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Prezračevanje stavb - Meritve pretoka zraka v sistemu ventilacije - 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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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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Introduction

The construction, function and maintenance of ventilation installations are of great importance for the perception of the interior climate of a building by those who work or live there. Since it is already clear that many buildings today have problems with their interior climate and air quality, it is essential to use reliable methods to check that the installation is functioning as intended. The result of an inspection can have large financial implications if the installation is not passed. It is thus vital that the inspector bases his judgement on measurement methods which are reliable and have small, known measurement uncertainties. The construction, function and maintenance of the installation also have a large impact on the annual running costs of the plant. It is for this reason necessary to pay close attention to these functions of the installation.

Measurement methods which are both correct and easy to use are developed and standardised 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 installation is designed at the planning stage to allow measurement and monitoring to be performed using established and approved methods.

Foreword

This document (prEN 16211:2010) 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 is currently submitted to fill with appropriate information.

Measurement methods which are both correct and easy to use are developed and standardised 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 installation is designed at the planning stage to allow measurement and monitoring to be performed using established and approved methods.

1 Scope

This standard applies to measurement of airflows on site. It provides the technician with a description of the methods, their protocols, and tables for noting measured and calculated values so that the necessary measurements are performed within the margins of stipulated method uncertainties.

Note : The duct traverse method in this standard is an alternative method to the duct traverse method of ISO 3966 and EN12599. It defines errors due to the simplified approach and describes also other methods of measurements.

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)

EN12599 *Ventilation for buildings - Test procedures and measuring methods for handing over installed ventilation and air conditioning systems*

EN14277 *Ventilation for buildings – Air terminal devices – Methods for airflow measurement by calibrated sensors in or close to ATD/Plenum boxes*

ISO 3966, *Measurement of fluid flow in closed conduits. Velocity area method using Pitot static tubes.*

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices. Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full.*

ISO 5167-2 *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full-Part 2: Orifice plates*

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*

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*

ISO 5221, *Air distribution and air diffusion. Rules to methods of measuring air flow rate in an air-handling duct.*

ISO 4053-1, *Measurement of gas flow in conduits -- Tracer methods -- Part 1: General*

VIM :/ JCGM see reference – International Vocabulary of Metrology – basic and general concepts and associated terms (VIM°) – 3rd edition, Jan 2008-04-03

ENV 13005 Guide to the expression of uncertainty of measurement

3 Terms and definitions

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

3.1 Hydraulic diameter

The hydraulic diameter is the diameter of a circular duct which would have the same linear pressure drop, and is defined by the following formula:

$D_h = 4 \cdot A/O$ m *eq.3-2*

where

A = the cross sectional area of the duct, m^2

O = the circumference of the duct or perimeter, m

For a rectangular duct this becomes:

$D_h = 2 \cdot L1 \cdot L2 / (L1 + L2)$ m *eq. 3-3*

where $L1$ and $L2$ are the sides of the duct.

For a circular duct this becomes:

$D_h = D$ m *eq. 3-4*

where

D = duct diameter, m

3.2 Flow disturbances

Flow disturbances result in velocity profiles in ducts that are non symmetrical.

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 will also become disturbed by a damper, T-piece as well as before and after a fan.

3.3 Air density, ρ

The density of dry air varies with air pressure and temperature according to the following formula:

$$\rho = 1{,}293 \cdot \frac{B}{1013} \cdot \frac{273}{273 + \vartheta} \text{ kg/m}^3 \qquad \textit{eq. 3-5}$$

where

B = barometric pressure, h Pa (hPa). (Normal air pressure is 1013 hPa)
ϑ= air temperature, °C

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 1013-hPa which is saturated with water vapour is only approx. 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:

$$\rho = 1{,}293 \cdot \frac{B + 0{,}01 \cdot p_s}{1013} \cdot \frac{273}{273 + \vartheta} \qquad \textit{eq. 3-6}$$

where

p_s = static overpressure in the duct, Pa

ϑ = air temperature in °C

3.4 Dynamic pressure, p_d

$$p_d = \frac{\rho \cdot u^2}{2} \text{ Pa} \qquad \textit{eq. 3-7}$$

where

ρ = air density, kg/m^3

u = air velocity, m/s

3.5 Corrections for air density, ρ

When presenting a measured flow or velocity, it should be stated if it is real flow or standardised flow that is presented. Below in this section it is described how to convert between standardised and real velocity. The same conversion is valid for air flow.

