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BSI Standards Publication

Ventilation for buildings — Air diffusion — Aerodynamic testing and rating for mixed flow application: non-isothermal procedure for cold jet

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National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Lüftung von Gebäuden - Luftverteilung - Aerodynamische Prüfung und Bewertung von Mischstromanwendungen: Nicht-isothermes Verfahren für einen Kaltluftstrahl

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Foreword

This document (EN 16445:2013) has been prepared by Technical Committee CEN/TC 156 “Ventilation for buildings”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2013, and conflicting national standards shall be withdrawn at the latest by August 2013.

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1 Scope

This European Standard specifies methods for the laboratory aerodynamic testing and rating of air terminal devices for mixed flow applications, including the specification of suitable test facilities and measurement techniques. This standard applies to laboratory testing of ATD for technical characterisation.

The standard gives only tests for the assessment of characteristics of the air terminal devices for mixed flow applications, under non-isothermal conditions with a cold jet. It does not cover the testing of isothermal or low velocity terminal devices which are covered by other published standards.

This European Standard applies to ventilation or air conditioning systems designed for the maintenance of comfort conditions for buildings. It is not applicable in the case of systems for the control of industrial or other special process environments. In the latter case however, it may be referred to if the system technology is similar to that of the above mentioned ventilation and air conditioning systems.

The principles described in this European Standard can also be used on site or in a lab for full-scale measurements.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable 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.

EN 12238, *Ventilation for buildings — Air terminal devices — Aerodynamic testing and rating for mixed flow application*

EN 12239, *Ventilation for buildings — Air terminal devices — Aerodynamic testing and rating for displacement flow applications*

EN 13182, *Ventilation for buildings — Instrumentation requirements for air velocity measurements in ventilated spaces*

3 Terms and definitions

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

3.1
supply air
air entering a supply air terminal device from an upstream duct

3.2
exhaust air
air leaving an exhaust air terminal device into a downstream duct

3.3
local measured mean air velocity
measured value of local airstream velocity as described in EN 12238

3.4
treated space
enclosure served by an air distribution system; in this standard this is the test room

3.5
envelope
geometrical surface in a treated space where the local measured air velocity has the same value and is the reference velocity (generally 0,5 m/s) associated with this envelope

3.6
throw (for a supply air terminal device)
maximum distance between the centre of the core and a plane which is tangent to a specified envelope, such as 0,25 $m.s^{-1}$, 0,5 $m.s^{-1}$, etc. and the centre of the ATD

3.7
drop (for a supply air terminal device)
vertical distance between the lowest horizontal plane tangent to a specified envelope, such as 0,25 $m.s^{-1}$, 0,5 $m.s^{-1}$, etc., and the centre of the ATD

3.8
rise (for a supply air terminal device)
vertical distance between the highest horizontal plane tangent to a specified envelope, such as 0,25 $m.s^{-1}$, 0,5 $m.s^{-1}$, etc., and the centre of the ATD

3.9
spread (for a supply air terminal device)
maximum distance between two vertical planes tangent to a specified envelope, such as 0,25 $m.s^{-1}$, 0,5 $m.s^{-1}$, etc., and perpendicular to a plane through the centre of the ATD

Note 1 to entry: There may be two different spreads, not always equal: One for the left side, the other for the right side (considered when looking at the treated space from the supply air terminal device).

3.10
distance to maximum spread
distance from the centre of the ATD to the maximum spread determined

3.11
separation distance
for cold jet with Coanda effect on ceiling, distance between the centre of the ATD and the point where the jet separates from the ceiling to drop

3.12
supply temperature
temperature of air in supply ATD

3.13
room air temperature
arithmetical average value of room air temperature measured in the occupied zone outside the envelope of the jet

3.14
temperature quotient
ratio of the local temperature difference at point x and at the point of discharge

$$\theta_Q = \Delta\theta_x / \Delta\theta_0$$

where

$\Delta\theta_0$ is the temperature difference between supply and room air

$\Delta\theta_x$ is the temperature difference between the point of maximum velocity in the distance x from the ATD and room air

3.15
free area
A_f
sum of the minimum measured areas at each opening in the ATD through which air can pass

3.16
effective area
A_k
effective area in the ATD measured as described in EN 12238

3.17
effective velocity
v_k
effective velocity in the ATD measured as described in EN 12238

4 Symbols (and abbreviated terms)

Symbol	Quantity	SI unit
h h_1 h_2…	Distances from ceiling at which measurements are made on vertical sections	m
Δp	Pressure difference (for a pressure difference device)	Pa
q_v	Volume rate of flow	$m^3.s^{-1}$
v	Velocity	$m.s^{-1}$
v_x	Maximum mean velocity at distance x from centre of supply air terminal device	$m.s^{-1}$
x	Distance from supply ATD along the centreline of the jet	m
x_s	Separation distance	m
X	Throw	m
Y	Spread	m
Z	Drop	m
θ_Q	Temperature quotient	
$\Delta\theta_0$	Temperature difference between supply and room air	K
$\Delta\theta_x$	Temperature difference between the point of maximum velocity in the distance x from the ATD and room air	K
ρ	Density of air	$kg.m^{-3}$
A_f	Free area of the ATD	m^2
A_k	Effective area of the ATD (k factor area)	m^2
A_d	Area corresponding to the cross section of the nominal size of the duct to which the device is fitted (neck area)	m^2
b_R	Test room width (Figure 1)	m
h_R	Test room height (Figure 1)	m
l_R	Test room length (Figure 1)	m
R	Area parameter that relates to the effective size of the ATD (see EN 12238)	m^2
S	Linear parameter that relates to the effective size of the ATD (see EN 12238)	m
v_k	Effective velocity in the ATD $\left(\frac{q_v}{A_k}\right)$	$m.s^{-1}$

5 Requirements

5.1 Instrumentation

5.1.1 Air flow rate measurement

The air flow rate shall be measured according to one of the standards quoted in Clause 2 with maximum uncertainty of $\pm$ 5 %.

