Eurovent Industry Recommendation / Code of Good Practice

EUROVENT

EUROPE'S INDUSTRY ASSOCIATION FOR **INDOOR CLIMATE**, **PROCESS COOLING**, AND **FOOD COLD CHAIN** TECHNOLOGIES

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Air curtain unit - Classification, test conditions and energy performance calculations

First Edition

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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 against previous editions in the following manner:

Modifications as against	Key changes
1st edition	Present document

Preface

In a nutshell

- This code of good practice defines air curtain unit classifications
- This code of good practice defines the requirements and test methods to calculate air curtain unit performance
- This code of good practice defines the methods to calculate air curtain unit efficiency and building energy savings

Authors

This document was published by the EUROVENT association and was prepared in a joint effort by participants of the Special Project of the Product Group 'European Air Curtains' (PG-CUR), which represents a vast majority of all manufacturers of these products active on the EMEA market. For a detailed composition list, please contact the Eurovent Secretariat (secretariat@eurovent.eu).

Adoption

It has been approved and adopted through a formal voting procedure by Europe's national member associations from 20+ European countries, which ensures a wide-ranging representativeness based on democratic decision-making procedures. More information on these members can be found on www.eurovent.eu.

The EUROVENT Association 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.

Contents

PART 1: Testing Methods and Climate Separation Efficiency Indexes

1. Scope

The scope of this Eurovent Industry Recommendation / Code of Good Practice is to define the classification of air curtain units, to specify the requirements and test methods to calculate air curtain energy performance and define the methods to calculate air curtain efficiency and building energy savings obtained by using them.

2. Normative and legislation references

The following documents, in whole or in part, are normatively referenced in this document and are necessary for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5801: Industrial fans - Performance testing using standardized airways

ISO 5167: Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full

ISO 27327-1: Fans - Air curtain units - Part 1: Laboratory methods of testing for aerodynamic performance rating

ISO 27327-2: Fans - Air curtain units - Part 2: Laboratory methods of testing for sound power

EN 60335-1 (LVD+MD) Household and similar electrical appliances – Safety – Part 1: General requirements

EN 60335-2-30 (LVD+MD) Household and similar electrical appliances - Safety - Part 2-30: Particular requirements for room heaters

EN 60204-1 (LVD+MD) Safety of machinery. Electrical equipment of machines. General requirements

EN 61000-6-2; Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments

EN 61000-6-3; Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for residential, commercial and light-industrial environments

EN 61000-3-12 Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current ↑16A and ≤75 per phase

EN 55014-1 Electromagnetic compatibility (EMC) - Requirements for household appliances, electric tools and similar apparatus Part 1: Emission

EN 55014-2 Electromagnetic compatibility (EMC) - Requirements for household appliances, electric tools and similar apparatus - Part 2: Immunity - Product family standard

EN 55022 Electromagnetic compatibility (EMC) Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement

EN 61000-4-2 Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test

EN 61000-4-4 Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test

EN 61000-4-5 Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test

EN 61000-4-6 Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields

EN 61000-4-11 Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity test

3. Terms and definition

For the purposes of this document, the following terms and definitions apply.

3.1 Air curtain unit (ACU)

Air-moving device which produces an air curtain airstream.

3.2 Air curtain airstream

Directionally-controlled airstream, moving across the entire height and width of an opening, which can reduce the infiltration or transfer of air from one side of the opening to the other and/or inhibit the passage of insects, dust and debris.

3.3 Motor input power

Electrical power supplied at the terminals of an electric motor drive.

3.4 Total Electrical Energy Consumption

Total daily electrical energy consumption of an ACU.

3.5 Cold cell

Test chamber used to simulate the outdoor test condition or a cold storage room.

3.6 Warm Cell

Test chamber used to simulate the indoor test condition

3.7 Standard rating condition

Mandatory condition that is used for comparison purposes

3.8 Field condition

Typical condition which represents the air curtain installed in the field

3.9 Stable conditions

Conditions as reached in both climate cells, at the same time and for not less than 10 minutes, the temperature difference varying no more than 1K of the defined climate class temperature, with a standard deviation of 0,3K

3.10 Mixing time

Is the time during the temperature test, between the door closing and when the mean temperatures in both climate cells (warm and cold) achieve stable conditions. During the mixing time the standard deviation is $\leq$ 0,3 K.

3.11 Sound Power Level

Sound Power Level is the inherent acoustic power of a sound source

3.12 Sound Pressure Level

Sound Pressure Level is what the human ear hears and a microphone will respond to. The Sound Pressure Level can be specified in the form of a single figure noise criterion: dB(A).

3.13 Performance Factor due to temperature difference

Factor used to compare the performances of different air curtain units subjected to a range of temperature differences.

3.14 Performance Factor due to wind action

Factor used to compare the performances of different air curtain units subjected to a range of different wind actions.

3.15 Infiltration Efficiency due to wind action

Infiltration efficiency due to wind action being the ratio described by the difference in air flow through an opening subjected to wind action, without and with an air curtain unit, divided by the air flow without an air curtain unit.

3.16 Climate Separation Efficiency index due to temperature difference (CSE_T)

Climate separation efficiency index due to temperature difference being the ratio described by the difference in energy loss through an opening subjected to a temperature difference, without and with an air curtain, divided by the energy loss without an air curtain.

3.17 Climate Separation Efficiency index due to wind action (CSE_W)

Climate separation efficiency index due to wind action being the ratio described by the difference in energy loss through an opening subjected to wind action, without and with an air curtain, divided by the energy loss without an air curtain.

4. Symbols

H	Door opening height	[m]
W	Door opening width	[m]
CSE_T	Climate Separation Efficiency index due to temperature difference	[-]
PF_T	Performance Factor due to temperature difference	[-]
Q_T	Heat loss due to air temperature difference	[kW]
$Q_{T\ with}$	Heat loss due to temperature difference through an open door with ACU	[kW]
$Q_{T\ without}$	Heat loss due to temperature difference through an open door without ACU	[kW]
$Q_{Tc\ with}$	Heat loss due to temperature diff. through an open door with ACU in the cold cell	[kW]
$Q_{Tc\ without}$	Heat loss due to temperature diff. through an open door without ACU in the cold cell	[kW]
$Q_{Tw\ with}$	Heat loss due to temperature diff. through an open door with ACU in the warm cell	[kW]
$Q_{Tw\ without}$	Heat loss due to temperature diff. through an open door without ACU in the warm cell	[kW]
Q_{cold}	Heat capacity of the cold cell with ACU	[kW]
$Q_{cold\ without}$	Heat capacity of the cold cell without ACU	[kW]
Q_{warm}	Heat capacity of the warm cell with ACU	[kW]
$Q_{warm\ without}$	Heat capacity of the warm cell without ACU	[kW]
T	Door opening time	[s]
T_{mix}	Temperature mixing time	[s]
t*	Temperature test: door closing time	[s]
t_0	Temperature test: door opening time	[s]
t_1	Temperature test: end of temperature mixing time	[s]
θ_{0c}	Avg. instant temperature at t_0 of all temperature sensors in the cold cell (with ACU)	[ºC]
$\theta_{0c/o}$	Avg. instant temperature at t_0 of all temperature sensors in the cold cell (without ACU)	[ºC]
θ_{0w}	Avg. instant temperature at t_0 of all temperature sensors in the warm cell (with ACU)	[ºC]
$\theta_{0w/o}$	Avg. instant temperature at t_0 of all temperature sensors in the warm cell (without ACU)	[ºC]
θ_{1c}	Avg. instant temperature at t_1 of all temperature sensors in the cold cell (with ACU)	[ºC]
$\theta_{1c/o}$	Avg. instant temperature at t_1 of all temperature sensors in the cold cell (without ACU)	[ºC]

