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

Part 5:
Test method for filter elements

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

Partie 5: Méthode d'essai des éléments filtrants

Reference number
ISO 29463-5:2022(E)

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 195, *Air filters for general air cleaning,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 29463-5:2011), which has been technically revised.

The main changes are as follows:

— normative references have been updated;

— Annex C has been revised.

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/members.html.

Introduction

The ISO 29463 series is derived from the EN 1822 series with extensive changes to meet the requests from non-European participating members (P-members). It contains requirements, fundamental principles of testing and the marking for high-efficiency particulate air filters with efficiencies from 95 % 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 actually covers most requirements of different applications. The difference between the ISO 29463 series 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 MPPS, which is, for micro-glass filter mediums, 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 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 Annex C. Specific requirements for testing method, frequency, and reporting requirements can be modified by agreement between users and suppliers. For lower-efficiency filters (group H, as described in 4.2), alternate leak test methods are described in ISO 29463-4:2011, Annex A.

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. For information, a brief summary of these methods and their reference standards are provided in Annex D.

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

Part 5:
Test method for filter elements

1 Scope

This document specifies the test methods for determining the efficiency of filters at their most penetrating particle size (MPPS). It also gives guidelines for the testing and classification for filters with an MPPS of less than 0,1 µm (Annex B) and filters using media with (charged) synthetic fibres (Annex C). It is intended for use in conjunction with ISO 29463-1, ISO 29463-2, ISO 29463-3 and ISO 29463-4.

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 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*

ISO 16890-4, *Air filters for general ventilation — Part 4: Conditioning method to determine the minimum fractional test efficiency*

ISO 21501-4, *Determination of particle size distribution — Single particle light interaction methods — Part 4: Light scattering airborne particle counter for clean spaces*

ISO 29463-1:2017, *High efficiency filters and filter media for removing particles from air — Part 1: Classification, performance, testing and marking*

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, *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*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 29463-1, ISO 29463-2, ISO 29463-3, ISO 29463-4, and the following 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/

3.1.1
sampling duration
time during which the particles in the sampling volume flow are counted (upstream or downstream)

[SOURCE: ISO 29464:2017, 3.2.153]

3.1.2
particle counting and sizing method
particle counting method which allows both the determination of the number of particles and also the classification of the particles according to size

EXAMPLE By using an optical particle counter.

[SOURCE: ISO 29464:2017, 3.2.123]

3.2 Symbols and abbreviated terms

C channel for particle counters

c_N number concentration

d_p particle diameter, µm

E efficiency

k dilution factor

N particle counts

P penetration, %

p absolute pressure, Pa

T temperature, K

t sampling duration, s

$\dot{V}$ volume flow rate, cm^3/s

Δp differential pressure, Pa

φ relative humidity, %

CPC condensation particle counter

DEHS di(2-ethylhexyl) sebacate

DMPS differential mobility particle sizer

DOP dioctyl phthalate

ePTFE expanded polytetrafluoroethylene

IPA isopropyl alcohol (isopropanol)

MPPS most penetrating particle size

OPC optical particle counter

4 Efficiency test methods

4.1 Reference efficiency test method

In order to determine the efficiency of the test filter, the test filter is fixed in the filter mounting assembly and subjected to a test air volume flow corresponding to the nominal volume flow rate.

After the pressure drop at the nominal volumetric flow rate is measured, the test aerosol produced by the aerosol generator is mixed with the prepared test air along a mixing section, so that it is spread homogeneously over the cross-section of the duct.

The efficiency is always determined for the MPPS; see ISO 29463-3. The size distribution of the aerosol particles can optionally be measured using a particle size analysis system, for example, a DMPS.

The testing can be carried out using either a mono-disperse or poly-disperse test aerosol. When testing with (quasi-) mono-disperse aerosol, the total particle count method may be used with a CPC or an OPC, e.g. a laser particle counter. It shall be ensured that the number median particle diameter corresponds to the MPPS, i.e. the particle diameter at which the filter medium has its minimum efficiency.

When using a poly-disperse aerosol, the particle counting and sizing method, e.g. an OPC or DMPS, shall be used, which, in addition to counting the particles, is also able to determine their size distribution. It shall be ensured that the count median diameter, D_M, of the test aerosol lies in the range given by Formula (1):

$$\frac{S_{MPPS}}{1,5} < D_M < 1,5 \times S_{MPPS} \qquad (1)$$

where S_{MPPS} is the most penetrating particle size.

In order to determine the overall efficiency, representative partial flows are extracted on the upstream and downstream sides of the filter element and directed to the attached particle counter via a fixed sampling probe to measure the number of particles. It is necessary to have a mixing section behind the test filter to mix the aerosol homogeneously with the test air over the duct cross-section (see 6.2.4). When testing filters with large face dimensions, achieving adequate aerosol mixing may not be possible. In these cases, the test method with moving probe described in Annex A shall be used.

4.2 Alternate efficiency test method for groups H and U filters

The standard efficiency test method, as described in 4.1, uses downstream mixing and a fixed downstream probe. However, an alternate efficiency test method using scan test equipment with moving probe(s) is provided and described in Annex A.

4.3 Statistical efficiency test method for low efficiency filters — Group E filters

For filters of group E, the overall efficiency shall be determined by one of the statistical test procedures described in this subclause, and it is not necessary to carry out the test for each single filter element (as is mandatory for filters of groups H and U). The overall efficiency of group E filters shall be determined by averaging the results of the statistical efficiency test as described in this subclause.

A record of the filter data in the form of a type test certificate or alternatively a factory test certificate is required. However, the supplier shall be able to provide documentary evidence to verify the published filter data upon request. This can be done by either:

a) maintaining a certified quality management system (e.g. ISO 9000), which requires the application of statistically based methods for testing and documenting efficiency for group E filters in accordance with this document; or

b) using accepted statistical methods to test all of production lots of filters.

The skip lot procedure as described in ISO 2859-1 or any equivalent alternative method may be used.

The skip lot procedure as described in ISO 2859-1 implies that at the beginning, the test frequency is high and is, in the course of further testing, reduced as the production experience grows and that the products produced conform to the target. For example, for the first eight production lots, 100 % of the produced filters are tested. If all the tests are positive, the frequency is reduced to half for the next eight production lots. If all the tests are positive again, the number is reduced by half again, and so on until it is necessary to test only one out of eight lots (e.g. the minimum test frequency). Each time one of the tested filters fails, the test frequency is doubled again. In any case, the number of samples per lot tested shall be greater than three filters.

5 Test filter

The filter element being tested shall show no signs of damage or any other irregularities. The filter element shall be handled carefully and shall be clearly and permanently marked with the following details:

— designation of the filter element;

— upstream side of the filter element.