5.1.2 Temperature measurements

Measurements of temperatures (in room and in jet) shall be made by means of resistance thermometers, thermocouples or other suitable instruments as long as they are calibrated with an accuracy better than ± 0,25 K. The objective is to achieve a global accuracy better than ± 0,5 K.

The measurement of temperature in jet may involve exploration in areas with gradients and this may place restrictions on the size of the sensing head. In addition, when temperature and velocity measurements are done together, the temperature sensor shall be as close as possible to the correct location in jet with a minimum perturbation of the velocity measurement.

A minimum measuring period of 60 s is recommended.

When temperature fluctuations with low frequency occur, this may be due to air stream major instability which can be determined by jet flow visualisation (e.g. using smoke). If this is the case, these results shall be reported. If the air stream appears stable, increase the measuring period to provide a stable temperature reading.

5.1.3 Velocity measurements

The measurements of low velocities within treated spaces to determine air terminal device performance characteristics shall be made with a measuring device in accordance with EN 13182.

5.2 Test room and conditions

The test room (size, walls, equipment…) shall be as described in EN 12238.

If heating elements are necessary, they shall be distributed uniformly over the floor area and covered by the floor. The surface temperature of the floor should not exceed the room air temperature by more than 4 K.

The temperature of all other walls shall not differ from the air temperature of the test room by more than 1 K unless there are special requirements associated with full scale/mock up testing (e.g. solar gain through a window).

In any case, the sum of all room heat loads shall be equal to the cooling capacity of supply air to match the steady state conditions described in 6.2.2.

Where high cooling performance is required (high $\Delta\theta_0$), it might not be possible to achieve this with heat loads only on the floor. If this is the case, point heat sources may be used and shall be equally distributed over the test room floor. The details and locations of such heat loads shall be reported

When used for mock-up testing, representation of actual specified heat loads shall be used.

5.3 ATD isothermal characteristics

Determination of the ATD isothermal characteristics shall be made according to EN 12238 including pressure drop, rise, drop, throw and spread.

6 Test to measure the non isothermal air discharge characteristics of a supply ATD

6.1 Installation of ATD

Terminal devices can be divided into four broad classes as described in EN 12238:

a) Class I Devices from which the jet is essentially three dimensional (e.g. conical):

   Class I.A nozzles;

   Class I.B grilles and registers;

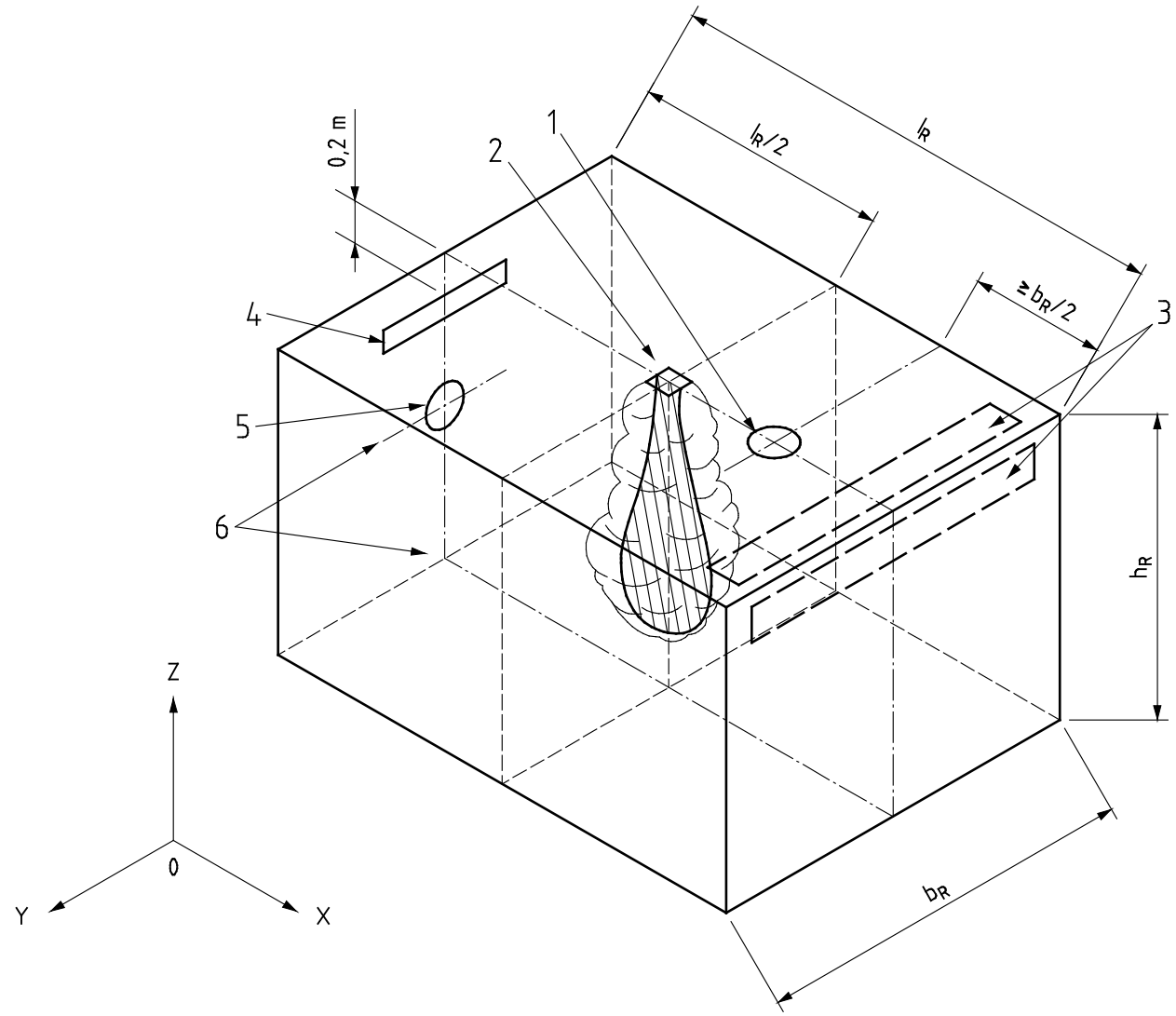
   Class I.C ceiling diffusers with vertical discharge.

