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High efficiency filters and filter media for removing particles in air —

Part 1: Classification, performance, testing and marking

Filtres à haut rendement et filtres pour l'élimination des particules dans l'air —

Partie 1: Classification, essais de performance et marquage

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 142, *Cleaning equipment for air and other gases.*

This third edition cancels and replaces the second edition (ISO 29463-1:2017), which has been technically revised.

The main changes are as follows:

— two E classes have been included in Tables 1 and 2;

— informative Annex C for measuring air velocity uniformity has been added.

A list of all parts in the ISO 29463 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/member.html.

Introduction

The ISO 29463 series is derived from the EN 1822 series. It contains requirements, fundamental principles of testing and the marking for high-efficiency particulate air filters with efficiencies from 85 % to 99,999 995 % that can be used for classifying filters in general or for specific use by agreement between users and suppliers.

The ISO 29463 series establishes a procedure for the determination of the efficiency of all filters on the basis of a particle counting method using a liquid (or alternatively a solid) test aerosol and allows a standardized classification of these filters in terms of their efficiency, both local and overall efficiency, which covers most needs of different applications. The difference between this document and other national standards lies in the technique used for the determination of the overall efficiency. Instead of mass relationships or total concentrations, this technique is based on particle counting at the most penetrating particle size (MPPS), which for micro fibre-glass filter media is usually in the range of 0,12 µm to 0,25 µm. This method also allows testing ultra-low penetration air filters, which was not possible with the previous test methods because of their inadequate sensitivity. For membrane filter media, separate rules apply, and are described in ISO 29463-5:2022, Annex B. Although no equivalent test procedures for testing filters with charged media is prescribed, a method for dealing with these types of filters is described in ISO 29463-5:2022, Annex C. Specific requirements for testing method, frequency, and reporting requirements may be modified by agreement between supplier and customer. For lower efficiency filters (Group H, as described in Clause 5), alternate leak test methods noted in ISO 29463-4:2011, Annex A may be used by specific agreement between users and suppliers, but only if the use of these other methods is clearly designated in the filter markings, as noted in the annex. Although the methods prescribed in this document can be generally used to determine filter performance for nano-size particles, testing or classification of filters for nano-size particles are beyond the scope of this document (see Annex A for additional information).

There are differences between the ISO 29463 series and other normative practices common in several countries. For example, many of these rely on total aerosol concentrations rather than individual particles. A brief summary of these methods and their reference standards is provided in ISO 29463-5:2022, Annex A.

High efficiency filters and filter media for removing particles in air —

Part 1: Classification, performance, testing and marking

1 Scope

This document establishes a classification of filters based on their performance, as determined in accordance with ISO 29463-3, ISO 29463-4 and ISO 29463-5. It also provides an overview of the test procedures and specifies general requirements for assessing and marking the filters, as well as for documenting the test results. It is intended to be used in conjunction with ISO 29463-2, ISO 29463-3, ISO 29463-4 and ISO 29463-5.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 29463-2:2011, *High-efficiency filters and filter media for removing particles in air — Part 2: Aerosol production, measuring equipment and particle-counting statistics*

ISO 29463-3:2011, *High-efficiency filters and filter media for removing particles in air — Part 3: Testing flat sheet filter media*

ISO 29463-4:2011, *High-efficiency filters and filter media for removing particles in air — Part 4: Test method for determining leakage of filter elements-Scan method*

ISO 29463-5:2022, *High-efficiency filters and filter media for removing particles in air — Part 5: Test method for filter elements*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
filter medium
material used for separating contaminants from air and characterized by its porous structure

[SOURCE: ISO 29464:2024, 3.1.25]

3.2
filter element
filter
structure made of the filtering material, its supports and its interfaces with the filter housing

[SOURCE: ISO 29464:2024, 3.2.59, modified — "filter" has been added as a preferred term.]

3.3
removal efficiency
efficiency
fraction or percentage of a challenge contaminant that is removed by an air cleaner

[SOURCE: ISO 29464:2024, 3.1.17 modified — "efficiency" has been added as a preferred term.]

3.4
fractional removal efficiency
fractional efficiency
ability of an air cleaning device to remove particles of a specific size or size range

Note 1 to entry: The efficiency plotted as a function of particle size gives the particle size efficiency spectrum.

[SOURCE: ISO 29464:2024, 3.2.134, modified — "fractional efficiency" has been added as a preferred term.]

3.5
particle diameter
geometric mean diameter (equivalent spherical, optical or aerodynamic, depending on context) of the particles of an aerosol

Note 1 to entry: Particle diameter is often referred to simply as "particle size".

[SOURCE: ISO 29464:2024, 3.2.106, modified — "mean" has been added to the definition.]

3.6
integral removal efficiency
overall efficiency
efficiency (3.3), averaged over the whole *superficial face area* (3.10) of a filter under given operating conditions

[SOURCE: ISO 29464:2024, 3.2.136, modified — "removal" has been removed from the preferred term "overall removal efficiency" and from the definition.]

3.7
local filter removal efficiency
local filter efficiency
efficiency (3.3) at a specific point of a *filter element* (3.2) under given operating conditions

[SOURCE: ISO 29464:2024, 3.2.137, modified — "local filter efficiency" has been added as a preferred term; "removal" has been removed from the definition.]

3.8
nominal air volume flow rate
air volume flow rate at which the *filter element* (3.2) is tested as specified by the manufacturer

3.9
filter face area
air cleaner face area
cross-sectional face area of the air cleaner through which air flows into the device

[SOURCE: ISO 29464:2024, 3.1.22]

3.10
superficial face area
cross-sectional area of the *filter element* (3.2) through which the air flow passes

[SOURCE: ISO 29464:2024, 3.2.48]

3.11
effective filter medium area
area of the *filter medium* (3.1) contained in the *filter element* (3.2) through which air passes during operation

Note 1 to entry: This excludes areas covered by sealant, spacers, struts, etc.

Note 2 to entry: Effective filter medium area is expressed in m^2.

[SOURCE: ISO 29464:2024, 3.1.27]

3.12
medium velocity
nominal filter medium face velocity
volumetric air flow rate divided by the *effective filter medium area* (3.11) of the *filter* (3.2)

Note 1 to entry: Filter medium velocity is expressed in m/s (fpm).

Note 2 to entry: In devices where the filter medium surface area has been increased by use of pleats, folds or bags, the filter medium velocity may be much less than the filter face velocity.

[SOURCE: ISO 29464:2024, 3.1.28, modified — “nominal filter medium face velocity” has been added as a preferred term.]

3.13
quasi-monodisperse test aerosol
aerosol, the width of whose distribution function, described by the geometric standard deviation σ_g, is between 1,15 µm and 1,5 µm

[SOURCE: ISO 29464:2024, 3.2.7, modified — “test” has been added to the term.]

3.14
coefficient of variation
CV
standard deviation of a group of measurements divided by the mean

[SOURCE: ISO 29464:2024, 3.2.28]

4 Symbols and abbreviated terms

d_p	particle diameter
E	efficiency
P	penetration
p	pressure
Δp	differential pressure, pressure drop
CPC	condensation particle counter
DEHS	sebacic acid-bis (2 ethyl hexyl-) ester (trivial name: di-ethyl-hexyl-sebacate)
DMA	differential electric mobility analyser

DMPS	differential mobility particle sizer
MPPS	most penetrating particle size, that is the particle size for which the filtration efficiency is a minimum
OPC	optical particle counter
PAO	poly-alpha-olefin (CAS Registry Number® 68649-12-7)[1)]
PSL	poly-styrene latex (solid spheres)
φ	relative humidity
T	temperature
v	velocity
x, y, x	notation for three cartesian planes

5 Classification

Filters and filter elements are classified in groups and classes based on their efficiency or penetration for the MPPS particles by testing as prescribed in Clause 6 and in ISO 29463-5. According to this document, filter elements fall into one of the following groups.

a) Group E: EPA filters (efficient particulate air filter), also commonly referred to as sub-HEPA.

   The efficiency of the filters shall be determined by statistical sample testing only in accordance with ISO 29463-5. Group E filters cannot and shall not be leak tested.

b) Group H: HEPA filters (high-efficiency particle air filter)

   Filters are individually tested, and their efficiency shall be determined at MPPS in accordance with ISO 29463-5. The filter should be leak tested in accordance with ISO 29463-4, where, in addition to the reference leak scan method, four alternate methods for leak testing are allowed. Alternate methods used for leak testing should be clearly identified on the filter and certifications.

c) Group U: ULPA filters (ultra-low penetration air filter)

   Filters are individually tested, and their efficiency shall be determined at MPPS in accordance with ISO 29463-5. Filters shall be leak tested according to the scan method in accordance with ISO 29463-4. No alternate leak testing is allowed.

