INTERNATIONAL STANDARD

ISO 29463-4

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

Part 4:
Test method for determining leakage of filter elements — Scan method

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

Partie 4: Méthode d'essai pour déterminer l'étanchéité de l'élément filtrant (méthode scan)

Reference number
ISO 29463-4:2011(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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 29463-4 was prepared by Technical Committee ISO/TC 142, *Cleaning equipment for air and other gases*.

ISO 29463 consists of the following parts, under the general title *High-efficiency filters and filter media for removing particles in air*:

— *Part 1: Classification, performance, testing and marking*

— *Part 2: Aerosol production, measuring equipment, particle-counting statistics*

— *Part 3: Testing flat sheet filter media*

— *Part 4: Test method for determining leakage of filter element — Scan method*

— *Part 5: Test method for filter elements*

Introduction

ISO 29463 (all parts) is derived from EN 1822 (all parts) with extensive changes to meet the requests from non-EU 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.

ISO 29463 (all parts) 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 ISO 29463 (all parts) 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 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 they are described in ISO 29463-5:2011, 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 29463-5:2011, Annex C. Specific requirements for test method, frequency, and reporting requirements can be modified by agreement between supplier and customer. For lower efficiency filters (group H, as described below), alternate leak test methods described in Annex A of this part of ISO 29463 can 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 described in Annex A of this part of ISO 29463.

There are differences between ISO 29463 (all parts) 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 ISO 29463-5:2011, Annex A.

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

Part 4:
Test method for determining leakage of filter elements — Scan method

1 Scope

This part of ISO 29463 specifies the test procedure of the “scan method”, considered to be the reference method, for determining the leakage of filter elements. It is applicable to filters ranging from classes ISO 35 H to ISO 75 U. It also describes the other normative methods, the oil thread leak test (see Annex A) and the photometer leak test (see Annex B), applicable to classes ISO 35 H to ISO 45 H HEPA filters, and the leak test with solid PSL aerosol (see Annex E). It is intended for use in conjunction with ISO 29463-1, ISO 29463-2, ISO 29463-3 and ISO 29463-5.

2 Normative references

The following referenced documents are indispensable for the application 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 29463-1:2011, *High-efficiency filters and filter media for removing particles in 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, 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 29463-5:2011, *High-efficiency filters and filter media for removing particles in air — Part 5: Test method for filter elements*

ISO 29464[1)], *Cleaning equipment for air and other gases — Terminology*

1) To be published.

3 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 29463-5, ISO 29464 and the following apply.

3.1
sampling duration
time period during which the particles in the sample are counted upstream and downstream

3.2
total particle count method
particle counting method in which the total number of particles in a certain sample volume is determined without classification according to size

EXAMPLE By using a condensation nucleus counter.

3.3
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.

3.4
particle flow rate
number of particles that are measured or that flow past a specified cross-section per unit time

3.5
particle flow distribution
distribution of the particle flow over a plane at right angles to the direction of flow

3.6
aerosol photometer
light-scattering airborne particle mass concentration measuring apparatus, which uses a forward-scattering-light optical chamber to make measurements

4 Principle

For most high-efficiency filter applications, a leak-free filter is essential. The reference leakage test serves to test the filter element for local penetration values and determine whether it exceeds permissible levels (see ISO 29463-1). For group H filters, alternatives to the reference scan method provide equivalent filter leakage determination and are described as alternate methods in Annexes A, B, E and F. Although not considered equivalent, the particle count method using 0,3 µm to 0,5 µm PSL given in Annex F may be used instead of the oil thread method (see Annex A).

For leakage testing, the test filter is installed in the mounting assembly and subjected to a test airflow corresponding to the nominal airflow rate. After measuring the pressure differential at the nominal air flow volume flow rate, the filter is purged and the test aerosol produced by the aerosol generator is mixed with the prepared test air along a mixing duct, so that it is spread homogeneously over the cross-section of the duct.

The particle flow rate on the downstream side of the test filter is smaller than the particle flow rate reaching the filter on the upstream side by the mean penetration factor.

The manufacturing irregularities of the filter media or leaks lead to a variation of the particle flow rate over the filter face area. In addition, leaks at the boundary areas and within the components of the test filter (sealant, filter frame, seal of the filter mounting assembly) can lead locally to an increase in the particle flow rate on the downstream side of the test filter.

For the leakage test, the particle flow distribution shall be determined on the downstream side of the filter in order to check where the limit values are exceeded. The coordinates of these positions shall be recorded.

The scanning tracks shall also cover the area of the filter frame, the corners, the sealant between filter frame and the gasket, so that possible leaks in these areas can also be detected. It is advisable to scan filters for leaks with their original gasket mounted and in the same mounting position and airflow direction as they are installed on site.

In order to measure the downstream particle flow distribution, a probe with defined geometry shall be used on the downstream side to take a specified partial flow as sample. From this partial flow, a sample volume flow rate shall be directed to a particle counter, which counts the particles and displays the results as a function of time. During the testing, the probe moves at a defined speed in adjoining or overlapping tracks without gaps (see C.3.2 and C.3.3) close to the downstream side of the filter element. The measuring period for the downstream particle flow distribution can be shortened by using several measuring systems (partial flow extractors/particle counters) operating in parallel.

The measurement of the coordinates of the probe, a defined probe speed, and measurement of the particle flow rate at sufficiently short intervals allow the localization of leaks. In a further test step, the local penetration shall be measured at this position using a stationary probe.

The leakage tests shall always be conducted using MPPS particles (see ISO 29463-3), except for filters with membrane medium in accordance with Annex E. The size distribution of the aerosol particles can be checked using a particle size analysis system (for example, a differential mobility particle sizer, DMPS).

The leakage testing can be carried out using either a mono-disperse or poly-disperse test aerosol. It shall be ensured that the mean particle diameter corresponds to the most penetrating particle size (MPPS) particle diameter, at which the filter medium has its minimum efficiency.

When testing with a mono-disperse aerosol, the total particle counting method may be used with a condensation particle counter (CPC) or an optical particle counter (OPC; e.g. a laser particle counter).

When using a poly-disperse aerosol, an optical particle counter that counts the particles and measures their size distribution shall be used.

5 Test filter

A test filter shall be used for the leak testing that does not show any visible signs of damage or other irregularities and that can be sealed in position and subjected to air flow in accordance with requirements. The temperature of the test filter during the tests shall correspond to the temperature of the test air. The test filter element shall be handled with care and shall be clearly and permanently marked with the following details:

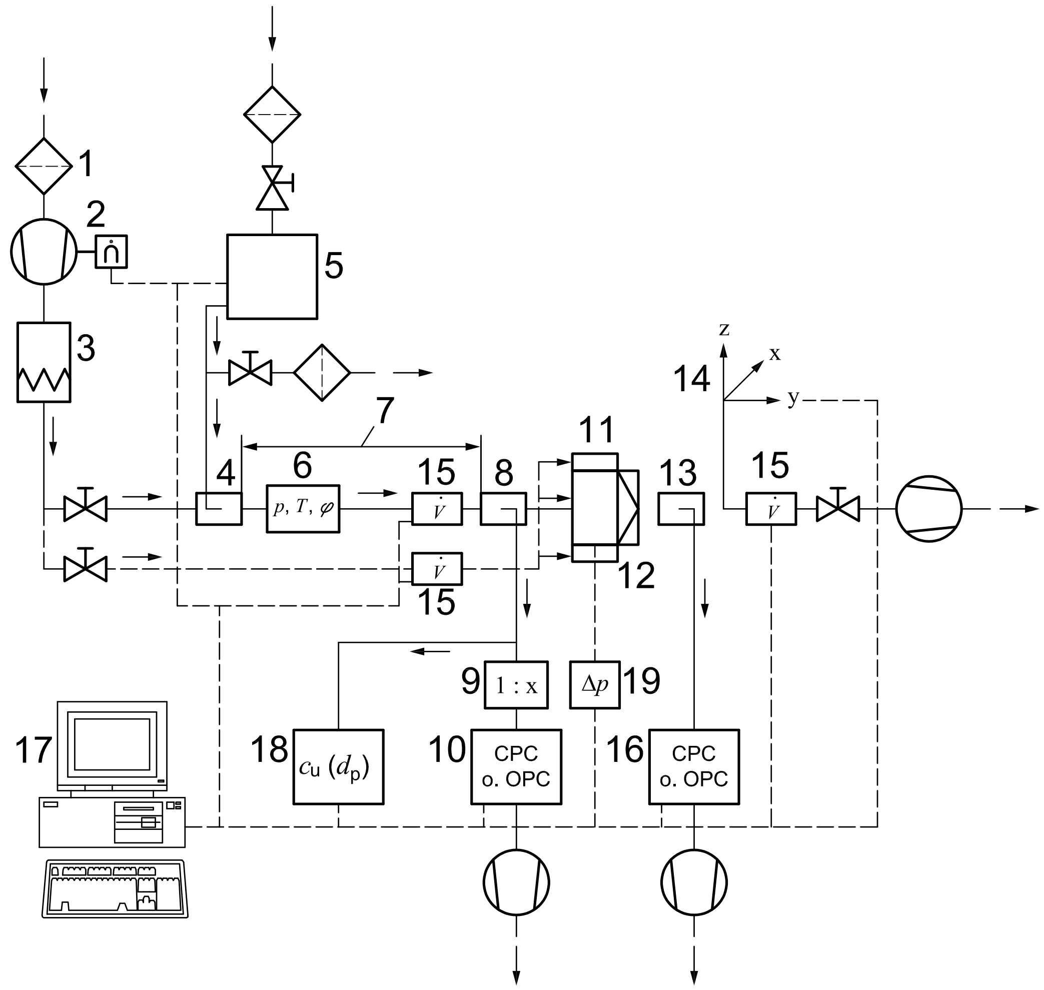
a) designation of the test filter element;

b) upstream side of the filter element.

6 Test apparatus

6.1 Set-up of the test apparatus

Figure 1 shows the set-up of the test apparatus. This layout is valid for tests with a mono-disperse or with a poly-disperse aerosol. The only differences between these lie in the technique used to measure the particles and the way the aerosol is generated.

