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Air filters for general ventilation —

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

Filtres à air de ventilation générale —

Partie 1: Spécifications techniques, exigences et système de classification fondé sur l'efficacité des particules en suspension (ePM)

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Foreword

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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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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 16890-1, together with ISO 16890-2, 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 ≤ × ≤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 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 this part of ISO 16890. 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 ISO 16890-2. 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 1:
Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM)

1 Scope

This part of ISO 16890 establishes an efficiency classification system of air filters for general ventilation based upon particulate matter (PM). It also provides an overview of the test procedures, and specifies general requirements for assessing and marking the filters, as well as for documenting the test results. It is intended for use in conjunction with ISO 16890-2, 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 inch × 24 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 % when tested according to the procedures defined within ISO 16890-1, ISO 16890-2, ISO 16890-3 and ISO 16890-4. Air filter elements with a higher initial efficiency are evaluated by other applicable test methods (see ISO 29463-1, ISO 29463-2, ISO 29463-3, ISO 29463-4 and ISO 29463-5).

Filter elements used in portable room-air cleaners are excluded from the scope of this part of ISO 16890.

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. Other factors influencing performance to be taken into account are described in Annex A.

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 15957, *Test dusts for evaluating air cleaning equipment*

ISO 16890-2, *Air filter for general ventilation — Part 2: Measurement of fractional efficiency and air flow resistance*

ISO 16890-3, *Air filter 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 filter for general ventilation — Part 4: Conditioning method to determine the minimum fractional test efficiency*

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 Arrestance and efficiency

3.1.1
arrestance
gravimetric efficiency
A
measure of the ability of a filter to remove mass of a standard test dust from the air passing through it, under given operating conditions

Note 1 to entry: This measure is expressed as a weight percentage.

3.1.2
initial arrestance
initial gravimetric efficiency
A_i
ratio of the mass of a standard test dust retained by the filter to the mass of dust fed after the first loading cycle in a filter test

Note 1 to entry: This measure is expressed as a weight percentage.

3.1.3
average arrestance
average gravimetric efficiency
A_m
ratio of the total mass of a standard test dust retained by the filter to the total mass of dust fed up to final test pressure differential

3.1.4
efficiency
fraction or percentage of a challenge contaminant that is removed by a filter

3.1.5
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 (3.7.1) gives the particle size efficiency spectrum.

[SOURCE: ISO 29464:2011, 3.1.61]

3.1.6
particulate matter efficiency
$e\text{PM}_x$
efficiency (3.1.4) of an air cleaning device to reduce the mass concentration of particles with an optical diameter between 0,3 µm and *x* µm

3.2
filter element
structure made of the filtering material, its supports and its interfaces with the filter housing

3.3
group designation
designation of a group of filters fulfilling certain requirements in the filter classification

Note 1 to entry: This part of ISO 16890 defines four groups of filters. Group designations are “ISO coarse”, “ISO *e*PM10”, “ISO *e*PM2,5” and “ISO *e*PM1” as defined in Table 4.

3.4 Air flow rates

3.4.1
air flow rate
q_V
volume of air passing through the filter per unit time

[SOURCE: ISO 29464:2011, 3.2.38]

3.4.2
nominal air flow rate
$q_{V,nom}$
air flow rate (3.4.1) specified by the manufacturer

3.4.3
test air flow rate
q_{Vt}
air flow rate (3.4.1) used for testing

3.5 Particulate matter

3.5.1
particulate matter
PM
solid and/or liquid particles suspended in ambient air

3.5.2
particulate matter PM_{10}
particulate matter (3.5.1) which passes through a size-selective inlet with a 50 % efficiency cut-off at 10 µm aerodynamic diameter

3.5.3
particulate matter $PM_{2,5}$
particulate matter (3.5.1) which passes through a size-selective inlet with a 50 % efficiency cut-off at 2,5 µm aerodynamic diameter

