

High efficiency air filters (EPA, HEPA and ULPA)

Part 1: Classification, performance testing, marking

ICS 13.040.40; 23.120

National foreword

This British Standard is the UK implementation of EN 1822-1:2009. It supersedes BS EN 1822-1:1998 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MCE/21/3, Air filters other than for air supply for I.C. engines and compressors.

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

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 December 2009
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ISBN 978 0 580 61789 8

Amendments/corrigenda issued since publication

Date	Comments

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1822-1

November 2009

ICS 13.040.40

Supersedes EN 1822-1:1998

English Version

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

Filtres à air à haute efficacité (EPA, HEPA et ULPA) -
Partie 1: Classification, essais de performance et
marquage

Schwebstofffilter (EPA, HEPA und ULPA) - Teil 1:
Klassifikation, Leistungsprüfung, Kennzeichnung

This European Standard was approved by CEN on 17 October 2009.

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Foreword

This document (EN 1822-1:2009) 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of an identical text or by endorsement, at the latest by May 2010, and conflicting national standards shall be withdrawn at the latest by May 2010.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 1822-1:1998.

It is dealing with the performance testing of efficient particulate air filters (EPA), high efficiency particulate air filters (HEPA) and ultra low penetration air filters (ULPA) at the manufacturers site.

EN 1822, *High efficiency air filters (EPA, HEPA and ULPA)*, consists 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*

This European Standard is based on particle counting methods which actually cover most needs of different applications. The difference between this European Standard and its previous edition lies in the addition of:

- an alternative test method for using a solid, instead of a liquid, test aerosol;
- a method for testing and classification of filters made out of membrane type filter media;
- a method for testing and classification filters made out of synthetic fibre media; and
- an alternative method for leak testing of group H filters with other than panel shape.

Beside that, various editorial corrections have been implemented.

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. For Membrane filter media, separate rules apply, see Annex A of EN 1822-5:2009. This method also allows testing ultra low penetration air filters, which was not possible with the previous test methods because of their inadequate sensitivity.

1 Scope

This European Standard applies to high efficiency particulate and ultra low penetration air filters (EPA, HEPA and ULPA) 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 a liquid (or alternatively a solid) test aerosol, and allows a standardized classification of these filters in terms of their efficiency, both local and integral efficiency.

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 1822-2:2009, *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 1822-4:2009, *High efficiency air filters (EPA, HEPA and ULPA) — Part 4: Determining leakage of filter elements (scan method)*

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*

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)*

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

nominal air volume flow rate

air volume flow rate specified by the manufacturer, at which the filter element has to be tested

3.2

superficial face area

cross-sectional area of the filter element which is passed by the air flow

3.3

nominal filter medium face velocity

nominal air volume flow rate divided by the effective filter medium area

4 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply:

d_p	Particle diameter
E	Efficiency
P	Penetration
p	Pressure
RH	Relative humidity
T	Temperature
σ_g	Geometric standard deviation
CNC	Condensation nucleus counter
DEHS	Sebacic acid-bis (2 ethyl hexyl-) ester (trivial name: di-ethyl-hexyl-sebacate)
DMA	Differential electric mobility analyser
DMPS	Differential mobility particle sizer
DOP	Phthalic acid-bis (2-ethyl hexyl-) ester (trivial name: di-octyl-phthalate)
MPPS	Most penetrating particle size (= particle size, for which the filtration efficiency is a minimum)
OPC	Optical particle counter
PSL	Poly-Styrol Latex (solid spheres)

5 Classification

5.1 General

Filter elements are classified in groups and classes according to their filtration performance (efficiency or penetration).

5.2 Groups of filters

According to this standard, filter elements fall into one of the following Groups:

- Group E: EPA filters (Efficient Particulate Air filter);
- Group H: HEPA filters (High Efficiency Particulate Air filter);
- Group U: ULPA filters (Ultra Low Penetration Air filter).

5.3 Groups and Classes of filters

Filters are classified in Groups and Classes. For each group a slightly different test procedure applies. All filters are classified according to their filtration performance (see 6.5).