b) Class II Devices from which the jet flows radially along a surface or as a free jet, ceiling diffusers.

c) Class III Devices from which the jet is essentially two dimensional; linear grilles, slots and linear diffusers.

d) Class IV Low velocity air terminal devices; not included in this standard (see EN 12239).

The air terminal device shall be installed (using the method recommended by the manufacturer) in the following positions (see Figure 1).



Key

1 Class II
2 Class I.C
3 Class III
4 Class I.B
5 Class I.A
6 Centrelines

Figure 1 — ATD position for test installation

Class IA devices (nozzles) shall be mounted in such a position as to provide the maximum throw with a minimum effect from adjacent boundaries, for example at the centre of one of the smaller test room walls.

Class IB devices (grilles and registers) shall be positioned on the centre line of one of the smaller walls of the test room with the inner upper surface of the ATD 0,2 m from the ceiling.

Class IC devices shall be mounted so that the centre of the test duct is no closer to any one wall than approximately half the width of the test room.

Class II devices (diffusers) shall be mounted flush with the mounting surface and in a position defined by:

a) diffusers of radial pattern such that the centre of the test duct is no closer to any one wall than approximately half the width of the test room;

b) diffusers of directional pattern shall be that as typically applied and installed in accordance with the manufacturer's recommendation.

Class III devices (linear) when tested as side wall ATDs shall be mounted as class IB devices. Slot ATDs shall be mounted as Class I or II, whichever is applicable. Artificial side walls shall be employed with ATDs that would normally span the distance between two walls. The minimum length of the ATD tested shall be equal to or greater than 1,2 m when artificial side walls are employed.

Diffusers producing other flow patterns shall be positioned as typically applied in accordance with the recommendations of the manufacturer.

In order to ensure stable flow conditions, it is recommended that the test duct be perpendicular to the surface in which the air terminal devices are mounted unless otherwise recommended by the manufacturer or for full scale/mock up test.

The highest flow rate for an ATD that may be utilised in a given room size shall be limited to the one for which the maximum air jet velocity does not exceed 0,5 $m.s^{-1}$ at a distance of 1,0 m from the boundary wall in the direction under investigation.

6.2 Test procedure for horizontal cold jet

6.2.1 Test conditions

The test can be carried out at any temperature difference between supply and exhaust if needed. However, the standard recommendation is:

— $\Delta\theta$ = 6 K $\pm$ 0,5 K for average difference;

— $\Delta\theta$ = 10 K $\pm$ 0,5 K for high difference.

Exhaust temperature which is representative of average room temperature shall be kept within a normal operation range for ventilated room (for example: no short circuiting between supply and exhaust air).

Care shall be taken in order to prevent condensation during the test. This also applies to full scale/mock up testing.

Air flow rates shall be determined by the manufacturer for the purpose of the test. For characterisation of ATDs, four airflows shall be regularly distributed over the working range for each ATD tested.

6.2.2 Preliminary conditions prior to formal measurement

Testing shall commence after steady state non-isothermal conditions have been achieved. Such conditions shall be considered to exist when the temperature difference measured by probes placed

a) in the supply duct, upstream of the air terminal device,

b) or at the centre of the exhaust terminal device,

do not vary more than $\pm$ 1 K for a period of 15 min prior to, and at any time during the test. In addition, each of the two temperatures shall not vary more than $\pm$ 1 K in the same period.

The temperature in the room shall be measured in at least four points in the occupied zone, outside the jet itself, and the average value shall be reported. All points shall be situated at 1,1 m height.

The average temperature in the room shall be close to the exhaust temperature in mixing conditions. If this is not the case, non-homogeneous conditions exist and shall be checked and reported.

The flow rate shall not vary by more than ± 2 % before and during the test.

