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Smoke and heat control systems —

Part 2:
Specification for natural smoke and heat exhaust ventilators

Systèmes de contrôle de fumée et de chaleur —

Partie 2: Spécifications pour les dispositifs d'évacuation naturelle des fumées et de la chaleur

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 21927-2 was prepared by Technical Committee ISO/TC 21, *Equipment for fire protection and fire fighting*, Subcommittee SC 11, *Smoke and heat control systems and components*.

ISO 21927 consists of the following parts, under the general title *Smoke and heat control systems*:

— *Part 1: Specification for smoke barriers*

— *Part 2: Specification for natural smoke and heat exhaust ventilators*

— *Part 3: Specification for powered smoke and heat exhaust ventilators*

Introduction

In a fire situation, smoke- and heat-exhaust ventilation systems create and maintain a smoke-free layer above the floor by removing smoke. They also serve simultaneously to exhaust hot gases released by a fire in the developing stages. The use of such systems to create smoke-free areas beneath a buoyant layer has become widespread. Their value in assisting in the evacuation of people from buildings and other construction works, reducing fire damage and financial loss by preventing smoke damage, facilitating access for fire-fighting by improving visibility, reducing roof temperatures and retarding the lateral spread of fire is firmly established. For these benefits to be obtained, it is essential that smoke- and heat-exhaust ventilators operate fully and reliably whenever called upon to do so during their installed life. A smoke- and heat-exhaust ventilation system (referred to in this part of ISO 21927 as a SHEVS) is a system of safety equipment intended to perform a positive role in a fire emergency.

Smoke and heat control systems —

Part 2:
Specification for natural smoke and heat exhaust ventilators

1 Scope

This part of ISO 21927 specifies requirements and gives test methods for natural smoke- and heat-exhaust ventilators that are intended to be installed in a roof and/or wall as a component of a natural smoke- and heat-exhaust system.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6182-1, *Fire protection — Automatic sprinkler systems — Part 1: Requirements and test methods for sprinklers*

ISO 7240-7, *Fire detection and alarm systems — Part 7: Point-type smoke detectors using scattered light, transmitted light or ionization*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943 and the following apply.

3.1
aerodynamic free area
product of the geometric area multiplied by the coefficient of discharge

3.2
ambient
properties of the surroundings

3.3
automatic activation
initiation of operation without direct human intervention

3.4
aspect ratio
ratio of length to width

3.5
automatic natural smoke- and heat-exhaust ventilator
smoke- and heat-exhaust ventilator that is designed to open automatically after the outbreak of fire if called upon to do so

NOTE Automatic natural smoke- and heat-exhaust ventilators can also be fitted with a manual control or release device.

3.6
coefficient of discharge
C_v
ratio of actual flow rate, measured under specified conditions, to the theoretical flow rate, through the ventilator, as defined in Annex B

NOTE 1 The coefficient takes into account any obstructions in the ventilator, such as controls, louvers and vanes, and the effect of external side winds.

NOTE 2 Also called aerodynamic efficiency.

3.7
dual-purpose ventilator
smoke- and heat-exhaust ventilator that has provision to allow its use for comfort (i.e. day-to-day) ventilation

3.8
exhaust ventilator
device for the movement of gases out of the construction works

3.9
fire-open position
configuration of the ventilator specified by its designer to be achieved and sustained while venting smoke and heat

3.10
gas container
vessel containing gas in a compressed form, the energy of which, when released, opens the ventilator

3.11
geometric area
A_v
area of the opening through a ventilator, measured in the plane defined by the surface of the construction works, where it contacts the structure of the ventilator

NOTE No reduction is made for controls, louvers or other obstructions.

3.12
initiation device
device that activates the operating mechanism of the component (e.g. of a damper or a ventilator) on receipt of information from a fire detection system or thermal device

3.13
manual operation
initiation of the operation of a smoke- and heat-exhaust ventilator by a human action (e.g. pressing a button, or pulling a handle)

NOTE A sequence of automatic actions in the operation of a smoke- and heat-exhaust ventilator started by the initial human action is regarded as manual operation for the purposes of this part of ISO 21927.

3.14
manually opened natural smoke- and heat-exhaust ventilator
natural smoke- and heat-exhaust ventilator that can be opened only by a manual control or release device

3.15
mass flux
total mass of gases crossing a specified boundary per unit time

3.16
natural ventilation
ventilation caused by buoyancy forces due to differences in density of the gases because of temperature differences

3.17
opening mechanism
mechanical device that operates the ventilator to the fire-open position

3.18
opening time
period between the information to open being received by the ventilators and achieving the fire-open position of the ventilator

3.19
projection area
cross-sectional area of the natural smoke- and heat-exhaust ventilator in its fire-open position above the plane of the roof, at a right angle to the side-wind flow

3.20
range of natural smoke- and heat-exhaust ventilators
ventilators of various sizes having the same method of construction and the identical number and type of opening devices

3.21
smoke- and heat-control system
arrangement of components installed in a construction works to limit the effects of smoke and heat from a fire

3.22
smoke- and heat-exhaust system
smoke and heat control system that exhausts smoke and heat from a fire in a construction works or part of a construction works

3.23
smoke- and heat-exhaust ventilation system
SHEVS
components jointly selected to exhaust smoke and heat in order to establish a buoyant layer of warm gases above cooler and cleaner air

3.24
smoke- and heat-exhaust ventilator
SHEV
device specially designed to move smoke and hot gases out of a construction works under conditions of fire

3.25
thermal device
temperature-sensitive device that responds to initiate a subsequent action

3.26
throat area
smallest cross-sectional area of the flow path through the ventilator

3.27
ventilator
device for enabling the movement of gases into or out of the construction works

3.28
wind-sensitive control system
control system designed to control two or more banks of ventilators on separate elevations so that only the ventilators not subject to positive wind pressures open in case of fire

3.29
wall
external building surface with an inclination of more than 60° relative to the horizontal

3.30
roof
external building surface with inclination of 60° or less relative to the horizontal

NOTE Shed roofs, independent of inclination angle, are considered to be part of roofs.

4 Symbols

Symbol	Definition	Unit
A	any number used in the classifications	
A_{a}	aerodynamic free area, expressed in square meters	(m^2)
A_{n}	nozzle exit area (for open jet facilities), expressed in square meters	(m^2)
A_{pr}	projection area of the ventilator for the side-wind flow, expressed in square meters	(m^2)
A_{sc}	horizontal cross-section area of the settling chamber, expressed in square meters	(m^2)
A_{v}	geometric area of the ventilator, expressed in square meters	(m^2)
B	width of the open hole of the settling chamber, expressed in meters	(m)
B_{n}	width of nozzle exit area in open jet facilities, expressed in meters	(m)
B_{v}	maximum width of the ventilator in the fire-open position, expressed in meters above the upper surface of the settling chamber	(m)
C_{v}	coefficient of discharge, dimensionless	–
C_{v0}	coefficient of discharge without side-wind influence, dimensionless	–
C_{vw}	coefficient of discharge with side-wind influence, dimensionless	–
H_{n}	height of nozzle exit area in open jet facilities, expressed in meters	(m)
H_{v}	maximum height of the ventilator in the fire-open position above the upper surface of the settling chamber, expressed in meters	(m)
L	length of the open hole of the settling chamber, expressed in meters	(m)
$\dot{m}_{\mathrm{ing}}$	mass flow rate entering the settling chamber, expressed in kilograms per second	(kg/s)
p_{amb}	ambient pressure, expressed in pascals	(Pa)
p_{d}	wind-stagnation pressure, expressed in pascals	(Pa)
p_{int}	internal static pressure, expressed in pascals	(Pa)
$p_{\mathrm{int,\,v0}}$	internal static pressure without side wind, expressed in pascals	(Pa)
$p_{\mathrm{int,\,vw}}$	internal static pressure with side wind, expressed in pascals	(Pa)

T	temperature, expressed in degrees Celsius	(°C)
ΔT	temperature difference, expressed in Kelvin	(K)
V_∞	side-wind velocity, expressed in meters per second	(m/s)
$V_{\text{m, sc}}$	mean velocity of the settling chamber, expressed in meters per second	(m/s)
V_{n}	mean nozzle velocity, expressed in meters per second	(m/s)
V_{sc}	local velocities in plane above settling chamber, see Figure B.6, expressed in meters per second	(m/s)
W_{s}	snow load, expressed in pascals	(Pa)
W_{w}	wind load, expressed in pascals	(Pa)
W_{wd}	design wind load, expressed in pascals	(Pa)
α	opening angle of the ventilator, expressed in degrees	°
β	angle of attack, expressed in degrees	°
β_{crit}	incidence angle at which the smallest value of C_{vw} obtained with side wind occurs, expressed in degrees	°
θ	angle of installation of ventilators on a roof, expressed in degrees	°
Δp	pressure difference, expressed in pascals	(Pa)
Δp_{v0}	reference-pressure difference between the static pressure in the settling chamber and the ambient pressure without side wind, expressed in pascals	(Pa)
Δp_{vw}	reference-pressure difference between the static pressure in the settling chamber and the ambient pressure with side wind, expressed in pascals	(Pa)
Δp_{int}	pressure difference between the static pressure in the settling chamber and the ambient pressure, expressed in pascals	(Pa)
ρ_{air}	density of air, expressed in kilograms per cubic meter	(kg/m^3)

5 Design requirements

5.1 Initiation device

5.1.1 General

To ensure that the natural smoke and heat ventilator opens in the event of a fire, it shall be fitted with an automatic initiation device.

