

High efficiency air filters (EPA, HEPA and ULPA)

Part 4: Determining leakage of filter elements (scan method)

ICS 13.040.40; 23.120

National foreword

This British Standard is the UK implementation of EN 1822-4:2009. It supersedes BS EN 1822-4:2000 which is withdrawn.

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

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**High efficiency air filters (EPA, HEPA and ULPA) - Part 4:
Determining leakage of filter elements (scan method)**

Filtres à air à haute efficacité (EPA, HEPA et ULPA) -
Partie 4: Essais d'étanchéité de l'élément filtrant (méthode
d'exploration)

Schwebstofffilter (EPA, HEPA und ULPA) - Teil 4:
Leckprüfung des Filterelementes (Scan-Verfahren)

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Foreword

This document (EN 1822-4:2009) has been prepared by Technical Committee CEN/TC 195 “Air filters for general air cleaning”, the secretariat of which is held by UNI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2010, and conflicting national standards shall be withdrawn at the latest by May 2010.

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

This document supersedes EN 1822-4:2000.

It contains requirements, fundamental principles of testing and the marking for efficient particulate air filters (EPA), high efficiency particulate air filters (HEPA) and ultra low penetration air filters (ULPA).

The complete European Standard EN 1822, *High efficiency air filters (EPA, HEPA and ULPA)* will consist of the following parts:

- *Part 1: Classification, performance testing, marking*
- *Part 2: Aerosol production, measuring equipment, particle counting statistics*
- *Part 3: Testing flat sheet filter media*
- *Part 4: Determining leakage of filter elements (scan method)*
- *Part 5 : Determining the efficiency of filter elements*

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

As decided by CEN/TC 195, this European Standard is based on particle counting methods which actually cover most needs of different applications. The difference between this European Standard and previous national standards lies in the technique used for the determination of the integral efficiency. Instead of mass relationships, 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 to test ultra low penetration air filters, which was not possible with the previous test methods because of their inadequate sensitivity.

For Membrane and synthetic filter media, separate rules apply; see Annexes A and B of EN 1822-5:2009.

1 Scope

This European Standard applies to efficient air filters (EPA), high efficiency air filters (HEPA) and ultra low penetration air filters (ULPA-filters) used in the field of ventilation and air conditioning and for technical processes, e.g. for applications in clean room technology or pharmaceutical industry.

It establishes a procedure for the determination of the efficiency on the basis of a particle counting method using an artificial test aerosol, and allows a standardized classification of these filters in terms of their efficiency.

This part of EN 1822 applies to the leak testing of filter elements. The scan method which is described in detail regarding procedure, apparatus and test conditions in the body of this standard is valid for the complete range of group H and U filters and is considered to be the reference test method for leak determination. The "Oil Thread Leak Test" according to Annex A and the "0,3 μm - 0,5 μm Particle Efficiency Leak Test" according to Annex E may be used alternatively but for defined classes of group H filters only.

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.

EN 1822-1:2009, *High efficiency air filters (EPA, HEPA and ULPA) — Part 1: Classification, performance testing, marking*

EN 1822-2, *High efficiency air filters (EPA, HEPA and ULPA) — Part 2: Aerosol production, measuring equipment, particle counting statistics*

EN 1822-3, *High efficiency air filters (EPA, HEPA and ULPA) — Part 3: Testing flat sheet filter media*

EN 1822-5:2009, *High efficiency air filters (EPA, HEPA and ULPA) — Part 5: Determining the efficiency of filter elements*

EN 14799:2007, *Air filters for general air cleaning — Terminology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 14799:2007 and the following apply.

3.1

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 (e.g. by using a condensation nucleus counter)

3.2

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 (e.g. by using an optical particle counter)

3.3

particle flow rate

number of particles which are measured or which flow past a specified cross section in unit time

3.4

particle flow distribution

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

4 Description of the procedure

The leakage test serves to test the filter element for local penetration values which exceed permissible levels (see EN 1822-1).

For leakage testing the test filter is installed in the mounting assembly and subjected to a test air flow corresponding to the nominal air flow rate. After measuring the pressure drop at the nominal 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 factor mean penetration.

The manufacturing irregularities of the filter material 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 air flow 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 led 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 touching or overlapping tracks without gaps (see B.4.2 and B.4.3) 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 localisation 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 EN 1822-3), except for filters with Membrane medium as per Annex E of this standard. 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 monodisperse or polydisperse test aerosol. It shall be ensured that the median particle diameter corresponds to the MPPS particle diameter, at which the filter medium has its minimum efficiency.

When testing with a monodisperse aerosol, the total particle counting method can be used with a condensation nucleus counter (CNC) or an optical particle counter (OPC; e.g. a laser particle counter).

When using a polydisperse aerosol, an optical particle counter shall be used which counts the particles and measures their size distribution.

If scan testing is carried out as an automatic procedure it also allows determination of the mean efficiency of the test filter from the measurement of the particle concentration. The mean particle concentration on the downstream side is calculated from the total particle number counted while the probe traverses the passage area. The reference volume is the volume of air analyzed by the particle counter over this period of time. The particle concentration on the upstream side of the test filter shall be measured at a representative position on the duct cross-section. This method for determining the integral efficiency is equivalent to the method with fixed probes specified in EN 1822-5.

