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Ventilation for buildings — Test procedures and measurement methods to hand over air conditioning and ventilation systems

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National foreword

This British Standard is the UK implementation of EN 12599:2012. It supersedes BS EN 12599:2000 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee RHE/2, Ventilation for buildings, heating and hot water services.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Ventilation for buildings - Test procedures and measurement methods to hand over air conditioning and ventilation systems

Ventilation des bâtiments - Procédures d'essai et méthodes de mesure pour la réception des installations de conditionnement d'air et de ventilation

Lüftung von Gebäuden - Prüf- und Messverfahren für die Übergabe raumlufttechnischer Anlagen

This European Standard was approved by CEN on 25 August 2012.

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Foreword

This document (EN 12599:2012) 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of an identical text or by endorsement, at the latest by April 2013, and conflicting national standards shall be withdrawn at the latest by April 2013.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 12599:2000.

The significant technical changes between this edition and the previous one are:

— the scope was modified so that the test methods and measuring instruments can be used before, during and after handing over instead of at the stage of handing over, and also in the frame of EPBD-measurements;

— the scope was modified so that EN 12599 does not exclude dwellings;

— the normative references have been updated;

— Table 1 now includes requirements for the cleanliness and leakage of the system;

— in Table 2, the uncertainty of the air flow rate has been reduced from ± 20 % to ± 15 % for each individual room and from ± 15 % to ± 10 % for each system;

— a formula to calculate the uncertainty of the measuring location τ_u has been added to Table E.4

— methods to measure the electrical power have been added.

According to the CEN/CENELEC Internal Regulations, the national standards organisations 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 checks, test methods and measuring instruments in order to verify the fitness for purpose of the installed systems primarily for handing over which will be partially performed before, during and after handing over.

This European Standard enables the choice between simple test methods, when sufficient, and extensive measurements, when necessary.

This European Standard applies to mechanically operated ventilation and air conditioning systems as specified in EN 12792 and comprising any of the following:

- air terminal devices and units,
- air handling units,
- air distribution systems (supply, extract, exhaust),
- fire protection devices,
- automatic control devices.

When the system is set, adjusted and balanced measurement methods described in this European Standard apply.

This European Standard does not apply to:

- heat generating systems and their control,
- refrigerating systems and their control,
- distribution of heating and cooling medium to the air handling units,
- compressed air supplying systems,
- water conditioning systems,
- central steam generating systems for air humidifying,
- electric supply systems.

This European Standard applies to ventilation and air conditioning systems designed for the maintenance of comfort conditions in buildings. It is not applicable in the case of systems for the control of industrial or other special process environments. In the latter case, however, it may be referred to if the system technology is similar to that of the above mentioned ventilation and air conditioning systems.

This European Standard does not include any requirements concerning the installation contract. However, in order to facilitate the application of this standard, the installation contract should refer to the provisions which are listed in Annex F.

The measuring methods in this European Standard can be used in the frame of the energy inspection of air-conditioning systems according to EU Directive 2010/31/EU "Energy performance of buildings Directive" (see EN 15239, EN 15240).

This European Standard may be used for residential and dwelling ventilation systems.

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 308, *Heat exchangers — Test procedures for establishing performance of air to air and flue gases heat recovery devices*

EN 1507, *Ventilation for buildings — Sheet metal air ducts with rectangular section — Requirements for strength and leakage*

EN 1822-1, *High efficiency particulate air filters (EPA, HEPA and ULPA) — Part 1: Classification, performance testing, marking.*

EN 12097, *Ventilation for buildings — Ductwork — Requirements for ductwork components to facilitate maintenance of ductwork systems*

EN 12237, *Ventilation for buildings — Ductwork — Strength and leakage of circular sheet metal ducts*

EN 12238, *Ventilation for buildings — Air terminal devices — Aerodynamic testing and rating for mixed flow application*

EN 13182, *Ventilation for buildings — Instrumentation requirements for air velocity measurements in ventilated spaces*

EN 13779, *Ventilation for non-residential buildings — Performance requirements for ventilation and room-conditioning systems*

EN 14239, *Ventilation for buildings — Ductwork — Measurement of ductwork surface area*

EN 15423:2008, *Ventilation for buildings — Fire precautions for air distribution systems in buildings*

EN 15726, *Ventilation for buildings — Air diffusion — Measurements in the occupied zone of air conditioned/ventilated rooms to evaluate thermal and acoustic conditions*

EN 15780, *Ventilation for buildings — Ductwork — Cleanliness of ventilation systems*

EN 60584-1, *Thermocouples — Part 1: Reference tables (IEC 60584-1)*

EN 60584-2, *Thermocouples — Part 2: Tolerances (IEC 60584-2)*

EN 60751, *Industrial platinum resistance thermometers and platinum temperature sensors (IEC 60751)*

EN 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications (IEC 61672-1)*

EN ISO 3740, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards (ISO 3740)*

EN ISO 3744, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane (ISO 3744)*

EN ISO 3746, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane (ISO 3746)*

EN ISO 3747, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering/survey methods for use in situ in a reverberant environment (ISO 3747)*

EN ISO 7726, *Ergonomics of the thermal environment — Instruments for measuring physical quantities (ISO 7726)*

EN ISO 11201, *Acoustics — Noise emitted by machinery and equipment — Determination of emission sound pressure levels at a work station and at other specified positions in an essentially free field over a reflecting plane with negligible environmental corrections (ISO 11201)*

EN ISO 12569, *Thermal performance of buildings — Determination of air change in buildings — Tracer gas dilution method (ISO 12569)*

ENV 13005, *Guide to the expression of uncertainty in measurement*

CR 1752, *Ventilation for buildings — Design criteria for the indoor environment*

3 Test and check procedure

The following steps shall be carried out in the given order:

a) completeness checks;

b) functional checks;

c) functional measurements;

d) special measurements;

e) report.

Functional checks and measurements on the system can be performed to a variable extent which is specified by means of 4 levels (see Annex C). The choice of a level should be agreed upon and be part of the installation contract.

The special measurements in accordance with Clause 7 and Annex E shall only be carried out when required and especially agreed.

A summary of the different tests and measurements is included in Table 1.

Table 1 — Summary of tests, measurements and report to verify the quality of the systems

Required Steps	Purpose	Activities	Annexes
Step a Completeness checks	To ensure that the ventilating and air conditioning system has been installed entirely in accordance with contract	1. Comparison of equipment with the installation list 2. Compliance with technical rules (contract and official) 3. Accessibility 4. Cleanliness 5. Balancing 6. Air tightness 7. Documents necessary for operating	Annex A With more specified information on the activities 1 to 7
Step b Functional checks	Verifying the operation of the system	1. Put system into use 2. Operation of components and system	Annex C Determination of extent Annex B Survey of performance of components and systems
Step c Functional measurements	Verifying on a statistical basis that the system achieves the values according to design	1. Determine which measurements and recordings are necessary 2. Extent of functional measurements, specified by means of classes A, B, C and D 3. Measurements 4. Accompanying measurements (see 6.4)	Annex C Determination of extent Annex D Measuring methods and measuring devices
Step d Special measurements (if necessary)	In case of doubts concerning the quality of parts of the system after application of steps a to c or especially agreed.	1. Determine which measurements and recordings are necessary 2. Determine uncertainty of the measurements 3. Measurements	Annex D + E Measuring methods and measuring devices and Special measurements
Step e Report See chapter 9		1. Report 2. Handing over the report	Annex A Example of completeness check report Annex I Examples of measuring protocols

4 Completeness checks

The completeness check is intended to assure that installation is done according to specification and in compliance with the relevant technical rules.

The following checks are included:

— Comparison of the delivered system with the specification, both with regard to volume and material and, if necessary, also with regard to characteristics and spare parts.

— Check of compliance with legal and specified technical rules.

— Check of the accessibility of the system especially with regard to operation, cleaning and maintenance according to EN 12097.

— Check of the cleanliness of the system as specified in EN 15780 also in respect to air handling units and system if especially agreed.

— Check that all documents necessary for operation are available.

— Check that the balancing has been done.

— Check that the air tightness test has been done.

A description of the completeness check is included in Annex A.

5 Functional checks

5.1 General

The purpose of the functional check is to prove the operation of installation in different operational conditions in compliance with the relevant technical rules and the specification. The check shows whether the particular elements of the system such as filters, fans, heat exchangers, coolers, humidifiers etc. have been properly installed.

5.2 Put system into use

Put the system in running, adjusted and safe condition.

Adjustment protocols and operation instructions shall be available.

5.3 Procedure

Functional checks shall be carried out on every kind of installed equipment.

Before starting the checks, a checklist shall be drawn up.

The extent of functional checks is defined in Annex C.

The locations for the checks shall be the subject of prior agreement by the parties concerned.

Instruction for the procedure and a list of usual functional checks are given in Annex B.

6 Functional measurements

6.1 General

The purpose of the functional measurements is to give proper assurance that the system achieves the design conditions and set points as specified.

When judging the results of measurements in a ventilated or air conditioned space the influence of physical characteristics of the building should be taken into account.

Functional measurements can take place at other conditions than design conditions. The measurements are allowed to be calculated into design conditions if the calculation is possible. (e.g. possible: heat exchanger, not possible: air flow pattern)

6.2 Range of functional measurements

Table 2 indicates which measurements and recordings are necessary for each type of ventilation and air conditioning system.

The extent of functional measurements is defined in Annex C.

Table 2 — Functional measurements

Measurement at		Total System	Central System/Appliance				Duct work	Room					
Parameters		Additional cleanliness test	Current drawn and power by the motor [D.6]	air flow *) [D.1]	air temperature *) [D.3]	pressure drop across filter [D.7]	ductwork leakage test [D.8]	supply air flow [D.1]	exhaust air flow [D.1]	supply air temperature **) and air temperature in the room [D.3]	air humidity [D.4]	sound pressure level [D.5]	Indoor air velocity [D.2]
Ventilation System	(F) Z	2	1	1	0	1	2	1	2	0	0	2	0
	(F) H	2	1	1	1	1	2	1	2	2	0	2	2
	(F) C	2	1	1	1	1	2	1	2	2	2	2	2
	(F) M/D	2	1	1	1	1	2	1	2	2	1	2	2
Partial air conditioning system	(F) HC	2	1	1	1	1	2	1	2	1	2	2	2
	(F) HM/HD/ CM/CD	2	1	1	1	1	2	1	2	1	1	2	2
	(F) MD	2	1	1	1	1	2	1	2	2	1	2	2
	(F) HCM/M CD/CHD /HMD	2	1	1	1	1	2	1	2	1	1	2	2
Air conditioning system	(F) HCMD	2	1	1	1	1	2	1	2	1	1	2	2

*) Outdoor air, supply and exhaust air

**) Depending on control principles, if relevant

Explanations
0 measurement not necessary
1 to carry out in all cases
2 to carry out only in the case of contracted agreement

Figures 0-2 indicate whether there has to be a test within the stage of functional measurements during the handing over. Some of the tests are already done by the installer prior to the handing over and the documentation shall be verified in the completeness check.

C cool
D dehumidify
F filter
H heat
M humidify (moisture)
Z without any thermodynamic air handling functions (zero)

6.3 Procedure

Before starting the functional measurement, the measuring locations shall be specified and the procedures and measuring devices shall be agreed upon and given in the technical documents.

The number of measuring points in a room should take into account the floor area and the measured parameters. At least one measuring position is required for measurements in rooms of area up to 20 m² ; larger rooms should be subdivided accordingly. For the measurements in the room, the measuring positions in the occupied zone shall be agreed between the parties concerned, preferably at positions intended for intensive occupancy.

With regard to the selection of the measuring instruments the overall uncertainty shall be taken into account. Calibrated devices shall be used.

The indoor climate factors and air flow rates, heating, cooling and humidifying performances, electrical characteristics and other design data shall be measured at the ventilation system design air flow rate. The permissible uncertainties of the measured values are given in Table 3.

Table 3 — Permissible uncertainty of the measurement

Parameter	Uncertainty*)
Air flow rate, each individual room	± 15 %
Air flow rate, each system	± 10 %
Supply air temperature	± 2 °C
Relative humidity [RH]	± 15 % RH
Air velocity in occupied zone	± 0,05 m/s
Air temperature in occupied zone	± 1,5 °C
A-weighted sound pressure level in the room	± 3 dBA
*) This European Standard does not define tolerances for the design values itself. The result is accepted when the design value is in the range of the uncertainty of the measurement.	

If the performance of the system requires closer uncertainties, this shall be specially defined in the documentation of the system. If product standards, national or local regulations require closer uncertainties, this shall be adhered to. All temperatures and heating or cooling performances shall simultaneously comply with the given uncertainties.

6.4 Measuring methods and measuring devices

6.4.1 General

Annex D provides information concerning measuring methods and devices which are adequate for the functional measurement.

In the case of measurements in ducts and air conditioning systems with negative pressure, measuring errors due to an infiltration by the measuring device opening of air shall be avoided.

In any case, the openings in the ducts have to be closed after measuring.

6.4.2 Measurement of the air flow rate

The air flow rate can be evaluated by different methods. Usually, it is calculated from the air velocity and the corresponding cross-section. The air velocity can be measured by means of an appropriate anemometer, Pitot Static Tube (Prandtl tube) or a pressure drop across a throttling device.

Air flow rates should be measured at an appropriate cross-section of a duct. As air velocity is seldom uniform, it should be measured at an appropriate number of locations in the cross-section and averaged for the mean velocity.

The total air flow rate of a system should preferably be measured within the air handling unit or fan casing with integrated measurement if equipment like inlet nozzles is available.

For air terminal devices, other methods (e.g. bag method, reference pressure methods or funnel measurement) can be applied. The air terminal devices with a low pressure drop should be measured by means of the compensation method or other methods with a non-significant pressure drop.

The different measuring methods and devices are described in D.1.

6.4.3 Measurement of the ductwork leakage

The leakage of the ductwork is important for the energy efficiency of the complete air conditioning system. The tightness class according to EN 1507 and EN 12237 shall be checked.

In large and complex air duct systems, the leakage can only be measured in a part of the system. The leakage measurement shall be performed while the duct is being installed and accessible.

After start of operation a second tightness test can be necessary, only if an irregularity happens during the start up. (In the case of a malfunction e.g. of fire dampers, the pressure can exceed the allowed pressure and damage the ductwork.)

The measuring methods and devices are described in D.8.

6.4.4 Measurement of the indoor air velocity

Indoor air flow is usually a turbulent flow. The air velocity varies from place to place within the room, the variations being random with regard to magnitude and direction. Therefore, an exact measurement of the air velocity is complicated. Generally, it is sufficient to measure the mean air velocity at selected positions (see D.2.1).

In rooms up to approximately 20 m² floor area, one measurement position is sufficient. Large rooms (e.g. landscaped offices) should be measured on the similar basis to the foregoing and positions in the occupied zone should be chosen where higher air velocities can be expected. Measurements should preferably be taken at positions intended for intensive occupancy, e.g. at the desk in an office.

The measuring methods and devices are described in D.2. More detailed information is given in EN 15726.

6.4.5 Measurement of air temperature

Air temperature measurements may be required in the room, at the exhaust air terminal device or in the duct.

When – due to high or low surface temperatures (windows, cooling/heating panels etc.) – thermal discomfort is suspected, it may be necessary to evaluate the operative temperature (see D.3.1).

The measurement of the air temperature is described in D.3.

6.4.6 Measurement of the air humidity

The measurements of the air humidity in the room provide information regarding the humidifying or dehumidifying operation of the system. In general, the relative humidity is measured. To calculate the absolute humidity it is also necessary to measure the air temperature at the same location.

The use of recording instruments is necessary. The recording period shall last for 24 h at least.

The measurement of the air humidity is described in D.4.

6.4.7 Measurement of the sound pressure level

The A-weighted sound pressure level shall be determined at places of work. Corresponding conditions within the room are given in CR 1752.

Outside the building, measurements of sound pressure level can be necessary at locations such as property boundaries or 0,5 m in front of a neighbouring open window taking account of any special conditions.

In all cases the background sound pressure level shall additionally be recorded when the system is not in operation. The measurement of the sound pressure level is described in D.5.

6.4.8 Measurement of the electrical power of the fan

The electrical power (including auxiliary) consumed is measured either directly by a power meter (watt-meter) or indirectly from the electrical work (kWh-meter) performed by taking the electric meter readings before and after the test for a measured period of time.

For three-phase motors the power is determined by the 2-watt-meter method. For single phase motors, the power is determined by the 1-watt-meter method.

Specific requirements shall be considered when a frequency converter is being used.

The measurement of the electrical power of the fan is described in D.6.

6.4.9 Measurement of the pressure difference at the air filter

Check that the filter is properly installed and is seated with no visible leaks.

The measurement of the pressure difference across the air filter is described in D.7.

