INTERNATIONAL STANDARD

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Cleanrooms and associated controlled environments —

Part 1: Classification of air cleanliness by particle concentration

Salles propres et environnements maîtrisés apparentés —

Partie 1: Classification de la propreté particulaire de l'air

Reference number
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Contents

Page

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 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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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 209, *Cleanrooms and associated controlled environments*.

This second edition cancels and replaces the first edition (ISO 14644-1:1999), which has been technically revised throughout.

ISO 14644 consists of the following parts, under the general title *Cleanrooms and associated controlled environments*:

— *Part 1: Classification of air cleanliness by particle concentration*

— *Part 2: Monitoring to provide evidence of cleanroom performance related to air cleanliness by particle concentration*

— *Part 3: Test methods*

— *Part 4: Design, construction and start-up*

— *Part 5: Operations*

— *Part 7: Separative devices (clean air hoods, gloveboxes, isolators and mini-environments)*

— *Part 8: Classification of air cleanliness by chemical concentration (ACC)*

— *Part 9: Classification of surface cleanliness by particle concentration*

— *Part 10: Classification of surface cleanliness by chemical concentration*

Attention is also drawn to ISO 14698, *Cleanrooms and associated controlled environments — Biocontamination control:*

— *Part 1: General principles and methods*

— *Part 2: Evaluation and interpretation of biocontamination data*

Introduction

Cleanrooms and associated controlled environments provide for the control of contamination of air and, if appropriate, surfaces, to levels appropriate for accomplishing contamination-sensitive activities. Contamination control can be beneficial for protection of product or process integrity in applications in industries such as aerospace, microelectronics, pharmaceuticals, medical devices, healthcare and food.

This part of ISO 14644 specifies classes of air cleanliness in terms of the number of particles expressed as a concentration in air volume. It also specifies the standard method of testing to determine cleanliness class, including selection of sampling locations.

This edition is the result of a response to an ISO Systematic Review and includes changes in response to user and expert feedback validated by international enquiry. The title has been revised to “Classification of air cleanliness by particle concentration” to be consistent with other parts of ISO 14644. The nine ISO cleanliness classes are retained with minor revisions. Table 1 defines the particle concentration at various particle sizes for the nine integer classes. Table E.1 defines the maximum particle concentration at various particle sizes for intermediate classes. The use of these tables ensures better definition of the appropriate particle-size ranges for the different classes. This part of ISO 14644 retains the macroparticle descriptor concept; however, consideration of nano-scale particles (formerly defined as ultrafine particles) will be addressed in a separate standard.

The most significant change is the adoption of a more consistent statistical approach to the selection and the number of sampling locations; and the evaluation of the data collected. The statistical model is based on adaptation of the hypergeometric sampling model technique, where samples are drawn randomly without replacement from a finite population. The new approach allows each location to be treated independently with at least a 95 % level of confidence that at least 90 % of the cleanroom or clean zone areas will comply with the maximum particle concentration limit for the target class of air cleanliness. No assumptions are made regarding the distribution of the actual particle counts over the area of the cleanroom or clean zone; while in ISO 14644-1:1999 an underlying assumption was that the particle counts follow the same normal distribution across the room, this assumption has now been discarded to allow the sampling to be used in rooms where the particle counts vary in a more complex manner. In the process of revision it has been recognized that the 95 % UCL was neither appropriate nor was applied consistently in ISO 14644-1:1999. The minimum number of sampling locations required has been changed, compared with ISO 14644-1:1999. A reference table, Table A.1, is provided to define the minimum number of sampling locations required based on a practical adaptation of the sampling model technique. An assumption is made that the area immediately surrounding each sampling location has a homogeneous particle concentration. The cleanroom or clean zone area is divided up into a grid of sections of near equal area, whose number is equal to the number of sampling locations derived from Table A.1. A sampling location is placed within each grid section, so as to be representative of that grid section.

It is assumed for practical purposes that the locations are chosen representatively; a “representative” location (see A.4.2) means that features such as cleanroom or clean zone layout, equipment disposition and airflow systems should be considered when selecting sampling locations. Additional sampling locations may be added to the minimum number of sampling locations.

