INTERNATIONAL STANDARD

ISO 29461-1

Second edition
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Air intake filter systems for rotary machinery — Test methods —

Part 1: **Static filter elements**

Systèmes de filtration d'air d'admission pour machines tournantes — Méthodes d'essai —

Partie 1: Éléments filtrants pour filtres statiques

Reference number
ISO 29461-1:2021(E)

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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).

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).

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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 29461-1:2013), which has been technically revised.

The main changes compared to the previous edition are as follows:

— a new test method, referring to ISO 16890 (all parts) and ISO 29463 (all parts), has been added;

— a classification table has been added;

— previous Annexes A, B, C and D have been deleted; previous Annex E has become Annex A.

A list of all parts in the ISO 29461 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

In rotating machinery applications, the filtering systems, typically a set of filter elements arranged in a suitable manner, are an important part of the whole turbine/compressor system. The development of turbine machinery used for energy production or others has led to more sophisticated equipment; and therefore the importance of good protection of these systems has become more important in the recent years. It is known that particulate contamination can deteriorate a turbine power system quite substantially if not taken care of.

This event is often described as “erosion”, “fouling” and “hot corrosion” where salt and other corrosive particles are known as potential problems. Other particulate matters can also cause significant reduction of efficiency of the systems. It is important to understand that air filter devices in such systems are located in various environmental conditions. The range of climate and particulate contamination is very wide, ranging from deserts to humid rain forests to arctic environments. The requirements on these filter systems are obviously different depending on where they will be operating.

ISO 29461 (all parts) has based the performance of the air intake filter systems not only upon heavy dust collection but also particulate efficiency in a size range that is considered to be the problematic area for these applications. Both ultra-fine and fine particles, as well as larger particles, should be considered when evaluating turbine fouling. In typical outdoor air, ultra-fine and fine particles in the size range from 0,01 µm to 1 µm contribute to > 99 % of the number concentration and to > 90 % of the surface contamination. The majority of the mass normally comes from larger particles (>1,0 µm).

Turbo-machinery filters comprise a wide range of products from filters for very coarse particles to filters for very fine, sub-micron particles. The range of products varies from depth to surface loading systems, which can be regenerated e.g. by pulse cleaning. The filters and the systems have to withstand a wide temperature and humidity range, very low to very high dust concentration and mechanical stress. The shape of products existing today can be of many different types and have different functions such as droplet separators, coalescing products, filter pads, metal filters, inertial filters, filter cells, bag filters, panel-type, cleanable and depth loading filter cartridges and pleated media surface filter elements.

ISO 29461 (all parts) provides a way to compare these products in a similar way and define what criteria are important for air filter intake systems for rotary machinery performance protection. The aim is to compare different filters and filter types with respect to the operating conditions they finally will be used in. For instance, if a filter or a filter system is meant to operate in an extreme, very dusty environment, the real particulate efficiency of such a filter cannot be predicted because the dust loading of the filter plays an important role. A further part of ISO 29461 will address the performance of cleanable and surface loading filters. Filters in turbo-machinery applications can also face very harsh operating conditions such as high air flow rates or water and salt ingress. Further parts of ISO 29461 will address the performance of filters under such harsh conditions.

Air intake filter systems for rotary machinery — Test methods —

Part 1: Static filter elements

1 Scope

This document specifies methods and procedures for determining the static performance of particulate air filters used in air intake filter systems for rotary machinery such as stationary gas turbines, compressors and other stationary internal combustion engines. It applies to air filters with an efficiency of 85 % or more for the MPPS (EPA and HEPA filters) which are tested according to ISO 29463 (all parts) and filters with a lower efficiency which are tested according to ISO 16890 (all parts). The procedures described in both ISO 16890 (all parts) and ISO 29463 (all parts) are applied and extended by this document to air filters which operate at flow rates within the range 0,24 m^3/s (850 m^3/h) up to 2,36 m^3/s (8 500 m^3/h).

Static filter systems normally use multiple stages of coarse, fine and optional EPA or HEPA filter elements to protect the machinery. The scope of this document includes methods for performance testing of individual filter elements. It does not include methods for the direct measurement of the performance of entire systems as installed in service except in cases where they can meet the qualification criteria for the test assembly. Nevertheless, cumulative filter efficiencies of multistage systems of fine filters can be calculated by using the methods described in ISO 16890-1.

This document refers to static (barrier) filter systems but can also be applied to other filter types and systems in appropriate circumstances, for example to evaluate the initial efficiency of cleanable and surface loading filters.

The performance results obtained in accordance with this document cannot be quantitatively applied (by themselves) to predict performance in service with regard to efficiency and lifetime.

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 15957, *Test dusts for evaluating air cleaning equipment*

ISO 16890 (all parts), *— Air filters for general ventilation*

ISO 29463 (all parts), *— High efficiency filters and filter media for removing particles from air*

ISO 29464, *Cleaning of 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.

