Energy Savings in Buildings through Integrated Air Curtain Design
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Fax
Air curtains
Fan heaters
Convectors
Radiant heating
Why Air Curtains?

Without the air curtain, outdoor air affects the indoor climate.
Why Air Curtains?

Source: Malmö University
Why Air Curtains?

An air curtain with optimized air stream efficiently protects the entrance from the outdoor climate.
Why Air Curtains?

Source: Malmö University
Problems with open doors
The solution
Efficiency of Air curtains
Selection of air curtain

Tests are showing that a correct installed air curtain significantly can reduce the energy losses in an open door

• Ghent University ’Study of air curtains used to restrict infiltration into refrigerated rooms’, 2009
• Purdue University ’Application of Air Curtains in Refrigerated Chambers’, 2008
• SP Swedish National Testing and Research Institute ’Investigation of industrial gateways – evaluation of energy losses and the function of air curtains’, 2005:08
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A correct installed air curtain…

How to judge which air curtain is suitable for a specific opening?

- Size of opening (width and height)
- Loads

\[
Q_T = \frac{W \cdot H^{1.5}}{3} \cdot \mu_0 \cdot \sqrt{\frac{g \cdot \Delta \rho}{\rho_m}} \quad [\text{m}^3/\text{s}]
\]

\[Q_w = W \cdot H \cdot \frac{\nu_{10}}{2} \cdot 0.25 \cdot L \quad [\text{m}^3/\text{s}]
\]

\[Q_p = W \cdot H \cdot \sqrt{\frac{\Delta P \cdot 2}{\rho_{out}}} \cdot 0.8 \quad [\text{m}^3/\text{s}]
\]

Where:
- \(W\) = Width of the door \([\text{m}]\)
- \(H\) = Height of the door \([\text{m}]\)
- \(\Delta \rho\) = Density difference \([\text{kg/m}^3]\)
- \(\rho_m\) = Average density of the cold air \([\text{kg/m}^3]\)
- \(\nu_{10}\) = Average wind speed at 10 m elevation \([\text{m/s}]\)
- \(L\) = Position factor \([\text{m}]\)
- \(\Delta P\) = Pressure difference \([\text{Pa}]\)

Open door:
- How often?
- How long time?

Difference in air temperature

Wind
- Pressure difference
- Ventilation
- Building design
Losses in MWh per year through open doors

- Losses [MWh/yr]

- Opening width [m]

- Opening height [m]

Industrial building/warehouse
Year mean temperature: 6,5°C
Year mean wind speed: 4 m/s
Door open 1h/day
Parameters that affects the energy losses through the entrance

- Temperature
- Density
- Pressure
- Humidity
- Door Size
- Wind
- Opening time/ frequency
- Stack effect
Efficiency of Air curtains
Selection of air curtain

A correct installed air curtain…

How to judge which air curtain is suitable for a specific opening?

- Size of opening (width and height)
- Loads

Selection of air curtain based on the performance of air volume $[m^3/h]$, installation height and building design.

Power of the air barrier (impulse):
- volume $\times$ velocity $\times$ density $[kg \times m/s^2 = Newton]$
Efficiency of Air curtains
Selection of air curtain

A correct installed air curtain…

How to judge which air curtain is suitable for a specific opening?

- Size of opening (width and height)
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Selection of air curtain based on the performance of **air volume** \([m^3/h]\), installation height and building design.

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**Table 7. Examples of specific air flow rates** \(q_0\) **in m^3/h per metre of door width**, for single-stream air curtains, as a function of the door height:

<table>
<thead>
<tr>
<th>Door height, in m</th>
<th>2.2</th>
<th>2.5</th>
<th>2.7</th>
<th>3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of blow-out port, in m</td>
<td>2.3</td>
<td>3.0</td>
<td>3.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Door with draught lobby or rarely used door</td>
<td>1200</td>
<td>1500</td>
<td>2000</td>
<td>2700</td>
</tr>
<tr>
<td>Door without draught lobby, not permanently open</td>
<td>1900</td>
<td>2500</td>
<td>3000</td>
<td>3400</td>
</tr>
<tr>
<td>Door without draught lobby, occasionally to permanently open, normal building orientation(^a)</td>
<td>2700</td>
<td>3200</td>
<td>3600</td>
<td>3800</td>
</tr>
</tbody>
</table>

\(^a\) wind exposure at site as per DIN EN 12831

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*German norm; VDI 2082 - 2010*
Efficiency of Air curtains
Selection of air curtain

A correct installed air curtain…
How to judge which air curtain is suitable for a specific opening?
- Size of opening (width and height)
- Loads

Selection of air curtain based on the performance of air volume \([\text{m}^3/\text{h}]\), installation height and building design.

