EUROVENT
EUROPEAN INDUSTRY ASSOCIATION

Eurovent 16/5 - 2025

Air Curtain Units – Technical Overview

First Edition

Published on Thursday, 13 March 2025 by
Eurovent, 80 Bd A. Reyers Ln, 1030 Brussels, Belgium
secretariat@eurovent.eu

Document history

This Eurovent Industry Recommendation / Code of Good Practice supersedes all of its previous editions, which automatically become obsolete with the publication of this document.

Modifications

This Eurovent publication was modified as against previous editions in the following manner:

Modifications as against	Key changes
1st edition	Present document

Preface

In a nutshell

The present document is dedicated to the technical audience and illustrates the physics behind the functioning of an air curtain unit, including an indication of the energy loss through an opening with and without an air curtain. This recommendation also introduces the most relevant aspects and performance factors to be taken into account for the optimal use of an air curtain unit and provides tools for making the right system choice.

The present document is largely based on the Dutch standard ISSO 110.

Authors

This document was published by Eurovent and prepared in a joint effort by participants of the Product Group 'Air Curtains and Fan Heaters' (PG-CUR), which represents a vast majority of all manufacturers of these products active on the EMEA market.

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Suggested citation

Eurovent AISBL / IVZW / INPA. (2025). Eurovent 16/5 - 2025 - Air Curtain Units – Technical Overview. Brussels: Eurovent.

Important remarks

Eurovent does not grant any certification based on this document. All certification-related issues are managed by the association's independent subunit Eurovent Certita Certification in Paris. For more information, visit www.eurovent-certification.com.

Contents

Introduction

Air curtains have long been recognised as a simple and effective method to reduce energy consumption for buildings and promote indoor air quality. Whilst even the non-technical reader can appreciate the principles of how the units work, more technical audiences (who typically specify the products) can use this document to develop a strong technical foundation about the physics behind them.

This report has been split into two sections:

- How air curtains work
- Site conditions that can affect their selection, installation, operation and maintenance

It is completed by the Eurovent Recommendations 16-3[1] and 16-4[2].

Thanks to this document, it emerges once more how air curtain units can help in energy savings for buildings, and it is known that energy efficiency is one of the pillars of the European Green Deal and the new Energy Performance of Buildings Directive.

This document also illustrates the many factors that influence the correct functioning of an air curtain unit and therefore how important it is to assess the environmental conditions for the proper design and functioning of an air curtain unit.

This Recommendation was derived from the Dutch ISSO 110 standard, a document that the air curtain industry developed in cooperation with the TNO Institute and is based on tests and methodologies developed in TNO test laboratory. The Product Group 'Air Curtains and Fan Heaters' (PG-CUR) would like to thank the TNO Institute for the precious clarifications given over time.

Within the document, the term 'air curtain' is used to describe both the air curtain unit and the air curtain stream that the air curtain unit produces.

[1] Eurovent AISBL / IVZW / INPA. (2023). Eurovent 16/3 - 2023 - Air curtain unit: Acoustic performance and calculations. Brussels: Eurovent.
[2] Eurovent AISBL / IVZW / INPA. (2024). Eurovent 16/4 - 2024 – Classification and correct positioning of an air curtain unit. Brussels: Eurovent.

80 Bd A. Reyers Ln
1030 Brussels
BELGIUM
www.eurovent.eu
+32 (0)466 90 04 01
secretariat@eurovent.eu

1. Energy saving: reduction of losses using an air curtain

1.1. The climate separation effectiveness of an air curtain

The energy saving potential, thanks to the installation of an air curtain, will depend on the effectiveness of the air curtain in reducing energy loss. In this document, the term 'energy loss' is used for both the winter and the summer seasons, since air curtains reduce the energy exchange between two climates, which could be inside and outside a building but also between two different areas with different temperatures inside the same building.

The effectiveness of an air curtain is determined by what is commonly referred to as the climate separation effectiveness (CSE) and is defined as:

"*Climate separation effectiveness indexes provide the end user with useful energy saving information for the installed air curtain unit. They describe how much heat energy is saved through a door opening if an air curtain unit is correctly installed and maintained. These indexes take into account the two different forces which influence the air curtain unit, namely temperature difference and wind action. The two indexes are defined as the CSE_T and the CSE_W. and represent the efficiency (or effectiveness) of an air curtain unit subjected to temperature differences and wind action respectively.*[3]"

$$CSE = 1 - \Phi_{rest}/\Phi_0 \qquad [-]$$

Where

Φ_0	= energy loss through an opening without an air curtain	[kW]
Φ_{rest}	= the remaining energy loss through the opening with an air curtain, including the electric power consumption	[kW]

Conversely, energy loss can be determined through an opening if the CSE is known. A method to determine the CSE in a laboratory is published in Eurovent 16/1[4] Recommendation. Currently, the wide range of temperatures and boundary conditions of air curtain installations make it difficult to determine the CSE for each application. The optimum point from the CSE curve is given in the below Figure 1.

The CSE will depend on the discharge speed. The relationship between the discharge speed and the CSE is shown in Figure 1 in general terms.

[3] Eurovent 16/1 - 2016 Air curtain unit - Classification, test conditions and energy performance calculations, 29 September 2016 - Eurovent, 80 Bd. A. Reyers Ln, 1030 Brussels, Belgium
[4] Eurovent 16/1 - 2016 Air curtain unit - Classification, test conditions and energy performance calculations, 29 September 2016 - Eurovent, 80 Bd. A. Reyers Ln, 1030 Brussels, Belgium

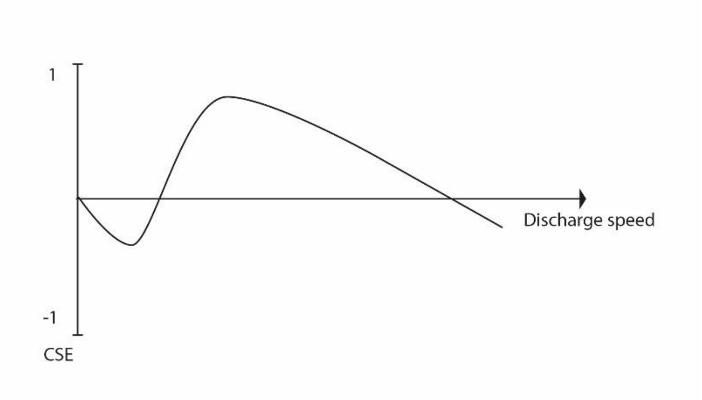


Figure 1: Example of the air curtain performance (preheated supply air): CSE as a function of discharge speed.

The above figure shows that there is a discharge speed where the CSE is at an optimum. The air jet does not reach the floor when the discharge speed is too low and, therefore, deflects to the cold area or room or outside. The energy loss will then be higher with an air curtain than without an air curtain and thus results in a negative CSE. If the discharge speed is higher than the optimum, the air jet will reach the floor too hard and, as a result, additional turbulence will occur and the exchange of indoor and outdoor air will increase. It is, therefore, also important that attention is paid to the continued implementation of the CSE design value during the management phase.

1.1.1. Influence of the pressure differences on climate separation effectiveness

The CSE is also dependent on the pressure difference over the air jet.

An illustration of the CSE depending on the pressure difference is shown in Figure 2.

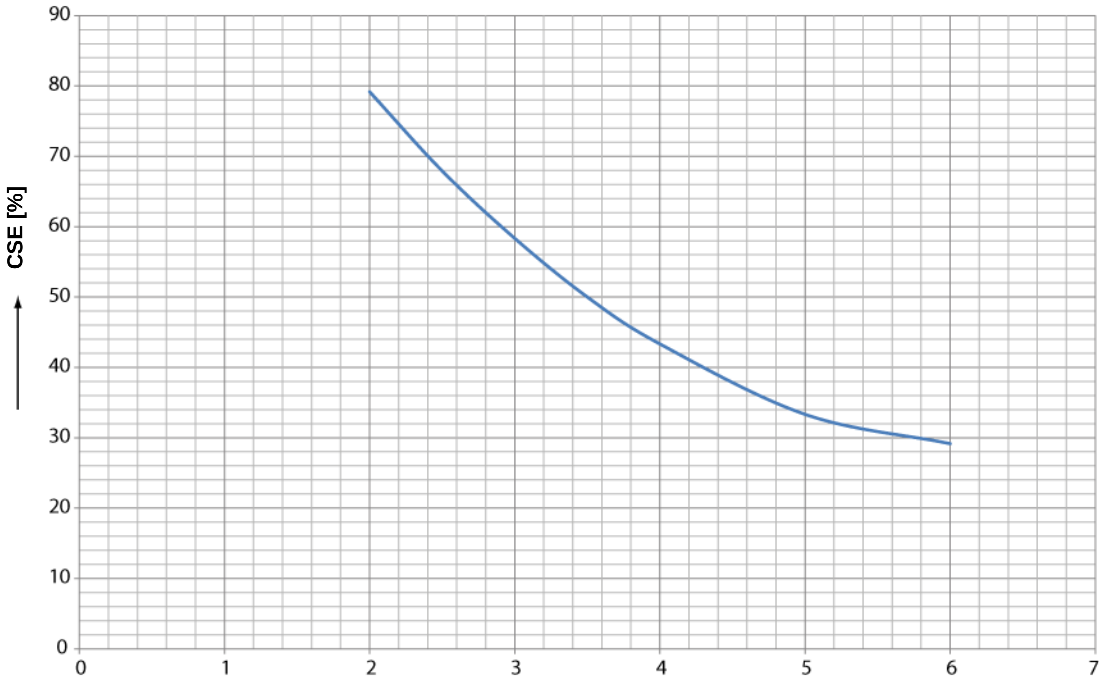


Figure 2: CSE in% as a function of the pressure difference over the air jet

Figure 2 shows that the CSE will depend strongly on the pressure difference. If the pressure difference becomes greater than approximately 3 Pa, the CSE will be considerably reduced when compared to the design value.

Whether a wind pressure of 3 Pa is exceeded regularly over, an opening will depend on the orientation and environment of the relevant wall and the quality of the relevant building; for more information see Annex B - Wind nuisance and air curtains.

The Table 1 below gives an indication of relevant wind speeds.

