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In situ test methods for high efficiency filter systems in industrial facilities

Méthodes d'essai in situ pour les systèmes filtrants à très haute efficacité dans les installations industrielles

Reference number
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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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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 documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www. iso. org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www. iso. org/patents).

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

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

This document was prepared by Technical Committee ISO/TC 142, *Cleaning equipment for air and other gases*.

This corrected version of ISO 16170:2016 incorporates the following corrections.

All figures have been replaced with higher quality diagrams.

In C.3.2 the key and cross-references within the text to Figure C.3 have been corrected.

Introduction

Methods for measuring the performance of high efficiency gas cleaning devices are described in a number of existing standards. These specify procedures for quality assurance following manufacture (e.g. ISO 29463 and EN 1822).

Some other standards specify the filter medium used in such devices, how they are constructed and how they are installed within industrial facilities.

Installations of high efficiency particulate filters are extensively used within nuclear and toxic material processing plants and laboratories to confine these materials within the facility and prevent their discharge to the environment.

Radioactive and other toxic materials are confined within processing facilities inside containment zones bordered by barriers. Air and gases vented from these zones are decontaminated by passage through a series of highly efficient particulate filters before final discharge to the environment. The membrane (filter medium) of the filters acts as part of the containment barrier. In view of its perceived fragility, confirmation of its integrity is required on a periodic basis because operational safety cases depend on the knowledge that the effectiveness of these filters is maintained at all times. These periodic checks are made by the procedure(s) known as “in-situ” or “in-place” testing.

The basic principles of *in situ* tests on installed filters are the same as for laboratory tests, such as those described in EN 1822 and ISO 29463, insofar as known quantities of a challenge aerosol are dispersed into the airstream upstream of the filter installation; the particulate contents of the unfiltered and filtered air are sampled and analysed to determine whether the integrity of the filters has been compromised.

In the case of testing a single unit (manufacturer’s production test or in the case of a laboratory testing on a single filter unit), the purpose is to confirm that the unit performance [efficiency/penetration at Most Penetrating Particle Size (MPPS) and other parameters] lies within specified limits, and further, that the results are globally reproducible. To achieve this requires the use of a laboratory test rig setup with full dispersion of a challenge aerosol, prescribed geometry of the test rig, and to obtain and analyse fully representative particulate samples both upstream and downstream of the test filter. Some ventilation systems are highly complex and it should be noted that many facilities use ventilation systems in which a high percentage of the air is recirculated.

The purpose of an *in situ* test is to detect any adverse change in the filtration performance of the installation and to compare it with the expected efficiency or decontamination factor. Such a change might be caused by deterioration of a unit or units or a faulty sealing system and would be manifested by the appearance of a proportion of unfiltered aerosol in the effluent airstream. Testing methodologies developed in this International Standard do not cover the other requirements that relate to filters in terms of mechanical resistance, burst strength or temperature and moisture resistance.

It is neither fully necessary nor useful for the results of an *in situ* test to replicate the results of production tests on the individual filters in the installation, nor is it necessary to confine the test aerosol size distribution to one which replicates that used in production tests.

No International Standard for general *in situ* testing of high efficiency filters has been produced before, explaining the needs for such an International Standard.

This International Standard describes the requirements for test equipment, data interpretation and reporting for the *in situ* testing of HEPA and ULPA air cleaning installations designed for the removal of airborne particulate contamination in high-integrity ventilation systems.

This International Standard includes specification of the test interval, aerosol type, aerosol mixing and measurement methods, i.e. the following:

— aerosol: solid or liquid, monodisperse or polydisperse;

— mixing: degree of mixing, mixing lengths, etc.;

— method: injection, detection.

This International Standard proposes an outline testing philosophy to highlight the following:

— principle of the method;

— prerequisites;

— preparatory conditions;

— injected aerosol properties;

— qualification and selection of measuring devices;

— qualification of test personnel;

— test setup;

— test sequence;

— evaluation and reporting.

