SLOVENSKI STANDARD
SIST EN 16211:2025

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Nadomešča:
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Prezračevanje stavb - Meritve pretoka zraka v sistemu prezračevanja - Metode

Ventilation for buildings - Measurement of air flow rates on site - Methods

Lüftung von Gebäuden - Luftvolumenstrommessung vor Ort - Verfahren

Ventilation des bâtiments - Mesurages des débits d'air sur site - Méthodes

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ICS:

91.140.30	Prezračevalni in klimatski sistemi	Ventilation and air-conditioning systems

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Ventilation for buildings - Measurement of air flow rates on site - Methods

Ventilation des bâtiments - Mesurages des débits d'air sur site - Méthodes

Lüftung von Gebäuden - Luftvolumenstrommessung in Lüftungssystemen - Verfahren

This European Standard was approved by CEN on 30 September 2024.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (EN 16211:2024) 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of an identical text or by endorsement, at the latest by May 2025, and conflicting national standards shall be withdrawn at the latest by May 2025.

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

This document supersedes EN 16211:2015.

In addition to a number of editorial revisions, the main changes compared with EN 16211:2015 are as follows:

— the whole document has been rearranged;

— the method described previously in EN 12599:2012 to measure air (volume) flow rate in ductwork has been included;

— the tracer gas method has been moved in Annex A (informative);

— two new methods to measure air flow rate at exhaust and intake grille have been added in Annex A (informative);

— parts dealing with uncertainty have been replaced by Annex B (informative);

— requirements on measuring devices are now expressed in MPME (maximum permissible measurement error).

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

Introduction

Measurement of the air (volume) flow rate in a ventilation system is of general interest that is not related to a specific operation or stage (e.g. installation, inspection, commissioning or handover). It was therefore agreed to take advantage of the simultaneous revision of EN 16211:2015 and EN 12599:2012 to address this subject in a single document (EN 16211:2024) rather than scattering or repeating it in various documents.

In this document, all types of measurements are air (volume) flow rate. For the sake of readability, the term "air (volume) flow rate" is replaced in the text by the contracted term "air flow rate".

1 Scope

This document specifies methods for the measurement of air flow rates on site. It provides a description of the air flow rate measurement methods and how measurements are performed within the margins of stipulated method uncertainties. It gives the necessary measurement conditions (e.g. length of straight duct, uniform velocity profile) to achieve the stipulated measurement uncertainties.

The methods for measuring the air flow rate inside ducts do not apply to:

— ducts that are not circular or rectangular (e.g. oblong ducts);

— flexible ducts.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

EN 12792, *Ventilation for buildings — Symbols, terminology and graphical symbols*

EN 14277, *Ventilation for buildings — Air terminal devices — Method for airflow measurement by calibrated sensors in or close to ATD/plenum boxes*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12792 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp/

3.1
measuring interval
set of values of quantities of the same kind that can be measured by a given measuring instrument or measuring system with specified instrumental measurement uncertainty, under defined conditions

Note 1 to entry: In some fields, the term is “measuring range” or “measurement range”.

[SOURCE: JCGM 200:2012, 4.7, modified – Note 2 has not been reproduced.]

3.2
maximum permissible measurement error
extreme value of measurement error, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument or measuring system

Note 1 to entry: More information on the calculation of the measurement uncertainty based on the maximum permissible measurement error is given in Annex B.

[SOURCE: JCGM 200:2012, 4.26, modified – The accepted terms “maximum permissible error” and “limit of error” have been removed, NOTE 1 and NOTE 2 have been removed, a Note 1 to entry has been added.]

3.3
standard uncertainty
measurement uncertainty expressed as a standard deviation

Note 1 to entry: More information on the use of standard uncertainty in measurement uncertainty is given in Annex B.

[SOURCE: JCGM 200:2012, 2.30, modified – The preferred term and the first accepted term have been removed and a Note 1 to entry has been added.]

3.4
calibration
operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

[SOURCE: JCGM 200:2012, 2.39, modified — NOTE 1 and NOTE 2 have been removed.]

3.5
correction
compensation for an estimated systematic effect

[SOURCE: JCGM 200:2012, 2.53, modified — NOTE 1 and NOTE 2 have been removed.]

3.6
hypothetical
<value> obtained by making hypothesis on the existing conditions

3.7
dynamic pressure
velocity pressure
pressure equivalent of the kinetic energy of the fluid at a point

3.8
static pressure
pressure exerted, in a moving fluid, on an element moving at the same velocity as the fluid

3.9
total pressure
sum of *static pressure* (3.8) and *dynamic pressure* (3.7) at any point of a fluid

4 Symbols and abbreviated terms

For the purposes of this document, the symbols given in Table 1 and the abbreviated terms given in Table 2 apply.

