Energy Savings in Buildings through Integrated Air Curtain Design

Adam Balogh
International Area Manager

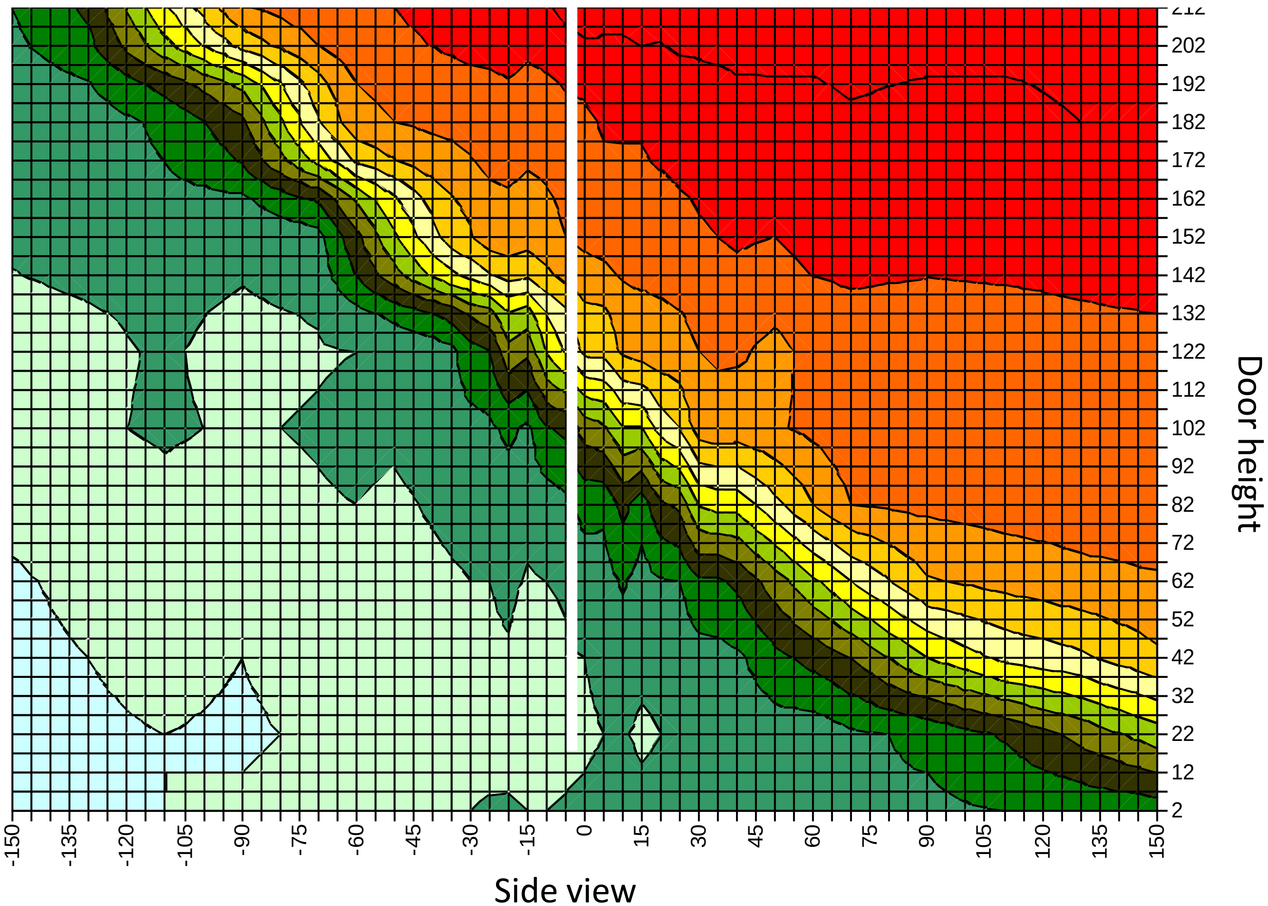
Direct + 46 31 336 86 41
Adam.balogh@frico.se

Frico AB, PO Box 102,
433 22 Partille
Phone +46 31 336 86 00
Fax +46 31 26 28 60
www.frico.se

Air curtains
Fan heaters
Convectors
Radiant heating

Why Air Curtains?

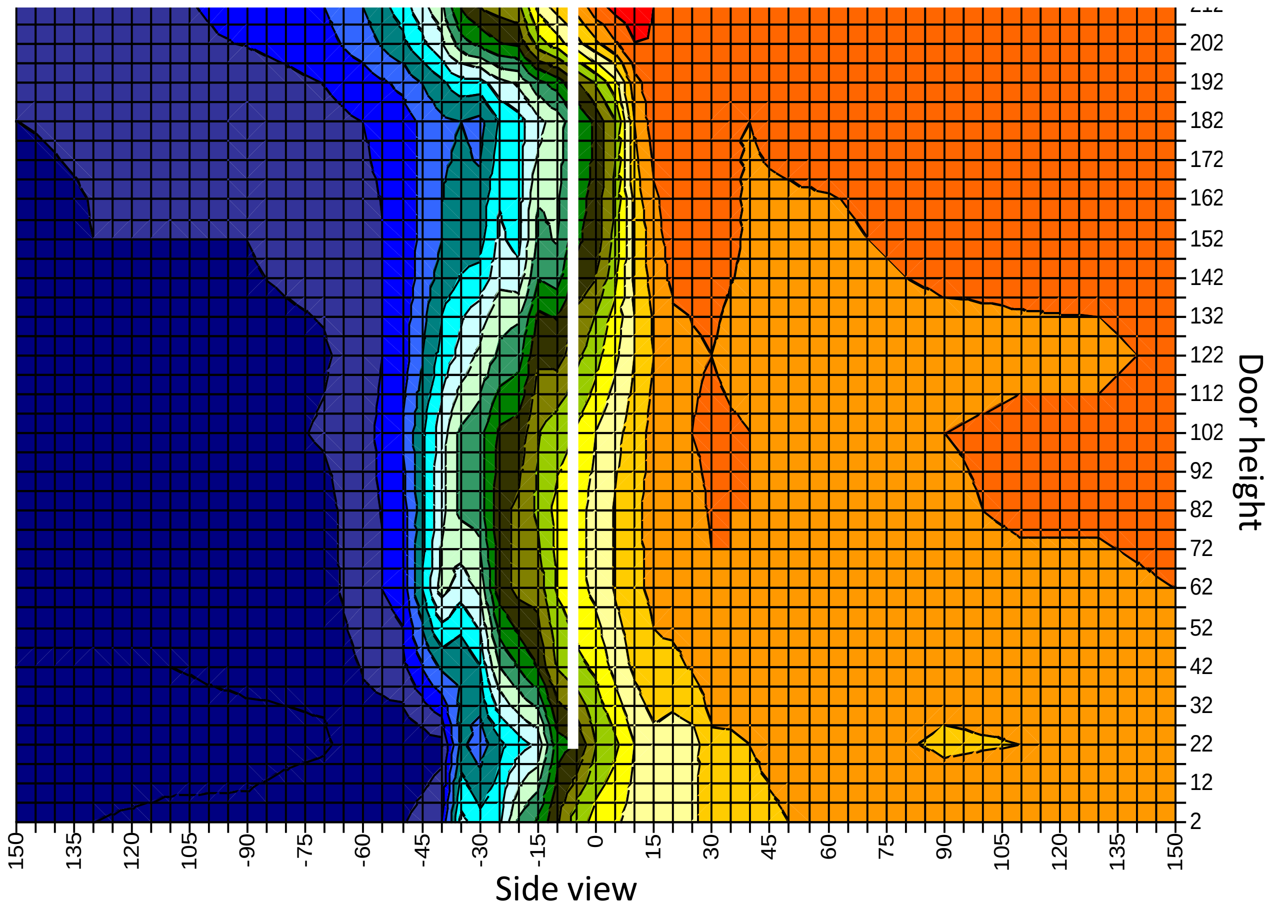
Why Air Curtains?



Source: Malmö University

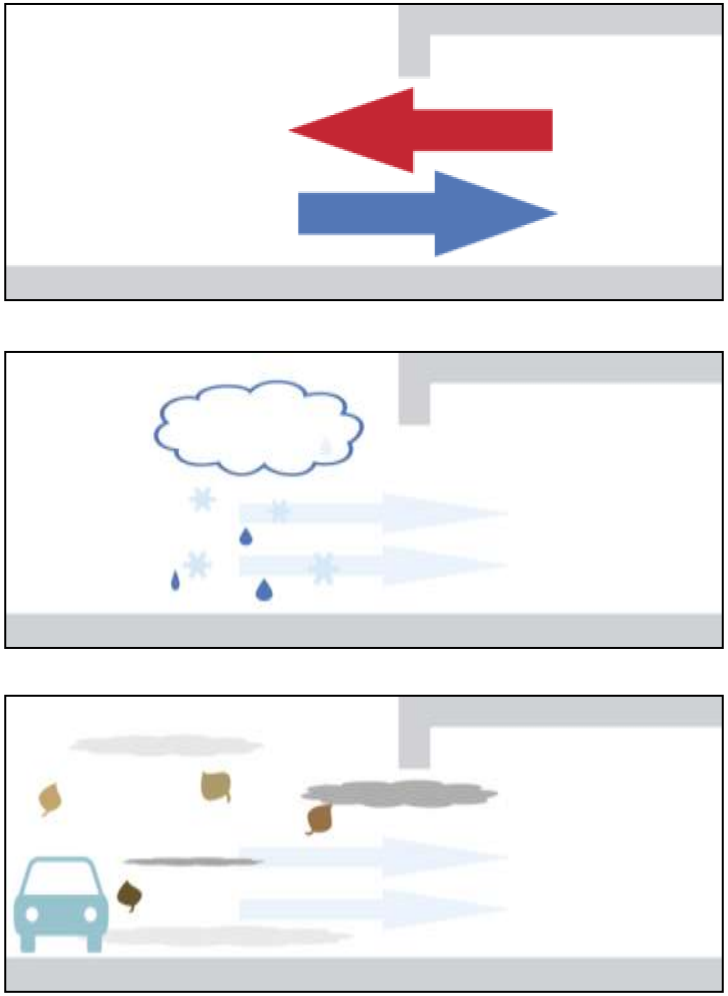
Why Air Curtains?

Why Air Curtains?