Each ventilator shall be fitted with one or more of the following automatic initiation devices:

a) thermal initiation device;

b) initiation device activated by an electrical signal from a remote source, e.g. a smoke and heat detector system, the interruption of electrical supply or a manually actuated “fire override” switch;

c) pneumatic initiation device, e.g. a pneumatic signal or a loss of compressed air;

d) initiation device able to respond to other types of release signal.

The response behaviour of thermal automatic initiation devices shall comply with the requirements of ISO 6182-1. Smoke detectors shall comply with the requirements of ISO 7240-7. In addition, a manually operated initiation device may be fitted.

A pneumatic non-fail-safe SHEV, which does not open automatically on loss of power, shall have at least a thermal device and one power source that is mounted directly in the SHEV, unless the required control panel monitors the lines to the SHEV and indicates a failure.

In some specific design cases where it is suitable that the ventilator shall be only manually initiated, the ventilator may be installed without an automatic initiation device.

5.1.2 Thermal initiation device

Any thermal initiation or release device shall be within the ventilator and shall be exposed to the hot gas entering the closed ventilator.

There are two exceptions to this requirement, where an automatic thermal initiation or release device shall not be fitted to the ventilator:

a) if the ventilators are installed as wall-mounted ventilators;

NOTE Adverse wind conditions can cause a ventilator, which has been opened by the automatic initiation device, to let in air and not remove heat and smoke.

b) in specific design cases where it is suitable that the ventilators are only manually initiated.

5.2 Opening mechanism

5.2.1 General

The ventilator shall be provided with an opening mechanism with energy within the ventilator, e.g. gas containers, spring systems, electrical power supply and/or with an external energy source. For the external links, the manufacturer shall specify the operating requirements for the initiation device and the opening mechanism, e.g. voltage, energy.

5.2.2 Integral gas containers

Any gas container forming an integral part of the ventilator shall be equipped with a pressure-release device to prevent an explosion if the container overheats.

5.3 Opening of the ventilator

For on-site testing purposes, there are two types of ventilators:

a) type A, which are able to be opened into their fire-open position;

b) type B, which are able to be opened into their fire-open position and closed remotely.

5.4 Size of the geometric area

The size and form of the geometric area shall be such that it complies with the limitation set by the test apparatus available for the heat exposure test.

The side length shall not exceed 2,5 m and the aspect ratio of the geometric area shall not exceed 5:1 when using the simple assessment procedure to determine the aerodynamic free area; see Clause B.1.

NOTE As of the publication date of this part of ISO 21927, maximum dimensions of the test apparatus for the heat exposure test are in the range of 3 m.

For ventilators larger than the largest ventilator tested in accordance with Annex G, an assessment of the heat exposure effect shall be made by the testing station to ensure that the performance is not negatively affected.

5.5 Inputs and outputs (connections)

The SHEV shall be equipped with inputs and/or output that allow its connection with the control panel and power supplies.

6 General testing procedures

For type approval testing, tests shall be carried out in the sequence specified in Clause A.1.

For each test, a test report shall be prepared in accordance with Clause A.2.

Some of the tests mentioned may be omitted when type testing a new product belonging to a product range that has been tested if only detail changes have been made.

The use of additional functions to smoke ventilation (e.g. daily ventilation) and/or add-ons to the SHEVs are permitted if they do not negatively alter the performance of the SHEV.

7 Aerodynamic free area of the ventilator

The aerodynamic free area of the ventilator shall be determined in accordance with Annex B.

For roof-mounted ventilators, the aerodynamic free area is written $A_{\text{a Roof}}$.

For wall-mounted ventilators, the aerodynamic free area is written $A_{\text{a Wall}}$.

8 Performance requirements and classification

8.1 Reliability

8.1.1 Reliability classification

The ventilator shall be classified as one of the following:

a) Re A;

b) Re 50;

c) Re 1 000.

The designation A, 50 and 1 000 represents the number of openings into the fire-open position and closing under no applied load in accordance with Annex C.

8.1.2 Reliability performance

The ventilator shall open, reach its fire-open position not more than 60 s after actuation without damage and remain in position without an external energy supply (until reset).

8.1.3 Dual purpose ventilator

If the ventilator is a dual purpose ventilator, it shall open to its normal comfort position when tested under no load 10 000 times in accordance with Annex C prior to testing the same ventilator under 8.1.1 and 8.1.2.

8.2 Opening under load

8.2.1 Loads

8.2.1.1 Snow-load classification

The ventilator shall be classified as one of the following:

a) SL 0;

b) SL 125;

c) SL 250;

d) SL 500;

e) SL 1 000;

f) SL A.

The designations 0, 125, 250, 500, 1 000 and "A" represent the test snow load, expressed in pascals, applied when the ventilator is tested in accordance with Annex D.

NOTE A ventilator classified SL 0 can be installed in accordance with the manufacturer's instructions with a minimum angle of installation > 45° from the horizontal (combining roof pitch and vent pitch (see Figure 1), except where the snow is prevented from slipping from the ventilator, e.g. by wind deflectors.

Except for SL 0 for ventilators fitted with deflectors, the snow-load classification should not be less than SL = 2 000 d, where d is the depth of snow, expressed in metres, that can be contained within the confines of the deflectors.

8.2.1.2 Load due to side-wind simulation

To simulate the side-wind influence, the ventilator shall be subjected to the most unfavourable wind direction to a side wind of 10 m/s velocity when tested in accordance with Annex D.

This test does not apply for wall-mounted SHEVs.

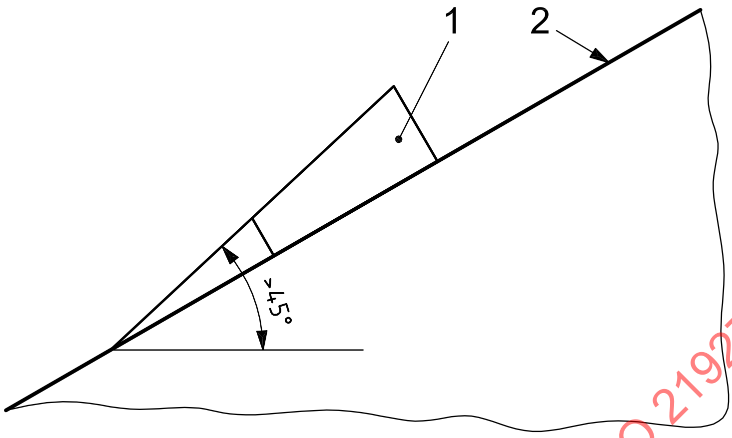
8.2.2 Performance under load

The ventilator shall open, reach its fire-open position not more than 60 s after actuation and remain in position without an external energy supply (until reset), when tested under the snow load appropriate to its classification and under the specified side wind in accordance with Annex D.

For ventilators fitted with wind deflectors, the deflectors shall be at least 80 mm from the nearest part of the ventilator and they shall not be fitted in such a way to encourage snow or ice to collect to the detriment of the operation of the ventilator.

It is recommended that louver-type ventilators be classified not less than SL 500 when used in sub-zero conditions.

This test does not apply for wall-mounted SHEVs.



Key

1 ventilator

2 roof

Figure 1 — Combined roof pitch and vent pitch angle > 45° from the horizontal

8.3 Low ambient temperature

8.3.1 Classification

The ventilator shall be classified as one of the following:

a) T(– 25);

b) T(– 15);

c) T(– 05);

d) T(00);

e) T *A*.

The designations 25, 15, 05 and "*A*" represent the number of °C below zero at which the ventilator is tested in accordance with Annex E. T(00) ventilators are regarded as suitable only for use in construction works where the temperature is above 0 °C.

8.3.2 Performance at low temperature

When tested in accordance with Annex E, the opening mechanism of a classified ventilator, except those classified as T(00) (see 8.3.1), shall operate in a manner corresponding to the load-versus-stroke correlation of the same opening mechanism when it is built-in and tested under ambient temperature. It shall reach the stroke that corresponds to the fire-open position of the ventilator in not more than 60 s.

8.4 Wind load

8.4.1 Wind-load classification

The ventilator shall be classified as one of the following:

a) WL 1 500;

b) WL 3 000;

c) WL A.

The designations 1 500, 3 000 and "A" represent the test wind-suction load, expressed in pascals, applied when the ventilator is tested in accordance with Annex F.

8.4.2 Performance under wind load

The ventilator shall not open under the wind load appropriate to its classification, and shall not suffer permanent deformation when tested in accordance with Annex F; following this test, it shall open into the fire-open position within 60 s of actuation.

8.4.3 Resistance to wind-induced vibration

If wind deflectors form an integral part of the ventilator, their natural frequency of vibration shall be higher than 10 Hz with a logarithmic decrement of damping greater than 0,1 when tested in accordance with F.4.2.

8.5 Resistance to heat

8.5.1 Classification

The ventilator shall be classified as given under a) and/or b):

a) For a wall-mounted ventilator:

1) B_{Wall} 300,

2) B_{Wall} 600,

3) B_{Wall} A.

b) For roof-mounted ventilator:

1) B_{Roof} 300,

2) B_{Roof} 600,

3) B_{Roof} A.

The designations 300, 600 and "A" represent the temperature, expressed in degrees Celsius, at which the ventilator is tested in accordance with Annex G.

8.5.2 Performance

8.5.2.1 The reaction to fire of the materials of the ventilator shall be tested and classified in accordance with national requirements.

8.5.2.2 The throat area shall not be reduced by more than 10 % of the initial throat area when the ventilator is tested in accordance with Annex G.

9 Evaluation of conformity

9.1 General

The compliance of natural smoke and heat ventilators with the requirements of this part of ISO 21927 shall be demonstrated by

— type testing;

— factory production control by the manufacturer.

9.2 Type testing

Type testing, which shall be performed on first application of this part of ISO 21927, shall demonstrate conformity with Clauses 5, 7 and 8, with the tests being carried out in the order specified in Clause 6.