3.5.4
particulate matter PM_1
particulate matter (3.5.1) which passes through a size-selective inlet with a 50 % efficiency cut-off at 1 µm aerodynamic diameter

3.6
particle counter
device for detecting and counting numbers of discrete airborne particles present in a sample of air

[SOURCE: ISO 29464:2011, 3.27]

3.7 Particle size and diameter

3.7.1
particle size
particle diameter
geometric diameter (equivalent spherical, optical or aerodynamic, depending on context) of the particles of an aerosol

[SOURCE: ISO 29464:2011, 3.1.126]

3.7.2
particle size distribution
presentation, in the form of tables of numbers or of 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]

3.8
resistance to air flow
pressure differential
difference in pressure between two points in an airflow system at specified conditions, especially when measured across the filter element (3.2)

3.9
test dust capacity
amount of a standard test dust held by the filter at final test pressure differential

4 Symbols and abbreviated terms

A_i Initial arrestance, %

d_i Lower limit particle diameter in a size range *i*, µm

d_{i+1} Upper limit particle diameter in a size range *i*, µm

$\bar{d}_i$ Geometric mean diameter of a size range *i*, µm

Δd_i Width of a particle diameter size range *i*, µm

$\Delta\ln d_\mathrm{i}$ Logarithmic width of a particle diameter size range, *i*; ln is the natural logarithm to the base of *e*, where *e* is an irrational and transcendental constant approximately equal to 2,718 281 828

$\Delta\ln d_i = \ln d_{i+1} - \ln d_i = \ln(d_{i+1} / d_i)$, dimensionless

d_{50} Median particle size of the log-normal distribution, µm

E_i Initial fractional efficiency of particle size range, *i*, of the untreated and unloaded filter element, % (equals to the efficiency values E_ps of the untreated filter element resulting from ISO 16890-2)

$E_{\mathrm{D},i}$ Fractional efficiency of particle size range, *i*, of the filter element after an artificial conditioning step, % (equals to the efficiency values E_ps of the filter element resulting from ISO 16890-2 after a conditioning step has been carried out according to ISO 16890-4)

$E_{\mathrm{A},i}$ Average fractional efficiency of particle size range *i*, %

$e\mathrm{PM}_{x,\,\mathrm{min}}$ Minimum efficiency value with x=1 µm, 2,5 µm or 10 µm of the conditioned filter element, %

$e\mathrm{PM}_x$ Efficiency with x=1 µm, 2,5 µm or 10 µm, %

$q_3(d)$ Discrete particle volume distribution, dimensionless

$Q_3(d)$ Cumulative particle volume distribution, dimensionless

σ_g Standard deviation of the log-normal distribution

y	Mixing ratio of the bimodal particle size distribution
ASHRAE	American Society of Heating Refrigeration and Air Conditioning Engineers
CEN	European Committee for Standardization

5 Technical specifications and requirements

5.1 General

The filter element shall be designed or marked for air flow direction in a way that prevents incorrect mounting.

The filter shall be designed in a way that no leaks occur along the sealing edge when correctly mounted in the ventilation duct. 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 are permitted, provided no leaks occur in the resulting filter configuration.

5.2 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 to withstand mechanical constraints that are likely to occur during normal use.

5.3 Nominal air flow rate

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

However, many national and association bodies use 0,944 m^3/s (2 000 ft^3/min or 3 400 m^3/h) as nominal air flow for classification or rating of air filters that are nominal 610 mm × 610 mm (24 inch × 24 inch) in face area. Therefore, if the manufacturer does not specify a nominal air flow rate, the filter shall be tested at 0,944 m^3/s. The air flow velocity associated with this air flow rate is 2,54 m/s (500 ft/min).

5.4 Resistance to air flow

The resistance to air flow (pressure differential) across the filter element is recorded at the test air flow rate as described in detail in ISO 16890-2.

5.5 Fractional efficiency curves (particle size efficiency spectrum)

The initial fractional efficiency curve, E_i, of the unloaded and unconditioned filter element as a function of the particle size is measured at the test air flow rate in accordance with ISO 16890-2.