θ_{1w}	Avg. instant temperature at t_1 of all temperature sensors in the warm cell (with ACU)	[ºC]
$\theta_{1w/o}$	Avg. instant temperature at t_1 of all temperature sensors in the warm cell (without ACU)	[ºC]
ηI	Infiltration efficiency due to wind action	[-]
CSE_W	Climate Separation Efficiency index due to wind action	[-]
PF_W	Performance Factor due to wind action	[-]
Q_W	Heat loss due to wind action	[kW]
$Q_{W\ with}$	Heat loss through an open door subjected to wind action with ACU	[kW]
$Q_{W\ without}$	Heat loss through an open door subjected to wind action without ACU	[kW]
q	Airvolume flow rate	[m^3/s]
$q_{with\ acu}$	air volume flow rate in the exhaust system with ACU	[m^3/s]
$q_{without\ acu}$	air volume flow rate in the exhaust system without ACU	[m^3/s]
P_C	Cooling capacity	[kW]
P_e	Motor Input power	[W]
P_H	Heating capacity	[kW]
L_w	Sound power level	[dB]
L_p	Sound pressure level (A weighted criteria)	[dB(A)]
Q	Directivity factor (for sound propagation)	[-]
r	distance between ACU and observer	[m]
FEEC	Fan electrical energy consumption	[kWh]
τ	ACU daily functioning hours	[h]
c_p	Specific heat of air	[kJ/kg K]
g	Acceleration of gravity	[m/s^2]
ρ	Density of air	[kg/m^3]
ρ_{in}	Density of air (warm side)	[kg/m^3]
ρ_{out}	Density of air (cold side)	[kg/m^3]
$\theta_{air\ inlet}$	ACU inlet air temperature	[°C]
$\theta_{air\ outlet}$	ACU outlet air temperature	[°C]
ΔP	Pressure difference across a door opening	[Pa]
ΔT	Temperature difference across a door opening (warm and cold side)	[K]

v_{10}	Average wind speed at 10m elevation	[m/s]
L	Position factor	[-]

5. Classification

Air curtain units shall be classified accordingly to their application of use.

5.1 Commercial/comfort air curtain units

Air curtain units used to reduce physical barriers to entry for customers; preferred by high street retailers (Shops & Stores), Public buildings, Shopping malls, Banks & office buildings, Hotels etc. Their main purpose is to realise a climate division between two areas, or rooms, or an area or room and the outdoor air where comfort requirements for people are mandatory for the supply air temperature and speed. The barrier created by the air curtain unit allows a significant reduction of the heat losses through the opening and increases building energy savings.

5.2 Industrial air curtain units

Air curtain units used in the large opening of an Industrial building related to the production and/or transportation processes. Their main purpose is to protect the internal (working environment) from the external conditions to maintain comfort for staff and reduce the ingress of dirt and other particulates. The barrier created by the air curtain unit allows a significant reduction of the heat losses through the opening and significantly increases building energy savings.

5.3 Cold storage air curtains

Air curtain units used for chilled or cold storage applications. They are placed on the warm side of the doorway into the cold space to create a barrier of air to reduce warm air entering the refrigerated space and cold air leaving the space. Their main purpose is to create a non-obstructive barrier to limit refrigeration energy losses, ice forming on the cold room cooling system which increases maintenance and ice forming on the floor of the doorway which is a slip hazard.

5.4 Air curtains field conditions

In the following table 1 the typical air curtains field conditions are described.

Air curtain unit class.	H door [m]	W door [m]	Warm cell temp [°C]	Cold cell temp [°C]	ΔT [°C]	ΔP [Pa]	Wind load [m/s][1]	Region	Climate classes
Commercial/comfort	2.3	2.0	20	2	18	0	4	Central Europe	ACUCC1
			20	-7	27	0	5	Northern Europe	ACUCC2
			20	7	13	0	3	Southern Europe	ACUCC3

[1] at 10 m elevation

			20	-7	27	0	4	Russia	ACUCC4
			46	25	21	0	4	GCC	ACUCC5
Industrial	4.0	4.0	15	2	13	0	4	Central Europe	ACUI1
			15	-7	22	0	5	Northern Europe	ACUI2
			15	7	8	0	3	Southern Europe	ACUI3
			15	-7	22	0	4	Russia	ACUI4
			46	25	21	0	4	GCC	ACUI5
Cold storage	3.0	3.0	20	5	15	0	0	EUROPE	ACUCS1
			20	5	15	0	0	Russia	ACUCS2
			25	5	20	0	0	GCC	ACUCS3

Table 1: Air curtains field conditions

6. Tests

When the energy performance of an air curtain unit is to be verified, all the tests and inspections shall be applied to one and the same air curtain unit. These tests and inspections may also be made individually for the study of a particular characteristic. General test conditions which are common for all tests carried out inside the test room are defined following. These conditions concern the test room, and the measuring instrument.

6.1 Standard rating conditions

When an air curtain unit is tested the conditions defined in the following Table 2 shall be intended as the standard rating conditions.

Air curtain unit class.	H door [m]	W door [m]	Warm cell temp [°C]	Cold cell temp [°C]	ΔT [°C]	ΔP [Pa]	Wind load [m/s]	Climate classes
Commercial/comfort	2.0	1.5	20	2	18	0	2	ACUCC1
Industrial	3.0	2.0	15	2	13	0	2	ACUI1
Cold storage	2.0	1.5	20	5	15	0	0	ACUCS1

Table 2: Standard rating conditions

6.2 Test room

6.2.1 Design, walls, floor, door

The test environment shall consist of two separated climate rooms: the cold cell and the warm cell. The cold cell shall be used to simulate the outdoor conditions; the warm cell shall be used to simulate the indoor conditions. The two rooms shall be separated by a door opening equipped with a hinged or sliding door. The door opening dimensions are defined accordingly to the standard rating conditions in Table 2 above (H and W). The door shall be in the middle of the separating wall between the cold and warm cells. Both the cold cell and the warm cell shall be a parallelepiped volume.

The dimensions (length, width, height) and volume of the warm and cold cells are defined in the following table 3 and should be selected against the size of the air curtain to be tested. Figure 1 shows the general arrangement for the test room design.

Dimension	Min	Max
Width [m]	3	6
Length [m]	3	8
Height [m]	3	5
Volume [m^3]	50	200

Table 3: Test rooms minimum dimensions

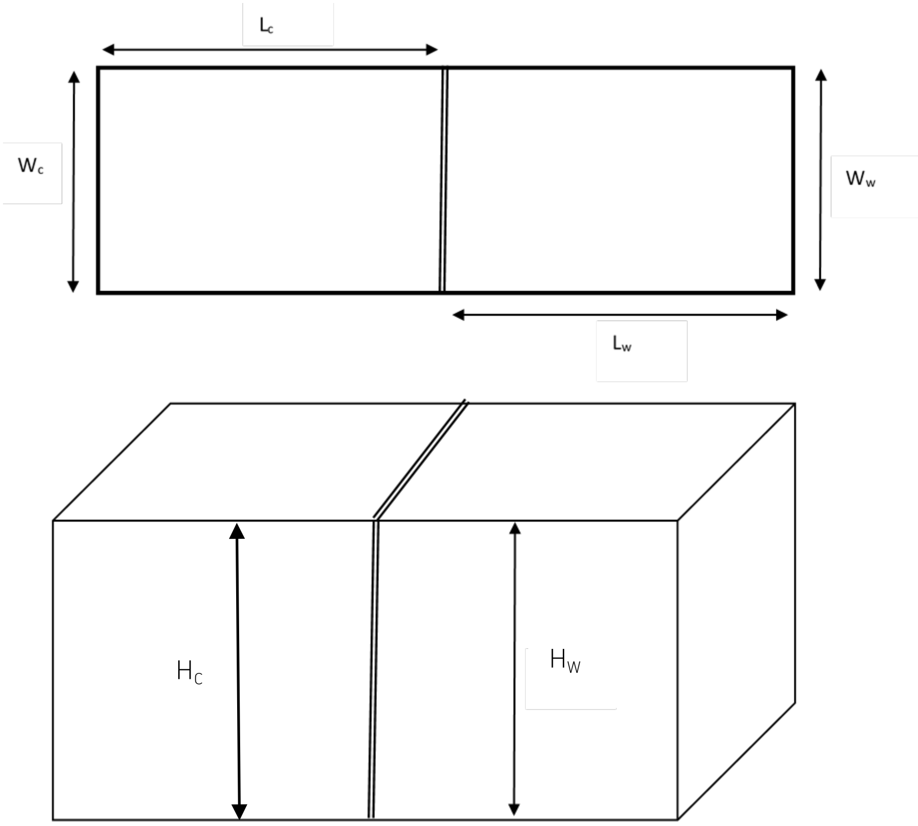

Figure 1: Test room design

KEY

W_c= Width of the cold cell [m]

