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Air filters for general ventilation —

Part 2:
Measurement of fractional efficiency and air flow resistance

Filtres à air de ventilation générale —

Partie 2: Mesurage de l'efficacité spectrale et de la résistance à l'écoulement de l'air

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Contents

Page

Foreword ... **vi**
Introduction ... **vii**
1 Scope ... **1**
2 Normative references ... **1**
3 Terms and definitions ... **2**
4 Symbols and abbreviated terms ... **4**
4.1 Symbols ... 4
4.2 Abbreviated terms ... 6
5 General test requirements ... **6**
5.1 Test device requirements ... 6
5.2 Test device installation ... 6
5.3 Test rig requirements ... 6
6 Test materials ... **7**
6.1 Liquid phase aerosol ... 7
6.1.1 DEHS test aerosol ... 7
6.1.2 DEHS/DES/DOS - formula ... 7
6.1.3 DEHS properties ... 7
6.1.4 Liquid phase aerosol generation ... 7
6.2 Solid phase aerosol ... 8
6.2.1 Potassium chloride (KCl) test aerosol ... 8
6.2.2 KCl - formula ... 8
6.2.3 KCl properties ... 8
6.2.4 Solid phase aerosol generation ... 9
6.3 Reference aerosols ... 10
6.3.1 Reference aerosol for 0,3 µm to 1,0 µm ... 10
6.3.2 Reference aerosol for 1,0 µm to 10,0 µm ... 10
6.3.3 Other reference aerosols ... 10
6.3.4 Matching criteria ... 11
6.4 Aerosol loading ... 11
7 Test equipment ... **11**
7.1 Test rig ... 11
7.1.1 Dimensions ... 11
7.1.2 Construction materials ... 12
7.1.3 Test rig shape ... 12
7.1.4 Test rig air supply ... 13
7.1.5 Test rig isolation ... 13
7.1.6 D/S mixing orifice ... 13
7.1.7 Aerosol sampling ... 14
7.1.8 Test rig air flow rate measurement ... 16
7.1.9 Resistance to air flow measurement ... 16
7.1.10 Non 610 mm × 610 mm (24,0 inch × 24,0 inch) test devices ... 17
7.1.11 Dust injection testing ... 18
7.2 Aerosol particle counter ... 18
7.2.1 General ... 18
7.2.2 OPC sampled size range ... 18
7.2.3 OPC particle size ranges ... 18
7.2.4 Sizing resolution ... 19
7.2.5 Calibration ... 19
7.2.6 Air flow rate ... 19
7.2.7 Zero counting ... 19
7.2.8 Dual OPC(s) ... 19
7.3 Temperature, relative humidity ... 20

8 Qualification of test rig and apparatus **20**
8.1 Schedule of qualification testing requirements 20
8.1.1 General 20
8.1.2 Qualification testing 20
8.1.3 Qualification documentation 20
8.2 Qualification testing 21
8.2.1 Test rig — Pressure system testing 21
8.2.2 OPC — Air flow rate stability test 22
8.2.3 OPC — Zero test 22
8.2.4 OPC — Sizing accuracy 23
8.2.5 OPC — Overload test 23
8.2.6 Aerosol generator — Response time 24
8.2.7 Aerosol generator — Neutralizer 24
8.2.8 Test rig — Air leakage test 25
8.2.9 Test rig — Air velocity uniformity 26
8.2.10 Test rig — Aerosol uniformity 27
8.2.11 Test rig — Downstream mixing 28
8.2.12 Test rig — Empty test device section pressure 29
8.2.13 Test rig — 100 % efficiency test and purge time 30
8.2.14 Test rig — Correlation ratio 30
8.3 Maintenance 30
8.3.1 General 30
8.3.2 Test rig — Background counts 31
8.3.3 Test rig — Reference filter test 32
8.3.4 Test rig — Pressure reference test 33
8.3.5 Test rig — Final filter resistance 33