5 Test filter

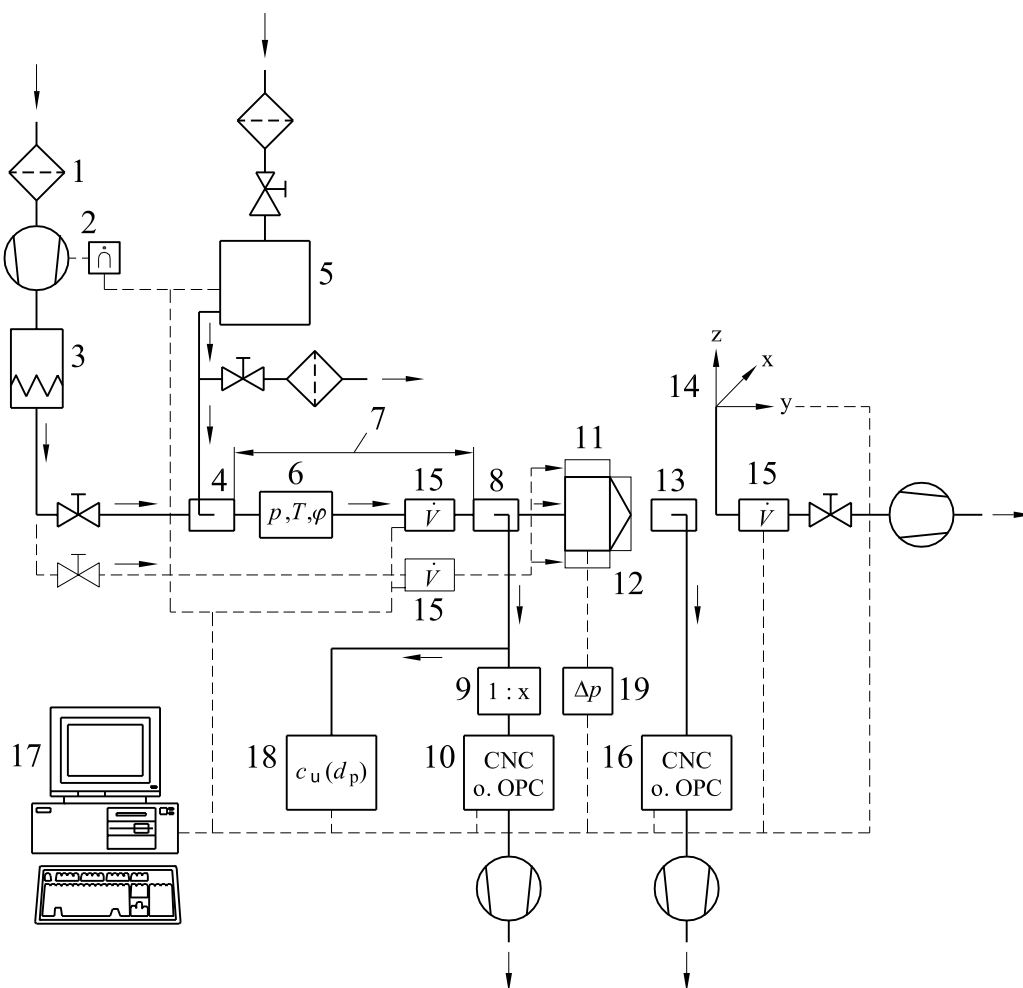
A test filter shall be used for the leak testing which does not show any visible signs of damage or other irregularities, and which can be sealed in position and subjected to flow in accordance with requirements. The temperature of the test filter during the tests shall correspond to the temperature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

- a) Designation of the filter element;
- b) The 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 monodisperse or with a polydisperse aerosol. The only differences between these lie in the technique used to measure the particles and the way the aerosol is generated.

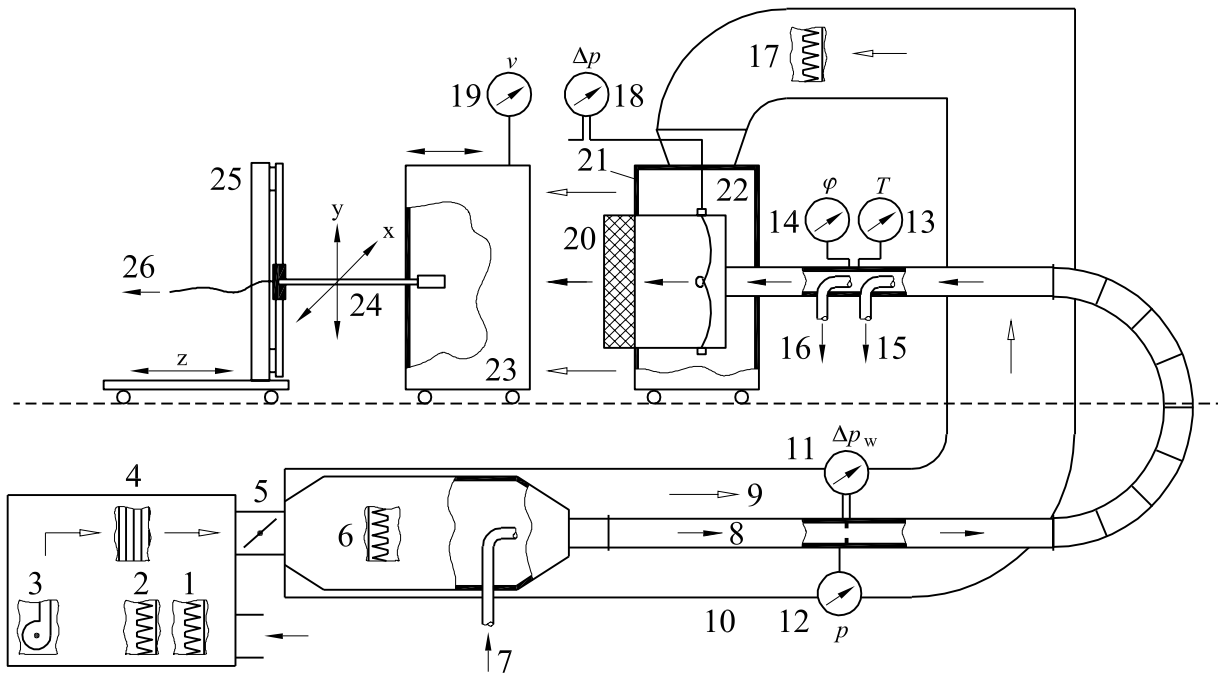


Key

- | | | | |
|---|--|----|--|
| 1 | Pre-filter for the test air | 10 | Particle counter, upstream |
| 2 | Fan with speed regulator | 11 | Sheath flow (optional) |
| 3 | Air heater | 12 | Test filter |
| 4 | Aerosol inlet in the duct | 13 | Sampling point and partial flow extraction, downstream |
| 5 | Aerosol generator with conditioning of supply air and aerosol flow regulator | 14 | Traversing system for probe |
| 6 | Measurement of atmospheric pressure, temperature and relative humidity | 15 | Volume flow rate measurement |
| 7 | Upstream side mixing section | 16 | Particle counter, downstream |
| 8 | Sampling point for upstream particle counting | 17 | Computer for control and data storage |
| 9 | Dilution system (optional) | 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 is shown in Figure 2 (without particle measuring equipment).



Key

- | | |
|---|--|
| 1 Coarse dust filter | 15 Sampling point for particle size analysis |
| 2 Fine dust filter | 16 Sampling point, upstream |
| 3 Fan | 17 High efficiency air filter for the sheath air |
| 4 Air heater | 18 Measurement of pressure drop |
| 5 Dampers to adjust test and sheath air | 19 Measurement of sheath air speed |
| 6 High efficiency air filter for the test air | 20 Test filter |
| 7 Aerosol inlet in the duct | 21 Flow equalizer for the sheath air flow |
| 8 Test air flow | 22 Filter mounting assembly |
| 9 Sheath air flow | 23 Screening (linked to the filter mounting assembly during the testing) |
| 10 Effective pressure measuring device | 24 Traversing probe arm with downstream sampling probe |
| 11 Differential pressure | 25 Probe traversing system |
| 12 Atmospheric pressure | 26 Downstream sampling point |
| 13 Temperature measurement | |
| 14 Hygrometer | |

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 contained in EN 1822-2.