Table 1: Wind speed where the wind pressure on the wall ≥ 3 Pa

Situation:	Little wind attack on the wall	Average wind attack on the wall	Considerably wind loaded wall
Used wind pressure factor (Cp) for the situation	0.1	0.3	0.7
Wind speed where the pressure on the wall ≥ 3 Pa	7 m/s	4 m/s	2.7 m/s

The wind speed is higher in the open field than in the built-up area except near high buildings. It can be determined with a wind nuisance study whether a wind pressure of 3 Pa is exceeded regularly for specific locations.

If the wind nuisance study shows that a wind pressure of 3 Pa is exceeded regularly, it is important that the building is properly made airtight. If this is not the case, the air curtain must be combined with an entrance facility such as a revolving door.

1.2. Target values for the climate separation effectiveness

The CSE values can be used when designing the air curtain as indicated in the summary below.

Table 2: CSE design value depending on process and wind attack

CSE specified in the supplier's documentation (in accordance with Eurovent 16/1)	Management phase measures for the assurance of the CSE.	Design value of the CSE
No	No	0.3
Yes	No	Supplier's specification 75%
No	Yes, or automatically controlled air curtain	0.5
Yes	Yes, or automatically controlled air curtain	Supplier's specification (in accordance with 16/1). CSE approximately 0.6 – 0.8

1.3. Determination of the energy loss through an opening

If a CSE value has been selected, the remaining energy loss of the opening can be determined with the following formula:

$\Phi_{rest} = (1\text{-}CSE) \cdot \Phi_o$ [kW]

Where:

Φ_{rest} = remaining energy loss through the opening if an air curtain is used [kW/m]

CSE = climate separation effectiveness based on Table 2 [-]

Φ_o = energy loss through the opening without an air curtain based on the section 4 [kW/m]

In addition, information is also required with regard to supply performance for the determination of the design heating power of the air curtain.

2. How air curtains work

2.1. Air speed of the curtain as a function of height

The air speed of the air jet is equal to the core discharge speed at the outlet. The speed of the airflow in the core of the air jet decreases as the distance from the outlet increases.

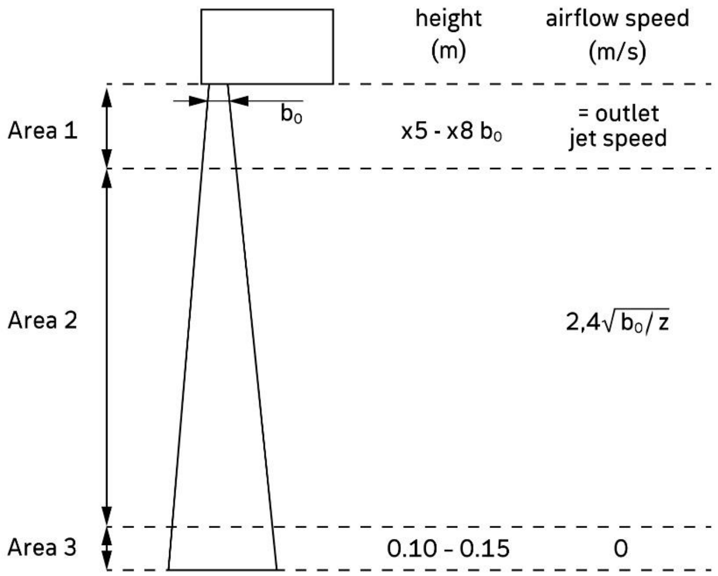


Figure 3: Air speed of the curtain as a function of the height

There are several different zones that can be distinguished:

- Area 1 is the potential core. In this area, the core speed is equal to the discharge speed of the air jet. The length of the potential core is equal to approximately 5 to 8 times the width of the outlet;
- Transition area between area 1 and area 2 in which the airflow will develop. The length of this transition area is a number of times the width of the outlet;
- The airflow has fully developed in area 2. The air speed decreases progressively here. An analytic approach to the core air speed v(z) in this area is:

  $$v(z) = 2{,}4\sqrt{\frac{b_0}{z}} \qquad \text{[m/s]}$$

  Where:

  b_0 = width of the air jet [m]

  z = height [m]

- Area 3 is the area in which the air jet touches the floor (impingement area). This area is the area between the floor and approximately 0.10-0.15 H. The vertical component of the air speed decreases here linearly to zero.

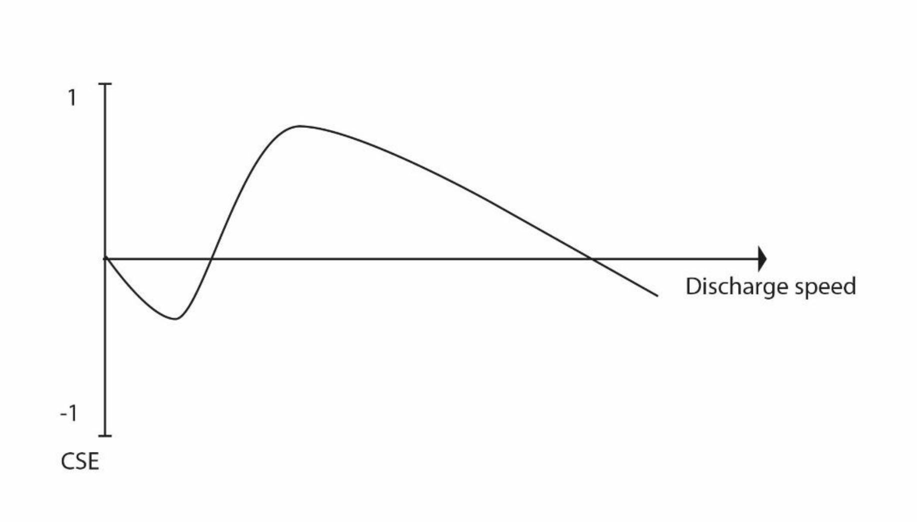


Figure 4: stagnation point and discharge speed. The picture is an example of a possible situation with a given dimension of the opening.

The point at which the CSE is zero is the stagnation point. Next to the stagnation point, the air speed is not equal to zero: to the right of the stagnation point, the air stream will overspill out of the building. To the left of the stagnation point, the air stream won't reach the ground and will either temper incoming air, acting like an overdoor heater, or remain buoyant and be pushed out the doorway.

If the air speed is measured according to the ISO 27373-1 standard, the data of the air speed as a function of the height is available. In that case, the correct setting of the air curtain can in practice be controlled by measuring the air speed at different heights and by comparing it with the laboratory data. If there is no laboratory data available, the nomogram in Figure 5 can be used for this.

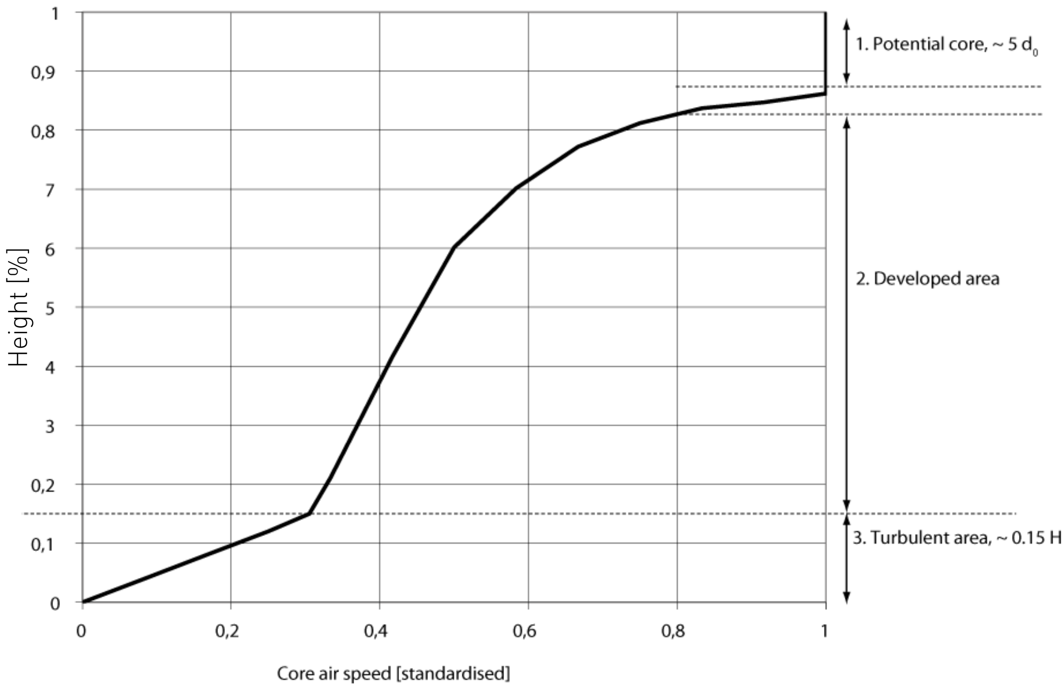


Figure 5: Vertical component of the core air speed (standardised) of a correctly set air curtain as a function of the height

A two-point measurement of the air speed to check for a correct setting consists of the following two measurement points:

1. Measurement point at a height between H and H-5·d0, where 5 is an indicative figure, that will depend on the unit that is being used. The measured air speed is the core discharge speed. This air speed must be equal to the specified discharge speed of the air curtain;
2. Measurement point at a height of 0.15·H. The measured air speed should be approximately 0.3 times the discharge speed at this height.

2.2. Air speed and air volume flow

Both air speed and quality play a role in the performance of an air curtain.

For an effective air barrier, the air speed that covers the distance from the air curtain to the floor must be sufficiently large. This means that a supply air facility is required that guarantees the best possible ratio between the air volume flow and the air speed.

The force F_0 of an air jet can be determined as follows:

$F_0 = \Delta p_0 \cdot B \cdot b_0 = 1/2 \cdot \rho \cdot v_L^2 \cdot B \cdot b_0$ [N]

Where:

B	= width of the door opening	[m]
b_0	= width of the air jet	[m]
v_L	= speed of the air jet at the discharge grille	[m/s]
ρ	= Air density	[kg/m^3]

The air jet force is proportional to the quadrant of the air speed.

