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**Cleanrooms and associated controlled environments —**

Part 14:  
**Assessment of suitability for use  
of equipment by airborne particle  
concentration**

*Salles propres et environnements maîtrisés apparentés —*

*Partie 14: Évaluation de l'aptitude à l'emploi des équipements par  
la détermination de la concentration de particules en suspension  
dans l'air*



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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](http://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](http://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 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](http://www.iso.org/iso/foreword.html).

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

A list of all part in the ISO 14644 series, published under the general title *Cleanrooms and associated controlled environments*, can be found on the ISO website.

## Introduction

Cleanrooms and associated controlled environments provide for the control of contamination to levels appropriate for accomplishing contamination-sensitive activities. Products and processes that benefit from the control of contamination include those in such industries as aerospace, microelectronics, optics, nuclear and life sciences (pharmaceuticals, medical devices, food and healthcare).

This part of ISO 14644 links the cleanroom classification of air cleanliness by particle concentration to the suitability of equipment for use in cleanrooms and associated controlled environments.

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# Cleanrooms and associated controlled environments —

## Part 14:

# Assessment of suitability for use of equipment by airborne particle concentration

## 1 Scope

This part of ISO 14644 specifies a methodology to assess the suitability of equipment (e.g. machinery, measuring equipment, process equipment, components and tools) for use in cleanrooms and associated controlled environments, with respect to airborne particle cleanliness as specified in ISO 14644-1. Particle sizes range from 0,1  $\mu\text{m}$  to equal to or larger than 5  $\mu\text{m}$  (given in ISO 14644-1).

NOTE Where regulatory agencies impose supplementary guidelines or restrictions, appropriate adaptation of the assessment methodology can be required.

The following items are not covered by this part of ISO 14644:

- assessment of suitability with respect to biocontamination;
- testing for suitability of decontamination agents and techniques;
- cleanability of equipment and materials;
- requirements on design of equipment and selection of materials;
- physical properties of materials (e.g. electrostatic, thermal properties);
- optimizing performance of equipment for specific process applications;
- selection and use of statistical methods for testing;
- protocols and requirements for local safety regulations.

## 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 14644-1:2015, *Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness by particle concentration*

## 3 Terms and definitions

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

### 3.1

#### **cleanliness**

condition not exceeding a specified level of contamination

**3.2  
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.

[SOURCE: ISO 14644-1:2015, 3.1.1]

**3.3  
cleanroom suitability**

ability to maintain the critical control attributes or condition of any clean zone when used as intended

Note 1 to entry: For the purposes of this part of ISO 14644, the assessment is based on airborne particle concentration.

**3.4  
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.

[SOURCE: ISO 14644-1:2015, 3.1.2]

**3.5  
decontamination**

reduction of unwanted matter to a defined level

[SOURCE: ISO 14644-7:2004, 3.7]

**3.6  
equipment**

system designed for specific function(s), integrating materials, components and/or controls

EXAMPLE Testing and manufacturing equipment and machinery, equipment for transport and handling, storage units, tools, furniture, doors, ceilings, Information Technology (IT) hardware and handling robots.

**3.7  
test environment**

space in which the test is carried out, described by a set of parameters

## 4 General outline of the assessment

Cleanroom suitability assessment has the following outline.

- a) Before the assessment can be executed, the customer and supplier shall agree upon the particle size range(s), with reference to air cleanliness by particle concentration, designated by ISO Class *N* as given in ISO 14644-1 and item to be tested including the modes of operation(s). Each selected mode of operation shall be assessed separately.
- b) A short description regarding how the equipment will be used in routine operation (with operating parameters) shall be given to promote setting the appropriate testing condition and parameters.
- c) Visual inspection (see [Clause 5](#)).
- d) The procedure described in [Clause 6](#) shall be used in order to establish a link to the ISO 14644-1 classification system.
- e) Execution of measurements (see [6.2](#)).
- f) The data gathered will be processed and the results linked to the ISO classification system (see [6.2.9](#) and [6.2.10](#)).
- g) The results obtained shall conclude the equipment's cleanroom suitability; the statement shall follow the defined designation (see [Clause 8](#)).