A detailed specification for each filter group and class is given in Tables 1 and 2. Either of these tables can be used for filter classification purposes.

Detailed information about the permissible test methods in accordance with the ISO 29463 series for each filter group and class of filters is given in Annex B, Table B.1.

1) Chemical Abstracts Service (CAS) Registry Number® is a trademark of the American Chemical Society (ACS). This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

Table 1 — Filter classification: allowed filter classes (5/10th filter efficiency)

Filter class and group	Overall value		Local value [a,b]	
	Efficiency (%)	Penetration (%)	Efficiency (%)	Penetration (%)
ISO 05 E	≥ 85	≤ 15	— [c]	— [c]
ISO 15 E	≥ 95	≤ 5	— [c]	— [c]
ISO 25 E	≥ 99,5	≤ 0,5	— [c]	— [c]
ISO 35 H [d]	≥ 99,95	≤ 0,05	≥ 99,75	≤ 0,25
ISO 45 H [d]	≥ 99,995	≤ 0,005	≥ 99,975	≤ 0,025
ISO 55 U	≥ 99,999 5	≤ 0,000 5	≥ 99,997 5	≤ 0,002 5
ISO 65 U	≥ 99,999 95	≤ 0,000 05	≥ 99,999 75	≤ 0,000 25
ISO 75 U	≥ 99,999 995	≤ 0,000 005	≥ 99,999 9	≤ 0,000 1

[a] See 7.5.2.4 and ISO 29463-4.

[b] Local penetration values lower than those given in this table can be agreed upon between the supplier and customer.

[c] Filters of Group E cannot and shall not be leak tested for classification purposes.

[d] For Group H filters, local penetration is given for reference MPPS particle scanning method. Alternate limits may be specified when photometer or oil thread leak testing is used.

Table 2 — Filter classification: allowed filter classes (1/10th filter efficiency)

Filter class and group	Overall value		Local value [a,b]	
	Efficiency (%)	Penetration (%)	Efficiency (%)	Penetration (%)
ISO 10 E	≥ 90	≤ 10	— [c]	— [c]
ISO 20 E	≥ 99	≤ 1	— [c]	— [c]
ISO 30 E	≥ 99,90	≤ 0,1	— [c]	— [c]
ISO 40 H [d]	≥ 99,99	≤ 0,01	≥ 99,95	≤ 0,05
ISO 50 U	≥ 99,999	≤ 0,001	≥ 99,995	≤ 0,005
ISO 60 U	≥ 99,999 9	≤ 0,000 1	≥ 99,999 5	≤ 0,000 5
ISO 70 U	≥ 99,999 99	≤ 0,000 01	≥ 99,999 9	≤ 0,000 1

[a] See 7.5.2.4 and ISO 29463-4.

[b] Local penetration values lower than those given in this table can be agreed upon between the supplier and customer.

[c] Filters of Group E cannot and shall not be leak tested for classification purposes.

[d] For Group H filters, local penetration is given for reference MPPS particle scanning method. Alternate limits may be specified when photometer or oil thread leak testing is used.

6 Requirements

6.1 General

The filter element shall be designed or marked to prevent incorrect mounting.

The filter element shall be designed so that when correctly mounted in the ventilation duct, no leak occurs along the sealing edge.

If, for any reason, dimensions do not allow testing of a filter under standard test conditions, assembly of two or more filters of the same type or model is permitted, provided no leaks occur in the resulting filter. Cutting or trimming of larger filters is not permitted for testing.

If the filter is tested without the filter seal fitted, and if designed to have a filter seal, then the filter test certificate shall be clearly marked “filter efficiency tested without filter seal fitted”.

6.2 Material

The filter element shall be made of suitable material to withstand normal usage and exposures to those temperatures, humidity and corrosive environments that are likely to be encountered.

The filter element shall be designed so that it will withstand mechanical constraints that are likely to be encountered during normal use.

Dust or fibres released from the filter media by the air flow through the filter element shall not constitute a hazard or nuisance for the people (or devices) exposed to filtered air.

6.3 Nominal air volume flow rate

The filter element shall be tested at its nominal air volume flow rate for which the filter has been designed by the manufacturer.

6.4 Pressure difference

The pressure difference across the filter element shall be recorded at the nominal air volume flow rate.

6.5 Filtration performance

The filtration performance is expressed by the efficiency or the penetration as measured by the prescribed procedures in ISO 29463-5. After testing in accordance with Clause 7, filter elements are classified in accordance with Tables 1 and 2.

Filters with filter media having an electrostatic charge are classified in accordance with Tables 1 and 2, based on their discharged efficiency or penetration in accordance with ISO 29463-5:2022, Annex C.

7 Test methods — General requirements and test procedures overview

7.1 General

The complete test method comprises the following three steps, which can be performed independently:

— test for flat sheet filter media, in accordance with ISO 29463-3;

— test for determining the leakage of filter elements (scan method), in accordance with ISO 29463-4;

— test for determining the efficiency of filters, in accordance with ISO 29463-5.

Clause 7 provides the general requirements for the features common to all tests, as well as an overview of the test procedures.

Detailed information about the permissible test methods for filter elements in accordance with the ISO 29463 series for each filter group and class of filters is given in Table B.1.

7.2 Test rigs

Test rigs shall be in accordance with ISO 29463-3, ISO 29463-4 and ISO 29463-5 for the respective tests. The measuring equipment shall be in accordance with ISO 29463-2.

7.3 Test conditions

The air in the test channel used for testing shall comply with the following requirements:

— temperature: 23 °C ± 5 °C

— relative humidity < 75 %.

The temperature shall remain constant during the entire test procedure within ± 2 °C, the relative humidity shall remain within ± 5 %.

The cleanliness of the test air shall be ensured by appropriate pre-filtering, so that in operation without addition of aerosol the particle number concentration measured with the particle counting method is less than 352 000 particles/m^3. The test specimen shall have the same temperature as the test air and hence shall be conditioned at test requirements (temperature and relative humidity) long enough to be in equilibrium.

7.4 Test aerosols

For the testing of filters in accordance with this document, a liquid test aerosol shall be used as the reference test method. Alternatively, a solid aerosol may be used for leak testing (see ISO 29463-4:2011, Annex E). Possible aerosol substances include, but are not limited to, DEHS, PAO and PSL. For further details, see ISO 29463-2:2011, 4.1.

The use of alternative materials for challenge aerosols shall be agreed between supplier and customer when the materials specified in this document are unacceptable.

The concentration and the size distribution of the aerosol shall be constant, within experimental limits, over time. Details of aerosol generation for testing are addressed in the other parts of ISO 29463. For the leak test and the efficiency test of the filter element, the count mean particle diameter of the test aerosol shall correspond to the most penetrating particle size (MPPS) for the filter medium.

7.5 Test methods — Principles

7.5.1 Test method for flat sheet filter media

7.5.1.1 General

The fractional efficiency curve of flat sheet filter medium samples is determined in new condition (material as supplied by the medium manufacturer) and in discharged condition (see ISO 29463-5:2022, Annex C). If these measurements reveal that the filter medium is having a significant charge, the filter elements shall be classified based on the discharged flat sheet efficiency or penetration measurements in accordance with ISO 29463-5:2022, Annex C.

From the fractional efficiency curve generated this way, the most penetrating particle size (MPPS) shall be determined.

7.5.1.2 Test samples

The testing procedure requires at least five flat sheet samples of the filter material that will make up the filter elements.

The test samples shall be free of folds, creases, holes and other irregularities. The flat sheet samples for testing shall have a minimum size of 200 mm × 200 mm.

7.5.1.3 Test apparatus

The arrangement of the test apparatus is shown in Figure 1. The test rig is described in detail in ISO 29463-3. The individual measuring instruments and other devices are described in ISO 29463-2. An aerosol is produced in the aerosol generator, then passed through a conditioner (for example, to evaporate a solvent) and neutralised, before being brought together with the particle-free mixing air to the test filter medium mounting assembly.

Sampling points are positioned upstream and downstream from the test filter medium mounting assembly from which a part of the flow is led to the particle counter. The upstream sampling point is connected with a known ratio dilution circuit to reduce the high particle concentration down to the actual measuring range of the particle counter.

When using the total count counting method (CPC), a differential electric mobility analyser (DMA) is included before the aerosol neutralizer to separate out a quasi-monodisperse fraction of the required particle size from the initial polydisperse aerosol.

