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Air quality — Test method for filtration characterization of cleanable filter media

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Air quality — Test method for filtration characterization of cleanable filter media

Qualité de l'air — Méthode d'essai pour la caractérisation de la filtration des filtres lavables

Reference number
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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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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11057 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 1, *Stationary source emissions*.

Introduction

Cleanable filters are usually employed for the separation of particles from gases containing dust concentrations in the range of some hundred milligrams per cubic metre up to some hundred grams per cubic metre. Depending on the inlet dust concentrations concerned, a dust cake is more or less rapidly formed upon the surface of the filter medium which is periodically removed in order to maintain the filtration process. With most filters in use at the time of publication, this is usually accomplished by injecting a pulse of compressed air from the clean-gas side, i.e. inside the filter bag or cartridge. The design service life of these filters is usually 2 years to 4 years. They provide clean-gas concentrations of some milligrams per cubic metre without an excessive rise in residual pressure drop for the cleaned filter and a low cleaning frequency, respectively.

Although extensive investigations have been carried out concerning the operating conditions and design of filters and cleaning systems as well as the design and selection of the filter media (References [14] to [17]), the layout and operation of bag filters are still extensively based on data which were empirically obtained in industrial-sized installations or pilot plants.

The systematic characterization and evaluation of filter media with respect to their relevant long-term operational properties (filtration and cleaning behaviour) and emission, in addition to their well-defined textile properties, are still a major problem not only for the developers and manufacturers of filter media, but also for the producers and users of filter installations.

Therefore there is a demand for improved methods for the characterization and evaluation of cleanable filter media. This demand concerns data allowing statements about the filtration properties of a medium in long-term operation, which exceed the data supplied by filter media manufacturers about the non-dusted material.

This International Standard is based on VDI 3926 Part 1:2004[13], ASTM D6830-02:2008[8], JIS Z 8909-1:2005[10], and GB/T 6719:2009[9].

INTERNATIONAL STANDARD ISO 11057:2011(E)

Air quality — Test method for filtration characterization of cleanable filter media

1 Scope

This International Standard specifies a standard reference test method for the comparative characterization of pulse-jet cleanable filter media, to be used in filter elements (e.g. bag filters, pocket filters, cartridge filters) applied in dry gas cleaning under standardized test conditions. The main purpose of testing is to gain information about both the operational performance and the particle emission of cleanable filter media.

It should be noted that while one test apparatus and operating method has been chosen and described herein, it is recognized that other apparatus and operating arrangements can be found acceptable. In order for a candidate apparatus to become an equivalent apparatus, a comparison has to be performed with the standard reference apparatus according to a specified procedure (6.1). The test procedure, the characteristics of the required test facility, and the test conditions, as well as the evaluation and presentation of the results, are specified.

The results obtained from this test method are not intended for prediction of the absolute performance of full-scale filter facilities. However, they are helpful for the selection and development of appropriate cleanable filter media and the identification of suitable operating parameters.

Additional tasks such as verifying filter media concerning $PM_{2,5}$ emissions, the classification of different media according to their filtration performance or the cleanability and durability of filter elements (i.e. projection of bag lifetime) can be addressed using the test method specified.

2 Terms and definitions

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

2.1
aerosol
suspension in a gaseous medium of solid particles, liquid particles or solid and liquid particles having a negligible falling velocity

[ISO 4225:1994[2], 3.2]

2.2
ageing
⟨air quality⟩ process applied to a filter medium to simulate long-term filter operation

NOTE Examples of changes in process behaviour are pressure drop and cycle time.

2.3
filter face velocity
flow rate (under operating conditions) of gas through the exposed filter area divided by that area

NOTE 1 Other frequently used terms are: air-to-cloth ratio and gas-to-cloth ratio.

NOTE 2 Filter face velocity is often expressed in cubic metres per square metre hour, i.e. metres per hour. Alternative units are metres per minute or feet per minute (deprecated).

2.4
calibration
⟨air filtration characterization⟩ comparison of a measuring device (e.g. an optical particle counter) with another instrument for reference measurements using, for example, a reference test aerosol with the objective of an exact determination of an experimental parameter

2.5
clean gas
gas flow exiting the filter

2.6
cleanable filter medium
filter medium whose aerodynamic and particle collection characteristics are regeneratable or recoverable

2.7 Particle concentration

2.7.1
particle number concentration
⟨air filtration characterization⟩ total number of particles per carrier gas volume

NOTE Particle number concentration is expressed in particle numbers per cubic metre or reciprocal cubic metres.

2.7.2
particle mass concentration
total mass of particles per carrier gas volume

NOTE Particle number concentration is expressed in grams per cubic metre.

2.8
cycle time
⟨air quality⟩ time between two cleaning pulses under defined operational conditions

2.9
detection limit of the clean gas concentration
⟨air filtration characterization⟩ minimum concentration in the clean gas which can be unambiguously determined by the described gravimetric method

2.10
dirty gas
dust-loaded gas which is fed into the inlet side of the filter

2.11
dispersion air
gas flow necessary for the dispersion of test dust, i.e. for the transformation of test dust into an aerosol

NOTE Dispersion air needs to be dry, oil-free, and at constant temperature and gas flow rate.

2.12
dust collection efficiency
mass of particulate material collected by the filter divided by the mass of inlet particulate material

2.13
equivalent particle diameter
⟨air filtration characterization⟩ particle size obtained on the basis of a specific method of measurement, and expressed in terms of the diameter of an “equivalent” sphere for that respective method

NOTE 1 Examples of specific measurements are: projected area, surface area, volume, mass, settling velocity or relaxation time, electrical mobility, scattered light intensity, and diffusion rate.

NOTE 2 It is in the nature of this definition that different measurement methods can produce equivalent diameters which do not necessarily coincide. Some of the relevant equivalent diameters are defined in 2.14 to 2.16.

2.14
aerodynamic diameter
⟨air filtration characterization⟩ measure of size for a particle of non-defined shape and density defined on the basis of settling velocity or inertial behaviour (both lead to the same equivalent diameter), which is also relevant for the separation behaviour of particles by inertial effects

NOTE 1 The aerodynamic diameter is based on an equivalent sphere of density $\rho = 1\ 000$ kg/m^3.

NOTE 2 Typical measuring methods employ impactors or particle classifiers.

2.15
equivalent light-scattering particle diameter
measure of size for a particle of non-defined shape obtained on the basis of the scattered light signal detected by an optical particle counter, reflecting the diameter of an equivalent sphere of the aerosol (usually latex particles) used for the calibration of the measuring device

2.16
volume equivalent particle diameter
diameter of a sphere of the same volume as the unknown particle

2.17
exposed filter area
cross-sectional area of a filter medium which is directly exposed to the gas flow during the test

2.18
feed rate stability
measure of the degree of deviation of mass flow rate of the solid from the nominal value

NOTE The value obtained for the feed rate stability depends on the duration of the measurement, which itself can vary substantially from case to case (short or long time feeding).

2.19
filter face
upstream side of the filter medium where the dust is deposited during operation

2.20
filter medium
material separating particulate material from gases characterized by its separating structure and its structural and/or textile-technological characteristics

2.21
filtration characterization
⟨air filtration characterization⟩ determination of certain aerodynamic behaviour of a filter medium as it collects and rejects particulate material from a moving gas stream by measuring parameters, including pressure drop characteristic, development of residual pressure drop, cycle time, residual dust loading, and dust emission

2.22
nominal gas flow rate
⟨air quality⟩ flow rate determined (for the most part by the manufacturer) for a filter medium to be tested

2.23
operating gas flow rate
flow rate existing at the current operating conditions relating to temperature, pressure, humidity, gaseous composition or dust concentration

2.24
standard gas flow rate
flow rate under standard conditions, i.e. standard temperature, $T_n = 273{,}15$ K (0 °C) and standard pressure, $p_n = 1\ 013{,}25$ hPa

NOTE Additional specifications, e.g. for the humidity of the gases, are indicated separately.

2.25
mixing section
part of the test apparatus (often the dirty-gas duct), which ensures that, over the duration of the test, concentration and dispersion of the test dust in the gas stream (i.e. the test aerosol) remain constant and homogeneous when arriving at the test filter

NOTE The particle size distribution and concentration can vary due to changes in the dust properties or in the device parameters of the dust generator and this can affect the uniformity of the dust distribution on the filter surface.

2.26
particle
⟨air filtration characterization⟩ small contiguous object in the solid or liquid state of aggregation that can be transported in the gas flow as a single unit

NOTE Since in practice particles very often present an irregular shape, it is difficult to assign simple geometric dimensions to them. This problem can be bypassed by specifying an equivalent diameter for a particle.

2.27
particle separator
dust collector
⟨air filtration characterization⟩ device for the removal of particles from a gaseous medium

2.28
particle size distribution
⟨air quality⟩ correlation between the quantity of the size fractions and particle size

NOTE 1 Distributions are not characterized adequately by only specifying the parameters characterizing the position of the distribution, such as median, mode or the mass median aerodynamic diameter. In addition, at least a specification relative to the width of distribution is required for which the standard deviation of pairs of variables, such as the minimum, x_{min}, and the maximum, x_{max}, particle diameters or better (since they allow a more precise measurement) $x_{0,05}$ and $x_{0,95}$, could be of use.

NOTE 2 Furthermore, for the unambiguous evaluation of a distribution, the type of measured quantity needs to be exactly defined. Also, the equivalent diameter, the measuring method and the test apparatus are to be specified. It is for instance not sufficient to state “optical particle counter with 90° detection”. In this case, the nature of the light source (laser or white light) and details of the shape of the measuring volume in the aerosol flow are missing.

2.29
optical particle counter
OPC
optical particle size measuring device with a fine classification according to sizes

2.30
photometer
⟨air quality⟩ optical measuring device for the monitoring and the recording of relative fluctuations of particle concentration and size distribution in the aerosol on the basis of multiple particle light extinction

NOTE The use of a photometer for recording variations of the concentration implies a constant particle size distribution.

2.31
pressure drop
difference of the static pressures at the entrance and the exit of a delimited system exposed to a gas flow, in this case the filter medium

NOTE This pressure difference has to be maintained in order to convey a certain amount of flowing medium through the system during steady state operation.