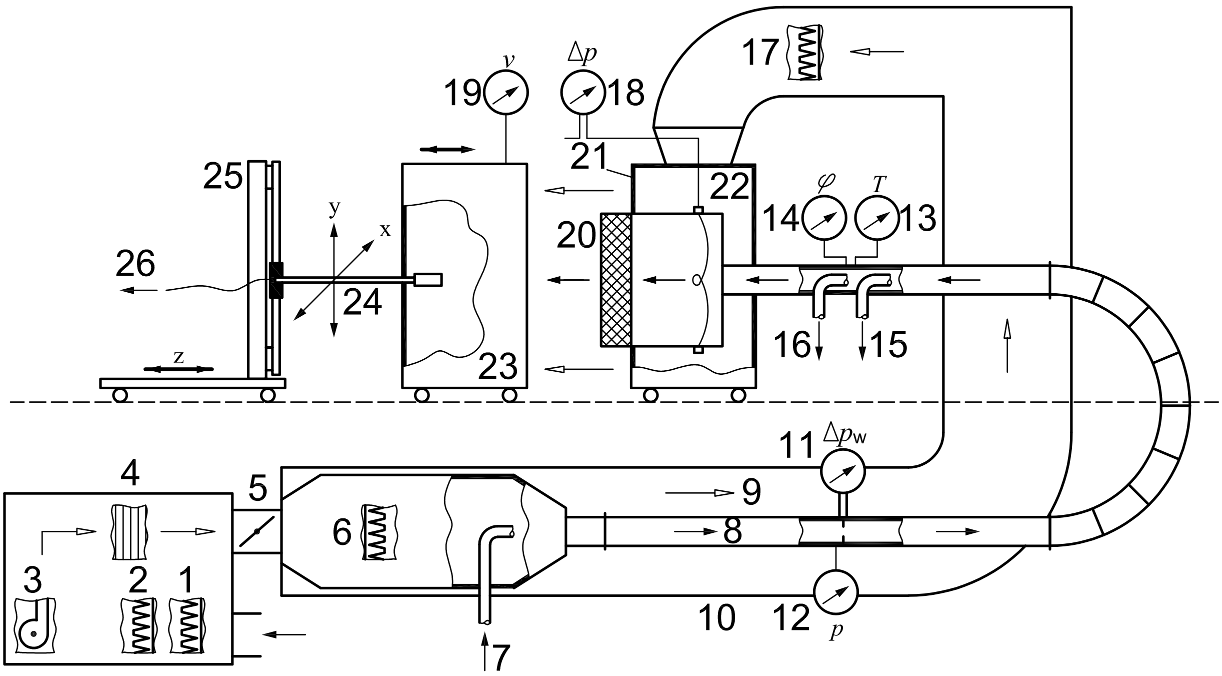


Key

1 pre-filter for the test air
2 fan with speed regulator
3 air heater
4 aerosol inlet in the duct
5 aerosol generator with conditioning of supply air and aerosol flow regulator
6 measurement of atmospheric pressure, temperature and relative humidity
7 upstream side mixing section
8 sampling point for upstream particle counting
9 dilution system (optional)
10 particle counter, upstream
11 sheath flow (optional)
12 test filter
13 sampling point and partial flow extraction, downstream
14 traversing system for probe
15 volume flow rate measurement
16 particle counter, downstream
17 computer for control and data storage
18 measuring system to check the test aerosol
19 measurement of differential pressure

Figure 1 — Diagram of test apparatus

An example of a test rig, without particle measuring equipment, is shown in Figure 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
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 downstream sampling probe
25 probe traversing system
26 downstream sampling point

Figure 2 — Test duct for scan testing

The basic details for the generation and neutralization of the aerosol, together with the details of suitable types of equipment and detailed descriptions of measuring instruments needed for the testing, are given in ISO 29463-2.

6.2 Test duct

6.2.1 Test air conditioning

The test air conditioning unit contains the equipment required to condition the test airflow (see Clause 7).

The test airflow shall be so prepared that it is in accordance with Clause 7 and does not exceed the limit values specified during the course of the efficiency testing.

6.2.2 Adjustment of the volume flow rate

It shall be possible by means of a suitable provision (e.g. changes to the speed of the fan, or by dampers) to produce the volume flow rate with a reproducibility of ±3 %. The nominal volume flow rate shall then remain in this range throughout the testing.

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 pressure drop using standardized damper equipment such as orifice plates, 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 duct

The aerosol input and the mixing duct (see example in Figure 2) shall be so constructed that the aerosol concentration measured at individual points of the duct cross-section directly in front of the test filter does not deviate by more than 10 % from the mean value obtained from at least 10 measuring points spread evenly over the duct 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 media area of the filter.

It is advisable to scan filters for leaks in the same mounting position and airflow direction as they are installed on site.

6.2.6 Measuring points for the pressure difference

The measuring points for pressure shall be so arranged that the mean value of the difference between static pressure in the upstream flow and the pressure of the surrounding air can be measured. The plane of the pressure measurements shall be positioned in a region of uniform flow.

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 duct walls, normal to the direction of flow. The four measurement holes shall be interconnected with a circular pipe.

6.2.7 Sampling, upstream

Samples are taken upstream by means of one or more sampling probes in front of the test filter. The probe diameter shall be chosen such that, at an average flow velocity, isokinetic conditions pertain at the given volume flow rate for the sample. Sampling errors that arise due to higher or lower flow velocities in the duct can be disregarded due to the small size of the particles in the test aerosol. The tubing connections to the particle counter shall be as short as possible.

The sampling shall be representative, i.e. the aerosol concentration measured from the sample shall not deviate by more than 10 % from the mean value determined in accordance with 6.2.4.

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

6.2.8 Screening

The downstream side of the test filter shall be completely screened from impurities in the surrounding air. Furthermore, for the correct detection and localization of leaks in the edges of the filter, in the gasket, the filter frame or the sealant, the particles emitted in these sections shall be swept away from the section that is covered by scanning. This can be achieved, for example, if the outer sides of the filter frame are enclosed by a shrouding flow of particle-free air flowing in the downstream direction.

The scanning tracks shall also cover the area of the filter frame, the corners, and the sealant between filter frame and the gasket so that possible leaks in these areas are detected. A validation of the test rig shall be performed to verify that leaks in these areas are detected with the same probability and sensitivity as media leaks, being located in the middle of the filter.

6.3 Scanning assembly

In addition to the automated testing for leaks, manual scanning is also permitted, provided that there is adherence to the most important parameters for the test procedure.

However, when the probe is moved manually, it is not possible to avoid irregularities, since the movement over the filter surface cannot be smooth and even. As a result, quantitative assessments are usually possible only to a limited extent, if at all. Furthermore, it is extremely time-consuming to keep a record of the coordinates of leaks and particularly to evaluate the particle counts.

The remainder of 6.3 describes an automatic scanning apparatus.

6.3.1 Sampling — Downstream

The sampling conditions affect the local resolution for the determination of the particle flow distribution on the downstream side. In order to ensure the comparability of the measurements for the local value of the penetration, the sampling shall be carried out under standardized conditions.

The geometry of the probe aperture may be rectangular or circular. The relationship between the sides of a rectangular probe shall not exceed 15 to 1. The inlet area of the probe shall be 9 $cm^2 \pm 1$ cm^2. The volume flow rate in the probe shall be chosen so that the speed at the probe aperture does not differ by more than 25 % from the face velocity of the filter (see C.5).

If the probes have a rectangular aperture, then the measuring time can be shortened by using several probes next to each other (for several particle counters).

The probe shall be positioned at a distance of 10 mm to 50 mm from the downstream face of the filter element.

For specially constructed filter forms and extremely high face velocities, it is permissible to deviate from the dimensional requirements specified here. However, it is then possible to arrive at only a conditional determination of the local efficiency within the meaning of this part of ISO 29463.

The alternative method of testing with the aerosol photometer is found in Annex B.

6.3.2 Probe arm

The partial flow probe on the downstream side shall be fixed to a moveable probe arm. This probe arm shall be designed in such a way that neither the arm nor the provisions made to move the arm disturb the airflow in the proximity of the filter.

6.3.3 Aerosol transport lines

The aerosol transport lines downstream shall lead the particles to the measuring chamber of the particle counter with the least possible delay and without losses. The lines shall, therefore, be as short as possible and without tight bends. They shall be made of a conductive material and have smooth surfaces that do not emit particles.

6.3.4 Provisions to move the probe

These provisions include drive, guidance and control to move the probe arm at right angles to the direction of flow with a constant probe speed.

The speed of the probe may be selected and shall not exceed a maximum of 10 cm/s (see C.6). During a run, the speed shall not deviate from the set value by more than 10 %.

Suitable provisions shall also be made to measure the position of the probe in the coordinates X, Y and Z during the probe run, and also to reposition the probe over a leak determined during a run. The accuracy of repositioning to any point in the downstream cross-section of the test filter shall be at least 1 mm.

6.4 Aerosol generation and measurement techniques

6.4.1 General

For a poly-disperse test aerosol, the operating parameters of the aerosol generator shall be adjusted to produce a test aerosol whose mean diameter does not deviate by more than ±50 % from the MPPS for the plane filter medium. For a mono-disperse test aerosol, the operating parameters of the aerosol generator shall be adjusted to produce a test aerosol whose mean diameter does not deviate by more than 10 % from the MPPS for the plane filter medium.

It shall be possible to set the mean value of the number distribution of the test aerosol within ±10 %.

The particle generation rate 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 counters, and significantly above the zero count rate of the instruments.

The number distribution of the test aerosol may be determined using a suitable particle size analysis system (e.g. a DMPS) or with a laser particle counter suitable for these test purposes. The limit error of the measurement method used to determine the mean value shall not exceed ±10 % relative to the measured value.

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

The maximum measurable concentration can also be limited by the maximum possible processing speed of the evaluation electronics of the test apparatus. The measuring uncertainties involved in determining the sample volume flow rate and the duration of measurement can also influence the concentration measurements. The result for the particle concentration, including all sources of error at the interface of the apparatus responsible for the recording, shall not differ by more than 10 % from the true value.

The particle flow rate shall be registered at time intervals (counting intervals Δt_i) that correspond, at least, to the time taken by the probe to traverse the width of its own aperture (a_p). The transmission characteristics of the particle counter and the evaluation electronics shall satisfy these requirements. The uncertainty in determining the duration of the counting interval shall be less than 10 %.

6.4.2 Set-up 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 leakage testing of the filter element, either optical particle counters or condensation nucleus counters may be used to determine the particle number concentration.

When using a condensation nucleus counter, it shall be ensured that the test aerosol does not produce appreciable numbers of particles that are very much smaller than the MPPS. Such particles, which can be produced by an aerosol generator that is no longer working properly, for example, are also counted by a condensation nucleus counter and can lead to a considerable error in the determination of the local efficiency. Therefore, when using a condensation nucleus counter, the number distribution of the test aerosol shall be determined with a measuring procedure that stretches over a range from the lower range limit of the condensation nucleus counter up to a particle size of approximately 1 µm. The geometric distribution thus determined shall be ≤1,5 (quasi-mono-disperse).