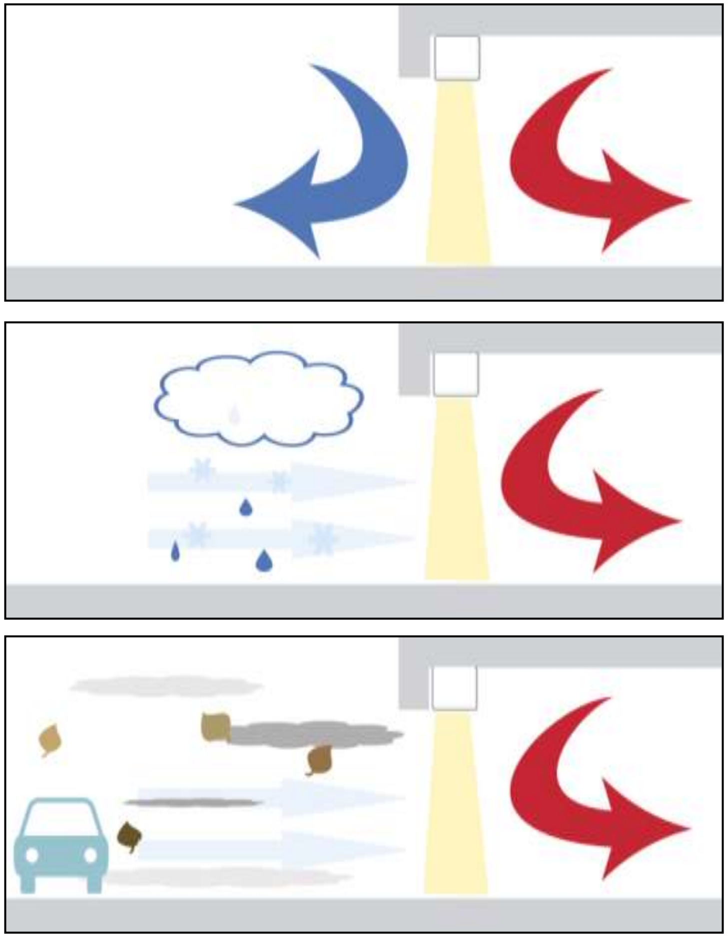


Source: Malmö University

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 inflitration 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
- London South Bank University and CIBSE ’Air curtains for saving energy in buildings’, 2007

Efficiency of Air curtains

Selection of air curtain

Ghent University 'Study of air curtains used to restrict infiltration into refrigerated rooms', 2009

STUDY OF AIR CURTAINS USED TO RESTRICT INFILTRATION INTO REFRIGERATED ROOMS

ABSTRACT

NOMENCLATURE

INTRODUCTION

REFERENCES

80%

Efficiency of Air curtains

Selection of air curtain

- Purdue University 'Application of Air Curtains in Refrigerated Chambers', 2008

Purdue University
Purdue e-Pubs

International Refrigeration and Air Conditioning Conference

School of Mechanical Engineering

2008

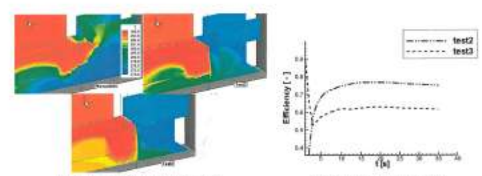
Application of Air Curtains in Refrigerated Chambers

results using different time steps are compared. The time steps considered are: $dt1 = 0.01s$, $dt2 = 0.05s$ and $dt3 = 0.1s$. No influence of the time step used in the simulation is observed. Therefore, results obtained using a time step $dt2 = 0.05s$ or $dt3 = 0.1s$ can be considered time independent.

Even though the study of the results presented by two or more turbulence models can not be considered as part of a verification procedure, actually it is important to compare the different results obtained if various turbulence models are used. Therefore, in this work IL ($k - \epsilon$) (Ince and Launder, 1989) and WXT ($k - \omega$) (Wilcox, 1993), two-equation linear eddy viscosity models, representative of $k - \epsilon$ and $k - \omega$ platforms, are applied to the same case (cases test1 and test3 in Table 1), in order to check the influence of the turbulent length scale determining variable on the final results. Thus, mean temperature and entrainment rate are compared for both IL and WXT models using the $N1$ grid and a $dt2 = 0.05s$ for the first 8s of simulation. The differences presented by the models are not significant, thus any of these models could be used. However, IL model is selected due to WXT model has presented convergence instabilities at the beginning of the simulation.

4.2 Influence of air curtain location.

In a first set of studies the analysis is centred in the influence of the side where the air curtain is placed. Furthermore, for comparison purposes, first a simulation of the situation without air curtain is done (case *no − curtain* Table 1), after that, the air curtain is placed in the cold side, behind the wall separating spaces (test3 Table 1), and finally the air curtain is located in front of the door, thus the suction is of warm air (test2 Table 1). A temperature comparison at time $t = 7.5s$ is presented in Figure 5(a). As it can be observed, without air curtain, warm air entries to the refrigerated space and fills almost completely its top part. However, when an air curtain is located in the cold side, it prevents warm air entering top part, but because of mixing process, warm air crosses the jet and contributes to increase temperature in the bottom part of the refrigerated space. Furthermore, when the air curtain is placed in the warm side, it brings warm air to the bottom part of the cold room, but it still remains colder than in the *test3* configuration.



(a) Temperature comparison at $t = 7.5s$. (b) Air curtain sealing efficiency.
Figure 5: Parametric study: influence of air curtain location.

In terms of sealing efficiency, air curtain reduces gains of the refrigerated space (see Figure 5(b)). Moreover, placing the air curtain in the exterior warm space seems to be the best option for long door opening periods. But, if the door is opened for very short time intervals, it is better to place the curtain in the cold side (major efficiency). A combination of both suctions would improve results. Finally, it is important to highlight that in both cases the air curtain reaches an almost constant value for the efficiency: for *test2* it is of 0.75 and for *test3* it is of 0.62.

75%

Efficiency of Air curtains

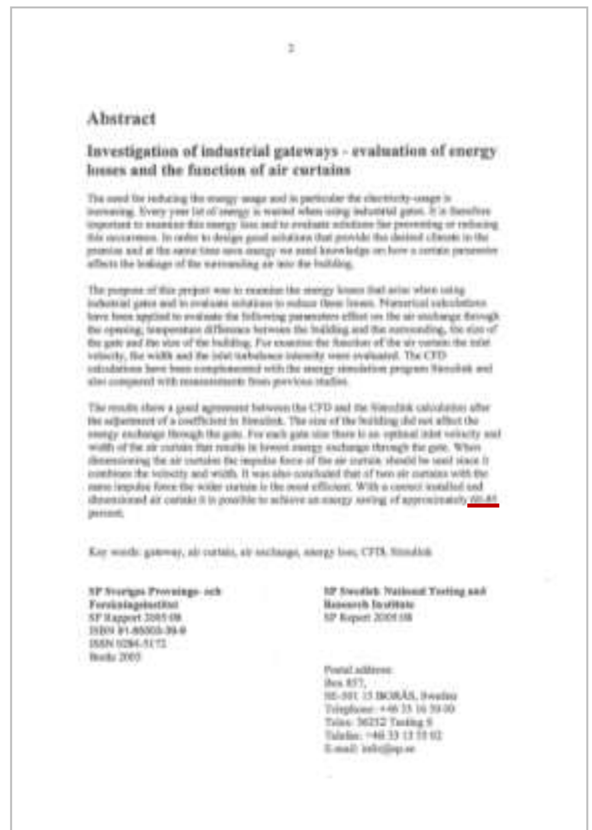
Selection of air curtain

- SP Swedish National Testing and Research Institute 'Investigation of industrial gateways – evaluation of energy losses and the function of air curtains', 2005:08

Tobias Törnström, Henrik Quicklund, Monica Axell

Utvärdering av industriportar –bedömning av energiförluster och luftridåers funktion

SP Sveriges Provnings- och Forskningsinstitut



Abstract

Investigation of industrial gateways - evaluation of energy losses and the function of air curtains

85%

Efficiency of Air curtains

Selection of air curtain

- London South Bank University and CIBSE 'Air curtains for saving energy in buildings', 2007


Air curtains for saving energy in buildings

Welcome to our regular series of CPD modules, designed to help you broaden your professional knowledge while you work. This module covers the use of air curtains to save energy in buildings and is sponsored by Biddle.

70%

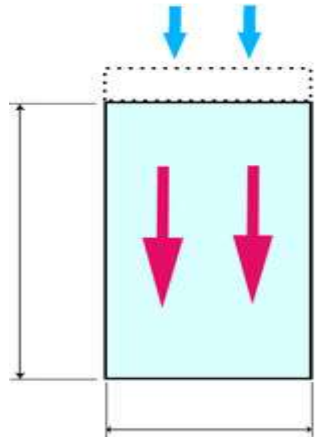
Efficiency of Air curtains

Selection of air curtain

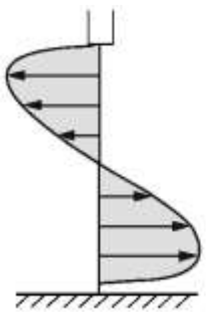
A correct installed air curtain…

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

- Size of opening (width and height)
- Loads



Q_T



$$Q_T = \frac{W \cdot H^{1,5}}{3} \cdot \mu_0 \cdot \sqrt{g \cdot \frac{\Delta\rho}{\rho_m}} \quad [m^3/s]$$

W = Width of the door [m]

H = Height of the door [m]

$\frac{\Delta\rho}{\rho_m}$ = Density difference [1]

$\Delta\rho = |\rho_{out} - \rho_{in}|$ [kg/m^3]

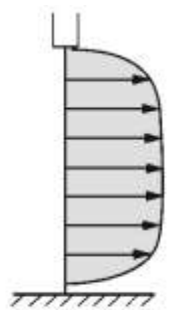
$\rho_m = \frac{(\rho_{out} + \rho_{in})}{2}$ [kg/m^3]

g = Gravity constant ($\approx$ 9,81) [m/s^2]

μ_0 = Flow coefficient (0,8 - 1,0) [1]

Difference in air temperature

$Q_W + Q_P$



$$Q_w = W \cdot H \cdot \frac{v_{10}}{2} \cdot 0{,}25 \cdot L \quad [m^3/s]$$

$$Q_P = W \cdot H \cdot \sqrt{\Delta P \frac{2}{\rho_{out}}} \cdot 0{,}8 \quad [m^3/s]$$

W = Width of the door [m]

H = Height of the door [m]

v_{10} = Average wind speed at 10 m elevation [m/s]

ρ_{out} = Density of the cold air [kg/m^3]

L = Position factor [1]

Exposed position: 1,2

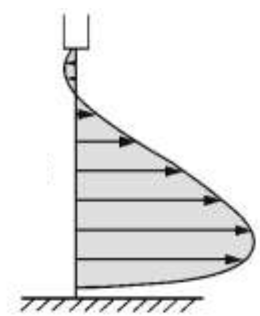
Normal position: 1,0

Sheltered position: 0,8

ΔP = Pressure difference $\leq$ 5 Pa ($\approx$ 3 m/s)