2.32
residual pressure drop
stable difference of the static pressures across the filter medium, determined shortly after its (pulse-jet) cleaning

NOTE Since an online pulse-jet cleaning is a dynamic procedure, the time period between the cleaning by pressure pulse and the reading of the residual pressure drop needs to be defined (e.g. 4 s). This can be done by comparing the pressure drop immediately after the pulse-jet cleaning with the pressure drop that is reached when the dust supply is disconnected.

2.33
repeatability conditions
observation conditions where measurement results are obtained with the same method on identical filter media in the same test apparatus by the same operator using the same equipment within short intervals of time

NOTE 1 Adapted from ISO 3534-2:2006[1], 3.3.6.

NOTE 2 Conditions of measurement include the same measurement procedure, same operators, same measuring system, same operating conditions and same location, and replicate measurements on the same objects over a short period of time.

NOTE 3 The spread is determined from several repeated individual measurements: the smaller the spread, the greater the repeatability.

2.34
reproducibility conditions
observation conditions where measurement results are obtained with the same method on identical filter media in different test apparatus with different operators using different equipment

NOTE 1 Adapted from ISO 3534-2:2006[1], 3.3.11.

NOTE 2 Conditions of measurement include different locations, operators, measuring systems, and replicate measurements on the same or similar objects.

NOTE 3 The reproducibility of a filter testing method, for example, can only be determined by a round robin test.

2.35
residual dust
particulate matter remaining on or in the filter medium after cleaning

2.36
test dust
⟨air quality⟩ particulate matter with defined physical and chemical properties and particle size distribution

2.37
weighing accuracy
d
specification for the balance supplied by the manufacturer relating to a certain measurement range.

EXAMPLE An analytical balance whose $d = 0{,}01$ mg at a maximum range of 60 g. The weighing accuracy is normally an integer multiplied by the detection limit of the instrument.

3 Gases and materials

3.1 Compressed air. The compressed air used by the dust feeder shall be dry and oil-free. It is suggested to use a refrigerant compressed air dryer providing a constant water vapour dew point of 3 °C at 0,6 MPa.

3.2 Filter material for compressed air. The dehumidified compressed air should additionally be cleaned, using a 2-stage filter, comprising a prefilter with pore size of 0,3 µm and a fine filter of 0,01 µm.

3.3 Test dust. Pural NF[1)] consists of boehmite, an aluminium-oxide-hydroxide [γ-AlO(OH)] mineral. The mass mean particle size, $x_{50,3}$, is about 4,5 µm (further specifications by the manufacturer are $x_{10,3}$ = 1,2 µm, $x_{90,3}$ range, 15 µm to 20 µm, measurement by light diffraction spectrometry in aqueous suspension after 2 min ultrasonic treatment). The manufacturer has specified this special fraction of the Pural product as being suitable for testing filters, but does not guarantee the specifications on the particle size for each batch; they are subject to variations in production and thus are nominal values. For each production batch they have to be verified anew and selected especially for filter testing. Comparative tests shall always be done with the same reference batch.

3.4 Filter medium for gravimetric clean gas measurements. Glass fibre filters should be used as absolute filters to measure the particle mass content in the clean gas. They shall offer a separation efficiency of at least 99,95 % (e.g. according to EN 1822-1[6], H13: 99,95 % or equivalent).

4 Principle

When selecting an appropriate test method, practicability and flexibility of the filter tests were taken into account. At the same time, the execution of the test should not be too time consuming and should be easy to handle. The experience over many years with existing filter testing methods referred to herein shows that the results provide useful performance information about the comparability of different filter media under prescribed standard conditions indicating the operating and separation behaviour of various filter media during practical use (see Figure 1, References [3][4][12][18] to [23]).

The test method for filter media to be used in cleanable filters (e.g. bag filters, pocket filters, cartridge filters) was developed with the application of these filter types in mind. It was designed so that the local filtration and cleaning conditions of a filter element are simulated as exactly as possible, in accordance with knowledge at the time of publication. The loading of the filter sample with the test dust is executed in a constant and reproducible manner. The test is performed on flat, round samples of the test filter media in a laboratory filter test apparatus.

During the test, the filter sample is exposed to a constant gas flow and a constant dust concentration. When the predetermined maximum pressure drop is reached, a cleaning pulse is activated to remove the dust cake towards the dirty-gas (upstream) side. The cleaning pulse shall be a well-defined and reproducible pressure pulse leading to a uniform pressurization across the exposed filter sample area.

The test filter media are compared and assessed on the basis of the development of so-called characteristic filtration data, which are the shape of pressure drop curves, the development of residual pressure drop, filtration/cleaning cycle time, residual dust cake mass, and dust penetration through the test sample. Test conditions and materials (e.g. test dust) for this method are specified exactly in this International Standard.

5 Standard reference apparatus and procedure

5.1 General

The standard reference apparatus and the standard test procedure are chosen to ensure good reproducibility and repeatability of the test. Figure 1 shows a schematic design of the standard reference apparatus.

1) Pural NF is the trade name of a product supplied by Sasol. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

To generate a dust-laden, dirty-gas flow, ambient air is first introduced into the vertical dirty-gas duct. Dust is dispersed into this flow with the help of a dust feeder using dry and oil-free compressed air so that a uniform dust concentration is attained over the entire filter face. Part of this dirty-gas flow is sucked through the filter sample which is mounted flush with the duct wall. The dust forms a filter cake causing an increase in the pressure drop. Once a predetermined pressure drop is reached across the filter sample, the test sample is cleaned (dust cake removed) by means of a defined pulse of compressed air from the clean gas side without interrupting the flow (online cleaning).

The removed filter cake, as well as any excess dust feed, is drawn vertically downwards with the flow. They are collected in a reception space located beneath the dirty gas duct and in the dirty-gas backup filter to avoid re-entrainment of dust and thus disturbance of dust concentration in the vicinity of the test filter sample during filtration.

The test apparatus consists of the following main components:

a) a continuously and uniformly operating dust feeder positioned on a weighing system;

b) a section at the dust inlet providing for mixing of ambient air and dust-laden gas from the dust feeder;

c) a vertical dirty-gas duct providing for a homogeneously distributed dust and uniform flow towards the test filter;

d) a concentration monitoring system comprising a photometer for the dirty gas directly upstream of the filter;

e) a cylindrical, horizontal clean-gas duct with the filter holder mounted flush with the dirty-gas duct wall;

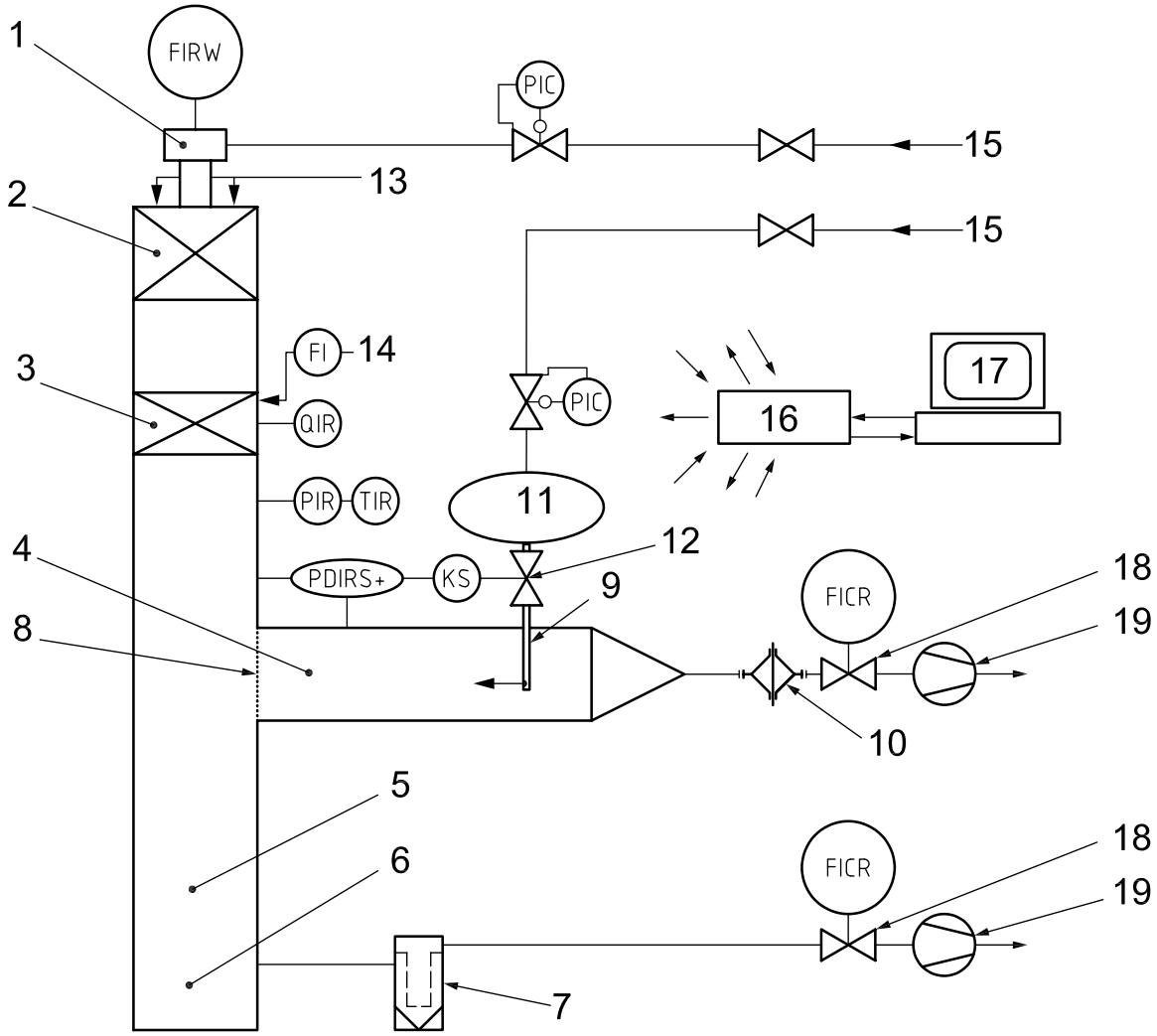
f) a pulse-cleaning system, comprising a pressure tank, a fast diaphragm valve and a blow tube with defined nozzle;

g) a device for the mass-based determination of the dust concentration in the clean gas (absolute filter);

h) transducers for the measurement of gas temperature and static pressure in the dirty-gas duct and differential pressure across the filter sample;

i) a pump and control and measurement device for the gas flow through the filter;

j) a second flow extraction at the bottom of the dirty-gas duct with a final dust filter as well as a gas flow control and measurement device.