Additional optional tests (not linked to ISO class *N*), such as total emission of particles or operational life cycle test, are described in [Annex B](#).

The method described in [B.4](#) may be used to determine the average total emission of equipment and provides data that may be used to determine the particle load on a cleanroom.

## 5 Visual inspection

Visual inspection of the equipment shall be carried out before and after any measurement-based assessment.

The visual inspection shall ensure that all packaging has been removed and that the equipment is undamaged and that it is correctly assembled and appropriately connected to its required utilities.

Visual surface cleanliness shall be qualitatively assessed such that any subsequent quantifiable tests shall not be compromised. This part of the visual inspection can include assessment for particles, surface films or inappropriately located lubricants.

The objectives of this inspection are the following:

- identify contamination, such as particles and films originated from manufacturing, packaging, transportation or initial assembly;
- identify contamination that has withstood any prior decontamination process.

It is not intended that this inspection will provide a measurement of surface cleanliness.

Depending on the location of the contamination, the results from visual inspection shall be

- recorded and available for comparison with the post-test visual inspection of surface cleanliness, and
- used as basis to direct a repeat or improved decontamination process.

Detection efficiency of visible contamination on equipment will depend upon the following factors:

- the accessibility and orientation of the surface to be inspected;

- the materials used for equipment construction, their surface condition and treatment;
- the viewing parameters (e.g. illumination, field of view, vision magnification, viewing distance).

## 6 Assessment of suitability by airborne particle concentration measurements

### 6.1 General

The objective of [Clause 6](#) is to describe a suitability methodology using measurement of airborne particle emissions at critical locations. By including measurement locations at, or close to, the locations of high particle concentration (HPC), the intended use of the application is reflected.

This assessment methodology enables a link to the classification system of ISO 14644-1, in one or more particle size ranges to be established.

In order to assess the cleanroom suitability of equipment, it is intended that the location(s) with HPC emitted by the equipment be identified and included in the final suitability measurement. Since the size distribution of the emitted particles is not known in advance, it is required that more than one particle size range is measured. Ideally, three widely spread particle size ranges should be selected.

Subsequently, the particle concentrations thus determined from equipment assessment are compared with the air cleanliness by particle concentration limits for ISO Class *N* as specified in ISO 14644-1.

For the equipment to be tested, it shall be ensured that cleanroom compliant design principles have been incorporated. These principles include, but are not limited to, the following:

- selection of appropriate materials and surface finishes;
- avoidance of static air zones;
- design principles for cleanability;
- considerations for maintenance.

This measurement methodology is not intended to determine overall emission rates for the equipment under test.

### 6.2 Assessment procedure

#### 6.2.1 Overview

The flowchart in [Figure 1](#) gives an overview of the necessary assessment steps.