W_w= Width of the warm cell [m]

L_c= Length of the cold cell [m]

Lw= Length of the warm cell [m]

H_C= Height of the cold cell [m]

H_W= Height of the warm cell [m]

In order to ensure that external climatic conditions do not affect air temperatures during the performance tests, the walls, floor, and ceiling of the test room shall be insulated with a maximum U-value of 0,51 W/m²K.

6.2.2 Thermal and air flow characteristics

The tests shall be carried out in one of the climate classes according to Table 2.

During the test, the test rooms shall be capable of maintaining values of temperature difference between the warm and cold cells to within 1K. These values shall be measured at the specified climate measuring point(s) (see 6.3.3). In order to mix the air of the warm cell, one or more fans shall be installed on the longitudinal centre line of the ceiling of the cell.

6.3 Test inside the test rooms

6.3.1 Instruments, measuring equipment and expanded measurement uncertainty

All measurements shall be carried out with instruments that have been calibrated to national standards and the measurement methods shall be in accordance with ISO 5801, except where specifically noted. The apparatus and instruments used in the test shall be listed. Names, model numbers, serial numbers, scale ranges and calibration information shall be recorded.

The instruments' expanded measurement uncertainty shall be:

- Temperature measurements shall be made to an expanded measurement uncertainty of ± 0,1K.
- Electrical energy consumption shall be measured to an expanded measurement uncertainty of ± 2 %.
- Time interval measurements shall be made to an expanded measurement uncertainty of ± 1 % or better.
- All temperature measurements shall be recorded at a maximum time interval of 5 seconds.
- Differential pressure transmitters with scale 0-50 Pa shall have pressure measurements measured to an expanded uncertainty of ±3%

6.3.2 Selection, installation and positioning of the ACU within the test room

Each air curtain unit to be tested, unless it is a prototype, shall be selected from stock or routine production and shall be representative of normal construction.

The air curtain unit, including all components required for normal operation, shall be assembled, set up and positioned as it would be installed in service as far as practicable and in accordance with the manufacturer's instructions. All permanently located accessories required for normal use shall be in their respective places.

The air curtain unit shall be installed and positioned as close as possible to the door opening. The door opening shall not be partly covered by the ACU installation. In the case of a horizontal installation, the width of the air curtain shall be at least equal to the width of the door opening as defined in table 2. In the case of a vertical installation, the height of the air curtain shall be at least equal to the height of the door opening as defined in table 2.

The air curtain unit shall be mounted with its inlet connecting to the test chamber room and in accordance with the above. If the air curtain unit has multiple inlets, it shall be mounted so that all of the inlets are contained within the testing chamber. The air curtain unit can be mounted horizontally or vertically.

6.3.3 Test room climate measuring point

The climate cells shall be fitted with temperature sensors according to 6.3.1. Each climate cell (cold and warm) shall be fitted with a minimum of 4 temperature sensors, depending on the preselected room dimensions. One located 0,3m under the centre of the ceiling and 3 sensors located 0,5m above the centre line of the opening and at distances from the opening of 0,5m, 1,5m and 2,5m.

6.3.4 Temperature Test: Test procedure

This temperature test is carried out to obtain the climate separation efficiency of an air curtain unit installed in a door opening subjected to a temperature difference.

6.3.4.1 Stable conditions

Each climate cell shall operate under stable conditions before measurements are taken. The stable conditions are reached when in both climate cells, at the same time and for not less than 10 minutes, the temperature difference varies no more than 1K of the defined climate class temperature, with a standard deviation of 0,3K.

6.3.4.2 Temperature test without an air curtain unit

For the temperature test without an air curtain unit the procedure described in Figure 2 shall be followed.

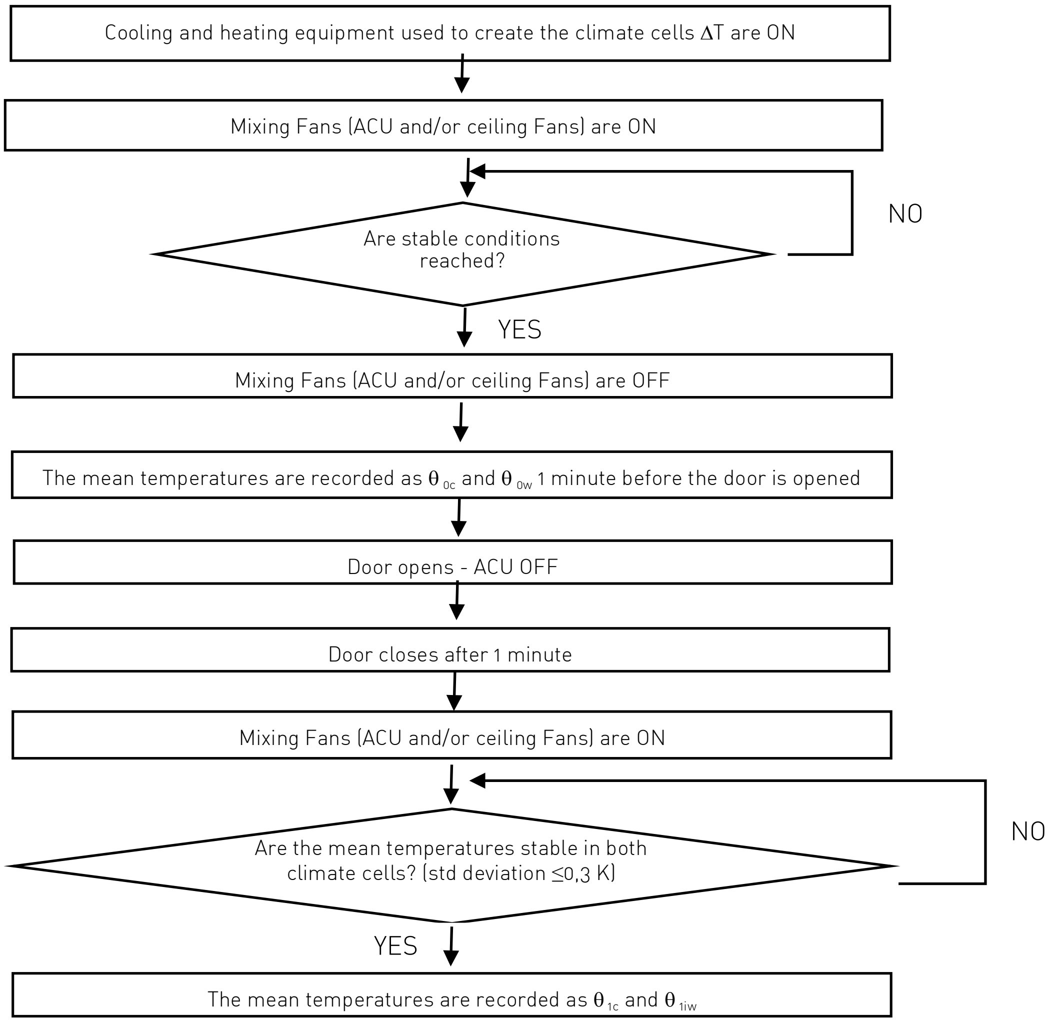

Figure 2: Temperature test without Air Curtain procedure

The temperature measurements shall start and stop in accordance with figure 2.