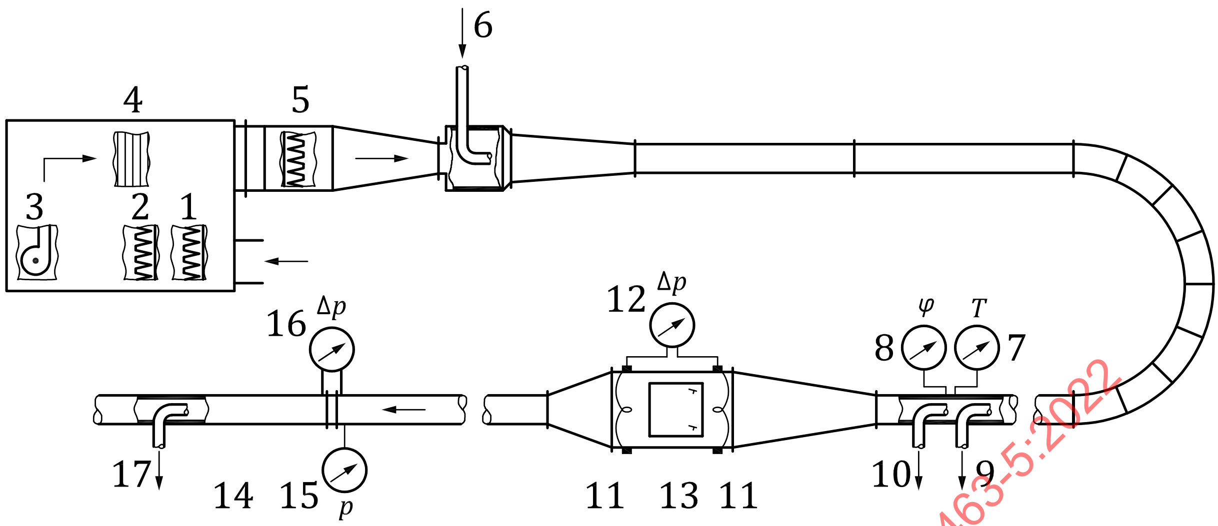
The temperature of the test filter during the testing shall correspond with that of the test air.

6 Test apparatus

6.1 General

A flow sheet showing the arrangement of apparatus comprising a test rig is given in ISO 29463-1:2017, Figure 4. An outline diagram of a test rig is given in Figure 1.

The fundamentals of aerosol generation and neutralization with details of suitable types of equipment as well as detailed descriptions of the measuring instruments required for the testing are given in ISO 29463-2.



Key
1 coarse dust filter
2 fine dust filter
3 fan
4 air heating
5 high-efficiency air filter
6 aerosol inlet to the test duct
7 temperature measurement (T)
8 hygrometer (φ)
9 sampler, particle size analysis
10 sampler, upstream
11 ring pipe for differential pressure measurement
12 manometer (Δp)
13 test filter mounting assembly
14 measuring damper (see ISO 5167-1)
15 measurement of absolute pressure (p)
16 manometer measuring differential pressure (Δp)
17 sampler, downstream

Figure 1 — Example of a test rig

6.2 Test duct

6.2.1 Test air conditioning

The test air conditioning equipment shall include equipment required to control the condition of the test air so that it can be brought in conformity with the requirement of Clause 7.

6.2.2 Adjustment of the volume flow rate

Filters shall always be tested at their nominal air flow rate. It shall be possible to adjust the volume flow rate by means of a suitable provision (e.g. by changing the speed of the fan, or with dampers) to a value ±5 % of the nominal flow rate, which shall then remain constant within ±2 % throughout each test.

6.2.3 Measurement of the volume flow rate

The volume flow rate shall be measured using a standardized or calibrated method (e.g. measurement of the differential pressure using standardized damper equipment, such as orifice plates, or nozzles, Venturi tubes in accordance with ISO 5167-1).

The limit error of measurement shall not exceed 5 % of the measured value.

6.2.4 Aerosol mixing section

The aerosol input and the mixing section (see Figure 1 for an example) shall be so constructed that the aerosol concentration measured at individual points of the duct cross-section, directly in front of the test filter, do not deviate by more than 10 % from the mean value of at least nine measuring points over the channel cross-section.

6.2.5 Test filter mounting assembly

The test filter mounting assembly shall ensure that the test filter can be sealed and subjected to flow in accordance with requirements.

It shall not obstruct any part of the filter cross-sectional area.

6.2.6 Measuring points for the pressure drop

The measuring points for pressure drop shall be so arranged that the mean value of the static pressure in the flow upstream and downstream of the filter can be measured. The planes of the pressure measurements upstream and downstream shall be positioned in regions of an even flow with a uniform flow profile.

In rectangular or square test ducts, smooth holes with a diameter of 1 mm to 2 mm for the pressure measurements shall be bored in the middle of the channel walls, normal to the direction of flow. The four holes shall be interconnected with a circular pipe.

6.2.7 Sampling

In order to determine the efficiency, sampled volumes of air are extracted from the test volume flow by sampling probes and led to the particle counters. The diameter of the probes shall be chosen so that isokinetic conditions are maintained in the probe at the given volume flow rate in the duct. In this way, sampling errors can be neglected due to the small size of the particles in the test aerosol. The connections to the particle counter shall be as short as possible. Samples on the upstream side are taken by a fixed sampling probe in front of the test filter. The sampling shall be representative, on the basis that the aerosol concentration measured from the sample does not deviate by more than ±10 % from the mean value determined in accordance with 6.2.4.

A fixed sampling probe is also installed downstream, preceded by a mixing section that ensures a representative measurement of the downstream aerosol concentration. This is taken to be the case when, in event of an artificially made big leak in the test filter, the aerosol concentration measured downstream the filter does not at any point deviate by more than ±10 % from the mean value of at least nine measuring points over the duct cross-section. It is necessary, however, to verify beforehand that the artificially made leak is big enough to increase the filter penetration by at least a factor of five relative to the penetration of the non-leaking filter.

The mean aerosol concentrations determined at the upstream and downstream sampling points without the filter in position shall not differ from each other by more than 5 %.

6.3 Aerosol generation and measuring instruments

6.3.1 General

The operating parameters of the aerosol generator shall be adjusted to produce a test aerosol whose number median diameter is in the range of the MPPS for the sheet filter medium.

The median size of the mono-disperse test aerosol shall not deviate from the MPPS by more than ±10 %. A deviation of ±50 % is allowed when using a poly-disperse aerosol.

The particle output of the aerosol generator shall be adjusted according to the test volume flow rate and the filter efficiency, so that the counting rates on the upstream and downstream sides lie under the coincidence limits of the counter (the maximum coincidence error shall be of 10 % in accordance with ISO 21501-4), and significantly above the zero-count rate of the instruments.