6.5 Accompanying measurements

The following data can be determined and registered if required in order to record the operating conditions during the functional test:

— outdoor temperature and humidity,

— hot and cold water temperature at the distributor or at the air heater and air cooler,

— water flow rate in the hot water and cold water pipe system and

— pressure difference at the pumps.

7 Special measurements (see Annex E)

7.1 General

The measurements together with the appropriate measuring instruments can necessitate a considerable amount of work and associated costs. These require special contractual agreements which cover the nature and scope of performance.

Special measurements are appropriate where functional measurements are not sufficient to verify the quality of the system in the desired range of accuracy.

The programme of measurements, the parameters to be measured, the measuring instruments and the measuring points shall be agreed separately. The agreement should also cover the permitted uncertainty of the measured results. The agreement should be made before the particular system is installed. The work and cost involved in the measurements shall be commensurate with the requirements of the system. If the measuring uncertainty cannot be achieved for an acceptable cost, the client shall be informed with adequate notice before the measuring has commenced. The measurements should be performed only by persons possessing the necessary knowledge and experience.

The measurements can be restricted to equipment or components in the system.

It may be necessary to test the system during summer and winter operation.

The operating mode during the measurements should, where possible, reflect the agreed conditions. If this is not the case, it shall be possible to deduce the design data. For certain components (e.g. heat exchanger, cooler), it is necessary to convert the measuring results to the design data.

If operational or technical aspects do not permit a component or element to be measured when it is installed, then the item may be tested on a test bed.

When judging the results of measuring in an air conditioned space the influence of physical characteristics of the building should be taken into account.

For approval measuring instruments see E.1.

7.2 Parameters

The measurement of the parameters is described in E.2.

7.3 Measurements of components

7.3.1 Fans

7.3.1.1 Measuring

For testing a fan which forms part of an air-conditioning system the following data shall be determined:

— air flow according to E.2.4,

— total pressure difference according to E.2.1,

— pressure and temperature in the measurement cross-section according to E.2.1 and E.2.2,

— electric power according to E.2.7 and

— speed of rotation (rpm).

The speed of rotation is usually measured with a tachometer, a stroboscope, or a pulse counter.

7.3.1.2 Measurement uncertainty

The air flow and total pressure difference shall be converted by calculation to density ρ = 1,2 kg/m³. The assessment should take account of the installed situation and the inflow conditions.

The uncertainty shall be calculated in accordance with Clause 8.

7.3.2 Filters

7.3.2.1 Measuring

For testing an installed filter the following data shall be measured:

- air flow according to E.2.4,
- velocity distribution at the filter using the network measurement in D.1.2 (determination of the velocity profile for air flow measurements) and
- pressure drop according E.2.1.

Check that the filter is properly installed and is seated with no visible leaks.

For high efficiency particulate air filters of classes H and U, in accordance with EN 1822-1, evidence shall be provided that no leaks are present in the filter material, the joint between the filter and the frame and the frame itself.

Depending on the installed situation of the filter two methods can be used to test such filters:

- the oil thread test,
- the particle count method.

7.3.2.2 Measurement uncertainty

The uncertainty of the measurements of the air flow, air velocities and the pressure drop shall be calculated in accordance with Clause 8.

7.3.3 Heat exchangers

7.3.3.1 General

It is assumed that the characteristic curves of the heat exchanger (operation characteristic data) are available from which the heating or cooling of the air as a temperature difference or as a relative parameter (related to the maximum temperature difference) as a function of the other mass flow (e. g. water) - and the pressure drop on the air side as a function of air flow - can be seen.

For air coolers, designed such that water condenses, the characteristic curves, under consideration of the humidity precipitation on the entire cooling surface, are - also for wet operation - decisive. In this case, enthalpies shall be used instead of temperatures.

A heat recovery system is a type of heat exchanger, so the same rules as for heat exchangers apply analogously.

Regenerative heat recovery systems which also transmit air humidity (category III according to EN 308) are characterised not only by the heating but also by the humidification (returned humidity index). The returned humidity index is a dimensionless ratio of the latent heat regain. It is the ratio of two differences. The difference of the absolute humidity of the supply air and the outdoor air is divided by the difference of the absolute humidity of the extract air (leaving the room) and the outdoor air.

In general, not only the parameters determining the thermal performance and the pressure drop but also the uniformity of temperature over the duct cross-section after the individual heat exchangers shall be tested.

7.3.3.2 Measuring

The following parameters shall be measured:

- air flow and air temperature at inlet and outlet of the heat exchanger,
- maximum deviation of air temperature from a mean value at inlet and outlet of the heat exchanger and
- pressure drop of the air flow and the flow of heating medium or coolant.

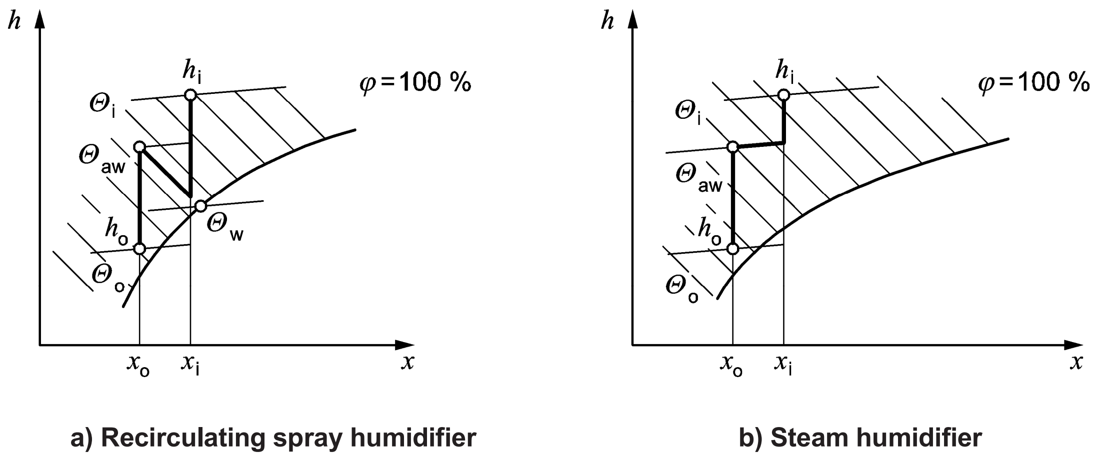
Additionally, the following should be measured:

- in the case of air heaters, the flow rate of the heating medium and its cooling, and the air humidity at the air terminal device,
- in the case of air coolers, the flow rate of the coolant and its heat gain, and also the reduction of humidity,
- in the case of heat recovery systems with humidity transmission (category III according to EN 308), the increase of humidity (return humidity index),
- in the case of regenerative heat recovery systems (categories II and III according to EN 308), the flow rate of the heat medium (e.g. also indirectly through the rotor rpm) and the power taken by the drive motor (e.g. for driving the rotor or a circulation pump).

If the characteristic curves are available, it is sufficient to measure at a single operating point.

If no characteristic curves are available and if the measured air flow rate differs greatly (> 30 %) from the design rated value, then the heating index (return heating index) or the cooling index should be measured with at least three different air flow rates and converted by calculation to the design operating point. During this time, the other mass flow rate shall be held within the design region (± 20 %).

Measurements on air heaters before and after the humidifier are basically performed together with the humidifier (see 7.3.4). It is not necessary to make separate measurements on the individual heat exchangers and on the concurrently operated humidifier. This assumes that with uniform temperatures at the air inlet to the air heater the temperatures at the air outlet from the air heater do not vary over the cross-section by more than 10 % from a mean value. In this case it is sufficient to measure the flow rate of the heating medium and its cooling at one of the heat exchangers. The heating power of the individual air heaters is calculated from the total heating power and the enthalpy differences taken from the "h, x - diagram", (see Figure 1).



Key

Θ_I supply air temperature (outlet of "post-heater")

Θ_{aw} air temperature at humidifier inlet

Θ_O outside air temperature (inlet of "pre-heater")

x_i humidity of supply air (outlet of "post-heater")

x_o humidity of outside air (inlet of "pre-heater")

h_i enthalpy of supply air (outlet of "post-heater")

h_o enthalpy of outside air (inlet of "pre-heater")

φ relative humidity

Θ_w water temperature

Figure 1 — Course of process in *h*, *x* diagram as example

The course of state of the air in the humidifier is given by the air temperature at the inlet and;

— in the case of spray or trickle humidifiers, by the wet-bulb temperature at the outlet (whereby for re-circulating humidifiers, quasi-adiabatic, operating in equilibrium it is sufficient to measure the water temperature instead of the air temperatures),

— in the case of steam or vapour humidifiers by the temperature of the steam or vapour.

If necessary, the thermal balance shall consider heat flows through duct walls or casings.

7.3.3.3 Measurement uncertainty

The uncertainty limits of the measurement shall be calculated in accordance with Clause 8.

7.3.4 Air humidifiers

7.3.4.1 General

For measurements on air humidifiers the same rules as for heat exchangers (see 7.3.3) apply analogously. The measurement shall be made together with the heat exchangers in the same test (see 7.3.3.2).

In the case of spray and trickle humidifiers it is assumed that the characteristic curves for the humidifier are available which show the humidification in terms of difference in the humidity content of the air or as a relative parameter related to the maximum difference of the humidity content and the pressure drop on the air side (including separator) as a function of the air flow rate. Additional characteristics apart from the design features such as number and arrangement of spray nozzles are the water flow and its pressure and temperature.

In the case of steam or vapour humidifiers the decisive parameters are the temperature, pressure and flow rate of the steam. In addition to these parameters, the degree of freedom from mist in the humidified air stream should be tested, characterised for instance by the necessary distance of certain filters or other components after the steam humidifier at various steam flow rates in relation to the air flow rate.

In addition to the steam flow rate and parameters determining the humidity, measurement should also be made of the uniformity of the humidity over the cross-section after the humidifier.

7.3.4.2 Measuring

Measurement should be made of the parameters listed in 7.3.3.2 for heat exchangers and also of the following additional parameters:

— for water humidifiers, the temperature and pressure of the water before the nozzles (in certain circumstances, e.g. in evaporation humidifiers, the circulating water flow instead of the pressure), and the power taken by the motor driving the circulation pump (if necessary, the sludge removal should be temporarily stopped),

— for steam or vapour humidifiers the temperature, pressure and flow rate of the steam,

— the parameters of state of the air before and after the humidifier using an "h, x - diagram",

— the maximum deviations of humidity of the air from a mean value at the outlet of the humidifier.

It is sufficient to perform the measurements only at a single operating point (set of operating conditions). If in the case of spray or trickle humidifiers no characteristic curves are available and if the measured air flow rate differs greatly (> 30 %) from the design rating value, then the measurements of humidity should be made at least at three different air flow rates and converted by calculation to the design air flow rate. In the case of a spray humidifier the water flow rate should be measured while in the case of a trickle humidifier the water flow rate is to be held within ± 20 % of the (warranted) design condition.

7.3.4.3 Measurement uncertainty

The uncertainty of the measurement shall be calculated in accordance with Clause 8.

7.4 Check of regulating, control and switching systems

7.4.1 General

To check the control characteristic and to be able to check that the control and regulation devices function correctly in conjunction with the corresponding controlled system, it is not sufficient to test the individual system devices, since successful control function depends not only on the transmission characteristics of the control device but also on the characteristics of the controlled system itself.

Sensors in pipes, chambers and air ducts shall have directly beside them a convenient measuring point, or preferably, shall be fitted with an appropriate indicating instrument to allow checking of the actual measured value.

In the case of pressure difference sensors or controllers having no indicating instrument, it is advisable to have at least two closable pressure connections for test measurements.

7.4.2 Controls

a) Direction of actuation:
The set value shall be altered in positive and in negative direction and a check made that the change in direction of the actuating element corresponds to the correct direction.

b) Set point:
For one or more set points (depending on specification) it shall be checked that – in adjusted condition – the actual value is in compliance with the set value. If P control (proportional control) devices are used, a specified load condition shall be determined.

c) Influence of master controls:
In case of master controls, it shall be checked that for a linear relationship the gradient, the direction of actuation and the operating point meet the requirements. In case of non-linear relationship, this curve shall be checked for agreed values.

d) Master cascade control:
Since the master cascade consists of two control loops, the pilot and the follow-up control, stability checks shall be made on each of these control loops.

8 Uncertainty of measurements

8.1 General

Every measurement is always subject to an uncertainty which arises from the layout and method of measurement, the measuring equipment and taking the reading. For a value calculated from measurements of several individual values the uncertainty of the resultant value is determined by applying the law of propagation of uncertainties of the individual values measured. It is assumed that the uncertainties are independent of one another and that each follows a normal Gaussian distribution. Thus, for instance, two randomly selected values might both have an uncertainty in the same direction. However, the uncertainty for each parameter will lie within the limits stated in the previous sections. If the operating data fluctuate during the measurement period, the effect of this on the measured results shall be taken into consideration. If necessary, measurements shall be repeated several times to determine the size of such effects.

The expression of uncertainties shall be done in accordance with ENV 13005. The measurement results should be expressed with an expanded uncertainty for probability coverage of approximately 95 %. When calculating the total uncertainty of the measurement based on different uncertainty values (e.g. Instrument, reading, method uncertainties etc.) each of the used uncertainties shall be based on the same probability coverage of 95 %.

8.2 Uncertainty of measuring devices

8.2.1 Instrument uncertainty (u_1)

Information on this uncertainty shall be supplied by the instrument manufacturer and it is important to check that the coverage probability of approximately 95 % is used.

Some instruments have an upper and lower uncertainty value (limit, $x \pm \Delta x$) and the uncertainty can in this case be judged to be rectangular distribute:

$$u_1 = \frac{\Delta x}{\sqrt{3}} \tag{1}$$

Corrections are known errors and not included in the instrument uncertainty. Correct the measurement values by using corrections from the calibration certificate.

8.2.2 Reading uncertainty (*u_2*)

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

For digital instruments, reading uncertainty is

$$u_2 = \frac{k}{2\sqrt{3}} \text{ of resolution,} \tag{2}$$

with a coverage factor k=2 for a probability coverage of about 95 %.

In case of digital pulse readout the uncertainty has to be estimated or an average function over time can be used for certain instruments. For instruments with an analogue display, the uncertainty can be estimated as *k*/6 of a scale interval (u_{2s}).

8.3 Uncertainty of measurement results

In determining the uncertainty of the measurement the following factors shall be considered:

- uncertainty due to influences at the point of measurement,
- reading uncertainty,
- uncertainty of mean values (if the parameter being measured fluctuates),
- uncertainty of the measuring equipment display (measuring equipment error),
- uncertainty in characteristics of substances, e. g. density and
- uncertainty in conversion.

The uncertainty limit of the primary parameters measured depends on the first four of the above listed sources of uncertainty. The individual sections of this standard give reference values for the uncertainty of measurement to be expected. As far as possible the measurement uncertainty should be estimated before taking the measurements, calculated on this basis and recorded in the measurement protocols.

Making use of the error propagation law the total uncertainty can be calculated from the uncertainties of the individual measured parameters as follows:

If the measured result *x* is formed from the sum or difference of several individual measured values x_i, for example

$$x = x_1 + x_2 + x_3 + ...x_i \tag{3}$$

then the total uncertainty u_y is calculated from the formula:

$$u_y = \pm \sqrt{u_1^{\ 2} + u_2^{\ 2} + u_3^{\ 2} + ... + u_i^{\ 2}} \tag{4}$$

Here u_i is the individual uncertainty (confidence limit).

If the measured result x is formed as a product or quotient of several individual measured values x_i for instance

$$x = \frac{x_1 \cdot x_2}{x_3} \tag{5}$$

then it is appropriate to use the relative uncertainty

$$\tau = \frac{u}{x} \tag{6}$$

This gives the total uncertainty as

$$\tau_y = \pm \sqrt{\tau_1^2 + \tau_2^2 + \tau_3^2} \tag{7}$$

If the measured result is formed from a power-function of several individual values, for instance

$$x = \frac{{x_1}^2 \cdot \sqrt{x_2}}{x_3} \tag{8}$$

then the total uncertainty is calculated by the formula:

$$\tau_y = \pm\sqrt{(2\tau_1)^2 + (\tfrac{1}{2}\tau_2)^2 + {\tau_3}^2} \tag{9}$$

8.4 Calculation of the error of the measuring equipment

The uncertainty of measured parameters is defined as the confidence limit of the total measurement uncertainty for a statistical confidence level P = 95 %.

The error limits (confidence limits) of the individual measuring devices are therefore found:

- by applying the rules for particular individual measurements (e.g. flow rate measurements),
- from the known error limits (accuracy classes) of measuring equipment, unless a calibration of the measuring equipment is available,
- in the case of calibrated measuring equipments from the stated test uncertainty and
- according to the general measuring experience.