Table 1 — Symbols

Symbol	Description	Unit
a, *b*, *c*, *d*, *e*, *f*	Dimensions of length	mm
a/D_h	Relative distance	—
A	Cross-section area	m^2, mm^2
A_g	Effective cross-section area of the probe	m^2, mm^2
C_i	Initial tracer gas concentration	cm^3/m^3
C_s	Tracer gas concentration in the sampling cross-section	cm^3/m^3
D	Diameter	mm
D_h	Hydraulic diameter	mm
D_i	Diameter of the centroidal ring of the annulus	mm
D_{so}	Probe diameter	mm
e	Device’s flow exponent given by the manufacturer (usually 0,5)	—
H	Height of the duct	mm
i	Ordinal number	—
I	Irregularity of the velocity profile	%
k *(k-factor)*	Characteristic of the fixed device depending on its setting	—
K	Coverage factor	—
K	Correction factor (for method IN2 and EX2)	—
k_1	Correction factor for density	—
k_2	Correction factor for duct shape	—
L	Length of head of the pitot static tube	mm
L	Mixing length for the tracer gas	mm
L_1	Smaller dimension of a rectangular duct cross section	mm
L_2	Larger dimension of a rectangular duct cross section	mm
n	Number	—
n_{L1}	Number of measuring points along the smaller dimension	—
n_{L2}	Number of measuring points along the larger dimension	—
p_{atm}	Atmospheric pressure	Pa
$p_{atm,act}$	Atmospheric pressure in actual conditions	Pa
$p_{atm,hyp}$	Atmospheric pressure in device hypothetical condition	Pa
$p_{atm,std}$	Atmospheric pressure in standardized conditions (101 325 Pa)	Pa
p_d	Dynamic pressure	Pa
p_s	Static pressure	Pa

Symbol	Description	Unit
p_t	Total pressure	Pa
P	Perimeter of the cross-section	m, mm
q	Air flow rate	m³/s, m³/h, l/s
q_s	Tracer gas flow rate	m³/s, m³/h, l/s
$q_{s\vartheta duct}$	Tracer gas flow rate at duct temperature	m³/s, m³/h, l/s
$q_{s\vartheta tracer}$	Tracer gas flow rate at rotameter temperature	m³/s, m³/h, l/s
$q_{v,act}$	Actual air flow rate (in actual conditions)	m³/s, m³/h, l/s
$q_{v,hyp}$	Hypothetical air flow rate assuming device default conditions	m³/s, m³/h, l/s
$q_{v,m}$	Measured air flow rate	m³/s, m³/h, l/s
$q_{v,std}$	Standardized air flow rate (in standard conditions)	m³/s, m³/h, l/s
t	Time	s
T_{act}	Air temperature in actual conditions	K
T_{hyp}	Air temperature in device default condition	K
T_{std}	Air temperature in standardized conditions (293,15 K)	K
u	Standard uncertainty	—
u_c	Combined standard uncertainty	—
U	Expanded uncertainty	—
v	Air velocity	m/s
v_{act}	Actual air velocity	m/s
v_g	Air velocity reading	m/s
v_k	Air velocity for measuring point k	m/s
v_m	Average air velocity	m/s
v_{max}	Maximum of the arithmetic mean of velocities in a quarter of the cross-section or at a radius	m/s
v_{min}	Minimum of the arithmetic mean of velocities in a quarter of the cross-section or at a radius	m/s
v_q	Air velocity for a given quarter	m/s
v_r	Air velocity for a given radius	m/s
V	Volume of the measuring bag	m³
W	Width of the duct	mm
x_i	Distance from the duct wall	mm
y_i	Distance from the duct wall	mm
Δl	Tolerance for the probe location	mm
Δp	Measured pressure difference	Pa
θ_{act}	Air temperature in actual conditions (= T_{act} − 273,15)	°C

Symbol	Description	Unit
ρ	Air density	kg/m³
ρ_{act}	Air density in actual conditions	kg/m³
ρ_{hyp}	Air density in device default condition	kg/m³
ρ_{std}	Air density in standardized conditions	kg/m³
$\rho_{\vartheta duct}$	Air density at the temperature inside the duct	kg/m³
$\rho_{\vartheta tracer}$	Air density at the temperature of tracer gas	kg/m³
ϑ	Temperature of air	°C
ϑ_{duct}	Temperature inside the duct	°C
ϑ_{tracer}	Temperature of tracer gas	°C

Table 2 — Abbreviated terms

Abreviated terms	Description
ATD	Air terminal devices
MPME	Maximum permissible measurement error
RH	Relative humidity of the air

5 Expression of air flow rate and parameters of influence

5.1 Hydraulic diameter

The hydraulic diameter, D_h, is the diameter of a circular duct which causes the same pressure drop, at equal air velocity and equal roughness factor, than the considered duct and is defined by Formula (1).

$$D_h = 4 \cdot \frac{A}{P} \tag{1}$$

where

A is the area of the cross-section, in mm²;

P is the perimeter of the cross-section, in mm.