If a counting method with particle size analysis (OPC) is used, the size distribution of a polydisperse aerosol can be measured before and after the test specimen.

Instead of using a single particle counter, which measures the unfiltered and filtered air consecutively, it is also permissible to use two particle counters of equal optical design (wavelength of the light source, light scattering angle, etc.) simultaneously for both measurements. When using two particle counters, the two counters shall be correlated by measuring the same aerosol to correct for any response differences. It is known that OPCs of the same model can give different responses.

After the downstream sampling point, the test aerosol is led through an exhaust filter and extracted by a pump. The apparatus is completed by devices to measure (and regulate) the air volume flow rate and the differential pressure across the filter under test.

The measurement data are recorded and evaluated by a computer.

The test apparatus can also be operated in an overpressure mode. In this case, the extraction pump is not required and the mixing air is supplied from a compressed air line. If so desired, the measurement and regulation of the air volume flow rate can then be carried out on the upstream side.

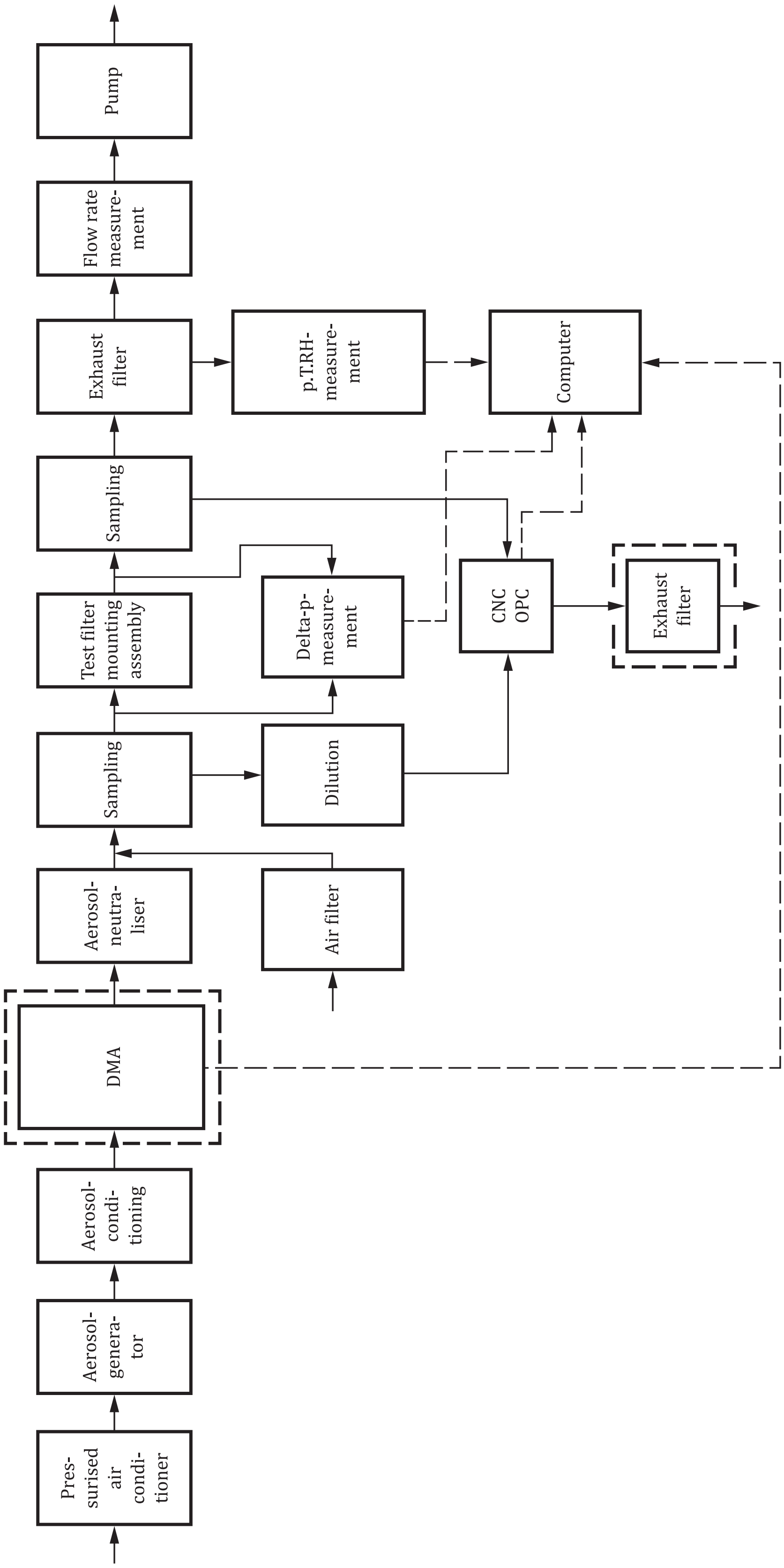


Figure 1 — Arrangement of apparatus for testing the filter medium

7.5.1.4 Measurement procedure

The performance of the filter medium is determined by testing a circular sample with an exposed area of 100 cm^2 at the nominal filter medium face velocity. Details of the measurements are described in ISO 29463-3. In order to establish the penetration versus particle size curve, the penetration values for at least six logarithmically, approximately equidistant particle size points are determined.

For this measurement, quasi-monodisperse test aerosol from a DMA with appropriate median values of the particle diameter is used, and the concentrations of the particles are determined upstream and downstream of the test sample. Alternatively, the size distribution of a polydisperse aerosol can be determined by OPC's upstream and downstream of the test sample in at least six particle size classes. In each case, it shall be ensured that the measuring range of the particle counter and the range of produced particle sizes envelopes the minimum of the efficiency curve (MPPS).

7.5.1.5 Evaluation of test results

From the measurements on the five test samples, the efficiency versus particle size curve shall be drawn (see Figure 2 for an example) from which the position and value of the minimum efficiency shall be determined.

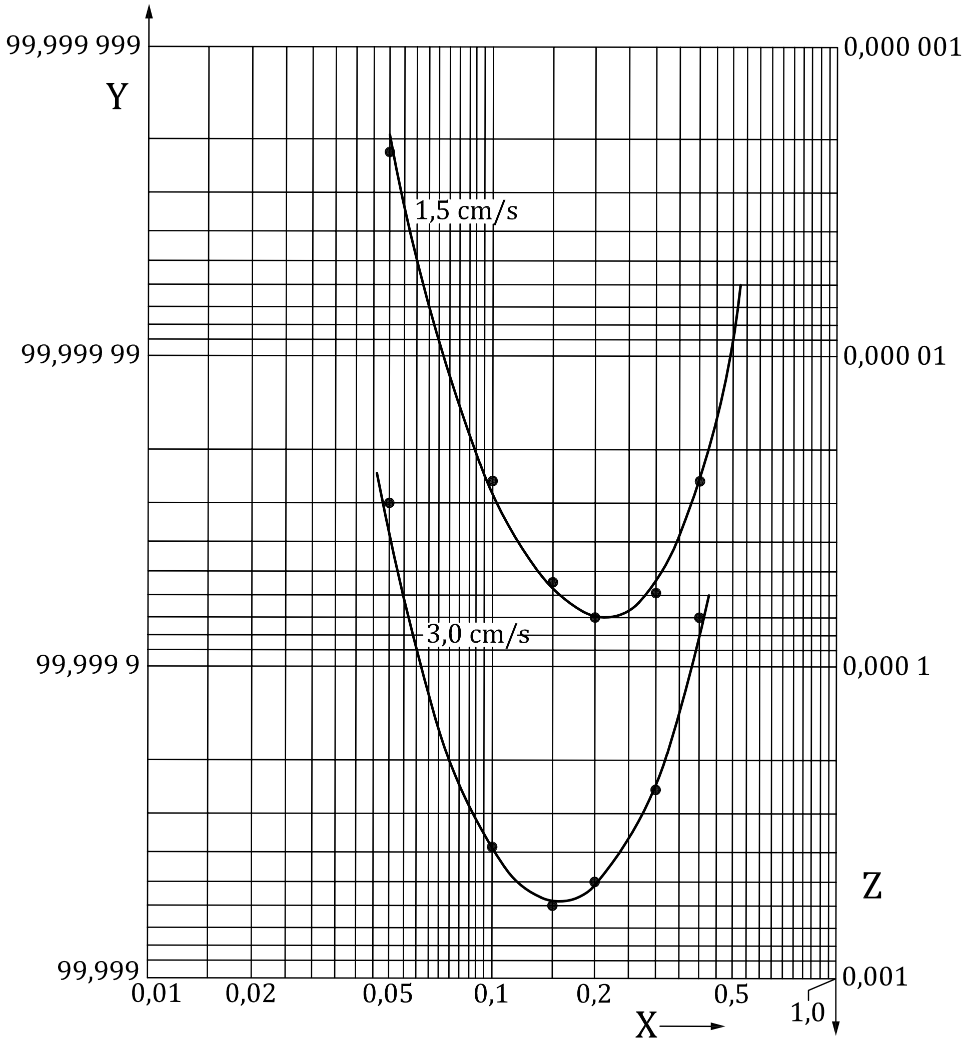
Arithmetic mean values shall be determined for:

— the minimum efficiency;

— the particle size at the minimum efficiency (MPPS);

— the pressure difference, i.e. resistance.