Wind
Pressure difference
- Ventilation
- Building design

$Q_{tot} = Q_T + Q_W + Q_P$



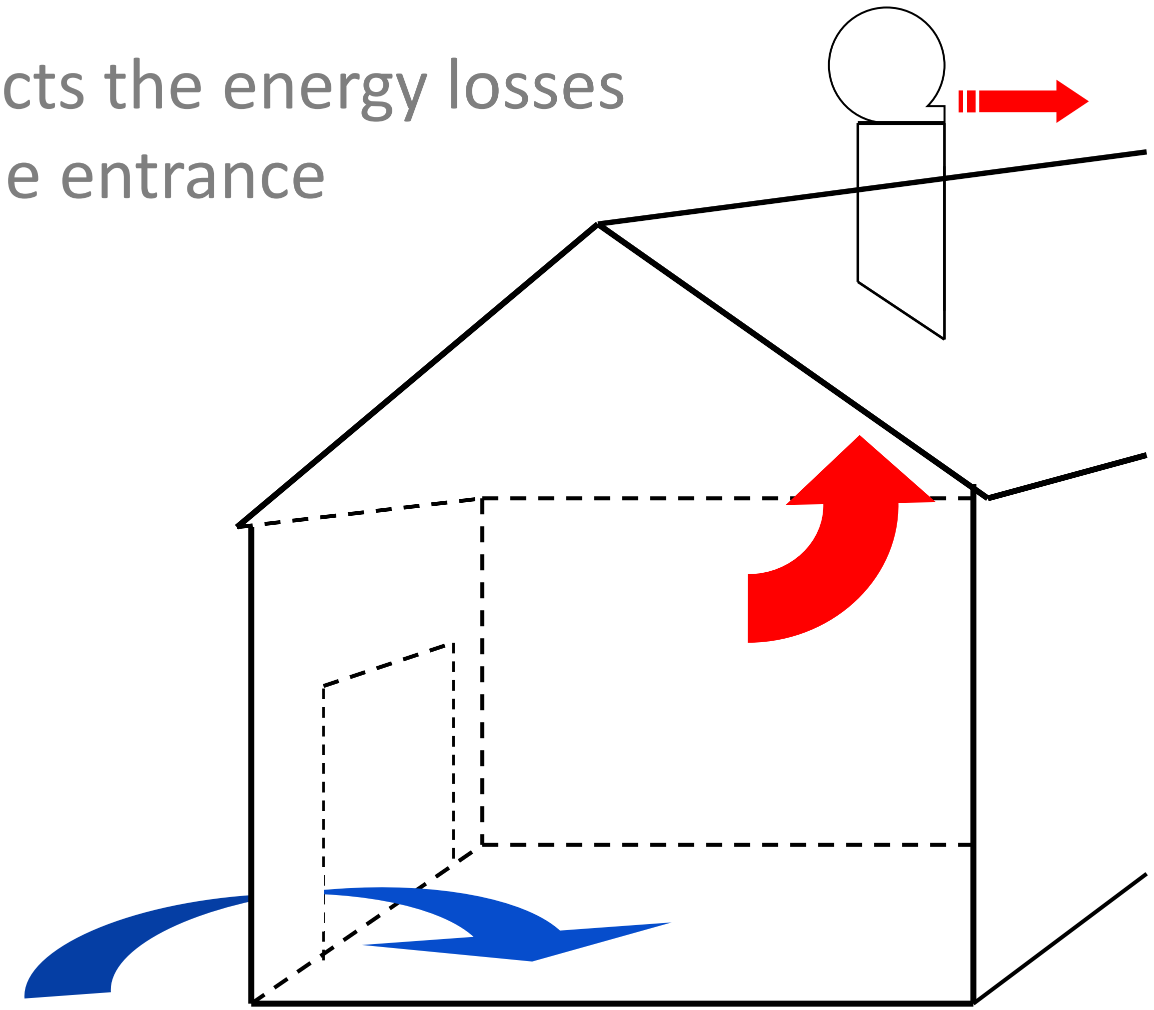
Open door
- How often?
- How long time?

Losses in MWh per year through open doors

Industrial building/warehouse
Year mean temperature: 6,5ºC
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** [m³/h], installation height and building design.

Air volume at the outlet of the air curtain!

Power of the air barrier (impulse);

- **volume** x velocity x density
  [kg x 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)
- Loads

Selection of air curtain based on the performance of **air volume** [m³/h], installation height and building design.

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

Door height, in m	2,2	2,5	2,7	3,0
Height of blow-out port, in m	2,5	3	3,5	4
Door with draught lobby or rarely used door	1200	1500	2300	2700
Door without draught lobby, not permanently open	1900	2500	3000	3400
Door without draught lobby, occasionally to permanently open, normal building orientation[a]	2700	3200	3600	3800
Entrance area of multi-storey sales outlets, or permanently open plus extreme building orientation[a]	3800	4000	—	—

[a] wind exposure at site as per DIN EN 12831


VDI-RICHTLINIEN

VEREIN DEUTSCHER INGENIEURE

Raumlufttechnik
Verkaufsstätten
(VDI-Lüftungsregeln)

Air conditioning
Sales outlets
(VDI ventilation code of practice)

VDI 2082

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** [m^3/h], installation height and building design.

- **Will all air curtains with the same air volume give the same protection?**

  - ***No!***

- **Why not?**

Air volume at the outlet of the air curtain!

Power of the air barrier (impulse);

- **volume** x velocity x density [kg x m/s^2= Newton]

Efficiency of Air curtains

Selection of air curtain

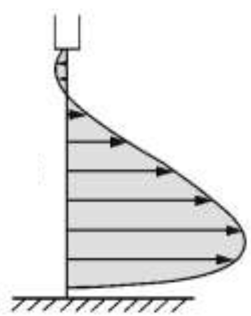
A correct installed air curtain…

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

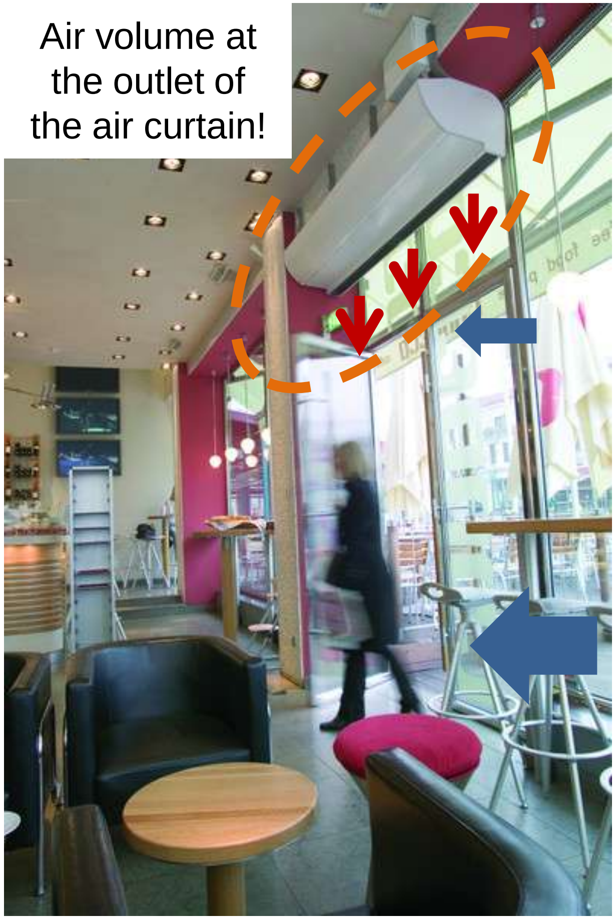
- Size of opening (width and height)
- Loads

- 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!



Air volume at the outlet of the air curtain!



Power of the air barrier (impulse);

- **volume** x velocity x density
  [kg x m/s^2= Newton]

Efficiency of Air curtains

Selection of air curtain

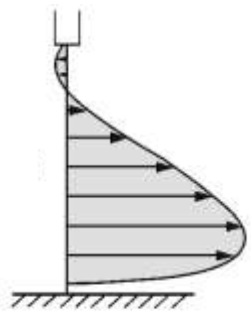
A correct installed air curtain…

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

- Size of opening (width and height)
- 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
  [kg x m/s^2= Newton]

Efficiency of Air curtains

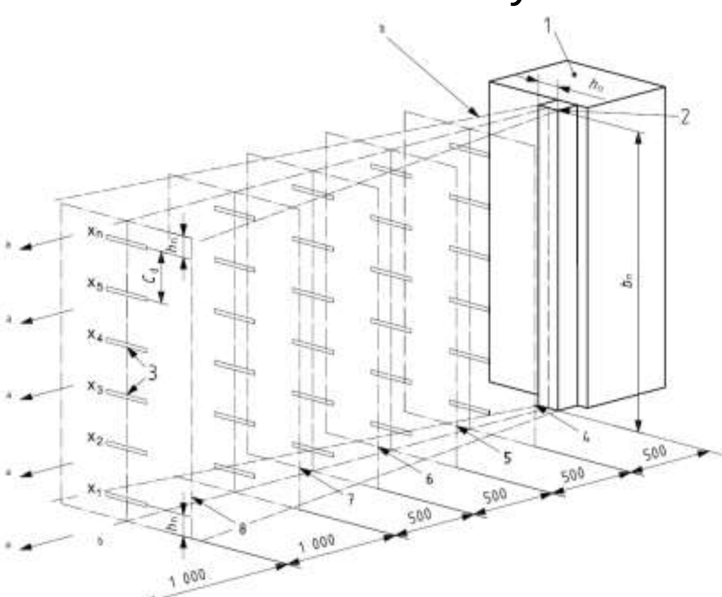
Selection of air curtain

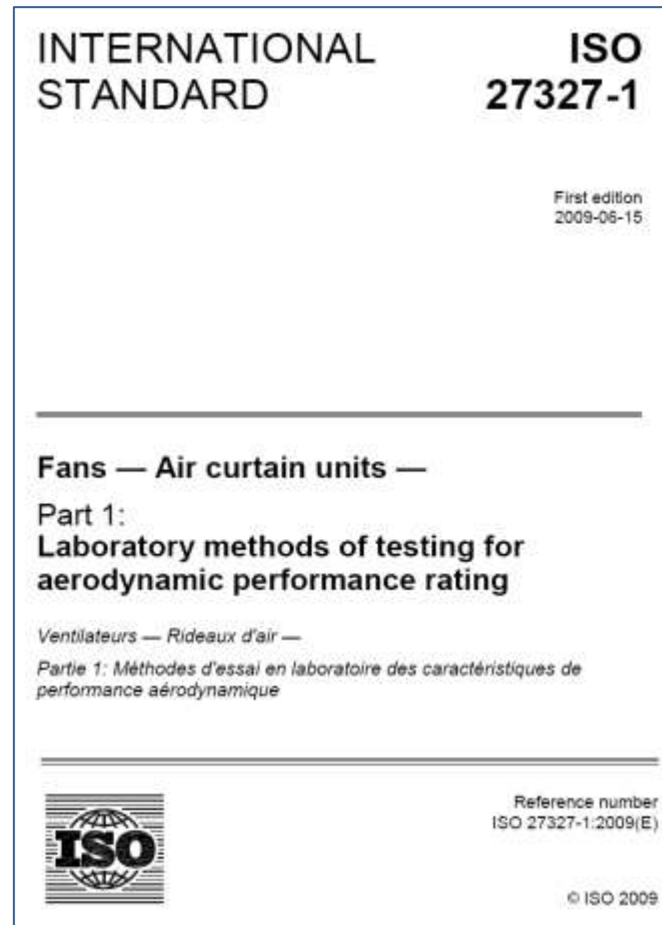
A correct installed air curtain…

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

- Size of opening (width and height)
- Loads

How to measure the velocity?