Key

1	dust feeder on platform balance	FI	flow rate measurement and indication
2	mixing tube	FICR	automatic flow rate measurement, indication, control and recording
3	photometric concentration monitor		
4	horizontal clean-gas duct	FIRW	dust flow rate measurement, indication and recording
5	vertical dirty-gas duct	KS	signal generator and timer
6	dust container	PDIRS+	differential pressure measurement, indication, recording and switch gear (to trigger cleaning pulse)
7	dirty-gas backup filter		
8	test filter sample (free diameter 140 mm)	PIC	pressure indication and control
9	blow tube	PIR	pressure indication and recording
10	absolute filter for gravimetric clean-gas measurement	QIR	concentration measurement, indication and recording
11	compressed air tank (2,5 l/0,5 MPa)		
12	diaphragm valve	TIR	temperature measurement, indication and recording
13	ambient air inlet		
14	clean purge air		
15	compressed air 0,6 MPa		
16	control and data acquisition system		
17	industrial PC		
18	mass flow controller		
19	pump		

Figure 1 — Schematic presentation of the reference test apparatus

5.2 Components of the standard reference apparatus

5.2.1 General

Components of a reference test apparatus are specified in 5.2.2 to 5.2.12. It is recognized that other apparatus arrangements may be found acceptable. An apparatus will be considered to be equivalent when its test results are equivalent to those of the standard reference apparatus. The equivalence requirements are defined in 6.1.

5.2.2 Dust feeder and dust concentration

The dust feeding device (Reference [24]) shall assure an average dust mass concentration immediately upstream of the test filter of 5 g/m^3 with a maximum deviation of ±7 %. In addition, three consecutive concentration measurements within a single test shall be within 5 % of each other. Compressed air used by the dust feeder shall be dry and oil-free (see also 3.1 and 3.2).

The average dust mass concentration shall be determined by weighing the dust mass deposited on a filter sample over a fixed period of time and relative to the cleaned gas volume (see also 5.6.6).

5.2.3 Dirty-gas concentration monitor

Continuously monitor the uniformity of dust dispersion and dust concentration in the dirty gas before the test filter with an appropriate device such as a photometer. For the positioning of the photometer, select a representative location with respect to the monitoring of the dirty-gas dust concentration relevant to the test filter. Ensure that the integration period of the photometer does not exceed a value of 10 s, so that temporary fluctuations can still be resolved.

5.2.4 Dirty-gas duct

The dirty-gas duct shall ensure that the dust-laden gas flow is transported to the filter medium under test in a constant and reproducible manner. The dust concentration and formation of the dust cake shall not be interfered with by the detachment or redispersion of the filter cake when cleaning the filter sample. Two tappings for pressure and pressure drop measurement and one for temperature measurement are located within 300 mm upstream of the filter sample.

In the standard reference apparatus, only part of the dirty-gas flow is transported through the test filter which leaves more flexibility in the design and selection of the dust feeder and air supply to achieve the test dust concentration. It also removes the redispersed dust from the vicinity of the filter sample during cleaning and prevents redeposition of the cleaned dust on the filter sample. It requires a second pump and flow measurement and control device, and a dirty-gas backup filter, but allows long-term testing without interruption by frequent cleaning of the dirty side duct.

5.2.5 Filter holder

The test filter holder shall present an exposed filter diameter of 140 mm to the dirty-gas duct and shall ensure a smooth and crease-free mounting for the filter sample. On the clean-gas side of the filter holder, three parallel equidistant bars are located which simulate the cage wires of a filter bag installation and by which the filter sample is supported during filtration. The maximum axial distance allowed between the plane of insertion of a filter sample and the supports is 2 mm. A proposed design for the filter sample holder is shown in Figure A.2.

A balance, capable of being read to at least 0,01 g, for weighing the filter holder with the inserted filter sample shall be available.

5.2.6 Commissioning and calibration of the pressure drop increase of the standard reference apparatus

Besides dust concentration, the increase in filter pressure drop is also influenced by the particle size distribution, i.e. by the state of agglomeration of the dust. By using a filter medium which supports the formation of a homogeneous dust cake, the increase in pressure drop shall be linear shortly after cleaning and the gradient shall be constant with constant velocity, constant concentration, and uniform particle size distribution of the collected dust.

It is recommended that a surface filter medium, e.g. with a membrane or micro fibre surface, be used to create a linear pressure drop curve over a pressure increase of a minimum of 1 000 Pa. Using Pural NF as the test dust (3.3), a filter face velocity of 2 m/min, and a dust concentration of 5 g/m^3, the gradient of the pressure drop curve shall be 180 Pa/100 s with a maximum deviation of ±7 %. In addition, three consecutive measurements within a single test shall be within 5 % of each other.

If this requirement is not fulfilled, take the following steps:

a) adjust the concentration within the specified limits (see Table 1); or

b) replace the dust batch.

5.2.7 Clean-gas duct

On the clean-gas side, a horizontal, cylindrical duct follows the filter; its inner diameter is to be equal to the diameter of the filter sample area exposed to the gas flow, i.e. 140 mm. A minimum of four tappings with diameter of 4 mm for pressure drop measurement are distributed around the circumference and located directly downstream of the filter sample. Following the cleaning device, the cylindrical channel tapers immediately to a flange for the connection of an analytical filter.

The reference test apparatus design is shown in Figure A.1.

5.2.8 Cleaning system

The filter sample is cleaned pneumatically by a pulse of compressed air. The cleaning system consists of a compressed air tank with a volume of at least 2,5 l, a fast acting diaphragm valve with adjustable opening time, and a blow tube. The distance between blow tube opening and filter sample is $6D \pm 0{,}5D$ (where $D = 140$ mm). The pressure in the tank is adjusted by a pressure regulator and kept constant. The blow tube presents a length of 210 mm and a minimum interior diameter of 28 mm (with a typical outer diameter of 33,7 mm) with a nozzle diameter of 3 mm pointing towards the filter sample and an axis perpendicular to the plane of the filter sample.

Using a perforated plate (see Figure A.3) to calibrate the cleaning system, the cleaning pressure pulse is measured and adjusted to the reference values by means of high-speed pressure transducers (high-speed transducer and data logger: sampling rate 1 kHz). The pressure pulse signal shall show the following boundary values: pressure peak ~3 200 Pa ± 160 Pa, mechanical pulse duration approximately 700 ms ± 70 ms as shown in Figure A.4. Deviating values in a specific standard reference apparatus may be corrected by adjusting the electric valve opening time or the blow hole diameter.

5.2.9 Gravimetric measuring devices for the clean-gas dust-loading concentration measurement with absolute filter

For the purpose of measuring the total dust concentration in the emitted (clean) gas of the test filter sample, a filter holder is attached at the end of the clean-gas duct to mount this absolute filter. The filter material shall present a maximum diameter of 50 mm and an exposed diameter of at least 40 mm. In order to maintain a low detection limit when weighing the filter, use only absolute filters of a mass of less than 0,3 g (see 3.4). Use a new absolute filter for each test.

The balance used for weighing the absolute filter shall be capable of being read to at least the nearest 0,01 mg.

5.2.10 Differential pressure gauge

A differential pressure sensor with an analogue or digital outlet is employed to measure and to record the difference of the static pressures across the filter sample. The measuring range shall be between 0 Pa and 2 000 Pa with an accuracy of the measuring system of 0,5 % of full scale deflection (FSD). The sensor shall feature the following properties: step function response time full scale (FS) <2,5 s, repeat precision ±0,1 % FSD, long-term-stability ±0,5 % FSD/year, maximum temperature error ±1 % of FS for 0 °C to 50 °C.

5.2.11 Pressure and temperature transducers for the dirty gas

Temperature and static pressure in the dirty-gas duct at the test filter sample shall be measured to calculate and set the correct filter face velocity. Standard transducers with an accuracy of 0,5 °C for temperature and 500 Pa for pressure may be used for this purpose. It is suggested to use the tappings for differential pressure measurement for this purpose also (see 5.2.4).

5.2.12 Gas flow measurement and control device

Mass flow controllers are recommended for the measurement and the control of volume flows. These work independently from the operating conditions of the test apparatus, and ensure a rapid and exact control and recording of the preset values. It is recommended that the mass flow controllers be protected by prefilters of a high efficiency (e.g. in accordance with EN 1822-1[6], H13: 99,95 % or equivalent) to prevent fouling.

Other devices are considered acceptable provided the gas flow rate results in a face velocity compliant with the tolerances in Table 1. It is recommended that a measuring and control range of the selected device be chosen between 0 l/min and 50 l/min or 0 l/min and 100 l/min for the flow through the filter sample and between 0 l/min and 200 l/min for the dirty-gas side (values under standard conditions: 1 013,25 hPa and 0 °C) with an accuracy of 1 % of the measured value. Mass flow controllers are calibrated for standard conditions, therefore for the calculation of the actual gas flow rates, the actual values for pressure and temperature across the test filter are to be used for the correction. The overall accuracy for the actual flow measurement and therefore the filter face velocity should be ±3 % or better (see Table 1).

5.3 Operating parameters for the test

The filter test sample is operated at a constant filter face velocity of 2 m/min throughout the entire test. The flow control system has to be capable of reacting to changes of the pressure drop but shall not be disturbed by the cleaning pressure pulse.

The standard test utilizes an alumina dust (3.3) at a concentration of 5 g/m^3.

The pulse-jet cleaning is performed at a compressed air pressure of 0,5 MPa and an electrical valve opening time of 60 ms and is triggered by exceeding a pressure drop across the filter sample of 1 000 Pa (see Table 1). The relative humidity in the standard reference apparatus shall not exceed 50 %. Normally, this is ensured when operating the dust feeder with compressed air dried by refrigerant cooling which results in a dew point of +3 °C (see 3.1). The selected test parameters shall be observed within the tolerances specified in Table 1.