The particle size at the MPPS shall subsequently be used as the mean size of the test aerosol in the filter element leakage test (see 7.5.2) and in the efficiency test (see 7.5.3).



Key

X particle diameter (µm)

Y particle size efficiency (%)

Z penetration (%)

Figure 2 — Example of particle size efficiency (*E*) and penetration (*P*) of an ULPA-filter medium as a function of the particle diameter (d_p) for two different filter medium velocities

7.5.2 Test method for determining the leakage of filter elements — Scan method

7.5.2.1 General

The leak test serves to test the filter elements of groups H and U for local penetration and the absence of leaks, respectively (see Tables 1 and 2). The reference method and basis for this test is the particle counting scan method as described in ISO 29463-4.

Filter elements of Group H shall be leak tested using one of the five leak test methods described in ISO 29463-4:2011; the reference scanning method, the oil thread leak test, the aerosol photometer filter scan leak test, the PSL leak test, or the 0,3 µm to 0,5 µm particle efficiency leak test (see ISO 29463-4:2011, Annexes A, B, E and F).

For Group H filters with filter shapes creating highly turbulent air flow (e.g. V-bank or cylindrical filters), for which the reference scan method cannot be applied, leak testing by either of the two alternative methods can be applied; the oil thread leak test (ISO 29463-4:2011, Annex A) or the 0,3 µm to 0,5 µm particle efficiency leak test (ISO 29463-4:2011, Annex F).

Filter elements of Group U shall be leak tested using the MPPS scanning method only, in accordance with ISO 29463-4, unless the configuration does not allow scanning (e.g. V-bank or cylindrical filters). In this case, it is possible that the alternative methods noted for Group H filters are not sensitive enough to measure the local penetration limits specified in Tables 1 and 2. Therefore, Group U filters, leak tested with the alternative methods shall be marked “Alternative leak tested, method A or F” on their label and test report, to clearly indicate that a less stringent leak test criterion has been applied.

All leak tests, whether by the reference method or alternate method, shall be performed at the nominal/rated air flow of the tested filter element.

Note Since the photometer and particle count test are based on different principles, the results between a photometer leak test and particle counter leak test cannot be compared. The photometer test of ISO class 35H to 45H as per ISO 29463-4:2011, Annex B, is usually more stringent while the ISO factory test of these ISO class filters according to ISO 29463-4:2011, Annex C, allows leaks of a higher level.

7.5.2.2 Test specimen

For leak testing, a filter element is required which can be sealed into the test rig and subjected to an air flow direction in accordance with the final requirements.

7.5.2.3 Test apparatus

The arrangement of the individual components of the test apparatus for the scan test is shown in Figure 3. The pre-filtered test air is drawn in by a fan and passed through a secondary filter (see 7.2). The air volume flow rate is measured by a standardised air volume flow measuring device according to ISO 5167-1, or any other volume flow rate measuring device which can be calibrated and shall be kept constant by a flow rate controller. A neutralised aerosol with a mean size corresponding to the MPPS of the filter medium and at the nominal face velocity of the filter element is introduced and distributed uniformly upstream of the filter. One or more mechanically movable sample probes are provided downstream to permit traversing the entire face.

Upstream and downstream particle count measurements are made with OPC’s or DMPS (see ISO 29463-2) with or without dilution.

7.5.2.4 Measurement procedure

Leak testing is performed at the nominal air flow rate of the filter. The test aerosol is introduced uniformly upstream of the filter. The downstream concentration is sampled by the sampling probes which traverse the entire (100 %) face of the filter in overlapping scan tracks and at a defined linear rate of movement. The particle concentration is compared with that upstream side and the local penetration at each location of the traversing probe determined. In the scanning operation, the entire surface of the filter element shall be covered in overlapping tracks.

7.5.2.5 Evaluation of test results

Using the test parameters of the leak test (see ISO 29463-4), the permissible local value of the efficiency (see Tables 1 and 2) and taking statistical relationships into account (see ISO 29463-2), it is possible to calculate a limit value for the particle counting rate that indicates a leak.

If the limit value for the particle counting rate is not exceeded at any point on the filter surface, the filter has passed the leakage test and is considered to be leak free.

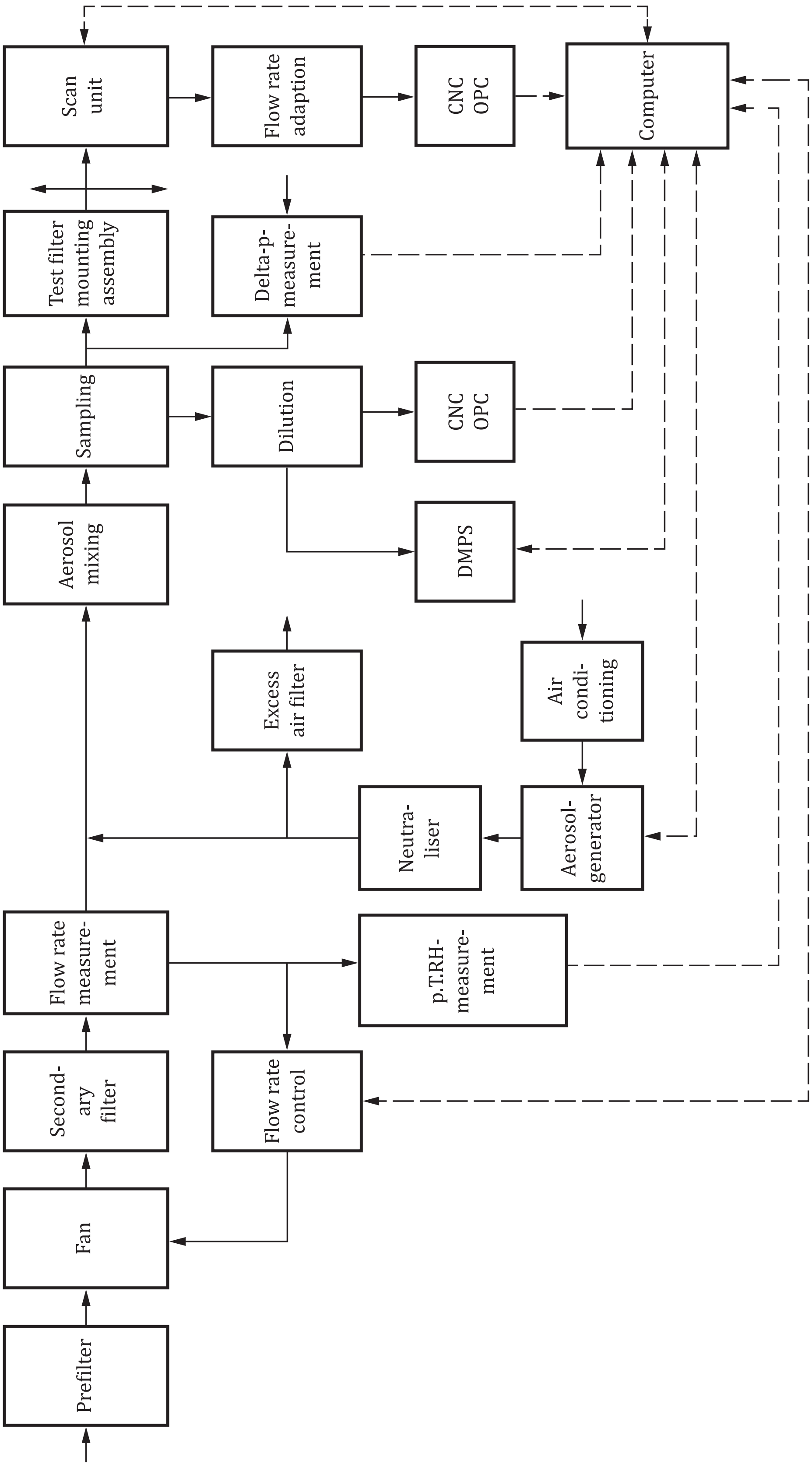


Figure 3 — Arrangement of apparatus for leak testing

7.5.3 Test method for determining the efficiency of filter elements

7.5.3.1 General

The overall efficiency of the complete filter element is determined by measuring the average particle concentration on the upstream and downstream sides of the filter with stationary sampling probes. For all filter classes, measurements are made with discrete particles and particle counters. For Group H filters, as noted above, other test methods that may be used by agreement between supplier and customer are noted in ISO 29463-5:2022, Annexes A, B and C.

