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Thermal performance in the built environment — Determination of air flow rate in building applications by field measuring methods

Performance thermique des bâtiments — Détermination du taux de renouvellement d'air dans les bâtiments par des méthodes de mesure sur site

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Foreword

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The committee responsible for this document is ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 1, *Test and measurement methods*.

Thermal performance in the built environment — Determination of air flow rate in building applications by field measuring methods

1 Scope

In the cooling and heating loads of a building, the air taken in from outside account for a large portion of the entire load; in order to estimate this load, it is necessary to correctly grasp the air flow rate of ventilation and air-conditioning systems. This International Standard stipulates the methods for measuring the rate of air flow through the ducts in a steadily operating ventilation and air-conditioning system and in the air control ports including air diffuser, suction opening, and exhaust opening.

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.

ISO 5168, *Measurement of fluid flow — Procedures for the evaluation of uncertainties*

3 Terms and definitions

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

3.1
orifice plate
thin plate having a hole, or holes, bored through it

Note 1 to entry: These are used for measuring the difference in static pressure of the flow before and after the disc and obtaining the air flow rate in the duct by multiplying by a predetermined coefficient.

3.2
tracer gas
gas used to measure its concentration varying in the air

Note 1 to entry: This gas is mixed with a sufficiently small amount of air so as not to affect the flow, and the amount of air is determined by measuring the gas concentration diluted in the air.

3.3
volumetric concentration
ratio of the volume of the specific gas to the unit volume of the mixture of air

Note 1 to entry: It is expressed in cubic meters per cubic meters or 10-6 · vol.

3.4
mass flow
mass of air or tracer gas flowing in unit time

Note 1 to entry: It is expressed in mg per second or kg per hour.

3.5
volumetric flow
volume of air flowing in unit time

Note 1 to entry: It is expressed in cubic meters per hour.

4 Symbols and abbreviated terms

Among the symbols used in this International Standard, only those common to all items are shown below. Individual symbols are explained at the relevant sub clauses.

Symbol	Quantity	Unit
A	Area of evaluation section of air flow rate. Sectional area of duct and sectional area of air control port	m^2
N	Number of divisions for measurement of evaluation section. The number of lattice-like divisions of rectangular duct section and radial number of divisions in round duct.	-
V	Average air velocity of section of measured portion. The section is divided into n and if the time average air velocity at the centre of each is v_i, the following formula is applied: $v = \frac{1}{n}\sum_{i=1}^{n} v_i$	m/s

5 Types and selection of measurement method

5.1 Types of measurement methods and their application

The measurement methods covered in this International Standard are the multipoint air velocity measurement method, tracer gas measurement method for air flow rate in air duct, flow hood method, pressure compensation measurement method, and pressure difference measurement method between outlet and inlet. The method selected should be suitable for the purpose, as well as for the field conditions.

5.2 Selection of measurement method

The measurement method is selected considering the following items specified in Clause 7 and Clause 8:

a) ventilation/air-conditioning equipment subject to measurement;

b) position for measurement;

c) measurement period;

d) accuracy;

e) practicability (equipment size and composition simplicity, preparation, ease of data processing, and cost).

6 Basic specifications measuring instruments and utilization methods

6.1 General

The following describes air velocity measuring instruments common to various measurement methods.

6.2 Thermal anemometer

In the category of thermal anemometers, there are the hot-wire anemometer and the semiconductor anemometer. The hot-wire anemometer has less resistance against flow and is suitable for multipoint air velocity measurement in air duct when measuring very low air velocity. Attention should be paid to the directivity of the sensor. The sensor should be calibrated as necessary to avoid errors due to deterioration and adhesion of dust.

Since the semiconductor anemometer has improved accuracy beyond 1 m/s and the distance between the sensor and transducer can be extended, it is suitable for multipoint air velocity measurement for fixed setting in air duct for permanent installation.

6.3 Pitot tube and manometer

The Pitot tube has less resistance to flow and is suitable for multipoint measurement, but to be accurate, the flow velocity in the straight-pipe section should be 4 m/s or higher. However, when the cross-section of the duct is small, the Pitot tube is not used.

When the air velocity is calculated from the dynamic pressure, it is obtained by using the density of measured air depending on air temperature and atmospheric pressure as given in Formula (1):

$$v=\sqrt{(2/\rho)P_v} \tag{1}$$

where

v is the air velocity, in meter per second;

ρ is the air density, in kg per cubic meters;

P_v is the dynamic pressure, in Pa.

The result of Formula (1) is multiplied by the compensation coefficient k of the Pitot tube, if it is shown. Air density, ρ, is obtained from measured air temperature θ and atmospheric pressure P, using Formula (2):

$$\rho=\rho_0\cdot\frac{T_0}{T}\cdot\frac{P}{P_{atm}}=1{,}293\frac{273{,}15}{273{,}15+\theta}\cdot\frac{P}{101325} \tag{2}$$

where

ρ_0 is the density when dry air temperature Θ is 0,0°C (= 1,293), in kg per cubic meters;

T is the thermodynamic temperature of dry air, in K;

Θ is the air temperature, in °C;

T_0 is the thermodynamic temperature when Θ is 0,0 °C (273,15), in K;

P is the atmospheric pressure, in Pa;

P_{atm} 1 atmospheric pressure (101 325); in Pa.

6.4 Vane-type anemometer

The vane-type anemometer generally cannot be used for multipoint measurement because the vane is too large. If it is used, it is advisable to select a mini-vane anemometer with the measured portion made smaller.