6.2 Test duct

6.2.1 Test air conditioning

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

The test air flow shall be so prepared that it complies with the specifications in Clause 7 and does not exceed the limit values specified there 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 $\pm 3\%$. 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 EN 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 1) shall be so constructed that the aerosol concentration measured at individual points of the duct cross section directly in front of the test filter shall not deviate by more than 10 % from the mean value obtained from at least nine 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 passage area of the filter.

It is advisable to scan filters for leaks in the same mounting position and air flow 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 so that, at an average flow velocity, isokinetic conditions pertain at the given volume flow rate for the sample. Sampling errors which arise due to other flow velocities in the duct 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.

The sampling shall be representative, which is taken to be the case when 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.

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 localisation of leaks in the edges of the filter, in the gasket, the filter frame or the sealant the flow of particles in these sections shall be led away directly in 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 if possible the area between filter frame and 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

6.3.1 General

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

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 only possible 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.

In the following, an automatic scanning apparatus is described.

6.3.2 Sampling, downstream

The sampling conditions determine 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 area of the probe shall be $(9 \pm 1) \text{ cm}^2$. 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 B.6).

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 special constructional forms of filter and extremely high face velocities it is permissible to deviate from the dimensional requirements specified here. However, it is then only possible to arrive at a conditional determination of the local efficiency within the meaning of this standard.

6.3.3 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 it disturb the flow in the proximity of the filter.

6.3.4 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 of a conducting material and have smooth surfaces which do not emit particles.

6.3.5 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 can be selected, and shall not exceed a maximum of 10 cm/s (see B.7). During a run it 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

The operating parameters of the aerosol generator shall be adjusted to produce a test aerosol whose median diameter is in the range of the most penetrating particle size (MPPS) for the plane filter medium. The median for a monodisperse test aerosol shall not deviate by more than 10 % from the MPPS. For a polydisperse test aerosol a deviation of up to 50 % is permissible.

It shall be possible to set the median value of the number distribution of the test aerosol within $\pm 10\%$.

The particle flow 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 can be determined using a suitable particle size analysis system (e.g. a differential mobility particle sizer - DMPS) or with a laser particle counter suitable for these test purposes. The limit error of the measurement method used to determine the median value shall not exceed $\pm 10\%$ (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 measuring range of the upstream particle counter. If the upstream number concentration exceeds the range 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 Δ_{ti}) which at least correspond 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 %.

In order to allow the determination of the mean efficiency, the processing unit for the counting signals shall be able to register the total number of particles counted while the probe traverses the passage area and to record the overall time taken.

6.4.2 Set-up for testing with a monodisperse test aerosol

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

When using a monodisperse 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 which are very much smaller than the MPPS. Such particles, which may be produced by an aerosol generator which 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 which stretches over a range from the lower range limit of the condensation nucleus counter up to a particle size of approximately 1 μm . The number distribution thus determined shall be quasi-monodisperse.

6.4.3 Set-up for testing with a polydisperse test aerosol

When testing a filter element for leaks using a polydisperse 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 cover the following particle sizes (in accordance with Figure 4 of EN 1822-5:2009):

MPPS/1,5 to MPPS x 1,5 (Range I, Figure 4 of EN 1822-5:2009).

The distribution of the size classes shall be such that one class limit meets the following condition:

$\text{MPPS}/2 < \text{Class limit} \leq \text{MPPS} / 1,5$ (Range IIa, Figure 4 of EN 1822-5:2009)

and a further class limit meets the following condition:

$\text{MPPS} \times 1,5 \leq \text{Class limit} < \text{MPPS} \times 2$ (Range IIb, Figure 4 of EN 1822-5:2009).

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 above conditions 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 $< 350\,000\text{ m}^{-3}$) 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: $(23 \pm 5) ^\circ\text{C}$;
- Relative humidity: $< 75 \%$.

8 Test 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 parameters for the probe tracking shall be determined. These are:

- the distance between the probe aperture and the filter element (10 mm to 50 mm; see 6.3.2);
- the speed of the probe (to be determined in accordance with B.7);
- the 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. Further 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 B and the adjustments made to the test apparatus.

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 can be used for this purpose for which defined leakages have already been determined.

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 makers shall be observed and the condensation nucleus counters shall be filled with operating liquid.

If the instrument makers 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 causes shall be eliminated before commencing the test proper.

— **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. If this is not the case then appropriate corrections shall be made.

8.3 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 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, facing the right way, 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 the position of any leaks to be determined after the tests. It is advisable to scan filters for leaks with their original gasket mounted and in the same mounting position and air flow 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 addition 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 then the test filter shall be flushed for a long 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.

8.5 Testing

8.5.1 Measuring the pressure drop

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

8.5.2 Testing with monodisperse test aerosol

In the mixing duct the test air is mixed with test aerosol, the median 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 $\pm 3\%$. Measurements shall begin as soon as the system has reached a stable operating state.

The probe is moved in accordance with a tracking program. 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 program measured.

The concentration of the aerosol on the upstream side can be measured continuously or intermittently, using either a dedicated counter, or switching with the 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 polydisperse test aerosol

The test shall be carried out in analogy with 8.5.2, using a polydisperse test aerosol with a median diameter which shall not deviate by more than $\pm 50\%$ from the MPPS (see 6.4).

In contrast to the test with a monodisperse test aerosol, in the test using polydisperse 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 classes which lie wholly or partially within the range MPPS/1,5 to MPPS $\times 1,5$ (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 free of leaks. If the signal value is exceeded then this is an indication that the limit value for the local penetration may 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 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 to be 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 EN 1822-1, then the test filter cannot be classified as free from leaks. If all of the maximum values for the local penetration are below the limit value, the filter is free from leaks.

A filter may be repaired if necessary and shall then be retested.

NOTE 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 buyer and seller.

8.5.5 Determining the mean efficiency of the filter element

In order to calculate the mean efficiency the particle number is counted during the run over the traverse area, and the overall duration of this part of the probe run measured. The mean particle concentration in the passage area is the quotient from the particle number counts and the volume of air analyzed (sampling volume flow rate multiplied by the duration of sampling).

The mean efficiency of the test filter is calculated from the mean particle concentration on the downstream side and the value also obtained for the upstream side. Taking into account the expected statistical scattering, an appropriate maximum penetration or minimum efficiency shall be determined (see Clause 9).