Table 1 — Primary test parameters and tolerances

Parameter	Unit	Value	Tolerance
Filter face velocity	m/min	2	±3 %
Dust concentration presented to the sample filter	g/m^3	5	±7 %
Test dust		Pural NF	see 3.3
Pressure drop prior to pulse-jet cleaning	Pa	1 000	±1 %
Tank pressure	MPa	0,5	±3 %
Valve opening time (electric)	ms	60	may be adjusted to correct cleaning pulse duration, see 5.2.8 and A.3

5.4 Measured parameters

Prior to each test, the dirty-gas dust concentration has to be determined gravimetrically and then to be kept constant within narrow limits during the entire test duration (see Table 1). For that purpose, an appropriate filter medium is inserted in the sample holder and is loaded at test conditions with the test dust for a predetermined time period (minimum 6 min). The average dirty-gas dust concentration is to be determined from the increase in mass relative to the air volume at test conditions transported through the sample during loading. In addition to the dust concentration, the effective particle size distribution shall also be kept constant. If necessary, the feeder properties have to be reassessed.

Throughout the filter test, pressure and temperature in the dirty gas, the pressure drop across the filter sample, and the volumetric gas flow rate through the sample are to be continuously measured and recorded. The residual pressure drop shall be recorded separately. For this purpose, the period between initiation of the cleaning pulse and the detection of the residual pressure drop is to be 4 s so that the dynamically obtained residual pressure drops coincide with those obtained during operation of the system without dust feed.

To manually measure the residual pressure drop of the cleaned filter sample at the end of a test sequence, the flow through the test filter has to be stopped immediately after the cleaning pulse with the main air flow still on. After waiting until the dust is removed from the dirty gas duct (after ~3 min or when the photometer no longer shows a reading) re-establish the air flow through the filter and record the residual pressure drop value after one additional (manually triggered) pressure pulse.

For each particular test, the average particle concentration in the clean gas is determined using the devices described in 5.2.9. The average mass concentration, in milligrams per metre cubed, is calculated from the increase in mass of the analytical filter divided by the total air volume at actual conditions passing through the filter during the test (see also 5.7). If the difference between the total mass of the absolute filter at the beginning and the ending of the test segment is below 0,1 mg, the detection limit corresponding to the concentration may be specified instead. An error in the gravimetric analysis of 0,1 mg at an assumed test duration of 2 h and corresponding to a total volume of approximately ~3,7 m^3 passing through the filter results in a detection limit of ~0,03 mg/m^3.

5.5 Test sequences

During the standard test, the test filter sample is loaded with the test dust at the test conditions as previously specified. Each time when the predetermined maximum pressure drop of 1 000 Pa is reached, a cleaning pressure pulse is applied. The cleaning pulse is applied online, i.e. while dirty gas is still flowing through the sample. A period of 4 s after the 30th cleaning pulse, dust feeding and gas flow along the horizontal clean-gas duct, i.e. through the filter sample, are stopped thus completing the first phase of the standard test.

The first test phase is followed by the ageing phase (see Table 2). The filter is exposed to 2 500 cleaning pulses at intervals of 20 s. During this phase, the gravimetric evaluation of the backup filter is carried out for monitoring purposes only so determination of the clean-gas dust concentration during ageing is not required.

Between the ageing phase and the second measuring phase, the stabilization phase (recovery of 10 loading cycles with differential pressure controlled cleaning) is executed in order to stabilize the operating conditions and the test filter sample behaviour. This phase also does not require a gravimetric evaluation.

Following the artificial ageing and recovery period, at least 30 loading cycles with differential pressure controlled cleaning are executed again on the lines of the first test phase. During this last phase of the test, a gravimetric evaluation of the clean-gas concentration is performed for a second time. This last test phase shall last a minimum of 2 h in order to achieve an acceptable sample mass on the absolute filter for the dust-concentration calculation on the clean-gas side.

As an option, a fifth measuring phase may be added if the filtration cycle time during the fourth phase has developed to very short values (<30 s) and cake filtration, showing a linear pressure drop development, is no longer established (i.e. the pressure drop curve shows a distinct convex shape). In this case, it is suggested to add this fifth phase and choose a higher cleaning set point of 1 800 Pa. During this phase of the test, a gravimetric evaluation of the clean-gas concentration is also performed and measuring time may be chosen according to the desired measuring accuracy but shall cover at least 2 h.

Table 2 — Sequence of the standard test phases

Measuring phases	Conditions	Determination of clean-gas concentration
Phase 1: conditioning	30 loading cycles with differential pressure controlled pulse-jet cleaning and a cleaning set point of 1 000 Pa	yes
Phase 2: ageing	2 500 pulse-jet cleaning cycles at an interval of 20 s each	no
Phase 3: stabilizing	10 loading cycles with differential pressure controlled pulse-jet cleaning	no
Phase 4: measuring	30 loading cycles but at least 2 h measuring time with differential pressure controlled pulse-jet cleaning and a cleaning set point of 1 000 Pa	yes
Phase 5: optional measuring	2 h loading cycles with raised cleaning set point of 1 800 Pa	yes

5.6 Test preparations and environment

5.6.1 Handling of test dust and absolute filters

The dust should be stored in a dry place, although Pural NF is not hygroscopic.

It is suggested that test dust from a single lot be used for direct comparison of different filter samples, for the reason that properties of the test dust, e.g. particle size distribution, can change slightly between production lots.

The absolute filters are to be weighed with high accuracy using an analytical balance. They should be stored in a desiccator after being heated in an oven for ~2 h at 200 °C. Only binder-free filters should be used.

5.6.2 Analytical balance

The analytical balance should be positioned in an air-conditioned room in accordance with the manufacturer's instructions. This is especially important for highly efficient filter media which require a very accurate detection of the changes in mass of the absolute filters.

5.6.3 Temperature, pressure and humidity

Before and after the test temperature, atmospheric pressure and humidity in the lab should be measured and recorded. Additionally, during the test run, temperature and pressure of the dirty gas have to be measured continuously directly upstream of the filter sample. These are state variables and shall be known to calculate the actual filtration velocity from the readings of the mass flow controllers.

NOTE In modern rigs these corrections are done automatically by the control unit.

The relative humidity in the standard reference apparatus shall not exceed 50 %. In most environments, this is ensured when operating the dust feeder with compressed air dried by refrigerant cooling which results in a dew point of +3 °C (see also 3.1 and 3.2). This means ~4 m^3/h of dry compressed air is blown into the apparatus via the dust feeder and the photometer sheath air. The additional air flow sucked from the environment is mixed with the compressed air at the top of the rig and amounts to ~1,8 m^3/h. If, in special cases, the humidity of the air from the environment is considered to be too high, this additional flow should be drawn from an air-conditioned room or compartment.

5.6.4 Maintenance and calibration of standard reference apparatus and components

The test apparatus should be checked or maintained once a year by the manufacturer or other suitably skilled personnel.

a) Key rig components, e.g. transducers — check or recalibrate regularly.

b) Mass flow controllers “zero” — check before each use.

c) Mass flow controllers “span” — check quarterly or annually.

d) Differential pressure transducer for sample “zero” — check before each use.

e) Differential pressure transducer for sample “span” — check quarterly or annually.

f) Transducers for temperature, pressure and humidity — check annually.

g) Dust feeder load cell “zero” — check quarterly or annually.

h) Dust feeder load cell “span” — check annually.

i) Photometer “zero” — check before each use.

j) Photometer “functionality” — check before each use.

k) Cleaning system “functionality” — check annually.

l) “Leak-test” for clean gas suction part — check quarterly or annually.

m) Balances — in accordance with the maintenance instructions of the manufacturer — check annually.

n) Filters which are used throughout the rig, e.g. safety filters for mass flow controllers, internal filters of pumps, filter cartridges in backup filter and secondary air filter — check every year and replace if necessary.

5.6.5 Cleaning procedure for dirty- and clean-gas sides

For trouble-free operation of the standard reference apparatus, it is essential to perform cleaning routines on a daily basis.

The clean-gas duct between filter sample and absolute filter shall be cleaned before each single gravimetric measurement of the clean-gas dust concentration to avoid memory-effects by dust deposition on the walls.

This is done when the filter sample is removed and the suction tube detached from the vertical duct by opening the absolute filter holder and mounting an adapter piece to the upstream side to connect a strong vacuum cleaner. While sucking with the vacuum cleaner, compressed air is blown into the duct from the sample side to remove all deposits.

For the dirty-gas side, there is a short cleaning procedure which should always be performed after finishing an ageing phase of the test because, during ageing, dust is deposited inside the hoses leading to the secondary air filter and inside the filter. For cleaning, the hose leading from the top of the rig to the secondary air inlet filter is detached and a vacuum cleaner is used to aspirate both sides. At the same time, while aspirating from the standard reference apparatus, the dirty-gas backup filter is cleaned by manually triggering the cleaning pulse several times. This causes dust being blown from the filter cartridge and from the connecting hose towards the vertical duct to be aspirated by the vacuum cleaner.

It should be checked weekly whether the dust containers below the vertical duct and below the backup filter should be emptied. Emptying is also performed using the vacuum cleaner.

The dust feeder should be cleaned in accordance with the manufacturer's instructions.

5.6.6 Setting the dirty-gas dust concentration

Setting the dust concentration arriving at the filter sample is one of the most important daily tasks. Proceed as follows.

a) Insert a filter sample into the holder for gravimetric determination of dust concentration, weigh, and mount it into the device (it is suggested that a needle felt filter sample with a non-treated surface be used in order not to loosen any dust when removing the sample).

b) Load the filter over a minimum of 6 min. It is suggested that 30 s be added to the loading time of 6 min in order to account for the starting period of the dust feeding where the dust concentration is still rising. For the calculation of the dust concentration though, only 6 min are used.

c) After shutdown, remove the filter holder and determine the mass (make sure no dust falls off the filter before weighing).

d) Calculate the dirty-gas dust concentration, γ, in grams per metre cubed, from the equation

$$\gamma = \frac{\Delta m}{\Delta V}$$

where

Δm is the increase in mass;

ΔV is the air volume at actual conditions drawn through the sample.

e) If necessary adjust the dust feeder and repeat procedure.

