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Cleanrooms and associated controlled environments —

Part 21: Airborne particle sampling techniques

Salles propres et environnements maîtrisés apparentés —

Partie 21: Techniques de prélèvement des particules en suspension dans l'air

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Foreword

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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 document 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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This document was prepared by ISO/TC 209, *Cleanrooms and associated controlled environments*.

A list of all parts in the ISO 14644 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document provides clarification on the application of sound airborne particle sampling techniques in support of ISO 14644-1:2015 for classification of cleanrooms and clean zones, and ISO 14644-2:2015 for airborne particle monitoring, to provide evidence of cleanroom performance related to air cleanliness by particle concentration. It provides information on how to gather appropriate, accurate and repeatable data, and how to interpret this information for the purpose of improving process protection. This also includes information on the choice of measurement methods and apparatus configuration, calibration, repeatability/reproducibility and the uncertainty associated with measurement. In short, what can be reasonably attained with the current technology.

This document addresses potential misinterpretation of the use of ISO 14644-1:2015, C.4.1.2 in informative Annex C, which suggests the use of limited tubing length for sampling macroparticles. The phrase in question has been applied beyond the context intended in ISO 14644-1, to other applications. This document also provides extra clarity on the use of the M Descriptor in ISO 14644-1:2015, Annex C, specifically in relation to consideration of ≥5,0 μm alongside ISO Class 5 (EU-PIC/S GMP Grade A and B at rest).

It provides information on the uncertainty associated with sampling particles ≥5,0 μm and macro-particles, and measures that can be taken to reduce that uncertainty.

It addresses the importance of understanding that:

— for classification, the quality of the sample is the most important factor;

— for monitoring, the quality of the data is the most important factor;

— direct sampling without tubing is preferred. However, sample tubing is sometimes necessary to get a representative sample at a significant or critical location;

— to reduce sampling loss in tubing, this tubing is as short and straight as possible;

— a sampling system is evaluated to assess the impact of any compromises in its set up.

An evaluation of existing sampling systems can deem them suitable for continued use even if the system is assessed as less than optimal.

The scientific basis for airborne particle counting, and the performance characteristics of airborne particle counters, particularly LSAPC, is amply documented in established technical publications (see Bibliography).

Cleanrooms and associated controlled environments —

Part 21:
Airborne particle sampling techniques

1 Scope

This document discusses the physical limitations of probe and particle counter placement, and any tubing that connects the two, particularly in providing representative samples where particles 5 micrometres and greater are of interest.

The document further identifies the key factors of sampling performance when classifying and monitoring, and good practice to determine and maintain an acceptable compromise between attainable accuracy in counting and feasibility of counting in real-life situations.

This document includes a decision tree, used to identify key considerations when sampling airborne particles, and whether the system requires further assessment. There are also examples provided to illustrate typical application challenges and show how the decision tree can be used.

It is assumed that this document is read in conjunction with ISO 14644-1 and ISO 14644-2. This document is not a manual, but an explanatory document. It does not describe measurement methods, which is handled in ISO 14644-1 and ISO 14644-2, but provides information to help make effective choices of sampling configuration, when evaluating a new or existing system.

2 Normative documents

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org

3.1
classification
method of assessing level of cleanliness against a specification for a cleanroom or clean zone

Note 1 to entry: Levels should be expressed in terms of an ISO Class, which represents maximum allowable concentrations of particles in a unit volume of air.

[SOURCE: ISO 14644-1:2015, 3.1.4]

3.2
monitoring
observations made by measurement in accordance with a defined method and plan to provide evidence of the performance of an installation

Note 1 to entry: Monitoring may be continuous, sequential or periodic; and if periodic, the frequency shall be specified.

Note 2 to entry: This information may be used to detect trends in operational state and to provide process support.

[SOURCE: ISO 14644-2:2015, 3.2]

3.3
particle size
diameter of a sphere that produces a response, by a given particle-sizing instrument, that is equivalent to the response produced by the particle being measured

Note 1 to entry: For discrete-particle light-scattering instruments, the equivalent optical diameter is used.

[SOURCE: ISO 14644-1:2015, 3.2.2]

3.4
macroparticle
particle with an equivalent diameter greater than 5 µm

[SOURCE: ISO 14644-1:2015, 3.2.5]

3.5
M descriptor
designation for measured or specified concentration of macroparticles per cubic metre of air, expressed in terms of the equivalent diameter that is characteristic of the measurement method used

Note 1 to entry: The M descriptor can be regarded as an upper limit for the averages at sampling locations. M descriptors cannot be used to define air cleanliness classes by particle concentration, but they may be quoted independently or in conjunction with air cleanliness classes by particle concentration.

