# INTERNATIONAL STANDARD

# ISO 29463-2

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## High-efficiency filters and filter media for removing particles in air —

## Part 2: Aerosol production, measuring equipment and particle-counting statistics



*Filtres à haut rendement et filtres pour l'élimination des particules dans l'air —*

*Partie 2: Production d'aérosol, équipement de mesure et statistique de comptage de particules*



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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 29463-2 was prepared by Technical Committee ISO/TC 142, *Cleaning equipment for air and other gases*.

ISO 29463 consists of the following parts, under the general title *High-efficiency filters and filter media for removing particles in air*:



— *Part 1: Classification, performance, testing and marking*

— *Part 2: Aerosol production, measuring equipment, particle-counting statistics*



— *Part 3: Testing flat sheet filter media*

— *Part 4: Test method for determining leakage of filter element — Scan method*

— *Part 5: Test method for filter elements*

## Introduction

ISO 29463 (all parts) is derived from EN 1822 (all parts) with extensive changes to meet the requests from non-EU p-members. It contains requirements, fundamental principles of testing and the marking for high-efficiency particulate air filters with efficiencies from 95 % to 99,999 995 % that can be used for classifying filters in general or for specific use by agreement between users and suppliers.

ISO 29463 (all parts) establishes a procedure for the determination of the efficiency of all filters on the basis of a particle counting method using a liquid (or alternatively a solid) test aerosol, and allows a standardized classification of these filters in terms of their efficiency, both local and overall efficiency, which actually covers most requirements of different applications. The difference between ISO 29463 (all parts) and other national standards lies in the technique used for the determination of the overall efficiency. Instead of mass relationships or total concentrations, this technique is based on particle counting at the most penetrating particle size (MPPS), which, for micro-glass filter mediums, is usually in the range of 0,12 μm to 0,25 μm. This method also allows testing ultra-low penetration air filters, which was not possible with the previous test methods because of their inadequate sensitivity. For membrane filter media, separate rules apply, and are described in ISO 29463-5:2011, Annex B. Although no equivalent test procedures for testing filters with charged media is prescribed, a method for dealing with these types of filters is described in ISO 29463-5:2011, Annex C. Specific requirements for test method, frequency, and reporting requirements can be modified by agreement between supplier and customer. For lower efficiency filters (group H, as described below), alternate leak test methods noted in ISO 29463-4:2011, Annex A, can be used by specific agreement between users and suppliers, but only if the use of these other methods is clearly designated in the filter markings as described in ISO 29463-4:2011, Annex A.



There are differences between ISO 29463 (all parts) and other normative practices common in several countries. For example, many of these rely on total aerosol concentrations rather than individual particles. For information, a brief summary of these methods and their reference standards are provided in ISO 29463-5:2011, Annex A.

# High-efficiency filters and filter media for removing particles in air —

# Part 2:
# Aerosol production, measuring equipment and particle-counting statistics

## 1 Scope

This part of ISO 29463 specifies the aerosol production and measuring equipment used for testing high-efficiency filters and filter media in accordance with ISO 29463-3, ISO 29463-4 and ISO 29463-5, as well as the statistical basis for particle counting with a small number of counted events. It is intended to be used in conjunction with ISO 29463-1, ISO 29463-3, ISO 29463-4 and ISO 29463-5.



## 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 29463-1, *High-efficiency filters and filter media for removing particles in air — Part 1: Classification, performance, testing and marking*

ISO 29463-3, *High-efficiency filters and filter media for removing particles in air — Part 3: Testing flat sheet filter media*

ISO 29463-4:2011, *High-efficiency filters and filter media for removing particles in air — Part 4: Test method for determining the leakage of filter element — Scan method*

ISO 29463-5:2011, *High-efficiency filters and filter media for removing particles in air — Part 5: Test method for filter elements*

ISO 29464[1)], *Cleaning equipment for air and other gases — Terminology*

1) To be published.

# 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 29463-1, ISO 29464, and the following apply.

**3.1**
**counting efficiency**
expression of that proportion of the particles of detectable size suspended in the volume flow under analysis that make their way through the measured volume and are counted by the particle counter

EXAMPLE The ratio of the concentration measured to actual aerosol concentration.

NOTE The counting efficiency depends on the particle size, and decreases progressively in the proximity of the lower detection limit of the particle counter.

# 4 Aerosol production

When testing a filter, a test aerosol with liquid particles shall be used as reference test method in accordance with ISO 29463-1. Alternatively, a solid PSL aerosol may be used for local efficiency (leak) testing (see ISO 29463-4:2011, Annex E).