Tests previously performed in accordance with the provisions of this part of ISO 21927 [same product, same characteristic(s), test method, sampling procedure, system of attestation of conformity, etc.] may be taken into account.

In addition, initial type testing shall be performed at the beginning of the production of a new product type or at the beginning of a new method of production (where these may affect the stated properties).

9.3 Factory production control (FPC)

The manufacturer shall establish, document and maintain an FPC system to ensure that the products placed on the market conform with the stated performance characteristic. The FPC system shall consist of procedures, regular inspections and tests and/or assessments and the use of the results to control raw and other incoming materials or components, equipment, the production process and the product, and shall be sufficiently detailed to ensure that the conformity of the product is apparent.

An FPC system conforming with the requirements of ISO 9001, and made specific to the requirements of this part of ISO 21927, shall be considered to satisfy the above requirements.

The results of inspections, tests or assessments requiring action shall be recorded, as shall any action taken. The action to be taken when control values or criteria are not met shall be recorded.

10 Marking

The ventilator shall be marked with the following:

a) name or trade mark of the supplier and/or manufacturer;

b) type and model;

c) year of manufacture;

d) technical characteristics of the external energy supply (e.g. power, current, voltage, pressure); if integral gas containers are used, they shall be marked with at least the following: mass and type of gas, fill ratio and nominal temperature;

e) temperature of the thermal initiation device (if fitted);

f) aerodynamic free area (see B 2.5) in square metres;

g) classes for wind load, snow load, low ambient temperature, reliability and heat-exposure temperature if provided;

h) number and year of this part of ISO 21927;

i) indication of suitability for wall mounting with wind-sensitive control system only (if tested to B.2.4.2).

11 Installation and maintenance information

11.1 Installation information

The supplier shall provide appropriate installation information for the following:

— attachment;

— connection to external services (e.g. electrical and pneumatic installation).

11.2 Maintenance information

The supplier shall provide appropriate maintenance information for the ventilator, which shall include the following:

— inspection and maintenance procedures;

— recommended frequency of operational checks;

— recommended checks for the effects of corrosion.

Annex A
(normative)

General testing procedures

A.1 Test sequence

For type approval testing, carry out the tests in the following sequence:

a) determination of the aerodynamic free area; see Annex B;

b) reliability test; see Annex C;

c) opening test under load; see Annex D;

d) low ambient temperature test; see Annex E;

e) wind load test; see Annex F;

f) heat exposure test; see Annex G.

The same ventilator shall be used for the reliability test (see Annex C) and opening under load test (see Annex D).

A.2 Test report

A test report shall be prepared including the following:

— name or trade mark and address of the supplier and/or manufacturer;

— name of the product (type and model);

— date(s) of the test(s);

— name(s) and address(es) of the testing organization;

— description of the test specimen;

— reference to the test method(s);

— conditions of test(s);

— observations during the test(s);

— test results;

— classifications achieved, if relevant.

Annex B
(normative)

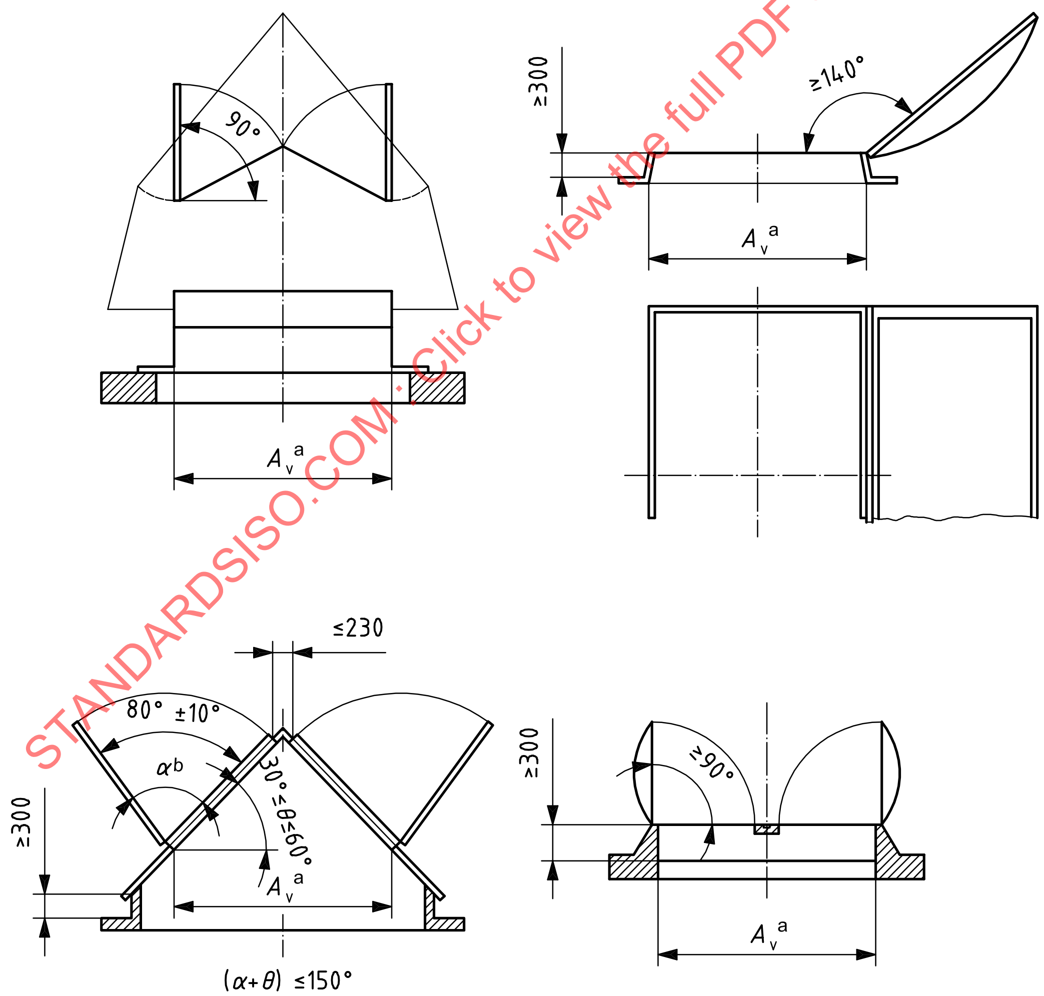
Determination of the aerodynamic free area

B.1 Simple assessment procedure

B.1.1 Roof-mounted ventilators

For the types of ventilator shown in Figure B.1 and that are in accordance with 5.4, the discharge coefficient may be taken as $C_v = 0{,}4$ for installation situations with an upstand height of at least 300 mm and for the specified opening angle. An inflow of air into the fire room instead of a discharge of smoke from the fire room shall be avoided. Small opening angles and/or other installation situations, e.g. see Figure B.2, can lead to negative discharge coefficients.

Dimensions in millimetres, unless otherwise noted

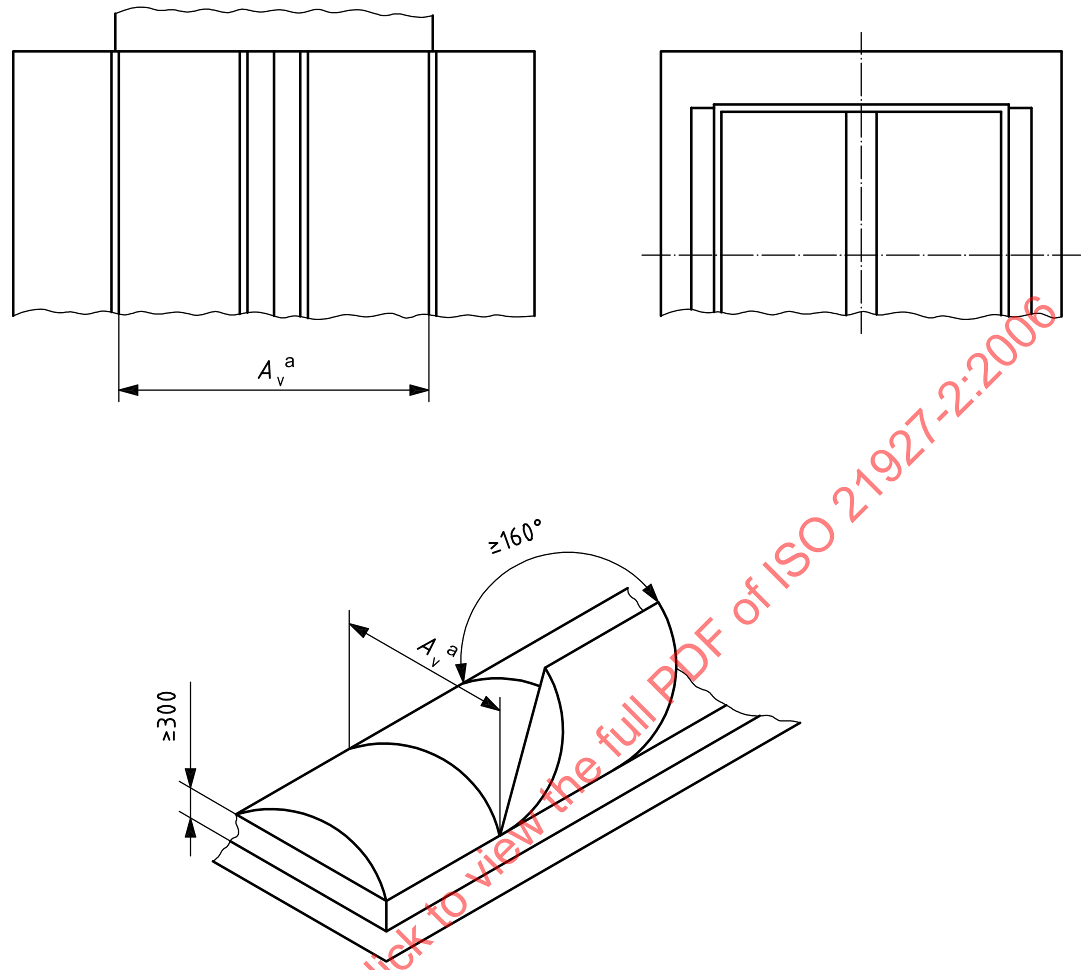


a A equals length times width.

b $(\alpha + \beta)_{max}$ = 140°.