9 Test methods **33**
9.1 Air flow rate 33
9.2 Measurement of resistance to air flow 33
9.3 Measurement of fractional efficiency 33
9.3.1 Aerosol sampling protocol 33
9.3.2 Background sampling 33
9.3.3 Testing sequence for a single OPC 34
9.3.4 Testing sequence for dual OPC testing 36

10 Data reduction and calculations **38**
10.1 Correlation ratio 38
10.1.1 Correlation ratio general 38
10.1.2 Correlation ratio data reduction 38
10.2 Penetration and fractional efficiency 40
10.2.1 Penetration and fractional efficiency general 40
10.2.2 Penetration data reduction 40
10.3 Data quality requirements 43
10.3.1 Correlation background counts 43
10.3.2 Efficiency background counts 43
10.3.3 Correlation ratio 43
10.3.4 Penetration 44
10.4 Fractional efficiency calculation 44

11 Reporting results **45**
11.1 General 45
11.2 Required reporting elements 45
11.2.1 Report general 45
11.2.2 Report values 45
11.2.3 Report summary 45
11.2.4 Report details 47

Annex A (informative) **Example** **50**

Annex B (informative) **Resistance to air flow calculation** **57**

Bibliography **59**

Foreword

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

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

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

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

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

The committee responsible for this document is ISO/TC 142, *Cleaning equipment for air and other gases*.

This first edition of ISO 16890-2, together with ISO 16890-1, ISO 16890-3 and ISO 16890-4, cancels and replaces ISO/TS 21220:2009, which has been technically revised.

ISO 16890 consists of the following parts, under the general title *Air filters for general ventilation*:

— *Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM)*

— *Part 2: Measurement of fractional efficiency and air flow resistance*

— *Part 3: Determination of the gravimetric efficiency and the air flow resistance versus the mass of test dust captured*

— *Part 4: Conditioning method to determine the minimum fractional test efficiency*

Introduction

The effects of particulate matter (PM) on human health have been extensively studied in the past decades. The results are that fine dust can be a serious health hazard, contributing to or even causing respiratory and cardiovascular diseases. Different classes of particulate matter can be defined according to the particle size range. The most important ones are PM_{10}, $PM_{2,5}$ and PM_1. The U.S. Environmental Protection Agency (EPA), the World Health Organization (WHO) and the European Union define PM_{10} as particulate matter which passes through a size-selective inlet with a 50 % efficiency cut-off at 10 µm aerodynamic diameter. $PM_{2,5}$ and PM_1 are similarly defined. However, this definition is not precise if there is no further characterization of the sampling method and the sampling inlet with a clearly defined separation curve. In Europe, the reference method for the sampling and measurement of PM_{10} is described in EN 12341. The measurement principle is based on the collection on a filter of the PM_{10} fraction of ambient particulate matter and the gravimetric mass determination (see EU Council Directive 1999/30/EC of 22 April 1999).

As the precise definition of PM_{10}, $PM_{2,5}$ and PM_1 is quite complex and not simple to measure, public authorities, like the U.S. EPA or the German Federal Environmental Agency (Umweltbundesamt), increasingly use in their publications the more simple denotation of PM_{10} as being the particle size fraction less or equal to 10 µm. Since this deviation to the above mentioned complex “official” definition does not have a significant impact on a filter element’s particle removal efficiency, the ISO 16890 series refers to this simplified definition of PM_{10}, $PM_{2,5}$ and PM_1.

Particulate matter in the context of the ISO 16890 series describes a size fraction of the natural aerosol (liquid and solid particles) suspended in ambient air. The symbol ePM_x describes the efficiency of an air cleaning device to particles with an optical diameter between 0,3 µm and x µm. The following particle size ranges are used in the ISO 16890 series for the listed efficiency values.

