BS EN ISO 16890-3:2016

BSI Standards Publication

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 16890-3:2016)

National foreword

This British Standard is the UK implementation of EN ISO 16890-3:2016. Together with BS EN ISO 16890-1:2016, BS EN ISO 16890-2:2016 and BS EN ISO 16890-4:2016 it supersedes BS EN 779:2012 and DD ISO/TS 21220:2009 which are withdrawn.

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Filtres à air de ventilation générale - Partie 3: Détermination de l'efficacité gravimétrique et de la résistance à l'écoulement de l'air par rapport à la quantité de poussière d'essai retenue (ISO 16890-3:2016)

Luftfilter für die allgemeine Raumlufttechnik - Teil 3: Ermittlung des gravimetrischen Wirkungsgrades sowie des durchflusswiderstandes im Vergleich zu der aufgenommenen Masse von Prüfstaub (ISO 16890-3:2016)

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European foreword

This document (EN ISO 16890-3:2016) has been prepared by Technical Committee ISO/TC 142 "Cleaning equipment for air and other gases" in collaboration with 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of an identical text or by endorsement, at the latest by June 2017, and conflicting national standards shall be withdrawn at the latest by June 2017.

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 779:2012.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

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Endorsement notice

The text of ISO 16890-3:2016 has been approved by CEN as EN ISO 16890-3:2016 without any modification.

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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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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 16890-3, together with ISO 16890-1, ISO 16890-2 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 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 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 this part of ISO 16890.

Air filters for general ventilation —

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

1 Scope

This part of ISO 16890 specifies the test equipment and the test methods used for measuring the gravimetric efficiency and resistance to air flow of air filter for general ventilation.

It is intended for use in conjunction with ISO 16890-1, ISO 16890-2 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 in × 24 in).

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

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 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.

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 16890-1, *Air filters for general ventilation — Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM)*

ISO 16890-2:2016, *Air filters for general ventilation — Part 2: Measurement of fractional efficiency and resistance to air flow*

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

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

ISO 29464, *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

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

3.1.3
filter face velocity
air flow rate (3.1.1) divided by the face area

Note 1 to entry: Filter face velocity is expressed in m/s.

3.1.4
resistance to air flow
difference in pressure between two points in an air flow system at specified conditions, especially when measured across the *filter element* (3.2.2)

Note 1 to entry: Resistance to air flow is measured in Pa.

3.1.5
recommended final resistance to air flow
maximum operating *resistance to air flow* (3.1.4) of the filter as recommended by the manufacturer

Note 1 to entry: Recommended final resistance to air flow is measured in Pa.

3.1.6
final resistance to air flow
resistance to air flow (3.1.4) up to which the filtration performance is measured to determine the *average arrestance* (3.3.3) and *test dust capacity* (3.3.4)

Note 1 to entry: Final differential pressure to air flow is measured in Pa.

3.1.7
initial resistance to air flow
resistance to air flow (3.1.4) of the clean filter operating at its test *air flow rate* (3.1.1)

Note 1 to entry: Initial resistance to air flow is measured in Pa.

3.1.8
test air
air to be used for testing purposes

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)

3.2.5
coarse filter
filtration device with particle removal efficiency <50 % in the PM_{10} particle range

3.2.6
fine filter
filtration device with particle removal efficiency ≥50 % in the PM_{10} particle range

3.2.7
final filter
air filter used to collect the *loading dust* (3.3.5) passing through or shedding from the filter under test

3.2.8
effective filter media area
area of the media contained in the filter and effectively passed by air during operation

Note 1 to entry: Effective filter media area is expressed in m^2.

3.2.9
filter media velocity
air flow rate (3.1.1) divided by the *effective filter media area* (3.2.8)

Note 1 to entry: Filter media velocity is expressed in m/s to an accuracy of three significant figures.

3.3 Gravimetric efficiency

3.3.1
arrestance
measure of the ability of a filter to remove a standard test dust from the air passing through it, under given operating conditions

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

3.3.2
initial arrestance
value of *arrestance* (3.3.1) determined after the first loading cycle in a filter test

Note 1 to entry: Initial arrestance is expressed as a weight percentage.

3.3.3
average arrestance
ratio of the total amount of *loading dust* (3.3.5) retained by the filter to the total amount of dust fed up to final test pressure differential

3.3.4
test dust capacity
amount of *loading dust* (3.3.5) retained by the filter up to final pressure differential

Note 1 to entry: Test dust capacity is expressed in grams.

3.3.5
loading dust
synthetic dust formulated specifically for determination of the *test dust capacity* (3.3.4) and *arrestance* (3.3.1) of air filters

3.3.6
particle size
geometric diameter (equivalent spherical, optical or aerodynamic, depending on context) of the particles of an aerosol

3.4 Other terms

3.4.1
HEPA filter
filters with performance complying with requirements of filter class ISO 35H – ISO 45H as per ISO 29463-1

3.4.2
reference device
primary device possessing accurately known parameters used as a standard for calibrating secondary devices

3.4.3
filter face area
area of the inside section of the test duct immediately *upstream* (3.2.3) of the filter under test

Note 1 to entry: Nominal values 0,61 m × 0,61 m = 0,37 m^2.