During this temperature test the measured values of all temperature sensors, both in the warm cell and in the cold cell, shall be recorded. The maximum time between measurements shall be 5 seconds (see. 6.3.1).

6.3.4.3 Temperature test with an air curtain unit

For the temperature test with an air curtain unit the procedure described in Figure 3 shall be followed.

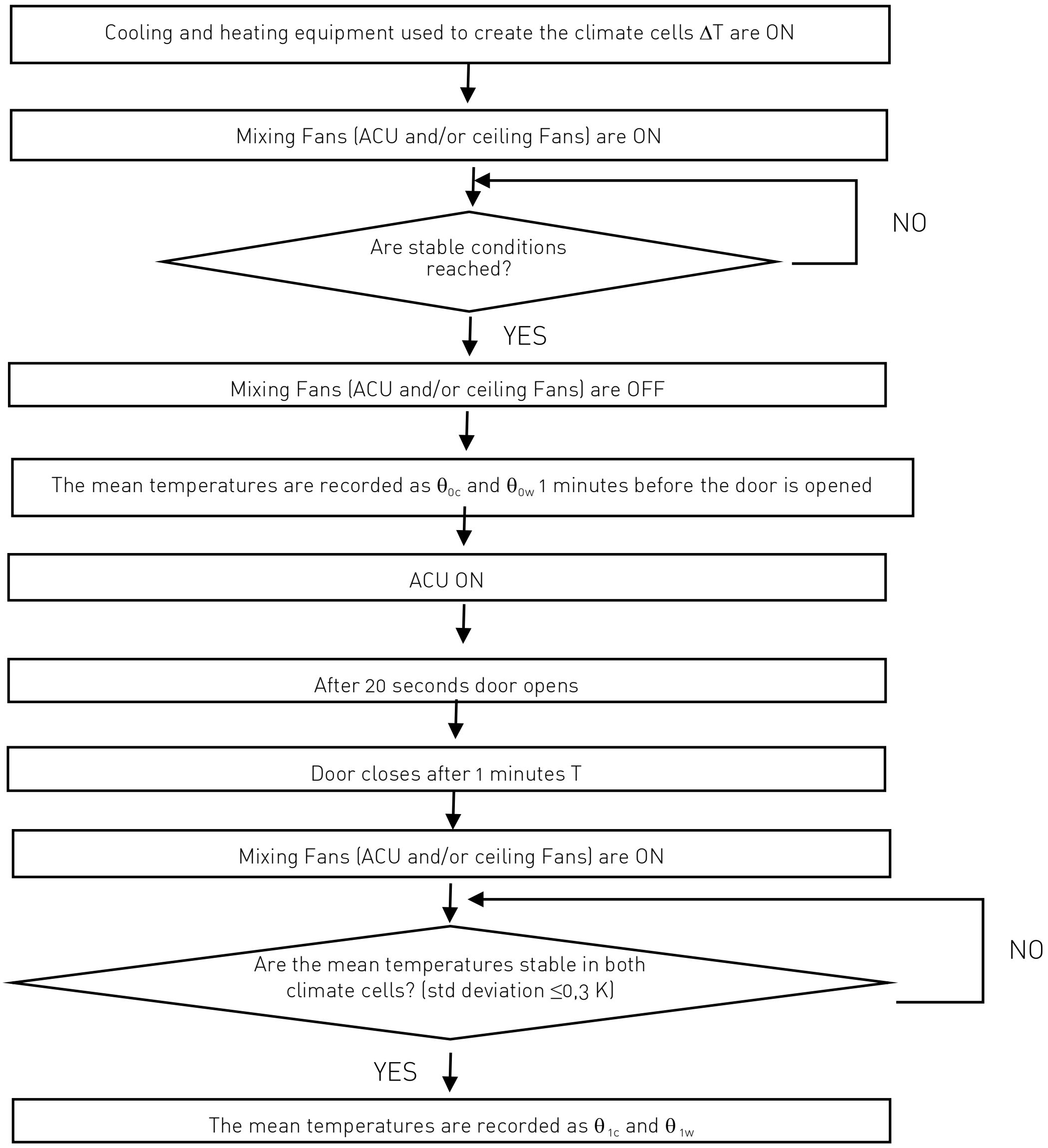

Figure 3: Temperature test with Air Curtain procedure

If the air curtain unit is equipped with a heating and/or cooling battery (i.e. hydronic or heat pump coil, electric heater or gas heater), it shall be attached as per the manufacturer's instructions if not already incorporated into the unit. The battery shall not be powered or energised during any part of the test unless it contributes to the active generation of air volume flow rate. Only the fan section(s) shall be energized.

The temperature measurements shall start and stop in accordance with figure 3.

During this temperature test the measured values of all temperature sensors, both in the warm and in the cold cells, shall be recorded. The maximum time between measurements shall be 5 seconds (see. 6.3.1).

6.3.4.4 Calculation of average mean temperature

The average instant temperature at measuring sample *n* of all temperature sensors in the cold cell, θ_{cn} (curves c_w and $c_{w/o}$ in Figure 4), is expressed by the following equation:

$$\theta_{cn} = \frac{1}{K_{maxc}} \times \sum_{k=1}^{K_{maxc}} (\theta_k)_n \qquad [1]$$

Where:

n is the time index for the instant measuring sample;

k is the index for the individual temperature sensor;

K_{maxc} is the number of temperature sensors;

$(\theta_k)_n$ is the instant measured temperature of a temperature sensor *k* at the measuring sample *n*.

The average instant temperature at measuring sample *n* of all temperature sensors in the warm cell, θ_{wn} (curve w_w and $w_{w/o}$ in Figure 4), is expressed by the following equation:

$$\theta_{wn} = \frac{1}{K_{maxw}} \times \sum_{k=1}^{K_{maxw}} (\theta_k)_n \qquad [2]$$

Where:

n is the time index for the instant measuring sample;

k is the index for the individual temperature sensor;

K_{maxw} is the number of temperature sensors;

$(\theta_k)_n$ is the instant measured temperature of a temperature sensor *k* at the measuring sample *n*.

6.3.4.5 Temperature curves of average mean temperature

In the same graph, for each temperature test (6.3.4.2 – 6.3.4.3), the average mean temperature curves w and c (see 6.3.4.4) shall be plotted as a function of time. All the other temperatures shall be available for reference if required.

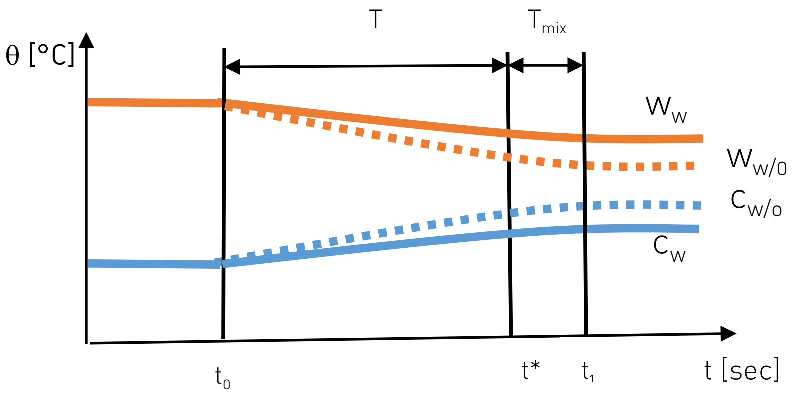

Figure 4: Arithmetic mean temperature of temperature-probes.

