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Second edition
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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

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.

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).

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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:

— IEC Electropedia: available at http://www.electropedia.org/
— 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)* (3.4) 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)

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)* (3.4) that is composed of *calibration particles* (3.1) 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.

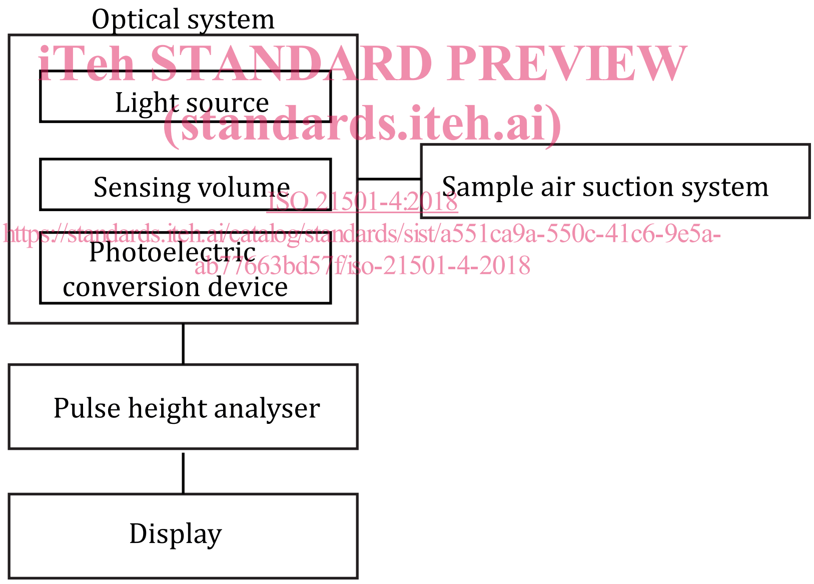


Figure 1 — Example of basic configuration of LSAPC

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 ε according to Formula (1).

$$\varepsilon = \frac{x_i{}' - x_i}{x_i} \tag{1}$$

where

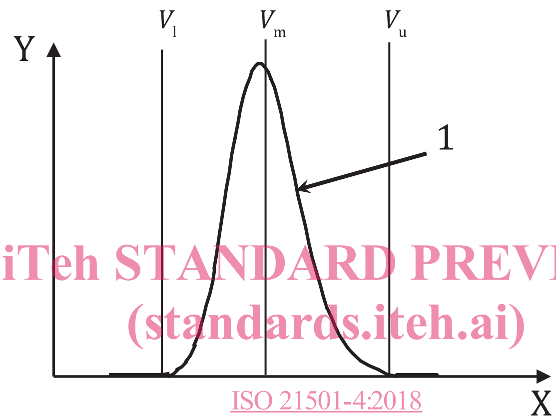
x_i is the size setting specified for the LSAPC;

x_i' is the actual size setting corresponding to V_{ti} (see 7.1.2 for the meaning of V_{ti}).

7.1.2 Procedure of size setting

By use of a PHA connected to the output terminal for signal pulses of the LSAPC, or by use of a built-in PHA if one is contained as a part of the LSAPC, obtain a pulse height distribution for a test aerosol in which calibration particles are suspended. Let V_l and V_u denote the lower and upper voltage limits, respectively, of the range of pulse heights for the calibration particles (see Figure 2). The median voltage V_m of the pulse height distribution in the range from V_l to V_u, shall be calculated, and is assigned to the certified size of the calibration particles, x_c.

When a built-in PHA is used, the abscissa of the pulse height distribution may be given in channel number instead of voltage. In this case, the term “voltage” above and in relevant descriptions below should be interpreted as channel number of the PHA.



Key

X pulse height voltage

Y frequency

1 pulse height distribution

V_l lower voltage limit

V_m median voltage

V_u upper voltage limit

Figure 2 — Pulse height distribution for the test aerosol

If a noise distribution is observed in the pulse height distribution, and if it is separated distinctly from the main peak corresponding to the calibration particles, the voltages V_l and V_u shall be chosen so that the range (V_l, V_u) encompasses only the main peak [see Figure 3 a)]. If the noise distribution overlaps with the main peak, V_l and V_u shall be chosen so that the range (V_l, V_u) corresponds to the full width at half maximum of the main peak [see Figure 3 b)]. The latter way of determining V_l and V_u is allowed only when the height of the valley between the noise distribution and the main peak is at most half the main peak height.