# INTERNATIONAL STANDARD

# ISO 21501-4

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**AMENDMENT 1**
**2023-02**

# Determination of particle size distribution — Single particle light interaction methods —

## Part 4: Light scattering airborne particle counter for clean spaces

## AMENDMENT 1

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*Détermination de la distribution granulométrique — Méthodes d'interaction lumineuse de particules uniques —*

*Partie 4: Compteur de particules en suspension dans l'air en lumière dispersée pour espaces propres*

*AMENDEMENT 1*

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# Determination of particle size distribution — Single particle light interaction methods —

## Part 4: Light scattering airborne particle counter for clean spaces

## AMENDMENT 1

*3.2*

Add the following text at the end of the definition: "or ratio of the particle number measured by an LSAPC to that introduced to the LSAPC for a given sampling time", so that the entry reads:

**3.2**
**counting efficiency**
ratio of the number concentration measured by a light scattering airborne particle counter (LSAPC) (3.4) to that measured by a reference instrument for the same test aerosol, or ratio of the particle number measured by an LSAPC to that introduced to the LSAPC for a given sampling time

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*6.2*

Add the following paragraph at the end of the subclause:

> It can be appropriate to evaluate counting efficiency for some applications at sizes larger than twice the minimum detectable size. It is recognized that the counting efficiency range of 0,90 to 1,10 [(100 ± 10) %] specified above does not remain relevant at all larger sizes due to particle losses within the LSAPC; depending on the application requirements, a tolerance of ±10 to ±30 % is recommended at a nominal particle diameter of 5 µm.

*7.2*

Add the following subclause heading above the first paragraph:

> **7.2.1 Parallel comparison method**

Add the following subclause at the end of subclause 7.2.1:

> **7.2.2 Generator method**
>
> Clause A.2 describes the generator method for evaluating the counting efficiency of LSAPC. Generator method uses monodisperse particles whose sizes are defined as the volume equivalent diameter. The method uses an inkjet aerosol generator (IAG) as a monodisperse particle number standard. In this method, the counting efficiency, $\eta$, is evaluated according to Formulae (3) and (4).

$$\eta = \frac{N_1}{N_0} \tag{3}$$

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$$N_0 = t \cdot L_0 \tag{4}$$

where

| | |
|---|---|
| $N_1$ | is the number of particles measured by an LSAPC under test; |
| $N_0$ | is the number of particles introduced to the LSAPC; |
| $t$ | is the sampling time set to the LSAPC; |
| $L_0$ | is the particle generation rate of the IAG. |

The counting efficiencies of Formula (2) is equivalent to Formula (3) when $N_0$ is evaluated by

$$N_0 = V \cdot C_0$$

where $V$ is the volume of test aerosol sampled by the LSAPC.

Renumber subsequent Formulae (3) to (7) as (5) to (8).

*Annex A*

Replace Annex A with the following:

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# Annex A
(informative)

# Counting efficiency

## A.1 Introduction

This annex introduces the parallel comparison method and the generator method. The parallel comparison method is the general method, and the generator method is the alternative method. Table A.1 summarizes the characteristics of these two methods.

**Table A.1 — Characteristics of the parallel comparison method and the generator method**

| Parallel comparison method | Generator method |
|---|---|
| Liquid or solid particles nebulised from solutions/particle suspensions or dispersed from dry powder; PSL spheres can be used as test particles. | Monodisperse solid or liquid particles are generated from aqueous solutions; PSL spheres cannot be used as test particles. |
| Particle size range: typically from 100 nm PSL optical diameter. | Particle size range: typically from 0,5 µm. |
| Since the method can select the particle size by using classification devices such as DEMC or AAC, the cut-off region of the counting efficiency curve can be evaluated. | Not an appropriate method to evaluate the lower cut-off diameter of the counting efficiency curve. |
| SI-traceability of the PSL geometric diameter can be established. | SI-traceability of the particle volume equivalent diameter can be established. |
| The number of particles delivered to a DUT-LSAPC must be measured with a reference instrument (e.g. a reference LSAPC or CPC). | The number of particles delivered to a DUT- LSAPC is accurately and precisely known. |

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## A.2 Parallel comparison method

### A.2.1 Principle

Figures A.1 and A.2 show the test system for counting efficiency. The particle generator generates an aerosol that consists of dry monodisperse PSL particles (100 nm to 10 µm) suspended in clean air.