4 Symbols and abbreviated terms

A	Arrestance, %
A_j	Arrestance in loading phase “j”, %
A_m	Average arrestance during test to final resistance to air flow, %
M_j	Mass of dust fed to the filter during loading phase “j”, g
mean	Mean value
m_d	Dust in duct after filter, g
m_j	Mass of dust passing the filter at the dust loading phase “j”, g
m_{tot}	Cumulative mass of dust fed to filter, g
m_1	Mass of final filter before dust increment, g
m_2	Mass of final filter after dust increment, g
p	Pressure, Pa
p_a	Absolute air pressure upstream of filter, kPa
p_{sf}	Air flow meter static pressure, kPa
q_m	Mass flow rate at air flow meter, kg/s
q_V	Air flow rate at filter, m^3/s
q_{Vf}	Air flow rate at air flow meter, m^3/s
t	Temperature upstream of filter, °C
t_f	Temperature at air flow meter, °C

ρ	Air density, kg/m³
φ	Relative humidity upstream of filter, %
Δm	Dust increment, g
Δm_{ff}	Mass gain of final filter, g
Δp	Filter resistance to air flow, Pa
Δp_f	Differential pressure used for determination of air flow rate, Pa
$\Delta p_{1,20}$	Filter resistance to air flow at air density 1,20 kg/m³, Pa
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASTM	American Society for Testing and Materials
CEN	European Committee for Standardization
EN	European Norm
EUROVENT	European Committee of Air Handling and Refrigeration Equipment Manufacturers

5 General test device requirements

5.1 Test device requirements

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

The complete test device (test device 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 preparation

The test device shall be mounted in accordance with the manufacturer's recommendations and after equilibration 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 leakages. 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.

6 Loading dust

The synthetic loading dust as specified in ISO 15957 as L2 shall be used as a loading dust for reporting results. This procedure is applicable to loading a filtration device with other dust types mentioned in ISO 15957, but not for reporting results in accordance with this part of ISO 16890.

7 Test equipment

7.1 Test rig, as described in ISO 16890-2:2016, Clause 7.

Parts not described in ISO 16890-2 and used in this part of ISO 16890 are described below.

7.2 Upstream mixing orifice

For all dust load measurements the upstream mixing orifice shall be installed.

The mixing orifice is made up of an orifice plate (1) and a perforated plate as the mixing baffle (2) as shown in ISO 16890-2:2016, Figure 4.

7.3 Liquid aerosol testing devices

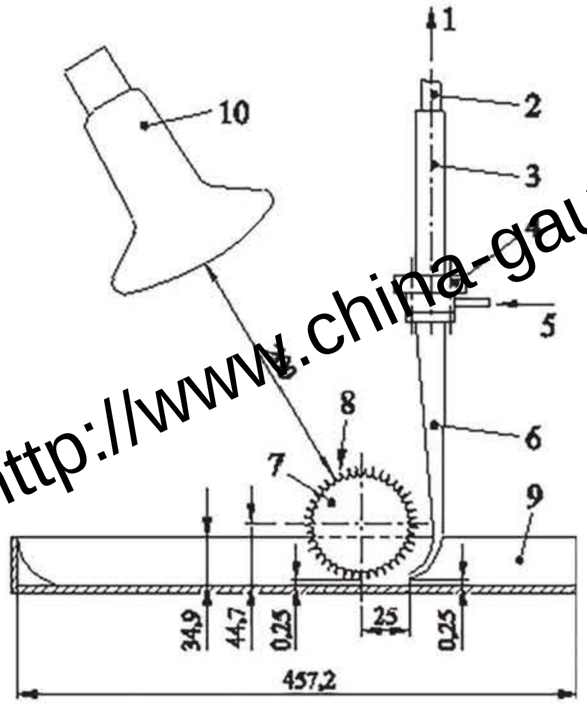
The downstream aerosol sampling head, upstream aerosol sampling head, downstream mixing orifice liquid and aerosol injection as have been shown in ISO 16890-2:2016, Figure 3, are not used in this part of ISO 16890.

7.4 Dust feeder

The purpose of the dust feeder is to supply the synthetic dust to the filter under test at a constant rate over the test period. A certain mass of dust previously weighed is loaded into the mobile dust feeder tray. The tray moves at a uniform speed and the dust is taken up by a paddle wheel and carried to the slot of the dust pickup tube of the ejector. The ejector disperses the dust with compressed air and directs it into the test rig through the dust feed tube. The dust injection nozzle shall be positioned at the entrance of duct section B in Figure 1 as shown in ISO 16890-2:2016, Figure 3, and be collinear with the duct centre line.