INTERNATIONAL STANDARD

ISO 27327-1

First edition
2009-06-15

Fans — Air curtain units —

Part 1:
Laboratory methods of testing for aerodynamic performance rating

Ventilateurs — Rideaux d'air —

Partie 1: Méthodes d'essai en laboratoire des caractéristiques de performance aérodynamique

Reference number
ISO 27327-1:2009(E)

© ISO 2009

Efficiency of Air curtains

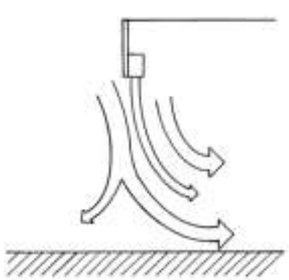
Selection of air curtain

A correct installed air curtain…

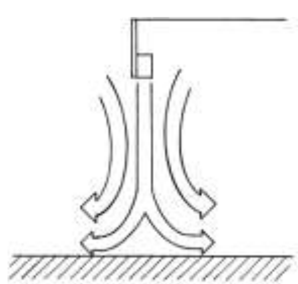
How to judge which air curtain is suitable for a specific opening?

- Size of opening (width and height)
- Loads

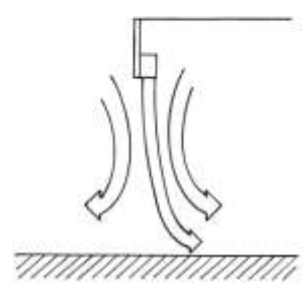
Which velocity at floor level?



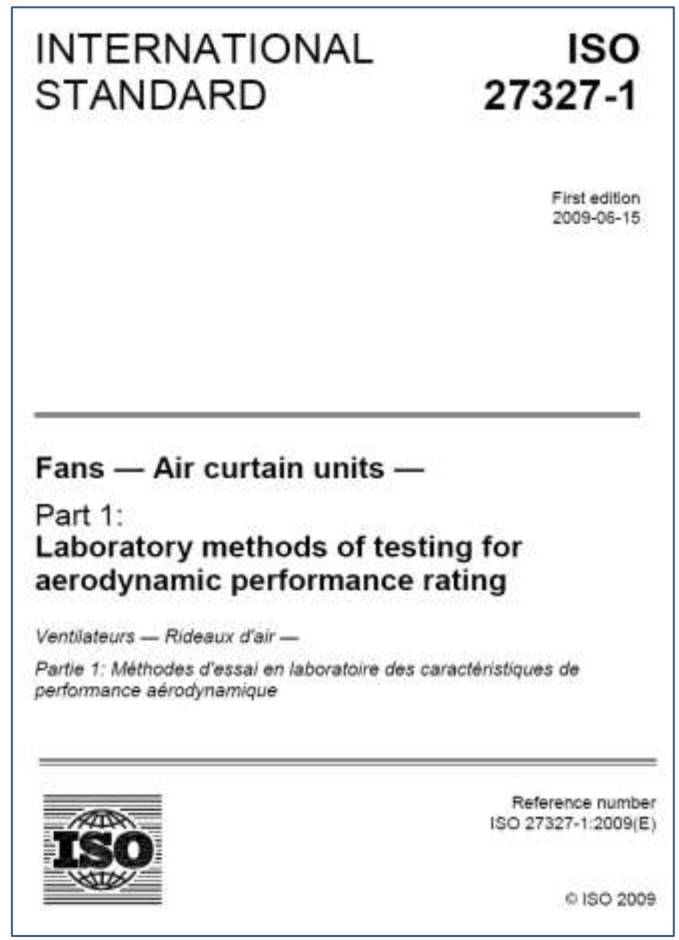
Low velocity
- Weak protection



High velocity
- Creates turbulance, weak protection



Correct velocity
- Good protection



INTERNATIONAL STANDARD

ISO 27327-1

First edition
2009-06-15

Fans — Air curtain units —

Part 1:
Laboratory methods of testing for aerodynamic performance rating

Ventilateurs — Rideaux d'air —

Partie 1: Méthodes d'essai en laboratoire des caractéristiques de performance aérodynamique

Reference number
ISO 27327-1:2009(E)

© ISO 2009

Efficiency of Air curtains

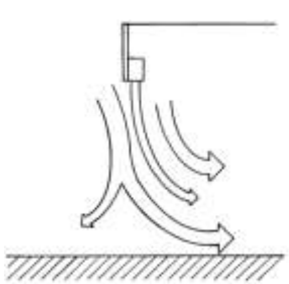
Selection of air curtain

A correct installed air curtain…

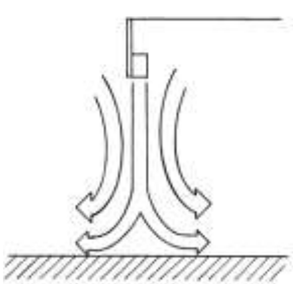
How to judge which air curtain is suitable for a specific opening?

- Size of opening (width and height)
- Loads

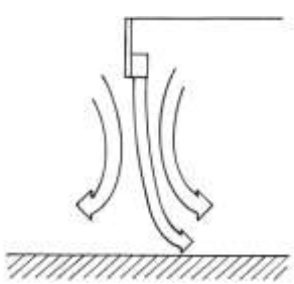
Which velocity at floor level?



Low velocity
- Weak protection



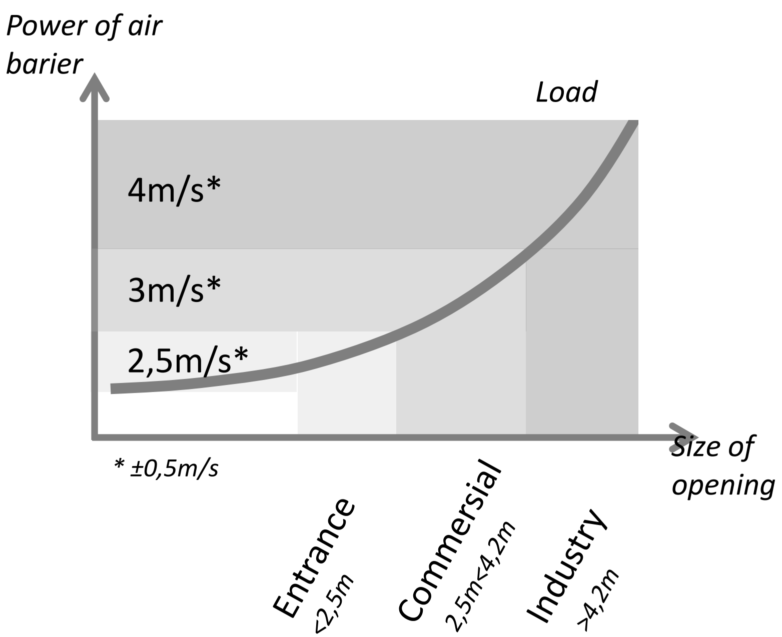
High velocity
- Creates turbulance, weak protection



Correct velocity
- Good protection

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

Frico experience of a suitable velocity at floor level…

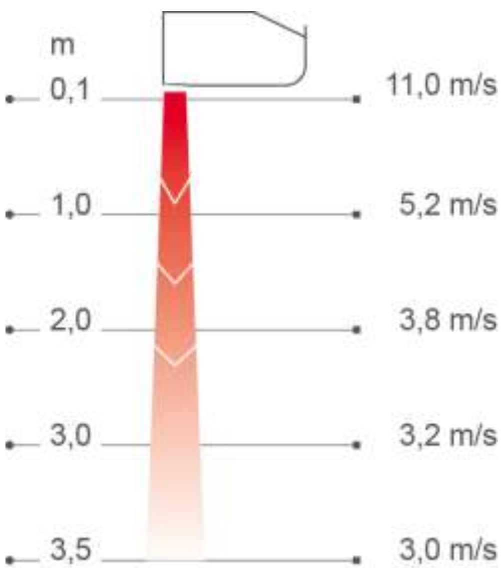


Thermozone technology

Performance and energy efficiency

Our statement;

Throw length of the air barrier is more important than air volume!