Group E filters are subdivided in three Classes:

- Class E 10;

- Class E 11;
- Class E 12.

Group H filters are subdivided in two Classes:

- Class H 13;
- Class H 14.

Group U filters are subdivided in three Classes:

- Class U 15;
- Class U 16;
- Class U 17.

6 Requirements

6.1 General

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

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

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

6.2 Material

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

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

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

6.3 Nominal air volume flow rate

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

6.4 Pressure difference

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

6.5 Filtration performance

The filtration performance is expressed by the efficiency or the penetration of MPPS particles.

After testing in accordance with Clause 7, filter elements are classified according to Table 1, on the bases of their integral (Group E) or their integral AND local (Groups H and U) MPPS efficiency or penetration.

Filters with filter media having an electrostatic charge are classified according to Table 1, on the bases of their discharged efficiency or penetration as per EN 1822-5:2009, Annex B.

Table 1 — Classification of EPA, HEPA and ULPA filters

Filter Group Filter Class	Integral value		Local value ^{a b}	
	Efficiency (%)	Penetration (%)	Efficiency (%)	Penetration (%)
E 10	≥ 85	≤ 15	--- ^c	--- ^c
E 11	≥ 95	≤ 5	--- ^c	--- ^c
E 12	≥ 99,5	≤ 0,5	--- ^c	--- ^c
H 13	≥ 99,95	≤ 0,05	≥ 99,75	≤ 0,25
H 14	≥ 99,995	≤ 0,005	≥ 99,975	≤ 0,025
U 15	≥ 99,999 5	≤ 0,000 5	≥ 99,997 5	≤ 0,002 5
U 16	≥ 99,999 95	≤ 0,000 05	≥ 99,999 75	≤ 0,000 25
U 17	≥ 99,999 995	≤ 0,000 005	≥ 99,999 9	≤ 0,000 1
^a See 7.5.2 and EN 1822-4. ^b Local penetration values lower than those given in the table may be agreed between supplier and purchaser. ^c Group E filters (Classes E10, E11 and E12) cannot and shall not be leak tested for classification purposes.				

7 Test methods

7.1 Test rigs

The test rigs are described in detail in EN 1822-3, EN 1822-4 and EN 1822-5. The individual methods of measurement and the measuring instruments are described in EN 1822-2.

7.2 Test conditions

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

- Temperature: $(23 \pm 5) ^\circ\text{C}$;
- Relative humidity < 75 %.

The temperature shall remain constant during the entire test procedure within $\pm 2 ^\circ\text{C}$ the relative humidity within ± 5 %.

The cleanliness of the test air shall be ensured by appropriate pre-filtering, so that in operation without addition of aerosol the particle number concentration measured with the particle counting method is less than $350\,000\text{ m}^{-3}$. The test specimen shall have the same temperature as the test air.

7.3 Test aerosols

For the testing of EPA, HEPA and ULPA filters in accordance with this standard, a liquid test aerosol shall be used. Alternatively a solid aerosol may be used for leak testing (see EN 1822-4:2009, Annex D). Possible aerosol substances include but are not limited to DEHS, PAO and PSL. For further details, see EN 1822-2:2009, 4.2.

NOTE The use of alternative materials for challenge aerosols may also be agreed between supplier and purchaser when the materials specified in this standard are unacceptable.

The concentration and the size distribution of the aerosol shall be constant over time. For the leak testing and the efficiency test of the filter element the mean particle diameter of the test aerosol shall correspond to the most penetrating particle size (MPPS) for the filter medium.

7.4 Survey of test procedures

7.4.1 General

The complete testing procedure for EPA, HEPA and ULPA filters in accordance with this standard consists of three steps, each of which may be implemented as an independent test.

7.4.2 Step 1: Testing sheet filter medium

The efficiency of flat sheet filter medium test samples shall be determined for a range of particle sizes at the nominal filter medium velocity. From the efficiency versus particle size curve, generated this way, the most penetrating particle size (MPPS) shall be determined.

See 7.5.1.