The compressed air supply shall be fitted with a filter-dryer system to provide clean, oil-free air with a dew point no higher than 1,7 °C (35 °F). The general design of the dust feeder and its critical dimensions are given in Figure 1 and Figure 2. The vertical pickup tube version of the dust feeder is shown in Figure 1 as an example. Backflow of air through the pickup tube from the positive duct pressure shall be prevented when the feeder is not in use. The degree of dust dispersion by the feeder is dependent on the characteristics of the compressed air, the geometry of the aspirator assembly and the rate of air flow through the aspirator. To ensure the consistency of the results, the test feeder shall provide (140 ± 14) mg/m^3 (4,0 ± 0,4 g/1 000 ft^3). The gauge pressure on the air line to the Venturi corresponding to an air flow of the dust-feeder pipe of (6,8 ± 0,2) dm^3/s (14,4 cfm ± 0,4 cfm) shall be measured periodically for different static pressures in the duct.

Dimensions in mm



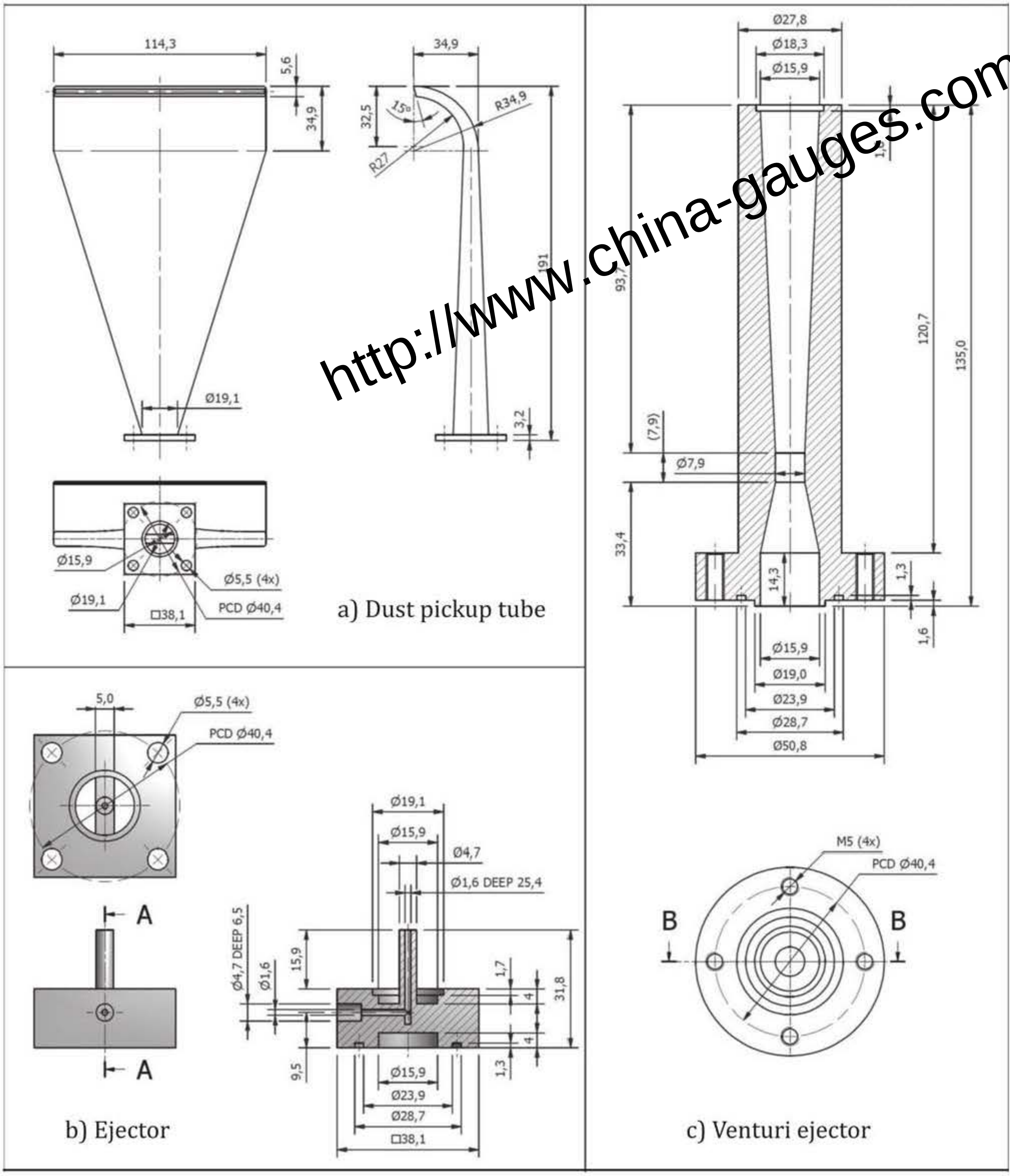
Key

1 dust feed tube (to inlet of test duct)
2 thin-wall galvanised conduit
3 venturi ejector
4 ejector
5 dry compressed air feed
6 dust pickup tube (0,25 mm (0,01 inch) from dust feed tray)
7 dust paddle wheel Ø 88,9 mm (3,5 inch) (outer dimension), 114,3 mm (4,5 inch) long with 60 teeth 5 mm (0,2 inch) deep
8 teeth in paddle wheel (60 teeth)
9 dust feed tray
10 150 W infrared-reflector lamp

NOTE The optional infrared reflector lamp can be used if the dust is hydroscopic, making dust pickup easier.