Please note that the dust concentration measured using this procedure may deviate from the average dust concentration (depending on particle size distribution) determined over the cross-section of the dirty-gas duct. Nevertheless, the concentration measured using the above procedure is experienced by the filter sample and, as a convention, is used here as the appropriate concentration value.

5.6.7 Functionality tests for complete standard reference apparatus

5.6.7.1 Leak test

It is strongly advised to do a leak test, at least quarterly, as follows.

a) Use a plate of diameter 180 mm to seal the inlet of the horizontal clean gas tube (e.g. aluminium, 5 mm thick, mounted instead of the filter holder).

b) Put in a new absolute filter.

c) Remove the hose leading to the differential pressure transducer (to protect the transducer) and seal the tapping into the tube.

d) Switch on the pump to start the flow (set point 2 m^3/h).

e) The flow will decrease quickly to near 0 at full vacuum of the pump (when the mass flow controller opens up completely).

f) It should be possible to reach a flow $<0{,}1$ m^3/h.

g) If the flow does not reduce to this value, there is a leak which is influencing the measuring results.

h) At the end of the test, break the vacuum by switching off the pump and slowly allow air back into the horizontal clean gas tube by the tapping to the differential pressure transducer.

CAUTION — If an apparatus other than the standard reference apparatus is used, check whether the vacuum can be applied without damage.

5.6.7.2 Gradient of pressure drop curve

This quick test shows whether all components and also the control and correction of the flow through the filter sample are working correctly, including the dispersion of the dust by the feeder. This short test should be done after doing the standard cleaning routine and after checking the transducers, the dust concentration and the feeder setting. The procedure is as follows.

a) Use an expanded polytetrafluoroethylene (ePTFE) membrane on needle felt (not on woven material) as a test sample or a sample with a micro fibre surface, providing the formation of an undisturbed, homogeneous filter cake.

b) Test dust (3.3) is Pural NF (report the lot number; values might differ slightly for different lots).

c) Ensure that the dust concentration at the filter is 5 g/m^3.

d) Ensure that the filter face velocity is 2 m/min (calculated for actual conditions) at ambient temperature.

e) Set the measuring interval to 1 s, cleaning valve opening time to 60 ms, and tank pressure to 0,5 MPa (over-pressure).

f) Start the standard test procedure and perform at least one cycle up to 1 800 Pa.

The pressure drop curve should be linear between 800 Pa and 1 800 Pa and should always show the same gradient at constant filtration velocity and dust concentration (see also 5.2.6).

5.6.7.3 Cleaning pulse signal

The cleaning system is specified in 5.2.8 and the pressure pulse arriving at the filter sample is defined by the geometry of the horizontal clean gas tube, i.e. the clean gas tube, the blow tube and blow hole, the pressure

tank and the valve design and opening time. The pressure pulse can change, e.g. if the function of the valve is deteriorating. Therefore its function should be tested periodically, at least annually.

The test requires a perforated plate (see Figure A.3) and a measuring system with a quick-acting transducer and should be done by the manufacturer or the personnel performing the annual maintenance.

The perforated plate is inserted into the filter holder instead of a test filter, the filter face velocity is set to the standard value of 2 m/min and a pressure pulse is triggered with parameters set to standard values.

5.7 Step-by-step procedures of the standard test

Step-by-step procedures of the standard test are as follows.

a) Log the ambient conditions within the test room (atmospheric pressure, temperature, relative humidity).

b) Set operating parameters of test apparatus: volume gas flow rates, dust feeder settings, cleaning set-point pressure, number of cleaning pulses, tank pressure, valve opening time.

c) Check dust feeder contents.

d) Check the dirty-gas dust concentration (see 5.2.2).

e) Place the filter holder with the new test filter sample into the test apparatus.

f) Weigh the absolute filter and mount into the absolute filter holder.

g) Determine the initial pressure drop without dust feed. First switch on the vertical duct air flow manually and wait until the photometer is not showing any dust in the gas flow. Then start the flow through the sample and measure the initial pressure drop.

h) Start the first phase of the filter test.

    1) After shutdown of the dust feeder and the flow through the test filter sample at the end of the first measuring phase, wait until the dirty gas is dust-free, then restart the gas flow through the test filter sample and determine the residual filter pressure drop; execute one additional cleaning pulse manually before reading the pressure drop value.

    2) Remove the filter holder with the test filter sample and weigh it, to determine the residual dust mass remaining on the test filter sample after cleaning.

i) Remove the absolute filter and weigh it, to determine the clean-gas dust concentration.

j) Reinsert the test filter sample and a new absolute filter, then start the ageing phase.

k) Immediately thereafter (without changing the absolute filter) start the stabilization phase with 10 filter cleaning cycles controlled by filter differential pressure.

l) Measure the residual dust mass and residual pressure drop as described above.

m) Do a cleaning procedure as described in 5.6.5, including cleaning the dust feeder.

n) Reinsert the test filter sample and determine the mass of a new absolute filter and mount it in the filter holder.

o) Start the fourth phase of the filter test.

p) After shutdown of the dust feed at the end of the fourth phase, proceed as after the first measuring phase as described above.

q) If necessary, start the fifth phase of the filter test.

r) After shutdown of the dust feeder at the end of the fifth phase, proceed as after the first measuring phase as described above.

s) Log the ambient conditions within the test room at the end of the test (atmospheric pressure, temperature, relative humidity).

6 Procedure and filter media for testing of equivalent apparatus and selection of test houses

6.1 Procedure and filter media for testing of equivalent apparatus with the standard reference apparatus

In order for a candidate type of apparatus to become an equivalent apparatus, a comparison shall be performed with the standard reference apparatus according to the following procedure: three filter media shall be tested on both apparatus simultaneously (same location and same time) with the same batch of test dust:

— A: ePTFE membrane on polyester needle felt, nominal ~550 g/m^2 and 50 l/dm^2·min;

— B: Polyester needle felt calendered, nominal ~550 g/m^2 and 150 l/(dm^2·min); and

— C: Polyester needle felt singed, nominal 500 g/m^2 and ~200 l/(dm^2·min).

From these materials, select samples for testing whose areal mass lies within a range having a maximum of ±1 % and an air permeability lying within a range having a maximum of ±2 % of the average value.

Of each of the media A, B, and C, three samples shall be tested once on each standard reference apparatus and equivalent apparatus applying the operational conditions defined in Table 1.

For a candidate apparatus type to become an equivalent apparatus, the results from the candidate apparatus for all three tests shall agree with the results of the standard reference apparatus for the parameters and within the tolerances specified in Table 3.

Table 3 — Equivalence requirements:
Acceptable deviation of reading from the standard reference apparatus

Test parameter	Acceptable deviation %
Residual pressure drop	±10
Cleaning cycle time	±10
Residual dust mass	±10
Clean-gas dust concentration	±10

6.2 Selection of test houses

Qualifying test houses shall:

a) comply with ISO/IEC 17025;

NOTE Accreditation of the test house to ISO/IEC 17025[5] is one means of increasing confidence in its performance.

b) be commercially independent of the manufacture, sales, and operation of the equivalent apparatus.

7 Processing of data and presentation of results

7.1 Processing of data

The processing of the filter test data is subdivided into two parts: the collection of those data sets recorded continuously by the operating software with respect to pressure drop and cycle duration, and the processing of data obtained manually during the filter test such as mass changes of the test filter sample and the absolute filter.

The course of the pressure drop can be determined from the data set produced by the operating software. The residual pressure drop is recorded at a predetermined interval after each cleaning cycle and is presented as a diagram either over a number of cycles or over the test duration. It is also reasonable to present, as a diagram, the duration of the different filtration cycles over a number of cycles or the test duration.

From the increase in mass divided by the effective filter area, the dust mass deposited in and on the test filter sample is calculated in grams per metre squared. The development of this value serves as an evaluation criterion for the ability of the filter medium to regenerate its operational characteristics. This value is determined repeatedly after each test phase.

The dust concentration on the clean-gas side is expressed as a mean value for each of phases 1, 4 and 5 in milligrams per metre cubed (for actual flow conditions).

7.2 Presentation of results

The test results are recorded in a test report containing a table (see example in Table 4) with an overview of the measured data and additionally various diagrams displaying the characteristic data: residual pressure drop versus time (see Figure 2) and cycle duration versus time (see Figure 3).

Another very informative possibility of evaluation is the superposed representation of the pressure drop over time of selected loading cycles (see Figure 4). The origin of each curve coincides with the residual pressure drop of the preceding cleaning pulse.

Templates for numerical and graphical test results are given below (data are given as examples only).

Also compare VDI 3926 Part 1[13], ASTM D6830-02[8], JIS Z 8909-1[10] and GB/T 6719[9], and add items if appropriate.