Table 1 — Optical particle diameter size ranges for the definition of the efficiencies, ePM_x

Efficiency	**Size range**, µm
ePM_{10}	$0,3 \leq \times \leq 10$
$ePM_{2,5}$	$0,3 \leq \times \leq 2,5$
ePM_1	$0,3 \leq \times \leq 1$

Air filters for general ventilation are widely used in heating, ventilation and air-conditioning applications of buildings. In this application, air filters significantly influence the indoor air quality and, hence, the health of people, by reducing the concentration of particulate matter. To enable design engineers and maintenance personnel to choose the correct filter types, there is an interest from international trade and manufacturing for a well-defined, common method of testing and classifying air filters according to their particle efficiencies, especially with respect to the removal of particulate matter. Current regional standards are applying totally different testing and classification methods which do not allow any comparison with each other, and thus hinder global trade with common products. Additionally, the current industry standards have known limitations by generating results which often are far away from filter performance in service, i.e. overstating the particle removal efficiency of many products. With this new ISO 16890 series, a completely new approach for a classification system is adopted, which gives better and more meaningful results compared to the existing standards.

The ISO 16890 series describes the equipment, materials, technical specifications, requirements, qualifications and procedures to produce the laboratory performance data and efficiency classification based upon the measured fractional efficiency converted into a particulate matter efficiency (*e*PM) reporting system.

Air filter elements according to the ISO 16890 series are evaluated in the laboratory by their ability to remove aerosol particulate expressed as the efficiency values ePM_1, $ePM_{2,5}$ and ePM_{10}. The air filter elements can then be classified according to the procedures defined in ISO 16890-1. The particulate removal efficiency of the filter element is measured as a function of the particle size in the range of 0,3 µm to 10 µm of the unloaded and unconditioned filter element as per the procedures defined in this part of ISO 16890. After the initial particulate removal efficiency testing, the air filter element is conditioned according to the procedures defined in ISO 16890-4 and the particulate removal efficiency is repeated on the conditioned filter element. This is done to provide information about the intensity of any electrostatic removal mechanism which may or may not be present with the filter element for test. The average efficiency of the filter is determined by calculating the mean between the initial efficiency and the conditioned efficiency for each size range. The average efficiency is used to calculate the $e\text{PM}_x$ efficiencies by weighting these values to the standardized and normalized particle size distribution of the related ambient aerosol fraction. When comparing filters tested in accordance with the ISO 16890 series, the fractional efficiency values shall always be compared among the same $e\text{PM}_x$ class (ex. $e\text{PM}_1$ of filter A with $e\text{PM}_1$ of filter B). The test dust capacity and the initial arrestance of a filter element are determined as per the test procedures defined in ISO 16890-3.

Air filters for general ventilation —

Part 2: Measurement of fractional efficiency and air flow resistance

1 Scope

This part of ISO 16890 specifies the aerosol production, the test equipment and the test methods used for measuring fractional efficiency and air flow resistance of air filters for general ventilation.

It is intended for use in conjunction with ISO 16890-1, ISO 16890-3 and ISO 16890-4.

The test method described in this part of ISO 16890 is applicable for air flow rates between 0,25 m^3/s (900 m^3/h, 530 ft^3/min) and 1,5 m^3/s (5 400 m^3/h, 3 178 ft^3/min), referring to a test rig with a nominal face area of 610 mm × 610 mm (24,0 inch × 24,0 inch).

ISO 16890 (all parts) refers to particulate air filter elements for general ventilation having an $e\mathrm{PM}_1$ efficiency less than or equal to 99 % and an $e\mathrm{PM}_{10}$ efficiency greater than 20 % when tested as per the procedures defined within ISO 16890 (all parts).

NOTE The lower limit for this test procedure is set at a minimum $e\mathrm{PM}_{10}$ efficiency of 20 % since it will be very difficult for a test filter element below this level to meet the statistical validity requirements of this procedure.

Air filter elements outside of this aerosol fraction are evaluated by other applicable test methods, (see ISO 29463 (all parts)).

Filter elements used in portable room-air cleaners are excluded from the scope.