An example for the uncertainty of measurements is included in Annex H.

9 Test Reports

9.1 General

When handing over the system a complete report according to 9.2 shall be provided.

However, in some cases special measurements have to be carried out after the handing over process if there is doubt on the proper performance of the installation. In addition, the fitness of installed system may be verified during the operation period for inspections or maintenance. According to the requirements of the inspection or maintenance the tests and measurements may only cover parts of the measurements necessary for handing over. The test report of these tests shall be done according to the handing over report in 9.2 whereas some of the parts of the inspections and measurements may not be present.

9.2 Handing over report

The handing over report shall consist of a

- general part,
- inspection report of the completeness check (see 9.3),
- inspection report on the functional check (see 9.4),
- report on the measurements results of the functional tests (see 9.5),
- report on the special measurements (see 9.6),
- summary of the test results.

Each part of test or inspection (9.3 to 9.6) shall be clearly identified and contain at least following information:

- dates and place of test/inspections,
- building or project reference,
- test personnel and witnesses.

The general part shall contain at least the following information:

- description on the building and systems;
- the agreed specifications;
- an overview of the agreed test extent:
  - mandatory tests,
  - a list of the agreed supplementary functional tests and special tests;
- measurement equipment used with their accuracy.

The summary of the handing over report shall summarise and evaluate the measurements and inspections and shall identify all necessary corrective actions. Each deviation from the specifications shall be documented with its severity and period for correction.

9.3 Inspection report on the completeness check

The inspection report shall contain a detailed evaluation of the completeness of the installed system particularly with regard to

- accessibility for operation and maintenance,
- cleanliness,
- balancing,
- air tightness test,
- safety and fire protection,
- insulation,
- marking and Type designation,
- damages.

The report shall also contain an evaluation of the completeness of the accompanying documentation (e.g. for operation and maintenance).

An example of a report of the completeness check is given in A.3.

9.4 Inspection report on the functional check

The report shall contain the results and evaluation of the functional check including the following:

- operation conditions,

- measurement devices used to check the function,
- check tests performed and physical responses observed,
- verification of reports concerning previously performed tests (e.g. balancing).

9.5 Test report on the functional measurements

The measuring protocols shall normally contain the following information:

- set points and permitted tolerances,
- operating conditions such as load, control settings and weather conditions which can influence the measurement results,
- measuring locations and measuring points and drawings if necessary,
- measuring instruments and measuring procedure,
- measuring values including date and time,
- uncertainty of measuring results,
- evaluation of the measurements (within or outside the permitted tolerances).

Examples of measuring protocols for the air-flow rate are given in Annex I.

9.6 Test report on the special measurements

The test report of the special measurement shall contain the same information as the test report on the functional measurements, see 9.5. It shall contain the agreed measurements, set values and agreed tolerances.

Annex A
(informative)

Completeness check

A.1 Documents

All relevant documents shall be available

A.1.1 List of agreed specifications:

- the performance of systems (for each functional part):
  - room conditions (summer, winter),
  - operating times,
  - indoor heating loads (duration, type),
  - other emission sources,
  - ventilation efficiency,
  - outdoor air rate at normal (minimum, maximum) or design outdoor air conditions,
  - number of occupants,
  - building physics (facades, windows, shading, roofs, air tightness, etc.),
  - indoor pressure ratios in relation to adjacent areas (+/-),
  - indoor air velocities,
  - A-weighted indoor sound pressure level and A-weighted sound pressure level at outdoor and extract air openings,
  - contamination class (basis for measuring),
  - filter grades/filter classes
  - basic meteorological data (summer/winter)
  - heating, cooling, electric energy,
  - design data for heat exchanger (summer/winter temperatures),
  - water quality,
  - pressure difference at the point of energy transmission,
  - voltage and frequency of electrical supply,
  - air tightness of ducts according to EN 13779,

  - location of measurement points,

- basic data for checking economic efficiency in order to optimise the operating cost at the time of planning:
  - energy cost,
  - operating times of systems per year,
  - return on investment/interest on investment,
  - personnel cost,
  - parameter for cost modification,
  - other basic data.

A.1.2 Inventory documents:

Inventory list with specifications for all components of the air conditioning system

- inventory drawings in agreed scale, coloured,
- connection diagrams of the air conditioning system including automatic control functions,
- control schemes including wiring diagram, pipework diagram (terminal wiring diagram),
- diagrams for all control systems including terminal wiring diagrams,
- approval certifications for special components (e.g. fire dampers),
- report by the installation company on the supervision to be carried out,
- result of tightness test, if required.

A.1.3 Documents for operation and maintenance:

- report that the operating staff - if available - has been instructed appropriately,
- operation and fault finding manual,
- maintenance instructions for all components of the system,
- spare parts list detailing all parts of the system subjected to wear and tear,
- list of the components of all automatic control equipment (sensing elements, controllers, regulators, contactors, cut outs),
- software documentation on programmable and digital automatic control systems.

A.2 Tests

A.2.1 General inspection of:

- accessibility of components for operation and maintenance,

- state of cleanliness of devices, of heat exchangers and of distribution system,
- arrangement and accessibility of openings for cleaning devices and ductwork,
- completeness of marking and type designation,
- performance of fire protection measures as planned (arrangement of fire dampers, fire-proof coatings etc.),
- arrangement of heat and steam-tight insulations as planned,
- corrosion protection of mounting and supporting constructions as per contract,
- vibrationless installation of devices, fixing of ducts etc.,
- measures of earthing at the devices and the duct system,
- check if the safety equipment is installed.

A.2.2 Balancing

- Check that the balancing of the system has been done.

A.2.3 Separate tests of:

A.2.3.1 Central devices, fans:

- checking whether the separate components are arranged logically,
- checking the nameplate rating (performance data),
- construction and performance (e. g. double casing),
- tightness test of the devices and the flexible connections by observation,
- installation of vibration absorbers,
- motor fixing,
- number of belts (including delivery of spare parts),
- belt protection,
- drainage with drain seal,
- checking the arrangement of fan blades (forward/backward bent),
- checking of fan speed and motor speed according to nameplate rating,
- checking of electrical connection of the fan.

A.2.3.2 Heat exchanger

- Checking the nameplate rating (performance data),
- checking the tightness within the casing,

- checking with respect to damage (e.g. wrong-bent lamellas),
- checking the material of the heat exchangers,
- checking of inlet and outlet direction at the water side connection,
- checking the installation condition of control valves,
- checking the mist eliminators with respect to damage,
- anti-freezing device at/within the heat exchanger.

A.2.3.3 Air filter

- Checking of filter system and its quality as per type designation,
- checking the installation and sealing to the casing,
- checking the filter system with respect to possible damage,
- checking the pressure difference indicator with respect to possible damage and fluid level,
- checking the set of spare filters (set as per contract),
- cleanliness check.

A.2.3.4 Air humidifier

- Checking the nameplate rating (performance data),
- checking the installation conditions including volume of the humidifying chamber,
- checking the completeness of separate components (pump, water level control,…),
- checking the drainage and make sure that no reverse flow of waste water can occur,
- checking the water (steam) distribution system.

A.2.3.5 Outdoor air inlet and exhaust openings

Inspection of size, material and design of the weatherproof louvre.

A.2.3.6 Multi leaf dampers

- Checking whether types, sizes, numbers and arrangement correspond to the design data.

A.2.3.7 Fire dampers

See EN 15423:2008, 5.6 for the requirements for components, installation and commissioning of fire dampers.

A.2.3.8 Ductwork

- Check that the air tightness test of the system has been done,
- spot check whether the performance of fittings complies with contract,

- check of sealing material,
- check the location of airflow measurement points,
- check the location of access panels (see EN 12097),
- check the fire resistance,
- check the thermal insulation,
- check the hangers.

A.2.3.9 Sound attenuator

- Checking whether types, sizes, numbers and arrangement correspond to the design data,
- checking the surfaces of the splitters in respect to damage.

A.2.3.10 Mixing section

Spot check in respect of correspondence to the design data.

A.2.3.11 Air terminal devices (supply air/exhaust air) and VAV dampers

- Checking whether types, sizes, numbers and arrangement correspond to the design data,
- checking the location of airflow measurement points.

A.2.3.12 Control devices and the electrical control cabinet

- Checking each closed loop of the control system with respect to its completeness as per control scheme,
- checking the arrangement of sensors,
- checking the completeness and arrangement of regulators,
- inspection of the electrical control cabinet in respect of performance in compliance with contract:
  - location, accessibility,
  - arrangement of power parts and regulating parts,
  - system of protection,
  - ventilation,
  - marking,
  - types of cable,
  - earthing,
  - connection schemes in the electrical control cabinet,
  - space reserve.

A.3 Test Report for the completeness check

Report of the completeness check according to EN 12599				
Building/ Project reference		Reference of installed system		
Responsible				
Company		Tel.		
Address		Fax.		
	Evaluation:	-: not applicable to the installed ventilation system 0: OK 1: minor deviation (has to be corrected) 2: major deviation (has to be corrected immediately)		
Ref. to EN 12599		**Applicable**	**Findings/Remarks**	**Evaluation**
A1	**Documents**			
A1.1	List of agreed specifications	YES		
A1.2	Inventory documents	YES		
A1.3	Documents for operation and maintenance	YES		
A2	**Tests**			
A2.1	General inspection	YES		
A2.2	Balancing			
A.2.3	Separate tests			
A2.3.1	Central devices / fans			
A2.3.2	Heat exchanger			
A2.3.3	Air filters			
A2.3.4	Air humidifier			
A2.3.5	Outdoor air inlet and exhaust openings			
A2.3.6	Multi leaf dampers			
A2.3.7	Fire dampers			
A2.3.8	Ductwork			
A2.3.9	Sound attenuators			
A2.3.10	Mixing section			
A2.3.11	Air terminal devices			
A2.3.12	Control devices and the electrical control cabinet			
Date and Place		Signature		

Annex B
(informative)

Functional checks

B.1 General

Functional checks should progress from equipment or components through subsystems to complete systems.

Components and subsystems should be operated through their specified modes of operation (e.g. heating/cooling, occupied/unoccupied, full and part capacity, emergency conditions as applicable). This should include interlocks and conditional controls, control sequences and simulation of abnormal conditions for which a specific system or control response exists.

The actual physical responses of system components shall be observed. Reliance on control signals or other indirect indicators is not adequate. The input and output actions of the control components shall also be observed in order to confirm that the components function correctly.

However, functioning of a controller can be checked by successively altering the set point in both directions while checking the action caused by the controller. If this check shows a defect, the physical input signal shall be checked.

The stability of the system as a whole shall be observed.

Verification of the report concerning previously performed tests, adjustments and balancing of the system should be included in the functional check.

B.2 Separate checks for components

B.2.1 Central devices, fans

- Direction of rotation of fans,
- speed or other air flow regulation of fans,
- reset switch,
- switch-on and switch-off of regulation and of damper control system,
- function of the anti-freeze system,
- direction of movement of multi leaf dampers,
- function and regulating direction of control devices,
- safety devices of the drive motors.

B.2.2 Heat exchanger

- direction of rotation of circulation pumps at the heat exchangers,
- control function at rotary heat exchangers,

— supply of heating and cooling medium,

— function and regulating direction of control devices.

B.2.3 Air filter

The pressure difference shall be indicated and monitored.

B.2.4 Humidifier

— feeding and drainage,

— function and sense of circulation pump,

— water tightness,

— condensation risk,

— control function.

B.2.5 Multi leaf dampers

— The direction and range of movement of actuators,

— sealing.

B.2.6 Fire and smoke dampers

Maintenance routine according to EN 15423:2008, 5.6.5 and EN 15423:2008, Annex C shall be applied.

— Testing the releasing device and releasing signal,

— testing of the direction, and limits of movement of the damper and indicator.

B.2.7 Mixing section

— Check the regulating and control functions of the dampers in accordance with the design.

B.2.8 Ductwork

— Make sure there is no vibration and loose parts.

B.2.9 Air flow pattern in the room as a function of the air terminal devices and geometrical obstacles

— Testing the function by spot check,

— smoke test (e.g. smoke tubes) for an initial evaluation of the air flow in the room and also for the indication of the air circulation at individual points within the room.

B.2.10 Control devices and switch cabinets

Spot check of the automatic control functions and lock-ins in different operational states by different set-point adjustments, in particular:

— set-point of indoor temperature,

— set-point of indoor humidity,

— starting switch,

— anti-freezing functions,

— regulation of air flow,

— heat recovery systems,

— interface with fire safety systems,

— fire dampers (release and signal).

Annex C
(normative)

Determination of the extent of functional checks or measurements

C.1 General

In the case of functional checks or measurements on a system, it can often be necessary to repeat the same procedure at different locations.

In order to reduce the amount of work, spot checks may be used.

This annex specifies a method to determine the required number of checks or measurements which shall be carried out in the above mentioned case.

The extent of checks or measurements should be specified before installation by means of one of the four levels A, B, C or D. Otherwise, level A shall be adopted.

These levels are independent of classes which concern other items such as comfort level etc.

Unless otherwise agreed, the level for functional measurements should be the same as for functional checks.

C.2 Parameters and similar locations

C.2.1 Parameter

The state of a system component (response to controls, operating condition etc.) which shall be checked, or physical quantities (e.g. temperature, air flow rate, current etc.), which shall be measured.

C.2.2 Similar locations

The parts of the building (rooms, zones), or the components of the system (fans, air diffusers, ducts, fan-coil units etc.) the functions of which are of the same kind and which involve actions of the same order of magnitude by the system.

C.3 Determination of the total number n of similar locations

For systems, building elements or components to be considered as similar, it is not necessary that they are identical nor that their parameters have identical values (nominal or real), e. g. all air diffusers of the same kind which serve rooms of comparable size and use are deemed to be similar locations for measuring the air flow rates.

If a parameter is maintained by the design of the system at the same value at a set of similar locations, one location only can be considered. For example, if the supply air temperature is controlled only by zone, it can be measured only at one location in every zone. Therefore, locations are judged to be similar or not separately for each given parameter and depending on the design and controls of the system.

In so far a system has been installed at the same time by persons working in a similar way, the total number of similar locations identified in the building shall be taken as n, even though similar sub-systems may be identified within the system.

For instance, if a 10-storey building is served by a separate air conditioning system on each floor, every one having 20 diffusers, the calculation shall be based on n = 200 diffusers.

C.4 Extent of checks or measurements

Checks and measurements shall be carried out at least on a number p, out of the total number n of similar locations. p is given by the curves in Figure C.1 as a function of n and of the levels A, B, C and D of the extent of the functional checks and measurements.

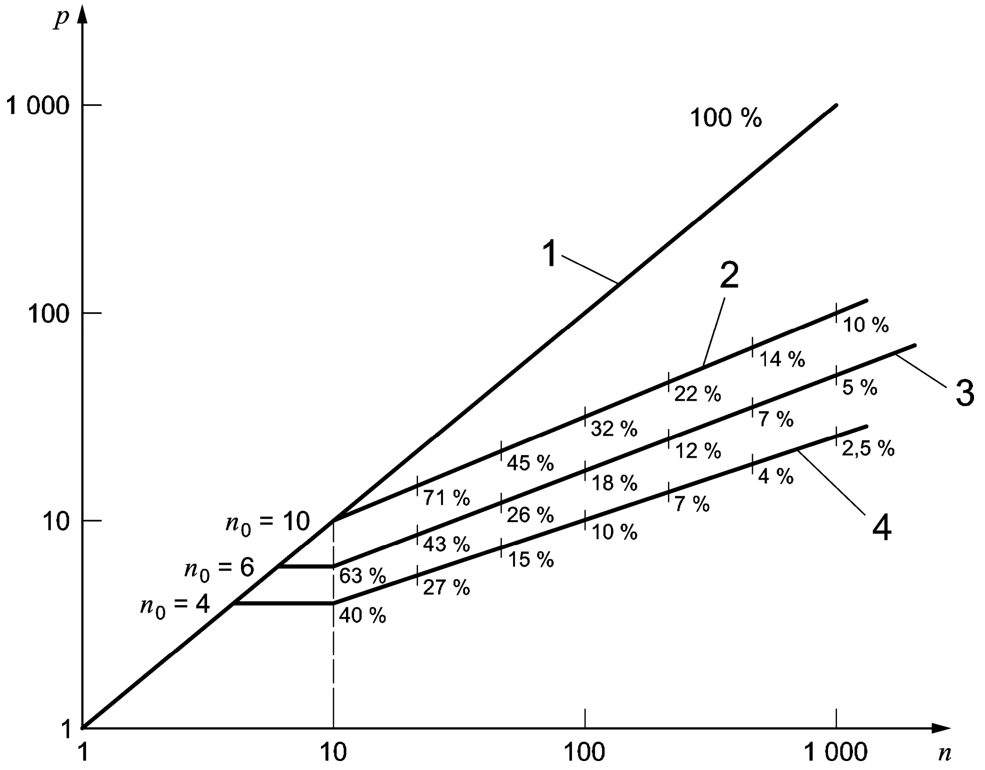
When adjustment of the systems is being checked for quality control purposes before handing over, the number of checks or measurements will generally be greater than given in Figure C.1.

