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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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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).

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

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

This document was prepared by Technical Committee ISO/TC 142, *Cleaning equipment for air and other gases,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 195, *Cleaning equipment for air and other gases,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 16890-2:2016), which has been technically revised.

The main changes are as follows:

— definition of light scattering airborne particle counter (LSAPC) has been added in Clause 3;

— rewording of 6.3.1 and removal of 6.3.3 and 6.3.4 eliminating the matching criteria and use of alternate aerosols;

— in Figure 3, the distance between pressure drop taps and test device (7-8), wrongly indicated as 350 mm has been modified with “≥350 mm”;

— in 7.1.6 and 8.3.3.4, a sentence has been added to specify that the D/S mixing orifice shall not be installed during resistance to airflow measurement;

— in 7.2.1, aerosol particle counters (APC) and light scattering aerosol particle counter (LSAPC) have been added as common examples of aerosol particle counter;

— in 7.2.5, the incorrect reference to ISO 21501-4 has been corrected with ISO 21501-1;

— in 10.3.2, “correlation” has been changed to “efficiency” to be consistent with the title of the subclause;

— in 11.2.3, c), 6), iv), the word “additive” has been changed to “adhesive” to be consistent with the template of Table 10;

— the example of the test report in Figure A.1 has been updated to match the template report of Table A.10.

A list of all parts in the ISO 16890 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The 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 PM can be defined according to the particle size range. The most important ones are PM_{10}, $PM_{2,5}$ and PM_1. The United States Environmental Protection Agency (EPA), the World Health Organization (WHO) and the European Union define PM_{10} as PM 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 PM and the gravimetric mass determination (see Reference [10]).

As the precise definition of PM_{10}, $PM_{2,5}$ and PM_1 is quite complex and not easy to measure, public authorities, such as the US EPA or the German Federal Environmental Agency (Umweltbundesamt), increasingly use in their publications the simpler 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.

PM 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 as shown in Table 1.

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

Efficiency	**Size range**, µm
ePM_{10}	0,3 ≤ × ≤10
$ePM_{2,5}$	0,3 ≤ × ≤2,5
ePM_1	0,3 ≤ × ≤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 PM. 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 PM. Current regional standards are applying completely 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 the 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 document. 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 can possibly 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 $e\mathrm{PM}_x$ 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 are always compared among the same $e\mathrm{PM}_x$ class (e.g. $e\mathrm{PM}_1$ of filter A with $e\mathrm{PM}_1$ 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.

The results from this document can also be used by other standards that define or classify the fractional efficiency in the size range of 0,3 µm to 10 µm when electrostatic removal mechanism is an important factor to consider, for example ISO 29461.

The performance results obtained in accordance with the ISO 16890 series cannot by themselves be quantitatively applied to predict performance in service with regard to efficiency and lifetime.

Air filters for general ventilation —

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

1 Scope

This document 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 to be used in conjunction with ISO 16890-1, ISO 16890-3 and ISO 16890-4.

The test method described in this document 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 inches × 24.0 inches).

This document refers to particulate air filter elements for general ventilation having an ePM$_1$ efficiency less than or equal to 99 % and an ePM$_{10}$ efficiency greater than 20 % when tested as per the procedures defined within the ISO 16890 series.

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

This document is not applicable to filter elements used in portable room-air cleaners.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

3 Terms and definitions

For the purposes of this document the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Air flow and resistance

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

[SOURCE: ISO 29464:2017, 3.1.24]

3.1.2
resistance to airflow
difference in absolute (static) pressure between two points in an airflow system at specified conditions, especially when measured across the *filter element* (3.2.2)

[SOURCE: ISO 29464:2017, 3.1.36, modified — "at specified conditions, especially when measured across the filter element (3.2.2)" has been added.]

3.2 Test device

3.2.1
test device
filter element (3.2.2) being subjected to performance testing

[SOURCE: ISO 29464:2017, 3.1.38]

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

[SOURCE: ISO 29464:2017, 3.2.77]

3.2.3
upstream
U/S
area or region from which fluid flows as it enters the *test device* (3.2.1)

[SOURCE: ISO 29464:2017, 3.1.39]

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

[SOURCE: ISO 29464:2017, 3.1.11]

3.3 Aerosol

3.3.1
liquid phase aerosol
liquid particles suspended in a gas

[SOURCE: ISO 29464:2017, 3.2.2]

3.3.2
solid phase aerosol
solid particles suspended in a gas

[SOURCE: ISO 29464:2017, 3.2.8]

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

[SOURCE: ISO 29464:2017, 3.2.7]

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 29464:2017, 3.2.114]

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 the number of particles in multiple size intervals

Note 1 to entry: See ISO 21501-1.