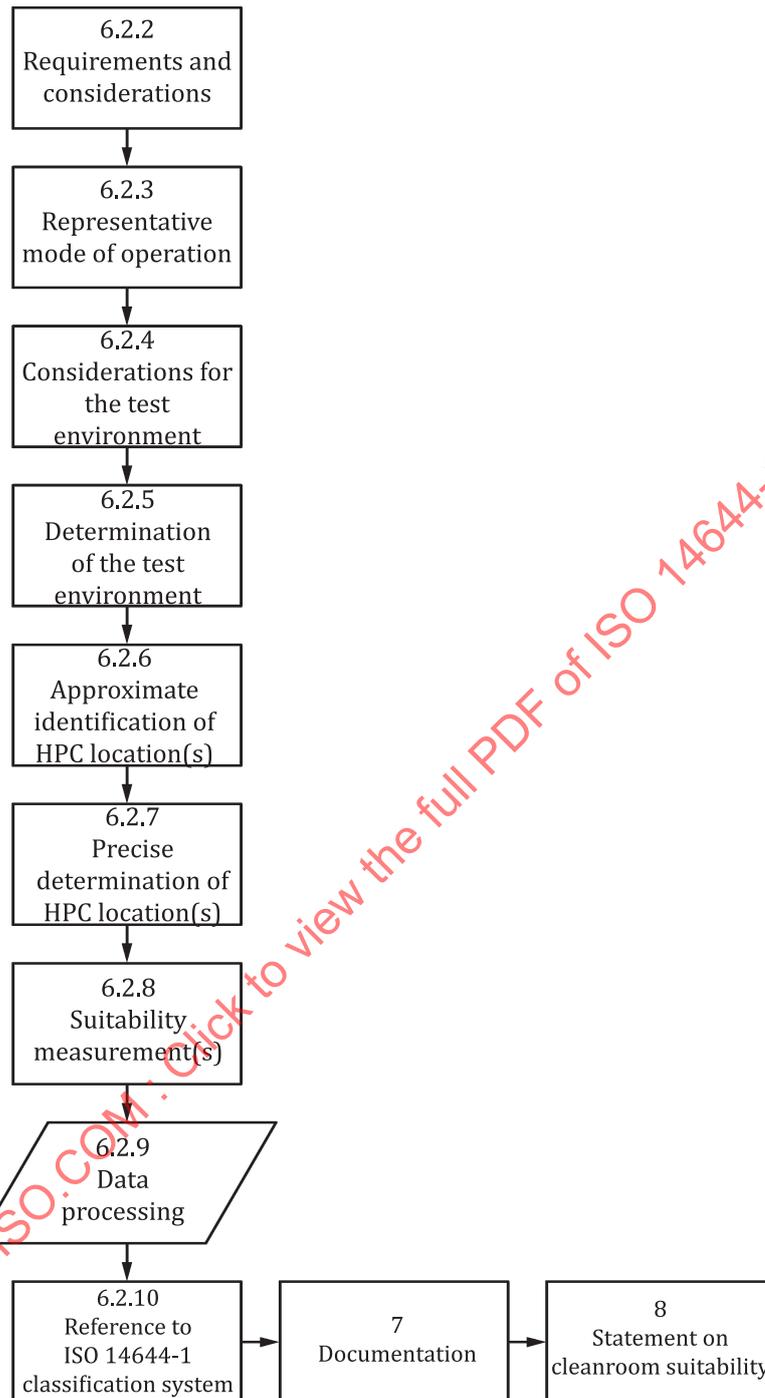


Figure 1 — Overview of the assessment procedure

### 6.2.2 Requirements and considerations

When defining the scope of the suitability assessment, aspects that could influence the assessment results shall be considered, for example (but not limited to):

- variability between the same type of equipment;
- pre-conditioning of the equipment to be tested (accumulated operating hours);
- running-in of equipment.

The test environment shall be agreed upon before testing (see [6.2.4](#) and [6.2.5](#)).

### 6.2.3 Representative mode of operation

A representative mode of operation of equipment shall be defined, which ensures that particle emission sources are detected. The mode of operation shall reflect the intended use of the equipment. If the equipment can be operated in different modes of operation (e.g. with or without product), it shall be decided which of these different modes form part of the assessment. Equipment parameters of operation shall be defined and agreed upon before testing.

If standardized procedures exist, these procedures shall be taken into consideration. For non-standardized handling, the manner of handling chosen shall be documented, and reasons for this choice shall be given.

### 6.2.4 Considerations for the test environment

The objective of these tests is to characterize and select a test environment prior to installing the equipment that is to undergo assessment for cleanroom suitability.

Consideration should be given to whether all or some pre-tests are conducted at more than one measuring plane. An illustration of selected measurement plane(s) may be added.

Information on measurement test methods and equipment can be obtained from ISO 14644-1 and ISO 14644-3. The following shall be considered.