7.5.3.2 Test specimen

For H and U elements, the test specimen used shall be tested for leakage and be leak-free in accordance with 7.5.2. For E elements the leakage test is not mandatory.

7.5.3.3 Test apparatus

The test to determine the overall efficiency of the filter element shall be carried out in the test apparatus shown in Figure 4. The upstream portion of the system used in the efficiency test setup is schematically similar to the test apparatus used for the leakage test and is discussed further in ISO 29463-5. The test filter mounting assembly is followed by a flow channel, which mixes the aerosol on the downstream side uniformly over the whole cross-section of the channel. A stationary sample port is provided downstream of the filter for particle measurement. The air is discharged through an exhaust filter.

The test procedure is described in detail in ISO 29463-5. The individual methods of measurement are described in ISO 29463-2.

7.5.3.4 Measurement procedure

The filter element shall be subjected to the nominal air volume flow rate with the same aerosol as used for the leak test. The particle concentration shall be measured on the upstream and downstream sides of the filter element being tested. A dilution circuit is included on the upstream side to adjust the concentration to that measurable by the particle counters (see ISO 29463-2). The pressure differential across the filter element is measured before the filter is subject to test aerosol.

7.5.3.5 Evaluation of test results

The overall efficiency shall be calculated from the particle concentrations measured on the upstream and downstream sides of the filter element being tested (see ISO 29463-2 and ISO 29463-5).

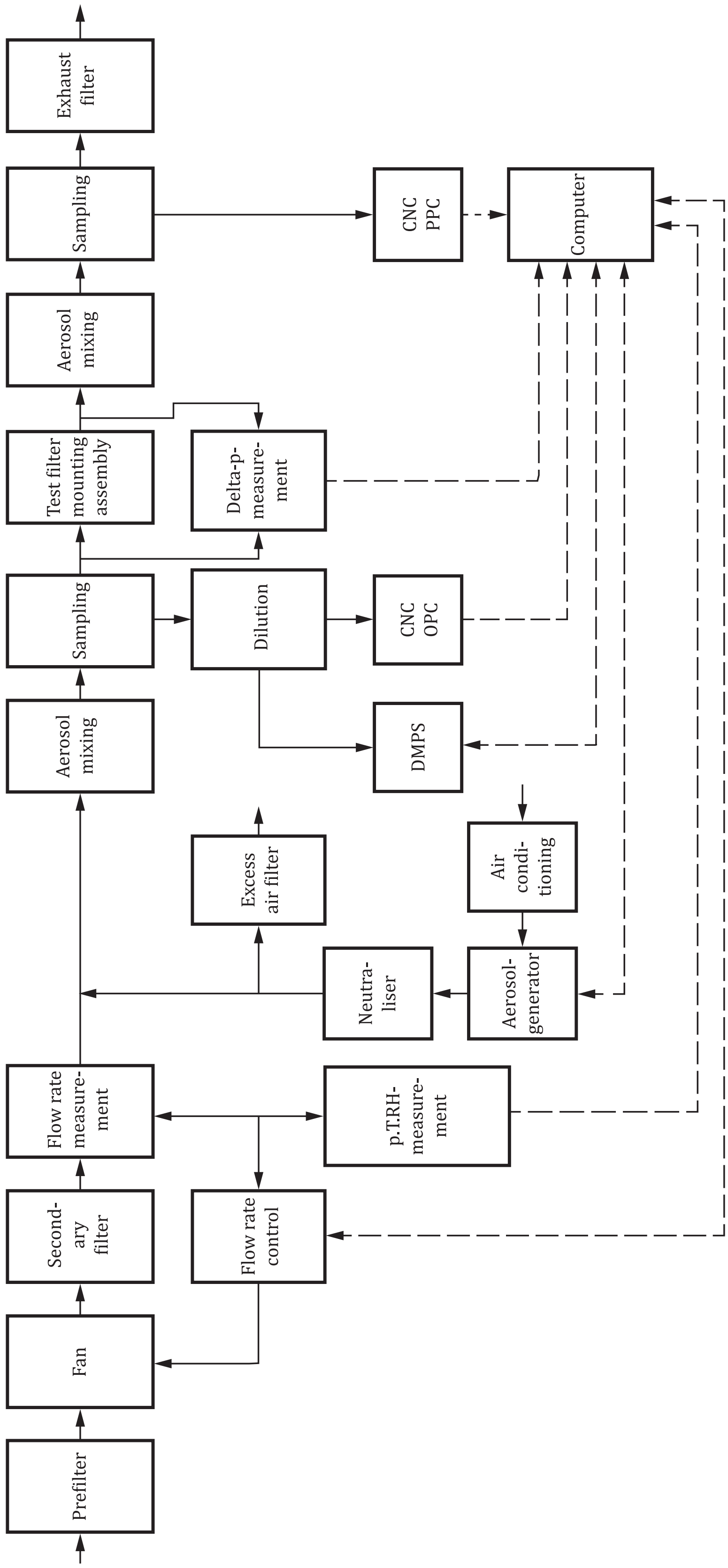


Figure 4 — Arrangement of apparatus for efficiency testing using the static measuring method

7.5.4 Remarks

On the basis of the value(s) determined for overall efficiency, and for filters of groups H and U for local filter efficiency (absence of relevant leaks), filter elements shall be assigned to a filter class as specified in 6.5. This classification is only valid if the fixed test conditions and procedures are met.

In all three procedural steps given in 7.5.1, 7.5.2 and 7.5.3, it is permissible to use either a monodisperse or a polydisperse test aerosol. The particle counting method used can be a total count method (CPC) or a method involving particle size analysis (OPC).

Since total count particle counting methods provide no information about the particle size, they can only be used to determine the efficiency in 7.5.1 with monodisperse test aerosols of a known particle size.

For the determination of the minimum efficiency of the flat sheet filter medium (7.5.1), the test method using a monodisperse test aerosol shall be considered as the reference test method. Care shall be taken for the correlation with the reference test method if using a polydisperse aerosol for the steps in 7.5.2 and 7.5.3.

For production testing, filter manufacturers can use data of their filter medium supplier, instead of doing these tests themselves, as long as the data are fully traceable and documented and the tests are done in full accordance with the ISO 29463 series and, in particular, with ISO 29463-3.

However, it is necessary to be aware that in any case, it remains the responsibility of the filter manufacturer to ensure the correctness in accordance with this document, traceability and documentation of the data. This can be accomplished by maintaining a quality management system, e.g. ISO 9000, including supplier audits and regular cross checking of the data provided by the filter medium supplier or verified by third party measurements. The cross checking of the filter medium data shall be done using an accepted statistical method, which can be the skip lot procedure as described in ISO 2859-1 or any equivalent alternative method.

7.5.5 Air flow distribution

Often, the uniformity of the velocity of the air exiting a high efficiency filter can be as important as the filter efficiency. A method for determining the uniformity of the air velocity across the face of the filter is given in Annex C. Although not mandatory, if the test is performed, the results should be included in the test report for the filter.

8 Assessment of the filter, documentation and test reports

The EPA, HEPA or ULPA filter tested fully in accordance with this document shall be assigned to a filter class in accordance with Tables 1 and 2 on the basis of its overall efficiency (penetration) as determined in accordance with 7.5.3. For filters of Groups H and U, this is done on the basis of the requirements for its local filter efficiency, that is, absence of relevant leaks, determined in accordance with 7.5.2.

The test results shall be documented in a test certificate or test report. The test report shall give full information about the tested object (filter medium or filter), test parameters [e.g. air flow volume, test method, aerosol and particle or aerosol sampling instrumentation (particle counters) used], and the test results.