7.4.3 Step 2: Leak test of the filter element

Filter elements of Groups H and U shall be individually tested for absence of leaks at their nominal air volume flow rate. Filter elements of Group H shall be leak tested using one of the three leak test methods described in EN 1822-4. Filter elements of Group U shall be leak tested using the MPPS scanning method, described in EN 1822-4, only.

See 7.5.2.

7.4.4 Step 3: Efficiency test of the filter element

Using the MPPS test aerosol (the same as used in step 2), the integral efficiency of the filter element shall be determined at its nominal air volume flow rate.

For filters of Group E, this has to be done on statistical bases (see EN 1822-5:2009, 4.4). For filters of Groups H and U, this has to be done on each individual filter, except for filters tested as per EN 1822-4:2009, Annex A, where testing on statistical bases is acceptable.

See 7.5.3.

7.4.5 Remarks

On the basis of the value(s) determined for integral efficiency and for filters of Groups H and U also for local efficiency (= absence of relevant leaks), filter elements shall be assigned to a filter Class as specified in 6.5. This assignment is only valid if the fixed test conditions are met.

In all three procedural steps it is permissible to use either a monodisperse or a polydisperse test aerosol. The particle counting method used may be a total count method (CNC) or a method involving particle size analysis (OPC).

Since total count particle counting methods provide no information about the particle size, they may only be used to determine the efficiency in procedural step 1 with monodisperse test aerosols of a known particle size.

For the determination of the minimum efficiency of the flat sheet filter medium (step 1) the test method using a monodisperse test aerosol has to be considered as the reference test method. Care has to be taken for the correlation with the reference test method if using a polydisperse aerosol for steps 2 and 3.

For production testing, filter manufacturers may use data of their filter medium supplier for procedural step 1, instead of doing these test themselves, as long as these data are fully traceable and documented and the tests are done in full accordance with this standard, and in particular with EN 1822-3.

7.5 Test procedures

7.5.1 Testing sheet filter media

7.5.1.1 General

The fractional efficiency curve of flat sheets filter medium samples shall be determined in new condition (material as supplied by the medium manufacturer) AND in discharged condition (see EN 1822-5:2009, Annex B). If these measurements reveal that the filter medium is having a significant charge, the filter elements shall be classified on the bases of the discharged flat sheet efficiency or penetration measurements as per EN 1822-5:2009, Annex B.

7.5.1.2 Test samples

The testing procedure requires at least five flat sheet samples of the filter material; the filter elements will be made off.

The test samples shall be free of folds, creases, holes and other irregularities. The test samples shall have a minimum size of 200 mm x 200 mm.

7.5.1.3 Test apparatus

The arrangement of the test apparatus is shown in Figure 1. An aerosol is produced in the aerosol generator, then passed through a conditioner (for example to evaporate a solvent) and neutralised, before being brought together with the particle-free mixing air to the test filter mounting assembly.

Upstream and downstream from the test filter mounting assembly, there are sampling points from which a part of the flow is led to the particle counter. The upstream sampling point is connected with a dilution circuit to dilute the high particle concentration down to the actual measuring range of the particle counter.

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

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

Instead of using a single particle counter, which measures the unfiltered and filtered air consecutively, it is also permissible to use two particle counters of equal optical design (wave length of light source, light scattering angle, etc.) simultaneously for both measurements.

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

The measurement data are recorded and evaluated by a computer.

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

The test rig is described in detail in EN 1822-3. The individual methods of measurement are described in EN 1822-2.

7.5.1.4 Measurement procedure

The test sample shall be mounted in a test filter holding assembly with a cylindrical cross-section giving an exposed area of 100 cm² and subjected to a flow of test air at the nominal filter medium face velocity.

The test aerosol shall be added to the test air flow at a uniform rate. In order to establish the penetration versus particle size curve the penetration values for at least six logarithmically, approximately equidistant particle size points shall be determined.

