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**Respiratory protective devices —  
Methods of test and test equipment —**

**Part 3:  
Determination of particle filter  
penetration**

*Appareils de protection respiratoire — Méthodes d'essai et  
équipement d'essai —*

*Partie 3: Détermination de la pénétration d'un filtre à particules*



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.

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 16900-3 was prepared by Technical Committee ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 15, *Respiratory protective devices*.

ISO 16900 consists of the following parts, under the general title *Respiratory protective devices — Methods of test and test equipment*:

- *Part 1: Determination of inward leakage*
- *Part 2: Determination of breathing resistance*
- *Part 3: Determination of particle filter penetration*
- *Part 4: Determination of gas filter capacity and migration, desorption and carbon monoxide dynamic testing*
- *Part 11: Determination of field of vision*

The following parts are under preparation:

- *Part 5: Breathing machine/metabolic simulator/RPD headforms/torso, tools and transfer standards*
- *Part 8: Measurement of RPD air flow rates*
- *Part 10: Resistance to ignition, flame, radiant heat and heat*
- *Part 12: Determination of volume averaged work of breathing and peak respiratory pressures*

## Introduction

This part of ISO 16900 is intended as a supplement to the respiratory protective devices (RPD) performance standard ISO 17420 (all parts). Test methods are specified for complete devices or parts of devices that are intended to comply with ISO 17420. If deviations from the test method given in this part of ISO 16900 are necessary, these deviations will be specified in ISO 17420.

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# Respiratory protective devices — Methods of test and test equipment —

## Part 3: Determination of particle filter penetration

### 1 Scope

This part of ISO 16900 specifies the test methods for particle filter penetration of separate or integral filters for respiratory protective devices.

### 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16972, *Respiratory protective devices — Terms, definitions, graphical symbols and units of measurement*

ISO 21748, *Guidance for the use of repeatability, reproducibility and trueness estimates in measurement uncertainty estimation*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16972 apply.

### 4 Prerequisites

The performance standard shall indicate the conditions of the test. This includes the following:

- a) number of specimens;
- b) sequence of preconditioning;
- c) challenge aerosol flow rate(s) through the filter under test.

### 5 General test requirements

Unless otherwise specified, the values stated in this part of ISO 16900 are expressed as nominal values. Except for temperature limits, values which are not stated as maxima or minima shall be subject to a tolerance of  $\pm 5$  %. Unless otherwise specified, the ambient temperature for testing shall be between 16°C and 32°C and  $(50 \pm 30)$  % relative humidity. Any temperature limits specified shall be subject to an accuracy of  $\pm 1$  °C.

### 6 Principle

A challenge aerosol of known characteristics is generated and passed through the filter under test. The concentration of aerosol downstream of the filter divided by the aerosol concentration upstream of the filter as measured on the same type of detector, multiplied by a factor of 100, is the percentage penetration of the filter under test.

The two reference aerosols are sodium chloride and paraffin oil. The sodium chloride is a solid aerosol and the paraffin oil is a liquid aerosol.

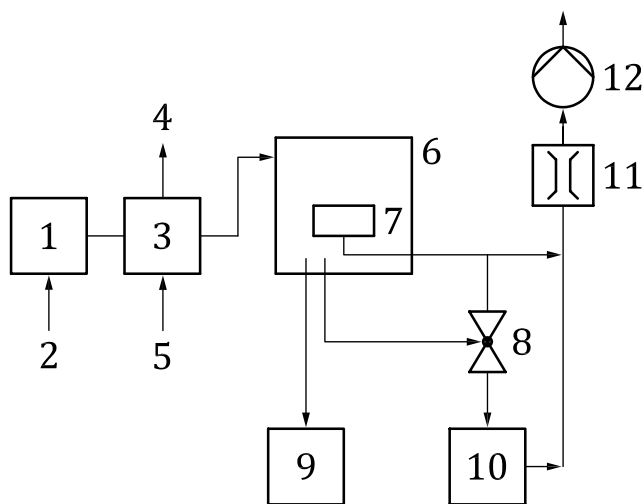
## 7 Apparatus

### 7.1 General

The test apparatus consists of four modules:

- a) aerosol generator;
- b) flow control;
- c) filter test chamber;
- d) aerosol detector.

