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

Part 4:
Light scattering airborne particle counter for clean spaces

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
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreword</td>
<td>iv</td>
</tr>
<tr>
<td>Introduction</td>
<td>v</td>
</tr>
<tr>
<td>1 Scope</td>
<td>1</td>
</tr>
<tr>
<td>2 Normative references</td>
<td>1</td>
</tr>
<tr>
<td>3 Terms and definitions</td>
<td>1</td>
</tr>
<tr>
<td>4 Principle</td>
<td>2</td>
</tr>
<tr>
<td>5 Basic configuration</td>
<td>3</td>
</tr>
<tr>
<td>6 Requirements</td>
<td>3</td>
</tr>
<tr>
<td>6.1 Size setting error</td>
<td>3</td>
</tr>
<tr>
<td>6.2 Counting efficiency</td>
<td>4</td>
</tr>
<tr>
<td>6.3 Size resolution</td>
<td>4</td>
</tr>
<tr>
<td>6.4 False count</td>
<td>4</td>
</tr>
<tr>
<td>6.5 Maximum particle number concentration</td>
<td>4</td>
</tr>
<tr>
<td>6.6 Sampling flow rate error</td>
<td>4</td>
</tr>
<tr>
<td>6.7 Sampling time error</td>
<td>4</td>
</tr>
<tr>
<td>6.8 Response rate</td>
<td>4</td>
</tr>
<tr>
<td>6.9 Calibration interval</td>
<td>4</td>
</tr>
<tr>
<td>6.10 Reporting of test and calibration results</td>
<td>5</td>
</tr>
<tr>
<td>7 Test and calibration procedures</td>
<td>5</td>
</tr>
<tr>
<td>7.1 Size setting</td>
<td>5</td>
</tr>
<tr>
<td>7.1.1 Evaluation of size setting error</td>
<td>5</td>
</tr>
<tr>
<td>7.2 Evaluation of counting efficiency</td>
<td>6</td>
</tr>
<tr>
<td>7.3 Evaluation of size resolution</td>
<td>9</td>
</tr>
<tr>
<td>7.4 Evaluation of false count</td>
<td>10</td>
</tr>
<tr>
<td>7.5 Estimation of coincidence loss at the maximum particle number concentration</td>
<td>11</td>
</tr>
<tr>
<td>7.6 Evaluation of sampling flow rate error</td>
<td>12</td>
</tr>
<tr>
<td>7.7 Evaluation of sampling time error</td>
<td>12</td>
</tr>
<tr>
<td>7.8 Evaluation of response rate</td>
<td>12</td>
</tr>
<tr>
<td>Annex A (informative) Counting efficiency</td>
<td>14</td>
</tr>
<tr>
<td>Annex B (informative) Size resolution</td>
<td>16</td>
</tr>
<tr>
<td>Annex C (informative) False count</td>
<td>17</td>
</tr>
<tr>
<td>Annex D (informative) Response rate</td>
<td>18</td>
</tr>
<tr>
<td>Annex E (informative) Procedure for evaluating the uncertainties of the performance tests</td>
<td>19</td>
</tr>
<tr>
<td>Bibliography</td>
<td>25</td>
</tr>
</tbody>
</table>

© ISO 2018 – All rights reserved
ISO 21501-4:2018(E)

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 [see www.iso.org/directives].

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received [see www.iso.org/patents].

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO’s adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 24, Particle characterization including sieving, Subcommittee SC 4, Particle characterization.

This second edition cancels and replaces the first edition (ISO 21501-4:2007), which has been technically revised.

The main changes from the previous edition are:

— Clause 4 for “Principle” and Clause 5 for “Basic configuration” have been added;
— “Size calibration” and “Verification of size setting” have been combined as “Size setting error” in the requirements clause;
— “Test report” (3.11 in the previous edition) has been changed to 6.10 on “Reporting of test and calibration results”;
— information about uncertainties has been enriched and is now the subject of Annex E.

