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

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National foreword

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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

Reference number
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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*.

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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.

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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.

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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

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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):

$$Q = 3\,600 \times S \cdot v \quad (3)$$

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):

$$D_e = 2ab / (a + b) \quad (4)$$

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.

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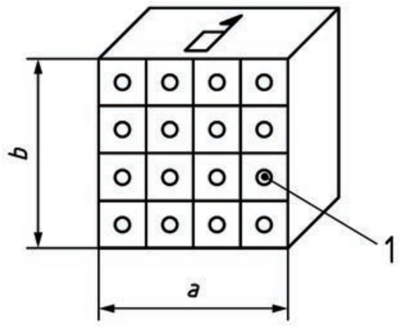

Key

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):

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

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 $R \le 0{,}15$ m

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

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

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

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

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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

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at the connection on the suction side. With the measuring points of air velocity as per 7.1.1.3 a), the measurement is made at the centre points of 16 or more equal-area zones and the average air velocity is determined. Refer to Annex A.

7.1.3 Selection of measuring instruments

For cross-section air velocity measurement, the thermal anemometer (hot-wire anemometer and semi-conductor anemometer), Pitot tube, precise manometer, vane-type anemometer, etc. are used.

7.2 Tracer gas measurement method

The tracer gas measurement method estimates the flow rate in the duct by steadily injecting a fixed amount of tracer gas with known concentration and measuring of dilution of concentration at the downstream in the duct. The measurement items are gas concentration in the air on the upstream and downstream sides of the tracer gas injection point and the injection rate of the tracer gas. As preconditions for this measurement, the tracer gas shall be sufficiently mixed at the point where the air is collected and the concentration distribution on the inner cross-section of the duct shall be lower than the accuracy of the measuring instrument. It is also necessary to use a gas that is not adsorbed onto the inner surfaces of the duct or sampling tube.

7.2.1 Formula

A fixed amount of tracer gas of known concentration is continuously injected into air duct, as shown in Figure 3, and the mass conservation law for the tracer gas is applied at a point sufficiently downstream from the injection position.

The flow rate in the duct can be obtained by Formula (6):

$$f_U = \frac{(C_I - C_D)}{(C_D - C_U)} \cdot f_I \tag{6}$$

The mass flow rate F_U can be determined by Formula (7):

$$F_U = \frac{(C_I - C_D)}{(C_D - C_U)} \cdot F_I \tag{7}$$

where

F_U is the mass flow rate in duct, in kg per hour;

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

F_I is the tracer gas injection rate (weight unit), in kilogram per hour;

f_I is the tracer gas injection rate (volume unit), in cubic meter per hour;

C_U is the volume concentration on upstream side of tracer gas, in cubic meter per cubic meter;

C_D is the volume concentration on downstream side of tracer gas, in cubic meter per cubic meter;

C_I is the volume concentration of injected tracer gas, in cubic meter per cubic meter;

ρ_I is the density of injected tracer gas, in kilogram per cubic meter;

ρ_U is the density of tracer gas on upstream side, in kilogram per cubic meter.

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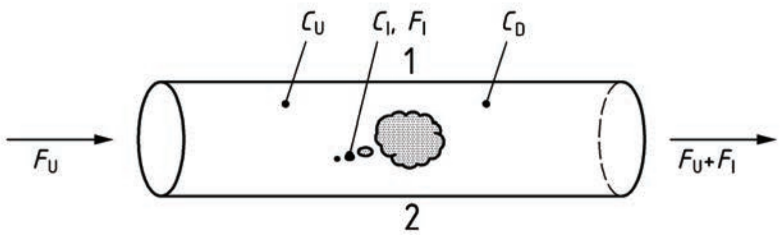

Key

1 sampling

2 tracer gas injection

Figure 3 — Concept of tracer gas measurement method for air flow rate in duct

7.2.2 Tracer gas

The tracer gas normally used for this measurement method shall not be a substance whose discharge into the atmosphere is prohibited and its concentration level during measurement shall not be toxic to humans. In comparison with the amount of tracer gas, the absorption and adsorption of tracer gas on the wall surface and in the sampling tube shall be negligibly small. For selection, see Annex C.