A schematic drawing of an example for a test apparatus is shown in Figure 1.



#### Key

- 1 aerosol generator
- 2 compressed air supply
- 3 flow control module
- 4 air bleed (test flows less than the output of the generator)
- 5 make-up air (test flows greater than the output of the generator)
- 6 filter test chamber
- 7 filter under test
- 8 two-way sample selection valve
- 9 second aerosol detection photometer (optional)
- 10 aerosol detection photometer
- 11 flow meter
- 12 suction pump

Figure 1 — Schematic example of test apparatus



## 7.2 Aerosol generator

### 7.2.1 General

Sodium chloride (NaCl) aerosol shall be neutralized by the injection of both positive and negative ions into the drying or dilution air flow so that the charge distribution is brought to the state of equilibrium, commonly known as the Boltzmann distribution. Paraffin aerosol shall not be neutralized since this increases variability in the test results.

NOTE The ions should be generated by electrical means and adjusted so that there is no overall charge bias on the aerosol.

### 7.2.2 Sodium chloride test method

**7.2.2.1** The test aerosol is generated by atomising by compressed air a solution of sodium chloride in demineralized water. The atomized solution is mixed with dry air to cause the water to evaporate. The resultant aerosol shall have the following properties:

- a) the number median of particle size distribution is between 0,06  $\mu\text{m}$  and 0,10  $\mu\text{m}$  electromobility diameter, with a geometric standard deviation between 1,4 and 1,8;
- b) the aerosol concentration is within the range 8  $\text{mg}/\text{m}^3$  to 35  $\text{mg}/\text{m}^3$ ;
- c) the variation of the concentration is not greater than  $\pm 10\%$  during the test;
- d) the relative humidity is 40 % or less at  $(22 \pm 3)^\circ\text{C}$ .

The aerosol mass concentration, particle size distribution and humidity shall be measured within the filter test chamber.

NOTE It is recommended that an electrical mobility method be used to determine the particle size distribution. Additional information on electrical mobility measurements may be found in ISO 15900.

**7.2.2.2** The NaCl solution shall be completely replaced and not replenished in order to maintain the correct solution concentration.

### 7.2.3 Paraffin oil test method

**7.2.3.1** The test aerosol is generated by atomising by compressed air the liquid paraffin oil. The paraffin oil characteristics at  $20^\circ\text{C}$  shall be:

- a) CAS number: 8012-95-1;
- b) density: 0,818  $\text{g}/\text{cm}^3$  to 0,875  $\text{g}/\text{cm}^3$ ;
- c) dynamic viscosity: 0,025 Pa·s to 0,080 Pa·s; [kinematic viscosity:  $< 35 \text{ mm}^2/\text{s}$  (at  $40^\circ\text{C}$ : 13,5  $\text{mm}^2/\text{s}$  to 16,5  $\text{mm}^2/\text{s}$ )].

**7.2.3.2** Laboratories shall consider the following:

- a) paraffin oil in the test rig shall be replaced with fresh oil every three months irrespective of use, or more frequently if exposed continuously to heating and compressed air;
- b) where the generator requires the oil to be heated, it is recommended not to heat the oil above  $60^\circ\text{C}$ .

**7.2.3.3** The paraffin aerosol shall have the following properties:

- a) the number median of particle size distribution is between 0,16  $\mu\text{m}$  and 0,21  $\mu\text{m}$  electromobility diameter, with a geometric standard deviation between 1,4 and 1,8;
- b) the aerosol concentration is within the range 15  $\text{mg}/\text{m}^3$  to 35  $\text{mg}/\text{m}^3$ ;
- c) the variation of the concentration is not greater than  $\pm 10\%$  during the test.

The aerosol mass concentration and particle size distribution shall be measured within the filter test chamber.

**NOTE** It is recommended that an electrical mobility method be used to determine the particle size distribution.

Additional information on electrical mobility measurements may be found in ISO 15900.

### 7.3 Flow control module

The flow control module is used to bleed off excess aerosol where the required test flow is less than the output of the aerosol generator.

Where the performance standard calls for a flow in excess of the output of the aerosol generator, extra air shall be mixed with the output to increase the flow to the filter test chamber. Action shall be taken to ensure that the challenge concentration remains within the permissible range. If necessary, two or more aerosol generators may be used in parallel in order to maintain the challenge concentration within the specified range at high flow rates.