- Will all air curtains with the same air volume give the same protection?
  - No!

- Why not?

Power of the air barrier (impulse);
- \text{volume} \times \text{velocity} \times \text{density} \quad [\text{kg} \times \text{m/s}^2 = \text{Newton}]

Air volume at the outlet of the air curtain!
A correct installed air curtain…

How to judge which air curtain is suitable for a specific opening?
- Size of opening (width and height)
- Loads
  - The load/stress is largest at the floor level!
  - A better criteria would be to compare the power of the air barrier at floor level!

Power of the air barrier (impulse);
- volume x velocity x density
  [kg x m/s² = Newton]
Efficiency of Air curtains
Selection of air curtain

A correct installed air curtain…

How to judge which air curtain is suitable for a specific opening?

- Size of opening (width and height)
- Loads

- The load/stress is largest at the floor level!
- A better criteria would be to compare the power of the air barrier at floor level!

- Will air curtains with the same velocity at floor level give the same protection!?
  - **YES, to a great extent!**

The power of the air barrier (impulse):
- Volume x **velocity** x density
  \[ \text{[kg} \times \text{m/s}^2 = \text{Newton}] \]
Efficiency of Air curtains
Selection of air curtain

A correct installed air curtain…

How to judge which air curtain is suitable for a specific opening?
- Size of opening (width and height)
- Loads

How to measure the velocity?
A correct installed air curtain…

How to judge which air curtain is suitable for a specific opening?

- Size of opening (width and height)
- Loads

Which velocity at floor level?

Low velocity - Weak protection
High velocity - Creates turbulence, weak protection
Correct velocity - Good protection
**Efficiency of Air curtains**

**Selection of air curtain**

A correct installed air curtain…

How to judge which air curtain is suitable for a specific opening?

- Size of opening (width and height)
- Loads

Which velocity at floor level?

The load is increasing with a bigger opening, which requires a more powerful air barrier!

Frico experience of a suitable velocity at floor level…

![Diagram showing power of air barrier and load](Image)

- Low velocity - Weak protection
- High velocity - Creates turbulence, weak protection
- Correct velocity - Good protection

* ±0,5m/s

*4m/s*

*3m/s*

*2,5m/s*
Throw length of the air barrier is more important than air volume!

Air speed is measured according to ISO 27327-1 (AMCA 220)
The efficiency of air curtains with the same air volume can be compared by measuring the throw length.

Example;
Efficiency of Air curtains
Thermozone technology

Frico experience;
Throw length of air beam is created by correct size of air outlet.
Efficiency of Air curtains
Thermozone technology

Frico experience;
Throw length of air beam is created by correct design of air outlet.
Efficiency of Air curtains
Thermozone technology

Theoretical test; CFD analysis at 1800m³/h

Considerable difference in performance
Efficiency of Air curtains
Thermozone technology

Practical test; at 2000m³/h

Considerable difference in performance

Installation height

~3m/s
Comparing throw length and strength of the air barrier with a ‘wind-board’

The angle $X$ of the ”wind board” indicates the strength/efficiency of the air barrier.

The power of the air barrier (impulse); volume $\times$ velocity $\times$ density $[\text{kg} \times \text{m/s}^2 = \text{Newton}]$
Efficiency of Air curtains
Comparing the efficiency between different air curtains

Comparing throw length and strength of the air barrier with a ‘wind-board’

The power of the air barrier (impulse); volume x velocity x density $[\text{kg} \times \text{m/s}^2 = \text{Newton}]$
Efficiency of Air curtains
Comparing the efficiency between different air curtains

Comparing throw length and strength of the air barrier with a 'wind-board'
- Head to head competition!