7.2.3 Procedures for measuring air flow rate

For the tracer gas method, the following procedures are used:

a) a fixed amount of tracer gas of known concentration is continuously injected into the duct;

b) at a portion where the gas is uniformly mixed downstream from the tracer gas injection point (more than 10 times the diameter of the duct), the tracer gas concentration is measured at a minimum N+1 points (Table 2) including one point at the centre of the duct cross-section and the centre of each area when the duct cross-section is divided into N areas (see Figure 4);

c) if return air is included in the duct system, fluctuation in concentration is expected upstream from the tracer gas injection point and thus, the concentration of N areas should also be measured upstream from the injection point to confirm that the distribution is small;

d) the tracer gas injection rate is recorded;

e) either the air flow rate or mass flow rate is calculated, as required.

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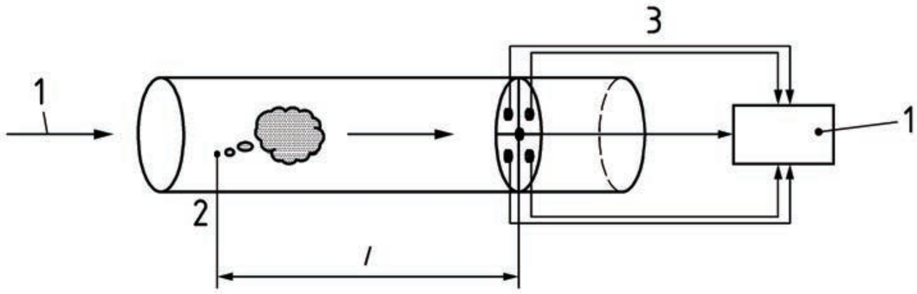

Key

1 air in duct/analyser

2 tracer gas

3 sampling

l for a straight pipe, the yardstick is more than 10 times the diameter; it may be shorter if there is a bend, etc. that enforce mixing

Figure 4 — Tracer gas injection and sampling position, example of a duct sectional area smaller than 0,2 m^2

Table 2 shows the “number of areas dividing a cross-section and number of sampling points” by the size of duct sectional area, obtained through error analysis to decrease measurement errors in the air flow rate in the duct.

Table 2 — Minimum number of sampling points downstream[7]

Duct sectional area m^2	Number of areas N	Number of sampling points N+1
0,2 or less	4	5
0,2 to 2,3	12	13
2,3 or more	20	21

7.2.4 Tracer gas injection procedures

The tracer gas is injected into the duct as follows.

a) The tracer gas is injected upstream away from the sampling point so that it is uniformly mixed in the duct or a portion is selected with one or more bends on the downstream side of the injection point and multiple injection points are used. When the injection is made into the supply air duct, care should be taken so that the tracer gas will not flow out through the peripherical clearance around the injection port.

b) A fixed amount of known concentration is injected. Using the orifice, mass flowmeter, or mass flow controller, etc., the flow rate of the tracer gas is adjusted to be constant. The instruments are calibrated so that both the error and deviation of the injection rate do not exceed 3 %.

c) The tracer gas is injected through one tube or via a manifold composed of multiple tubes connected to the flow measurement device. The flowmeter is calibrated with the gas to be used in advance.

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7.2.5 Tracer gas sampling procedures

The tracer gas is sampled as follows.

a) For sampling the tracer gas, one tube connected to a pump for concentration analysis is used. For sampling the air downstream and upstream from the tracer gas injection point in the duct, different tubes are used.

b) The sampled air is sent directly to the gas analyser or it is sampled using a syringe, sampling bag, or other proper container.

c) Prior to this measurement, concentration distribution at the sampling point is investigated as preliminary measurement. If the tracer gas is not sufficiently mixed in the duct or if the tracer gas concentration in the divided areas shown in Table 2 exceeds 3 % of the duct cross-section average concentration, mixing should be enforced using the following methods:

   1) move the sampling point to a point in the downstream direction as far away as possible from the tracer gas inspection point or enforce mixing by moving the sampling point to a downstream area with one or more bends;

   2) move the tracer gas injection point upstream away from the sampling point or promote mixing by moving the injection point to an upstream area with one or more bends;

   3) promote uniformity of the tracer gas by increasing the number of injection tubes or injection holes of each tube.