Figure 6 shows an example of a possible air speed profile. The figure reveals that the air speed is about 11 m/s when it exits this unit and, subsequently, it drops to a speed of about 2 m/s at approximately 50 cm above the floor. The air curtain will not reach the floor and the barrier is reduced when the discharge speed is too low. Much turbulence occurs on the floor when the discharge speed is too high and, therefore, the air curtain barrier effectiveness will be negatively impacted.

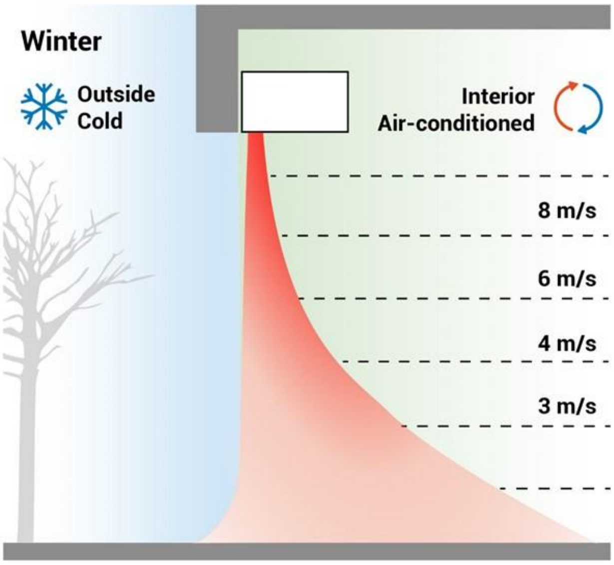


Figure 6: Example of an approximated air speed profile for a winter application without the effect of the wind (numeric values do not represent a recommendation)

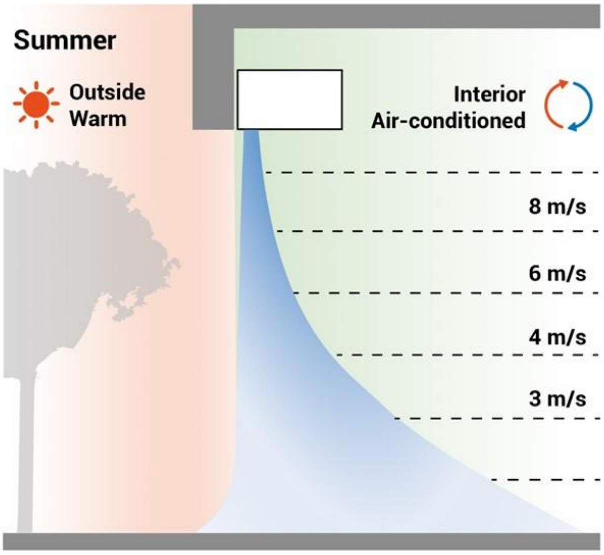


Figure 7: Example of an approximated air speed profile for a summer application without the effect of the wind (numeric values do not represent a recommendation)

The larger the opening, the higher the required velocity and width of the air stream should be. In practical terms, this performance of the air stream can limit the application of the air curtain meaning both horizontal and vertical mounting options should be considered. Standard products are available that cover openings up to 7-8m wide or tall and beyond these customized products are available, please refer to the Eurovent Recommendation 16-4[5] for a more in-depth description.

[5] Eurovent AISBL / IVZW / INPA. (2024). Eurovent 16/4 - 2024 – Classification and correct positioning of an air curtain unit. Brussels: Eurovent.

3. Comfort

3.1. Choice of comfort air curtain or industrial air curtain

The Eurovent Recommendation 16-4[6] illustrates the classification and correct positioning of air curtain units and helps the choice of the correct application considering the installation requirements.

3.2. Thermal comfort when going through the air curtain

When a person passes through an air curtain, he or she will be in an airflow with an air speed of approximately 3 -10 m/s for a short period of time. Four parameters are important when considering thermal comfort:

- The air speed in the air jet;
- The turbulence intensity of the air jet;
- The temperature of the air jet;
- The period of time that a person is present in the air jet.

Since the period of time that a person is present in the air jet is relatively short (< 1 s), the requirements to be set can, in this case, be derived from the common comfort criteria for usable floor areas in line with ISO 7730 standard.

Consideration should be given to avoid excessively high core discharge speeds (measured in accordance with the standard ISO 27327-1) and/or excessively high discharge temperatures (above 40°C).

3.3. Thermal comfort for people who are in close proximity to the air curtain

Depending on the application, it may be necessary for people to remain a short distance from the air curtain. This may be a workplace, e.g. a desk/reception in the case of a hotel or a cash desk in the case of a shop. Thermal comfort requirements should be considered at this location depending on the function. The thermal comfort requirements to be met are specified by the customer and depend on the nature of the work or activity performed.

Depending on the situation, local legal requirements regarding local working conditions may decree certain conditions are met. In the absence of nothing being formally defined, the air speed and temperature should be considered.

3.4. Acoustic Comfort

The noise emitted by an air curtain is determined by a number of aspects in the design, in particular, the production of noise and vibrations by the fan, but also the production of airflow noise as a result of the air inlet and discharge and turbulences in the unit.

The noise production will strongly depend on the speed of the fan and, therefore, the actual supplied quantity of air at a specific moment.

[6] Eurovent AISBL / IVZW / INPA. (2024). Eurovent 16/4 - 2024 – Classification and correct positioning of an air curtain unit. Brussels: Eurovent.

3.4.1. Quality requirements

The noise production of an air curtain to be used must be determined based on the standard ISO 27327-2 and the Eurovent Recommendation 16-3[7].

If the sound production, geometry and finish of the area or room behind are known, an acoustic consultant can determine the acting sound pressure where the entrance and the area or room behind can be found.

It is important to take into account the proximity of people working close to an air curtain, in such cases the noise can be reduced by controlling the airflow of the air curtain.

3.4.2. Comfort air curtain or industrial air curtain

As introduced in paragraph 3.1, air curtains can be used in different situations (as defined by the Eurovent Recommendation 16-4[8]) that can be distinguished as follows:

- A. The opening where the air curtain is used is primarily intended to allow people through. Eurovent recommends using a comfort air curtain in this case.
- B. The opening where the air curtain is used is primarily intended for logistics applications. Eurovent recommends using an industrial air curtain in this case.

In the case of an industrial air curtain, no legal requirements are set about sound pressure as a result of the air curtain. An exception to this may possibly be the health and safety requirements (LEX,8h ≤ 80 dB) where the adjacent workplaces are. This, however, typically isn't an issue for comfort air curtains as these products typically produce air streams that don't reach this level of sound production.

Requirements are set with regard to the maximum sound pressure in the following situations in the case of a comfort air curtain:

- I. Sound pressure observed by people who walk through the air curtain;
- II. Sound pressure noticed by people who stay in the adjacent and/or a nearby residential area and/or living space.

3.5. Sound pressure when going through the air curtain

3.5.1. Quality requirements

The target value to be used with regard to the maximum permitted sound pressure to which passers-by are exposed will depend on the situation. If the air curtain is used in an entrance area that must meet high-quality requirements (a shop and/or a hotel) rather than if the air curtain is used in, for example, a supermarket or an industrial environment.

If a high-quality level is required, a target value for the occurring sound pressure can be included on an observation level (headroom) of, for example, LA,eq = 60 – 65 dB[A] in a Technical Schedule of

[7] Eurovent AISBL / IVZW / INPA. (2023). Eurovent 16/3 - 2023 - Air curtain unit: Acoustic performance and calculations. Brussels: Eurovent.
[8] Eurovent AISBL / IVZW / INPA. (2024). Eurovent 16/4 - 2024 – Classification and correct positioning of an air curtain unit. Brussels: Eurovent.

Requirements. This observation level is at approximately 1.80 metres from the floor. The distance from the observation level to the air curtain will depend on the height of the opening.

2.6 Sound pressure and sound power

The Eurovent Recommendation 16-3 'Acoustic performance and calculations'[9] defines sound pressure and sound power as:

2.6.1 Sound pressure

Sound pressure is the pressure wave with which the sound moves in a medium, for instance, air.

The human ear interprets these pressure waves as sound. They are measured in Pascal [Pa].

The weakest sound pressure that the ear can interpret is 0,00002 Pa (p_0), which is the threshold of hearing. The strongest sound pressure which the ear can tolerate without damage is 20 [Pa], referred to as the upper threshold of hearing.

The large difference in pressure, as measured in [Pa], between the threshold of hearing and the upper threshold of hearing, makes the figures difficult to handle. So, a logarithmic scale is used instead, which is based on the difference between the actual sound pressure level (p) and the sound pressure at the threshold of hearing. This scale uses the decibel (dB) unit of measurement, where the threshold of hearing is equal to 0 [dB] and the upper threshold of hearing is 120 [dB].

To recalculate [dB] from [Pa] you can use the following formula:

$$L = 20 \cdot \log(p/p_0)\ [dB]$$

The sound pressure reduces as the distance from the sound source increases and is affected by the room's characteristics and the location of the sound source. Sound pressure can be measured by the microphone.

2.6.2 Sound power

Sound power is the energy per time unit (Watt) that the sound source emits.

The sound power is not measured, but it is calculated from the sound pressure. There is a logarithmic scale for sound power similar to the scale for sound pressure.

The sound power is not dependent on the position of the sound source or the room's sound properties, and it is, therefore, easier to compare between different objects. Sound power is not measured directly, it is calculated from the sound pressure.

[9] Eurovent AISBL / IVZW / INPA. (2023). Eurovent 16/3 - 2023 - Air curtain unit: Acoustic performance and calculations. Brussels: Eurovent.

4. Energy loss through openings without an air curtain

This section describes energy loss through an opening where air curtains aren't installed. As stated in the section 1, in this document the term 'energy loss' is used for both the winter and the summer seasons, since air curtains reduce the energy exchange between two climates, which could be inside and outside a building but also between two different areas with different temperatures inside the same building.

Energy loss can occur because of three contributions:

- A net ventilation flow through the opening if a net mechanical discharge of ventilation air occurs from the area or room behind. This is typically seen when there is an unbalanced ventilation system that cause the building to be over-pressurised or under-pressurised;
- A net ventilation flow through the opening because of wind pressure differences over the opening that may occur in combination with openings elsewhere in the building;
- Air exchange because of temperature differences on both sides of the opening where hot air flows to the cold area or room and vice versa because of a thermal draught or natural convection. In this case, the net ventilation flow remains equal to zero because both sub-flows are of the same volume.