6.4.3 Set-up for testing with a poly-disperse test aerosol

When testing a filter element for leaks using a poly-disperse test aerosol, the particle concentration and size distribution by number shall be determined using an optical particle counter (e.g. laser particle counters).

The measuring range of the optical particle counter used in testing efficiency shall comply with the following requirements.

a) The measuring range shall cover the particle size range $\frac{S_{\mathrm{MPPS}}}{1{,}5}$ to $1{,}5 \times S_{\mathrm{MPPS}}$, where S_{MPPS} is the most penetrating particle size, in accordance with ISO 29463-5:2011, Figure 4, range I.

b) The distribution of the size classes shall be such that one class limit, C_{L}, meets the condition: $\frac{S_{\mathrm{MPPS}}}{2} < C_{\mathrm{L}} \leq \frac{S_{\mathrm{MPPS}}}{1{,}5}$ (ISO 29463-5:2011, Figure 4, range IIa).

c) A further class limit shall be the condition: $1{,}5 \times S_{\mathrm{MPPS}} \leq C_{\mathrm{L}} < 2 \times S_{\mathrm{MPPS}}$ (ISO 29463-5:2011, Figure 4, range IIb).

All classes between these two limits are evaluated to determine the efficiency. There is no requirement for a minimum number of classes in this range, so that in the extreme case the conditions in a) to c) may be met by only one size class.

7 Test air

The test air shall be prepared before mixing it with the test aerosol. The purity of the test air (particle number concentration <352 000 particles/m^3) shall be ensured by suitable pre-filtering (for example using commercially available coarse and fine dust filters and high-efficiency particulate air filters).

The temperature and relative humidity of the test air in the test duct shall be measured on the upstream side and can be adapted to meet the following requirements using an air heating system:

— temperature: (23 ± 5) °C:

— relative humidity: <75 %.

8 Procedure

8.1 General

Before beginning the scan test, the test parameters shall be determined or calculated, if this has not already been done for earlier tests, and the appropriate adjustments made.

On the basis of the dimensions of the filter and the probe, the following parameters for the probe tracking shall be determined:

- distance between the probe aperture and the filter element (10 mm to 50 mm; see 6.3.1);
- speed of the probe (determined in accordance with C.6);
- number and position of the probe tracks.

The other test parameters shall be determined on the basis of the nominal air volume flow rate and the anticipated penetration for the test filter. Additional test parameters are the aerosol concentration on the upstream side, the volume flow rate in the probe, the speed of the probe and the signal value for the counting rate. The parameters shall be determined in accordance with Annex C and the adjustments made to the test apparatus. An example of this determination is given in Annex D.

Before beginning a test with newly determined test parameters, the interaction of the test parameters shall be checked as well as the ability to recognize limit-values for leakages. Reference filters for which defined leakages have already been determined may be used for this purpose.

Testing shall not commence until it has been shown that leaks can be detected adequately.

8.2 Preparatory checks

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

- Operational readiness of the measuring instruments:
  - The warming-up times specified by the instrument manufacturers shall be observed.
  - The condensation nucleus counters shall be filled with operating liquid.
  - If the instrument manufacturers recommend further regular checks before taking measurements, then these checks shall also be carried out.
- Zero count rate of the particle counter:
  - The measurement of the zero count rate may be carried out using filtered flushing air.
- Zero value of the test apparatus:
  - The test shall be carried out using a reference filter with the aerosol generator switched off.
  - If the measured particle flow rate on the downstream side, either locally or as the mean value, is significantly higher than the long-term zero value of the apparatus, then the cause shall be eliminated before proceeding further with the test.
- Temperature, relative humidity and purity of the test air:
  - These parameters shall be checked to ensure that they comply with the specifications in Clause 7. Appropriate corrections to achieve the specifications in Clause 7 shall be made, as applicable.

8.3 Starting up the aerosol generator

When starting up the aerosol generator, a standby filter element shall be installed in the test filter mounting assembly in place of the test filter.

After adjusting the operating parameters of the aerosol generator and observing an appropriate warming-up period, the particle concentration and the particle-size distribution of the test aerosol shall be checked to ensure that they comply with the requirements specified in 6.4.

8.4 Preparing the test filter

8.4.1 Installing the test filter

The test filter shall be handled in such a way as to ensure that it is not damaged. It shall be installed appropriately, oriented to the designed airflow direction, and without by-pass leaks in the test filter mounting assembly.

The position of the test filter in the mounting assembly shall be recorded in order to allow a determination of the position of any leaks after the tests. It is advisable to scan filters for leaks with their original gasket mounted and in the same mounting position and airflow direction as they are installed on site.

8.4.2 Flushing the test filter

In order to reduce the emission of particles by the test filter itself and to equalize the temperature 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.

If necessary, the particle self-emission of the test filter shall be measured by scan testing at the nominal volume flow rate without the generation of test aerosol. If the particle counting rate recorded downstream is locally higher or the mean concentration of the downstream air is significantly higher than the zero value (see 8.2) for the apparatus reference filter, then the test filter shall be flushed for an additional period and then the particle emission measured again.

The testing shall not commence until the particle emissions do not significantly exceed the zero value for the apparatus reference filter.

8.5 Testing

8.5.1 Measuring the pressure differential

The pressure differential across the test filter shall be measured in the unloaded (pre-particle generation) state at the nominal volume flow rate using the test air. The volume flow rate shall correspond to the nominal air volume flow rate with a reproducibility of ±3 %. The measurements shall be made when a stable operating state has been reached.

8.5.2 Testing with mono-disperse test aerosol

In the mixing duct, the test air is mixed with test aerosol, the mean diameter of which corresponds to the most penetrating particle size (deviation 10 %; see 6.4).

The volume flow rate is determined, taking into account the proportion introduced by the aerosol generator, and adjusted to the nominal volume flow rate ±3 %. Measurements shall begin as soon as the system has reached a stable operating state.

The downstream probe is moved in accordance with a tracking programme. The coordinates of the places on the test filter at which the signal value is equalled or exceeded shall be recorded. The total number of particles counted over the passage area shall be calculated and the counting period for this part of the programme measured.

The concentration of the aerosol on the upstream side may be measured continuously or intermittently, using either a dedicated particle counter, or switching with the particle counter for the downstream side. Care shall be taken that the testing does not last so long that the test filter is overloaded with aerosol.

8.5.3 Testing with poly-disperse test aerosol

The test shall be carried out by analogy with 8.5.2, using a poly-disperse test aerosol with a mean diameter that shall not deviate by more than ±50 % from the MPPS (see 6.4).

In the test using poly-disperse test aerosol, in contrast to the test with a mono-disperse test aerosol, both the total number and size distribution of the aerosol shall be measured with an optical particle counter. In order to determine the efficiency (penetration), the upstream and downstream concentrations shall be used for all size channels that lie wholly or partially within the range $\frac{S_{\text{MPPS}}}{1{,}5}$ to $1{,}5 \times S_{\text{MPPS}}$ (see 6.4.3).

8.5.4 Leak testing — Local penetration

If the signal value is not exceeded during the probe run, then the filter is classified as free of leaks. If the signal value is exceeded, then this is an indication that the limit value for the local penetration can be exceeded at this position. If it is necessary to check the local penetration, then the probe is returned to the coordinates for which the signal value was reached in the scan test. The aim is to find the point with the maximum count rate. The count rate shall be measured there with a stationary probe. The concentration of the aerosol on the upstream side shall also be measured continually or intermittently.

Due to the statistical scattering of the particle numbers on the upstream and downstream sides, which is expected, the statistical maximum value of the local penetration is determined (see Clause 9). If this maximum value is above the limit value for the filter class of the test filter as specified in ISO 29463-1, then the test filter cannot be classified as free of leaks. If all of the maximum values for the local penetration are below the limit value, the filter is classified as free of leaks.

A filter may be repaired, if necessary, and shall then be retested. All repairs together (including those made by the filter manufacturer) shall not block or restrict more than 0,5 % of the filter face area (not including the frame) and the maximum length of each single repair shall not exceed 3,0 cm. Alternative repair criteria may be otherwise agreed between the supplier and the customer.

9 Test report

The test report for the leak test of the filter element shall at least contain the following information:

a) test object:

   1) type designation, part number and serial number of the filter,

   2) overall dimensions of the filter,

   3) installation position of the filter (gasket upstream or downstream);

b) test parameters:

   1) temperature and relative humidity of the test air,

   2) nominal air volume flow rate and test air volume flow rate of filter,

   3) MPPS of filter media at corresponding medium velocity (see ISO 29463-3),

   4) aerosol generator (type designation and part number),

5) test aerosol (substance, mean diameter, geometrical standard deviation),

6) alternative aerosol statement: “In case a solid aerosol (e.g. PSL) is used, the requirements of Annex E shall be met.”,

7) particle counter(s), upstream and downstream [type designation and part number(s)] and particle size channel(s) used (in case of OPC),

8) dilution system for upstream particle counter (type designation and part number),

9) sampling probe downstream side (geometry, sampling airflow),

10) reference leak penetration and signal value setting (relevant limit value indicating a leak);

c) test results:

1) mean differential pressure across the filter at test air volume flow,

2) mean upstream and downstream particle concentration,

3) confirmation of freedom from leaks (mentioning reference leak penetration).

10 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 is listed in Table 1, 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, inspections and 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. Maintenance work and inspections of the test apparatus are intended to prevent the permitted limit values for the measurement deviations of the measuring equipment from being exceeded.

The maximum limit errors specified in ISO 29463-2 for the measuring equipment apply for the interface of the measuring chain at the test apparatus, which is responsible for the recorded measuring result. In order to avoid impermissible measurement deviations arising between two testing sessions, reference filters shall be used. The reference filters shall be replaced periodically in order to avoid a change by loading with aerosol. The test results with the reference filters shall be recorded. Measures shall be taken to correct deviations when the result of the penetration deviates by more than 30 % and the result of the pressure drop deviates by more than 10 % from the arithmetic means of the comparative test.

The necessary maintenance, inspection and calibration intervals can be influenced by the nature of the test rig and its operation. This shall be taken into account when deciding on or checking the intervals.