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 http://www.electropedia.org/

3.1
EPA filter
efficient particulate air filter
filters with performance complying with requirements of filter class ISO T10 to ISO T12 as per this document

Note 1 to entry: EPA filters cannot be and shall not be leak tested.

3.2
initial gravimetric arrestance
A_{100}
ratio of the mass of a standard test dust retained by the filter to the mass of dust fed after the first 100 g of dust load

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

4 Symbols and abbreviated terms

For the application of this document, the following symbols and abbreviated terms apply:

$e\text{PM}_{x,\text{ min}}$	Minimum efficiency value with x = 1 µm, 2,5 µm or 10 µm of the conditioned filter element, % (see ISO 16890-1)
$e\text{PM}_x$	Efficiency with x = 1 µm, 2,5 µm or 10 µm, % (see ISO 16890-1)
MPPS	Most penetrating particle size

5 Testing and classification of filter efficiencies

Filters with an efficiency of 85 % or more for the MPPS (EPA and HEPA filters) shall be tested according to ISO 29463 (all parts), while filters with a lower efficiency shall be tested according to ISO 16890 (all parts). Filters are classified in groups and classes based on their efficiency as defined in Table 1.

NOTE For the classification of ISO $e\text{PM}_1$ and ISO $e\text{PM}_{2,5}$ filters only the $e\text{PM}_{x,\text{ min}}$ values are used.

HEPA filters (class T13) shall be individually tested and their efficiency determined at MPPS according to ISO 29463-5. Filters shall be individually leak tested according to ISO 29463-4 where, in addition to the reference leak scan method, four alternate methods for leak testing are allowed. For HEPA filters with geometries which do not allow a scan testing, like e.g. cartridges or V-bank filters, the oil thread test method or one of the other suitable (non-scanning) methods described in ISO 29463-4 can be applied. Alternate norms used for leak testing should be clearly identified on the filter and certifications.

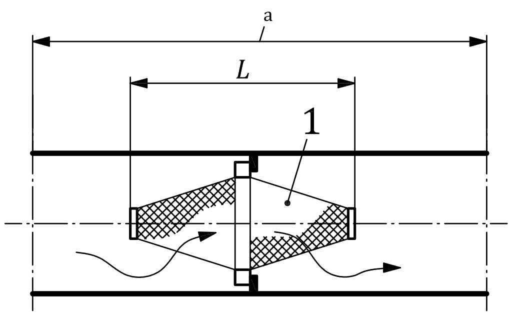
In order to extent the volume flow rate and the range of filter geometries (e.g. cylindrical filters), deviations and extensions to the test rig defined by ISO 16890-2 and ISO 29463-5, respectively, are described below.

The test rig consists of several square duct sections with typical 610 mm × 610 mm nominal inner dimensions except for the section where the filter is installed. This section has nominal inner dimensions between 616 mm and 622 mm. The length of this duct section shall be at least 1,1 times the length of the filter, with a minimum length of 1 m as shown in Figure 1 (for more details on the test rig see ISO 16890-2). The filter shall be within the section and shall not protrude out of this section, either upstream or downstream. The test duct may need to have larger dimensions in cases when very large filters or integrated filter-system-element are to be tested. In those cases, other dimensions are allowed as long as the qualification procedures described in ISO 16890-2 are fulfilled. An example of a special (large) filter transition can be seen in Figures 2 and 3.

Table 1 — Filter classification

Class	Group	ISO 29463 (all parts)	ISO 16890 (all parts)			
		MPPS efficiency	$e\mathrm{PM}_{1,\,\mathrm{min}}$	$e\mathrm{PM}_{2,5,\,\mathrm{min}}$	$e\mathrm{PM}_{10}$	Initial gravimetric arrestance A_{100}
ISO T1	Coarse					20 % < A_{100} < 50 %
ISO T2						≥ 50 %
ISO T3						≥ 70 %
ISO T4						≥ 85 %
ISO T5	$e\mathrm{PM}_{10}$				≥ 50 %	
ISO T6	$e\mathrm{PM}_{2,5}$			≥ 50 %		
ISO T7	$e\mathrm{PM}_1$		≥ 50 %			
ISO T8			≥ 70 %			
ISO T9			≥ 85 %			
ISO T10	EPA	≥ 85 %				
ISO T11		≥ 95 %				
ISO T12		≥ 99,5 %				
ISO T13	HEPA	≥ 99,95 %				

In case of circular cartridges, the test setup (mounting of the filters in the test duct) shall be as close to the real application as possible. In cases of large cylinders, a mounting plate with an additional hole for the air inlet/outlet can be sufficient (see Figure 4). In terms of much smaller cylinders an additional transition could be inserted in the duct (see Figure 3). This shall however be analysed specifically for each construction, taking into consideration possible jetting effect that can affect the velocity and aerosol concentration in the test duct cross section.