[SOURCE: ISO 14644-1:2015, 3.2.6]

4 Determination of airborne particle concentration

4.1 General

Airborne particle concentration is the primary attribute and essential parameter that determines and denotes the cleanliness level of a cleanroom or clean zone.

In classification, ISO 14644-1 states that "The use of light scattering (discrete) airborne particle counters (LSAPC) is the basis for determination of the concentration of airborne particles, equal to and greater than the specified sizes, at designated sampling locations".

ISO 14644-1 does not provide for classification of particle populations that are outside the specified lower threshold particle-size range, 0,1 µm to 5 µm. According to ISO 14644-1, an M descriptor (see ISO 14644-1, Annex C) may be used to quantify populations of macroparticles (particles larger than 5 µm).

In monitoring, an LSAPC is also used for airborne particle counting, often supported by other methods, as indicated in ISO 14644-2.

For both classification and monitoring, the choice of the counter takes account of the effective particle size range and sampling flowrate with regard to sample size.

For monitoring, the effectiveness of the sampling system is determined by the appropriate choice of sampling location and the ability of the system to capture particles and deliver them to the counting mechanism.

A key driver in quality management is continuous improvement. When we apply the dynamic cycle tool Plan-Do-Check-Act (PDCA) to cleanroom contamination control, key information is used from classification and monitoring activities to establish and demonstrate that control. Changes and improvements will lead to re-evaluation and a repeat of this cycle. Figure 1 below illustrates the importance of classification and monitoring and how these influence the process of continual improvement.

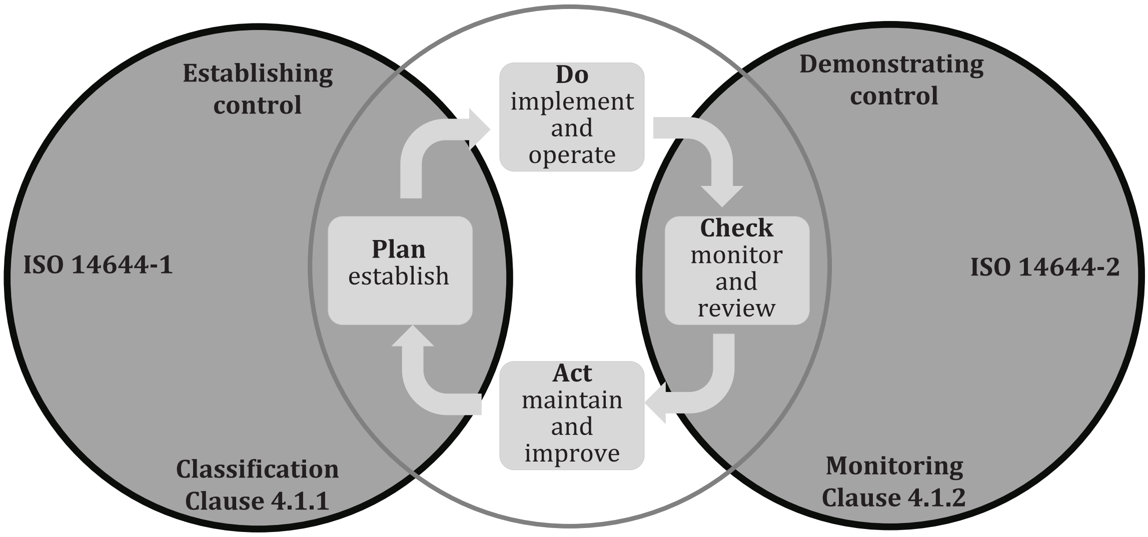

Figure 1 — Strategy for contamination control

All particle counting systems have the potential to delay or prevent a particle from reaching the counting mechanism of the LSAPC. The likelihood of this increases with the particle's size and the length and complexity of its pathway through the system. Good practice is applied to minimise particle loss and potential gain through shedding and false counts. The following sections explain the relevant aspects of the determination of airborne particle concentration that is performed in classification and monitoring. Guidance will be given in Clause 5 on the application of particle counting technologies and associated sampling methods.

4.2 Classification

In classification, the cleanliness of the cleanroom is specified for a state of occupancy and considered particle size(s). The sizes available for classification are defined in ISO 14644-1:2015, Table 1, and all sizes considered are measured simultaneously, with the same LSAPC instrument. Sampling locations and minimum sample volumes are selected using the procedure described in ISO 14644-1. Satisfactory airborne particle concentration results obtained by sampling at these locations provide confidence that the volume measured will comply with the specified class.