Table 1 — Maintenance and inspection intervals for components of the test apparatus

Component	Type and frequency of maintenance/inspection
Test air preparation system; test air duct entire system test air filter	Annually, or — when maximum pressure drop is reached, or — in the event of leaks
Lines taking aerosol to the measuring instruments	Cleaning annually or before every change of the aerosol substance
Volume flow rate meter	Annually
Repeatability of the adjustment of the test volume flow rate with reference resistances	Annually
Air-tightness of parts of apparatus at low pressure	When the zero count rate of the particle counter is unsatisfactory; otherwise annually
Air-tightness of the pressure measurement lines	Annually
Air-tightness of the aerosol transport lines	Annually
Measuring equipment for the volume flow rates in the probe	Annually
Particle concentration profile over the passage area	Annually
Aerosol transport losses on the upstream and downstream sides	Annually
Coordinate measurement of the scanning system	Annually
Probe speed of the scanning system	Annually
Checking the apparatus with reference filters	Annually

Annex A
(normative)

Oil thread leak test

The leak test serves to verify that filter elements have no leaks, which means local penetration values above the permissible limits (see ISO 29463-1:2011, Table 1). The oil thread leak test may be carried out as an alternative leak test method for group H filters. The reference for this leak test is, however, the particle count scan method as described in the body of this part of ISO 29463. The oil thread leak test is also acceptable as a test procedure for filter shapes for which the scan method cannot be applied (e.g. filter elements with V-bank media panels or for cylindrical filters). For proper application of this method, see ISO 29463-1:2011, Table 2.

The oil thread leak test is a qualitative test method where the absence of leaks is demonstrated visually. Therefore, it is essential to carry out regular training of the test personnel and to verify the sensitivity of the procedure and the method at regular intervals by using reference filter elements with well-defined leaks, characterized by the reference scan test method. The local penetration of the leaks in the reference filter elements shall be between the limit values for the filter class defined in ISO 29463-1:2011, Table 1, and double the maximum corresponding limit value.

In the test set-up, the filter shall be subjected to a flow of a poly-disperse oil-drop aerosol with a speed of approximately 1,3 cm/s (42 m^3/m^2h), which may be varied to optimize the procedure. The filter shall be placed horizontally on a diffuser or box. The test filter mounting assembly shall ensure that the test filter can be sealed and subjected to the flow in accordance with the requirements. It shall not obstruct any part of the filter cross-sectional area.

The poly-disperse test aerosol shall be generated by nebulizing from a liquid aerosol substance in accordance with ISO 29463-2:2011, 4.1. The mean value of the particle diameter shall lie between 0,3 µm and 1,0 µm. The mass concentration shall be 1,5 g/m^3, as determined by gravimetric methods.

The downstream side of the filter shall be illuminated from vertically above with a white (≥4 000 K) fluorescent lamp or halogen lamps. The brightness of the lamp shall be >1 000 Lx at the working plane. The surroundings of the filter shall be darkened, and the observational background shall be black. Uncontrolled air currents from the surroundings shall be screened out.

Under these conditions, leaks can be recognized from a clearly visible oil thread that appears due to the leakage. If no oil threads can be seen, the filter up to class ISO 45 H is free from leaks in accordance with the leak limit values defined in ISO 29463-1:2011, Table 1.

The position and the brightness of the lamp may be adapted to the examiner's subjective perception by using reference filter elements with well-defined leaks characterized by the scan test method. It is also recommended that reference filters be used with well-defined leaks in the medium, in the frame corners and in the medium, close to the sealant.

The test report for the oil thread test shall contain at least the following:

— details of the filter tested (type, dimensions, identification number, nominal technical data);

— details of the test parameters (flow velocity, test aerosol, mean particle diameter and mass concentration of test aerosol);

— identification of tester and date of test;

— test result (confirmation of absence of leaks).

On the test report it shall be clearly stated that the filter was tested using the test method in accordance with Annex A.

Annex B
(normative)

Aerosol photometer filter scan test method

B.1 Background

This leak test serves to verify that filter elements have no leaks. The aerosol photometer scan test may be carried out as an alternative leak test method for group H filters. The aerosol photometer is used extensively to leak test HEPA and ULPA filters for a variety of filtration industries. The use of the aerosol photometer to perform the scan test by the factory can provide a closer correlation to like equipment used in *in-situ* HEPA and ULPA leak testing situations.

B.2 General

This clause establishes the basis for choosing the conditions for conducting the filter leak test with an aerosol photometer. The choice of specific test conditions is a matter for agreement between the supplier and the customer. This agreement should specify the following:

— aerosol photometer being used and its response time constant;

— filter exit airflow velocity at which the leak test is to be conducted; unless otherwise specified, the exit airflow velocity is 0,45 ± 0,05 m/sec;

— challenge aerosol material and generation method;

— standard leak penetration of the designated leak (see ISO 29463-1:2011, Table 1);

— maximum scan rate: unless otherwise specified, the maximum scan rate when using a square probe should not exceed 3 m/min (5 cm/sec). With a rectangular probe, the maximum area scan rate should not exceed 0,093 m^2/min unless otherwise specified.

This annex provides a method for determining the sampling probe inlet size. It also relates the linear scan rate, the photometer response time constant, the sampling probe inlet size, the standard leak penetration of the designated leak, and the threshold that indicates a possible leak during scanning.

This test procedure has been an industry standard method for defining defects in filters or filter systems.

NOTE As presented in this part of ISO 29463, the procedure has been modified to account for the response time of the photometer and to account for rectangular probes.

The test provides both qualitative and quantitative results in identifying leaks. The test can easily be reproduced. The generation of a reasonably consistent concentration of liquid aerosol to challenge most systems is not difficult. A concentration of approximately 10 µg/l to 90 µg/l of air is an adequate challenge.

CAUTION — When the test system or clean-air device is located in a non-clean environment, or in a partial-coverage cleanroom, aerosol from the surrounding space can interfere with the leak tests.

B.3 Apparatus and equipment

B.3.1 Laskin nozzle aerosol generator, or other aerosol source compatible with an aerosol photometer.

B.3.2 Poly-thermal aerosol generator, which produces a liquid aerosol by means of an evaporation-condensation process in the absence of controlled nucleation.

The particle size distribution and mass mean diameter (MMD) of an aerosol produced by a thermal generator are measurably smaller than those of an aerosol from a Laskin nozzle.

B.3.3 Aerosol photometer, with logarithmic or linear read-out (see definition in 3.6), with a sample flow rate of 28,3 l/min and a known response time constant.

B.3.4 Sampling probe, with an inlet opening of square or rectangular configuration, which has an inlet airflow velocity within ±10 % of the average exit airflow velocity of the filter(s) being scanned when operating at the sample flow rate of the photometer. (See example configuration illustrated in Figure 2.)

The dimension, D_p, of the opening of the probe inlet parallel to the direction of scanning should be no less than 6 mm. The dimension, W_p, of the opening of the probe inlet perpendicular to the direction of scanning is determined from the sample flow rate. The transition section of the probe, the portion between the inlet and the connection to the instrument tubing should have an overall length, T_L, at least equal to the maximum dimension, W_p, of the probe inlet.

B.4 Procedure

B.4.1 Principle

This test is performed by introducing the specified challenge aerosol upstream of the filters and searching for leaks by scanning the downstream side of the filters with the photometer probe.

B.4.2 Sampling probe inlet size

The sampling probe inlet dimension, a_p, parallel to the scan direction, should be calculated from the photometer sample flow rate and the filter exit airflow velocity so that the probe inlet air velocity approximates the average filter exit airflow velocity within ±10 %, as given in Equation (B.1).

$$a_\mathrm{p} = \frac{F_\mathrm{a}}{VW_\mathrm{p}} \tag{B.1}$$

where

F_a is the flow rate of the photometer;

V is the average exit airflow velocity of the filter;

W_p is the probe dimension perpendicular to the scan direction.

Linear scan rate is related to area scan rate as given by Equation (B.2):

$$S_\mathrm{r} = \frac{A_\mathrm{r}}{W_\mathrm{p}} \tag{B.2}$$

where

S_r is the linear scan rate in cm/sec;

A_r is the area scan rate.

B.4.3 Set-up

B.4.3.1 The design airflow velocity should be established and uniformity confirmed prior to performing this test.

B.4.3.2 The aerosol should be introduced into the air supplied to the filter or filters under test in a manner that produces a uniform challenge concentration over each filter's surface. Minimize exposure of the filters to the challenge aerosol.

B.4.3.3 The aerosol challenge should be verified as uniform in accordance with 6.2.4.

B.4.3.4 The concentration of the challenge aerosol should be measured at the representative upstream sample location, using a photometer whose sensitivity is adjusted to a baseline of 100 µg/l in accordance with the manufacturer's instructions or calibration curve. A reading of 10 % to 90 % (which corresponds to 10 µg/l to 90 µg/l of air) on the photometer should be obtained for correct challenge concentration. The upstream concentration should be stable over time such that four consecutive readings at 1 min intervals are within 15 % of the average of the readings.

— If a representative upstream sample is not available, see Annex H.

— If the reading is high, it can be desirable to reduce the concentration of the challenge aerosol in order to limit exposure of the filter under test to the challenge material. Conversely, if the reading is low, it is necessary to increase the amount of aerosol in order to maintain the sensitivity to small leaks.

— After the correct reading has been obtained, adjust the photometer sensitivity, gain, or span for a reading of 100 %, or full scale, while sampling the upstream aerosol.

B.4.3.5 The entire face of each filter should be scanned for leaks, using slightly overlapping strokes of the probe and moving the probe at a rate not exceeding the maximum scanning speed.

Also scan the perimeter of each filter to locate leaks in the bond between the filter pack and the frame and to locate leaks in the seal between the frame and the support structure. The probe should be held approximately 25 mm from the filter media during scanning.

B.4.3.6 Possible leaks while scanning are indicated by a photometer response equal to or greater than the penetration response. The maximum penetration, P_{m}, indicated as the probe is scanned over a leak the size of the designated leak, is calculated by Equation (B.3):

$$P_{\mathrm{m}} = L_{\mathrm{s}}\left[1 - \exp\left(\frac{-a_{\mathrm{p}}}{S_{\mathrm{r}}T_{\mathrm{c}}}\right)\right] \tag{B.3}$$

where

L_{s} is the standard leak penetration of a designated leak, expressed as a fraction of the upstream concentration, e.g. 0,01 % = 0,000 1;

a_{p} is the probe dimension parallel to the scan direction, expressed in centimetres;

S_{r} is the maximum linear scan rate, expressed in centimetres per second;

T_{c} is the response time constant of the photometer as if being used for scanning (i.e. with the same range setting, the same tubing, etc.).

If the value calculated for P_{m} is less than three times the minimum sensitivity of the photometer, or if P_{m} is less than 0,1 times L_{s}, then it is necessary to chose a slower maximum scan speed, S_{r}, and to calculate a new P_{m}.