In situ test methods for high efficiency filter systems in industrial facilities

1 Scope

This International Standard specifies *in situ* test methods for high efficiency particulate air filters used to limit releases towards the environment (e.g. from nuclear facilities or facilities with aerosol toxic or biological releases). This applies where installations of these filters are used to clean effluent air before discharge to the environment from industrial (including nuclear) installations where toxic/radioactive/biological materials are handled or processed.

This International Standard excludes the application already covered by ISO 14644-3.

The scope of this International Standard includes detail of two methods, either of which applies to the periodic testing of high efficiency filters which are used in demanding applications aiming at protecting the environment, such as the nuclear industry.

In the case of nuclear applications, this International Standard is applicable to installations covered by ISO 17873 (applications other than nuclear reactors) and ISO 26802 (nuclear reactors).

The two reference methods specified in this International Standard are not equivalent, but related to, the requirements to be addressed by the test results. The choice of which of the two methods is adopted in any specific case depends on whether the outcome requires an integrity test or a statutory efficiency accountancy test.

For industries handling or processing radioactive or toxic materials giving rise to a risk of possible release, the main goal of the tests is to confirm that the filter installation is fit for purpose. In the case of integrity tests (Annex B), this is to confirm that no significant leakage of toxic aerosols through the filter installation is possible.

In the case of efficiency accountancy tests (Annex C), the test is designed to make an accurate measurement of decontamination factor with respect to the MPPS size range of particles.

The reference method described in Annex B (integrity test) requires a test aerosol of dispersed oil particles mainly submicrometre in size range, which is stable during the test procedure and compatible with other installation components. Particle concentrations are measured in real time by light scattering instrumentation (optical detectors).

The reference method described in Annex C (efficiency accountancy test) requires a test aerosol of particles having a narrow size range centred on MPPS size range for HEPA filter media. Their concentration both upstream and downstream the filters is measured by fluorimetric analysis of aqueous solution obtained by washing the membrane sampling filters.

It should be noted that the requirements for an efficiency accountancy test also cover the requirements of an integrity test, which is considered to be a minimum requirement.

Test methods developed in this International Standard do not cover the other *in situ* performance requirements, such as mechanical resistance, bursting resistance or humidity resistance. Specific systems operating at high temperature or with specific gaseous effluents might require specific test methods.

The engineering design of HEPA and ULPA filter installations does not fall within the scope of this International Standard.

NOTE In the field of filters for general ventilation applications, ISO 29462 is a detailed and comprehensive description of a method which uses scanning and particle counting methods to evaluate the performance of a filter in terms of particle grade efficiency, as well as pressure drop. Such a method and procedure would not be applicable in those nuclear installations where quantification of the decontamination factor at MPPS size is needed.

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 29463-1, *High-efficiency filters and filter media for removing particles in air — Part 1: Classification, performance testing and marking*

ISO 14644-3:2005, *Cleanrooms and associated controlled environments — Part 3: Test methods*

ISO 17873, *Nuclear facilities — Criteria for the design and operation of ventilation systems for nuclear installations other than nuclear reactors*

ISO 26802, *Nuclear facilities — Criteria for the design and the operation of containment and ventilation systems for nuclear reactors*

ISO 2889, *Sampling airborne radioactive materials from the stacks and ducts of nuclear facilities*

3 Terms and definitions

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

3.1
aerosol
system of solid or liquid particles suspended in gas

Note 1 to entry: In general, one divides the atmospheric aerosol into three size categories: the ultrafine range $x \leq 0{,}1$ µm, the fine range $0{,}1$ µm $< x \leq 1$ µm, and the coarse range $x > 1$ µm, where x is the particle diameter.