The power of the air barrier (impulse): volume x velocity x density \[ \text{[kg x m/s}^2\text{]} = \text{Newton} \]
Efficiency of Air curtains
Comparing the efficiency between different air curtains

Competitor Y
2550m³/h

PA3515WL
2600m³/h

The power of the air barrier (impulse): volume x velocity x density [kg x m/s² = Newton]
Efficiency of Air curtains
Comparing the efficiency between different air curtains

Competitor Y
2900 m³/h

10% lower air volume!
PA3515WL
2600 m³/h

The power of the air barrier (impulse); volume x velocity x density [kg x m/s² = Newton]
Conclusion – efficiency of air curtains

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Conclusion – efficiency of air curtains

Frico experience;
The velocity of the air beam at floor level is as important as the air volume of the air curtain.
The efficiency of air curtains with the same air volume can be compared by measuring the throw length of the air beam.

Example;
Conclusion – efficiency of air curtains

The air velocity profile is measured according to ISO 27327-1
The air velocity profile is measured according to ISO 27327-1

The load is increasing with a bigger opening, which requires a more powerful air barrier!

Frico experience of a suitable velocity at floor level…

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**Power of air barrier**

- 4m/s*
- 3m/s*
- 2,5m/s*

* ±0,5m/s

**Size of opening**

- Entrance ≤2,5m
- Commercial 2,5m-4,2m
- Industry >4,2m

**Load**
The air velocity profile is measured according to ISO 27327-1

Note! When a door/opening is exposed to wind and other loads, the velocity at floor level will be lower than what is stated according to the ISO 27327-1

The load is increasing with a bigger opening, which requires a more powerful air barrier!

Frico experience of a suitable velocity at floor level…

Conclusion – efficiency of air curtains

- Power of air barrier
- Load
- * ±0,5m/s
- 4m/s*
- 3m/s*
- 2,5m/s*

* Size of opening
  - Entrance ≤2,5m
  - Commercial 2,5m-4,2m
  - Industry >4,2m
Conclusion – efficiency of air curtains

The air velocity profile is measured according to ISO 27327-1

Note! When a door/opening is exposed to wind and other loads, the velocity at floor level will be lower than what is stated according to the ISO 27327-1

Changes in wind and other loads will be handled with the control system.
Conclusion – efficiency of air curtains
Specifications in the future…

Today;
…air curtain with a performance of 2500m³/h per meter unit…

Tomorrow;
…air curtain with a performance of 2500m³/h per meter unit and a speed of the air beam of 3m/s at a distance of 3m from the outlet of the air curtain, measured according to ISO27327-1…
AMCA study; Air Curtains vs Vestibules

350 CFD simulations covering:
- Different climate zones
  - Temperature differences
- Different ventilation scenarios
  - Neutral building pressure
  - Negative building pressure
  - Positive building pressure
- Wind loads
- Number of people passing by
Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use

L. Wang

Executive Summary

BACKGROUND

The U.S. was reported to consume 19% of the global energy in 2011, and the building sector (residential, commercial, and government buildings) accounted for about 41% of the primary energy usage. The top four end uses of the building sector are space heating (37%), space cooling (18%), water heating (12%), and lighting (9%), which sum up to about 70% of the buildings site energy consumption. For commercial buildings, air infiltrations can be as high as 18% of the total heat loss. Air infiltrations (or air leakages) are often caused by unintentional or accidental introduction of outside air into a building through cracks in the building envelope and/or entrance doors. Infiltrations through door openings become quite significant when the doors are used frequently such as in restaurants, retail stores, supermarkets, offices and hospitals (DOE 2012).

A common energy code solution to reducing energy loss from air infiltration through open doors has been requiring a vestibule rather than having a single door. Currently based on the American Society of Heating, Refrigerating and Air Conditioning Engineers Standard 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings (ASHRAE 2010), and the International Energy Conservation Code (IECC), in most cases, vestibules are required in climate zones 3 – 8. However, vestibules seem not to cater to building owners’ taste due to the concerns over space and construction cost. A vestibule could cost anywhere from $20,000 to $60,000. In addition, a vestibule becomes ineffective when both entrance doors open simultaneously during heavy traffic periods so as to allow cold outdoor air to penetrate.