This section first describes energy loss in a situation without an air curtain. Subsequently, energy savings can be obtained by using an air curtain.

4.1. Energy loss due to airflow because of ventilation

The optimum operation of an air curtain is reached if both sides of the air curtain have a balanced ventilation system as this creates a pressure difference over the opening of zero. When the ventilation system is unbalanced, there is a net ventilation flow through the opening, either over-pressurising the building causing conditioned air to escape, or under-pressuring the building causing draughts and infiltration. In both cases, the net energy gain or loss should be calculated and used as part of the building services design.

The climate separation efficiency of the air curtain will become noticeably reduced if the ventilation is unbalanced. Therefore, the use of air curtains in buildings with balanced ventilation systems is applied as a quality requirement in this publication.

4.2. Energy loss through an opening without an air curtain because of wind

If a large airflow because of wind pressure can occur, for example, if two large openings on both sides of a corridor can be opened at the same time, this will contribute considerably to energy loss. This airflow will depend on many factors and, generally, a custom-made solution will be required for this. Annex A gives a concise calculation approach. A detailed calculation method for this is not part of the scope of this publication.

An indication of the air ingress because of wind attack can be obtained by applying the following formula:

$$Q_{v,w} = H \cdot B \cdot C_D \cdot \sqrt{(R \cdot C_p)} \cdot v_w \qquad [m^3/s]$$

Where:

B	= width of the opening	[m]
C_D	= the discharge coefficient of the opening, approximately 0.6	[-]
Cp	= wind pressure coefficient	[-]
H	= height of the opening	[m]
$Q_{v,w}$	= air ingress	[m³/s]
R	= reduction factor because of the air tightness of the building	[-]
v_w	= local wind speed	[m/s]

Substantiated choices for the values of the wind pressure coefficient, local wind speed and air tightness of the building are important when using the above equation. Tools are given in the annexes or for example in free online tools (like the ASHRAE database) that can be used to determine these parameters for simple situations.

The Cp factor is explained in Annex D - Energy loss as a result of wind.

Design guidelines are given in this publication based on the following standard principles:

- I. The (local) wind speed up to where the air curtain must operate contributes 5 m/s at most. This agrees with a local wind climate class A or B in accordance with the NEN 8100 standard. Annex B - Wind nuisance and air curtains, provides tools for investigating the local wind climate;
- II. The building in which the air curtain is being installed is in a sheltered environment. The Cp value amounts to 0.38 at most because of this. Tools to determine the Cp factor are given in Annex D - Energy loss as a result of wind;
- III. The building in which the air curtain is being installed has appropriate air tightness. The R value amounts to 0.2 at most because of this. Tools for determining R are given in Annex C - Atmospheric tightness of buildings and air curtains.

If the standard principles are not met, an expert must be consulted for the design.

If these conditions, however, are met, the above equation can be used and the design air volume flow amounts to:

$$Q_{v,w} = 0{,}83H \cdot B \qquad [m^3/s]$$

Where:

$Q_{v,w}$	= air ingress	[m³/s]
B	= width of the opening	[m]
H	= height of the opening	[m]

The design energy loss in the instant of time because of wind attack Φ_{wind} can be determined with the following formula:

$$\Phi_{wind,without} = Q_{v,w} \cdot \rho \cdot c_v \cdot \Delta\theta \qquad [kW]$$

Where:

c_v	= specific heat of air	[kJ/(kgK)]
$Q_{v,w}$	= air ingress	[m³/s]
$\Delta\theta$	= temperature difference between inside and outside	[K]
ρ	= Air density	[kg/m³]

Based on a design indoor temperature of 18°C, this leads to energy loss as indicated in Table 3.

Table 3: Energy loss in kW because of wind attack per m² opening in the instant of time. The dark blue shading refers to a combination of extreme design conditions and the light blue shading is an example of a more moderate design requirement.

V wind [m/s]	5	4	3	2	1
θout [°C]					
-7	25.0	19.9	14.9	9.9	5.0
0	18.0	14.7	11.0	7.4	3.7
5	14.0	11.0	5.5	8.3	2.8
10	9.0	7,.4	5.5	3.7	1.8

The table shows that energy loss can quickly increase in the case of a wind attack when the outdoor temperatures are low. Nearly twice as much heating power is required per m² compared to less stringent design requirements for a combination of low outdoor temperatures and high wind speeds (dark blue), for example, because the door opening can be closed partially under extreme conditions (light blue). The design of outdoor temperature where the air curtain must still work is an important principle in the schedule of requirements where the customer must make a choice in close consultation with the installation expert. The choice must be set down in the schedule of requirements.

4.3. Energy loss through an opening without an air curtain: thermal draught

For areas or rooms in which moisture or condensation may be ignored, energy loss is determined in accordance with Annex A - Energy loss through openings because of thermal draught.

An example calculation of energy loss through an entrance area to an area or room without moisture accumulation is given in Table 4.

Table 4: Example of energy loss per metre of width through an opening because of thermal draught (Φ_{tt}) in the instant of time; temperature of the indoor room/area/conditioned room/area is 20 ºC

Outdoor temperature [ºC]	Heat loss at H=2.5 m [kW]	Heat loss at H=3 m [kW]	Heat loss at H=3.5 m [kW]	Heat loss at H=4 m [kW]	Heat loss at H=5 m [kW]	Heat loss at H=6 m [kW]
-10	29.7	39.0	49.2	60.1	83.9	110.3
-7	24.2	31.8	40.1	48.9	68.4	89.9
0	15.3	20.2	25.4	31.1	43.4	57.0
5	8.9	11.6	14.7	17.9	25.1	32.9
10	5.7	7.5	9.5	11.6	16.2	21.3

4.4. Energy loss calculation model

The total energy loss through an opening Φ_o is the sum of the contributions made by the mechanical ventilation, wind pressure and thermal draught:

$\Phi_0 = \Phi_{mech} + \Phi_{wind} + \Phi_{tt}$ [kW]

Where:

Φ_{mech} = energy loss because of the ventilation unbalance [kW]

Φ_{wind} = energy loss through wind influences [kW]

Φ_{tt} = energy loss through thermal draught [kW]

The following is assumed as the design principle: $\Phi_{mech} \approx 0$.

5. Supply performance of a heated air curtain

The supply performance of a heating unit is defined as the heating power that benefits the area or room in which the unit is being installed divided by the supplied heating power. The supply performance is not completely 100% for heating units installed near the outside shell of a heated area or room such as, for example, a radiator because the outer wall is heated by radiator radiation and convection.

An air curtain unit is installed near an opening and therefore a supply performance η_{afg} smaller than 100% must be taken into account analogously with the situation of a wall radiator.

Figure 8 shows the situation of a heated air curtain. A correctly adjusted air curtain has been installed in the opening, which closes the opening completely. This ensures that a high CSE can be achieved of approximately 80%. The fact that the CSE does not amount to 100% is due to the fact that the discharged air causes some turbulence, in particular, at the floor area where the air blows against the floor at a speed of 2-3 m/s. The turbulence causes an air exchange between the area inside and outside that is proportional to (1-CSE). The heat of the air curtain will also end up in this turbulent area so that an energy loss to the outside is also expected to be proportional to (1-CSE). Based on this, the supply performance of a correctly adjusted air curtain is estimated to be $\eta_{afg} \approx$ CSE.

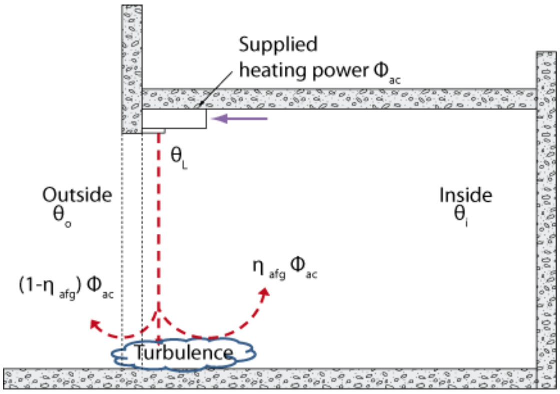


Figure 8: Supply performance of a heated air curtain

Heating power $\Phi_{L,N}$ that must be supplied to the air curtain to compensate for the remaining energy loss through the opening can be determined based on the supply performance:

$\Phi_{L,N} = \Phi_{rest}/\eta_{afg}$ [kW]

Where:

Φ_{rest} = remaining energy loss through the opening if an air curtain is used [kW/m]

η_{afg} = output effectiveness of the air curtain [-]

If the supplied power of the unit Φ_L equals $\Phi_{L,N}$, a thermally neutral air curtain is involved.

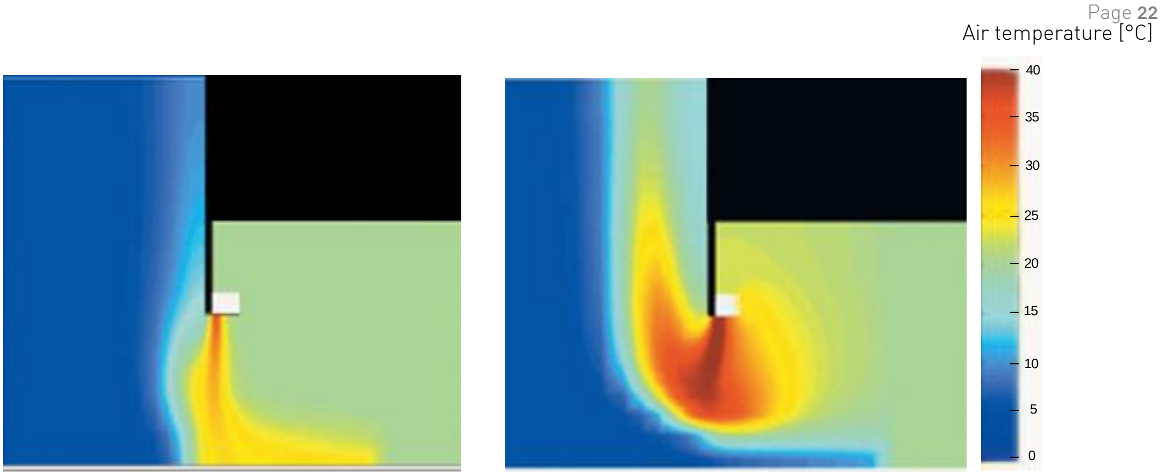


Figure 9: Correctly adjusted (left) and incorrectly adjusted (right) air curtain

If the air curtain is not correctly adjusted, large output losses may occur. This is illustrated in Figure 9.