Figure B.1 — Types of ventilator for the simple assessment procedure

Dimensions in millimetres, unless otherwise noted



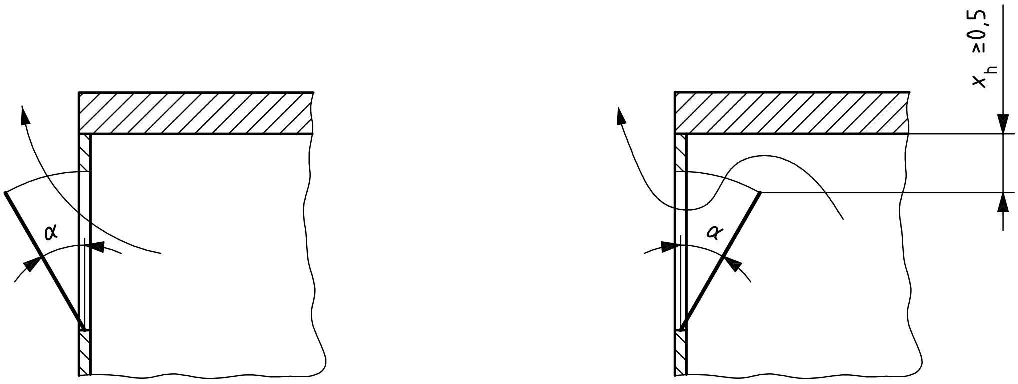
a A equals length times width.

b $(\alpha + \beta)_{max} = 140°$.

Figure B.1 (*continued*)

B.1.2 Wall-mounted ventilators

For the types of ventilators shown in Figure B.2 and that are in accordance with 5.4, the discharge coefficient given in Table B.1 may be taken for the specified opening angles. An inflow of air into the fire room instead of a discharge of smoke from the fire room shall be avoided. This can necessitate a wind-direction-dependent opening of the ventilators.



a) Opening to the outside

b) Opening to the inside

Figure B.2 — Examples of types of ventilator probably leading to negative discharge

The aerodynamic free area according to the simple assessment procedure shall be approved by a notified testing station.

Tableau B.1 — Discharge coefficients for wall-mounted ventilators using the simple assessment procedure for various opening angles, α

α degrees	Coefficient [a]	
	SHEV opening to the outside	SHEV opening to the inside
30	0,25	0,20
45	0,30	0,25
60	0,40	0,30
90	0,50	0,40

[a] If the height, x_h, as indicated in Figure B.2, b), is reduced to less then 0,5 m, then the values in this table are not applicable and it is necessary that they be reconsidered accordingly.

B.2 Experimental procedure

B.2.1 General

Unless the simple assessment procedure of Clause B.1 is used, determine A_a experimentally, either directly or indirectly from results on ventilators of different size or scaled-down models.

B.2.2 Test apparatus

Use a test apparatus with an open jet or a closed test-section facility calibrated in accordance with Clause B.3.

This consists of a settling chamber onto which the ventilator can be mounted in accordance with Figure B.4, so that the mass flow through the ventilator can be determined, and a side-wind simulator by means of which the ventilator can be subjected to a side wind. The flow in the settling chamber approaching the smoke ventilator shall be steady state and uniform.

This can be achieved if the ratio, A_v/A_{sc}, of the geometric area of the ventilator to the horizontal cross-sectional area of the settling chamber is less than or equal to 0,15 and the velocity, V_{sc}, measured in the open hole (without ventilator) at the points specified in Figure B.6 varies by only ± 10 % of the mean velocity, $V_{m,sc}$, of the settling chamber.

To obtain a uniform side-wind condition when the ventilator is subjected to side wind, the tests shall be carried out in side-wind simulation facilities.

The following conditions for each facility shall be satisfied:

Table B.2 — Required conditions for tests in side-wind simulation facilities

Ratio	Open-jet facilities	Closed test-section facilities
A_{pr}/A_n	$\leqslant$ 0,3	$\leqslant$ 0,08
H_n/H_v	$\geqslant$ 1,3	$\geqslant$ 3
B_n/B_v	$\geqslant$ 1,5	$\geqslant$ 2
V_n, metres per second	$\geqslant$ 10	$\geqslant$ 10
$I_{u,\, hUS}$, percent	$\leqslant$ 10	$\leqslant$ 10

The following conditions shall be satisfied for both facilities.

The velocity, $V_{hus/2}$, at mid-height of the upstand above the test-section floor shall meet the condition given in Equation (B.1):

$$0{,}85 \cdot V < V_{(hus/2)} < 1{,}05 \cdot V \quad \text{(B.1)}$$

where

$$V = \frac{V_{(Hv/2)} + V_{(3Hv/4)} + V_{Hv} + V_{(5Hv/4)}}{4} \quad \text{(B.2)}$$

subscript Hv represents the maximum height of the ventilator in the fire-open position.

None of the velocities measured at the points indicated in Figure B.6 in the entrance area to the test section, for either the open jet or the closed test-section facilities, varies by more than ± 10 % of the mean nozzle velocity, V_n.

NOTE Using larger side-wind velocities increases the accuracy of the measurements.

When using larger side-wind velocities, the discharge coefficient, c_{vw}, shall be taken for the dimensionless pressure ratio, $\Delta p_{int}/p_d = 0{,}082$.

B.2.3 Test specimen

Carry out tests on full-size smoke ventilators as supplied by the manufacturer and/or supplier, or on accurately scaled-down models. For testing, the similarity of flow characteristics of scaled-down models shall be established. This is always achieved if the Reynolds number of the scaled-down model is identical to the full-scale ventilator. To achieve the Reynolds number similarity usually requires model scales of 1:6 or larger. Smaller scales (down to 1/10) may be used if justification is given for the flow similarity.

When testing scaled-down models, all features of the ventilators in contact with the airflow (e.g. opening elements or details of flaps) shall be included and shall satisfy the similarity requirement.

NOTE Experience has shown that it is difficult to model ridge vents and louver type ventilators.

It is not considered necessary to test all sizes of a range of similar ventilators, provided tests are carried out on a representative selection of sizes. For a range of similar ventilators consisting of eight or more sizes, at least four sizes shall be investigated experimentally, two with a length-to-width ratio smaller than 1,5 and two with a length-to-width ratio larger or equal 1,5. The sizes (at least eight) to be investigated for larger ranges shall be chosen in such a way that the relative upstand height, which equals the upstand height, h_{US}, divided by the hydraulic diameter, $d_{h,g}$, of the geometric opening, evenly covers the whole range of possible $h_{US}/d_{h,g}$ ratios. For small (fewer than eight) ranges, the smallest and the largest ventilator shall be investigated. For testing ventilators differing in dimensions but belonging to the same range, A_a may be calculated for intermediate sizes. The method of calculation shall be mentioned in the test report.

For ventilators designed as part of a continuous roof-light, the test specimen shall be mounted on the rig with parts of the roof-lights. Those parts shall have a minimum width of half the external dimension of the ventilator parallel to the line of the roof-light. For ventilators intended for use in continuous roof-lights, the gable ends of the roof-light ends shall be streamlined or fitted with a deflection device as shown in Figure B.8.

B.2.4 Test procedure

B.2.4.1 Roof-mounted ventilators

Quantify the outside ambient static pressure with and without wind using the following procedure. Make sure the settling chamber is airproof. Fit into the exit opening of the settling chamber and flush with the exterior of the settling chamber ceiling a thin plate with evenly spaced holes with a diameter of 5 cm in order to get a geometric porosity. The ratio of hole area to exit area of settling chamber equals to (5 ± 1) %. Measure the static pressure in the settling chamber without wind, $p_{int,v0}$, [Equation (B.3)] and with wind $p_{int,vw}$ [Equation (B.4)] according to the side-wind conditions specified below with reference to the atmospheric pressure, p_{amb}:

$$p_{int,v0} = p_{amb,1} + \Delta p_{v0} \tag{B.3}$$

$$p_{int,\,vw} = p_{amb,1} + \Delta p_{vw} \tag{B.4}$$

Record the Δp_{v0} and Δp_{vw} values, remove the drilled plate, and fit the ventilator on the settling chamber. Carry out the tests with and without wind.

For the no-side-wind case, set the full-scale ventilator onto the settling chamber to get the internal static pressure, p_{int}, as given in Equation (B.5):

$$p_{int} = p_{amb,2} + \Delta p_{v0} + \Delta p_{int} \tag{B.5}$$

where

Δp_{int} ranges from 3 Pa to 12 Pa, with an accuracy of at least + 5 %;

$p_{amb,2}$ is the atmospheric pressure at the time of the measurement.

Measure the ambient atmospheric pressure and temperature, the static pressure of the air in the settling chamber and the volume flow entering the settling chamber. Determine for each value of Δp_{int} the corresponding mass flow $\dot{m}_{ing}$.

Take at least six readings of Δp_{int} and $\dot{m}_{ing}$ for testing without side wind.