9 Evaluation

9.1 Calculating the penetration and the efficiency

The penetration and the efficiency are calculated from the count data as follows:

$$c_{N,u} = \frac{k_D \times N_u}{\dot{V}_{s,u} \times t_u} \quad (1)$$

$$c_{N,d} = \frac{N_d}{\dot{V}_{s,d} \times t_d} \quad (2)$$

$$P = \frac{c_{N,d}}{c_{N,u}} \quad (3)$$

$$E = 1 - P \quad (4)$$

where:

- P is the penetration (usually as a percentage);
- E is the efficiency (usually as a percentage);
- N_u is the number of particles counted upstream;
- N_d is the number of particles counted downstream;
- k_D is the dilution factor;
- $c_{N,u}$ is the number concentration upstream;
- $c_{N,d}$ is the number concentration downstream;
- $\dot{V}_{s,u}$ 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.

In order to calculate the minimum efficiency $E_{95\%,\min}$, the less favourable limit value for the 95 % confidence level 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 Clause 7 of EN 1822-2:2009. The values for the 95 % confidence level shall only be calculated with pure counting data, without corrections being made for the dilution factor.

The following applies:

$$c_{N,u,95\%min} = \frac{k_D \times N_{u,95\%min}}{\dot{V}_{s,u} \times t_u} \quad (5)$$

$$c_{N,d,95\%max} = \frac{N_{d,95\%max}}{\dot{V}_{s,d} \times t_d} \quad (6)$$

$$P_{95\%max} = \frac{c_{N,d,95\%max}}{c_{N,u,95\%min}} \quad (7)$$

$$E_{95\%max} = 1 - P_{95\%max} \quad (8)$$

where:

- $P_{95\%max}$ is the maximum penetration taking into account the particle counting statistics (usually given as a percentage);
- 95%min is the minimum efficiency taking into account the particle counting statistics (usually given as a percentage);
- $N_{u,95\%min}$ is the lower limit of the 95 % confidence level of the particle count upstream;
- $N_{d,95\%max}$ is the upper limit of the 95 % confidence level of the particle count downstream;
- $c_{N,d,95\%max}$ is the maximum downstream particle number concentration;
- $c_{N,u,95\%min}$ is the minimum upstream particle number concentration.

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

By calculating the minimum efficiency only the measurement uncertainty due to the low count rates is to be taken into account. Other errors involved in the measurement have to be corrected additionally if they are known.

9.2 Local penetration

In order to calculate local penetration values, measurements obtained from scan testing for leaks in accordance with 8.5.4 shall be inserted in the formulae in 9.1.

Values for local penetration shall be designated with the coordinates of the position on the downstream filter face detected at which the leakage signal was tested.

9.3 Mean efficiency

For the calculation of the mean efficiency or mean penetration, the mean particle concentration downstream of the test filter determined according to Clause 8 shall be used as downstream concentration.

9.4 Classification

The minimum efficiency or the maximum penetration is the basis of the classification in accordance with EN 1822-1. The limit values shall not be exceeded either for the integral value or for the local values.

10 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) Most penetrating particle size of filter media (MPPS) at corresponding medium velocity (see EN 1822-3);
 - 4) Aerosol generator (type designation and part number);
 - 5) Test aerosol (substance, median diameter, geometrical standard deviation);

NOTE In case a solid aerosol (e.g. PSL) is used, requirements of EN 1822-5:2009, A.5 have to be met.
 - 6) Particle counter(s), upstream and downstream (type designation and part number(s)) and particle size channel(s) used (in case of OPC);
 - 7) Dilution system for upstream particle counter (type designation and part number);
 - 8) Sampling probe downstream side (geometry, sampling air flow);
 - 9) 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);

- 4) Mean integral efficiency and minimum integral efficiency $E_{95\%min}$ (in case of combined local and integral efficiency test);
- 5) Filter class in accordance with EN 1822-1.

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 is listed in Table 1, and shall be carried out at least once within the time periods specified there. In the event of disturbances which 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 EN 1822-2, 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 EN 1822-2 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 are to 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 may 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 | – If 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 EN 1822-1:2009, Table 1). The Oil Thread Leak Test may be carried out as an alternative leak test method for filters of group H (classes H13 and H14). The reference for this leak test is however the particle count scan method as described in the body of this standard. 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).

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 EN 1822-1:2009, Table 1 and maximum double the corresponding limit value.

In the test set-up the filter shall be subjected to a flow of a polydisperse oil-drop aerosol with a speed of approximately 1,3 cm/s ($42 \text{ m}^3/\text{m}^2/\text{h}$), 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 polydisperse test aerosol shall be generated by nebulising from a liquid aerosol substance in accordance with 4.2 of EN 1822-2:2009. The median value of the particle diameter shall lie between $0,3 \mu\text{m}$ and $1,0 \mu\text{m}$. The mass concentration shall be $1,5 \text{ g}/\text{m}^3$ (determined by gravimetric methods).

The downstream side of the filter shall be illuminated from vertically above with a white ($\geq 4\,000 \text{ K}$) fluorescent lamp or halogen lamps. The brightness of the lamp shall be $> 1\,000 \text{ Lux}$ 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 in form of a clearly visible oil thread which appears due to the leakage. If no oil threads can be seen the filter up to class H14 is free from leaks as per the leak limit values defined in EN 1822-1:2009, 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 are used with well-defined leaks in the medium, in the frame corners and in the medium, close to the sealant.

A test report for the oil thread test shall contain at least:

- details of the filter tested (type, dimensions, identification number, nominal technical data);
- details of the test parameters (flow velocity, test aerosol, median particle diameter and mass concentration of test aerosol);
- identification of tester and date of test; and
- the 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 as per EN 1822-4:2009, Annex A.

Annex B (normative)

Determining the test parameters

B.1 General

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 may lead to parameters which cannot be achieved, so 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 monodisperse test aerosol or to the particle size range used to determine the filter efficiency with a polydisperse aerosol (see 8.5.3).

B.2 Boundary conditions

The following boundary conditions shall be complied with:

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

B.3 Test filter data

The following data for the test filter are to be taken into consideration when determining the test parameters:

The filter class which is to be established, characterized by the limit values of the penetration:

| | |
|------------------------------|-----------------------|
| — integral penetration value | $P_{\text{class}, i}$ |
| — local penetration value | $P_{\text{class}, l}$ |
| — Nominal volume flow rate | \dot{V} |
| — Nominal filter face area | A_d |

B.4 Data for the apparatus

B.4.1 Particle counters

The following data is relevant for the particle counters employed:

Counter data:

- 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 EN 1822-2), 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 follows:

$$\dot{N}_{\min,c} = 10 \times \dot{N}_{\text{zero}} \quad (\text{B.1})$$

where

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

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

B.4.2 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 B.2). The ratio of lengths of sides for a rectangular probe shall not exceed 15 to 1 (see 6.3.2).