If measurements are carried out in similar rooms, some parameters can be measured in a reduced number of rooms which is only a fraction of *p*. Table C.1 gives the number of the necessary measurements.

Examples for determination of the number of functional checks or measurements are given in Annex G.

Table C.1 — Number of measurements to be carried out as a fraction of number *p*

Parameter	Number of measurements	
	normal	minimum
Room air temperature continuously recorded over 24 h	*p*/10	1
Room air humidity continuously recorded over 24 h	*p*/10	1
Vertical temperature profile	*p*/10	1
Indoor air velocity	*p*/10	1
Sound pressure level	*p*/5	3



Key

1 Level D $p = n$

2 Level C $p = 3{,}16 \cdot n^{0{,}5}$

3 Level B $p = 2{,}23 \cdot n^{0{,}45}$

4 Level A $p = 1{,}6 \cdot n^{0{,}40}$

Formulae for levels A, B and C apply to $n \geq 10$.

Approximate percentages *p*/*n* are displayed on the graph. Numbers *p* shall be rounded off to the nearest integer.

Figure C.1 — Number p of similar elements to be tested among *n*

Annex D
(normative)

Measuring methods and measuring devices for functional measurements

D.1 Measurement of the air flow rate

D.1.1 General

The measurement can be carried out either

— in the duct cross-section or

— with calibrated throttle devices or

— in the cross-section of a chamber, fan-casing or device or

— at the air terminal devices.

If an appropriate measuring section (see Table D.1) is available, then the measurements shall be performed within the duct. If not, then cross-sections within the central unit or appliance can be used in order to determine the mean air velocity. This measurement may be used when a uniform flow and a clearly corresponding cross-section are given. Direct measurements at air terminal devices are only possible in the case of quite simple constructions (e.g. a nozzle with a known cross-section). An additional measuring device is usually necessary.

D.1.2 Measurement in the duct cross-section

D.1.2.1 General

In installed systems the requirement concerning an even velocity distribution over the cross-section of the duct is seldom fulfilled. In consequence, it is usually necessary to subdivide the cross-section into a sufficient number of fields by means of a "network measurement" in order to determine the mean air velocity from the measured velocities and the corresponding fields.

With regard to the network measurement the number of the measuring points is important in addition to the accuracy of the measuring devices. During the performing of the measurement it is necessary that the coordinates of the measuring points and the direction of the probe are exactly kept.

Attention shall be paid to the influence of swirling flow.

Table D.1 gives the minimum number of measuring points for the uncertainties 10 % and 15 % including an error of 5 % (10/5 or 15/5 according to Table D.1) or 10 % (15/10 according to Table D.1) of the measuring device as a function of the relative distance a/D_h.

The relative distance a/D_h arises from the ratio of a distance a between the measuring section and an upstream disturbance and the hydraulic diameter D_h [1)] of the duct at the measurement plane.

[1)] $D_h = 4\ A/U$, where A the cross-section and U the perimeter

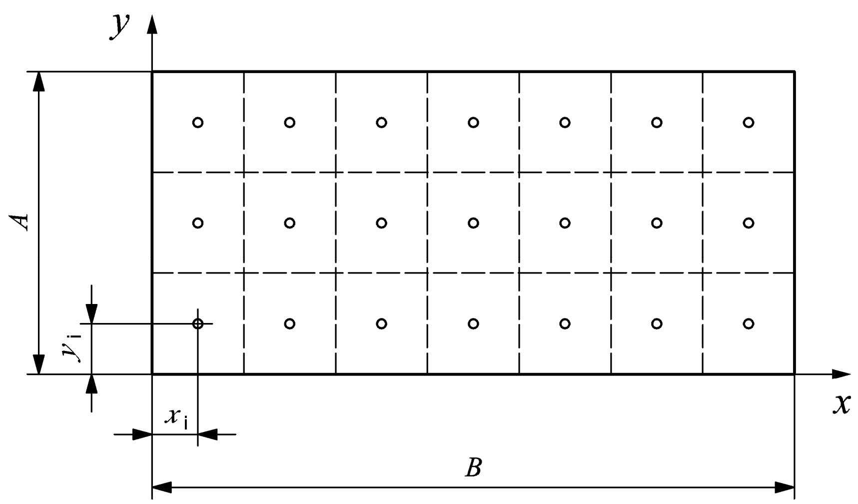
Table D.1 — Required number of measuring points as a function of the relative distance a/D_h from a disturbance and the relative uncertainty

Required number of measuring points			
Relative distance	Total uncertainty in %/uncertainty of the measuring device in %		
a/D_h	"10/5"	"15/5"	"15/10"
1,6		30	44
2,0	50	21	30
2,5	34	16	24
3,0	25	12	18
4,0	16	8	12
5,0	12	6	9
6,0	9	4	6

For determination of the measuring uncertainty for measurements within the duct cross-section see E.2.4.2 to E.2.4.4 and Annex H.

D.1.2.2 Method for rectangular ducts (simple method)

In rectangular ducts, the measurement cross-section should be divided into elements of equal area (see Figure D.1).



Key

x_i, y_i coordinates of the measuring points

A, B dimension of the duct

Figure D.1— Dividing a rectangular cross-section into measuring areas of equal size

The relative distance from the measurement point to the duct wall is then given by the following formula:

$$\frac{y_i}{A} = \frac{x_i}{B} = \frac{2i - 1}{2n} \tag{D.1}$$

where

y_i; x_i coordinates of measuring point

B width of air duct

A height of air duct

i ordinal number of the measuring point (on a measurement straight line)

n number of measuring points (on a measurement straight line)

The measurements are evaluated by taking the arithmetic mean of the individual velocity measurements in the measuring areas.

See also Table D.2.

Table D.2 — Relative wall distance of measuring points in a rectangular duct (simple method)

Number of measuring points for each measuring straight line	Measuring point *i*, $\frac{x_i}{B}$ *or* $\frac{y_i}{A}$									
n	1	2	3	4	5	6	7	8	9	10
3	0,167	0,500	0,833							
4	0,125	0,375	0,625	0,875						
5	0,100	0,300	0,500	0,700	0,900					
6	0,083	0,250	0,417	0,583	0,750	0,917				
7	0,071	0,214	0,357	0,500	0,643	0,786	0,929			
8	0,062	0,187	0,312	0,438	0,563	0,688	0,813	0,938		
9	0,056	0,167	0,278	0,389	0,500	0,611	0,722	0,833	0,944	
10	0,050	0,150	0,250	0,350	0,450	0,550	0,650	0,750	0,850	0,950

The term "simple method" covers all measuring methods in which special assumptions cannot be made about the velocity profile. The velocity field is measured point by point along any desired number of measurement lines. The number of measurement points depends not only on the geometrical size of the cross-section but also and decisively on the velocity profile. In regions of large velocity differences, the distance between measurement points should be smaller and the measurements should be appropriately differently evaluated.

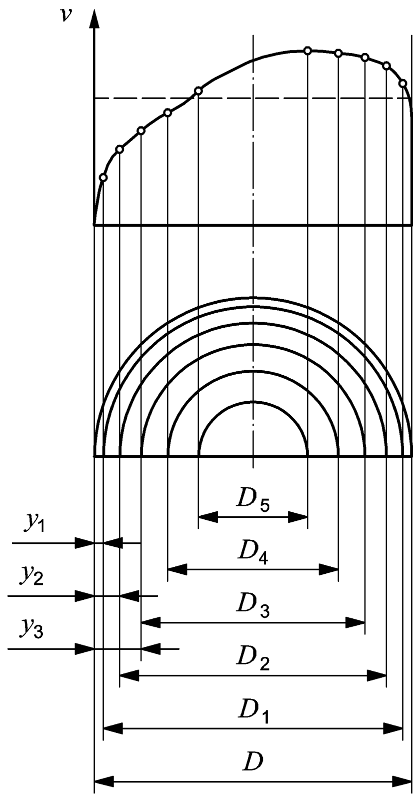
D.1.2.3 Method for circular ducts (centroidal axis method)

The velocity profile shall be determined at least at two diameters which are perpendicular to each other. The measuring points are chosen such that:

— each measurement corresponds to an annulus of equal area,

— if the velocity distribution is linear, the representative velocity does not lie on the centre line but on the centroidal axis of the annulus.

The measurements are evaluated by taking the arithmetic mean of the individual velocity measurements in the centroidal axes (see Figure D.2).



Key

D_i centroidal axis diameter

y_i distance from wall

v velocity

Figure D.2 — Dividing a circular cross-section into annular rings of equal area

The diameter of the centroidal axis D_i or the distance from the pipe or duct wall y_i shall be calculated from the following formulas:

$$D_i / D = \sqrt{1 - \frac{2i - 1}{2n}} \quad \text{(D.2)}$$

$$y_i / D = \frac{1}{2}\left(1 - \sqrt{1 - \frac{2i - 1}{2n}}\right) \quad \text{(D.3)}$$

where

D is the diameter of the outside circle

i is the ordinal number of the annular ring, starting from the outside

n is the number of annular rings

The centroidal axis diameter D_i or the distance y_i to the wall are summarised in Table D.3 as a function of the number of rings selected.

Table D.3 — Dividing up the circular cross-section into annular rings of equal area (centroidal axis method)

a) Relative wall distance of the centroidal axes y_i/D

n \ *i*	1	2	3	4	5	6	7	8	9	10
1	0,1464									
2	0,0670	0,2500								
3	0,0436	0,1464	0,2959							
4	0,0323	0,1047	0,1938	0,3232						
5	0,0257	0,0817	0,1464	0,2261	0,3419					
6	0,0213	0,0670	0,1181	0,1773	0,2500	0,3557				
7	0,0182	0,0568	0,0991	0,1464	0,2012	0,2685	0,3664			
8	0,0159	0,0493	0,0854	0,1250	0,1693	0,2205	0,2835	0,3750		
9	0,0141	0,0436	0,0751	0,1091	0,1464	0,1882	0,2365	0,2959	0,3821	
10	0,0127	0,0390	0,0670	0,0969	0,1292	0,1646	0,2042	0,2500	0,3064	0,3882

n Number of the centroidal axes
i Ordinal number of the centroidal axes (counted from outside)

b) Relative centroidal axis diameter D_i/D

n \ *i*	1	2	3	4	5	6	7	8	9	10
1	0,7071									
2	0,8660	0,5000								
3	0,9129	0,7071	0,4082							
4	0,9354	0,7906	0,6124	0,3536						
5	0,9487	0,8367	0,7071	0,5477	0,3162					
6	0,9574	0,8660	0,7638	0,6455	0,5000	0,2887				
7	0,9636	0,8864	0,8018	0,7071	0,5976	0,4629	0,2673			
8	0,9682	0,9014	0,8292	0,7500	0,6614	0,5590	0,4330	0,2500		
9	0,9718	0,9129	0,8498	0,7817	0,7071	0,6236	0,5270	0,4082	0,2357	
10	0,9747	0,9220	0,8660	0,8062	0,7416	0,6708	0,5916	0,5000	0,3873	0,2236

n Number of the centroidal axes

i Ordinal number of the centroidal axes (counted from outside)

D.1.3 Measurement with throttle devices

Components such as heat exchangers, sound attenuators, perforated metal sheets, etc. can be used as calibrated throttle devices provided there is a clear and definite relationship between the air flow rate and the pressure drop, and the same air inflow and outflow conditions exist when installed as during calibration.

D.1.4 Measurement in the cross-section of a chamber, the fan-casing or device

This measurement should be done preferably with integrated equipment (fan-casing with measurement in the inlet cone).

In other cases, this measurement is only permitted, if the impact on the air flow caused by the person or the measuring device and the impairment of the measuring cross-section (e. g. at the cooler, heater and filter) are negligible. The cooler or the heater should not be in operation because an irregular distribution of temperature can cause additional errors. Moreover, the direction of the flow shall be verified and an even flow shall exist. The measuring cross- section shall be subdivided again into fields.

The measuring locations shall be determined such that velocities are representative for the chosen field.

D.1.5 Measurement at the air terminal devices

D.1.5.1 General

Where air terminal devices are equipped with calibrated air flow measurement units (e.g. certain types of plenum boxes), the air flow can be determined by using this calibrated units.

The distribution of the velocity at air terminal devices is so irregular that a determination of the air flow by means of the network measurement is not possible. However, this method can be used in the case of simple geometrical cross-sections like nozzles.

In the case of air terminal devices with a sufficiently high pressure drop it is possible to determine the air flow by means of a pressure measurement, if a characteristic relation between air flow and pressure is available which has been determined by the manufacturer on the test bed. In this case, the air terminal device represents a calibrated throttle device.

D.1.5.2 Measurement using the effective area A_k - method

The principle of the method is given in EN 12238.

For a given Air Terminal Device (ATD), this method gives:

— A_k: effective area of air terminal device in m²,

— i: location of the air velocity measuring device from the ATD giving the average value v_k in m/s.

On site, the air flow rate q_v for a given ATD is

$$q_V = v_k \cdot A_k \tag{D.4}$$

— measure n values v_{ki} (i from 1 to n) in accordance with the methodology given by the manufacturer, calculate the average $v_k = (\Sigma\ v_{ki}) / n$

— calculate q_v with the given value of A_k.

Uncertainty of the measurement:

— the uncertainty for the parameter A_k is less than ± 5 % (see EN 12238),

— the uncertainty for the parameter v_{ki} follows the general requirement of this standard ± 10 %,

— it follows that the uncertainty for the parameter q_v is ± 11 %.

D.1.5.3 Bag method:

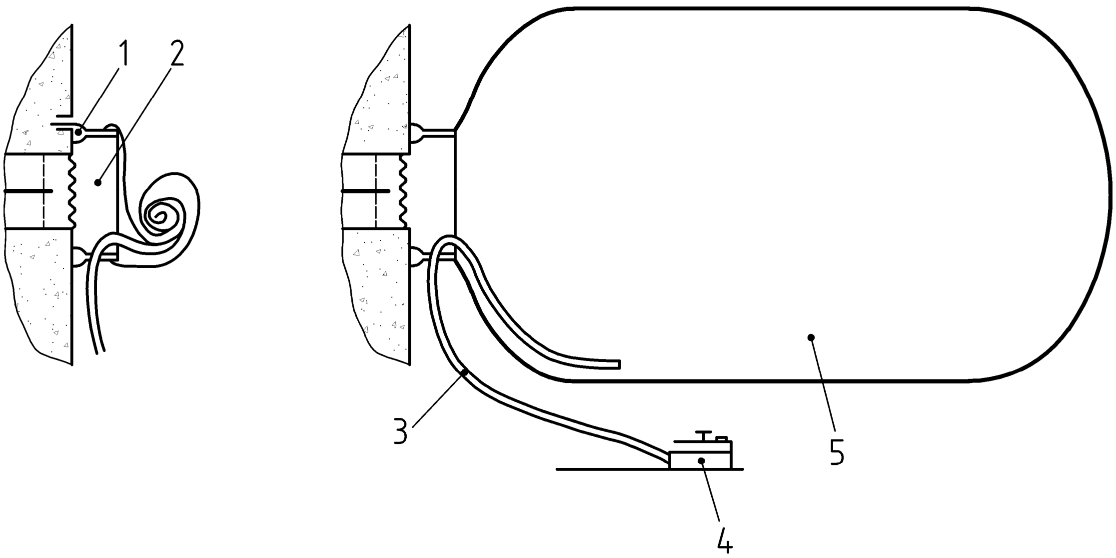
The method illustrated by Figure D.3 for measurement at supply air terminal devices implies that a rolled-up measuring bag, of a certain volume and mounted upon a frame, is placed over the device so that this is completely covered. The time that elapses until the bag is filled with air to a certain overpressure is measured. The airflow rate q_v is then obtained from the formula:

$$q_V = \frac{V}{t} \qquad \text{(D.5)}$$

where

V is the volume of the measuring bag in m^3

t is the filling time in s



Key

1 sealing

2 frame to which the plastic bag is fastened

3 measuring tube connected to micromanometer

4 micromanometer

5 plastic bag, thickness of material 0,03 mm to 0,04 mm

Figure D.3 — Scheme of measurement in accordance with the bag method

The pressure drop for the air terminal device shall be greater than 10 Pa when installed in a ceiling and 50 Pa for air terminal devices in walls.

Filling time to an overpressure of 3 Pa is noted. If the filling time is under 10 s, the measurement shall be repeated with a larger bag. If such a bag is not available, the measurement should be repeated two or three times. In this case, the measurement uncertainty can be significantly higher.