A Computational Fluid Dynamics (CFD) calculation is shown in the left situation related to a correctly adjusted air curtain. A correct climate division between inside and outside air can be seen in the figure, also it is possible to see that the hot airflow of the air curtain mainly benefits the area or room behind. A CFD calculation is shown in the right situation related to an incorrectly adjusted air curtain. An insufficient climate divide between inside and outside air can be seen in the figure from the cold air that flows inside along the floor. You can also see that the heat that is blown out mainly deflects to the outside. The colder the air that flows in, the more the hot air is pushed outside.

The CSE appears once in the design calculation with regard to an ambient air curtain (= air curtain without heating or cooling), that is, when limiting the air exchange between the inside and outside.

The CSE appears twice in the design calculation with regard to a heated air curtain, that is, first in limiting the air exchange between the inside and outside and, subsequently, in the heating supply performance. This means that it is even more important to always aim for the maximum CSE with regard to a heated air curtain in the design and maintenance.

Important remarks when choosing and installing an air curtain unit

Filtering

To protect the heat exchanger against dust and particles accumulation, it is usually necessary to install filters.
The manufacturer must determine whether an air filter is necessary or not depending on the installation conditions and type of equipment.

Electricity

Manufacturers and installers must comply with the existing regulations and standards, according also to existing legislation which applies to the local place of installation.

Annex A - Energy loss through openings because of thermal draught

The method described in this Annex calculates the energy loss between a hot and a cold area or room and implicitly assumes that the absolute atmospheric humidity in both areas or rooms is equal. This is, for example, the case of an entrance to an area in which no moisture production or condensation occurs. This method bases the energy loss only on temperature differences and is not suitable for areas with moisture production or condensation. The method can also be applied in areas or rooms with a thermal gradient.

The simplified method

When the influence of the absolute atmospheric humidity is negligible, the advantage of this method is that calculations can be done with only indoor and outdoor temperatures.

Energy loss calculation for a large vertical opening with height h, airflow v(z) at height z, where v(z) is the air speed at height z, with

$z_b < z < z_b + h$ (see Figure 10).

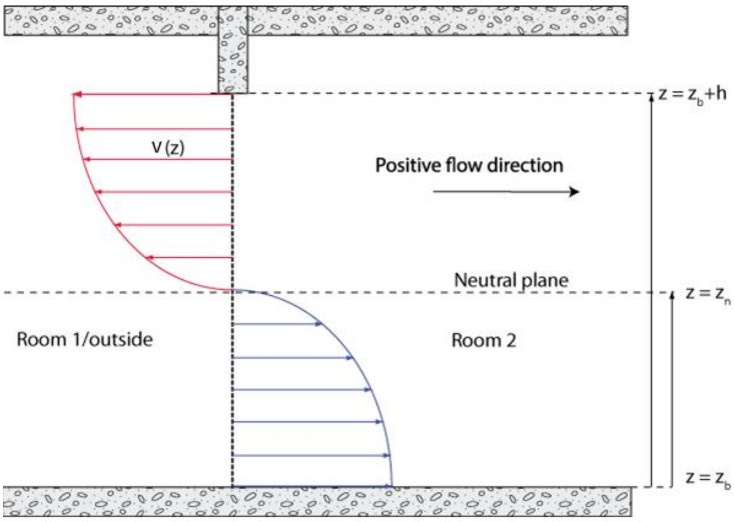


Figure 10: Thermal and mass exchange through an open passage between colder and warmer areas

A comparison for v(z) is given based on Bernoulli's equation:

$$v(z) = \sqrt{\frac{2\Delta p}{\rho}} = \sqrt{\frac{2\Delta p}{\rho} \cdot g \cdot (z - z_n)} = \sqrt{\frac{2g}{\theta} \cdot \Delta\theta \cdot (z - z_n)} \quad \text{[m/s]}$$

Where:

g	= gravitational acceleration	[m/s²]
v	= air speed	[m/s]
z	= height	[m]
Δp	= pressure difference over air curtain	[Pa]
ρ	= air density	[kg/m³]

$\Delta\theta$	= temperature difference inside/outside	[K]

v(z)=0 in the neutral plane z= z_n. When it is assumed that there is no net airflow, then z_n = 0.5 h. The total air volume flow is calculated through the integration of v(z) from z=0 to z=z_n (positive direction) or from z=z_n to z=h (negative direction), which results in two equal air volume flows with opposite signs.

The calculation of the corresponding energy loss is based on:

$$\Phi_{tt} = (1/3) \cdot \rho_1 \cdot C_D \cdot c_p \cdot B \cdot H^{(3/2)} \cdot \Delta\theta^{(3/2)} \cdot \sqrt{\frac{g}{T}} \cdot C_{corr} \quad [kW]$$

$$C_{corr} = 1 + \big(0{,}3 \cdot H \cdot (b_1 + b_2)\big)/\Delta\theta \quad [-]$$

Where:

B	= width of the opening	[m]
b_1	= cold room/outside temperature gradient	[K/m]
b_2	= hot room temperature gradient	[K/m]
C_D	= coefficient of resistance	[-]
C_{corr}	= correction factor for thermal gradient	[-]
c_p	= heating capacity of air	[kJ/(kg·K)]
H	= height of opening	[m]
Φ	= energy loss	[kW]

Energy loss calculation with the simplified method

To determine energy loss, is it possible to use the above equations or the tables below in which the equations for a number of values are worked out.

- Step 1: With the help of Table 5, determine the correction factor C_{corr} due to the thermal gradient. As you can see in the table, this is especially important with minor temperature differences between the two areas;
- Step 2: With the help of Table 6, determine the energy loss per metre-width of the opening in one instant of time. The determined energy loss is without correction factor for the thermal gradient;
- Step 3: Multiply the results of step 1 and step 2. This is energy loss per metre of opening in one instant of time;
- Step 4: Multiply the result of step 3 (loss of energy per metre of opening) by the width of the opening. This is the total energy loss because of temperature differences Φ_{tt} in one instant of time [kW].

Table 5: Correction factor C_{corr} because of the thermal gradient

b1 , b2 [K/m]	H [m]	Δ θ [K]	C_{corr} [-]
0	*	*	1
1	2	5	1.2
		10	1.1
		15	1.1
		20	1.1
		25	1.0
		30	1.0
	3	5	1.4
		10	1.2
		15	1.1
		20	1.1
		25	1.1
		30	1.1
	4	5	1.5
		10	1.2
		15	1.2
		20	1.1
		25	1.1
		30	1.1
	5	5	1.6
		10	1.3
		15	1.2
		20	1.2
		25	1.1
		30	1.1
2	2	5	1.5
		10	1.2
		15	1.2
		20	1.1
		25	1.1
		30	1.1
	3	5	1.7
		10	1.4
		15	1.2
		20	1.2
		25	1.1
		30	1.1
	4	5	2.0
		10	1.5
		15	1.3
		20	1.2

		25	1.2
		30	1.2
	5	5	2.2
		10	1.6
		15	1.4
		20	1.3
		25	1.2
		30	1.2

Table 6: Energy loss per metre of the width of the opening in the instant of time, for different temperatures and heights of the opening

H [m]	ϴ [°C]	Δ θ [K]	Q (per metre width) [kW/m]		H [m]	ϴ [°C]	Δ θ [K]	Q (per metre width) [kW/m]
2	-10	5	1.5		3	-10	5	2.8
		10	4.4				10	8.0
		15	8.0				15	14.7
		20	12.4				20	22.7
		25	17.3				25	31.7
		30	22.7				30	41.7
	-5	5	1.5			-5	5	2.8
		10	4.3				10	8.0
		15	8.0				15	14.6
		20	12.2				20	22.5
		25	17.1				25	31.4
		30	22.5				30	41.3
	0	5	1.5			0	5	2.8
		10	4.3				10	7.9
		15	7.9				15	14.5
		20	12.1				20	22.3
		25	17.0				25	31.1
		30	22.3				30	40.9
	5	5	1.5			5	5	2.8
		10	4.2				10	7.8
		15	7.8				15	14.3
		20	12.0				20	22.1
		25	16.8				25	30.9
		30	22.1				30	40.6
	10	5	1.5			10	5	2.7
		10	4.2				10	7.7
		15	7.7				15	14.2
		20	11.9				20	21.9
		25	16.6				25	30.6

		30	21.9				30	40.2
	15	5	1.5			15	5	2.7
		10	4.2				10	7.7
		15	7.7				15	14.1
		20	11.8				20	21.7
		25	16.5				25	30.3
		30	21.7				30	39.9
	20	5	1.5			20	5	2.7
		10	4.1				10	7.6
		15	7.6				15	14.0
		20	11.7				20	21.5
		25	16.4				25	30.1
		30	21.5				30	39.5
4	-10	5	4.4		5	-10	5	6.1
		10	12.4				10	17.3
		15	22.7				15	31.7
		20	35.0				20	48.8
		25	48.8				25	68.3
		30	64.2				30	89.7
	-5	5	4.3			-5	5	6.0
		10	12.2				10	17.1
		15	22.5				15	31.4
		20	34.6				20	48.4
		25	48.4				25	67.6
		30	63.6				30	88.9
	0	5	4.3			0	5	6.0
		10	12.1				10	17.0
		15	22.3				15	31.1
		20	34.3				20	47.9
		25	47.9				25	67.0
		30	63.0				30	88.1
	5	5	4.2			5	5	5.9
		10	12.0				10	16.8
		15	22.1				15	30.9
		20	34.0				20	47.5
		25	47.5				25	66.4
		30	62.5				30	87.3
	10	5	4.2			10	5	5.9
		10	11.9				10	16.6
		15	21.9				15	30.6
		20	33.7				20	47.1
		25	47.1				25	65.8
		30	61.9				30	86.5
	15	5	4.2			15	5	5.8
		10	11.8				10	16.5

		15	21.7				15	30.3
		20	33.4				20	46.7
		25	46.7				25	65.2
		30	61.4				30	85.8
	20	5	4.1			20	5	5.8
		10	11.7				10	16.4
		15	21.5				15	30.1
		20	33.1				20	46.3
		25	46.3				25	64.7
		30	60.8				30	85.0

Annex B - Wind nuisance and air curtains

Europe has a variable wind climate where wind speed and wind direction can vary greatly. This depends on the location in the country (close to the coast or more inland), the surrounding environment (lots or little shelter or enclosing buildings or landscapes) and specific forms of buildings that could have a negative or positive influence on local wind speeds. High buildings and narrow passageways often result in high wind speeds.