Any velocity measurements made within the following distances from a wall towards which the air is flowing shall not be used for rating purposes:

— Class I: 1 m

— Class II: 0,5 m

— Class III: 1 m (without side walls); 0,5 m (with side walls)

6.2.3 Measurements

6.2.3.1 Determination of the main air stream direction

The air velocity measurements shall be carried out in the main air stream direction. This main air stream direction may be visually identified by use of smoke or any other means. See the example in Figure 2:

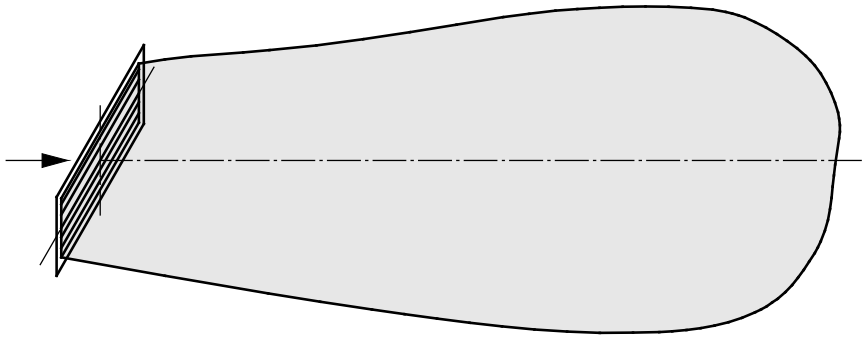
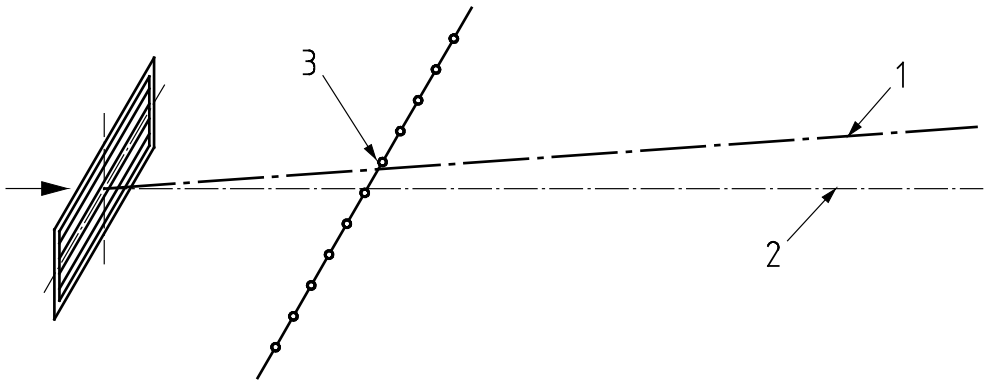


Figure 2— Use of smoke to identify the main air stream

If the main air stream direction cannot be identified by smoke, air velocity measurements shall be carried out in a horizontal line (or circle in case of radial discharge diffusers) perpendicular to the preliminary identified main air stream direction and at a distance from the ATD where the air velocity is within the range of 1,0 $m.s^{-1}$ to 1,5 $m.s^{-1}$ (see Figure 3). These measurements shall be carried out in approximately ten points located at 50 mm from the ceiling for ATD with wall effect or at the same level as the centreline of the ATD without wall effect, on both sides of the supposed main air stream direction with a maximum spacing of 50 mm.



Key

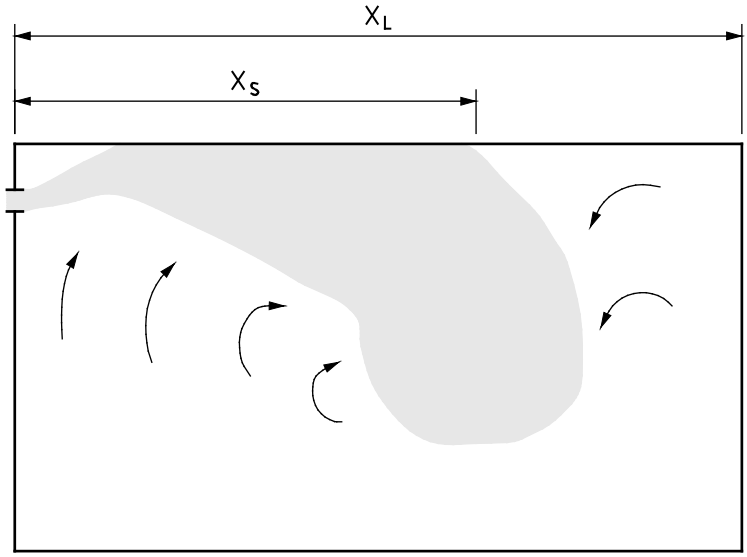
1 supposed main air stream direction
2 measured main air stream direction
3 1,0 $m.s^{-1}$ < v < 1,5 $m.s^{-1}$.

Figure 3 — Use of velocity measurements to identify the main air stream direction in a horizontal line.

The line from the middle of the ATD to the point of maximum measured velocity is the main air stream direction.

6.2.3.2 Determination of separation distance (x_s)

For cold jet along ceiling (Coanda effect), determine the separation distance (see Figure 4). This distance is to be measured in the main direction of the jet.



Key

x_L room length
x_s separation distance

Figure 4 — Separation distance x_s

Separation distance can only be determined by a smoke test or any appropriate way of visualisation (i.e. laser visualisation…). The visualised distance may vary during the test. With the smoke test, a minimum of three

visualisations shall be done (or a total time of 5 min for other means of visualisation). Average x_s value as well as minimum and maximum shall be reported.

NOTE If the x_s value varies a lot, this indicates an unstable situation that may be due to unsteady test conditions (check 6.2.2), or to other specific conditions in case of full scale/mock up testing.

6.2.3.3 Measurement of air stream velocities and temperatures

The procedures described below can be used for the following situations:

a) jet in free space;

b) jet with ceiling and/or wall effect;

c) jet with ceiling effect which then detaches as in 6.2.3.2 above or due to any obstacle or collision with a jet from another diffuser (mock up testing).