The number distribution concentration of the test aerosol can be determined using a suitable particle size analysis system (e.g. a DMPS) or with an OPC suitable for these test purposes. The limit error of the measurement method used to determine the number median value shall not exceed ±20 % relative to the measurement value.

The number of counted particles measured upstream and downstream shall be sufficiently large to provide statistically meaningful results, without the concentration exceeding the measuring range of the upstream particle counter. If the upstream number concentration exceeds the range of the particle counter (in the counting mode), a dilution system shall be inserted between the sampling point and the counter.

The particle counting may be carried out using either a pair of counters operating in parallel on the upstream and downstream sides, or using a single counter to measure the number concentrations on the upstream and downstream sides alternately. If measurements are made with only one counter, it shall be ensured that the relevant properties of the test aerosol (e.g. the number concentration, particle size distribution, homogeneous distribution over the channel cross-section) remain constant over time. If two counters are used in parallel, both should be of the same type and calibrated as dual devices.

6.3.2 Apparatus for testing with a mono-disperse test aerosol

For technical reasons, the particle size distribution produced by the aerosol generator is usually quasi-mono-disperse.

When using a mono-disperse aerosol for the efficiency testing of the filter element, not only OPCs but also condensation particle counters may be used.

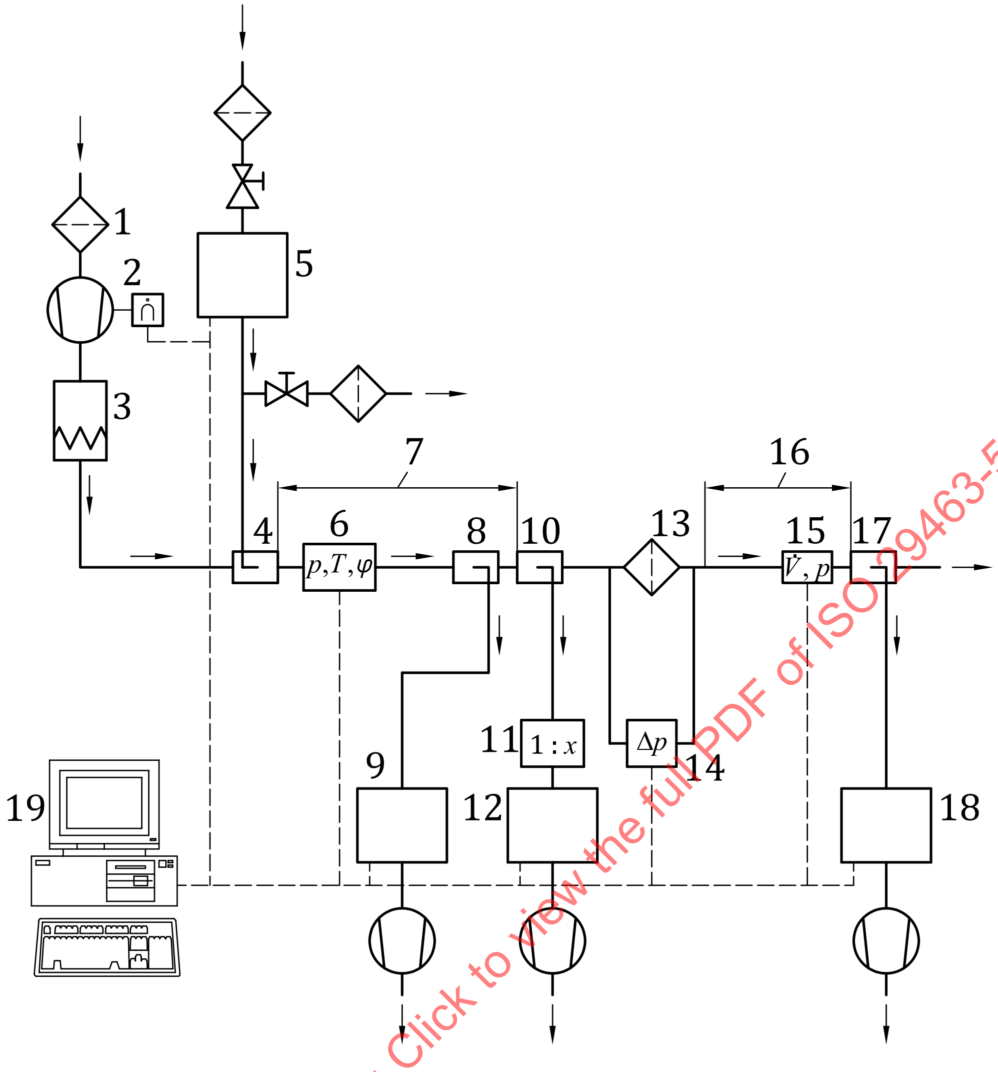
When using a condensation particle counter, it shall be ensured that the test aerosol does not contain appreciable numbers of particles that are very much smaller than the MPPS. Such particles, which can be produced, for example, by an aerosol generator that is no longer working properly, are also counted by a condensation particle counter and can lead to a considerable error in the determination of the efficiency. One way of checking for this error is to determine the number distribution of the test aerosol with a measuring device that stretches over a range from the lower range limit of the condensation particle counter up to a particle size of approximately 1 µm. The number distribution thus determined shall be quasi-mono-disperse and without the large concentration of very small particles.

The apparatus for testing with mono-disperse aerosol is shown in Figure 2.

6.3.3 Apparatus for testing with a poly-disperse test aerosol

When determining the efficiency of a filter element using a poly-disperse test aerosol, the particle number concentration and size distribution shall be determined using an OPC (e.g. laser particle counters).