When testing scaled-down models at an increased pressure difference, Δp_{int}, due to the requirement for the similarity of Reynolds numbers, the accuracy required of measurement shall be + 3 % of the reading. The required accuracy of the mass flow measurement is + 2,5 % of the reading. Measure the temperature and the pressure of the ambient air with an accuracy of + 0,5 K and + 0,5 %, respectively.

To carry out tests on full-scale ventilators with a side-wind speed of 10 m/s upstream of the test section, measure the atmospheric pressure and temperature of the air in the wind flow upstream of the test section. Set the ventilator onto the settling chamber to get the internal static pressure, as given in Equation (B.6):

$$p_{int} = p_{amb,3} + \Delta p_{vw} + \Delta p_{int} \tag{B.6}$$

where

Δp_{int} ranges from 0,005 p_d to 0,15 p_d;

$$p_d = \frac{1}{2} \rho_{air} V_n^2 \quad (B.7)$$

$p_{amb,3}$ is the atmospheric pressure at the time of the measurement.

For larger side-wind velocities ($V_n > 10$ m/s) for full scale models, the pressure difference, Δp_{int}, shall be increased according to Equation (B.8):

$$\Delta p_{int}/p_d = 0{,}082 \quad (B.8)$$

EXAMPLE If $V_n = 14$ m/s, Δp_{int} is close to 10 Pa.

This gives the pressure measurements a higher degree of accuracy.

For full-scale tests, in order to reduce the atmospheric conditions effects on the measurements (fluctuations of the ambient pressure field due to the atmospheric wind), the mass flow rate, the wind velocity and the static pressure measurements should be carried out during 10 min. Diminution of the duration should be justified.

Measure $\dot{m}_{ing}$, taking at least six readings of Δp_{int} and $\dot{m}_{ing}$ for testing with side wind.

Plot a graph of C_{vw} versus $\Delta p_{int}/p_d$ and determine the discharge coefficient with side wind, C_{vw}, from the regression line of the readings at $\Delta p_{int}/p_d = 0{,}082$ for the least favourable angle of incidence β_{crit}.

To determine β_{crit}, measure the C_{vw} value for various angles, β. β_{crit} is obtained when measurements for angles $\beta = \beta_{crit} \pm 5$ lead to higher C_{vw} values than determined for β_{crit}.

Use the same procedure when measuring the discharge coefficient with side wind for scaled-down models. However, to ensure the similarity of the flow around the full-size and the scale-model ventilator, it is necessary to increase Δp_{int}. This leads to an increase in the wind-stagnation pressure according to Equation (B.8) and, thus, to an increase in nozzle exit velocity as compared to full-size testing. To avoid compressibility effects, do not test at a side-wind velocity greater than 100 m/s.

The usually fluctuating measurement signals shall be averaged over a time period long enough for the pressure and air volume flow values to be, respectively, in the range of ± 2,5 % and ± 5 % for several similar successive experiments. The averaging technique shall be given in the test report.

B.2.4.2 Wall-mounted ventilators

For wall-mounted ventilators, follow the test procedure of B.2.4.1 in the “without wind” condition only.

B.2.5 Evaluation of test results

Calculate the discharge coefficient using Equation (B.9):

$$C_v = \frac{\dot{m}_{ing}}{A_v \cdot \sqrt{2 \cdot \rho_{air} \cdot \Delta p_{int}}} \quad (B.9)$$

From the C_v values thus determined, calculate the mean discharge coefficients C_{v0} (without side wind) and C_{vw} (with side wind). Calculate the aerodynamic free area using the lower value of the C_{v0} and C_{vw} values rounded to two digits according to Equation (B.10):

$$A_a = A_v \cdot C_v \quad (B.10)$$

Wall-mounted ventilators have a C_{v0} value only.

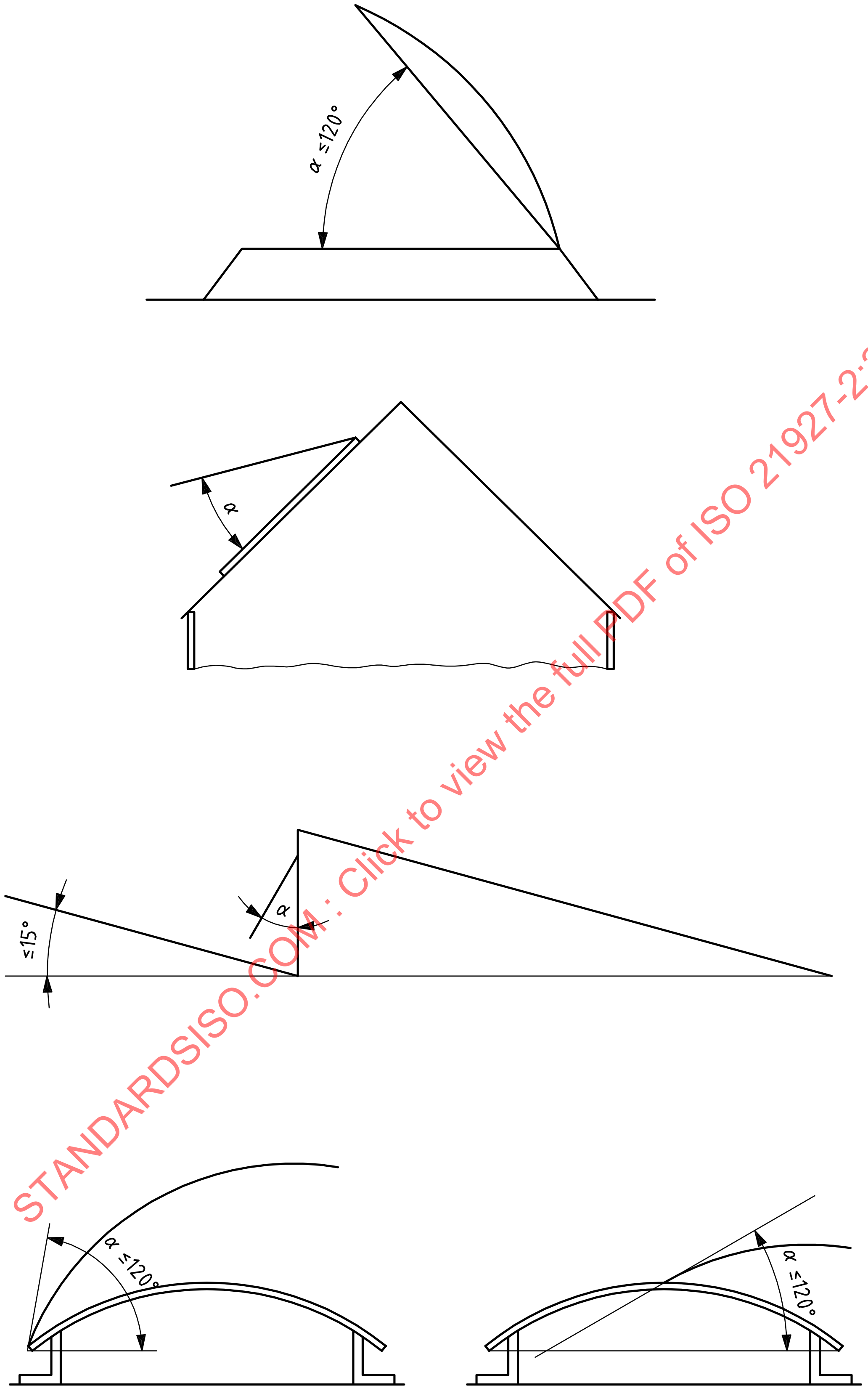
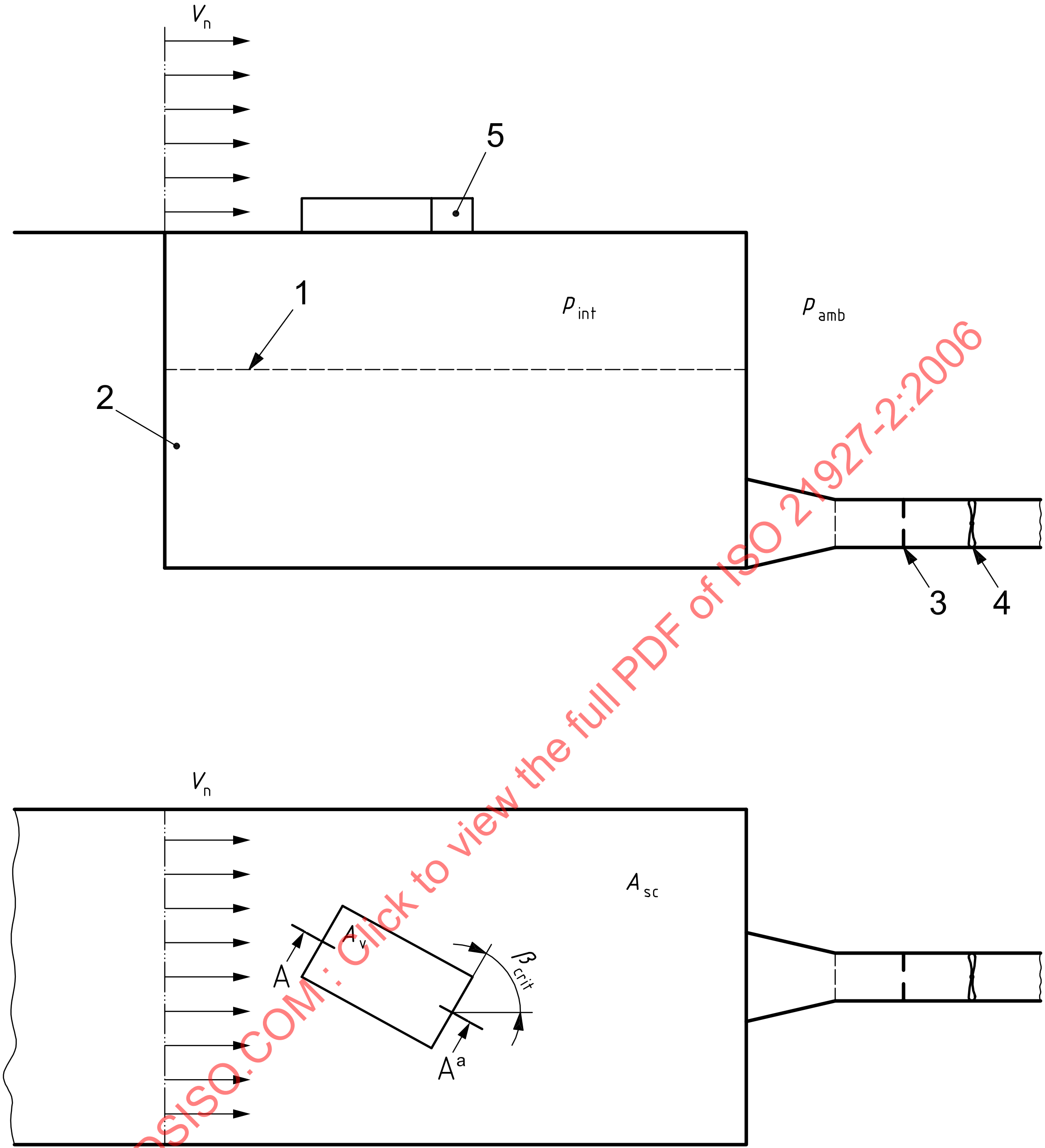