The reference method for classification supposes a degree of reproducibility to establish control for a specified state of occupation, both initially and when classification is reconfirmed. As such, the quality of the sample taken and precision of the values recorded is paramount.

The measurement of airborne nanoscale particles, <0,1 µm, uses another type of instrument, not included in this document. Values obtained at the nanoscale are not appropriate for classification. This application is considered in ISO 14644-12.

ISO 14644-1:2015, Table 1 provides the range of particle sizes and particle concentrations deemed statistically appropriate for classification.

NOTE ISO 14644-1, Table E.1 shows application of the same threshold particle sizes for decimal classes, and ISO 14644-1, Formula E.1 enables calculation of the maximum particle concentration for intermediate particle sizes within the normative range.

Note f) to ISO 14644-1:2015, Table 1, indicates a special case for recording larger particles when classifying at ISO 5. It provides an example where particles ≥5 µm are sampled with a specified limit of 29 particles/m^3 as a complement to classification at ISO 5 measured on sizes that are included in ISO 14644-1:2015, Table 1 as appropriate for that class. This complement is expressed via the M

Descriptor, in this case as “ISO M (29; ≥5 µm); LSAPC” for ISO 5 and refers on to ISO 14644-1:2015, C.7. For some applications, it can be necessary to also sample other sizes outside those for which ISO 14644-1:2015, Table 1 defines concentrations. ISO 14644-1:2015, C.7 in informative Annex C provides an example of adaptation of the M descriptor to accommodate consideration of ≥ 5 µm particle size for ISO Class 5 at this particle size threshold, where ISO 14644-1:2015, Table 1 does not specify a concentration limit.

ISO 14644-1:2015, Annex C is concerned with the broader techniques of measurement of macroparticles (particle size thresholds not in ISO 14644-1:2015, Table 1), by a variety of appropriate methods and instrumentation, including the LSAPC, and expression of the result. This subject is not considered within the scope of this document. When measuring and recording particles > 5,0 µm (macroparticles) alongside those measured within the ISO 14644-1:2015, Table 1 range, their value is expressed as an M descriptor, in support of classification.

4.3 Monitoring

Monitoring is explained and illustrated in ISO 14644-2:2015. The activity involves recording and analysing data on a variety of parameters to support demonstration of control.

The trending of data obtained from monitoring with LSAPC is used to understand the variation in the number of particles over time and its relationship with the specified and maintained cleanliness of the cleanroom or clean zone. Data obtained and analysed is used to evaluate whether air quality is maintained at a satisfactory level at locations considered significant or critical for the process, at the appropriate occasions. This data can be analysed along with other monitoring parameters to provide a holistic approach to demonstrating control.

Monitoring is applied to demonstrate that the air cleanliness at a defined location complies with the required level at a defined point in time, during operation, and often during periods at rest. Particle sizes used for monitoring can be different from those required for classification. This is clearly shown in EU & PIC/S GMP Annex 1 (2022) where monitoring is subject to limits for particle sizes (>5,0 µm) not identified as reliable for the purpose of classification at ISO5. Results are often expressed per unit of time, rather than accumulated to a unit volume. Other indirect indicators may also inform on the satisfactory operation of the installation or equipment.

In ISO 14644-2, guidance is provided on where, when and how to monitor the airborne particle concentration, and how to complement this with other indicators of cleanroom or process zone performance.

In monitoring, the reproducibility of sampling efficiency, and the ability to detect variations over time, are more important than absolute precision in the data obtained at a particular point in time.

Analysis of variations over time can help to understand the process, and provide trending data to assist the management of critical parameters in order to maintain control as required.

Monitoring performed using a mobile or fixed LSAPC can be periodic or continuous. In monitoring, minor particle loss in the sampling system is typically accepted since this will not affect the trending of the local air cleanliness unless the alert or action level is very low.

NOTE It is important that the system is verified as able to record the considered particle sizes in a satisfactory manner.

4.4 Other LSAPC applications

LSAPCs are also used for measuring high airborne particle concentration at defined sample locations during the Recovery Test (ISO 14644-3:2019, B.4), the installed filter system leakage test (ISO 14644-3:2019 B.7) the containment leak test (ISO 14644-3:2019, B.8) and the Segregation Test (ISO 14644-3:2019, B.11). This document does not examine the detail of these and other applications.

In addition, the LSAPC can be used for investigation of particle concentrations at specific locations for the purposes of characterisation, without any attempt to predict compliance of a whole surface or room to a specified class. This activity is not expressly considered in ISO 14644-1 and ISO 14644-2, except in ISO 14644-1:2015, Annex C but can be a valuable part of establishing and demonstrating control.