Figure 1 — Critical dimensions of dust feeder assembly

Dimensions in mm



Tolerances: for integers: 0,8 mm
for decimals: 0,03 mm

Figure 2 — Ejector, Venturi ejector and dust pickup tube details for the dust feeder

7.5 Final filter

The final filter captures any loading dust that passes through the test device during the dust loading procedure.

The final filter shall retain at least 98 % of the loading dust and have an $e\text{PM}_1$ efficiency of at least 75 %. The design is optional and it should not gain more than one gram as a result of humidity variations during one test cycle.

8 Qualification of test rig and apparatus

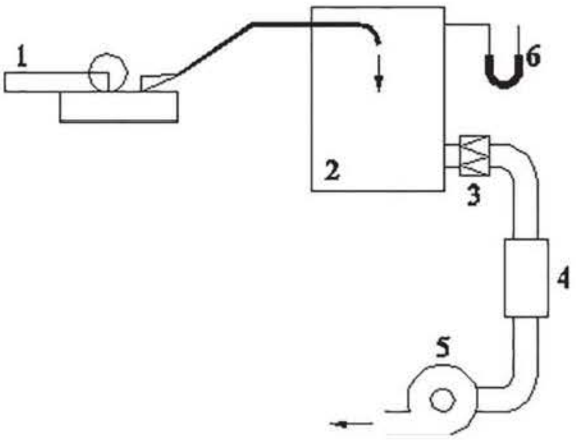
8.1 Schedule of qualification testing requirements

Apparatus qualification tests as described in ISO 16890-2:2016, Clause 8, shall verify quantitatively that the test rig and sampling procedures are capable of providing reliable arrestance measurements and resistance to air flow measurements. Maintenance testing will help keep the system in good operating order. Additional cleaning and maintenance operations subject to any normal laboratory operation will also be needed beyond what is listed in Clause 8.

8.2 Dust feeder air flow rate

The purpose of this test is to verify that the air flow rate for the dust feeder is correct.

The aspirator Venturi is subject to wear from the dust and compressed air and will thereby become enlarged. It is therefore important periodically to monitor the air flow rate from the dust feeder. The flow shall be (6,8 ± 0,2) dm^3/s (14,4 cfm ± 0,4 cfm) while maintaining the static pressures to (0,0 ± 0,1) Pa. For other types of dust feeders, the air flow does not have to be the same as long as it gives the same test result as the dust feeder described in 7.1.3. The required gauge pressure on the ejector tube supply line necessary to provide this air flow at discharge duct pressures of at least 300 Pa (1,2 inch H_2O) above ambient pressure shall be determined using the test device shown in Figure 3.



Key

1 dust feeder

2 plenum with minimum volume of 0,25 m^3 (8,8 ft^3)

3 HEPA filter (ISO 29463-1 class ISO 40 H or higher efficiency)

4 flow metering device

5 fan

6 pressure differential measurement device

Figure 3 — Dust feeder air flow rate

8.3 Final filter efficiency qualification test

Weigh the final filter to the nearest 0,1 g and install it in the test duct without the test device installed. The method specified in 9.2.1 shall be used to challenge the filter with 100 g of loading dust. Remove and weigh the filter. Its weight increase shall be within 2 g of 100 g.

9 Test sequence dust-loading procedure

9.1 Test procedure for the filter

9.1.1 Preparation of the test device

The test device shall be mounted in accordance with the manufacturer's recommendations and after equilibration with the test air (23 ± 5) °C and RH (45 ± 10) % as defined in ISO 16890-2:2016, 7.1.4.2, 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 filter, including any normal mounting frame, shall be sealed into duct in a manner that prevents leakages. 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 within the applicable air flow rates of the duct [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) at standard test conditions], assembly of two or more test devices of the same type or model is permitted, provided that no leaks occur in the resulting test device. The operating conditions of such accessory equipment shall be recorded.

9.1.2 Initial resistance to air flow

Resistance to air flow will be measured at 50 %, 75 %, 100 % and 125 % of the rated air volume flow rate as described in ISO 16890-2:2016, 9.1. These values will establish a curve of resistance to air flow as a function of the air flow rate. The resistance to air flow readings shall be corrected to an air density of 1,20 kg/m^3 (0,075 lb/ft^3). See Annex A.

NOTE When measuring the initial resistance, the upstream mixing orifice as described in 7.1.1 can cause incorrect measurements due to turbulent air flow. Initial resistance to air flow may be slightly different to the value as measured in ISO 16890-2.