Air speed is measured according to ISO 27327-1 (AMCA 220)

THERMOZONE TECHNOLOGY

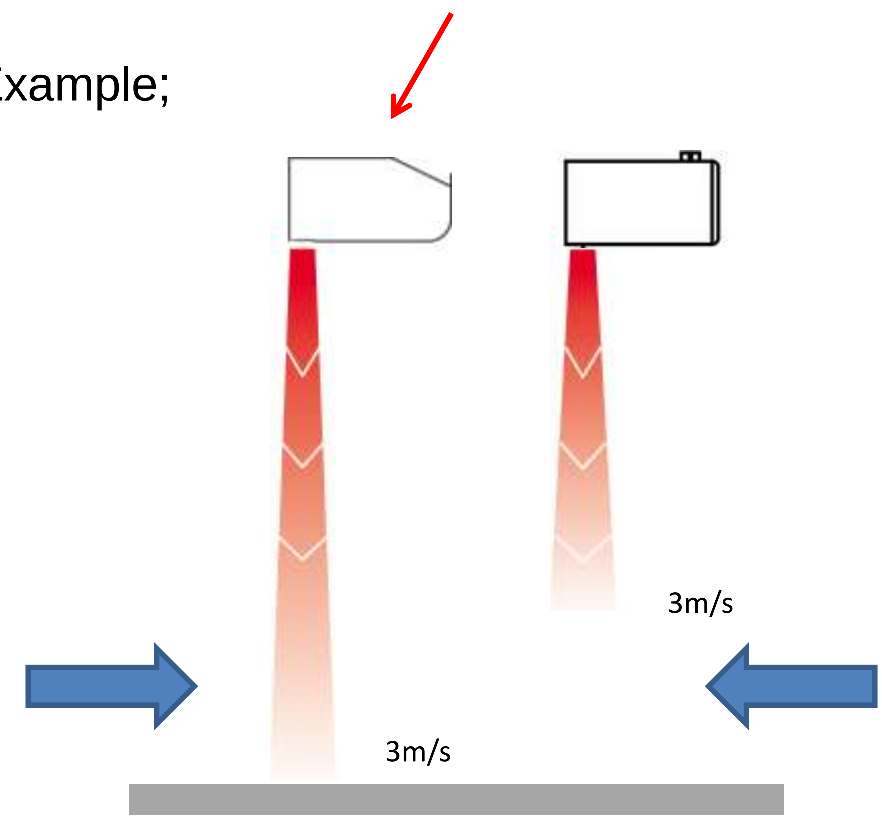
Efficiency of Air curtains

Thermozone technology

Frico experience;

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

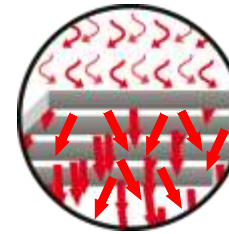
Frico experience;

Throw length of air beam is created by correct size of air outlet.

THERMOZONE TECHNOLOGY

Efficiency of Air curtains

Thermozone technology



Frico experience;

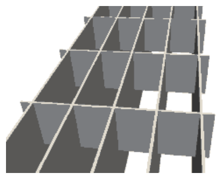
Throw length of air beam is created by correct design of air outlet.

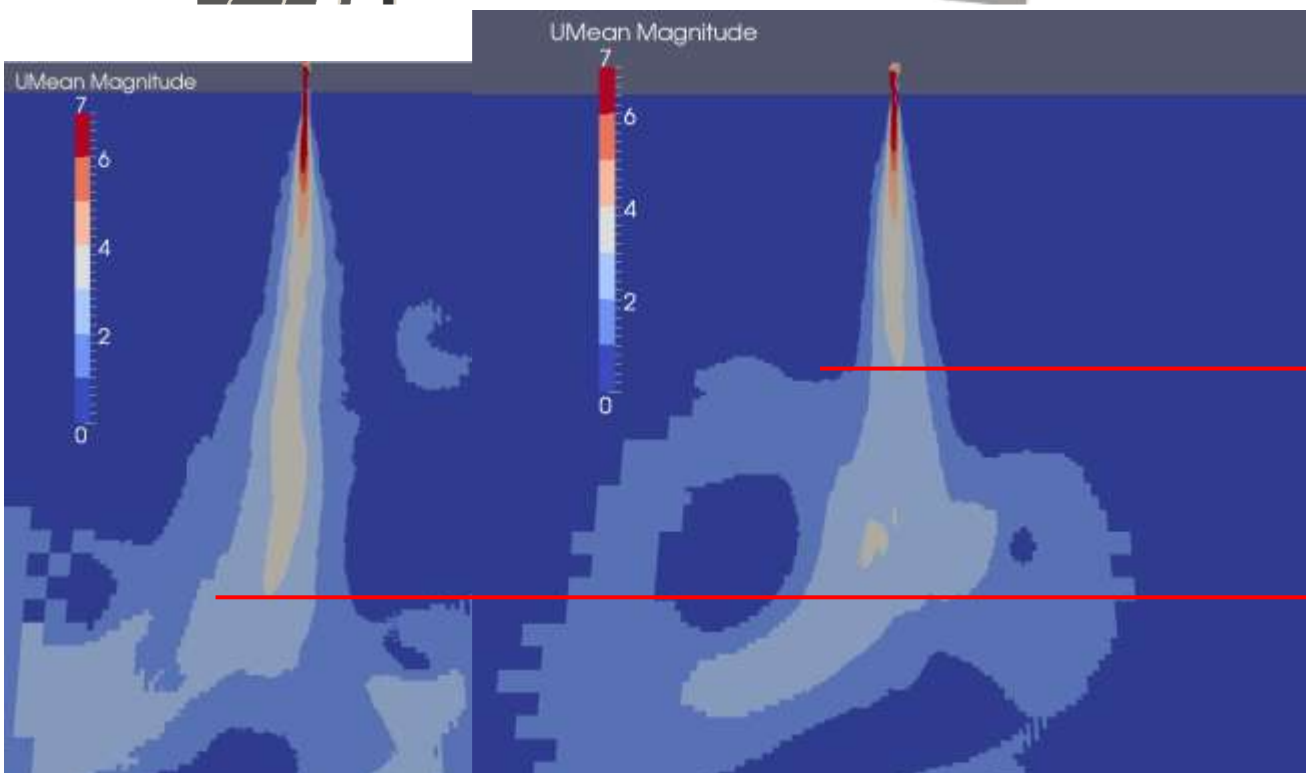
THERMOZONE TECHNOLOGY

Efficiency of Air curtains

Thermozone technology

Theoretical test; CFD analysis at 1800m³/h





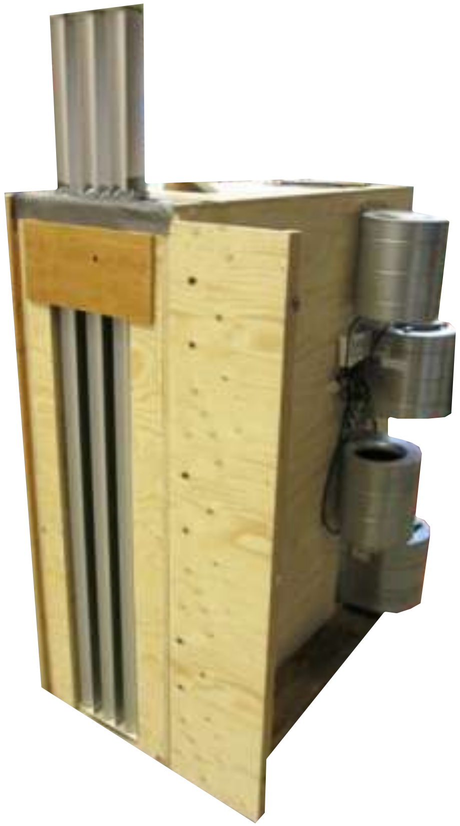
Considerable difference in performance

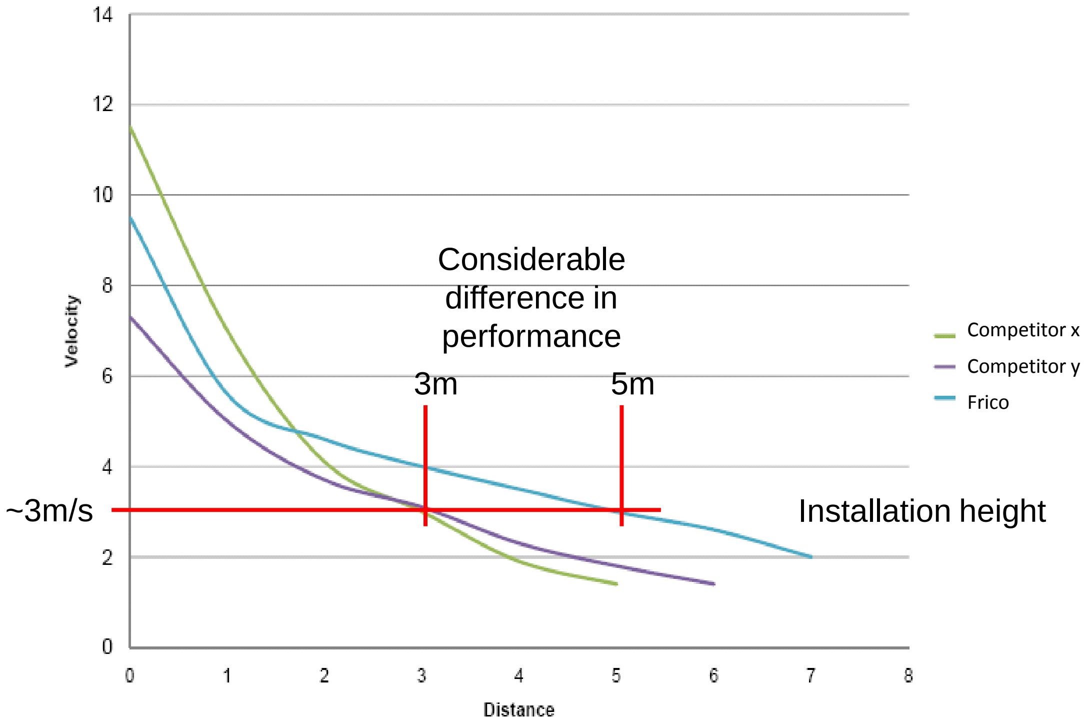
THERMOZONE TECHNOLOGY

Efficiency of Air curtains

Thermozone technology

Practical test; at 2000m³/h



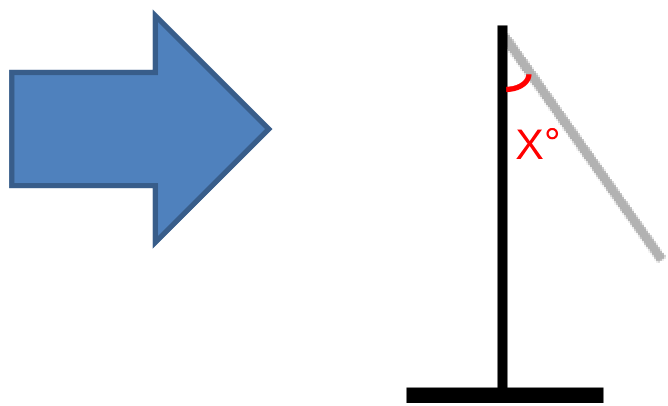


THERMOZONE TECHNOLOGY

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

The power of the air barrier(impulse); volume x velocity x density [kg x m/s^2= 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’