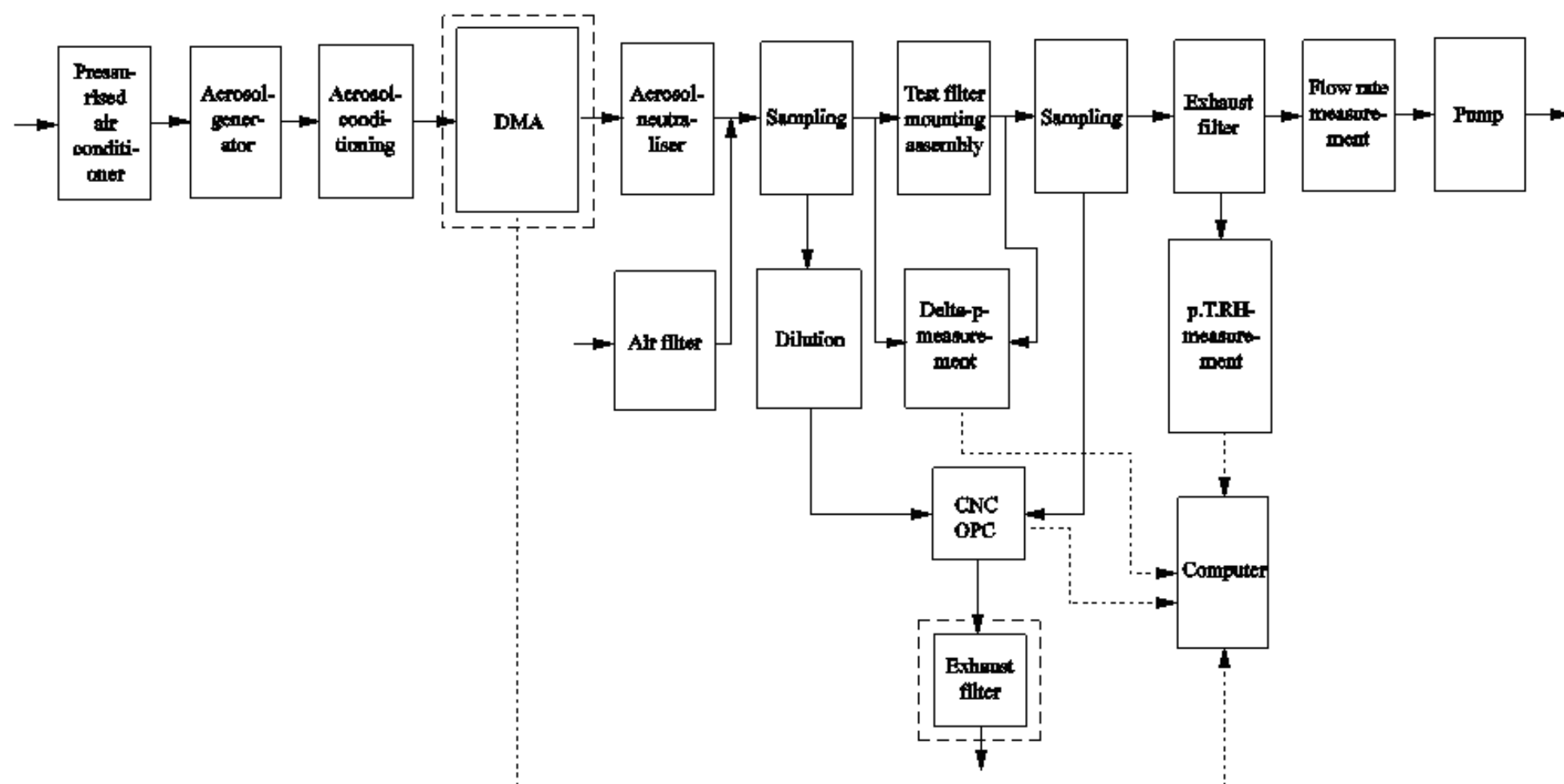


Figure 1 — Arrangement of apparatus for testing the filter medium

By means of the DMA at least six quasi-monodisperse test aerosols shall be produced with appropriate median values of the particle diameter and their concentrations shall be determined upstream and downstream of the test sample. As an alternative procedure, the size distribution of a polydisperse aerosol may be determined upstream and downstream of the test sample in at least six size classes.