The error of the measuring method depends on the calibration of the plastic bag volume and the fastening of the frame over the device. Laboratory measurements have shown that an error of ≈ ± 6 % can be set.

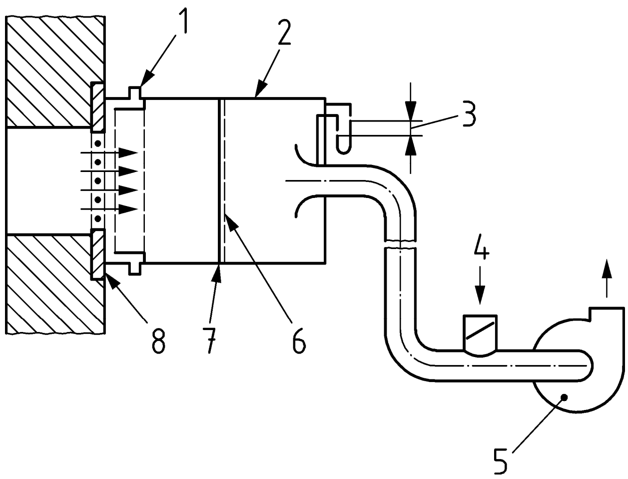
D.1.5.4 Funnel measurement

Measuring funnels with built-in hot wire element (direct reading funnel) or in conjunction with hot wire probes, Pitot or Pitot Static tube (Prandtl tube) probes or vane anemometer probes are used for measurements at air terminal devices. In case of high requirements on accuracy the compensation method should be used. Preferably funnels with a large free cross sectional area resulting in a low pressure drop should be used to minimise the influence on the measured device by the funnel.

Uncertainty according to the manufacturer of the device

D.1.5.5 Compensation method

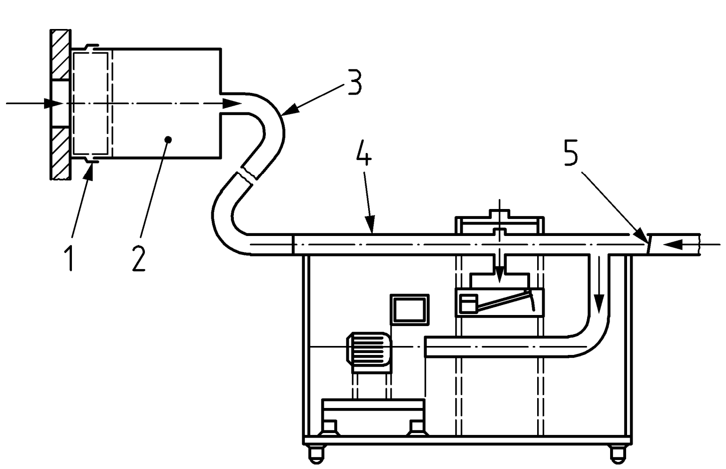
The air flow through a ventilation opening can be measured by the compensation method (zero method). To do this, a measurement chamber is connected to the ventilation opening. An auxiliary fan blows air into (or sucks air from) the measurement chamber through an air flow measuring device (see Figure D.4). The fan pressure is adjusted until the static pressure in the chamber equals the environmental pressure (pressure membrane). The air flow can alternatively be measured by a gas meter or a floating-body measuring equipment.



Key

1 pressure membrane
2 measuring chamber
3 Δp nozzle
4 bypass
5 auxiliary fan
6 material sieve
7 perforated plate
8 connection plane

a) Air flow measuring device with intake nozzle



Key

1 pressure membrane

2 measuring chamber

3 flexible connection

4 measuring section

5 bypass damper

b) Air flow measuring device with cover plate

Figure D.4 — Examples of air flow measurements using the compensation method

The following relations on the cross-sections should be fulfilled for a low uncertainty especially for measurements at radial or tangential supply outlets:

— exhaust air terminal device $A_{MC} > A_{vo}$ (D.6)

— supply air terminal device $A_{MC} \geq 10\ A_{vo}$ (D.7)

where

A_{vo} is the area of ventilation opening

A_{MC} is the cross-section of measurement chamber

D.1.5.6 Measurement of reference pressure

The method is mainly applicable for traditional exhaust air terminals (control valves). If an adequate specification of the manufacturer of the supply air terminal device is available the reference pressure method is also suitable for such devices. A measurement probe is placed at a location in the terminal specified by the manufacturer where a pressure (p_u) is measured. The principle is illustrated in Figure D.5a). With information on the terminal's settings a, the air flow can subsequently be determined either by means of a graph (see Figure D.5b)) or a k-factor.

Uncertainty according to the manufacturer of the device

The following formula is used when the principle of k- factors is applied:

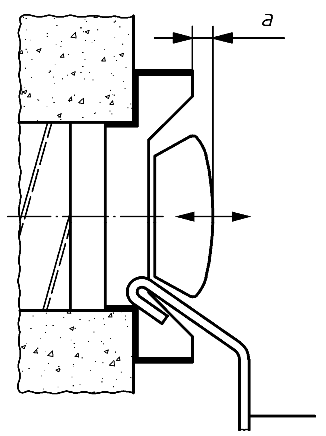
$$q_v = k \cdot (p_u)^n \quad \text{(D.8)}$$

where

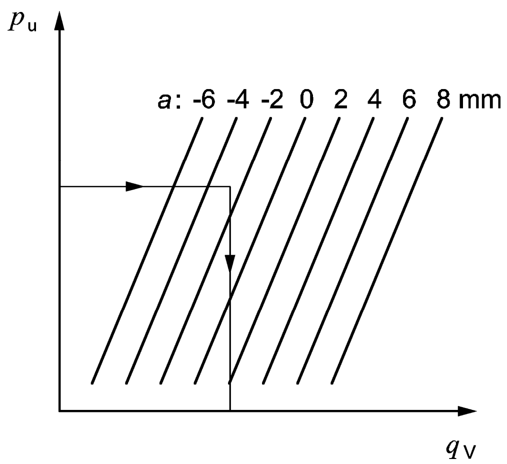
k is obtained as a function of the terminal's setting.

n exponent which has to be given by the manufacturer (normal range: 0,5 – 1,0)

p_u pressure



a) Measurement probe connected to the manometer



b) Graph showing air flow as a function of measured pressure

Key

a representative distance (terminal's setting)

Figure D.5 — Measurement of reference pressure

D.1.6 Measuring devices (Examples)

a) Throttle devices:
In the case of measurements by means of standardized or calibrated throttle devices, liquid pressure gauges (e.g. U-tube, vertical tube, projection, micro and compensation inclined pressure gauges) or electronic pressure gauges are used.

b) Pitot or Pitot Static tubes (Prandtl tube):
Local velocities in the duct can be measured by means of probes in conjunction with liquid pressure gauges, digital manometers or direct reading probes. The Pitot Static Tube (Prandtl tube) is primarily used as a probe. In conjunction with high resolution manometers the lowest allowed velocity shall be calculated from the given resolution of the pressure measuring device. If Pitot tubes are used, additional devices to measure the static pressure are necessary.

c) Vane anemometers:
Vane anemometers can be used in the case of velocities at or above 1 m/s.

d) Hot-wire anemometer and thermal probes:
The field of application begins at a velocity of 0,2 m/s. Thermal probes are particularly suitable for measuring low velocities (< 3 m/s).

e) Bag method:
For the bag method a stopwatch/clock and high resolution manometers have to be used.

D.2 Measurement of the indoor air velocity

D.2.1 Measuring methods

Because the permissible mean indoor air velocities are given as a function of the turbulence intensity (and the air temperature), it is necessary that mean air velocity and turbulence intensity are measured. If, however, the curves for a turbulence intensity higher than 40 % are used, only mean air velocity needs to be determined.

Due to the various magnitudes of the velocity fluctuations different measurement times are necessary. Generally, a measurement period of 100 s is sufficient. For every fifth measurement point, the measurements should be repeated. For room air velocities with large fluctuations a measuring time of 180 s is required. Fluctuations are deemed large, if the means of two consecutive measurements at a single measurement point differ by more than 10 %.

The air temperature shall be measured at all measurement points. Supply air temperature should also be measured.

Attention should be given to:

— position of sun shade blinds,

— temperatures of windows, walls, floor, ceiling,

— occupation of the room,

— distribution of casual and other heat sources (lighting, machines),

— control systems (maintain steady conditions during the measurement),

— air leakage of the room enclosures,

— type and location of furniture, fittings, machines etc.,

— estimation of the thermal load in the room.

For more information, see EN ISO 7726 and EN 13182.

D.2.2 Measuring devices

The indoor air velocity should preferably be determined by means of an omnidirectional probe which is sensitive to the velocity from whatever direction.

For more information see EN ISO 7726.

Table D.4 gives the requirements for air velocity v_a measuring devices.

Table D.4 — Requirements for air velocity measuring devices

Measuring range m/s	Uncertainty m/s	Time constant (90 %)	Directional sensitivity	Comments
0,05 - 1	± [0,05+0,05· v_a]	0,2 s if fluctuations are measured 2 s if no fluctuations are measured	omnidirectional, see EN 13182	The probes shall be calibrated in a calibration duct with unidirectional low-turbulent flow. The relative standard deviation of the fluctuations as a function of time shall be less than 5 %. Calibration with laser anemometer can also be used. The change in measured value due to air temperature fluctuation within ± 4 K shall be negligibly small.

The accuracy of the results of measurement of room air flow using the measurement methods described depends mainly on the differing properties of the measurement probes and on the systematic error of the measuring equipment. The probes shall meet the minimum requirements and be regularly calibrated.

D.3 Measurement of air temperature

D.3.1 Measuring methods

When measuring the air temperature precautions shall be taken in order to reduce the effect of thermal radiation and inertia of the probe (see EN ISO 7726).

A thermometer placed in a given environment does not indicate the air temperature instantaneously but needs time to reach equilibrium. A measurement should not be made before a period has elapsed equal to at least 1,5 times the time constant (90 %) of the probe.

A thermometer will respond more rapidly

— the smaller and the lighter the sensor element is and the lower its specific heat,

— the better the thermal exchanges with the environment (increasing the coefficient for convective heat transfer).

For measuring temperatures in pipes or ducts containing a non-uniform temperature distribution, network measurements shall be employed.

For determination of the radiant temperature see EN ISO 7726.

The operative temperature θ_o is the uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment. In most practical cases where the velocity is small (< 0,2 m/s), or the difference between radiant and air temperature is small (< 4 °C), the operative temperature can be calculated with sufficient approximation as the mean value of the air temperature (θ_a) and the mean radiant temperature (θ_r). For higher precision, the following formula may be used:

$$\theta_O = A\theta_a + (1 - A)\theta_r \qquad \text{(D.9)}$$

where *A* can be determined as a function of the air velocity v_a (see Table D.5).

The mean radiant temperature (θ_r) is the weighted average temperature of the surrounding surfaces.

Table D.5 — Values of A as a function of the air velocity v_a

v_a m/s	*A*
< 0,2	0,5
≥ 0,2 < 0,6	0,6
≥ 0,6 ≤ 1,0	0,7

D.3.2 Measuring devices

See EN ISO 7726.

D.4 Measurement of the air humidity

See EN ISO 7726.

Hygrometers shall be frequently checked, cleaned and recalibrated. They require long adjustment periods.

All humidity measuring equipment shall be protected from dirt and impurities, and should be tested for accuracy prior to measuring. Table D.6 shows the error limits for the various types of humidity measuring equipment. The error limits quoted can only be attained, if the equipment is properly used and carefully maintained.

Table D.6 — Error of humidity measuring devices

Measuring device	Measurement range		Uncertainty	
	Relative humidity %	Air temperature °C	Dew point K	Relative humidity*) %
Hair hygrometer	> 40	- 10 to 50		5
Electrolysis hygrometer	> 20	- 40 to 100		3
LiCl hygrometer	> 10	- 10 to 50	0,5 to 1	1 to 3
Dew point mirror hygrometer	> 0	- 20 to 40	0,5	1 to 2
Psychrometer	> 0	- 10 to 60	0,3	0,5 to 2
Capacitive meters	> 0	- 40 to 110	0,3	2 to 3
*) Additionally also heavily dependent on the state of the air; the values quoted apply only in favourable circumstances and may be exceeded.				

D.5 Measurement of the sound level

See EN ISO 3740, EN ISO 3746 and EN ISO 3747.

The measuring devices shall comply with EN 61672-1.

D.6 Measurement of the electrical power of the fan

D.6.1 Measuring method

The voltage and the current drawn by the motors of the air handling units shall be measured after the last fuse for each phase.

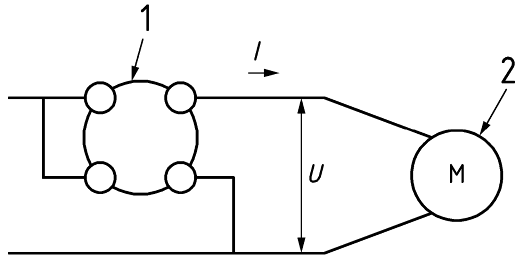
The electrical power consumed is measured either directly by a power meter (watt-meter) or indirectly from the electrical work (kWh-meter) performed by taking the electric meter readings before and after the test.

Before measuring the setting of the motor safety cut-out should be checked. For DC- motors, the power is determined by measuring the voltage (U) and the current (I).

The electrical power is

$$P_e = U \cdot I \tag{D.10}$$

For AC single-phase motors (see Figure D.6), the electrical power is determined by the watt-meter method



Key

1 wattmeter

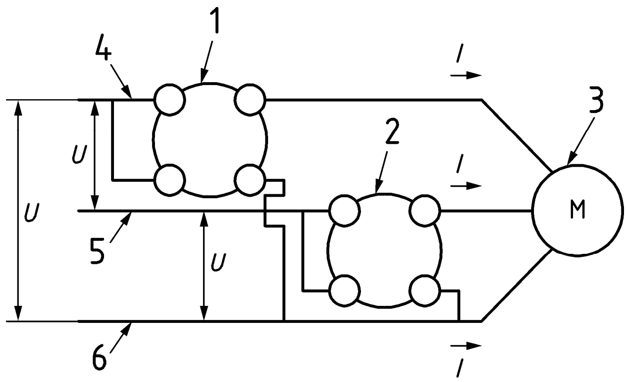
2 motor

Figure D.6 — AC single-phase motor

The watt-meter gives directly the electrical power

$$P_e = U \cdot I \cdot \cos(U, I) \quad \text{(D.11)}$$

For AC three-phase motors (see Figure D.7), the electrical power is determined by the 2-watt-meter method:



Key

1 wattmeter 1

2 wattmeter 2

3 motor

4 phase 1

5 phase 2

6 phase 3

Figure D.7— AC three-phase motor

Watt-meter 1 gives electrical power P_1 with

$$P_1 = U \cdot I \cdot \cos(-30° + \varphi) \quad \text{(D.12)}$$

Watt-meter 2 gives electrical power P_2 with

$$P_2 = U \cdot I \cdot \cos(30° + \varphi) \quad \text{(D.13)}$$

The total electrical power P_e is given by P_2+P_2

$$P_e = \sqrt{3} \cdot U \cdot I \cdot \cos(\varphi) \tag{D.14}$$

The reactive power Q is given by P_1-P_2

$$Q = \sqrt{3} \cdot U \cdot I \cdot \sin(\varphi) \tag{D.15}$$

φ is given by

$$\tan(\varphi) = \frac{\sqrt{3} \cdot (P_1 - P_2)}{P_1 + P_2} \tag{D.16}$$

For only current measurements:

Current transformer pliers or screw caps with ampere meter can be used as measuring instruments.

D.6.2 Measuring equipment

For measuring the power instrument transformers, power meters and electricity consumption meters of an accuracy appropriate to the accuracy of the result needed shall be used. When using instrument transformers care shall be taken not to exceed the rated load.

D.6.3 Measuring section

The measuring equipment should be connected as near as possible to the connection terminals of the individual system components. The layout of the measuring equipment and cables should be such that no errors due to interference from magnetic fields can occur. The cables should be of sufficient rating that an error is not introduced into the measured result.

D.6.4 Measurement uncertainties

The uncertainty of the measurement is given by the accuracy classes of the individual measuring equipment components used. Note that the class accuracy depends on the magnitude of the measured value. Accuracy classes are shown in Table D.7.

Table D.7 — Electric measuring equipment

Measuring equipment	Accuracy classes
Ampere meter	1
Ampere meter and measuring transformer	1,5
Voltmeter	1
Voltmeter and measuring transformer	1,5
Effective power meter (Aron circuit)	0,5 to 1,0
- with measuring transformer	0,5 to 1,5
Effective power meter with three measuring systems	0,5 to 1,5
- with measuring transformer	0,5 to 1,5
Other multifunctional digital instruments	According to the information of the manufacturer (see also clause 9)

The accuracy class of measuring equipment is the relative uncertainty of a measurement corresponding to the gauge scale used. This value is valid for any measuring point inside the gauge scale.

