INTERNATIONAL STANDARD

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Filters for compressed air — Test methods —

Part 3: **Particulates**

Filtres pour air comprimé — Méthodes d'essai —

Partie 3: Particules

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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 12500-3 was prepared by Technical Committee ISO/TC 118, *Compressors and pneumatic tools, machines and equipment*, Subcommittee SC 4, *Quality of compressed air*.

ISO 12500 consists of the following parts, under the general title *Filters for compressed air — Test methods*:

— *Part 1: Oil aerosols*

— *Part 2: Oil vapours*

— *Part 3: Particulates*

A Part 4 dealing with water removal is under development.

Introduction

Particulates are a typical contaminant found in compressed air streams. Particulate filters are designed to remove particulates from compressed air.

The most important performance characteristics are the ability of the filter to remove particulates from the air stream and the amount of pressure drop caused by the filter as compressed air flows through it.

This part of ISO 12500 provides a means of comparing the performance of filters.

Filters for compressed air — Test methods —

Part 3:
Particulates

1   Scope

This part of ISO 12500 provides a guide for choosing an appropriate method of determining the solid particulate removal efficiency rating by particle size of filters used in compressed air systems.

This part of ISO 12500 specifies the layouts and procedures for testing these filters. Measurement methods are recommended based on the size range of the particulates that the filter being tested has been designed to remove. The test is performed as a "type-test" on filters as being representative of a range.

The following two particle diameter size ranges are identified in this part of ISO 12500:

— fine filter range   0,01 µm to $<$ 5,0 µm;

— coarse filter range $\geqslant$ 5,0 µm to $\leqslant$ 40 µm.

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 1219-1, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 1: Graphic symbols for conventional use and data-processing applications*

ISO 5598, *Fluid power systems and components — Vocabulary*

ISO 8573-1:2001, *Compressed air — Part 1: Contaminants and purity classes*

ISO 8573-4:2001, *Compressed air — Part 4: Test methods for solid particle content*

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

EN 1822-1, *High efficiency air filters (HEPA and ULPA) — Part 1: Classification, performance testing, marking*

EN 1822-2:1998, *High efficiency air filters (HEPA and ULPA) — Part 2: Aerosol production, measuring equipment, particle counting statistics*

3   Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8573-1, ISO 5598 and the following apply.

1

3.1
channel
subset, defined by an upper and a lower limit, of data for the full spectral range of a particle counting instrument in which the particle counts are stored

3.2
efficiency
ratio of the particle concentration removed, i.e. upstream concentration minus downstream concentration, to the upstream particle concentration

3.3
filter
component for the removal of solid particles which includes the filter element and its housing and other components as required

3.4
most penetrating particle size
MPPS
particle size at which the minimum particle collection efficiency is found to occur and thus is the most difficult particle size for the filter to remove

4 Units and symbols

General use of SI units (Système international d'unités; see ISO 1000) as given throughout this part of ISO 12500 is recommended. However, in agreement with accepted practice in the pneumatic field, some non-preferred SI units, accepted by ISO, are also used.

1 bar = 100 000 Pa

NOTE   bar (e) is used to indicate effective pressure above atmospheric.

1 L (litre) = 0,001 m^3

Symbols used are in accordance with ISO 1219-1.

5 Reference conditions

The reference conditions for gas volumes shall be as follows:

— air temperature   20 °C

— absolute air pressure   100 kPa (a) [1 bar (a)]

— relative water vapour pressure   0

6 Summary of test methods

A summary of the size ranges and recommended test methods that are covered by this part of ISO 12500 are shown in Figure 1.

Figure 1 — Summary of recommended test methods

7 Test requirements

7.1 Standard rating parameters

The standard rating parameters are as identified in Table 1.

Table 1 — Standard rating parameters

Reporting parameters	Units	Rating conditions [a]	Maintain within actual gauge value	Instrument accuracy
Inlet temperature	°C	20	± 5	± 2
Inlet pressure	kPa (e) [bar (e)]	700 (7)	± 10 (0,1)	± 10 (0,1)
Ambient temperature	°C	20	± 5	± 2
Minimum compressed-air purity [b]	—	ISO 8573-1:—: 1 - 2		
Air flow for testing	L/s	100 % rated flow	± 2 %	± 4 % of gauge reading
Pressure drop	hPa (mbar)	Not applicable	Not applicable	± 10 % of gauge reading

[a] The reference conditions are as indicated in Clause 5.