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 may, however, be applied by analogy for use with circular probes.

Probe dimensions:

- internal side-length in scan direction a_p ;
- internal side-length at right-angles to scan direction b_p .

B.4.3 Loss factor

The minimum counting rate for a leak specified in B.2 shall also be achieved if the leak is at the edge of the path covered by the probe. It is therefore to be expected that the mean counting rate for a leak at the centre of the path will be higher.

$$N_{\min} = \frac{N_{\min, \text{leak}}}{k_b} \quad (\text{B.2})$$

where

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

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

B.5 Sequence of calculation steps

Figure B.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 B.10.2) then the initial parameters are to be altered until the results allow the test to be carried out.

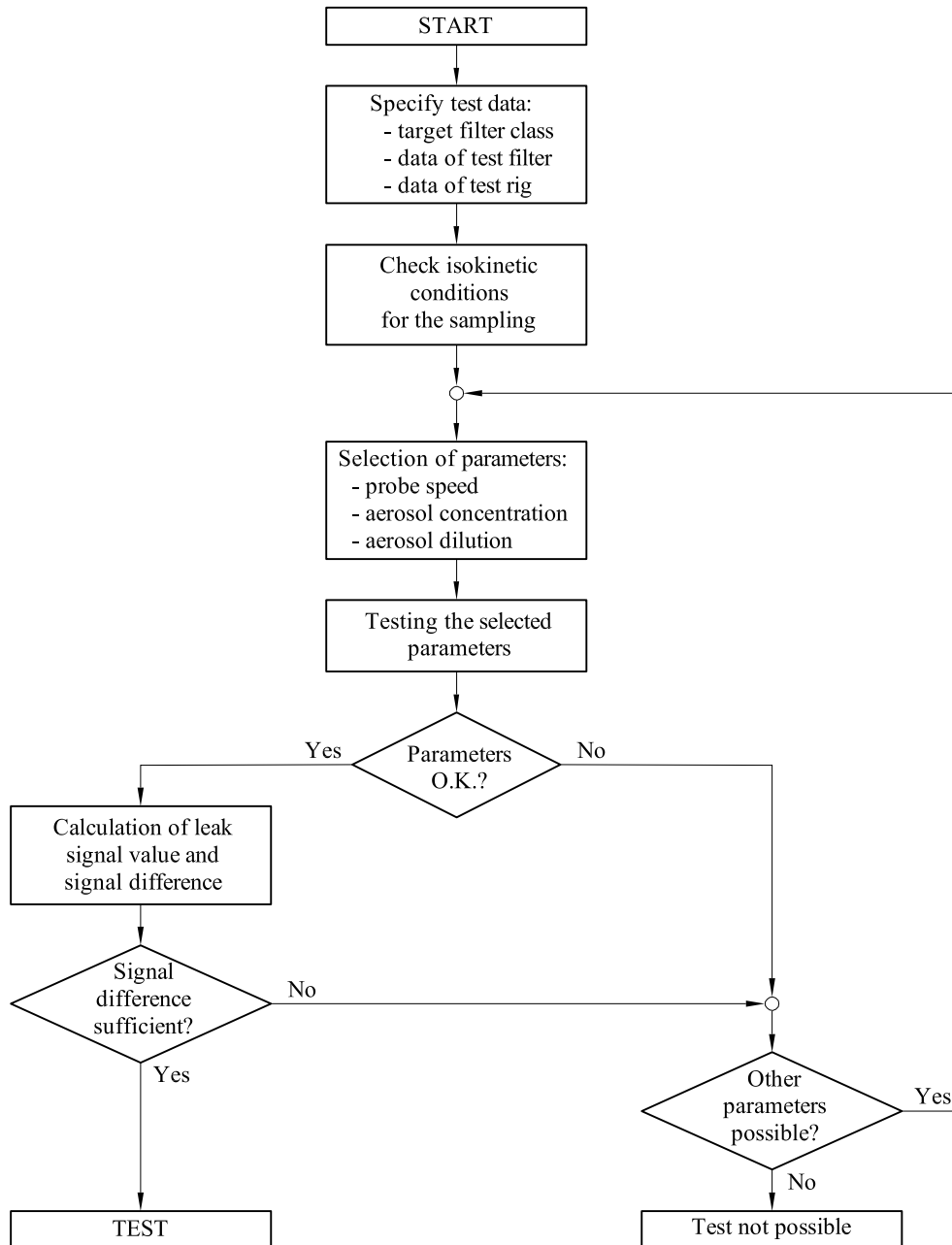


Figure B.1 — Flow diagram of determination of test parameters

B.6 Checking the isokinetic sampling

The mean air speed in the probe is calculated as follows from the volume flow rate in the probe and its cross-sectional area:

$$\bar{w}_p = \frac{\dot{V}_p}{A_p} \quad (\text{B.3})$$

where

- \bar{w}_p is the mean air speed in the probe;
 \dot{V}_p is the volume flow rate in the probe;
 A_p is the probe intake cross-section.

The calculated value of \bar{w}_p shall be compared with the mean air speed \bar{w}_d for the passage area downstream. The deviation between the two speeds shall not exceed 25 % (see 6.3.2).

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

B.7 Choosing the probe speed

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

The time taken by the probe to cross a leakage can be calculated using the chosen probe speed u_p as follows:

$$t_{\text{leak}} = \frac{a_p}{u_p} \quad (\text{B.4})$$

where

- t_{leak} is the time spent crossing a leak;
 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 $t_{p,\text{tot}}$ during the scan test.

The counting rate shall be determined at least at time intervals (counting intervals Δt_i) which correspond 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 %.

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 will be 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 will be 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 spent by the aerosol in the transport line:

$$t_{\text{del}} \leq \frac{a_p}{u_p} \quad (\text{B.5})$$

where

| | |
|------------------|--|
| t_{del} | is the time spent by the aerosol in the transport line; |
| u_p | is the speed of probe; |
| a_p | is the aperture width of probe in direction of movement. |

B.8 Minimum aerosol concentration

The minimum aerosol concentration is the maximum value permitted by the four boundary conditions or limiting parameters specified below.

