

BS EN 12599:2012



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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 It supersedes BS EN 12599:2000 which is withdrawn.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.

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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 raumluftechnischer Anlagen

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Contents

Page

Foreword.....	5
1 Scope	6
2 Normative references	7
3 Test and check procedure	8
4 Completeness checks	10
5 Functional checks.....	10
5.1 General.....	10
5.2 Put system into use	10
5.3 Procedure	10
6 Functional measurements	11
6.1 General.....	11
6.2 Range of functional measurements.....	11
6.3 Procedure	12
6.4 Measuring methods and measuring devices	13
6.4.1 General.....	13
6.4.2 Measurement of the air flow rate.....	13
6.4.3 Measurement of the ductwork leakage	13
6.4.4 Measurement of the indoor air velocity	13
6.4.5 Measurement of air temperature	14
6.4.6 Measurement of the air humidity.....	14
6.4.7 Measurement of the sound pressure level	14
6.4.8 Measurement of the electrical power of the fan.....	14
6.4.9 Measurement of the pressure difference at the air filter	14
6.5 Accompanying measurements	14
7 Special measurements (see Annex E)	15
7.1 General.....	15
7.2 Parameters	15
7.3 Measurements of components.....	15
7.3.1 Fans.....	15
7.3.2 Filters	16
7.3.3 Heat exchangers.....	16
7.3.4 Air humidifiers	18
7.4 Check of regulating, control and switching systems	19
7.4.1 General.....	19
7.4.2 Controls	19
8 Uncertainty of measurements	20
8.1 General.....	20
8.2 Uncertainty of measuring devices	20
8.2.1 Instrument uncertainty (u_1).....	20
8.2.2 Reading uncertainty (u_2)	20
8.3 Uncertainty of measurement results	21
8.4 Calculation of the error of the measuring equipment.....	22
9 Test Reports	22
9.1 General.....	22
9.2 Handing over report.....	22
9.3 Inspection report on the completeness check	23
9.4 Inspection report on the functional check	23

9.5	Test report on the functional measurements	24
9.6	Test report on the special measurements	24
Annex A	(informative) Completeness check	25
A.1	Documents	25
A.1.1	List of agreed specifications:	25
A.1.2	Inventory documents:	26
A.1.3	Documents for operation and maintenance:	26
A.2	Tests	26
A.2.1	General inspection of:	26
A.2.2	Balancing	27
A.2.3	Separate tests of:	27
A.3	Test Report for the completeness check	30
Annex B	(informative) Functional checks	31
B.1	General	31
B.2	Separate checks for components	31
B.2.1	Central devices, fans	31
B.2.2	Heat exchanger	31
B.2.3	Air filter	32
B.2.4	Humidifier	32
B.2.5	Multi leaf dampers	32
B.2.6	Fire and smoke dampers	32
B.2.7	Mixing section	32
B.2.8	Ductwork	32
B.2.9	Air flow pattern in the room as a function of the air terminal devices and geometrical obstacles	32
B.2.10	Control devices and switch cabinets	32
Annex C	(normative) Determination of the extent of functional checks or measurements	34
C.1	General	34
C.2	Parameters and similar locations	34
C.2.1	Parameter	34
C.2.2	Similar locations	34
C.3	Determination of the total number n of similar locations	34
C.4	Extent of checks or measurements	35
Annex D	(normative) Measuring methods and measuring devices for functional measurements	37
D.1	Measurement of the air flow rate	37
D.1.1	General	37
D.1.2	Measurement in the duct cross-section	37
D.1.3	Measurement with throttle devices	43
D.1.4	Measurement in the cross-section of a chamber, the fan-casing or device	43
D.1.5	Measurement at the air terminal devices	43
D.1.6	Measuring devices (Examples)	47
D.2	Measurement of the indoor air velocity	48
D.2.1	Measuring methods	48
D.2.2	Measuring devices	48
D.3	Measurement of air temperature	49
D.3.1	Measuring methods	49
D.3.2	Measuring devices	50
D.4	Measurement of the air humidity	50
D.5	Measurement of the sound level	51
D.6	Measurement of the electrical power of the fan	51
D.6.1	Measuring method	51
D.6.2	Measuring equipment	53
D.6.3	Measuring section	53
D.6.4	Measurement uncertainties	53
D.7	Pressure difference at the air filter	54
D.8	Air leakage	54
D.8.1	Measuring method	54