Measurement of aerosol concentration and particle size distribution shall not be affected by the flow measuring device. This can be achieved by placing the flow measuring device downstream of the test chamber.

### 7.4 Filter test chamber

The filter test chamber shall be sufficiently large to accommodate the filter system under test and allow exposure of the entire filter working area to the aerosol. Care shall be taken that the influent aerosol is not directed preferentially on to one part of the filter or filter system unless this is caused by the filter design.

The construction of the chamber shall be resistant to the aerosol, shall be leaktight and shall safely withstand any pressures, either positive or negative, that may be generated.

The filter test chamber shall be designed to minimize air velocity variations across the surface of the filter under test. Localized high air velocity ("jets") may result in artificially high filter penetration.

### 7.5 Aerosol detector

#### 7.5.1 General

The aerosol detector shall have sufficient sensitivity and resolution to accurately determine penetrations to at least an order of magnitude better than the pass/fail criterion specified in the performance standard for the relevant class.

The sampling flow rate should be minimized to reduce the effects of sampling on the aerosol within the test chamber or downstream of the filter. Where necessary, the sample shall be returned to the system to prevent errors in the determination of the test flow rate.

It is permissible to use two aerosol detectors, one monitoring the upstream concentration and one monitoring the downstream concentration, provided that they are both accurately calibrated for the appropriate aerosol size and concentration range in which they are used.

#### 7.5.2 Sodium chloride

The sodium chloride aerosol shall be analysed by flame photometry.

Sodium chloride particles in air passing through the flame tube are vaporized giving the characteristic sodium emission at 589 nm. The intensity of this emission is proportional to the concentration of sodium in the air flow.

The intensity of the light emitted by the flame is measured by using a photomultiplier tube. To separate the sodium emission from background light of other wavelengths, a narrow band interference filter with appropriate sideband filters to remove interference from H<sub>2</sub>O and CO<sub>2</sub> shall be used. As the photomultiplier output is only proportional to the incident light over a relatively small range, high light intensities are attenuated by neutral density filters.

### 7.5.3 Paraffin oil

The reference detector is a forward light scattering photometer that has an effective scattering angle of up to 45°. Other detectors may be employed provided equivalence to the reference detector can be demonstrated when using the test aerosol specified in 7.2.3.

## 8 Methods

### 8.1 General

The filter under test is mounted in the filter test chamber and exposed to the appropriate aerosol challenge. The specified flow is passed through the filter. Where an exhalation valve is incorporated into the filter, it shall be sealed during the test.

Where one filter of a multiple filter device is tested separately, the air flow specified for a test shall be divided by the number of filters through which the air flow is proportioned, provided that the filters resistances satisfy Formula (1):

$$\frac{R_{\max} - R_{\min}}{\bar{R}} \leq 0,2 \quad (1)$$

where

$R_{\max}$  is the maximum resistance;

$R_{\min}$  is the minimum resistance;

$\bar{R}$  is the mean resistance.

The aerosol concentration is monitored both before and after the filter in order to calculate the filter penetration. It is not necessary to monitor both concentrations simultaneously, provided that the challenge concentration can be shown to be stable over the duration of the measurement cycle.

### 8.2 Short-term particle penetration test

After a stabilization time of 3 min, the recording of the filter penetration shall start. The short-term penetration value is the average value over the following 30 s.

The stabilization time shall start when the chamber is sealed.

### 8.3 Full exposure particle penetration test

#### 8.3.1 Unassisted RPD filters

Where required by the performance standard, the filter shall be exposed to  $m = 150$  mg of the challenge aerosol by extending the duration of the test. The duration shall be calculated using Formula (2):

$$t = \frac{m \cdot 1000}{Q \cdot c} \quad (2)$$

where

- $t$  is the time, expressed in minutes (min);
- $m$  is the mass of 150 mg of the challenge aerosol;
- $Q$  is the challenge flow, expressed in litres per minute (l/min);
- $c$  is the challenge concentration, expressed in milligram per cubic metres (mg/m<sup>3</sup>).

Where practicable, the exposure should be confirmed gravimetrically by weighing the filter before and after the test. This may not be possible with filters that contain sorbents that take up water vapour, due to the difference in weight caused by a change in humidity.

