SLOVENSKI STANDARD
SIST EN 16211:2015

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Prezračevanje stavb - Meritve pretoka zraka v sistemu prezračevanja - Metode

Ventilation for buildings - Measurement of air flows on site - Methods

Lüftung von Gebäuden - Luftvolumenstrommessung in Lüftungssystemen - Verfahren

Systèmes de ventilation pour les bâtiments - Mesurages de débit d'air dans les systèmes de ventilation - Méthodes

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ICS:

91.140.30	Prezračevalni in klimatski sistemi	Ventilation and air-conditioning

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Ventilation for buildings - Measurement of air flows on site - Methods

Systèmes de ventilation pour les bâtiments - Mesurages de débit d'air dans les systèmes de ventilation - Méthodes

Lüftung von Gebäuden - Luftvolumenstrommessung in Lüftungssystemen - Verfahren

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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Foreword

This document (EN 16211:2015) 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of an identical text or by endorsement, at the latest by January 2016, and conflicting national standards shall be withdrawn at the latest by January 2016.

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Measurement methods which are both correct and easy to use are developed and standardized to enable the commissioning and operational monitoring of air processing installations. Interior climate and air quality can often be improved considerably if the heating and ventilation system is managed in a way that ensures good functioning in the long term. It is thus important that the system is designed and constructed to allow measurement and monitoring to be performed using established and approved methods.

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

1 Scope

This European Standard specifies simplified methods for the measurement of air flows on site. It provides a description of the air flow methods and how measurements are performed within the margins of stipulated method uncertainties.

One measurement method is to take point velocity measurements across a cross-section of a duct to obtain the air flow. This simplified method is an alternative to the method described in ISO 3966 and EN 12599. This European Standard requests certain measurement conditions (length of straight duct and uniform velocity profile) to be met to achieve the stipulated measurement uncertainties for the simplified method.

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 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, definitions and symbols

3.1 Terms and definitions

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

3.2 Symbols

The following symbols are used.

Symbol	Description	SI Unit	Symbol	Description	SI Unit
t	Time	s	O	Perimeter	m
ρ	Density	kg/m^3	p	Pressure	Pa
ρ_s	Standard conditions air density = *1,2*	kg/m^3	p_d	Dynamic pressure	Pa
ρ_r	Real density	kg/m^3	p_s	Static pressure	Pa
$\rho_{\vartheta\ tracer}$	Tracer gas density	kg/m^3	p_t	Total pressure	Pa
$\rho_{\vartheta\ duct}$	Duct air density	kg/m^3	p_u	Measured pressure	Pa
A	Cross-section Area	m^2	Δp	Differential pressure	Pa
a, b, c, etc.	Dimensions of length	mm	Δp_u	Measured differential pressure	Pa
L	Mixing length	mm	q	Air flow	m^3/s, l/s
H	Height of duct	mm	q_k	Corrected air flow	m^3/s, l/s
W	Width of duct	mm	q_s	Tracer gas flow	m^3/s, l/s
B	Barometric pressure	hPa	$q_{s\vartheta duct}$	Tracer gas flow at duct temperature	m^3/s, l/s
C	Contaminant concentration	ppm	$q_{stracer}$	Tracer gas flow at rotameter temperature	m^3/s, l/s
C_i	Initial tracer gas concentration	ppm	q_t	Total air flow	m^3/s, l/s
C_s	Tracer gas concentration in stationary condition	ppm	q_u	Measured air flow	m^3/s, l/s
D	Diameter	mm	ϑ	Temperature	°C
D_h	Hydraulic diameter	mm	ϑ_{duct}	Temperature in duct	°C
k_c	coverage factor	-	ϑ_{tracer}	Temperature of tracer gas	°C
k_1	Correction factor for density	-	V	Volume	m^3
k_2	Correction factor for duct shape	-	v	Air velocity	m/s
k	Flow factor	-	v_s	Standard air velocity	m/s
L_1	Smaller dimension of a rectangular duct	mm	v_r	Real air velocity	m/s
L_2	Larger dimension of a rectangular duct	mm	v_m	Air velocity, mean value	m/s
u_1	Standard Instrument uncertainty	-			
u_2	Standard Method uncertainty	-			
u_3	Standard Reading uncertainty	-			
u_m	Standard measurement uncertainty	-			
U_m	Expanded measurement uncertainty	-			

4 Principles and parameters of influence

4.1 Hydraulic diameter

The hydraulic diameter is the diameter of a circular duct which causes the same pressure drop at equal air velocity and equal friction coefficient, and is defined by the following formula:

$$D_h = 4 \cdot A/O \quad (1)$$

For a rectangular duct this becomes:

$$D_h = 2 \cdot L_1 \cdot L_2 / (L_1 + L_2) \quad (2)$$

where

L_1 and L_2 are the sides of the duct.