The testing of high-performance filters (ISO 65 U and higher) requires methods of aerosol production with high production rates ($10^{10}$ $s^{-1}$ to $10^{11}$ $s^{-1}$), in order to provide statistically significant measurements downstream of the filter.

By adjusting the operating parameters of the aerosol generator, it shall be possible to adjust the mean particle diameter of the aerosol so that it is equal to the MPPS. The concentration and the size distribution of the aerosol produced shall remain constant throughout the test.



## 4.1 Aerosol substances

A suitable aerosol substance for the reference test method is a liquid with a vapour pressure that is so low at the ambient temperature that the size of the droplets produced does not change significantly due to evaporation over the time scale relevant for the test procedure (in the order of a few seconds).

**4.1.1** Possible substances include, but are not limited to,

— DEHS,

— PAO,

— paraffin oil (low viscosity).

**4.1.2** The most critical properties of a possible aerosol substance are the following, which should not differ significantly from the values given for the three substances suggested in Table 1:

— index of refraction;

— vapour pressure;

— density.

Standard laboratory safety regulations shall be observed when handling these substances. It shall be ensured by means of suitable exhaust systems and air-tight aerosol ducting systems that the test aerosols are not inhaled. In case of doubt, the safety data sheets for the appropriate substances shall be consulted.

**Table 1 — Important data for aerosol substances at** 20 °C

| **Trivial name** | DEHS | PAO[a] | Paraffin oil (low visc.) |
|---|---|---|---|
| **Chemical designation** | Sebacic acid-bis(2-ethylhexyl) ester (e.g. CAS No. 122-62-3) | Poly-alpha-olefin (e.g. CAS[b] No. 68649-12-7) | Mixture (e.g. CAS # 64742-46-7) |
| **Trivial name** | Diethylhexylsebacate | Polyalphaolefin | Paraffin oil |
| **Density,** kg/m$^3$ | 912 | 800 to 820 (820[c]) | 843 |
| **Melting point,** K | 225 | ~280 | 259 |
| **Boiling point,** K | 529 | 650 to 780 (674[c]) | 526 |
| **Flash point,** K | >473 | 445 to 500 | 453 |
| **Vapour pressure at** 293 K, kPa | 1,9 < 0,1 kPa at 423 K | 0,1 to 0,13 | <0,1 |
| **Dynamic viscosity,** kg/m·s | 0,022 to 0,024 | 0,003 1 to 0,003 4 at 373 K<br>0,014 at 313 K[c] | 0,026<br>0,002 5 to 0,003 8 at 313 K |
| **Kinematic viscosity,** mm$^2$/s | — | 3,8 to 4,2 at 373 K | 3,0 to 4,5 at 313 K |
| **Index of refraction/wavelength,** nm | 1,450/650<br>1,452/600<br>1,4535/550<br>1,4545/500<br>1,4585/450<br>1,475/400 | (1,455 6[c]) | (1,466[c]) |

[a] US Patents 5,059,349, 5,059,352, and 5,076,965 describe and restrict the use of PAO for filter testing.

Material properties of PAO are as given in Japan JACA Standard No. 37-2001 and ISO 14644-3.

[b] CAS #, Chemical Abstract Service Registry Number, substances have been registered in Chemical Abstract, issued by American Chemical Society.

[c] Data for “Emery 3004” as a specific example of a PAO.

Source: Crosby, David W., *Concentration produced by a Laskin nozzle generator, a comparison of substitute materials and DOP*, 21st DOE/NRC Nuclear Air Cleaning Conference.



## 4.2 Producing mono-disperse aerosols

### 4.2.1 Condensation methods

Condensation methods are preferred for the creation of mono-disperse aerosols, i.e. the particles are formed by condensation from the vapour phase. It is necessary to distinguish between heterogeneous and homogeneous condensation.