Table 4 — Example of a test data overview

Test report number			
Customer:		Testing lab:	
Project:		Tester:	
Test reference number:		Date:	

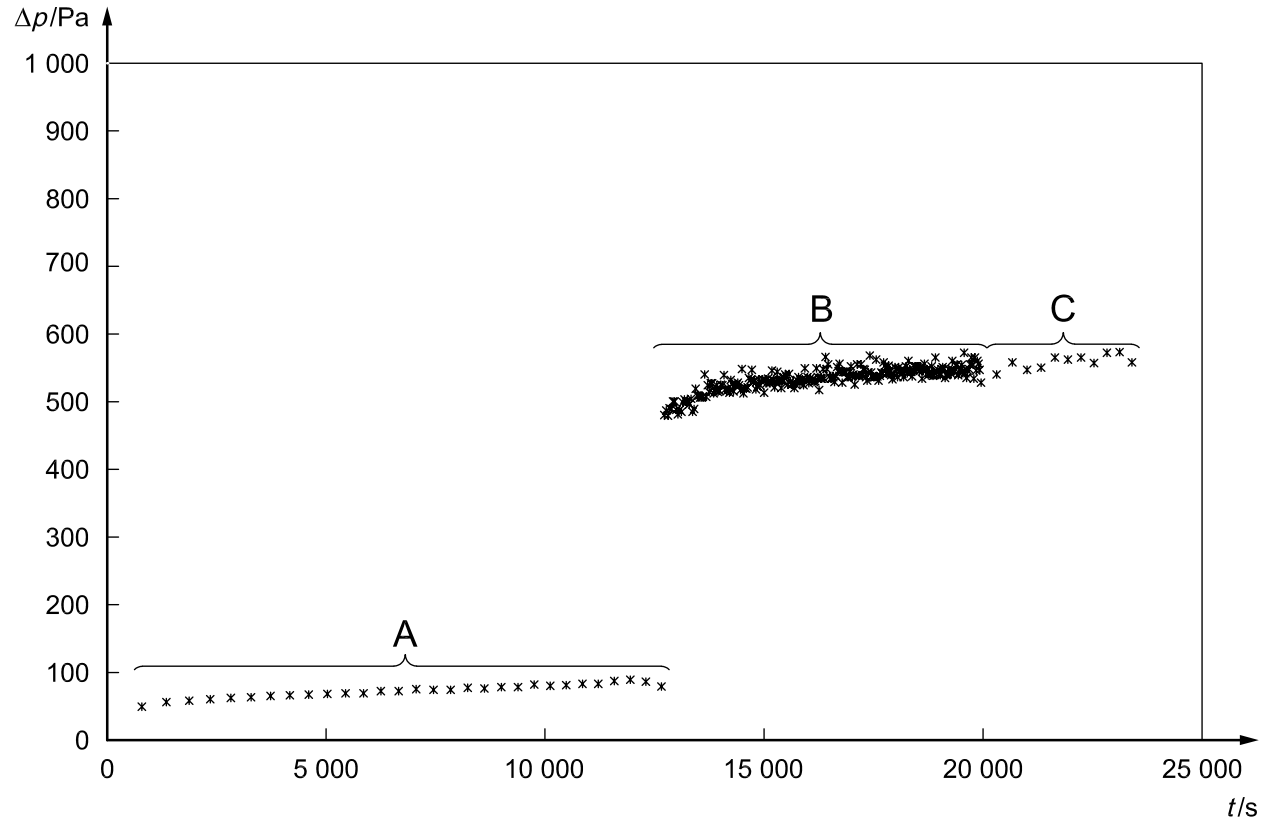
Test parameters			
Test dust:	Pural NF	Cycle time during ageing [s]:	5
Dust concentration [g/m^3]:	5,1	Cleaning air pressure [MPa]:	0,5
Filter face velocity [m/h]:	120	Valve opening time [ms]:	60
Cleaning set-point pressure/Pa:	1 000 and 1 800	Humidity start/end of test [%]:	38/40
Sample area [m^2]:	0,017 7	Air temp. start/end of test [°C]:	22/24
Exposed sample area [m^2]:	0,015 4	Air pressure start/end of test [hPa]:	1 008/ 1 003
Test phases:	30 cycles + ageing 2 500 cycles + 10 cycles stabilization + 2 h (1 000 Pa) + 2 h (1 800 Pa)		

Filter medium			
Manufacturer:		Equipment:	
Type:		Lot number:	
Filter description:		Condition:	
Fibre description:		Air permeability at 200 Pa; L_d [l/dm^2·min]:	
Areal mass [g/m^2]:	497,4	Thickness; δ [mm]:	
Mass filter [g]:	8,79		

Test results

	Start	**After 30th cycle**	**Ageing**	**Measuring**	**Measuring**
Mass filter holder + filter [g]:	533,07	533,94	534,82	534,88	534,93
Mass gain of filter [g]:	—	0,87	1,75	1,81	1,86

	Cleaning at	**1 000 Pa**	**Every 20 s**	**1 000 Pa**	**1 800 Pa**
State of test/cycles	0	30	**Ageing: 2 500 cleaning pulses**	241	25
(Residual) pressure drop; Δp_{Res} [Pa]:	47	91		610	620
Residual dust mass; Δm_{Res} [g/m^2]:	0	56,5		117,6	120,8
Cycle time; t_{Cycle} [s]:	—	355		28	289
Test phase:	**First 30 cycles**			**2 h**	**2 h**
Dust penetration; m_{Abs}[mg]:	21,58			6,02	0,50
Measuring time; t_m [s]:	12 642			7 200	7 200
Clean-gas concentration; γ_2 [mg/m^3]:	3,32			1,60	0,13



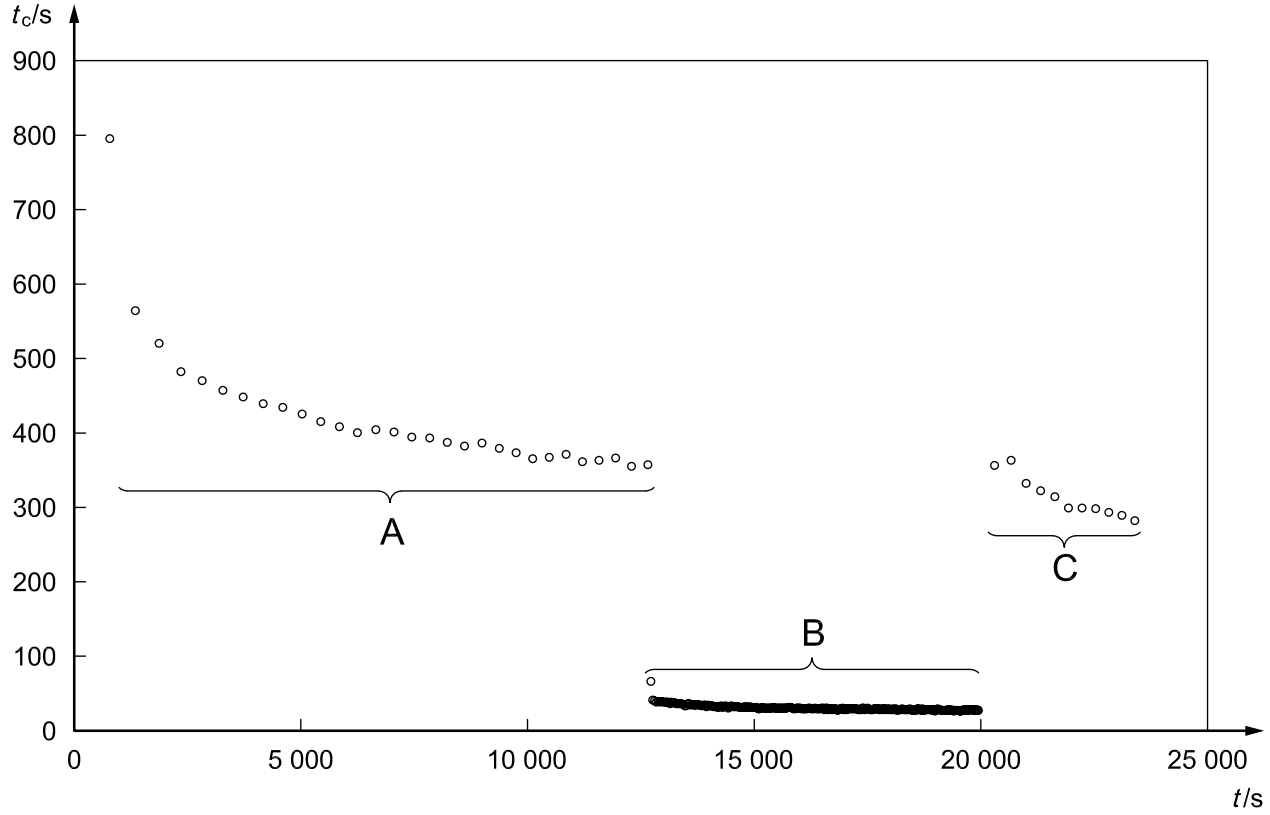
Key

Δp	residual pressure drop
t	time
A	prior to ageing, first 30 cycles, cleaning at 1 000 Pa
B	after ageing, first 30 cycles, cleaning at 1 000 Pa
C	after ageing, first 30 cycles, cleaning at 1 800 Pa

Test conditions

Temperature:	25 °C
Dust:	Pural NF
Tank pressure:	0,5 MPa
Velocity:	2 m/min
Cleaning at:	1 000 Pa and 1 800 Pa

Figure 2 — Development of residual pressure drop versus time before and after ageing



Key

t_c cleaning cycle time

t time

A prior to ageing, first 30 cycles, cleaning at 1 000 Pa

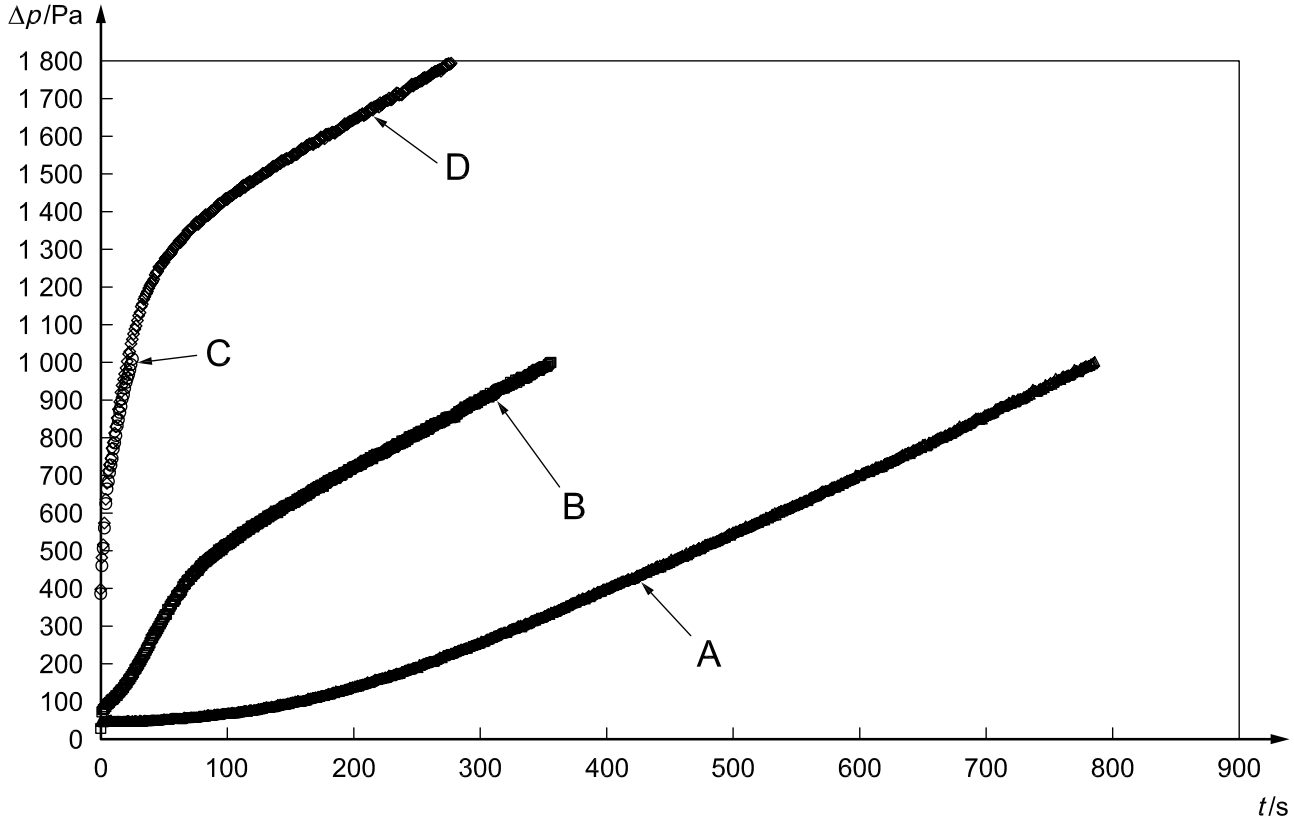
B after ageing, first 30 cycles, cleaning at 1 000 Pa