KEY:

c_w= average instant temperature at measuring sample n of all temperature sensors in the cold cell with air curtain

$c_{w/o}$= average instant temperature at measuring sample n of all temperature sensors in the cold cell without air curtain

w_w= average instant temperature at measuring sample n of all temperature sensors in the warm cell with air curtain

$w_{w/o}$= average instant temperature at measuring sample n of all temperature sensors in the warm cell without air curtain

t_0= door opening time

t*= door closing time

t_1= end of the mixing time

T= door opening time

T_{mix}=Temperature mixing time

6.3.5 Wind Test: Test procedure

A simplified approach to simulate wind that blows at or over a building is to consider the wind as an even and stable pressure difference across the opening. This can be achieved by having a big fan sucking air from the test chamber.

6.3.5.1 Test room setup

The volume of the test room should be 50m^3 minimum and the wall in which the opening is located shall be 3m x 3m minimum. The size of the door opening is given in 6.1.

Wall pressure tappings (in accordance with ISO 5801, see Figure 5) shall be located in the dividing wall on both sides of the doorway opening and at halfway up the height of the opening to be tested. The distance from the door is shown in the figure 6.

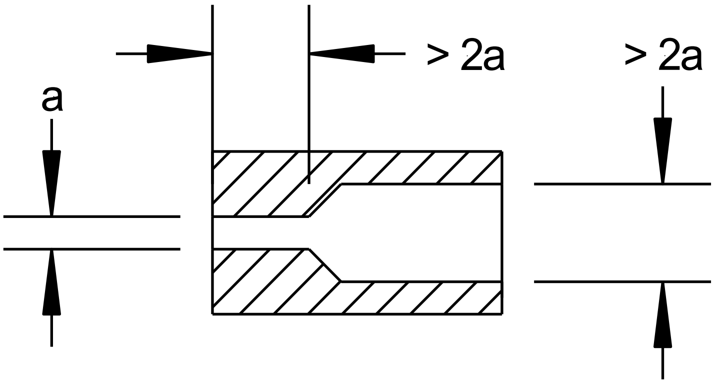

Figure 5: Wall pressure tappings

NOTE: 1,5 mm≤ a≤ 5 mm

The opening of the exhaust duct should be aligned with the centre of the doorway.

Test rooms that are used for temperature tests can also be used for the wind test. Aperture *b* shall be larger than aperture *a* (see figure 6).

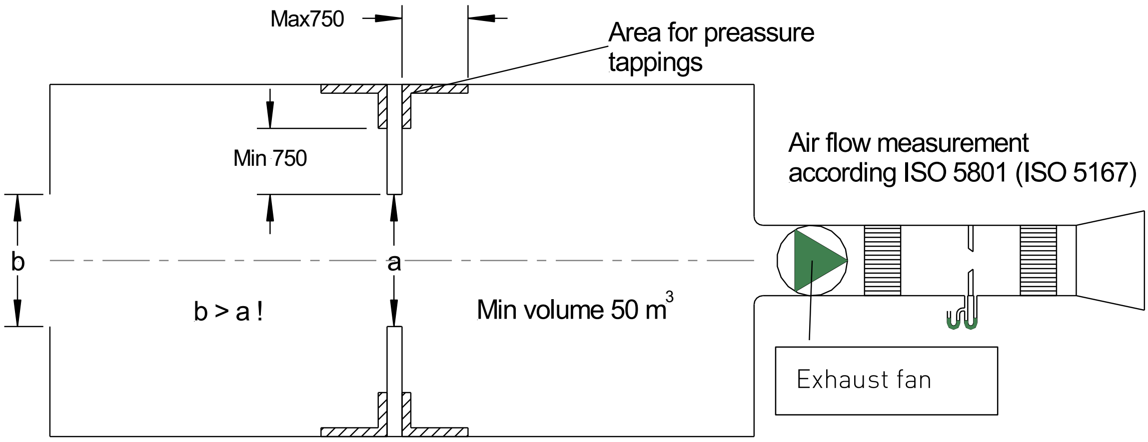

Figure 6: Wind pressure test setup

The airtightness of the room shall be tested with the door and exhaust openings taped shut. The leakage rate must be no more than 1 m^3/h at 50 Pa positive pressure.

6.3.5.2 Wind test with and without an air curtain unit

The exhaust fan shall be regulated so that the pressure difference across the opening *a* varies in steps. The pressure difference steps shall be as close as possible to the Datum values in Table 4. The air volume flow rate (Airflow) shall be measured in accordance with ISO 5801 for each step and the result documented in the following table 4.

Datum	ΔP [Pa]	Airflow [m³/h]
0.5		
1		
2		
4		
6		
8		

Table 4: Pressure difference and airflow results

This test procedure shall be performed with and without an air curtain unit and the values from table 4 shall be plotted as per Figure 7.

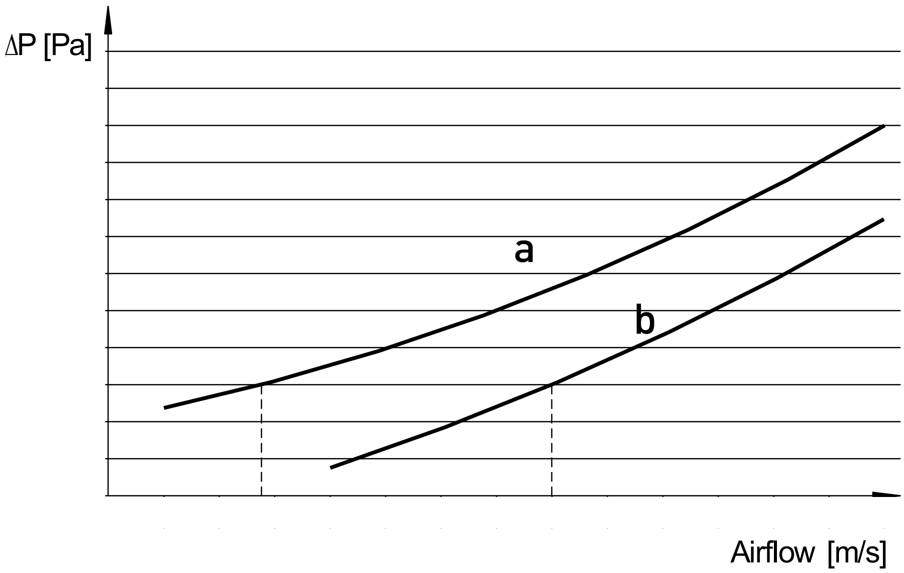

Figure 7: Air volume flow rate (with and without air curtain unit) at various pressure differences across the door opening

Key:

a: Air volume flow rate with ACU

b: Air volume flow rate without ACU

The infiltration efficiency of the air curtain unit at a certain pressure difference can be calculated as:

$$\eta I = 1 - \frac{q_{with\ ACU}}{q_{without\ ACU}} \quad [3]$$

Where:

ηI= Infiltration Efficiency due to wind action

$q_{with\ ACU}$= Airflow measured in the exhaust system with air curtain unit

$q_{without\ ACU}$= Airflow measured in the exhaust system without air curtain unit

7 Heat loss through an open door subjected to temperature difference and wind action: Calculation methods

This test method calculates the heat loss through a door opening (with or without an air curtain unit) when subjected to a temperature difference and/or wind action.

7.1 Heat loss through an open door subjected to temperature difference

This test method calculates the heat loss through a door opening (with or without an air curtain unit) when subjected to a temperature difference. It shall apply to: Commercial/comfort, Industrial, and cold storage air curtain units.