7 Field measuring methods of air flow rate of ventilation and air conditioning systems

7.1 Multipoint air velocity measurement method

The multipoint air velocity measurement method obtains the air flow rate by measuring the average air velocity in the duct and multiplying it by the sectional area of the duct. For both a round duct and rectangular duct, the cross-section is divided into multiple equal areas, the representative air velocity is measured and the average air velocity is calculated. The air flow rate is expressed by Formula (3):

$$Q = 3\,600 \times S \cdot v \tag{3}$$

where

Q is the air flow rate in the duct, in cubic meters per hour;

S is the duct sectional area of measured portion, in square meters;

v is the average air velocity of cross-section of measured portion, in meter per second.

7.1.1 Measurement in a duct

7.1.1.1 Position for cross-section measurement

The position for cross-section measurement is selected in accordance with Annex A. Normally, it is a place having a straight section of not less than six times the equivalent diameter, D_e, of the duct on the upstream side in the air flow direction. When precise measurement is required, a straightening or wire grid is provided upstream.

In the case of a rectangular duct, the equivalent diameter, D_e, is calculated by Formula (4):

$$D_e = 2ab/(a+b) \tag{4}$$

where

D_e is the equivalent diameter when a rectangular duct is converted to a round duct, in meter;

a is the width of rectangular duct, in meter;

b is the height of rectangular duct, in meter.

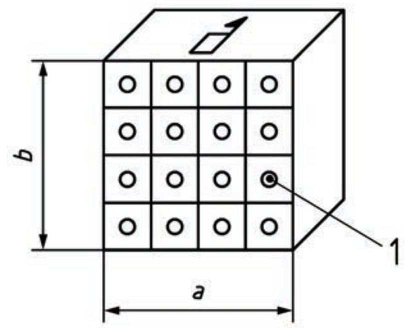
7.1.1.2 Simplified measurement method

With the simplified measurement method, as shown in A.4, the measured cross-section is divided into four equal parts and the four centres and the centre of the whole, five points in total, are selected as the measuring points. The arithmetic average of the five points is used as the average air velocity. If the required conditions are met, including securing the length of the straight-pipe section, the uncertainty can be minimized (approximately ±10 %) even with this method. If, however, a sufficient straight-pipe length cannot be secured upstream from the measurement position, the measuring points are increased to a number closer to the precise measurement method.

7.1.1.3 Precise measurement method

a) In the case of a rectangular cross-section

With the precise measurement method, the rectangular cross-section is divided into multiple equal rectangles in such a way that the length of one side will be about 15 cm or less and the air velocity is measured at their centres. However, the number of divisions need not exceed 64.



Key

1 measuring point

Figure 1 — Air velocity measuring points of rectangular duct

b) In the case of a round cross-section

Figure 2 shows the measuring points in the precise measurement method for a round cross-section. The measured cross-section is divided into *n* doughnut-shaped equal areas, which are then divided into four or more equal sectors with a common straight line passing through the centre of the cross-section, and the measuring point is provided at the centre of each figure. The distance r_i from the centre of the cross-section of the measuring point in area *i* is given by Formula (5):

$$r_i = R\sqrt{\frac{i-1/2}{n}} \quad (5)$$

where

R is the radius of cross-section, in meter;

r_i is the distance from the centre of cross-section to measuring point, in meter;

n is the number of divisions in diameter direction of cross-section;

i is the measuring point position number in radial direction from centre of cross-section

The relationship between *R* and *n* is as follows.

$n = 2$ when $R < 0{,}13$ m

$n = 3$ when $R \leq 0{,}15$ m

$n = 4$ when $R \leq 0{,}30$ m

$n = 5$ when $R \leq 0{,}50$ m

$n = 6$ when $R \geq 0{,}75$ m

When $R > 0{,}75$, 1 is added every 0,25 m.

Figure 2 — Air velocity measuring points of round duct

Formula (5) and the above conditions are arranged in Table 1, which may be used.

Table 1 — Measuring positions of round cross-section

Diameter of round cross-section (m)	Number of divisions	Number of measuring points	Distance *r* from centre of cross-section (mm)				
			r_1	R_2	R_3	R_4	R_5
0,075	2	8	20	30	-	-	-
0,100	2	8	25	45	-	-	-
0,125	2	8	30	55	-	-	-
0,150	2	8	35	65	-	-	-
0,175	2	8	45	75	-	-	-
0,200	2	8	50	85	-	-	-
0,225	2	8	55	95	-	-	-
0,250	3	12	50	90	115	-	-
0,300	3	12	60	105	135	-	-
0,350	4	16	60	105	140	165	-
0,400	4	16	70	120	160	185	-
0,450	4	16	80	135	175	210	-
0,500	4	16	90	155	195	235	-
0,550	4	16	95	170	215	255	-
0,600	4	16	105	185	235	280	-
0,650	5	20	100	180	230	270	310
0,700	5	20	110	190	245	290	330
0,750	5	20	120	205	265	315	355

7.1.1.4 Semi-precise measurement method for round cross-section

With the semi-precise measurement method, for a round cross-section of 0,3 m or less in diameter ($R < 0{,}15$ m), the number of divisions of cross-section $n = 2$ is adopted in Figure 2. That is, the measurement can be made at eight measuring points.[6]

7.1.2 Measurement method at duct connection of air-conditioning system

When the amount of intake air from outside and the amount of air returned are measured at the duct connection of the air-conditioning system, the position selected should have less velocity distribution