Finally, the annexes have been reordered to improve the logic of this part of ISO 14644 and portions of the content of certain annexes concerning testing and test instruments have been included from ISO 14644-3:2005.

The revised version of this part of ISO 14644 addresses the ≥ 5 µm particle limits for ISO Class 5 in the sterile products annexes of the EU, PIC/S and WHO GMPs by way of an adaptation of the macroparticle concept.

The revised version of this part of ISO 14644 now includes all matters related to classification of air cleanliness by particle concentration. The revised version of ISO 14644-2:2015 now deals exclusively with the monitoring of air cleanliness by particle concentration.

Cleanrooms may also be characterized by attributes in addition to the classification of air cleanliness by particle concentration. Other attributes, such as air cleanliness in terms of chemical concentration, may

be monitored and the attribute's grade or level may be designated along with the classification of the ISO Class of cleanliness. These additional attributes do not suffice alone to classify a cleanroom or clean zone.

Cleanrooms and associated controlled environments —

Part 1:
Classification of air cleanliness by particle concentration

1 Scope

This part of ISO 14644 specifies the classification of air cleanliness in terms of concentration of airborne particles in cleanrooms and clean zones; and separative devices as defined in ISO 14644-7.

Only particle populations having cumulative distributions based on threshold (lower limit) particle sizes ranging from 0,1 µm to 5 µm are considered for classification purposes.

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.

This part of ISO 14644 does not provide for classification of particle populations that are outside the specified lower threshold particle-size range, 0,1 µm to 5 µm. Concentrations of ultrafine particles (particles smaller than 0,1 µm) will be addressed in a separate standard to specify air cleanliness by nano-scale particles. An M descriptor (see Annex C) may be used to quantify populations of macroparticles (particles larger than 5 µm).

This part of ISO 14644 cannot be used to characterize the physical, chemical, radiological, viable or other nature of airborne particles.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14644-2:2015, *Cleanrooms and associated controlled environments — Part 2: Monitoring to provide evidence of cleanroom performance related to air cleanliness by particle concentration*

ISO 14644-7, *Cleanrooms and associated controlled environments — Part 7: Separative devices (clean air hoods, gloveboxes, isolators and mini-environments)*

3 Terms and definitions

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

3.1 General

3.1.1
cleanroom
room within which the number concentration of airborne particles is controlled and classified, and which is designed, constructed and operated in a manner to control the introduction, generation and retention of particles inside the room

Note 1 to entry: The class of airborne particle concentration is specified.

Note 2 to entry: Levels of other cleanliness attributes such as chemical, viable or nanoscale concentrations in the air, and also surface cleanliness in terms of particle, nanoscale, chemical and viable concentrations might also be specified and controlled.

Note 3 to entry: Other relevant physical parameters might also be controlled as required, e.g. temperature, humidity, pressure, vibration and electrostatic.

3.1.2
clean zone
defined space within which the number concentration of airborne particles is controlled and classified, and which is constructed and operated in a manner to control the introduction, generation and retention of contaminants inside the space

Note 1 to entry: The class of airborne particle concentration is specified.

Note 2 to entry: Levels of other cleanliness attributes such as chemical, viable or nanoscale concentrations in the air, and also surface cleanliness in terms of particle, nanoscale, chemical and viable concentrations might also be specified and controlled.

Note 3 to entry: A clean zone(s) can be a defined space within a cleanroom or might be achieved by a separative device. Such a device can be located inside or outside a cleanroom.

Note 4 to entry: Other relevant physical parameters might also be controlled as required, e.g. temperature, humidity, pressure, vibration and electrostatic.

3.1.3
installation
cleanroom or one or more clean zones, together with all associated structures, air-treatment systems, services and utilities

3.1.4
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.

3.2 Airborne particles

3.2.1
particle
minute piece of matter with defined physical boundaries

3.2.2
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.