7.3 Flow hood method

7.3.1 General

Flow hood method measures the air flow rate by setting a flow hood (air flow meter with hood) to an air outlet or inlet at wall or ceiling surface. Although the air flow meter becomes itself as the resistance to the air flow, no pressure-loss compensation is made during measurement. This is, therefore, suitable for measurement when the flow velocity is low at 3 m/s or less.

7.3.2 Equipment composition

The equipment is composed of the following elements as shown in Figure 5:

a) hood element: catches supply/exhaust air;

b) measuring/indicator element: air flow rate is measured and indicated;

c) supporting element: supports the equipment.

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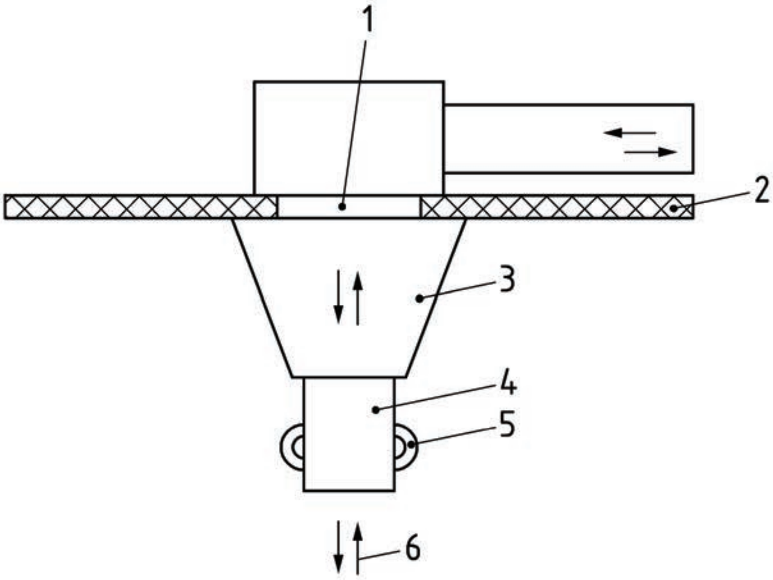

Key

1 inlet or outlet

2 ceiling

3 hood element

4 measuring/indicator element

5 supporting element

6 outlet: downward airflow

Figure 5 — Equipment composition of flow

7.3.3 Measurement procedures

Measurement is performed as follows.

a) The calibrated condition of the equipment is checked.

b) The equipment is connected to the diffuser or suction port in the wall or ceiling surface. Be careful not to create a gap.

c) The air flow rate is taken from the indicator portion of the measuring equipment. For the measured value, the instantaneous value are measured at least 10 s and the average value is calculated. Both a visual reading type and recordable type are available. To provide the air flow rate, Formula (3) is used.

If the size between the ventilation and measuring side does not match, measurement is difficult. Especially for a line type or large diffuser/exhaust port, measurement might not be possible. In such a case, repeat measuring at the separated ports or prepare new hood fitting in the shape of the port. In the case of drift, the measurement produces a large error.

7.4 Pressure compensation measurement method

This measurement method is a variation of the method using a hood. If the hood is applied in the case of a ventilation system with low static pressure, accurate measurement might not be possible due to pressure loss of the hood itself. With the pressure compensation measurement method, the air flow rate is measured by controlling the pressure using an auxiliary fan so that the pressure in the hood of the hood-type air pressure meter will be identical to the outside pressure. This measurement method will

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reproduce the air flow rate in a state without the hood installed to the ventilation system or the air flow rate in an ordinary ventilation state, thus allowing more accurate measurement.

7.4.1 Equipment composition

This method uses the hood-type air flow meter having the following functions (see Figure 6):

a) means to measure the pressure in the hood (differential pressure gauge such as a manometer for static pressure);