[SOURCE: ISO 29464:2011, 3.1.1]

3.1.1
monodisperse aerosol
aerosol (3.1), the width of whose distribution function, described by the geometric standard deviation σ_g, is less than 1,15 µm

[SOURCE: ISO 29464:2011, 3.1.2]

3.1.2
polydisperse aerosol
aerosol (3.1), the width of whose distribution function, described by the geometric standard deviation σ_g, exceeds 1,5 µm

[SOURCE: ISO 29464:2011, 3.1.3]

3.1.3
quasi-monodisperse aerosol
aerosol (3.1), the width of whose distribution function, described by the geometric standard deviation σ_g, is between 1,15 µm and 1,5 µm

[SOURCE: ISO 29464:2011, 3.1.4]

3.1.4
test aerosol
aerosol (3.1) used for determining filter efficiency

3.2
decontamination factor
ratio between the concentration or particles number upstream the filter and the concentration or particles number contamination downstream the filter

Note 1 to entry: This ratio is also defined by 1/(1- *overall efficiency* (3.13)).

3.3
effective filter media area
area of the media contained in the filter (without adhesive spaces or ligament) and passed by air during operation

[SOURCE: ISO 29464:2011, 3.1.11]

3.4
efficiency
E
fraction of contaminant entering the filter which is retained

[SOURCE: ISO 29464:2011, 3.1.55]

3.5
efficiency accountancy test
in-situ test procedure meeting a requirement for an accurate system *overall efficiency* (3.13) determination at *MPPS* (3.11)

3.6
integrity test
in-situ test procedure meeting the requirement for confirming the absence of unfiltered leakage of the system

3.7
filter element
filtering material in a preformed shape being a part of a complete filter

[SOURCE: ISO 29464:2011, 3.1.67]

3.8
filter face area
frontal face area of the filter including the header frame

[SOURCE: ISO 29464:2011, 3.1.83]

3.9
HEPA filter
filter with performance complying with requirements of filter class ISO 35 – ISO 45 as per ISO 29463-1

[SOURCE: ISO 29464:2011, 3.1.88]

3.10
filter medium
material used for filtering

[SOURCE: ISO 29464:2011, 3.1.90]

3.11
most penetrating particle size
MPPS
particle size at which the minimum of the *particle size efficiency* (3.14) curve occurs under test conditions

Note 1 to entry: This MPPS is media and ventilation conditions dependent. This MPPS is in the 0,1 µm to 0,2 µm medium aerodynamic size range for fibreglass type filters commonly used in nuclear applications.

[SOURCE: ISO 29464:2011, 3.1.129]

3.12
user nominal air volume flow rate
$q_{v,nom}$
air volume flow rate specified by the user, at which the *filter element* (3.7) is tested *in situ*

Note 1 to entry: This flow rate may be different from the one specified by the manufacturer.

3.13
overall efficiency
efficiency averaged over the whole *superficial face area* (3.15) of a *filter element* (3.7) under given operating conditions of the filter

Note 1 to entry: It is expressed in percentage (%).

3.14
particle size efficiency
efficiency for a specific particle diameter

Note 1 to entry: The efficiency plotted as a function of the particle diameter gives the fractional efficiency curve.

Note 2 to entry: It is expressed in percentage (%).

3.15
superficial face area
cross-sectional area of the *filter element* (3.7) through which the air flow passes

3.16
ULPA filter
filters with performance complying with requirements of filter class ISO 55 – ISO 75 as per ISO 29463-1

[SOURCE: ISO 29464:2011, 3.1.100]

3.17
user nominal filter medium face velocity
nominal air volume flow rate divided by the effective *filter medium* (3.10) area

4 Principle of the method

For industries handling radioactive and/or toxic materials, the main goals of the tests are the following.

a) For efficiency accountancy tests: to confirm that the overall filtration efficiency, in particular the decontamination factor for the MPPS size range and other performance parameters, remain within the operating envelope criteria authorized in the site operating licence.

b) For integrity tests: to detect any significant leakages of airborne particles bypassing the filter media.