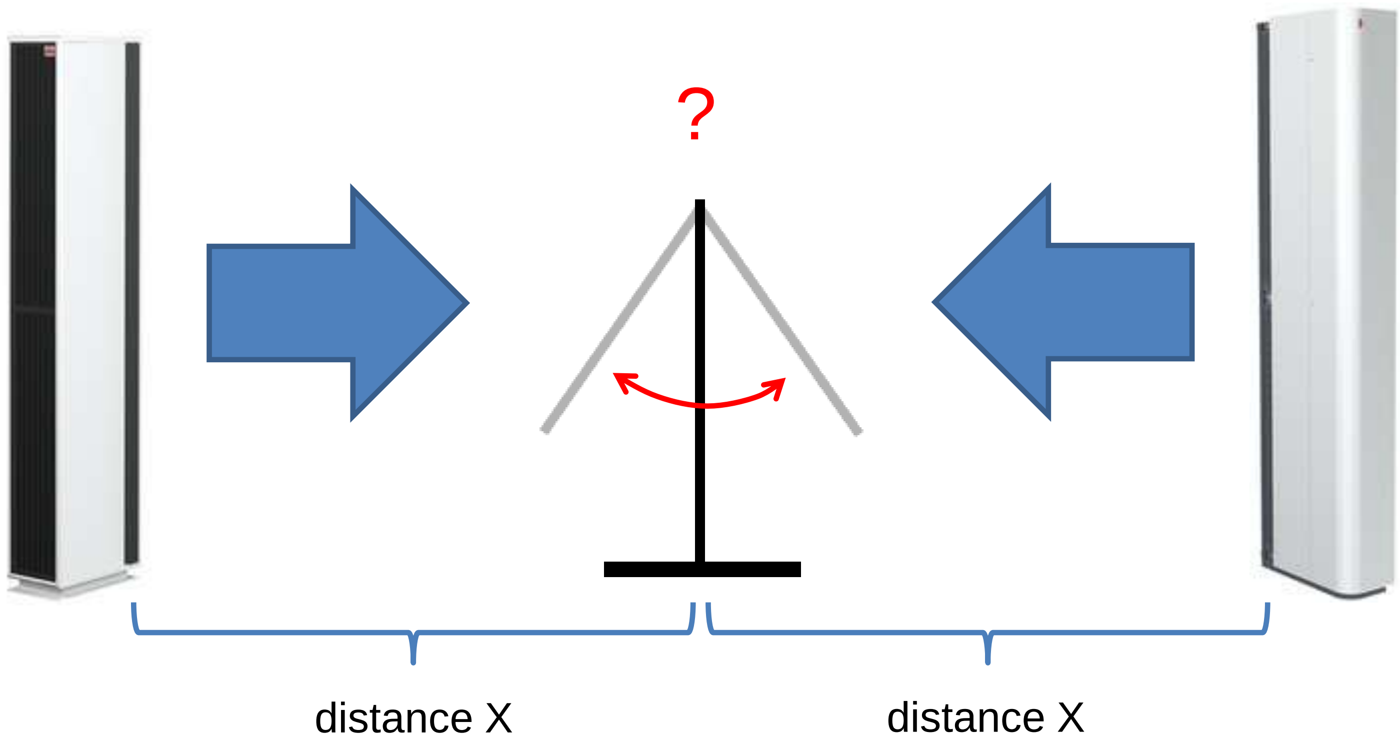
The power of the air barrier(impulse); volume x velocity x density [kg x m/s^2= Newton]

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 [kg x m/s^2= Newton]

THERMOZONE TECHNOLOGY

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
2900m³/h

10% lower air volume!

PA3515WL
2600m³/h

The power of the air barrier(impulse); volume x velocity x density [kg x m/s^2= Newton]

Conclusion – efficiency of air curtains

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 inflitration 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
- London South Bank University and CIBSE ’Air curtains for saving energy in buildings’, 2007

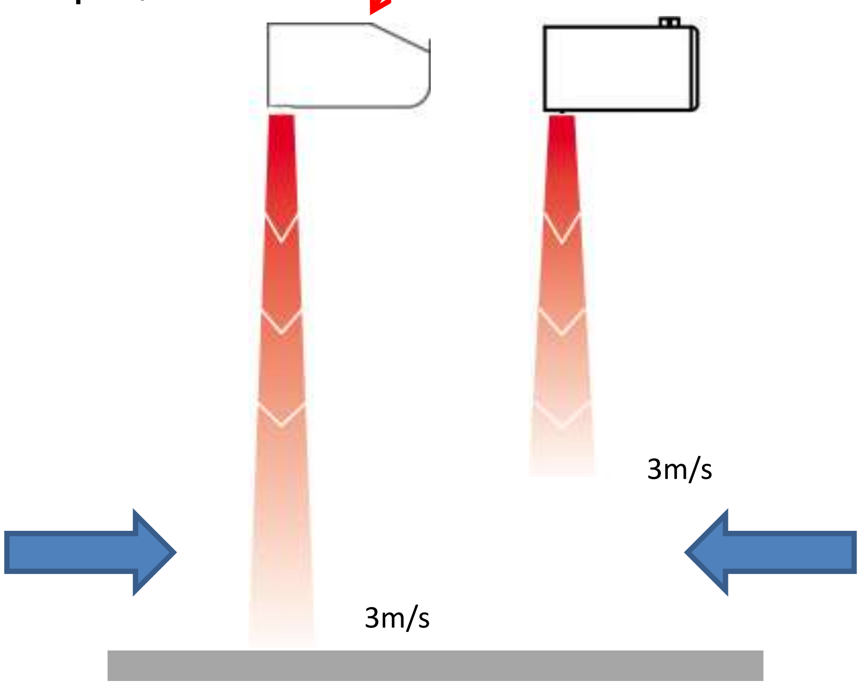
Conclusion – efficiency of air curtains

Frico experience;

The velocity of the air beam at floor level is as important as the air volume of the air curtain.

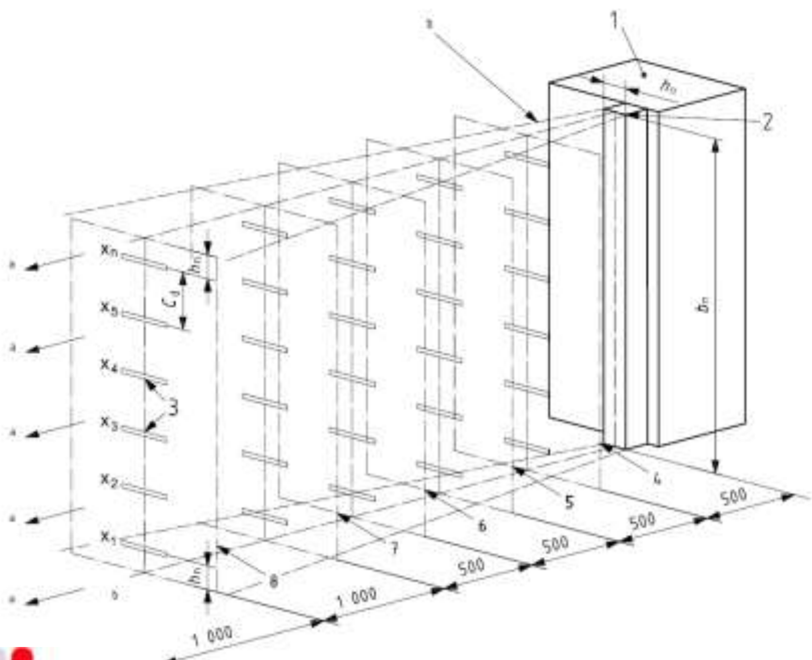
The efficiency of air curtains with the same air volume can be compared by measuring the throw length of the air beam.

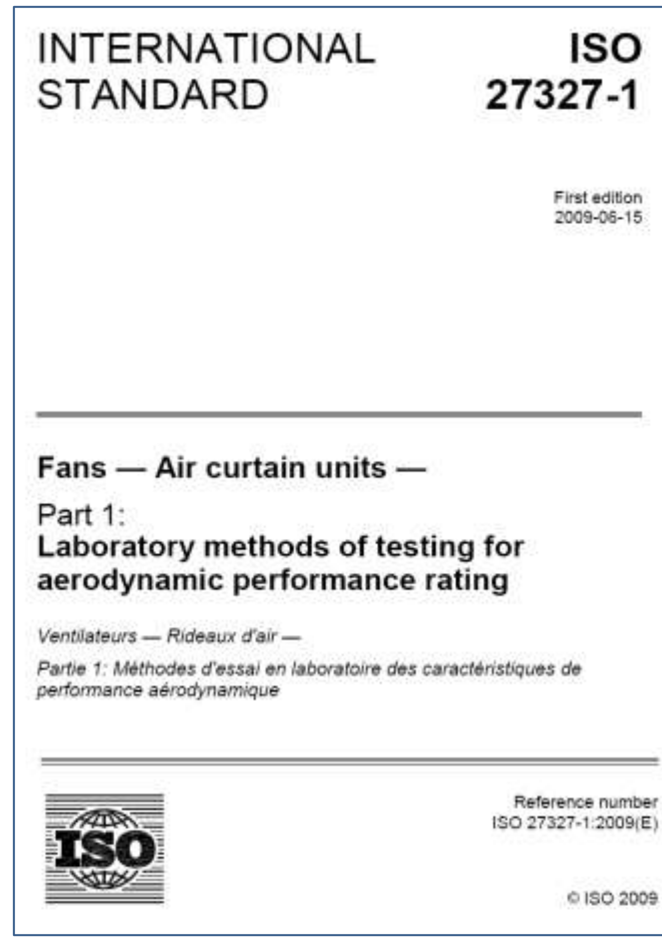
Example;



Conclusion – efficiency of air curtains

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





INTERNATIONAL STANDARD

ISO 27327-1

First edition
2009-06-15

Fans — Air curtain units —

Part 1:
Laboratory methods of testing for aerodynamic performance rating

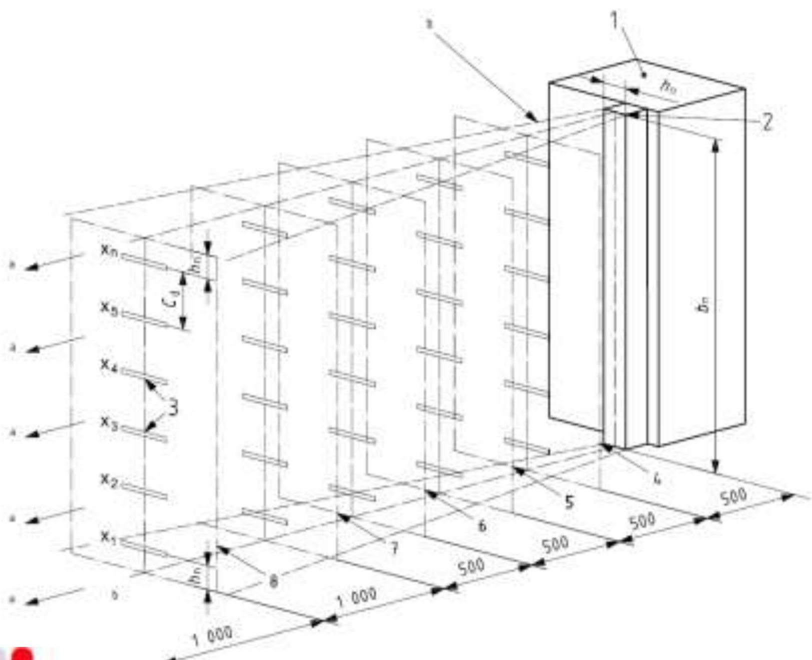
Ventilateurs — Rideaux d'air —

Partie 1: Méthodes d'essai en laboratoire des caractéristiques de performance aérodynamique