9.2 Dust loading

9.2.1 Dust loading procedure

The test device is progressively loaded with the synthetic test dust and the consequent changes in resistance to air flow are determined. Dust increments are weighed to ±0,1 g and placed in the dust tray. The dust is fed to the test device at a concentration of (140 ± 14) mg/m^3 (4,0 ± 0,4 g/1 000 ft^3) until each air flow resistance step value is attained. The arrestance is determined after each incremental dust addition. Before stopping the dust feeding, brush whatever dust remains in the feeder tray to the dust pickup tube so that it is entrained in the duct air flow. Vibrate or rap the dust feeder tube for 30 s. The dust fed to the test device could also be estimated by weighing the remaining dust in the feeder. With the test air flow on, re-entrain any synthetic dust in the duct upstream of the test device by the use of a compressed air jet directed obliquely away from the tested test device.

Stop the test and reweigh the final filter (to at least 0,5 g accuracy) to determine the amount of synthetic dust collected and calculate the arrestance. Any dust deposited in the duct between the test device and the final filter should be collected with a fine brush and included in the final filter weight.

The first 30 g dust loading [or 10 Pa (0,04 inch H_2O) increase, whichever comes first] will give the initial arrestance and the additional dust increments should give a smooth curve arrestance versus dust loading up to the final resistance.

For filters with particle removal efficiency <50 % in the PM_{10} particle range, the final resistance to air flow is 200 Pa (0,8 inch H_2O), while for filters with a particle removal efficiency ≥50 % in the PM_{10} particle range, the final resistance to air flow is 300 Pa (1,2 inch H_2O).

NOTE Reporting at these final resistance to air flow values is required, but testing can go beyond.

The test dust loading curve should be built up by a minimum of five data points evenly distributed to create a smooth curve. However, a filter with low initial pressure loss, or a filter with low increase of pressure versus loading dust, requires one or more measuring points in the beginning of the dust loading procedure, while other filters may need an extra measuring point at the end of the dust loading procedure to give an even distribution of measuring points (see Table 2).

Table 2 — Performance values to measure or calculate after each dust loading step

State	Parameter to be determined		
	Arrestance	**Test dust capacity**	**Resistance to air flow**
Initial, before dust loading	NO	NO	YES
After 30 g dust, or 10 Pa (0,04 inch H_2O) increase, whichever comes first (the first loading to give initial arrestance)	YES	NO	YES
At the end of each intermediate increment	YES	NO	YES
After the last increment (final resistance to air flow)	YES	YES	YES

9.2.2 Arrestance

The arrestance shall be determined after each dust loading step.

After reaching the next resistance to air flow level, the previously weighed final filter is removed from the test rig and reweighed. The weight increase indicates the mass of dust that has passed the test device. The arrestance, A_j, for the dust loading step "j" shall be calculated as given in Formula (1):

$$A_j = \left(1 - m_j / M_j\right) 100\,\% \tag{1}$$

where

m_j is the mass of dust passing the filter (the mass gain of final filter Δm_{ff} and the dust after the device m_d) at the dust loading phase "j";

M_j is the mass of loaded dust (dust increment Δm) during the dust loading phase "j".

The test is stopped if the arrestance is lower than 75 % of the maximum measured arrestance or if two values are lower than 85 % of the maximum measured value. The initial arrestance is calculated after the first 30 g loading dust [or 10 Pa (0,04 inch H_2O) increase, whichever comes first]. If test has to be stopped, test dust capacity shall be reported "not applicable due to loss of arrestance during loading process".

An average arrestance is calculated from at least five single values of the arrestance. The average dust arrestance, A_m, shall be calculated as given in Formula (2):

$$A_m = \left(1/M\right) \times \left[M_1 \times A_1 + M_2 \times A_2 + \ldots + M_n \times A_n\right] \tag{2}$$

where

$M = M_1 + M_2 + ... + M_n$ is the total mass of dust fed;

$M_1, M_2, ... M_n$ are dust masses successively fed to reach the final resistance to air flows $\Delta p_1, \Delta p_2 .... \Delta p_n$.

Arrestance values above 95 % should be reported as >95 %.

In plotting a continuous curve of arrestance against loaded dust, the curve shall be drawn through arrestance values plotted at the mid-point of their associated weight increment.

9.2.3 Test dust capacity

The test dust capacity for a given final resistance to air flow is calculated by multiplying the total mass of loaded dust (corrected for the losses upstream of the test device) by the average arrestance.

10 Reporting results

10.1 General

Test results shall be reported using the test report format shown in this part of ISO 16890. Figure 4 and Figure 5 comprise the complete test report and are examples of acceptable forms. Use of this exact format is not required, but the report shall include all of the items shown in 10.2.

10.2 Required reporting elements

The following information is required in every test report. Any report not containing all required elements shall be considered invalid.

10.2.1 Report values

All data values for arrestance shall be reported as whole number values only (no decimal or fractions).