EXAMPLE An ammeter with an accuracy class 1 is used with the gauge scale 500 mA. A measurement gives a value of 240 mA. Class 1 means that the relative uncertainty of a measurement with a value of 500 mA is 1 %. It comes a relative uncertainty 500 mA x (1/100) = 5 mA for any value measured in the gauge scale 500 mA. In the example it comes 235 mA < measurement < 245 mA.

NOTE Closer to the gauge scale value, the measurement value is, the more accurate the measurement is. The accuracy class is the same for analogical or digital instruments.

D.7 Pressure difference at the air filter

The pressure difference shall be measured by means of suitable manometers. Manometers incorporated at the filters are sufficient for the functional measurement of the pressure difference.

D.8 Air leakage

D.8.1 Measuring method

The leakage measurements can be performed while the duct system is being installed.

As soon as a sufficiently large section of the air duct system has been installed, all openings are sealed off. A fan which is connected to the sealed duct system through an equipment for measuring is used to generate a test pressure difference above or below atmospheric pressure. The test pressure should be adjusted to one of the following values which should be chosen to be as near as possible to mean operating pressure of the system, preferably:

200 Pa, 400 Pa, or 1 000 Pa above atmospheric in case of supply air ducts or 200 Pa, 400 Pa or 750 Pa below atmospheric in case of exhaust air ducts.

If measurement equipment is used to verify tightness class A or B, it is possible that the above named pressure values could not be achieved at a greater ductwork surface area.

In this cases, the tightness class could be determine by a lower pressure, using the following formula to calculate the leakage airflow approximately:

$$\frac{\dot{q}_{v1}}{\dot{q}_{v2}} = \left(\frac{\Delta p_1}{\Delta p_2}\right)^{0,65} \tag{D.17}$$

where

$\dot{q}_{v1}$ is the air leakage at test pressure Δp_1

$\dot{q}_{v2}$ is the air leakage at mean operating pressure Δp_2

Δp is the pressure difference from atmospheric pressure

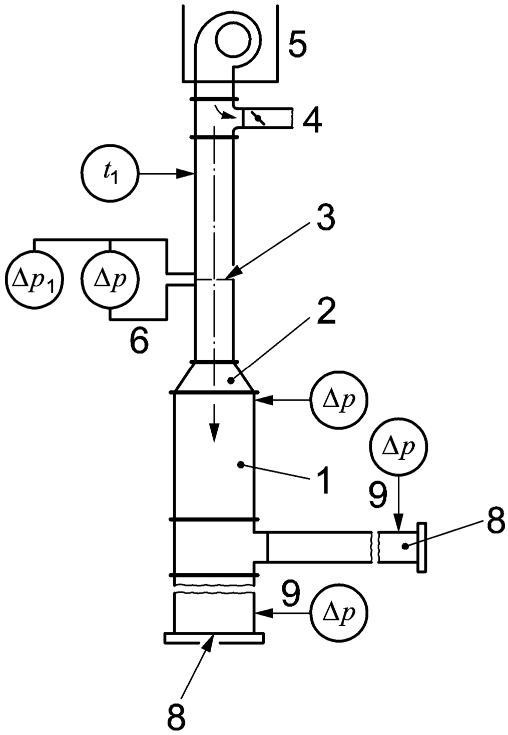
The mean operating pressure is the arithmetic mean of the static pressure at the beginning and end of a section of air ducting.

D.8.2 Measuring equipment

The measuring equipment for pressure is given in E.2.1.2 and for air flow in E.2.4.2.

D.8.3 Measuring section

Figure D.8 shows the principle layout for the measurements. A fan with controllable air flow blows or sucks air through a measuring path containing a calibrated airflow device into or from the installed section of air ducting. The static pressure in the air duct and the leakage flow rate are measured.



Key

1 section of ductwork to be tested
2 transformation piece
3 volume measuring device
4 bypass
5 fan
6 pressure measurement (for the air flow rate)
8 sealed openings
9 operating pressure

Figure D.8 — Measuring system for measuring air leakage

The leakage test is described in EN 12237 and EN 1507. The surface area is calculated according to EN 14239.

D.8.4 Measurement uncertainty

The total uncertainty can be calculated in accordance with Clause 8.

Annex E
(normative)

Special measurements

NOTE This annex gives additional information on special measurements, to be used along with Annex D.

E.1 Measuring instruments

The following measuring instruments are recommended:

— measuring instruments of known error, the use of which has been agreed between the parties involved,

— measuring instruments which are calibrated,

— built in operating measuring instruments, the error of which has been established,

— instruments with a calibration certificate[2)].

E.2 Measuring of parameters

E.2.1 Pressure

E.2.1.1 General

A distinction is made between:

— static pressure p_s

— dynamic pressure p_d

— total pressure p_t

E.2.1.2 Measuring methods

The actual quantity measured is a pressure difference. It is therefore necessary for each measurement to state the reference pressure. Exceptions are measurements of barometric pressure, i.e. atmospheric pressure.

E.2.1.3 Measuring equipment

Small pressure differences are usually measured by a liquid or electronic manometer, while higher pressures and pressure differences may also be measured by piston or spring manometer or even by electronic manometer.

The hoses from the measuring point to the measuring equipment shall be tight and clean.

Various instruments, their application ranges and examples of uncertainty are given in Table E.1.

[2)] In accordance with calibration regulations and calibration validity regulations if required.

Table E.1 — Pressure measuring instruments

Measuring instrument	Measuring range Pa	Uncertainty of the primarily measured values
Direct mechanical measurement of pressure		
Liquid manometers		
U-tube-manometer	$0 < p < 0{,}1 \cdot 10^{6}$	$\pm \frac{1\,\text{mm to } 2\,\text{mm}}{\text{reading value in mm}}$ x 100 in %
Inclined tube manometer	$0 < p < 2 \cdot 10^{3}$	$\pm \frac{0{,}5\,\text{mm}}{\text{reading value in mm}}$ x 100 in %
Projection manometer (Betz)	$0 < p < 4 \cdot 10^{3}$ $(8 \cdot 10^{3})$	$\pm \frac{0{,}1\,\text{mm to } 0{,}2\,\text{mm}}{\text{reading value in mm}}$ x 100 in %
Vertical tube manometer (Prandtl)	$0 < p < 4{,}5 \cdot 10^{3}$	$\pm \frac{0{,}1\,\text{mm}}{\text{reading value in mm}}$ x 100 in %
Compensation micromanometer	$0 < p < 2 \cdot 10^{3}$	$\pm \frac{0{,}02\,\text{mm}}{\text{reading value in mm}}$ x 100 in %
Pressure balances and piston manometers		
Ring balance	$7 < p < 0{,}7 \cdot 10^{3}$	± 1 % of the end scale value
Compressed air balance	$20 \cdot 10^{3} < p < 0{,}1 \cdot 10^{6}$	$\pm \frac{0{,}3\,\text{mm}}{\text{reading value in mm}}$ x 100 in %
Piston manometer (general)	$0{,}1 \cdot 10^{3} < p < 20 \cdot 10^{6}$	± 0,5 % of the end scale value
Piston manometer (immersion bell)	$0 < p < 0{,}6 \cdot 10^{3}$	± 0,5 % of the end scale value
Indirect mechanical measurement of pressure		
Spring manometers		
Encapsulated spring manometers	$20 \cdot 10^{3} < p < 0{,}8 \cdot 10^{6}$	± 1 % of the end scale value
Diaphragm pressure range	$20 \cdot 10^{3} < p < 70 \cdot 10^{6}$	± 1 % of the end scale value
Pressure capsula manometer, e. g.:		
a) bronze bourdon tube gauge	$0 < p < 0{,}1 \cdot 10^{9}$	± 1 % of the end scale value
b) steel bourdon tube gauge	$30 \cdot 10^{6} < p < 1 \cdot 10^{9}$	± 1 % of the end scale value
Measuring transducers		
Electric transducer	$p < 10 \cdot 10^{3}$	± 0,5 % of the final value
Pneumatic transducer	$p < 10 \cdot 10^{3}$	± 1,0 % of the final value
Digital instruments	According to the information of the manufacturer	see also clause 9

E.2.1.4 Measuring section

The measuring point should lie within the reference cross-section. In exceptional cases, the pressure difference between the measuring point and the reference cross-section can be calculated and allowed for.

Thermal effects, the density of the transmission medium and the influence of the measuring height, for instance a difference in height between the measuring point and the location of the measuring equipment, should be considered where applicable.

When measuring the static pressure in a duct, the holes made for the measurement points should be at right angles to the inside surface of the air duct. The inside end of each hole shall end sharply and be free of burrs. The diameter of the hole should be as small as possible (0,5 mm to 3 mm). In a flowing medium, the pressure measurement should be made at a point where the flow is parallel to the wall.

In general, the lower the flow velocity, the better the accuracy of a static pressure measurement. If various points of different cross-sections are available, then those with larger cross-sections and low flow velocities should be chosen.

E.2.2 Temperature

E.2.2.1 General

See also EN ISO 7726.

E.2.2.2 Measuring section

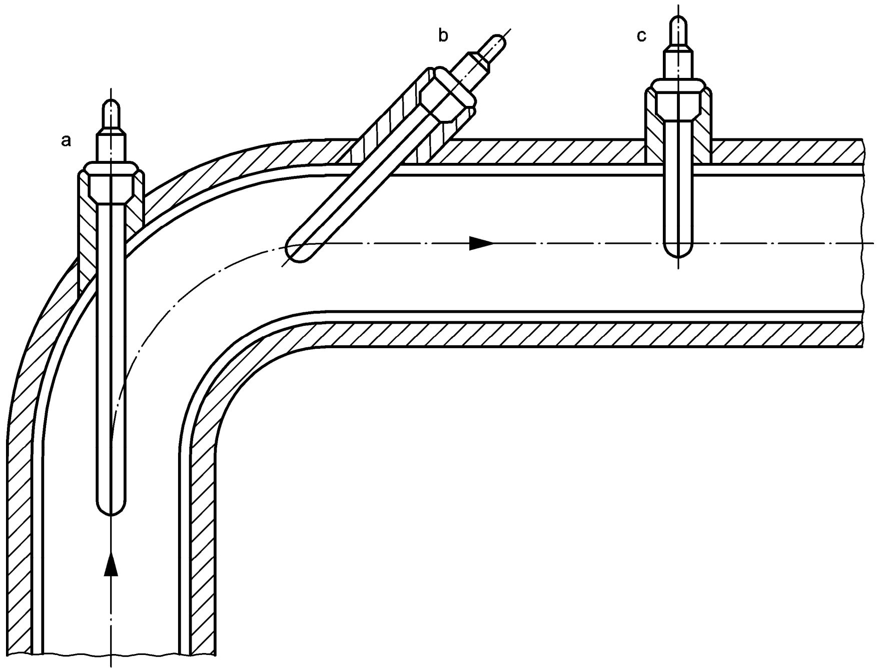
Consideration should be given to measurement errors due to conduction or thermal radiation.

When using a liquid thermometer, a thread correction should be made.

When using thermocouples, extraneous voltages shall be prevented or compensated.

When using resistance thermometers, resistive heating in the resistor itself shall be considered.

If it is not possible to insert the temperature sensor directly into the flow medium, it is recommended to use a protective tube (see Figure E.1).



Key

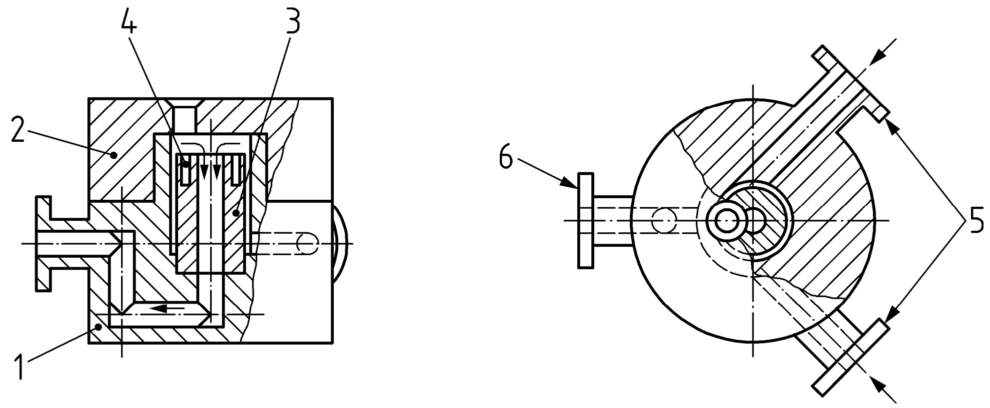
a) in elbows contrary to the flow direction

b) in narrow ducts angled opposite to the flow direction

c) perpendicular to the flow direction (higher measuring faults shall be considered)

Figure E.1 — Installation of protective tubes in circular ducts with uniform temperature distribution

For measurements (mean of several values) where high accuracy is required, it is recommended to use special measurement inserts (see Figure E.2).



Key

1 plastic case part with connections

2 plastic case part with inlets for thermocouples or other thermometer

3 copper cylinder

4 bores for thermocouples or other thermometer

5 inlet connections; the inferior connection is locked by a plug

6 flow off connection

Figure E.2 — Example of the design of a measuring head

E.2.2.3 Measurement uncertainty

When measuring with glass thermometers, the measurement uncertainty is taken as the calibration accuracy. When measuring with resistance thermometers or thermocouples, the measurement uncertainty shall be taken from the error of the measurement resistance or the deviation of the thermoelectric voltage characteristic line (which shall be narrowed down by calibration) and from the accuracy class of the meters used.

If the measurement sensors are unsuitably installed, this may substantially increase the uncertainty of any type of temperature measurement.

Application areas and examples of uncertainty are shown in Table E.2.

Table E.2 — Temperature, sensors, measuring equipment

Measuring instrument	Measuring range °C	Uncertainty of the primarily measured values
Sensors		
Liquid-in-glass thermometer	- 58 to - 5 - 5 to 60 60 to 100 110 to 210	± 0,3/ 0,7/ 1,0 K ± 0,04/ 0,1/ 0,15/ 0,5/ 0,7 K ± 0,04/ 0,15/ 0,25/ 0,5/ 1,0 K ± 1,0/ 1,5 K
Liquid spring thermometer	- 35 to 500	± 1 % ± 2 %
Vapour-pressure spring thermometer	- 50 to 350	± 1 % ± 2 %
Metal expansion thermometer	0 to 1 000	± 1 % ± 2 %
Resistance thermometer, gauged or calibrated in accordance with EN 60751)	- 220 to 850	± (0,15 + 0, 002 t^a) K Class A ± (0,03 + 0, 005 t^a) K Class B
Thermocouples, gauged or calibrated in accordance with EN 60584-1 and EN 60584-2)	- 50 to 500	± (0,05 + 0,01 t^a) K
Measuring equipment		
Normal instruments (moving-coil and quotient meters)		1,0% to 1,5 %
Precision instruments (moving-coil and quotient meters)		0,2% to 0,5 %
Pen-recording instruments (moving coil and quotient meters)		1,5 %
Normal compensation instruments with - manual compensation		 0,1% to 0,5 %
- automatic compensation		0,2% to 0,5 %
Precision compensation instruments with manual compensation		≤ 0,1 %
Digital voltmeters		≤ 0,3 %
Other multifunction digital instruments		According to the information of the manufacturer (see also Clause 9)
[a] *t* is the absolute value of the temperature in °C.		

E.2.3 Humidity

E.2.3.1 Measuring methods and equipment

See EN ISO 7726.

E.2.3.2 Measuring section

Measurements should consider of variation of humidity over the cross-section, especially after a steam air humidifier or a cooler.

The maximum incident flow velocity specified by the manufacturer shall be considered.

E.2.4 Air flow

E.2.4.1 Measuring methods

E.2.4.1.1 General

The air flow rate can be measured in the following ways:

— by measuring the flow velocity in a measurement cross-section using the network method,

— by the compensation (zero) method (D.1.5.5) or by funnel method (see D.1.5.4) at ventilation openings,

— using calibrated throttle devices (see D.1.3),

— using gas meters,

— by the tracer gas method.

E.2.4.1.2 Funnel measurement

See D.1.5.4.

The air flow through a ventilation opening can also be measured by the funnel measurement. Therefore, the measuring funnel should tightly cover the whole opening cross section. Measuring devices with low pressure drop are recommended. In general, the measurement result should be corrected by the pressure drop of the funnel according to the manufacturers instruction of the measuring device.

E.2.4.1.3 Tracer gas method

By introducing tracer gas to the air, the air flow can be estimated by means of concentration measurements. As various methods exist, no details are given here.