A list of all parts in the ISO 21501 series can be found on the ISO website.
Introduction

Monitoring particle contamination levels is required in various fields, e.g. in the electronic industry, in the pharmaceutical industry, in the manufacturing of precision machines and in medical operations. Particle counters are useful instruments for monitoring particle contamination in air. The purpose of this document is to provide a calibration procedure and verification method for particle counters, so as to minimize the inaccuracy in the measurement result by a counter, as well as the differences in the results measured by different instruments.
Determination of particle size distribution — Single particle light interaction methods —

Part 4:
Light scattering airborne particle counter for clean spaces

1 Scope

This document describes a calibration and verification method for a light scattering airborne particle counter (LSAPC), which is used to measure the size distribution and particle number concentration of particles suspended in air. The light scattering method described in this document is based on single particle measurements. The typical size range of particles measured by this method is between 0,1 μm and 10 μm in particle size.

Instruments that conform to this document are used for the classification of air cleanliness in cleanrooms and associated controlled environments in accordance with ISO 14644-1 and ISO 14644-2, as well as the measurement of number and size distribution of particles in various environments.

The following parameters are within the scope of this document:
— size setting error;
— counting efficiency;
— size resolution;
— false count;
— maximum particle number concentration;
— sampling flow rate error;
— sampling time error;
— response rate;
— calibration interval;
— reporting results from test and calibration.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:
— ISO Online browsing platform: available at https://www.iso.org/obp
3.1 calibration particle
monodisperse spherical particle with a certified mean particle size, e.g., a polystyrene latex (PSL) particle, where the certified size is traceable to the International System of Units (SI), a relative standard uncertainty equal to or less than 2.5%, and a refractive index that is approximately 1.59 at the wavelength of 589 nm (sodium D line).

3.2 counting efficiency
ratio of the number concentration measured by a light scattering airborne particle counter (LSAPC) to that measured by a reference instrument for the same test aerosol.

3.3 false count
apparent count per unit volume when a sample air containing no measurable particles is measured by the light scattering airborne particle counter (LSAPC).

3.4 LSAPC
light scattering airborne particle counter
instrument that measures airborne particle numbers by counting the pulses as the particles pass through the sensing volume, and also particle size by scattered light intensity.

Note 1 to entry: The optical particle size measured by the LSAPC is the light scattering equivalent particle size and not the geometrical size.

3.5 PHA
pulse height analyser
instrument that analyses the distribution of pulse heights.

3.6 size resolution
measure of the ability of an instrument to distinguish between particles of different sizes.

3.7 coincidence loss
reduction of particle count caused by multiple particles passing simultaneously through the sensing volume and/or by the finite processing time of the electronic system.

3.8 test aerosol
aerosol to be used for calibration or testing of a light scattering airborne particle counter (LSAPC) that is composed of calibration particles suspended in clean air.

3.9 MPE
maximum permissible error
limit of error
extreme value of measurement error, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument, or measuring system.

Note 1 to entry: This document uses decimal numbers for the requirements to MPEs to avoid confusion that may arise when relative uncertainties of test results are reported in percent figures.

4 Principle
The measurement principle of the LSAPC is based on detection of light scattered by a particle when the particle passes through an incident light beam.
The particle size is determined from the intensity of the scattered light, and the number of particles from the number of light pulses scattered by individual particles.

To be more specific, sample air is drawn from the inlet of the LSAPC at a constant flow rate, and introduced to the sensing volume of the LSAPC where a light beam is irradiated. When a particle suspended in the sample air passes through the light beam, it scatters the light, emitting a light pulse. The light pulse is detected by a photo detector, and converted to an electrical pulse. The electrical pulse height is proportional to the scattered light intensity, and depends on the optical system design, the electronic components used, and the light source. The intensity of the scattered light is dependent on the size, refractive index, and shape of the particle. If the particle is spherical, the scattered light intensity is described by the Mie theory. In order to establish a relationship between the electrical pulse height and the particle size, calibration of each LSAPC with use of particles having a well-defined size, refractive index, and shape is required.

## 5 Basic configuration

An LSAPC is composed typically of a light source, a sample air suction system, a sensing volume, a photoelectric conversion device, a pulse height analyser, and a display (see Figure 1). Some LSAPCs do not contain a sample air suction system and/or a display.

To make the particle size calibration possible, the LSAPC should be constructed so that pulse height distributions for calibration particles can be measured.