- Airborne particle concentration measurement: The aim is to confirm that the test environment is at least one ISO class *N* (as given in ISO 14644-1) cleaner than the cleanroom or clean zone within which the equipment is intended to be used.
- Airflow velocity measurement: Guidance range for vertical velocity should be in the range of 0,3 m/s to 0,5 m/s.
- Temperature: Guidance range should be 18 °C to 25 °C.
- Humidity: Guidance range should be 30 % RH to 70 % RH.

Additional informative pre-tests can include the following:

- airflow direction test and visualization;
- electrostatic and ion generator test;
- particle deposition test.

The results of the considerations shall be used for the determination of the test environment (see [6.2.5](#)).

### 6.2.5 Determination of the test environment

The test environment shall provide a background level at least one ISO Class *N* (as given in ISO 14644-1) cleaner than the cleanroom or clean zone in which the equipment is intended to be used.

NOTE Testing of equipment for ISO Class 1 suitability is accomplished in an ISO Class 1 environment.

The test environment shall not contain any other particle sources than the equipment to be assessed to avoid influencing the measurement results. This can be achieved using unidirectional airflow.

### 6.2.6 Approximate identification of HPC location(s)

For equipment with moving elements/components, there is frequently a significant variation in the concentration of particles generated between different zones of the equipment. The intention of the

cleanroom suitability methodology is to include those zones that contain HPC(s) within the suitability assessment measurements.

The objective of this stage of the assessment is to determine the measuring locations of HPC(s) that shall be included in the subsequent final suitability measurement. It is essential that moving elements/components, utilities, interfaces, etc., are included in this assessment.

NOTE The number of moving elements/components can influence the number of approximate HPC locations.

Although safe sampling can impose sampling position limitations, the objective is to vary the distance and/or position of the sampling probe in order to identify the HPC location(s).

The approximate identification shall be performed using a systematic scan of the equipment with a light scattering discrete airborne particle counter (LSAPC). The entire system including product spaces of the equipment should be scanned by the sampling probe. While the equipment is scanned using a sampling probe of the LSAPC, a correlation between its position and the HPC is acquired. Depending on the make/model of the LSAPC used, the feedback required to establish this correlation can use visual and/or acoustic means. The sample acquisition time shall be chosen to ensure that the location of the HPC(s) can be identified appropriately.

Previously identified contamination sources (output of any pre-tests) should be included in this part of the assessment.

The conclusions of the measurements undertaken for the approximate identification of particle sources are qualitative in nature.

#### 6.2.7 Precise determination of HPC location(s)

Following the approximate identification, a precise determination of HPC location(s) is carried out using a LSAPC assessing at least 28,3 l/min of air with a probe having an openness limited to 20 cm<sup>2</sup>. During this measurement stage, the geometrical position of the LSAPC sampling probe is adjusted to achieve the optimum sampling of the HPC location. Probe position shall be set and recorded. This is repeated for each HPC location identified under [6.2.6](#).

NOTE The number of measuring locations will be influenced by the number of moving elements/components.

#### 6.2.8 Suitability measurement(s)

The HPC location(s) with the highest particle concentration obtained in [6.2.7](#) shall be selected for the suitability measurement. Select at least one HPC location. Measurement locations of specific point of interest, e.g. associated with product handling, can be added.

Perform particle concentration measurement(s) at selected location(s) using a LSAPC as described in [6.2.7](#).

The following parameters, required for performing the suitability measurements, shall be specified and documented:

- modes of operation of the equipment;
- number of operating cycles of the equipment;
- positioning of the equipment to be tested;
- HPC location(s) derived from approximate identification and precise determination;
- additional measurement point(s) derived from a specific point of interest (e.g. product critical location);
- positioning of the measuring LSAPC sampling probe(s);
- particle size range(s) being assessed;

- sampling volume and time;
- number of consecutive independent readings at each individual measurement location. For statistical reasons this number shall be  $\geq 100$ .

NOTE The acquired data from the LSAPC can be captured, processed and then analysed using suitable software in order to avoid transcription errors.

## 6.2.9 Data processing

### 6.2.9.1 General

The following data processing procedure shall be applied to the readings of particle concentrations obtained in [6.2.8](#).