Figure B.3 — Examples of types of ventilator probably leading to negative discharge



Key

1 screen

2 settling chamber

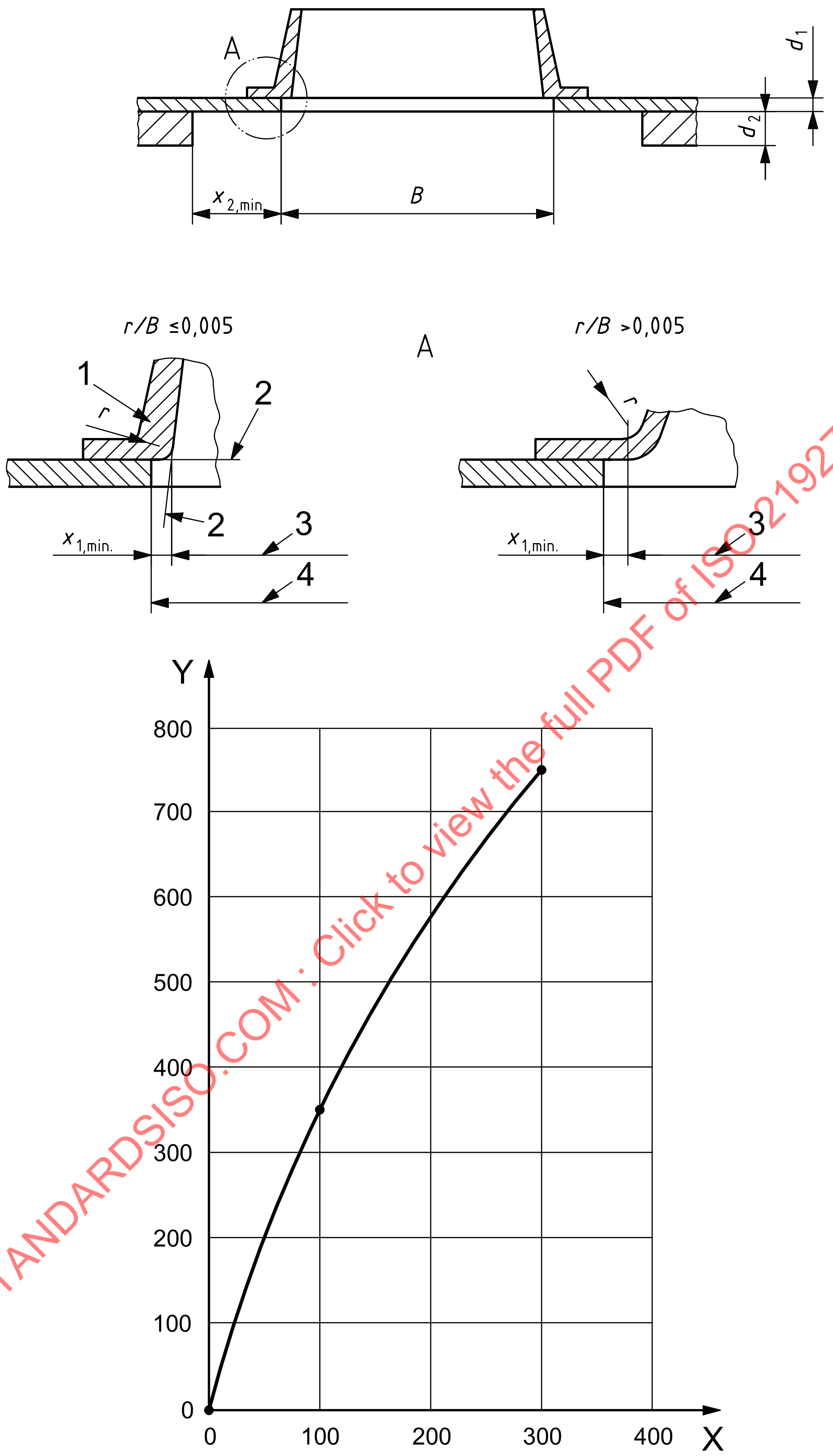
3 volume flow measurement

4 fan

5 smoke vent

a See Figure 5.