Detailed requirements for test reports depend on the type of test conducted and can be found in:

— ISO 29463-3:2011, Clause 11 for filter medium testing;

— ISO 29463-4:2011, Clause 9 for filter element leak testing;

— ISO 29463-5:2022, Clause 10 for filter element efficiency testing.

Test reports for the filter medium, in accordance with ISO 29463-3, are meant for internal use and shall form part of the quality assurance documentation of a company. Test reports for the filter element of filters of Groups H and U shall be part of the documentation that is normally supplied together with such filters. On the test reports for Group H and U filters, it is recommended to combine the information required in ISO 29463-4 and in ISO 29463-5 and issue a combined test report with all required information.

9 Marking

The filter shall be marked with the following type identification details:

a) name, trade mark or other means of identification of the manufacturer;

b) model, serial number and date of manufacture of the filter;

c) a reference to this document, i.e. ISO 29463-1:2024;

d) class of the filter (see Tables 1 and 2), including marking if another normative method in ISO 29463-4 is used for leak scanning;

e) nominal air volume flow rate at which the filter has been classified;

f) differential pressure sampled value at which the filter has been classified;

g) date of testing.

Marking of airflow direction through the filter shall be recorded to indicate proper installation orientation (e.g. with “TOP”, “Direction of flow” or an arrow symbol).

The marking shall be as clearly visible and as durable as possible.

Annex A
(informative)

Filtration of nanoparticles

Nano-aerosols are made of particles having one or more dimensions of the order of 100 nm or less. There is a lot of interest around nanoparticles because, at the nanoscale, their physical properties are quite different than the bulk material from which they are made of. However, currently there are concerns about man-made nanoparticles escaping into the environment, both indoors and outdoors, causing adverse health effects. There are some safety issues that are currently not fully understood and assessed.

Since the cleanliness of indoor environments is usually ensured by filtration systems, nanoparticle filtration is a key topic in the development of filtration test standards and their applications. The theory of particle capture by fibrous filters resulted in the now commonly known penetration curve with its distinct most penetrating particle size (MPPS). The efficiency of the filter is at its minimum, or its penetration at its maximum, for the MPPS and better at all other particle sizes, both larger and smaller than the MPPS. For typical current glass fibre media of Group H and U filters, the MPPS is between 120 nm and 250 nm. It has been speculated that the theory of particle capture could fail for nanoparticles, i.e. the penetration at these particle sizes will increase instead of decrease as the particle size decreases. Current research[11][12][13] shows that the penetration curve is valid for particles down to 5 nm. The research illustrates that testing and classifying filters at or near their MPPS will continue to yield the worst-case performance, and safest classification, even down to nanoparticles. Hence, the procedures and classification schemes prescribed in the ISO 29463 series are valid for filters used for nanoparticles. These filters result in a filter performing better than at their MPPS at which they are evaluated and classified. Thus, it is believed that Group H and U filters classified according to the ISO 29463 series result in filters with efficiencies for removing nanoparticles equal to or better than the ones measured for MPPS particles in accordance with the ISO 29463 series.

While the filters discussed in the ISO 29463 series show higher efficiencies for nanoparticle filtration, the actual efficiency of a filter for a specific nano-size particle is dependent on the particle measurement device and not on the procedures prescribed in the ISO 29463 series. Current measurement devices and methods capable of detecting nanoparticles are more common in research than in commercial measurements, mostly due to economic reasons. Discussions of these devices and their merits are outside the scope of the ISO 29463 series.

Annex B
(informative)

Summary of classification and test methods

Table B.1 provides detailed information about the permissible test methods in accordance with the ISO 29463 series for each filter group and class of filters.

Table B.1 — Overview of classification and test methods

Filter class (number) Filter group (letter)	Limit for overall value [a]		Limit for local value [a,b]		Test procedures							
	Efficiency (%)	Penetration (%)	Efficiency (%)	Penetration (%)	Overall efficiency test		Local filter efficiency test = Leak test [b]					
ISO 05 E	≥ 85	≤ 15	—	—	X [c]	X [c]	Filters of Group E cannot and shall not be leak tested for classification purposes.					
ISO 10 E	≥ 90	≤ 10	—	—	X [c]	X [c]						
ISO 15 E	≥ 95	≤ 5	—	—	X [c]	X [c]						
ISO 20 E	≥ 99	≤ 1	—	—	X [c]	X [c]						
ISO 25 E	≥ 99,5	≤ 0,5	—	—	X [c]	X [c]						
ISO 30 E	≥ 99,90	≤ 0,1	—	—	X [c]	X [c]						
ISO 35 H	≥ 99,95	≤ 0,05	≥ 99,75	≤ 0,25	X [d]	X [d]	X	X	X	X [e]	X	X
ISO 40 H	≥ 99,99	≤ 0,01	≥ 99,95	≤ 0,05	X [d]	X [d]	X	X	X	X [e]		
ISO 45 H	≥ 99,995	≤ 0,005	≥ 99,975	≤ 0,025	X [d]	X [d]	X	X	X	X [e]		
ISO 50 U	≥ 99,999	≤ 0,001	≥ 99,995	≤ 0,005	X [d]	X [d]	X			X [e]		
ISO 55 U	≥ 99,999 5	≤ 0,000 5	≥ 99,997 5	≤ 0,002 5	X [d]	X [d]	X			X [e]		
ISO 60 U	≥ 99,999 9	≤ 0,000 1	≥ 99,999 5	≤ 0,000 5	X [d]	X [d]	X			X [e]		
ISO 65 U	≥ 99,999 95	≤ 0,000 05	≥ 99,999 75	≤ 0,000 25	X [d]	X [d]	X			X [e]		
ISO 70 U	≥ 99,999 99	≤ 0,000 01	≥ 99,999 9	≤ 0,000 1	X [d]	X [d]	X			X [e]		
ISO 75 U	≥ 99,999 995	≤ 0,000 005	≥ 99,999 9	≤ 0,000 1	X [d]	X [d]	X			X [e]		
[a] See also Tables 1 and 2. [b] Local penetration values lower than those given in Tables 1 and 2 may be agreed upon between the supplier and customer. [c] Statistical efficiency test method may be applied per ISO 29463-5:2022, 4.2. [d] Efficiency test of each individual filter applies per ISO 29463-5:2022, Clause 8. [e] Comment in the test protocol and classification shall be made that filter is tested per ISO 29463-4:2011, Annex E.					ISO 29463-4, Test with movable probe	ISO 29463-5, Test with static probe	ISO 29463-4:2011, Annex C, Scan test (reference)	ISO 29463-4:2011, Annex A, Oil tread leak test	ISO 29463-4:2011, Annex B, Photometer scan test	ISO 29463-4:2011, Annex E, PSL leak test	ISO 29463-4, Annex F, 0,3 µm leak test	ISO 29463-4:2011, Annex B, Photometer overall test

Annex C
(informative)

Air flow distribution test on the autoscan testing system

C.1 General

In installations where HEPA and ULPA filters are used, in addition to the usual testing for efficiency, leakage and resistance, it is also customary to specify minimum levels of uniformity of air flow velocities over the entire filter.

The air flow velocity distribution is dependent on the air flow velocity distribution over the face area of each filter. Laminar air flow has become an increasingly important factor in today's cleanroom and clean bench technology. Air flow turbulence, which can transport contaminated air into critical areas, is caused by variances in the laminarity of the air flow. This can cause product contamination resulting in failure, even if the product is far away from the contamination source. The root cause of turbulence is often associated with a poor design of the air supply system. A poor filter design or construction can also contribute to air flow turbulence. A well designed and constructed laminar flow filter will not correct a poorly designed air supply system. Small differences in the filter caused by slight variations in the filter media, such as thickness, fibre-distribution and local resistance, can create some turbulence. However, dimensional deficiencies associated with the design and construction of the filter have a more significant impact.

Air velocity can be measured with a variety of available equipment, including but not limited to: rotating vane anemometers, thermo-anemometers, ultrasonic anemometers, pitot tubes etc. Using these types of instruments, a separate setup can be made to test a filter for airflow distribution. When performing this test, care shall be taken to have a good upstream airflow distribution with laminar airflow pattern. Downstream airflow patterns can be measured by hand with hand-held equipment including multiple, independent velocity sensors installed onto a collapsible lattice frame for simultaneous velocity uniformity measurements. Examples are shown in Figure C.1 and the measuring equipment selected for use needs to have the appropriate measuring interval and accuracy.

