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

Lüftung von Gebäuden - Luftvolumenstrommessung vor Ort - Verfahren

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COMITÉ EUROPÉEN DE NORMALISATION
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Contents

Page

European foreword ... 4
Introduction ... 5
1 Scope ... 6
2 Normative references ... 6
3 Terms and definitions ... 6
4 Symbols and abbreviated terms ... 8
5 Expression of air flow rate ... 10
5.1 Hydraulic diameter ... 10
5.2 Flow disturbances ... 11
5.3 Stability of the flow rate ... 11
5.4 Air density ... 11
5.5 Conversion of dynamic pressure into air velocity ... 12
5.6 Correction and conversion of measured air flow rate ... 12
5.6.1 General ... 12
5.6.2 Correction of the air flow rate ... 13
5.6.3 Conversion of the air flow rate ... 14
6 Measuring instruments requirements ... 14
6.1 General ... 14
6.2 Air flow rate measuring instruments ... 15
6.3 Differential pressure measuring instruments ... 15
6.4 Air velocity measuring instruments ... 15
6.4.1 General ... 15
6.4.2 Anemometers ... 15
6.4.3 Pitot static tubes ... 15
6.5 Temperature measuring instruments ... 16
6.6 Atmospheric pressure measuring instruments ... 16
7 Methods for measurement of air flow rates ... 16
7.1 Overview of described methods ... 16
7.2 Multi-point measurement in the duct cross-section – with measurement plane criteria (ID1) ... 17
7.2.1 Principle ... 17
7.2.2 Apparatus ... 18
7.2.3 Measurement procedure ... 19
7.2.4 Expression of results ... 23
7.3 Multipoint measurement in the duct cross-section – without measurement plane criteria (ID2) ... 25
7.3.1 Principle ... 25
7.3.2 Apparatus ... 25
7.3.3 Measurement procedure ... 26
7.3.4 Expression of results ... 34
7.4 Fixed devices for air flow rate measurement (ID3, ST1 and ET1) ... 38
7.4.1 Principle ... 38
7.4.2 Apparatus ... 39
7.4.3 Measurement procedure ... 39

7.4.4 Expression of results ... 39
7.5 Air flow rate measurement with tight bag at supply ATDs (ST2) ... 40
7.5.1 Principle ... 40
7.5.2 Apparatus ... 41
7.5.3 Measurement procedure ... 41
7.5.4 Expression of results ... 42
7.6 Air flow rate measurement with flow hood (ST3 and ET2) ... 42
7.6.1 Principle ... 42
7.6.2 Apparatus ... 43
7.6.3 Measurement procedure ... 44
7.6.4 Expression of results ... 46

Annex A (informative) Additional methods ... 47

A.1 Tracer gas measurement (ID4) ... 47

A.1.1 Principle ... 47

A.1.2 Apparatus ... 47

A.1.3 Measurement procedure – Conditions for homogeneous mixing of tracer gas ... 48

A.1.4 Expression of result – Calculation of air flow rate ... 49

A.2 Measurement using anemometer at air intake (IN1) or air exhaust (EX1) ... 50

A.2.1 Principle ... 50

A.2.2 Apparatus ... 50

A.2.3 Measurement procedure ... 50

A.2.4 Expression of results ... 51

A.3 Point measurements using thermal anemometers on rectangular intake (IN2) and exhaust (EX2) grilles on walls ... 51

A.3.1 Principle ... 51

A.3.2 Measurement instruments/Apparatus ... 52

A.3.3 Measurement procedure ... 52

A.3.4 Standard measurement uncertainty ... 54

Annex B (informative) Measurement uncertainty ... 56

B.1 Uncertainty of the result of a measurement ... 56

B.2 Type B evaluation of standard uncertainty ... 56

B.3 Combined standard uncertainty ... 58

B.4 Expanded uncertainty ... 59

B.5 Examples ... 59

Bibliography ... 64

European foreword

This document (prEN 16211:2023) has been prepared by Technical Committee CEN/TC 156 “Ventilation for buildings”, the secretariat of which is held by BSI.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 16211:2015.

In addition to a number of editorial revisions, the following main changes have been made with respect to EN 16211:2015:

— the whole document has been rearranged;

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

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

— two new methods to measure 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).

Introduction

Measurement of the air 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 (prEN 16211:2023) rather than scattering or repeating it in various documents.