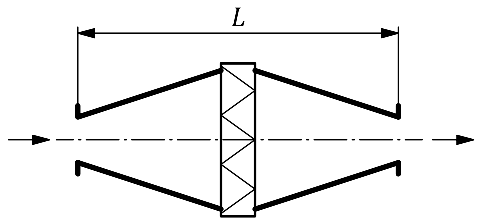
Key

1 filter to be tested

L filter length

a Duct section length (<1 000 mm and/or 1,1 × *L*).

Figure 1 — Duct section including filter to be tested

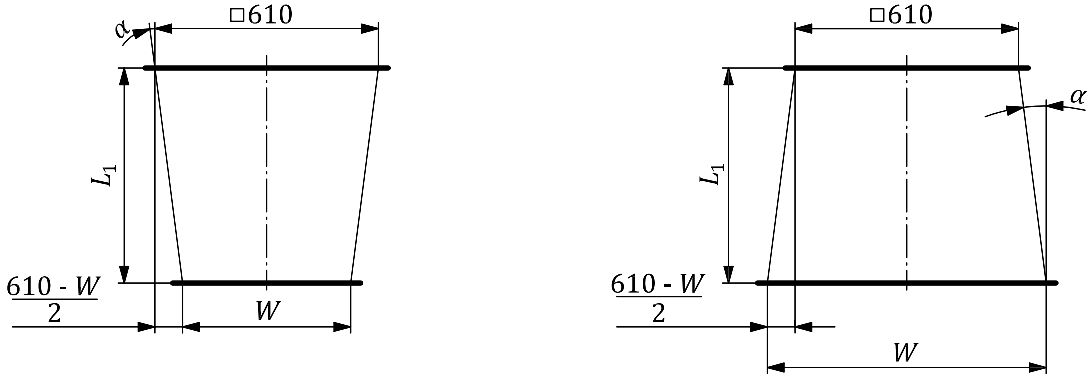


Key

L filter length

Figure 2 — Example of a filter section with transition for special filter constructions

Dimensions in millimetres



a) Mounting filter smaller than the test duct **b) Mounting filter larger than the test duct**

Key

L_1 length of the transition duct

W width of the filter element to be tested

α angle of maximum 7°

Figure 3 — Details of transition ducts for mounting filters

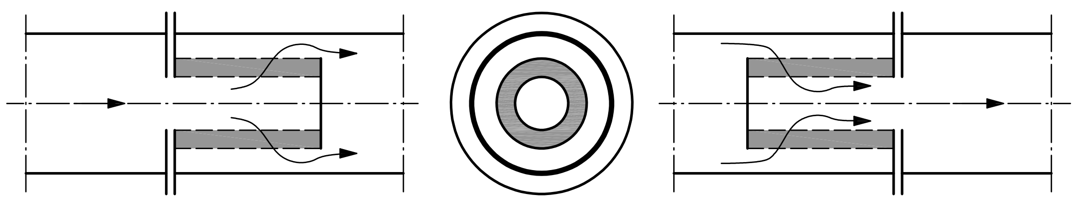


Figure 4 — Examples of mounting circular cartridges in the test duct

6 Determination of the air flow resistance versus the mass of test dust captured

For the determination of the air flow resistance versus the mass of test dust captured, the procedures described in ISO 16890-3 shall be applied. The synthetic loading dust as specified in ISO 15957 as L2 shall be used as a loading dust for reporting results. Filters with particle removal efficiency $e\text{PM}_{10}$ < 50 % (ISO coarse according to ISO 16890-1) shall be loaded to a final resistance to air flow of 375 Pa, while filters with a particle removal efficiency $e\text{PM}_{10}$ ≥ 50 % (fine filter groups ISO $e\text{PM}_{10}$, ISO $e\text{PM}_{2,5}$ and ISO $e\text{PM}_1$ according to ISO 16890 (all parts)) and EPA and HEPA filters up to ISO 45H according to ISO 29463-1 shall be loaded to a final resistance to air flow of 625 Pa. As additional data points, higher values for the final resistance to air flow can be defined between vendor and buyer for information.

The first 100 g dust loading (or 15 Pa increase, whichever comes first) gives the initial gravimetric arrestance; and the additional dust increments should give a smooth curve arrestance versus dust loading up to the final resistance

7 Conditioning method to determine the minimum fractional test efficiency

Certain types of filter media rely on electrostatic effects to achieve high efficiencies at low resistance to airflow. Exposure to some types of challenge, such as combustion particles or other fine particles, can inhibit such electrostatic effects with the result that filter performance suffers. The test procedure described in ISO 16890-4 and ISO 29463-5 provides techniques for identifying this type of behaviour. This procedure is used to determine whether the filter particulate efficiency is dependent on the electrostatic removal mechanism and to provide quantitative information about the importance of the electrostatic removal. Applying these procedures is a mandatory part of the filter testing and classification of filters according to this document.

8 Reporting

The one-page summary section of the performance report according to this document shall include the following information:

— General:

  a) testing organization including name, location and contact information;

  b) report number;

  c) date of the report;

  d) name of report supervisor;

  e) test(s) requested by;

  f) date when and how the tested device (filter) was obtained.