The readings per specified particle size range obtained in [6.2.8](#) are subject to statistical analysis. In most cases of the measurements, where the expected value (mean value,  $\bar{x}$ ) for the particle size under consideration is assumed to be larger than 10 particles per measurement, procedure a) (see [6.2.9.2](#)) shall be applied. In case that the expected value of the measurements is 10 or below, procedure b) (see [6.2.9.3](#)) shall be applied.

### 6.2.9.2 Procedure a)

The arithmetic mean of the particle numbers is calculated using [Formula \(1\)](#):

$$\bar{x} = \frac{(x_{i,1} + x_{i,2} + \dots + x_{i,n})}{n} \tag{1}$$

where

$\bar{x}$  is the mean value;

$x_i$  is a single reading in the consecutive measuring of a particle size range  $i$ ;

$n$  is the number of readings.

For the calculation of the standard deviation, [Formula \(2\)](#) is used:

$$s = \sqrt{\frac{(x_{i,1} - \bar{x})^2 + (x_{i,2} - \bar{x})^2 + \dots + (x_{i,n} - \bar{x})^2}{(n - 1)}} \tag{2}$$

where

$s$  is the standard deviation;

$x_i$  is a single reading in the consecutive measuring of a particle size range  $i$ ;

$\bar{x}$  is the mean value;

$n$  is the number of readings.

[Formula \(3\)](#) shall be used to calculate the upper confidence limit:

$$P_u = \bar{x} + 1,66 \times \frac{s}{\sqrt{n}} \quad (3)$$

where

$P_u$  is the upper confidence limit for a confidence level of  $(1 - \alpha) = 95 \%$ ;

$\bar{x}$  is the mean value [according to [Formula \(1\)](#)];

$s$  is the standard deviation [according to [Formula \(2\)](#)];

1,66 is the factor from Student's  $t$  distribution.

NOTE  $t_{\alpha,v} = 1,66$  for the upper confidence limit for a confidence level of  $(1 - \alpha) = 95 \%$  and 100 individual measured values.

[Formula \(4\)](#) shall be used to calculate the z-value:

$$z = \sqrt{n} \frac{G - P_u}{s} \quad (4)$$

If the calculated value of  $z$  according to [Formula \(4\)](#) is larger than 1,645, the class limit  $G$  will not be exceeded with a confidence level of 95 %.

The derived classification number  $N$  which corresponds to the class limit  $G$  (maximum permitted particles of the considered size range within the ISO class number  $N$ ) will be used in [6.2.10](#) to establish reference to the ISO 14644-1 classification system.

NOTE A detailed example is given in [Annex A](#).

### 6.2.9.3 Procedure b)

If the expected value (mean value,  $\bar{x}$ ) of the measurement result is less than or equal to 10, [Table 1](#), which is based on Poisson statistics, is used to determine the upper confidence limit.

The mean value is calculated using [Formula \(1\)](#).

**Table 1 — Upper confidence limit for procedure b)**

Mean value $\leq \bar{x}$	Upper confidence limit $P_u$
0,051 2	0
0,355	1
0,818	2
1,366	3
1,970	4
2,613	5
3,285	6
3,981	7
4,695	8
5,425	9
6,169	10

NOTE [Table 1](#) is based on Poisson distribution for 95 % confidence limit.

Table 1 (continued)

Mean value $\leq \bar{x}$	Upper confidence limit $P_u$
6,924	11
7,690	12
8,464	13
9,247	14
10,000	15

NOTE Table 1 is based on Poisson distribution for 95 % confidence limit.

The derived  $P_u$  will be used in 6.2.10 to establish reference to ISO 14644-1 classification system.

NOTE A detailed example is given in Annex A.

### 6.2.10 Reference to ISO 14644-1 classification system

For each particle size range measured, a reference to the ISO 14644-1 classification system shall be made. For this purpose, ISO 14644-1:2015, Table 1 is used to identify the respective ISO class number  $N$ .