[b] To ensure that there is no liquid water on the inlet of the test filter, the air quality shall satisfy class 4. To minimize electrostatic effects on the test dust, the air dewpoint shall be greater than the maximum dewpoint of class 3.

7.2   Alternative flow and pressure rating conditions

The preferred test pressure is 700 kPa (e) [7 bar (e)] but may be reduced where

a)   the maximum pressure rating is other than 700 kPa (e) [7 bar (e)],

b)   there is insufficient flow capacity to satisfy the flow rating at standard pressure,

c)   it is desired to perform the test at a pressure other than 700 kPa (e) [7 bar (e)], or

d)   there are pressure limitations for the aerosol generation.

In these cases, the test pressure can be reduced provided that the equivalent flow velocity is maintained.

The following relationship ensures that the flow velocity is correct. In this case, reference to this part of ISO 12500 includes pressure applied during the test; see Clause A.2. The test flow, q_{test}, at the test pressure, expressed in litres per second at reference conditions, is given by Equation (1):

$$q_{test} = K_T \; q_{rated} \left(p_{test} + 1 / p_{rated} + 1 \right) \tag{1}$$

where

K_T is the compressibility factor of air at rated pressure and 20 °C, generally equal to 1,000 for the rating conditions in Table 1;

q_{rated} is the rated flow at 700 kPa (e) [7 bar (e)] or at the manufacturer's rated pressure when other than 700 kPa (e) [7 bar (e)], expressed in litres per second;

p_{test} is the test pressure, expressed in kPa (e)[bar (e)];

p_{rated} is 700 kPa (e) [7 bar (e)], or the manufacturer's rated pressure when a pressure other than 700 kPa (e) [7 bar (e)] is used.

7.3   Fine test conditions

The aerosol challenge for test shall be produced by the use of an aerosol generator that is capable of generating either solid particles of sodium chloride (NaCl), potassium chloride (KCl) or liquid aerosols of diethylhexylsebacat (DEHS) in accordance with EN 1822-1. In order for the results to be statistically valid, the generation rates of the challenge aerosol shall be in accordance with EN 1822-2. Tests performed to determine the location of the MPPS shall be performed using a monodisperse aerosol distribution.

7.4   Detection method

The sampling methods and equipment used for fine particles shall be in accordance with ISO 8573-4. For coarse filters, the method identified in 8.3 in this part of ISO 12500 shall be used.

7.5   Coarse test conditions

The test dust for determining the particle-removal efficiency shall be in accordance with ISO 12103-1, A4 coarse. Before use, the test dust shall be mixed for a minimum of 15 min and dried to constant weight at a temperature of 105 °C ± 5 °C. The test dust shall then be allowed to acclimatize to ambient conditions.

Prior to introducing the challenge test dust, the test filter shall be stabilized to the temperature and humidity conditions for at least 15 min. The test equipment, including the filter, shall be purged until such time that the upstream particle level has been reduced to < 1 % of the intended upstream particle concentration level.

7.6 Turbulent airflow determination

Turbulent flow conditions within the main air-stream are required for sampling (i.e. a Reynolds number greater than 4 000).

In normal industrial use, compressed air is in a state of turbulent flow when the conditions in Equation (2) for the pipe flow, q, expressed in litres per second, referenced in Clause 5, are met:

$$q > D/20 \tag{2}$$

where D is the pipe bore, expressed in millimetres.

8 Test methods

8.1 General

A minimum of three complete test cycles should be run and the efficiency results averaged for each particle size range under consideration. For efficiency measurement, a new filter shall be used each time. The measurement shall not be repeated with a filter element that has already been tested, as it is already loaded with either solid or liquid test agent.

The pressure drop of the test filter assembly shall be measured and recorded at the start and end of the test.

Care should be exercised to minimize any effects on the measured efficiency of the device due to particles from sources such as the device itself, test equipment or the cleanliness of the air supplied.

The filter shall be fitted and operated in the test stand in its intended final operating orientation. The bore of the pipe shall be continuous and of the same size as that connected to the filter under test, at least in the portion between the upstream sampling point and downstream sampling point. The test stand shall be designed to minimize particle losses. Dust-delivery tubing and sampling line lengths shall be kept to a minimum.