The test procedure follows the following sequence:

— measure the main ventilation parameters (e.g. flow rates, pressure drops, temperature and humidity) of the system under test;

— inject the appropriate quantity/quantities and type of the test aerosol into the airstream(s) upstream of the filter installation with a size distribution covering the MPPS range;

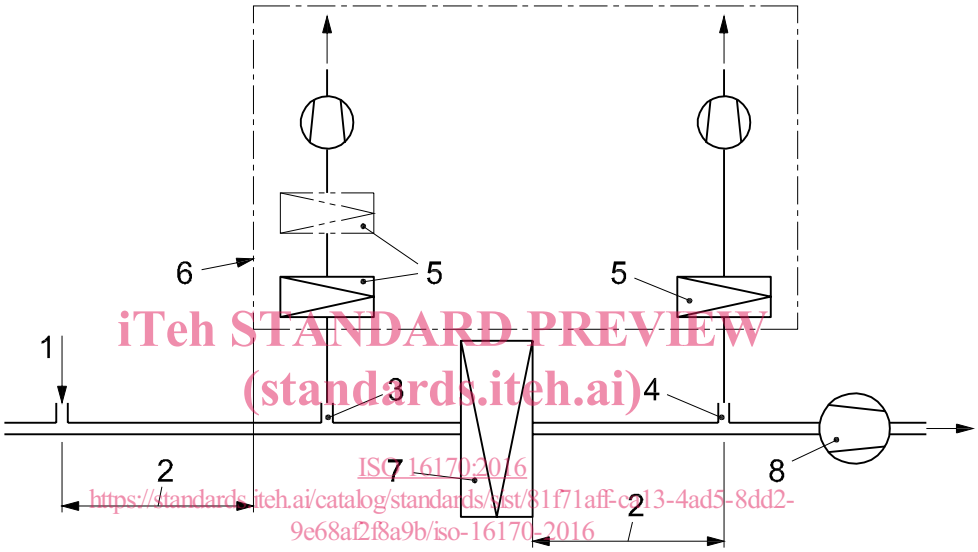
— measure the concentration of aerosol challenging the filter installation upstream of the filters;

— measure the quantity of aerosol present in the airflow downstream of the filter installation;

— calculate the efficiency or decontamination factor(s) within a size range covering the most penetrating particle size (MPPS);

— compare the measured value(s) against the required regulatory value(s) or other criteria, such as MPPS filter classification.

Figure 1 shows one general principle of the method, which is then further refined for the different methods.



Key

1 injected particles injection
2 provisions for homogenization
3 upstream representative sampling
4 downstream representative sampling
5 representative samples (this is done using different techniques in Annex B and Annex C)
6 mobile or fixed unit
7 filter(s) to be tested
8 fan (in many nuclear installations, it is customary to return the sample to the duct from which it was originally withdrawn downstream of the original sampling point)

Figure 1 — Principle of the method for representative sampling

According to ISO 29463-1, the MPPS range value should be obtainable from the media manufacturer for the typical media that are installed (e.g. 0,1 µm to 0,2 µm for HEPA filters constructed with glass microfibre media).

For efficiency accountancy tests, the chosen method shall be capable of measuring values within the range of 10 to 100 000 (efficiency range 90 % to 99,999 %), for particles sizes covering the MPPS range.

For integrity tests, an accurate measurement is not as important as for efficiency accountancy tests but the method shall cover ranges of efficiency between 90 % and 99,99 %.

If it is needed to compare further the efficiency results, the parameters having an impact on the filter efficiency results should be reliably known for the test (e.g. flow rates, pressure drop, temperature, humidity).

Specific limitations on the applicability of the test results shall be detailed on the results sheet(s); for example, limitations on access to ideal sampling locations because of high dose rates, or difficulty in ensuring design flow rates, temperature, humidity, etc. within the ventilation system.

The results of the tests are provided only for the ventilation regime at which the test has been performed.

NOTE The specific case of continuous efficiency monitoring is rarely implemented in industrial facilities but obeys to the same principles.

5 Prerequisites

5.1 Filter initial characterization

The filter, bank of filters or filters in series to be tested shall have been initially certified in the manufacture according to a given standard (e.g. ISO 29463) for new filters or for filters already installed in the facilities according to relevant national standards.