PSL particles in the range of 100 nm to 5 µm can be generated by nebulizing aqueous suspensions. After nebulization of a PSL suspension, the aerosol typically contains residue particles which can bias the measurement of the counting efficiency. Measurement errors should be minimized by:

— separating the PSL particles from surfactants, for example, in several mixing/settling separation steps in ultrapure water before preparing the suspension for the aerosol generator;

— using a PSL suspension in the aerosol generator with very low concentration of impurities in the liquid phase, for example, traces of salt in ultrapure water, to a) achieve a low enough background of residue particles and b) avoid growth of PSL particles due to coating of impurities after evaporation of the suspension liquid droplet;

— optimising the concentration of PSL particles in the suspension to avoid measurement bias due to doublet PSL particles (two PSL particles were contained in a droplet);

— drying the aerosol to remove all suspension liquid from the surface of the PSL particles and to avoid condensation of suspension liquid vapour on the PSL particles.

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After drying the aerosol, size classifying the PSL particles with a DEMC (compare ISO 15900 and ISO 27891; commercial DEMCs can be used for particles up to about 1 µm) or an aerodynamic aerosol classifier[11] (AAC), applicable up to 5 µm, can be applied if the background of residue particles needs to be further reduced. This can especially be necessary if the requirements in Clause 7 (see Figure 3) cannot be fulfilled.

Since PSL aerosol generated from a suspension is electrostatically charged and since DEMC-classified PSL particles are unipolarly charged, a bipolar diffusion charge conditioner (as known as aerosol neutralizer) further increases the accuracy of the measurement of the counting efficiency by minimizing particle losses in both the particle counter to be inspected and the reference particle counter.

After generation and conditioning, the PSL aerosol is fed to the particle counter to be inspected and the reference particle counter via a device (e.g. a distributing box, see Figures A.1 and A.2) which shall be designed in such a way that the particle number concentration at the inlet of both particle counters is as close as possible. The uncertainty associated with the inhomogeneity in the particle number concentration should be evaluated according to the procedure given in Clause E.2 [1].

The counting efficiency is obtained by calculating the ratio of the particle number concentration measured by the particle counter under test and the particle number concentration measured by the reference particle counter. The particle number concentration of the sample should be less than 25 % of the maximum particle number concentration of both the reference particle counter and the particle counter under test.

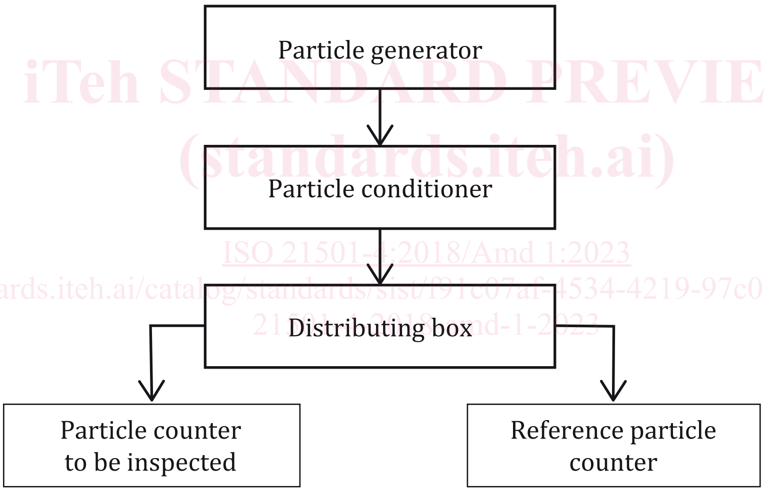


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**Figure A.1 — Example of counting efficiency test system**

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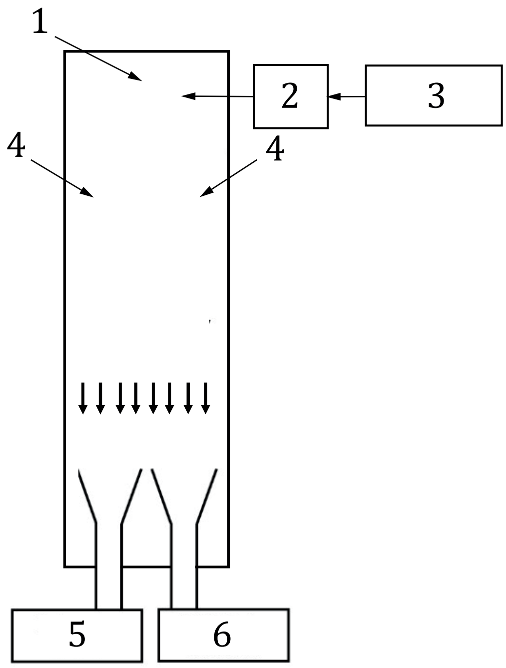