NOTE 1 ISO 14644-1:2015, Annex F provides calculation for intermediate class numbers and threshold particle sizes.

If a LSAPC is used that measures an air volume smaller or larger than one cubic meter per time interval, the class limits  $G$  (maximum permitted particles of the considered size range within the ISO class number  $N$ ) shall be calculated to derive the corresponding figure for  $G$ .

If  $P_u$  (see 6.2.9) is less than or equal to  $G$ , the reference to the measured particle size range and respective ISO Class  $N$  is established.

If  $P_u$  is larger than  $G$ , then the next higher ISO class number  $N$  shall be used.

The comparison shall be done for each specified particle size range.

The highest ISO class number  $N$  (as given in ISO 14644-1) of the specified particle size ranges shall be chosen for the cleanroom suitability assessment (see Clause 8). If more than one HPC location has been taken into account, the highest number of the ISO Class  $N$  (as given in ISO 14644-1) shall be chosen for the cleanroom suitability assessment.

NOTE 2 A detailed example is given in Annex A.

## 7 Documentation

### 7.1 General

The documentation shall contain all information required to reproduce the test for suitability.

Where applicable, the items listed in subsequent sections are recommended as minimum information. Further relevant items may be added to the list.

### 7.2 Common documentation requirements

- description of test
- reference to standards and/or guidelines used
- date

- d) place where the assessment is carried out
- e) person(s) performing the test
- f) customer
- g) description of piece of equipment including mode(s) of operation considered
- h) marking/identification of test object

### 7.3 Documentation for visual inspection

In addition to common documentation requirements:

- observations of the equipment to be tested; general condition, damage and compatibility with the utilities and services connection.
- For visual inspection of surfaces:
  - description of the visual inspection approach (e.g. normal or magnified; additional light sources, etc.);
  - description of any “critical” surfaces selected for inspection (with justification). Diagrams and/or photographs to be included.
  - In addition, for each surface location of the equipment visually inspected:
    - vision magnification when used;
    - description of any additional light source used;
    - distance between inspector and the surface being examined;
    - description of contamination observed;
    - results from any assessment used to establish contamination mobility, including whether any contamination was removed during this assessment.

### 7.4 Documentation for assessment of test environment

In addition to the common documentation requirements, the type designations of each measuring instrument/apparatus used and their calibration status shall be required.

- a) airborne particle concentration;
  - 1) measurements at the agreed size range(s),
  - 2) derived test environment classification,
  - 3) sampling probe description and orientation,
  - 4) location(s) of sampling,
- b) airflow velocity measurement readings and their locations;
- c) temperature measurement readings and their locations;
- d) humidity measurement readings and their locations;
- e) additional informative pre-tests;
  - 1) airflow direction and visualization, method description, results summary and reference to any audio-visual files,

- 2) electrostatic and ion generator tests; method descriptions and results summary,
- 3) particle deposition test; method descriptions and results summary.

## 7.5 Documentation for classification measurement

- a) test setup photo (and drawing if applicable);
- b) ambient conditions/installation conditions of the test environment;
  - 1) temperature,
  - 2) relative humidity,
  - 3) mean air velocity,
  - 4) ISO Class  $N$  in accordance with ISO 14644-1,
- c) pre-tests that have been carried out and their results;
- d) agreed representative mode of operation chosen for the assessment;
- e) description of measuring probe location(s) and their justification;
- f) description of operating parameters;
- g) any extraordinary observations during the measurement(s);
- h) serial number/working range of LSAPC used, including reference to calibration certificate;
- i) type of probe;
- j) duration of measurement;
- k) number of measurements taken per location;
- l) sampling volume and time;
- m) particle size ranges under consideration and their results;
- n) analysis of data;
- o) result of visual inspection of the test object after the measurement.