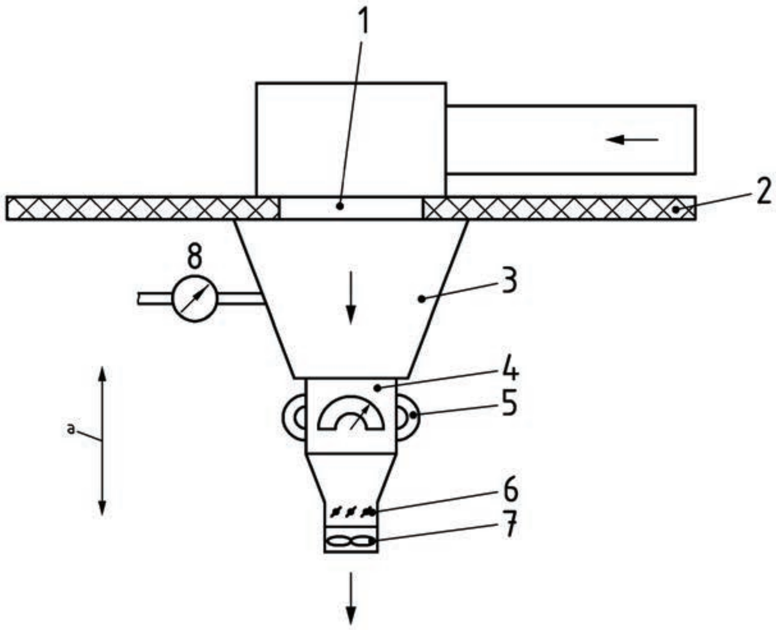
b) auxiliary fan capable of controlling the number of revolutions or means to directly adjust the air flow rate, equipped with an auxiliary fan and volume damper;

c) means to feed back the pressure in the hood and control the air flow rate to within a specified pressure range (either an automatic or manual method may be used for feedback control);

d) means to measure the air velocity and flow rate. For this, the Pitot tube or hot-wire anemometer may be selected;

e) the hood is made as large as possible (average air velocity in the hood is 1 m/s or lower) and the area of the section where air velocity is measured kept so small that the air velocity can be easily measured (air velocity of measured portion is 4 m/s or higher).

For the measurement, these functions are added to the existing hood-type air flow meter or the measurement system can be modified to realize the same functions.



Key

1 inlet or outlet
2 ceiling
3 hood element
4 measuring/indicator portion for flow rate
5 supporting element
6 damper for adjusting airflow
7 auxiliary
8 differential pressure gauge

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[a] Air flow rate of the auxiliary fan is controlled so that the differential pressure inside and outside the hood is adjusted to 0.

Figure 6 — Principle of pressure compensation method

7.4.2 Measurement procedures

Measurement is made as follows.

a) Before setting the equipment, the manometer for static pressure and for measuring the air flow rate should be checked to ensure that the differential pressure is 0 when the auxiliary fan is not in operation.

b) The hood part is brought into close contact with measured diffuser or inlet.

c) The auxiliary fan is operated and the rotational frequency of the auxiliary blower or air flow adjusting damper is adjusted so that the differential pressure of the manometer for static pressure is 0.

d) When the differential pressure of the manometer for static pressure becomes 0, the air flow measuring manometer or hot-wire anemometer is read.

7.4.3 Effective application range

With the pressure-loss compensation measurement method, measurement can be made without affecting the normal ventilation state. In the following cases, the application of this measurement method is much more effective. In these cases, any other methods would be difficult to apply.

a) The driving force of flow is relatively weak and if the air flow measuring equipment with hood, etc. is used, the air flow rate changes due to increased resistance of the passage.

   EXAMPLE Natural ventilation utilizing temperature difference or external air, air flow rate at the outlet, or inlet of passive ventilation systems.

b) Measurement of air flow rate at the opening for vent or inlet

   EXAMPLE Air flow rate in the exhaust port in a space where only supply fan is operated, air flow rate in the air intake in a space where only exhaust fan is operated.

c) Multiple diffusers or suction terminals are branched and connected, and if the air flow rate measuring equipment with hood, etc. is applied to one terminal for measuring the air flow rate, the resistance balance of the duct work changes.

7.5 Pressure difference measurement method

The pressure differential measurement method obtains the air flow rate by measuring the pressure differences between inside and outside of component, like as air terminal device where the relationship between the pressure difference inside/outside and air flow rate is clear. This method is often used by measuring pressure differences between two points inside the same component.

7.5.1 Measuring equipment

The measuring equipment comprises the following three components:

a) pressure difference meter;

b) tube for transmitting pressure;

c) air terminal device to be measured.