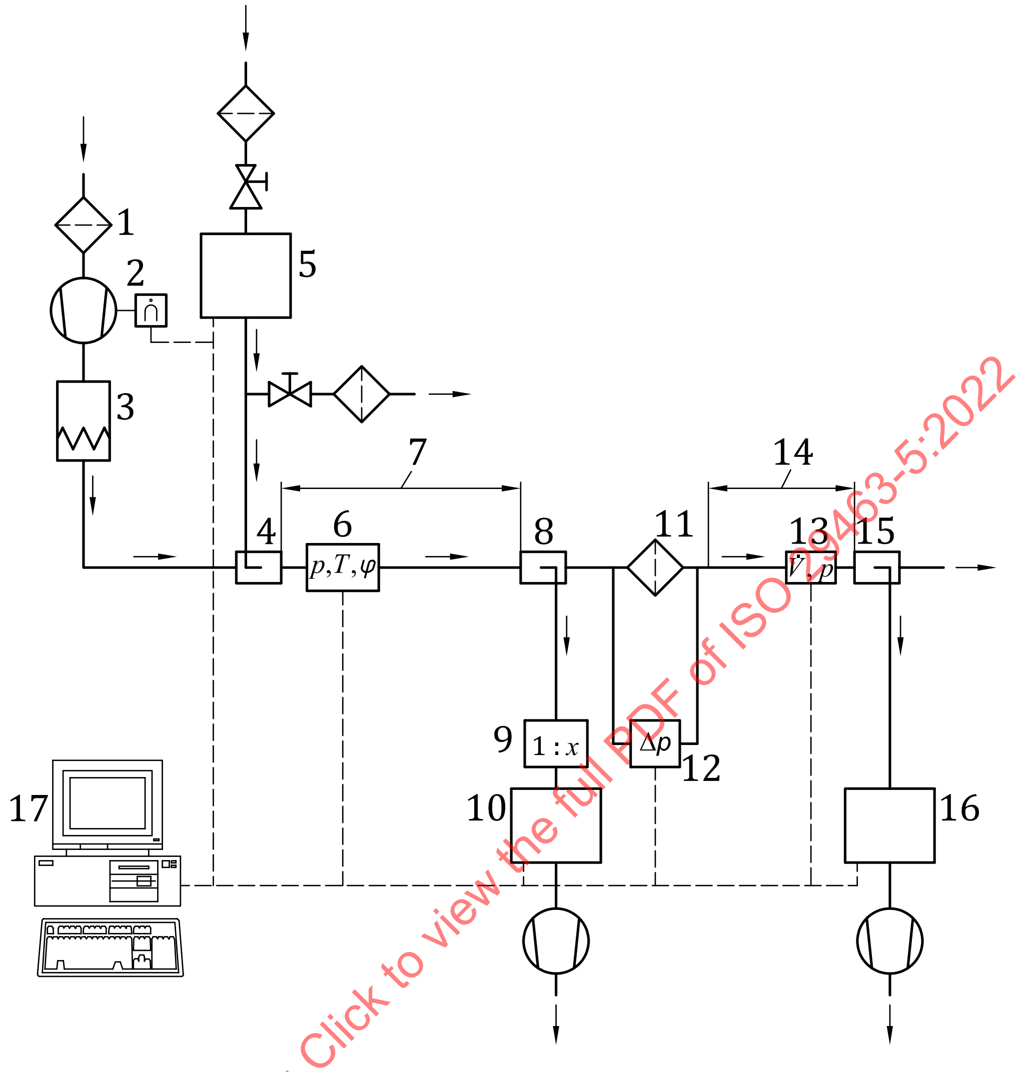
The test apparatus for testing with a poly-disperse aerosol is shown in Figure 3.



Key

1 pre-filter for test air
2 fan with variable speed control
3 air heater
4 aerosol inlet in the duct
5 aerosol generator for the mono-disperse aerosol
6 measurement of temperature (T), barometric pressure (p) and relative humidity (φ)
7 upstream side mixing section
8 sampling point for particle size analysis
9 particle size analysis system (DMPS or OPC)
10 sampling point for upstream particle counting
11 dilution system (optional: $1/x$)
12 upstream particle counter (CPC or OPC)
13 test filter
14 measurement of pressure drop across the test filter
15 measurement of absolute pressure (p) and volume air flow rate ($\dot{V}$)
16 downstream mixing section
17 sampling point for downstream particle counting
18 downstream particle counter (CPC or OPC)
19 computer for purposes of control and measurement recording

Figure 2 — Apparatus for testing with a mono-disperse aerosol



Key

1 pre-filter for test air
2 fan with variable speed control
3 air heater
4 aerosol inlet in the duct
5 aerosol generator for the poly-disperse aerosol
6 measurement of temperature (T), barometric pressure (p) and relative humidity (φ)
7 upstream side mixing section
8 sampling point for upstream particle count
9 dilution system (optional: 1/x)
10 upstream OPC
11 test filter
12 measurement of pressure drop of the test filter
13 measurement of absolute pressure (p) and volume air flow rate ($\dot{V}$)
14 downstream mixing section
15 sampling point for downstream particle count
16 downstream OPC
17 computer for control and measurement recording

Figure 3 — Apparatus for testing with a poly-disperse aerosol

To cover the different ranges of the MPPS, that are commonly encountered, at a minimum, the measuring range of the OPC used for efficiency testing shall cover at least the particle size range between $\frac{S_{MPPS}}{1,5}$ and $1,5 \times S_{MPPS}$.

The distribution of the channel limits shall be such that there is one (lower) channel limit in the diameter range between $\frac{S_{\mathrm{MPPS}}}{2}$ and $\frac{S_{\mathrm{MPPS}}}{1,5}$ (Figure 4, range II a) and one (upper) channel limit in the diameter range between 1,5 × S_{MPPS} and 2 × S_{MPPS} (Figure 4, range II b).

From a practical point of view, for most common filter media in use, diameter channels of 0,1 µm to 0,2 µm and 0,2 µm to 0,3 µm, readily available in most commercial OPCs, should sufficiently meet this requirement.

The distribution of the size classes shall be such that each of the class limits meets one of the conditions given in either Formula (2) (as shown in Figure 4, range II a) or Formula (3) (as shown in Figure 4, range II b):