Data values for resistance to air flow shall be reported as whole number values only (no decimal or fractions) in SI units (Pa). IP units (inch H_2O) with two decimal places may also be added.

10.2.2 Report summary

The one page summary section of the performance report (see Figure 4) shall include the following information:

a) laboratory information:

   1) laboratory name;

   2) laboratory location and contact information;

   3) test operator's name(s);

   4) method of air flow measurement;

b) test information:

   1) identification of this standard;

   2) unique test report identification;

   3) date of the test;

   4) how the sample was obtained;

c) test device information:

   1) manufacturer's name (or name of the marketing organization, if different from the manufacturer);

   2) brand and model number as marked on the test device;

   3) test device condition (e.g. clean, discharged according to ISO 16890-4, tested according to ISO 16890-2, used, etc.);

   4) dimensions (height, width and depth);

   5) physical description of construction (e.g. pocket filter, number of pockets; pleated panel, number and depth of pleats);

   6) media description including:

      i) type of media with description and identification code (e.g. glass fibre ABC123, inorganic fibre 123ABC), if known;

      ii) media colour;

      iii) effective filter media area;

      iv) type and amount of any additive to the media, if known;

      v) electrostatic charge, if known;

   7) a photo of the actual test device is highly recommended, but not required;

   8) any other pertinent descriptive attributes;

d) test device literature data or operating data as stated by the manufacturer, if known:

   1) test device initial resistance to air flow at the test air flow rate;

   2) rated final resistance to air flow at the test air flow rate;

   3) initial particle removal efficiency;

   4) any other literature data available or furnished operating data;

e) test conditions:

   1) test air flow rate;

   2) test air temperature and relative humidity;

   3) loading dust used;

f) test data:

   1) resistance to air flow data at the test air flow rate;

   2) resistance to air flow vs test dust load;

   3) arrestance values vs test dust load.

10.2.3 Report details

The report details shall include but are not limited to the following information.

a) Measured results

1) The resistance to air flow data at each of the required air flow rates shall be reported in table format (see Table 3) and as a graph of air flow vs. resistance to air flow.

i) The reported resistance to air flow shall be corrected to an air density of 1,20 kg/m^3. However, if the test air density is between 1,16 kg/m^3 (0,072 lb/ft^3) and 1,24 kg/m^3 (0,077 lb/ft^3), no corrections need to be made. The corrections are described in Annex A.

2) The results of the arrestance measurement shall be reported both in table (summary page) (see Table 4) and graphical format.

b) Concluding statement

1) The results of this test relate only to the test device in the condition stated herein. The performance results cannot by themselves be quantitatively applied to predict filtration performance in all "real life" environments.

ISO 16890-3:2016 - AIR FILTER TEST RESULT SUMMARY	**Testing Organization** Name Address Phone

GENERAL				
Test ID:		Date of test:		Operator:
			Air flow measurement:	Test device obtained from:

DEVICE TESTED		
Model:	Manufacturer:	Filter dimensions (W x H x D) (mm):
Type of media:	Net effective media area (m²):	Construction: *(# pleats, pockets, etc.)*
Filter/media electrostatic charge:	Media colour:	Media adhesive:
Device Condition: *(clean/initial, used, conditioned per ISO 16890-4, tested per ISO 16890-2, etc.)*		
Other descriptive information:		

TEST DATA SUMMARY				
Test air flow rate (m³/s):	Test air temperature (ºC):	Test air RH (%):		Loading dust:

RESULTS					
Resistance to air flow (Pa)		Dust loading results			
Measured:	Rated Initial:	Initial arrestance [%]	Average arrestance [%]	Test Dust capacity [g]	
	Rated Final:				

Test Device Photo

Remarks:

NOTE
The results of this test relate only to the test device in the condition stated herein.
The performance results cannot by themselves be quantitatively applied to predict filtration performance in all "real life" environments.
Units are shown in SI, but can be converted to IP

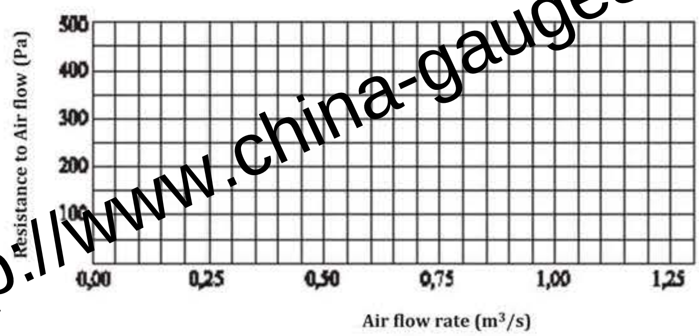
Figure 4 — Test report summary page format