Reference number
ISO 27327-1:2009(E)

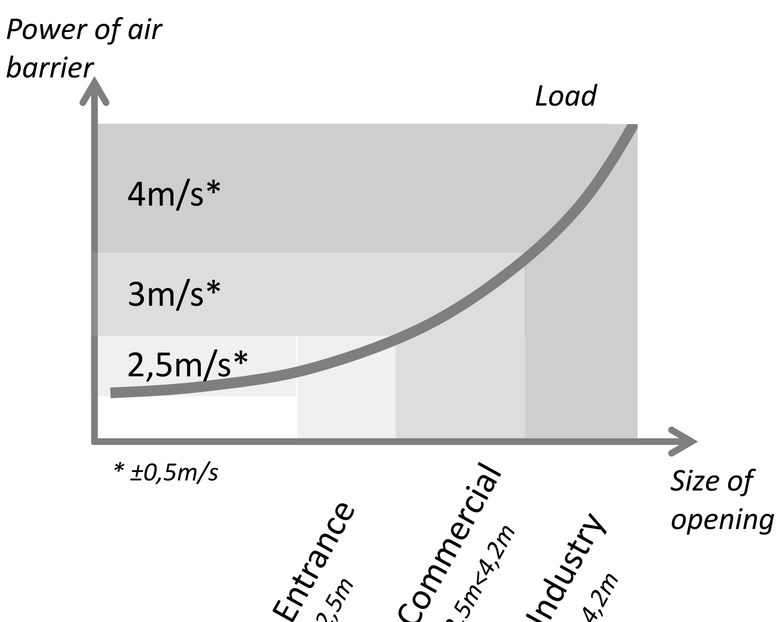
Conclusion – efficiency of air curtains

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…



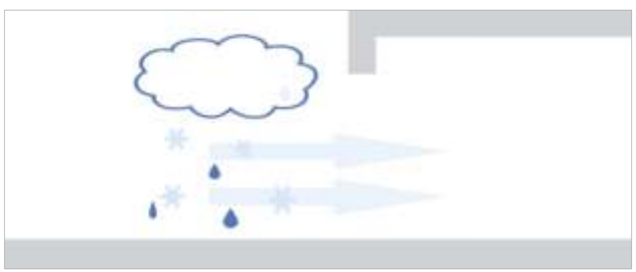
Conclusion – efficiency of air curtains

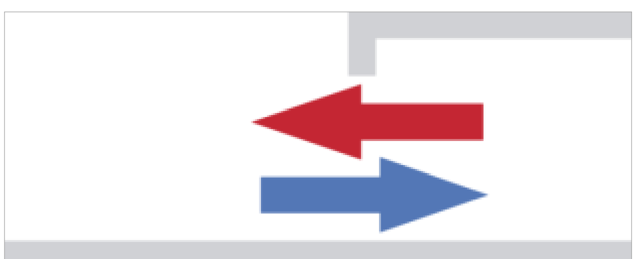
The air velocity profile is measured according to ISO 27327-1

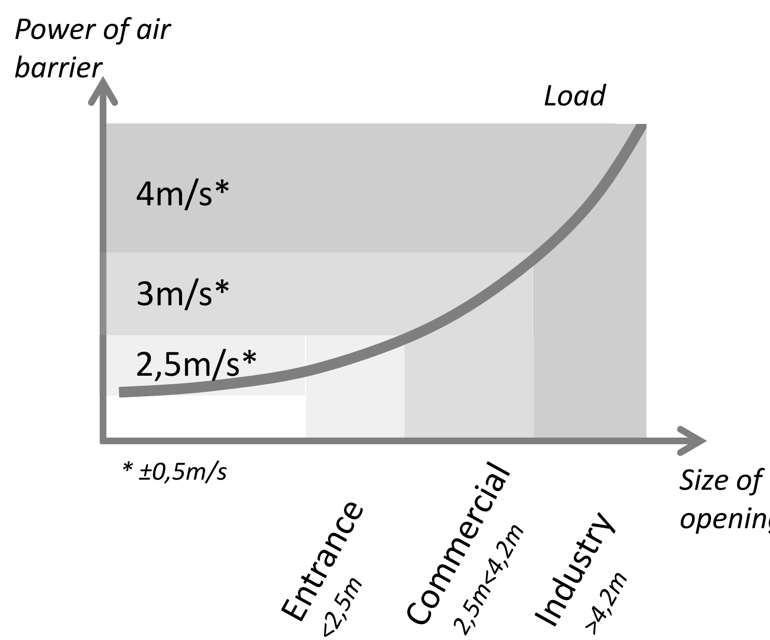
Note! When a door/opening is exposed to wind and other loads, the velocity at floor level will be lower than what is stated according to the ISO 27327-1

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

Frico experience of a suitable velocity at floor level…







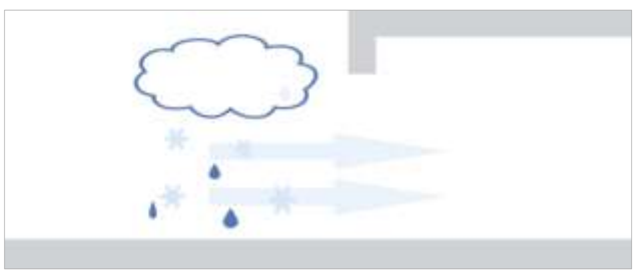
THERMOZONE TECHNOLOGY

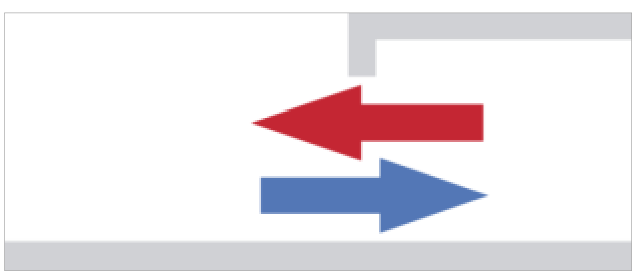
Conclusion – efficiency of air curtains

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…

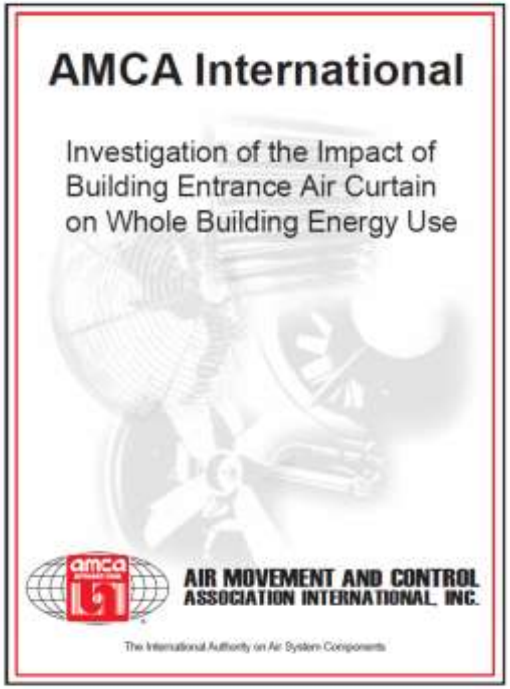
Today;

…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

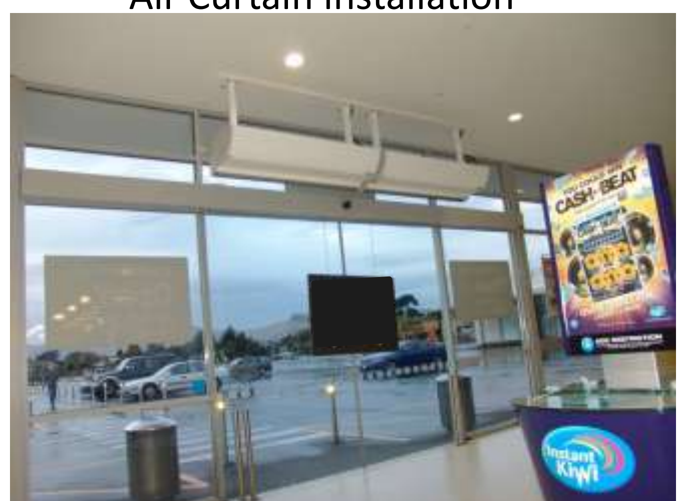


350 CFD simulations covering;
- Different climate zones
  - Temperature differences
- Different ventilation scenarios
  - Neutral building pressure
  - Negative building pressure
  - Positive building pressure
- Wind loads
- Number of people passing by

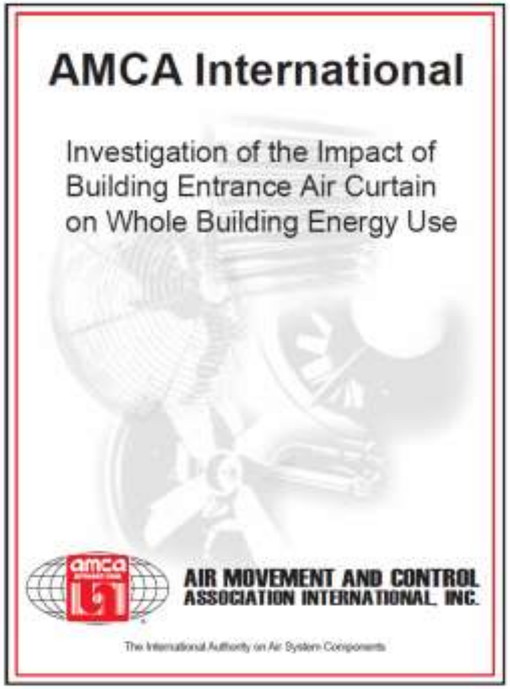
Vestibule construction

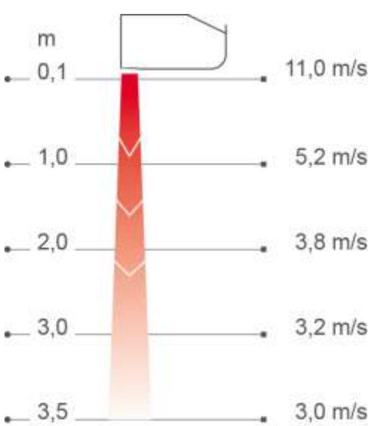
vs.