— Manufacturer's data of the tested device:

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

  h) brand and model name or number as marked on the tested device (full identification of the tested device); in case of HEPA filters, each filter shall be marked with an individual identifier, which allows to link the filter element to the individual test report;

  i) description of the physical construction (e.g. pocket filter, number of pockets);

  j) dimensions (width, height, depth);

  k) type of medium, if possible or available the following shall be described:

    — identification code (e.g. glass fibre type ABC123, inorganic fibre type 123ABC);

    — net effective filtering area as determined by the testing organization according to Annex A;

    — in case of HEPA filters the MPPS of the filter medium as tested per ISO 29463-3;

  l) additional information if needed;

  m) a photo of the actual test device is highly recommended, but not required.

— Test data:

n) test air flow rate;

o) number of the attached test report according to ISO 16890-2;

p) number of the attached test report according to ISO 16890-4;

q) number of the attached test report according to ISO 16890-3.

— Results:

r) initial and final test pressure differential;

s) in case of fine filters:

1) efficiency values $e\text{PM}_1$, $e\text{PM}_{2,5}$ and $e\text{PM}_{10}$, including uncertainties;

2) minimum efficiencies $e\text{PM}_{1,\text{ min}}$ and $e\text{PM}_{2,5,\text{ min}}$, including uncertainties;

t) in case of EPA and HEPA filters: the efficiency to MPPS;

u) in case of HEPA filters: the result of the leakage test according to ISO 29463-4;

v) initial and average arrestance;

w) test dust capacity;

x) ISO filter class according to Table 1.

— Concluding statement:

y) 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.

In the summary report, except for the efficiency to MPPS larger than 99 % for EPA and HEPA filters, the results shall be rounded to the nearest integer.

Annex A
(normative)

Net area calculation

A.1 Estimating effective filtering area of a filter used in air cleaning of rotary machinery

The information of the media area, provided by the filter manufacturer, shall be checked by measurements and calculation and reported. The filter area shall be calculated according to this annex. If the shape of the pockets/pleats deviates significantly from these schematic drawings an additional estimation to fit the standard shape should be made. This shall then be commented in the report.

A.2 Pocket filters

Pocket filters typically consists (for a full module, 592 mm × 592 mm face dimensions) of a set of pockets arranged vertically in a mounting frame (see Figure A.2). To calculate the net area the following procedure should be used:

a) Stretch each pocket in the airflow direction so that it expands to its full length (L).

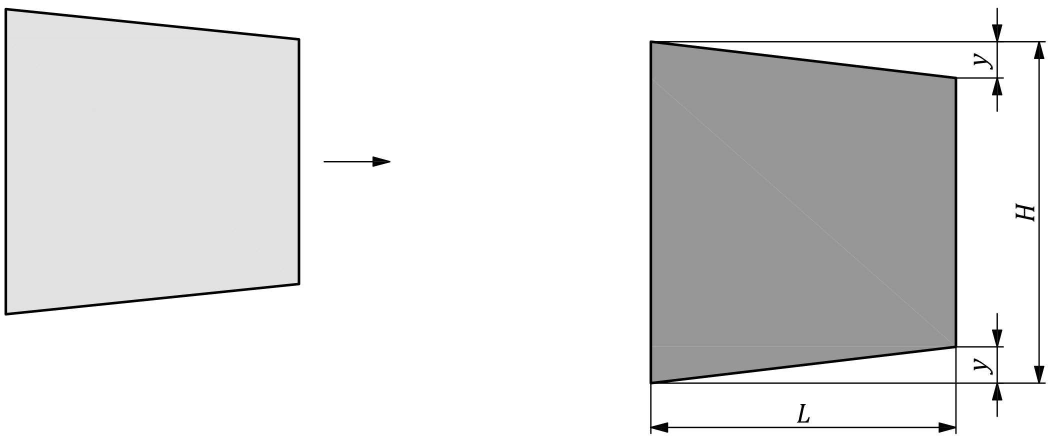
b) Measure the length of each pocket.

c) Measure the shape of the pocket according to Figure A.1 and Figure A.3.

d) Calculate the net area for each pocket.

e) Sum the pocket net areas to the total net area.

f) Estimate the error in measurement as tolerance range of the measured area.



a) In construction **b) Pocket flattened out**

Key

H height of the pocket, inlet side – flattened pocket

L length of pocket

y difference in height on top (and bottom) along the length (*L*) of pocket

Figure A.1 — Pocket filter, area calculation

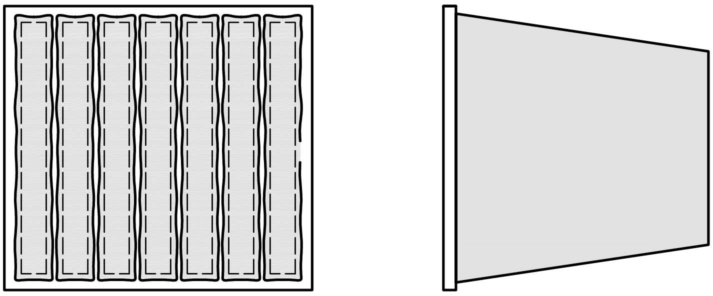
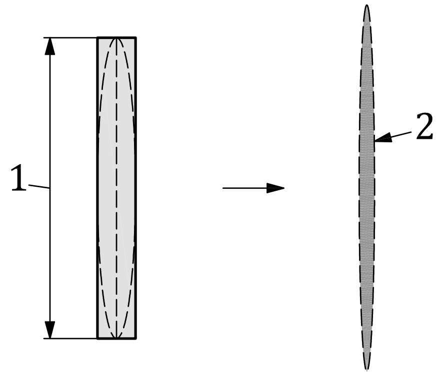