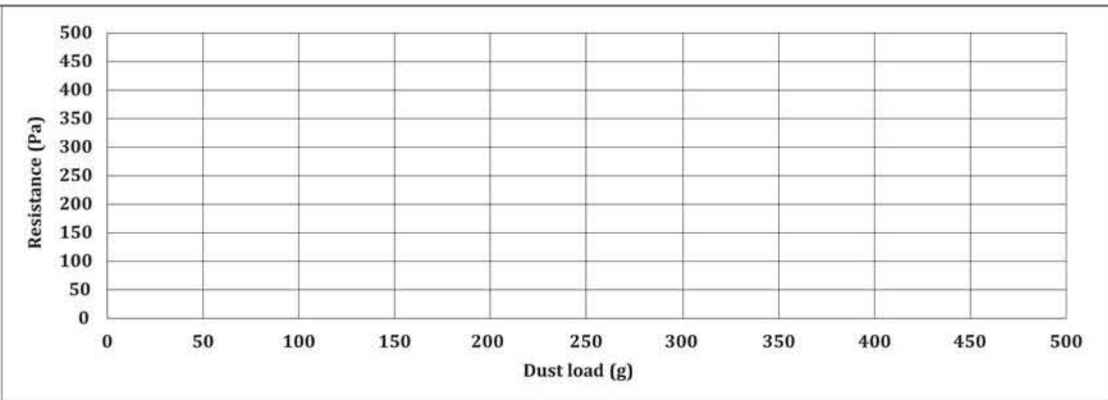
ISO 16890-3:2016 - AIR FILTER TEST RESULT DETAILS		**Testing Organization** Name Address Phone
Test ID:	Date of test:	Operator:

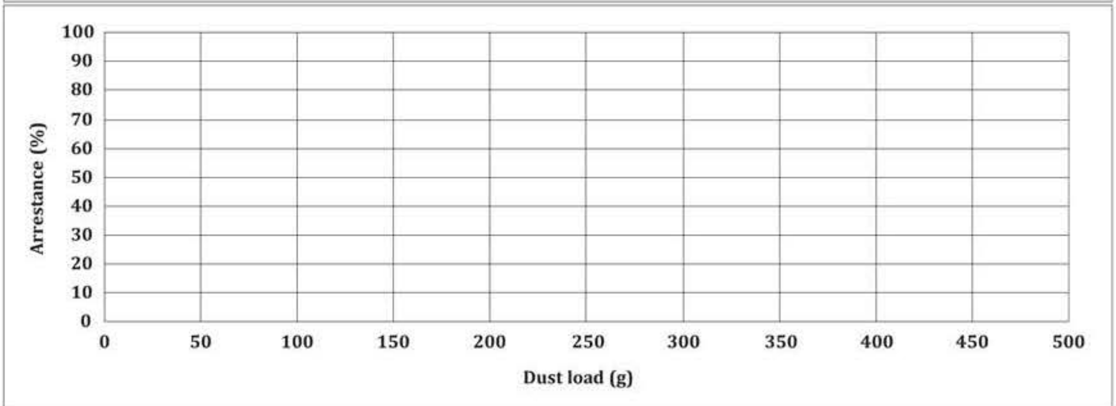
TEST DATA DETAILS

Resistance to air flow rate

% of Rated Air flow	Air flow (m³/s)	Resistance to Air flow (Pa)
50%		
75%		
100%		
125%		







NOTE
The results of this test relate only to the test device in the condition stated herein.
The performance results cannot by themselves be quantitatively applied to predict filtration performance in all "real life" environments.
Units are shown in SI, but can be converted to IP

Figure 5 — Test report details page format

Table 3 — Air flow rate and resistance to air flow after different dust loading phases

ISO 16890-3:2016 - Air flow rate and resistance to air flow after different dust loading phases												
Test device:												
Test no.:												
Test aerosol:												
Air flow rate: m^3/s												
Date	**Loaded dust**	**Air flow meter**				**Filter**						
	m_{tot} g	t_f °C	p_{sf} kPa	Δp_f Pa	q_m kg/m^3	t °C	φ %	p_a kPa	ρ kg/m^3	q_v m^3/s	Δp Pa	$\Delta p_{1,20}$ Pa
	Clean filter											
yyyy-mm-dd												
yyyy-mm-dd												
yyyy-mm-dd												
yyyy-mm-dd												
yyyy-mm-dd												
	Clean filter resistance to air flow is proportional to $(q_v)^n$, where *n* =											
	Dust loading phase											
yyyy-mm-dd												
yyyy-mm-dd												
yyyy-mm-dd												
yyyy-mm-dd												
yyyy-mm-dd												
yyyy-mm-dd												
yyyy-mm-dd												
yyyy-mm-dd												
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yyyy-mm-dd												

Symbols and units

m_{tot}	Cumulative mass of loaded dust to filter, g	t_f	Temperature at air flow meter, °C
p_a	Absolute air pressure upstream of filter, kPa	ρ	Air density upstream of filter, kg/m^3
p_{sf}	Air flow meter static pressure, kPa	φ	Relative humidity upstream of filter, %
q_m	Mass flow rate, kg/m^3	Δp	Measured filter resistance to air flow, Pa
q_v	Air flow rate at filter, m^3/s	Δp_f	Differential pressure used for determination of air flow rate, Pa
t	Temperature upstream of filter, °C	$\Delta p_{1,20}$	Filter resistance to air flow at air density 1,20 kg/m^3, Pa

NOTE Units are shown in SI, but can be converted to IP.