The performance results obtained in accordance with ISO 16890 (all parts) cannot by themselves be quantitatively applied to predict performance in service with regard to efficiency and lifetime.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16890-1, *Air filters for general ventilation — Part 1: Technical specifications, requirements and efficiency classification system based upon Particulate Matter (PM)*

ISO 16890-3, *Air filters for general ventilation — Part 3: Determination of the gravimetric efficiency and the air flow resistance versus the mass of test dust captured*

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

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 21501-1, *Determination of particle size distribution — Single particle light interaction methods — Part 1: Light scattering aerosol spectrometer*

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

ISO 29463, *High-efficiency filters and filter media for removing particles in air*

ISO 29464:2011, *Cleaning equipment for air and other gases — Terminology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 29464 and the following apply.

3.1 Air flow and resistance

3.1.1
air flow rate
volume of air passing through the filter per unit time

[SOURCE: ISO 29464:2011, 3.2.38]

3.1.2
nominal air flow rate
air flow rate (3.1.1) specified by the manufacturer

3.1.3
resistance to airflow
difference in pressure between two points in an airflow system at specified conditions, especially when measured across the *filter element* (3.2.2)

3.2 Test device

3.2.1
test device
filter element (3.2.2) to be tested

3.2.2
filter element
structure made of the filtering material, its supports and its interfaces with the filter housing

3.2.3
upstream
U/S
region in a process system traversed by a flowing fluid before it enters that part of the *test device* (3.2.1)

3.2.4
downstream
D/S
area or region into which fluid flows on leaving the *test device* (3.2.1)

3.3 Aerosol

3.3.1
liquid phase aerosol
liquid particles suspended in a gas

3.3.2
solid phase aerosol
solid particles suspended in a gas

3.3.3
reference aerosol
defined approved aerosol for test measurement within a specific size range

3.3.4
neutralization
action of bringing the aerosol to a Boltzmann charge equilibrium distribution with bipolar ions

3.4 Particle counter

3.4.1
particle counter
device for detecting and counting numbers of discrete airborne particles present in a sample of air

[SOURCE: ISO 29464:2011, 3.1.27]

3.4.2
optical particle counter
OPC
particle counter (3.4.1) which functions by illuminating airborne particles in a sample flow of air, converting the scattered light impulses to electrical impulse data capable of analysis to provide data on particle population and size distribution

[SOURCE: ISO 29464:2011, 3.29]

3.4.3
sampling air flow
volumetric flow rate through the instrument

3.4.4
particle size
ps
geometric diameter (equivalent spherical, optical or aerodynamic, depending on context) of the particles of an aerosol

[SOURCE: ISO 29464:2011, 3.1.126]

3.4.5
particle size distribution
presentation, in the form of tables, numbers or graphs, of the experimental results obtained using a method or an apparatus capable of measuring the equivalent diameter of particles in a sample or capable of giving the proportion of particles for which the equivalent diameter lies between defined limits

[SOURCE: ISO 29464:2011, 3.1.128]

3.4.6
isokinetic sampling
technique for air sampling such that the probe inlet air velocity is the same as the velocity of the air surrounding the sampling point

[SOURCE: ISO 29464:2011, 3.1.144]

3.5 Efficiency

3.5.1
efficiency
fraction or percentage of a challenge contaminant that is removed by a *test device* (3.2.1)

3.5.2
fractional efficiency
ability of an air cleaning device to remove particles of a specific size or size range

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

[SOURCE: ISO 29464:2011, 3.1.61]

3.5.3
penetration
P
ratio of particle count detected downstream versus the particle count upstream

[SOURCE: ISO 29464:2011, 3.1.130]

3.5.4
correlation ratio
R
calculation of any potential bias between the upstream and downstream sampling systems

3.6 Other terms

3.6.1
HEPA filter
filters with performance complying with requirements of filter class ISO 35 to ISO 45 as per ISO 29463-1

[SOURCE: ISO 29464:2011, 3.1.88]

3.6.2
reference filter
primary device possessing accurately known parameters used as a standard for calibrating secondary devices

[SOURCE: ISO 29464:2011, 3.39]