In each case it shall be ensured that the measuring range of the particle counter and the range of produced particle sizes envelopes the minimum of the efficiency curve (MPPS).

7.5.1.5 Evaluation of test results

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

Arithmetic mean values shall be determined for:

- the minimum efficiency;
- the particle size at the minimum efficiency (MPPS);
- the pressure difference.

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

7.5.2 Leak test of the filter element

7.5.2.1 General

The leak test serves to test the filter elements of Groups H and U for local penetration and absence of leaks, respectively (see Table 1). The reference method and basis for this test is the particle counting scan method as described in EN 1822-4.

Filter elements of Group H shall be leak tested using one of the three leak test methods described in EN 1822-4; the reference scanning method, the Oil Thread Leak Test (EN 1822-4:2009, Annex A) or the 0,3 μm – 0,5 μm Particle Efficiency Leak Test (EN 1822-4:2009, Annex E, for Class H13 only).

Filter elements of Group U shall be leak tested using the MPPS scanning method, described in EN 1822-4, only.

All leak tests shall be performed at the nominal/rated air flow of the tested filter element.

For filter shapes creating highly turbulent air flow (e.g. V-bank or cylindrical filters), for which the reference scan method can not be applied, leak testing by either of the two alternative methods; Oil Thread Leak Test method (EN 1822-4:2009, Annex A) or 0,3 μm – 0,5 μm Particle Efficiency Leak Test method (EN 1822-4:2009, Annex E) may be applied. Oil Thread Leak Test method permits verification of the local penetration limits for classification of filters of Group H (H13 and H14). 0,3 μm – 0,5 μm Particle Efficiency Leak Test method permit verification of the local penetration limits for classification of filters of Class H13 only. For higher Classes of filters, the two alternative methods might not be sensitive enough to measure the local penetration limits specified in Table 1. Therefore, higher Classes of filters, leak tested with either of the two alternative methods have to be marked with “Alternative leak tested, method A” or “Alternative leak tested, method E” on its label and test report, to indicate that a less stringent leak test criteria has been applied.