For fine-filter testing, the pipework shall be constructed from stainless steel and be electrically grounded to assist with particle transportation and prevent static charge.

8.2 Fine filter testing

8.2.1 Fine filter equipment arrangement

A typical test assembly for fine filters is shown in Figure 2.

The aerosol generation, sample counting and method statement can be found in EN 1822-2 and EN 1822-5.

If two different particle-measuring systems are used as represented in Figure 2, it is necessary that the counting efficiency of each particle-measuring system be known. If a particle-measuring system with a lower counting efficiency is used for the upstream measurement, then the evaluation of the filter efficiency is understated; if it used for the downstream measurement, then it is overstated. As a consequence, it is necessary to correct the results based on the counting efficiency of each particle-measuring system.

The zero counting rate of the particle-measuring system shall also be considered. Thus, for example, the particle-measuring system with the lower zero counting rates shall be used for downstream measurement.

If it is known that the upstream conditions are stable and/or are controlled by another measuring device, then the measurement can be carried out with only one particle-measuring system, which then avoids the problems mentioned earlier. The procedure then involves taking the upstream measurement first in order not to operate the particle-measuring system within coincidence and then taking the downstream measurement, both times using the same particle-measuring system.

Key
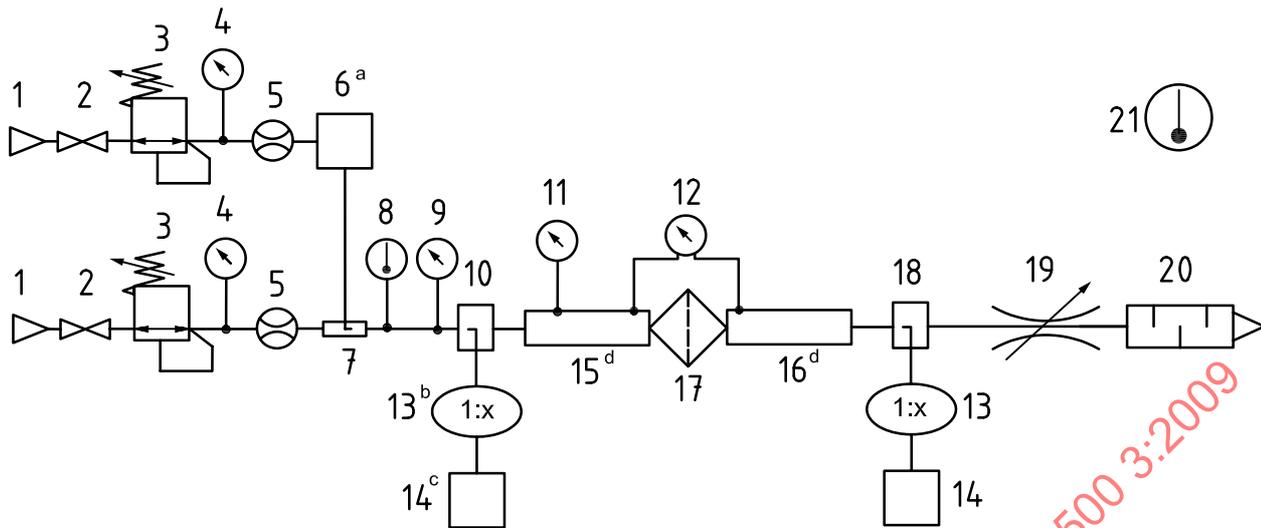
1	compressed air source	12	differential pressure gauge
2	full-flow ball valve	13	dilution/diffuser system
3	pressure reducing valve	14	particle sensing/measuring
4	pressure sensing/measuring	15	upstream pressure measuring tube
5	flow sensing/measuring	16	downstream pressure measuring tube
6	particle generator/neutralizer	17	test filter
7	particle mixer	18	downstream iso-kinetic sampling
8	temperature sensing/measuring	19	multi-turn flow control valve
9	pressure sensing/measuring	20	silencer
10	upstream iso-kinetic sampling	21	ambient temperature sensing/measuring
11	pressure sensing/measuring		

a   For further details of the particle generation and charge neutralization system, see EN 1822-2.

b   The selection of a dilution/diffuser system is dependent on system pressure, particle concentration, filter efficiency and particle counting equipment design. Consult the manufacturer for further advice.

c   The particle sensing/measuring devices are required to have matched efficiencies.

d   Details of the construction of the measuring tubes are given in ISO 7183:2007, Annex D.