The tracer gas method can be used to measure the air flow in rooms and the air flow within ducts of ventilation systems. In ventilation systems the tracer gas method can be preferably used when other methods do not provide accurate results due to disturbances (e.g. dampers, bends, etc.). The disturbances promote the mixing of the tracer gas with the air.

The air flow in rooms (air change) using tracer gas can be measured according to EN ISO 12569.

The air flow in ducts of ventilation systems is measured by the constant injection method analogues to EN ISO 12569. The tracer gas is injected into the air duct at a constant flow rate. The concentration of the tracer gas in the duct is measured at a distance from the location of injection at which the tracer gas is homogeneously mixed with the air (mixing length). The air flow can be calculated by:

$$q = 10^6\, ppm * \frac{q_{Ts}}{C_S - C_0} \qquad \text{(E.1)}$$

Where

q air flow in the duct (m³/s)

q_T injected flow of pure tracer gas (m³/s)

C_S mean concentration of the tracer gas at the sampling cross-section (ppm)

C_0 background concentration of the tracer gas in the transported air (ppm)

If a tracer gas is used, which is present in the transported air in the duct a measurement of the background concentration in the injecting cross-section is required. It has to be proven, that the background concentration is constant during the measurement.

In larger ducts, it is recommended to inject the tracer gas uniformly through a number of holes in the cross-section (at least four) to assure the homogeneous mixing with the air within the distance to the sample cross-section. It is also recommended to sample the tracer gas at different locations spread uniformly on the cross-section, as minor variations in concentrations across the cross-section cannot be avoided. Sampling at multiple locations reduces the uncertainty of the method and can be used to verify the homogeneity of the mixing. If the concentration of the tracer gas is measured at different positions in the sampling cross-section, the mean value of the measured concentrations is taken.

The mixing length (duct length for homogeneous mixing of the tracer gas and the air) depends on the number of probes for injection and sampling, the flow profile and the disturbances within the duct. Table E.3 gives standard values for the relative mixing length L related to the hydraulic diameter (D_h).

Table E.3 — Standard values for the relative mixing length L related to the hydraulic diameter (D_h)

Conditions	Relative mixing length (L/D_h)
Straight duct without disturbances. Injection and sampling in centre.	80
Straight duct without disturbances. Injection via 4 or more holes.	
Sampling in centre	25
Sampling at four points (same positions as for injection)	15
Duct with disturbances (e.g. two 90° bends, fan). Injection before these disturbances via 4 or more holes.	
Sampling in centre	20
Sampling at four points (same positions as for injection)	10

Various tracer gases might be used. Commonly used tracer gases are nitrous oxide (N_2O), sulfur hexafluoride (SF_6) and carbon dioxide (CO_2). CO_2 may only be used if the background concentration is constant. For selecting a tracer gas following aspects should be taken in consideration:

— The tracer gas should not be naturally present in the air in high concentrations or at least constant in concentration.

— The tracer gas density shall be comparable to the density of air in order to facilitate mixing.

— The tracer gas shall not react with other compounds in the air.

— The tracer gas shall not be adsorbed at surfaces in a manner that it influences the measurement results.

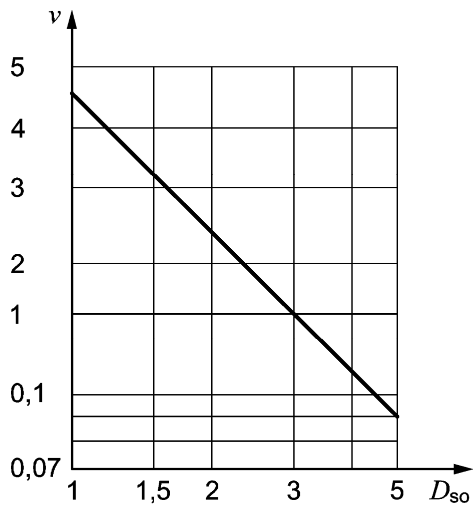
— The tracer gas shall be measurable within a sufficient accuracy.

— The tracer gas shall be non flammable and non toxic and causing no environmental harm.

— The tracer gas shall be provided in a high purity.

E.2.4.2 Measuring equipment

For measurements using standardized or calibrated throttling devices, adequate manometers shall be used (see Table E.1). The velocity is measured by probes in conjunction with liquid or electronic manometers. Usually a Pitot Static Tube (Prandtl tube) is used as probe. It is not necessary to correct the measured results provided the distance from the centre of the probe to the wall exceeds twice the probe diameter, and the Reynolds number Re > 300 (formed with the probe diameter). The necessary minimum velocity to achieve this for dry air (20 °C, 1 bar) as a function of probe diameter is shown in Figure E.3.



Key

v minimum velocity (m/s)

D_{so} probe diameter (mm)

Figure E.3 — Relationship between minimum velocity *v* and probe diameter D_{so}

Under rapidly changing velocity conditions, a vane anemometer will measure a too high mean reading. In addition, a correction is needed if the density of the flowing medium varies greatly. A density change of around 10 % will give an uncertainty of around 5 % in the velocity measurement.

For measurements in air ducts in which the ratio of effective cross-section of the probe to the duct cross-section is greater than 0,01 a correction shall be applied using the following formula:

$$v = \frac{A_K - A_g}{A_K} v_g \qquad \text{(E.2)}$$

where

v is the velocity in non-constricted air stream in m/s

v_g is the velocity reading in m/s

A_K is the free cross-section of duct in m^2

A_g is the effective cross-section of the probe in m^2

(if not stated by manufacturer, assume the entire cross-section of the anemometer)

Tracer gas method: For injecting the tracer gas a pressure regulator, a dosing/control valve, a flow meter and probes are necessary. The flow meter shall measure the tracer gas flow in an accuracy of ± 2 %. The tracer gas flow shall be constant during the measurement. The equipment for sampling consists on sampling probes and a gas analyser for the injected tracer gas.

E.2.4.3 Measuring section

Downstream of obstacles, separation or disturbances of the flow will appear and irregular velocity profiles will occur. These are among the decisive factors causing uncertainty in the measurement.

For network measurements the following formula is used as a measure of the irregularity U of the velocity profile:

$$U = \frac{v_{max} - v_{min}}{2\bar{v}} \tag{E.3}$$

where

$\bar{v}$ is the arithmetic mean velocity over the entire cross-section in m/s

v_{min}; v_{max} is the minimum and maximum of the arithmetic mean of velocities in a quarter of the cross-section or at a radius in m/s

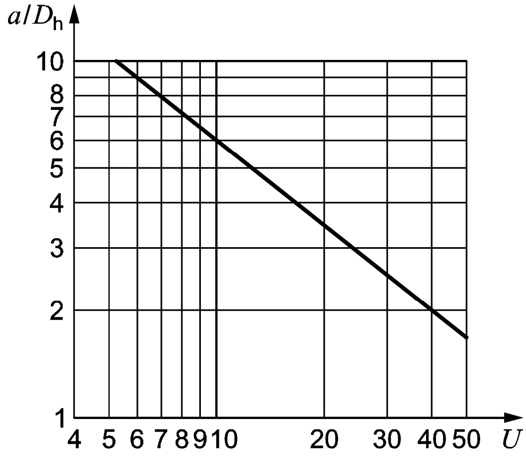
In the case of a rectangular cross-section, the maximum and minimum values of mean velocity are selected from the quarters of the total cross-section, of side length equal to half the duct side length. In the case of a circular cross-section, the mean values are taken from four measurement radii at right angles to one another.

For the calculation of v_{min} the velocity in the boundary layer at the wall of the duct is neglected.

Figure E.4 shows the empirical relationship which exists between the relative distance a/D_h arising from the ratio of the distance a between the measurement path and an upstream disturbance to the hydraulic diameter D_h of the duct at the measurement plane, and the irregularity U of the velocity profile.

If no measured data are available, Figure E.4 can be used to find the anticipated irregularity of a profile.

Figure E.4 is valid for disturbances which uniformly affect the entire duct, e. g. after an inlet opening, after a single flap, after a bend, a fan or a branch junction.



Key

a/D_h relative distance

U irregularity in %

Figure E.4 — Empirical relationship between irregularity *U* in % of the profile and relative distance a/D_h of the measuring point from the disturbance

Multiple disturbances which are uniformly distributed over the entire cross-section behave analogously. In this case, however, instead of the hydraulic diameter of the air duct, the module (characteristic dimension of the disturbance) is used to form the relative distance from the disturbance point, e.g. in case of heat exchangers, counterflow flaps, guide vanes, drop separators and similar components.

Disturbances downstream from the measurement point have less impact than upstream disturbances. Nevertheless they shall still be taken into account, especially if they cause a dynamic pressure build-up.

The measuring devices shall be built-in in such a way that together with their mounting they obstruct only a negligibly small part of the total flow cross-section.

In the case of some measuring devices, minimum distances from the air duct walls or from upstream or downstream obstacles shall be complied with to ensure that the flow pattern around the measuring device is the same as it was during calibration. Thus, for instance, a vane anemometer shall be located at least 1,5 vane wheel diameters downstream from a filter or heat exchanger.

Measuring devices which are inserted through the wall of the duct shall have devices which ensure correct positioning and accurate directional guidance. The openings around the probes shall be sealed especially where the pressure inside the duct is lower than outside.

E.2.4.4 Measurement uncertainties

When calculating the total uncertainty of the measurement as described in Clause 8, the errors of the measurement method and of the measuring equipment shall be considered.

a) Uncertainty due to the measurement method

The uncertainty of an air flow measured by calibrated throttle devices is given by the calibration.

For an air flow measurement in a defined cross-section with a given irregularity of the velocity profile, the measurement uncertainty depends mainly on the number of measurement points in the cross-section. For parallel flow Table E.4 shows approximately the uncertainty of the measurement; suitable distribution of the measuring points is assumed.

Table E.4 — Uncertainty of measurement in a flow having approximately zero radial motion, as a function of number of measuring points

Number of measuring points *n*	Uncertainty of the measuring location τ_u in %					
	Irregularity of the profile section *U* in %					
	2	10	20	30	40	50
4	6	12	19	26	34	41
5	5	10	17	23	30	36
6	4	9	15	21	27	33
8	3	7	13	18	23	28
10	3	6	11	16	21	25
20	1	4	7	11	14	17
30	1	3	6	9	11	14
50	1	2	4	6	9	11
100	0,4	1	3	4	6	7
200	0,2	1	2	3	4	5

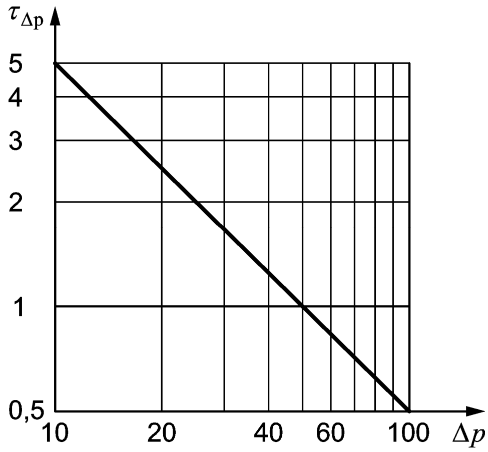
The uncertainty of the measuring location τ_u in this table is given by the following approximation:

$\tau_u = 2{,}314 \cdot U \cdot n^{-0{,}552} - 0{,}895 \cdot U \cdot n^{-0{,}698} + 13{,}725 \cdot n^{-0{,}778}$. If the formula is not used, a linear interpolation is also sufficient for determination of the uncertainty of the measuring position for values of n and U not given in the table.

The figures apply to a normal distribution of individual measurements. If the disturbances to the duct flow have any periodicity, then the distance between measuring points shall not be equal to the periodic interval.

When using the compensation method, the uncertainty depends on the adjustment of pressure in the chamber, on the pressure drop between the branch-off point in the air duct network and the ventilation opening (branch pressure drop), and on the air flow measurement.

If the uncertainty of the pressure adjustment in the chamber is 1 Pa, the additional uncertainty arising from this can be read off from the diagram in Figure E.5.



Key

$\tau_{\Delta p}$ uncertainty of air flow measurement (%)

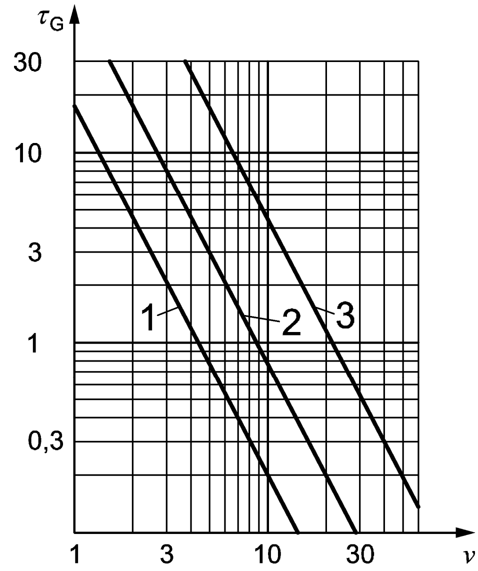
Δp branch pressure drop (Pa)

Figure E.5 — Uncertainty of air flow measurement $\tau_{\Delta p}$ using the compensation method for an uncertainty of 1 Pa in pressure difference

The uncertainty of an air flow measured by tracer gas method is given by leakage in the duct and the homogeneity of the tracer gas concentration in the sampling cross-section. If a homogeneous tracer gas mixture is obtained, the method uncertainty is as a rule negligible and only depends on leakage in the duct between the point of injection of tracer gas and the sampling cross-section.

b) Uncertainty due to the measuring equipment

The error of the equipment for measuring the pressure difference using a pitotstatic tube is shown in the diagram in Figure E.6.



Key

1 resolution 0,2 Pa

2 resolution 1 Pa

3 resolution 5 Pa

τ_G relative uncertainty (%)

v velocity (m/s)

Figure E.6 — Relative uncertainty in measured value τ_G of the air velocity *v* in pitotstatic tubes with pressure difference measuring equipment for various resolutions

The determining factors here are the type of pressure measuring equipment used and the velocity present at the measuring point. Additionally, the error of the probe should be considered.

The uncertainty due to the injecting and measuring equipment for the tracer gas method is given by the accuracy of the measurement of the injected tracer gas flow (flow meter) and the accuracy of the gas analyser. As the accuracy of the measuring equipment vary significantly, data provided by the manufacturer shall be used.

E.2.5 Sound

See EN ISO 3740, EN ISO 3746 and EN ISO 3747.

E.2.6 Air pollution

E.2.6.1 General

The indoor air pollution is determined by contaminants in the air such as volatile organic (VOC) and inorganic compounds, combustion products, particulate matter, bio effluences and microorganisms. These contaminants may affect the health and comfort of the occupants.

Air pollution is manifold and to check and evaluate air pollution different measurement can be performed, such as:

— measuring particles and the dust,

— gas analysis and determination of concentration of known volatile compounds,

— sensory methods using panels of human judges to assess the impact of the contaminants on the perception of indoor air quality (e.g. odour).

For further information see EN 15251.

E.2.6.2 Measuring methods and equipment

For the measurement of dust and particulate matter, part of the flow is sucked off and filtered to determine the amount of dust contained in the air by means of weighing.

The measurement of the number of particles can be made by the scattered light method or the membrane filter method. A scattered-light particle counter can continuously measure the concentration of airborne particles. In the membrane filter method particles from the air to be tested are collected on a membrane filter. The filter has the property that the particles deposit mainly on its surface. This is then weighed to determine the particle mass and eventually viewed under a microscope.

Gas concentration measurement is performed by sucking the sample through a measuring equipment which then measures and displays the concentration. It is also possible to take samples of the air in special containers or adsorption tubes and perform a laboratory analysis of the composition.

The sensory measurements to determine the perception of the air (e.g. odour) were performed by assessments of human judges who enter the space and directly assess the air quality at the centre or at the working place. The judges perform the assessments consecutively to avoid disturbances by other present judges. Each judge has to assess the air quality according to a given questionnaire. It is also possible to collect the air in large sampling bags and perform the assessments in a laboratory. The indoor air quality has to be assessed with and without the operating ventilation system. As various methods exist, no details are given here.

E.2.6.3 Measuring section

Measurements of air purity by measuring the concentration of particles or dust load as well as the sensory measurements can be performed either at the undisturbed workplace or during normal working.

Depending on the objective of the measurement, the air to be tested for gaseous impurities can be taken from an air duct or sucked from a room. If stratification of the air in the duct is anticipated, then a network measurement shall be performed. In a work room the samples shall be taken at several points within the occupied zone, preferably at positions intended for intensive occupancy.

Where transfer of impurities by the system is possible, the supply air shall be measured accordingly.

E.2.6.4 Error limits

The error limits of the equipment used for measuring air purity and particle count are shown in Table E.5, related to the measured value.