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 terminological 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 use of maximum permissible measurement error in measurement uncertainty 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]

3.5
correction
compensation for an estimated systematic effect

[SOURCE: JCGM 200:2012, 2.53]

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
total gauge pressure
sum of static gauge pressure and *dynamic pressure* (3.6) at any point of a fluid

4 Symbols and abbreviated terms

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

Table 1 — Symbols and abbreviated terms

Symbol Abbreviated terms	Description	Unit
a/D_h	Relative distance	—
A	Cross-section area	m^2
A_K	Free cross-section area of the duct	m^2
A_g	Effective cross-section area of the probe	m^2
W	Width of the duct	mm
C_i	Initial tracer gas concentration	ppm
C_s	Tracer gas concentration in the sampling cross-section	ppm
D	Diameter	m
D_h	Hydraulic diameter	m
D_i	Centroidal ring of the annulus	
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 of the measuring point (on a measurement straight line)	—
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	m
L_1	Smaller dimension of a rectangular duct	mm
L_2	Larger dimension of a rectangular duct	mm
$MPME(p_d)$	Maximum permissible measurement error at the measured dynamic pressure	—
n	Number of measuring points or measurement	—

Symbol Abbreviated terms	Description	Unit
n	Number of annular rings	—
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
p_{t}	Total pressure	Pa
P	Perimeter of the cross-section	m
q	Air flow rate	m^3/s, l/s
q_{s}	Tracer gas flow rate	m^3/s, l/s
$q_{s\vartheta duct}$	Tracer gas flow rate at duct temperature	m^3/s, l/s
$q_{s\vartheta tracer}$	Tracer gas flow rate at rotameter temperature	m^3/s, l/s
$q_{v,act}$	Actual air volume flow rate (in actual conditions)	m^3/h
$q_{v,hyp}$	Hypothetical air volume flow rate assuming device default conditions	m^3/h
$q_{v,m}$	Measured air volume flow rate	m^3/s
$q_{v,std}$	Standardized air volume flow rate (in standard conditions)	m^3/h
Re	Reynolds number	—
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_{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

Symbol Abbreviated terms	Description	Unit
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	Volume	m^3
x_i	Coordinate of the measuring point	—
y_i	Coordinate of the measuring point	—
y_i	Distance from wall	mm
W	Width of the duct	mm
θ_{act}	Air temperature in actual conditions (= T_{act} −273,15)	°C
ρ	Air density	kg/m^3
ρ_{act}	Air density in actual conditions	kg/m^3
ρ_{hyp}	Air density in device default condition	kg/m^3
ρ_{std}	Air density in standardized conditions	kg/m^3
ϑ	Temperature of air	°C
ϑ_{duct}	Temperature inside the duct	°C
ϑ_{tracer}	Temperature of tracer gas	°C
ATD	Air terminal devices	—
MPME	Maximum Permissible Measurement Error	—
RH	Relative Humidity of the air	—

5 Expression of air flow rate

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).

$$D_h = 4 \cdot \frac{A}{P} \quad (1)$$

where

A is the area of the cross-section, in m^2;

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

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

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

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).

$$D_h = D \tag{3}$$

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 a damper and T-piece as well as before and after a fan.

5.3 Stability of the 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).

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

where

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

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

NOTE More information is available in CEN/TS 17153.

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.

In a low-pressure system it is hardly necessary to consider the influence of static pressure on air density. In a high-pressure system, however, it can be necessary. 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;

p_{atm} is the atmospheric pressure, 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).

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

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/m^3 corresponding to 293,15 K and 101 325 Pa). This hypothetical air flow rate is neither the actual air volume flow rate nor the standardized air volume 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 volume flow rate into actual air volume flow rate (air volume flow rate occurring in actual conditions) depends on the measuring device used.

To obtain the actual air volume 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.

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

— When the air flow rate varies with the inverse of the air density (e.g. for hot-wire anemometers) Formula (8) shall be used.

$$q_{v,act} = q_{v,hyp} \cdot \frac{\rho_{hyp}}{\rho_{act}} = q_{v,hyp} \left(\frac{p_{atm,hyp}}{p_{atm,act}}\right)\left(\frac{T_{act}}{T_{hyp}}\right) = q_{v,hyp} \left(\frac{p_{atm,hyp}}{p_{atm,act}}\right)\left(\frac{\theta_{act} + 273,15}{T_{hyp}}\right) \quad (8)$$

where

$q_{v,hyp}$ is the hypothetical air volume flow rate assuming device default conditions, in m^3/h;

$q_{v,act}$ is the actual air volume flow rate (in actual conditions), in m^3/h;

ρ_{hyp} is the air density in device default condition, in kg/m^3;

ρ_{act} is the air density in actual conditions, in kg/m^3;

$p_{atm,hyp}$ is the atmospheric pressure in device default condition, in Pa;

$p_{atm,act}$ is the atmospheric pressure in actual conditions, in Pa;

T_{hyp} is the air temperature in device default condition, in K;

T_{act} is the air temperature in actual conditions, in K;