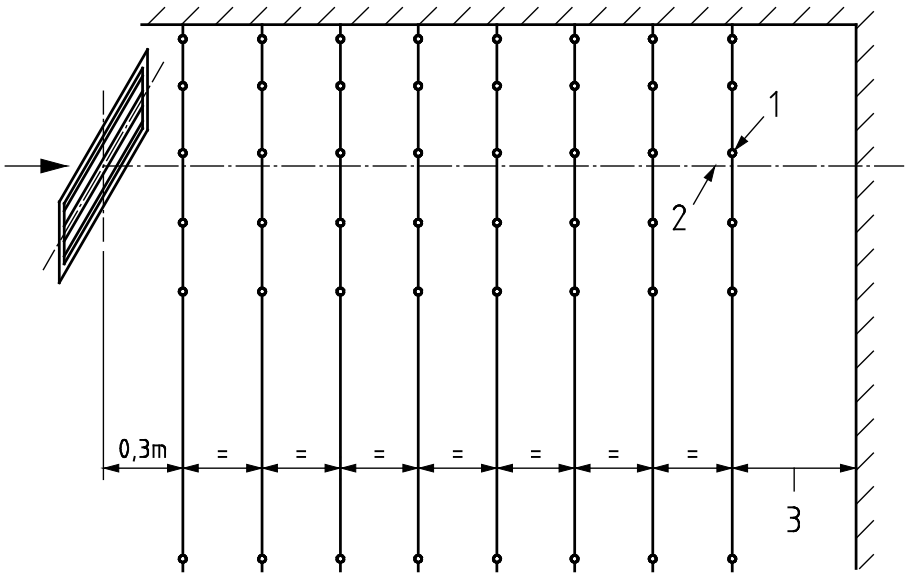
The throw and drop shall be measured in the main air stream direction. First of all, a quick air velocity measurement has to be carried out to determine the distance from the ATD where the velocity is about 0,2m.s^{-1}. This point has to be at least 0,5 m or 1,0 m (depending on the class of ATD, see 6.2.2) in distance from the opposite wall.

If during visualisation, it has been noted that the jet continues attached to the opposite wall, or if multiple diffusers are used which results in air penetrating downwards away from walls then measurements shall be continued in this part down to the velocity range defined below.

Temperatures shall be measured at the same points as velocities.

If the jet temperature differential and momentum in the jet is such that the ceiling effect breaks down, the distance at which ceiling effect discharge characteristics occur is determined (see 6.2.3.2 above). Even though the measurement of velocity is outside the scope of this standard, in practice the same principles of measurement can be adopted.

Air velocity measurements shall be carried out in at least eight equally spaced points. The first measurement position has to be located 0,3 m from the ATD, and the last measurement position has to be the position where the velocity is in the range of 0,2 m.s^{-1} to 0,3 m.s^{-1} (see Figure 5).



Key

1 $v \approx 0{,}5\ m.s^{-1}$
2 measured main air stream direction
3 L > 1 m or L > 0,5 m (see 6.2.2)

Figure 5 — Measurement of air stream velocities in a number of vertical lines to determine throw and drop

At each distance, measurements shall be made at a vertical line through the point of maximum velocity and perpendicular to the main air stream direction. A survey shall be made at a number of points at each side of the main air stream direction so as to be able to determine the points were the velocity equals $0{,}25\ m.s^{-1}$. Through these points, a vertical section of the envelope (isovel) can be determined by plotting the point. See Figures 6 to 9.

NOTE If necessary, spread can be determined and reported as described in EN 12238.

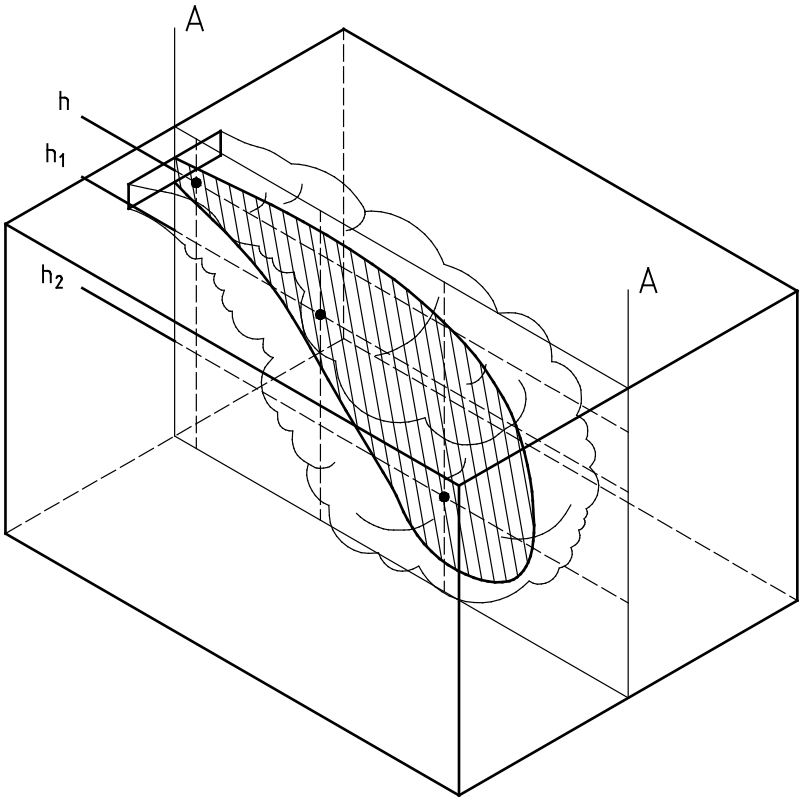
At each position, measurements shall be carried out at different levels in a vertical plane, in order to determinate the throw and the drop.