Figure A.2 — Front view (left) and side view (right), pocket filter



Key

1 pocket height in construction

2 pocket flattened out

Figure A.3 — Front view, pocket filter, flattened

The pocket (i) net area is calculated using Formula (A.1).

$$A_i = 2 \times (H \times L - y \times L) \tag{A.1}$$

For practical reasons, it is allowed to measure the pocket height at $L/2$, if the tapering is linear proportional.

Then the formula becomes:

$$A_i = 2 \times (H_{L/2} \times L) \tag{A.2}$$

The total net area (i = 1 to N) is calculated using Formula (A.3).

$$A_{\text{tot}} = \sum_{i=1}^{N} A_i \tag{A.3}$$

where N is the total number of pockets.

See Formulae (A.4) and (A.5) for a calculation example of the tolerance range.

H: ± 0,002 m (2 mm)

L: ± 0,003 m (3 mm)

y: ± 0,001 m (1 mm)

$$A_{\mathrm{min}} = \Sigma\ [2 \times (\{H - 0{,}002) \times \{L - 0{,}003\} - \{y + 0{,}01\} \times \{L - 0{,}002\})]_i \quad \text{(A.4)}$$

$$A_{\mathrm{max}} = \Sigma\ [2 \times (\{H + 0{,}002) \times \{L + 0{,}003\} - \{y - 0{,}01\} \times \{L + 0{,}002\})]_i \quad \text{(A.5)}$$

Formula (A.6) shows the reported result.

$$A_{\mathrm{net}} = A_{\mathrm{tot}}\ (A_{\mathrm{max}}, A_{\mathrm{min}}) \quad \text{(A.6)}$$

A.3 Pleated filters

Pleated filters are normally constructed by mini-pleat technology or with the separator pleating (typically aluminium, plastic or paper). Example of the different type of filters can be seen in Figure A.4 and Figure A.5. A pleated filter can consist of a pleated package that comprises all filter media, or it may be constructed out of several packages that are assembled into a complete filter. To measure and calculate the net area of the filter, the following procedure is used:

a) Measure the effective width (W) of the (each) filter pack (cross pleating direction).

b) Measure the height (H) of the (each) air filter media pack. This can be difficult to measure (practical reasons). Instead of the height the pleat depth could be measured with, for instance, a small paper strip or calliper device.

c) The effective width (W) that shall be measured shall not include sealant (potting) material that cover the air filter media (where obviously no air can penetrate the filter media).

d) Count the number of pleat tips within the effective length (pleat direction).

e) In case of separator filter (rectangular pleat shape) measure the pleat tip width (t).

f) In case of mini-pleated filter (V-shaped pleat shape), $t = 0$.

g) In the case of a filter consisting of several packages, the total sum of all packages is the total area of the filter.

h) Estimate the error in measurement as tolerance range of the measured area.

The pleat (i) net effective area is calculated using Formula (A.7).

$$A_i = 2 \times (H \times W + t \times W) \quad \text{(A.7)}$$

The total net area ($i = 1$ to N) is calculated using Formula (A.8).

$$A_{\mathrm{tot}} = \sum_{i=1}^{N} A_i \quad \text{(A.8)}$$

where N is the total number of pleats.

See Formulae (A.9) to (A.12) for a calculation example of the tolerance range.

H: ± 0,001 m (1 mm)

W: ± 0,002 m (2 mm)

t: ± 0,000 5 m (0,5 mm)

In case of mini-pleat filter:

$$A_{\text{min}} = \Sigma \, [2 \times (\{H - 0{,}001) \times \{W - 0{,}002\})]_i \tag{A.9}$$

$$A_{\text{max}} = \Sigma \, [2 \times (\{H + 0{,}001) \times \{W + 0{,}002\})]_i \tag{A.10}$$

In case of separator filter:

$$A_{\text{min}} = \Sigma \, [2 \times (\{H - 0{,}001\} \times \{W - 0{,}002\} + \{t - 0{,}000\,5\} \times \{W - 0{,}02\})]_i \tag{A.11}$$

$$A_{\text{max}} = \Sigma \, [2 \times (\{H + 0{,}001\} \times \{W + 0{,}002\} + \{t + 0{,}000\,5\} \times \{W + 0{,}02\})]_i \tag{A.12}$$

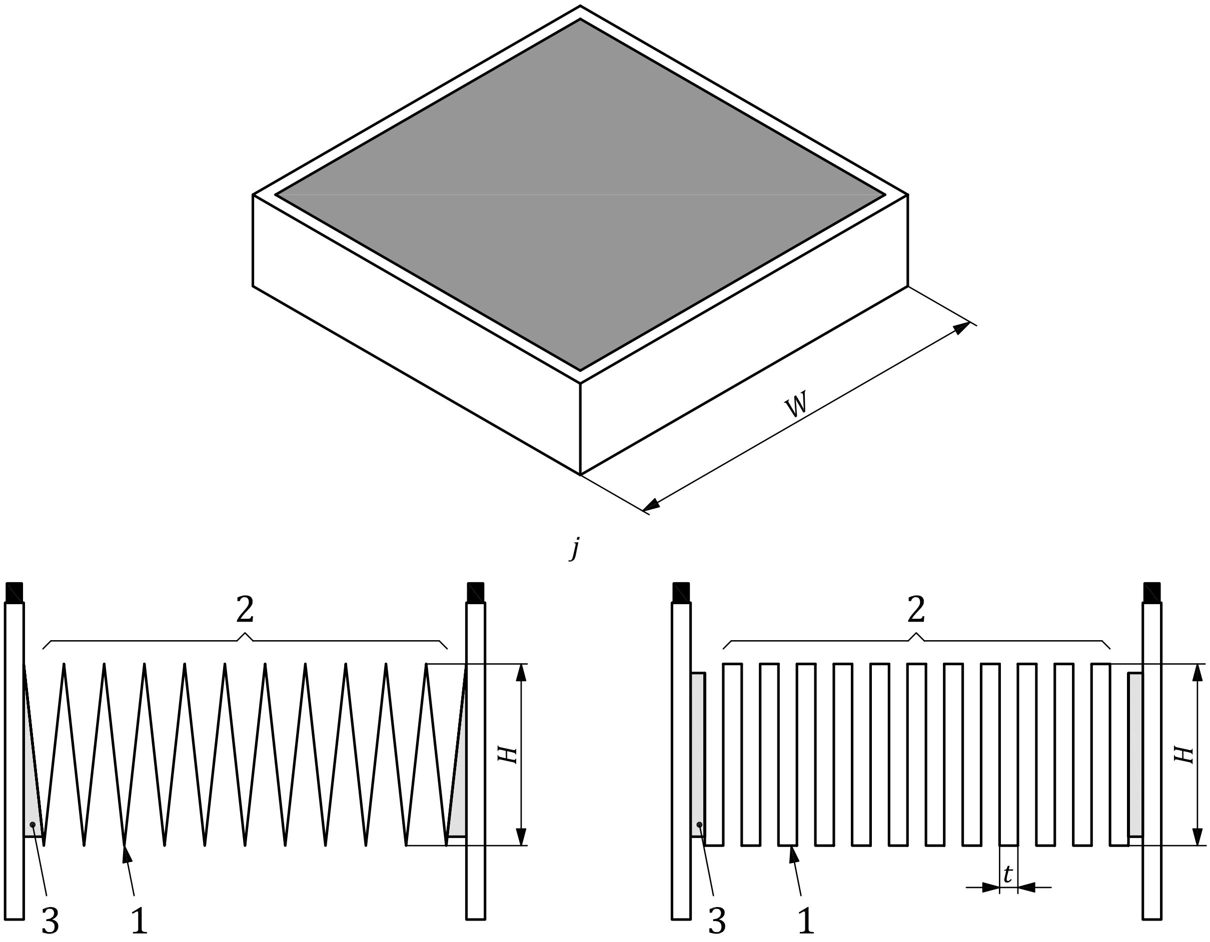
Formula (A.13) shows the reported result in case of one pack filter.

$$A_{\text{net}} = A_{\text{tot}} \, (A_{\text{max}}, A_{\text{min}}) \tag{A.13}$$

Formula (A.14) shows the reported result in case of several pack filters.

$$A_{\mathbf{tot}} = \Sigma \, A_{\text{tot}\,(j)} \tag{A.14}$$

where j is the number of packs (see Figure A.5).

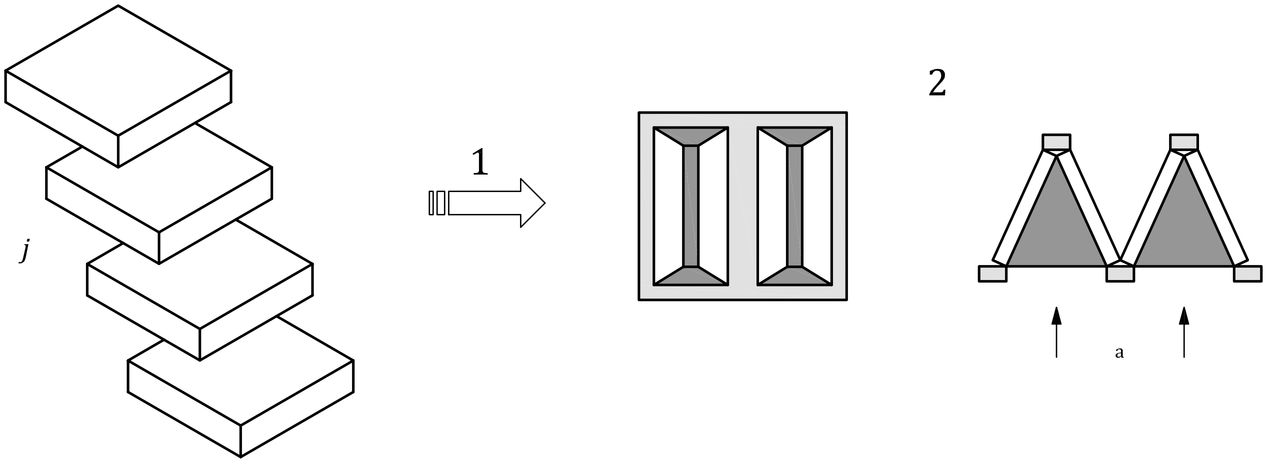


B C

Key

1	pleat tip (*i*)	B	minipleat filter
2	total number of pleat tips (*N*)	C	separator filter
3	sealant (potting)	*j*	filter pack containing one pleated pack
		t	tip width

Figure A.4 — Pleated filter with one pack



Key

1 assembling

2 complete filter

j filter packs (in this case *j* = 4)

a Airflow direction.

Figure A.5 — Pleated filter with several packs

A.4 Cylindrical pleated filters

Pleated filters are normally constructed by mini-pleat technology or with the separator pleating (typically aluminium, plastic or paper). A cylindrical (tube shape) pleated filter can consist of a pleated package that comprises all filter media, or it may be constructed out of several packages (tubes) that are assembled into a complete filter. To measure and calculate the net area of the filter following procedure is used (see Figure A.6):

a) Measure the effective length of the (each) filter pack (L).

b) Measure the effective height (H) of (each) pack.

c) Count the number of pleat tips around the perimeter (pleat direction).

d) In case of separator filter (rectangular pleat shape) measure the pleat tip width (t).

e) In case of mini-pleated filter (V-shaped pleat shape), $t = 0$.

f) In the case of a filter consisting of several packages, the total sum of all packages is the total area of the filter.

g) Estimate the error in measurement as tolerance range of the measured area.

The pleat (i) net effective area is calculated using Formula (A.15).

$$A_i = 2 \times (H \times L + t \times L) \tag{A.15}$$

The total net area (i = 1 to N) is calculated using Formula (A.16).

$$A_{tot} = \sum_{i=1}^{N} A_i \tag{A.16}$$

where N is the total number of pleats.

See Formulae (A.17) to (A.20) for a calculation example of the tolerance range.

H: ± 0,001 m (1 mm)

W: ± 0,002 m (2 mm)

t: ± 0,000 5 m (0,5 mm)

In case of mini-pleat filter:

$$A_{min} = \Sigma\ [2 \times (\{H - 0{,}001) \times \{W - 0{,}002\})]_i \tag{A.17}$$

$$A_{max} = \Sigma\ [2 \times (\{H + 0{,}001) \times \{W + 0{,}002\})]_i \tag{A.18}$$

In case of separator filter:

$$A_{min} = \Sigma\ [2 \times (\{H - 0{,}001\} \times \{W - 0{,}002\} + \{t - 0{,}000\,5\} \times \{W - 0{,}02\})]_i \tag{A.19}$$

$$\mathrm{A}_{max} = \Sigma\ [2 \times (\{H + 0{,}001\} \times \{W + 0{,}002\} + \{t + 0{,}000\,5\} \times \{W + 0{,}02\})]_i \tag{A.20}$$

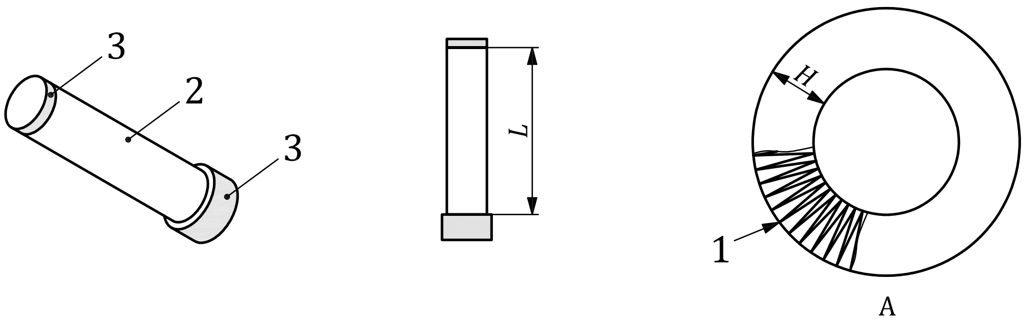
Formula (A.21) shows the reported result in case of one pack filter.

$$A_{net} = A_{tot}\ (\mathrm{A}_{max}, \mathrm{A}_{min}) \tag{A.21}$$

Formula (A.22) shows the reported result in case of several pack filters.

$$\mathrm{A}_{tot} = \Sigma\ \mathrm{A}_{tot\,(j)} \tag{A.22}$$

where j is the number of packs.



Key

1 pleat tip

2 filter media pack

3 end cap

A top view

Figure A.6 — Cylindrical, pleated filter

A.5 Conical pleated filters

Circular or tube shaped filters may have on both ends different diameters and hence form a conical shape.

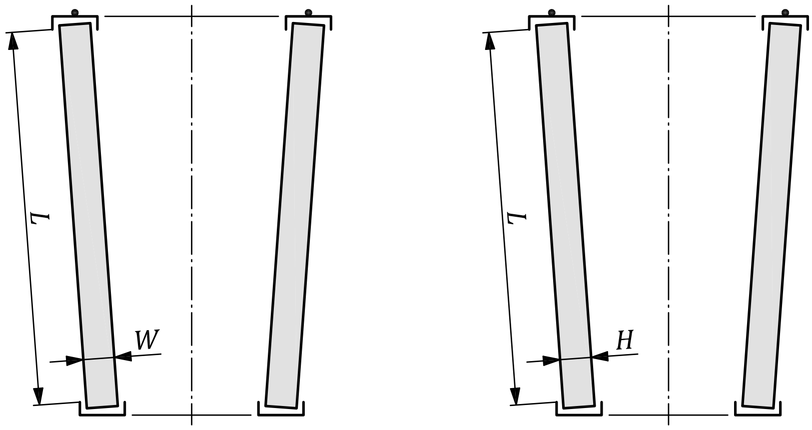


Figure A.7 — Conical, pleated filter

$$A = 2 \times L \text{ x H x } N \tag{A.23}$$

where N is the total number of pleats and the dimensions L and H in mm as shown in Figure A.7.

A.6 Other constructions

If other air filter constructions with totally different shapes and techniques are checked, it is up to the test institute to describe how the net area, including tolerance range was determined.

Bibliography

[1] ASME Standard MFC-3M-1985, *Measurement of fluid flow in pipes using orifice nozzle and venturi*

[2] ASTM-F328-98, *Standard practice for calibration of an airborne particle counter using monodispersed spherical particles*

[3] ASTM-F649-80, *Standard practice for secondary calibration of airborne particle counter using comparison procedures*

[4] Baron P., Willeke K., Aerosol Measurement: Principles, Techniques, and Applications. Wiley-Interscience, Second Edition, 2005

[5] Eurovent 4/9:1997, Method of testing air filters used in general ventilation for determination of fractional efficiency

[6] Hinds W.C., Aerosol Technology: Properties, Behavior and Measurement of Airborne Particles. Wiley-Interscience, 1999

[7] No JACA, 37-2001: The Guideline of Substitute Materials for DOP

[8] JIS Z 8901:2006, *Test powders and test particles: Test particle 2, 8.1 a) poly-alpha olefins with specific gravity between 0,80 to 0,82 and kinematic viscosity between 3,8 to 4,1 mm2/s (100 °C)*

[9] Kuehn T.H., Yang C.H., Kulp R.H., Effects of Fan Cycling on the Performance of Particulate Air filters used for IAQ Control. (Indoor Air '96, The 7th International Conference on Indoor Air Quality and Climate, Vol. 4, page 211)

[10] Nordtest NT VVS 117:1998, Test method for electret filters — Determination of the electrostatic enhancement factor of filter media

[11] Phillips B.A., Davis W.T., Dever M., *Investigation of the Effect of a Topically Applied Tackifier in Reducing Particle Bounce in a Melt-Blown Air Filter*. Filtration & Separation, 1996, pp. 933.

[12] Reichert F., Ohde A., Untersuchung zur Freisetzung von Filterfasern und zur Ablösung von schadstoffbelasteten Partikeln durch Luftfilter in RLT-Anlagen unter besonderer Berücksichtigung der in der Praxis auftretenden Schwingungszustände. Abschlussbericht zum bmb+f Forschungsvorhaben FKZ 1701199. FHTW Berlin, 2002

[13] Reichert F., Ohde A., Untersuchungen des Fasershedding an typgeprüften Feinstaubtaschenfiltern in Raumlufttechischen Anlagen. Colloquium Filtertechnik. Universität Karlsruhe, 2004

[14] Rivers R. D., Murphy D. J., Determination of Air Filter Performance under Variable Air Volume (VAV) Conditions. (ASHRAE 675-RP:1996)

[15] Qian Y., Willeke K., Ulevicius V., Grinshpun S.A., Particle Re-entrainment from Fibrous Filters. Aerosol Sci. Technol. 1997, **27** p. 394

[16] IEST-RP-CC001.4, *HEPA and ULPA filters*

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