5 Sampling airborne particles – things to consider

5.1 General

The sampling of airborne particle concentration at a specific location, to determine air cleanliness, cannot always be performed by placing the LSAPC directly at the location, due to limitations on access, instrument size and the need to avoid disturbance of a critical volume by the counter exhaust and heat gain. Consequently, a sample will often need to be drawn from the test location to the instrument for measurement.

The approach taken ensures that:

— the sample is representative;

— a suitable volume is taken, relative to the particle size;

— collecting the sample does not affect the operation of the process;

— the particles sampled do reach the device;

— the location of the LSAPC is not influenced by other factors.

Consideration of influencing factors is discussed further in this clause.

5.2 Instrument selection

5.2.1 General

There are several types of LSAPC that can be used to determine classification, and in routine monitoring. The choice of instrument type, for classification or monitoring, is typically a balance between:

— Sample volume required for statistical significance:

  — a minimum number of particles is required to determine a classification state;

  — low concentrations of particles require large sample volumes, and/or sequential sampling.

— Total test time:

  — particle counter sample at a fixed volumetric flow rate;

  — minimum sample volumes determine the time required to sample at each location;

  — higher flowrates will reduce test duration;

— sample tubing requirements.

Manufacturers will provide recommended dimensions for tubing.

Table 1 describes different types of instrument and their typical applications.

Table 1 — Comparison of particle counter types

Function	Portable particle counter	Handheld particle counter	Remote particle sensor
Number of size channels	Typically 4-6	Typically 2-6	Typically 2-6
Smallest channel (sensitivity)	Application dependant, typically 0,1 µm, 0,3 µm or 0,5 µm	Application dependant, typically 0,2 µm, 0,3 µm or 0,5 µm	Application dependant, typically 0,1 µm, 0,2 µm, 0,3 µm or 0,5 µm
Sample flow rate	28,3 l/min (1 cfm) or greater (50 l/min, 75, l/min, 100 l/min)	Low flowrate of 2,83 l/min (0,1 cfm)	Flowrates of 28,3 l/min or 2,83 l/min
Power	Mains or battery	Mains or Battery	Mains, or power over Ethernet
Mobility	Carried by hand, placed on mobile cart, probe on tripod/stand or fixed to the top of the LSAPC	Lightweight carried in hand or placed on tripod/stand	Fixed location mounted to equipment or infrastructure
Display	Local interactive display with many operator features	Local display with fewer operator features	None – connected to central system for data display
Printer	Onboard	External accessory	None – connected to central system
Typical applications	Cleanroom classification, portable and in-situ monitoring. HEPA filter leak testing, recovery tests,	Cleanroom classification, and portable monitoring, recovery tests	Continuous monitoring of individual locations[a]

[a] Fixed monitoring devices in cleanrooms and clean zones are sometimes used to support classification, on condition that the sample volume considered is consistent with the requirements of ISO 14644-1, and the timing and duration of the sample are designated for classification activity. Appropriate sensitivity for capture of the specified particle sizes, positioning of the sampling head and absence of disturbance of the critical location are determined for each case, to assess the suitability of this use of the remote sensor.

5.2.2 Considered particle size selection

The range of particle sizes considered in the ISO 14644-1, Table 1 classification is ≥0,1 µm, ≥0,2 µm, ≥0,3 µm, ≥0,5 µm, ≥1,0 µm and ≥5,0 µm. Selected particle sizes will include all particles equal to or greater than the selected size.

For classification and for monitoring, the chosen size(s) can be driven by the significance, for product or process cleanliness, of specific particle sizes and concentrations, but are also often determined by applicable regulation or industry guidance. It is also possible to select specific sizes not featured in ISO 14644-1:2015, Table 1. Concentrations for intermediate sizes within the table can be calculated.

The measurement of airborne nanoscale particles, <0,1 µm, uses another type of instrument, not included in this document. This application is considered in ISO 14644-12.

In some scenarios, alternative levels of air cleanliness are selected, at specific particle sizes larger than 5 µm which are not within the size range applicable to classification. These are defined as macroparticles and ISO 14644-1:2015, Annex C provides guidance for sampling only these larger particles. Their measured concentration can be described by use of the M Descriptor, with mention of the measurement method used.

This specific mention does not mean that the whole of ISO 14644-1:2015, Annex C applies to classification. The rest of the guidance expressed in this informative Annex is solely concerned with the measurement of macroparticles per se.

In particular, the guidance given in ISO 14644-1:2015, Clauses C.3, C.4, C.5 is not applicable to classification of particles in the size ranges detailed in ISO 14644-1:2015, Table 1.