Air curtains, which are typically mounted above doorways, separate indoor and outdoor temperatures with a stream of air strategically engineered to strike the floor with a particular velocity and position. The air prevents cold air from entering when a door is open. When an unheated pedestrian entrance is open, air curtains are often less than $6,000 plus installation costs. It also helps to block flying insects, dust, wind, cold/warm, and ambient moisture to achieve a better indoor comfort. Furthermore, building entrances equipped with air curtains are believed to be more energy efficient than the entrances with single doors and with vestibules as well. However, an exhaustive literature search revealed that no previous studies to quantify the impact of building entrance air curtains on whole building energy usage.

OBJECTIVE

The objective of this study is to decide if air curtains can be considered comparable in energy performance to that of buildings with vestibules where they are required by building energy codes and standards in climate zones 3 – 8 by means of whole building annual energy simulations and computational fluid dynamics (CFD) modeling of air curtains. For the climate zones 1 and 2, where vestibules are not required by the codes, this study will also quantify the potential energy savings of air curtains compared to the baseline case of the building entrance without air curtain or vestibule.

METHODOLOGY

To achieve the objective, two major tasks were carried out:

- Determination of the amount of air infiltration through building entrance for different door setups: a single door with a vestibule (hereafter, a vestibule door), a single door with an air curtain (hereafter, an air curtain door or an air curtain means an air curtain applied to a single door), or a single door without either of them (a single door).
- Determination of the impact of infiltrations on the whole building annual energy use for different door setups.

Air infiltrations through a single door and a vestibule door can be determined 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 (1990) conducted extensive experimental studies to provide the orifice equation models for both single and vestibule doors based on door usage frequency, geometry, and pressure

Executive Summary
AMCA study; Air Curtains vs Vestibules

Automatic door; Width - 2m; Height - 2,4m

Annual infiltration reduction with balanced (100%) and unbalanced (95% & 90%) ventilation systems

<table>
<thead>
<tr>
<th>Systems</th>
<th>100% Supply</th>
<th>95% Supply</th>
<th>90% Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Min / Max Pressure Difference $\Delta P$ (Pa)</td>
<td>0.8 / 9.4 / 27.4</td>
<td>1.3 / 7.0 / 29.6</td>
<td>1.8 / 8.5 / 31.5</td>
</tr>
<tr>
<td>Annual Infiltration Reduction (%)</td>
<td>Vestibule</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Air Curtain</td>
<td>62</td>
<td>65</td>
</tr>
</tbody>
</table>

Correctly installed Air Curtain gives;

- Reduction of airflow speed over door opening compared to Single door
- Reduction of airflow speed over door opening compared to Vestibule construction
- Increase of airflow speed over door opening compared to Vestibule construction
- Increase of airflow speed over door opening compared to Single door
## Online Selection Guide

### Basic criteria

<table>
<thead>
<tr>
<th>Installation dimensions</th>
<th>Mounting method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Installation height</strong></td>
<td>Horizontal: Standard, Recessed in the, Blow from below, Revolving door</td>
</tr>
<tr>
<td>2.4 m</td>
<td>Vertical: Standard, Revolving door</td>
</tr>
<tr>
<td><strong>Installation width</strong></td>
<td></td>
</tr>
<tr>
<td>3.0 m</td>
<td></td>
</tr>
</tbody>
</table>

### Application type

- Small openings
- Entrance
- Industry
- Cold room

### Heating method

- Water
- Electricity
- No heating

### Casing color

- White
- Stainless

### Advanced criteria

<table>
<thead>
<tr>
<th>Building type</th>
<th>Wind attack</th>
<th>Door opening interval</th>
<th>Entrance type</th>
<th>Design outdoor temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small, single storey building, e.g. Kiosk, cold room, gas station</td>
<td>Entrance under the lee of the building, No influence</td>
<td>Door always open, Opened only during passage</td>
<td>With airlock, Without airlock</td>
<td>Below -15 °C, Between -15 and -5 °C, Between -5 and 5 °C, Above 5 °C</td>
</tr>
</tbody>
</table>
Selection guide, output calculations, articles, printed material, animations, product information …
Thank you for your attention!