![Figure 1 — Example of basic configuration of LSAPC](https://www.sis.se/std-80004178)

## 6 Requirements

### 6.1 Size setting error

The MPE for size setting in the minimum detectable particle size and other sizes specified by the manufacturer of an LSAPC is 0,10 (corresponding to 10 % of the specified size).

Size setting shall be conducted before the LSAPC is shipped from the manufacturer and when the size setting error is found not fulfilled in a periodic calibration.

A recommended procedure for size setting is described in 7.1.2. If other methods are used, their uncertainty shall be evaluated and described.
6.2 Counting efficiency
The counting efficiency shall be within 0.30 to 0.70 [corresponding to (50 ± 20) %] for calibration particles with a size close to the minimum detectable particle size, and it shall be within 0.90 to 1.10 [(100 ± 10) %] for calibration particles with a size 1.5 to 2 times larger than the minimum detectable particle size.

When calibration particles with exactly the same size as the minimum detectable particle size are not available, particles whose size is within ±5 % of the minimum detectable particle size may be used and the diameter of the calibration particles shall be reported.

6.3 Size resolution
The size resolution shall be less than or equal to 0.15 (corresponding to 15 % of the specified particle size), when it is evaluated using calibration particles of a certified average size specified by the manufacturer.

A recommended procedure is described in 7.3. If other methods are used, their uncertainty shall be evaluated and described.

6.4 False count
The false count per volume in cubic meters and its 95 % upper confidence limit (UCL) shall be determined according to 7.4. The 95 % UCL shall be less than or equal to the value specified and reported by the manufacturer of the LSAPC.

6.5 Maximum particle number concentration
The maximum measurable particle number concentration shall be specified by the manufacturer. The coincidence loss at the maximum particle number concentration of an LSAPC shall be less than or equal to 0.1 (10 %).

NOTE The probability of occurrence of coincidence loss increases with increasing particle number concentration.

6.6 Sampling flow rate error
The MPE of the volumetric sampling flow rate determined according to 7.6 compared to the flow rate specified by the manufacturer shall be 0.05 (corresponding to 5 %) of the specified flow rate.

6.7 Sampling time error
The MPE in the duration of the sampling time shall be 0.01 (corresponding to 1 %) of the preset value.

If the LSAPC does not have a sampling time control system, this subclause does not apply.

6.8 Response rate
The response rate of the LSAPC obtained according to the test method given in 7.8 shall be equal to or less than 0.005 (corresponding to 0.5 %).

6.9 Calibration interval
The calibration of the LSAPC should be conducted at an interval equal to or shorter than one year. The requirements should be met during the calibration interval.
6.10 Reporting of test and calibration results

The following is the minimum information that shall be recorded in a test report:

a) date of test/calibration;
b) test/calibration particles used;
c) results for the parameters:
   1) size setting error;
   2) counting efficiency;
   3) sampling flow rate error;
   4) size resolution (with the particle size used);
   5) false count;
d) threshold voltage values or channels of the built-in PHA corresponding to the size settings;
e) a statement of the test/calibration method used (e.g. ISO 21501-4);
f) report/certificate identification, test/calibration location, title and identification of test/calibration provider including signature and date;
g) identification of customer and device under test, including how output was obtained for counting efficiency (e.g. analogue, display or digital output).

A calibration certificate shall furthermore include:

h) identification and - if possible - statement of metrological traceability of all reference equipment and calibration particles used;
i) relevant environmental conditions (e.g. temperature, air pressure and humidity) under which the calibration was performed;
j) a stated uncertainty for each result for the parameters 1 to 4 with reference to the calculation method (e.g. ISO/IEC Guide 98-3) - Annex E contains procedures for evaluating the uncertainty of the results of the performance tests recommended in this document for parameters 1 and 2;
k) a stated false count at a 95 % confidence limit (see Annex C).

NOTE Calibration certificates issued by ISO/IEC 17025 accredited laboratories and covering all results for the parameters 1 to 5 are considered to comply with the requirements above.

7 Test and calibration procedures

7.1 Size setting

7.1.1 Evaluation of size setting error

Calculate the size setting error $\varepsilon$ according to Formula (1).

$$\varepsilon = \frac{x_i' - x_i}{x_i}$$  \hspace{1cm} (1)

where