7.1.1 Heat loss through an open door subjected to temperature difference without air curtain: Calculation method

The heat loss through an open door due to temperature difference without an air curtain unit shall be calculated by using the following formula [4].

$$Q_{T\,without} = \frac{V \cdot \rho \cdot c_p \cdot (\theta_{0w/o} - \theta_{1w/o})}{T} \qquad [4]$$

Where:

$Q_{T\,without}$ = Heat loss due to temperature difference through an open door without ACU (kW)

V = Volume of the warm cell [m^3]

ρ = Density of air in the warm cell [kg/m^3]

c_p = Specific heat of air in the warm cell [kJ/kg K]

$\theta_{1w/o}$ = Average instant temperature at t_1 of all temperature sensors in the warm cell (without ACU) [°C]

$\theta_{0w/o}$ = Average instant temperature at t_0 of all temperature sensors in the warm cell (without ACU) [°C]

T = Door opening time [s]

7.1.2 Heat loss through an open door subjected to temperature difference with an air curtain: Calculation method

The heat loss through an open door due to temperature difference with an air curtain unit shall be calculated by using the following formula [5].

$$Q_{T\,with} = \frac{V \cdot \rho \cdot c_p \cdot (\theta_{0w} - \theta_{1w})}{T} \qquad [5]$$

Where:

$Q_{T\,with}$ = Heat loss due to temperature difference through an open door with ACU [kW]

V = Volume of the warm cell [m^3]

ρ = Density of air in the warm cell [kg/m³]

c_p = Specific heat of air in the warm cell [kJ/kg K]

θ_{1w} = Average instant temperature at t_1 of all temperature sensors in the warm cell (with ACU) [°C]

θ_{0w} = Average instant temperature at t_0 of all temperature sensors in the warm cell (with ACU) [°C]

T = Door opening time [s]

7.1.3 Energy balance conditions: verification procedures

Verification procedures I or II aim to verify that the energy balance conditions have been achieved during the temperature tests. Before assessing the Climate Separation Efficiency index due to temperature difference (CSE_T), the following procedures (7.1.3.1 or 7.1.3.2) shall be followed. The Test Laboratory at its own discretion can choose to use verification procedure I or II.

7.1.3.1 Verification Procedure I

1. Calculation of the heat loss through an open door without an air curtain unit at the warm cell:

$$Q_{Tw\ without} = \frac{V \cdot \rho \cdot c_p \cdot (\theta_{0w/o} - \theta_{1w/o})}{T} \quad [6]$$

Where:

$Q_{Tw\ without}$ = Heat loss due to temperature difference through an open door without an air curtain at the warm cell [kW]

V = Volume of the warm cell [m³]

ρ = Density of air in the warm cell [kg/m³]

c_p = Specific heat of air in the warm cell [kJ/kg.K]

$\theta_{1w/o}$ = Average instant temperature at t_1 of all temperature sensors at the warm cell (without ACU) [°C]

$\theta_{0w/o}$ = Average instant temperature at t_0 of all temperature sensors at the warm cell (without ACU) [°C]

T = Door opening time [s]

2. Calculation of the heat loss thorough an open door without air curtain unit at the cold cell:

$$Q_{Tc\ without} = \frac{V \cdot \rho \cdot c_p \cdot (\theta_{0c/o} - \theta_{1c/o})}{T} \quad [7]$$

Where:

$Q_{Tc\ without}$ = Heat loss due to temperature through an open door without an air curtain at the cold cell [kW]

V = Volume of the cold cell [m³]

ρ = Density of air in the cold cell [kg/m^3]

c_p = Specific heat of air in the cold cell [kJ/kg.K]

$\theta_{1c/o}$ = Average instant temperature at t_1 of all temperature sensors in the cold cell (without ACU) [°C]

$\theta_{0c/o}$ = Average instant temperature at t_0 of all temperature sensors in the cold cell (without ACU) [°C]

T = Door opening time [s]

3. Calculation of the energy balance equation without air curtain unit:

$$Q_{Tw\,without} = Q_{Tc\,without} \pm 10\% \quad [8]$$

If equation [8] is verified the climate chambers shall be deemed to be in energy balance. If equation [8] does not verify the climate chambers shall be deemed to not be in energy balance and the result $Q_{T\,without}$ ([4]) shall not be deemed as representative of the heat loss through an open door without an air curtain unit. Accordingly, it shall be calculated again by performing the temperature test procedure as in the 6.3.4.2.

4. Calculation of the heat loss through an open door with air curtain unit at the warm cell:

$$Q_{Tw\,with} = \frac{V \cdot \rho \cdot c_p \cdot (\theta_{0w} - \theta_{1w})}{T} \quad [9]$$

Where:

$Q_{Tw\,with}$ = Heat loss due to temperature through an open door with an air curtain unit at the warm cell [kW]

V = Volume of the warm cell [m^3]

ρ = Density of air in the warm cell [kg/m^3]

c_p = Specific heat of air in the warm cell [kJ/kg K]

θ_{1w} = Average instant temperature at t_1 of all temperature sensors in the warm cell (with ACU) [°C]

θ_{0w} = Average instant temperature at t_0 of all temperature sensors in the warm cell (with ACU) [°C]

T = Door opening time [s]

5. Calculation of the heat loss through an open door with air curtain unit at the cold cell:

$$Q_{Tc\,with} = \frac{V \cdot \rho \cdot c_p \cdot (\theta_{0c} - \theta_{1c})}{T} \quad [10]$$

Where:

$Q_{Tc\,with}$ = Heat loss due to temperature through an open door with an air curtain unit at the cold cell [kW]

V = Volume of the cold cell [m^3]

ρ = Density of air in the cold cell [kg/m^3]

c_p = Specific heat of air in the cold cell [kJ/kg K]

θ_{1c} = Average instant temperature at t_1 of all temperature sensors in the cold cell (with ACU) [°C]

θ_{0c} = Average instant temperature at t_0 of all temperature sensors in the cold cell (with ACU) [°C]

T = Door opening time [s]

6. Calculation of the energy balance equation without air curtain:

$$Q_{Tw\ with} = Q_{Tc\ with} \pm 10\% \qquad [11]$$

If equation [11] is verified the climate chambers shall be deemed to be in energy balance. If equation [11] does not verify the climate chambers shall be deemed to not be in energy balance and the result $Q_{T\ with}$ ([5]) shall not be deemed as representative of the heat loss through an open door with an air curtain unit. Accordingly, it shall be calculated again by performing again the temperature test procedure as in the 6.3.4.3.

7.1.3.2 Verification Procedure II

This procedure is based on determining the heat capacity of the warm cell and cold cell with and without the air curtain unit.

1. Calculation of the energy balance equation without an air curtain unit:

$$Q_{warm\ without} = Q_{cold\ without} \pm 10\% \qquad [12]$$

Where:

$Q_{warm\ without}$ = heat capacity of the warm cell without an air curtain unit (it includes all the heat supplied to and removed from the warm cell) [kW]

$Q_{cold\ without}$ = heat capacity of the cold cell without an air curtain unit (it includes all the heat supplied to and removed from the cold cell) [kW]

If equation [12] is verified the climate chambers shall be deemed to be in energy balance. If equation [12] does not verify the climate chambers shall be deemed to not be in energy balance and the result $Q_{T\ without}$ ([4]) shall not be deemed as representative of the heat loss through an open door without an air curtain unit. Accordingly, it shall be calculated again by performing the temperature test procedure as in the 6.3.4.2.