[SOURCE: ISO 29464:2017, 3.2.119, modified — "particle population and size distribution" has been replaced for clarity with "the number of particles in multiple size intervals".]

3.4.3
sampling air flow
volumetric flow rate through the instrument

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

[SOURCE: ISO 29464:2017, 3.2.133]

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 29464:2017, 3.2.135]

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 29464:2017, 3.2.105]

3.5 Efficiency

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

[SOURCE: ISO 29464:2017, 3.1.12]

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 29464:2017, 3.2.59]

3.5.3
penetration
P
ratio of contaminant concentration *downstream* (3.2.4) of the test device to the *upstream* (3.2.3) (challenge) concentration

Note 1 to entry: Penetration is sometimes expressed as a percentage.

Note 2 to entry: Penetration is related to efficiency (E) by the expression: $E = (1 - P) \times 100$ %.

[SOURCE: ISO 29464:2017, 3.1.34]

3.5.4
correlation ratio
R
calculation of any potential bias between the *upstream* (3.2.3) and *downstream* (3.2.4) sampling systems

[SOURCE: ISO 29464:2017, 3.2.33]

3.6 Other terms

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

Note 1 to entry: Reference particle filters are laboratory tested for removal efficiency by particle size and/or resistance to air flow.

[SOURCE: ISO 29464:2017, 3.2.84]

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

[SOURCE: ISO 29464:2017, 3.1.35, modified — Note 1 to entry has been deleted.]

4 Symbols and abbreviated terms

4.1 Symbols

R_a	current radioactivity of the source
R_{a0}	radioactivity of the source at date of manufacturer
t	time (years)
$t_{0,5}$	half-life time (years)
C_v	coefficient of variation

δ	standard deviation of the data points
$\bar{m}$	mean value of the data points
$U_{c,i,p}$	upstream correlation count for sample *i*, and particle size, *p*
$D_{c,i,p}$	downstream correlation count for sample *i*, and particle size, *p*
$U_{\mathrm{B,b},p}$, $U_{\mathrm{B,f},p}$	upstream beginning or final background average count at a specific particle size, *p*
$D_{\mathrm{B,b},p}$, $D_{\mathrm{B,f},p}$	downstream beginning or final background average count at a specific particle size, *p*
$D_{\mathrm{B},p}$	downstream background average count for efficiency sample, *i*, and for particle size, *p*
$D_{\mathrm{B,c},p}$	downstream background average count for correlation sample, *i*, and for particle size, *p*
$B_{\mathrm{b},i,p}$, $B_{\mathrm{f},i,p}$	measured beginning or final upstream background count for sample, *i*, and particle size, *p*
$d_{\mathrm{b},p}$, $d_{\mathrm{f},p}$	measured beginning or final downstream background count for particle size, *p*
$U_{\mathrm{B},p}$, $U_{\mathrm{B,c},s}$	upstream background average count for efficiency or correlation at a specific particle size, *p*
$N_{i,p}$	measured upstream efficiency count for sample, *i*, and particle size, *p*
$U_{i,p}$	upstream efficiency average for sample, *i*, and for particle size, *p*
$U_{\mathrm{tot},p}$	sum of the upstream particle counts for particle size, *p*
$D_{i,p}$	downstream efficiency average for sample, *i*, and for particle size, *p*
$R_{i,p}$	correlation ratio for sample, *i*, and for particle size, *p*
$\bar{R}_p$	correlation ratio at a specific particle size, *p*
N	number of samples
$e_{\mathrm{c},p}$	95 % uncertainty of the correlation value at a specific particle size, *p*
S_t	student's *t* distribution variable
v	number of degrees of freedom for student's *t* distribution variable
$\bar{R}_{lcl,p}$	lower confidence limit of the correlation ratio at a specific particle size, *p*
$\bar{R}_{ucl,p}$	upper confidence limit of the correlation ratio at a specific particle size, *p*
$\delta_{\mathrm{c},p}$	standard deviation of the correlation value at a specific particle size, *p*
$U_{\mathrm{c,tot},p}$	sum of the upstream particles sampled during correlation at a specific particle size, *p*
$U_{c,i,p}$	correlation particles sampled for sample, *i*, and for particle size, *p*
p	particle size
P	penetration or the fraction of particulate that penetrates the test device
$\bar{P}_{o,p}$	observed penetration at a specific particle size, *p*
$\bar{P}_p$	final penetration at a specific particle size, *p*
$\bar{P}_{lcl,p}$	lower confidence limit of the penetration at a specific particle size, *p*