Figure 2 — Typical fine filter test arrangement

8.2.2   Calculating fine filter efficiency

Filtration efficiency, F_E, expressed as a percentage, can be calculated from Equation (3):

$$F_E(\chi) = \left\{ 1 - \left[C_{down}(\chi) / C_{up}(\chi) \right] \right\} \times 100 \tag{3}$$

where

$C_{down}(\chi)$ is the particle concentration downstream (as a function of the particle diameter) of filter under test;

$C_{up}(\chi)$ is the particle concentration (as a function of the particle diameter) upstream of filter under test;

χ is the particle diameter.

Results may be presented as a curve of efficiency versus particle size. An example curve is given in Figure A.1.

8.3 Coarse filter testing

8.3.1 General

The efficiency of coarse filters is established by collecting the dust on suitable membranes. The particles are washed from the membrane to suspend them in solution for analysis by a suitable particle counter. It is necessary that the counter be able to count particles over the 0,5 μm to 100 μm range when suspended in a suitable solution.

The membranes are composed of cellulose acetate or cellulose nitrate with a pore size that shall not exceed 20 % of the nominal rating of the filter under test. The membrane housing shall give adequate support to the membrane and limit the face approach velocity to that specified by the membrane manufacturer.

The flow rate used for the test shall be that specified by the filter manufacturer.

If no flow is specified, it shall be taken from Table 2.

Table 2 — Test flow at rated conditions

Supply pressure kPa (e) [bar (e)]	Port size	Flow rate L/s
700 (7.0)	1/8	2,7
	1/4	6,3
	3/8	13,9
	1/2	25,8
	3/4	38,7
	1	72
	1 1/4	147
	1 1/2	223
	2	431

8.3.2 Challenge dust characterisation

Suspend an accurately known mass of the challenge dust, m_{sample}, in a suitable liquid for the counter used in the test.

Establish the particle count, $N_{sample}(\chi)$, over the particle size range of 0,5 μm to 100 μm, where $N_{sample}(\chi)$ is the count for a given particle size of the sample.

NOTE   The mass of challenge dust and the volume of liquid depend upon the characteristics of the counter and are confirmed by experience.

8.3.3 Dust injection

Injection of ISO fine test dust into a pressurized compressed-air system at 700 kPa (e) [7 bar (e)] is not possible using the traditional method of dust injection via an ISO dust injector.

Another method of aerosol delivery into the system is required for a pressurized system. For example, one method employs a syringe filled with the test dust driven by a stepper motor to precisely deliver the dust into

the throat of a venturi. The high velocity of the air in the throat of the venturi disperses the particles into the carrier gas stream.

A dust injection rate of approximately 0,25 mg/L of air at reference conditions shall be used over a test period of 15 min. It can be necessary to adjust this injection rate depending on the test-filter efficiency. Low efficiencies can give an excessive dust loading on the membrane.

Over the period of the test run, record the increase of differential pressure across the filter under test.

For the test to be valid, the increase in differential pressure shall not exceed 50 hPa [50 mbar].

It is necessary to determine the mass, $m_{injected}$, of dust injected.

The determination of $m_{injected}$ depends on the method of dust injection. For example, the mass injected can be calculated from the test filter mass gain, δm_{filter}, and the mass of dust in the downstream air flow, m_{down}.

In full-flow sampling, m_{down} is equal to δm_{mem}, the mass gain of the membrane.

In the case of isokinetic sampling, Equation (4) applies:

$$m_{down} = qT\delta m_{mem}/q_{iso}t \tag{4}$$

where

   q is the full test flow, expressed in litres per second;

   q_{iso} is the isokinetic sampling flow, expressed in litres per second;

   T is the dust-injection time, expressed in seconds;

   t is the isokinetic sampling time, expressed in seconds.