The minimum aerosol concentration for identifying limit leakages shall satisfy the condition:

$$c_{u,\min} \geq \frac{N_{\min}}{P_{\text{class},l} \times t_{\text{leak}} \times \dot{V}_s} \quad (\text{B.6})$$

where

| | |
|----------------------|---|
| $c_{u,\min}$ | is the minimum aerosol concentration for the identification of limit leaks; |
| 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}_s | is the sampling volume flow rate. |

The minimum aerosol concentration necessary to ensure the required minimum counting rate in the downstream particle counters shall satisfy the condition:

$$c_{u,\min} \geq \frac{l}{P_{\text{eff},i}} \times \dot{N}_{\min,c} \times \frac{l}{\dot{V}_s} \quad (\text{B.7})$$

where

| | |
|--------------------|---|
| $c_{u,\min}$ | is the minimum aerosol concentration for the particle counter on the downstream side; |
| $P_{\text{eff},i}$ | is the effective value of the integral penetration; |
| $\dot{N}_{\min,c}$ | is the minimum counting rate for the particle counter; |
| \dot{V}_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 $P_{\text{class},i}$. For this calculation the effective value has to be used. 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 needed for the determination of the penetration are provided by the particle counters. For downstream counters the condition is:

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

where

$c_{u,\min}$ is the minimum aerosol concentration to reach $N_{\text{min,abs}}$ on the downstream side;

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

$N_{\text{min,abs}}$ is 100 (= min. particle number (see B.2));

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

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

For the upstream particle counter the condition is:

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

where

$c_{u,\min}$ is the minimum aerosol concentration to reach $N_{\text{min,abs}}$ on the upstream side;

k_D is the dilution factor, upstream;

$N_{\text{min,abs}}$ is 100 (= min. particle number (see B.2));

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

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

B.9 Maximum aerosol concentration

There are three boundary conditions for the maximum aerosol concentration, and these also have to 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 following maximum concentration shall not be exceeded:

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

where

$c_{u,\max}$ is the maximum aerosol concentration to avoid aerosol losses.

The maximum concentration measurable by the particle counters provides the other two boundary conditions.

For the counters on the downstream side the condition is:

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

where

$c_{u,max}$ is the maximum aerosol concentration for the downstream counter;

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

$P_{max,l}$ is the maximum measurable local penetration (shall be specified and is $\geq P_{class,l}$).

Correspondingly, for the counter on the upstream side:

$$c_{u,max} \leq c_{max,c} \times k_D \quad (B.12)$$

where

$c_{u,max}$ is the maximum aerosol concentration for the upstream counter;

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

k_D is the dilution factor on the upstream side.

B.10 Leak signal

B.10.1 Effective value

The minimum expected value for the counting rate when the probe crosses a leak in the middle of the probe path is given by:

$$N_{min,em} = c_u \times P_{class,l} \times \dot{V}_s \times t_{leak} \quad (B.13)$$

where

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

c_u is the measured number concentration on the upstream side;

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

\dot{V}_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 equation is:

$$N_{\min,eb} = N_{\min,em} \times k_b \quad (\text{B.14})$$

where

$N_{\min,eb}$ is the expected minimum particle number for a leak at the edge of the probe path;

$N_{\min,em}$ 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 $N_{\min,eb}$ is determined in accordance with EN 1822-2, and designated $N_{\min,eb,95\%}$. When this value is reached the apparatus shall report a leak (leak signal value).

B.10.2 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 which is free from leaks.

The mean expected value for the particle number 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:

$$N_{em} = c_u \times P_{\text{class},i} \times \dot{V}_s \times t_{\text{leak}} \quad (\text{B.15})$$

where

N_{em} is the mean expected value of the particle number;

c_u is the number concentration on the upstream side of the test filter;

$P_{\text{class},i}$ is the limit integral penetration value;

\dot{V}_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 EN 1822-2, and designated $N_{em,95\%}$ ¹⁾.

The signal difference is then defined as:

$$S = N_{\min,eb,95\%} - N_{em,95\%} \quad (\text{B.16})$$

where

S is the signal difference;

1) 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 EN 1822-2. Although the numerical values for the confidence level and the error band differ, the confidence level is used also here for reasons of simplicity.

- $N_{\text{min,eb,95 \%}}$ 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 shall be expected during the scan tests.

Annex C (informative)

Example of an application with evaluation

Typical test parameters for a filter of class H14 are summarized in Table C.1.

Table C.1 — Typical test parameters for a filter of class H14

| Term | Symbol | Value |
|--|---------------------------|---|
| Data of test filter: | | |
| Filter class | | H14 |
| Limit value for the integral 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 x 610 mm x 78 mm |
| Dimensions of fold packet | | 1 190 mm x 580 mm |
| Nominal volume flow rate | | 1 205 m ³ /h |
| Passage velocity | \dot{V} | 0,485 m/s |
| Particle concentrations: | | |
| upstream | c_u | 1,73 x 10 ⁴ cm ⁻³ |
| downstream, integral | | 0,87 cm ⁻³ |
| downstream, local | | 4,33 cm ⁻³ |
| Downstream sampling: | | |
| Dimensions of probe aperture | $a_p \times b_p$ | 18 mm x 50 mm |
| Volume flow rate in the probe | \dot{V}_p | 28,3 l/min |
| Mean air speed in the probe | \bar{w}_p | 0,524 m/s |
| Probe speed | u_p | 30 mm/s |
| Probe time spent above site of leak | t_{leak} | 0,6 s |
| Analyzed 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 $k_b = 0,7$ | $N_{\text{min,eb}}$ | 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 C.1.