For ATD with ceiling effects (Figure 6): 25 mm, 75 mm, 150 mm, 225 mm, 300 mm from the ceiling and down to the occupied zone with steps of 300 mm.

For ATD with free jet (Figure 7): same procedure but up and down from the centerline. Sensors should be placed in the expected envelope of the jet with sufficient vertical positions to determine correctly the maximum velocity in the jet.

For ATD with wall and ceiling effects (Figure 8): 25 mm, 75 mm, 150 mm, 225 mm, 300 mm from the ceiling and down to the occupied zone with steps of 300 mm.

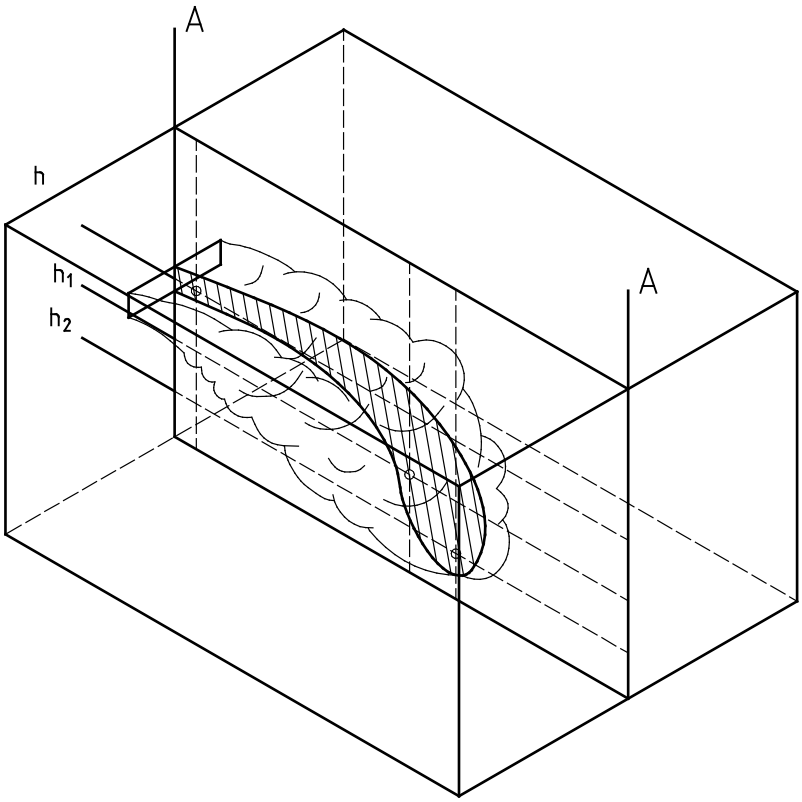
For ATD with ceiling effects which collision with a jet from another diffuser (Figure 9): 25 mm, 75 mm, 150 mm, 225 mm, 300 mm from the ceiling until the point of collision with the other jet and down to the occupied zone with steps of 300 mm.