For a rectangular duct, Formula (1) becomes Formula (2).

$$D_h = 2 \cdot \frac{L_1 \cdot L_2}{\left(L_1 + L_2\right)} \tag{2}$$

where

L_1 is the smaller dimension of the rectangular duct, in mm;

L_2 is the larger dimension of the rectangular duct, in mm.

For a circular duct, Formula (1) becomes Formula (3).

$$D_h = D \quad (3)$$

5.2 Flow disturbances

Within an air flow, disturbances result in irregular velocity profiles. Irregular velocity profile can induce additional measurement errors and complicate the measurement. Away from any disturbance the velocity profile gets more and more regular. For some methods, requirements are set regarding the position of the measurement device from flow disturbances.

NOTE Flow seldom has a symmetrical appearance except after long straight sections. The symmetry is often disturbed by varying resistance, for example after a bend, an area decrease or an area increase. The velocity profile also becomes disturbed by singularities such as damper and branch as well as before and after a fan.

5.3 Stability of the air flow rate

Measurement methods described in this document are based on the assumption that the air flow rate does not change during the measurement time.

NOTE Variation of the air flow rate increases the measurement uncertainty.

5.4 Air density

The density of dry air, ρ, varies with atmospheric pressure and temperature in accordance with Formula (4).

$$\rho = 1{,}293 \cdot \frac{p_{atm}}{101\ 325} \cdot \frac{273{,}15}{273{,}15 + \vartheta} \quad (4)$$

where

p_{atm} is the atmospheric pressure, in Pa;

ϑ is the temperature of the air, in °C.

The relative humidity of the air (RH) has very little influence on the density of air at room temperature. The density of air at 20 °C and 101 325 Pa which is saturated with water vapour is only approximately 1 % less than equivalent dry air.

If the static pressure of the ventilation system is above about 2 000 Pa, the influence of the static pressure on air density should be considered and the calculation is then performed using Formula (5).

$$\rho = 1{,}293 \cdot \frac{p_{atm} + p_s}{101\ 325} \cdot \frac{273{,}15}{273{,}15 + \vartheta} \quad (5)$$

where

p_s is the static pressure in the ductwork, in Pa.

5.5 Conversion of dynamic pressure into air velocity

Dynamic pressure within an air flow can be measured with a Pitot static tube connected to a manometer (see Figure 1 in 6.4.3).

Air velocity can be calculated from dynamic pressure using Formula (6).

$$v_{act} = \sqrt{\frac{2p_d}{\rho_{act}}} \quad (6)$$

where

v_{act} is the actual air velocity (in prevailing conditions);

p_d is the dynamic pressure;

ρ_{act} is the air density (in prevailing conditions).

5.6 Correction and conversion of measured air flow rate

5.6.1 General

By nature, air flow rate measurements on site are done in actual conditions (i.e. conditions existing in a particular place and at a particular time).

The actual conditions refer to the place where measurements are made. For measurements in ducts, atmospheric pressure may be measured outside the duct for practical reasons. In this case, the static pressure in the duct should be added to the atmospheric pressure for calculation purpose. When the static pressure in the duct is below 2 000 Pa in absolute value it may be neglected.

However, depending on their settings, some measuring systems may:

— give uncorrected air flow rate, $q_{v,hyp}$, by making the hypothesis that the air is at the device default condition (e.g. 1,204 kg/m³ corresponding to 293,15 K and 101 325 Pa). This hypothetical air flow rate is neither the actual air flow rate nor the standardized air flow rate and corrections given in 5.6.2 shall be done;

— automatically calculate or convert quantity values into different than actual conditions (e.g. standard conditions). In this case, conversion to actual conditions, as given in 5.6.3, shall be done.

In any case, the technical data sheet should be consulted to find out to which conditions (actual, standard, etc.) the indicated quantity values correspond and how to correct or convert them into actual conditions.

5.6.2 Correction of the air flow rate

The formula to convert hypothetical air flow rate into actual air flow rate (air flow rate occurring in actual conditions) depends on the measuring device used.

To obtain the actual air flow rate, the user shall refer to manufacturer specifications to determine whether:

— the correction is done automatically, in this case no further corrections shall be done, the read value is equal to the actual value; or

— the correction shall be done by the user.

If formulae to perform the correction are available in the manufacturer specifications they should be used.

If the correction is not done automatically and no correction’s formula is available on manufacturer specifications the following corrections should be used:

— When the air flow rate varies with the inverse of the square root of the air density (e.g. for Pitot static tubes or fixed measuring device with exponent (reference of the measurement method ID3X)), Formula (7) shall be used.

$$q_{v,act} = q_{v,hyp} \cdot \sqrt{\frac{\rho_{hyp}}{\rho_{act}}} = q_{v,hyp} \sqrt{\left(\frac{p_{atm,hyp}}{p_{atm,act}}\right)\left(\frac{T_{act}}{T_{hyp}}\right)} = q_{v,hyp} \sqrt{\left(\frac{p_{atm,hyp}}{p_{atm,act}}\right)\left(\frac{\theta_{act} + 273,15}{T_{hyp}}\right)} \qquad (7)$$