For a circular duct this becomes:

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

4.2 Flow disturbances

Flow disturbances in ducts result in irregular velocity profiles.

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.

4.3 Air density, ρ

The density of dry air varies with air pressure and temperature in accordance with the following approximating formula:

$$\rho = 1{,}293 \cdot \frac{B}{1013{,}25} \cdot \frac{273{,}15}{273{,}15 + \vartheta} \quad (4)$$

NOTE 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 1 013,25 hPa 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 as follows:

$$\rho = 1{,}293 \cdot \frac{B + 0{,}01 \cdot p_s}{1013{,}25} \cdot \frac{273{,}15}{273{,}15 + \vartheta} \quad (5)$$

4.4 Dynamic pressure, p_d

When measuring with a Pitot static tube a dynamic pressure is measured. The dynamic pressure can be used to calculate the air velocity by the use of the following formula:

$$p_d = \frac{\rho \cdot v^2}{2} \quad (6)$$

4.5 Corrections for air density, ρ

When presenting a measured air flow or velocity, it should be stated if it is the real air flow or the flow converted to standard conditions that is presented. The measurements should correspond to the designed air flow values of the system (real or standard air flow). The methods in this standard present the measurements as real air flow. How to convert between standard and real velocity is described in 4.5. The same conversion is also valid for air flow.

The real flow rate of air is as it is at the present temperature and barometric pressure of the air. Standard air flow is used to present the air flow at standard condition of 1 013,25 hPa and 20 °C. A fan transports approximately the same amount of air independent of air density. The amount of standard flow changes with air density.

The instrument in use can measure real or standard air flow or it could require calibration conditions to display correctly. Compensate accordingly, especially when used for other conditions than calibration condition or standard conditions of 1 013,25 hPa and 20 °C. The barometric pressure will decrease with altitude and also vary with weather.

Convert real flow or velocity to standard flow or velocity by using the following formula:

$$v_s = v_r \cdot \rho_r / \rho_s \quad (7)$$

5 Sources of errors

5.1 General

There are many factors which affect the measurement results which shall be checked in connection with measuring. These factors are for example:

a) calibration equipment, which shall be regularly compared with a traceable norm (calibration unit);

b) calibrated measurement instruments;

c) calibration intervals;

d) examination of instruments' long term stability;

e) instruments' temperature or density compensation;

f) random instrument uncertainties;

g) random reading uncertainties;

h) variations in the measured quantity;

i) measurement methods adapted to different installation cases;

j) random uncertainties in measurement methods;

k) measurement methods' influence on the flow rate;

l) variations in the exterior climate;

m) air flow stability.

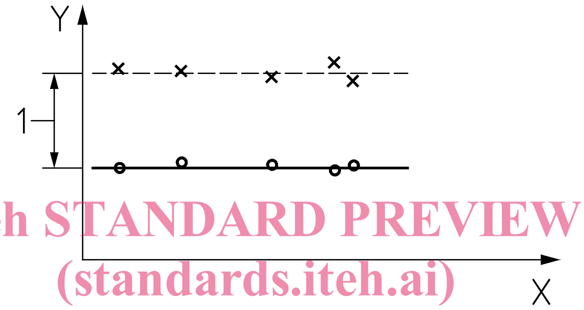
Certain sources of error are difficult to manipulate, others can be reduced or even eliminated. Errors in given data input can be the result of measurements which have been affected by system errors or temporary disturbances. Errors in measurement data can be divided into:

- gross errors, which can happen as a result of the human factor and should be avoided to comply with this standard;
- systematic errors;
- random errors.

5.2 Systematic errors

According to the definition, systematic errors occur if the individual measurement values deviate in the same direction from the “true” value or if they vary in a regular fashion.

The result of measurements where systematic errors occur can appear as in Figure 1.



Key

1 systematic Error

X time

Y value

Figure 1 — Explanation of systematic error

The circles represent measured numbers which lie randomly spread around the true value and which according to the definition are thus free from systematic errors.

The crosses represent results of measurements where the measured numbers lie too high, for example as a result of an uncalibrated measuring instrument being used. This error can easily be rectified by calibrating the instrument and determining a correction.

The following applies to a correction:

Correction = (estimate of true value) – (read value)

or

(Read value) + (correction) = estimate of true value

Estimates of true values are also often called measured values. To make corrections it is recommended to add a correction value (positive or negative) instead of multiplying with a correction factor.

Calibration is a part of the determination of the systematic errors of an instrument, which allows the understanding of the calibration uncertainty, to eventually set up the instrument or correct the measurements and by its repetition to assess the drift uncertainty.