**Key**

1 filtered dilution air

2 DEMC or AAC

3 wet or dry PSL dispersion

4 turbulent airjets

5 reference LSAPC

6 LSAPC under test

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**Figure A.2 — Example of counting efficiency test system**

As mentioned before, the method described above is most useful for PSL particles smaller than approximately 5 µm. If calibration with larger particles (e.g. 10 µm) is required, dry PSL particles generated with a dry powder dispenser are better suited. The counting efficiency of the LSAPC under test can decrease considerably for particles with a diameter larger than 1 µm. The monodisperse, dry PSL powder needs to be free of surfactants to avoid errors during the calibration. Homogenization of large particles (larger than about 0,5 µm) can require mixing by turbulent airjets as shown in Figure A.2. Moreover, distributing the aerosol between the reference particle counter and the particle counter to be inspected in Figure A.1 requires special attention for larger particles since particle losses due to inertial impaction and gravitational settling become important. To minimize errors, it is recommended to:

— use a distribution tube in Figure A.2 instead of a distribution box in Figure A.1;

— use isokinetic and isoaxial probes to extract the calibration aerosol for both particle counters;

— use vertical tubing to connect the distribution tube with the particle counters;

— use a large radius of curvature (radius larger than 10 times the inner diameter of the tube), if bends in the connection tubing cannot be avoided;

— use metallic, grounded tubing with polished inner surface for connection;

— avoid changes in tubing diameter; in particular avoid step changes.

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### A.2.2 Traceability

A sample traceability chart is shown in Figure A.3. Traceability is provided by calibrating LSAPCs against a reference LSAPC at a National Metrology Institute (NMI). An example of how to put the recommendations of this document into practice is provided in Reference [12]. The reference LSAPC is custom made. The sampled aerosol flow, measured with a traceably calibrated mass flow meter, is typically set to 60 ml $min^{-1}$ to avoid coincidence losses. The sampled aerosol enters the detection chamber through a nozzle with an orifice of 0,2 mm and is surrounded by a sheath-air flow, which prevents the particle beam from diverging. A laser beam is generated by a continuous-wave laser (5 W) at a wavelength of 532 nm and focused at the point of intersection with the aerosol stream using a cylindrical lens. This results in a laser beam with a width of 0,7 mm. Particles cross the laser beam scatter light, which is detected by a photomultiplier tube placed at a 90° angle. The peak detection algorithm has been traceably validated using a pulse generator coupled to a traceable frequency standard.

The reference LSAPC at NMI is further validated through international inter-comparisons.

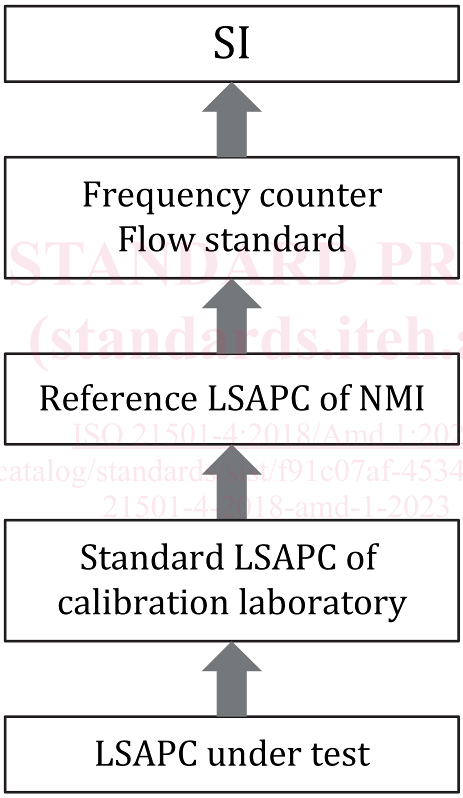


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**Figure A.3 — Metrological traceability of the particle concentration measured by an LSAPC under test**

Traceably calibrated CPCs can also be used as reference counters for particle diameters up to 1 µm.

## A.3 Generator method

### A.3.1 Principle

The generator method is an alternative method that can be applied over the size range from 0,5 µm to 10 µm. The particle number concentration of the test aerosol depends on the sampling flowrate of an LSAPC since the particle generation rate of the test aerosol is set at the constant value. For example, when the particle generation rate is set to 30 $s^{-1}$ and the flowrate is 2,83 l $min^{-1}$ and 28,3 l $min^{-1}$, the particle number concentration at the inlet of LSAPC is 0,64 $cm^{-3}$ and 0,064 $cm^{-3}$, respectively.

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