If an operator watches a meter during scanning to detect leaks, then any meter indication equal to or greater than P_m is considered an indication of a leak. If alarm settings are used to signal the operator or automatic scanning system, then the alarm level should be set to P_m. Any indication of a leak equal to or greater than P_m should be cause for sustained residence time of the probe at the leak location. The size and location of the leak are identified by the position of the probe that maintains the maximum sustained reading on the photometer.

If these procedures regarding P_m are not followed, the result is generally that leaks near the designated leak size are missed while larger leaks are still detected.

Be aware that prolonged exposure of filters to the challenge aerosol should be avoided.

B.5 Leak criteria — Acceptance for the aerosol photometer filter scan test

See ISO 29463-1:2011, Table 1 for penetration local values. Alternative filter integrity requirements are a matter for agreement between the supplier and the customer.

B.6 Repairs for the filter scan test

The size of the repairs should be limited as follows.

a) Use a material acceptable to the owner for the application.

b) All repairs together (including those made by the filter manufacturer) shall not block or restrict more than 0,5 % of the filter face area (not including the frame) and the maximum length of each single repair shall not exceed 3,0 cm. Alternative repair criteria may be otherwise agreed between the supplier and customer.

c) After the repair is complete and a suitable cure time has been allowed for the patch to set, check for leaks in the vicinity of the repair. Repairs to filter leaks may be made by procedures acceptable to the supplier and the customer.

B.7 Reporting

For group H filters, unless otherwise specified, the designated leak size is the penetration local value found in ISO 29463-1:2011, Table 1. That is, report all leaks for which the stationary reading exceeds the following:

a) for a linear read-out photometer, a reading greater than the penetration local value, in accordance with ISO 29463-1:2011, Table 1, of the upstream challenge aerosol concentration or as otherwise agreed;

b) for a logarithmic read-out photometer, a reading greater than the penetration local value, in accordance with ISO 29463-1:2011, Table 1, on instruments with a direct-reading scale or equivalent reading on the instrument calibration curve (one minor scale division), or as otherwise agreed;

c) for group U filters, see ISO 29463-1:2011, Table 1 for other values.

Annex C
(normative)

Determining the test parameters

Before commencement of the test, the test parameters shall be calculated on the basis of the specified boundary conditions and the data of the test filter. The calculation can lead to parameters that cannot be achieved, such that, if necessary, it shall be carried out as an iterative process with changing input data.

All values given for particle numbers and number concentrations refer to the particle size range covered by the mono-disperse test aerosol or to the particle size range used to determine the filter efficiency with a poly-disperse aerosol (see 8.5.3).

C.1 Boundary conditions

The following boundary conditions shall apply:

Probe aperture cross-section	A_p = 9 cm^2 ± 1 cm^2
Minimum particle number for a leak signal (lower limit of the 95 % confidence interval)	$N_{min,95\ \%}$ = 5
Value for particle number to be expected traversing a leak	$N_{min,leak}$ = 10
Minimum particle number on the downstream side for determining the efficiency	$N_{min,abs}$ = 100
Probe traversing speed	$u_p \leq$ 10 cm/s

C.2 Test filter data

The following data for the test filter shall be taken into consideration when determining the test parameters.

The filter class, which is established according to ISO 29463-1, is characterized by the following limit values of the penetration:

— overall value $P_{class,i}$;

— local value $P_{class,l}$;

— nominal volume flow rate $\dot{V}$;

— filter face area A_d.

C.3 Data for the apparatus

C.3.1 Particle counters

The following counter data are relevant for the particle counters employed:

— sampling volume flow rate $\dot{V}_s$;

— maximum concentration $c_{max,c}$;

— number of counters operating in parallel M.

Instead of the zero count rate of the counter (see ISO 29463-2), here the zero count rate of the entire system for the downstream side shall be known. The counting rates of the downstream counters are determined with the test filter in place and the aerosol generator switched off. The zero count rate of the test rig includes impurities in the test air and possible release of particles by the measuring lines.

The minimum counting (particle flow) rate of the counter on the downstream side is determined from the zero count rate of the apparatus as given by Equation (C.1):

$$\dot{N}_{\text{min,c}} = 10 \cdot \dot{N}_{\text{zero}} \tag{C.1}$$

where

$\dot{N}_{\text{min,c}}$ is the minimum counting rate of the downstream particle counter;

$\dot{N}_{\text{zero}}$ is the zero count rate of the system on the downstream side.

C.3.2 Downstream sampling probes

The probes used may have either a circular or a rectangular cross-section. The chosen diameter or lengths of sides shall give the specified probe cross-sectional area (see C.1). The ratio of lengths of sides for a rectangular probe shall not exceed 15:1 (see 6.3.1).

The use of probes with a circular cross-section involves a number of problems. For example, the time spent crossing a leakage depends on the position of the leak in relation to the probe, so that reliable leak detection cannot be guaranteed without a certain overlap between passage runs. For circular probes, an overlap of 20 % of the probe diameter normally results in reasonable figures for a_{p}.

The following considerations refer to a probe with a rectangular cross-section. The calculations can, however, be applied by analogy for use with circular probes.

Probe dimensions are designated as follows:

- internal side length in scan direction: a_{p};
- internal side length at right angles to scan direction: w_{p}.

C.3.3 Loss factor

The minimum counting rate for a leak specified in C.1 shall also be achieved if the leak is at the edge of the path covered by the probe. It is therefore expected that the mean counting rate, N_{min}, for a leak at the centre of the path is higher, as given by Equation (C.2).

$$N_{\text{min}} = \frac{N_{\text{min,leak}}}{k_{\text{b}}} \tag{C.2}$$

where

$N_{\text{min,leak}}$ is the expected minimum particle number for a leak;

k_{b} is the loss factor for a leak at the edge of the probe path.

In the case of probe paths that touch but do not overlap, the loss factor can be set at $k_{\text{b}} = 0{,}5$. In this case, the minimum counting rate for a leak would be $N_{\text{min}} = 20$. With overlapping, the value of the loss factor may be increased. In case of doubt, it is advisable to determine the loss factor experimentally with a stationary probe.

C.4 Sequence of calculation steps

Figure C.1 shows a flow diagram of the calculation of test parameters. This clearly shows that if parameters are not in accordance with requirements or the signal difference is insufficient (see C.9.2), then it is necessary to alter the initial parameters until the results allow the test to be carried out.

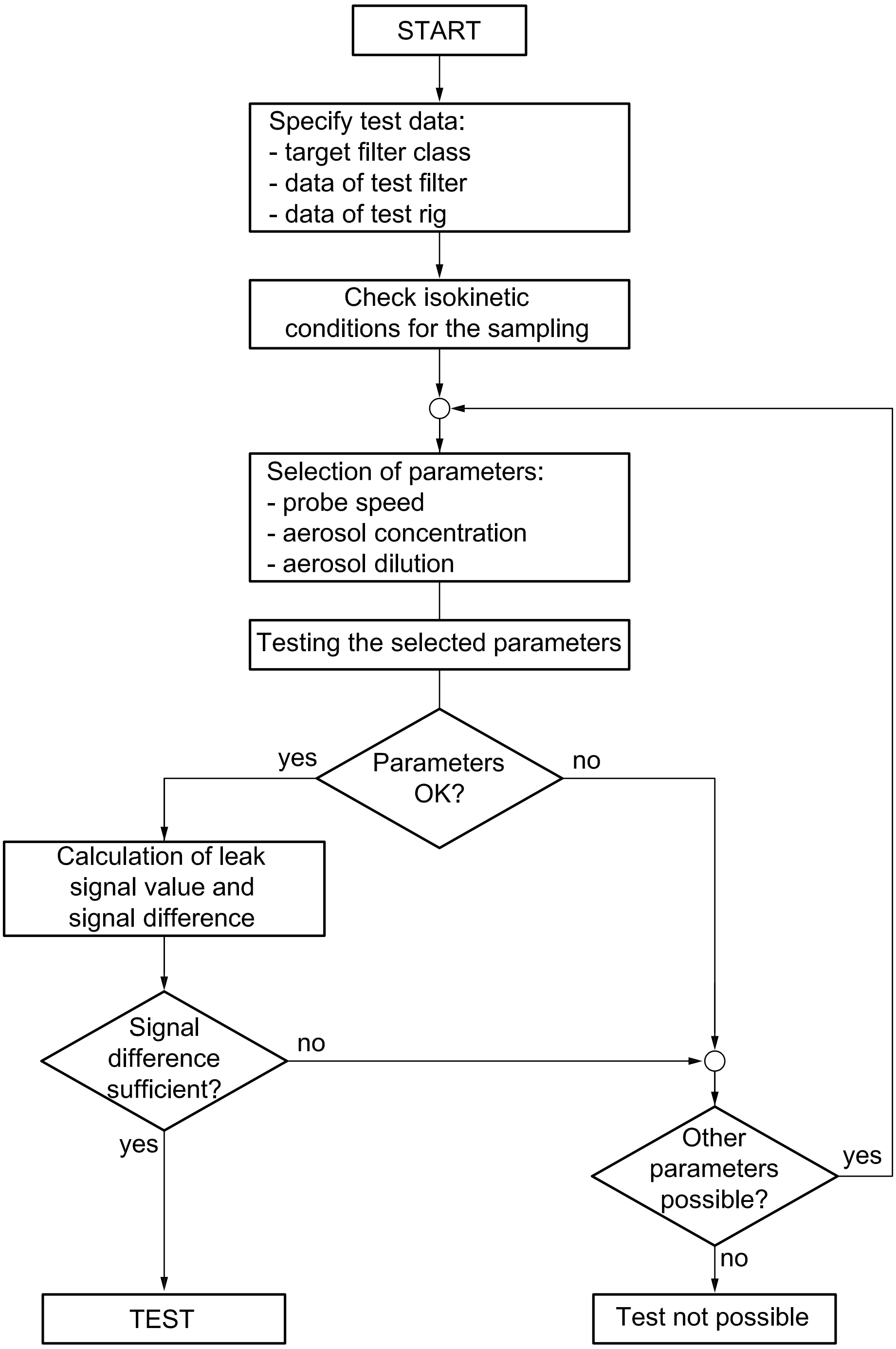


Figure C.1 — Flow diagram for the determination of test parameters

C.5 Checking the isokinetic sampling

The mean air speed, $\overline{w}_p$, in the probe is calculated from the volume flow rate in the probe and its cross-sectional area as given in Equation (C.3):

$$\overline{w}_p = \frac{\dot{V}_p}{A_p} \tag{C.3}$$

where

$\dot{V}_p$ is the volume flow rate in the probe;

A_p is the probe intake cross-section.