#### 4.2.1.1 Heterogeneous condensation

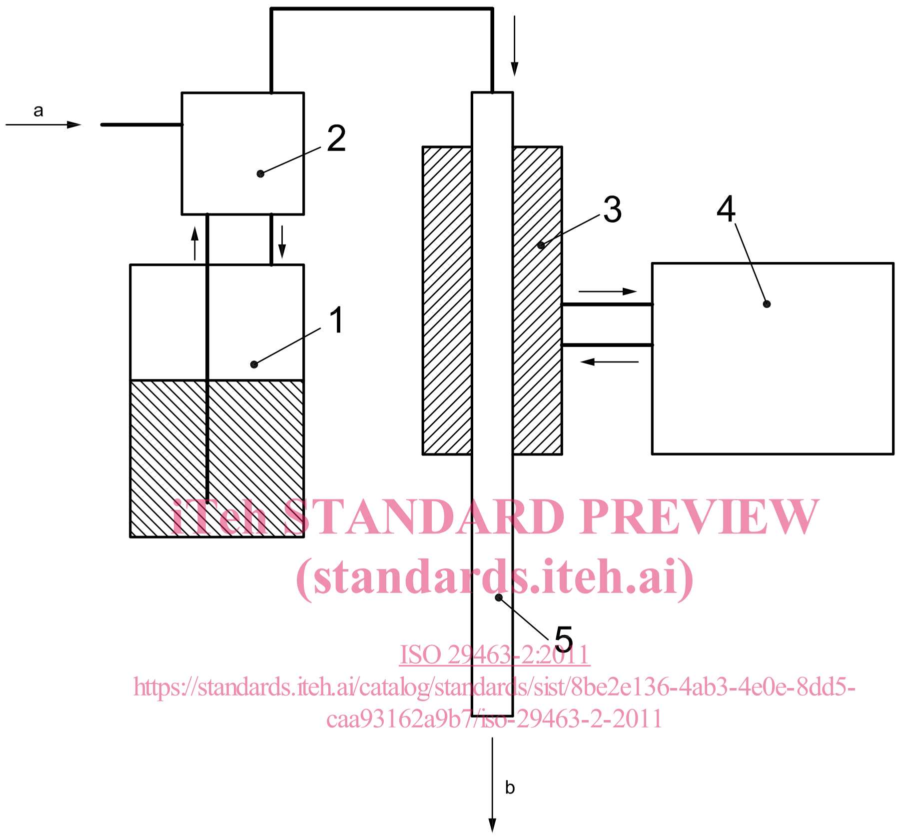
In the case of heterogeneous condensation, the vapour condenses at a relatively low level of super-saturation onto very small particles that are already present, the so-called condensation nuclei. The size distribution of the resultant aerosol has a geometrical standard deviation between $\sigma_g = 1{,}05$ and $\sigma_g = 1{,}15$.

One type of aerosol generator that operates using the principle of heterogeneous condensation and that is suitable for testing filters in accordance with this part of ISO 29463 is the Rapaport-Weinstock generator (see Figure 1).

#### 4.2.1.1.1 Rapaport-Weinstock generator

NOTE See Figure 1.

An aerosol substance is nebulized through a nozzle, either as a pure substance or in solution, and the resultant poly-disperse aerosol is then vaporized along the heated section of a glass tube. Residual nuclei of the impurities in the material remain.






**Key**

1 liquid reservoir
2 nebulizer
3 vaporization section
4 thermostat
5 condensation section

a Compressed air.
b Aerosol.

**Figure 1 — Structure of the Rapaport and Weinstock aerosol generator**

In the subsequent condensation section, the aerosol substance then condenses on these nuclei to form a mono-disperse aerosol (see also Reference [1]).

The particle diameter of this aerosol is determined by the mixing ratio of aerosol substance and solvent. The final aerosol contains the solvent used (e.g. propanol) as a vapour.

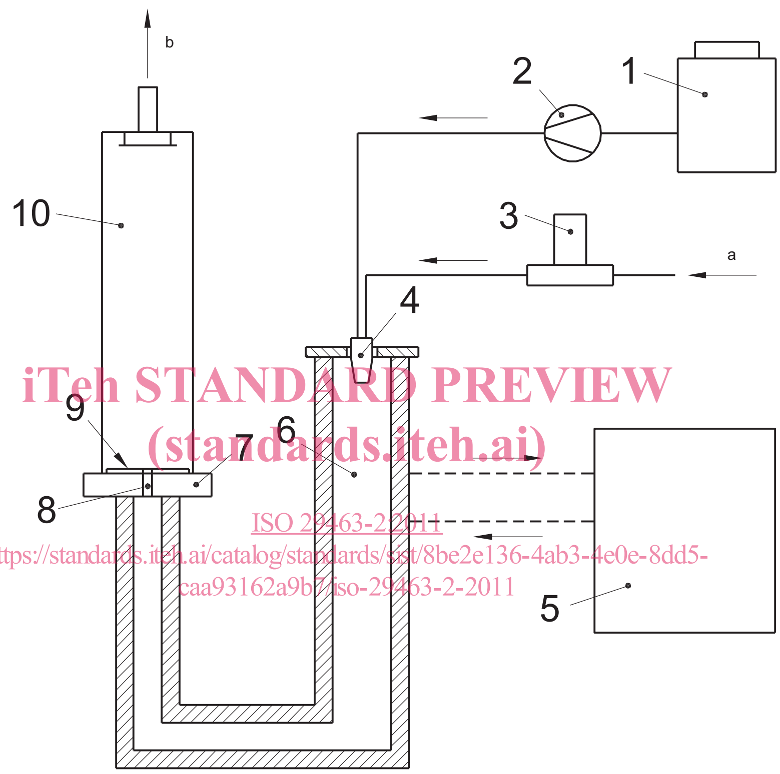
Generators of this type achieve particle production rates of $10^9$ $s^{-1}$; the particle diameter can be adjusted between approximately 0,1 µm and 1,5 µm.