7.5.2.2 Test specimen

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

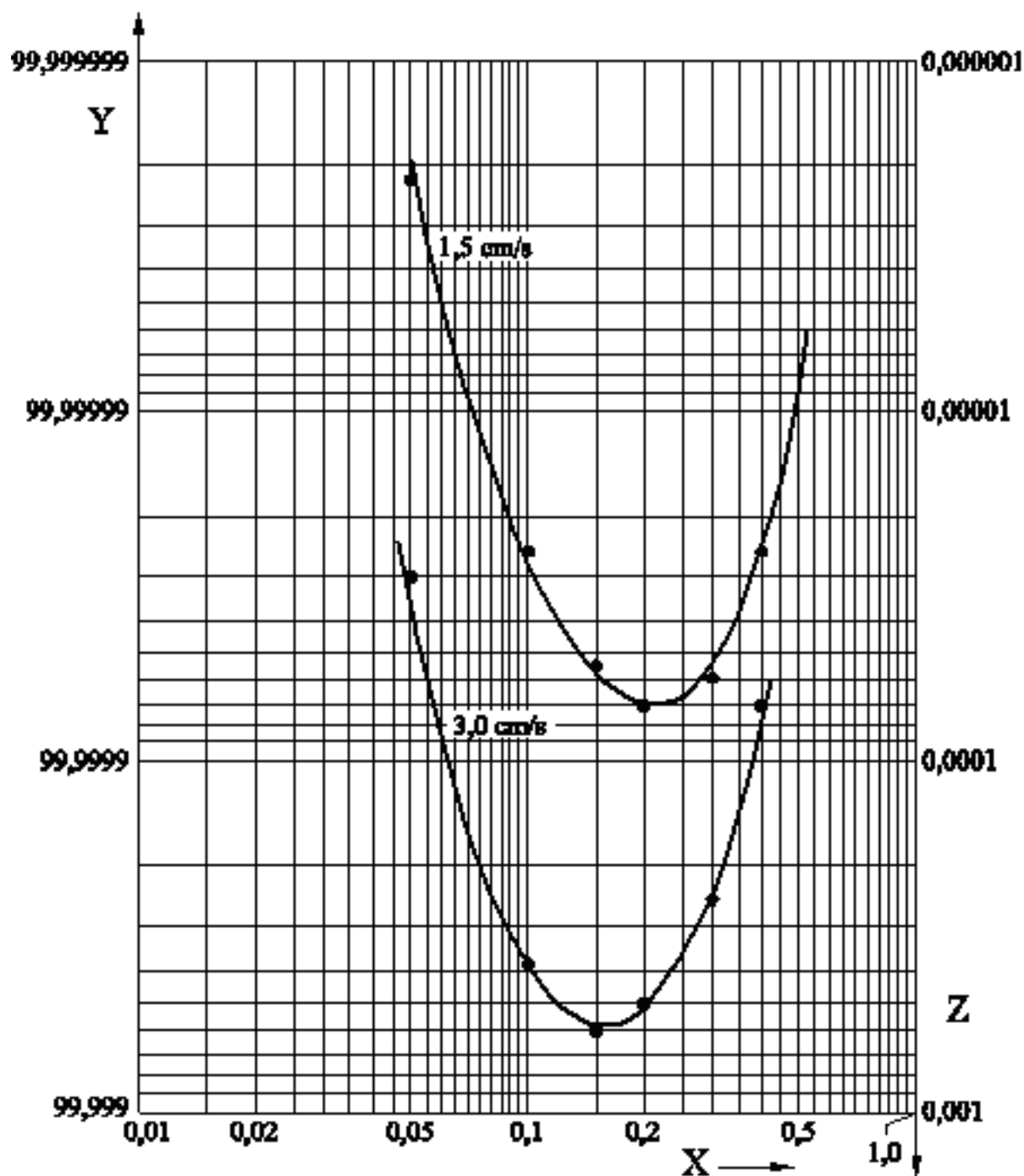


Figure 2 — Fractional efficiency E and penetration P of an ULPA-filter medium as function of the particle diameter d_p for two different filter medium velocities (example)

7.5.2.3 Test apparatus

The arrangement of the individual components of the test apparatus for the scan test is shown in Figure 3. The prefiltered test air is drawn in by a fan and passed through a secondary filter (see 7.2). The air volume flow rate shall be measured by a standardised air volume flow measuring device according to EN ISO 5167-1, or any other volume flow rate measuring device which can be calibrated, and shall be kept constant by a flow rate controller.

The neutralised test aerosol shall be introduced into the channel downstream from the volume flow rate measuring device and shall be distributed equally over the cross section of the channel. The test aerosol

may also be introduced upstream from the volume flow measuring device, if its introduction does not disturb the measurement.

Upstream of the test filter mounting assembly a part of the flow shall be taken and led via a dilution circuit to the particle counting equipment (CNC or OPC). The size distribution of the test aerosol can optionally be controlled by a so-called DMPS system (see EN 1822-2).

Downstream of the test filter a scanning device with one or more mechanically moveable probes has to be installed, with which the entire surface of the filter can be traversed. The probes shall be connected to the particle counters, where necessary via a device to adapt the volume flow rate.

The measurements for volume flow, the pressure drop across the filter, the position of the probe and the particle counting rates shall be recorded and processed by a computer.

The individual components of the test rig are described in detail in EN 1822-4. The individual methods of measurement are described in EN 1822-2.

7.5.2.4 Measurement procedure

During the course of the leak test the test specimen shall be subjected to the nominal air flow rate. The test aerosol, whose mean diameter shall correspond to the MPPS of the filter medium (see 7.5.1.5), shall be distributed homogeneously over the entire test cross section.

On the downstream side of the filter element being tested the particle concentration shall be sampled by means of one or more sampling probes which shall be moved at a defined rate. The particle concentration shall be compared with the concentration applied on the upstream side.