Figure B.4 — Schematic drawing of test set up for the determination of A_v



Key

X ceiling thickness d_1 and d_2, expressed in millimetres

Y distance measure $x_{1,min.}$ and $x_{2,min.}$, expressed in millimetres

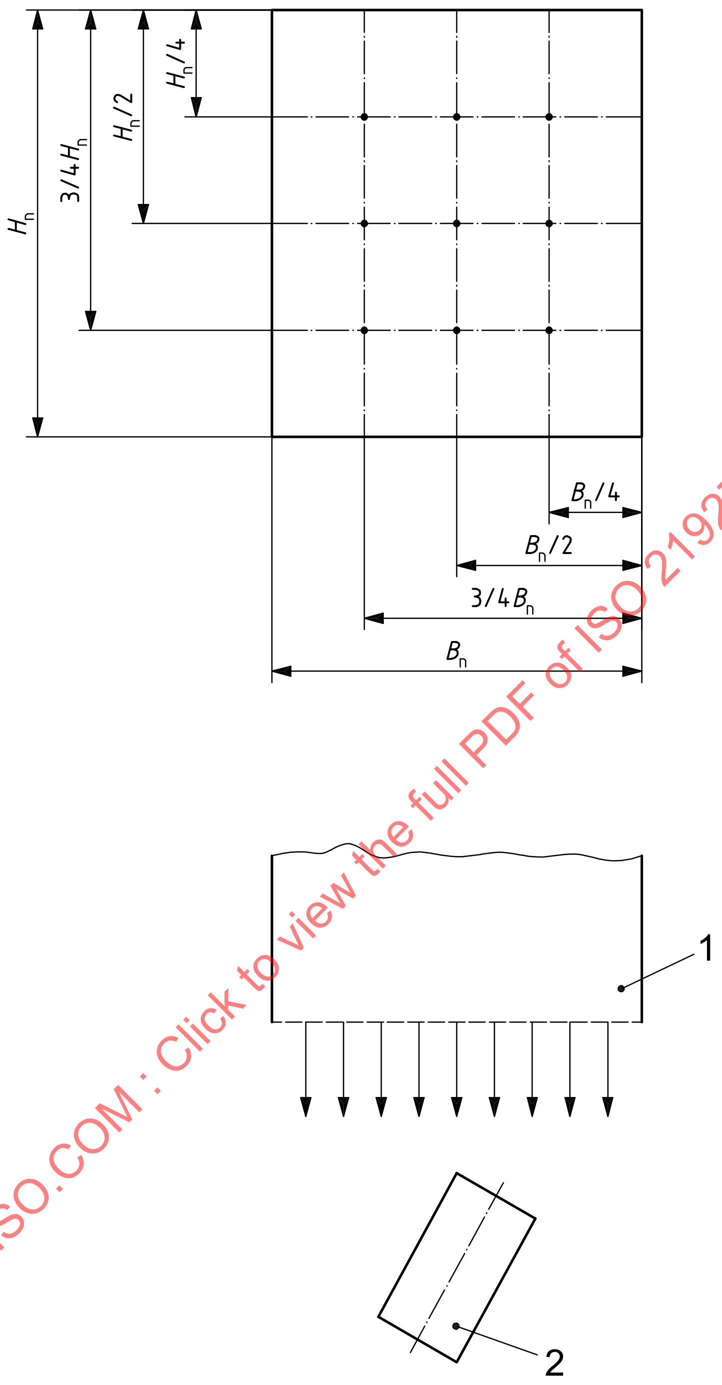
1 ventilator

2 tangent

3 geometric dimension of ventilator

4 ceiling dimension

Figure B.5 — Data for the mounting of the ventilator onto the settling chamber



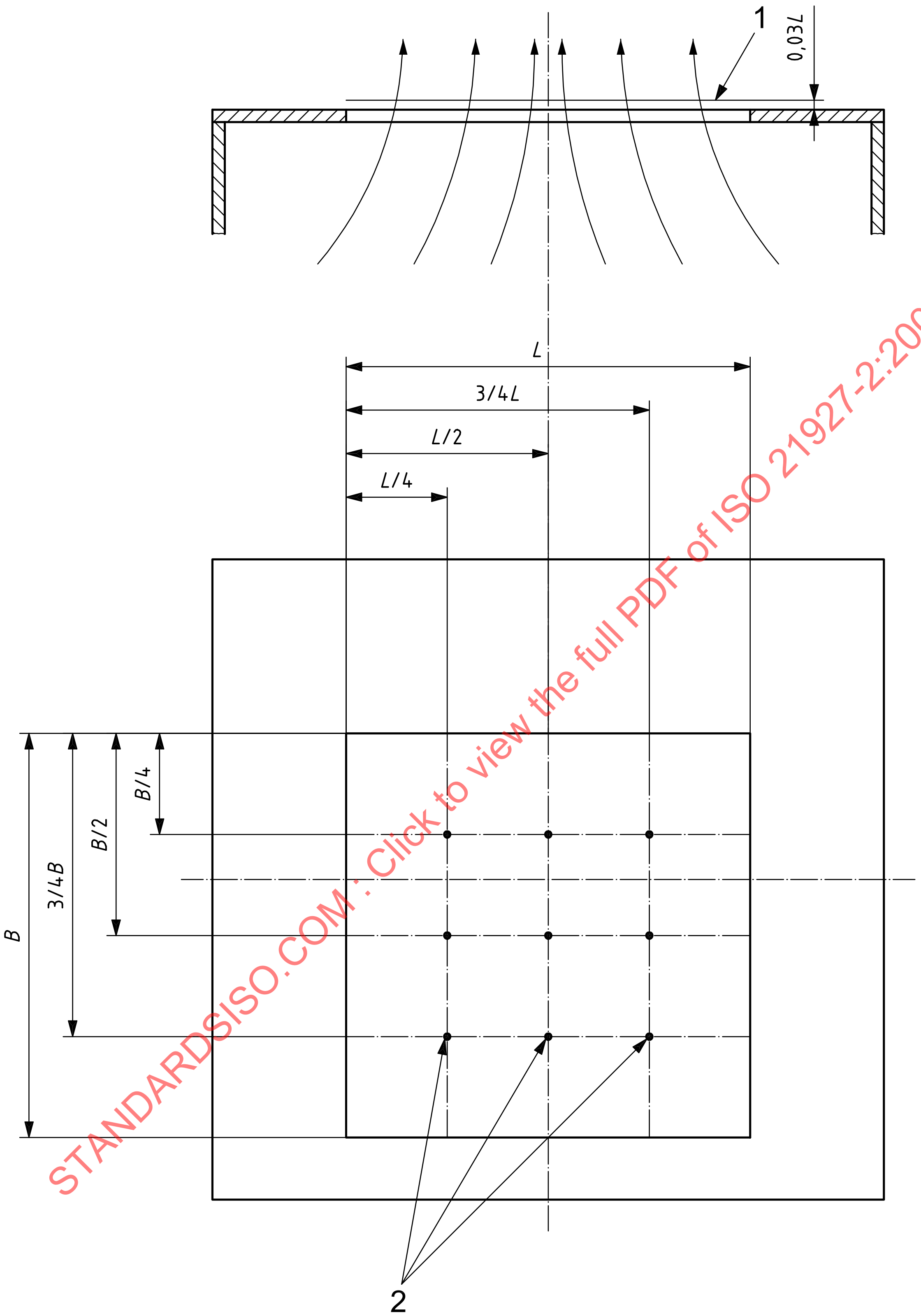
Key

1 plane of measurement

2 smoke vent

Figure B.6 — Measuring positions for the side-wind velocity at the entrance plane to the test section

(See Figure B.4)



Key

1 plane of measurement

2 measuring points to determine V_{sc}

Figure B.7 — Measuring positions for the flow velocity in the exit opening of the settling chamber

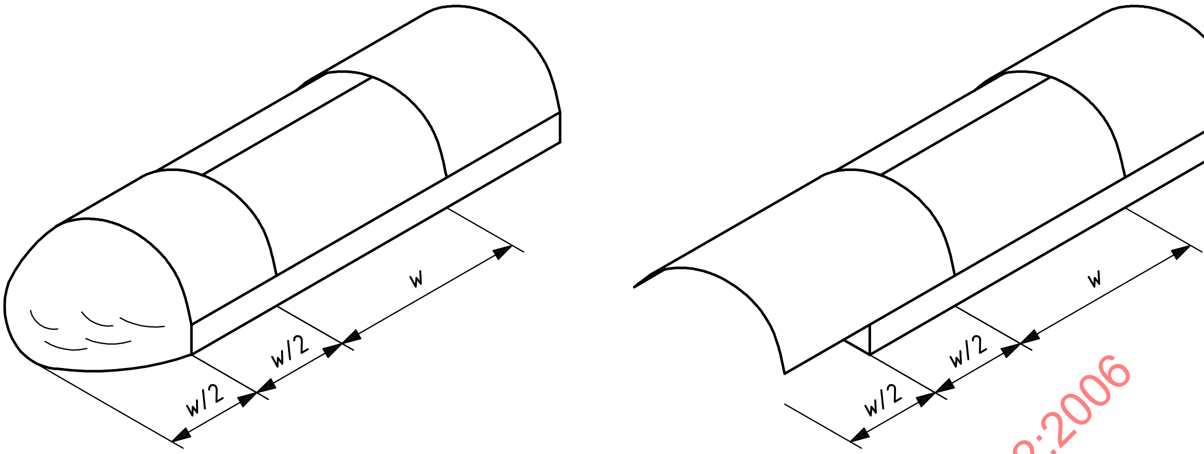


Figure B.8 — Aerodynamic boundary conditions and devices when testing SHEVs for use in continuous roof-lights

B.3 Assessment of the aerodynamic test facilities using reference tests

B.3.1 General

In order to check and validate each test installation, four reference tests shall be carried out.

B.3.2 Reference test without side wind

Dimensions in millimetres, unless otherwise indicated

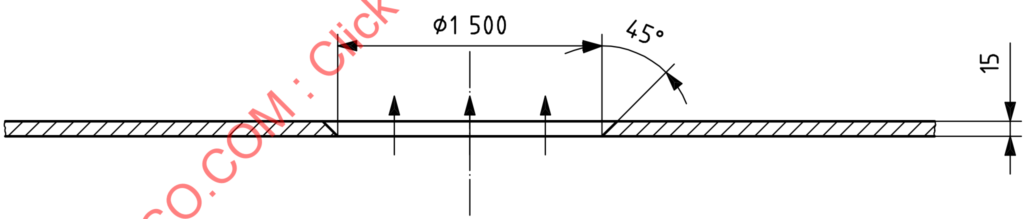


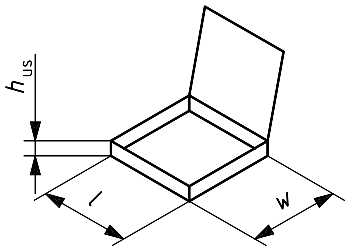
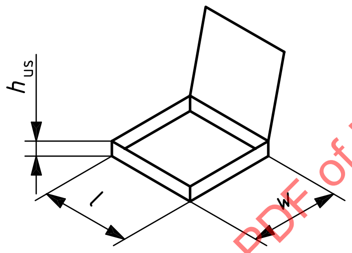
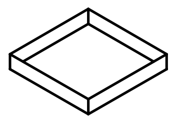
Figure B.9 — Reference test arrangement without side wind

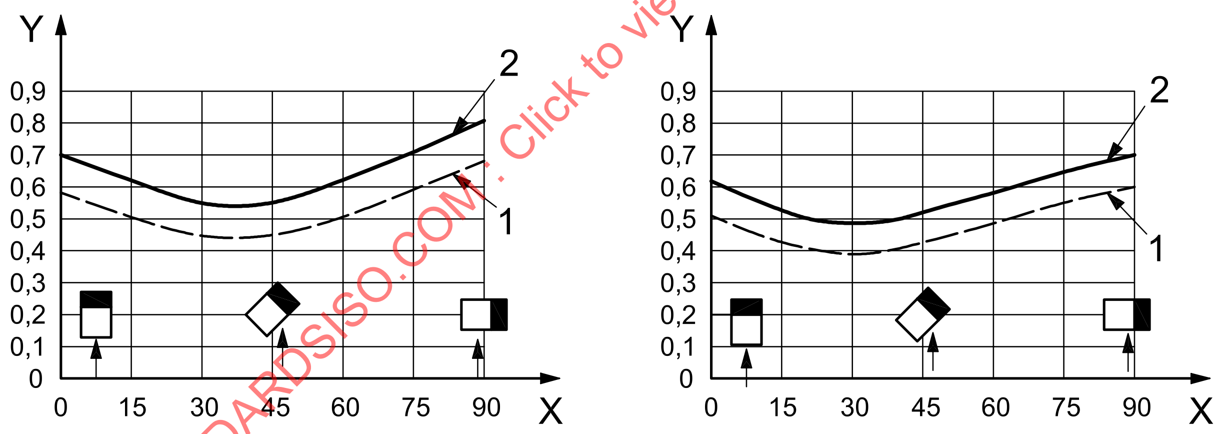
$C_{v0} = 0,6 \pm 0,01$ with following values for ΔP_{int} = 5 Pa, 10 Pa, 15 Pa and 20 Pa.

The test in this subclause shall be conducted before testing in accordance with B.2.4.