To predict the local wind climate, a wind nuisance expert can make use of a theoretical consideration of the situation, experimental research using a wind tunnel or a numerical simulation, or actual measurements in the case of an existing situation. With all these methods, a connection is made between local wind effects (depending on specific forms of buildings and the immediate environment) and local wind statistics (depending on the location in the country). Ultimately, a statement can be made about how often a certain wind speed will occur, or what percentage of the time it will blow harder than a certain wind speed.

With a wind investigation, it can be determined how often a certain wind speed occurs, on the basis of which it can be assessed if additional measures are needed when installing an air curtain. In this annex, for such an assessment, a concise approach is elaborated with the following objectives:

- Based on this annex, a customer can assess if he is dealing with:
  - A. A project with low wind speeds where a standard air curtain can be installed;
  - B. A project where it is possible that high wind speeds occur often and, therefore, more research into wind nuisance is necessary.

In the case that it concerns a project where there are relatively low wind speeds at the entrance door, a methodology has been developed that allows the determination of the influence of wind on the air curtain for the benefit of the design phase.

Backgrounds

To determine how often a certain wind speed occurs at the location of an entrance, a link is sought between the quantities and parameters as specified in NEN 8100 (Dutch standard for the assessment of wind nuisance). In NEN 8100, the assessment of the wind (nuisance) climate is based on how often a certain nuisance boundary occurs throughout the year. The following two aspects are mentioned:

- A threshold speed $v_{dr,h}$ to assess the wind nuisance for the local wind speed at walking or staying level v_{lok};
- A possibility of exceeding p ($v_{lok} > v_{dr,h}$).

As a nuisance boundary (the so-called threshold wind speed), NEN 8100 maintains an average per hour wind speed of 5 m/s. Depending on the location, environment and situation, a possibility of exceeding is then determined. The greater the possibility of exceeding the threshold wind speed, the worse the assessment of the wind climate.

For the assessment of the applicability of an air curtain, the same quantities can be used. With a local wind speed of 5 m/s, the wind pressure on the façade amounts to between approximately 3 and 9 Pa, depending on a number of factors. With a sufficiently air-tight building, the pressure difference over the opening in which the application of an air curtain is being considered amounts to approximately

0.5 - 3 Pa. A wind pressure up to approximately 3 Pa in the context of this publication is regarded as acceptable with the design of a standard air curtain.

Because of the relationship between the wind pressure and the local wind speed described above, the possibility of exceeding a certain wind speed provides insight into the applicability of an air curtain. After all, it allows for the possibility that the acceptable situation for the application of an air curtain (pressure difference 3 Pa, wind speed 5 m/s) may be exceeded. Depending on what possibility of exceeding is regarded as acceptable, then with a possibility of exceeding that is too high it can be decided that additional measures are needed to reduce the wind pressure over the air curtain to a lower level by means of, for example, an airlock or a revolving door.

Wind nuisance standard NEN 8100 distinguishes between different quality grades of the wind climate, where quality grade A stands for the best wind climate, and quality grade E for the most unfavourable wind climate. The Table 7 below is partially taken from NEN 8100 and supplemented with a column in which the applicability of an air curtain is included.

Table 7: Quality grades based on NEN 8100

Possibility of exceeding $p(v_{lok} > v_{dr,h})$ in percent of the number of hours per year	Quality grade	Applicability air curtain
< 2,5	A	Good
2.5 – 5	B	Good
5-10	C	Detailed assessment is to be done on a case-by-case basis.
10-20	D	
>20	E	

Based on the assumption that a possibility of exceeding a maximum of 5% is acceptable (that is, the air curtain has sufficient strength to stop wind pressure for 95% of the time), it applies that, with quality grades A and B from NEN 8100, the wind climate is sufficiently suitable for the application of an air curtain and no further research is needed. If quality grade A or B do not occur, further research must determine how great the possibility of exceeding is. Then, based on the degree of exceeding, taking further measures can be considered.

As shown in Table 7, exceeding the design value is possible in each situation. This means that even in the event of a good wind climate and a correct design, there may be incidental hours during which the wind attack on the air curtain is too strong.

Example: Wind climate in the Netherlands

Wind speed and wind direction

The wind speed will depend on various factors, including the location. Figure 11 has been taken from "The Climate Atlas of the Netherlands" and by means of a colour scale indicates the location of the annual average wind speed at a height of 10 metres above ground level.

In Figure 11 it can be seen that the highest wind speeds occur at coastal locations. In addition to the average wind speed, the wind direction is also important for an assessment. In the Netherlands, most of the wind blows from the direction between south and west. See by way of illustration the compass card located in De Bilt.

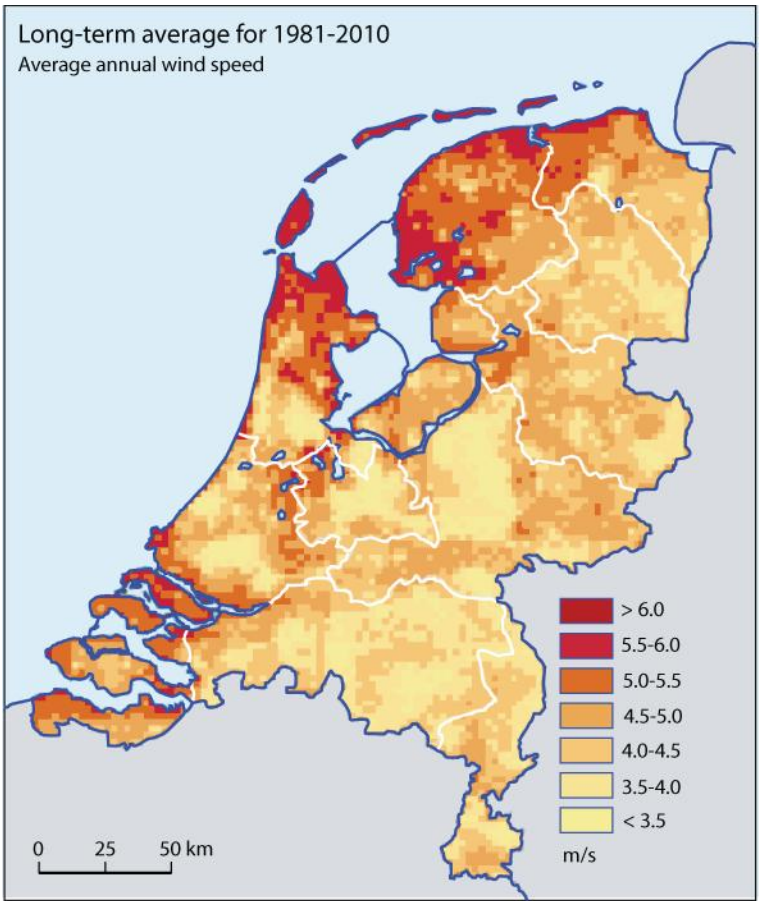


Figure 11: Wind climate in the Netherlands: average wind speed at a height of 10 metres

The possibility of exceeding for a certain entrance is acquired by the aggregate of the possibilities of exceeding all separate wind directions. It is clear that an entrance location with an orientation toward the dominant south-westerly direction has a higher possibility of exceeding than an entrance location with a north-easterly orientation.

The broader environment and the foreland

The direct environment of a location determines the wind airflow at a location to a large degree. Thus, in an urban or woody environment, the wind speeds are much lower than on open terrain, such as a pasture. It is also important to link with the compass card here. The possibility of exceeding on the southwestern side of the city is greater than, for example, the northern edge of it.

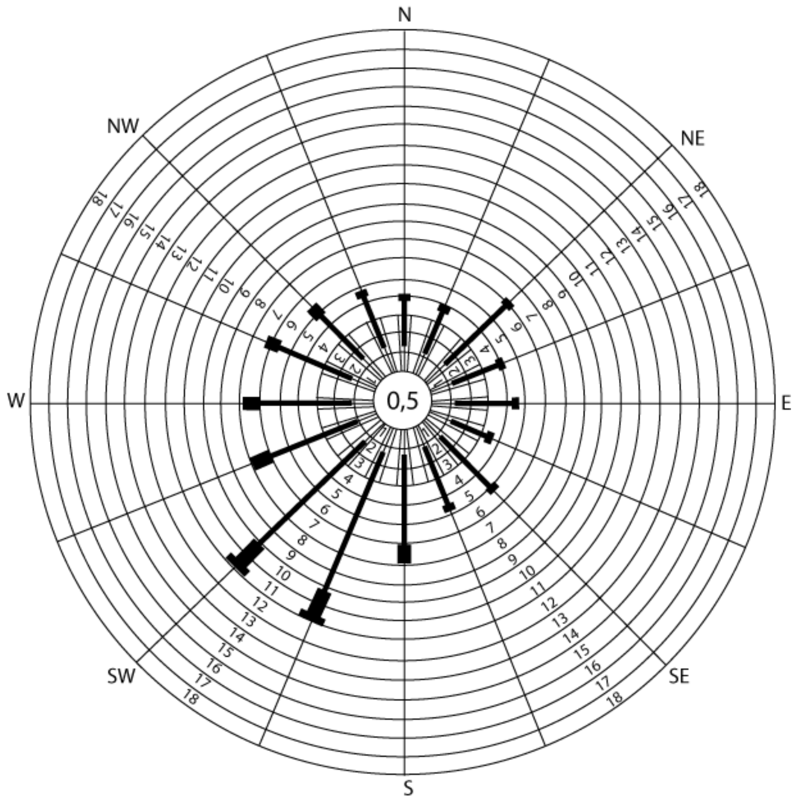


Figure 12: Compass card for De Bilt location

The immediate environment and the building

In addition to the broader environment, wind effects because of specific forms of buildings play a role in the wind climate at a certain location. Buildings with a height of more than 30 metres result in an increase in the wind speed at ground level (especially at the location of the building corners). Therefore, if the entrance is located in a tall building or the entrance is located in the proximity of a tall building, there is the risk of exceeding that is too high. Even if the entrance is located in the proximity of a narrowing of cubic volumes (a draughting hole), there is the risk that the exceedance will be too high.