3.2.3
particle concentration
number of individual particles per unit volume of air

3.2.4
particle size distribution
cumulative distribution of particle concentration as a function of particle size

3.2.5
macroparticle
particle with an equivalent diameter greater than 5 μm

3.2.6
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 ISO Classes, but the M descriptor may be quoted independently or in conjunction with ISO Classes.

3.2.7
unidirectional airflow
controlled airflow through the entire cross-section of a cleanroom or a clean zone with a steady velocity and airstreams that are considered to be parallel

3.2.8
non-undirectional airflow
air distribution where the supply air entering the cleanroom or clean zone mixes with the internal air by means of induction

3.3 Occupancy states

3.3.1
as-built
condition where the cleanroom or clean zone is complete with all services connected and functioning but with no equipment, furniture, materials or personnel present

3.3.2
at-rest
condition where the cleanroom or clean zone is complete with equipment installed and operating in a manner agreed upon, but with no personnel present

3.3.3
operational
agreed condition where the cleanroom or clean zone is functioning in the specified manner, with equipment operating and with the specified number of personnel present

3.4 Testing instrumentation (see Annex F)

3.4.1
resolution
smallest change in a quantity being measured that causes a perceptible change in the corresponding indication

Note 1 to entry: Resolution can depend on, for example, noise (internal or external) or friction. It may also depend on the value of a quantity being measured.

[SOURCE: ISO/IEC Guide 99:2007, 4.14]

3.4.2
maximum permissible measurement 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: Usually, the term “maximum permissible errors” or “limits of error” is used where there are two extreme values.

Note 2 to entry: The term “tolerance” should not be used to designate “maximum permissible error”.

[SOURCE: ISO/IEC Guide 99:2007, 4.26]

3.5 Instrument specifications

3.5.1
LSAPC
light scattering airborne particle counter
light scattering discrete airborne particle counter
instrument capable of counting and sizing single airborne particles and reporting size data in terms of equivalent optical diameter

Note 1 to entry: The specifications for the LSAPC are given in ISO 21501-4:2007.

3.5.2
discrete-macroparticle counter
instrument capable of counting and sizing single airborne macroparticles

Note 1 to entry: See Table F.1 for specifications.

3.5.3
time-of-flight particle sizing apparatus
discrete-particle counting and sizing apparatus that defines the aerodynamic diameter of particles by measuring the time for a particle to accommodate to a change in air velocity

Note 1 to entry: This is usually done by measuring the particle transit time optically after a fluid stream velocity change.

Note 2 to entry: See Table F.2 for specifications.

4 Classification

4.1 Occupancy state(s)

The air cleanliness class by particle concentration of air in a cleanroom or clean zone shall be defined in one or more of three occupancy states, viz. “as-built,” “at-rest” or “operational” (see 3.3).

4.2 Particle size(s)

One, or more than one, threshold (lower limit) particle sizes situated within the range from ≥0,1 µm to ≥5 µm are to be used to determine air cleanliness particle concentration for classification.

4.3 ISO Class number

Air cleanliness class by particle concentration shall be designated by an ISO Class number, *N*. The maximum permitted concentration of particles for each considered particle size is determined from Table 1.

Particle number concentrations for different threshold sizes in Table 1 do not reflect actual particle size and number distribution in the air and serve as criteria for classification only. Examples of classification calculations are included in Annex B.

Table 1 — ISO Classes of air cleanliness by particle concentration

ISO Class number (*N*)	Maximum allowable concentrations (particles/m³) for particles equal to and greater than the considered sizes, shown below[a]					
	0,1 µm	0,2 µm	0,3 µm	0,5 µm	1 µm	5 µm
1	*10*[b]	d	d	d	d	e
2	100	*24*[b]	*10*[b]	d	d	e
3	1 000	237	102	*35*[b]	d	e
4	10 000	2 370	1 020	352	*83*[b]	e
5	100 000	23 700	10 200	3 520	832	d, e, f
6	1 000 000	237 000	102 000	35 200	8 320	293
7	c	c	c	352 000	83 200	2 930
8	c	c	c	3 520 000	832 000	29 300
9[g]	c	c	c	35 200 000	8 320 000	293 000

[a] All concentrations in the table are cumulative, e.g. for ISO Class 5, the 10 200 particles shown at 0,3 µm include all particles equal to and greater than this size.