B.3.3 Reference tests with side wind

Table B.3 — Characteristics of the reference ventilators (full-scale size)

Parameters	Single flap SHEV A_v = 1,4 × 1,4	Single flap SHEV A_v = 1,8 × 1,8	Box-type SHEV without flap
Length, l, metres	1,4	1,8	1,4
Width, w, metres	1,4	1,8	1,4
Vertical upstand heigh, h_{us}, metres	0,32	0,32	0,32
Opening design	Single flat	Single flap	No flap
Opening angle	140°	140°	none
Diagram	 h_{us}, l, w	 h_{us}, l, w	



a) **Single flap SHEV** (A_v = 1,4 × 1,4 m^2)

b) **Single flap SHEV** (A_v = 1,8 × 1,8 m^2)

Key

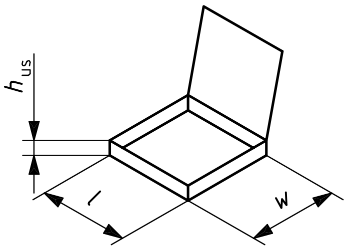
X wind incidence angle, expressed in degrees

Y discharge coefficient, C_v

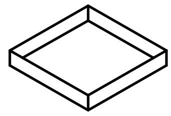
1 $C_{v,min.}$

2 $C_{v,max.}$

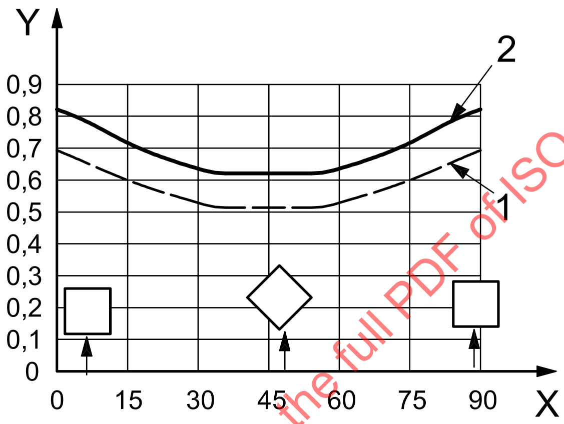
Figure B.10 — Discharge coefficients for test ventilators
(installation on the apparatus shown in Figures B.4 and B.5)



c) Single-flap SHEV



d) Box-type SHEV



e) Box-type SHEV: $A_v = 1{,}4 \times 1{,}4\ m^2$

Key

X wind incidence angle, expressed in degrees

Y discharge coefficient, C_v

1 $C_{v,min.}$

2 $C_{v,max.}$

Figure B.10 (*continued*)

The test shall be conducted once a year.

B.3.4 Evaluation of test results

The discharge coefficient for the four tests shall be determined according to the test procedure given in B.2.4. The discharge coefficients obtained shall be within the limits specified in B.3.1 and B.3.2.

Annex C
(normative)

Test method for reliability

C.1 Objective of test

The objective of this test is to determine the ability of the installed ventilator to open and close for the number of cycles specified in 8.1.1 and 8.1.3.

C.2 Test apparatus

The ventilator shall be mounted onto a test rig having an energy source to activate the opening and closing mechanism and a device to automatically count the number of cycles.

C.3 Test specimen

A test on the ventilator with the largest geometric area and a test on the ventilator with the largest side length (both achieving the objective of the test) may be considered representative of all ventilators in a particular range. (Where a ventilator has both the largest area and the largest side length, only one test is necessary.)

C.4 Test procedure

During the test, do not maintain, repair or replace any part involved in the opening or closing of the ventilator. Mount the specimen ventilator securely onto the test rig at the angle within the range of angles specified by the supplier and/or manufacturer that imposes the highest stresses on the ventilator during use. Do not apply any external load to the ventilator.

Using the ventilator's energy source, or using an external energy source to simulate the effect of the ventilator's energy source, open the ventilator to the fire-open position through the number of cycles according to the reliability classification in 8.1.1. Following this, open the ventilator to the fire-open position through three cycles using the ventilator's energy source. The fire-open position shall be reached in no more than 60 s.

If the ventilator is designed to be remotely opened and closed for on-site testing purposes, the ventilator shall be closed in the test remotely using the ventilator's closing mechanism during each cycle.

If the ventilator is a dual purpose ventilator, carry out 10 000 cycles to the normal comfort ventilation position prior to the above test.

If more than one energy source can be used, the most critical energy source shall be chosen for the test.

Report any maintenance, repair or replacement of any part not involved in the opening or closing. Such maintenance, repair or replacement shall not constitute a failure of the test.

Annex D
(normative)

Test method for opening under load

D.1 Objective of test

The objective of this test is to establish the ability of the ventilator to open and remain open against an applied wind or snow load.

D.2 Test apparatus

Use a test rig onto which the ventilator can be mounted and subjected to a test snow load applied by one of the following methods:

— plates (one or more per louver blade/flap when testing louver-type ventilators);

— bags containing up to 5 kg each of solid particles or liquid;

— for ventilators with pivoting flaps, both the test snow load and the wind load may be replaced by equivalent torque leading to the same torque/opening angle relation.

Spread the loads over the whole of the external surface of the individual elements of the opening parts of the ventilator to produce a uniformly distributed load equal to the appropriate load specified in 8.2.1.

For ventilators in which, under practical conditions involving wind, flaps are opened into the wind flow, carry out the test with a side wind having a speed of (10 ± 1) m/s taken over the projection area of the ventilator in addition to the test snow load, in the direction critical for opening, i.e. leading to the largest wind resistance against opening.

D.3 Test specimen

A test on the ventilator with the largest geometric area and a test on the ventilator with the largest side length (both achieving the objective of the test) may be considered representative of all ventilators in a particular range. (Where a ventilator has both the largest area and the largest side length, only one test is necessary.)

D.4 Test procedure

Mount the ventilator onto the test rig at the supplier's minimum recommended installation angle. Apply the appropriate load. Actuate the ventilator and check that it opens, reaches the fire-open position within 60 s and remains in position without an external energy supply, without damage, using the primary energy source. Reset the ventilator and repeat the actuation test a further two times, applying the same opening requirement.

Annex E
(normative)

Test method for low ambient temperature

E.1 Objective of test

The objective of this test is to establish the ability of the opening mechanism of the ventilator to operate at low ambient temperature.

E.2 Test apparatus

Use the test apparatus described in Clause D.2. The test apparatus shall be constructed to simulate the forces due to side wind, snow and the mass, of the ventilator parts affected, e.g. the mass of the flap upon the opening mechanism.

E.3 Test specimen

A test on the most critical ventilator tested according to Annex D may be considered representative of all ventilators in a particular range, for the purpose of the ambient temperature test.

E.4 Test procedure

E.4.1 General

A simplified test or a test with a complete ventilator shall be conducted.

E.4.2 Simplified test method

Mount the ventilator onto a test rig at the supplier's minimum recommended installation angle according to Annex D. The temperature shall be (25 ± 10) °C. Actuate the ventilator and measure the necessary force on the opening mechanism and the stroke of the opening mechanism. Measure the force on the opening mechanism with an accuracy of not more than 3 % of the maximum force. Measure the stroke of the opening mechanism with an accuracy of not more than 3 % of the maximum stroke. The temperatures measured in this test shall be measured with an accuracy of at least ± 1,5 °C. The time to be measured in this test shall be measured with an accuracy of at least ± 0,5 s.

Check for the correct relationship between the load and stroke, for the correct function of the opening mechanism and check that the evaluated correlation between load over stroke is not more than 80 % of the correlation between maximum allowed load over stroke given by the manufacturer of the opening mechanism.

Reduce the temperature of the temperature-sensitive parts of the opening mechanism (i. e. springs, energy source, all levers pushing or pulling the ventilator flaps, but not including the flaps) and the internal ventilator energy source to the appropriate value specified in 8.3.1.

Repeat this test three times and check for the correct relationship between the load and stroke of the opening mechanism and for the time necessary for the opening mechanism to reach the stroke position, which corresponds to the fire-open position of the ventilator.

If several energy sources are available, the most critical energy source shall be chosen for the test.

E.4.3 Test with complete ventilator

Mount the ventilator in a climatic chamber at the supplier's minimum recommended installation angle. Reduce the temperature in the climatic chamber to the appropriate value specified in 8.3.1. It shall be ensured that the deviation of the sample temperature during the performance of the test is not greater than $^{+2}_{-5}$ °C of the appropriate value specified in 8.3.1. Open the ventilator into its fire-open position using the ventilator's proposed energy source.

Annex F
(normative)

Test methods for wind load

F.1 Objective of test

The objectives of this test are to establish the integrity of the ventilator such that it remains closed under suction loads imposed by the wind but opens into its fire-open position after being subjected to the suction load.

F.2 Test apparatus

Use a test rig onto which the ventilator can be mounted and subjected to a uniformly distributed load applied by one of the following methods:

a) air pressure;

b) air pressure bags;

c) bags containing not more than 10 kg of solid particles or liquids.

F.3 Test specimen

A test on the ventilator with the largest geometric area and a test on the ventilator with the largest side length (both achieving the objective of the test) may be considered representative of all ventilators in a particular range. (Where a ventilator has both the largest area and the largest side length, only one test is necessary.)

F.4 Test procedure

F.4.1 Wind load

Mount the ventilator on the test rig in accordance with the supplier's and/or manufacturer's recommendations. Apply a load using one of the methods given in Clause F.2, increasing the load from zero to the appropriate upper limit specified in 8.4, and maintain this load for (10 ± 1) min. Remove the load.

On completion of the test, the ventilator, in its normal operating position, shall be opened without the applied load and remain in position without an external energy supply.

F.4.2 Vibration

The vibrational behaviour of wind deflectors with regards to wind-induced vibration shall be characterized by the structure's lowest natural frequency and the logarithmic decrement of damping of free oscillation. The natural frequency and the logarithmic decrement of damping can be determined, e.g. with an accelerometer fixed to the structural element.

The obtained acceleration-versus-time curve shall be evaluated to give the natural frequency and logarithmic decrement.