During the duration:

- a) for filters being tested using paraffin oil, continue the test until the filter has been exposed to 150 mg of test aerosol;
- b) for filters being tested using sodium chloride, continue the test until
  - 1) the filter has been exposed to 150 mg of test aerosol, or
  - 2) the penetration shows continued decline for 5 min or 5 sample intervals, whichever is the greater.

Report the maximum penetration during exposure. During the duration of the exposure the penetration shall be continuously monitored or recorded at intervals not exceeding 5 min.

Where one filter of a multiple filter device is tested separately, the challenge weight shall be divided by the number of filters through which the air flow is proportioned, provided that the filter resistances satisfy Formula (1).

#### 8.3.2 Assisted RPD filters

Where required by the performance standard, the filter shall be exposed to a  $c \cdot t$  of the challenge aerosol of 2 400 min·mg/m<sup>3</sup> by calculating the duration of the extended test. The duration shall be calculated using Formula (3):

$$t = \frac{2400}{c} \quad (3)$$

where

- $t$  is the time, expressed in minutes (min);
- $c$  is the challenge concentration, expressed in milligram per cubic metres (mg/m<sup>3</sup>).

The test flow shall be the peak interactive flow (this can be determined using ISO 16900-8).

#### 8.4 Storage after exposure test

Filters that are not designated for single shift use only shall be exposed to 150 mg of paraffin oil as described in 8.3 then stored in a sealed container at ambient conditions for a period of  $(24 \pm 1)$  h. During storage, ensure that the filters are not in contact with each other. After storage, the filters shall be subjected to a short-term particle penetration test according to 8.2 using paraffin oil.

#### 8.5 Calculation of percent penetration

The percent penetration of the filter under test shall be calculated using Formula (4):

$$p = \frac{c_1}{c_2} \cdot 100 \quad (4)$$

where

- $p$  is the penetration, in percent;
- $c_1$  is the concentration of aerosol in the air stream after passing through the filter;
- $c_2$  is the concentration of aerosol in the filter test chamber.

### 9 Test report

The test report shall include at least the following information:

- a) number of specimens;
- b) sequence of preconditioning;
- c) challenge aerosol flow rate(s) through the filter under test;
- d) filter efficiency.

### 10 Uncertainty of measurement

An estimate of the uncertainty of measurement associated with this test method shall be established in accordance with ISO 21748 and used according to Annex A for the assessment of conformity.

NOTE The use of transfer standards may assist in establishing common uncertainties of measurement between laboratories.

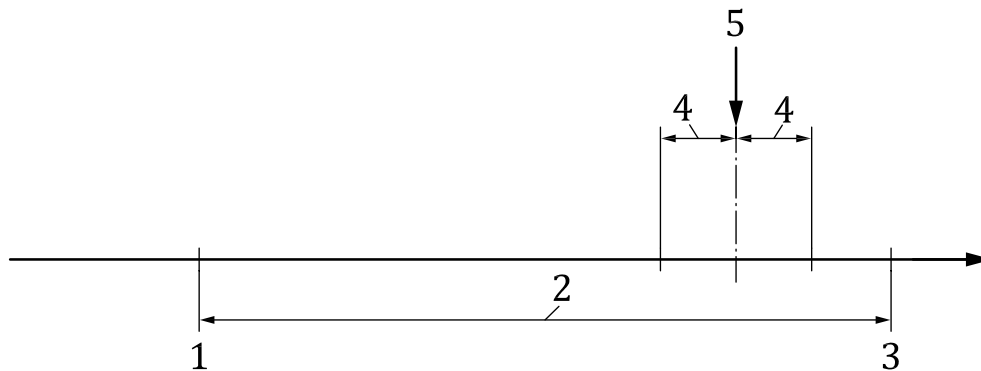
## Annex A (normative)

### Application of uncertainty of measurement

#### A.1 Determination of compliance

In order to determine compliance or otherwise of the measurement made in accordance with this test method, when compared to the specification limits given in the protective device standard, the following protocol shall be applied.