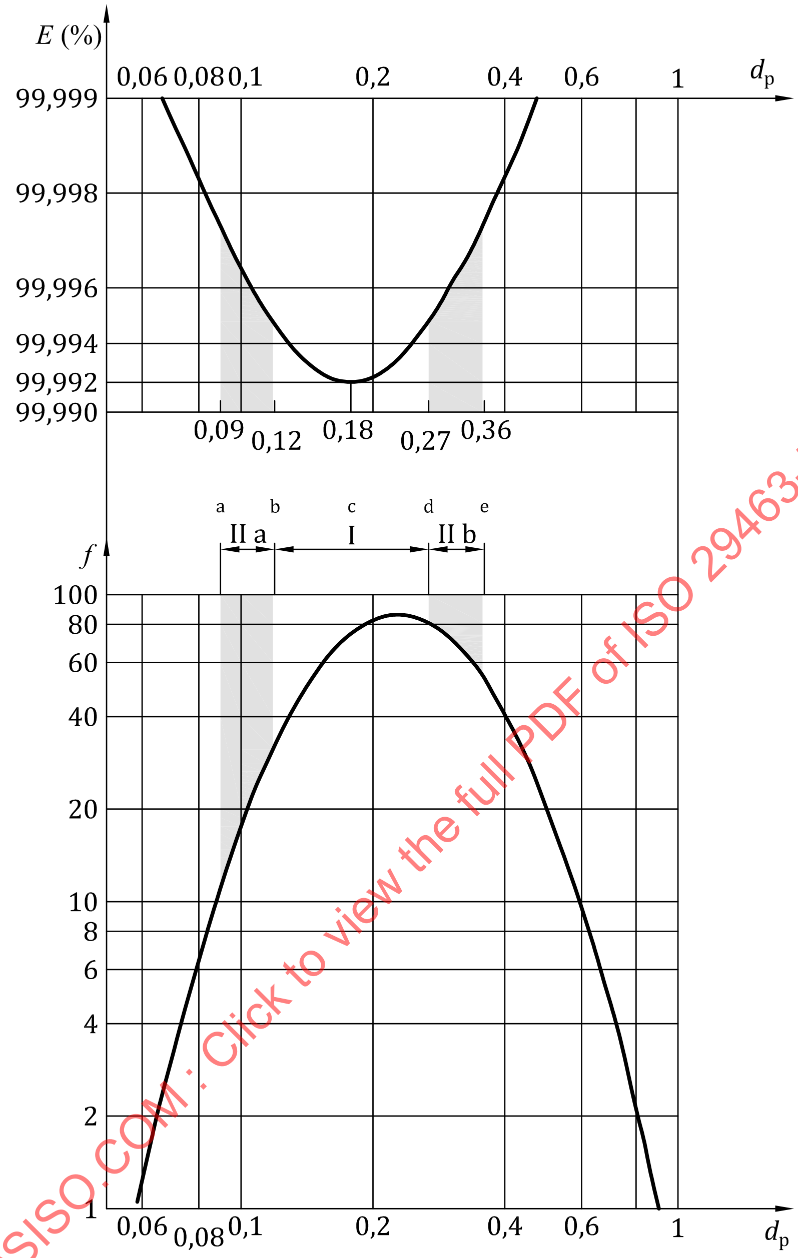
$$\frac{S_{\mathrm{MPPS}}}{2} < C_{\mathrm{LL}} \leq \frac{S_{\mathrm{MPPS}}}{1,5} \quad (2)$$

where C_{LL} is the lower channel limit.

$$1,5 \times S_{\mathrm{MPPS}} \leq C_{\mathrm{UL}} < 2 \times S_{\mathrm{MPPS}} \quad (3)$$

where C_{UL} is the upper channel limit.

All channels between these two limits can be evaluated to determine the filter efficiency. However, it is not required for there to be more than one channel, so that the above condition can also be met, in an extreme case, by only one channel.



a $S_{MPPS}/2$.

b $S_{MPPS}/1,5$.

c S_{MPPS}.

d $S_{MPPS} \times 1,5$.

e $S_{MPPS} \times 2$.

Figure 4 — Particle size efficiency, E, and permissible measuring ranges relative to efficiency minimum (S_{MPPS} equal to 0,18 µm) and number distribution, f, of a poly-disperse test aerosol with particle diameter, D_M, equal to 0,23 µm

7 Conditions of the test air

The test air shall be conditioned before being mixed with the test aerosol such that its temperature, relative humidity and purity conform to the requirements specified in ISO 29463-1:2017, 7.3.

8 Test procedure

8.1 Preparatory checks

After switching on the test apparatus, the following parameters shall be checked.

a) Operational readiness of the measuring instruments:

The condensation particle counters shall be filled with operating liquid.

The warming-up times specified by the instrument makers shall be observed.

b) Zero-count rate of the particle counter:

The measurement of the zero-count rate shall be carried out using flushing air that is free from particles.

c) Absolute pressure, temperature and relative humidity of the test air.

These parameters shall be checked to ensure that they are in accordance with ISO 29463-1:2017, 7.3; and if they are not, appropriate corrections shall be made.

8.2 Starting up the aerosol generator

When starting up the aerosol generator, a stand-by filter element shall be installed in the test filter mounting assembly.

After adjusting the operating parameters of the aerosol generator and observing an appropriate warming-up period, the particle concentration and the distribution of the test aerosol shall be checked to ensure that they are in accordance with 6.3. The test aerosol distribution and concentration shall be determined as close to the filter mounting assembly as possible.

8.3 Preparation of the test filter

8.3.1 Installation of the test filter

The test filter shall be handled in such a way as to ensure that the filter material is not damaged.

The test filter shall be installed in the mounting assembly with proper regard to air flow direction and gasketing side.

The seal between the test filter and the test filter mounting assembly shall be free from leaks.

8.3.2 Flushing the test filter

In order to reduce the self-emission of particles by the test filter and to equalize the temperatures of the test filter and the test air, the test filter shall be flushed with test air for a suitably long period at the nominal volume flow rate. Following this, the residual self-emission may be measured at the downstream particle counter.

8.4 Testing

8.4.1 Measuring the pressure drop

The pressure drop across the test filter shall be measured in the unloaded state using the pure test air. The nominal volume flow rate shall be set up in accordance with 6.2.2. The measurements shall be made when a stable operating state has been reached.

8.4.2 Testing with a mono-disperse test aerosol

In the mixing section, the test air is mixed with test aerosol, the median diameter of which corresponds to the particle size, MPPS, at the efficiency minimum of the sheet filter medium (deviation ±10 %; see 6.3).

The particle concentrations are measured on the upstream and downstream sides. This may be carried out using either a pair of counters operating in parallel or a single counter to measure the particle concentrations on the upstream and downstream sides alternately. The upstream particle number concentration and the duration of measurement shall be chosen so that the difference between the counted and minimum particle number on the upstream side (corresponding to the lower limit of the 95 % confidence range of a Poisson distribution; see ISO 29463-2) does not vary by more than 5 % from the measured particle number (which corresponds to at least $1,5 \times 10^3$ particles). On the downstream side, the difference between the maximum particle number (corresponding to the upper limit of the 95 % confidence range of a Poisson distribution; see ISO 29463-2) and the counted particle number shall not deviate by more than 20 % (which corresponds to at least 100 particles) from the measured particle number (see Table 1).

When choosing the measurement duration, care shall be taken that the test filter is not overburdened with aerosol.

8.4.3 Testing with a poly-disperse test aerosol

The testing is done in accordance with 8.4.2 using a poly-disperse aerosol, the median diameter of which shall not deviate from the MPPS by more than 50 % (see 6.3).

When testing with a poly-disperse test aerosol, in contrast to the testing with a mono-disperse test aerosol, the number distribution concentration and the number concentration are measured using an OPC or DMPS. In order to determine the efficiency, the upstream and downstream number concentrations are collected for all size classes which lie entirely or partially in the range $\frac{S_{\text{MPPS}}}{1,5}$ to $1,5 \times S_{\text{MPPS}}$ (see 6.3.2).