#### 4.2.1.2 Homogeneous condensation

At higher levels of super-saturation, clusters of vapour molecules form spontaneously without the presence of condensation nuclei, and these then grow to particles that are some nanometres in diameter (homogeneous condensation). Larger particles then form as a result of coagulation of these particles with one another. The resultant size distribution has a standard deviation of $\sigma_g \sim 1{,}5$ independent of the median particle size, and can thus only be referred to as quasi-mono-disperse. On the other hand, rates of production of particles achieved can be as much as two orders of magnitude larger than those possible using heterogeneous condensation (more than $10^{11}$ $s^{-1}$).

Figure 2 shows the structure of a free-jet condensation aerosol generator that makes use of this principle.






**Key**

1 DEHS tank
2 pump
3 flow controller
4 ultra-sonic nebulizer
5 thermostat
6 vaporization pipe with heater and insulation
7 sheath air
8 nozzle
9 sintered metal plate
10 coagulation section

a Nitrogen.
b Aerosol.

**Figure 2 — Set-up of a free-jet condensation aerosol generator**

A pump delivers aerosol substance to an ultrasonic nebulizer at a defined rate. The relatively large (> 20 µm) droplets that are produced are then vaporized in a heated pipe. The concentration of residual nuclei is so low that they do not influence the subsequent homogeneous condensation process. The hot stream of nitrogen carrying the vapour then passes through a nozzle into a cold, laminar flow of sheath air. The turbulent mixing of the free jet with the cold air produces the super-saturation necessary for the homogeneous condensation.

The particle size and particle concentration can be adjusted by varying the volume flow rates of the aerosol substance (DEHS), nitrogen and envelope air.

#### 4.2.2 Particle size classification

Using a differential mobility analyser as described in 5.3, it is possible to separate a fraction with almost the same electrical mobility from a poly-disperse aerosol (see also Reference [2]). Provided all these particles carry only a single electrical charge, then this mono-mobile fraction is also mono-disperse. If necessary, larger particles that carry a multiple charge, and that thus have the same electrical mobility as the single-charged particles, shall be removed from the poly-disperse input aerosol by suitable means.

Since the proportion of singly charged particles in the relevant size range is less than 10 %, from which only a narrow size band is selected, then the number concentration of the mono-disperse output aerosol is lower than the input concentration by a factor of at least 100. As a consequence, this method of producing mono-disperse aerosols is suitable only for the measurement of the particle size efficiency of the filter medium (see ISO 29463-3).

The degree of mono-dispersity achieved by this method can be described by a geometrical standard deviation of $\sigma_g < 1{,}1$. In practise, however, the operating parameters are often amended to increase the particle concentration at the expense of a greater standard deviation.



### 4.3 Generating poly-disperse aerosols



Poly-disperse liquid aerosols are usually produced by nebulizing the aerosol substance through a binary nozzle using compressed air.

A subsequent inertial separator, in the form of baffle plates or a cyclone separator, serves to precipitate larger particles and to reduce the range of the size distribution. The geometrical standard deviation of the distribution generated lies between 1,6 and 2,5. The particle diameter can be influenced to a small degree by changing the operating pressure of the nozzle. Greater influence on the particle size is usually achieved by dissolving the aerosol in a volatile solvent (e.g. propanol) before nebulization. When the solvent evaporates, it leaves behind particles whose size is governed by the ratio of aerosol substance to solvent that was used.

It is comparatively simple to increase the particle production rate by using a number of jets in parallel.

The maximum rate of particle production that can be achieved using one nozzle is $5 \times 10^{10}\ s^{-1}$.

NOTE A typical jet nebulizer is described, for example, in Reference [3].

Where higher aerosol outputs are desired (ISO 29463-5), a Laskin Nozzle aerosol generator is recommended.

#### 4.3.1 Laskin Nozzle poly-disperse aerosol generator

The Laskin Nozzle aerosol generator system uses a nozzle to generate a poly-disperse aerosol from a liquid, such as DOP, DEHS or PAO and employs a source of compressed gas (see also Reference [4]). The generator creates an aerosol having a mass mean diameter of approximately 0,45 µm, a light-scattering geometric diameter of approximately 0,72 µm, and a light-scattering mean droplet-size distribution as shown in Figure 3 (see also Reference [4]).