2. Calculation of the energy balance equation with an air curtain unit:

$$Q_{warm\ with} = Q_{cold\ with} \pm 10\% \qquad [13]$$

Where:

$Q_{warm\ with}$ = heat capacity of the warm cell with an air curtain unit (it includes all the heat supplied to and removed from the warm cell) [kW]

$Q_{cold\ with}$ = heat capacity of the cold cell with an air curtain unit (it includes all the heat supplied to and removed from the cold cell) [kW]

If equation [13] is verified the climate chambers shall be deemed to be in energy balance. If equation [13] does not verify the climate chambers shall be deemed to not be in energy balance and the result $Q_{T\ with}$ ([5]) shall not be deemed as representative of the heat loss through an open door with an air curtain unit. Accordingly, it shall be calculated again by performing again the temperature test procedure as in the 6.3.4.3.

7.2 Heat loss due to wind action

This test method calculates the heat loss through a door opening (with or without an air curtain) when subjected to wind action. It shall apply to: Commercial/comfort and Industrial air curtain units. The air curtain unit shall be tested at its maximum fan speed.

7.2.1 Heat loss through an open door subjected to wind action without an air curtain unit: Calculation method

The heat loss through an open door due to wind action without an air curtain unit shall be calculated by using the following formula [14].

$$Q_{W\ without} = (q_{without\ ACU\ @2.5Pa} \cdot \rho \cdot c_p \cdot (\theta_{\frac{0w}{o}} - \theta_{\frac{1w}{o}}))/T \qquad [14]$$

Where:

$Q_{W\ without}$ = Heat loss through an open door subjected to wind action without an air curtain unit [kW]

$q_{without\ ACU\ @2.5Pa}$ = Airflow measured in the exhaust system without an air curtain unit (at ΔP of 2.5 Pa) [m³/s]

ρ = Density of air in the warm cell [kg/m³]

c_p = Specific heat of air in the warm cell [kJ/kg K]

$\theta_{1w/o}$ = Average instant temperature at t_1 of all temperature sensors in the warm cell (without ACU) [°C]

$\theta_{0w/o}$ = Average instant temperature at t_0 of all temperature sensors in the warm cell (without ACU) [°C]

T= Testing time [sec]

7.2.2 Heat loss through an open door subjected to wind action with an air curtain unit: Calculation method

The heat loss through an open door due to wind action with an air curtain unit shall be calculated by using the following formula [15].

$$Q_{W\ with} = (q_{with\ ACU\ @2.5Pa} \cdot \rho \cdot c_p \cdot (\theta_{0w} - \theta_{1w}))/T \qquad [15]$$

Where:

$Q_{W\,with}$ = Heat loss through an open door subjected to wind action with an air curtain unit [kW]

$q_{with\ ACU\ @2.5Pa}$ = Airflow measured in the exhaust system with an air curtain unit (at ΔP of 2.5 Pa) [m^3/s]

ρ = Density of air in the warm cell [kg/m^3]

c_p = Specific heat of air in the warm cell [kJ/kg K]

θ_{1w} = Average instant temperature at t_1 of all temperature sensors in the warm cell (with ACU) [°C]

θ_{0w} = Average instant temperature at t_0 of all temperature sensors in the warm cell (with ACU) [°C]

T= Testing time [sec]

8 Climate Separation Efficiency indexes

Climate separation efficiency 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.

8.1 Climate Separation Efficiency due to temperature difference (CSE_T)

$$CSE_T = 1 - \frac{Q_{T\,with} + P_e}{Q_{T\,without}} \quad [16]$$

Where:

CSE_T = Climate separation efficiency index due temperature difference

$Q_{T\,with}$ = Heat loss due to temperature difference through an opening with an air curtain unit [kW]

$Q_{T\,without}$ = Heat loss due to temperature difference through an opening without an air curtain unit [kW]

P_e = Motor input power [kW]

8.2 Climate Separation Efficiency due to wind action (CSE_W)

$$CSE_W = 1 - \frac{Q_{W\,with} + P_e}{Q_{W\,without}} \quad [17]$$

Where:

CSE_W = Climate separation efficiency index due to wind action

$Q_{W\ with}$ = Heat loss through an open door subjected to wind action with an air curtain unit [kW]

$Q_{W\ without}$ = Heat loss through an open door subjected to wind action without an air curtain unit [kW]

P_e = Motor input power [kW]

8.3 Performance factor

The performance factor is a factor used to compare the performance of different air curtain units against each other.

8.3.1 Performance factor due to temperature difference (PF_T)

$$PF_T = \frac{Q_{T\ without} - Q_{T\ with}}{P_e} \qquad [18]$$

Where:

PF_T = Performance Factor due to temperature difference

$Q_{T\ with}$ = Heat loss due to temperature difference through an opening with an air curtain unit [kW]

$Q_{T\ without}$ = Heat loss due to temperature difference through an opening without an air curtain unit [kW]

P_e = Motor input power [kW]

8.3.2 Performance factor due to wind action (PF_W)

$$PF_W = \frac{Q_{W\ without} - Q_{W\ with}}{P_e} \qquad [19]$$

Where:

PF_W = Performance Factor due to wind action

$Q_{W\ with}$ = Heat loss through an open door subjected to wind action with an air curtain unit [kW]

$Q_{W\ without}$ = Heat loss through an open door subjected to wind action without an air curtain unit [kW]

P_e = Motor input power [kW]

PART 2: Comfort Parameters

This part aims to provide useful information for the definition of air curtain unit comfort parameters.

1 Heating Capacity calculation method

The heating capacity calculation method is an air-side calculation using the air volume flow rate and the inlet and outlet air temperature difference of the air curtain unit.

$$P_H = \rho_{in} \cdot c_p \cdot q \cdot (\theta_{air\ outlet} - \theta_{air\ inlet}) \qquad [1]$$

Where:

P_H = Heating capacity	[kW]
c_p = Specific heat of air at inlet of air curtain unit	[kJ/kg K]
ρ_{in} = Density of air at inlet of air curtain unit	[kg/m^3]
q = Air volume flow rate of air curtain unit	[m^3/s]
$\theta_{air\ outlet}$ = Air curtain unit outlet air temperature	[°C]
$\theta_{air\ inlet}$ = Air curtain unit inlet air temperature	[°C]

2 Cooling Capacity calculation method (without condensation)

For air curtain units that cool, the cooling capacity calculation method is an air-side calculation using the air volume flow rate and the outlet and inlet air temperature difference of the air curtain unit. The calculation is done for the sensible cooling capacity only (i.e. without condensation).

$$P_C = \rho_{in} \cdot c_p \cdot q \cdot (\theta_{air\ inlet} - \theta_{air\ oultet}) \qquad [2]$$

Where:

P_C = Cooling capacity (sensible)	[kW]
c_p = Specific heat of air at inlet of air curtain unit	[kJ/kg K]
ρ_{in} = Density of air at inlet of air curtain unit	[kg/m^3]
q = Air volume flow rate of air curtain unit	[m^3/s]
$\theta_{air\ inlet}$ = Air curtain unit inlet air temperature	[°C]
$\theta_{air\ outlet}$ = Air curtain unit outlet air temperature	[°C]

3 Sound power level

The sound power level of an air curtain unit shall be measured in accordance with ISO 27327-2. ISO 27327-2 is intended as fully reproduced within this code of good practice. The air curtain unit shall be tested at its maximum fan speed.

4 Sound pressure level

Sound Pressure Level is what the human ear hears and a microphone will respond to. For convenience sound pressure level is specified in the form of a single figure noise criterion: dB(A). It is derived from the sound power level (L_w) data for an air curtain unit tested to ISO 27327-2.

The following formula [3] defines the L_p calculation formula:

$$L_p = L_w + 10log\left(\frac{Q}{4\pi r^2}\right) \qquad [3]$$

Where:

L_p = Sound Pressure Level [dB]

L_w = Sound Power Level [dB]

Q = Directivity Factor, Q=2 (hemisphere) or Q=4 (¼ field)

r = Distance between air curtain and observer [m]

Figure 1 shows how to determine the directivity factor Q.