Key

AA measurement plane

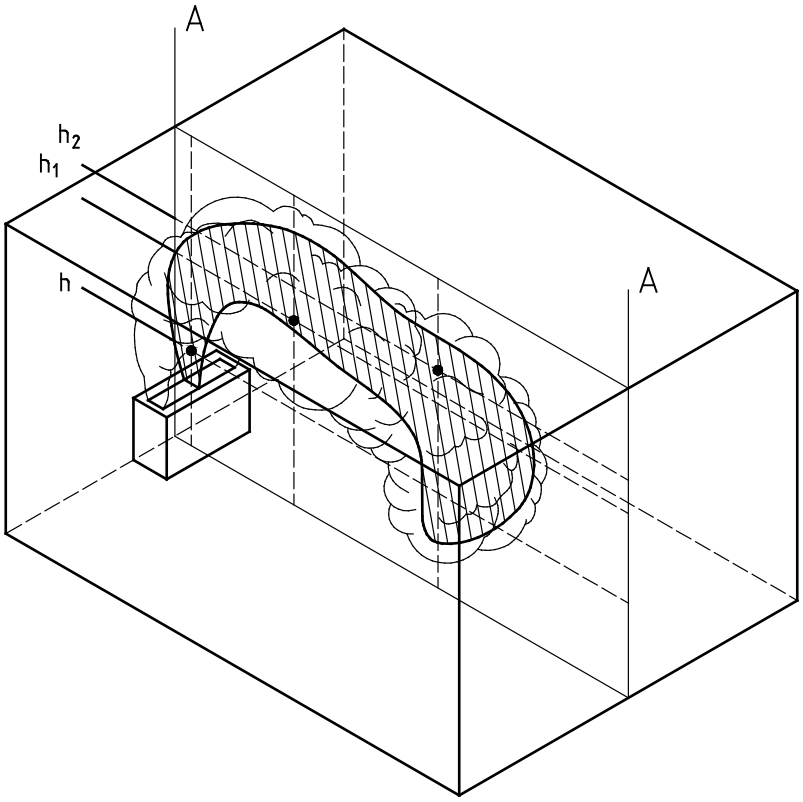
Figure 6 — Jet with ceiling attachment



Key

AA measurement plane

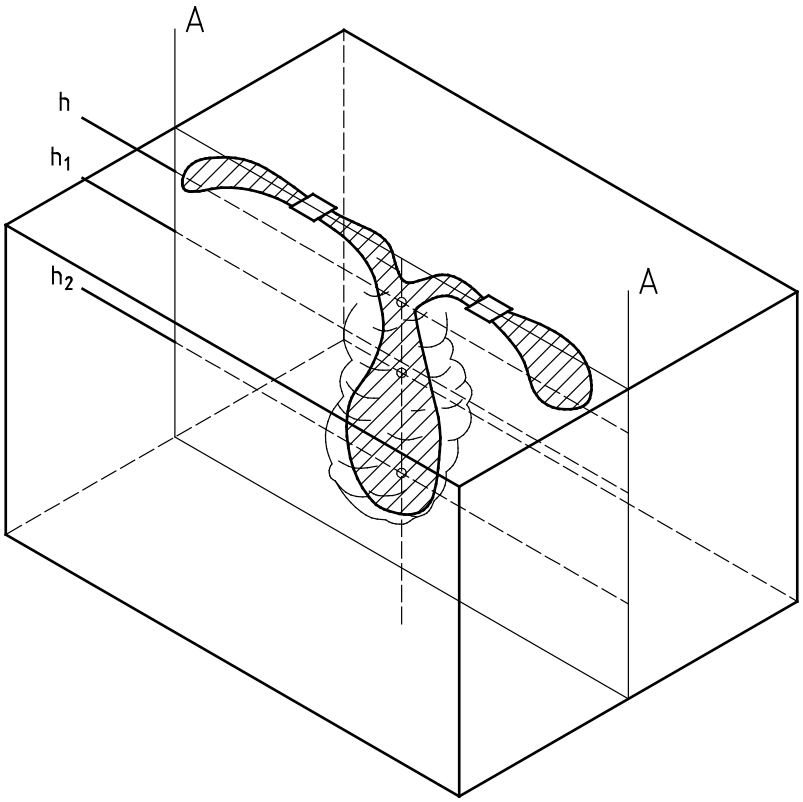
Figure 7 — Free jet



Key

AA measurement plane

Figure 8 — Discharge with wall and ceiling effect



Key

AA measurement plane

Figure 9 — Ceiling effect which collision with another jet

6.2.3.4 Determination of throw

Draw a graph of the results of the maximum air velocity measurements at various distances from the air terminal device, for each test conducted in accordance with 6.2.3.3, on logarithmic axes in the form:

$$\frac{R}{q_v} * v_x \text{ against } \frac{x}{S}$$

NOTE The most appropriate value of *R* is likely to be the minimum area through which the air passes within the air terminal device, but as this is rarely a measurable parameter, the following values are commonly used:

Class IA and IB: $R = A_f$ (free area) $S = \sqrt{A_f}$

Class IC: $R = A_d$ (neck area) $S = \sqrt{A_d}$

Class II: $R = A_d$ (neck area) $S = \sqrt{A_d}$

Class III: $R = A_f$ (free area) $S = A_f / n$

where

n is the length of the air terminal device.

If tests have been conducted on a series of modularly similar air terminal devices, superimpose the results for each device on the same graph.

Draw a single curve to the average values of the points plotted. If the plotted points fall within a band ± 0,2 x/S about this curve, then it can be used as the basis for presenting throw performance data for the range of sizes tested.

In order to perform the throw, a tangent to the average curve shall be drawn with a slope of:

— 1 for Class I and II devices;

— 0,5 for Class III devices.

See an example in Figure 11.

If the plotted points do not fall within the tolerance band stated ± 0,2 x/S, derive separately, for each size of the device tested, the performance data for presentation from the average curve through the individual set of plotted points for that size. Under these circumstances, no interpolation or extrapolation to other device sizes shall be made.

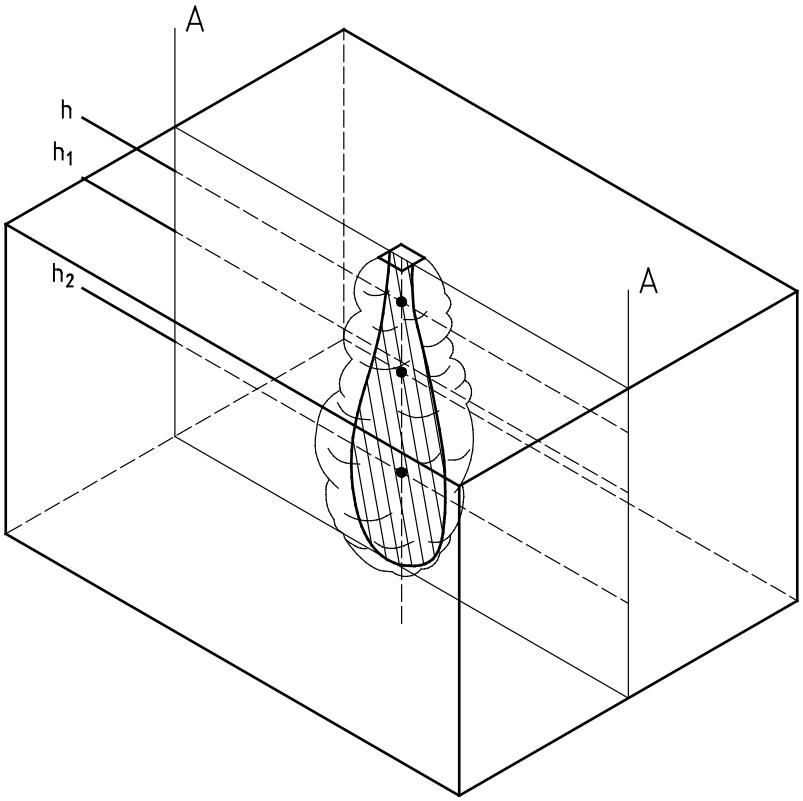
The throw X for a given airflow rate can be based on any appropriate velocity v_x. The v_x selected shall be referenced in the recorded data.