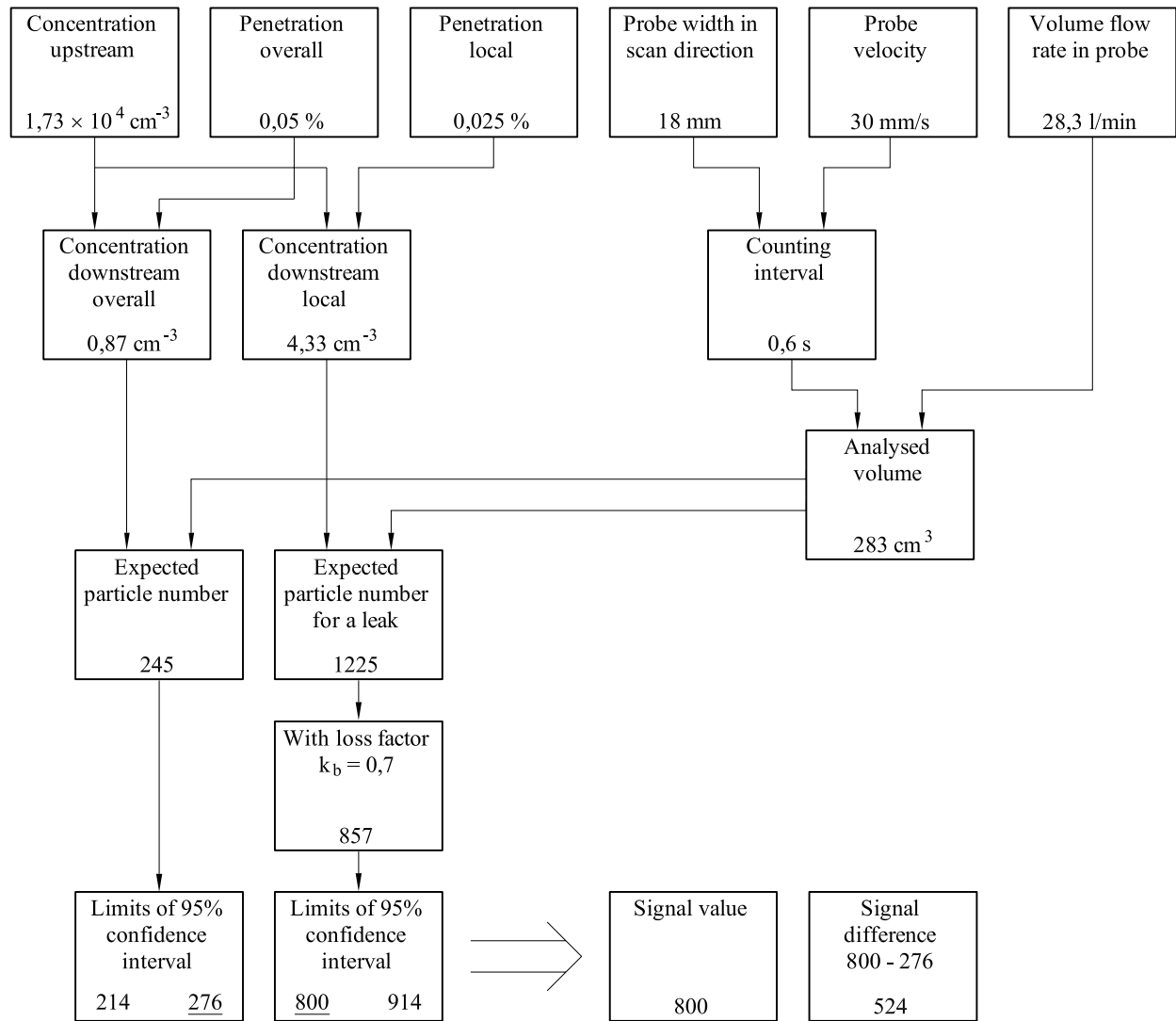


Figure C.1 — Determining the signal value and the signal difference from the test parameters for a filter of class H14

In Table C.2 the most important test parameters for filters of the classes H13 up to class U17 are compared.

Table C.2 — Examples of important test parameters for the filter classes H13 to U17

| Term | Symbol | Unit | Filter class | | | | |
|--|---------------------------------|------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| | | | H 13 | H 14 | U 15 | U 16 | U 17 |
| Limit value for the integral 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 | | | | | | | |
| Probe speed | c_u | cm^{-3} | $4,40 \times 10^3$ | $1,73 \times 10^4$ | $3,31 \times 10^4$ | $8,41 \times 10^4$ | $1,54 \times 10^5$ |
| Counting interval | u_p | mm/s | 30 | 30 | 30 | 12 | 12 |
| Volume analyzed | Δt_i | s | 0,6 | 0,6 | 0,6 | 1,5 | 1,5 |
| | | cm^3 | 283 | 283 | 283 | 708 | 708 |
| Expected particle number: | | | | | | | |
| without leak | N_{em} | - | 623 | 245 | 47 | 30 | 5 |
| with leak | $N_{\text{min},\text{em}}$ | - | 1 246 | 1 225 | 234 | 149 | 109 |
| with leak; $k_b = 0.7$ ^a | $N_{\text{min},\text{eb}}$ | - | 872 | 857 | 164 | 104 | 76 |
| Max. particle number without leak | $N_{\text{em},95\%}$ | - | 672 | 276 | 60 | 43 | 12 |
| Min. particle number with leak | $N_{\text{min},\text{eb},95\%}$ | - | 814 | 800 | 139 | 84 | 59 |
| Signal value | $N_{\text{min},\text{eb},95\%}$ | - | 814 | 800 | 139 | 84 | 59 |
| Signal difference | S | - | 142 | 524 | 79 | 41 | 47 |
| Min. aerosol concentration | $c_{u,\text{min}}$ | 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 | $c_{u,\text{max}}$ | 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 ($k_b = 0,7$).

Annex D (informative)

Leak Test with solid PSL Aerosol

D.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 HEPA and ULPA filters, to be used in Cleanrooms within these industries. The liquid particles are collected and accumulate in the filter during the test and may eventually outgas during operation of the filter. This outgassing may 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 EN 1822 (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 influences every part of EN 1822 (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, a separate annex (Annex D) has been created, which describes an alternative leak test and classification method for filters which have to be tested with solid particles. Annex D defines an alternative leak test (scanning method) with solid PSL aerosol. The efficiency determination and classification, however, is still performed as described in EN 1822-1, using the reference test method with liquid DEHS aerosol.

D.2 General Remarks

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 according to EN 1822-1. This value for the integral efficiency will not match that determined with the liquid DEHS reference aerosol, due to electrostatic effects.

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 as per EN 1822-1:2009, Table 1, given for each filter class.

For classification of the filter, a representative number of filters taken from the same production batch is to be subjected to an efficiency test as per EN 1822-5 (reference test method with DEHS aerosol). These filters are regarded as a reference regarding efficiency and subsequent classification as per EN 1822-1 for to the entire batch. All other filters are then only PSL leak tested as per Annex D. The specification and test data (filter size and design, test air flow, etc.) of the reference filters (which have been DEHS tested) and the PSL tested filters must however be absolutely identical.

D.3 Test Procedure

For the PSL leak test as per this annex, the test equipment and test procedure, given for DEHS aerosol in the body of EN 1822-4 may be used. The only exception applies to the type and use of the aerosol generator, which must 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, needs special generating equipment.

Presently, there is only one high output PSL aerosol generator commercially available from: MSP Corporation, Shoreview, MN 55126, USA (www.mspcorp.com), PSL generator model No. 2045²).