Air Curtain installation



AMCA study; Air Curtains vs Vestibules





THERMOZONE TECHNOLOGY

Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use

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 (10%), water heating (12%), and lighting (9%), which sums 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 outdoor air infiltration while also permitting an unobstructed pedestrian entryway. An air curtain for a single six-foot-wide entrance/exit opening is 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 reviewed 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

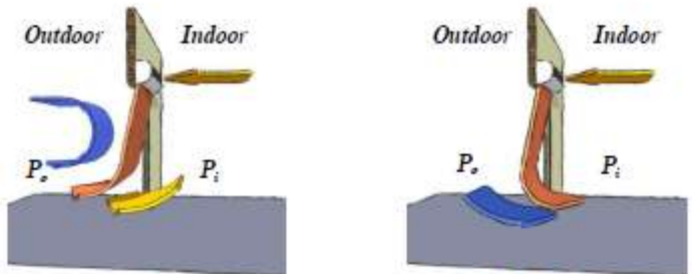
To achieve the objective, two major tasks were carried out:

- 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 (1996) conducted extensive experimental studies to provide the orifice equation models for both single and vestibule doors based on door usage frequency, geometry, and pressure

AMCA study; Air Curtains vs Vestibules

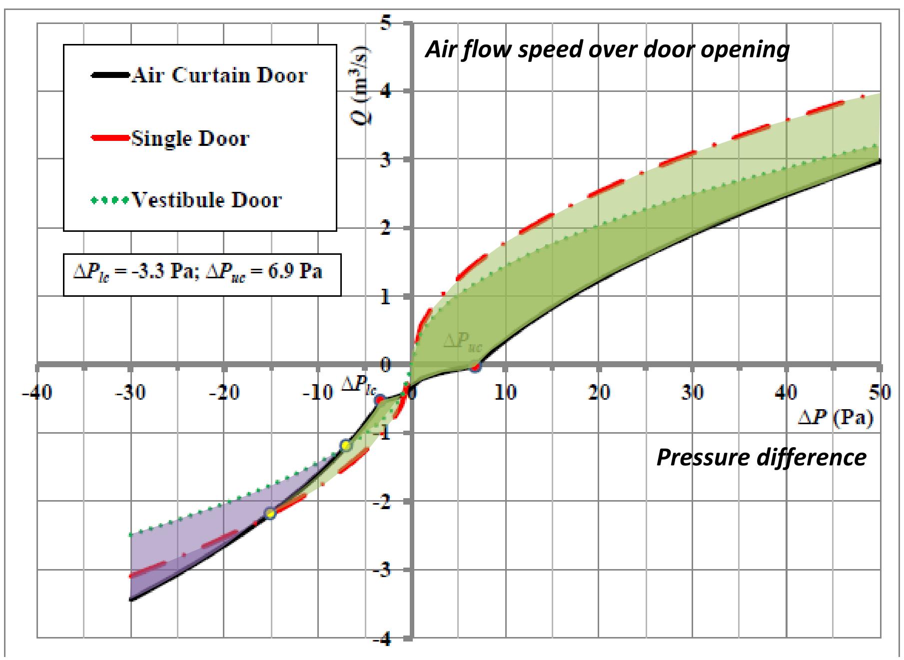
Automatic door; Width - 2m; Height - 2,4m



(c). Exfiltration (b). Infiltration

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

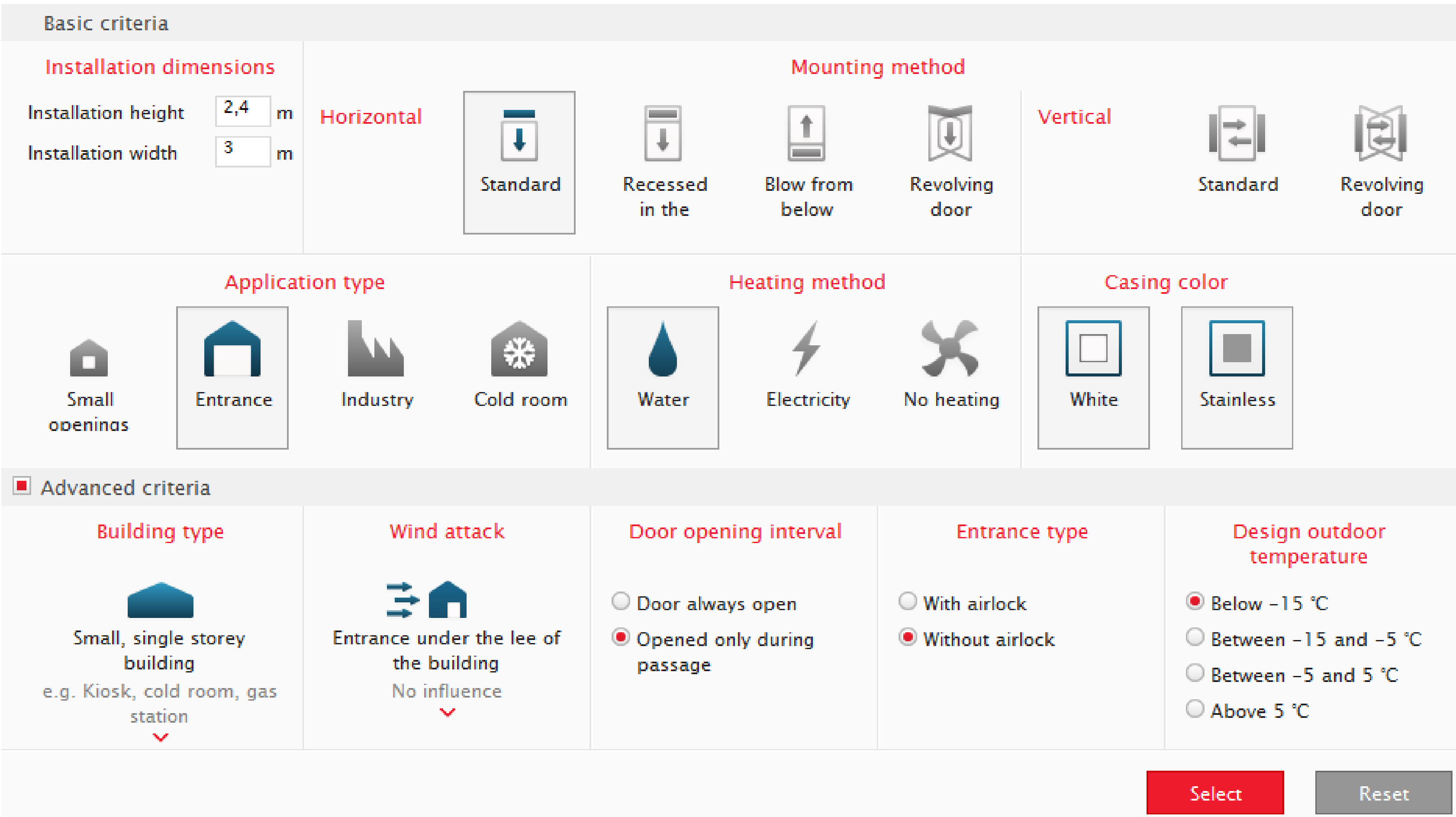
Systems		100% Supply	95% Supply	90% Supply
Average/Min /Max. Pressure Difference, ΔP (Pa)		0.8/-9.5/27.4	1.3/-7.9/29.6	1.8/-6.5/31.5
Annual Infiltration Reduction (%)	Vestibule	23	23	24
	Air Curtain	62	65	67

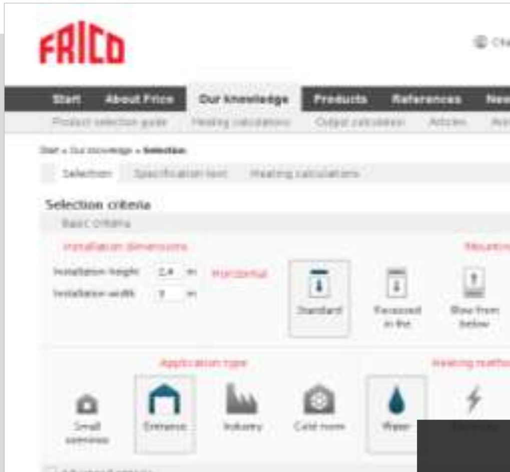


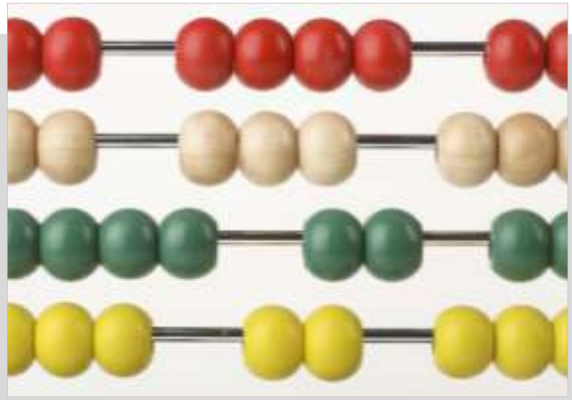
Correctly installed Air Curtain gives;

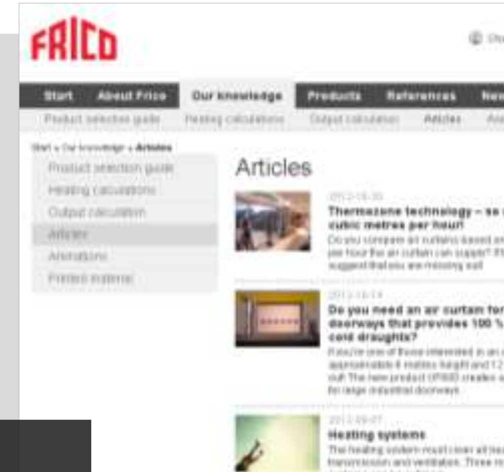
- Reduction of airflow speed over door opening compared to Single door
- Reduction of airflow speed over door opening compared to Vestibule construction
- Increase of airflow speed over door opening compared to Vestibule construction
- Increase of airflow speed over door opening compared to Single door

Online Selection Guide









Selection guide, output calculations, articles, printed material, animations, product information …

Thank you for your attention!

THERMOZONE TECHNOLOGY