The calculated value of $\overline{w}_p$ shall be compared with the mean air speed $\overline{w}_d$ for the passage area downstream. The deviation between the two speeds shall not exceed 25 % (see 6.3.1).

If the volume flow rate of the probe is variable, then the speed in the probe may be adjusted to the speed in the passage area.

C.6 Choosing the probe speed

Any traversing speed can be chosen for the probe up to the limit value of 10 cm/s.

The time, t_{leak}, taken by the probe to cross a leakage can be calculated using the chosen probe speed, u_p, as given by Equation (C.4):

$$t_{leak} = \frac{a_p}{u_p} \tag{C.4}$$

where

a_p is the width of probe aperture in scan direction;

u_p is the speed of probe.

It is also possible to determine the total scanning time, $t_{p,tot}$, during the scan test.

The counting rate shall be determined at least at time intervals (counting intervals Δt_i) that correspond to the time taken by the probe to traverse the width, a_p, of its own aperture. The transmission characteristics of the particle counter and the evaluation electronics shall satisfy these requirements. The uncertainty in determining the duration of the counting interval shall be less than 10 %.

If a leak happens to be at the leading edge of the probe at the beginning of a counting interval, then all the particles passing through the leak in this interval are registered. However, if, for example, the leak is already in the middle of the path covered by the probe in the time interval, then the counts attributable to the leak are spread over two counting intervals. It is therefore advisable to combine the two neighbouring counting intervals for the evaluation.

In order to localize the leaks, it is also necessary to know the delay time, t_{del}, spent by the aerosol in the transport line as given by Equation (C.5):

$$t_{\text{del}} = \leq \frac{a_{\text{p}}}{u_{\text{p}}} \tag{C.5}$$

where

u_{p} is the speed of probe;

a_{p} is the aperture width of probe in direction of movement.

C.7 Minimum aerosol concentration

The minimum aerosol concentration is the maximum value permitted by the four boundary conditions or limiting parameters specified in Equations (C.6) to (C.9).

The minimum aerosol concentration, $c_{\text{u,min}}$, for identifying limit leakages shall satisfy the condition given by Equation (C.6):

$$c_{\text{u,min}} \geq \frac{N_{\text{min}}}{P_{\text{class,l}} \cdot t_{\text{leak}} \cdot \dot{V}_{\text{s}}} \tag{C.6}$$

where

N_{min} is the minimum counting rate for a leak in middle of the probe;

$P_{\text{class,l}}$ is the limit value for the local penetration of the filter class;

t_{leak} is the time spent by the probe above a leak;

$\dot{V}_{\text{s}}$ is the sampling volume flow rate.

The minimum aerosol concentration, $c_{\text{u,min}}$, necessary to ensure the required minimum counting rate in the downstream particle counters shall satisfy the condition given by Equation (C.7):

$$c_{\text{u,min}} \geqslant \frac{l}{P_{\text{eff,i}}} \cdot \dot{N}_{\text{min,c}} \cdot \frac{l}{\dot{V}_{\text{s}}} \tag{C.7}$$

where

$P_{\text{eff,i}}$ is the effective value of the overall penetration;

$\dot{N}_{\text{min,c}}$ is the minimum counting rate for the particle counter;

$\dot{V}_{\text{s}}$ is the sampling volume flow rate.

As the effective value of the penetration of the test filter, $P_{\text{eff,i}}$, may be considerably lower than the limit value for the local penetration, $P_{\text{class,i}}$, it is necessary to use the effective value for Equation (C.7). If the effective value is not known from earlier measurements, it shall be estimated or determined by measurement.

Further boundary conditions for the minimum aerosol concentration, $c_{u,min}$, to reach $N_{min,abs}$ on the downstream side are provided by the particle counters. For downstream counters, the condition is as given in Equation (C.8):

$$c_{u,min} \geq \frac{l}{P_{eff,i}} \cdot \frac{N_{min,abs}}{\dot{V}_s} \cdot \frac{l}{t_{p,tot}} \qquad \text{(C.8)}$$

where

$P_{eff,i}$ is the effective value of the overall penetration;

$N_{min,abs}$ is 100 [= min. particle number (see C.1)];

$\dot{V}_s$ is the sampling volume flow rate;

$t_{p,tot}$ is the total path time of probe.

The minimum aerosol concentration, $c_{u,min}$, to reach $N_{min,abs}$ on the upstream side is the condition given by Equation (C.9):

$$c_{u,min} \geq k_D \cdot \frac{N_{min,abs}}{\dot{V}_s} \cdot \frac{l}{t_{p,u}} \qquad \text{(C.9)}$$

where

k_D is the dilution factor, upstream;

$N_{min,abs}$ is 100 [= min. particle number (see C.1)];

$\dot{V}_s$ is the sampling volume flow rate;

$t_{p,u}$ is the duration of sampling on the upstream side.

C.8 Maximum aerosol concentration

There are three boundary conditions for the maximum aerosol concentration as given by Equations (C.10) to (C.12), and it is necessary that these be examined individually. In this case, the lowest resultant concentration gives the maximum concentration.

In order to avoid an alteration of the size distribution of the test aerosol due to coagulation, the maximum concentration, $c_{u,max}$, as given by Equation (C.10) shall not be exceeded:

$$c_{u,max} \leq 10^7 \text{ cm}^{-3} \qquad \text{(C.10)}$$

The maximum concentration, $c_{u,max}$, measurable by the particle counters provides the other two boundary conditions.

For the counters on the downstream side, the condition is as given in Equation (C.11):

$$c_{\text{u,max}} \leq \frac{c_{\text{max,c}}}{P_{\text{max,l}}} \quad \text{(C.11)}$$

where

$c_{\text{max,c}}$ is the maximum concentration measurable with the particle counter on the downstream side;

$P_{\text{max,l}}$ is the maximum measurable local penetration, which shall be specified and which is equal to or greater than $P_{\text{class,l}}$.

Correspondingly, for the maximum concentration, $c_{\text{u,max}}$, for the counter on the upstream side, the condition is as given in Equation (C.12):

$$c_{\text{u,max}} \leq c_{\text{max,c}} \cdot k_{\text{D}} \quad \text{(C.12)}$$

where

$c_{\text{max,c}}$ is the maximum concentration measurable with the upstream particle counter;

k_{D} is the dilution factor on the upstream side.

C.9 Leak signal

C.9.1 Effective value

The minimum expected particle number, $N_{\text{min,em}}$, for the counting rate when the probe crosses a leak in the middle of the probe path is given by Equation (C.13):

$$N_{\text{min,em}} = c_{\text{u}} \cdot P_{\text{class,l}} \cdot \dot{V}_{\text{s}} \cdot t_{\text{leak}} \quad \text{(C.13)}$$

where

c_{u} is the measured number concentration on the upstream side;

$P_{\text{class,l}}$ is the class limit value for the local penetration;

$\dot{V}_{\text{s}}$ is the sampling volume flow rate;

t_{leak} is the time spent by the probe over the leak.

For a leak at the edge of the path, the expected minimum particle number, $N_{\text{min,eb}}$, is given by Equation (C.14):

$$N_{\text{min,eb}} = N_{\text{min,em}} \cdot k_{\text{b}} \quad \text{(C.14)}$$

where

$N_{\text{min,em}}$ is the expected minimum particle number for a leak in the middle of the path;

k_{b} is the loss factor for a leak at the edge of the probe path.

The statistical minimum value for the 95 % confidence level of $N_{\text{min,eb}}$ is determined in accordance with ISO 29463-2, and designated $N_{\text{min,eb,95\,\%}}$. When this value is reached, the apparatus shall report a leak (leak signal value).

C.9.2 Signal difference

The term signal difference refers to the difference between the leak signal value and the signal resulting from the particle flow rate for a part of the filter that is free from leaks.

The mean expected value for the particle number, N_{em}, for a probe traversing a section of the filter for which the penetration corresponds exactly to the limit value for the class is given by Equation (C.15):

$$N_{\text{em}} = c_{\text{u}} \cdot P_{\text{class,i}} \cdot \dot{V}_{\text{s}} \cdot t_{\text{leak}} \tag{C.15}$$

where

- c_{u} is the number concentration on the upstream side of the test filter;
- $P_{\text{class,i}}$ is the limit overall value of penetration;
- $\dot{V}_{\text{s}}$ is the sampling volume flow rate;
- t_{leak} is the time spent by the probe over the leak.

The statistical maximum value for the 95 % confidence level of N_{em} is determined in accordance with ISO 29463-2, and designated $N_{\text{em,95 \%}}$[2].

The signal difference, S, is then defined as given in Equation (C.16):

$$S = N_{\text{min,eb,95 \%}} - N_{\text{eb,95 \%}} \tag{C.16}$$

where

- $N_{\text{min,eb,95 \%}}$ is the lower limit value of the 95 % confidence level for the minimum expected counting rate when passing over a leak at the edge of the probe path;
- $N_{\text{em,95 \%}}$ is the upper limit value of the 95 % confidence level for the expected counting rate when passing over a part of a filter free from leaks whose penetration value lies exactly on the class limit.

A positive value for S can be regarded as an adequate signal difference. If S acquires a negative value, then an increased number of false leak signals can be expected during the scan tests.

Typical test parameters for a filter of class ISO 45 H are summarized in Annex D.

2) Since the counting rate calculated from the particle concentration is the actual expected value, the so-called error band should really be used instead of the confidence level introduced in ISO 29463-2:2011. Although the numerical values for the confidence level and the error band differ, the confidence level is also used here for reasons of simplicity.

Annex D
(informative)

Example of an application with evaluation

Typical test parameters for a filter of class ISO 45 H are summarized in Table D.1.