Table 4 — Resistance to air flow and arrestance after different dust loading phases

ISO 16890-3:2016 - Resistance to air flow and arrestance after different dust loading phases

Test device:

Test no.:

Test aerosol:

Air flow rate: m^3/s

Date	Δp_1 Pa	Δm g	m_{tot} g	Δp_2 Pa	m_1 g	m_2 g	Δm_{ff} g	m_d g	A %
yyyy-mm-dd									
yyyy-mm-dd									
yyyy-mm-dd									
yyyy-mm-dd									
yyyy-mm-dd									
yyyy-mm-dd									

Mass of tested device

Initial mass of tested device: g

Final mass of tested device: g

Symbols and units

A Arrestance, %

m_d Dust in duct after device, g

m_{tot} Cumulative mass of loaded dust to filter, g

m_1 Mass of final filter before dust increment, g

m_2 Mass of final filter after dust increment, g

Δm Dust increment, g

Δm_{ff} Mass gain of final filter, g

Δp_1 Resistance to air flow before dust increment, Pa

Δp_2 Resistance to air flow after dust increment, Pa

NOTE Units are shown in SI, but can be converted to IP.

Annex A
(informative)

Resistance to air flow calculation

All resistances to air flow measured during the test should be corrected to a reference air density of 1,20 (1,1987) kg/m³ (0,075 lb/ft³) which corresponds to standard air conditions: temperature 20 °C (68 °F), barometric pressure 101,325 kPa (14,7 lb/in²), relative humidity 50 %. However, as long as the air density is between 1,16 kg/m³ (0,072 lb/ft³) and 1,24 kg/m³ (0,077 lb/ft³), no corrections need to be made. All calculations are expressed in SI units only.

The resistance to air flow of a test device can be expressed as given in Formula (A.1) and Formula (A.2):

$$\Delta p = \mathrm{c}\left(q_{\mathrm{V}}\right)^{\mathrm{n}} \tag{A.1}$$

$$c = k \times \mu^{2-\mathrm{n}} \times \rho^{\mathrm{n}-1} \tag{A.2}$$

where

Δp is the resistance to air flow, in Pa;

k is a constant;

q_{V} is the air flow rate, in m³/s;

μ is the dynamic viscosity of air, in Pa s;

n is an exponent;

ρ is the air density, in kg/m³.

The readings of the air flow measuring system shall be convened to the volumetric air flow rate at the conditions prevailing at the inlet of the tested device. With these air flow rate values and the measured resistances to air flow, the exponent "n" from Formula (A.1) could be determined by using a least square technique.

With a known value of exponent "n", the measured resistances to air flow can be corrected to standard air conditions using the Formula (A.3):

$$\Delta p_{1,20} = \Delta p\left(\frac{\mu_{1,20}}{\mu}\right)^{2-\mathrm{n}} \times \left(\frac{\rho_{1,20}}{\rho}\right)^{\mathrm{n}-1} \tag{A.3}$$

where the unsubscripted quantities refer to the values at the test conditions, the subscripted quantities to values at the standard air conditions and:

$\rho_{1,20}$ = 1,1987 kg/m³

$\mu_{1,20}$ = 18,097 × 10^{-6} Pa s

The exponent "n" is usually determined only for a clean test device. During the dust loading phase, exponent "n" can change. As it is undesirable to measure pressure loss curves after each dust loading phase, the initial value of exponent "n" may be used during the device test. The air density ρ (kg/m³) of temperature t (°C), barometric pressure p (Pa) and relative humidity φ (%) can be obtained by Formula (A.4):

$$\rho = \frac{p - 0{,}378 p_{\mathrm{w}}}{287{,}06\left(t + 273{,}15\right)} \tag{A.4}$$

where p_{w} (Pa) is the partial vapour pressure of water in air given by the Formula (A.5):

$$p_{\mathrm{w}} = \frac{\varphi}{100} p_{\mathrm{ws}} \tag{A.5}$$

and p_{ws} (Pa) is the saturation vapour pressure of water in air at temperature t (°C) obtained from Formula (A.6):

$$p_{\mathrm{ws}} = \exp\left[59{,}484\,085 - \frac{6\,790{,}498\,5}{t + 273{,}15} - 5{,}028\,02 \times \ln\left(t + 273{,}15\right)\right] \tag{A.6}$$

The dynamic viscosity μ (Pa s) at a temperature t (°C) can be obtained from Formula (A.7):

$$\mu = \frac{1{,}455 \cdot 10^{-6}\left(t + 273{,}15\right)^{0{,}5}}{1 + 110{,}4 / \left(t + 273{,}15\right)} \tag{A.7}$$

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