In the scanning operation the entire surface of the filter element shall be covered in overlapping tracks.

7.5.2.5 Evaluation of test results

Using the test parameters of the leak test (see EN 1822-4), the permissible local value of the efficiency (see Table 1) and taking statistical relationships into account (see EN 1822-2) it is possible to calculate a limit value for the particle counting rate that indicates a leak.

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



7.5.3 Efficiency test of the filter element

7.5.3.1 General

The integral efficiency of the complete filter element can be determined by one of the following methods:

- by measuring of the average particle concentration on the upstream and downstream sides of the filter with stationary sampling probes (static measuring method);
- by the continuous measurement of the particle concentration on the upstream and downstream sides of the filter in the course of the leakage test, with a stationary sampling probe on the upstream side and a scanning sampling probe on the downstream side which moves over the entire filter element (scan method).

7.5.3.2 Efficiency test using the static measuring method

7.5.3.2.1 Test specimen

The test specimen used shall be tested for leakage and be leak-free in accordance with 7.5.2.

7.5.3.2.2 Test apparatus

The test to determine the integral efficiency of the filter element shall be carried out in a test apparatus (see Figure 4) which is, upstream of the test filter, identical with the test apparatus used for the leakage test. The test filter mounting assembly is followed by a section which mixes the aerosol on the downstream side evenly over the whole cross section of the channel. This is followed by a stationary sampler and an exhaust filter. The downstream sample flow is also led to a particle counter.

The test procedure is described in detail in EN 1822-5. The individual methods of measurement are described in EN 1822-2.

7.5.3.2.3 Measurement procedure

The filter element shall be subjected to the nominal air volume flow rate with the same aerosol as used for the leak test. The particle concentration shall be measured on the upstream and downstream side of the filter element being tested. A dilution circuit shall be included on the upstream side to adjust the concentration to that measurable by the particle counters (see EN 1822-2).

The pressure drop across the filter element has to be measured, before the filter is loaded with test aerosol.

7.5.3.2.4 Evaluation of test results

The integral efficiency shall be calculated from the particle concentrations measured on the upstream and downstream side of the filter element being tested (see EN 1822-2 and EN 1822-5).

7.5.3.3 Efficiency testing using the scan method

The integral efficiency shall be determined by calculation using the particle number concentrations determined in the course of the leak test (see 7.5.2) with the stationary sampling probe on the upstream side of the filter and the moving scan sampling probe or probes on the downstream side (for further details, see EN 1822-4 and EN 1822-5).