Table D.1 — Typical test parameters for a filter of class ISO 45 H

Term	Symbol	Value
Data of test filter:		
Filter class	—	ISO 45 H
Limit value for the overall penetration	$P_{\text{class,i}}$	0,005 %
Limit value for the local penetration	$P_{\text{class,l}}$	0,025 %
Dimensions of filter element	—	1 220 mm × 610 mm × 78 mm
Dimensions of fold packet	—	1 190 mm × 580 mm
Nominal volume flow rate	$\dot{V}$	1 205 m^3/h
Passage velocity		0,485 m/s
Particle concentrations:		
Upstream	c_{u}	1,73 × 10^4 cm^{-3}
Downstream, overall		0,87 cm^{-3}
Downstream, local		4,33 cm^{-3}
Downstream sampling:		
Dimensions of probe aperture	$a_{\text{p}} \times b_{\text{p}}$	18 mm × 50 mm
Volume flow rate in the probe	$\dot{V}_{\text{p}}$	28,3 l/min
Mean air speed in the probe	$\bar{w}_{\text{p}}$	0,524 m/s
Probe speed	u_{p}	30 mm/s
Probe time spent above site of leak	t_{leak}	0,6 s
Analysed volume	—	283 cm^3
Expected particle number per time interval Δt_i :		
Without leak	N_{em}	245
With leak	$N_{\text{min,em}}$	1 225
With leak; loss factor, $k_{\text{b}} = 0{,}7$	$N_{\text{min,eb}}$	857
Limit value from Poisson statistics:		
Max. particle number without leak	$N_{\text{em,95 \%}}$	276
Min. particle number with leak	$N_{\text{min,eb,95 \%}}$	800
Signal value	$N_{\text{min,eb,95 \%}}$	800
Signal difference	S	524

The relationship between the individual test parameters and the determination of signal value and signal difference is presented graphically in Figure D.1.

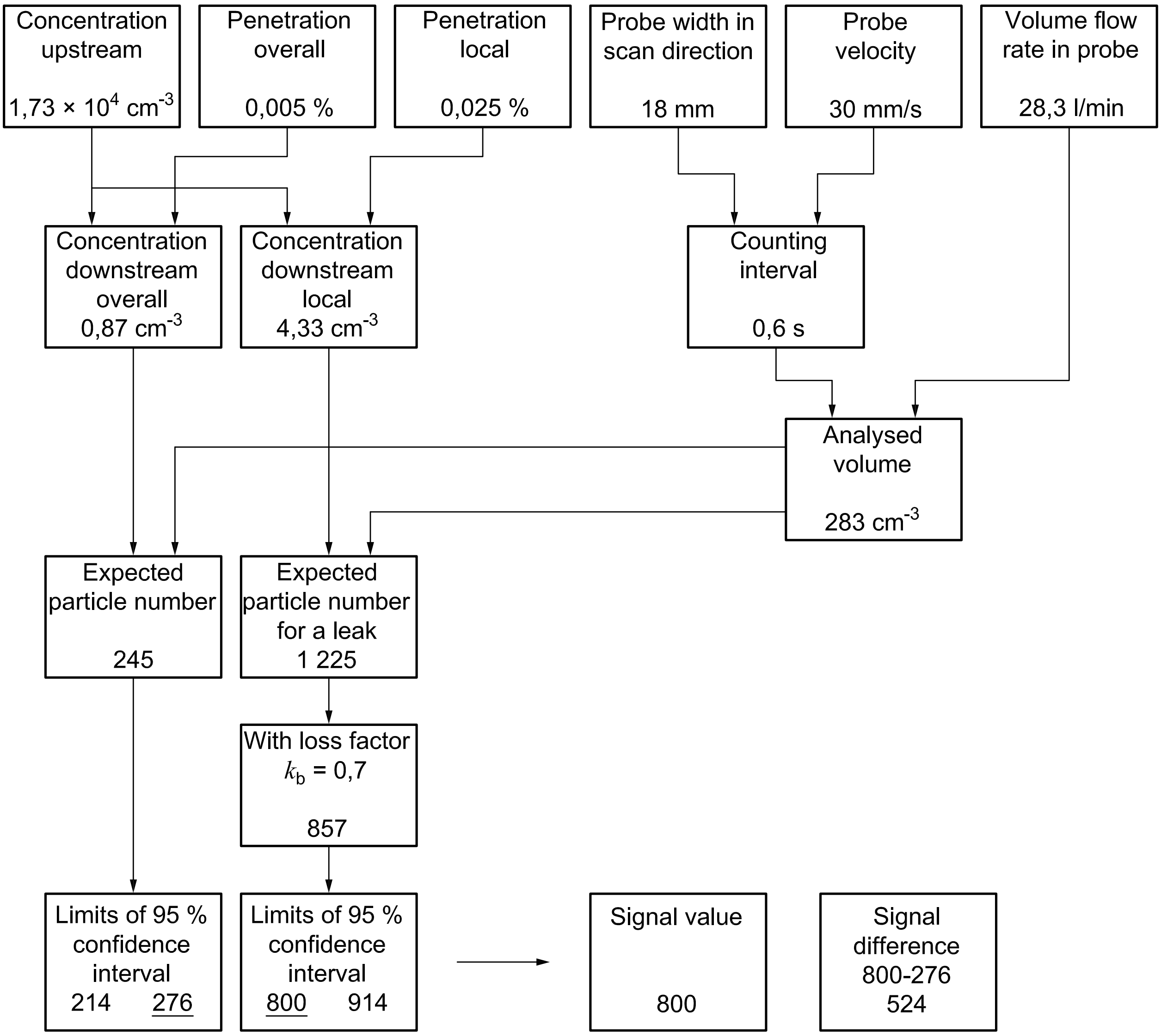


Figure D.1 — Determining the signal value and the signal difference from the test parameters for a filter of class ISO 45 H

In Table D.2, the most important test parameters for filters of the classes ISO 35 H up to class ISO 75 U are compared.

Table D.2 — Examples of important test parameters for the filter classes ISO 35 H to ISO 75 U

Term	Symbol	Unit	Filter class					
			ISO 35 H	ISO 40 H	ISO 45 H	ISO 55 U	ISO 65 U	ISO 75 U
Limit value for the overall penetration	$P_{\text{class,i}}$		0,05	—	0,005	0,000 5	0,000 05	0,000 005
Limit value for the local penetration	$P_{\text{class,l}}$		0,25	—	0,025	0,002 5	0,000 25	0,000 1
Upstream particle concentration	c_{u}	cm^{-3}	$4{,}40 \times 10^3$	—	$1{,}73 \times 10^4$	$3{,}31 \times 10^4$	$8{,}41 \times 10^4$	$1{,}54 \times 10^5$
Probe speed	u_{p}	mm/s	30	—	30	30	12	12
Counting interval	Δt_i	s	0,6	—	0,6	0,6	1,5	1,5
Volume analysed	—	cm^3	283	—	283	283	708	708
Expected particle number:								
without leak	N_{em}	—	623	—	245	47	30	5
with leak	$N_{\text{min,em}}$	—	3 113	—	1 225	234	149	109
with leak; $k_{\text{b}} = 0{,}7$[a]	$N_{\text{min,eb}}$	—	2 179	—	857	164	104	76
Max. particle number without leak	$N_{\text{em,95 \%}}$	—	672	—	276	60	43	12
Min. particle number with leak	$N_{\text{min,eb,95 \%}}$	—	2 086	—	800	139	84	59
Signal value	$N_{\text{min,eb,95 \%}}$	—	2 086	—	800	139	84	59
Signal difference	S	—	1 413	—	524	79	41	47
Min. aerosol concentration	$c_{\text{u,min}}$	cm^{-3}	$1{,}55 \times 10^2$	—	$1{,}98 \times 10^2$	$1{,}98 \times 10^3$	$8{,}48 \times 10^3$	$8{,}48 \times 10^4$
Max. aerosol concentration	$c_{\text{u,max}}$	cm^{-3}	$5{,}30 \times 10^3$	—	$2{,}12 \times 10^4$	$2{,}12 \times 10^5$	$4{,}55 \times 10^5$	$4{,}55 \times 10^5$

[a] For leak at the edge of the probe path, $k_{\text{b}} = 0{,}7$.

Annex E
(informative)

Leak test with solid PSL aerosol

E.1 Background

Particularly in the semiconductor and space industry, together with others, a liquid oil-like substance may be considered as a potential risk and may, therefore, not be allowed for testing groups H and U filters, for use in cleanrooms within these industries. The liquid particles are collected and accumulate in the filter during the test and can eventually outgas during operation of the filter. This outgassing can affect the production process. The use of liquid particles during leak tests of filters with PTFE-membrane filter media is also not appropriate, due to the specific material properties of this filter medium.

All standardized methods for leak and efficiency testing and the classification to ISO 29463 (all parts) are based on the use of liquid particles as test aerosols (DEHS, PAO, paraffin oil). The use of liquid particles like DEHS is easy and gives reproducible results. The test aerosol exerts an influence on all the provisions of ISO 29463 (all parts): all instruments, test rigs, statistics, test results and classification. Therefore, the liquid test aerosol cannot simply be substituted with a solid one without having major effects on all aspects of test results and filter classification.

For this reason, this annex has been created to describe an alternative leak test and classification method for filters that it is necessary to test with solid particles. This annex defines an alternative leak test (scanning method) with solid PSL aerosol. The efficiency determination and classification, however, is still performed as described in ISO 29463-1, using the reference test method with liquid DEHS aerosol.

E.2 General

If a solid test aerosol such as PSL is employed for the scanning procedure, the efficiency, calculated from the average upstream and downstream particle concentrations, shall not be used for the classification of the filter in accordance with ISO 29463-1. This value for the integral efficiency will not match that determined with the liquid DEHS reference aerosol, due to electrostatic effects.

The PSL aerosol can be the true MPPS aerosol, 0,14 µm aerosol or a poly-dispersed PSL aerosol (90 % of the particle concentration shall be below 0,3 µm), since aerosol size does not significantly influence the result of leak testing.

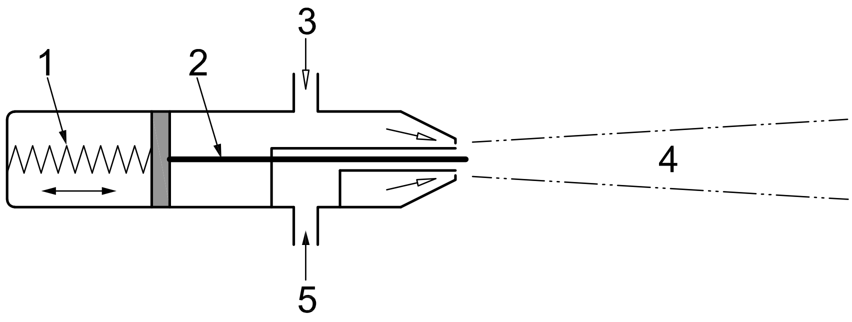
The scanning procedure with solid testing aerosol is used only for the verification of the absence of leaks in a filter. They are regarded as boundary values, corresponding with the values for maximum leak penetration in accordance with ISO 29463-1:2011, Table 1, given for each filter class.