4 Symbols and abbreviated terms

4.1 Symbols

DEHS	(DiEthylHexylSebacate)
KCl	potassium chloride solid phase aerosol
Ra	current radioactivity of the source
Ra_0	radioactivity of the source at date of manufacturer
t	time (years)
$t_{0,5}$	half-life time (years)
CV	coefficient of variation
δ	standard deviation of the data points
mean	mean value of the data points
$U_{c,i,ps}$	upstream correlation count for sample i, and particle size, ps
$D_{c,i,ps}$	downstream correlation count for sample i, and particle size, ps
$U_{\mathrm{B,b},ps}$, $U_{\mathrm{B,f},ps}$	upstream beginning or final background average count at a specific particle size, *ps*
$D_{\mathrm{B,b},ps}$, $D_{\mathrm{B,f},ps}$	downstream beginning or final background average count at a specific particle size, *ps*
$D_{\mathrm{B},ps}$	downstream background average count for efficiency sample, *i*, and for particle size, *ps*

$D_{B,c,ps}$ downstream background average count for correlation sample, *i*, and for particle size, *ps*

$B_{b,i,ps}$, $B_{f,i,ps}$ measured beginning or final upstream background count for sample, *i*, and particle size, *ps*

$d_{b,ps}$, $d_{f,ps}$ measured beginning or final downstream background count for particle size, *ps*

$U_{B,ps}$, $U_{B,c,ps}$ upstream background average count for efficiency or correlation at a specific particle size, *ps*

$N_{i,ps}$ measured upstream efficiency count for sample, *i*, and particle size, *ps*

$U_{i,ps}$ upstream efficiency average for sample, *i*, and for particle size, *ps*

$U_{tot,ps}$ sum of the upstream particle counts for particle size, *ps*

$D_{i,ps}$ downstream efficiency average for sample, *i*, and for particle size, *ps*

$R_{i,ps}$ correlation ratio for sample, *i*, and for particle size, *ps*

$\bar{R}_{ps}$ correlation ratio at a specific particle size, *ps*

n number of samples

$e_{c,ps}$ 95 % uncertainty of the correlation value at a specific particle size, *ps*

st student's *t* distribution variable

v number of degrees of freedom for student's *t* distribution variable

$\bar{R}_{lcl,ps}$ lower confidence limit of the correlation ratio at a specific particle size, *ps*

$\bar{R}_{ucl,ps}$ upper confidence limit of the correlation ratio at a specific particle size, *ps*

$\delta_{c,ps}$ standard deviation of the correlation value at a specific particle size, *ps*

$U_{c,tot,ps}$ sum of the upstream particles sampled during correlation at a specific particle size, *ps*

$U_{c,i,ps}$ correlation particles sampled for sample, *i*, and for particle size, *ps*

P penetration or the fraction of particulate that penetrates the test device

$\bar{P}_{o,ps}$ observed penetration at a specific particle size, *ps*

$\bar{P}_{ps}$ final penetration at a specific particle size, *ps*

$\bar{P}_{lcl,ps}$ lower confidence limit of the penetration at a specific particle size, *ps*

$\bar{P}_{ucl,ps}$ upper confidence limit of the penetration at a specific particle size, *ps*

e_{ps} 95 % uncertainty of the penetration value at a specific particle size, *ps*

δ_{ps} standard deviation of the penetration value at a specific particle size, *ps*

e_i static or dynamic uncertainty

$U_{tot,ps}$ sum of the upstream particles sampled during penetration at a specific particle size, *ps*

E_{ps} fractional efficiency at a specific particle size, *ps*

4.2 Abbreviated terms

ASHRAE	American Society of Heating Refrigeration and Air Conditioning Engineers
CEN	European Committee for Standardization
CL	concentration limit
NIST	National Institute of Standards and Technology
PSL	polystyrene latex spheres
RH	relative humidity, %
TR	test rig

5 General test requirements

5.1 Test device requirements

The test device shall be designed so that when correctly mounted in the ventilation test rig, no air/dust leaks occur around the exterior test device frame and the test rig sealing surfaces. The test device shall be designed or marked so as to prevent incorrect mounting.