A wind nuisance expert can determine the risk quantitatively in these situations.

Risk stocktaking

Based on the previous aspects, in the context of a wind attack on an entrance, a number of risk factors can be listed indicatively:

- The entrance is located in the country where there are relatively high wind speeds. The red areas based on Figure 11;
- The entrance is located in a façade with an orientation between south and west and is not located in an urban environment;
- The entrance is located in a building with a height of at least 30 metres;
- The entrance is located in the proximity of a building with a height of at least 30 metres;
- The entrance is near a narrowing of building volumes such as a passageway or an underpass.

If one of the risk factors listed above is present, a wind nuisance investigation is needed to determine the design wind speed on the façade.

If these risk factors are not present, in this Eurovent Recommendation an environment with the possibility of exceeding the threshold wind speed of 5 m/s of a maximum of 5% (class A or B in accordance with NEN 8100) is assumed. In that case, the application of a standard air curtain suffices 95% of the time. With a very complex building geometry, the wind climate must always be assessed.

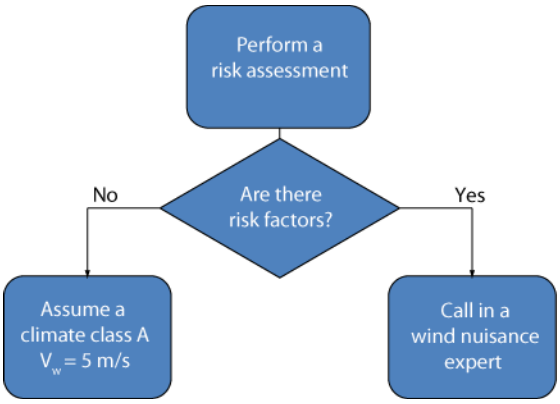


Figure 13: Working method assessment of wind nuisance risk

Annex C - Atmospheric tightness of buildings and air curtains

The atmospheric tightness of the building in which the air curtain will be installed is very important for the operation of an air curtain unit at an entrance.

The wind pressure over the air curtain depends on the wind pressure on the façade:

$$\Delta p = R \cdot \Delta p_w \quad \text{[Pa]}$$

Where:

R	= reduction factor	[-]
Δp	= pressure difference over air curtain	[Pa]
Δp_w	= wind pressure on the wall	[Pa]

The reduction factor R will depend on the atmospheric tightness of the building.

Two components contribute to the atmospheric tightness of the building:

- The atmospheric tightness of the building shell with closed doors and windows.
- Any openings and open doors and windows elsewhere in the building.

For the determination of the atmospheric tightness of the building shell, a number of methods are available.

Measurement methods for the atmospheric tightness of the building shell are given in EN ISO 9972 standard. The atmospheric tightness in accordance with these methods is expressed in a specific $q_{v,10}$-value, which is the air volume flow by infiltration per square metre of surface, with a reference pressure of 10 Pa over the building shell.

If openings such as doors and windows are present elsewhere in the building, special attention is required. If these openings are used regularly during the air curtain's operating time, this could influence the operation of the air curtain. In that case, it is preferred to have dividing doors that reduce the draught through the building.

If doors are present elsewhere in the building that are open permanently, it is preferred to place a provision in the entrance where the air curtain is installed in the form of a vestibule, air lock, revolving door or similar.

This annex provides a number of indicative calculation methods with which the size of R can be estimated.

Reduction factor of a building based on building characteristics

In Figure 14, a number of possible situations are outlined where the reduction factor R is given, depending on building characteristics.

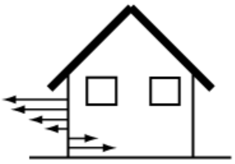
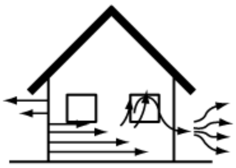
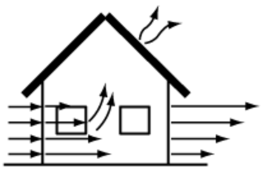
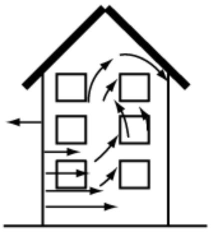
		Reduction factor R	
		Shielded	Unshielded
	One storey building Airtight building (new build) with no opposite doors	0.15	0.2
	One storey building Non-airtight building (old building) wit no opposite doors	0.2	0.3
	One storey building Non-airtight building with opposite doors	0.4	0.5
	Multistorey building Airtight building	0.6	0.75
	Multistorey building Non-airtight building (open skylights, etc.)	0.8	1.0

Figure 14: Reduction factor R for different building characteristics. The side on which the air curtain is installed influences the performance of the air curtain to create climate separation.

Quantitative determination method for simple situations

In the previous section, a general indication of the reduction factor R is given, based on building characteristics.

For buildings with simple geometry, restricted dimensions (< 1,000 m^2) and no more than one storey, it is possible to indicate several quantitative determination methods.

In the following figures, three situations are given in which R can be determined with a reasonable degree of accuracy. The total value of R can be a sum of the three different contributions.

Two openings on opposite sides

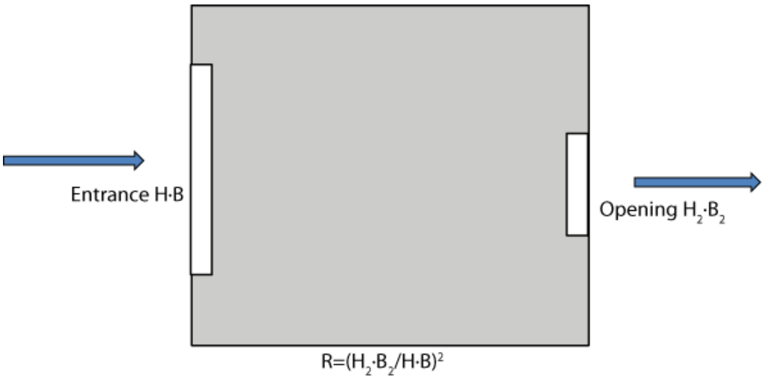


Figure 15: Reduction factor for two doors on opposite sides, where the opening with the HB dimension is the largest of the two. The reduction factor R depends on the size of the second opening with the H2.B2 dimension in the rear façade. H2.B2 << H.B

Opening in a side façade

For a situation with an opening in the façade situated in a side façade next to the entrance, a calculation method is given in Figure 16. The calculation is valid if the opening in the side façade is much smaller than the entrance with the air curtain. In this case, a reduction factor can be used that is half of the value in Figure 15.

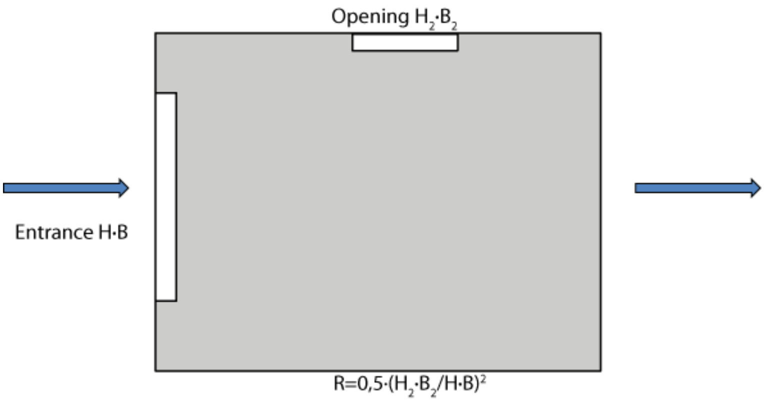


Figure 16: Reduction factor in the case of a door or window opening in a side façade, where the opening with the HB dimension is the largest of the two. The reduction factor R depends on the size of the second opening in the side façade. H2.B2 << H.B

Determination of the influence of the atmospheric tightness of the building shell

The atmospheric tightness of the building shell can be determined in accordance with the methods given in the first section of this annex based on the atmospheric tightness of the building shell.

For example, for a shop unit of 100 m^2 with an atmospheric tightness of 0.15 $dm^3/(s \cdot m^2)$, the comparison yields an R-value of 0.06.

For a geometry and building method that is known, a more accurate calculation can be made by replacing the term $A \cdot q_{v,10,spec}$ in the comparison with the infiltration of the rear façade, based on cracks and seams present. The calculation of the infiltration can be done based on the information from the

SBR publication Building Air-Tight, possibly in combination with numeric software for the calculation of airflows.

For a request for an integrated environmental permit for the aspect of a building, a value for $q_{v,10,spec}$ is often entered in the energy performance calculation.