For classification of the filter, a representative number of filters taken from the same production batch is subjected to an efficiency test in accordance with ISO 29463-5 (reference test method with DEHS aerosol). These filters are regarded as a reference regarding efficiency and subsequent classification in accordance with ISO 29463-1 for the entire batch. All other filters are, then, only PSL leak tested in accordance with this annex. The specification and test data (filter size and design, test airflow, etc.) of the reference filters (which have been DEHS tested) and the PSL tested filters shall, however, be absolutely identical.

E.3 Procedure

For the PSL leak test in accordance with this annex, the test equipment and test procedure given for DEHS aerosol in the body of this part of ISO 29463 may be used. The only exception applies to the type and use of the aerosol generator, which shall be different because of the PSL aerosol. The main task is to achieve sufficient concentration levels for PSL particles in the upstream air which, in case of PSL particles, requires special generating equipment.

Figures E.1 and E.2 show examples of a specific design of a high-output PSL particle generator, operating with a PSL-water emulsion, with spray nozzles and with a corresponding drying section.



Key

1 spring

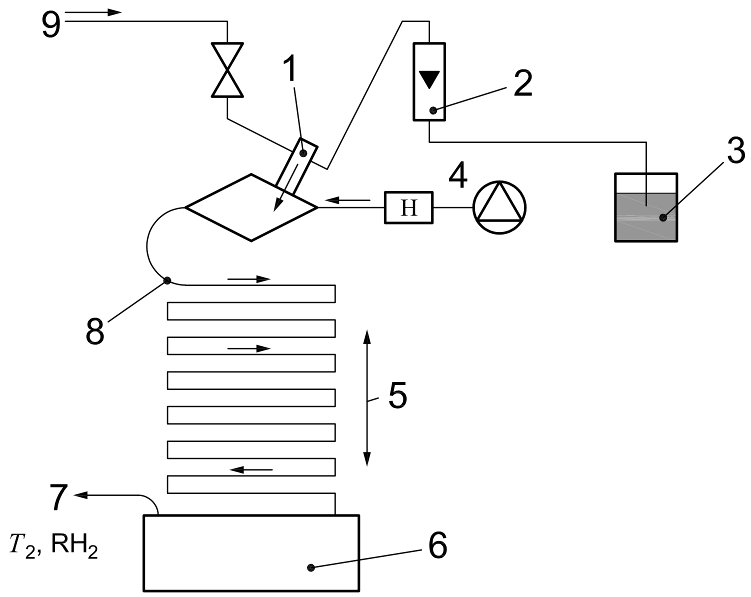
2 needle

3 compressed air at pressure, P

4 aerosol droplets

5 liquid

Figure E.1 — Nozzle 1



Key

1 nozzle 1

2 flow meter

3 solid suspension

4 heater and fan

5 cooling and condensation section; tube,100 mm, aluminium; tube length, approx. 25 m

6 water trap

7 aerosol out

8 measuring point T_1

9 compressed clean air

Figure E.2 — PSL generator design

E.3.1 Design description

Nozzle 1 sprays an aqueous solution (PSL particles with clean water) with the help of clean compressed air of pressure, P, into a chamber. This chamber is supplied with HEPA-filtered hot air at temperature T_1 in order to get a quick distribution and evaporation of the water. The heated air is produced by an adjustable heater and a fan with an airflow of 40 m^3/h to 50 m^3/h. The air then passes a cooling/condensation section in which the air temperature decreases to T_2 and to relative humidity, RH. A water trap (container) takes care of any excess water from the cooling section and decreases the risk of water entering the test system.

E.3.2 Recommended operation settings

The following apply.

a) T_1 100 °C to 175 °C;

b) P 100 kPa to 500 kPa (1 bar to 5 bar);

c) q 5 ml/min to 25 ml/min;

d) T_2 20 °C to 23 °C (preferably at or below test air temperature);

e) RH >0 %.

E.4 Test report

The test report, in addition to the requirements mentioned under Clause 9, shall contain the following additional information:

a) statement that the filter was leak tested using the test method in accordance with this annex and efficiency tested on statistical bases;

b) test aerosol used (e.g. solid PSL);

c) aerosol generators used;

d) statement that the average PSL particle concentrations cannot be used for the classification of the filter.

Annex F
(informative)

0,3 µm to 0,5 µm particle efficiency leak test

F.1 Background

Since the oil thread leak test (Annex A) is a visual test, leak detection results can be different from one operator to another or can vary between start time and end time of the operator's shift. The intention of the test described in this annex is to detect leaks automatically by means of an integral efficiency measurement in the particle size range 0,3 µm to 0,5 µm.

F.2 General

This efficiency measurement method uses a particle counter in its 0,3 µm to 0,5 µm particle size channel to test filters of class ISO 35 H for leaks as an alternative to the oil thread test (Annex A). The 0,3 µm to 0,5 µm particle efficiency leak test may be used as a reference test procedure for filters of class ISO 35 H with turbulent airflow that cannot be scan-tested because of their construction type (for example V-bank or cylindrical filters).

From a theoretical calculation with a predefined leak, a filter of class ISO 35 H with a local MPPS efficiency of 99,75 %, the minimum global efficiency at 0,3 µm to 0,5 µm shall be higher than 99,999 6 %.

F.3 Procedure

For classification in accordance with ISO 29463-1, these filters are placed in a test bench for measuring the integral MPPS efficiency, e.g. as described in ISO 29463-5. The 0,3 µm to 0,5 µm efficiency test can be carried out at the same time and under the same conditions, using the corresponding particle size channel of the particle counter. It is essential to have a good aerosol distribution upstream of the filter and a good mixing of the air downstream of the filter to perform this test.

If a poly-disperse aerosol is used, it can be basically the same as that used for integral MPPS efficiency measurements in accordance with ISO 29463-5. However, for the 0,3 µm to 0,5 µm particle efficiency leak test, it is essential to have enough 0,3 µm to 0,5 µm particles upstream of the filter. Therefore, a mono-disperse aerosol is not suitable. In order to have an accurate measurement, it is necessary to sample more than 10 particles in the 0,3 µm to 0,5 µm size range downstream of the filter. It is therefore necessary that the minimum 0,3 µm to 0,5 µm particle count upstream of the filter be 2 500 000 particles per sampling time interval.

F.4 Leak criteria

For the filter class ISO 35 H (local MPPS efficiency >99,75 %), the integral efficiency for the 0,3 µm to 0,5 µm range shall be >99,999 6 %.

F.5 Verification of the test procedure

It is necessary to verify the sensitivity and accuracy of the procedure at regular intervals using reference filters with well-defined leaks characterized by the leak test scan method. The local penetration of these leaks should not exceed the limit value specified for the ISO 35 H filter class by more than a factor of two. To verify adequate upstream aerosol distribution and the effectiveness of the mixing of the air downstream of the filter, the procedure shall also be verified at regular intervals using reference filters with well-defined leaks in a frame corner and in the medium close to the frame/sealant. Such filters may be characterized by the oil thread leak test; however, these leaks should not exceed the limit value specified for the ISO 35 H filter class by more than a factor of two. Ideally, these filters will be square shaped so that they can be turned 90° and the measurement can be repeated four times. Good aerosol distribution and downstream mixing is essential to identify those filters containing leaks in accordance with the given criteria.

F.6 Reporting

Whenever a class ISO 35 H filter is leak tested by using the 0,3 µm to 0,5 µm particle efficiency leak test, it shall be indicated on the filter and in the test report (e.g. with a remark “leak tested in accordance with ISO 29463-4:2011, Annex F”). In the test report, the actual measured efficiency at 0,3 µm to 0,5 µm shall also be reported.

Annex G
(informative)

Calculation of aerosol challenge

This annex provides a method to determine the approximate concentration of the challenge aerosol. This method should be used only if it is impractical to obtain a representative upstream sample. This method may lead to less accurate knowledge of the upstream concentration and make determinations of the size of leaks less accurate. The aerosol concentration is calculated from the previously known aerosol generator output and the airflow through the clean-air device. Values are provided for typical Laskin Nozzle output when using DOP. Other aerosol generators or materials may be used if similar output information is available.

G.1 Calculation when given the output into volume of airflow

G.1.1 The following values are given:

a) aerosol generator output:

1) C_1, expressed in micrograms per litre or number per litre per nozzle, when discharged into a flow rate of Q_1, expressed in cubic metres per minute,

2) N, the number of nozzles in use;

b) airflow through the clean-air device of Q_2, expressed in cubic metres per minute.

G.1.2 The concentration, C_2, expressed in micrograms per litre or number per litre per nozzle when discharged into a flow rate of Q_2 using N nozzles is given by Equation (G.1):

$$C_2 = NC_1\left(\frac{Q_1}{Q_2}\right) \tag{G.1}$$

G.1.3 If a photometer is used, then adjust the photometer so that full scale represents C_2, expressed in micrograms per litre, using calibration data from the photometer manufacturer.

G.2 Calculation when given output per unit time

G.2.1 The following values are given:

a) aerosol generator output:

1) E, expressed in micrograms per minute or number per minute per nozzle,

2) N, the number of nozzles in use;

b) airflow through the clean-air device of Q_2, expressed in cubic metres per minute.

G.2.2 The concentration, C_2, expressed in micrograms per litre or number per litre per nozzle when discharged into a flow rate of Q_2, using N nozzles is given by Equation (G.2):

$$C_2 = \frac{NE}{1000\,Q_2} \tag{G.2}$$

where the factor “1 000” converts cubic metres to litres.

G.2.3 If a photometer is used, then adjust it so that full scale represents C_2, expressed in micrograms per litre, using calibration data from the photometer manufacturer.

G.3 Example using Laskin Nozzles and an aerosol photometer

G.3.1 The aerosol in this example is produced by a Laskin Nozzle generator using two nozzles operated at 138 kPa pressure with DOP. Other liquids can give different results. A concentration of approximately 10 µg/l of air is generated in a flow of 38 m^3/min. A compressed-air source capable of delivering 75 l/min of air (volume at standard conditions) at 138 kPa is required for each Laskin Nozzle. This concentration is equivalent to approximately 3×10^7 droplets per litre of air.

G.3.2 The following values are given:

a) aerosol generator output:

1) C_1 10 µg/l per nozzle when discharged into a flow rate of Q_1 cubic metres per minute,

2) Q_1 38 m^3/min,

3) N two nozzles in use;

b) airflow through the clean-air device of $Q_2 = 56$ m^3/min.

G.3.3 The calculation is given by Equation (G.3):

$$\begin{aligned} C_2 &= 2 \cdot 10\left(\frac{38}{56}\right) \\ &\approx 14\ \mu\text{g/l} \end{aligned} \tag{G.3}$$

Adjust the aerosol photometer so that full scale represents ~14 µg/l using calibration data from the aerosol photometer manufacturer.

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