8.4.4 Testing filters with charged media

When testing filters made with charged media, the efficiency shall be corrected for the effect of charge according to the discharge procedures for the filter medium used in the filter as prescribed in Annex C (see Clause C.3 or Clause C.4) for the entire filter.

9 Evaluation

The penetration, P, expressed as a percentage, is calculated as given in Formula (4):

$$P = \frac{c_{N,\text{d}}}{c_{N,\text{u}}} \tag{4}$$

where

$c_{N,\text{d}}$ is the number concentration downstream, equal to $\frac{N_\text{d}}{\dot{V}_{\text{s,d}} \cdot t_\text{d}}$;

$c_{N,\text{u}}$ is the number concentration upstream, equal to $\frac{k_\text{D} \cdot N_\text{u}}{\dot{V}_{\text{s,u}} \cdot t_\text{u}}$;

where

N_u is the number of particles counted upstream;

N_d is the number of particles counted downstream;

k_D is the dilution factor;

$\dot{V}_{s,u}$ is the sampling volume flow rate upstream;

$\dot{V}_{s,d}$ is the sampling volume flow rate downstream;

t_u is the sampling duration upstream;

t_d is the sampling duration downstream.

The efficiency, E, expressed as a percentage, is calculated as given in Formula (5):

$$E = 1 - P \tag{5}$$

In order to calculate the minimum efficiency, $E_{95\ \%\text{min}}$, the less favourable limit value for the 95 % confidence range for the actual particle count shall be used as the basis for the calculations. The calculation shall be carried out taking into account the particle counting statistics specified in ISO 29463-2:2011, Clause 7. The values for the 95 % confidence range shall be calculated only with pure counting data, without corrections being made for the dilution factor. The minimum efficiency, $E_{95\ \%\text{min}}$, expressed as a percentage, taking into account the particle counting statistics, is given by Formula (6):

$$E_{95\,\%\,\text{min}} = \left(1 - \frac{c_{N,\text{d},95\,\%\,\text{max}}}{c_{N,\text{u},95\,\%\,\text{min}}}\right) \cdot 100 \tag{6}$$

where

$c_{N,\text{d},95\ \%\ \text{max}}$ is the maximum downstream particle number concentration, equal to $\dfrac{N_{\text{d},95\,\%\,\text{max}}}{V_{\text{s,d}} \cdot t_{\text{d}}}$;

$c_{N,\text{u},95\ \%\ \text{min}}$ is the minimum upstream particle number concentration, equal to $\dfrac{N_{\text{u},95\,\%\,\text{min}} \cdot k_{\text{D}}}{V_{\text{s,u}} \cdot t_{\text{u}}}$;

$N_{\text{d},95\ \%\ \text{max}}$ is the upper limit of the 95 % confidence range of the particle count downstream, calculated in accordance with ISO 29463-2, equal to $N_\text{d} + 1{,}96 \cdot N_\text{d}^{1/2}$;

$N_{\text{u},95\ \%\ \text{min}}$ is the lower limit of the 95 % confidence range of the particle count upstream, calculated in accordance with ISO 29463-2, equal to $N_\text{u} - 1{,}96 N_\text{u}^{1/2}$.

If the manufacturers' instructions for the particle counter include coincidence corrections for the measured concentrations, then these shall be taken into account in the evaluation.

For the minimum efficiency, allowance is made only for measurement uncertainty due to low count rates.

The minimum efficiency is the basis of the classification in accordance with ISO 29463-1.

Table 1 shows a specimen calculation of the statistical uncertainty for the measurement of the efficiency.

Table 1 — Specimen statistical uncertainty when measuring the efficiency for different particle counts

Test parameter[a]	Filter class						
	ISO 15 E	ISO 25 E	ISO 35 H	ISO 45 H	ISO 55 U	ISO 65 U	ISO 75 U
N_u [b,c]	124 825	124 825	124 825	124 825	1 872 380	1 872 380	1 872 380
$N_{u,95\ \%min}$ [b,c]	124 133	124 133	124 133	124 133	1 869 698	1 869 698	1 869 698
$c_{N,u}$, in cm^{-3}	10 587	10 587	10 587	10 587	158 811	158 811	158 811
$c_{N,u,\ min}$, in cm^{-3}	10 529	10 529	10 529	10 529	158 583	158 583	158 583
t_d, in s	250	250	250	250	250	1 000	1 000
N_d	1 716 348	171 635	17 163	1 716	2 575	1 030	103
$N_{d,95\ \%max}$	1 718 916	172 447	17 420	1 798	2 674	1 093	123
$c_{N,d}$, in cm^{-3}	291	29,1	2,91	0,29	0,44	0,044	0,004 4
$c_{N,d,max}$, in cm^{-3}	292	29,3	2,95	0,30	0,45	0,046	0,005 2
E, in %	97,25	99,725	99,972 5	99,997 25	99,999 725	99,999 972 5	99,999 997 25
E_{min}, in %	97,23	99,722	99,971 9	99,997 10	99,999 714	99,999 970 7	99,999 996 70
$\left\|\frac{N_u - N_{u,95\,\%\,min}}{N_u}\right\|$ in %	0,55	0,55	0,55	0,55	0,14	0,14	0,14
$\left\|\frac{N_{d,95\,\%\,max} - N_d}{N_d}\right\|$ in %	0,15	0,47	1,50	4,78	3,84	6,12	19,42

[a] Constant upstream test parameters: $\dot{V}_S$ = 23,58 cm^3/s; t_u = 50 s; dilution factor k_D of 100.

[b] Actual particle count without allowing for the dilution factor.

[c] Using Poisson statistics.

10 Test report

The test report on the efficiency testing of a filter element shall contain at least the following information:

a) general information about the testing:

   1) filter element (type and dimensions),

   2) type of particle counters used,

   3) nominal volume flow rate,

   4) particle size at the minimum efficiency of the filter medium MPPS,

   5) test aerosol (substance, median diameter, geometrical standard deviation, concentration),

   6) dilution factor (upstream);

b) test results:

   1) pressure drop across the test filter at the start of testing,

   2) particle count (upstream),

   3) particle count (downstream),

   4) efficiency, E,

   5) minimum efficiency, $E_{95\ \%min}$,

6) achieved ISO filter class in accordance with ISO 29463-1:2017, Tables 1 and 2.

11 Maintenance and inspection of the test apparatus

All components and measuring instruments of the test apparatus shall be regularly maintained, inspected and calibrated.

The necessary maintenance and inspection work are listed in Table 2 and shall be carried out at least once within the time periods specified. In the event of disturbances that make maintenance work necessary, or after major alterations or refurbishments, inspection work and, if appropriate, calibration work shall be carried out immediately.