6.2.3.5 Determination of spread

From the measurements made in the horizontal plane, the maximum distance between the tangents to the 0,5 $m.s^{-1}$ envelope at each side of the main air stream direction can be determined. This distance is the spread. The ratio between the throw at 0,5 $m.s^{-1}$ and this spread shall be used to determine the spread for extrapolation to other geometrically similar devices or other airflow rates.

6.2.3.6 Measurement for vertical cold jet

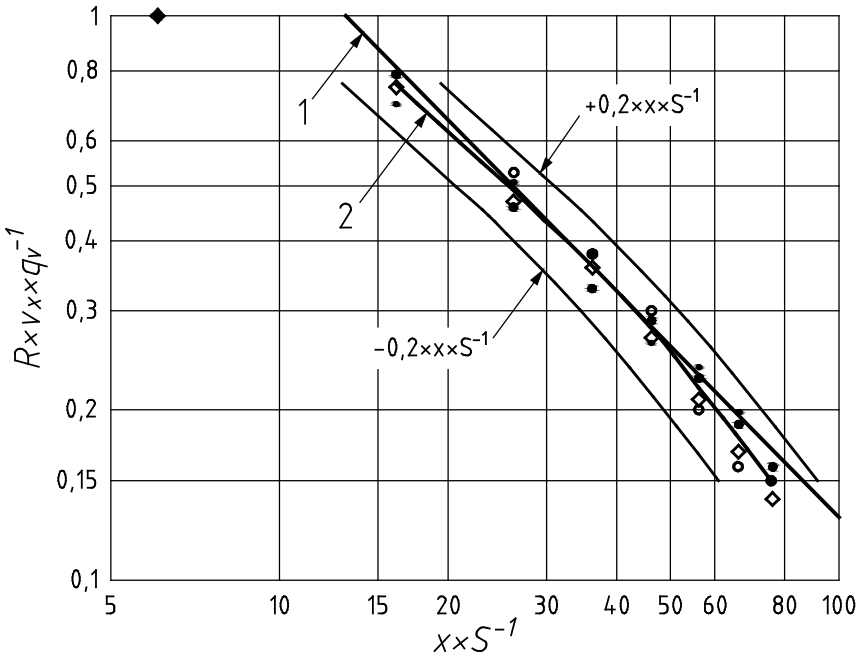
The same procedure applies as for horizontal (see 6.2) but vertical plane in measurements are changed to horizontal and vice versa (see Figure 10). For the attached jet, the distance from ceiling is changed to distance from wall.



Key

AA measurement plane

Figure 10 — Vertical discharge



Key

1 tangent to the average curve

2 single curve of average values

Figure 11 — Typical plot used in the determination of throw

7 Report

7.1 Test conditions

— Airflow rate and tolerance.

— Average supply temperature as well as minimum and maximum during test periods.

— Average exhaust temperature as well as minimum and maximum during test periods.

— Average room temperature as well as minimum and maximum during test periods.

7.2 Results

— Report description of the main axis of the jet.

— Report the average separation distance for each test conditions tested, (minimum-maximum for Coanda effect only).

— Show the logarithmic plots of the values of $R^*v_x^*q_v^{-1}$ versus x^*S^{-1} typically as in Figure 11.

— Report the temperature in the jet. This shall be presented in a chart with the temperature quotient as function of the distance from ATD. The temperature quotient $\Delta\theta_x/\Delta\theta_0$ shall be plotted in logarithmic scale against the distance x as shown in Figure 12 for each effective area (A_k) or free area (A_f):

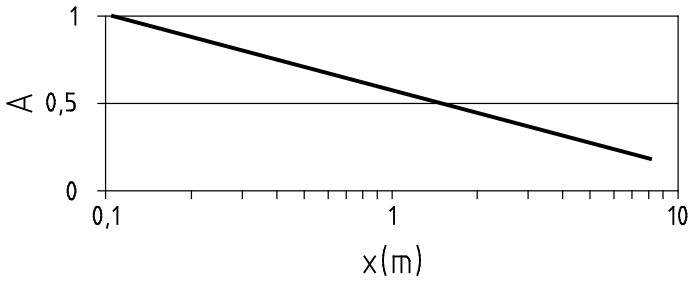


Figure 12 — Example of temperature quotient curve for a given Ak

— Report spread and distance to maximum spread.

— Report the drop and rise: Note the maximum vertical upward and downward distances between the envelope and note, as the rise and drop respectively, a line perpendicular to the face of the air terminal device through its centre (see Figures 6 and 7).

Bibliography

[1] EN 12792, *Ventilation for buildings — Symbols and terminology*

[2] ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*

[3] ISO 5167-2, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 2: Oriface plates*

[4] ISO 5167-3, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 3: Nozzles and Venturi nozzles*

[5] ISO 5167-4, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 4: Venturi tubes*

[6] ISO 7726, *Ergonomics of the thermal environment — Instruments for measuring physical quantities*

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