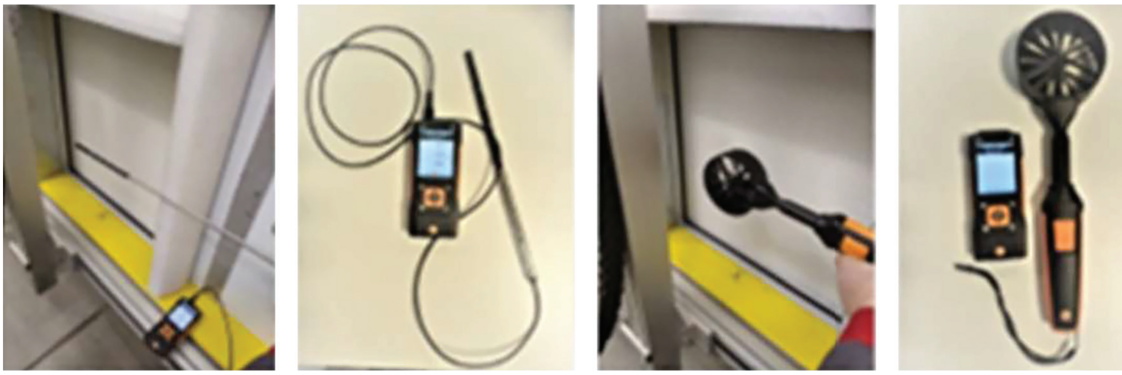


Figure C.1 — Examples of hand-held velocity measurement instruments

This annex provides a method for determining the air flow distribution over filters by testing filter velocities using the auto-scan test rig described in ISO 29463-4 and prescribed for determining leaks in HEPA and ULPA filters. Other test rigs can also be used if the supply air velocity uniformity can fulfil the requirements of this annex.

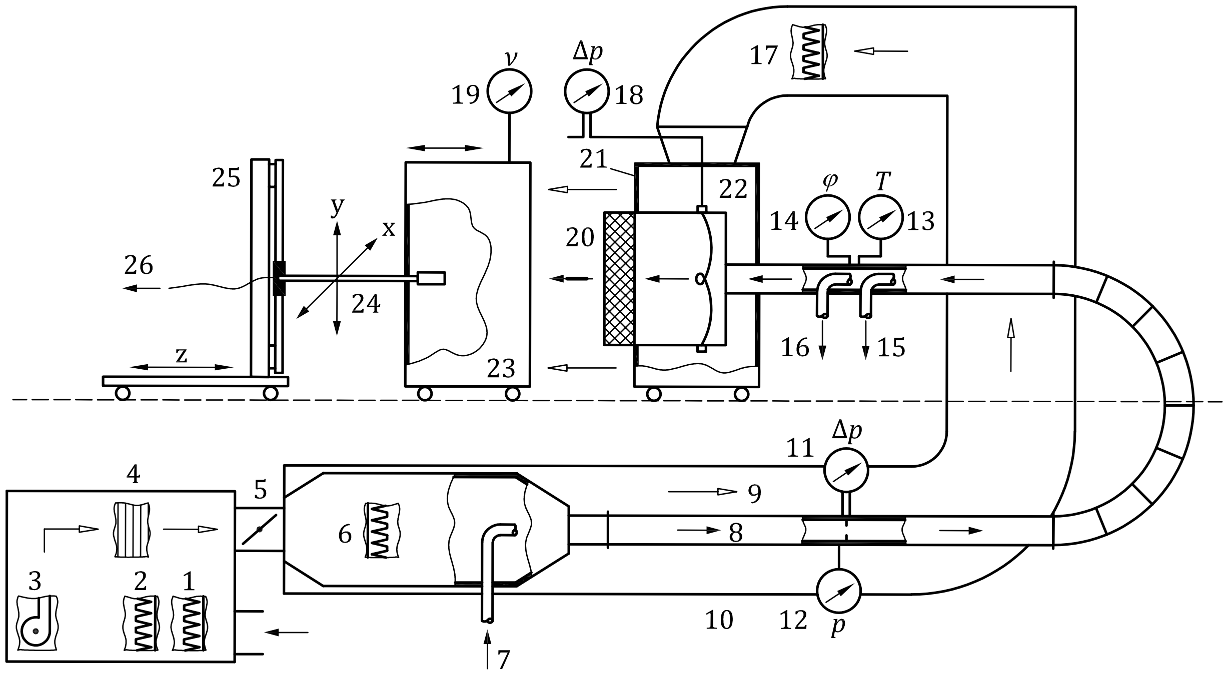
C.2 Test method overview

The test method described in this annex, is a factory test suitable for determining the air flow velocity distribution over the face of H and U class filters as defined according to the ISO 29463 series. The method is not applicable to non-flat panel geometry, such as V-bank or cylindrical filters.

The measured velocity distribution is not only a property of the tested air filter but is also influenced by the design of the whole test system. The test results therefore will likely not be reproduceable unless the system precautions described in C.3 have been taken to improve the air velocity pattern.

C.3 Test set up

The equipment and test rig required for this test are the same as specified in ISO 29463-4 for auto scanning for leaks in H and U class filters. The schematic of the test system is shown in Figure C.2.



Key

1	coarse dust filter
2	fine dust filter
3	fan
4	air heater
5	dampers to adjust test and sheath air
6	high efficiency air filter for the test air
7	aerosol inlet in the duct
8	test airflow
9	sheath airflow
10	effective pressure measuring device
11	differential pressure
12	atmospheric pressure
13	temperature measurement
14	hygrometer
15	sampling point for particle size analysis
16	sampling point, upstream
17	high efficiency air filter for the sheath air
18	measurement of pressure drop
19	measurement of sheath air speed
20	test filter with air straightener and airflow correcting screen
21	flow equalizer for the sheath airflow
22	filter mounting assembly
23	screening (linked to the filter mounting assembly during the testing)
24	traversing probe arm with multi-direction velocity probe
25	probe traversing system
26	downstream sampling point

Figure C.2 — Schematic of the test rig for the auto-scan test

Depending on the design of the auto scanning test system in ISO 29463-4, the system can require modification by adding air flow straighteners (honeycomb, 10 mm × 10 mm pattern) as shown in Figure C.3, to improve the air flow uniformity supplied to the test filter. A minimum depth of 150 mm for the straightener is needed.

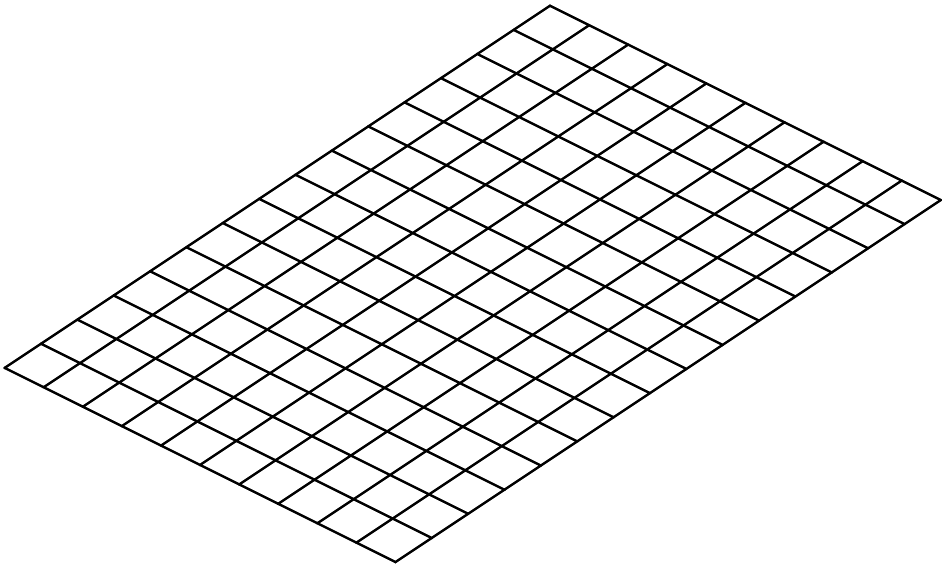
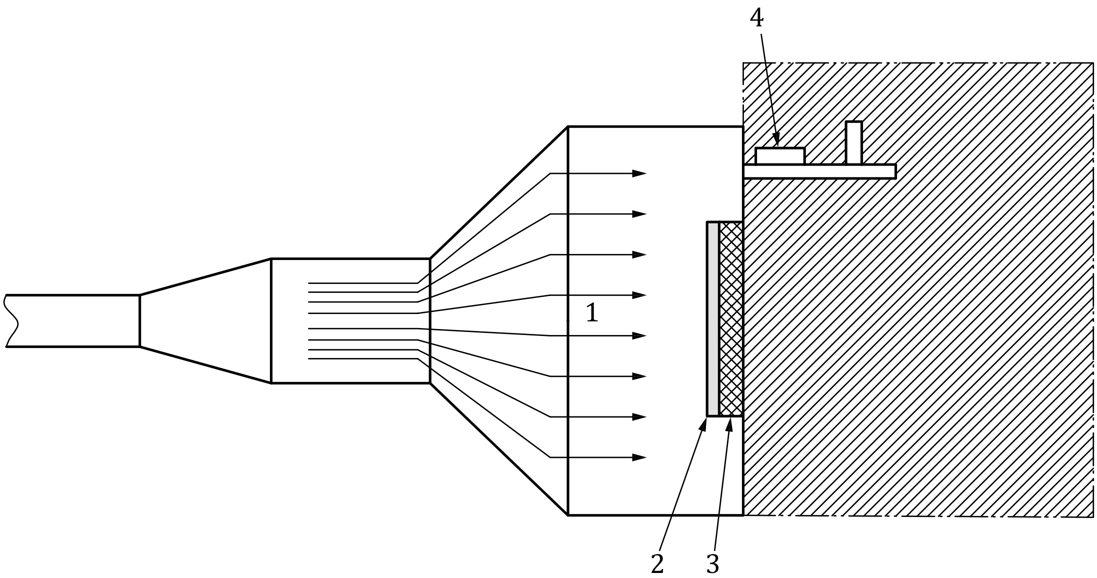