Details of the maintenance and inspection work are specified in ISO 29463-2, which also contains details of the calibration of all components and measuring instruments of the test apparatus.

Table 2 — Summary of the maintenance and inspection intervals of the components of the test set-up

Component	Type and frequency of the maintenance/inspection
Operating materials	Daily checks, exchange after use
Test air preparation system: Test channel Entire system Test air filter Exhaust air filter	Annually When maximum pressure drop is reached or in the event of leaks
Aerosol generator	According to manufacturer's instructions and in accordance with ISO 29463-2
Pipes leading aerosol to the measuring instruments	Annual cleaning or after an aerosol change
Volume flow rate meter	Annually or after alterations to the instrument
Air tightness of parts of apparatus at low pressure	Check if the zero-count rate of the particle counter is unsatisfactory
Air tightness of the testing point switch valve (if present)	Check annually
Purity of the test air	Check weekly

Annex A
(normative)

Alternate efficiency test method from scan testing

A.1 General

The reference efficiency test method, as described in 4.1, uses downstream mixing and a fixed downstream probe. This annex provides an alternate efficiency test method using the scan test equipment with moving probe(s) downstream of the test filter. It has been shown to give test results similar to the reference efficiency test method described in 4.1. This test method with moving probe can be useful in overcoming difficulties in achieving homogeneous downstream air streams when testing filters with large face dimensions (e.g. over 1,2 m × 0,6 m).

This method determines the overall efficiency of a filter by measuring the upstream concentration as described in Clause 9 and integrating and averaging the downstream readings from the result of the leak test (scan method).

A.2 Alternate efficiency test method from scan testing

The test rig for the alternate efficiency test method is described in ISO 29463-4:2011, Figures 1 and 2.

This alternate efficiency test method may be applied only for filters that have proven to be leak free in accordance with the definition in ISO 29463-1 and ISO 29463-4. This means that when leak scanning in accordance with ISO 29463-4 is performed first, the data are analysed in accordance with ISO 29463-4 to verify absence of leaks; and, if this is the case, the data are afterward analysed in accordance with this annex to determine the efficiency.

The downstream sampling is carried out as for the scan method (ISO 29463-4) directly behind the test filter, using one or several moveable sampling probes that traverse the entire cross-sectional area of the filter and its frame in overlapping tracks without any gaps.

The test apparatus corresponds largely with that used with stationary sampling probes. The differences in the scanning method are that there is no downstream mixing section and, instead, a three-dimensional tracking system is included downstream that moves the probe(s). Since the test duct is usually open on its downstream end, provisions shall be made to prevent the intrusion of contaminated outside air into the test air flow.

In the scan efficiency test method, all the particles counted during the entire downstream scan in the course of the leak testing are added together. The duration of the sampling is measured as well. The total downstream particle count is averaged over time as well as the analysed sample flow volume to obtain the downstream particle counts per volume.

With this downstream particle concentration, the efficiency is calculated in the same way as described Clause 9.

Annex B
(informative)

Testing and classification method for filters with MPPS ≤ 0,1 µm (e.g. membrane medium filters)

B.1 Background

Groups E, H and mainly U filters with ePTFE membrane or other filter medium have become an alternative to the traditional filters using a micro fibreglass medium. Although these types of filter media can be membranes, they have a fibrous structure and, hence, properties for particle retention similar to those of glass fibre media. However, the user of this type of filter should be aware of two distinct features that can affect its testing and its performance in use, namely a media much thinner than traditional microfibre glass media and with a much smaller MPPS as discussed in Clauses B.2 and B.3.

B.2 MPPS of filters with membrane medium filter

The mean size of the fibrous structure of membrane medium filter is much smaller than that of micro fibre media such as glass or synthetic fibre media, resulting in an MPPS significantly less than 0,1 µm (typically approximately 0,07 µm for a commonly used PTFE membrane). For comparison, the MPPS for a similar micro fibreglass media is typically between 0,1 µm and 0,25 µm. Hence, testing this variety of filters at their MPPS (as set out in the ISO 29463 series) requires the ability to detect particles as small as 0,05 µm, which is well outside the useful range of OPCs. Membrane medium filters therefore require the use of CPCs sensitive to these small particle sizes. Testing membrane medium filters with commercially available particle generators with, for example, 0,15 µm DEHS particles and OPCs with 0,1 µm lower detection limit typically results in penetrations at least one order of magnitude lower than those measured at the MPPS. Classification of such filters according to the principles of the ISO 29463 series based on MPPS values is, therefore, not directly possible.

B.3 Penetration consistency and uniformity of membrane medium filter

Unlike the traditional micro fibreglass media, the membrane medium is a thin (e.g. 0,02 mm) membrane mono-layer with a fibrous structure. Since the membrane alone is too delicate to handle, it is layered on to other more easily handled webs that might or might not affect filtration. The influence of the consistency and uniformity of a mono-layer on its filtration properties is always a problem in practice. Therefore, some manufacturers layer the membrane to partially compensate for spatial non-uniformity and for leaks in each membrane layer. For penetration measurements on mono-layer membrane medium, one should typically allow for local differences in penetration of at least two orders of magnitude.

B.4 Test procedures

B.4.1 Integral penetration

B.4.1.1 Primary procedure

Define the MPPS of a flat sheet of filter medium in accordance with ISO 29463-3.

Measure the integral penetration of the filter element with membrane medium filter in accordance with this document with a DEHS aerosol at its MPPS (typically between 0,06 µm and 0,08 µm), using corresponding aerosol generation and detection methods (typically CPCs).

Particle counters used for this procedure/measurement shall have at least 50 % counting efficiency at a particle size of MPPS/1,5.

B.4.1.2 Alternative procedure

This procedure is applied if the standard procedure, described in B.4.1.1, cannot be followed due to lack of adequate measurement equipment.

Define the MPPS and measure the penetration at MPPS of a flat sheet of membrane medium filter for the air velocity corresponding to the nominal air flow of the filter element in accordance with ISO 29463-3. Also measure penetration for the (0,14 ± 0,02) µm particle size of a flat sheet of filter medium in accordance with ISO 29463-3. Define the correlation factor, F, between the two penetration values as given in Formula (B.1):

$$F = P_{\text{MPPS}}/P_{0,14\ \mu\text{m}} \tag{B.1}$$

where

P_{MPPS} is the penetration at MPPS;

$P_{0,14\ \mu\text{m}}$ is the penetration at 0,14 µm.

Measure the integral penetration of the filter element with membrane medium filter in accordance with Clause 8 with DEHS aerosol of a particle size of (0,14 ± 0,02) µm, using OPCs with a lower detection limit of 0,1 µm.