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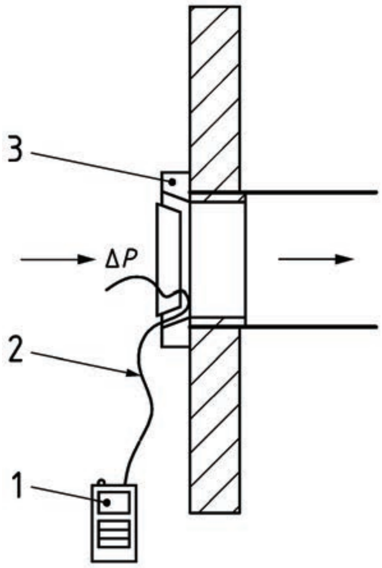
The pressure difference meter is used for converting the obtained pressure difference to the air flow rate. The pressure transmitting tube is used for connecting the measured portion and the pressure difference meter, and it is connected so as to prevent loosening between the two components. The inlet and outlet to be measured is employed in ductwork and it is provided in advance with point(s) for measuring pressure difference and the relationship between the pressure difference of the specified measuring point and the air flow rate is known. The measurement outline is shown in Figure 7 where the pressure difference inside the air terminal device and in the room is measured and converted to the air flow rate.



Key

1 pressure difference meter

2 pressure transmitting tube

3 measured inlet or outlet

Figure 7 — Concept of measurement by pressure difference measurement method

7.5.2 Selection of measuring instruments

In the case of ventilation equipment for a house with a low air flow rate, the differential pressure gauge should have a resolution of 1 Pa or less because the pressure difference in the measured component is difficult to distinguish and its mechanism should be capable of calculating the time average. The pressure difference meter shall be fixed in a stable and level position, and zero adjustment shall be made.

7.5.3 Measuring procedures

When this method is applied for a component, at least one measurement point inside the device is needed. And in the test room, multiple data should be obtained on the flow rate Q and pressure difference ΔP

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(pressure difference between the two measuring points in the component), and the values of k and n in Formula (8) are determined:

$$Q = k\Delta P^{n} \quad (8)$$

where

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

k is the flow coefficient in pressure differential method, in cubic meters per (hour $Pa^{1/n}$), referred to as k value [flow rate (cubic meters per hour) at pressure difference 1 Pa];

n is the constant determined by experiment, n = 0,5 to 1,0 (n = 0,5 is often used);

ΔP is the pressure difference between air control port inside/outside, in Pa.

8 Uncertainty

8.1 Uncertainty of each measurement

8.1.1 Multipoint air velocity measurement method

With the multipoint air velocity measurement method in the duct, a total measurement error of about 10 % is generally expected.[2][8] The results are used to investigate the uncertainty. For individual measuring instruments, the measuring accuracy described in each specification is expected or Annex B is used as a reference.

8.1.2 Tracer gas measurement method

The accuracy and errors of the measurement results depend on the accuracy of the tracer gas concentration meter, tracer gas concentration used, and position of sampling point. For the sampling position, therefore, it is important to select a place where the standard deviation of concentration at each point is less than 3 % or the mixed state is such that sampling can be maintained within the accuracy of the concentration meter or the gas monitor.

8.1.3 Flow hood method

For air flow meters sold on the market, the range for measuring the air flow rate is (0 to 4 000) m^3/h, and the air flow rate to be measured differs depending on the equipment size and shape. The resolution range is (0,1 to 20) m^3/h. The error is ±3 % to ±5 % for the largest scale.

8.1.4 Pressure-loss compensation measurement method

This method does not affect the ventilation rate of the system. Therefore, only accuracy of measuring instruments should be taken into consideration. Uncertainty of air flow velocity meters are provided in Annex B (provisions).

8.1.5 Pressure difference measurement method

The total measurement uncertainty is approximately ±10 %.

8.2 Analysis of uncertainty

Normally, errors are involved in all measurements. Even in the results for air flow rate and pressure of the ventilation system that are calculated using measurement data, it is clear that errors in approximate

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calculation processes are involved. Therefore, the errors of measured values or calculation results can be quantified by an analysis of uncertainty.

It is desirable to conduct an analysis of uncertainty for the air flow rates obtained in accordance with this International Standard and the analysis shall be conducted in accordance with ISO 5168.

9 Measurement report

The air flow rate of ventilation/air-conditioning systems is measured for various purposes, such as air flow adjustment during construction, completion tests, or confirmation inspection when the building is in use. Therefore, the details to be described in the measurement report differ depending on the purpose of the measurement, and so the verification process for the measurement results is clarified by the following items.