The method describes how to compensate and correct the air flow to real flow, that is real flow (real velocity). The volume of air is as it is at present temperature and barometric pressure. Real flow is not the same as standardised flow. Standardised flow is used to present the air flow by recalculating the air volume into standard condition of 1013 hPa and 20°C (68°F). Standardised flow can directly be interpreted as a mass flow. The reason to use real flow is that the fan approximately transports the same real air flow irrespective of the air density. The amount of standardised flow will change with air density. Even though the dimensioning air flow is made by using ρ = 1.20 kg/m^3 at the fan inlet, the measured velocity is comparable if the flow is presented as real flow. Providing that the other parameters are identical, correction of real flow is only necessary if the density at the time of measuring, ρ_m, deviates from the density at the fan intake, ρ_f.

No corrections for air density are required during the proportional balancing of terminals and branch ducts providing that the entire installation is balanced under the same running conditions. For this reason, heaters in terminals and branch ducts, for example, must be switched off.

The instrument in use may measure real or standardised flow or the instrument requires calibration conditions to display correctly. Compensate accordingly, especially when used at other conditions than calibration condition or standard conditions of 1013 hPa and 20°C. The barometric pressure will decrease with altitude and also vary with weather. Temperature can also vary especially when the house is not conditioned.

To calculate from measured (real) velocity or air flow to standard velocity or air flow use the following formula:

$v_s = v_m \cdot \rho_m / \rho_s$ m/s   *eq. 3-8*

where:

v_s = standard velocity, m/s

v_m = measured (real) velocity, m/s

ρ_m = density at time of measurement, kg/m^3

ρ_s = standard density ρ = *1,2* kg/m^3

Note that heating or cooling devices in the duct between the fan and the place of measurement must be switched off while measuring air flow, q_m or air velocity, v_m.

4 Symbols (and abbreviated terms)

The following symbols are used in the report.

Symbol	Description	SI Unit	Symbol	Description	SI Unit
t	Time	s	n	Revolutions	r.p.m.
α	Quotient of measured and planned air flow	-	O	Perimeter	m
			P	Power	W
η	Efficiency	-	p	Pressure	Pa
ρ	Density	kg/m^3	p_d	Dynamic pressure	Pa
			p_p	Planned pressure	Pa

A	Area	m^2	p_s	Static pressure	Pa
a,b	Dimensions of length, e.g. height of a duct	m	p_t	Total pressure	Pa
B	Barometric pressure	hPa	p_u	Measured pressure	Pa
C	Contaminant concentration	ppm	Δp	Differential pressure	Pa
C_i	Initial concentration	ppm	Δp_i	Differential commissioning pressure	Pa
C_s	Tracer gas concentration in stationary condition	ppm	q	Air flow	m^3/s, l/s
D	Diameter	m	q_k	Corrected air flow	m^3/s, l/s
D_h	Hydraulic diameter	m	q_p	Planned air flow	m^3/s, l/s
k	Flow factor	-	q_s	Trace gas flow	m^3/s, l/s
L_1	Smaller dimension of a rectangular duct	mm	q_t	Total air flow	m^3/s, l/s
L_2	Larger dimension of a rectangular duct	mm	q_u	Measured air flow	m^3/s, l/s
u_1	Std Instrument uncertainty	mm	ϑ	Temperature	°C
u_2	Std Method uncertainty		T	Temperature	K
u_3	Std Reading uncertainty		$\Delta\vartheta$, ΔT	Temperature difference	°C, K
u_m	Standard measurement uncertainty		V	Volume	m^3
U_m	Expanded measurement uncertainty		v	Air velocity	m/s
			v_c	Air velocity in duct centre	m/s
			v_k	Corrected velocity	m/s
			v_m	Air velocity, mean value	m/s

5 Preparation of measurement

5.1 Factors influencing measurements

The measurement methods which are to be used must have known and small method uncertainties. The requirements for method uncertainties must be to some extent related to the requirement for flow tolerances.

There are many factors which affect the measurement results and which must be checked in connection with measuring. Examples of these are:

- Calibration equipment, which must be regularly compared with a traceable norm (calibration unit).
- Calibrated measurement instruments.
- Calibration intervals.
- Examination of instruments' long term stability.
- Instruments' temperature or density compensation.
- Random instrument uncertainties.

- Random reading uncertainties.
- Variations in the measured quantity.
- Measurement methods adapted to different installation cases.
- Deviations when measuring from calibrated installation cases.
- Random uncertainties in measurement methods.
- Measurement methods' influence on the flow rate.
- Variations in the exterior climate.
- Air flow stability.