An instrument shall always be able to give a correct measured value. This means that calibration shall take place at regular time intervals. It is recommended that electronic instruments used for pressure, flow and velocity measurements are calibrated regularly according to their drift to obtain the uncertainty required. The instrument and other equipment that influence the measurement result (e.g. the bag in the tight bag measuring method) should be calibrated using a method with a (known) low uncertainty, traceable to international calibration standards.

Calibration tables where corrections, or alternatively the real value, are evident should be used.

5.3 Random errors

Even if systematic errors are successfully eliminated, repeated measurements of the same quantity cannot produce identical results despite the measurements being made thoroughly. This type of error is usually defined as a result of chance and is called uncertainty. This means that the size and character of the uncertainty cannot be accounted for in advance. There are several possible sources of random uncertainties, e.g. reading uncertainties, instrument uncertainties, method uncertainties, problem of repeatability due to the operator, variation of the environmental conditions, etc. In general, the random uncertainties can be reduced by increasing the number of measured points or by increasing the time of measurement thanks to instruments with mean value function.

The random uncertainties due to the reading, the instrument and the method are discussed in more detail in Clause 6.

6 Measurement uncertainty

6.1 Overall measurement uncertainty

The overall measurement uncertainty should be presented as expanded measurement uncertainty with a coverage probability of approximately 95 %. See 6.5. and the Example in Annex A. When calculating uncertainty using Formula (8) the uncertainties shall all have the same coverage probability of approximately 68 %.

The measurement standard uncertainty, u_m, is calculated using the following formula:

$$u_m = (u^2_1 + u^2_2 + u^2_3)^{½} \quad (8)$$

where

- u_1, u_2 and u_3 are random standard uncertainties with a coverage probability of approximately 68 %;
- u_1 is the standard instrument uncertainty, such as hysteresis, temperature compensation, drift, etc. The instrument uncertainty is normal distributed;
- u_2 is the standard method uncertainty, resulting from deviations from the calibration method for the measurement method. In this type are also included deviations from the calibration curve for series-produced measurement devices, dampers or terminals with in-built measurement outlets. The method uncertainty is normal distributed;
- u_3 is the standard reading uncertainty. The reading uncertainty is rectangular distributed for digital instruments.

6.2 Standard instrument uncertainty, u_1

Even after correcting a read value or a measured mean value with regards to different influences, there still remain random uncertainties in measurements. Instrument uncertainty includes calibration uncertainty and uncertainty from the instrument itself, such as hysteresis, temperature compensation, drift, etc.

Information on this uncertainty shall be supplied by the instrument manufacturer and it is important to check that the coverage probability of approximately 68 % is used. The user shall make an estimate of the standard instrument uncertainty that also includes hysteresis, drift, environmental influence, etc.

Some instruments have an upper and lower uncertainty value (limit) and the uncertainty can in this case be judged to be rectangular distributed:

$$u_1 = \frac{\text{value}}{\sqrt{3}} \tag{9}$$

Corrections are known errors and not included in the instrument uncertainty. Correct the measurement values by using corrections from the calibration certificate. Even after correcting a read value or a measured mean value with regards to different influences, such as corrections, there still remains random uncertainties in measurements. Instrument uncertainty includes calibration uncertainty and uncertainty from the instrument itself, such as hysteresis, temperature compensation, drift, etc.

6.3 Standard method uncertainty, u_2

When measurements are taken, an accurately specified method should be used. As a result of deviations from the method, e.g. the orientation of a probe, distance between the probe and a grille, etc., certain random uncertainties are produced by the method. For those methods described in Clause 8 to Clause 10, the uncertainty is stated as a standard uncertainty with 68 % coverage probability – one standard deviation for each method. The method uncertainties are normal distributed.

6.4 Standard reading uncertainty, u_3

This type of uncertainty can be attributed to reading uncertainties, so that the resolution can play a large part, especially with analogue instruments.

For digital instruments, reading uncertainty:

$$u_3 = \frac{1}{2\sqrt{3}} \text{ of resolution.} \tag{10}$$

EXAMPLE For an instrument with 0,1 resolution u_3 is 0,03.

In case of digital pulse readout the uncertainty shall be estimated; if this is not possible then an average function over time can be used. For instruments with an analogue display, the standard uncertainty can be estimated as 1/6 of a scale interval.

6.5 Expanded measurement uncertainty, U_m

In order to cover most measurement results it is necessary to present the overall measurement uncertainty with a coverage probability of approximately 95 %. The expanded uncertainty of measurement is stated for a normal distribution as the standard uncertainty of measurement multiplied by the coverage factor $k_c = 2$. That means that the measurement uncertainty covers 95 % of the measurements and that 5 % fall outside the stated uncertainty.

Expanded measurement uncertainty, U_m: