ISO/TC 142/WG 9
Particulate air filter intake systems for rotary machinery and stationary internal combustion engines

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EN ISO 29461-5:2015

Air intake filter systems for rotary machinery - Test methods

Part 5: Offshore (Fixed Platform & FPSO) environment filter systems (ISO 29461-5:20

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Air intake filter systems for rotary machinery - Test methods - Part 5: Offshore (Fixed Platform & FPSO) environment filter systems (ISO 29461-5:2015)

Systèmes de filtration d'air d'admission pour machines tournantes - Méthodes d'essai - Partie 5: Systèmes de filtration du milieu offshore (plate-fome fixe et FPSO) (ISO 29461-5:2015)

Luftfiltereinlasssysteme von Rotationsmaschinen - Prüfverfahren - Teil 5: Offshore (feste Plattform und FPSO) –Umgebung Filtersysteme (ISO 29461-5:2015)

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Foreword

This document (EN ISO 29461-5:2015) 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of an identical text or by endorsement, at the latest by October 2013, and conflicting national standards shall be withdrawn at the latest by October 2013.

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Endorsement notice

The text of ISO 29461-5:2015 has been approved by CEN as EN ISO 29461-5:2015 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.

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ISO 29461-5 was prepared by Technical Committee ISO/TC 142, *Cleaning equipment for air and other gases*.

ISO 29461 consists of the following parts, under the general title *Air intake filter systems for rotary machinery — Test methods*:

— *Part 1: Static filter elements*
— *Part 2:*
— *Part 3:*
— *Part 4:*
— *Part 5 Offshore (Fixed Platform & FPSO) environment systems*
— *Part 6:*

Static filter elements, cleanable (pulse jet) and surface loading filters, mechanical integrity of filter elements, *in situ* testing and cleanable (pulse Jet) filter elements form the subjects of other parts of this test standard.

0. Introduction

0.1. Filters in power generating/compressor applications

In rotating machinery applications, the filtering system, 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 may 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 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 self-cleaning to depth and surface loading systems. 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, self-cleanable and depth loading filter cartridges and pleated media surface filter elements.

ISO 29461 will provide 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 performance of products in this broad range must be compared in a good manner. Comparing different filters and filter types must be done 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. ISO 29461-2 will address the performance of cleanable and surface loading filters.

0.2 Filtration characteristics

Initiatives to address the potential problems of particle re-entrainment, shedding and the in-service charge neutralization characteristics of certain types of media have been included in Annexes A and B.

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, may inhibit such charges with the result that filter performance suffers. The normative test procedure, described in Annex A, 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. The procedure was selected because it is well established, reproducible, relatively fast and easy to perform.

In an ideal filtration process, each particle would be permanently arrested at the first contact with a filter fibre, but incoming particles may impact on a captured particle and dislodge it into the air stream. Fibres or particles from the filter itself could also be released, due to mechanical forces. From the user’s point of view it might be important to know this, see Annex B.

Filters with a low initial or conditioned particulate efficiency (<35 %) for sub-micron particles (0,4 µm) that do not increase their efficiency during the operation will typically not provide any major protection for the operating machinery when challenged with typical atmospheric aerosols where the majority of particles are smaller than 1,0 µm. However, in some cases with aerosols having a dominant fraction of coarse particles, filters with low efficiencies at sub-micron particles can serve as a protection for later filter stages and can also have a higher average particulate efficiency (e.g. surface loading filters) at 0,4 µm due to the dust loading. Therefore a gravimetric test can provide some information about capacity and gravimetric efficiency for those aerosols. In general, a lower total filtration level than 35 % at 0,4 µm should not be recommended for an air intake filter system for rotary machinery when the aerosol loading of the filters are not contributing to a significant increase of the efficiency during the operation.

0.3 Organization of ISO 29461

The methods and procedures for determining particulate efficiency, pressure drop and the corresponding reporting formats are the same for all types of static filter element.

The test methods concerning particulate efficiency, pressure drop and reported values are the same for all filters, except for loading characteristics and cleaning procedure, which are different for cleanable surface loading filters. These filters incorporate cleaning procedures and have different loading characteristics; therefore, they require appropriately modified test methods, which will be defined in Part 2.

Part 3 will provide methods for determining the mechanical integrity of filters under conditions that may be encountered in abnormal operating environments.

Part 4 will describe methods of testing installed filters under in-service operating conditions (*in situ* testing).

Part 5 will cover test methods for the specific requirement of offshore (fixed platform and FPSO) application, and specify methods for determining the sea salt removal efficiency of individual filters and/or complete filter systems.

Part 6 will cover test methods for cleanable filter elements, and will not cover the system testing (e.g. cleaning device) as in Part 2.

This part of ISO 29461 describes the test methods for static filter units, typically of the depth loading type (see definitions 3.43 and 3.44). All filters can be tested in the same manner, thus obtaining comparable results. However, for surface loading filters, reverse pulse filters, Offshore (Fixed Platform & FPSO) filter systems, as well as other filter systems that are not regarded as static filter units, the appropriate part shall be used.

For multi-stage systems that use a number of components (e.g. equipment for cleaning, filters), this part of ISO 29461 may be used as long as the qualification requirements of the test rig can be fulfilled. In cases where this is not possible, Part 4 (*in situ* testing) procedures may be applied.

Air intake filter systems for rotary machinery — Test methods

Part 5:
Offshore (Fixed Platform & FPSO) environment systems

1. Scope

ISO 29461 specifies methods and procedures for determining the 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 having an initial particle efficiency up to 99,9 % with respect to 0,4 µm particles. Filters with higher initial particle efficiencies are tested and classified according to other standards (e.g. EN 1822). These procedures are intended for filters which operating at flow rates within the range 0,25 m^3/s (900 m^3/h) up to 1,67 m^3/s (6000 m^3/h).

This part of ISO 29461 refers to filter systems used in Offshore (Fixed Platform & FPSO) environments, but can be applied to other filter types and systems in appropriate circumstances.

This part of ISO 29461 focuses on two main challenges facing air intake filter systems operating in Offshore (Fixed Platform & FPSO) environment:

— filter/system efficiency at removing salt and moisture from the airstream

— filter/system efficiency with the additional burden of oil mist introduced

The performance results obtained in accordance with this part of ISO 29461 cannot be quantitatively applied (by themselves) to predict performance in service with regard to efficiency and lifetime. Other factors influencing performance to be taken into account are described in the annexes.

2. Normative references

The following referenced documents are indispensable for the application 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 2854, *Statistical interpretation of data — Techniques of estimation and tests relating to means and variances*

ISO 5167 (all parts), *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full*

ISO 12103-1, *Road vehicles — Test dust for filter evaluation — Part 1: Arizona test dust*

ISO 14644-3:2005, *Cleanrooms and associated controlled environments — Part 3: Test methods*

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

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

ASHRAE 52.2:1999, *Method of testing general ventilation air-cleaning devices for removal efficiency by particle size*

IEST-RP-CC014, *Calibration and Characterization of Optical Airborne Particle Counters*

JIS Z 8901:2006, *Test powders and test particles*

JACA No.37:2001, *Guideline of Substitute Materials for DOP*

3. Terms and definitions

3.1.
test airflow rate
volumetric airflow rate used for testing

[Source: ISO 29464:2011; 3.1.106]

3.2 Velocity

3.2.1
filter face velocity
airflow rate divided by the filter face area

[Source: ISO 29464:2011, 3.1.84]

3.2.2
media velocity
airflow rate divided by the effective filtering area

Note 1 to entry: Expressed at an accuracy of three significant figures.

3.3 Efficiency

3.3.1
particulate efficiency
percentage particulate removal efficiency of the filter at specified particle sizes measured with a particle counter in the range of 0,3 µm to 3,0 µm

3.3.2
initial efficiency
particulate efficiency of the clean filter operating at the test airflow rate

Note 1 to entry: A clean filter is a filter not exposed to any test aerosol or substance prior to the efficiency test.

3.3.3
minimum efficiency
lowest particulate efficiency of initial, conditioned or dust loaded efficiencies

3.3.4
conditioned efficiency
efficiency of the conditioned filter media (per Annex A) operating at an average media velocity corresponding to the test airflow rate in the filter

3.3.5
gravimetric efficiency
A_{50}
weighted (mass) removal of loading dust after 50 g of dust load

3.3.6
average gravimetric efficiency
A_{avg}
ratio of the total amount of loading dust retained by the filter to the total amount of dust fed up to final test pressure drop

3.3.7
dust loaded efficiency
efficiency of the filter operating at test flow rate and after dust loadings up to final test pressure differential

3.4
penetration
ratio of the particle concentration detected downstream versus the concentration upstream of the filter

3.5 Pressure drop (differential pressure)

3.5.1
initial pressure drop
pressure drop of the clean filter operating at the test airflow rate

3.5.2
final test pressure drop
maximum pressure drop of the filter up to which the filtration performance is measured

3.5.3
final test pressure drop – recommended
maximum operating pressure drop of the filter as recommended by the manufacturer at rated airflow

3.6 Filter area

3.6.1
filter face area
frontal face area of the filter including the header frame

[Source: ISO 29464:2011, 3.1.83]

Note 1 to entry: Typical nominal values: 0,610 m × 0,610 m (24 in × 24 in).

3.6.2
effective filtering area
area of filter medium in the filter which collects dust

[Source: ISO 29464:2011; 3.1.79]

3.7 Filters

3.7.1
static filter
air filter that will be removed (exchanged) after it has reached its final test pressure drop and that is not cleaned with jet pulses or other means in order to fully, or partially, retrieve its initial performance (pressure drop and efficiency)

3.7.2
pulse jet filter
cleanable air filter, that typically is cleaned with air jet pulses to provide a longer service life

3.7.3
surface loading filter
filter in which the dust is collected on the surface of the filter medium

3.7.4
depth loading filter
filter in which particles penetrate into the filter medium and are collected on the fibres in the depth of the filter medium

3.7.5
low efficiency filter
air filter with an initial particulate efficiency at 0,4 µm particles in the range $E < 35$ %

3.7.6
medium efficiency filter
air filter with an initial particulate efficiency at 0,4 µm particles in the range 35 % ≤ E ≤ 85 %

3.7.7
high efficiency filter
air filter with an initial particulate efficiency at 0,4 µm particles in the range $E \geq 85$ %

3.7.8
EPA filter
air filter with a particulate efficiency at most penetrating particle size (MPPS) in the range 85 % ≤ E ≤ 99,95 % (typically 0,05 µm to 0,3 µm size range)

3.7.9
final filter
air filter used to collect the loading dust passing through or shedding from the filter under test

[Source: ISO 29464:2011; 3.1.86]

3.7.10
charged filter
filter in which the medium is electrostatically charged or polarized

[Source: ISO 29464:2011; 3.1.75]

3.7.11
untreated filter
air filter not submitted to conditioning per Annex A

3.8 Test aerosol

3.8.1
test aerosol
aerosol used for determining the particulate efficiency of the filter

3.8.2
particle size
geometric diameter (equivalent spherical, optical or aerodynamic, depending on the context) of the particles of an aerosol

[Source: ISO 29464:2011; 3.1.126]

3.8.3
mean diameter
geometric mean value of the upper and lower border diameters in a size range

3.8.4
particle number concentration
number of particles per unit volume of air

3.8.5
neutralization
action of bringing the aerosol to a Boltzmann charge equilibrium distribution with bipolar ions

3.9 Test dust

3.9.1
loading dust
synthetic test dust
synthetic dust formulated specifically for determination of the test dust capacity and arrestance of air filters

3.9.2
test dust capacity
dust loading capacity
TDC
amount of loading dust held by the filter at final test pressure drop

3.10 Particle sampling

3.10.1
isokinetic sampling
technique for air sampling such that the probe inlet air velocity is the same as the velocity of the air surrounding the sampling point

[Source: ISO 29464:2011; 3.1.144]

3.10.2
counting rate
number of counting events per unit time

[Source: ISO 29464:2011; 3.1.41]

3.10.3
correlation ratio
downstream particle concentration divided by the upstream particle concentration (measured without filter)

[Source: ISO 29464:2011; 3.1.26]

3.11 Particle shedding

3.11.1
shedding
release to the airflow of particles due to particle bounce and re-entrainment effects and to the release of fibres or particulate matter from the filter or filtering material

[Source: ISO 29464:2011; 3.1.150]

3.11.2
particle bounce
behaviour of particles that impinge on the filter without being retained

[Source: ISO 29464:2011; 3.1.121]

3.11.3
re-entrainment
release to the airflow of particles previously collected on the filter

[Source: ISO 29464:2011; 3.1.142]

4 Symbols and abbreviated terms

A_{50}	gravimetric efficiency after 50 g dust load, %
A_{avg}	average gravimetric efficiency %
CL	concentration limits of particulate counter
C_V	coefficient of variation
$C_{V,i}$	coefficient of variation in size range “i”
$C_{mean,i}$	mean of measuring points value for size range “i”
CL_E	lower confidence limit of particulate efficiency (95 % confidence level)
$\overline{CL_E}$	average lower confidence limit of particulate efficiency (95 % confidence level). Average value from repeated measurement cycles for one efficiency calculation
CL_{Nd}	upper confidence limit (95 %) of number of particles downstream of the filter
CL_{Nu}	lower confidence limit (95 %) of number of particles upstream of the filter
d_i	geometric mean of a size range, µm
d_l	lower border diameter in a size range, µm
d_u	upper border diameter in a size range, µm
DR	dilution ratio, when diluter is used
$\overline{E}_i$	average particulate efficiency in a size range “i”
m	mass passing the filter, g
m_d	mass of dust downstream of the test filter, g
m_{50}	mass of dust fed to filter in order to test gravimetric efficiency (50 g), g
m_{p50}	mass of dust that has passed the filter (the mass gain of final filter and the dust in the duct between the filter and the final filter) after 50 g of dust loading
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
N	number of points
N_d	number of particles downstream of the filter
$N_{d,i}$	number of particles in size range “i” downstream of the filter
$\overline{N}_d$	average number of particles downstream of the filter
N_u	number of particles upstream of the filter
$N_{u,i}$	number of particles in size range “i” upstream of the filter

$\overline{N}_u$	average number of particles upstream of the filter
n	exponent
p	pressure, Pa
p_a	absolute air pressure upstream of filter, kPa
p_{sf}	airflow meter static pressure, kPa
q_m	mass flow rate, kg/s
q_V	airflow rate at filter, m^3/s
q_{Vf}	airflow rate at airflow meter, m^3/s
R	correlation ratio
R_i	correlation ratio for size range “i”
T	temperature upstream of filter, °C (°F)
T_f	temperature at airflow meter, °C
$t_{(1-\alpha/2)}$	distribution variable
U	uncertainty, % units
v_{mean}	mean value of velocity
δ	standard deviation
ν	number of degrees of freedom
ρ	air density, kg/m^3
φ	relative humidity upstream of filter, %
Δm	dust increment, g
Δm_{ff}	mass gain of final filter, g
Δp	filter pressure drop, Pa
Δp_f	Differential pressure, Pa
$\Delta p_{1,20}$	filter pressure drop at air density 1,20 kg/m^3, Pa
ΔE_C	difference in particulate efficiency between initial particulate efficiency (E_0) of media sample and conditioned efficiency (media samples) per Annex A
OPC	optical particle counter
DEHS	liquid (DiEthylHexylSebacate) used for generating the DEHS test aerosol
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASTM	American Society for Testing and Materials

CAS	Chemical Abstracts
CEN	European Committee for Standardization
EN	European Standard
EUROVENT	European Committee of Air Handling and Refrigeration Equipment Manufacturers
ISO	International Organization for Standardization

5 General requirements

Static filter systems normally use multiple stages of coarse and fine filter elements to protect the machinery. The scope of this part of ISO 29461 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.

6 Test rig and equipment

6.1 Test conditions

Room air or outdoor air may be used as the test air source. Relative humidity shall be in the range of 30 % to 70 % in the tests. The air temperature shall be in the range of 10 °C to 38 °C. The exhaust flow may be discharged outdoors, indoors or re-circulated. Requirements of certain measuring equipment may impose limits on the temperature of the test air.

Filtration of the exhaust flow is recommended when test aerosol, loading dust or smell from filter may be present.

6.2 Test rig

The test rig (see Figure 1) consists of several duct sections (may be rectangular or square) with a typical 610mm x 610mm (24” x 24”) nominal inner dimensions. If different, cross section dimensions to be stated in the report. The section where the test filter/system is installed is to be representative of the cross-sectional area and geometry for a single filter within the proposed offshore inlet system(s).

When testing the final filter element (plus vane for high velocity) only, no pre-filtration components are to be installed in the test rig.

When performing a full system test, the plenum for the final filter element must be positioned in such a way that all proposed pre-filtration component(s) (e.g. coalescer/prefilter pads, moisture removal vanes etc.) are installed the correct distance upstream from the final filter, so as to best replicate the movement of air within the proposed offshore inlet system(s). In addition, any downstream vanes are to be located at the correct distance from the final filter, to best replicate the movement of air on the downstream side.

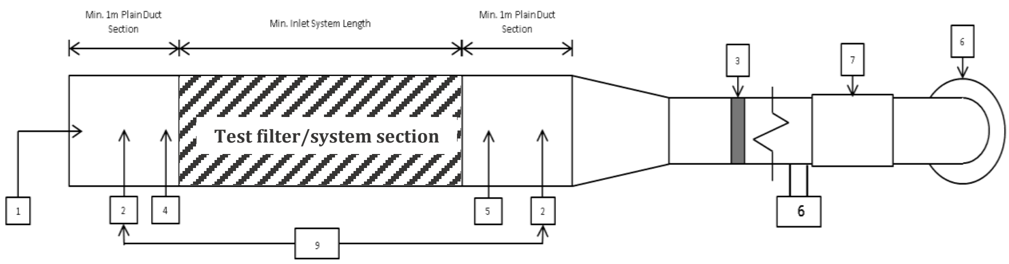
In case of circular cartridges, the test setup (mounting of the filters in the test duct) shall be as close to the real application as possible. In case of large cylinders, a mounting plate with an additional hole for the inlet/outlet can be sufficient. In terms of much smaller cylinders an additional transition could be inserted in the duct. This must 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.

The duct material shall be electrically conductive, electrically grounded, and shall have a smooth interior finish whilst being sufficiently rigid to maintain its shape at the operating pressure. Smaller parts of the test duct could be made in transparent material to see the test filter/system and equipment. Specifically, at least one (1) window both upstream and downstream of the test filter/system is required.

Pressure rings are required fore and aft of the test filter/system to measure pressure drop across the test filter/system. They should be located in positions that allow the full system pressure drop to be measured also.

Salt mass concentration readings are required to be made using a flame photometer, and should be read from tap off positions similar to for the pressure rings. They should be located fore and aft of the test filter/system, and should allow for readings across the full system to be taken also.

The test rig is operated in a negative pressure airflow arrangement, which represents the typical air flow condition for a gas turbine. A positive pressure arrangement is not typically encountered in gas turbine air inlet systems.



Key

1 Dust and mineral oil injection points
2 Pressure ring
3 Exhaust filter
4 Upstream sampling point
5 Downstream sampling point
6 Fan
7 Flow Control
8 Flow meter
9 Manometer

Figure 1 — Schematic diagram of the test rig

6.3 Aerosol Generation

6.3.1 Saline Solution Aerosol Generation

An Air Spectrum Vortex Rotary Atomiser shall be used to produce the saline solution aerosol. The saline solution to be used should be made using 3.5%W.T concentration with potable water for the tests. The volumetric flow of the mist shall correspond to 14.1ml/m^3 of airflow. For example:

- At an airflow of 3400m^3/h, the volume of saline solution aerosol produced will be 47940ml (47.94l)
- At an airflow of 4250m^3/h, the volume of saline solution aerosol produced will be 59925ml (59.95l)

The particle distribution of the saline solution aerosol shall fall in the range of 0.5microns to 10microns, with typical particle size distribution as shown in Figure 2.

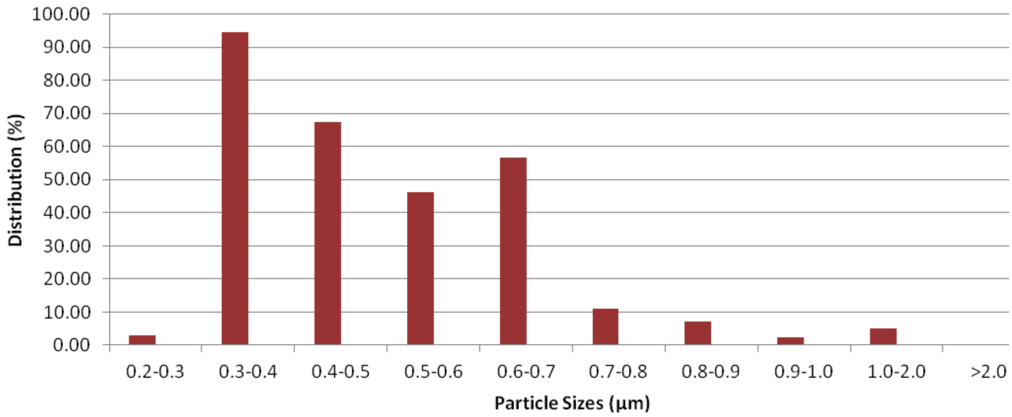


Figure 2 — Saline solution aerosol particle size distribution

6.3.2 Mineral Oil Aerosol Generation

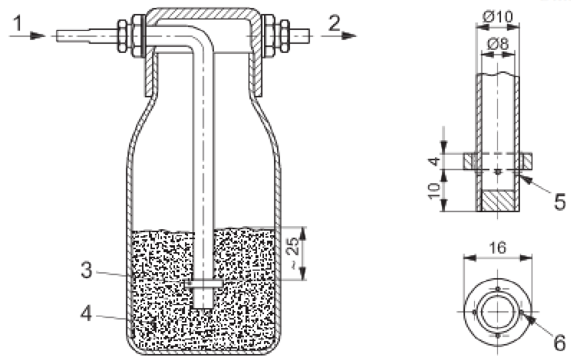
The hydrocarbon challenge shall be generated using Ondina 917L Mineral oil aspirated through a Laskin aerosol generator. The Laskin aerosol generator delivers a very fine aerosol although the droplet size is not measured during these tests, it should remain suitably fine to embed itself into the filter media substrate. Figure 3 gives an example of a system for generating the aerosol. It consists of a small container with mineral oil and a Laskin nozzle.

The aerosol is generated by feeding compressed, particle free air through the Laskin nozzle. The atomised droplets are then directly introduced into the test rig. The pressure and airflow to the nozzle are varied according to the test flow and the required aerosol concentration. For a test flow of 3400m^3/h the pressure is about 17kPa, corresponding to an airflow of about 0.39dm^3/s (1.4m^3/h) through the nozzle. For a test flow of 4250m^3/h the pressure is about XXkPa, corresponding to an airflow of about 0.XXdm^3/s (X.Xm^3/h) through the nozzle.

Kommenterad [L1]: Values to be calculated for 4250m^3/h

Any other generator capable of producing droplets in sufficient concentrations in the size range of 0.3-3.0microns can be used.

Dimensions in millimetres



Key

1 particle-free air (pressure about 17 kPa)

2 aerosol to test rig

3 Laskin nozzle

4 test aerosol (for instance DEHS)

5 four 1,0 mm diameter holes 90° apart top edge of holes and just touching the bottom of the collar

6 four 2,0 mm diameter holes next to tube in line with radial holes

Figure 3— Mineral oil aerosol generation system

6.4 Saline Solution Sampling System

A sodium flame photometer shall be used to determine the salt removal efficiency of the test filter/system. This is achieved by measuring the upstream salt mass concentration in either parts per million (ppm) or as a percentage of the sample of air taken. Air samples shall be extracted directly from the airstream via a port. The flame photometer shall be capable of logging the salt content over a prescribed timeframe.

6.5 Flow Measurement

Flow measurement shall be made by standardised or calibrated flow measuring devices in accordance with ISO 5167. Examples are orifice plates, nozzles, Venturi tubes, etc.

The uncertainty of measurement shall not exceed 5 % of the measured value at 95 % confidence level.

6.6 Differential Pressure Measuring Equipment

Measurements of pressure drop shall be taken between measuring points located in the duct wall as shown in Figure 4. Each measuring point shall comprise four interconnected static taps equally distributed around the periphery of the duct cross section.

The pressure measuring equipment used shall be capable of measuring pressure differences with an accuracy of ±2 Pa in the range of 0 Pa to 70 Pa. Above 70, the accuracy shall be ±3 % of the measured value.

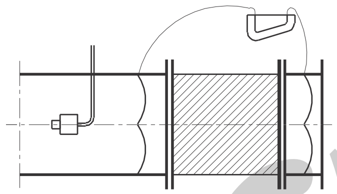


Figure 4 — Duct section showing upstream and downstream pressure measurement points

6.7 Dust Feeder

The purpose of the dust feeder is to supply the loading dust to the filter under test at a constant rate and over the test period. The general design of the dust feeder and its critical dimensions are given in Figure 5 and Figure 6. Any dust feeder can be chosen as long as it gives the same test result as the described dust feeder. The angle between the dust pickup tube and dust feed trough is 90° in the figure but could be less in real application. 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 2 and be collinear with the duct centre line.

Backflow of air through the pickup tube from the positive duct pressure shall be prevented when the feeder is not in use.

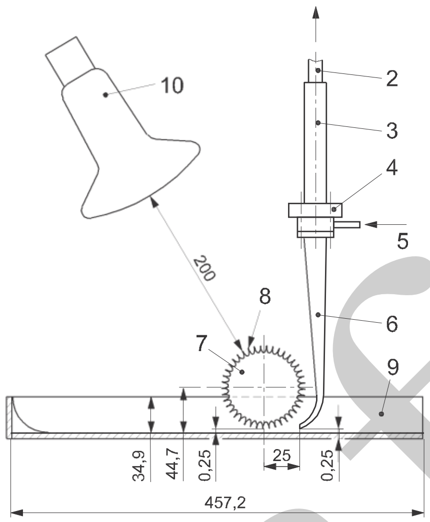
All tubing, nozzles, etc. that are in direct contact with the dust during the operation must be electrically conductive and grounded. This is needed in order to minimize the errors in measurements due to electrostatic charging of dust during the operation of the dust feeder.

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 airflow through the aspirator. The aspirator Venturi is subject to wear from the aspirated dust and will become enlarged with use. Its dimension shall be monitored periodically to ensure that the tolerances shown in Figure 6 are met. The dust should preferably be homogenized in a shaker, maintained at a given temperature and in a controlled relative humidity.

The gauge pressure on the air line to the Venturi corresponding to an airflow of the dust-feeder pipe of 6,8 × 10^{-3} m^3/s ± 0,24 × 10^{-3} m^3/s shall be measured periodically for different static pressure in the duct. See 7.6 for qualification requirements of the dust feeder

The dust feeder is positioned in the test rig at a sufficient distance in front of the test filter/system to prevent uneven loading of dust on the test filter/system during dust loading operations.

Dimensions in millimetres

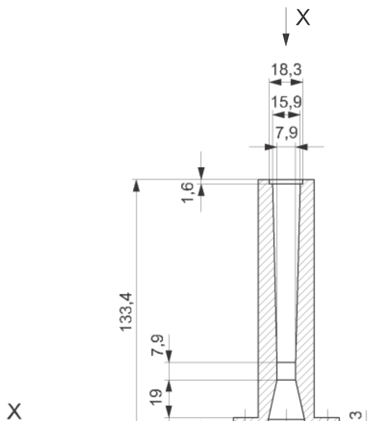


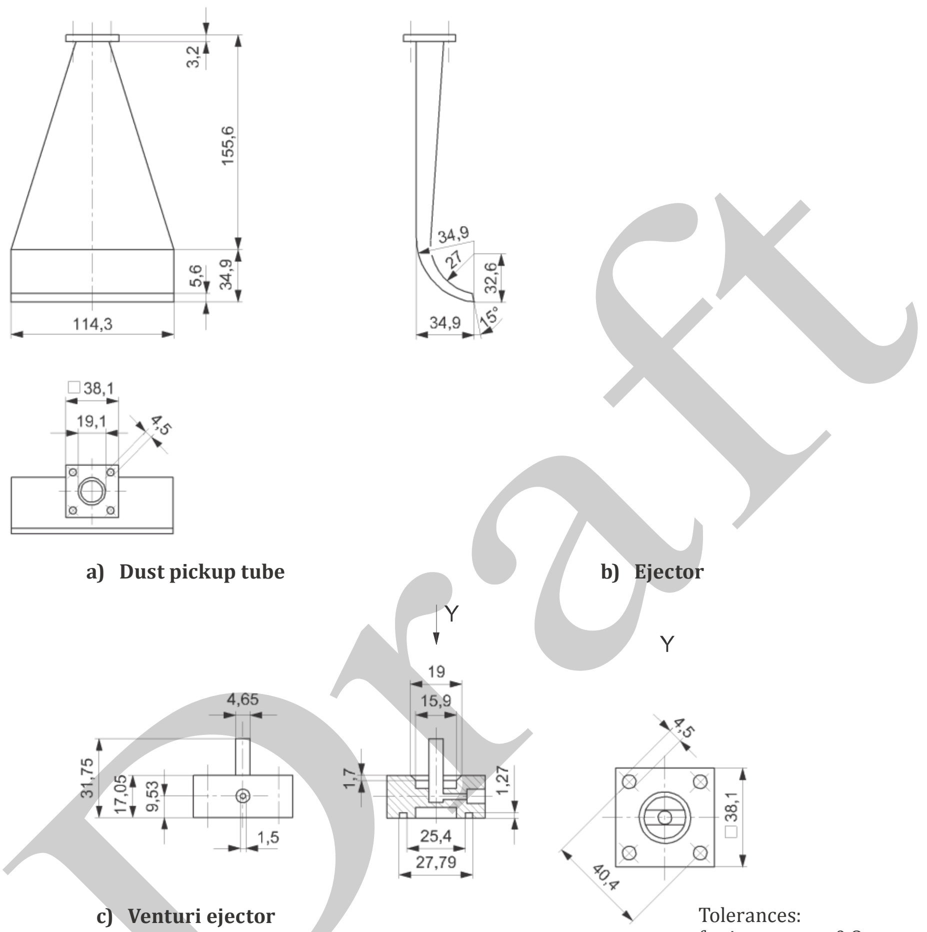
Key

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

Figure 5 — Critical dimensions of dust feeder assembly

Dimensions in millimetres





a) Dust pickup tube **b) Ejector**

c) Venturi ejector

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

Figure 6 — Ejector, Venturi ejector and pickup details for the dust feeder

7 Qualification of test rig and apparatus

7.1 General

The summary of the qualification requirements and frequency of maintenance are specified in 7.8 and 7.9.

7.2 Air Velocity uniformity in the test duct

The uniformity of the air velocity in the test duct shall be determined by measuring the velocity at nine points located as in Figure 7, immediately upstream of the test filter section without the test filter and the mixing device. Measurements shall be made with an instrument having an accuracy of ±10 % with a resolution of minimum 0,05 m/s.

Measurements shall be conducted at 0,25 m^3/s, 0,944 m^3/s and 1,5 m^3/s. It is important that no significant disturbance of the airflow occurs (from instrument, operator, etc.) when measuring the velocities.

For each measurement, a sample time of at least 15 s shall be used. The average of three measurements shall be calculated for each of the nine points and the mean and the standard deviation shall be calculated from these nine values.

The coefficient of variation C_V shall be calculated as follows:

$$C_V = \delta / v_{mean} \quad (1)$$

where

δ is the standard deviation of the nine measuring points;

v_{mean} is the velocity mean value of the nine measuring points.

The C_V shall be less than 10 % at each airflow setting.

Dimensions in millimetres

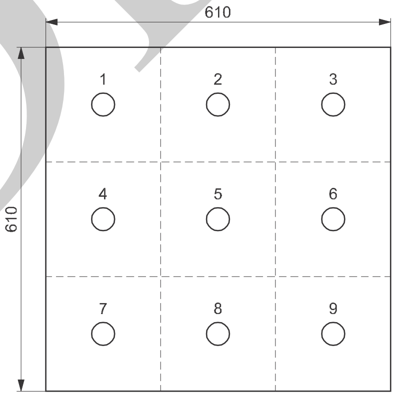


Figure 7 — Air velocity and uniformity: sampling points for measuring uniformity of air velocity

7.3 Zero % Efficiency Test

Kommenterad [L2]: To be modified to be relevant to the Part 5 test

The zero % particulate efficiency test is a test of the accuracy of the overall duct, sampling system, measurement and aerosol generation systems. The test shall be performed as a normal particulate efficiency test but with no test filter installed. The test airflow shall be 0,944 m^3/s. Two tests shall be done according to standard test procedure and the calculated zero efficiency shall meet the following criteria:

— 0 % ± 3 % for particle sizes equal to or less than 1,0 µm;

— 0 % ± 7 % for particle sizes larger than 1,0 µm.

The total number of counted particles for each size shall be >500 in order to limit the statistical error.

7.4 Correlation Ratio

Kommenterad [L3]: Same as for 7.3

The correlation ratio, R, shall be used to correct for any bias between the upstream and downstream sampling systems. If the zero % efficiency test fails but the correlation ratio limits are within requirements in 7.8, the correlation ratio correction shall be used to continue the test. If particulate efficiency is outside the limits, the test shall not be allowed.

The correlation ratio shall be established from the ratio of downstream to upstream particle counts without the test device installed in the test duct and before testing an air cleaner. The test shall be performed at the airflow rate of the test filter. The general equation for the correlation ratio, R, as used in this standard is

$$R = N_d / N_u \tag{2}$$

where

N_d is the number of particles downstream of the filter;

N_u is the number of particles upstream of the filter.

The particle generator shall be on, but without a test device in place. Upstream and downstream sampling times shall be the same during this test. The aerosol used shall be the same as the aerosol to be used to test the filters (DEHS). The data from the zero % efficiency test can be used for this calculation.

The average upstream count $\overline{N}_u$ and average downstream count $\overline{N}_d$ shall be calculated for each particle size channel “i”.

$$\overline{N}_u = \frac{\sum_{i=1 \to n} N_{u,i}}{N} \tag{3}$$

$$\overline{N}_d = \frac{\sum_{i=1 \to n} N_{d,i}}{N} \tag{4}$$

where

N is the number of points.

The correlation ratio shall be calculated for each particle size channel “i”.

$$R_i = \frac{\overline{N}_d}{N_u} \tag{5}$$

7.5 Pressure Drop Checking

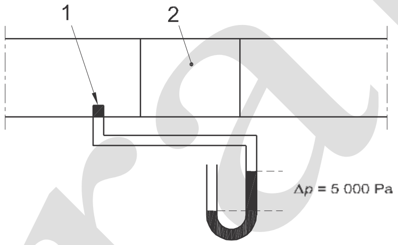
All equipment for pressure drop readings shall meet the requirements in 7.8.

This test is to verify that leaks in the equipment for pressure drop readings, instrument lines, etc. do not significantly affect the accuracy of the measurements of airflow or pressure drop. The test may be made by calibrated devices or by the system described below.

Seal the pressure sample points in the test duct carefully. Disconnect the pressure drop meter. Pressurize the tubes with a constant negative pressure of 5 000 Pa. Check all sampling lines in this manner (see Figure 8). No changes in pressure are allowed.

Pressurise the pressure drop measuring equipment at the maximum permitted pressure according to the instrument specification. The procedure shall be carried out sequentially on both positive and negative pressure lines. No changes in pressure are permitted on either inlet.

As an addition, a perforated plate (or other reference) having known pressure drops at 0,5 m^3/s, 0,75 m^3/s, 0,944 m^3/s and 1,5 m^3/s may be used for periodic checks on the pressure drop measurement system.



Key

1 sealed pressure inlet

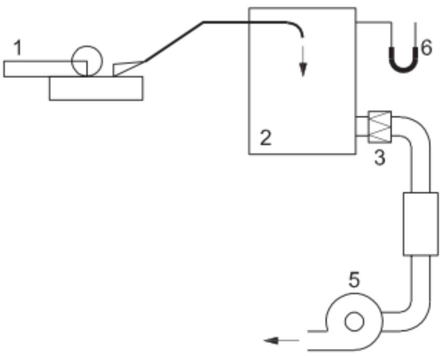
2 test device section

Figure 8 — Pressure line test

7.6 Dust Feeder Airflow rate

The purpose of this test is to verify that the airflow 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 airflow rate from the dust feeder. The flow shall be $6{,}8 \times 10^{-3}$ m^3/s $\pm$ $0{,}24 \times 10^{-3}$ m^3/s. This airflow is determined as in Figure 9.



Key

1 dust feeder
2 plenum with minimum volume of 0,25 m^3
3 high efficiency filter (minimum H13 class)
4 flow metering device
5 fan
6 pressure drop measurement device (the differential pressure should be zero)

Figure 9 — Dust feeder airflow rate

7.7 Reference filter check

Kommenterad [L4]: Same as for 7.3 & 7.4

For each test duct a minimum of three identical reference filters shall be maintained by the testing facility solely for initial particulate efficiency testing on a bi-weekly basis and these filters shall not be exposed to dust loading. The three filters shall be labelled as “primary”, “secondary” and “reserve”. The “primary” filter shall be checked every two weeks. The filters should be pleated, compact-style filters utilizing glass filter media. This type of filter elements has shown very little deviation in particulate efficiency and pressure drop when used as reference filters in laboratories.

If the filtration particulate efficiency values shift by >2 percentage points for any of the particle sizing channels, the “secondary” filter shall be tested. If both “primary” and “secondary” filters shows shifts >2 percentage points for any of the particle sizing channels, the particle counter shall be recalibrated or other system maintenance performed as needed (e.g. clean sample lines) to restore the reference filter particulate efficiency test to <2 percentage point shift. The reserve filter shall be used if either the primary or secondary filters become unusable (e.g. damaged).

The measured pressure drop across the reference filter shall be within 5 % or 5 Pa, whichever is the highest value, of the reference value. If the pressure drop deviates by more than 5 %, system maintenance shall be performed to restore the pressure drop to be within 5 % of the reference value. The pressure drop can also be checked versus a perforated plate with reasonable pressure drop instead of a filter.

The reference filter tests shall be performed at 0,944 m^3/s and particulate efficiency of the reference filter shall have about 50 % and 90 % particulate efficiency for 0,4 µm, and 1 µm particles respectively.

Immediately after calibration of the particle counter, retest each of the reference filters (or a new set of filters) to establish new filtration efficiency and pressure drop reference values.

When either the primary or secondary filtration particulate efficiency values shift by >2 percentage points for any of the particle sizing channels and either the secondary or the reserve filter does not, the primary or secondary filter shall be replaced with an identical filter or filters; if available, a new set of identical filters shall be obtained.

7.8 Summary of qualification requirements

Table 1 — Summary of qualification requirements

Parameter	Subclause	Requirement
Air velocity uniformity	7.2	C_V (coefficient of variation) < 10 %
0 % efficiency test	7.3	Sizes ≤.1,0 µm: ±3 % Sizes > 1,0 µm: ±7 %
Correlation ratio	7.4	Sizes > 0,3 µm to 1 µm: ±10 % Sizes > 1,0 µm to 3,0 µm: ±20 %
Manometer calibration	7.5	Size range: (0 Pa to 70 Pa) ± 2 Pa > 70 Pa ± 3 % of the measured value
Pressure drop test	7.5	No detectable leaks
Dust feeder airflow rate	7.6	$6{,}8 \times 10^{-3}$ m^3/s ± $0{,}24 \times 10^{-3}$ m^3/s
Reference filter check	7.7	≤ 2 % particulate efficiency measurement (absolute value) shift in each size channel

7.9 Apparatus maintenance

Table 2 — Frequency of maintenance

Maintenance item	Subclause	Daily	Monthly	Bi-annually	Annually	After any change that might alter performance
TEST DUCT						
Air velocity uniformity	7.2					X
0 % efficiency test	7.3	X				X
Pressure drop test	7.5			X		X
INSTRUMENT						
Manometer calibration	7.12				X	X
Particle counter - sizing accuracy	7.4	X[a]			X	X
Dust feeder airflow rate	7.6			X		X
Reference filter check	7.7		Every 2nd week			X

NOTE Regular cleaning of all equipment should be undertaken so that the performance of the test system is maintained.

[a] It is a good practice to check the sizing accuracy of the particle counter on a regular basis, such as at the start of every day or a new test. This quick calibration check will help the operator discover potential measurement problems prior to running the filter test. By generating an aerosol of a known size of polystyrene micro spheres and verifying these particles appear in the corresponding size class(es) of the OPC(s), the user can quickly verify the accuracy of the sizing capabilities of the equipment. Checks with polystyrene micro spheres at the low and high ends of the particle size range(s) are especially meaningful.

8 Test Materials

8.1 Test Air

Room air or outdoor air is used as the test air source. In the efficiency tests the air is filtered with high efficiency filters to obtain a test air free of background particles. The test conditions shall be in accordance with Section 6.1. The exhaust flow may be discharged outdoors, indoors or re-circulated. Filtration of the exhaust flow is recommended when test aerosol and loading dust may be present.

The compressed air for the dust feeder shall be dry, clean and free from oil.

8.2 Mineral Oil

Shell Ondina Oil 917L shall be the light mineral oil to be used to provide the hydrocarbon challenge to the filter/system during this test regime.

Mineral Oil formula:

Mineral Oil Properties: White mineral oil (petroleum). The highly refined mineral oil contains <3% (w/w) DMSO-extract, according to IP346.
Density: Circa 854 kg/m^3 at 15°C.
Vapour Pressure: <0.5 Pa at 20°C.
Boiling Point: Above 280°C.
Flash Point: Circa 200°C (COC).
Pour Point: Circa -15°C.
Kinematic Viscosity: Circa 18.0mm^2/s at 40°C.

8.3 Loading Dust

ASHRAE test dust shall be used for the loading of filters according to the method in BS EN779:2012 Section 9.3 and 10.4.

ASHRAE test dust is defined in BS EN779:2012 as:

- 72 % by weight test dust “fine“ ISO 12103-A2
- 23 % by weight carbon black;
- 5 % by weight cotton linters.

Test dust “fine“ according to ISO 12103-1, identified as ISO 12103-A2, consists mainly of silica particles with the size distribution given in Table 4.

Size pm	Volume larger than size %
1	96,5 - 97,5
2	87,5 - 89,5
3	78,0 - 81,5
4	70,5 - 74,5
5	64 - 69
7	54 - 59
10	46 - 50
20	26 - 30
40	9 - 12
80	0 - 0,5

Table 3— Size distribution of ISO 12103-A2 loading dust (ISO 12103-1:1997)

8.4 Exhaust Filter

The exhaust filter captures any loading dust that passes through the test filter/system during the dust loading procedure. The exhaust filter shall have a minimum particulate efficiency of >85 % with respect to 0,4 µm DEHS particles and not gain or lose more than one gram, e.g. as a result of humidity variations met during one test cycle.

9 Test Procedure

The test method involves introducing an increasingly difficult challenge to the test filter/system, whilst measuring the effectiveness of the test filter/system at removing salt particles from the airflow in the test duct. This is achieved by using a combination of a saline solution aerosol, ASHRAE test dust and a mineral oil aerosol to load the test filter/system in a series of steps. All filters shall be tested the same way; however, if a certain filter is determined to be of low efficiency (i.e. high levels of salt particles detected downstream of the test filter/system), the test can be terminated at any given stage without the need to perform the subsequent steps of the test procedure. Salt particle removal efficiency is determined using a flame photometer.

This section describes the sampling sequence and data analysis procedures for sequential upstream- downstream sampling with one flame photometer. For dual flame photometer systems with simultaneous upstream-downstream sampling, the same procedures apply. The data quality requirements for single and dual flame photometer systems are identical.

9.1 Preparation of filter /system to be tested

The test filter/system shall be mounted/installed in accordance with the manufacturer's recommendations. Devices requiring external accessories shall be operated during the test with accessories having characteristics equivalent to those used in actual practice. The test filter/system, including any normal mounting frame(s), shall be sealed into the duct in a manner that prevents leakages.

NOTE This test method does not test the filter/system sealing mechanism(s).

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 filter/system under standard test conditions, assembly of two or more final

filters of the same type or model is permitted, provided no leaks occur in the resulting filter/system. The operating conditions of such accessory equipment shall be recorded.

Adequate drainage is to be accommodated for the test filter/system in order to prevent standing water occurring within the ductwork. Drains are to have a sufficient column height to prevent bypass conditions through the drainage pipework into the duct.

9.2 Initial pressure drop

The value of the initial pressure drop shall be recorded at the rated airflow for the test filter/system. The airflow is reported as measured at the local conditions. If the air density is not between 1,16 kg/m^3 and 1,24 kg/m^3 then the pressure drop reading shall be corrected to an air density of 1,20 kg/m^3 (see Annex D), which corresponds to standard air conditions: temperature 20 °C (68 °F), barometric pressure 101,3 kPa and relative humidity 50 %.

9.3 Test Filter Saline Solution Aerosol Efficiency Test

The below is a summary of the test procedure steps for testing the salt particle removal efficiency of the test filter/system.

1. Load the test filter/system into its intended position within the test duct as per Section 9.1.

2. Measurements to be taken for initial test filter/system pressure drop as per Section 9.2, as well as test duct temperature and %RH. Pressure drop, temperature and %RH are to be logged throughout the test procedure.

3. The volumetric airflow rate in the test duct is set to the rated airflow for the proposed test filter/system.

4. Allow the pressure drop across the test filter/system to stabilize. This usually takes 3-5minutes.

5. Turn on the saline solution aerosol generation system. The concentration of the aerosol is to be set as per Section 6.3.1. Monitor the rise in pressure drop across the test filter/system.

6. After the saline solution aerosol generation system has been running for 10 minutes, take readings of the salt concentration upstream of the test filter/system with the flame photometer. A total of five (5) readings should be taken, at an interval of 5 minutes between each reading. The average upstream salt concentration can now be calculated.

7. After the saline solution aerosol generation system has been running for 30 minutes, take readings of the salt concentration downstream of the test filter/system with the flame photometer. A total of five (5) readings should be taken, at an interval of 5 minutes between each reading. The average downstream salt concentration can now be calculated.

8. Allow the saline solution aerosol generation system to operate for a total of one (1) hour. Throughout the test period visual checks to be conducted to check for water bypass through the test filter/system.

9. Turn off the saline solution generation system, and turn off the fan so there is no airflow over the test filter/system. Allow any water contained within the test filter/system to drain freely due to the effects of gravity.

10. Dry out the test filter/system. This can be done either by running the fan at a reduced setting so that a low airflow (around 300m^3/h) passes over the test filter/system, until the pressure drop across the test filter/system drops to the initial value recorded in Step 2, or by removing the test filter/system from the test rig and drying in an oven to accelerate the dying process, providing the temperature does not compromise the materials used in the construction of the test filter/system.

11. If the test filter/system has been removed from the test rig, reload the test filter/system into the test rig as per Step 1.

12. Repeat Steps 2, 3 and 4.

13. The test filter/system is loaded with ASHRAE test dust until the pressure drop across the test filter/system reaches 500Pa.

14. Repeat Steps 5-9.

15. Dry out the test filter/system as per Step 10, with the exception that the test filter returns to 500Pa, not the initial pressure drop of the test filter/system. If test filter/system has been removed form the test rig, repeat Steps 11 and 12.

16. The test filter/system is loaded with mineral oil aerosol. Mineral oil aerosol generation system is turned on and allowed to run for a period of three (3) hours.

17. Repeat Steps 5-9.

18. Repeat Step 15.

19. Repeat Steps 5-8, with the exception that the saline solution aerosol generation system is allowed to run for a period of three (3) hours. Upstream and downstream sampling is to be performed in the final hour of this part of the test.

20. Turn off the saline solution generation system, and turn off the fan so there is no airflow over the test filter/system. End of test procedure.

9.4 Filter System Saline Solution Aerosol Efficiency Test

The test procedure for testing the salt particle removal efficiency of the filter system follows the same procedure and steps as outlined in Section 9.3 for the test filter. In addition, for the filter system test the below step is also included:

19a. Repeat Step 19, with the exception that the duration of this part of the test is either three (3) hours, or the time it takes for the salt particle removal efficiency of the filter system to drop to the same value as for the test filter/system alone, whichever is soonest.

10 Reporting

10.1 General

The test report shall include an explanation of the test results and a description of the test method and any deviations from it. The type and identification number of the particle counter used should be reported, as well as the method of airflow rate measurement. The report shall include the following:

— the interpretation of test reports, as detailed in 10.2;

— summary of the results;

— measured efficiencies and their uncertainties;

— data and results of airflow rate and test pressure drop measurements.

Test results shall be reported using the test report format presented in this standard. Figures 10 and 11 and Tables 5 to 9 comprise the complete test report and are examples of acceptable forms. Exact formats

are not requested, but the report shall include all items shown. The legend of each table and graph should preferably include the following:

— type of filter;

— the number of this standard

- test number;
- test aerosol and loading dust;
- test airflow rate.

10.2 Interpretation of test reports

This brief digest shall be included in the test reports and summary reports. This shall be included after the issued report and shall be a one-page addition with the text sized to fill the page.

The interpretation of test reports

This brief review of the test procedures, including those for addressing the testing of electrostatically charged filters, is provided for those unfamiliar with this ISO procedure. It is intended to assist in understanding and interpreting the results in the test report/summary.

Many types of air filter rely on the effects of passive electrostatic charge on the fibres to achieve high efficiencies, particularly in the initial stages of their working life. Environmental factors encountered in service may affect the action of these electrostatic charges so that the initial particulate efficiency may drop substantially after an initial period of service. In many cases this is offset or countered by an increase in efficiency ("mechanical efficiency") as dust deposits build up to form a dust cake. In the later stages of operating life the efficiency may increase to equal or exceed the initial efficiency. The reported, untreated and conditioned (discharged) efficiency shows the extent of the electrostatically charge effect on initial performance and indicates the level of efficiency reachable when the charge effect is completely removed and there is not a compensating increase of the mechanical efficiency.

The reported untreated and conditioned (discharged) efficiencies show the extent of the electrostatically charge effect on initial performance. It should not be assumed that the measured conditioned (discharged) particulate efficiency represents real life behaviour. It merely indicates the level of efficiency obtainable with the charge effect completely removed and with no compensating increase in mechanical efficiency.

For reasons of consistency filter efficiencies are measured using artificially generated dust clouds of synthetic dusts with closely controlled particle size. The test dust selected for testing a given filter depends on its initial filtration particulate efficiency with respect to 0,4 µm liquid droplets

The particulate efficiency measurements are repeated after the filter has been loaded with ISO fine loading dust until the resistance has risen to a value of 375 Pa in the case of test of low efficiency filters, and up to a value of 625 Pa for the medium and high efficiency filters.

Test dust capacities measured in this way should not be assumed to simulate real life operating conditions as the properties of dusts encountered in service conditions vary very widely. Comparative performances and rankings may be established, but it should always be borne in mind it's the actual conditions on site that will determine the in-service filter performance.

10.3 Summary

When applicable the one page summary section of the performance report (Figure 10) shall include the following information:

— **General:**

1) Testing organization;
2) Date of test;
3) Name of test operator;
4) Report number;
5) Test requested by;

6) Name of supplier of device;

7) Date of receiving the device.

— **Manufacturer's data of the tested device:**

8) Description of the device;

9) Type, identification and marking;

10) Manufacturer of device;

11) Physical description of construction (e.g. pocket filter, number of pockets);

12) Dimensions (actual width, height and depth. In case of cylindrical cartridges the inner and outer diameter of the cartridge);

13) Type of media, if possible or available the following shall be described:

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

— Effective filtering area in device;

— Type and amount of dust adhesive on filter media if feasible.

14) Photographs of the air entering and air leaving sides of the as received device;

15) Additional information as needed for proper filter identification.

— **Test data:**

16) Test airflow rate;

17) Test air temperature, relative humidity and barometric pressure;

18) Type of loading dust and test aerosol;

19) Initial pressure drop and final test pressure drop;

21) Table of salt particle removal efficiency for each stage of the saline solution aerosol test. See Table 4.

Table 4 — Salt particle removal efficiency for tested filter/system

Test filter/system condition	Salt particle concentration		Salt particle removal efficiency
	Upstream	**Downstream**	
Initial, clean			
Loaded with dust			
Loaded with dust and oil			
Three hour test			

— **Statement:**

23) The results relate only to the tested item;

24) The performance results cannot by themselves be quantitatively applied to predict filter performance in service.

In the summary report, the results shall be rounded to the nearest integer except for filters with efficiencies >95 %. The efficiency result shall be reported with a two-digit accuracy of the penetration value.

10.4 Efficiency

Kommenterad [L5]: From this point on document is as per. ISO 29461-1. Test report layout and content to be revised

In addition to the summary report, when applicable, results of the efficiency measurements shall be reported both in tables and as graphs.

— **Tables:**

1) Particulate efficiency and uncertainty at each particle size after dust loading to final test pressure drop (Table 5);

2) Pressure drop versus airflow for clean filter (Table 6);

3) Pressure drop and gravimetric efficiency (Table 7);

4) Particulate efficiency and pressure drop in the conditioning test (Annex A) (Table 8 and Table 9).

— **Graphs:**

1) Initial and dust loaded particulate efficiency (final test pressure drop) versus particle size (Figure 11).

10.5 Pressure drop and airflow rate

When applicable all required data and results of the airflow rate and pressure drop measurements throughout the complete test shall be reported in table format. The pressure drop curve for the clean filter is reported in the summary section.

The airflow shall be reported as measured while the pressure drops shall be corrected to an air density of 1,20 kg/m^3 if required in accordance with 10.2. The corrections can be made as described in Annex D.

10.6 Marking

The filter shall be marked with a type identifying marking. The following details shall be provided:

— Name, trade mark or other means of identification of the manufacturer;

— Type and reference number of the filter;

— Number of this standard;

— Flow rate at which the filter has been tested.

If the correct mounting cannot be deduced, marking is necessary for correct fitting in the test duct (e.g. ”top”, ”direction of flow”).

The marking shall be as clearly visible and as durable as possible.

ISO 29461-1			
Testing organization:		**Report #:**	
GENERAL			
Test no.:	Date of test: yyyy-mm-dd	Supervisor:	
Test requested by:		Device receiving date: yyyy-mm-dd	
Device supplied by:			
DEVICE TESTED			
Model:	Manufacturer:	Construction:	
Type of media:	Effective filtering area:	Actual filter dimensions ($W \times H \times D$):	
TEST DATA			
Test airflow rate:	Test air temp:	Test air relative humidity: %	Test aerosol: **DEHS** Loading dust: **ISO 12103-A2**

RESULTS				
Initial pressure drop:	**Final test pressure drop:**	A_{50} (gravimetric efficiency at 50g):	**Test dust capacity**	**Remark:**

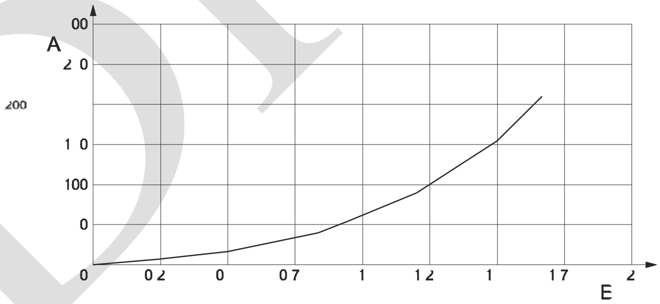
Efficiency versus DEHS-particles

	Particle Size[b]			
Efficiency	**0,4 µm**	**0,6 µm**	**0,8 µm**	**1,2 µm**
Filter				
Initial (E_0)	±	±	±	±
Conditioned[a] (Initial - ΔE_C)				
Dust loaded 50g	±	±	±	±
Dust loaded (final dp)	±	±	±	±
Media				
Initial	±	±	±	±
Conditioned	±	±	±	±
ΔE_C (Initial-Conditioned)				

a The conditioned filter efficiency is calculated from the media test: conditioned efficiency (filter) = E_0 (filter) - ΔE_C

b See the attached Interpretation of Test Report.

Pressure vs. airflow



Key

A pressure drop

B airflow

NOTE The performance results are only valid for the tested item and cannot by themselves be quantitatively applied to predict filter performance in service.

Figure 10 — Summary section of performance report

Table 5 — Initial particulate efficiency and loaded particulate efficiency inclusive of uncertainty

ISO 29461-1, Initial and loaded efficiency incl. uncertainty
Air filter:
Test no.:
Test aerosol:
Air flow rate:

Particle size (µm)		**Efficiency** % **Pressure drop and dust fed**			**Remark**
Interval	**Mean**	Pa (in WG) 0 g	Pa (in WG) 50 g	Final Pa (in WG) g	
-		±	±	±	
-		±	±	±	
-		±	±	±	
-		±	±	±	
-		±	±	±	
-		±	±	±	
-		±	±	±	
-		±	±	±	
-		±	±	±	
-		±	±	±	

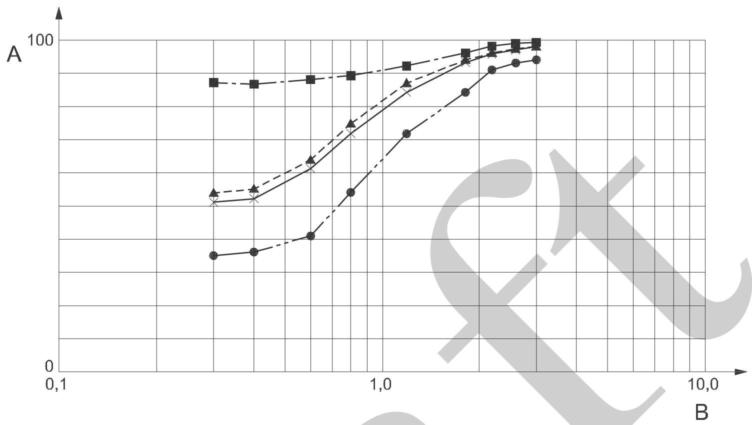
NOTE The uncertainty of the measured efficiencies is reported on a 95 % confidence

Report any correction of efficiency based on release of particles from filter.

Air filter........................

Initial and dust loaded particulate efficiency

ISO 29461-1



Test no: ....

Test aerosol: ....

Loading dust: ....

Airflow rate: ....

Final test pressure drop: ....

Key

A Efficiency (%)

B Particle size (µm)

—×— Initial

-▲- - - 50 g

■-·- Final pressure drop

●-··- Conditioned

Figure 11 — Initial and dust loaded efficiencies

Table 6 — Airflow rate and pressure drop of clean filter

ISO 29461-1 – Airflow rate and pressure drop of clean filter

Air filter:

Test no.:

Airflow rate:

Date		Airflow meter				Filter						
		T_f °C	p_{sf} kPa	Δp_f Pa	q_m kg/m³	T °C	φ %	p_a kPa	ρ kg/m³	q_v m³/s	Δp Pa	$\Delta p_{1,20}$ Pa
	Clean filter											
yyyy-mm-dd												
	Clean filter pressure drop is proportional to $(q_v)^n$**, where** n **=**											

Symbols and units

p_a	Absolute air pressure upstream of filter, kPa	T_f	Temperature at airflow meter, °C
p_{sf}	Airflow meter static pressure, kPa	ρ	Air density upstream of filter, kg/m³
q_m	Mass flow rate, kg/m³	φ	Relative humidity upstream of filter, %
q_v	Airflow rate at filter, m³/s	Δp	Measured filter pressure drop, Pa
T	Temperature upstream of filter, °C	Δp_f	Airflow meter differential pressure, Pa
		$\Delta p_{1,20}$	Filter pressure drop at nominal air density of 1,20 kg/m³, Pa

Table 7 — Pressure drop and Gravimetric efficiency after dust loading to final test pressure drop

ISO 29461-1 – Pressure drop and gravimetric efficiency after dust to final test pressure drop

Air filter:

Test no.:

Type of loading dust:

Airflow rate:

Date	Δp_1 Pa (in WG)	Δm g	m_{tot} g	Δp_2 Pa (in WG)	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

Gravimetric efficiency, A_{50} [%]

Dust in duct after device, m_d [g]

Cumulative mass of dust fed to filter, m_{tot} [g]

Mass of final filter before dust increment, m_1 [g]

Mass of final filter after dust increment, m_2 [g]

Dust increment, Δm [g]

Mass gain of final filter, Δm_{ff} [g]

Pressure drop before dust increment, Δp_1 [Pa]

Pressure drop after dust increment, Δp_2 [Pa]

Table 8 — Particulate efficiency and pressure drop of untreated filter material

ISO 29461-1 – Efficiency and pressure drop of untreated filter material

Air filter:

Test no.: Test aerosol:

Airflow rate: Media velocity:

Size of material sample:

Particle size (µm)		**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Average**	
				Efficiency (%)				
				Pressure drop				
Interval	**Mean**	Pa (in WG)	Pa (in WG)	Pa (in WG)	Pa (in WG)	Pa (in WG)	Pa (in WG)	
-		±	±	±	±	±		
-		±	±	±	±	±		
-		±	±	±	±	±		
-		±	±	±	±	±		
-		±	±	±	±	±		

NOTE The uncertainty of the measured efficiencies is reported on a 95 % confidence level

Table 9 — Particulate efficiency and pressure drop of conditioned filter material

ISO 29461-1 – Efficiency and pressure drop of treated filter material

Air filter:

Test no.: Test aerosol:

Airflow rate: Media velocity:

Size of material sample:

Particle size (µm)		**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Average**	
				Efficiency (%)				
				Pressure drop				
Interval	**Mean**	Pa (in WG)	Pa (in WG)	Pa (in WG)	Pa (in WG)	Pa (in WG)	Pa (in WG)	
-		±	±	±	±	±		
-		±	±	±	±	±		
-		±	±	±	±	±		
-		±	±	±	±	±		
-		±	±	±	±	±		

NOTE The uncertainty of the measured efficiencies is reported on a 95 % confidence level

Annex A
(normative)

Conditioning test procedure

A.1 General

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. This is accomplished by measuring the removal efficiency of an untreated filter material and the corresponding efficiency after the effect of the electrostatic removal mechanism has been eliminated or inhibited.

Many types of air filter rely to different extents on the effects of passive electrostatic charges on the fibres to achieve high efficiencies, particularly in the initial stages of their working life, at low resistance to airflow. Exposure to some types of challenge, such as combustion particles, fine particles or oil mist in service may affect the action of these electric charges so that the initial efficiency may drop substantially after an initial period of service. In some cases this is offset or countered by an increase in efficiency (“mechanical efficiency”) as dust deposits build up to form a dust cake. In the later stages of operating life the efficiency may increase to equal or exceed the initial efficiency.

The procedure described here quantitatively shows the extent of the electrostatic charge effect on the initial performance on a sample of the filter medium. It indicates the level of efficiency obtainable with the charge effect completely removed and with no compensating increase in mechanical efficiency. Also, the influence of the converted three-dimensional filter structure is not covered by the procedure described here. It should not be assumed that the measured conditioned (discharged) efficiency always represents real life behaviour. The chemical treatment of a filter medium described below may affect the structure of the fibre matrix or chemically affect the fibres or even fully destroy the filter medium. Hence, the procedure described below may not be applicable to all types of filter media.

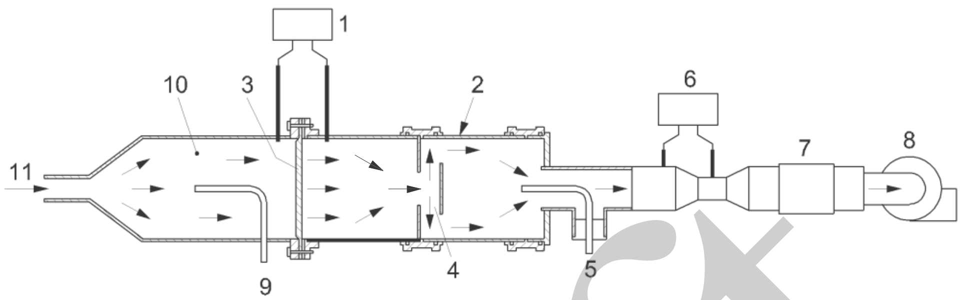
A.2 Test method for conditioning of filter material

A.2.1 Equipment

The described procedure is based on a Standardized treatment with isopropanol (IPA) to evaluate electrostatic influence on filter particulate efficiency.

The isopropanol test is made by first measuring the particulate efficiency of untreated media samples. Next, the samples are treated with IPA vapour (>99,9 % technical grade). If IPA is reused the IPA purity must remain above 99,9 %. After filter samples have been exposed to the IPA vapour, they are placed on a flat, inert surface in a fume cupboard for drying. After the drying period of 15 min the particulate efficiency measurements are repeated. To verify that sample is free from residual IPA the sample is purged for 30 min with clean dry air and the particulate efficiency test is repeated.

The principle of the filter material test equipment is shown in Figure A.1. This system consists of a test duct, a flow meter, a flow control valve, a (downstream) sampling tube and a manometer. The filter sample to be tested is fixed to the test tube by means of a flange. The test tube also includes a mixing section, which ensures a representative sampling downstream of the filter. The sampling tubes are connected to the sampling system of the optical particle counter. Air and test aerosol could be taken from the main duct system, which means that the normal aerosol generation system can be used.

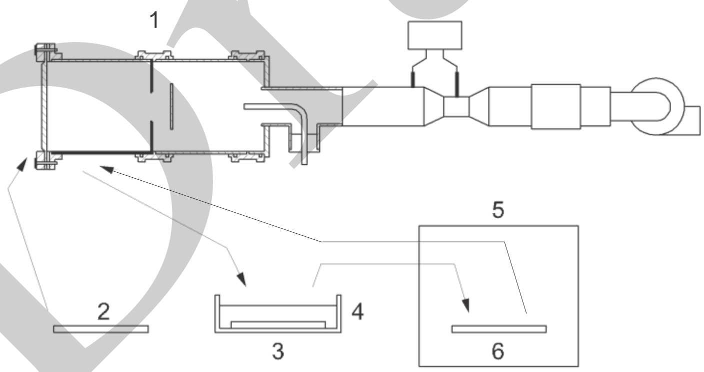


Key

1	manometer	7	flow control
2	test duct	8	fan
3	filter sample	9	upstream sampling
4	mixing section	10	upstream duct
5	downstream sampling	11	aerosol
6	flow meter		

Figure A.1 — Filter material test equipment

The isopropanol vapour treatment is made using the system shown in Figure A.2. This system includes a vessel for the isopropanol. The system also includes flat perforated surfaces on which filter samples are placed for drying. The drying of the filter samples should take place in a laboratory fume cupboard.



Key

1 efficiency measurement
2 filter sample
3 isopropanol treatment
4 isopropanol vessel
5 fume cupboard
6 drying

Figure A.2 — Principle of the isopropanol test system

A.2.2 Preparation of test samples

A minimum of three media samples shall be tested. And the total surface of the samples must be ≥600 cm^2. Representative samples shall be supplied by the customer or selected from a second filter, identical with the filter used in the main test. Samples from the filter shall be selected (e.g. by cutting) in such a way that they represent the complete filter. The locations where media samples are to be cut shall be randomized. If flat samples cannot be cut from the filter a small piece from the filter shall be cut out and sealed into a frame fitting into the test system.

Each effective media sample area should be ≥200 cm^2 (0,215 ft^2) and must be ≥100 cm^2 (0,1 075 ft^2). The media area samples could be extended to get more representative samples of the filter but effective media size shall be maximum 0,61 m × 0,61 m (24 in × 24 in).

A.2.3 Measurement of the filter medium efficiency

The test is started by mounting the filter sample in the test equipment. The velocity through the filter sample is adjusted to be the same as the nominal media velocity used in the filter (using effective filtering area). The filter sample pressure drop is measured.

The particulate filtration efficiency of the sample is determined by measuring the particle concentrations from upstream and downstream of the filter sample. The criteria for test aerosol, size range and particulate efficiency measurement are made according to the main body of this standard.

A.2.4 Isopropanol vapour treatment test

The isopropanol vapour exposure test is carried out as follows:

— Initial particulate efficiency and pressure drop values of the filter samples are measured.

— Filter samples are treated (exposed) with isopropanol vapour for 24 h, see A.2.5.

— Filter samples are placed on a flat inert surface for drying (this should take place in a laboratory fume cupboard). To allow quick evaporation of the IPA the samples should be placed on a perforated surface surrounded by air.

— After a drying period of 15 min, the particulate efficiency and pressure drop measurements are repeated.

— After purging for 30 min with dry, clean air the particulate efficiency test is repeated for one of the samples. If efficiency has changed more than ±3 percentage points or the pressure drop has changed by more than ±5 Pa (±0,2 in WG), all samples are purged for 30 min with clean air and retested.

— If the required accuracy above cannot be met, there shall be a clear remark in the report that this requirement has not been met and the reason for this.

A.2.5 Isopropanol vapour treatment method

— The allowed temperature range for the test container and the ambient air is +20 °C to +30 °C.

— The container with IPA shall not be in direct contact with sunlight or any other heat radiation that may alter the vapour characteristics significantly.

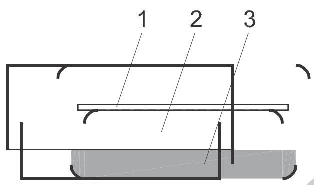
— The ambient humidity shall be within 40–80 % RH.

— Add IPA into containers to about 10 mm in depth. Well above the liquid surface, place a screen to hold the sample media.

— Place samples onto the screens and seal the containers.

— The mixture of ambient (room) air and IPA (and vapour) in the container shall not interact with the ambient air (proper seal).

— After a period of 24 h, open the containers and prepare the media for particulate efficiency test (see A.2.4).



Key

1 sample

2 IPA vapour

3 liquid IPA

Figure A.3 — Principle of the isopropanol container (vessel and lid)

Isopropanol vessel:

— executor (container with IPA);

— holder with filter media.

A.3 Expression of results

The average efficiencies of the untreated and conditioned filter samples are calculated. The average initial particulate efficiency of the media samples is compared with the initial particulate efficiency measured at the entire filter. If these two efficiencies differ more than 5 percentage points, more media samples shall be tested and the results included in the average calculation of the initial particulate efficiency of the media samples until the two values differ less than 5 percentage points. If this goal can not be reached, a corresponding remark must be made in the test report. The average efficiencies of the untreated and conditioned filter samples are reported together with the aerosol and size range. (DEHS, 0,3 µm to 3 µm). The difference in particulate efficiency from the media tests (initial – conditioned) are calculated by:

ΔE_C = initial media particulate efficiency (E_0) – conditioned media efficiency [%] (33)

This difference is then used to calculate the conditioned filter efficiency by:

conditioned filter efficiency = $E_0 - \Delta E_C$ (34)

Annex B
(informative)

Shedding from filter elements

The term “shedding” comprises three separate aspects of filter behaviour: re-entrainment of particles, particle bounce and release of fibres or particulate matter from the filter material. Some or all of these phenomena are likely to occur to some extent during the life cycle of an installed filter, especially in dry weather conditions.

Literature about shedding and its effect on filter performances can be found in Bibliography references[14],[16],[17],[18],[19] and.[20]

B.1 Shedding

B.1.1 Re-entrainment of particles

As the quantity of the arrested dust on the filter increases, the following effects may lead to re- entrainment of already captured particles into the air stream:

— An incoming particle may impact on a captured particle and re-entrain it into the air stream.

— The air velocity in the channels through the medium will increase because of the space occupied by captured particles. Furthermore, the filter medium may become compressed by the increased resistance to airf low thereby causing even further increase in velocity in the air channels. The consequent increased fluid drag on deposited particles may re-entrain some of them.

— Movements of the filter medium during operation cause re-arrangement of dust in the filter medium structure. This leads to an immediate re-entrainment of dust. Filter media movements can be caused by a variety of circumstances such as:

1) normal airflow through the filter;

2) periodic (e.g. daily) start/stop operation of the air conditioning plant;

3) varying airflow rates, caused by airflow control;

4) mechanical vibration, caused by the fan or other equipment.

Re-entrainment of particles may be measured and quantified (see Bibliography references[3] and[4]).

This effect is more pronounced for low efficiency filters than for high efficiency filters.

B.1.2 Particle bounce

In an ideal filtration process, each particle would be permanently arrested at the first collision with a filtering surface such as a fibre, or with an already captured particle. For small particles and low air velocities, the energy of adhesion greatly exceeds the kinetic energy of the airborne particle in the air stream, and once captured, such particles are very unlikely to be dislodged from the filter. As particle size and air velocity increase, this is progressively less so; larger particles may “bounce” off a fibre. Thereby they normally lose enough energy to be captured in a subsequent collision with a fibre. However, if no contact with a fibre follows, the particle will be shed, i.e. discharged from the filter, which will result in a corresponding reduction of efficiency for particles of this size range (see Bibliography references[1] and[2]).

A measurement method to quantify this type of shedding is defined in ASHRAE 52.2:1999, using solid KCl particles of relatively big size (>3 µm). Using liquid aerosol, the particle bounce effect cannot be measured at all.

The particle bounce effect is more pronounced for low efficiency filters than for high efficiency filters.

B.1.3 Release of fibres or particulate matter from filter material

Some designs of filter include filter media either containing or generating loose fibres or particulate matter from the filter design materials (e.g. binder). During constant volume filter operation, but especially during variable flow or start-stop operation, these materials can be lost into the air stream. The extent of such shedding depends on the integrity of the media fibre structure and its rigidity and stability in the face of varying air velocities, as well as the stability of the filter design materials (e.g. the binder which holds fibres together), throughout the operating life of the filter. It should be noted, however, that the quantity of fibres or particulate matter shed in this way is normally negligible in comparison with the total amount of dust penetrating through a filter loaded by typical environmental dust burden (see Bibliography references[5] and[6]).

B.2 Testing of shedding effects

Users should be aware of the possibility of filters exhibiting shedding behaviour in practical use. From the user's point of view it would be advantageous to detect any shedding behaviour of a filter. However, such measurements are not that easy to perform.

The gravimetric efficiency measurements for low efficiency filters prescribed in this standard reflect the above described shedding effects only partly, if at all. However, any drop in the value of the gravimetric efficiency or resistance during the course of a filter loading test should be taken as a serious indication that shedding may have occurred.

The particulate efficiency results for higher efficiency filters provided in this standard reflect normally none of the above described shedding effects, as the aerosol used for these filters is a liquid (DEHS) aerosol. Membrane sampling downstream of filters and microscopic analyses of the membranes could determine occurrence of this type of shedding, but such a method is not defined here.

Annex C
(informative)

Commentary

C.1 General

The procedures described in this standard have been developed from those given in ISO/TS 21220. The following gives a brief description of the principles of the test methods and procedures contained in this standard.

C.2 Principle of the test method

C.2.1 Basic

The test is designed for airflow from 0,25 m^3/s (900 m^3/h) up to 1,67 m^3/s (6000 m^3/h). Filter classification is made at air test flow rate specified by the manufacturer.

Two efficiency measurement methods are used in the standard: the "particulate efficiency" and "gravimetric efficiency". Samples from filter shall be conditioned (discharged) to provide information about the intensity of the electrostatic removal mechanism. Two filters of same quality are needed; one for the main filter test and one for media samples (or partial/complete filter) for the electrostatic condition (discharge) test.

After the determination of the initial particulate efficiency, the filters are loaded with dust in two steps up to final test pressure drop. This may give information of the shedding behaviour of the filter as well as test dust capacity and filtration efficiency with respect to the loading dust (gravimetric efficiency). The measurement methods use different particle size ranges, loading dusts and final test pressure drops.

Table C.1 — Summary of test methods

Test method	Size range	Test aerosol	Conditioning	Loading dust in two steps (first step 50 g)	Final test pressure drop Pa (in WG)
Particulate efficiency	0,3 µm – 3,0 µm	DEHS	Yes	ISO fine (140 mg/m^3) (4,0 g/1 000 ft^3) [two steps]	625 (2,5)
Gravimetric efficiency	ISO 12103-A2	ISO 12103-A2	Yes	ISO fine (140 mg/m^3) (4,0 g/1 000 ft^3) [two steps]	375 (1,5)

C.2.2 Size range

One size range is used, 0,3 µm to 3,0 µm for particulate efficiency measurement. Gravimetric efficiency (mass) is mostly important for filters with lower efficiency.

C.2.3 Test aerosol

High efficiency filters are not noticeably influenced by the type of test aerosol (liquid/solid). The DEHS aerosol shall be used undiluted without any charge on the particles (charging or neutralization). The aerodynamic, geometric and light scattering sizes are close to each other when measured with optical particle counters. The DEHS (or equivalent) was chosen for the following reasons:

— Easy to generate in size range with simple equipment (Laskin nozzle).

— The response time of DEHS (PAO) generator is fast and testing can start almost immediately.

— Clean to use. No corrosion problem.

— Commonly used in testing of high efficiency filters and *in situ* tests.

— Do not need radioactive source (not allowed in some countries) or corona discharge ionizer.

— Same geometric and aerodynamic particle size.

— Particulate efficiency results close to solid particles in size range 0,3 µm to 1,2 µm.

— The maintenance cost and work is low with DEHS (PAO). No need to rinse the generator, no need to calibrate any neutralizer, etc.

— In most cases DEHS (PAO) does not affect the pressure drop of the filter.

C.2.4 Loading dust

One type of dust is used - ISO fine (ISO 12103-A2). The filters are loaded to final test pressure drop in two steps. The loaded particulate efficiency is then measured to indicate any change in performance.

This loading dust is not representative of the real world, but is used to “simulate” dust loading. The loading could give information of the filter’s mechanical and aerodynamic design but there is no general correlation between synthetic dust capacity and real life capacity and the test dust capacity is not presented in the summary report. The dust loading tests can, to some extent, indicate shedding problems.

ISO “fine” dust is clean and easy to use and the specification of this dust is better defined than for the ASHRAE dust used in earlier air filter standards. The dust will indicate shedding performance better than the ASHRAE dust. The test dust capacity will increase two to five times with the ISO dust. To reduce the required test time, the loading concentration has increased from former values of 70 mg/m^3 (2,0 g/1 000 ft^3) to 140 mg/m^3 (4,0 g/1 000 ft^3).

C.2.5 Conditioning test

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, fine particles or oil mist may neutralize such charges with the result that filter efficiency can decrease over time. The exact efficiency is dependent on the media type, the actual particle content of the ambient intake air as well as other environmental factors. It is important for users of filters to be aware of the possibility of performance degradation during operational life.

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. This is accomplished by measuring the removal particulate efficiency of an untreated filter material and the corresponding efficiency after the effect of the electrostatic removal mechanism has been eliminated or inhibited.

Conditioning according to the IPA method in Annex A was chosen because:

— the test indicates the minimum particulate efficiency of the filters, which could happen in real applications;

— there have been round robin tests, research works and tests confirming the uniformity of the method and its relevance;

— no or moderate increase in pressure drop of media or filters;

— many years of experience with the method;

— existing Standardized methods.

The procedure was selected because it is well established, reproducible, easily performed and relatively fast. Selection of this approach in the standard is not intended to slow or preclude the development of aerosol-based conditioning procedures by other organizations; an aerosol-based procedure may better reflect filtration changes that occur in actual use.

C.3 Interpretation of test results

This following interpretation of test results shall be included in the test report (see 11.2).

This brief review of the test procedures, including those for addressing the testing of electrostatically charged filters, is provided for those unfamiliar with this ISO procedure. It is intended to assist in understanding and interpreting the results in the test report/summary.

Many types of air filter rely on the effects of passive electrostatic charge on the fibres to achieve high efficiencies, particularly in the initial stages of their working life. Environmental factors encountered in service may affect the action of these electrostatic charges so that the initial particulate efficiency may drop substantially after an initial period of service. In many cases this is offset or countered by an increase in particulate efficiency ("mechanical efficiency") as dust deposits build up to form a dust cake. In the later stages of operating life the efficiency may increase to equal or exceed the initial particulate efficiency. The reported, untreated and conditioned (discharged) efficiency shows the extent of the electrostatically charge effect on initial performance and indicates the level of efficiency reachable when the charge effect is completely removed and there is not a compensating increase of the mechanical efficiency.

The reported untreated and conditioned (discharged) efficiencies show the extent of the electrostatically charge effect on initial performance. It should not be assumed that the measured conditioned (discharged) efficiency represents real life behaviour. It merely indicates the level of particulate efficiency obtainable with the charge effect completely removed and with no compensating increase in mechanical efficiency.

For reasons of consistency filter efficiencies are measured using artificially generated dust clouds of synthetic dusts with closely controlled particle size. The test dust selected for testing a given filter depends on its initial filtration efficiency with respect to 0,4 µm liquid droplets.

In the case of using the industry practice of taping the filter unit into the test duct in combination with the test method, the results may not adequately represent the filter sealing mechanism performance which is a vital component of the filtration system.

The particulate efficiency measurements are repeated after the filter has been loaded with ISO fine loading dust until the resistance has risen to a value of 375 Pa in the case of testing low efficiency filters and up to a value of 625 Pa for the medium and high efficiency filters.

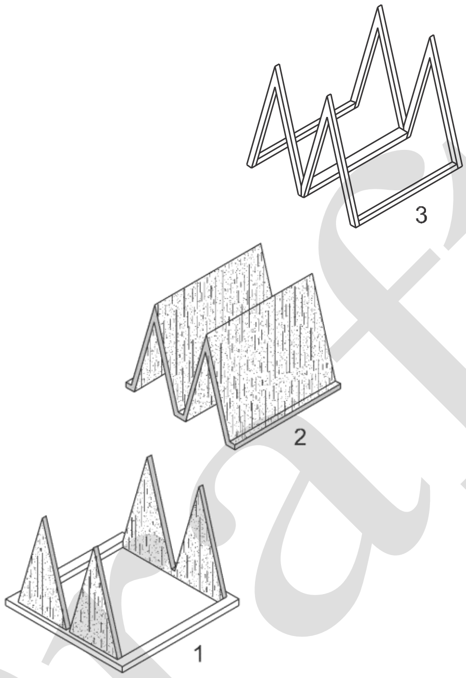
Test dust capacities measured in this way should not be assumed to simulate real life operating conditions as the properties of dusts encountered in service conditions vary very widely. Comparative performances and rankings may be established, but it should always be borne in mind it's the actual conditions on site that will determine the in-service filter performance.

C.4 Flat sheet test (media testing in test duct)

The minimum airflow in the standard is 0,25 m^3/s, which means that flat sheet material using a speed lower than 0,65 m/s cannot be tested directly as a flat sheet in the test duct. For testing at lower velocities through the material in the test duct, it has to be mounted with an extended surface. If the material is fixed to a W-shaped frame system, it can be tested as a common filter. There is no correlation between the W-shape and flat sheet but the method could be used for comparing and evaluating material.

Figure C.1 describes a typical W-form construction that could be used for evaluating filter material. The W-form gives one square metre (1,0 m^2) effective filtering area, and therefore the same figures representing the flow rate (in m^3/s) and the media velocity (in m/s). 0,4 m^3/s gives 0,4 m/s through media.

The filter material to be tested shall be laid on the frame and stretched and fastened to the frame with the help of the counter frames.



Key

1 W-form frame

2 filter material (1 m^2)

3 W-form counter frame

Figure C.1 — Example of W-form frame and details for testing filter material

Annex D
(normative)

Pressure drop calculation

All pressure losses measured during the test should be corrected to a reference air density of 1,198 8 kg/m³, which corresponds to standard air conditions: temperature 20 °C, barometric pressure 101,325 kPa, relative humidity 50 %. However, as long as the air density is between 1,16 kg/m³ and 1,24 kg/m³, no corrections need to be made.

The pressure loss of a filter can be expressed as:

$$\Delta p = c\left(q_{\text{v}}\right)^{n}$$

(D.1)

$$c = k \times \mu^{2-n} \times \rho^{n-1} \quad \text{(D.2)}$$

where

Δp is the pressure loss, Pa

k is a constant;

q_v is the airflow rate, m^3/s

μ is the dynamic viscosity of air, Pa s

n is an exponent;

ρ is the air density, kg/m^3.

The readings of the airflow measuring system shall be convened to the volumetric airflow rate at the conditions prevailing at the inlet of the tested filter. With these airflow rate values and the measured pressure losses, the exponent *n* from Formula (D.1) could be determined by using a least square technique.

With a known value of exponent *n*, the measured pressure losses can be corrected to standard air conditions using the following equation:

$$\left(\mu \quad \right)^{2-n} \left(\rho \right.$$

$$^{n-1}$$

$$\Delta p_{1,20} = \Delta p \left| \frac{1,20}{} \right| \times \left| \frac{1,20}{} \right|$$

(D.3)

(μ)

(ρ)

where the un-subscripted quantities refer to the values at the test conditions and the subscripted quantities to values at the standard air conditions and:

$\rho_{1,20}$ = 1,198 8 kg/m^3

$\mu_{1,20}$ = 18,097 × 10^{-6} Pa s

The exponent n is usually determined only for a clean filter. 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 filter test. The air density ρ (kg/m^3) of temperature T (°C), barometric pressure p (Pa) and relative humidity φ (%) can be obtained by Formula (D.4):

$$\rho = \frac{p \times 0,378 p_w}{287,06 \times (T + 273,15)} \quad \text{(D.4)}$$

where p_w (Pa) is the partial vapour pressure of water in air given by the Formula (D.5):

$$p_w = \frac{\phi}{100} p_{ws}$$

(D.5)

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

$$p \quad = \exp \lceil$$

$$,484\,085 \times \frac{6\,790{,}498\,5}{} \times 5{,}028\,02 \times \ln(T + 273{,}15$$

(D.6) ws |59)

$(T + 273,15)$

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

$$\mu = \frac{1,455 \times 10^{6} (T + 273,15)^{0,5}}{1 + \frac{110,4}{(T + 273,15)}}$$

⌋

(D.7)

Annex E
(normative)

Net Area Calculation

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 the guidelines described in this paragraph. 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.

E.1 Pocket filters

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

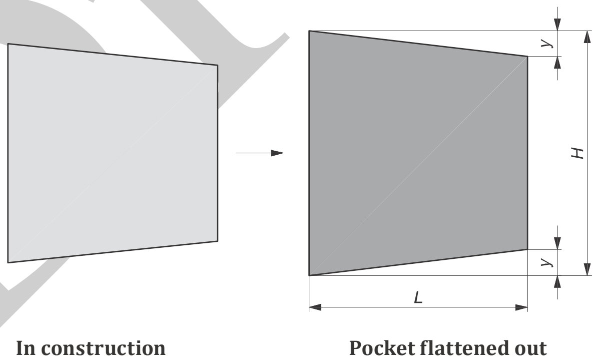
a) Stretch each pocket in the airflow direction so it will expand to its full length (*L*). b) Measure the length of each pocket.

c) Measure the shape of the pocket according to Figure E.1, below.

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.



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 E.1 — Pocket filter, area calculation

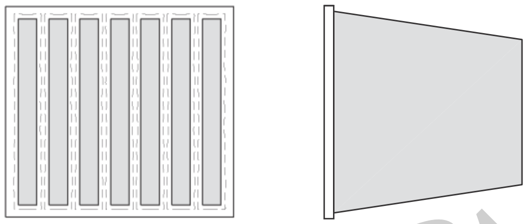
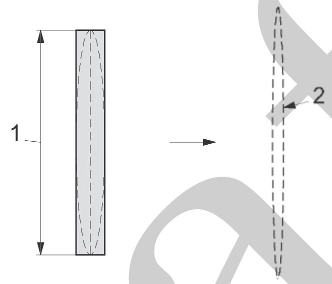


Figure E.2 — Front view (left) and side view (right), pocket filter



Key

1 pocket height in construction

2 pocket flattened out

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

Pocket (i) net area:

$$A_\mathrm{i} = 2 \times (H \times L - y \times L)$$

(E.1)

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

Then the equation becomes:

$$A_i = 2 \times (H_{L/2} \times L) \quad [m^2] \qquad (E.2)$$

Total net area:

$$A_{tot} = \sum_{1}^{N} A_i \quad [m^2] \qquad (E.3)$$

where N is the total number of pockets.

Tolerance range, example

H: ± 0,002 m (2 mm) L: ± 0,003 m (3 mm) y: ± 0,001 m (1 mm)

$$A_{min} = \Sigma\,[2 \times (\{H - 0{,}002\} \times \{L - 0{,}003\} - \{y + 0{,}01\} \times \{L - 0{,}002\})]i\ m^2 \qquad (E.4)$$

$$A_{max} = \Sigma\,[2 \times (\{H + 0{,}002\} \times \{L + 0{,}003\} - \{y - 0{,}01\} \times \{L + 0{,}002\})]i\ m^2 \qquad (E.5)$$

Tolerance (–) = (A_{min} - A_{tot}) m^2

Tolerance (+) = (A_{max} - A_{tot}) m^2

Reported result:

$$A_{net} = A_{tot} \pm \text{Tolerance } m^2 \qquad (E.6)$$

E.2 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 Figures E.4 and E.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 may 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 must not include sealant (potting) material that covers 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 will be the total area of the filter.

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

Calculate the pleat (i) net effective area by:

$$A_i = 2 \times (H \times W + t \times W)$$

Calculate the total net area by:

(E.7)

$$A_{tot} = \sum_{1}^{N} A_i \qquad [m^2] \tag{E.8}$$

where N is the total number of pleats.

Tolerance range, example

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:

$$A_{min} = \Sigma\ [2 \times (\{H - 0{,}001\} \times \{W - 0{,}002\})]i\ m^2 \tag{E.9}$$

$$A_{max} = \Sigma\ [2 \times (\{H + 0{,}001\} \times \{W + 0{,}002\})]i\ m^2 \tag{E.10}$$

In case of separator filter:

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

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

Tolerance (–) = (A_{min} - A_{tot}) m²

Tolerance (+) = (A_{max} - A_{tot}) m²

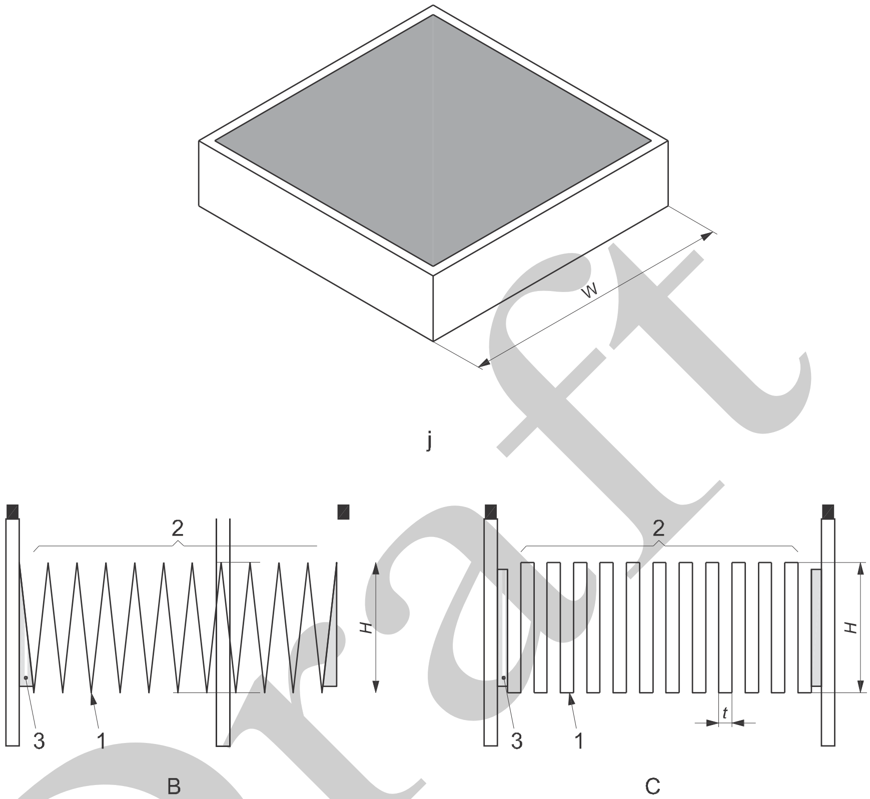
Reported result (one pack filter):

$$A_{net} = A_{tot} \pm \text{Tolerance}\ m^2 \tag{E.13}$$

Reported result (several pack filter):

$$A_{net} = \Sigma\ A_{tot\ (j)} \pm \text{Tolerance}\ m^2 \tag{E.14}$$

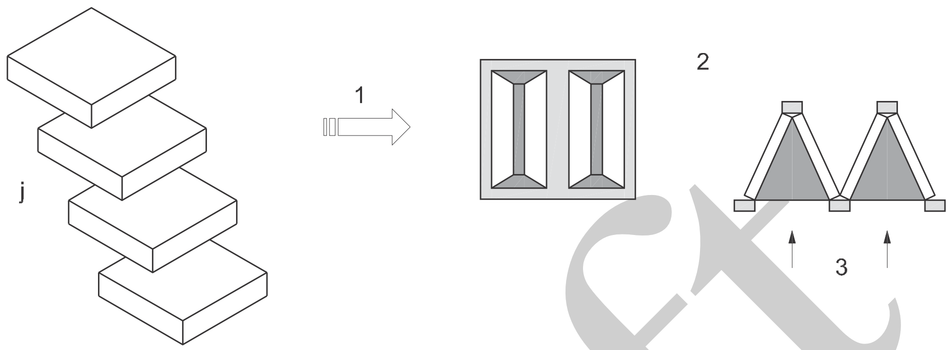
where j is the number of packs (see Figure E.5).



Ke

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

Figure E.4 — Pleated filter, with one pack - Estimation of net filtering area



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1 Assembling

2 complete filter

3 airflow direction

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

Figure E.5 — Pleated filter with several packs- Estimation of net filtering area

E.3 Circular pleated filters

Pleated filters are normally constructed by mini-pleat technology or with the separator pleating (typically aluminium, plastic or paper). A circular (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:

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 will be the total area of the filter.

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

Calculate the pleat (i) net effective area by:

$A_i = 2 \times (H \times L + t \times L)$

Calculate the total net area by:

(E.15)

$$A_{tot} = \sum_{1}^{N} A_i \qquad [m^2] \tag{E.16}$$

where N is the total number of pleats.

Tolerance range, example

H: ± 0,001 m (1 mm)

W: ± 0,002 m (2 mm)

t: ± 0,0005 m (0,5 mm)

In case of mini-pleat filter:

$$A_{min} = \Sigma\ [2 \times (\{H - 0{,}001\} \times \{W - 0{,}002\})]i\ m^2 \quad (E.17)$$

$$A_{max} = \Sigma\ [2 \times (\{H + 0{,}001\} \times \{W + 0{,}002\})]i\ m^2 \quad (E.18)$$

In case of separator filter:

$$A_{min} = \Sigma\ [2 \times (\{H - 0{,}001\} \times \{W - 0{,}002\} + \{t - 0{,}0005\} \times \{W - 0{,}02\})]i\ m^2 \quad (E.19)$$

$$A_{max} = \Sigma\ [2 \times (\{H + 0{,}001\} \times \{W + 0{,}002\} + \{t + 0{,}0005\} \times \{W + 0{,}02\})]i\ m^2 \quad (E.20)$$

Tolerance (–) = (A_{min} - A_{tot}) m^2

Tolerance (+) = (A_{max} - A_{tot}) m^2

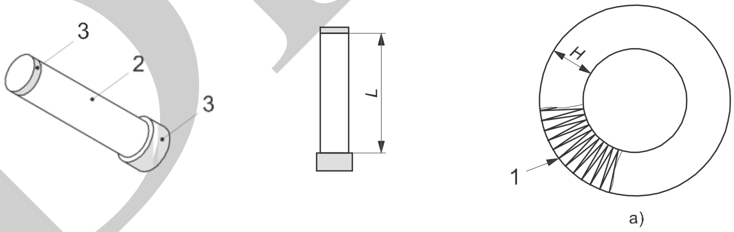
Reported result (one pack filter):

$$A_{net} = A_{tot} \pm \text{Tolerance}\ m^2 \quad (E.21)$$

Reported result (several pack filter):

$$A_{net} = \Sigma\ A_{tot\ (j)} \pm \text{Tolerance}\ m^2 \quad (E.22)$$

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



Key

1 pleat tip

2 filter media pack

3 end cap

a) top view

Figure E.6 — Circular, pleated filter

E.4 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.

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