C after ageing, first 30 cycles, cleaning at 1 800 Pa

Test conditions

Temperature:	25 °C
Dust:	Pural NF
Tank pressure:	0,5 MPa
Velocity:	2 m/min
Cleaning at:	1 000 Pa and 1 800 Pa

Figure 3 — Development cycle duration versus time before and after ageing



Key		Test conditions	
Δp	pressure drop	Temperature:	25 °C
t	time	Dust:	Pural NF
A	first cycle	Tank pressure:	0,5 MPa
B	30th cycle	Velocity:	2 m/min
C	after ageing, cleaning at 1 000 Pa	Cleaning at:	1 000 Pa and 1 800 Pa
D	after ageing, cleaning at 1 800 Pa		

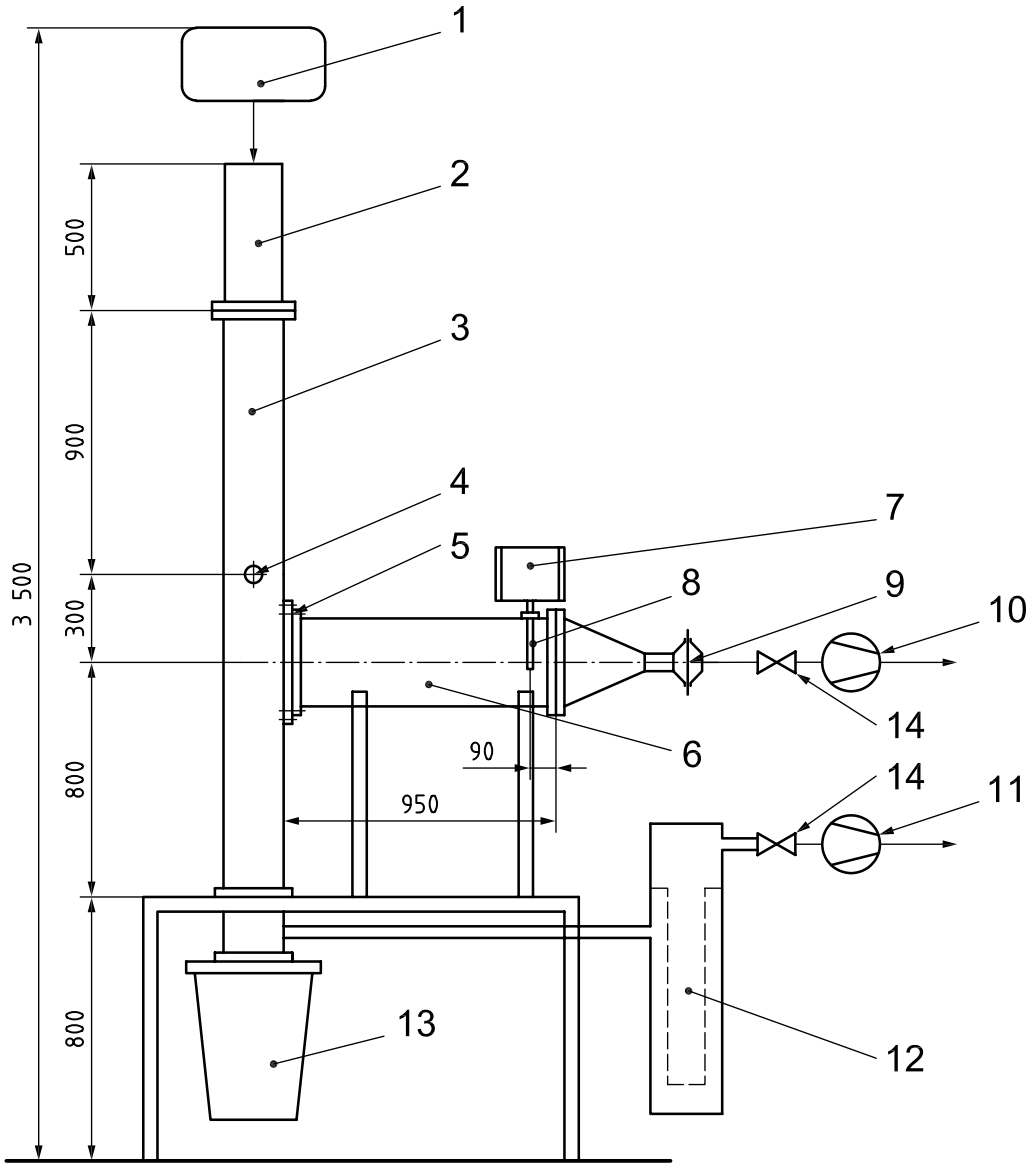
Figure 4 — Superimposed representation of the pressure drop curves versus time of selected loading cycles (the origin of each curve coincides with the preceding residual pressure drop)

Annex A
(normative)

Test apparatus

A.1 Design of the reference standard test apparatus

Dimensions in millimetres

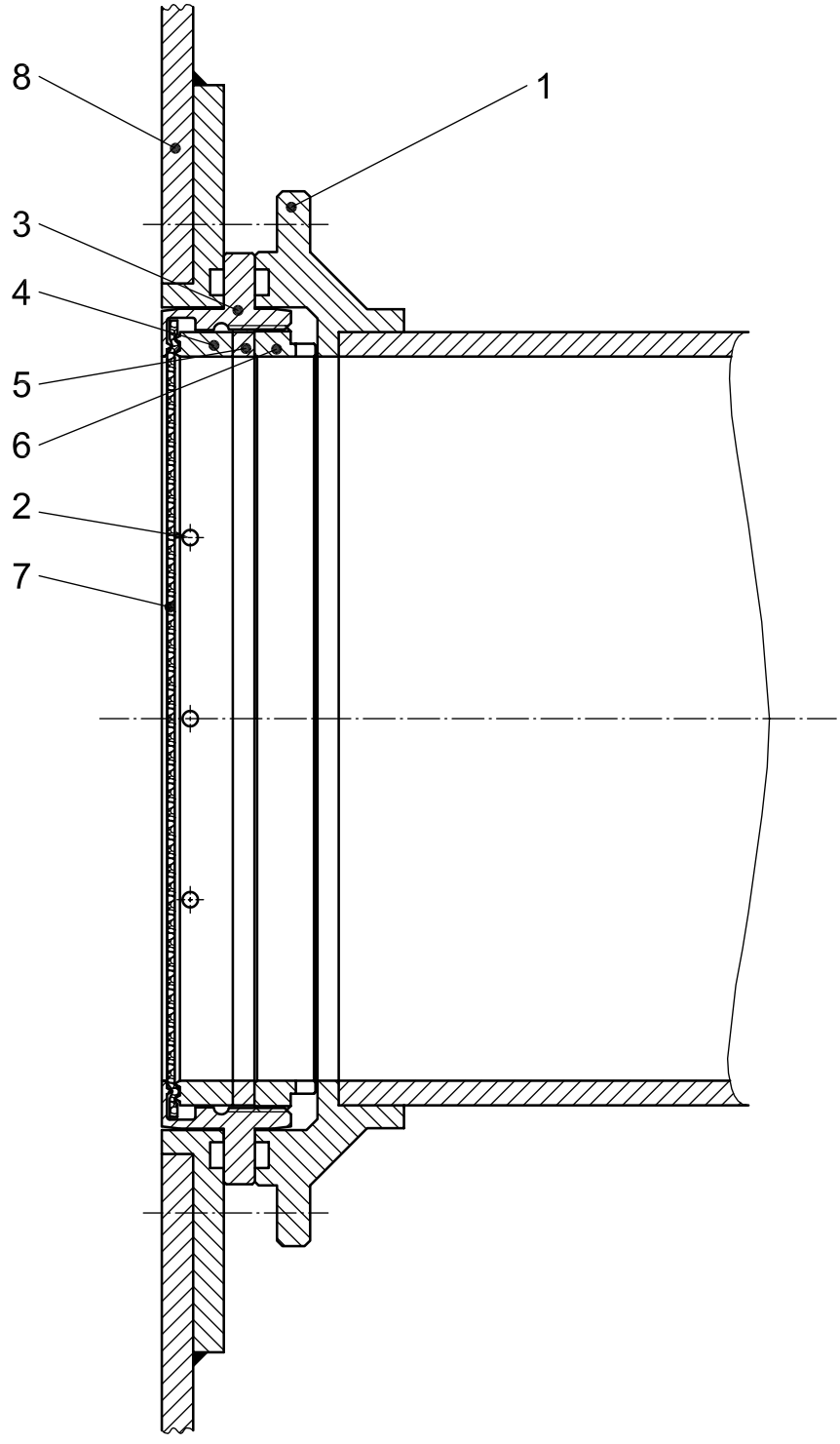


Key

1 dust feeder on platform balance
2 mixing tube
3 vertical dirty-gas duct, cross-section 120 mm × 300 mm
4 photometric concentration monitor
5 test filter holder, free sample diameter 140 mm
6 horizontal clean-gas duct, diameter 150 mm
7 compressed air tank (2,5 l/0,5 MPa)
8 blow tube
9 absolute filter for gravimetric clean-gas measurement
10 clean-gas suction (pump)
11 suction from vertical dirty-gas duct (pump)
12 dirty-gas backup filter
13 dust container vertical duct
14 mass flow controller