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

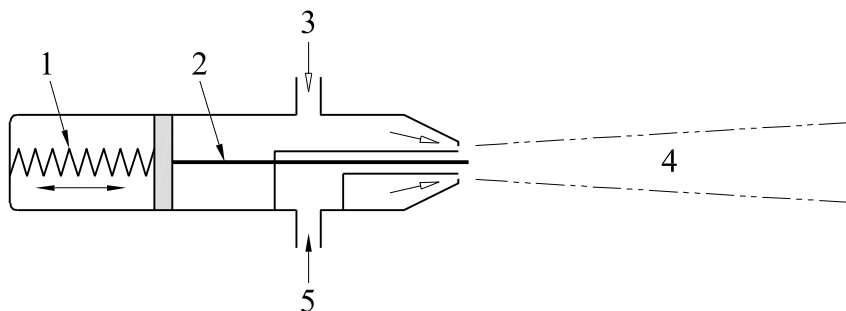


Figure D.1 — Nozzle 1

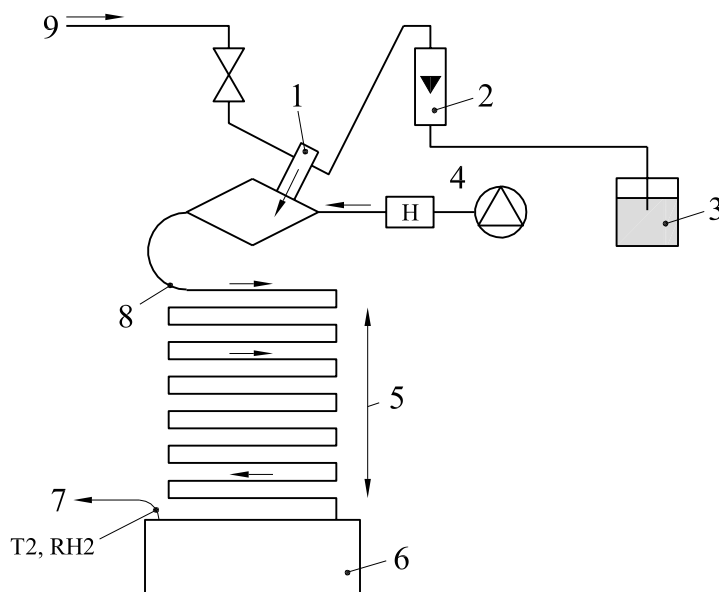


Figure D.2 — PSL Generator Design

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 of 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 air flow of $40 \text{ m}^3/\text{h}$ to $50 \text{ m}^3/\text{h}$. 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)

2) High output PSL aerosol generator is the trade name of a product supplied by MSP Corporation. This information is given for the convenience of users of this European Standard and does not constitute an endorsement by CEN of the product named. Equivalent products may be used if they can be shown to lead to the same results.

takes care of any excess water from the cooling section and decreases the risk of water entering the test system.

Recommended operation settings

T1 = 100 °C to 175 °C
P = 1 bar to 5 bar
q = 5 ml/min to 25 ml/min
T2 = 20 °C to 23 °C (preferably at or below test air temperature)
RH = > 90 %

D.4 Test Protocol

The test protocol, in addition to the requirements mentioned under EN 1822-4:2009, Clause 10, shall contain the following additional information:

- Statement, that the filter was leak tested using the test method as per EN 1822-4:2009, Annex D and efficiency tested on statistical bases;
- Test aerosol used (e.g. solid PSL);
- Aerosol generators used;
- Statement that the average PSL particle concentrations cannot be used for the classification of the filter.

Annex E (informative)

0,3 µm – 0,5 µm Particle Efficiency Leak Test

E.1 Background

Since the “Oil Thread Leak Test” (Annex A) is a visual test, leak detection result 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 this “0,3 µm – 0,5 µm Particle Efficiency Leak Test” (Annex E) is to detect leaks automatically by means of an efficiency measurement in the particle size range of 0,3 µm to 0,5 µm.

E.2 General remarks

This efficiency measurement method is using a particle counter in its 0,3 µm – 0,5 µm particle size channel to test filters of class H13 for leaks as an alternative to the oil thread test (Annex A). The 0,3 µm – 0,5 µm Particle Efficiency Leak Test may be used as a reference test procedure for filters of class H13 with turbulent airflow which cannot be scan tested because of their construction-type (for example V-bank or cylindrical filters).

From experience and according to a theoretical calculation with a predefined leak we know that for a filter of class H13 with a local MPPS efficiency of 99,75 %, the minimum global efficiency at 0,3 µm – 0,5 µm must be higher than 99,999 6 %.

E.3 Test Procedure

For classification as per EN 1822-1, these filters are placed in a test bench for measuring the integral MPPS efficiency, e.g. as described in EN 1822-5. The 0,3 µm – 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 good aerosol distribution upstream of the filter and good mixing of the air downstream of the filter to perform this test.

If a polydisperse aerosol is used it can be basically the same as that, used for integral MPPS efficiency measurements as per EN 1822-5. However, for the 0,3 µm – 0,5 µm Particle Efficiency Leak Test it is essential to have enough 0,3 µm – 0,5 µm particles upstream of the filter. Therefore, a monodisperse aerosol is not suitable. In order to have an accurate measurement, more than 10 (ten) particles in the 0,3 µm – 0,5 µm size range have to be sampled downstream of the filter. The minimum 0,3 µm – 0,5 µm particle count upstream of the filter must therefore be 2 500 000 particles per sampling time interval.

E.4 Leak criteria

For the filter class H13 (integral MPPS efficiency > 99,95 %, local MPPS efficiency > 99,75 %), the efficiency at 0,3 µm – 0,5 µm must be > 99,999 6 %.

E.5 Verification of Test Procedure

It is necessary to verify the sensitivity and accuracy of the procedure at regular intervals using reference filters with well defined leaks characterised by the leak test scan method as per EN 1822-4. The local

penetration of these leaks should not exceed the limit value specified for the H13 filter class by a factor of more than two. To verify adequate upstream aerosol distribution and the effectiveness of the mixing of the air downstream of the filter, the procedure must 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 characterised by the oil thread leak test, however, these leaks should not exceed the limit value specified for the H13 filter class by a factor of more than two. Ideally, these filters are 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 such filters as containing leaks according to the given criteria.

E.6 Reporting

Whenever a H13 filter is leak tested by using the “0,3 µm – 0,5 µm Particle Efficiency Leak Test”, it must be noted on the filter and in the test report (e.g. with a remark “leak tested as per EN 1822-4:2009, Annex E”). In the test report, the actually measured efficiency at 0,3 µm – 0,5 µm shall also be reported.

Bibliography

- [1] Wepfer, R. (1995): "Characterisation of HEPA and ULPA filters by proposed new European test methods", *Filtration & Separation*, vol. 32, n° 6, pp. 545-550.
- [2] EN 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 5167-1:2003)*

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