The fractional efficiency curve, $E_{D,i}$, of the filter element after an artificial conditioning step defined in ISO 16890-4 is determined as a function of the particle size in accordance with ISO 16890-2.

5.6 Arrestance

The initial arrestance, the resistance to air flow versus the mass of test dust captured and the test dust capacity are determined in accordance with ISO 16890-3 using L2 test dust as specified in ISO 15957.

6 Test methods and procedure

The technical specifications of the test rig(s), the related test conditions, test aerosols and standard test dust used for this part of ISO 16890 are described in detail in ISO 16890-2, ISO 16890-3 and ISO 16890-4. The full test according to this part of ISO 16890 consists of the steps given below, which all shall be carried out with the same filter test specimen under the same test conditions and at the same test air flow rate:

a) measure the resistance to air flow as a function of the air flow rate according to ISO 16890-2;

b) measure the initial fractional efficiency curve, E_i, of the unloaded and unconditioned filter element as a function of the particle size in accordance with ISO 16890-2;

c) carry out an artificial conditioning step in accordance with ISO 16890-4;

d) measure the fractional efficiency curve, $E_{D,i}$, of the conditioned filter element as a function of the particle size in accordance with ISO 16890-2, which is equal to the minimum fractional test efficiency;

e) calculate the *e*PM efficiencies as defined in Clause 7;

f) load the filter with synthetic L2 test dust as specified in ISO 15957 according to the procedures described in ISO 16890-3 to determine the initial arrestance, the resistance to air flow versus the mass of test dust captured and the test dust capacity (this step is optional for filters of group ISO *e*PM10, *e*PM2,5 or *e*PM1).

The initial fractional efficiency curve, E_i, of the untreated and unloaded filter element (see 5.5) and the fractional efficiency curves, $E_{D,i}$, after an artificial conditioning step are used to calculate the average fractional efficiency curve, $E_{A,i}$, using Formula (1).

$$E_{A,i} = 0,5 \cdot (E_i + E_{D,i}) \quad (1)$$

NOTE For further explanations on the test procedure according to ISO 16890-4, please refer to 8.2.

The procedure described in ISO 16890-4 quantitatively shows the extent of the electrostatic charge effect on the initial performance of the filter element without dust load. It indicates the level of efficiency obtainable with the charge effect completely removed and with no compensating increase in mechanical efficiency. Hence, the fractional efficiencies, $E_{D,i}$, after an artificial conditioning step could underestimate the fractional efficiencies under real service conditions. Since the real minimum fractional efficiencies encountered during service strongly depend on the operating conditions defined by numerous uncontrolled parameters, its real value lays unpredictably between the initial and the conditioned value. For good sense, in this part of ISO 16890, the average between the initial and the conditioned value is used to predict the real fractional efficiencies of a filter during service, as defined by Formula (1). Therefore, it shall be noted that fractional efficiencies measured in real service may differ significantly from the ones given in this part of ISO 16890. Additionally, the chemical treatment of a filter medium applied in ISO 16890-4 as an artificial ageing step may affect the structure of the fibre matrix of a filter medium or chemically affect the fibres or even fully destroy the filter medium. Hence, not all types of filters and media may be applicable to the mandatory procedure described in ISO 16890-4 and, in this case, cannot be classified according to this part of ISO 16890.

7 Classification system based on particulate matter efficiency (*e*PM)

7.1 Definition of a standardized particles size distribution of ambient air

To evaluate air filters according to their *e*PM efficiencies, standardized volume distribution functions of the particle size are used which globally represent the average ambient air of urban and rural areas, respectively. Typically, in the size range of interest (>0,3 µm), the particle sizes in ambient air are bimodal distributed with a fine and coarse mode. Fine filters, mostly designed to filter out the PM_1 and $PM_{2,5}$ particle size fractions, are evaluated using a size distribution which represents urban areas,