D.8.2	Measuring equipment.....	54
D.8.3	Measuring section	54
D.8.4	Measurement uncertainty	55
Annex E	(normative) Special measurements	56
E.1	Measuring instruments	56
E.2	Measuring of parameters	56
E.2.1	Pressure.....	56
E.2.2	Temperature	58
E.2.3	Humidity.....	62
E.2.4	Air flow	62
E.2.5	Sound	69
E.2.6	Air pollution	69
E.2.7	Electric Power	72
E.3	Measurements in rooms	72
E.3.1	General.....	72
E.3.2	Thermal environment	72
E.3.3	Ventilation effectiveness.....	73
E.3.4	Acoustic environment	74
Annex F	(informative) Contractual agreements	75
Annex G	(informative) Examples for determination of the number of functional checks and measurements.....	76
G.1	Functional checks.....	76
G.2	Functional measurements	77
Annex H	(informative) Examples for measurement uncertainty	78
H.1	Measuring equipments for measuring of the velocity and the cross-section.....	78
H.2	Velocity measurement by Pitot Static Tube (Prandtl tube)	78
H.3	Example as H.1 using the same references but lower velocity, larger distance	79
H.4	Example: Measurement of velocity by axial vane anemometer.....	79
Annex I	(informative) Examples of measuring protocols for the air-flow rate	81
Bibliography		85

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 $\pm 20\%$ to $\pm 15\%$ for each individual room and from $\pm 15\%$ to $\pm 10\%$ 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
<u>Step a</u> 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
<u>Step b</u> 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
<u>Step c</u> 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
<u>Step d</u> 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
<u>Step e</u> 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/MCD/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 $\rho = 1,2 \text{ kg/m}^3$. 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.

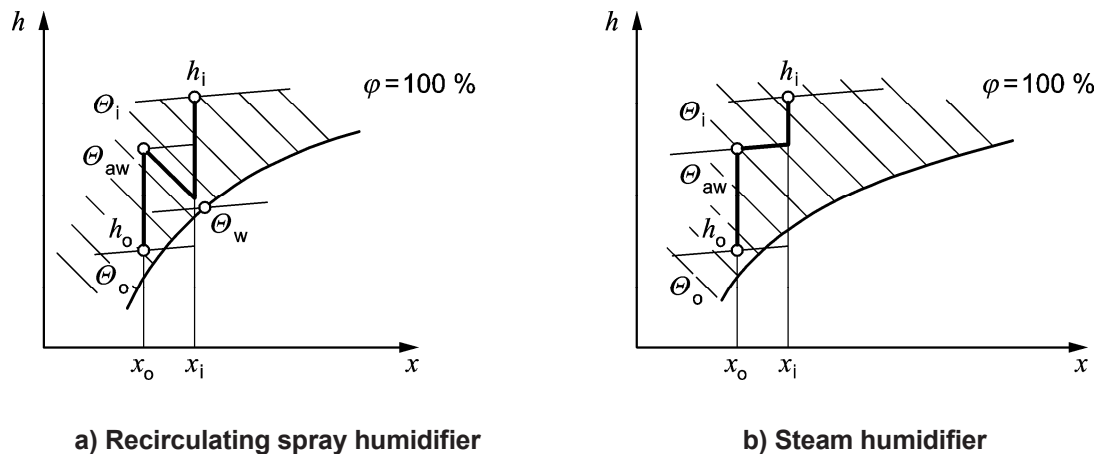
Additionally, the following should be measured:

- 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 ($\pm 20\%$).

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 recirculating 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 $\pm 20\%$ 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:

$$u_1 = \frac{\Delta x}{\sqrt{3}} \quad (1)$$

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

$$u_2 = \frac{k}{2\sqrt{3}} \text{ of resolution,} \quad (2)$$

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

$$x = x_1 + x_2 + x_3 + \dots + x_i \quad (3)$$

then the total uncertainty u_y is calculated from the formula:

$$u_y = \pm \sqrt{u_1^2 + u_2^2 + u_3^2 + \dots + u_i^2} \quad (4)$$

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

$$x = \frac{x_1 \cdot x_2}{x_3} \quad (5)$$

then it is appropriate to use the relative uncertainty

$$\tau = \frac{u}{x} \quad (6)$$

This gives the total uncertainty as

$$\tau_y = \pm \sqrt{\tau_1^2 + \tau_2^2 + \tau_3^2} \quad (7)$$

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

$$x = \frac{x_1^2 \cdot \sqrt{x_2}}{x_3} \quad (8)$$

then the total uncertainty is calculated by the formula:

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

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,