8.3.4   Membrane particle analysis

8.3.4.1   Particle-counter method

Wash the particles collected on the membrane using a solution appropriate for the counter and establish the membrane particle count, $N_{mem}(\chi)$, over the size range 0,5 µm to 100 µm, where $N_{mem}(\chi)$ is the count for a given particle size.

Repeat the washing to check the efficiency of particle removal. If necessary, add the counts for each particle size.

8.3.4.2   Microscope method

The system employs a gridded membrane with a classification suitable for the intended measurement range, in conjunction with a microscope. The method is used to measure particles of diameter in the range 0,5 µm to 100 µm. To determine particle concentration by microscopy, the method described in BS 3406-4 should be employed.

The optimum duration of a test measurement may be determined after an initial test to determine the approximate particle concentration present.
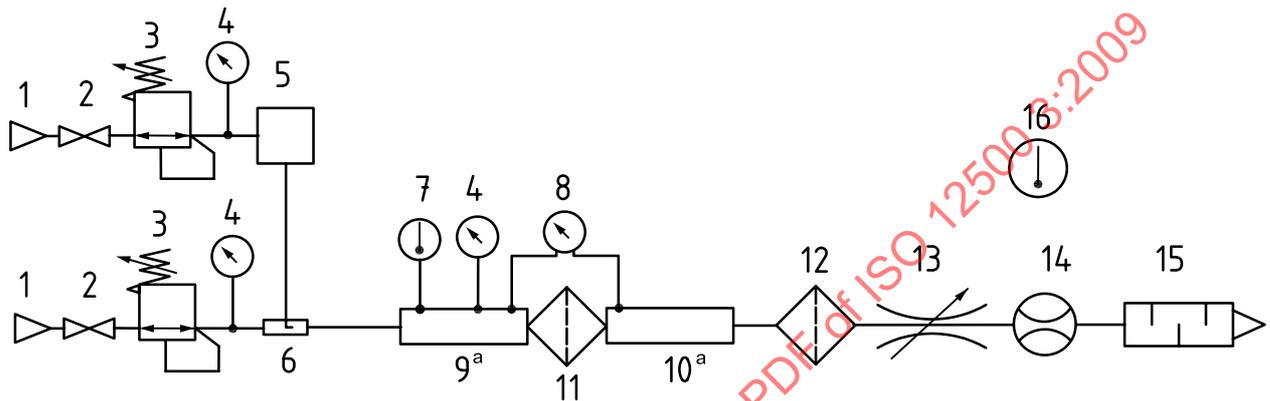
8.3.5 Sampling

8.3.5.1 Full-flow sampling

A typical test assembly for full-flow sampling is shown in Figure 3.

Pressurize the rig and set the appropriate test flow for the filter under test.

Inject the challenge dust gradually until sufficient dust has been carried to the downstream membrane for reliable counting of the downstream particles.

Key

1	compressed-air supply	9	upstream pressure-measuring tube
2	full-flow ball valve	10	downstream pressure-measuring tube
3	pressure-reducing valve	11	filter under test
4	pressure sensing/measuring	12	membrane holder
5	particle generator	13	multi-turn flow-control valve
6	particle injection	14	flow sensing/measuring
7	temperature sensing/measuring	15	silencer
8	pressure-differential sensing/measuring	16	ambient temperature-sensing/measuring

^a   Details of the construction of the measuring tubes are given in ISO 7183:2007, Annex D.

**Figure 3 — Typical coarse-filter full-flow sampling**

8.3.5.2   Iso-kinetic sampling

A typical test assembly for iso-kinetic sampling is shown in Figure 4.

Pressurize the rig and set the appropriate rated flow for the filter under test.

Inject the challenge dust gradually and, during the dust injection period, sample the downstream air iso-kinetically.

Iso-kinetic sampling should be carried out in accordance with ISO 8573-4:2001, 7.3.