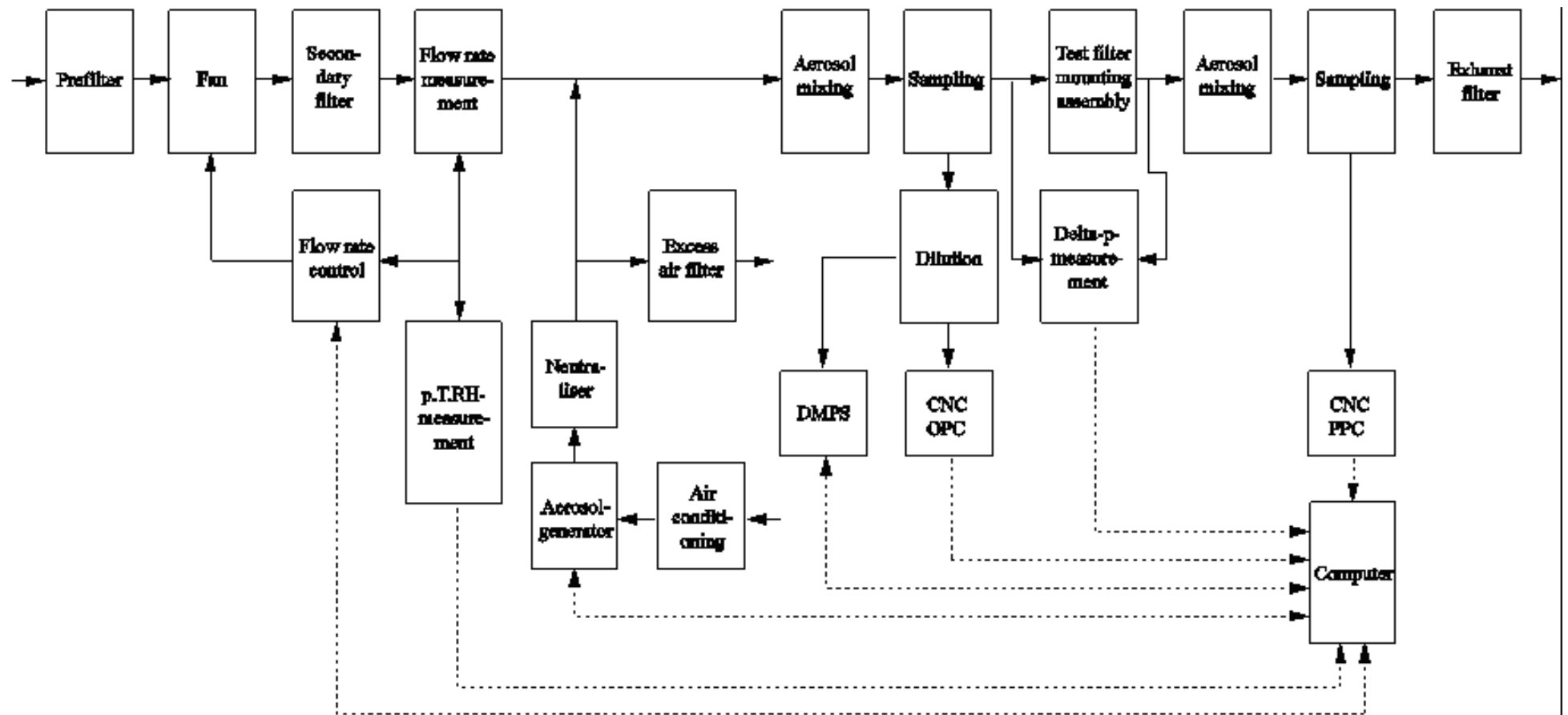


Figure 4 — Arrangement of apparatus for efficiency testing using the static measuring method

8 Assessment of the filter, documentation, test reports

The EPA, HEPA or ULPA filter tested fully in accordance with this test standard shall be assigned to a filter Class as specified in Table 1 on the basis of its integral efficiency (penetration) determined in accordance with 7.5.3 and – for filters of Groups H and U – also on the bases of its local efficiency (= absence of relevant leak) determined in accordance with 7.5.2.

The test results shall be documented in a test certificate or test report. The test report shall give full information about the tested object (filter medium or filter), test parameters (air flows, test method, aerosol and particle counters used) and the test results.

Detailed requirements for test reports depend on the type of test and can be found in the corresponding sections of EN 1822: in EN 1822-3 for filter medium testing, in EN 1822-4 for filter element leak testing and in EN 1822-5 for filter element efficiency testing.

Test reports for the filter medium as per EN 1822-3 are meant for internal use and shall form part of the Quality Assurance documentation of a company. Test reports for the filter element of filters of Groups H and U shall be part of the documentation that is normally supplied together with such filters. On the test reports for Group H and U filters, it is recommendable to combine the information required in EN 1822-4 and in EN 1822-5 and issue a combined test report with all required information.

9 Marking

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

- a) name, trade mark or other means of identification of the manufacturer;
- b) type and serial number of the filter;
- c) number of this standard;
- d) Class of the filter (see Table 1);
- e) nominal air volume flow rate at which the filter has been classified.

9.2 If the correct mounting in the ventilation duct cannot be deduced, marking of air flow direction is also necessary (e.g. with "TOP", "Direction of flow" or an arrow symbol).

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

Bibliography

- [1] EN ISO 14644-3:2005, *Cleanrooms and associated controlled environments — Part 3: Test methods (ISO 14644-3:2005)*

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