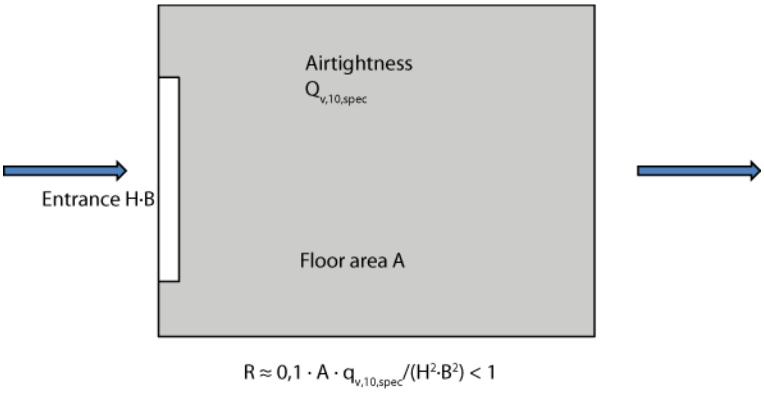


Figure 17: Reduction factor R in the case of an otherwise closed area with floor surface A and specific atmospheric tightness q v,10,spec. The comparison is an indication with a restricted accuracy

Risk inventory

There are several risk factors that must be mentioned in the context of insufficient atmospheric tightness of the building:

- Several openings in the building shell, such that the value of R determined is greater than 0.2;
- A type of building based on Figure 14, such that the value of R is greater than 0.2;
- Older buildings (year of construction before approximately 2005) of which the atmospheric tightness of the building shell $q_{v,10,spec}$ is not known;
- Buildings with a floor surface > 1000 m^2;
- A building with high open internal spaces (i.e., large atriums, staircases, lift shafts etc.) where the chimney effect can occur;
- Unbalanced ventilation systems;
- Entrance provisions for special buildings. Some examples are covered shop passages, station buildings and buildings consisting of several building sections that have a combined air handling or movement system;
- Special buildings where there is a significant change in internal pressure during the building's operating hours (i.e., subway station where air is pressurised by passing trains).

If one of the risk factors is present, a more detailed study is needed to determine whether the building is sufficiently air-tight to install an air curtain, or whether an additional provision (air lock construction) is needed to reduce the wind pressure over the air curtain.

If these risk factors are not present, in this Eurovent Recommendation it is assumed that there is a sufficient air-tight building with R = 0.2. The flow chart for the risk inventory is given in Figure 18.

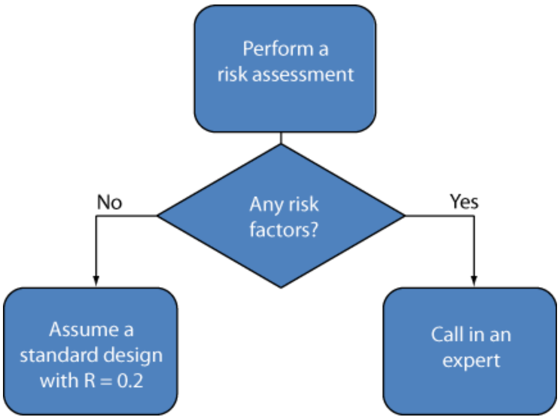


Figure 18: Working method of evaluation risk for building with insufficient atmospheric tightness

Annex D - Energy loss as a result of wind

Energy loss as a result of wind through an opening without an air curtain

An indication of the air ingress because of a wind attack on an entrance of a reasonably air-tight building can be achieved with the following formulas:

$$\Delta p_w = 0{,}5 \cdot \rho \cdot C_p \cdot v_w^2 \qquad \text{[Pa]}$$

$$\Delta p_L = R \cdot \Delta p_w \qquad \text{[Pa]}$$

$$Q_{v,w} = H \cdot B \cdot C_D \cdot \sqrt{\frac{2 \cdot \Delta p_L}{\rho}} \qquad [m^3/s]$$

Where:

B	= width of the opening	[m]
C_D	= discharge coefficient of the opening (Cd =approximately 0.55)	[-]
C_p	= wind pressure coefficient	[-]
H	= height of the opening	[m]
$Q_{v,w}$	= air ingress	[m^3/s]
R	= dimensionless correction factor that depends on the tightness of the building.	[-]
v_w	= local wind speed	[m/s]
Δp_w	= wind pressure on the wall	[Pa]
Δp_L	= pressure difference over air curtain	[Pa]
ρ	= air density (1.2 kg/m^3)	[kg/m^3]

A combination of the above gives:

$$Q_{v,w} = H \cdot B \cdot C_D \cdot \sqrt{R \cdot C_D \cdot v_w} \qquad [m^3/s]$$

Where:

B	= width of the opening	[m]
C_D	= discharge coefficient of the opening (C_D =approximately 0.55)	[-]
C_p	= wind pressure coefficient	[-]
H	= height of the opening	[m]
$Q_{v,w}$	= air ingress	[m^3/s]
R	= dimensionless correction factor that depends on the tightness of the building.	[-]
v_w	= local wind speed	[m/s]

The energy loss through this opening without an air curtain as a result of wind, Φ_{wind}, amounts to

$$\Phi_{wind} = Q_{v,w} \cdot \rho \cdot C_v \cdot \Delta\theta \qquad [kW]$$

Where:

C_v	= specific heat of the air (cold side)	[kJ/(kg·K)]
$Q_{v,w}$	= air ingress	[m³/s]
$\Delta\theta$	= design temperature difference between inside and outside conditions	[K]
ρ	= air density (1.2 kg/m³) at temperature/humidity.	[kg/m³]

The wind pressure over the air curtain can be calculated by:

$$\Delta p_L = R \cdot 0{,}5 \cdot \rho \cdot C_p \cdot v_w^2 \qquad [Pa]$$

Where:

C_p	= wind pressure coefficient	[-]
R	= dimensionless correction factor that depends on the tightness of the building.	[-]
v_w	= local wind speed	[m/s]
Δp	= pressure difference over air curtain	[Pa]
ρ	= air density (1.2 kg/m³)	[kg/m³]

Determining the wind pressure coefficient

The static wind pressure coefficient is a dimensionless ratio between the wind pressure exerted on the opening and the associated wind speed. Its value indicates how easily the wind velocity can be increased. The value depends on the location, the building geometry, the height of surrounding obstacles, etc. A number of examples of wind pressure coefficients are given in Table 8. From Table 8 it follows that the degree of shelter has a strong influence on the wind pressure coefficient meaning that the wind velocities are typically lower.

Table 8: Wind pressure coefficient on the front façade of a building with a height of up to 10 metres

	Angle of approach of the wind (0 ° is directly on the façade)							
	0 °	45 °	90 °	135 °	180 °	225 °	270 °	315 °
C_p value (sheltered)	0.06	-0.12	-0.2	-0.38	-0.3	-0.38	-0.2	0.12
C_p value (not sheltered)	0.7	0.35	-0.5	-0.4	-0.2	-0.4	-0.5	0.35
C_p factors in more different situations are available in the literature [AIVC]. C_p factors in more complex urban geometries can be calculated with numeric software.								

For a standard design of an air curtain in a sheltered environment, in this publication, a value of C_p=0,38 is maintained as this is reflective of a typical air curtain installation across Europe.

Approach to assessment of wind attack

Step 1: Perform an indicative assessment of the wind climate.
If the wind climate is assessed as quality grade C or worse, then consider taking an additional measure. Depending on the quality grade of the wind climate, the application of an air curtain without additional measures may lead to comfort complaints for a part of the year.

If the wind climate is assessed as "good," then continue with step 2;

Step 2: Determine the C_p factor for the entrance for the normative wind direction;

Step 3: Determine the reduction factor R;

Step 4: Determine the design wind pressure Δp_L over the air curtain.
The starting point is a local wind speed of 5 m/s, unless otherwise indicated in the customer's requirements or unless the wind nuisance expert advises using a higher wind speed.
The design wind pressure Δp_L over the air curtain is used in the design phase for determining air discharge speed;

Step 5: Determine the air volume flow that appears through the opening comparison because of wind pressure.

Step 6: Determine the energy loss because of this air volume flow or with the help of the tables below. Select the correct value for $\Delta\theta$ based on the schedule of requirements.

For intermediary values of $\Delta\theta$, interpolation may be done. The tables are determined for R=0.2.

Table 9: Energy loss in the instant of time [kW/m²], design $\Delta\theta$=30 K. R=0.2

	Energy loss at a $\Delta\theta$ of 30 K		
Wind speed [m/s]	Cp= 0.2	Cp= 0.38	Cp= 0.6
1	4.0	5.5	6.9
2	8.0	11.0	13.9
3	12.0	16.6	20.8
4	16.0	22.1	27.8
5	20.0	27.6	34.7
6	24.0	33.1	41.6
7	28.1	38.7	48.6

Table 10: Energy loss in the instant of time [kW/m²], design $\Delta\theta$=27 K. R=0.2

	Energy loss at a $\Delta\theta$ of 27 K		
Wind speed [m/s]	Cp= 0.2	Cp= 0.38	Cp= 0.6
1	3.6	5.0	6.3
2	7.2	9.9	12.5
3	10.8	14.9	18.7
4	14.4	19.9	25.0
5	18.0	24.9	31.2
6	21.6	29.8	37.5
7	25.2	34.8	43.7

Table 11: Energy loss in the instant of time [kW/m²], design Δθ=20 K. R=0.2

	Energy loss at a Δ θ of 20 K		
Wind speed [m/s]	Cp= 0.2	Cp= 0.38	Cp= 0.6
1	2.7	3.7	4.6
2	5.3	7.4	9.3
3	8.0	11.0	13.9
4	10.7	14.7	18.5
5	13.4	18.4	23.1
6	16.0	22.1	27.8
7	18.7	25.8	32.4

Table 12: Energy loss in the instant of time [kW/m²], design Δθ=10 K. R=0.2

	Energy loss at a Δ θ of 10 K		
Wind speed [m/s]	Cp= 0.2	Cp= 0.38	Cp= 0.6
1	1.3	1.8	2.3
2	2.7	3.7	4.6
3	4.0	5.5	6.9
4	5.3	7.4	9.3
5	6.7	9.2	11.6
6	8.0	11.0	13.9
7	9.4	12.9	16.2

About Eurovent

Eurovent is Europe's Industry Association for Indoor Climate (HVAC), Process Cooling, and Food Cold Chain Technologies. Its members from throughout Europe represent more than 1.000 organisations, the majority small and medium-sized manufacturers. Based on objective and verifiable data, these account for a combined annual turnover of more than 30bn EUR, employing around 150.000 people within the association's geographic area. This makes Eurovent one of the largest cross-regional industry committees of its kind. The organisation's activities are based on highly valued democratic decision-making principles, ensuring a level playing field for the entire industry independent from organisation sizes or membership fees.

Our Member Associations

Our Member Associations are major national sector associations from Europe that represent manufacturers in the area of Indoor Climate (HVAC), Process Cooling, Food Cold Chain, and Industrial Ventilation technologies.

The more than 1.000 manufacturers within our network (Eurovent 'Affiliated Manufacturers' and 'Corresponding Members') are represented in Eurovent activities in a democratic and transparent manner.

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