Figure A.1 — Schematic diagram of the standard reference standard apparatus

A.2 Design of the filter sample holder for the standard reference apparatus

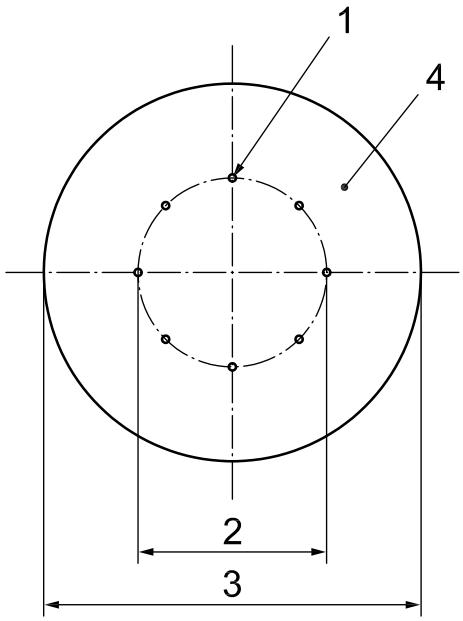


Key

1 flange horizontal duct
2 supporting rods
3 filter holder body
4 clamping ring, inner diameter 140 mm
5 distance ring
6 clamping nut
7 test filter sample
8 wall and flange vertical duct

Figure A.2 —Design of the filter sample holder for the standard reference apparatus

A.3 Perforated plate for calibrating the cleaning system of the standard reference apparatus



Key

1 one of eight holes, diameter 3 mm, distribution 8 × 45°
2 pitch circle of holes diameter 75 mm
3 diameter of plate 150 mm
4 aluminium plate thickness 2 mm

Figure A.3 — Perforated plate for calibrating the cleaning system of the standard reference apparatus

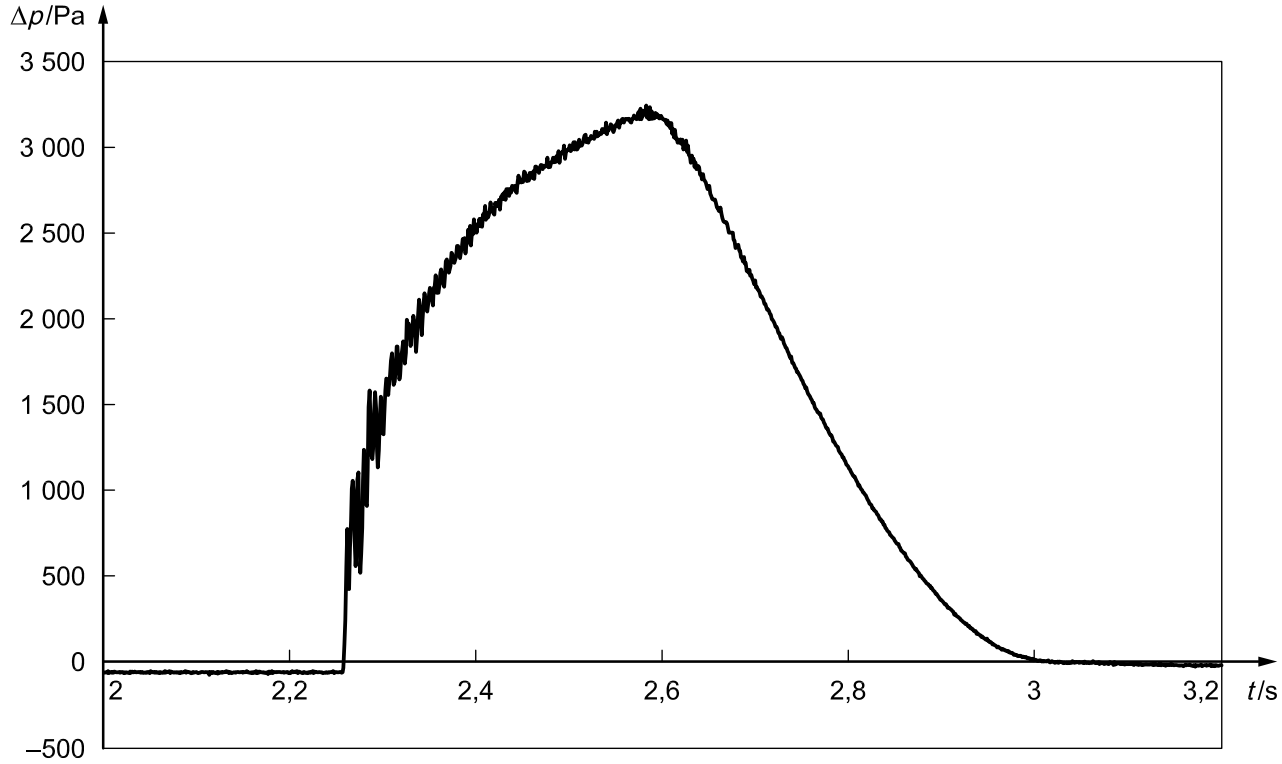
The calibration of the cleaning system is usually done by the manufacturer of the standard reference apparatus (or appropriately skilled personnel) and shall be checked during annual maintenance.

For this purpose, a perforated plate as shown in Figure A.3 is placed in the filter holder and sealed with a rubber or silicone gasket.

A flow representing a filtration velocity of 2 m/min is drawn through the plate and a standard cleaning pulse is activated.

The pulse is measured by means of high-speed pressure transducers (high-speed transducer with data logger with a sampling rate of 1 kHz).

The pressure pulse signal shall show the following boundary values: pressure peak ~3 200 Pa ± 160 Pa, mechanical pulse duration ~700 ms ± 70 ms as shown in Figure A.4.



Key

Δp	pressure difference
t	time

Test conditions	
Online, velocity:	2 m/min
Side flow:	1,85 m^3/h
Main flow:	4 m^3/h
Temperature:	24 °C
Tank pressure:	500 kPa
Valve opening time:	60 ms
Blow hole diameter:	3 mm

Figure A.4 — Pressure pulse signal using the perforated plate in Figure A.3 for calibration

Annex B
(informative)

Other information and considerations

B.1 Testing of woven filter media

There are woven filter media on the market which are explicitly designed to be used in pulse-jet filters; others are designed for reverse-flow applications.

If filter media are to be tested which are, from their construction, not capable of withstanding the intensive pulse cleaning applied in this International Standard, there is the possibility to do the testing under analogous conditions, but using a (weaker) cleaning pulse adapted to the capabilities of the samples.

There are also possibilities to modify the reference standard test rig to enable the use of reverse-flow cleaning. The cleaning applied in shaker filters cannot be simulated within the chosen test rig design.

Another specific problem encountered with woven media is the sealing of the sample in the filter holder without creating leaks on its circumference.

There are different solutions to solve the problem of sealing samples which are not compressible enough and self-sealing, such as needle felts, where there is the possibility to use silicone rubber or flat sealing rings cut from a suitable needle felt.

B.2 Testing of rigid filter media

Rigid filter media can be tested in the same manner as flexible textiles, but additional care has to be applied with the sealing of the samples in the filter holder. In most cases, flexible sealing may be used, very similar to the application in B.1.

Depending on the specific properties of the rigid material, the differential pressure used in the tests, prior to triggering the cleaning pulse, might have to be adapted to a higher level.

B.3 Optional $PM_{2,5}$ measurement devices

The $PM_{2,5}$ dust concentration, averaged over an appropriate number of cycles, may be determined by one of several acceptable devices. The $PM_{2,5}$ concentration, expressed in milligrams per metre cubed, is based on the total dust mass in the aerodynamic particle size range specified by the $PM_{2,5}$ standard curve.

Acceptable devices include:

a) inertial impactors (see ASTM D6830-02[8]);

b) cyclones with $PM_{2,5}$ cut-off characteristic with analytical backup filter (References [11][25][26]);

c) optical particle counters (OPCs) calibrated in terms of mass versus aerodynamic diameter and using the $PM_{2,5}$ weighting curve (Reference [25]) — these optical counters shall cover the particle size range of ~0,3 µm to ~17 µm and shall have a suitable resolution.

For each of these devices, an appropriate isokinetic sample extraction system connected to the clean-gas duct shall be provided according to its own sampling gas flow rate.

Solutions incorporating a $PM_{2,5}$ cyclone (or a PM_1 cyclone) in the reference standard apparatus have been developed and are in routine use.

B.4 Classification and selection of filter media

The selection of the filter medium takes up a special position in system planning, and at the time of publication is often still based on empirical criteria.

Classification of filter media is a great help for the selection of a filter material for a special task and is at the time of publication still done on the basis of efficiency testing on the new materials or elements.

The material-specific or textile data as well as data concerning particle separation (see EN 60335-2-69[7]) are usually communicated by the manufacturers and data on the pressure drop of the new filter media do not provide enough information about their long-term filtration behaviour.

Therefore it seems obvious to use the results of the presented testing method to also classify cleanable filter media into several performance classes.

B.5 Cleanability and durability of filter elements

The forecast or projection of bag lifetime in a filter plant is one of the major concerns of plant manufacturers and operators because the changing of a set of bags includes very often considerable investment.

There are several procedures in development and/or use to gain information about the pneumatic cleanability of filter elements and additional data about the possible effect of washing them.

Other data gathered concern the development of the tensile strength of the material, regarding its thermal and chemical stability, e.g. under the influence of enhanced temperature, SO_x and/or NO_x.

The standard reference apparatus introduced in this standard may be used to quantify the cleanability or effects of ageing caused by miscellaneous agents, e.g. gas and dust composition.

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