In preparing the measurement report, the following items are to be selectively applied in accordance with the purpose of the air flow rate measurement:

a) information related to measured object;

b) items related to measurement method;

c) measurement results.

9.1 Information related to measured object

The following information shall be described in the report:

a) name of building, location, building usage, floor area;

b) time/date of measurement;

c) information on measurer: name of measuring equipment/institution, address, contact, name of person in charge;

d) purpose of measurement: inspection during construction, confirmation inspection after air flow rate is adjusted, periodical inspection during use of the building, etc.;

e) information on ventilation/air-conditioning equipment: system diagram, design value of air flow rate, equipment specifications, installation position of equipment.

9.2 Items related to measuring method

a) Description of measurement made in accordance with this International Standard

b) Selected measuring method

c) Measurement position

d) Name of measuring equipment

9.3 Measurement results

a) Recorded data

b) Method of calculating the air flow rate of ventilation equipment and the results

c) Conditions to be recorded for ventilation equipment (e.g., variable air volume system and CO_2 control, etc.)

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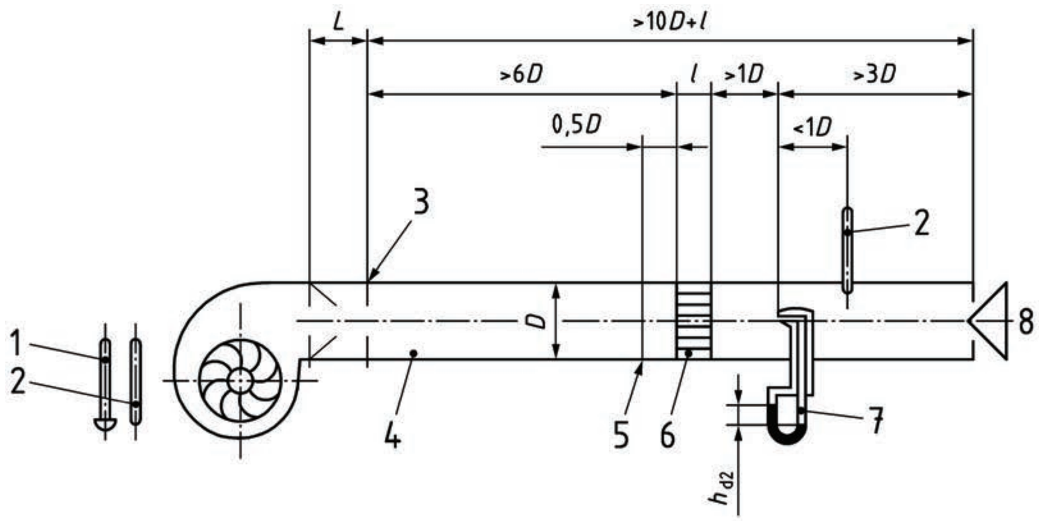
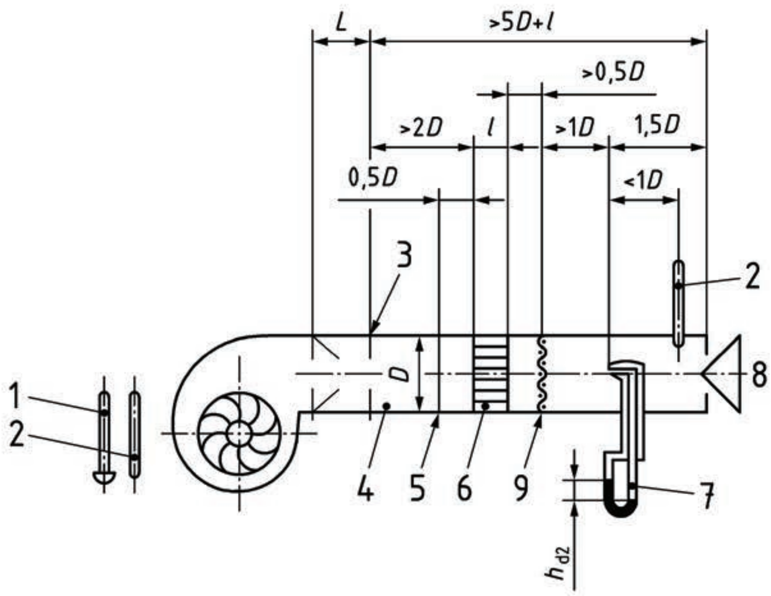
Annex A
(normative)

Position for cross-section measurement in a duct using multipoint measurement method

A.1 Position for cross section measurement

An example of the direct distance of the upstream and downstream sides of the measurement section is shown in Figure A.1. When a highly accurate measurement is required, use a straightening as shown in the figure.