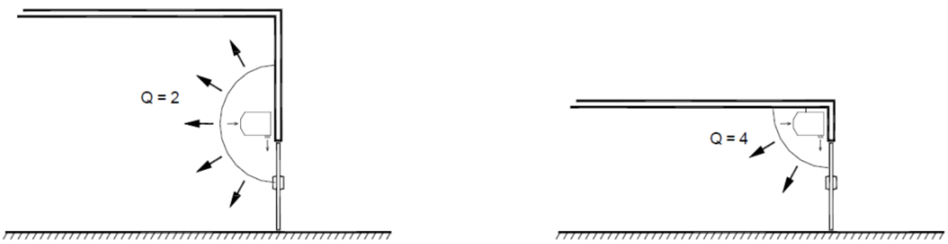

Figure 1: Directivity factor calculation

The sound pressure level (L_p) of an air curtain unit is measured on site using a precision sound level meter set to the dB(A) weighting scale or dB at octave bands centre frequencies 63Hz to 4000Hz. The sound level meter can be hand held or fitted onto a tripod and the microphone is placed at a distance (r) from the air curtain unit, as determined by the manufacturer. The distance (r) and also the directivity factor (Q) shall be declared in the manufacturers ʽcatalogue information. Figure 2 shows a typical set up for site measurement with the door closed during measurements. The air curtain unit shall be tested at its maximum fan speed.

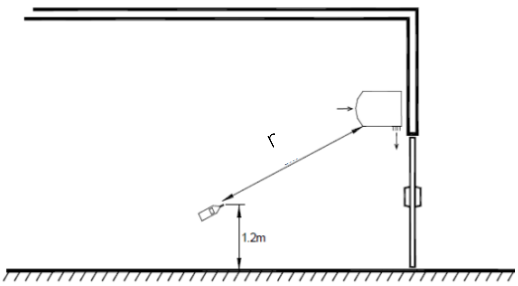

Figure 2: Site measurement of sound pressure level of an air curtain unit

5 Fan electrical energy consumption

The fan electrical energy consumption of an air curtain unit shall be calculated as follow:

$FEEC = P_e * \tau$ [4]

Where:

FEEC = Fan Electrical Energy Consumption [kWh]

P_e = Motor power input corresponding to the air volume flow rate of the air curtain unit during the temperature test [kW]

τ = ACU daily functioning hours [h]

τ is assumed to be equal to 1 for every ACU application.

ANNEX A: Theory in brief

This part describes how to calculate the heat losses through a door opening without an air curtain unit. In general, three types of heat losses can be distinguished in an open door without an air curtain unit:

- A net ventilation flow through the door opening caused by pressure difference across the opening because of mechanical ventilation.
- A net ventilation flow through the door opening caused by wind pressure and/or a temperature gradient inside the building creating a natural ventilation chimney effect the so-called stack effect.
- Heat loss through the door opening caused by the temperature difference between outside and inside, also known as natural convection.

1 Heat loss because of mechanical ventilation

When the ventilation system in a building is not balanced (i.e. restaurants with exhaust fans) there will be heat losses at the open doorway. The heat loss due to ventilation can be calculated by:

$$Q_v = c_p \cdot \rho \cdot \varphi \cdot \Delta T \qquad [1]$$

Where:

Q_v	= Heat loss due to mechanical ventilation	[kW]
c_p	= Specific heat of air	[kJ/kg.K]
ρ	= Density of air	[kg/m³]
φ	= Air volume flow rate across doorway by ventilation	[m³/s]
ΔT	= Temperature difference between cold and warm side	[K]

2 Heat loss caused by wind action

Wind action can cause additional heat losses at an open doorway because of cold air entering the building. The air volume flow rate entering an open doorway because of wind pressure can be can be calculated by:

$$\phi_w = H \cdot W \cdot \frac{v_{10}}{2} \cdot 0.25 \cdot L \qquad [2]$$

Where:

Φ_w	= Air volume flow rate entering doorway by wind pressure	[m³/s]
H	= Door height	[m]
W	= Door width	[m]
V_{10}	= Average wind speed at 10 m elevation	[m/s]
L	= Position factor of open doorway	[-]

where L = 1.2 (exposed position)

L = 1.0 (normal position)

L = 0.8 (sheltered position)

From the calculated air volume flow rate the heat loss caused by wind action can be calculated by:

$$Q_w = \Phi_w \cdot \rho_{pout} \cdot c_p \cdot \Delta T \qquad [3]$$

Where:

Q_w	= Heat loss caused by wind action	[kW]
Φ_w	= Air volume flow by wind action	[m³/s]
c_p	= Specific heat of air (cold side)	[kJ/kg K]
ρ_{out}	= Density of air (cold side)	[kg/m³]
ΔT	= Temperature difference between cold and warm side	[K]

3 Heat loss caused by temperature difference

If a temperature difference is present across an open doorway warm air will flow out from the warm side to the cold side at the top of the opening. On the bottom of the door opening cold air will flow in from the cold side to the warm side.

This natural convection heat loss can be calculated by:

$$Q_T = \frac{W \cdot H^{1.5}}{3}\, 0.6 \cdot \sqrt{g \frac{\Delta\rho}{\rho_m}} \cdot \rho_{out} \cdot c_p \cdot \Delta t \qquad [4]$$

Where:

Q_T	= Heat loss caused by temperature difference	[kW]
W	= Door width	[m]
H	= Door height	[m]
g	= Acceleration of gravity (9,81)	[m/s²]
$\Delta\rho$	= Density of air, difference $\lvert \rho_{out} - \rho_{in} \rvert$	[kg/m³]
ρ_m	= Mean Density of air ($\rho_{out} + \rho_{in}$)/2 [kg/m³]	
ρ_{out}	= Density of air (cold side)	[kg/m³]
ρ_{in}	= Density or air (warm side)	[kg/m³]
c_p	= Specific heat of air (cold side)	[kJ/kg K]
ΔT	= Temperature difference between cold and warm side	[K]

ANNEX B: Test report

For the air curtain unit under test the test report shall at least contain some or all of the following:

- Date;
- Air curtain unit classification;
- Test room climate class;
- Serial number;
- Name of the manufacturer;
- Trade name of the air curtain unit;
- Reference to this Eurovent code of good practice (Eurovent 16/1 - 2016);
- Climate class;
- Plot of the temperature curves of average mean temperatures (warm and cold cell) with and without an air curtain unit;
- Volume of the warm cell;
- Average instant temperature at t_1 of all temperature sensors in the warm cell (without an air curtain unit);
- Average instant temperature at t_1 of all temperature sensors in the warm cell (with an air curtain unit);
- Average instant temperature at t_0 of all temperature sensors in the warm cell (without an air curtain unit);
- Average instant temperature at t_0 of all temperature sensors in the warm cell (with an air curtain unit);
- Air curtain fans, power input;
- Number of fans;
- Heating capacity;
- Cooling capacity;
- Air inlet and air outlet temperature difference in cooling mode;
- Air inlet and air outlet temperature difference in heating mode;
- Plot of the arithmetic mean temperature of temperature-probes (for warm and cold cell) with and without an air curtain unit;
- Plot of the air volume flow rate across the door opening at different ΔP with and without an air curtain unit;
- CSE_T;
- CSE_W;
- ηl;
- L_p;
- L_w;
- PF_T;
- PF_W;
- Q,
- $Q_{T\ with}$;
- $Q_{T\ without}$;
- $q_{with\ ACU\ @2.5Pa}$
- $q_{without\ ACU\ @2.5Pa}$
- $Q_{W\ with}$;

- $Q_{W\ without}$;
- r;
- Test room dimensions (warm and cold) (W – L - H – Volume);
- FEEC.