## 8 Statement on cleanroom suitability

The cleanroom suitability of the equipment shall be stated in the following way:

- a) *An assessment including an agreed upon representative mode of operation, according to ISO 14644-14 showed that:*

*Equipment Z has cleanroom suitability for use within a cleanroom of ISO Class X ( $Y \mu\text{m}$ ).*

where

- X is the ISO class number  $N$ , highest value according to [6.2.10](#);
  - Y is the particle size range measured;
  - Z is the designation of equipment and unique identification (e.g. type, serial number, manufacturer).
- b) *The representative mode of operation is as stated in the documentation.*

The documentation according to [Clause 7](#) (including results of visual inspection) is an integral part of the statement on cleanroom suitability and shall be attached.

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## Annex A (informative)

### Example for data processing deriving from measurements

#### A.1 General

The following facts are assumed:

- 0,1  $\mu\text{m}$ , 0,2  $\mu\text{m}$  and 5,0  $\mu\text{m}$  are specified as particle size ranges;
- six particle size ranges were measured;
- a LSAPC was used with a sampling volume of 28,3 l/min (1 ft<sup>3</sup>/min);
- 100 consecutive measurements for the suitability measurements were performed.

#### A.2 Measurement values at one single HPC

For this example, the following individual values in [Table A.1](#) have been obtained during suitability measurement.

**Table A.1 — Values measured per 28,3 l measuring air volume during classification measurements**

Value number	$\geq 0,1 \mu\text{m}$	$\geq 0,2 \mu\text{m}$	$\geq 0,3 \mu\text{m}$	$\geq 0,5 \mu\text{m}$	$\geq 1,0 \mu\text{m}$	$\geq 5,0 \mu\text{m}$
1	1	0	0	0	0	0
2	33	11	3	3	1	1
3	27	13	13	10	9	3
...						
100	0	0	0	0	0	0

Applying [Formula \(1\)](#) and [Formula \(2\)](#) provides the most important data that are needed to assess the cleanroom suitability of the equipment (see [Table A.2](#)).

**Table A.2 — Statistical data of the suitability measurement**

	$\geq 0,1 \mu\text{m}$	$\geq 0,2 \mu\text{m}$	$\geq 0,3 \mu\text{m}$	$\geq 0,5 \mu\text{m}$	$\geq 1,0 \mu\text{m}$	$\geq 5,0 \mu\text{m}$
Number of measured values, $n$	100	100	100	100	100	100
Mean value, $\bar{x}$	16,33	7,39	5,88	4,19	2,87	0,90
Standard deviation, $s$	68,12	28,13	22,34	15,79	10,70	2,27
Maximum	586	216	166	116	74	10
Minimum	0	0	0	0	0	0

The readings per specified particle size range obtained in [6.2.8](#) are subject to statistical analysis. In most cases of the measurements, where the expected value (mean value) for the particle size under consideration is assumed to be larger than 10 particles per measurement, procedure a) (see [6.2.9.2](#)) shall be applied. In case that the expected value of the measurements is 10 or below, procedure b) (see [6.2.9.3](#)) shall be applied.

To determine which statistical procedure according 6.2.9 is to be used, the expected values (mean values) for the particle size under consideration are reviewed. Therefore,  $\geq 0,1 \mu\text{m}$  particle size range is subjected to procedure a) (see 6.2.9.2),  $\geq 0,2 \mu\text{m}$  and  $\geq 5,0 \mu\text{m}$  particle size range are subjected to procedure b) (see 6.2.9.3).

**For particle size range  $\geq 0,1 \mu\text{m}$ , Formula (3) is used.**

$$P_u = \bar{x} + 1,66 \times \frac{s}{\sqrt{n}} \quad (\text{A.1})$$

$$P_u = 16,33 + 1,66 \times \frac{68,12}{10} = 27,64 \quad (\text{A.2})$$

For ISO Class 3 and the particle size range  $\geq 0,1 \mu\text{m}$ , the limit  $G$  is 28 particles per sampling volume of 28,3 l (see Table A.3).

$$z = 10 \frac{(28 - 27,64)}{68,12} = 0,05 \quad (\text{A.3})$$

As the calculated value  $z = 0,05$  does not fulfil the demand of the confidence level ( $z$  has to be larger or equal to 1,645), the corresponding ISO class number  $N = 3$  is not applicable (see ISO 14644-1).