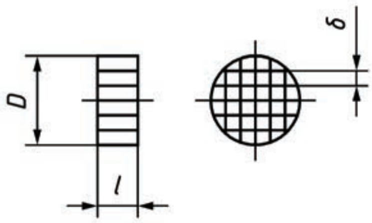
Key

1 barometer
2 thermometer
3 measurement duct line
4 connecting tube
5 static pressure measuring position
6 straightening
7 Pitot tube (air volume)
8 choke equipment
9 mesh

Figure A.1 — Position of measurement section (ISO 5801)

A.2 Straightening

The length δ of one side of the straightening grid shall be 1/4 to 1/12 of the inside diameter D of the measurement duct line as shown in Figure A.2 and the axial length l of the straightening shall be more than triple δ.



NOTE $l \geq 3\delta\ ;\ \delta = \left(\frac{1}{4} \to \frac{1}{12}\right) D$

Figure A.2 — Size of straightening grid (ISO 5801)

A.3 Wire grid

The opening ratio μ of the wire grid shall be 0,6 to 0,45.

μ shall be obtained from Formula (A.1):

$$\mu = \left(1 - \frac{d}{t}\right)^2 \tag{A.1}$$

where

d is the wire size of the mesh, in millimetre;

t is the pitch of the mesh, in millimetre.

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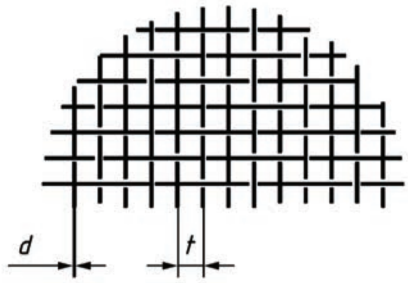

Figure A.3 — Wire mesh (ISO 5801)

A.4 Simplified measurement method

With the simplified measurement method, as shown in Figure A.4, five points are selected as the measuring points. The arithmetic average of the five points is used as the mean air velocity. If the required conditions are met, including securing the length of the straight-pipe, practical accuracy (approximately ±10 %) can be secured even with fewer measuring points. 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.

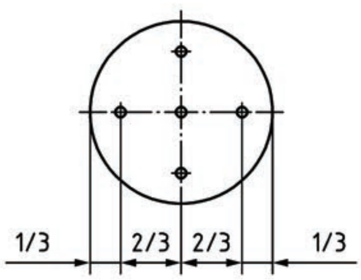

Figure A.4 — Position of measuring points in simplified measurement method

A.5 Measurement method at duct connection of air-conditioning system

When the amount of air introduced 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 drift at the connection on the suction side shown in Figure A.5. The measuring points of the air speed shall be according to 7.1.1.3 a), making 16 partitions or more with equal area and measuring at the centre point to obtain the average air speed. In this case, because the straight duct portion is short and the air often drifts, one

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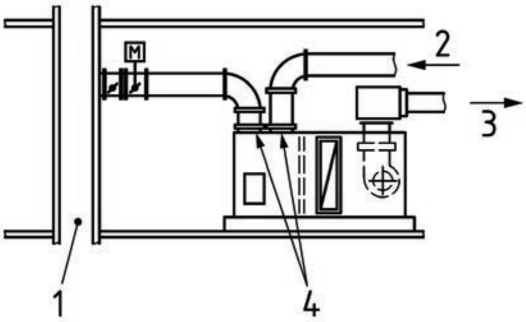
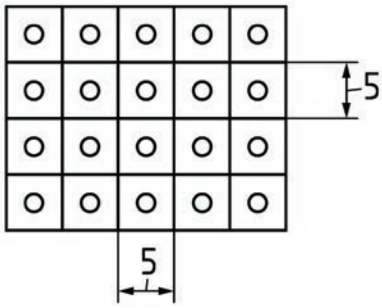
side of the partition shall be around 15 cm. It is not necessary to make more than 64 partitions. If the air velocity is not stable, consider applying the tracer gas measuring method.



a) Position of measurement of fresh air amount and return air amount in air-conditioner



b) Example of partitions of section and measuring points

Key

1 fresh air shaft

2 return

3 air supply

4 measuring position

5 around

Figure A.5 — Measurement at air-handling unit

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Annex B
(normative)

Accuracy of air velocity measurement instrument

For the accuracy of air velocity meter instrument for common ventilation system, refer to the values indicated in Table B.1.