[b] These concentrations will lead to large air sample volumes for classification. Sequential sampling procedure may be applied; see Annex D.

[c] Concentration limits are not applicable in this region of the table due to very high particle concentration.

[d] Sampling and statistical limitations for particles in low concentrations make classification inappropriate.

[e] Sample collection limitations for both particles in low concentrations and sizes greater than 1 µm make classification at this particle size inappropriate, due to potential particle losses in the sampling system.

[f] In order to specify this particle size in association with ISO Class 5, the macroparticle descriptor M may be adapted and used in conjunction with at least one other particle size. (See C.7.)

[g] This class is only applicable for the in-operation state.

4.4 Designation

The designation of airborne particle concentration for cleanrooms and clean zones shall include

a) the ISO Class number, expressed as “ISO Class *N*”,

b) the occupancy state to which the classification applies, and

c) the considered particle size(s).

If measurements are to be made at more than one considered particle size, each larger particle diameter (e.g. *D*2) shall be at least 1,5 times the next smaller particle diameter (e.g. *D*1), i.e. $D2 \geq 1{,}5 \times D1$.

EXAMPLE ISO Class number; occupancy state; considered particle size(s)

ISO Class 4; at rest; 0,2 µm, 0,5 µm

4.5 Intermediate decimal cleanliness classes and particle size thresholds

Where intermediate classes, or intermediate particle size thresholds for integer and intermediate classes are required, refer to informative Annex E.

5 Demonstration of compliance

5.1 Principle

Compliance with air cleanliness (ISO Class) requirements specified by the customer is verified by performing specified testing procedures and by providing documentation of the results and conditions of testing.

At-rest or operational classification may be performed periodically based upon risk assessment of the application, typically on an annual basis.

For monitoring cleanrooms, clean zones and separative devices, ISO 14644-2:2015 shall be used.

NOTE Where the installation is equipped with instrumentation for continuous or frequent monitoring of air cleanliness by particle concentration and other parameters of performance as applicable, the time intervals between classification may be extended provided that the results of the monitoring remain within the specified limits.

5.2 Testing

The reference test method for demonstrating compliance is given in Annex A (normative). Alternative methods or instrumentation (or both), having at least comparable performance, may be specified. If no alternative is specified or agreed upon, the reference method shall be used.

Tests performed to demonstrate compliance shall be conducted using instruments which are in compliance with calibration requirements at the time of testing.

5.3 Airborne particle concentration evaluation

Upon completion of testing in accordance with Annex A, the concentration of particles (expressed as number of particles per cubic metre) in a single sample volume at each sampling location shall not exceed the concentration limit(s) given in Table 1 or Table E.1 for intermediate decimal classes for the considered size(s). If multiple single sample volumes are taken at a sampling location, the concentrations shall be averaged and the average concentration must not exceed the concentration limits given in Table 1 or Table E 1. Intermediate particle sizes shall be derived from Formula (E.1).

Particle concentrations used for determination of compliance with ISO Classes shall be measured by the same method for all considered particle sizes.

5.4 Test report

The results from testing each cleanroom or clean zone shall be recorded and submitted as a comprehensive report, along with a statement of compliance or non-compliance with the specified designation of air cleanliness class by particle concentration.

The test report shall include

a) the name and address of the testing organization, and the date on which the test was performed,

b) the number and year of publication of this part of ISO 14644, i.e. ISO 14644-1:2015,

c) a clear identification of the physical location of the cleanroom or clean zone tested (including reference to adjacent areas if necessary), and specific designations for coordinates of all sampling locations (a diagrammatic representation can be helpful),

d) the specified designation criteria for the cleanroom or clean zone, including the ISO Class number, the relevant occupancy state(s), and the considered particle size(s),

e) details of the test method used, with any special conditions relating to the test, or departures from the test method, and identification of the test instrument and its current calibration certificate, and

f) the test results, including particle concentration data for all sampling locations.

If concentrations of macroparticles are quantified, as described in Annex C, the relevant information should be included with the test report.