conjunction with the multi-model CFD program described above.

FINDINGS

For the modeled DOE[3] medium office building, the major conclusions demonstrated the annual energy use of the whole building with the air curtain installed is less in all of the climate zones. Energy use is less than the single door in Climate Zones 1-3 and less than the vestibule door in Climate Zones 3-8.

Additionally, the modeled air curtain door reduces air infiltration significantly under the same conditions when compared to either the single door or the vestibule door.

The modeled air curtain door also provided comparable performance to the modeled vestibule door for climate Zones 3–8. Compared to the vestibule door, the air curtain door can reduce energy use by 0.3 percent to 2.2 percent for Zones 3-8, corresponding to 1,146 kWh – 18,986 kWh in energy savings, with greater performance achieved in colder climate zones.

The study illustrated heating efficiency accounted for the air curtain door's major savings. As no changes were made to the operating characteristics of the air curtain, total savings in Zones 1 and 2 were marginal, or 0.0 percent – 0.1 percent (81 kWh ~ 132 kWh) when compared to the single door.

The study also found building entrance orientation, building pressure and frequency of door usage affect air infiltration/exfiltration, and the resultant energy performance of the air curtain door. In particular, the effects of building entrance orientation and the balance of the HVAC system were shown to be as important as door usage frequency. BSJO

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[1] Wang, Liangzhu 2013: Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use.
[2] Yuill, G.K. 1996. Impact of High Use Automatic Doors on Infiltration. Project 763 TRP, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta, Georgia.
[3] Cho, H., K. Gowri and B. Liu. 2010. Energy saving impact of ASHRAE 90.1 vestibule requirements: modeling of air infiltration through door openings. Oak Ridge, Tennessee, Pacific Northwest National Laboratory: 47.

Code Development

This research has led to the addition of air curtain language in both the IECC and IgCC.

2015 IECC

Section C202 General Definitions

Air Curtain: A device, installed at the building entrance that generates and discharges a laminar air stream intended to prevent the infiltration of external, unconditioned air into the conditioned spaces, or the loss of interior, conditioned air to the outside.

Section C402.5.7 Vestibules. Building entrances shall be protected with an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule, it is not necessary for the interior and exterior doors to open at the same time. The installation of one or more revolving doors in the building entrance shall not eliminate the requirement that a vestibule be provided on any doors adjacent to revolving doors.

Exceptions: Vestibules are not required for the following:

1. Buildings in *Climate Zones* 1 and 2.
2. Doors not intended to be used by the public, such as doors to mechanical or electrical equipment rooms, or intended solely for employee use.
3. Doors opening directly from a sleeping unit or dwelling unit.
4. Doors that open directly from a space less than 3,000 square feet (298 m^2) in area.
5. Revolving doors.
6. Doors that have an air curtain with a velocity of not less than 6.56 feet per second (2 m/s) at the floor that have been tested in accordance with ANSI/AMCA 220 and installed in accordance with the manufacturer's instructions. Manual or automatic controls shall be provided that will operate the air curtain with the opening and closing of the door. Air curtains and their controls shall comply with Section C408.2.3.

2015 IGCC

The 2015 IgCC has the same definition, and because it is an overlay code, has language that harmonizes with the IECC.

605.1.2.3 Where air curtains are provided at building entrances or building entrance vestibules, the curtain shall have a minimum velocity of 2 m/s at the floor, be tested in accordance with ANSI/AMCA 220 and installed in accordance with manufacturer's instructions. Manual or automatic controls shall be provided that will operate the air curtain with the opening and closing of the door. Air curtains and their controls shall comply with Section C408.2.3 of the *International Energy Conservation Code*.

These code provisions require that when an air curtain is used, it must be tested to the appropriate standard (AMCA 220), installed properly and function as intended.