Table B.1 — Measuring equipment and required accuracy

Air velocity meter	Measuring range	Accuracy of measurement
Thermal-type air velocity meter (Hot wire type and semiconductor type)	0,05 m/s to 40 m/s	±10 % rdg (Reading value) when 0,5 m/s or more
Pitot tube and precise manometer	3 m/s or more	±5 % FS (Full scale)
Vane-type air velocity meter	0,25 m/s to 50 m/s	±10 % rdg (Reading value)

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Annex C
(informative)

Types of tracer gas

The types of tracer gas to be used regularly for this measurement are indicated in Table C.1. Each tracer gas shall be the one that is not prohibited from being discharged to atmospheric air and has no toxicity for human body with the concentration level at the measurement. In addition, concerning the amount of tracer gas, the absorption and the adsorption of tracer gas on a wall surface or in a sampling tube shall be small enough to be ignored.

Table C.1 — Types of tracer gas

Type of gas	Helium	Carbon dioxide		Sulfur hexafluoride		Perfluorocarbon	Ethylene	Nitrous oxide
Chemical symbols	He	CO_2		SF_6		CF_4 (PFC-14) C_2F_6 (PFC-116)	C_2H_4	N_2O
Measurement method[a]	GC-TCD, etc.	Infrared gas absorption method	GC-ECD, etc.	Infrared gas absorption method	GC, etc.	GC-ECD, etc.	Infrared gas absorption, GC	Infrared gas absorption
Example of the minimum limit of detection	300×10^{-6}	1×10^{-6}	70×10^{-6}	0,001 $\times10^{-6}$	0,001 $\times 10^{-6}$	-	$0,1 \times 10^{-6}$	$0,1 \times 10^{-6}$
Permissible concentration Note[b]	-	$5\ 000 \times 10^{-6}$		$5\ 000 \times 10^{-6}$		-	-	25×10^{-6}
Density Relative against air [-]	0,138	1,545		5,302		Example: PFC-14:3,06 PFC-116:4,80	0,974	1,53
Globalwarming potential (GWP)[c]	-	1		23 900		Example: PFC-14:6500 PFC-116:9200	-	310
Remarks	Chemically stable	CO_2 is not suitable for accurate measurement because it dissolves in water and adheres to construction materials and furniture. However, because it is easy to measure and safe, CO_2 is often used when highly accurate measurement is not required. Be careful when there are residents because they can become the emission source of CO_2.		Because SF_6 has a high global warming potential, avoid using it in large amounts. SF_6 has a large molecular weight and is hard to mix with air. When it is heated to 500 °C, it generates toxic gas. Therefore, do not use it in a room where burning appliances are used.		Because PFC has a high global warming potential, avoid using it in large amounts.	Ethylene is easy to mix with air because they have a similar density. However, it is flammable gas and caution will be necessary for its handling it. The explosion limit is 2,7 to 36,0 [vol %].	Because N_2O has a high global warming potential, avoid using it in large amounts. N_2O dissolves in water and initiates a chemical reaction with aluminium. It fires at high temperatures. Because health might be affected, caution will be necessary not to exceed acceptable concentration.

NOTE In addition to the above, hydrogen, carbon monoxide, ethane, methane, octafluorocyclobutane, bromo-3 fluoromethane, dichloro-2 fluoromethane, dichloro-4 fluoromethane, etc. may be used as tracer gas. Be careful of toxicity, permissible concentration, safety, etc. when using each gas.

[a] GC in the table means the gas chromatography in general. GC-TCD indicates the use of the thermo conductivity detector as a detector. GC-ECD indicates the use of the electron capture detector.

[b] According to ASTM E2029.

[c] The global warming potential (GWP) is a relative greenhouse effect coefficient per weight using carbon dioxide as reference.

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