5.2 Sources of errors and uncertainties

The result of numerical work is influenced by many types of error. Certain sources of error are difficult to manipulate, others can be reduced or even eliminated.
Errors in given data input may 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
- Systematic errors
- Uncertainties

5.2.1 Gross errors

Gross errors should not be allowed but they may happen by accident as a result of the human factor. The risk of gross errors arising can be reduced by suitable design of working

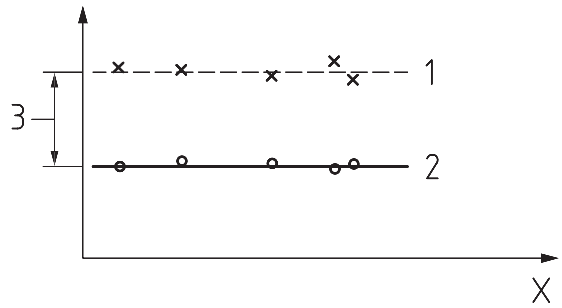
conditions and working routines. Stress, tiredness and poor lighting are common reasons for gross errors.

Checks should be planned, either of the end result before it is approved or of the work in progress, to prevent large amounts of work being repeated as a result of an early error. Incorrect magnitude of measured values or insufficient regularity can often be discovered at an early stage. It is also possible to make a check on the likelihood of many results by examining associations between them. Time taken on designing working conditions and verification measures is time well spent.

5.2.2 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 may appear as in Figure 1.



Key

1 Measured

2 True value

3 Systematic error

X Time

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 = (true value) – (read value)

or

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

Estimates of true values are also often called *measured values*.

5.2.3 Calibration

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 must always be able to give a correct measured value. This means that calibration must 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 (ex. Bag in bag 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.

The measured value is obtained by correcting the read-out value according to:

Measured value = (read-out value) + (correction for the instrument)

The correction should therefore be stated as an absolute value, not as a factor, considering that corrections will be made in the field

5.2.4 Uncertainties

Even if systematic errors are successfully eliminated, repeated measurements of the same quantity may not 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 shown to follow any known law and it can therefore not be calculated or corrected for in advance. These uncertainties are normally assumed to be composed of a number of small instrument uncertainties together with rapid and uncontrolled variations in environmental conditions.

Temporary (random) uncertainties are divided into *instrument uncertainties*, *method uncertainties* and *reading uncertainties,* and are discussed in more detail in section 6

5.3 Measurement requirement

A measurement must be based on a well-defined method, in which both measurement points as well as the measuring instrument must be decided. This does not mean that certain selected instruments should be standardised, but that there is a decided procedure with norms for the instrument to be used.

Measurement values are evaluated in a specified way for the method chosen, after which the values are corrected for the method. A correction factor is commonly used at this point, from which:

Correct value = (measured value) · (correction factor for the method)

5.3.1 Measurements using a manometer

When measuring with a manometer, digital display instruments with a resolution according to table 1 should be used.

Table 1 – Resolution for the ranges of manometers

Range Pa	Resolution Pa
Up to and including 50	0.1
Above 50	1

The lowest acceptable pressure measurement is 3 Pa when mean values are taken over at least 1.5 second. If only single measurements are made the lowest acceptable measured pressure is 5 Pa.

The manometer should be zeroed before each measurement or the manometer should be equipped with a function which automatically zeros the instrument after a certain time period or before each measurement or compensates the measurement with the offset checked with a following auto zero.

5.3.2 Measurements using an anemometer

Hot wire anemometers should not be used for measuring velocities less than 0.5 m/s when the air flow is to be determined. If a hot wire anemometer is used at lower velocity, the total uncertainty (in %) will be increased due to the influence of the hot wire absolute uncertainty.

Mechanical anemometers should not be used when measuring velocities less than 1 m/s If a vane anemometer is used at lower velocity (in close range of the start threshold of the device), the total uncertainty (in %) will be increased due to the influence of the vane anemometer absolute uncertainty.

The overall diameter of the device obstructing the duct passage area should not exceed 1/10 of the duct diameter.

5.3.3 Measurements using Pitot static tube

The diameter of the Pitot static tube obstructing the duct passage area should not exceed 1/30 of the diameter

Measurement using a Pitot static tube should not be used for making velocity measurements of less than 2.5 – 3 m/s

Note : it is linked to the minimum acceptable pressure measurement (see 5.3.1)

5.3.4 Mean value calculation of measurement signal

In order to eliminate reading uncertainties as much as possible, instruments with a mean value calculation function should be used.

6 Measurement uncertainty

It is important that when calculating uncertainties, u, using eq. 6-1 they shall all have the same coverage probability of approximately 68%. [5]

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

$u_m = (u^2{}_1 + u^2{}_2 + u^2{}_3)^{½}$ *eq. 6-1*

where u_1, u_2 and u_3 are random standard uncertainties with a coverage probability of approximately 68%.

u_1 = standard instrument uncertainty,

u_2 = 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 = standard reading uncertainty, % The reading uncertainty is rectangular distributed for digital instruments.

6.1 Standard instrument uncertainty, u_1

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

Information on this uncertainty must be supplied by the instrument manufacturer and it is important to check that the coverage probability of approximately 68% is used.