ISO 29463-1 provides a classification of all filters with efficiencies ranging from 95 % to 99,999 999 5 %. Since the efficiencies are measured at the MPPS of the filter, the efficiency of a filter at any particle size is better than at the filter class. That is, these filters provide particle removal at, or better than, the filter class efficiency at *all* particle sizes. In addition, in this classification, filters with efficiencies higher than 99,95 % are tested for leaks. Although this document deliberately avoids prescribing specific filter classes for specific end use, the classification scheme provides a sound basis for selecting filters for nuclear protection where a minimum decontamination safety factor is required. For this end use, ISO Class 35H to 45H, and 50U (99,95 %, 99,995 % and 99,999 %, respectively at MPPS) generally provides commonly acceptable decontamination safety factors. For some specific applications where higher safety factors are required, ISO Class 55 to 75U filters may be specified for the last filtration stage.

NOTE The selection of the filter to be tested considers that the filter operating flow rate (user nominal flowrate) is as close as possible, or lower than, the nominal flow rate specified by the manufacturer in order to ensure that the filter performs as classified.

5.2 Preparatory conditions

5.2.1 General

To obtain the most valuable and useful in-situ test results, the test procedure shall be carried out when the plant is operating either at or as close as possible to its normal operating conditions.

Unlike production testing in industrial environments, access limitations may be created by factors such as radiation levels or even straightforward physical obstruction, preventing access to otherwise best possible sampling locations. These considerations should be addressed in advance to the best possible extent, e.g., by carrying out full system characterization tests before the introduction of radioactive/toxic materials, i.e., the following:

— qualification of injection and sampling locations to ensure fully mixed aerosol both upstream and downstream of the filter;

— conditions in the ventilation system and its operation during the test;

— apparatus selection and preparation;

— qualification of test personnel;

— test conditions;

— climatic conditions of the air and rooms during the tests, if needed;

— aerosol preparation;

— health and safety.

Where this is no longer possible, more specialized means of addressing the problem need to be developed and implemented.

5.2.2 Choice of injection and sampling locations

The sampling location shall provide the ability to extract a representative sample. For existing plants, where it is not possible, sampling locations should be selected to provide representative samples to the best feasible extent. The injection and sampling locations shall be located in a way to ensure the optimum possible homogeneity of concentrations at sampling locations (ISO 14644-3 and ISO 2889) according to the guidelines defined in the annexes, particularly Annex C and Annex E. The expected homogeneity at the sampling point depends on the expected accuracy of the filter's decontamination factor.

The design of new injection and sampling ports/probes should, as far as possible, ensure that a suitable cross section of the duct can be accessed to extract representative samples to the best feasible extent and that sampling points are appropriately placed to assist fault identification. Representative sample(s) shall be extracted from location(s) where the contributing airstreams are blended to the greatest prevailing extent. If the sample is extracted from another location (e.g., because of accessibility conditions), then the uncertainties that are induced shall be assessed. The sample probe shall be located at the best available location (see Annex E). Consideration may be given to installing a device or devices to improve mixing. In this case, the sampling probe may contain a single or multiple sampling points. In circumstances where the well-mixed criteria are not achieved, a multi-sampling probe may be used or needed to get a representative sample.

For facilities that could not characterize fully the filtration system after careful evaluation, one or more of the following steps should be taken in circumstances where these previous criteria cannot be satisfied in effluent systems designed and constructed prior to the publication of this International Standard:

a) select another well mixed location for the sampling probe;

b) install features that promote mixing;

c) perform an *in situ* test or simulation demonstrating that a representative sample is being collected.

The values of the properties that signify a well-mixed location for sample extraction can be characterized by certain parameters that are specified in 5.2.5.

5.2.3 Conditions for the ventilation systems on which the test is performed

The ventilation systems on which the *in situ* test is performed should be under normal operating conditions (e.g. not in degraded mode) when the test is performed. If normal conditions are not achieved when the test is performed, then the effects on the tests results shall be evaluated. The results' validity depends on the chosen test conditions. Generally, for the filters meeting the specifications described in 5.1, the tests results show greater decontamination factors for lower flow rates.

5.2.4 Climatic conditions in the rooms where the injection/sampling is performed

Room air temperature and air humidity should be established under nominal conditions where the sampling is performed.

The conditions in the ventilation system during normal operations shall not exceed the following:

— during normal operations: the stated maximum rating for any component contained within the system;