Key
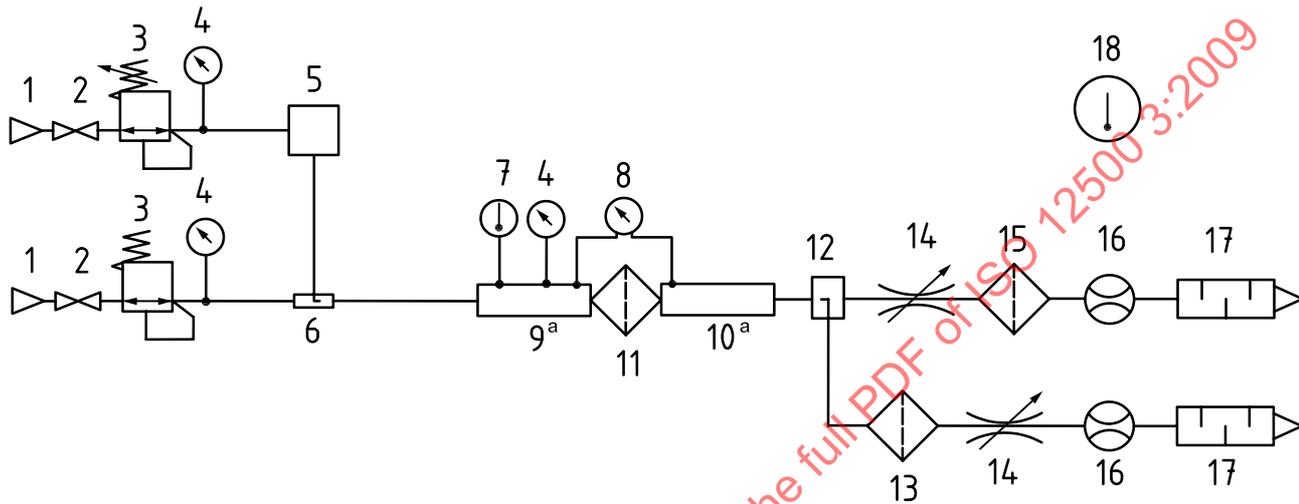
1	compressed-air supply	10	downstream pressure-measuring tube
2	full-flow ball valve	11	filter under test
3	pressure-reducing valve	12	iso-kinetic sampling point
4	pressure sensing/measuring	13	membrane holder
5	particle generator	14	multi-turn flow-control valve
6	particle injection	15	filter to protect flow meter
7	temperature sensing/measuring	16	flow sensing/measuring
8	pressure-differential sensing/measuring	17	silencer
9	upstream pressure-measuring tube [a]	18	ambient temperature-sensing/measuring

[a]   Details of the construction of the measuring tubes are given in ISO 7183:2007, Annex D.

Figure 4 — Typical coarse-filter iso-kinetic sampling

8.3.6   Efficiency calculation

The number of particles, $N_{up}(\chi)$, for a given particle size in the upstream challenge dust is given by Equation (5):

$$N_{up}(\chi) = m_{injected} \, N_{sample}(\chi)/m_{sample} \tag{5}$$

$N_{mem}(\chi)$ is the particle count from the membrane analysis for a given particle size.

For full-flow sampling, $N_{down}(\chi)$ is equal to $N_{mem}(\chi)$.

For isokinetic sampling, $N_{down}(\chi)$ is given by Equation (6):

$$N_{\text{down}}(\chi) = N_{\text{mem}}(\chi) \frac{q}{q_{\text{iso}}} \frac{T}{t} \tag{6}$$

where

q is the full test flow, expressed in litres per second;

q_{iso} is the iso-kinetic flow, expressed in litres per second;

T is the time period of dust injection;

t is the time period of iso-kinetic sampling.

The filtration efficiency, F_{E}, for a given particle size is given by Equation (7):

$$F_{\text{E}}(\chi) = \left\{ 1 - \left[N_{\text{down}}(\chi) / N_{\text{up}}(\chi) \right] \right\} \times 100 \tag{7}$$

9   Data reporting

A graph of filtration efficiency ratio, F_{E}, expressed as a percentage, against particle size, expressed in micrometres, shall be produced after the average efficiency has been determined at each channel size measured.

The test results given in Annex A shall include at least the MPPS size (fine filters only) and efficiency and may show further test results of interest.

The results of the test shall be reported on a test report form and shall include the actual test conditions as indicated in the form; see Annex A.

10   Uncertainty

Counting particles is subject to statistical variation. For the purposes of determining the uncertainty for this part of ISO 12500, reference shall be made to EN 1822-2:1998, Clause 7, where a table gives limits for the 95 % two-sided confidence interval for a given number of events using the Poisson distribution.