For the ISO Class 4 and the particle size range  $\geq 0,1 \mu\text{m}$ , the limit  $G$  is 283 particles per sampling volume of 28,3 l.

$$z = 10 \frac{(283 - 27,64)}{68,12} = 37,49 \quad (\text{A.4})$$

As the calculated value  $z = 37,49$  fulfils the demand of the confidence level ( $z$  has to be larger or equal to 1,645), the corresponding ISO class number  $N = 4$  is applicable (see ISO 14644-1).

**For particle size range  $\geq 0,2 \mu\text{m}$**

As in the previous measurement example, the assumed value (mean value) of the particle size range  $> 0,2 \mu\text{m}$  has a value of 7,39, which is smaller than 10. The probability of not exceeding the given class limit values  $G$  has to be calculated with Table A.4, based on Poisson statistics.

Table A.4 leads to an upper confidence limit of  $P_u = 12$ .

In the above-mentioned example,  $P_u = 12$  is smaller than the class limit  $G = 67$  (see Table A.3) of the particle size  $\geq 0,2 \mu\text{m}$  at ISO Class 4.

The calculations performed demonstrate cleanroom suitability for the equipment, as derived from the measurements, for the particle size range  $\geq 0,2 \mu\text{m}$  for ISO Class 4 ( $0,2 \mu\text{m}$ ), as the likelihood of not exceeding the limit is  $\geq 95 \%$ .

**For particle size range  $\geq 5,0 \mu\text{m}$**

As in the previous measurement example, the assumed value (mean value) of the particle size range  $> 5,0 \mu\text{m}$  has a value of 0,90, which is smaller than 10. The probability of not exceeding the given class limit values  $G$  has to be calculated with Table A.4, based on Poisson statistics.

Table A.4 leads to an upper confidence limit of  $P_u = 3$ .

In the above-mentioned example,  $P_u = 3$  is smaller than the class limit  $G = 8,28$  (see Table A.3) of the particle size  $\geq 5,0 \mu\text{m}$  at ISO Class 6.

The calculations performed demonstrate cleanroom suitability for the equipment, as derived from the measurements, for the particle size range  $\geq 5,0 \mu\text{m}$  for ISO Class 6 ( $5,0 \mu\text{m}$ ), as the likelihood of not exceeding the limit is  $\geq 95 \%$ .

**Establishing reference to ISO 14644-1:2015, Table 1**

For establishing reference to ISO 14644-1:2015, Table 1, the following has to be taken in consideration.

Sampling volume was 28,3 l, which is equivalent to 0,028 3 m<sup>3</sup>. Multiplication of the respective figure of ISO 14644-1:2015, Table 1 leads to the corresponding figures for *G* in [Table A.3](#).

**Table A.3 — Calculated *G* figures**

ISO class number <i>N</i>	Calculated class limit <i>G</i> for specified particle size ranges		
	≥0,1 μm	≥0,2 μm	≥5,0 μm
1	0,28	0,07	0,00
2	2,83	0,67	0,00
3	28	6,70	0,01
4	283	67	0,08
5	2 832	671	0,83
6	28 321	671 2	8,28
7	283 206	671 20	83
8	2 832 059	671 198	830
9	28 320 589	671 198 0	829 8

NOTE Grey areas indicate particle size ranges not intended for classification according to ISO 14644-1.

**Table A.4 — Upper confidence limit for procedure b)**

Mean value ≤ $\bar{x}$	Upper confidence limit $P_u$
0,051 2	0
0,355	1
0,818	2
1,366	3
1,970	4
2,613	5
3,285	6
3,981	7
4,695	8
5,425	9
6,169	10
6,924	11
7,690	12
8,464	13
9,247	14
10,000	15

NOTE [Table A.4](#) is based on Poisson distribution for 95 % confidence level.

**A.3 Result**

For the specified particle size ranges, the following ISO class numbers have been established.