Figure C.3 — Air flow straighteners (honeycomb 10 mm × 10 mm)

Airflow straighteners can be used in scanning mode as shown in Figure C.4, without influencing the aerosol concentration. In most cases, this is not enough to completely correct the airflow uniformity and a monofilament printing screen is also used.



Key

1 air flow direction

2 frame with screen

3 tested filter

4 scanning traverse

Figure C.4 — Scanning mode with air flow straighteners

C.4 Air flow measurements

First, the air flow to the test rig is verified. The air flow rate through the test rig is measured accurately by means of an orifice or other pressure differential devices specified in ISO 5167-1 in order to ensure that the rig can maintain an average air flow velocity of 0,45 m/s across the filter face area.

In general, the upstream velocity pattern should have a CV value of 3 % or better, measured using the method described in this section without the filter in place. The upstream velocity uniformity should be determined prior to testing a filter.

C.4.1 Air velocity measurements

The air velocity is determined by omni-directional hot wire anemometer or other equivalent device mounted on the scanning head of the test rig (see Figure C.5), and by measuring velocity at different positions on the face of the filter according to a sampling grid made up of 30 cm × 30 cm squares. It is recommended that an anemometer with an accuracy of at least 1 % full scale be used for this test with a full range 2 × the face velocity of the filter.

A hot wire anemometer is recommended because this instrument is very responsive and sufficiently accurate. An anemometer will provide a large quantity of measurement data. Hence it is recommended to collect the data via a data acquisition system and that the data is analysed by a computer. In order to avoid outside influences on the air flow, such as movements by the operator, the filter should be protected by a transparent protective shroud or screen.

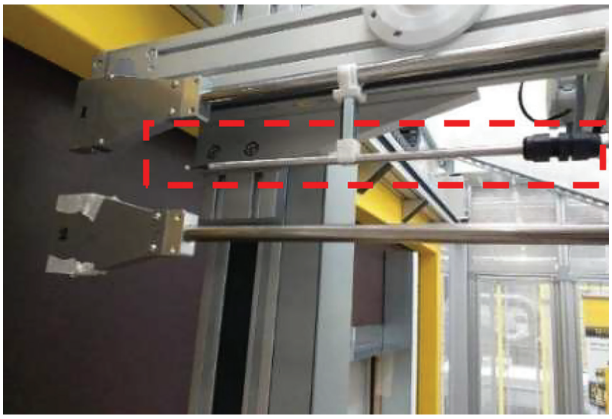


Figure C.5 — Hot wire anemometer shown mounted on the scan head

C.4.2 Measurement procedure

Mount the filter to be tested in the test rig. Ensure that the air flow through the filter is set at the rated air flow for the filter. This flow is commonly set at 0,45 m/s of the filter face area. The air velocity is continuously measured by the anemometer at 150 mm from the face of the filter as it scans the face of the filter (distance range is 50 mm to 300 mm). The measurement procedure is controlled by the microcomputer. Every second, the computer reads the values in the buffer of the interface card belonging to the anemometer. For each measuring point, the average of a 30 s measurement interval is determined. The total measurement arrangement consists of 12 measuring points, so that approximately 6 min are required to complete the measurement of the entire filter.

The arithmetical average is determined from the test data using Formula (C.1):

$$\bar{V} = \frac{1}{30}\sum_{j=1}^{30} V_{j(x,y)} \tag{C.1}$$

These values are determined per measuring point.

Then, per n measuring points, the average air velocity $\bar{x}$ is calculated using Formula (C.2):

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{C.2}$$

The standard deviation σ is calculated using Formula (C.3):

$$\sigma_n = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}} \tag{C.3}$$

and CV is calculated using Formula (C.4):

$$CV = \frac{\sigma}{\bar{x}} \times 100\ \% \tag{C.4}$$

The CV expressed as percentage is a value for the uniformity of the air distribution.

C.5 Reporting

The measurement results (by point measuring over 30 s) are automatically fed into a spreadsheet program, which provides the calculation and reports. The test report (see Figure C.6 for an example) consists of:

a) filter test data, such as supplier, filter type, dimensions, distance to the filter surface, etc.;

b) measurement data by measuring point;

c) calculated test results;

d) graphic presentation of the test data.

The test report enables a quick comparison of various filters. Distance range is 50 mm to 300 mm, whereby a measuring distance between 150 mm and 300 mm provides the most valuable data about filters used in cleanrooms.

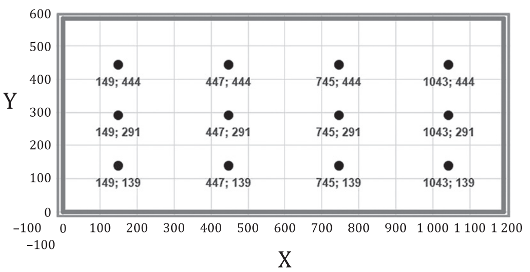
Air velocity pattern according to ISO 29463-1 Annex C	**AIR VELOCITY TEST**

Report number	
Date	yyyy/mm/dd
Filter description	HEPA Filter
Size mm	610 × 1 220
Filter depth	69
open face area height:	590
open face area width:	1 190
Distance to filter media [mm]	150
Filter resistance [Pa]	100
Airflow [m³/h]	1 206
Airvelocity [m/s] (based on open face area)	0,477
Remark: Equally spaced 3 × 4 pattern, Measurement in the middle of the section	

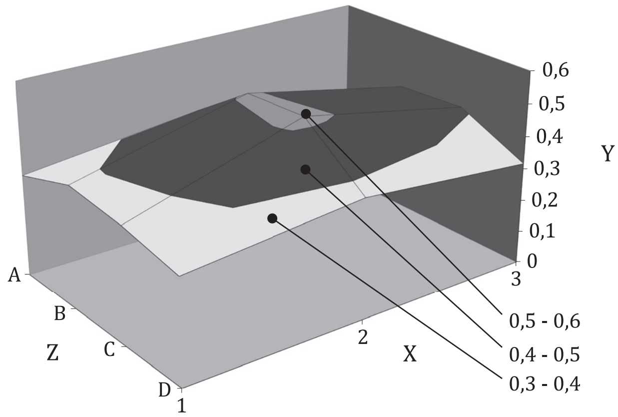
	Column						
Row	A	B	C	D	Row average [m/s]	Row standard deviation	Row Variation coefficient [%]
1	**0,315**	**0,378**	**0,358**	**0,320**	0,34	0,03	9
2	**0,375**	**0,510**	**0,520**	**0,370**	0,44	0,08	19
3	**0,305**	**0,401**	**0,412**	**0,317**	0,36	0,06	15
Column Average [m/s]	0,33	0,43	0,43	0,34			
Column Standard deviation	0,04	0,07	0,08	0,03			
Column Variation coefficient [%]	11	16	19	9			

average [m/s]	0,382
standard deviation	0,07
Variation coefficient [%]	19

Max	0,520	Max + % to avg,	36,2
Min	0,305	Min – % to avg,	−20,1



Air flow distribution pattern 3 × 4



Key

X row

Y air velocity (m/s)

Z column

Figure C.6 — Example of test report

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