Table E.5 — Equipment for measuring the air purity, concentration of pollutants and particle concentration

Measuring instrument	Field of application	Relative error %
Massometer	0,1 mg/m³ to 20 mg/m³	
Gravimetric method	2 mg/m³ to 100 mg/m³	
Scattered-light particle counter	≥ 0,1 µm	According to the calibration method
Particle-size spectrometer	≥ 1 µm	
Aerosol photometer	Filter testing	± 20
Membrane filter method	≥ 0,1 µm	± 10
Test tube	Gases and vapours 0,1 ppm to 12 ppm	± 5 to 30
	Multiatomic non-elemental gases Spectral region 0,25 nm up to 1,2 nm	≥ 5
Gas-phase chromatograph	≥ 1 ppm	≥ 5

The error of sensory measurements depends on the method of assessment, the questionnaire, the experience and number of the judges. It is determined by the standard deviation of the panel of the assessment and the number of judges (see Table E.6).

Table E.6 — Sensory methods for indoor air quality assessments (examples)

Measured values	Measuring method	Absolute error
Acceptability	Naive judges n>25, continuous scale from +1 (clearly acceptable) to -1 (clearly not acceptable)	approx. ±0,2
Odour intensity	Naive judges n>25, category scale (7 point) from 0 (no odour) to 6 extreme odour	approx. ±1,0
	trained judges, n>15 , continuous scale, open ended, unit perceived intensity (pi)	approx. ±2 pi
Hedonic tone	Naive judges, n>25, category scale (9 point) from 4 (extremely pleasant to -4 (extremely unpleasant	approx. ±1,0

E.2.7 Electric Power

E.2.7.1 Measuring method

See D.6.

E.3 Measurements in rooms

E.3.1 General

After installation of the system, it can be required to verify that the desired indoor environment is accomplished during typical operational conditions. The measuring methods are explained in the following clauses.

E.3.2 Thermal environment

E.3.2.1 Location of measurements

Measurements should be carried out in occupied zones of the building according to EN ISO 7730 and EN 15251. Such locations can be work stations, seating or sleeping areas, depending on the function of the space. In occupied spaces, measurements shall be carried out at a representative sample of locations spread throughout the occupied zone.

If the distribution of occupancy cannot be estimated, the following locations can be used: The centre of the space or zone or 0,6 m inward from each of the walls of the space, but within the occupied zone.

In either case measurements within the occupied zone shall be carried out where the most extreme values of the thermal parameters are observed or expected.

Absolute humidity shall be determined at only one location in each occupied zone.

E.3.2.2 Heights of measurements

The recommended measuring heights are head, middle and foot level which corresponds to 1,1 m, 0,6 m and 0,1 m above the floor for seated persons and 1,7 m, 1,1 m and 0,1 m for standing persons.

E.3.2.3 Measuring conditions

Measurements during the heating period (winter condition) should be carried out at an indoor-outdoor temperature difference not less than 50 % of the design temperature difference and at cloudy to partly cloudy sky conditions.

Measurements during the summer period should be carried out at the above mentioned indoor-outdoor temperature difference and at clear to partly cloudy sky conditions.

Measurements in interior zones of large buildings should be carried out at a zone load not less than 50 % of the design load. The measurements should include the most critical time of the day which depends on either the outdoor climate or the internal load.

The following system data should be documented or measured at the same time with the environmental measurements:

— supply outdoor air rate,

— temperature difference between room and supply air,

— diffuser or air terminal device, location and type,

— discharge velocity,

— perimeter heating devices; type, location and status,

— exhaust air terminal device, location and size,

— type of air supply system.

The outdoor climatic conditions (temperature, humidity, sun, wind speed) should be documented during the measuring period.

E.3.3 Ventilation effectiveness

E.3.3.1 General

The indoor air quality is determined by emitted contaminants from building materials, furnishing, plants and occupants as well as by the supply air quality and the ventilation effectiveness. The ventilation system is installed to remove these contaminants. Ventilation effectiveness shall be evaluated by measuring air flow rates provided that the design assumptions are correct (see for information EN 13779 and EN 15251).

Tracer gas method can be used to measure the ventilation effectiveness, contaminant removal effectiveness and the mean age of air. It can be determined by global measurements in the room or locally at given measurement points, e.g. the working place.

NOTE For further information, see RHEVA Guidebook 2

E.3.3.2 Location of measurements

Measurements should be carried out in occupied zones of the building according to EN ISO 7730 and EN 15251. Such locations can be work stations, seating or sleeping areas, depending on the function of the space. In occupied spaces, measurements shall be carried out at a representative sample of locations spread throughout the occupied zone. If the distribution of occupancy cannot be estimated, the centre of the space or zone shall be used.

The recommended measuring heights are for seated persons 1,1m and for standing persons 1,7 m.

E.3.3.3 Measurement methods using tracer gas

Most measurements on ventilation effectiveness require the injection of tracer gas. For selecting a tracer gas following aspects should be taken in consideration:

— The tracer gas should not be naturally present in the room air in high concentrations or at least constant in concentration.

— The tracer gas density shall be comparable to the density of air in order to facilitate mixing.

— The tracer gas shall not react with other compounds in the room air.

— The tracer gas shall not be adsorbed at surfaces in a manner that it influences the measurement results.

— The tracer gas shall measureable within a sufficient accuracy.

— The tracer gas shall be non flammable and non toxic and causing no environmental harm.

As tracer gases nitrous oxide (N_2O), sulphur hexafluoride (SF_6) and carbon dioxide (CO_2) are mainly used as they adequately fulfil the above requirements. However, care shall be taken concerning carbon dioxide as it is present in the room air.

The ventilation effectiveness or the mean age of the air can be evaluated by different tracer gas techniques:

- Tracer step-down (decay) method
- Tracer step-up method
- Pulse method

For the step-down method a small amount of tracer gas is initially released in the room and thoroughly mixed with the room air so the room air contains uniform concentration. The tracer decays due to the ventilation air flow. The concentration decay is measured either in the exhaust (global) or at a measurement point in the room (local).

For the step-up method the tracer gas is released in a continuous and constant flow in the supply duct. It also can be released at a point in the room to measure the ability to remove airborne contaminants. The concentration increase of the tracer is measured either in the exhaust (global) or at a measurement point in the room (local). Step-up tests are more difficult to use as they take a long time to reach the equilibrium concentration.

For the pulse method a short pulse of tracer gas is injected into the supply air. The concentration of the tracer is measured either in the exhaust (global) or at a measurement point in the room (local). When plotting the cumulated concentration as a function of time this method corresponds to the step-up method.

E.3.4 Acoustic environment

Instruments and methods for measuring the acoustic environment shall comply with EN ISO 3744, EN ISO 11201 and EN 61672-1.

The location should be chosen as specified in E.3.2.1.

The recommended measuring height corresponds to the height of the human head i.e. 1,1 m for seated persons and 1,7 m for standing persons.

Annex F
(informative)

Contractual agreements

Concerning the applicability of this standard, the installation contract should include specification of the following points:

- reference to this standard and specification of the extent of the testing procedures (e.g. tolerances, measuring methods etc.) as well as any exceptions or alterations;
- identification of the responsibilities for carrying out of the test procedures and/or eventual supervision including drafting of the test report;
- conditions for the design of the ventilation and air conditioning system (e.g. use of the building);
- conditions for a later carrying out of tests which could not be concluded due to special reasons (e.g. weather conditions, non-effective occupancy);
- level of extent of the functional checks and measurements;
- extent and methods of eventual special measurements;
- necessary actions in the case of inappropriate test results (e.g. possible test resumption after revision of the system).

The installation contract should specify partly or completely the kind and quantity of the equipment which shall be installed. However, it may also specify only the performance which shall be achieved by the system.

Completeness checks should be carried out in compliance with a list of the installed equipment and its technical specifications. If the equipment specifications are under the agreement, this list will reproduce these specifications. It will be referred to as the "specification list".

Annex G
(informative)

Examples for determination of the number of functional checks and measurements

G.1 Functional checks

An example for determination of the number of functional checks is given in Table G.1.

Table G.1 — Determination of the number of functional checks

Parameter	Direction of rotation of fan			Response of fan-coil unit controls		
System description	Exhaust ventilation system, 9 roof fans serving 135 dwellings			Building comprising 500 4-pipe fan-coil units		
Check performed	Visual control			Check of correct response of unit controls to a change of set point: - emission of cold for low set point - emission of heat for high set point - check of the existence of a neutral zone by manipulating set point		
Level	A	B	C	A	B	C
Number of checks	4	6	9	19	37	71

G.2 Functional measurements

An example for determination of the number of functional measurements is given in Table G.2.

Table G.2 — - Determination of the number of functional measurements

Parameter	**Air flow at the terminal device**			**Room temperature**	
System description	Department store with zone air handling units (15 zones), diffusion by linear difffusers in ceilings (average of 12 diffusers by zone)			Office building comprising 96 single rooms, and landscaped spaces divided into 48 zones - VAV system in landscaped spaces, fan-coil units in single rooms	
Measurement performed	Air flow measurement at diffuser connection ducts (alternatively at diffuser outlet with compensation method). Although there are 15 independent systems, calculation of n is based on total number of diffusers = 180.			Room air temperature measurements in near-design conditions. Single and landscaped zones are not similar, the calculation is applied separately $p_1 = 2,23 * 96^{0,45} \approx 17$ $p_2 = 2,23 * 48^{0,45} \approx 13$	
Level	A	B	C	B	
Number of measurements	13	23	42	single	landscaped
				spot readings	
				15	12
				Recordings over 24 h	
				2	1
				total	
				17	13

Annex H
(informative)

Examples for measurement uncertainty

H.1 Measuring equipments for measuring of the velocity and the cross-section

Table H.1 — Velocity measuring equipment

Measuring instrument	**Measuring range** m/s	**Angle range within which uncertainty 1%** °	**Uncertainty of primarily measured values** %
Pitot tube (thin walled probe)	see Figure E.4	± 23	± 0,1 [b]
Pitot Static Tube (Prandtl tube)	see Figure E.4	± 12	± 1 [b]
Pitot Static tube with ellipsoidal head	see Figure E.4	± 21	± 1[b]
Vane anemometer	1 to 20	± 10	± 5 of the end of scale value
Thermal probes	0,2 to 5	[a]	± 5 of the end of scale value
Hot-wire anemometer	> 0,2	[a]	± 10 to ± 1,0 (according to the information of the manufacture)
Laser	According to the information of the manufacturer.		
[a] depending on probe design [b] related to dynamic pressure			

H.2 Velocity measurement by Pitot Static Tube (Prandtl tube)

a) Duct size

Given duct 200 mm x 200 mm

(± 2 mm) τ_s = 1 %

b) Cross-section

Measuring position 800 mm

behind an elbow: $a/D_h = 4$

Irregularity of the profile, from Figure E.5 = 16 %

Chosen number of measuring positions: 10

Table E.4 gives the uncertainty: τ_u = 10 %

c) Probe

Pitot Static Tube (Prandtl tube) ± 1 % of p_{dyn}

Table H.1: Uncertainty τ_p = 1 %

d) Pressure measuring device

Resolution 1 Pa

Velocity in the duct 5m/s

Figure E.6: Uncertainty τ_G = 3 %

e) Density

Uncertainty of the density measurement τ_d = 2 %

Total uncertainty:

$$\tau_t = \sqrt{(2 \cdot \tau_s)^2 + (\tau_u)^2 + \left(\frac{1}{2} \cdot \tau_p\right)^2 + (\tau_G)^2 + \left(\frac{1}{2} \cdot \tau_d\right)^2} \qquad \text{(H.1)}$$

$$\tau_t = \sqrt{4 \times 0{,}0001 + 0{,}01 + \frac{1}{4} \times 0{,}0001 + 0{,}0009 + \frac{1}{4} \times 0{,}0004} \qquad \text{(H.2)}$$

$$\tau_t = \sqrt{0{,}01143} \qquad \text{(H.3)}$$

$\tau_t = 11\,\%$

To reduce the uncertainty, increase either the number of measurements or the distance from the elbow.

H.3 Example as H.1 using the same references but lower velocity, larger distance

a) Distance from the elbow: 1200 mm a/D_h = 6

Irregularity of the profile 10 %, τ_u = 7 %

b) Resolution of pressure gauge 1 Pa

Velocity 3 m/s, τ_G = 8 %

$$\tau_t = \sqrt{4 \cdot 0{,}0001 + 0{,}0049 + 0{,}000025 + 0{,}0064 + 0{,}0001} \qquad \text{(H.4)}$$

$\tau_t = 10{,}8\,\%$

τ_s, τ_p, τ_d are negligible.

H.4 Example: Measurement of velocity by axial vane anemometer

Mechanical vane anemometer

Table H.1: Uncertainty ± 5 %, τ_v = 5 %

Measurement behind a fan in a duct exit

size 500 mm x 500 mm

distance from the measuring cross-section 1 m.

$\rightarrow$ $a/Dh = 2$

Irregularity of the profile, Figure E.5;

U = 40 %, 10 measuring positions

Table E.4: τ_u = 20 %

τ_t = 21 %

Annex I
(informative)

Examples of measuring protocols for the air-flow rate

Measurement Records — Circular Air Duct

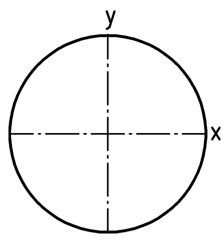
Project		Order No.	
		Department	
Plant		Contact	
		Date	Page of
Measurement location		**Measuring point**	
Measurement device			

☐ Total air flow ☐ External air ☐ Supply air ☐ Exhaust air Setpoint value: ______ m^3/h

☐ Partial air flow ☐ Recirculation air ☐ Extract air Actual value: ______ m^3/h

Dimension of duct D**(m)** = ______ **Measurement values in** ______ m/s (Dimension)

Nr.	Distance to duct wall (mm)	x-axis			y-axis		
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							



Number of measurement points: ______ **Sum of values:** ______

Average air velocity	v =	______	m/s
Dimensions of Measuring point	A =	______	m^2
Correction factor (temp/pressure)	f =	______	
Air flow ($v \times A \times f \times 3600$)	q =	______	m^3/h ± ______ m^3/h

Pressure-measure point	Δp_{stat} =	______	Pa	Air temp.	______	°C
Pressure-fan	Δp_{stat} =	______	Pa	Air pressure	______	mbar
Pressure filter*	Δp_{stat} =	______	Pa			

Fan type*		______				
Fan speed*	n =	______	min^{-1}	Frequency inverter	______	Hz
Nominal current fan motor*	I_N =	______	A			
Carging rate fan motor*	I_A =	______	A			
Total measurement uncertainty	τ_t =	______	%			
Uncertainty of duct size	τ_s =	______	%	Irregularity of profile	U = ______	%
Uncertainty of measurement position	τ_u =	______	%			
Uncertainty of measurement device	τ_G =		%	* if required		
…						

Remarks:

______

______

______

______

______	______	______	______
Place/Date	Name/Signature	Place/Date	Name/Signature

Measurement Records — Rectangular Air Duct

Project ______________ Order No. ______________
______________ Department ______________
Plant ______________ Contact ______________
______________ Date ______________ Page ______ of ______

Measurement location ______________ **Measuring point** ______________

Measurement device ______________ ______________

☐ Total air flow ☐ External air ☐ Supply air ☐ Exhaust air Setpoint value: ______________ m^3/h

☐ Partial air flow ☐ Recirculation air ☐ Extract air Actual value: ______________ m^3/h

Dimension of duct A**(m) =** ______________ B**(m) =** ______________ **Measurement values in:** ______ m/s (Dimension)

Nr	Distance from wall	1	2	3	4	5	6	7	8	9	10
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

Number of measurement points: ______________ **Sum of values:** ______________

Average air velocity $v =$ ______________ m/s
Dimensions of Measuring point $A =$ ______________ m^2
Correction factor (temp/pressure) $f =$ ______________
Air flow ($v \times A \times f \times 3600$) $q =$ ______________ m^3/h ± ______________ m^3/h

Pressure-measure point $\Delta p_{stat} =$ ______________ Pa Air temp. ______________ °C
Pressure-fan $\Delta p_{stat} =$ ______________ Pa Air pressure ______________ mbar
Pressure filter* $\Delta p_{stat} =$ ______________ Pa

Fan type* ______________
Fan speed* $n =$ ______________ /min Frequency inverter ______________ Hz
Nominal current fan motor* $I_N =$ ______________ A
Carging rate fan motor* $I_A =$ ______________ A

Total measurement uncertainty $\tau_t =$ ______________ %
Uncertainty of duct size $\tau_s =$ ______________ % Irregularity of profile $U =$ ______________ %

Uncertainty of measurement position	τ_u =	________	%	
Uncertainty of measurement device	τ_G =	________	%	* if required
…				

Remarks:

____

____

____

Place/Date	Name/Signature	Place/Date	Name/Signature

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