The complete test device (filter and frame) shall be made of material suitable to withstand normal usage and exposure to the range of temperature, humidity and corrosive environments likely to be encountered in service.

The complete test device shall be designed so that it will withstand mechanical constraints that are likely to be encountered during normal use. Dust or fibre released from the test device media by air flow through the test device shall not constitute a hazard or nuisance for the people (or devices) exposed to filtered air.

5.2 Test device installation

The test device shall be mounted in accordance with the manufacturer's recommendations and after environmental equilibrium with the test air weighed to the nearest gram. Devices requiring external accessories shall be operated during the test with accessories having characteristics equivalent to those used in actual practice. The test device, including any normal mounting frame, shall be sealed into the test rig in a manner that prevents leakage. The tightness shall be checked by visual inspection and no visible leaks are acceptable. If for any reason dimensions do not allow testing of a test device under standard test conditions, assembly of two or more devices of the same type or model is permitted, provided no leaks occur in the resulting assembly. The operating conditions of such accessory equipment shall be recorded.

5.3 Test rig requirements

Critical dimensions and arrangements of the test apparatus are shown in the figures of this part of ISO 16890 and are intended as guides to help construct a test rig to meet the performance requirements of this part of ISO 16890. All dimensions shown are mandatory unless otherwise indicated. Tolerances are shown in the figures herein. Units are in mm (inch) unless otherwise indicated. The design of equipment not specified (including, but not limited to, blowers, valves and external piping) is discretionary, but the equipment shall have adequate capacity to meet the performance requirements of this part of ISO 16890.

6 Test materials

6.1 Liquid phase aerosol

6.1.1 DEHS test aerosol

Liquid phase aerosol of DEHS (DiEthylHexylSebacate) produced by a Laskin nozzle arrangement is widely used in the testing of high efficiency filters. DEHS is the same as DES Di (2-ethylhexyl) Sebacate or Bis (2-ethylhexyl) Sebacate since the aerodynamic, geometric and light scattering sizes are close to each other when measured with optical particle counters (OPC). The DEHS aerosol shall be used untreated and introduced directly into the test rig.

6.1.2 DEHS/DES/DOS - formula

$C_{26}H_{50}O_4$ or $CH_3(CH_2)_3CH(C_2H_5)CH_2OOC(CH_2)_8COOCH_2CH(C_2H_5)(CH_2)3CH_3$

6.1.3 DEHS properties

Molecular weight	426,69 g/mol
Density	912 kg/m^3 (57 lb/ft^3)
Melting point	225 K
Boiling point	505 K to 522 K
Flash point	>473 K
Vapour pressure	<1 Pa at 293 K
Refractive index	1,452 at 600 nm wavelength
Dynamic viscosity	0,022 Pa·s (0,015 lb/ft·s) to 0,024 Pa·s (0,016 lb/ft·s)
CAS number	122-62-3

6.1.4 Liquid phase aerosol generation

The test aerosol shall consist of untreated and undiluted DEHS, or other liquid phase aerosols in accordance with 6.3 aerosol reference.

Figure 1 gives an example of a system for generating the aerosol. It consists of a small container with DEHS liquid and a Laskin nozzle. The aerosol is generated by feeding compressed particle-free air through the Laskin nozzle. The atomized droplets are then directly introduced into the test rig. The pressure and air flow to the nozzle are varied according to the test flow and the required aerosol concentration.

NOTE For a test air flow rate of 0,944 m^3/s (2 000 ft^3/min), the pressure is about 17 kPa (2,5 lb/in^2), corresponding to an air flow of about 0,39 dm^3/s [1,4 m^3/h, (0,82 ft^3/min)] through the nozzle.

Any other generator capable of producing droplets in sufficient concentrations in the particle size range of 0,3 µm to 1,0 µm can be used.

Before testing, regulate the upstream concentration to reach steady-state and to have a concentration below the coincidence level of the OPC.