NOTE For filters with membrane medium, this is not an MPPS measurement.

B.4.2 Classification

B.4.2.1 Primary procedure

If the integral penetration has been measured with the standard procedure (MPPS) in accordance with B.4.1.1, classify the membrane medium filters in accordance with ISO 29463-1:2017, Tables 1 and 2, using the actually measured efficiency values.

B.4.2.2 Alternative procedure

If the integral penetration has been measured with the alternative procedure (non-MPPS) in accordance with B.4.1.2, apply the correlation factor, F, determined with the flat sheet measurement to define the calculated MPPS penetration, $P_{\text{MPPS-C}}$, as given in Formula (B.2):

$$P_{\text{MPPS-C}} = F \times P_{0,14\ \mu\text{m}} \tag{B.2}$$

Classify the membrane filter medium filters in accordance with ISO 29463-1:2017, Tables 1 and 2, using the calculated MPPS penetration, $P_{\text{MPPS-C}}$.

B.4.3 Local penetration

Measure the filter element with membrane medium filter for local penetration by the scan testing method described in ISO 29463-4. The leak criteria to be used are those given in ISO 29463-1:2017, Tables 1 and 2, for the filter class in which the filter has been classified as in B.4.2. The filter may be leak tested with either its true MPPS aerosol or with a 0,14 µm aerosol, since for leak testing the aerosol size does not influence the result significantly.

B.5 Publication of data and labelling of products with membrane medium filter

For publication of data, test reports and labelling of products made with membrane medium filter, the following rules shall apply in addition to those mentioned in Clause 10.

— Indicate that the filter medium is a membrane medium.

— Indicate that integral and local efficiency measurement as well as classification was made according to this annex.

— Indicate that the integral MPPS penetration was measured with the standard procedure (true MPPS) or with the alternative procedure (non-MPPS particle size). The selected procedure shall be clearly indicated on the test report.

EXAMPLE 1 Filter tested in accordance with the standard procedure:

Penetration 99,999 95 % for MPPS in accordance with ISO 29463-1. The filter class is ISO 65 U.

EXAMPLE 2 Filter tested in accordance with the alternative procedure:

Efficiency 99,999 98 % for MPPS in accordance with ISO 29463-1:2017, Annex A, alternative procedure. The filter class is ISO 65 U in accordance with ISO 29463-1.

Annex C
(normative)

Method for testing and classification of filters using media with charged fibres

C.1 General

In recent years, charged fibre filter media with minimum efficiencies in the range of 99,95 % and higher have become available. The high efficiency may be achieved by using fibres with small diameters and by enhancing the filtration property by electrostatically charging the fibres. Several commercial and patented processes for charging are known, with different performance claims. Commercially available filters using these media are expected to be considered as alternatives to the traditional high efficiency filters with glass fibre media.

Unlike actively charged electrostatic precipitators which use external power to maintain its charge, electrostatic charge in these media dissipates with time (through charge neutralization by collected particles). Charge dissipation is particularly evident when liquid, sub-micrometre or charged particles are used. Consequently, the performance of these charged filters may vary considerably depending on test conditions and especially the type of aerosol material used. Further, their performance can deteriorate over time as they collect particles. In some cases, the performance deteriorates by several orders of magnitude when all the effects of charge are dissipated. Since filters with minimum efficiencies in the range of 99,95 % and higher are frequently used in critical applications and in continuous service for typically many years at a time, these adverse effects on performance shall be considered when testing and classifying such filters. These filters are classified according to their efficiencies in accordance with ISO 29463-1; 95 % and 99,5 % efficiency filters are grouped as EPA, 99,95 % and 99,995 % efficiency filters as HEPA, and higher efficiency filters as ULPA.

C.2 Scope

This annex prescribes the method for quantifying and accounting for the effect of charge in filter media to enhance the performance and classification of filters when classified according to ISO 29463-1. Quantifying the effect of charge shall be determined either from tests performed on flat sheet medium as described in Clause C.3 or on full filter elements as described in Clause C.4.

C.3 Procedure for discharging of filter medium and classification of high efficiency filters using media with charged fibre filter medium

C.3.1 General

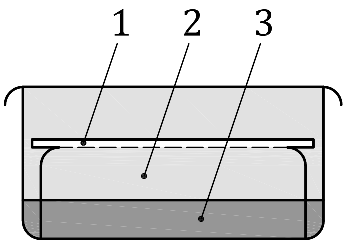
The described procedure is based on a standardized treatment with IPA vapour to discharge electrostatic influence on filter medium or filter on particulate penetration.

The isopropanol test is made by first measuring the particulate penetration of untreated media samples. Next, the samples are exposed to IPA vapour (> 99,9 % technical grade). If IPA is reused the IPA purity shall remain above 99,9 %. After filter samples have been exposed to the IPA vapour, their penetration is measured to assess the performance enhancement due to charge. The medium may be discharged in sequential steps or in one longer duration step. The details of the discharge procedure and the equipment needed for completing it are given in C.3.2 to C.3.8.

C.3.2 Equipment

The test equipment for measurement of the filter medium particulate penetration should meet the requirements as specified in ISO 29463-3.

A typical chamber utilized to discharge the medium sample, if discharging a single sample, is shown in Figure C.1.



Key

1 sample

2 IPA vapour

3 liquid IPA

Figure C.1 — Principle of the isopropanol container (vessel and lid)

If exposing multiple samples in unisons, the chamber as defined in ISO 16890-4 shall be utilized. The addition of a flat sheet medium holder that suspends the medium samples from one edge and maintains a spacing of at least 19 mm between samples is also possible.

C.3.3 Test samples

The samples should be taken directly from a finished production roll of filter medium. Each sample should be the same size and appropriate for the test system utilized to measure the particle removal efficiency as specified in C.3.4.

C.3.4 Measurement of the filter medium initial penetration

Flat sheet filter medium MPPS penetration tests should be performed on all medium samples in new condition according to ISO 29463-3, which is usually the nominal design media velocity in the filter. The default test velocity when none is specified or available is 2,0 cm/s. Since the calculated mean value is dependent on the variability of the samples, the coefficient of variation (C_V) should be calculated and is defined per Formula (C.1).

$$C_V = \frac{\sigma}{\overline{P}} \quad \text{(C.1)}$$

where

C_V is the coefficient of variation of the penetration of the samples;

σ is the standard deviation of the penetration of the samples;

$\overline{P}$ is the mean penetration of the samples.

The calculated C_V should be less than or equal to 1,5.

The mean penetration should be calculated from all the samples tested and the three samples selected for the new, possibly charged condition should be those with the penetration values closes to the calculated mean value. The average penetration of these three samples should be calculated and saved as $\overline{P}_c$.