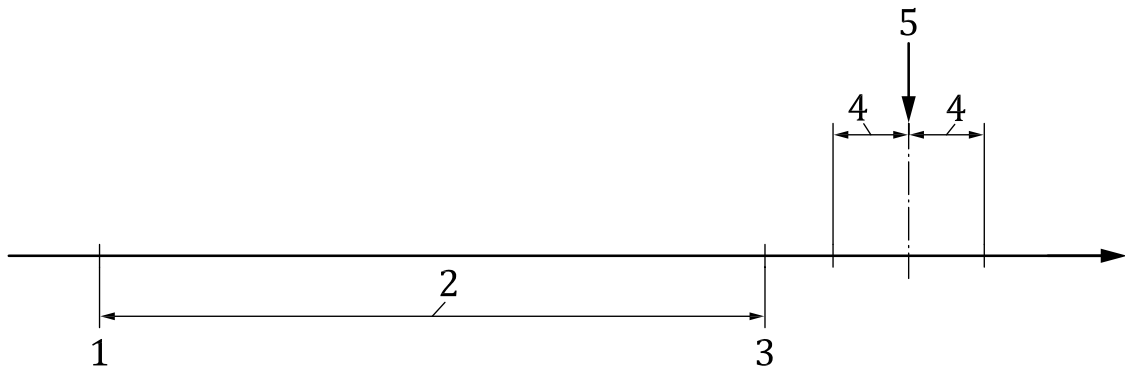
If the test result  $\pm$  the uncertainty of measurement,  $U$ , falls completely inside or outside of the specification zone for the particular test given in the protective device standard, then the result shall be deemed to be a straightforward pass or fail (see Figures A.1 and A.2).



**Key**

- 1 lower specification limit
- 2 specification zone
- 3 upper specification limit
- 4 uncertainty of measurement,  $U$
- 5 measured value

**Figure A.1 — Result pass**

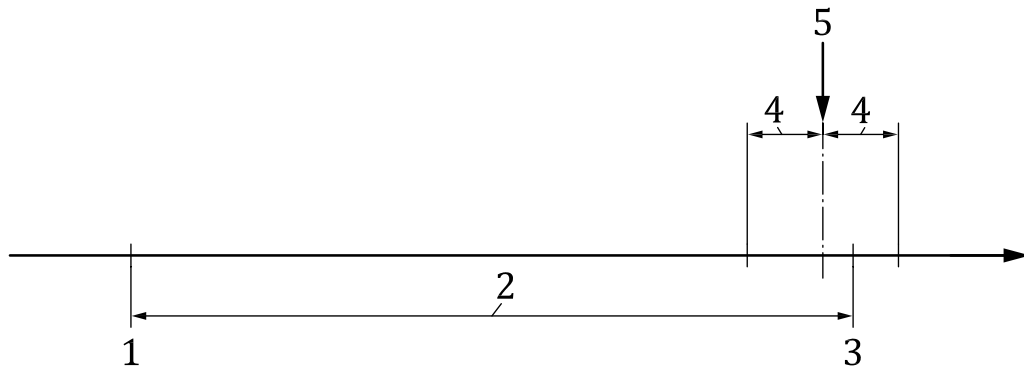


**Key**

- 1 lower specification limit
- 2 specification zone
- 3 upper specification limit
- 4 uncertainty of measurement,  $U$
- 5 measured value

**Figure A.2 — Result fail**

If the test result  $\pm$  the uncertainty of measurement,  $U$ , overlaps a specification limit value (upper or lower) for the particular test given in the protective device standard, then the assessment of pass or fail shall be determined on the basis of safety for the wearer of the device; that is, the result shall be deemed to be a fail (Figure A.3).



**Key**

- 1 lower specification limit
- 2 specification zone
- 3 upper specification limit
- 4 uncertainty of measurement,  $U$
- 5 measured value

**Figure A.3 — Result fail**

## Bibliography

- [1] ISO 15900, *Determination of particle size distribution — Differential electrical mobility analysis for aerosol particles*
- [2] ISO 16900-8, *Respiratory protective devices — Methods of test and test equipment — Part 8: Measurement of RPD air flow rates<sup>1)</sup>*
- [3] ISO 17420 (all parts), *Respiratory protective devices — Performance requirements<sup>2)</sup>*

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1) Under preparation.

2) ISO 17420-1 and ISO 17420-2 are under preparation; ISO 17420-3 is to be published.





